Marine geophysical study of southern Nares Strait

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Bathymetry and gravity contour maps of southern Nares Strait (herein termed North Water Bay) based mainly on previously unpublished data, together with seismic reflection and magnetic data, indicate the preservation of two major sedimentary basins. These basins are elongate approximately parallel to major onshore faults. Both are filled with disturbed strata.

Kane Basin to the north is probably filled with five to ten km of gently northeast-dipping sediments, disturbed by minor northeast-trending faults.

Gravity modelling indicates a possible, fault-bounded, basalt-filled 'fracture' off southeastern Ellesmere Island. This structure may continue northeastward into Nares Strait as a sediment-filled trough. This indicates only that Nares Strait is a fault-bounded feature, and not necessarily that there has been any horizontal motion, major or otherwise, along it.

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Marine geophysical data provided by the Bedford Institute of Oceanography, Dartmouth, Nova Scotia were analysed in the area from 75°N to 80°N and 64°W to 84°W (Fig. 1), as part of the research for an M.Sc. thesis (Newman 1977). These data provide clues relating to the question of the existence of a transform fault through Nares Strait, the linear seaway separating Greenland and Ellesmere Island.

The main study area is defined to the south by a bathymetric sill separating it from Baffin Bay (Fig. 2), and to the north by the narrows of Smith Sound. For the purpose of this paper it is termed North Water Bay.

The main data base for the research analysis comprised cruises Baffin 70–021, Hudson 71–032, Hudson 74–026 and Hudson 76–023, though data from earlier cruises were reviewed and used for qualitative control.

Seismic data

Seismic coverage is shown in Fig. 3. Work in western North Water Bay and Kane Basin was restricted due to heavy ice. In general, the 1971 records are good (Keen & Barrett 1973), but those of 1974 and 1976 are poorer. A major problem with all the records is the water depth multiple. In the deep ocean waters, with depths of thousands of metres, this is not a serious problem, but in areas of relatively shallow depths any sub-bottom structures below a few hundred metres are obscured.

From magnetic data, Keen & Barrett (1973) and Hood & Bower (1975) proposed the existence of a single, deep sedimentary basin trending northwestward from Thule Air Base. However, seismic data indicate two major sedimentary basins, separated by a basement high (Ross & Falconer 1975), and these basins are here named the Steensby Basin and the North Water Basin (Fig. 7).

The thickness and somewhat disturbed nature of the sediments in the arcuate North Water Basin can be seen well in line 74–12 (Fig. 4). A syncline can be seen between 'a' and 'b', and 'c' and 'd' (Figs 3 and 4), as well as on several other lines. Farther south this feature becomes shallower and much more disturbed. Keen & Barrett (1973) infer shallow magnetic basement here, and thus the southern termination of the North Water Basin. To the north, the trace of the syncline is lost because of poor records.

The 1971 sonobuoy in the west-central portion of North Water Basin (Fig. 3) found about 1.5 km of velocity 3.02 km/sec overlying a velocity of 4.64 km/sec of undetermined thickness. The velocity of 4.64 km/sec (density in the order of 2.5 g/cc; Ludwig et al. 1970) is relatively high for sedimentary rocks, possibly indicating old, dense sedimentary rocks (Keen & Barrett 1973). This would affect the timing of any tectonic activity along Nares Strait.

North of North Water Basin through Smith Sound in similar water depth to that found farther south, the seismic records emphasize the extreme ruggedness and lack of any unconsolidated sediments seen on the bathymetric records.

The eastern boundary of the North Water Basin,

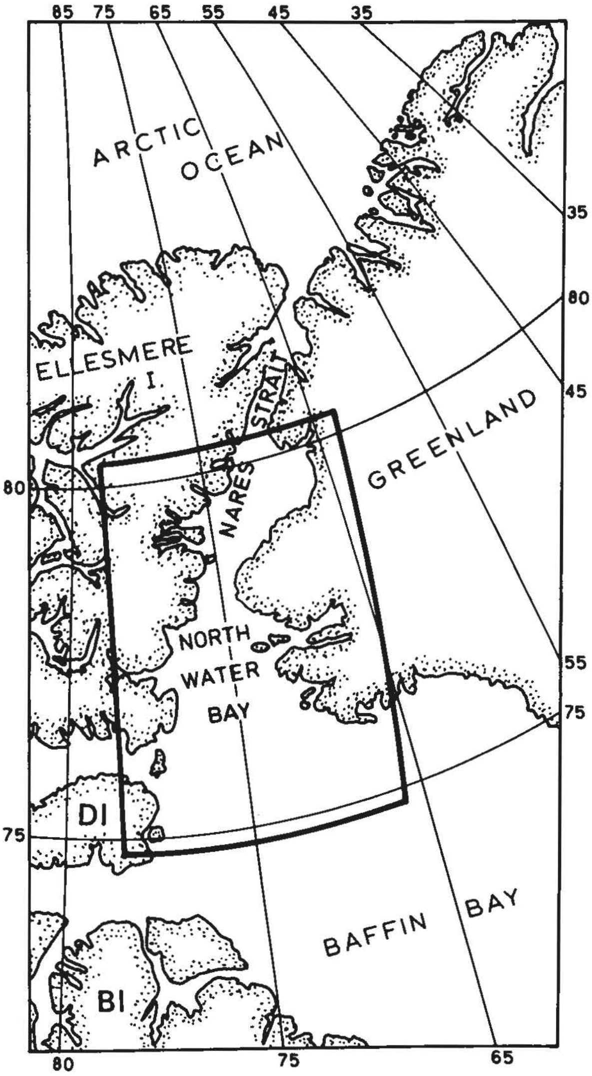

Fig. 1. Index map showing area of marine geophysical study. DI = Devon Island, BI = Baffin Island.

curving around the broad shelf of Greenland (Fig. 2), is defined by a sharp shelf-break and rugged topography. Bedrock is locally exposed. Line 74–12 (Fig. 4) shows the rugged, bare bedrock coming off the Greenland shelf. A bedrock sample of Precambrian granitic gneiss was obtained by electric drill in this area in 1974 by the Bedford Institute (R. K. H. Falconer, pers. comm.). It was found to have a density of 2.62 g/cc and a P-wave velocity of 6.2 km/sec.

A reversed refraction line south of North Water Basin (Fig. 3) defined three sediment layers, with a total thickness of 7 km, and maximum velocity of 4.16 km/sec, over a refractor of velocity 5.5 km/sec. This 'basement' refractor was interpreted as probably carbonate, but possibly Precambrian crystalline basement (Keen & Barrett 1972).

Free air gravity

A free air gravity map (Newman 1977) has been prepared from the marine data from the four Bedford Institute cruises in North Water Bay between 1970 and 1976, and from Dominion Observatory Bouguer land data from the coasts of Devon and Ellesmere Islands south of latitude 78°N. No land data were available north of 78°N on Ellesmere Island, or for any part of northern Greenland. A simplified version of this map is shown in Fig. 5.

Ross (1973) published free air and Bouguer maps of Baffin Bay as far north as approximately 77°30′N from 1970 and 1971 data. The present paper includes more recent and detailed data, and extends his work farther north.

In the absence of any detailed seismic data, a number of 2–D gravity models were attempted for selected profiles in this area to get some feel for the basement topography and density, and the density and thicknesses of any overlying sediments (Newman 1977). This modelling exercise illustrated well the fact that gravity mod-

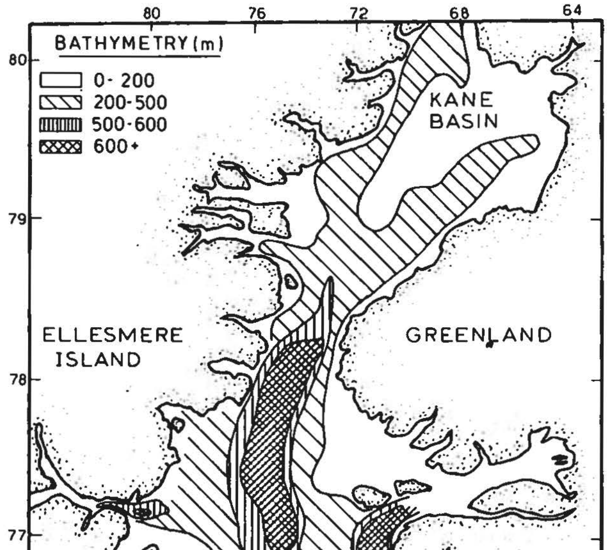

Fig. 2. Simplified bathymetric contour map of southern Nares Strait region.

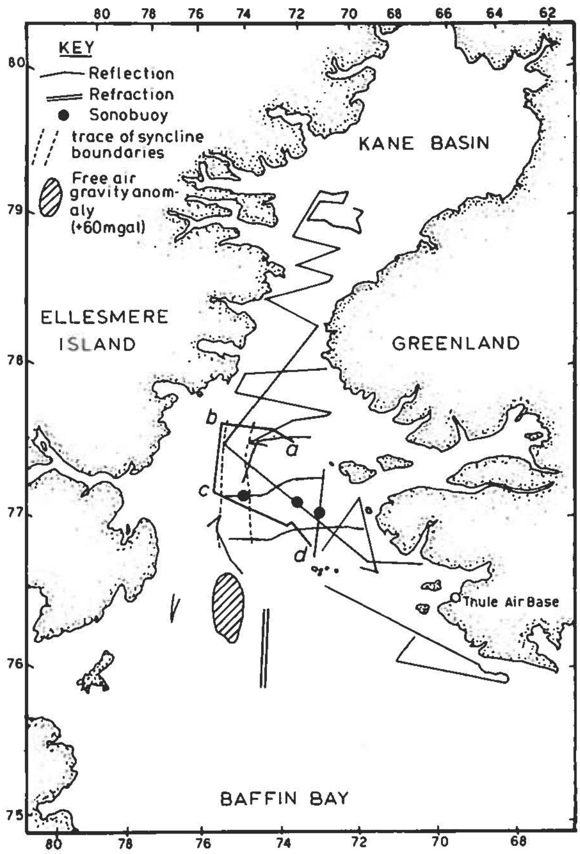

Fig. 3. Seismic coverage map of the North Water Bay area, showing trace of syncline on reflection profiles and the position of the free air gravity high.

elling cannot provide unique solutions, even when partly controlled by seismic reflection profiling. It was still felt, however, that these models could contribute a useful qualitative picture. Fig. 6 shows one of the 'best-fit' models for each of the three profiles located on Fig. 5.

For the models, densities of 2.7, 2.1–2.5, and 1.03 g/cc were assumed for crystalline basement, sediments, and water, respectively. From the few refraction data of the area and the more extensive studies of Lancaster Sound and the Baffin Island Shelf (Jackson et al. 1977) these sediment densities seem reasonable.

A detailed description of the line running northwest from Thule Air Base (Fig. 6, model 2) has been published by Ross & Falconer (1975). As there is good seismic control of basement topography, modelling was used to get an indication of density. It was found that a rough fit could be obtained if all the basement was assumed to have a density of 2.7 g/cc, and the sediment 2.4 g/cc. A better fit was obtained by assuming a density of 2.4 g/cc in the Steensby Basin, and a 2.1 g/cc layer overlying a layer of 2.4 g/cc in the North Water Basin. To fit the depression in the observed gravity near the western end of the line, it was necessary to assume a narrow 4 to 5 km deep body of 2.4 to 2.5 g/cc density below the seismically determined basement. There is no seismic evidence to support either the division of the North Water Basin into two layers or the existence of the deeper, narrow sedimentary basin, but due to the water depth multiple and the poorer quality of the records at depth, the seismic data do not refute these features either.

Profile 1 (Fig. 6), across southern Smith Sound can be explained by inferring about 2 km of material of either 2.5 or 2.2 g/cc density, filling a possibly fault-bounded depression in the basement. A deep (up to 5 km of 2.5 g/cc density), narrow basin of this sediment density is required to fit the small negative anomaly within the larger anomaly. This is possibly a fracture zone or narrow, fault-bounded depression filled with sediments, similar in position and form to that at the western end of profile 2 (Fig. 6). It appears that the syncline noted on the seismic reflection records (Fig. 4) is associated with this fracture in the models. This suggests that the faults were either active during sedimentation, or have been since.

The most intense gravity low of the mapped area (–90 mgal) occurs over the very shallow Kane Basin (Fig. 5). This may indicate a deep sedimentary section, and modelling was consistent with this (Newman 1977). Even with very low density sediment (1.9 g/cc), which seismic reflection profiles do not substantiate, at least 2.5 km of sediment are required. With more dense (2.5 g/cc) sediments, up to 10 km are necessary.

A relatively sharp positive gravity anomaly (max. greater than +80 mgal) located east of southeastern Ellesmere Island (Figs 3 and 5) is crossed by profile 3. Ross (1973) also mentioned this and stated that modelling indicated a shallow basement with a density difference of 0.5 g/cc. He postulated the presence of a basalt-filled fracture zone. Profile 3 (Fig. 6) was modelled for the study of this feature. It is interpreted as an essentially block-faulted basement with a deep depression beneath the free air gravity high, all overlain by high density material. Using basement density of 2.7 g/cc, a density of 3.1 g/cc for the overlying material gave the best fit, requiring a depth of about 10 km beneath the most intense gravity high. The same fit could be achieved with a basement density of 2.6 g/cc, overlain by material of density 3.0 g/cc, which is equally reasonable. Using a lower density, e.g. 2.9 g/cc, for the overlying material, gave unreasonable depths (25 km) of material required, and densities higher than 3.1 g/cc approach those densities expected of the upper mantle.

Magnetics

Magnetic data have been collected on all Bedford Institute's cruises in the area, but due to the large iono-

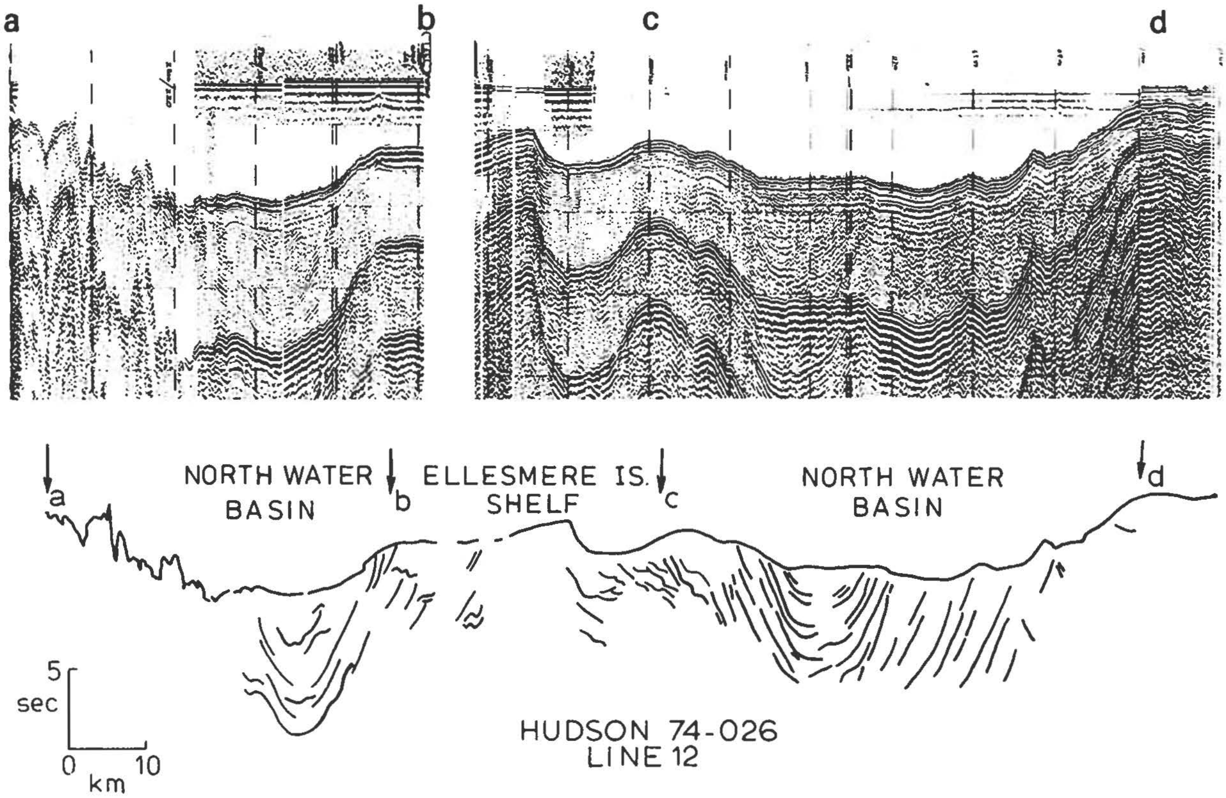

Fig. 4. Above: CSS Hudson line 74–12 seismic reflection profile. Sea surface is the heavy line seen across the top of parts of the record. Below: line drawing of line 74–12. Scale is the same for both profile and line drawing. The locations of points a–d are shown on Fig. 3.

spheric disturbances in these northern latitudes, interpretation and contouring of the data are problematic. However, in conjunction with aeromagnetic data, the marine data can be used qualitatively to characterize particular features.

All lines, marine and aeromagnetic, show a smooth negative anomaly trending northwest through the centre of North Water Bay (Fig. 7). Hood & Bower (1975) interpreted this as a half-graben containing over 20 km of sediments in the east, and shallowing to about 10 km in the west. This is the same feature that has been interpreted to be two sedimentary basins from seismic and gravity data. The basement high, which is distinct on seismic and gravity maps, can be detected only as a small increase in the magnetic signature, offset a little to the west.

As the tracks cross onto the Greenland continental shelf, the anomalies change suddenly to short wavelength positive anomalies. They indicate shallow, probably rugged basement. Farther north these anomalies disappear. Possibly this indicates smoothing or burial of the shelf beneath sediment cover.

To the south of the sedimentary basin anomalies, the magnetic anomalies increase again to form a high which can be followed from east to west almost continuously to both mainlands.

All magnetic lines crossing the region of the positive gravity anomaly off southeastern Ellesmere Island, even with no diurnal correction, are characterized by high amplitude, short wavelength anomalies. This is possibly an indication of the presence of basaltic material, as suggested by Ross (1973) and the gravity modelling.

Discussion

North Water Bay shows a number of interesting features, primarily associated with the North Water Basin (Fig. 7). This is a large arcuate basin, visible on the bathymetry (Fig. 2), free air gravity (Fig. 5) and seismic reflection data (Fig. 4). It is filled with disturbed sediments and trends roughly parallel to the major Precambrian fault and dyke systems on either side of Nares Strait (i.e. trending approximately northeasterly in the west and southeasterly in the east) (Dawes 1976, Frisch et al. 1978). Seismic refraction velocities, and densities from gravity modelling suggest that the sediments in

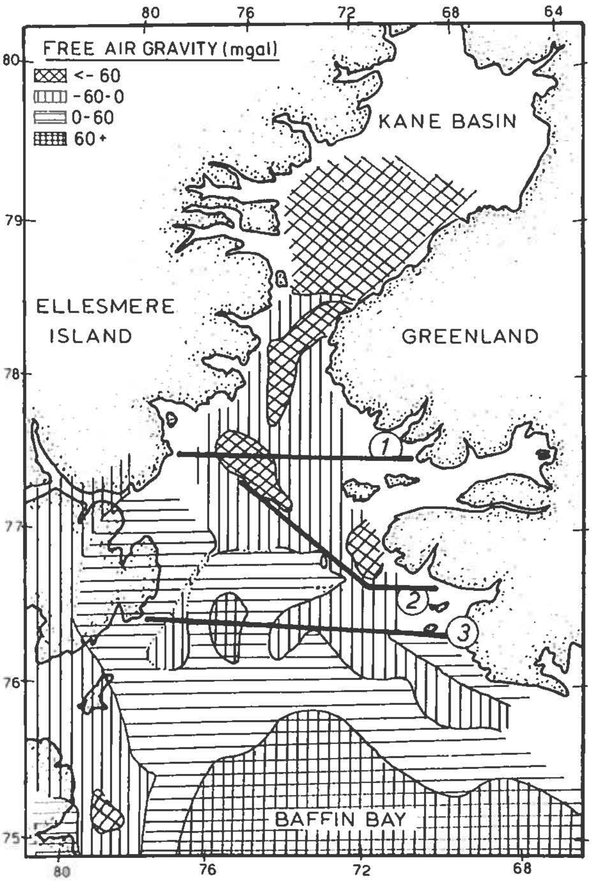

Fig. 5. Simplified free air gravity contour map of the North Water Bay area with location of 2–D model profiles shown in Fig. 6.

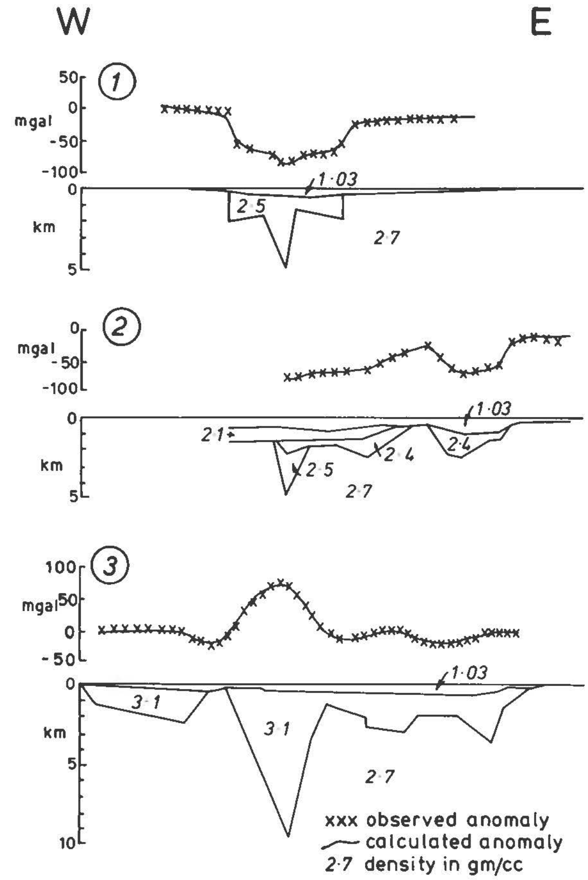

Fig. 6. Free air gravity 2–D models; locations are given in Fig. 5.

these basins are fairly consolidated and therefore probably of Tertiary age or older. The present topography of the basins is probably due to glacial erosion.

Seismic reflection records show relatively disturbed sediments throughout the basin, but in particular show a very clear, sharply-bounded syncline in the west, trending approximately north–south into the southern end of Nares Strait (Figs 3 and 4). Gravity modelling of several lines across this basin (Fig. 6) indicates two major layers of sedimentary density (2.1 and 2.4 g/cc) and this is borne out by seismic refraction results (Keen & Barrett 1973). However, the 'best-fit' models also require a deep, relatively narrow trough filled with fairly high density sediment (2.5 g/cc) directly beneath the syncline seen on the reflection records. This could indicate a fault origin for the syncline and either syntectonic deposition of the sediments in the syncline or considerable (and continuing) compaction of the basal sediments, or both.

Gravity modelling and the short wavelength, high amplitude magnetic anomalies over the anomalous free air gravity high to the south of North Water Basin (Figs

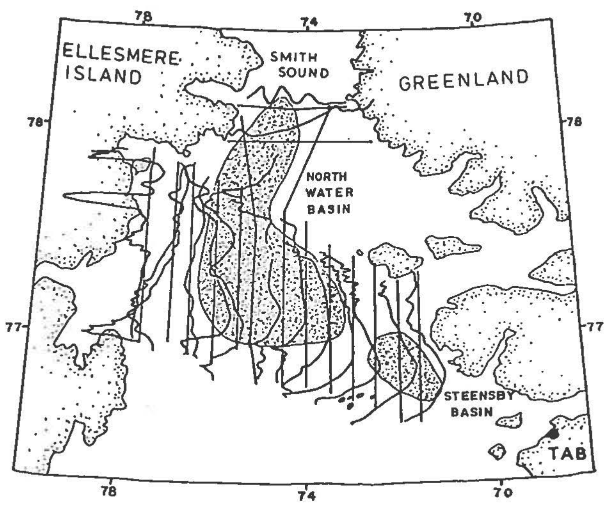

Fig. 7. Positions of North Water and Steensby Basins, as defined by bathymetry, gravity, and seismic reflection, shown in relation to aeromagnetic profiles (modified from Ross & Falconer 1975). Magnetic anomalies are shown positive to the west or north of the flight lines. TAB = Thule Air Base.

5 and 6) tend to confirm Ross's (1973) interpretation of this feature as a basalt-filled fracture. This feature is directly in line with the sediment-filled depression and syncline of western North Water Basin to the north (Fig. 3). It is possible that this basalt(?) and sediment filled 'fracture' trends into Nares Strait, though there is as yet no direct evidence of this. The synclinal sediments of North Water Basin cannot be traced to the north into Smith Sound, which is bathymetrically very rough and shows little seismic penetration. Although the irregular magnetic signature is similar to the typical Precambrian crystalline crustal signature (Hood & Bower 1975), gravity modelling indicates that there is probably a thick sequence (more than 2 km) of high density sediment located in Smith Sound (Newman 1977).

Kane Basin, with a depth of less than 200 m, forms a shallow sill between Baffin Bay and the Arctic Ocean. From seismic work and gravity modelling, it appears to have been the site of substantial sediment deposition. The minimum thickness of sediment possible to explain the less than – 90 mgal gravity anomaly is about 2.5 km of very low density material (too low as indicated by seismic reflection character). Five to ten km of higher density material is more likely. The sediments appear to dip gently northwards, with minor northerly-trending faults. Since the dip is visible only on the lines striking NNE, and the faults only on those striking ESE, this northerly designation may well approach northeast.

Conclusions

Faulting appears to have made a significant contribution to the structure of the offshore, as well as onshore, southern Nares Strait. In particular, a deep (10 km+ ?), relatively narrow, fault-bounded trough, filled with sediments to the north and basalt(?) to the south appears to exist and trend into Nares Strait, though it cannot definitely be traced as far as Smith Sound with the available data.

The minor, shallow northeast(?)-trending faults of Kane Basin, and the fact that the syncline of western North Water Basin appears to continue to the ocean bottom surface, may indicate some minor continuing activity along basement faults, or they may simply be the result of compaction of sediment under the influence of the faulted basement topography. The present aseismic nature of Nares Strait (Basham et al. 1977) may indicate the latter.

From these data, it appears that Nares Strait is a reasonably old, fault-bounded feature, but there is as yet no control on the horizontal movement along these faults.

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