ATTACHMENT K

ANALYSIS OF HUMMOCKY SUBBOTTOM RELIEF FROM REPETITIVE OBSERVATIONS NORTH OF TIGVARIAK ISLAND, BEAUFORT SEA

by

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Introduction

Subbottom seismic reflectors in the arctic have been ascribed to many sources including lithologic boundries, ancient erosional surfaces, gas, gas hydrates, and permafrost(Grantz, et al. 1982, Reimnitz, et al., 1972, Neave and Sellmann, in press). The availability of reptitive observations of a hummocky subbottom reflector along with an evaluation of navigation accuracies has allowed us to discuss the three dimensional morphology of the subbottom relief and therby place limits on the mode of origin of this reflector.

The repetitive survey trackline used in the comparison below is located about 40 km northeast of Prudhoe Bay seaward of a chain of sand and gravel islands (Fig. 1). This track line, as well as several others, was initially established for the prupose of monitoring the yearly occurrences and character of ice gouging (See Attachment G).

Methods

Accurate positioning systems were used to ensure repeatability of line position from year to year. In 1980 and 1981 shore based navigation equipment was positioned on Narwhal and Pole Islands(Fig. 1) . Positioning of the line in real time was accomplished by maintaining a match of ranges (ie. being equidistant) from each shore station as the vessel moved seaward along the trackline. Although the manufacturer of the navigation system was different in each year, both systems have an expected precision of 3 meters. Bathymetry, side scan monographs, and 7 kHz subbottom profiles were acquired in 1980 and 1981 . Boomer seismic records were only acquired in 1980. Approximately two kilometers of 7 kHz subbottom profiles, starting near the islands and extending seaward, form the basis for comparison.

Observations

An undulating subbottom reflector was recorded on the 7 kHz records between two and five meters below the seafloor in both years. The reflector itself, irregular and hummocky in nature, is characterized by sharply pointed highs and lows which could not be matched from year to year. The broad scale highs and 10WS(1OO'S to 1000's of meters) of the reflector were also not comparable from year to year. We do not suspect that the location of the reflector moved from year to year if the reflector represents a geologic surface. Movement or migration of a reflector might be expected if the reflector were related to gashydrates or permafrost processes if related to permafrost depths. To assess the possibility of reflector movement in the year intervening between surveys, the navigation in the two years was carefully evaluated.

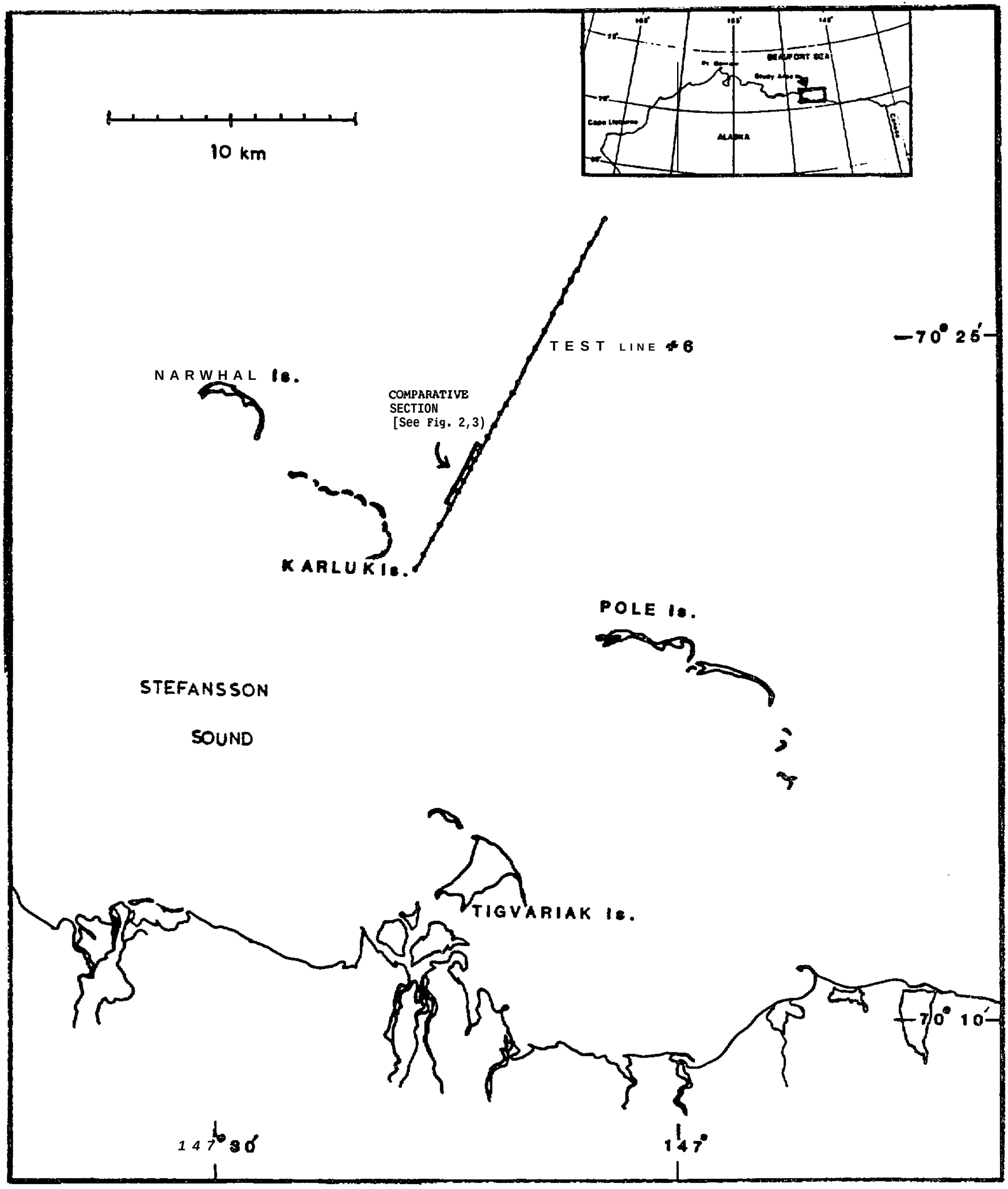

Figure 1. Location of area investigated in 1980 and 1981.

Comparison of trackline navigation data from both years shows lateral deviation of up to 20 m to the left and right from a hypothetical straight line course(See Fig. 2-I). Similar features on both the 1980 and 1981 7 kHz records suggested that the plotted navigation as distance from shore could be in error. If the records were moved anlong one track relative to the other a very close match of the overall reflector morphology could be achieved. In an effort to test this hypothesis and asses validity of the navigation data, the side scan sonar records for each year where studied. Four seafloor features common to each line were identified (points A - D on figure 2). One of these features (B) is shown on figure 3. One can identify the apex of an ice gouge feature on both records(shown by the arrows). The feature shows that the boat passed approximately 24 meters farther from the target in 1981 than in 1980. However, the plotted postions of the point of passage differed by more than 150 m. Similar positioning analysis was accomplished for the remaining three targets. Side scan matched positions along the 1980 line were shifted to match the locations along the 1981 line. Shifts from the navigated postions of 153 m at A, 163 m at B, 122 m at C and 110 m at D were required to match monographs. On completion of this adjustment, a close match of both 7 kHz profiles and the boomer record was achieved(Fig 2-III,IV,V).

The closely parallel 1980 and 1981 tracklines suggest that navigation error was systematic. That is by matching ranges we were able to repeat the track, however position fixes along track from one year to the next were in error by 100m or more. Such errors could be a result of improper or lack of system calibration, weather phenomenon, power available at the shore sites or a combination of all parameters. Without the aid of sea floor features on the monographs' for locating position match points, year to year comparison of subbottom data at the same location would not have been possible. Errors in interpretation could have resulted if the validity of the navigation data was left untested.

In summary the comparison of two 7 kHz records taken in 1980 and 1981 was validated using side scan sonar records to verify navigation positions which had systematic errors of over 100 meters.

Hummocky Topography - The saw tooth pattern shown in figure 2 along the 7kHz subbottom profile has a relief of approximately 1 - 2 meters near position B, C, and D, and as much as 3 meters near A. The relief becomes greater when both sets of profiles are superimposed. Lines drawn through the peaks and through the troughs of the combined profiles indicate an overall relief to the surface of to 4.5 meters. Removal of the 20:1 vertical exaggeration along a small section of the saw-tooth pattern revealed the subbottom surface to consist of "swells and swales" with wavelengths of 20 - 40 meters peak to peak. Overlaying the two 7 kHz profiles revealed no correlation of individual peaks and troughs, although the saw-tooth pattern and broad scale relief were the same. As the records obtained were up to a maximum of 20 m apart, linear features of up to 3m relief and 40 m wave length should correlate from track to track. This suggests that the overall 7 kHz surface is hummocky in nature and that linear features such as buried channels or ice gouges are not readily evident or traceable. Thus, it is evident that the relief is so varied in

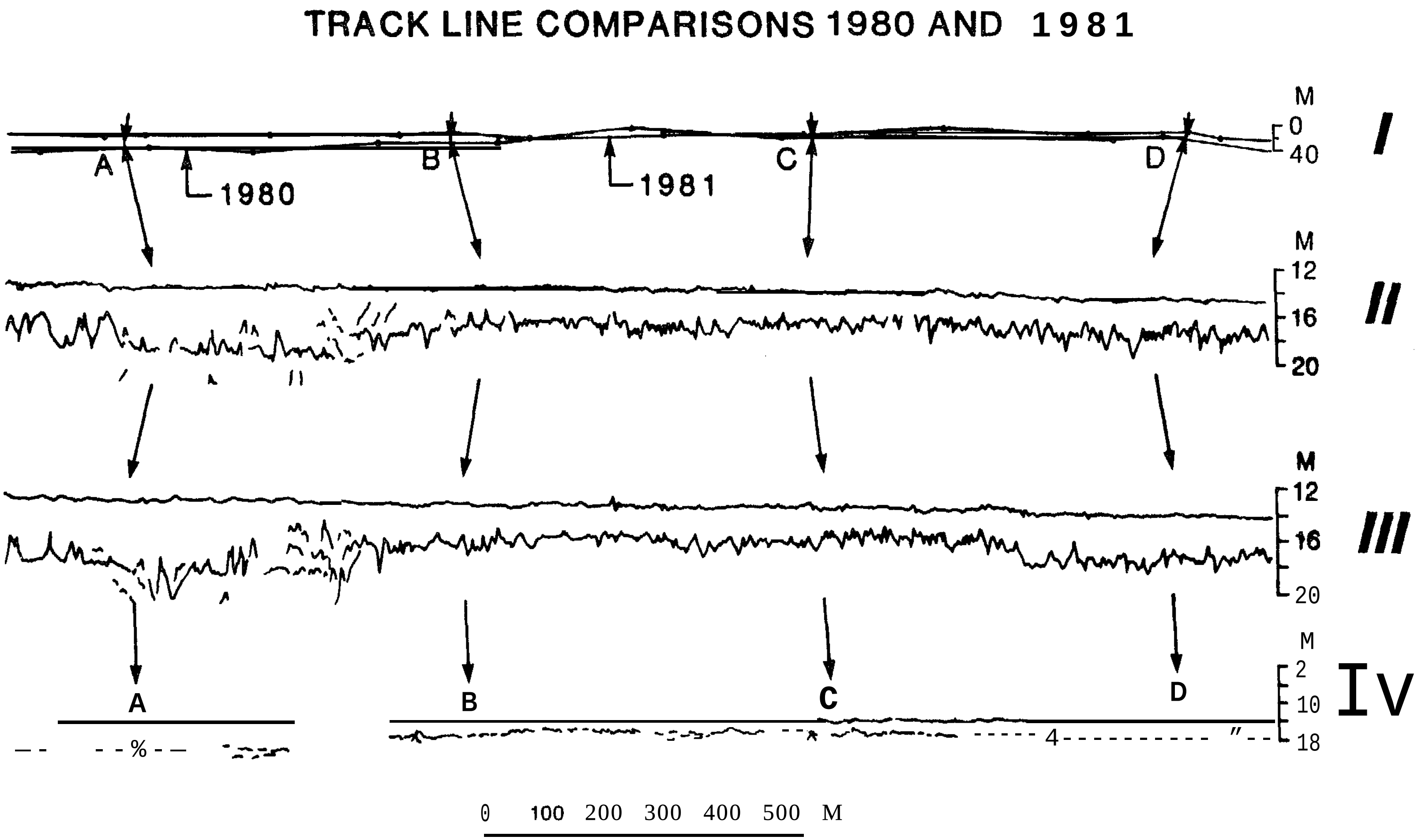

Figure 2. Trackline deviation (I) and corrections calculated from four features observed on side scan sonar records (see Fig. 3) for the years 1980 and 1981. Upper line drawing shows amount of lateral deviation along the testline between the two years. 7KHz records (II and III) show the lack of correlation at a small scale. Boomer record (IV) shows broad scale correlation of reflector morphology. Vertical exaggeration 20:1 on 7 KHz record and 6.6:1 on Boomer record

very short horizontal distances that only broad scale features such as the high represented by B and C can be traced over larger areas.

Differences between the acoustic signature of the reflector on the 7 kHz and boomer record make it difficult to locate the surface if only the boomer record were available. The longer pulse length of the first bottom arrival tends to obscure the surface when it is within a meter or two of the seafloor. The seismic records show a transparent, non reflective sediment layer above the surface which correlates with reflectors observed on the 7 kHz profiles. This particular subsurface reflector can therefore be traced on Boomer records with the aid of 7 kHz profiles.

Discussion

Insufficient data and areal coverage at this stage of analysis makes it difficult to determine the age and/or significance of the reflector and its hummocky appearance. Certain trends are however evident. As one follows the reflector shoreward toward Karluk Island(Fig. 1), the reflector surface outcrops on the seafloor seaward of Pole, Karluk, and Narwhal Islands. Side scan sonar records show an ice scoured seafloor to the north of the outcrop and a rough seafloor with boulders scattered about the surface to the south and through the opening between Karluk and Narwhal Islands. A 7 kHz profile obtained about 30 km to the east, near Flaxman Island, exhibits the same hummocky reflector. This eastern profile passes through a borehole whose stratigraphy has been studied(Hartz, 1979) . Stratigraphic and paleontologic data from the borehole indicate a boundry at the level of the acoustic reflector with Holocene above and the Flaxman Formation below(Hopkins et al., 1978, K. Mcdougall, personal communication, 1983) . This correlation suggests that this reflector may be the top of the. Flaxman Formation while the occurrence of seafloor boulders suggests a non-depositional, perhaps an erosional surface at the present day seafloor. The Flaxman Formation is generally described as a bedded sandy silt and clay unit containing ice rafted glacial boulders up to 3 m in diameter(Hopkins, 1978). This unit is generally overlain by a variety of deposits which are of beach, delta, lagoon, marine and shoal origin.

The broad scale morphology may have analogs in the present day coastal plain. The broad high between B and D on the 7 kHz profiles(Fig. 2-1,11) may be buried counterpart of the high areas presently seen on shore(Tigvariak Is.). Inshore from some of these high islands are shallow lagoons. The broad low between A and B on the profiles perhaps represent a similar feature. In essence the area between B and D may represent an older island high somewhat erosional in nature, like Tigvariak Island with a low lagoonal (A to B) feature to the south. This correlates rather well with the interpreted outrcrop inshore from the broad high and suggests that the boulders discussed earlier are from the Flaxman Formation which are at present a lag deposit of that unit. The similarities between the present coastal morpholgy with the seismic morphology shown along the profiles between A and D as well as borehole association with Flaxman Formation is rather striking.

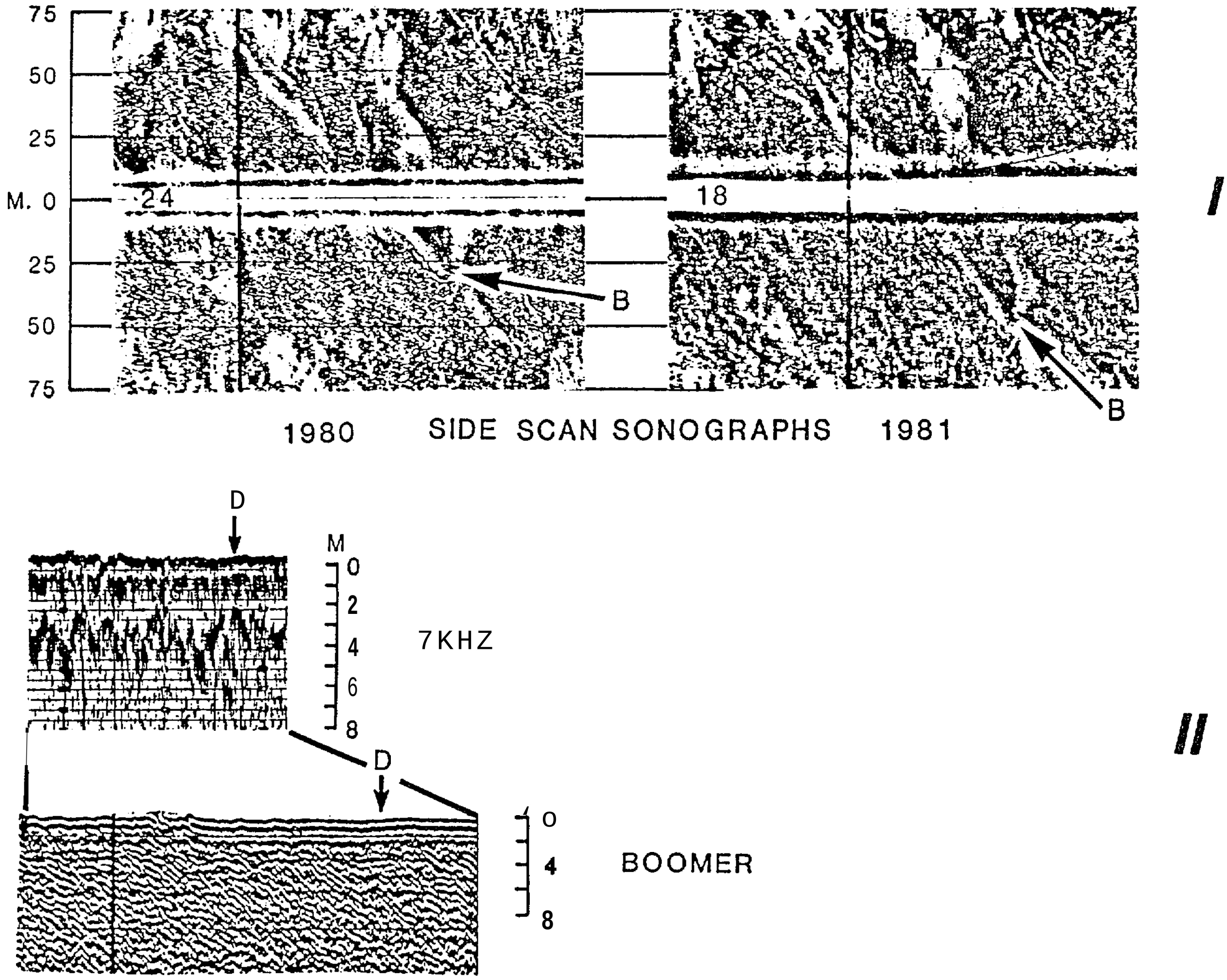

Figure 3. Monographs (I) show correlation feature B (see Fig. 2) and amount of trackline deviation. 7 KHz and Boomer records (II) from 1981 show position of feature D and resolution differences between seismic record types.

The small scale hummocky morphology of the suburface reflector could be ascribed to several causes. The present tundra surfaces exhibit relief features of highs, lows, somewhat circular basins, some dry, some as small lakes. 'The small scale features of 2-3 m relief and 20-40 m may represent the similar small circular basins or lows on the present day tundra surface and lagoonal sea floor, although the modern features have much less relief. This reflector may alternately represent an erosional surface with cut and fill, such as incised delta front channels.

Another possible source of this jagged relief is ice gouging(Reimnitz and Barnes, 1974). However, as most gouging is parallel to the coast we sould expect some correlation of relief as the tracklines were taken close togeather and perpendicular to the coastline, yet no correlations were observed. Furthermore, modern ice gouge relief is much less than the relief of the hummocky surface.

Lastly, the relief may not be related to a stratigraphic unit but to a gas or permafrost boundry within the section. Changes in the surface relief of the top of the bonded permafrost over short distances have been reported from the Canadian Beaufort Shelf. At this stage of the analysis we are unprepared to ascribe a cause for the hummocky relief, although the regional reflector does seem to correspond well with the top of the Flaxman Formation.

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