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

by

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INTRODUCTION

Subbottom seismic reflectors in the Arctic have been ascribed to many sources including lithologic boundaries, ancient erosional surfaces, gas, gas hydrates and permafrost (Grantz and others, 1982; Reimnitz and others, 1972, Neave and Sillmenn, 1984). A highly irregular near surface, subbottom reflector has been observed on many 7 kHz records particularly in the area between Flaxman Island and Prudhoe Bay, Alaska. This reflector outcrops north of the barrier islands and extends seaward to water depths of tens of meters where it steepens in dip. Where horizontal, it generally lies two to five meters below a moderately ice gouged sea floor.

During the past decade, specific tracklines orientated normal to the coastline and barrier islands were established over which yearly surveys were conducted. These lines were primarily established for the purpose of monitoring the yearly occurrence and character of ice gouging. Side-scan sonographs, bathymetric, and subbottom geophysical data were acquired.

Data taken during 1980 and 1981 were examined to determine the three dimensional morphology of this shallow subbottom reflector and thereby enabling us to place limits on its mode of origin.

Close scrutiny of navigational data for both years was required to assess the accuracy and repeatability of the plotted navigational poistions along each trackline. The methodology and results of this examination are presented below. A significant result of this process was that had not the data been questioned and analyzed, serious erroneous interpretation would have resulted.

METHODS

The survey tracklines used in the comparison below are located about 40 km northeast of Prudhoe Bay seaward of a chain of sand and gravel islands (Fig. 1). Accurate positioning systems were used to ensure repeatability of line position from year-to-year. In 1980 and 1981, shore based navigation equipment were positioned on Narwhal and Pole Islands (Fig. 1). Positioning of the line in real time was accomplished by maintaining equidistant ranges from each shore station as the vessel moved seaward along the trackline. Although different navigation systems were used in each year, both systems have an expected precision of 3 meters. Approximately two kilometers of 7 kHz subbottom profiles starting near Narwhal and Pole Islands and extending seaward form the basis for comparison.

OBSERVATIONS

A distinctive undulating subbottom reflector was identified on the 7 kHz records between two and five meters below the seafloor in both years. This reflector outcrops shoreward and deepens seaward. The reflector itself, irregular and hummocky in nature, is characterized by sharply pointed peaks and troughs superimposed on broad highs and lows. Comparison of 7 kHz data from one year to the next revealed no correlation of small scale features.

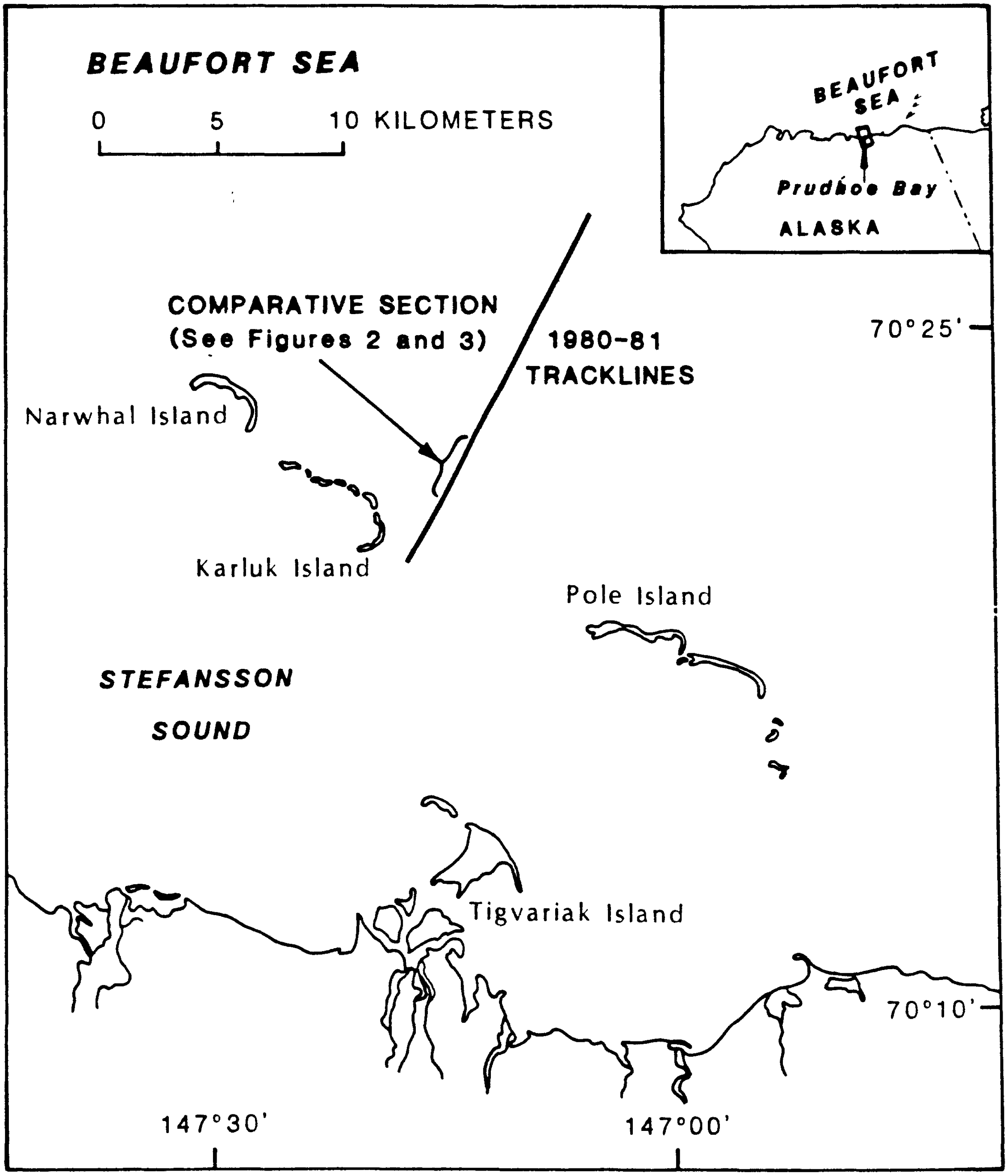

Figure 1. Location of tracklines investigated.

Even the broad scale features, which were at similar depths, did not coincide. We do not suspect that the location of the reflector moved from year to year assuming the reflector represents a geologic surface. Movement or migration of a reflector might be expected if the reflector were related to gas hydrates or permafrost processes. To evaluate the possibility of reflector movement in the year intervening between surveys, the trackline positions from both years were carefully analyzed.

Analysis of Trackline Data ---- 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 (Fig. 2-I). Similar features on both the 1980 and 1981 7 kHz records suggested that the plotted navigation could be in error. If the records were moved along 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 assess validity of the navigation data, the side-scan sonar records for each year were 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-I. One can identify the apex of an ice gouge feature on both records (shown by the arrows). This feature suggests that the boat passed approximately 24 meters farther from the target in 1981 than in 1980. However, the plotted positions of the points of passage differed by more than 150 m along track. 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 plotted positions of 153 m at A, 163 m at B, 122 m at C and 110 m at D were required to match sonographs. On completion of this adjustment, a close match of both 7 kHz profiles and the Boomer record was achieved (Fig. 2-II, III, IV).

The nearly parallel 1980 and 1981 tracklines suggest that the navigation error was systematic. That is by matching ranges, we were able to repeat the track; however, position fixes along the track from one year to the next were in error by 100 m or more. Such errors could be a result of improper system calibration (or lack of), weather phenomenon, power available at the shore sites or combination of all parameters. Without the aid of sea floor features on the snongraphs 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.

Subbottom Hummocky Topography ---- The saw-tooth pattern along the 7 kHz subbottom profile has a relief of approximately 1 - 2 meters near position B, C, and D, and as much as 3 meters near A (Figure 2). 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 hmmocky surface of up to 4.5 meters. Removal of the 20:1 vertical exaggeration along a part of the saw-tooth pattern revealed that the subbottom surface consists of "swells and swales" with wavelengths of 20 - 40 meters peak-to-peak at the same magnitude of relief. Overlaying the two 7 kHz profiles revealed no correlation of individual peaks and troughs, although the

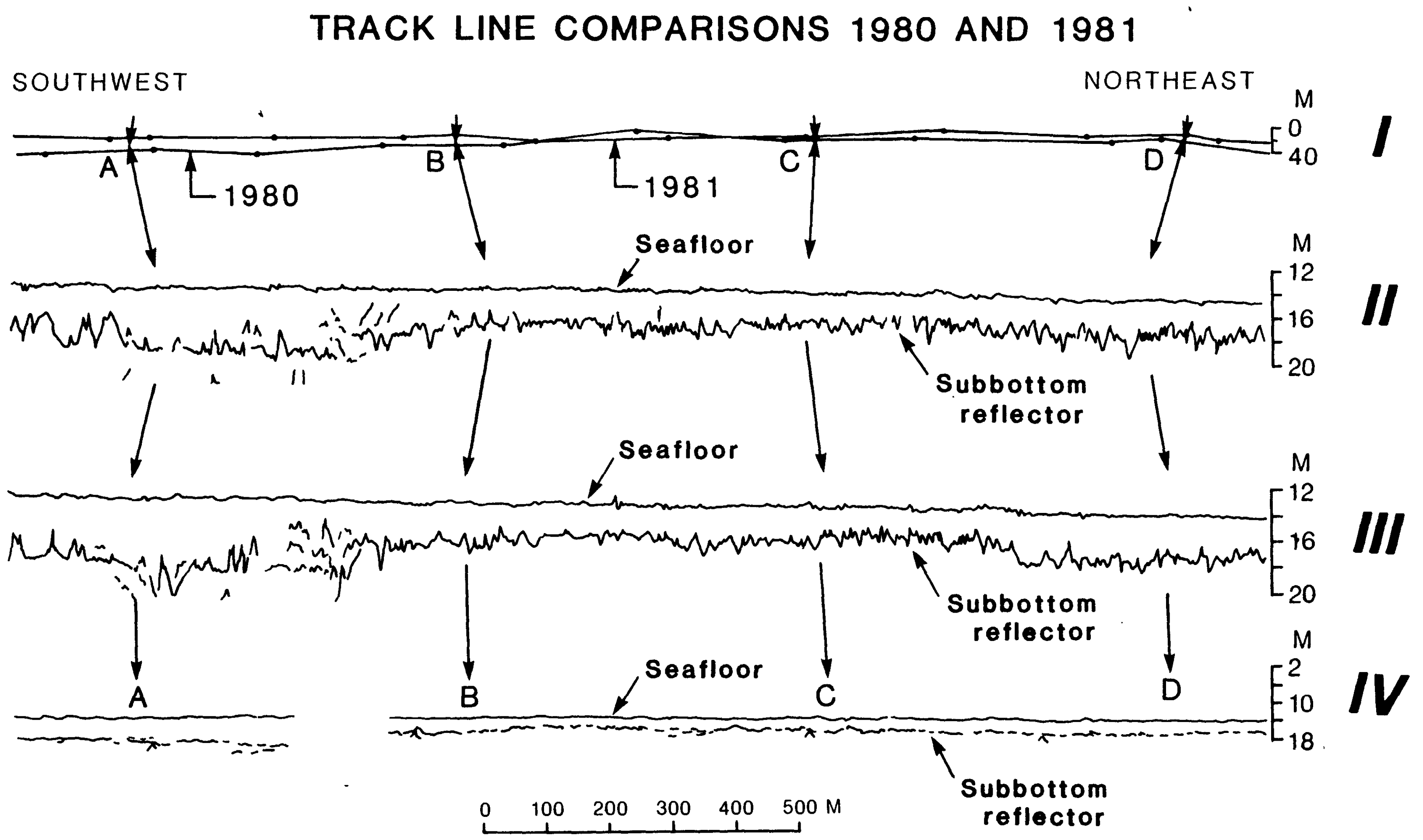

Figure 2. Trackline deviation (I) and corrections calculated from four features observed on side-scan sonar records (Fig. 3) for the years 1980 and 1981. Upper line drawing shows amount of lateral deviation along the testline between the two years. 7 kHz records (II and III) show the lack of correlation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

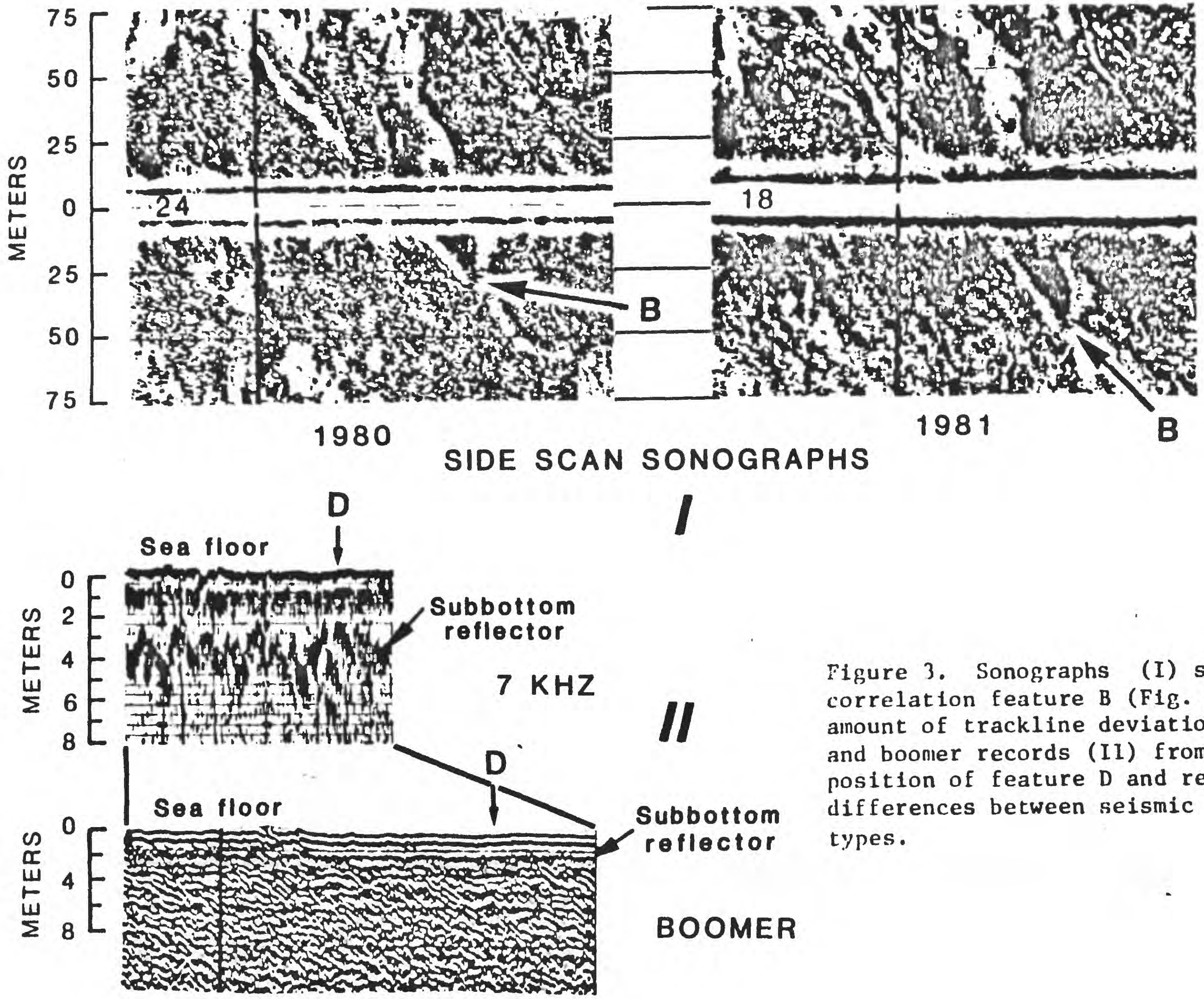

Figure 3. Sonographs (I) show correlation feature B (Fig. 2) and amount of trackline deviation. 7 kHz and boomer records (II) from 1981 show position of feature D and resulution differences between seismic record types.

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 3 m relief and 40 m wavelength should correlate from track to track. Therefore, this lack of correlation suggests that the overall 7 kHz surface is hummocky in nature and that linear features such as buried channels or buried ice gouges are not readily evident or traceable. Thus, it is evident that the relief is so varied in very short lateral distances that only broad scale features such as the high represented by B and C (Figure 2-II, III, IV) can be traced.

Differences between the acoustic signature of the reflector on the 7 kHz and Boomer record make it difficult to locate the surface using only the Boomer record. The longer pulse length of the first bottom arrival on the Boomer record tends to obscure the hummocky surface when it is within a meter or two of the sea floor. The seismic records show a transparent, internally nonreflective layer above the hummocky surface which correlates with reflectors observed on the 7 kHz profiles. This particular subsurface reflector can, therefore, be traced on Boomer records only 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 the origin of the hummocky surface. Certain trends are evident, however. As one follows the reflector shoreward toward Karluk Island (Fig. 1), the strata forming the hummocky reflector outcrops on the seafloor seaward of Pole, Karluk, and Narwhal Islands. Side-scan sonar records show an ice scoured seafloor seaward of the outcrop and a rough seafloor with gravel and boulders scattered on the seafloor 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 at similar depths below seafloor. This eastern profile passes through a borehole whose stratigraphy has been studied (Hartz, 1979). Stratigraphic and paleontologic data from the borehole indicate a boundary at the level of the acoustic reflector with Holocene above and the Flaxman Formation below (K. McDougall, oral communication, 1983). This correlation suggests that the hummocky reflector may be the top of the Flaxman Formation while the occurrence of seafloor boulders suggests a non-depositional, or 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, and others, 1978). This unit is generally overlain by a variety of deposits which are of beach, delta, lagoon, marine and shoal origin.

The board 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-II, III) may be a buried counterpart of the high areas presently seen near shore, Tigvariak Island, for example. Inshore from some of these high islands are shallow lagoons. The broad low between A and B on the profiles (Fig. 2-II, III) may perhaps represent a similar feature. In essence the area between B and D may represent an older island high somewhat erosional in nature, with a low lagoonal (A to B) feature to the south. This correlates rather well with the interpreted outcrop inshore from the broad high and suggests that the boulders discussed earlier are from the Flaxman Formation which at present form a lag deposit. The similarities between the present coastal morphology with the seismic morphology shown along the profiles between A and D as well as borehole association with Flaxman Formation is rather striking.

The small scale hummocky morphology of the subsurface reflector could be ascribed to several causes. The present tundra surfaces exhibit relief features of highs, and low, somewhat circular basins, some dry, some as small lakes. The small scale features of 2-3 m refief and 20-40 m wavelengths on the profiles may similarly represent small circular basins or lows on a surface formed at a lower stand of sea level and now buried, although the modern features have much less relief. Alternatively, this reflector may represent an erosional surface with cut and fill features such as incised delta front channels.

Another possible source of this jagged relief is ice gouging (Reimnitz and Barnes, 1974). However, as much gouging is parallel to the coast, we should expect some correlation of relief as the tracklines were taken close together and perpendicular to the costline, 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 gas or a permafrost boundary 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.

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Copies of the data are available through the National Geophysical Data Center, NOAA/EDIS/NGDC, Code D64, 325 Broadway, Boulder, CO 80303. Telephone (303) 497-6338.