SEA MARC I SIDESCAN SONAR SURVEY LINE ACROSS THE SOUTHEAST BAFFIN SHELF AND SLOPE, NORTHWEST LABRADOR SEA

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ABSTRACT

This open file report presents the results of a 280 km long, 5 km wide swath Sea MARC I sidescan sonar survey line run across water depths of 300-2000 m off southeastern Baffin Island (latitude 62°20'N). The report includes (1) photoreproductions of the sonograms, at 1:40,000 scale, (2) hand-drawn interpretations, including bathymetry, and (3) a descriptive text. The seabed of the continental shelf and upper continental slope is dominated by iceberg scours (furrows and pits), which display variations in abundance, orientation, size and definition; ponded sediments and surface expressions of the subsurface bedrock are also observed locally. Iceberg scours are present to a maximum water depth of approximately 715 m on the upper continental slope. The continental slope below this depth appears largely featureless except across the southern tip of the Gjoa Spur, which contains ponded sediments and slope-transverse lineations related to mass movement in association with gradients up to 20° and relief up to 180 m.

INTRODUCTION

This open file report presents the results of a Sea MARC I sidescan sonar survey line run on the continental shelf and slope off southern Baffin Island, as part of a program of research conducted by the Atlantic Geoscience Centre offshore eastern Canada using the Sea MARC I system (e.g. Piper et al., 1984; Pereira et al., 1985; Josenhans et al., 1986.). The survey line is 280 km long, and encompasses water depths of 300 to 2000 m (Fig. 1). The report contains: (1) photoreproductions of the sidescan sonograms, orthorectified and geographically positioned, at a scale of 1:40,000, (2) a preliminary interpretation, including contoured bathymetry, on plastic overlays, and (3) a brief text describing and discussing sonogram features.

The Sea MARC I survey line was positioned in order to: (1) examine the type and distribution of iceberg scours on the continental shelf and slope, (2) determine the maximum depth at which iceberg scours occur on the upper continental slope, and (3) investigate continental slope features, particularly evidence for mass movement. The line crosses the positions of two exploratory wells on the southeast Baffin Shelf, Aquitaine et al. Hekja 0-71 (Klose et al., 1982) and Canterra Ralegh N-18 (Fig. 1); another well, Esso H.B. Gjoa G-37 (Klose et al., 1982), is 65 km north of the line (Fig. 1).

METHODS

The Sea MARC I survey line was run during September 18-21, 1984 as part of CSS Hudson cruise 84-035. The Sea MARC I system is described by Kosalos and Chayes (1983), and comprises a dual channel sidescan sonar with 27 and 30 kHz transducers, and a 4.5 kHz subbottom profiler. The system is housed in a neutrally buoyant vehicle, which was towed up to 2500 m behind the ship at altitudes of about 300 m off the seabed. A 5 km swath width was used throughout the survey. Vehicle positioning relative to the ship was done using the wire-out indicator and vehicle depth, as an Oceano short-baseline navigation system failed to operate properly. Ship's navigation was by rho-rho Loran C supplemented by satellite navigation, integrated by the BIONAV system (Wells and Grant, 1981); accuracy was generally within 250 m.

The sidescan sonar data were digitally recorded and processed in real time to give orthorectified images with horizontal slant range corrections. Subsequently, reproductions of these images were manually compiled at a scale of 1:40,000; the images were cut and either spaced or overlapped where paper speed variations were insufficient to correct for tow speed variations, or where changes in course produced relative distortion between channels. Photoreproductions of these sidescan images at 1:40,000 scale are presented as Sections 1-9.

Preliminary interpretations of Sections 1-9 were drawn directly on plastic overlays, using the legend in Section 1. The ship's track was plotted to compare with the Sea MARC I tow vehicle position, which is indicated on the sidescan imagery. Bathymetric contours were drawn using depths from the ship's echograms along the Sea MARC I survey line in combination with depth postings from previous BIO cruises, which are located along 5 minute lines of latitude and locally at intermediate latitudes. The positions of sample stations, and of the Hekja and Ralegh wellsites, were also plotted.

REGIONAL SETTING

The Sea MARC I survey line extends across the Southeast Baffin Shelf for 140 km, from the northern margin of the Resolution Basin at a depth of 400 m, across central shelf depths up to 320 m, to the shelf break at 460 m (Fig. 1). The continental shelf slopes generally southeast toward a large depression east of Hudson Strait, at gradients less than 1°. The survey line extends another 140 km across the continental slope, which descends seaward at gradients less than 2° to about 1500 m depth, beyond which gradients up to 20° and relief up to 180 m are observed in association with the southern tip of the Gjoa Spur (informal term) and its seaward flank to 2000 m depth (Fig. 1).

The continental shelf along the Sea MARC I survey line is underlain by gently seaward-dipping semi-consolidated sedimentary strata, generally Tertiary in age (MacLean et al., 1977; Klose et al., 1982), which are separated by an angular unconformity from overlying unconsolidated sediments less than 10 m thick (Fig. 2). The unconsolidated sediments have been mapped as gravelly sandy muds of Davis Strait Silt Subunit B (Praeg et al., 1986) , which are characterized on high resolution seismic reflection profiles by both a general lack of acoustic stratification and a rough surface attributed to iceberg scours (Fig. 2). Subunit B is laterally equivalent to acoustically stratified, unscoured, gravelly sandy muds of Davis Strait Silt Subunit A, which are present in the Resolution Basin below depths of 500-550 m (Figs. 1, 2). The immediate seabed in the area has been affected by both the southward flowing Baffin Current and by tidal currents associated with Frobisher Bay (Osterman, 1982), resulting in the formation of a thin (<50 cm) surface veneer composed dominantly of sand and gravel (Praeg et al., 1986).

SIDESCAN IMAGERY

Photoreproductions of the sidescan sonograms at a scale of 1:40,000 are presented as 9 sections (Fig. 1), which are described individually below. A general description and a discussion of interpretation are given first.

Sidescan Interpretation

Interpretations of the sidescan imagery were drawn directly using the legend in Section 1. Iceberg scours have been previously reported across the area (Praeg et al., 1986), and were recognized by their linear (furrows) to equant (pits) form and characteristic cross-cutting relationships. In tracing scours, a line was drawn along each berm or edge. While most scours were traced, some less prominent features were neglected. Symbols for ridges and troughs in the legend refer to features larger than scours, or which may not be scours. Lineations of indeterminate origin were indicated with a single line.

Low reflectivity areas other than acoustic shadows are indicated with a dotted line. These areas represent seabed textural differences, and are interpreted to indicate ponding of 'finer' sediment within 'coarser' highly reflective seabed areas. Reflectivity is a relative characteristic, so the actual texture of both finer and coarser sediments may vary across the area. Previous research indicates that the immediate seabed of the continental shelf is composed primarily of sands and gravels (Praeg et al., 1986), while finer sediments are observed on the continental slope and Gjoa Spur (see General Description). Low reflectivity areas indicative of fine sediment include the troughs of many larger iceberg scours, although these are not indicated separately. Such troughs frequently occur in association with scour margins which are poorly defined, in contrast to well defined or 'fresh-looking' scours nearby. These features suggest degradation of scour berms and infilling of troughs, a pattern of seabed modification previously recognized on both the Southeast Baffin and Labrador Shelves (Praeg et al., 1986; Josenhans and Barrie, 1982). Although only some scours show significant evidence of degradation and/or infilling, many others may be modified to a degree or at a scale too small to be resolved by the Sea MARC I system.

The variations in scour, abundance, size and orientation across the area were evaluated qualitatively. Abundance was assessed as proportion of seabed scoured (high, medium, low). Scour depths (from bottom profiles) and widths were fairly consistent in a given area, so that representative values were easily estimated. Scour orientations were assessed as consistency of the population, and direction relative to the bathymetric contours. Scour orientations on sidescan imagery can have some dependence on the direction of insonification, i.e. scours parallel to the survey line can appear more prominent than those transverse to it (Todd, 1984). In the case of the mid-range Sea MARC I imagery, scours can generally be observed in numerous orientations in a given area, and apparent scour orientations vary in consistency and direction across the study area despite the generally fixed orientation of the survey line (Fig. 1), suggesting that true relative variations are being portrayed.

General Description

The seabed of the continental shelf and upper continental slope is dominated by iceberg scours, including both linear furrows and subcircular pits (Sections 1-6); ponded sediments and surface expressions of the subsurface bedrock are observed locally (e.g. Section 1). The shelf along the survey line is divided into inner, central and outer parts for convenience in discussion. Iceberg scours are most abundant in the central part of the shelf, where the entire seabottom has been reworked (Sections 2-4), while reduced abundances are observed on the inner and outer shelf and upper continental slope (Sections 1, 4-6). Iceberg pits occur throughout, but are locally abundant across the transition from the central to outer shelf (Section 4). Iceberg furrow orientations appear to bear a relationship to bathymetry in the central shelf, where most are approximately parallel to the local gradients (Sections 2-4), but orientations are less consistent elsewhere (Sections 1, 4-6). Furrow sizes are fairly consistent across the area at up to 50 m width and up to 3-4 m depth, but exceptional features up to 100 m width are observed (e.g. Section 2). Degradation and/or infilling of scours is recognized across the area in greater (Sections 1, 6) and lesser (Sections 2, 3) degrees. The maximum water depth of iceberg scours occurs on the upper continental slope at approximately 715 m depth (Section 6). Below this depth to about 1500 m the seabottom appears largely featureless (Sections (6-8), and subbottom profiles indicate a mud layer 3-5 m thick. The seaward end of the line crosses the southern tip of the Gjoa Spur (Fig. 1), which is associated both with ponded sediments, and with slope-transverse lineations which may relate to mass movement (Section 9).

Data quality was affected by both water and weather conditions. The outer kilometre of each channel of records from the continental shelf and upper continental slope is dominated by seasurface or water column interference (Sections 1-6), due to the relatively shallow tow-depths. Transverse white lines are present across records from the continental slope below approximately 900 m (Sections 7-9), due to increased ship and vehicle motion and poor reception in response to deteriorating weather conditions; loss of bottom tracking also occurs in several places (Sections 8, 9).

Section Descriptions

Section 1

The section shows the inner part of the continental shelf, at the northeast margin of the Resolution Basin (Fig. 1) from depths of 400 m up to 325 m. Gradients are up to 0.7° on the basin flank, and are up to 0.4° over the variable bottom to seaward. The outer kilometre of each channel is dominated by interference.

Resolution is poor at the beginning of the record on the basin flank, but the sidescan imagery suggests a complex seabed pattern below about 375 m consisting of moderate abundances of iceberg furrows and pits which show little consistency in orientation. Relief across this pattern is subdued (<2 m on bottom profiles). Individual scours are generally poorly defined, are difficult to trace laterally, and are often associated with low reflectivity troughs indicative of fine sediment infilling. These latter features increase in abundance downslope, grading into sub-linear to sub-circular low reflectivity patches near the beginning of the record interpreted as ponded sediment. These characteristics suggest significant degradation and infilling of the scours. On the basin flank above approximately 375 m, these subdued scours are cross-cut by moderate abundances of well-defined furrows, which are associated with more hummocky relief (1-3 m on bottom profiles), and which appear to be an extension of the main population observed seaward of the basin (Sections 2 and 3).

Scours are abundant on the bathymetric high immediately seaward of the basin, and are somewhat less numerous in the adjacent bathymetric low at the eastern end of Section 1. Furrow orientations vary from almost slope-transverse to slope-parallel, with perhaps more tending towards slope-parallel. Scours here and to seaward (Sections 2 and 3) are generally well-defined on sonograms and associated with hummocky relief (1-3 m) on bottom profiles, distinct from the subdued texture on the flank of the Resolution Basin, although individual examples of poorly defined, and/or infilled scours can be found.

At the seaward end of Section 1, three ridges and associated troughs with 10 m relief are observed on bottom profiles. These are faintly visible on the sidescan imagery, highlighted by ponded sediments in two of the troughs, and by the orientation of some individual furrows which appear to follow or at least reflect the local variations in bathymetry. These ridges and troughs are observed on a high resolution subbottom profile across the area, which indicates they represent a subsurface erosional 'hill and valley' topography cut into the Tertiary bedrock (Praeg et al., 1986, Fig. 25).

Sections 2 and 3

The sections show the central part of the continental shelf from depths of 375 m up to 320 m. The line crosses the Hekja well site, then turns north and east again to cross the Ralegh well site (Fig. 1). The seabed slopes generally southeastward at gradients of 0.2° - 0.5°. The outer kilometre of each channel is dominated by interference.

Iceberg scour abundances are high across this interval, the entire seabottom having been affected; high resolution subbottom profiles from the area show acoustically unstratified sediments of Davis Strait Silt Subunit B similar to those in Fig. 2. Furrow orientations vary, from almost slope-transverse to slope-parallel, but the dominant trend is close to slope-parallel. Individual furrows can be traced through both orientations (see Trend 1, Section 3). A small number of furrows are observed which appear to trend almost north-south, and which are generally cross-cut by the dominant population (see Trend 2, Section 3). Furrow sizes are generally similar at up to 50 m width and up to 3 m depth, but exceptional scours up to 100 m wide are present, for example southeast of the Hekja well site (Section 2). Most scours are well-defined and appear relatively unmodified, but some are poorly-defined and/or have low reflectivity troughs suggesting degradation and/or infilling. The well-defined scours may be modifed to a degree not resolved by the Sea MARC I system. This is supported by randomly collected samples and bottom photographs from the area of the Hekja well site (Section 2), which indicate a bottom that is locally texturally variable from sandy mud to sandy gravel.

Section 4

The section shows the transition from the central shelf above about 375 m, with gradients generally greater than 0.3°, to the outer shelf below about 375 m, with gradients generally less than 0.1° (Fig. 1). The outer kilometre of each channel is dominated by interference.

On the central shelf, the seabed is similar to Sections 2 and 3: iceberg scour abundances are high, and furrows are fairly consistently oriented, most lying close to slope-parallel. On the lower gradients of the outer shelf, scours are both reduced in abundance and less consistently oriented (see Section 5). The transition is marked by a large number of sub-circular pits 50 - 150 m in diameter. At least one of these occurs at the beginning of an iceberg furrow and is therefore demonstratably an iceberg grounding pit, while most others appear to be isolated impact features. Most have low-reflectivity floors suggestive of fine sediment infilling; a grab sample in the middle of Section 4 consists of sandy gravel, demonstrating the significance of current activity in this area. The pits are most abundant between approximately 380-410 m, but extend to the end of Section 4 and across the outer shelf (Section 5) in reduced numbers.

Section 5

The section crosses the outer part of the continental shelf, from approximately 400 m to 500 m (Fig. 1). The seabed slopes gently southeastward at gradients less than 0.1° to the shelf break at approximately 460 m, near the eastern end of the section. The outer kilometre of each channel is dominated by interference, which is more pronounced in the eastern half of the section in response to increased fish depth.

Iceberg scour abundances are reduced in comparison to the central shelf (Sections 2-4), and patches of unscoured or partly-scoured seafloor are evident. A high resolution subbottom profile located along the Sea MARC I line (Geonautics Ltd., 1982) shows that these unscoured or partly-scoured patches coincide with intervals of subsurface stratification within Davis Strait Silt Subunit B. Iceberg furrows are poorly-oriented, varying from approximately slope-transverse to slope-parallel as on the central shelf, but showing no marked preference for a particular orientation. Furrow widths are up to 50 m, similar to the central shelf, but depths are slightly greater at up to 4 m; exceptional features, up to 100 m wide and 8 m deep are also present. Many scours are poorly defined, some in association with low reflectivity troughs, and sub-linear to sub-circular low reflectivity patches including infilled pits are present in places. These features suggest a greater degree of degradation and/or infilling than observed on the central shelf (Sections 2-4).

A linear trough approximately 150 m wide and 7 m deep is observed on the sidescan imagery at approximately 61°45'W longitude, oriented almost perpendicular to the survey line. It could be either an exceptionally large scour, or a surface expression of the subsurface unconformity between unconsolidated sediments and Tertiary sedimentary bedrock. A high resolution subbottom profile across the area (Geonautics Ltd., 1982) shows several large scours, of comparable size, and a fairly smooth bedrock surface.

Seaward of the shelf break at 460 m, gradients increase to almost 2° and iceberg scours are less consistently oriented and appear less laterally continuous. Upper continental slope features are discussed in Section 6.

Section 6

The section crosses the upper continental slope from approximately 500 m to 900 m depth (Fig. 1). The seabed slopes generally eastward, with gradients decreasing from almost 2° below the shelf break to 0.8° at the eastern end of the section. Interference in the outer kilometre of each channel decreases seaward and finally disappears, due to the increasing water and fish depths.

Iceberg scour abundances are low below the shelf break, similar to the outer continental shelf (Section 5), and gradually decrease seaward. A high resolution subbottom profile shows intervals of subsurface stratification, which abruptly become dominant below approximately 600 m depth (Geonautics Ltd., 1982). Furrows are almost randomly oriented, and several individual scours appear to exhibit sudden changes in orientation. Furrows appear shorter (less laterally continuous) than on the continental shelf, and sub-circular pits are present. Furrow sizes are still generally up to 50 m wide and up to 4 m deep; a few larger features are present, for example at approximately 670 m where a 10 m deep trough on subbottom profiles corresponds to an approximately 100 m wide furrow on the sidescan imagery. Seabed features are generally poorly defined, and low reflectivity areas including scour troughs are increasingly common in deeper water, suggesting degradation and/or infilling.

The maximum depth of iceberg scours is observed on the sidescan imagery at approximately 715 m. On subbottom profiles this depth corresponds to the lower limit of hummocky seabed with hyperbolic reflections, below which a smooth-surfaced 3 - 5 m thick transparent (mud) layer occurs. The base of the mud layer shows some broad, low relief which is not associated with hyperbolic reflections, and is not considered to reflect buried scours. Two sub-circular low reflectivity areas are observed below this depth on the southern channel, at about 850 m, and correspond to a local reduction in gradient on bottom profiles. The surface of the mud layer appears largely featureless on the sidescan imagery, save for numerous fine, discontinuous, low reflectivity lineations which show a preference for orientations 45° to the survey line. The lineations are thought to subtly reflect large-scale surface relief, rather than actual seabed events.

Sections 7 and 8

The sections cross the continental slope from approximately 900 m to 1200 m depth(Section 7) and 1200 m to 1500 m depth (Section 8) (Fig. 1). The seabed slopes generally eastward, gradients decreasing from 0.8° to less than 0.5°. From the beginning of Section 7 to seaward the sidescan imagery contains increasing numbers of transverse white lines (data gaps), due to deteriorating weather conditions.

Subbottom profiles show that the 3 - 5 m thick mud layer observed below 715 m in Section 6 is continuous across these two sections. As in Section 6, the surface of the mud layer appears largely homogenous on the sidescan imagery, save for numerous fine, discontinuous, low reflectivity lineations, which appear to subtly reflect large-scale surface relief. An exception is the interval on Section 8 between approximately 1250 m and 1325 m depth, where variations in reflectivity are observed in the outer kilometre of both channels, similar to the water column interference observed in Sections 1-6. This interval does not correspond to any surface irregularities on bottom profiles, but does coincide with the appearance of a subsurface reflector at approximately 15 m depth on subbottom profiles. The possible relationship between the reflector and the sidescan imagery is unclear.

Section 9

The section crosses the southern tip of the Gjoa Spur and its irregular seaward flank (Fig. 1). Depths range from 1300 m at the spur crest to over 2000 m in a trough to seaward; two other troughs are present, one on the seaward flank of the spur at approximately 1600 m depth and the other at the spur crest. Gradients average 4° on the flanks of the spur, and locally increase to approximately 10° and 20° on the walls of the troughs at the spur crest, and farthest seaward, respectively. The record is crossed by numerous transverse white lines (data gaps) due to weather conditions; bottom tracking was intermittent or absent over much of the section.

Subbottom profiles indicate that the 3 - 5 m thick mud layer observed in Sections 6-8 extends across the beginning of Section 9 and terminates against the base of the Gjoa Spur at approximately 1500 m depth; sidescan imagery is uninformative across this interval. Wavy, slope-transverse lineations and tonal changes are observed on both flanks of the Gjoa Spur, on slopes with gradients of approximately 4°. These features are similar to lineations observed on Sea MARC I records from the Nova Scotia continental slope, which have been interpreted to reflect mass movement (Piper et al., 1984). The fine, discontinuous, low reflectivity lineations observed on the surface of the mud layer in Sections 6 - 8 are present across the Gjoa Spur in Section 9, and to some extent grade into the slope-transverse features; as in Sections 6 - 8, they appear to subtly reflect large-scale surface relief. Three large low reflectivity areas are observed in Section 9, coincident with the three troughs on the spur crest and seaward flank. On subbottom profiles, the middle of these three areas corresponds with ponded sediments; the other two are not as well resolved, but ponded sediments seem likely by extension. On the steep western wall of the seawardmost trough, a linear low reflectivity zone oriented transverse to the regional isobath trend is observed on the southern edge of the sidescan imagery, suggesting a local channel on the wall of the trough. The distribution of low reflectivity ponded sediments on the northern side of both this trough, and the one at the spur crest, is suggestive of meandering linear areas which may be channels distributary to the trough floors..

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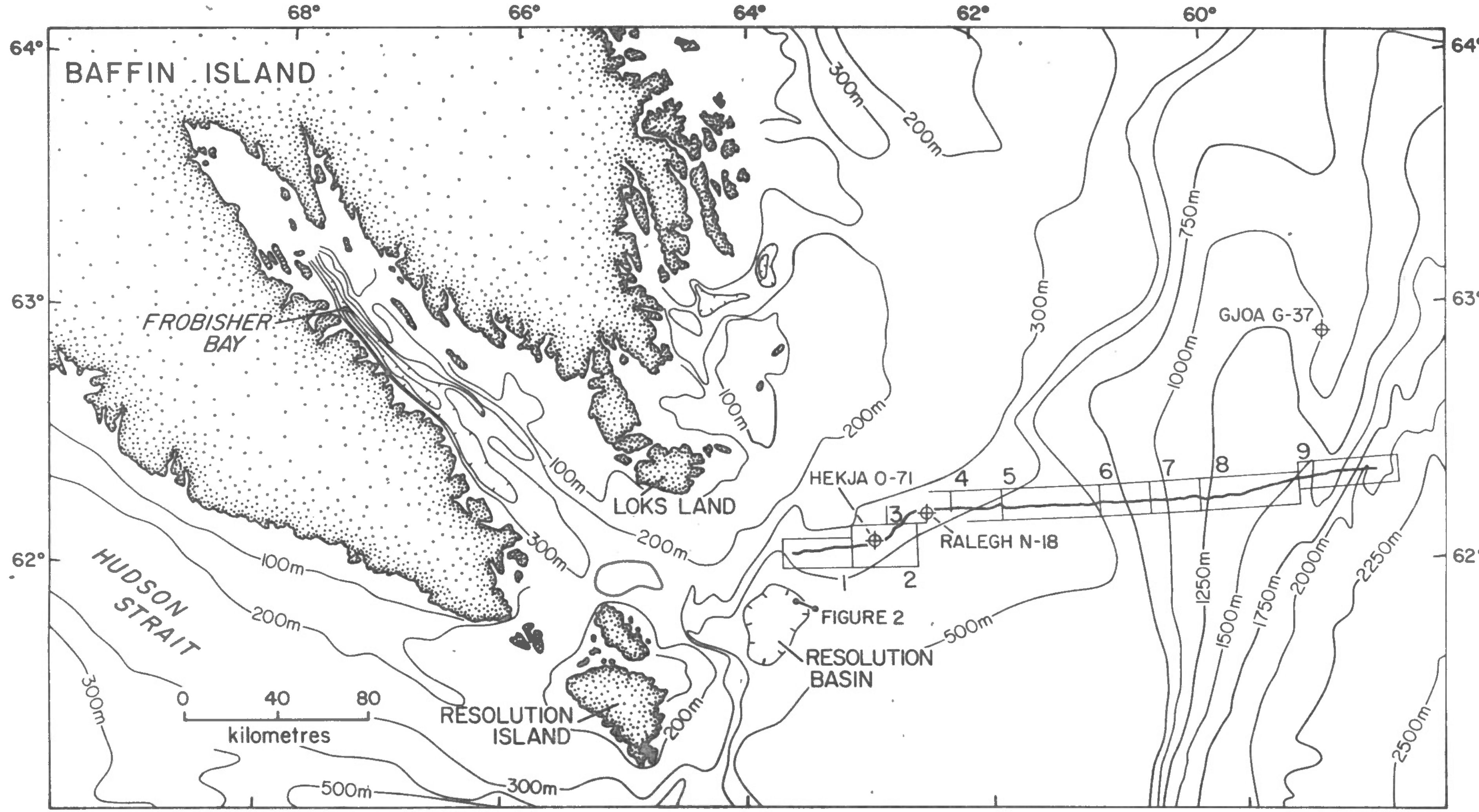

FIGURE 1. Index map of the continental shelf and slope off southern Baffin Island, showing the locations of the Sea MARC I survey line and Sections 1-9, and of Fig. 2. The positions of 3 offshore exploratory wells are also shown.

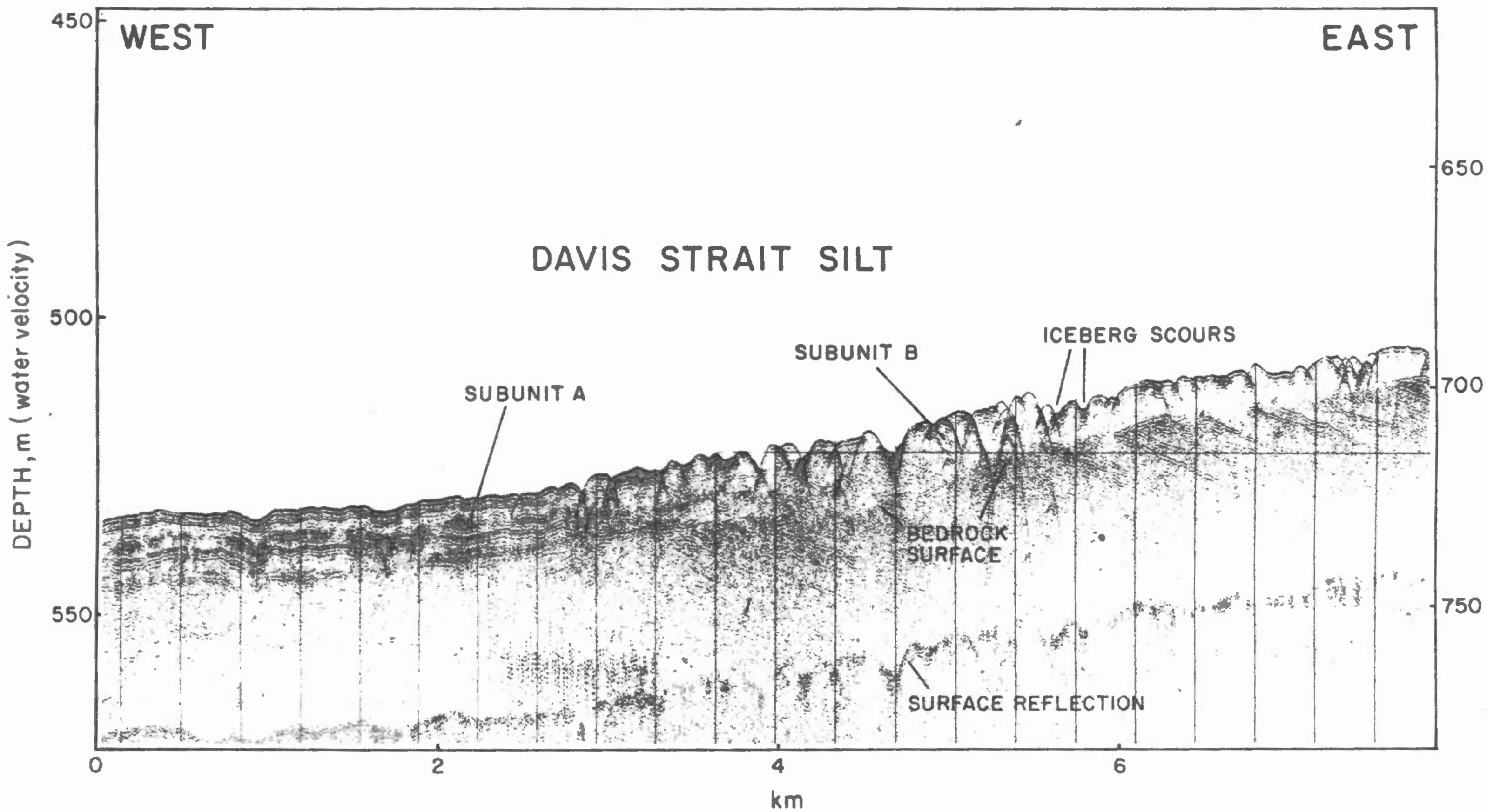

FIGURE 2. Huntec DTS high resolution seismic reflection profile illustrating lateral equivalency between the acoustically stratified sediments of Davis Strait Silt Subunit A and the acoustically unstratified, iceberg scoured sediments of Subunit B. The unconsolidated sediments unconformably overlie gently seaward dipping strata of semi-consolidated Tertiary sedimentary bedrock. See Figure 1 for location. (From Praeg et al., 1986.)