Marine Geological Investigations in the Beaufort Sea in 1981 and Preliminary Interpretations for Regions from the Canning River to the Canadian Border.

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INTRODUCTION

The USGS vessel R/V KARLUK ran approximately 1000 km of geophysical tracklines on the inner shelf of the Beaufort Sea, Alaska from July 14 to August 20, 1981. In addition to the trackline surveys, 37 sediment grab samples were collected, one area was investigated by scuba divers, and 5 sites were monitored with Ocean Bottom Seismographs (OBS), three per site. The R/V KARLUK left the Beaufort Sea on August 20 to support investigations by Drs. Ralph Hunter and Larry Phillips in the Chukchi Sea.

In our 1981 field efforts, the emphasis was on reconnaissance data collection from the eastern sector, between the Canning River and the international border. This work was accomplished in two legs, the first one under P.W. Barnes, the second under Erk Reimnitz. Ice and weather conditions were about average to favorable for inner shelf navigation during the first half of the available open-water season. In this report we outline the general scope of our 1981 field efforts in the Beaufort Sea, the types of equipment used, list much of the data gathered, present those parameters and relationships already extracted from the geophysical records, and give preliminary interpretations of our findings.

DESCRIPTION OF FIELD OPERATIONS

Reconnaissance work

Our primary goal, a reconnaissance survey from the Canning River to the Canadian border, where almost no inner shelf data had been available, was accomplished (see Fig. 1). Geophysical lines were run as far offshore as ice concentrations allowed. All lines from the Canning River eastward extend seaward into very tight pack ice, beyond which further penetration was impossible. Early in the season this tight pack ice was near the coastline. As the season progressed, lines could extend farther seaward. One bay and one lagoon were surveyed. Thirty-seven grab samples were collected, mainly on the open shelf. For this reconnaissance work navigational control is based on radar fixes and dead reckoning. The probable uncertainty in position ranges from 100 or 200 m near shore, to as much as 3 km under dead reckoning on the seaward ends of several tracklines.

Site-specific work

Between the Canning River and the Colville River, surveys were site specific. Detailed surveys for preparation of side-scan sonar mosaics with bathymetry were run in four small areas, two on Stamukhi Shoal, one on the 18-m bench seaward of Narwhal Island, and another one on the 18-m bench seaward of Reindeer Island. Detailed bathymetric surveys were run around the "West Dock," and around two artificial gravel islands: Niakuk 3 and B.F. 37. Two test lines from previous years were re-run (first run in 1973, see Reimnitz, et al., 1977; and Barnes, et al., 1978) and two new test lines were established with side-scan sonar to determine yearly rates of ice gouging. For all of these detailed surveys, positions were plotted using a Del Norte Trisponder system with a distance measuring accuracy of ± 3 m. This system provides a position accuracy of ± 8 m.

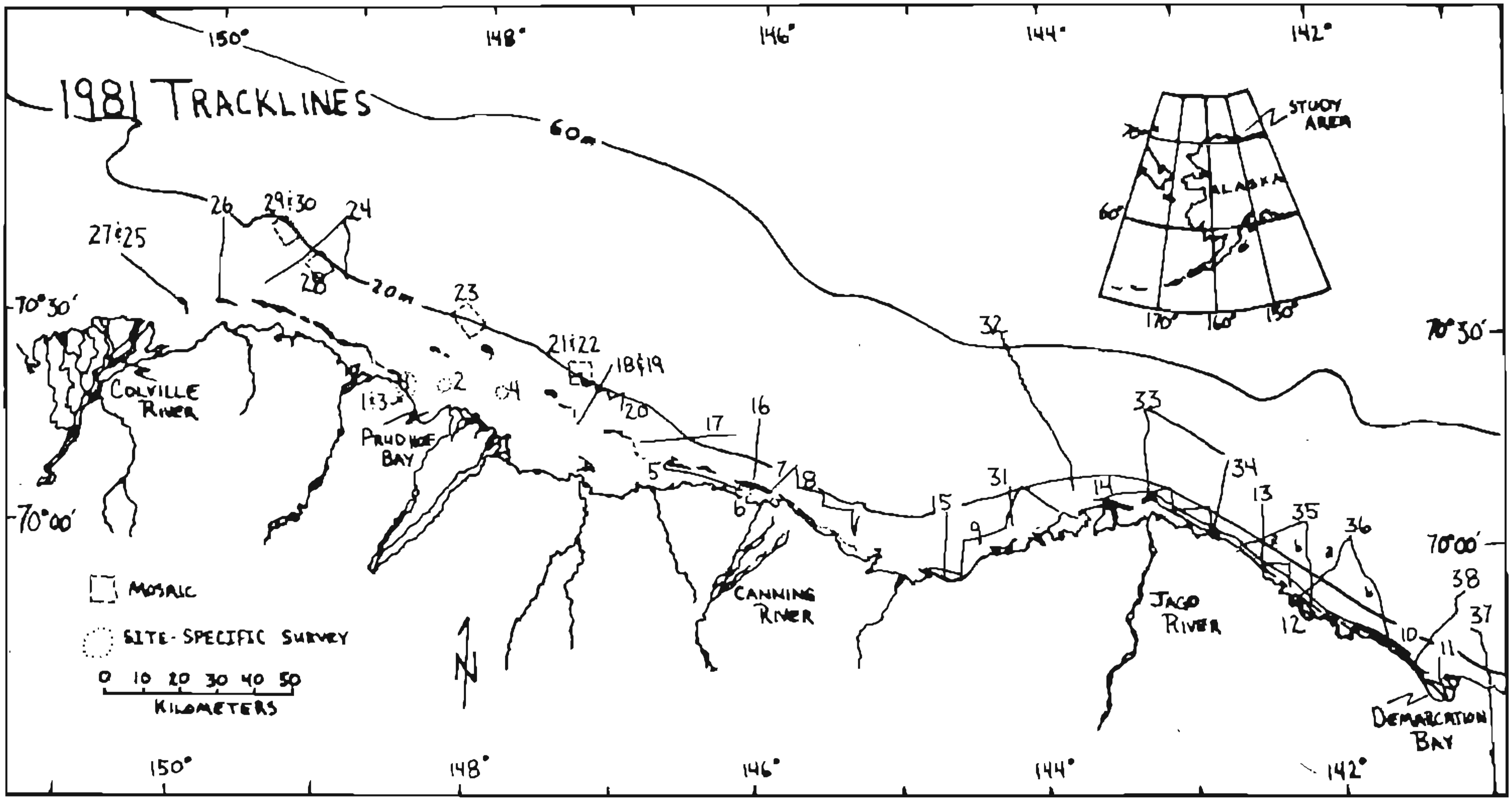

Figure 1.- 1981 geophysical tracklines, side-scan sonar mosaics, and site specific surveys, with line numbers listed in Table 1.

Miscellaneous Studies

Three ocean-bottom seismographs (OBS) were deployed overnight at five different localities in shallow water between longitude 148° West and the Canadian border. The water depth ranged up to about 4 m. The purpose of this work was to monitor reported low-frequency natural seismicity in areas of decaying permafrost.

The diving investigation consisted of a roughly 1.5 km dive sled traverse through the area of the North Stamukhi Shoal side-scan sonar mosaic. Pingers were placed on the sea floor at each end of the traverse to facilitate rerunning of the ship- and diving surveys in later years. A large area around each transponder was seeded with lead birdshot for follow-up studies of sedimentation and shoal migration.

EQUIPMENT USED

Bathymetry was recorded on a Raytheon RTT 1000 dry paper recorder using either a hull-mounted 200 kHz transducer with an 8° beam width, or a 200 kHz transducer with a 4° beam width (narrow beam). All records were corrected for draft of vessel or tow depth. A 7 kHz transducer was used in conjunction with the RTT 1000, recording subbottom reflectors up to 10 m below the sea floor. Deeper penetration high-resolution seismic data were recorded on an EPC model 1400 recorder using 1/4 second sweep and firing rate with a 300 Joule EG&G Model 234 Uniboom as a sound source. The signal was filtered to approximately 600-1600 Hz.

Side-scan sonar records were taken using a Model 259-3 EG&G wet paper system and a Model 272 sonar fish with a 105 kHz 1/10 second pulse at a 20° beam angle depression. Records were also taken on a EG&G Model SMS 960 digital system. The digital data for the mosaics were recorded on magnetic tape on a Kennedy Model 9000 magnetic tape recorder. The Model 272 sonar fish was used for both systems--the digital and the wet paper recorders.

OBS data were recorded on a 3-receiver system designed and built by Polar Research Laboratories of Santa Barbara, California. The three units were deployed in triangular arrays at each of 5 sites, with an internal spacing of about 100 m. These systems are capable of recording seismic signals in the frequency range from 0 - 50 Hz.

DATA ACQUIRED

Geophysical data acquired (see table 1) consist of approximately 1005 km of trackline bathymetry along with 7 kHz subbottom profiles, 800 km of side-scan sonar records, and 500 km of Uniboom seismic reflection records. The data listed in table 1 are keyed to figure 1. The data are in the form of 29 rolls of bathymetry, 20 rolls of side-scan sonar, 10 rolls of Uniboom records, 5 rolls of Simrad fathometer records, 38 reels of recorded side-scan magnetic

Table 1 - Geophysical data*

Line No.	Description	Raytheon	Side-scan	Uniboom	Kilometers
1	West Dock	yes	--	--	22
2	Niakuk Island	1	--	--	10
3	West Dock	1	--	--	22
4	Exxon Island	2	--	--	7
5	Outside Leffingwell Lagoon	2	--	1	24
6	Flaxman Island channel	2	--	1	6
7	Outside Flaxman Island	3	1	--	9
8	West Camden Bay	3	1	--	17
9	East Camden Bay	4	2	1	56
10	East of Jago Spit	6	5	--	81
11	Demarcation Bay	7	6	2	30
12	Beaufort Lagoon	8	7	3	17
13	Outside Beaufort Lagoon	9	7	3	29
14	East of Jago Spit to Barter Island	10	8	4	43
15	Test Line 7	11	9	4	19
16	Test Line 8	12	9	5	17
17	East of Pole Island	12	--	--	26
18	Test Line 6	13	10	5	17
19	Reciprocal, Test Line 6	13	11	--	17
20	18-m bench delineation	14	--	--	28
21	Mosaic northeast of Narwhal Island	15	12	--	55
22	Continue mosaic	16	12	--	
23	18-m bench north of Reindeer Island	16	13	--	23
24	Cat Shoal	17	--	--	45
25	Test Line 1	--	13	--	10
26	Test Line 2	18	14	--	20
27	Test Line 1	18	14	--	19
28	South Stamukhi Shoal Mosaic	19	14	--	46
29	North Stamukhi Shoal Mosaic	21	16	--	
30	Rerun 1977 lines on Stamukhi Shoals	23	--	--	65
31	Camden Bay to Barter Island	23	--	6	9
32	Continental Shelf Run off Barter Is.	23	17	6	48
33	Seaward leg offshore east of Barter Island (+ 14 km run over)	25	18	7	20
34	Shoreward leg east of Barter Island	26	18	7	19
35	Dogleg offshore & back into Pogok Bay	26	19	8	41
36	Offshore and back outside Beaufort Lagoon	27	19	8	52
37	Line at U.S./Canadian Border	29	20	9	19
38	Offshore Demarcation Bay	29	20	10	24

*Numbers in the Raytheon, side-scan and uniboom columns represent beginning roll numbers and signify data gathered on that line by that system. No number means the system was off.

tape, 120 hours of OBS magnetic tape, 8 field maps, and the ship's log. The ship's log contains important information on systems in use on each line, system settings (scale, filters, etc.), navigational data used in plotting positions, severity of ice conditions and course-holding problems and unique observations or systems difficulties. Copies of all field data are available on microfilm from the National Geophysical and Solar Terrestrial Data Center, NOAA, Boulder, Colorado. The microfilm is a copy of the geophysical records, ship's log and computer print-out of digitized way points. The printout of these way points would allow for reproduction of tracklines at any scale, and correlation to geophysical records through time points. Originals are archived at the U.S. Geological Survey, Deer Creek Facility, 3475 Deer Creek Road, Palo Alto, California 94304.

Surface samples collected are listed in table 2, along with water depth, longitude, and latitude, and shipboard sample descriptions and observations. The locations are shown in figure 2. Almost all samples were obtained with a grab sampler. The bulk of the material is being kept at our facility in Palo Alto, California.

DATA ANALYSIS

In our analysis of the geophysical reconnaissance data obtained between the Canning River and the Canadian border the focus has been on ice gouging. For the analysis we have basically used the shore-normal transects and eliminated shallow-water, shore-parallel lines (Fig. 3). The short time available for analysis required reduction of the number of parameters extracted from sonographs and fathograms, compared to the very thorough analysis completed for the region west of the Canning River (Rearic et al., 1981). A copy of the completed data sheets used in this study is presented here as an Appendix. As in previous work, the tracklines are broken for statistical analysis into 1-km-long segments, as listed in the first column of the data sheets. The parameters we considered most significant for this study are the following:

1. Water depth - to find relationships to severity of gouging.
2. Gouge depth - maximum gouge incision depth per km segment.
3. Ridge height - to allow calculation of total relief from gouging.
4. Gouge width - maximum per km segment.
5. Gouge density - the number of gouges actually counted is to the left of the normalized count listed in this column and separated by a slash.
6. Gouge orientation - dominant trend with respect to trackline is to the left of the true north orientations and separated by a slash.
7. Sediment cohesion - an attempt to judge from geophysical records whether the bottom is composed either of sand and coarser non-cohesive material, or of fine and cohesive material, as reflected in the shape and character, of the gouges.

We also measured the depth below sea level of the first continuous subbottom reflector seen on the 7kHz records ("Reflector A"). The main purpose of extracting this data was an attempt to relate ice gouges to the geology of the shelf surface. Subtracting water depth from the structural depth to "Reflector A" gives what we consider the maximum possible thickness of Holocene marine sediments blanketing the inner shelf. Given the fact that

TABLE 2

1981 Sample Descriptions

Station Number	Latitude	Longitude	Water Depth(m)	Type Sample	Reference Location	Description
4	70.387°	148.515°	2	Pachunka	W. Dock	Core length 37.5 cm. Very thin soup on top overlying mud with gravelly mud at base.
5	70.105°	)45.324°	15.5	Grab	Line 8	On seaward flank of shoal. Sand
6	70.104°	145.326°	12.5	Grab	Line 8	On seaward flank of shoal. Clean sand
7	70.103°	145.328°	9.5	Grab	Line 8	On crest of shoal. Coarse sand
8	70.102°	145.330°	13	Grab	Line 8	Inside shoal. Coarse sand and pea gravel (1-2 cm) over grey mud.
9	70.101°	145.333°	13	Grab	Line 8	Inside shoal. Sandy mud. Few pebbles
10	70.020°	145.315°	on beach		Camden Bay	Outcrop of stiff silty clay (?)
11	69.675°	141.319°	5	Grab	Demarcation Bay	Sandy mud with bivalves.
12	69.656°	141.281°	4	Grab	Demarcation Bay	Organic mud, silt and clay with trace of sand.
13	69.655°	141.356°	4	Grab	Demarcation Bay	Organic mud w/worm tubes.
14	69.859°	142.163°	2.2	Grab	Beaufort Lagoon	Sandy organic-rich mud. Peaty material - brown to black
15	69.898°	142.253°	3	Grab	Beaufort Lagoon	Muddy organic sand
16	69.909°	142.315°	2.5	Grab	Beaufort Lagoon	Muddy organic sand
17	70.127°	142.500°	35	Grab	Offshore Pokok Bay	Muddy sand. Soft!
18	70.056°	142.488°	23.5	Grab	Offshore Pokok Bay	Sandy mud
19	70.031°	142.536°	18.5	Grab	Offshore Pokok Bay	After 3 lowerings muddy gravel. Gravel w/benthic growth Stiff, silty clay below?
20	70.017°	142.522°	16	Grab	Offshore Pokok Bay	Fairly clean sand overlain by 1-2 cm of muddy sediments.
21	69.989°	142.518°	7	Grab	Offshore Pokok Bay	Clean fine sand

TABLE 2

1981 Sample Descriptions

Station Number	Latitude	Longitude	Water Depth(m)	Type Sample	Reference Location	Description
22	70.633	148.160°	---	Ice	N. of Reindeer	Stamukhi ice
23	70.633°	148.169°		Ice	N. of Reindeer	Gravelly mud on only one surface of blocky ice floe.
24	70.620°	148.127°	18	Grab	18-m bench/Reindeer	Crest of ridge. Muddy gravel, overconsolidated?
25	70.620°	148.146°	18	Grab	18-m bench/Reindeer	Samples 24,25,26 at top of break in slope on 18-m bench all muddy gravel of various consistencies, from soupy on the west to stiff on the east.
26	70.620°	148.167°	18	Grab	18-m bench/Reindeer	
27	70.498°	143.203°	52	Grab	Line 32	Gravel, up to 3 cm diameter w/bryozoans and other small growth in big gouge terrain with rounded relief. Between pebbles apparently is a trace of trapped transient mud.
28	70.357°	143.292°	40		Offshore Barter Is.	Medium firm grey mud w/ a few scattered very small pebbles.
29	70.230°	142.747°	40	Grab	Offshore Pokok Bay	Firm mud w/ a 5-cm layer of soft mud on top. No shells or pebbles.
30	69.873°	141.717°	23	Grab	Line 36	Pebble rich, sandy mud, soft. Pebbles up to 5 cm w/coral growth, bryozoans.
31	69.882°	141.147°	34	Grab	Line 38	Soft mud, perhaps even transient layer separated by thin black line from finer mud below. No pebbles, probably no sand.
32	69.885°	141.242°	32	Grab	Line 38	Slightly silty clay, increasing very gradually from soupy on surface to slightly firmer below. Several small shells, no pebbles.
33	69.816°	141.259°	30	Grab	Line 38	Silty clay, grey as sample 32 w/gradual increase in strength downward, no sand, small brittle star.
34	69.786°	141.370°	23	Grab	Line 38	Slightly pebbly, sandy mud. Soft at surface (5 cm) and firmer at bottom (15 cm).
35	69.754°	141.444°	16.5	Grab	Line 38	Pebbly, slightly muddy sand. One large pebble (6 cm), subrounded, with much growth, including bryozoans, coral, etc
36	69.739°	141.464°	12.5	Grab	Line 38	Clean pebbly sand, one clast 6 cm. No growth, no mud.
37	69.719°	141.479°	7.5	Grab	Line 38	After 3 lowerings: muddy gravel, clast to 10 cm, no growth.

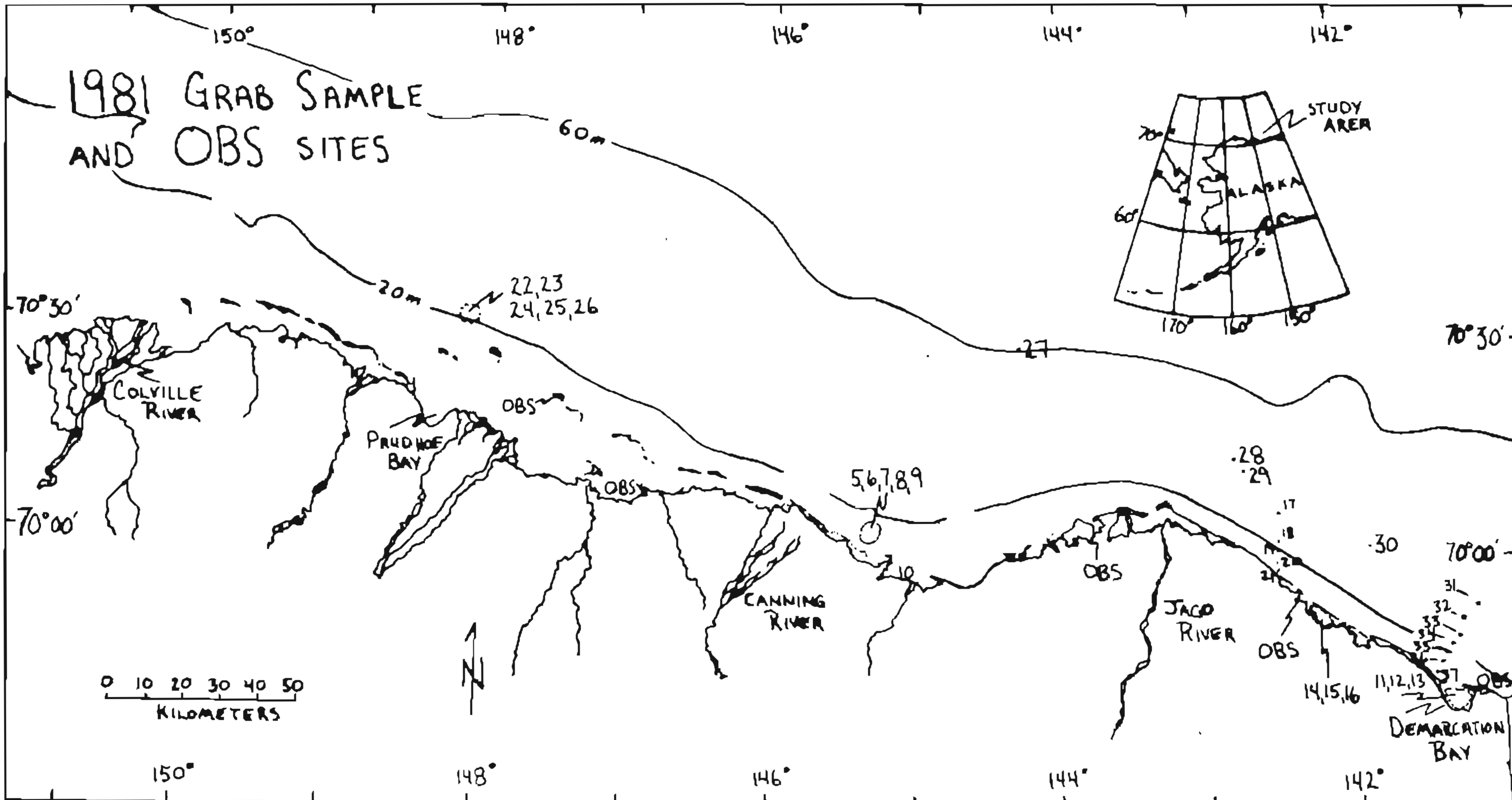

Figure 2. 1981 station locations for grab samples and Ocean Bottom Seismographs (OBS).

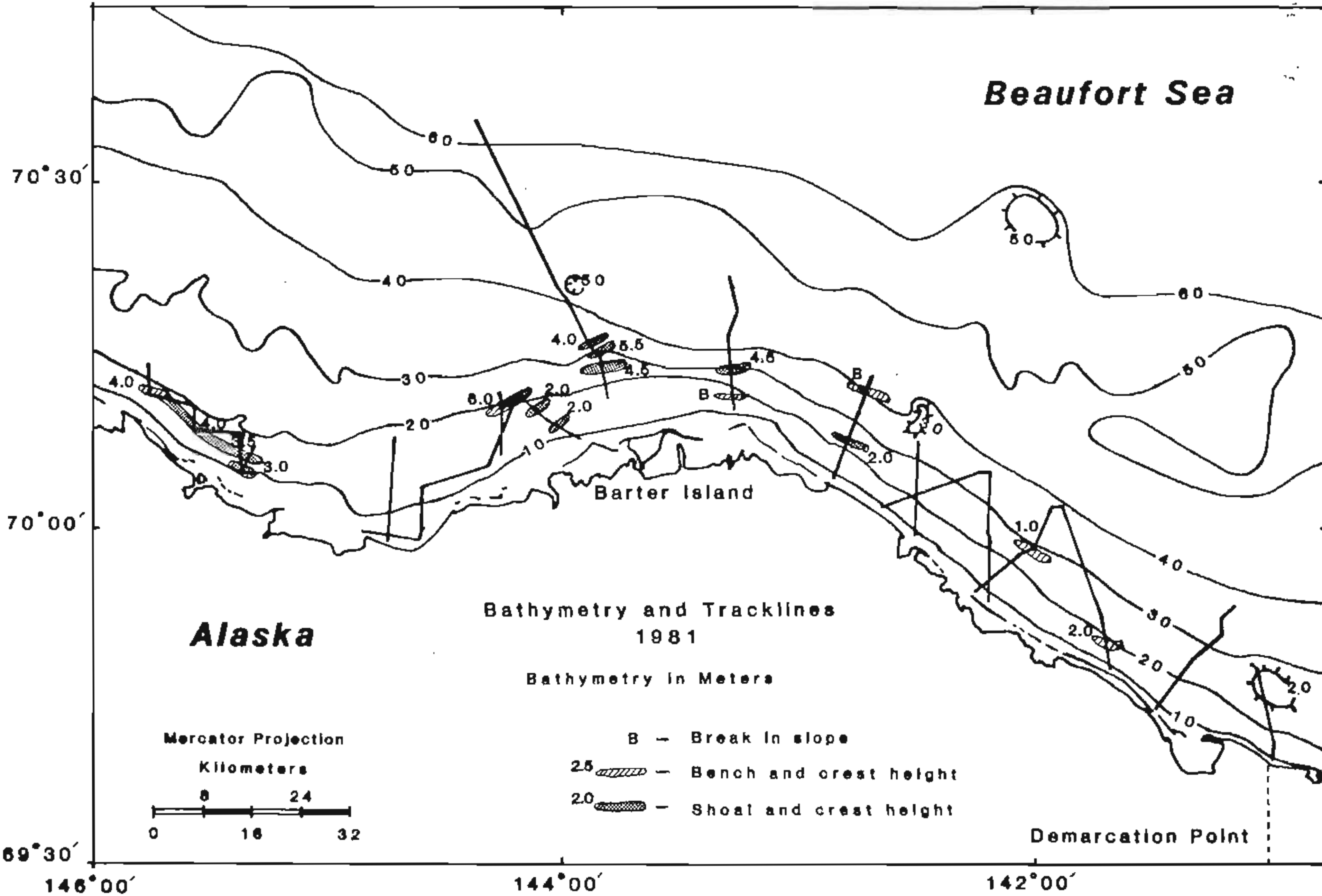

Figure 3.- Bathymetry (from Greenberg et al., 1980) and 1981 tracklines used in the data analysis for the present study area. Shoals and benches, with relief in meters above the surrounding sea floor, are shown.

ice gouging has repeatedly disrupted the sediments here since the last transgression, the Holocene marine sediments should not contain continuous internal reflectors in seismic records, an assumption that has strong support from detailed studies done in the Prudhoe Bay region. But until more detailed work allows us to correlate through the entire region of this reconnaissance survey, we can not put much emphasis on this data.

A computer was used for plotting certain gouge parameters on maps, for simple statistical analyses, and for preparing scatter plots of gouge parameters.

RESULTS

Bathymetry

The bathymetry shown in figure 3 is from Greenberg, et al. (1980), and we generally found no major disagreements with the water depths recorded along our tracklines. However, the trackline off the Canadian border should have crossed a broad shoal suggested by published data, but we found no indications of this feature. Previous work has shown the important role played by shoals in ice dynamics and in controlling ice zonation (Rearic and Barnes, 1980; Reimnitz et al., 1978), and we therefore indicate the major topographic highs crossed by our survey lines, along with the relief above the surrounding sea floor. We assume that these features are oriented generally shore parallel as suggested in figure 3. Only the shoal off the Canning River was surveyed by a zigzag trackline pattern and is well defined.

Ice Gouging

The pattern of dominant ice gouge alignment parallel to regional isobaths as mapped west of the Canning River (Barnes et al., 1981) continues eastward to the Canadian border (Fig. 4). The Barter Island region, forming a major promontory jutting out into the pack-ice drift of the clockwise rotating Beaufort Gyre, separates two regions with distinctly different isobath trends and ice-gouge trends. In figure 5 we plotted water depth against dominant gouge orientation. A clear break is shown at 18-20 m water depth, with considerable orientation scatter shoreward, and parallel alignment seaward. The mean gouge orientation of 103°T in the study area is heavily weighted by trend determinations corresponding to the NW-SE trending isobaths east of Barter Island. By comparison, the mean gouge orientation west of the Canning River is 90°T.

Ice gouge density values (adjusted gouge counts per km of trackline) have been contoured in figure 6. A very well defined zone with over 150 gouges per km of trackline lies in water 18-36 m deep. This zone has been defined by Reimnitz et al. (1978) as the stamukhi zone. The scattergram (Fig. 7) shows a clear trend of increasing gouge densities from the shore to the stamukhi zone, and decreasing gouge densities from there to 58 m water depth. The greatest depth at which a gouge was seen was at 58 m on line 32, which extends to the edge of the shelf. The mean gouge density in the survey area is 108, compared to a value of 63 for the region west of the Canning River. We believe that these higher gouge counts are explained largely by the fact that mean water

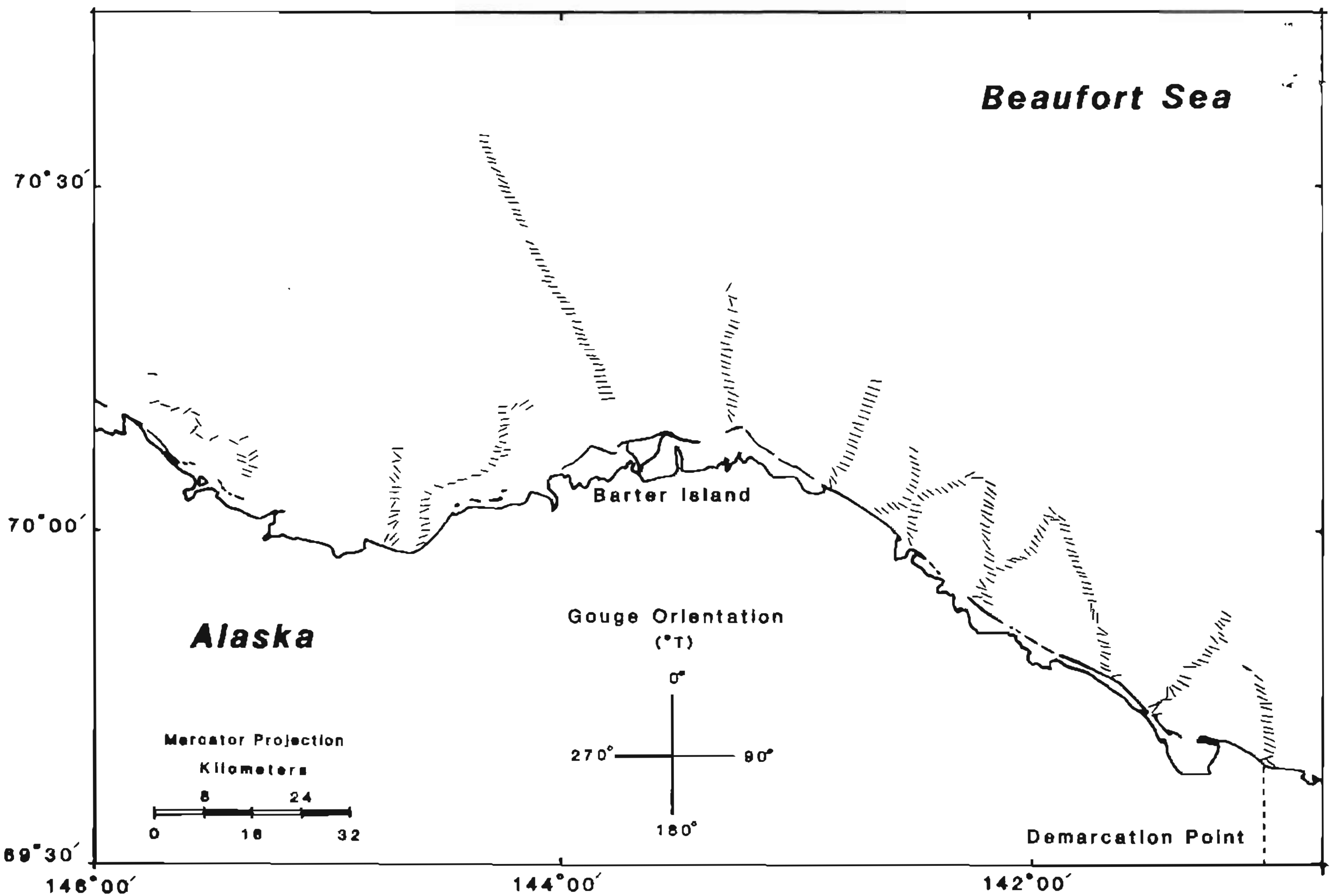

Figure 4.- Gouge orientations in the Barter Island area. Each line represents the dominant gouge orientation measured over 1 km of trackline.

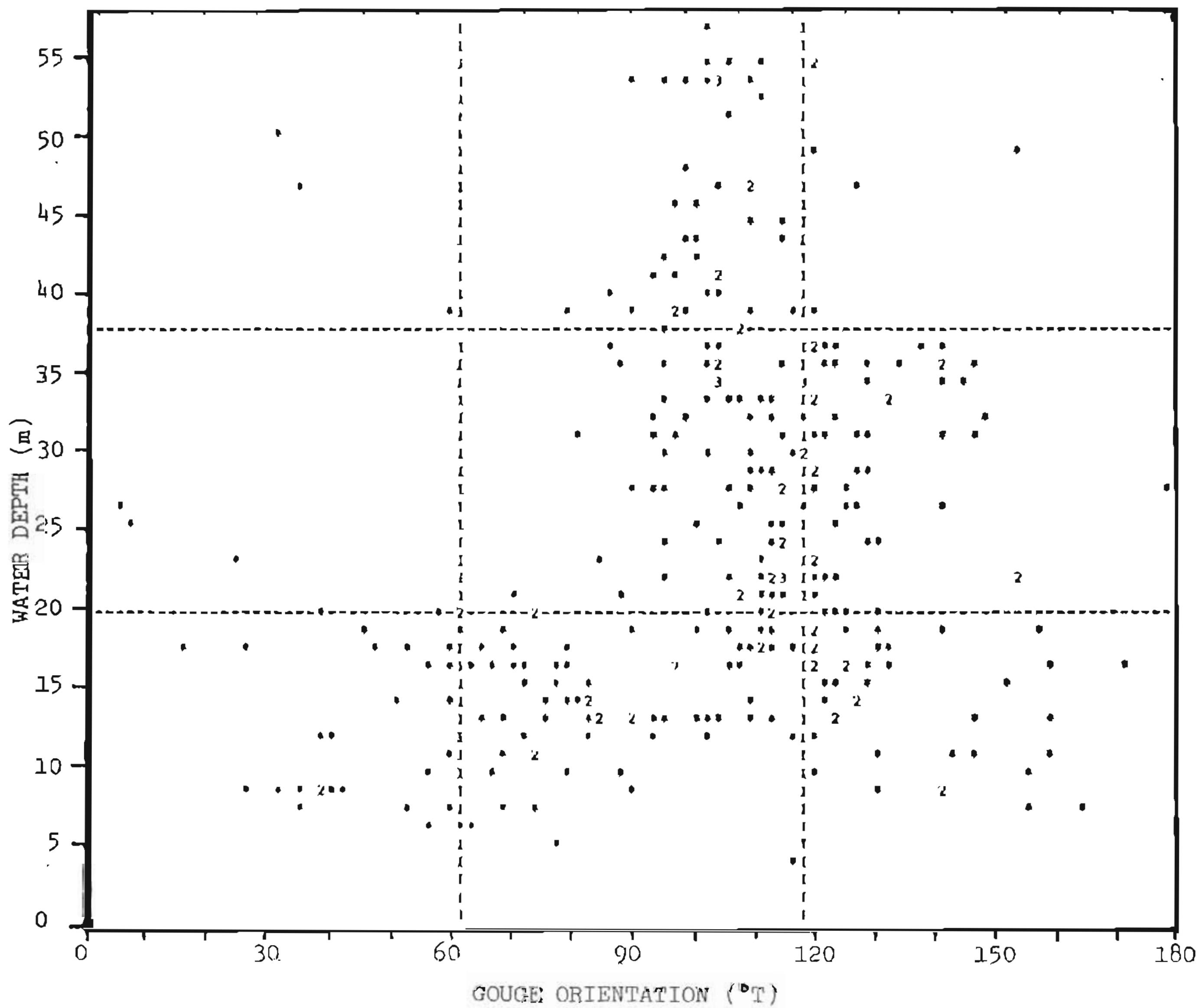

Figure 5.- Scattergram of gouge orientation versus water depth, showing wide scatter at water depths shallower than 18 meters.

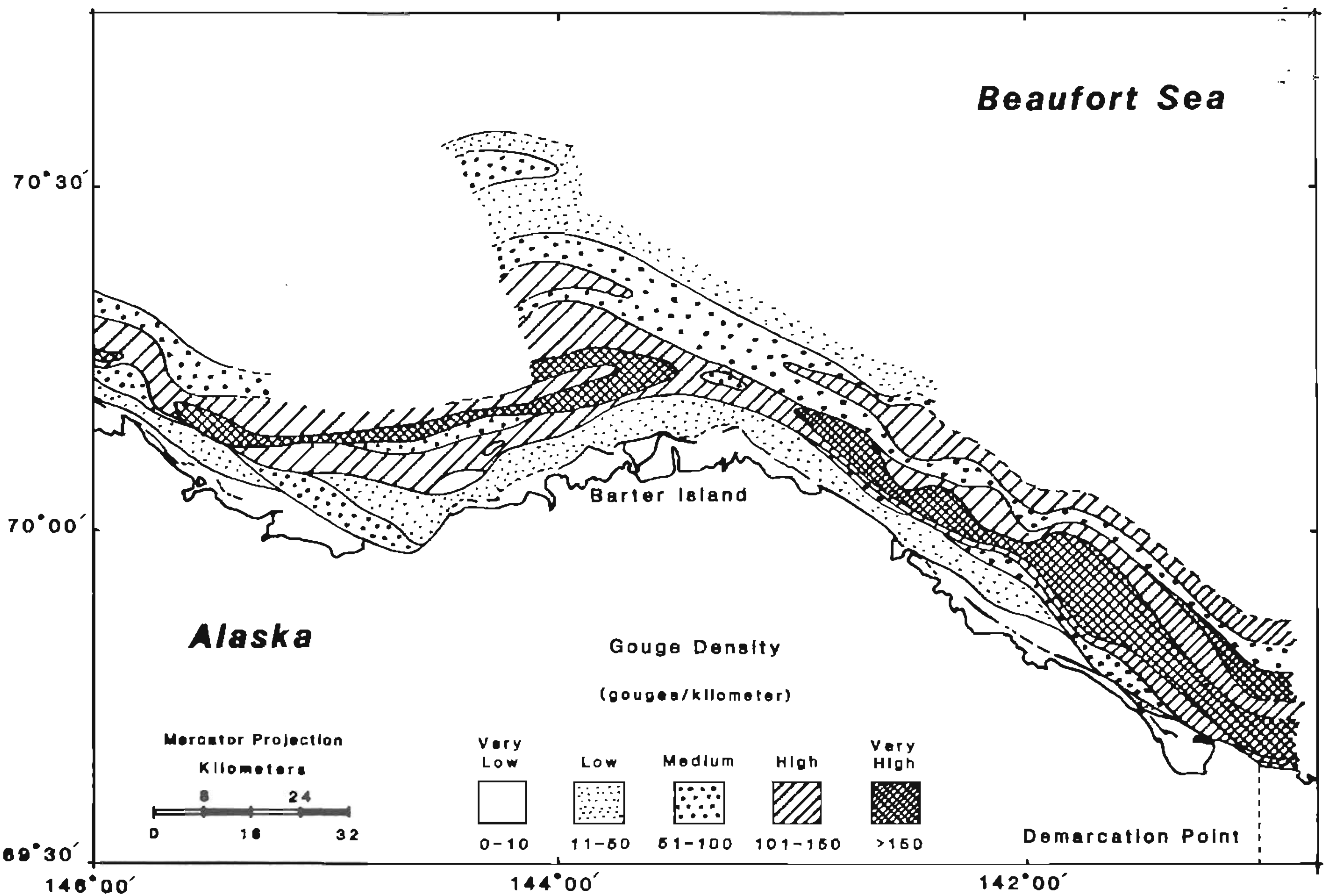

Figure 6.- Contours of ice gouge density values from Camden Bay to the Canadian border.

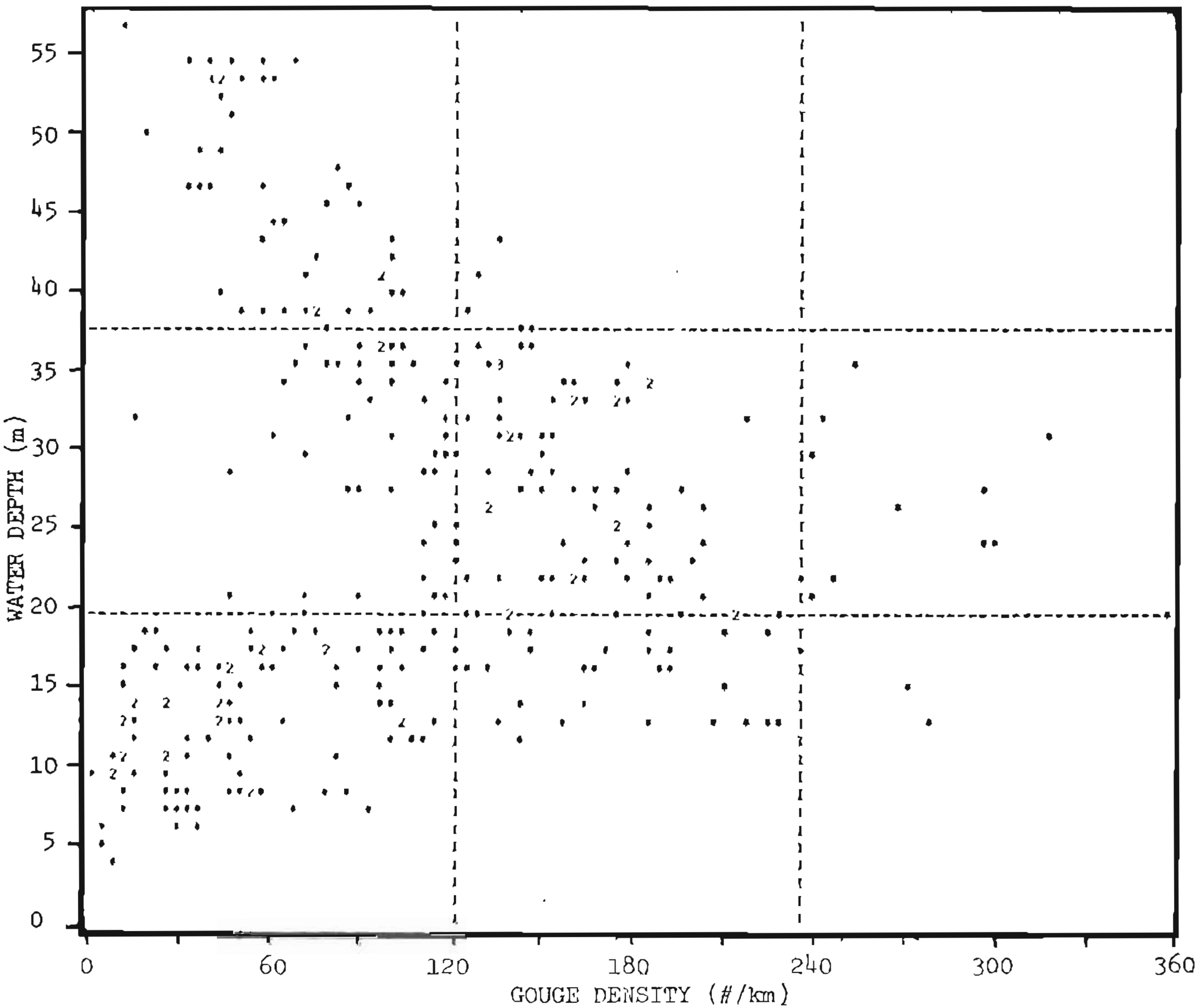

Figure 7.- Scattergram of gouge density versus water depth.

depth for the areas surveyed here is 25 m, which places them largely within the Stamukhi Zone, whereas west of the Canning River the mean depth is 17 m, so that much of the area is shoreward of the Stamukhi Zone.

The maximum gouge incision depths have been contoured in figure 8. Again the 18 m isobath is a dividing line between maximum incision depths of less than 1 m inshore and greater than 1 m offshore, as also shown on the scattergram in figure 9, but the maximum incision depths and the maximum gouge widths (Fig. 10) continue to increase seaward and do not begin to decrease until the very outer ice-gouge limit observed on lines 32 and 33. The mean for all maximum incision depths in the study area is .8 m, compared to .5 m for the western region. The mean of the maximum incision widths is 10 m, versus 8 m for the western region. Again the larger gouge size can be explained in part by the greater average water depth in the present study area.

Figure 11 is a scattergram of ridge height versus water depth. This shows that shoreward of the 18 m isobath ridges are no higher than 1 m. Ridges are highest between the 25-m and 45-m isobaths, and decrease from there seaward. This is contrary to the continuous increase in gouge depth and width measurements with increasing water depth. This is most likely due to the greater age of gouges in deep water, because ridges are first to disappear in the process of gouge obliteration, as is shown by years of monitoring specific gouges. Total ice gouge relief (incision depth plus ridge height) was plotted against water depth in figure 12 and shows an increase offshore with a slight drop near the outer limit of ice gouging. Barnes et al. (1980), based on the highest ridges and greatest incision depths seen in the western area, speculated that total relief could reach 8 m in a single gouge. In the present study the greatest value for total relief seen in a single gouge was 8 m and found in water 38 m deep.

Figures 13 and 14 are scattergrams of gouge density plotted against maximum incision depth and maximum incision width respectively. Both scattergrams show that with increasing gouge density there is a corresponding decrease in gouge size. This inverse relationship is partly an artifact, due to the fact that large gouges take up more space in each counting interval than smaller gouges and correspondingly fewer large gouges can be fit into such an interval. Many small gouges may also be reworked by the formation of one large gouge.

Figure 15 shows a plot of gouge density versus gouge orientation. A correlation between these two parameters is not as apparent as the correlation between water depth and orientation (Fig. 5) and water depth and gouge density (Fig. 7).

Seismic reflection studies

The central portion of the study area is interpreted by Grantz and Dinter (1980) as being tectonically and seismically active during the Holocene and as having been uplifted during the Quaternary. The geology here is more favorable for seismic profiling than in most of the regions west of the Canning River, where the data are very difficult to decipher. Figure 17 is a

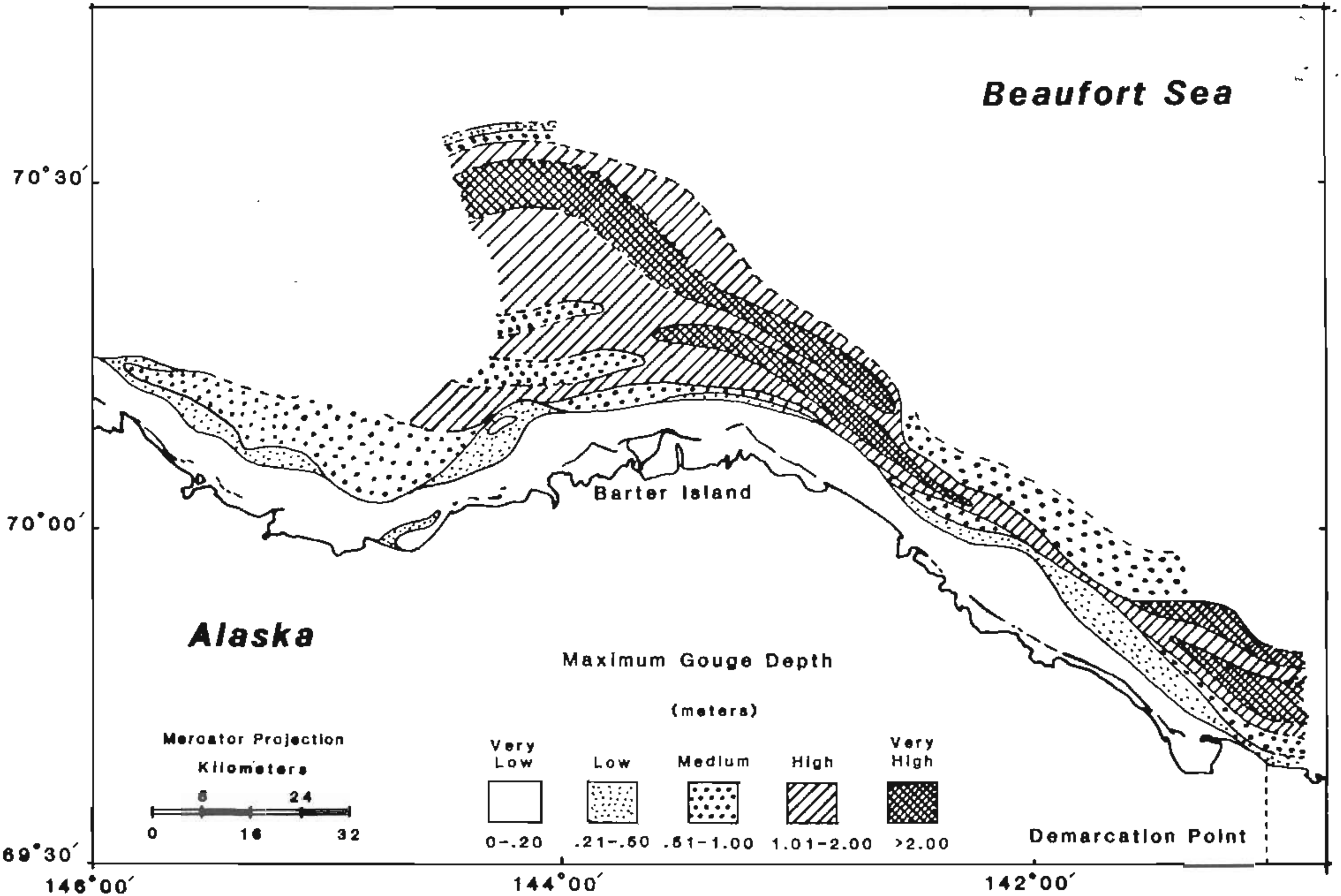

Figure 8.- Contour map of ice gouge maximum incision depth for the area from Camden Bay to the Canadian Border.

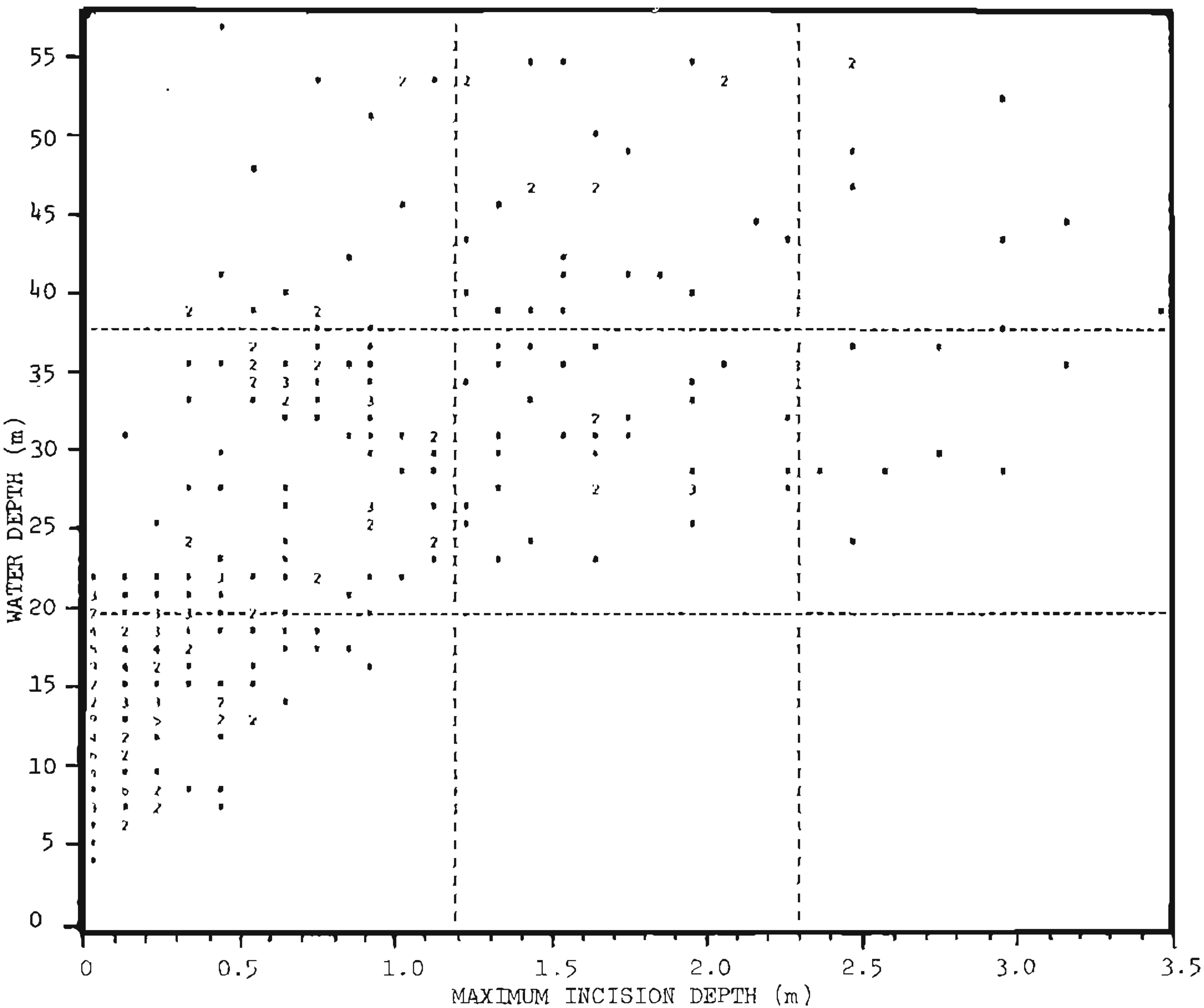

Figure 9.- Scattergram of ice gouge maximum incision depth versus water depth.

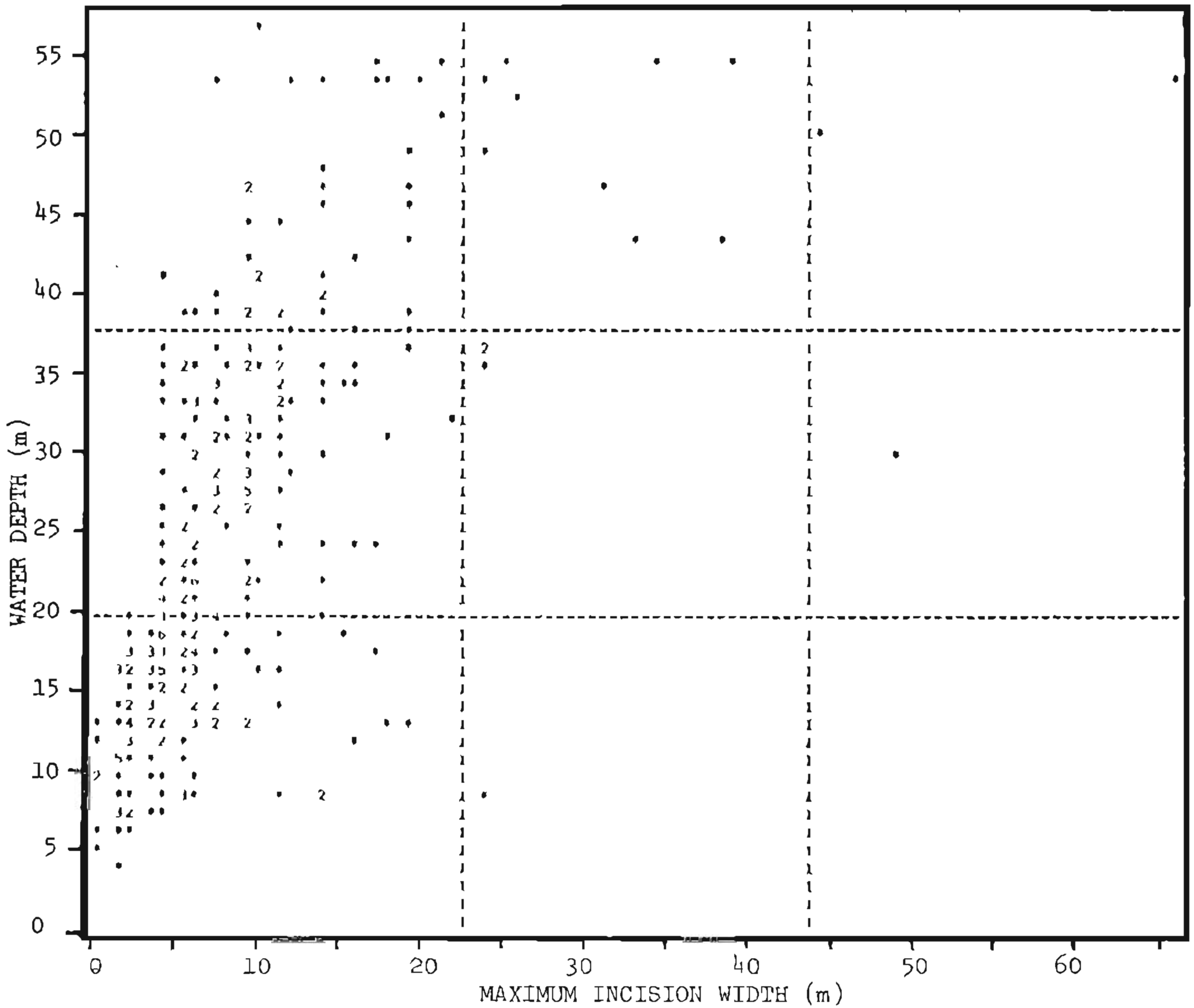

Figure 10.- Scattergram of ice gouge maximum incision width versus water depth.

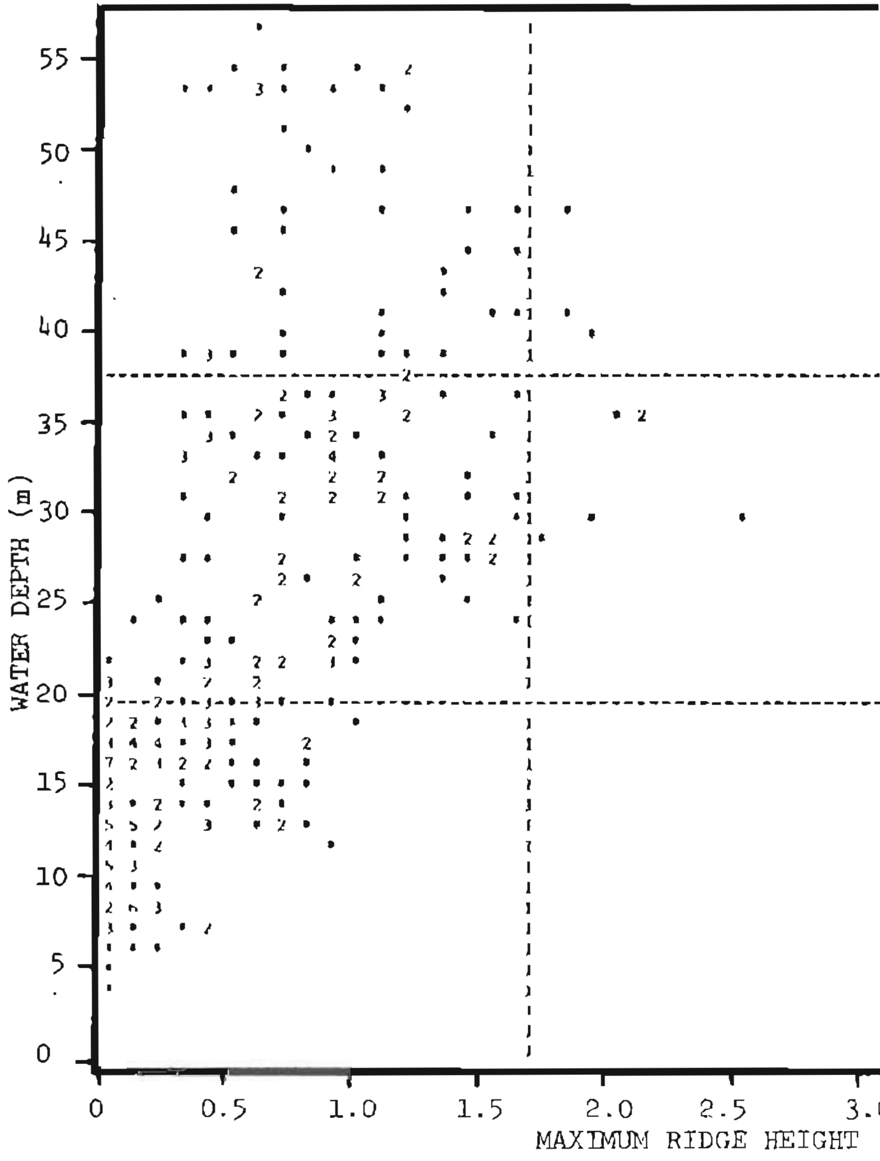

Figure 11.- Scattergram of maximum height of flanking ri

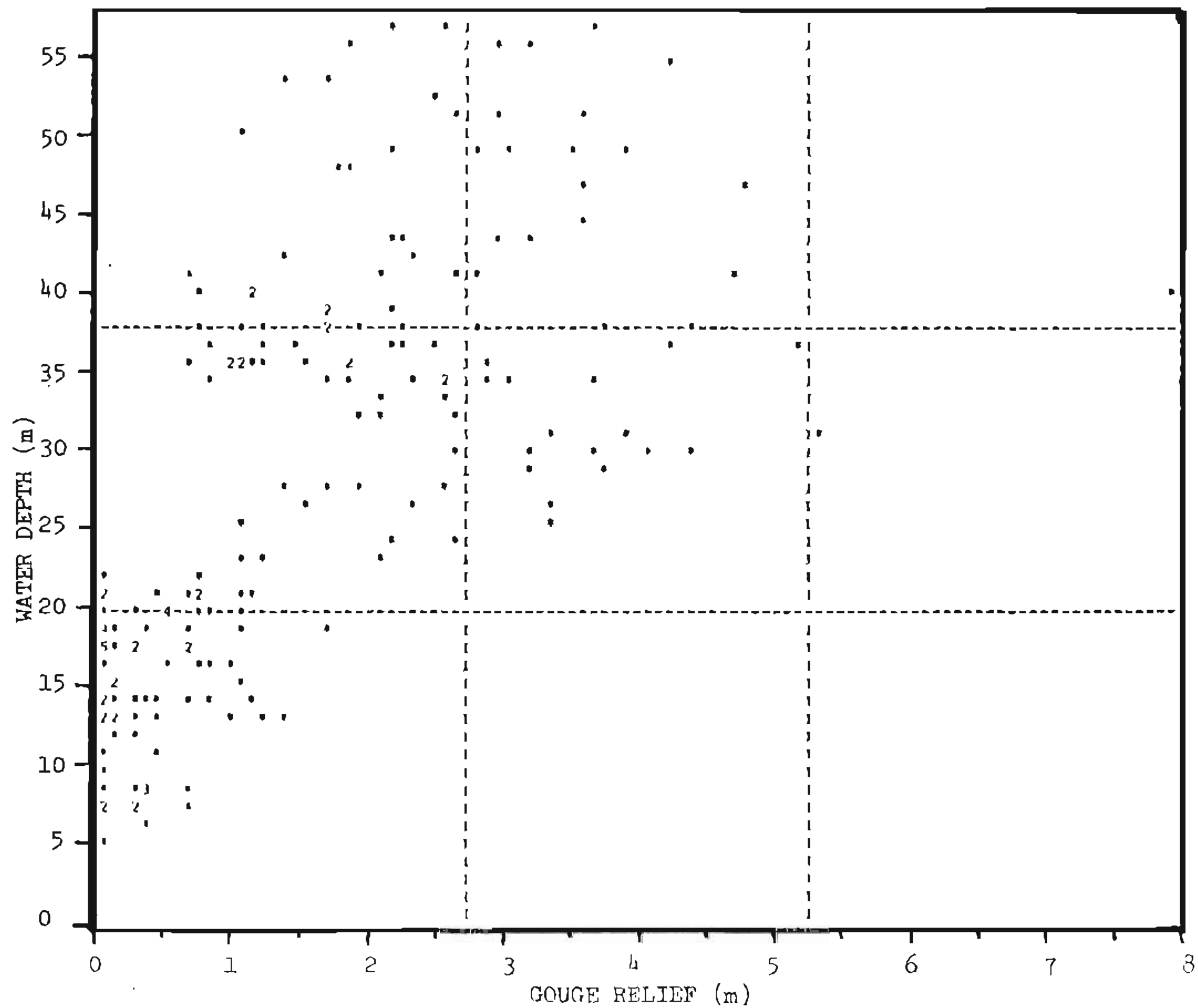

Figure 12.- Scattergram of gouge relief (ridge height plus incision depth) versus water depth.

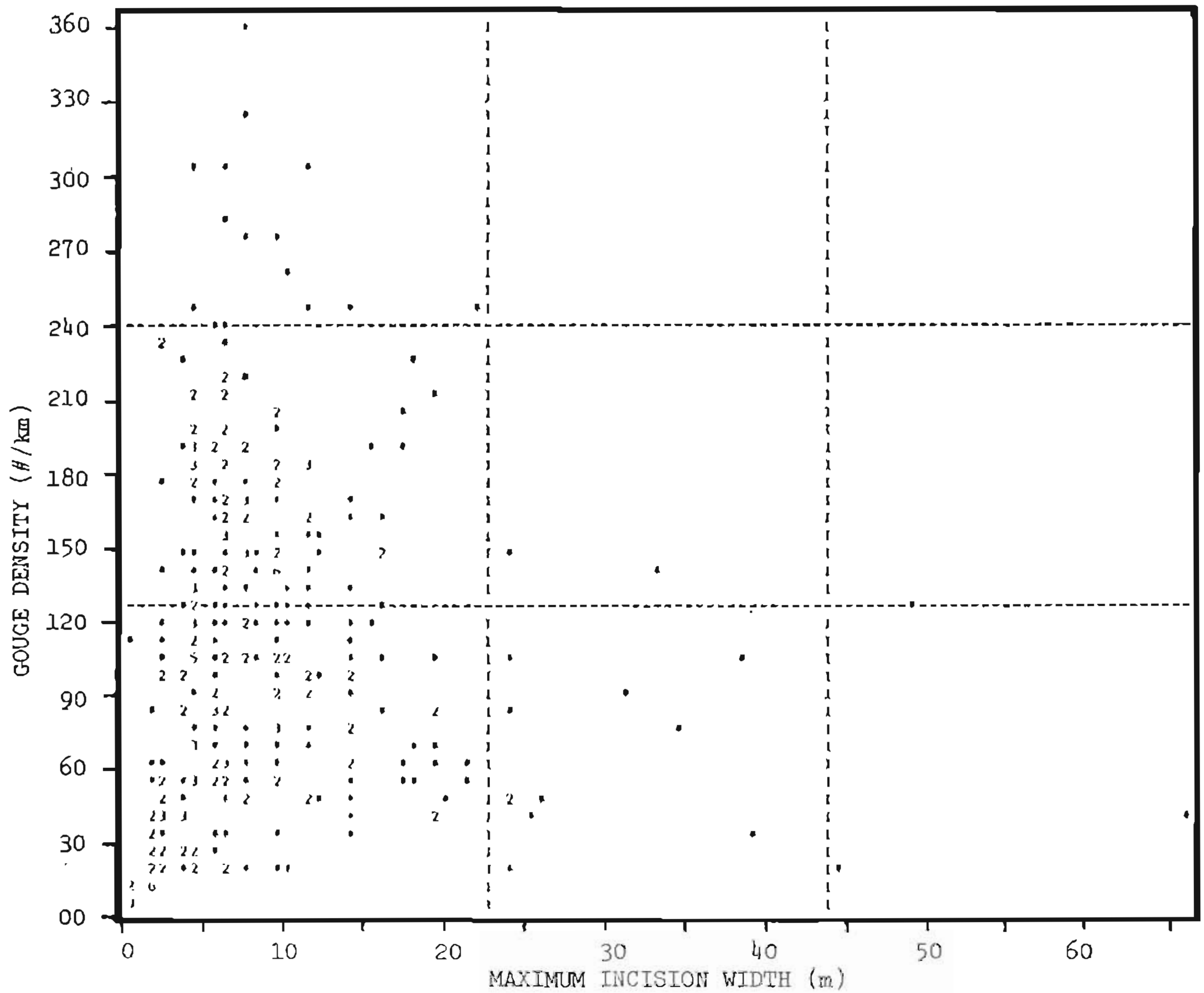

Figure 14.- Scattergram of maximum gouge incision width versus gouge density.

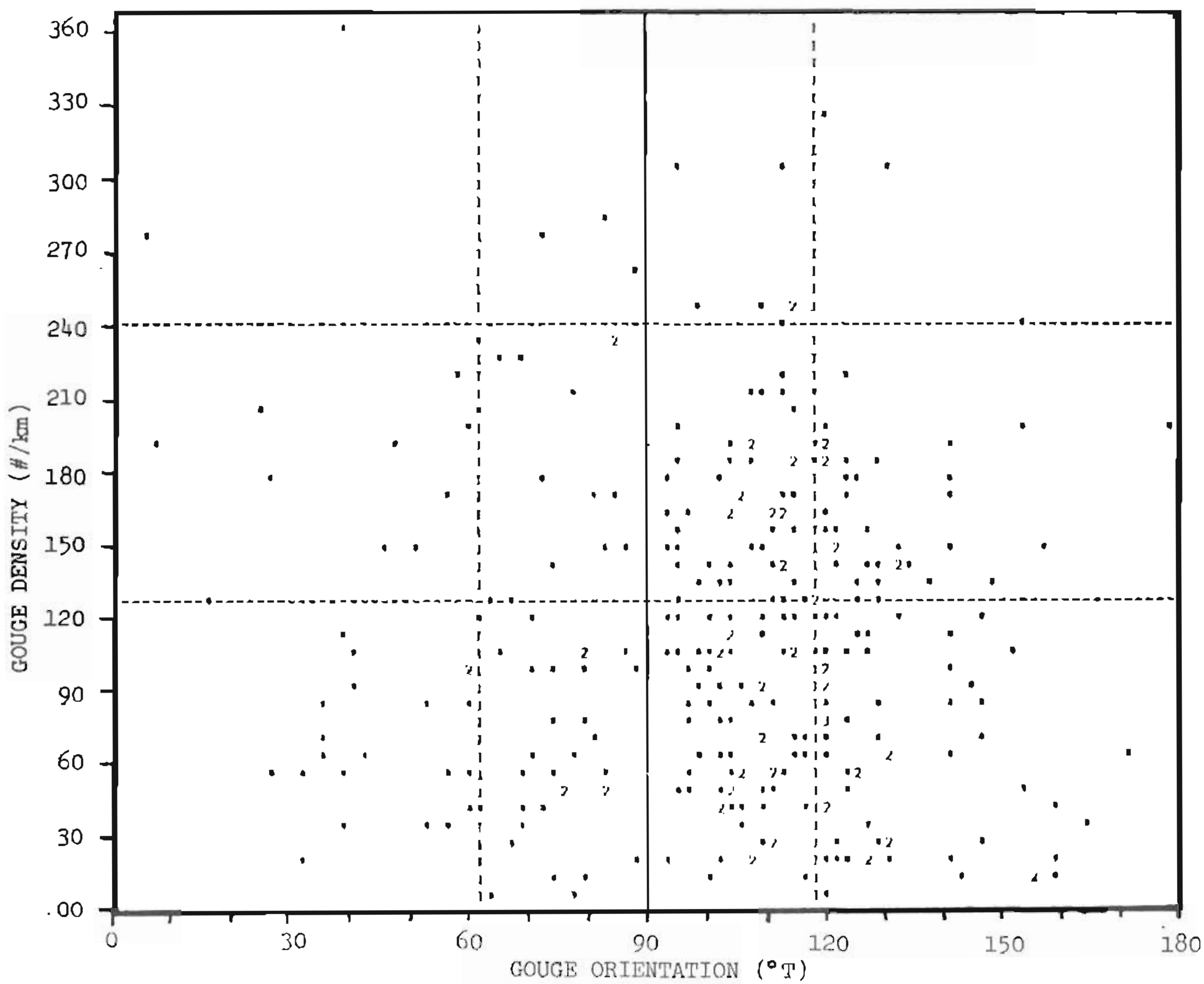

Figure 15.- Scattergram of gouge orientation versus gouge density.

sample Uniboom record (for location see figure 16) on which the most prominent sets of reflectors have been enhanced with inked lines. A major angular unconformity lies at a depth of 10-12 msec below the sea floor. Only 3 msec below the sea floor a discontinuous faint reflector can be traced. (Assuming a high sound velocity of 2,000 msec in sediment, 1 msec is 1 m on this record.) Figure 18 is a sample Uniboom record with the angular unconformity at the sea floor possibly overlain by an extremely thin veneer of soft sediment that cannot be traced on this record. The hyperbolic patterns within the upper 10 msec of the record are largely a result of the ice gouge relief on the shelf surface. But the hyperbolas could also be generated by reflections from the edges of truncated beds. We do not know whether these gouges are cut into the old dipping strata truncated at the sea floor, or whether scouring by ice has resulted in a thin residual deposit in which the gouges are formed.

Very thin surface sediment layers are best resolved on the 7 kHz record. Examples of these records are shown in figure 19 (A and B). In figure 19B the strong dark band 1 m below the sea floor, and precisely conforming to the ice gouge relief, is the 7 kHz trace of the sea floor. The faint reflector at about 58 m below sea level is a real subbottom reflector. All such shallow reflectors were traced from the 7 kHz records at a very shortened horizontal scale, giving a high vertical exaggeration, and are presented as figures 20 through 23. Tracklines and figures are arranged in order from the Canning River to the Canadian border and all lines are oriented with the shoreward (S-SW) end on the left side, except tie line 33-34, which parallels the slope. The seafloor trace also distinguishes between surface material types, as interpreted in the next section.

None of the sections traced in figures 20 through 23 contain reflector patterns revealing sediment accretion. On the contrary, most areas show shallow subbottom reflectors at varying angles to the sea floor, and cropping out somewhere along the traverse. We can detect no thickening of surface units towards rivers and coastal bluffs, the modern sediment sources. The tracings also do not reveal a thickening of units towards the shelf edge. Much more work will be necessary to gain an understanding of the stratigraphic complexities below the shelf surface. We prepared a scattergram with water depth plotted against sediment thickness above the first reflector (Fig. 24) and found that in the areas covered by our tracklines, the first reflector thickness is nowhere greater than 10 m and in most cases is less than 6 m.

Surficial Sediments

In our appraisal of surface sediment textures for the region from the Canning River to the Canadian border we used the surface sediment samples collected in 1981, the classification of geophysical records into cohesive and non-cohesive sediment types in 1-km-track segments, and sediment analyses of samples reported by P. W. Barnes (1974).

The 1981 shipboard sample descriptions are condensed in table 2. Dots mark the sampling sites in figure 25 (station numbers are shown in Fig. 2). The comparison of the texture of surface sediment samples with the appearance of ice gouge relief on fathograms and sonographs showed good correlation. Our

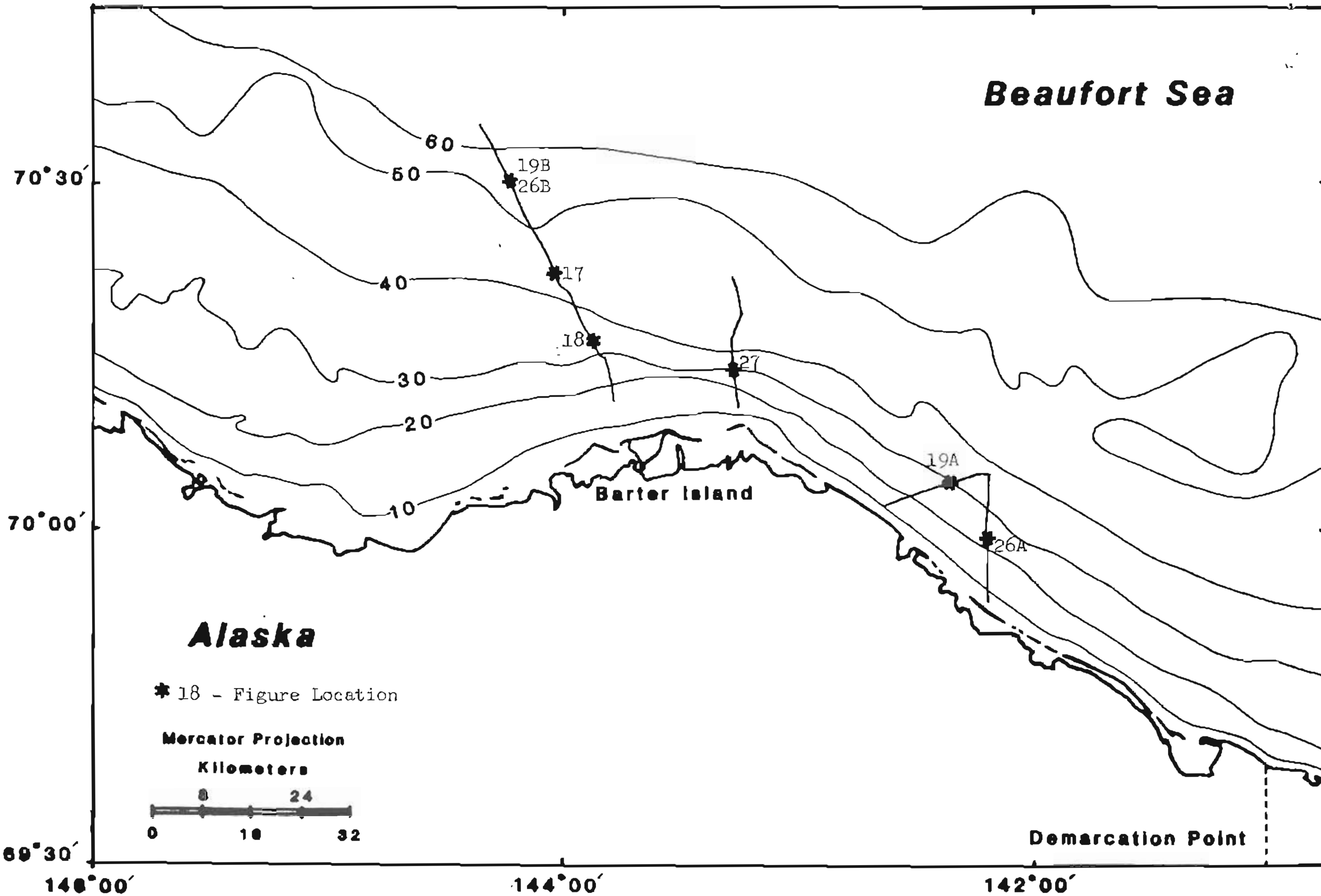

Figure 16.- Locations for fathograms and sonographs shown in Figures 17,18,19 A and B, 26 A and B, and 27. The tracklines from which these examples stem are also shown.

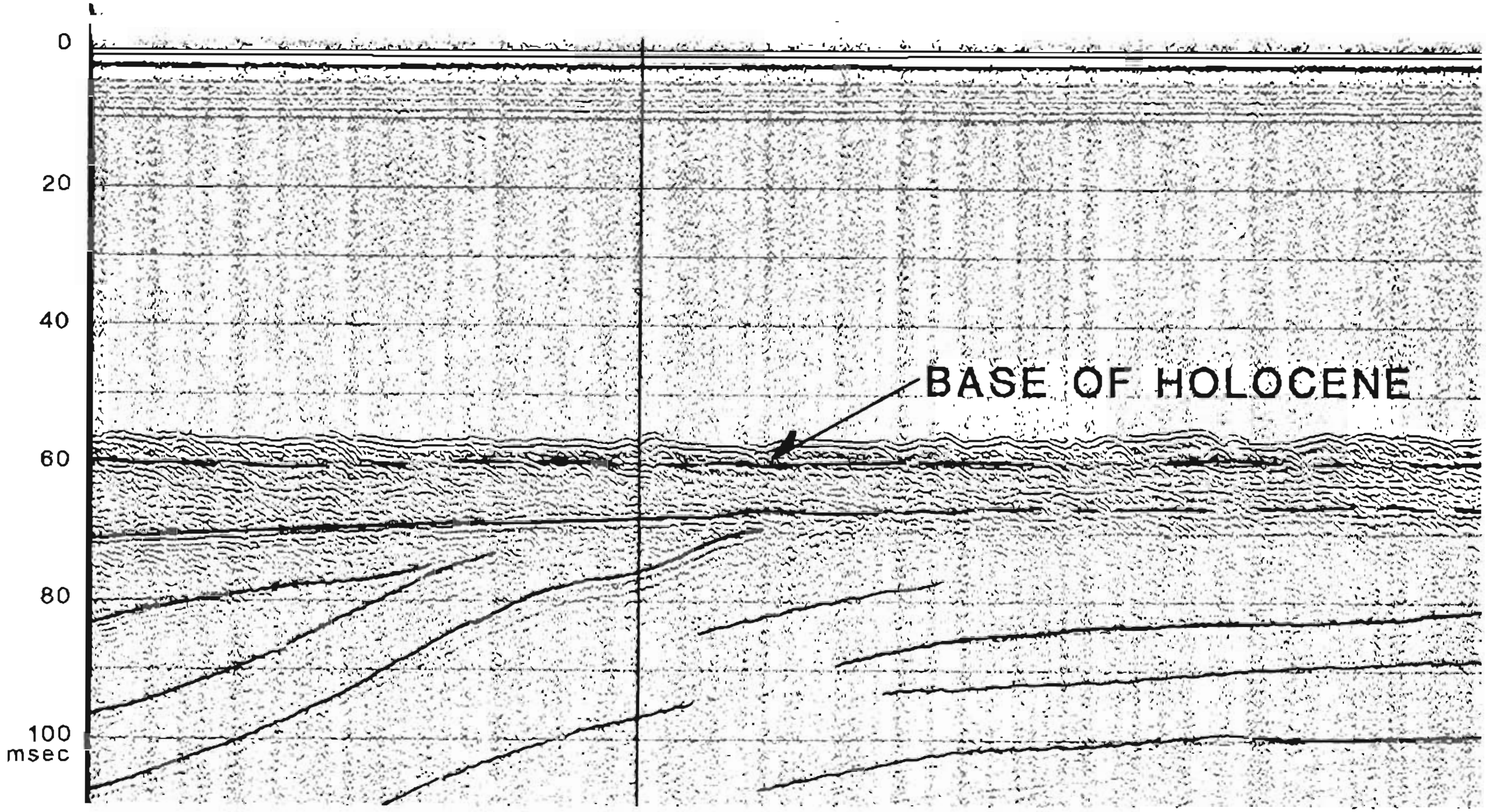

Figure 17.- High resolution siesmic record showing an angular unconformity below the base of the Holocene. Some of the reflectors have been highlighted for clarity.

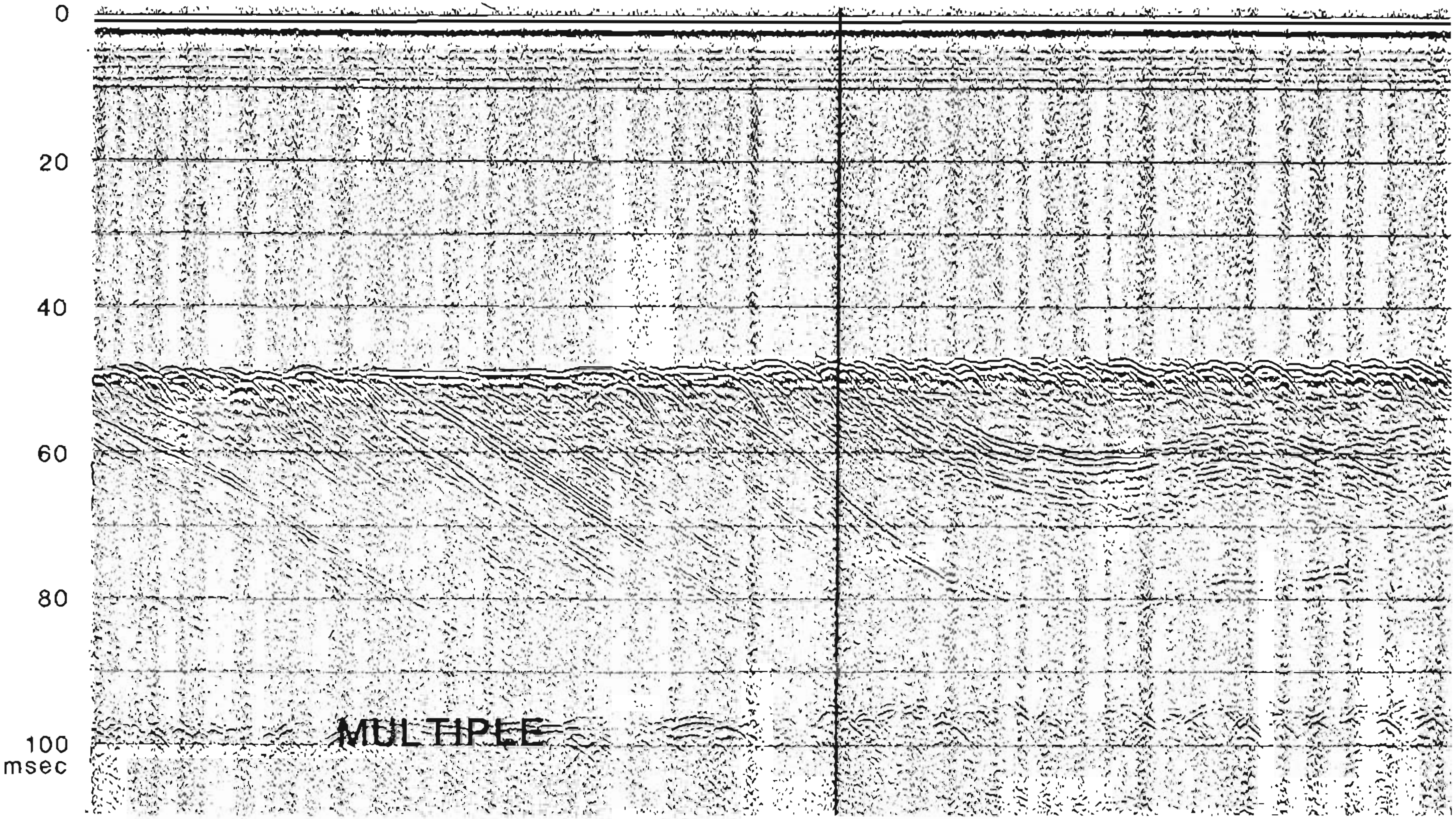

Figure 18.- High resolution seismic record showing dipping sediments truncated by the seafloor. The hyperbolas seen in the first 10 msec below the seafloor, and the rough seafloor relief, are largely a result of ice gouging, but could also result from reflections from the edges of truncated beds.

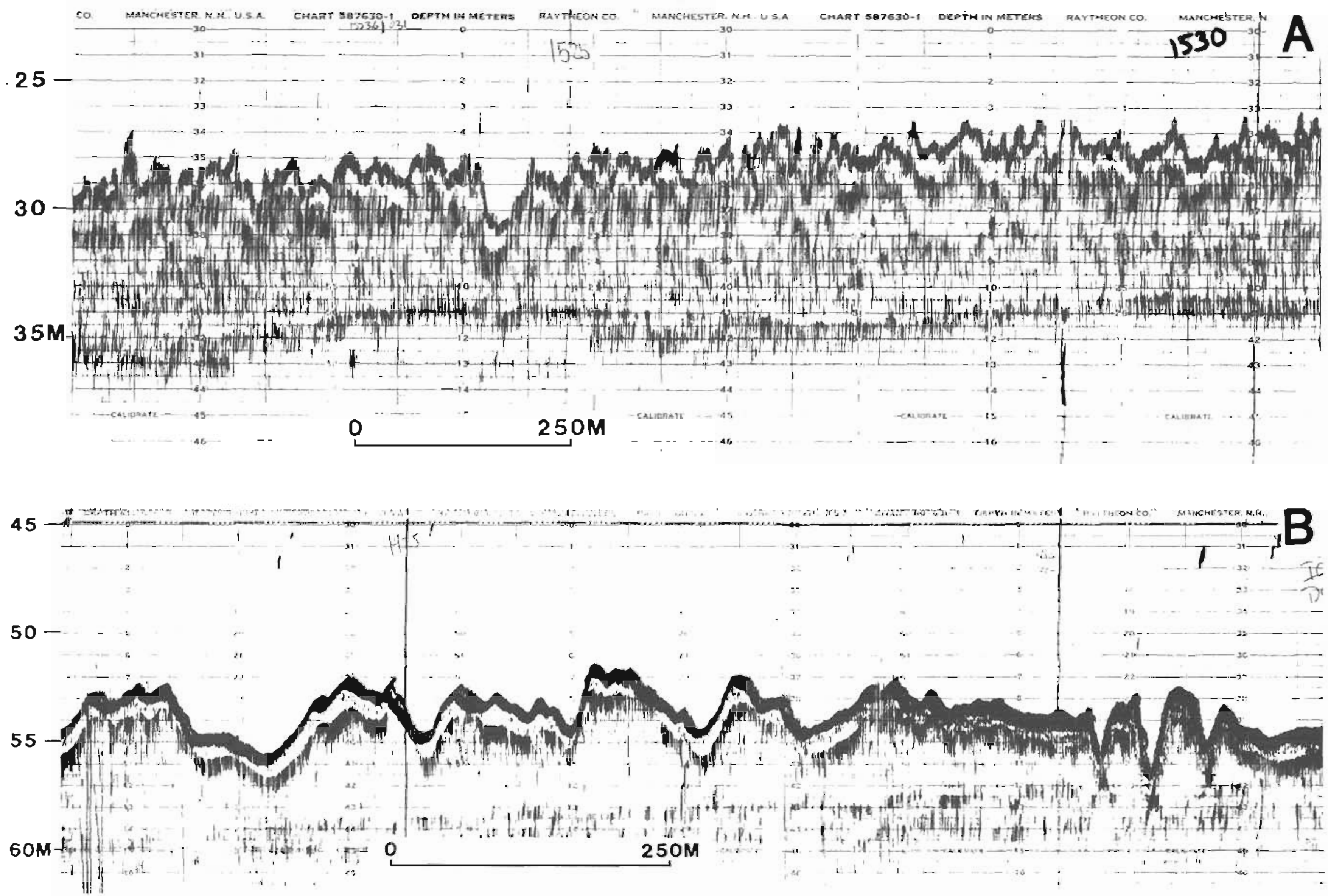

Figure 19.- Fathograms showing the extremes in bottom character: (A) rough relief and (B) smooth relief, which we interpret as cohesive and non-cohesive sediments, respectively. An undulating sub-bottom reflector is visible at approximately 35m in fathogram A, and a faint, left-dipping sub-bottom reflector is visible at approximately 60 m in fathogram B. Fathogram B covers the same section of trackline as sonograph B in Fig.26. (See Figures 16 and 26.)

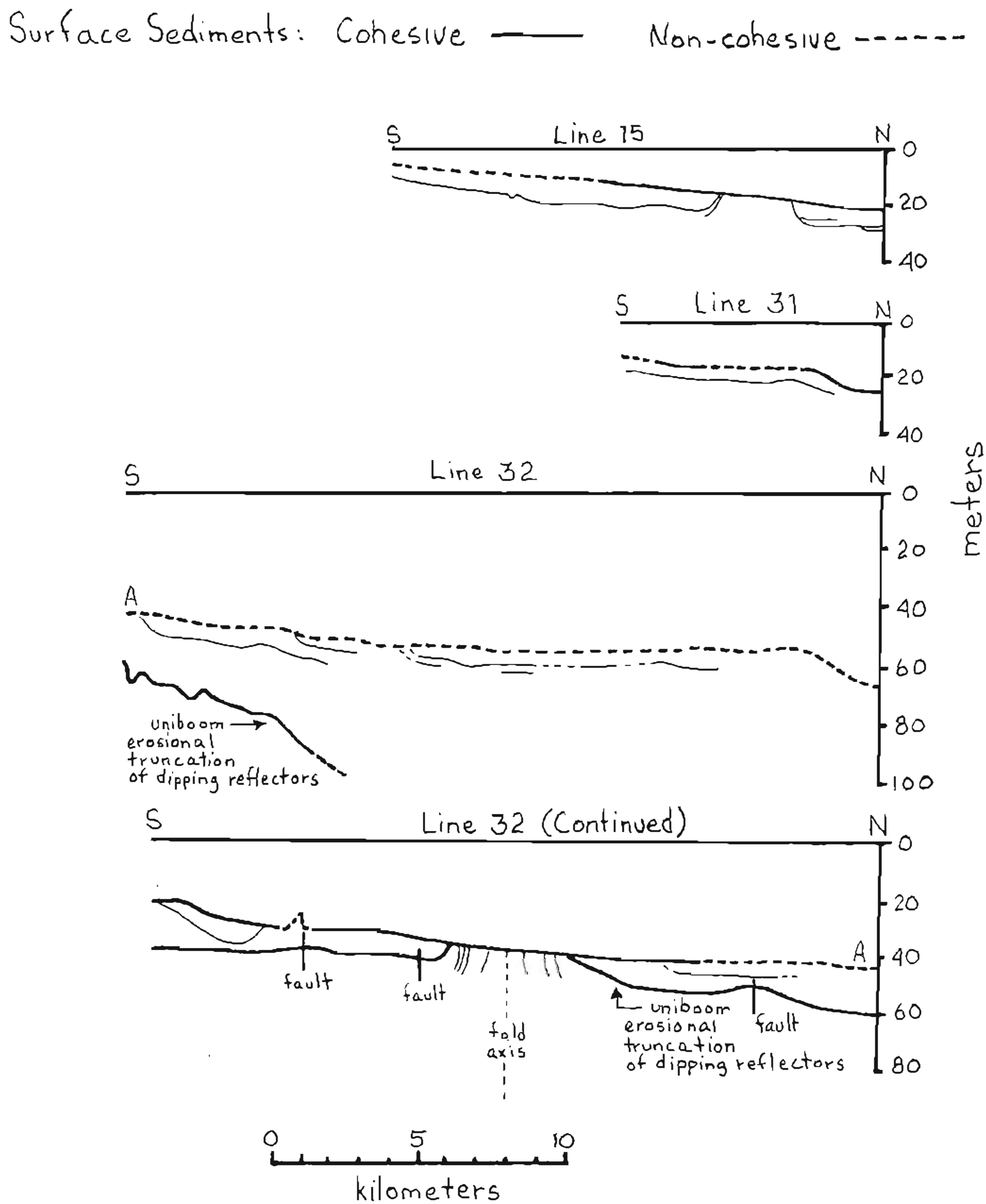

Figure 20.- Line drawings of 7kHz and Uniboom sub-bottom reflectors from tracklines between Camden Bay and Barter Island. Surface sediment textures in Figures 20 thru 23 are interpreted from sonargraphs and fathograms.

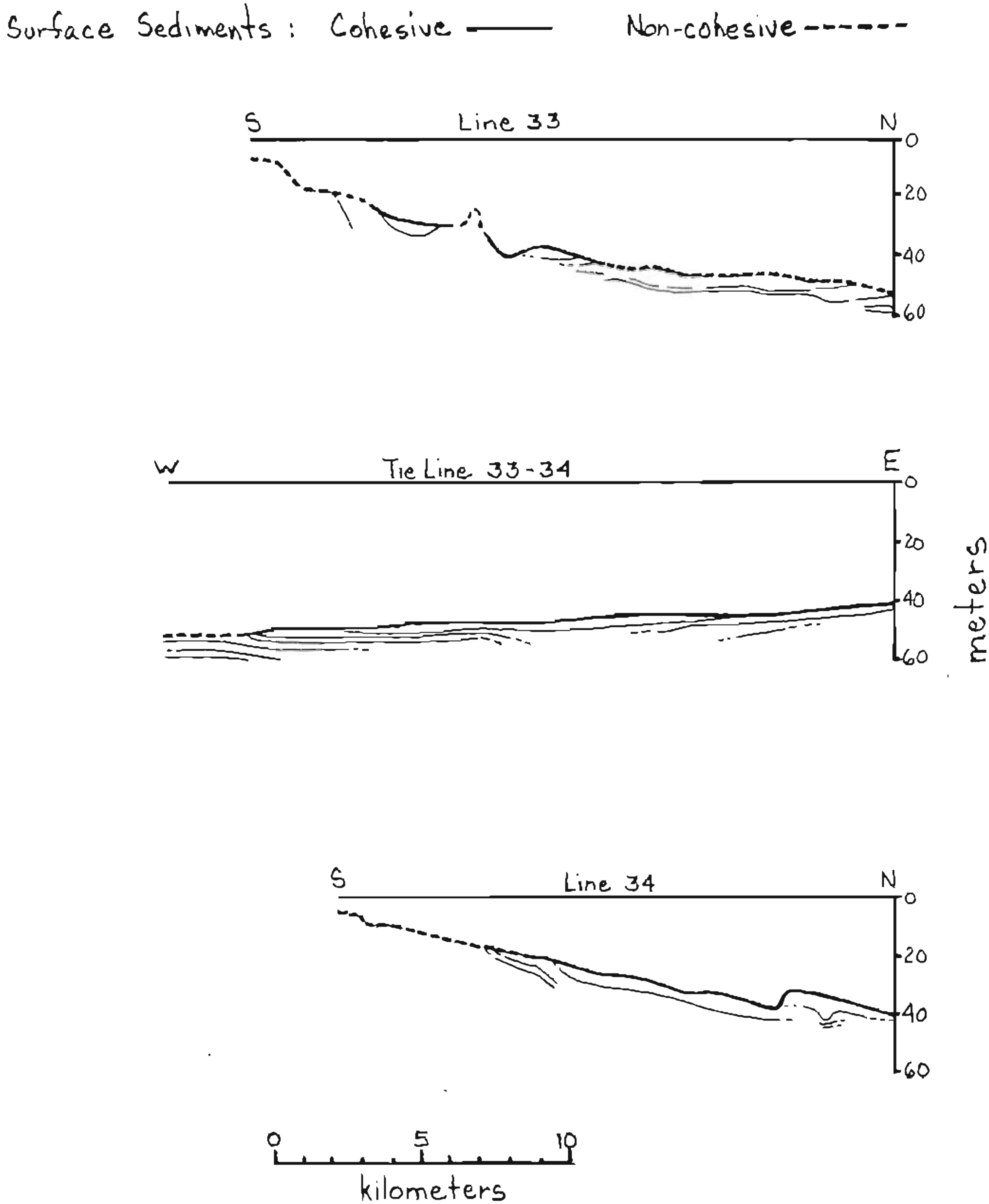

Figure 21.- Line drawings of 7kHz sub-bottom reflectors from tracklines between Barter Island and the Jago River.

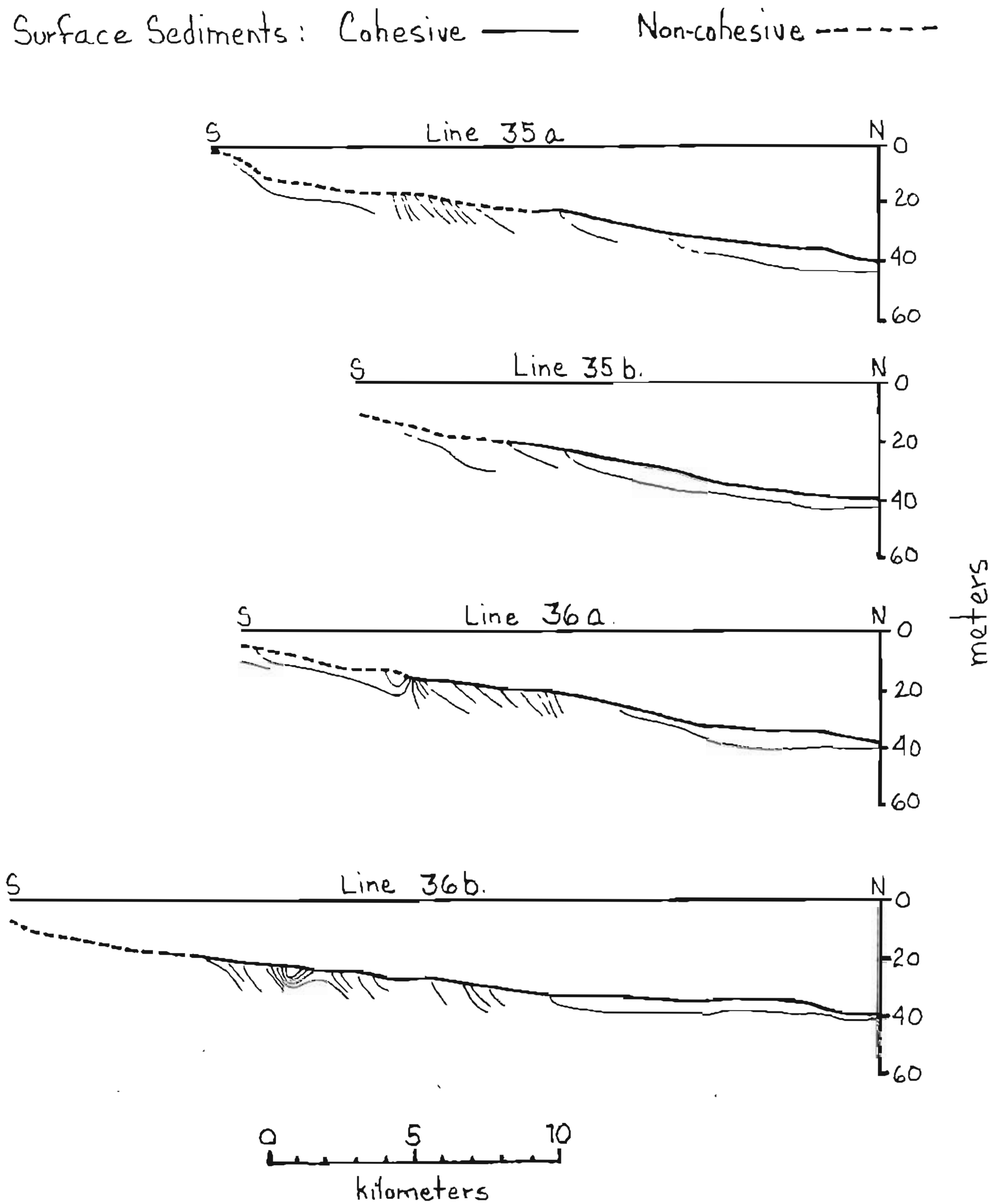

Figure 22.- Line drawings of 7kHz sub-bottom reflectors from tracklines between the Jago River and Beaufort Lagoon.

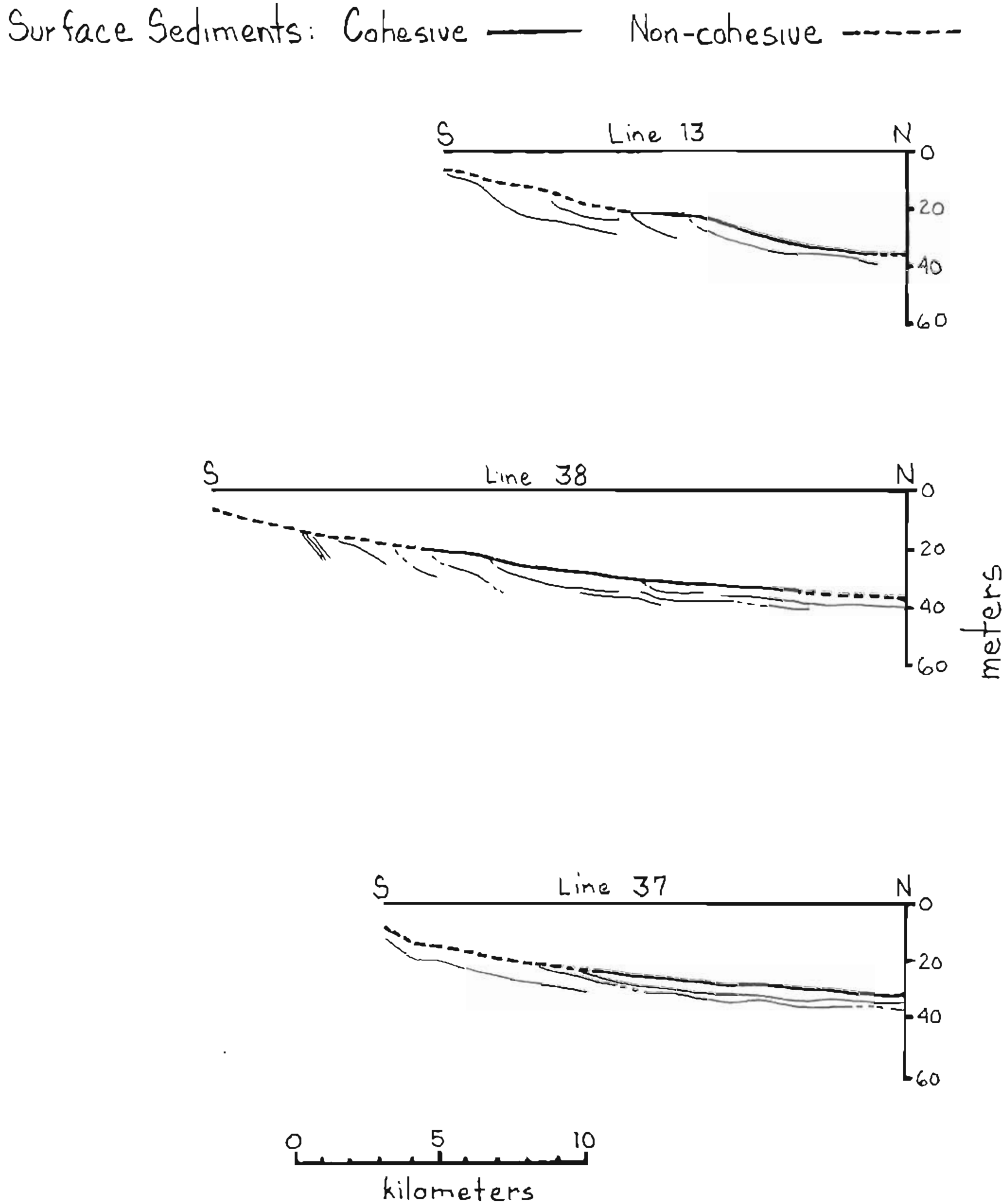

Figure 23.- Line drawings of 7kHz sub-bottom reflectors from tracklines between Beaufort Lagoon and Canadian border.

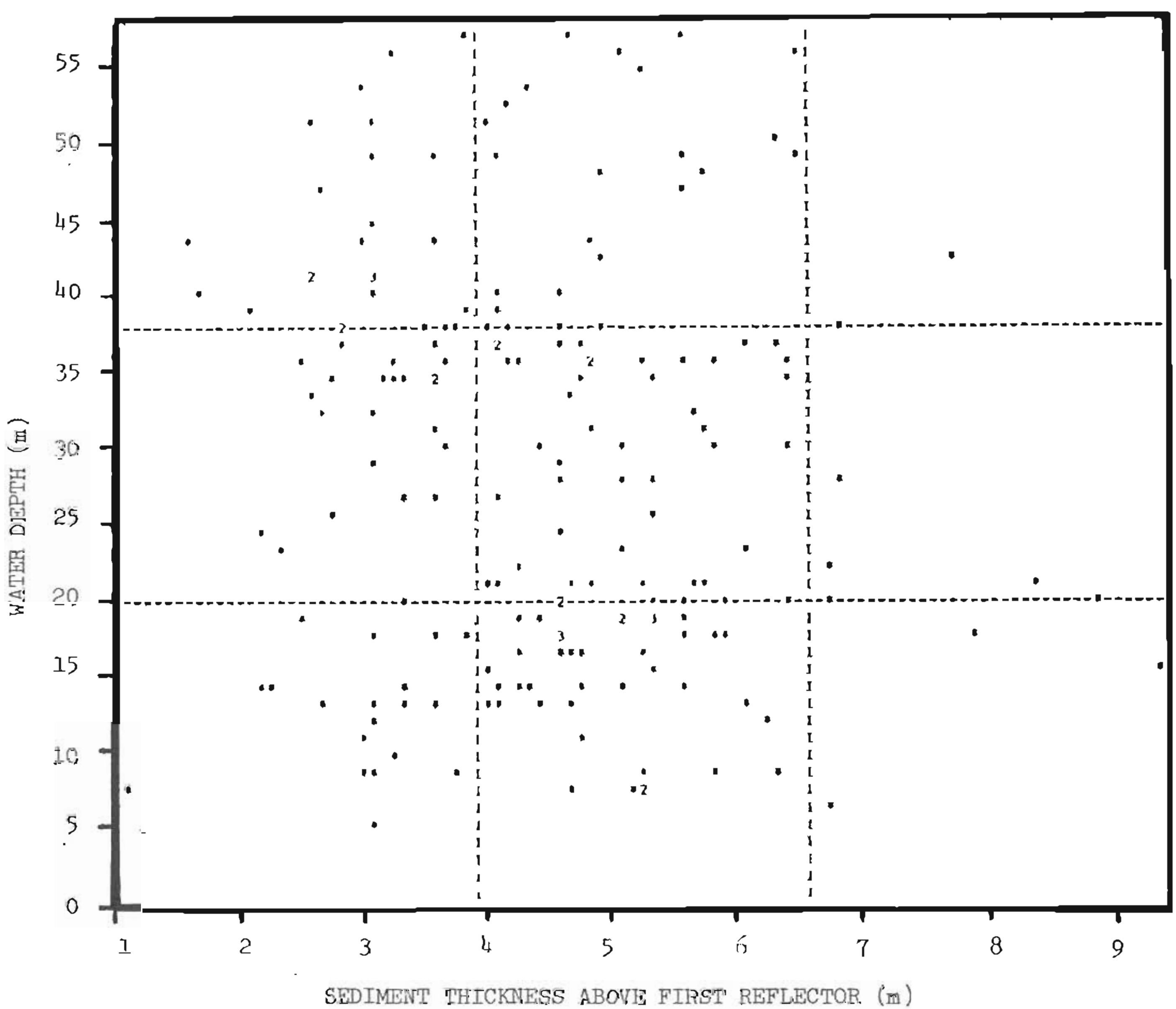

Figure 24.- Scattergram of sediment thickness above the first reflector versus water depth.

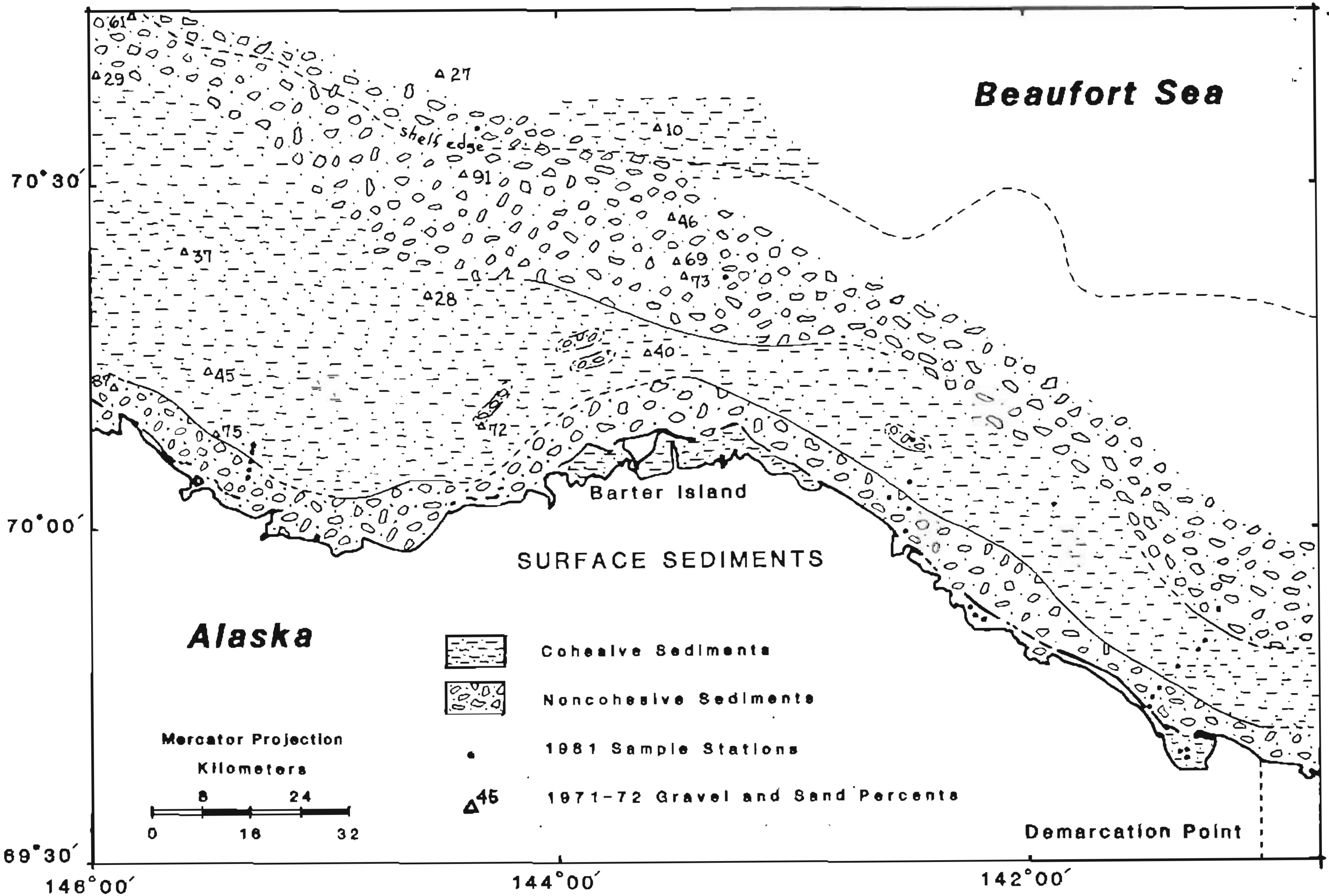

Figure 25.- Map of surface sediment textures, as interpreted from geophysical records and sediment samples. Percentages of combined sand and gravel are next to the old sample stations of Barnes (1974).

interpretation of the geophysical records and the classification of relief forms into "rough" and "subdued," and classification of surface sediment textures into "cohesive" and "non-cohesive," is, of course, strongly influenced by detailed diving and sampling investigations made west of the Canning River. Figure 19 is a sample of fathograms recorded in areas of cohesive, muddy surface sediments (A) and non-cohesive, coarse, granular sediments (B). In the latter case the materials piled up in flanking ridges during the ice-gouging process move downslope to assume the angle of repose as the ice passes. Subsequently the aging process, aided by current effects on non-cohesive materials results in broadly rounded ice-gouge forms. The fine-grained surface sediments, on the other hand, assume relatively steep slopes, sometimes blocky shapes, during disruption by ice and remain in this position even through periods of current activity. The sonographs shown in figure 26 represent samples of these two distinct bottom types. In figure 26 A the gouges are cut into cohesive materials, and are characterized by flanking ridges consisting of irregular piles of jagged materials. The roughness depends on the degree of consolidation of sediments disrupted, and is manifested as crisp, irregular discontinuous reflectors paralleling each individual gouge. Figure 26 A also records a first-year pressure ridge at the terminus of the parallel set of rake marks it produced. Figure 26 B shows gouges cut into coarse granular materials, where ridges flanking the gouges are smooth, even subdued, and continuous. The smooth ridges of figure 26 B correspond in time and place to the fathogram shown in figure 19 B.

The two bottom types interpreted from the geophysical records were plotted and the results are shown on the map in Figure 25. Coarse, granular materials blanket a strip from the coast to about 15-m water depth. Seaward of the 15-m water depth lies a zone of fine, cohesive surface sediments, which grade seaward into coarse granular materials. Coarse-grained materials can be traced uniformly for many kilometers on line 32, the long track extending northwestward from Barter Island to the shelf break. At 53-m depth we interrupted the line to collect a sample for verification and retrieved essentially clean gravel with attached organisms. The shoals within the belt of cohesive materials on the central shelf (Fig. 25) appear to be generally sand and gravel. The numbers shown on the shelf west of Barter Island in figure 25 represent percentages of sand plus gravel taken from surface sediments analyzed by Barnes (1974). These values substantiate that much of the shelf surface, and especially the outer half, is covered with coarse granular materials.

Shoals of the Stamukhi Zone

The relationship of coastal promontories and shoals acting as strong points in the control of ice dynamics and zonation has been of considerable interest to our studies (Rearic and Barnes, 1980; Reimnitz et al., 1978). The published charts for the study area do not show a pattern of shoals downdrift of the Barter Island promontory, similar to the pattern developed west of the Cross Island promontory. However our reconnaissance survey lines provide single crossings of a number of shoals. One long linear shoal off the Canning River was crudely defined by a number of crossings (Line 8 in figure). A number of samples collected around that shoal show it to be composed of sand and gravel, similar to the shoals west of the Canning River which have been

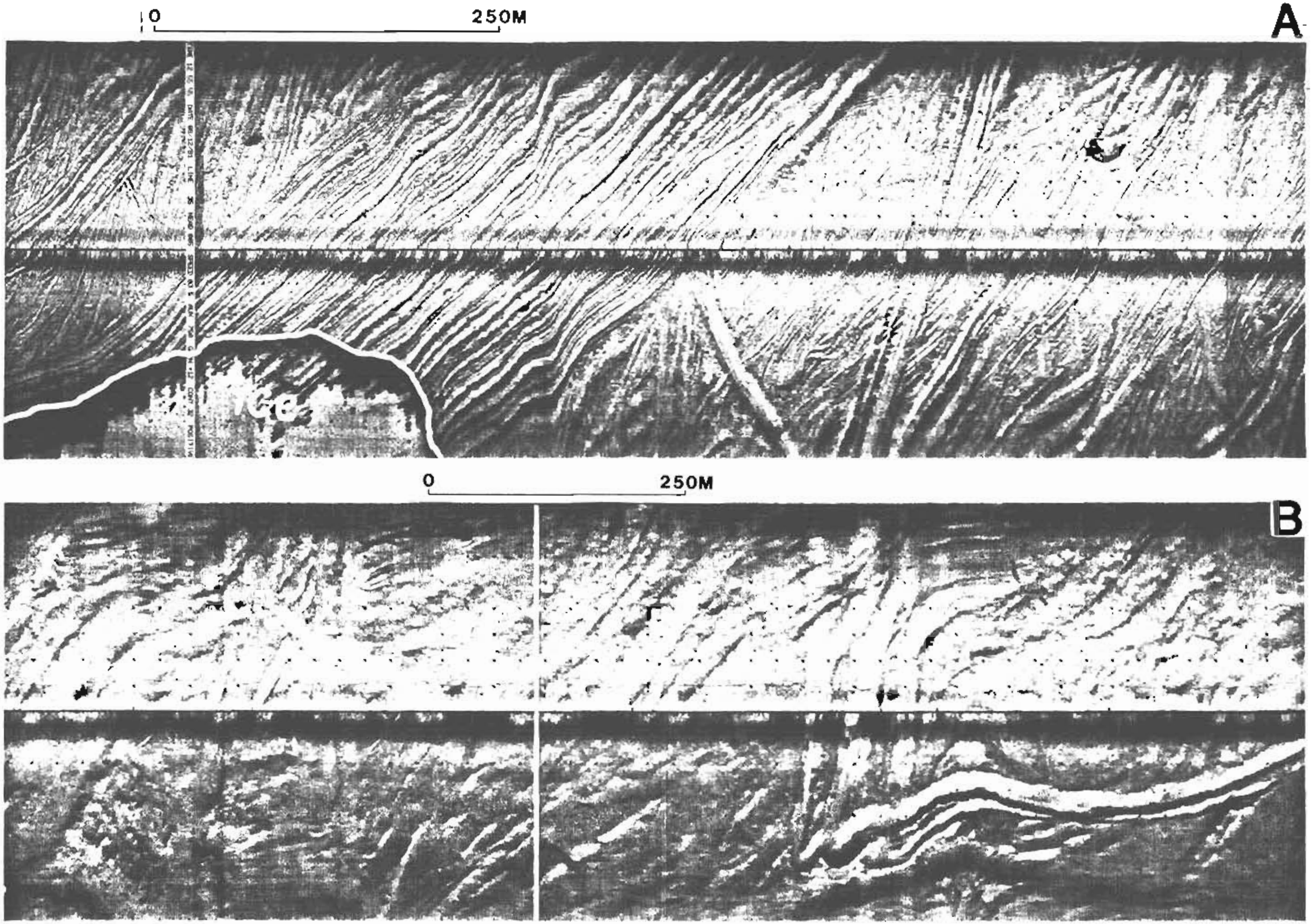

Figure 26.- Sonographs of rough (A) and smooth (B) gouge relief, a difference we interpret as due to the presence of cohesive (A) and non-cohesive (B) sediments. A large piece of ice is grounded in the lower center part of sonograph A, gouges under the ice are hidden. Sonograph B corresponds to fathogram B in Fig. 19. The 3 sharp gouges on the fathogram are clearly visible on the sonograph. Even though there is a lot of relief in the area, the seafloor texture is smooth because of the non-cohesive nature of the sediments.

thoroughly studied. Most of the other shoals as well are composed of coarse granular materials as interpreted from the geophysical records. A sample crossing is shown in figure 27. The sonograph shows an intensely gouged sea floor on both sides of the shoal. Here the gouge flanks have the rough appearance typical of flanks associated with fine-grained cohesive materials. The shoal itself, is composed of coarse granular material with a smoothed, rounded surface and a trace of current ripples on the crest. Ice hangups are most common on such shoals and the sonograph shows such a stamukhi along the crest.

DISCUSSION AND CONCLUSIONS

Sedimentation

From combined coring, diving, and seismic profiling studies in numerous different marine geological environments and settings west of the Canning River, we are convinced that where repeated ice plowing occurs with slow sediment accretion, no continuous sedimentary units develop. Sediments come to rest mainly in troughs of gouges, and the shape and extent of a trough define the limits of sedimentary units.

We believe that the depositional environment in early Holocene time was similar to today's environment. The sea advanced across the 60-km-wide shelf at an average rate of 5 m yr^{-1}, while the present rate of bluff retreat is 1 to 2 m yr^{-1}. Bluff height at present is 2-5 meters and we believe was similar in the past. Thus the rate of sediment supply from bluff erosion has changed relatively little. The first seawater encroaching onto the outer shelf brought ice, which probably included a high proportion of ice of land origin calved from retreating glaciers. This ice began plowing and re-plowing the former land surface, and the developing sediment blanket, at a higher rate than the sediment accretion rate (Reimnitz, et al., 1977; Barnes, et al., 1978; Reimnitz, 1978; Barnes and Reimnitz, 1979; Barnes and Reimnitz, 1981; and Reimnitz and Barnes, 1981). Like today, the plowing action of ice aided in sediment winnowing, resuspension, and transport, and thereby resulted in slow rates of sediment accretion. Very slow rates of shallow water sediment accretion are observed around the entire Arctic Ocean, and we see no reason for very high rates of shallow water sediment accretion during the early Holocene time. Viewed in this light, we see no possibility for the blanket of Holocene sediment to contain continuous internal reflectors that can be traced on seismic reflection records.

All incidations are that a thick wedge of Holocene marine sediments, consisting of unconsolidated silt and mud (Dinter, 1982), does not exist on the central and outer shelf. Such deposits, while present in lagoons and bays, are essentially lacking on the open shelf. The fine-grained, cohesive sediment mapped in a band on the central shelf, may be Holocene deposits of several meters thickness, and most likely the shoals of the stamukhi zone are constructional features post-dating the last transgression. The coarse granular materials on the inner shelf and on the outer shelf seem to be relict deposits. The relict nature of the shelf edge gravels has been discussed by Barnes and Reimnitz (1974), Naidu and Mowatt (1974), and Rodeick (1975). Their interpretations are based on: a) low rates of modern ice rafting of

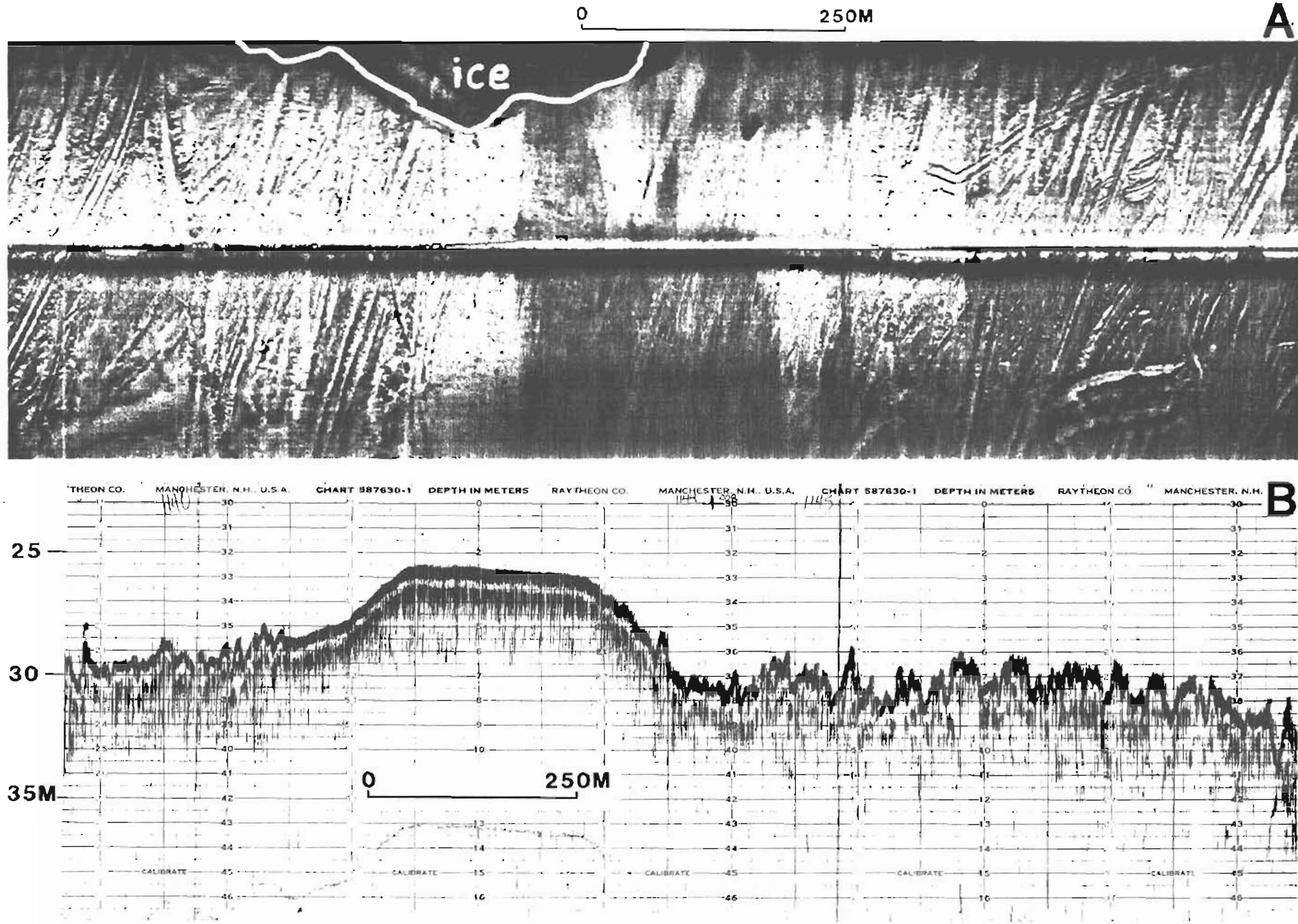

Figure 27.- Sonograph (A) and fathogram (B) of a shoal crossing in the stamukhi zone. The shoal crest is characterized by a smooth, noncohesive texture, while the surrounding bottom exemplifies the jagged, cohesive sediment texture. The smoothness of the shoal crest, which is gouged by ice more frequently than the surrounding bottom, indicates that hydraulic processess rapidly rework the sediments on the shoal crest.

coarse clasts compared to overall sediment accretion rate, b) observed ferromanganese coatings on cobbles, c) about 15,000 year old C^{14} ages for near-surface shelf edge and upper slope sediments, d) source rock considerations, and e) lack of seaward decrease in sediment grain size from coarse grained near the sediment source to fine grained near the outer edge of the shelf.

Dinter (1982) mapped a seaward thickening wedge of Holocene marine sediment on the Beaufort Sea shelf, using high resolution seismic reflection records. In the Barter Island area in particular, he shows a large area of structurally deformed and truncated stratified deposits lacking any Holocene marine sediments, and flanked on the northeast and northwest side by Holocene marine sediments thickening to 30 and 40 m at the shelf edge. Line #32 of the present study was aimed at reaching the shelf edge where Holocene marine sediments are 40 m thick, where, as a consequence, active deposition should occur, and where the greatest water depth at which ice gouges exist would correspond with the present maximum ice keel depth to be encountered within the Beaufort Gyre. We reasoned that active deposition would eliminate gouges within a period of several hundred years. Line #32 (for cross section see figure 20) does indeed cross the erosional region on the mid shelf, where older sediments are truncated by the seafloor, but it does not show a thick homogenous wedge of Holocene sediments to seaward. The character of the gouges recorded, in fact, made us suspect gravelly surface sediments prompting us to interrupt the geophysical survey for sampling (Fig. 2, Sample 27). The gravel retrieved at 53-m water depth, along with the homogenous appearance of the records for tens of kilometers, supports previous sedimentological interpretations that much of the outer shelf in the eastern Alaskan Beaufort Sea is blanketed by relict gravels, and not by Holocene marine sediments as interpreted by Dinter (1982).

One of the major potential modern sediment sources for the eastern Alaska Beaufort Sea shelf may be the Mackenzie River. Therefore, a comparison with the sediment distribution on the shelf between our study area and the Mackenzie Delta will shed additional light on our contention that the outer shelf off northern Alaska is presently a surface of non-deposition. Figure 28 is a compilation of our sediment texture map extending to the Canadian border, and a map of sand-plus-gravel percentages for the region east of the border by Vilks et al. (1979). The Canadian shelf surface is covered by sand and gravel. Yorath et al. (1970) interpreted the sandy gravels, sands, and hard pebbly lutites as "relict glacial deposits and ice-pressed tills." Thus, these combined interpretations of shelf surface sediments, while not matching across the border in detail, leave no room for a thick wedge of Holocene sediment on the outer shelf. The extensive regions west of the MacKenzie River also indicate that the sediments supplied by this large river are not dispersed westward from its mouth. A thorough study of this problem is urgent because the interpretation that slumping, sliding, and faulting are active geohazards in this area (Grantz and Dinter, 1980) is strongly dependent on whether the shelf edge sediments are old or recent. If there is no active sedimentation, then surface relief features related to mass movement and faulting may have been produced in the distant past, by processes inactive today.

scarps. The ice pack acting on an extensive, non-homogenous surface, however, seems to take the different lithologic units down to the same level by focusing mainly on the high points. Viewed in this light, the existence of major, well defined shoals is more perplexing.

So far we have been unable to relate the intensity of ice gouging to the underlying geology. Thus, one could also argue that all geologic strata exposed to the action of ice in the study area are relatively weak compared to the forces of the moving ice keels.

New Evidence for Greater-than-Expected Ice-keel Depth

Favorable ice conditions in 1981, and a relatively narrow shelf east of the Canning River enabled the R/V KARLUK to survey ice gouges in generally greater water depth than has been possible in the western sector. One particular line was extended to the very shelf edge. In general, the relationship between ice gouging and water depth in the study area is similar to that determined for areas west of the Canning River, with lowest values for certain gouge parameters inshore and offshore of the stamukhi zone. In the present study, ice gouges were traced to maximum water depth of 58 meters. Beyond that we saw only very broad, subdued relief features unrelated to ice keel interaction. Among the bedforms beyond the deepwater gouge limits we found slope-parallel, rhythmic lineations of 3 m wave length but less than 20 cm of relief, which we interpret as probable hydraulic bedforms. These indicators, along with the presence of surface gravels rather than fine materials, the subdued nature of gouge relief forms, the seaward decrease in ridge height relative to trough depth and width, and especially the recorded current pulses of up to 50 cm per second along the shelf edge (Aagard, 1977) all suggest that active currents rework the deep water gouges. Based on these considerations, the gouges found at 58 m water depth are modern rather than relict (produced during lower stands of sea level). Surficial hyperbolic reflections on Uniboom crossings of the shelf edge between Barrow and the Canadian border, and the accompanying surface roughness, are fairly certain indicators for the presence of ice gouges. These indicators can be traced in 28 representative traverses to maximum water depths of between 60 and 64 meters (Dave Dinter, U.S. Geological Survey, oral communications, 1982).

Our previous contention that ice gouges seen on the Beaufort Sea shelf at depths greater than 47 m (the deepest keel actually observed) are modern has recently found additional support. Marine geologic studies by Canadian researchers in the southern Beaufort Sea no longer call for lower sea levels to account for the deepest gouges observed. Also, statistical treatment of ice keel distributions in Arctic deep water allow for 60 m deep keels to occur at a rate of one every few hundred years (Peter Wadhams, oral communication, 1982). These findings are of little consequence at the present stage of petroleum development in the Alaskan Beaufort Sea, but may in the future assume considerable importance.

Shallow Seismic Stratigraphy

Our analysis of seismic records has not progressed to the stage where correlating individual units from line to line, and interpreting their geologic history, can be attempted. However, we can put some limits on the thjickness of the surface units - the Holocene marine sediments. Our reasoning leading to the conclusion that Holocene marine sediments cannot contain continuous seismic reflectors has been presented above. This is not only a theory, it has been proven true in numerous site specific studies in the west. Based on this fact, the sediment thickness above the first sub-bottom reflector is the upper limit for the thickness of Holocene marine sediments. A plot of these values (Fig. 24) against water depth shows no trend. The mean depth below the sea floor is nearly 7 meters. But as discussed before, the geometry of units defined by the shallow reflectors excludes them in most regions from being Holocene marine sediments. They must be older units.

Thick sections of stratified, tectonically deformed, probably Pleistocene strata dipping at various angles are truncated by the seafloor over extensive regions in the Barter Island area. We have not been able to trace any portions of the section to Barter Island from the Flaxman Island area, where well known stratigraphy exists from boreholes. Some faults extend to near the sea floor, but we are unable to detect surface scarps or other signs of recent fault displacements. However, the smooth truncation surface, extending for many kilometers and cutting across numerous strata of presumably different erodability, suggests that ice scouring is an efficient planation agent that treats all available materials uniformly. Thus, the lack of modern fault scarps in our data is not necessarily evidence against recent movement postulated by Grantz and Dinter (1980).

Sand Gravel Resources

Triggered in part by the high demand for sand and gravel as construction material for offshore petroleum development, the Federal Government is making preparations for managing these resources on the Arctic shelf through a leasing program. In the present study area all indications are that gravel is plentiful, even in deep water, and need not be hauled great distances. In areas where active gouging creates up to 8 m of vertical relief, the seafloor reflectivity and overall appearance is homogenous for many kilometers. If such areas on the outer shelf were underlain by interbedded mud, sand and gravel, the plowed ridges would reveal such inhomogeneities. The sea floor would be littered with slabs of stiff silty clay. The appearance of the geophysical records suggests to us that on the outer shelf fairly clean, coarse granular materials have a thickness of at least several meters. However, several box cores from the outer shelf contain firm mud units (Barnes and Reimnitz, 1974), raising questions that need answers.

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APPENDIX

Ice Gouge Data Sheets

T= transitional R=Rough S=Smooth [illegible] DMK

Line Number : 08 Year : 1981 gouge measurements in meters

	Fathogram Measurements				Sonograph Measurements				
SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density	Orientation (°T)	Sediment Cohesion	REMARKS
000	24.3	—	.4	.4	17	168/	105 / 285	R / C	.4 Km of sonar missing. Count adjusted. 555 Range 150 m
001	22.8	—	.8	.1	—	—	—	R / C	no sonar for this segment
002	22.1	27.1	.8	.6	—	—	—	R / C	no sonar for this segment
003	21.3	25.5	.4	.5	—	—	—	R / C	no sonar for this segment
004	17.4	22.7	<.2	<.2	—	—	—	S / N	no sonar for this segment 4 meter bench at start of segment (includes 1 meter shoal on crest).
005	17.0	22.0	.2	.3	3	37/	190 / 260	S / N	.4 Km of sonar missing. Count adjusted.
006	16.1	20.6	<.2	<.2	11	88/	156 / 246	S / N	1 multi-gouge - 12 inc, 18 m, 144°T
007	17.3	22.3	<.2	<.2	5	70/	20 / 110	S / N	gouge orientations are highly variable
008	18.0	23.5	<.2	.2	5	87/	36 / 126	S / N	" " " " "
009	18.8	24.3	.2	.2	4	142/	158 / 248	R / C	Orientation is highly variable. 3 Multi-Gouges - 24 inc, in largest - 125 m wide - 240°T
010	19.1	24.4	.4	.3	8	152/	24 / 114	R / C	
011	19.6	25.3	.4	.5	7	175/	151 / 241	R / C	orientation is highly variable.
012	20.1	25.3	.5	.7	5	169/	26 / 116	R / C	orientation is highly variable. large multi gouge with 13 incisions and oriented 90°T. width = 65m.
013	20.2	25.8	.4	.5	5	124/	70 / 250	R / C	sonar quality poor - many range changes.
014	18.1	24.5	.4	.5	16	156/	143 / 323	R / C	orientation is highly variable.
015	16.9	22.8	.3	.5	5	121/	26 / 206	R / C	300 m of sonar missing. Count adjusted.
016	15.9	21.4	<.2	<.2	5	39/	126 / 306	S / N	4 meter shoal in middle of segment. most gouging ends on offshore slope of the shoal
017	12.7	18.2	<.2	<.2	4	25/	166 / 256	S / N	
018	13.0	—	.2	.2	10	42/	35 / 125	S / N	
019	15.8	—	.2	.3	7	137/	145 / 235	T	orientation is highly variable.
020	16.4	—	.2	.3	5	149/	150 / 240	R / C	orientation is highly variable
021	17.0	—	.4	.9	—	—	—	R / C	no sonar this segment
022	16.9	—	.3	.6	6	167/	23 / 113	R / C	orientation is highly variable.
023	17.8	—	.5	.5	5	148/	23 / 113	R / C	orientation is highly variable
024	17.5	22.8	.9	.9	18	172/	136 / 226	R / C	orientation is highly variable.
025	18.2	24.9	.6	.6	7	126/	45 / 225	R / C	orientation is variable.
026	17.2	22.5	.7	.5	—	—	—	R / C	no sonar this segment
[illegible]	16.4	20.7	.4	.4	4	86/	110 / 200	T	400 m of sonar missing. Count adjusted
[illegible]	13.7	19.0	.2	<.2	3	16/	128 / 308	S / N	3.5 m shoal in middle of segment

DMK

Line Number : 08					Year : 1981				gouge measurements in meters
	Fathogram Measurements				Sonograph Measurements				
SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density	Orientation (°T)	Sediment Cohesion	REMARKS
029	10.3	15.0	<.2	<.2	2	25/	131/311	S/H	A series of shoals (4-5) with gouging on crest & sand waves in troughs (λ ≈ [illegible], θ ≈ 147°T)
030	10.6	—	<.2	<.2	3	21/	147/327	S/N	
031	9.0	—	<.2	<.2	2	6/	127/157	S/N	
032	10.2	—	<.2	<.2	2	72/	40/60	S/H	Large [illegible]-gouge (pressure ridge type?) 58 incisions, 205 m wide, θ = 60°T
033	11.9	15.2	.2	<.2	6	57/	83/103	S/H	
034	12.3	18.3	.3	.8	7	47/	47/69	T	3 meter shoal at beginning of segment. Heavier gouging at seaward base.
035	15.8	20.5	.2	.5	5	113/	43/63	R/C	Orientation is highly variable
036	17.2	21.7							

BMR

Line Number : 09 Year : 1981 gouge measurements in meters

	Fathogram Measurements				Sonograph Measurements				
SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density	Orientation (°T)	Sediment Cohesion	REMARKS
000	4.1	—	<.2	<.2	—	—	—	—	no sonar this segment.
001	6.1	—	<.2	<.2	—	—	—	—	no sonar this segment.
002	7.5	—	<.2	<.2	—	—	—	—	no sonar this segment.
003	8.0	—	.2	.2	6	57/	121/221	N ?	Sonar Range : 150 m
004	8.1	—	.5	<.2	6	51/	117/217	N	
005	8.0	13.2	.3	.2	5	54/	110/210	N ?	Secondary orientation : 130°T
006	7.7	13.5	.2	.2	6	85/	115/215	N ?	30 cm hole noted on both BATS AND sonar. Other holes noted on sonar (1 meter diameter)
007	9.2	13.5	<.2	<.2	—	—	—	—	no sonar this segment.
008	6.9	11.5	<.2	<.2	3	67/	153/253	N	250 m of sonar missing count adjusted.
009	6.5	11.7	.2	.2	2	26/	133/233	N	30 cm hole noted on BATS & SONAR.
010	6.0	12.7	.2	.3	3	28/	45/55	N	
011	6.2	11.3	.2	.2	2	37/	51/61	N	
012	6.8	12.0	.3	.5	3	34/	50/60	N	SMOOTH SUBBOTTOM DIPS UNDER AN UPPER REFLECTOR (ROUGH) THAT SURFACES AT KM 12 *
013	7.3	11.0	.3	.5	4	37/	59/69	N	SUBBOTTOM is very rough.
014	8.2	11.1	.2	.3	7	24/	80/90	N	SUBBOTTOM is very rough (gouge like appearance).
015	9.1	12.3	<.2	<.2	5	25/	56/66	N	ROUGH SUBBOTTOM
016	9.5	12.4	.3	.3	4	17/	78/88	N	ROUGH SUBBOTTOM
017	10.5	13.5	<.2	.2	2	10/	63/73	N	ROUGH SUBBOTTOM. 200 m of sonar missing count adjusted
018	11.5	14.5	<.2	.3	3	36/	62/72	N	ROUGH SUBBOTTOM. 100 m sonar missing. count adjusted
019	12.3	15.1	<.2	.2	5	74/	21/96	N ?	ROUGH SUB.
020	12.7	14.8	<.2	.5	3	81/	30/105	T ?	ROUGH SUB.
021	12.8	15.0	.6	.7	20	171/	34/109	R/C	Gouge character change. Pressure Ridge gouging at end of segment. Many larger gouges.
022	13.0	—	.5	.8	19	110/	169/244	R/C	Secondary orientation 85°T
023	13.0	17.4	<.2	.3	8	100/	19/94	R/C	Gouging becoming less intense.
[illegible]	12.9	17.2	.3	.2	7	123/	8/83	R/C	SUBBOTTOM BECOMES FLAT AGAIN.
[illegible]	12.8	17.0	.3	.5	3	108/	10/85	R/C	Multiplex gouge 13 incisions, 45 m wide, 86°T
[illegible]	12.7	16.7	<.2	.2	3	110/	9/84	R/C	
[illegible]	12.5	16.4	<.2	<.2	4	102/	15/90	R/C	
[illegible]	12.3	15.6	—	—	7	134/	10/85	RC	no fathogram for segment. Pressure Ridge type gouging.

Line Number : 09 | Year : 1981 | gouge measurements in meters

	Fathogram Measurements				Sonograph Measurements				
SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density	Orientation (°T)	Sediment Cohesion	REMARKS
029	12.1	16.5	.3	.3	10	75/136.5	15/90	R/C	
030	11.9	16.5	.5	1.0	17	69/144.3	8/83	R/C	
031	12.2	16.2	.5	.9	3	108/103.7	113/113	R/C	
032	13.3	16.6	.2	.8	7	105/102.9	60/80	R/C	
033	14.0	17.9	.5	.7	8	171/167.6	61/81	R/C	very high gouge density but gouges are small and shallow.
034	14.8	20.0	.5	.6	5	217/212.7	58/78	R/C	[illegible]
035	15.4	19.9	.3	.7	8	263/273.5	52/72	R/C	400 m of sonar missing Count adjusted
036	15.8	20.4	.3	.6	3	165/171.6	52/72	R/C	high density gouging stops at middle of segment for no apparent reason (no shoals, etc.)
037	16.1	19.9	<.2	.3	7	58/58.6	57/77	R/C ?	
038	16.5	22.3	<.2	.2	3	59/61.0	153/173	R/C ?	(Because are shallow they may be covered by a transitory layer ??)
039	17.2	—	<.2	.2	7	56/58.2	51/71	R/C ?	
040	17.9	22.1	.3	.5	—	—	—	—	NO SONAR THIS SEGMENT HIGH DENSITY GOUGING STARTS AGAIN AT SEG. START (NO APPARENT REASON).
041	19.0	23.5	.3	.7	8	226/306.6	18/38	R/C	2 SUBBOTTOM REFLECTORS – TOP ONE APPEARS TO SURFACE AT ~ 40 km point *
042	19.7	24.3	.3	.3	5	140/141.4	53/73	S/N ?	long low shoal with little gouging on it. Probably sand – and will not hold gouges. 50 m sonar missing-adj.
043	19.0	—	.4	.6	7	214/216.1	123/238	R/C	high density gouging starts again after shoal crossing.
044	20.0	24.0	.3	.5	10	198/200.0	126/241	R/C	END OF SONAR
045	18.5	23.0	.3	.4	—	—	—	–	
046	18.2	22.3	<.2	<.2	—	—	—	—	2 meter shoal at beginning of segment
047	18.6	22.1	<.2	<.2	—	—	–	—	
048	17.2	—	<.2	<.2	—	–	—	–	
049	15.3	–	<.2	<.2	—	–	—	–	
050	14.5	—	<.2	<.2	—	–	—	–	2 meter shoal at mid segment.
051	13.9	—	<.2	.2	—	–	–	–	
052	11.6	—	<.2	<.2	—	–	–	–	
053	12.1	—	<.2	<.2	—	—	–	–	
054	11.2	—	<.2	<.2	–	–	--		
055	9.5	—							

Line Number : 13 | Year : 1981 | gouge measurements in meters

	Fathogram Measurements				Sonograph Measurements				
SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density	Orientation (°T)	Sediment Cohesion	REMARKS
000	7.0	8.0	<.2	<.2	2	15/	165/165	N/S	coarse sand ?
001	8.0	11.0	.2	.3	2	48/	142/142	N/S	2 mult. gouges - 10 inc., 151°T, 32m wide,
002	11.2	17.5	<.2	.3	3	92/	117/117	N/S	
003	13.8	23.2	<.2	.2	8	16/	128/128	N/S	
004	16.1	24.0	.2	.2	12	45/	97/97	N/S	
005	18.1	27.0	.3	.4	9	105/	100/100	T ?	orientations are variable
006	20.0	28.4	.5	.8	7	160/	113/113	C/R	multi gouge - 6 inc., 016°T, 25m wide.
007	21.4	—	.8	.5	10	166/	113/113	C/R	
008	23.1	—	1.2	1.0	7	124/	112/112	C/R	3 small mult. gouges
009	24.1	—	1.5	1.2	15	114/	115/115	C/R	many deep gouges (1.0m +)
010	26.8	31.8	1.3	1.4	10	125/	128/128	C/R	different sub bottom reflector.
011	28.5	34.9	3.0	1.5	10	104/	128/128	C/R	5 gouges over 2m deep.
012	29.9	35.6	2.8	2.6	10	122/	117/117	C/R	deepest incision and highest ridge are the same gouge (5.4 m relief)
013	33.3	36.5	1.0	.8	13	93/	121/121	C/R	gouges become much smaller than previous segments.
014	34.9	37.7	1.3	1.1	17	100/	118/118	T ?	
015	35.2	39.2	.9	.7	17	115/	129/129	N/S	gouges are wider and very subdued on sonar
016	34.8	—							

Line Number : 15 Year : 1981 gouge measurements in meters

	Fathogram Measurements				Sonograph Measurements				
SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density	Orientation (°T)	Sediment Cohesion	REMARKS
000	6.4		.5	.4	5	55	32/35	- C	Wet paper, range 125 m
1	7.8		.4	.3	15	30	34/37	S C	
2	8.2		.3	.2	15	65	23/26	S C	
3	8.5		.2	.2	12	12	36/39	S C	
4	9.3		.2	.2	7	39	52/55	S C	
5	10.0		.2	.2	6	37	65/68	S C	
6	10.7		.2	.2	4	16	70/73	S C	
7	11.6		.2	.2	5	72	36/39	R C	[illegible]
8	12.3		.5	.5	8	52	100/103	R C	
9	13.3		.7	.7	12	38	30/33	R C	
10	14.2		.5	.4	3	36	80/83	R C	
11	14.5		.6	.8	6	82	150/153	R C	
12	16.3		.6	.9	7	120	130/133	R C	
13	16.8		.8	.5	10	133	130/133	R C	
14	19.0		.7	1.1	12	129	58/61	R C	
15	19.0		.6	.7	5	114	120/123	R C	
16	19.8		.6	.7	8	96	70/73		
17	21.0								

BNK

Line Number : 31 Year : 1981 gouge measurements in meters

	Fathogram Measurements				Sonograph Measurements				
SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density	Orientation (°T)	Sediment Cohesion	REMARKS
000	24.2	—	1.2	1.7	12	128/	106/096	R/C	
001	23.2	—	1.4	1.0	6	170/	091/084	R/C ?	
002	18.4	—	.8	.5	6	80/	100/090	T ?	
003	17.1	—	.4	.5	3	57/	070/060	S/N	Sediment waves (ripples) λ= 6 meters θ= 144°T
004	17.0	—	.2	.2	7	81/	063/053	S/N	
005	17.0	—	.4	.3	5	106/	075/065	T ?	
006	16.2	—	.3	.5	4	102/	080/070	R/C ?	
007	15.3	—	.4	.9	6	53/	092/082	R/C	
008	14.2	—	.3	.3	7	48/	086/076	T ?	
009	13.1	—							

Line Number : 32 Year : 1981 gouge measurements in meters

SEGMENT	Fathogram Measurements				Sonograph Measurements				REMARKS
	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density	Orientation (°T)	Sediment Cohesion	
000	65.6	—	—	—	—	O	—	N	Possible sand waves. Very subdued θ=116°T Range 150m * h=<20 cm λ=3 M
001	64.2	—	—	—	—	O	—	N	Possible sand waves and ripples. θ=118°T h=<20cm λ=3 M
002	57.3	—	.5	.7	11	12/	137/102	S/N	Range change to 200m. Possible shelf edge at * midsegment. Probably granular sediments.
003	53.6	—	1.1	.8	13	42/	131/96	S/N	Gouges are large but subdued on sonar (sand + gravel) Most gouges are wide (>5m)
004	54.3	—	.8	.5	8	41/	125/90	S/N	
005	54.2	—	1.1	.4	15	57/	134/99	S/N	
006	53.5	—	1.2	.7	18	57/	120/105	S/N	
007	54.0	59.0	1.3	.7	19	48/	136/104	S/N	1st subbottom reflector appears midway through segment 6-7.
008	54.5	58.3	2.5	1.3	35	61/	140/120	S/N	350m of sonar missing. Count adjusted.
009	54.3	—	2.5	.5	—	—	135/115	S/N	no sonar this segment.
010	54.7	—	2.5	.6	22	51/	140/120	S/N	some BATS missing
011	55.0	—	2.0	1.2	18	46/	131/111	S/N	
012	54.5	60.0	1.6	1.1	26	40/	123/103	S/N	2 SUBBOTTOM REFLECTORS
013	54.7	59.3	1.5	.8	40	32/	127/107	S/N	
014	53.5	60.0	2.1	1.2	67	40/	123/103	S/N	
015	52.8	58.0	3.0	1.3	27	41/	131/111	S/N	
016	53.3	56.5	2.1	1.0	25	44/	124/104	S/N	upper reflector surfaces at mid segment.
017	53.4	—	1.3	.7	21	39/	129/109	S/N	gouges become much smaller at this point.
018	51.7	56.0	1.0	.8	22	48/	127/107	S/N	2nd sub bottom reflector.
019	51.2	54.1	1.0	.5	—	—	—	S/N	no sonar this segment. 3rd reflector begins this segment
020	49.7	53.6	2.0	1.1	—	—	—	S/N	2nd reflector surfaces at mid segment.
021	47.3	53.8	1.5	.8	32	72/	144/109	S/N	
[illegible]	47.7	54.0	.6	.6	15	78/	134/99	S/N	
[illegible]	46.3	52.0	1.1	.8	15	85/	135/100	S/N	
[illegible]	45.5	50.4	1.4	.6	20	76/	132/97	S/N	
[illegible]	42.5	49.5	—	—	23	91/	133/98	S/N	3rd sub bottom reflector surfaces
[illegible]	42.6	—	1.3	1.4	39	92/	134/99	S/N	
[illegible]	43.0	—	2.3	.7	34	126/	135/100	S/N	[illegible]
[illegible]	41.5	—	1.8	1.9	11	114/	140/105	S/N	

Line Number : 32					Year : 1981				gouge measurements in meters
	Fathogram Measurements				Sonograph Measurements				
SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density	Orientation (°T)	Sediment Cohesion	REMARKS
029	—	—	.5	1.0	15	95/	139/104	S/N	Point 029 is not on fathometer.
030	42.0	45.5	1.6	.8	17	72/	136/101	S/N ?	Possibly 2 subbottom reflectors (4+5)
031	41.2	46.0	1.9	1.2	15	89/	133/098	T ?	Gouging becoming rougher (sharper on sonar)
032	40.4	45.2	1.3	1.2	8	90/	138/103	T ?	[illegible] reflector surfaces (4)
033	42.0	44.9	.9	1.4	10	98/	131/096	R/C ?	Gouges becoming smaller, subbottom reflector surfaces (5).
034	41.6	—	.5	1.6	11	96/	129/094	R/C ?	
035	40.0	47.7	.7	.8	15	105/	121/086	R/C ?	subbottom reflector begins (6)
036	39.4	42.4	1.4	.8	15	117/	134/099	R/C ?	reflector surfaces mid segment
037	38.2	—	.8	1.3	13	122/	143/108	R/C ?	steeply (relatively) dipping reflectors (offshore)
038	38.0	—	1.0	1.3	17	140/	131/096	R/C ?	Steeply dipping reflectors
039	37.1	—	1.5	1.2	8	151/	122/087	R/C ?	Axis of fold at ~ point 039 - Steeply dipping reflectors now dip other way (onshore)
040	35.9	—	.7	1.3	9	121/	139/104	R/C ?	steeply dipping reflectors
041	35.1	—	1.0	2.2	11	162/	123/088	R/C ?	1 meter shoal at mid segment
042	32.1	—	.7	.6	22	155/	159/099	S/N ?	5.5 meter shoal at mid segment.
043	32.8	—	.7	1.0	12	124/	155/095	R/C ?	
044	31.0	—	.9	.8	9	148/	103/093	R/C ?	
045	31.3	—	.2	.4	19	64/	091/081	S/N ?	4.5 meter shoal at end segment. Asymetric shape with steeper side offshore. STAMUKI APPEARANCE.
046	28.0	—	.7	.8	8	104/	115/090	R/C ?	
047	30.7	—	1.2	1.5	6	169/	107/097	R/C ?	
048	29.6	—	1.2	1.7	7	157/	106/096	R/C ?	
049	26.0	—	—	—	6	127/	105/095	R/C ?	no fathogram this segment.
050	21.7	—	.8	1.0	5	201/	105/095	R/C ?	
051	21.5								

Line Number : 33 Year : 1981 gouge measurements in meters

	Fathogram Measurements				Sonograph Measurements				θ = orientation λ = period
SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density	Orientation (°T)	Sediment Cohesion	[illegible] REMARKS
000	6.4	—	<.2	<.2	2	6	157	N	N= non cohesive C= cohesive
001	8.5	—	<.2	<.2	25	7	142	N	sand waves λ2.5m θ 005°
002	17.6	22.0	<.2	<.2	3	15	103	N	
003	18.2	21.5	.3	.4	5	110	120	T	
004	22.2	—	.6	1.0	11	150	120	C	
005	27.6	—	1.4	1.1	10	117	106	C	
006	30.0	-	1.4	2.0	15	75	103	C	
007	29.1	--	1.1	1.6	12	10	113	C([illegible])	Shoal / sand waves λ1.5m θ 005°
008	30.4	—	1.4	1.3	11	121	116	C	
009	41.5	43.0	1.6	1.7	5	55	95	C	
010	36.7	40.5	1.0	.8	10	65	120	C	
011	39.5	42.0	3.5	1.3	2	58	95	C (T)	
012	43.0	46.0	3.0	.7	20	70	116	N	
013	45.0	47.6	2.2	1.5	10	59	110	N	bottom appears smooth [illegible] sediment non cohesive
014	44.5	50.0	3.2	1.7	12	46	115	N	
015	47.0	50.5	1.5	1.7	10	10	127	N	waves [illegible]
016	47.0	50.0	1.7	1.9	20	40	105	C	
017	46.5	50.5	2.5	1.5	10	20	55	N	
018	46.5	52.0	1.7	1.2	15	22	110	C	
019	49.5	52.0	2.5	1.2	25	32	155	N	
020	49.0	52.0	1.8	1.0	20	11	120	N	
021	50.5	54.6	1.7	.9	45	8	21	N	[illegible]
022	52.5	54.3							END LINE

Line Number : 34					Year : 1981			gouge measurements in meters
	Fathogram Measurements				Sonograph Measurements			
SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density	Orientation (°T)	Sediment Cohesion	REMARKS

SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density	Orientation (°T)	Sediment Cohesion	REMARKS
000	40.2	—	2.0	2.0	15	411	104	C	
001	38.0	41.0	3.0	5.0	20	17	108	C	
002	35.0	39.0	2.1	2.2	12	153	95	C	
003	32.3	31.5	2.0	1.2	8	140	107	C	33 m bench
004	39.0	42.0	1.6	1.2	20	33	110	C	[illegible] infilled gouges & depress.; [illegible] bench (depression)
005	35.5	41.5	1.6	1.3	12	46	102	C	
006	32.6	39.0	2.3	1.5	10	135	109	C	
007	32.5	36.0	1.8	1.2	10	215	94	C	
008	28.5	33.5	2.3	1.5	10	260	120	C	2" grwp, θ = 71°
009	27.0	31.5	2.3	1.6	8	194	115	C	
010	26.0	30.5	1.0	1.1	5	240	108	C	
011	23.5	28.0	1.2	1.1	5	245	114	C	
012	20.3	27.0	<.4	<.4	1	330	108	C	First reflector surfaces, 2nd reflector appears!
013	19.4	24.2	<.3	<.4	5	141	126	C	~ 30 sec SS record missing, not taken [illegible]
014	17.6	20.0	<.2	<.2	8	20	132	C	
015	15.2	—	<.2	<.2	3	12	124	C	Breaks in SS record
016	12.6	—	<.2	<.2	2	12	160	C	
017	9.9	—	<.3	<.2	2	3	144	C	
018	9.8	—	—	—	—	—	—	C	
019	6.5	—							END LINE

Line Number : 35					Year : 1991				gouge measurements in meters
	Fathogram Measurements				Sonograph Measurements				
SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density	Orientation (°T)	Sediment Cohesion	REMARKS
000	1.6	—	—	—	—	—	—	N	
001	4.0	7.0	—	—	—	—	—	N	
002	11.7	15.2	<.3	<.3	5	17	120	N	Funny bottom windows (Cohesive) in non cohesives.
003	13.0	19.0	<.3	<.3	7	19	124	N	[illegible] in [illegible] bottom
004	14.8	19.0	<.3	<.3	5	14	122	N	
005	16.0	19.5	<.3	<.3	2	9	123	N	
006	16.5	21.0	<.3	<.3	2	35	160	N	
007	16.5	19.5	<.3	<.3	2	70	126	N	seaward dipping stratified section truncated at seafloor (erosional) - no holocene -
008	18.6	24.5	<.3	<.3	5	63	120	N	
009	20.1	24.0	<.3	<.3	6	93	(120) ~~165~~	N	gouges appear infilled.
010	21.5	27.5	.4	.8	7	175	115	N	
011	22.2	—	.7	.7	7	181	107	[illegible]	gouges become fresh looking.
012	21.5	—	.5	.8	7	249	112 ~~335~~	C	[illegible] ice ridge [illegible] gouges [illegible]
013	24.2	29.5	.7	.5	7	227	126	C	
014	26.7	33.5	.7	.8	8	164	126	C	
015	23.2	--	1.2	1.3	5	152	129	C	
016	~30	—	1.0	.8	7	140	119	C	
017	37.0	36.6	1.0	1.2	7	165	113	C	
018	32.7	38.0	1.0	1.0	7	151	133	C	
019	33.6	40.0	.7	.7	6	133	133	C	
020	35.5	41.8	.6	.8	10	117	135	C	
021	35.7	42.5	.5	.7	15	99	124	C	
022	33.5	42.5	.8	.5	7	97	117	C	change course
023	39.4	—	.6	.6	12	41	116	R C	
024	39.5	42.5 ?	.4	.4	10	47	114	F C	
025	39.5	43.0	.4	.5	12	65	110	R C	
026	37.0	41.0	.6	1.2	12	37	120	R C	
027	36.5	40.2	.3	1.0	20	112	125	R C	
028	35.7	38.5	1.4	1.0	10	130	123	R C	

Line Number : 35 (con't) Year : 1981 gouge measurements in meters

	Fathogram Measurements				Sonograph Measurements				
SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density	Orientation (°T)	Sediment Cohesion	REMARKS
029	33.5	37.7	1.0	1.0	15	118/	60/300	R C	strong sub-bottom
030	30.6	36.2	1.1	1.0	8	141/	62/302	R C	
031	28.0	33.8	2.0	.8	10	143/	66/306	R C	
032	26.7	32.0	1.0	.8	7	133/	58/298	R C	sub bottom coming up
033	25.5	29.5	1.0	.7	5	131/	65/305	R C	
034	22.5	—	.7	.6	5	135/	66/301	R C	
035	[illegible]	—	.5	.7	7	101/	62/302	R C T	
036	20.0	—	.2	.5	3	163/	52/292	S C	BCR71 Change course 240°
037	19.0	(29) B	<.2	<.2	15	70/	72/312	S C	Patchy c/c 260
038	18.4	—	<.3	.7	7	23/	52/312	Patchy	
039	15.8	(24.5)B	<.3	.4	6	13/	50/310	S N	Patchy
040	13.5	—	<.3	<.3	2	35/	42/302	S N	
041	11.0	~~—~~	~~<.3~~	~~[illegible]~~	~~2~~	~~20/~~	~~[illegible]~~	~~S N~~	END LINE

Line Number : 36 | Year : 1981 | gouge measurements in meters

SEGMENT	Fathogram Measurements: Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Sonograph Measurements: Gouge Width	Density	Orientation (°T)	Sediment Cohesion	150m range REMARKS
000	5.0	—		-	—	2	21/78	R C	Lumpy bottom (stiff clay) & sand (?)
001	7.3	—	—	—	—	0	~~/~~	S N	
002	9.2	—	—	—	—	+	61/121	RS CN	Lumpy bottom
003	12.7	—	—	—	—	~~10~~	~~44~~ 101	S N	
004	13.7	—	.3	.3	4	23	75/110	S N	
005	15.6	—	<.3	<.2	4	51	50/107	S N	Gouging in sub-bottom, sand gouging
006	16.9	—	.3	.3	4	58	55/112	S C	
007	17.7	—	.2	.2	7	86	55/112	S C	
008	18.5	—	.2	.3	5	39	62/112	S N	
009	20.1	—	<.2	<.2	5	66	62/112	S N	
010	21.2	—	.2	.3	6	92	40/89	S N	
011	21.6	—	.2	.4	6	116	43/114	R C	
012	22.3	—	.5	.5	10	156	52/111	R C	
013	26.2	—	1.2	1.1	8	124	118/143	R C	
014			.6	.6	5	119	102/127	R C	
015	30.5	33.5	1.0	1.2	5	138	123/148	R C	Gouges are [illegible] (filled or in unconsolidated [illegible])
016	34.0	37.2	.7	.5	5	114	120/145	R C	
017	34.0	37.5	1.0	1.0	8	107	105/130	R C	
018	35.5	40.2	.6	.4	6	98	118/143	R C	
019	35.6	40.5	.8	1.3	7	113	90/115	R C	
020	35.7	39.[illegible]	.9	1.0	6	103	117/142	R C	
021	36.5	41.0	.6	.8	5	77	70/138	R C	
022	33.4	40.[illegible]	.8	.5	6	74	65/120	R C	
023	39.5	42.[illegible]	1.5	1.4	10	30	118/278	R C	[illegible]
024	31.1	31.1	1.4	.9	10	117	125/285	R C	
025	36.6	[illegible]	.4	.5	5	170	125/2[illegible]	R C	
026	34.5	31.0	.7	1.6	8	110	125/285	R C	
027	34.4	[illegible]	.8	.9	8	177	138/298	R C	
028	34.2	40.[illegible]	.7	.6	12	153	135/293		

Line Number : 36 (con't)					Year : 1981				gouge measurements in meters
	Fathogram Measurements				Sonograph Measurements				
SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density	Orientation (°T)	Sediment Cohesion	Passing 1573 m REMARKS
029	34.2	39.0	.6	.5	16	114	124/284	RC	CS 160°
030	34.2	39.0	.6	.5	12	200	125/235	RC	
031	33.3	39.0	.4	.4	7	147	132/292	RC	
032	33.6	37.7	.3	.4	7	160	123/283	RC	
033	33.2	36.5	.6	.4	5	160	123/283	RC	outcrop? ([illegible] – 3/4 distance)
34	31.6	?	.8	.6	7	~160	145/305	RC	"
35	30.5	—	1.2	.8	8	203	140/300	RC	
36	29.5	—	.5	.5	12	288	130/290	RC	many [illegible] gouges
37	27.0	—	.5	.4	12	225	115/275	RC	many wide multi gouges
38	26.3	—	1.0	.9	10	310	124/134	RC	"
39	27.3	—	.4	.5	10	275	120/180	RC	
40	24.7	—	.3	.3	6	298	126/186	RC	
41 Not real	24.3	—	.3	<.3	?	?	?	?	slip line sample 1536-1546
42	23.7	—	.4	.2	7	224	152/312	RC	outcrop cliff silty clay?
43	22.2	—	<.3	<.3	5	186	115/287	RC	C/C 172°
44	21.5	—	.3	.5	7	228	120/212	RC	
45	19.6	—	.7	.4	5	137	122/182	RC T)	shoaled [illegible] ? C/C 160 [illegible]
46	18.3	—	<.2	<.2	3	70	127/237	SN	
47	17.5	—	<.2	.4	4	38	135/300	SN	
48	17.0	—	.2	.3	6	66	132/297	SN	
49	14.5	-	.2	.4	4	58	145/310	SN	
50	12.5	-	.3	.2	5	19	162/327	SN	
51	11.4	-	.3	<.2	3	153	103/273	SN	
52	7.2	-							END LINE

Line Number : 38 Year : 198[illegible] gouge measurements in meters

	Fathogram Measurements				Sonograph Measurements				
SEGMENT	Water Depth (meters)	Reflector "A"	Gouge Depth	Ridge Height	Gouge Width	Density	Orientation (°T)	Sediment Cohesion	REMARKS
000	5.5	—	—	—	—	—	—	S N	ripples 150m θ: 137 λ = 3m h = <.2
001	9.7	—	—	—	—	—	—	S N	ripples
002	11.6	—	<.2	<.2	1	74	0° / 38°	S N	c/c 338°
003	14.2	—	.2	<.2	4	58	21° / 59°	S N	truncated fields
004	16.6	—	<.2	<.2	5	141	42 / 30° (?)	S N	much wider
005	16.8	—	.3	.2	4	122	45 / -15 (?)	S N	
006	18.7	—	.3	.4	5	208	120 / 158	S N	[illegible] c/c 38°
007	20.2	—	.3	.5	10	147	75 / 113	R C	
008	21.7	—	.5	.5	10	195	78 / 116	R C	Mud
009	22.0	—	1.0	1.0	15	329	78 / 116	R C	Bed 1
010	25.2	—	1.0	.7	12	146	78 / 116	R C	
011	27.2	—	1.7	1.5	10	186	55 / 93	R C	
012	28.0	—	2.0	1.4	10	134	78 / 116	R C	
013	28.6	—	2.0	1.6	8	172	72 / 110	R C	
014	30.0	—	1.7	1.3	50	232	80 / 118	R C	clay
015	31.0	—	1.8	1.7	10	227	105 / 143	R C	Bed 2 truncated [illegible]
016	32.3	35.0	1.7	1.0	10	149	75 / 113	R C	Bed 3 appears
017	32.5	35.6	1.7	1.0	12	147	112 / 150	R C	
018	33.0	36.5	1.5	1.0	12	169	76 / 114	R C	
019	34.0	36.4	2.0	1.0	15	125	105 / 143	R C	
020	35.0	38.5	3.2	2.1	25	93	110 / 148	R C	[illegible] some gouges appear SUBDUED. [illegible] ?
021	36.1	40.0	1.7	1.2	10	96	105 / 143	R C	
022	36.6	39.4	2.5	1.4	25	137	65 / 103	R C	c/c [illegible]
023	36.4	40.0	2.8	1.7	25	147	85 / 123	R C	
024	37.5	40.7							Bed 1 mud