UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Nearshore marine geologic investigations, Icy Cape to Wainwright, northeast Chukchi Sea

by

R. Lawrence Phillips and Thomas E. Reiss

Open-file Report 84-828

CONTENTS

INTRODUCTION

This report summarizes the results of reconnaissance investigations in the Chukchi Sea within the nearshore region (less than 30 m depth) from Icy Cape (70° 20' N) north to Wainwright (70° 36' N) (figure 1). The survey was conducted between August 1 and August 21, 1982. The purpose of this investigation is to identify marine geologic hazards as well as locate potential shelf sand and gravel resources.

Approximately 138 km of side-scan sonar records, subbottom profiles, sea floor profiles and eight surficial grab samples were collected during this study (figure 2).

The study area is bordered on land by a gently sloping coastal plain. The Kuk River dissects the coastal plain and enters the Chukchi Sea through Wainwright Inlet. North of Wainwright the coastal region is bounded by low vegetated cliffs. Southwest of Wainwright the cliffs abruptly decrease in height and slope toward the Chukchi Sea. A narrow barrier island chain borders most of the coastal area from approximately 25 km south of Wainwright to south of Icy Cape, a distance of 87 km (figure 2). Two inlets, Pingorarok Pass and Akoliakatat Pass, cut through the barrier island into the northern part of Kasegaluk Lagoon. Both inlets are relatively shallow: at the time of the survey, water in Pingorarok Pass was less than 1.5 m deep and in Akoliakatat Pass water reaches depths of 6 m. The unnamed pass 3 km south of Icy Cape contained a sill that extended to within one meter of the water surface and restricted exchange between the open ocean and the southern part of Kasegaluk Lagoon.

The oldest bedrock underlying the offshore region between Icy Cape and Wainwright consists of Cretaceous sandstones, siltstones and mudstones of the Nanushuk Group (Grantz and others, 1982). These strata are unconformably overlain by Quaternary sediment throughout the region. Bedrock crops out locally in the nearshore zone. The youngest Holocene deposits are found in the sand banks off Icy Cape and in the barrier island chain.

The weather conditions during this part of the study were adverse with persistent winds from the west to northwest of up to 45 knots. Associated with these winds were storms lasting upto 2 to 3 days. Short period wind waves generated during the storms were over 2 meters in height.

The pack ice was located to the north of Barrow during this part of the study.

BATHYMETRY

Along the coastal region from Wainwright to Icy Cape, the inner shelf gradually deepens seaward to a depth of 20 m about 6 km from Wainwright Inlet and 15 km from Akoliakatat Pass. A series of arcuate, 6 to 16 m high, sand banks (Blossom Shoals) extends seaward over 20 km off Icy Cape (figure 3). These sand banks increase in length and become more locally complex in shape with distance from shore.

CURRENTS

The oceanographic regime along this part of the Chukchi Sea coast is dominated by wind-generated currents and the offshore Alaska Coastal

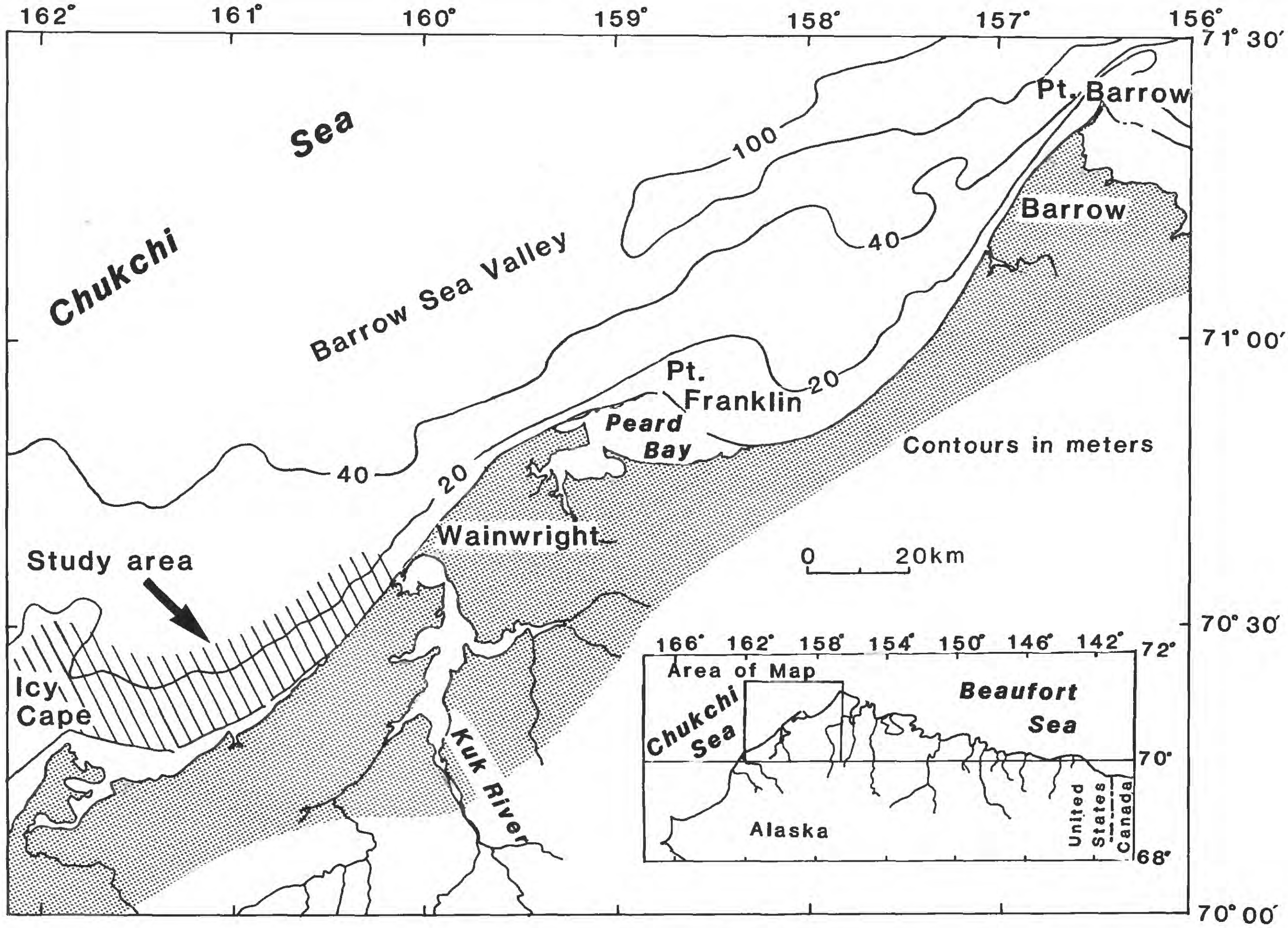


Figure 1. Location of nearshore shelf investigated during 1982 in the northeastern Chukchi Sea between Wainwright and Icy Cape.

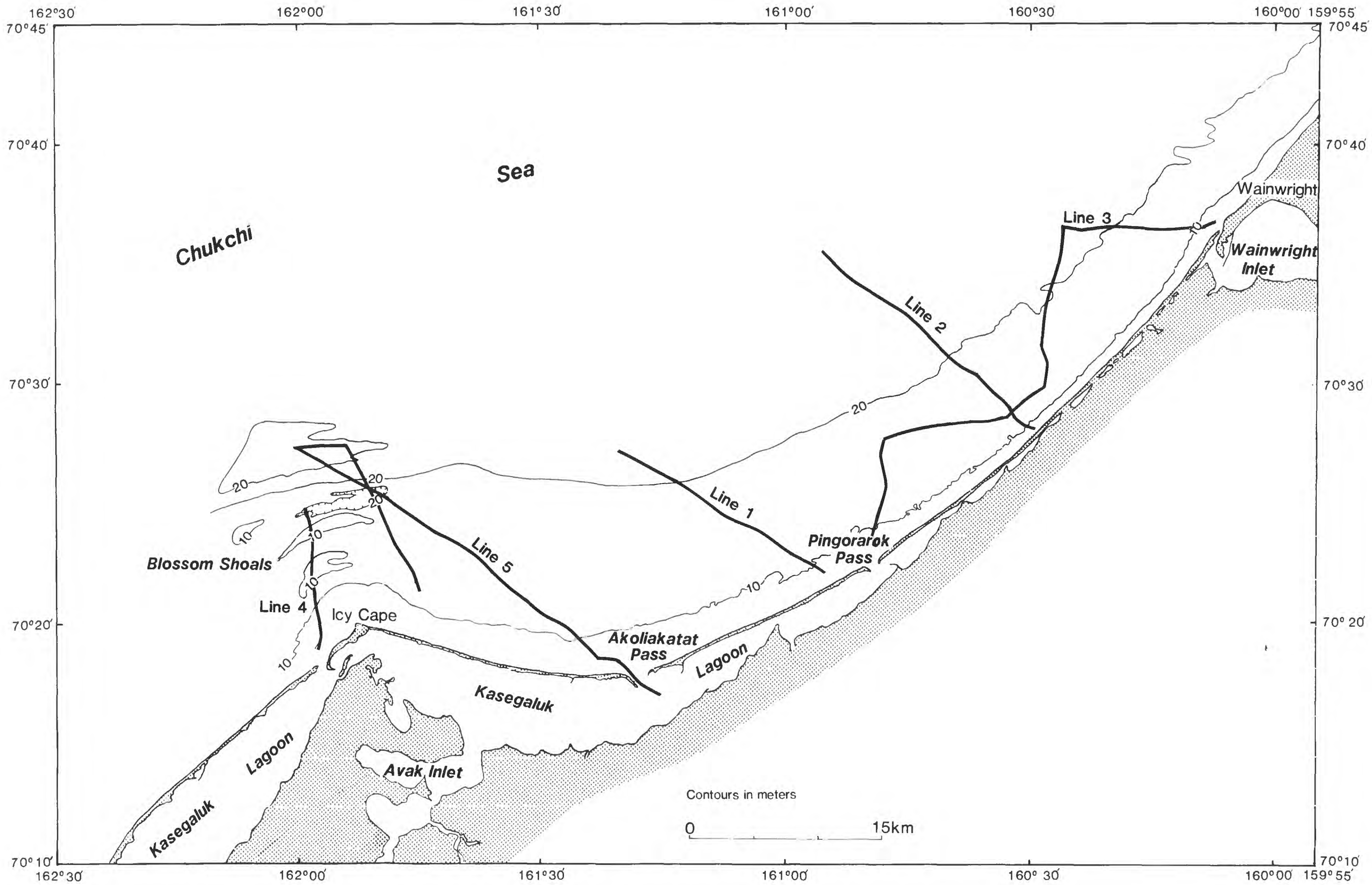


Figure 2. Trackline map 1982 R/V Karluk cruise, Icy Cape to Wainwright, Chukchi Sea.

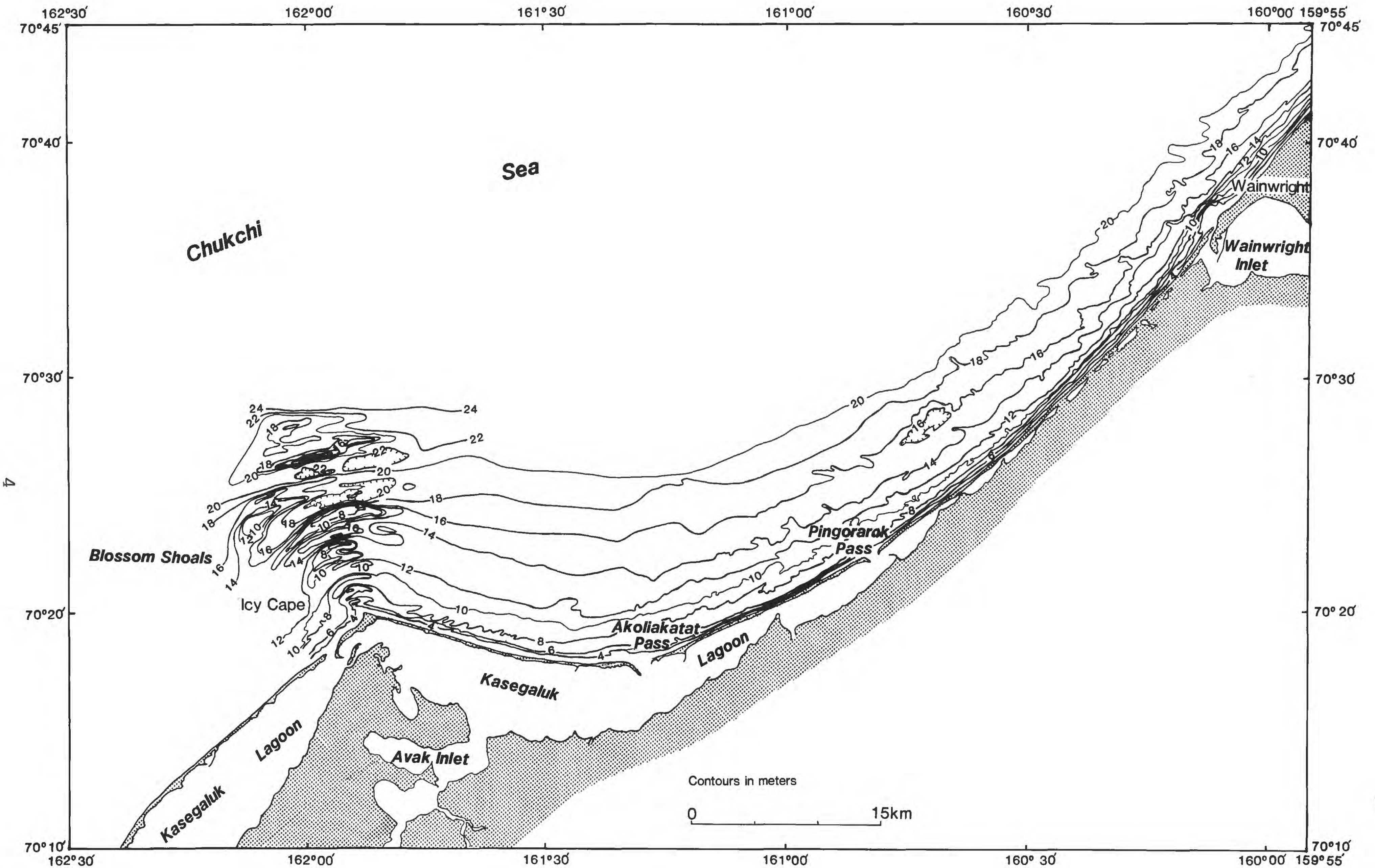


Figure 3. Bathymetric map of nearshore region, Icy Cape to Wainwright, Chukchi Sea. Contours are in meters. Depth data obtained from NOAA hydrographic survey sheets, No. H-7664 and H-7665, 1947.

Current. The wind-generated currents associated with westerly and southwesterly storms rework the nearshore sediments to water depths of 10 to 12 m.

The northward flowing Alaska Coastal Current dominates the offshore region (Hufford, 1977). The sea floor effects of the northward flowing current are documented by northward migrating sand wave fields between Wainwright and Peard Bay (Phillips and others, 1984). The effect of the Alaska Coastal Current on bottom sediments in the study area is poorly known; sandwaves, which reflect in part the influence of bottom currents, were identified only in the region of Blossom Shoals. Sand wave fields exist both on the flanks of the individual sand banks and also nearshore, directly off Icy Cape. Further offshore and to the northeast of Icy Cape westward-directed bottom currents, as indicated by the sand wave orientation, are observed in the outer offshore regions (figure 4). The westward flowing currents may have originated as a clockwise gyre formed on the east flank of the northward flowing Alaska Coastal Current; alternately they may represent a counter-current flowing parallel to the Alaska Coastal Current. A third possibility is that they are a seaward extension of southwesterly flows between Wainwright and Icy Cape. The currents, especially off of the capes, appear to be complex and are poorly understood. The capes along the Chukchi Sea represent regions of longshore convergence both of currents and sediment transport (Short, 1975, 1979).

Other evidence of currents as indicated by bedform orientations were observed nearshore between Akoliakatat Pass and Pingorarok Pass. Gravel-sand patches containing small-scale shore-normal oriented bedforms were observed in water depths of less than 12 m. The bedforms oriented parallel to the shoreline formed from surface waves moving onshore.

QUATERNARY SEDIMENT

High-resolution seismic records identify at least two seismic units. The basal seismic unit consists of horizontal to gentle dipping and folded strata of probable Cretaceous age. The upper most part of the thick basal unit contains an irregular truncated surface incised with local small channels. The upper seismic unit is thin, less than 5 m thick, and contains horizontal or gently inclined strata formed from migrating channels. The upper unit probably represents strata of Quaternary age (figure 5).

Areas containing a thin sediment cover (2 m or less in thickness) overlying bedrock (basal seismic unit) are identified in the offshore region between Wainwright and Akoliakatat Pass. Regions containing thick Quaternary sediment include; 1) the nearshore coastal zone adjacent to the barrier islands, 2) Blossom Shoals where the sand banks may contain over 15 m of Holocene(?) sediment, 3) toward the northwest in the outer-most parts of the offshore areas investigated and 4) locally within a paleochannel of the Kuk River located off of Wainwright Inlet. A maximum channel-fill thickness of 23 m is identified (figure 6).

Regions of thin sediment cover (offshore between Wainwright and Akoliakatat Pass) are probably areas of low sediment input and erosion (wave-generated currents in combination with long shore currents remove sediment). The major depocenter occurs off of Icy Cape (a region of probably converging currents) where the transported sediment is deposited.

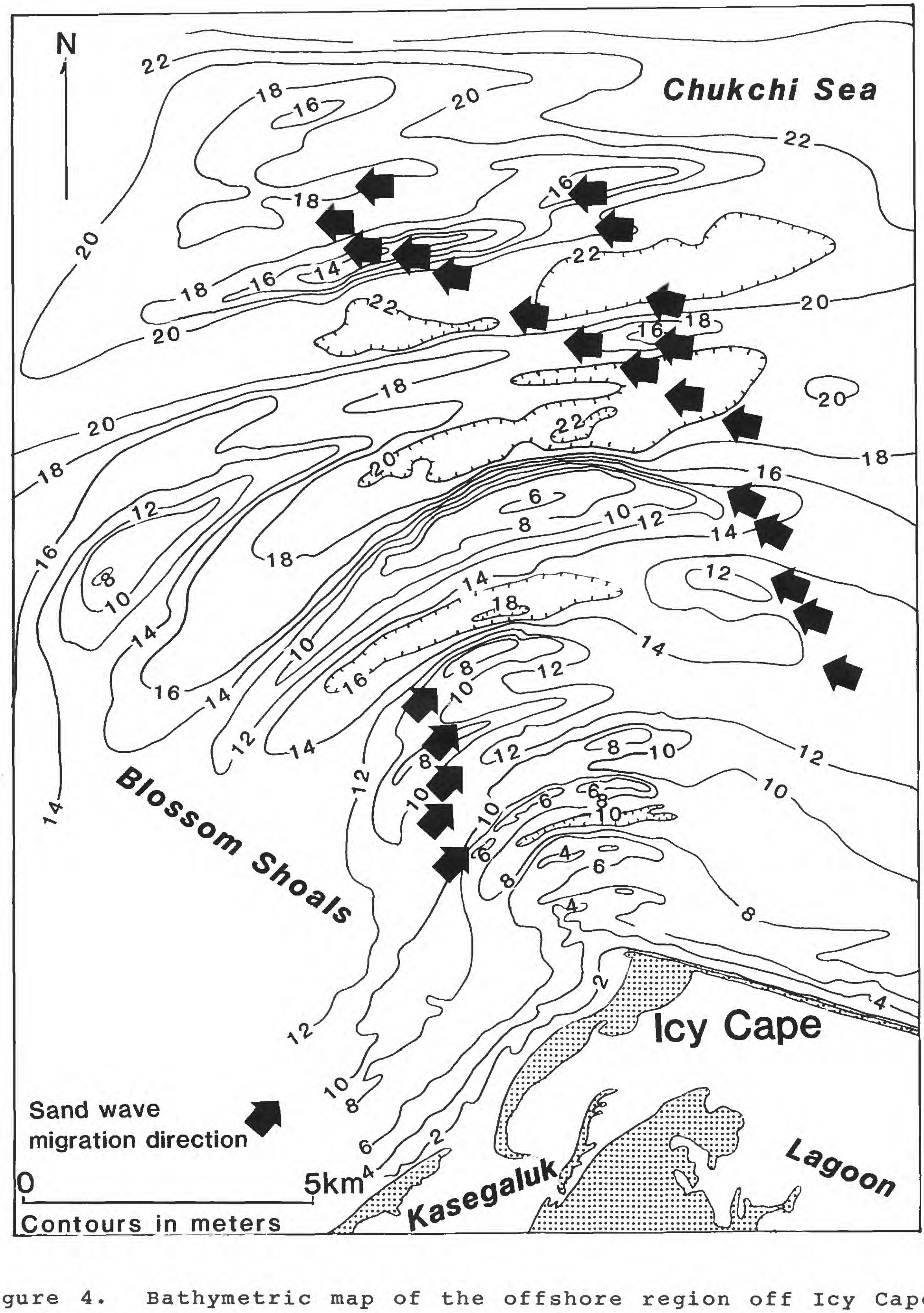


Figure 4. Bathymetric map of the offshore region off Icy Cape, Chukchi Sea. Contours are in meters. A series of arcuate sand banks form Blossom Shoals. The arrows indicate sand wave migration directions.

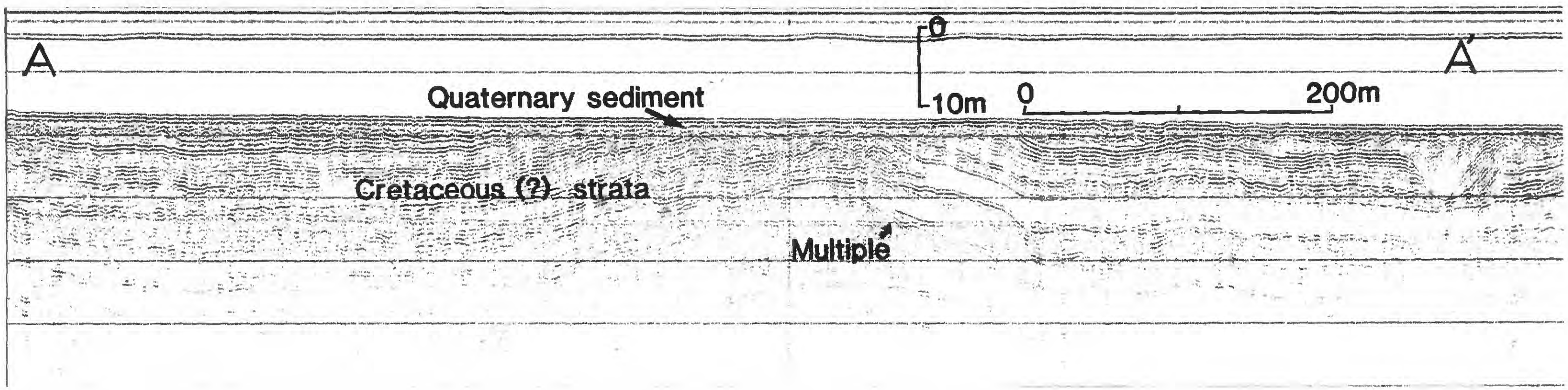


Figure 5. High-resolution seismic profile east of Icy Cape (see figure 6, letter A, for location of profile. The Quaternary sediment cover is thin, less than 2 to 3 m thick, for much of the region northeast of Icy Cape north to Wainwright. The underlying gentle dipping strata is assumed to be of Cretaceous age.

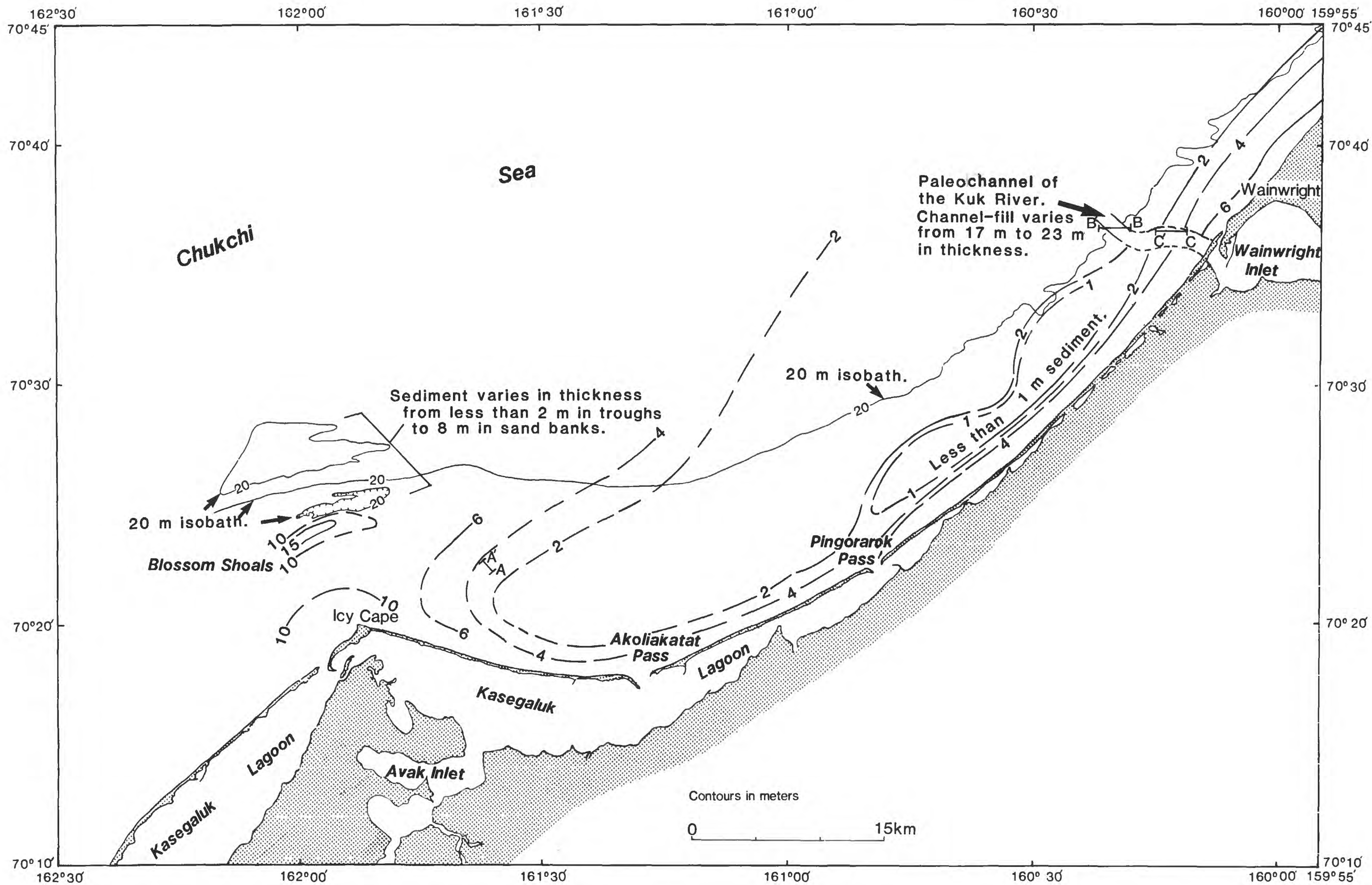


Figure 6. Isopach map of Quaternary sediment cover overlying Cretaceous(?) bedrock between Icy Cape and Wainwright, Chukchi Sea. The maximum sediment thickness, 15 m, occurs in the largest sand bank in Blossom Shoals. The offshore sand banks contain up to 8 m of Holocene sediment. The letters indicate seismic profile locations.

The Kuk River paleochannel was initially identified nearshore by Hunter and others (1982). The seaward extension of the paleochannel system was identified during this study. The paleochannel is at least 600 m wide, contains a multi-storied fill history (figure 7) and may also contain gas within the channel-fill sediment (figure 8). The tentative identification of gas within the channel-fill is suggested by the "wipe-out" of the acoustic seismic signal (figure 8) and by apparent near-bottom water column anomilies identified on high resolution profiles.

SURFICIAL SEDIMENT

The surficial sediment within this coastal area, based on samples and side-scan sonar surveys, show that the sediment texture varies from gravelly sand nearshore to silty sand (sample number 2, figure 9) offshore. Sand-size sediment forms the most abundant texture in this region. The sediment distribution reflects the dominance of active erosional and depositional processes on the nearshore zone of this shallow shelf. Bedrock of probable Cretaceous age may also outcrop on the sea floor as well as possible consolidated Quaternary deposits. Possible Quaternary outcrops are identified directly east of Icy Cape at water depths of 12 m. At this depth distinctive circular-shaped depressions, varying from 12 to 20 m in diameter, are observed on side-scan sonar records (figure 10). A raised border surrounds the depressions. The maximum relief from the base of the depression to the area of highest relief is 0.5 m. Approximately 2 m of Quaternary sediment overlie Cretaceous(?) bedrock at this locality. The sea floor depressions may represent eroding ice-formed polygons of Quaternary age or they may represent gas cratering of the sea floor sediments?

<u>Gravel-coarse sediment</u> Surficial coarse-grained sediment is identified offshore where thin Quaternary sediment cover exists and nearshore adjacent tothe barrier island between Akoliakatat Pass and Wainwright. Three surface grab samples contain abundant gravel associated with sand. The gravel varies from angular to well-rounded clasts, the maximum clast size was 4.0 cm. Iron-stained invertebrate remains were also found with the gravels. Barnacles were the most abundant biogenic component.

Sea bed sonograph patterns indicate that coarse-grained sediment (coarse sand or gravel) exists on the sea floor surface. Light and dark patches (light=sand, dark=coarse sand or gravel) or a mottled pattern indicates areas of sediment grain size segregation. Irregular dark patches identified east of Icy Cape at depths of 7.5 m are restricted to areas of low relief with lighter colored areas occuppying bathymetric highs (figure 11). Samples collected in these dark-light colored areas confirmed the presence of gravel on the sea bed. This confirms that the dark areas identified on sonographs represent coarse-grained lag deposits. Dark patches on the sea bed are also common from west of Akoliakatat Pass to Wainwright. Mottled sediment patterns on the sea floor also indicates gravel associated with sand (figure 12a,12b). Local relief ranges from 40 cm up to 1 m with the darker patches located in the bathymetric lows. The coarse-grained deposits are thought to be lag deposits produced by winnowing of finer particles from the sea bed.

Side-scan records show that the shallow (11-13 m) sea floor between Wainwright and Pingoraruk Pass contains a mottled texture (figure 13). At the completion of the side-scan survey in this area kelp fronds over 2 m in length and 0.25m in width were recovered from the instrument, suggesting the presence

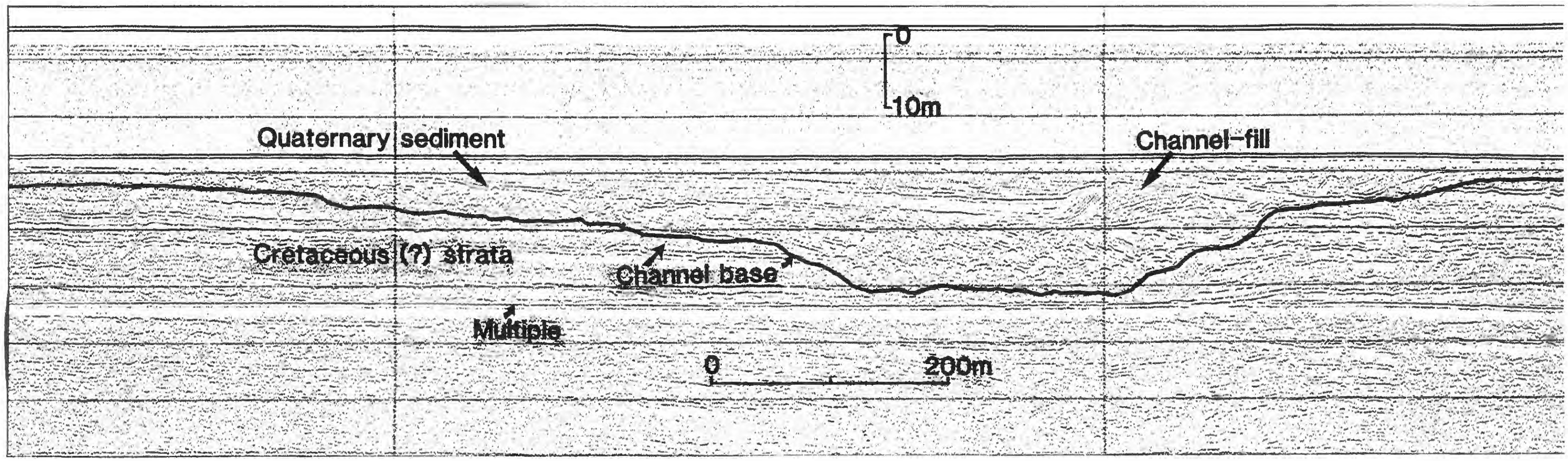


Figure 7. A) Seismic profile of paleochannel of the Kuk River west of Wainwright, Chukchi Sea. The channel cuts into gentle dipping Cretaceous strata. The maximum channel-fill here is 17 m. Both lateral (channel bank) and vertical accretion of the channel is recorded in the upper part of the channel-fill. Only 2 to 3 m of marine sediment overlies the channel-fill (see figure 6, letter B, for profile location).

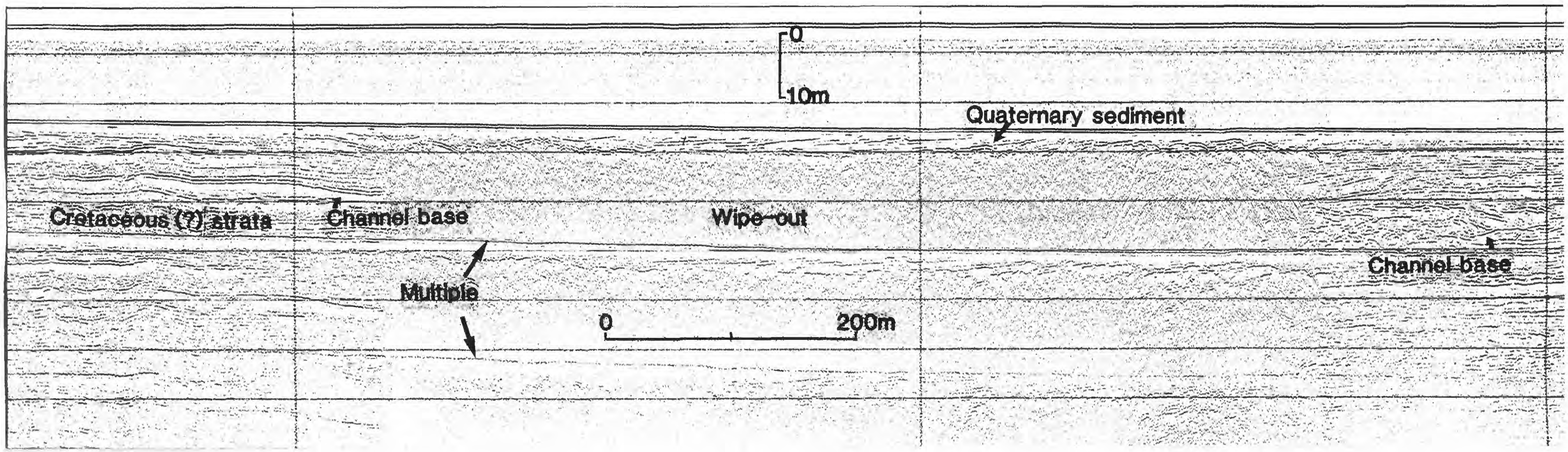


Figure 8. Seismic profile of part of the paleochannel of the Kuk River west of Wainwright, Chukchi Sea. The acoustic seismic signal is wiped-out suggesting that gas may occur in the channel-fill sediment (see figure 6, letter C, for profile location).

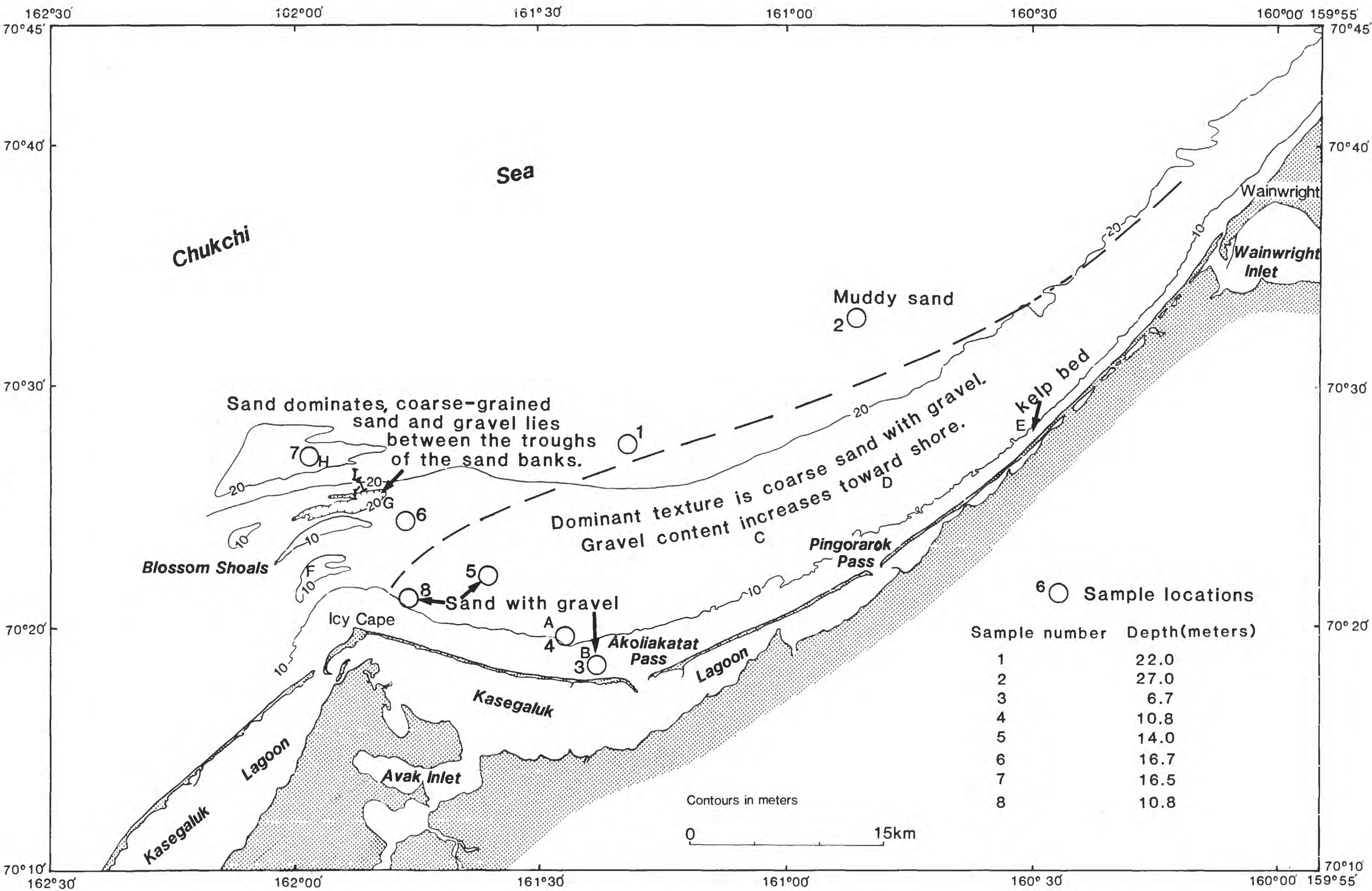


Figure 9. Surficial sediment texture determined from sampling and from sonographs. The dash line is an approximate boundary that separates the nearshore coarse-grained sediment from offshore finer-grained sediment. Sand dominates in the shoals off Icy Cape. The letters indicate the sonograph or seismic profile locations.

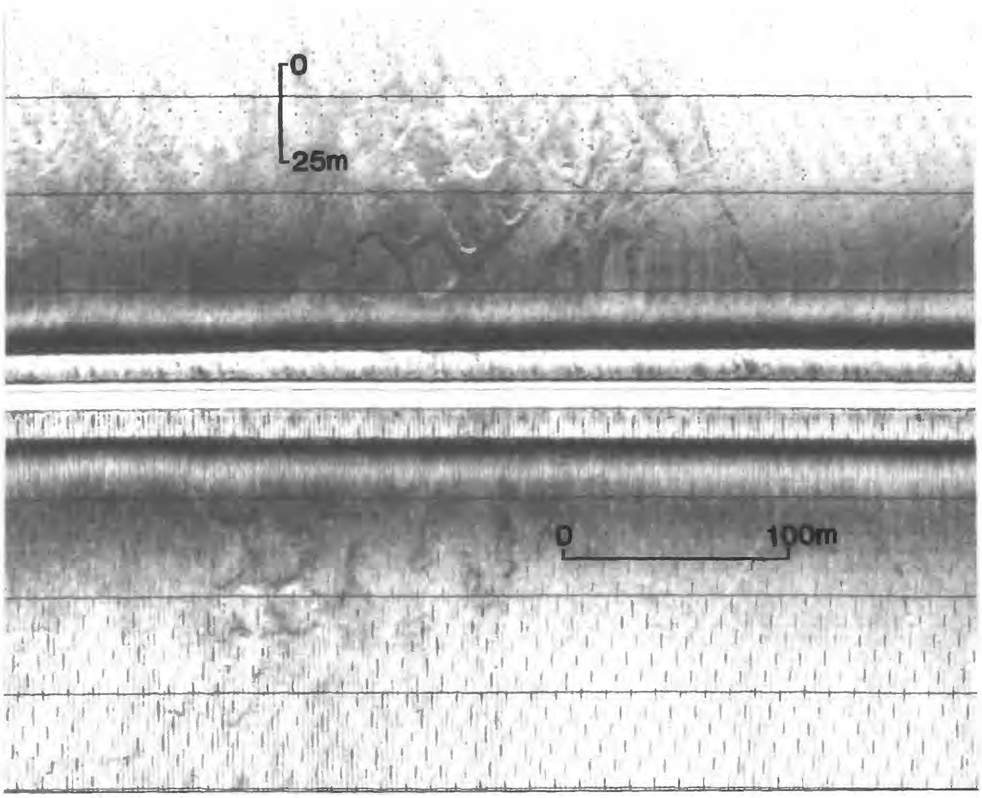


Figure 10. Possible outcrops of Quaternary sediment at 12 m depth east of Icy Cape. A series of circular to irregular-shaped depressions are exposed on the sea floor. The depressions vary from 12 to 20 m in diameter and contain a raised border. The maximum relief from the floor of the depression to the raised border is 0.5 m (see figure 9, letter A, for location of the sonagraph).

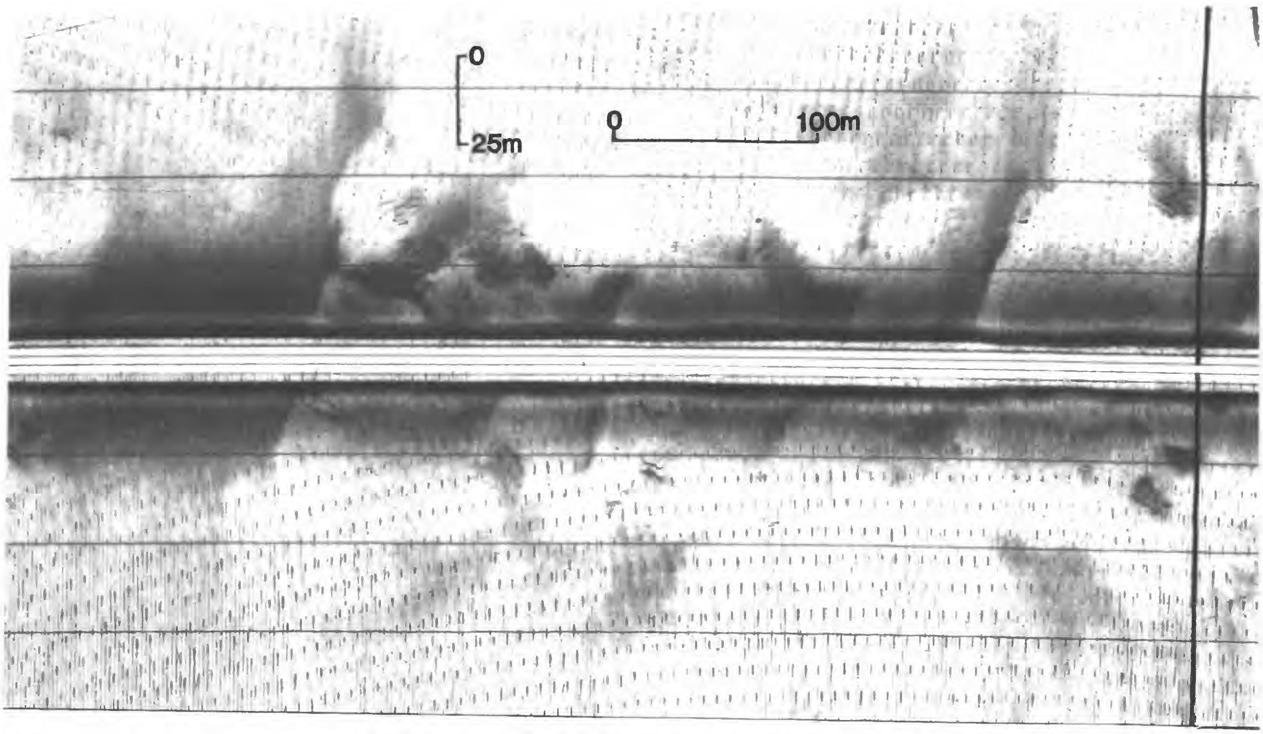


Figure 11. Sonograph containing light (sand) and dark (gravel) patches on the sea floor at a depth of 7.5 m east of Icy Cape. The dark areas occupy areas of lower relief than the light areas. Sample number 3, collected from these light-dark patches, contained abundant gravel with sand suggesting that the dark areas contain gravel or coarse sand and the light areas consist of sand (see figure 9, letter B, for sonograph location).

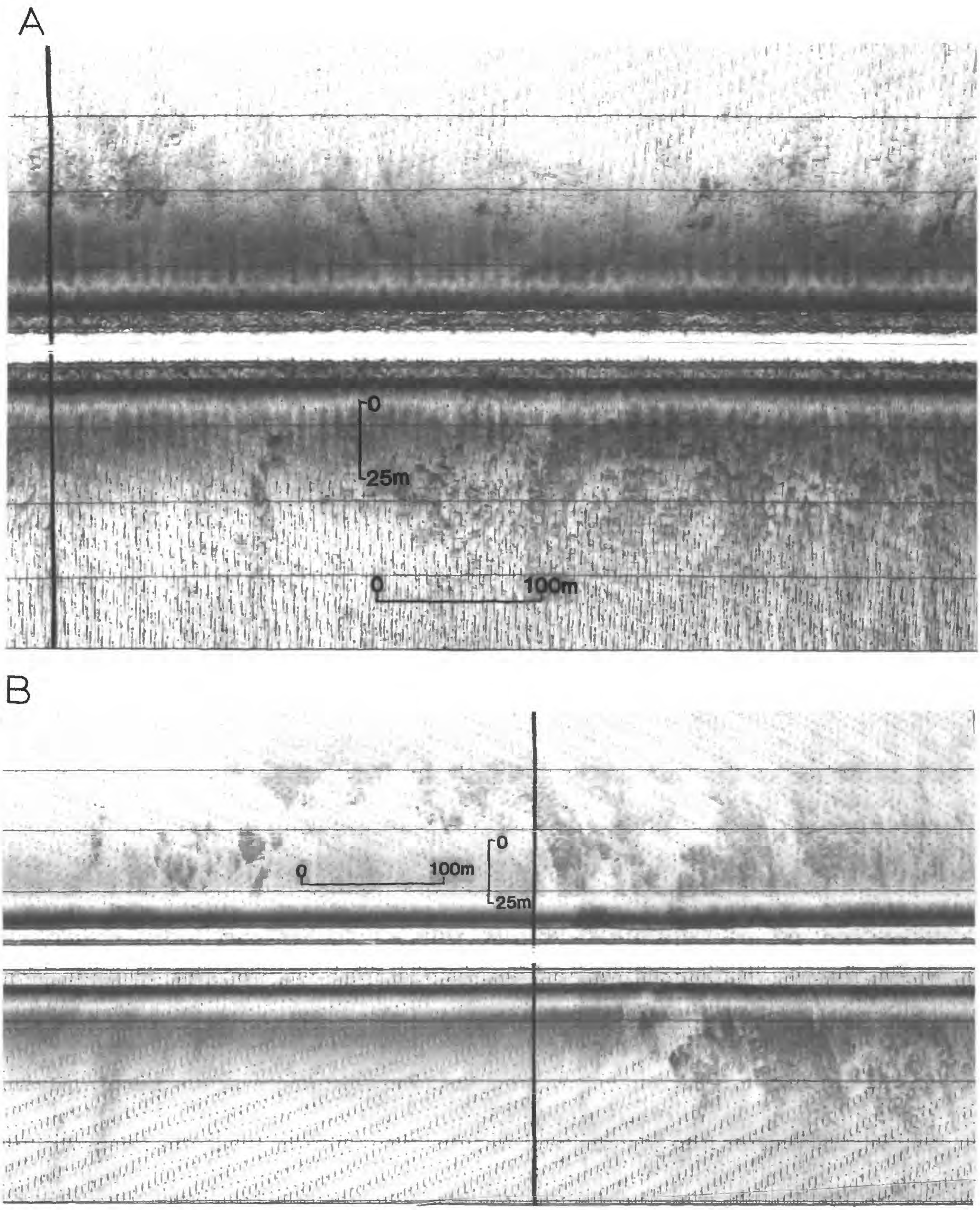


Figure 12. A) Sonograph of sea floor at 14.5 m depth west of Pingorarok Pass (see figure 9, letter C, for sonograph location). The mottled texture indicates that coarse sediment, sand or gravel, exists on the sea bed. B) Sonograph of dark patches on sea floor at a depth of 16 m (see figure 9, letter D, for sonograph location). Relief on the sea floor can be up to 1 m. The dark areas represent coarse sediment or possibly bedrock outcrops.

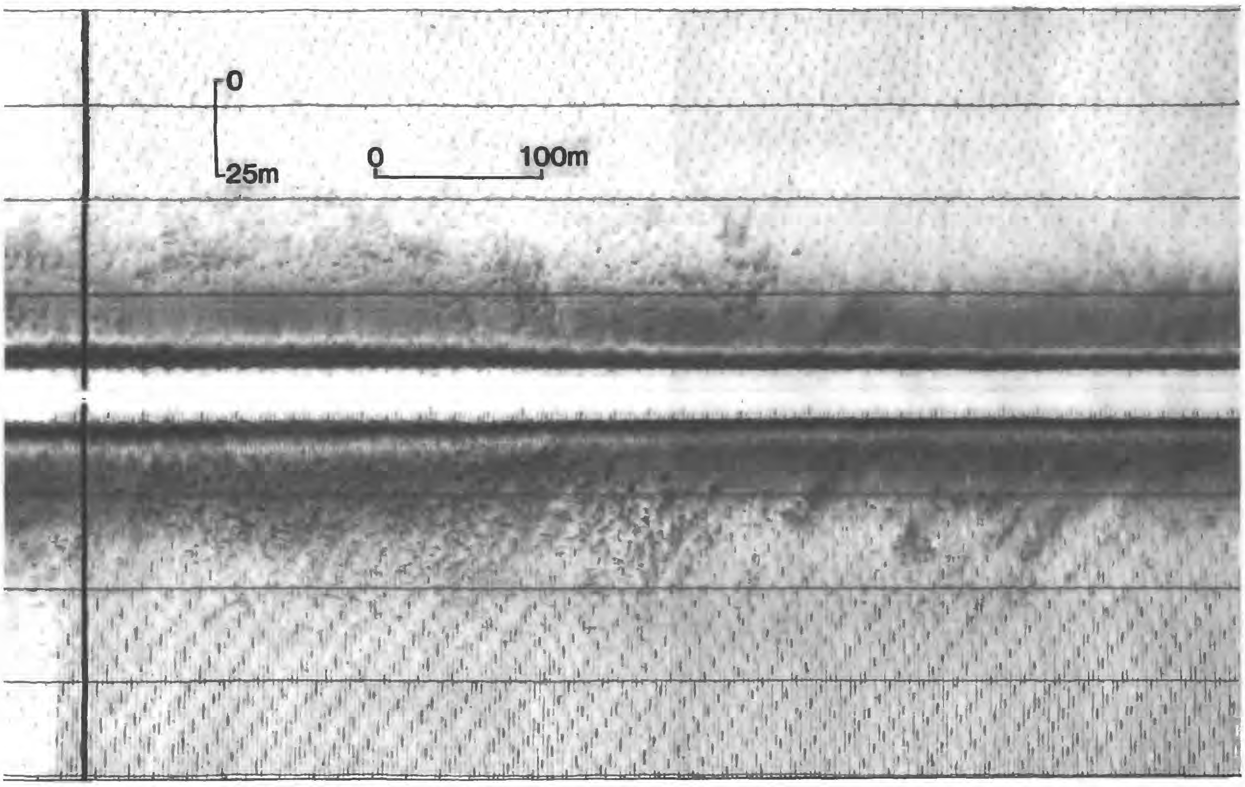


Figure 13. Sonograph obtained nearshore at 11 m depth (see figure 9, letter E, for sonograph location). The mottled sea bed indicates gravel and sand. When the side-scanning sonar was pulled landward of this locality it was completely covered with kelp fronds suggesting that kelp communities exist nearshore where a substrate (gravel) exists on which the kelp attaches.

of nearshore kelp beds. The kelp fronds are attached by their holdfasts to gravel or bedrock. The distribution, abundance or depths to which kelp occurs between Wainwright and Icy Cape is unknown, but could be expected where the sediment contains gravel-size sediment generally in areas where the sediment cover is less than 1 m thick in the nearshore zone (figure 6).

Sand Sand appears to be the most common particle size within the study area. Sand has accumulated into large banks with local relief up to 16 m off Icy Cape in Blossom Shoals. Sand wave fields cover and are found adjacent to the banks documenting the current regimes in this region. Coarse sand or gravel may be also be found between some of the sand banks. Silty sand was identified in only one sample at 27 m depth west of Wainwright (figure 9). An overall sea-ward fining texture probably exists along this coastal area.

PROCESSES

Two physical processes, active currents and ice groundings, modify and change the character of the sea floor between Icy Cape and Wainwright. The major effects of the processes are somewhat depth dependent and include both sand wave migration and ice gouging.

Sand waves Migrating bedforms, ripples and sand waves, are identified in the nearshore zone in depths less than 10 m and off Icy Cape within Blossom Shoals. The nearshore sand-gravel patches contain the smallest bedforms. The bedforms appear symmetric in shape, are oriented normal to shore and form from wave action. Similar shore normal bedform fields have been previously identified (Hunter and others, 1982) and can be expected in the nearshore zone along this coast.

Bedform fields containing large sand waves are located within Blossom Shoals. Sinuous- to straight-crested sand waves migrating to the northeast are identified nearshore off Icy Cape whereas western-directed bedforms are identified offshore. The sand waves contain wave lengths of 15 to 20 m nearshore and 25 to 30 m offshore. The bedform height decreases from 2 m at 7.5 m depth (figure 14) to 70 cm at 18 m depth (figures 15, 16). Below 20 m depth the sand waves rapidly diminish in height. The sand waves also increase in height from the top of the sand bank down the flanks and then diminish in height in the troughs between the sand banks (figure 15). The sand waves migrate up and over the sand banks in essentially the same orientation and migration trend (figure 5).

The sand banks, based on high-resolution seismic profiles, contain gentle seaward inclined strata. An offshore (northern-directed) accretion and migration direction of the sand banks is apparent (figure 17). Erosion on the landward flank of the sand banks, sediment transported over the ridge by migrating bedforms and sediment deposition on the seaward flank results in the offshore migration of the sand shoals.

Ice gouging Movement of ice by wind, currents and pack ice pressure results in ice groundings on the sea floor which disrupts the surficial sediments forming ice gouges. Ice gouging between Wainwright and Icy Cape generally is limited or sparce (figure 18). Nearshore, at depths less than 10 to 11 m, ice gouges were not observed. Active marine currents, both longshore currents and currents generated by shoaling waves, rapidly fill in and eliminate traces of nearshore ice gouging. Seaward of the 10 m isobath

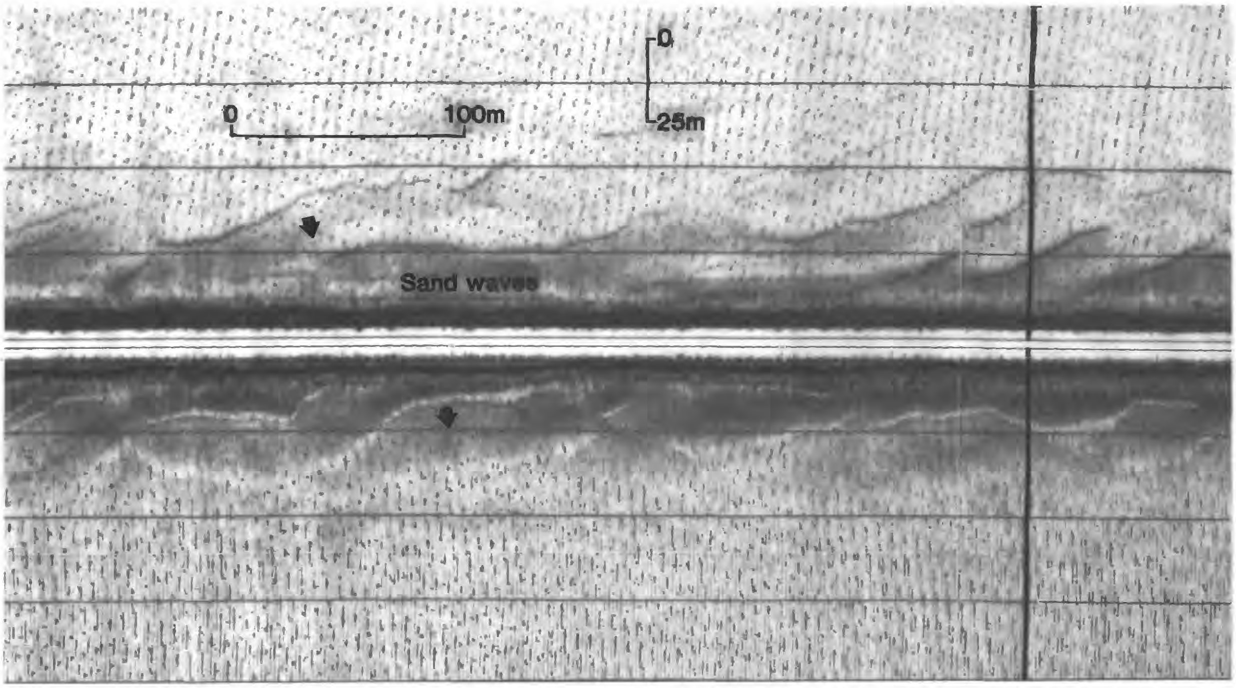


Figure 14. Northeast migrating sand wave field directly off Icy Cape (see figure 9, letter F, for location of sonagraph). The straight- to sinuous-crested sand waves are up to 2 m in height at 7.5 m depth. The arrows indicate the migration direction of the bedforms.

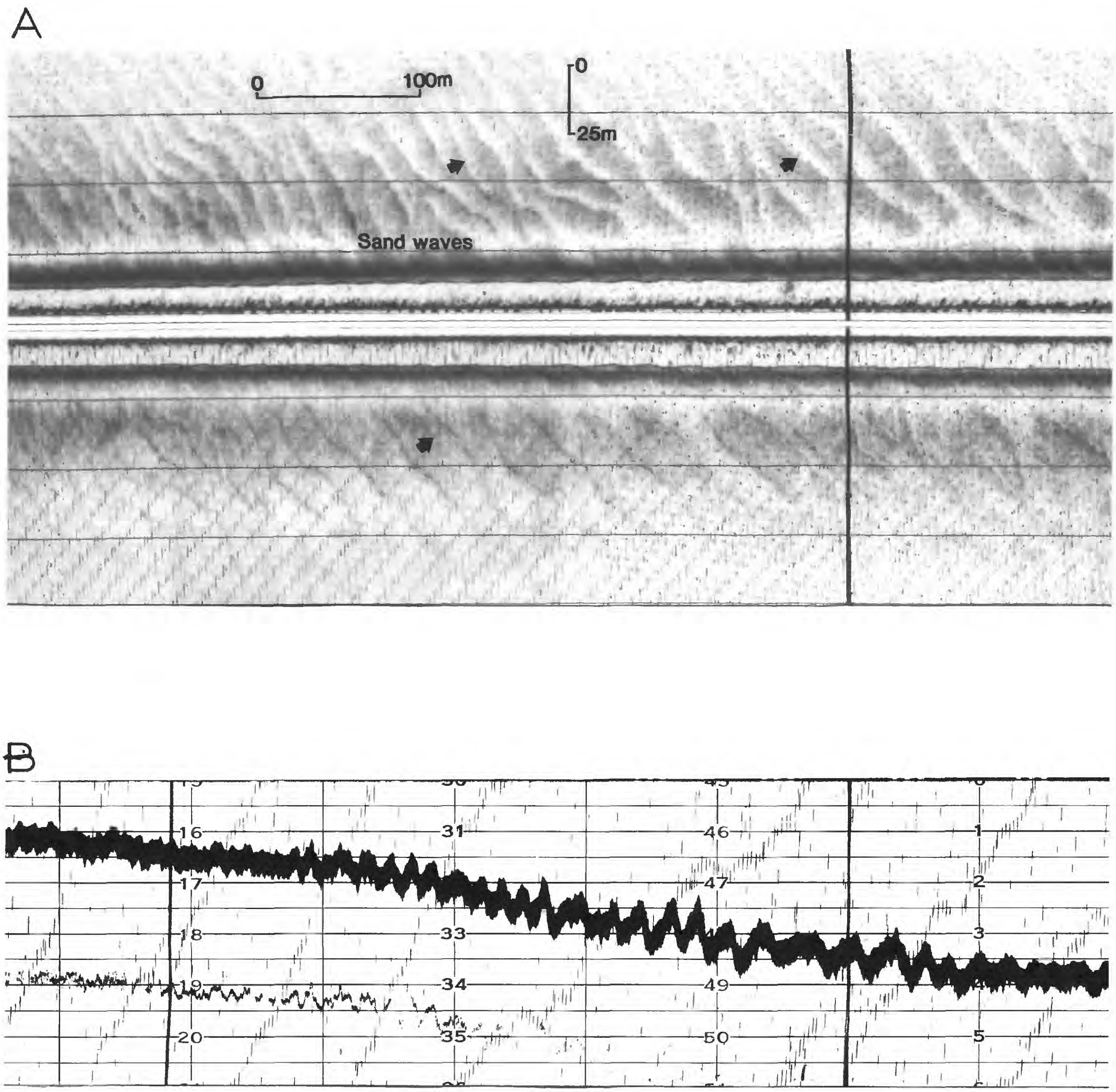


Figure 15. A) Sonograph of straight- to sinuous-crested sand waves at 16.5 to 18.5 m depth north of Icy Cape in Blossom Shoals, Chukchi Sea (see figure 9, letter G, for location of sonograph). The sand waves are migrating to the west (to the right on the figure) The arrows indicate the migration direction of the bedforms. B) Bottom profile of area in figure A. The crest of the sand bank is to the left. The sand waves increase in height with increasing depth down the flank of the sand bank.

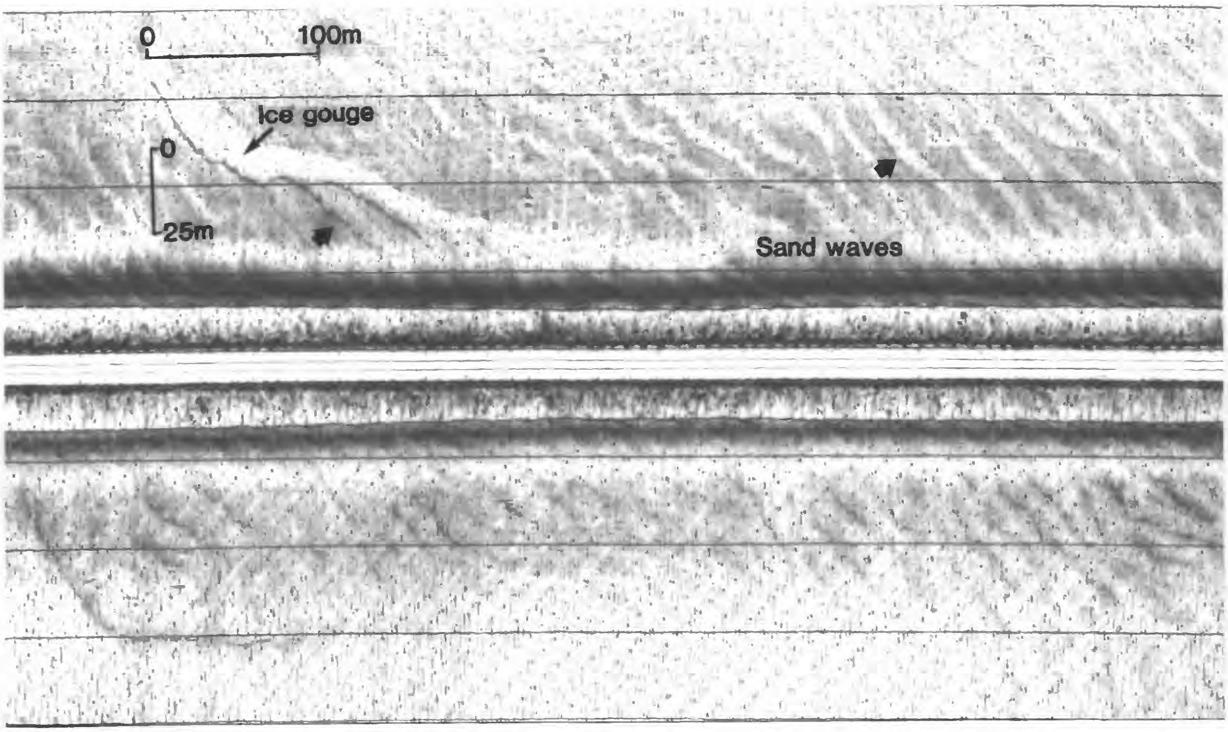


Figure 16. Sonograph of straight- to sinuous-crested sand waves at 18 m depth northwest of Icy Cape, Chukchi Sea (see figure 9, letter H, for location of sonograph). The sand waves are migrating to the west (to the right on the figure). The arrows indicate the migration direction of the bedforms.

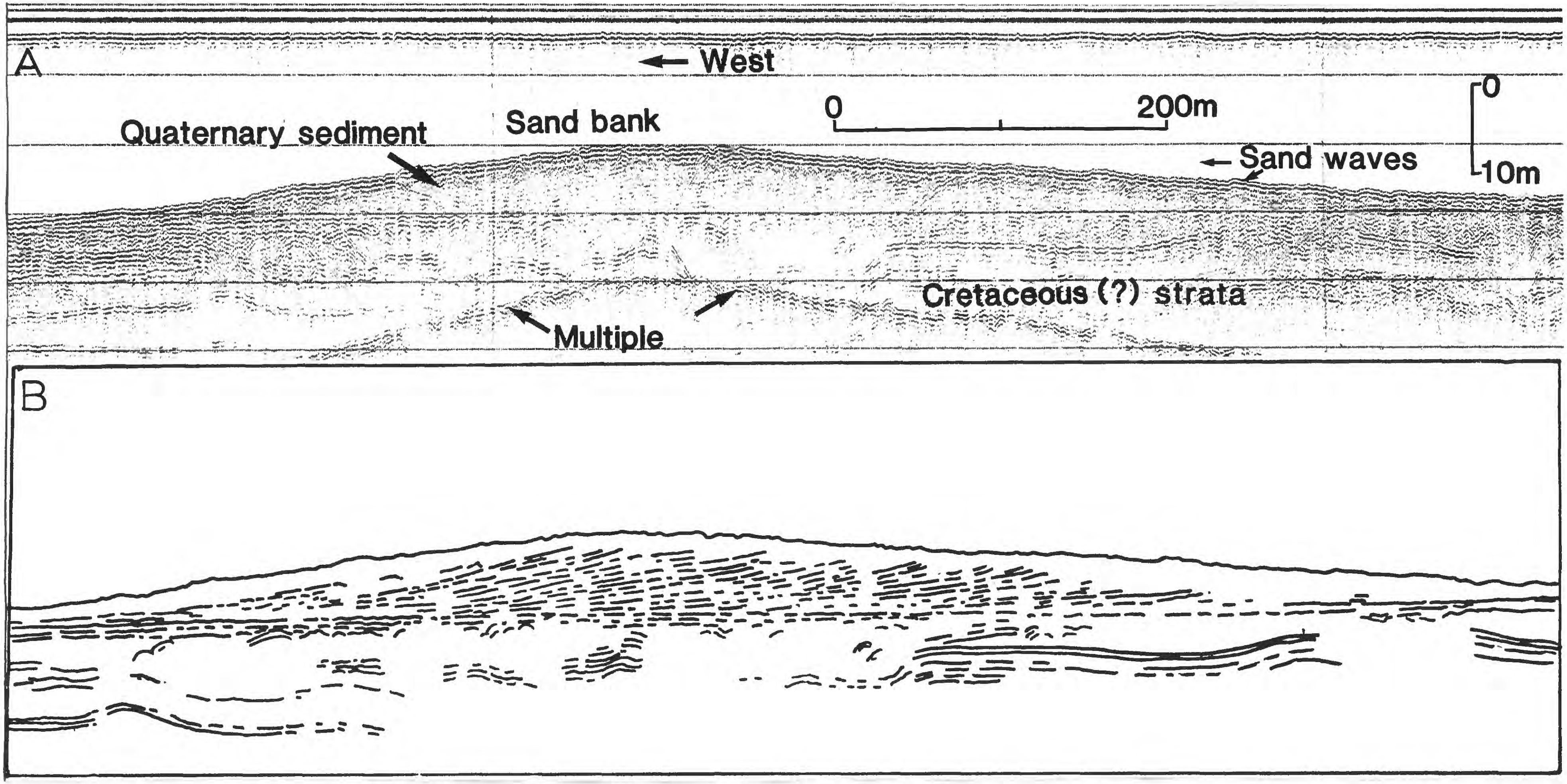


Figure 17. A) High-resolution seismic profile of sand bank off Icy Cape (see figure 9, area I-I', for profile location). Gentle northward inclined strata overlying a horizontal reflector (lag deposit) forms the internal structures of this sand bank. The northward inclined strata document a seaward migration direction of this sand bank. B) Tracing of internal elements recorded in the seismic profile.

offshore to 16 to 18.5 m depth, there are less than 2 ice gouges per kilometer of track line. The gouges are shallow, less than 30 cm deep, and oriented normal or at an angle to the shore. Some gouges may contain terminations where the ice stopped (figure 19).

Between depths of 18 and 22.8 m the maximum ice gouge density is identified (figure 18). The gouge density increases to between 6 and 9 gouges per kilometer of trackline (figure 20). Most gouges are oriented parallel to the shore. The maximum gouge depth is 50 cm with most gouge depths between 20-30 cm deep. Ice gouges are also concentrated on local bathymetric highs which may rise up to 1.5 m above the sea bed. Ice groundings may have formed these local areas of raised relief. Seaward of 23 m depth the ice gouge density rapidily decreases to less than 2 gouges per kilometer of track line. The outer gouges generally parallel the isobaths and are shallow less than 30 cm deep.

The deepest ice gouge, 2.5 m deep, occurred at 19 m depth on the seaward flank of the outer sand bank off Icy Cape. Ice gouges on the sand banks on Blossom Shoals are restricted to the crests of the ridges (figure 21). Sand wave migration fills in the ice gouges on the flanks of the shoals.

CONCLUSION

1. The offshore coastal region between Wainwright and Icy Cape contains a thin (2 to 4 m thick) Quaternary sediment cover overlying Cretaceous(?) strata.

2. Much of the surficial sediment, especially in areas where it is exceedingly thin, is coarse-grained sand and gravel lag deposits.

3. Kelp beds are present in the nearshore region between Wainwright and Pingorurok Pass.

4. The paleochannel of the Kuk River has been traced onto the shelf. Sediment filling the channel locally obtains a thickness in excess of 20 m and may contain gas.

5. Northeast-directed currents nearshore and western-directed currents offshore of Icy Cape as indicated by the orientation of sand wave fields suggest a complex current regime.

6. Blossom Shoals represent a region of sediment deposition, forming parallel arcuate sand banks. The sand banks are migrating in a seaward direction as indicated by seismic profiles.

7. The zone of maximum ice gouge density occurs between depths of 16 and 22.8 m and parallels the coast. Most gouges are oriented parallel to shore.

REFERENCES

Grantz, A., Dinter, D. A., Hill, E. R., Hunter, R. E., May, S. D., McMullin, R. H., and Phillips, R. L., 1982, Geologic framework, hydrocarbon potential, and environmental conditions for exploration and developmental of proposed oil and gas lease sale 85 in the central and northern Chukchi Sea, U.S. Geological Survey Open file Rept. 82-1053.

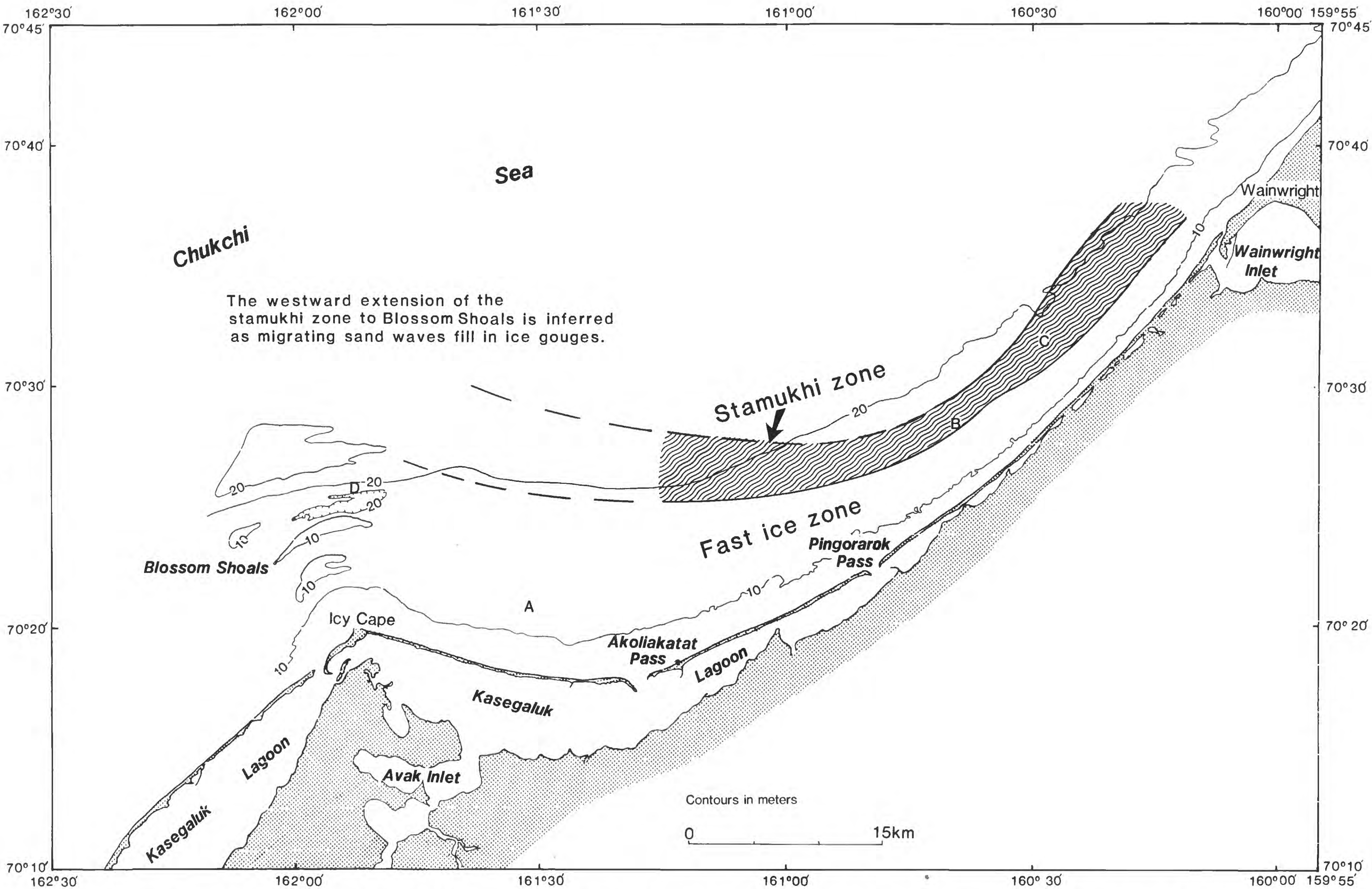


Figure 18. Ice zonation based on the abundance of ice gouges. The stamukhi zone ranges from 16.5 m to at least 22 m depth and represents a region of intense ice gouging of the sea floor. The western projected trace of the stamukhi zone toward Blossom Shoals is inferred as migrating bedforms, sand waves and ripples, apparently fill in the ice gouges near the shoals. The letters indicate sonograph locations.

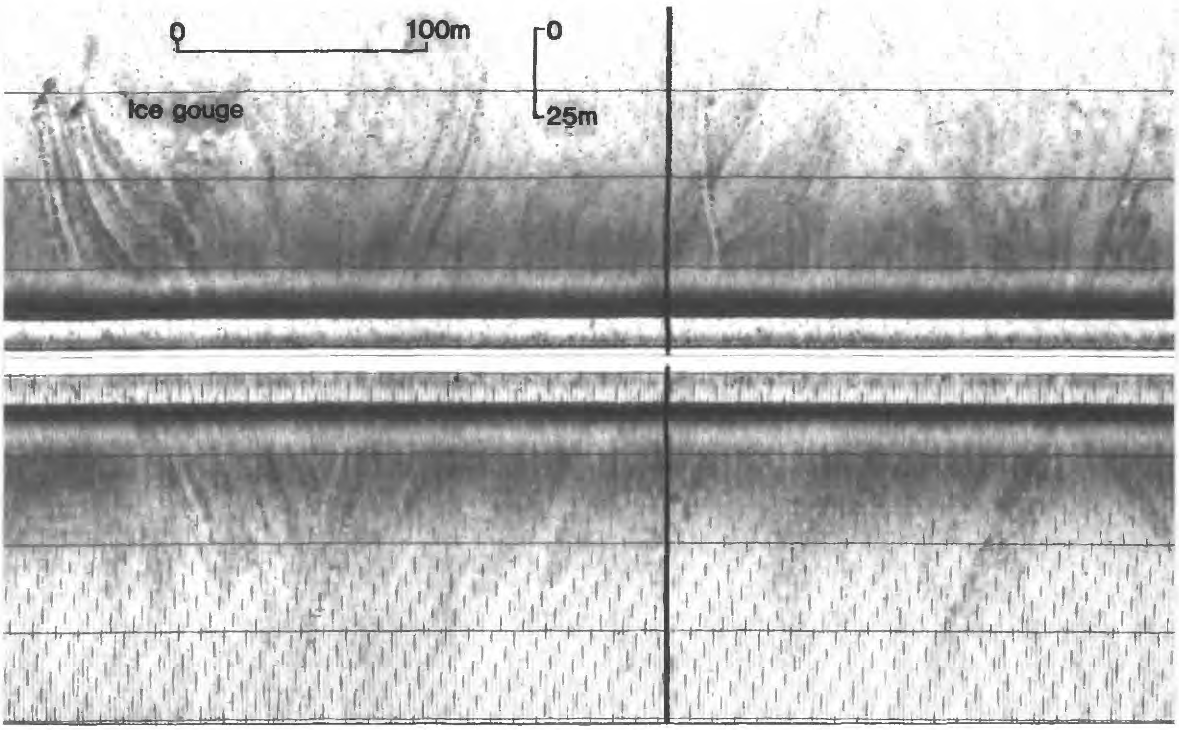
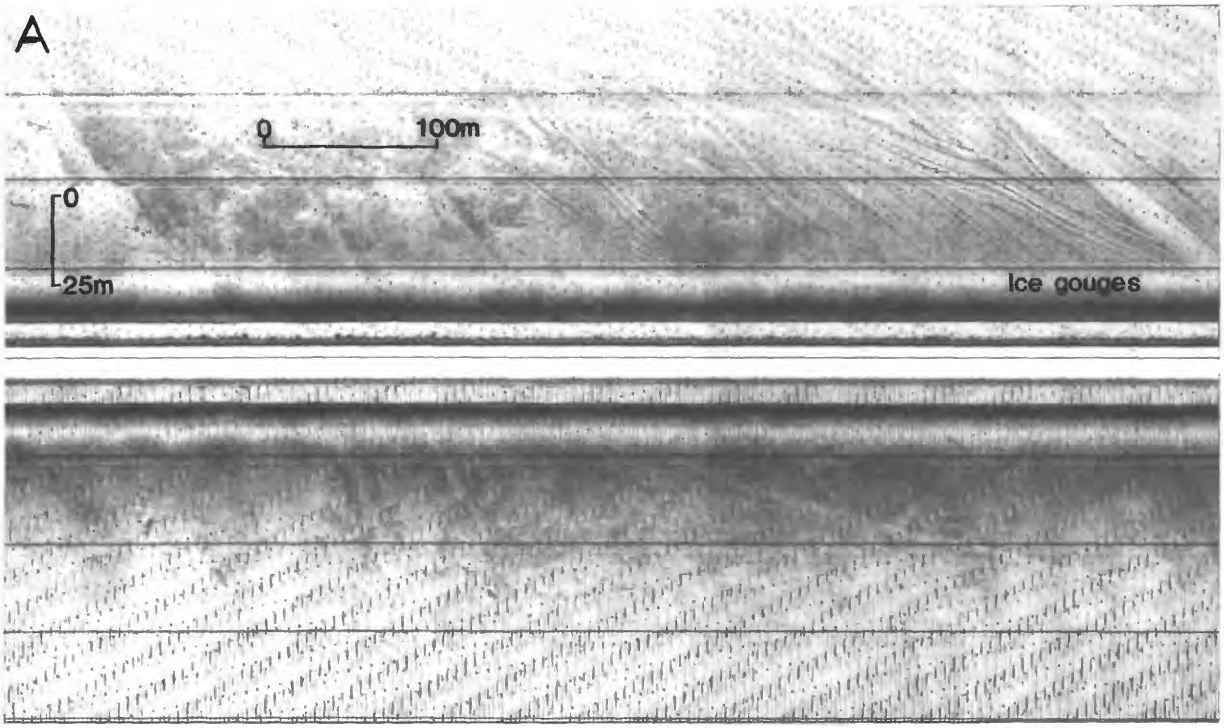


Figure 19. Sonograph containing ice gouge termination (at left) at 13 m depth east of Icy Cape (see figure 18, letter A, for location of sonograph). The ice gouges lie at an angle or parallel to the isobaths.



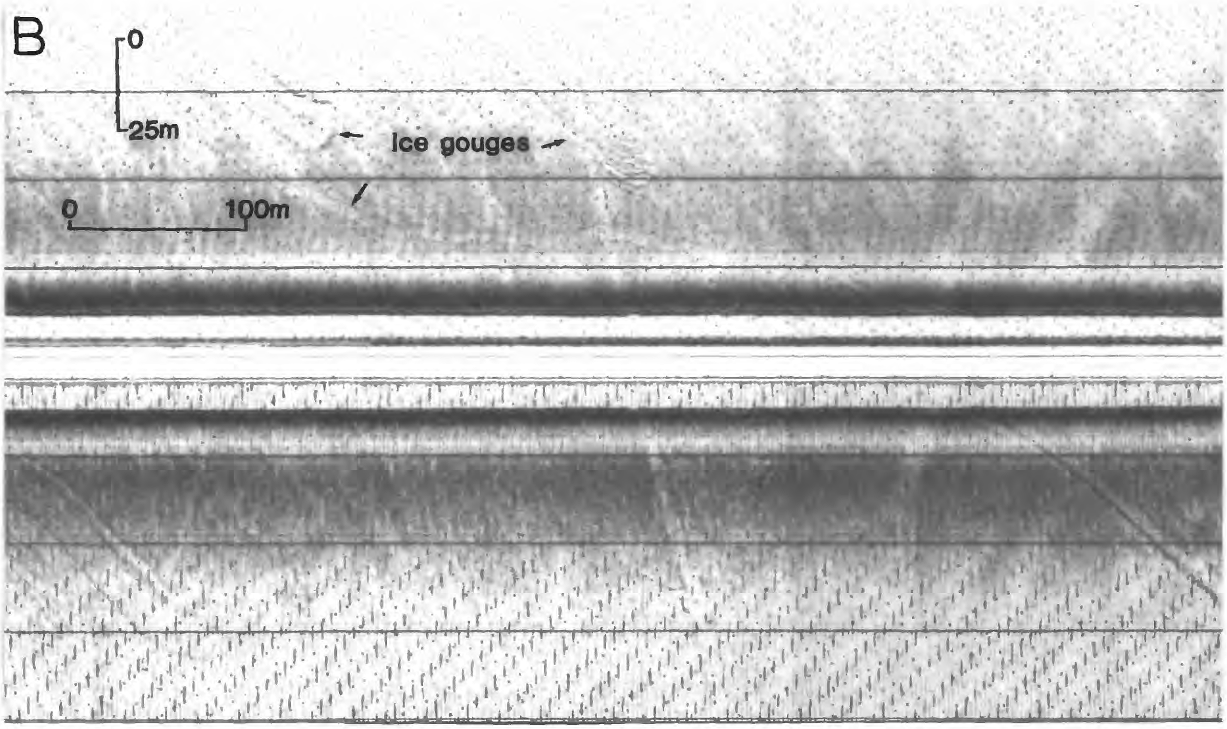


Figure 20. A) Sonograph of repeated ice gouges at 16.5 m depth (see figure 18, letter B, for location of sonograph). B) Sonograph of ice gouges, some containing terminations, at 18 m depth (see figure 18, letter C, for location of sonograph).

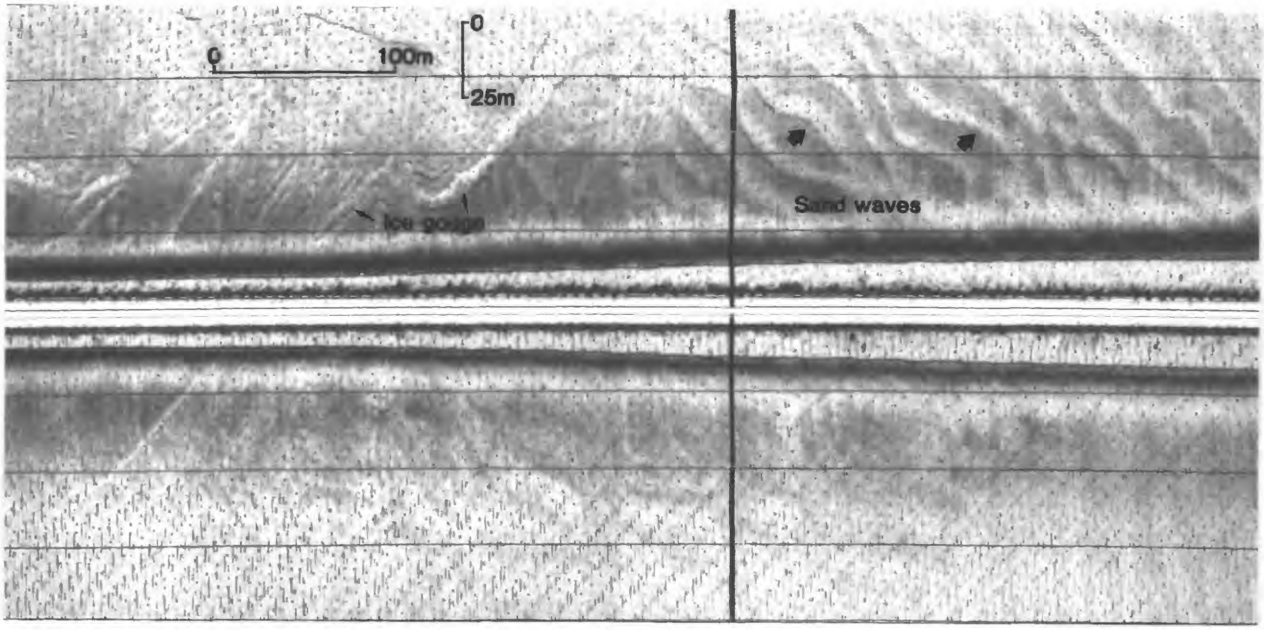


Figure 21. Sonograph of ice gouges on the crest of a sand bank at 14 m depth off Icy Cape (see figure 18, letter D, for location of sonograph). The arrows indicate the migration direction of the sand waves.

Hufford, G. L., 1977, Northeast Chukchi Sea Coastal Currents, Geophysical Research Letters, v. 4, no. 10, p. 457-460.

Hunter, R. E., Barnes, P. W., Kempema, E. W., and Reiss, T. E., 1982, Inner-shelf geology of the Chukchi Sea from Point Lay to Wainwright, in National Oceanic and Atmospheric Administration, Environmental Assessment of the Alaska Continental Shelf: Annual Reports of Principal Investigators for the year ending March, 1982, p. B1-B18.

Phillips, R. L., Reiss, T. E., Kempema, E. W., and Reimnitz, E, 1982, Nearshore marine geologic investigations, Wainwright to Skull Cliff, northeast Chukchi Sea, U.S. Geological Survey Open-File Rept., 84-108, 33 p.

Short, A. D., 1975, Offshore bars along the Alaskan Arctic coast, Jour. Geol., v. 83, no. 2, p. 209-221.

Short, A. D., 1979, Barrier island development along the Alaskan-Yukon coastal plains, Geol. Soc. American Bull., v. 86, p. 199-202