UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Nearshore marine geologic investigations, Wainwright to Skull Cliff, northeast Chukchi Sea

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Introduction

Between August 21 and September 1, 1981, marine geologic investigations were conducted on part of the inner shelf of the northeast Chukchi Sea using the USGS R/V Karluk. The purpose of this continuing investigation is to define marine processes and geologic hazards that characterize the sea floor for the regions generally shallower than 20 to 30 m depth on the inner shelf of the Chukchi Sea. The area of the initial reconnaissance investigation covered the nearshore region from Wainwright (70° 36' N) north to Skull Cliff at approximately 71° 00'N (figure 1). This area was selected based on the availability of a protected harbour, Peard Bay, from which to operate.

Approximately 339 km of side-scanning-sonar records, 317 km of subbottom profiles (Uniboom) and 448 Km of bottom profiles were collected during the study. Twenty four sediment samples were collected and 5 stations were observed with television (Figure 2 and appendix 1).

The study area is boardered on the east by the gently sloping coastal plain. Steep cliffs ranging to approximately 15 m height bound the northern region along Skull Cliff and part of the southern area between Point Belcher and Wainwright. Narrow barrier islands form the boundaries between Peard Bay and the Chukchi Sea between the cliffed areas. Two channels, located at the west side of Peard Bay directly off Point Franklin and on the north side of Peard Bay, allow access across the shoals (Figure 3).

The oldest bedrock underlying the region consists of Cretaceous sandstones. The Cretaceous strata are reported to outcrop discontinously from approximately 10 km south of Point Barrow to near Wainwright. Along Skull Cliff the sandstones rise to at least 5 m height above sea level. Overlying the Cretaceous strata are the Pleistocene sands, gravels and muds of the Gubic Formation of Black (1964). A wave-cut cliff of Sangamon age, starts at the east end of Peard Bay and trends to the west to north of Wainwright (Williams et al, 1977). Peard Bay lies to the west of this older shoreline (Figure 3). The youngest Holocene deposits are the sands and gravels of the barrier islands that enclose Peard Bay.

Bathymetry

The Barrow Sea Valley lies to the northwest of Peard Bay obtaining a depth of 55 m approximately 17 km northwest of Point Belcher and increasing to 90 m depth 29 km north of Point Franklin. A gently rising slope extends shoreward from the Barrow Sea Valley to 20 m depth where the slope increases. The sea floor between Point Belcher and Point Franklin exhibits a rapid rise between the 20 m to the 14 m isobath (Figure 3). Bathymetric highs and a broad flat (Between 12 and 14 m depth) occur directly to the west of Peard Bay. Northeast of Peard Bay the sea floor is smooth exhibiting a gentle rise toward the shore. An irregular bottom, indicated by a variable irregular contour pattern nearshore at depths less than 10 m, suggests areas of small-scale relief north of the barrier island (Figure 3). Three shore-parallel bars are also identified nearshore by gounded ice and on subbottom profiles

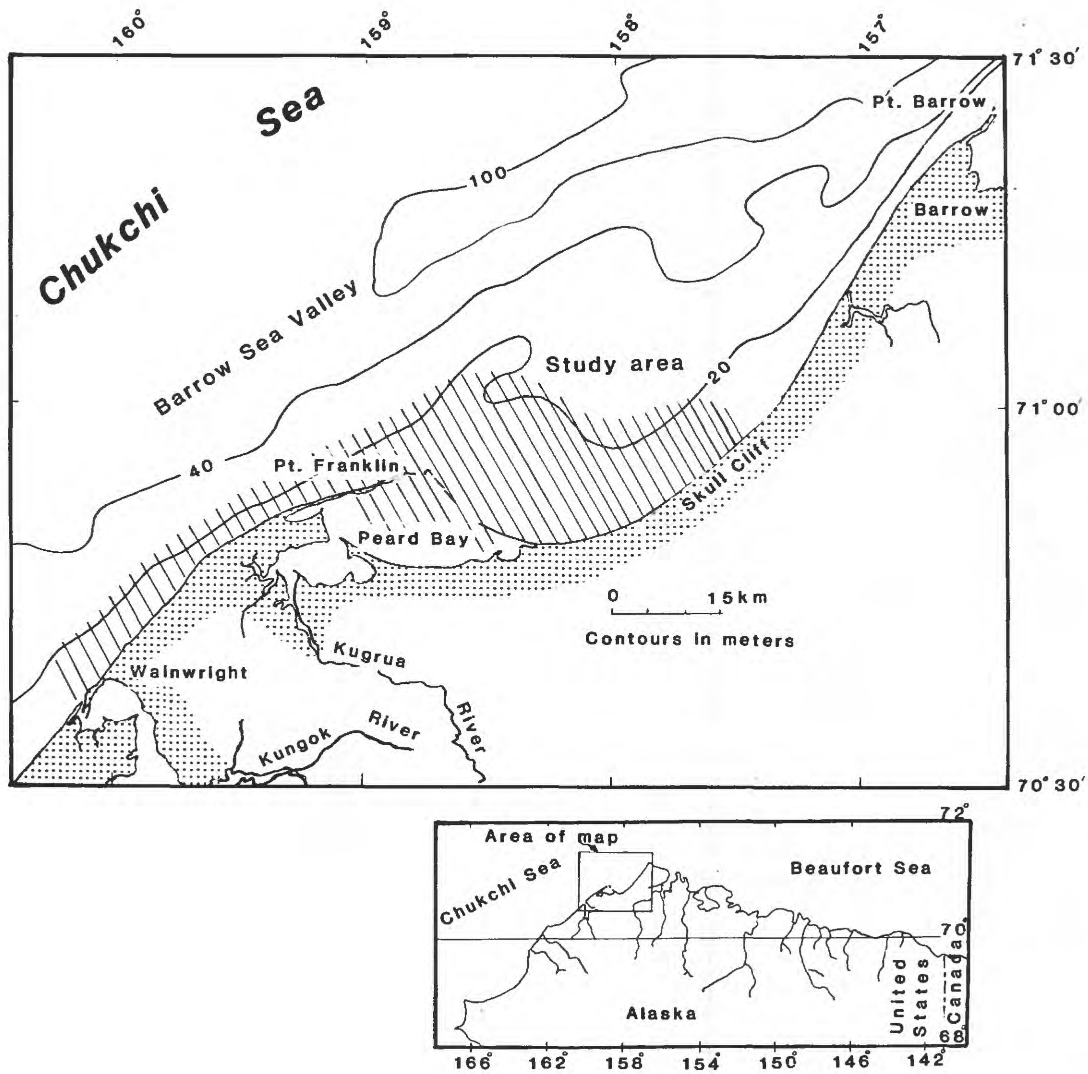

Figure 1. Location of area investigated during 1981 in the northeastern Chukchi Sea. Contours are in meters.

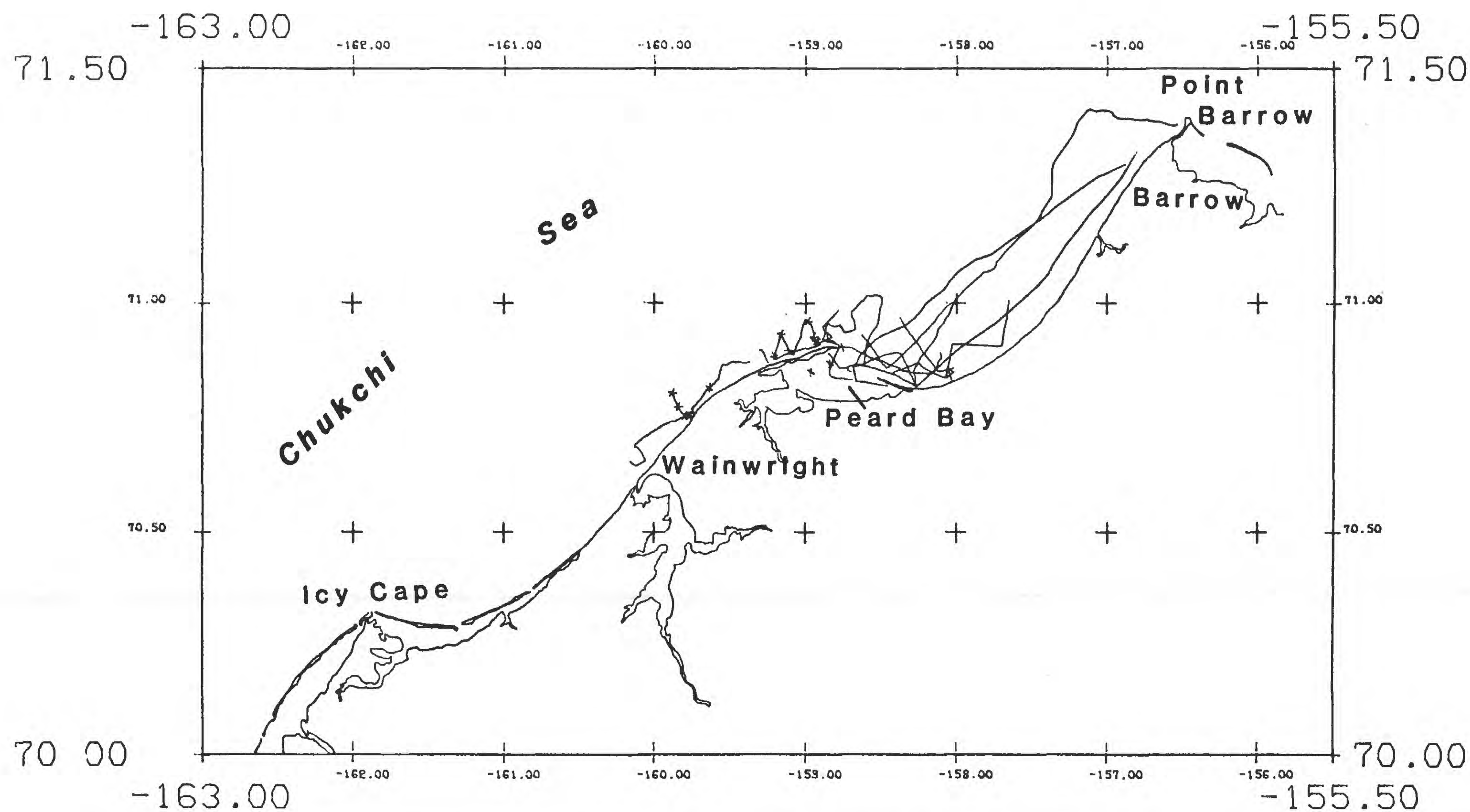

Figure 2. Trackline map and sediment sample locations (indicated by x), 1981 Karluk cruise, Chukchi Sea.

Figure 3. Bathymetric map of the nearshore region, Wainwright to Skull Cliff, Chukchi Sea. Contours are in meters. Depth data obtained from NOAA hydrographic survey sheets, No. 7606, 7607, and 7609, 1947. The location of the wave-cut cliff (indicated by hatchures) on land taken from Williams et al, 1977.

(Figure 4). The seaward most bar starts at a depth of 8 m and rises 1.5 m; the landward most bar starts at a depth of 7 m on the seaward side and only rises 1 m. The nearshore bathymetry reflects and partly controls the processes of ice gouging and bedform migration.

Currents

Wind-generated currents and the offshore, shore parallel Alaska Coastal Current dominate the oceanographic regime within this region. The wind-generated currents generally result from storms moving in from the southwest allowing the maximum fetch to develope across the Chukchi Sea. The largest waves observed during this investigation, 2 m in height, can rapidly form especially in the shallow regions northeast of Peard Bay.

The northward flowing Alaska Coastal Current dominates the region west of Peard Bay. Surface velocities of up to 200 cm/sec and a mid-depth velocity of 71 cm/sec are reported from north of Wainwright within the Alaska Coastal Current (Hufford, 1977). The effects of the northward flowing current are readily evident on the sea floor north and west of Point Franklin where northward migrating sandwave fields exist.

The area of this investigation is dominated to the west by the Alaska Coastal Current transporting sediment to the north, whereas the region northeast of Peard Bay contains a clockwise flowing shore parallel current (Figure 5). The direction of sediment transport is toward Point Franklin from the south and from the east and away from Skull Cliff region. The capes along the Chukchi Sea coast represent regions of longshore convergence of currents and sediments (Short, 1975, 1979). Sediment deposition results where the converging currents meet. The shallow regions, generally less than 10 m depth, are influenced by wave-generated currents moving on shore or parallel to shore.

Quaternary sediments

A thin veneer of sediment overlies gentle southeast dipping Cretaceous bedrock throughout the areas surveyed. Bedrock outcrops have been observed on T.V. surveys northeast of Peard Bay, and are also suggested from subbottom profiles. The present thickness distribution of the Quaternary deposits indicate regions of deposition and erosion which have been influenced by wave-generated currents and other coastal currents (Figure 6).

The areas containing thin sediment cover (less than 2 m thick) are north and east of Peard Bay, especially seaward of regions where Cretaceous bedrock is exposed at Skull Cliff, and in the deeper offshore regions surveyed between Peard Bay and Wainwright. Regions of thick Quaternary sediment accumulation are; 1) toward the shore between Wainwright and Peard Bay where the sediment cover increases from 2 m thick at depths ranging from 20 to 27 m to 6 m thick nearshore, 2) directly off Point Franklin within the shoal areas where a maximum sediment thickness of 16 m is identified, and 3) north of Point Franklin where sandwave fields exist at depths greater than 18 m. At least 11 m of sediment overlies the bedrock beneath the sandwave fields.

The landward thickening of sediments toward the barrier island west of Peard Bay is recognized in seismic profiles. Offshore the Cretaceous strata

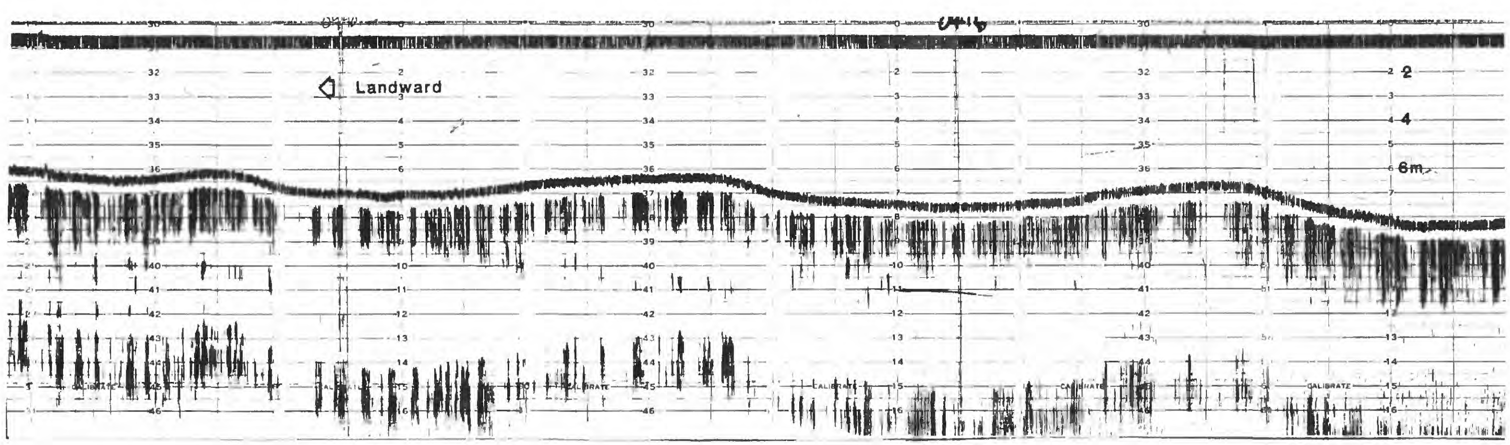

Figure 4. Three offshore bars occur to the north of the barrier island on the northeast side of Peard Bay. The bars are found between depths of 6 to 8 m. Grounded ice along the bar system shows the bars to be attached to the shore to the east.

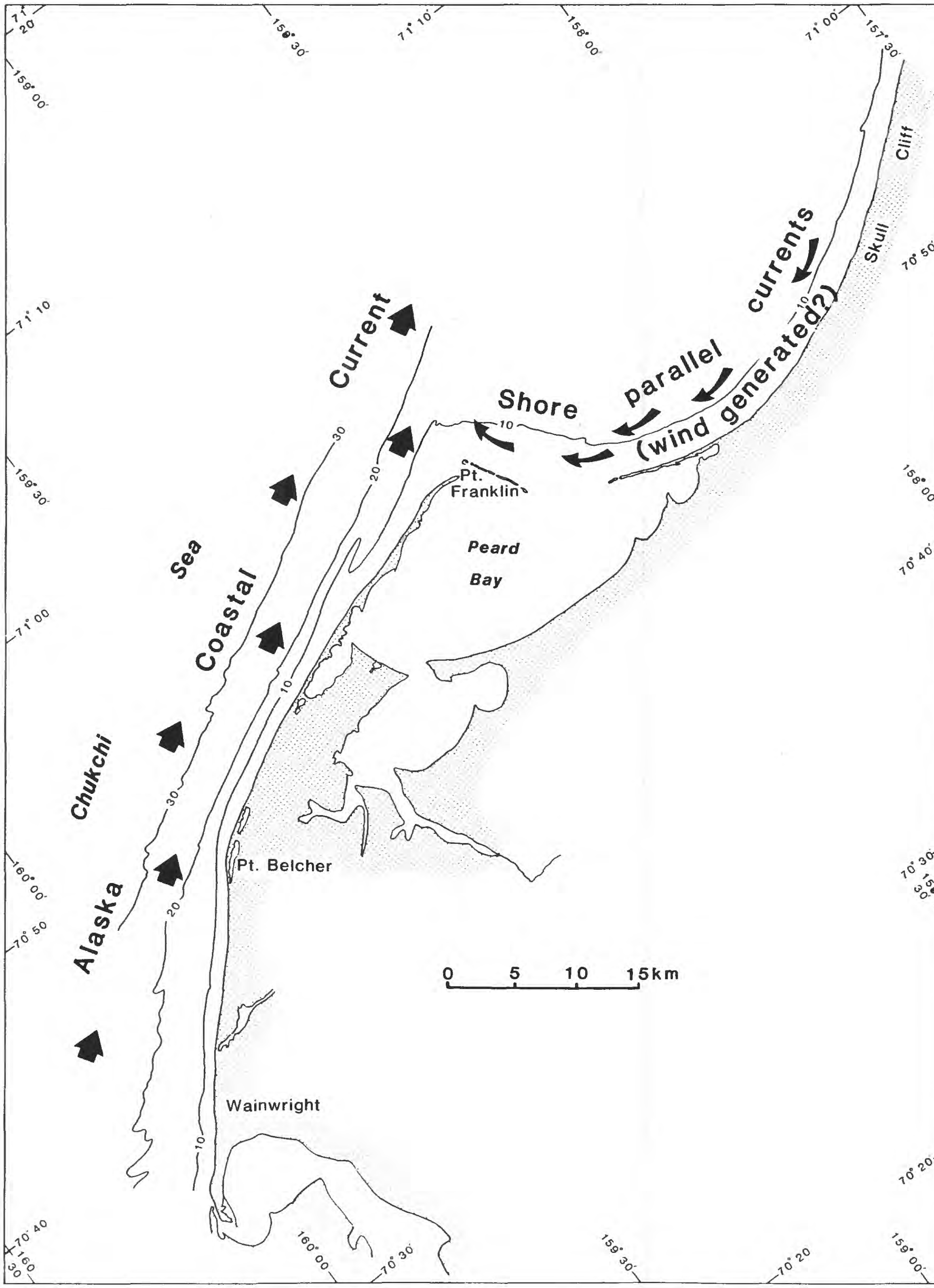

Figure 5. Dominant coastal current regime. The northward flowing Alaska Coastal Current obtains velocities of up of 200 cm/sec within this region (Hufford, 1977). The shore-parallel currents on the northeast side of Peard Bay are probably wind-generated. The converging currents result in sediment deposition off Point Franklin. The arrows indicate the current direction. Contours are in meters.

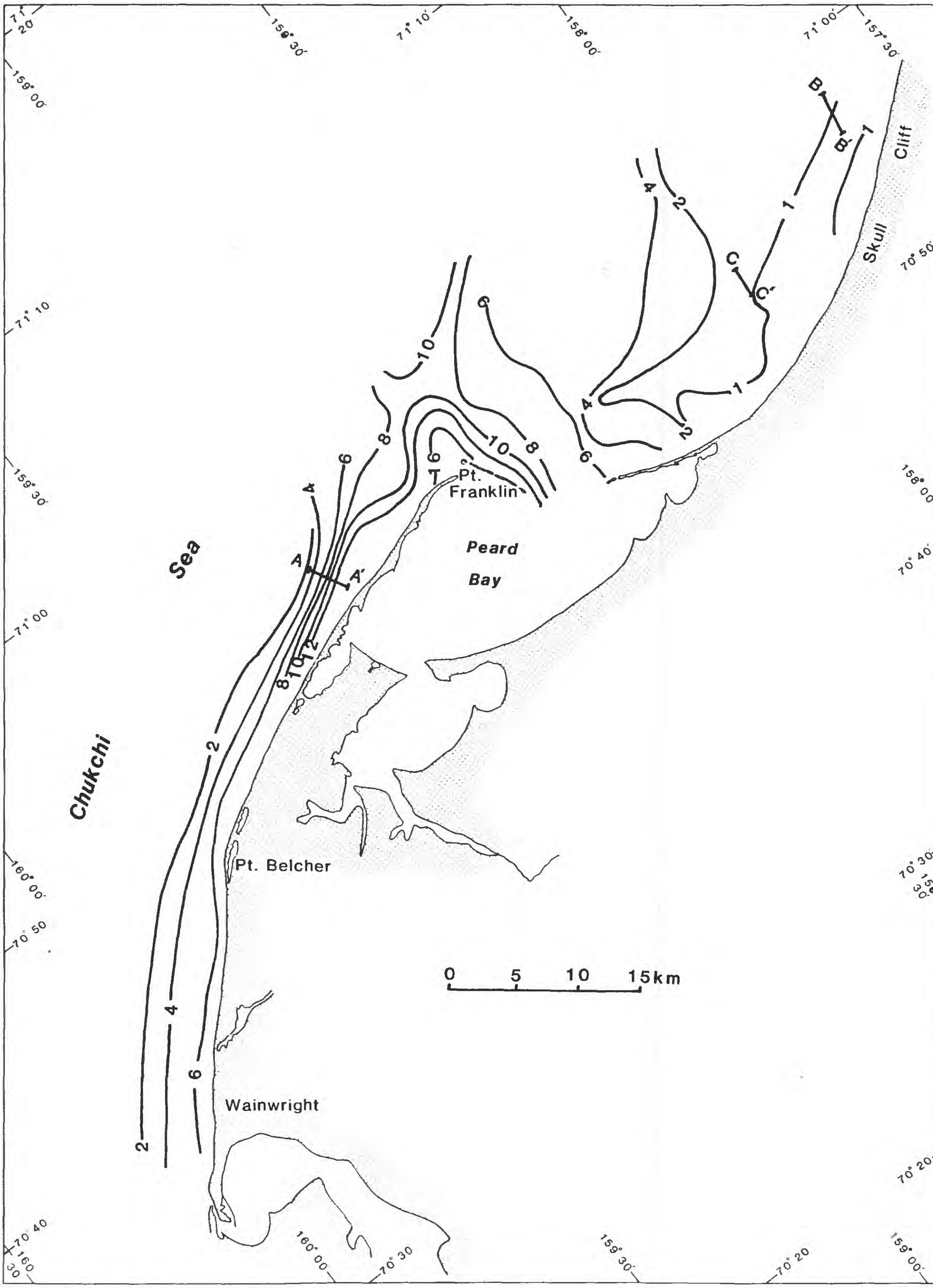

Figure 6. Isopach map of Quaternary sediments overlying Cretaceous bedrock. Contours are in meters. The sediment increases in thickness toward the shore between Wainwright and Peard Bay obtaining a maximum thickness of 16 m off Point Franklin. The thinnest sediment cover occurs off Skull Cliff adjacent to areas where Cretaceous bedrock lies above sea level. The lettered sections indicate high-resolution profile locations for figures 7 and 9.

underlie approximately 2 to 3 m of Quaternary gravel-sand lag. Locally, bedrock may outcrop in the deeper offshore regions. A landward increase in sediment thickness is readily apparent in seismic profiles (Figure 7).

Two stages of Quaternary sedimentation are recorded, a basal horizontal bedded unit which is in turn truncated and overlain by a gentle seaward inclined unit (Figure 8). The basal horizontal-bedded strata overlying the Cretaceous strata may represent in part bay-fill formed during the Holocene transgression which may have resulted in the landward migration of the barrier island to its present position or it could represent the Gubic Formation. Evidence for at least two stages of sediment deposition is suggested where the horizontal-bedded strata are in turn truncated and overlain by gently seaward dipping strata (Figure 8). The upper-most seaward inclined strata could represent sediment progradation or could also represent the zone of maximum depth of ice gouging and reworking of the sea floor. The zone of intense ice gouging the stamukhi zone, in this region occurs along the inclined bathymetric slope observed in Figures 7 and 8. Repeated ice gouging of the slope, sediment reworking and longshore sediment transport has resulted in truncation of the underlying horizontal-bedded strata and resulted in deposition of the seaward inclined strata.

East of Point Franklin the nearshore Quaternary sediment cover thins rapidly toward Skull Cliff. The tidal pass at the north end of Peard Bay is approximately 12 m deep suggesting an equal thickness of Holocene sediments. Directly offshore from the tidal pass, at depths of 10 m, the sediment cover thins to less than 3 m in thickness (Figure 6). To the north and northeast toward Skull Cliff the Quaternary sediment thins to approximately 1 m and bedrock outcrops occur on the sea floor (Figure 9).

The regions of thin sediment cover (northeast of Peard Bay and the offshore region from Wainwright to Point Franklin) must overall be considered areas of erosion. The major depocenter occurs off Point Franklin (a region of converging currents) and represents longshore sediment transport and deposition off the cape.

Permafrost

The Coast and Geodetic Survey of the region in 1947 apparently identified permafrost in the Holocene barrier island sediments exposed in the northeastern deep channel entrance to Peard Bay and reported on by Lewellen (1972). Lewellen (1972) suggests that Cretaceous bedrock instead of permafrost may exist in the tidal pass. Geophysical surveys conducted during this study through the channel entrance, on the seaward side of the barrier island, and within Peard Bay identifies at least 12 to 14 m of sediment cover over the Cretaceous bedrock. The reported occurrence of permafrost here must be assumed to be true, therefore, the Holocene sediment cover within this study area must be assumed to contain some permafrost.

Surficial sediments

The surficial sediments within the area investigated range in composition from mud to gravel with sand size sediment the most abundant texture (Appendix 1). Television sea floor scans, side-scanning-sonar surveys and 24 sediment samples defines some of the major surficial sediment types within the

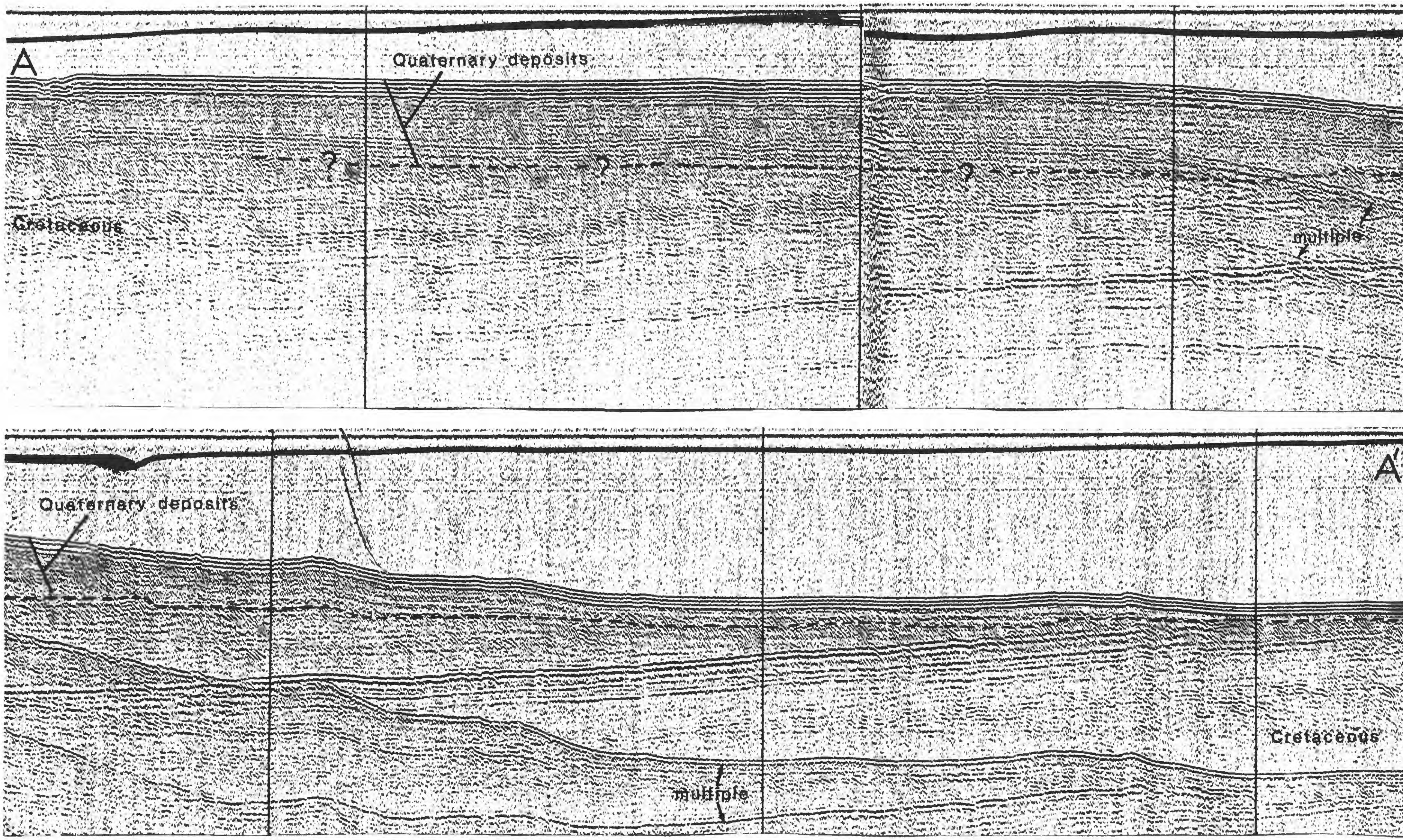

Figure 7. Contact between gently landward dipping Cretaceous strata and overlying Quaternary sediment. See figure 6 for location of profile. The Quaternary sediments increase in thickness landward from approximately 3 m at 22 m depth to over 10 m at 12 m depth. The dashed line indicates the contact between the Cretaceous strata and the overlying Quaternary sediments.

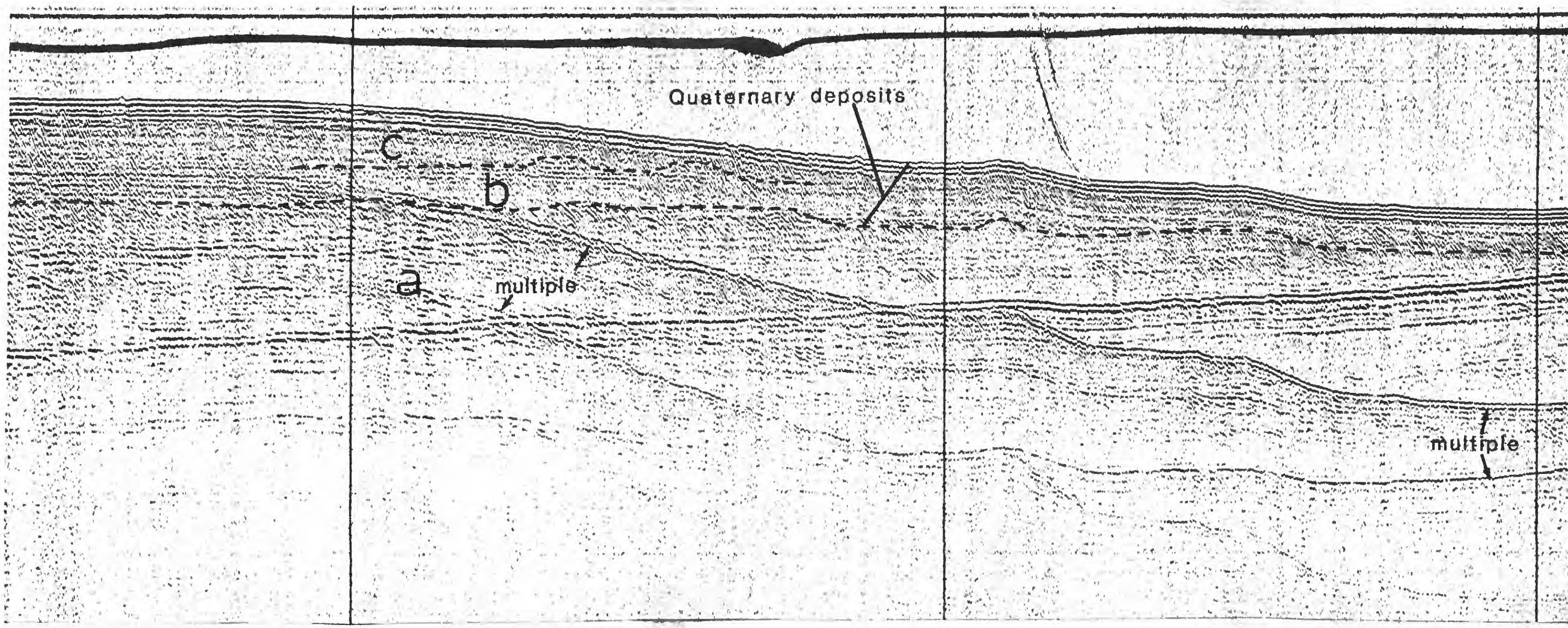

Figure 8. High-resolution seismic profile taken west of Peard Bay (enlargement of figure 7). Gentle dipping Cretaceous strata (A) forms the basal section. The Quaternary section can be divided into a basal horizontal-bedded unit (B) and an overlying prograding, seaward inclined unit (C). The basal Quaternary unit may be equivalent to part of the Gubic Formation exposed on land or it may represent bay-fill material formed during the Holocene transgression? The dashed line indicates the contact between the different sedimentation units.

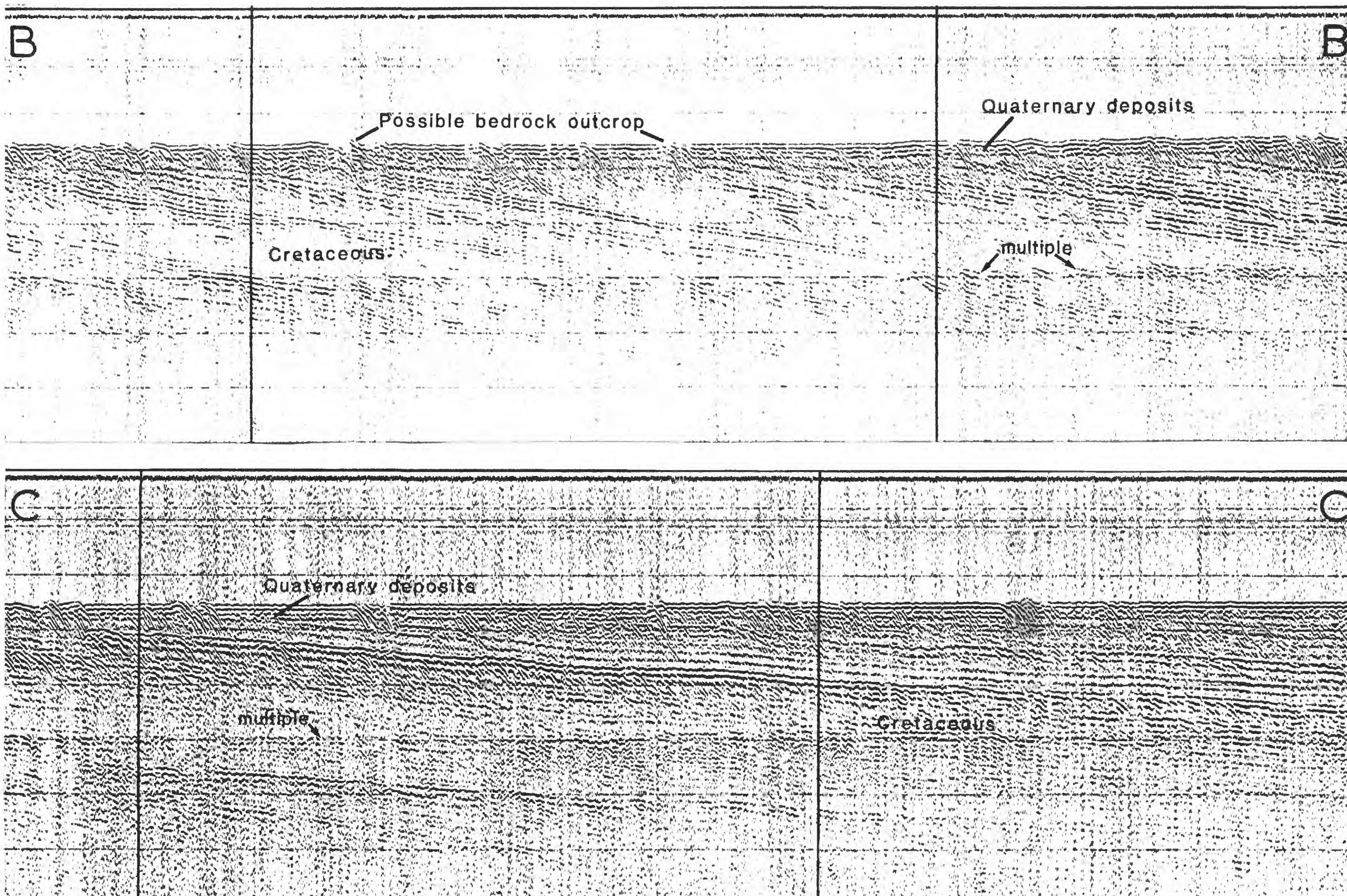

Figure 9. High-resolution seismic profiles northeast of Peard Bay. See figure 6 for profile locations. The Cretaceous strata dip to the southeast toward land. The Quaternary sediment cover is very thin, less than 2 to 3 m, within this region. Possible bedrock outcrops occur on the sea floor. The hyperbolas and depressions on the sea floor mainly represent ice gouges.

region (Figure 10). Biological communities are associated with certain textures. Worms (tubes) form dense communities within Peard Bay muds and occur as scattered individuals in all other sediment samples and T.V. runs. Gravels likewise contain distinctive biological communities with algae dominating in the shallow depths (less than 15 m) and barnacles at the deeper depths (greater than 24 m). The overall sediment distribution reflects the dominance of active erosional and depositional processes occurring on the shallow nearshore shelf.

Gravel The coarse sediment fraction is located in regions of thin Quaternary sediment cover and suggests that these regions are undergoing erosion or sediment bypass. This suggests that the gravels are only erosional surficial lags on the present sea floor. Two main areas containing gravel size sediment are identified: 1) west of Peard Bay at depths greater than 24 m, (identified by distinctive side-scanning-sonar patterns and sampling), and northeast of Peard Bay within shallow areas at depths less than 15 m (identified by distinctive side-scanning-sonar patterns and T.V. runs).

West of Peard Bay--Continuous to discontinuous gravel patches associated with sandwave fields occur west of Point Franklin to south of Point Belcher, a distance of 37 km, at depths generally greater than 24 m. The gravel deposits are located where the Quaternary sediment cover is 2 m thick or less. Possible Cretaceous bedrock outcrops may also be exposed within this area. The seaward extent of the gravel fields is unknown.

Side-scanning-sonar surveys show distinctive linear patches of sand and gravel at depths greater than 24 m. The linear features are oriented north-south and parallel the isobaths, the main coastal current trend and follow the trend of ice gouging (Figure 11).

Samples confirm the presence of gravel associated with sand. Samples 8 and 10 both contain gravel clasts associated with abundant invertebrate remains. Barnacles, as abundant fragments, and as whole individuals or as partial remains are found on the larger shell fragments and on many of the rock clasts. Other invertebrates include gastropods, pelcypods and bryozoans. Worm tubes also are abundant. Bryzoans occur as encrusting and as stalked colonial forms attached to the clasts. To the south sample 19 also contains pelcypods, gastropods, and abundant bryozoans but only a few very small barnacles.

The association of encrusting organisms with the gravel clasts, especially samples 8 and 10, suggests that the offshore region is a zone of non-deposition of finer sediment (silt and clay) and that various currents, including the Alaskan Coastal Current, are winnowing the sediment. Sample 19, gravelly sand, is associated with sandwave fields actively migrating to the north. A basal coarse lag can also be produced by the migration of sandwaves.

The gravel composition varies dominated by gray angular to slightly rounded dolomitic clasts (to 6.5 cm), to well rounded siliceous black (abundant) to brown (abundant to 1.3 cm), to angular dolomitic brown clasts (rare, to 3 cm). The invertebrate remains contain whole shells or abundant angular broken fragments.

East of Peard Bay--Discontinous gravel patches, associated with muddy

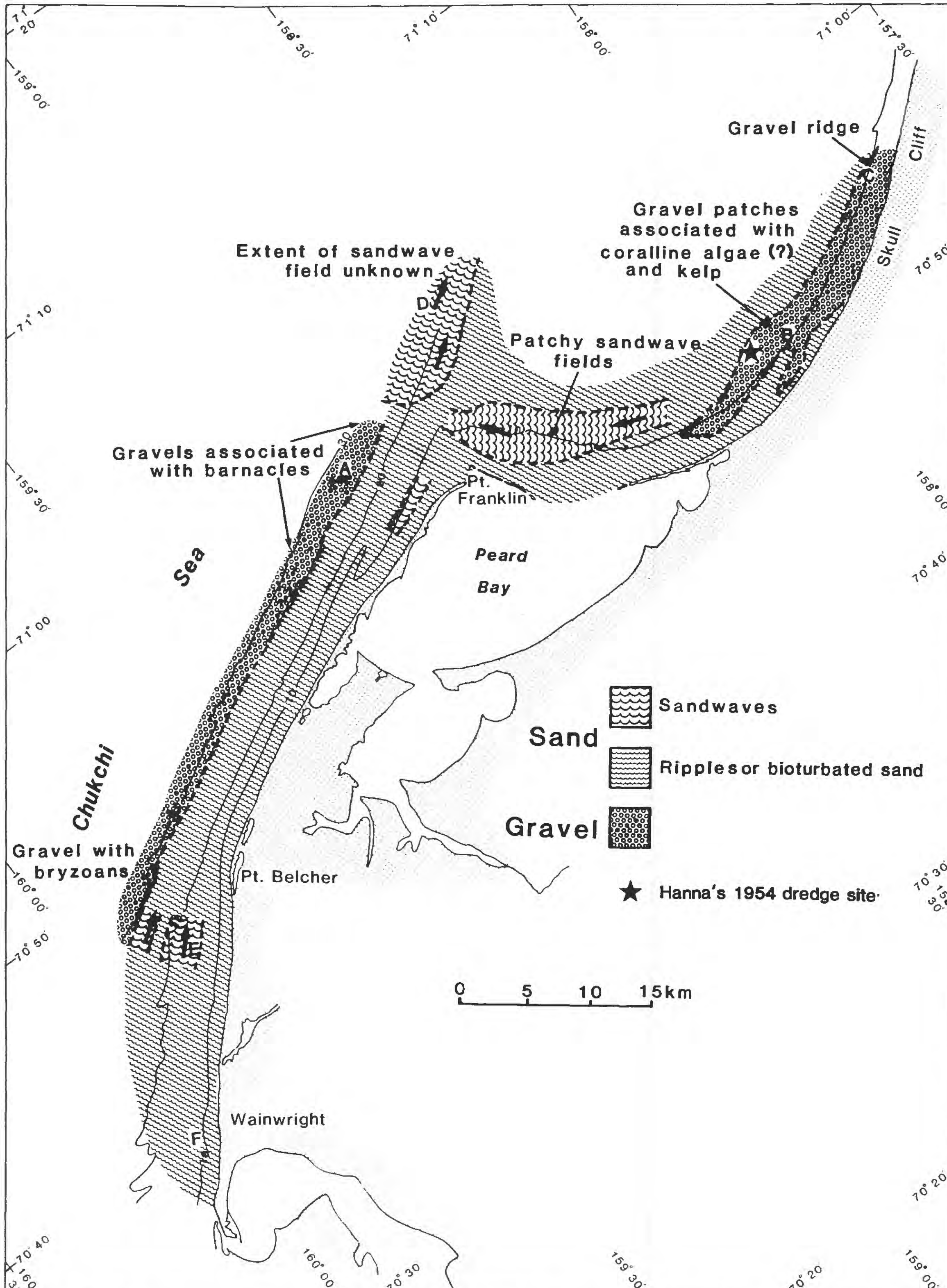

Figure 10. Dominant textures of surficial sediments with major bedform types. At depths less than 10 m sand usually contains shore parallel ripples, at deeper depths sandwaves may develope. Bioturbation is abundant in most sediment types. The gravel patches occur in regions of thin Quaternary sediment cover suggesting the deposits are erosional surficial lags. The arrows indicate the migration direction of the bedforms. The letters indicate sonograph or sample locations. Contours are in meters.

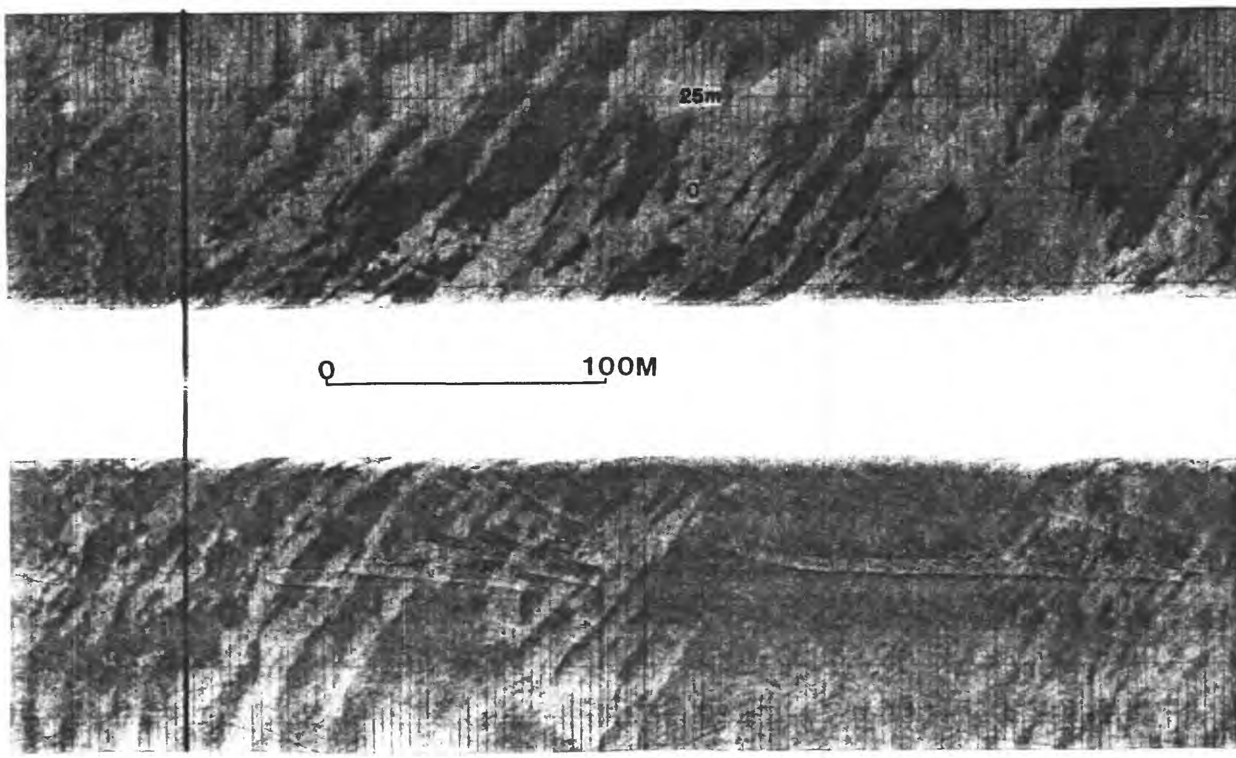

Figure 11. Sonograph of gravel-sand ribbons at a depth of 28 m west of Peard Bay. The gravel patches are aligned essentially parallel to the coast, to the isobaths, the Alaskan Coastal Current trend and to the ice gouge trend. The clasts, to 6.2 cm maximum size, are composed of dolomite and dark siliceous material occurring with abundant invertebrate remains. Barnacle fragments are the most abundant invertebrate remains. See figure 10, location A, for the profile location. Sample number 8 was taken in this gravel patch.

sand and Cretaceous bedrock outcrops(?) are found northeast of Peard Bay. The deposit parallels the shore at depths from approximately 15 m to 8 m (Figure 10). The band of gravel varies in width averaging 2.5 km and extends north to the Skull Cliff region, a distance of 30 km. This deposit also occurs where the Quaternary sediment cover is thin, less than 2 m thick.

Side-scanning-sonar surveys indicate a mottled sea floor pattern which when investigated with T.V. confirmed the presence of gravel and boulders on the sea floor (Figure 12). Large bedrock blocks, greater than 1 m wide, were also observed at T.V. station 5 (Appendix 1). The variability of the sea floor texture was characterized at T.V. station 3 where abundant gravel was observed covering the sea floor; a grab sample obtained at the same time the T.V. was operating only collected sand; when the anchor was pulled a layer of overconsolidated clay greater than 20 cm thick had adhered to the flukes.

Associated with the gravel-boulder fields northeast of Peard Bay are extensive biological communities dominated by algal (kelp) beds. The kelp beds extend to at least 12 to 13 m depth based on T.V. observations and may continue to 15 m depth. Hanna (1954) initially reported the occurrence of kelp beds within the same general area and Mohr et al (1957) describes the biota from Hanna's dredge sample.

The macroscopic brown alga *Phyllaria dermatodea* (de La Pylaie) Le Jolis is reported to be most abundant form (Mohr et al, 1957). A depth zonation has been suggested with coralline algae occurring in deeper water and the brown algae occurring in the shallower water based on the position of the plants within the dredge haul taken from offshore to inshore (Mohr et al, 1957). This is also suggested from T.V. drifts where a decrease in brown algae and an increase in red algae(?) was observed on the sea floor at T.V. station 5. Other organisms observed within the algal fields include worm tubes, gastropods, shrimp and a relatively abundant 6-rayed starfish, *Leptasterias*.

Observations onshore along Skull Cliff record brown algae scattered along the beaches. Directly offshore in depths less than 6 m Cretaceous bedrock occurs as stepped platforms (observed on high-resolution profiles) suggesting a substrate on which the algae may attach and grow. At deeper depths starting at 15 m, off Skull Cliff the gravel forms a distinctive ridge, rising to 12 m depth (Figure 13). Algae may also be growing on these gravels. The northern limit of the algal fields is unknown, but can be expected to occur where the substrate, gravel or bedrock, exists on which the algae can attach, and in depths at least to 13 m.

The origin of the gravel deposits identified in the northeast Chukchi Sea suggests that they are mainly surficial lags produced by the erosion of the Quaternary sediments by currents, both wave and shore-parallel coastal currents. The thin sediment cover (generally less than 2 m thick) over bedrock where the gravel fields are found supports an erosional lag origin for the deposits west of Peard Bay. Wave-dominated and shore-parallel coastal currents (moving to the west toward Point Franklin) produce the shore-parallel lags east of Peard Bay. The gravel ridge off Skull Cliff (Figure 13) may represent an ice-pushed ridge winnowed by currents.

Sand Sand size sediment dominates within the area investigated and is affected by two processes, currents and bioturbation. Active currents result

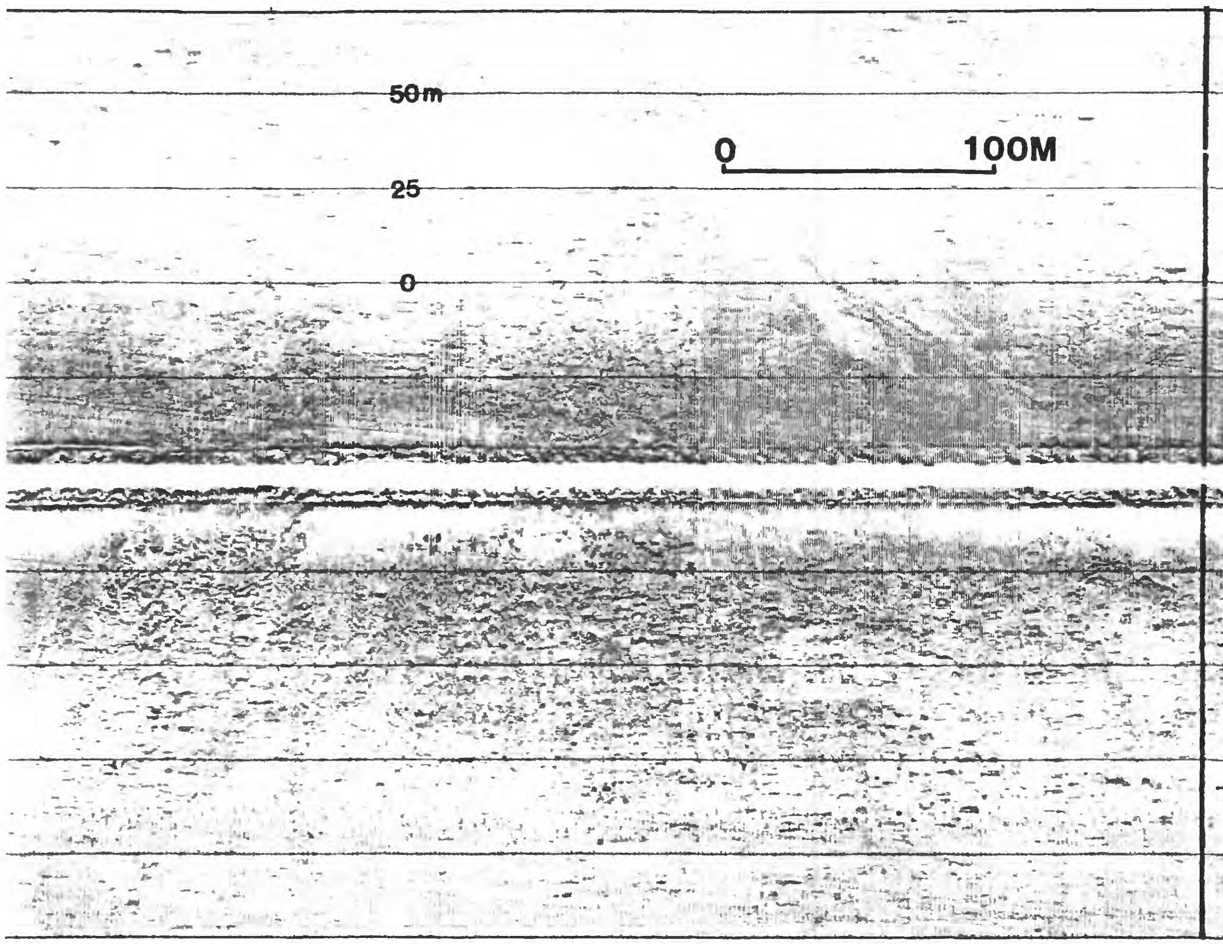

Figure 12. Sonograph of the sea floor northeast of Peard Bay at a depth of 11 m. The mottled character of the sea floor indicates gravel-boulder fields. T.V. scans confirm the presence of gravel and possible bedrock outcrops with attached benthic communities. Kelp beds occur attached to the gravel in this region at least to depths of 13.5 m, the landward extent of the kelp beds is unknown. Ice gouges occur in the upper half of this sonograph. North and increasing depth is toward the top of the sonograph. See figure 10, location B, for the profile location.

A

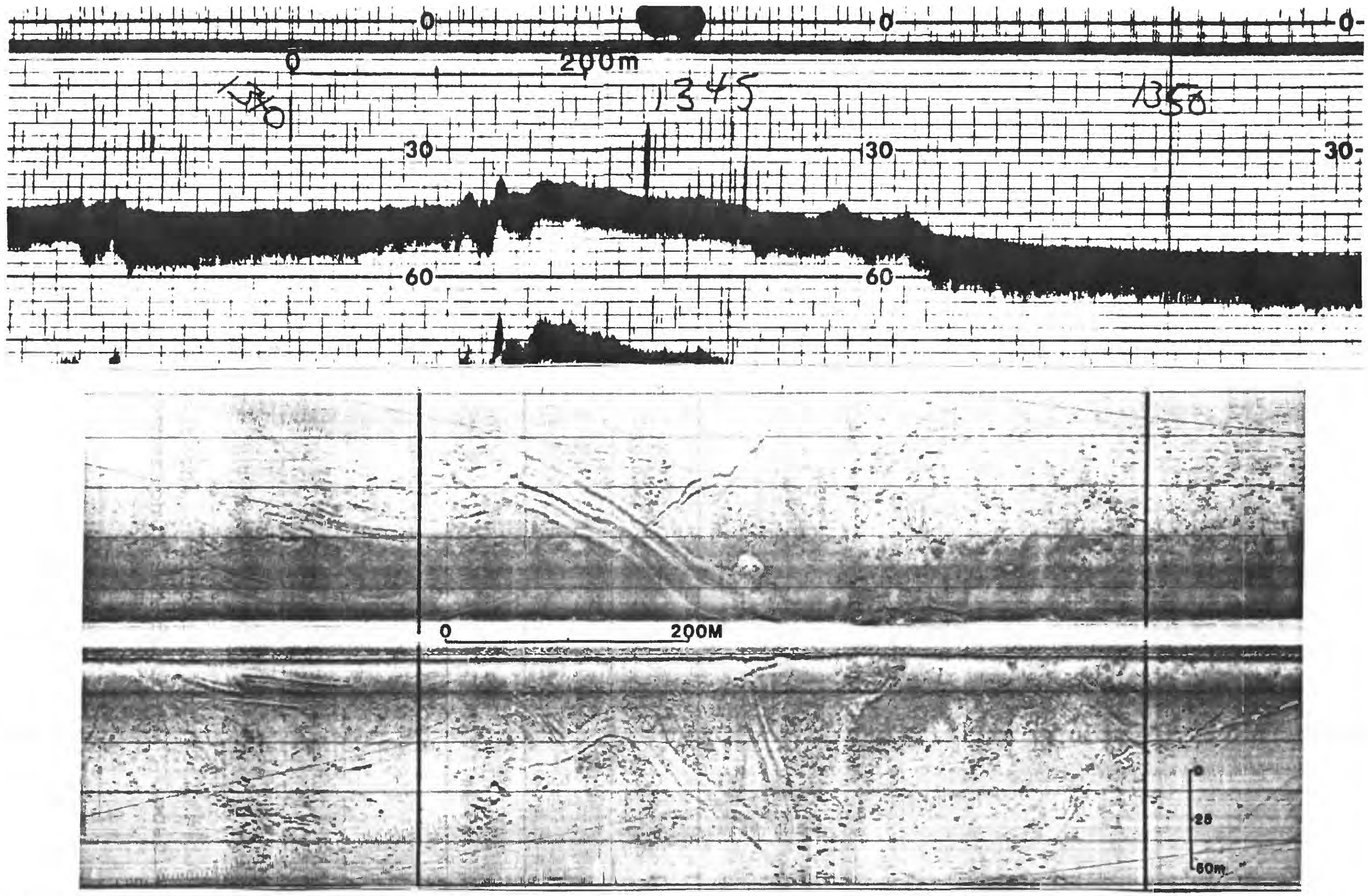

Figure 13. A) Bottom profile off Skull Cliff. See figure 10, location C, for sonograph and bottom profile location. The depths are in feet, land is to the left. A ridge rises from 13.7 m on the landward side to 11.6 m at the highest point. The irregular profile is caused by ice gouging on the bathymetric high. B) Side-scanning sonar record of the sea floor across the ridge. The mottled character of the sea floor suggests that the ridge surface is covered with gravel. Kelp beds may be associated with the gravel here also. The ridge is aligned parallel to the shore. The profiles cross the ridge obliquely.

in the formation of ripple fields nearshore and shore parallel sand wave fields (the sandwave crests are oriented perpendicular to shore) in the deeper off shore regions. Biological cummunities may locally occupy the sea floor. The surficial biologically stabilized sea floor will contain abundant stalked worm tubes as observed in T.V. drifts and in most surficial sediment samples. Side-scanning-sonar surveys and sampling defines the areas dominated by sand size sediment (Figure 10).

The sand ranges in size from coarse- to medium-grained texture. Sorting is generally poor. A decrease in grain size is suggested to the northeast of Peard Bay east of the influence of the Alaska Coastal Current.

Mud Fine-grained sediments (silts and clay) are some what restricted and occur within the deeper part of Peard Bay associated with extensive tube worm mats and as evidenced by one isolated sample south of Point Belcher at a depth of 8.1 m (sample no. 14, assumed to represent filling of an ice gouge by fine-grained sediment as subsequent sampling in the area did not encounter mud), and in the area north of Peard Bay and west of Skull Cliff. Over-consolidated mud was also collected within the gravel patch north of Peard Bay at a depth of 13.5 m.

Fine-grained sediment deposition is restricted to regions of low current activity. These areas are located within Peard Bay and east of the influence of the Alaska Coastal Current and west of Skull cliff at depths greater than 20 m which is below the effective wave base of the short period surface waves.

Processes

The sea floor from Wainwright to Skull cliff is dominated by two physical processes, active currents and ice gouging, that modify and change the character of the sea floor. The major effects of the processes are some what depth dependent and include both sandwave migration and ice gouging.

Sandwaves Migrating bedforms, sandwaves and ripples, are identified within the northeast Chukchi Sea with bedform crests oriented either shore perpendicular or shore parallel. The specific orientation of the bedforms depends upon the currents; shore perpendicular fields resulting form coastal currents moving essentially parallel to the coast whereas the shore normal fields resulting from surface waves moving toward shore (Figure 10).

Northeast migrating sandwave fields document sediment transport along the eastern boundary of the Alaska Coastal Current (Figure 14). Sandwave fields containing large-scale bedforms are identified: 1) directly north and northeast of Peard Bay, and 2) southwest of Point Belcher. The field north of Peard Bay has only been partially surveyed.

The bedforms within the fields represent actively migrating straight- to sinuous-crested sandwaves. The bedforms north of Peard Bay initially start at depths of 18 m and extend to at least 24 m depth (Figure 15). The maximum bedform height is 0.5 m and the wave length is approximately 18 to 20 m at 20 to 22 m depth. The sandwaves southwest of Point Belcher have a wave length of approximately 10 m (Figure 16). All of the large-scale sandwave fields west and north of Peard Bay exhibit a northeastward migration direction documenting the effects of sediment transport by the Alaska Coastal Current. Current

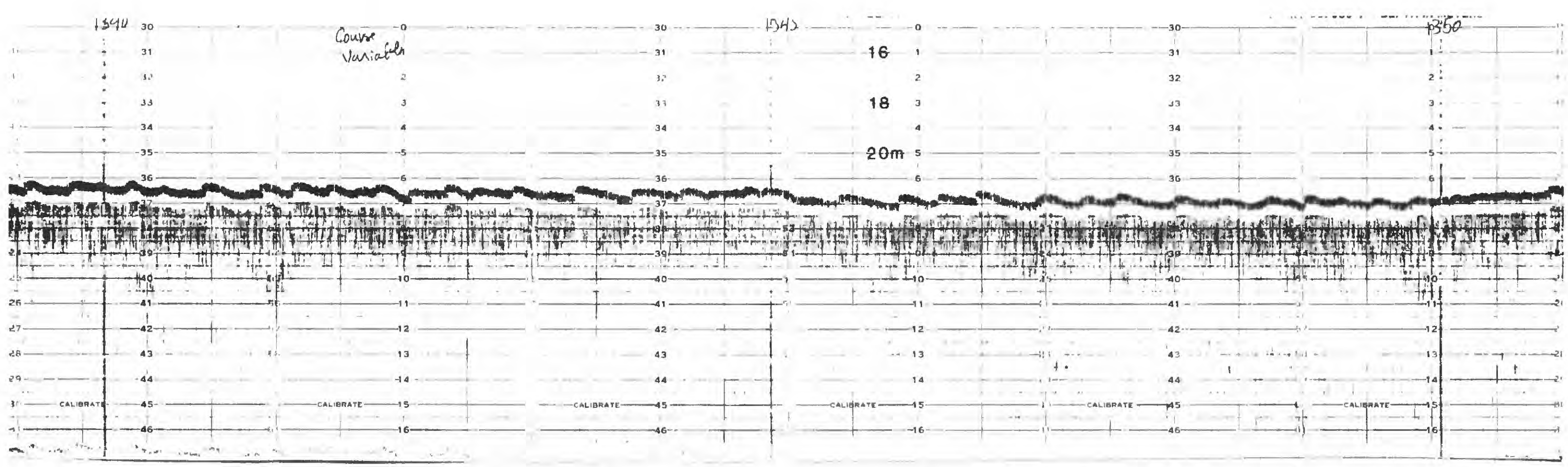

Figure 14. Bottom profile of large sandwave field north of Peard Bay. Large-scale sandwaves are migrating to the north along the eastern boundary of the Alaskan Coastal Current. The depth is approximately 21.5 m here. The sandwaves are approximately 0.3 m in height.

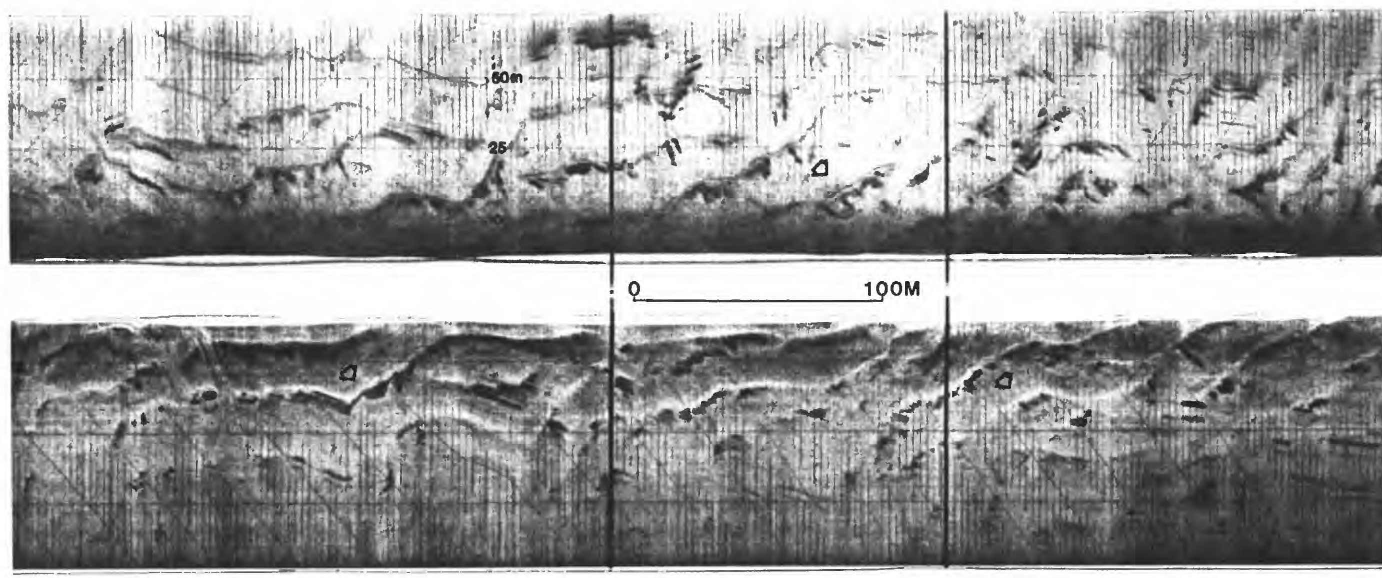

Figure 15. Sonograph of large-scale sandwaves migrating to the north. The sandwave field occurs north of Peard Bay at depths of 18 to 22 m along the eastern boundary of the Alaskan Coastal Current. The arrows indicate the migration direction of the bedforms. See figure 10, location D, for the profile location.

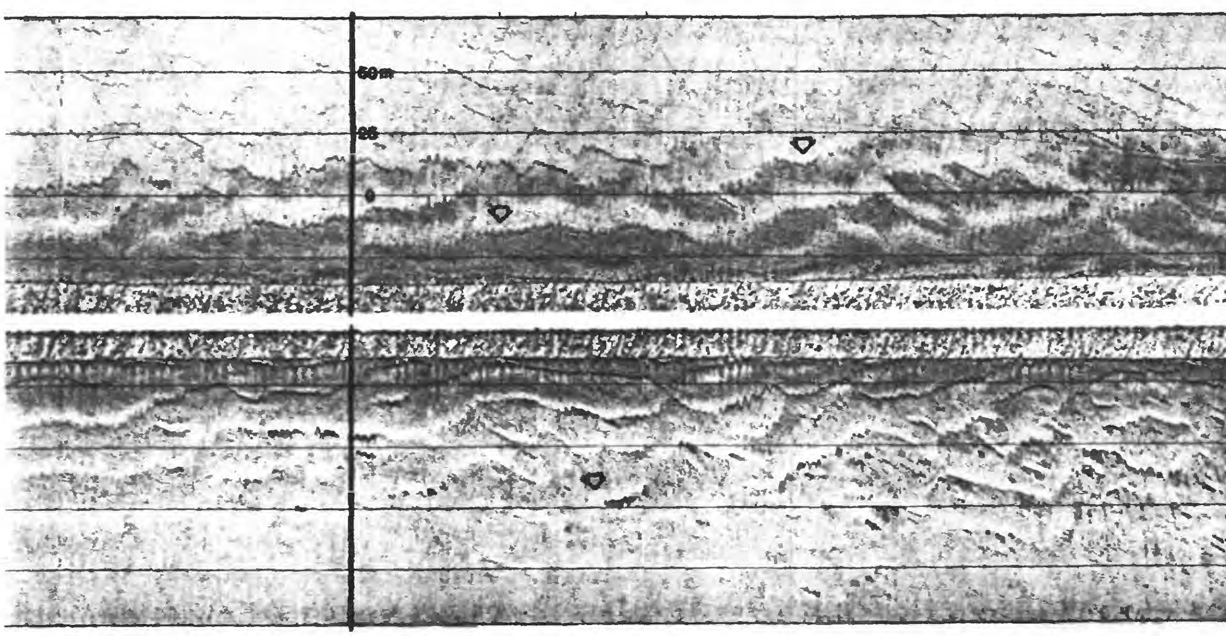

Figure 16. Sonograph of northward migrating large-scale sandwaves southwest of Point Belcher. This bedform field occurs between depths of 16 and 22 m. Another sandwave field also occurs seaward of this field at depths of 24 to 27 m, ripples or coarse-grained sediment occurs between the two fields. The arrows indicate the migration direction of the bedforms. See figure 10, location E, for the profile location.

velocities of 200 cm/sec for surface currents and 70 cm/sec at mid depth (10 m = mid depth) are reported from northwest of Point Franklin (Hufford, 1977). This current velocity should produce velocities sufficient to transport sand size sediment on the sea floor.

The sandwave field northeast of Peard Bay represents sediment transport to the west toward Point Franklin. Shore perpendicular bedforms have been identified to depths as shallow as 6 m in this area. The sandwaves occur in irregular scattered patches.

The sandwave fields are also modified by ice gouging (Figure 17). The ice gouges are essentially normal to the bedform crest orientation suggesting that the current transporting the ice and migrating the bedforms is the same. No ice gouging was observed in the sandwave fields off Point Belcher even though the field occurs on a slope and within the projected trace of the stamukhi zone. This suggests that actively migrating bedforms have filled in the ice gouges since ice breakup during the summer.

Ripples are superimposed on larger bedforms throughout the region and also occur as shore-parallel fields in water depths generally less than 10 m in regions of strong wave activity (directly north of Peard Bay channel entrance, along the coast between Wainwright and Point Franklin, Figure 10). The shore-parallel ripples form in response to wave activity. Where variations in grain size exist on the sea floor the ripples may form distinctive patches as observed with side-scanning-sonar (Figure 18).

Associated with the ripple fields directly west of Point Franklin were extensive benthic biological communities of the ascidian Rhizomogula globularis which were observed on T.V. drifts. An estimated density of as much as 100 per square meter may exist between the ripples.

Ice gouging Movement of ice by wind, currents and pack-ice pressure result in ice groundings on the sea floor which disrupt the surficial sediments forming ice gouges. Ice gouging of the Chukchi Sea sediments is reported to at least 38 m depth where the sea floor was gouged to 4.5 m depth (Barnes and Hopkins, 1978). The deepest ice gouge observed during this study was 1.6 m deep at 8 m depth directly west of Point Franklin, most gouges observed range between 0.7 and 0.2 m deep.

Intense ice gouging of the sea floor occurs on the seaward flanks of steep slopes and within the stamukhi zone (Figure 19). Both the stamukhi zone and area of steep slopes concide south of Point Franklin. Northeast of Point Franklin the stamukhi zone is indicated by a high density of gouges on a slight rise of 1 to 2 m of the sea floor.

The gouges west of Peard Bay within the stamukhi zone occur in the highest density at depths ranging from 14 to 24 m. The gouges are oriented parallel to the isobaths (Figure 20). Directly northwest of Point Franklin one gouge at 22 m depth was over 175 m wide and was traced for 1.8 km. Sandwaves eventually covered the gouge. South of the Peard Bay region the ice gouge density abruptly decreases. Profiles normal to the coast between depths of 11 to 20 m yields only 1 gouge per kilometer in comparison to the intense gouging recorded to the north as illustrated in Figure 20. The possible reasons for low gouge density within the projected trace of the stamukhi zone

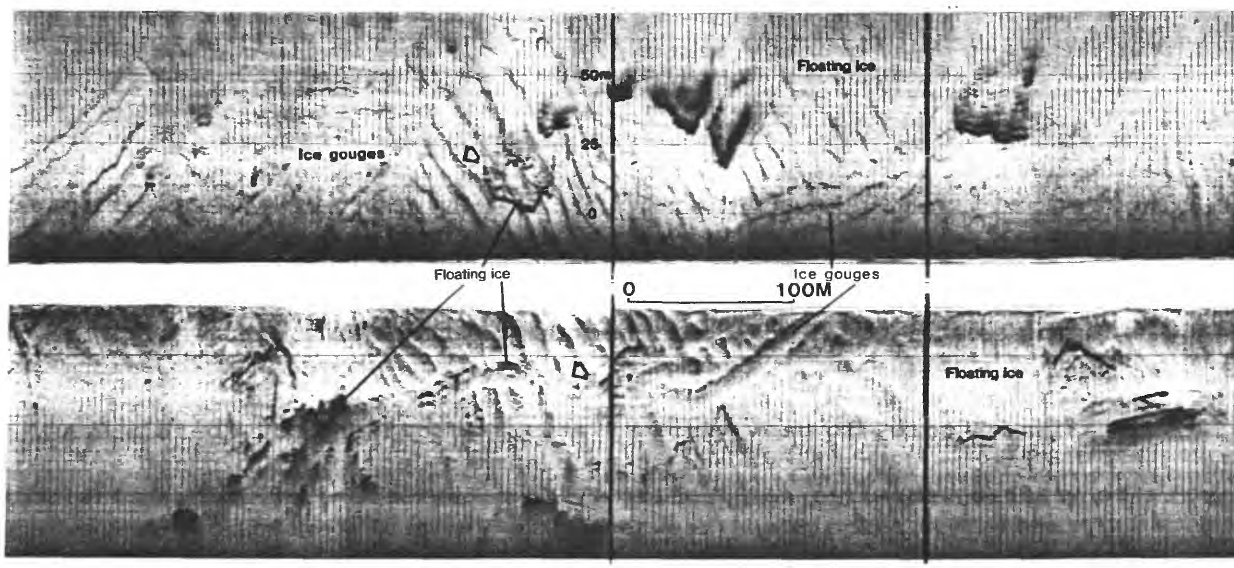

Figure 17. Sonograph of large-scale sandwaves containing ice gouges. The migration direction of the sandwaves is indicated by the arrows. The migration direction of the sandwaves (northward) and the ice gouge orientation (north-south) is essentially normal to the bed form migration direction which suggests that the same current is moving both the sandwaves and the ice. Floating ice is indicated on the sonograph. This sandwave field occurs north of Peard Bay at depths of 18 m.

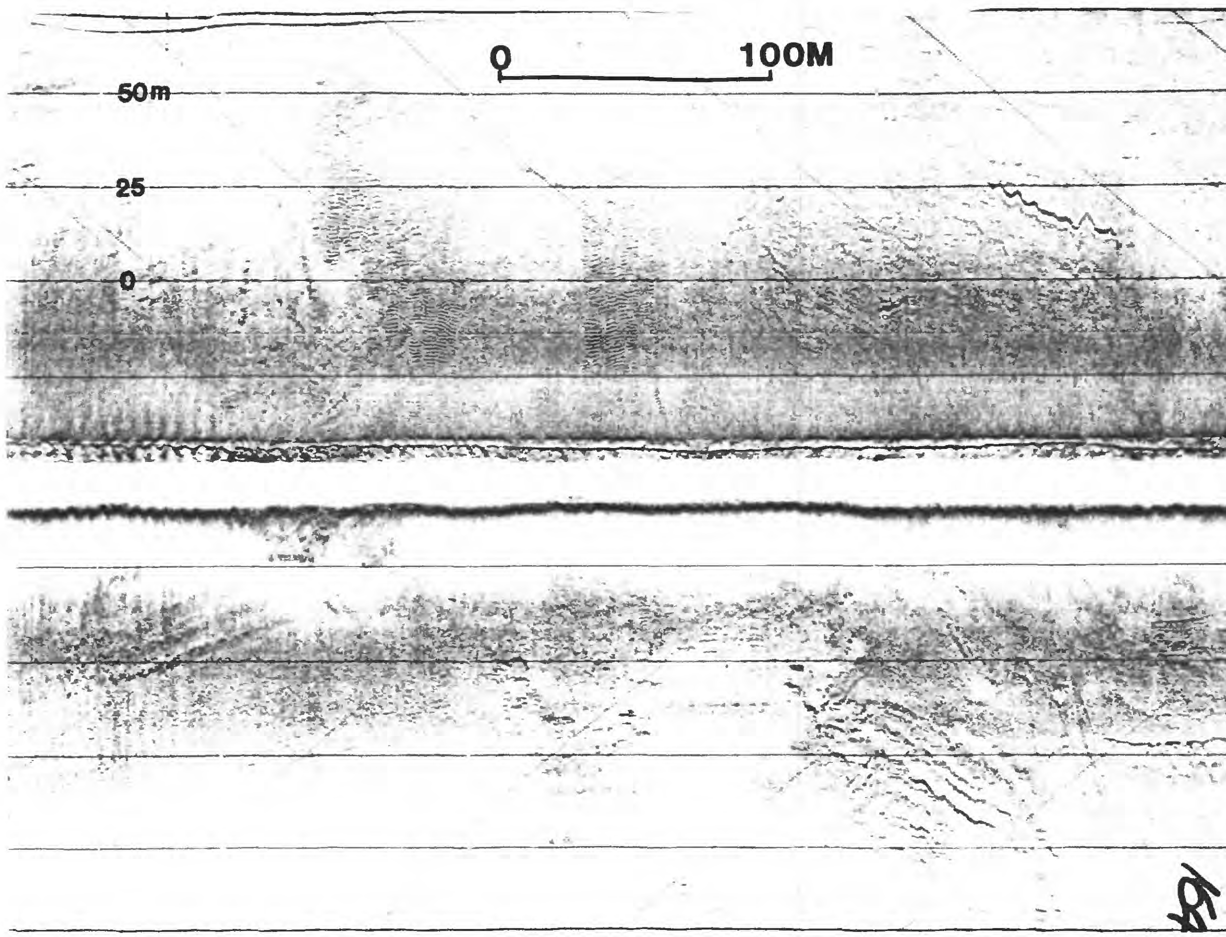

Figure 18. Sonograph of small-scale, shore-parallel ripples at depths of 10.8 m northwest of Wainwright. The ripple fields here occur in distinct patches with irregular boundaries suggesting distinct variations in texture exist on the sea floor. The ripples may be developed in sand-size sediment, whereas, coarser sediment may underly and separate the ripple fields. See figure 10, location F, for the sonograph location.

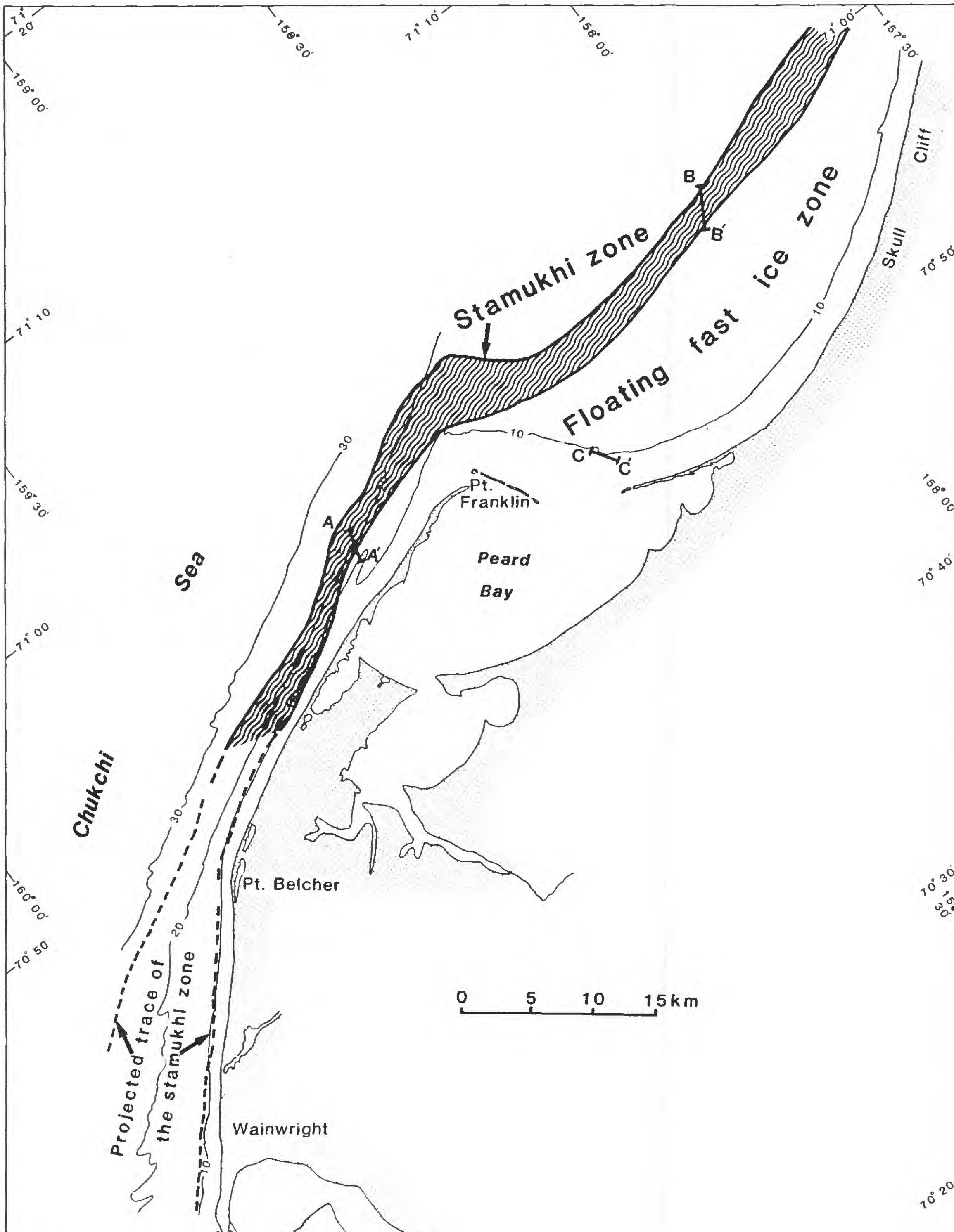

Figure 19. Ice zonation based on the abundance of ice gouges. The stamukhi zone represents a region of intense ice gouging of the sea floor. A ridge occurs at the northern end of the stamukhi zone possibly formed from ice push. The southern projected trace of the stamukhi zone is based on an increased bathymetric slope where ice would impinge. Migrating bedforms, sandwaves and ripples, apparently rapidly fill in the ice gouges within the southern region. The letters indicate sonograph location. Contours are in meters.

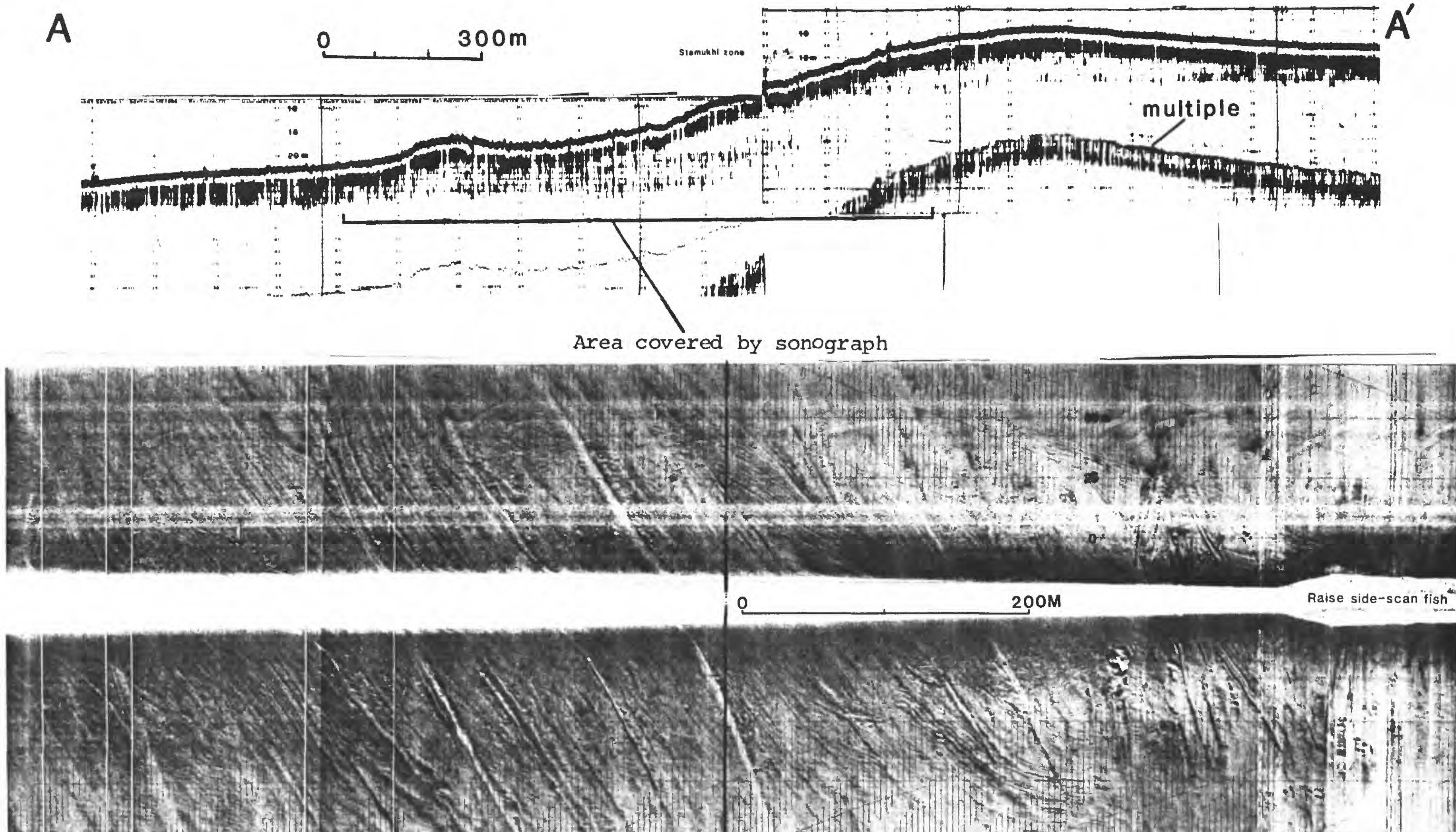

Figure 20. Bottom profile and side-scanning sonar profile of the sea floor west of Peard Bay. See figure 19, location A, for profile location. The stamukhi zone and the area of steep slopes where ice impinges coincide in this area. The side-scanning sonar profile shows intense ice gouging of the sea floor with the gouges oriented essentially parallel to the isobaths. The stamukhi zone ranges between 10 and 21 m on this profile decreasing to 14 to 22 m depth off Point Franklin. Sandwaves occur in the upper half of the sonograph.

south of Peard Bay region (Figure 19) may be due to the rapid filling of the gouges by migrating sandwaves and ripples. Northward migrating sandwave fields occur within this area (Figure 16) which would be capable of filling the gouges.

North and east of Peard Bay the stamukhi zone starts at depths of 20 to approximately 22 m on the slightly rising sea floor. A ridge of 2 m height starts at 22 m depth here. The highest density of ice gouging in on this ridge (Figure 21). Most gouges are oriented parallel to the isobaths or perpendicular to the isobath, some gouges appear to be randomly oriented.

Shoreward of the stamukhi zone north of Peard Bay the gouges are generally oriented parallel to the isobaths or may appear randomly oriented. The gouges are scattered narrow features within this area (Figure 22). No gouges were observed at depths less than 11 m directly north of Peard Bay after a storm passed through the region whereas before the storm the gouges were relatively abundant at depths less than 11 m. This suggests that storm-generated waves can rapidly eliminate traces of ice gouging at shallow depths.

Conclusions

The nearshore features observed on the northeast Chukchi Sea shelf can be explained as a combination of active marine processes involving both currents and ice groundings. The combination of active currents and active ice movement results in the present distribution of sediment textures, bedforms, biological communities, morphology and sea floor ice gouging. Identification of the major surficial features contained on the sea floor can, therefore, be explained by a combination of factors as wave-generated currents, shore-parallel coastal currents, surface ice zonation and ice grounding.

Currents, both wave-generated and shore parallel; 1) transport sediment as migrating ripples and sandwaves, 2) erode the substrate exposing bedrock outcrops and producing surficial gravel lag deposits which in areas of long term erosion allows extensive benthic biological communities to develope, 3) masks the intensity of ice gouging by rapidly filling in the gouged troughs, and 4) where shore parallel currents converge, as off Point Franklin, results in sediment deposition.

The effects of ice gouging are; 1) intense disruption of the sea floor sediments by grounded ice, especially between depths of 22 to 12-14 m (the stamukhi zone) northeast of Peard Bay and on the slopes west of Peard Bay, and 2) forms low relief ice-pushed ridges northeast of Peard Bay at depths of 22 m and possibly at 12 to 14 m depth nearshore directly off Skull Cliff.

Acknowledgment

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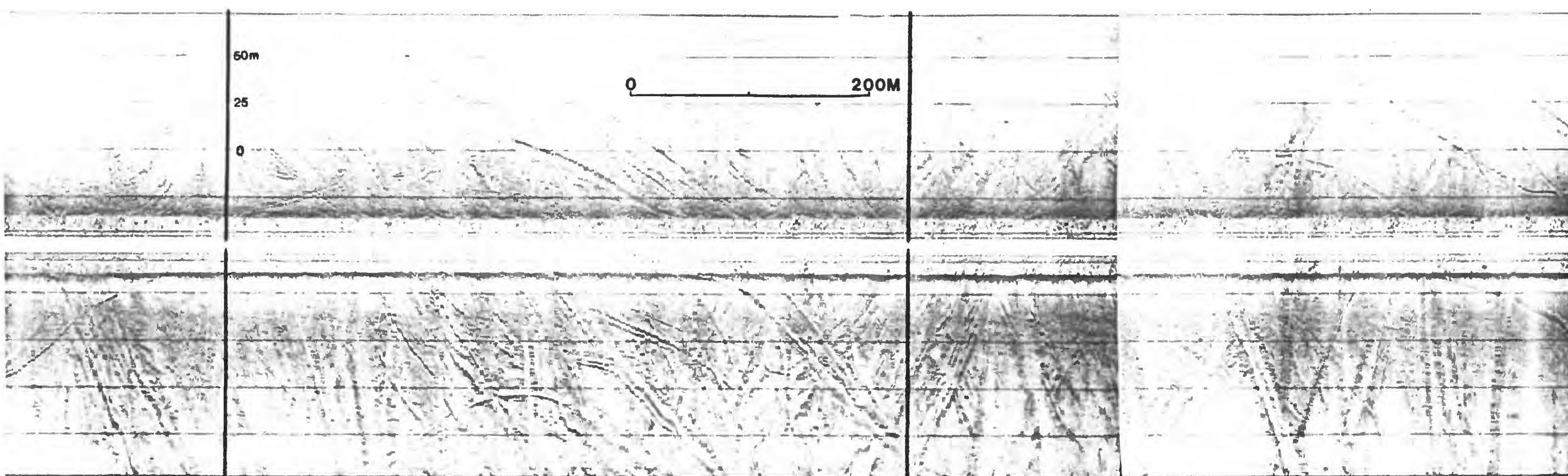

Figure 21. Side-scanning sonar record of the stamukhi zone northeast of Peard Bay. See figure 20, location B, for the sonograph location. A rapid rise in the sea floor of 2 m occurs between 22 and 20 m depth. Intense ice gouging occurs here. The ridge may have formed from ice gouging of the sea floor. Most of the ice gouges are parallel to the ridge trend. The ridge was crossed obliquely.

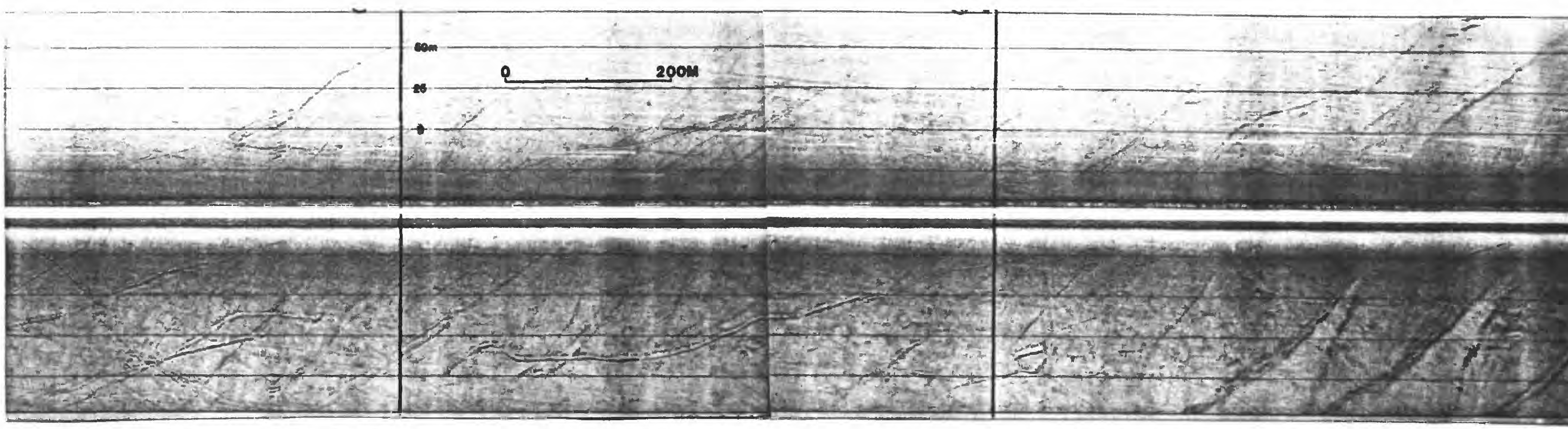

Figure 22 Side-scanning sonar record of the sea floor northeast of Peard Bay landward from the staumkhi zone. The depth ranges from 9 to 10 m here. The ice gouges are isolated narrow features. Most ice gouges parallel the isobaths. See figure 19, location C, for the sonograph location.

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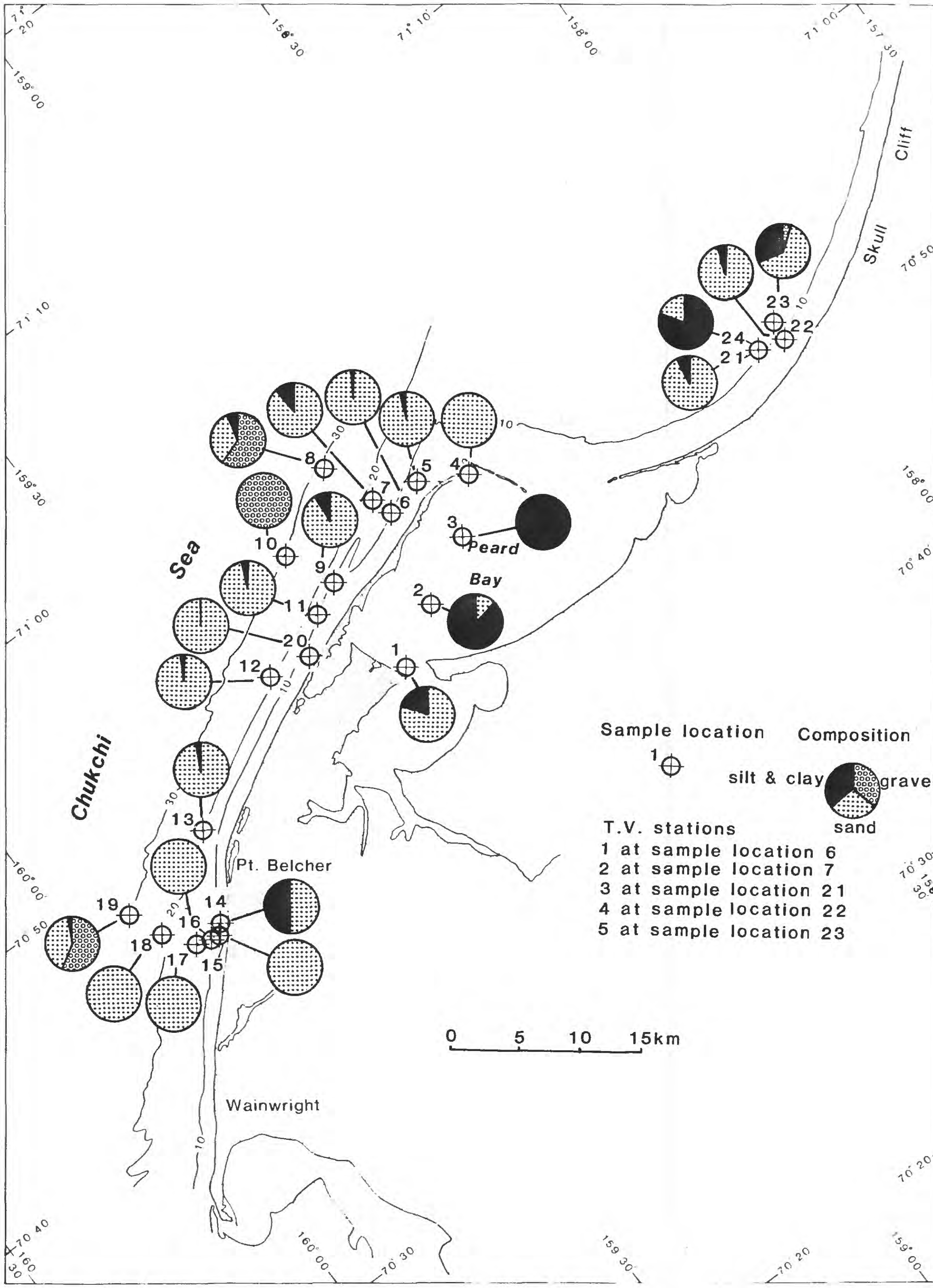

Appendix 1. Sample locations, composition and television station locations, northeast Chukchi Sea. Contours are in meters. See following page for percent composition of sediment components.

Appendix 1
Sample Composition, Chukchi Sea, 1981

Sample No.	Location		Depth (m)	Gravel	Percent Sand	Silt and Clay
1	70.83°	159.11°	3.0	-	78.9	21.0
2	70.85°	158.96°	7.0	0.3	11.4	88.3
3	70.87°	158.84°	6.5	-	0.7	99.1
4	70.90°	158.75°	3.0	-	99.6	0.4
5	70.92°	158.88°	6.0	2.8	96.8	0.4
6	70.91°	158.92°	9.3	0.7	97.5	1.8
7	70.93°	158.94°	13.8	0.9	88.3	10.8
8	70.96°	158.98°	28.6	59.9	34.5	5.5
9	70.90°	159.11°	8.4	0.3	88.3	11.4
10	70.93°	159.16°	29.1	100.0	(washed)	?
11	70.88°	159.20°	12.5	0.7	96.7	2.6
12	70.87°	159.34°	17.1	0.3	96.5	3.2
13	70.82°	159.63°	18.0	2.2	93.9	3.9
14	70.76°	159.74°	8.1	9.1	50.0	40.6
15	70.75°	159.75°	6.0	-	99.6	0.4
16	70.75°	159.76°	10.5	-	98.9	1.1
17	70.75°	159.80°	15.2	-	99.0	-
18	70.77°	159.84°	19.8	-	99.0	-
19	70.80°	159.88°	29.3	55.0	42.4	2.6
20	70.87°	159.24°	7.2	-	98.9	1.1
21	70.85°	158.10°	11.7	1.2	92.9	5.9
22	70.84°	158.04°	9.0	0.2	96.0	3.7
23	70.86°	158.04°	12.9	3.5	65.5	31.0
24	70.87°	159.24	11.7	0.8	21.9	77.3