UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Nearshore marine geologic investigations, Point Barrow to Skull Cliff, northeast Chukchi Sea

by

R. Lawrence Phillips and Thomas E. Reiss

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and nomenclature.

Menlo Park, California

CONTENTS

INTRODUCTION

Between August 1 and August 21, 1982, marine geologic investigations were conducted on the inner shelf of the northeast Chukchi Sea from onboard the R/V Karluk. This report summarizes the results of the reconnaissance investigation of the Chukchi Sea shelf from 14 km north of Pt. Barrow (71° 29') south to Skull Cliff (71° 08'), (figure 1). The purpose of this study is to identify marine geologic hazards and locate potential sand and gravel deposits on the inner shelf of the Chukchi Sea.

The study area is bordered to the northeast by the Beaufort Sea shelf. A narrow barrier island extends from Pt. Barrow southwest 7 km to where the barrier chain attaches to the coastal plain north of the town of Barrow. The coastal region south of the barrier island contains low relief south to Barrow. Steep cliffs front the sea south of the town of Barrow. The cliffs extend to the south to the east end of Peard Bay and rise to a maximum height of 18 m (Harper, 1978).

Cretaceous bedrock is exposed at the base of the sea cliff from about 71° 10' south to Skull Cliff (Hanna, 1954). The oldest bedrock consists of Cretaceous sandstones, siltstones and mudstones of the Torok Formation overlain by sandstones, siltstones and mudstones of the Nanushuk Group (Grantz and others, 1982). Unconformably overlying the Cretaceous strata is the Quaternary Gubic Formation of Black (1964). The Barrow unit of the Gubic Formation is exposed within the sea cliffs. The unit consists of clay, silt, sand and gravel; ice locally constitutes more than half the volume of the Barrow unit (Black, 1964). The Cretaceous bedrock and the overlying Gubic Formation extends offshore. The west to northwest trending Barrow Arch forms the major bedrock structure in the northern part of the study area.

One hundred four km of subbottom profiles and 146 km of side-scan sonar records were collected during this investigation (figure 2).

The pack ice was located over 30 km north of Pt. Barrow during this study moving south to the vicinity of Barrow on the 21 of August. Persistent west to northwest-directed storms and accompanying strong winds dominated in the Chukchi Sea during the study period.

BATHYMETRY

The northeast trending Barrow Sea Valley parallels the shore and is incised into the Chukchi Sea shelf. A platform extends from the beach to water depths of 12 to 14 m from Pt. Barrow south to the end of line 11 (figure 2). The shallow platform is 3 km wide off of Pt. Barrow rapidly narrowing to less than one km at Barrow (figure 3). Seaward of the break in slope off Pt. Barrow, at depths of 30 to 32 m, the sea floor slope rapidly increases. Seismic profiles indicate that bedrock outcrops on the steep slopes of the sea floor. Two discontinous northeast-trending linear ridges rise above the sea floor at approximate depths of 44 m and 56 m. The deeper ridge zone is well developed containing up to 6 m of relief (figure 3). Northeast of Pt. Barrow the sea floor gradually slopes toward the northeast on the Beaufort Sea shelf.

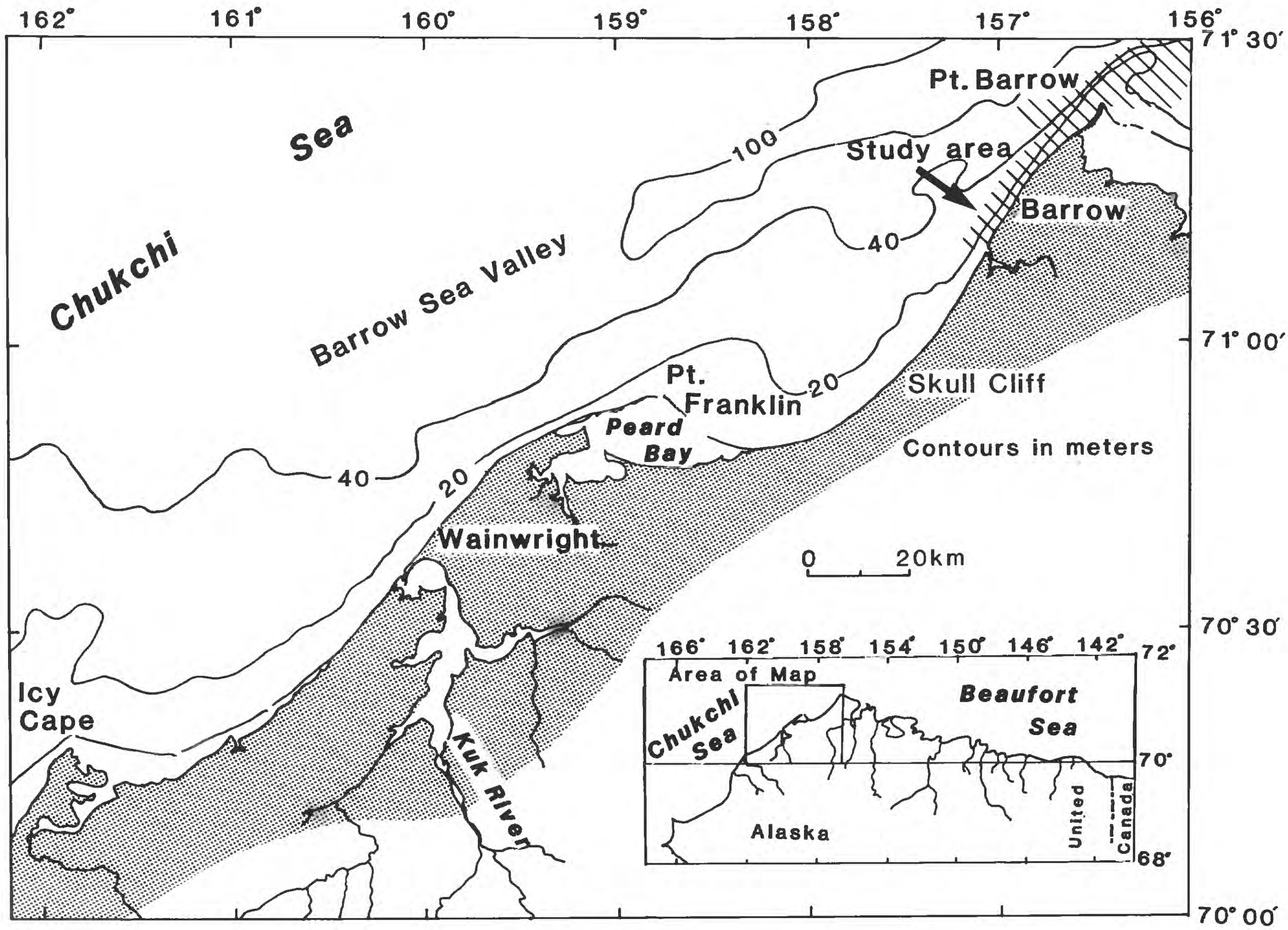

Figure 1. Location of nearshore shelf investigated during 1982 in the northeast Chukchi Sea between Pt. Barrow and Skull Cliff.

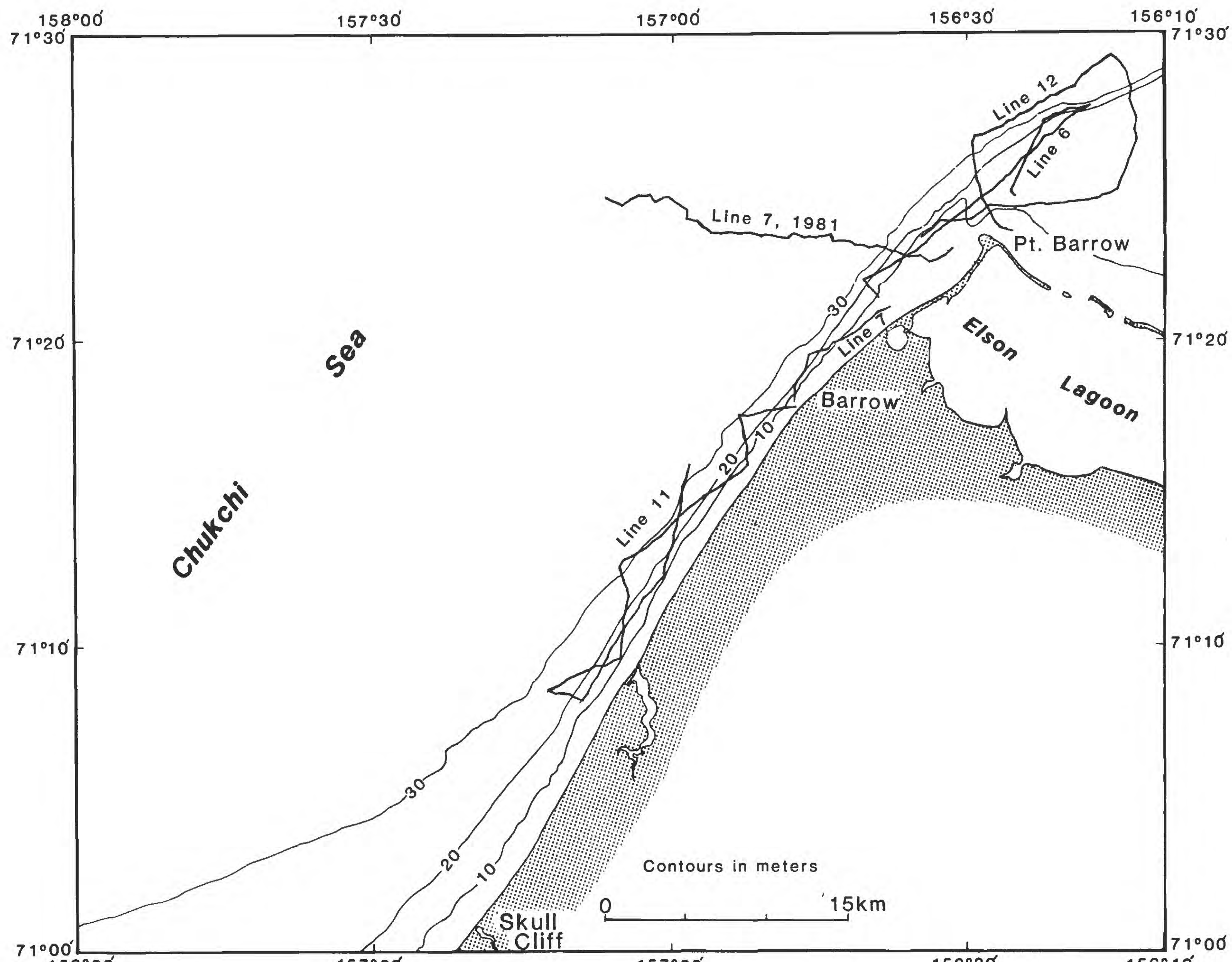

Figure 2. Trackline map, 1982 R/V Karluk cruise, Pt. Barrow to northern part of Skull Cliff, northeast Chukchi Sea. One line (line 7, 1981) was obtained the previous year.

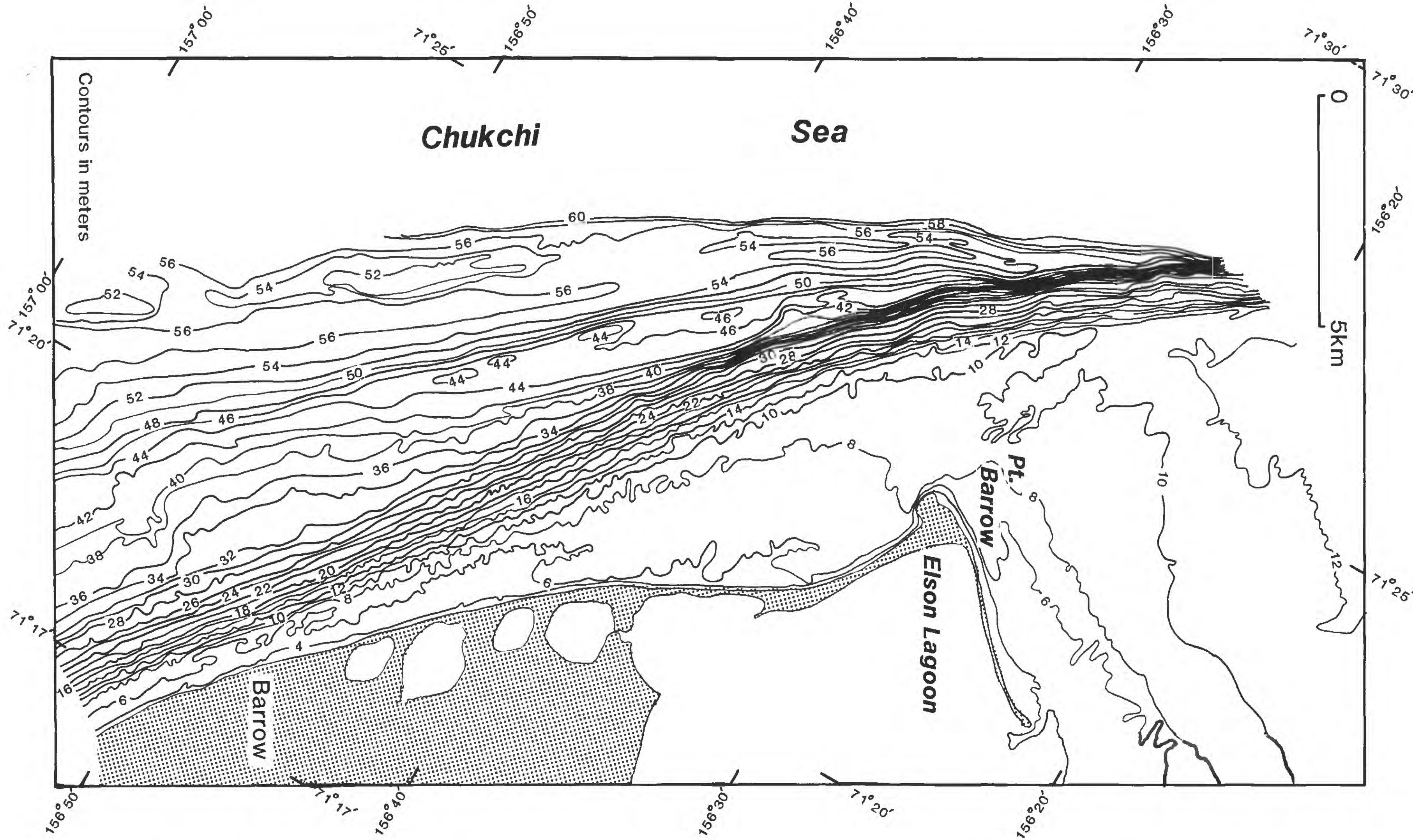

Figure 3. Bathymetric map of part of the northeast Chukchi Sea near Barrow, Alaska. the shallow shelf rapidly drops away at about the 12 m depth contour into the Barrow Sea Valley. Discontinous northeast-trending ridges occur at approximate depths of 44 and 56 m.

CURRENTS

The northeast flowing water of the Alaskan Coastal Current is compressed against the east side of the Barrow Sea Valley (Aagaard and Coachman, 1964). The current can range up to 37 km in width, narrowing directly north of Pt. Barrow. Surface velocities of up to 100 cm/sec are reported within the Alaska Coastal Current (Paquette and Bourke, 1974, Hufford, 1977). Bottom velocities of 80 cm/sec were reported directly off Barrow at 38 m depth (Shumway and Beagles, 1959). Hufford (1977) reports a returning southwest-directed current with surface velocities up to 130 cm/sec west of the Alaska Coastal Current off Skull Cliff. North of Pt. Barrow clockwise rotating currents have been identified which may reflect the interaction of the north flowing Alaska Coastal Current and the west flowing currents of the Beaufort gyre (Solomon and Ahlnas, 1980).

Asymmetrical sandwaves also define the direction of bottom currents. Sandwaves have been identified directly north of Pt. Barrow where northeast-migrating bedforms are found near the slope break into the Barrow Sea Valley. The bedforms change orientation becoming eastward-directed sandwaves to the east on the Beaufort shelf. Eastward coastal flow in the Beaufort Sea in the summer has also been identified by Hufford (1973) and Paquette and Bourke (1974). The eastward-directed sandwaves may reflect the eastward sediment transport by the coastal current (figure 4).

Evidence for nearshore northward moving currents and sediment transport is also indicated by the building to the north of the sand-gravel barrier island forming Pt. Barrow (Hume and others, 1972, Rex, 1964).

GEOLOGY

The Alaska Coastal Current has eroded the Quaternary sediment exposing bedrock on the sea floor. Cretaceous strata outcrop on the sea floor at depths generally greater than 24 m. Moore (1964) reports that gentle dipping bedrock is also exposed on the sea floor at deeper depths within the Barrow Sea Valley off Barrow. A thin Quaternary sediment cover, less than one meter in thickness, may surround the bedrock outcrops (figure 5). At depths between 42 and 56 m (line 7, 1981, figure 2) the Quaternary sediment locally thickens to 8 to 10 m on two apparent linear (northeast trending) ridges (figure 3). Apparent northward dipping Cretaceous strata are identified throughout the study area in the subbottom profiles.

High angle reverse faults with displacements of a few meters are identified within the Cretaceous strata (figure 6). Faults within the Quaternary section have not been identified suggesting the faulting is older than the Quaternary sediments and is probably related to folding of the Cretaceous strata.

An apparent slightly northward dipping flat erosional surface truncates the underlying Cretaceous strata. Quaternary sediment, probably the Gubic Formation, overlies the erosional surface. The Quaternary strata thicken toward land obtaining a maximum thickness of 15 m at 7 m water depth (line 11), (figures 7 and 8). An isopach map of the southern part of the study area shows the landward thickening of the Quaternary sediment (figure 9). A paleochannel, containing up to 11 m of fill, cuts into the Cretaceous strata,

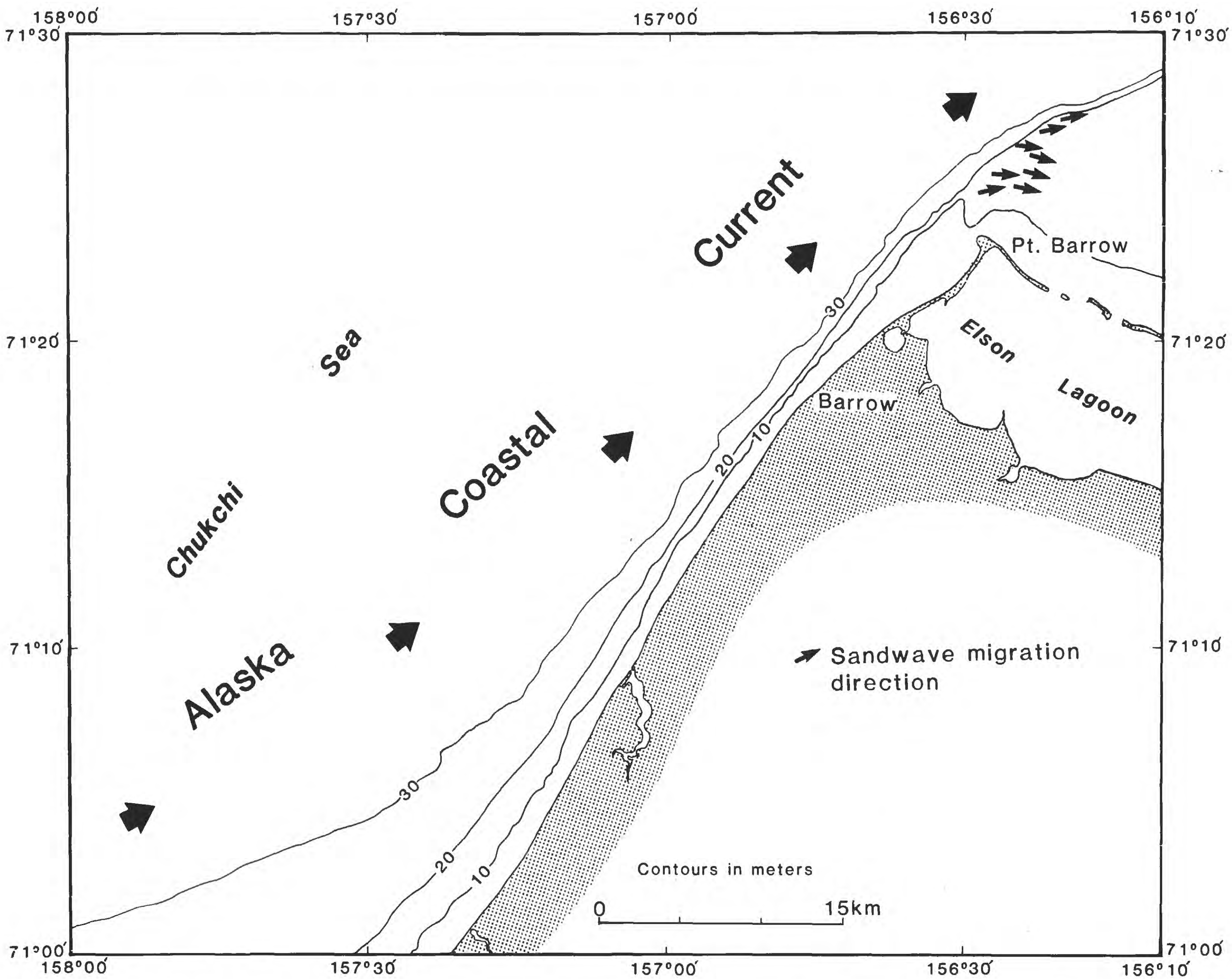

Figure 4. Coastal currents along the northeast Chukchi Sea. The Alaska Coastal Current with surface velocities up to 100 cm/sec. dominates this coastal region. Eastward-directed sandwaves, identified directly north of Pt. Barrow, on the shallow shelf reflects part of the Alaska Coastal Current flowing to the east.

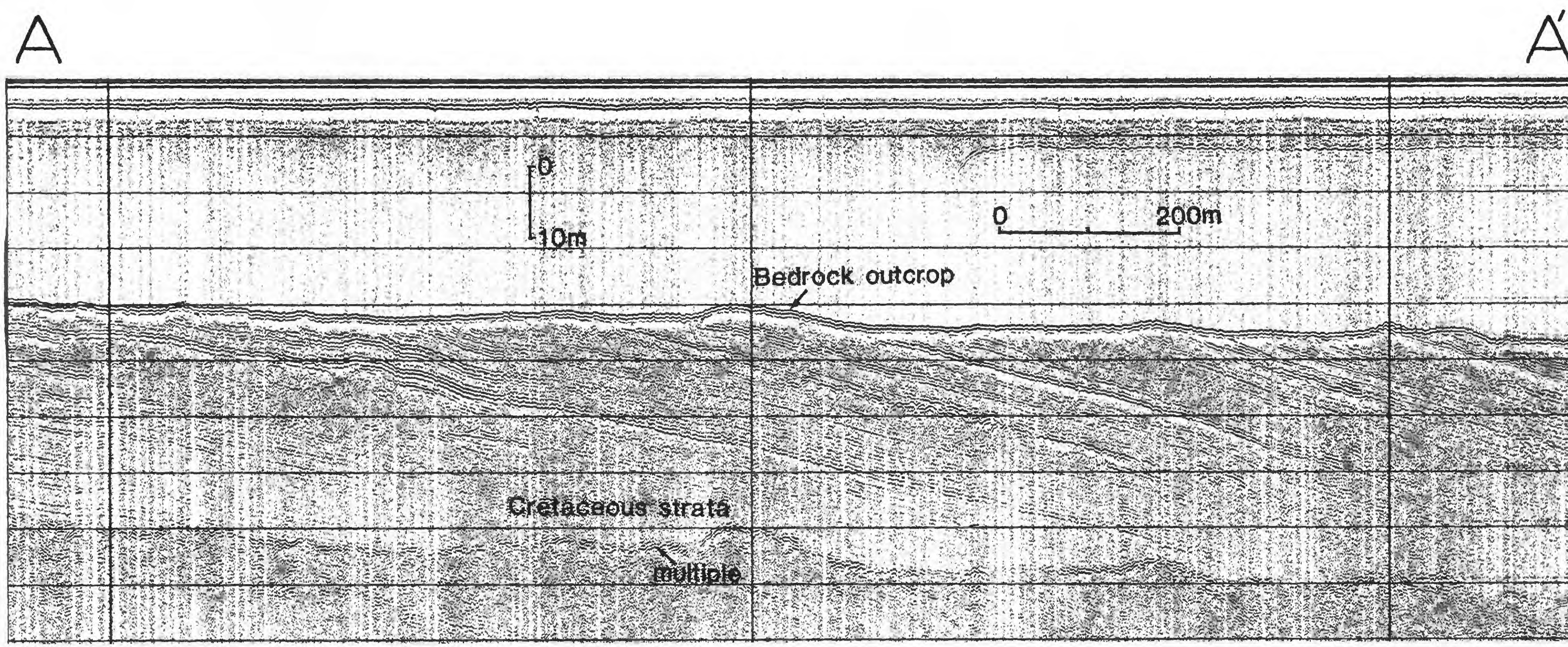

Figure 5. Gentle northward dipping Cretaceous stata (see figure 9 for location of profile). A thin veneer of Quaternary-Holocene sediment cover overlies the bedrock. The bedrock outcrops protrude above the younger sediment.

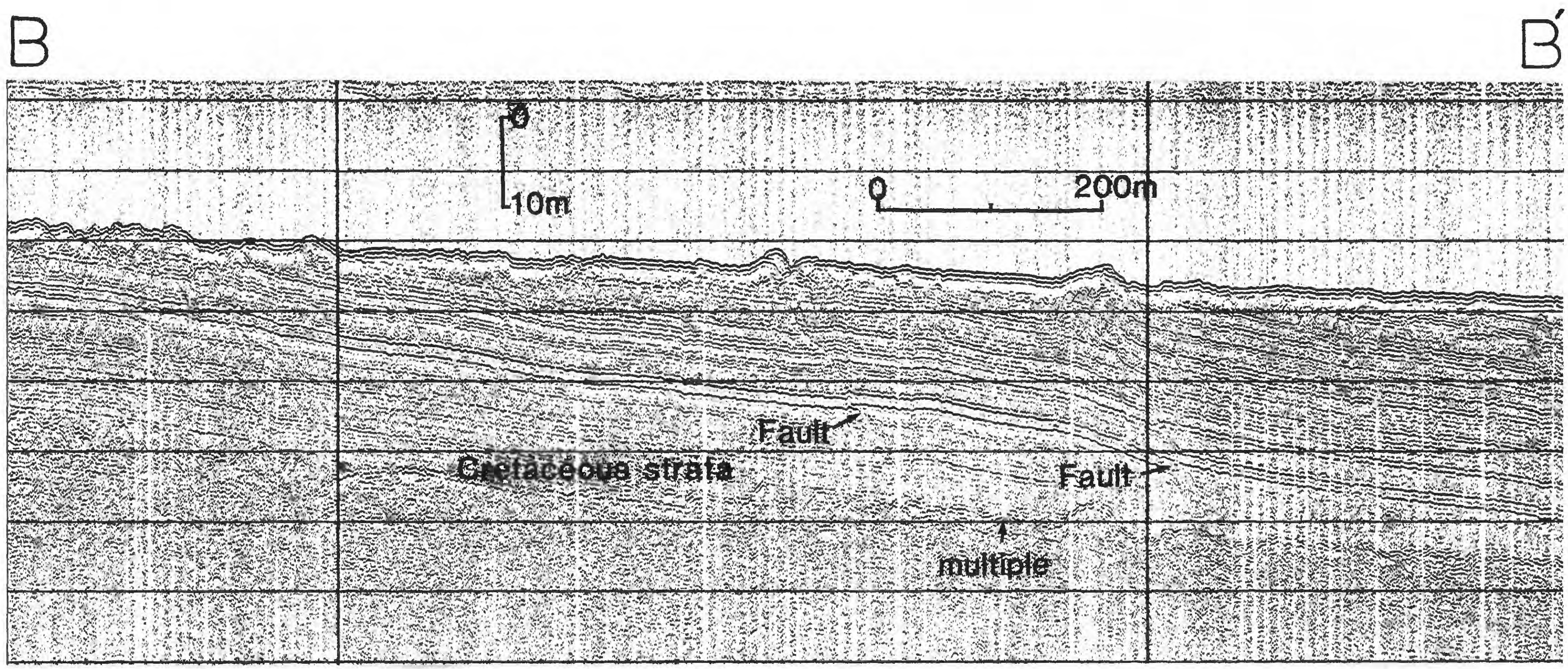

Figure 6. Gentle apparent northward dipping Cretaceous strata containing high angle reverse faults with apparent displacements of a few meters (see figure 9 for location of profile). Bedrock outcrops and ice gouging form the irregular surface relief on the sea floor.

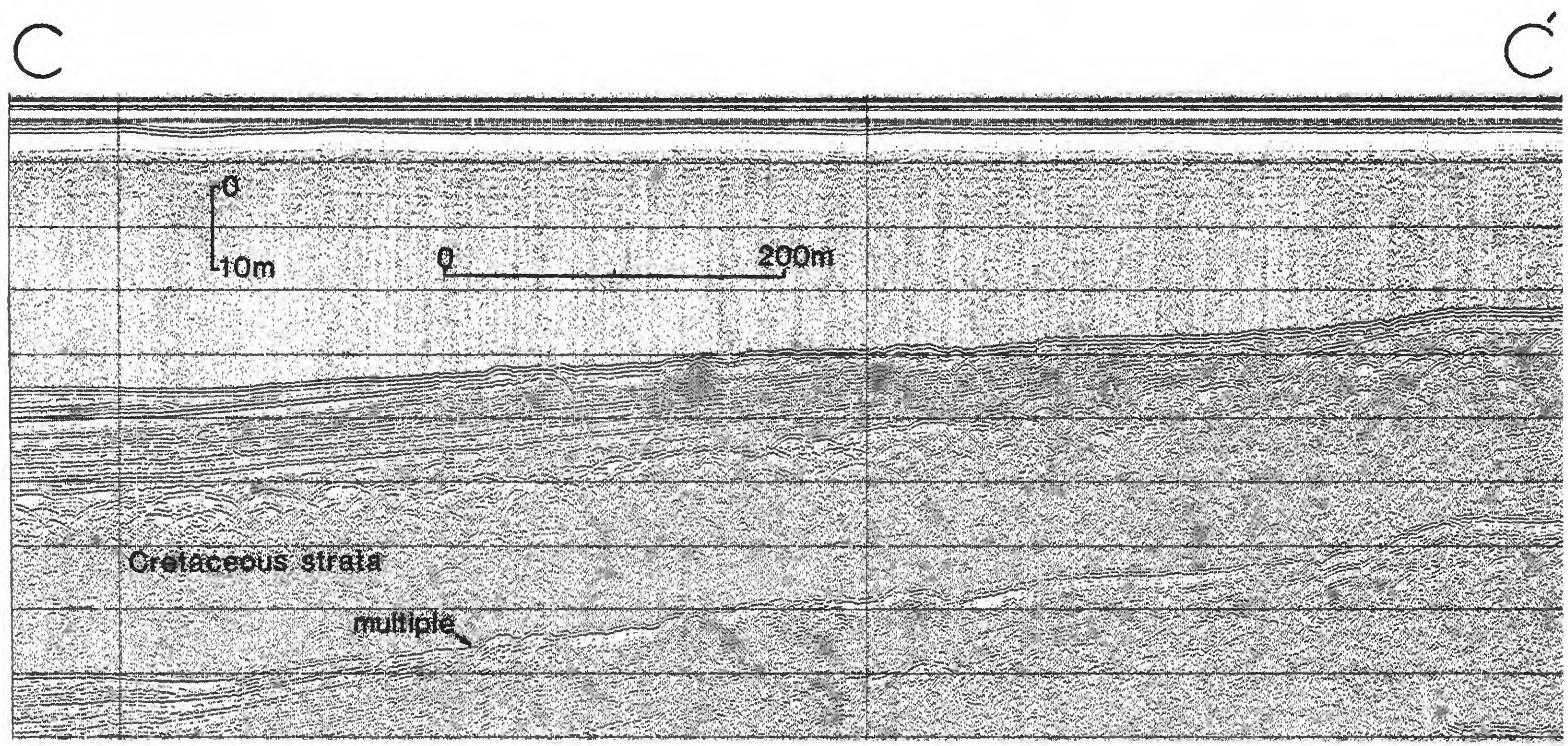

Figure 7. High-resolution seismic profile southwest of Barrow (see figure 9 for location of profile). Gentle northward dipping Cretaceous strata outcrop on the sea floor. The Quaternary sediment forms a thin veneer, less than 1 m thick, over the Cretaceous strata thickening as the depth decreases toward land (to the right).

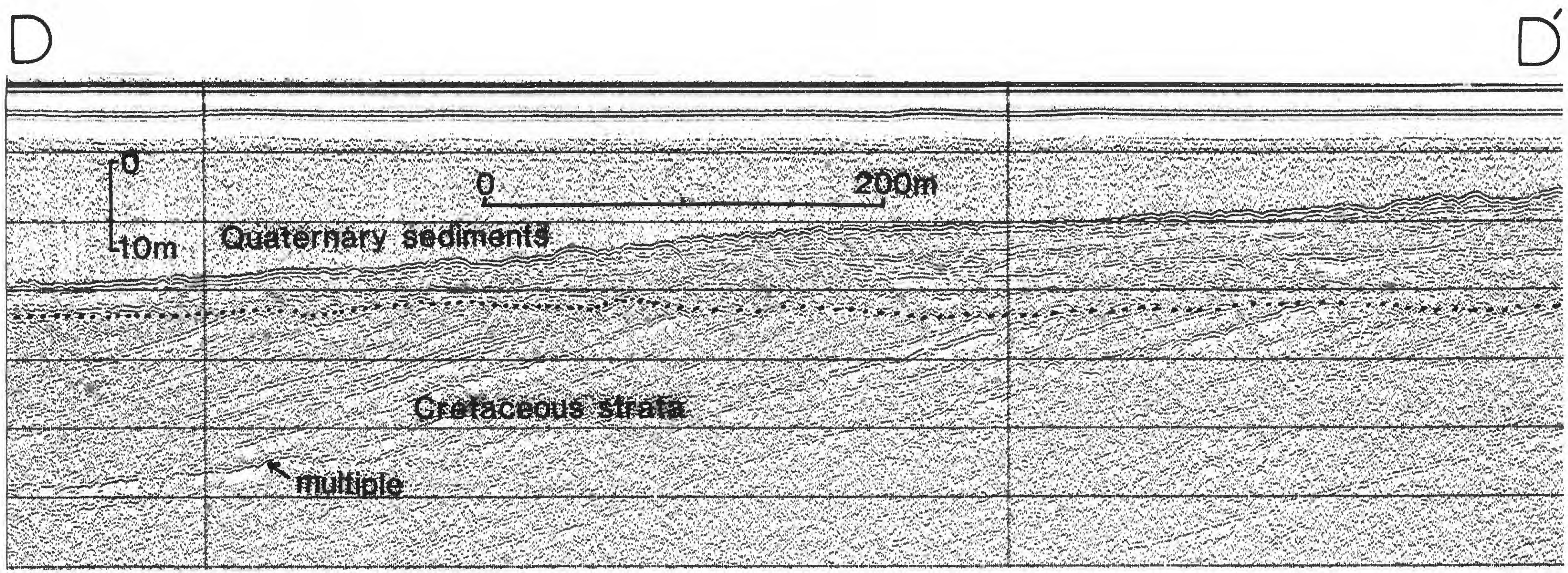

Figure 8. High resolution seismic profile southwest of Barrow (see figure 9 for location of profile). Northward dipping Cretaceous strata form the basal beds. An essentially flat but northward dipping erosional surface truncates the Cretaceous strata (dotted line). The Quaternary sediments (Gubic Formation) increase in thickness toward shore as the depth decreases. A maxmum thickness of 15 m of Quaternary sediment is identified in the nearshore region to the southeast of this profile section.

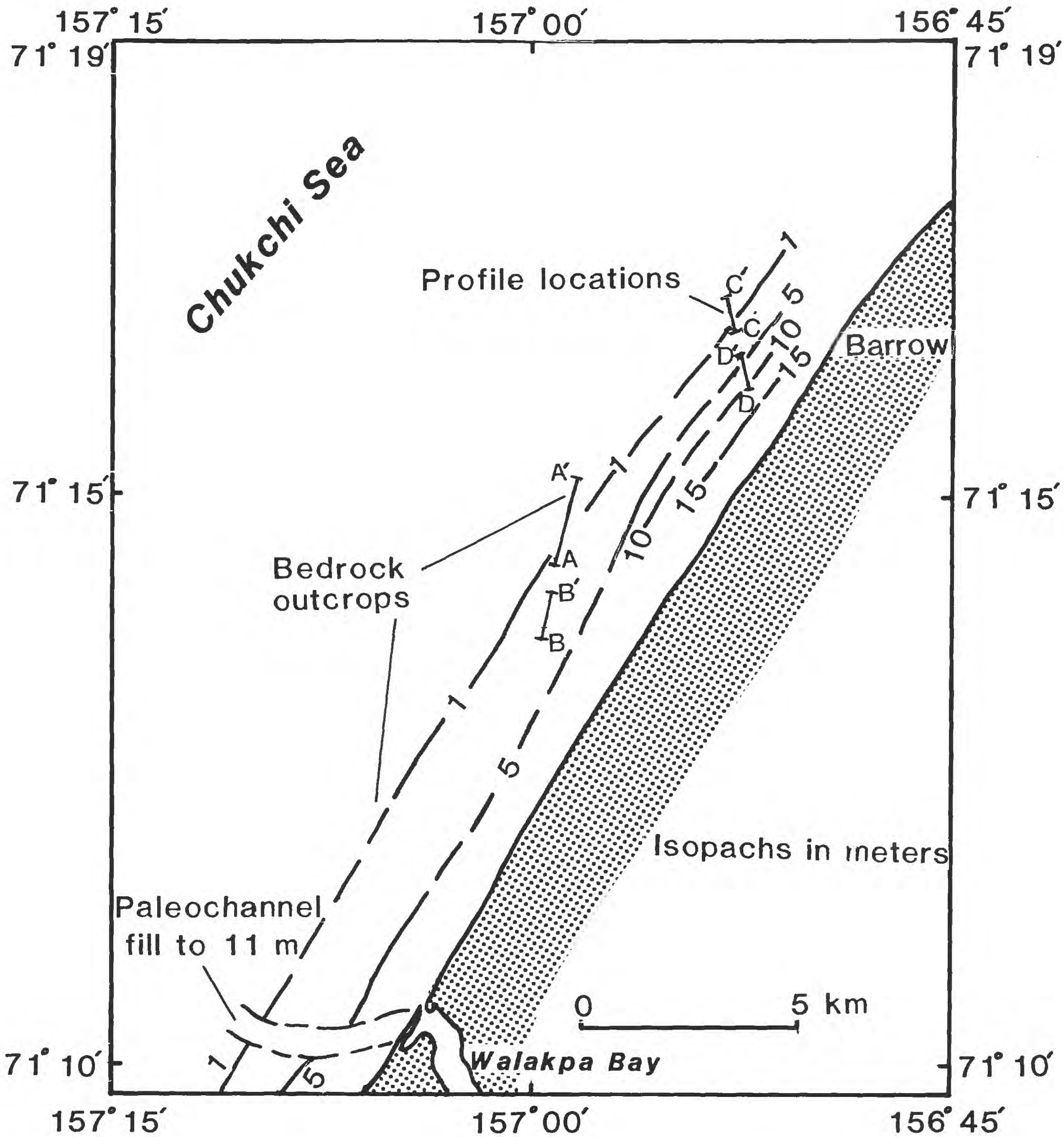

Figure 9. Isopach map of Quaternary sediment in the southern part of the study area. The Quaternary sediment increases in thickness toward land obtaining at least 15 m of sediment thickness 1 kilometer from shore. In the offshore regions, generally below depths of 28 to 32 m bedrock outcrops on the sea floor. A paleochannel, with fill to 11 m, is located directly seaward of Walakpa Bay.

west of Walakpa Bay (figure 9).

North of Pt. Barrow at 10 m water depth at least 20 m of Quaternary sediment overlies bedrock, however, a thicker Quaternary section may exist. The Cretaceous strata are identified below depths of approximately 42 to 45 m directly north of Pt. Barrow where the sea floor slope increases into the Barrow Sea Valley. This suggests a thickness of 20 to 32 m for the overlying Quaternary sediments on the nearshore shelf directly north of Pt Barrow.

The youngest sediment, of Holocene age, comprise the sands and gravels of the barrier island that forms Pt. Barrow.

SURFICIAL SEDIMENT

The offshore surficial sediment is composed of material reworked from the Gubic Formation and range from gravel and sand nearshore to dominately silt offshore. A seaward fining texture is reported off Barrow from diving observations. Nearshore coarse sand and gravel is found from the beach out to 5 m depth changing to silty sand with scattered pebbles at 9 m depth on the shallow shelf platform. Silt occurs at 21 m depth and silt with cobbles at 38 m depth (Shumway and Beagles, 1959). Two cores obtained north of Barrow, one on the shallow platform at a depth less than 10 m and one at an approximate depth of 30 m, both contained 2 to 5 feet of soft grey silt overlying compacted silt (Rex, 1964). The presence of bedform fields north of Pt. Barrow and small-scale ripples near the edge of the shallow platform also confirms the presence of sand size sediment on the shelf. The strong northward-flowing coastal currents would be expected to transport the sand-size fraction to the north into the Barrow Sea Valley as well as erode sediment.

Extensive biological communities are also identified within the nearshore region north of Barrow and consist of abundant pelcypods and brown algae (kelp). As many as 400 pelcypods per square meter were counted on the shallow shelf north of Barrow (Shumway and Beagles, 1959). Kelp was associated with the pelcypods and was attached to the gravel. The composition and extent of the biological communities is not known for this region.

ICE GOUGING

Movement of ice by wind, currents and pack ice pressures results in ice groundings on the sea floor which disrupts the surfical sediments forming ice gouges. Ice gouging along this part of the Chukchi Sea coast is locally intense with an apparent gouge zonation based on water depth, currents and pressure ridge groundings.

Ice gouges are identified to at least a depth of 52 m on the deepest northeast trending ridge located northwest of Barrow (figure 3). A bottom profile northwest of Pt. Barrow, into the Barrow Sea Valley, documents the zone of maximum ice gouge intensity as well as the zone of maximum ice gouge incision (figure 10). Intense ice gouging is found to depths of 28 to 30 m confirming the previous observations of Rex (1964) who reports a similar depth for the high density of ice gouging in the nearshore shelf near Barrow. The rapid reduction in ice gouge abundance and reduction in incision depth below water depths of 30 m is probably related to the substrate on which the ice

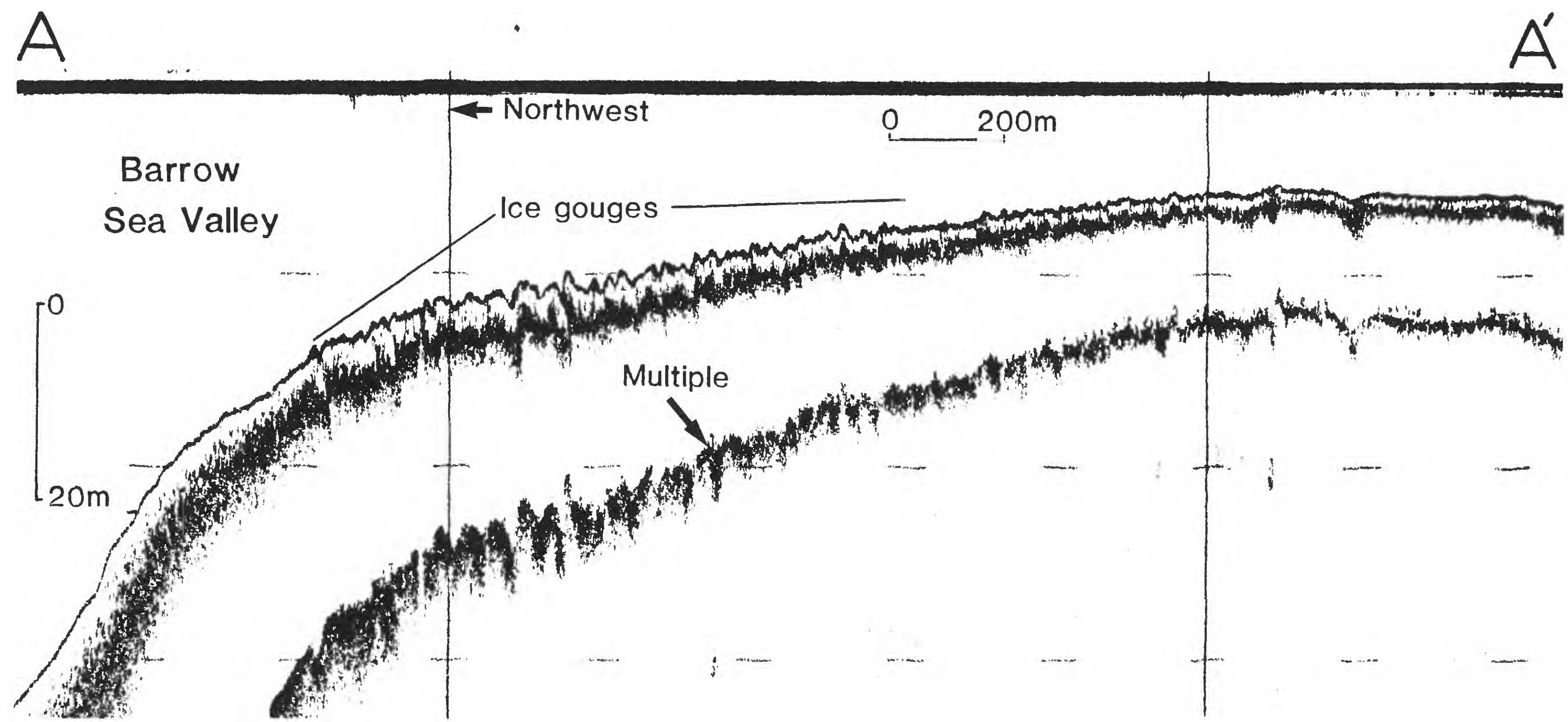

Figure 10. Bottom profile taken directly north of Pt. Barrow shows the microrelief produced by ice gouging (see figure 11 for profile location). The zone of intense gouging and maximum gouge relief occurs between 16 and 30 m. Bedrock probably outcrops on the steep slope into the Barrow Sea Valley.

grounded. Below depths of 30 m the Quaternary sediment cover is thin or lacking and Cretaceous bedrock is exposed; above depths of 30 m Quaternary sediments are readily gouged.

The ice gouged terrain also records a depth control on the ice gouge incision depth into the sea floor. Above depths of 10 m on the platform west of Barrow to Pt. Barrow the maximum ice gouge incision depth is 20 cm; northeast of Pt. Barrow the 20 cm incision depth contour extends to depths of approximately 11 m (figure 11). Seaward of the 10 m contour the ice gouge incision depth increases to a maximum of 1.7 m. Rex (1964), likewise, reports the maximum ice gouge relief of 12 feet (3.6 m) between 6.1 m and 30 m depth in this region. Below approximately 30 m depth the ice gouge incision depth decreases.

Along the northeast slope of the Barrow Sea Valley off Barrow the ice gouges also exhibit a depth related zonation based on the gouge orientation. Below depths of approximately 12 m multiple ice gouges parallel the isobaths (figure 12). This suggests that the northward flowing Alaska Coastal Current transports the deep draft ice parallel to the slope resulting in ice gougings with a northeast-southwest orientation. Near the crest of the break in slope from the shallow nearshore platform to the Barrow Sea Valley between depths of 9 to 12 m the ice gouges contain varied orientation with gouge trends ranging from northwest-southeast to northeast-southwest (figure 13). The two major trends in ice gouging still reflect ice moving parallel to the isobath (northeast-southwest trend) and also ice moving directly onshore (northwest-southeast trend). At shallower depths on the nearshore platform the ice gouge incisions are shallow (less than 30 cm), narrow and show some varability in orientation (figure 14). Most of the shallow gouges also appear to be formed from ice moving onshore or parallel to shore. North of Pt. Barrow on the shallow shelf platform the ice gouges are oriented mainly parallel to shore.

The ice gouges are also modified in shape and are filled with sediment transported by the northward flowing Alaska Coastal Current. The multiple ice gouge incisions located directly off Barrow contain abundant small-scale bedforms within the gouges and on the surrounding sea floor (figure 15). Likewise, northeast of Pt. Barrow, bedform fields are identified within the ice gouge terrain (figure 16). The migrating bedforms would be capable of filling in the gouge traces but the rate of filling and the yearly rate of ice gouging is unknown for this region.

CONCLUSIONS

1. The offshore coastal region between the northern part of Skull Cliff and Pt. Barrow contains a thin Quaternary sediment cover in the offshore regions thickening toward land and overlies northward dipping Cretaceous strata. The Cretaceous strata outcrop on the sea floor generally below depths of 24 to 32 m.

2. A narrow shelf platform, varying in width for one kilometer to 3 kilometers, extends from the beach seaward to depths of approximately 12 m. Seaward of the 12 m contour the sea floor slope rapidly increases into the Barrow Sea Valley.

3. Ice gouges are identified to 52 m depth on linear, northeast trending

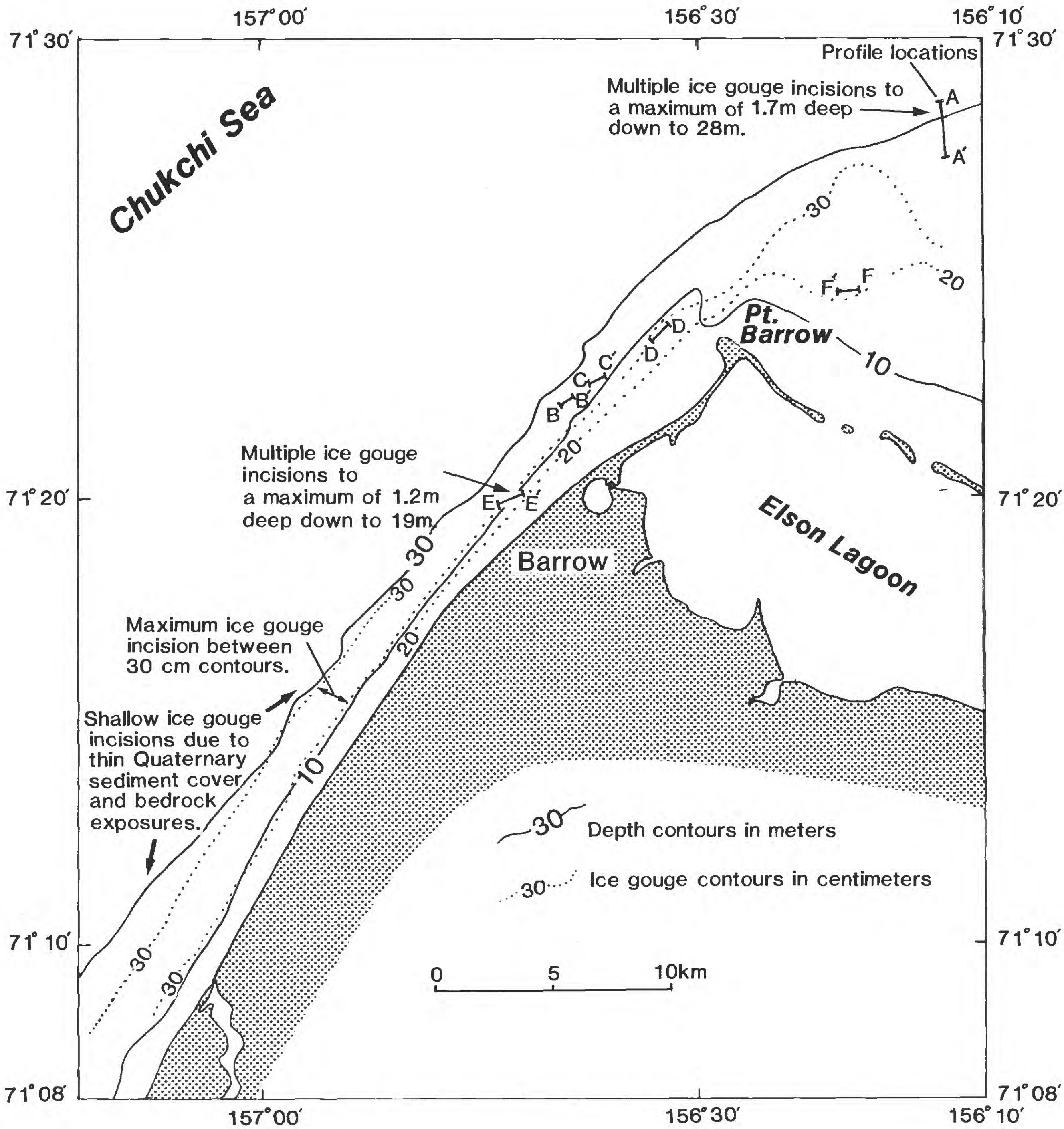

Figure 11. Map of ice gouge incision depth for the shallow nearshore shelf regions of the northeast Chukchi Sea near Barrow, Alaska. The maximum ice gouge incision depth and zone of intense ice gouging occurs between the 10 m and the 30 m contours on the slope into the Barrow Sea Valley. Below 30 m depth the ice gouge incision depth generally decreases probably due to thin Quaternary sediment cover and the presence of exposed bedrock. The lettered sections are profile locations for other figures.

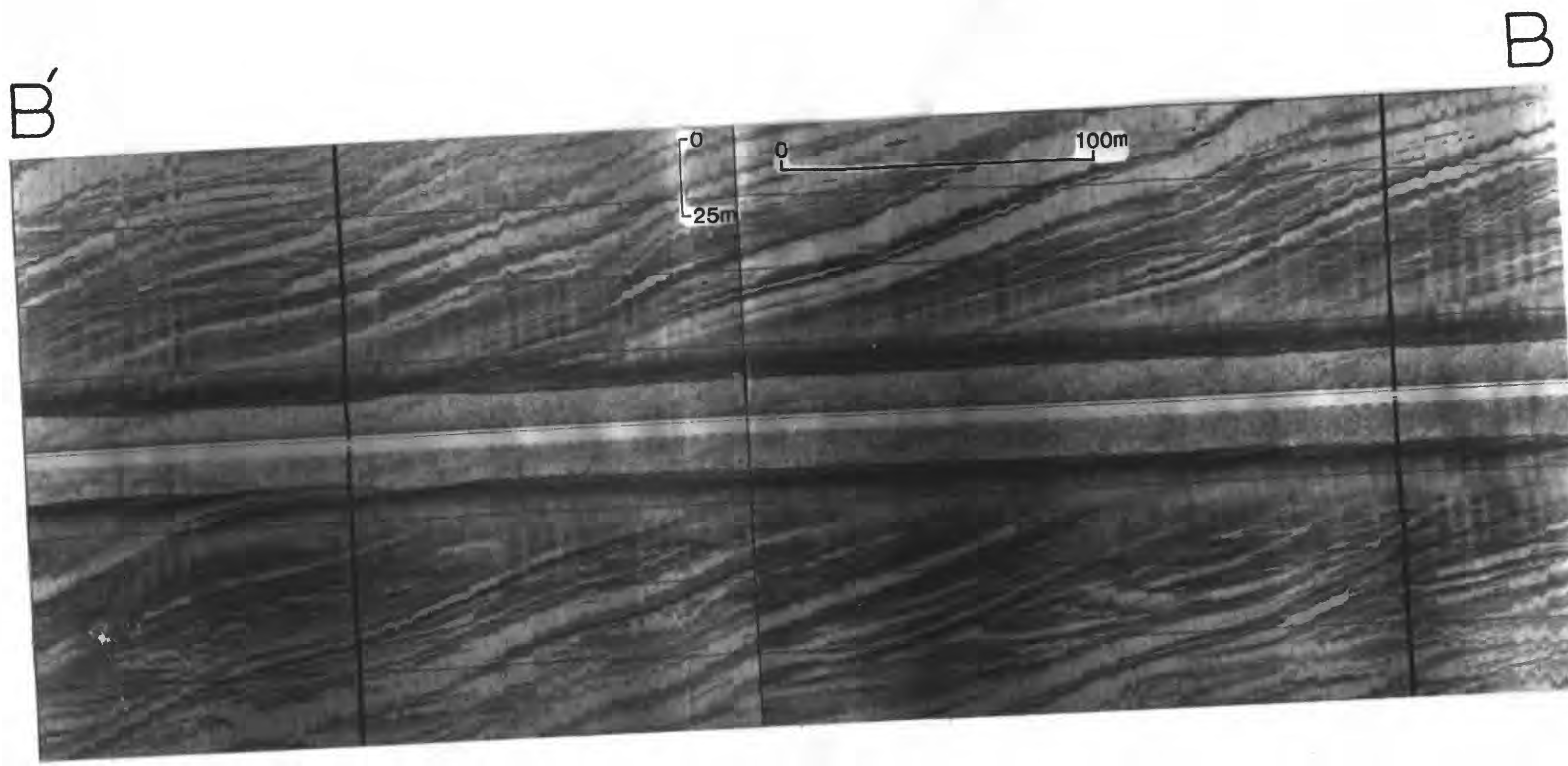

Figure 12. Multiple ice gouge incisions between depths of 14 m (left) and 16 m (right) directly north of Barrow (see figure 11 for profile location) The ice gouges parallel the bathymetric contours along the steeper slopes on the northeast flank of the Barrow Sea Valley.

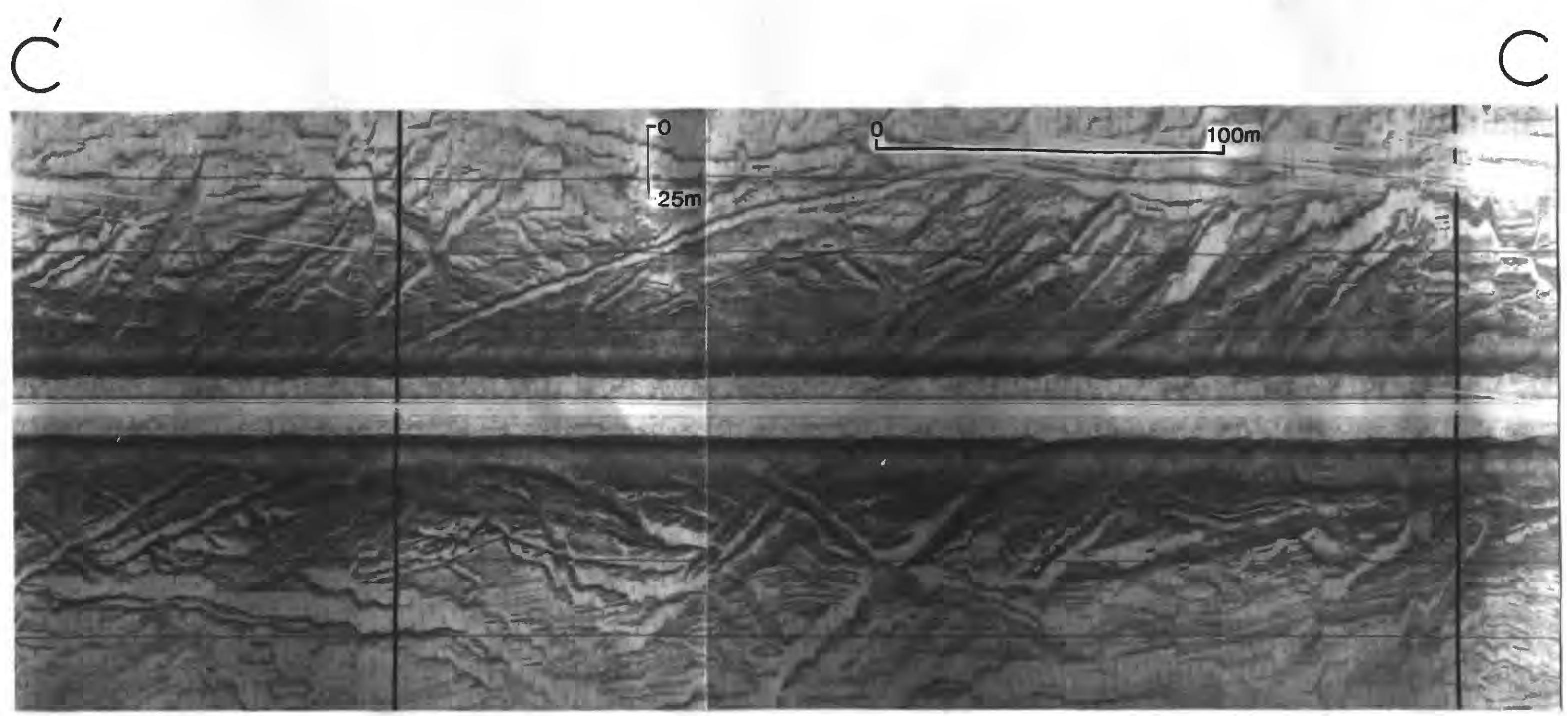

Figure 13. Multiple ice gouge incisions near the break in slope into the Barrow Sea Valley between depths of 10.5 m (left) and 11.0 m (right) directly north of Barrow (see figure 11 for profile location). The maximum ice gouge incisions are identified within this area. The gouges are variable in orientation now in relation to gouges at deeper depths (figure 12). Major gouge trends and northwest-southeast and northeast-southwest (southwest is to the right).

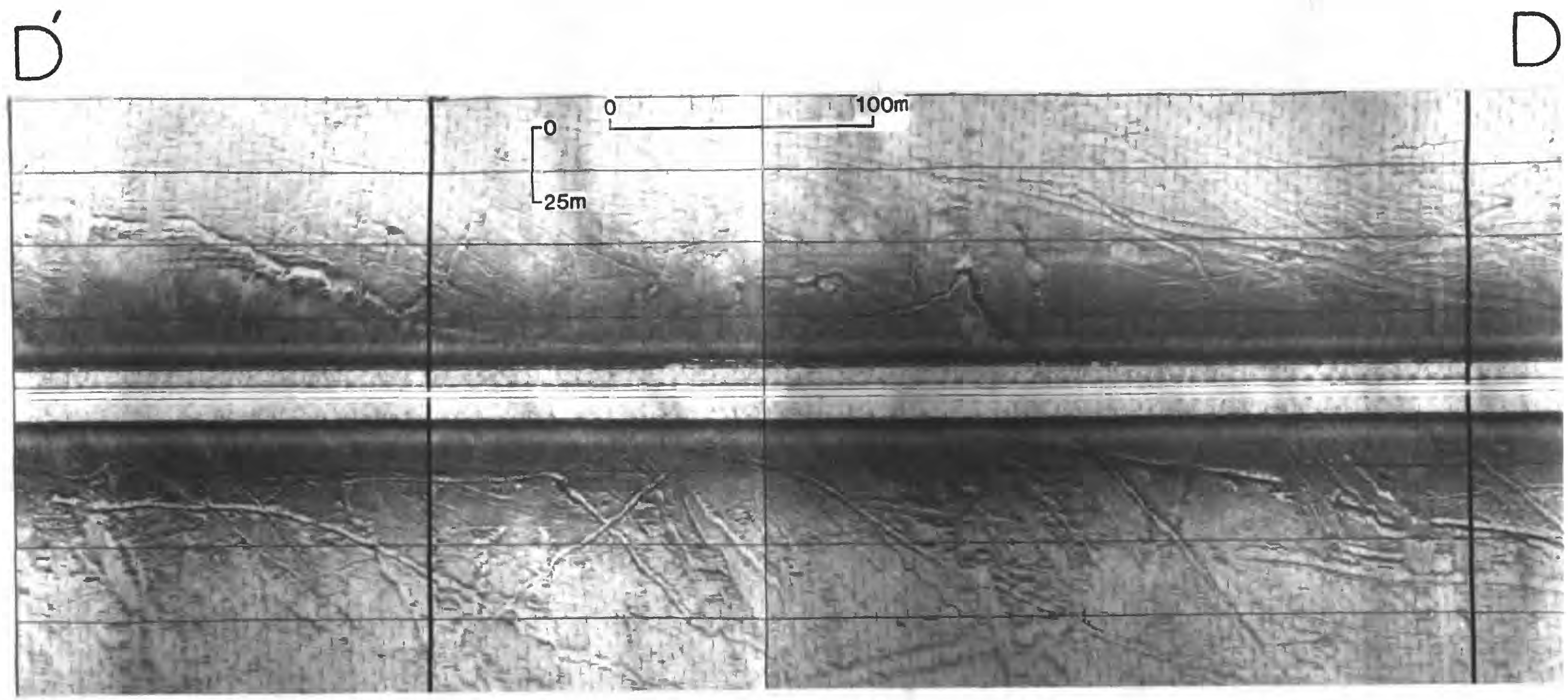

Figure 14. Ice gouge incisions at 8.5 to 9.0 m depth directly north of Barrow (see figure 11 for profile location). Most of the ice gouges now are oriented east-west and are shallow features less than 30 cm deep.

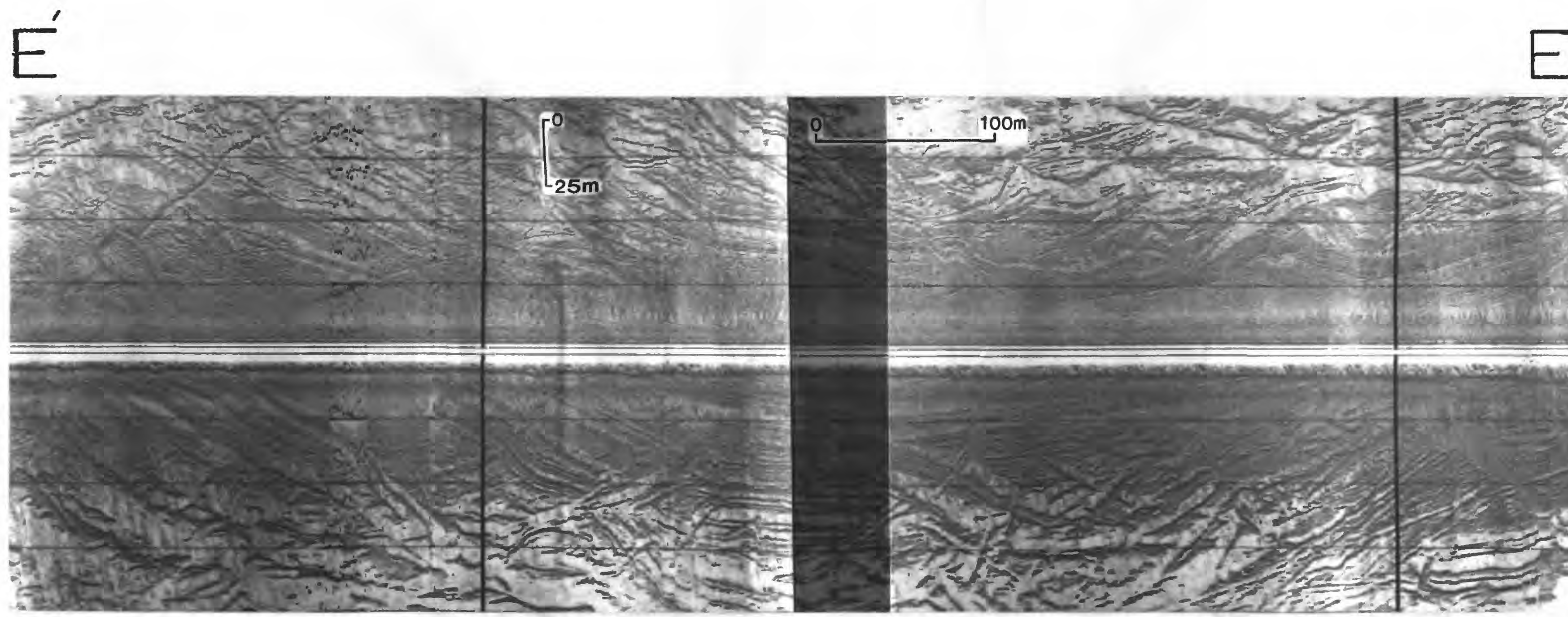

Figure 15. Multiple ice gouges directly off Barrow between depths of 8.5 m (left) and 10.2 m (right), (see figure 11 for profile location). The ice gouges are being modified apparently by currents of the Alaska Coastal Current as abundant small-scale bedforms are abundant in the top half of the sonograph.

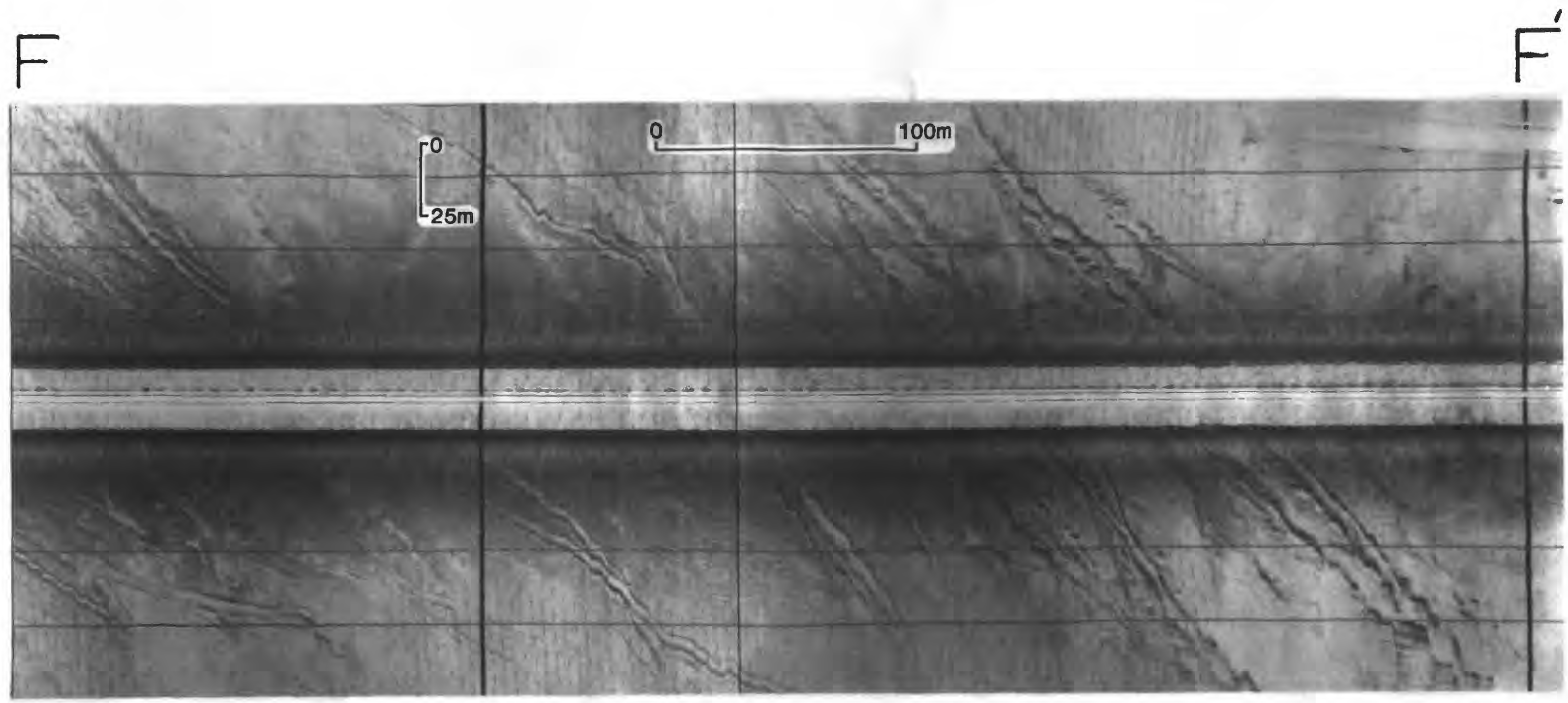

Figure 16. Ripple field (in center of photograph) of small-scale bedforms with parallel, east-west trending, shallow gouges (see figure 11 for profile location.

ridges within the Barrow Sea Valley. Multiple ice gouge incisions, as deep as 1.7 m, occur between depths of approximately 12 to 30 m; above 12 m depth the maximum ice gouge incision depth is less than 30 cm.

4. The ice gouges parallel the isobaths below depths of 12 m suggesting that the Alaska Coastal Current is moving the deep draft ice. Above depths of 12 m the ice gouge orientation is variable probably caused by both pack ice movement as well as eastward-directed storms moving individual ice fragments.

REFERENCES

Aagaard, K., and Coachman, L. K., 1964, Notes on the physical oceanography of the Chukchi Sea, in U. S. Coast Guard Oceanographic Rept. no. 1: Wash., D. C., U.S. Govt. Printing Office, p. 13-16.

Black, R. F., 1964, Gubic Formation of Quaternary age in Northern Alaska, U.S. Geological Survey Prof. Paper 302-C, p. 59-91.

Grantz, A., Dinter, D. A., Hill, E. R., May, S. D., McMullin, R. H., Phillips, R. L., and Reimnitz, E., 1982, Geological framework, hydrocarbon potential and environmental conditions for exploration and development of proposed oil and gas lease sale 87 in the Beaufort and northeast Chukchi Seas, U.S. Geological Survey open file Rept. 82-482, 73 p.

Hanna, G. D., 1954, Submarine geological investigations off Point Barrow, Alaska, 1954, Calif. Academy of Sciences, San Francisco pub., 10 p.

Harper, J. R., 1978, Coastal erosion rates along the Chukchi Sea coast near Barrow, Alaska, Arctic, v. 31, no. 4, p. 428-433.

Hufford, G. L., 1973, Warm water advection in the southern Beaufort Sea, August-September 1971, Jour. Geophys. Res., v. 78, p. 2702-2707.

Hufford, G. L., 1977, Northeast Chukchi Sea coastal currents, Geophys. Res. Letters, v. 4, no. 10, p. 457-460.

Hume, J. E., Schalk, M., and Hume, P. W., 1972, Short-term climate changes and coastal erosion, Barrow, Alaska, Arctic, v. 25, no. 4, p. 272-278.

Moore, D. G., 1964, Acoustic reflection reconnaissance of continental shelves: the Bering and Chukchi Seas, in Papers in Marine Geology, Shepard Commemorative vol., Miller, R. I., ed., MacMillan, New York, p. 319-362.

Paquette, R. G., and Bourke, R. H., 1974, Observations on the coastal current of Arctic Alaska, Jour. Mar. Res., v. 32, no. 2, p. 195-207.

Rex, R. W., 1955, Microrelief produced by sea ice grounding in the Chukchi Sea near Barrow Alaska, Arctic, v. 8, p. 177-186.

Shumway, G., and Beagles, J. A., 1959, Arctic SCUBA diving, 1958. 1: Observations on the Alaskan Arctic shelf and under ice in the polar sea; 2: Notes on the Arctic diving operation, U.S. Navy electronics laboratory research and development rept., rept. 916, 17 p.

Solomon, H., and Ahlnas, K., 1980, Ice spirals off Barrow as seen by satellite, Arctic, v. 33, no. 1, p. 184-188.

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