UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

SUBMARINE TOPOGRAPHY AND PHYSIOGRAPHY OF LOWER COOK INLET, ALASKA

by

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Open-File Report
81-1335

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

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ABSTRACT

The submarine topography of lower Cook Inlet, Alaska, is complex because the bathymetric aspects and water depths change rapidly over short distances. The folded upper Tertiary subbottom was eroded during the first of five major Quaternary glacial advances over the inlet, and later fluvial, fluvioglacial, glacial, and marine erosional and depositional processes shaped the bottom to its present configuration.

Most of lower Cook Inlet has a relative smooth topography showing small local highs and lows, and slopes with gradients generally ranging from less than a degree to locally about 5°. Around the southwestern Kenai Peninsula and the Barren and Kodiak Islands, strong faulting with vertical movement has added to the complexity of bottom topography. Less complex, nonfaulted areas occur near Kalgin Island and south Kachemak Bay and around Augustine Island.

To facilitate description of lower Cook Inlet the estuarine body is divided into three large regions, northern and central, southern, and eastern; and these regions are divided into smaller physiographic areas on the basis of submarine topographic characteristics and 20-m depth zonations. Each area is named by combining the geographic name of a nearby place or feature on land with a common term for a marine physiographic feature -- trough, platform, ramp, slope, plateau. Local highs and deeps having less than 5-m relief, which can be important to fisheries and specific research or economic studies, are not named, mentioned in text, or shown on the figures.

INTRODUCTION

Lower Cook Inlet (LCI), Alaska, is the southern part of the large estuarine water body that connects Anchorage with the Pacific Ocean. Its natural northern boundary is where Cook Inlet narrows suddenly at the Forelands. For this report, however, the north limit is placed between Harriet Point and Cape Kasilof because of lack of detailed information farther north. The southern boundary of lower Cook Inlet at Shelikof Strait is drawn between Cape Douglas and the north point of Shuyak Island, and the southeastern boundary of the Kodiak shelf runs from Shuyak Island to Perl Island (the central one of the Chugach Islands).

The bathymetry of lower Cook Inlet is complex and reflects both its geologic history and the influence of present circulation patterns. Fairly smooth areas change abruptly into irregular trough-shaped patterns or peaky regions. Extensive folding of the upper Tertiary subbottom, followed by later planning by the first of five major Quaternary glacial advances exposed layers and formations of different resistance to erosion by currents and ice. Sedimentation by glaciers, glacial outwash, rivers, and currents during various stages of the Pleistocene epoch and the Holocene further modified the seafloor.

The first systematic survey, conducted by the U.S. Coast & Geodetic Survey early in this century, has resulted in several charts used for navigation. The original manuscripts of hydrographic surveys were later contoured in great detail by Continental Shelf Data Service (1967) at a contour interval of 1 fathom to a water depth of 50 fathoms and 5 fathoms for deeper water. A new survey by the National Ocean Survey is underway, but official publications are not scheduled for the near future. Because of the need for appropriate data for the first lease sale in this area, the U.S. Geological Survey in Achorage let a geophysical contract to Petty-Ray Geophysical, Inc. One of the products was a bathymetric chart at a scale of 1:96,000 with 2-m depth contours to a water depth of 100 m and a 5-m interval for deeper water (McGarity, 1977). The datum plane used was mean low sea level.

Bouma and his associates extended the coverage of the Petty-Ray chart by using the C&GS Boatsheets to produce a bathymetric chart with a 5-m contour interval throughout the area (Bouma and others, 1978a). The original 1:250,000-scale map with 5-m isobaths allows reduction to page size with sufficient definition of the seafloor to show its main physiographic features (Bouma and others, 1978b, c; fig. 1).

Figure 1: Bathymetry of lower Cook Inlet (contour interval 5 m). Sources: U.S. C&GS Boatsheets, Continental Shelf Data Service (1967), and McGarity (1977). Minor improvements of Bouma and others (1978b) are included.

Figure 1. Bathymetric map of lower Cook Inlet (contour interval 5m)

The bathymetry and bottom-sediment characteristics provide a basis for dividing lower Cook Inlet into three major regions, each containing several smaller physiographic areas characterized by a number of bottom features that differ from those in adjacent areas. Most names given to the physiographic areas are a combination of the geographic name for a nearby place or feature on land and a common marine term*. Because lower Cook Inlet is a large estuarine area in a continental shelf setting, we have not used more typical open marine topographic terms and physiographic provinces as given by Heezen and Menard (1966). Small features that may be important to local fishermen or to special scientific or economic studies are not shown.

Acknowledgments. Only the cooperation of many persons made it possible to produce the bathymetric and physiographic maps as Open-File Reports. John W. Whitney contacted the port and fisheries authorities in Homer concerning the suggested physiographic names. Whitney, Monty A. Hampton, and Joshua I. Tracey made several improvements in the report. The original study was conducted to support the OCSEAP studies in lower Cook Inlet.

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* The physiographic names herein mentioned have been accepted tentatively by the U.S. Board on Geographic Names and by polled officials and fishermen in Homer, Alaska. To conform with the Board's definition on terms, some of the present names differ from those of the published Open-File Report (Bouma and others, 1978b).

BATHYMETRY

Water depth in lower Cook Inlet ranges from very shallow to more than 200 m, and the complex bathymetry varies in aspect from place to place. The area east of the Kenai Peninsula-Shuyak Island line presents a good example of such complexity. An irregular sea bottom is also present in southern Kachemak Bay and in the northeastern area near Kalgin Island (fig. 1). In the rest of lower Cook Inlet, the bottom is comparatively smooth in appearance, although locally steeper slopes and small shallow depressions are common.

In detail, the bathymetry is complex owing to the presence of bedforms ranging in height from a few centimeters to more than 12 m and to the presence of different types of bottom materials ranging from clay to boulders. Detailed seismic-reflection surveys, side-scan sonar, bottom sampling, and underwater television and photography reveal the effect of microscale variations on the distribution of sediment types, benthic plant and animal communities, local direction of bottom flow, and local transport of sediment. The bathymetry portrayed in figure 1 not only eliminates features smaller than 5-m relief, but also overlooks those that are areally smaller than the distance between survey lines. Although high accuracy has been maintained during preparation of the bathymetry, neither the 1:250,000-scale map nor its page-size reduction is intended for navigation purposes. Local details can be found on the 2-m contour chart of McGarity (1977) and the 1-fathom chart of Continental Shelf Data Service (1967).

Before the physiographic map was developed, a 1:250,000-scale bathymetric chart was colored in 20-m intervals. This depth zonation proved effective in revealing certain isobaths that seem to be natural boundaries for physiographic areas, accentuating areas that are bathymetrically complex and showing similarities between a number of areas (see fig. 2, a reduced black-and-white version of the 1:250,000-scale map).

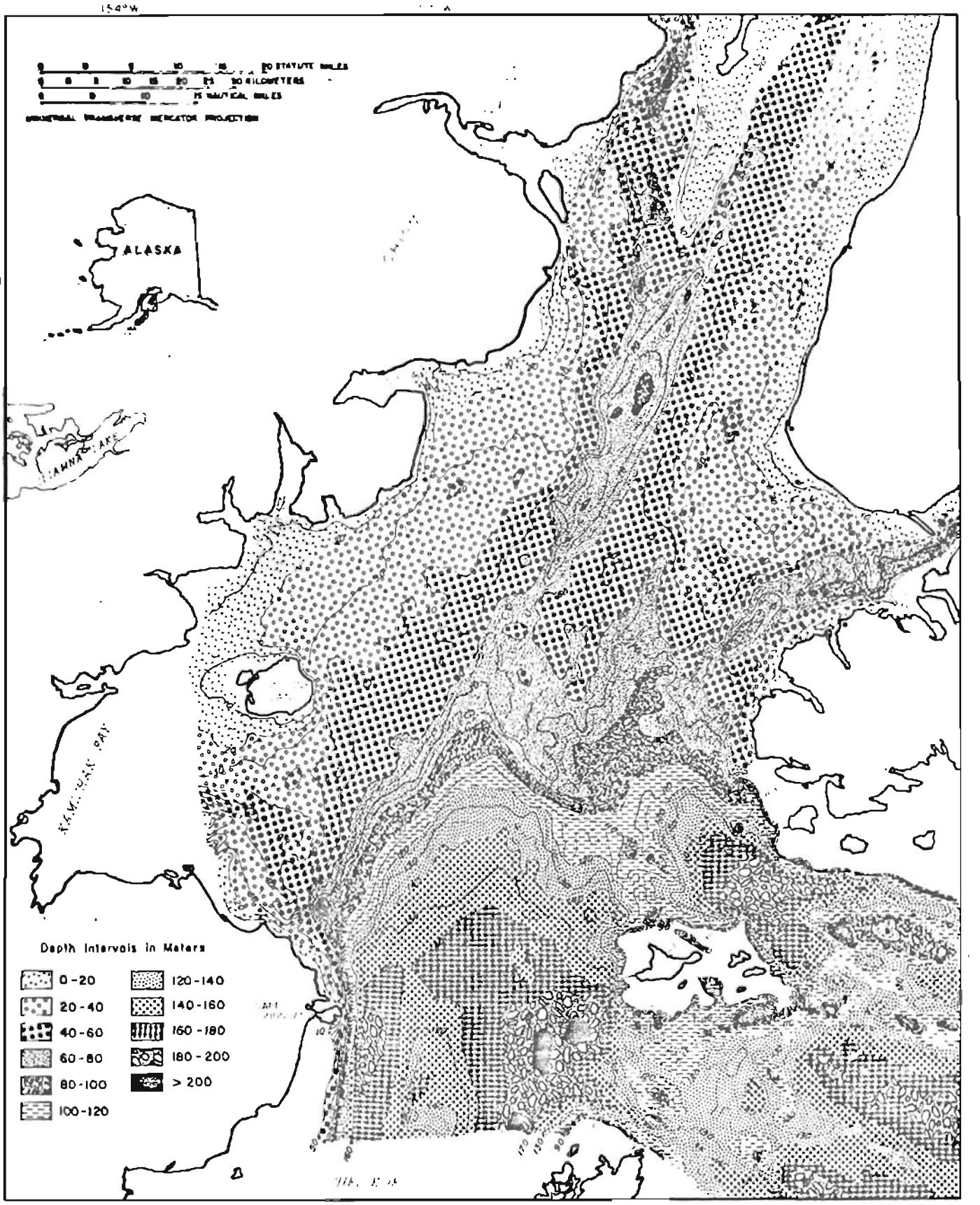

Figure 2. Bathymetric map of lower Cook Inlet (contour interval 20 m)

PHYSIOGRAPHY

Using bathymetric characteristics and the shapes and distribution of the 20-m depth zonation, lower Cook Inlet can be divided into three major physiographic regions: northern and central, southern, and eastern. Each region is divided into physiographic areas to which a name is attached (fig. 3). It should be realized that many of the gradients as well as the depth changes may look small relative to subaerial changes. Underwater, however, such gradients can significantly influence natural processes and industrial activities. For this reason, many of these "small" features are pointed out and even named. Bathymetric profiles (figs. 5 and 6) and bottom photographs (figs. 7 and 8) show selected locations shown on the index map (fig. 4).

Northern and Central Region, lower Cook Inlet

The northern and central physiographic region contains a central elongate and relatively shallow depression named Cook Trough. Upsloping areas form its western and eastern sides, and these slopes merge into wide shelf-like platforms that connect to the shorelines. The southern boundary of the region is placed at the top of a boomerang-shaped increase in slope (Cook Ramp) and along the north side of a channel in Kachemak Bay (Kachemak Trough).

Cook Trough

Cook Trough, a central depression covering about one fifth of the northern and central part of lower Cook Inlet, is locally the most significant physiographic feature. The upsloping areas that start at about the 60-m isobath bound it on the west and east. The axis of this depression contains a number of small basins having depths greater than 80 m. To the north, the trough bifurcates around Kalgin Island. At the latitude of Seldovia, the area narrows southward, forming a rather smooth sloping triangle (part of Cook Plateau) that terminates at Cook Ramp.

Figure 3: Major physiographic regions (northern and central, southern, and eastern; denoted by heavier boundaries) and named physiographic features of lower Cook Inlet.

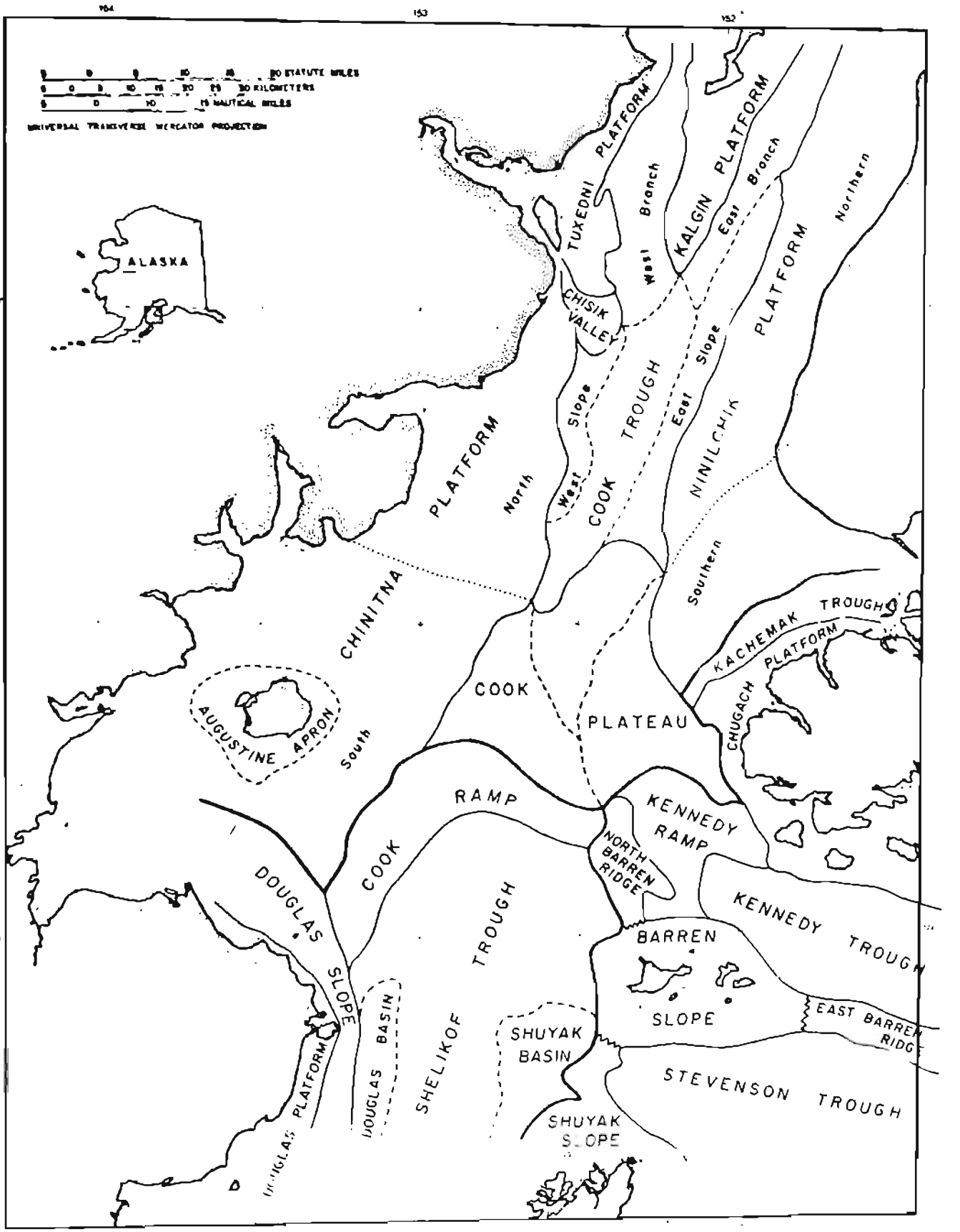

Figure 3. Map showing major physiographic regions and named physiographic features of lower Cook Inlet

Figure 5: Tracings of selected sections of bathymetric profiles from 12- and 3.5-kHz records originally recorded at 1/4-second firing and sweep rates. Numbered arrow indicates beginning of trackline segment (see fig. 4 for location); azimuths are shown for beginning and ending segments of each line.

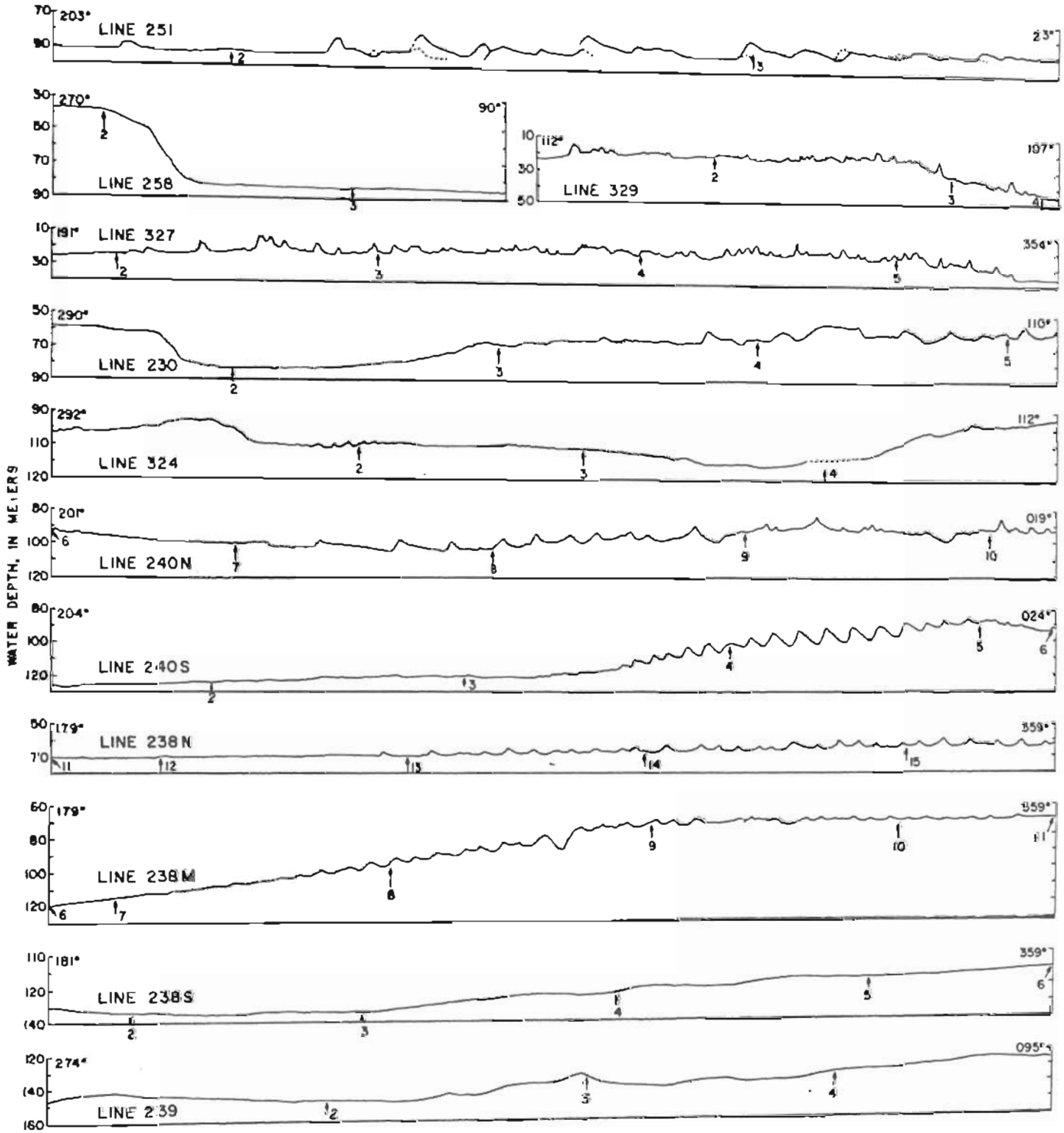

Figure 5. Bathymetric profiles from 12- and 3.5-kHz records

Kalgin Platform

The east and west branches of Cook Trough are separated by the Kalgin Platform, a narrow shoal that surrounds Kalgin Island. To a depth of 20 m, the slope is very gentle; below 20 m, the slope increases to an average gradient of 0.7° (0.57°-0.76°). The east side of the platform dips gently. The west side contains two gently sloping parts divided by a steeper gradient between 15-20 and 28-30 m.

Tuxedni Platform

A narrow shelf-like platform, Tuxedni Platform, occupies the area between the west branch of Cook Trough and the eastern shore of the Chigmit Mountains. This physiographic area contains a bulge that may be a delta at the north outlet of Tuxedni Bay. Formed of morainal or deltaic material from the Tuxedni River and/or the Crescent River, this feature can be Holocene in age or slightly older.

Chisik Valley

Chisik Valley, a feature forming the southeast continuation of the southern outlet of Tuxedni Bay, divides the platform along the western shore of lower Cook Inlet into two areas. Just offshore it contains a long, narrow depression with a maximum depth of 75 m. Between the mainland of Iliamna and Chisik Island, a sill of typical glacial material separates the outer deep area from a series of inshore basins running along the island.

Tuxedni Bay extends inland into and drains parts of the Chigmit Mountains. Large areas of the bay are swamp with extensive tidal mudflats that are exposed only at low tide; the bay forms a large water reservoir at high water. Offrunning ebb waters flowing through Chisik Valley transport significant amounts of suspended matter that form a surface mud plume into Cook Inlet.

Chinitna Platform

The widening platform south of Chisik Valley, named Chinitna Platform, covers a large part of lower Cook Inlet, including Kamishak Bay. The surface is generally smooth but contains numerous small highs and depressions. Slopes are relatively steep along most of the shoreline. Most of the bottom is hard and covered by cobbles, gravel, and shells and locally by sand. Some of the embayments have a muddy bottom (Continental Shelf Data Service, 1967).

A separate physiographic area within the Chinitna Platform, Augustine Apron, can be delineated around Augustine Island by mapping the extent of volcanic flows and ejecta. The bathymetry around the island is complex on both macroscale and microscale (National Ocean Survey). Large areas are too shallow and contain many peaks too close to the water surface to allow a survey with a large vessel. The irregular topography of this area and its shallowness are displayed on the bathymetric profile tracings of lines 327 and 329 (figs. 4 and 5). The shape of the peaks on the profiles is irregular and sufficiently different from that of bedforms to prevent misinterpretation. Observations with bottom television and photography confirm that the local bottom forms are related to volcanism, although the nature of the bottom is at many places difficult to investigate because of heavy overgrowth by sessile plants and animals (fig. 6). The boundary of Augustine Apron is delineated on the physiographic map (dashed, fig. 3).

An arbitrary line trending east-southeastward off Oil Point divides Chinitna Platform into northern and southern subareas. In comparing the bathymetry (fig. 1) and the depth zones (fig. 2), it becomes apparent that the west slope of Cook Trough south of lat. 59°40' N. abruptly loses gradient. The zone between the 40- and 60-m isobaths south of this latitude has the same overall morphologic aspect as the adjacent Chinitna Platform. For that reason, it is incorporated into the platform despite the sudden drop of the eastern boundary of the platform from the 40-m isobath to the 60-m depth contour.

Ninilchik Platform

A large platform that includes the northern part of Kachemak Bay occupies the eastern side of northern and central lower Cook Inlet. The northern section is generally smooth to lat. 60°20'N., although it contains many small depressions and some highs. The depressions tend to be aligned. North of this latitude the platform develops into a system of low ridges parallel to the axis of the inlet (Continental Shelf Data Service, 1967). The southern area is slightly more irregular (fig. 7, line 222T). A line separates the Ninilchik Platform into northern and southern subareas based on the general characteristics of the bottom morphology.

The gradients along the shoreline of north Ninilchik Platform are low, becoming steeper in the southern part. South Ninilchik Platform is bounded along its west and south sides by slopes that appear to be erosional.

In general, the surficial sediments are rocky in the north, and become more gravelly to the south with some patches of sand or shell. Inside Kachemak Bay, sediments vary widely ranging from mud to gravel. The west side has a generally hard smooth bottom.

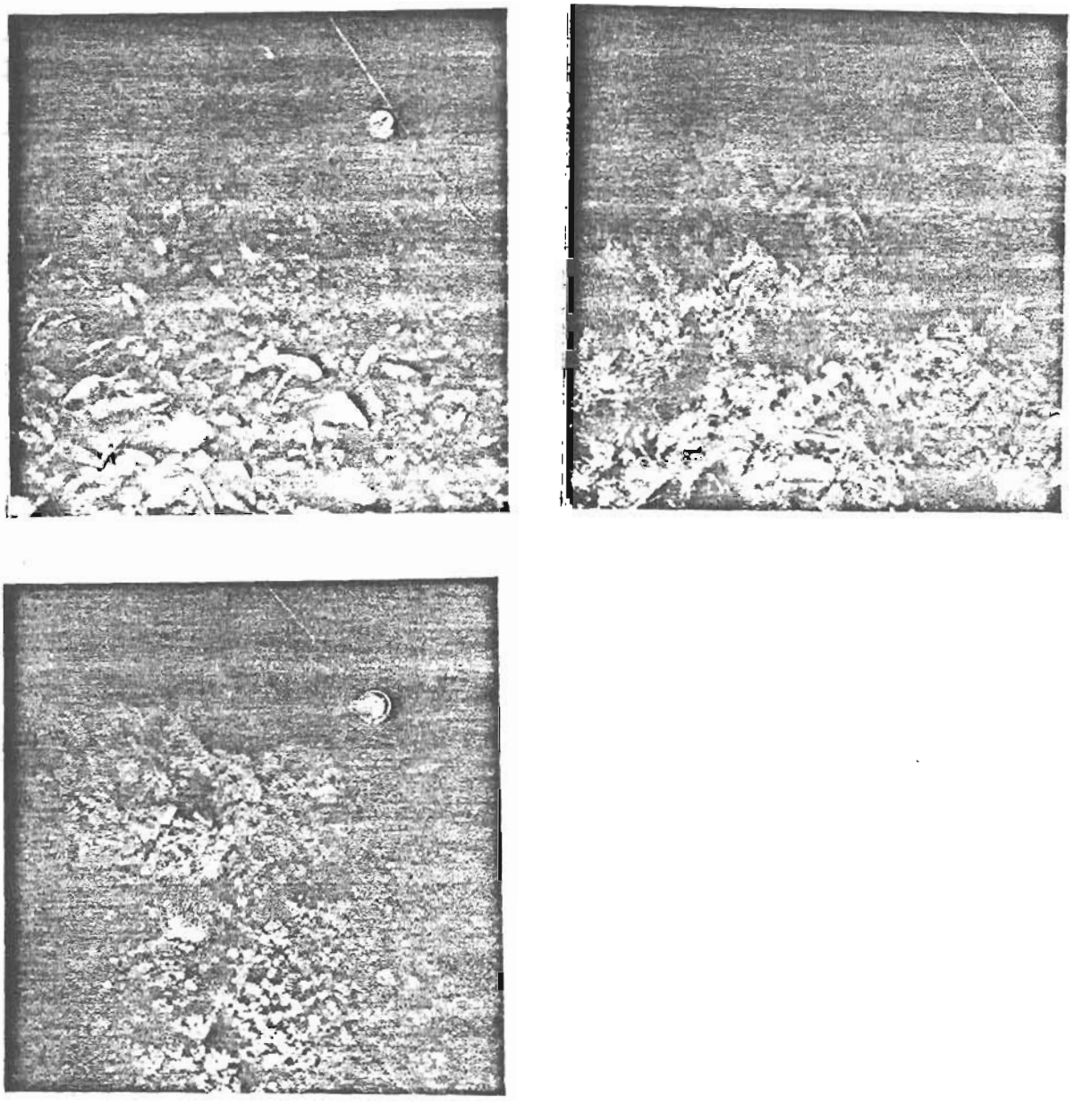

Figure 6. Representative bottom photographs of east side of Augustine Apron

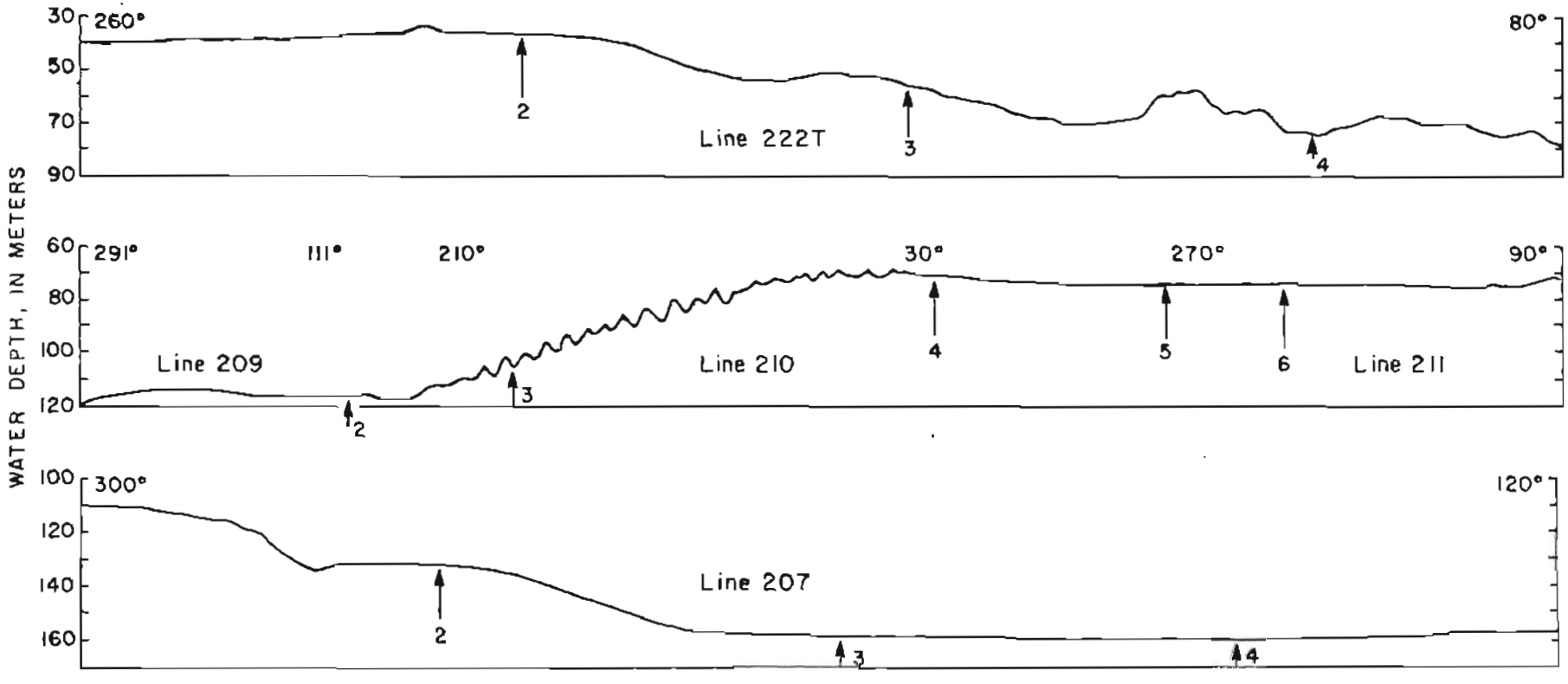

Figure 7. Bathymetric profiles from 3.5-kHz records

Cook Plateau

Three small areas with slightly different morphologic characteristics form Cook Plateau. On the west side, the plateau contains the triangular area that peaks at the constriction of the 60-m isobaths forming the lower end of Cook Trough and has its base at the top of Cook Ramp. The area is largely covered by bedforms of various sizes, either nearly symmetric or slightly asymmetric to the south (fig. 5, lines 238N and 240N). Other characteristics of the southern part of this triangle are discussed under Cook Ramp.

Adjacent to this fan-shaped triangle is an area that is shallower than its surroundings by about 10 m. This bank-like feature is the southern extension of the east slope of Cook Trough. Most of this bank is covered by medium and small-size bedform.

To the east of the bank is another triangular area, bounded on its east side by southern Ninilchik Platform and at its south by a moderately sloping ramp called Kennedy Ramp. The basinal form of this area helps direct the flooding bottom waters to the north. It is partly covered by medium and smaller bedforms with an asymmetry to the north.

Southern Region, lower Cook Inlet

The southern part of lower Cook Inlet contains a large basinal area in its center and is bounded primarily by slopes adjacent to platforms. Its northern boundary is formed by Cook Ramp. The southern boundary is arbitrarily placed between Cape Douglas and Shuyak Island because the continuation of Shelikof Trough to the south provides no topographic boundary for lower Cook Inlet. The west side is formed by the Aleutian Range, the east side by submarine highs.

Cook Ramp

A striking physiographic feature within lower Cook Inlet is a gently sloping ramp whose base separates sandy sediments to the north from muddier sand to the south. The base of the ramp delineates the southern boundary of bedform fields. The top of the eastern part of the ramp, into the western triangular section of Cook Plateau is devoid of large bedforms. It forms a shallow topographic depression between the large sand waves to the north and those on the ramp (fig. 5, lines 238N, 238M, 240N, 220S; fig. 7, line 209-211). The bedforms rarely show a distinct asymmetry, but where observable, indicate a net transport to the south.

Bathymetric profiles over the southern part of Cook Trough and the adjacent ramp clearly show the variety of bedforms in both areas. All profiles show the "smooth-surfaced" shallow depression just north of the ramp and sand waves on the ramp with their greatest height at mid-ramp (lines 238 and 240, fig. 5, and line 209-211, fig. 7). Very low sand waves (< 25 cm) in the "smooth" area north of the ramp are covered by various small ripples (fig. 8).

The ramp starts at a water depth of about 70 m and terminates at about 120-130 m. Gradients range from as low as 0.3° to as high as 2.6°. The ramp has a boomerang shape, its apex pointing north, more or less in line with the axis of Cook Trough. The southwestern part of Cook Ramp is devoid of large bedforms and presents a rather smooth transition between the shallow southern Chinitna Platform and the north end of Shelikof Trough (fig. 6, line 207).

Shelikof Trough

The central and largest part of southern lower Cook Inlet is occupied by the north end of Shelikof Trough starting at the base of Cook Ramp and extending southward into Shelikof Strait. The trough deepens gradually to the south and is deeper in some areas along its lower eastern and western sides. The bathymetry along the western side forms an elongate basin, Douglas Basin, with a depth slightly greater than 190 m. On the east side is a series of depressions more than 200 m deep collectively termed "Shuyak Basin". A rather steep slope (average 2.5°) connects this basin with Shuyak Slope. The connection between Shelikof Trough and Barren Slope and North Barren Ridge is more irregular and less steep (fig. 5, line 239).

Douglas Platform and Douglas Slope

Cook Ramp joins with a steep-sided valley coming out of southern Kamishak Bay. Together they continue south as a steep slope that touches Cape Douglas. Douglas Slope, running from about 15-40 m down to 100-180 m depth, is the steepest slope in lower Cook Inlet. Local gradients are as high as 8.4°. A narrow platform runs between Douglas Slope and the adjacent land. It is divided into north and south Douglas Platform by Cape Douglas, where the width of the platform is nearly zero.

Figure 8: Representative bottom photographs of "smooth" area north of Cook Ramp showing the variety in small ripples over low sand waves. Vertical bands on compass vane are 5 cm wide.

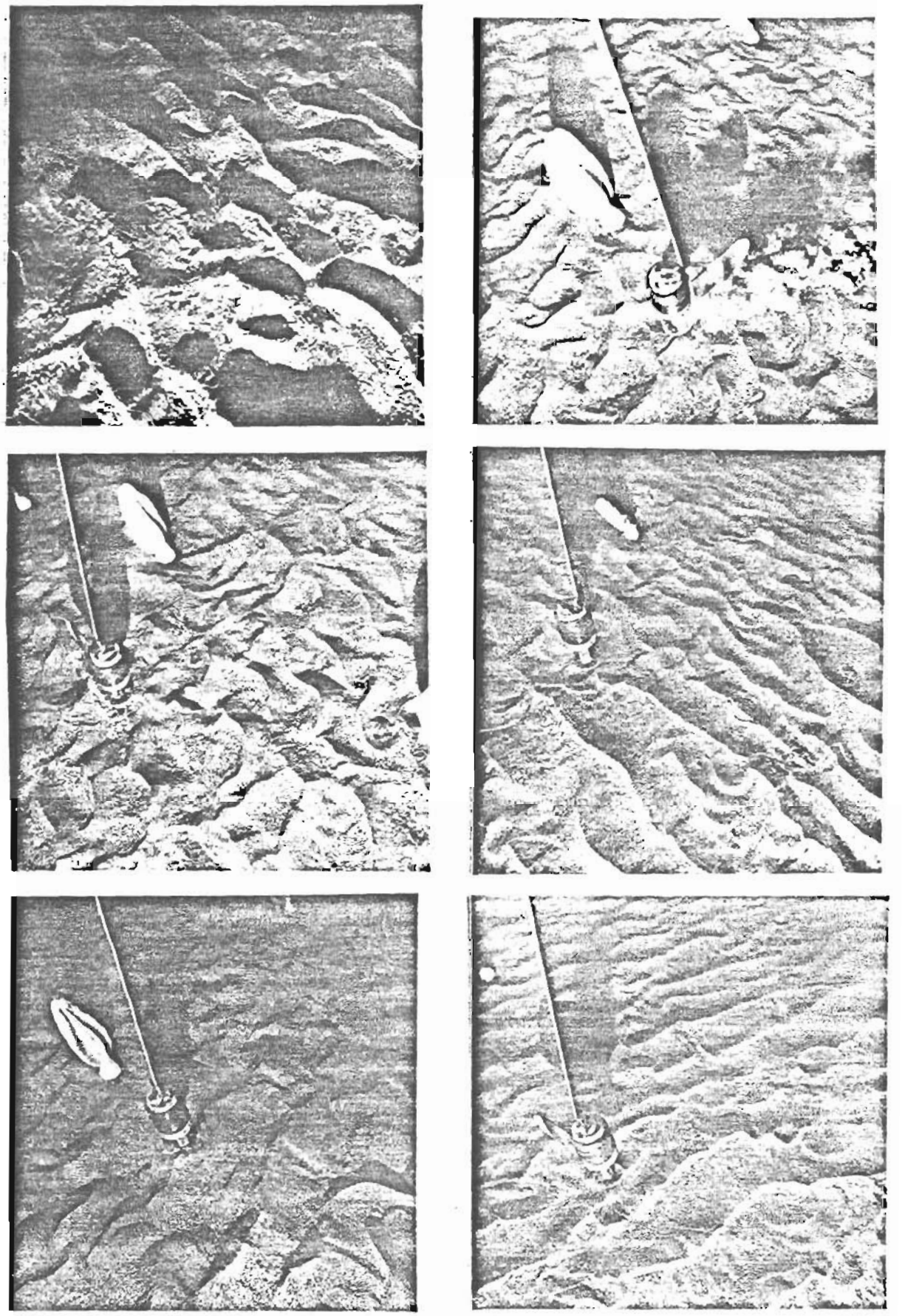

Figure 8. Representative bottom photographs of "smooth" area north of Cook Ramp

North Douglas Platform is topographically very irregular northward to lat. 59°02' N., where it widens and becomes part of Kamishak Bay. The platform south of Cape Douglas is unsurveyed, but is known to contain numerous shoaling peaks (Continental Shelf Data Service, 1967). No steep slopes are apparent adjacent to the rocky shores.

Eastern Region, lower Cook Inlet

The eastern part of lower Cook Inlet includes the areas underlying Stevenson and Kennedy Entrances, which lie north of Shuyak Island and are separated by the Barren Islands (fig. 3). Kennedy Entrance, in the north, is the principal ship passage from the Pacific Ocean into Cook Inlet. Stevenson Trough terminates against the Shuyak Slope, but Kennedy Trough extends far into lower Cook Inlet. These troughs have a more complex morphology than either Cook Trough or Shelikof Trough. The eastern part of lower Cook Inlet, as defined here, includes part of the area along the Kenai Peninsula and the southern part of Kachemak Bay.

Barren Slope

Southern lower Cook Inlet is separated from the eastern region by a series of islands and submerged highs. The central part of this shallower area is formed by Barren Slope, which surrounds the Barren Islands. At the base of the slope is a narrow platform-like zone characterized by irregular bathymetry, many fault scarps, horsts, and grabens.

The overall water depth increases rapidly away from the islands. Below the 90 to 100-m isobath, the bathymetry of Barren Slope is more regular than in the shallower area because a cover of unconsolidated sediment masks part of older formations. Rather shallow zones extend from the Barren Slope area to the north, south, and east.

North Barren Ridge

An irregular ridge extends north from the Barren Island toward the east end of Cook Ramp, separating the Kennedy Entrance area from the north end of Shelikof Trough. No details about this ridge and the surficial sediments are available.

REFERENCES CITED

Bouma, A.H., Hampton, M.A., Frost, T.P., Torresan, M.E., Orlando, R.C., and Whitney, J.W., 1978a, Bottom characteristics of lower Cook Inlet, Alaska: U.S. Geological Survey Open-File Report 78-236, 90 p.

Bouma, A.H., Hampton, M.A., Whitney, J.W., and Noonan, W.G., 1978b, Physiography of lower Cook Inlet, Alaska: U.S. Geological Survey Open-File Report 78-728, 16 p.

Bouma, A.H., Hampton, M.A., Rappeport, M.L., Whitney, J.W., Teleki, P.G., Orlando, R.C., and Torresan, M.E., 1978c, Movement of sand waves in lower Cook Inlet, Alaska: Offshore Technology Conference, 10th, Houston, Texas, OTC 3311, p. 2271-2284.

Continental Shelf Data Service, 1967, Bathymetric map; Shelikof Strait - Cook Inlet, Alaska. Denver, Colorado, scale 1 inch = 4,000 feet, 31 sheets.

Heezen, B.C., and Menard, H.W., 1966, Topography of the deep-sea floor. in Hill, M.N., ed., The sea, ideas and observations on progress in the study of the seas, volume 3, 2d ed.: New York, Interscience Publications, p. 233-280.

Karlstrom, T.N.V., 1964, Quaternary geology of the Kenai lowland and glacial history of the Cook Inlet region, Alaska: U.S. Geological Survey Professional Paper 443, 69 p.

McGarity, G.E., 1977, Bathymetry map, Marine high-resolution survey, lower Cook Inlet, Alaska: U.S. Geological Survey Open-File Report 77-358, scale 1:96,000.

National Ocean Survey, Hydrographic Survey, H-9073, Alaska Cook Inlet, vicinity of Augustine Island. National Oceanic and Atmospheric Administration, Washington, D.C., 1 sheet, contoured by C. Comer, U.S. Geological Survey, Anchorage, Alaska. Fieldsheet PF-20-2-69, scale 1:20,000. Sounding in fathoms. Advance information.

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