QUATERNARY GEOLOGY OF LOWER COOK INLET, ALASKA

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ABSTRACT

Lower Cook Inlet is a northeast trending tidal embayment of the North Pacific Ocean located in southcentral Alaska between the Alaska-Aleutian Range on the west and the Chugach Range on the east. Five major glaciations are recorded for the region during the Pleistocene. The first three completely filled Cook Inlet trough, truncating Tertiary bedrock and creating an inlet-wide angular unconformity. In the last two glaciations, ice coalesced only across the southern part of the inlet possibly creating a dam to water flowing from the north.

Interpretation of marine high-resolution seismic reflection data reveal many glacial and related features both on the seabottom and buried beneath Holocene marine sediments. Seabottom features identified include wave-cut benches, outwash fans, sand waves, megaripples, sand ribbons, lag deposits, and ice-rafted boulders forming comet marks. Subbottom features include terminal, lateral, and ground moraines, glacio-fluvial, glacio-marine, and lacustrine deposits, drainage channels and tunnel valleys, eskers, outwash fans, and sand waves.

The seafloor may be divided into four morphological provinces separated by the 60, 120, and 190 m isobath contour lines. The deeper two provinces are predominantly an expression of ice-erosional morphology and reflect marine depositional conditions, whereas, the shallower two provinces are expressions of ice-depositional morphology and reflect non-marine and marine sedimentary environments. The morphology of the seafloor and the features described are almost all the result of depositional and erosional processes during the last two glaciations and subsequent modification by high velocity tidal currents and marine deposition.

INTRODUCTION

Lower Cook Inlet is a tidal embayment of the North Pacific Ocean that projects north-northeast for over 150 mi (240 km) into the Southcentral Alaska coast (Figs. 1 and 4). Lower Cook Inlet narrows to the north from a width of 85 mi (140 km) at the latitude of Kamishak and Kachemak Bays to 30 mi (50 km) near Kalgin Island. The inlet occupies a structural trough that lies between the Chugach and Kenai Mountains on the southeast, the Talkeetna Mountains on the northeast, and the Alaska-Aleutian Range on the northwest. To the southeast, lower Cook Inlet connects to the Pacific Ocean via the Kennedy and Stevenson Entrances at the Barren Islands. To the southwest, lower Cook Inlet is connected to Shelikof Strait, which extends for another 170 mi (270 km) to a juncture with the North Pacific Ocean.

REGIONAL QUATERNARY GEOLOGY

Lower Cook Inlet and Shelikof Strait are structural troughs formed by plate subduction tectonics. These structural lows and the mountains surrounding them have been sculpted into their present morphology primarily by the direct or indirect action of glaciers. The processes responsible in the past for shaping the geomorphology of this region are active today: earthquakes, structural offset, volcanism, ice fields, alpine glaciation, tsunamis, and high-velocity-tidal currents. Several historically active volcanoes line the northwestern side of Cook Inlet and Shelikof Strait. They include, north to south (eruptions in brackets), Mount Spurr (1953, 1992), Mount Redoubt (1989-90), Mount Iliamna (steam and ash eruptions), Mount St. Augustine Island (1812, 1883, 1902, 1935, 1963-64, 1976, 1986), and Mount Katmai/Novarupta (1912). The mountains and lowlands surrounding Cook Inlet and Shelikof Strait exhibit a full range of glacial features including ice fields, active alpine glaciers, arêtes, horns, hanging valleys, U-shaped valleys, drumlins, erratic boulders, outwash plains, eskers, glacial lakes, and ground, terminal, medial, and lateral moraines.

The offshore geology of Cook Inlet and Shelikof Strait also displays evidence for past glaciations. High-resolution seismic data from lower Cook Inlet reveal seafloor and subsurface features originating from glaciers and modified by high tidal currents and Holocene marine deposition (Thurston and Whitney, 1979; Whitney and Thurston, 1980; and Thurston, 1985). The seafloor features include sand waves, megaripples, sand ribbons, lag gravel, and ice-rafted boulders with associated comet marks. The subsurface features include terminal, lateral, and ground moraines, lacustrine, glaciofluvial, and glaciomarine deposits, drainage channels, tunnel valleys, eskers, outwash fans, and sand waves. High-resolution geophysical data from Shelikof Strait reveal extensive deposits of Pleistocene glaciomarine and Holocene marine deposits. The Shelikof Strait seafloor generally is featureless with the exception of a few tectonic structures, such as fault scarps and possible remnant volcanic features (Hoose and Whitney, 1980).

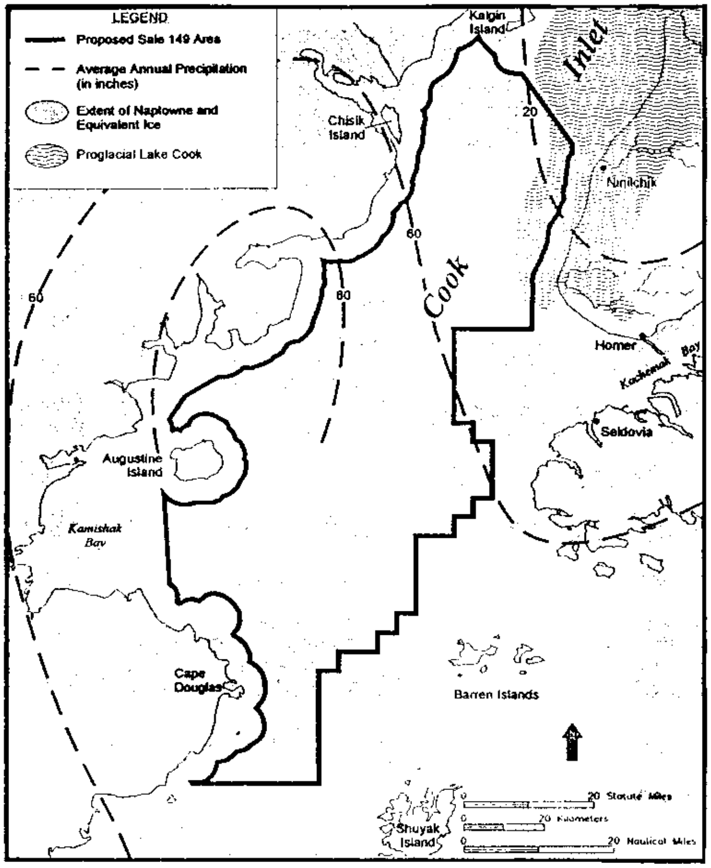

Fig.1. Lower Cook Inlet showing modern rainfall amounts, proglacial Lake Cook, and extent of Naptowne and equivalent ice (after Karlstrom, 1964).

LATE PLEISTOCENE AND HOLOCENE CHRONOLOGY

Five major Pleistocene glaciations have been recorded in the region (Karlstrom, 1964). These glaciations and the age of their maximum advances are the Mount Susitna (200,000-230,000 B.P.), the Caribou Hills (155,000-190,000 B.P.), the Eklutna (90,000 - 110,000 B.P.), the Knik (50,000-65,000 B.P.), and the Naptowne (20,000-25,000 B.P.). In addition, there is abundant evidence of the "Little Ice Age" advance in the Holocene, which has been termed the Alaskan Glaciation (Karlstrom, 1964). Late Pleistocene and Holocene events are the focus of this summary. The glacial chronology of the Cook Inlet region is depicted in Table 1 (Karlstrom, 1964).

EXTENT OF GLACIATIONS

During the first three glaciations (Mount Susitna, Caribou Hills, and Eklutna), ice completely filled the Cook Inlet trough to elevations of 4,000 to 2,000 ft (1,300 to 630 m), extending from the Talkeetna Mountains in the north through Cook Inlet and Shelikof Strait out to the edge of the continental shelf. Evidence for this distribution is the presence of ice-erosional landforms and the stratigraphic position and relative elevations of moraines in surrounding mountains and lowlands of the Cook Inlet region (Karlstrom, 1964).

In addition, evidence from seismic surveys in lower Cook Inlet and Shelikof Strait, such as glacial erosion and moraine deposits, indicate that glaciers once occupied the offshore areas. On the Kodiak shelf, ubiquitous ground moraine deposits and glacially eroded bedrock are evidence that ice covered the continental shelf during these early glacial advances (Thrasher, 1979). During the last two glaciations (Knik and Naptowne), ice coalesced across the lower Cook Inlet trough and filled Shelikof Strait out to the continental shelf (Karlstrom, 1964 and Whitney et al., 1980). A large proglacial lake covering parts of upper Cook Inlet region to the Talkeetna Mountains may have formed behind the ice dam in lower Cook Inlet. Lake levels reached elevations of + 275 ft (84 m) about 12,000 B.P. The youngest lake strandlines were formed between 9,500 and 10,500 B.P. and may date the last time ice coalesced across lower Cook Inlet (Karlstrom, 1964).

Table 1 Holocene and Late Pleistocene Glacial Chronology

Glaciation North America	Glaciation Alaska	Maximum Advance or Retreat	Years Before Present	Sea Level Stand (in feet)
Holocene	Alaskan	Tunnel II Advance	500-150	-.5 to -2
·	·	Tunnel I Advance	1000	-4.5 to -2.5
·	·	Retreat	1050	-4
·	·	Tustumena III Advance	2000	-13.5 to -9.5
·	·	Retreat	2500	-13.5
·	·	Tustumena II Advance	3000	-15.5 to -14.5
·	·	Tustumena I Advance	4000	> -15.5
·	·	Pro Tustumena	5000	-
·	Naptowne	Retreat	5500	+5 to +10
·	·	Tanya III Advance	6000	-14*
·	·	Retreat	6500	-
Wisconsin (Valderan Adv.)	·	Tanya II Advance	7000	-32*
·	·	Tanya I Advance	8500	-90*
·	·	Retreat	9000	-
·	·	Skilak III Advance	9500	-105*
·	·	Skilak II Advance	10,500	-130*
(Two Creekan Retreat)	·	Skilak I Advance	12,000	-187*
(Woodfordian Advance)	·	Retreat	12,500	-
·	·	Killey Advance	14,000	-250*
·	·	Moosehorn Advance	17,000	-330*

Extrapolated from worldwide sea-level data from Dott and Batten, 1971.

Late Wisconsin Sea-Level Stillstands

Past sea-level stands have been calculated for the Cook Inlet region from lowland-coastal bog and tidal bog stratigraphy, which record past water-table levels, and radiocarbon dating of organic material (Karlstrom, 1964).

Sea-level stillstands have been deduced from analysis of bathymetry (Dixon et al., 1979; 1986). Relative depths of seafloor features, such as benches, sills, and closed depressions, are related to sea-level stillstands. Using this method, Dixon et al. (1979; 1986) postulated a correlation of stillstands for six isobath lines at -125 m, -82 m, -66 m, -55 m, -38 m, and -28 m. Stillstands are thought to be associated with periods of maximum glaciation when relatively lower sea levels prevailed. The six isobaths were therefore correlated to regional and worldwide glacial maximums (Dixon et al., 1979; 1986) and assigned the following ages: -125 m from between 21,500 and 18,000 B.P.; -82 m from between 15,000 and 14,800 B.P.; -66 m at about 13,750 B.P.; -55 m at about 12,700 B.P.; -38 m from between 9,770 and 9,330 B.P.; and -28 m at about 8,700 B.P.

In lower Cook Inlet, a prominent bathymetric notch is identified on seismic profiles along the western slopes of the seafloor. This notch lies at a depth of -65 m and may correspond to the -65-m stillstand of Dixon (et al., 1979; 1986). Outwash fans from glacial streams reaching their base level also formed in the same areas at about -65- to -80-m water depth.

OFFSHORE GEOLOGY

Bathymetry

In Federal waters, bathymetric relief ranges from less than 10 m near Kalgin Island in the north to greater than -240 m along the southeastern side of Shelikof Strait. Lower Cook Inlet generally is configured as a two-tier plateau, with the shallower (-10 to -90 m) northern part separated from the deeper (-90 to -200 m) southern part by an arcuate, open-to-the-south "ramp" feature (Bouma et al., 1977 and Whitney et al., 1979). The northern tier is dissected to a depth of -45 m by a central sea valley, which bifurcates in the north around Kalgin Island, and the "Kachemak" channel, which forms the axis of Kachemak Bay. The northern plateau area also is covered with seafloor bedforms, including sand waves with amplitudes approaching 15 m (Fig. 2). The southern tier is characterized by shallower slopes and deep closed basins (Fig. 3) separated by narrow ridges, such as the ridge defined by the -125-m isobath that connects the Barren Islands to the Kenai Peninsula and Afognak Island (Fig. 4). At water depths shallower than this ridge, Cook Inlet is connected to Prince William Sound waters to the southeast via Kennedy and Stevenson Entrances. Cook Inlet is open to the southwest and continues as Shelikof Strait. In Shelikof Strait, water depths generally exceed -100 m. The seafloor of the central strait is broad and generally flat with closed basins. The northwestern side of the strait exhibits relatively steep slopes descending from the mountain front with water depths of around -100 m in the north and over -190 m in the south. Areas of deepest water occur along the southeastern side of the strait adjacent to Kodiak Island, where they reach -240 m.

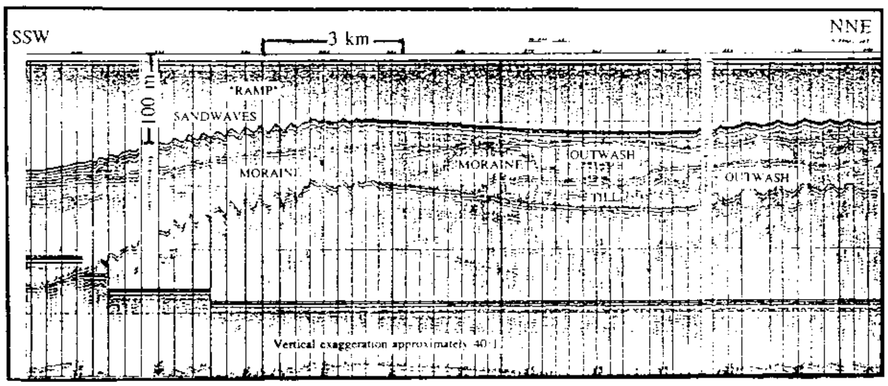

Fig. 2. Minisparker high-resolution seismic profile of the northern tier of lower Cook Inlet bathymetry including the Ramp. Glacial deposits and stratigraphic features (moraines, till, and outwash) overlain by Pleistocene (?) sand (sand waves) and Holocene marine deposits.

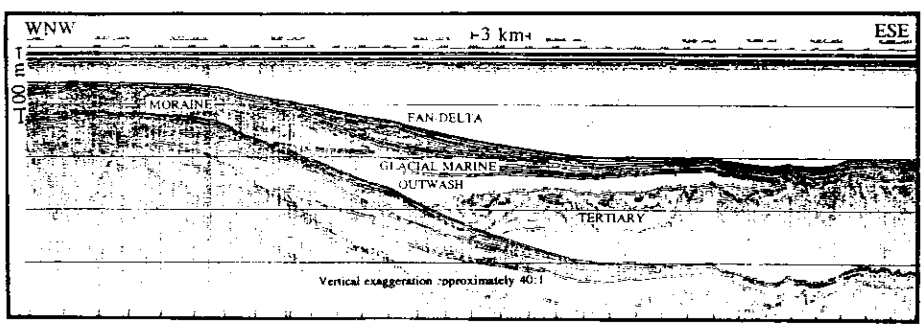

Fig. 3. Minisparker profile across the western moraine complex, western Ramp, fan delta, and central depression of lower Cook Inlet.

Geomorphology

A study of bathymetry and subsurface deposits (Thurston, 1985) resulted in the classification of lower Cook Inlet morphology into four provinces: (I) 0 to -60 m: Constructional morphology, glacial deposition and subordinate erosion; (II) -60 to -120 m: Constructional morphology, glacial and marine deposition with subordinate hydraulic erosion; (III) -120 to -190 m: Erosional morphology, gently sloping seafloor formed by glacial erosion and subordinate glacio-marine deposition; and (IV) > -190 m: Erosional morphology, closed basins formed by glacial erosion and subordinate glacio-marine deposition. Geomorphological provinces I and II correspond to the area of the northern bathymetric tier and the ramp. Geomorphological provinces III and IV correspond to the southern bathymetric tier and Shelikof Strait. Bathymetric characteristics of the northern part of lower Cook Inlet are manifestations of thick deposits of glacial moraine and associated strata. The ramp feature is the manifestation of the joining of two arcuate morainal lobes from Kachemak and Kamishak Bays. The bathymetric profile of the southern plateau and Shelikof Strait is due to deep scour by glaciers and thin Pleistocene and Holocene marine and glacio-marine sediment cover.

Quaternary Deposits

The Quaternary unconformity is present throughout the sale area (Thurston, 1985). The surface was eroded into underlying rock by ice flowing out of Cook Inlet and Shelikof Strait. It is characterized by truncated tilted Tertiary strata overlain in the north by unstratified or poorly stratified moraine or till deposits and in the south by stratified glaciofluvial, glaciomarine, and marine sediments. The relative depth of the unconformity surface is a direct measure of the intensity of ice erosion and, by inference, ice depth. The greatest relief exhibited by the unconformity surface in lower Cook Inlet occurs north of Cape Douglas, where it lies at -250 m, and southwest of the Barren Islands, where it lies at depths of -300 m. These areas of deep ice scour correspond to the route of thick ice tongues that flowed into lower Cook Inlet and Shelikof Strait from the Alaska-Aleutian Range and from what appears to have been a spreading center on the site of the Barren Islands. An isopach map of Quaternary sediment shows that the area of thickest Quaternary deposits also occurs where the unconformity surface is at its deepest level (Thurston, 1985).

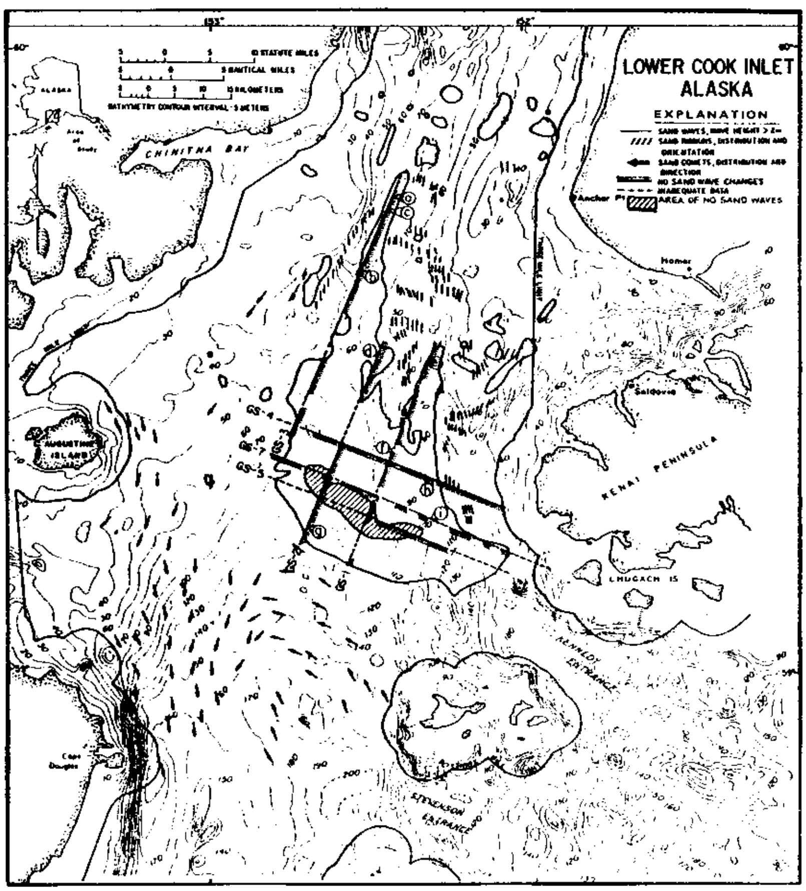

Fig.4. Lower Cook Inlet bottom features. Profile lines are from Whitney et al., 1981, sand wave migration study. Shaded lines indicate no detectable movement in a five-year span, letters in circles are profile sections presented in Whitney et al., 1981.

Quaternary deposits consist of ground moraine and drift deposits; lateral and terminal moraines; outwash sediments; and glacio-fluvial, glacio-marine, lacustrine, and marine sediments. Seafloor sediments have been sampled and their distribution mapped (Bouma et al., 1977; 1978a). Generally, the northern area is mantled by coarse sand and gravel; the mid-inlet is covered by medium- to fine-grained sand that is sculptured into bedforms; and sediments of the southern inlet and Shelikof Strait that consist of fine-grained sand, silt, and clay.

Sediment provenance is spatially determined within the Cook Inlet trough. Microtexture analyses of bottom sediments (Hampton et al., 1978) indicate that quartz grains in the northern part of lower Cook Inlet showed characteristics of unaltered glacial affiliation. Bottom quartz grains in the central sand wave area show characteristics of glacial deposits altered by hydraulic reworking. Seafloor sediments in the west and south show chemical overgrowth over a glacial texture, which is indicative of high-residency time in a low-energy environment. Clay mineralogy studies (Hein et al., 1977) indicate that suspended sediment sampled from the eastern side of the inlet was derived from the Copper River, which flows into Prince William Sound to the east. These sediments are carried by the counterclockwise Alaska gyre into the inlet via the Kennedy and Stevenson Entrances, where they travel up the east side of lower Cook Inlet. Suspended sediments sampled on the western side of the inlet have Susitna and Matanuska River mineralogical characteristics.

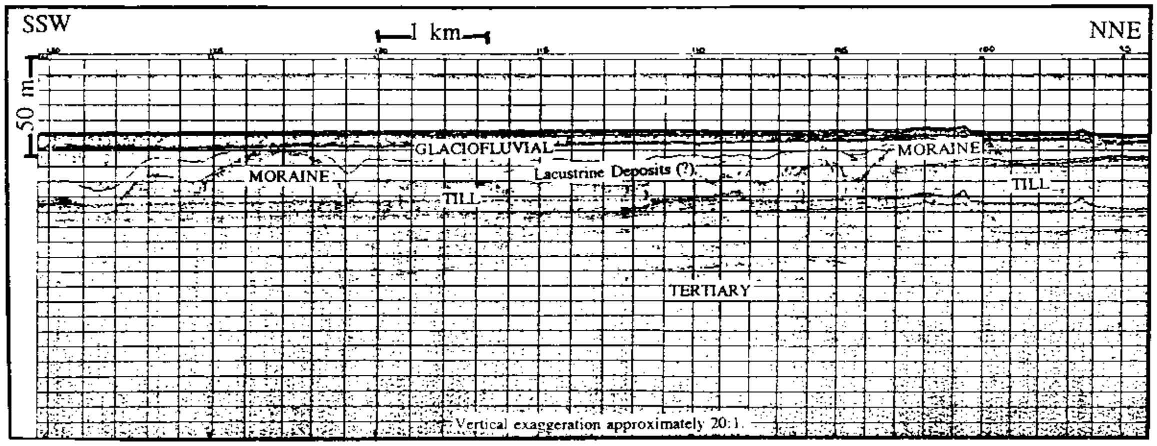

Fig.5. Acoustipulse high-resolution seismic profile showing the Kamishak Bay outer and inner moraine lobe. The contour-following strata above the moraine are possible lacustrine and/or volcanic ash deposits. Seismic profile courtesy of Fugro-McClelland Engineers.

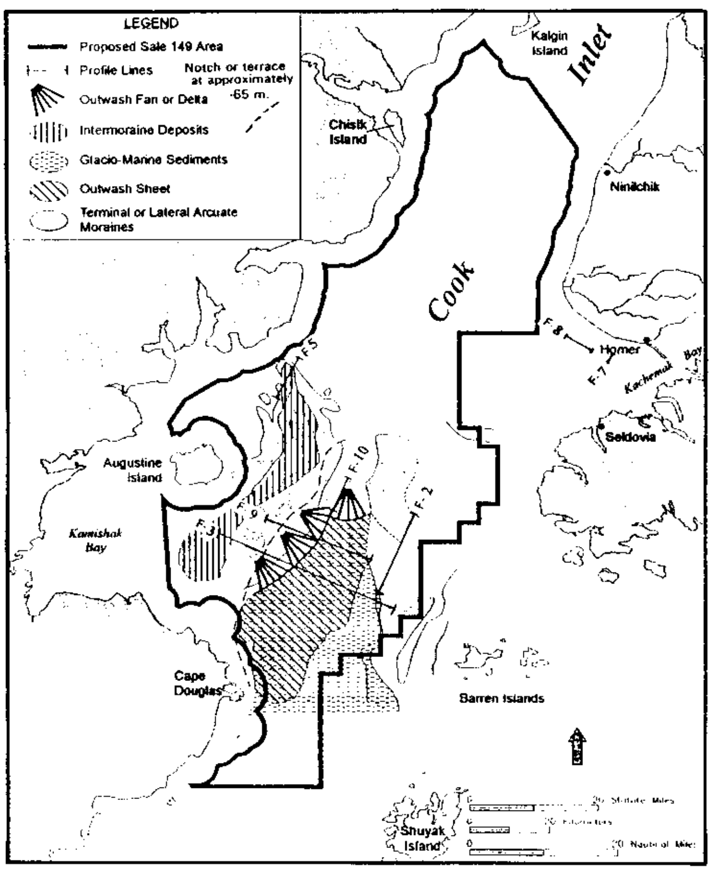

Fig.6. Sub-glacial features. Location of profiles in Figs. 2, 3, 5, 7, 8, 9, and 10 are shown.

Seafloor Features

The seafloor of lower Cook Inlet is characterized by a wide variety of bedforms and other geomorphic features (Fig. 4). The seafloor of Shelikof Strait generally is featureless with the exception of some tectonic relief (Hoose and Whitney, 1980).

Lag Gravel: Areas of the northern lower Cook Inlet near Kalgin Island are covered with lag gravel. These sediments were deposited by glaciers and subsequently winnowed of their fine- and medium-grain size particles. Microtexture analysis of sediment grains indicates that these deposits display textures associated with unaltered glacial sediment (Hampton et al., 1978).

Sand Ribbons: Sand ribbons are found in the northern and central lower Cook Inlet in areas flanking the sand-wave field and the central and Kachemak channels. These bedforms consist of strips of sand oriented generally north-south, parallel to the prevailing tidal currents. The strips of sand are separated by lag gravel and support sand ripples, which are oriented transverse to the current direction. Sand ribbons are believed to form in bottom areas where currents are moderately higher than the minimum to entrain sand grains and where there is a limited supply of sand.

Sand Waves: The lower Cook Inlet sand-wave field covers approximately 850 km^2 of the seafloor (Whitney et al., 1979). These bedforms reach amplitudes of 15 m and wavelengths of 600 m. Sand waves occur in water depths ranging from less than -40 m to over -120 m. A study of the sand-wave dynamics using comparative sidescan-sonar images and seismic profiles after a 4- and 5-year period showed no evidence that these large bedforms migrate (Whitney et al., 1979). Sand grains are known to move in response to the tidally induced bottom currents (Bouma et al., 1979), which can reach 1 knot (kn) in the central inlet area, and microtexture analysis indicates reworking of these sediments; however, bedform-migration studies and the absence of microtextures of the sand-wave-field type south of the ramp indicate that there is no net movement of bedforms or sediments. Sand waves in deepwater, where currents may not be strong enough to form such features, and the presence of buried sand waves near the apex of the ramp suggest the possibility that the sand-wave field is at least partially relict.

Comet Marks: Comet marks are formed by the creation of an erosional tail of lag gravel behind an obstruction on the seafloor (Thurston, 1985). These features are interpreted as having at their head an ice-rafted boulder that lies in a shallow depression and has a tail of coarse material pointing away, downcurrent. The circulation pattern in lower Cook Inlet indicated by these features is counterclockwise in the southern deeper part and generally south along the west side of the inlet (Fig. 4).

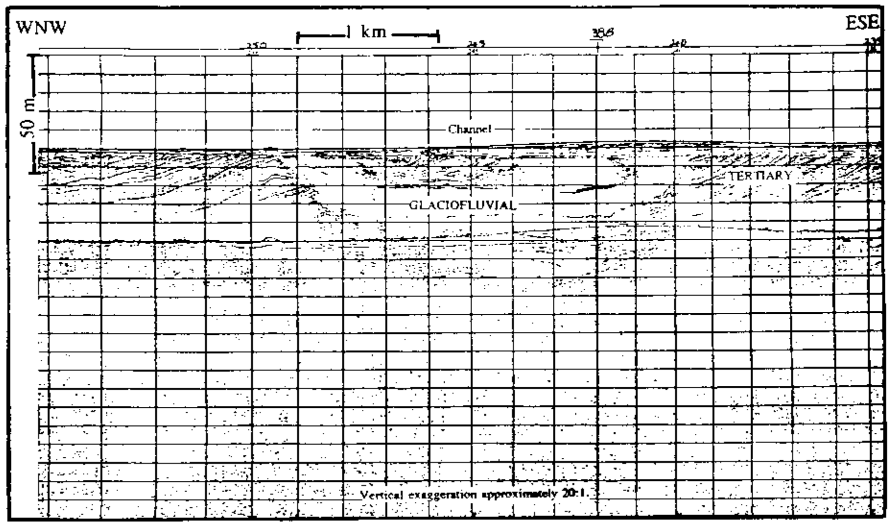

Fig.7. Buried channel feature near Kachemak Bay, cut into Tertiary bedrock. The shape of the channel indicates that it was initially eroded by ice. The migrating channel axis in the upper part indicates that it was subsequently filled by water draining receding glaciers. Seismic profile courtesy of Fugro-McClelland Engineers.

Subsurface Features

Moraines: (a) Northern Inlet: Kalgin Island, just north of the planning area boundary, is a terminal moraine from an ice lobe that flowed east from the Alaska Range into Redoubt Bay. The Quaternary unconformity in the northern lower Cook Inlet is covered by unstratified, hummocky, mounded, and heavily dissected strata which are most likely ground moraine and till deposits. There are several stratigraphic intervals represented in these type of deposits.

(b) Central Inlet: The geomorphological structure called the ramp (Bouma et al., 1978b) has an inverted V-shape and exhibits bathymetric relief of over -60 m. The ramp is formed by the joining of two moraines; the Kamishak Bay moraine forms the western limb, and the Kachemak Bay moraine forms the eastern limb (Thurston, 1985). In cross-section, the moraines have a domal shape (Fig. 5). The position of these moraines indicates the maximum advance of ice into the middle part of the inlet during the Knik and Naptowne maximums. The Kamishak Bay moraines appear to have been deposited by ice flowing northwest out of the Cape Douglas area. This moraine complex is composed of an inner and an outer spatulate-shaped belt (Fig. 6). The outer belt represents the terminal phase of ice advance and the inner belt may be a recessional phase of the same advance or a later, less-intense advance. The Kachemak Bay moraine generally is not as well preserved as those in the west. It forms an arcuate mound with a domal cross section for most of its discernable length.

(c) Southern Inlet: In water deeper than -100 m, moraines are found around the western side of the Barren Islands. These moraines are well preserved and exhibit domal cross sections. These may be terminal moraines from ice flowing from a now exhausted or submerged spreading center at the site of the Barren Islands, or these moraines may be medial moraines from large ice lobes flowing from the Kenai Mountains and the Alaska-Aleutian Range mountain fronts.

Channels: A network of buried channels is present in the central part of lower Cook Inlet. Buried channels are absent south of the ramp. These channels are discontinuous and branching, and they dissect different stratigraphic levels. Buried channels fit into one of three categories:

(a) Glacial Channels or Valleys (Fig. 7) exhibit a U-shaped profile and are generally wider and more continuous than hydraulic channels. They are the predominate type of channel observed in the northernmost area.

(b) Tunnel Valleys were sub-ice glacial-drainage channels. These channels generally are characterized by the presence of eskers; ice-contact stream deposits, which form sinuous mounds of unstratified sediments in the central channel (Fig. 8).

(c) Glacial Outwash Stream Channels, which formed in front of the glacier and carried melt water to the Pacific Ocean, are characterized by cut-and-fill structures, short and discontinuous courses, and multiple or overlapping channels. Because of their relative position at the apex of the ramp, these channels may be partly due to streams formed when the ice damming lower Cook Inlet was breached and water from the large pro-glacial lake broke out and flowed to the sea.

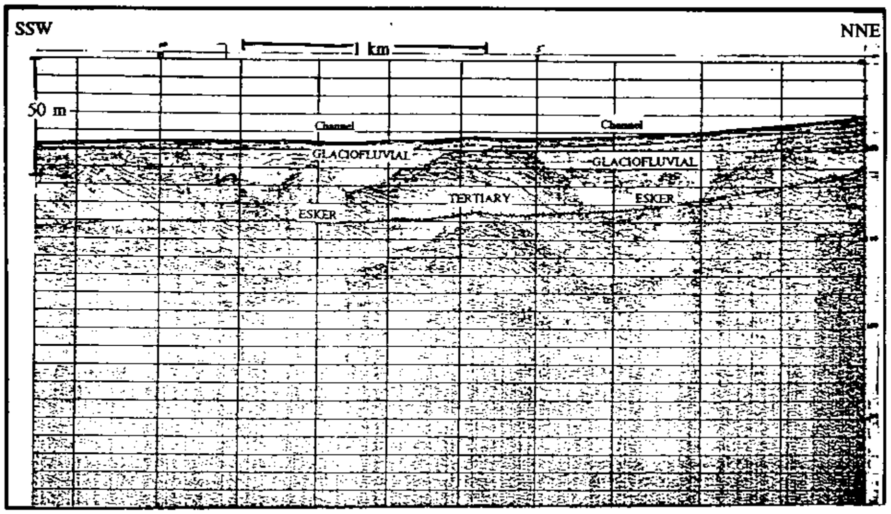

Fig.8. Buried channel feature near Kachemak Bay, cut into Tertiary bedrock. The channel shape indicate that the initial erosion by ice and possible eskers in the channel bottom may indicate that melt-water ran under the glacier. Data courtesy of Fugro-McClelland Engineers.

Outwash Fans: At the apex of the ramp where the Kamishak and Kachemak moraines meet, there are distinct delta-type outwash fans (Figs. 3 and 9). These fans are interpreted to have formed as the result of glacial outwash streams dumping their sediment bedload at the paleoshoreline. The present depth of these fans indicate that they were formed at the shoreline during a sea-level lowstand or stillstand of from -65 to -80 m. This depth range is in general agreement with stillstand depths of -66 m and -82 m proposed by Dixon et al. (1979; 1986). As in the case of the buried channels, these fans also may be partially from the breakout of water from and the draining of the large pro-glacial lake in upper Cook Inlet.

Sand Waves: Large sand waves in the area of the apex of the ramp are buried beneath outwash and glacio-marine deposits (Fig. 10).

Lacustrine Sediments: Covering the inner belt and deposited against the inner wall of the outer belt of the Kamishak Bay moraine, seismically transparent strata of uniform thickness mimic underlying topography (Fig. 5). The uniform thickness of these deposits, even over terrain relief, indicates a low-energy depositional environment and the seismic "transparency" indicates that the deposits are texturally homogenous. These are characteristics of lacustrine deposits. The proximity to Augustine Island may mean that these deposits are ash laid down in a low-energy depositional environment. These probably represent lacustrine deposits laid down in a lake formed by damming of meltwater runoff by the outer morainal belt.

CONCLUSIONS

During the Naptowne Glaciation, sea-level stillstands occurred at approximately 18,000 to 21,500 B.P. (-125 m), 14,800 to 15,000 B.P. (-82 m), 13,700 B.P. (-66 m), 12,700 B.P. (-55 m), 9,770 to 9,330 B.P. (-38 m), and 8,700 B.P. (-28 m). Pro-glacial lake strandline elevations indicate that ice last coalesced across the central Cook Inlet at about 9,500 to 10,500 B.P. The southeast facing slope of the outer Kamishak Bay moraine on the west side of the inlet has been notched by water at a stillstand of -65 m, placing the age of the outer moraine feature at pre-Skilak Advance (older than 12,500 B.P.). Outwash fans, which are younger than the south facing outer Kamishak Bay moraines, also occur at -65 to -80 m, corresponding to ages of 12,700 to 15,000 B.P. The inner moraine complex stands at a higher relative elevation than the outer moraine and is undoubtedly younger.

Effects of isostatic rebound and vertical tectonic movements have not been well documented in the Cook Inlet region. According to Dixon et al. (1986), there was some tectonic uplift associated with beach deposits on the western side of the inlet. The apparent rise of Augustine Island volcano in the last 10,000 years may have affected the relative elevation of the western side of the inlet. The Alaska earthquake of 1964 resulted in up to 2 ft (0.6 m) of tectonic subsidence of the Cook Inlet and Shelikof Strait region. Geomorphological evidence suggests that the area of the Kenai Mountains may have subsided substantially since the Wisconsin maximum glaciation (Mobley et al., 1991).

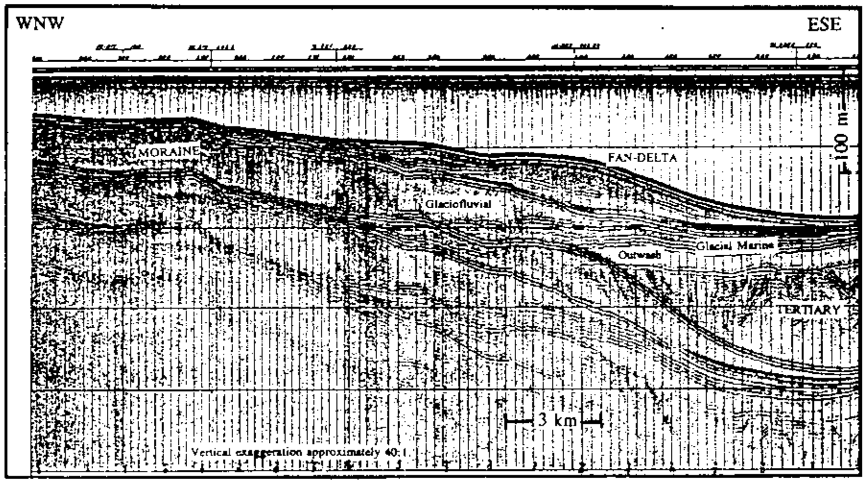

Fig.9. Minisparker profile of the transition between the northern bathymetric tier and the southern bathymetric province, separated by the ramp. Here it can be seen that the northern tier is underlain by moraine and other glacial deposits. The ramp is a manifestation of an outwash fan and the southern provinces are underlain predominantly by outwash, glacial marine, and marine deposits.

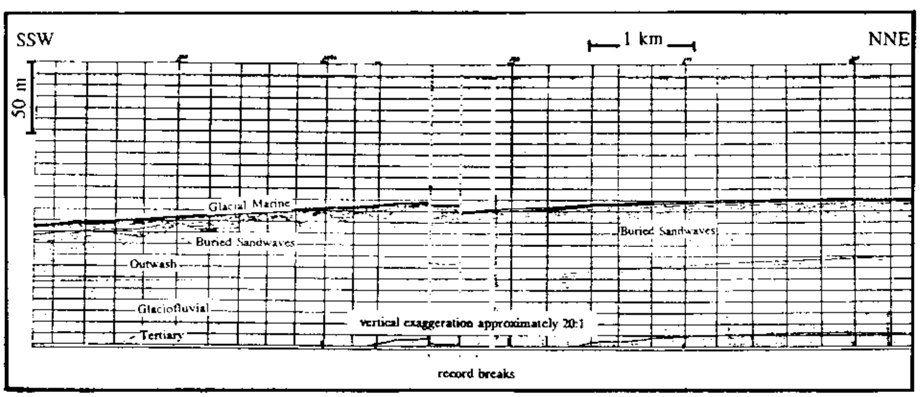

Fig.10. Acoustipulse high-resolution seismic profile showing buried sand waves in the vicinity of Augustine Island. Seismic profile courtesy of Fugro-McClelland Engineers.

Ice scour and moraine deposits of various types and ages on the shelf and the absence of moraine deposits in the Shelikof Strait support the possibility that ice completely filled Shelikof Strait and spilled out to the continental shelf during the Moosehorn and Killey advances.

Ice-rafted boulders forming comet marks in the deepwater of lower Cook Inlet indicate that the last ice retreating from the trough formed tidewater glaciers.

Sand waves in the central inlet may have formed at lower sea-level stands (-65 m) and been stranded in deeper water by a rapid rise in sea level after the last major ice advance.

ACKNOWLEDGMENTS

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