HIGH-RESOLUTION SEISMIC SURVEY OF AN OFFSHORE AREA NEAR NOME, ALASKA

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By A. R. TAGG *and* H. G. GREENE

STUDIES ON THE MARINE GEOLOGY OF THE BERING SEA

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Description and interpretation of data from seismic records and bathymetric charts

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ABSTRACT

A high-resolution seismic survey was made south of Seward Peninsula in Norton Sound, Alaska, during the summer of 1967, to identify sites of possible offshore gold concentrations. Interpretation of the seismic records was confined primarily to the parts above the first sea-bottom multiple, generally less than 150 feet below the sea floor. Sediments within this interval consist mostly of unconsolidated Holocene sand and gravel covering Pleistocene glacial and marine sediments. Paleozoic metamorphic rocks are near or at the sea floor in the northwestern part of the area.

Interpretation of bottom topography and subbottom structures disclosed many features that may be important in gold exploration. Bottom-surface features include at least five outwash fans, several beach ridges, and discontinuous stream channels. Subbottom features include many buried stream channels, areas of glacial drift, and at least three shallow faults. Also noted were acoustical sinks that have been interpreted as gravels associated with buried stream channels and beach ridges. In addition, six areas were delineated where placer gold may have been concentrated.

INTRODUCTION

This report describes and interprets features seen on high-resolution seismic-profiling records and bathymetric charts of an offshore area near Nome, Alaska, and discusses the possible significance of these features as placer-gold exploration sites. It is based upon a continuous seismic-reflection survey conducted in the summer of 1967 by the U.S. Department of the Interior. The investigation was conducted jointly by the Geological Survey and the Bureau of Mines. The 1967 studies included offshore drilling at sites chosen on the basis of this seismic survey, sampling of the sea bottom and modern beach, seismic-refraction surveys of part of the modern beach, and onshore geologic studies.

The continuous seismic profiles were interpreted jointly by the Geological Survey and the Bureau of Mines. Interpretation of the deeper reflectors, mostly of Tertiary age, was undertaken at the Marine Minerals Technology Center of the Bureau of Mines. This report describes the shallower reflectors, probably all of Quaternary age, that extend to depths of less than 150 feet below the sea bottom. Information from drill logs and bottom samples taken in 1967 and 1968 was used in the interpretation of the seismic records. These data provide the basis for extending the coastal-plain geology at Nome (Hopkins, 1967) into the offshore area.

The study area is in the northwestern part of Norton Sound, an embayment of the northern Bering Sea (fig. 1). The area extends 10 miles east and west of Nome, from Cape Nome to Rodney Creek, and up to 10 miles offshore.

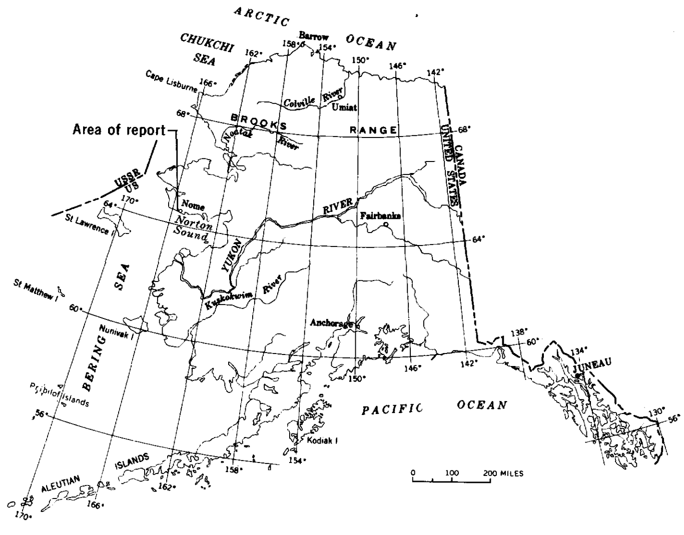


FIGURE 1.— Index map of Alaska showing location of study area.

Several reconnaissance seismic-reflection studies, both shallow and deep, have been made of the Bering Sea. Moore (1964) discussed the results of a high-resolution shallow seismic-reflection survey of parts of the Bering and Chukchi Seas. Scholl, Buffington, and Hopkins (1968) have made deep seismic-reflection surveys of the outer shelf areas of the Bering Sea, and Scholl and Hopkins (1969) extended this work to the northern Bering Sea. The results of a shallow seismic-profiling survey of the northern Bering Sea have been reported by Grim and McManus (1970). Private groups have undertaken seismic surveys of nearshore waters along parts of the south coast of Seward Peninsula, but these studies have not been published.

We thank Warren Woodward and Arthur Daily of Shell Oil Co., Ralph Saleski, John Fagerstrom, and Ben Herman of the U.S. Army Corps of Engineers, and Burton Barnes, Gary Leo, Adolph Poston, and Dale Stevenson of the U.S. Bureau of Mines for assistance in various parts of the fieldwork.

GEOLOGIC SETTING

The Nome coastal plain and adjacent offshore areas are underlain by Pliocene and Pleistocene marine and glacial sand and gravel. A geologic map and a cross section of the Nome coastal plain are shown in figure 2. Separate deposits are recognized onshore and are locally known as Submarine Beach, Fourth Beach, Third Beach, Monroeville Beach, Intermediate Beach, and Second Beach. They were produced during six different sea-level stands in late Pliocene and Pleistocene time (Hopkins, in Hopkins and others, 1960, p. 46). Submarine Beach, Intermediate and Third Beaches, and Second Beach are separated from one another by glacial drift of the Iron Creek (pre-Illinoian) and Nome River (Illinoian) Glaciations. Fourth Beach, Third Beach, and Monroeville Beach lie on bedrock beneath the Nome River drift. The glacial drift and marine sediment on the Nome coastal plain are overlain by alluvium, colluvium, windblown silt, and peat of Wisconsin and Holocene age.

Paleozoic schist and limestone bedrock underlie the coastal-plain sediments and crop out north of them (Collier and others, 1908, p. 149; Hummel, 1962a, b). Beach, glacial, and alluvial sediments occur offshore; however, substantial quantities of marine sand, silt, and clay are present at several subbottom levels.

An older beach deposit is recognized only in the subbottom just offshore and west of the mouth of the Snake River (fig. 2). This buried beach, however, lies beneath water too shallow for continuous seismic profiling, and it was recognized as a result of compilation of borehole data and information on bedrock depths obtained from seismic-refraction studies along the beach (Greene, 1970a). This oldest shoreline deposit lies at a depth of about 70 feet below sea level and contains a Pliocene molluscan assemblage. It overlies bedrock with an irregular contact and is in turn overlain by glacial deposits (Hopkins, written commun., 1969).

The next younger shoreline deposits, Inner and Outer Submarine Beach, lie at depths of −35 and −20 feet onshore at Nome, in the area between the lower course of the Snake River and the present shore. The Submarine Beach complex rests on bedrock in some places and on Pliocene(?) sediments in others. Submarine Beach has yielded pollen and mollusks of a late Pliocene or early Pleistocene age and is a product of the Beringian transgression (Hopkins, 1967, p. 53).

Submarine Beach is overlain by four lithologic units: drift of the Iron Creek Glaciation of pre-Illinoian age, a layer of fossiliferous marine sand and gravel, till and outwash of the Nome River Glaciation of Illinoian age, and marine sediments of Second Beach of Sangamon age (fig. 2). Mollusks and pollen in the marine layer between the two drift sheets suggest that the marine layer is correlative with Intermediate Beach, a shoreline deposit on bedrock beneath Nome River drift at an approximate altitude of 20 feet (Hopkins, written commun., 1969). Inland from Submarine Beach are three other shoreline deposits: Monroeville Beach at an altitude of 40 feet, Third Beach at an altitude of 70 feet, and Fourth Beach at 125 feet. All three transgress onto bedrock beneath the Nome River drift (MacNeil and others, 1943).

The Bering Sea, an epicontinental sea, was most likely emergent to late Tertiary time. Crustal warping then created the present marine Norton Basin, which is partly filled by a prism of Tertiary and Quaternary sediments having a total thickness of more than 6,000 feet in central Norton Sound (Scholl and Hopkins, 1969). Although the bedrock surface beneath Norton Basin is an erosional surface, it was steepened by tectonic subsidence during development of the basin. The bedrock surface beneath the Nome coastal plain slopes rather smoothly seaward at about 25–35 feet per mile, but just offshore the gradient steepens abruptly to 130–230 feet per mile (U.S. Bur. Mines, unpub. data).

Sediments that fill the Norton Basin include coal-bearing strata at least as old as late Oligocene. These strata are exposed at the southwestern edge of the basin on St. Lawrence Island (J. A. Wolfe, written commun., 1968) but do not occur at Nome. The older beds, however, may be represented by some of the deeper seismic reflectors that appear to lap on to the basement reflectors several miles offshore from Nome (fig. 13) (Scholl and Hopkins, 1969). Paleogeographic reconstructions suggest that the Norton Basin was first invaded by the sea in late Miocene time (Hopkins, 1967, p. 454). Marine clay containing fossils of early Pliocene age was brought up

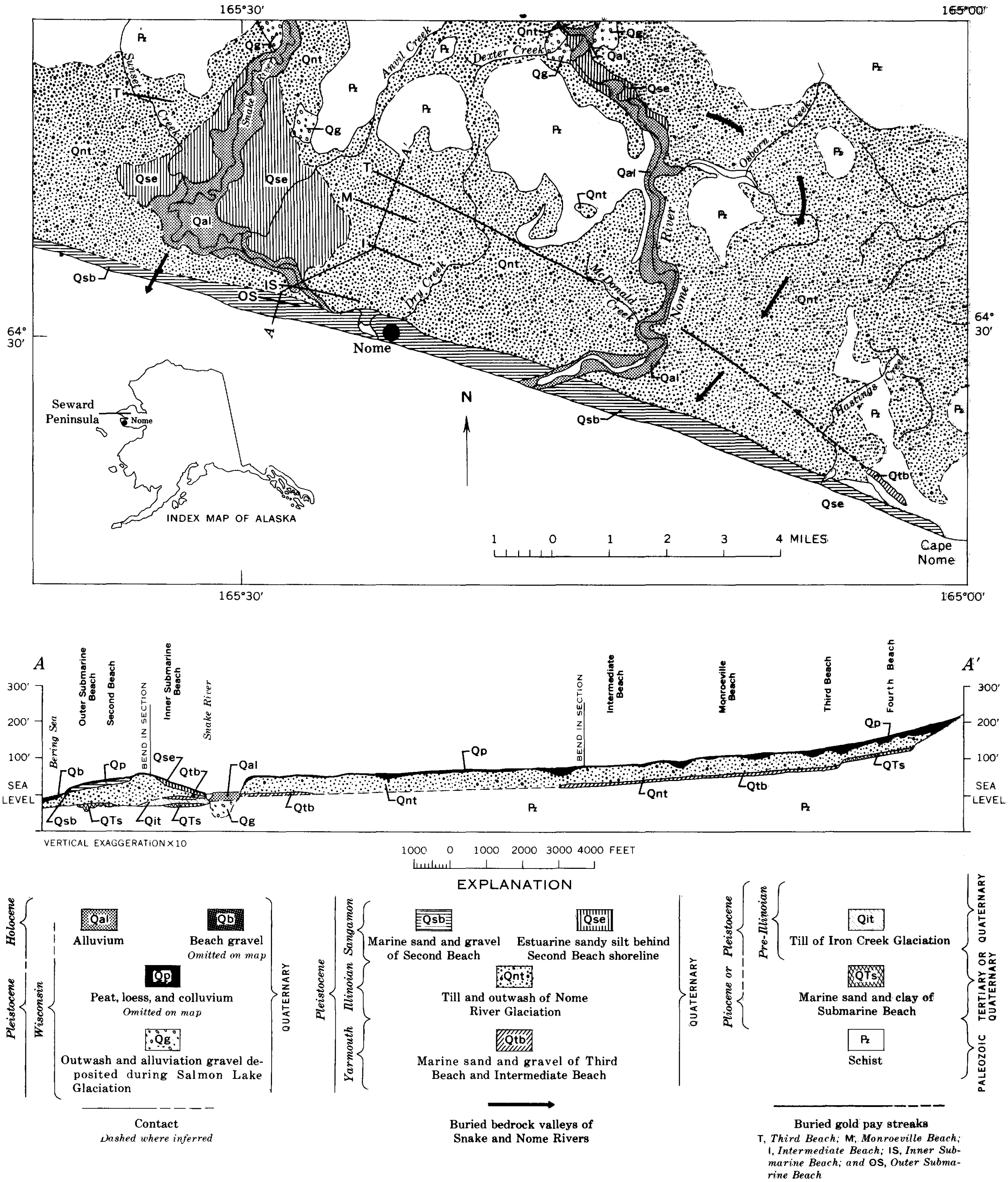


FIGURE 2. — Generalized geologic map and cross section of the coastal plain at Nome. (After Hopkins, in Hopkins and others, 1960.)

from a depth of 240 feet below the sea bottom in one of the holes drilled in 1967 about 3 nautical miles off the mouth of the Nome River (J. A. Wolfe, written commun., 1968).

Seismic-reflection profiles of the northern Bering Sea commonly depict an unconformity at depths ranging from a few tens of feet to several hundred feet between nearly flat-lying beds and more steeply dipping underlying beds (Scholl and Hopkins, 1969; Grim and McManus, 1970). This unconformity may correspond in time to the abrupt change in slope of the bedrock surface just offshore of Nome. If so, it probably indicates a slackening of the rate of subsidence of the Norton Basin during middle or late Pliocene time.

Since late Cenozoic time the sea has transgressed beyond the present shoreline several times, producing the buried beaches which have been important onshore gold producers. Between some of these transgressions, sea level receded below the present level, at which time the offshore features mentioned in this report were produced. At least two of these recessions were accompanied by glacial invasions beyond the present shoreline — that is, Nebraskan (First) or Kansan (Second) and Illinoian (Third). Either or both of these invasions may have carried placer gold offshore from existing onshore lode or placer deposits.

The Nome area produced some 5 million ounces of placer gold from 1897 through 1964, according to an unpublished compilation by A. H. Daily (mining engineer, Oakland, Calif., written commun., 1968). The greater part of the production was derived from placers on the coastal plain.

The beach placers resting on bedrock probably derived most of their gold from erosion of mineralized rocks adjoining the Anvil Creek fault zone. Submarine Beach, Intermediate Beach, Monroeville Beach, Third Beach, and Fourth Beach all contained productive placers that were richest in their western parts and attenuated in value eastward. Net longshore drift on the modern beach is eastward (Greene, 1970b), and judging from locations of mined areas, eastward drift was probably the predominant agent in transporting gold along the older shorelines as well.

EQUIPMENT, PROCEDURES, AND METHODS

A continuous seismic-profiling system mounted aboard a small tugboat was used to obtain the seismic records. The sound source was a sparker type having electrical storage capacitors which discharged a total of 450 joules through a multipoint electrode producing a fundamental frequency of 1000 Hz (hertz). Returning seismic energy was recovered with a 20-foot nonpreamplified hydrophone streamer with 11 crystal elements. Both the electrode and the first element of the hydrophone cable were towed about 100 feet behind the survey vessel, about 15 inches beneath the water surface and about 12 feet apart.

The recovered signals were filtered to pass the 300–1300 Hz band and then amplified. A wet-paper recorder graphically recorded the data at a 0.25-sec (second) sweep rate and 1.0-sec fire rate.

Seismic profiles were obtained along more than 500 nautical miles of track in the Nome nearshore area (fig. 3). The track lines were oriented roughly parallel and perpendicular to the coastline to form a grid with approximately a 1-mile spacing. Tracks parallel to the coastline were approximately 20 miles long, and most lines normal to the coast were 5 miles long, but four lines extended 10 miles out. Most of the tracks normal to the coastline begin about 400 feet offshore. The survey was made at an average speed of 5.7 knots over water 10–100 feet deep.

Sea-bottom multiples (reverberation of seismic energy between the sea floor and the sea-air interface) were very strong because of the shallowness of the water. These multiples, because of their harmonics and internal multiples (reverberation of seismic energy between two subsurface reflectors), complicated the records and made interpretation difficult; however, most reflectors in this study were between the sea bottom and the primary or first sea-bottom multiple.

All seismic reflectors picked were plotted on a general work map. The data were divided into surface (bottom) and subsurface (subbottom) features and transferred to three separate maps. Most of the recorded reflectors are discontinuous, and as a result correlation from one line to another was not successful until the final computation stage, when features recognized on the seismic records were related to bathymetric features, bottom samples, drilling results, and onshore geology.

Depths of reflectors were calculated using velocities of 4,900 fps (feet per second) in water and 6,000 fps in sediments; sound velocities in sediments at Nome have been obtained from Arne Junger (written commun., 1967) and from onshore seismic-refraction work (Greene, 1970a). No corrections were made for changes in sea level because lunar tides at Nome are generally less than 1.5 feet. Storm-surge seiches produce greater sea-level changes, at times 5 feet or more above or below normal sea levels, but we have no data upon which

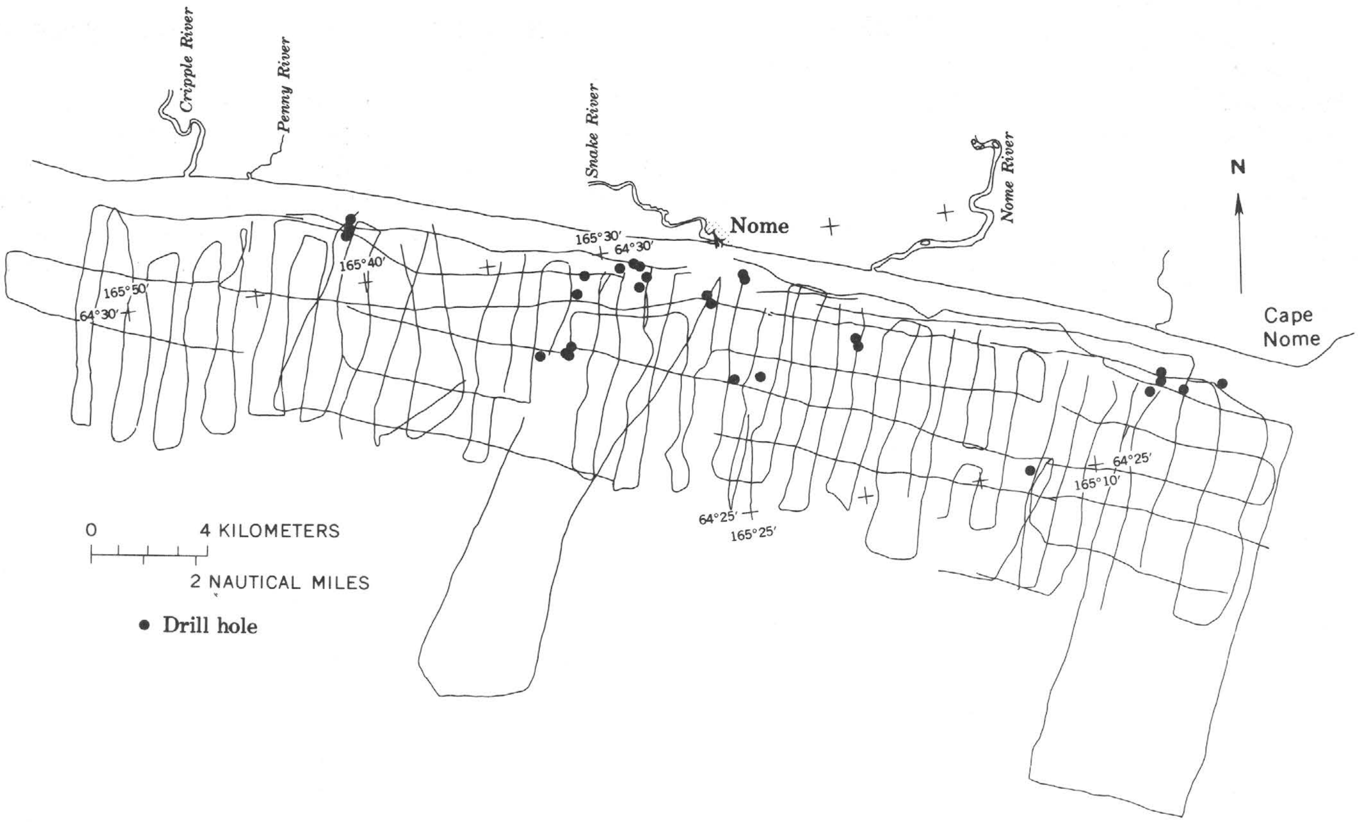


FIGURE 3. — Track chart of Nome nearshore seismic survey.

to base corrections for these effects, and most of the records were obtained during periods of good weather.

Bathymetric data were obtained from U.S. Coast and Geodetic Survey smooth sheets for the central part of the study area and from the seismic profiles elsewhere. Features observed on the sea floor offshore near Nome will be described in another report.

INTERPRETATION

Structures observed in the seismic records are divided into (1) surface and shallow subsurface and (2) deeper subsurface features. Surface and shallow subsurface features are defined here as those recognized on the seismic records, and they are expressed in the topographical relief of the sea floor. They may extend, as seismic reflection features, as much as 20 feet below the sea floor and include beach ridges, alluvial fans or deltas, and filled channels marked by depressions in the sea bottom. These surface and shallow subsurface features are shown in figure 4. Topographic expressions of the drift can also be seen in profile (fig. 11). Deeper subsurface structures are defined here as those features at depths generally more than 20 feet below the sea bottom; most do not affect the form of the sea bottom. Shallow and deep buried channels, acoustical sinks, and surface expressions associated with buried channels, where present, are shown in figure 5. Terminal moraines, recessional moraines, faults, and outcropping bedrock are shown in figure 6. Moraines and acoustical sinks (sound-absorbing layers which cause a signal loss) are shown on both the surface and the subsurface maps (figs. 4, 5, and 6).

SURFACE (SEA-FLOOR) TOPOGRAPHY

The present-day Nome offshore topographic features are a result of processes that have acted during the Pleistocene and Holocene. These features consist of beach ridges, fans, and surface channels.

BEACH RIDGES

Most beach ridges are defined in the seismic records by a gentle convex-upward profile, steepest on the seaward side and nearly flat on the landward side. Some beach ridges are acoustically transparent, but others show internal stratification consisting of beds that dip gently seaward beneath the steepest part of the surface profile (fig. 7); a few ridges show bedding that dips gently landward beneath the backshore slope. A strong reflector that can be correlated with the sea floor on either side of the beach ridge commonly extends beneath the ridge. Some features interpreted as beach ridges have a nearly symmetrical convex profile, equally steep on both the seaward and the landward sides, and may represent barrier bars.

All profiles of beach ridges are graded "good" or "poor" depending on sharpness of definition in the seismic record. Those rated "good" have distinct, sharp topographic profiles and clearly defined interior structure. Those rated "poor" have little surface expression and lack well-defined internal seismic characteristics.

Limits of the beach ridges are picked from points on the seismic records where the internal structures pinch out or where a distinct change in slope occurs on the sea floor. The backshore of many beach ridges is difficult to locate because of the absence of internal structures and the lack of distinct change in slope.

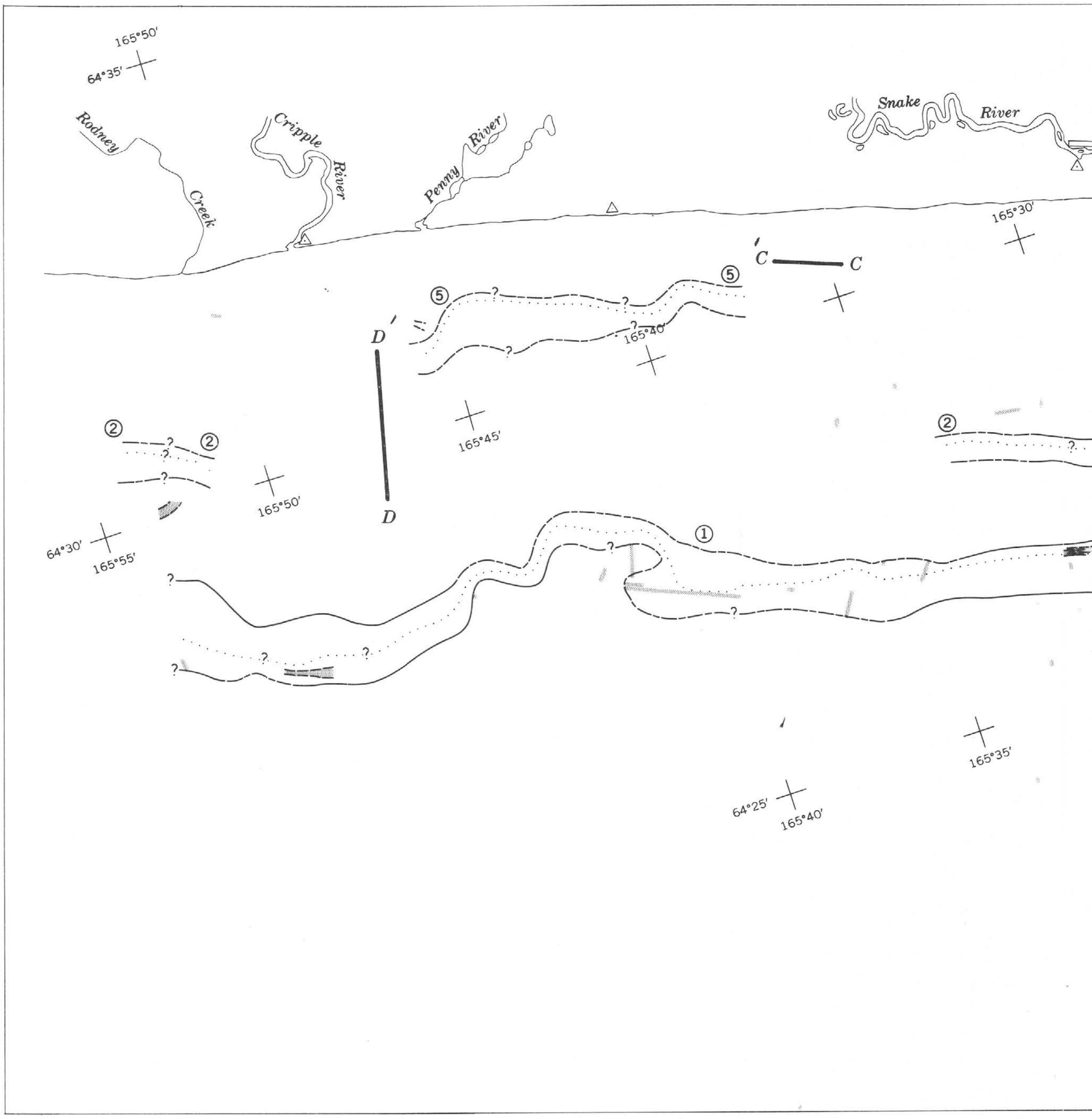
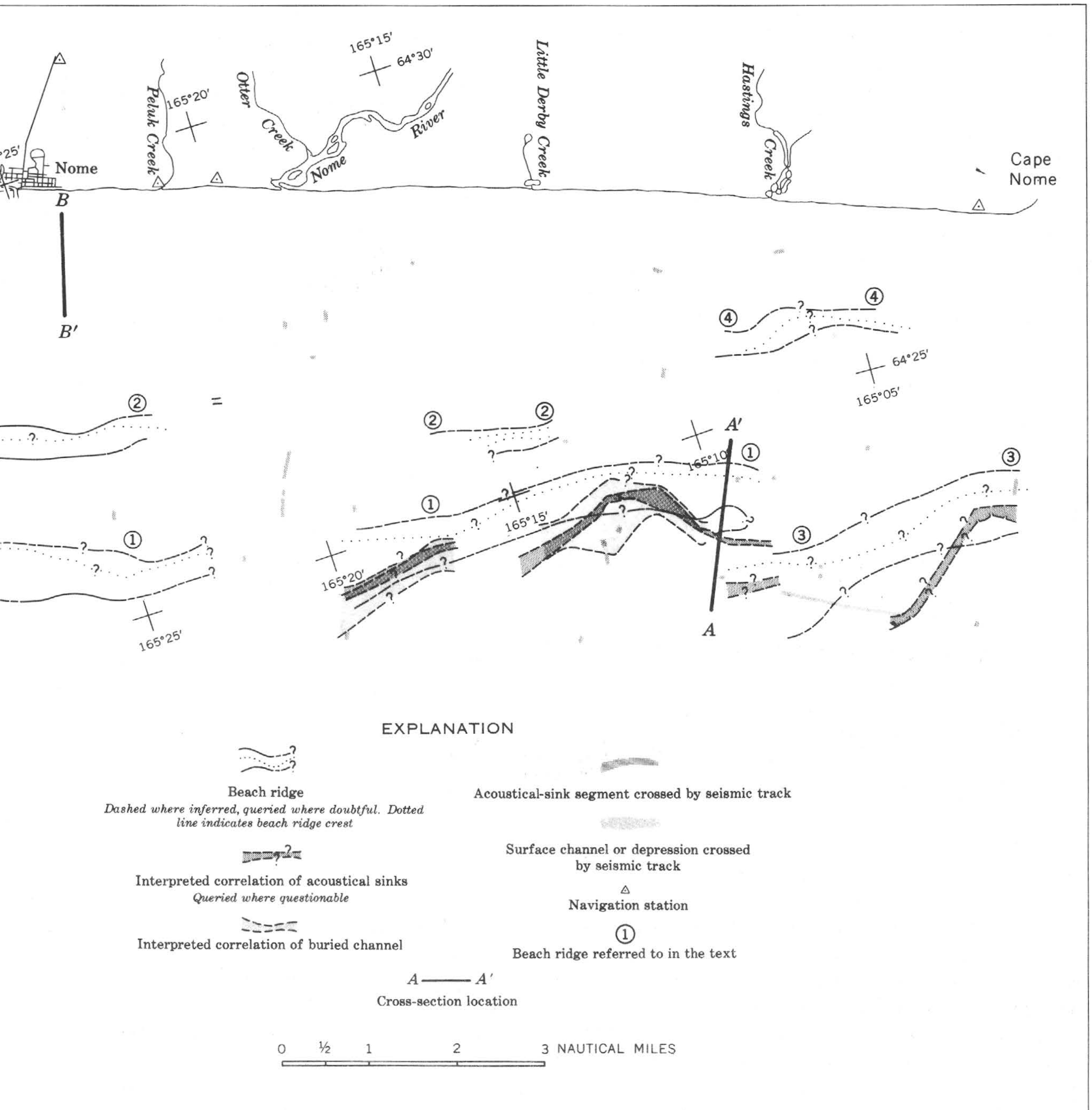


FIGURE 4. — Map showing surface and shallow

Bottom topography and samples were taken into account in determining widths of the beach ridges and their correlation from line to line.

Distribution. — Two major beach ridges were mapped; one lies at a water depth of 65–70 feet (indicated by a circled 2 in fig. 4) and the other at a water depth of 75–80 feet (indicated by a circled 1 in fig. 4). Two minor, smaller, beach ridges occur at the eastern limits of the survey area; one at a water depth of 85–90 feet (indicated by a circled 3 in fig. 4) and another at a water depth of 55–60 feet (indicated by a circled 4 in fig. 4). The −85- to −90-foot beach ridge lies approximately 4 miles offshore of Hastings Creek and is about three-fourths of a mile wide and at least 3 miles long; this beach ridge may possibly be an extension of the −75- to −80-foot beach ridge. Another minor beach ridge (indicated by a circled 5 in fig. 4)



subsurface features of the Nome nearshore area.

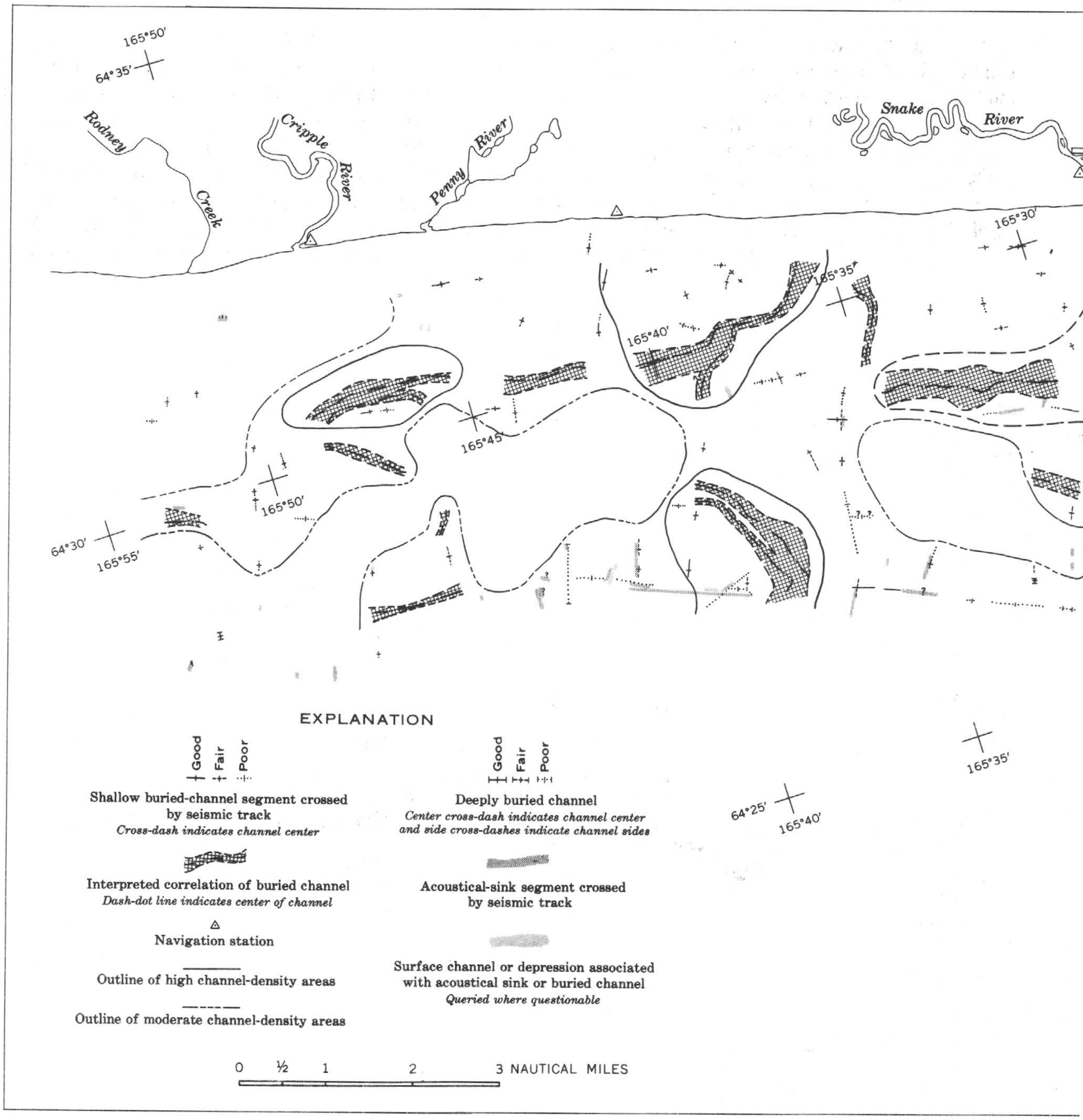
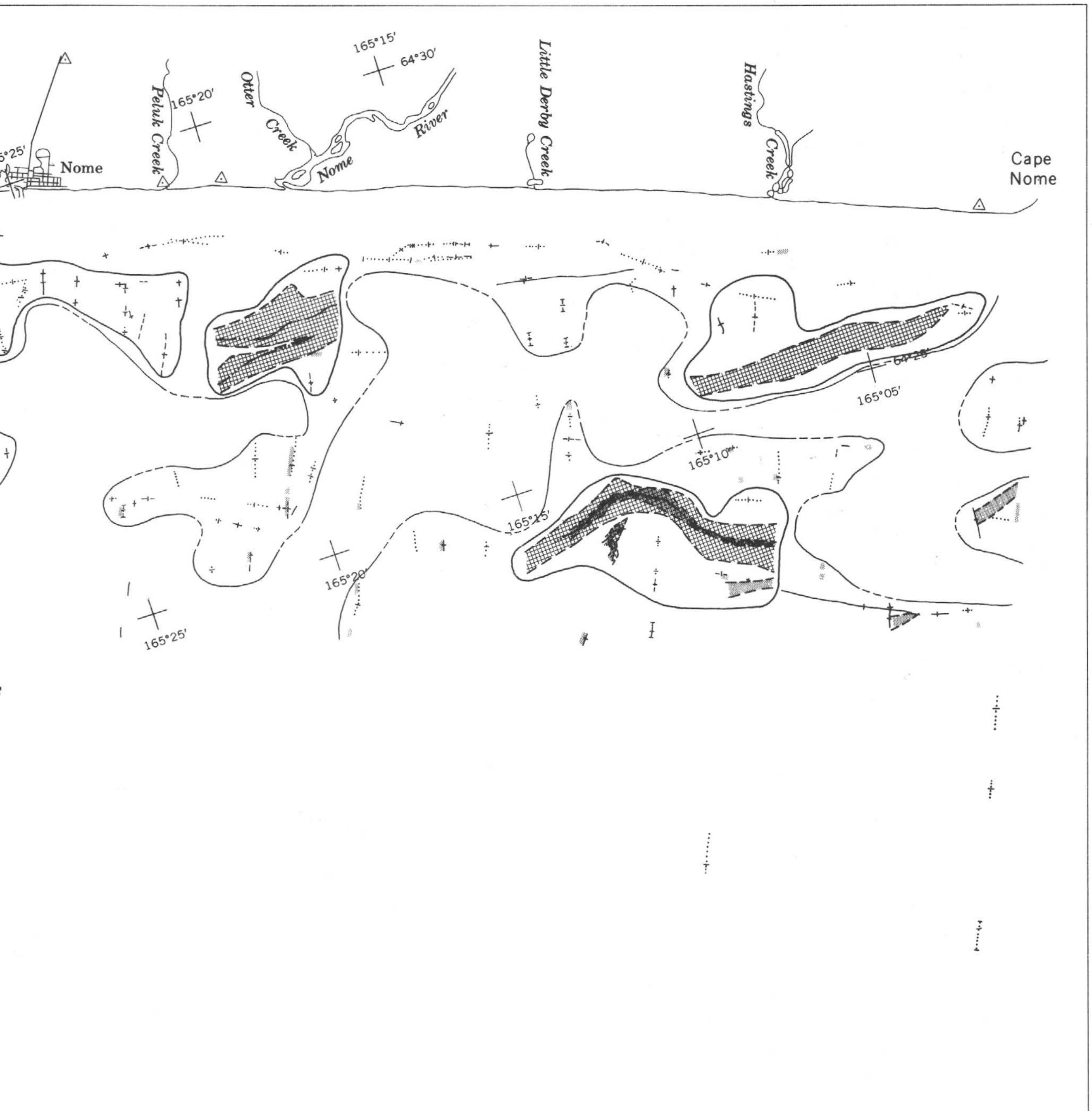


FIGURE 5.— Map showing deeper subsurface features of the Nome nearshore area.

occurs at a water depth of 45–55 feet about a mile off the Penny River and measures about 4½ by ½ miles. This ridge may be an extension of the −55- to −60-foot ridge of the eastern part of the survey area.

Stratigraphic position.— Because most of the beach ridges are expressed in the sea-floor topography and in the upper 20 feet of sediment, they are likely to be of late Pleistocene age. They probably represent stillstands during the Woronzofian (mid-Wisconsin) or Krustensternian (late Wisconsin and Holocene) transgressions discussed by Hopkins (1967).

Significance.— Beach ridges offshore are significant as possible sites of placer gold deposits, as the beaches onshore were mined for their placer gold during the Nome gold rush. Wave action concentrated a considerable amount of placer gold in the



onshore beach ridges and may have similarly concentrated placer gold in the offshore beaches. However, the shallow beaches offshore at Nome are not necessarily products of erosion of bedrock in the study area, and any included gold probably was derived from reworking of till in the nearshore or onshore area. Therefore, the most promising areas for offshore placer gold deposits are where beaches are carved in or rest on drift. Because of the eastward longshore drift (Greene, 1970b), nearby areas to the east of Nome fulfill such conditions and are likely sites of offshore placer gold deposits.

FANS OR DELTAS

Some geomorphic features observed in the bathymetry of the Nome offshore area appear to be alluvial or outwash fans, or deltas. Of the five fans first identified from the bathymetric data, two were recognized seismically in the subsurface. Sedimentological data (Nelson and Hopkins, 1972) and

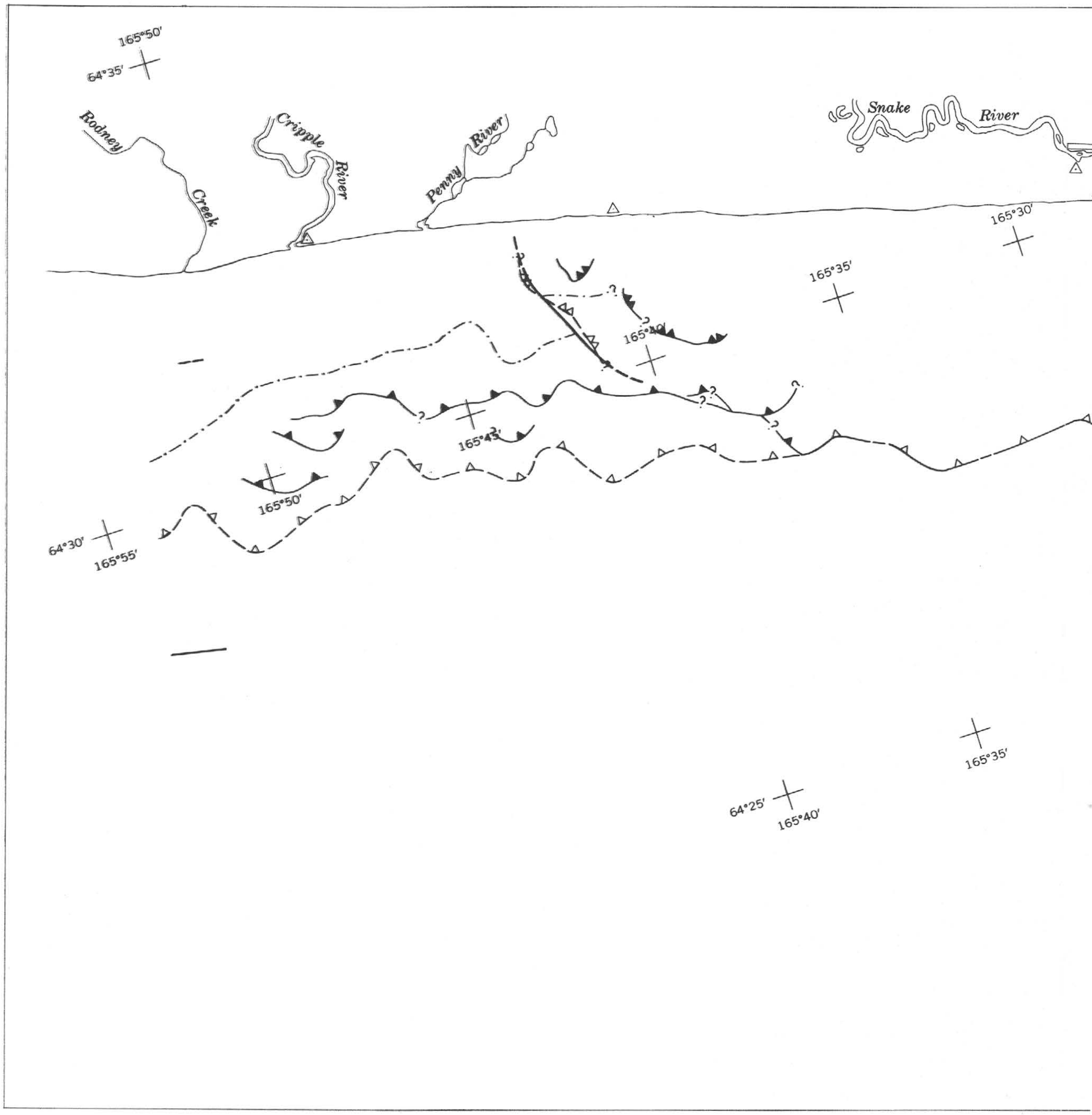
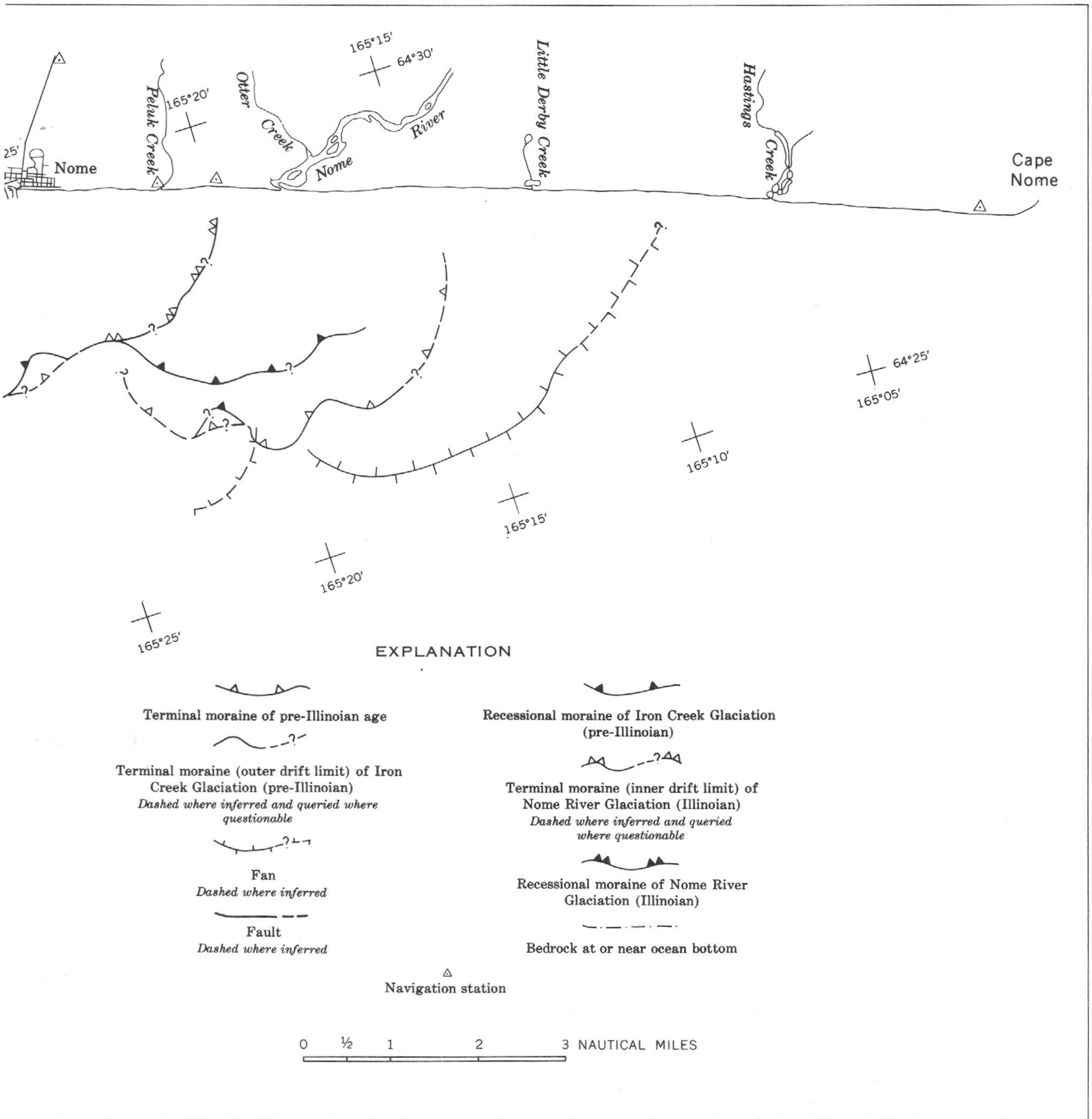


FIGURE 6. — Map showing shallower subsurface

bathymetric data (Tagg, unpub. data) also confirmed the two fans seen on the seismic records. These fan or deltalike features are characterized by thin beds that dip gently away from the shoreline (fig. 8). The reflectors are few, and none are more than 50 feet thick.

Distribution. — The three fans observed on the bottom-contour map but not in the seismic records have an average areal extent of 3½ miles. One fan is 2 miles west of the mouth of the Snake River (fig. 9). The apex of this fan is not visible and is truncated at the —40-foot contour about 1 mile offshore; the fan proper extends about 1 mile farther offshore, where its foot has been located at about the —54-foot contour.

The other two fans that were not seen on the seismic records are approximately 4½ miles directly off Nome; the inner fan appears to be superimposed



features of the Nome nearshore area.

over the other. The apex is not visible on the overlying fan, which is truncated near the —72-foot-contour; it extends about one-half mile farther offshore to the —30-foot contour. The apex of the lower fan is obscured by the overlying fan; its foot is on the —90-foot contour.

Both of the seismically identified fans occur offshore of the mouth of the Nome River (figs. 6 and 9). The first and largest fan lies a little south of Nome River and covers approximately 5 square miles. The apex of this fan is not well defined and appears to be truncated along the —40-foot contour about 1 mile offshore; the foot of this fan extends about 3 miles offshore, where it pinches out near the —70-foot contour. The second fan is much smaller and covers about 2 square miles south of Nome. The apex of this fan is also not well defined and appears to be truncated between the —60- and —70-

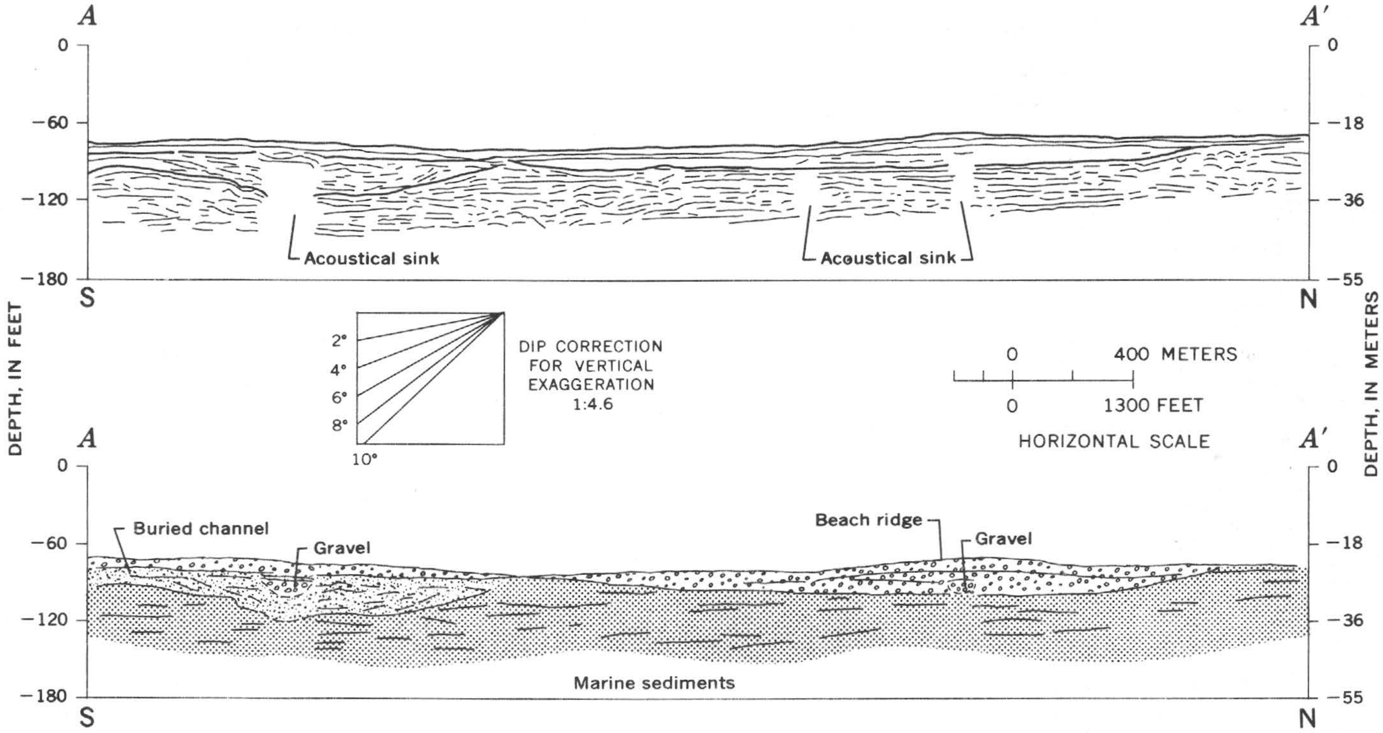


FIGURE 7. — Line drawing and geologic interpretation of seismic profile *A–A'* across a buried stream channel, beach ridge, and acoustical sinks. Location in figure 4.

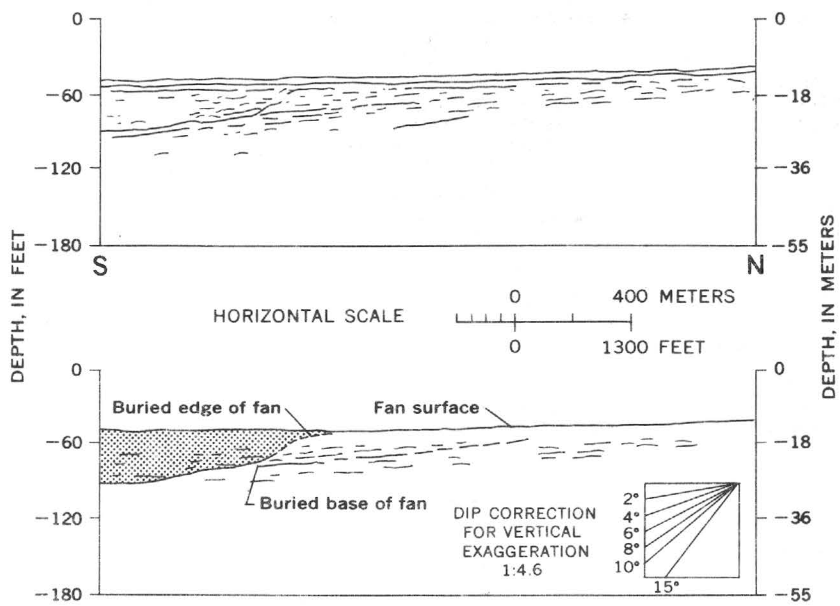
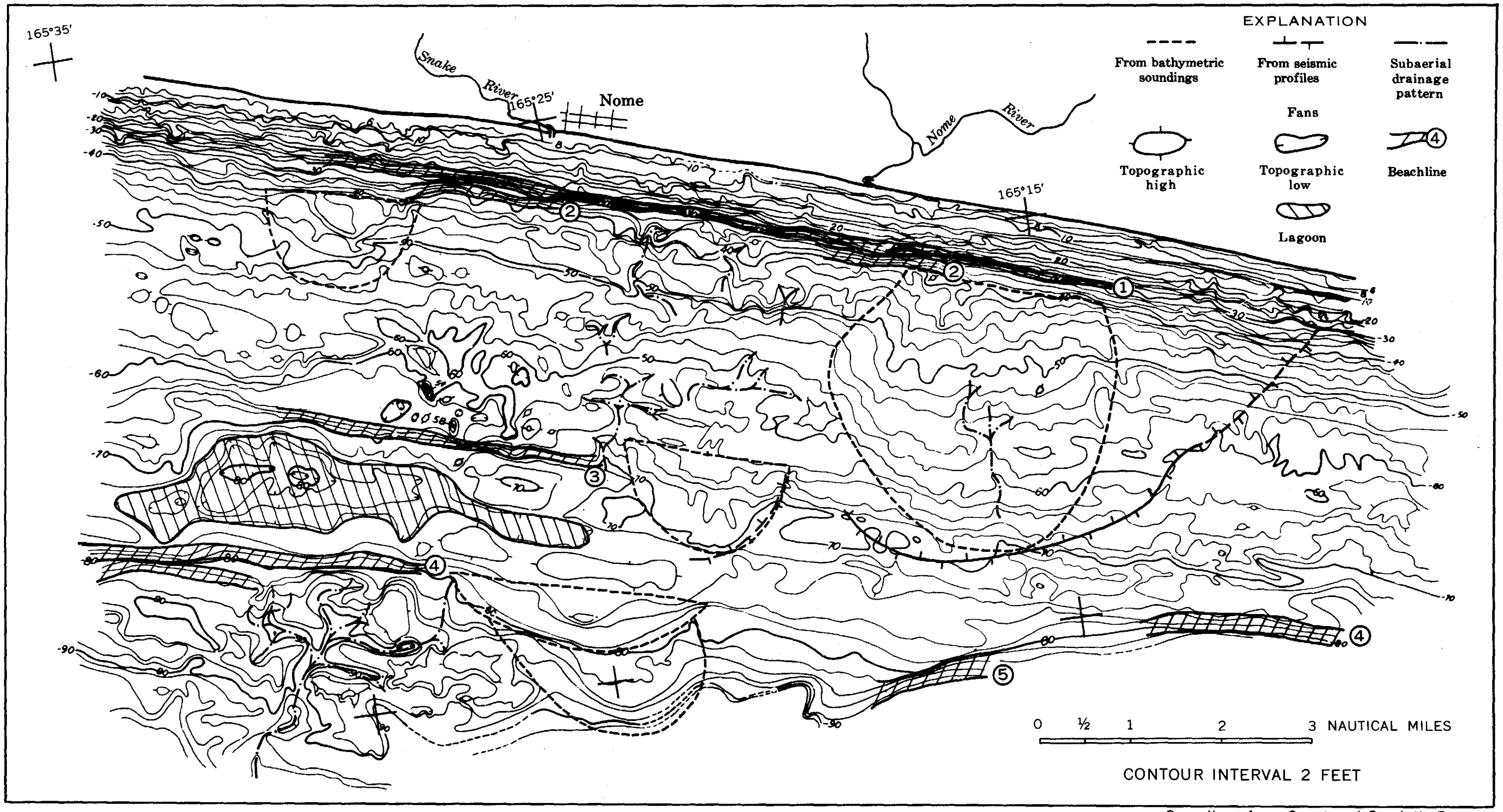


FIGURE 8. — Line drawing and geologic interpretation of a seismic profile across a fan.

foot bottom contours, about 2½ miles offshore. The foot of the fan pinches out near the —70 foot contour, about 3 miles offshore.

Stratigraphic position. — All fans or deltas in the Nome offshore area were probably developed during the Pleistocene or early Holocene. Sedimentological data and onshore geological evidence indicate an age of middle Pleistocene (Illinoian) for the large fan off the mouth of Nome River. A moraine of Illinoian age occurs behind Second Beach just on-



Soundings from Coast and Geodetic Survey
Contours by A. R. Tagg

Figure 9. — Map showing bottom topographic features off Nome.

shore of this large fan. Second Beach (post-Illinoian, Sangamon) sediments in a gravel-pit exposure overlie outwash derived from this Illinoian moraine. And offshore bottom-sample and drill-hole data indicate that a small tongue of alluvium is immediately offshore of the mouth of Nome River and overlies a large quantity of outwash that extends for several miles east and south of the alluvium (Nelson and Hopkins, 1972).

Significance. — Because fans are sites of aggradation, there is little opportunity for the repeated winnowing and reworking that is generally involved in the development of rich placer deposits. Even so, rivers and glaciers in the Nome region that have carried auriferous sand and gravel as part of their sediment load may have transported at least some of the finer gold to the fans or deltas offshore.

SURFACE CHANNELS OR DEPRESSIONS

Approximately 20 surface channels or depressions can be seen in the seismic profiles. They are characterized by a concave-upward profile in the surface of the sea floor (fig. 10).

Distribution. — Most of the surface channels are discontinuous, or at least cannot be correlated from one line to another and are scattered fairly evenly throughout the entire survey area. Surface channels can be correlated in only two locations, both offshore of Hastings Creek (fig. 5).

Association. — Many of the surface channels are associated with acoustical sinks and buried channels. In the area south of Hastings Creek, surface channels are associated with both acoustical sinks and buried channels. Another surface channel 5–6 miles west of Hastings Creek is associated with an acoustical sink (fig. 5).

Stratigraphic position. — Surface channels on the sea floor have sharp profiles that indicate a young, possibly Holocene, age. However, many of them are surface expressions of buried channels that have not been completely filled with Holocene sediments. Therefore, some surface channels may be of late Pleistocene age and may have formed when sea level was low during the Wisconsin Glaciation.

Significance. — Surface channels are significant in placer exploration because they mark sites of fluvial deposits that may contain concentrations of placer gold. Especially significant to offshore mining are those channels that are most extensive and associated with acoustical sinks and buried channels; these in particular indicate sites of fluvial gravel deposits. The best prospects for placer gold deposits in the submerged channels offshore of the Nome coastal plain are those channels cut either into bedrock or through auriferous Illinoian drift.

BURIED TOPOGRAPHY — SUBSURFACE STRUCTURES

Subsurface structures in the Nome offshore area are complex and consist mainly of a discontinuous

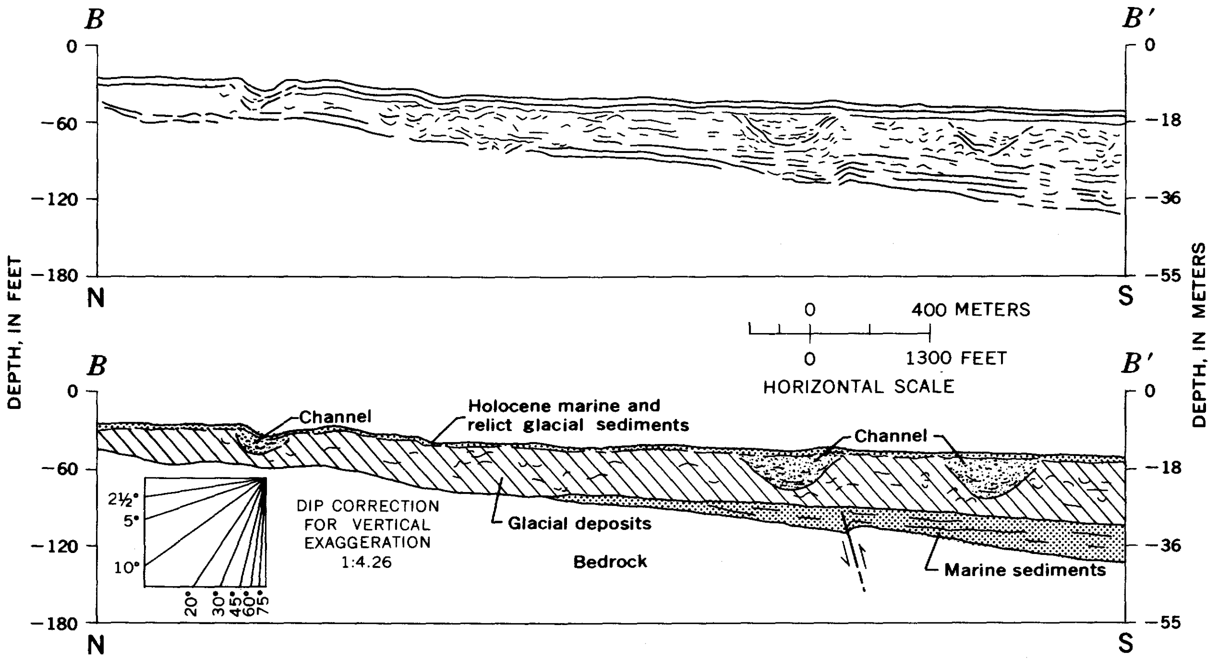


FIGURE 10. — Line drawing and geologic interpretation of seismic profile *B–B'* across buried channels at the mouth of Snake River at Nome.

Pleistocene drainage pattern, glacial deposits, and acoustical sinks. These buried features vary considerably in depth, indicating several stages of development.

BURIED CHANNELS

Most buried channels are well defined and exhibit characteristic features such as a concave-upward profile and an acoustically transparent or sometimes stratified internal structure (figs. 10, 11, and 12). Both shallow and deep channels can be identified in the seismic profiles. Shallow channels have sides truncated at or near the sea bottom (fig. 10); deep channels are overlain by sediments of variable thickness.

Shallow channels. — Shallow channels are plentiful in the Nome offshore area and are by far the dominant subbottom feature. Approximately 370 shallow channels are shown on the seismic records. Depths of the bottoms of these channels range from 12 to 150 feet beneath the sea bottom; average depth is 38 feet. Although most channels have a single symmetrically located low point, some are asymmetrical and a few have two low points divided by a low sill (figs. 11 and 12). The side walls of the shallow channels extend nearly up to the bottom surface and are usually covered by a thin veneer of sediment. Few channels can be correlated from one line to another; those that can be correlated trend parallel to the present coastline (fig. 5).

A buried extension of the Snake River that Greene (1970a) detected in refraction seismograms onshore at Nome is shown by the seismic-reflection records to extend offshore (fig. 11). The onshore and offshore channels have similar profiles that show a relatively shallow tributary on the east side separated by a small ridge from a deeper tributary on the west.

Deep channels. — Deep channels in the Nome offshore area are less common than shallow channels; only about 15 deep channels were identified in the seismic records. Bottom depths of the deep channels range from 36 to 115 feet beneath the sea bottom and average 72 feet. The top of the sides of these channels range in depth from 22 to 85 feet below the bottom and average 45 feet.

Channel density and distribution. — Most buried channels in the Nome offshore area are difficult to correlate. To find out if the poor correlation was due to the seismic-line locations, a facsimile of the offshore seismic grid was overlaid on a map of the onshore area of the Nome coastal plain, and positions where lines cut streams were marked. A poorly correlated pattern developed that was similar to the random pattern offshore. Outlined areas of greatest stream-channel densities from this onshore grid corresponded to outlines of known areas of stream and river courses. Therefore, areas of greatest channel densities were similarly outlined offshore, and the resulting general pattern is assumed to represent areas of stream and river courses (fig. 5) similar to those produced onshore. In many areas of high channel densities, a correlation from one line to another may be made with relative certainty.

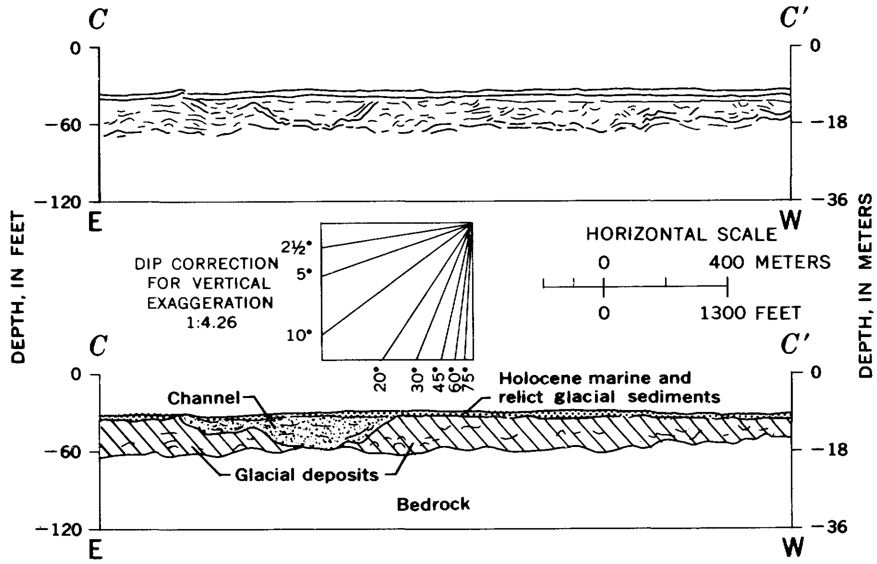


FIGURE 11. — Line drawing and geologic interpretation of seismic profile *C–C′*, across an ancestral channel of the Snake River.

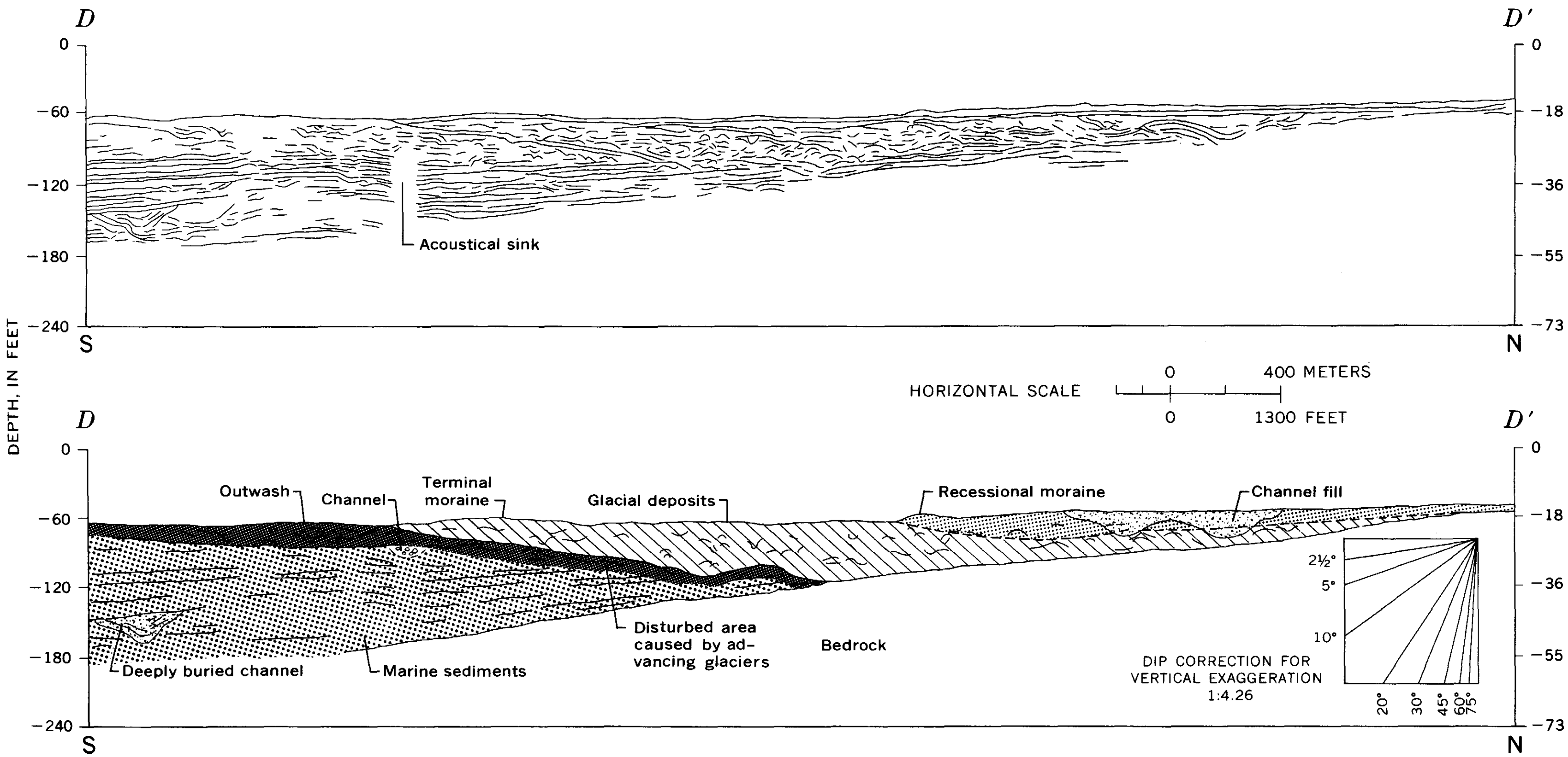


Figure 12.—Line drawing and geologic interpretation of seismic profile *D–D′*, across a terminal and a recessional moraine.

One possible reason for such a proliferation of discontinuous channels at Nome is the geomorphic province in which these channels developed. The onshore Nome area is a shallow seaward-dipping coastal plain that slopes 67 feet per mile (about ¾°). This slightly sloping plain contains an abundance of meanders, cutoffs, and oxbow lakes. Offshore, the sea floor and surficial sediments slope more gently at about 15 feet per mile (about ⅛°). Therefore, it is reasonable to assume that the same type of stream-channel development that exists onshore today existed offshore during the time the offshore channels were formed. The offshore subbottom drainage pattern most likely consists of buried meanders, cutoffs, and oxbow lakes that are shown as discontinuous channels in the seismic profiles.

In this report, areas with a significant number of buried channels are separated from areas with a general lack of channels (fig. 5). Within the region of buried channels, seven areas of high channel densities, as described above, are outlined. The criteria used to define these channel areas are (1) relative density of channels, (2) degree of development of the channel, and (3) good channel correlation from line to line.

Buried channels are distributed throughout most of the Nome offshore area. However, about 1 mile offshore is a mile-wide linear zone that generally lacks channels. And in the northwestern part of the area, where bedrock is closest to the surface, buried channels are uncommon.

Stratigraphic position. — Most channels are buried beneath 20 feet or more of Holocene sediments and are not normally detected deeper than 100 feet beneath the sea bottom. They probably formed during the Illinoian and Wisconsin Glaciations. The ancestral Snake River channel is an exception, as it is covered by Illinoian drift and is therefore of pre-Illinoian age (Hopkins, written commun., 1969).

Significance. — Buried channels are important sites for concentration of heavy minerals. In the Nome onshore area, large amounts of placer gold have been recovered from them. Offshore buried channels probably also contain quantities of detrital mineral deposits, especially in the nearshore area.

ACOUSTICAL SINKS

An area in which a weak reflected seismic signal is received is here called an acoustical sink (figs. 7 and 12). The prime characteristic of an acoustical sink is acoustic opacity which means that most of the seismic energy is absorbed or scattered and little or no signal is returned to the surface.

Distribution and density. — Seismic records in the Nome offshore area exhibit 81 acoustic sinks: 58 in the eastern half of the survey area and 23 in the western half. Sinks tend to be scattered instead of concentrated. The highest concentration and correlativity of acoustical sinks are within the area 4 miles off Hastings Creek (figs. 4 and 5). Many sinks in the Nome offshore can be correlated between lines. In the eastern half of the survey area, 24 sinks are correlated, compared with 4 in the western half. Some acoustical sinks, though usually identified as gravel fill in buried channels, may be gravel in beach ridges. Gravels are a common constituent in the present-day beaches of the area and have been noted, for instance, off Point Hope by Creager and McManus (1966), closer to Nome, off Port Clarence in the Bering Strait, by Hopkins (1967), and at Nome by Greene (1970a).

Significance. — Association of the acoustical sinks with buried channels and beach ridges suggests that stream-and-wave-deposited materials absorb scatter of the seismic energy. Therefore, acoustical sinks are interpreted here to be the result of scattering seismic energy by gravels associated with buried stream channels and beach ridges. Because detrital deposits of heavy minerals, especially gold, are concentrated in coarse-grained stream and beach deposits, acoustical sinks are significant features that may help locate these deposits.

Stratigraphic position. — The acoustical sinks are the same age as the Pleistocene buried stream channels and beach ridges with which they are associated.

GLACIAL DEPOSITS

Glacial deposits extend 3–4 miles offshore at Nome and from about 1 mile east of the Nome River to the western limits of the survey area (fig. 6). These deposits are the most extensive of the offshore deposits and cover approximately 30 square miles.

Glacial drift is represented in the seismic records by highly distorted reflectors that often show hummocky internal structures and intraformational folding and faulting and that strongly reflect or scatter seismic energy. A very strong reflector at what appears to be the base of the glacial drift bends upward at the drift limit and is truncated by the ocean bottom (fig. 12). This reflector is concave seaward, away from the main body of the drift. Thin tightly folded marine beds commonly abut the outer edge of the drift at depth and appear to have been compressed by the overriding glacier (fig. 12).

The drift is thickest, 100 feet or more, near its outer limit. The drift limits, shown in figure 6, appear to be terminal moraines (fig. 12). Seaward of the terminal moraines, marine sediments overlap the drift. Thinly bedded sediments, probably glacial outwash, dip gently seaward from the terminal moraine. Landward of the drift limits, the glacial deposits become thinner and are covered by a thin veneer (20 ft or less) of marine sediments.

After glacial deposition, transgressions of the sea altered, reshaped, and locally destroyed glacial features. Outwash and other glaciofluvial deposits have distorted the original glacial structures, making interpretation of glacial features difficult.

Distribution. — The terminal moraine that lies farthest offshore at Nome, here called the "outer drift limit," appears to continue unbroken from the western limit of the survey area to just offshore of the mouth of the Nome River, where it becomes less distinct and appears to die out. A moraine better defined on the seismic records lies seaward of the outer drift limit off the mouth of the Nome River (fig. 6). This moraine is probably an extension of the outer drift limit, which has been distorted or obliterated in the area just offshore of the town of Nome; the weaker moraine feature landward is probably a recessional moraine. The outer moraine, probably an extension of the outer drift limit, bends landward approximately 1 mile east of the mouth of Nome River. The moraine that bends shoreward just west of the mouth of the Nome River may possibly be a younger terminal moraine. Buried channels and fan deposits distort the subbottom features in the area offshore of the Nome River.

Several weakly defined morainelike features in the western part of the survey area are probably recessional moraines. These features generally have the same seismic characteristics as the outer drift limit except that relief and definition in the subbottom are subdued. Drift features in the western nearshore area, just inshore of the most continuous recessional moraine (fig. 6), appear to consist of a younger terminal moraine, here called "inner drift limit," and a recessional moraine. Recessional moraines between the inner and outer drift limits in this western part of the survey area seem to indicate at least three stages of glacial stability or readvances (fig. 6).

Stratigraphic position. — Deposition of glacial drift in the Nome offshore area probably took place during the glacial advances of early to late Pleistocene time. The outer drift and its associated recessional moraines were most likely formed during the Iron Creek Glaciation. The inner drift must be younger than the outer or it would have been destroyed; hence, the inner drift and its recessional moraines are probably Illinoian in age and most likely represent the Illinoian glacial maximum.

Data from drill holes just shoreward of the inner drift limit off the mouth of Penny River show two layers of till separated by a layer of marine sediments. These data suggest that the inner drift limit represents the Illinoian Glaciation and is younger than the outer drift limit.

Significance. — Illinoian glaciers scoured deeply into highly mineralized bedrock in the interior areas of the Seward Peninsula and probably crossed over auriferous gravels during their advance to the sea.

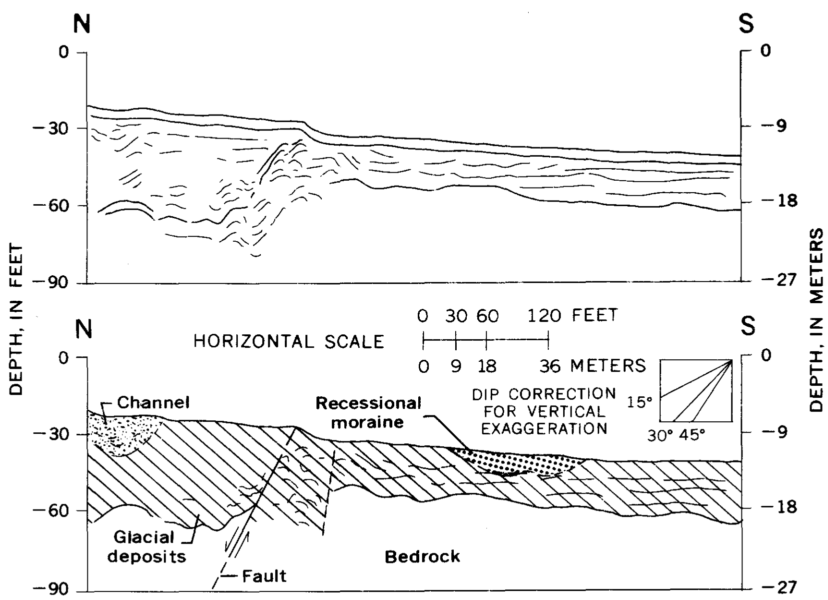


FIGURE 13. — Line drawing and geologic interpretation of a seismic profile across the large bedrock fault zone east of Penny River.

Auriferous material eroded by the glaciers was carried away from the source areas and deposited as glacial drift on the coastal plain. Considerable amounts of this material were deposited in terminal, recessional, and lateral moraines. Those morainal features that were subject to wave and current action during transgressions most likely lost fine constituents through winnowing, and their coarse constituents were left as lag deposits.

FAULTS

Several faults are shown by the seismic records, but only three are defined well enough to map (fig. 6). Two of the three faults are very small; one displaces only the sediments overlying bedrock, and the other both bedrock and sediments, and has a 3- to 4-foot scarp on the ocean bottom. The third fault displaces bedrock and the overlying sediment and has an apparent displacement of about 15 feet and a 4- to 6-foot escarpment on the sea floor (fig. 13).

Significance. — It has not been determined what relation, if any, faults in the Nome offshore area may have to the offshore placer gold deposits. Mineralization may have taken place along fault planes in the bedrock, as in the Anvil Creek fault. Faults may elevate bedrock to a level where its surface can be worked by offshore mining equipment, or they may create natural catch basins for heavy minerals.

BEDROCK

An acoustical basement is well defined in many seismic records of the Nome offshore area. The acoustical basement at Nome represents a metamorphic bedrock that, onshore, consists of deformed Paleozoic schist and limestone (Collier and others, 1908, p. 149; Hummel, 1962a, b). Bedrock was only mapped in areas where it cropped out on or closely approached the sea floor (fig. 6).

Distribution. — Bedrock crops out in the northwestern part of the survey area. A line representing points where the bedrock surface is truncated at the sea bottom is shown in figure 6. It angles toward the coastline for about 5 miles eastward from the western limit of the survey. About 2 miles southeast of Penny River the bedrock surface is displaced by a fault. Landward of the mapped bedrock-outcrop line, bedrock is exposed on the sea bottom or is covered with a thin veneer (less than 12 ft) of Holocene sands and gravels.

Significance. — Bedrock depth and surface configuration are significant in offshore placer mining because detrital heavy minerals often concentrate on bedrock surfaces, particularly in small pockets or depressions. Also there is some possibility of finding lode gold in the bedrock or of enrichment of placer deposits from bedrock sources.

SUMMARY AND CONCLUSIONS

In the Nome offshore area, subbottom features, most of which were formed between early and late Pleistocene time, consist of stream channels, glacial deposits, and acoustical sinks. On the bottom and at shallow depths below the bottom, features, most of which were formed during late Pleistocene and Holocene time, consist of beach ridges, surface channels, and acoustical sinks.

The outer terminal moraine and associated recessional moraines were probably deposited by glaciers of the Iron Creek Glaciation and then eroded, reshaped, and covered by marine sediments during the Anvilian, Einahnuhtan, and Kotzebuan transgressions discussed by Hopkins (1967). During Illinoian time advancing glaciers of the Nome River Glaciation eroded older marine sediments, onshore and nearshore in the area west of Nome, and deposited glacial detritus that makes up the inner terminal moraine and associated recessional moraines. The outer and inner drift limits represent glacial maxima of the Iron Creek (pre-Illinoian) and Nome River (Illinoian) Glaciations, respectively. Also, during Illinoian time, a large outwash fan was formed at the terminus of a Nome River Glaciation ice lobe in the nearshore area east of Nome. The other four fans seen in the offshore area formed either from outwash of glacial ice lobes similar to the one that constructed the large Illinoian outwash fan or as deltas during the Pelukian, Woronzofian, or Krusensternian transgressions.

The buried Pleistocene drainage pattern that is prominent in the subbottom of the Nome offshore area probably developed during the latter parts of the Illinoian and Wisconsin Glaciations, when sea level was lower and the area south of the present Nome coastal plain was exposed to erosion. Streams and rivers fed by glaciers nearby were near base level during this time, and the drainage pattern consequently consisted of meandering streams with cutoffs and oxbow lakes. Some of the channels were not filled by sediments of the Krusensternian transgression and appear as discontinuous surface channels on bathymetric charts. Other channels were partly filled by coarse detritus carried from the terminus of glaciers and appear as acoustical sinks in the seismic records. Fine-grained marine sediments covered the coarse detritus filling the channels, leaving no surface expression.

The last major geologic event to affect the Nome offshore area was the Krusensternian transgression of late Pleistocene to Holocene time, during which at least three offshore beach ridges developed, representing sea-level stillstands. Some of the beach ridges may have formed as long ago as the Pelukian (Sangamon) transgression. In late Pleistocene time sea level rose to between −90 and −75 feet, where it remained long enough to form the outer beach ridge. In latest Pleistocene or earliest Holocene time, possibly during Woronzofian (mid-Wisconsin) transgressions, sea level rose to form the −65- to −70-foot beach ridge. The last stillstand of the Krusensternian transgression was later in the Holocene time and formed the inner beach ridge between −45 and −60 feet.

Nelson and Hopkins (1972) have shown that the glacial drift offshore of Nome is generally covered by a thin boulder-rich lag deposit and is commonly auriferous. This lag deposit was formed by wave erosion during the Pelukian, Woronzofian, and Krusensternian transgressions.

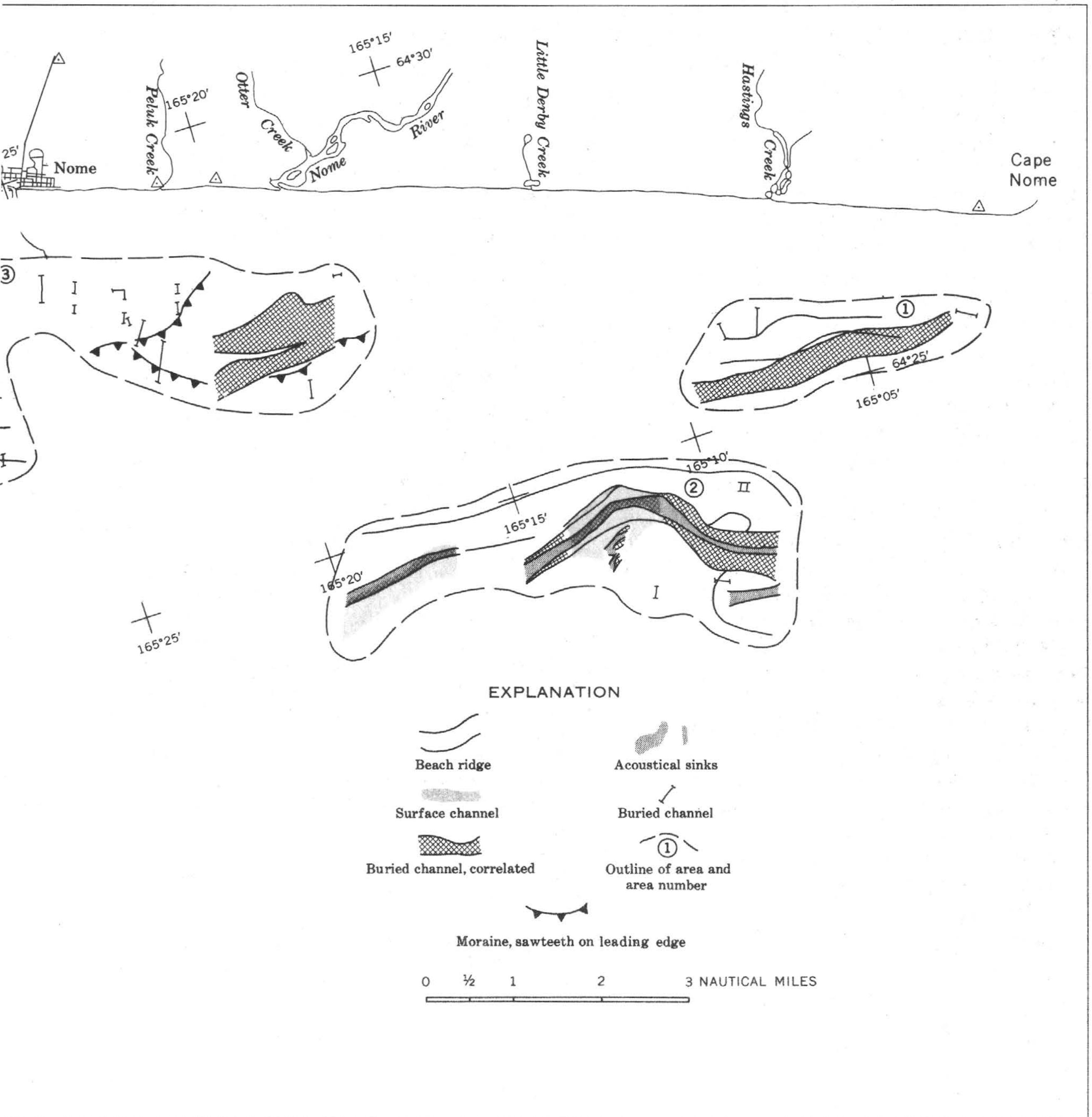
FIGURE 14. — Map showing six offshore areas of possible

A thin veneer of marine sediments laid down during latest Holocene time covers bottom features in the Nome offshore area. This veneer consists of mud, sand, and gravel and, in places, ice-rafted boulders. The swift, predominantly eastward longshore current keeps the sediment cover thin.

Truncation of bedrock in the western Nome nearshore area probably began in middle or late Pliocene time, when subsidence of Norton Basin decreased. However, erosion and beveling of the truncated bedrock surface continued during the Iron Creek and Nome River Glaciations and throughout the many transgressions that affected the Nome offshore area.

Two faults offset both the overlying sediments and bedrock. This indicates that the faults have had late Pleistocene movement.

Many of the structures — fans, ridges, and channels — in the bottom and subbottom Nome offshore area may contain concentrations of detrital heavy minerals. Beach ridges and buried stream channels



concentration of placer gold and other heavy detrital minerals.

tend to have heavy minerals concentrated by waves and currents. Deposits of coarse-grained sediments in beach ridges and buried channels are particularly important sites for potential placer gold deposits.

Glacial drift deposits in the Nome offshore area may contain small quantities of placer gold. Glaciers that deposited material on the Nome coastal plain crossed mineralized bedrock and auriferous stream channels as they advanced across the Seward Peninsula toward the Bering Sea. The highest concentrations of gold should be in the marginal and terminal moraines, especially where gold in these moraines has been concentrated by wave and current action during marine transgressions.

Since bedrock in the Nome area is the source of the placer gold, it may indicate the location of placer deposits offshore. In the western part of the Nome offshore area, bedrock crops out at the sea bottom and could possibly be supplying small quantities of gold that may be concentrated and deposited to the east by the longshore current. In addition, bedrock exposed elsewhere at various earlier times may have contributed to gold deposits.

A map showing six offshore areas of possible concentration of placer gold and other heavy detrital minerals was constructed from seismic-reflection data (fig. 14). Criteria for delineating these areas are (1) the presence of more than one feature that may contain concentrations of placer gold (that is, a beach ridge and a buried channel), (2) high density of buried channels, having good correlation from one seismic track to another, (3) high density of acoustical sinks, associated with either beach ridges or buried channels, and (4) the presence of drift close to beach ridges.

The first area is about 1½ miles off Hastings Creek and contains a beach ridge and a well-correlated continuous buried channel; both of these features lie east of the mouth of the Nome River, where small amounts of placer gold may be present in the Illinoian terminal moraine onshore (fig. 14). The second area is about 3½ miles off Hastings Creek and contains a beach ridge and correlatable surface and subsurface channels that are associated with acoustical sinks. Area three, off Nome, contains several buried channels and acoustical sinks; most of the buried channels are correlatable (fig. 14). Drift limits and recessional moraines are close to each other in this area, and small quantities of gold from the glacial drift may have been concentrated by wave action and deposited in the beach ridge. Area four, which touches shore west of Nome, contains a well-correlated extension of the buried Snake River channel, which passes through an area onshore that is known to contain significant gold, and also contains a beach ridge that is close to a terminal and recessional moraine. Area five, about a mile farther offshore, contains a beach ridge associated with several correlatable acoustical sinks and correlatable buried channels. Area six is off the Cripple River and contains correlatable buried stream channels and a beach ridge close to terminal and recessional moraines. However, the most important reason for outlining this area is that bedrock crops out on the sea bottom to the east and may be supplying gold to this area.

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