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

By

A. R. Tagg and H. G. Greene

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

A. R. Tagg and H. G. Greene

Abstract

A high-resolution seismic survey was made south of Seward Peninsula in Norton Sound, Alaska, during the summer of 1967. The area investigated extends 10 miles east and west of the town of Nome and about 10 miles offshore. The objective of this survey was to identify sites of possible offshore gold concentrations.

Interpretation of the seismic records was confined primarily to the portions 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 sub-bottom 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. Sub-bottom features include many buried stream channels, areas of glacial drift, and at least three shallow faults. Also noted were acoustical "sinks" that are thought to be gravels associated with buried stream channels and beach ridges.

Introduction

This report describes and interprets features seen on high resolution seismic profiling records and bathymetric charts in the Nome area and discusses their possible significance as placer-gold exploration sites. It is based upon a continuous seismic reflection survey conducted in the summer of 1967. The investigation was conducted jointly by the U.S. Geological Survey's Office of Marine Geology and Hydrology and the U.S. Bureau of Mine's Marine Minerals Technology Center. The 1967 studies also included ocean bottom drilling of some of the sites chosen on the basis of the survey described here, as well as sampling of the sea bottom and modern beach, and geologic studies onshore.

Interpretation of the continuous seismic profiles was shared by the U.S. Geological Survey and the U.S. 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 and will be reported elsewhere (Staff, U.S.B.M., in press). Described here are the shallower reflectors, probably all of Quaternary age, that extend to depths of less than 150 feet below the sea bottom. Information obtained 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 located offshore from Nome, Alaska, in the northwestern portion of Norton Sound, an embayment of the northern Bering Sea (Fig. 1). The area extend 10 miles east and west of Nome from Cape Nome to Rodney Creek, and up 10 miles offshore.

Previous Investigation

Several reconnaissance seismic reflection studies, both shallow and deep, have been made of the Bering Sea. D. G. Moore (1964) discusses the results of a high resolution, shallow seismic reflection survey of parts of Bering and Chukchi Seas. D. W. Scholl and others (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. The U.S. Bureau of Mines (Staff, U.S.B.M., written commun.) have made a study of the deeper reflectors, mostly of Tertiary age, displayed in the seismic records of the joint 1967 survey at Nome.

Acknowledgments

We wish to thank Warren Woodward and Arthur Daily of Shell Oil Company; Ralph Saleski, John Fagerstrom and Ben Herman of the U.S.

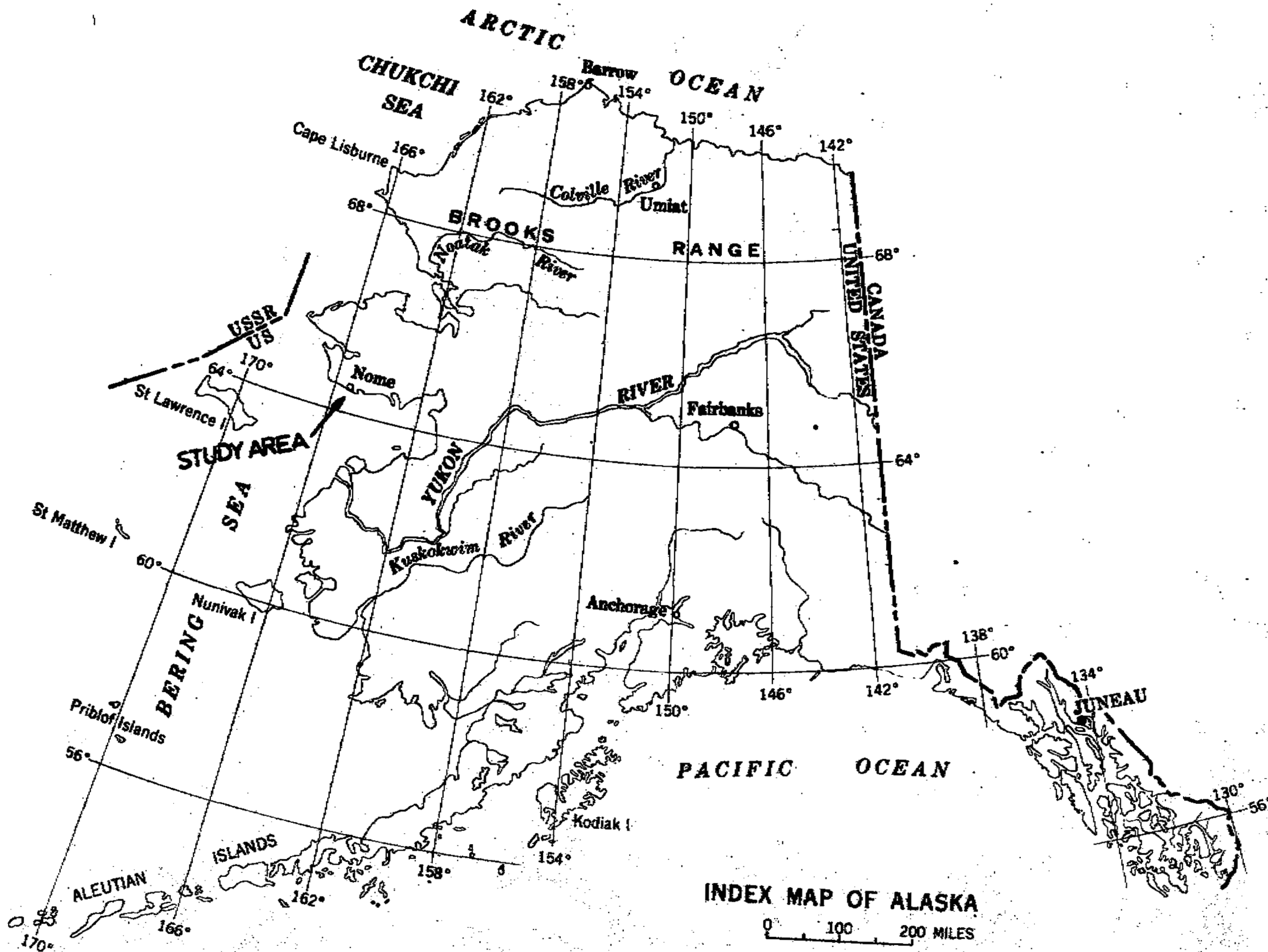


Figure 1. Index map of Alaska with Location of Study Area.

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 field work.

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 cross section of the Nome coastal plain are shown in Figure 2. Five sets of shoreline deposits are recognized onshore and are locally known as Submarine Beach, Fouth Beach, Third Beach, Monroeville Beach, Intermediate Beach and Second Beach. They were produced during five different sea level stands in late Pliocene and Pleistocene time (Hopkins, 1960, p. 46). Submarine Beach, Intermediate Beach, and Second Beach are separated from one another by glacial drift of the Iron Creek (pre-Illinoian) and Nome River (Illinoian) glacial stages. 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, wind-blown silt, and peat of Wisconsin and Holocene age.

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

TOP

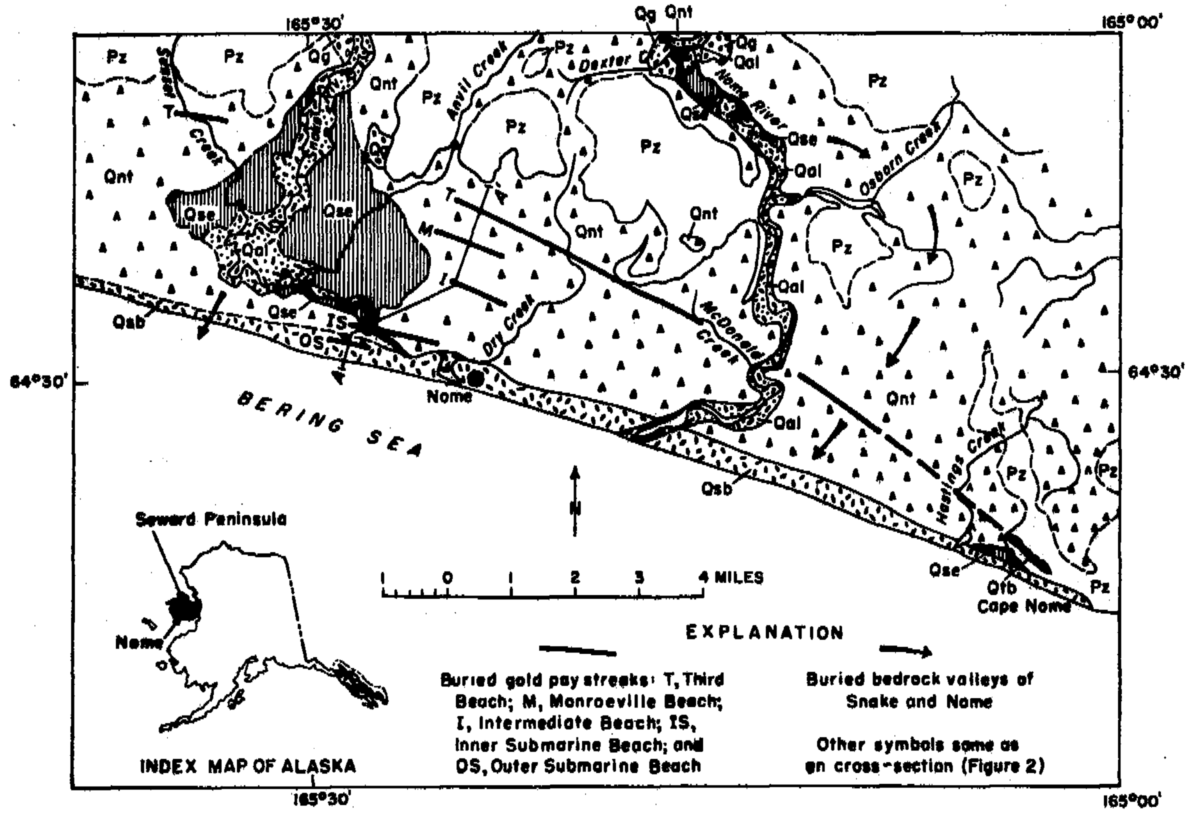


Figure 2A Generalized geologic map of the coastal plain at Nome.
After Hopkins, 1960

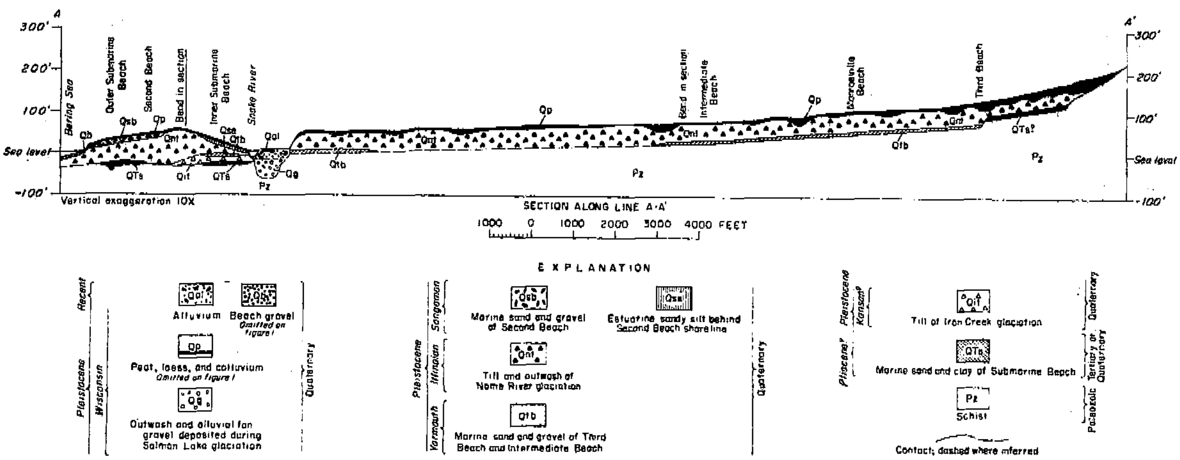


Figure 2B Cross section through the coastal plain at Nome along line AA', figure 2A.

After Hopkins, 1960

The oldest offshore beach deposit is recognized in the subsurface just offshore, west of the mouth of Snake River (fig. 2). This buried beach, however, lies beneath water too shallow for continuous seismic profiling, and was recognized as a result of compilation of borehole date 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 molluskan 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 onshore at Nome are locally called "Inner" and "Outer Submarine Beach", and lie at depths of -35 and -20 feet in the area between the lower course of Snake River and the present shore. The submarine Beach complex rests on bedrock in some places and upon 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 4 lithologic units: drift of the Iron Creek Glaciation of early Pleistocene age; a layer of fossiliferous marine sand and gravel; till and outwash of the Nome River Glaciation of Illinoian age; by marine sediments of Second Beach of Sangamon age (fig. 2). Mollusks and pollen in the marine layer between the two drift sheets suggest that it 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 these transgress onto bedrock beneath the Nome River Drift (MacNeil and others, 1943).

The Bering Sea, a shallow epicontinental shelf sea, was most likely emergent to late Tertiary time. Crustal warping then created the present marine Norton Basin which is partially 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). The bedrock surface beneath Norton Basin is erosional but has been steepened by tectonic subsidence during the development of the basin. The bedrock surface beneath the Nome coastal plain slopes rather smoothly seaward at a gradient of about 25 to 35 feet per mile, but just offshore, the gradient steepens abruptly to 130 to 230 feet per mile (Staff, U.S.B.M., in press).

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 wedge out against the basement reflectors several miles offshore from Nome (fig. 10) (Scholl and Hopkins, 1969). Paleographic reconstructions suggest that the Norton Basin was first invaded by the sea in late Miocene time (Hopkins, 1967, p. 454). Marine clay with fossils of early Pliocene age was encountered 3 nautical miles offshore 240 feet below the sea bottom in one of the 1967 drill holes located about three miles off the mouth of the Nome River (J.A. Wolfe, written commun., 1968).

Seismic reflection profiles of 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; Staff, USBM, written Commun.). This unconformity may correspond in time to the abrupt chane 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 bureid beaches which have been important gold producers onshore. 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 accompained by glacial invasions beyond the present shoreline i.e., Nebraskan (First) or Kansan (Second), and Illinoian (Third). Either or both of these may have carried placer gold offshore from existing onshore lode or placer deposits.

The Nome area has produced some 5,000,000 ounces of placer gold from 1897 through 1964, according to an unpublished compilation by A. H. Daily (mining engineer, Oakland, California, 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, Monroevill Beach, Third Beach, and Fourth Beach all contained productive placers that are richest in their western portions and attenuate in value eastward. Net longshore drift on the modern beach is eastward (Greene, 1970b), and judging from locations of mined areas eastward drift probably predominated along the older shorelines as well.

Equipment, Procedures and Methods

A continuous seismic profiling system mounted aboard a small tug was used to obtain the seismic records. The sound source was of a sparker type with electrical storage capacitors discharging a total of 450 joules of energy through a multi-point electrode producing a fundamental frequency of 1000 Hz. A 20-foot, non-pre-amplified hydrophone streamer with 11 crystal elements was used to recover returning seismic energy. Both the electrode and the first element of the hydrophone cable was towed about 100 feet behind the survey vessel at a depth of about 15 inches beneath the surface and about 12 feet apart.

The recovered signals were filtered to pass the 300 Hz to 1300 Hz band and then amplified. A wet paper recorder was used to graphically record the data at a 0.25 sec sweep rate with 1.0 sec fire rate.

Seismic profiles were obtained along 527 miles of track in the Nome offshore area (fig. 3). The track lines were oriented roughly parallel and perpendicular to the coast line to form a grid network with approximately a one mile spacing. Tracks parallel to the coast line are approximately 20 miles long and most lines normal to the coast are 5 miles long, but 4 lines extend 10 miles out. Most of the tracks normal to the shoreline begin about 400 feet offshore. The survey was made at an average speed of 5.7 knots over water ranging from 10 to 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, with their harmonics and internal multiples (reverberation of seismic energy between two subsurface reflectors) complicate the records and make interpretation difficult, however, most reflectors picked in this study were located between the sea bottom and the primary or first sea-bottom multiple.

All seismic reflectors picked were plotted on a general work map (Plate 1). The data shown on the general work map were divided into surface and subsurface 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

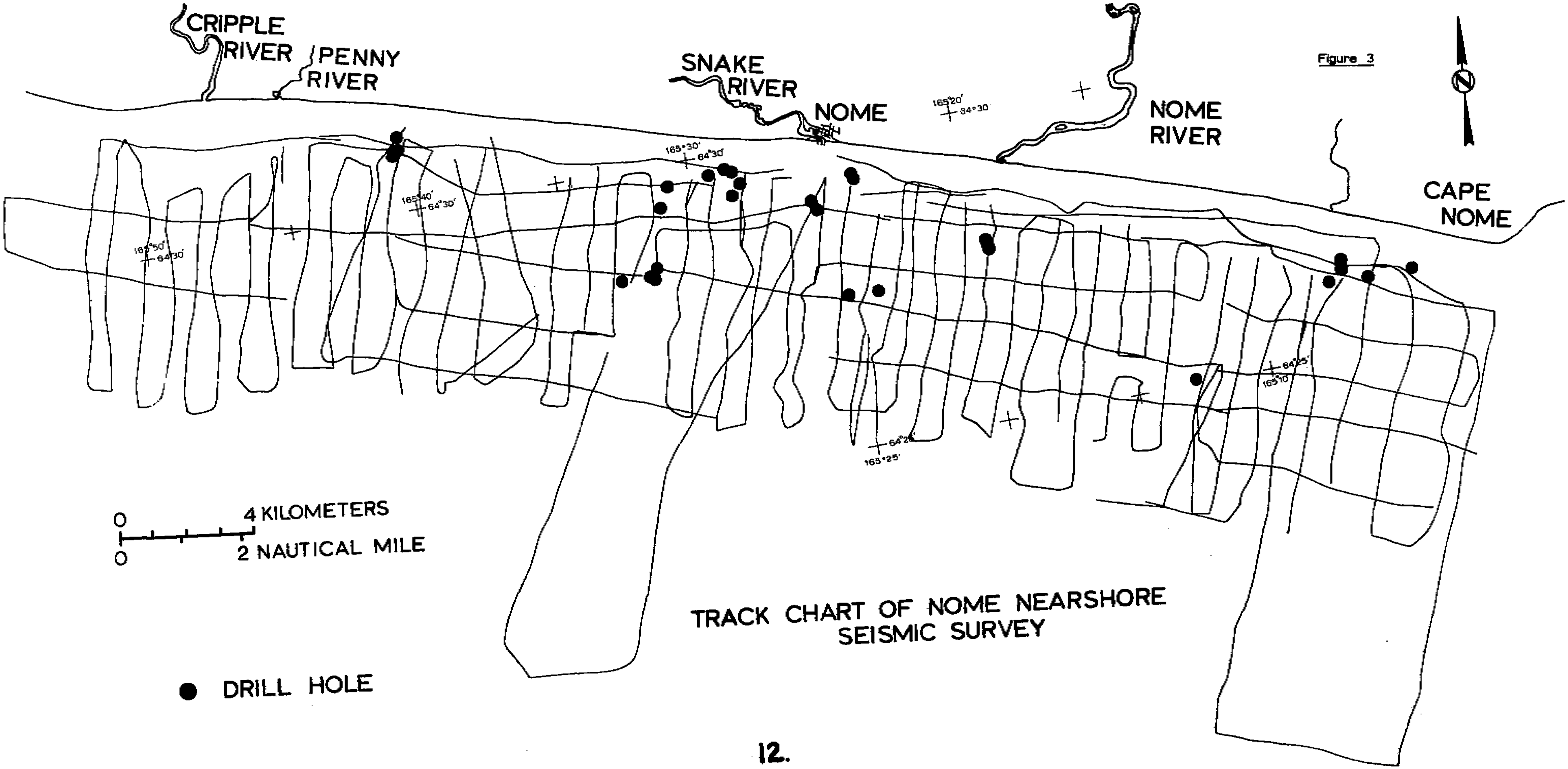


Figure 3

TRACK CHART OF NOME NEARSHORE SEISMIC SURVEY the final computations stage, at which time the 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 4900 feet per second in water and 6000 feet per second in sediments; sound velocities in sediments at Nome have been obtained from Arne Junger (written commun., 1967) and 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 larger sea level changes, ranging at times to 5 feet or more above or below normal sea levels, but we have no data upon which to base corrections for these effects and in general the records were obtained only during periods of good weather.

Bathymetric data was obtained from U.S. Coast and Geodetic Survey smooth sheets from the central part of the study area and from the seismic profiles elsewhere. Features observed on the sea floor offshore near Nome will be reported in a later publication by A. R. Tagg.

Interpretation

Structures observed in the seismic records are divided into surface-to-shallow subsurface and deeper subsurface features. Surface-to-shallow subsurface features are defined here as those recognized on the seismic records and are expressed in the topography of the sea floor. They may extend, as seismic 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-to-shallow subsurface features are shown on Plate 2. In profile, topographic expressions of the drift can also be seen (fig. 8). 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 on Plate 3. Terminal moraines, recessional moraines, faults, and outcropping bedrock are shown on Plate 4. Moraines and acoustical sinks, (sound absorbing layers which cause a signal loss), are shown on both the surface and subsurface maps (Plates 2,3, and 4).

Surface Topography

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

Beach Ridges

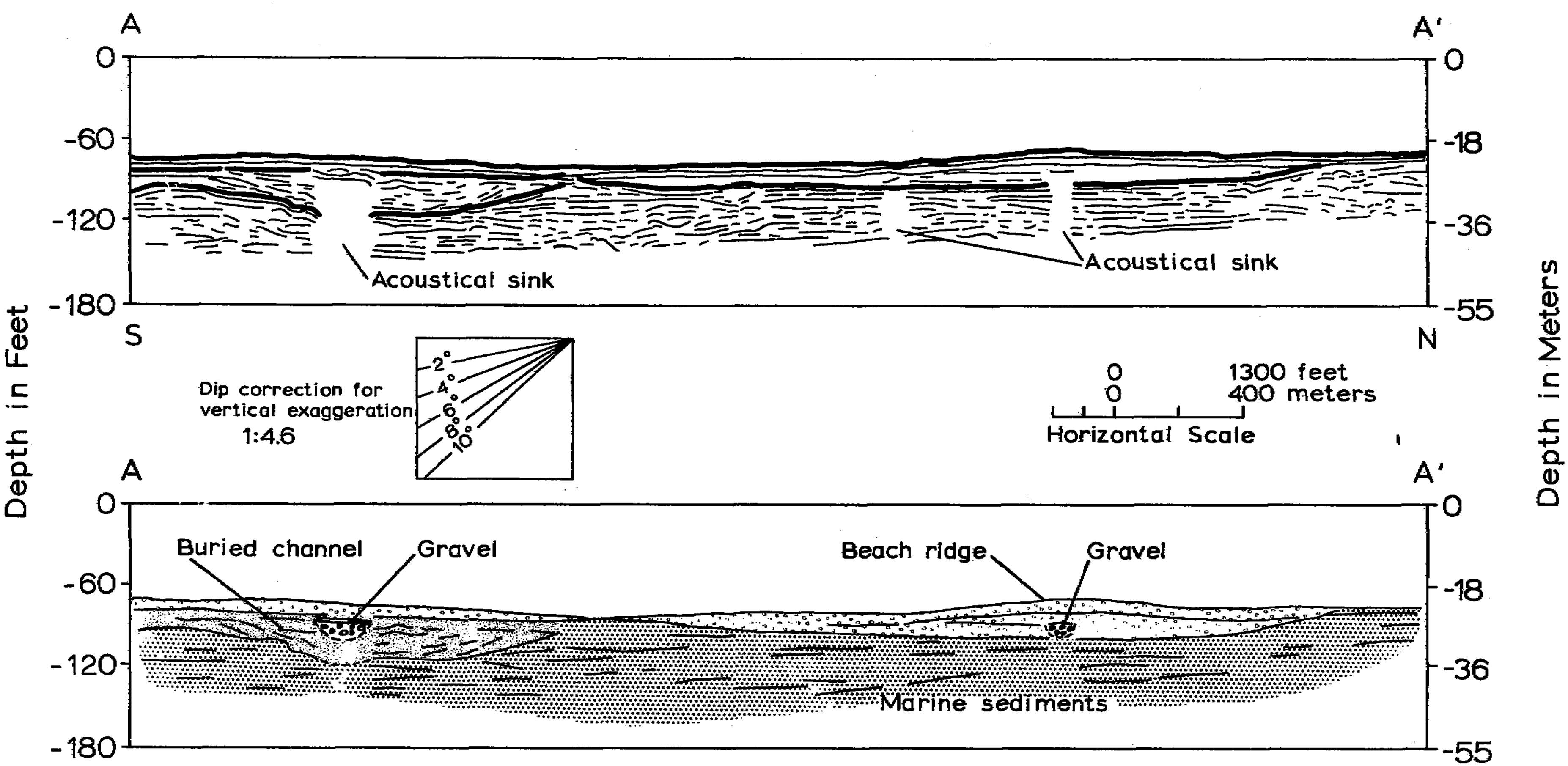
Most beach ridges are defined in the seismic records by a gentle convex-upward profile, steepest on the seaward side and nearly flat on the landward side. Some beach ridges are acoustically transparent but others show internal stratification consisting of beds that dip gently seaward beneath the steepest portion of the surface profile (fig. 4); 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 landward sides and may represent barrier bars.

All profiles of beach ridges are graded "good" or "poor" depending on how well they are defined in the seismic profiles. 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 are difficult to locate because of the absence of internal structures and lack of distinct change in slope. 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 to 70 feet (indicated by a 2 on Plate 2) and the other at a water depth of 75 to 80 feet (indicated by a 1 on Plate 2).

Figure 4



Line drawing and geologic interpretation of seismic profile A-A' across a buried stream channel, beach ridge and acoustical sinks.

Two minor, smaller, beach ridges occur at the eastern limits of the survey area; one at a water depth of 85 to 90 feet (indicated by 3 on Plate 2) and another at a water depth of 55 to 60 feet (indicated by 4 on Plate 2). The -85 to -90-foot beach ridge lies approximately 4 miles offshore of Hastings Creek, is about 3/4 miles 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 5 on Plate 2) occurs at a depth of 45 to 55 feet about a mile off Penny River and has an areal dimension of 4 1/2 by 1/2 miles. This ridge may be an extenstion of the -55 to -60 foot ridge of the eastern part of the survey area.

Stratigraphic Position.--Because 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 still-stands during the Woronzofian (mid-Wisconsin) or Krusensternian (late Wisconsin and Holocene) transgressions of Hopkins (1967).

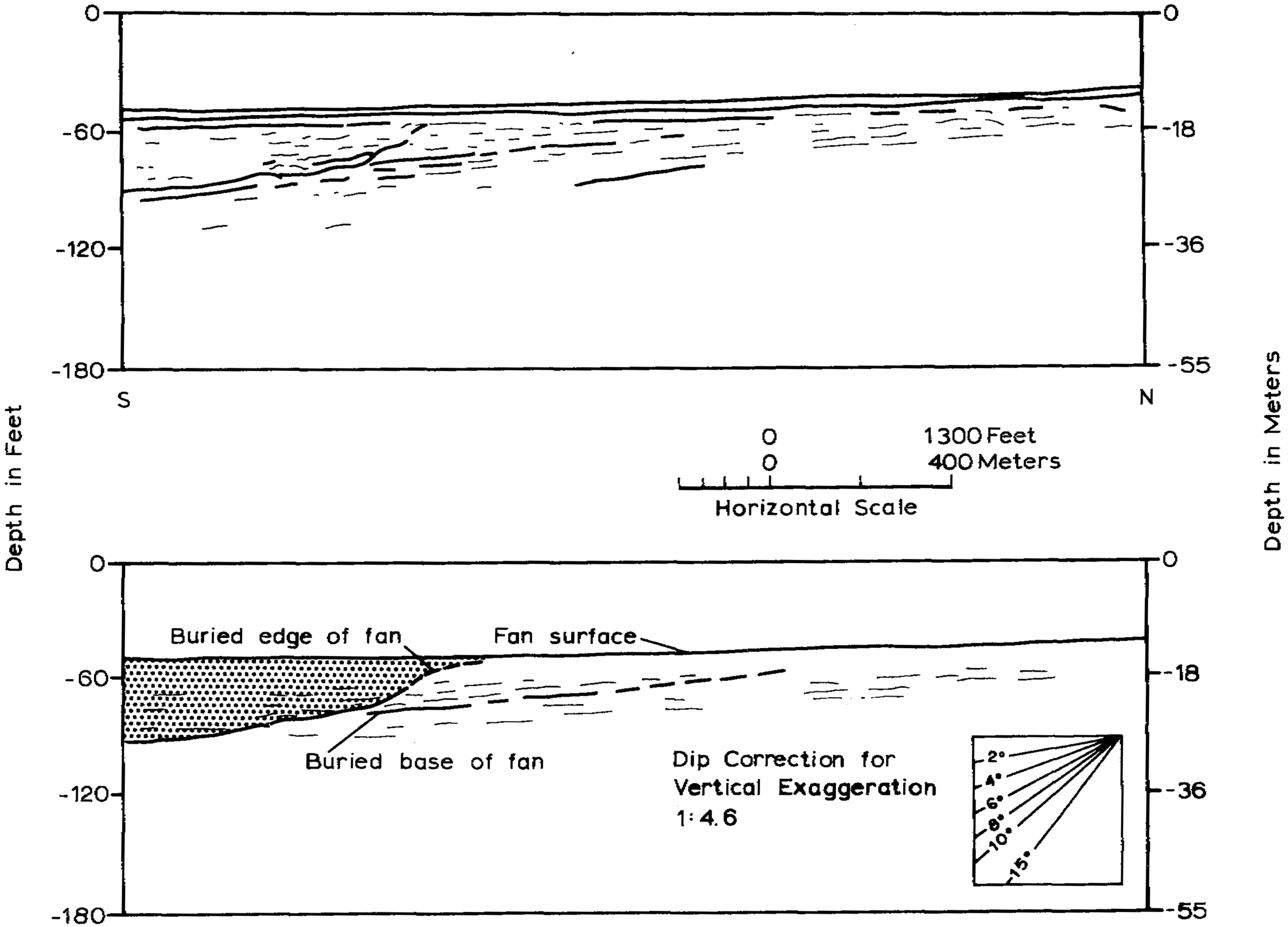
Significance.--Beach ridges offshore are significant as possible sites of placer gold deposits, as during the Nome gold rush the beaches onshore were mined for their placer gold. Wave action concentrated a considerable amount of placer gold in the onshore beach ridges, and it is quite possible that an equivalent concentration was made in their counterparts offshore. 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 would be where beaches are carved in or rest on drift and, because of eastward longshore drift (Greene, 1970b), in nearby areas to the east of Nome.

Fans or Deltas

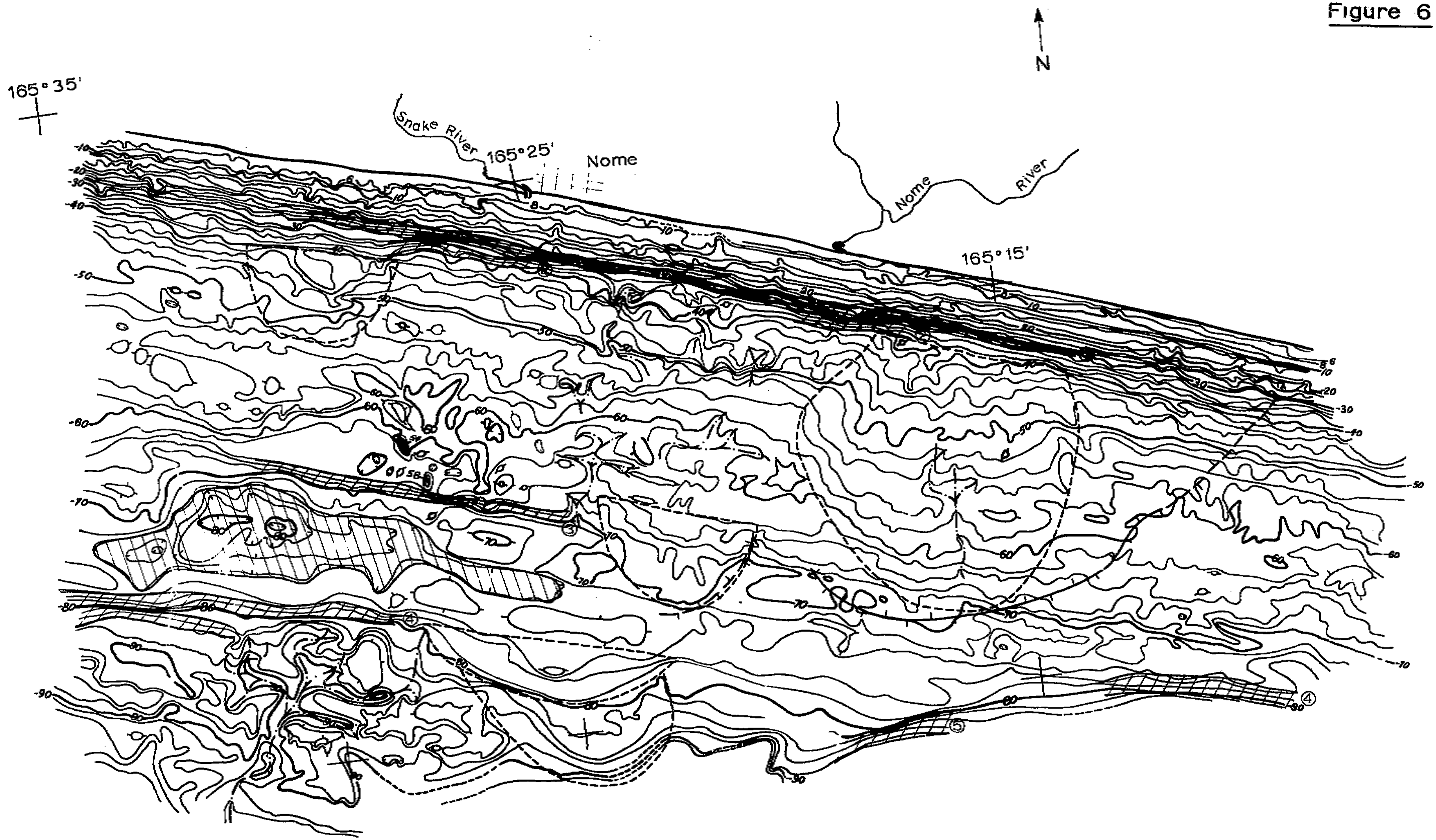
Some geomorphic features observed in the bathymetry of the Nome offshore area appear to be alluvial or outwash fans, or deltas. Five of these fans were first identified from the bathymetric data and two are recognized seismically in the subsurface. Sedimentological data (Nelson and others, in press) and bathymetric data (Tagg, written commun.) also confirmed the two fans seen on the seismic records. These fan or delta-like features are characterized by gentle, thin, beds that dip away from the shoreline (fig. 5). The reflectors are few and overall thickness never exceeds 50 feet.

Distribution.--The fans observed on the bottom contour map but not in the seismic records have an average areal extend of 3 1/2 miles. One fan is located 2 miles west of the mouth of Snake River (fig. 6). 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 further offshore where its foot has been located at about the -54 foot sea bottom contour.

Figure 5



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



Bottom Topographic Features
off Nome, Alaska

Soundings from U.S.C. & G.S.
Contours by A.R. Tagg

Scale 1:50,000

Fan as interpreted from bathymetry
as interpreted from seismic profiles

Topographic
high
low

Drainage
(1) Beach lines
Lagoon

The other two fans that were not seen on the seismic records are located approximately 4 1/2 miles directly off Nome; the inner fan appears to be superimposed over the other. The apex is not visible on the overlying fan which is truncated near the -72 foot contour; it extends about 1/2 mile further offshore to the -80 foot bottom contour. The apex of the lower fan is obscured by the overlying fan; its foot is located on the -90 foot sea bottom consour.

Both of the seismically identified fans occur offshore of the mouth of Nome River (Plate 4). 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 foot bottom contour, about 2 1/2 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 times. 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 Illinoian age occurs behind Second Beach just onshore of this large fan. Second Beach (Post-Illinoian, Sangamon) sediments in a gravel pit exposure overlie outwash derived from this Illinoian moraine. Also, offshore bottom sample and drill-hole data indicate that a small tongue of alluvium is present immediately offshore of the mouth of Nome River and overlies a large quantity of outwash that extend for several miles east and south of the alluvium (Nelson and others, in press).

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

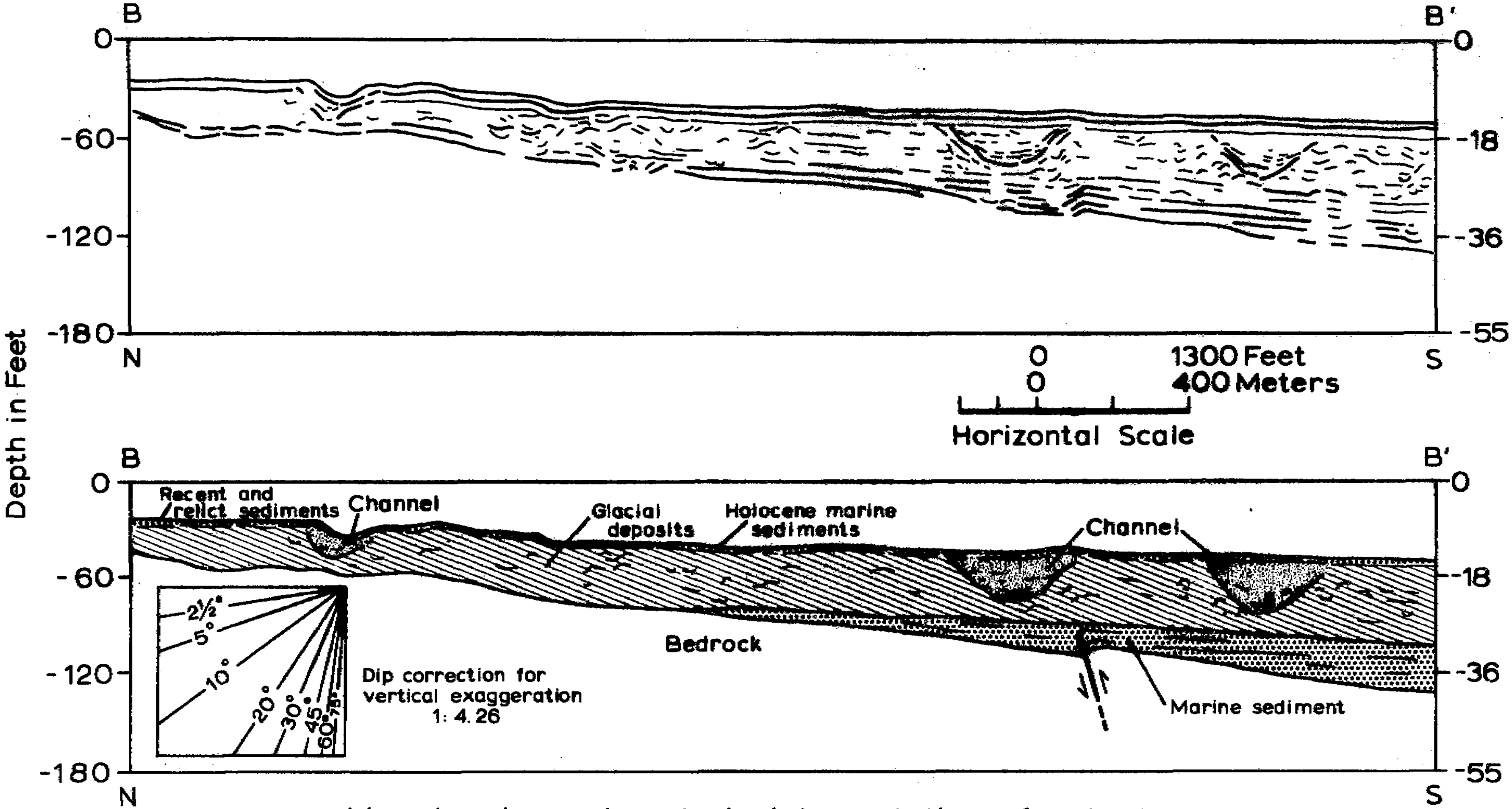
Surface channels or depression

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. 7).

Distribution.--Most of the surface channels are discontinuous, or at least they cannot be correlated from one line to another and are scattered fairly evenly throughout the entire survey area. In only two locations, offshore of Hastings Creek some surface channels are correlatable (Plate 3).

Association.--Many of the surface channels are associated with acoustical sinks (see pages 14 and 26) and buried channels. In the area south

Figure 7



Line drawing and geologic interpretation of seismic profile B-B' across buried channels.

of Hastings Creek surface channels are correlatable and are associated both with acoustical sinks and buried channels. Five or six miles west of Hastings Creek is another surface channel associated with an acoustical sink (Plate 3).

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 formed during the Wisconsin low sea level interval.

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 generally consist of a discontinuous Pleistocene drainage pattern, glacial deposits, and acoustical sinks. These buried features vary considerable in depth indicating several stages of development.

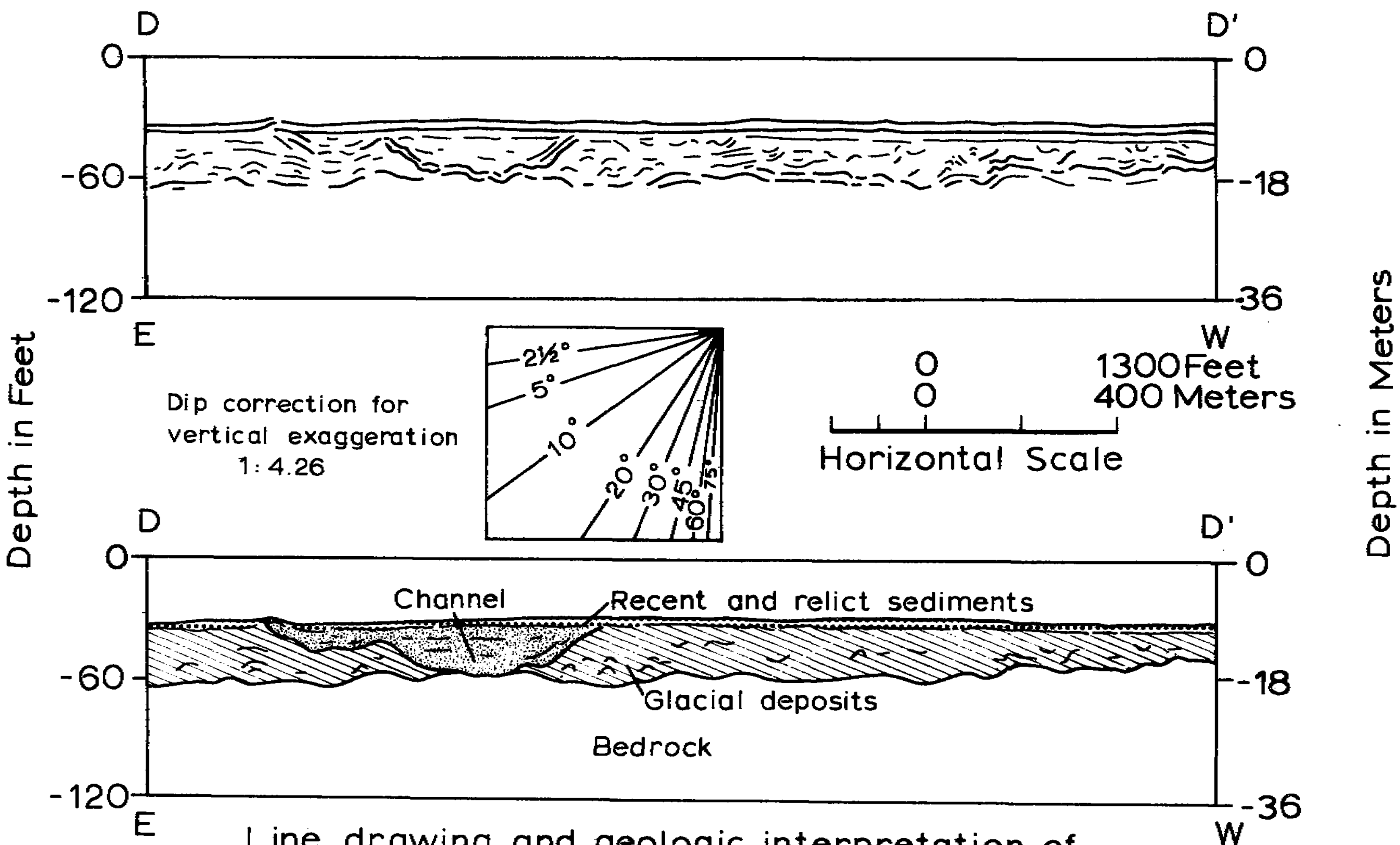
Buried channels

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 (fig. 7, 8, and 9). Both shallow and deep channels can be identified in the seismic profiles. Shallow channels have sides truncated at or near the sea bottom (fig. 7); deep channels are overlain by a varying thickness of sediments.

Shallow Channels.--Shallow channels are plentiful in the Nome offshore area and are by far the dominant subsurface feature. Approximately 370 shallow channels are shown on the seismic records. Depths of the centers of these channels range from 12 to 150 feet beneath the sea bottom; average depth is 38 feet. Several channels have two centers divided by a low still (fig. 8 and 9), but most have only a single center; some have centers skewed to one side although most are symetrical. The side walls of the shallow channels extend nearly to the ocean bottom and are usually covered by a thin veneer of sediment. Few channels can be correlated from one line to another; however, those that are correlatable trend in a direction parallel to the present coast line (Plate 3).

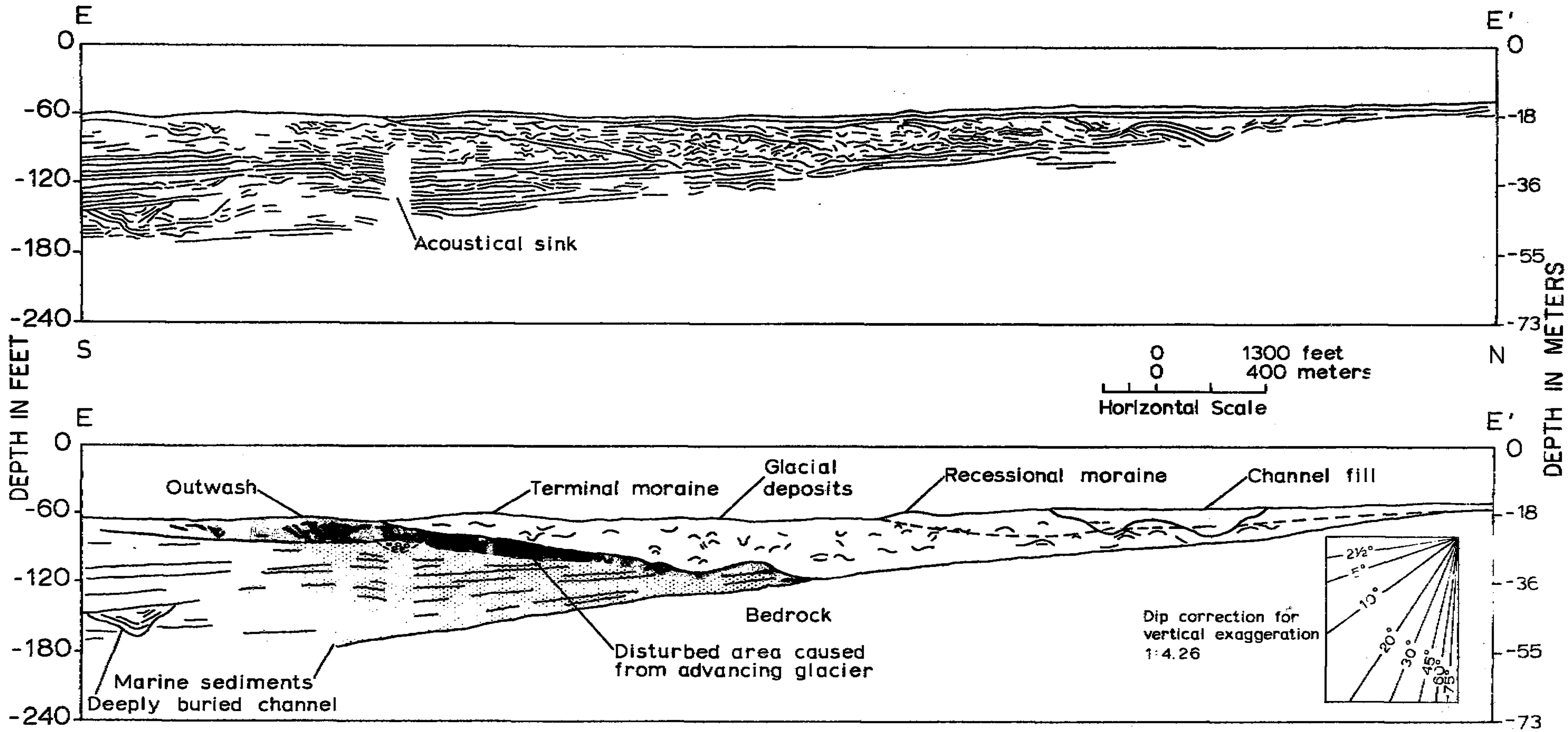
A buried extension of the Snake River detected in refraction seismorgrams by Greene (1970) onshore at Nome is shown by the seismic reflection records to extend offshore (fig. 8). The onshore and offshore channels have similar profiles that show a relatively shallow

Figure 8



Line drawing and geologic interpretation of seismic profile D-D' across ancestral channel of Snake River.

Figure 9



S Line drawing and geologic interpretation of seismic profile E-E' across a terminal and a recessional moraine. N 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. Depths of the deep channels range from 36 to 115 feet beneath the sea bottom with an average depth of 72 feet; the sides of these channels range in depth from 22 to 85 feet with an average depth of 45 feet.

Channel Density and Distribution.--Most buried channels in the Nome offshore area are difficult to correlate. To find out if this was a function of 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 pattern similar to the random, poor correlation pattern found offshore developed. In outlining areas of greatest stream channel densities from this onshore grid it was found that known areas of stream and river courses were outlined. 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 (Plate 3) similar to that produced onshore. In many areas where high densities of channels exist, a correlation from one line to another may be made with relative certainty.

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 has a slope of 67 feet per mile (about 3/4 of a degree). This gently sloping plain contains an abundance of meanders, cut-offs, and oxbow lakes. Offshore the sea floor and surficial sediments have a more gentle slope of about 15 feet per mile (about 1/6 degree). Therefore, it is reasonable to assume that the same type of stream channel development existed offshore during the time the offshore channels were formed as exist onshore today. The subsurface offshore drainage pattern most likely consists of buried meanders, cut-offs, 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 (Plate 3). Within the region of buried channels, 7 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, there is a mile wide linear zone that generally lacks channels which is located about 1 mile offshore. Also, in the northwestern portion of the area, where bedrock is closest to the surface, buried channels are uncommon.

Stratigraphic Position.--Most channels are buried beneath 20 or more feet of Holocene sediments and are not normally seen deeper than 100 feet beneath the sea bottom. They were probably developed during the Illinoian and Eisconsin 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 comm., 1969).

Significance.--Buried channels are important sites for concentration of heavy minerals. Many dredges have worked buried channels in the Nome onshore area and recovered large amount of placer gold. Offshore buried channels probably also contain quantities of detrital mineral deposits, especially in the nearshore area.

<u>Acoustical sinks</u>

Areas of a particular type of weak or no seismic signal return are here called "acoustical sinks" (figs. 4 and 9). The prime characteristic of an acoustical sink is its acoustic opacity which indicates that most of the seismic energy is absorbed and little signal is returned to the surface.

Distribution and Density.--Seismic records in the Nome offshore area exhibit 81 acoustic sinks; 58 of them in the eastern half of the survey area and 23 in the western half. Areas of abundant acoustical sinks are rare, most are randomly scattered about the region. The highest concentration and best correlatibility of acoustical sinks are found within the area 4 miles off Hastings Creek (Plates 2 and 3). Many sinks in the Nome offshore can be correlated between lines. In the eastern half of the survey area 24 sinks are correlated compared to 4 in the western half. Most acoustical sinks are associated with buried channels since they are presumably gravel fill in the channels. Some are associated with beach ridges, however, and these, too, may be gravel. 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, 1970) and closer to Nome, off Port Clarence in the Bering Strait by Hopkins (1967), and at Nome by Greene (1970[2]).

Significance.--Association of the acoustical sinks with buried channels and beach ridges suggest that stream-and-wave-deposited material is responsible for absorption of the seismic energy. Therefore, acoustical sinks are interpreted here to be the result of absorption of 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 associated with buried stream channels and beach ridges are the same age as the Pleistocene features with which that are associated.

Glacial deposits

Glacial deposits extend 3 to 4 miles offshore at Nome and from about 1 mile east of Nome River to the western limits of the survey area (Plate 3). 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 structure, and intraformational folding and faulting, and strongly reflect or absorb, 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. 9). This reflector is concaved seaward, away from the main body of the drift. Small tightly folded marine beds commonly abut the outer edge of the drift at depth and appear to have been compressed by the advancement of the glacier (fig. 9).

The thickest part of the drift is at its outer limit where glacial deposits attain a thickness of 100 feet or more. The outer limits appear to be terminal moraines and are mapped as drift limits (fig. 9). Seaward of the terminal moraines, marine sediments, onlap and cover 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 feet or less) of marine sediments.

After glacial deposition, transgressions of the sea altered, reshaped, and in some cases destroyed glacial features. Outwash and other glacial-fluvial 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 on the "outer drift limit", appears to continue unbroken from the western limit of the survey area to just offshore of the mouth of Nome River where it is less well defined: and eventually becomes obscure. A better defined moraine, shown by the seismic records, lies seaward of the outer drift limit off the mouth of the Nome River (Plate 4). 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, the probable extension of the outer drift limit, bends landward approximately 1 mile east of the mouth of Nome River. There is a possibility that the moraine that bends shoreward just west of the mouth of Nome River is a younger terminal moraine. Buried channesl and fan deposits distort the subsurface features in the area offshore of the Nome River.

Several weakly defined moraine-like features in the western portion 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 subsurface is subdued. Drift features located in the western nearshore area, just inshore of the most continuous recessional moraine (Plate 4), appear to consist of a younger terminal moraine, here called "inner drift limit", and recessional moraine. Recessional moraines located between the inner and outer drift limits in this western portion of the survey area seem to indicate at least three stages of glacial stability or readvancement of the ice (Plate 4).

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 is probably Illinoian in age and most likely represents the Illinoian glacial maximum.

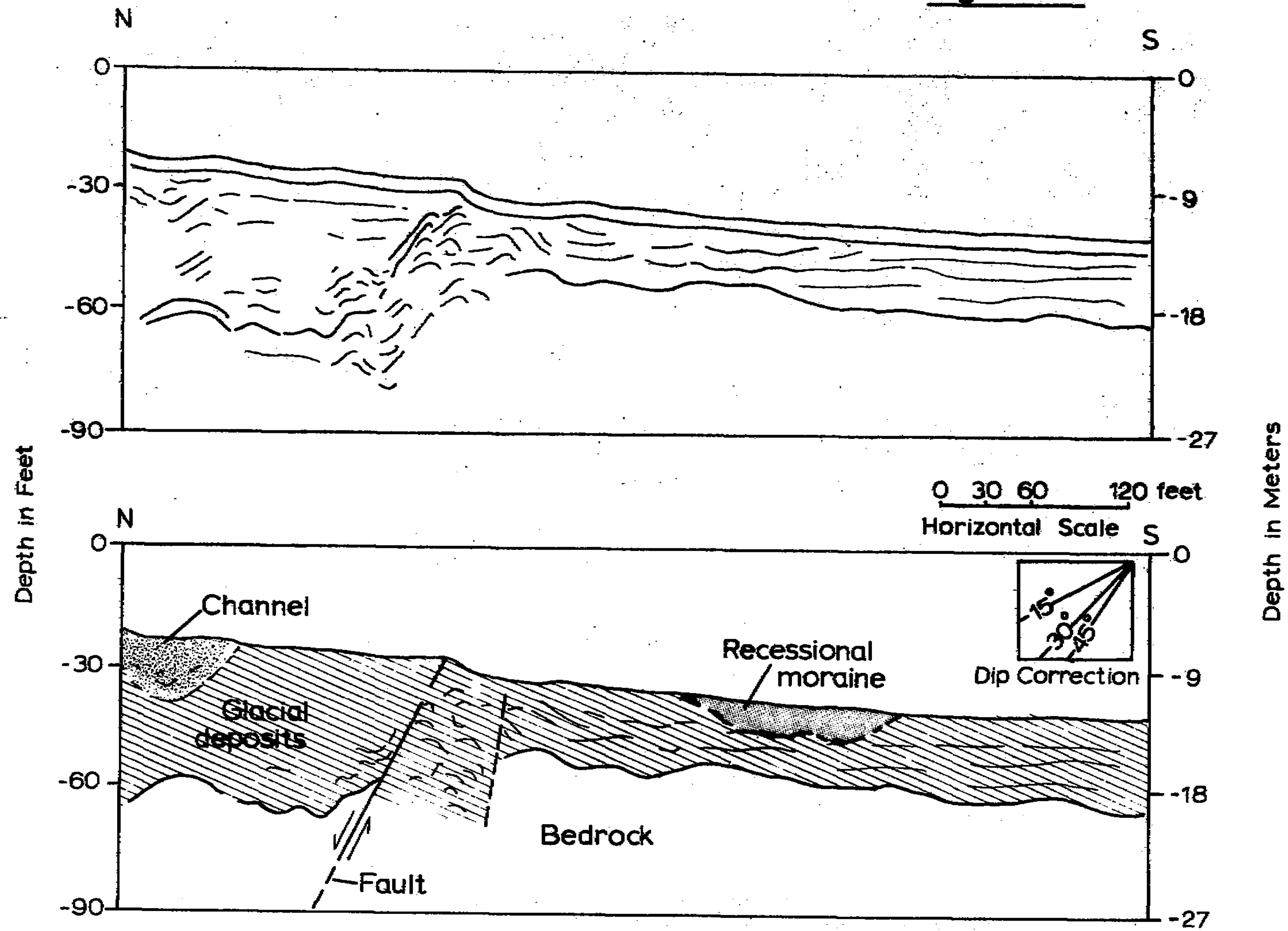
Data from drill holes just shoreward of the inner drift limit off the mouth of Penny River show two layers of till separated by a layer of marine sediments. These data suggest the inner drift limit represents the Illinoian glaciation and is younger than the outer drift limit.

Significance.--Illinoian glaciers scoured deeply into highly mineralized bedrock in the interior areas of the Seaward Peninsula and probably crossed over auriferous gravels during their trek to the sea. Material, including gold, 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 transgression most likely lost fine constituents to winnowing and their coarse constituents were left as lag deposits.

Faults

Several faults are shown by the seismic records but only three are well enough defined to map (Plate 4). Two of the three faults are quite small and one displaces only the sediments overlying bedrock while the other displaced both bedrock and sediments and has a 3 to 4 foot scarplet 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 enscarpment on the sea floor (fig. 10). Significance.--It has not been determined what relationship, if any, faults in the Nome offshore area may have to the offshore placer gold deposits. However, it is possible that mineralization may have taken place along fault plains of the bedrock faults, as in the Anvil Creek Fault. Possibly a significant factor about the bedrock faults is the elevation of the bedrock to a level where bedrock surfaces can be worked by offshore mining equipment or the development of natural catch basins for heavy minerals.

Figure 10



Line drawing and geologic interpretation of a seismic profile across the large bedrock fault zone east of Penny River.
Vertical Exaggeration 1:2.5.

Bedrock

A strong 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 other, 1908, p. 149 and Hummel, 1962 a and b). Bedrock was not mapped except in areas where it crops out or closely approaches the seafloor (Plate 4).

Distribution.--Bedrock crops out in the northwestern portion of the survey area. A line representing points where bedrock surface are truncated at the sea bottom in shown in Plate 4 and angles toward the coast line 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 covered with a thin veneer (less than 12 feet) 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

Subsurface features in the Nome offshore area consist of buried stream channels, glacial deposits, and acoustical sinks, most of which were formed between early and late Pleistocene time. Surface and shallow subsurface features consist of beach ridges, surface channels, and acoustical sinks, most of which were formed during late Pleistocene and Holocene times.

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 Anvillian, Einahnuhtan, and Kotzebuan Transgressions of Hopkins (1967). During Illinoian times 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 make 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) Glaciation, 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 either formed from outwash of similar glacial ice lobes, as constructed the large Illinoian outwash fan, or formed as deltas during the Pelukian, Woronzofian or Krusensternian transgressions.

The buried Pleistocene drainage pattern that is prominent in the subsurface topography of the Nome offshorearea was probably developed during the latter parts of the Illinoian and Wisconsin Glaciations when sea level was lower and subaerial erosion took place south of the present Nome coastal plain. Streams and rivers fed by glaciers nearby were near base level during this time, and the drainage pattern consequently consisted of meandering streams with cut-offs and oxbow lakes. Some of the channels were not filled by sediments of the Krusensternian transgression and are now preserved as discontinuous surface channels in the bathymetry. Other channels were partially filled by coarse detritus carried from the terminus of glaciers and are seen in the seismic records as acoustical sinks, these channels were subsequently filled by other fine-grained marine sediments, 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 this time at least three offshore beach ridges were developed and represent sea level still-stands. It is possible that some of the beach ridges formed as long ago as the Pelukian (Sangamon) transgression. In late Pleistocene time sea level rose 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 still-stand of the Krusensternian transgression was later in the Holocene time and fromed the inner beach ridge between -45 to -60 feet.

Nelson and Hopkins (in press) have shown 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 Pelukian, Worozofian and Krusensternian transgressions.

A thin veneer of marine sediments laid down during latest Holocene time covers surface features in the Nome offshore area. This veneer consists of mud, sand, and gravel and in places ice rafted boulders. The swift predominatly 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 bevelling of the truncated bedrock surface continued during the Iron Creek and Nome River Glaciations and throughout the many transgresstions 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 surface and subsurface Nome offshore area may contain concentrations of detrital heavy minerals. Beach ridges and buried stream channels tend to have heavy minerals concentrated by waves and currents. Coarse grained sediments deposits 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 dilute 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 found in the marginal and terminal moraines, especially where gold in these moraines has been concentrated by current action of a transgressing sea.

Since bedrock in the Nome area is the source of the placer gold, it is also an exploration site if only as a guide to location of placer deposits. In the western portion of the Nome offshore area bedrock crops out at the sea bottom and could possibly be supplying dilute 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 may showing six areas where placer gold and other heavy detrital minerals are possibly concentrated was constructed from the Nome offshore seismic reflection data (Plate 5). Criteria for delineating these areas are (a) the presence of more than one feature thay may have concentrations of placer gold; i.e., a beach ridge and a buried channel, (b) high density of buried channels with good correlation from one seismic track to another, (c) high density of acoustical sinks, either associated with beach ridges or buried channels and (d) the presence of drift in close proximity to beach ridges.

The first area is about 1 1/2 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 dilute amounts of placer gold may be present in the Illinoian terminal moraine onshore (Plate 5). The second area is about 3 1/2 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 (Plate 5). Drift limits and recessional moraines are in close proximity to each other in this area and dilute quantities of gold present in 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 a significant gold, and because of the present of a beach ridge in close proximity to a terminal and recessional moraine. Area five, about a mile further offshore contains a beach ridge associated with several correlatable acoustical sinks and correlatable buried channels. Area six is off Cripple River and contains correlatable buried stream channels and a beach ridge in close proximity 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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