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The continental terrace west of Oregon between 43° 50'N and 44° 40' N latitude is 50 to 55 miles wide. It consists of a continental shelf, 16 to 35 miles wide, and a continental slope, 16 to 37 miles wide. The eastern portion of the shelf is a smooth, sediment covered area that slopes very gently west. The western portion of the shelf contains four rocky bank areas. The banks are topographically irregular and appear to be of structural origin. West of the banks the shelf edge occurs at depths of 71 to 90 fathoms.

The continental slope extends from the edge of the shelf to the abyssal plain at depths of 1530 to 1610 fathoms. A smooth upper slope of less than three degrees extending to depths of 117 to 250 fathoms occurs north and south of Heceta Bank. West of Heceta Bank the upper slope is formed by a scarp that slopes 10° to 16° to 560 to 725 fathoms. West of the upper slope there is an area of irregular topography, including benches, hills and scarps, which extends to depths

of 380 to 1100 fathoms. The lower part of the slope is formed by a north-striking scarp which is 3000 to 6000 feet high and slopes 04° to 15°. The bathymetry indicates that the continental slope was formed by step-type, block faulting.

Sediments form a thin surface layer over much of the terrace. Detrital sand, similar to the coastal sand, covers the shelf from the shoreline to approximately 50 fathoms. The deeper areas on the shelf and upper part of the slope are covered by glauconitic sands and silts on the topographic highs and olive green, clayey silts in the topographic lows. The intermediate and lower portions of the slope are blanketed with olive-green, clayey silt. In these sediments the sand fraction, which generally comprises less than five percent of the sample, is composed chiefly of diatoms, Foraminifera, Radiolaria, and sponge spicules. Sands are also present on the intermediate and deep portions of the slope. Dredge hauls west of Newport obtained sand composed mainly of detrital grains which may have been derived from an underlying friable sandstone. Thin layers of sand occur in cores from other portions of the slope. These sands may have been derived by down slope movement of sediment from the upper slope and the shelf.

Sedimentary rocks of Upper Miocene and Pliocene age crop out on the shelf banks and on the continental slope. The banks consist of a sequence of diatomaceous, clayey siltstones with interbeds and concretions of calcareous siltstones. Glauconite sandstone, graywacke sandstone, and limestone breccia are exposed along with the siltstone, on the northern end of Heceta Bank. Most of the rocks obtained from the slope are similar to those from the shelf. Friable, wacke sandstone is exposed on the slope west of Newport.

Foraminifera, the sand fraction compositions, and textural analyses all indicate that the sediment forming the siltstones from the shelf were deposited at lower littoral to lower bathyal depths.

The sediments forming the rocks were deposited in one or more sedimentary basins during the Miocene and Pliocene. The subsidence continued until the Late Pliocene when the area began to rise. The area was uplifted as much as 1000 fathoms by the Late Pleistocene when the shelf was eroded by transgressions and regressions resulting from sea level changes. The last rise in sea level resulted in the erosion of the shelf to its present form and the deposition of a thin layer of sediment. Sand is presently being deposited on the shallow areas adjacent to the continent, and silt and clay are being laid down on the slope and the sheltered areas of the outer shelf.

GEOLOGY OF THE CONTINENTAL TERRACE OFF THE CENTRAL COAST OF OREGON

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GEOLOGY OF THE CONTINENTAL TERRACE OFF THE CENTRAL COAST OF OREGON

INTRODUCTION

Over much of the earth the margins of the oceans adjacent to continents consist of two topographic regions, the continental shelf and the continental slope. The continental shelf is a platform-like area extending from the shore line to the first pronounced change in slope. The slope, located seaward from the shelf, is called the continental slope. The area encompassed by the continental shelf plus the continental slope is referred to as the continental terrace.

This thesis deals with the geology of the continental terrace off the central coast of Oregon. The study includes the area bounded on the east by the shore line (124° 04' W to 124° 10'W), on the west by the base of the continental slope, at about 125° 20' W, on the south by latitude 43° 50'N., and on the north by latitude 44° 40' N (Plate 1).

Relatively few investigations have been made of the continental terrace off Oregon. The first organized study of the terrace was a bathymetric survey conducted by the United States Coast and Geodetic Survey between 1924 and 1928. During this survey echo soundings were taken along east-west lines and lead line soundings were taken at widely scattered positions. Soundings were obtained to depths of 1,000 to 1,200 fathoms, however, more detailed sounding grids were

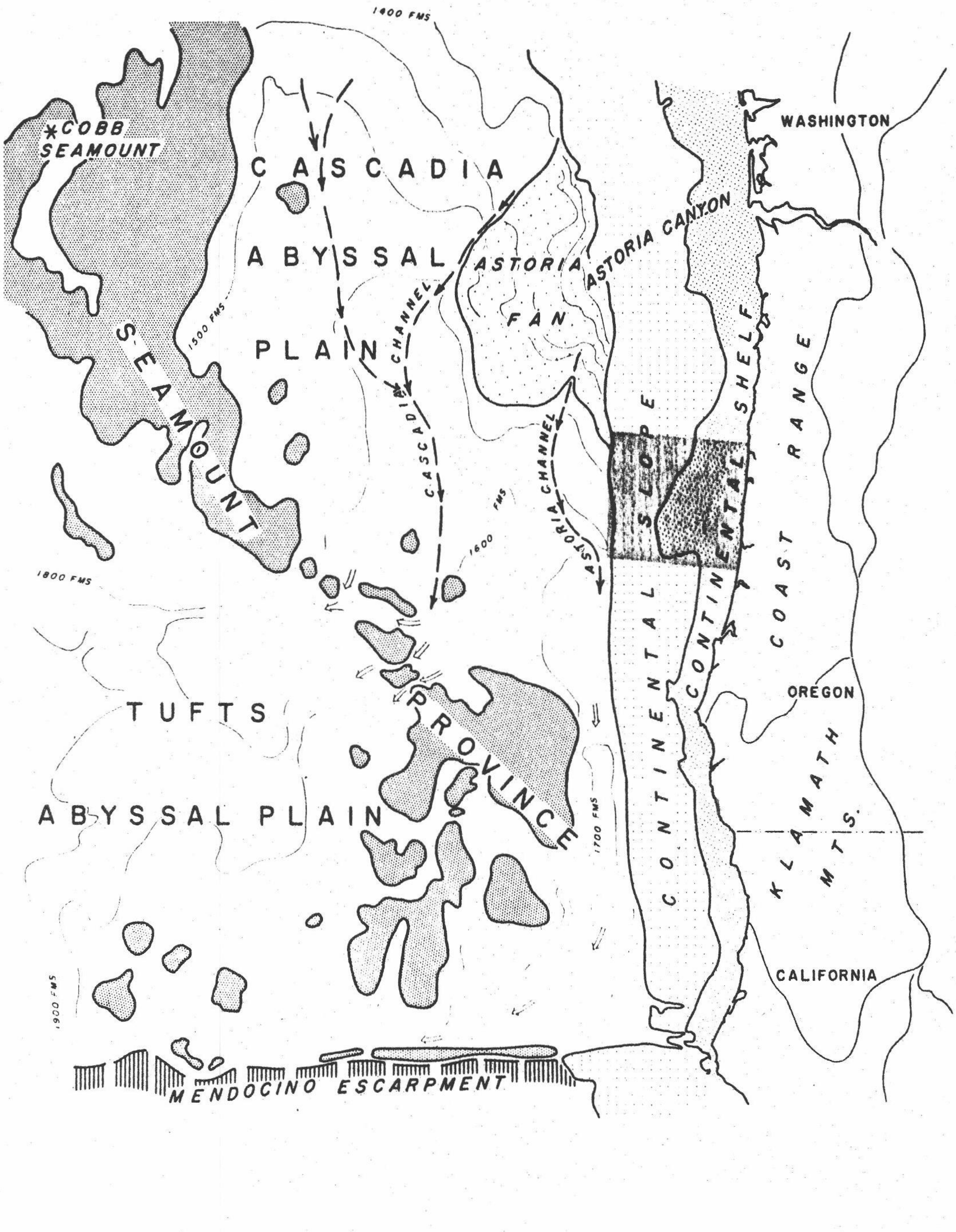


Plate 1. Index map showing the area of study.

obtained at depths of less than 200 fathoms, especially over possible navigational hazards. These soundings resulted in the publication of U. S. Coast and Geodetic Survey Bathymetric Charts 5702, 5802, and 5902. Byrne (1962, 1963b, and 1963c) has recently recontoured the original survey smooth sheets and constructed three bathymetric charts which, together, include the continental terrace for the entire length of Oregon out to a depth of at least 1, 000 fathoms.

The original lead line soundings yielded small samples of the bottom material, and the general types of rock and sediment obtained were noted on the published charts. Byrne (1962) studied these data along with several rocks obtained from biological hauls, the bathymetry, and coastal geology and concluded that the terrace is composed of a thick sequence of folded and faulted sedimentary rocks.

A considerable period of time elapsed after the initial USC&GS survey during which there was little or no active study of the terrace. This inactivity continued until 1960 when several research programs were initiated. Cummings (1962) collected and studied sediment samples from the continental shelf between the Umpqua and Coquille Rivers. This sampling was done in conjunction with a study of the sediments of Coos Bay. Jarman (1962) investigated the Foraminifera and sediments from bottom samples obtained along three traverses across the continental shelf west of Siletz, Yaquina, and Alsea Estuaries. He described the Foraminifera faunas from the shore line to the upper bathyal zone and found that the sediments changed from beach-like sands to fine grained chloritic and glauconitic sediments offshore. A more detailed study of the sediments in the same general area was accomplished by Bushnell (1964). He analysed the sediments from 120 bottom samples taken on a three nautical mile grid over the shelf and the upper part of the slope to a depth of 200 fathoms between 44° 20'N and 44°58'N latitude. Stump (1963) studied the glauconite in some of Bushnell's samples, using x-ray defraction and gas adsorbtion techniques for clay mineral analyses. The author extended the sampling grid south to 43° 50'N latitude, and Runge (1965) has continued it still farther south to Cape Blanco and north to the Columbia River.

Several geophysical studies have been conducted in the area of the continental shelf. Rinehart and Berg (1963) established a gravity range consisting of 149 stations between 44° 10'N and 44° 50'N latitude and 124° 07'W and 124° 20'W longitude. Whitcomb (1965) made a seismic sparker survey and correlated this information with the available gravity and magnetic data.

The coast which forms the eastern boundary of the area has been studied more extensively. Baldwin (1945, 1950, and 1964), Byrne (1963a), Cooper (1958), Dicken (1961), North (1964), and Smith (1933) have all investigated aspects of the coastal geomorphology. Twenhofel (1946) published a reconnaissance of the mineralogy of the Oregon beach sands. Foraminifera contained in the beach sands of California and Oregon were identified by Cooper (1961).

In addition to the previously mentioned work of Cummings (1962) in Coos Bay, the only other estuarine sediments studied in any detail are those of Yaquina Bay. Kulm (1965) has described the sediments in Yaquina Bay and related their distribution to the dynamics of the estuarine system. The distribution of the Foraminifera in Yaquina Bay was described by Maloney (1962). Manske (1964), Hunger (1965) and Rooth (1964) have studied the Foraminifera in Alsea, Netarts, and Siletz Bays respectively.

Cascadia Abyssal Plain, which lies to the west of the continental terrace, has been treated in only a very general manner. Hurley (1959) and Menard (1955, 1964) described the bathymetry and structure of the northeastern Pacific Ocean. Nayudu (1959) described the sediments of the northeastern Pacific Ocean, and McManus (1964) discussed the sediments in Cascadia Basin.

The principal aims of this thesis are to describe the bathymetry, sediments, and rocks of the continental terrace off the central coast of Oregon, and from the data to make inferences as to the age, structure, and geologic history of the continental terrace in this area.

The data used in this thesis were obtained on cruises of the Oregon State University, Department of Oceanography research vessel Acona between the summer of 1961 and the fall of 1963. During this time 12,500 nautical miles of sounding lines, 252 sediment samples and 138 rock samples were obtained.

REGIONAL GEOLOGY

Western Oregon

Western Oregon is dominated by two north trending mountain ranges, the Cascade Range to the east and the Coast Range to the west. The Cascades are divided into two major parts, both of which are volcanic in origin. The High Cascades, on the east side of the range, consist of a linear group of discrete volcanic cones with a maximum elevation of 11, 245 feet (Mt. Hood). The volcanic cones are of Pliocene to Recent age and include olivine basalt, basaltic andesite, dacite, welded tuff and other pyroclastics as their chief rock types. The Western Cascades are lower in elevation and are older than the High Cascades. They are of Eocene to Miocene age, and contain basalts, andesites, agglomerates, mudflows, conglomerates, pyroclastics, and water-laid tuffs (Baldwin, 1964).

The Willamette Valley occupies the trough between the Cascade and Coast Ranges. The north sloping valley is a structural depression which includes numerous hills and terraces. Sedimentary and volcanic rocks ranging in age from Eocene to Pleistocene are found at various locations in the valley.

The Coast Range is a geanticline composed of marine sedimentary rocks, basalt, and local intrusives of diorite, nepheline syenite, and gabbro. The range is low having an average crestal elevation of about 1,500 feet and a maximum elevation of 4,097 feet at Marys Peak (Baldwin, 1964). The geanticline is dissected so that the oldest rocks, Eocene, crop out near the center of the range and the youngest units are exposed on the flanks, near the coast and in the Willamette Valley.

South of the Coast Range are the Klamath Mountains. These rugged mountains have a maximum elevation of 7,530 feet at Mount Ashland (Baldwin, 1964). The Klamath's are composed of a variety of sedimentary, igneous, and metamorphic rocks ranging in age from Silurian to Cretaceous. The sedimentary rocks consist mainly of sandstones, graywackes, mudstones, and limestones. Volcanic and intrusive igneous rocks are found throughout the range. Dacitic to andesitic flows and pyroclastic deposits form the bulk of the volcanic rocks. The intrusive bodies are ultramafic to granitic in nature. Peridotites, commonly serpentinized, are the most abundant ultramafic rocks. The granitic bodies range from granite to diorite in composition, with quartz diorite and diorite the most abundant rock types. Most of the older rocks have been metamorphosed to some extent. As a result, greenstones, serpentines, marbles, gneisses, and schists occur throughout the Klamath Mountains.

Central Oregon Coast

The central part of the Oregon coast lies to the west of the Coast Range. In this region the coast, consisting of uplifted, wave-cut terraces and coastal dune and spit areas, is narrow or absent.

South of Heceta Head the coast consists of a sheet of sand dunes as much as three miles wide (for geographic locations see Plate 2). The Siuslaw and Umpqua Rivers cross the dune area as narrow, shallow estuaries; however, many of the smaller creeks are dammed by the dunes and as a result fresh water lakes are present at several places along this portion of the coast.

Basaltic headlands are present at Heceta Head, Cape Perpetua, Seal Rock, and Yaquina Head. In these areas steep rocky cliffs extend down to the shore line. Beaches are absent along most of the head land area, and, where present, the beaches are commonly composed of basalt gravel. At Heceta Head and Cape Perpetua the hills of the Coast Range meet the ocean as a sea cliff. Yaquina Head and Seal Rock differ in that they are topped by a wave-cut, uplifted, marine terrace.

The coast line between Cape Perpetua and Yaquina Head includes long stretches of sand beach. The beach is fairly narrow ending landward at a sea cliff some 10 to 100 feet high. West dipping sedimentary rocks are exposed on the lower portion of the cliff; the upper

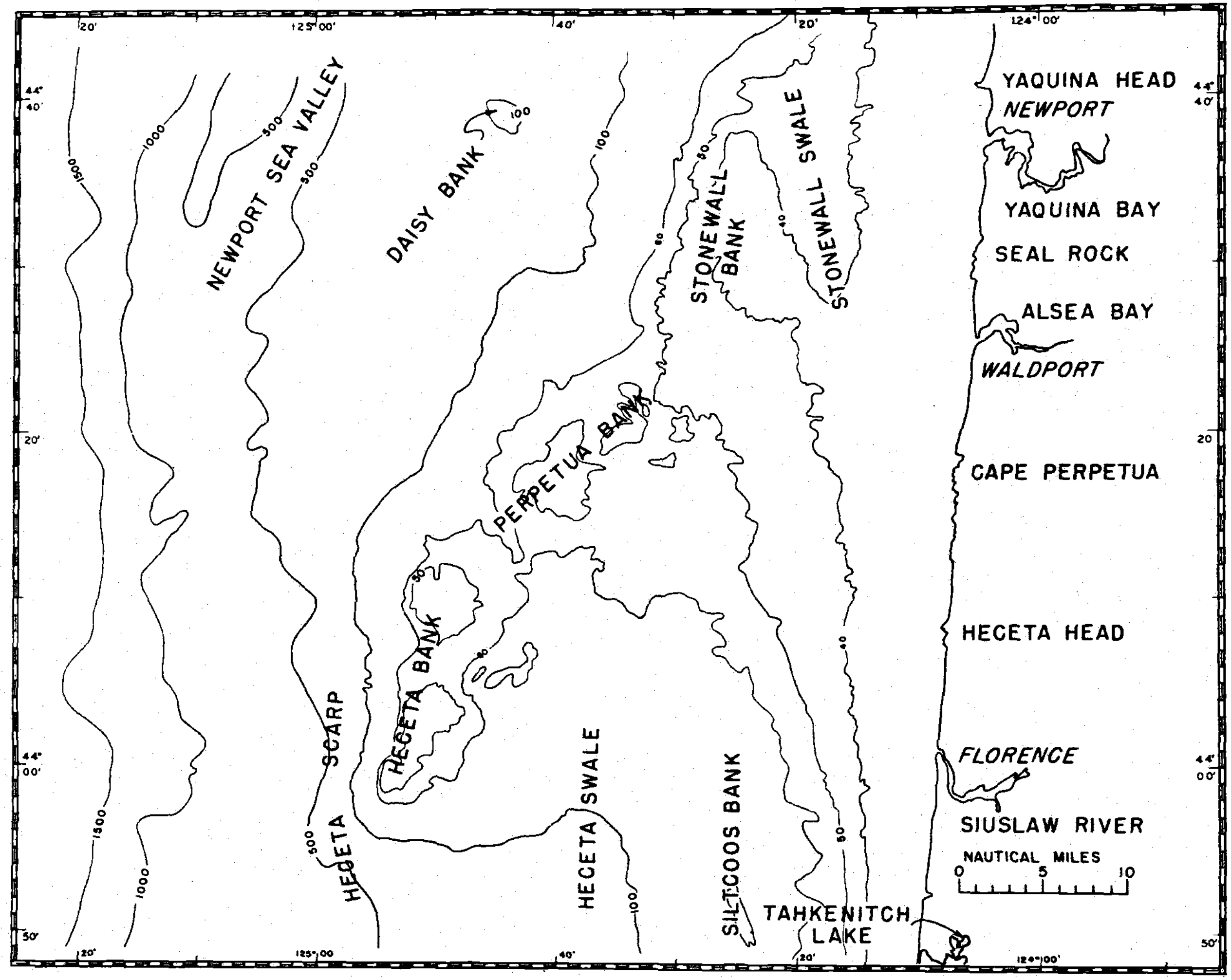


Plate 2. Map showing the geographic locations on the continental terrace off central Oregon.

part of the cliff contains unconsolidated sand plus local lenses of gravel. East of the sea cliff the coast is formed by an uplifted marine terrace. The terrace and sea cliff are interrupted by three estuaries: Alsea Bay, Beaver Creek, and Yaquina Bay. Sand spits are present on the south side of Yaquina Bay and the north side of Alsea Bay.

Continental Terrace

The continental terrace, located west of the Oregon coast, forms an area with a maximum width of more than 60 miles* off Astoria and a minimum width of less than 35 miles off Cape Blanco (Byrne, 1962). The continental shelf varies from a width of 8 miles, west of Cape Blanco, to 35 miles, west of Heceta Head. The shelf is almost flat as it extends from the shore line westward to depths of 70 to 100 fathoms at the shelf edge. For the most part the shelf has a smooth sediment-covered topography; however bank areas, exposing sedimentary rocks, are present at several locations on the middle and outer portions of the shelf. The only canyon crossing the shelf is Astoria Submarine Canyon which heads some ten miles west of the mouth of the Columbia River.

The continental slope occupies the area between the shelf edge

*One nautical mile equals 6, 076. 12 feet.

and the abyssal plain. It is 11 to 52 miles wide and extends to depths of 1500 to 1700 fathoms. The continental slope consists of a number of separate slopes and scarps interrupted by benches, depressions, and small valleys. Astoria Canyon is the only sizeable submarine valley completely crossing the slope. However, several smaller valleys are present at various places along the slope.

Cascadia Abyssal Plain

Cascadia Abyssal Plain occupies an area of some 170,000 square miles west of the Oregon continental terrace. The plain is limited on the west by the Pacific Seamount Province and is, in fact, an oceanic basin. Off Oregon, the smooth floor of the basin slopes to the south at about 0° 09' away from apex of Astoria Fan. The chief physiographic features on the abyssal plain are two south-trending sea channels. Astoria Channel, located between 126° 00'W and 125° 30'W longitude, has a relief of about 30 fathoms and a maximum width of about five miles. Cascadia Channel is located to the west at 127° 20' W longitude. It is about six miles wide and has a relief of 50 to 200 fathoms. According to Hurley (1959), the channels are bounded by levees suggesting that turbidity currents originating from Astoria Canyon or canyons to the north flow down the channels and contribute to the sediment filling the basin.

McManus (1964) distinguishes four types of sediments in

Cascadia Basin. Olive gray to green silty clay occurs near the apex and along the southern slope of Astoria Fan. The remaining fan area and the central basin area contain dark brown, silty clays in contrast with the western border which is covered with brownish black, clayey silt. The sea channels contain a mixture of the olive gray to green, clayey silts with varying quantities of terrigenous sand.

OCEANOGRAPHY

Oceanographic conditions influence the nature of the marine geology of the continental terrace. The distribution and magnitude of the surface and bottom currents together with the effective wave action, control the erosion, transportation, and deposition of sediments on the terrace. The physical and chemical properties of the water influence the types and rates of chemical reactions in the sediments, and they also influence the number and kinds of benthonic animals which rework and alter the sediments. In addition, the abundance and type of plankton deposited on the bottom are dependent upon the oceanographic conditions.

Relationships between the oceanography and the sediment distribution in the world oceans provide information from which the paleoecology and paleogeography of sedimentary rocks can be interpreted.

Water Masses

Sverdrup, Johnson, and Fleming (1942) characterized the water off Oregon as being transitional between Subarctic and Pacific Equatorial Water. This transition is believed to result from the mixing of the Subarctic Water having a temperature range from 2° to 4°C and a salinity of 32 $^{o}/_{oo}$ to 34 $^{o}/_{oo}$ with the Equatorial Water having a temperature of 8° to 15°C. and a salinity of 34.6 $^{o}/_{oo}$ to 35.2 $^{o}/_{oo}$.

Rosenberg (1962) described three water masses off the Oregon coast, namely Modified Subarctic Water, Modified Equatorial Pacific Water, and Coastal Water. The Modified Subarctic Water occurs offshore at depths of 200 to 1000 meters where the water contains more than 80 percent Subarctic Water. Closer to shore, in the vicinity of the continental terrace, there is an increase in the percentage of Equatorial Water near the surface. Rosenberg (1962) called this Coastal Water. There is an even greater increase in Equatorial Water with depth below the Modified Subarctic Water. This water mass is referred to as Modified Equatorial Water (Rosenberg, 1962).

The surface water near the coast varies in temperature from 7° to 17° C. and in salinity from 20 $^{o}/_{oo}$ to 34.0 $^{o}/_{oo}$ but is usually about 33.0 $^{o}/_{oo}$. Offshore, the water is coldest in the winter and warmest in the summer. This is in contrast to the near shore areas where, as a result of upwelling, the coldest surface water commonly occurs during the summer.

A great number of streams and rivers discharge into the northeastern Pacific Ocean. As a result the inshore surface water is somewhat diluted in many areas. The Columbia River provides the greatest quantity of fresh water along the Oregon coast as it discharges more than 180, 100, 000 acre-feet per year (Lockett, 1963). At sea the Columbia River effluent is confined to the upper 40 meters of water. Budinger, Coachman, and Barnes (1964) report that during the summer the effluent extends from the mouth of the river some 750 kilometers to near 40° N latitude, but the western boundary is 210 kilometers from shore. In the winter the effluent occupies a 40 to 55 kilometer wide belt that lies adjacent to the continent and extends from about 40 kilometers south of the mouth of the Columbia River to north of the Strait of Juan de Fuca.

Currents

Subarctic Water is carried east toward the North American continent by the North Pacific Drift between 40° N and 50° N latitude. As the drift approaches the continent it separates into two currents. One flows north into the Gulf of Alaska and the other flows south as the California Current. Sverdrup, Johnson, and Fleming (1942) state that the California Current is a broad, sluggish current bounded on the west by the Eastern North Pacific Central Water Mass some 700 kilometers from the coast at 32° N latitude. The California Current extends eastward to the region of coastal water where, during the period of time between October and February, a surface counter current, the Davison Current, develops. The fact that Modified Equatorial Water occurs at depths below the California Current suggests that there is a deep north-flowing countercurrent under the California Current (Sverdrup, Johnson, and Fleming, 1942).

Maughan (1963) estimated currents at a position some 55 miles west of Newport, Oregon, during January, February, June, September, and November of 1962, by means of drogues, ship drift, and drift bottles. He found that the surface currents are directed to the north during the period from November through March and to the south from April through November. This pattern of surface flow corresponds with the seasonal wind patterns. His September data show that the current just below the surface, shallower than 100 meters, corresponds almost exactly in direction with the computed geostrophic current which was directed to the east. Below 100 meters, to a depth of at least 250 meters, the current directions were highly variable. Maughan (1963) measured a maximum velocity of 25.8 cm/sec at a depth of ten meters. The other current measurements ranged from 22.5 cm/sec to 1.4 cm/sec. Burt and Wyatt (1965) also observed the seasonal change in surface current direction. They state that the surface current appears to be the direct result of the local wind stress. Smith (1964) calculated the net meridinal geostrophic mass transport for the surface layer and for the depth interval between 100 and 1,000 meters. He concluded that the geostrophic flow is very small and is, in fact, less than the uncertainty of the method.

Cold surface water occurs near the coast during the summer months. Lane (1964) demonstrated a high correlation between winds from the north and northwest and the appearance of the cold water at Seaside, Oregon. This lends evidence to the hypothesis that a north wind at the eastern boundary of an ocean in the northern hemisphere causes the surface water to be carried west by Ekman transport and to be replaced at the surface by colder water from below. Smith, Pattullo and Lane (1965) reported currents and transports estimated from a case of upswelling observed off Brookings, Oregon in May, 1963. During three days of strong northerly winds, offshore velocities averaged 5 cm/sec in the upper 90 meters; below there was a slow onshore drift. Vertical velocities reached a maximum of 30 meters in three days at the edge of the continental terrace.

Erickson (1964) observed strong currents while anchored on Stonewall Bank during August 1964 (Plate 2). The currents were spasmodic, lasting for several minutes at a time. On one occasion the ship dragged anchor for over a mile and at another time the anchor was lost. In addition, hydrophones placed on the bottom were bounced up and down. It is not known at the present whether currents of this magnitude occur often or whether they are common on other parts of the continental shelf.

Waves

Naturally occurring ocean waves are found primarily in two different forms, deep water waves and shallow water waves. In deep water waves the water particles move in a circular manner and their particle velocities decrease exponentially with depth. Waves in which the wave lengths are more than two times the water depth are called shallow water waves. In these waves the particle motion is back and forth and in theory the horizontal particle velocity does not diminish with depth but the vertical velocity goes to 0. Sea and swell are common deep water waves, and tides and tsunamies are shallow water waves.

Lamb (1945) states that from the general case of simple harmonic, progressive waves, the horizontal and vertical particle displacements are expressed by the equations:

$$X = a\frac{\cosh k(y+h)}{\sinh kh} \cos (kx - \sigma t) \tag{1}$$

$$Y = a\frac{\sinh k(y+h)}{\sinh kh} \sin (kx - \sigma t) \tag{2}$$

where:

X = horizontal displacement

Y = vertical displacement

$k = \frac{2\pi}{L}$

$\sigma = \frac{2\pi}{T}$

L = wave length

t = time

a = amplitude

T = period

x = horizontal position

y = vertical position

h = water depth

At the lower boundary Y = 0 and -y = h. Therefore, at the boundary, equations (1) and (2) reduce to

$$X = \frac{a}{\sinh kh} \cos (kx - \sigma t). \tag{3}$$

Differentiating (3) with respect to t we obtain

$$u = \frac{a\sigma}{\sinh kh} \sin (kx - \sigma t) \tag{4}$$

in which u is the particle velocity. The maximum particle velocity occurs when sin (kx - σt) = 1. Therefore,

$$u_{max} = \frac{a\sigma}{\sinh kh} . \tag{5}$$

Equation (5) can now be used to calculate the theoretical maximum bottom currents produced by water waves.

Sea and Swell

National Marine Consultants, Inc. (1961) calculated hindcast wave data off Oregon for the 20 years from 1940 to 1960. They found that 16 storms were of sufficient magnitude to produce waves with significant heights ranging from 5. 8 to 9. 4 meters and significant periods of 12 to 14 seconds. Using equation (5) it was found that a wave ten meters high with a period of 14 seconds traveling in water 130 meters deep will have a maximum particle velocity of 31 cm/sec at the sea floor. A wave eight meters high with a period of 13 seconds in water 100 meters deep has a maximum particle velocity of 37 cm/sec at the bottom.

Sundborg (1956) has shown that a velocity of 23 cm/sec taken 0.01 meters above the bottom is sufficient to erode fine sand. Thus, fine sand and unconsolidated silt and clay found at depths of less than 100 to 150 fathoms might be subjected to erosion by wave action during major storms. These values for wave action on the bottom are in general agreement with results obtained by Bushnell (1964).

Tides

Tides assume a major role in the erosion and transportation of sediment along the coast. In this part of the Pacific Ocean the tides are mixed semidiurnal, and have an average amplitude of about one meter at the shore line. This amplitude is thought to decrease to the west, although no tidal measurements have been made over the continental shelf.

Maximum tidal currents have been computed by Fleming (1938) for certain types of continental shelf areas. He has shown that for wide, fairly deep shelf areas the maximum tidal currents are

$$u_{max} = \frac{\sigma a x}{h}$$

where x is the distance from shore, a the amplitude of the tide, and h the depth of water. This equation was applied to the shallowest areas on Stonewall and Heceta Banks, and particle velocities of seven cm/sec and nine cm/sec were obtained (for bank location see Plate 2 , page 10). Both values are higher than the maximum velocity of three cm/sec computed by McAlister (Bushnell, 1964). None of the velocities computed herein are rapid enough to erode sediment or prevent deposition.

Tsunamis

Tsunamis are waves generated by earthquakes that occur on or near the ocean floor. These waves have periods of 10 to 120 minutes in the Pacific Ocean , wave lengths of several hundred kilometers, and amplitudes of less than a meter in the open ocean. They are shallow water waves and have particle velocities equal to

$$u = \frac{a\sigma}{kh} \sin(kx - \sigma t)..$$

A tsunami having a period of 16 minutes and an amplitude of 0. 5 meters travelling in water 4, 000 meters deep will have a maximum particle velocity of 24. 5 cm/sec. If the amplitude was one meter the computed particle velocity is 49 cm/sec. A wave of the same dimensions in water only 200 meters deep would have a computed particle velocity of 110 cm/sec. The above figures indicate that large tsunamis produce particle velocities capable of eroding sediment from the continental slope and that most tsunamis can erode sediment on the continental shelf.

Internal Waves

Internal waves are waves formed along density discontinuities within the water. They have periods ranging from a few minutes to a few days and wave heights in the tens to hundreds of feet. Shepard (1963) states that internal waves measured at LaJolla, California, form bottom currents strong enough to erode, or at least to prevent sedimentation, on the high areas of the ocean floor. Whether internal waves affect the ocean floor off Oregon is not known.

Summary

Certain waves produce high enough particle velocities to erode sediment from the continental terrace. Large storm waves can erode sediment to depths of 100 to 150 fathoms. Tsunamis are capable of eroding sediment over the entire continental terrace. Other types of waves and currents were calculated and speeds were found to be too slow to erode bottom sediment. Spasmodic, strong currents were observed on a single occasion over Stonewall Bank, and, while the origin and nature of these currents are not known, they appear to have been strong enough to erode sediment from the bottom. The distribution and velocities of bottom currents and the nature of internal waves are at present largely unknown. Until more is known of these phenomena any conclusions concerning the effects of currents on the formation of the sediment pattern is speculative.

PHYSIOGRAPHY

The continental terrace off Oregon constitutes the strip of ocean floor lying adjacent to the coast line extending seaward 35 to 60 miles to Cascadia Abyssal Plain at depths of 1, 500 to 1, 700 fathoms. The terrace has its maximum width of 60 miles west of Astoria and its minimum width of 35 miles west of Cape Blanco. The base of the terrace deepens from north to south away from the apex of Astoria Fan.

Off Oregon the continental shelf ranges from 8 to 35 miles wide. Byrne (1962) calculated that the average slope of the shelf varies from 0^{o} 08' to 0^{o} 43' and that the outer edge of the continental shelf is found at depths ranging from 70 to 100 fathoms. These values differ from the world averages, given by Shepard (1963) as 42 miles, 0° 07', and 72 fathoms. Thus the continental shelf off Oregon is narrower, steeper, and deeper than the average continental shelf.

According to Byrne (1962), the continental slope off Oregon is 11 to 52 miles wide with an average slope of 1° 17' to 7° 18'. Shepard (1963) gives a world average of 4° 17' for the slope above 1, 000 fathoms.

The continental terrace between 43° 50' N and 44° 40'N latitude is 50 to 55 miles wide and has a terminal depth of 1, 530 to 1, 610 fathoms. The shelf is 16 to 35 miles wide and extends to depths of

71 to 90 fathoms. The width of the continental slope varies inversely with that of the shelf as it ranges from 17 to 37 miles in width.

Methods

The physiography of the continental terrace between 43° 50' N and 44° 40' N latitude was investigated using soundings from the United States Coast and Geodetic Survey and from the Department of Oceanography, Oregon State University. The USCGS sounding lines are closely spaced over the shelf. The smooth sheets have from 15 to 20 soundings per square mile with as many as 60 per square mile on certain bank areas. The sounding density is much lower on the continental slope. The USCGS made one east-west sounding line every five miles and their smooth sheets have a sounding density of two to five soundings per square mile. The bathymetric survey completed for this thesis, herein referred to as the OSU survey, obtained east-west sounding lines at one and one-half mile intervals and north-south sounding lines at five mile intervals (Plate 3). The average sounding density on the four smooth sheets (Plates 4, 5, 6, and 7, pages 234 to 237) is six soundings per square mile.

The OSU soundings were obtained with a Percision Depth Recorder attached to an Edo sounder. Ship positions were determined at 15 minute time intervals with a Loran A or radar. The soundings were taken from the Precision Depth Records and plotted on the

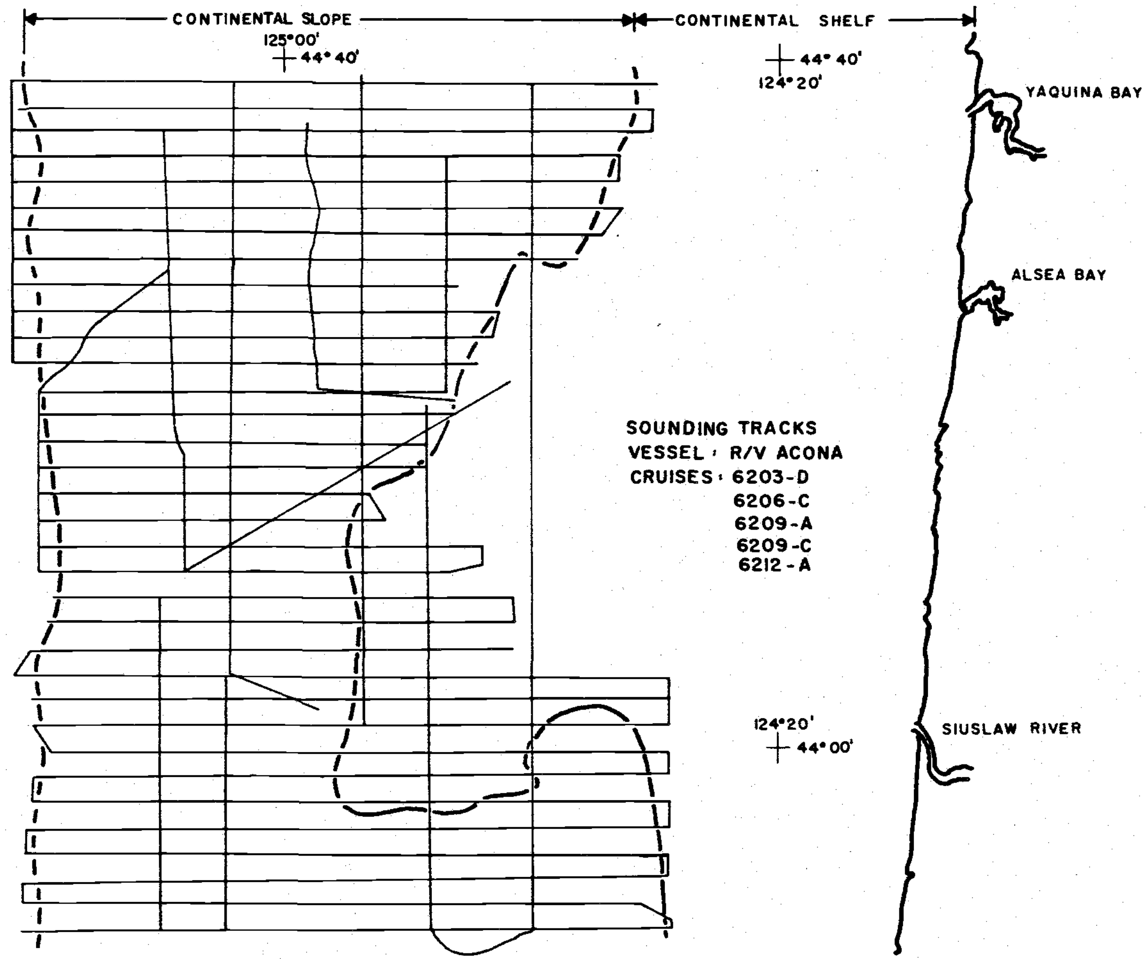


Plate 3. Map showing the sounding lines made by the Department of Oceanography, Oregon State University research vessel Acona.

smooth sheets without making any corrections. The bathymetric chart obtained from these soundings is given as Plate 8, page 238. The bathymetric chart covering the entire width of the continental terrace (Plate 9, page 239) was constructed using the USCGS soundings as contoured by Byrne (1962) for the topography to a depth of 200 fathoms and the contours, reduced in scale, from Plate 8 for the topography at depths greater than 200 fathoms.

The geographic names utilized in this report are shown in Plate 2, and the physiographic areas discussed in the following sections are outlined on the map in Plate 10.

Continental Shelf

The continental shelf is narrowest in the north and south where it is 16 to 20 miles wide. It widens to a maximum of 35 miles at Heceta Bank. The eastern boundary is formed by the almost straight N 05° E-trending shoreline. The upper part of the continental shelf slopes westward between 0° 30' and 1° 08' to depths of 20 to 50 fathoms. West of the upper shelf is a smooth almost flat region, herein called the central shelf area. In the south the central shelf area extends west to the edge of the shelf, but in the north it ends at a series of discontinuous banks located on the outer portion of the shelf. Broad depressions of very low relief occur east of the bank areas where the sloping sides of the banks join the slightly west-sloping central shelf

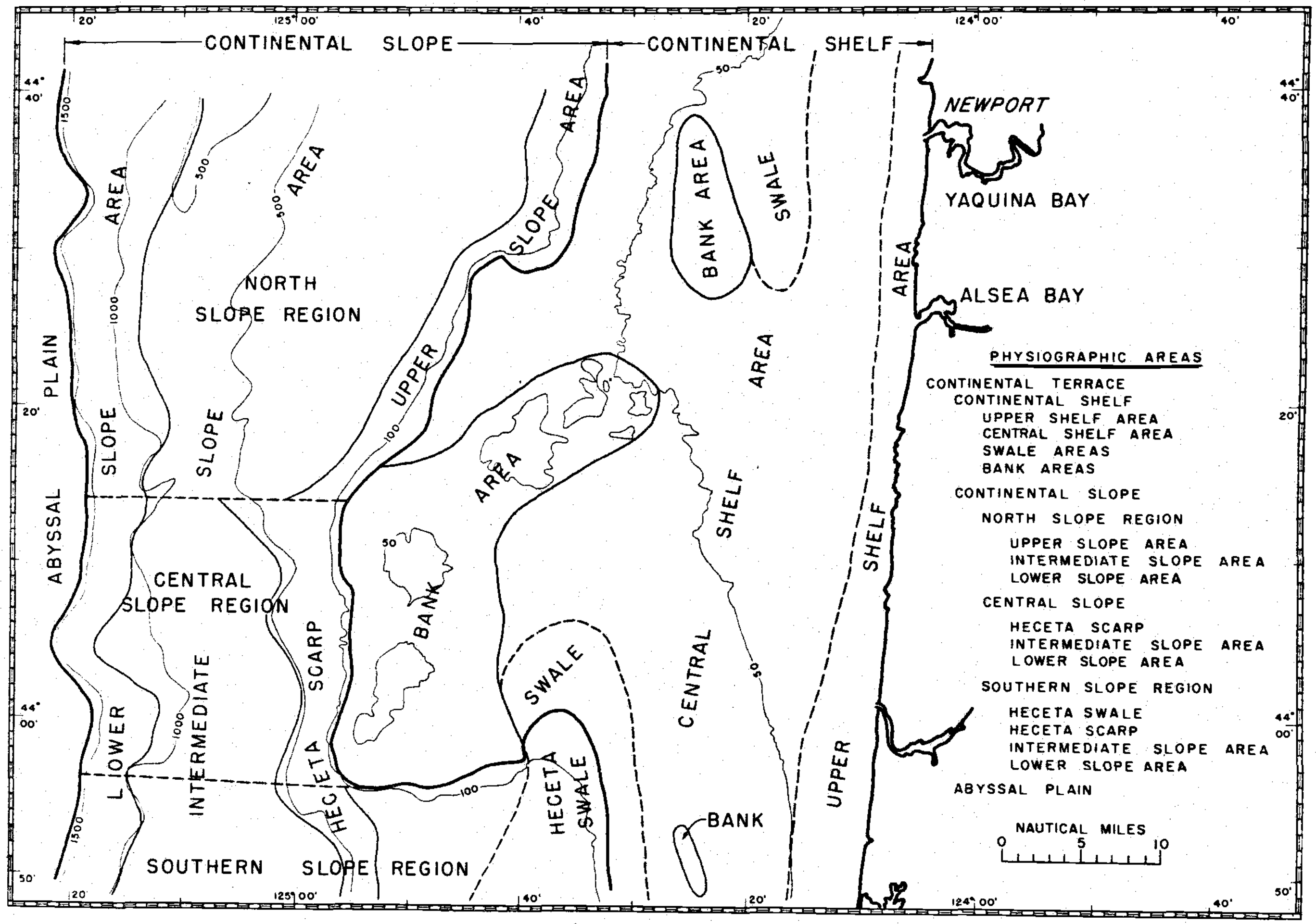


Plate 10. Physiographic map of the continental terrace off central Oregon.

area. These low areas are herein referred to as swales.

In the north, the upper shelf area is present to depths of 20 to 25 fathoms. It is made somewhat irregular by basalt "reefs" extending six miles south from Yaquina Head and by basalt "reefs" and stacks located within a half mile of Seal Rock. West of the upper shelf, the central shelf area slopes gently westward 0° 12' to depths of 40 to 48 fathoms at the axis of Stonewall Swale. Stonewall Swale trends N 10° W from a depth of 38 fathoms at 44° 28' N to a depth of 48 fathoms at 44° 40' N. The swale is about eight miles wide and has a relief of about 35 fathoms. It is broad and shallow with a smooth, gently sloping bottom.

Stonewall Bank forms the west side of the swale. West of the bank the bottom is mostly smooth, but has areas of rough bottom. These rough areas are small and have little relief suggesting that they are rock outcrops in a sediment covered region. Small terraces are present at depths of 52 to 59, 67 to 73, and 71 to 78 fathoms. The shelf edge has a depth of 71 to 78 fathoms. It exhibits an increase of slope of less than three degrees, in some places less than one degree, and is rounded and smooth.

No bank or swale exists south of Stonewall Bank in the area between 44° 21'N and 44° 22'N. Two banks, Perpetua and Heceta Banks, are present between 44° 22' and 43° 57' N. Heceta Swale occurs east of the banks. The swale descends south - southwest from a depth of 50 fathoms at 44° 20' N to a depth of 230 fathoms on the continental slope at 43° 50' N. The swale is approximately ten miles wide and has a maximum relief of about 70 fathoms. The central portion of the swale is smooth with very gently sloping sides. One steep, 20 fathom high, northeast facing scarp occurs on the west side of the swale.

East of Heceta Swale, the central shelf area is present at depths of 35 to 70 fathoms. This area is very smooth and has a slight regional slope to the west-southwest. The smooth topography together with the large number of sediment samples collected from the central shelf area indicate that it is completely covered with sediment. The upper shelf area in this region is similar to that in the north. It differs in that it is slightly steeper, averaging 0° 50', and that it extends into slightly deeper water, 25 to 28 fathoms.

The outer edge of the continental shelf has a northeasterly orientation, south to about 44° 13' N where it turns and assumes a northerly trend to 43° 57' N. At this latitude the shelf edge turns abruptly and trends eastward for about 20 miles. The outermost part of the shelf on the west side of Heceta Bank is marked by several small terraces at depths greater than 54 fathoms. The most continuous terrace occurs at depths of 77 to 81 fathoms, and the shelf break is present at depths of 78 to 90 fathoms. The change in slope is prominent in going from Heceta Bank to Heceta Scarp which slopes 6° to 30° to the west.

South of latitude 43° 57' N the shelf is about half as wide as it is at Heceta Bank. In this region the upper shelf area has an average slope of 0° 44' and extends to depths of 50 to 55 fathoms. The central shelf area is almost flat, sloping west 0° 06', to the edge of the shelf. It is interrupted by one small bank, Siltcoos Bank, centered at 43° 50' N, 124° 25' W. The shelf edge is smooth and rounded with a change in slope of less than two degrees.

Shelf Banks

Stonewall Bank. Stonewall Bank is a shoal located on the continental shelf 15 miles southwest of Newport, Oregon (Plates 2 and 11). The bank is 12 miles long and has a maximum width of six miles. Its crest includes three high areas which are aligned in a N 10° W direction. The southern and central highs both crest at 13 fathoms. The northern high is deeper, cresting at 27 fathoms. With respect to the swale on the east, the bank has a maximum relief of about 34 fathoms.

The southern high is the most symmetrical in cross section. The upper part of the bank is rough with numerous features of up to ten fathoms relief. This roughness is more pronounced on the east side. Four small, straight scarps paralleling the bank crest occur on the southern high.

The southern and central highs are separated by a saddle which leads to a shallow valley on the east side of the bank. The valley bottom begins at 30 fathoms on the saddle and descends to 37 fathoms in

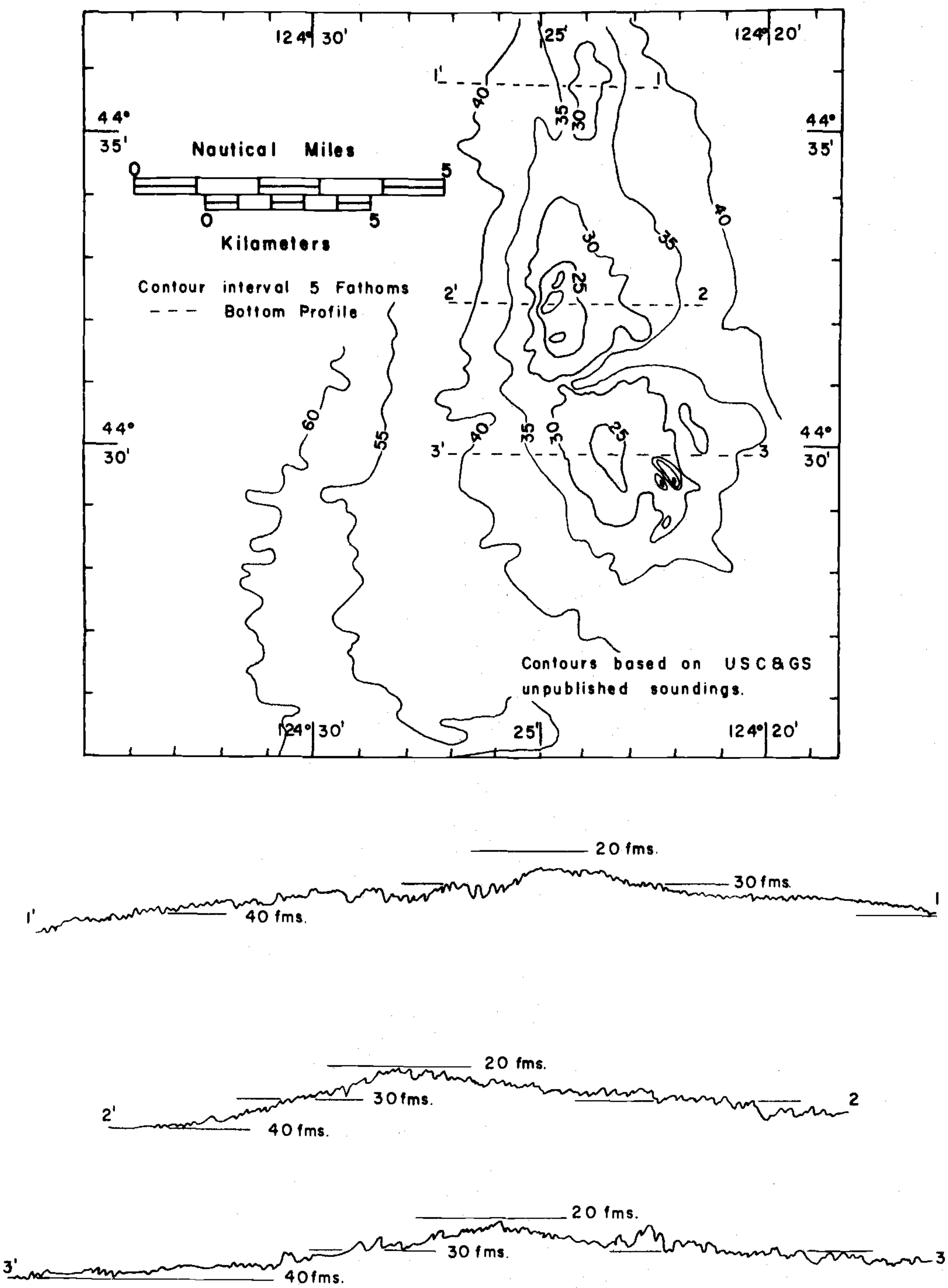


Plate 11. Bathymetric map and profiles of Stonewall Bank. The profiles were obtained from Precision Depth Records. Their exact scale is unknown.

the swale one mile to the east. The upper surface of the central high is irregular. The west side is slightly steeper, but the irregular topography continues farther down the east side.

The saddle between the central and northern highs is very gentle; the maximum depth on the crest is 32 fathoms. This gives a relief of 19 fathoms with respect to the central high but a relief of only five fathoms with regard to the northern high. Irregular topography is present over the entire northern part of the bank.

The irregular topography on Stonewall Bank suggests that rock exposures occur over the entire bank area. The lineation of the highs and the parallelism of the small scarps suggest that the bank was structurally emplaced.

Perpetua Bank. The unnamed bank located between Stonewall and Heceta Banks is herein called Perpetua Bank (Plates 2 and 12). Perpetua Bank has a broad irregular surface including a number of small hills or hummocks of which the largest is centered at 44° 17' N, 124° 42' W. The average depth on the bank is between 43 and 47 fathoms with the highest point at 38 fathoms. This gives the bank a relief of only 15 fathoms. A smooth west-sloping area at depths of 35 to 50 fathoms separates Perpetua Bank from Stonewall Bank to the northeast. Heceta Bank, to the southwest, is set off from Perpetua Bank by a northwest-trending valley at depths of 60 to 63 fathoms.

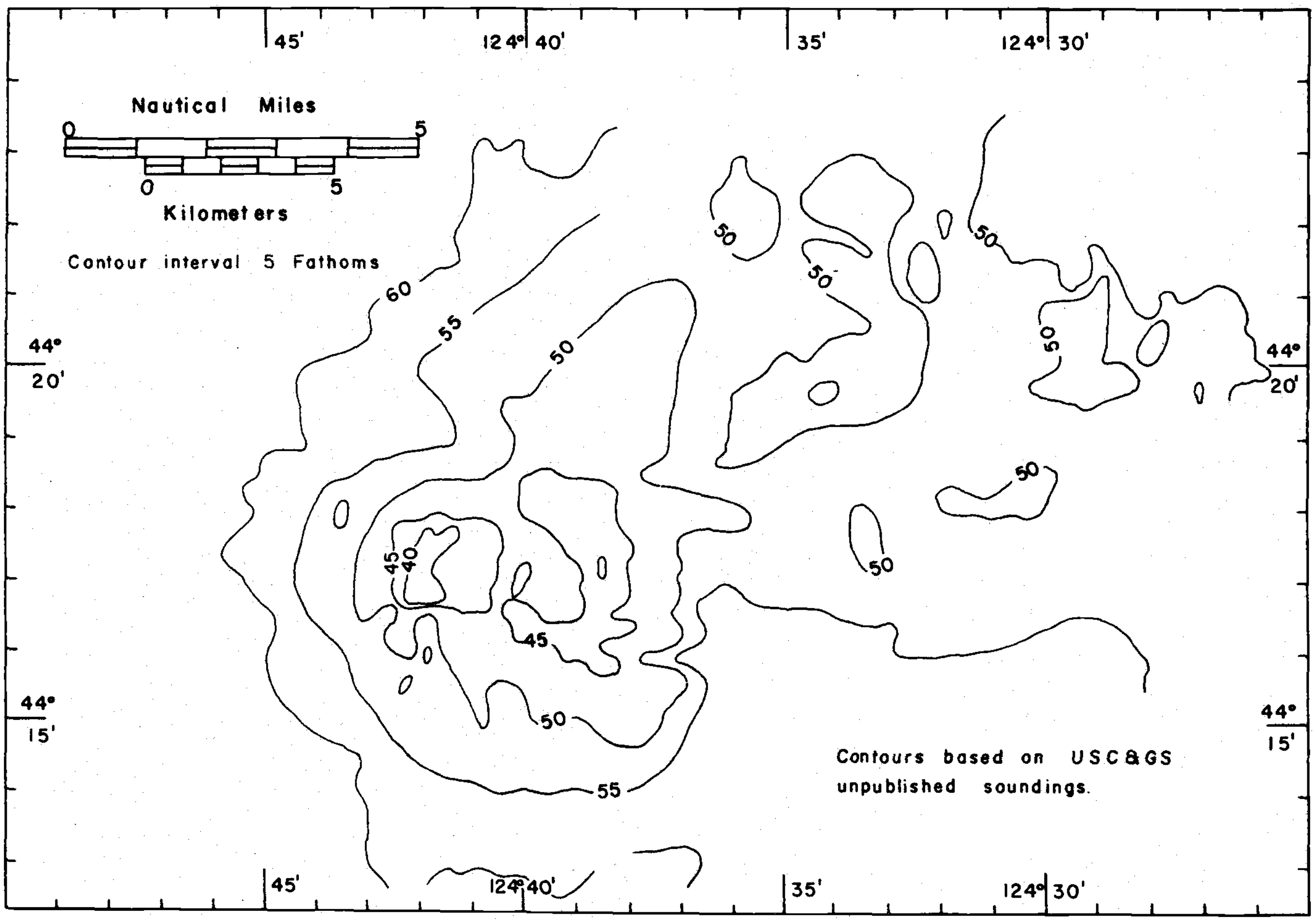


Plate 12. Bathymetric map of Perpetua Bank.

Irregular relief features of two to six fathoms are present on Perpetua Bank indicating that it contains numerous rock exposures. The lower areas between the hummocks are smooth and probably are sediment covered.

Heceta Bank. Heceta Bank forms the outermost part of the continental shelf in the area where the shelf has its maximum width, between 43° 57' N and 44° 13' N (Plates 2, 13, and 14). The bank is 18 miles long and up to eight miles wide. The crest consists of two highs separated by a saddle. The southern high trends N 35° E and has a minimum depth of 27 fathoms. It is marked by smooth terraces and irregular hills with local relief features of five fathoms. The flanks of the southern high are notched with small valley-like features.

The high area to the north is offset some two or three miles west of the northeasterly projected axis of the southern high. The saddle separating the two highs has a maximum depth of 57 fathoms, and the northern high has a minimum depth of 25 fathoms. The northern high is almost equidimensional with a diameter of five to six miles. Its upper surface is marked by irregular features, three to five fathoms in relief. One small valley with four fathoms of relief plunges north off the bank.

East of the bank proper there are a number of small hills bounded by steep scarps and separated by smooth topography. This

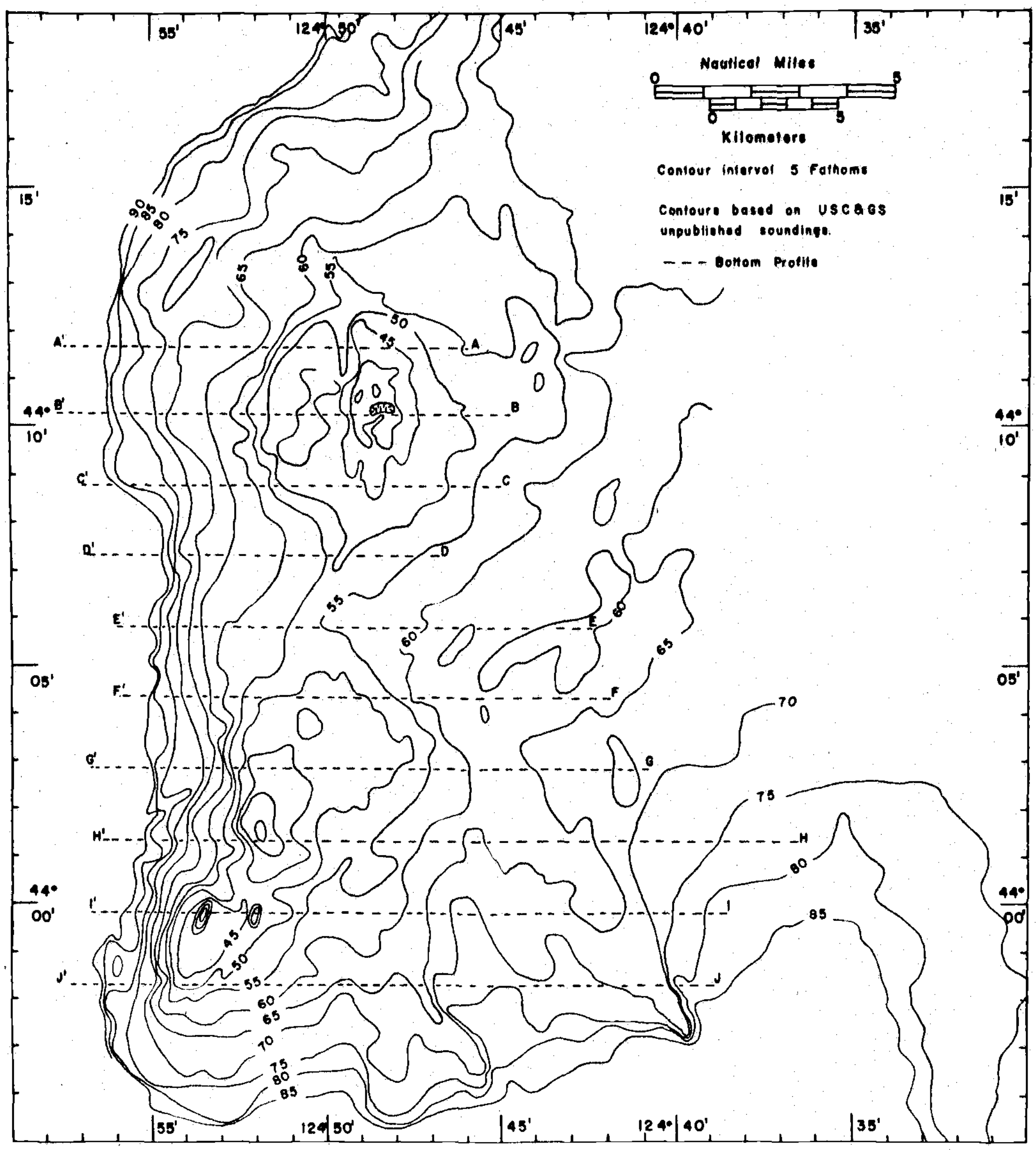


Plate 13. Bathymetric map of Heceta Bank. Dashed lines locate profiles obtained from Precision Depth Records shown on Plate 14.

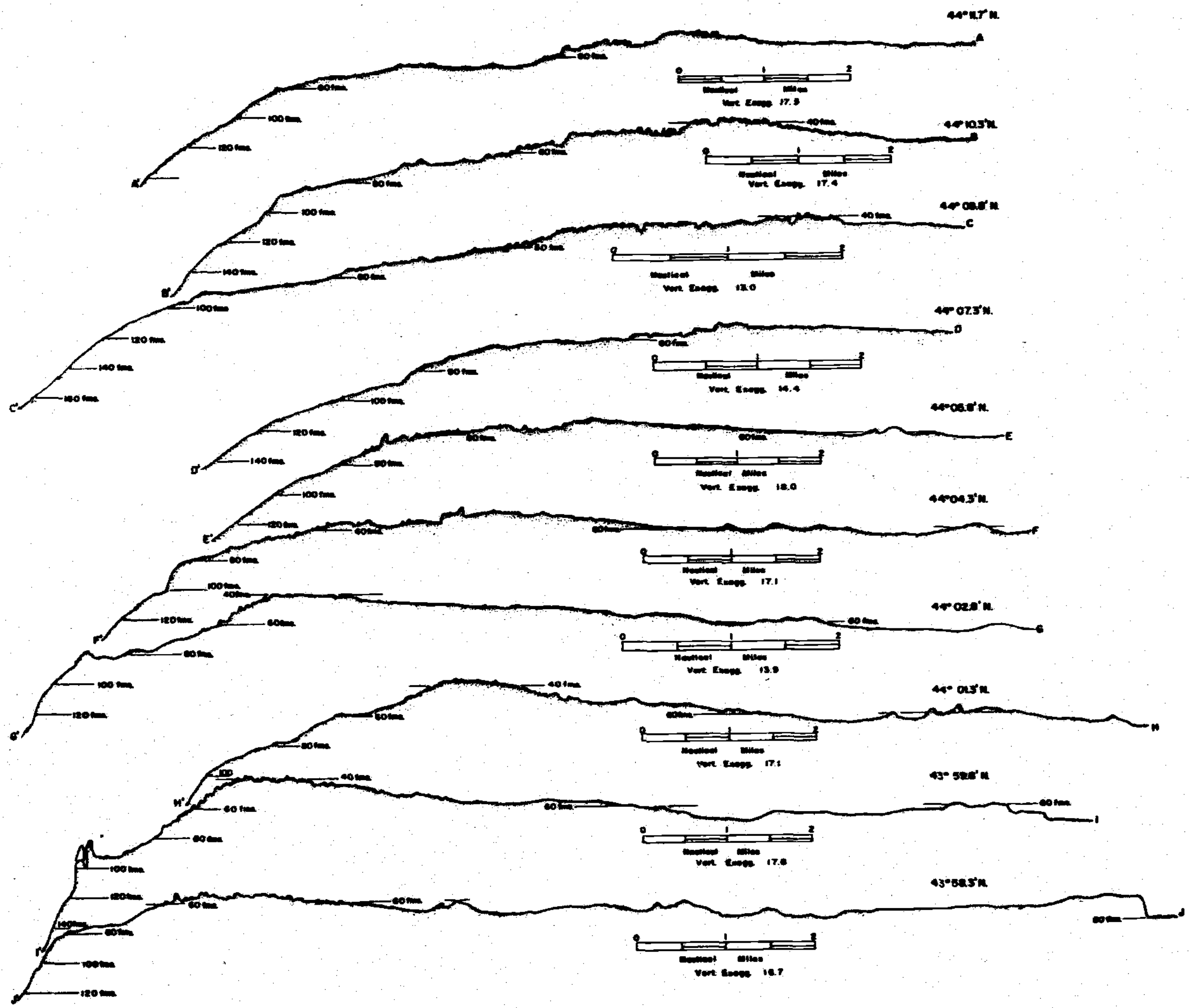
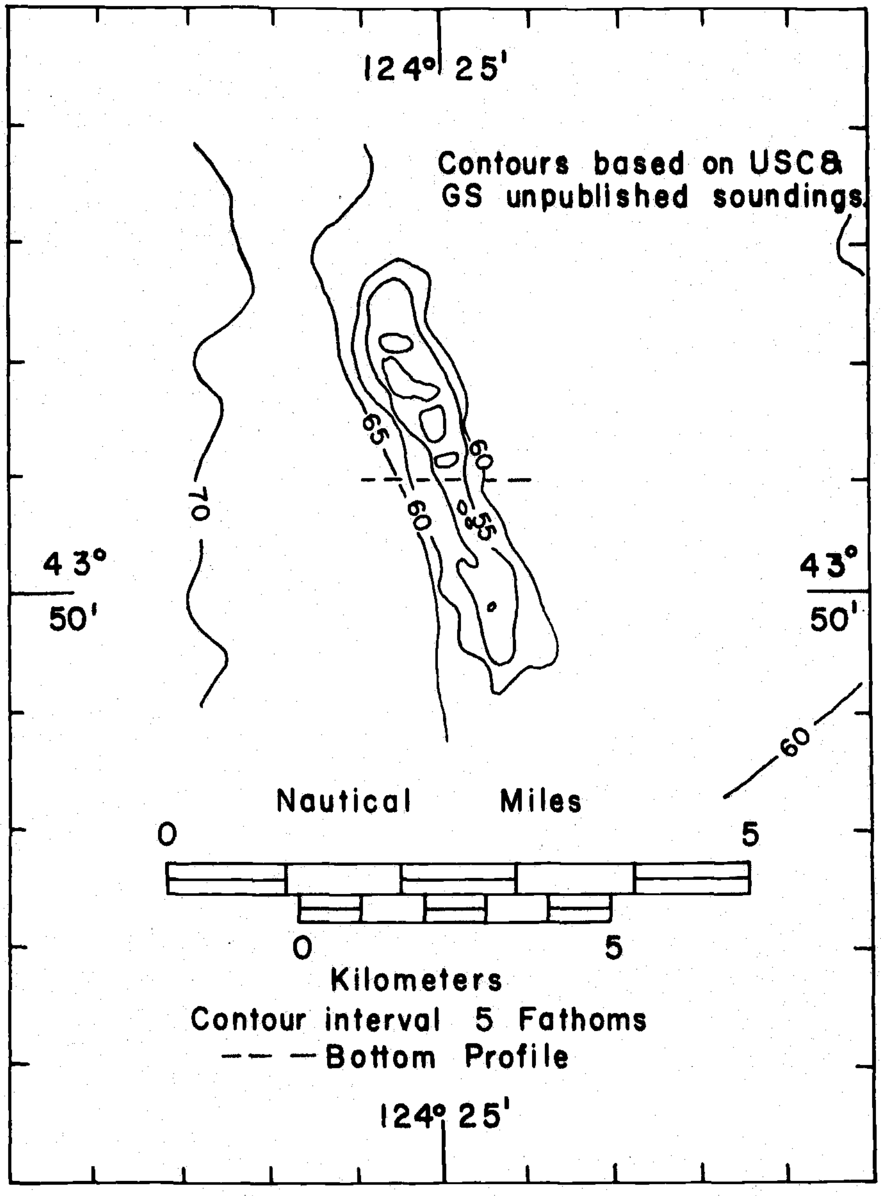


Plate 14. East-west profiles of Heceta Bank. Profile locations are shown on Plate 13.

area reaches its maximum width of eight miles at latitude 43° 58' N. The average depth ranges from 50 to 65 fathoms and there is up to 30 fathoms of relief. The most impressive scarp extends from 43° 57' N, 124° 39' W to 44° 01' N, 124° 42' W. It is 20 fathoms high, trends N 25° W, and faces northeast. The scarp disappears to the northwest, but the curving of the contour lines suggest a gentle slope that is traceable from the northwestern end of the scarp to the west side of Heceta Bank at 44° 05' N, 124° 40' W. A subparallel scarp, five to ten fathoms high, occurs to the west of the first scarp. This scarp faces to the west and trends N 35° W.

Irregular topography on Heceta Bank and east of the bank indicates the presence of large areas of exposed bedrock. Heceta Scarp, which forms the upper part of the continental slope, and the numerous smaller scarps present to the east of the bank suggest that faulting was involved in the formation of the bank. The small valley-like features occurring on the bank may well have resulted from subareal erosion during the Pleistocene lower stands of sea level.

Siltcoos Bank. Siltcoos Bank is the name applied herein to the small sub-rectangular shoal area located 12 to 13 miles offshore between 43° 49' N and 43° 53' N latitude (Plates 2 and 15). The bank is four and one-half miles long and one mile wide. It trends N 20° W, has a minimum depth of 49 fathoms, and has 17 fathoms of relief.



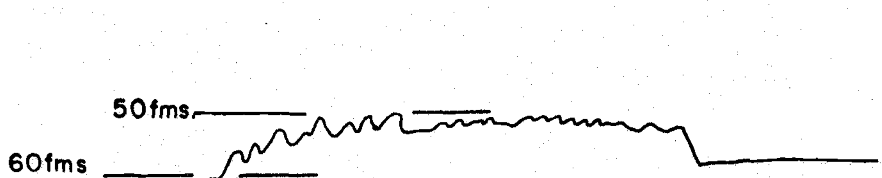


Plate 15. Bathymetric map and profile across Siltcoos Bank. Profile taken from Precision Depth Record for which the exact scale is not known.

One Precision Depth Record from Siltcoos Bank shows that the top is nearly level but irregular, with two to three fathoms of local relief. The relief is somewhat greater on the west side. Both sides of the bank are steep and are sharply defined at both top and bottom. One dredge haul obtained sedimentary rocks from the bank.

Siltcoos Bank appears to be a structurally emplaced rocky bank. The sides of the bank might represent either fault scarps or dip slopes of stratigraphic units.

Summary

The continental shelf off central Oregon occupies the area between the shore line and a depth of 71 to 90 fathoms where the first prominent change in slope occurs. The shelf is narrowest both in the north and in the south where the widths are 20 and 16 miles respectively. It is widest west of Heceta Head where it is 35 miles across.

The upper portion of the shelf is generally the steepest part. It slopes west at between 1° 08' and 0° 30' to depths of 20 to 55 fathoms. To the west, the shelf flattens out, sloping 0° 12' to 0° 3', forming the central shelf area. In the south, the central shelf area extends to the shelf edge; however, to the north the outer portion of the shelf contains a discontinuous series of banks. The three banks, Stonewall, Perpetua, and Heceta Banks, rise to 13, 38, and 25 fathoms respectively. Gentle swales are formed where the east sides of the banks merge with the central shelf area. Stonewall Swale occurs at depths of 38 to 48 fathoms and is directed to the north-northeast. Heceta Swale, on the other hand, trends south-southwest from 50 to 230 fathoms.

The central shelf area is smooth and almost flat suggesting that it is sediment covered. By contrast the banks have irregular topography formed by rock outcrops. The topographically high position of these rock exposures, 12 to 40 miles offshore, may mean that the area has been tectonically uplifted. The prominent scarps in the vicinity of Heceta Bank suggest that this area was emplaced by faulting. The swales may also have resulted from the uplift of the bank areas.

Continental Slope

The continental slope off the central coast of Oregon extends from the shelf edge, at 71 to 90 fathoms, west to the abyssal plain at 1530 to 1610 fathoms. It is 16 to 37 miles wide with the widest portion generally adjacent to the narrowest portion of the shelf and vice versa (Plate 10). The bathymetric map of the continental slope is given as Plate 8, page 238.

Based upon the bathymetry, the continental slope has been divided into northern, central and southern regions. The boundary between the northern and central regions is marked by a change in the trend of the shelf edge, a steepening of the upper part of the slope, and a discontinuity of the bench areas on the slope (Plate 16). The boundary between the central and southern regions is taken at the southern end of Heceta Bank where the width of the slope is doubled.

Northern Slope Region

The northern portion of the continental slope includes the area between 44° 14' N and 44° 40' N latitude. It is divided into upper, intermediate, and lower slope areas. The bathymetry of the northern region is illustrated by the profiles of the continental slope shown in Plates 17, 18 and 23.

The top of the continental slope has a general trend of N 20° to 30° W, but it is not straight as it curves east in the vicinity of Stonewall Bank. The upper part of the slope extends from the shelf break at 71 to 85 fathoms, west to the first hill or bench at depths of 160 to 280 fathoms. North of latitude 44° 20' N the upper slope is smooth and slightly convex upward with a westward slope of 01° to 03°, to depths of 160 to 220 fathoms. South of this latitude the upper slope is steeper, averaging about 07°, and extends to depths of 200 to 280 fathoms. The upper slope is smooth and in all likelihood covered with sediment in most places. However, irregular topography is present between latitudes 44° 30' N and 44° 25' N indicating the presence of rock exposures.

West of the upper slope there is a region of irregular topography,

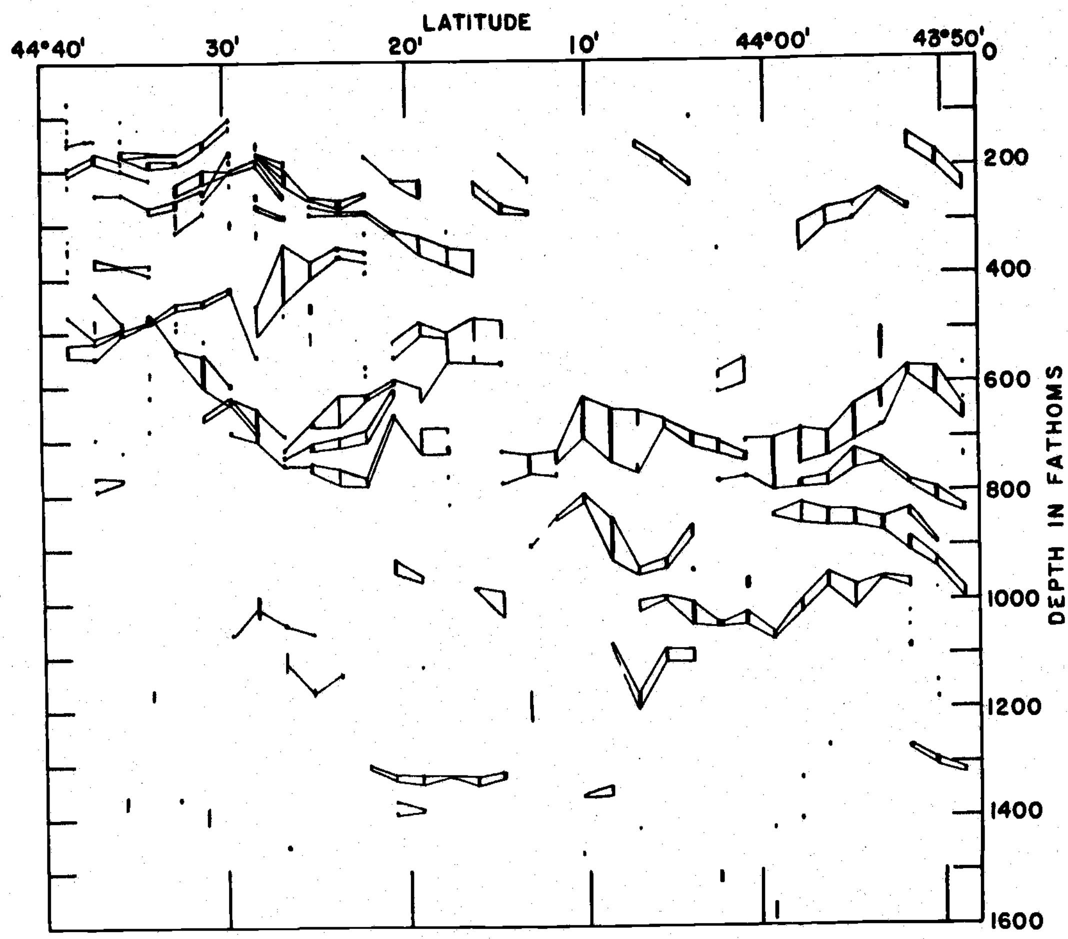


Plate 16. Bench depths according to latitude. The horizontal axis is in degrees of latitude and the vertical axis is depth in fathoms. The bars indicate benches interpreted from Precision Depth Records of east-west sounding lines. The length of the bar represents the depth range of the bench. The connecting lines correlate the benches on succeeding profiles.

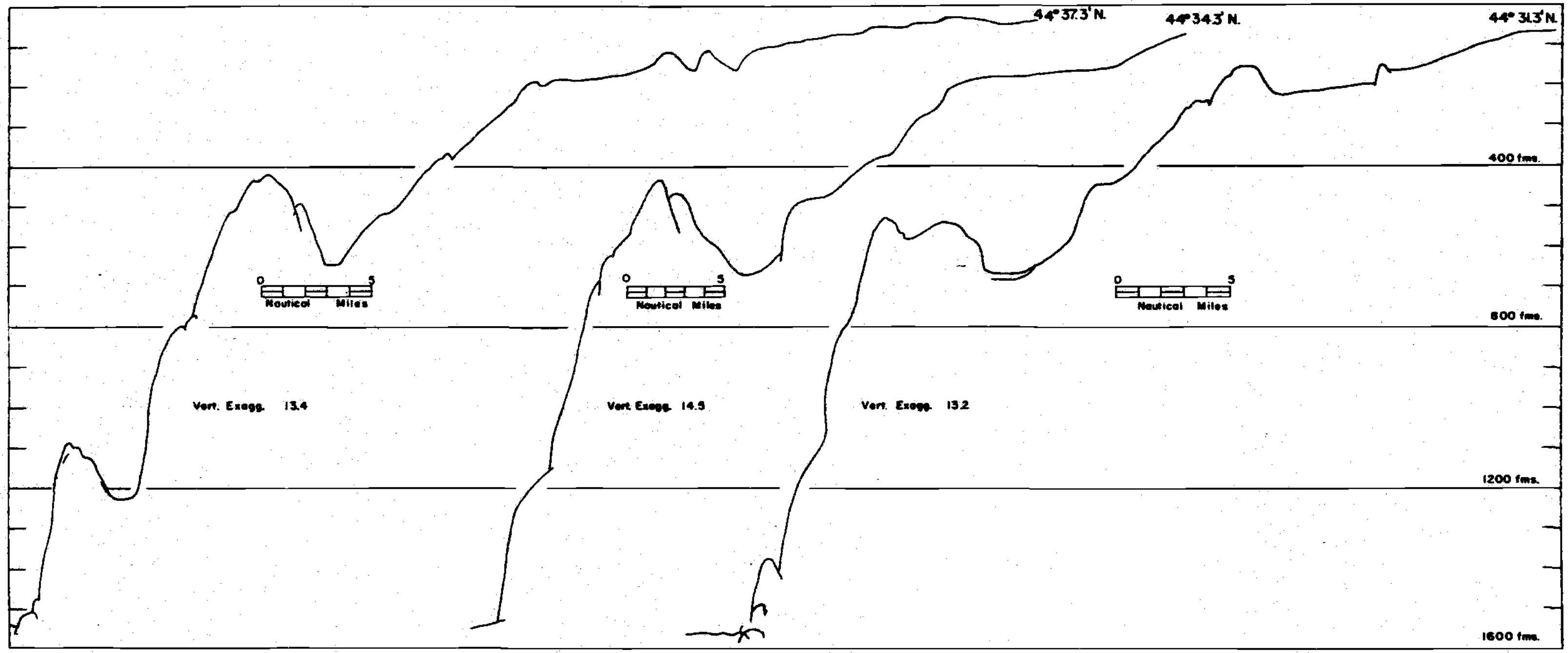


Plate 17. Continental slope profiles along latitude 44° 37. 3' N and 44° 34. 3' N, and 44° 31. 3' N.

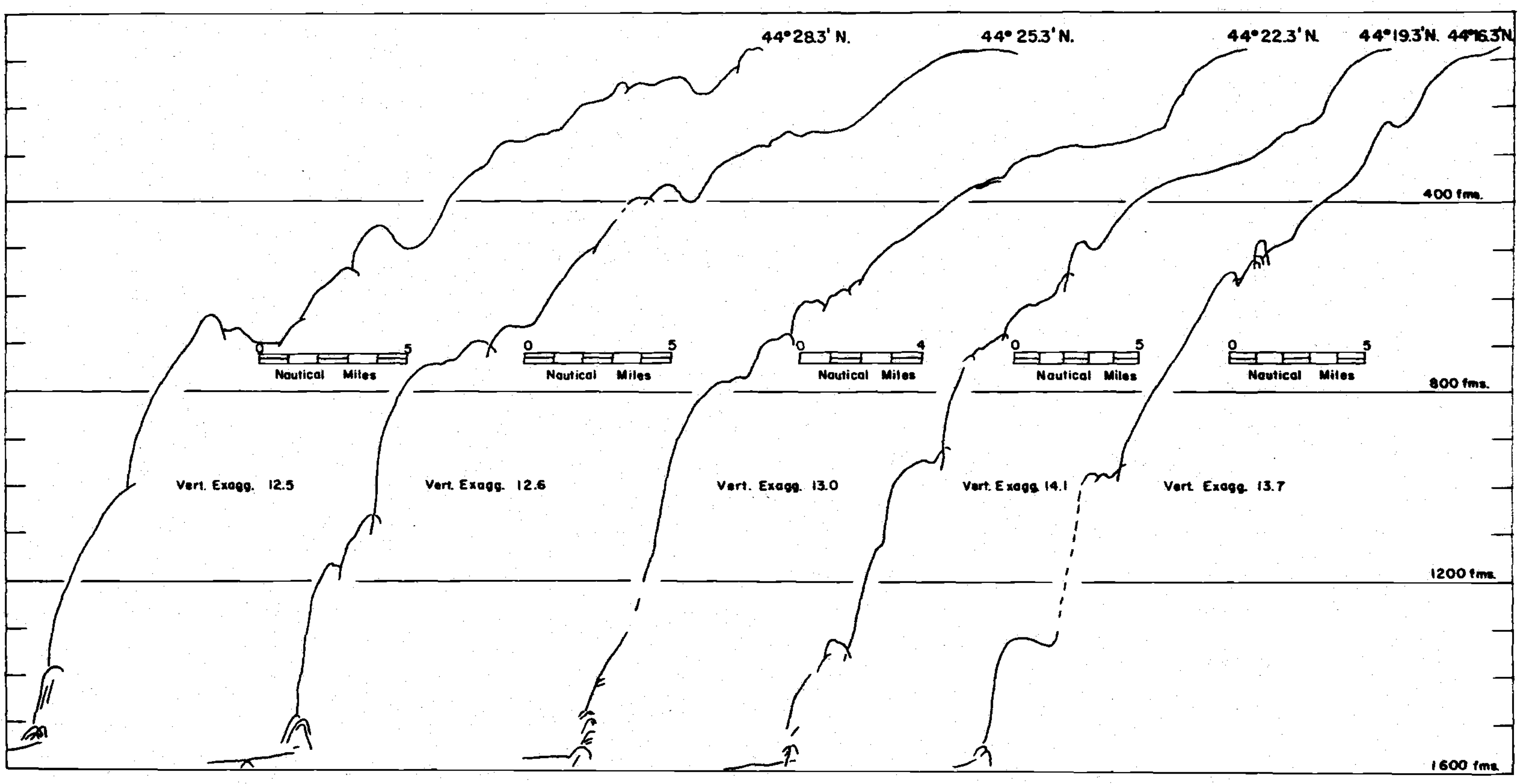
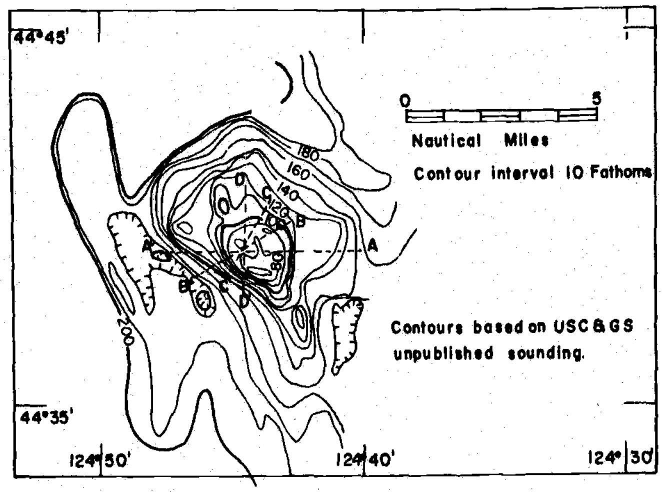


Plate 18. Continental slope profiles along latitudes 44° 28. 3' N, 44° 25. 3'N, 44° 22, 3'N, 44° 19. 3'N, and 44° 16. 3'N.

herein called the intermediate slope area. It includes numerous straight slopes separated by areas of benches, hills, and valleys. The benches occur at almost all depths, and range from nearly flat level surfaces to undulating, sometimes irregular, areas with small hills and depressions. The most prominant area of benches is located west of the upper slope and north of the latitude 44° 28' N at depths of 160 to 200 fathoms. These benches are generally smooth and slope gently to the west. Locally they are interrupted by hills. South of 44° 28' N the benches become more restricted and slope southwest to a depth of 400 fathoms at 44° 15' N.

Several small hills occur in the intermediate slope area. The largest of these are Daisy Bank at 44° 39' N, 124° 44' W, and two unnamed hills at 44° 30' N, 124° 50' W, and 44° 27' N, 124° 43' W. Daisy Bank is the name used by local fisherman for a hill located 34 miles west of Newport at the base of the upper slope (Plates 2 and 19). This bank shoals from a depth of 170 fathoms on the landward side to 69 fathoms on top. The bank top is nearly flat with slightly raised areas at the outer perimeter of the top. Benches are present on the east side of the bank at 105 and 114 fathoms. The west side has benches and irregular topography at depths of 152 and 210 fathoms. The lower portion of the hill extends south to 44° 35' N as two ridges which shoal to 108 and 112 fathoms (Plate 17, profile 44° 37.3'). Byrne (1962) has suggested that the flat top on Daisy Bank is the



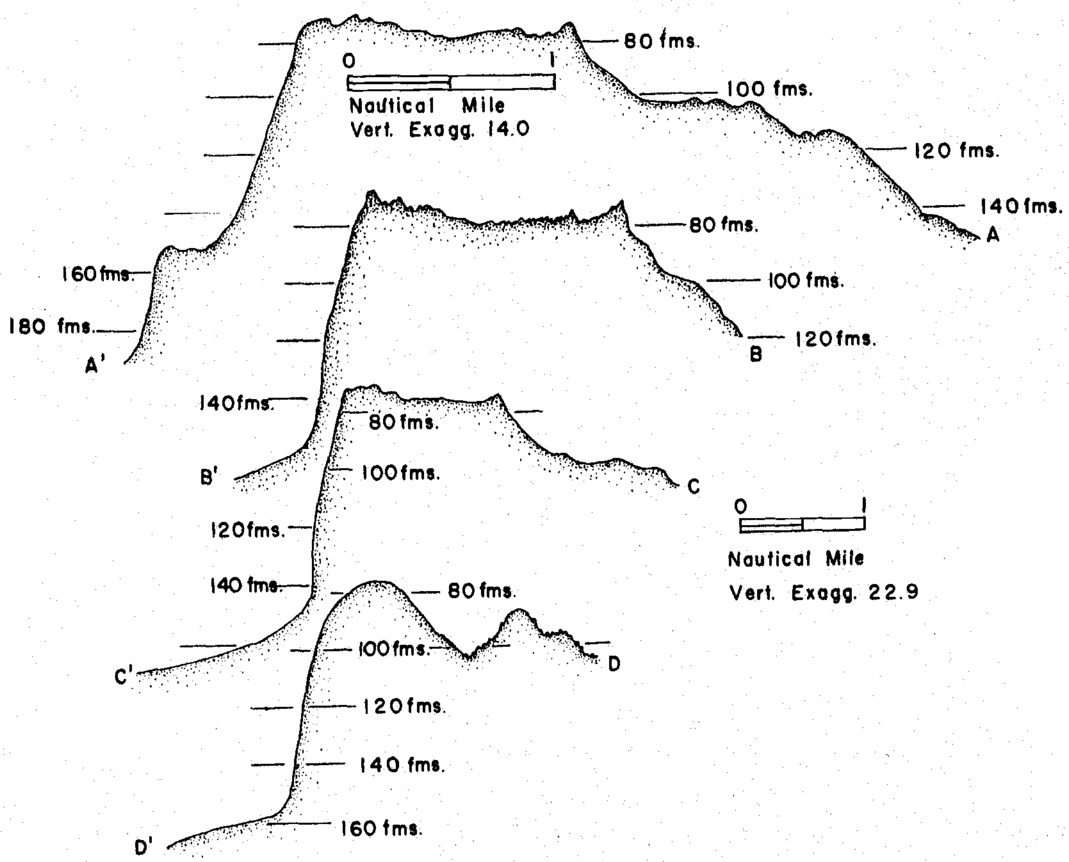


Plate 19. Bathymetric map and profiles of Daisy Bank. The profiles are from Precision Depth Records. The exact scales for profiles B and D are not known.

result of truncation by wave erosion which took place during Pleistocene lowering of sea level.

The unnamed hill at 44° 30' N, 124° 50' W is also located at the base of the upper slope (Plate 20). Its highest point has a depth of 119 fathoms, and the bank, thus, has a total relief of approximately 100 fathoms. Most profiles of the bank show it as having a rounded top with local relief features of one to ten fathoms. One east-west profile at latitude 44° 29.9' N shows that the upper surface is fairly flat but tilted slightly to the west. The west side of the hill is modified by small irregular benches and hills with up to 15 fathoms of relief.

The third hill is located to the west near the center of the intermediate slope at 44° 27' N, 125° 03' W (Plate 21). This hill has a relatively smooth, conical top with a minimum depth of 341 fathoms. A depression with a maximum depth of 497 fathoms is present on the east side of the hill.

The only sea valley of any magnatude is located approximately 48 miles west of Newport and is herein named Newport Valley (Plate 22). It trends S 30° W, has an axial slope of 0° 14' and descends from 600 to 750 fathoms. It exhibits a maximum relief of 294 fathoms at latitude 44° 39' N. The valley bottom changes in character from a V-shaped valley north of latitude 44° 38' N to a broad U-shaped valley south of latitude 44° 32' N where the gradient decreases to zero. The southernmost Precision Depth Record showing the valley is at

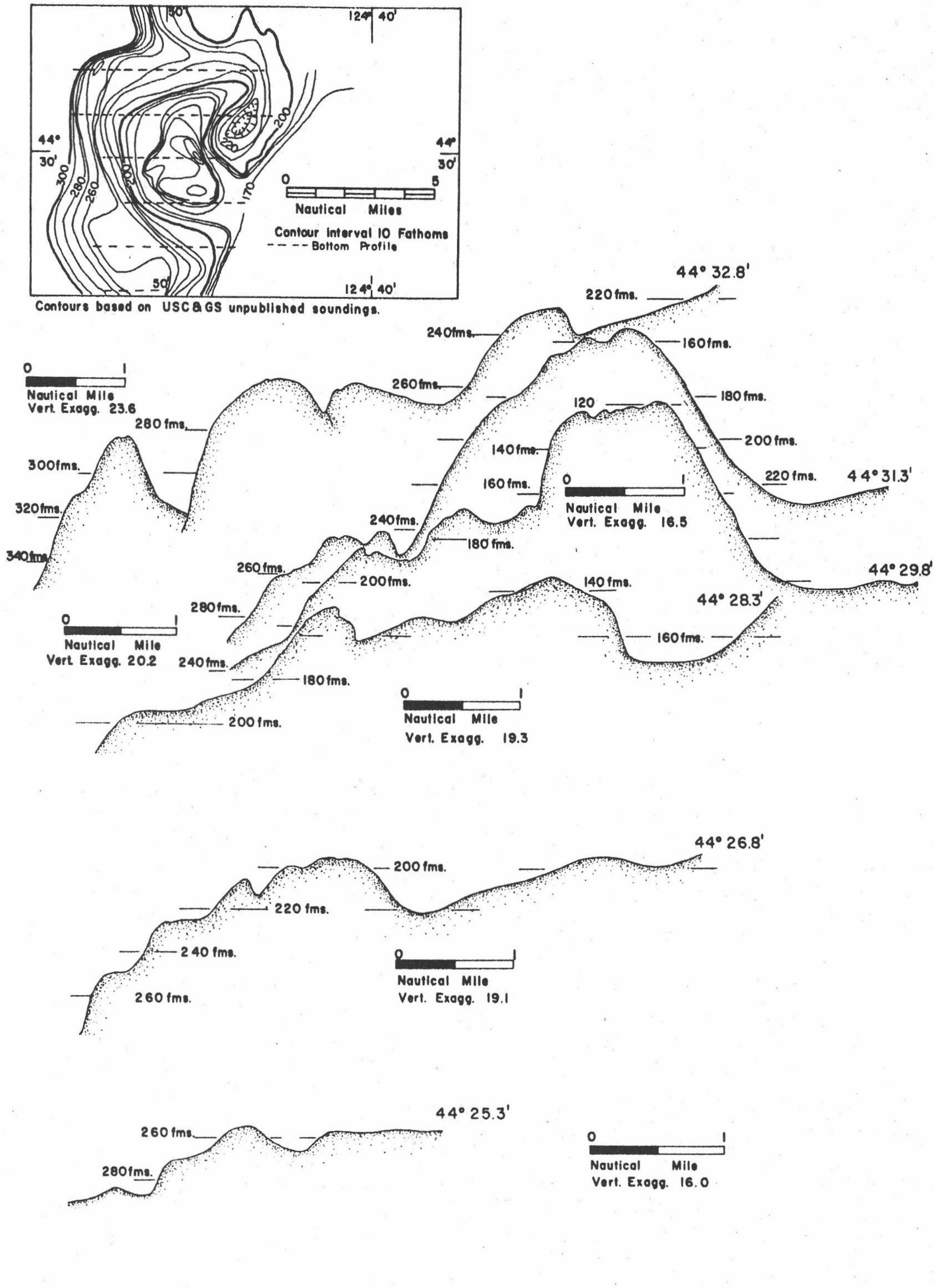


Plate 20. Bathymetric map and profiles of the unnamed hill at 44° 30' N, 124° 50'N. The profiles are from Precision Depth Records.

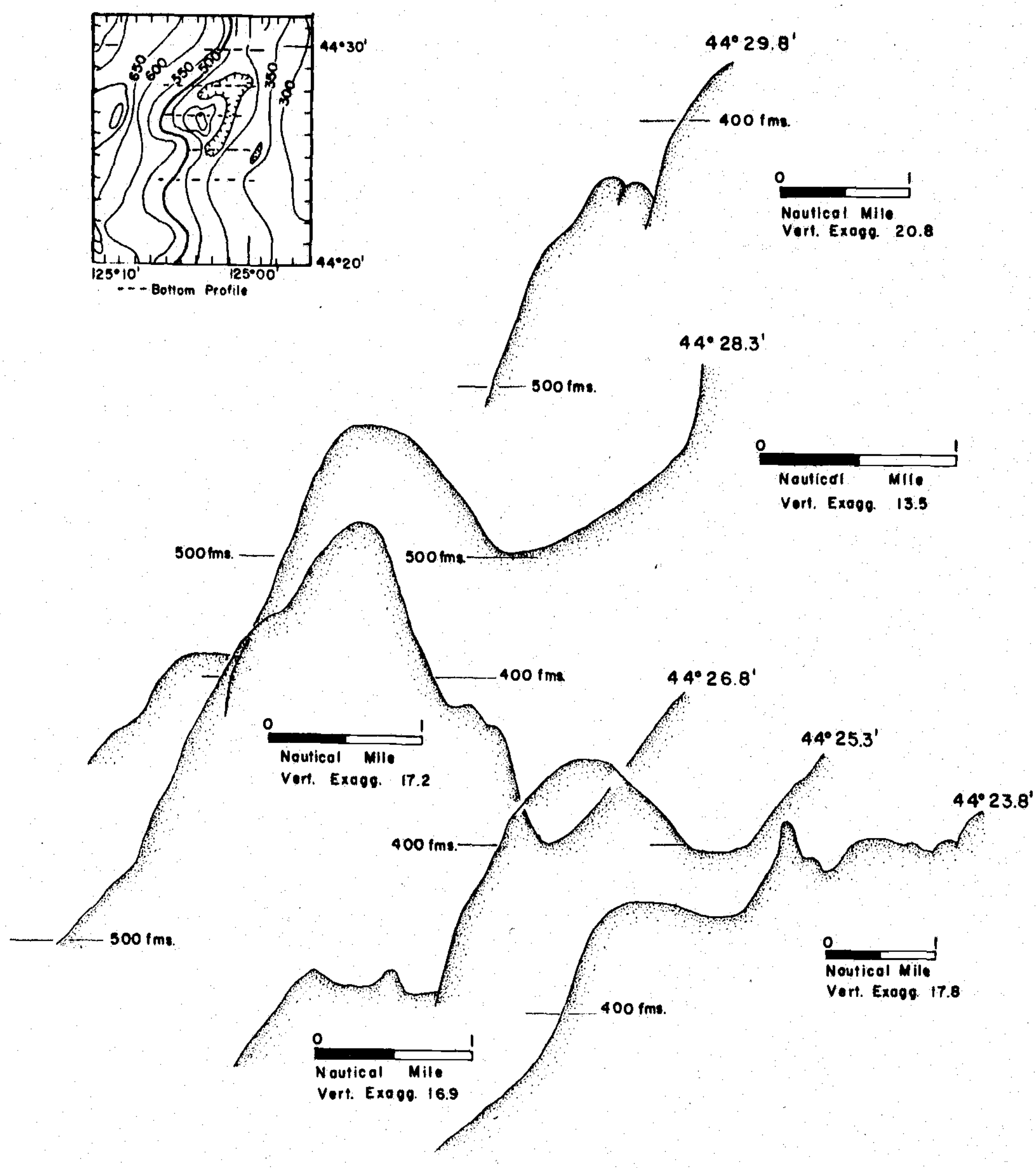


Plate 21. Bathymetric map and profiles of unnamed hill at 44° 27' N, 125° 03' W. The profiles are from Precision Depth Records.

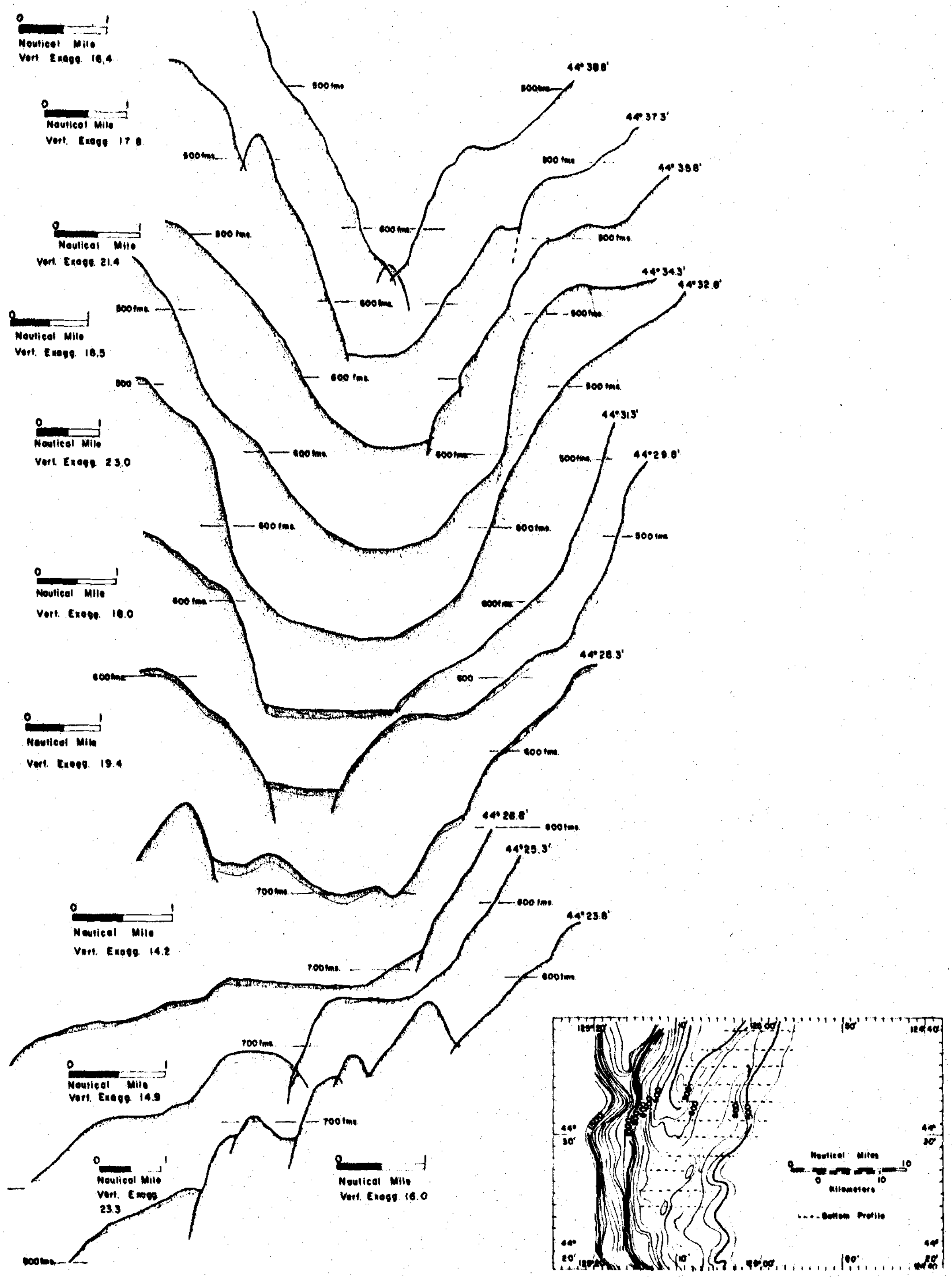


Plate 22. Bathymetric profiles of Newport Sea Valley. Profiles are from Precision Depth Records.

latitude 44° 28.3' N. Here the valley bottom is hummocky and has about 30 fathoms of relief. The east side of the valley contains a bench at depths that vary from 350 to 550 fathoms. The bench decreases in depth to the south where it veers away from the valley.

The hill forming the west side of Newport Valley is aligned with the valley. It has a minimum depth of 322 fathoms near 44° 40' N, and it decreases in elevation southwest to 44° 26' N where it merges with the lower end of the valley and forms a bench. The bench ends abruptly on the west at a steep scarp.

The lower slope area is formed by a scarp extending from the intermediate area of the slope to the abyssal plain (Plate 10). The scarp strikes north and slopes west at 04° to 12°; in local areas it is as high as 35°. It is interrupted by three benches and a hill.

The hill, located north of 44° 34' N, has a minimum depth of about 1080 fathoms and has a relief of 140 fathoms with respect to the depression on the east side. One Precision Depth Record shows a much smaller hill on the bottom of the depression.

Benches are much less developed on the lower slope. One bench is located between 44° 26' N and 44° 30' N at depths of 1050 to 1100 fathoms. It is an area of lesser westward slope and the western, or lower edge, is rounded and difficult to define. Two benches are present between 44° 14' N and 44° 22' N. The upper bench occurs at depths of 940 to 1000 fathoms. It has a maximum width of two miles,

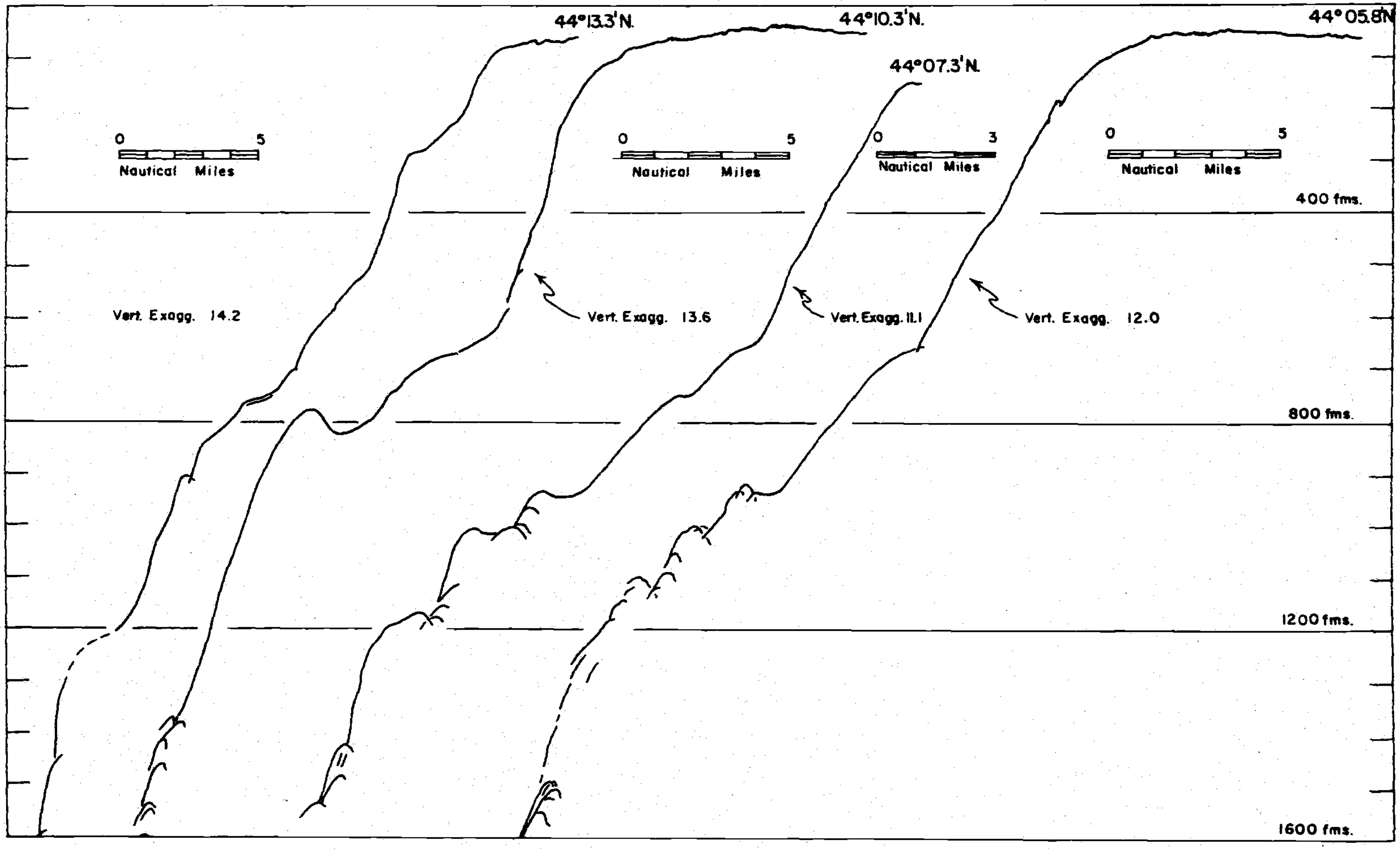


Plate 23. Profiles of the continental slope taken along latitudes 44° 13.3' N, 44° 10.3'N, 44° 07.3' N, and 44° 05.8' N. The profiles were traced from Precision Depth Records.

and its surface is undulating, with relief features of up to 40 fathoms. The lower bench occurs at depths of 1310 to 1340 fathoms and is up to 2.5 miles wide. This bench slopes to the east (Plate 18, 44° 16.3'N).

The lower portion of the continental slope forms a sharp intersection with the abyssal plain. Precision Depth Records show numerous conical side echoes near the base of the slope. In addition, several records show raised surfaces of 5 to 20 fathoms on the abyssal plain adjacent to the slope. These topographic irregularities may have resulted from slumping on the continental slope or from small faults at the base of the slope.

Central Slope Region

The central slope region, located between latitudes 43° 57' N and 44° 13' N, is the narrowest and steepest portion of the continental slope. It is 16 to 18 miles wide and has an average slope of 4° 20'. This region is also subdivided into three areas, the upper, intermediate, and lower slope areas.

North-trending Heceta Scarp forms the upper slope area in this region. The scarp extends the length of the region and from the shelf edge to depths of 580 to 710 fathoms. It has an average westward slope of 10° to 16° and locally it increases to 30°. The steep, straight nature of this scarp suggests that it is a fault scarp.

The intermediate slope is interrupted by benches and small hills.

In the north this area includes only a single bench which is an area of lesser slope at 500 to 760 fathoms (Plate 23, profile 44° 13.3' N). To the south the intermediate slope area widens and becomes more complex. West of Heceta Bank it occupies an area 11 miles wide between the base of Heceta Scarp and the top of the lower slope at 900 to 1100 fathoms. The eastern part of the intermediate slope is formed by an area which slopes west at a smaller angle than Heceta scarp. It extends to depths of between 580 and 800 fathoms, and is fairly smooth on most profiles. An exception occurs at latitude 44° 02.8' N where it is hilly. The western, or deep, portion of the intermediate slope contains numerous small hills and benches. Conical side echoes are abundant on many of the Precision Depth Records. The hilly topography suggests the presence of rock exposures. Many of the scarps separating benches and hills are of possible fault origin.

The lower slope is formed by the same scarp occurring in the northern region. The top of the scarp occurs at 800 to 1100 fathoms, and the base is at the abyssal plain at 1560 to 1600 fathoms. The scarp trends north and has an average slope of 10 to 15°. The scarp is somewhat curved between latitudes 44° 07' N and 43° 57' N. North of 44° 03' N it bulges one to two miles to the west and south of that latitude it curves two to five miles to the east. Precision Depth Records across the scarp show numerous side reflections and a few small hills. The traverses between latitude 43° 59' N and 44° 11' N

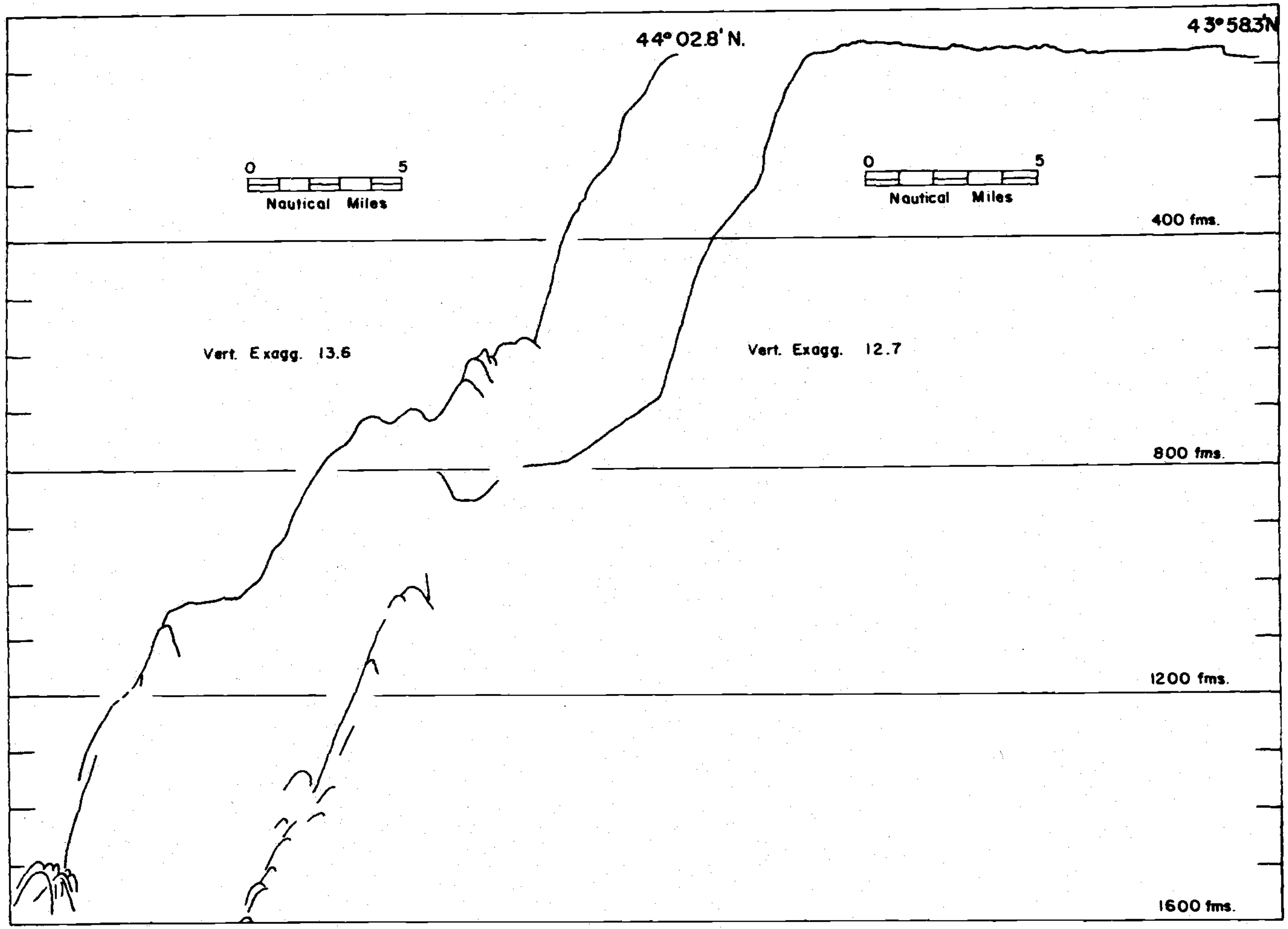


Plate 24. Profiles of the continental slope along latitudes 44° 02.8' N and 43° 58.3' N. Profiles from Precision Depth Records.

show a number of small hills close to the base of the slope. One hill, 30 to 35 fathoms high, was recorded on the abyssal plain adjacent to the slope at 44° 00' N latitude.

Southern Slope Region

South of latitude 43° 57' N the continental slope attains its maximum width of 37 miles. Profiles of the southern slope region are shown in Plates 25 and 26.

The upper part of the slope is inclined to the south at the southern end of Heceta Bank, and west from the shelf south of the bank. At Heceta Bank the upper slope is irregular in some areas and smooth in others. South of the bank it is smooth and slopes less than 02°. The upper slope forms the east side of Heceta Swale which continues southwest from the shelf edge to 230 fathoms on the slope. Here the swale is five miles wide and has about 20 fathoms of relief. It has a smooth almost flat bottom. The west side of the swale is formed by broad low hills, or hummocks, having a maximum relief of 30 fathoms. The hummocks deepen to the southwest parallel with the swale. They are quite irregular in the vicinity of Heceta Bank, but are smooth to the south.

The west side of the hummocks is formed by the southern extension of Heceta Scarp. The scarp slopes west 8° to 18° to depths of 550 to 700 fathoms. Over most of its distance the scarp is straight

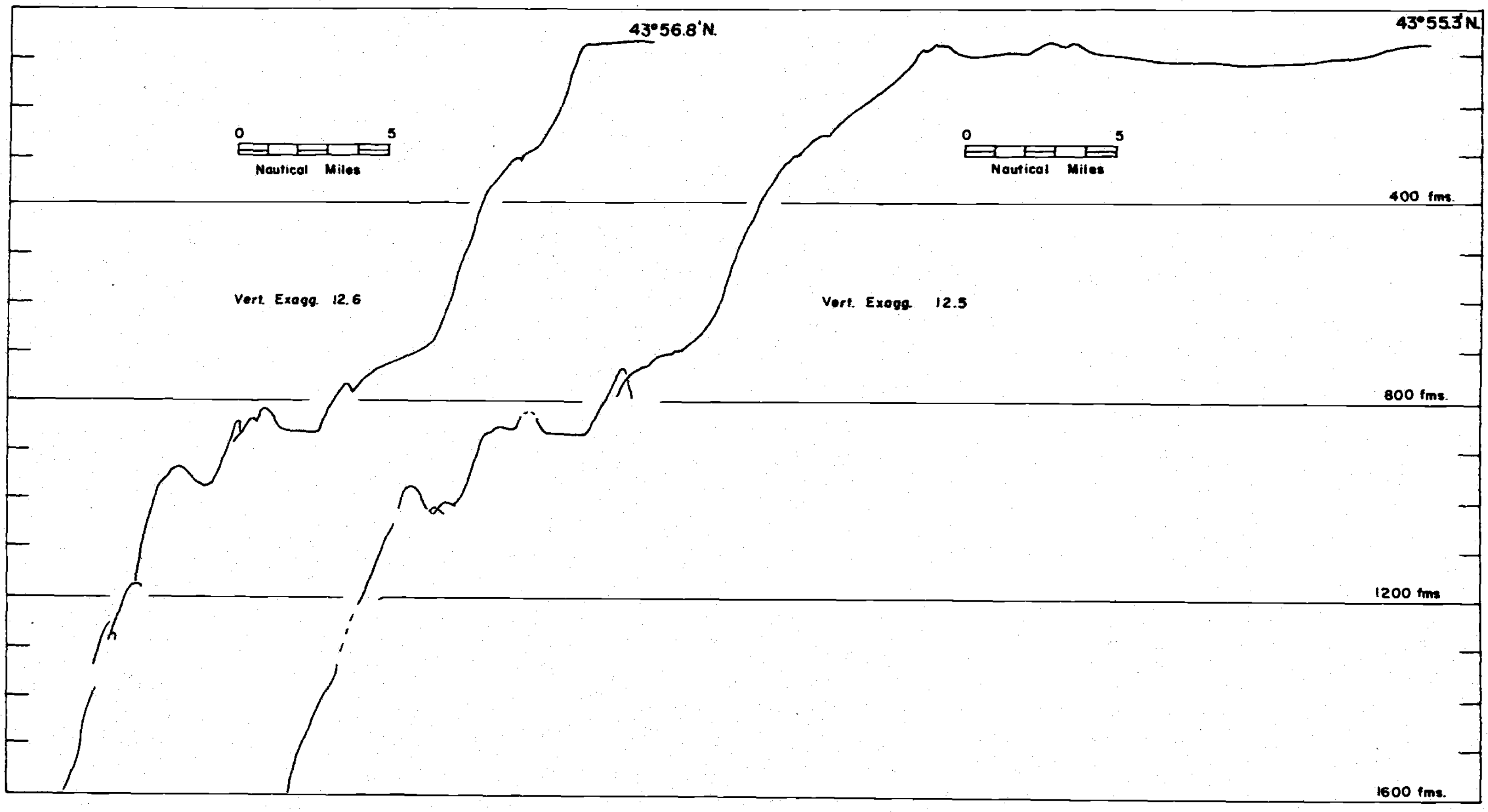


Plate 25. Bathymetric profiles of the continental slope along latitudes 43° 56.8' N and 43° 55.3' N. Profiles from Precision Depth Records.

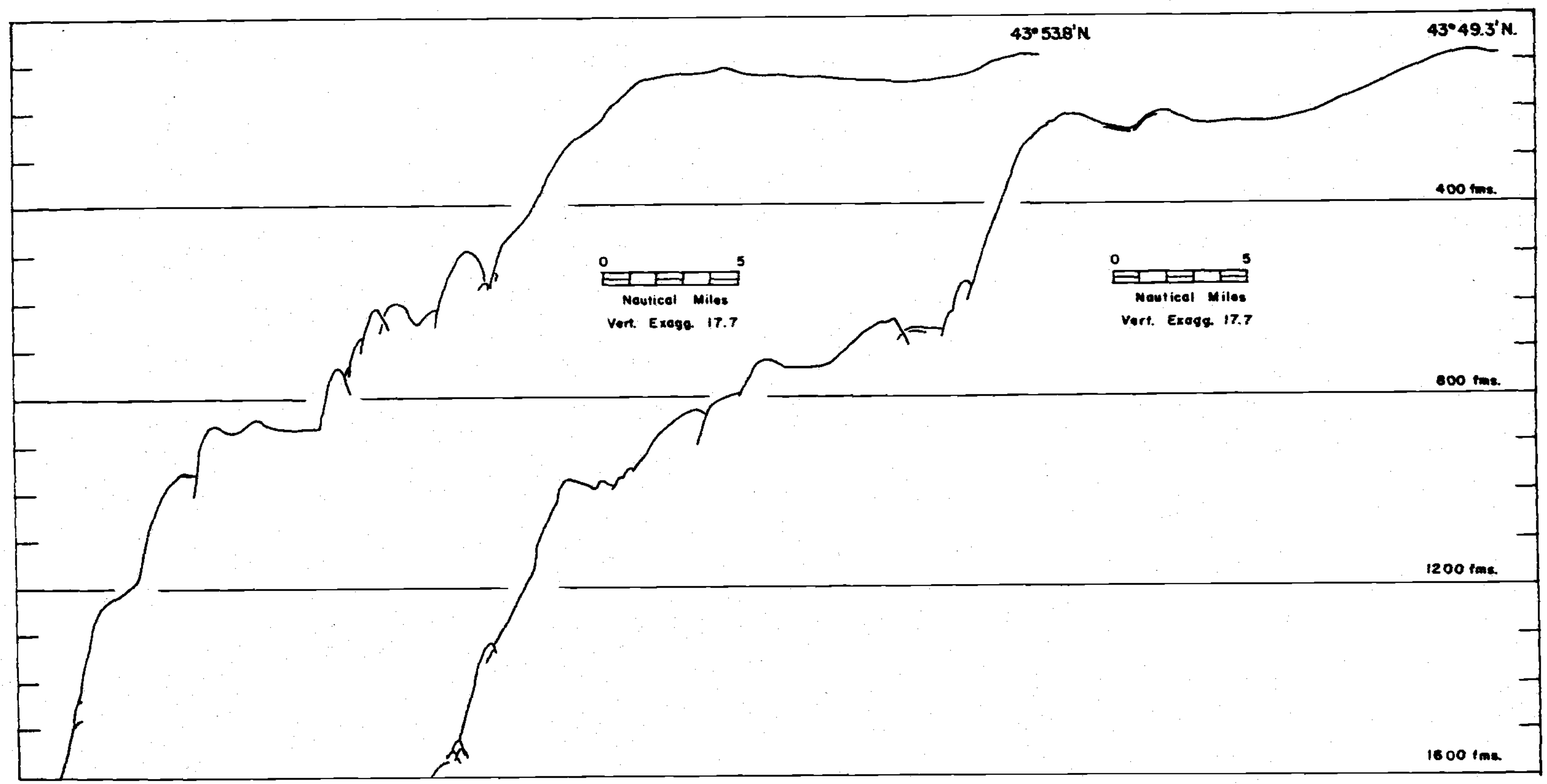


Plate 26. Profiles of the continental slope along latitudes 43° 53. 8'N and 43° 49. 3'N. The profiles were made from Precision Depth Records.

and north trending. The one major deviation is at the southern end of Heceta Bank where the scarp bends two to three miles to the east.

The intermediate slope area consists of numerous hills and benches located between Heceta Scarp and the top of the lower slope at depths of 930 to 1100 fathoms. The eastern, or upper, part of the intermediate area is much hillier than in the central region. Many of the benches tilt to the east, and south of latitude 43° 52.3' N they also slope to the south. Several of the benches and hills are separated by steep scarps that are suggestive of fault scarps.

The steep scarp forming the lower slope in the northern and central regions continues through the southern region. In this region the scarp extends from 930 to 1100 fathoms at the western edge to the intermediate slope westward to about 1610 fathoms at the abyssal plain. The scarp slopes west with an average inclination of 07° to 12°. It is interrupted locally by two small benches occurring at depths of 1100 and 1300 fathoms. The base of the slope is obscured on all of the Precision Depth Records, and for this reason the exact nature of the intersection of the continental slope and the abyssal plain is uncertain. The long, straight, steep nature of this scarp suggests that it could be a fault scarp of major proportions.

Summary

The continental slope off central Oregon is 17 to 37 miles wide as it extends from the shelf edge at 71 to 90 fathoms to the abyssal plain at 1530 to 1610 fathoms. The upper part of the slope trends N 20° E and has a smooth, gentle slope of less than 03° to depths of 160 to 220 fathoms in the region north of latitude 44° 30' N. South of this latitude to 44° 13' N it trends N 30° E and is a more irregular, steeper slope, averaging 07° to depths of 200 to 280 fathoms. Heceta Scarp forms the upper part of the slope between latitudes 44° 13' N and 43° 57' N. This scarp trends north and has an average westward slope of 10 to 16° to depths of 585 to 715 fathoms. South of Heceta Bank the upper slope becomes smooth and gentle sloping less than 02° to depths of as much as 230 fathoms at the bottom of Heceta Swale. Heceta Swale is a broad, smooth topgraphic low that plunges south-southwest. It is five miles wide and has a relief of 20 fathoms with respect to the low hummocks to the west.

Benches and hills with separating scarps occur at intermediate depths on the slope. The largest hills and the only valley of any magnitude, Newport Valley, are located in the north. Benches are abundant. In some areas they are almost flat, in others merely areas of lower declivity. In other places they are irregular and marked by small hills. North of latitude 44° 13' N some of the most significant benches occur at depths of from 160 to 300 fathoms, but south of this latitude almost all the benches of any magnitude are at depths of more than 550 fathoms. In many places, especially south of 44° 13' N, successive benches and/or hills are separated by steep scarps. These scarps are nearly straight and trend north.

The lower part of the continental slope is formed by a north trending scarp. This scarp slopes 04° to 15°, with local slopes of as much as 35°, from depths of between 380 and 1100 fathoms to depths of 1530 to 1610 fathoms at the abyssal plain. One large hill and a number of small hills and benches occur on the scarp. Precision Depth Records show that the continental slope-abyssal plain intersection is sharp and that no continental rise is present.

The genesis of the physiographic features of the continental slope is discussed in the Geologic Structure and Geologic History sections of the thesis.

SEDIMENTOLOGY

Unconsolidated sediment covers large areas of the continental terrace off central Oregon. This sediment consists chiefly of sand, silt, and clay which was derived primarily from the continent.

Central Oregon Coast

Sediments are present along the central Oregon coast as beach, estuarine, and terrace deposits. Fine to medium grained sands form the dominant sediment type in all environments. These sands are texturally and mineralogically immature, with heavy minerals comprising two to five percent of the sand. Significantly higher concentrations of heavy minerals occur locally in beach and terrace deposits; they approach 100 percent in a few areas. Bright yellow grains of weathered plagioclase and rock fragments are abundant in the coastal sands. Kulm (1965) observed that the "yellow" grains were most abundant in the terrace deposits and suggested that the yellow color is the result of weathering in the terrace. Much of this sand has since found its way onto the beaches and into estuaries by means of coastal erosion and long shore and tidal currents.

Gravel occurs on the beaches adjacent to headlands and is present at a few places in the terrace deposits. Well rounded basalt gravel forms beach deposits at Yaquina Head, Cape Perpetua, and

Heceta Head. Large well rounded cobbles and boulders of siltstone are present on the beach at Newport. The siltstone, however, breaks up very quickly on the beach and is not transported far from its source.. Thin lenses of gravel are present in the terrace deposits near Newport. They contain a large variety of lithologies including opal, chalcedony, and quartz.

Fine grained sediments (silt and clay) occur in the slough and tidal flat areas of the estuaries. The fine grained sediments not trapped in these local areas bypass the coast and are carried out to sea.

Several portions of the central Oregon coast are undergoing rapid erosion. In other areas sediment is deposited as sand dunes and spits. The sand could be transported from the erosional areas by longshore currents. The coastal rivers appear to be depositing most of their coarse sediment in the estuaries. Kulm (1965) found that sand from the beach and continental shelf has intruded into Yaquina Bay and that the traction load of river sediment is restricted to the upper part of the estuary. It appears then that most of the coastal rivers are providing only a small amount of sand to the continental shelf, whereas coastal erosion, especially in areas containing thick terrace deposits, is contributing considerable sand to the shelf. Silt and clay carried in suspension could be transported from both the river and shoreline areas.

Continental Terrace

Sampling Methods

Bottom samples from 379 locations were obtained from the continental terrace off central Oregon (Plate 27, Appendix 1); 253 of these samples included unconsolidated sediment. These samples collected by means of bottom grabs, dredges, and coring devices were utilized in the study of the sediment distribution on the continental terrace. The different sampling devices obtain different types of samples. Grab samples were taken with a Dietz-LaFond sampler which obtains a relatively small quantity of material from the upper three inches of the sediment. The advantages of using the grab are that it takes a spot sample and that it samples either sand or mud. The drawbacks are that the grab is too light weight for operating in deep water, provides a disturbed sample, and fails to give a vertical profile of the sediment.

Dredge samples were taken with a pipe dredge and an anchor dredge. These samples are obtained by dragging a dredge along the bottom for 10 to 30 minutes. The sediment obtained in this manner is a mixture of the material from the upper eight to ten inches of the bottom over the length of the tow. None of the dredge samples were taken for the express purpose of collecting sediment. Most of the

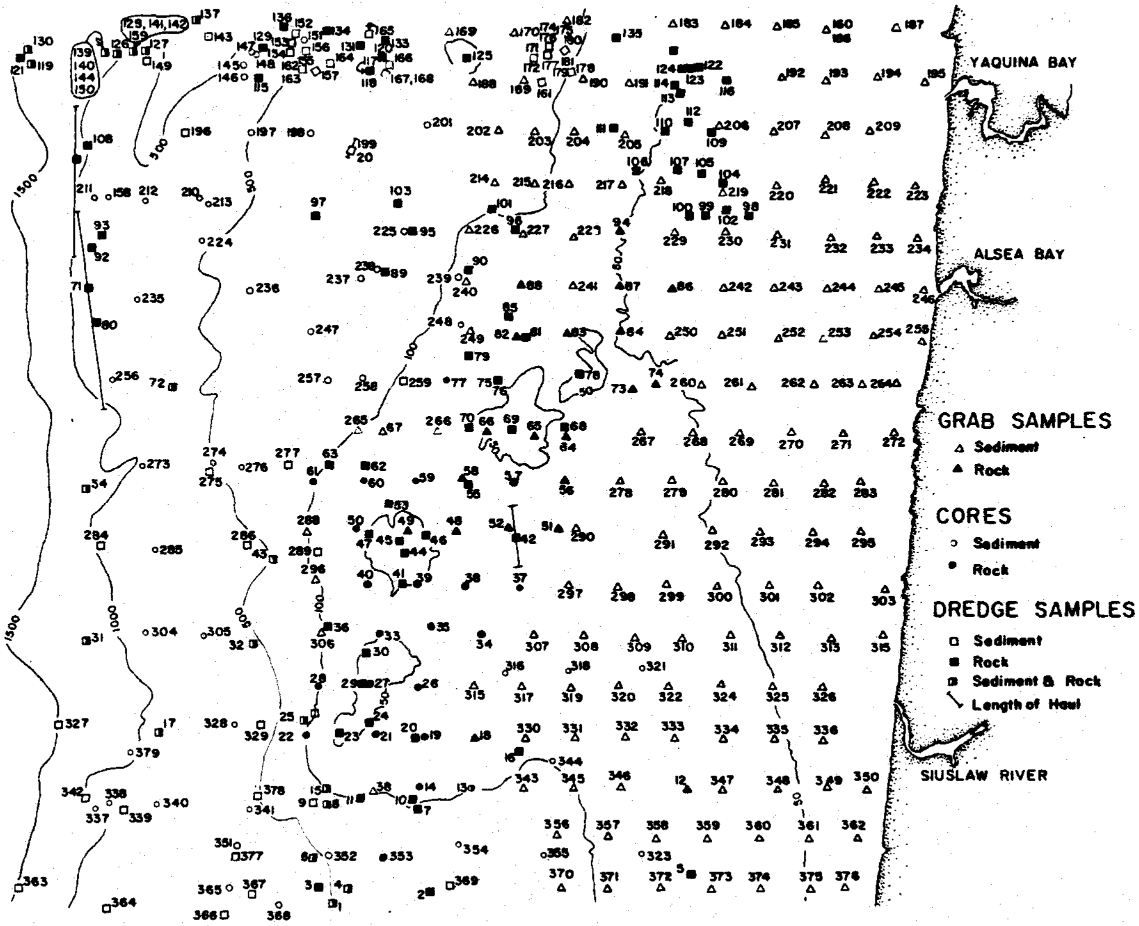


Plate 27. Map showing the bottom sample locations on the continental terrace off the central coast of Oregon. Sample 138 is located north of the map at 44° 44.8' N and 124° 32.3 W.

dredge samples obtained along the line west of Newport were taken for benthonic biological specimens. The clustering of samples found at several locations along this line has resulted from seasonal biological sampling. Most of the dredge hauls from other portions of the terrace were taken to obtain rock samples.

Coring devices obtain the best sediment samples. They collect a relatively undisturbed vertical column of sediment at a single position. A simple gravity corer with barrels two and five feet long was utilized in this study. The major drawbacks to the use of coring devices are that they frequently do not work in sand and that they do not collect a large quantity of surface sediment.

From the above discussion it can be seen that the different samplers obtain sediment samples of differing quantity and quality. A certain lack of uniformity is then introduced to this study as a result of using a heterogeneous group of sampling devices.

The distribution of sediment samples has resulted from several different surveys. The shelf samples were obtained on a systematic three mile grid in conformity with the preexisting survey by Bushnell (1964). Many of the slope samples were taken at positions preselected for geographic distribution, depth, and topography. Other slope samples were obtained from rock and biological dredge hauls. A result of the variation in sampling programs is that the sample density varies considerably from one place to another. As a result the averages and ranges obtained for the sediment statistics are biased towards the areas of high sample concentrations.

Methods of Analysis

Size Analysis. Mechanical analyses were carried out on all surface sediment samples. Most of the cores were analysed at two or three depths. The settling tube (Emery 1938) was used for the analysis of most of the sand samples. Samples containing shells and pebbles and some of the samples containing appreciable quantities of glauconite were sieved using a set of standard Tyler screens.

Samples containing more than four percent silt and clay were analysed in a different manner. These samples were first weighed and dispersed in 0.2 percent Calgon (sodium hexametaphosphate) solution. The dispersion was then filtered through a millipore filter to remove the sea water from the sample. The sediment residue was then covered with the Calgon solution to exactly 1000 cc, completely dispersed, and hydrometer readings were taken at 1, 2, 5, 15, 30, 60, 120, and 1440 minutes after the dispersion. Following the hydrometer analysis the sediment was wet sieved through a 0.062 mm screen. The sand fraction was then weighed, and if the sand fraction comprised more than four percent of the sample it was analysed using the settling tube.

Cumulative curves and particle size statistics were calculated using IBM 1410 and IBM 1620 computers. The median diameter, sorting, skewness, and kurtosis were calculated after the method of Trask (1932). In addition, Inman's (1952) values for phi mean diameter, phi deviation, phi skewness, phi kurtosis, and phi second skewness were calculated (Appendix 2). The text discussion utilizes only the median diameter (in millimeters), the phi deviation, and the phi skewness.

In addition to the above statistics, the computer calculated the percentage of sand, silt and clay in each sample. These values were used to classify the sediments into size groups.

Composition of Sand Fraction. A split of sand from each sample was spread over the grid on a micropaleontology slide and the composition of 150 to 250 grains were noted with the aid of a binocular microscope. For the very fine sand, the grains situated on the lines were counted, but for the medium grained sands the grains located in alternate boxes were counted.

Texture

Sand-silt-clay Ratios. Sediments from the continental terrace are classified according to textural groupings based on percentages of sand, silt, and clay. The areal distribution of the sand-silt-clay ratios is presented in Plate 28. Plates 29, 30, and 31 give the

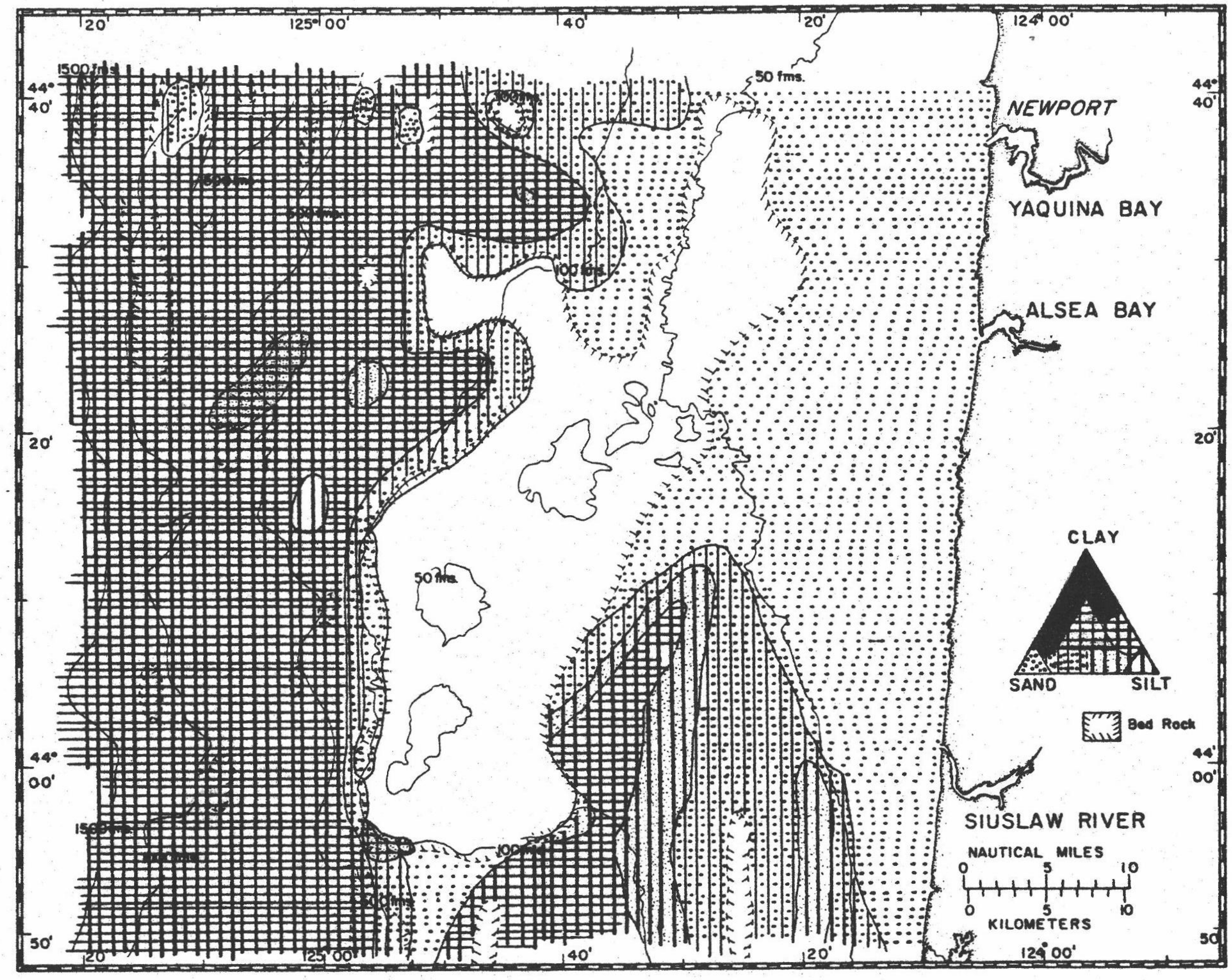


Plate 28. Map of sand-silt-clay ratios. The classification is after Shepard (1954).

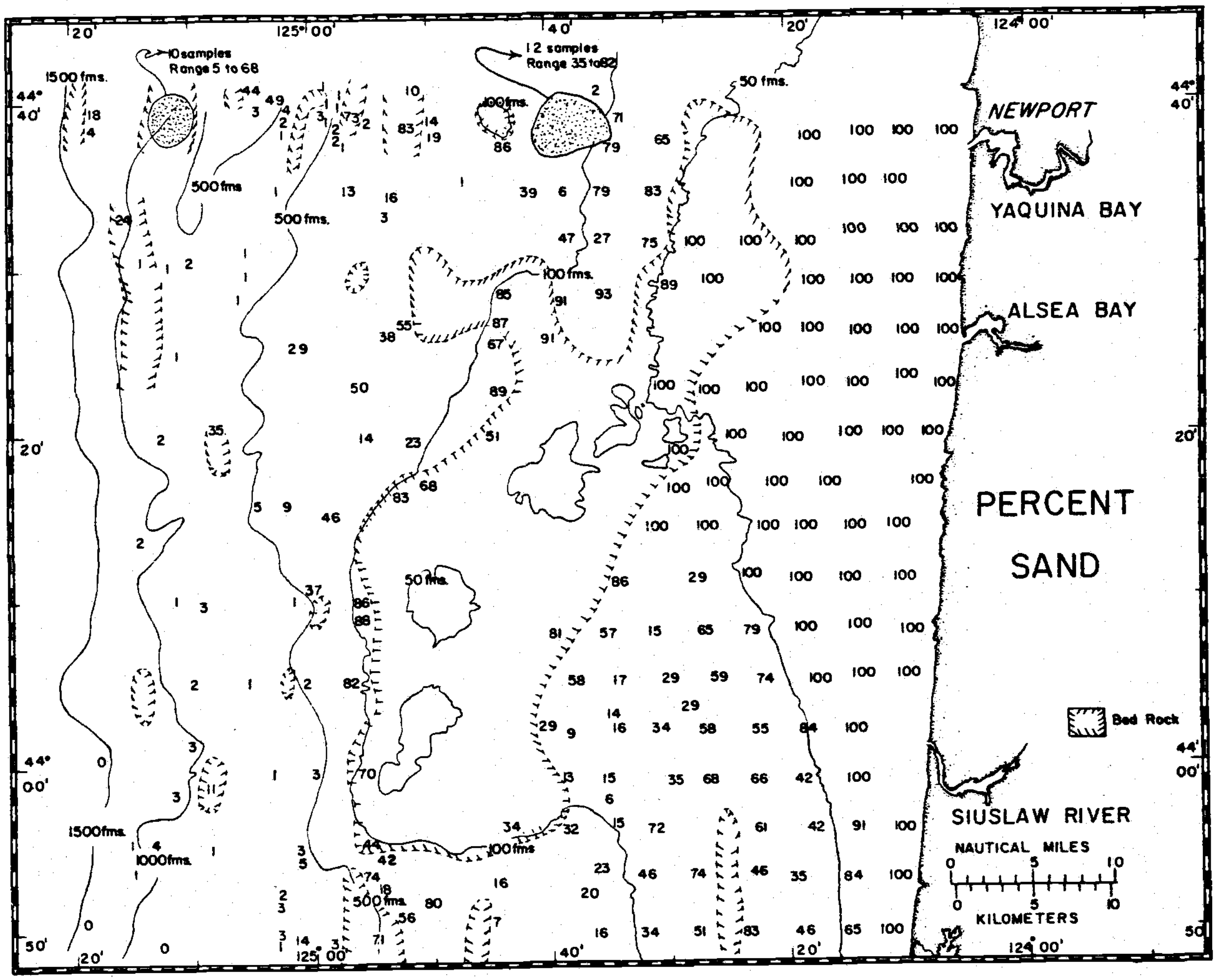


Plate 29. Percentage of sand in the sediment samples.

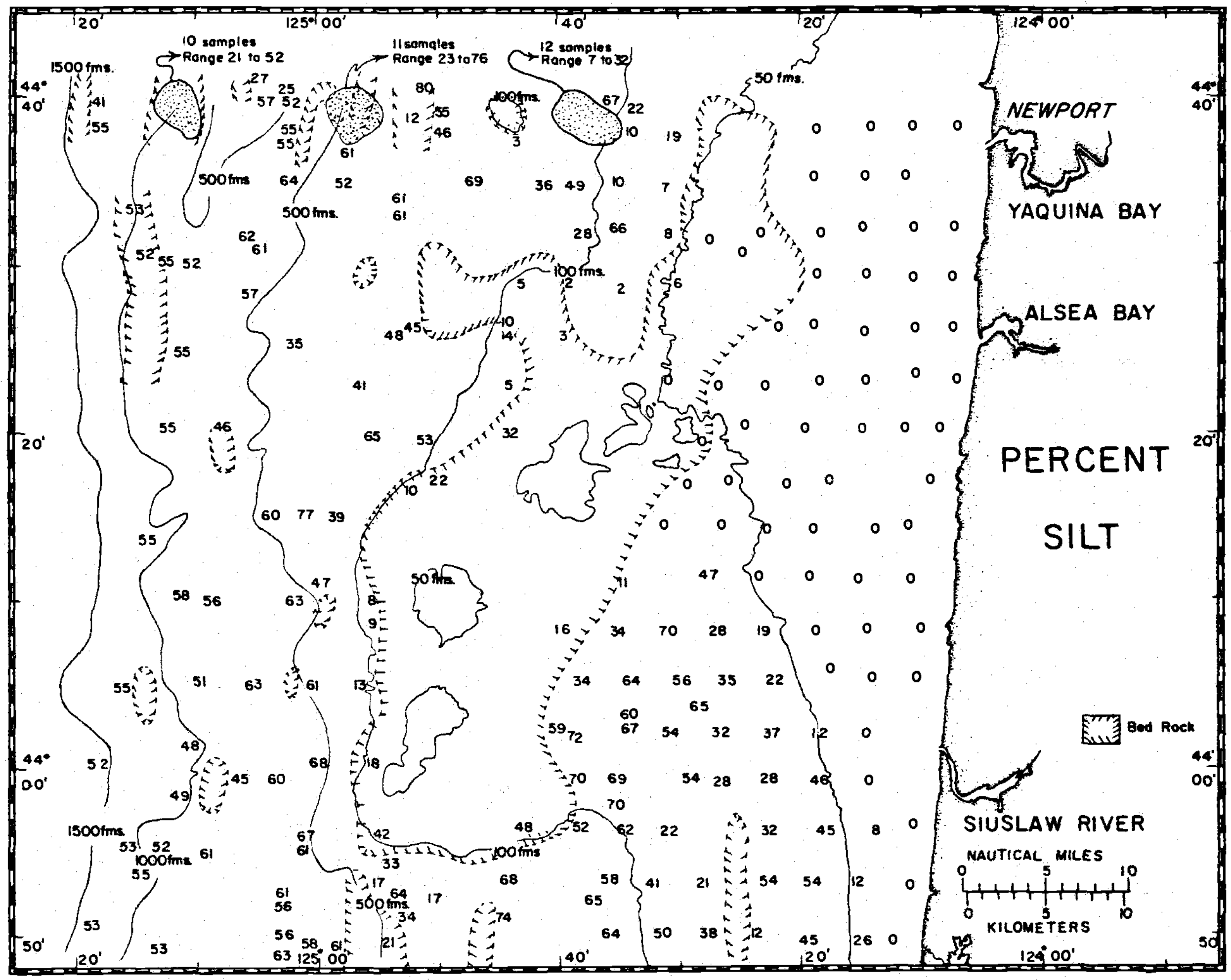


Plate 30. Percentage of silt in the sediment samples.

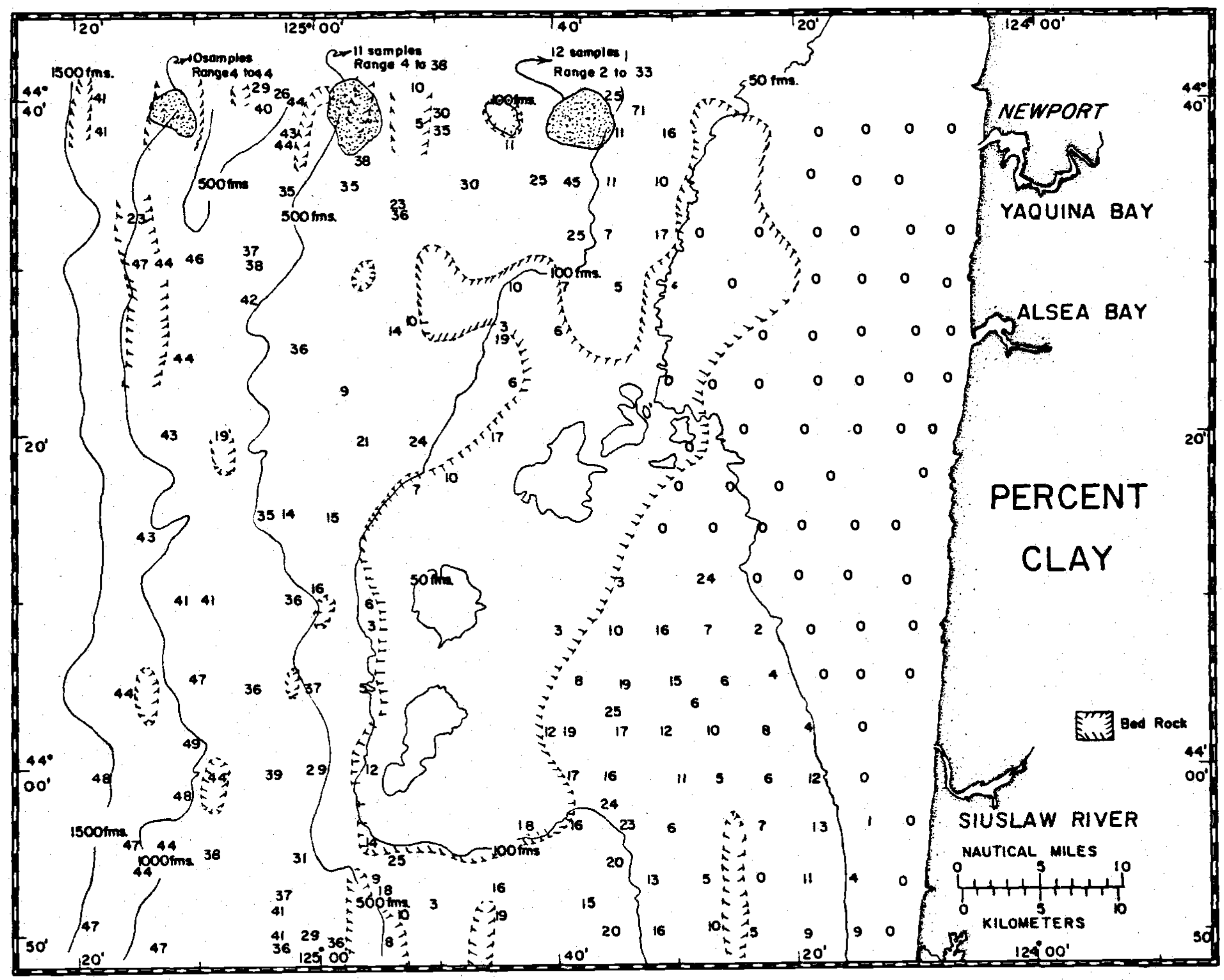


Plate 31. Percentage of clay in the sediment samples.

percentages of sand, silt and clay in the samples.

The sediments grade from sand near shore to clayey silt on the continental slope. This distribution appears to vary both with the water depth and local topography. The inner part of the continental shelf to depths of about 50 fathoms is covered with sand and local patches of gravel. In the north this sand belt extends west to Stonewall Bank. By contrast in the south, where the shelf is much narrower, the sand reaches only three to four miles off shore before it grades into silty sand.

Seaward of the 50-fathom contour to depths of around 200 fathoms the sediment distribution is influenced greatly by the local topography. The low areas contain fine sediments and the high area sandy sediments. The axis of Heceta Swale is characterized by olive green, clayey silt. Here, in relatively shallow water, the sediment contains as much as 70 percent silt and 25 percent clay. The sediment coarsens on both sides of the swale.

The borders of the banks are covered by sandy sediment. One sample from Siltcoos Bank is 83 percent sand. The western edge of Heceta Bank is covered by a thin band of sediment containing 44 to 89 percent sand, and samples from the outer part of the shelf west of Stonewall Bank are composed of up to 100 percent sand. By contrast the low areas between Daisy and Stonewall Banks, on the outer shelf and upper slope, contains much less sand and more silt-clay. The finest grained sample from this low area contains two percent sand, 67 percent silt, and 31 percent clay.

An area of anomalously fine-grained sediment occurs at depths of 50 to 60 fathoms south of latitude 44° 00'N. Here the sediment is sandy silt, having 35 to 46 percent sand, 45 to 54 percent silt, and 9 to 13 percent clay. Seaward, the sediment grades into a silty sand, and landward, into the sand of the inner portion of the shelf.

Most of the continental slope is blanketed by olive-green, clayey silt. In this area the sand fraction normally comprises less than five percent, often less than two percent, of the samples, whereas the silt fraction usually makes up 50 to 70 percent of the sediment. The percentage of sand increases up the slope and on hills. The high areas such as Daisy Bank and the hummocks south of Heceta Bank are covered by sandy sediment. In a general way the upper slope sediments are intermediate between the shelf and the normal slope sediments.

Sandy sediments have been dredged from intermediate and deep portions of the slope west of Newport. Anchor dredge samples from this region contain up to 73 percent sand. The coexistence of these sandy sediments with friable silty sandstone indicates that the sediment may be residual in origin. It is also possible that the sands could be turbidity current deposits. This does not seem likely, however, because Newport Valley and the hill west of the valley are located between the samples and the potential source of sand on the continental shelf.

The nature of the change in sand-silt-clay ratio with water depth is shown in Plate 32. Part A of the diagram shows that sand is present to a depth of 50 fathoms; 66 of the samples are sands and two are silty sands. The silty sands occur on the narrow portion of the shelf in the south. The samples obtained at depths of 50 to 100 fathoms are plotted in triangle B. Sand, silty sand, sandy silt, and clayey silt occur in this depth interval. The fine grained sediments occur in the topographic lows and include up to 70 percent silt in Heceta Swale. The sandy sediments occur on the high areas such as the banks and the exposed areas such as the shelf edge.

The continental slope sediment samples from between 100 and 500 fathoms are shown in part C. These sediments exhibit an even greater diversity than those in B. On the average, the sediment from the upper slope includes more silt. The sediments from 500 to 1000 and 1000 to 1600 fathoms are shown in parts D and E. Most are clayey silts with zero to seven percent sand, 55 to 65 percent silt, and 35 to 50 percent clay. Several sandier samples, including four silty sands, were obtained west of Newport at depths between 500 and 1200 fathoms.

The sand-silt-clay ratios of sediment obtained from the abyssal plain west of the continental terrace are shown in part F. Most of the samples taken from this area are silty clay with less than five

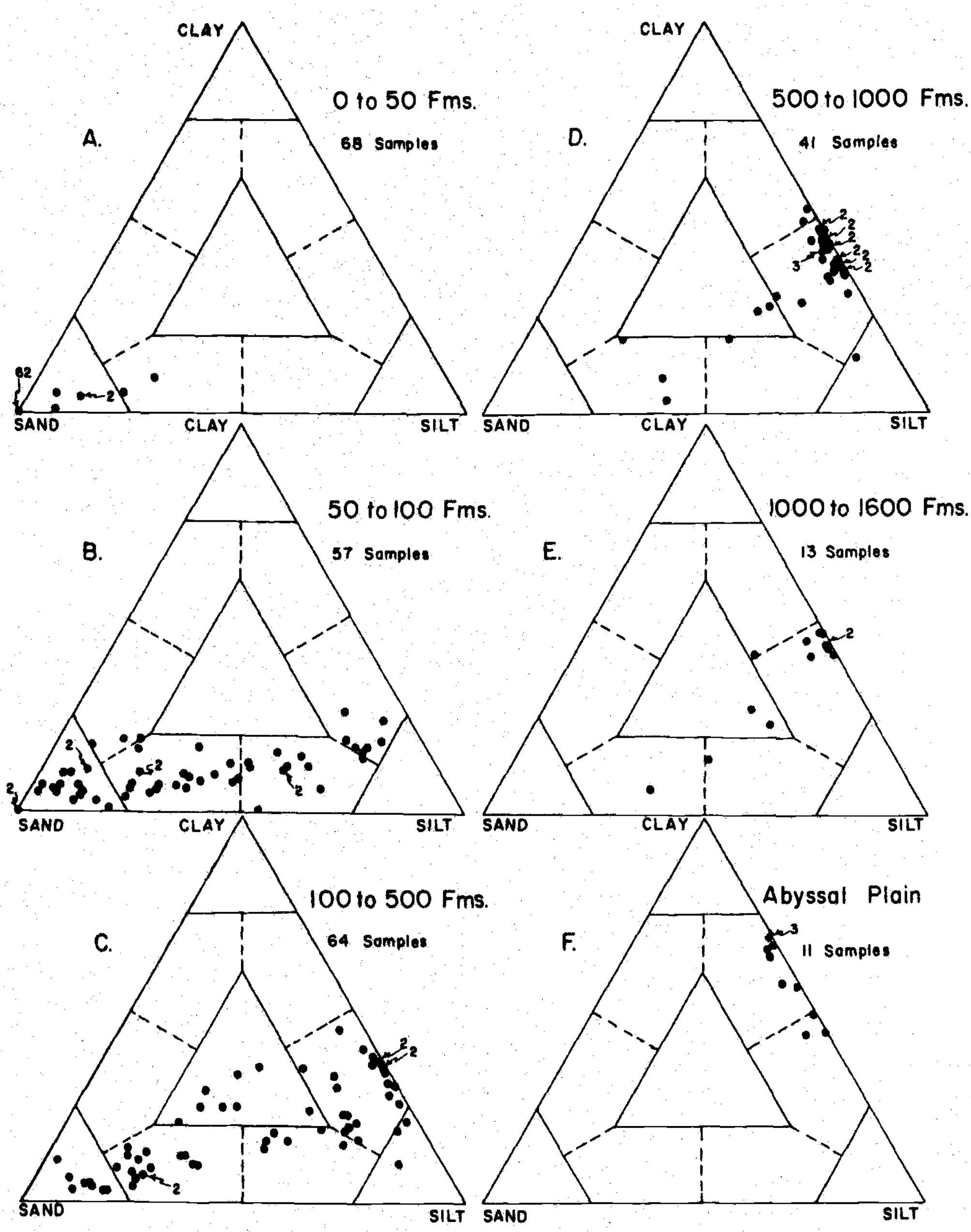


Plate 32. Triangular diagrams showing sand, silt, and clay percentages for various depth intervals.

percent sand, 25 to 54 percent silt and 45 to 70 percent clay. The percentage of clay appears to increase with distance from the bottom of the continental slope.

<u>Median Diameter.</u> The median diameter like the sand-silt-clay ratio can be used as an indicator of sediment grain size. As might be expected, the median diameter map (Plate 33) shows the same general pattern as the sand-silt-clay ratio map (Plate 28).

The inner part of the continental shelf, located from the shore line to about 50 fathoms, is covered with sand having an average median diameter of 0.222 mm. The range in median diameters for the 61 samples from this area is 0.717 mm to 0.105 mm. This range is from coarse to very fine sand according to the Wentworth Size Classification (Wentworth, 1922). Seventy-eight percent of the samples are of fine sand. The coarsest sand occurs at depths of 30 to 40 fathoms in an area north of latitude 44° 10' N.

Between 50 and 100 fathoms the median diameter ranges from medium silt, 0.017 mm, to medium sand, 0.326 mm. The average median diameter for the samples in this depth range is 0.115 mm, very fine sand. The diverse nature of the sediment is shown by the fact that 25 percent of the samples are fine sand; 29 percent very fine sand; 23 percent coarse silt; and 15 percent medium silt. Most of the silt occurs in Heceta Swale and in an area south of latitude 44° 00'N

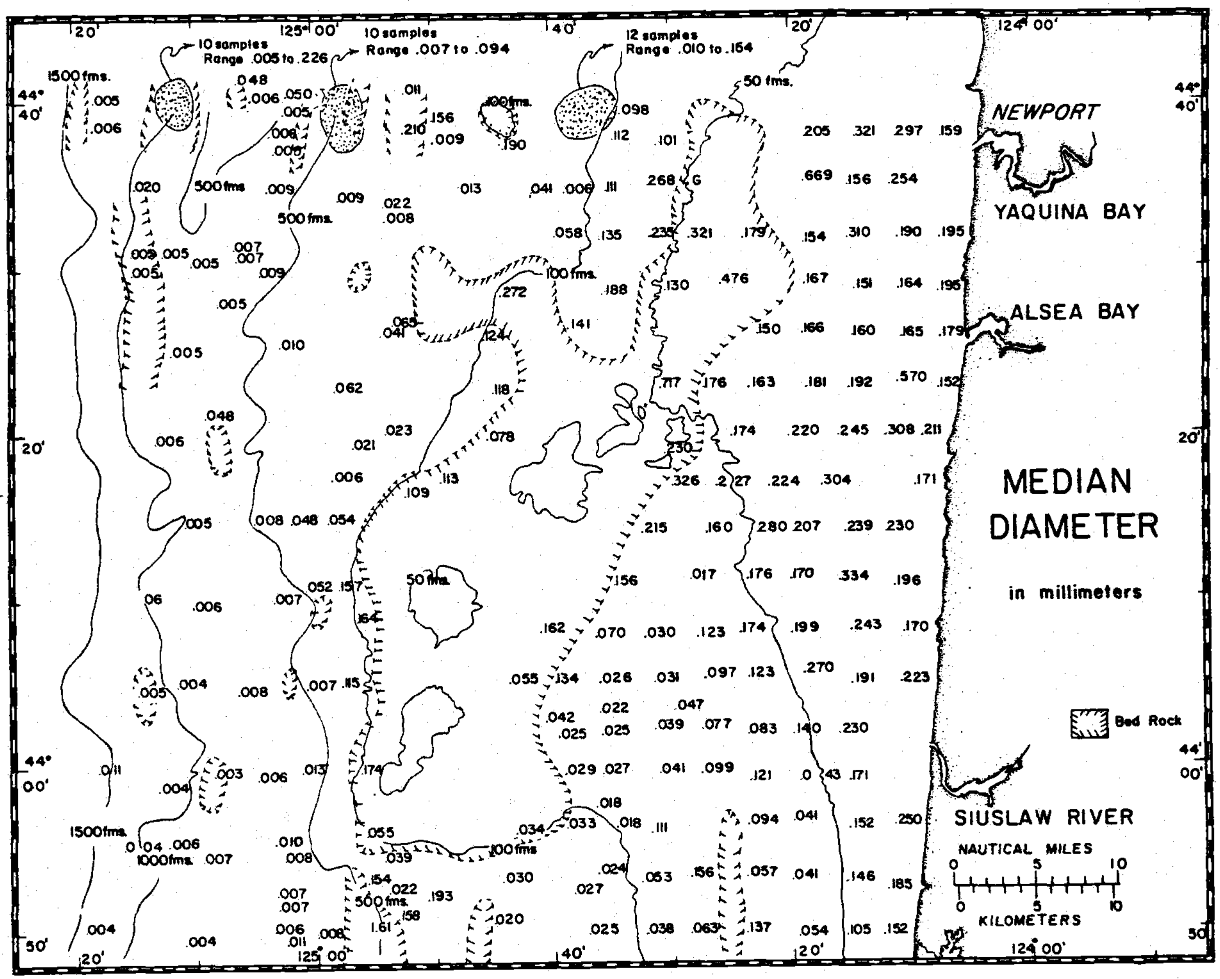


Plate 33. Distribution of sediment median diameters (millimeters) on the continental terrace off central Oregon.

at depths of 50 to 60 fathoms. No size analyses were done on the locally derived gravels obtained from flanks of Stonewall and Heceta Banks.

The samples from the upper part of the continental slope to a depth of 500 fathoms have an average median diameter of 0. 048 mm. Individual samples range from fine sand, 0. 210 mm, to fine silt, 0. 006 mm. Variation among the samples is considerable; eight percent are fine sand; 21 percent very fine sand; 14 percent coarse silt; 23 percent medium silt; 19 percent fine silt; and 15 very fine silt. The sediment with the larger median diameters occur on the topographic highs.

The median diameters of 70 percent of the samples taken from depths of 500 to 1000 fathoms are in the very fine silt class. The coarsest sample is a very fine sand, median diameter of 0.078 mm, and the finest samples are very fine silt, 0. 004 mm. Most of the samples obtained from the continental slope below 1000 fathoms are medium, fine, and very fine grained silts. Three very fine grained sands were dredged from the slope west of Newport Valley. The range in median diameters is 0. 082 mm to 0. 004 mm. Samples from the abyssal plain to the west are clay, having a median diameter of 0. 005 to 0. 002 mm.

In summary, the sediments of the continental terrace decrease in median diameters from fine sand on the inner part of the shelf to fine silt on the lower slope, to clay on the abyssal plain. The maximum variation in median diameter occurs in the depth interval between 50 and 500 fathoms where the topographic highs are characterized by coarse sediment and the topographic lows by fine sediment. The finest grained sediment of all is the clay which occurs on the abyssal plain west of the continental terrace.

Phi Deviation. Inman (1952) utilized phi deviation as a graphic approximation of the standard deviation in phi notation. He defines the relationship as

$$\sigma_\phi = \frac{1}{2}(\phi_{84} - \phi_{16}) \qquad (6)$$

where ϕ_{84} is the 84th and ϕ_{16} the 16th percentile diameters on the cumulative frequency curve and ϕ is defined as

$$\phi = -\log_2 \text{diameter in millimeters.} \qquad (7)$$

ϕ is a geometric value in which one division of phi is equal to one size division on the Wentworth scale (Wentworth, 1922). As a result, the phi deviation gives the dispersion of the size frequency curve in terms of Wentworth units.

Phi deviation is an estimate of the dispersion of grain sizes in a sediment sample, and it is therefore a measure of sorting. The phi deviation equals the standard deviation in samples having a normal distribution of grain sizes. However, in skewed samples the phi deviation differs from the standard deviation. From equation (6) it can be seen that samples with perfect size sorting have a phi deviation of 0, and that samples with progressively poorer sorting have progressively larger values of phi deviation.

The distribution of phi deviation values on the continental terrace is shown in Plate 34. From this plate it is seen that sands from the shallow portion of the shelf exhibit the best sorting. Phi values range from 1.94 to 0.21 and average 0.35. The sands from the outer portion of the shelf are more poorly sorted having values that range from 5.55 to 0.30. The clayey silts of the continental slope and Heceta Swale have sorting values intermediate between the two sand areas. Samples from Heceta Swale range from 3.17 to 1.95, while the values for sediment from the slope are somewhat greater, ranging from 4.29 to 1.29.

Generally, the inner shelf sands exhibit the best sorting. The clayey silts of the slope and outer shelf are more poorly sorted, and the sandy sediments occurring on the outer shelf and upper slope exhibit the greatest range in sorting varying from the most poorly sorted samples on the terrace to samples that are well sorted.

Phi Skewness. Inman (1952) utilized phi skewness as a graphical approximation of the skewness of the size frequency curve. He

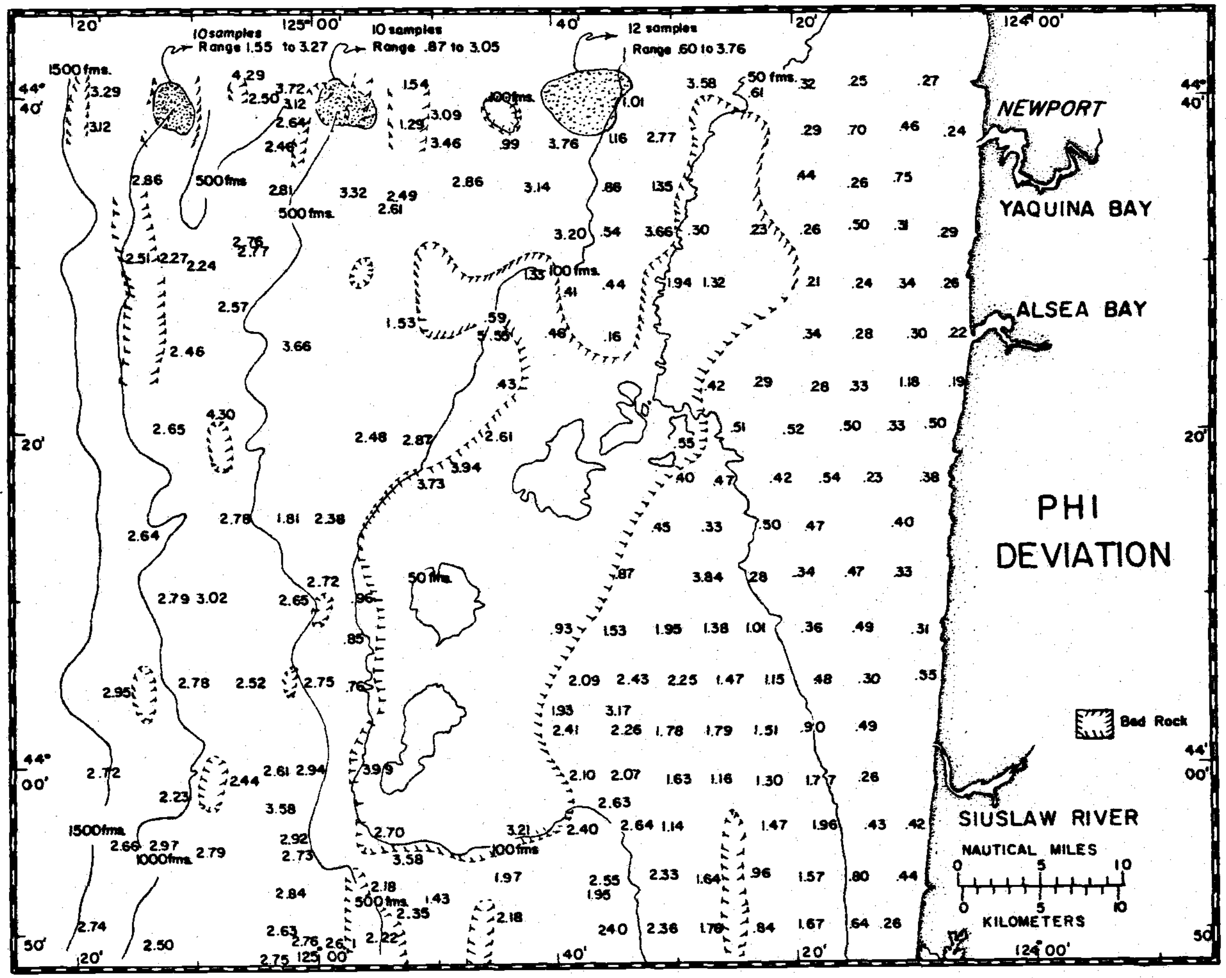


Plate 34. Distribution of phi deviation values for the surface sediment on the continental terrace.

defined phi skewness as

$$\alpha_{\phi} = \frac{0.5(\phi_{16} + \phi_{84}) - Md_{\phi}}{\sigma_{\phi}} = \frac{M_{\phi} - Md_{\phi}}{\sigma_{\phi}} \tag{8}$$

where M_{ϕ} is the phi mean diameter and Md_{ϕ} is the phi median diameter. For normal curves the moment skewness and the phi skewness are 0. The moment skewness is approximately six times the phi skewness in curves having nearly a normal distribution (Inman, 1952). This approximation is good to phi skewness values of $\pm$ 0.2.

Skewness is a measure of the deviation of the size frequency curve from a curve for a normal distribution. Equation (8) shows that when the phi mean diameter is larger than the phi median diameter the phi skewness is positive. From equation (7) it can be seen that increasing values of phi correspond to decreasing values in millimeters. Therefore, positive skewness indicates that the curve is skewed to the fine grained side of the median diameter.

The distribution of phi skewness values on the continental terrace is shown on Plate 35. The most striking feature of the distribution is that most of the inner shelf sand is skewed to the larger grain sizes, while most of the outer shelf and slope samples are skewed to the smaller grain sizes. Interesting exceptions to this general distribution are found on a line across the inner portion of the shelf west of Newport where the samples are skewed slightly to the finer

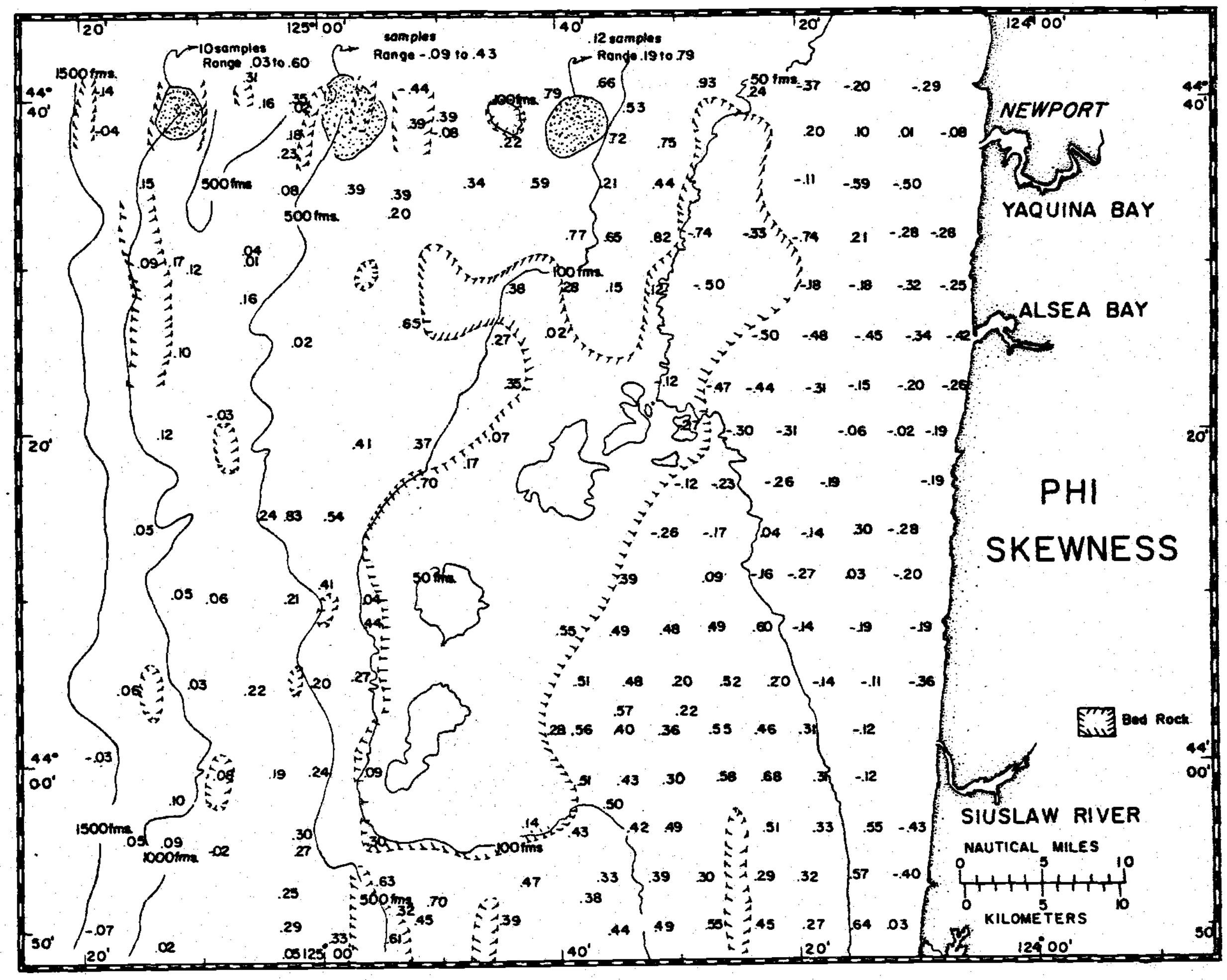


Plate 35. Distribution of phi skewness values for the surface sediment.

fractions. This change in skewness might be caused by an outflow of suspended finer sediments from Yaquina Bay.

In the south positively skewed samples occur increasingly close to shore. All of the samples in the southern most line of sediment samples are skewed to the fine fractions. This change in skewness to the south reflects the narrowing of the shelf and the sand belt. It also may be influenced by the outflow of fine grained sediment from the Siuslaw and Umpqua Rivers.

The largest values of positive skewness occur on the outer portion of the shelf and upper portion of the slope. The skewness decreases in the clayey silts with depth on the slope. A number of the samples from near the base of the slope are skewed slightly negative. However, all of the deep water sand samples are skewed positive.

The overall skewness pattern suggests that the coarser grained sediments are deposited on the landward portion of the continental shelf, and the finer grained sediments are carried to the outer portions of the shelf and the continental slope.

Roundness. The quartz grains in the sand fractions are angular to sub-angular. Generally angularity increases with decreasing grain size. Feldspar grains exhibit greater rounding than quartz grains.

The pebbles and cobbles present in the locally derived gravels vary from angular to well rounded. Siltstone pebbles are usually very well rounded; whereas, the limestone and calcareous siltstone pebbles are often angular.

Summary. The continental shelf is covered with sand to a depth of about 50 fathoms. The sand ranges in median diameter from 0.717 to 0. 105 mm, averaging 0. 222 mm. It is well sorted with an average phi deviation of 0. 35, and it is skewed slightly to the coarse fractions. The outer portion of the shelf is covered by sediments that range from sand to clayey silt. Median diameters vary from 0. 326 to 0. 017 mm, with the coarse sediments occurring on the banks and the fine grained sediments in the low areas below 50 fathoms. Phi deviation values are highly variable ranging from 5. 55 to 0. 30. All of the samples are skewed to the fine.

The upper part of the continental slope is covered by sandy sediments in the high areas and clayey silts in the low areas. As a result there is a range in median diameters from 0. 210 to 0. 006 mm. The lower portion of the slope is blanketed with clayey silt; notable exceptions are the sandy sediment present to the west of Newport. In general, the slope sediments exhibit poorer sorting than the shelf sediments, as they have phi deviation values ranging from 4. 29 to 1. 29. Most of the slope samples are skewed to the fine size fractions. However, near the base of the slope the sediment is skewed slightly negative.

The sand size quartz grains are generally angular to subangular in roundness. The angularity tends to increase with decreasing size and increasing distance from shore.

Composition of Sand Fraction

General. The sand-sized material is grouped into three broad genetic classes: detrital, biogenic, and authigenic. Transported mineral and rock fragments are grouped together as the detrital fraction. The biogenic fraction is composed of planktonic and benthonic plant and animal remains, and the authigenic fraction is composed mainly of the mineral glauconite.

This three component system is used for the interpretation of the nature and rate of deposition of the sand-size material. Abundant detrital grains indicate a relatively rapid rate of deposition of terrestrial sediment. The presence of large quantities of authigenic minerals indicates an area of slow deposition, and an area in which the physical-chemical conditions permit the formation of such minerals. Biogenic sand fractions suggest slow detrital deposition in areas where authigenic minerals are absent, or in areas in which the detrital sediment consists mainly of silt and clay.

Distribution of the detrital, biogenic, and authigenic sand fractions over the continental terrace is shown in Plate 36. When evaluating these percentages, it should be remembered that the three

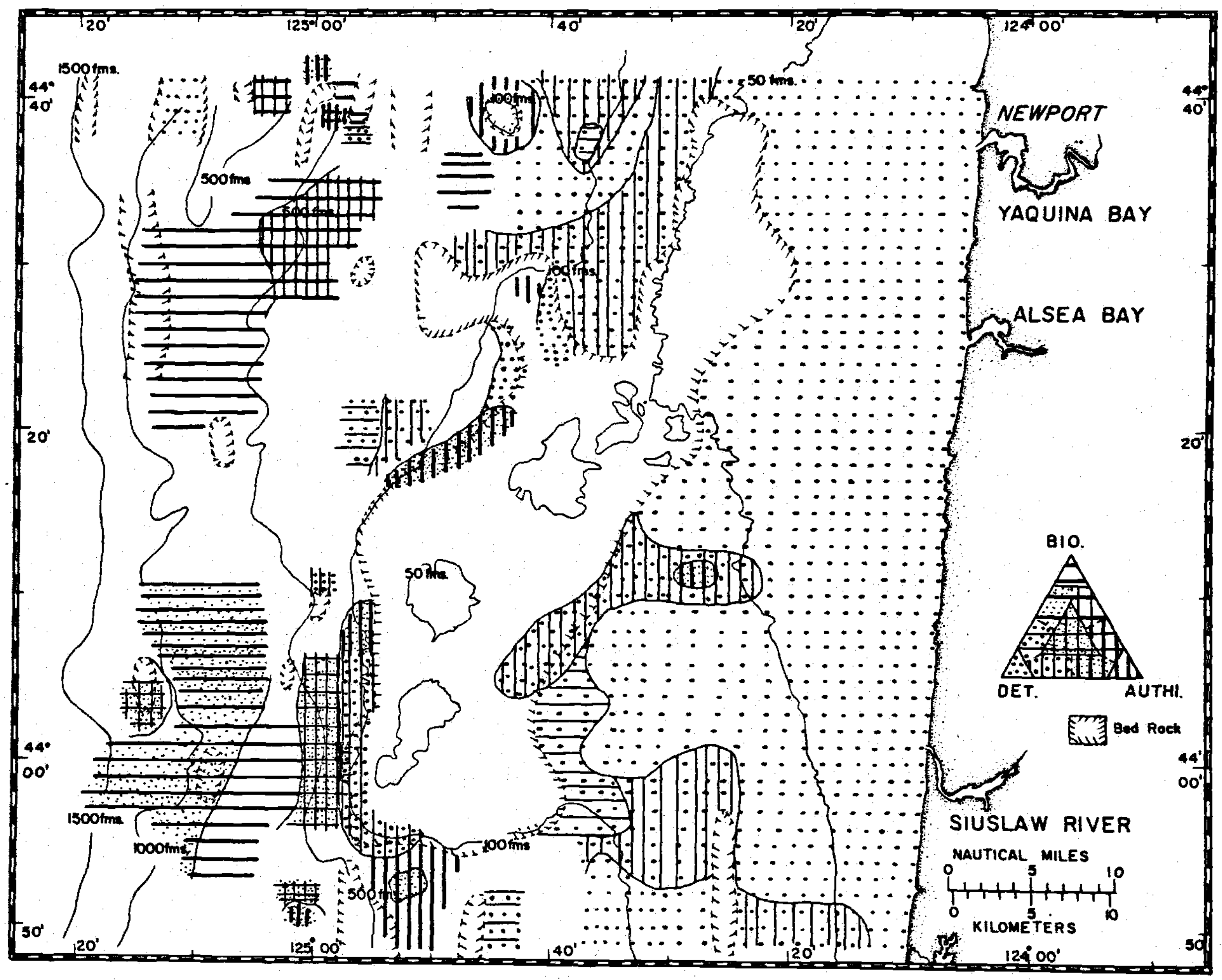


Plate 36. Sand fraction compositions of surface sediments.

components add up to 100 percent, no matter what percentage of sand is present in the sample.

All of the sand samples from the eastern portion of the shelf contain more than 75 percent detrital material. From the shore to 30 fathoms the sand is 97 percent or more detrital grains. With the exception of one sample the remaining sand consists of authigenic glauconite. The one exception is a sample from Stonewall Bank that contains 17 percent benthonic Foraminifera.

Sand from the outer parts of the shelf is high in authigenic glauconite. Shelf samples taken west of Stonewall Bank consist of up to 43 percent glauconite, and the samples from the west side of Heceta Bank are comparable, having 30 to 57 percent glauconite. The sand fraction of a single sample on Daisy Bank includes 91 percent glauconite, and one sample from Siltcoos Bank has 23 percent glauconite.

The clayey silt contains small amounts of sand-sized material. In most samples these sand fractions are rich in biogenic material; however, the sand fractions from Heceta Swale contain high percentages of detrital minerals. They have 58 to 92 percent detrital grains and only 4 to 34 percent biogenic particles. This percentage of biogenic material, while lower than the percentages on the slope, is higher than the percentages found in the surrounding sediment. The slope sediment includes 32 to 96 percent biogenic material in the sand fractions. Thus, the continental slope samples have the highest percentages of biological material in their sand of any area on the continental terrace. The silty sand samples from deep on the slope west of Newport form a strong contrast to this generality as they consist of 89 to 96 percent detrital sand.

Summarizing: the inner shelf sands are composed almost entirely of detrital sand grains while the outer shelf and upper slope sand fractions contain fairly large percentages of authigenic glauconite. The sand fractions from the clayey silts on the continental slope are high in biogenic grains. The sand in the clayey silts of Heceta Swale has smaller percentages of biological material than the slope sediments but more than the surrounding sandy shelf sediment.

Detrital Sand. The light minerals, mainly quartz and feldspar, comprise more than 90 percent of the inner shelf sand samples. Quartz is the most abundant mineral and plagioclase feldspar the second most abundant. Bushnell (1964) states that due to the low quartz-feldspar ratio the sediment is classified as an arkosic sand. He studied eight samples on a traverse across the shelf north of Yaquina Head and found an average of 52 percent quartz, 28 percent plagioclase, 12 percent potassium feldspar, and five percent rock fragments. The sand is an arkose under classification of Williams, Turner, and Gilbert (1954).

Many of the plagioclase grains are weathered to a yellow or orange color. Kulm (1965) found these "yellow" grains in the coastal beach and terrace sands. The distribution of "yellow" grains on the continental shelf is shown in Plate 37. There is a noticeable offshore decrease in the size and abundance of the "yellow" grains. The grains are absent from the sediment beyond the 50-fathom contour. This suggests that the 50-fathom contour approximately marks the outer limit to which beach and near shore sand is transported.

Rock fragments form a sizable fraction of the sand in some samples bordering the bank areas. These samples contain rounded sand-size fragments of siltstone that commonly are partially altered to glauconite. One sample collected southwest of Alsea Bay is made up of pebbles and granules of basalt; quartzite and opal are also present. The basalt was probably transported from the headland at Cape Perpetua. Quartzite and opal occur in some of the terrace deposits and in the beach deposits. Sand size grains of basalt are present in most of the shelf sand samples.

A variety of heavy minerals constitute a small percentage of the detrital sand grains. Bushnell (1964) determined the percentage of heavy minerals in 27 samples from the continental shelf and the upper part of the slope. He found that the heavy minerals compose from 0.3 to 10.2 percent of the sand fractions.

Some 40 heavy mineral species and varieties were identified by Bushnell (1964) from seven samples. The most abundant heavy

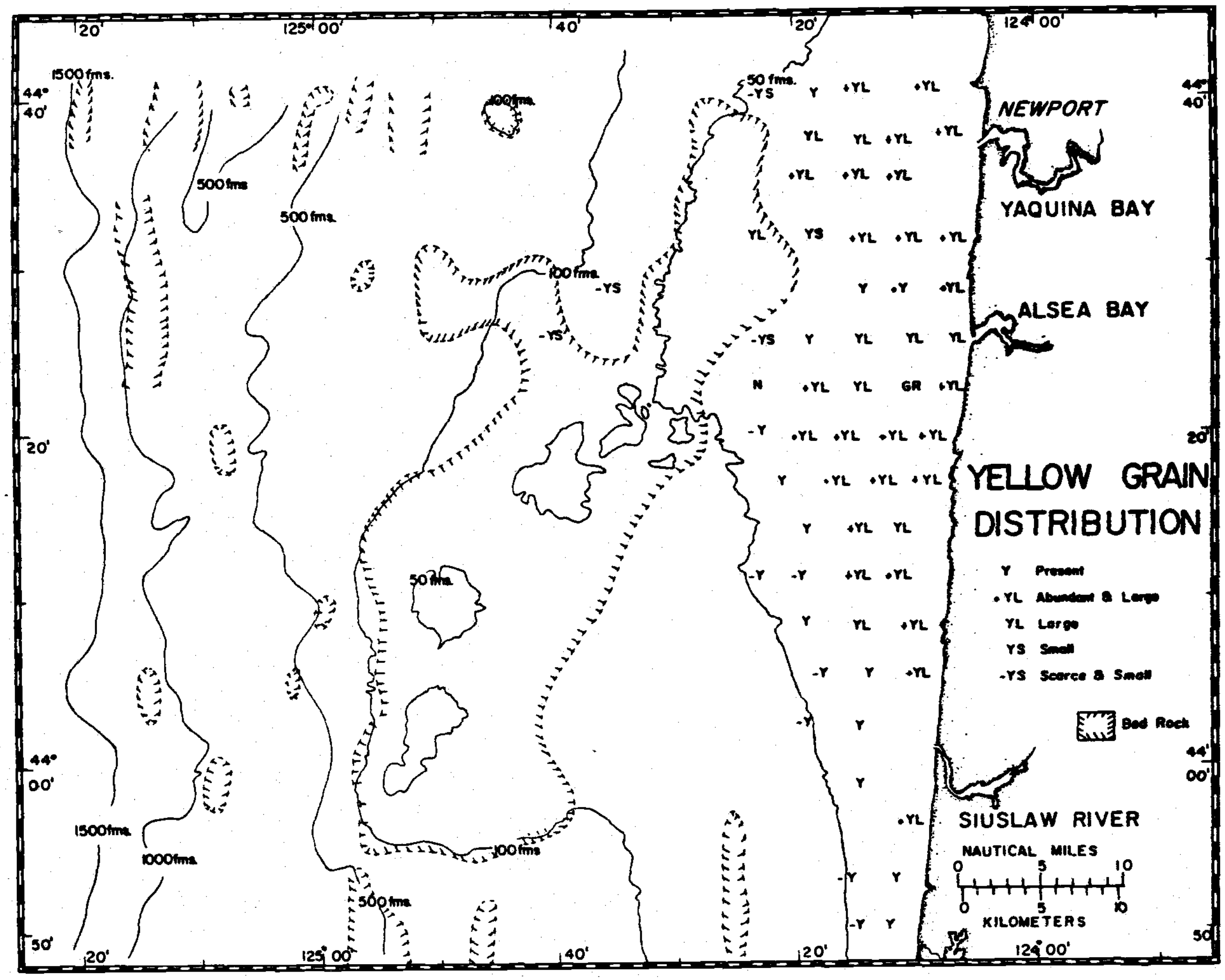


Plate 37. Distribution of "yellow" grains on the continental terrace off central Oregon.

minerals noted by Bushnell (1964) are: augite, comprising 9 to 19 percent of the heavy minerals; hornblende, 7 to 24 percent; opaque minerals, 3 to 22 percent; and rock fragments 9 to 29 percent. In addition hypersthene, diopside, epidote, garnet, basaltic hornblende, and chlorite are present in all seven of the samples.

The composition of the detrital portion of the sand indicates that the sediment was derived from a number of sources. The high percentage of plagioclase, the volcanic rock fragments, and many of the heavy minerals suggest that volcanic and intrusive igneous rocks of intermediate composition served as a source. Many such rocks crop out in the Coast Range, the Cascades, and the Columbia River Plateau. Certain heavy minerals normally found in metamorphic rocks, such as sillimanite, glaucophane, kyanite, and staurolite, occur in very small quantities. They could have been derived from the Klamath, northern Cascade, or Rocky Mountains.

Biogenic Sand. Planktonic and benthonic plant and animal remains form as much as 98 percent of the sand fractions in the fine grained sediments. The highest percentages of biogenic material occur at the tops of cores obtained from intermediate and deep positions on the continental slope. By contrast, the inner shelf sand includes almost no biological material. The clayey silt of Heceta Swale is similar to the sediment of the slope, but has lower percentages of biological material in the sand fraction, 2 to 32 percent.

Sponge spicules, diatoms, radiolarians, and planktonic Foraminifera are the dominant biological components of the sand fractions from the slope. Spicules comprise more than 40 percent of the sand in ten samples, with a maximum of 44 percent in sample 151 at a depth of 411 fathoms west of Newport. Diatoms form 47 percent of the sand fraction in sample 158 and 48 percent of the sand in 340 at a depth of 867 fathoms. However, most of the slope samples have lower percentages of diatoms than spicules. Planktonic Foraminifera occur in still smaller quantities having a maximum concentration of 42 percent in sample 342. The highest percentage of Radiolaria in the sand fractions from the slope is 40 percent in sample 363 at a depth of 1300 fathoms. Higher concentrations occur on the abyssal plain where radiolarians were found to comprise up to 74 percent of the sand. By contrast the clayey silt of Heceta Swale contains few Radiolaria, zero to two percent. Sponge spicules and diatoms are the most abundant biological components in this area. Benthonic Foraminifera are abundant in the sand fractions of sediment around the banks and on the high areas of the slope.

The biological components form a large percentage of the sand only when the sand fraction comprises a very small portion of the total sediment. The biogenic sand does not form a large percentage of the sediment at any location on the central part of the continental terrace off Oregon.

Authigenic Sand. Glauconite pellets constitute the principal authigenic component of the sand fractions. In addition, authigenic pyrite is present as very small crystals in a number of the cores. Some limonite and hematite may be authigenic. The limestone samples dredged from the top of Daisy Bank are coated with a thin layer of brown material which could be authigenic phosphorite.

The term glauconite is used here for green pellet material which is thought to be composed of clay minerals and to have formed in situ. These pellets are generally of medium to very fine sand size. They are normally poorly sorted and skewed positive. Individual pellets are of two types: a dark green pellet with smooth lobate surfaces, checked by concentric fractures; and a lighter yellowish-green one with a granular, unfractured surface. Many of the light yellowish-green pellets appear transitional between faecal pellets or rock fragments and the dark green glauconite.

Stump (1963) conducted x-ray defraction and surface area analyses on several glauconite samples. The dark green pellets produce defraction peaks corresponding to interlayered clays and to clay with an illite structure. Hendricks and Ross (1951) state that the mineral glauconite has the structure of a dioctahedral illite in which the aluminum of the octahedral layer is replaced by magnesium ferric iron, and ferrous iron. It seems probable that the green pellets from the continental terrace are composed of the mineral glauconite; some of the glauconite is interlayered with other clay minerals.

The origin of glauconite has been considered by a number of authors (Cloud, 1955; Galliher, 1935; Takahashi, 1955; and Pratt, 1963). It has been shown that glauconite has formed by the alterational faecal pellets, rock fragments, and detrital mineral grains. Glauconite has also been found as fillings of Foraminifera and sponge spicules. Most of the dark green pellets collected from the continental terrace off central Oregon give no evidence of their origin. A few of the pellets have shapes which suggest that they might have formed as casts of Foraminifera. Many of the yellowish-green pellets are difficult to distinguish from altered sand sized siltstone grains. This may indicate that at least some of the glauconite was formed by alteration of the siltstone exposed on the terrace.

Authigenic glauconite accumulates in areas of slow deposition of detrital sediment. Off Oregon these areas include the banks on the shelf, certain areas along the shelf edge, and the hills on the slope.

Sediment Cores

Forty-five sediment cores have been taken from the continental terrace and abyssal plain off the central coast of Oregon. Logs and descriptions of the individual cores are presented in Appendix 4. The sediment thicknesses given in the appendix are from the measurements made on the extruded cores. The in situ thickness may be as much as two times greater than the measured thickness in the core. This is a result of compaction in the core barrel.

The cores taken in Heceta Swale and a large number of the cores taken on the continental slope consist of nearly homogeneous olive-green, clayey silt. Many of the cores from the slope contain thin layers, less than one-fourth inch thick, of slightly more silty sediment. Some of the cores are marked by small sediment-filled burrows and faint mottles.

Thin sand layers are present in several cores from the continental slope. One core, sample 351, collected from near the base of Heceta Scarp at a depth of 591 fathoms, contains one-half inch thick crudely graded sand layer at a depth of 43 inches (Plate 38, Figure 1). The sand consists of Foraminifera, detrital grains, and glauconite. Core 304, located northwest of 351 in 898 fathoms, has a sand lens about one-half inch thick at a depth of 41 inches. The contacts of the sand layer with the overlying and underlying green clayey silt are irregular, with relief features up to one-eighth of an inch. The sand is mainly detrital with a small percentage of glauconite. Farther north (44° 09.9' N, 820 fathoms) core 285 has one sandy layer at a depth of 17 to 19 inches and another layer at a depth of 24 inches. The upper layer is crudely graded (Plate 38, Figure 2). Both layers

(1) (2) (3) (4) (5)

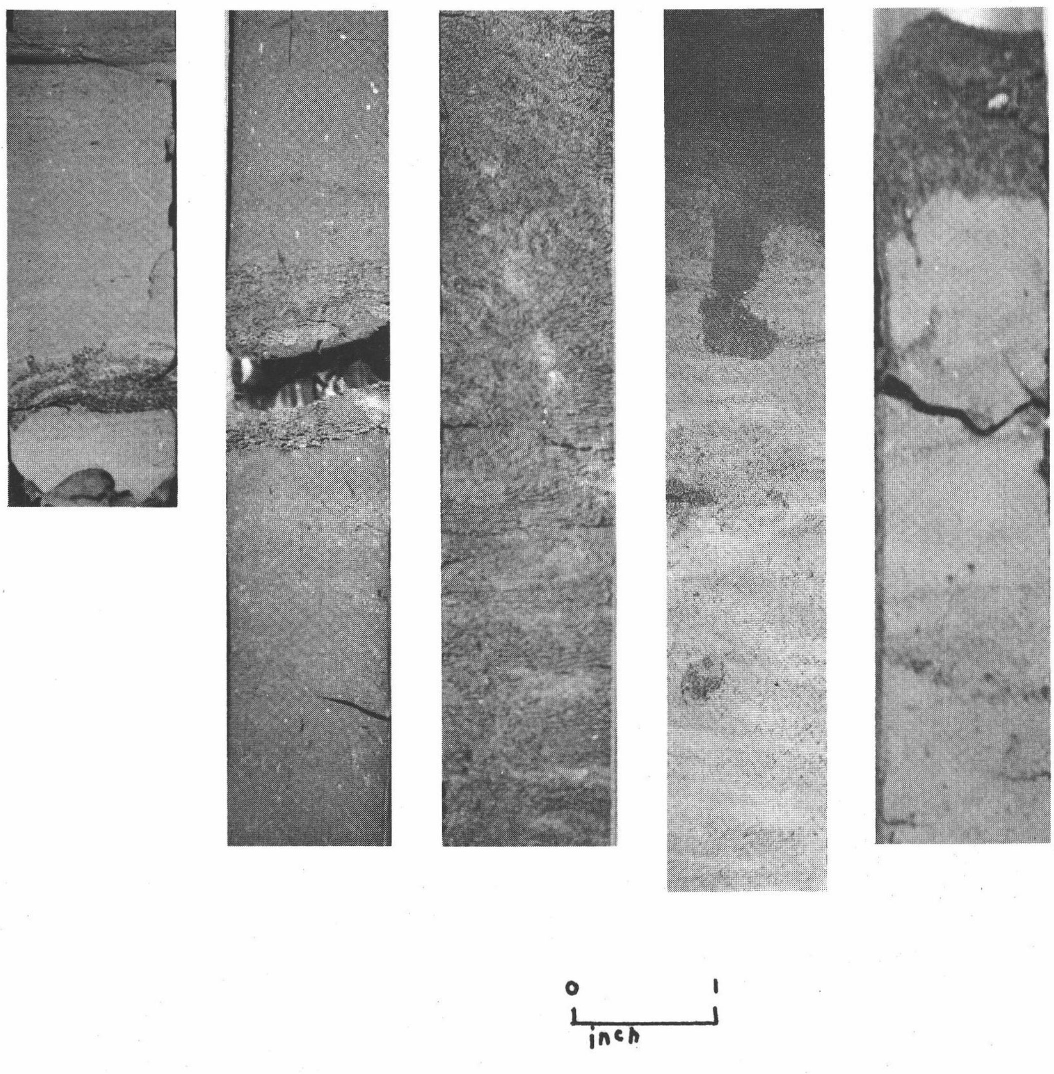


Plate 38. (1) Sand layer at a depth of 43 inches in core 351. (2) Upper sandy layer in core 285. (3) Glauconite sand in core 238. (4) Glauconitic silt overlying gray clayey silt in core 377. Note fossil burrow. (5) Glauconitic sand overlying stiff, gray clay silt in core 148.

consist of very fine sand composed of detrital grains and Foraminifera.

Sandy silt is also present in the two cores obtained from the abyssal plain west of Newport. Both samples consist mainly of olive-green, silty clay. Sandy beds are present at depths of 1, 37, and 41 inches in sample 384 and at depths of 18 and 35 inches in 385. The sand in these beds is mixed with a great deal of silt and clay, and it is composed primarily of very fine grained detrital minerals, chiefly quartz.

Cores consisting of mottled glauconitic mud were obtained at two places on the continental slope. One short core, ten inches long, was taken from the hummocks south of Heceta Bank. This core is highly mottled with pods, stringers, and layers of glauconite sand and olive-green mud. It gives the appearance of having been subjected to intensive burrowing by benthonic organisms. The other glauconitic core is sample 238 which is located at an intermediate depth of 220 fathoms on the slope at 44° 26.6' N, 124° 51.1' W. This core penetrates at least one foot of glauconitic sandy mud (Plate 38, Figure 3). The core is similar in appearance to the one from the hummocky area.

Cores from topographically high areas at intermediate depths on the slope have a thin layer of glauconitic mud overlying stiff gray, clayey silt. Sample 338 obtained from a small hill, has a two inch thick surface layer of green clayey silt with glauconite pellets, overlying stiff gray, clayey silt containing discrete, widely scattered glauconite pellets. The core is disrupted by numerous burrows. The median diameter of the sediment in the upper layer is 0.006 mm and that of the sediment in the lower layer is 0.005 mm. Sample 377, located at a depth of 200 fathoms near the northern end of Heceta Bank, has similar lithologies (Plate 38, Figure 4). The core has a fossil burrow that starts at the contact between the two layers and extends into the stiff clayey silt. The glauconitic sandy silt of the surface layer was entrained into and now fills the burrow.

A single core from the middle of the slope at latitude 44° 25' N, sample 236, has a surface layer of glauconitic sandy mud two inches thick. Beneath this surface layer the corer penetrated at least four feet of stiff clayey silt. The upper part of the lower layer is mottled to streaky brown. Pods of sand occur throughout the core; they are most abundant near the bottom. Irregular sandy layers are present at depths of 24, 31 to 32, and 54 inches. The sand consists of abundant Foraminifera with lesser amounts of detrital grains and glauconite pellets. The median diameter of the clayey silt decreases with depth in core; 0.009 mm at the top, 0.005 mm in the middle, 0.004 mm at the bottom.

Cores from the east side of Newport Valley include a thin surface layer of glauconitic sandy mud and an underlying layer of stiff bluish-gray, clayey silt. In sample 147 from near the valley bottom, the upper layer is four inches thick. It consists of a highly disturbed mixture of glauconite pellets, stiff clayey silt, and shale chips. The lower layer is mostly stiff, gray, clayey silt, but also contains a number of thin irregular silt layers and burrow-like pods of glauconite pellets and silt. The entire core appears to have been highly disturbed by benthonic organisms. The other core, 148, collected from the side of the valley, has a well-defined two inch thick surface layer of glauconite mud (Plate 38, Figure 5). The stiff gray, clayey silt beneath the surface layer contains pods and thin beds of glauconite sand. This core differs from 147 in that it appears to have been much less disturbed by the benthonic organisms.

The cores from Heceta Swale and the majority of the cores from the continental slope consist of nearly homogeneous olive-green, clayey silt. Glauconitic sandy mud occurs as a thin surface layer on the topographic highs of the slope. The glauconitic sediment is underlain by stiff, gray, clayey silt containing scattered glauconite pellets and numerous burrows. Many of the cores from the slope and abyssal plain contain thin beds and pods of sand composed of detrital minerals, Foraminifera, and glauconite.

Summary

Large portions of the continental terrace are covered by unconsolidated sediments. The occurrence of rock outcrops on the outer part of the continental shelf and at a number of locations on the continental slope suggest, however, that the unconsolidated sediment comprises only a thin superficial layer. The landward portion of the shelf is covered with medium to very fine grained sand composed of detrital minerals, mostly quartz and plagioclase. This sand is very similar to the coastal beach and terrace sands. The sediments on the outer portion of the shelf and the upper slope are variable in grain size and composition. The topographic highs are blanketed by glauconitic sand, silty sand, and sand-silt-clay. This glauconitic surface layer is underlain by bed rock or stiff, gray, clayey silt. The low areas on the shelf and much of the slope are covered by nearly homogeneous olive-green, clayey silt. Biological fragments, including diatoms, radiolarians, Foraminifera, and sponge spicules, form a significant part of the sand present in the clayey silt. Thin sandy beds and pods consisting of detrital grains, glauconite pellets, and Foraminifera occur in some of the cores from the slope and the abyssal plain. Sandy sediment is present at the surface deep on the slope west of Newport. This sand is composed of detrital minerals, and is thought to be derived from underlying friable silty sandstone.

Origin of Sediment Pattern

Coastal erosion by small streams, ocean waves, and tides provide sediment which is transported to the beaches. Most of this sediment is sand derived from the coastal terrace deposits. The ocean waves and currents transport the sediment along the shore and/or offshore onto the continental shelf. Sand containing the "yellow" grains distinctive of the coastal sediment is present on the shelf to a depth of approximately 50 fathoms. This suggests that coastal sand has been transported offshore and deposited on the inner part of the continental shelf. The outer limit of this sand at about 50 fathoms corresponds closely with the depth to which storm waves can erode sand on the bottom. However, net transport by the waves should be landward as the waves come from the west. If sediment is transported to the west then there must be some type of westward current which counteracts the transport of the waves.

Another possibility is that the sand was deposited initially during the Pleistocene. Shepard (1963) states that it is probable that sea level was lowered 60 to 90 fathoms during the maximum glaciation. This means that much of the shelf was exposed during the Pleistocene and that the shelf sand could have been deposited along transgressive and regressive strand lines. Wave action may stir up the sediment preventing the formation of glauconite but not causing any significant sediment transport. This hypothesis does not seem to provide an adequate explanation of the "yellow" grain distribution. It is more likely that both present day wave and current action and the Holocene transgression of the sea have influenced sedimentation on the inner portion of the continental shelf.

Sorting and skewness values suggest that the silt and clay fractions of the suspended sediment are not deposited landward of the 50 fathom contour. It would seem that turbulence at depths of less than 50 fathoms is sufficient to keep the fine grained sediment in suspension. Gravel occurs at a number of locations around the banks and at a few places near shore. These are probably Pleistocene shore line deposits.

Large areas of bed rock are exposed on the banks. These areas were probably eroded during the lower stands of sea level of the Pleistocene.. Erosion was reduced and perhaps stopped altogether during the subsequent rise of sea level. The waves and currents do appear to have enough strength to prevent sedimentation of the suspended sediment load, and the high elevation of the banks relative to the surrounding portions of the shelf, precludes sedimentation of the traction sand load.

Seaward of the 50-fathom contour to intermediate depths on the continental slope the sediment pattern conforms to the bathymetry. Silts and clays carried seaward from the continent are deposited in the low areas and the somewhat sheltered areas like Heceta Swale. By contrast the high areas receive little sediment because of their exposure to the action of the waves and currents. It is on these high areas that authigenic glauconite has the time plus the proper chemical and physical environment in which to form. Suspended sediment (silt and clay) is deposited on the intermediate and deep areas of the slope and on the abyssal plain. The small amount of sand present is made up of plankton and sponge spicules. Detrital and glauconitic sand grains occur as thin layers and pods at various depths in the continental slope sediment. This sand was probably transported down the slope from the continental shelf and the upper part of the slope by slumping, creep, or turbidity currents. The sandy sediments from deep on the slope west of Newport are probably residual in origin.

PETROLOGY

The Coast Range of Oregon is a geanticline of Tertiary sedimentary and volcanic rocks. The oldest rocks, Eocene in age, are exposed near the center of the range and the rocks are progressively younger towards the coast where Middle Miocene rocks crop out. Upper Miocene and Pliocene sedimentary rocks are exposed on the continental terrace off central Oregon. This suggests that the continental terrace is a more recent structural and stratigraphic development than the Coast Range uplift. A brief summary of the stratigraphic units of the central portion of the Coast Range is presented prior to the discussion of the rocks of the continental terrace. A geological map of the coastal and continental terrace regions is given in Plate 39, page. 240.

Central Coast Range

Rocks Eocene to Miocene in age and unconsolidated sediments of Pleistocene to Recent age are exposed on the western flank of the central Coast Range.

The Early Eocene, Siletz River Volcanic Series is the oldest exposed unit. It consists of flows, tuffs, and volcanic breccias. An abundance of pillow structures with glassy borders, and secondary zeolites indicate that some of the rocks were extruded under water.

In outcrops much of the basalt is altered to chlorite. The total thickness of the Siletz River Volcanics is unknown, but in the vicinity of Marys Peak the section may well exceed 10, 000 feet (Baldwin, 1964, p. 9). The upper part of the unit, some 3, 000 feet thick, is composed of water lain tuff which Volkes, Norbisrath, and Snavely (1949) have named the Kings Valley Siltstone Member. This unit was evidently lain down in a marine environment during a late phase of the volcanism.

The Tyee Formation unconformably overlies the Siletz River Volcanics. Along the Yaquina River the Tyee is composed of at least 6, 000 to 7, 000 feet of sandstone and siltstone beds which have individual thicknesses of 1 to 12 feet (Volkes, et al., 1949). Individual beds are composed of medium to coarse-grained, highly micaceous sandstone which grade upward into siltstone and mudstone. Thus, the beds are graded upward and often several sequences of grading are present in a single layer. Balls of mudstone and rolled shale chips are found in the sandstone beds. Flow casts, flute casts, and grove casts are common structures along the contacts between the beds. The recurrent graded bedding and the sedimentary structures have lead Snavely and Wagner (1963) to the conclusion that the Tyee was emplaced by turbidity currents flowing into the central portion of an eugeosynclinal basin. Mineralogically the sandstones are somewhat calcareous and contain angular grains of quartz, feldspar, tuffaceous material, muscovite and biotite (Vokes, Norbisrath, and Snavely, 1949). The abundance of mica together with the orientation of the sole markings suggest that the sand was derived from the Klamath Mountains.

The Toledo Formation which is composed of two members, the Lower Member and the Upper Sandy Member, overlies the Tyee Formation (Baldwin, 1964). The Lower Member forms the lower 1, 500 to 1, 800 feet of the formation. It is composed of dark gray to black, hard, tuffaceous, clayey shale and mudstone with occasional thin discontinuous bands of hardened limey rock. In addition there are interbeds of fine to medium grained sandstone which contains abundant pumice and glauconite. Carbonaceous material and plant fragments are common near the base of the formation.

The Upper Sandy Member is 1, 000 to 1, 200 feet thick. Its lower part consists of fine grained, argillaceous, micaceous, tuffaceous sandstone and shale with thin glauconitic interbeds (Vokes, Norbisrath, and Snavely, 1949). The upper part is a poorly stratified, firm, micaceous, tuffaceous siltstone containing numerous limey concretions.

The Lower Member is dated as Upper Eocene based upon megafossils, and the Upper Sandy Member is dated as Middle Oligocene (Baldwin, 1964).

Volcanic and near surface intrusive rocks of Late Eocene to

Oligocene age are exposed in the vicinity of Cape Perpetua. Many of the flows in this region are seen to interfinger with sedimentary rocks of the Toledo Formation. Both the intrusive and extrusive rocks are holocrystalline to hemicrystalline, porphyritic basalt. The phenocryst minerals consist of labradorite, augite, olivine, and magnetite (Vokes, Norbisrath, and Snavely, 1949).

The volcanic rocks are intruded by a large number of dikes. These are probably feeder dikes for the flows, and they may indicate larger intrusive body at depth.

Uppermost Oligocene rocks of the Yaquina Formation disconformably overlie the Toledo Formation. The Yaquina Formation is composed of 2, 700 feet of shallow water deposits predominantly light gray to brown, tuffaceous and usually carbonaceous, poorly consolidated sandstone (Vokes, Norbisrath, and Snavely, 1949). The lower one-third of the unit is made up of coarse-grained, massive, micaceous sandstones containing an abundance of carbonaceous material. Several seams of coal are present. Crossbedding is common and conglomerates with quartz and basalt pebbles are present. The upper two-thirds of the unit is fine to medium grained, gray to brown, massive, micaceous, tuffaceous sandstone (Vokes, Norbisrath and Snavely, 1949). Weaver (1937) reports that the mineral grains consist of quartz, plagioclase, muscovite, basalt and tuff.

Some 4, 400 feet of Nye Mudstone disconformably overlies the

Yaquina Formation. The Nye consists of a monotonous series of dark gray to black, smooth fracturing mudstones with occasional calcareous layers and concretions. Snavely, Rau, and Wagner (1964) found that at Yaquina Bay the Nye is a sandy siltstone with 0 to 27 percent sand, 54 to 83 percent silt, and 17 to 32 percent clay. An Early Miocene age is indicated by the microfossil assemblage (Baldwin, 1964).

Overlying the Nye is a series of sandstone and siltstone beds that are correlated with the Middle Miocene Astoria Formation of northwestern Oregon. Based upon this correlation the name Astoria has come into general use for the unit exposed on the sea cliff at Newport. Here there is about 500 feet of olive to blue-gray, fairly soft, fine to medium grained, micaceous, arkosic sandstone with interbeds of dark gray, carbonaceous, sandy siltstone. There is some coarse grained, basaltic sandstone near the base of the formation. Thin beds of waterlaid tuff form distinctive markers in the formation. Snavely, Rau, and Wagner (1964) found the tuff to have an andesitic to dacitic composition and contain fragments of pumice and carbonaceous material. The sandstone beds include numerous calcareous concretions which are as much as several feet in diameter. Molluscan faunas suggest that the Astoria is a shallow marine deposit.

Shallow intrusive and volcanic rocks of probable Middle or Late Miocene age are present at Yaquina and Cascade Heads, and in two drill holes one and one-fourth miles west of the mouth of Yaquina Bay

(Sanvely, Rau, and Wagner, 1964). The headlands are mainly basaltic agglomerates which have been intruded by basalt dikes. The dikes have nearly the same composition as the agglomerate and are, therefore, thought to be feeder dikes. The basalt "Reef" west of Newport is a flow, correlated with the headlands to the north. Waterlaid fragmental basalt debris and fine grained sandstone are associated with the flow. The sandstone is crossbedded.

Gabbro, diorite, nepheline syenite, camptonite, and basalt are present in the Coast Range as small intrusive bodies of uncertain age (Baldwin, 1964). The most abundant intrusive rock type is granophyric gabbro, composed of labradorite and augite with quartz and orthoclase as secondary accessory minerals. The nepheline syenite consists of nepheline, alkaline feldspar, riebeckite, aegirine, aegirine-augite, and small quantities of olivine. Its groundmass consists mainly of albite and kaolite-like material; analcite, zeolites, serpetine, and chlorite occur as alteration products (Volkes, Norbisrath, and Snavely, 1949).

No Pliocene rocks are known to occur in the central Coast Range. The unconsolidated terrace sands and gravels are thought to be Pleistocene in age (Baldwin, 1950). Beds of sand-silt-clay, sand, and gravel are present near the base of the terrace deposits at Nye Beach. Baldwin (1964) considers these sediments as estuarine or river deposits and correlates them with the Coquille Formation of southern Oregon. The younger terrace capping sand has the form of ancient stabilized dunes. Baldwin (1964) correlates this sand with the Elk River Formation of the Cape Blanco region.

Continental Terrace

Methods

Rocks have been obtained at 138 sample locations on the continental terrace. The sample locations are shown in Plate 27, and are listed in Appendix 1. The rocks were collected by means of grab, dredge, and punch core samples. Frame, pipe, and anchor dredges were utilized to obtain large samples of rock. The frame dredge has a fairly coarse-meshed net and as a result the smallest specimens obtained have an intermediate diameter of about one inch. The other dredges collect all sizes of sediment and rock. A Dietz-LaFond grab was used to take small fist sized bottom samples on the shelf. On a number of occasions the jaws caught on small rock fragments. The punch corer consists of a small length of pipe attached to a 50 pound weight. This corer was used to obtain small siltstone samples from the continental shelf.

The quantity of rock and the preciseness of the sample locations are influenced by the type of sampling devise. Grab and core samples are taken at spot locations, whereas the dredge samples are obtained by dragging the sampler along the bottom. However, the dredge hauls obtain much larger samples.

It is important, but not always possible, to distinguish the rock fragments that have been transported from those obtained directly from the outcrop. Emery and Shepard (1945) listed the following criteria for determining rocks that are essentially in place:

(1) fresh fractures.

(2) large size of individual rock fragments.

(3) abundant rocks of the same lithology.

(4) general angularity.

(5) presence of fragile or poorly consolidated rocks.

(6) catching of the dredge on rock firm enough to stop ship's progress.

(7) strong pull on cable.

To this could be added:

(8) highly irregular bottom topography.

(9) high reflectivity of the bottom surface.

(10) high elevation relative to surrounding areas.

The criteria for transported rocks is in general (Emery and Shepard, 1945):

(1) varied lithologies.

(2) general rounded character.

(3) small size of individual rocks.

To this can be added:

(4) the presence of foreign rock types known to occur on an adjacent land mass.

(5) the opposites of 1, 5, 6, 7, 8, 9, and 10 form the criteria for in place rocks.

Not all of the criteria for determining the in situ nature of a sample were applicable to the samples obtained off central Oregon. Fresh fractures in the siltstones may have formed by breakage during the dredging. The size factor is not valid because the friable siltstones break into small chunks in the vicinity of the outcrop whereas the calcareous concretions have large diameters a considerable distance from their parent outcrop. On the continental terrace, the transportation of rock fragments increases the percentage of resistant calcareous rocks at the expense of the more friable siltstone causing less diversity in the rock types. Lastly, the angularity of the siltstone fragments is affected by animal burrowing and breakage during the dredging, and the calcareous concretions are well rounded at the outcrop. The best criteria are probably the pull of the line and roughness of the bottom. If the dredge becomes lodged on the bottom and jerks, stops, or turns the ship, then it is probably in an area of rock outcrops. Irregular bathymetry also suggests outcrop areas, whereas smooth bathymetry may indicate sediment cover.

Several indirect methods were utilized to try to establish the distribution of the bed rock exposures. As mentioned above, irregular bottom topography, shown on the Precision Depth Records, indicates areas of bed rock exposure. The relative reflectivity of the bottom provides some information as to its nature since rock reflects the sound more strongly than does sediment. Sub-bottom echoes occur on some of the Precision Depth Records. They are interpreted as a thin sediment layer overlying bed rock or more consolidated sediment. Side echoes are also common on the Precision Depth Records. They indicate hilly topography, and probably areas of rock outcrop.

A geologic map is shown in Plate 39. It is probable that more areas of bed rock are present than are shown on the map, especially in the intermediate and deep areas of the continental slope where the sampling density is very low. Plate 40 shows the distribution of the rock types obtained from the continental terrace. The hand specimen and petrographic discriptions of the rock samples are listed in Appendix 6, and the statistics derived from grain size analyses of 11 rocks are presented on Plate 41 and listed in Appendix 5.

Continental Shelf

Stonewall Bank. Rock samples were obtained at 17 locations on and around Stonewall Bank. They vary from samples containing only a single small rock fragment to others having a number of specimens some of which are almost two feet long. All of the rocks collected from the bank are siltstones. These siltstones are classified as non-calcareous or calcareous siltstones.

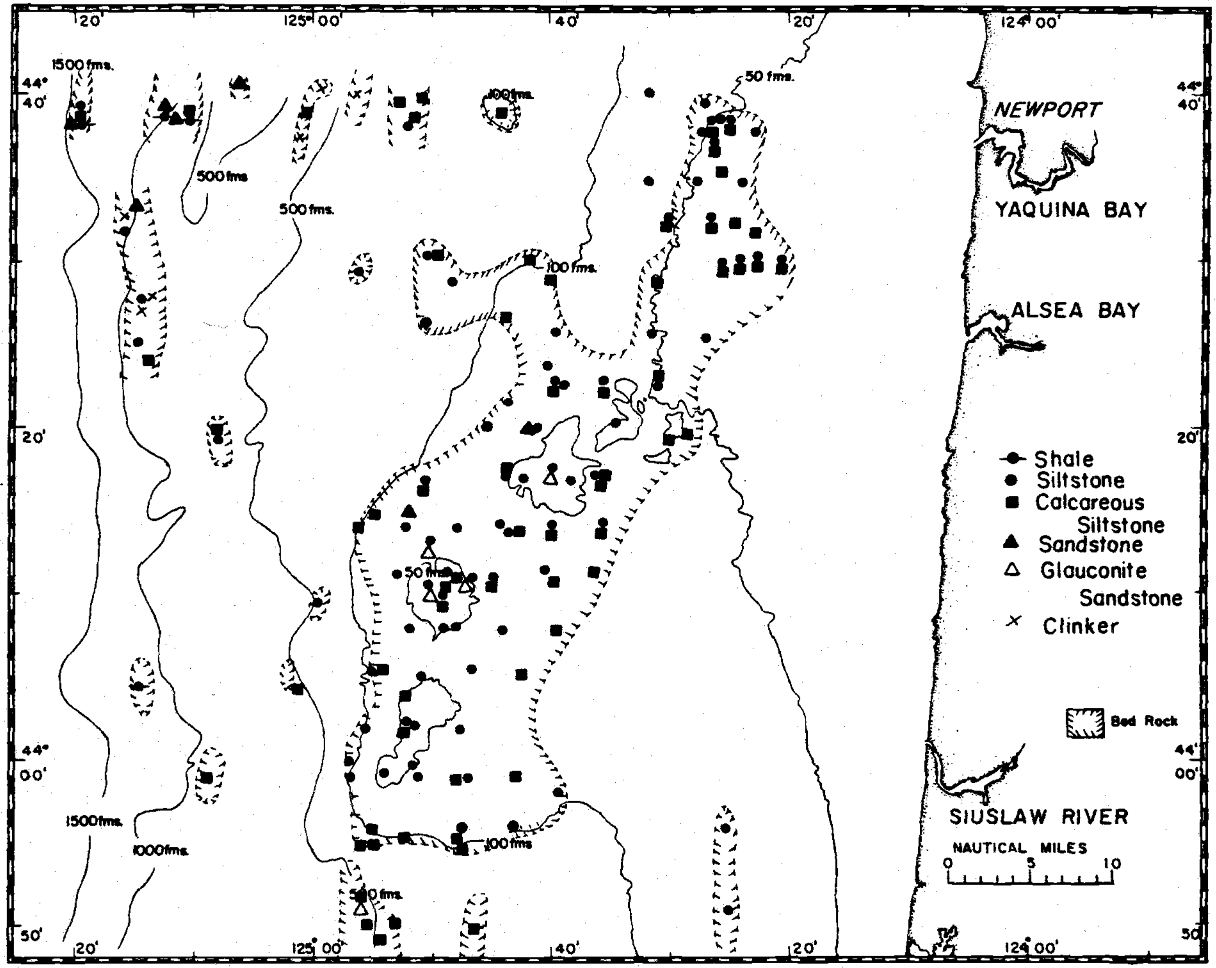


Plate 40. Distribution of lithologies on the continental terrace off central Oregon.

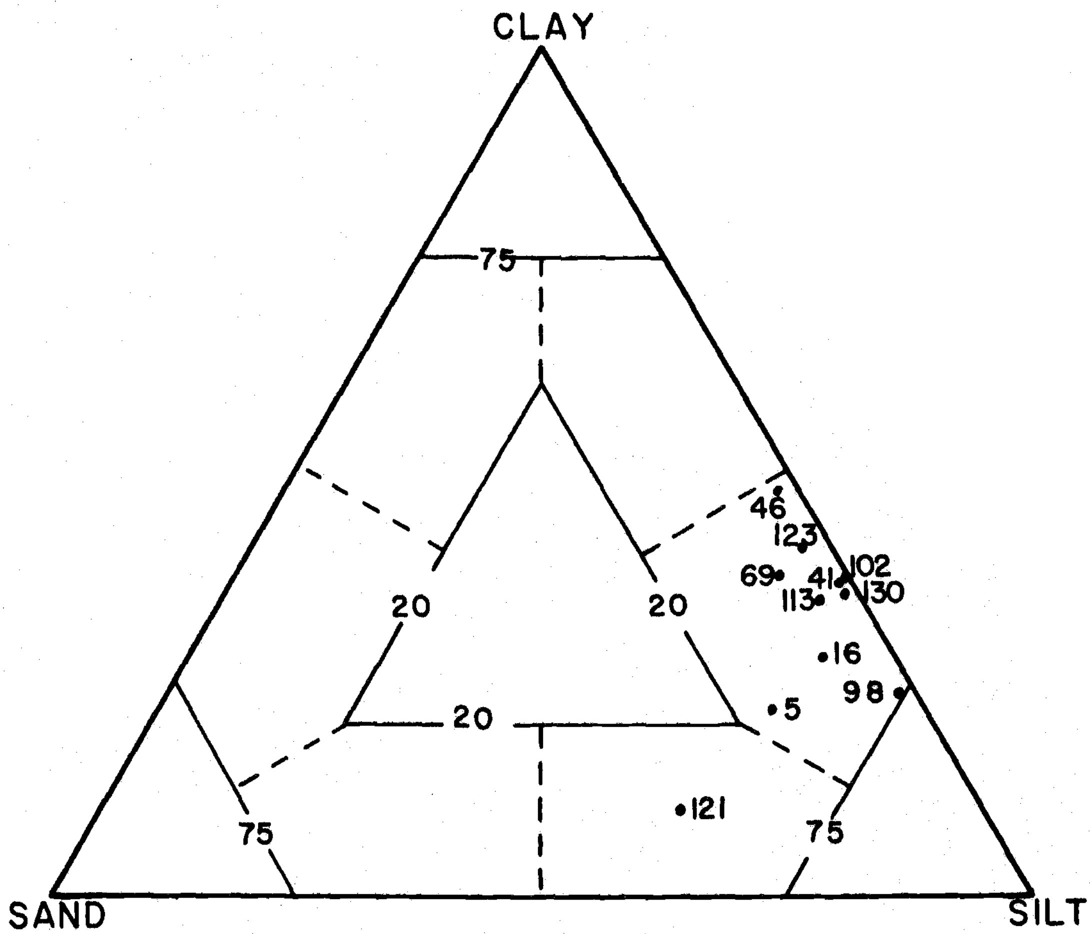
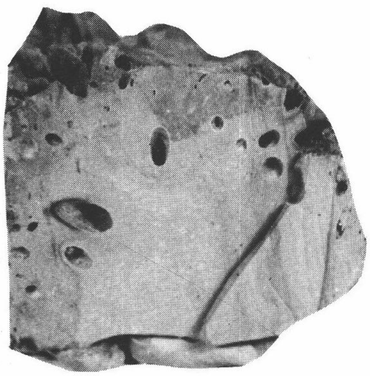


Plate 41. Triangular diagram showing the percentages of sand, silt, and clay in 11 rock samples.

The non-calcareous siltstone was obtained in samples from all parts of the bank. These rocks are soft and light weight. They are normally massive and light gray with crudely conchoidal fracture. Some of the samples contain small vein-like structures of darker siltstone (Plate 42, Figure 3). These veinlets are short, somewhat wedged shaped, and oriented normal to the bedding. They might be fracture and fill structures. Most of the rock specimens are discolored yellowish brown in their outer one to three inches (Plate 42, Figure 1). This outer zone resembles the weathered outer portions of the Astoria siltstone and sandstone exposed on the sea cliff at Newport. Many rock specimens from the bank are pitted with pholad and worm borings, but no living pholads were found in the burrows (Plate 42, Figure 2). Pholads do live along the rocky intertidal zone of central Oregon. Both the discoloration and the burrows suggest that Stonewall Bank was exposed to intertidal and perhaps terrestrial conditions at some time in the past, possibly the Pleistocene. Many of the pholad burrows are partially filled with recent sediment containing large concentrations of Foraminifera.

Grain size analyses were completed for four siltstone samples from the Stonewall Bank area. The analyses show that the non-calcareous siltstone is a clayey silt (Plate 41, Appendix 5). Samples 102 and 123 are very fine silts with median diameters of 0.007 mm and 0.006 mm, 113 is a fine silt with a median diameter of 0.009 mm,

(1)



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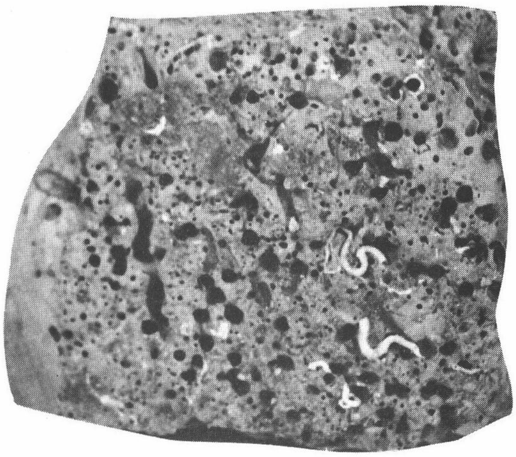


(3)

(4)

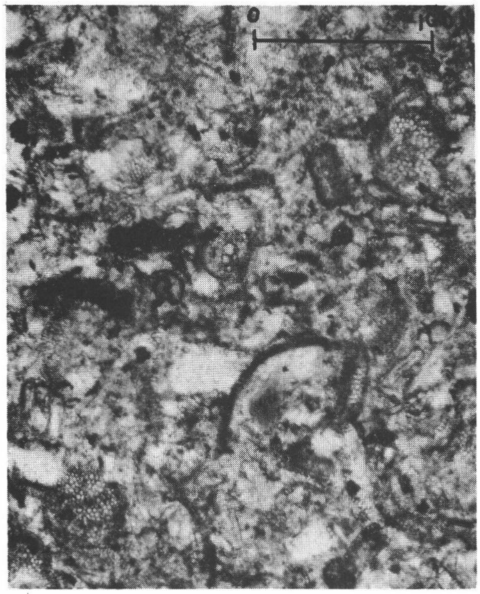
Plate 42. (1) Siltstone from sample 123. Note the change in color at the outer borders. (2) Burrowed surface of the siltstone in sample 123. (3) Veinlets of siltstone oriented normal to the bedding in sample 106. (4) Concretionary looking calcareous siltstone with two directions of fracturing in sample 45.

and 98 is a medium grained silt with a median diameter of 0.016 mm. All of the samples are skewed to the fine fraction with phi skewness values of 0.02 to 0.43. The sorting is fairly poor and the phi deviation values range from 2.54 to 2.98. The textural characteristics of the non-calcareous siltstone are similar to the textural properties of the clayey silt from the intermediate and deep portions of the continental slope (see Plate 28).

The clayey siltstone is composed mainly of silt and clay. This matrix includes an intermeshing of clay minerals, diatoms, opaque minerals, quartz, sponge spicules, radiolarians, carbon, Foraminifera and a large amount of unidentified material. Much of the clay has a greenish color. Diatoms are extremely abundant in many of the samples (Plate 43, Figure 1), and several of the rocks might well be called diatomites. In other samples, however, diatoms are widely scattered. Hematite, limonite, and magnetite are the most abundant opaque minerals. Many of the thin sections contain small irregular patches of an unidentified brown isotropic material.

Coarse silt and sand make up a small percentage of the non-calcareous siltstone. The major components of the coarse fraction are quartz, plagioclase, diatoms, sponge spicules, radiolarians, hornblende, biotite, muscovite, chlorite, glauconite, and rock fragments. Large diatoms form sizeable percentages of the coarse fraction in

(1)



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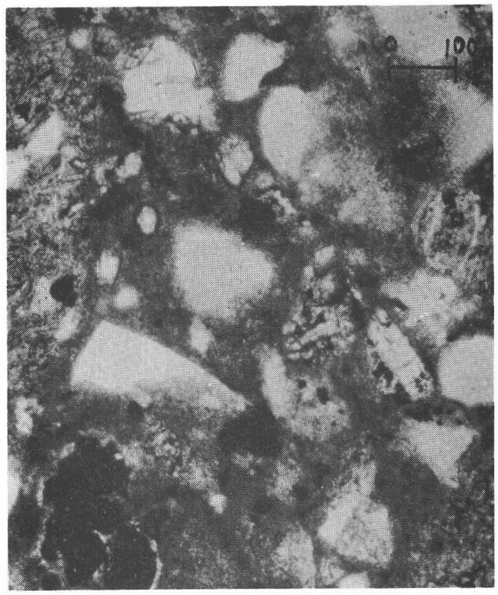

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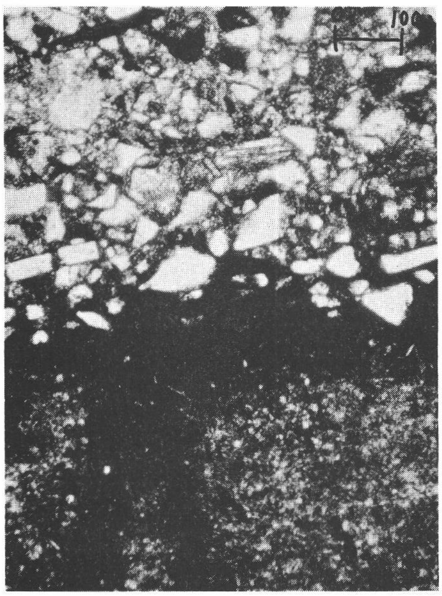

(4)

Plate 43. Photomicrographs. (1) Diatomaceous siltstone from sample 123. (2) Calcareous sandy siltstone from sample 105. (3) Contact between sandstone and siltstone in sample 121. The dark material is hematite. (4) Calcareous siltstone rich in glass shards from sample 120.

many samples. The quartz and feldspar grains are much smaller than the large diatoms. These detrital grains are angular and commonly have etched surfaces. Most of the chlorite occurs in the form of secondary minerals. Glauconite pellets are present as minor accessory minerals in most of the non-calcareous siltstone rocks. The pellets are commonly altered and somewhat discolored. Rock fragments were found in a few of the thin sections. They consist of small fragments of siltstone and volcanic rocks.

The sand fraction of the clayey siltstone includes a fairly high percentage of biological debris and variable amounts of detrital grains. Authigenic minerals comprise only a very small percentage of the sand. This general composition for the sand fractions of the clayey siltstones agrees most nearly with the unconsolidated sediment present on the intermediate and upper portions of the continental slope (see Plate 36).

Post depositional changes in the sediment during the formation of the rock have modified the non-calcareous siltstone. The glauconite was formed authigenically on the ocean floor, and then during the lithification process the pellets were altered, fractured, and distorted. Many of the detrital mineral grains have been etched and in some rocks their edges have become fuzzy. Most of the diatoms and radiolarians are broken, compressed, or torn apart. Some of this may have resulted from the action of animals in the sediment and some may have resulted from compaction and lithification.

Foraminifera were separated from five samples taken on Stonewall Bank. Fowler (1964) identified the faunas and compared them with the depth zonations occurring in the Recent environment. He estimates that the sediment forming the rocks was deposited at depths of 70 to 700 fathoms (Plate 44). The rocks on the west side of the bank were deposited in deeper water than those on the east side. This suggests that there was either a west facing slope or that the rocks are of different ages and that the water depths changed with time. In either case the Foraminifera indicate that the siltstone was deposited at bathyal depths.

Fowler (1964) associates three of the faunas with the Pliocene and one, sample 113, with the Relizian to Luisian stages of the Upper Miocene (after Kleinpell, 1938). The rocks dredged from Stonewall Bank are younger than the youngest rocks exposed along the coast to the east.

Calcareous siltstone has been dredged from nearly all parts of the bank. The hand specimens vary from calcilutites to calcareous sandstones. Most of the specimens are light to dark gray, almost black in color. Several slabbed rocks show alternating bands of light and dark gray, up to one-half an inch thick. One of the slabs includes minute lenticular areas of light gray aligned with the bands. Fine streaks of black material, possibly carbon, are present in at

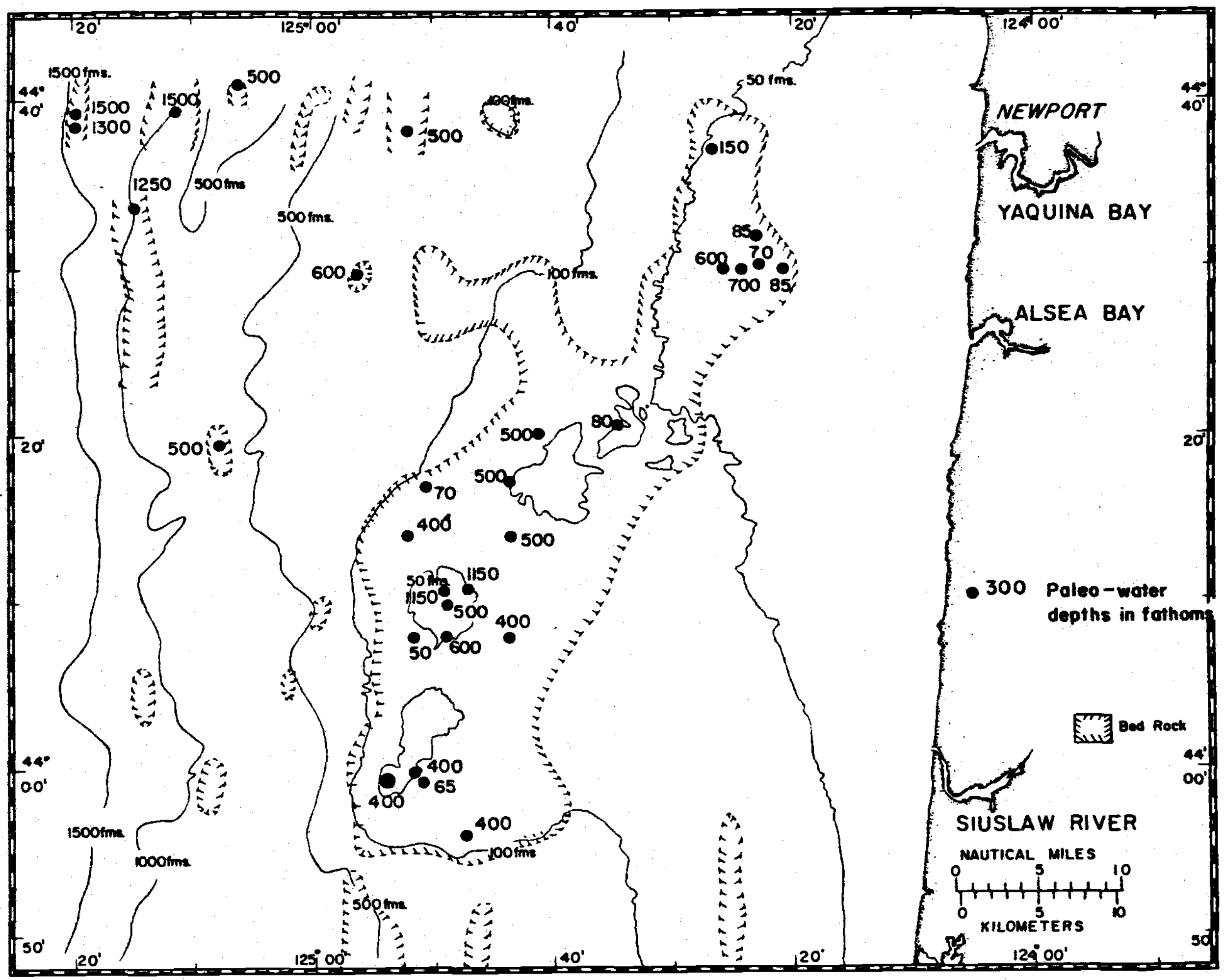

Plate 44. Map showing the Paleo-water depths of the siltstones from the continental terrace off central Oregon. Depths were interpreted from the Foraminiferal faunas by Fowler (1964).

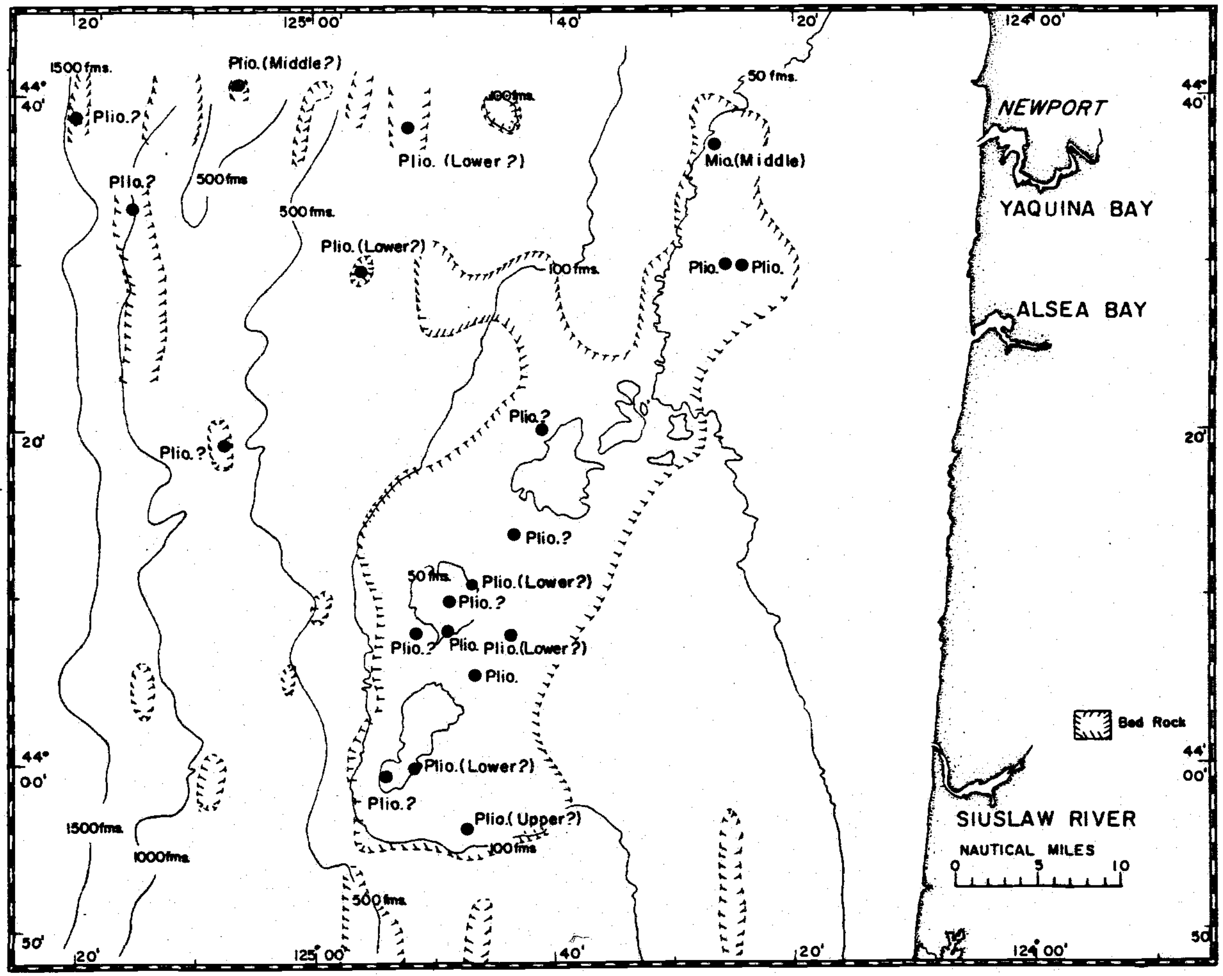

Plate 45. Ages of rocks exposed on the continental terrace off central Oregon. Ages interpreted from Foraminifera faunas by Fowler(1964).

least one sample. Small veinlets of calcite occur in some of the rocks. The veinlets are formed of calcite that is slightly more coarsely crystalline than the country rock, fine grained breccias of the country rock recemented with calcite are included within a number of the veinlets. Two of the rock samples are not gray. Sample 112 includes a brown rock. A gray rock with green, wavy bands of glauconite was taken from the southern high area in sample 100. In addition to the bands the slabbed specimen shows an egg shaped feature about one-half an inch long that includes a concentration of glauconite. The bands above and below the object are bent suggesting a pressure directed outward from the center.

The calcareous cement gives these rocks their character. It makes them considerably harder than the other siltstones and for this reason much less susceptible to mechanical breakdown. The cement also increases the density and reduces the permeability and porosity.

Most of the calcareous siltstone samples are dominantly silt-clay and calcite cement. A few samples from the central and southern high areas contain a considerable quantity of sand. The fine grained non-calcaneous grains in most of the rocks consist of clay minerals, diatoms, opaque minerals, and unidentified materials. Sponge spicules, radiolarians, and glass shards are common in many of the rock thin sections. The coarse silt and sand fractions commonly consist of quartz, plagioclase, large diatoms, Foraminifera, rock fragments, and glauconite. Hornblende, chlorite, muscovite, hypersthene, sponge spicules, opaque minerals, and glass shards also occur in the coarse silt and sand fractions. The opaline test of diatoms and radiolarians are partially to wholly replaced by calcium carbonate; secondary calcite has crystallized in their central cavities. Pyrite, hematite, limonite, and magnetite are the most abundant opaque minerals. The pyrite occurs as very fine euhedral crystals scattered almost randomly throughout the thin sections and as larger subhedral to euhedral crystals which are found associated with glauconite pellets. Labradorite and andesine are the principal plagioclase minerals. Fragments of basalt, non-calcareous siltstone, and chert occur in a few samples. The calcareous cement has the form of very fine grained calcite, but the veinlets are somewhat more coarsely crystalline, and the coarsest crystals of calcite are found in the chambers of diatoms, radiolarians and Foraminifera. The wall structure of the Foraminifera is partially dissolved in some rocks, but well preserved in others.

The sediment forming the calcareous siltstone is not unlike that comprising the non-calcareous siltstone. However, during the process of lithification these sediments were cemented with calcium carbonate. The ellipsoidal shapes of many of the specimens suggest that they formed as concretions. During the cementation of the rock the calcium carbonate permeated much of the original sediment. The glauconite was altered, the quartz etched, and the diatoms were replaced by calcite.

In summary, Stonewall Bank is composed of siltstone deposited at bathyal depths during the Late Miocene and Pliocene. The stratigraphic section is thought to be composed of a sequence of non-calcareous, often diatomaceous, siltstone with interbeds and concretions of calcareous siltstone.

Perpetua Bank. Siltstones similar to those described for Stonewall Bank were obtained at 17 locations on and around Perpetua Bank. In addition to the siltstones, a number of pieces of glauconite sandstone were collected (sample 69).

Soft, somewhat friable, low density, light gray, usually diatomaceous siltstone was collected from nearly all of the samples taken over the bank. A size analysis was completed for the siltstone in sample 69. It is a clayey silt with a median diameter of 0.008 mm, a phi deviation of 2.74 and a skewness of 0.12. These values are highly comparable to those determined for the samples from Stonewall Bank. Also, petrographic study of thin sections from both banks reveals that they are of almost identical composition.

Foraminifera from two samples on Perpetua Bank indicate that the sediments were deposited at depths of 80 and 500 fathoms, with the deeper sample on the west. The foraminifera also indicate that the rocks are Pliocene in age (Fowler, 1964). The water depths conform generally with those of the rocks from Stonewall Bank; both areas contain Pliocene rocks.

The information gained on the grain sizes, composition, paleogeography, and age of the rocks indicates that siltstones on Stonewall Bank correlate with those on Perpetua Bank.

Calcareous siltstones were obtained from one sample on the east side of Perpetua Bank and from three locations on the westward projection of the continental shelf north of Perpetua Bank. The rock from the east side of the bank is laminated with light and dark gray bands. Microscopic lineations are also visible. The composition of this sample is very similar to that of the calcareous siltstones of Stonewall Bank. The coarse silt fraction is distributed throughout the rock in clusters. Pyrite, hematite, limonite, magnetite, leucoxene, quartz, feldspar, and muscovite form the coarse fraction.

The samples from the western projection of the continental shelf north of Perpetua Bank contain a dense, black, calcareous siltstone. This rock is highly diatomaceous, but, as on Stonewall Bank, the opaline structure of the diatoms is almost entirely replaced by calcite. The silt-sand fraction is nearly absent in these samples. The largest crystals are calcite fillings in the chambers of Foraminifera and diatoms. One sample is rich in sponge spicules. Extensively replaced glauconite pellets are sparsely scattered over two of the thin sections. Pyrite is the most abundant opaque mineral, but hematite and limonite are also common.

The one rock that differs greatly from the rocks dredged from Stonewall Bank is the glauconite sandstone of sample 69. This rock includes about 50 percent green glauconite pellets imbedded in a dark gray matrix. The glauconite pellets are concentrated in clusters up to 0. 3 inch in diameter and have the appearance of burrows. In addition, brecciated fragments of siltstone as much as 0. 4 inches across are scattered throughout the rock. The outer half inch of the sample is yellow. This coloration is thought to have been brought about by the alteration of the matrix material and the siltstone fragments. The glauconite pellets, on the other hand, retain their green color in the altered zone. One of the rock specimens has a nearly eliptical shape with a long axes of 3. 5 inches. It has all the appearances of a concretion that has "weathered" out of an outcrop.

In thin section, the glauconite grains occur as yellowish-green and dark green pellets. They have the form of smooth, ovoid grains with fractures that radiate from the center of the pellet. Numerous pyrite crystals and black opaque material occur as inclusions in the glauconite. In addition to glauconite, there is an abundance of detrital sand grains consisting principally of quartz, labradorite, and rock fragments. The rock fragments include diatomaceous siltstone, limestone, and basalt. The basalt grains are finely crystalline, equigranular rocks which are composed mostly of lath shaped crystals of labradorite. The only ferro-magnesium mineral present in the basalt is chlorite. It is probably a secondary mineral formed from the original olivine, pyroxene, biotite, or amphibole. A small portion of the sand fraction is made up of augite, muscovite, chert, quartzite, sponge spicules, glass shards and an isotropic brown substance. The groundmass is formed of chloritic clay minerals, opaque minerals, and fine detrital silt grains. A calcium carbonate cement occurs in patches throughout the rock. The sand grains have highly etched surfaces. They may have been etched by the calcium carbonate.

The glauconitic sediments of the continental terrace are confined to the topographically high areas of the outer portion of the shelf and upper part of the slope. The glauconitic rocks might have been deposited under similar conditions. This glauconite sandstone occurs with siltstones, suggesting that either it comes from a small Pliocene hill or that the siltstones are of different ages than the glauconitic sandstone and the glauconitic sandstone represents a period of non-deposition.

Heceta Bank. Calcareous and non-calcareous siltstones, detrital and glauconitic sandstones, and a limestone breccia were dredged from Heceta Bank. The siltstones were obtained from most of the bank, but the sandstones and breccia were found only on the northern portion of the bank.

Glauconite pellet sandstones were dredged from three locations on the northern high area. These sandstones are massive, medium density, impermeable, greenish-gray to green rocks. The green color comes from sand size glauconite pellets and the gray color from the matrix material. Slabs of two specimens show that the glauconite pellets are concentrated in clusters. This clustering may be the result of burrowing and filling in with younger glauconite-rich sediment. In areas where the pellets are separated by matrix material they have smooth oval to circular outline with fractures that radiate towards the center of the pellet. However, in the areas where the glauconite pellets are clustered the individual pellets are squashed together, distorted in shape, and extensively ruptured. It appears then that these clusters have been more affected by compaction and the lithification processes which occurred during the formation of the rock. Petrographic examination indicates that the glauconite pellets are unstable and they have reacted with the matrix and cementing agents to form pyrite and a brownish clay mineral. In addition to the glauconite, quartz, plagioclase, muscovite, biotite, hornblende, chlorite, calcite grains, leucoxene, basalt fragments, and sponge spicules contribute to the sand fraction. The matrix is formed of a brownish clay, diatoms, spines, glass shards, chlorite, muscovite, pyrite, iron oxides, fine detrital silt, and a good deal of unidentified material. Calcite is present as a fine-grained cement which occurs in patches throughout the rocks.

The glauconite sandstone samples from the northern high area of Heceta Bank are similar to the glauconitic sandstone from Perpetua Bank. The most noticeable difference is that the the Heceta Bank samples are cemented with calcite. The calcite may be derived from Foraminifera as glauconitic sediments often contain large quantities of benthonic Foraminifera. The sediment forming the sandstone may have been deposited on a topographic high; perhaps the same hill as the Perpetua Bank sample.

Sample 62 contains a graywacke sandstone. It is dense, well-cemented, gray, medium-grained sandstone. The rock exhibits poor sorting and contains highly angular grains. Feldspar, quartz, shell material, and muscovite are readily visible in the hand specimen. In thin section it is seen that the most abundant sand grains are quartz, plagioclase, biotite, and rock fragments. Muscovite, microcline, hypersthene, augite, hornblende, calcite, chlorite, garnet, zircon, apatite, hematite, limonite, and leucoxene are found in smaller quantities.

A variety of rock fragments including fragments of siltstone, volcanic rocks, schist, chert, quartzite, and vein quartz are present. Andesite and basalt are most abundant. One fine-grained rock contained a thin vein of quartz. Some of the rock fragments are badly altered to chlorite. The result is that many masses of chlorite contain ghost structures of the replaced minerals.

The quartz grains are highly angular. They have edges which are extensively etched. Most of the quartz grains have sharp, well-defined extinction positions; however, a few of the grains exhibit wavy or patchy extinction. Almost all of the quartz grains contain inclusions in the form of dust trails, irregular to globular blobs, and isolated crystals.

Many of the minerals show large quantities of alteration products. Much of the plagioclase is altered to clay minerals, and the ferro-magnesium minerals are extensively altered to chlorite and iron ores.

The matrix of sample 62 is composed of clay minerals, opaque minerals, and fine detrital silt grains. This piece of graywacke sandstone is both texturally and mineralogically immature. The sand was derived from both superficial rocks, volcanic and sedimentary, and deep seated rocks, metamorphic and possibly granitic. The origin of the graywacke is uncertain. Rocks of this same general nature in the Tyee Formation of the Oregon Coast Range have been ascribed to turbidity currents (Snavely and Wagner, 1963).

Sample 30, located on the center of the bank, contains a silty sandstone. The sand is composed of very angular, etched grains of quartz, labradorite, basalt, glauconite, glass shards, sponge spicules, and diatoms. Biotite, chlorite, muscovite, hypersthene, augite, hornblende, non-carbonate siltstone, chert, and radiolarians are found in small concentrations. Many of the rock fragments and biotite are chloritized. Also, it appears that some radiolarians are partly filled with glauconite but that the glauconitization was arrested by the crystallization of calcium carbonate in the central voids. A few Foraminifera are present; their wall structure is readily visible but the outer surfaces of the tests are fuzzy and the inner void areas are filled with calcite. The matrix is composed of clay which is probably chloritic, diatoms, spines, and opaque minerals. Pyrite is abundant as fine scattered specks and as large subhedral crystals, many of which are located within diatom tests and glauconite pellets. Magnetite, hematite, and limonite are present in smaller concentrations. The matrix is completely cemented with a fine-grained calcite. In addition, there are a few small veins of more coarsely crystalline calcite.

Sample 42 is a sandy siltstone. The sand fraction is greatly similar to that of sample 30. The chief differences are that there are fewer sand grains and that the grains present are more extensively replaced. The matrix, however, is quite different being mostly clay which is almost entirely free of diatoms. The clay together with an abundance of finely divided opaque minerals is cemented by calcite.

Low density, gray, diatomaceous siltstone similar in appearance to the siltstone described from Stonewall and Perpetua Banks was collected at a large number of sample stations on and around Heceta Bank. Mechanical analyses were run on two samples from the bank, 41 and 46, and one sample from a scarp east of the bank. All three samples are clayey siltstones. Their median diameters range from fine silt, 0.011 mm, to very fine silt, 0.005 mm. The phi deviation values range from 2.32 to 2.86 and the phi skewness from 0.07 to 0.10. These statistics compare almost exactly with those obtained from the rocks on Perpetua and Stonewall Banks to the north and for clayey silt covering the continental slope and the low areas of the continental shelf.

As in the other areas, the siltstone consists mostly of silt and clay. Large quantities of diatoms, sponge spicules, and minute spines are present throughout the rock. Sample 46 contains a higher percentage of clay than any of the other samples, almost 50 percent. It also differs in that it has layers with high concentrations of Foraminifera, crushed shell material, diatoms, and fish scales. Most of the siltstone samples contain very little sand. The largest grains are usually the diatom tests. Bits of carbonaceous material, probably small wood chips, occur in many specimens. Overall the siltstone from Heceta Bank has a composition greatly similar to the siltstone on the other banks.

Several punch core samples were taken to the east of Heceta

Bank. They obtained dark gray, poorly indurated clayey siltstones. These samples are micaceous, contain abundant Foraminifera, and have a few diatoms. In general they appear less indurated and less diatomaceous than the siltstone from the banks. The lesser induration may suggest that the samples from east of Heceta Bank are younger than the samples from the bank itself.

Foraminifera were separated from samples on Heceta Bank. They suggest that the sediments which now form the rocks, were deposited during the Pliocene in water 50 to 1200 fathoms deep with most of the samples having depths around 500 fathoms. These paleo-water depths and ages compare almost exactly with those found on the banks to the north.

Calcareous siltstone was dredged from a number of locations on the bank. As on the other banks, the calcareous siltstone is a dense, gray, well cemented rock. Many of the specimens appear to be concretions. Some samples are highly diatomaceous; in others, the diatoms are completely replaced with calcite and only vague ghost structures of the diatom tests remain. The siltstone contains very little sand. The overall composition of these rocks is almost identical with the calcareous siltstone from Stonewall and Perpetua Banks.

A specimen of limestone breccia was collected from the northern part of Heceta Bank. This breccia includes angular clasts up to an inch in diameter. In thin section the rock appears as a very fine grained limestone with varying quantities of clay, vugular fillings of quartz, and ghost structures of diatoms. The edges of the clasts are sharply defined, though some large clasts include smaller ones. Bands of brown clay form lineations in many of the fragments. In adjacent clasts these lineations are as often as not orientated at distinct angles to one another indicating that the fragments have been at least rotated if not moved. This rock may well be a fault breccia that has been re-cemented by calcium carbonate obtained from the rock itself.

In general, Heceta Bank is dominantly siltstone. The siltstone is highly diatomaceous and in some areas cemented with calcium carbonate. Foraminifera faunas indicate that the sediment now forming the siltstone was deposited in bathyal water depths during the Pliocene. From this it is concluded that the siltstone is generally correlative with the siltstone of Stonewall and Perpetua Banks.

The northern high area of Heceta Bank has the greatest variety of rocks with glauconitic, graywacke, and calcareous sandstones and a limestone breccia in addition to the siltstone. This could mean that a different formation is present in this area. However, the fact that siltstone was obtained in the same dredge hauls as the sandstones indicates that these rocks represent local beds or facies within the thick sequence of siltstone. The glauconitic rocks may indicate that a topographic high existed in the north sometime during the Pliocene. This high may have extended northward to Perpetua Bank.

<u>Siltcoos Bank</u>. Massive, light weight, gray, diatomaceous siltstone was dredged from the top of Siltcoos Bank. A grain size analysis of the disaggregated sediment shows that it is a clayey silt with a median diameter of 0.018 mm, a phi deviation of 2.31, and a phi skewness of 0.22. Sixteen percent of the sample is sand, making this siltstone sandier than any of the other samples analysed. The recent sediment of greatest textural similarity is the clayey silt present in Heceta Swale at depths greater than 60 fathoms.

Carbonaceous material, muscovite, sponge spicules, and diatoms are visible in the hand specimens. In thin section, the rock is dominantly fine silt and clay throughout which coarse silt and sand is scattered. The coarsest grains consist mainly of plagioclase, quartz, and glauconite. Hornblende, muscovite, biotite, pyrite, hematite, limonite and magnetite are common but less abundant. The glauconite pellets are fragmental suggesting that they may be detrital. Most of the larger pyrite crystals are associated with glauconite pellets.

The siltstone from Siltcoos Bank has the same general appearance and composition as the siltstone on the other bank areas and may correlate with them. The presence of higher percentages of sand in the Siltcoos Bank siltstone suggests that it may have been deposited in shallower water closer to shore.

<u>Summary</u>. The banks of the continental shelf consist of Upper

Miocene to Upper Pliocene siltstone. Much of the siltstone is soft, light weight, massive, and diatomaceous. Dense, well cemented calcareous siltstone occurs as concretions and beds interstratified in the sequence of non-calcareous siltstone. Analyses of the grain size, sand composition, and Foraminifera indicate that the sediment forming the siltstone was deposited at bathyal water depths.

Glauconite sandstone was dredged from Perpetua Bank and the north end of Heceta Bank suggesting that this area was a topographic high at some time during the Pliocene. The limestone breccia from the same area is a possible fault breccia and the graywacke sandstone is of uncertain origin.

Continental Slope

Northern Slope Region. Most of the upper part of the continental slope opposite Stonewall Bank is covered by sediment. As a result only four rock samples have been obtained. Two of the samples contain low density, diatomaceous siltstones and the other two calcareous siltstones. All of the samples are similar to the rocks dredged from Stonewall Bank.

Three samples of calcareous siltstone were dredged from the upper part of the Northern Slope Region opposite the north end of Heceta Bank. One of the samples consisted of rounded pebbles of calcareous siltstone; the second, angular fragments of calcareous siltstone; and the third, small chips of the siltstone. These rocks are similar to the calcareous siltstones from Perpetua and Heceta Banks. They may have been transported downslope from the bank areas.

Only a limited number of rock samples, 16 in all, were obtained from the intermediate area of the Northern Slope Region and ten of these samples were collected on a line due west of Newport.

A number of rocks were dredged from one location on the relatively flat top of Daisy Bank. Two rock types were secured from this bank. Most of the specimens are of a dense, dark, calcilutite. The limestone is massive, nonporous, and dark gray. The exposed surfaces are bored by benthic organisms and coated with a thin layer of brown material that could be phosphorite. Microscopically the limestone is composed of very fine grained calcite and clay. More coarsely crystalline calcite occurs in the chambers of the Foraminifera and diatoms. Fine subhedral to euhedral grains of pyrite are evenly distributed throughout the thin section studied. Very fine grains of quartz and plagioclase occur in small numbers. These grains are highly etched and have serrate edges.

The limestone from Daisy Bank is similar in appearance to the calcareous siltstones found on the shelf bank areas. The major difference is that the limestone contains less sand and silt and more calcite than the shelf samples.

The second rock type recovered from Daisy Bank is coal. The coal occurs as small, fairly soft chunks having a subvitreous luster. It is the author's opinion that these pieces of coal were deposited by coal burning ships which pass over the bank on their way to and from the harbor at Newport.

The samples obtained from the intermediate slope west of Daisy Bank include four samples of calcareous siltstone, two of non-calcareous siltstone, two of coal and one clinker. The calcareous siltstone is a dense, gray, nonporous rock similar to the rocks found on the shelf banks.

A calcareous siltstone collected west of Daisy Bank, sample 131, is interesting in that it contains a fairly large percentage of glauconite pellets. An entirely different type of siltstone, sample 120 was collected about two miles southeast of sample 131. This rock is dark gray on fresh surfaces and light gray on the exposed surfaces. The lighter gray rock also occurs as vein-like bodies in the darker siltstone. In thin section, the rock is seen to have a great abundance of glass shards, most of which are partly replaced by the calcareous cement (Plate 43, Figure 4). Hornblende is common throughout the slide, and muscovite, quartz, plagioclase, and glauconite occur in small quantities. In addition, there is a large quantity of opaque minerals, of which pyrite is the most abundant; magnetite and leucoxene are less abundant. A few non-calcareous siltstone fragments are present in the thin section.

Low density siltstone was dredged from nearly the same location. These rocks are well indurated and include patches of calcareous cement. They appear to be intermediate between the non-calcareous and the calcareous siltstones of the bank areas.

One dredge sample was obtained from the outer part of the intermediate slope area near the top of the hill west of Newport Valley. This dredge haul contained green glauconitic mud mixed with angular pieces of siltstone. Gray to brownish gray, glauconitic clayey siltstone containing angular fragments of siltstone was also present. When dried and wetted again this "rock" decomposed. The glauconite occurs in pods and poorly defined bands throughout the "rocks". Glauconite, Foraminifera, and shell fragments comprise the largest grains in the siltstone; and hornblende, quartz, plagioclase, hematite, and magnetite occur in small quantities as coarse silt. Chlorite is present as an alteration product, and authigenic pyrite is scattered throughout the rock. The glauconite pellets appear to have reacted with the matrix forming reaction rims of pyrite, hematite, and a black opaque material. The matrix which dominates the rock is composed of clay minerals, opaque minerals, sponge specules, spines, diatoms, and unidentified materials.

Foraminifera separated from samples 118 and 137 suggest that the rocks are Pliocene in age, and were deposited in water depths comparable to the depths from which they were collected (Fowler, 1964).

Two samples were obtained from the hill at 44° 30' N, 124° 50' W. Sample 95 is a pliable clayey, foraminiferal siltstone. It is only slightly more consolidated than the surrounding sediment. The other sample, number 103, contains a dense, gray, silty, clayey limestone. Calcite veins are present throughout the rock and are more coarsely crystalline than the country rock, though still fine grained. The sand fraction is composed predominantly of larger sponge spicules and Foraminifera. The spicules are partially to wholly replaced by calcium carbonate. Foraminifera are abundant; they are, however, somewhat altered and their central chambers are filled with calcite. As in many of the other carbonate rocks the fine fraction is clayey with silt size opaque minerals, ghost structures of diatoms, and spines. The opaque minerals are pyrite, hematite, and magnetite.

Down slope from the hill a single sample of friable, fossiliferous, sandy siltstone was collected. It is a poorly cemented rock which is pliable when wet. The specimens are riddled with recent animal burrows. They also contain abundant, poorly preserved fossil pelecypods. To the south, small chips and rounded pebbles of siltstone were dredged from near the middle of the slope.

Rocks were obtained from six biological dredge hauls taken on the lower slope west of Newport. Three of the samples were collected near the top of the lower slope at depths of 650 to 900 fathoms. Calcereous, clayey, and sandy siltstones, and lithic wacke sandstone were obtained at these locations. The clayey siltstone is a dark gray, medium weight, massive, somewhat friable rock. It is porous but nonpermeable owing to the fairly large quantity of clay. One of the samples has specimens of silty shale or mudstone. This rock is dark gray to black and contains abundant Foraminifera. A single specimen of dense, gray, calcareous siltstone was dredged from the same general area. Irregular dark gray and brown patches are evident in the hand specimen, but in thin section is appears to be a calcareous siltstone greatly similar to those taken from Stonewall Bank.

Friable sandy siltstone and sandstone were also dredged from the upper part of the lower slope area west of Newport. The sandy siltstone contains particles of quartz, plagioclase, muscovite, chlorite, basalt, diatoms, and radiolarians as the principal components of its sand fraction. The matrix is composed of diatoms, spines, hematite, magnetite, pyrite, and clay. The sandstone includes in addition to the above mentioned minerals, hornblende, biotite, microcline, augite, glass shards, and rock fragments. Labradorite is the dominant plagioclase, and hematite, limonite, magnetite, and pyrite are the opaque minerals. In addition basalt, siltstone, and possibly quartzite fragments are present in the sandstone.

Foraminifera separated from two of the siltstone specimens collected in 900 to 1200 fathoms indicate that the sediment forming the rock was deposited in water 1100 to 1500 fathoms deep (Fowler, 1964). This suggests that the sediments forming the rocks were deposited at or near the base of the continental slope. The Foraminifera faunas also indicate that the rocks are Pliocene in age and thus roughly correlative with the rocks exposed on the continental shelf.

Three samples containing friable sandstones and somewhat compacted mudstones are available from near the base of the continental slope west of Newport. These "rocks" are easily disaggregated when placed in water.

The mudstone is a gray, somewhat friable, massive rock with a crudely conchoidal fracture. Lenses and pockets of sand occur in some of the specimens. Hornblende, biotite, chlorite, quartz, muscovite, plagioclase, and radiolarians were identified in the sand fraction. The matrix consists primarily of clay and opaque minerals. A grain size analysis was made on a single mudstone sample. It is a clayey silt with a median diameter of 0.008 mm, a phi deviation 2.85 and a phi skewness of 0.15. The grain size distribution of this rock is similar to the grain size distribution of the sediment samples from the intermediate and deep areas of the continental slope.

Friable sandstone and sandy siltstone were obtained from the same area near the base of the slope. A grain size analysis of a single sample shows it to be a sandy siltstone with a median diameter of 0. 046 mm, phi deviation of 2. 02, and phi skewness of 0. 33.

These sandy rocks contain abundant muscovite which is readily visible in hand specimen. In addition, biotite, quartz, plagioclase, limonite, and hematite can be observed with the aid of a hand lens. A thin section of the sandstone shows, in addition to the above mentioned minerals, an abnormally high percentage of hornblende. Glass shards, chlorite, basalt fragments, and siltstone fragments are also common in the sand fraction. Less abundant are calcite, augite, zircon, and hematite. Many of the grains are altered to secondary minerals. The biotite is altered to chlorite, and much of the plagioclase is altered to clay minerals. In additon hematite appears to have formed as a secondary mineral. The matrix consists of spicules, chlorite, glass shards, diatoms, hematite, magnetite, pyrite, clay minerals, and unidentified minerals.

A thin section was made across the contact between siltstone and sandstone (Plate 43, Figure 3). The clayey siltstone is composed of chlorite, sericite, hematite, other opaque minerals, quartz, and numerous other unidentified grains. The contacts between the sandstone and siltstone are irregular. The irregularity is caused by fractures in the siltstone which extend to the contact but not into the sandstone. In fact the sand seems to fill the displacements made by the fractures in the siltstone. These contacts are also marked by concentrated bands of hematite. The hematite stops at the sandstone but extends into the siltstone along the fractures. This suggests to the author that the sand was plastered on to the siltstone after it had broken loose from its bed rock position.

Foraminifera separated from the mudstone indicate that the sediment forming this rock was deposited at depths of around 1, 500 fathoms. This depth corresponds to the depth from which the sample was collected. The similarity of paleo-depths of this sample and of the sample collected up slope five miles to the east suggests the possibility that the sediments forming these rocks were deposited either on an abyssal plain or a continental rise.

Comparison of the rocks with the sediments occurring near the base of the slope and on the abyssal plain reveals that the clayey silts forming the mudstone is similar to the sediment, but the sandstones are atypical. The facts that these sandstones are poorly sorted, skewed to the fine fractions, contain chips of mudstone, and were deposited in deep water suggest that they are turbidity current deposits.

Rocks were collected from seven sample locations on the lower part of the continental slope between 44° 37' N and 44° 14' N. Stiff, gray silty clay, siltstone, diatomite, clinkers, wood and sandstone were obtained in these samples. With the exception of the clay all of the samples are small in size and number of specimens. The siltstone and sandstone samples consist of small rounded pebbles and in all likelihood have been transported to their site of deposition. The sandstone has a burrowed surface. Many of the burrows are filled with sand which is better sorted and of lighter color than the sand making up the rock. Quartz, plagioclase, muscovite, biotite, chlorite, hematite, green minerals, and black grains are observed in the hand specimen.

Central Slope Region. Rock samples have been obtained from only seven locations over the central portion of the continental slope. Four of these locations are on Heceta Scarop where low density, gray siltstone was obtained. A thin section of one specimen shows that it is highly diatomaceous, and has an overall composition similar to the siltstones from Heceta Bank. A number of the specimens are well rounded pebbles and cobbles which presumably have been transported down slope from the bank.

In addition to the low density siltstone one of the samples from Heceta Scarp contains a piece of calcareous siltstone. This rock is a somewhat rounded cobble which may also be displaced down slope from the bank to the east.

Two samples were taken from near the base of the scarp. One sample contains rounded pebbles of calcareous siltstone and the other angular fragments of glauconite rich, calcareous siltstone. This second rock has a light gray color with interspersed specks of green and thin veins of darker gray rock. In thin section the glauconite is yellow-green and apple-green in color. Pyrite crystals occur within and along the edges of the pellets. In some areas of the slide the pellets are partially coated with hematite, while in other areas the pellets are surrounded by more coarsely crystalline calcite. Some of the pyrite crystals that border the glauconite are in turn coated with hematite. The majority of the rock is composed of matrix which contains abundant diatoms, spicules, pyrite, hematite, and clay. This matrix is completely cemented by fine grained calcium carbonate. There is a small quantity of coarse silt and fine sand present. It is mainly quartz and plagioclase.

Sample 17, dredged from midway down the slope, is a dark gray, dense foraminiferal limestone. The largest particles present are the Foraminifera. The wall structure of the Foraminifera is well intact and the chambers are empty. Coarse silt forms only a small percentage of the rock; it consists mostly of replaced sponge spicules and quartz. Most of the rock is groundmass of very fine-grained calcium carbonate cement with a matrix of chloritic clay, hematite, pyrite, magnetite, and fine quartz grains.

Southern Slope Region. Twelve rock samples were obtained from southern slope area. None of these samples were collected from the slope deeper than Heceta scarp. Seven of the samples come from Heceta Scarp, four from the southern edge of Heceta Bank, and one from the hummocky area south of the bank.

Rounded to subangular pebbles, cobbles, and boulders of limestone were collected from Heceta Scarp in samples 1, 3, 8 and 9. These rocks are gray, dense and fine-grained in nature. Sample 9 is darker than the other samples. A thin section of sample 1 shows that it is mostly fine-grained groundmass. This groundmass is composed of clay, pyrite, hematite, and unidentified silt grains completely cemented with fine-grained calcium carbonate. The coarse fraction composed of pyrite, quartz, plagioclase, chlorite, glauconite, rock fragments, and shell fragments forms only a small percentage of the rock. The glauconite grains are extensively altered; some are tan colored. The quartz and feldspar grains are small and highly etched.

The southern end of Heceta Bank extends onto the uppermost part of the continental slope east of Heceta Scarp. Samples 7, 10, 11, and 15 were taken from this area. Rounded pieces of limestone and calcareous siltstone were obtained in 7, 11, and 15. These samples might be either transported pebbles and cobbles or rounded concretions. A fairly large sample of laminated limestone was collected at location 10. Sample 13 obtained stiff gray clay having properties intermediate between sediment and rock.

One sample, number 2, was obtained from the hummocky area south of the bank. This sample consists of a gray, calcareous siltstone with non-calcareous patches and large areas of vugular aragonite. The aragonite has the form of spheroidal masses which generate from the walls into what were void areas. The rock itself is principally fine silt and clay, cemented with fine-grained calcium carbonate. Hematite, limonite, and magnetite are abundant.

Summary. Relatively few rock samples have been obtained from the continental slope, and these samples are poorly spaced. All of the rocks that have been dredged are sedimentary. Many of the specimens from the upper part of the slope are siltstone similar to the rocks on the shelf banks. Daisy Bank is composed of a dense, dark gray to black limestone that is similar to the calcareous siltstone of the shelf and surrounding slope areas. Abundant glass shards are present in the calcareous siltstone from sample 120. Mudstones and lithic wacky sandstone are present on the lower portion of the slope west of Newport. Foraminifera from the mudstone indicate that the sediment was deposited in deep water. This suggests that the sandstone is also a deep water deposit, possibly a turbidity current deposit.

Age

Foraminifera were separated from the non-calcaneous siltstone samples obtained from the continental terrace, and the following ages were determined by Fowler (1964).

Samples	Age
14	Late Pliocene
137	Middle Pliocene
24, 38, 46, 60, 97, 118, 130	Early Pliocene
23, 35, 40, 41, 44, 55, 72, 76, 99, 100, 108	Pliocene(undifferentiated)
113	Late Miocene (Relizian to Luisian)

A map showing the distribution of the dated samples is shown in Plate 45.

The rocks exposed on the continental terrace appear to be mostly Pliocene in age, but are at least as old as Late Miocene on the northwestern part of Stonewall Bank. Thus, the rocks exposed on the continental terrace are younger than the Early Miocene, Astoria Formation, the youngest rock unit exposed on the continent to the east.

Environment of Deposition

Fowler (1964) has compared the Foraminifera separated from the sedimentary rock of the continental terrace with the depth zonations of Recent Foraminifera as determined by Bandy (1953) and Enbysk (1960). The probable water depths at the times of deposition are shown in Plate 44. These data indicate that the sediment making up the rocks exposed on the shelf was deposited in lower bathyal to lower literal depths. The rocks located near the base of the slope west of Newport were deposited at depths generally corresponding to their present position.

A comparison of the sand-silt-clay ratios of the siltstones (Plate 41) with those of the unconsolidated sediments (Plate 28) shows that the rocks have ratios which are almost identical to those of the continental slope below 500 fathoms. With respect to the sand fractions the siltstones are comparable with the slope sediment samples in that they both contain fairly high percentages of siliceous plankton. Thus, interpretation of the Foraminifera, grain size, and sand composition indicate that the siltstones were deposited at bathyal depths either on a continental slope, a continental rise or in an open basin.

The glauconite rich rocks located at the northern end of Heceta Bank and on Perpetua Bank probably indicate areas of slow deposition. The glauconite may have been deposited on a relatively high area where the currents prohibited the deposition of silt and clay.

The silty sandstones that were dredged from deep on the slope west of Newport are thought to have been emplaced by turbidity currents. This origin is indicated by the poor sorting of the sand, the presence of shale chips in the sandstone, and the presence of deep water Foraminifera in the accompanying shale. The occurrence of the sandstone on the lower portions of the continental slope along with the general absence of detrital sandstones on the continental shelf banks may indicate that these Pliocene turbidity currents bipassed the banks, at that time the continental slope, and deposited their load on a continental rise at the base of the slope. It is also possible that detrital sandstone is present on the shelf but was not sampled.

Diagenesis

The post-depositional changes in the original sediment, both as it lies on the sea floor and it is changed into rock with burial, involve the processes of authigenesis, compaction, solution, and replacement.

Authigenic glauconite formed in abundance on the Pliocene sea floor at the north end of Heceta Bank and on Perpetua Bank. Glauconite is an iron-magnesium clay mineral that grows into pellet sized particles on the ocean bottom. Many of the pellets contain inclusions of euhedral crystals of pyrite and irregular patches of dark organic material. In addition to authigenic glauconite and pyrite, phosphorite may be present as a thin brown coating on the limestone from Daisy Bank.

The effects of compaction of the sediment during the formation of rock was observed in many samples. Most of the diatoms are flattened and often fragmental. Much of the radiolarian material is crushed and the spines are broken and separated from the radiolarian. In a few rocks where the concentration of glauconite grains is large the pellets are deformed and ruptured as a result of the grains pressing together.

The effects of solution and replacement are most noticeable in the calcareous rocks. Most of these rocks were siltstones not unlike the low density, diatomaceous siltstones that are so common on the continental terrace. These siltstones became saturated with a calcium carbonate solution which then crystallized as very fine-grained cement. In addition to cementing the rock the calcium carbonate replaced the pre-existing mineral and biological grains, Most of the opaline skeletal material of the diatoms, radiolarians, and sponge spicules has been replaced by calcite. Crystals of calcite formed as solution fillings of void areas such as the central chambers of diatoms and Foraminifera. Large cavities in sample 2 are partially filled with needles of aragonite-like calcium carbonate.

Weathering

Many of the rock samples from the continental shelf bank areas appear to have been subareally weathered. The light gray siltstones from Stonewall Bank are discolored to a tan or light brown and to a rusty yellow. Many of the discolored specimens are pitted with pholad borings. The fact that pholads are currently found living in rocky intertidal zones strengthens the contention that the bank areas were exposed to subareal weathering.

The glauconite sandstone from Perpetua Bank has a sharp color change from its normal gray-green to tan near the surface. It is interesting that the color change is only in the matrix; the glauconite pellets retain their green color.

Summary

Miocene and younger clayey siltstones, calcareous siltstones, clayey limestones, glauconite sandstones, and wacke sandstones are exposed on the bank areas of the continental shelf and at scattered locations on the continental slope.

The dominant lithology of the continental shelf bank areas is a diatomaceous, clayey siltstone. Almost as abundant is the same type of siltstone completely cemented with calcium carbonate. In these rocks the opaline material of the diatoms, spicules, and radiolarians is partially to entirely replaced with calcite.

Glauconite sandstone, one piece of volcanic wacke, and a limestone breccia were dredged from the northern end of Heceta Bank along with the more normal siltstones.

Most of the samples obtained from the upper and intermediate parts of the continental slope are gray, fine-grained limestones. Some of these rocks show relic structures of diatoms and spicules completely replaced by calcium carbonate. Friable sandstones and mudstones are exposed on the intermediate and deep portions of the continental slope west of Newport. The sandstones are very poorly sorted with some of the rock being sandy siltstone. The mudstone is dark gray in color and highly foraminiferal in composition.

The siltstone forming the dominant lithology of the shelf bank areas was probably deposited on the outer part of the continental shelf and the intermediate and upper portions of the continental slope. Since that time this area of the continental terrace has risen as much as 1000 fathoms, and the rocks are now exposed in relatively shallow water on the shelf. The mudstones dredged near the base of the slope west of Newport were deposited at water depths that are about the same as those that they presently occupy. The silty sandstone from the same area appears out of place. These rocks may have been emplaced by turbidity currents on a continental slope or rise.

GEOLOGIC STRUCTURE

The central Oregon coast lies on the western limb of the Coast Range anticline and the rocks along the Coast dip to the west. Whitcomb (1964) conducted an underway reflection seismic survey in the vicinity of Stonewall Bank and found that the rocks dip east. From this evidence he concluded that a north-striking syncline exists between the edge of the continental shelf and the shore. He also determined, using Bouguer anomalies from gravity profiles, that the syncline contains 19,000 to 21,500 feet of low density sediment and rock at its axis which is located just to the east of Stonewall Bank and that the syncline thins to the south, disappearing before it reaches 44° 25' N latitude. The swale to the east of Stonewall Bank is the bathymetric expression of the syncline. However, the axis of the swale lies east of the axis of the gravity low.

Heceta Bank and swale may present a situation analogous to that of Stonewall Bank. Southeast of the bank there is a series of northwest striking scarps which may well be fault scarps. Thus, even if the Heceta Bank-swale area is a syncline there is a good chance that the syncline is complicated by faulting. Unfortunately no geophysical data are available in this area.

Between Stonewall and Heceta Synclines lies an area of high gravity and magnetic anomalies extending west from Cape Perpetua to about 124° 25' W longitude (Whitcomb, 1964). Whitcomb (1964) states that these anomalies are due to a seaward extension of the Upper Eocene basalt intrusive body which is found on Cape Perpetua. The swales to the north and south plunge gently away from the anomalies.

Siltcoos Bank is believed to be structural in origin. One Precision Depth Record over the bank shows it to have a flat top with relatively steep sides. This suggests that it may be a horst. But there is also the possibility that the bank might be a truncated fold.

The lower part of the continental slope is a continuous, straight, north-trending scarp some 3, 000 to 6, 000 feet high. The straight, steep nature of the scarp, its abrupt lower termination, and the fact the rocks sampled from the shelf banks have risen as much as 1000 fathoms suggest that the scarp is a major fault along which the continental terrace has been uplifted. To the east in the vicinity of Heceta Bank, the slope above the lower scarp is made up of a number of smaller scarps with intervening benches and hills. The author interprets these scarps and benches as step fault blocks. Heceta Scarp, as much as 3500 feet high, is the largest of these step-type normal faults. These faults differ from common type of normal faults in that both the hanging wall and the foot wall moved up. The foot wall moved father than the hanging wall making the net displacement like that of a normal fault.

North of Heceta Bank the structure of the outer shelf and the slope east of the lower scarp appears to be more complex. Newport Sea Valley is thought to be a structural feature, as it is straight, has no tributaries and has a bench on the east side. It may be a graben or possibly a southwest plunging syncline. The valley terminates abruptly at the basal scarp.

There are two areas on the continental terrace where major east-west structures might occur. One of the areas lies to the west of Cape Perpetua. Geophysical evidence indicates that intrusive basalt found on Cape Perpetua extends under the shelf as far as 124° 25' W longitude. To the west, on the slope, there is a major discontinuity between the benches to the north and those to the south (Plate 16) In addition, this is where the banks are offset, with Heceta Bank being located west of Stonewall Bank, and the area in which a Pliocene topographic high is suggested by the presence of glauconite rich rock samples. All these independent features when considered together suggest the existence of some type of deep seated east-west structure.

The second east-west trend is the scarp forming the southern boundary of Heceta Bank at 43° 56' N latitude. North-striking Heceta Scarp appears to be displaced about two miles in a left lateral manner at this west-striking scarp. To the west, near the base of the continental slope there are two scarps which form what may be a graben between 43° 57' N and 44° 01' N latitude. These scarps run along the same trend as that along the southern border of Heceta Bank and therefore the two features may indicate the existence of an east-west fault zone.

It appears then that the initial deposition took place on a subsiding continental slope. Continued subsidence and sedimentation resulted in the formation of one or more structural basins in which the thickest sections of sediments were located to the east of the shelf bank areas. The subsidence was followed by uplift of the continental terrace. The uplift was greatest at the shelf where the accumulation of sedimentary rocks is the greatest, and it was accomplished along a series of north striking faults which formed what is now the continental slope. The uplift of the western portion of the terrace resulted in the formation of topographic lows to the east of the banks. The axis of these shallow depressions lie to the east of the axis of the older basins, but the position of the continental slope has moved to the west from the vicinity of the shelf banks to its present position.

GEOLOGICAL HISTORY

A deep north-striking sedimentary basin was present in the position of the present Oregon Coast Range during the Early Eocene. This elongated sedimentary trough accepted in excess of 10,000 feet of sandstones, shales, and submarine volcanic rocks. The region then began to rise during the Middle and Late Eocene with the result that the region of sedimentation was shifted seaward to the west. By the Early Miocene the area of sedimentation had shifted westward to the coastal and continental terrace regions. This region continued to subside and accumulate sediments, chiefly diatomaceous, clayey silts, through the Miocene and into the Upper Pliocene. A shallow basaltic intrusive of Late Eocene age extending westward from Cape Perpetua may well have separated the near shore area into two basins which thicken to the north and south respectively. The existence of glauconite-rich rocks on the northern part of Heceta Bank and Perpetua Bank may indicate that this high extended west of the intrusive to the vicinity of the present shelf bank area. In the basin to the north the subsidence continued and a maximum of about 20,000 feet of sediment was deposited along an axis located at or just east of Stonewall Bank.

The continental terrace began to rise during the Pliocene. The greatest rise occurred on the bank areas of the continental shelf where rocks were elevated as much as 1,000 fathoms. The axes of the synclines were shifted to the east and are marked by swales which plunge gently away from Cape Perpetua east of Stonewall and Heceta Banks. The major portion of the uplift took place along step-like normal faults on the continental slope. On these faults both the hanging wall and the foot wall moved up.

The shelf area had risen high enough by the Middle to Late Pleistocene to expose the bank areas to subareal weathering and erosion during the glacial stages when sea level was lowered. The continental shelf was eroded during this time of fluctuating sea level. The transgression of the sea resulting from the Post-Pleistocene rise in sea level eroded the shelf to its present form and left a thin layer of sediment.

The coastal beach sand was derived chiefly from the coastal terrace deposits. Sand similar to the beach sand is present on the shelf to depths of about 50 fathoms. It was probably distributed over the inner part of the shelf during the Pleistocene and Post-Pleistocene transgressions and regressions of the ocean and by the action of waves and currents during Recent time. In deeper water the low areas were covered with deposits of green, clayey silts and the high areas remained without appreciable sediment accumulation. This allowed authigenic glauconite to form on the high areas.

SUMMARY AND CONCLUSIONS

The continental terrace west of the central Oregon coast occupies an area 50 to 55 miles wide. The landward portion of the terrace is formed by a continental shelf, 16 to 35 miles wide. A large proportion of the shelf has smooth, almost flat topography; exceptions are found on the outer part of the shelf where there exists a series of irregular banks (Stonewall, Perpetua, Heceta, and Siltcoos Banks). The shelf is widest at Heceta Bank and narrowest to the north and south of the major bank areas. The seaward edge of the shelf occurs at depths of 71 to 90 fathoms where the change in slope varies less than 02° in the north and south to as much as 30° at Heceta Scarp. To the west, the continental slope, 16 to 37 miles wide, extends to the abyssal plain at depths of 1530 to 1610 fathoms. The upper part of the slope is smooth and gentle in the north and south, but it is steep at Heceta Scarp, averaging 10° to 16°. An intermediate area of benches, hills, valley, and scarps exists seaward of the upper slope. Daisy Bank, west of Newport, is the most conspicuous hill. The only prominant valley is Newport Sea Valley trending south-southwest from 44° 40' N to the scarp forming the lower portion of the slope.

The lower part of the continental slope is an almost straight, west sloping scarp whose top is at depths of between 380 and 1100 fathoms. It has an average slope of 04° to 15° and a maximum inclination, over a short distance, of 35°. The scarp is disrupted at several places by hills and benches, and although the base of the slope makes a sharp intersection with the abyssal plain, small hills and scarplets occur at the base of the slope.

Large portions of the continental terrace are covered with sediment. Well sorted, fine grained sand, containing "yellow grains" distinctive of the coastal terraces and beaches, blankets the shelf out to approximately the 50-fathom contour. Seaward of the 50-fathom contour the topographically low areas contain olive-green, clayey silts, and the hill and bank areas are rocky with a patchy sediment cover consisting of glauconitic silts and sands. All of the sediments, except the glauconite sands, are composed predominantly of detrital minerals. However, the sand fractions from the clayey silt covering the slope are in large part composed of skeletal fragments of diatoms, Foraminifera, sponge spicules, and Radiolaria. The percentage of radiolaria in the sand increases from the slope onto the abyssal plain.

The distribution of the inner shelf sand is related to the Pleistocene fluctuations in sea level and the effective depth of storm waves. Over much of the slope and in the protected low areas on the shelf turbulence is insufficient to keep the sediment suspended. The topographically high areas, however, occupy positions where the current is sufficiently strong to prevent deposition of the suspended load. It is in these areas that the authigenic glauconite has formed. Thin layers of sand occur in few of the cores from the continental slope suggesting that there has been some down slope movement of sediment. However, the predominance of clayey silt over the slope and flatness of the abyssal plain at the base of the slope strongly indicate that there has been little down slope sediment movement.

Sedimentary rocks of Upper Miocene to Upper Pliocene age are exposed on the shelf banks and at scattered locations on the continental slope. Siltstone makes up the dominant rock type over the bank areas and at some locations on the slope. Two types of siltstone are present. One is a massive, light weight, tan to gray colored diatomaceous siltstone, and the other is an almost identical rock that has been cemented by calcite, making it harder and denser. The calcareous siltstone appears to have formed as concretions and beds interstratified in a thick section of non-calcareous siltstone.

Glauconite and graywacke sandstones and calcareous breccia were dredged along with the normal siltstone from the northern part of Heceta Bank, and friable silty sandstones and mudstones were obtained from the intermediate and deep areas of the continental slope west of Newport.

The texture, composition, and Foraminifera of the siltstones exposed on the shelf banks indicate that the sediments forming the rock were deposited at bathyal water depths. Foraminifera from some of the rocks suggest that they have been uplifted as much as

1000 fathoms. The mudstone samples collected from near the base of the slope contain Foraminifera indicating that the rocks were formed at nearly the same depths they presently occupy. Sandstones obtained from the same hauls are mineralogically immature, poorly sorted, and contain chips of mudstone. These observations along with the fact that they were deposited in deep water suggest that the sands are turbidity current deposits which may have been laid down on a continental rise.

The continental terrace appears to be composed of Upper Tertiary sedimentary rocks, covered in most areas by a thin veneer of recent sediment. It also appears that the area of the continental shelf was downwarped during the Upper Tertiary, forming one or more structural basins. At some time during the Pliocene, the terrace, principally in the shelf area, began to rise. This uplift was accomplished mainly by faulting on the continental slope, though it is probable that folding occurred at the same time. The uplift was well along by the end of the Pleistocene for portions of Stonewall Bank were exposed to subareal conditions during the last glacial stage.

Structurally the continental shelf consists of one or more synclines. The bank and swale areas are topographic expressions of the synclines which may contain as much as 20, 000 feet of rock. Numerous small scarps on the banks suggest that the synclines are complicated by faults and smaller folds. The scarp and bench topography of the continental slope has probably resulted from step type normal faulting in which both the hanging wall and the foot wall moved up.

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APPENDIX I

SAMPLE LOCATION

No.	OSU Sample No.	Latitude	Longitude	Type of Sampler [1/]	Samples	Depths in Fathoms
1	6308-1	43 48.1	124 53.7	P	Siltstone, sand	320
		43 50.0	124 55.0			
2	OC-0023	43 49.8	124 46.5	OT	Siltstone	200
3	6306-2	43 50.1	124 55.5	P	Siltstone	308
4	6306-3	43 50.3	124 53.1	P	Siltstone, silty sand	265
5	6301-16	43 51.0	124 25.0	F	Siltstone	51
6	6306-4	43 52.0	124 56.0	P	Siltstone, sand	350
7	6306-10	43 54.6	124 47.1	P	Siltstone	76
		43 55.0	124 47.6			
8	6308-15	43 55.1	124 54.2	P	Siltstone, sand-silt-clay	295
9	6306-8	43 55.1	124 56.0	P	Siltstone, silty sand	210
10	6209-23	43 55.4	124 47.7	F	Siltstone	75
11	6306-9	43 55.4	124 42.2	P	Siltstone	90
12	6301-2-100	43 56.0	124 25.4	G	Siltstone	65
13	6301-2-96	43 56.0	124 43.0	C	Siltstone, sandy silt	89
14	6301-2-95	43 56.0	124 47.2	C	Siltstone	76
15	6301-2-93	43 56.0	124 55.4	C	Siltstone	100
16	6301-17	43 57.7	124 40.0	F	Siltstone	69
		43 58.4	124 41.6			
17	6308-16	43 58.5	125 08.3	P	Limestone, clayey silt	820
		43 59.8	125 09.0			
18	6301-2-89	43 59.0	124 42.8	G	Siltstone	71
19	6301-2-90	43 59.0	124 46.9	C	Siltstone	66
20	6209-24	43 59.0	124 47.7	F	Siltstone	65
21	6301-2-91	43 59.0	124 51.0	C	Siltstone	54
22	6301-2-92	43 59.0	124 56.7	C	Siltstone	100
23	6209-25	43 59.3	124 53.9	F	Siltstone	43
24	6209-21	43 59.8	124 51.6	F	Siltstone	50
25	6306-11	44 00.0	124 56.8	P	Siltstone, silty sand	120
26	6301-2-73	44 02.0	124 47.4	C	Siltstone	61
27	6301-2-72	44 02.0	124 51.5	C	Siltstone	35
28	6301-2-71	44 02.0	124 55.5	C	Siltstone	61
29	6209-20	44 02.1	124 51.9	F	Siltstone	35
30	6209-19	44 04.0	124 51.5	F	Sandstone	48
31	6308-18	44 04.5	125 14.4	P	Siltstone, clayey silt	1020
		44 04.3	125 14.2			
32	6306-15	44 04.9	125 01.0	P	Siltstone, clayey silt	485
33	6301-2-69	44 05.1	124 50.5	C	Siltstone	48

[1] Type of Sampler--C-Corer, F-Frame Dredge, G-Grab Sampler, OT-Otter Trawl, P-Pipe Dredge, AD-Anchor Dredge.

No.	OSU Sample No.	Latitude	Longitude	Type of Sampler	Sample	Depth in Fathoms
34	6301-2-67	44 05.2	124 42.2	C	Siltstone	63
35	6301-2-68	44 05.5	124 46.3	C	Siltstone	63
36	6209-18	44 05.5	124 54.3	F	Siltstone	80
37	6301-2-51	44 08.0	124 39.2	C	Siltstone, sand	66
38	6301-2-50	44 08.0	124 43.5	C	Siltstone	60
39	6301-2-49	44 08.0	124 47.5	C	Siltstone	54
40	6301-2-48	44 08.0	124 51.6	C	Siltstone	63
41	6209-17	44 08.1	124 48.5	F	Siltstone	50
		44 08.1	124 48.9			
42	OC-0048	44 09.2	124 39.2	OT	Siltstone	65
		44 12.7	124 39.7			
43	6306-18	44 09.7	124 59.3	P	Siltstone, sandstone, sandy	300
		44 09.5	124 59.7		silt	
44	6209-16	44 09.8	124 48.5	F	Siltstone	40
45	6209-14	44 10.5	124 48.8	F	Siltstone, sandstone	42
		44 10.7	124 49.1			
46	6209-12	44 10.8	124 46.6	F	Siltstone, Sandstone	48
47	6209-13	44 10.8	124 51.4	F	Siltstone, sandstone, breccia	52
48	6301-2-43	44 11.1	124 44.4	G	Siltstone	53
49	6301-2-44	44 11.1	124 48.4	G	Siltstone	37
50	6301-2-45	44 11.1	124 52.6	C	Siltstone	67
51	6301-2-41	44 11.3	124 35.8	G	Siltstone	59
52	6301-2-42	44 11.3	124 40.0	G	Siltstone	63
53	6209-15	44 12.4	124 49.5	F	Sandstone	52
		44 12.6	124 49.9			
54	6308-23	44 13.0	125 14.1	P	Siltstone, clayey silt	1300
		44 13.9	125 14.1			
55	6209-11	44 14.1	124 43.5	F	Siltstone	58
56	6301-2-28	44 14.2	124 35.3	G	Siltstone	55
57	6301-2-27	44 14.2	124 39.5	C	Siltstone	57
58	6301-2-26	44 14.2	124 43.6	G	Limestone, sandstone	59
59	6301-2-25	44 14.2	124 47.7	C	Siltstone	57
60	6301-2-24	44 14.2	124 52.0	C	Siltstone	66
61	6301-2-23	44 14.2	124 56.2	G	Siltstone	100
62	6301-15	44 14.8	124 52.5	F	Sandstone	75
		44 15.1	124 51.2			
63	6301-14	44 14.9	124 55.0	F	Siltstone	84
		44 15.0	124 54.3			
64	6301-2-17	44 17.0	124 35.5	G	Siltstone	54
65	6301-2-18	44 17.0	124 37.9	G	Siltstone	45
66	6301-2-19	44 17.0	124 42.0	G	Siltstone	41
67	6301-2-21	44 17.0	124 50.3	G	Siltstone, silty sand	87
68	6209-7	44 17.2	124 35.5	F	Siltstone	45
69	6209-8	44 17.2	124 39.8	F	Siltstone, sandstone	42
70	6209-9	44 17.3	124 43.4	F	Siltstone	58
71	OC-0018	44 18.1	125 13.2	OT	Siltstone	1000
		44 29.7	125 15.4			
72	6308-28	44 19.0	125 07.7	P	Siltstone, sandy silt	720
		44 20.0	125 07.7			

No.	OSU Sample No.	Latitude	Longitude	Type of Sampler	Sample	Depth in Fathoms
73	6301-2-4	44 19.7	124 30.0	G	Gravel	50
74	6301-2-5	44 19.9	124 28.3	G	Siltstone, silty sand	50
75	6301-2-3	44 20.0	124 41.0	C	Siltstone	53
76	6209-10	44 20.0	124 41.0	F	Siltstone	55
77	6301-2-2	44 20.0	124 45.2	C	Siltstone, silty sand	75
78	6212-18	44 20.6	124 34.4	F	Siltstone	50
79	OC-0022	44 21.9	124 43.6	OT	Siltstone	68
		44 21.0	124 43.6			
80	OC-0002	44 22.5	125 13.8	OT	Siltstone	900 ±
		44. 24.0	125 14.2			
81	OC-0015	44 22.7	124 38.8	OT	Siltstone	60
82	OC-0029	44 22.7	124 39.3	G	Siltstone	60
83	OC-0032	44 22.8	124 35.4	G	Siltstone	51
84	OC-0024	44 23.0	124 31.0	G	Siltstone	58
85	OC-0012	44 23.9	124 40.1	OT	Siltstone	60
86	OC-0028	44 25.6	124 26.8	G	Siltstone	42
87	OC-0026	44 25.6	124 31.2	G	Siltstone	49
88	OC-0033	44 25.8	124 39.3	G	Siltstone	70
89	6209-4	44 26.3	124 50.6	F	Siltstone	232
90	6209-5	44 26.3	124 42.8	F	Siltstone	73
		44 26.7	124 44.1			
91	OC-0017	44 27.0	125 15.6	OT	Siltstone, clinker	1100 ±
		44 35.8	125 15.6			
92	OC-0005	44 27.6	125 14.2	OT	Siltstone, clinker, wood	900 ±
93	OC-0014	44 28.3	125 13.4	OT	Clinker	850
94	OC-0027	44 28.8	124 31.2	G	Siltstone	50
95	OC-0043	44 28.8	124 48.1		Siltstone	140
96	6212-17	44 28.9	124 39.5	F	Siltstone	85
97	6301-4	44 29.5	124 56.0	F	Siltstone	313
		44 30.0	124 56.0			
98	6212-8	44 30.0	124 20.5	F	Siltstone	35
99	6212-9	44 30.0	124 24.0	F	Siltstone	30
100	6212-10	44 30.0	124 25.5	F	Siltstone	35
101	6301-1	44 30.0	124 41.6	F	Siltstone	95
102	OC-0021	44 30.2	124 22.6	OT	Siltstone	25
103	6301-2	44 30.2	124 49.3	F	Siltstone	150
		44 30.6	124 49.4			
104	OC-0016	44 31.7	124 22.8		Siltstone	30
105	6212-6	44 32.4	124 24.5	F	Sandstone	25
106	6212-16	44 32.4	124 30.0	F	Siltstone	55
107	6212-7	44 32.5	124 26.4	F	Siltstone	40
108	OC-0036	44 33.5	125 14.5	AD	Sandstone, sand-silt-clay	1092
109	6212-2	44 34.7	124 23.7	F	Siltstone	30
110	OC-0025	44 34.7	124 27.5	G	Siltstone	45
111	6212-15	44 34.8	124 31.5	F	Siltstone	60
112	6212-4	44 35.3	124 27.2	F	Siltstone	35
113	OC-0001	44 37.2	124 26.4	F	Siltstone	45
114	OC-0035	44 37.5	124 26.7	G	Siltstone	50
115	OC-0047	44 37.0	125 01.5	AD	Coal, clinker	650
		44 37.8	125 00.6			

No.	OSU Sample No.	Latitude	Longitude	Type of Sampler	Sample	Depth in Fathoms
116	OC-0031	44 37.7	124 22.5	G	Siltstone	49
117	OC-0004	44 38.1	124 51.8	OT	Siltstone	300
118	OC-0042	44 38.1	124 51.8	AD	Siltstone	300
119	OC-0040	44 38.3	125 19.3	AD	Siltstone, clayey silt	1420
		44 38.8	125 19.5			
120	OC-0046	44 38.5	124 50.7	AD	Siltstone	300
121	OC-0045	44 38.6	124 20.1	AD	Siltstone, sandstone	1400
122	OC-0019	44 38.6	124 25.6		Siltstone	50
123	OC-0009	44 38.6	124 25.7		Siltstone	50
124	OC-0010	44 38.6	124 26.2	F	Siltstone	55
125	OC-0007	44 38.8	124 43.5	F	Limestone	90
		44 39.0	124 44.0			
126	OC-0039	44 38.8	125 12.1	AD	Siltstone, sandstone, silty sand	1000
127	OC-0037	44 39.0	125 10.0	AD	Siltstone	700
128	OC-0041	44 39.0	125 11.0	AD	Siltstone, silty sand	875
129	OC-0008	44 39.1	125 00.5		Siltstone	600
130	OC-0038	44 39.1	125 19.5	AD	Siltstone, clayey silt	1200
131	OC-0006	44 39.6	124 52.6		Siltstone	235
132	OC-0020	44 39.7	124 27.0	F	Siltstone	55
133	OC-0003	44 39.9	124 50.3	F	Siltstone	200
134	OC-0013	44 40.0	124 56.0	F	Clinker	350
135	OC-0034	44 40.5	124 31.5	G	Siltstone	80
136	OC-0011	44 40.6	124 58.9	F	Coal	400
137	6305-3	44 41.0	125 06.0	P	Siltstone, sand-silt-clay	360
138	OC-0044	44 44.8	124 32.3	F	Siltstone	90
139	AD13	44 39.0	125 13.2	AD	Sandy mud	1200
140	AD62	44 39.1	125 13.2	AD	Sandy silt	1100
141	AD61	44 39.2	125 11.0	AD	Sandy silt	780
142	AD39	44 39.1	125 11.0	AD	Silty sand	780
		44 39.5	125 11.1			
143	AD59	44 40.0	125 05.0	AD	Clayey silt	440
144	AD63	44 39.1	125 13.2	AD	Clayey silt	1150
145	6212-11	44 38.6	125 02.0	C	Clayey silt	638
146	6212-12	44 37.7	125 02.0	C	Clayey silt	637
147	6212-13	44 39.1	125 01.4	C	Glauconite and stiff clayey silt	640
148	6212-14	44 39.2	125 01.1	C	Glauconite and stiff clayey silt	550
149	AD16	44 39.0	125 10.0	AD	Silty sand	440
		44 38.0	125 10.0			
150	6305-2	44 39.1	125 13.2	P	Silty sand	360
151	6305-1	44 39.8	124 57.6	C	Clayey silt	411
152	AD28	44 40.3	124 57.9	AD	Clayey silt	440
153	AD22	44 39.7	124 58.0	AD	Clayey silt	440
		44 39.6	124 58.0			
154	AD4	44 40.3	124 59.0	AD	Silt	440
		44 39.0	124 58.2			
155	AD20	44 39.1	124 58.0	AD	Clayey silt	440
		44 39.4	124 58.0			

No.	OSU Sample No.	Latitude	Longitude	Type of Sampler	Sample	Depth in Fathoms
156	AD30	44 39.3	124 57.0	AD	Sand	440
157	AD48	44 38.7	124 56.5	AD	Clayey silt	440
		44 37.6	124 55.7			
158	6301-9	44 30.4	125 13.0	C	Clayey silt	737
159	AD40	44 39.1	125 11.0	AD	Silt mud	770
160	6107-3	44 40.5	124 14.5	G	Sand	39
161	AD2	44 37.8	124 36.9	AD	Sand	110
		44 37.4	124 38.6			
162	AD38	44 40.0	124 58.0	AD	Clayey silt	440
		44 35.7	124 56.0			
163	AD37	44 40.0	124 58.0	AD	Clayey silt	440
		44 35.7	124 56.6			
164	AD5	44 38.8	124 54.9	AD	Clayey silt	330
		44 38.4	124 55.4			
165	AD 10	44 40.4	124 51.8	AD	Silt	440
166	AD15	44 38.6	124 50.0	AD	Clayey silt	220
167	AD51	44 38.3	124 50.8	AD	Sand	220
		44 38.1	124 50.1			
168	AD52	44 38.5	124 50.7	AD	Clayey silt	220
		44 37.7	124 50.1			
169	6107-10	44 40.7	124 45.3	G	Sand	117
170	6107-9	44 40.5	124 40.0	G	Rock and fine sand	174
171	AD58	44 39.1	124 39.7	AD	Silty sand	120
		44 39.1	124 37.4			
172	AD57	44 39.1	124 36.3	AD	Silty sand	120
		44 39.6	124 37.9			
174	AD35	44 39.7	124 36.3	AD	Silty sand	110
		44 39.7	124 37.6			
175	AD26	44 39.1	124 36.3	AD	Silty sand	110
176	AD36	44 39.1	124 36.3	AD	Silty sand	110
		44 39.1	124 37.1			
177	AD14	44 38.7	124 36.4	AD	Silty sand	110
		44 38.3	124 35.8			
178	AD46	44 38.6	124 35.4	AD	Sand	110
		44 37.8	124 35.2			
179	AD45	44 38.6	124 35.4	AD	Sand	110
		44 37.8	124 35.2			
180	AD27	44 39.3	124 35.3	AD	Clayey silt	110
		44 40.2	124 36.7			
181	AD34	44 39.0	124 36.3	AD	Silty sand	96
		44 39.1	124 37.6			
182	6107-8	44 40.8	124 35.5	G	Silty sand	124
183	6107-6	44 40.5	124 27.1	G	Silty sand	53
184	6107-5	44 40.5	124 23.0	G	Sand	46
185	6107-4	44 40.5	124 18.6	G	Sand	45
186	6107-2	44 40.5	124 14.5	G	Sand	40
187	6107-1	44 40.5	124 07.0	G	Sand	17
188	6107-81	44 37.4	124 43.4	G	Sand	117
189	6107-82	44 37.6	124 39.3	G	Sand-silt-clay	132
190	6107-83	44 37.7	124 34.4	G	Sand	94

No.	OSU Sample No.	Latitude	Longitude	Type of Sampler	Sample	Depth in Fathoms
191	6107-84	44 37.3	124 30.7	G	Silty sand	67
192	6107-87	44 37.7	124 18.2	G	Sand	41
193	6107-88	44 37.6	124 14.3	G	Sand	40
194	6107-89	44 37.8	124 10.2	G	Sand	26
195	6107-90	44 37.6	124 06.3	G	Sand	18
196	6308-36	44 34.7	124 06.6	P	Clayey silt	470
		44 34.0	125 07.0			
197	6308-35	44 34.5	125 01.3	C	Clayey silt	663
198	6308-37	44 34.4	124 56.7	C	Clayey silt	480
199	AD49	44 34.2	124 52.6	AD	Clayey silt	330
		44 32.9	124 53.4			
200	AD 50	44 32.9	124 53.4	AD	Clayey silt	330
201	6308-38	44 34.7	124 46.9	C	Clayey silt	348
202	6107-40	44 34.7	124 41.3	G	Sand-silt-clay	190
203	6107-39	44 34.7	124 38.2	G	Clayey silt	160
204	6107-38	44 34.7	124 35.0	G	Sand	81
205	6107-37	44 34.5	124 30.8	G	Sand	65
206	6107-36	44 34.7	124 27.5	G	Gravel	45
207	6107-34	44 34.8	124 18.5	G	Sand	45
208	6107-33	44 34.6	124 14.2	G	Sand	39
209	6107-32	44 34.9	124 10.1	G	Sand	28
210	6308-34	44 30.5	125 05.7	C	Clayey silt	678
211	6301-10	44 30.3	125 14.0	C	Clayey silt	---
212	6301-8	44 30.3	125 10.0	C	Clayey silt	625
213	6301-7	44 30.2	125 04.9	C	Clayey silt	675
214	6107-41	44 31.7	124 41.3	G		180
215	6017-42	44 31.7	124 38.2	G	Sand-silt-clay	117
216	6107-43	44 31.7	124 35.0	G	Sand	73
217	6107-44	44 31.7	124 30.8	G	Sand	59
218	6107-45	44 31.8	124 27.5	G	Sand	44
219	6107-46	44 31.6	124 23.1	G	Sand	27
220	6107-47	44 31.6	124 18.2	G	Sand	47
221	6107-48	44 31.8	124 14.4	G	Sand	40
222	6107-49	44 31.9	124 10.3	G	Sand	29
223	6107-50	44 31.7	124 07.1	G	Sand	19
224	6308-33	44 28.1	125 05.5	C	Clayey silt	710
225	6200-04	44 28.8	124 48.1	C	Silty Sand	---
226	6107-60	44 28.8	124 43.9	G	Sand	84
227	6107-59	44 28.7	124 39.2	G	Sand	80
228	6107-58	44 28.6	124 35.0	G	Sand	67
229	6107-57	44 28.8	124 31.2	G	Sand	50
230	6107-56	44 28.8	124 26.8	G	Sand	40
231	6107-54	44 28.7	124 18.4	G	Sand	40
232	6107-53	44 28.5	124 13.8	G	Sand	35
233	6107-52	44 28.7	124 10.0	G	Sand	25
234	6107-51	44 28.6	124 06.5	G	Sand	15
235	6308-31	44 24.6	125 10.5	C	Clayey silt	738
236	6308-32	44 25.2	125 01.5	C	Sand-silt-clay	377
237	6200-02	44 25.8	124 52.4	C	Sandy silt	---
238	6209-3	44 26.6	124 51.1	C	Silty sand	220

No.	OSU Sample No.	Latitude	Longitude	Type of Sampler	Sample	Depth in Fathoms
239	6200-03	44 25.8	124 44.2	C	Sand	---
240	6107-61	44 25.8	124 43.9	G	Sand	72
241	6301-6	44 30.3	125 03.9	P	Clayey silt	640
242	6107-66	44 25.6	124 22.6	G	Sand	42
243	6107-67	44 25.6	124 18.4	G	Sand	38
244	6107-68	44 25.6	124 14.1	G	Sand	35
245	6107-69	44 25.6	124 10.0	G	Sand	27
246	6107-70	44 25.6	124 05.2	G	Sand	08
247	6200-01	44 22.7	124 56.5	C	Silty sand	---
248	6209-6	44 23.4	124 44.2	C	Sand	70
249	6107-80	44 22.8	124 43.6	G	Sand	74
250	6107-76	44 22.7	124 27.0	G	Sand	45
251	6107-75	44 22.8	124 22.7	G	Sand	44
252	6107-74	44 22.6	124 18.2	G	Sand	39
253	6107-73	44 22.6	124 14.4	G	Sand	37
254	6107-72	44 22.8	124 10.2	G	Sand	27
255	6107-71	44 22.6	124 06.0	G	Sand	15
256	6308-29	44 19.7	125 12.5	C	Clayey silt	950
257	6308-27	44 19.7	124 55.2	C	Clayey silt	328
258	6200-05	44 20.0	124 52.0	C	Clayey silt	---
259	6308-26	44 20.0	124 48.7	P	Sand-silt-clay	150
		44 19.5	124 48.6			
260	6301-2-6	44 20.0	124 24.1	G	Sand	48
261	6301-2-7	44 19.8	124 19.7	G	Sand	42
262	6301-2-8	44 19.9	124 15.4	G	Sand	37
263	6301-2-9	44 20.0	124 11.2	G	Sand	27
264	6301-2-10	44 20.0	124 08.3	G	Sand	21
265	6301-2-22	44 17.0	124 52.7	G	Sand	100
266	6301-2-20	44 17.0	124 46.2	G	No sample	71
267	6301-2-16	44 17.0	124 29.4	G	Sand	55
268	6301-2-15	44 17.0	124 25.2		Sand	51
269	6301-2-14	44 17.0	124 21.1	G	Sand	45
270	6301-2-13	44 17.0	124 16.8	G	Sand	39
271	6301-2-12	44 17.0	124 12.7	G	Sand	33
272	6301-2-11	44 17.0	124 08.5	G	Sand	18
273	6301-11	44 14.8	125 10.1	C	Clayey silt	850
274	6301-12	44 14.9	125 04.5	C	Clayey silt	650
275	6308-24	44 14.8	125 04.5	P		600
		44 14.2	125 04.9			
276	6301-13	44 14.8	125 02.2	C	Silt	512
277	6308-25	44 15.2	124 58.5	P	Silty sand	290
		44 14.8	124 58.3			
278	6301-2-29	44 14.2	124 31.0	G	Sand	53
279	6301-2-30	44 14.2	124 26.8	G	Sand	55
280	6301-2-31	44 14.1	124 22.6	G	Sand	48
281	6301-2-32	44 14.1	124 18.4	G	Sand	44
282	6301-2-33	44 14.2	124 14.2	G	Sand	37
283	6301-2-34	44 14.2	124 11.1	G	Sand	26
284	6308-21	44 10.3	125 13.6	P	Clayey silt	1075
285	6308-20	44 09.9	125 09.1	C	Clayey silt	820

No.	OSU Sample No.	Latitude	Longitude	Type of Sampler	Sample	Depth in Fathoms
286	6306-19	44 09.7	125 01.9	P	Clayey silt	580
		44 09.4	125 01.5			
287	No sample					
288	6301-2146	44 11.0	124 56.8	C	No sample	100
289	6306-17	44 10.0	124 55.9	G	Sand	110
		44 09.7	124 55.9			
290	6301-2-40	44 11.3	124 34.7	G	Sand	57
291	6301-2-39	44 11.2	124 27.5	G	Sand-silt-clay	57
292	6301-2-38	44 11.2	124 23.3	G	Sand	50
293	6301-2-37	44 11.2	124 19.4	G	Sand	46
294	6301-2-36	44 11.2	124 15.2	G	Sand	39
295	6301-2-35	44 11.2	124 11.1	G	Sand	28
296	6301-2-47	44 08.0	124 56.0	G	Sand	100
297	6301-2-52	44 08.1	124 35.2	G	Silty sand	65
298	6301-2-53	44 08.0	124 31.2	G	Silt	65
299	6301-2-54	44 08.0	124 27.0	G	Silty sand	56
300	6301-2-55	44 08.0	124 22.9	G	Sand	52
301	6301-2-56	44 08.0	124 18.7	G	Sand	43
302	6301-2-57	44 08.0	124 14.6	G	Sand	37
303	6301-2-58	44 07.8	124 09.8	G	Sand	17
304	6308-19	44 05.0	125 09.8	C	Clayey silt	898
305	6306-14	44 04.9	125 05.5	C	Clayey silt	725
306	6301-2-70	44 05.0	124 55.4	G	Sand	133
307	6301-2-66	44 05.0	124 38.1	C	Silty sand	68
308	6301-2-65	44 05.0	124 34.0	G	Silt	70
309	6301-2-64	44 05.0	124 29.9	C	Sandy silt	68
310	6301-2-63	44 05.0	124 25.9	G	Silty sand	63
311	6301-2-62	44 05.0	124 21.8	G	Sand	57
312	6301-2-61	44 05.0	124 17.7	G	Sand	44
313	6301-2-60	44 04.8	124 13.6	G	Sand	35
314	6301-2-59	44 05.0	124 09.4	G	Sand	16
315	6301-2-74	44 02.0	124 43.0	G	No sample	56
316	6305-14	44 02.8	124 40.2	C	Sandy silt	67
317	6301-2-75	44 02.0	124 39.0	C	Silt	74
318	6305-15	44 02.9	124 35.0	C	Clayey silt	72
319	6301-2-76	44 02.0	124 34.9	G	Silt	78
320	6301-2-77	44 02.0	124 31.0	C	Sandy silt	74
321	6305-16	44 03.0	124 29.0	C	Sandy silt	72
322	6301-2-78	44 02.0	124 26.8	C	Silty sand	76
323	6305-12	43 51.8	124 29.6	C	Silty sand	172
324	6301-2-79	44 02.0	124 22.6	G	Sand	63
325	6301-2-80	44 02.0	124 18.3	G	Sand	50
326	6301-2-81	44 02.0	124 14.3	G	Sand	38
327	6308-17	44 00.1	125 19.0	P	Clayey silt	1550
		43 59.3	125 15.5			
328	6306-13	43 59.8	125 03.4	C	Clayey silt	715
329	6306-12	43 59.9	124 59.6	P	Clayey silt	415
330	6301-2-88	43 59.0	124 38.7	G	Silt	81
331	6301-2-87	43 59.0	124 34.7	G	Silt	92
332	6301-2-86	43 59.0	124 30.6	G	Sandy silt	77

No.	OSU Sample No.	Latitude	Longitude	Type of Sampler	Sample	Depth in Fathoms
333	6301-2-85	43 59.0	124 26.6	G	Silty sand	70
334	6301-2-84	43 59.0	124 22.5	G	Silty sand	53
335	6301-2-83	43 59.0	124 18.3	G	Sandy silt	57
336	6301-2-82	43 59.0	124 14.3	G	Sand	37
337	6308-10	43 54.7	125 13.8	C	Clayey silt	1000
338	6308-11	43 54.9	125 12.7	C	Clayey silt	920
339	6308-12	43 55.0	125 11.5	P	Clayey silt	850
		43 54.1	125 10.5			
340	6308-13	43 54.8	125 08.7	C	Clayey silt	865
341	6308-14	43 54.6	125 01.5	C	Clayey silt	660
342	6308-9	43 54.7	125 14.8	P	Clayey silt	950
		43 55.8	125 14.5			
343	6301-2-97	43 56.0	124 38.8	G	Sandy silt	109
344	6305-13	43 57.6	124 36.1	C	Clayey silt	92
345	6301-2-98	43 56.0	124 34.7	G	Clayey silt	105
346	6301-2-99	43 56.0	124 30.8	G	Silty sand	74
347	6301-2-101	43 56.0	124 22.5	G	Silty sand	59
348	6301-2-102	43 56.0	124 18.0	G	Sandy silt	56
349	6301-2-103	43 56.0	124 14.0	G	Sand	35
350	6301-2-104	43 56.0	124 10.6	G	Sand	14
351	6305-7	43 52.4	125 02.4	C	Clayey silt	594
352	6305-8	43 51.9	124 54.9	C	Silt	230
353	6305-9	43 51.8	124 50.3	C	Sand	160
354	6305-10	43 52.7	124 44.2	C	Silt	137
355	6305-11	43 52.1	124 37.2	C	Sandy silt	147
356	6301-2-111	43 53.0	124 36.1	G	Sandy silt	131
357	6301-2-110	43 53.0	124 31.9	G	Silty sand	88
358	6301-2-109	43 53.0	124 27.8	G	Silty sand	36
359	6301-2-108	43 53.0	124 23.7	G	Sandy silt	63
360	6301-2-107	43 53.0	124 19.4	G	Sandy silt	61
361	6301-2-106	43 53.0	124 15.4	G	Sand	47
362	6301-2-105	43 53.0	124 11.4	G	Sand	15
363	6308-7	43 50.0	124 21.5	P	Clayey silt	1300
		43 50.0	124 19.1			
364	6308-6	43 49.9	125 13.6	P	Clayey silt	930
		43 48.2	125 12.4			
365	6308-4	43 50.0	125 03.0	C	Clayey silt	665
366	6308-5	43 48.7	125 03.5	P	Clayey silt	740
		43 47.8	125 03.5			
367	6308-3	43 49.7	125 01.2	P	Clayey silt	625
		43 49.2	125 01.3			
368	6308-2	43 49.1	124 58.9	C	Clayey silt	649
369	6306-1	43 50.0	124 45.0	G	Silt	195
370	6301-2-112	43 50.0	124 35.8	G	Clayey silt	144
371	6301-2-113	43 50.0	124 31.8	G	Sandy silt	94
372	6301-2-114	43 50.0	124 27.5	G	Silty sand	74
373	6301-2-115	43 50.0	124 23.4	G	Sand	59
374	6301-2-116	43 50.0	124 19.4	G	Silty sand	58
375	6301-2-117	43 50.0	124 15.4	G	Silty sand	48

No.	OSU Sample No.	Latitude	Longitude	Type of Sampler	Sample	Depth in Fathoms
376	6301-2-118	43 50.0	124 12.4	G	Sand	22
377	6306-5	43 52.0	125 02.7	P	Clayey silt	590
378	6306-7	43 55.3	125 00.9	P	Clayey silt	570
379	6305-6	43 58.0	125 11.0	C	Silty clay	843
380	6301-2-94	43 56.0	124 51.3	G	Gravel	87
381	AD 9	44 36.4	125 24.8	AD	Clayey silt	1530
382	AD53	44 39.5	127 54.3	AD	Silty clay	1530
383	AD54	44 42.2	127 52.8	AD	Silty clay	1530
384	6305-4	44 44.8	125 36.0	C	Clayey silt	1519
385	6305-5	44 34.8	125 57.5	C	Silty clay	1554
386	AD56	44 38.6	127 28.2	AD	Silty clay	1400
		44 38.8	127 25.5			
387	AD18	44 39.1	126 31.0	AD	Silty clay	1550
388	AD55	44 39.1	127 28.2	AD	Silty clay	1510

APPENDIX 2

TEXTURAL ANALYSES OF SEDIMENT SAMPLES

No.	Md (mm)	Trask So	Trask Sk	Trask Kurt	Inman M_ϕ	Inman σ_ϕ	Inman α_ϕ	Inman $\alpha_{2\phi}$	Inman β_ϕ	Sand %	Silt %	Clay %
1	.1612	2.2023	.4615	.2887	3.9896	2.2237	.6101	1.2735	.8533	71	21	8
4T	.1583	4.2533	.3271	---	3.9169	.4526	.9389	.6150		56	34	10
B	.0077	3.5680	.5482	.2422	7.7178	2.6131	.2670	.3576	.3969	1	64	35
6	.1534	1.9436	.5875	.2725	4.0695	2.1782	.6267	1.3230	.8853	74	17	9
8	.0385	6.9238	.4186	---	5.7754	3.5830	.3006	.4504	.2734	42	33	25
9	.0554	3.6035	.6062	.2910	4.9891	2.6972	.3023	.5768	.5706	44	42	14
13	.0340	4.5444	1.0101	.2578	5.3250	3.2068	.1402	.4156	.4711	34	48	18
17	.0034	3.2137	.6990	.1064	8.3749	2.4358	.0845	.0796	.5151	1	47	52
	.0053	3.9246	.6144	.1153	7.8004	2.9421	.0899	-.0127	.4694	11	46	43
25	.1744	3.0742	.5524	.0199	2.8800	3.9926	.0903	.0517	.9007	70	18	12
31	.0050	3.6909	.8364	.1583	7.4489	2.9542	-.0575	.0417	.2197	1	56	43
32	.0072	4.0020	.6390	.2333	7.6664	2.7531	.2049	.2838	.3620	2	61	37
37	.1624	1.2208	.9562	.1801	3.1622	.9272	.5832	1.7576	1.4192	81	16	3
43	.0522	3.5975	.3916	.2376	5.37194	2.7194	.4089	.4990	.8035	37	47	16
54	.0052	3.4453	.7330	.1477	7.7103	2.6375	.0518	.0544	.3521	2	55	43
67	.1228	4.1566	---	---	2.6605	3.7319	-.0976	.1533	.7261	68	32	10
72	.0483	7.0549	.7855	.0793	4.2387	4.3033	-.0306	-.0156	.3596	35	46	19
74	.2304	1.4149	1.2408	.3545	1.9667	.5498	-.2740	-.4297	.4579	68	32	10
77	.0775	7.0191	.5331	.1237	3.9409	4.0576	.1719	---	---	51	32	17
108	.0198	3.520	.713	.167	6.009	2.857	.146	.222	.359	24	53	23
119*	.0059	---	---	---	7.251	3.120	-.041	-.049	.347	6	53	41
126	.082	2.309	.768	.212	4.242	1.972	.328	.581	.923	59	35	6
128	.0769	2.936	.585	.289	4.490	2.320	.340	---	---	55	37	9
130*	.0054	---	---	---	7.0387	3.2854	-.1424	-.2387	.4116	18	41	41
137	.0475	10.5224	.3118	.3028	5.7241	4.2875	.3104	.4348	.2697	44	27	29
139	.0201	4.384	.521	.172	6.239	3.160	.191	.241	.400	26	47	27
140	.0760	3.8788	.3627	.2833	4.9614	2.7932	.4435	.6805	.5869	43	43	14
141	.0124	5.0333	.8554	.1945	6.6768	3.2511	.0996	-.0047	.5201	19	51	30
142	.0772	2.0522	.7355	.2551	4.0792	1.5746	.2445	.6426	.7939	57	39	3
	.0736	2.0280	.7911	.2544	4.1043	1.5495	.2196	.6254	.7694	58	38	4
143	.0062	3.4357	.6608	.2113	7.7808	2.4958	.1641	.1607	.4079	3	57	40
144	.0045	4.0024	.7123	.1633	7.8468	2.9793	.0258	-.0263	.3847	5	50	45
145	.0057	3.6171	.5748	.1716	7.9152	2.6423	.1807	.1465	.4345	2	56	42
146	.0049	3.3978	.5484	.2157	8.2130	2.4569	.2293	.1662	.4722	1	54	45
147	.0580	8.1933	.2129	.3251	5.8315	3.9489	.4370	.6009	.3080	49	25	26
	.0494	6.6666	.4166	.3160	5.6288	3.7179	.3463	.5507	.3616	46	32	22
148T	.0053	4.5353	.8266	.2010	7.5995	3.1224	.0189	.1004	.2562	4	52	44
B	.0058	4.0681	.6763	.1592	7.6362	2.9496	.0790	.0237	.4184	9	49	42
149	.0778	5.1423	.1544	.2774	5.4958	3.2734	.5535	---	---	54	25	21
150	.2264	2.8051	.4311	.2756	4.0426	3.1694	.5995	.8875	.4500	68	21	11
151T	.0085	3.6378	.5801	.2397	7.4722	2.6760	.2234	.3320	.3563	1	65	34

No.	Md (mm)	Trask So	Trask Sk	Trask Kurt	Inman M_ϕ	Inman σ_ϕ	Inman α_ϕ	Inman $\alpha_{2\phi}$	Inman β_ϕ	Sand %	Silt %	Clay %
151M	.0068	4.1813	.5403	.2128	7.8251	2.9833	.2105	.3045	.3579	1	63	36
152	.0088	---	---	---	7.202	3.046	.124	.180	.412	1	64	35
153	.0071	3.3645	.8459	.2143	7.3843	2.7128	.0973	.1699	.3344	1	62	37
154	.0091	2.6520	2.0691	.2958	6.5941	2.0691	-.0879	.2388	.5290	3	76	21
155	.0082	---	---	---	7.3426	2.8715	.1494	.3109	.2776	1	64	35
156	.0941	1.4448	.8042	.2598	3.7874	.8736	.4339	1.9986	1.7325	73	23	4
157	.0071	---	---	---	7.5040	2.6279	.1446	.1661	.3731	2	60	38
158	.0049	3.0608	.6577	.1601	8.0223	2.2731	.1651	.0087	.5502	1	55	44
159	.0321	---	---	---						24	52	23
	.0141	2.5503	2.5154	.2681	6.6045	2.8858	.1591	.3286	.3401	22	51	27
161	.0898	1.4922	.7708	.2570	3.8836	.9196	.4426	3.3708	3.1287	70	23	7
	.0940	1.4656	.6889	.2569	3.9197	.8835	.5763	3.6065	3.2744	69	24	7
162	.0078	3.0995	.8044	.2147	7.3478	2.5008	.1406	.2006	.3229	1	63	36
163	.0076	---	---	---	7.4191	2.6873	.1444	---	---	1	62	37
164	.0136	---	---	---	6.806	2.364	.260	.482	.369	2	72	25
165	.0114	2.386	2.274	---	5.774	1.534	-.442	---	---	10	80	10
166	.0157	---	---	---	7.2003	3.0910	.3910	.5215	.4326	14	56	30
167	.2158	1.5767	.8763	.2512	2.7150	1.3254	.3793	---	---	83	12	5
	.2100	1.5085	.9889	.2484	2.7565	1.2880	.3921	---	---	83	12	5
168	.0091	---	---	---	6.4899	3.4624	.0829			19	46	35
170*	.1539	---	---	---	4.55	2.33	0.79	---	---	79	7	14
171	.0659	2.0597	.4861	.3109	5.1807	1.9714	.6380	1.5332	1.0160	65	22	13
172	.0731	1.7632	.6758	.3036	4.9122	1.7872	.6375	1.6654	1.2011	58	30	12
174	.0879	1.5813	.7354	.2676	4.1020	1.1678	.5087	---	---	66	25	9
175	.0749	1.9016	.4774	---	4.9408	1.7839	.6738	1.6804	1.1755	57	31	12
176	.0927	1.5016	.7713	.2569	3.8527	.9442	.4475	---	---	69	24	7
177	.0838	1.4312	.8967	.2357	3.8839	.8729	.3512	---	---	71	23	6
	.0962	1.4026	.6731	.2405	3.9085	.7836	.6782	---	---	71	23	6
178	.1059	1.3133	.8538	.2531	3.5382	.6789	.4405	2.3159	2.3398	79	18	3
	.1087	1.4565	.8010	.2703	3.4761	.7488	.3071	1.9908	2.1879	78	18	4
179	.1009	1.2748	.9353	.2465	3.5062	.6045	.3273	2.7123	2.5356	82	15	4
180	.0095	---	---	---	7.2417	2.7928	.1908	.3804	.3337	2	67	31
181	.0984	1.5143	.7139	.2693	3.8752	1.0011	.5296	---	---	71	22	7
182*	.0791	---	---	---	4.94	1.93	0.66	---	---	69	17	14
183*	.1805	---	---	---	5.80	3.58	0.58	---	---	63	18	19
184*	.1436	---	---	---	2.85	0.21	0.24	0.16	0.68	100	0	0
185*	.1817	---	---	---	2.34	0.32	-0.37	-1.02	1.04	100	0	0
186*	.1743	---	---	---	2.48	0.25	-0.15	-0.41	0.65	100	0	0
187*	.1528	---	---	---	2.63	0.27	-0.29	-0.50	0.79	100	0	0
188*	.1895	---	---	---	2.61	0.99	0.22	4.50	4.52	86	3	11
189*	.0265	---	---	---	7.14	3.76	0.51	0.69	0.26	35	32	33
190*	.1119	---	---	---	4.00	1.16	0.72	---	---	79	10	11
191*	.1008	---	---	---	5.39	2.77	0.75	1.26	0.62	65	19	16
192*	.2045	---	---	---	2.35	0.29	0.20	-0.13	0.68	100	0	0
193*	.3209	---	---	---	1.70	0.70	0.09	0.16	0.22	100	0	0
194*	.2912	---	---	---	1.79	0.46	0.00	-0.03	0.47	100	0	0
195*	.1593	---	---	---	2.63	0.24	-0.08	-0.61	0.93	100	0	0
197T	.0085	3.6324	.8511	.2424	7.0979	2.8070	0.0800	.2227	.2155	1	64	35
197M	.0056	3.3669	.8249	.1630	7.4142	2.6785	-.0230	.0383	.2701	1	58	31

No.	Md (mm)	Trask So	Trask Sk	Trask Kurt	Inman $M\phi$	Inman $\sigma\phi$	Inman $\alpha\phi$	Inman $\alpha 2\phi$	Inman $\beta\phi$	Sand %	Silt %	Clay %
197B	.0049	3.5272	.5817	.1334	8.0868	2.5942	0.1616	.1048	.4357	1	54	45
198T	.0094	5.3454	.3032	---	8.0259	3.3225	---	---	---	13	52	35
198B	.0063	3.6264	.5974	.1891	7.7826	2.6300	0.1807	.1857	.4021	3	57	40
199*	.0215	---	---	---	6.51	2.49	0.39	---	---	16	61	23
200	.0080	3.2443	.7490	.2198	7.4802	2.6090	0.2028	.2847	.3827	3	61	36
201T	.0126	4.0144	.4515	.3091	7.2735	2.8561	0.3397	.5418	.3319	1	69	30
201M	.0136	3.7325	.3423	.2742	7.6563	3.0622	0.4766	.7581	.4563	4	69	27
202*	.0407				6.49	3.14	0.59			39	36	25
203*	.0058									6	49	45
204*	.1111				3.35	0.86	0.21			79	10	11
205*	.2679				2.49	1.34	0.44	3.20	3.16	83	7	10
207*	.6690				0.53	0.44	-0.11	-0.21	0.82	100	0	0
208*	.1560				2.53	0.26	-0.59	-1.14	1.04	100	0	0
209*	.2535				1.81	0.35	-0.50	-0.92	0.77	100	0	0
210T	.0066	3.4178	.6804	.1690	7.3420	2.7598	.0404	.1407	.2631	1	62	37
210B	.0055	3.6665	.6141	.1669	7.9143	2.6640	.1573	.1628	.3877	1	57	42
211	.0045	3.3814	.7083	.1424	8.0317	2.5056	.0948	.0216	.4326	1	52	47
212	.0045	3.0086	.7070	.2090	8.0524	2.2445	.1175	.0901	.3917	2	52	46
213	.0066	3.4509	.7660	.1820	7.2588	2.7713	.0072	.1236	.2418	1	61	38
215*	.0407				6.49	3.14	0.59	---	---	47	28	25
216*	.1350				3.24	0.54	0.65	6.96	6.55	87	6	7
217*	.2349				5.07	3.66	0.82	---	---	75	8	17
218*	.3209				1.42	0.30	-0.74	-1.45	1.02	100	0	0
219*	.1780				2.41	0.23	-0.33	-0.63	0.75	100	0	0
220*	.1539				2.51	0.26	-0.74	-1.26	1.04	100	0	0
221*	.3099				1.79	0.50	0.21	0.34	0.48	100	0	0
222*	.1895				2.32	0.31	-0.28	-0.70	0.74	100	0	0
223*	.1948				2.28	0.28	-0.28	-0.44	0.74	100	0	0
224T	.0052	3.4812	.6214	.1742	7.9913	2.5655	.1589	.0874	.4672	1	57	42
224B	.0059	3.3769	.6769	.1750	7.7460	2.4734	.1398	.1265	.4011	1	58	41
225	.0823	1.5842	.7706	.2734	4.1134	1.1305	.4524	2.3774	2.1572	69	23	8
226*	.2717				2.40	1.33	0.38	2.44	2.44	85	5	10
227*	.1267				3.09	0.41	0.28	6.62	6.88	91	2	7
228*	.1975				2.40	0.44	0.15	4.95	5.64	93	2	5
229*	.6741				-2.70	1.94	0.12	---	---	89	6	5
230*	.4763				0.41	1.32	-0.50	-0.71	0.56	100	0	0
231*	.1672				2.54	0.21	-0.18	-0.65	0.99	100	0	0
232*	.1507				2.68	0.24	-0.18	-0.54	0.90	100	0	0
233*	.1684				2.47	0.34	-0.32	-0.69	0.62	100	0	0
234*	.1743				2.46	0.26	-0.25	-0.38	0.58	100	0	0
235T	.0049	3.2031	.6872	.1389	7.8849	2.4573	.0968	.0430	.4244	1	55	44
235M	.0045	3.2622	.6521	.1980	8.1339	2.3847	.1518	.0657	.4616	0	54	46
235B	.0040	3.2699	.5575	.2200	8.4639	2.3826	.2162	.2083	.4014	4	48	48
236T	.0096	7.0829	1.1981	.2142	6.7517	3.6572	.0166	.0412	.3177	29	35	36
236A	.0030	3.5210	.9154	.1654	8.3523	2.5723	-.0061	-.1498	.4651	3	42	55
236J	.0054	4.2323	1.1658	.1621	7.2610	2.9508	-.0892	-.1115	.3192	12	45	43
236B	.0025	3.3034	.9683	.1354	8.5111	2.4812	-.0423	-.0280	.2955	10	32	58
237T	.0410	2.6476	.6792	.1197	4.9860	2.6538	.1428	.4823	.7569	38	48	14
237B	.0529	3.8714	1.5842	.2814		2.8670	.0091	.5352	.6417	45	43	12
238	.0657	1.6736	---	---	4.9225	1.5347	1.5204	---	---	55	35	10

No.	Md (mm)	Trask So	Trask Sk	Trask Kurt	Inman M_ϕ	Inman σ_ϕ	Inman α_ϕ	Inman $\alpha_{2\phi}$	Inman β_ϕ	Sand %	Silt %	Clay %
239T	.1242	1.2073	.9538	.1791	3.2310	.5924	.3760	.6584	2.0047	87	10	3
239	.1145	1.4081	.7245	.2846	3.4422	.6988	.4526	.5078	.7375	78	22	0
240*	.1340				4.41	5.55	0.27	---	---	69	14	19
241	.0065	3.4930	.6858	.1924	7.6088	2.6013	.1341	.1637	.3808	2	60	38
242*	.1530				2.64	0.16	-0.50	-0.92	1.01	100	0	0
243*	.1661				2.43	0.34	-0.48	-0.80	0.75	100	0	0
244*	.1604				2.52	0.28	-0.45	-0.86	1.16	100	0	0
245*	.1649				2.50	0.30	-0.34	-0.76	0.62	100	0	0
246*	.1792				2.39	0.22	-0.42	-0.66	1.00	100	0	0
247B	.0621	2.3484	.5255	.3042	4.8739	1.8653	.4653	.8815	.8297	50	41	9
249*	.1183				3.23	0.43	0.35	6.79	6.92	89	5	6
250*	.7170				-0.64	1.21	-0.12	-0.66	0.99	100	0	0
251*	.1750				2.31	0.42	-0.47	-0.78	0.73	100	0	0
252*	.1805				2.39	0.28	-0.31	-0.60	0.69	100	0	0
253*	.1921				2.33	0.33	-0.15	-0.40	0.59	100	0	0
254*	.5704				-0.59	1.10	0.20	1.03	1.10	100	0	0
255*	.1518				2.67	0.19	-0.25	-0.12	0.75	100	0	0
256T	.0055	3.5127	.6465	.1562	7.7975	2.6490	.1164	.1252	.3742	2	55	43
256B	.0047	3.3977	.6743	.1729	8.0467	2.4729	.1367	.0594	.4541	2	53	45
257T	.0245	2.9198	.5510	.2826	6.3896	2.5517	.4081	.7438	.5126	14	65	21
258T	.0125	3.6801	1.4798	.3018	6.2807	2.3031	-.0164	-.0262	.3644	16	62	22
258B	.0064	7.3890	.9438	.2807	7.6626	3.7053	.1013	.2114	.2704	17	41	42
259	.0227	3.7154	.4717	.2818	6.5281	2.8659	.3731	.5831	.4297	23	53	24
260	.1741	1.2593	1.1226	.2135	2.3681	.5059	.3031	.6462	.6873	100	0	0
261	.2200	1.3055	1.1608	.2722	2.0240	.5203	-.3081	-.4295	.5497	100	0	0
262	.2452	1.2769	1.0471	.2811	1.9987	.5018	-.0575	-.2309	.5030	100	0	0
263	.3079	1.1807	1.0000	.2955	1.7072	.3338	.0235	.2113	.5036	100	0	0
264	.2106	1.2429	1.0346	.2248	2.1539	.5020	-.1850	-.4333	.6576	100	0	0
265	.1087	1.3841	.8727	.2118	3.3744	.6953	.2492	3.9800	4.1969	83	10	7
267	.3256	1.2131	1.0253	.2689	1.5707	.4022	-.1186	-.1200	.4638	100	0	0
268	.2271	1.2245	1.0443	.2167	2.0294	.4708	-.2312	-.4476	.6135	100	0	0
269	.2240	1.2243	1.0883	.2713	2.0479	.4184	-.2630	-.2847	.4908	100	0	0
270	.3044	1.2911	1.0400	.2495	1.6228	.5362	-.1730	-.1562	.5458	100	0	0
272	.1707	1.1914	1.0497	.2328	2.4798	.3765	-.1871	-.5632	.8858	100	0	0
274	.0081	3.9036	.5307	.2290	7.6124	2.7832	.2426	.3233	.3745	5	60	35
276	.0481	2.1048	.3074	.3639	5.8840	1.8104	.8325	1.2286	.9985	9	77	14
277	.0539	2.7981	.4105	.3163	5.5034	2.3799	.5420	1.0288	.6607	46	39	15
278	.2150	1.2481	1.1006	.2724	2.1022	.4502	-.2555	-.3043	.4207	100	0	0
279	.1600	1.1598	1.0301	.2385	2.5858	.3292	-.1738	-.4466	.9543	100	0	0
280	.2795	1.2712	.9815	.2597	1.8592	.5040	.0409	-.0184	.5261	100	0	0
281	.2072	1.2216	1.0081	.2239	2.2053	.4666	-.1393	-.1940	.5428	100	0	0
282	.2387	1.0985	.9859	.2321	2.1390	.2431	.2986	.6547	.5830	100	0	0
283	.2302	1.1950	1.0710	.2355	2.0079	.3990	-.2770	-.3669	.5319	100	0	0
284	.0055	3.5150	.9065	.1741	7.3454	2.7850	-.0517	.0412	.2389	1	58	41
285T	.0061	4.5839	.8461	.2407	7.5085	3.0221	.0573	.1489	.2635	3	56	41
285B	.0061	4.6608	.4983	.1944	8.0852	3.1052	.2357	.1212	.5530	9	50	41
286	.0070	3.4795	.5835	.1835	7.7079	2.6471	.2130	.2484	.4372	1	63	36
289	.1578	1.4637	1.0144	.1746	2.6992	.9554	.0378	2.2141	2.9628	86	8	6
290	.1560	1.3654	.8881	.2364	3.0157	.8715	.3853	1.8580	1.8198	86	11	3

	Md	Trask			Inman					Sand	Silt	Clay
No.	(mm)	So	Sk	Kurt	M_ϕ	σ_ϕ	α_ϕ	$\alpha_{2\phi}$	β_ϕ	%	%	%
291	.0174	4.1881	1.1926	.1377	6.1957	3.8437	.0919	.2778	.5535	29	47	24
292	.1761	1.1496	1.0403	.2250	2.4604	.2775	-.1596	-.3954	.9484	100	0	0
293	.1699	1.1641	1.0935	.2236	2.4655	.3419	-.2657	-.8781	1.0195	100	0	0
294	.3339	1.2602	.9992	.2893	1.5985	.4690	.0349	.2257	.5022	100	0	0
295	.1962	1.1612	1.0518	.2044	2.2823	.3334	-.1995	-.3944	.9117	100	0	0
296	.1636	1.4603	.7672	.2790	2.9792	.8460	.4351	1.6574	1.4375	88	9	3
297	.0703	1.8642	.6785	.2922	4.5713	1.5299	.4856	2.1761	1.9010	57	34	9
298	.0296	2.1309	.5880	.2420	6.0121	1.9542	.4783	1.1432	1.0880	15	70	15
299	.1227	2.0593	.5028	.2932	3.8056	1.5813	.4927	1.6997	1.4175	65	28	7
300	.1735	1.3124	.8552	.2218	3.1342	1.0065	.6034	1.2765	.8549	79	19	1
301	.1992	1.1741	1.0248	.1928	2.2752	.3641	-.1427	-.4854	1.0354	100	0	0
302	.2432	1.2728	1.1007	.2845	1.9487	.4888	-.1856	-.1609	.4305	100	0	0
303	.1695	1.1499	1.0762	.2088	2.5021	.3077	-.1883	-.7294	1.0531	100	0	0
304T	.0044	3.5558	.6964	.1335	7.8832	2.7820	.0263	.0286	.3334	2	51	47
304M	.0041	3.5773	.6483	.1694	8.2555	2.5918	.1288	.0394	.4547	3	49	48
304B	.0041	3.4295	.7233	.1677	8.2359	2.4264	.1274	-.0015	.5015	3	48	49
305	.0076	3.3917	.5515	.1904	7.6045	2.5246	.2239	.2672	.3917	1	63	36
306	.1148	1.3778	.9287	.2313	3.3264	.7624	.2684	2.7063	3.1338	82	13	5
307	.1338	2.7074	.4021	.3208	3.9655	2.0896	.5090	1.4003	1.0717	58	34	8
308	.0264	2.4106	.5580	.2417	6.4011	2.4292	.4785	.8338	.6561	17	64	19
309	.0314	2.5813	1.2069	.3269	5.4457	2.2536	.2019	.9501	.8286	29	56	15
310	.0969	2.0378	.5293	.3441	4.1336	1.4708	.5215	1.5876	1.2280	59	35	6
311	.1232	1.7431	.7297	.2414	3.2518	1.1472	.2015	1.1607	1.4827	74	22	4
312	.2694	1.2661	1.0551	.2599	1.8230	.4827	-.1420	-.3056	.4930	100	0	0
313	.1915	1.1433	1.0006	.2071	2.3526	.3020	-.1050	-.5476	.9412	100	0	0
314	.2228	1.3092	1.1363	.2526	1.9712	.5453	-.3571	0.5356	.4832	100	0	0
316	.0420	2.1081	.7362	.2281	5.1172	1.9308	.2823	.9481	1.0634	29	59	12
317	.0247	2.2724	.5297	.2730	6.6777	2.4109	.5564	1.0645	.8542	9	72	19
318	.0216	3.7019	.2654	.2554	7.3435	3.1730	.5711	.8576	.5379	14	60	26
319	.0248	2.6462	.5450	.2567	6.2402	2.2557	.4041	.8831	.8006	16	67	17
320	.0389	1.9596	.9104	.2894	5.3263	1.7795	.3620	1.3219	.1974	34	54	12
321	.0470	1.6607	.8301	.1978	4.7109	1.3579	.2224	1.0349	1.2611	29	65	6
322	.0768	2.2592	.5189	.3520	4.6970	1.7931	.5547	1.6710	1.3550	58	32	10
324	.0827	1.9313	.7104	.3206	4.2843	1.5093	.4567	1.8190	1.5550	55	37	8
325	.1403	1.2794	1.0108	.1624	3.1133	.9028	.3102	1.7256	2.0368	84	12	4
326	.2304	1.2578	1.0712	.2708	2.0586	.4903	-.1196	-.1656	.3739	100	0	0
327	.0042	3.2298	.6965	.1058	7.8114	2.7234	-.0250	-.0363	.3266	1	52	47
328	.0063	3.3927	.5861	.1669	7.8096	2.6133	.1934	.2333	.4143	1	62	37
329	.0125	3.9166	.7113	.3515	6.9638	2.6721	.2427	.4350	.3132	3	69	28
330	.0291	2.3404	.5790	.2867	6.1802	2.1047	.5141	.9472	.8393	13	70	17
331	.0268	2.3722	.5904	.2557	6.1156	2.0696	.4341	.8156	.8364	15	69	16
332	.0411	1.9237	.9177	.2748	5.1008	1.6332	.3042	1.1490	1.2280	35	54	11
333	.0987	1.7472	.5354	.3189	4.0155	1.1577	.5829	1.3221	1.7192	68	28	5
334	.1208	1.8410	.4431	.3289	3.9393	1.3000	.6847	1.8695	1.3612	66	28	6
335	.0428	2.0904	.8911	.2795	5.0984	1.7731	.3130	1.2076	1.2097	42	46	12
336	.1710	1.1300	1.0315	.2682	2.5158	.2593	-.1225	-.3626	.7726	100	0	0
337M	.0048	3.2282	.8017	.1341	7.5946	2.6347	-.0372	-.0255	.3068	1	55	44
337B	.0044	3.1017	.6259	.1181	8.1546	2.3361	.1501	.0057	.5188	1	53	46
338U	.0056	3.9889	.6140	.1777	7.7359	2.9671	.0944	.1587	.3062	4	52	44
338H	.0048	3.6435	.6182	.1587	8.0497	2.6829	.1388	.0920	.4309	4	51	45

	Md	Trask			Inman					Sand	Silt	Clay
No.	(mm)	So	Sk	Kurt	M_ϕ	σ_ϕ	α_ϕ	$\alpha_{2\phi}$	β_ϕ	%	%	%
338L	.0054	3.8783	.5294	.1877	8.1072	2.7666	.2136	.2041	.4263	4	53	43
338B	.0048	3.6025	.6328	.1623	8.0264	2.6586	.1244	.0880	.4089	2	52	46
340T	.0066	4.1638	1.1873	.2715	7.1577	2.7940	-.0232	.1058	.2187	1	61	38
340B	.0059	3.3357	.6913	.1609	7.5416	2.6824	.0590	.1254	4.3146	1	59	40
341T	.0079	3.6367	.5317	.2336	7.7303	2.7271	.2771	.3534	.4405	5	61	34
341M	.0086	3.3789	.6153	.2309	7.3815	2.5505	.2070	.3046	.3680	2	65	33
341B	.0080	3.5661	.6068	.2330	7.5882	2.7026	.2341	.3591	.3909	1	66	33
342	.0043	3.2739	.6273	.1093	7.9793	2.6620	.0547	.0171	.3868	1	53	46
343	.0334	3.0007	.5094	.3293	5.9294	2.3961	.4288	.8883	.6467	32	52	16
344	.0178	2.8811	.4867	.2949	7.1126	2.6300	.4969	.8411	.5347	6	70	24
345	.0192	2.8840	.4676	.2199	6.7961	2.6414	.4153	.6568	.5275	15	62	23
346	.1105	1.6867	.6600	.2965	3.7326	1.1404	.4869	1.9227	1.7595	72	26	6
347	.0939	1.9869	.5736	.3313	4.1657	1.4672	.5132	1.5159	1.2164	61	32	7
348	.0414	2.1583	.8337	.2638	5.2398	1.9551	.3302	1.0797	.9942	42	45	13
349	.1524	1.1516	.9166	.1661	2.9509	.4294	.5537	1.2168	1.3364	91	8	1
350	.2492	1.2212	1.2276	.2558	1.8226	.4150	-.4373	-.3066	.6027	100	0	0
351T	.0070	3.9675	.5172	.2267	7.8559	2.8418	.2519	.3451	.3773	2	61	37
351U	.0068	4.9667	.2896	.2165	8.4836	3.3572	.3872	.5154	.4000	2	48	40
351K	.0085	3.9021	.4695	.2172	7.5256	2.9529	.2247	.3604	.3224	2	63	35
351L	.0055	4.2677	.5027	.2217	8.2046	2.9159	.2401	.2566	.4138	4	53	43
351I	.0068	---	---	---	8.0828	2.8064	.3173	.2265	.5690	7	53	40
351B	.0065	4.1539	.5440	.2099	7.8223	2.9368	.1909	.2408	.3678	6	54	40
352	.0219	2.5251	.6039	.2041	6.2488	2.3428	.3158	.5717	.6965	18	64	18
353	.1930	1.4910	.6698	.2266	3.3780	1.4318	.7021	1.3703	.9390	80	17	3
354	.0299	2.2805	.5805	.2637	5.9959	1.9733	.4728	.8872	.8352	16	68	16
355	.0301	2.2319	.6539	.2656	5.7928	1.9495	.3792	1.1157	.9161	20	65	15
	.0270	2.1962	.7179	.2486	5.7783	1.8628	.3053	1.0376	.9817	18	68	14
356	.0244	3.1199	.5660	.2502	6.1962	2.5524	.3291	.4766	.6779	23	57	20
357	.0532	2.8546	.6795	.3494	5.1329	2.3266	.3872	.9226	.6710	46	41	13
358	.1564	2.1779	.6719	.2774	3.1765	1.6429	.3047	1.2341	1.2431	74	21	5
359	.0570	1.5359	.8605	.2804	4.4109	.9603	.2918	.6913	.9554	46	54	0
360	.413	1.9232	.8657	.2891	5.0903	1.5654	.3164	1.2130	1.1976	35	54	11
361	.1456	1.1685	1.0252	.1318	3.2359	.8019	.5687	2.3229	2.1949	84	12	4
362	.1850	1.1619	1.0175	.1153	2.2581	.4453	-.3957	-1.0115	.9298	100	0	0
363	.0043	3.1180	.7279	.1052	7.6402	2.7355	-.0705	-.0568	.2870	0	53	47
364	.0044	3.0997	.7183	.1097	7.8565	2.4995	.0200	-.0487	.4008	0	53	47
365T	.0064	3.5797	.4640	.2401	8.0418	2.6295	.2930	.2904	.4704	3	56	41
365B	.0062	3.4805	.5591	.2148	7.9026	2.5179	.2305	.1930	.4646	4	56	40
366	.0070	3.5155	.7498	.2002	7.2733	2.7518	.0466	.1710	.2571	1	63	36
367	.0112	3.8300	.8447	.0976	6.8958	2.7590	.1522	.2400	.8963	14	58	29
	.0882	2.0829	.3667	.2871	4.9948	2.0432	.7308	1.4113	.9007	63	25	12
368T	.0078	3.6101	.5099	.2232	7.7331	2.6083	.2823	.3318	.4223	3	61	36
368B	.0084	3.4313	.5747	.2208	7.4751	2.6212	.2268	---	---	3	64	33
369	.0195	2.4161	.6782	.2856	6.5261	2.1778	.3885	.8474	.6969	6	75	19
370	.0247	2.8904	.4880	.2678	6.4006	2.4024	.4435	.6458	.5854	16	64	20
371	.0396	2.7716	.4667	.3139	5.8144	2.3622	.4906	.8805	.5553	34	50	16
372	.0633	1.9196	.6046	.2854	4.9556	1.9815	.5469	1.3032	.9835	51	38	10
373	.1368	1.2805	.9556	.1723	3.2428	.8394	.4453	2.5492	2.7346	83	12	5
374	.0535	2.0212	.9317	.3016	4.6723	1.6741	.2682	1.412	1.0303	46	45	9

No.	Md (mm)	Trask So	Trask Sk.	Trask Kurt	Inman M_ϕ	Inman σ_ϕ	Inman α_ϕ	Inman $\alpha_{2\phi}$	Inman β_ϕ	Sand %	Silt %	Clay %
375	.1046	1.9665	.5460	.3157	4.4507	1.8712	.6385	1.3736	.8603	65	26	9
376	.1519	1.1425	.9584	.2522	2.7245	.2615	.0253	.1071	.9562	100	0	0
377	.0065	3.9438	.4805	.2261	7.9927	2.7598	.2708	.3114	.4019	3	56	41
378	.0098	3.7540	.5196	.2422	7.4634	2.9241	.2705	.4645	.3638	3	67	31
379T	.0040	3.0089	.7456	.1860	8.1680	2.2290	.0988	-.1125	.5669	3	48	49
379B	.0052	3.0619	.8088	.1417	7.6489	2.3666	.0347	-.0187	.4054	1	57	42
380	.0071	3.8701	.5650	.2443	7.7926	2.6691	.2489	.3048	.3900	1	51	48
381	.0046	4.5679	1.8918	.2969	7.4756	2.7833	-.1032	-.0360	.2512	1	54	45
382	.0020	2.7916	.8719	.0509	8.8234	2.1806	-.0400	-.4593	.7071	1	30	68
383	.0020	2.7138	.8076	.0493	8.7916	2.1705	-.0280	-.4449	.7069	1	31	68
384T	.0050	5.8127	1.7383	.3377	7.4576	3.1194	-.0554	.0496	.2104	5	51	44
384M	.0029	3.1702	.9420	.1068	8.2621	2.4817	-.0642	-.2395	.4466	1	43	56
384B	.0028	3.2162	.9834	.1137	8.2203	2.5311	-.0879	-.2395	.4466	4	39	57
385T	.0019	2.6324	1.0071	.1692	8.9796	1.9259	-.0175	-.5338	.8341	1	32	67
385B	.0039	3.7035	.8378	.2451	8.1694	2.5492	.0757	.0809	.3428	1	50	49
386	.0020	2.5542	.8480	.0453	8.9022	1.8854	.0301	-.5735	.9087	1	30	69
387	.0020	3.2726	---	.0795	9.0000	3.1202	-.440	---	---	3	33	64
388	.0019	2.8488	.7866	.0492	8.8033	2.2334	-.0029	-.4107	.7051	3	31	66

T = top of core
U = upper part of the core
M = middle of the core
L = lower part of core
B = bottom of core

236A = Gray silty clay at a depth of 7 to 18 inches in the core
236J = From a depth of 24 to 30 inches in the core
338H = second layer in core
351K = two feet deep in core
I = one foot deep in core

* Analyses from Bushnell (1964).

APPENDIX 3

COMPOSITION OF SEDIMENT SAND FRACTIONS

(Values Given as Percent of Sand Fraction)

	Detrital				Biogenic					Authigenic			
No.	Rk.	Mica	Other	Total	Spic.	Diat.	Foram.	Rad.	Total	Glauc.	Pyrite	Total	
1	0	1	9	10	1	0	0	0	1	88	3	91	0
4	0	0	4	4	3	0	0	4	7	89	0	89	0
6	0	0	0	0	0	0	0	0	0	100	0	100	0
6	0	26	66	92	1	1	1	2	5	1	0	1	2
31	18	3	4	25	12	17	7	19	55	15	6	21	0
32	9	9	13	31	20	1	14	5	40	29	0	29	0
33	2	4	19	25	1	0	16	1	18	58	0	58	0
37	2	3	63	68	1	13	0	0	14	16	0	16	2
43	2	5	41	53	4	1	0	2	7	40	0	40	1
67	42	2	10	54	8	0	10	4	22	23	0	23	1
67	37	5	15	57	15	0	1	3	19	23	0	23	1
67	7	4	13	24	17	1	0	2	20	57	0	57	1
98	18	20	53	91	0	1	0	0	1	5	0	5	3
140	8	13	76	97	0	2	0	0	2	1	0	1	1
141	5	14	71	90	2	1	2	1	6	5	0	5	0
143	2	5	1	8	35	3	14	17	69	22	0	22	1
144	3	15	71	89	2	2	0	0	4	3	0		
147	0	1	5	6	0	0	8	0	8	82	5	87	0
147	2	2	7	11	0	0	17	1	18	64	7	71	0
148	14	3	3	20	5	5	39	5	54	26	0	26	0
151	0	10	10	20	41	9	13	5	68	12	0	12	0
151	3	12	18	33	44	3	9	4	60	8	0	8	0
152	0	6	6	12	42	6	15	17	80	8	0	8	0
156	3	12	49	64	0	1	0	1	2	32	0	32	2
158	0	0	0	0	35	47	7	7	96	4	0	4	0
160				100	0	0	0	0	0	0	0	0	0
161	4	9	49	62	3	12	1	1	17	14	0	14	3
164	22	22	2	46	28	1	8	6	43	10	0	10	0
171	7	12	44	63	6	2	2	1	11	26	0	26	1
172	2	12	30	44	10	1	0	1	12	44	0	44	1
177	4	17	32	53	5	13	2	0	20	26	0	26	1
178	4	5	61	70	1	0	0	0	1	27	0	27	1
179	3	4	45	52	6	0	0	0	6	37	0	37	1
182	4	3	68	75	3	0	0	0	3	22	0	22	0
183	1	1	1	3	4	18	10	65	97	0	0	0	0
184	0	2	94	66	0	0	0	0	0	4	0	4	0
185	0	0	0	97	0	0	0	0	0	2	0	2	0
187				100	0	0	0	0	0	0	0	0	0
188	0	0	1	1	7	0	1	0	8	91	0	91	0
189	10	6	72	88	1	0	1	1	3	9	0	9	0
190	14	2	79	95	0	0	0	0	0	5	0	5	0
191	10	1	75	86	1	0	0	0	1	13	0	13	0

	Detrital				Biogenic					Authigenic			
No.	Rk.	Mica	Other	Total	Spic.	Diat.	Foram.	Rad.	Total	Glauc.	Pyrite	Total	
192				99	0	0	0	0	0	1	0	1	0
193				100	0	0	0	0	0	0	0	0	0
197	0	9	1	10	40	27	3	10	80	10	0	10	1
198	4	8	2	14	30	14	11	8	63	22	0	22	1
201	0	6	0	6	40	33	7	6	86	8	0	8	0
204	5	6	78	89	0	0	0	0	0	11	0	11	0
207				100	0	0	0	0	0	0	0	0	0
208				100	0	0	0	0	0	0	0	0	0
211	0	9	6	15	29	14	21	15	79	5	0	5	1
219	0	0	78	78	0	0	17	0	17	5	0	5	0
220	0	4	92	96	0	0	0	0	0	4	0	4	0
224	0	3	0	3	41	36	12	9	98	0	0	0	0
226	0	0	5	5	2	0	0	0	2	78	0	78	0
227	10	2	76	84	0	0	1	0	0	11	0	11	0
228	0	0	0	66	0	0	0	0	0	33	0	33	0
231	0	0	100	100	0	0	0	0	0	0	0	0	0
233				100	0	0	0	0	0	0	0	0	0
234	0	5	93	98	0	0	0	0	0	2	0	2	0
235	0	4	0	4	31	28	25	12	96	0	0	0	0
237	0	5	9	14	6	1	11	0	18	68	0	68	0
239	1	3	53	57	1	0	0	0	0	1	40	0	2
241	0	10	4	14	27	11	12	15	64	21	0	21	0
242	0	1	98	99	0	0	0	0	0	1	0	1	0
243	2	4	90	96	0	0	0	0	0	4	0	4	0
244				97	0	0	0	0	0	3	0	3	0
245				100	0	0	0	0	0	0	0	0	0
246				100	0	0	0	0	0	0	0	0	0
248	1	7	77	85	0	0	0	0	0	13	0	13	2
249	2	0	91	93	0	0	0	0	0	7	0	7	0
250	0	2	86	88	0	0	1	0	1	11	0	11	1
251	2	3	85	90	0	0	0	0	0	10	0	10	0
252	0	2	95	97	0	0	0	0	0	3	0	3	0
253				100	0	0	0	0	0	0	0	0	0
255				100	0	0	0	0	0	0	0	0	0
256	0	7	6	13	22	17	13	21	73	13	0	13	1
257	5	11	41	57	8	2	3	4	17	23	0	23	2
257	0	13	49	62	6	10	5	2	23	12	0	12	2
258	6	9	58	73	6	3	8	1	18	7	0	7	1
260	3	5	75	83	0	0	0	0	0	17	0	17	1
261	0	6	1	79	86	0	0	0	0	15	0	15	0
262	0	9	4	73	86	0	0	0	0	13	0	13	1
263	0	0	100	100	0	0	0	0	0	0	0	0	0
264	6	5	78	89	0	0	3	0	3	5	0	5	3
265	0	5	27	32	8	4	2	1	15	53	0	53	0
267	2	2	76	80	0	0	0	0	0	17	0	17	3
268	6	6	75	87	0	0	0	0	0	12	0	12	1
269	5	3	74	82	0	0	0	0	0	16	0	16	2
270	11	1	83	95	0	0	1	0	1	4	0	4	1
271	3	4	77	84	0	0	0	0	0	15	0	15	1
272	1	2	88	91	0	0	0	0	0	7	0	7	2
274	1	8	70	79	14	1	2	4	21	0	0	0	0

	Detrital				Biogenic					Authigenic			
No.	Rk.	Mica	Other	Total	Spic.	Diat.	Foram.	Rad.	Total	Glauc.	Pyrite	Total	
275	3	12	32	47	10	4	8	10	32	21	0	21	1
276	7	14	34	55	7	1	3	3	14	30	0	30	1
278	2	1	76	79	0	1	0	0	1	20	0	20	2
279	13	7	60	80	0	0	0	0	0	20	0	20	1
280	6	1	73	80	0	0	0	0	0	18	0	18	2
281	3	2	71	76	0	0	0	0	0	23	0	23	2
282				99	0	0	0	0	0	1	0	1	0
283				99	0	0	0	0	0	1	0	1	0
284	12	9	16	37	20	8	3	13	44	19	0	19	0
285	5	16	13	34	4	2	37	2	45	19	0	19	2
286	2	6	1	9	41	12	8	6	67	25	0	25	0
289	4	10	16	30	12	4	13	7	36	35	0	35	0
290	1	4	66	71	0	0	0	0	0	27	0	27	2
291	3	4	21	28	1	0	1	0	2	71	0	71	0
292	2	8	64	74	0	0	0	0	0	24	0	24	1
293	1	5	75	81	0	0	0	0	0	19	0	19	1
294	3	2	82	87	0	0	0	0	0	9	0	9	3
295	3	7	72	82	0	0	0	0	0	16	0	16	4
296	0	3	28	31	11	0	0	2	13	56	0	56	0
297	0	11	72	83	0	0	0	0	0	12	0	12	5
298	0	22	68	90	6	0	1	0	7	2	0	2	0
299	8	6	76	90	0	0	0	0	0	8	0	8	0
300	4	3	75	82	1	0	0	0	1	14	0	14	2
301	2	3	81	86	0	0	0	0	0	14	0	14	0
302	6	9	71	86	0	0	0	0	0	7	0	7	2
304	10	4	19	33	15	6	23	7	51	7	8	15	1
305	2	14	5	21	22	31	7	12	72	8	0	8	0
306	17	1	45	63	0	0	0	0	0	30	0	30	0
307	3	6	46	55	2	0	0	0	2	43	0	43	0
308	0	23	58	81	8	2	0	1	11	9	0	9	1
309	3	11	78	92	2	0	1	1	4	3	0	3	1
310	1	11	61	73	1	0	2	0	3	24	0	24	2
311	0	5	86	91	0	0	0	0	0	9	0	9	0
312	2	2	85	89	0	0	0	0	0	10	0	10	1
313	5	6	80	91	0	0	1	0	1	8	0	8	1
314	1	2	92	95	0	0	0	0	0	5	0	5	1
316	1	2	81	84	1	0	1	0	2	13	0	13	1
317	1	20	34	55	11	16	5	0	32	11	0	11	2
318	13	13	39	65	4	10	4	5	23	12	0	12	0
319	0	25	54	79	4	2	2	1	9	13	0	13	0
320				95	5	0	0	0	5	0	0	0	0
322	2	4	82	88	0	0	1	0	1	9	0	9	2
324	3	11	61	74	0	0	2	0	2	18	0	18	0
325	3	7	79	89	0	0	0	0	0	8	0	8	3
326	2	0	85	87	0	0	0	0	0	10	0	10	1
327	8	9	7	24	14	20	1	26	61	14	0	14	0
328	0	4	0	4	41	29	8	7	85	11	0	11	0
329	6	10	17	33	11	9	10	6	36	32	0	32	0
330	0	13	54	67	5	10	6	1	22	10	0	10	1

	Detrital				Biogenic					Authigenic			
No.	Rk.	Mica	Other	Total	Spic.	Diat.	Foram.	Rad.	Total	Glauc.	Pyrite	Total	
331	2	11	64	77	8	2	2	1	13	9	0	9	2
332	3	0	71	74	9	0	1	1	11	15	0	15	0
333	0	10	47	57	3	0	0	0	3	38	0	38	2
334	0	9	68	77	0	0	0	1	1	21	0	21	2
335	8	21	60	89	0	2	1	1	4	5	0	5	0
338	6	8	0	14	7	7	17	9	40	23	23	46	0
340	0	6	0	6	28	48	8	9	93	0	0	0	0
342	5	8	5	18	8	15	42	16	81	1	0	1	1
343	7	8	57	72	3	2	3	0	8	15	0	15	5
344	0	12	46	58	20	11	1	2	34	6	0	6	1
345	0	11	60	71	7	6	4	1	18	10	0	10	1
346	1	4	59	64	0	0	0	0	0	34	0	34	3
347	0	6	72	78	1	1	0	0	2	19	0	19	2
348	2	19	62	83	3	1	1	0	5	12	0	12	0
349				100	0	0	0	0	0	0	0	0	0
351	2	16	9	27	9	2	22	6	39	33	0	33	0
352	1	6	49	56	6	1	2	1	10	34	0	34	0
355	3	15	56	74	7	1	2	2	12	23	0	23	2
356	1	15	65	81	5	6	1	2	14	5	0	5	0
357	7	10	47	64	2	2	1	1	6	30	0	30	0
358	0	17	51	68	0	0	2	0	2	29	0	29	1
359	1	10	79	90	5	0	0	0	5	5	0	5	1
360	2	8	0	8	50	20	3	14	87	4	0	4	0
361	0	0	88	88	0	0	1	0	1	9	0	9	1
363	11	3	1	15	12	29	4	40	85	0	0	0	0
364	2	4	4	10	15	12	12	32	71	20	0	20	0
366	0	8	0	8	21	23	17	13	74	17	0	17	0
367	0	1	7	8	12	0	2	3	17	73	0	73	0
369	1	7	49	57	4	2	9	9	24	18	0	18	1
370	0	21	62	83	2	1	2	1	6	10	0	10	1
371	0	20	55	75	5	0	2	1	8	16	0	16	2
372	5	13	65	83	5	0	0	0	5	12	0	12	0
373	2	3	69	74	1	0	0	0	1	23	0	23	1
374	3	14	56	73	0	0	3	0	3	23	0	23	1
375	1	6	62	69	1	1	5	0	7	23	0	23	2
377	1	21	8	30	1	2	37	4	44	15	9	24	2
379	2	8	5	15	27	7	19	15	68	16	0	16	0
383	1	1	1	3	4	18	10	65	97	0	0	0	0
385	0	13	2	15	30	23	7	25	85	0	0	0	0
386	2	0	0	2	8	25	3	61	97	0	0	0	0
387	0	3	2	5	42	8	18	16	84	11	0	11	0

APPENDIX 4

CORE DESCRIPTIONS

Sample Number

145

Corer: 2 foot, gravity
Penetration:
Length of Core: 12.5 inches

Depth Intervals	Sediment Types
0 to 5.5 inches	Homogeneous, olive-green, clayey silt.
5.5 to 7.8 inches	Thin layers of silty and clayey sediment.
7.8 to 12.5 inches	Olive-green, clayey silt. Appears to be finer grained than the surface layer.

146

Corer: 2 foot, gravity
Penetration: 12 inches
Length of Core: 10 inches

Depth Intervals	Sediment Types
0 to 10 inches	Homogeneous, drab olive-green, clayey silt.

147

Corer: 2 foot, gravity
Penetration:
Length of Core: 10 inches

Depth Intervals	Sediment Types
0 to 3.7 inches	Greatly disturbed. Blue-gray clay mixed with glauconite sand. Also pieces of brownish gray shale.
3.7 to 10 inches	Stiff, blue-gray, silty clay, containing layers, up to an inch thick, and pods of glauconite sand. Also large blue-green glauconite pellets

Sample
Number

147 (continued)

Depth Intervals	Sediment Types
	are scattered through the clay. All of the sediment in the core is disturbed by benthonic organisms.

148 Corer: 2 foot, gravity
Penetration:
Length of Core: 16.3 inches

Depth Intervals	Sediment Types
0 to 1.2 inches	Dark green, sandy mud. Contains dark green, clauconite pellets, musconite and pyrite.
1.2 to 16.3 inches	Stiff, bluish gray, silty clay. It contains pods and stringers of silt and glauconite. Some of these structures may be burrow fillings. Foraminifera are abundant.

151 Corer: 5 foot, gravity
Penetration: 60 inches
Length of Core: 42 inches

Depth Intervals	Sediment Types
0 to 32 inches	Drab olive-green, clayey silt. Two clayey mottles at a depth of 11 to 12 inches.
32 to 42 inches	Clayey silt which contains 1 to 10 mm thick layers of higher silt concentration

151 Corer: 2 foot, gravity
Penetration: 24 inches
Length of Core: 12.5 inches

Depth Intervals	Sediment Types
0 to 12.5 inches	Homogeneous, gray-green, clayey silt.

Sample Number

158 Corer: 2 foot, gravity
Penetration:
Length of Core: 14.1 inches

Depth Intervals	Sediment Types
0 to 14.1 inches	Olive-green, clayey silt. Four thin silt layers are present near the base of the core.

197 Corer: 5 foot, gravity
Penetration:
Length of Core: 27 inches

Depth Intervals	Sediment Types
0 to 27 inches	Olive-green, clayey silt. 21 poorly defined silt layers.

198 Corer: 5 foot, gravity
Penetration:
Length of Core: 33 inches

Depth Intervals	Sediment Types
0 to 15.5 inches	Green, clayey silt.
15.5 to 17 inches	Green, clayey silt containing 6 pods of sand and silt.
17 to 32 inches	Green, clayey silt.
32 to 32.5 inches	Silty sand.
32.5 to 33 inches	Green, clayey silt.

201 Corer: 5 foot, gravity
Penetration:
Length of Core: 33 inches

Depth Intervals	Sediment Types
0 to 26 inches	Green, clayey silt. Contains 11 silty layers. Foraminifera are abundant. Fine-grained crystals of pyrite are present. One sand pod occurs at a depth of 24 inches.

Sample
Number
201 (continued)

Depth Intervals	Sediment Types
26 to 26. 5 inches	Sand
26. 5 to 33 inches	Green, clayey silt. A sandy burrow is present at 28. 5 inches.

210

Corer: 5 foot, gravity
Penetration:
Length of Core: 28 inches

Depth Intervals	Sediment Types
0 to 28 inches	Nearly homogeneous, olive-green, clayey silt. Some faint mottling.

211

Corer: 2 foot, gravity
Penetration:
Length of Core: 12. 3 inches

Depth Intervals	Sediment Types
0 to 12. 3 inches	Olive-green, clayey silt. The core contains two thin silt layers and a large number of silt pods, 2 to 5 mm in diameter. Shell material is present near the top. The core appears to be more clayey near the bottom.

212

Corer: 2 foot, gravity
Penetration:
Length of Core: 11. 8 inches

Depth Intervals	Sediment Types
0 to 11. 8 inches	Olive-green, clayey silt. The percentage of clay appears to increase downward in the core. The core contains thin, indistinct layers of slightly siltier sediment.

Sample Number

213 Corer: 2 foot, gravity
Penetration:
Length of Core: 10.5 inches

Depth Intervals	Sediment Types
0 to 10.5 inches	Homogeneous, olive-green, clayey silt.

224 Corer: 5 foot, gravity
Penetration: 36 inches
Length of Core: 29 inches

Depth Intervals	Sediment Types
0 to 29 inches	Olive-green, clayey silt. The top and bottom of the layer appear more silty than the middle. The core is homogeneous to a depth of 10 inches. Below this depth there are numerous poorly defined silt layers.

225 Corer: 2 foot, gravity
Penetration:
Length of Core: 8 inches

Depth Intervals	Sediment Types
0 to 2.7 inches	Glauconitic sand. Small pebbles present. Foraminifera abundant.
2.7 to 5.2 inches	Gray, silty clay. Foraminifera abundant.
5.2 to 6.2 inches	Glauconitic sandy silt.
6.2 to 8 inches	Gray, silty clay.

235 Corer: 5 foot, gravity
Penetration: 60 inches
Length of Core: 38.5 inches

Depth Intervals	Sediment Types
0 to 38.5 inches	Homogeneous, olive-green, clayey silt.

Sample Number

236

Corer:: 5 foot, gravity
Penetration: 60 inches
Length of Core: 52 inches

Depth Intervals	Sediment Types
0 to 2 inches	Glauconitic, sandy mud
2 to 4.5 inches	Stiff, gray, silty clay. Several burrows filled with glauconitic sand.
4.5 to 52 inches	Gray, silty clay. Distinctly mottled. Sand-silt layers occur at 20, 23 to 24, 31 to 32 and 38 to 39 inches. Pods of sand are present at depths of 29 and 30 inches. There are 16 sand pods below 43 inches. The sand is formed of detrital grains, glauconite pellets and Foraminifera. Glauconite is also present as widely scattered pellets in the clay. Foraminifera are abundant in the clay.

237

Corer: 2 foot, gravity
Penetration:
Length of Core: 11 inches

Depth Intervals	Sediment Types
0 to 0.5 inches	Glauconite, sandy silt with fish remains.
0.5 to 3 inches	Glauconitic, sandy silt.
3 to 8 inches	Gray, silty clay.
8 to 11 inches	Sand - silt - clay.

238

Corer: 2 foot, gravity
Penetration:
Length of Core: 11 inches

Depth Intervals	Sediment Types
0 to 11 inches	Green, clayey silt.

239

Corer: 2 foot, gravity
Penetration:
Length of Core: 5.2 inches

Depth Intervals	Sediment Types
0 to 5.2 inches	Green, glauconitic, silty sand.

Sample Number

247

Corer: 2 foot, gravity
Penetration:
Length of Core: 14 inches

Depth Intervals	Sediment Types
0 to 14 inches	Olive-green, clayey silt. The silt content increases down the core.

248

Corer: 2 foot, gravity
Penetration:
Length of Core: 3 inches

Depth Intervals	Sediment Types
0 to 3 inches	Green, silty sand. Rich in glauconite.

256

Corer: 5 foot, gravity
Penetration: 36 inches
Length of Core: 26.5 inches

Depth Intervals	Sediment Types
0 to 26.5 inches	Olive-green, clayey silt. The core is faintly mottled and contains small bits of shell material. There are 6 silty layers.

257

Corer: 5 foot, gravity
Penetration: 60 inches
Length of Core: 32.5 inches

Depth Intervals	Sediment Types
0 to 18.5 inches	Homogeneous, green, clayey silt.
18.5 to 32.5 inches	Same as above but with 6 silt layers. The largest layer is 1.5 inches thick. It is located at the base of the core.

258

Corer: 2 foot, gravity
Penetration:
Length of Core: 10 inches

Depth Intervals	Sediment Types
0 to 2.5 inches	Green, glauconitic, sandy silt.

Sample Number

258 (continued)

Depth Intervals	Sediment Types
2.5 inches	Contact with gray, silty clay. The top of a fossil burrow which extends some three inches into the clay. The burrow is filled with glauconitic sediment.
2.5 to 10 inches	Gray, silty clay with thin lamination.

274

Corer: 2 foot, gravity
Penetration: 17 inches
Length of Core: 13 inches

Depth Intervals	Sediment Types
0 to 13 inches	Olive-green, clayey silt. The percentage of clay appears to increase with depth to about 8 inches. Below 8 inches the percent of clay appears to decrease.

276

Corer: 2 foot, gravity
Penetration: 1 foot, 2 inches
Length of Core: 11.5 inches

Depth Intervals	Sediment Types
0 to 11.5 inches	Homogeneous, olive-green, clayey silt.

285

Corer: 5 foot, gravity
Penetration: 60 inches
Length of Core: 26 inches

Depth Intervals	Sediment Types
0 to 15 inches	Greenish-gray, clayey silt.
15 to 16.2 inches	Sand.
16.2 to 22.4 inches	Green, clayey silt.
22.4 to 23 inches	Sand
23 to 26 inches	Green, clayey silt.

Sample Number		
304	Corer: 5 foot, gravity Penetration: 60 inches Length of Core: 49 inches	

Depth Intervals	Sediment Types
0 to 40	Greenish-gray, clayey silt. There are 8 thin silt layers, 3 pods of sand and 6 of silt. Pyrite and Foraminifera abundant.
40 to 41.3 inches	Sand pods and a sand layer from 40.5 to 41.3.
41.3 to 48.3 inches	Greenish-gray, clayey silt.
48.3 to 49 inches	Sand.

305 — Corer: 5 foot, gravity
Penetration: 18 inches
Length of Core: 11 inches

Depth Intervals	Sediment Types
0 to 11 inches	Drab, olive-green, clayey silt.

316 — Corer: 2 foot, gravity
Penetration: 13 inches
Length of Core: 10 inches

Depth Intervals	Sediment Types
0 to 10 inches	Olive-green, clayey silt. It appears to be more clayey towards the base. Fine-grained crystals of pyrite occur throughout the core.

318 — Corer: 2 foot, gravity
Penetration: 10 inches
Length of Core: 8.2 inches

Depth Intervals	Sediment Types
0 to 8.2 inches	Dark, olive-green, clayey silt with very faint mottling.

Sample
Number

321

Corer: 2 foot, gravity
Penetration: 8 inches
Length of Core: 7 inches

Depth Intervals	Sediment Types
0 to 7 inches	Olive-green, clayey silt. Fine-grained crystals of pyrite are scattered throughout the core. The core is faintly mottled and has some indication of bedding.

328

Corer: 5 foot, gravity
Penetration: 24 inches
Length of Core: 11.3 inches

Depth Intervals	Sediment Types
0 to 11.3 inches	Olive-green, clayey silt. The upper 4 inches are siltier than the lower portion of the core. However, 4 thin silt layers do occur in the bottom 2.5 inches of the core.

337

Corer: 5 foot, gravity
Penetration: 60 inches
Length of Core: 32.5 inches

Depth Intervals	Sediment Types
0 to 32.5 inches	Olive-green, clayey silt. Appears to be siltier near the base. The middle portion of the core appears mottled. Shell fragments are scattered throughout. There are 15 silt layers.

338

Corer: 5 foot, gravity
Penetration: 60 inches
Length of Core: 42.5 inches

Depth Intervals	Sediment Types
0 to 2 inches	Glauconitic, sandy silt. Olive-green in color.

Sample
Number

338 (continued)

Depth Intervals	Sediment Types
2 inches	Contact with clayey silt. The contact has .5 inch of relief and it appears almost overturned.
2 to 42.5 inches	Green-gray, clayey silt. A number of silt layers, two of which are steeply inclined. Widely separated glauconite pellets and holes.

340 Corer: 5 foot, gravity
Penetration: 60 inches
Length of Core: 30 inches

Depth Intervals	Sediment Types
0 to 30 inches	Olive-green, clayey silt. Slightly siltier near base. Clam shell at depth of 4 inches. Foraminifera and pyrite abundant.

341 Corer: 5 foot, gravity
Penetration: 54 inches
Length of Core: 33.5 inches

Depth Intervals	Sediment Types
0 to 33.5 inches	Olive-green, clayey silt. Homogeneous to a depth of 12 inches. Below this depth there are 7 silty layers. Several small holes are present.

344 Corer: 2 foot, gravity
Penetration:
Length of Core: 11.5 inches

Depth Intervals	Sediment Types
0 to 11.5 inches	Homogeneous, dark to olive-green, clayey silt.

Sample Number

351

Corer: 5 foot, gravity
Penetration: 4 feet
Length of Core: 44.5 inches

Depth Intervals	Sediment Types
0 to 43 inches	Olive-green, clayey silt. Numerous thin silt stringers and layers. Several mottled areas. They look like burrows.
43 to 435 inches	Sand layer. Mica and quartz are present.
43.5 to 44.5 inches	Olive-green, clayey silt.

352

Corer: 2 foot, gravity
Penetration: 18 inches
Length of Core: 12.5 inches

Depth Intervals	Sediment Types
0 to 12.5 inches	Homogeneous, brownish gray, clayey silt.

353

Corer: 2 foot, gravity
Penetration: 1 foot
Length of Core: 7.3 inches

Depth Intervals	Sediment Types
0 to 7.3 inches	Glauconite sand and silt with poorly defined layers and patches of green, clayey silt. The core appears to have been mottled by benthonic organisms.

354

Corer: 2 foot, gravity
Penetration: 11 inches
Length of Core: 9.3 inches

Depth Intervals	Sediment Types
0 to 9.3 inches	Homogeneous, olive-green, clayey silt.

Sample Number		
355	Corer: 2 foot, gravity Penetration: 14 inches Length of Core: 11.5 inches	
	Depth Intervals	**Sediment Types**
	0 to 8 inches	Dark green, clayey silt. Abundant fine crystals of pyrite. Contains small holes and patches of clayey sediment.
	8 to 8.5 inches	Green, silty clay. The contact with overlying silt is sharp and undulating.
	8.5 to 11.5 inches	Dark green, clayey silt.
365	Corer: 5 foot, gravity Penetration: Length of Core: 34 inches	
	Depth Intervals	**Sediment Types**
	0 to 34 inches	Green, clayey silt. The lower part appears to be siltier than the upper part. Foraminifera and pyrite are abundant.
368	Corer: 5 foot, gravity Penetration: 60 inches (?) Length of Core: 22.5 inches	
	Depth Intervals	**Sediment Types**
	0 to 22.5 inches	Olive-green, clayey silt. Large, widely spaced glauconite pellets are dispersed throughout the core. Several clayey beds, 0.5 to 1.0 inch thick, occur below 6.5 inches.
379	Corer: 5 foot, gravity Penetration: 36 inches Length of Core: 26 inches	
	Depth Intervals	**Sediment Types**
	0 to 26 inches	Olive-green, clayey silt. Alternating thin layers of silty and clayey sediment. Shell fragments occur at three levels in the core.

Sample Number

384

Corer: 2 foot, gravity
Penetration: 2 feet
Length of Core: 15.5 inches

Depth Intervals	Sediment Types
0 to 15.5 inches	Homogeneous, olive-green, silty clay.

384

Corer: 5 foot, gravity
Penetration: 48 inches
Length of Core: 44 inches

Depth Intervals	Sediment Types
0 to 1 inches	Olive-green, silty clay.
1 to 2.5 inches	Irregular sand - silt - clay layer. Abundant detrital grains.
2.5 to 28.5 inches	Olive-green, silty clay. Contains numerous thin, silty layers. Shell fragments and holes are also present.
28.5 to 29 inches	Irregular pod of detrital, sandy sediment.
29 to 36.5 inches	Olive-green, silty clay.
36.5 to 37.0 inches	Sand pods.
37 to 41 inches	Olive-green, silty clay.
41 to 41.8 inches	White sand layer.
41.8 to 44 inches	Olive-green, silty clay.

385

Corer: 5 foot, gravity
Penetration: 36 inches
Length of Core: 25 inches

Depth Intervals	Sediment Types
0 to 17 inches	Homogeneous, olive-drab green, silty clay.
17 to 18 inches	Silt layer.
18 to 18.5 inches	Sand layer.
18.5 to 24.5 inches	Green, silty clay.
24.5 to 25 inches	Sand.

APPENDIX 5

TEXTURAL ANALYSES OF ROCK SAMPLES

	Md	Trask			Inman					Sand	Silt	Clay
No.	(mm)	So	Sk	Kurt	M_ϕ	σ_ϕ	α_ϕ	$\alpha_{2\phi}$	β_ϕ	%	%	%
5	.0178	3.1641	.7076	.2574	6.3212	2.3064	.2228	.3601	.5692	16	62	22
16	.0113	---	---	---	6.6962	2.3211	.0998	.2720	.4782	8	65	27
41	.0072	4.1626	1.2898	.3263	7.4046	2.8589	.1018	.2458	.2837	1	63	36
46	.0045	3.3129	.7748	.1769	7.9587	2.4349	.0721	-.0042	.4269	2	51	47
69	.0084	3.6071	1.1171	.2695	7.2099	2.7385	.1175	.1677	.3365	7	56	37
98	.0163	2.8570	.5830	.3094	7.0411	2.5419	.4345	.7568	.5332	2	74	24
102	.0073	4.6324	1.2258	.3548	7.4400	2.9801	.1202	.2841	.2718	1	62	37
113	.0090	3.4716	1.2907	.3047	7.0985	2.6836	.1151	.2388	.2633	5	60	35
121	.0463	3.3533	.5552	.2157	5.0874	2.0216	.3251	.7086	.8341	30	60	10
123	.0060	4.9427	1.4215	.3305	7.4314	2.9487	.0201	.1355	.2523	3	57	40
130	.0082	---	---	---	7.3464	2.8704	.1465	.3105	.2891	2	63	35

APPENDIX 6

ROCK SAMPLE DESCRIPTIONS

Sample Number

1 Pebbles and cobbles of fine-grained, calcareous siltstone. The rock is heavy, hard, and gray in color. It contains a groundmass of clay, hematite, pyrite, and silt grains. The coarse silt and sand fraction contain small quantities of chlorite, glauconite, plagioclase, pyrite, quartz, rock fragments, and shell fragments. The glauconite is highly altered; some pellets are tan. The quartz and feldspar grains are small and highly etched.

2 Gray, calcareous siltstone with patches that are not cemented with calcite. It contains large vugular areas partially filled with aragonite needles. The rock contains abundant silt and clay, cemented with fine grained calcite. Opaque minerals (Hematite, limonite, and magnetite) are abundant.

3 Pebbles of silty limestone. (Could be calcareous siltstone).

4 Small chips of non-calcareous siltstone.

5 Massive, light weight, gray, diatomaceous siltstone. It is a clayey siltstone but contains 16 percent sand. Carbonaceous material, diatoms, muscovite and sponge spicules can be seen in the hand specimen. In thin section, the rock appears to be mainly fine silt and clay. The coarse silt and sand fraction is composed of biotite, glauconite, hornblende, limonite, magnetite, muscovite, plagioclase, and pyrite. Much of the glauconite is fragmental and may be detrital. The largest pyrite crystals occur within the glauconite pellets.

6 Glauconitic, calcareous siltstone.

7 Rounded pebbles of calcareous siltstone.

8 A calcareous siltstone similar to sample 1. In thin section one observes numerous ghost structures of diatoms, spines, and

sponge spicules that are completely replaced by calcite. Foraminifera comprise the largest grains in the rock. Their tests are partially dissolved; many of the central chambers are filled with the most coarsely crystalline calcite in the rock.

9 Calcareous siltstone similar to sample 1. It is darker in color than the other samples of calcareous siltstone.

10 Laminated, calcareous, diatomaceous siltstone. It is a dense, gray, thoroughly cemented rock. The laminae alternate in color from vary light gray to dark gray. Sand comprises a small percentage of the rock. It is composed of biotite, calcite (in the chambers of Foraminifera and diatoms), diatoms, feldspar, Foraminifera, glauconite, muscovite, and quartz. Many of the glauconite pellets are replaced with calcite; much of the biotite is altered to chlorite. The bulk of the rock is formed of very fine grains of clay, diatoms, opaque minerals, spines, and sponge spicules. A fine grained calcite cement has impregnated the entire rock.

11 Pebbles of dark gray, calcareous siltstone (or silty limestone). The exposed surfaces are dark gray and the fresh surfaces a light gray. It is hard and dense.

12 Small piece of non-calcareous siltstone similar to sample 5.

13 Stiff, gray, clayey silt. Intermediate between rock and sediment.

14 Clayey siltstone. It is dark gray and contains abundant diatoms and Foraminifera.

15 Pebble of calcareous siltstone.

16 Massive, light gray, clayey siltstone. Carbon, detrital sand, diatoms, Foraminifera, and sponge spicules were observed in the hand specimen.

17 A dense, dark gray, foraminiferal limestone. The largest particles are the numerous Foraminifera. Their wall structure is well intact and their central chambers are empty. Coarse silt occurs as a small percentage of the rock; it is composed of replaced sponge spicules and quartz. Most of the groundmass is fine grained calcite; clay, hematite, magnetite, pyrite, and unidentified silt are also abundant.

18 Pebble of calcareous siltstone (or silty limestone).

19 Clayey siltstone like sample 14.

20 Calcareous siltstone. It is dense, hard, and gray in color.

21. Diatomaceous, clayey siltstone. It is gray and contains abundant Foraminifera.

22. Small pebbles of light gray, low density, diatomaceous siltstone.

23 Light weight, diatomaceous siltstone. It is massive and light gray in color. This sample includes one piece of calcareous siltstone. It is a dense, gray, hard rock. Abundant fractures are cemented with calcite.

24 A light gray, light to medium weight, diatomaceous, clayey siltstone.

25 Pebbles and cobbler of light weight, diatomaceous siltstone. In thin section the rock appears as a mishmash of clay minerals, diatoms, plagioclase, pollen grains, quartz, radiolarians, and sponge spicules.

26 Diatomaceous, clayey siltstone.

27 Diatomaceous, clayey siltstone.

28 Diatomaceous, clayey siltstone.

29 Diatomaceous, clayey siltstone. This sample also includes a calcareous siltstone pebble, which could be a concretion.

30 Sample 20 is a calcareous, silty sandstone. The sand size material is composed of very angular, etched grains of quartz, labradorite, basalt, glauconite, shards, sponge spicules, and diatoms. Biotite, chlorite, muscovite, hypersthene, augite, hornblende, non-calcareous siltstone, chert, and radiolarians occur in lower concentrations. Many of the rock fragments and the biotite are chloritized. Also it appears that some of the radiolarians are partly filled with glauconite but that the glauconitation has been arrested by the calcium carbonate which crystallized in the void central areas. A few Foraminifera are present; their wall structure is readily visible but their

outer surfaces of their tests are fuzzy and inner void areas are filled with calcite. The matrix is composed of clay, diatoms, spicules, and opaque minerals. Pyrite is abundant. It occurs as fine scattered specks and as large subhedral crystals many of which are located within diatom and glauconite grains. Magnetite, hematite, and limonite are present in smaller concentrations. The matrix is completely cemented with a fine-grained calcite. In addition there are a few small veins of more coarsely crystalline calcite.

31 Stiff, gray, clayey silt. It appears to be intermediate between sediment and rock.

32 Pebbles of calcareous siltstone which could be limestone.

33 Diatomaceous, clayey siltstone.

34 Pebbles of calcareous siltstone.

35 Clayey siltstone.

36 Diatomaceous, clayey siltstone. Also one cobble of dense, hard, very fine-grained, calcareous siltstone.

37 Pebbles of calcareous siltstone (could be limestone).

38 Diatomaceous, clayey siltstone.

39 Diatomaceous, clayey siltstone.

40 Diatomaceous, clayey siltstone.

41 Diatomaceous, clayey siltstone. A gray, massive, medium density rock. It is composed of clay, diatoms, feldspar, opaque minerals (hematite, limonite, magnetite), quartz and sponge spicules.

42 Calcareous, sandy siltstone. Similar to sample 30. The chief differences are that there are fewer sand grains and that the grains are more extensively etched and replaced with calcite in sample 42. No diatoms were found in the thin section. Clay and finely divided opaque minerals are abundant.

43 Angular pieces of glauconite rich calcareous siltstone were obtained in 43. This rock has a light gray color, which is broken

by specks of green and thin veins of darker gray rock. In thin section the glauconite is yellow-green and apple green in color. Pyrite crystals occur within and along the edges of the pellets. In some areas of the slide the pellets are partially coated with hematite, while other areas the pellets are surrounded by more coarsely crystalline calcite. Some of the pyrite crystals that border the glauconite are in turn coated with hematite. Most of the rock is composed of matrix which contains abundant diatoms, spines, pyrite, hematite, and clay. This matrix is completely cemented with fine grained calcite. There is a small quantity of coarse silt and fine sand. It is mainly quartz and plagioclase. This sample also obtained diatomaceous, clayey siltstone. It is massive, medium weight, and well indurated.

44 Diatomaceous, clayey siltstone. It is gray, massive, and well indurated. The rock contains little sand or coarse silt. Foraminifera and diatoms comprise the largest grains. The coarse silt is composed of glauconite, feldspar, muscovite, and opaque minerals.

45 Glauconite, pellet sandstone. The rock is green to greenish gray, massive and medium weight. The glauconite is concentrated as clusters of pellets. The sediment forming the rock appears as though it has been mottled by benthionic animals. Many of the pellets are distorted and crushed. Pyrite and a brownish clay mineral rim many of the glauconite grains. In addition to glauconite the sand fraction contains basalt, biotite, calcite, chlorite, hornblende, leucoxene, muscovite, plagioclase, quartz, and sponge spicules. The matrix is formed of brownish clay, chlorite, diatoms, glass shards, muscovite, opaque minerals, pyrite, quartz, and spines. Calcite is present as a fine-grained cementing agent which occurs in patches throughout the rock.

The second rock type of sample 45 is a calcareous siltstone that has been fractured and then the fractures cemented with calcium carbonate.

The third rock type is a diatomaceous, clayey siltstone.

46 Glauconite sandstone similar to sample 45.

The second rock type is a thin bedded, clayey siltstone. It is light weight and contains abundant diatoms, fish scales, Foraminifera, and radiolarians. Some carbonaceous material is present.

47 Limestone breccia. This breccia contains extremely angular clasts ranging in size up to an inch in diameter. In thin section the rock appears to be a very fine-grained limestone with varying quantities of brownish clay, vugular fillings of quartz, and ghost structures of diatoms. The edges of the clasts are sharply defined, though some of the large clasts contain smaller ones. A number of the fragments have lineations formed by bands of brown clay. In adjacent clasts these lineations are as often as not orientated as distinct angles to one another indicating that the clasts have been at least rotated if not moved. In a few areas the clasts can be seen to terminate at fractures that extend into the rock.

The second rock type is a calcareous siltstone similar to sample 10. It is marked by small veins of calcite that are more coarsely crystalline than the surrounding country rock.

The third rock type is glauconite sandstone similar to sample 45.

The fourth rock type is clayey siltstone.

48 Small pieces of diatomaceous, clayey siltstone. Also one pebble of calcareous siltstone.

49 Clayey siltstone. Foraminifera and diatoms abundant.

50 Diatomaceous, clayey siltstone.

51 Pebbles of calcareous siltstone which could be limestone.

52 Glauconitic siltstone. Diatoms and Foraminifera are present.

53 Glauconite siltstone like sample 45.

The second rock type is a diatomaceous, clayey siltstone.

54 A stiff, gray, clayey silt that is intermediate between sediment and rock.

55 Clayey siltstone. It is light gray and well indurated. Diatoms, Foraminifera, and radiolarians were noted in the hand specimen.

The second rock type is a dense, dark gray, calcareous siltstone.

56 Dark gray, calcareous siltstone or limestone pebbles. There is also a clayey silt that is intermediate between sediment and rock.

57 Semi-consolidated, clayey silt. Could be either a stiff sediment or a hydrated rock. Also a small piece of calcareous siltstone which could be limestone.

58 Small fragments of limestone (calcareous siltstone?) and hard fine-grained sandstone which could be sandy siltstone.

59 Clayey siltstone.

60 Stiff, clayey silt.

61 Limestone pebbles (calcareous siltstone?)

62 Sample 62 contains a graywacke sandstone. It is a dense, well-cemented, gray, medium-grained sandstone. The rock exhibits poor sorting and contains highly angular grains. Feldspar, quartz, shell material, and muscovite are readily visible in the hand specimen. In thin section it was observed that the most abundant sand grains are quartz, plagioclase, biotite, and rock fragments. Muscovite, microcline, hypersthene, augite, hornblende, calcite, chlorite, garnet, zircon, apatite, hematite, limonite, and leucoxene are found in smaller quantities.

A variety of rock fragments including fragments of siltstone, volcanic rocks, schist, chert, quartzite and vein quartz are present. Andesite and basalt are most abundant. One fine-grained rock fragment contained a thin vein of quartz. Some of the rock fragments are badly altered to chlorite. The result is that many masses of chlorite contain ghost structures of the replaced minerals.

The quartz grains are highly angular. They contain edges which appear to have been etched by the matrix or the cement. Most of the quartz grains have sharp, well-defined extinction positions; however, a few of the grains exhibit wavy or patchy extinction. Almost all of the quartz grains contain inclusions in the form of dust trails, irregular to globular blobs and isolated crystals.

Many of the minerals show large quantities of alteration products. Much of the plagioclase is altered to clay minerals. The ferro-magnesium minerals are extensively altered to chlorite and iron ores.

The matrix of sample 62 is composed of clay, opaque minerals, and fine detrital silt grains.

63 Calcareous siltstone or limestone. Looks like a concretion.

64 Two pebbles of calcareous siltstone or limestone.

65 One small fragment of a slightly glauconitic, clayey siltstone.

66 Clayey siltstone. Diatoms, Foraminifera and glauconite present.

67 Small chips of calcareous siltstone mixed with clayey siltstone chips and sediment.

68 Light weight, diatomaceous, clayey siltstone. It contains lower concentrations of diatoms and sand and higher percentages of clay than the siltstones in samples 69 and 70. The coarse fraction consists of feldspar, hematite, limonite, pyrite, quartz, and rock fragments.

Dense, gray, nonporous, calcareous siltstone was collected from the east side of the bank in sample 68. It is faintly laminated with alternating bands of light and dark gray material. On a much smaller scale laminations can be seen in a microscopic examination. The rock is mainly calcite cement and silt-clay matrix. The calcite is very fine grained and has completely cemented and partly replaced the matrix material. Pyrite, hematite, linonite, magnetite, leucoxene, quartz, feldspar, and muscovite form the coarse silt fraction. These coarse silt grains occur in clusters and there are large areas of the thin section that contain little or no coarse silt or sand.

69 Diatomaceous, clayey siltstone which is almost a diatomite. Clay, diatoms, muscovite, opaque minerals, radiolarians, spines, and sponge spicules are abundant. In addition altered pellets of glauconite, hypersthene and quartz are present. In addition sample 69 contains a green glauconite sandstone. This specimen has about 50 percent green glauconite pellets imbedded in a dark gray matrix. The glauconite pellets are concentrated in clusters up to 0. 3 inch in diameter and have the appearance of burrows. In addition brecciated fragments

of siltstone as much as 0.4 inches across are scattered throughout the rock. The outer half inch of the sample is colored a limonite yellow. This coloration is thought to have been brought about by the alteration of the matrix material and the siltstone fragments. The glauconite pellets, on the other hand, retain their green color in the altered zone. One of the rock specimens has a sub-eliptical shape with a long axes of 3.5 inches. It has all the appearances of a concretion.

In thin section, the glauconite grains occur as yellowish-green and dark green pellets. They have the form of smooth, oval grains with fractures that radiate toward the center of the pellet and contain numerous pyrite crystals and black opaque material as inclusions or alteration products. There is, in addition, an abundance of detrital sand grains consisting principally of quartz, labroadorite, and rock fragments. The rock fragments include diatomaceous siltstone, limestone, and basalt. The basalt grains are finely to coarsely crystalline equigranular rocks which are composed mostly of lath shaped crystals of labradorite. The only ferro-magnesium mineral present in the basalt is chlorite. It is probably a secondary mineral formed from the original olivine, pyroxene, biotite, or amphibole. A small portion of the sand fraction is made up of augite, muscovite, isotropic brown substance, chert, quartzite, spines and glass shards. The groundmass is formed of a matrix of clay minerals, opaque minerals, and fine detrital silt grains. A calcium carbonate cement occurs in patches throughout the rock. The matrix and cement have reacted with the sand grains and etched surfaces of the grains.

70 Diatomaceous, clayey siltstone, which is almost a diatomite. It is almost identical with sample 69; however, it also contains chert, hornblende, leucoxene, and quartzite.

One boulder of calcareous siltstone could be a concretion.

71 Clayey siltstone that has a few chips of diatomaceous siltstone approaching diatomite.

72 Chips and small pebbles of siltstone.

73 Gravel

74 Pebbles of calcareous siltstone or limestone.

75 Light weight, clayey siltstone.

76 Diatomaceous, clayey siltstone. Also one piece of dark gray, calcareous siltstone. It may be a concretion.

77 Light weight, clayey siltstone. Foraminifera abundant.

78 Clayey siltstone (more of a mudstone). It is diatomaceous and contains glauconite. It is well consolidated when dry but becomes pliable when it is wetted.

79 Clayey siltstone.

80 Dark gray, dense, hard limestone or calcareous siltstone. Could be a concretion. Foraminifera present.

81 Sample 81 contains a light gray, massive siltstone in which muscovite and limonite are readily seen. The rock is dominantly fine-grained, detrital material consisting of clays, fine silt grains, and opaque minerals, but it also contains a scattering of diatoms and radiolarians. The coarse silt fraction is composed of plagioclase, quartz, muscovite, hornblende, chlorite, and opaque minerals. Opaque minerals are found in much lower concentrations. Pyrite and magnetite are the most abundant opaque minerals with hematite and limonite occurring in lesser amounts.

82 A small fragment of clayey siltstone.

83 Pebbles of calcareous siltstone and clayey siltstone.

84 Fine-grained gravel of clayey siltstone.

85 One small fragment of diatomaceous siltstone.

86 Small piece of clayey siltstone.

87 Small fragment of clayey siltstone.

88 Clayey siltstone.

89 Calcareous siltstone.

90 Diatomaceous limestone or calcareous siltstone. The diatoms are replaced with calcite. Diatoms and Foraminifera

chambers are filled with large crystals of calcite. The thin section shows high concentrations of sponge spicules. These spicules are extensively etched and replaced. In hand specimen the rock is dense, granular, gray and hard.

91 Metalic clinker. Also rounded to angular pebbles of clayey siltstone. Some of the pebbles have burrowed surfaces. Fine muscovite, quartz, diatoms, and spicules were observed in the hand specimens.

92 This sample contains a clinker, a small piece of wood, a few small fragments of silty shale and a larger specimen of friable mudstone.

93 Clinker.

94 Cobbles of calcareous siltstone and small pebbles of clayey siltstone.

95 A stiff, clayey, foraminiferal silt. It is slightly more consolidated than the overlying sediment.

96 Diatomaceous limestone or calcareous siltstone similar to sample 90. It contains fewer sponge spicules and more pyrite than 90.

97 Friable, fossiliferous, sandy siltstone. It is poorly cemented and is pliable when wetted. The specimens are pitted with recent burrows. They also contain abundant, poorly preserved fossil pelecypods.

98 Clayey siltstone. It is light gray and massive. Also there is one boulder of limestone or calcareous siltstone. It may be a concretion. The rock is dark gray, almost black and is riddled on all sides by burrows.

99 A fine-grained, light gray, homogeneous, calcareous siltstone. The outer quarter of an inch is brown. The sand size grains are chlorite, glauconite, labradorite, muscovite, and quartz. The fine fraction contains clay and hematite. The entire rock is completely impregnated with a very fine-grained calcareous cement.

100 A highly glauconitic, sandy, calcareous siltstone. The glauconite appears to be concentrated as wavy greenish bands which

alternate with light and dark gray bands. The bands are bent around an egg-shaped burrow-like object one-half inch in longest dimension. The groundmass is composed of fine carbonate, clay, opaque minerals, diatoms, and spines. The sand grains are mainly quartz, plagioclase, glauconite, and rock fragments. Labradorite is the principle plagioclase. The rock fragments are, for the most part, basalt fragments which are often chloritized, and siltstone grains. Pyrite is very abundant and is evenly distributed throughout the rock. Hematitė is also abundant. It is present mostly as alteration products. Hornblende, muscovite, and hypersthene are present in small quantities.

101 It looks like a dense silty lithographic limestone. Petrographically, however, the rock consists primarily of a matrix of silt and clay that is completely cemented with calcite. Opaque minerals, sponge spicules, and diatoms are abundant throughout the slide. Foraminifera form the largest grains in the thin section. Their chambers are often filled with either fine-grained material or more coarsely crystalline calcite. The larger diatoms are replaced by calcite and are sometimes filled with euhedral pyrite crystals. Quartz, chert, plagioclase, muscovite, chlorite, glauconite, hematite, and magnetite are also present in small quantities.

102 Clayey siltstone. Light gray in color but tan on exposed edges.

103 Calcareous siltstone similar to 101. Calcite veins are present throughout the rock as more coarsely crystalline, though still fine grained calcite. The sand fraction is predominantly composed of larger sponge spicules and Foraminifera. The spicules are partially to wholly replaced by the calcium carbonate. Foraminifera are abundant; they are, however, somewhat altered and their central chambers are filled with calcite. As in many of the other carbonate rocks the groundmass is clayey with silt size opaque minerals and ghost structures of diatoms and spicules. The opaque minerals are pyrite, hematite, and magnetite.

104 A clayey siltstone with diatoms and Foraminifera.

105 Calcareous silty sandstone. The most abundant sand grains are andesine, glauconite, labradorite, quartz, and rock fragments. The rock fragments are mostly basalt, but clayey, diatomaceous,non-calcareous siltstone fragments are also

present. The glauconite occurs as rounded dark green and yellow-green pellets that are fractured and partially replaced. Carbon, chert, Foraminifera, glass shards, hematite, hornblende, limonite, and muscovite are present in small quantities. The matrix consists of clay, diatoms, opaque minerals and sponge spicules. The rock is completely cemented with fine-grained calcite.

106 A fine-grained, dense, well-cemented, dark gray calcareous siltstone. Could be a concretion. The rock surface contains a large number of burrows.

The second rock type is a laminated, light weight, diatomaceous, clayey siltstone.

107 Calcareous, sandy siltstone similar to 105 but contains less sand.

The second rock type is a gray, low density siltstone. A considerable quantity of carbon can be seen in hand specimens. Much of this carbon appears to be derived from small bits of wood. Finely divided muscovite is visible throughout in the thin section. The sample is massive without any apparent lineation. The fine-grained material consists of clay, diatoms, spicules, iron oxides, chlorite, and some brown isotropic material. The larger grains consist of quartz, feldspar, rock fragments, chlorite, glauconite, muscovite, and the opaque minerals. Pyrite, hematite, and limonite, are the principle opaque minerals. Many of the larger grains are irregular and give the appearance of having been etched by the matrix material. The glauconite is extensively altered.

108 A very poorly indurated sandstone. The outer part of the rock is burrowed by benthonic animals. This sandstone is cleaner and better sorted than any of the rocks previously mentioned, and the sand that fills many of the burrows is better sorted and lighter in color than the surrounding sand. Quartz, plagioclase, muscovite, biotite, chlorite, hematite, unidentified green minerals, and black grains were observed in the hand specimen.

109 Light weight, gray to tan, clayey siltstone.

110 Pebbles of clayey siltstone. Larger pebbles of laminated calcareous siltstone.

111 Light weight, brown, diatomaceous, clayey siltstone.

112 A calcareous siltstone that has the outward appearance of an eliptical concretion. It shows a lineation of light colored lenses and black streaks. In thin section it is very similar to 113. One hundred and twelve differs in that its sand grains are clustered in pods and layers, and the diatoms in the groundmass are obscured by brownish clay.

113 Sample 113 includes a dense, impermeable, gray, well-cemented, calcareous siltstone which is cut by small veinlets of calcite. These veinlets contain a microbreccia of the rock material. In cross section the rock exhibits alternating light and dark bands one-fourth to one inch in thickness. The bands appear to be parallel with the bedding and may be the result of increasing and decreasing quantities of argillaceous material. Many of the light bands contain small angular fragments of the darker rock. In this section the rock is predominantly fine silt, clay, and cement. The silt and clay fractions are a mish-mash of diatoms, glass shards, sponge spicules and clay minerals. This material has been completely impregnated and cemented with calcite. The coarser silt and sand grains consist of quartz, plagioclase, glass shards, Foraminifera, large diatoms with calcite fillings, and opaque minerals. Most of these coarse grains have been etched and partly to wholly replaced by the calcite. The most abundant opaque minerals are hematite, limonite, and pyrite. Hornblende, hypersthene, glauconite, chlorite, and brown isotropic material occur as minor components. The vein material is almost pure, fine-grained calcite with small areas of more coarsely crystalline calcite.

Sample 113 obtained fragments of low density siltstone which approaches diatomite. The hand specimens are light gray with still lighter colored fine, discontinuous streaks and thin veins of darker silt. Poorly preserved fossil Peleceopods occur throughout the rock. The outer surface of the rock is weathered to a light tan and contains a number of pholad burrows. Petrographically this sample is greatly similar to 124 as the groundmass is formed of an intermeshing of diatoms, hematite, limonite, chlorite, minute spicules, and clay. Quartz and feldspar make up the coarse silt fraction, and Foraminifera and volcanic rock fragments comprise the small quantity of sand size material that is present.

114 Cobbles and pebbles of calcareous siltstone.

115 Coal, clinker.

116 Small pieces of a sandy siltstone.

117 Small fragment of siltstone.

118 Clayey siltstone. Groundmass of clay and silt size opaque minerals. Some calcareous cement. Sand fraction is composed of glauconite, plagioclase, pyrite and quartz.

119 Sandy, diatomaceous siltstone. The dry hand specimen is a somewhat friable massive rock which exhibits a crude conchoidal fracture. The sand is found in lenses and pockets. Hornblende, biotite, chlorite, quartz, muscovite, plagioclase and radiolarians were identified in the sand fraction. The matrix of chlorite, sericite, opaque minerals, fine spicules, clay, and numerous unidentified minerals form most of the rock.

120 Sandy, calcareous siltstone. This rock is dark gray on fresh surfaces and light gray on the exposed surfaces. The lighter gray rock is also found as vein-like bodies in the darker siltstone. In thin section the rock can be seen to have a great abundance of glass shards most of which are partly replaced by the calcareous cement. Hornblende is common throughout the slide, and muscovite, quartz, plagioclase, and glauconite occur in small quantities. In addition there is a large quantity of opaque minerals of which pyrite is most abundant; magnetite and leucoxene are less abundant. A few non-calcareous siltstone fragments are present.

121 Mudstone and silty sandstone were obtained in 121. Both rock types are gray in color, intermediate in density, and somewhat friable in nature. The sandstone contains a sizeable admixture of silt and clay. Muscovite is readily visible in the hand specimen. In addition biotite, quartz, plagioclase, limonite, and hematite can be observed with the aid of a hand lense. A thin section of the sandstone shows in addition to the above mentioned minerals an abnormally high percentage of hornblende. Glass shards, chlorite, basalt fragments, and siltstone fragments are also common in the sand fraction. Less abundant are calcite, augite, zircon, and hematite. Many of the grains are altered to secondary minerals. The biotite is

altered to chlorite. Much of the plagioclase is altered to clay minerals. In addition hematite appears to have formed as a secondary mineral after some of the grains. The matrix consists of spicules, chlorite, glass shards, diatoms, hematite, magnetite, pyrite, clay minerals, and unidentified minerals.

One thin section was taken in a siltstone fragment in which the contacts are with two sandstone beds or lenses. The clayey siltstone is composed of chlorite, seracite, hematite, other opaque minerals, quartz, and numerous other unidentified grains. The contacts between the sandstone and siltstone are irregular. The irregularity is caused by fractures in the siltstone which extend to the contact but not into the sandstone. In fact the sand seems to fill the displacements made by the fractures in the siltstone. These contacts are also marked by concentrated bands of hematite. The hematite fades out into the sandstone but extends into the siltstone along the fractures. All this suggests to the author that the sand was plastered on to the siltstone after it had broken loose from its bed rock position.

122 Diatomaceous, clayey siltstone.

123 A number of pieces of siltstone, some as much as a foot in diameter were obtained in 123. These rocks are massive, light gray, clayey siltstones. The outer two inches of the rock has a yellowish-brown color which could be the result of weathering. Pholads and other animals have burrowed into the rocks, and recent sediment has filled into the holes. A thin section taken from 123 shows that there is little sand. The coarse silt fraction is made up of quartz, plagioclase, and hornblende. In addition there are a few widely scattered grains of glauconite and tests of Foraminifera. Grains of hematite and limonite are abundant, occurring in patches throughout the slide. The groundmass which forms the majority of the rock is composed of chlorite, hematite, clay, fine detrital silt grains, and small unidentified objects. Noticeably lacking are the diatoms so abundant in the other rocks.

124 Light weight, gray, diatomaceous, clayey siltstone. The groundmass is composed of clay, chlorite, diatoms, hematite, limonite, pyrite, radiolarians, spines, and unidentified material. The coarse silt and sand fractions consist mainly of etched grains of quartz and feldspar. Chlorite, diatoms, glauconite, hornblende, and sponge spicules are also found

in the coarse fraction.

125 Two rock types were obtained. One is a dense, dark, argillaceous limestone and the other is biatomaceous coal. The limestone is a dark gray to black, massive, impermeable rock. The exposed surface areas are bored by animals and are coated with a thin layer of brown substance that may be phospherite. Microscopically the limestone is composed of very fine grained calcium carbonate. More coarsely crystalline calcite occurs in the chambers of the Foraminifera and as cast inside the diatoms. Fine subhedral to euhedral grains of pyrite are found evenly distributed throughout the slide. Very fine grains of quartz and feldspar occur in small quantities. These grains have etched edges which appear to have formed by the reaction with calcium carbonate.

The coal was recovered as small fresh looking chunks. They are fairly soft and have a subiterous luster. It is the author's opinion that these pieces of coal have come from ships which pass over the Daisy Bank on their way to Newport.

126 Sample 126 contains two distinctly different rock types. One is a dark gray, silty shale or mudstone. It is a fairly hard, medium density, impermeable rock which contains a visible abundance of Foraminifera. The second rock type is a poorly indurated lithic wacke. The rock varies from silty sandstone to sandy siltstone and exhibits poor sorting. The sand fraction is composed of quartz, labradorite, hornblende, muscovite, biotite, chlorite, microcline, augite, glass shards, rock fragments, and opaque minerals. The opaque minerals are hematite, limonite, magnetite, and pyrite. Basalt, siltstone, and quartzite occur as rock fragments.

Many of the mineral grains in 126 have been altered. The quartz and feldspar grains exhibit serrated, etched edges. Biotite and many of the rock fragments are altered to chlorite.

127 A friable, light gray, massive clayey siltstone. It contains pods of detrital sand.

The second rock type is a calcareous siltstone. It is a dense, gray rock with irregular patches of dark gray and brown. Chlorite, diatoms, glauconite, hematite, magnetite, noncalcareous siltstone, plagioclase, pyrite and quartz are present in the coarse fraction. The opaline material of the diatoms has been replaced by calcite. Many of the detrital grains are etched and partially replaced.

128 A clayey siltstone similar to 127. Calcareous shell material and Foraminifera are scattered throughout.

129 Dense, gray, hard, calcareous siltstone. It contains an abundance of fine silt and clay. In addition, diatoms, sponge spicules and possible glass shards are scattered throughout the groundmass and they are partially to wholly replaced by the calcium carbonate cement. Hematite, pyrite, and magnetite occur as grains dispersed throughout the groundmass. Abundant Foraminifera make up the coarsest material in the rock. The tests are partly dissolved and some larger crystals of calcite have crystallized in the chambers. Quartz and plagioclase grains are found scattered throughout the slide as highly etched, angular fragments.

130 Mudstone (siltstone) and sandy mudstone. It is friable, massive, and contains abundant Foraminifera. Biotite, muscovite, plagioclase, and quartz are visible in the hand specimens.

131 A calcareous siltstone similar to 129. It, however, contains fewer Foraminifera, and contains a large number of glauconite pellets. Pyrite is common throughout the rock. It is frequently concentrated in the chambers of the Foraminifera. This sample contains more coarse silt and fine sand than sample 129. In addition to the quartz and plagioclase, vein quartz and non-calcareous siltstone fragments occur in the coarse fraction.

132 A small piece of siltstone.

133 Calcareous siltstone similar to 129 and 131. It contains more non-calcareous, diatomaceous siltstone fragments. Relic structures of replaced diatoms and spicules are present in the groundmass. Chlorite occurs as small particles in the groundmass.

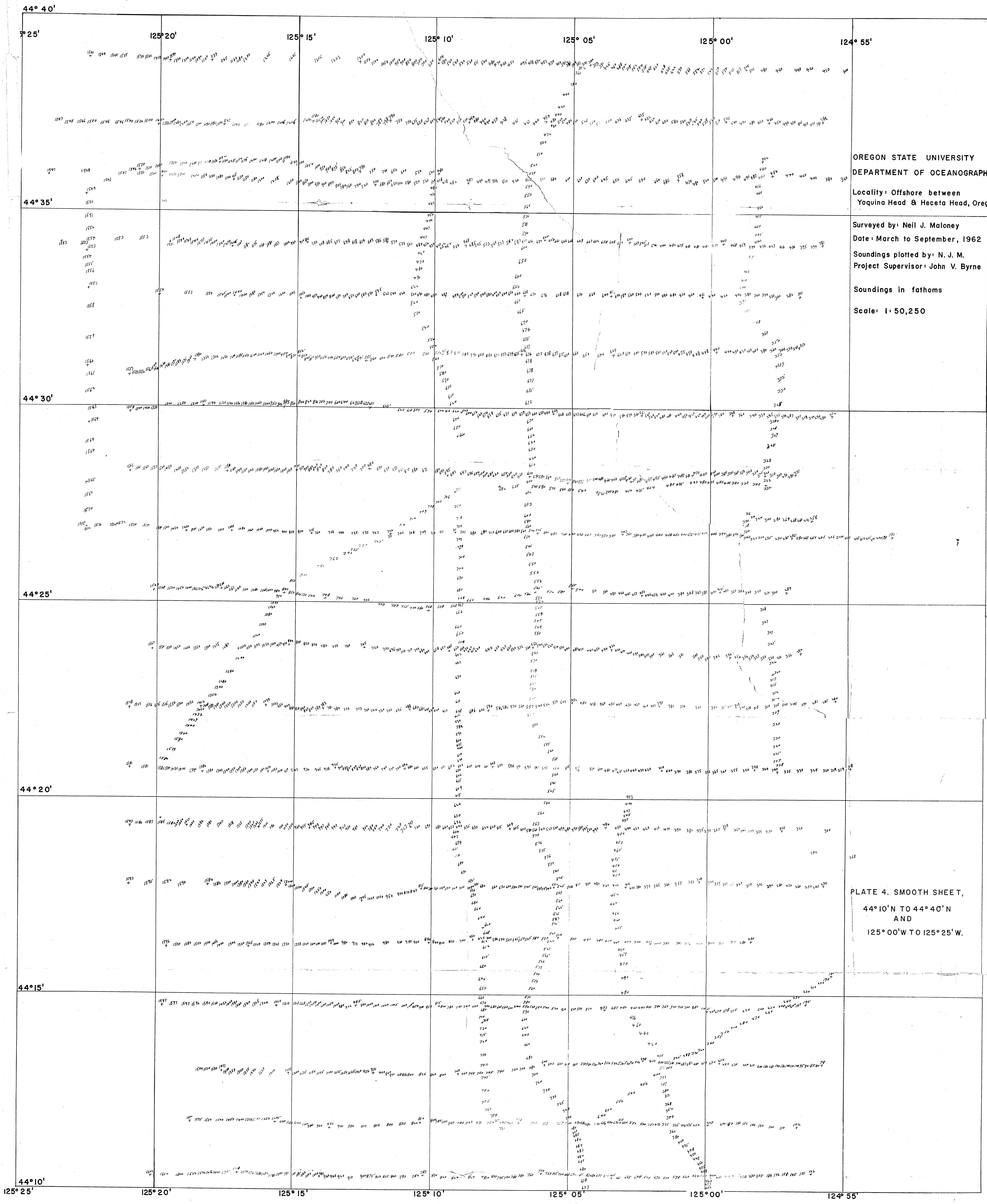
134 Clinker.

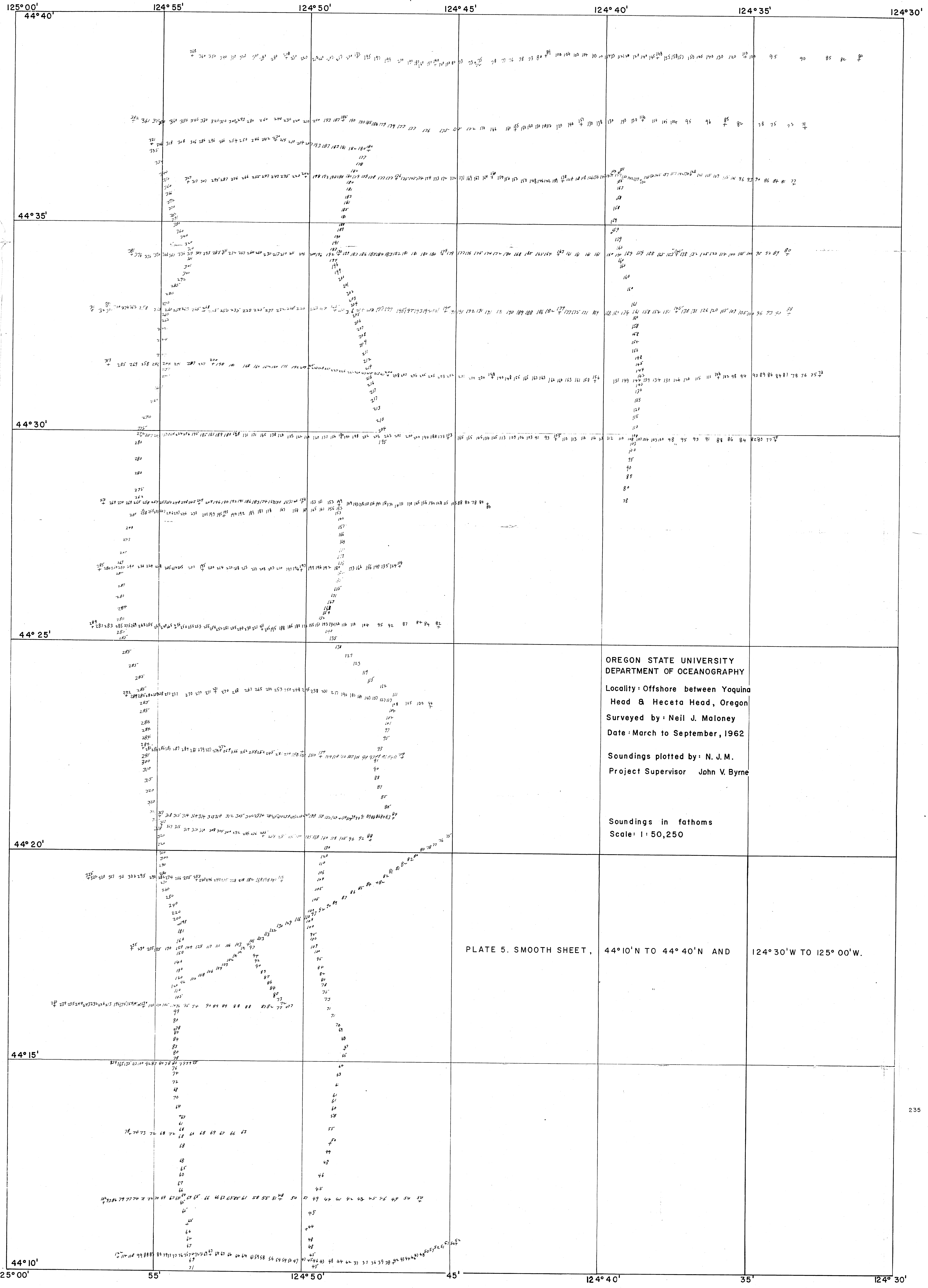
135 Light gray, diatomaceous siltstone similar to 111.

136 Small pieces of coal. It is probably derived from ships.

137 Two types of material are present in the haul. One type is a green glauconite mud which contains angular chunks of siltstone. The second type of material is a gray to brownish gray, glauconitic, clayey mudstone which contains angular clasts of the same mudstone. This material is a rather hard rock when it is dry but it decomposes readily when it is wet. Some specimens contain what appears to be a flow banding. The glauconite pellets are concentrated in pods and poorly formed bands. One thin section shows that the rock is a sandy mudstone. Most of the largest sand grains are glauconite pellets. There are also large grains of calcite and Foraminifera; shell fragments are scattered throughout. The principle detrital grains are much smaller and less abundant. They are hornblende, quartz, plagioclase, hematite, and magnetite. Chlorite and pyrite are present as alteration products. Sponge spicules are common. The matrix is composed of clay, opaque minerals, fine spines, and some diatoms. The matrix material seems to have reacted with the glauconite, and many of the pellets exhibit borders which are altered to pyrite, hematite, magnetite, and clay.

138 A light tan to light gray, medium density, calcareous rock. In hand specimen it appears to be an argillaceous limestone containing a fine boxwork of carbonate veins. In thin section, however, it looks like a calcareous siltstone with a groundmass of partially replaced diatoms, sponge spicules, and chloritic clays. The sand fraction is small. Non-calcareous siltstone grains, glass shards, and sponge spicules are the most abundant sand size grains. Quartz, chlorite, muscovite, plagioclase, Foraminifera, glauconite, hematite, and magnetite are present in small quantities.


OREGON STATE UNIVERSITY
DEPARTMENT OF OCEANOGRAPHY
Locality: Offshore between Yoquina Head & Heceta Head, Oregon
Surveyed by: Neil J. Maloney
Date: March to September, 1962
Soundings plotted by: N. J. M.
Project Supervisor: John V. Byrne
Soundings in fathoms
Scale: 1:50,250
PLATE 4. SMOOTH SHEET, 44°10'N TO 44°40'N AND 125°00'W TO 125°25'W.
44° 40'
44° 35'
44° 30'
44° 25'
44° 20'
44° 15'
44° 10'
125° 25'
125° 20'
125° 15'
125° 10'
125° 05'
125° 00'
124° 55'



125°00'
124°55'
124°50'
124°45'
124°40'
124°35'
124°30'
44°40'
44°35'
44°30'
44°25'
44°20'
44°15'
44°10'
OREGON STATE UNIVERSITY
DEPARTMENT OF OCEANOGRAPHY
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Date: March to September, 1962
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Project Supervisor John V. Byrne
Soundings in fathoms
Scale: 1:50,250
PLATE 5. SMOOTH SHEET, 44°10'N TO 44°40'N AND 124°30'W TO 125°00'W.
125°00'
55'
124°50'
45'
124°40'
35'
124°30'

PLATE 5

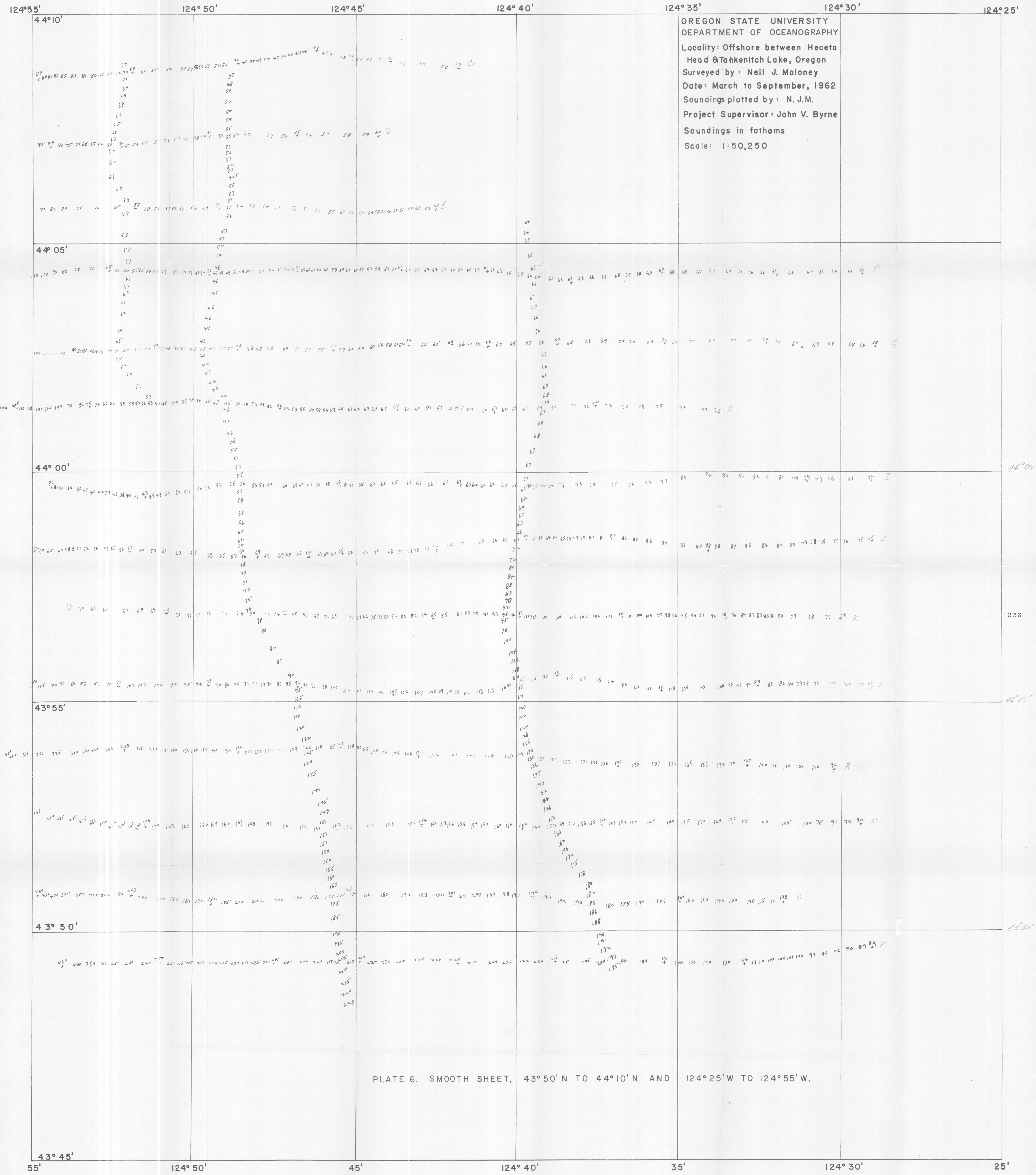

PLATE 6. SMOOTH SHEET, 43°50'N TO 44°10'N AND 124°25'W TO 124°55'W.

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Plate 6

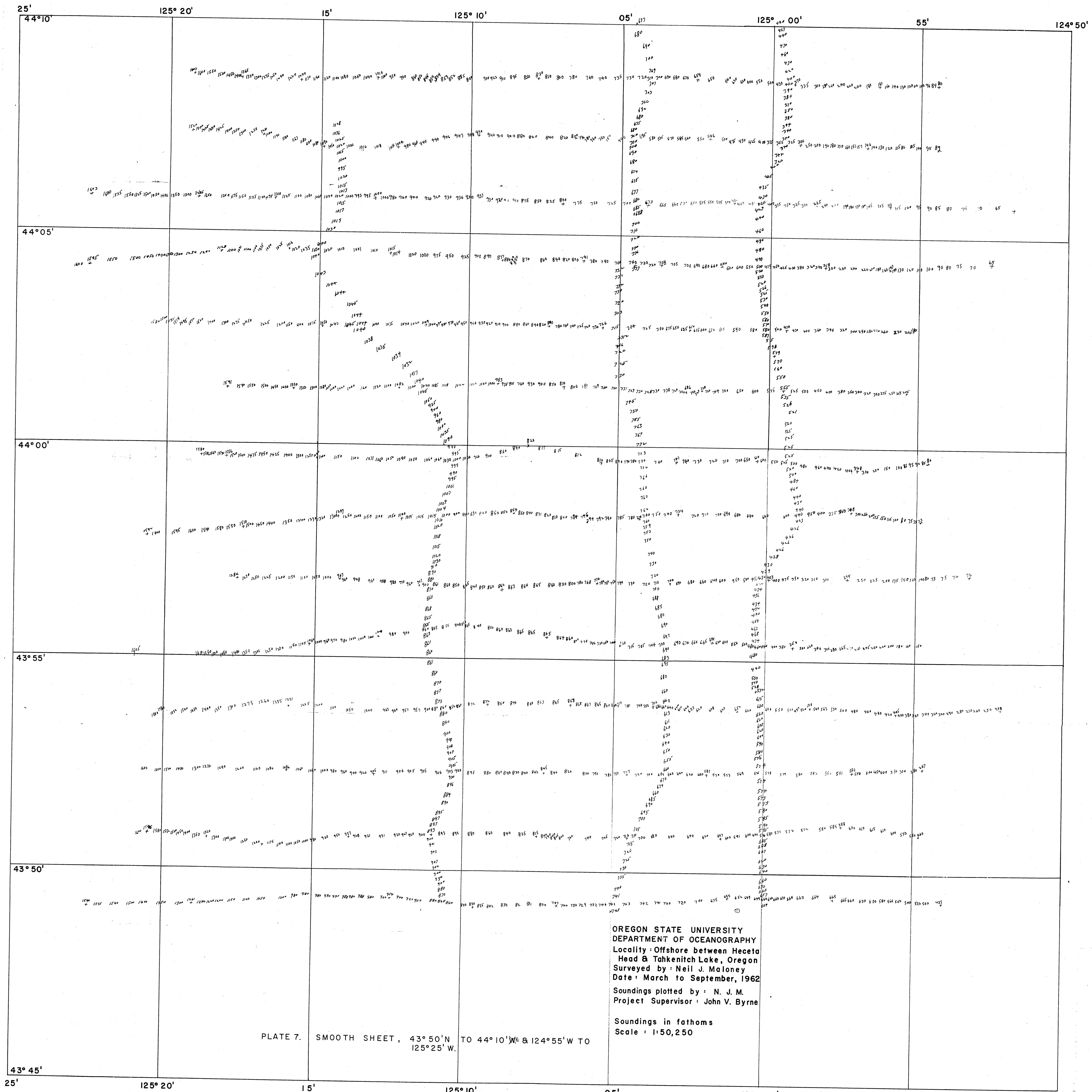

PLATE 7. SMOOTH SHEET, 43° 50'N TO 44° 10'N & 124° 55'W TO 125° 25' W.

Plate 7.

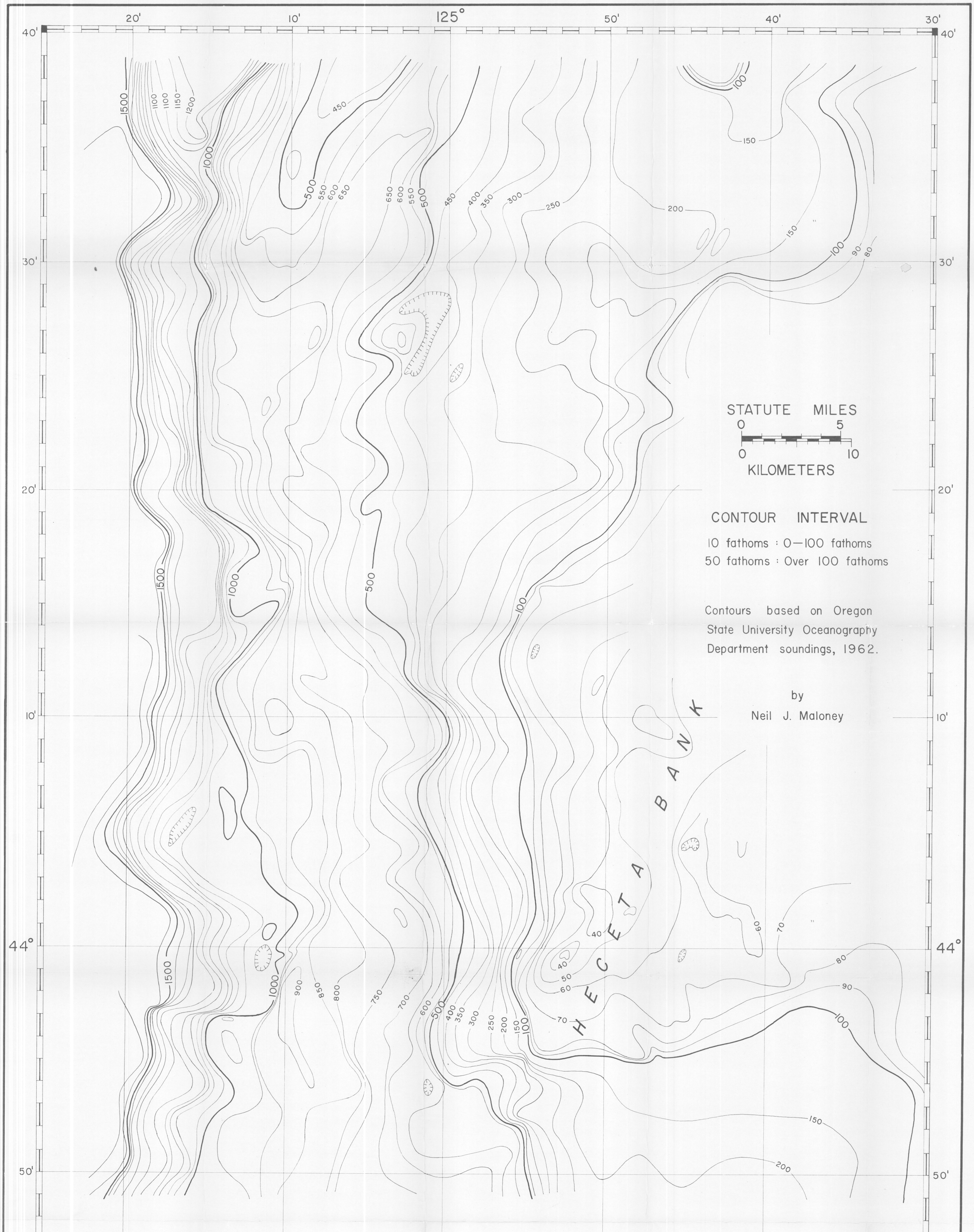

PLATE 8. BATHYMETRIC CHART OF THE CONTINENTAL SLOPE OFF CENTRAL OREGON.

DRAFTING BY J.O.L. ENTERPRISES

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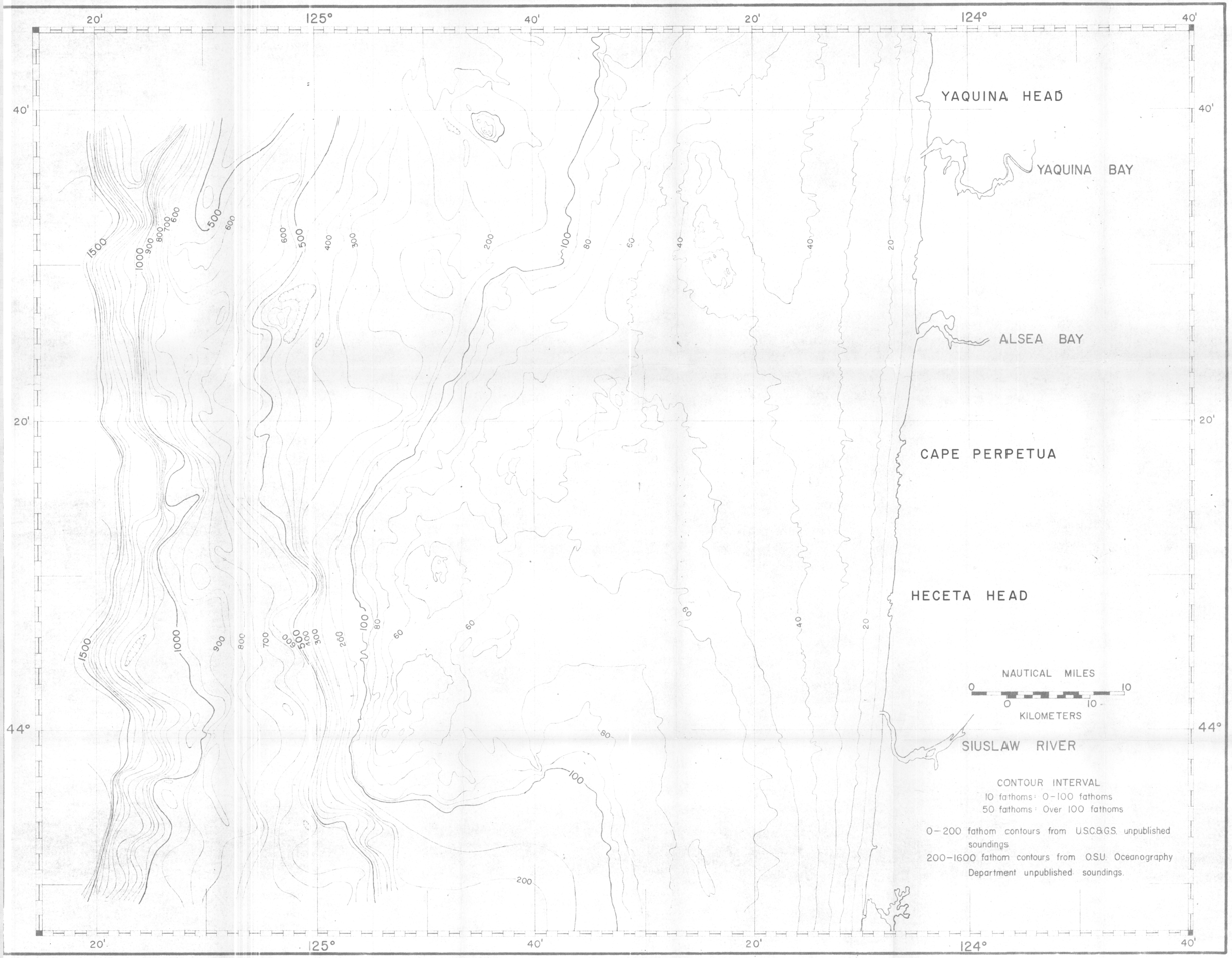

Plate 9. BATHYMETRIC CHART OF CONTINENTAL TERRACE OFF CENTRAL OREGON

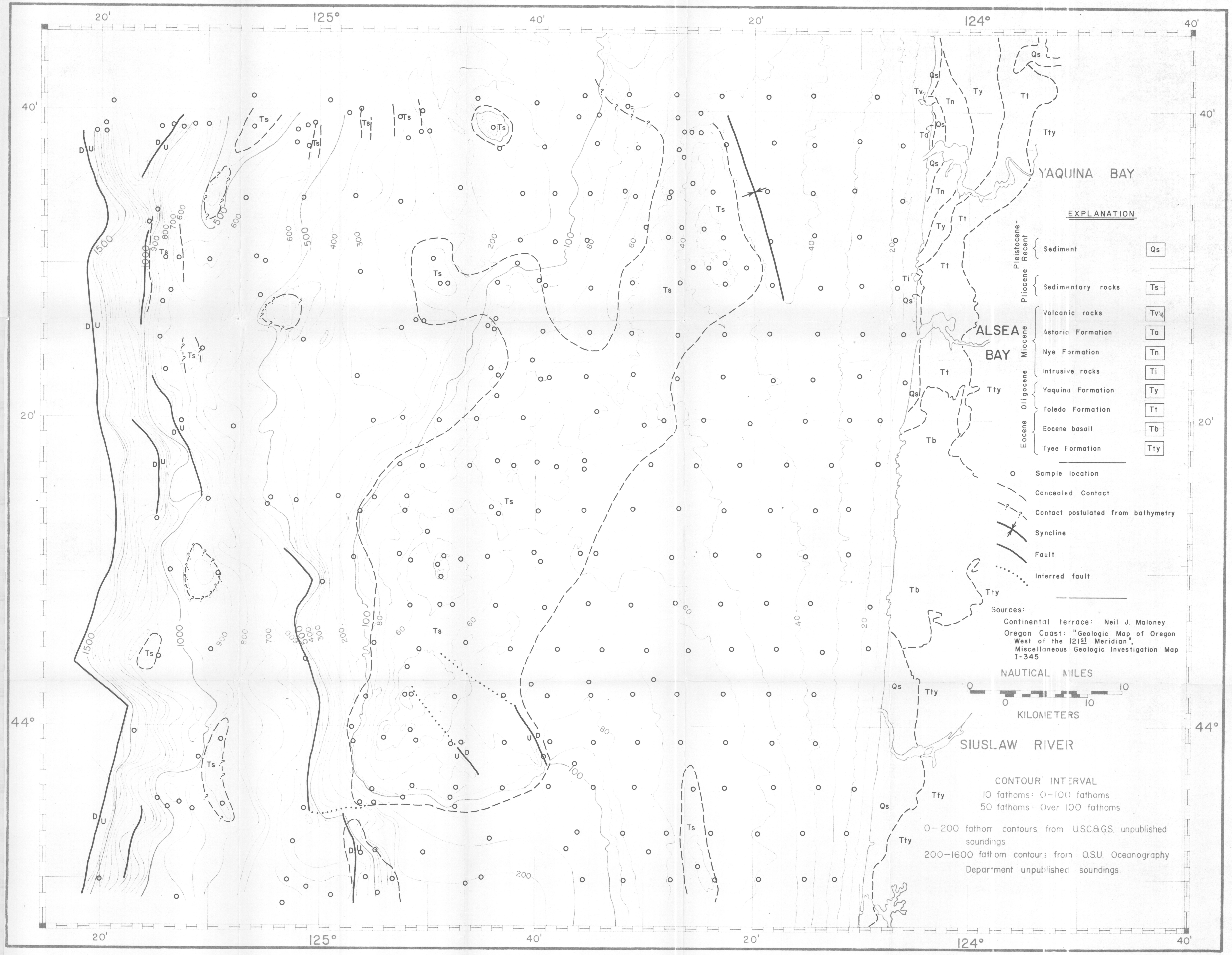

Plate 39. GEOLOGIC MAP OF THE CONTINENTAL TERRACE AND COAST OF CENTRAL OREGON