



**DEPARTMENT OF  
OCEANOGRAPHY  
UNIVERSITY OF  
WASHINGTON**

**Technical Report No. 60**

**COBB SEAMOUNT, A DEEP-SEA FEATURE  
OFF THE WASHINGTON COAST**

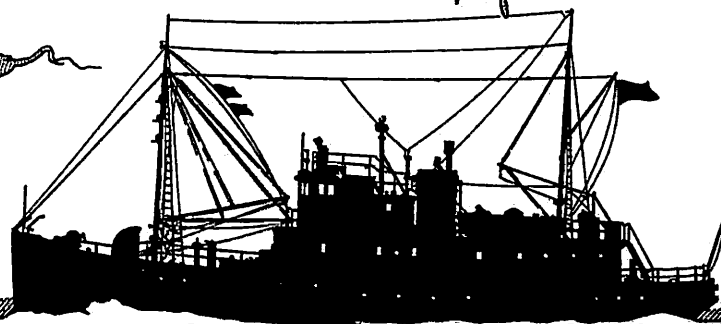
by

**Thomas F. Budinger and Betty J. Enbysk**

*Office of Naval Research*

*Ref. 59-6*

*March 1960*



**SEATTLE 5, WASHINGTON**



Frontispiece. Launching the navigational control.

UNIVERSITY OF WASHINGTON  
DEPARTMENT OF OCEANOGRAPHY  
Seattle 5, Washington

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COBB SEAMOUNT, A DEEP-SEA FEATURE OFF THE WASHINGTON COAST  
Topography, Geology, Biology and Hydrography

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Thomas F. Budinger and Betty J. Enbysk

Office of Naval Research  
Contract Nonr-477(10) and Nonr-477(01)

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RICHARD H. FLEMING  
Executive Officer

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## ABSTRACT

Cobb Seamount is a deep-sea feature located 270 nautical miles west of Gray's Harbor, Washington ( $46^{\circ}46.4'$  N and  $130^{\circ}48.8'$  W). The topography, geology, biology, and hydrography of this mountain were investigated by the University of Washington Department of Oceanography research vessel, M. V. Brown Bear; 500 miles of soundings, 34 bottom samples, 25 hydrographic stations, and other observations were taken.

This submarine mountain rises from a base at 1,500 fathoms below the sea surface to within 18.5 fathoms of the surface and comprises an area of 240 square nautical miles. The average slopes of 12 degrees are indented by three prominent terraces at 500, 100, and 45 fathoms. From the 45-fathom terrace rises a 160-foot pinnacle apparently composed of shells and characterized by a flat top and 45-degree slopes.

Fossil Foraminifera suggest that Cobb Seamount may be a pre-late Eocene volcano which has been terraced by wave abrasion and which has subsided about 500 fathoms subsequent to its formation. The preservation of this volcano since Early Tertiary with subsidence as the only active orogenic expression would negate the extension of the Pliocene-Pleistocene orogenic belt seaward into this area.

Abundant bottom fish and bottom fauna have been taken on the mountain. The red snapper, Sebastes ruberrimus, and the rock scallop, Hinnite multirugosus, were taken in the greatest quantities. The diatom, Rhizosolenia semispina, is the dominant plankton.

The hydrographic observations indicate that there are no anomalies in the water structure or current pattern which might be attributed to the influence of the mountain. A rotary current with both semidiurnal and inertial constituents was observed. The geostrophic flow during four periods of observations was 0.1 knot setting southeast. The water mass is dominantly Subarctic water mixed with 10-20 percent Equatorial Pacific water.



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## CHAPTER 1. INTRODUCTION

### Discovery and Location of Cobb Seamount

Cobb Seamount, named for the U. S. Fish and Wildlife Service vessel M. V. John N. Cobb, was discovered accidentally on 1 August 1950. This vessel, while investigating a report of large schools of tuna in waters offshore from the Washington coast, noticed a heavy concentration of sea birds in the vicinity of Cobb Seamount, then unknown, and proceeded toward the birds with the object of finding the school of fish commonly associated with such birds. En route the depth-finder registered a rapidly shoaling bottom and a minimum depth of 22 fathoms in an area previously thought to be much deeper. Cobb Seamount is located 270 nautical miles west of Grays Harbor, Washington (Figure 1). The geographic position, as determined by celestial fixes, is  $46^{\circ}46.4'$  N. and  $130^{\circ}48.8'$  W. (Appendix A).

### Regional Setting

The setting for Cobb Seamount in relation to the topography of the Northeast Pacific Ocean is shown in Figure 2. This chart shows the distribution, names, and summit depths of all the known prominent seamounts in the Gulf of Alaska and adjacent Northeast Pacific Ocean. The names of the seamounts and guyots were derived from those of former engineers of the U. S. Coast and Geodetic Survey, and from vessels which were used in the development of the topography. Most of these mountains are oval in plan, 10 to 25 miles wide, and 15 to 70 miles long at the base. Many mountains rise over 2 miles above the ocean floor. Generally they are concave upward and have maximum slopes of 24 degrees.

The many submarine mountains in the Gulf of Alaska rise from a southwest-sloping plain with contours roughly parallel to the continental slope. This plain is warped downward to the northwest where it joins the Aleutian Trench. To the west of the area shown in Figure 2 the basin grades into the deep floor of the North Central Pacific Ocean. The southern boundary of this plain is defined by an east-west submarine scarp, Mendocino Escarpment, near latitude  $40^{\circ}$  N. A more detailed description of the general topography of the Gulf of Alaska and the Northeast Pacific Ocean is given by Murray (1941) and by Menard and Dietz (1951). Cobb Seamount's significance to the latter's Province type designations will be considered in the Geology section.

The relationship of Cobb Seamount to the coast of Washington is shown in Figure 3. This profile, based on continuous soundings taken on the traverse, shown in Figure 1, presents an interesting and striking picture. The extensive flat plain at a depth of 1450 fathoms has the appearance of an abyssal plain or an area in which excessive deposition has obscured crustal vertical movements.

Unfortunately, soundings are limited in areas more than 20 miles from the mountain. Cobb Seamount apparently rises at the northern extremity of an elongate plateau, which trends northwest-southeast (Figure 4). This irregular plateau, exhibiting 200-fathom relief, has many small hills of 100-fathom relief. The southern extremity of this feature is poorly defined. Four other seamounts south and west of Cobb Seamount rise from this plateau:

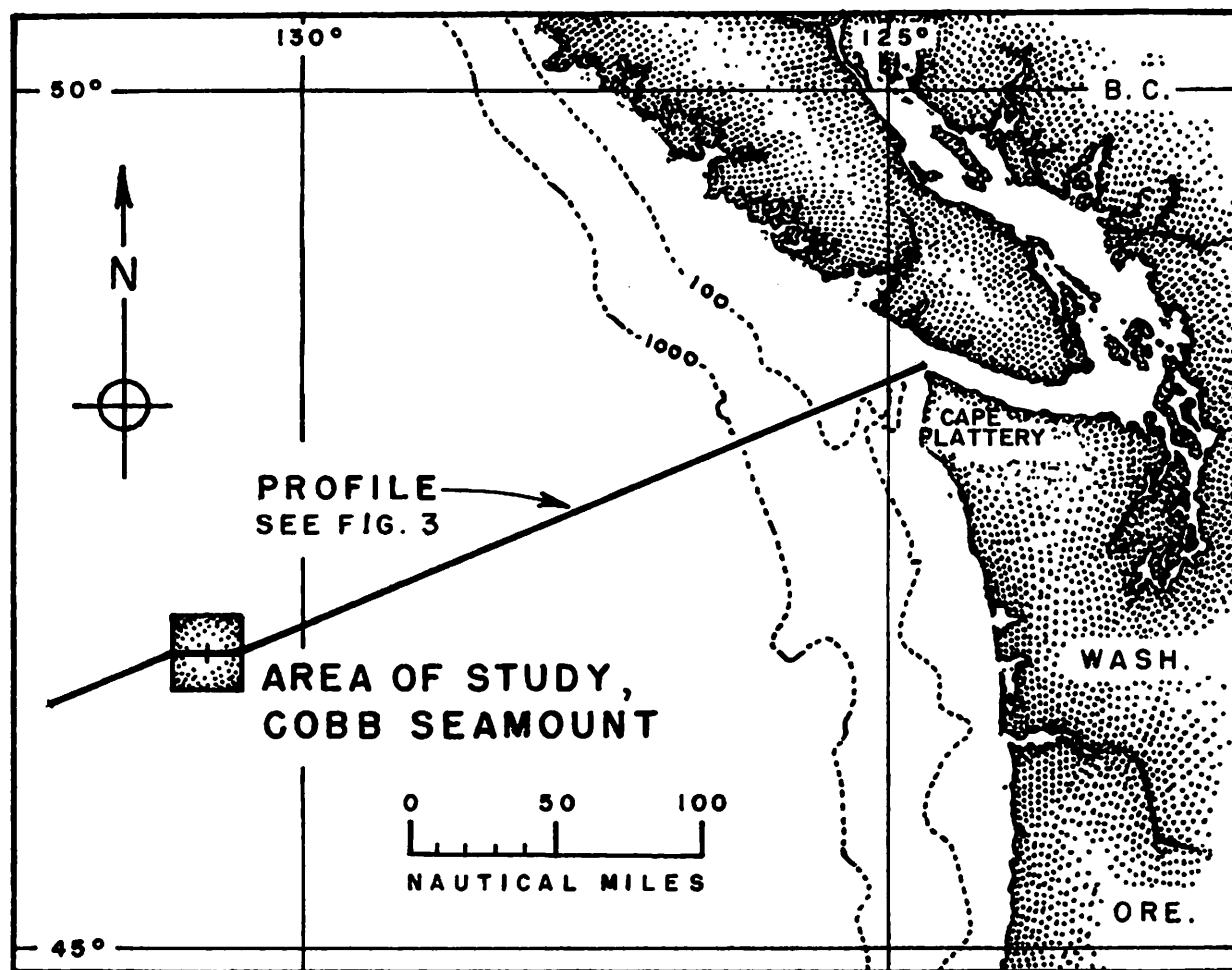


Figure 1. Location chart for area of study

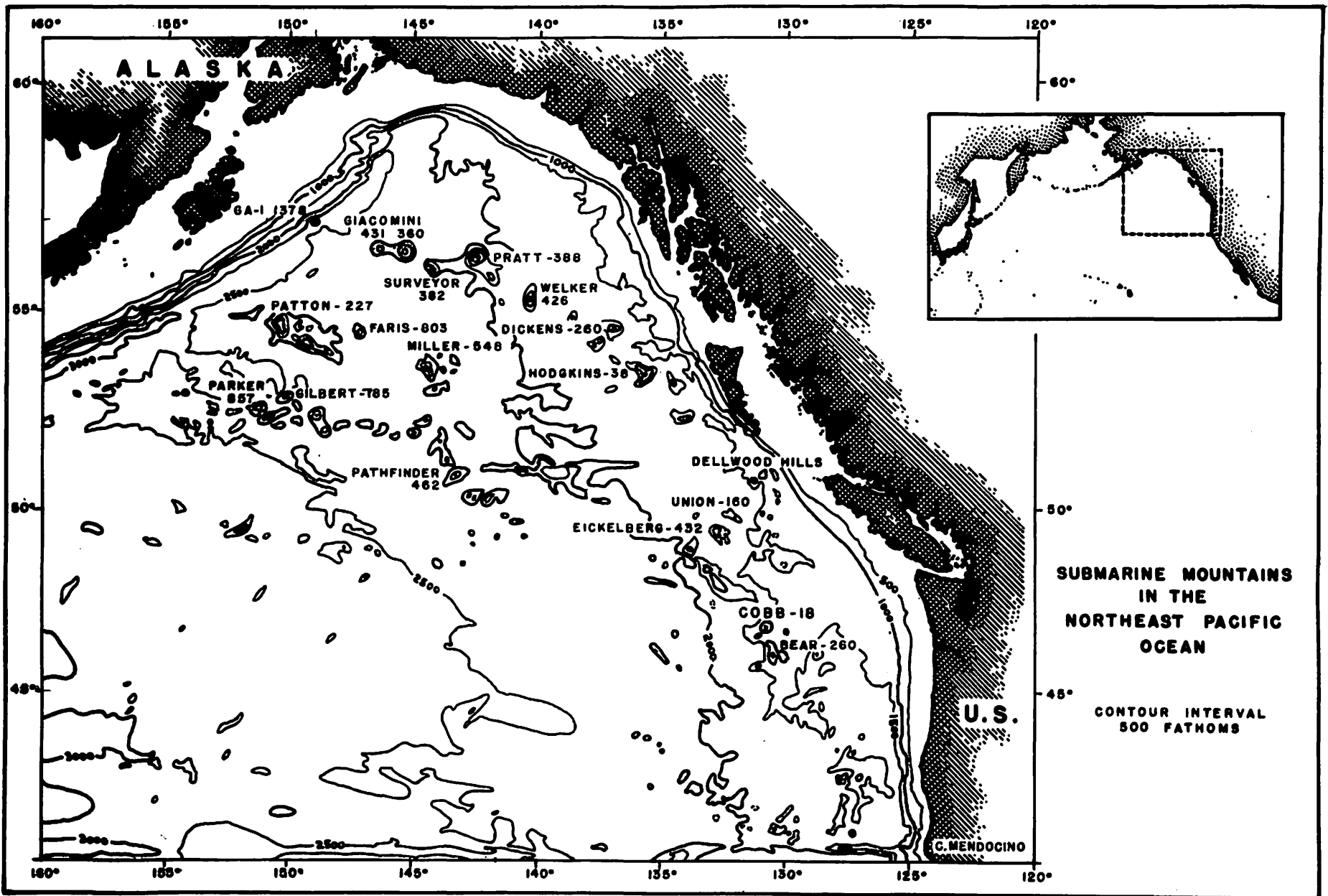


Figure 2. Distribution of submarine mountains in Northeast Pacific Ocean

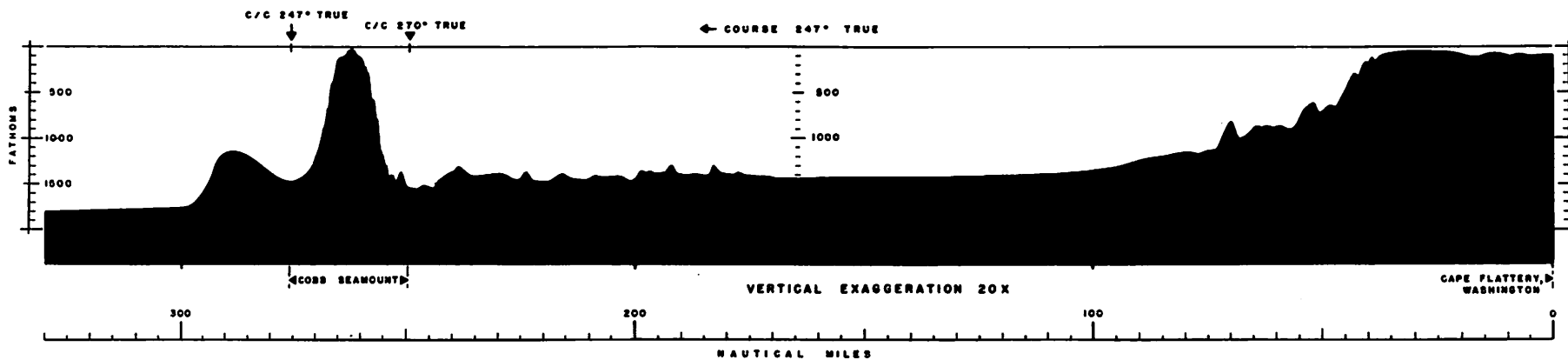


Figure 3. Bottom profile from Cape Flattery to Cobb Seamount  
 (based on continuous uncorrected soundings; see Fig. 1)

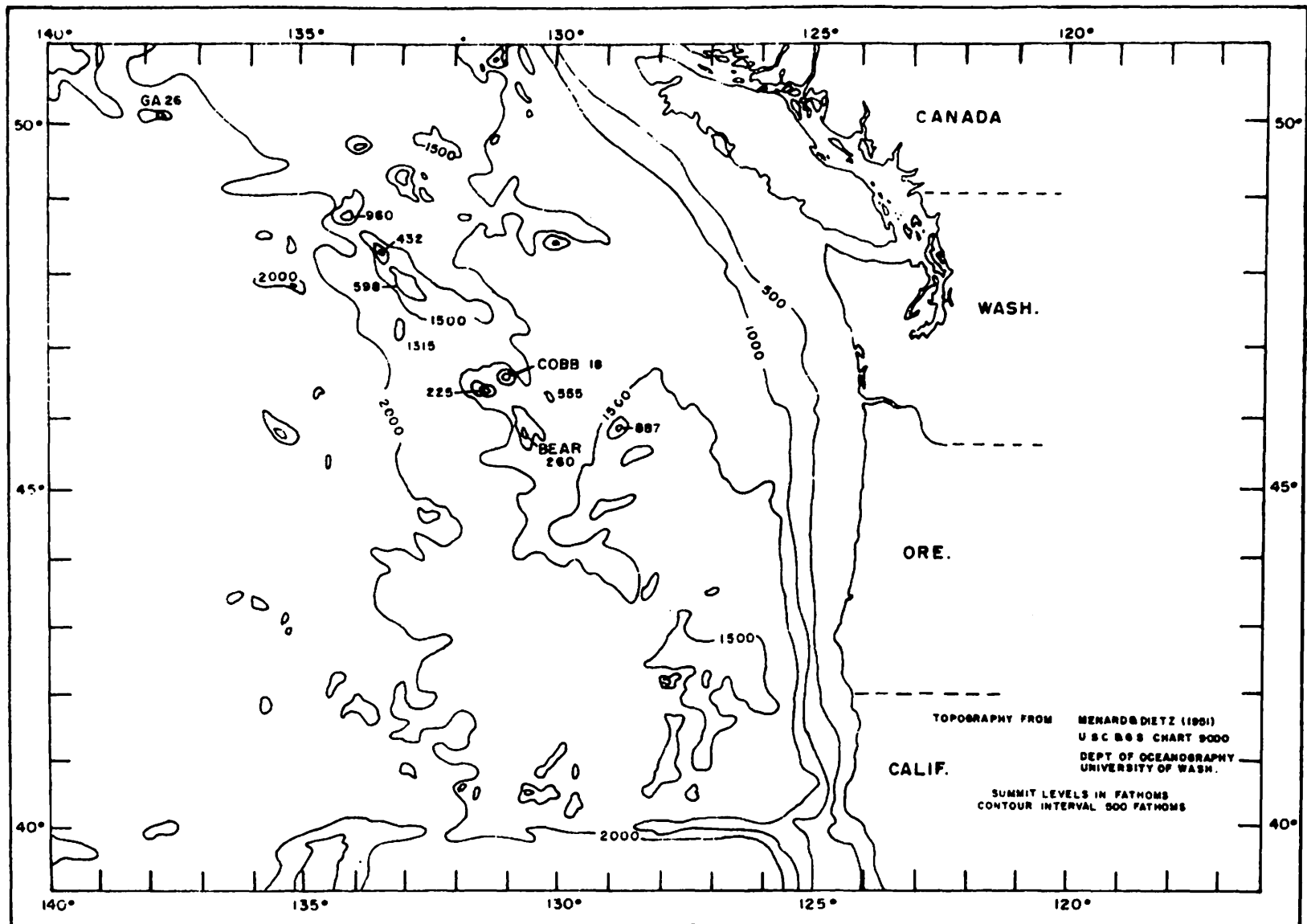


Figure 4. Topography in the area of Cobb Seamount

1. Approximately 15 miles SSW of Cobb a seamount rises to within 525 fathoms of the surface. Farther SW a recent sounding indicated a 225-fathom NW-trending ridge.
2. Another seamount, 35 miles SSE of Cobb, rises to within 573 fathoms of the sea surface.
3. The seamount located 45 nautical miles SSE of Cobb Seamount is here named "Bear Seamount" for the M. V. Brown Bear. This vessel surveyed the mountain during Cruise 29 (June 1953), and reported a summit depth of 260 fathoms.
4. Another seamount, 40 miles ESE of Cobb, has a summit depth of 555 fathoms.

### Previous Work

Since Cobb Seamount was discovered, the Department of Oceanography at the University of Washington, the U. S. Fish and Wildlife Service, and the U. S. Navy Hydrographic Office have made hydrographic and biological investigations in the vicinity of the seamount. The M. V. Brown Bear visited the mountain to make oceanographic observations during Cruise 9, August 1952 (Paquette et al, 1954a), and Cruise 31, August 1953 (Paquette et al, 1954b). The Fish and Wildlife Service vessel John N. Cobb investigated the types and abundance of pelagic and bottom fish in the vicinity of the mountain (Powell et al, 1952). The Hydrographic Office has run sounding traverses over the mountain on several occasions during the course of other surveys.

### Purpose and Scope

Within the past two decades, echo-sounding lines run by hydrographic agencies and oceanographic institutions have revealed many physiographic features on the floor of the Pacific Ocean. Of particular interest are the groups of submarine mountains which rise several thousand feet above the ocean floor. The distribution, origin, geomorphology, and age of these features are problems of increasing interest to geologists, oceanographers, seismologists, and biologists.

In the past the observations made on any individual seamount have been limited in number and kind. Recently, however, the authors have studied in some detail the topography, geology, biology, and hydrography of Cobb Seamount, located in the Northeast Pacific Ocean 270 miles west of Grays Harbor, Washington. The objectives of this study were as follows:

1. To determine the topography of Cobb Seamount and environs by numerous sounding traverses.
2. To map the distribution of sediments, rock types, fossils, and living bottom fauna by a systematic sampling program.
3. To interpret from these observations the origin, age, and history of Cobb Seamount.

4. To investigate the distributions of plankton and pelagic fishes, and determine the possible relation of their distribution to the presence of the seamount.
5. To explore the currents and water structure in the area and to locate anomalous patterns, if any, in the immediate vicinity of the mountain which might be attributed to its presence.

An expedition was organized by the senior author under the auspices of the Department of Oceanography of the University of Washington to investigate the mountain. During Brown Bear Cruise 139 in April 1956, ten days were spent in the vicinity of the mountain in order to run sounding traverses, collect bottom samples, and make hydrographic observations. To supplement these observations and to verify the results of Cruise 139 soundings, two days were spent on the mountain during Cruise 144 in August 1956.

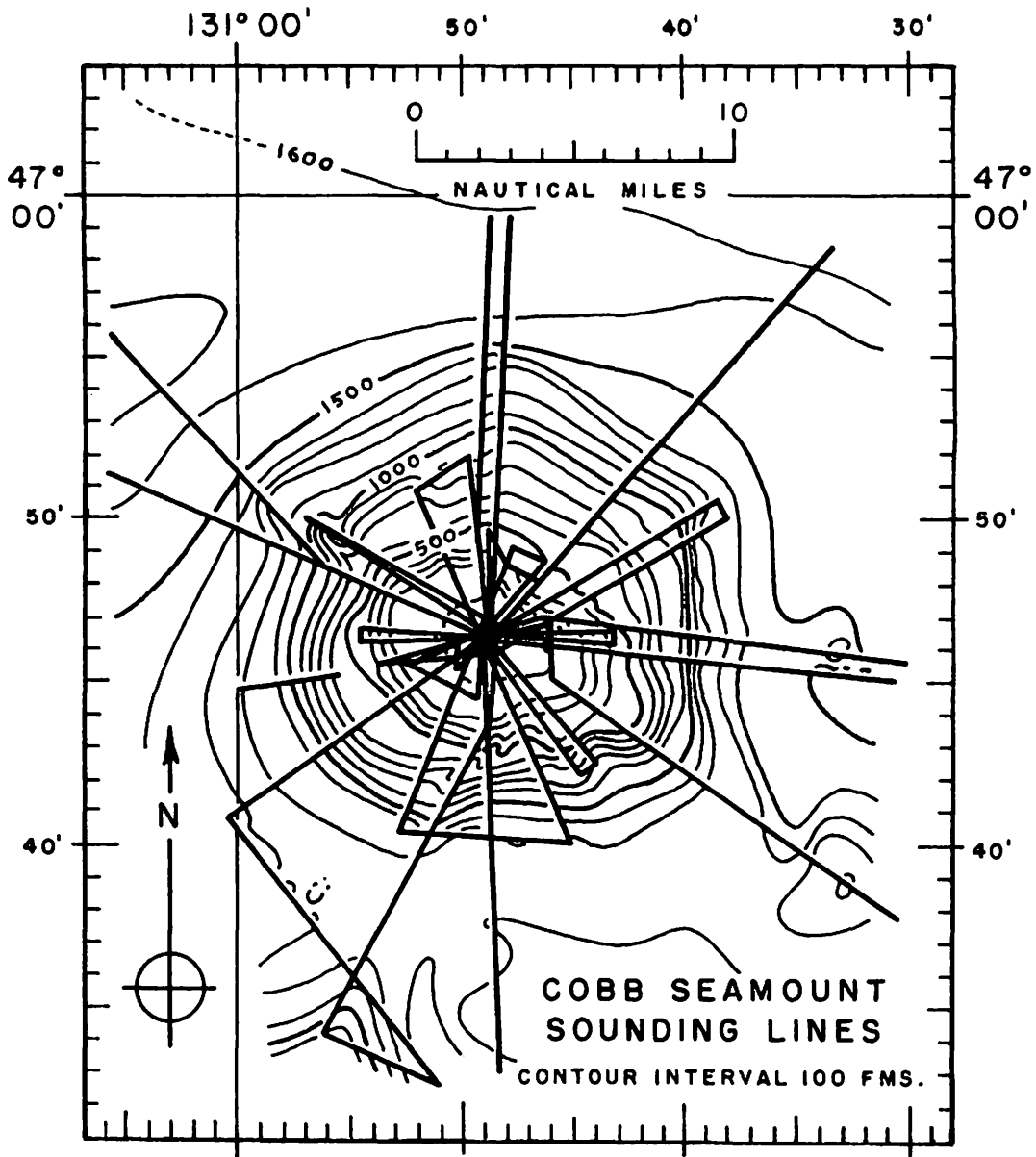


Figure 5. Sounding Traverses

## CHAPTER 2. TOPOGRAPHY

Methods

Any valid interpretation of the history of Cobb Seamount subsequent to its formation is in a large part dependent on the accuracy of the bathymetric survey. This accuracy is dependent in turn on the navigational control, precision of depth measurements, and distribution of the soundings.

Navigation. The accuracy of loran and celestial navigation in the area of Cobb Seamount is of the order of  $\pm 1$  nautical mile; however, a much greater degree of accuracy of the positions of all soundings on the mountain relative to one point, the top, must be maintained. In order to achieve the desired precision, a raft was constructed to support a radar reflector on an antenna. Attached to the raft, anchored on the top of the mountain, was a 6-foot blimp-like balloon. This balloon held another reflector about 90 feet aloft (Frontispiece). The raft and balloon were used as a reference point for horizontal control of all the sounding traverses. Because sea-return inhibited the use of radar, the sounding lines were controlled by alidade, dead reckoning and, at great distances, loran. To eliminate some of the errors of dead reckoning most of the sounding lines were reciprocal lines; that is, the return course to the raft was reciprocal to the departure course with whatever compensation alidade and sea conditions dictated. Although approximately 500 miles of soundings were taken over and near the mountain, only 300 miles were sufficiently accurate for use in determining the final contours (Figure 5).

Echo Sounding. A second consideration in the determination of the accuracy of a bathymetric chart is the precision of the sounding instrument. An EDO continuously-recording echo-sounder was used in this survey. This instrument was modified by installation of a frequency control unit which increased precision of timing, and multiple styli which afforded an expanded scale for determining the microrelief at greater depths. In an attempt to determine the shape of Cobb Seamount as accurately as possible it was decided to correct all soundings by using the true sound velocity as determined from salinity and temperature measurements in the area.

Slope Correction. The soundings represent the shortest distance between the ship and that portion of the bottom within the diameter of the sound cone which gives a recognizable return echo. The more-or-less directional sound cone of modern fathometers has an effective spread of approximately 30 degrees. In an area of irregular topography, the distance recorded is generally not the true depth under the ship but, in most cases, the distance from the ship to a position somewhat up-slope. A great deal of controversy exists concerning the application of slope corrections. These corrections have not been applied generally in the past because of inadequate knowledge concerning sound paths and the tedium of the correction methods. However, in order to present the shape of the mountain as accurately as possible, slope corrections have been made even though certain assumptions were involved. These corrections have been applied only to the profiles of the mountain illustrated in Figures 6 and 7.

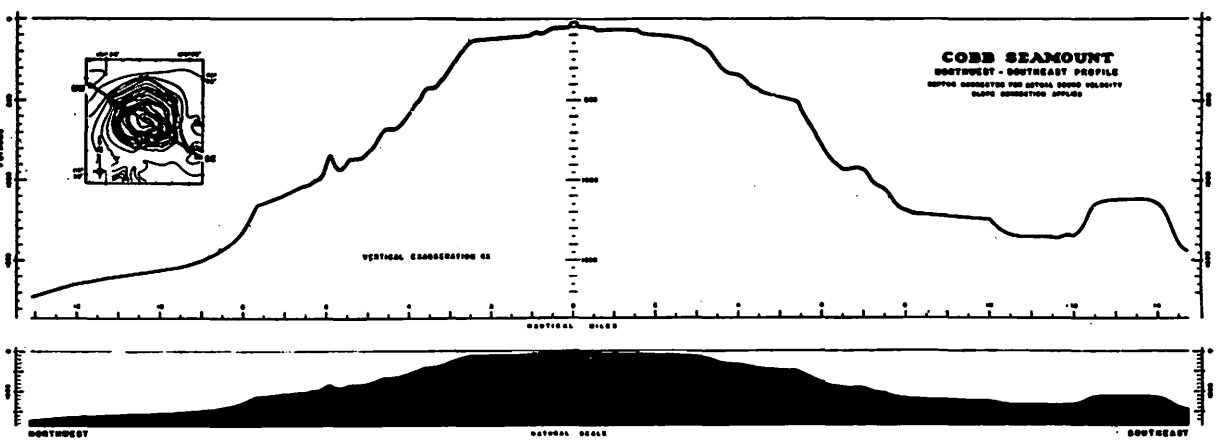
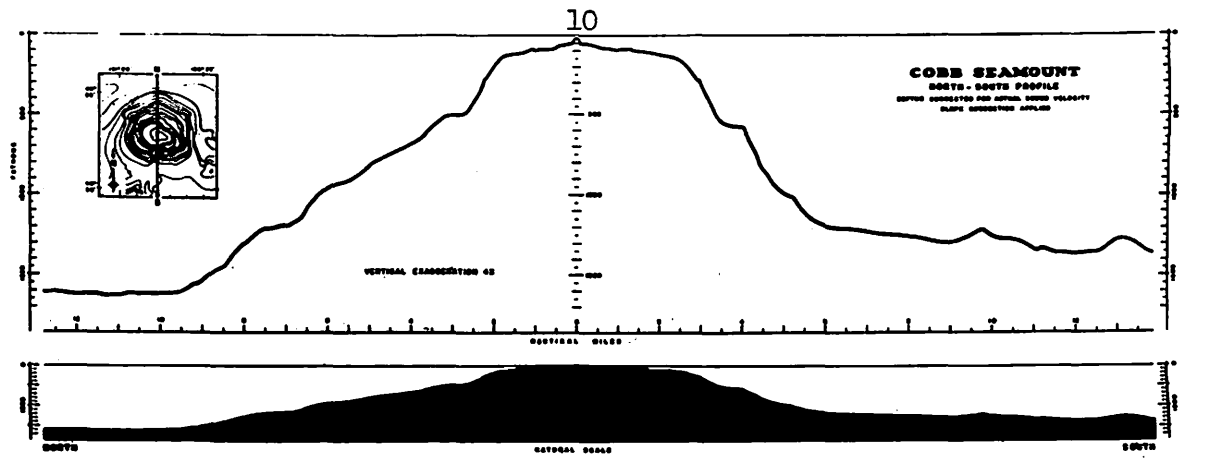


Figure 6. Profiles of Cobb Seamount.

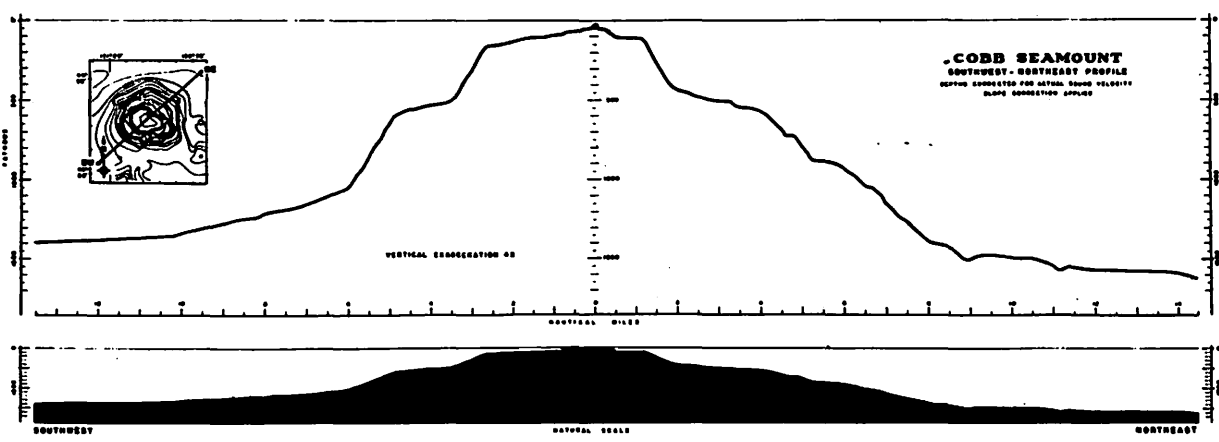
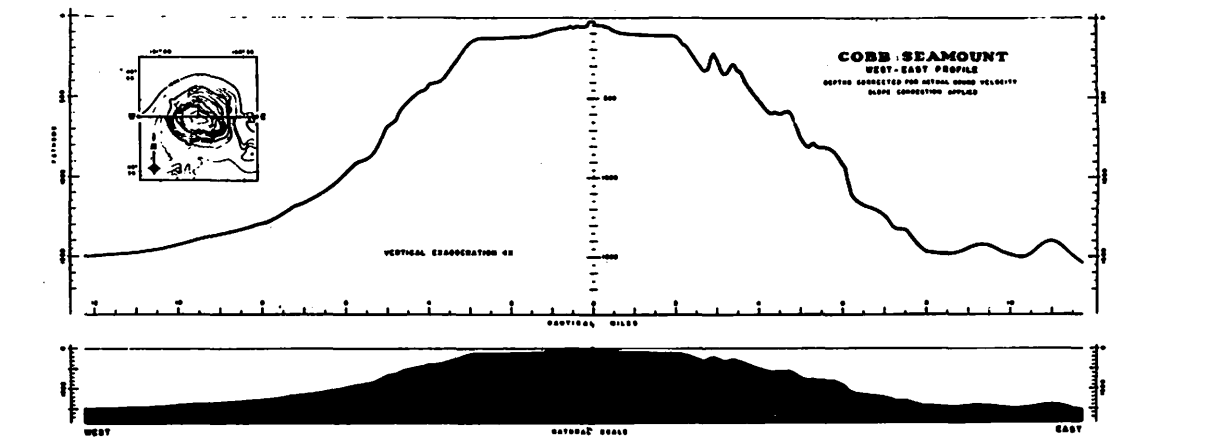


Figure 7. Profiles of Cobb Seamount.

## Morphology of Cobb Seamount

As shown in Figure 8, Cobb Seamount is approximately 1500 fathoms (9000 feet) in relief, 17 nautical miles wide at the base, and has an area of 240 square nautical miles. The mean slope is 12 degrees and slightly concave upward. The shoalest point on the mountain is 18 fathoms (108 feet), which is the top of the small pinnacle defined by the 25-fathom contour. The mountain is oval in plan and quite symmetrical in profile (Figures 6 and 7). The more significant features are discussed here in brief.

Pinnacle. The pinnacle of the mountain stands as a single spire with 160-foot relief. It rises from a 45-fathom terrace to within 18 fathoms (108 feet) of the surface and is characterized by steep slopes (45 degrees) and a flat top. Figure 9 shows representative fathograms of the pinnacle recorded on the 600-foot range of the echo-sounder. The break in slope at the top of the pinnacle is at 20 fathoms (120 feet). The area above this depth is about 400 yards east and west, and 300 yards north and south. An extensive investigation of the top of this pinnacle revealed that previously-reported shoal depths of 15 and 16 fathoms were probably a misinterpretation of the traces on the fathograms caused by echoes from fish.

Terraces. Cobb Seamount is indented by three pronounced terraces. The break in slope of the uppermost terrace ranges between 45 and 50 fathoms; however, this terrace is a well-developed feature. The distance from the base of the pinnacle to the break in slope of the uppermost terrace is approximately 0.5 nautical mile. Below the 45-fathom terrace there is an indication of a less prominent 80-fathom terrace on the southwest and southeast sides of the pinnacle.

The terraced pinnacle is located near the center of a 100-fathom plateau having a diameter of approximately 4.5 nautical miles. This "100-fathom" terrace actually varies in depth between 85 and 130 fathoms. The average depth at the break in slope is 120 fathoms and the slopes immediately below this terrace are about 22 degrees.

The third terrace, termed the "500-fathom" terrace (Figure 8), is not continuous around the mountain but is a series of terraces ranging from 450 to 650 fathoms in depth. Careful examination of the soundings and contours suggests that this range in depths cannot be attributed readily to regional tilting. Below this terrace the declivity of the bottom decreases gradually and, in general, the slopes of the mountain merge gently into the deep-sea floor.

Steep Scarp and Marginal Depression. Figure 8 and the west-east profile (Figure 7) reveal a 7.5-mile, straight scarp of about 300-fathom relief. This feature, with slopes greater than 50 degrees, occurs on the east side of the mountain below 950 fathoms.

A crescent-shaped marginal depression exists at the base of Cobb Seamount. This 100-fathom depression about 7 miles wide is concentric with the base of the mountain and occurs only on the northern side. The possible origin for this depression is discussed in a later section.

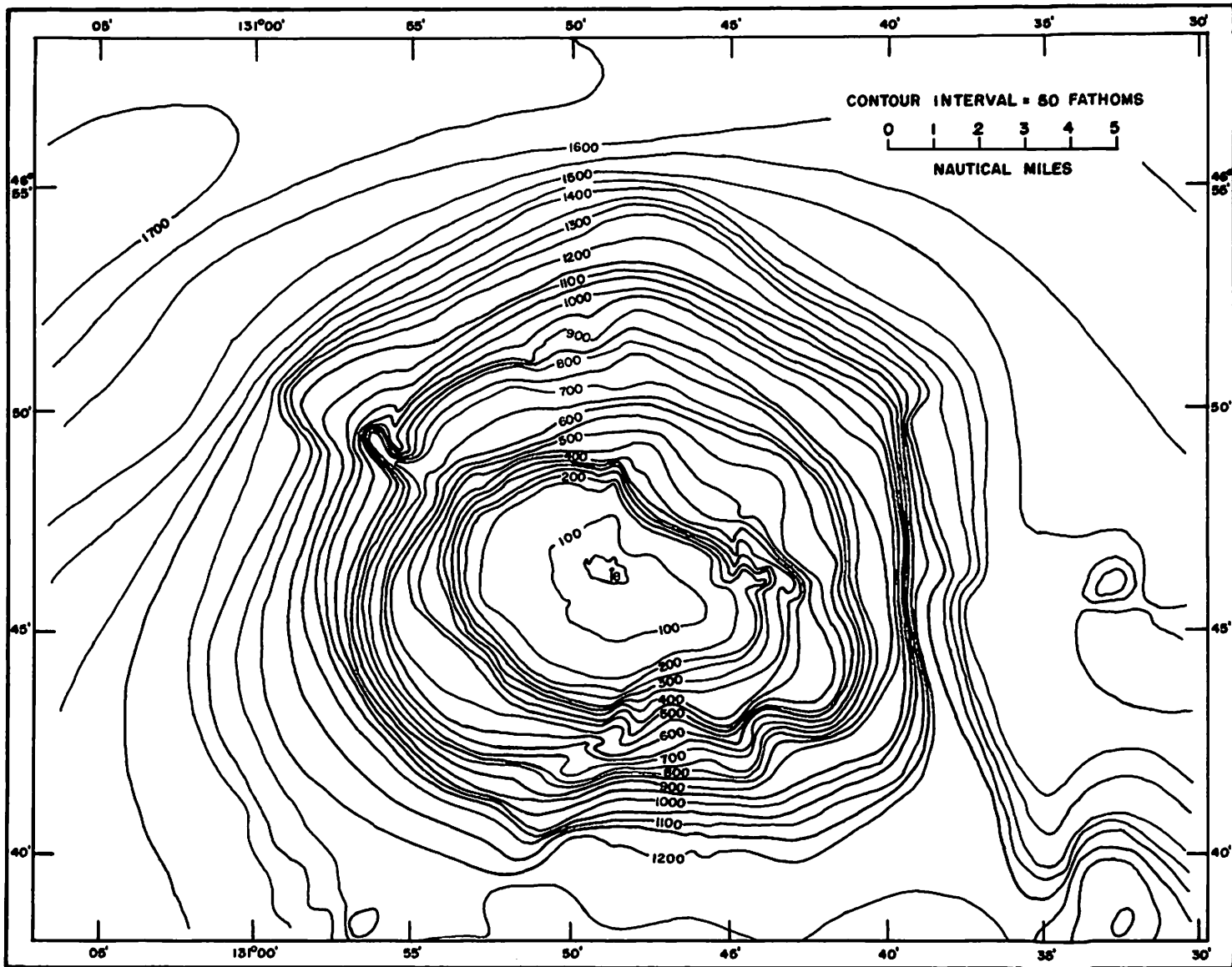
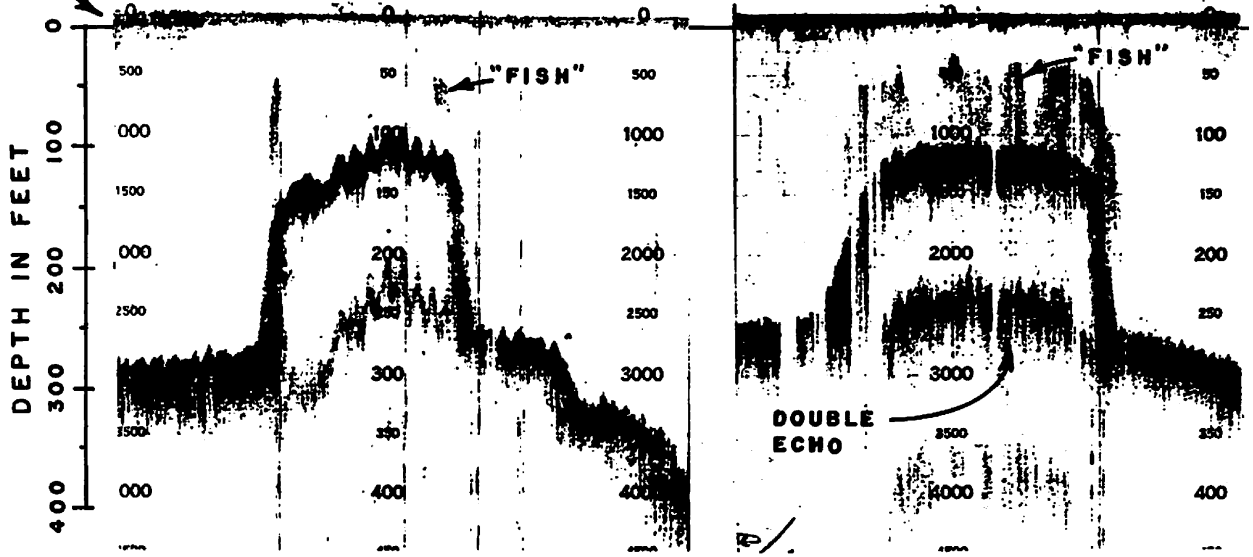
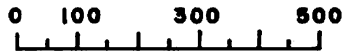


Figure 8. Bathymetry of Cobb Seamount

SCALE LOWERED ~10 FEET  
FOR DRAFT OF THE SHIP

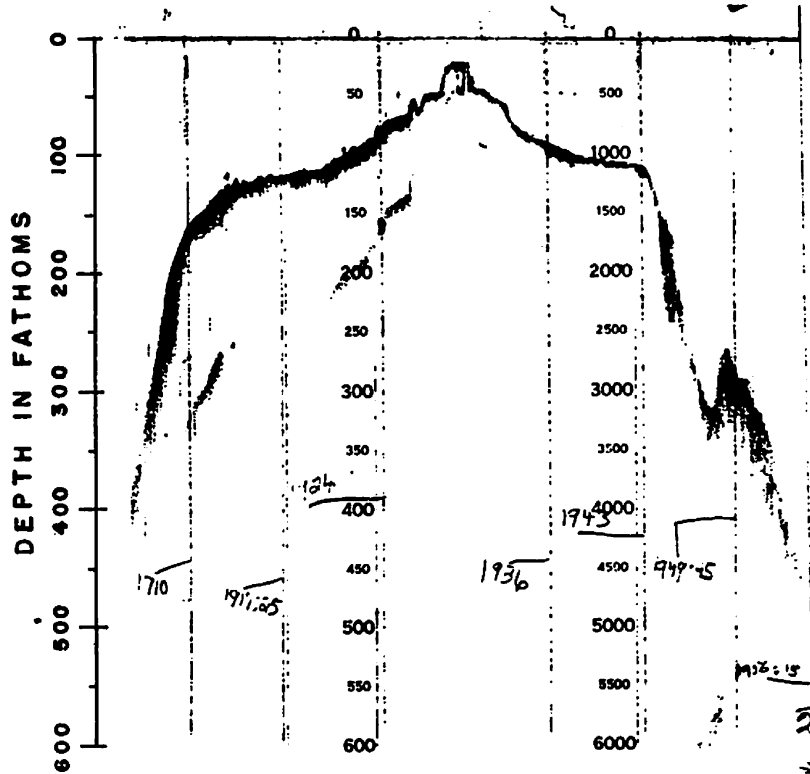
YARDS



A: North-South Fathogram of the Pinnacle; Note the "Fish" Traces

B: East-West Fathogram of the Pinnacle

NAUTICAL MILES



C: East-West Fathogram of the Upper Portion of Cobb Seamount

Figure 9. Fathograms of Cobb Seamount

Menard and Dietz (1951) have discussed the shallow depressions at the transition between the flank of seamounts and the sea floor. These depressions, discovered on echograms of some of the seamounts in the Gulf of Alaska, are from 5 to 100 fathoms below the surrounding floor. Because of lack of soundings it has not been established whether these depressions extend entirely around the mountains. From a study of one relatively well-surveyed seamount (Dickens Seamount), Menard and Dietz suggest that these depressions are possibly crescent-shaped.

## CHAPTER 3. GEOLOGY

Methods

Approximately 50 sampling attempts were made with gravity corers, dredges, and grabs. A description and discussion of the samplers used in this survey is included as Appendix B. The positions, depths, types of samplers, and general descriptions of the 34 samples retrieved are included in Tables 1 and 2. The sampling positions (Figure 10) are referred to the celestial positions of the pinnacle, and the depths are uncorrected for mean sounding velocity. The 30 samples taken in the immediate vicinity of the mountain are listed with respect to their age and their location on or near significant features of the mountain (Table 1).

Bottom Samples

Samples from Seamount. Many coring attempts were made above the base of the mountain; however, only 3 small samples were retrieved. These samples (C-11, C-12, C-13), obtained at 1200 fathoms on the western side of the mountain, consist of indurated globigerina ooze with manganese dioxide overlain by a very thin deposit of soft ooze.

Two large-pipe dredge hauls were taken from below the break in slope of the 100-fathom terrace. These samples consist of fragments of poorly cemented sandstones and basalt boulders. The sandstones of these dredge hauls (D-22 and D-23) contain an abundance of Late Miocene to "Recent" benthonic Foraminifera. Numerous fragments of algae are embedded in the sandstone of D-23 (Figure 11). These fragments, the largest of which is 0.25-inch long, were examined by Professors George B. Rigg of the University of Washington and Robert F. Scagel of the University of British Columbia. They believe that this alga is possibly of the genus Polysiphonia; however, the number of cells per unit area seems too great for this genus. Professor Scagel has indicated that a study of this specimen will be made by a paleobotanist of the University of British Columbia.

Four samples were taken on and just below the "500-fathom" terrace (D-24, D-25, D-26, C-8). Three of these samples were obtained by a small-pipe dredge trailing behind a tooth dredge (see Appendix B). The fourth was taken by a gravity corer. The sediments are dominantly (80%) benthonic and planktonic Foraminifera.

The three large-pipe dredge samples (D-16, D-17, D-18) taken from the 100-fathom terrace consist mainly of subangular to well-rounded basalt pebbles and cobbles and hydrocoral fragments. The minor sands associated with this gravel do not contain any recognized indicators of age. The hydrocorals from these samples were examined by Professor J. Wyatt Durham of the University of California. Doctor Durham considered the species to be new with affinity to Allopora moseleyana Fisher from the Bering Sea and Aleutian Islands. Hydrocoral fossils in general have little age determination value; it is possible at this time to say only that the specimens from Cobb Seamount are Tertiary or younger.



NAUTICAL MILES

• C-6

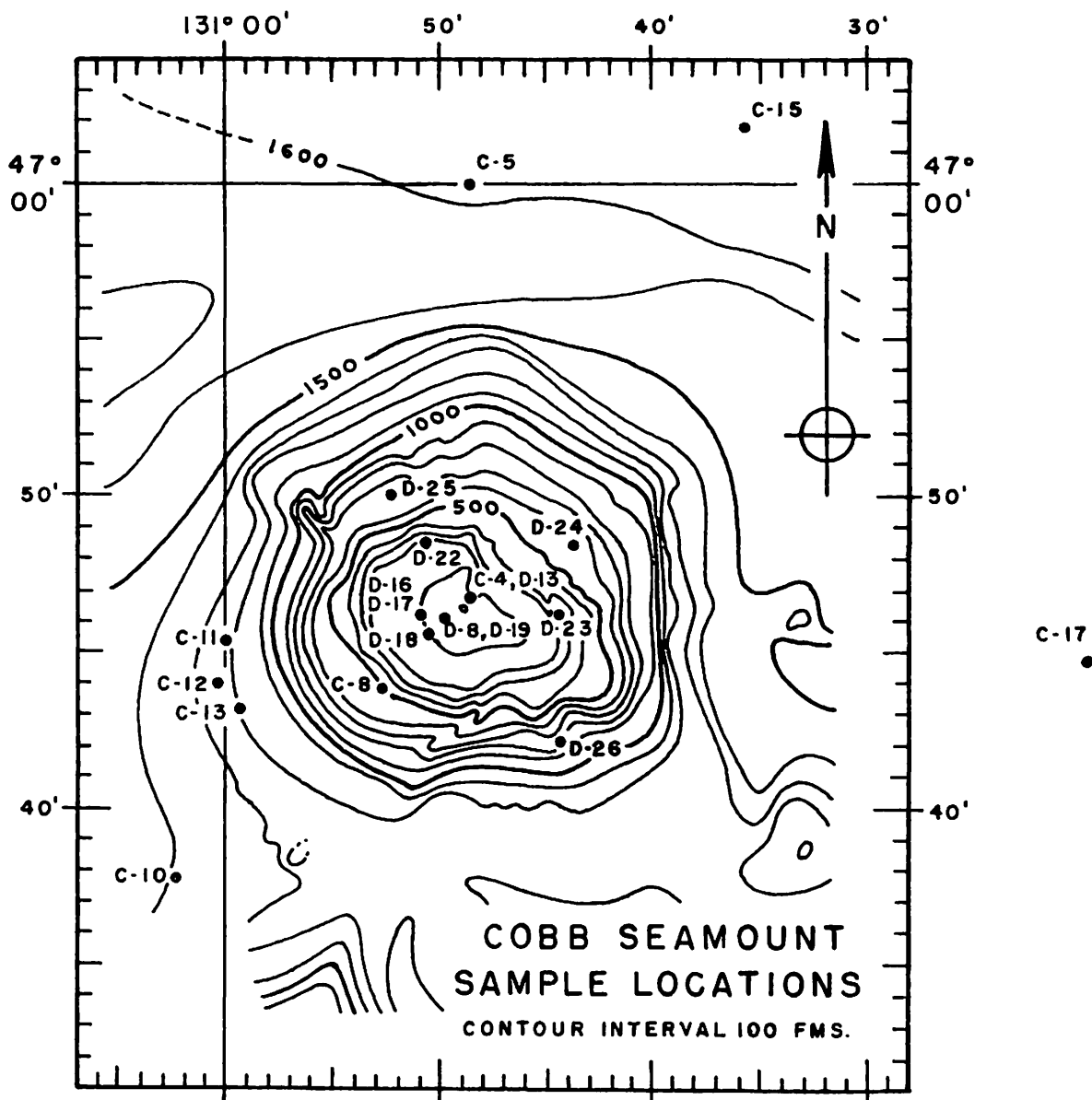


Figure 10. Location Chart for Bottom Samples

TABLE 1

## DESCRIPTION OF BOTTOM SAMPLES RETRIEVED FROM COBB SEAMOUNT

No.	Position	Depth (fms)	Position on mountain	Sampler	Description
C-12	46°43.9' N 131°00.3' W	1220	W. slope	Phleger core (disturbed)	Chunks of indurated globigerina ooze with minor benthonic Foraminifera, fine sand, clay and manganese dioxide grains. This fossil ooze covered evidently only by thin deposit of 'Recent' sediment.
C-13	46°43.2' N 130°59.2' W	1165	W. slope	Phleger core (disturbed)	Chunks of indurated, manganese-layered globigerina ooze with minor benthonic Foraminifera, manganese grains and clay.
C-11	46°45.3' N 130°59.8' W	1180	W. slope	Gravity core (disturbed)	Chunks of manganese dioxide, one containing <u>Globigerina</u> .
D-22	46°48.5' N	200- 150	NW. below 100-fm. terrace	Pipe dredge	One small boulder of dense basalt exhibiting a smooth, almost reniform, upper surface; cobbles of basalt covered with indurated, poorly sorted basalt gravel; chunks of fine to medium, pale yellowish orange, sand with very abundant benthonic Foraminifera, small Pelecypods and shell fragments, and echinoid spines. A few hydrocoral fragments (Figure 11).
D-23	46°46.2' N 130°44.2' W	210	NE. below 100-fm. terrace	Pipe dredge	Three small boulders of vesicular basalt; large cobble of porphyritic basalt; pebbles of basalt covered with the sand described below; chunks of medium, moderate olive brown sand containing abundant benthonic Foraminifera with minor shell fragments and echinoid spines, many fragments of algae (Figure 11).

TABLE 1. (continued)

No.	Position	Depth (fms.)	Position on mountain	Sampler	Description
D-25	46°49.9' N	650	NW. on 600-fm. terrace	Double dredge	Globigerina ooze with minor benthonic Foraminifera and very few fine sand grains.
D-24	46°48.4' N 130°43.8' W	540	NE. on 500-fm. terrace	Double dredge	Foraminiferal sand; <u>Globigerina</u> most abundant but benthonic forms, finely comminuted shell fragments, and echinoid spines give sandy texture coarser than D-25, finer than D-26.
D-26	46°42.2' N 130°44.7' W	695	SE. on slope below 500-fm. terrace	Double dredge	Poorly sorted, medium gravel with few shell fragments and echinoid spines; subrounded pebbles of basalt and angular to subangular fragments of ferruginous, manganiferous shale.
C-8	46°43.8' N 130°52.8' W	510	SW. on 500-fm. terrace	Gravity core (disturbed)	Foraminiferal sand, predominantly <u>Globigerina</u> but benthonic forms very abundant, minor manganese dioxide and mafic mineral grains.
. . . . .					
D-16	46°46.0' N 130°51.0' W	110	W. on 100-fm. surface	Pipe dredge	Two subrounded basalt pebbles.
D-17	46°46.2' N 130°51.0' W	108	W. on 100-fm. surface	Pipe dredge	Three subangular basalt cobbles, one evidently freshly broken from outcrop; brachiopods, hydrocorals.
D-18	46°45.6' N 130°50.8' W	110	W. on 100-fm. surface	Pipe dredge	Subrounded and rounded basalt pebbles and cobbles of three textures: (1) heavy dense - rounded, (2) vesicular - generally subrounded, (3) subhedral - slightly worn slabs; abundant hydrocoral fragments, brachiopod shells (Figure 12).

TABLE 1. (continued)

No.	Position	Depth (fms)	Position on mountain	Sampler	Description
C-4	46°46.7' N 130°48.5' W	63	NE. below 45-fm. terrace	Phleger core (disturbed)	Sand-size shell and hydrocoral fragments with echinoid spines; small mollusks and abundant benthonic Foraminifera; two algae-encrusted basalt pebbles.
D-8	46°46.2' N 130°49.4' W	49	SW. on slope below 45-fm. terrace	Pipe dredge	Microporphyritic basalt slabs and dense rounded cobbles and pebbles; abundant worm tubes and hydrocoral fragments, one Pecten valve (Figure 12).
S-1	46°46.2' N 130°49.2' W	55	SW. on slope below 45-fm. terrace	Petersen grab	Coarse shell fragments, gastropod shells, worm tube, and abundant Foraminifera.
.....	.....	.....	.....	.....	.....
D-19	46°46.2' N 130°49.0' W	55	SW. on 45-fm. terrace	Pipe dredge	Subrounded basalt cobbles and pebbles; large shell fragments, <u>Mytilus</u> sp., and Pectens, (120 x 50 mm) and smaller fragments; one phosphate-coated limestone cobble (Figure 12).
D-13	46°46.6' N 130°48.8' W	40	N. on 45-fm. terrace	Net dredge	Echinoids, gastropods (see Biology section).
C-1	46°46.4' N 130°48.6' W	42	E. on 45-fm. terrace	Phleger core (disturbed)	Minute amount of hydrocoral and shell fragments.
C-2	46°46.5' N 130°49.0' W	38	NW. on 45-fm. terrace	Phleger core (disturbed)	Minute amount of hydrocoral and shell fragments.
C-3	46°46.6' N 130°48.9' W	38	NW. on 45-fm. terrace	Phleger core (disturbed)	Minute amount of hydrocoral and shell fragments.
D-6	46°46.4' N 130°48.9' W	25-50	On pinnacle	Anchor dredge	One crinoid.

TABLE 1. (continued)

No.	Position	Depth (fms.)	Position on mountain	Sampler	Description
D-9	46°46.4' N 130°49.0' W	45-25	On pinnacle	Pipe dredge	Mollusks, echinoids, anemones (see Biology section).
D-10	46°46.4' N 130°48.8' W	25	On pinnacle	Pipe dredge	Barnacle, echinoids, pelecypods, anemones (see Biology section).
D-21	46°46.4' N 130°48.8' W	19	On pinnacle	Pipe dredge	Pelecypods, echinoids (Figure 12) (see Biology section).
D-27	46°46.4' N 130°48.8' W	35-20	On pinnacle	Tooth dredge	Pelecypods, worm tubes, echinoids (see Biology section).
D-14	46°46.4' N 130°48.8' W	20-45	On pinnacle	Net dredge	Pelecypods, echinoids, crabs, two heavy <u>Hinnites</u> shells; one subrounded basalt pebble (see Biology section).
D-1	46°46.4' N 130°48.8' W	20	On pinnacle	Pipe dredge	Pelecypods, echinoids (see Biology section).
D-2	46°46.4' N 130°48.8' W	24	On pinnacle	Pipe dredge	Pelecypods, worm tubes, echinoids (see Biology section).
D-3	46°46.4' N 130°48.8' W	30-20	On pinnacle	Pipe dredge	Pelecypods, echinoids (see Biology section).



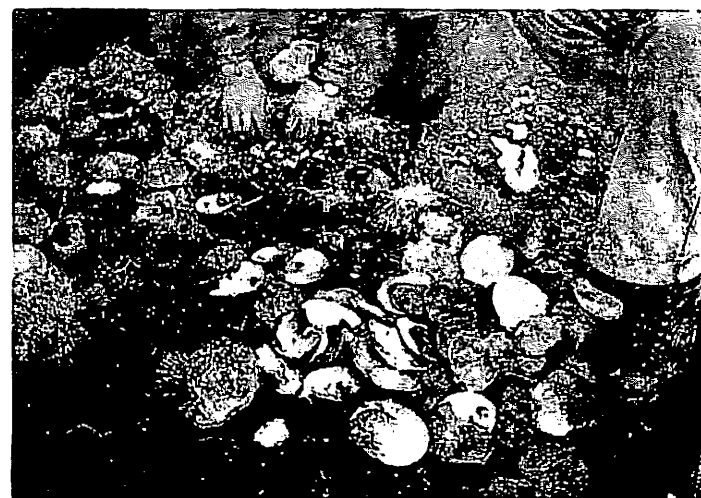
DREDGE HAUL D-18



DREDGE HAUL D-8



DREDGE HAUL D-19

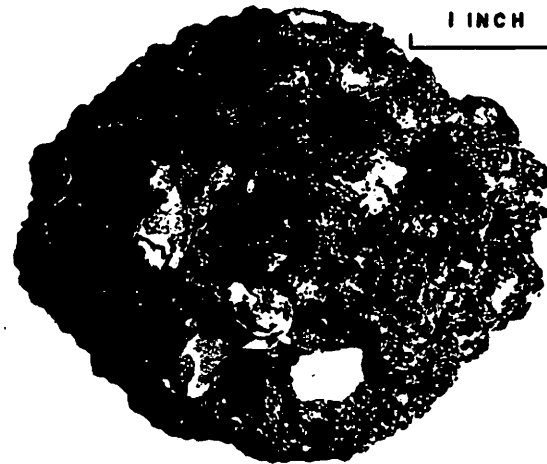


DREDGE HAUL D-21

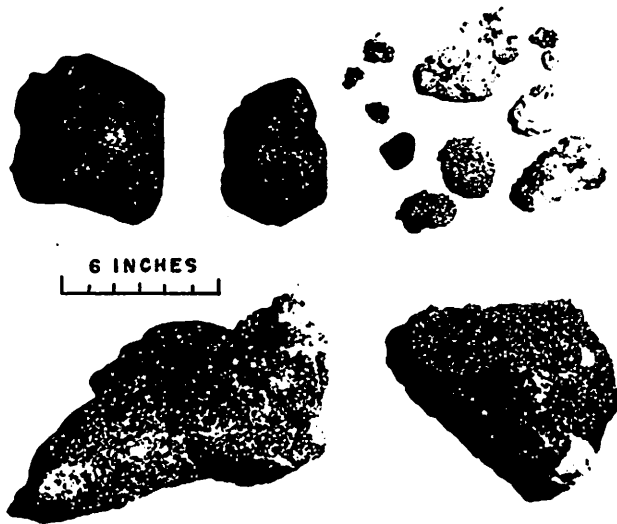
Figure 11. Photographs of samples below 100 fathoms.



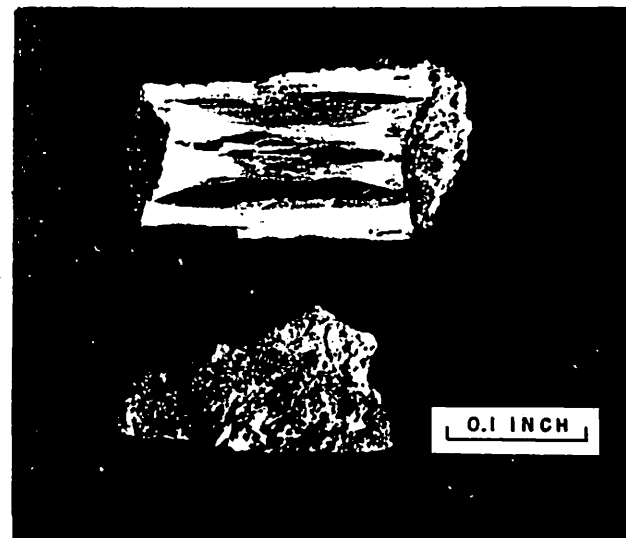
DREDGE HAUL D-22



ROUNDED SANDSTONE FROM D-22



DREDGE HAUL D-23



SPECIMEN OF ALGAE FROM D-23

Figure 12. Photographs of samples below 45 fathoms.

The eight samples taken by the pipe dredge, Phleger corer, and Petersen grab from on and just below the 45-fathom terrace are dominantly shells and shell fragments. Well-worn and rounded basalt pebbles and cobbles also were recovered. The shells are those of pelecypods, gastropods, brachiopods, and polychaetes. The most striking feature of these samples is the abundance of an intertidal mussel shell, similar in appearance to Mytilus californicus, but too massive to be immediately assigned to this species (Figure 12). The poor state of preservation of the shells precludes a positive identification.

The nine dredge hauls from the sides and top of the pinnacle reveal shells and living fauna (see Biology section). Although many attempts to break through the shell layer were made with ten different sampling instruments, no rocks or rock fragments were retrieved from the pinnacle.

Peripheral Sediments. Cobb Seamount lies at the center of a globigerina ooze band 100 by 150 miles in length paralleling the Oregon and Washington coasts, 300 miles offshore. All Northeast Pacific planktonic Foraminifera are more abundant in the sediments of this area and some ten species are abundant only within this area. It is possible that the northern limit of the ooze band was the northern limit of these species when the ooze was deposited. Diatoms increase north of the ooze band becoming abundant enough to constitute diatomaceous ooze. The eastern boundary of the ooze band is determined by the increasing clastic content of sediments onshore which mask the planktonic elements. The southern boundary is sharp and may be the function of local topography as it coincides with the southern end of a seamount chain. The western boundary of the ooze area is less well-defined. Radiolaria-rich sediments lie west of the ooze band. Although Radiolaria have not been systematically studied, there would seem to be a greater variety of genera within the ooze area than in the Radiolaria-rich sediments to the west, although numerically masked by Globigerina. The western boundary does not coincide with any pronounced depth changes and the depth of solution of planktonic tests is not approached. The few tests observed to the west do not show great solution. Surface currents may be the controlling factor.

The descriptions of the four gravity cores taken from the sea floor near Cobb Seamount are given in Table 2. These cores, 61 to 136 cm. in length consist of brown silt overlying globigerina ooze. The presence of a sharp contact between the brown silt and globigerina ooze noted in these cores and other samples from the ooze area indicate a change in sedimentary environment. A third environment is suggested by the massive clay encountered at the base of core 139-5.

Radio-carbon datings were done for two intervals of core 139-5 by Humble Oil and Refining Company, Exploration Department in connection with a current study of Northeast Pacific sediments and Foraminifera by Y. R. Nayudu and B. J. Enbysk. The intervals and dates are:

15-25 cm.	12,400± 375 years
90-100 cm.	19,300± 950 years

TABLE 2

DESCRIPTION OF CORES NEAR COBB SEAMOUNT\*  
(Cores on mount are included in Table 1)

Gravity Core No. 139-5	Depth: 1580 fms.	Lat. 47°00.0' N. Long. 130°47.0' W.
cms.		
0 - 8	Brownish black (5YR2/1) silt.	
8 - 16	Medium olive gray (5Y5/1) globigerina ooze with pockets of <u>Globigerina</u> . Also layers and pockets of silt with a few <u>Globigerina</u> .	
16 - 16½	Brownish black (5YR2/1) silt.	
16½ - 29	Light olive gray (5Y6/1) globigerina ooze with layers and pockets of olive gray silt less abundant in <u>Globigerina</u> .	
29 - 50½	Light olive gray (5Y6/1) globigerina ooze.	
50½ - 56½	Dusky yellow (5Y6/4) and 5Y6/1 mottled globigerina ooze with very thin olive gray layers.	
56½ - 111½	Light olive gray (5Y6/1) globigerina ooze with occasional layers (c-cm. thick) of olive gray ooze.	
111½ - 115	Light olive gray (5Y6/1) globigerina ooze layers alternating with olive black (5Y2/1) globigerina ooze.	
115 - 136	Light olive gray (5Y6/1) globigerina ooze grading from globigerina-rich clay to globigerina-poor massive clay.	
Gravity Core No. 139-6	Depth: 1555 fms.	Lat. 47°13.0' N. Long. 130°46.0' W.
cms.		
0 - 12	Dusky brown (5YR2/2) silt.	
12 - 21	Dusky brown (5YR2/2) and light olive gray (5Y5/1) mottled globigerina ooze.	
21 - 25½	Light olive gray (5Y6/1) globigerina ooze consisting of more than 90% <u>Globigerina</u> and a few quartz grains and rock fragments. White and brown stained <u>Globigerina</u> give salt-and-pepper appearance. Benthonic Foraminifera are mostly Cassidulinids.	
25½ - 61	Light olive gray globigerina ooze.	

\* Color designations from Munsell system determined on fractured, wet, inner core surfaces.

(continued)

TABLE 2 (continued)

Gravity Core No. 139-10	Depth: 1315 fms.	Lat. 46°36.7' N. Long. 131°01.3' W.
cms. 0 - 6	Dusky yellowish brown (YR2/2) silt. Benthonic Foraminifera fairly abundant. <u>Orbulina</u> flood.	
6 - 11	Dusky yellowish brown silt alternating with light brownish gray (5YR6/1) layers.	
11 - 13	Light brownish gray (5YR6/1) globigerina ooze. Benthonic Foraminifera fairly abundant. <u>Globorotalia</u> very abundant.	
13 - 13½	Light olive gray (5Y6/1) globigerina ooze.	
13½ - 23	Light brownish gray (5YR6/1) globigerina ooze.	
23 - 27	Light olive gray globigerina ooze. A subangular slate pebble orientated with major axis normal to bedding planes occurs at 33 cm. (foreign to area, probably ice or kelp rafted).	
37 - 60	Light brownish gray (5YR6/1) globigerina ooze.	
60 - 61	Light olive gray (5Y6/1) globigerina ooze.	
61 - 63	Light brownish gray (5YR6/1) globigerina ooze.	
63 - 63¼	Grayish green (10GY5/2) globigerina ooze. Somewhat indurated and platy. Benthonic Foraminifera rare.	
63¼ - 75	Light brownish gray (5YR6/1) globigerina ooze with abundant <u>Gyroïdina</u> .	

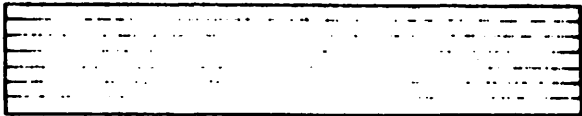
(continued)

TABLE 2 (continued)

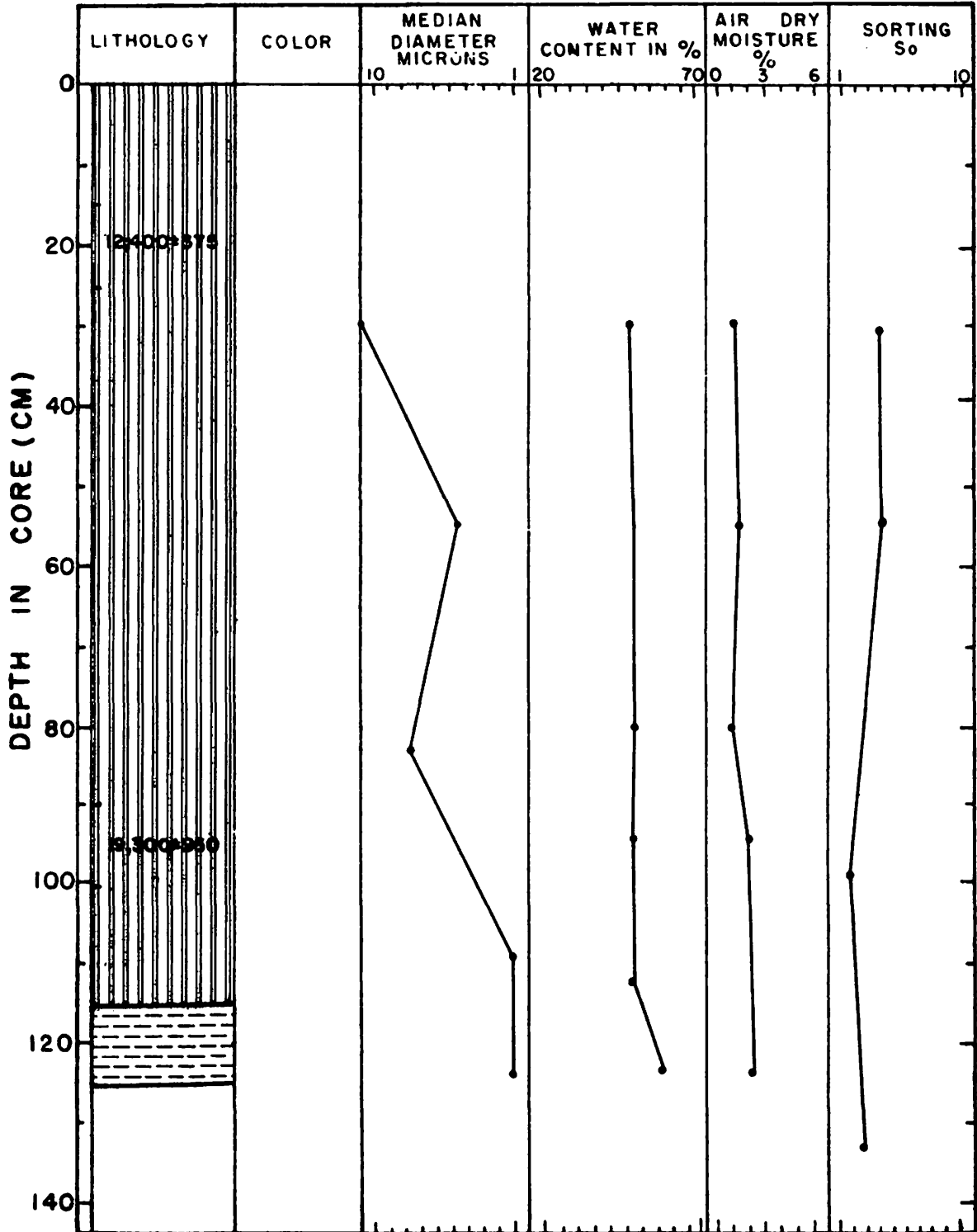
Gravity Core No. 139-15	Depth: 1450 fms.	Lat. 47°02.3' N. Long. 130°35.3' W.
cms. 0 - 4	Moderate brown (5YR3/4) silt.	
4 - 8	Light olive gray (5Y6/1) globigerina ooze (over 50% <u>Globigerina</u> )	
8 - 8½	Moderate brown (5YR3/4) silt.	
8½ - 32	Light olive gray (5Y6/1) globigerina ooze (over 50% <u>Globigerina</u> ).	
32 - 37	Dark yellowish gray globigerina ooze (over 50% <u>Globigerina</u> ). Flood of <u>Globorotalia</u> .	
37 - 53½	Light olive gray (5Y6/1) globigerina ooze (over 50% <u>Globigerina</u> ).	
53½ - 54½	Black (N1), finely fissile, partially consolidated silt rich in manganese with a few angular grains of quartz.	
54½ - 66	Alternating layers of light olive gray and moderate brown globigerina ooze. Occasional subangular small pebble.	
66 - 82	Moderate brown (5YR3/4) silt with black fissile manganiferous fragments, subangular quartz, and chalcedony grains. Some rounded, pitted quartz grains. <u>Globigerina</u> absent. Benthonic Foraminifera and rock fragments gradually decrease in abundance, absent below 85 cms.	
82 - 110	Greenish gray (5GY6/1) massive clay.	

(continued)

Table 2 (continued)

CORE	139-5	DEPTH fms 
LAT.	47° 00.0' N	
LONG.	130° 48.7' W	
DEPTH	1580 fms	
BOTTOM TOPOGRAPHY IN THE VICINITY OF CORE		

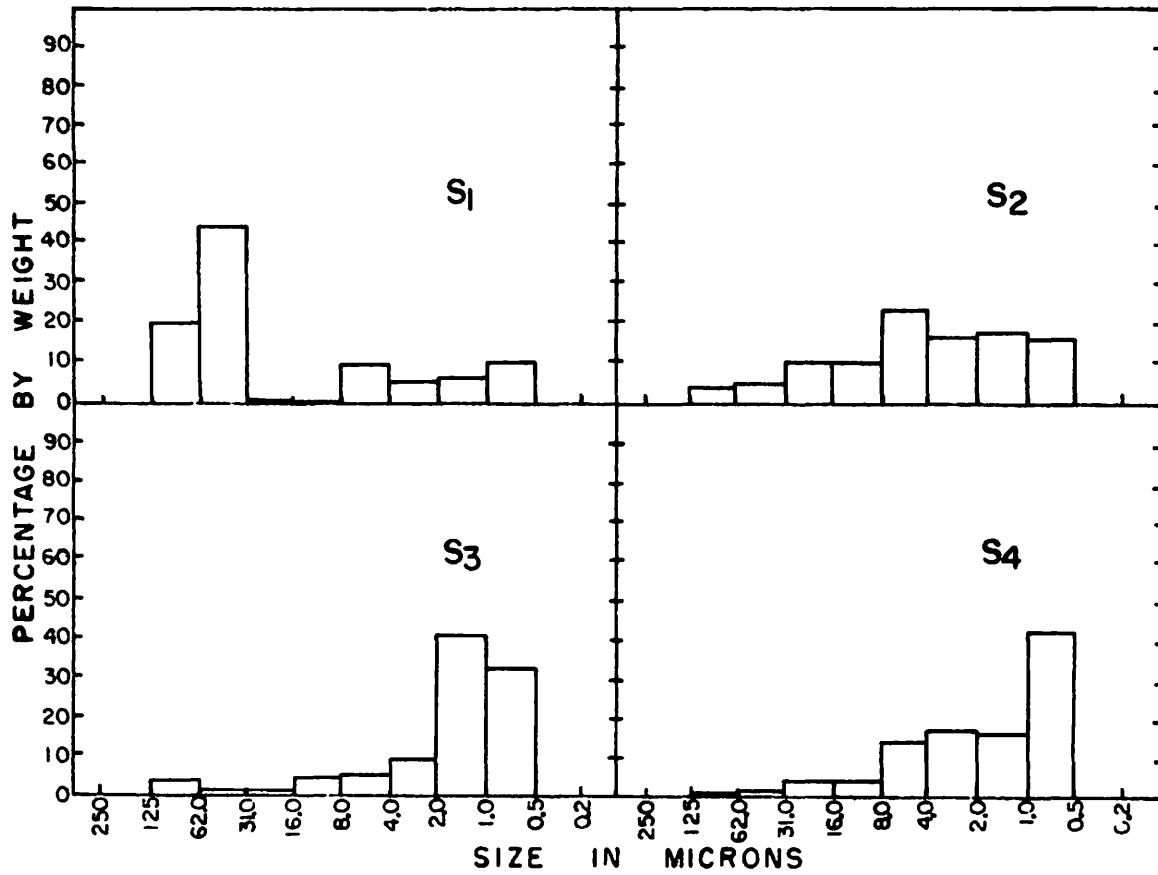
### LITHOLOGY AND ANALYTICAL DATA



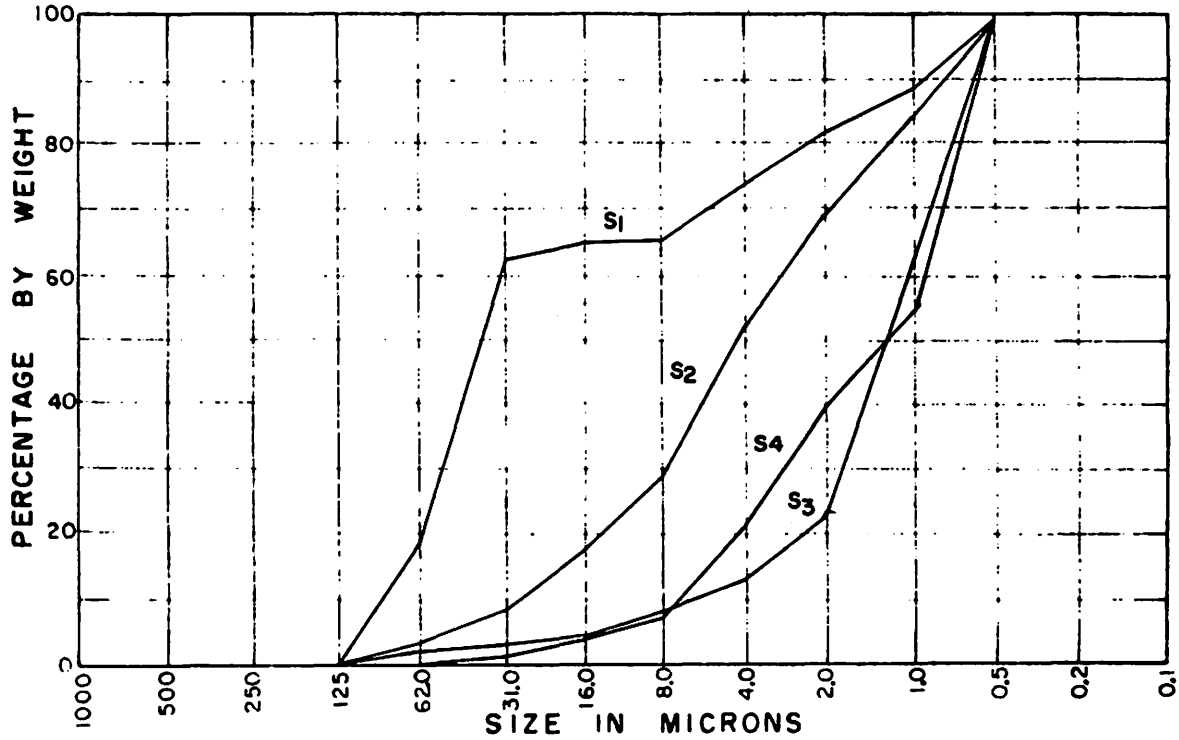
(continued)

CORE 139-5

HISTOGRAMS

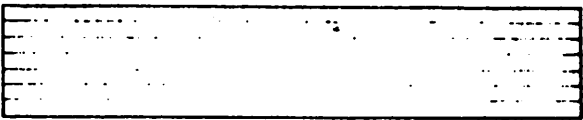


CUMULATIVE CURVES

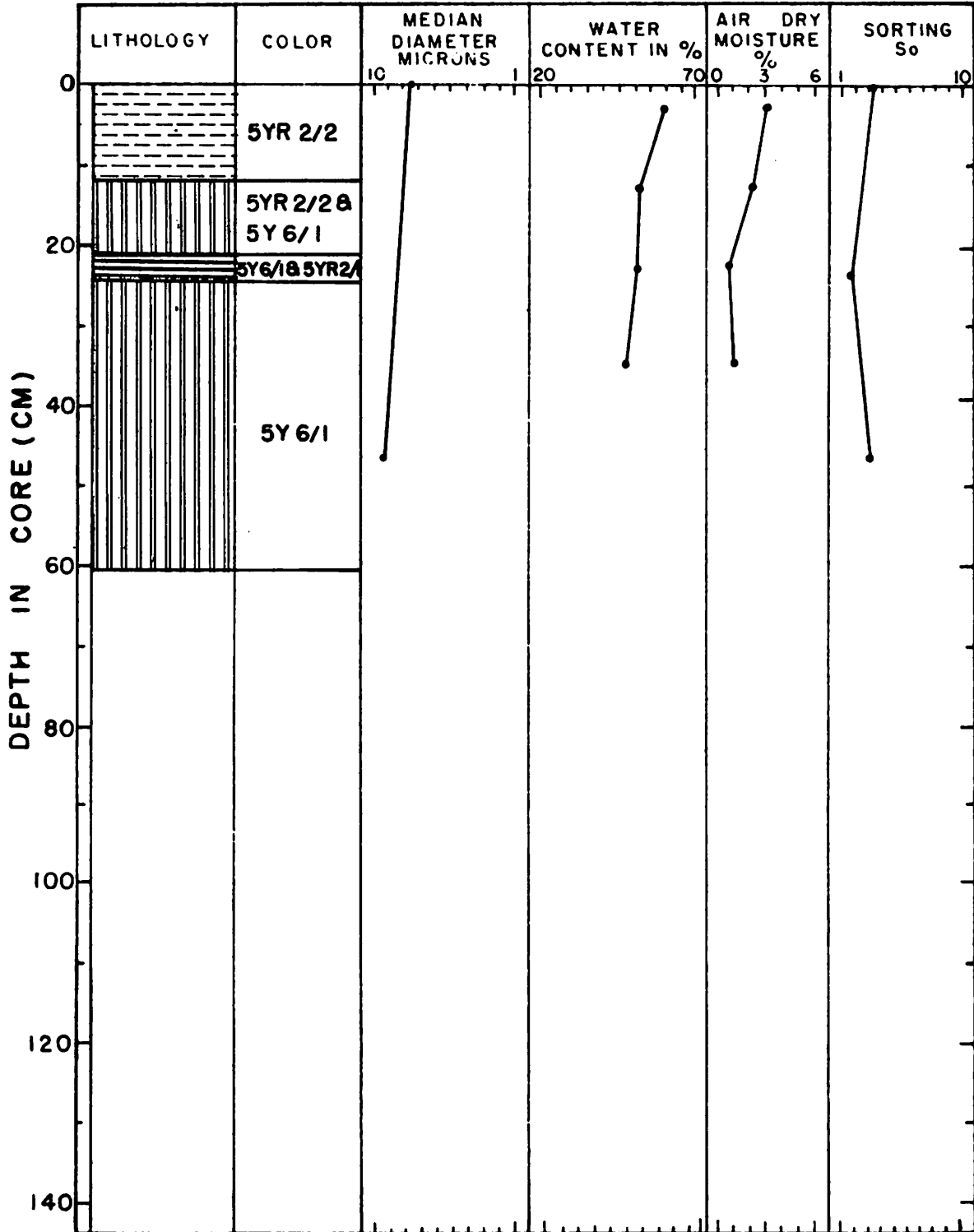


(continued)

Table 2 (continued)

CORE	139-6	
LAT.	47° 14.0' N	
LONG.	130° 47 8' W	
DEPTH	1555 fms	
BOTTOM TOPOGRAPHY IN THE VICINITY OF CORE		

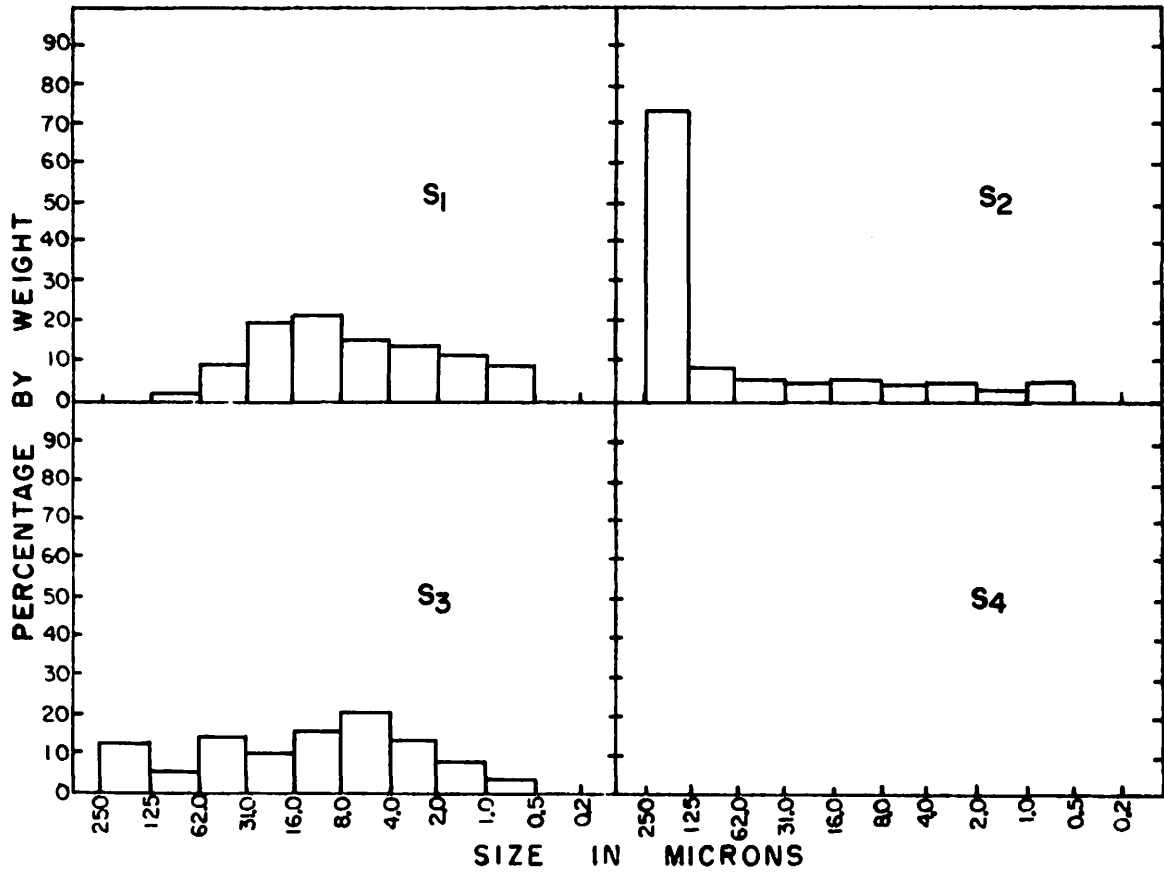
LITHOLOGY AND ANALYTICAL DATA



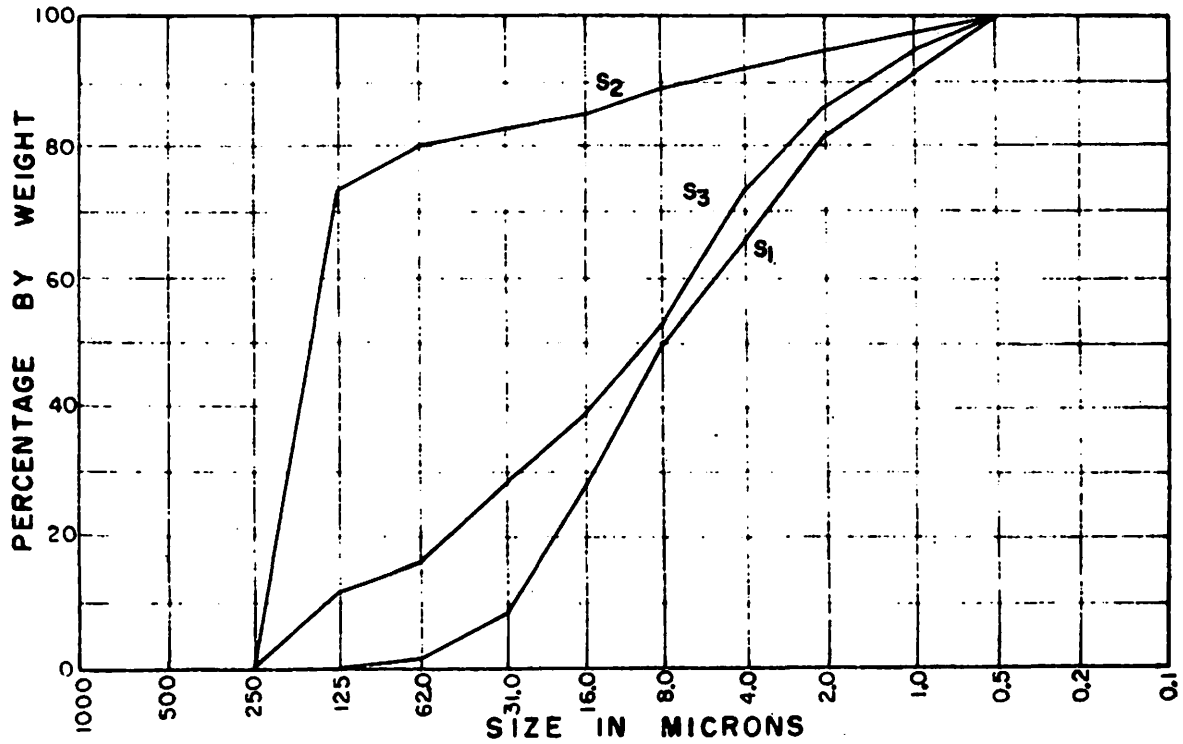
(continued)

Table 2 (continued)  
CORE 139-6


### HISTOGRAMS



### CUMULATIVE CURVES

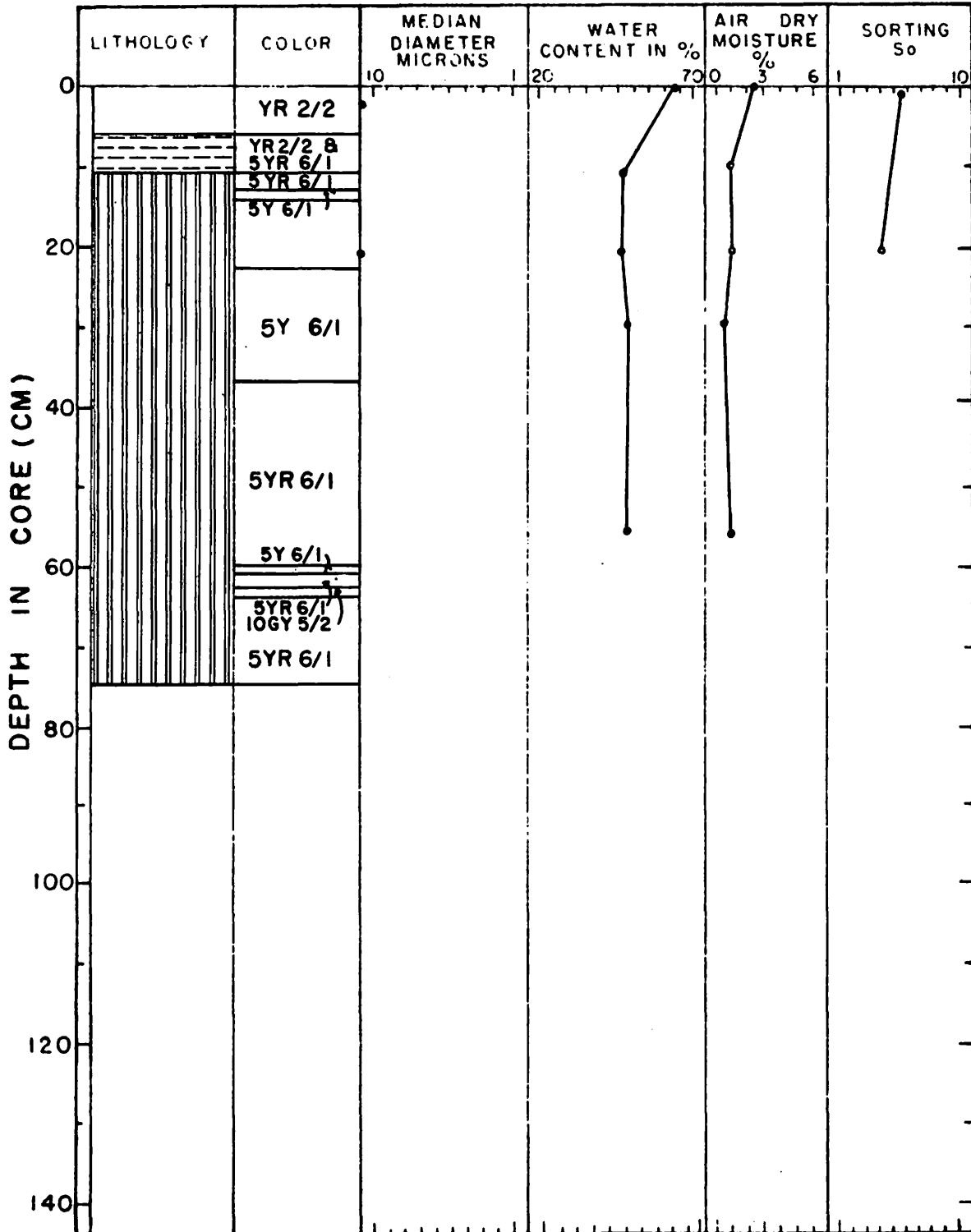


(continued)

CORE	139-10	
LAT.	46° 37.8 N	
LONG.	131° 02.3 W	
DEPTH	1315 fms	

BOTTOM TOPOGRAPHY IN THE VICINITY OF CORE

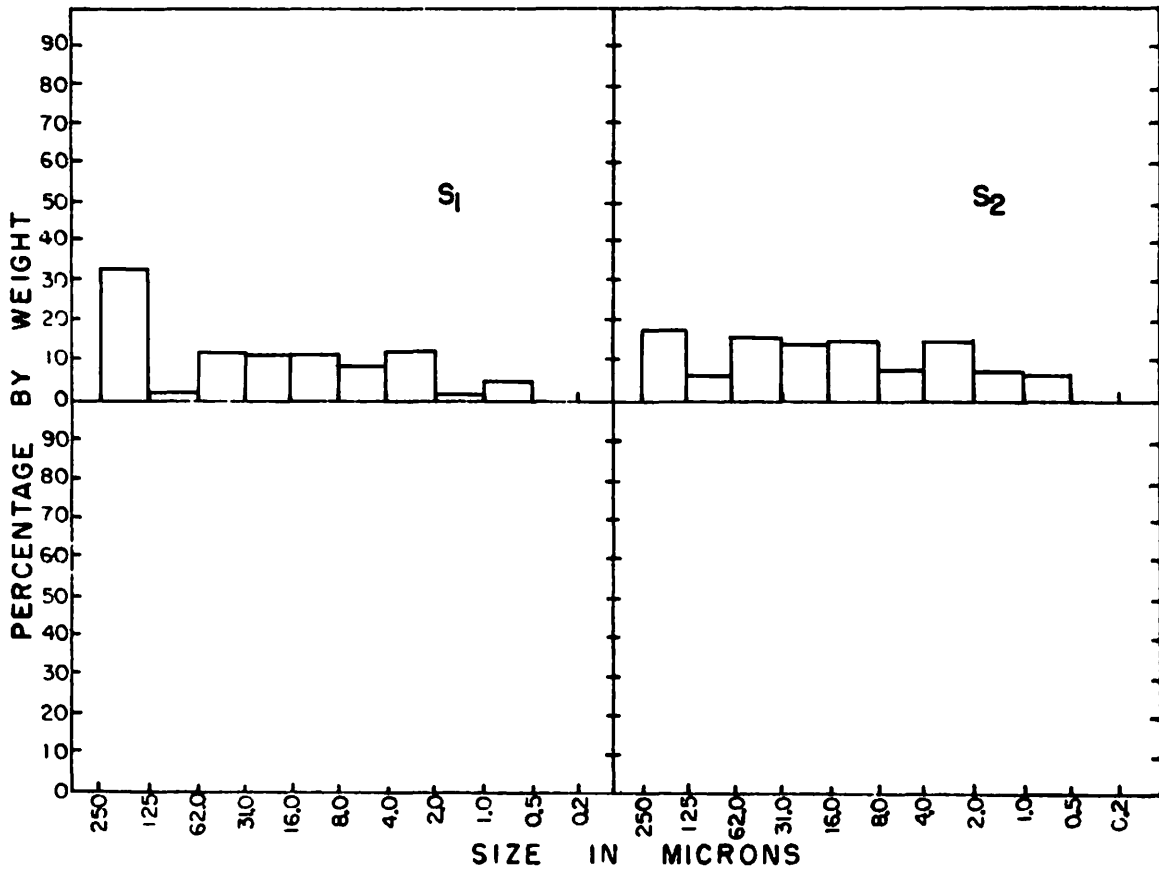
### LITHOLOGY AND ANALYTICAL DATA



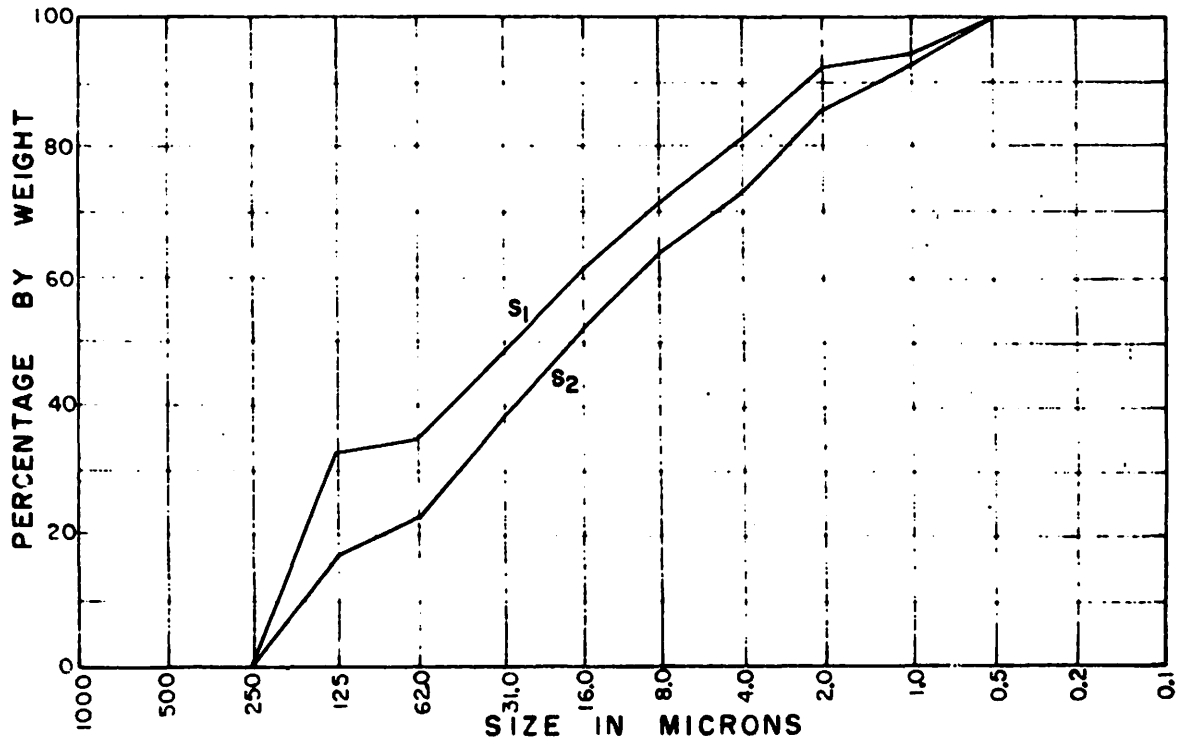
(continued)

Table 2 (continued)  
CORE 139-10

HISTOGRAMS



CUMULATIVE CURVES

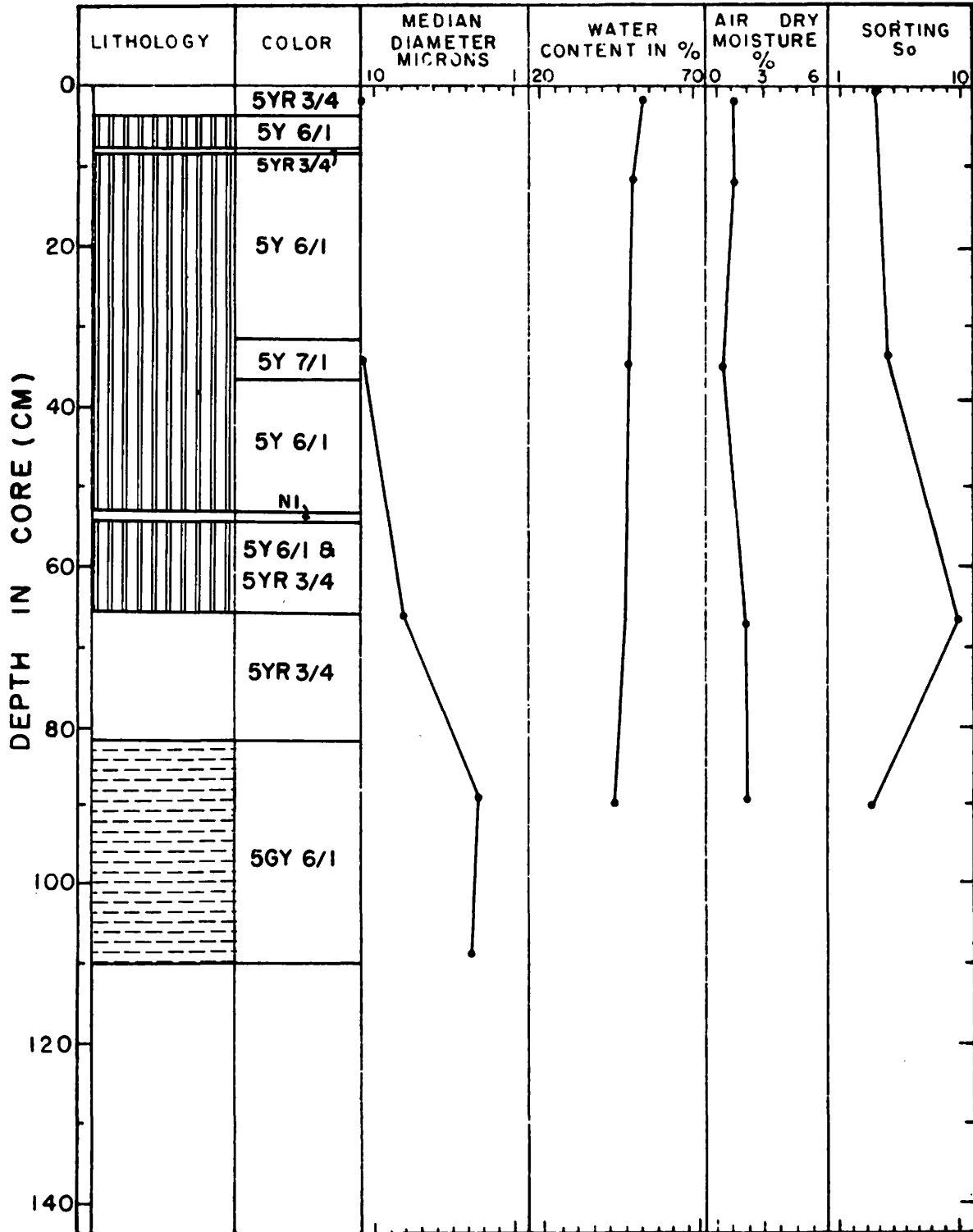


(continued)

CORE	139-15	
LAT.	47° 02.3' N	
LONG.	130° 35.3' W	
DEPTH	1450 fms	

BOTTOM TOPOGRAPHY IN THE VICINITY OF CORE

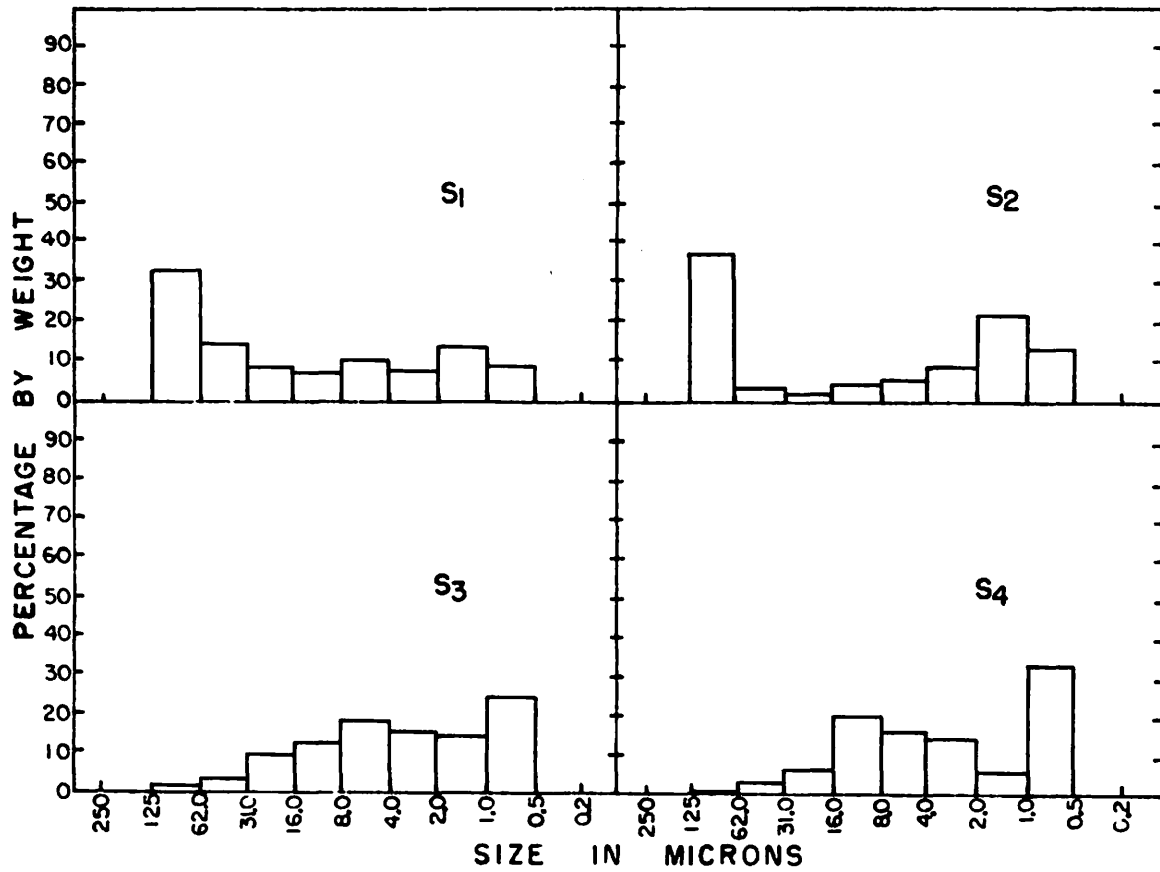
### LITHOLOGY AND ANALYTICAL DATA



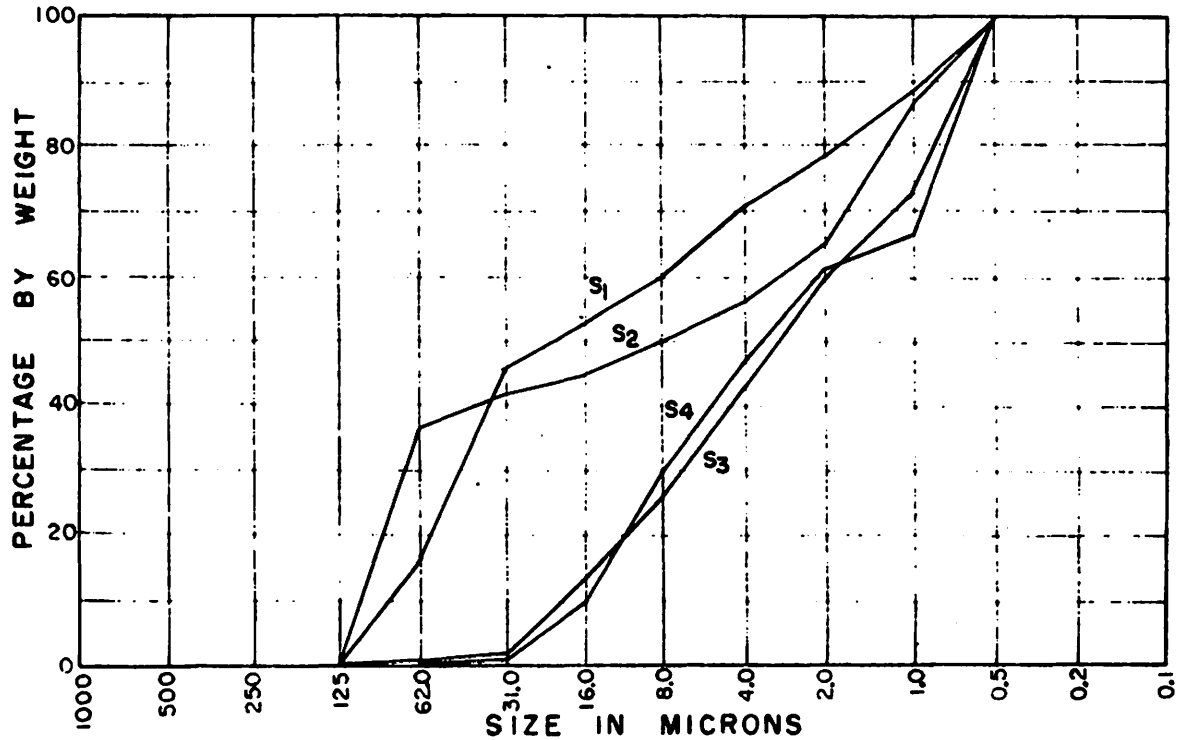
(continued)

Table 2 (continued)  
CORE 139-15

HISTOGRAMS



CUMULATIVE CURVES



The globigerina ooze of the interval 8 to 120 cm. of this core indicates that warmer than present conditions existed off the Oregon and Washington coasts from approximately 20,000 to 12,000 years ago. The lack of ooze above and below this interval is indicative of colder or present day temperatures. Estimates of deposition rates for the ooze are interesting. Considering the interval from top to 100 cm., the average rate is 5 cm. per 1000 years. Considering the radio-carbon date at the base of the upper 20 cm., the average sedimentation rate during the last 12,000 years is less than 2 cm. per 1000 years. The ooze between 20 and 100 cm. accumulated at the average rate of 10 cm. per 1000 years. Thus the ooze band is in the nature of a relict environment, only slightly if at all buried by present-day environment sediments.

Basalt. Basaltic rocks were recovered in most of the dredge hauls taken from the sampling stations between 45 and 210 fathoms on the mountain. These rocks were examined by Dr. Y. R. Nayudu, University of Washington. Samples thin-sectioned varied from basalt to olivine basalt. The basaltic rocks of the Pacific Basin are separated from the more acidic rocks of the continental platform by an "andesite line" (Hobbs, 1944; Hess, 1948). Cobb Seamount is west of this hypothetical line, which runs along the continental margin on the east side of the Pacific Basin. The presence of basalt on Cobb Seamount lends additional evidence to the validity of the hypotheses concerning the rock types to be expected within this province (Daly, 1942; Kuenen, 1950). The importance of ice-rafting during the Pleistocene in the Northeast Pacific Ocean has been emphasized by Menard (1953); however, Cobb Seamount is south of the glacial marine sedimentation area. The abundance of basaltic debris on and below the 45-fathom and 100-fathom terraces and the lack of varied lithologies further preclude the possibility that the basalts of the seamount are ice-rafted. The entire mountain therefore is considered to be basalt.

The basalt recovered occurs as pebbles, cobbles and boulders ranging from subangular to well-rounded. One large chunk seemed to have been freshly broken from a surface by action of the dredge. The rounding and signs of wear on most of the rocks from the 45-fathom and 100-fathom terraces suggest wave erosion.

#### Micropaleontology and "Recent" Microfaunas

The samples from Cobb Seamount and vicinity contain an abundant foraminiferal fauna. This is in general contrast with the deeper surrounding area outside the seamount-interrupted floor. The numerical abundance and, to lesser extent, specific abundance, compared with northern continental shelf and slope populations indicate that a very satisfactory environment is available on seamount slopes. Estimates of living-to-dead ratios from the top of the seamount were made utilizing the rose bengal technique (Walton, 1952). Foraminiferal abundance is actually great and is apparently little subject to masking by the slight sediment deposition. The explanation of the increased abundance involves a complex of ecologic factors such as nutrient upwelling, lessened predator and competitive pressures, and general isolation beyond the scope of this study.

The observation of Bandy (1952) that the benthonic forms tend to live at shoaler depths on seamounts than on continental shelves or slopes does not apply here or is obscured by the downslope movement of sediments. The author has noticed in other samples from the Northeast Pacific taken below seamounts or rough topography that invariably the bleak, deep cold-water fauna typical of the upper abyssal is enlivened by varied shoaler forms in abundance, indicating considerable displacement.

A discussion of probable age determinations and depth-temperature conditions suggested by the Foraminifera and other fauna is given for each sample group below. Taxonomic refinements, complete descriptions and illustration will be included in a paper by Enbyak now in preparation. The reader is referred to the description of bottom samples (Table 1) for the nature of the enclosing sediments and to Figure 10 for their location.

Fossil and "Recent" of G-12 and G-13 (1220 fm. and 1165 fm., west slope). The species listed below indicate that the fossil assemblage may be Late Eocene, based on ranges in West Coast material (V. S. Hallory, personal communication). It should be pointed out, however, that foraminiferal ranges and zones are for the most part determined on stratigraphic occurrences of sublittoral to upper bathyal species. Thus it is always possible that deeper species may have extended time ranges. This is of course true of any age determination problem, but is especially critical here as shallow forms are not present and there is no stratigraphic control.

It is also possible that synonyms are involved, as Tertiary Stratigraphers and "Recent" sediment micropaleontologists rarely examine each others' type material. The Globigerina identified below were found to be identical with Late Eocene specimens. Opinions from Parker and Branlette (personal communication, Scripps Institution) indicated that no reliable age indicators are present, either Foraminifera or coccoliths. Certain Globigerina had not been observed in the Recent by Parker. Globigerina would seem to be the best hope for dating purposes.

The species Bulimina corrugata, Cassidulina globosa, Eponides umbonatus, and Hoglundina eocenica and the absence of characteristic sublittoral species suggest a depth range greater than 500 fathoms, perhaps 1000 fathoms.

#### Fossil Foraminifera of G-12 and G-13:

- Anomalina garzaensis Cushman and Siegfus, Eocene
- Bolivian explicata Cushman and Hedberg, cf. var. lodoensis Hallory (MS), Mid to Late Eocene
- Bolivina explicata?
- Bulimina corrugata Cushman and Siegfus, Late Eocene-Oligocene?
- B. cf. B. truncanella Finley, Eocene
- Cassidulina globosa Hantken, Eocene-Oligocene
- Cibicides alazanensis Nuttall, Late Eocene-Oligocene
- C. eponidiformis Martin, Paleocene-Eocene
- C. pachydermis Galloway and Morrey, Eocene-Oligocene
- Cibicidoides coalingensis Cushman and Hanna, Mid Eocene-Oligocene

Globigerina coalingensis Cushman and G. D. Hanna, Early Eocene-Refugian  
G. decepta Martin, Early Eocene-Refugian  
G. cf. G. nitida Martin, Early Eocene Refugian  
G. cf. G. orbiformis Cole, Eocene  
G. pseudobulloides Plummer, Eocene  
G. triloculinoidea Plummer, Paleocene-Late Eocene  
Pullenia eocenica Cushman and Siegfus  
Hoglundina eocenica Cushman and M. A. Hanna, Early Eocene-Zemorrian  
Nonion planatus Cushman and Thomas, Eocene  
Pleurostomella alternans? Schwager, Early Eocene-Miocene  
Uvigerina garzaensis Cushman and Siegfus var. nudorobusta Mallory (MS), Late Eocene, Oligocene  
U. mexicana Nuttall, Late Eocene-Oligocene  
Valvulineria stainforthi Hofker, Mid to Late Eocene

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In addition to the fossil species listed above which are considered by Mallory to be restricted to the Lower Tertiary are the following which have not been observed in definitely "Recent" material of the Northeast Pacific: Bulimina alligata Cushman and Laiming; a very large, globose Cassidulina sp.; a robust, triangular Ehrenbergina sp.; and Parrella sp. The "Recent" Foraminifera of the unconsolidated ooze recovered in G-12 and G-13 are listed in Table 3. The depth ranges seem to be normal with the exception of Pullenia salisburyi and Astrononion gallowayi, usually not found below 1000 fathoms.

Mixed Tertiary and Quaternary of D-22 and D-23 (below 100-fms. terrace). The nature of sediments recovered in D-22 and D-23 and their position below the 100-fathom terrace suggest that they were derived from the cutting of this terrace. Abundant Mytilus fragments support this conclusion. The consolidated gravel and sand chunks were scraped to remove present-day sediments and Foraminifera. Unfortunately, the consolidated material contains no clear indicators of age. The Foraminifera, echinoid spines, and ostracods are glauconite-filled or stained, giving them an "old" look.

Some specimens look totally unlike any Recent types so far observed in the Northeast Pacific: Valvulineria sp., Quinqueloculina sp., Polymorphina sp., and Cassidulina sp.

An extremely long tapering Ehrenbergina compressa is also observed only in these two dredge samples. Three Gyroidina soldani are identical with G. soldani var. subangulata Plummer, an early Tertiary variety. One Nodosaria spinicosta resembles the variety adelinensis Palmer and Bermudez from the Oligocene. The above-mentioned species are responsible for the questionable Tertiary designation. No typically Miocene species are present. Several mixed Tertiary and "Recent" collections were reported by Hamilton (1953) from mid-Pacific seamounts. Other species in D-22 and D-23 are listed in Table 3.

TABLE 3

## "RECENT" FORAMINIFERA OF COBB SEAMOUNT

(A=abundant; C=common; R=rare; F=few; X=present; ( )=living)

Samples	C	D	D	D	D	C	D	C	S	D
	12 13	22 23	26	25	24	8	18	4	1	19
<i>Globigerina bulloides</i> d'Orbigny	R	C	C	A	A	C	C	C	F	C
<i>G. crassaformis</i> Galloway and Wissler		X								
<i>G. eggeri</i> Rhumbler	R	A	R	X	R	R	C	A	F	C
<i>G. hexagona</i> Natland						X				
<i>G. inflata</i> d'Orbigny			X		X					
<i>G. pachyderma</i> (Ehrenberg)	C	C	C	C	C	C	C	C	F	R
<i>G. quinqueloba</i> Natland					X		X			
<i>Globigerinita glutinata</i> (Egger)		R	X	F	F	R	R			
<i>Globorotalia</i> cf. <i>G. hirsuta</i> (d'Orbigny)		F			X	A				
<i>G. scitula</i> (H. B. Brady)	F	C	F	C	X					
<i>G.</i> cf. <i>G. tumida</i> (H. B. Brady)						X				
<i>Orbulina universa</i> d'Orbigny	C	F	C	R	C	F	C	A	F	C
<i>Angulogerina angulosa</i> (Williamson)	X									
<i>A. carinata</i> Cushman			X							
<i>A. fluens</i> Todd					F	C				
<i>A. semitrigona</i> (Galloway and Wissler)		X	F	R	C	C				
<i>Astacolus crepidulus</i> (Fichtel and Moll)					X					
<i>A. hyalacrulus</i> Loeblich and Tappan						X				
<i>A. sp.</i>			X							
<i>Astrononion gallowayi</i> Loeblich and Tappan	X		R	F	R	R		(X)		
var. A										
var. B			R	R	X	A		X		
var. C		R			C	F				
<i>A. sp.</i>							X			
<i>Bolivine acerosa</i> Cushman var. <i>pacifica</i> Cushman and McCulloch	X	X	X	F						

(continued)

TABLE 3. (continued)

Samples	C 12 13	D 22 23	D 26	D 25	D 24	C 8	D 18	C 4	S 1	D 19
<i>B. argentea</i> Cushman	X			X	R	R				
<i>B. decussata</i> Brady	C		F	C	C					
<i>B. digitale</i> Cushman					F	F				
<i>B. minuta</i> Natland						R	C			
<i>B. pseudobeyrichi</i> Cushman				X	(F)	R				
<i>B. pseudopunctata</i> Höglund						X				
<i>B. punctata</i> d'Orbigny	X									
<i>B. seminuda</i> Natland			X		X					
<i>B. spissa</i> Cushman					X	X				
<i>B. subadvena</i> Cushman var. <i>serrata</i> Natland				X						
<i>B. vertebrale</i> (Cushman)						X				
<i>B. sp.</i>				X						
<i>Bulimina barbata</i> Cushman			X	X		X				
<i>B. exilis</i> Brady	X			X	R	F				
<i>B. inflata</i> Seguenza	F									
<i>B. pupoides</i> d'Orbigny	X									
<i>B. rostrata</i> H. B. Brady	(C)									
<i>B. striata</i> d'Orbignyi var. <i>mexicana</i> Cushman				F	X	X				
<i>B. sp.</i>					X					
<i>Cassidulina californica</i> Cushman and Hughes		A	R	A	(F)	C				
<i>C. cf. C. cushmani</i>		X								
<i>C. delicata</i> Cushman	C		R	A	A	A				
<i>C. cf. C. globosa</i> Hantken	X		R							
<i>C. islandica</i> Nørvang		X								
<i>C. laevigata</i> d'Orbignyi var. <i>carinata</i> Cushman			F							
<i>C. limbata</i> Cushman and Hughes			R	F	F					
<i>C. lomitensis</i> var. <i>elegantula</i> Galloway and Wissler		A	A	A	A	A	F	(F)	X	
<i>C. pulchella</i> d'Orbigny		F								
<i>C. reflexa</i> Galloway and Wissler			F		X					
<i>C. subglobosa</i> H. B. Brady	X		C	F	A	A	C			

(continued)

TABLE 3. (continued)

Samples	C	D	D	D	D	C	D	C	S	D
	12 13	22 23	26	25	24	8	18	4	1	19
<i>C. tortuosa</i> Cushman and Hughes		R								
<i>C. translucens</i> Cushman and Hughes		C	X	F	X	C				
<i>C. cf. C. tumida</i> Natland		R								
<i>C. sp.</i>		C	F							
<i>Cassidulinoides mexicana</i> Cushman	X									
<i>Chilostomella oolina</i> Schwager			X							
<i>Cibicides cf. C. concentrica</i>		C								
<i>C. conoideus</i> Galloway and Wissler			X							
<i>C. fletcheri</i> Galloway and Wissler			X							
<i>C. cf. C. floridanus</i> (Cushman)				C						
<i>C. gallowayi</i> Cushman and Valentine								(R)	(R)	(A)
<i>C. lobatulus</i> (Walker and Jacob)		F	A	F	X	X	A	(A)	(C)	(A)
<i>C. lobatus</i> d'Orbigny		C			A	A				
<i>C. refulgens</i> (Montfort)		X								
<i>C. tenuimargo</i> (Brady)								C		
<i>C. sp.</i>					X					
<i>C. sp.</i>						X				
<i>C. sp.</i>						X				
<i>C. sp.</i>								X		
<i>Cornuspira planorbis</i> Schultze								X		
<i>Discorbis cf. D. praegeri</i> (Heron-Allen and Earland)								(X)	X	
<i>Dyocibicides biserialis</i> Cushman and Valentine		X								
<i>D. perforata</i> Cushman and Valentine			F		X	R	X	C	F	F
<i>Eggerella bradyi</i> Cushman	R		C	X						
<i>E. propinqua</i> (H. B. Brady)				X						
<i>E. pusilla</i> (Göes)			F	F						
<i>Ehrenbergina compressa</i> Cushman	C	A	C	C	(A)	A	A	C	F	F
<i>E. trigona</i> Göes	R	R								
<i>Epistominella bradyana</i> (Cushman)					X					
<i>E. sp.</i>					X					

(continued)

TABLE 3. (continued)

Samples	C 12 13	D 22 23	D 26	D 25	D 24	C 8	D 18	C 4	S 1	D 19
<i>Eponides repandus</i> (Fichtel and Moll)		X	F				X	(C)	(A)	(A)
<i>E. tenera</i> (H. B. Brady)	F									
<i>E. umbonatus</i> (Reuss)	C		X	X						
<i>Fissurina alveolata</i> var. <i>substriata</i> (Brady)					X					
<i>F. marginata</i> (Montagu)	X		X		X	X				
<i>F. quadrata</i> (Williamson)			X	C	F					
<i>F. serrata</i> (Schlumberger)				X						
<i>F. sp.</i>			X							
<i>F. sp.</i>					X					
<i>Globobulimina auriculata</i> (Bailey)						X				
var. <i>arctica</i> Höglund						X				
<i>Goesella flintii</i> Cushman		X								
<i>Gordiospira sp.</i>		X						X	X	
<i>Guttulina sp.</i>			X							
<i>G. sp.</i>									X	
<i>Gyroidina</i> cf. <i>G. gemma</i> Bandy				F	X	F				
<i>G. orbicularis</i> d'Orbigny	R		X			F				
<i>Haplophragmoides evoluta</i> Natland			X	X						
<i>H. trullisatum</i> (H. B. Brady)			F	F						
<i>H. sp.</i>			X							
<i>H. sp.</i>				X						
<i>Höglundina bradyi</i> (Galloway and Wissler)			C	X	R					
<i>H. elegans</i> (d'Orbigny)	F		X	A	(X)	C				
<i>Karrerella bradyi</i> (Cushman)			C	F						
<i>K. sp.</i>	R									
<i>Legena apiopleura</i> Löeblich and Tappan		X	X		X	X				
<i>L. aspera</i> Reuss	X									
<i>L. gracillima</i> (Seguenza)					X					
<i>L. gracilis</i> Williamson			F							
<i>L. lagenoides</i> (Williamson)			X							

(continued)

TABLE 3. (continued)

Samples	C 12 13	D 22 23	D 26	D 25	D 24	C 8	D 18	C 4	S 1	D 19
<i>L. cf. L. lyelli</i> (Seguenza)								X		
<i>L. orbignyana</i> (Seguenza) cf. var. <i>variabilis</i> Wright			X		X					
<i>L. sublagenoides</i> (Cushman) var. A			X		X	X				
var. B						X				
var. C					X	X				
<i>L. sulcata</i> (Walker and Jacob)		X	X				X			
<i>L. williamsoni</i> (Alcock)			X	X						
<i>Laticarinina pauperata</i> Parker and Jones	A									
<i>Loxostomum instabile</i> Cushman and McCulloch		X				X				
<i>L. porrectum</i> (H. B. Brady)			X							
<i>Massilina</i> sp.								X		
<i>Nonion barleeanus</i> (Williamson)	F									
<i>N. pompiliodes</i> (Fichtel and Moll)	R									
<i>N. sp.</i>							X			
<i>Oolina caudigera</i> (Wiesner)			X			X				
<i>O. costata</i> Williamson			X	X	X	F				
<i>O. cf. O. glososa</i> (Montagu)	X									
<i>O. melo d'Orbigny</i>		X	X	X		F				
<i>O. striato-punctata</i> (Parker and Jones)			X	X	X	X				
<i>Parafissurina</i> sp.					X					
<i>Planulina ornata</i> (d'Orbigny)	X		X	X						
<i>P. sp.</i>		C								
<i>Pleurostomella</i> sp.	X									
<i>Polymorphina charlottensis</i> Cushman			X							
<i>P. cf. P. cylindroides</i>					X					
<i>P. kincaidi</i> Cushman and Todd			X	X	?	X				
<i>P. sp.</i>					X	X				
<i>P. sp.</i>									F	
<i>Pullenia bulloides</i>	F									
<i>P. elegans</i> Cushman and Todd			R	C	X	A				

(continued)

TABLE 3. (continued)

Samples	C	D	D	D	D	C	D	C	S	D
	12 13	22 23	26	25	24	8	18	4	1	19
<i>P. salisburyi</i> Stewart and Stewart	F	A			X					
<i>P. subcarinata</i> (d'Orbigny)		F	X							
<i>P. sp.</i>						X				
<i>P. sp.</i>				R	F					
<i>Pyrgo depressa</i> (d'Orbigny)			X	X						
<i>P. sp.</i>			X							
<i>Quinqueloculina arctica</i> Cushman								X		
<i>Q. catalinensis</i> Natland			F					(R)	F	(G)
<i>Q. elongata</i> Natland				X					(X)	
<i>Q. microcostata</i> Natland									X	
<i>Q. cf. Q. weaveri</i> Rau			X							
<i>Q. sp.</i>			X							
<i>Q. sp.</i>				X	X					
<i>Q. sp.</i>								X		
<i>Robertina charlottensis</i> (Cushman)					X					
<i>Robulus alato-limbatus</i>								(X)	(R)	
<i>R. d'orbigny</i> (Bailey)			X							
<i>R. cf. R. gibba</i> (d'Orbigny)					X					
<i>R. cf. R. orbicularis</i> (d'Orbigny)		F	X							
<i>R. cf. R. rotulata</i> (Lamarck)				C						
<i>R. sp.</i>			X							
<i>R. sp.</i>								X		
<i>R. sp.</i>								X		
<i>Rupertia stabilis</i> Wallich		R	R	X	X	X				
<i>Sigmoilina tenuis</i> (Czjzek)			X							
<i>Sigmomorphina trilocularis</i> (Bagg)		X								
<i>Sphaeroidina sp.</i>	X		X							
<i>Spirillina cf. S. guttata</i> Cushman					X			(X)	X	
<i>S. limbata</i> Brady						X				
<i>S. vivipara</i> Ehrenberg							X			
<i>S. sp.</i>						X				

(continued)

TABLE 3. (continued)

Samples	C 12 13	D 22 23	D 26	D 25	D 24	C 8	D 18	C 4	S 1	D 19
<i>Spiroloculina</i> sp.							X			
<i>Spiroplectammina</i> sp.	X									
<i>Textularia</i> sp.			X							
<i>Triloculina oblonga</i> d'Orbigny			X							
<i>T. tricarinata</i> d'Orbigny			X							
<i>T. trigonula</i> (Lamarck)				X						
<i>T.</i> sp.			X							
<i>Trochammina</i> sp.			X							
<i>Uvigerina auberiana</i> d'Orbigny var. A.	F			X						
var. B			A	C	F	X				
<i>U. cushmani</i> Todd						X				
<i>U. hollicki</i> Thalman			C	F	R					
<i>U. hootsi</i> Rankin var. A			F	C						
var. B			R							
<i>U. peregrina</i> Cushman				X	C	X	C			
<i>U. peregrina</i> Cushman var. <i>disrupta</i> Todd				R						
<i>U. senticosa</i> Cushman var. A						A				
var. B			C							
var. C				C	X					
<i>U.</i> sp.					X					
<i>U.</i> sp.				X						
<i>Vaginulina</i> cf. <i>V. robusta</i> Galloway and Wissler			X	F						
<i>Valvulineria araucana</i> (d'Orbigny)				X		X				
<i>V.</i> cf. <i>V. laevigata</i> Phleger and Parker				X						
<i>V.</i> cf. <i>V. umbiliplicata</i> (d'Orbigny)		X								
<i>V.</i> sp.						F				
<b>Radiolaria</b>	F			X		F				
<b>Sponge species</b>				X		X				
<b>Echinoid spines and plates</b>									A	
<b>Small Gastropods</b>		X						(C)	C	C
<b>Pelecypod fragments</b>		C						C	A	A
<b>Ostracods</b>			X	R	X	R		F	F	(F)
<b>Diatoms</b>	X									

Assemblage slides were examined by Stewart and Stewart (personal communication), who indicated that a Pliocene age was most likely. Comparison with type material from Lomita Quarry (Galloway and Wissler, 1927) was made. The abundance of Cassidulina lomitensis and especially the variety elegantula may indicate a Pleistocene age; however, the Pliocene-Pleistocene boundary is difficult to derive from benthonic Foraminifera without stratigraphic evidence. Ostracods present range from Late Tertiary to "Recent". The abundance of Globigerina eggeri and Globigerinita glutinata compared with G. bulloides might indicate a warmer than present temperature. Very few diatoms are present.

The depth requirement for the fauna is not clear. Bandy (1953) found Cassidulina greater than 30 percent (as in these samples), characteristic of the "Lower Neritic Zone" (150 - 600 ft.). This zone would be likely, if the sediments of D-22 and D-23 were derived from the 100-fathom terrace when it was at sea level. The abundant Mytilus fragments, small gastropods, and echinoid spines fit this category. A somewhat deeper setting is suggested by Cassidulina lomitensis based on a Point Arguello traverse (Bandy, 1953). Shoaler species of Cassidulina also are numerous however, and the total aspect fits the Lower Neritic Zone. Perhaps a more definite depth range can be established when the author's current study of Foraminiferal distribution north of 40°N. is completed. It has been observed that a few species tend to creep upslope in the colder latitudes. This may explain discrepancies between California depth ranges and this northern area.

"Recent" Microfauna of D-24, -25, -26, and C-8 (below 500 fms.) No recognizably fossil Foraminifera were found in these samples. A few Cassidulina and Globigerina were glauconite-filled. Here in the Middle Bathyal Zone an abundant and varied fauna suggests downslope displacement. Following the work of Bandy, Natland, and others, and the author's observations in the Northeast Pacific, the following species are considered displaced: abundant Cassidulina California which are worn smooth; abundant Cibicides lobatulus in D-26; Eponides repandus; Polymorphina kincaidi. Ostracods are rather numerous. Generally ostracods are not found in abundance below 100 fathoms. The Foraminifera species are listed in Table 3. Samples from other seamounts northeast of Cobb show a similar amount of displacement.

"Recent" Microfauna of D-18 (on 100-fathom terrace). Very little material for analysis was available from this terrace. Foraminifera were removed from shells, rocks and pockets in rocks. Thus the species are more typical of pelagic or clinging habit than of a particular depth.

"Recent" Microfauna of C-4, S-1, and D-19 (below and on 45-fathom terrace). These samples from the top of the seamount contain a great abundance of Foraminifera of few species. It should be noted that certain shallow water species which are common on the continental shelf immediately to the east are absent here. These are: Eponides frigidus, Nonionella, Nonion (shallow water species), Elphidium, Elphidiella, and

Bulimina (shallow species). The forms present are usually coarse-sediment or rock-clinging types. Thus the type of substrate available on the seamount may be as important a limiting factor as distance from shore. The absence of typically shallow-water species gives a deeper-water appearance to the collection.

"Recent" Planktonic Foraminifera. Cobb Seamount lies in the center of a Globigerina core band, paralleling the Oregon-Washington coast. (See Peripheral Sediments Section above.) All Northeast Pacific planktonic Foraminifera are more numerous within this band. The following species seem to be restricted to it: Globorotalia cf. G. hirsuta, G. scitula (in abundance), Orbulina unviersa (in abundance), Globigerina eggeri, G. hexagona, G. quinqueloba, and Globigerinita glutinata (in abundance). Radio-carbon dating suggests a relict environment. Several plankton tow samples from this area and to the north have yielded only Globigerina pachyderma and G. bulloides in abundance. Study of tow material is now being made at the University of Washington, Department of Oceanography.

### Origin and History

The following observations are pertinent to the interpretation of the origin and probable history of Cobb Seamount:

1. This seamount is oval in plan and symmetrical in profile.
2. The slopes, which merge gradually into the sea floor, are concordant with those of subaerial volcanoes.
3. Basaltic rocks and debris are found throughout the area of the seamount in overwhelming proportion to other rock types.
4. A consolidated ooze containing possibly Tertiary Foraminifera lies near the base of the mountain (C-11, C-12, C-13).
5. A pronounced series of discontinuous terraces occur around the mountain at about 500 fathoms.
6. Pre-"Recent" Foraminifera occur just below the break in slope of a "100-fathom" terrace (D-22, D-23).
7. Well-rounded basalt cobbles and pebbles occur on the 100-fathom terrace.
8. On or just below a well-developed terrace at 45 fathoms are found intertidal mussels associated with rounded basalt pebbles.
9. Only shells and living bottom-fauna have been retrieved from the steeply sloping (45°) 160-foot pinnacle.

Volcanic Cone. Plan and profile of the mountain and basalt preponderance in dredge samples surely indicate that the seamount is a volcanic cone. That it may have developed before Late Eocene is indicated only by the possibly Late Eocene Foraminifera near the base (C-12 and C-13). If these were present before or during volcanism, they should have been covered by, or mixed with, an appreciable amount of volcanic debris and/or flows. Unfortunately the dating of the fossil Foraminifera is in question and thus the age of the volcanic cone is similarly in question.

The "500-Fathom" Terrace. It is unlikely that the prominent terraces at about 500 fathoms (Figure 6) can be attributed to the original volcanic cone development. Of the possible erosional processes which might have played a part in producing such a feature, slumping and wave erosion are considered the most likely. The hummocky topography, rippled slope pattern, or other irregularities indicative of slumping are not found on this mountain. Many sounding lines were run parallel to the contours in a search for re-entrant valleys and other irregularities which might not be detected by sounding traverses normal to the slope. These lines, although inadequately controlled for use in the final smooth sheet, show very few irregularities and, in general, validate the smoothness of the contours presented for Cobb Seamount. Further, it is unlikely that great masses of basalt would be moved from mid-slope at the same general level around a mountain by a landslide mechanism. These considerations seem to preclude a submarine-slide origin for the terraces found at about 500 fathoms; thus, these terraces are attributed to wave-cutting. The present variation in depth of the terraces probably has resulted from faulting, slumping, and tilting subsequent to their formation.

If these terraces are actually wave-cut then, from the conclusions of Dietz and Menard (1951) that the maximum depth of wave abrasion is about 5 fathoms, it is necessary to postulate a 500-fathom relative rise in sea level after the mountain was formed. Investigations of other submarine mountains by Carsola and Dietz (1952) and Hamilton (1956) have shown that relative changes in sea level of this magnitude are not improbable. Kuenen (1937, 1950), Umbgrove (1947), and others do not advocate an increase in ocean volume since middle Cretaceous time. In agreement with the findings of these authors the theory that subsidence rather than an increase in ocean volume is followed in interpreting the relative changes of sea level. Therefore, during the erosional period when the "500-fathom" terrace was being cut, the mountain was probably some 500 fathoms higher than it is now. Presumably this period of terrace-cutting was not subsequent to or contemporaneous with the deposition of the fossil Foraminifera, because the probable depth range of the species identified in samples from 1200 fathoms (C-12, C-13) is deeper than 700 fathoms. Furthermore, if these species were present prior to or at the time of erosion, it is difficult to account for the absence of erosional debris associated with these fossils if they were living only 700 fathoms below the zone of active wave abrasion. In short, the wave-cutting of this terrace must have been before fossil Foraminifera deposition when the mountain was some 500 fathoms higher than it is at present.

In view of the above conclusion and from geometric considerations of the present morphology of this mountain and that of other seamounts, guyots, and subaerial volcanoes, Cobb Seamount at one time was probably a volcano standing about 1900 fathoms above the ocean floor. This would mean that about 4500 feet of the mountain was above sea level during this time.

Submergence. The period of stillstand, during which the "500-fathom" terrace was cut, was followed by submergence and possibly by some downward tilting to the north. At this time the fossil Foraminifera of C-12 and C-13 were living on the slope below 1000 fathoms. The presence of the 100-fathom marginal depression at the base of the mountain on the north side only and the lower level of the terraces on this side of the mountain suggest that some tilting and possibly some faulting occurred during or after subsidence. No clear trends can be discerned. It may be necessary to conclude that during this period of submergence the entire mountain was lowered below wave base as the time involved before the 100-fathom terrace cutting is of such length that marine and subsequent erosion should have completely planed the top. If marine abrasion proceeds at the pace attributed to it relative to vertical movement (Dietz and Menard, 1951) a submergence and re-emergence is necessary before the stillstand of the 100-fathom terrace cutting.

The 100-Fathom Terrace. The rounded cobbles and pebbles of basalt covered by Lithothamion-like algae on the extensive 100-fathom terrace indicate that this surface is a wave-cut feature. This erosional feature was probably formed during Pliocene? to Pleistocene time, as indicated by the fossils associated with erosional basaltic debris just below the break in slope (D-22, D-23). Unfortunately, no more exact dating of the 100-fathom terrace is possible. Apparently the period of stillstand was not extensive enough for the complete truncation of the top. Subsequent to the erosional period the mountain subsided to its present position, with some slight downward tilting to the north as indicated by the variation in depth of the break in slope of this terrace.

Pleistocene Planation. The prominent 45-fathom terrace is related to the Pleistocene eustatic changes in sea level mainly because of the accordance of this level with that of other observed Pleistocene terraces. This is concluded also from the abundance of the intertidal mussel, Mytilus sp., associated with rounded basalt pebbles. This feature, then, was formed by wave abrasion during a lower stand of the sea.

Development of the Pinnacle. The shells that cover this 160-foot rise on the Pleistocene terrace have not been penetrated by repeated dredging attempts. Such would be the case if the shells were in the form of a thick blanket, or if the pinnacle were composed entirely of shells. If this pinnacle were a volcanic plug or other remnant of the

original basalt after erosion, it is unlikely that it would have kept its 45-degree slopes and symmetry during the Pleistocene, because during at least half of this epoch it would have been exposed to subaerial weathering and wave abrasion.

The other possibility is that the pinnacle is composed entirely of shells and has built up contemporaneously with the rise in sea level associated with the last retreat of ice. Although a feature similar to this has never been observed in high latitudes, it is certainly not in opposition to any biological principle. The noticeable absence of rocks and sand on the pinnacle and the steep slopes suggest that this feature might be a biostrome. Because the evidence for this theory is inadequate at present, the authors are reticent in proposing that the pinnacle of Cobb Seamount is a biostrome; however, this theory deserves consideration in planning future surveys. A desirable approach would be visual examination and collection of samples by divers. If the pinnacle is biostrome, carbon-14 dates on specimens obtained at different levels would indicate rate of growth of the biostrome. Oxygen isotope analysis of the shells in conjunction with the carbon-14 dating would yield invaluable data on the water temperature conditions during the Pleistocene and samples showing the possible succession of types and/or size of the fauna in the biostrome would be of great interest to the biologist.

The conservative theory is that a pinnacle with low slopes remained after the erosion of the 45-fathom terrace. This remnant presumably provided a site for the attachment of rock scallops and other sessile fauna, thus modifying the slopes and providing an "impenetrable" blanket of shells. The development of this "compromise" biostrome could have occurred contemporaneously with or subsequent to Pleistocene oscillations of sea level.

### Implications for Regional Geology

Relation to Ridge and Trough Province. Cobb Seamount and its associated plateau is within the Ridge and Trough Province described by Menard and Dietz (1951). The Province includes a band 300 to 400 miles wide off the coasts of southwestern Canada and northwestern United States. This area was contrasted with the Gulf of Alaska Seamount Province on the following characteristics: shoaler seamount summits, ridges and troughs, seismic activity and younger age. Profiles and bottom samples of Cobb Seamount and environs were not available to Menard and Dietz when they defined the Ridge and Trough Province. The mountains were considered orogenic rather than volcanic expressions. An extension of the Pliocene-Pleistocene coastal orogeny through the area was suggested. The seamounts of this coastal group were considered to be fold or fault mountains as the profiles examined showed irregular peaks and undulations along ridges, which in some places were the primary topographic features.

The morphologic and lithologic characteristics of Cobb Seamount as summarized above are similar to those of many volcanic islands and submarine mountains to which a volcanic origin has been ascribed and it

has been concluded that Cobb is of volcanic origin. This volcanic origin does not preclude a tectonic orogeny for the other summits in the Ridge and Trough Province, nor is the existence of a Ridge and Trough and a Gulf of Alaska Seamount Province disputed. However, comparison of Cobb Seamount area with typical Ridge and Trough areas is necessary to determine whether Cobb should be included in this province.

Recent soundings off the coast of Washington and Oregon indicate that the western boundary of ridged topography is about 150 miles from the coast rather than 300 to 400 miles as indicated by Menard and Dietz. A very important feature of the area is the smooth plain paralleling the Washington and Oregon Coasts separating the rough slope (more typically ridged) from the seamount plateau (Figures 3 and 4). This plain appears to be the result of deposition covering irregularities. Sediment dumping from the present north-south hinge line may obscure other older alignments. Evaluation of this trough may indicate that a physiographic characterization of the area may be made without comparison with the Gulf of Alaska Seamount Province. Speculation as to seaward trends of continental structures from maps presently available and without seismic data seems interesting but unrewarding at this time.

One is reminded of the juxtaposition of Mount Baker and Mount Shuksan in northwestern Washington. Entirely different histories are involved in the two peaks. There is no reason to believe that underwater features are less varied and complex within comparable areas. The shoaler summits in the Ridge and Trough Province, though noteworthy, are not indicative of common genesis nor of contemporaneity. The dating of post-Pleistocene because of supposed non-truncation by lowered Pleistocene seas does not apply to Cobb Seamount. Detailed bathymetry of other peaks in the area may show a truncation or the truncation may be obscured by bioherm development.

Hodgkins Seamount (included in the Ridge and Trough Province) would seem to be younger than Cobb Seamount. The Hodgkins basalts appear much fresher than the Cobb basalts, which show much alteration. According to R. J. Hurley (personal communication) no fossils were found on Hodgkins. The dissimilarities between Cobb and Hodgkins are as great as between Hodgkins and typical Gulf of Alaska seamounts, and Hodgkins seemingly typifies Ridge and Trough Province seamounts.

The suggestion (Menard and Dietz, 1951) that the Ridge and Trough Province may be fold or fault mountains was related to its correspondence with a belt of submarine earthquake epicenters. Figure 13 is a plot of earthquake epicenters to March 1958 from various sources. Menard and Dietz recognized that many seamounts of the coastal group in the Ridge and Trough Province occur in areas where no epicenters have been located. Cobb and adjacent seamounts are in such an area. The western arm of the odd bifurcation from the north dies out north of Cobb Seamount (Frank Neumann, personal communication) and the northwestern trend from California fails to enter the area. The one epicenter reported was of Class D type (Gutenberg and Richter, 1954) and is not accurately located. Seismic evidence, then, would tend to exclude the Cobb area rather than lend support to its inclusion as the seaward extension of Northern California orogenic activity.

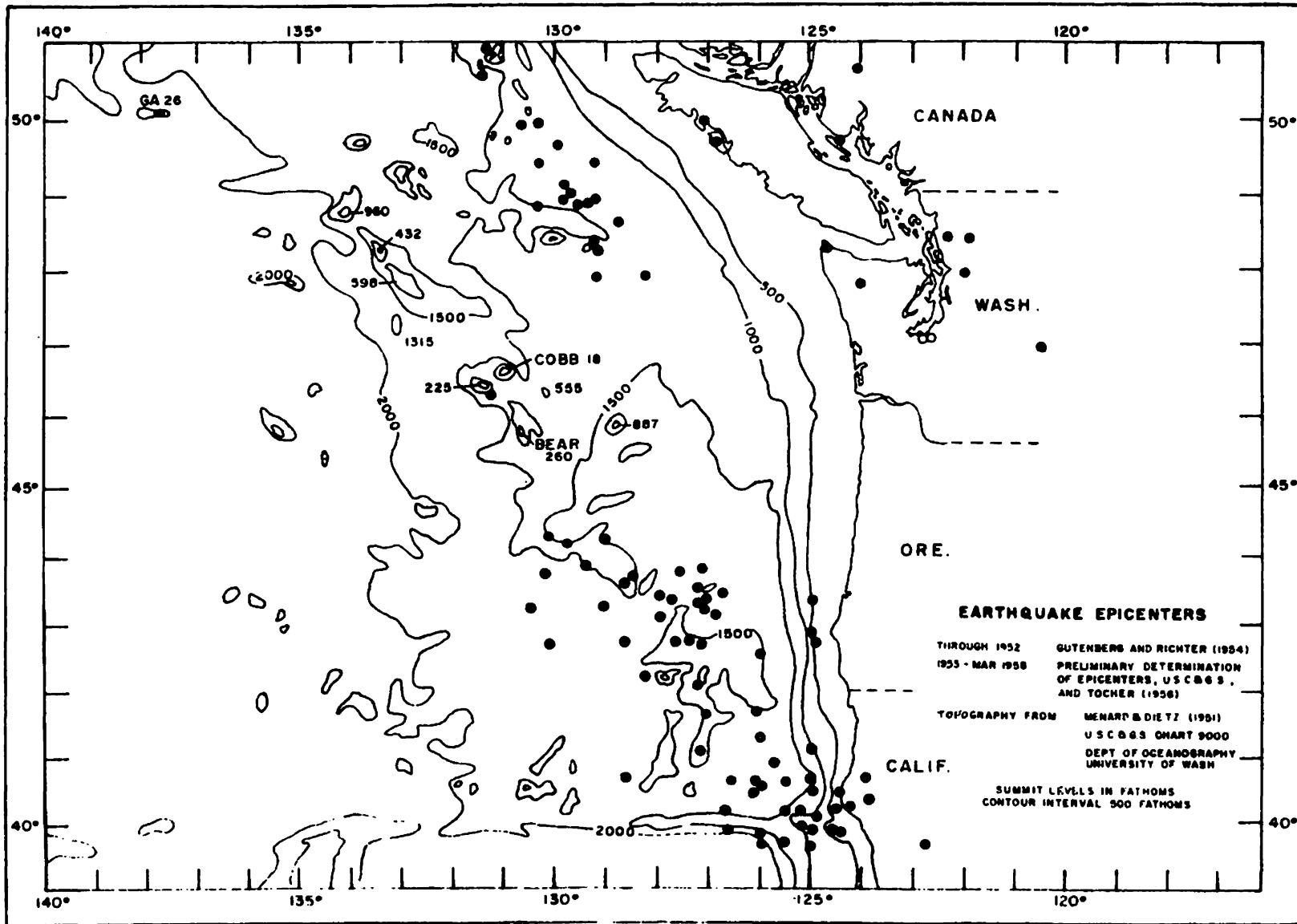


Figure 13. Earthquake epicenters in the region of Cobb Seamount

From the data presented above, the inclusion of Cobb Seamount in the Ridge and Trough Province seems unwarranted. Further information, soundings and rock samples may establish other meaningful province divisions beyond the pioneer efforts of Menard and Dietz.

Relation of the "500-Fathom" Terrace to the Summit Depths of Gulf of Alaska Seamounts. An attempt is usually made by submarine geologists to relate the histories of seamounts by comparing summit or prominent terrace depths. Examination of the profiles of the seamounts in the Gulf of Alaska presented by Murray (1941) reveals that there is little accordance of the depths of summits or terraces of other seamounts with the "500-fathom" terrace of Cobb Seamount. The seamounts which do show some accordance with this level are those of the Pratt-Welker Chain, described by Menard and Dietz (1951). This chain is defined by GA-1, Giacomini, Surveyor, Pratt, and Welker Seamounts (Figure 2). From considerations of the position of GA-1 in the Aleutian Trench, Menard and Dietz have postulated a pre-Early Tertiary age for the truncation of these guyots. The platform depth of this chain varies from 390 to 450 fathoms. This general accordance of depth and age of erosion surfaces between the Pratt-Welker Chain and Cobb Seamount elicits the following possibilities:

(1) If the Pratt-Welker Seamounts were exposed at the same time as Cobb Seamount, then Cobb necessarily started to subside earlier; otherwise Cobb Seamount would have been truncated. This would suggest that Cobb was subsiding in pre-Early Tertiary time, which is in accord with the history as interpreted in this report. If subsidence rates were the same, it is necessary that the Pratt-Welker Chain be eroded as Cobb was being formed. In this case also, the subsidence of Cobb would be pre-Early Tertiary.

(2) A second proposition would attribute the accordance of depth to an increase in ocean volume with a concomitant rise in sea level since the Cretaceous, subsidence not being a major or measurable factor. Those seamounts without terraces or true flat tops at the 500-fathom level would be considered more recent. This theory has been rejected in the interpretation of Cobb Seamount history.

(3) Perhaps the most reasonable suggestion is that no valid relationship can be discussed until more definite information is obtained as to the time of truncation of the Pratt-Welker mountains. Each seamount or seamount-studded plateau may have had a complicated and never-to-be-known history of ups and downs. Apparent accords are fortuitous. Nor is it likely that the interpretations of continental Tertiary diastrophism can be correlated with this oceanic province. Even were a phenomenon expressed in both provinces, which is unlikely, the differences in data available and used would obscure the relationship.

The immediate vicinity of Cobb Seamount is as yet unknown in detail. There is some indication of a 500- to 600-fathom terrace on Bear Seamount, 45 miles SSE of Cobb; however, the soundings are not adequate for the construction of an accurate profile.

It may be stated that this entire area from the seamount plateau, landward across the trough to the rough continental slope needs much more detailed charting and bottom sampling. Further conjecture seems pointless until more facts are available. It is hoped that an organized effort will be made on this area in the near future.

## CHAPTER 4. BIOLOGY

Bottom Megafauna

Nine dredge hauls from the top and sides of the pinnacle indicate abundant bottom fauna; however, there was a notable absence of fauna below 45 fathoms. The dominant forms obtained were the rock scallop, Hinnites multirugosus Gale, and the sea urchin, Strongylocentrotus sp. Attached to the empty Hinnites shells were small living specimens of Hinnites as well as tube-dwelling annelids and unidentified anemones. Other fauna taken in lesser amounts include the gastropod, Argobuccinium; hermit crab, Pagurus; polychaetes; spider crabs; anemones; and brittle stars. The vessel John N. Cobb reported specimens of the 21-rayed starfish, Pycnopodia sp., and the pen, Stylauta elongata (Powell et al., 1952). The description presented here is limited because identification of all the specimens has not been attempted. The bottom microfauna was discussed earlier, in the Geology section.

From cursory examination the community on Cobb Seamount appears to be similar to sublittoral communities in Puget Sound. Further examination of some of the material indicates, however, that subtle differences exist (perhaps at the varietal level) between seamount and Sound types. Demonstration of actual endemism will depend upon taxonomic work by specialists not available at the time of this report. The preserved or frozen specimens may be examined at the Department of Oceanography, University of Washington.

Hydrocoral fragments from D-18 (on the 100-fathom terrace) were identified by Professor J. Wyatt Durham, University of California. His comments follow: "The specimens from D-18 seem to be Allopora n. sp., cf. A. moseleyana Fisher (1938, Proc. U. S. Nat. Mus., vol. 84, p. 512-514, pl. 49, fig. 2; pl. 50; pl. 51; pl. 53, figs. 1-1b.). This species differs from moseleyana in that dactylostyles do not project above inner lip of dactylopores and surface of coenosteum is reticulate rather than glossy. A. moseleyana was described from the Bering Sea and Aleutian Islands. Specimens from other samples of Cobb Seamount probably represent the same new species but surface preservation is inadequate for positive determination."

Plankton

During Brown Bear Cruise 144, a series of hauls was made using the Isaacs-Kidd midwater trawl, Clarke-Bumpus samplers, and 1-meter plankton net. The volume of plankton and fish taken by the trawl in the area of the seamount was less than that taken at other stations in the Northeast Pacific during the same cruise. The diatom Rhizosolenia semispina was the dominant plankter, comprising more than 50 percent by volume of the plankton collected in the upper 75 meters. The copepods were next in abundance, with Calanus cristatus the dominant species. Other copepods included: Calanus plumchrus, C. finmarchicus, Pseudocalanus minutus, Eucalanus bungii, and Metridia lucens. In lesser abundance were noted chaetognaths, amphipods, euphausiids, siphonophores,

ostracods, and radiolarians. These forms were identified by Mr. Phillip E. Seelinger of the Department of Oceanography, University of Washington. Because of limited information concerning the plankton distribution and lack of synoptic observations in the area of Cobb Seamount no conclusions were made concerning the influence of the mountain on the planktonic communities.

### Fish

To determine the fishing potentialities of the seamount, the M. V. John N. Cobb made seven long-line sets (Powell et al., 1952). These observations and subsequent fishing from the Brown Bear indicate an abundant population of bottom fish. Powell and his coworkers report the following species obtained during the 1950 survey:

red snapper, Sebastes ruberrimus  
 vermilion rockfish, Sebastes miniatus  
 flyfish, Sebastes rhodochloris  
 blue shark, Prionace glauca  
 big skate, Raja binoculata  
 halibut, Hippoglossus stenolepis  
 rock sole, Lepidopsetta bilineata

The red snapper and vermilion rockfish were taken in the greatest quantities. During Brown Bear Cruise 144, four albacore, Thunnus alalunga, were caught in the vicinity of the pinnacle. Even though fish seem to be abundant, present utilization of the area by commercial fishermen appears to be impractical.

### Birds

During September 1950, the U. S. Fish and Wildlife Service vessel John N. Cobb observed an unusual abundance of bird life in the area of the pinnacle. This large population of birds was noted during subsequent visits of the John N. Cobb and the Brown Bear. Powell et al. (1952) reported large numbers of Beal's petrels, fork-tailed petrels, black-footed albatross, sooty shearwaters, and jaegers. Forster's terns, arctic terns, and one unidentified duck also were seen. Powell's report stated that this abundance of birds was an indication that the area of the seamount is probably well populated with marine life and might be a feeding area for pelagic fish.

## CHAPTER 5. HYDROGRAPHY

During four Brown Bear cruises (Nos. 9, 31, 139, and 144), hydrographic observations were made around Cobb Seamount. The purpose of these observations was to explore the currents and water structure, and to determine if any anomalies existed in the immediate vicinity of the mountain which might be attributed to its presence. The numbers and types of hydrographic observations made on and near the mountain are listed in Table 4.

TABLE 4  
NUMBERS AND TYPES OF HYDROGRAPHIC OBSERVATIONS

<u>Brown Bear</u> Cruise	Hydrographic Stations	Other Observations
No. 9 (August 1952)	10 (Nos. 183-191)	1-day time-study: $\frac{1}{2}$ -hourly BT's
No. 31 (August 1953)	4 (Nos. 839-842)	$3\frac{1}{2}$ -day time-study: currents and BT's
No. 139 (April 1956)	10 (Nos. 1-10)	BT grid
No. 144 (August 1956)	1 (No. 42)	BT grid, microtemp. measurements, currents

Although only a few observations have been made at any one time on the mountain, it is possible to draw certain preliminary conclusions and to offer suggestions for future investigators.

### Currents

From the theoretical considerations of the effect of bottom topography on a slope current in homogeneous water, Ekman (1932) found that a current in the northern hemisphere would be deflected to the right upon entering shallower water and to the left upon entering deep water, and that these deflections are independent of the absolute depth. Sverdrup, Johnson, and Fleming (1942) have examined qualitatively the effect of bottom topography on relative currents in nonhomogeneous water. They show that the alteration in the distribution of mass for a body of water flowing over a ridge is such that the isosteric surfaces slope upward when approaching the ridge and downward after passing the ridge. From the relation  $i_p = -\bar{i}_s(\sigma_1 - \sigma_2)$  where  $i_p$  is the slope of the isobaric surface, and  $\bar{i}_s$  is the average slope of the anomaly surfaces,  $\sigma_1$  and  $\sigma_2$ , it is apparent that the isobaric surfaces must then slope downward when the current approaches the ridge and upward after it has passed. Thus, for a geostrophic flow in the northern hemisphere,

the isohypses of the isobaric surfaces bend to the right when a current approaches a submarine ridge and to the left after it has passed the ridge. Such deflections have been observed in the North Equatorial Current (Schumacher, 1940). In the southern hemisphere the respective deflections of the Antarctic Circumpolar Current were to the left on approaching a ridge and to the right after passing the ridge (Deacon, 1937).

By the same considerations, it was shown that instead of an isobaric trough in the water mass, an isobaric low would develop over a submarine mountain or bank, thus resulting in a cyclonic eddy in northern latitudes. Extensive observations around the Altair "cone", which is a seamount rising from a base of about 1900 fathoms to within 525 fathoms of the surface in the North Atlantic Ocean, were made during the International Gulf Stream Expedition in 1938 (Defant and Helland-Hansen, 1939). These observations reveal a cyclonic (counter-clockwise) eddy both at the surface (Neumann, 1940) and at a depth of about 100 meters (Wüst, 1940). The density distribution and resulting eddy are in good agreement with the theoretical considerations (Sverdrup et al., 1942).

In order to detect this cyclonic eddy or any other anomalies which might be associated with the mountain, it is necessary to determine the relative importance of the currents not associated with the distribution of mass, i.e., the tidal currents, inertial currents, slope currents, and random wind currents not associated with the inertial currents. Present knowledge and methods do not provide a means for slope-current measurement. According to Yasui (1940), the surface-wind current may be estimated readily from knowledge of the ship's drift and by application of the equation:

$$U = k \sqrt{\frac{A}{B} \times W}$$

where U denotes the ship's drifting velocity due to the effect of wind; W the wind velocity; A and B the cross-sectional areas of the vessel above and below the sea surface, respectively, taken in a plane perpendicular to the direction of drift; and k is 0.03 when U and W are measured in cm/sec. The rotary currents (tidal and inertial) can be determined by a series of current-meter measurements; however, in order to separate the inertial and semidiurnal constituents of a rotary current, measurements must be extended over a period not less than 48 hours at the latitude of the mountain. During Cruise 31, half-hourly current-meter measurements at 20 meters, while the vessel was anchored near the pinnacle for  $3\frac{1}{2}$  days, revealed a rotary current. Both semidiurnal (12.4-hour period) and inertial (16-hour period) constituents were recognized and the maximum velocity was 0.8 knots setting  $110^{\circ}$  True (Barnes and Paquette, 1954). These rotary currents were superimposed on a geostrophic flow of about 0.1 knot setting southeast. However, the four hydrographic stations taken near the mountain immediately following this time-study were insufficient to show any influence of the mountain on the distribution of mass. Analysis of the data from the ten hydrographic stations taken during Cruise 9 and from those taken during Cruise 139 indicate that the geostrophic flow at these times was also approximately 0.1 knot setting southeast. The small differences in the dynamic heights from place to place in the proximity of the

mountain, when considered in the light of the limitations in accuracy of the salinity, temperature, and depth measurements, are not of sufficient magnitude to conclude whether or not a cyclonic eddy exists.

### Water Structure

If the conditions around the mountain were not stationary, then the influence of the mountain on the water structure might be determined by comparing the stability of the water columns at various hydrographic stations; however, no significant differences were found.

The greatest fluctuations in temperature, salinity, oxygen and inorganic phosphate are such as might be associated with a vertical displacement of the water at a particular level of the order of 30 meters. Lack of data and the limitations in accuracy of measurement preclude any correlation of these fluctuations with the presence of the mountain. The vertical distribution of temperature and salinity for stations taken 15 miles north of the mountain during April and August is represented in Figures 14 and 15, respectively. These curves show approximately the extreme seasonal conditions in the area of the mountain. The seasonal changes in temperature apparently are confined to the first 300 meters. The average temperature of the first 300 meters is  $6.6^{\circ}$  C during April, and  $7.3^{\circ}$  C in August. Figure 16 illustrates the vertical distribution of oxygen and inorganic phosphate near the mountain. The temperature-salinity diagram, Figure 17, is based on sixteen deep hydrographic stations taken within a radius of 15 miles from the mountain. Examination of the diagram reveals that the zone defined by these observations is quite narrow. It has been shown that the water at depths from about 150 to 1000 meters off the west coast of North America is a mixture of Sub-Arctic North Pacific water, defined by Carnegie Station 124, and Equatorial Pacific water, defined by Bushnell Station 299 (Tibby, 1941). The temperature-salinity relation for these two extreme water masses is shown by the dotted curves in the inset of Figure 17. The water mass around Cobb Seamount (solid curve) is dominantly Sub-Arctic water mixed with 10 to 20 percent Equatorial Pacific water.

### Detailed Temperature Structure in the Upper Layer

A bathythermograph grid was run in the area of the pinnacle to detect any small changes in the distribution of temperature which might be attributed to the mountain. As shown in Figure 18, there is apparently a pile-up of water as it approaches the pinnacle "barrier". There is also an indication of Bernoulli's effect near the top of the mountain. Repeated bathythermograph lowerings at one place for a period of 30 minutes, immediately following the 29-minute series of observations taken on the north-south section shown in Figure 18, supports the view that the variations are predominantly associated with a change in position and are not changes that might be associated with internal waves or other short-period time fluctuations. A northeast-southwest bathythermograph section across the current was run immediately prior to this sequence of measurements. Along this latter section (not shown), the only significant change in the thermal structure was a vertical spread of the isotherms over the 45-fathom terrace.

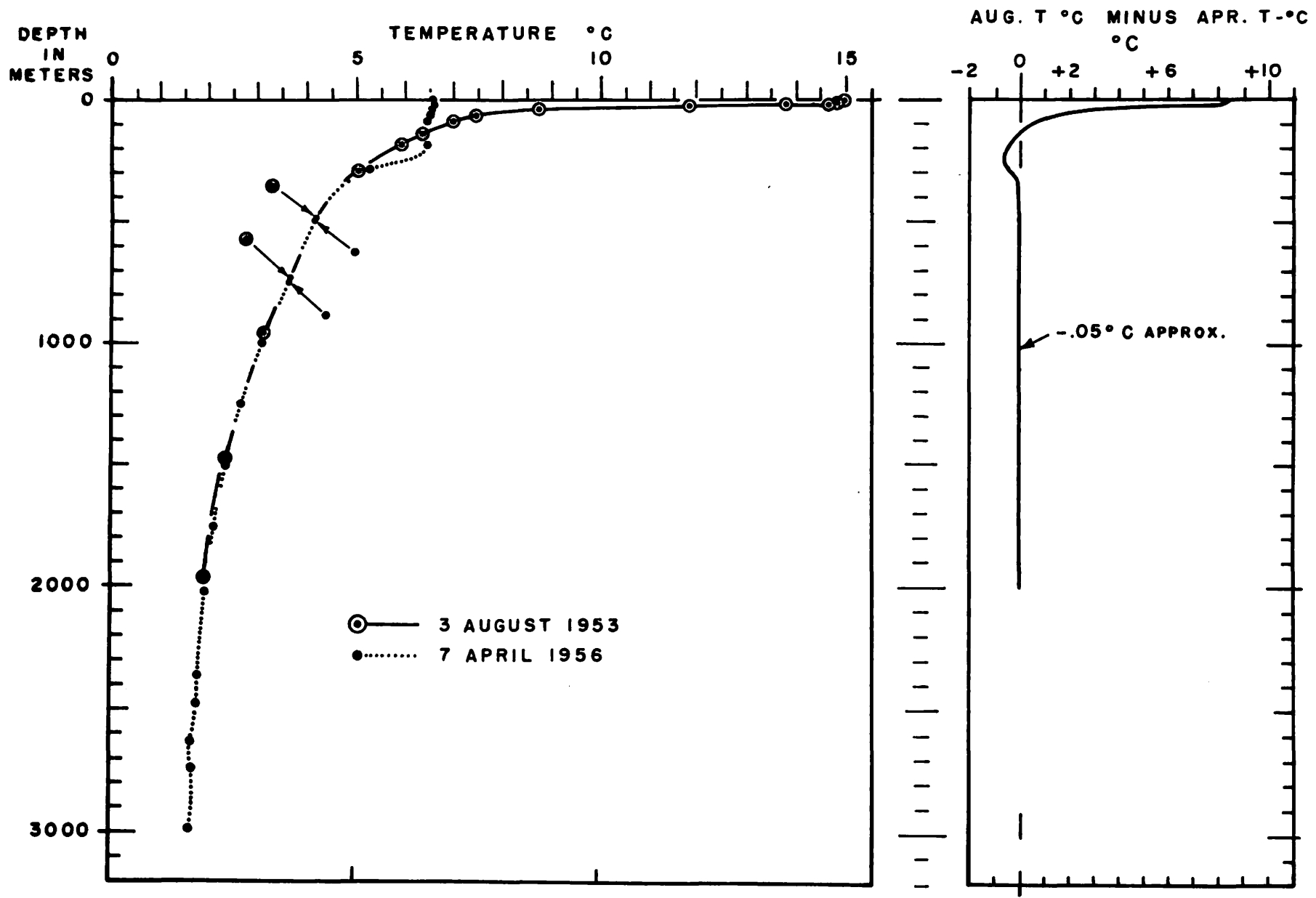


Figure 14. Vertical distribution of temperature

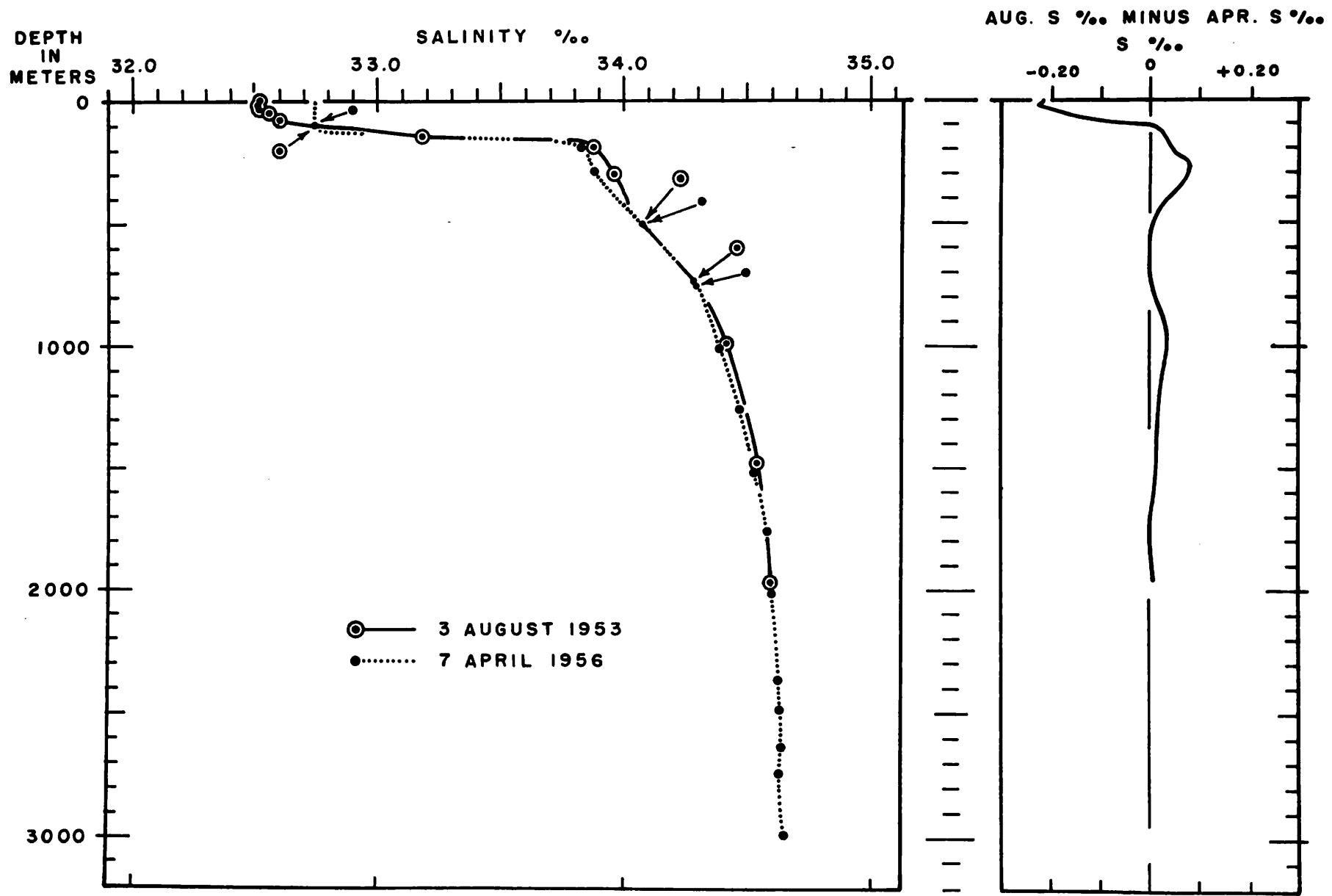


Figure 15. Vertical distribution of salinity

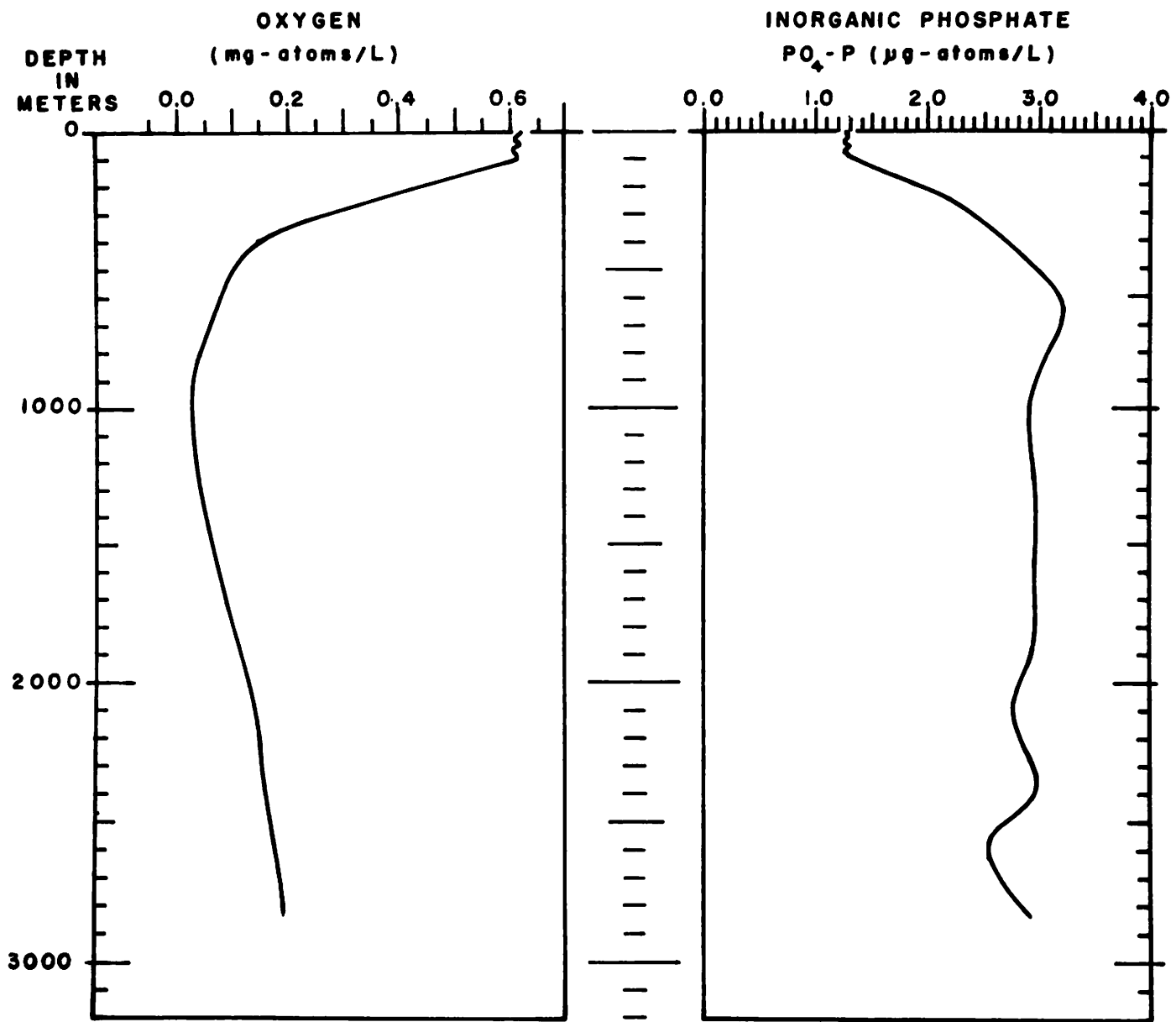


Figure 16. Vertical distribution of oxygen and inorganic phosphate

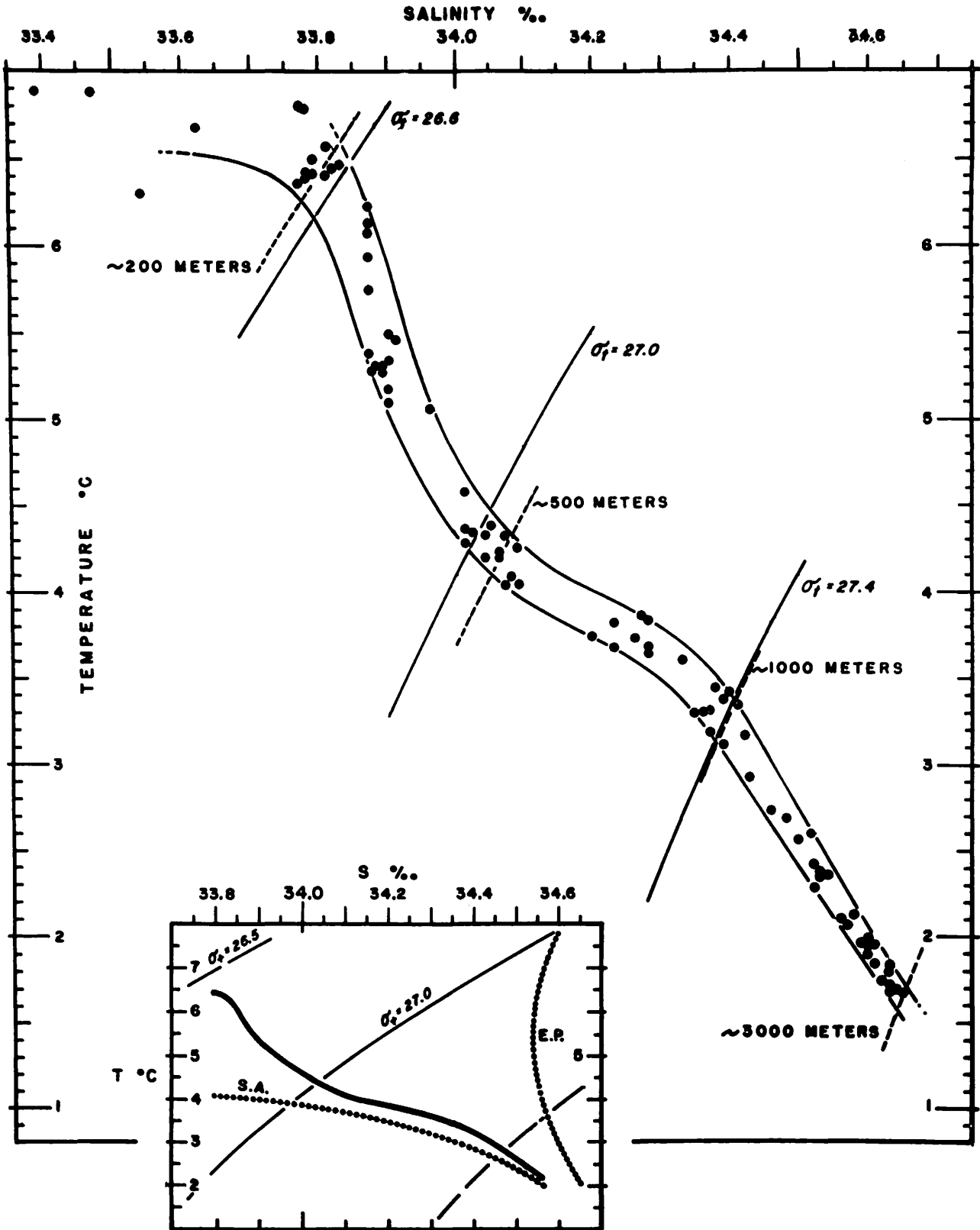
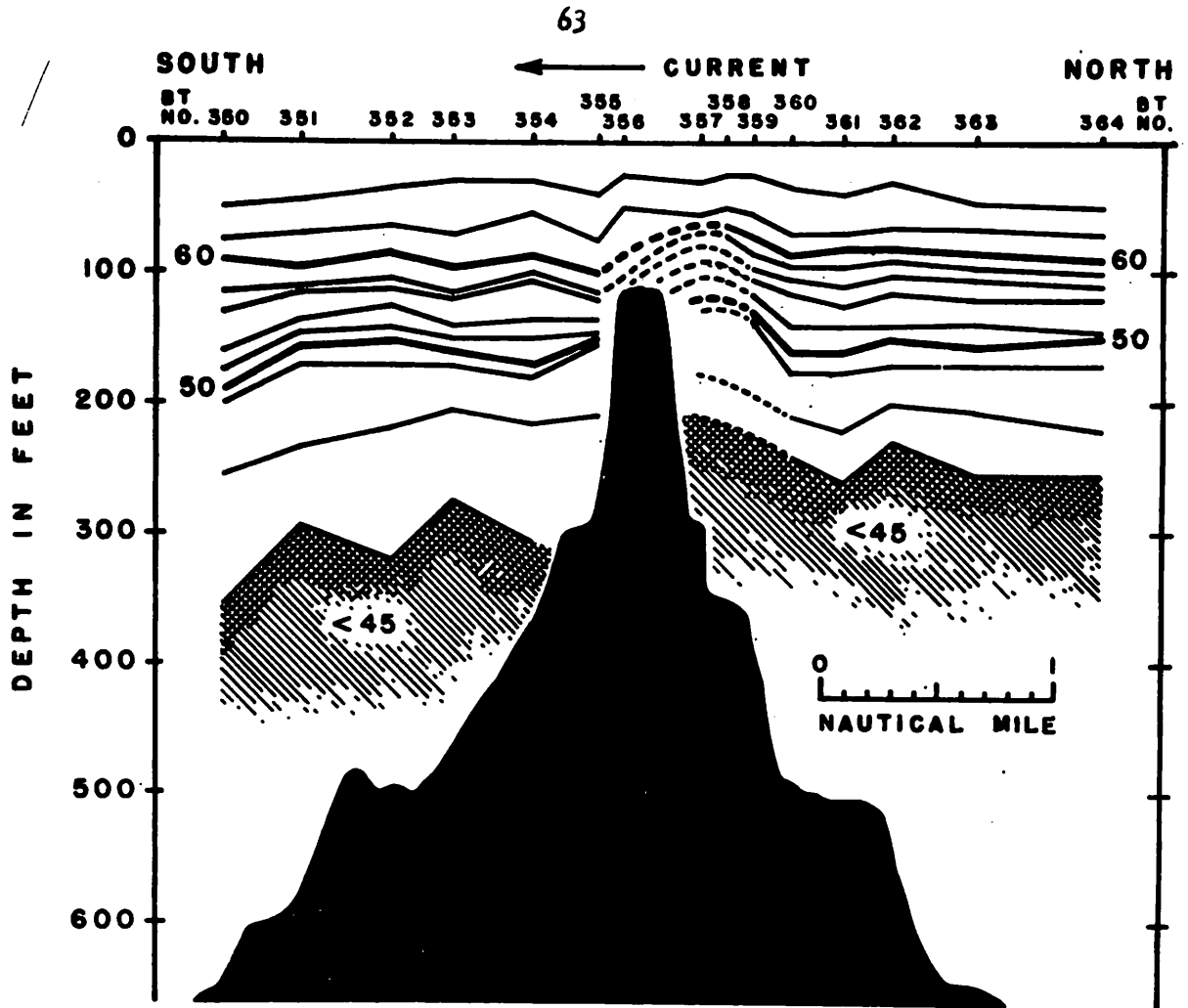
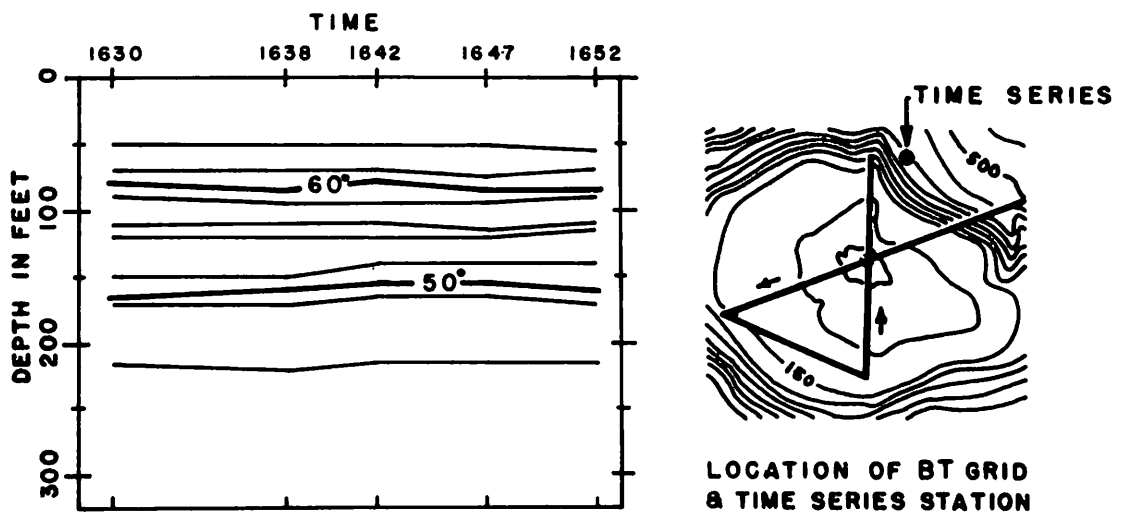


Figure 17. Temperature-salinity relations for 16 stations within a radius of 15 miles of pinnacle



VERTICAL TEMPERATURE DISTRIBUTION ( $^{\circ}$ F) IN NORTH - SOUTH SECTION FROM BATHYTHERMOGRAPH OBSERVATIONS, M/V BROWN BEAR CRUISE 144, 24 AUGUST 1956.



TIME CHANGE OF ISOTHERMS. OBSERVATIONS TAKEN IMMEDIATELY AFTER NORTH - SOUTH SECTION

Figure 18. Temperature near the pinnacle.

Further hydrographic observations around Cobb Seamount in order to demonstrate the effect of a submerged cone on geostrophic flow or water structure would be indicated if the current velocity were higher. However, the absence of large anomalies in the water structure which might be associated with this mountain, and the small velocities noted suggest that this seamount is not an ideal cone for such a study. The need for synoptic observations, in an area of fluctuations as small as those hitherto found on Cobb Seamount, is apparent from considerations of the magnitude of the variations with time, i.e., internal waves (Reid, 1956). In order to gain any confidence in the interpretation of changes in water structure associated with change in position relative to the mountain, repeated sampling at hydrographic stations located in a close network around the mountain should be made. This sampling program should be integrated with a series of observations of at least 48 hours duration, at an anchored station as far from the pinnacle as is practical. This latter restriction is mentioned because observations from the ship swinging on anchor near the peak, where the equiscalar surfaces are slightly tilted, may measure both space and time variations. The periodicity of the vertical temperature-fluctuations and the correlation between the maximum fluctuations and the ship's location near the edge of the pinnacle indicate that the temperatures measured during a  $3\frac{1}{2}$ -day time-study at an anchor position (Cruise 31) include variations associated with the passage of time, as well as changes arising from the movement of the ship within the field.

## CHAPTER 6. SUMMARY AND CONCLUSIONS

Topography and Geology

Cobb Seamount, located in the Northeast Pacific Ocean 270 nautical miles west of Grays Harbor, Washington, was discovered in 1950. This submarine mountain rises from a base at about 1500 fathoms to within 18 fathoms of the surface. A curious flat-topped pinnacle about 300 yards in diameter rises 160 feet with steep slopes (45 degrees) from a 45-fathom terrace. The slopes below the 45-fathom terrace are cut by a completely encircling 100-fathom level terrace averaging 4.5 miles in width. The average slopes of 12 degrees below this terrace are interrupted by rather discontinuous terraces at about 500 fathoms. The base of this seamount, which is oval in plan, is about 17 nautical miles wide and covers an area of about 240 square nautical miles.

The extensive bathymetric survey and bottom-sampling program on and about the mountain indicate that Cobb Seamount is a volcano of possibly pre-Late Eocene age. Assuming that the "500-fathom" terrace was wave-cut within 5 fathoms of the water surface, and considering normal slopes of volcanic cones during its early stages, Cobb Seamount exhibited 1900 fathoms relief. The top would have been 4500 feet above the sea surface. After the wave-cutting of the "500-fathom" terrace, the mountain subsided, possibly with some downward tilting to the north. The marginal depression at the northern base of the mountain is considered to be the result of this local subsidence. Complete submergence of the mountain may be a necessary postulate for its preservation. Lack of adequate dating of the 100-fathom terrace precludes a more detailed history. During Pliocene? to Pleistocene time the 100-fathom terrace was wave cut, after which the mountain subsided to its present position with a slight downward tilting to the north. During the Pleistocene epoch the lowered sea level planed-off the mountain at what is now 45 fathoms and during the subsequent rise in sea level either a 160-foot biostrome (present pinnacle) developed, or a blanket of shells was formed on a remnant basalt stack after Pleistocene erosion of the 45-fathom terrace.

From the age determination of this mountain, recent bathymetric surveys, and other considerations, the western limit of the Pliocene-Pleistocene orogenic belt and Menard and Dietz's Ridge and Trough Province is concluded to be less than 150 nautical miles from the coasts of Washington and Oregon.

Although Cobb Seamount has been more extensively surveyed than any other submerged mountain far offshore, there is still much to be desired in the interpretation of its history. A sampling program between 600 to 1200 fathoms and an extensive exploration of the pinnacle are two of the most important objectives for a future survey.

## Biology

The abundant bottom fauna on Cobb Seamount is apparently limited to the pinnacle above 45 fathoms. The dominant forms recovered were Hinnites multirugosus and the sea urchin, Strongylocentrotus sp. Examination of the bottom fauna suggests that this population might be endemic.

The dominant plankter in the area is the diatom, Rhizosolenia semispina. Fish eggs and larvae have been noted in the plankton hauls.

Bottom fish have been caught in abundance on the mountain. The dominant species were the red snapper, Sebastes ruberrimus, and the vermillion rockfish, Sebastes miniatus.

The demonstration that the bottom fauna of the seamount is endemic and the ecologic effects of the mountain in a deep sea area are worthy of future investigation.

## Hydrography

Hydrographic observations of the currents and water structure around this mountain have revealed no gross changes or anomalies which might be attributed to its presence. When considered in the light of the limitations in accuracy of the temperature, salinity, and depth measurements, the changes detected in water properties are not of sufficient magnitude to conclude whether or not the expected cyclonic eddy exists. The geostrophic flow during April and August was about 0.1 knot setting southeast. Isotherms obtained by an extensive bathythermograph grid over the 100-fathom terrace indicate a pile-up of water on the up-current side of the pinnacle "barrier". The isotherms also show some indication of Bernoulli's effect near the pinnacle.

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## APPENDIX A

## GEOGRAPHIC POSITION OF COBB SEAMOUNT

The top of Cobb Seamount, which is 18.5 fathoms deep, is 270 nautical miles bearing  $247^{\circ}$  True from Cape Flattery, Washington (Figure 1). One of the secondary objectives in the study of this mountain was to determine as accurately as possible the exact geographic position and, in so doing, compare the fixes obtained by the loran system of navigation with those obtained by celestial lines of position. The pinnacle of Cobb Seamount affords an excellent reference point for such a comparison.

The accuracy of loran, which is a radio location-device, has been a subject of much controversy among navigators. A rule of thumb used by most navigators when considering the combined effect of all errors is that the accuracy of a loran position should be less than 1 percent of the mean distance from the stations (The Loran System, 1945). From theoretical considerations presented by Alexander (1955), the average error for a fix 270 miles from the base line would be about  $\pm 1.2$  nautical miles. Because the accuracy of loran and celestial observations is of the order of  $\pm 1.0$  mile in the area of the seamount, a comparison of the methods seems useless. One would expect a random distribution of both loran and celestial fixes; however, discrepancies in a constant direction and distance between loran and celestial have been observed on numerous occasions by the Brown Bear while running sounding lines in the North Pacific Ocean. While maintaining location on Cobb Seamount, the vessel made an attempt to determine whether the distribution of loran and celestial fixes would be random or grouped according to the system used. Figure 19 shows the results of these observations.

The sixteen loran positions shown were taken on a Model DAS-3 receiver, which in all cases had been calibrated recently. The U. S. Coast Guard has confirmed that the transmitters were properly synchronized during the period of observations. As shown in Figure 19, the scattering of positions for the very small pinnacle is 2.0 miles east and west (neglecting Cruise 29 fix), and 1.0 mile north and south. The instrument can be read within  $\pm 1.0$  microsecond and the transmitted signals are within  $\pm 2.0$  microseconds; thus, in the area of Cobb Seamount the maximum possible error is  $\pm 0.8$  miles (0.25 miles per microsecond). The maximum discrepancy of 0.8 miles was observed in positions obtained while the Brown Bear was anchored east of the pinnacle in 40 fathoms during Cruise 9 (not shown in figure).

The fifteen sun lines shown in the inset of Figure 19 were taken on Cruises 29 and 139 during times of distinct horizon and body; however, ten of the lines were taken when moderate sea conditions prevailed. Thus, the scattering of these ten lines may be attributed to the ship's roll and the consequent error in dip. These observations were taken by five individuals: three of the ship's officers; Mr. C. M. Love; and the senior author of this study. The mean position of the pinnacle as

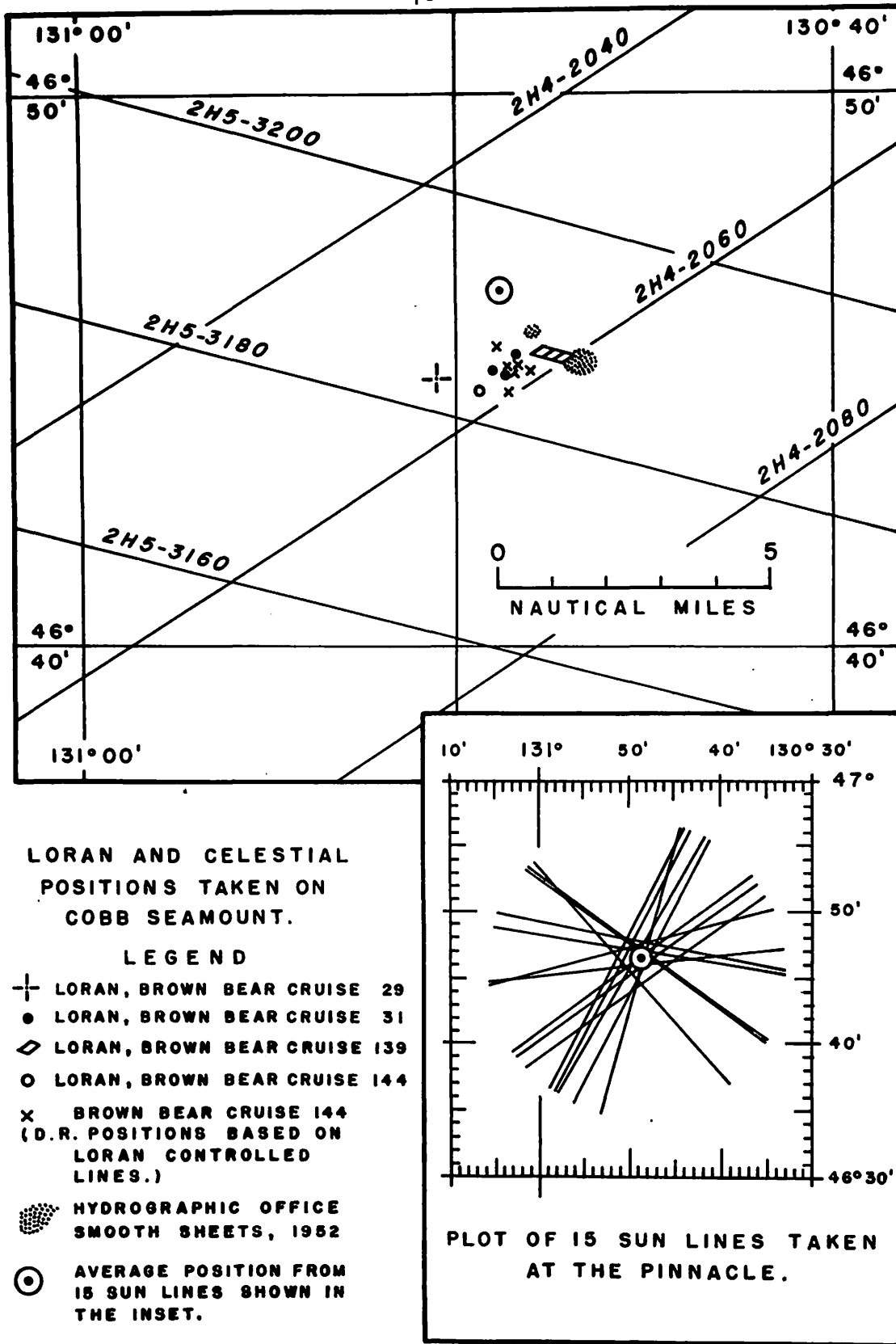


Figure 19. Comparison of Loran and Celestial Positions of the Pinnacle of Cobb Seamount

determined by the sun lines is  $46^{\circ}46.4'$  W and  $130^{\circ}48.8'$  N. The probable error as determined from the distribution of possible fixes is  $\pm 0.8$  nautical miles.

The mean celestial position is 1.5 miles NNW of the loran grouping. It is apparent that there is a discrepancy between the two systems in the area of Cobb Seamount, and this discrepancy appears to be a systematic error in the loran system. The most probable source for this error is disturbance in wave propagation. An examination of the effects of air-temperature gradients and magnetic disturbances is indicated.

Obviously neither position is accurate but, because an EPI or more accurate position is not available, all coordinates for soundings and sample positions are relative to the celestial position of the pinnacle.

## APPENDIX B

## BOTTOM SAMPLERS

Ten different bottom-sampling devices, shown in Figure 20, were used in the study of the area around Cobb Seamount. The stations at which the various samplers were used are noted in Tables 1 and 2. In order that future investigators of this mountain may benefit from the authors' experience, and in order to provide details for readers who are not familiar with bottom sampling, a discussion of sampling techniques is included here.

Type of Sampler

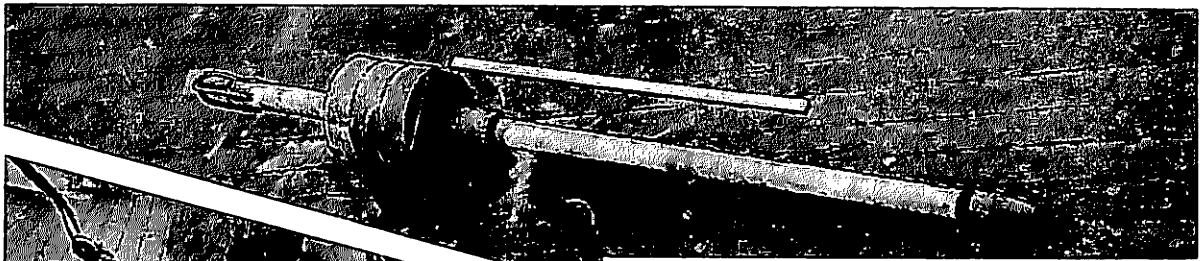
Phleger bottom-sampler (corer)  
 Gravity corer  
 Large-pipe dredge  
 Small-pipe dredge  
 Tooth dredge  
 Anchor dredge  
 Net dredge  
 Petersen grab  
 Snapper  
 Sounding lead

Phleger Bottom-Sampler

This is a coring device developed by Phleger (1951). Briefly, the corer is a  $1\frac{1}{2}$ -inch I. D. galvanized pipe to which are fitted doughnut-shaped lead weights. A one-way valve is included in this device to allow water and air to pass through the core barrel when it is lowered and to inhibit flushing when it is raised. Inside the core barrel is a plastic liner held in place by a cutting edge (nosepiece). An "orange-peel" core-catcher inside the nose usually inhibits the extrusion of the sediment while the sample is being retrieved.

Gravity Corer

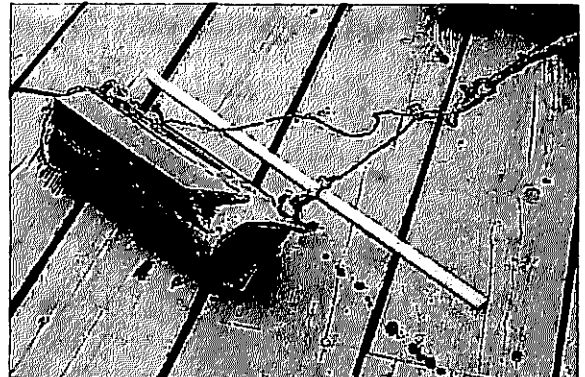
The gravity corer used is similar to the Emery-Dietz instrument (Emery and Dietz, 1941). This device differs from the Phleger corer in the location of the valve and in the diameter of the barrel (2-inch I. D.). Two gravity corers and about 6000 meters of wire were lost during Cruise 139 because of faulty wire and extremely rough weather. Both the Phleger and the gravity corer were used with the ship's  $3/16$ -inch hydrographic wire.



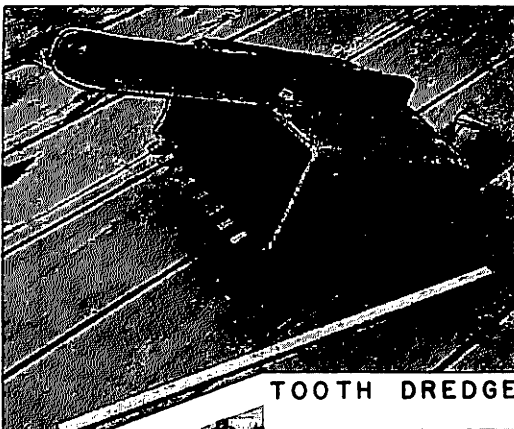
**GAVITY CORER**



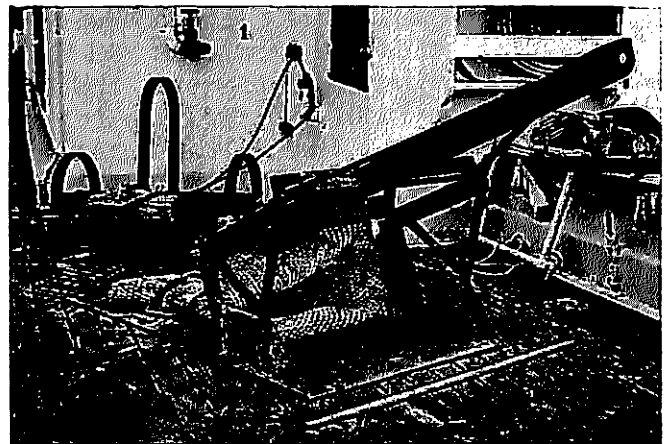
**LARGE-PIPE DREDGE**



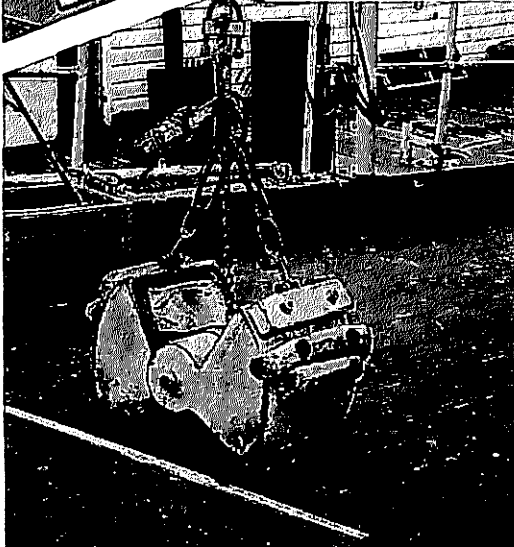
**SMALL-PIPE DREDGE**



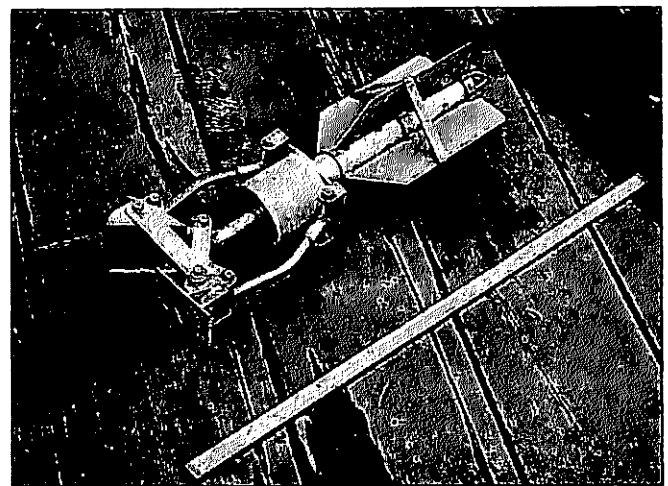
**TOOTH DREDGE**



**ANCHOR DREDGE**



**GRAB**



**SNAPPER**

**FIGURE 20. PHOTOGRAPHS OF BOTTOM SAMPLERS USED**

### Large-Pipe Dredge

The pipe dredge was found to be the most efficient rock sampler used on the mountain. This 120-pound dredge is 12 inches in diameter and 40 inches long. In order to lessen the tendency of the dredge to overturn, the mouth was cut in a curved fashion as shown in Figure 20. The back of the dredge is covered by a network of metal rods to which hardware cloth is attached. Experiments with a straight-mouth dredge of similar size and weight in comparison with the curved-mouth instrument indicate that a curved mouth does enhance the efficiency of the pipe dredge. This dredge was used with the 7/16-inch wire; the wire length was between one and three times the depth; and the time on bottom was usually 15 minutes. In retrieving the instrument, difficulties of fouling on the bottom and concomitant loss of time were a usual occurrence. A 1/8-inch shackle was used as the weak link on this expendable instrument (this shackle became badly distorted after a few hauls and was often replaced).

### Small-Pipe Dredge and Double Dredge

The amount of 7/16-inch wire on the Brown Bear limited the dredging to depths less than 300 fathoms; therefore, a small-pipe dredge 6.5 inches in diameter and 20 inches long was used on the longer 3/16-inch wire for sampling down to 650 fathoms. Both a safety line and a weak link were used to prevent loss of this light cable. This dredge was successful only after a weight (the tooth dredge) was attached about 2 fathoms above the sampler for the purpose of keeping it on the bottom. Only by using this combination of dredges (called double dredge in Table 1) was it possible to obtain samples on the "500-fathom" terrace.

### Tooth Dredge

This 200-pound sampler is made of 1/2-inch stock 18 inches wide, 9 inches high, and 18 inches long. Protruding 2 inches from the cutting edge are eight 1-inch wide teeth. The tooth dredge was designed especially to obtain samples of any rock that might be present under the shell layer on the pinnacle; however, the instrument retrieved only shells and fauna. The digging ability of this instrument could be increased by lengthening the tow bar and bending it upward, and/or by attaching a heavy weight a few fathoms above the dredge.

### Anchor and Net Dredges

The anchor dredge was designed primarily for biological sampling on soft bottoms. It is a 12 by 30-inch rectangular frame to which is attached a coarse-net bag. The instrument has a large cutting edge and is able to shear open if badly fouled. The net dredge is similar in size to the anchor dredge, but lacks a cutting edge and has a different tow-bar arrangement. Dredging with these instruments was not successful and usually resulted in much time lost in trying to retrieve the sampler. These dredges were used with 7/16-inch cable.

Petersen Grab and Snapper

The Petersen grab is a type of "clamshell" actuated on the bottom by a slack wire release. This instrument was used many times in shoal areas of the mountain with very poor results. The snapper used was similar to that described by LaFond and Dietz (1948). This instrument is actuated by a foot-type trip and by a loaded spring. It was not designed for sampling coarse or poorly sorted sediments, and therefore was not generally used.

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