AN ABSTRACT OF THE THESIS OF

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Title: STRUCTURE AND STRATIGRAPHY OF TERTIARY AND QUATERNARY STRATA HECETA BANK, CENTRAL OREGON SHELF

Abstract approved Redacted for Privacy
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Heceta Bank is located about 45km west of the Oregon Coast on the edge of the continental shelf. In places the bank is in less than 100 meters of water, and sediment of late Miocene to Holocene age are exposed. Lithologies were predominantly mudstones with one occurrence of a fine grained sandstone.

Rock texture compares well with the texture of recent sediments in modern environments. This information combined with a faunal analysis suggests that late Tertiary and Pleistocene environments were similar to present conditions, and that rock textures may be useful in establishing relative paleodepths for the Oregon continental margin.

Three distinct stratigraphic units constituting 2500 meters of measurable section are identified on Heceta Bank.

The oldest unit (late Miocene) occurs on the western and northern part of Heceta Bank and the youngest unit (Pleistocene) occurs most frequently on the southeastern portion of the bank. A lower and middle Pliocene unit is most predominant through the central portion of the bank and is the thickest unit sampled.

Deformation in the two older units is more severe than that observed in the youngest unit. The average strike in the older units is N55^{o}E compared to an average N30^{o}E in the youngest unit, which indicates a change in direction of the deformational forces sometime in the Pleistocene.

Faunal analyses suggest that the Heceta Bank area was a deep gradually shoaling basin during the latest Miocene and Pliocene. Maximum basin depth during the late Miocene was near 1500 meters and shoaled to less than 200 meters by Pleistocene time. Shoaling may have been the result of basin filling and uplift which began on the Oregon continental margin in the latest Miocene or earliest Pliocene.

A major angular unconformity occurs between the middle Pliocene and Pleistocene sections which indicates that Heceta Bank may have been an island or a headland at sometime during the late Pliocene and Pleistocene. All of Heceta Bank has been affected by a later period of erosion, and was subsequently overlain by a thin veneer of late Pleistocene and/or Holocene sediments.

Structure and Stratigraphy
of Tertiary and Quaternary Strata
Heceta Bank, Central Oregon Shelf

by

Gary Edward Muehlberg

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Typed by Myrna M. Muehlberg for Gary Edward Muehlberg

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INTRODUCTION

General

In recent years the Department of Oceanography, Oregon State University has centered its efforts on the physical, biological, chemical, and geological aspects of the continental margin adjacent to its home coast. Thus, the Oregon continental margin is perhaps one of the most intensely studied offshore areas in the world.

One of the interesting features of the Oregon continental margin is the presence of several prominent shallow submarine banks on the edge of the shelf. These banks have been recorded on hydrographic charts for years and perhaps fishermen knew about them before that. It is only in recent years that the geologists have become interested in them. Within the last ten years the oil industry has performed many surveys of these banks prospecting for oil and gas (Newton, 1966 and 1971). The marine geology group at Oregon State University is studying the area in order to better understand the geologic history of the Oregon continental margin.

The emphasis of this study is placed on Heceta Bank and provides the first integrated geologic study of one of these submarine banks. The area covered by this study is bounded by 44°00′ to 44°20′ north latitude and 124°30′ to 124°55′ west longitude (Figure 1). Heceta Bank is located about 80km southwest of Newport, Oregon. It is a shallow feature less than 110 meters (60 fathoms) deep and it is about 40km long and 10 to 13km wide, trending in a northeast direction (Byrne, 1962).

Heceta Bank was selected for study because of its proximity to shore, large areas of exposed rock, and relatively thick sedimentary section. Rock exposures with an occasional thin sediment layer facilitated sampling. Continuous seismic reflection surveys show a thick sedimentary section which was complicated by folding and faulting. The relationship of this section to onshore geology is not fully known at the present time. The objective of this study is to describe the geology of Heceta Bank and determine its relation to onshore geology and to decipher the geologic history of the region.

Previous Work

Byrne (1962, 1963a, b) first described the geomorphology of the Oregon continental margin and compiled a bathy-

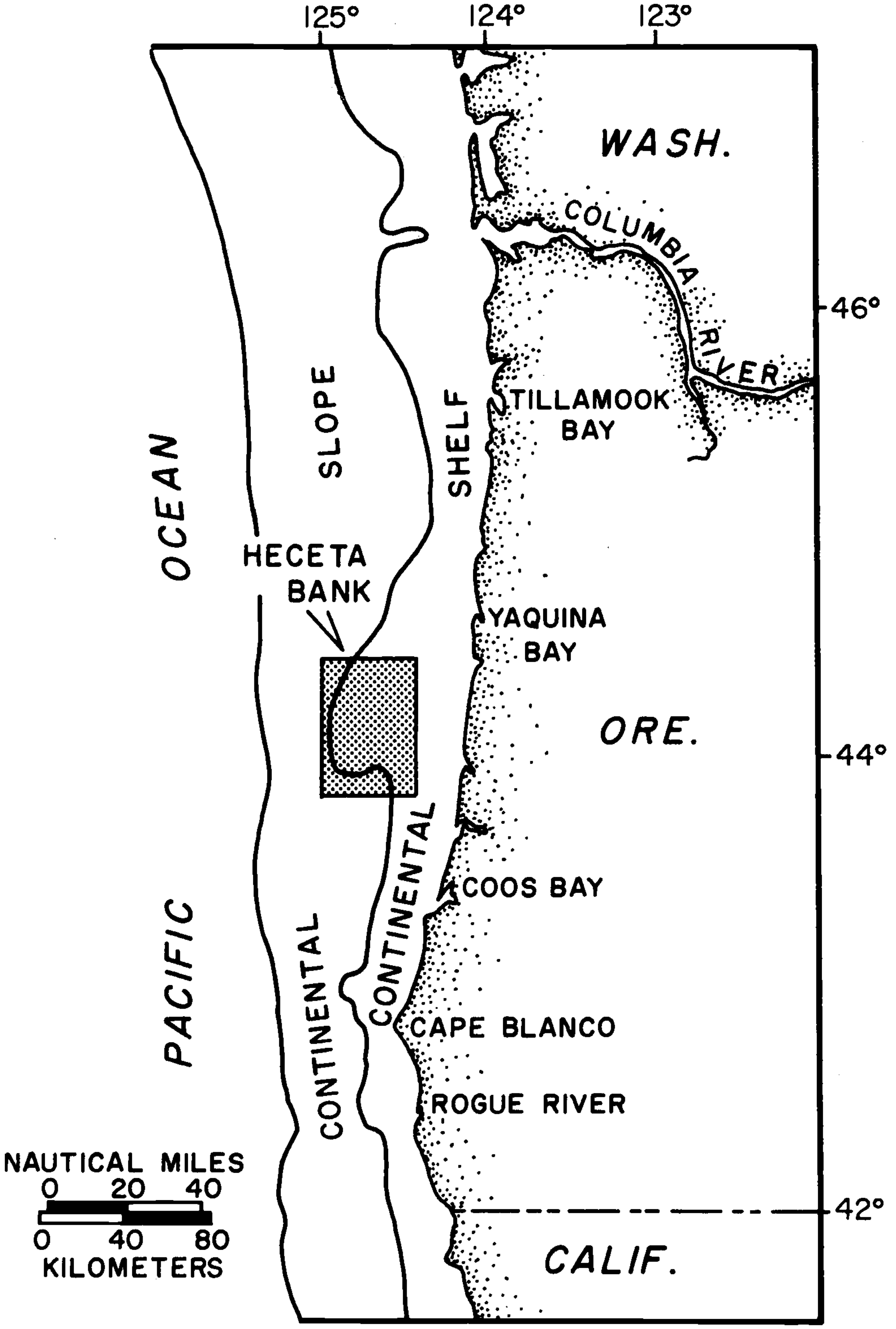

Figure 1. Index map showing area of study.

metric map in fathoms from United States Coast and Geodetic Survey data. Byrne (1962) found the Oregon continental shelf to be narrower, steeper, and deeper than the world wide average continental shelf of Shepard (1963). The break in slope is most pronounced in the Heceta Bank area and the strong lineations evident in the bathymetry strongly suggest structural features (Byrne, 1962).

Dredge samples from the Heceta Bank area consist mainly of siltstone, sandstone, calcareous mudstone, and some limestone breccia (Maloney and Byrne, 1964 and Maloney, 1965). The majority of the dredged rock is thought to be Pliocene in age with paleodepths ranging from 750 to 1050 meters (Byrne, Fowler and Maloney, 1966).

A more detailed analysis of the foraminifera is given by Fowler (1966). He points out the difficulties involved in making age and paleoenvironment determinations on samples which do not have onshore counterparts or local stratigraphic sections for comparative purposes. The nearest stratigraphic sections which could be used for faunal correlations are the Quinault Formation (Cushman, Stewart and Stewart, 1949) and the Wildcat Section of Humboldt County, California (Cushman, Stewart and Stewart, 1930 and Haller, 1967).

Fowler and Muehlberg (1969) point out the existence of at least two stratigraphic units over Heceta Bank. The older is believed to be Pliocene in age and was uplifted about 700 meters. The younger unit appears to be Pliocene or Pleistocene and has been uplifted about 250 meters.

Onshore Geology

The geology of the nearby onshore area (west central Oregon) is predominantly early to middle Tertiary volcanic and sedimentary sequences. The Coast Range of Oregon is a north-south trending low profile mountain range, and extends from the Klamath Mountains in southwestern Oregon to the Columbia River on the north (Baldwin, 1964). The Coast Range is a large gently folded anticlinorium with a maximum elevation of 4,097 feet.

The oldest rocks in the southern Coast Range are Eocene volcanic and sedimentary sequences. Late Miocene (Delmontian) diatomaceous rocks located at Bandon, Oregon have been described by Orr and Zaitzeff (1970). Rock dredges from Coos Bay have revealed fossil material similar to that in the Middle Miocene Astoria Formation at Newport (Baldwin, 1964). An unnamed unit of late(?) Miocene age, which unconformably overlies the Astoria Formation, has been sampled 2km west of the mouth of Yaquina Bay, and consists of basalt flows and a fine grained sandstone

(Snavely, et al., 1964). The Empire Formation which crops out at Coos Bay and south of Cape Blanco is considered to be Lower Pliocene by Bandy (1950). Rocks of Middle and Upper Pliocene age, which are referred to the Port Orford Formation, also crop out south of Cape Blanco (Baldwin, 1964). This formation lies unconformably between the Empire Formation and the Elk River Formation of Pleistocene age (Bandy, 1950). Terraces occur near the Cape Blanco area from sea level to 500 meters above sea level, and range in age from late Pliocene(?) to late Pleistocene (Baldwin, 1964 and Janda, 1969).

The oldest rocks in the northern Coast Range are the Siletz River volcanics of Eocene age (Baldwin, 1964). A rhythmically bedded sandstone and siltstone known as the Tyee Formation directly overlies the Siletz River volcanics. Upper Eocene and Oligocene strata in the area are represented by the Toledo Formation (Baldwin, 1964). The uppermost Oligocene is represented by the Yaquina Formation. The Miocene Nye Mudstone disconformably overlies the Yaquina Formation and unconformably underlies the Middle Miocene Astoria Formation which is also partially exposed at Yaquina Bay (Snavely, et al., 1964 and Baldwin, 1964). Pleistocene deposits occur at Newport and have been correlated with the Coquille Formation near Bandon (Baldwin, 1950). These beds were truncated and capped by beds equivalent to the Elk River beds near Cape Blanco (Baldwin, 1964).

The Central Coast Range, which is located east of Heceta Bank, is composed of predominantly Eocene volcanic and sedimentary rock. Pliocene and Pleistocene rocks are conspicuously absent there. The nearest Pliocene rocks occur at Coos Bay and farther to the south near Cape Blanco where Pleistocene terraces are also well developed. These terraces and extensive onshore stream erosion were caused by a Plio-Pleistocene uplift of the Coast Range which was coupled with a slowly retreating sea (Baldwin, 1964).

DATA COLLECTION PROCEDURES

Seismic Profiling

During the summers of 1968 and 1969 approximately 625km of seismic profiles were made over Heceta Bank (Figure 2). The tracklines were made with a 10,000 joule sparker system and a 20 cu. in. air gun system. The sparker system used is more desirable for shallow water depths (< 100 meters) because it gives higher resolution. The air gun system gave deeper sediment penetration and produced better records in deeper water. Since Heceta Bank lies in relatively shallow water, most the records used in this study were obtained with the sparker system. The nature of this system and the procedures used in its operation are explained by MacKay (1969).

Oregon State University research vessels *Cayuse* and *Yaquina* were used in obtaining all data used in this study. Navigation was by Loran A, radar, and bathymetry. The ships position could be established to ± 2km.

The seismic lines were generally run in a north-south and east-west direction to approximate a grid pattern over the bank. This pattern facilitated later interpretation because the east-west lines were approximately normal to

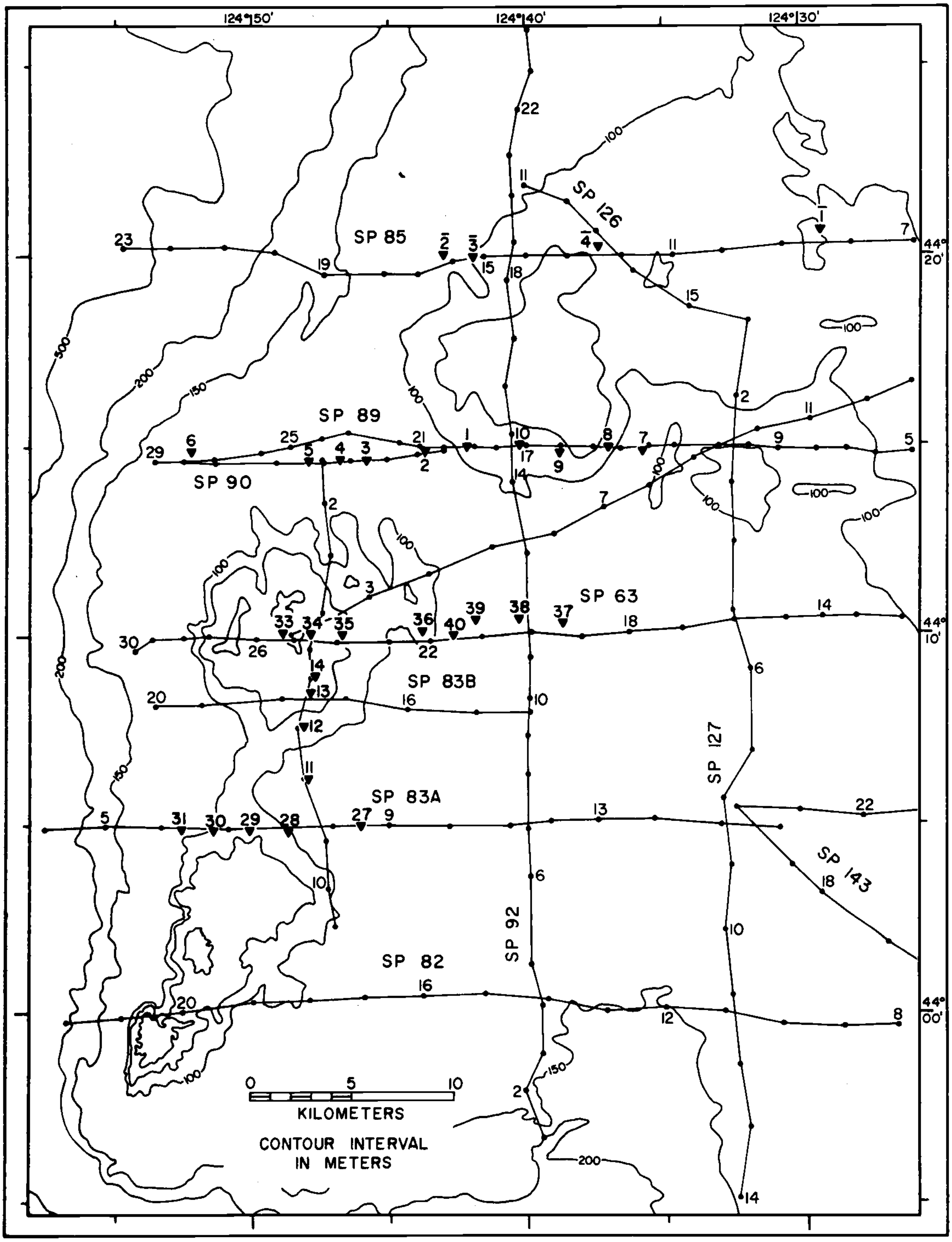

Figure 2. Map showing rock core locations and continuous seismic profile tracklines used in this study. Triangles denote sample locations; dots represent fix locations. 6907 sample numbers are overlined.

the regional strike, and the north-south lines provided intersection points for attitude calculations on the stratigraphic units.

Sampling

A total of 33 gravity (dart) cores were taken over Heceta Bank on the 1968 and 1969 cruises. Of these cores, 31 produced usable lithified sedimentary samples. Description and location of these cores is given in Appendix V. Locations of tracklines and cores are shown on Figure 2.

Two methods of locating sampling stations were used on these cruises. One method was to traverse an area with the seismic profiler and observe the record for structural units and unconformable relationships. Sampling sites were selected and marked on the record. At the end of the run, the course was reversed. When one of the selected localities was reached, the ship was stopped and the location was cored. This process was repeated until all of the selected sampling sites were cored.

The second method utilized marker buoys. An area was profiled until a good sampling locality was reached. At this point an anchored buoy was dropped and its position relative to the structure was marked on the seismic record. The main advantage of this method is that profiling is not required when returning to the selected sampling locality. Handling the buoys and relocating them are minor disadvantages. At night relocation was aided by fitting the buoys with spar poles and blinking lights. Both of these methods gave accurate position relative to the geologic structure which is vital to later interpretation.

LABORATORY ANALYTICAL PROCEDURE

Sediments

The lithified cores were described in detail with the aid of a microscope, and color coded using The Geologic Society of America color chart (1963). When the sedimentary rock was large enough, samples were taken for microfauna, sediment texture analysis, and rock thin sections.

Since most of the rocks were generally semilithified, they were broken down, disaggregated, and treated as sediment samples. This process consists of repeated cycles of soaking in buffered hydrogen peroxide and treatment with an ultrasonic probe. The sample was inspected under the microscope at the end of each cycle for the presence of grain aggregates. Distilled water was added to the disaggregated sample and then drawn off through micropore candle filters. A Calgon and water solution was then added to the sample and drawn off by candle filters. The process was repeated three or four times.

The sample was wet sieved to remove the sand fraction (> 62 microns); it was then dried and weighed. The fine fraction (silt and clay) analysis was done by pipette (Krumbein and Pettijohn, 1938). Percentages of sand, silt, and clay were calculated from these data.

A split of at least 300 grains was separated from the sand fraction and counted on a grid. The grains were divided into rock fragments, quartz and feldspars, mafic grains, micas, pyrite, glauconite, biogenous material (forams, sponge spicules, radiolaria, diatoms, etc.).

Selected rock samples were thin sectioned and examined with a petrographic microscope. Most samples were too fine grained for useful petrographic analysis and consequently were not used extensively in the final analysis of this study.

Microfauna

Samples prepared for microfaunal study were not processed as rigorously as the other samples. Care was taken to preserve the delicate foraminifera, radiolaria, and diatoms for analysis. These samples were first physically broken down into about one cubic centimeter pieces, soaked in water, and agitated gently on a ro-tap machine. Most samples could then be washed in a 62 micron screen. The 62 micron and larger portion was dried and weighed. The samples were floated three times in perchloretylene and the float was saved for inspection.

If the sample contained over 300 specimens it was split with a microsplitter. A fraction containing about 300 specimens was counted, and representative specimens of each species were picked and identified. Fauna data for all samples were supplied by Dr. Gerald Fowler (Appendix VIII).

Attitudes and True Stratigraphic Thickness

True dip and strike were calculated graphically from two apparent dips using a stereonet (Donn and Shimer, 1958). These calculations were made for the 18 intersection points in the Heceta Bank area. Apparent dips were computed by a computer program (MacKay, 1969).

True stratigraphic thickness was manually calculated using:

$$T = S \quad (\sin\theta\cos\alpha\sin\beta \pm \sin\alpha\cos\theta)$$

Where T = true stratigraphic thickness

S = slope distance

θ = true dip

α = slope angle along the traverse

β = acute angle between the direction of traverse and the strike

NATURE AND DISTRIBUTION OF LITHOLOGIES

The lithologies (Appendix V) were classified and described after a microscopic examination of the samples. The lithologic classification was based on an estimate of the percentages of sand, silt, and clay, where the dominant grain size determines the nomenclature (Ingram, 1953). Since sand is a minor constituent and the percentages of silt and clay (Appendix VI) were in most cases almost equal, the term mudstone seems to be the best lithologic classification for most of these rocks.

Generally, the coarser grained lithologies are located on the eastern side of the bank and the fine-grained ones to the west (Figure 3). This study shows that the sedimentary rocks from the western part of the bank are generally older and have a greater paleodepth than those from the eastern part of the bank. The Miocene rocks generally contain the highest percentage of sand. The Pliocene rocks contain a high percentage of clay, and the Pleistocene rocks tend to have more silt with a slight increase in sand over Pliocene rocks. These trends appear to have some significance.

Sample 6906-10, a fine grained sandstone, was the coarsest grained sample collected. It also may be the

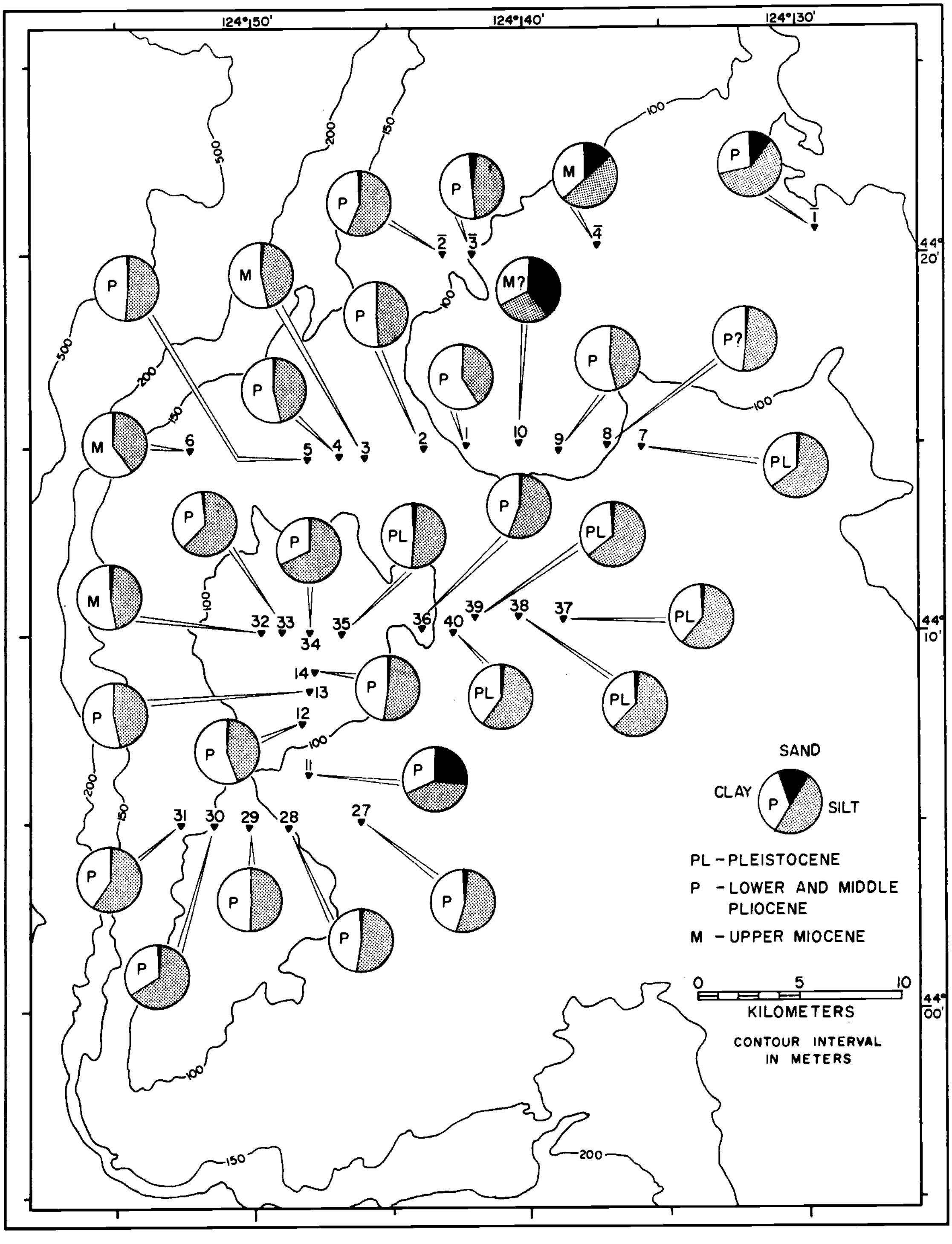

Figure 3. Map showing rock core locations, ages, and percentages of sand, silt, and clay. Triangles denote core locations. 6907 sample numbers are overlined.

oldest deposit and is stratigraphically close to the Middle Miocene(?) unconformity which is prominent on SP 89 directly below 6906-10 (Figure 7). This sandstone has an anomolously high authigenic component (49.9%) in the coarse fraction; glauconite is the principle authigenic material (Appendix VII). Another Miocene rock having a high percentage of authigenic material in the coarse fraction is 6907-4. Glauconite is again the dominant constituent.

Lithologies 6906-11 and 6907-1, have a high sand content. These deposits are generally rich in quartz, feldspar, ferromagnesians, and glauconite. The rest of the sediments are mudstone consisting of various proportions of silt and clay. The slight increase in the sand fraction of 6807-27, 28, 31, 39, 40, and 6907-2 is due to a high biogenous content which is reflected in the coarse fraction.

Samples 6906-3, 6, and 6907-4 have a high biogenous silica content. The silica is about evenly divided between radiolarians and diatoms, except for 6907-4 which has a preponderance of radiolarians. These rocks are considered to be Delmontian (late Miocene) in age (Fowler, et al., 1971), and seem to correlate well with upper Miocene and lower Pliocene silica rich rocks of the Pullen Formation in California (Haller, 1967).

Maloney (1965) analyzed the texture of unconsolidated sediments from the central Oregon continental margin and plotted them on ternary diagrams (Figure 4). He found that the grain size of these sediments steadily decreased with depth from the shelf to the abyssal plain. Continental slope sediments are predominantly silt and clay, and the percentage of clay becomes progressively greater as water depth increases.

Spigai (1971) obtained similar results with southern Oregon continental margin sediments. The slope sediments were also predominantly silt and clay, and the shelf sediments contained more sand.

An attempt to compare disaggregated rock samples with sediment samples may not seem entirely valid. In order to have complete agreement one would have to assume total breakdown of the rock into the exact grain size distributions as occurred in the sediment from which it was formed. Two factors exist which leads the writer to believe this was accomplished, at least well enough to make comparisons in trends. First, the majority of these sedimentary deposits had a high water content when collected and this greatly facilitated the breakdown process. Secondly, the breakdown process was closely monitored to assure complete disaggregation of the rock.

With these limitations in mind the distribution of

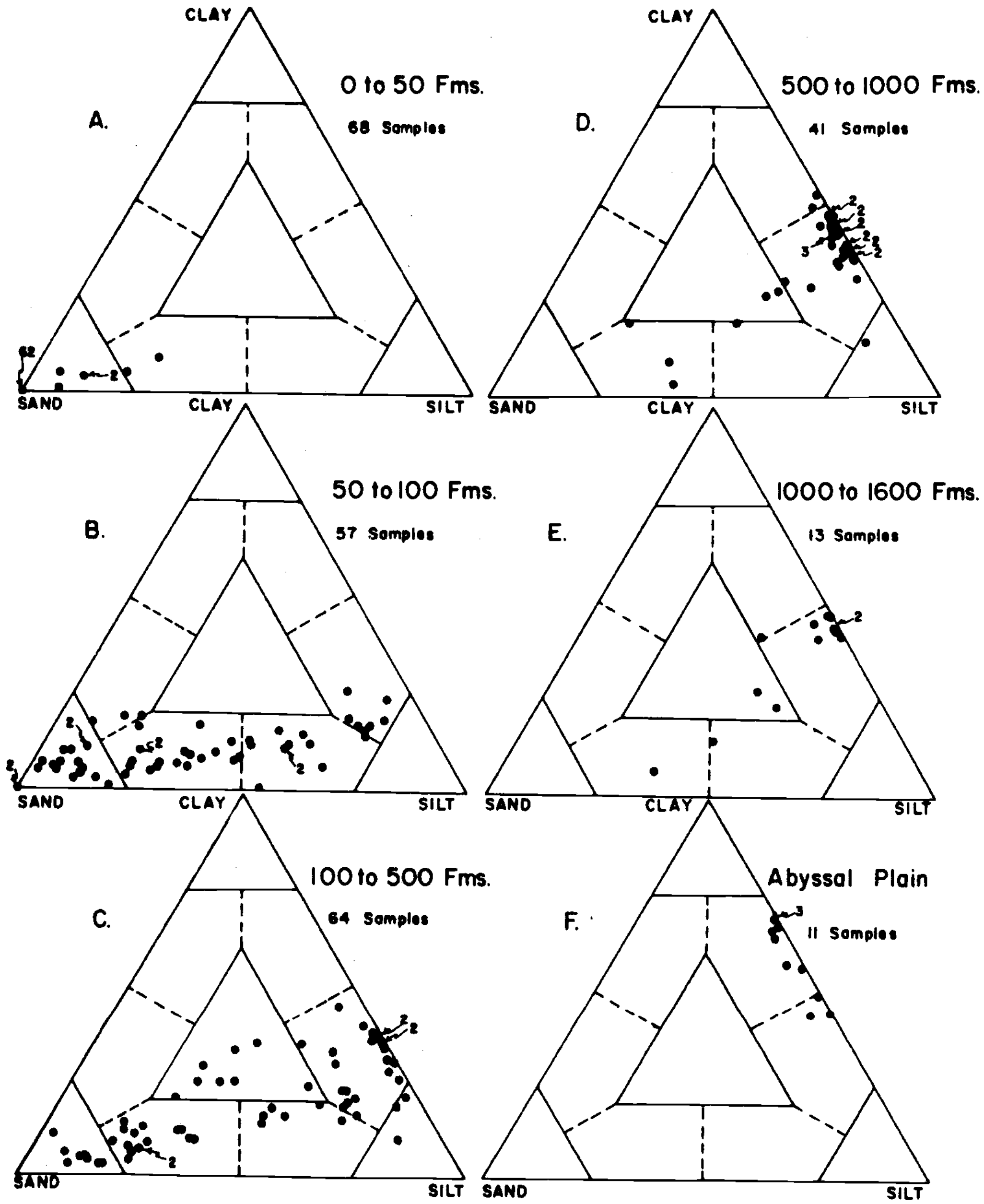

Figure 4. Ternary diagrams showing sand, silt, and clay percentages of sediments from the Oregon continental margin (from Maloney, 1965, pl. 32).

lithologies in Figure 3 can be studied more closely. When compared with the sediment texture analysis of Maloney (1965) (Figure 4) and Spigai (1971), the rock textures alone (Figure 5A) indicate paleodepths of from 100 to greater than 1600 fathoms (180 to 3000 m). The benthic faunal assemblages in these sediments indicate paleodepths of from 100 to 1500 meters (Appendix VIII). The majority of the lithologies follow the depth trend established with surface sediment texture, but the sediment texture groupings (Figure 4) indicate greater depths than the paleodepths of the lithologic groups (Figure 5) which occupy the same position on the diagram.

Lithologies 6906-10, 11, 6907-1, and 4 (Figure 5B) are relatively coarse grained. Compared with the sediment distribution of Maloney (1965) they would have a paleodepth of 100 to 500 fathoms (183 to 910 m) (Figure 4C). Faunal evidence for 6906-11 and 6907-1 indicates a paleodepth of from 400 to 1000 meters. Samples 6906-10 and 6907-4 did not contain foraminifera so paleodepths could not be determined.

The lithologies on Figure 5C have a lower sand content than those discussed above, but have a high percentage of silt. Sediments with this texture (Figure 4C) are found at a depth of 100 to 500 fathoms (183 to 910 m). Faunal evidence from 6807-37, 38, 39, 40, and 6906-7 indicates

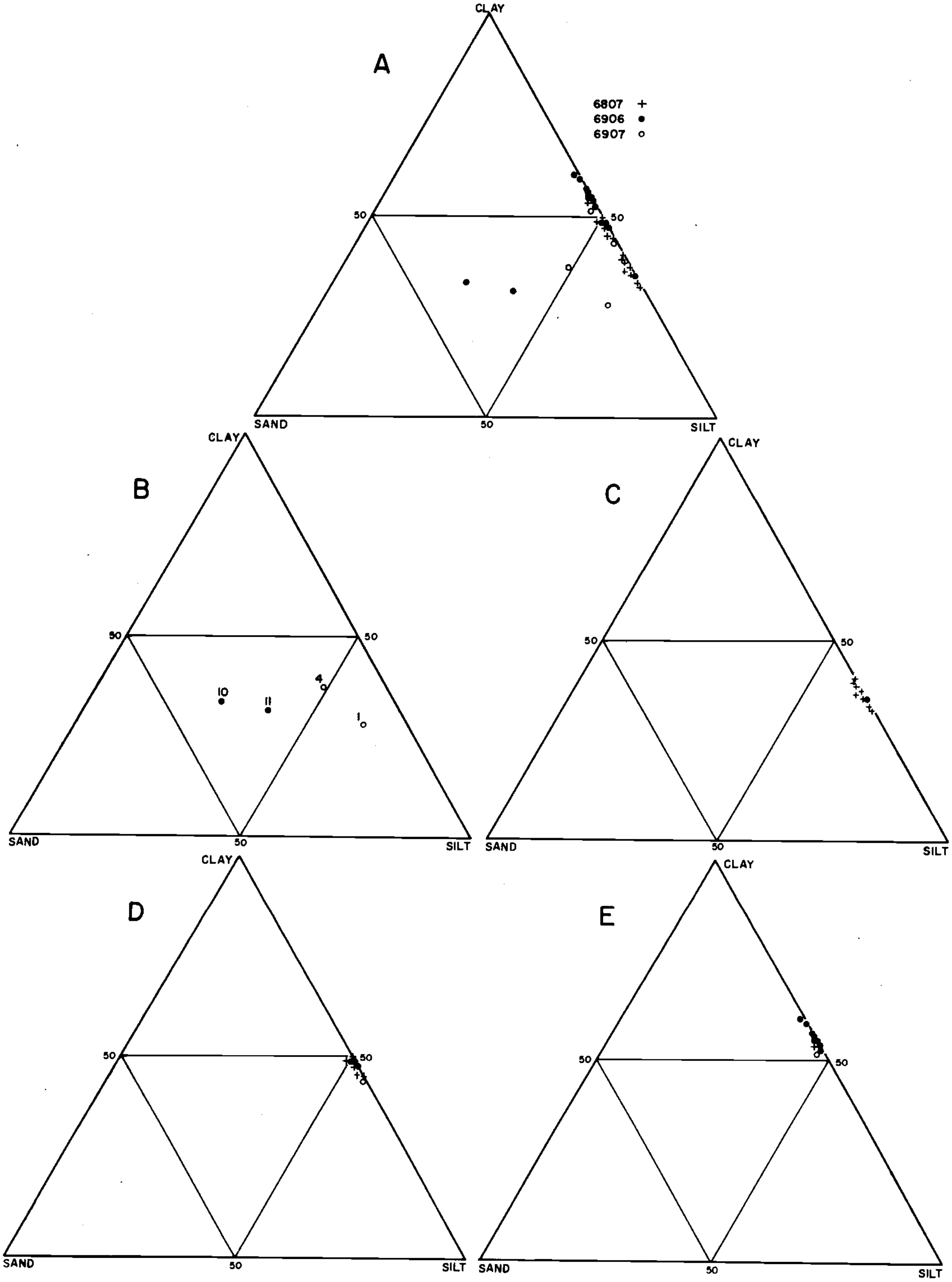

Figure 5. Ternary diagrams showing sand, silt, and clay percentages of rock cores from Heceta Bank.

paleodepths of 200 meters or less. Lithologies 6807-30, 31, 33, and 34 have greater paleodepths of from 500 to 1200 meters.

The grouping of lithologies on Figure 5D corresponds to the sediment texture grouping (Figure 4D) which has a depth of 500 to 1000 fathoms (910 to 1830 m). Paleodepths established from foraminiferal evidence is 500 to 1000 meters for 6807-27, 36, and 6906-5. Paleodepth for 6807-28, 29, 6906-14, and 6907-2 is 700 to 1500 meters. Fauna in 6807-35 indicates a shoal paleodepth of 100-200 meters, and 6906-8 did not contain sufficient fauna to make an accurate paleodepth determination.

The lithologies in Figure 5E have a high clay content and correspond with sediment groupings (Figure 4E and F) which were collected at depths greater than 1000 fathoms (1830 m). Lithologies 6807-32, 6907-3, 6906-3, and 4 all have paleodepths of from 700 to 1500 meters. Foraminiferal evidence indicates a slightly shoaler paleodepth of 500 to 1000 meters for 6906-1, 2, 12, and 13. A paleodepth of 200 meters is indicated for 6906-9, and 6906-6 did not contain fauna for paleodepth determinations.

Although complete and exact comparisons cannot be made between present unconsolidated sediment distributions and rock textures, the patterns and trends are similar. With few exceptions, the rock textures determined in this study become progressively more fine grained as the paleodepth increases, as recent sediment textures do. Since the rock texture data in this study was corroborated by faunal information and studies on sediment textures, the writer feels that sediment texture is a useful tool in establishing relative paleodepths in the offshore Oregon area. The close agreement between rock and sediment textures when considered with the faunal evidence seems to suggest that the late Miocene and younger environments off the Oregon coast were generally similar to the present conditions.

STRATIGRAPHY

General

A number of parameters were used in this study to determine the stratigraphy of Heceta Bank. Seismic profiles were used in conjunction with the faunal analysis of rock cores to determine the age and thickness of stratigraphic section.

The writer was able to distinguish three distinct seismic units and approximately 2500 meters of measurable section in the Heceta Bank area. Units range in age from Pleistocene to late Miocene. The oldest rocks generally occur on the western part of the bank and the youngest to the east. The general structural trend is northeast with considerable faulting and folding. Deformation becomes more intense in the older sedimentary units.

Seismic Unit A

The oldest unit sampled is late Miocene (Figures 6 and 8). It mainly occurs on the far western and northern part of the Heceta Bank (Figure 3). The seismic returns from this unit are characteristically poor (Figure 7) (SP 85, 42km and SP 89, 52km). Part of this is undoubtedly caused

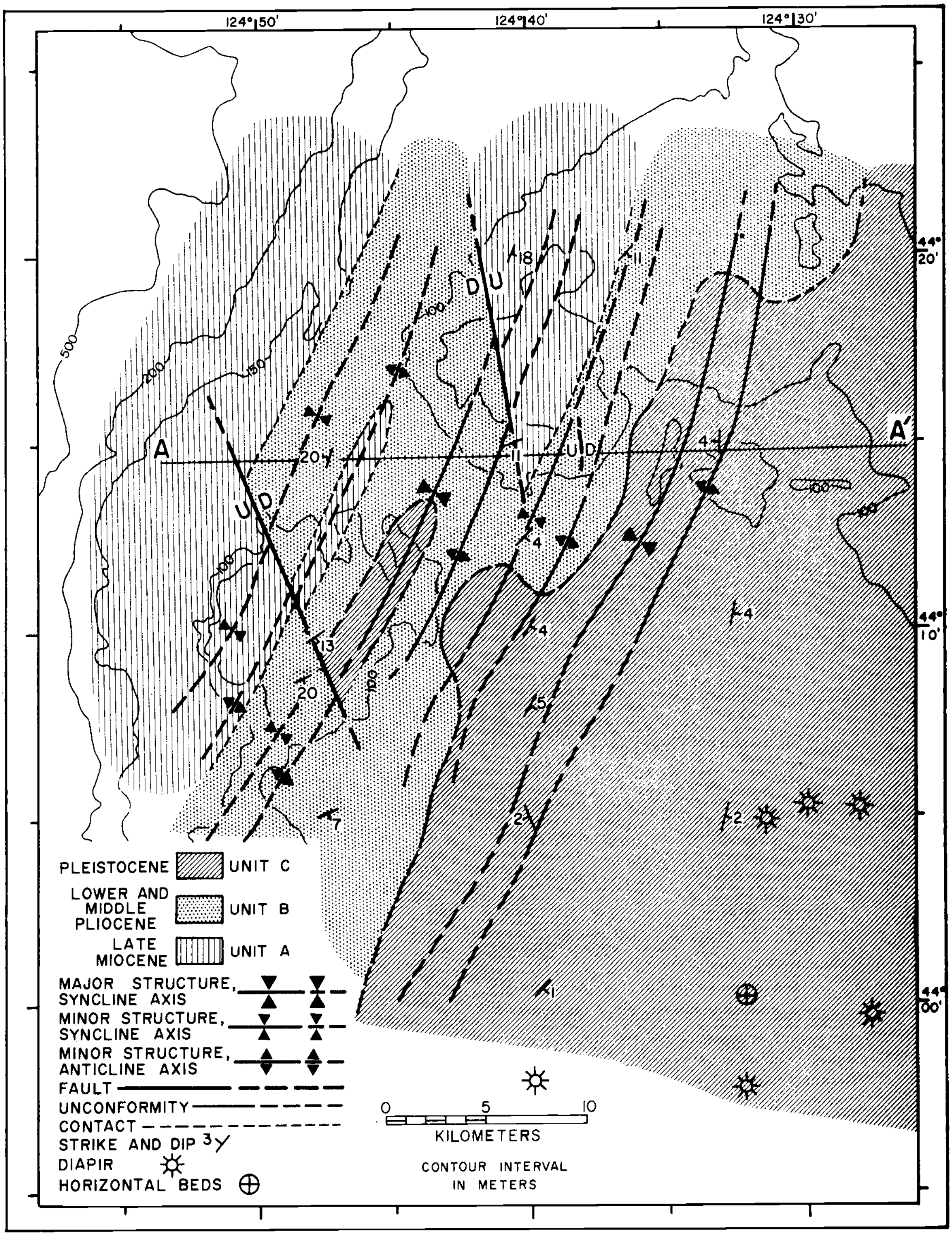

Figure 6. Geologic map of Heceta Bank

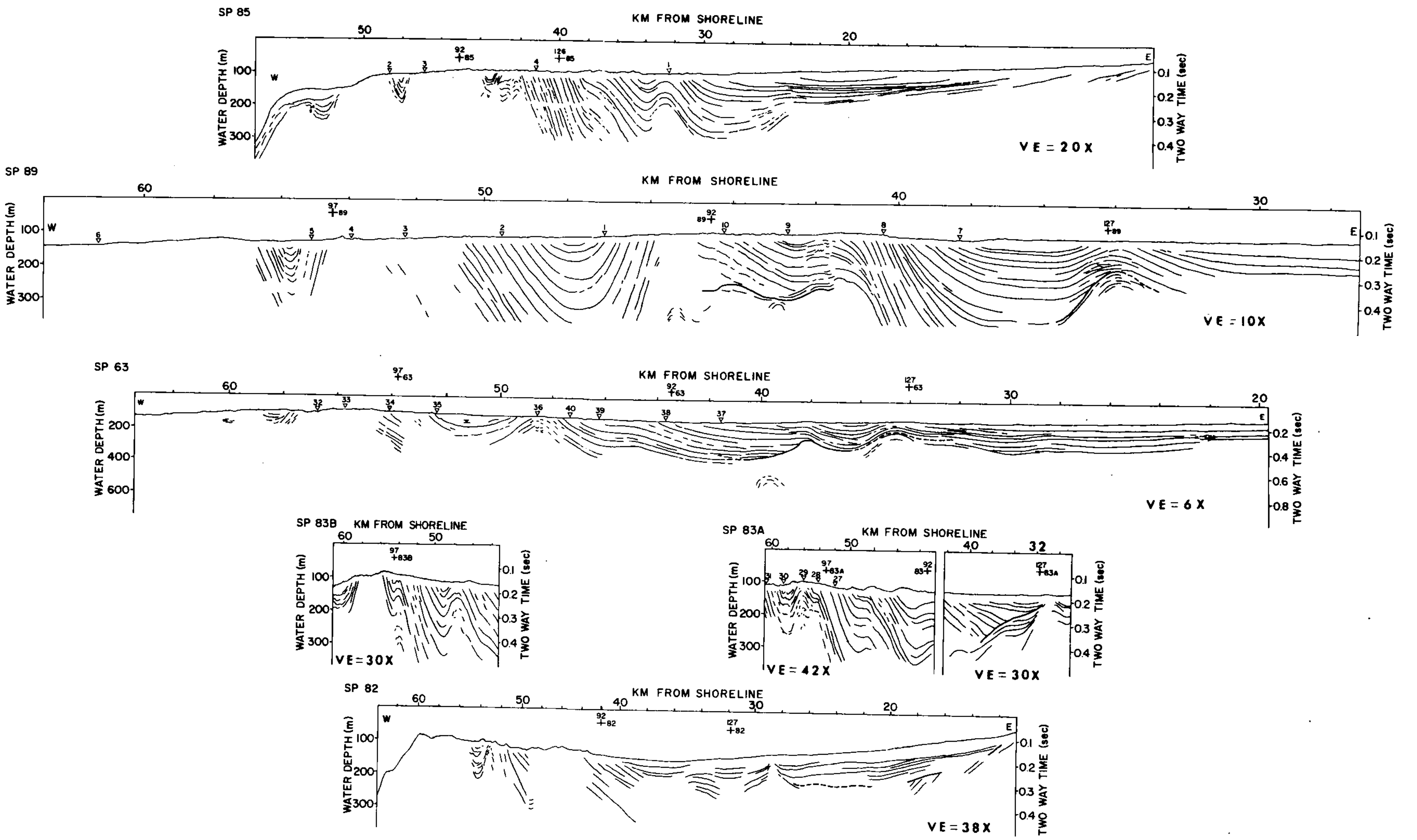

Figure 7. East-west seismic profile interpretations. Triangles denote core locations; + mark seismic trackline crossings.

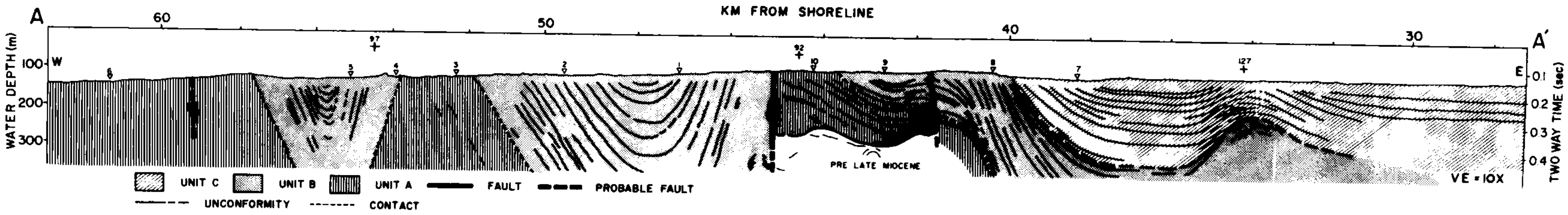

Figure 8. Geologic cross section A-A′. Triangles denote core locations; + mark seismic trackline crossings.

by the greater degree of folding and faulting which is characteristic of unit A. The lithologies are predominantly mudstones with the exception of a fine-grained sandstone (6906-10, Figure 3).

A reliable attitude was obtained at 44°20'N-124°36'W (Figure 6). A strike of N42E and a dip of 11° seems to agree quite well with slightly less reliable attitudes taken at 44°15'N-124°40'W (N68E 11SE) and 44°10'N-124°48'W (N56E 13SE) (Figure 6). The strike in the Miocene unit is more east of north and has a steeper dip than the youngest unit (unit C) on Heceta Bank.

The poor seismic returns from unit A (SP 85, 42km and SP 89, 52km, Figure 7) prevent accurate measurement of a stratigraphic section, but the top of the unit can be placed with some accuracy on SP 63. The section appears to be continuous between 6807-32 and 33 on SP 63 (Figures 9 and 10). Sample 6807-32 is upper Miocene and 6807-33 is lower Pliocene. The division between unit A and B can then be established to within ±50 meters of stratigraphic section.

The age of 6906-3, 6, and 6907-4 has been established as late Miocene (Fowler, et al, 1971). This age was determined with diatoms. They are abundant in 6807-32, 6906-3, 4, 6, 6907-3, and 4 (Appendix V). Rock samples 6907-3 and 6906-4 are considered lower Pliocene, but 6906-4 is

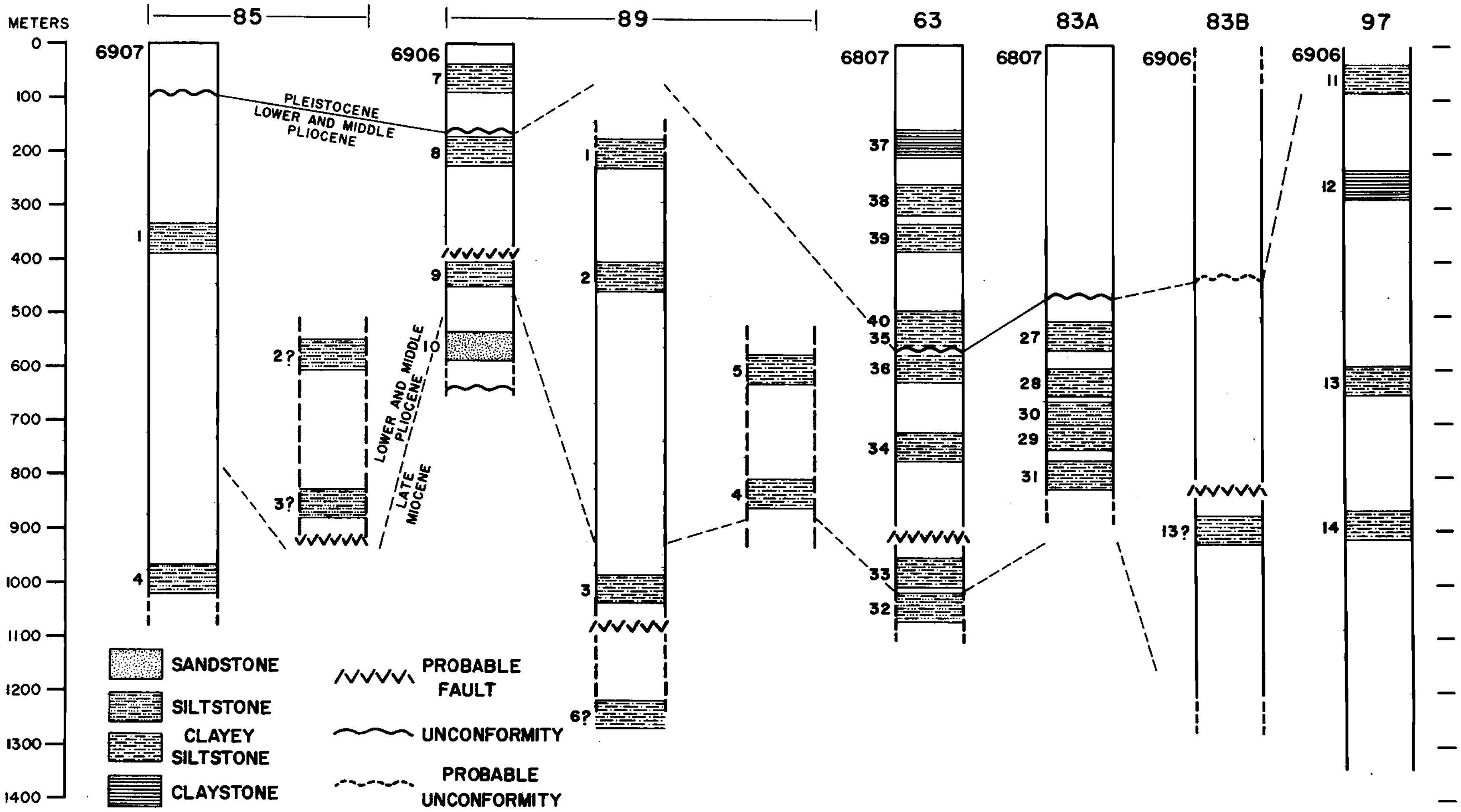

Figure 9. Columnar sections for each seismic profile.

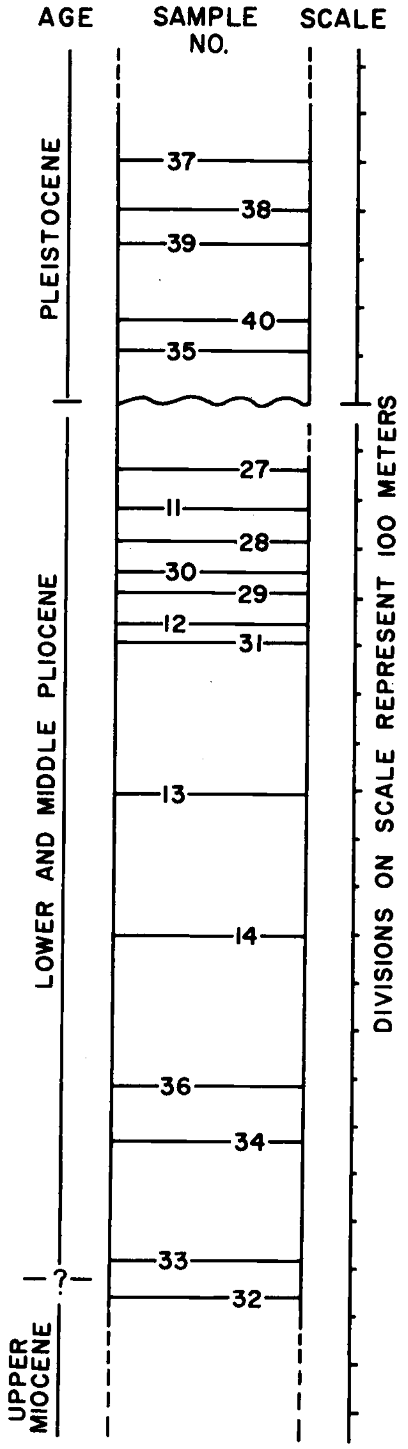

Figure 10. Composite columnar section. Total column thickness is 2600 meters.

questionable and may be late Miocene (Appendix VIII).

Haller (1967) reported a high siliceous (diatom and radiolarian) content in mudstones of the late Miocene Pullen Formation of the Wildcat Group in northern California. The abundance of siliceous mudstones in the upper Miocene of Heceta Bank appear to correlate well with those in Pullen Formation of northern California.

Foraminifera are absent in 6906-10 and 6907-4, and have a very low abundance in 6807-32, 6906-3, and 6. Dominant foram species in these rocks are <u>Bulimina subacuminata</u> and <u>Uvigerina peregrina hispidocostata</u>. These species are still living today and have been reported in greatest abundance at water depths greater than 500 meters (Bandy, 1953, Crouch, 1952, and Bandy, 1960). The frequent occurrence of <u>U. peregrina hispidocostata</u> in these samples indicates a paleodepth of 1000 meters or greater (Bandy, 1960 and Fowler, 1966).

The paleodepth for these upper Miocene rocks seems to be greater than 1000 meters and represents a lower slope environment in which fine-grained mudstones were deposited. The present depth is 100 meters or less, which indicates uplift of 900 meters or more.

Seismic Unit B

The second unit identified is considered middle and lower Pliocene. The majority of the rock cored on Heceta Bank is associated with this unit. Unit B occurs most frequently in the northeast, central and southwestern part of the bank (Figures 3 and 6). Mudstone is the prominent lithology in this unit, but the rocks are slightly finer grained than those found in unit A (Figures 3 and 5).

This unit seems to have distinctive seismic reflector characteristics. Relative to the other two units, the reflectors for unit B are thin and closely spaced. This is particularly evident on SP 85 (41km from the shoreline), SP 89 (40 and 46km), and SP 83A (51km) (Figure 7). The seismic returns are good and the degree of deformation and faulting is noticeably less than in unit A. Reliable attitudes were obtained at four intersections for unit B. The range is N42E 4SE to N63E 20SE and the average strike is N55E. Dips range from 7° to 20°, which is fairly steep for the Heceta Bank area (Appendix III and Figure 6).

In order to show the stratigraphic relations of lithologies from different seismic lines and determine a minimum stratigraphic thickness for unit B, a composite section (Figure 10) was constructed. This was accomplished by computing the amount of stratigraphic section (Appendix IV) between selected samples and the point of the two intersecting seismic lines on which the samples occurred. This method was used on SP 83A, SP 97, and SP 63, but could not be extended farther north because of poor seismic returns and insufficient areal sample coverage.

The sediments of unit B appear to conformably overlie those of unit A, and the upper limit of unit B appears to be an angular unconformity (Figure 8). Physical evidence for an unconformity can be seen on SP 63 (38 to 48km from shoreline), SP 83A (33 to 40km), and SP 127 (Figures 7 and 11). The faunal assemblages of 6807-40 and 36 (SP 63) exhibit different ages and paleodepths. The lower stratigraphic limit of unit C would be near the highest sample of unit B and the observed upper limit of unit B appears to be the unconformity. Within these limits, the minimum thickness of stratigraphic section for unit B (middle and lower Pliocene) is about 1700 meters (Figure 10).

Establishing the exact age of the rocks in unit B is a problem since onshore sections do not exist, and most of the species are living today (Fowler, 1966). The nearest sections available for study are those from the Wildcat Section in northern California (Cushman, Stewart, and Stewart, 1930 and Haller, 1967) and the Quinault Formation

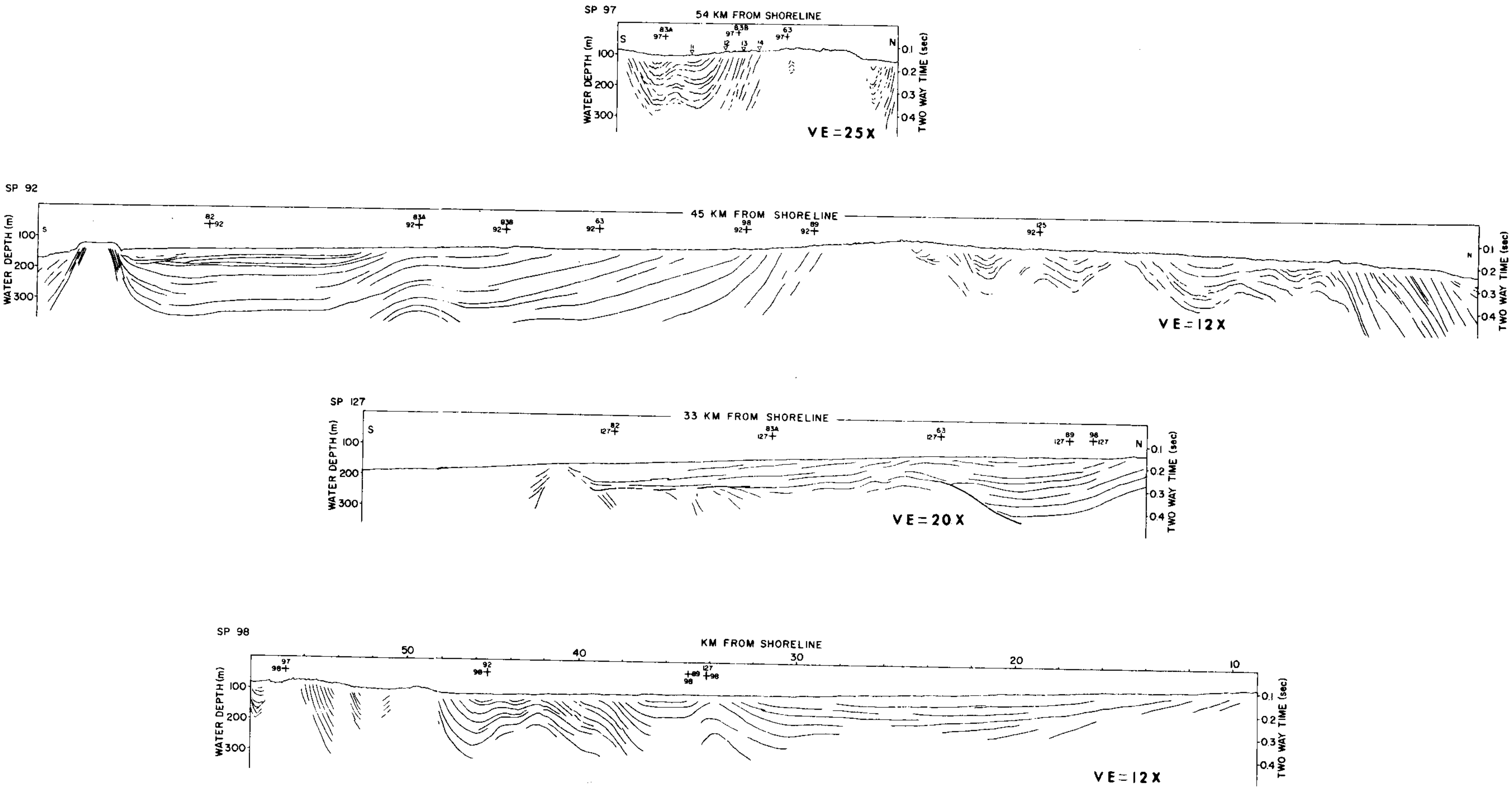

Figure 11. North-south seismic profile interpretations. Triangles denote core locations; + mark trackline crossings.

of western Washington (Cushman, Stewart, and Stewart, 1949 and Rau, 1970). Other sections for southern California have been described by Natland (1952), Martin (1952), and White (1956). Age determination of samples used in this study were made by G. A. Fowler, and in most cases were based on coiling direction of *Globigerina pachyderma* (Appendix VIII).

Other samples from the Heceta Bank area were studied by Fowler (1966) and considered to be Pliocene in age. Samples from that study are stratigraphically equivalent to 6807-27, 6906-11, 12, and 6807-35 in this study. His sample number 24 is geographically located along SP 82 at 58km from the shoreline. Cores were not taken along this line for this study.

The paleodepth for the rocks of unit B appears to be less than those of unit A. The abundance of *Bulimina subacuminata*, *Uvigerina peregrina*, *Cassidulina translucens*, *C. delicata*, and *Bolivina spissa* suggests paleodepths of 500 to 1000 meters (Crouch, 1952, Bandy, 1953, and Martin, 1952). Present water depths are less than 100 meters, which indicates a minimum of 400 meters difference between the present and paleodepth. Fowler (1966) estimates that the uplift in this area is between 640 and 980 meters.

Seismic Unit C

The youngest unit identified is believed to be Pleistocene in age, and unconformably overlies unit B. Evidence for the unconformity has been discussed above. Rocks from this unit were mostly found on the eastern margins of the bank. These lithologies consist of mudstones, but they are on the average more coarse grained than those of the other two units (Figures 3 and 5).

This unit is only slightly deformed and contains no identifiable faults. Since dips are extremely low, attitudes are not totally reliable. Attitudes with relatively high dips (4° to 6°) give strikes ranging from N20E to N46E (Figure 6). Other attitudes with dips of 1° and 2° have strikes ranging from N23W to N41E. These strikes are closer to north-south than those observed in the older units.

The top of the unit lies below the thin layer of Holocene and late Pleistocene unconsolidated sediments present on the eastern part of the bank. Since the amount of sediment in this area is negligible compared to the thickness of stratigraphic section being measured, the sediment surface can be considered as the top of unit C. A good measurement of the amount of section in this unit can be obtained from SP 63 (37 to 48km) and SP 83A (35 to 48km) (Figures 7 and 9). The amount of section on SP 83A and SP 63 is 470 and 570 meters, respectively.

The fauna in the rocks of unit C consists of abundant *Cassidulina minuta* and *Epistominella pacifica*. Occurrences of *Cassidulina limbata*, *C. tortuosa*, *Uvigerina juneca*, and *Elphidium translucens* are common.

The faunal assemblages in these rocks indicate paleodepths of from 150 to 250 meters. *Cassidulina limbata*, *C. tortuosa*, *C. minuta*, *Uvigerina juneca* are presently found at water depths less than 200 meters (Bandy, 1953, Uchio, 1960, and Boettcher, 1967). This represents a paleoenvironment of upper slope to outer shelf. Since these rocks presently occur in water depths of about 100 meters, the difference between present and paleodepth is 100 meters or less.

STRUCTURE

Folding

The folding in the Miocene strata on Heceta Bank is more intense than that in the Pleistocene. The seismic reflection profiles show structures ranging from less than one kilometer from limb to limb to over 5km. Since the true dip is small in all cases, the small folds tend to die out in short distances and this adds to the difficulty in correlating them across the bank. For convenience the folds which are 4 kilometers or larger in size will be considered as major structural features. Less emphasis will be given to the smaller folds and they will be discussed only when they are important in understanding the major trends.

A major syncline occurs on the eastern margin of the bank (Figure 6) and ranges from 2 to 6km from limb to limb. It occurs on profile crossings SP 85 (34km), SP 89 (37km), SP 98 (36km), SP 63 (42km), SP 83A (44km) (Figure 7). It is associated with a major anticline which lies directly to the east (SP 89, 34km). These structures are developed mainly in unit C rocks, but extend into unit B on SP 85.

The second major feature is also a syncline and it occurs in the central bank area. Its presence on SP 89 (48km), SP 98 (52km), and SP 63 (52km) facilitates correlation in this area but its size diminishes both to the north and the south. The synclinal feature on SP 85 (44km) is perhaps the remnant of this structure extended northward. The small synclines on SP 83B (54km) and 83A (58km) are perhaps the southern extension of this major feature. The associated anticline directly to the east is not clearly defined except on SP 63 (48km). Evidence for some secondary deformation of this anticline can be seen on every record, but the exact nature or degree cannot be determined (Figure 7).

Another important feature on the central bank is the synclinorium which is displayed best on SP 98 between 41 and 48km (Figure 11). This distinctive feature can also be seen on SP 63 (42 to 46km), SP 89 (41 to 45km), and SP 97 at the southern end (Figures 7 and 11). It is also present on SP 83A (48 to 54km), SP 83B (48 to 53km), and SP 85 (36 to 40km), but is more difficult to see because of the difference in vertical exaggeration. The anticline to the east of this synclinorium is clearly defined on the southern profiles, but is badly deformed or absent on SP 89 and SP 85.

This synclinorium is particularly interesting and useful. It becomes progressively smaller and more difficult to identify as one traces it northward. This feature is prominent on SP 63 (Figure 7), and SP 98 (Figure 11). Four kilometers to the north on SP 89 (Figure 6) it can still be distinguished as the same feature, but a considerable amount of section appears to be missing. Ten kilometers farther north on SP 85 only a slight flexure remains. The writer believes that the flexure represents the base of this same feature. This appears to be good evidence for a larger amount of uplift of the northern part of the bank prior to Pleistocene glaciation and subsequent erosion of a larger portion of the section. This is supported by the exposure of older rocks on the northern part of the bank (Figures 3 and 6).

Correlation of structures farther to the west is tenuous. The seismic profiles are poor in this area and deformation is more extreme. The quality of the record is directly related to the steeper dips caused by the more intense folding. One minor syncline can be seen on four records and is probably the same feature. The synclines on SP 83B (60km), SP 63 (58km), SP 89 (56km), and SP 85 (48km) (Figures 6 and 7) are on strike and are approximately the same size. Other features can be seen on individual profiles, but extension of their axes is impossible because the control on adjacent records is lacking.

Faulting

The sudden decline in the quality of the records in certain areas, the apparent displacement of fold axes, and the prominent lineation of the bathymetry all strongly suggest large scale faulting on Heceta Bank. Positions of suspected faults seen on the profiles are point locations and do not provide evidence of direction, dip, or type of faulting. The faults in Figures 6 and 8 are inferred from a subjective analysis of the total geology and represent a minimum of possible faults. The displacement which occurs on the bank is perhaps caused by a series of fault zones rather than a few discrete faults.

Good evidence for a fault exists on SP 89 (45km) (Figures 7 and 8). This same area on SP 92 (North of SP 89 crossing) shows a zone of poor return which could indicate faulting. The synclinorium discussed above appears to have been more deeply eroded on the northern part of the bank, but the major syncline directly to the west does not appear to have been eroded as much. One possible explanation is the differential uplift of the synclinorium with respect to the major syncline to the west.

This differential uplift is also indicated on SP 85. The syncline on SP 85 (44km) is the same as the one on

SP 89 (48km), but appears to be deeply eroded. The presence of upper Miocene sediments (6907-4) nearby also shows that much older strata are exposed on the syncline. Yet, a little to the west, Pliocene rocks are exposed in a syncline on SP 85 (49km) (6907-2 and 3). The differential uplift indicated on SP 89 and SP 85 could be explained by a fault extending from SP 89 (45km) to the zone of poor seismic return on SP 85 (46km). The relative movement would be up on the east and down on the west. The bathymetry also shows lineation along this line.

The zone of poor seismic return on SP 85 extends back to 42km, and SP 89 (41km) shows a possible displacement of reflectors. This suggests the possibility of a zone of faulting about 3km wide to the east of the one indicated on Figure 6.

Another fault with approximately the same strike is indicated on the central western bank (Figure 6). The reflection profiles from this area of the bank display many zones of poor return. The strike of the major syncline and anticline on SP 63 (48 to 51km respectively) is offset when compared to the same syncline-anticline system on SP 83B (55km) only 2 kilometers to the south. The syncline on SP 63 exposes younger rocks than the same syncline on SP 83B does, which indicates deeper erosion on SP 83B.

Possible displacement of reflectors can be seen on SP 83B (54km) and zones of poor return are noted on SP 63 (55km) (Figure 7), SP 98 (57km), and on SP 97 (north of 6906-14) (Figure 11). Since the zones occur on all records crossing the area and the dips are not excessive, it is believed that this particular area lacks continuous reflectors because of faulting. The strong lineation in the bathymetry in this area gives further evidence for extension of this fault to another zone of poor return on SP 89 (60km). The relative movement of this fault would be down on the northeast and up on the southwest.

The zones of poor seismic return on SP 89 (52 to 54km), SP 98 (48 to 54km), and on the northern part of SP 97 (Figures 7 and 11), along with the other strong lineations in the bathymetry indicates the existence of a fault zone or series of faults. Some evidence for displaced reflectors can be seen on SP 63 (48km) and could be considered part of the system described above.

Unconformities

A distinct angular unconformity is shown in SP 89 (41 to 45km) (Figures 7 and 8). It does not appear to surface anywhere on this profile. The closest sample to the unit below this unconformity is 6906-10 but it did not contain fauna or flora and consequently could not be dated. Sample 6906-9 is considered to be Pliocene in age, and is perhaps stratigraphically close to the upper Miocene sediments. Because of its proximity to the unconformity, sample 6906-10 may be upper Miocene and the unconformity may be early or middle Miocene. This unconformity is not seen on any other profile taken on Heceta Bank.

Another younger angular unconformity occurs on Heceta Bank and is more wide spread (SP 85 (16 to 18km), SP 89 (33 to 36km), SP 63 (32 to 40km), SP 83A (34 to 40km), SP 82 (12 to 28km), and SP 127). This unconformity may represent erosion of unit B during a Pleistocene sea level lowering, and separates unit B and unit C.

The dip above the unconformity is very low (1° to 6°) and angular discordances are extremely difficult to determine. Age determinations on fauna sampled and extrapolation of known unconformable relations were the only means available in determining the outcrop pattern.

An unconformable relationship is clear on SP 85 (16 to 18km) (Figure 7). If this unconformity is extrapolated it crops out at 28km on SP 85. Sample 6907-1 is Pliocene, but control to the east is lacking.

An unconformity on SP 89 (33 to 36km) crops out between 6906-8 and 7, when extended to the surface (Figures 6 and 8).

Sample 6906-7 is Pleistocene, but 6906-8 could not be dated. The same relationships are seen on SP 98 (34km) but are less clear. Since SP 89 and SP 98 are separated by less than one kilometer at this point (Figure 2), SP 89 was used as a guide in placing where the unconformity surfaces on SP 98. The unconformity is also clear on SP 63 between 32 and 40km. This reflector crops out between 6807-36 and 40 which are Pliocene and Pleistocene, respectively (Figure 7 and Appendix VIII).

A clear unconformable relationship can be seen on SP 83A (32 to 40km). Apparently this reflector crops out near 48km. Sediment sample 6807-27 is Pliocene and control farther to the east of the unconformity is lacking. Profile SP 82 shows an unconformity between 12 and 28 kilometers. The poor quality of this record makes extrapolation extremely difficult; the probable location would be located near the 40km mark.

The outcrop location on SP 83B is tentative and was positioned after considering the more positive locations on SP 63 and SP 83A. The unconformity on SP 127 (Figure 11) is most likely the same unconformity discussed above. It does not appear to surface on this record, but may do so a short distance to the north (Figure 6).

Diapirs

A number of diapir-like structures can be seen on the southeastern part of the bank (Figures 6, 7, and 11). Two of the structures shown occur on a portion of SP 143 which is not figured. The flat top on the diapir at the southern end of SP 92 (Figure 11) indicates that it has been eroded. This erosion most likely occurred during one of the Pleistocene sea level lowerings.

The structures were not sampled in this study so their composition is not known. The seismic return from the core of these features is poor, and reflectors suggesting possible stratigraphy are absent. The records show an onlap type stratigraphy at the edges of these features which suggests that the features have grown during the latest Tertiary and Pleistocene.

GEOLOGIC HISTORY

The base of unit A (late Miocene) on Heceta Bank is an unconformity, which indicates a period of erosion or non deposition sometime prior to late Miocene time. The rocks of unit A are most common on the western and northern part of Heceta Bank.

With the exception of a few late Miocene diatomaceous rocks, which crop out near Bandon, Oregon (Orr and Zaitzeff, 1970), late Miocene strata are absent onshore. The flora from three late Miocene rocks (6906-3, 6, and 6907-4) collected on Heceta Bank correlate well with those collected onshore. Faunal and textural analyses of other late Miocene rocks collected on Heceta Bank indicate paleodepths of 1000 meters or greater (Appendix VIII).

The presence of approximately 200 meters of measurable section of late Miocene strata on Heceta Bank and the occurrence of a single exposure near sea level onshore suggests that late Miocene time was a period of deposition in the Heceta Bank area. Snavely and Wagner (1963) consider that the late Miocene shoreline was very near the present day shoreline.

The late Miocene rock textures range from a fine grained sandstone to mudstone and are generally slightly more coarse grained than rocks from the Pliocene section. Paleodepths in excess of 1000 meters indicate that the Heceta Bank area was occupied by a deep water basin during late Miocene time.

The present strike of unit A averages N60E and measurable dips range from 11° to 20°. Seismic returns from this unit are generally poor which may be attributed to a combination of steep dips and probable faulting.

Lower and middle Pliocene rocks of unit B conformably overlie those of unit A. Unit B is the thickest stratigraphic unit examined in this study and has approximately 1700 meters of measurable section. Unit B is truncated by an angular unconformity.

Lower and middle Pliocene rocks are widespread on Heceta Bank, but occurrences are limited onshore. The nearest occurrence of lower and middle Pliocene marine rocks is approximately 80km to the southeast at Coos Bay, Oregon, and consists of massive sandstones and siltstones (Baldwin, 1964). The rocks of unit B on Heceta Bank are predominantly fine grained mudstones. The paleodepth of these rocks indicated by faunal and texture analysis is from 500 to 1500 meters (Figure 5 and Appendix VIII). The thick sedimentary section indicates continuing deposition in the Heceta Bank area during the early and middle Pliocene.

Deformation and uplift of the coast ranges began in the latest Miocene or early Pliocene (Snavely and Wagner, 1963 and Baldwin, 1964). Paleodepths on Heceta Bank indicate a gradually shoaling basin. The shoaling is perhaps due to a combination of basin filling and uplift.

The present strike of unit B is about N55E, approximately the same as that observed in unit A. Dips in unit B appear to be slightly less than those observed in unit A. Seismic returns in unit B are generally good which may be a result of the lesser degree of deformation.

The greater degree of deformation in the older rocks, evidence of a shoaling offshore basin, and exposure of early and middle Pliocene marine rocks above sea level onshore is good evidence that the deformation and uplift which affected the Oregon Coast Range during the latest Miocene and early Pliocene affected the offshore area as well. The presence of an unconformity truncating unit B indicates Heceta Bank may have been a peninsula at some time during the late Pliocene and Pleistocene. This unconformity could represent one or more periods of erosion during the late Pliocene or Pleistocene.

The youngest rocks (unit C) on Heceta Bank are Pleistocene in age and constitute approximately 600 meters of measurable section. These rocks lie unconformably over the lower and middle Pliocene sediments of unit B. Rocks of unit C are mudstones which are generally more coarse grained than those in unit B.

The Pleistocene rocks are found on the central and southeastern part of Heceta Bank. The nearest onshore Pleistocene rocks are located in the Coos Bay and Bandon area, and at Newport, Oregon (Baldwin, 1964). A series of marine terraces are exposed in the Coos Bay-Bandon, Oregon area which rise as much as 500 meters above sea level, and range in age from late Pliocene(?) to late Pleistocene (Baldwin, 1964 and Janda, 1969).

Faunal and rock texture analyses of unit C rocks infer paleodepths of 200 meters or less. These shoal paleodepths and the presence of elevated marine terraces onshore provide good evidence for continued uplift of the continental margin through the Pleistocene.

The present strike of unit C averages about N30°E which is considerably less east of north than the strike of the two older units on Heceta Bank. This indicates a change in direction of deformational forces affecting the Heceta Bank area. The change is from a NNW-SSE direction for units A and B to a WNW-ESE direction for unit C. Dips observed in unit C range from 0° to 6°, and are less than those in the older units (A and B). The low dips in this unit are most likely a function of the short time it has been present on the shelf and not of a radical change in the rate of deformation.

The age of the major faults indicated on Figure 6 is difficult to place accurately. They appear to truncate Pleistocene rocks near the center of Heceta Bank so the latest movement must have been during or shortly after the deposition of unit C, but before the last period of erosion which affected all of the units on the Bank.

At the present time much of Heceta Bank is covered with a thin veneer of late Pleistocene and/or Holocene unconsolidated sediments. These sediments thicken to the east on the eastern flanks of Heceta Bank.

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APPENDICES

APPENDIX I

TRACK LINE NAVIGATION DATA

Sparker Profile No.	Fix No.	Cruise - Time Date	Latitude (North)	Longitude (West)	Computed Course (Degrees)	Speed (m/min)	Speed (km/hr)
63	8	6807-11-0700	44° 9.7′	124°20.0′			
					275°	133	8.0
63	9	6807-11-0715	44° 9.8′	124°21.5′			
					290°	142	8.5
63	10	6807-11-0730	44°10.2′	124°23.0′			
					270°	159	9.6
63	11	6807-11-0745	44°10.2′	124°24.8′			
					280°	144	8.6
63	12	6807-11-0800	44°10.4′	124°26.4′			
					275°	151	9.1
63	13	6807-11-0815	44°10.5′	124°28.1′			
					270°	115	6.9
63	14	6807-11-0830	44°10.5′	124°29.4′			
					264°	116	6.9
63	15	6807-11-0845	44°10.4′	124°30.7′			
					270°	159	9.6
63	16	6807-11-0900	44°10.4′	124°32.5′			
					262°	170	10.2
63	17	6807-11-0915	44°10.2′	124°34.4′			
					266°	178	10.7
63	18	6807-11-0930	44°10.1′	124°36.4′			
					265°	151	9.1
63	19	6807-11-0945	44°10.0′	124°38.1′			
					274°	160	9.6
63	20	6807-11-1000	44°10.1′	124°39.9′			
					266°	160	9.6
63	21	6807-11-1015	44°10.0′	124°41.7′			
					261°	161	9.7
63	22	6807-11-1030	44° 9.8′	124°43.5′			
					270°	142	8.5
63	23	6807-11-1045	44° 9.8′	124°45.1′			
					270°	168	10.1
63	24	6807-11-1100	44° 9.8′	124°47.0′			
					275°	142	8.5
63	25	6807-11-1115	44° 9.9′	124°48.6′			
					270°	115	6.9
63	26	6807-11-1130	44° 9.9′	124°49.9′			
					275°	151	9.1
63	27	6807-11-1145	44°10.0′	124°51.6′			
					261°	81	4.8
63	28	6807-11-1200	44° 9.9′	124°52.5′			
					270°	106	6.4
63	29	6807-11-1215	44° 9.9′	124°53.7′			
					235°	65	3.9
63	30	6807-11-1230	44° 9.6′	124°54.3′			
82	1	6807-18-1430	43°59.8′	124°12.3′			
					282°	118	7.1
82	2	6807-18-1445	44°00.0′	124°13.6′			
					278°	188	11.3
82	3	6807-18-1500	44°00.2′	124°15.7′			
					270°	213	12.8
82	4	6807-18-1515	44°00.2′	124°18.1′			
					267°	214	12.8
82	5	6807-18-1530	44°00.1′	124°20.5′			
					270°	151	9.1
82	6	6807-18-1545	44°00.1′	124°22.2			
					259°	199	11.9

Sparker Profile No.	Fix No.	Cruise - Time Date	Latitude (North)	Longitude (West)	Computed Course (Degrees)	Speed (m/min)	Speed (km/hr)
82	7	6807-18-1600	43°59.8'	124°24.4'			
					267°	205	12.3
82	8	6807-18-1615	43°59.7'	124°26.7'			
					266°	178	10.7
82	9	6807-18-1630	43°59.6'	124°28.7'			
					274°	196	11.8
82	10	6807-18-1645	43°59.7'	124°30.9'			
					281°	190	11.4
82	11	6807-18-1700	44°00.0'	124°33.0'			
					274°	196	11.7
82	12	6807-18-1715	44°00.1'	124°35.2'			
					266°	187	11.2
82	13	6807-18-1730	44°00.0'	124°37.3'			
					281°	190	11.4
82	14	6807-18-1745	44°00.3'	124°39.4'			
					277°	197	11.8
82	15	6807-18-1800	44°00.5'	124°41.6'			
					267°	205	12.3
82	16	6807-18-1815	44°00.4'	124°43.9'			
					270°	187	11.2
82	17	6807-18-1830	44°00.4'	124°46.0'			
					266°	178	10.7
82	18	6807-18-1845	44°00.3'	124°48.0'			
					266°	178	10.7
82	19	6807-18-1900	44°00.2'	124°50.0'			
					264°	232	13.9
82	20	6807-18-1915	44°00.0'	124°52.6'			
					263°	206	12.3
82	21	6807-18-1930	43°59.8'	124°54.9'			
					266°	127	7.6
82	22	6807-18-1950	43°59.7'	124°56.8'			
83A	4	6807-18-2045	44° 4.9'	124°57.7'			
					86°	196	11.7
83A	5	6807-18-2100	44° 5.0'	124°55.5'			
					90°	186	11.2
83A	6	6807-18-2115	44° 5.0'	124°53.4'			
					93°	222	13.3
83A	7	6807-18-2130	44° 4.9'	124°50.9'			
					88°	328	19.7
83A	8	6807-18-2145	44° 5.0'	124°47.2'			
					90°	186	11.2
83A	9	6807-18-2200	44° 5.0'	124°45.1'			
					90°	195	11.7
83A	10	6807-18-2215	44° 5.0'	124°42.9'			
					90°	195	11.7
83A	11	6807-18-2230	44° 5.0'	124°40.7'			
					85°	134	8.0
83A	12	6807-18-2245	44° 5.1'	124°39.2'			
					90°	142	8.5
83A	13	6807-18-2300	44° 5.1'	124°37.6'			
					90°	186	11.2
83A	14	6807-18-2315	44° 5.1'	124°35.5'			
					93°	213	12.8
83A	15	6807-18-2330	44° 5.0'	124°33.1'			
					94°	196	11.7
83A	16	6807-18-2345	44° 4.9'	124°30.9'			
83B	13	6807-19-0818	44° 5.0'	124°39.7'			
					357°	199	11.9
83B	14	6807-19-0846	44° 8.0'	124°39.9'			
					270°	190	11.4

Sparker Profile No.	Fix No.	Cruise - Time Date	Latitude (North)	Longitude (West)	Computed Course (Degrees)	Speed (m/min)	Speed (km/hr)
83B	15	6807-19-0900	44° 8.0′	124°41.9′			
					273°	222	13.3
83B	16	6807-19-0915	44° 8.1′	124°44.4′			
					277°	205	12.3
83B	17	6807-19-0930	44° 8.3′	124°46.7′			
					270°	204	12.2
83B	18	6807-19-0945	44° 8.3′	124°49.0′			
					267°	257	15.4
83B	19	6807-19-1000	44° 8.2′	124°51.9′			
					270°	226	13.6
83B	20	6807-19-1010	44° 8.2′	124°53.6′			
					355°	197	11.8
83B	21	6807-19-1027	44°10.0′	124°53.8′			
					90°	207	12.4
83B	22	6807-19-1045	44°10.0′	124°51.0′			
					90°	213	12.8
83B	23	6807-19-1100	44°10.0′	124°48.6′			
					83°	196	11.8
83B	24	6807-19-1115	44°10.2′	124°46.4′			
					94°	186	11.2
83B	25	6807-19-1130	44°10.1′	124°44.3′			
85	3	6807-19-0000	44°20.1′	124°16.0′			
					273°	212	12.7
85	4	6807-20-0015	44°20.2′	124°18.4′			
					276°	249	14.9
85	5	6807-20-0030	44°20.4	124°21.2′			
					270°	203	12.2
85	6	6807-20-0045	44°20.4′	124°23.5′			
					267°	204	12.2
85	7	6807-20-0100	44°20.3′	124°25.8′			
					270°	212	12.7
85	8	6807-20-0115	44°20.3′	124°28.2′			
					267°	212	12.7
85	9	6807-20-0130	44°20.2′	124°30.6′			
					266°	195	11.7
85	10	6807-20-0145	44°20.1′	124°32.8′			
					266°	159	9.6
85	11	6807-20-0200	44°20.0′	124°34.6′			
					270°	168	10.1
85	12	6807-20-0215	44°20.0′	124°36.5′			
					270°	177	10.6
85	13	6807-20-0230	44°20.0′	124°38.5′			
					270°	133	8.0
85	14	6807-20-0245	44°20.0′	124°40.0′			
					270°	133	8.0
85	15	6807-20-0300	44°20.0′	124°41.5′			
					256°	100	6.0
85	16	6807-20-0315	44°19.8′	124°42.6′			
					252°	79	4.7
85	17	6807-20-0338	44°19.5′	124°43.9′			
					270°	246	14.8
85	18	6807-20-0345	44°19.5′	124°45.2′			
					270°	97	5.8
85	19	6807-20-0415	44°19.5′	124°47.4′			
					295°	175	10.5
85	20	6807-20-0430	44°20.1′	124°49.2			
					274°	159	9.6
85	21	6807-20-0445	44°20.2′	124°51.0′			
					270°	177	10.6
85	22	6807-20-0500	44°20.2′	124°53.0′			
					270°	150	9.0

Sparker Profile No.	Fix No.	Cruise - Time Date	Latitude (North)	Longitude (West)	Computed Course (Degrees)	Speed (m/min)	Speed (km/hr)
85	23	6807-20-0515	44°20.2′	124°54.7′			
89	1	6906-17-0215	44°15.0′	124°21.5′			
					257°	109	6.5
89	2	6906-17-0230	44°14.8′	124°22.7′			
					264°	116	6.9
89	3	6906-17-0245	44°14.7′	124°24.0′			
					262°	89	5.4
89	4	6906-17-0300	44°14.6′	124°25.0′			
					286	92	5.5
89	5	6906-17-0315	44°14.8′	124°26.0′			
					270°	115	6.9
89	6	6906-17-0330	44°14.8′	124°27.3′			
					277°	98	5.9
89	7	6906-17-0345	44°14.9′	124°28.4′			
					270°	97	5.8
89	8	6906-17-0400	44°14.9′	124°29.5′			
					270°	115	6.9
89	9	6906-17-0415	44°14.9′	124°30.8′			
					277°	107	6.4
89	10	6906-17-0430	44°15.0′	124°32.0′			
					270°	97	5.8
89	11	6906-17-0445	44°15.0′	124°33.1′			
					270°	142	8.5
89	12	6906-17-0500	44°15.0′	124°34.7′			
					270°	80	4.8
89	13	6906-17-0515	44°15.0′	124°35.6′			
					263°	98	5.9
89	14	6906-17-0530	44°14.9′	124°36.7′			
					279°	81	4.8
89	15	6906-17-0545	44°15.0′	124°37.6′			
					270°	106	6.4
89	16	6906-17-0600	44°15.0′	124°38.8′			
					270°	106	6.4
89	17	6906-17-0615	44°15.0′	124°40.0′			
					270°	97	5.8
89	18	6906-17-0630	44°15.0′	124°41.0′			
					270°	62	3.7
89	19	6906-17-0645	44°15.0′	124°41.8′			
					270°	106	6.4
89	20	6906-17-0700	44°15.0′	124°43.0′			
					270°	71	4.2
89	21	6906-17-0715	44°15.0′	124°43.8′			
					280°	72	4.3
89	22	6906-17-0730	44°15.1′	124°44.6′			
					278°	170	10.2
89	23	6906-17-0745	44°15.3′	124°46.5′			
					262°	89	5.4
89	24	6906-17-0800	44°15.2′	124°47.5′			
					256°	100	6.0
89	25	6906-17-0815	44°15.0′	124°48.6′			
					256°	100	6.0
89	26	6906-17-0830	44°14.8′	124°49.7′			
					265°	151	9.1
89	27	6906-17-0845	44°14.7′	124°51.4′			
					263°	98	5.9
89	28	6906-17-0900	44°14.6′	124°52.5′			
					270°	97	5.8
89	29	6906-17-0915	44°14.6′	124°53.6′			
92	1	6906-18-0400	43°56.7′	124°39.6′			
					343°	155	9.3

Sparker Profile No.	Fix No.	Cruise - Time Date	Latitude (North)	Longitude (West)	Computed Course (Degrees)	Speed (m/min)	Speed (km/hr)
92	2	6906-18-0415	$43^\circ 57.9'$	$124^\circ 40.1'$			
					23°	135	8.1
92	3	6906-18-0430	$43^\circ 58.9'$	$124^\circ 39.5'$			
					0°	161	9.6
92	4	6906-18-0445	$44^\circ 00.2'$	$124^\circ 39.5'$			
					345°	140	8.4
92	5	6906-18-0500	$44^\circ 01.3'$	$124^\circ 39.9'$			
					0°	148	8.9
92	6	6906-18-0515	$44^\circ 03.7'$	$124^\circ 39.9'$			
					357°	148	8.9
92	7	6906-18-0545	$44^\circ 04.9'$	$124^\circ 40.0'$			
					0°	173	10.4
92	8	6906-18-0600	$44^\circ 06.3'$	$124^\circ 40.0'$			
					0°	123	7.4
92	9	6906-18-0615	$44^\circ 07.3'$	$124^\circ 40.0'$			
					4°	124	7.4
92	10	6906-18-0630	$44^\circ 08.3'$	$124^\circ 39.9'$			
					0°	136	8.2
92	11	6906-18-0645	$44^\circ 09.4'$	$124^\circ 39.9'$			
					357°	173	10.4
92	12	6906-18-0700	$44^\circ 10.8'$	$124^\circ 40.0'$			
					0°	173	10.4
92	13	6906-18-0715	$44^\circ 12.2'$	$124^\circ 40.0'$			
					349°	239	14.3
92	14	6906-18-0730	$44^\circ 14.1'$	$124^\circ 40.5'$			
					0°	148	8.9
92	15	6906-18-0745	$44^\circ 15.3'$	$124^\circ 40.5'$			
					351°	175	10.5
92	16	6906-18-0800	$44^\circ 16.7'$	$124^\circ 40.8'$			
					15°	140	8.4
92	17	6906-18-0815	$44^\circ 17.8'$	$124^\circ 40.4'$			
					355°	186	11.2
92	18	6906-18-0830	$44^\circ 19.3'$	$124^\circ 40.6'$			
					12°	126	7.6
92	19	6906-18-0845	$44^\circ 20.3'$	$124^\circ 40.3'$			
					357°	161	9.6
92	20	6906-18-0900	$44^\circ 21.6'$	$124^\circ 40.4'$			
					356°	136	8.2
92	21	6906-18-0915	$44^\circ 22.7'$	$124^\circ 40.5'$			
					11°	138	8.3
92	22	6906-18-0930	$44^\circ 23.8'$	$124^\circ 40.2'$			
					15°	140	8.4
92	23	6906-18-0945	$44^\circ 24.9'$	$124^\circ 39.8'$			
					356°	136	8.2
92	24	6906-18-1000	$44^\circ 26.0'$	$124^\circ 39.9'$			
					353°	137	8.2
92	25	6906-18-1015	$44^\circ 27.1'$	$124^\circ 40.1'$			
					351°	175	10.5
92	26	6906-18-1030	$44^\circ 28.5'$	$124^\circ 40.1'$			
					17°	155	9.3
92	27	6906-18-1045	$44^\circ 29.7'$	$124^\circ 39.9'$			
97	1	6906-19-0730	$44^\circ 14.7'$	$124^\circ 47.5'$			
					177°	148	8.9
97	2	6906-19-0745	$44^\circ 13.5'$	$124^\circ 47.4'$			
					174°	174	10.4
97	3	6906-19-0800	$44^\circ 12.1'$	$124^\circ 47.2'$			
					189°	175	10.5
97	4	6906-19-0815	$44^\circ 10.7'$	$124^\circ 47.5'$			
					200°	131	7.9
97	5	6906-19-0830	$44^\circ 9.7'$	$124^\circ 48.0'$			
					175°	149	8.9

Sparker Profile No.	Fix No.	Cruise - Time Date	Latitude (North)	Longitude (West)	Computed Course (Degrees)	Speed (m/min)	Speed (km/hr)
97	6	6906-19-0840	44°08.9′	124°47.9′			
					195°	167	10.0
97	7	6906-19-0855	44°07.6′	124°48.4′			
					174°	163	9.8
97	8	6906-19-0911	44°06.2′	124°48.2′			
					160°	166	9.9
97	9	6906-19-0930	44°04.6′	124°47.4′			
					177°	201	12.1
97	10	6906-19-0942	44°03.3′	124°47.3′			
					172°	170	10.2
97	11	6906-19-0953	44°02.3′	124°47.1′			
98	1	6906-19-1315	44°10.0′	124°48.7′			
					68°	163	9.8
98	2	6906-19-1330	44°10.5′	124°47.0′			
					60°	123	7.4
98	3	6906-19-1345	44°11.0′	124°45.8′			
					66°	213	12.8
98	4	6906-19-1400	44°11.7′	124°43.6′			
					70°	217	13.0
98	5	6906-19-1415	44°12.3′	124°41.3′			
					76°	210	12.6
98	6	6906-19-1430	44°12.7′	124°39.0′			
					64°	168	10.1
98	7	6906-19-1445	44°13.3′	124°37.3′			
					64°	168	10.1
98	8	6906-19-1500	44°13.9′	124°35.6′			
					55°	173	10.4
98	9	6906-19-1515	44°14.7′	124°34.0′			
					71°	225	13.5
98	10	6906-19-1530	44°15.3′	124°31.6′			
					78°	172	10.3
98	11	6906-19-1545	44°15.6′	124°29.7′			
					72°	196	11.7
98	12	6906-19-1600	44°16.1′	124°27.6′			
					62°	160	9.6
98	13	6906-19-1615	44°16.7′	124°26.0′			
					74°	138	8.3
98	14	6906-19-1630	44°17.0′	124°24.5′			
					78°	181	10.8
98	15	6906-19-1645	44°17.3′	124°22.5′			
126	11	6907-8-1700	44°21.8′	124°40.0′			
					115°	146	8.8
126	12	6907-8-1715	44°21.3′	124°38.5′			
					129°	137	8.2
126	13	6907-8-1730	44°20.6′	124°37.3′			
					137°	169	10.1
126	14	6907-8-1745	44°19.6′	124°36.0′			
					125°	216	12.9
126	15	6907-8-1800	44°18.6′	124°34.0′			
					106°	184	11.0
126	16	6907-8-1815	44°18.2′	124°32.0′			
127	1	6907-8-1815	44°18.2′	124°32.0′			
					189°	237	14.2
127	2	6907-8-1830	44°16.3′	124°32.4′			
					184°	285	17.1
127	3	6907-8-1845	44°14.0′	124°32.6′			
					177°	198	11.9
127	4	6907-8-1900	44°12.4′	124°32.5′			
					182°	222	13.3

Sparker Profile No.	Fix No.	Cruise - Time Date	Latitude (North)	Longitude (West)	Computed Course (Degrees)	Speed (m/min)	Speed (km/hr)
127	5	6907-8-1915	44°10.6′	124°32.6′			
					164°	193	11.6
127	6	6907-8-1930	44°09.1′	124°32.0′			
					180°	240	14.4
127	7	6907-8-1947	44°06.9′	124°32.0′			
					211°	199	12.0
127	8	6907-8-2000	44°05.7′	124°33.0′			
					173°	224	13.4
127	9	6907-8-2115	44°03.9′	124°32.7′			
					187°	212	12.7
127	10	6907-8-2030	44°02.2′	124°33.0′			
					173°	224	13.4
127	11	6907-8-2045	44°00.4′	124°32.7′			
					173°	212	12.7
127	12	6907-8-2100	43°58.7′	124°32.4′			
					173°	224	13.4
127	13	6907-8-2115	43°56.9′	124°32.1′			
					187°	224	13.4
127	14	6907-8-2130	43°55.1′	124°32.4′			
143	15	6907-15-0315	43°59.6′	124°23.4′			
					316°	242	14.5
143	16	6907-15-0330	44°01.0′	124°25.3′			
					303°	180	10.8
143	17	6907-15-0345	44°01.8′	124°27.0′			
					309°	206	12.3
143	18	6907-15-0405	44°03.2′	124°29.4′			
					312°	196	11.7
143	19	6907-15-0415	44°03.9′	124°30.5′			
					316°	257	15.4
143	20	6907-15-0430	44°05.4′	124°32.5′			
					93°	204	12.3
143	21	6907-15-0445	44°05.3′	124°30.2′			
					93°	213	12.8
143	22	6907-15-0500	44°05.2′	124°27.8′			
					84°	232	13.9
143	23	6907-15-0515	44°05.4′	124°25.2′			
					90°	239	14.4
143	24	6907-15-0530	44°05.4′	124°22.5′			

APPENDIX II

APPARENT DIP DATA

SP No.	Between Fixes	Average Time	Latitude (North)	Longitude (West)	Aver. Depth Below Ocean Bottom (m)	Aver. Depth Below Sea Level (m)	Dip Direction (Degrees)	Apparent Dip Angle (Degrees)
63	15-16	0857.5	44°10.4′	124°32.2′	51	161	90°	1°
63	18-19	0937.5	44°10.1′	124°37.3′	34	159	85°	1°
63	19-20	0957.5	44°10.1′	124°39.6′	65	190	94°	3°
63	21-22	1027.5	44°09.8′	124°43.2′	90	200	81°	10°
63	22-23	1042.5	44°09.8′	124°44.8′	75	183	270°	3°
63	24-25	1107.5	44°09.9′	124°47.8′	88	176	95°	8°
63	26-27	1132.5	44°09.5′	124°43.4′	99	191	275°	12°
82	10-11	1657.5	43°59.9′	124°32.6′	63	213	101°	0°
82	14-15	1752.5	44°00.4′	124°40.5′	45	181	97°	1°
82	16-17	1827.5	44°00.4′	124°45.6′	23	147	90°	2°
82	18-19	1847.5	44°00.3′	124°48.3′	86	188	266°	7°
83A	6-7	2127.5	44°04.9′	124°51.3′	48	160	93°	3°
83A	7-8	2142.5	44°05.0′	124°47.8′	27	135	88°	3°
83A	9-10	2212.5	44°05.0′	124°43.3′	55	172	90°	3°
83A	11-12	2237.5	44°05.1′	124°40.0′	25	151	265°	2°
83A	12-13	2257.5	44°05.1′	124°37.9′	50	180	90°	3°
83A	15-16	2332.5	44°05.0′	124°32.7′	57	186	274°	2°
83B	14-15	0848.0	44°08.0′	124°40.2′	81	207	90°	4°
83B	15-16	0902.5	44°08.0′	124°42.3′	53	170	93°	3°
83B	16-17	0927.5	44°08.3′	124°46.3′	74	178	97°	8°
83B	17-18	0942.5	44°08.3′	124°48.6′	82	172	90°	9°
83B	18-19	0957.0	44°08.2′	124°51.4′	100	200	267°	7°
83B	21-22	1032.5	44°10.0′	124°52.9′	60	167	90°	6°
83B	23-24	1107.5	44°10.1′	124°47.5′	67	155	83°	7°
85	3-4	0005.0	44°20.2′	124°18.4′	58	136	273°	1°
85	5-6	0032.5	44°20.4′	124°21.6′	66	151	270°	0°
85	8-9	0122.5	44°20.3′	124°29.4′	52	148	87°	3°
85	12-13	0217.5	44°20.0′	124°36.8′	88	185	90°	8°
85	14-15	0246.0	44°20.0′	124°40.1′	39	129	270°	17°
85	15-16	0313.5	44°19.8′	124°42.5′	57	167	76°	10°

SP No.	Between Fixes	Average Time	Latitude (North)	Longitude (West)	Aver. Depth Below Ocean Bottom (m)	Aver. Depth Below Sea Level (m)	Dip Direction (Degrees)	Apparent Dip Angle (Degrees)
88	15-16	2337.5	44°20.3′	124°22.6′	57	137	263°	4°
88	22-23	0122.5	44°16.9′	124°25.1′	44	141	122°	0°
89	10-11	0442.5	44°15.0′	124°32.9′	66	166	270°	4°
89	14-15	0537.5	44°14.9′	124°37.2′	77	175	99°	7°
89	17-18	0620.0	44°15.0′	124°40.4′	55	149	90°	4°
89	18-19	0642.5	44°15.0′	124°41.7′	96	200	270°	27°
89	21-22	0717.5	44°15.0′	124°43.9′	62	174	100°	17°
89	23-24	0757.5	44°15.2′	124°47.3′	80	198	82°	18°
89	24-25	0812.5	44°15.0′	124°48.4′	91	217	76°	18°
92	4-5	0452.5	44°00.8′	124°39.7′	39	173	165°	1°
92	6-7	0537.5	44°04.3′	124°40.0′	80	204	177°	3°
92	7-8	0547.5	44°05.1′	124°40.0′	34	157	180°	1°
92	9-10	0622.5	44°07.8′	124°39.9′	51	170	184°	2°
92	11-12	0652.5	44°10.1′	124°40.0′	46	163	177°	2°
92	13-14	0717.5	44°12.5′	124°40.1′	66	180	169°	3°
92	14-15	0737.5	44°14.7′	124°40.5′	65	160	180°	10°
92	17-18	0827.5	44°19.1′	124°40.6′	68	165	175°	6°
92	18-19	0842.5	44°20.1′	124°40.3′	54	153	12°	4°
92	21-22	0917.5	44°22.9′	124°40.5′	74	181	11°	6°
92	24-25	1012.5	44°26.9′	124°40.1′	106	240	353°	11°
97	1-2	0741.0	44°13.8′	124°47.4′	94	204	177°	7°
97	4-5	0827.5	44°09.9′	124°47.9′	64	142	200°	8°
97	6-7	0842.5	44°08.7′	124°48.0′	70	154	195°	10°
97	6-7	0847.5	44°08.3′	124°48.1′	112	198	195°	15°
97	7-8	0857.5	44°07.4′	124°48.4′	45	137	174°	6°
97	8-9	0917.5	44°05.7′	124°47.9′	44	147	160°	2°
97	9-10	0935.5	44°04.0′	124°47.4′	144	238	357°	7°
98	5-6	1422.5	44°12.5′	124°40.1′	78	189	76°	2°
98	9-10	1522.5	44°15.0′	124°32.8′	77	181	251°	3°
98	13-14	1627.5	44°16.9′	124°24.8′	57	151	254°	0°
126	13-14	1742.5	44°22.4′	124°27.9′	94	199	137°	11°
126	15-16	1812.5	44°14.6′	124°28.0′	70	175	106°	2°

SP No.	Between Fixes	Average Time	Latitude (North)	Longitude (West)	Aver. Depth Below Ocean Bottom (m)	Aver. Depth Below Sea Level (m)	Dip Direction (Degrees)	Apparent Dip Angle (Degrees)
127	2-3	1837.5	44°15.1′	124°32.5′	26	139	184°	1°
127	5-6	1917.5	44°10.4′	124°32.5′	25	141	164°	0°
127	8-9	2007.5	44°04.8′	124°32.9′	21	158	173°	0°
127	11-12	2047.5	44°00.1′	124°32.6′	72	229	353°	0°

APPENDIX III

TRUE STRIKE AND DIP DATA

Crossing Points				Crossing Point Data					
E-W	Between	N-S	Between	E-W		N-S		True Strike and Dip[1]	
SP No.	Fixes	SP No.	Fixes	Dip	Dip Direction	Dip	Dip Direction		
85	12-13	126	13-14	8°	90°	11°	137°	N42E	11SE
85	14-15	92	18-19	17°	270°	4°	12°	N24E	18SE
89	10-11	127	2-3	4°	270°	1°	184°	N03E	4W
89	10-11	98	9-10	4°	270°	3°	251°	N40E	5NW
89	17-18	92	14-15	4°	90°	10°	180°	N68E	11SE
89	23-24	97	1-2	18°	82°	7°	177°	N16E	20NW
63	15-16	127	5-6	1°	90°	0°	164°	N ?W	~1E
63	19-20	92	11-12	3°	94°	2°	177°	N30E	4SE
63	24-25	97	4-5	8°	95°	8°	200°	N56E	13SE
83Bs	17-18	97	6-7	9°	90°	15°	195°	N63E	20SE
83B	14-15	92	9-10	4°	90°	2°	184°	N29E	5SE
83A	15-16	127	8-9	2°	274°	0°	173°	N ?E	~2E
83A	11-12	92	7-8	2°	265°	1°	180°	N23W	2SW
83A	7-8	97	7-8	3°	88°	6°	174°	N62E	7SE
83Bn	23-24	97	4-5	7°	83°	8°	200°	N54E	14SE
82	10-11	127	11-12	0°	101°	0°	353°	+	0°
82	14-15	92	4-5	1°	97°	1°	165°	N41E	1SE
98	5-6	92	13-14	2°	76°	3°	169°	N42E	4SE

[1]Derived graphically using a Wulf Stereonet

APPENDIX IV

STRATIGRAPHIC THICKNESS DATA

SP No.	Between Fixes	Between Times	Ship Speed (m/min)	Travel Time (min)	Slope Dist. (m)	True Dip	Sine True Dip	Ships Course	Strike	Acute Angle	Sine Angle	True Stratigraphic Thickness (m)[1]
63	14-15	0840-0845	116	5	580	1°	0.02	264°	NS	84°	0.99	12
63	15-17	0845-0905	160	20	3200	2°	0.03	268°	NS	84°	0.99	95
63	17-19	0925-0935	174	10	1740	1°	0.02	264°	N20E	64°	0.90	32
63	19-20	0945-1000	160	15	2400	4°	0.07	274°	N30E	64°	0.90	151
63	20-21	1000-1008	160	8	1280	3°	0.05	266°	N30E	60°	0.87	56
63	21-22	1015-1025	161	10	1610	11°	0.19	261°	N34E	49°	0.75	230
63	23-24	1058-1100	168	2	336	13°	0.23	270°	N56E	34°	0.56	43
63	24-25	1100-1115	142	15	2130	13°	0.23	275°	N56E	39°	0.63	309
63	25-26	1115-1120	115	5	575	13°	0.23	270°	N56E	34°	0.56	66
										Total for SP63		994 meters
83A				Horizontal beds measured from the seismic profile.								90
83A	14-13	2315-2300	186	15	2790	2°	0.03	90°	N23W	67°	0.92	77
83A	13-12	2300-2245	142	15	2130	3°	0.05	90°	N23W	67°	0.92	98
83A	11-8	2226-2156	194	30	5820	5°	0.09	90°	N60E	30°	0.50	262
83A	9-8	2156-2145	186	11	2046	6°	0.10	90°	N60E	30°	0.50	102
83A	8-7	2145-2142	328	3	984	6°	0.10	88°	N60E	28°	0.47	46
83A	7-6	2126-2115	222	11	2442	6°	0.10	93°	N60E	33°	0.54	132
										Total for SP83A		807 meters
83B	14-15	0846-0900	190	15	2850	5°	0.09	270°	N29E	61°	0.88	226
83B	16-17	0915-0923	205	8	1640	12°	0.21	277°	N55E	42°	0.67	231
83B	16-18	0923-0935	204	12	2448	20°	0.34	275°	N63E	32°	0.53	441
83B	17-18	0940-0945	204	5	1020	20°	0.34	270°	N63E	27°	0.45	156
83B	18-19	0945-0950	257	5	1285	20°	0.34	267°	N63E	24°	0.41	179
										Total for SP83B		1233 meters

SP No.	Between Fixes	Between Times	Ship Speed (m/min)	Travel Time (min)	Slope Dist. (m)	True Dip	Sine True Dip	Ships Course	Strike	Acute Angle	Sine Angle	True Stratigraphic Thickness (m)[1]
85	7-8	0105-0115	212	10	2120	3°	0.05	270°	N20E	70°	0.94	100
85	8-9	0115-0130	212	15	3180	4°	0.07	267°	N20E	67°	0.92	205
85	9-10	0144-0150	195	6	1170	5°	0.09	266°	N40E	46°	0.72	76
85	10-11	0150-0155	159	5	795	6°	0.11	266°	N40E	46°	0.72	63
85	11-12	0200-0207	177	7	1240	10°	0.17	270°	N40E	50°	0.77	162
85	11-13	0207-0228	173	21	3633	11°	0.19	270°	N42E	48°	0.74	511
										Total for SP85		1117 meters
89_1	8-10	0400-0430	110	30	3300	4°	0.07	274°	N03E	89°	1.00	231
89_1	13-14	0515-0530	98	15	1470	7°	0.12	263°	N20E	63°	0.89	157
89_1	14-15	0530-0545	81	15	1215	8°	0.14	278°	N25E	73°	0.96	163
89_1	16-17	0600-0615	106	15	1590	8°	0.14	270°	N68E	22°	0.37	83
89_1	17-18	0615-0625	97	10	970	11°	0.19	270°	N68E	22°	0.37	68
								Total for SP89, Section #1				702 meters
89_2	20-21	0700-0715	71	15	1065	18°	0.31	270°	N25E	65°	0.91	300
89_2	21-22	0715-0730	72	15	1080	18°	0.31	280°	N25E	75°	o.97	325
89_2	22-23	0730-0745	170	15	2550	18°	0.31	278°	N25E	73°	0.96	759
								Total for SP89, Section #2				1384 meters
89_3	23-24	0750-0800	89	10	890	20°	0.34	262°	N16E	66°	0.91	275
89_3	24-25	0800-0808	100	8	800	20°	0.34	256°	N16E	60°	0.87	237
								Total for SP89, Section #3				512 meters
92	3-6	0430-0515		Horizontal beds measured from the seismic profile.								40
92	6-7	0515-0545	148	30	4440	2°	0.04	357°	N23W	20°	0.34	60
92	7-9	0545-0615	150	30	4500	2°	0.04	0°	N23W	23°	0.39	70
92	9-11	0615-0645	130	30	3900	6°	0.10	2°	N46E	44°	0.70	272
92	11-13	0645-0715	173	30	5190	4°	0.07	0°	N34E	34°	0.56	204

SP No.	Between Fixes	Between Times	Ship Speed (m/min)	Travel Time (min)	Slope Dist. (m)	True Dip	Sine True Dip	Ships Course	Strike	Acute Angle	Sine Angle	True Stratigraphic Thickness (m)[1]
92	13-14	0715-0730	239	15	3585	4°	0.07	349°	N68E	79°	0.98	248
92	14-15	0730-0745	148	15	2220	11°	0.19	0°	N68E	68°	0.93	390
										Total for SP92		1284 meters
97	8-9	0926-0930	166	4	664	10°	0.17	160°	N60E	80°	0.98	111
97	9-10	0930-0935	201	5	1005	6°	0.10	177°	N60E	63°	0.89	89
97	7-8	0855-0857	163	2	326	10°	0.17	174°	N60E	66°	0.91	50
97	6-7	0838-0855	167	17	2839	20°	0.34	195°	N63E	48°	0.74	714
97	5-6	0830-0838	149	8	1192	16°	0.28	175°	N60E	65°	0.91	304
97	4-5	0825-0830	131	5	655	13°	0.23	200°	N56E	56°	0.83	125
										Total for SP97		1393 meters

[1] Product of slope distance, sine of true dip, and sine of the acute angle

APPENDIX V

ROCK CORE LOCATIONS AND DESCRIPTIONS

Sample No.	Latitude Longitude	Length of Rock Core	GSA Color and Code No.	Rock Type and Description
6807-27	44°05.0′ 124°46.2′	7cm	Greenish Black 5GY 3/1	Clayey Siltstone--Micromicaceous, some mafic grains, slightly laminated or fissle, forams common.
6807-28	44°04.8′ 124°48.8′	14cm	Greenish Black 5GY 3/1	Clayey Siltstone--Micromicaceous, rounded mafic grains (glauconite?) up to 1mm are common, more indurated and fissle than 6807-27, forams abundant.
6807-29	44°04.8′ 124°50.2′	12cm	Dark Greenish Grey 5GY 4/1	Clayey Siltstone--Micromicaceous, pyrite pods are common, slightly fissle, forams common.
6807-30	44°04.9′ 124°51.5′	12cm	Greenish Black 5GY 3/1	Siltstone--Micaceous, mafic grains are rare, core is extremely indurated, organic debris (plant or wood?) common, parts are very fissle.
6807-31	44°04.9′ 124°52.7′	9cm	Greenish Black 5GY 3/1	Clayey Siltstone--Micromicaceous, subrounded qtz. grains up to 2mm common and rounded glauconite(?) grains up to 1mm common, fissle, forams present. Concretion embedded in core has <u>Cibicides</u> and bryozoans attached. Appears contemporary, may be result of double entry of core barrel.
6807-32	44°10.0′ 124°49.7′*	10cm	Greenish Black 5GY 2/1	Siltstone--Angular qtz. grains up to 3mm are common, fibrous gypsum present, forams present, diatoms abundant.
6807-33	44°10.1′ 124°49.0′*	7cm	Greenish Black 5GY 3/1	Clayey Siltstone--micromicaceous, some pyrite pods, extremely fissle, forams present.
6807-34	44°10.0′ 124°48.0′*	6cm	Olive Grey 5Y 4/2	Clayey Siltstone--Micromicaceous, pyrite pods present, forams present, diatoms common.
6807-35	44°10.0′ 124°46.8′*	14cm	Olive Grey 5Y 3/2	Clayey Siltstone--rounded 1mm black glauconite(?) grains present, forams and diatoms common.
6807-36	44°10.1′ 124°43.8′	10cm	Olive Grey 5Y 4/2	Clayey Siltstone--Micromicaceous, much clay, moderately fissle, forams common.
6807-37	44°10.3′ 124°39.1′	13cm	Dark Greenish Grey 5GY 4/1	Claystone--Micromicaceous, very soft, some fine grained mafics, pyrite pods are common, forams present.

Sample No.	Latitude Longitude	Length of Rock Core	GSA Color and Code No.	Rock Type and Description
6807-38	44°10.3′ 124°39.1′	17cm	Dark Greenish Grey 5GY 4/1	Clayey Siltstone--Micromicaceous, soft, fine grained mafics common, forams common.
6807-39	44°10.4′ 124°42.7′	17cm	Dark Greenish Grey 5GY 4/1	Clayey Siltstone--Soft, pyrite crystals (0.1mm) common, fine grained mafics present, mega-fauna fragments common, forams common to abundant.
6907-40	44°10.0′ 124°42.7′	14cm	Greenish Black 5GY 3/1	Clayey Siltstone--Soft, micro-micaceous, micropelycepods present, forams present.
6906-1	44°15.0′ 124°41.6′	17.5cm	Dark Greenish Grey 3/1	Silty Claystone--Some silt sized subangular qtz., some mica and pyrite, forams common, (Lenticulina and Uvigerina).
6906-2	44°14.8′ 124°44.6′	10.5cm	Light Olive Grey 5Y 4/2	Silty Claystone--Some silt sized qtz., some mica and pyrite, forams present, pelycepod fragments (Pecten), diatoms common.
6906-3	44°14.6′ 124°45.8′	13cm	Olive Grey 5Y 4/1	Silty Claystone--Some mica and pyrite, forams present, diatoms abundant.
6906-4	44°14.7′ 124°46.8′	crumbled core	Olive Grey 5Y 4/2	Silty Claystone--Some mica, abundant diatoms.
6906-5	44°14.6′ 124°48.0′	19cm	Olive Grey 5Y 4/2	Silty Claystone--Micromicaceous, forams abundant (Bulimina and Uvigerina).
6906-6	44°14.8′ 124°52.6′	11cm	Olive Grey 5Y 3/1	Clayey Siltstone--Micromicaceous, slightly fissle, mottled appearance, forams present, diatoms and sponge spicules abundant.
6906-7	44°14.9′ 124°35.7′	17cm	Greenish Black	Clayey Siltstone--Micaceous, subrounded mafic grains present, forams present (Nonien?).
6906-8	44°15.0′ 124°37.0′	single chip	Olive Grey 5Y 4/2	Clayey Siltstone--Micromicaceous, some mafics, forams present, diatoms common.
6906-9	44°14.8′ 124°38.8′	8cm	Olive Grey 5Y 5/1 (weathered color-Yellowish Brown 10YR 6/4)	Siltstone--mafics are common, core has crumbly texture, iron stained, some iron in nodules, pyrite pods common, 2-3mm layer of pure siltstone, diatoms common.
6906-10	44°15.0′ 124°40.0′	7cm	Greenish Black 5GY 2/1	Sandstone--fine grained, top 1cm weathered, some mica, mafics (glauconite?) common, rest qtz. grains.

Sample No.	Latitude Longitude	Length of Rock Core	GSA Color and Code No.	Rock Type and Description
6906-11	44°06.2′ 124°48.2′	8cm	Olive Grey 5Y 3/2	Clayey Siltstone--Micaceous, some sand sized particles, mafic grains common, forams (Bolivina) present.
6906-12	44°07.6′ 124°48.4′	14cm	Dark Greenish Grey 5GY 4/1	Claystone--Some pyrite, fissle, very little silt, forams present.
6906-13	44°08.4′ 124°48.1′	11cm	Greenish Grey 5GY 3/1	Silty Claystone--Micromicaceous, irregular mottling with brown silt pods, forams (Loxostoma) present, diatoms common.
6906-14	44°08.9′ 124°47.9′	7cm	Olive Grey 5Y 3/2	Silty Claystone--Micromicaceous, slightly fissle, diatoms and forams common.
6907-1	44°20.6′ 124°29.4′	18cm	Greenish Black 5GY 2/1	Siltstone--Mafics common, iron stained mica and qtz., orthoclase(?) grains, mafics are subrounded, qtz. grains are subangular, many colors gives "rainbow effect" (oranges, reds, blues, greens, and black), megafauna fragments present, forams abundant (Bolivina and Eponides).
6907-2	44°20.0′ 124°43.0′	few chips	Greyish Olive Green 5GY 4/2 (weathered color Dusky Green 5G 3/2)	Siltstone--Very fissle (shale?), micromicaceous, mafics present, rock chips bored by Pholad pelycepods, forams present.
6907-3	44°19.9′ 124°41.9′	10cm	Olive Grey 5Y 4/2	Siltstone--Very fissle, micromicaceous, some mafic grains, black pyrite common, small brown stained lens and pods common throughout, forams present, diatoms abundant.
6907-4	44°20.2′ 124°37.3′	few chips and gravel	Greenish Black 5GY 3/1	Siltstone--Slightly fissle, some clay, mafic grains common, micromicaceous, grains are subrounded, surface of chips bored by Pholad pelycepods, forams present, radiolarians and diatoms common.

*Corrected Longitudes. Because of navigation limitations, particularly in Longitude, these fixes were taken from their relative positions on the seismic record where control is better.

APPENDIX VI

TEXTURE ANALYSIS OF ROCK SAMPLES

Sample No.	% Sand	% Silt	% Clay	Sand/Shale Ratio
6807-27	1.08	53.89	45.03	0.0108
6807-28	0.17	52.75	47.08	0.0017
6807-29	0.05	50.67	49.28	0.0005
6807-30	0.14	66.08	33.78	0.0013
6807-31	0.36	59.03	40.61	0.0036
6807-32	1.10	45.48	53.42	0.0111
6807-33	0.02	62.32	37.66	0.0002
6807-34	0.07	67.13	32.80	0.0006
6807-35	1.43	50.07	48.50	0.0144
6807-36	0.02	55.12	44.86	0.0001
6807-37	0.64	60.50	38.86	0.0064
6807-38	1.49	61.73	36.78	0.0151
6807-39	0.94	63.88	35.18	0.0094
6807-40	0.59	59.41	40.00	0.0059
6906- 1	0.03	40.59	59.38	0.0002
6906- 2	0.07	47.83	52.10	0.0006
6906- 3	0.32	44.87	54.81	0.0031
6906- 4	0.15	44.86	54.99	0.0015
6906- 5	0.24	51.62	48.14	0.0024

Appendix VI (Continued)

Sample No.	% Sand	% Silt	%Clay	Sand/Shale Ratio
6906- 6	0.76	38.88	60.36	0.0076
6906- 7	0.53	64.40	35.07	0.0053
6906- 8	0.51	50.59	48.90	0.0050
6906- 9	0.04	44.26	55.70	0.0003
6906-10	37.55	29.03	33.42	0.6013
6906-11	25.88	42.16	31.96	0.3490
6906-12	0.03	43.16	56.81	0.0002
6906-13	0.08	46.25	53.67	0.0007
6906-14	0.08	52.50	47.42	0.0007
6907- 1	9.77	62.32	27.91	0.1083
6907- 2	0.78	55.78	43.44	0.0078
6907- 3	1.84	46.91	51.25	0.0186
6907- 4	13.48	49.26	37.26	0.1557

APPENDIX VII

COARSE FRACTION COUNTS OF ROCK SAMPLES

	Sample Number															
Percent of Coarse Fraction	6807 -27	6807 -28	6807 -29	6807 -30	6807 -31	6807 -32	6807 -33	6807 -34	6807 -35	6807 -36	6807 -37	6807 -38	6807 -39	6807 -40	6906 -1	6906 -2
Quartz-feldspar group	10.2	26.2	21.0	40.0	7.0	39.1	8.0	22.2	25.6	40.0	9.3	15.3	3.1	4.1	26.6	7.4
Ferromagnesians	6.6	18.2	13.5	21.4	4.6	17.1	6.2	13.5	7.4	21.6	9.5	7.9	6.7	9.3	25.6	18.5
Micas	6.1	0.5	0.5	4.0	1.3	1.1	0.6	1.3	—	0.5	0.8	2.6	1.3	1.1	—	—
Rock fragments	6.1	3.0	12.2	14.2	11.6	8.4	4.9	10.1	19.7	13.0	36.6	33.5	30.8	11.0	4.2	9.2*
Volcanic glass	2.3	5.7	7.5	9.7	0.8	13.3	0.6	2.7	7.1	4.0	9.5	11.2	7.5	15.0	21.8	8.4
Terrigenous Subtotal	31.3	53.6	54.7	89.2	25.3	79.0	20.3	49.8	59.8	79.1	65.7	70.5	49.4	40.5	78.2	43.5
Glauconite	8.8	4.9	23.0	3.0	8.3	14.9	2.1	11.5	29.3	3.2	14.9	6.2	9.3	7.1	9.4	22.0
Pyrite	3.6	2.7	7.0	0.5	17.5	—	—	17.8*	—	4.6	11.4	4.8	2.3	3.3	1.6	5.8*
Authigenic Subtotal	12.4	7.6	30.7	3.5	25.8	14.9	2.1	29.3	29.3	7.8	26.3	11.0	11.6	10.4	11.0	27.8
Foraminifera	26.2	24.5	9.5	1.2	25.2	—	—	0.4	3.4	0.8	5.8	8.6	29.8	41.8	—	1.0
Radiolaria	4.8	10.9	2.0	0.4	20.8	6.2	77.4	19.4*	3.4	7.3	0.5	7.2	2.1	2.5	8.5	26.1
Sponge Spicules	25.2	2.4	1.5	1.5	0.8	—	0.3	—	1.5	3.5	0.8	—	6.2	1.4	1.3	0.8
Shell fragments	—	—	—	—	—	—	—	—	2.7	1.3	—	—	—	3.5	—	0.3
Statoliths	0.3	—	0.2	—	—	—	—	1.1	—	—	0.5	—	0.8	—	—	—
Fish Teeth	—	—	0.7	—	—	—	—	—	—	—	—	—	—	—	—	—
Fir Pollen	—	—	—	—	2.3	—	—	—	—	—	—	2.4	—	—	—	—
Biogenous Subtotal	56.5	37.8	13.9	6.7	49.1	6.2	77.7	20.9	11.0	12.9	7.9	18.2	38.9	49.2	9.8	28.2
Unknown	—	0.8	—	—	—	—	—	—	—	—	—	—	—	—	—	0.5
Total Number of Grains Counted	393	367	400	401	389	369	326	445	407	370	377	419	386	366	308	379

Percent of Coarse Fraction	Sample Number															
	6906 -3	6906 -4	6906 -5	6906 -6	6906 -7	6906 -8	6906 -9	6906 -10	6906 -11	6906 -12	6906 -13	6906 -14	6907 -1	6907 -2	6907 -3	6907 -4
Quartz-feldspar group	34.0	15.3	16.3	13.0	19.8	24.2	43.8	30.0	44.2	34.2	14.7	18.2	18.5	20.0	16.0	12.7
Ferromagnesians	31.6	22.4	19.0	26.8	14.6	17.4	17.8	6.0	22.9	12.9	9.9	10.2	41.5	25.0	12.0	20.2
Micas	—	0.3	0.3	0.8	0.8	—	—	0.6	2.8	—	0.3	—	1.7	2.0	—	—
Rock fragments	5.1	18.7*	8.0	1.6	13.7	17.8	12.3*	5.8	6.5	10.7*	25.4*	22.5*	5.6	21.0	4.7*	5.5
Volcanic glass	12.5	13.5	9.1	11.6	20.8	14.6	3.0	7.7	18.5	14.1	5.9	5.8	14.3	19.0	14.0	12.7
Terrigenous Subtotal	83.2	70.2	52.7	53.8	68.9	74.0	76.9	50.1	94.9	71.9	56.2	56.7	81.6	87.0	46.7	51.1
Glauconite	7.1	7.5	39.9	26.0	28.6	22.8	8.8	49.6	3.7	9.7	2.9	4.6	4.5	8.0	8.7	46.0
Pyrite	—	15.8*	5.6	0.3	0.5	0.5	13.6*	0.3	0.2	12.2*	15.5*	20.6*	0.8	1.5	41.0*	0.3
Authigenic Subtotal	7.1	23.3	45.5	26.3	29.1	23.3	22.4	49.9	3.9	21.9	18.4	24.2	5.3	9.5	49.7	46.3
Foraminifera	—	—	—	—	—	—	—	—	—	—	—	—	10.9	—	—	—
Radiolaria	9.2	5.5	0.3	17.5	0.8	1.6	0.3	—	0.7	5.6	26.0	18.6	0.6	3.0	3.5	1.2
Sponge Spicules	0.5	0.5	1.9	0.5	1.1	1.3	0.3	—	0.2	0.6	—	0.5	1.4	0.5	—	0.9
Shell fragments	—	—	—	—	—	—	—	—	—	—	—	—	—	1.0	—	—
Statoliths	—	—	—	—	—	—	—	—	—	—	—	—	0.3	—	—	0.3
Fish Teeth	—	—	—	—	—	—	0.3	—	—	—	—	—	—	—	—	—
Fir Pollen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Biogenous Subtotal	9.7	6.0	2.2	18.0	1.9	2.9	0.9	0.0	0.9	6.2	26.0	19.1	13.2	4.5	3.5	2.4
Unknown	—	0.5	—	2.1	—	—	—	—	—	—	—	—	—	—	—	—
Total Number of Grains Counted	392	385	375	378	364	385	398	313	431	319	374	413	357	456	425	347

*Constituents marked with an asterisk were counted as both since they fit both categories (i.e., pyritized radiolarians).

APPENDIX VIII

AGE AND PALEODEPTH DETERMINATIONS FOR OFFSHORE OREGON ROCK SAMPLES USED IN THIS STUDY

Unless otherwise noted, determinations are based upon foraminifera and were made by G. A. Fowler. In most cases the ages are based upon coiling direction trends in <u>Globigerina pachyderma</u>. Determinations based upon diatoms and silicoflagellates (DIA.) were made by W. N. Orr; those based upon radiolaria (RAD.) were by T. C. Moore.

SAMPLE	AGE	PALEODEPTH Range	(Meters) Best Estimate
6807-27	Middle Pliocene	500-1000	750
6807-28	? Middle Pliocene	700-1500	900
6807-29	Early Pliocene	700-1200	900
6807-30	? Middle Pliocene	(500-1000)?	750?
6807-31	Early Pliocene	700-1200	800
6807-32	Late Miocene	800-1500	1000?
6807-33	? Early Pliocene	(800-1200)?	1000?
6807-34	? Pliocene	700-1200	950
6807-35	Pleistocene	(100-200)?	150?
6807-36	? Pliocene	(700-900)?	800?
6807-37	Pleistocene	100-200	150
6807-38	Pleistocene	100-200	150
6807-39	Pleistocene	100-200	150
6807-40	Pleistocene	100-200	150

Appendix VIII (Continued)

SAMPLE	AGE	PALEODEPTH Range	(Meters) Best Estimate
6906- 1	? Pliocene	500-1000	750
6906- 2	? Early Pliocene	500-1000	750
6906- 3	Late Miocene (DIA.)	(700-1200)?	950?
6906- 4	? Early Pliocene	700-1200	950
6906- 5	? Pliocene	500-900	700
6906- 6	Late Miocene (RAD.)(DIA.)	?	
6906- 7	? Pleistocene	(100-300)?	200?
6906- 8	?	?	
6906- 9	? Pliocene	100-300	200
6906-10	No Fauna	?	
6906-11	Middle Pliocene	500-1000	800
6906-12	? Middle Pliocene	500-1000	800
6906-13	Middle Pliocene	700-900	800
6906-14	? Early Pliocene	800-1200	1000
6907- 1	? Middle Pliocene	400-1000	600
6907- 2	Early Pliocene	700-1200	1000
6907- 3	Early Pliocene	(800-1200)?	1000?
6907- 4	Late Miocene (DIA.)	?	