4. SITE 449: WEST SIDE OF THE PARECE VELA BASIN

Shipboard Scientific Party[1]

HOLE 449

Date occupied: 28 February 1978

Date departed: 1 March 1978

Time on hole (hrs): 29

Position: 18°01.84′N; 136°32.19′E

Water depth (sea level; corrected m, echo-sounding): 4712

Water depth (rig floor; corrected m, echo-sounding): 4722

Penetration (m): 151.5

Number of cores: 18

Total length of cored section (m): 151.5

Total core recovered (m): 93.4

Core recovery (%): 62

Oldest sediment cored:
　　Depth sub-bottom (m): 111.0
　　Nature: Nannofossil ooze
　　Age: Late Oligocene (NP 25)
　　Measured velocity (km/s): 1.55

Basement:
　　Depth sub-bottom (m): 111.0
　　Nature: Tholeiitic basalt
　　Measured velocity (km/s): 4.47

Principal results: At Site 449, located on the western side of the Parece Vela basin, one hole was drilled to a depth of 151.5 meters, at which point drilling was discontinued because of poor hole conditions. The sedimentary sequence consists entirely of pelagic units deposited from the late Oligocene to the Pleistocene. From the top downward, the hole comprises: Unit 1, 40.9 meters of uppermost middle Miocene to Pleistocene dark brown to yellow-brown pelagic clay with manganese nodules on the surface; Unit 2, 6.6 meters of middle Miocene dark yellow-brown radiolarian ooze that contains volcanic glass and pumice; Unit 3, 11.0 meters of middle-Miocene interbedded brown to dark brown radiolarian-rich pelagic clay and yellow to brownish yellow radiolarian-bearing nannofossil ooze containing pumice; Unit 4, 38.7 meters of lower to middle Miocene dark yellowish brown to very dark brown mottled, pelagic clay containing ash layers and manganese nodules; Unit 5, 13.8 meters of partly lithified, upper Oligocene to

lower Miocene yellow and brown mottled nannofossil ooze. The sedimentary section rests on tholeiitic oceanic crust, the upper 23.5 meters of which is plagioclase-olivine-spinel-phyric pillow basalt and the lower 17.0 meters a plagioclase-olivine-spinel-phyric basalt flow. The normal pelagic sequence of Units 4 and 5 suggests that the basement is probably not appreciably older than the sediments, possibly of the late Oligocene.

BACKGROUND AND OBJECTIVES

Although the Parece Vela Basin is thought to have been formed by back-arc spreading following sundering of the West Mariana arc from the Palau-Kyushu arc, the timing and pattern of spreading are not known. Drilling at Site 449 was done to date the basement on the western side of the basin and thus to test for the age and symmetry of the spreading.

The Parece Vela Basin is flanked by the West Mariana Ridge on the east, the Palau-Kyushu Ridge on the west, the Shikoku Basin on the north, and the Yap arc–trench system on the south (Fig. 1). Both flanking ridges are interpreted as having been active in the mid-Tertiary, and the Parece Vela Basin is supposed to have been formed approximately in the early Miocene (Karig, 1975). The Parece Vela Basin is roughly 5 km deep for the most part but is greater than 6 km deep in the IPOD Trough, one of a series of troughs forming the Parece Vela Rift (Mrozowski and Hayes, 1979), which approximately bisects the basin. If the age of the basin is early to middle Miocene, as proposed by Karig, then the basin is deeper than the depth versus age curves of Sclater (1972) would predict. Site 449 is located in the western part of the Parece Vela Basin (Fig. 1). In the eastern part of the basin, paleontologic dates of the oldest sediments at DSDP Sites 53 and 54 identify the age of the basement as early Miocene. Although the basalts recovered at these sites are highly altered, dredge samples collected by the International Working Group on the IGCP Project "Ophiolites" range from fresh to altered basalt and gabbros and appear to be chemically similar to mid-ocean ridge (MOR) tholeiitic basalts (Dietrich et al., 1978; Guram Zakariadze, personal communication).

The basement on the western side of the Parece Vela Basin is exceptionally rough and appears to consist of a two-part Layer 2: a low-velocity (3.1–3.7 km/s) Layer 2a overlying a more normal-velocity (4.3–5.1 km/s) Layer 2b (Murauchi et al., 1968). Although the sediment cover is generally thin, the cover thickens to the west, where thicknesses on the order of a few hundred meters are present on the Palau-Kyushu Ridge. Magnetic anomalies are of low amplitude in the basin; thus magnetic lineations are extremely difficult to interpret. Watts and Weissel (1975) have identified late Oligocene

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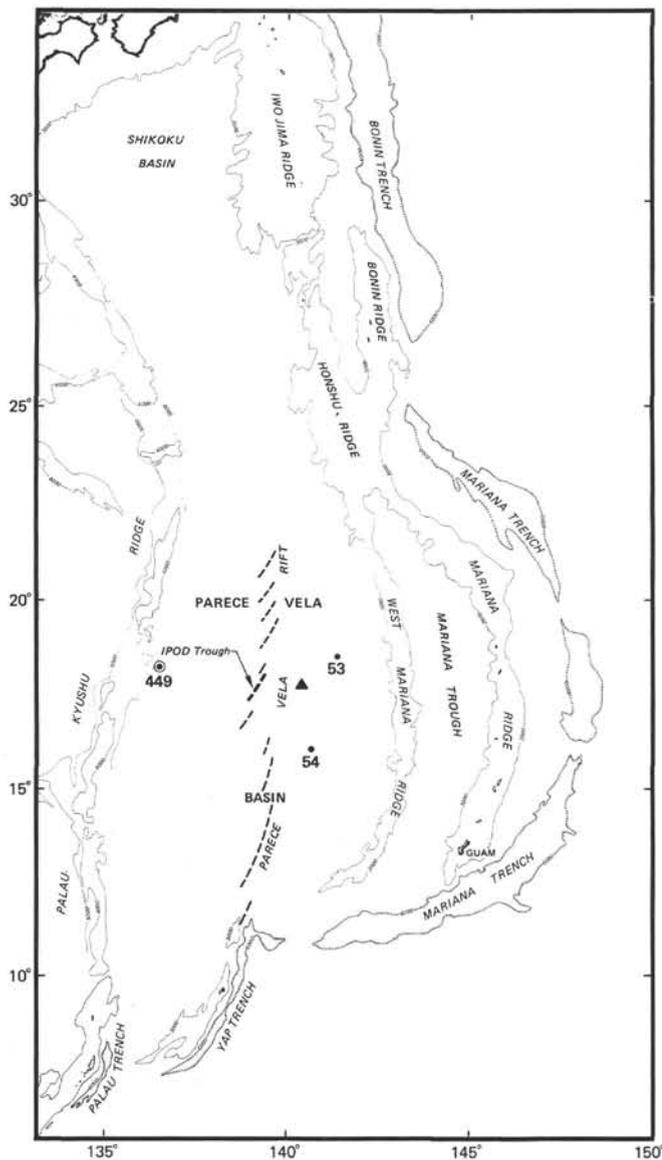
Figure 1. Location of DSDP Sites 449, 53, and 54 in the Parece Vela Basin. (The triangle marks the position of Site 1398 dredged by the *Dmitry Mendeleev*. Site 449 is marked by a concentric point and Sites 53 and 54 by solid dots. The Parece Vela Basin is bounded by the Palau-Kyushu Ridge on the west, the Yap Trench on the south, the West Mariana Ridge on the east, and the Shikoku Basin on the north.)

approximately 4700 meters, water depth in the area was found to vary generally between 4300 and 5700 meters, with the greatest depths in excess of 5800 meters (Fig. 2). The great roughness of the area, shown in Figure 2, in addition to making the seismic-refraction work very difficult, provided the evidence for significant large-scale block faulting. Sediment cover in the basin is generally thin; in fact, it commonly was found to be less than 0.1 s of reflection time (Fig. 3). Magnetic anomalies near the site are of low amplitude and appear to be aligned, more or less, in a north–south direction (Fig. 4). Slightly to the west of the site area, magnetic anomalies, which correlate with part of the Cenozoic anomaly series, may have been identified (Langseth and Mrozowski, this volume).

Thus the broad objective in drilling at Site 449 was to determine the mode of spreading that created the basement on the western side of the rift as well as its age. Some pertinent questions addressed included: What is the origin of the low, Layer-2a velocities? Are interarc basin basalts interbedded with significant amounts of volcaniclastic debris from the nearby interarcs? Does the age of the basement in the western Parece Vela Basin conform to the symmetrical spreading about the centrally located rift or to a nonspecific spreading mechanism, as Karig has suggested? Is the basalt chemistry of the Parece Vela Basin comparable to MOR chemistry or must new mechanisms of petrogenesis be developed to explain the origin of marginal basin basalts formed by back-arc spreading? Are Parece Vela Basin basalts similar to those studied by Hart et al. (1972) in the Mariana Trough? What type of metallogenesis occurs within the basal sediments and basaltic crust of marginal basins, and does this compare with ophiolite metallogenesis (Bonatti et al., 1979)?

The specific objective of Site 449 was to penetrate the sediments and to drill as far as possible into the low-velocity rough basement basalts.

OPERATIONS

At 1030 Local Time (L), 27 February 1978 the *Glomar Challenger* departed Site 448 and, after a short reflection-profiling survey, got underway for Site 449, which lies about 130 miles to the northeast of Site 448 and 160 miles south–southeast of Parece Vela Island. Head winds held the average speed to 8.1 knots, and the transit was made in 16 hours.

At about 0215 L on 28 February a presite survey was begun, and about 3.5 hours were spent profiling because of difficulty in locating a sediment pond of sufficient thickness in which to bury the bottom-hole assembly. A locality with marginal sediment thickness was finally located, and a beacon was launched. As the ship continued along its track preparatory to retrieving seismic gear, an appreciable thickening trend was observed, and a second beacon of alternate frequency was dropped about two miles from the first (Fig. 5).

After retrieving the profiling equipment and positioning the ship over the second beacon at the site on 28 February at 1500 L, the drill string was run to the sea floor and a hole was spudded in 4727.5 meters of water. An extra bumper sub was used in the bottom-

to middle Miocene anomalies (7 and 5E) in the Shikoku Basin to the north. Shih (Leg 58, in press) suggests that the Shikoku Basin began to open 25 m.y. ago by symmetrical spreading parallel to the Iwo Jima Ridge. The age predicted by extension of these trends into the Parece Vela Basin conforms roughly with the age determined by previous DSDP drilling.

Detailed site surveys conducted by Lamont-Doherty Geological Observatory (LDGO) and Scripps Institution of Oceanography (SIO) in the vicinity of Site 449 prior to final site selection defined the rugged topography and scant sedimentary cover, which were known to characterize the western half of the Parece Vela Basin. Although water depth in the vicinity of Site 449 is

Figure 2. Bathymetry in the vicinity of Site 449. (The contour interval is 200 meters. Solid dots with a number and a circled number indicate the core number and heat-flow station number, respectively. Dashed contours express inadequate bathymetric data. *Conrad* and *Vema* track lines are indicated; L-DGO Site Survey data—see Langseth and Mrozowski, this volume.)
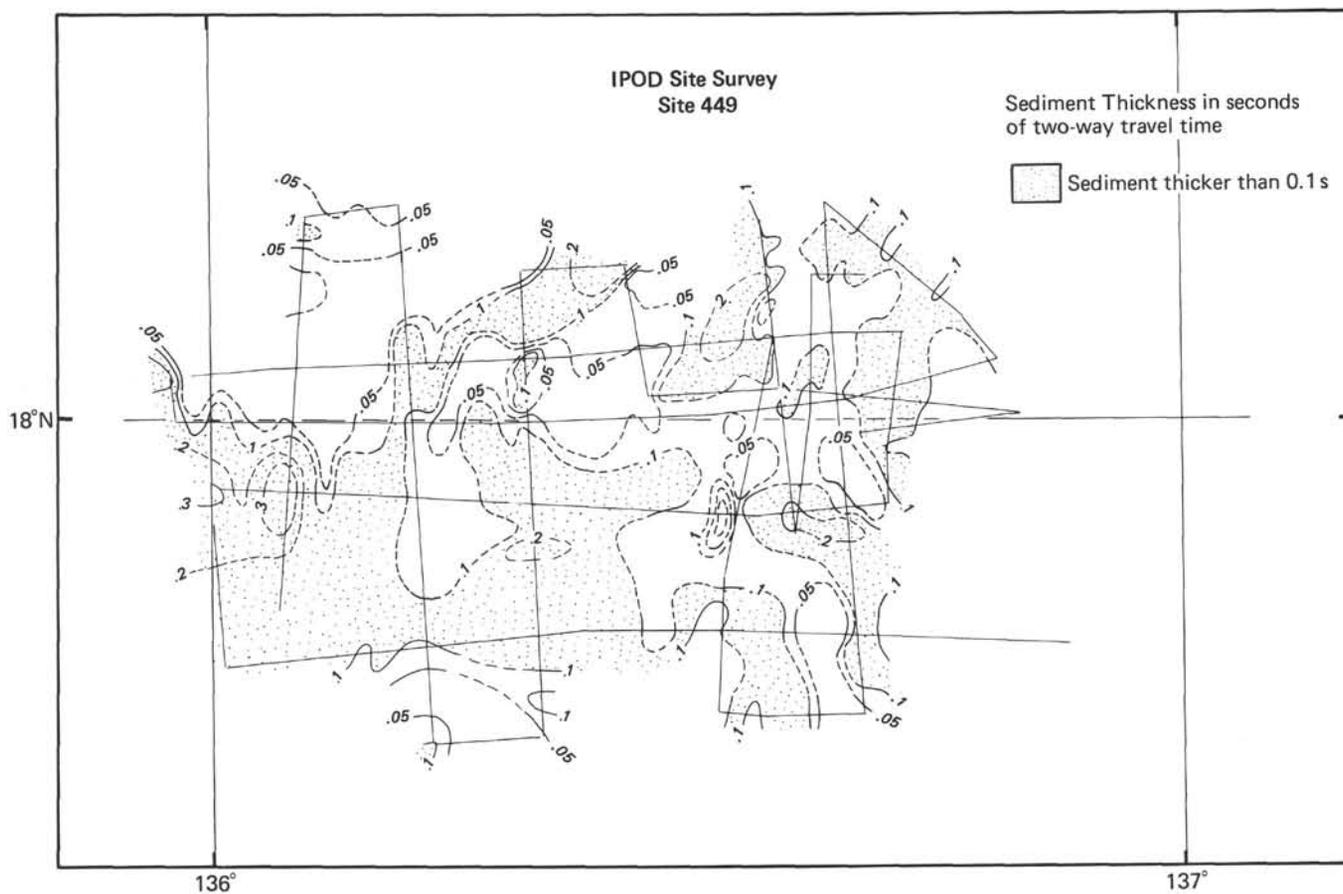
Figure 3. Sediment thickness (isochron) map of the area around Site 449 (L-DGO Site Survey data) indicated in seconds of two-way travel time. (The shaded area represents travel times greater than 0.1 s. The track lines appearing in Fig. 2 are shown.)
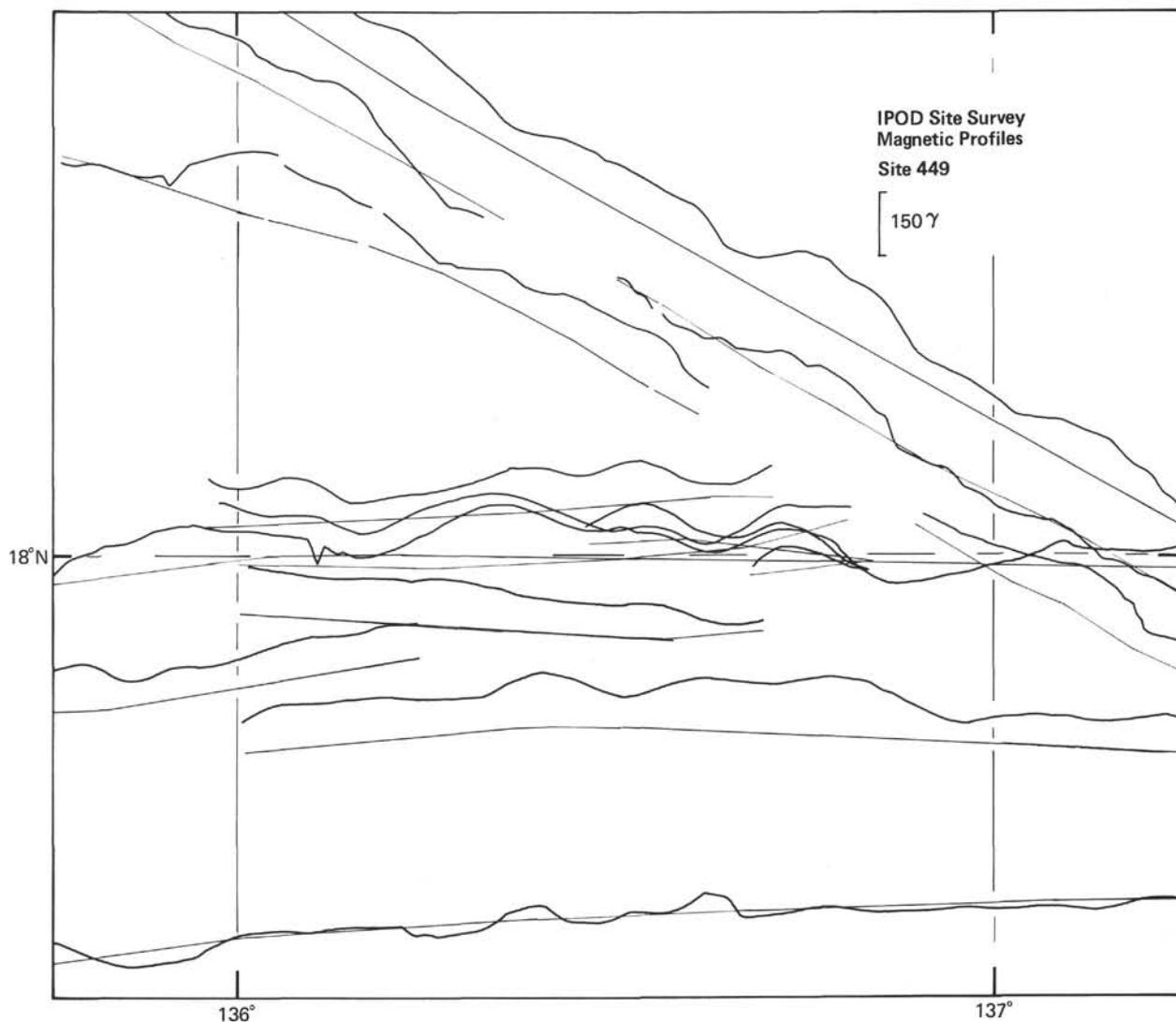
Figure 4. Magnetic-anomaly profiles and track lines in the vicinity of Site 449 (L-DGO Site Survey data). (Although the amplitudes of the anomalies are very low, distinct north–south lineations are apparent.)

hole assembly to compensate for large swells and the absence of the heave compensator. One hundred and eleven meters of soft pelagic sediments were cored before basalt was encountered (Table 1). The weathered and rubbly basalt produced low core recovery and difficult hole conditions, which deteriorated with torquing, sticking, and plugged bits. Up to 10 meters of fill began to accompany each core retrieval and pipe connection. Operations were discontinued after 40.5 meters of basalt were drilled, because of the increasing hazard to the drill string and the poor prospects for improved conditions.

The drill string was retrieved by 0415 L 1 March; after a short reflection-profile survey, the vessel was under way for Site 450, less than 48 hours after the beacon was dropped.

SEDIMENTARY LITHOLOGY

Of the 151.5 meters of sediment and basalts drilled at Hole 449, the upper 111.0 meters consist of a sequence
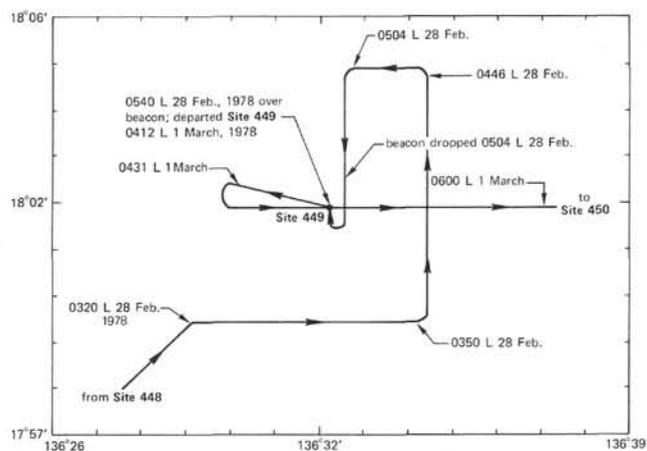
Figure 5. Track of the *Glomar Challenger* near Site 449 showing details of pre- and postsite surveys. (The solid dot marks the position of the beacon used for Site 449.)

of pelagic sediments ranging in age from late Oligocene to Pleistocene in which five lithologic units can be defined (Fig. 6).

Unit 1, 40.9 meters thick (Sample 1,CC to Section 6-2), is a middle Miocene to Pleistocene pelagic clay. Core 1 was barren except for three manganese nodules and very likely did not penetrate more than a few centimeters below the surface. For the most part, the pelagic clay is dark brown, with some yellowish brown intervals in Cores 3 through 6 in which iron oxides seem more abundant. Very pale brown and yellow mottling is rare and irregular. Unit 1 lithology is essentially uniform except for a thin layer of Pleistocene radiolarian-rich diatomaceous ooze in Section 1 of Core 2. The unit also contains numerous small pieces of more indurated clay in Cores 3 to 6; and in Core 5 there are also lithified fragments of clay rich in manganese dendroids and more or less coated by manganese films. A single manganese nodule, 4 cm in length, is also present in Core 3. Several small, dark gray pumice fragments and a 10-cm thick, yellow silt-sized ash layer are found near the bottom of the unit.

Unit 2, 6.6 meters thick (Core 6, Section 2 to the bottom of Core 6) is a middle Miocene radiolarian ooze.

Table 1. Coring summary for Hole 449.

Core No.	Date (February– March, 1978)	Local Time (L)	Depth from Drill Floor (m; top-bottom)	Depth below Sea Floor (m; top-bottom)	Length Cored (m)	Length Recovered (m)	Recovery (%)
1	February 28	1550	4727.5–4727.5	0.0– 0.0	Tr	Tr	100
2	28	1713	4727.5–4737.0	0.0– 9.5	9.5	5.3	56
3	28	1835	4737.0–4746.5	9.5– 19.0	9.5	6.2	65
4	28	1952	4746.5–4756.0	19.0– 28.5	9.5	8.0	84
5	28	2110	4756.0–4765.5	28.5– 38.0	9.5	9.3	98
6	28	2222	4765.5–4775.0	38.0– 47.5	9.5	6.6	69
7	28	2347	4775.0–4784.5	47.5– 57.0	9.5	7.7	81
8	March 1	0052	4784.5–4794.0	57.0– 66.5	9.5	9.5	100
9	1	0210	4794.0–4803.5	66.5– 76.0	9.5	2.9	31
10	1	0328	4803.5–4813.0	76.0– 85.5	9.5	8.5	89
11	1	0437	4813.0–4822.5	85.5– 95.0	9.5	8.4	88
12	1	0600	4822.5–4832.0	95.0–104.5	9.5	5.1	54
13	1	0725	4832.0–4838.5	104.5–111.0	6.5	9.0	138[a]
14	1	0905	4838.5–4841.5	111.0–114.0	3.0	1.2	40
15	1	1110	4841.5–4851.0	114.0–123.5	9.5	2.2	23
16	1	1410	4851.0–4860.5	123.5–133.0	9.5	1.3	14
17	1	1713	4860.5–4870.0	133.0–142.5	9.5	1.7	18
18	1	2001	4870.0–4879.0	142.5–151.5	9.0	0.5	5
Total					151.5	93.4	62

[a] Note that Core 13 recovery is 138% of the interval cored. The upper fraction of the core probably consists of material displaced from higher in the section.

The unit is dark yellowish brown and is rich in round, dark gray pumice fragments; it also contains patches, streaks, and mottles of yellow volcanic glass. Radiolarians are almost the exclusive component of the biogenous fraction, with only a few nannofossils present in the lowermost part of the unit. The clay content
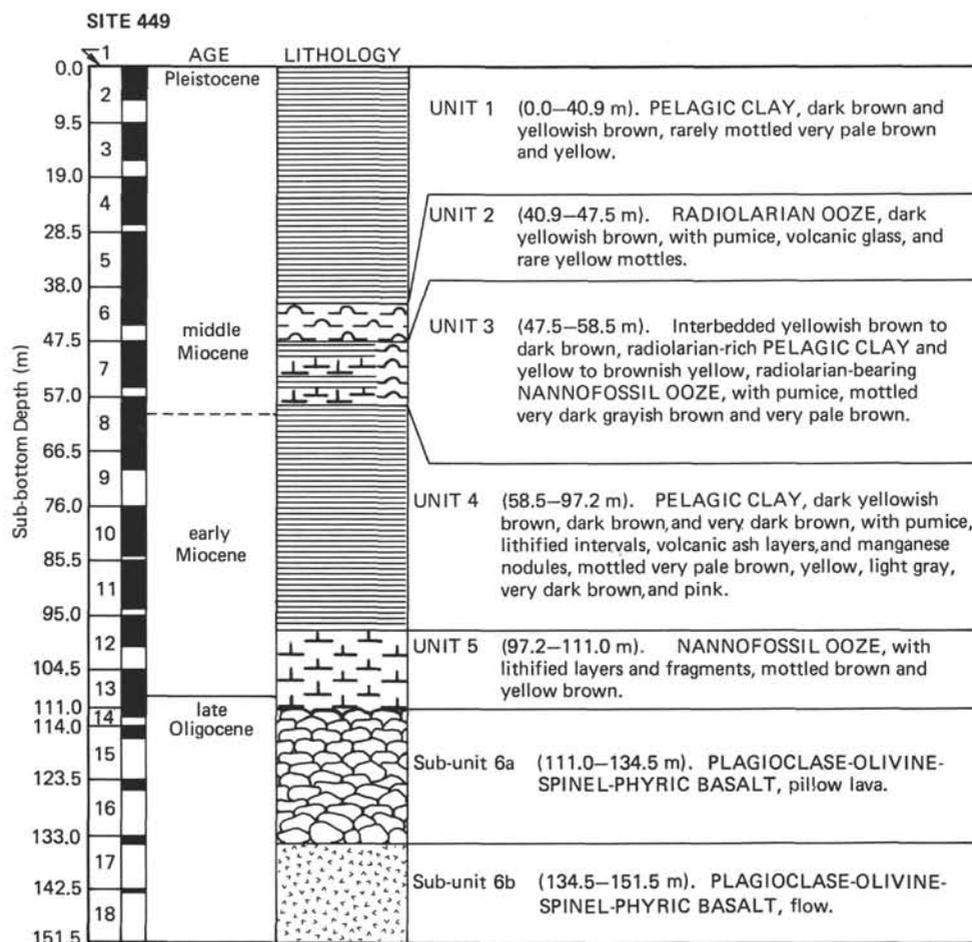
Figure 6. Lithology, age, and core recovery at Site 449. (The heavier line at the top of the pillows indicates the top of the pillow-lava sub-unit. The dashed line indicates an imprecisely determined age boundary. Core recovery is indicated by the solid symbol. Lithologic symbols are summarized in the Introduction to this volume.)

of the unit never exceeds 25%. The contact with underlying Unit 3 was not recovered and is established arbitrarily at the bottom of Core 6.

Unit 3, 11.0 meters thick, is an upper lower Miocene to middle Miocene interbedded radiolarian-rich pelagic clay and radiolarian-bearing nannofossil ooze extending down-core from the top of Core 7 through Core 8, Section 1. It consists of complexly mottled admixtures and interbedded layers of dark yellowish brown to dark brown radiolarian-rich pelagic clay, and yellow to brownish yellow radiolarian-bearing nannofossil ooze. In Sections 1 and 2 of Core 7, the nannofossil ooze occurs as rounded fragments in a matrix of pelagic clay. Wherever preserved, the contacts between the different lithologic layers are sharp. In the nannofossil ooze, which also contains pumice fragments, very dark grayish brown and very pale brown mottles are present. In some cases this mottling is intense. The lower contact of the unit, in Section 1 of Core 8, is gradational, with dark yellowish brown radiolarian-rich pelagic clay grading downward into normal pelagic clay without noticeable color changes.

Unit 4, 38.7 meters thick, is a lower Miocene pelagic clay that extends from the top of Core 8, Section 2 to Core 12, Section 2. Down-hole the color ranges from dark yellowish brown through dark brown to very dark brown. Common constituents are: altered pumice fragments, ash-rich clays, and thin yellow ash layers. The pumice fragments are olive-gray to black, commonly coated by manganese dendroids and films. The clays contain light gray lithified fragments and intervals enriched in volcanic ash, zeolites, and small manganese blebs. Rare manganese nodules 2 to 3 cm in diameter are found in Cores 8, 11, and 12. Mottling is slight, very pale brown to yellow and light gray in Cores 8 to 10, and concentrated mainly around pumice fragments. Very dark brown and pink mottles also occur in Core 11 and correspond to local enrichments in nannofossils and zeolites. The cores from the bottom of the unit contain a complex drilling admixture. Color change occurs at the contact with Unit 5.

Unit 5, 13.8 meters, is an upper Oligocene to lower Miocene nannofossil ooze that extends down-core from Core 12, Section 2 to the contact with the basaltic basement at the top of Core 14. Although only a 6.0-meter interval was drilled for Core 13, the entire 9.5-meter core barrel was filled with nannofossil ooze; the upper part of Core 13 probably consists of ooze that flowed from higher in the section, and the lower part may represent the cored interval. The unit is predominantly brown. Complex drilling admixtures of yellowish brown and dark yellowish brown oozes are the chief constituents of the unit. The yellowish brown colors are characteristic of typical nannofossil ooze, whereas the dark yellowish brown colors are characteristic of micronodule-bearing nannofossil ooze. Some brown and yellow-brown mottles and a few more indurated brown pieces are also present.

The sedimentary sequence in Hole 449 consists entirely of pelagic units, probably forming an uninterrupted oceanic succession. The oldest sediment is a nannofossil ooze of the late Oligocene (Unit 5). The deposition of pelagic clay at the beginning of the Miocene (Unit 4) records the progressive deepening of the sea floor below the carbonate compensation depth (CCD). However, a departure from the usual oceanic sedimentary sequence occurs with the reappearance of nannofossil ooze intermixed with pelagic clay (Unit 3). This was followed by the radiolarian ooze (Unit 2) in the middle Miocene sediments of Hole 449.

The reappearance of these carbonate oozes can be explained in three ways: (1) They may represent turbiditic influxes of carbonates from adjacent higher regions west on the Palau-Kyushu Ridge. Evidence for this origin lies in the occurrence of sharp lithologic boundaries and pumice fragments in the calcareous oozes. (2) They may represent tectonic uplift of the seafloor above the CCD. (3) They may represent rhythmic variations in the positions of the CCD. The last two possibilities are further dealt with by Balshaw (this volume) and Sartori (this volume). After the middle Miocene, the seafloor was permanently below the CCD, initially accumulating (in Unit 2) radiolarian ooze augmented by abundant pumice and glass. The uppermost unit of normal pelagic clays is almost barren of fossils (Unit 1, middle Miocene–Pleistocene). The diminution of disseminated ash suggests cessation of volcanism.

BIOSTRATIGRAPHY

In the one hole drilled at Site 449, there are 111.0 meters of sediment above basaltic basement. Within the sedimentary column, pelagic brown clays are dominant, and fossil occurrences are restricted to a few levels.

In the top of Core 2 (0.0–9.5 m), we found a mass occurrence of the diatom *Ethmodiscus rex*, along with upper Pleistocene radiolarians, rare silicoflagellates, and sponge spicules. Similar occurrences were previously noted at Sites 50, 51, 58, and 59 of Leg 6 (Fischer, Heezen, et al., 1971). Below a barren interval, middle Miocene radiolarians and calcareous nannoplankton occur in Core 6 (38.0–47.5 m) and in Core 7 (47.5–57.0 m) together with a few generally arenaceous foraminifers. Sediments encountered in Core 8 to the upper part of Core 10 are again essentially barren of fossils. Nannofossils reoccur in the lower part of Core 10 but are poorly preserved. At about the same level, rare calcareous foraminifers are present. The preservation of nannofossils and foraminifers improves downward, and, on the basis of a well-diversified tropical nannoplankton assemblage, it is possible to assign an age of early Miocene below Core 11 (85.5–95 m). The oldest sediments above the basalt are upper Oligocene, according to the nannofossils (Zone NP 25) and planktonic foraminifers (Zone P. 21?). In Core 14, below basalt, benthic foraminifers and lower Miocene nannofossils and radiolarians are found in sediments obviously caved from a higher level. (The sediment and fossil descriptions for Site 53 of Leg 6 [Fischer, Heezen, et al., 1971] are similar to that of Site 449.)

Calcareous Nannoplankton

In Hole 449, Core 1 to the upper part of Core 6 (~42.5 m) as well as the interval between Core 8 and the upper part of Core 10 (57.0–83.5 m) are barren of cal-

careous nannoplankton, with the exception of reworked late-Oligocene nannoplankton in Core 4.

The calcareous nannoplankton assemblage in the lower part of Core 6 is dominated by discoasters and can be placed in the middle Miocene Zone NN 6 (*Discoaster exilis* Zone). Samples from Core 7 contain rare *Sphenolithus heteromorphus*, indicating Zone NN 5 (*S. heteromorphus* Zone). Calcareous nannoplankton in the lower part of Core 10 and in the upper part of Core 11 are strongly etched, resulting in a selective preservation of shields of only sturdy species and of heavily overgrown discoasters. The poor preservation of this reduced assemblage does not allow a precise age determination, but the lower Miocene Zone NN 3 (*S. belemnos* Zone) may be represented by part of this interval. Below Core 11, assemblages are less affected by dissolution and are well diversified, especially in the lower Miocene Zone NN 1 (*Triquetrorhabdulus carinatus* Zone). The same applies to the upper Oligocene Zone NP 25 (*S. ciperoensis* Zone), which is encountered at the base of Core 13 above the basalt. Sphenolith-dominated tropical assemblages are present in Zone NN 1, including *S. delphix* and *S. capricornutus*. A similar assemblage, but also including *Discoaster druggi*, is found in the core-catcher sample of Core 14 below the basalt/sediment contact, representing lower Miocene material caved from above.

Foraminifers

Foraminifers are generally rare, with occurrences restricted to particular horizons and preservation only poor to fair. Cores 2 through 5 are barren. A few specimens, generally arenaceous, occur in Cores 6 to 9. In Core 10, a few poorly preserved calcareous specimens are present. Calcareous foraminifers increase in abundance and are better preserved down-hole from Core 10 to Core 13 (which is just above the basalt). The benthic assemblages from Cores 10 through 13 suggest a lower bathyal to abyssal depositional environment. A similar assemblage, probably caved from above, is found in Sample 14,CC (below the basalt/sediment contact). Core 13, Section 6 contains the upper-Eocene to lower Miocene species *Globigerina tripartita* s.l.; Sample 13,CC contains *Globorotalia* (1.) *opima opima*, which ranges from the middle to upper Oligocene (Zones P.19–P.21). No other samples from Site 449 could be dated using foraminifers.

Radiolarians

Most cores lack radiolarians. A sparse assemblage, belonging to the upper Pleistocene *Collosphaera tuberosa* Zone of Nigrini (1971), was found at the top of Core 2 (Section 1, 44–46 cm) in an extraordinarily rich diatomaceous layer. Farther down, the core-catcher samples of Cores 6 and 7 contain well-preserved and abundant fauna (*Dorcadospyris alata* and *Calocycletta costata* Zones, respectively). Radiolarians are also present in the core-catcher sample of Core 14, but they must be attributed to caving from a higher level within Hole 449—the rare and poorly preserved forms are middle lower Miocene (*Stichocorys wolffii* Zone), which con-

flicts with the upper Oligocene nannofossils and foraminifers in Sample 13,CC.

Diatoms and Silicoflagellates

A mass occurrence of the extremely large diatom *Ethmodiscus rex* was noted in the upper part of Core 2 which, on the basis of radiolarians, is upper Pleistocene. In addition, rare silicoflagellates and sponge spicules are present at this particular level.

PALEOENVIRONMENT

The distribution of calcareous fossils at Site 449 appears to be strongly influenced by their resistance to solution (nannofossils being more resistant than benthic foraminifers, planktonic foraminifers being least resistant). The only fossils in place above Core 6 are siliceous radiolarians and diatoms, indicating that this middle Miocene to Pleistocene interval was deposited below the CCD. Middle Miocene nannofossils are present in the lower portion of Core 6 and in Core 7, suggesting that the area was slightly shallower, the CCD was slightly deeper, or rapid turbiditic influx of carbonates did not provide time for dissolution during this period. Cores 8 and 9 are essentially barren; the area surrounding Site 449 presumably was again below the CCD when these sediments were deposited. Nannofossils and calcareous foraminifers occur near the base of Core 10, with in-place assemblages found through Core 13. The preservation of both fossil groups is poor in Core 10, but improves downward to Sample 13,CC, which contains a relatively diverse planktonic foraminiferal assemblage and fairly well-preserved nannofossils of the upper Oligocene. The upper Oligocene to lower Miocene sediments sampled in Cores 13 through the base of Core 10 were therefore deposited above the CCD, with the shallowest deposition, or the lowest level of the CCD, coinciding with the oldest datable sediment (Core 13).

Sample 11,CC through Core 13 contain a diverse benthic foraminiferal assemblage (including *Cibicides kullenbergi* and several species of *Stilostomella*); the presence of this assemblage suggests a lower bathyal to abyssal depositional environment. Benthic foraminifers are too rare above Sample 11,CC to allow for precise environmental interpretation.

ACCUMULATION RATES

Although some of the cores drilled at this site are virtually barren of planktonic fossils, nevertheless, a reasonably accurate estimate of sediment accumulation rates is possible. The resulting curve (Fig. 7) reflects the uniformly pelagic character which, on a broad scale, typifies the recovered sediments; it is probably best interpreted as a straight line representing about 4 m/m.y. The curve's minor variations are in all likelihood the result of short-term changes in depositional rates associated with the alternating layers of pelagic brown clays, biogenous oozes, and volcanic materials that are interspersed in the column. However, the reason that the nannofossil ooze of Unit 5 should accumulate slower (4.3 m/m.y.) than the thick pelagic clays of Units 3 and 4 (7.5 m/m.y.) is not clear. It is highly probable that
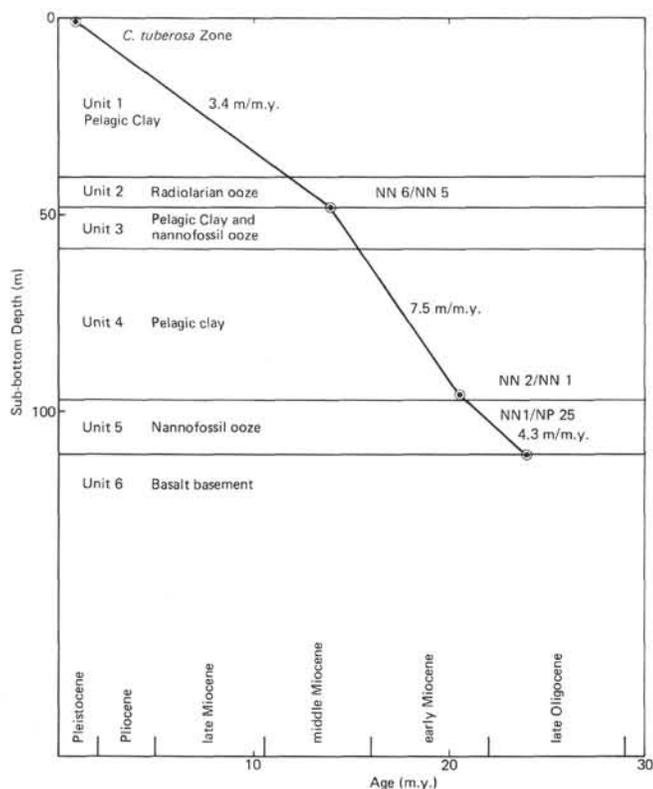
Figure 7. Accumulation rates estimated for the sedimentary sequence of Site 449. (The time-scale for the Neogene is from LaBrecque et al. [1977]; for the Oligocene, Martini's [1976] scheme was employed. Definition of the nannofossil zonal boundaries is that provided by Martini [1971]; that of the radiolarian Zone *Collosphaera tuberosa* is after Nigrini [1971]. Calibration to the time-scale of the nannofossil zonal boundaries follows Martini [1976].)

significant undetected erosion or nondeposition horizons are present in Unit 5.

ORGANIC GEOCHEMISTRY

No gas shows were observed in the cores recovered at Site 449; it is improbable that significant generation of hydrocarbon gases can have occurred within this sedimentary sequence. Therefore no gas analyses were made.

Twenty-three samples from Site 449 were analyzed for organic carbon and nitrogen contents using procedures outlined in the Introduction (this volume). The results from this site are given in Table 2 and plotted against sub-bottom depth in Figure 8 . Within Unit 1, a gradual decrease in the amount of organic carbon is seen. A similar pattern has been previously observed at other DSDP sites, particularly those of Leg 58 in analogously lean sediments (Klein and Kobayashi, in press). This phenomenon may be attributable to bacterial activity in the upper sediment layers that recycles the organic carbon within this shallow zone. Organic carbon values for the sediments (after carbonate dissolution) from Site 449 do not show an overall trend or pattern down-hole, but seem to be partly dependent on lithology, showing different trends within each sedimentary unit. The nitrogen content, apart from the

Table 2. Organic carbon and nitrogen contents (after carbonate dissolution).

Lithologic Unit	Sample (interval in cm)	Organic Carbon (wt. %)	Nitrogen (wt. %)	C:N (atomic ratio)
1	2-1, 70–71	0.30	0.084	4.2
		0.29	0.062	5.5
		0.28	0.084	3.9
1	2-3, 4–5	0.30	0.083	4.2
		0.26	0.082	3.7
		0.31	0.099	3.7
1	3-1, 40–41	0.25	0.072	4.1
		0.24	0.073	3.8
		0.23	0.079	3.4
1	3-3, 4–5	0.26	0.071	4.3
		0.21	0.066	3.7
		0.27	0.078	4.1
1	4-1, 70–71	0.20	0.032	7.3
		0.24	0.032	8.8
		0.14	0.026	6.3
1	4-3, 23–24	0.15	0.023	7.6
		0.15	0.015	11.7
		0.13	0.013	11.7
1	5-1, 60–61	0.11	0.016	8.0
		0.13	0.016	9.5
		0.13	0.015	10.1
1	5-3, 50–51	0.16	0.019	9.9
		0.14	0.016	10.2
		0.14	0.017	9.6
1	6-1, 120–121	0.29	0.023	14.8
		0.25	0.020	14.6
		0.25	0.024	12.2
2	6-3, 117–118	0.20	0.018	13.0
		0.18	0.016	13.2
		0.23	0.019	14.2
3	7-1, 16–17	0.24	0.052	5.4
		0.24	0.050	5.6
		0.32	0.059	6.3
3	7-5, 94–95	0.24	0.015	18.7
		0.24	0.016	13.3
		0.15	0.015	11.7
4	8-3, 80–81	0.24	0.015	18.7
		0.17	0.015	13.3
		0.27	0.014	22.6
4	9-1, 80–81	0.26	0.015	20.3
		0.27	0.019	16.6
4	10-1, 49–50	0.15	0.022	8.0
		0.13	0.020	7.6
4	10-6, 22–23	0.23	0.018	14.9
		0.21	0.018	13.7
		0.22	0.024	10.7
4	11-3, 9–10	0.33	0.019	20.3
		0.36	0.020	21.6
		0.36	0.021	20.1
4	11-5, 53–55	0.47	0.022	25.0
		0.43	0.026	19.4
		0.42	0.024	20.5
4	12-1, 140–141	0.18	0.013	16.2
		0.24	0.017	16.5
		0.19	0.013	17.1
5	12-3, 40–41	0.44	0.033	15.6
		0.47	0.031	17.7
5	13-1, 26–27	0.10	0.009	13.0
		0.13	0.011	13.8
5	13-3, 48–49	0.30	0.018	19.5
		0.27	0.016	21.9
5	13-6, 100–101	0.15	0.013	13.5
		0.13	0.010	15.2
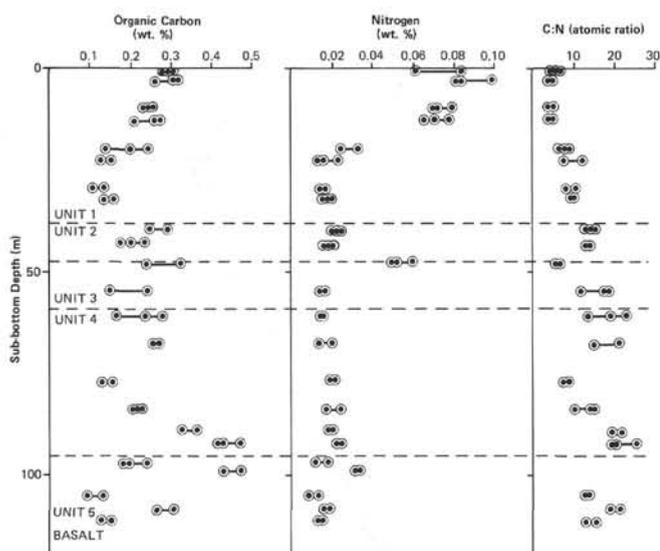
Figure 8. Results of organic carbon and nitrogen analyses plotted versus sub-bottom depth in meters.

uppermost 15 meters, where it averages 0.075 wt. % of the sediment, shows little deviation from the range 0.01 to 0.03 wt. %. The sharp drop in nitrogen content between Section 3-3 and Section 4-1 does not reflect a lithologic change. No continuous trend is discernible in the C:N ratio with depth, except for a gradual increase from 5 to 15 within the uppermost 40 meters of the sequence.

Rock Eval analyses were made by methods described in the Introduction (this volume). The results of these Rock Eval analyses are summarized in Table 3. Anomalous S_2 peaks that maximize at 550° appear in analyses of the pelagic clays and radiolarian oozes of Units 1, 2, and 4 and resemble the peaks of analyses of pelagic clays from Site 447. These S_2 peaks do not appear to result from pyrolyzable organic matter but are caused by an unidentified phenomenon associated with these particular unconsolidated lithologies. None of the other sediments, especially the nannofossil oozes of Unit 5, give significant hydrocarbon responses; these are effectively devoid of pyrolyzable organic matter.

The sediments at Site 449, like those of Sites 447 and 448, appear to be almost barren of organic matter; therefore they are of limited organic geochemical in-

Table 3. Qualitative estimate of the relative amounts of free hydrocarbons, bound hydrocarbons, and CO_2 from kerogen (and carbonate-rich sediments) based upon sizes of S_1, S_2, and S_3, respectively, from Rock Eval analyses.

Lithologic Unit	No. of Samples	Free Hydrocarbon (S_1)	Bound Hydrocarbon (S_2)	CO_2 from Kerogen (S_3)
Units 1 and 2	10	−/+	+++	−
Unit 4	9	+	−/+++	−
Unit 5	4	−	−	−

Note: − = undetectable, −/+ = undetectable to minor, + = minor, −/+++ = undetectable to major, and +++ = major relative amounts.

terest. It does appear, however, that within the uppermost 30 meters of the sedimentary sequence, bacterial activity may have occurred.

INORGANIC CHEMISTRY OF INTERSTITIAL WATER

Four samples—from Sections 2-2, 5-1, 8-4, and 11-4—were collected for interstitial water analyses according to the standard shipboard procedures described in the Introduction (this volume). The results are given in Figure 9. Apart from the chlorinity, which shows a slight increase, the inorganic parameters remain virtually constant with depth.

IGNEOUS PETROGRAPHY

Basaltic basement was encountered at a depth of 111.0 meters sub-bottom and was continuously cored to 151.5 meters. As a result of poor hole stability, drilling was terminated after penetrating 40.5 meters of the basalt of Unit 6. The sediment immediately overlying the basement consists of a mixture of nannofossil ooze with lithified patches of nannofossil chalk (Zone NP 25, upper Oligocene). The relationship between the uppermost basalt and these overlying sediments is not clear, but the absence of a simple chilled contact and the presence of relatively small, cognate, subspherical fragments of pillow basalt at the contact could result either from fault brecciation or simply from very poor drilling conditions. The pillow basalts in Cores 14 and 15 are so fragmented that coherent pillow structures are difficult to recognize (Figure 10).

Unit 6 is a plagioclase-olivine-spinel-phyric tholeiitic basalt, which may be divided into two sub-units based on flow structure. These two sub-units are indistinguishable from MOR basalts based upon petrographic and X-ray fluorescence (XRF) chemical criteria.

Sub-unit 6a, 23.5 meters thick (111.0–134.5 m), consists of pillow basalts. The uppermost 13.0 meters are very glassy; of the 96 fragments recovered (15 cm max. and 5–6 cm avg. length), one-third have glassy zones, probably indicating a relatively small pillow size. Both the rock and glass fragments are cemented in a palagonitic matrix. The lowermost 10.5 meters are relatively glass poor and may represent larger pillows.

Sub-unit 6b, more than 17 meters thick (134.5–151.5 m), contains fewer olivine and spinel phenocrysts than does Sub-unit 6a. The absence of glass and the relatively coarse grains in this interval suggest that Sub-unit 6b is a flow; however, two possible quenched zones exist that may be large pillow margins or separate massive flow contacts.

The total abundance of phenocrysts and groundmass constituents are given as percentages of the whole rock (e.g., the rock consists of 10% phenocrysts, 5% vesicles, and 85% groundmass), whereas the abundance of individual phenocrysts or groundmass constituents are given as percentages of the total phenocrysts or total groundmass constituents (e.g., the phenocrysts consist of plagioclase [60%, 0.8 mm] and olivine [40%, 0.4 mm, altered to green smectite]; the groundmass consists of plagioclase [50%], both pyroxenes [20%], opaques [5%], and glass [25%]).
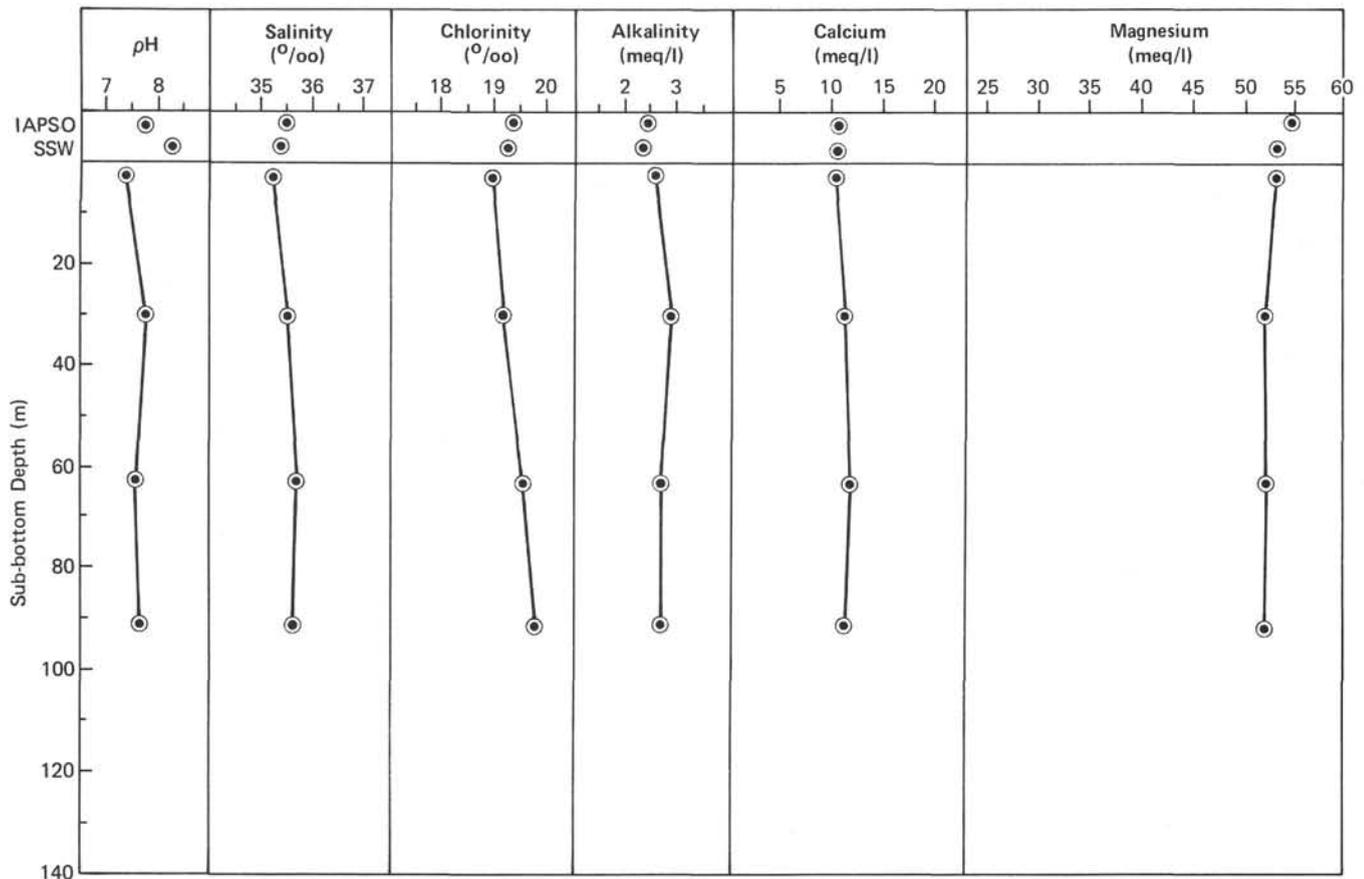
Figure 9. Results of analyses of interstitial water from sediment samples plotted versus sub-bottom depth in meters. (IAPSO standard and a surface sea-water sample, SSW, are shown for comparison.)

The plagioclase-olivine-spinel-phyric basalt of Sub-unit 6a is a gray to pale brown, fine-grained pillow lava with sparse, irregular vesicles (3-5%, 0.5-1 mm, rarely filled with carbonate). The inner parts of the pillows have a hyalopilitic texture and contain less than 10% phenocrysts of euhedral, oscillatory-zones plagioclase phenocrysts (~80%, 0.5-2.0 mm long, ~An_{70-75}) and sparse olivine and spinel. The groundmass consists of plagioclase laths (30%, 0.2-0.4 mm long), granular anhedral clinopyroxene (10%, 0.05-0.1 mm), sparse olivine, and devitrified glass (60%). A thin section of the marginal glass zone reveals a hyalopilitic groundmass that is composed of acicular microlitic plagioclase (0-30%) and devitrified glass (70-90%). The 8% of phenocrysts consist of euhedral, oscillatory-zoned plagioclase (60%, 0.4-1.2 mm, An_{45}) and euhedral, fresh olivine (40%, 0.4-0.8 mm, 2V = +90°) containing numerous octahedral chrome spinels (0.01-0.02 mm).

The Sub-unit 6b flow has a coarse-grained, gray to pale brown, pilotaxitic to intersertal interior. The 3% of phenocrysts consist of lathlike plagioclase (<90%, 0.3-0.5 mm) and sparse olivine and spinel. The groundmass consists of acicular plagioclase laths (40%, 0.2-4.0 mm, ~An_{40-50}), sheaf-like clinopyroxene (40%, 0.2-1.0 mm), skeletal opaque minerals (2%, 0.2-0.5 mm), euhedral, sparse olivine (0.1-0.4 mm), and glass

(5-10%). Empty vesicles (0.2-1.0 mm) comprise 20% of the rock.

Most of the basalts show a moderate amount of low-temperature alteration that is extensively developed in pillow margins and in pockets between the pillows. Low-temperature alteration minerals are clays (smectite), Fe-hydroxides, carbonates, and zeolites. Olivine and glass are more extensively altered than are clinopyroxene, plagioclase, and opaque minerals.

METAMORPHIC PETROGRAPHY

In the 40.5 meters of weathered basalts (111.0-151.5 m sub-bottom), which fortunately contain very fresh glassy rims, there is no indication of hydrothermal activity or metamorphism. The sediments obviously postdate the extrusion and thus no contact metamorphic effects are involved.

CONTACT RELATIONS AND STRATIGRAPHY

In the 40.5-meter interval of basalt drilled between the lowermost sediments (110.0 m sub-bottom) and the bottom of Hole 449, we encountered pillow lavas and massive flows. However, within this sequence, core recovery was poor and the basalt consisted of small rubbly pieces; this material did not provide sufficient contact relations for study. At the sediment/basalt inter-
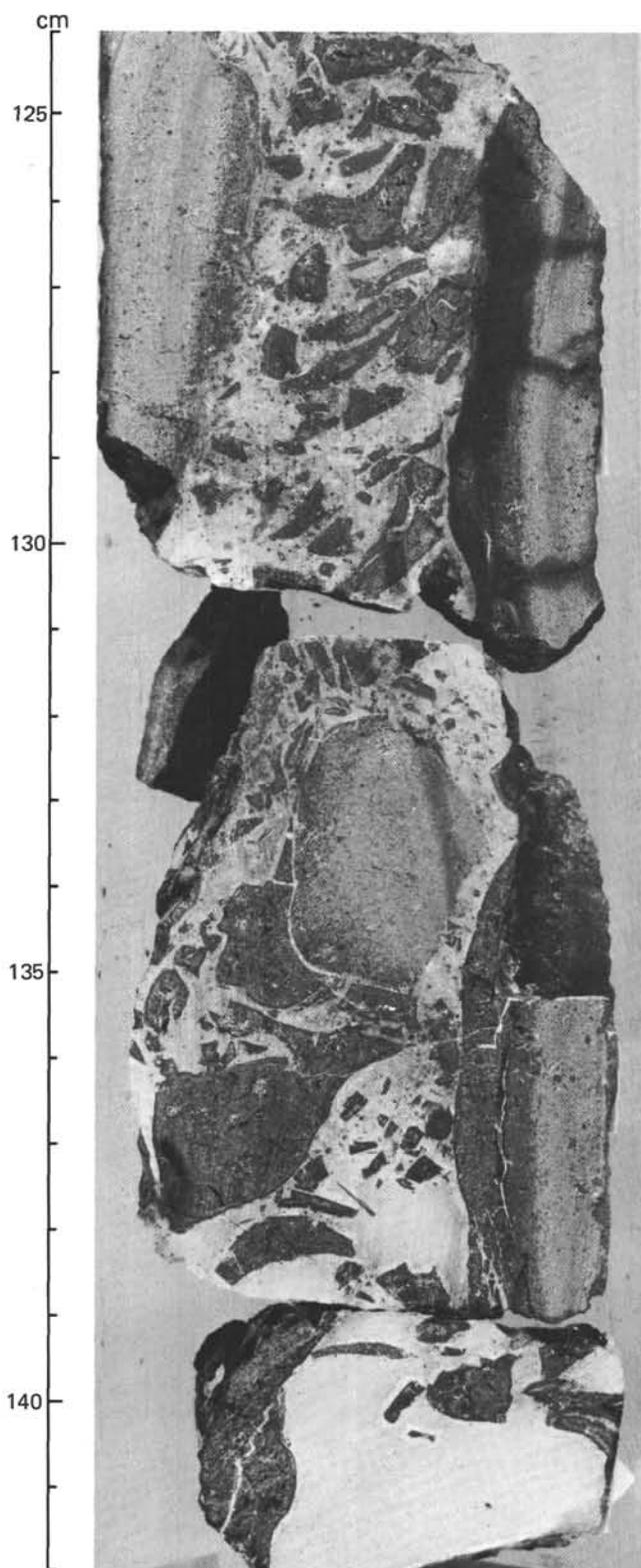
Figure 10. Highly fragmented pillow basalts cemented with calcium carbonate that largely appears to be recrystallized nannofossil chalk.

face, the basalt fragments have been cemented together by calcite and zeolites(?) across an interval several meters thick, but below that interval fractures have been left open. No evidence was recovered to suggest that sediments were interbedded with the basalts.

PALEOMAGNETISM

No paleomagnetic samples were collected from Site 449. The sediment column at this site is a red-brown pelagic clay that normally gives unreliable paleomagnetic results (Foster, 1972). In addition, the sediment cores showed significant drilling disturbance. The volcanic units recovered also appeared unsuitable for paleomagnetic study; alteration, specifically oxidation of iron oxides, was pervasive throughout, making them poor choices for study.

PHYSICAL PROPERTIES

Physical properties were measured on only a few samples from Hole 449 because of the severe disturbance of the pelagic clays and nannofossil oozes in the upper part of the hole. Sonic velocity measured on the same type, but less disturbed, sediments in Cores 11, 12, and 13 immediately overlying the basaltic basement averages about 1.55 km/s (Table 4, Fig. 11). Wet-bulk density of the less disturbed sediments ranges from 1.23 to 1.40 g/cm^3. The only exception is a thin 2-cm bed of lithified mudstone in Section 11-3, which has a velocity of 2.14 km/s and a wet-bulk density of 1.67 g/cm^3.

In the basalts, velocities ranged from about 3.9 to 4.3 km/s. The acoustic impedance in these basalts is typical, ranging from 10.0 to 11.2 $\times$ 10^5 g/(cm^{2}s).

GEOPHYSICS

The Parece Vela Basin, a back-arc or interarc basin, is situated between two aseismic remnant arcs: the Palau-Kyushu Ridge to the west and the West Mariana Ridge to the east. The basin is divided into approximately equal halves by the north–south trending Parece Vela Rift, which actually consists of a series of offset deep troughs located along a line extending northward from the Yap Trench. Site 449 is located about 300 km west of the rift and about 100 km east of the Palau-Kyushu Ridge.

Describing the crustal structure of the West Philippine Sea, Murauchi et al. (1968) present data from two seismic refraction lines in the western Parece Vela Basin. Both lines reveal a low-velocity (3.1–3.7 km/s) uppermost crustal layer (Layer 2a?) overlying a more normal-velocity (4.3–5.1 km/s) oceanic Layer 2 (Layer 2b?), in turn overlying a normal-velocity (6.8–7.0 km/s) oceanic Layer 3 above a slightly high-velocity (8.2–8.5 km/s) mantle. It is the low-velocity, uppermost crustal layer that is of interest here. On the one hand, single-channel seismic-reflection profiling has shown low-velocity, acoustically transparent sediments are generally very thin (100 m or less), perhaps with the exception of isolated ponds in topographic depressions. On the other hand, preliminary results from multichannel seismic data indicated 300 meters of sediment overlying a 4.21-km/s basement in the vicinity of the drill site.

Table 4. Physical properties of sediments and igneous rocks from Hole 449.

Sample (hole-core-section)	Sub-bottom Depth (m)	Sonic Velocity Horizontal		Vertical	Gravimetric (g/cm³)	Wet-Bulk Density Continuous GRAPE (section averages) (g/cm³)[b]	Special 2-min GRAPE (g/cm³)[b]	Water Content (%)	Porosity (%)	Calculated Grain Density (g/cm³)	Acoustic Impedance [× 10⁵ g/(cm²s)]
449-2-1	0.75	—	—	—	—	1.28	—	—	—	—	—
449-2-2	2.25	—	—	—	—	1.28	—	—	—	—	—
449-2-2	2.95	—	—	—	—	—	—	64.80	—	—	—
449-2-3	3.75	—	—	—	—	1.30	—	—	—	—	—
449-3-2	11.75	—	—	—	—	1.32	—	—	—	—	—
449-3-3	13.25	—	—	—	—	1.33	—	—	—	—	—
449-3-4	14.75	—	—	—	—	1.32	—	—	—	—	—
449-4-1	19.75	—	—	—	—	1.28	—	—	—	—	—
449-4-2	21.25	—	—	—	—	1.25	—	—	—	—	—
449-4-3	22.75	—	—	—	—	1.28	—	—	—	—	—
449-4-4	24.25	—	—	—	—	1.26	—	—	—	—	—
449-4-5	25.75	—	—	—	—	1.26	—	—	—	—	—
449-5-1	29.25	—	—	—	—	1.26	—	—	—	—	—
449-5-1	29.95	—	—	—	—	—	—	66.94	—	—	—
449-5-2	30.75	—	—	—	—	1.26	—	—	—	—	—
449-5-3	32.25	—	—	—	—	1.24	—	—	—	—	—
449-5-4	33.75	—	—	—	—	1.23	—	—	—	—	—
449-5-5	35.25	—	—	—	—	1.21	—	—	—	—	—
449-6-2	40.25	—	—	—	—	1.23	—	—	—	—	—
449-6-3	41.75	—	—	—	—	1.22	—	—	—	—	—
449-6-4	43.25	—	—	—	—	1.19	—	—	—	—	—
449-8-1	57.75	—	—	—	—	1.23	—	—	—	—	—
449-8-3	60.75	—	—	—	—	1.22	—	—	—	—	—
449-8-4	62.25	—	—	—	—	1.24	—	—	—	—	—
449-8-4	62.95	—	—	—	—	—	—	71.48	—	—	—
449-8-5	63.75	—	—	—	—	1.22	—	—	—	—	—
449-8-6	65.25	—	—	—	—	1.21	—	—	—	—	—
449-9-1	67.25	—	—	—	—	1.24	—	—	—	—	—
449-9-2	68.75	—	—	—	—	1.26	—	—	—	—	—
449-10-1	76.75	—	—	—	—	1.23	—	—	—	—	—
449-10-3	79.75	—	—	—	—	1.22	—	—	—	—	—
449-10-5	82.75	—	—	—	—	1.25	—	—	—	—	—
449-11-1	86.25	—	—	—	—	1.26	—	—	—	—	—
449-11-3	89.25	—	—	—	—	1.26	—	—	—	—	—
449-11-3	89.29	2.145	—	2.125	—	—	—	—	—	—	3.59
449-11-3	89.30	—	—	—	1.673	—	—	34.91	58.38	2.616	—
449-11-4	91.45	—	—	—	—	—	—	64.92	—	—	—
449-11-5	92.25	—	—	—	—	1.25	—	—	—	—	—
449-11-5	92.68	1.556	—	1.570	—	—	—	—	—	—	1.93
449-11-5	92.69	—	—	—	1.231	—	—	68.95	84.87	2.526	—
449-12-1	95.75	—	—	—	—	1.33	—	—	—	—	—
449-12-3	98.67	1.538	—	1. 4	—	—	—	—	—	—	2.11
449-12-3	98.68	—	—	—	1.374	—	—	55.90	76.80	2.612	—
449-12-3	98.75	—	—	—	—	1.34	—	—	—	—	—
449-13-1	105.25	—	—	—	—	1.37	—	—	—	—	—
449-13-3	108.25	—	—	—	—	1.43	—	—	—	—	—
449-13-5	111.25	—	—	—	—	1.43	—	—	—	—	—
449-13-5	111.82	—	—	1.556	—	—	—	—	—	—	1.66
449-13-5	111.84	—	—	—	1.403	—	—	54.19	76.05	2.683	—
449-13-6	112.75	—	—	—	—	1.46	—	—	—	—	—
449-14-1	111.61	—	4.209[a]	—	—	—	—	—	—	—	—
449-14-1	111.64	—	—	—	—	—	2.510	—	—	—	—
449-14-2	112.69	—	3.949[a]	—	—	—	—	—	—	—	—
449-14-6	118.76	—	—	—	—	—	2.349	—	—	—	—
449-15-1	114.52	—	4.172[a]	—	—	—	—	—	—	—	10.91
449-15-1	114.53	—	—	—	2.616	—	—	—	—	—	—
449-15-2	115.66	—	4.306[a]	—	—	—	—	—	—	—	11.23
449-15-2	115.67	—	—	—	2.609	—	—	—	—	—	—
449-16-2	125.38	—	3.967[a]	—	—	—	—	—	—	—	10.03
449-16-2	125.39	—	—	—	2.529	—	—	—	—	—	—

[a] Basalt average velocity.
[b] Based on an assumed grain density of 2.75 g/cm³.

Prior to drilling, as the target site was approached, reflection profiles recorded on board the *Challenger* revealed little, if any, appreciable sediment thickness in the area previously selected for drilling. After a short survey, however, a sufficiently thick accumulation was located nearby that permitted complete burial of the bottom-hole assembly. Approximately 0.13 s of reflection time is indicated in the reflection profile across the site (taken during the approach) as shown in Figure 12. Because of drilling disturbance encountered in cores from Hole 449, sonic velocities were not well determined. However, assuming the reflection time of 0.13 s
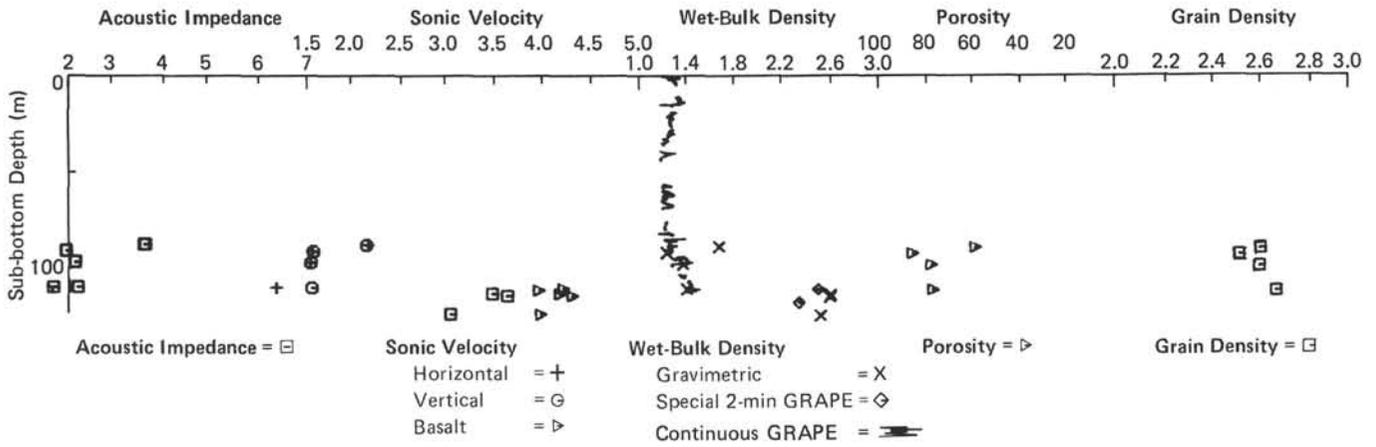
Figure 11. Physical properties of sediments and igneous rocks from Hole 449 plotted versus sub-bottom depth in meters. (Acoustic impedance is the product of velocity and bulk density. Sonic-velocity measurements include horizontal and vertical velocity of sediments and average velocity of basalts. Gravimetric determinations of wet-bulk density are shown. Special 2-minute and continuous GRAPE determinations of wet-bulk density are also shown, based on an assumed grain density of 2.75 g/cm³. Porosity was determined gravimetrically, and grain density was calculated from porosity and bulk density.)
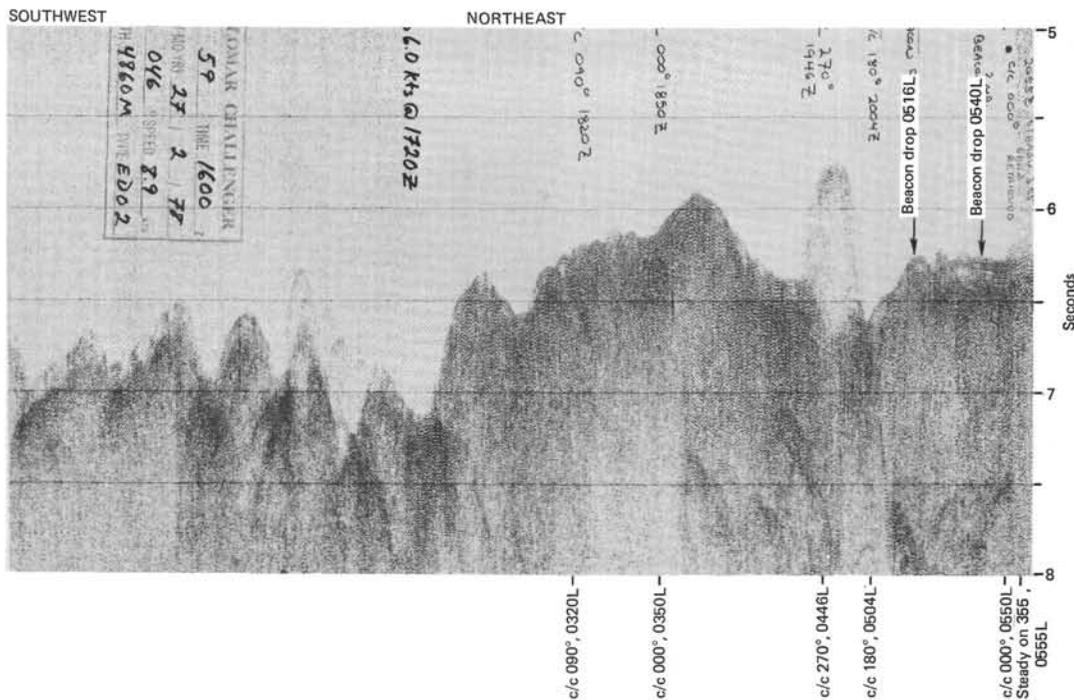
Figure 12. Seismic-reflection profile across Site 449 recorded on board the *Glomar Challenger* during approach to the site.

to basaltic basement has been correctly determined, an average velocity of 1.71 km/s for the sediment column is obtained.

SUMMARY AND CONCLUSIONS

Site 449 at 18°01.84'N and 136°32.19'E was drilled with the objective of determining (1) the age and pattern of back-arc spreading that formed the rough basaltic basement of the western side of the Parece Vela Basin and (2) the metallogenic features of basin sediments and underlying basalts. Continuous coring at Hole 449 resulted in a total recovery of 93.4 meters of 151.5

meters drilled. Sediments were cored to a depth of 111.0 meters before basalt was encountered. An additional 40.5 meters of basaltic pillow lavas and massive flows were cored before the total depth was reached. Hole 449 was terminated at a total depth of 151.5 meters because of severe hole instability associated with slumping of unconsolidated pelagic clay and basalt rubble into the hole. Six lithologic units were identified; the sedimentary section comprises five units that range from the upper Oligocene to the Pleistocene. The upper Oligocene (or older) igneous unit is divided into two additional sub-units, based upon flow mechanics.

The sedimentary section consists of:

Unit 1 (0.0–40.9 m), Pleistocene to middle Miocene dark brown and yellowish brown pelagic clay;

Unit 2 (40.9–47.5 m), middle Miocene dark yellowish brown radiolarian ooze with pumice and volcanic glass;

Unit 3 (47.5–58.5 m), middle Miocene interbedded yellowish brown to dark brown radiolarian-rich pelagic clay and yellow to brownish yellow radiolarian-bearing nannofossil ooze with pumice;

Unit 4 (58.5–97.2 m), lower Miocene to middle Miocene dark yellowish brown to very dark brown pelagic clay with pumice and ash layers; and

Unit 5 (97.2–111.0 m), lower Miocene to upper Oligocene mottled brown and yellow-brown nannofossil ooze.

The igneous section consists of two sub-units:

Sub-unit 6a(111.0–134.5 m), plagioclase-olivine-spinel-phyric pillow basalt; and

Sub-unit 6b(134.5–151.5 m), plagioclase-olivine-spinel-phyric basalt flow.

The thin sedimentary cover over the basement appears to be a normal, uninterrupted, deep-oceanic sedimentary section. A thin layer of ferromanganese nodules collected in the core catcher of Core 1 suggests that a ferromanganese pavement may exist in the area of Site 449. Ferromanganese nodules are also present in Units 1 (Core 3), 4 (Cores 8 and 11), and 5 (Core 12). Throughout the sedimentary section, color variations of reddish browns and dark browns are related to variations in abundances of ferromanganese micronodules and other forms of iron and manganese oxides. Lighter colors are related to additions of light-colored biogenous material. Ash and pumice occur in abundance as low as the lower Miocene (Zone NN 2) and as high as the middle Miocene.

Several fossil occurrences in the sediments recovered at Site 449 are restricted to a few levels. Upper Pleistocene radiolarians are found at the top of Core 2 (0–2 m). Below a nondiagnostic interval, middle Miocene radiolarians and calcareous nannoplankton (Zone NN 6) occur in Core 6 (42–45 m). Below a barren zone, more calcareous nannoplankton (Zone NN 2) are present in Core 10 (92–96 m). The oldest nannofossils (Zone NP 25) date the sediments just above the basalt as late Oligocene.

Upper Oligocene sediments contain calcareous fossils; lower Miocene sediments do not; middle Miocene sediments again contain calcareous layers but with alternating barren layers; and middle Miocene to Pleistocene sediments again do not contain calcareous fossils. This phenomenon is interpreted as turbiditic influxes or fluctuations of the CCD with respect to the seafloor by three processes: (1) the gradual submergence of a marginal basin with age; (2) independent fluctuations of the CCD; and (3) the tectonic processes of uplift and subsidence of the ocean floor through the CCD. After the middle Miocene, the separation between the CCD and the seafloor increased with time. During times when the seafloor was above the CCD, the average sedimentation rate was about 6 m/m.y., and after the CCD was

above the seafloor, the rate distinctly dropped to about 4 m/m.y.

In spite of the extreme degree of topographic roughness in the area, sonic velocities of 3.9 to 4.3 km/s measured on the basalts cored at Site 449 agree reasonably well with both the refraction velocities of 3.1 to 3.7 km/s for Layer 2a and the multichannel survey velocity of 4.2 km/s.

The limited petrographic and XRF studies conducted on the basalts encountered at Site 449 indicate that they appear to be indistinguishable from oceanic tholeiites. Chemical studies of samples obtained in 1976 from dredging in the Parece Vela Basin at Site 1398 (Fig. 1) aboard the *Dmitry Mendeleev* can be used to make a more detailed comparison of Site 449 basalts with MOR, arc, and other marginal-basin basalts (Table 5). The major-element abundances in the Parece Vela Basin basalts are somewhat similar to MOR basalts and to other marginal-basin basalts but distinctly different from arc basalts. TiO_2 values obtained by Dietrich et al. (1978) are all higher and the value obtained by Zakariadze (personal communication) is lower than typical MOR values. Although Dietrich et al. have average K_2O values that are close to MOR values and to Lau Basin basalts (Hawkins, 1977), they are significantly lower than the K_2O value for the Mariana Trough basalts. Zakariadze's K_2O value and K/Rb ratio are similar to those for Mariana Trough basalts, whereas Dietrich's data have higher Rb and/or lower K values. The entire question of contamination of K and Rb by sea-water and/or analytic resolution problems related to Rb analyses by XRF require that extreme care be used in interpreting these data. The comparison of K/Rb and K/Ba ratios of Lau Basin to Mariana Trough basalts suggests consistency of K/Rb ratios but large differ-

Table 5. Major- and trace-element analyses of various basalt samples.

Station and Sample	Major Elements (wt. %)								
	SiO_2	TiO_2	Al_2O_3	FeO^a	MgO	CaO	Na_2O	K_2O	P_2O_5
1398-2-1[b]	48.7	1.22	15.8	9.55	4.06	12.4	3.00	0.5	0.65
1398-1A[c]	50.0	1.67	16.1	9.54	6.01	11.6	2.99	0.16	0.15
1398-6[c]	48.8	1.88	15.8	11.2	5.84	11.4	3.10	0.16	0.24
1398-10[c]	48.2	1.62	17.4	9.61	5.33	12.1	2.89	0.16	0.18
1398-11[c]	50.4	1.60	16.8	9.59	6.23	11.5	2.87	0.19	0.15
1398-12[c]	50.0	1.72	15.8	10.35	6.09	11.4	3.06	0.20	0.16
1398-17[c]	50.2	1.65	16.4	9.38	6.10	11.7	3.07	0.12	0.15
Mariana Trough basalts[g]	49.5	1.49	16.6	8.79	6.81	11.4	3.23	0.42	0.16
Lau Basin Basalts[g]	48.0	1.0	16.0	8.6	9.3	12.8	2.2	0.12	0.07
Average MOR[e]	49.2	1.39	15.8	9.18	8.53	11.1	2.71	0.26	0.15
Average Arc[f]	49.0	0.8	18.0	9.57	5.1	9.0	3.0	0.58	0.14

	Trace Elements (ppm)						
	Ba	Rb	Sr	Zr	Y	K/Rb	K/Ba
1398-2-1[b]	35	7	210	130	43	710	140
1398-1A[c]	—	12	80	42	20	130	—
1398-6[c]	—	—	—	—	—	—	—
1398-10[c]	—	<9	136	125	41	>180	—
1398-11[c]	—	9	123	110	42	210	—
1398-12[c]	—	<9	123	110	48	>220	—
1398-17[c]	—	<9	126	110	42	>130	—
Mariana Trough Basalts[d]	38	4.5	186	—	—	933	110
Lau Basin Basalts[g]	<2	<1	91	—	—	>1200	600
Average MOR[e]	12	1	123	100	—	2600	216
Average Arc[f]	95	4	250	50	—	1450	61

[a] FeO = total Fe calculated as FeO.
[b] Personal communication from Guram Zakariadze.
[c] Dietrich et al. (1978).
[d] Hart et al. (1972).
[e] Melson and Thompson (1971).
[f] Ewart and Bryan (1972).
[g] Hawkins (1977).

ences in K/Ba ratios. Narrow ranges for the trace-element chemistries cannot be assigned to marginal-basin basalts, because marginal-basin basalts obviously range in composition from basin to basin and even within one basin (Hawkins, 1977).

The sequence of events from oldest to youngest at Site 449 can be summarized as follows:

1) Extrusion of tholeiitic basalt to form oceanic Layer 2a-type basement occurred just prior to deposition of upper Oligocene (NP 25) sediments. The 24 m.y. estimate of the age of the NP 25 Zone conforms well with the tentative identification of magnetic anomalies in the Western Parece Vela Basin in the Site 449 area (Langseth and Mrozowski, this volume). These data all suggest that the age of the western side of the Parece Vela Basin is considerably older than that suggested by Karig (1975) and that the age of initial formation of the basin coincides closely with the time of cessation of volcanism on the Palau-Kyushu Ridge.

2) Deposition of the normal pelagic sequence was marked by a distinct influx of ash between the early and middle Miocene, or the interval from about 20 m.y. to 13 m.y. ago. This influx can be interpreted as the result of a major period of arc volcanism east of the growing Parece Vela Basin.

3) The presence of abundant ferromanganese nodules and micronodules in the basin sediments may indicate that processes such as hydrothermal circulation during and after crust formation may have played an important role in marginal-basin metallogenesis.

4) The CCD became deeper by the middle Miocene. Deposition of calcareous oozes again at this time may record turbiditic influx, vertical tectonic fluctuations, or CCD depth fluctuations.

5) After the middle Miocene, the seafloor stayed below the CCD.

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| SITE 449 | HOLE | | CORE 1 | | CORED INTERVAL: 0.0-0.0 m | | | |

SITE 449 HOLE   CORE 1   CORED INTERVAL: 0.0-0.0 m

AGE	BIOSTR. ZONE			FOSSIL CHARACT.		SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
	NANNOS	FORAMS	RADS	FOSSIL ABUNDANCE	PRESERV.							
						CC	–	Mn			*	Manganese nodule

MANGANESE NODULE, black, the coalescence of three different spheroidal concretions, each ~1 cm in diameter, each deposited around separate nuclei. One of the nucleation centers, exposed by breakage, ~3 mm in diameter, consists of volcanic glass.

SMEAR SLIDE SUMMARY
	CC (M)
TEXTURE:	
Sand	5
Silt	10
Clay	85
TOTAL DETRITAL	87
COMPOSITION:	
Volcanic glass	87
Micronodules	3
Amorph Fe agg.	10

SITE 449 HOLE   CORE 2   CORED INTERVAL: 0.0-9.5 m

AGE	BIOSTR. ZONE			FOSSIL CHARACT.		SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
	NANNOS	FORAMS	RADS	FOSSIL ABUNDANCE	PRESERV.							
Quaternary			*Collosphaera tuberosa*	R N	A –	G –	1	0.5 — 1.0 —				*	10YR 3/3; 2 cm layer 5Y 6/3
		N	F	–	–		2					5YR 4/4; 10YR 7/4 .3-.5 cm mottle
							3		VOID			10YR 7/4 .5 cm mottle
							4		VOID			10YR 7/4 .5 cm piece; 10YR 3/3
		F R N	– –	– –		CC					

PELAGIC CLAY, dark brown, with some dark yellowish brown intervals in Section 2. Radiolarian-bearing DIATOMACEOUS OOZE occurs in Section 1 as a 2-cm thick pale olive layer (44-46 cm). Small (<0.5 cm) rare and irregular, very pale brown mottles and pieces are present, representing either more plastic zones, or patches impoverished in amorphous iron oxides. The sediment is soft; drilling disturbance is slight to moderate.

SMEAR SLIDE SUMMARY
	1-45 (M)	1-140 (D)	2-123 (M)	3-95 (D)	4-60 (D)	4-52 (M)
TEXTURE:						
Sand	2	0	0	0	0	0
Silt	10	10	1	5	3	6
Clay	88	90	99	95	97	94
TOTAL DETRITAL	4	91	98	94	96	94
COMPOSITION:						
Quartz	TR	–	–	–	–	–
Feldspar	–	TR	–	–	–	–
Heavy minerals	1	–	TR	–	–	–
Clay minerals	3	91	98	94	96	94
Volcanic glass	–	–	TR	TR	–	–
Micronodules	TR	TR	TR	1	TR	TR
Zeolites	1	1	TR	1	TR	TR
Amorph Fe agg.	3	5	1	3	3	5
Diatoms	80	1	–	–	–	–
Radiolaria	10	1	–	–	–	–
Fish remains	2	1	1	1	1	1

Smear Slides (Dominant): 2-140

GRAIN-SIZE:
4-52 (0.1, 53.2, 46.6)

CARBONATE BOMB:
4, 56-57 (1)

SITE 449 HOLE   CORE 3   CORED INTERVAL: 9.5-19.0 m

AGE	BIOSTR. ZONE			FOSSIL CHARACT.		SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
	NANNOS	FORAMS	RADS	FOSSIL ABUNDANCE	PRESERV.							
						1	0.5 — 1.0 —				*	10YR 3/3; 10YR 7/4 streak; 10YR 7/4 mottle 0.3 cm
						2		Mn				Mn nodule 3.8 × 2.2 cm
						3					*	10YR 7/4 mottle 0.2 cm
		N	–	–		4					*	mottle 10YR 7/4 1 cm; 10YR 4/4
		F R N	– –	– –		CC						10YR 3/3

PELAGIC CLAY, dark brown. An irregular 7-10 cm thick interval, dark yellowish brown and enriched in amorphous iron oxides, is present in Section 4. Very pale brown mottles and streaks, very rare and small (<1 cm) occur in Sections 1, 3 and 4. An irregularly shaped black manganese nodule, formed by coalescence of minor spheroidal concretions is present in Section 2. Sediment is soft, and drilling disturbance is slight to moderate.

SMEAR SLIDE SUMMARY
	1-140 (D)	3-140 (D)	4-101 (M)
TEXTURE:			
Sand	0	0	1
Silt	6	7	10
Clay	94	93	89
TOTAL DETRITAL	94	93	89
COMPOSITION:			
Clay minerals	94	93	89
Volcanic glass	TR	–	–
Micronodules	TR	1	1
Zeolites	1	1	2
Amorph Fe agg.	4	4	7
Nannofossils	–	TR	–
Radiolaria	TR	TR	TR
Fish remains	1	1	1

GRAIN-SIZE:
3-130 (0.1, 17.3, 82.6)

CARBONATE BOMB:
3, 135-136 (>1)

AGE	BIOSTR. ZONE			FOSSIL CHARACT.			SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
	NANNOS	FORAMS	RADS	FOSSIL ABUNDANCE	PRESERV.								

(NP 25 Reworked)

Fossil characters column readings (Core 4):
- F — — (Section 1)
- N F / R — / R P (Section 3)
- R N / N R — / — R / P P (CC)

10YR 3/3
0.5
1
1.0
10YR 5/4
10YR 3/3
10YR 5/4
10YR 3/3
2
streaks
10YR 6/4
streaks
10YR 6/4
yellow pieces
10YR 6/4
3
pieces
4
5
6
CC
10YR 5/4

PELAGIC CLAY, dark brown and yellowish brown. Minor alternations in color occur in Section 1 at sharp contacts. Below Section 1 the color is uniformly yellowish brown, and reflects a decrease of amorphous iron oxides. The yellowish brown sediment contains pieces (indicated by short arrows) about 2 mm-2 cm in diameter, either of the same color or light yellowish brown, which show higher zeolite and iron oxide contents. Yellow mottles and streaks are rare. Sediment is soft with some more plastic pieces; drilling disturbance is slight.

SMEAR SLIDE SUMMARY

	1-16 (D)	1-155 (M)	2-140 (D)	4-140 (D)	5-22 (M)	CC (M)
TEXTURE:						
Sand	0	0	0	0	0	0
Silt	7	6	4	2	3	10
Clay	93	94	96	98	97	90
TOTAL DETRITAL	93	94	96	98	97	71
COMPOSITION:						
Feldspar	—	TR	—	—	—	—
Clay minerals	93	94	96	98	97	70
Volcanic glass	TR	TR	TR	TR	TR	1
Micronodules	1	1	1	TR	TR	1
Zeolites	TR	2	1	TR	TR	1
Amorph. fe agg.	5	4	2	2	3	7
Fish remains	1	TR	—	TR	TR	TR

GRAIN-SIZE:
3-51 (0.4, 21.8, 77.8)

CARBON/CARBONATE:
3-55 (0.1, 0.1, 0.1)

CARBONATE BOMB:
3, 56-57 (1-2)
3, 55-56 (1-2)

AGE	BIOSTR. ZONE			FOSSIL CHARACT.			SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
	NANNOS	FORAMS	RADS	FOSSIL ABUNDANCE	PRESERV.								

Middle Miocene

Fossil characters column readings (Core 5):
- R N / N F — / — — (Section 1)
- N F — / — (Section 2)
- F N / R R / — / — P (CC)

3x6 cm lithified fragment with 1 mm Mn blebs
10YR 7/6
slightly mottled
0.5
1
moderately mottled
1.0
very slightly mottled
moderately mottled
very slightly mottled
VOID
intense mottling
slightly mottled
2
lithified fragments
very slight mottling
3
10YR 7/4
mottle 2 cm
4
10YR 7/4
mottle
moderately mottled
10% mottled
10YR 7/4
10% mottled
10YR 7/4
intense
10YR 2/1
mottling
5
10YR 7/4
mottle .5 cm
6
10YR 7/4 mottle
7
CC
10YR 4/3

PELAGIC CLAY, yellowish brown in Sections 1 and 2, dark brown in remainder. The yellowish brown sediment contains numerous subrounded lithified fragments (arrows) dark grayish brown to light yellowish brown and black. Their lithology is identical to the clay, and their width may exceed the width of the core liner, the thickness of the larger ones being 3 cm. They are covered partly or wholly by Mn films, and contain numerous Mn blebs and dendroids up to 3 mm in diameter. Several yellow and rare black mottles are present, mainly in Sections 2 and 5. Sediment soft, with some lithified fragments. Drilling deformation is slight in the upper sections to soupy in the lower sections.

SMEAR SLIDE SUMMARY

	1-2 (M)	1-77 (M)	1-140 (D)	3-80 (M)	3-140 (D)	6-140 (D)
TEXTURE:						
Sand	0	0	0	0	0	0
Silt	8	3	3	4	4	9
Clay	92	97	97	96	96	91
TOTAL DETRITAL	12	97	97	96	96	92
COMPOSITION:						
Quartz	TR	—	TR	TR	TR	TR
Heavy minerals	1	—	—	TR	—	TR
Clay minerals	9	97	97	96	96	91
Volcanic glass	2	TR	TR	TR	TR	1
Micronodules	3	TR	TR	1	TR	1
Zeolites	1	1	TR	1	1	2
Amorph Fe agg.	3	3	3	2	3	5
Nannofossils	—	—	—	—	TR	—
Fish remains	TR	TR	TR	TR	TR	TR

GRAIN-SIZE:
3-44 (0.3, 45.5, 54.2)

CARBON/CARBONATE:
3-46 (0.1, 0.1, 0.1)

CARBONATE BOMB:
3, 46-47 (1)

SITE 449 HOLE   CORE 6   CORED INTERVAL: 38.0-47.5 m

	BIOSTR. ZONE			FOSSIL CHARACT.					GRAPHIC LITHOLOGY				
AGE	NANNOS	FORAMS	RADS	FOSSIL ABUNDANCE	PRESERV.	SECTION	METERS			DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	

Column annotations (Graphic Lithology / notes):
- 10YR 3/4
- 10YR 7/4 mottle .5 cm
- 10YR 7/4 mottle 2 cm
- 10YR 7/4 mottle, 3x2 cm
- pumice fragments 2 1 cm
- slight mottling 10YR 7/4
- moderately mottled 10YR 7/4
- 10YR 8/3 ash layer
- very slightly mottled 7/4, 8/3 pumice
- pumice fragments
- pumice fragments
- pumice fragments
- 2 cm mottled 10YR 7/4
- 2 1 cm pumice fragments
- pumice
- pumice
- pumice
- 10YR 4/4

Section markers: N, F R P 3, N, F R P 4, N A P, N C M 5 / F F I M, N R N / CC (Pu, Pu)

AGE: Middle Miocene — Dorcadospyris alata — NN 6

LITHOLOGIC DESCRIPTION

PELAGIC CLAY and RADIOLARIAN OOZE. In Sections 1 and 2 the sediment is PELAGIC CLAY, dark yellowish brown, with small plastic pieces of the same color and lithology, rare yellow mottles, and rare dark gray pumice fragments up to 1 cm in diameter. Near the bottom of Section 2 is a 10 cm thick layer of yellow, silt-sized ash. Below this ash layer the sediment is a dark yellowish brown RADIOLARIAN OOZE rich in rounded, dark gray pumice fragments up to 2 cm in diameter, and in patches, streaks and mottles of yellow volcanic glass. The sediment is soft with some plastic pieces; drilling disturbance is slight to moderate.

SMEAR SLIDE SUMMARY

	1-140 (D)	2-140 (M)	3-140 (D)	5-41 (D)
TEXTURE:				
Sand	0	0	0	0
Silt	8	100	75	85
Clay	92	0	25	15
TOTAL DETRITAL	92	100	26	16
COMPOSITION:				
Quartz	TR	–	–	–
Feldspar	–	TR	–	–
Mica	–	TR	–	–
Heavy minerals	TR	TR	TR	–
Clay minerals	92	100	25	15
Volcanic glass	TR	–	1	1
Micronodules	TR	–	–	TR
Zeolites	1	–	TR	TR
Amorph Fe agg.	4	–	4	4
Nannofossils	–	–	–	5
Radiolaria	3	TR	70	75
Sponge spicules	TR	–	TR	TR
Silicoflagellates	–	–	TR	–
Fish remains	TR	–	–	–

GRAIN-SIZE:
2-43 (0.9, 39.5, 59.6)

CARBON/CARBONATE:
2-47 (0.1, 0.2, 0.1)

CARBONATE BOMB:
2, 46-47 (>1)

SITE 449 HOLE   CORE 7   CORED INTERVAL: 47.5-57.0 m

	BIOSTR. ZONE			FOSSIL CHARACT.					GRAPHIC LITHOLOGY				
AGE	NANNOS	FORAMS	RADS	FOSSIL ABUNDANCE	PRESERV.	SECTION	METERS			DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	

Column annotations:
- 10YR 3/4
- 7/4
- 7/4
- 7/4
- VOID
- 7/4
- transition 10YR 3/2
- 10YR 7/6 nannofossil ooze
- drilling admixture ooze, clay
- 10YR 3/2 clay
- intensely mottled nannofossil ooze
- 10YR 7/6 pumice 2x3.5 cm
- 3/2 pelagic clay
- 10YR 7/6 nannofossil ooze, 5/1 mottles
- irregularly mottled 3/2, 7/6; at 55 cm; cluster of pumice fragments
- 10YR 3/2
- 10YR 6/4
- 7/4 mottle
- 10YR 3/2, 4/2, 4/4, 5/4

Section markers: N F A R M P 3, N A P 4, F R N / R C A / P M P / CC (Pu)

AGE: Middle Miocene — Calocycletta costata — NN 5

LITHOLOGIC DESCRIPTION

Interbedded dark brown RADIOLARIAN-RICH PELAGIC CLAY and yellow to yellowish brown RADIOLARIAN-BEARING NANNOFOSSIL OOZE. Contacts between these alternating lithologies are sharp. The pelagic clay occurs as:
a) the uppermost 350 cm interval, where it contains small fragments (up to 1x3.5 cm) of nannofossil ooze;
b) several discrete homogeneous intervals 5 to 60 cm thick; and
c) in mottles and drilling admixtures.

The nannofossil ooze occurs as:
a) several discrete homogeneous intervals 30 to 60 cm thick;
b) dominant lithology in a 100-cm interval with diffuse mottling of pelagic clay and containing fresh pumice fragments up to 2x3.5 cm in size;
c) in drilling admixtures; and
d) as fragments and pieces in the uppermost 350 cm of the core (arrows).
The sediment is uniformly soft, and drilling disturbance is intense to soupy in Sections 1 through 4, moderate in Section 5.

SMEAR SLIDE SUMMARY

	1-120 (D)	2-123 (M)	4-98 (D)	4-143 (D)	5-113 (D)	5-143 (D)
TEXTURE:						
Sand	0	0	0	0	0	0
Silt	34	95	95	25	18	90
Clay	66	5	5	75	82	10
TOTAL DETRITAL	67	TR	TR	76	82	5
COMPOSITION:						
Heavy minerals	TR	TR	–	TR	TR	TR
Clay minerals	66	–	TR	75	82	5
Volcanic glass	TR	–	1	TR	TR	TR
Micronodules	–	–	–	TR	1	TR
Zeolites	TR	TR	TR	TR	1	TR
Amorph Fe agg.	3	1	1	4	5	1
Carbonate unspec.	–	5	5	–	–	5
Nannofossils	–	79	84	TR	–	80
Radiolaria	30	15	10	20	10	9
Sponge spicules	–	TR	1	–	–	TR
Silicoflagellates	–	–	–	–	TR	TR
Fish remains	TR	–	–	TR	1	–

Smear Slides (Minor): 3-100

GRAIN-SIZE:
4-100 (3.5, 50.1, 46.5)
5-79 (1.4, 48.0, 50.6)

CARBON/CARBONATE:
4-104 (0.0, 43.6, 5.3)
5-83 (0.0, 3.4, 0.4)

CARBONATE BOMB:
4, 105-106 (38)
5, 84-85 (2)

SITE 449 HOLE CORE 8 CORED INTERVAL: 57.0-66.5 m

AGE	BIOSTR. ZONE			FOSSIL CHARACT.			SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
	NANNOS	FORAMS	RADS	FOSSIL ABUNDANCE	PRESERV.								

Column notations within section (left-side annotations): 10YR 3/4, Pu, Pu, 5Y 4/2, Pu, Pu, lithified pieces, Pu, Pu, 10YR 7/4 mottle, Mn, Mn nodule .3 cm, VOID, Pu, lithified 2/1 mottle, Pu, 4/2 lithified pieces, Pu, lithified silt-sized fragments, Pu, 10YR 4/4 / 10YR 4/4, slight mottling 10YR 7/4, 5Y 5/2 lithified, Pu / Pu / Pu, moderate mottling 10YR 6/6, VOID, lithified layer, Pu, 8/3 mottle, intense 3/4, 7/4, mottling, moderate 8/3 mottle, Pu / Pu, lithified pieces 7/2 mottle, 7/2 mottle, slight to moderate mottling 10YR 7/6, Very slightly mottled 10YR 7/2, VOID, 10YR 4/4

Sections: 1 (0.5, 1.0), 2, 3 (N F R P), 4, 5, 6 (N – –), 7, CC (F R N – –)

PELAGIC CLAY, dark yellowish brown, radiolaria-rich and nannofossil-bearing in Section 1, barren in the other sections. Olive gray pumice fragments rich in Mn blebs and dendroids are present throughout the core. The pumice fragments are mostly angular, with maximum dimensions about 3x6 cm. In Sections 3 to 5 several layers, 5 to 10 cm thick, of olive gray pumice fragments also occur. Two Mn nodules are in Section 2. Mottling is slight and mainly concentrated near pumice fragments, with colors (very pale brown, brownish yellow, and light gray) due to enrichment in zeolites. The sediment is soft except for the intervals of more indurated volcanic glass. Drilling disturbance is intense in Sections 1 and 2, moderate elsewhere.

SMEAR SLIDE SUMMARY

	1-60 (D)	3-128 (M)	3-140 (D)	5-90 (D)	6-9 (M)	6-94 (M)
TEXTURE:						
Sand	0	0	0	0	0	0
Silt	33	85	9	6	95	94
Clay	67	15	91	93	5	6
TOTAL DETRITAL	1	92	93	95	99	96
COMPOSITION:						
Heavy minerals	TR	TR	TR	TR	2	TR
Clay minerals	67	15	91	93	5	6
Volcanic glass	1	77	2	2	92	90
Micronodules	1	2	1	2	–	2
Zeolites	1	2	1	2	–	1
Amorph Fe agg.	4	4	3	1	1	1
Nannofossils	10	TR	TR	TR	TR	TR
Radiolaria	15	TR	2	–	–	–
Sponge spicules	1	–	–	–	–	–
Fish remains	TR	–	TR	–	–	–

GRAIN-SIZE:
3-70 (3.5, 67.5, 29.0)

CARBON/CARBONATE:
3-72 (0.1, 0.1, 0.1)

CARBONATE BOMB:
3, 73-74 (1)

SITE 449 HOLE CORE 9 CORED INTERVAL: 66.5-76.0 m

AGE	BIOSTR. ZONE			FOSSIL CHARACT.			SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
	NANNOS	FORAMS	RADS	FOSSIL ABUNDANCE	PRESERV.								

Column annotations: 10YR 2/1 and 7/6, 2 cm layer of ash 2.5Y 7/6, 10YR 4/4, 2.5Y 7/2 ashy layer, 10YR 7/4 mottle, 2.5Y 7/2 layer, 10YR 4/4, 10YR 4/4

Sections: 1 (N F R P), 2, CC (F R N)

PELAGIC CLAY, dark yellowish brown, with light gray, more lithified intervals enriched in volcanic glass 15 cm thick in Section 1, 2.5 cm thick in Section 2, and as lumps in the Core-Catcher sample. Rare olive-colored pumice fragments up to 2x4 cm occur in Section 2, and one 2 cm thick layer of yellow volcanic glass occurs in Section 1. Yellow and very pale brown mottles are rare. The sediment is uniformly soft except for the layers of light gray clay. Drilling disturbance is slight to moderate.

SMEAR SLIDE SUMMARY

	1-100 (D)	2-5 (M)	2-100 (D)
TEXTURE:			
Sand	0	0	0
Silt	8	14	17
Clay	92	86	83
TOTAL DETRITAL	94	97	99
COMPOSITION:			
Heavy minerals	TR	1	1
Clay minerals	92	86	83
Volcanic glass	2	10	15
Micronodules	1	1	TR
Zeolites	3	2	1
Amorph Fe agg.	2	–	–
Fish remains	TR	–	–

GRAIN-SIZE:
1-65 (0.3, 62.1, 37.6)

CARBON/CARBONATE:
1-63 (0.0, 0.2, 0.1)

CARBONATE BOMB:
1, 62-63 (1-2)

SITE 449 HOLE   CORE 10   CORED INTERVAL: 76.0-85.5 m

AGE	BIOSTR. ZONE			FOSSIL CHARACT.			SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
	NANNOS	FORAMS	RADS	FOSSIL ABUNDANCE	PRESERV.								

Column left markings:
- N F − − (Section 1)
- N − − (Section 2)
- N − − (Section 3)
- F − − −
- N − −
- N − − (Section 4)
- N − − (Section 5)
- N F P / N F − − ?NN 3 (Section 6)

Graphic annotations (Core 10):
- 10YR 3/4
- .4 cm ashy bleb
- .4 cm ashy bleb
- ashy pieces / black mottles
- ashy fragment
- 5 cm patch mixed 3/4, 4/4
- slightly mottled 10YR 4/4
- ashy fragment 2 cm layer 10YR 7/6
- slight 7/6 mottling 10YR 5/4 ashy fragments
- 10YR 5/4 ashy fragments, 3 cm
- arrows are 2 cm 7/6 mottles
- 10YR 3/4, slightly mottled 10YR 4/4
- ashy fragments
- ashy fragments
- ashy fragments
- 10YR 3/4

LITHOLOGIC DESCRIPTION (Core 10):

PELAGIC CLAY, dark yellowish brown; slightly darker from Section 3 to Section 5. Gray to pale yellow clays rich in volcanic glass constitute more lithified angular fragments up to 3 cm in diameter and discrete intervals 3 to 13 cm thick; these are enriched in Mn blebs and zeolites. Yellow mottling is very slight and is usually associated with the more lithified fragments. The sediment is uniformly soft except for the fragments and layers of gray clay. Drilling disturbance is intense in parts of Sections 2, 5 and 6, and is slight to moderate elsewhere.

SMEAR SLIDE SUMMARY

	1-109 (M)	1-140 (D)	2-18 (M)	3-140 (D)	4-76 (M)	5-140 (D)
TEXTURE:						
Sand	0	0	0	0	0	0
Silt	20	15	16	16	38	27
Clay	80	85	84	84	62	73
TOTAL DETRITAL	100	95	94	94	92	80
COMPOSITION:						
Heavy minerals	TR	TR	TR	TR	TR	−
Clay minerals	80	85	84	84	62	73
Volcanic glass	20	10	10	10	30	7
Micronodules	−	2	2	2	2	2
Zeolites	−	2	3	3	4	2
Amorph Fe agg.	−	1	1	1	2	1
Nannofossils	−	−	−	−	−	15

GRAIN-SIZE:
1-75 (1.2, 50.4, 48.4)

CARBON/CARBONATE:
1-80 (0.1, 7.7, 1.0)

CARBONATE BOMB:
1, 79-80 (1)

SITE 449 HOLE   CORE 11   CORED INTERVAL: 85.5-95.0 m

AGE	BIOSTR. ZONE			FOSSIL CHARACT.			SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
	NANNOS	FORAMS	RADS	FOSSIL ABUNDANCE	PRESERV.								

Column left markings (Core 11):
- N F / N F   F R   P P (Section 1)
- N F   F R   P P (Section 2)
- ?NN 3
- N F   F −   P (Section 3)
- N F   C R   P P (Section 4)
- N C   P (Section 5)
- Early Miocene
- NN 2
- N F   C R   P P (Section 6)
- R N   R N   C −   A   PM P (CC)

Graphic annotations (Core 11):
- Mn
- Mn
- 7.5YR 3/4
- 1 cm mottle 7.5YR 4/4
- lithified claystone 3/4, with 3 mm white mottles
- disturbed admixture 7.5YR 3/4 and minor 7.5YR 3/4
- VOID
- VOID
- 2x3 cm 3/4 mottle
- 7.5YR 3/2
- 7.5YR 2/2
- streaked 3/2 mottle
- 3/2 flowed layer 7/4, 4/4 admixture 3/2, 2/2 admixture 7.5YR 2/2
- 7.5YR 3/2 with minor 4/4, 2/2 streaks 7.5YR 7/4 streak
- 7.5YR 3/2

LITHOLOGIC DESCRIPTION (Core 11):

Drilling gouge, pieces 1.5x2x4 of lithified 7.5YR 3/4 with elongate 3x8 mm burrows, .5 mm Mn blebs

Gouge 7.5YR 3/4

1.7x1.8x3 cm Mn 2x2x2 Mn; also a 1.2 cm lithified claystone layer

Disturbed admixture of 7.5YR 4/4 and 3/4

PELAGIC CLAY, dark brown. In Section 1 two Mn nodules, and in Sections 1 and 3 fragments of white indurated clay rich in volcanic glass, up to 7x9.5 cm thick are present. In Sections 5 and 6 disturbed layers and complex mottling produce complete admixtures of dark brown, very dark brown and pink colors. The latter correspond to local enrichments in nannofossils and zeolites. The sediment is uniformly soft except for the few indurated fragments. Drilling disturbance is intense in all sections.

SMEAR SLIDE SUMMARY

	3-66 (D)	3-79 (D)	3-79 (M)	5-131 (M)
TEXTURE:				
Sand	0	0	0	0
Silt	15	75	85	21
Clay	85	23	15	79
TOTAL DETRITAL	87	98	93	89
COMPOSITION:				
Heavy minerals	TR	TR	2	TR
Clay minerals	85	23	15	79
Volcanic glass	2	75	76	10
Micronodules	5	1	5	1
Zeolites	4	TR	−	3
Amorph Fe agg.	1	1	−	−
Nannofossils	3	−	−	7
Radiolaria	−	−	1	−
Silicoflagellates	−	−	1	−

Smear Slides (Dominant): 5-60

GRAIN-SIZE:
1-50 (0.3, 57.6, 42.0)

PHYSICAL PROPERTIES:

	Section 3 79-81 cm	Section 5 118-120 cm
$\bar{V}_p$ (km/s)		
parallel to beds	2.15	1.56
vertical to beds	2.13	1.57
Wet bulk density	1.67	1.23
Porosity (%)	58.4	84.9
Grain density	2.62	2.53
Acoustic impedance	3.50	1.93

CARBONATE BOMB:
1, 54-55 (4)

AGE	BIOSTR. ZONE			FOSSIL CHARACT.			SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
	NANNOS	FORAMS	RADS	FOSSIL ABUNDANCE	PRESERV.								

Detailed column readings (Core 12):

Age: Early Miocene
Nannos zone: NN 2 / NN 1
Rads: Stichocorys wolffii

Fossil character (top to bottom): N A M; N A M; N A M / N F A F M P; N A M; N A M; F R N / F R A / F R N, F P M / PM, CC

Lithologic description:

Drilling breccia and gouge; fragments of lithified pelagic claystone .8 to 3 cm thick. Gouge matrix 7.5YR 2/2

arrows indicate lithified fragments

PELAGIC CLAY, very dark brown in Section 1 and upper Section 2, containing several fragments of white indurated clays up to 0.8x3 cm in size, and 2 manganese nodules. From the lower portion of Section 2 down-core, brown NANNOFOSSIL OOZE consisting mainly of complex admixtures of brown, dark brown and dark yellowish brown colors, with some more lithified fragments in Section 3. The sediment otherwise is soft. Drilling disturbance is intense, the core consisting almost entirely of drilling gouge and breccia.

homogeneous 7.5YR 2/2 gouge

3 cm Mn nodule
3 cm Mn nodule

10YR 7/3 with minor 3/2; flow-in

10YR 4/4

10YR 5/3 layer

lithified

gouge disturbed admixture 4/4, 5/3

10YR 4/3

10YR 4/3 nannofossil ooze gouge

SMEAR SLIDE SUMMARY

	2-71 (D)
TEXTURE:	
Sand	0
Silt	90
Clay	10
TOTAL DETRITAL	5
COMPOSITION:	
Clay minerals	5
Micronodules	1
Zeolites	1
Carbonate unspec.	5
Nannofossils	88
Radiolaria	TR

GRAIN-SIZE:
2-104 (0.1, 47.6, 52.3)

CARBON/CARBONATE: 2-102 (0.0, 64.6, 7.8)

CARBONATE BOMB: 2, 101-102 (56)

PHYSICAL PROPERTIES: Section 3 67-69 cm

$\bar{V}_p$ (km/s)	
parallel to beds	1.54
vertical to beds	1.54
Wet bulk density	1.37
Porosity (%)	76.8
Grain density	2.61
Acoustic impedance	2.11

VOID

AGE	BIOSTR. ZONE			FOSSIL CHARACT.			SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
	NANNOS	FORAMS	RADS	FOSSIL ABUNDANCE	PRESERV.								

Detailed column readings (Core 13):

Age: Early Miocene / Late Oligocene
Nannos zone: NN 1 / NP 25
Forams zone: P.19-P.21

Fossil character (top to bottom): N F A F M P; N F A F M P; N F A F M P; N F A F M P; N F A F M P; N F A F M P; F R N / FC-A / PM-M, CC

Lithologic description:

Disturbed admixture of 10YR 3/4 (predominant) and 5/4

predominantly 5/4, less 3/4

predominantly 3/4 less 5/4

predominantly 5/4, less 3/4

predominantly 3/4, less 5/4

predominantly 5/4, less 3/4

disturbed admixture 50% 5/4, 50% 3/4

10YR 5/4, minor 3/4

lithified 7.5YR 4/4 3 cm piece with white mottles and Mn flecks

1 cm disturbed 10YR 4/4 layer
10YR 3/3
10YR 4/3
10YR 5/3
1 cm 3/2; rest 5/3
5/3, 3/4

4/2, slight 5/3 mottle at 134-6, 5/4

disturbed admixture 4/3, minor 5/3

10YR 5/2, slight 5/4

mottling 10YR 4.5/2
10YR 5/2, slight 5/4 mottling

10YR 4.5/2

NANNOFOSSIL OOZE, brown. Complex drilling admixtures of dark yellowish brown and yellowish brown colors in Sections 1 to 4, with few lithified fragments containing small white mottles and Mn flecks. Disturbed layering in Sections 5 and 6 separates alternations of dark brown intervals rich in clay and micronodules from yellowish brown intervals rich in clay. Brown and yellowish brown mottles are common in these lower sections. The sediment is uniformly soft except for the lithified fragments. Drilling disturbance is very intense in all sections.

SMEAR SLIDE SUMMARY

	5-92 (M)	5-131 (D)	5-135 (M)	6-135 (D)
TEXTURE:				
Sand	0	0	0	0
Silt	80	90	90	90
Clay	20	10	10	10
TOTAL DETRITAL	22	5	6	5
COMPOSITION:				
Heavy minerals	TR	—	—	—
Clay minerals	20	5	5	5
Volcanic glass	2	—	1	TR
Micronodules	5	3	1	3
Zeolites	1	1	—	1
Amorph Fe agg.	1	—	1	—
Carbonate unspec.	—	5	5	5
Nannofossils	70	85	87	85
Radiolaria	TR	1	TR	1
Fish remains	—	—	TR	TR

GRAIN-SIZE:
3-46 (0.2, 55.6, 44.2)

PHYSICAL PROPERTIES: Section 5 132-135 cm

$\bar{V}_p$ (km/s)	
parallel to beds	1.24
vertical to beds	1.56
Wet bulk density	1.40
Porosity (%)	76.1
Grain density	2.68
Acoustic impedance	2.17

CARBONATE BOMB: 3, 49-50 (47)

VOID

*Note: Recovery is 138% of the interval cored. The upper portion of this core probably consists of material displaced from higher in the section.

**VISUAL CORE DESCRIPTION
FOR IGNEOUS ROCKS**

LEG		SITE		H O L E	CORE		SECT.
5	9	4	4	9	1	4	1

Depth: 111.0-112.5 m

Visual Description

Plagioclase-olivine-spinel-phyric basalt, pillow lava. Plagioclase phenocrysts 10% of rock, elongate laths 1.5-2 mm. Groundmass variolitic, almost completely replaced with yellow brown smectite. Scattered irregular vesicles, 3-5%, 0.5-1 mm; empty.

Shipboard Data

Physical Properties:	61-67 cm
V̄p (km/s)	
parallel to beds	4.21
vertical to beds	—
Wet bulk density	—
Porosity (%)	—
Acoustic impedance	—
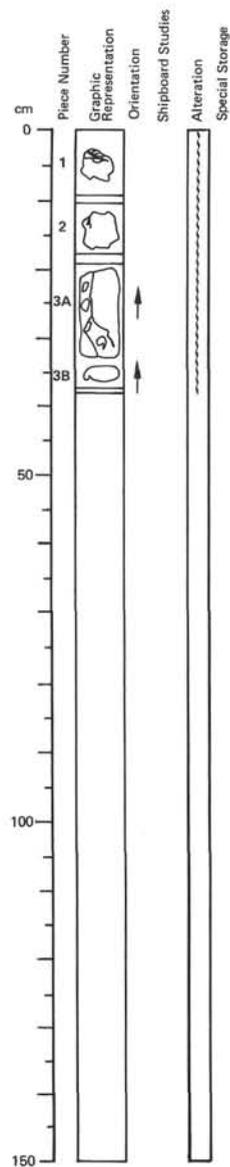
**VISUAL CORE DESCRIPTION
FOR IGNEOUS ROCKS**

LEG		SITE		H O L E	CORE		SECT.
5	9	4	4	9	1	4	2

Depth: 112.5 to 114.0 m

Visual Description

Plagioclase-olivine-spinel-phyric basalt as in Section 14-1. Groundmass 75-85% crystallized, hyalopilitic to intersertal and subophitic. Fractures filled with brecciated basaltic glass, cemented with carbonate.

Shipboard Data

Physical Properties:	19-34 cm
V̄p (km/s)	
parallel to beds	3.95
vertical to beds	—
Wet bulk density	—
Porosity (%)	—
Acoustic impedance	—

Piece Number | Graphic Representation | Orientation | Shipboard Studies | Alteration | Special Storage
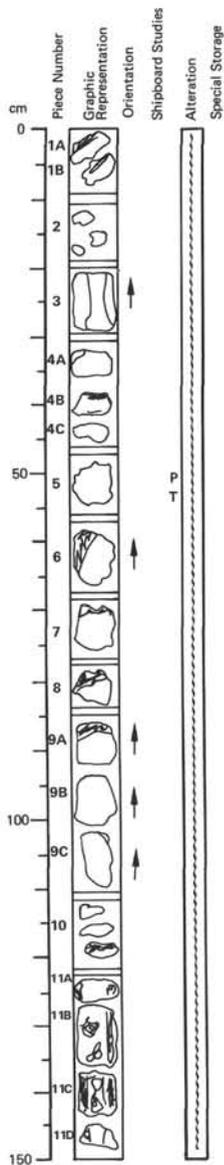
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	H O L E	CORE	SECT.
5 9	4 4 9		1 5	1

Depth: 114.0 to 115.5 m

Visual Description

Plagioclase-olivine-spinel-phyric basalt as in Sections 14-1, 14-2. Glassy rims, 0.5-1 cm thick, replaced with smectite, commonly brecciated and cemented with carbonate.

Thin Section Description

Location: 52-55 cm, pillow interior

Texture: hyalopilitic

Phenocrysts: 10%; mostly plagioclase, An_{70-75}, 0.5-2 mm, euhedral, oscillatory zoning; olivine trace

Groundmass: >85%; plagioclase 30%, 0.2-0.4 mm, acicular, flow-aligned microlites; clinopyroxene 10%, 0.05-0.1 mm, granular, anhedral; olivine trace; glass 55%, devitrified

Vesicles: 1-2%, 0.2-0.4 mm, empty

Alteration: glass partially replaced by clays

Shipboard Data

Physical Properties:	52-54 cm
$\bar{V}p$ (km/s)	
parallel to beds	4.17
vertical to beds	–
Wet bulk density	2.62
Porosity (%)	–
Acoustic impedance	10.93
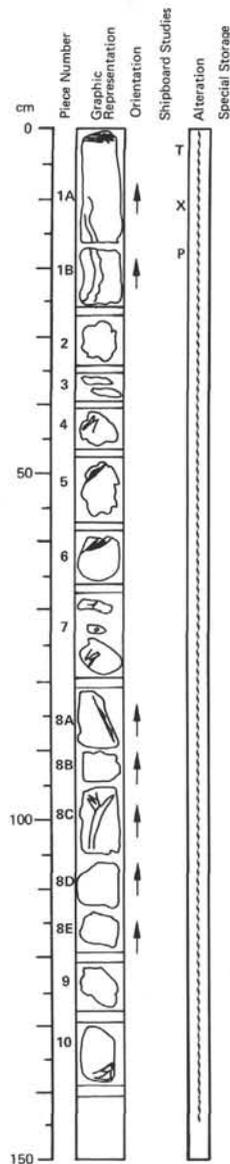
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	H O L E	CORE	SECT.
5 9	4 4 9		1 5	2

Depth: 115.5 to 117.0 m

Visual Description

Plagioclase-olivine-spinel-phyric basalt as in Section 15-1.

Thin Section Description

Location: 0-4 cm, glassy margin

Texture: partially devitrified microphyric glass

Phenocrysts: 10%; plagioclase 5%, $An_{45?}$, 0.4-1.2 mm, euhedral, oscillatory zoned; olivine 2-3%, 0.4-0.8 mm, euhedral, fresh, containing numerous spinels; spinel <1%, 0.01-0.02 mm, octahedral microphenocrysts, chrome rich, in olivine

Groundmass: >85%; plagioclase 20%, acicular microlites; glass 80%, devitrified

Vesicles: irregular 1%, 0.2-0.4 mm, filled with calcite

Shipboard Data

Bulk Analysis:	11 cm		Physical Properties:	16-18 cm
SiO_2	49.4		$\bar{V}p$ (km/s)	
TiO_2	0.99		parallel to beds	4.43
Al_2O_3	14.3		vertical to beds	4.18
Fe_2O_3	1.25		Wet bulk density	2.61
FeO	8.24		Porosity (%)	–
MnO	0.14		Acoustic impedance	11.56
MgO	9.14			
CaO	12.25			
Na_2O	2.76			
K_2O	0.46			
P_2O_5	0.08			
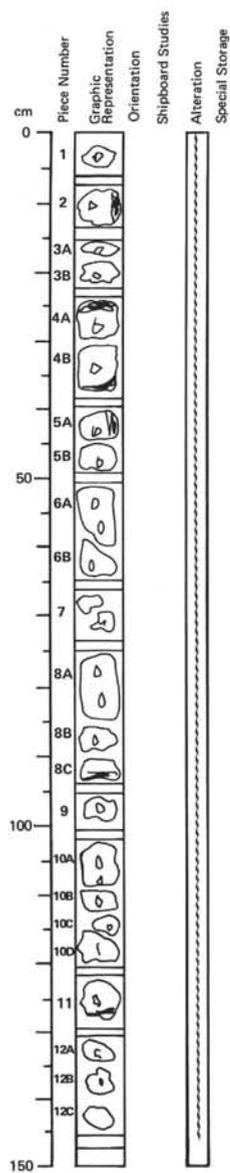
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	H O L E	CORE	SECT.
5 9	4 4 9		1 6	1

Depth: 123.5 to 125.0 m

Visual Description

Plagioclase-olivine-spinel-aphyric basalt as in Sections 15-1, 15-2. Four pillows, inner parts of which are fine-grained and extremely altered. Plagioclase phenocrysts, ~5% of rock, 0.3-0.5 mm, partially altered to smectites and iron oxides. Groundmass variolitic to intersertal, extremely altered. Glass rims ~0.5 cm thick, with interpillow brecciation.
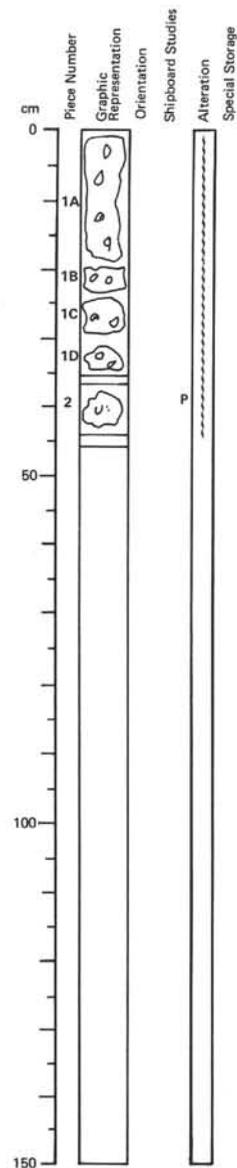
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	H O L E	CORE	SECT.
5 9	4 4 9		1 6	2

Depth: 125.0 to 126.5 m

Visual Description

Plagioclase-olivine-spinel-phyric basalt as in Section 16-1.

Shipboard Data

Physical Properties:	38-40 cm
$\overline{V}p$ (km/s)	
parallel to beds	3.97
vertical to beds	–
Wet bulk density	2.53
Porosity (%)	–
Acoustic impedance	10.03
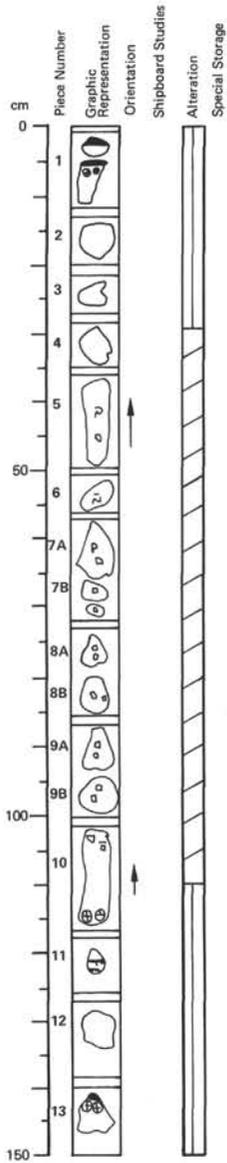
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	H O L E	CORE	SECT.
5 9	4 4 9		1 7	1

Depth: 133.0 to 134.5 m
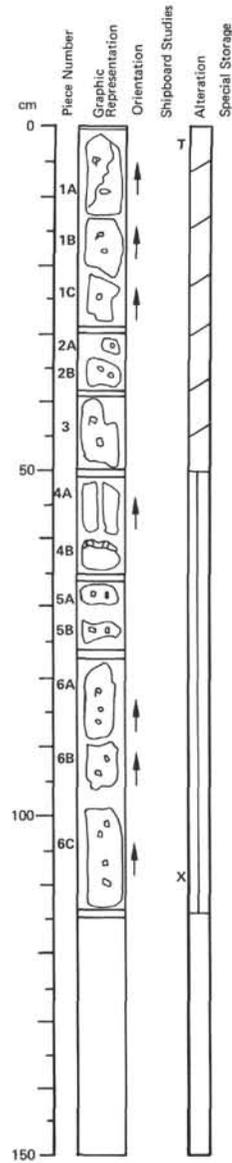
Visual Description

Plagioclase-olivine-spinel-phyric basalt as in previous sections; fine-grained at top and bottom of core, coarse-grained in central part of core.

VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	H O L E	CORE	SECT.
5 9	4 4 9		1 7	2

Depth: 134.5 to 135.5 m

Visual Description

Plagioclase-clinopyroxene-phyric basalts flow.

Thin Section Description

Location: 4-7 cm, flow interior

Texture: intersertal to hyalopilitic

Phenocrysts: <5%; plagioclase, 0.5-4 mm, anhedral, strongly zoned

Groundmass: >90%; plagioclase 45%, 0.5-2 mm, lath-like to acicular; clinopyroxene 35%, subophitic plates; magnetite/ilmenite 5%, skeletal in glassy mesostasis; glass 10%, locally concentrated, partly fresh

Vesicles: <5%, 0.5-4 mm, empty or clay-lined

Alteration: <10%, glass replaced by clay

Shipboard Data

Bulk Analysis:	109 cm
SiO_2	49.0
TiO_2	1.02
Al_2O_3	14.9
Fe_2O_3	1.31
FeO	8.66
MnO	0.15
MgO	7.74
CaO	11.43
Na_2O	2.95
K_2O	0.39
P_2O_5	0.11

VISUAL CORE DESCRIPTION
FOR IGNEOUS ROCKS

LEG	SITE	H O L E	CORE	SECT.
5 9	4 4 9		1 8	1

Depth: 142.5 to 143.5 m

Visual Description
Plagioclase-clinopyroxene-phyric-basalt as in Section 17-2.

Thin Section Description
Location: 20-23 cm, flow interior
Texture: pilotaxitic to intersertal
Phenocrysts: >5%; plagioclase <3%, 0.3-0.5 mm, lath-like to equant
Groundmass: >75%; plagioclase 45%, An_{40-50}, 0.2-4 mm, thin laths; clinopyroxene 40%,
  0.2-1 mm, sheaf-like, rare laths; olivine trace, 0.1-0.4 mm; magnetite/ilmenite 2%,
  0.2-0.5 mm, skeletal acicular; glass 5-10%
Vesicles: 20%, irregular, 0.2-1 mm, empty
Alteration: <10% clay replacing glass

Hole 449
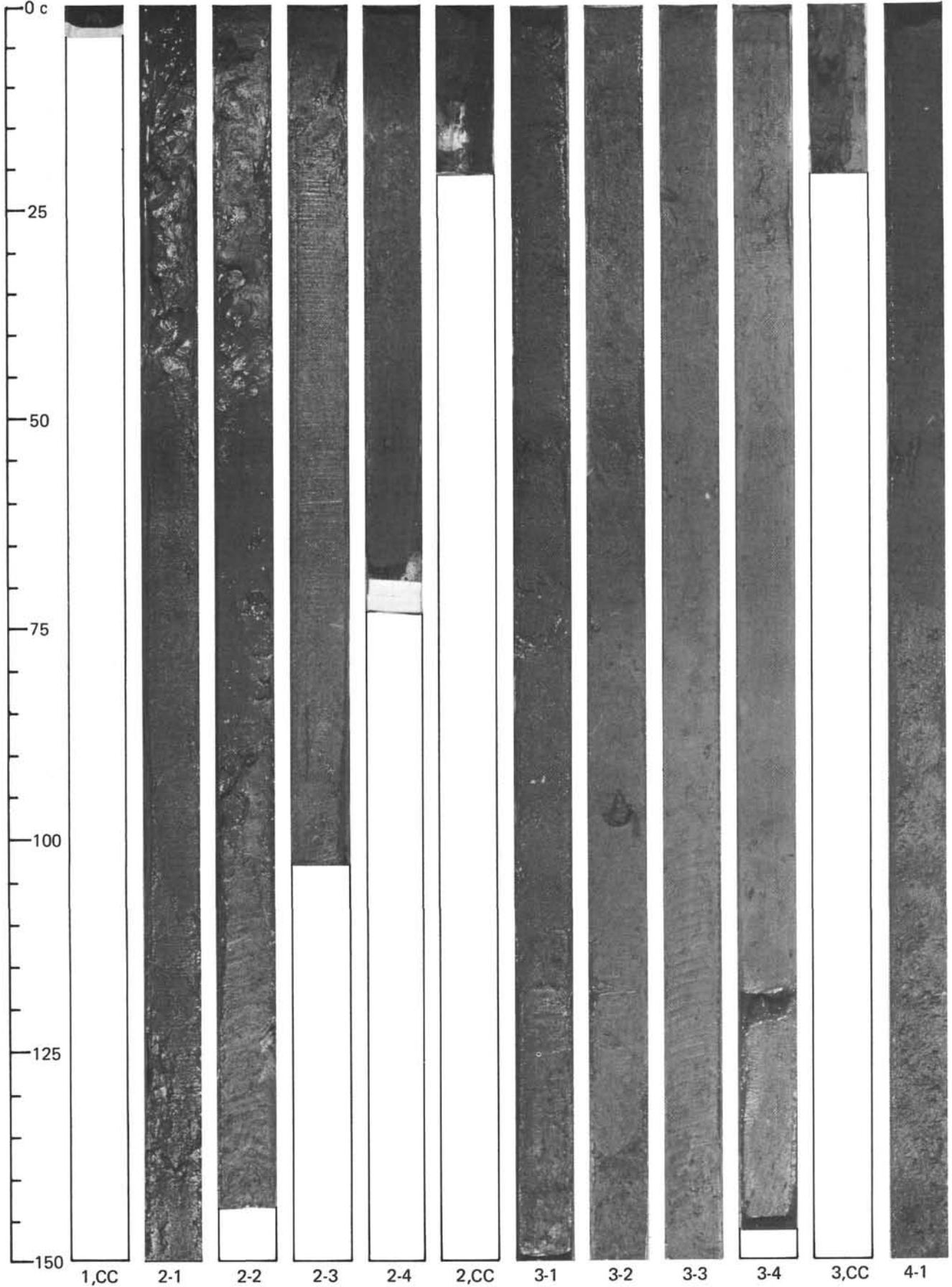
Hole 449
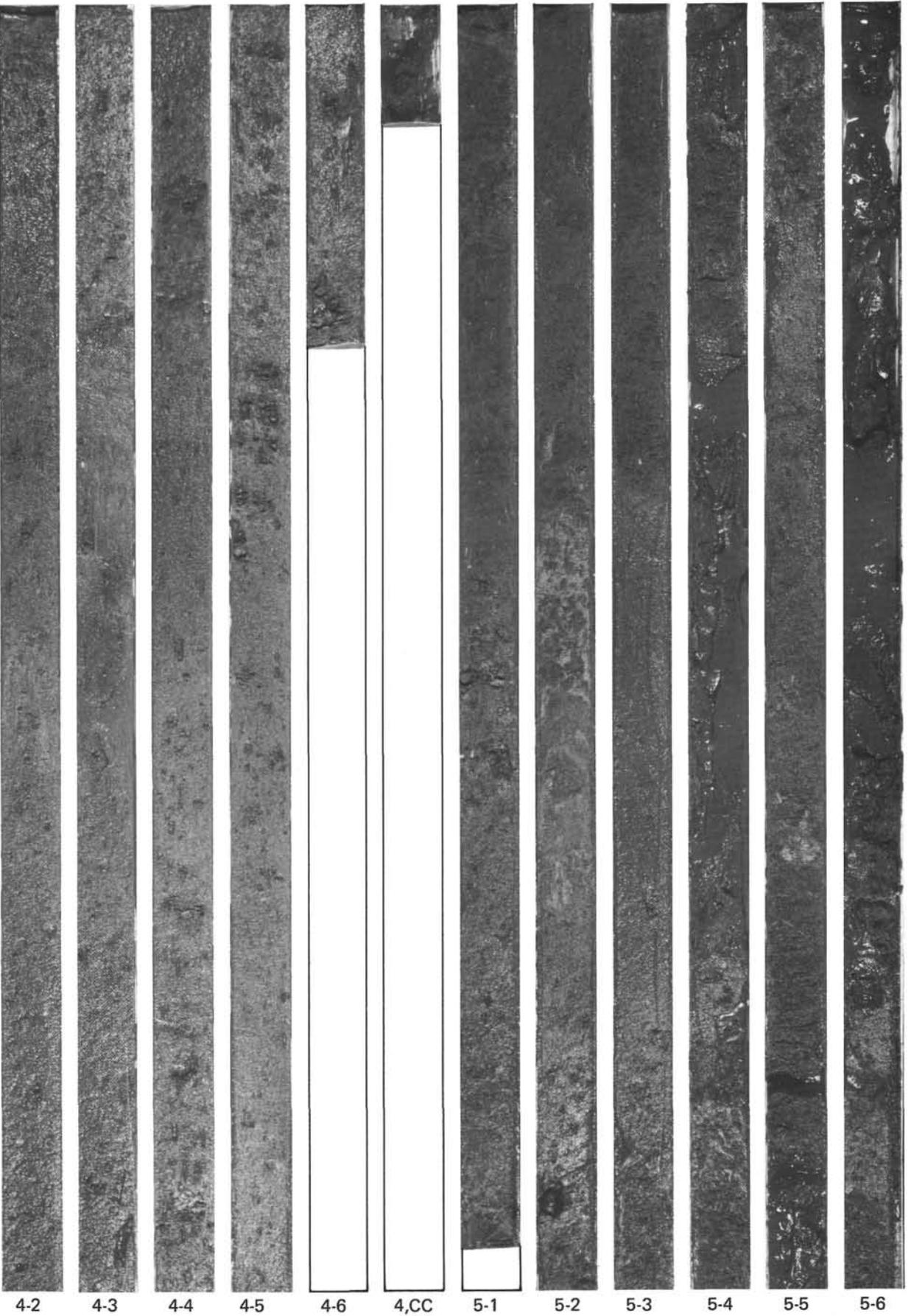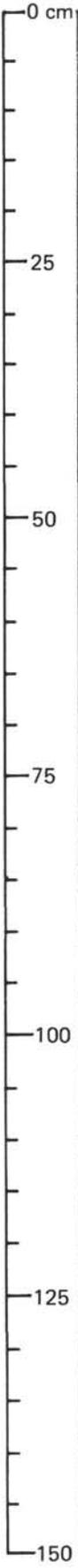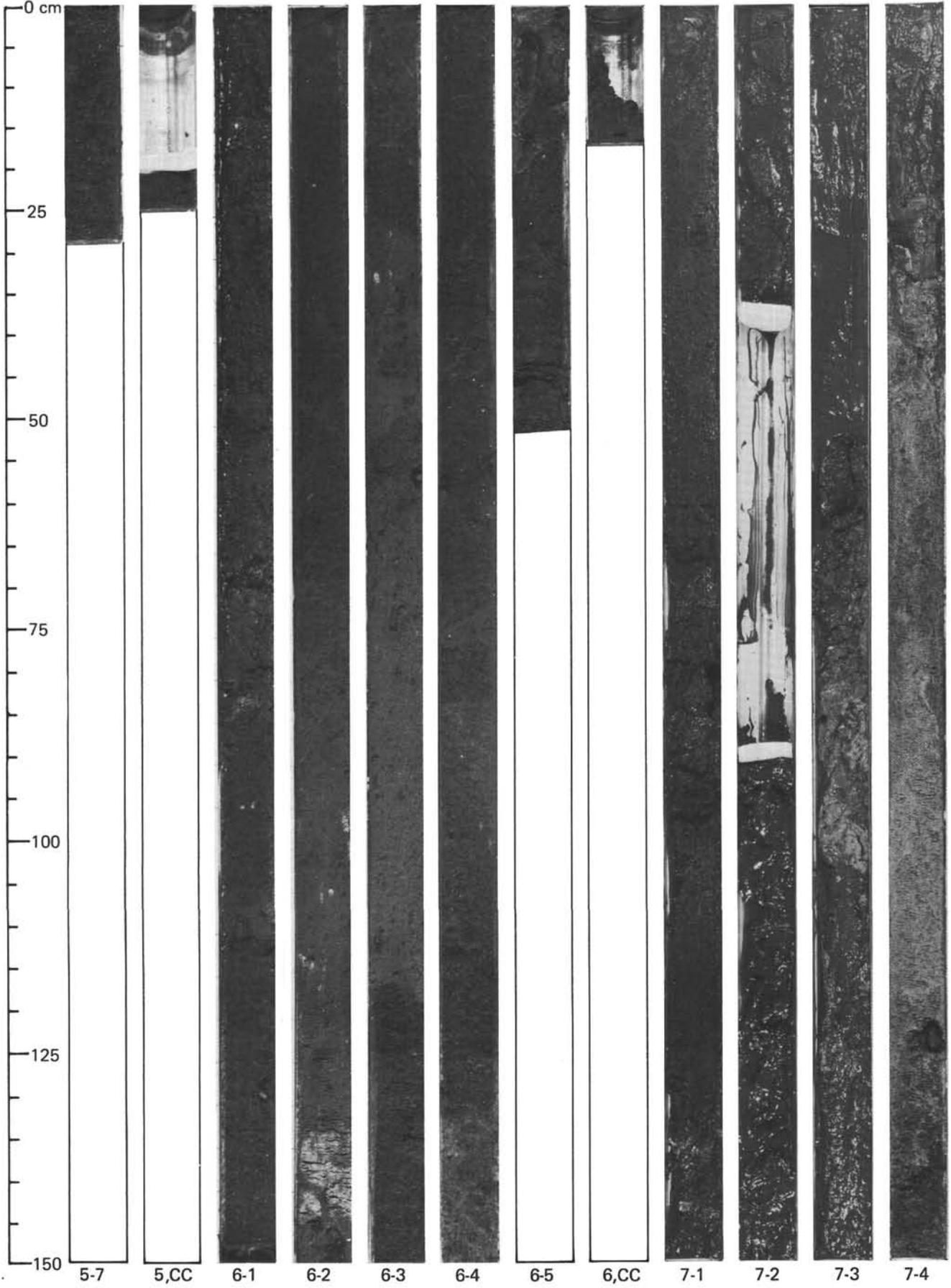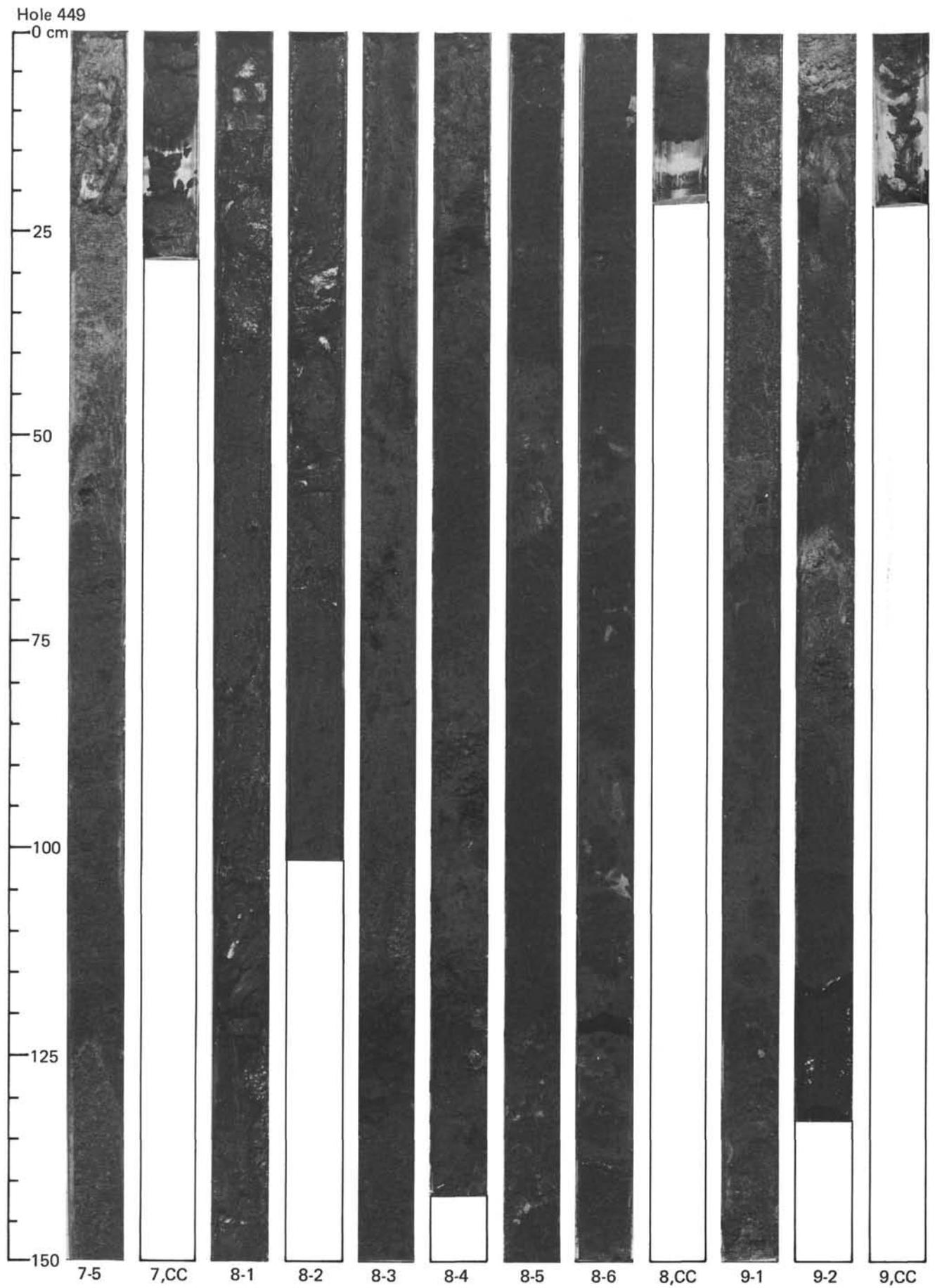
Hole 449
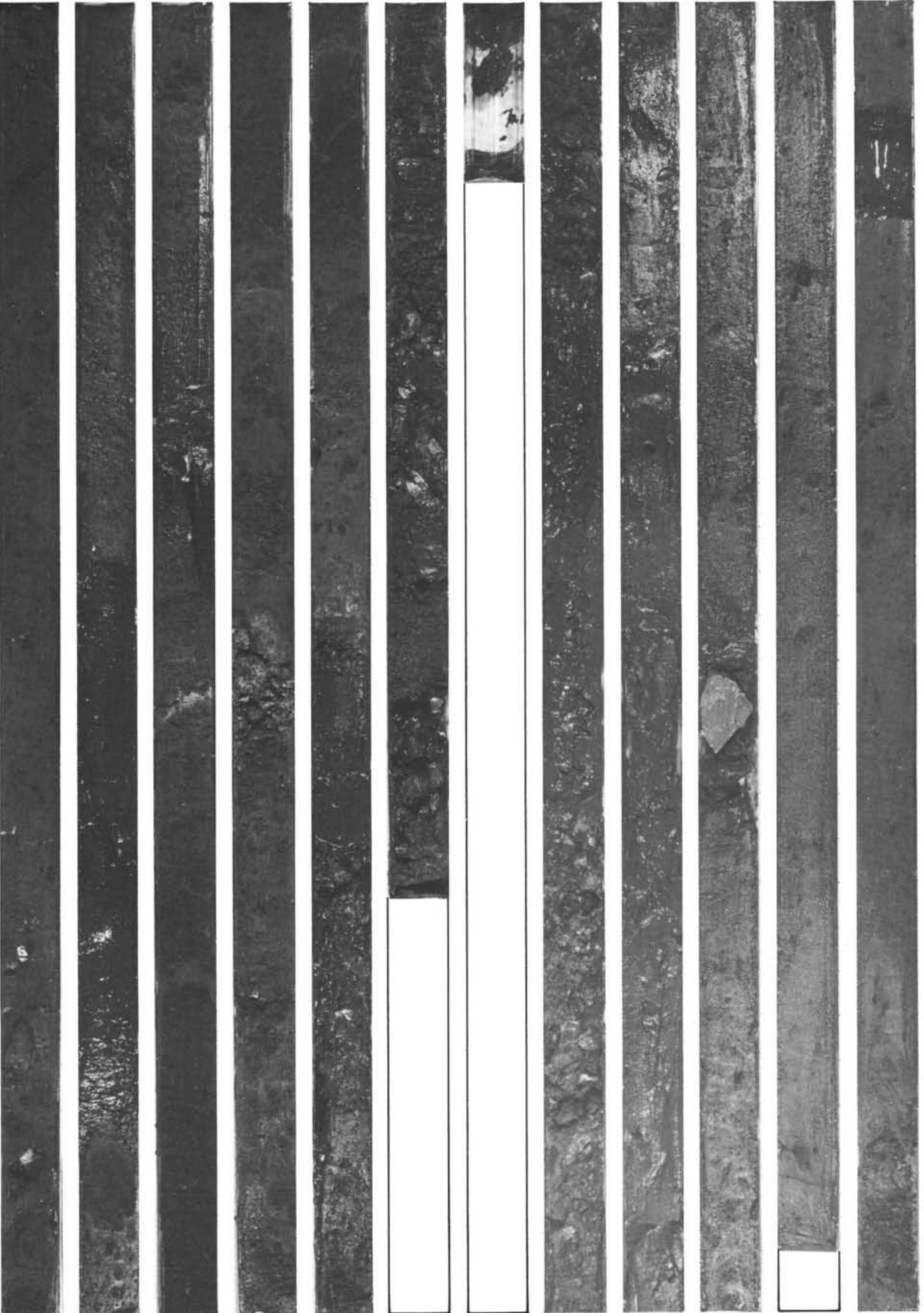
Hole 449

NO PHOTOGRAPH AVAILABLE

11-6 11,CC 12-1 12-2 12-3 12-4 12-5 12,CC 13-1 13-2 13-3 13-4
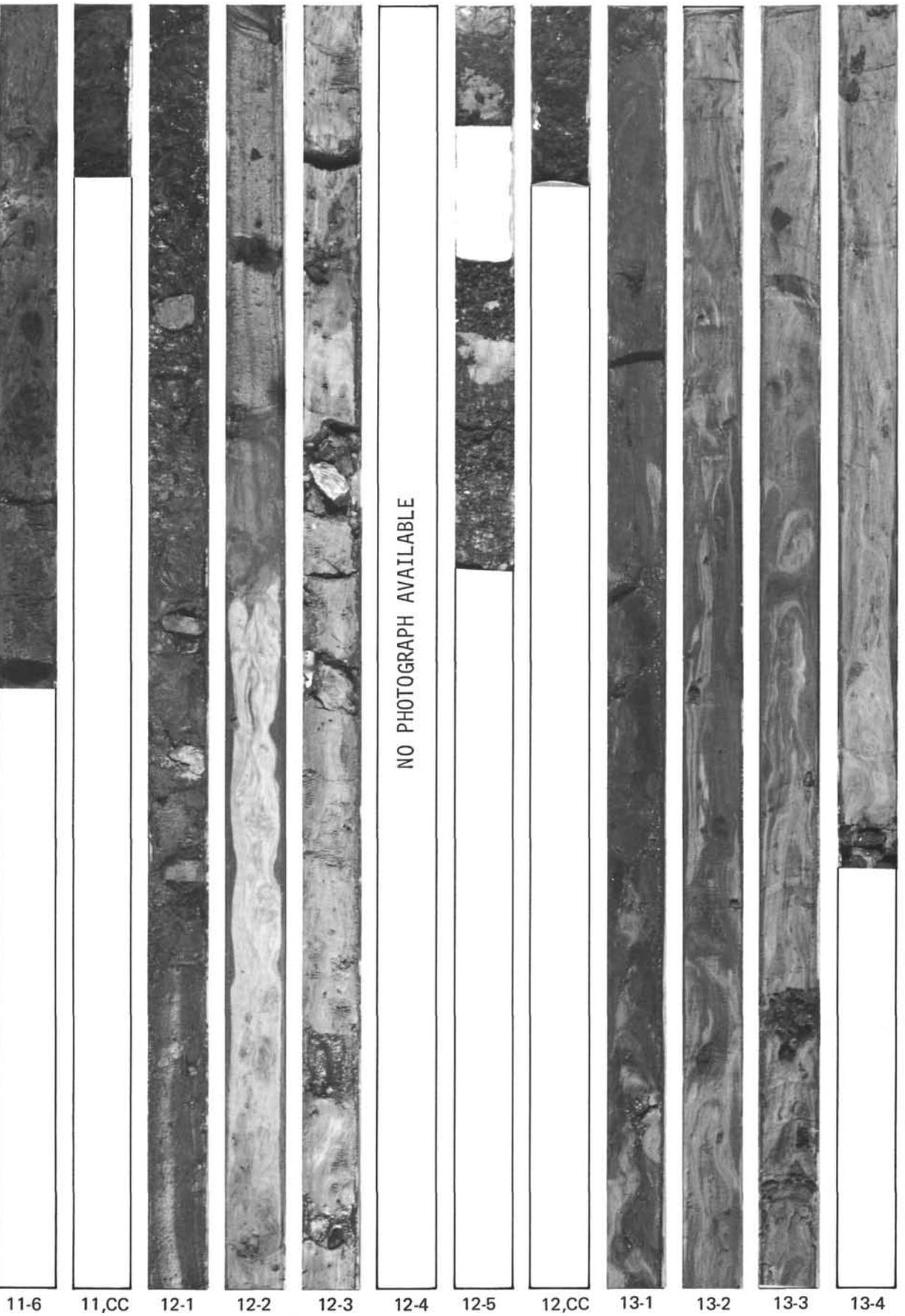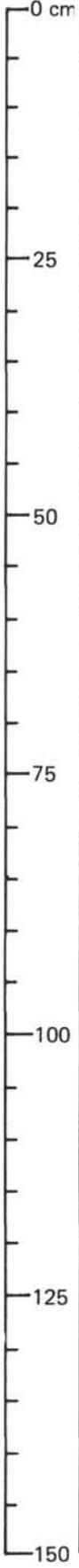
Hole 449 (No photograph available for 14-2 to 14-6)

| 13-5 | 13-6 | 13,CC | 14-1 | 14-6 | 15-1 | 15-2 | 16-1 | 16-2 | 17-1 | 17-2 | 18-1 |