2. SITE 447: EAST SIDE OF THE WEST PHILIPPINE BASIN

Shipboard Scientific Party[1]

HOLES 447, 447A

Date occupied: 6 February 1978

Date departed: 12 February 1978

Time on hole (hrs): 1.5 (Hole 447), 137.5 (Hole 447A)

Position: 18°00. 88′N; 133°17.37′E

Water depth (sea level; corrected m, echo-sounding): 6022

Water depth (rig floor; corrected m, echo-sounding): 6032

Penetration (m): 296.5

Number of cores: 1 (Hole 447), 37 (Hole 447A)

Total length of cored section (m): 9 (Hole 447), 296.5 (Hole 447A)

Total core recovered (m): 0.4 (Hole 447), 155 (Hole 447A)

Core recovery (%): 4.4 (Hole 447), 52.3 (Hole 447A)

Oldest sediment cored:
Depth sub-bottom (m): 113
Nature: Volcaniclastic breccia
Age: Middle Oligocene (NP 24)
Measured velocity (km/s): 3.6–4.6

Basement:
Depth sub-bottom (m): 113
Nature: Tholeiitic basalts
Velocity range (km/s): 4.7–5.2

Principal results: Site 447 is located on the eastern side of the West Philippine Basin between the Central Basin Ridge and the Palau-Kyushu Ridge. Two holes were drilled at the site, the first of which was abandoned when only a core-catcher sample was recovered from the first core. The sample contained manganese nodules, fragments of manganiferous crust, and traces of brown pelagic clay. Ichthyoliths, tentatively ascribed to the early Miocene, were also present. A second hole (447A) was successfully drilled at the site to a sub-bottom depth of 296.5 meters; the upper 113 meters consist of sediments and the lower 182.5 meters consist of extrusive phyric and aphyric tholeiitic basalts.

The sedimentary section is divisible into five units. From the top downward they are: Unit 1, 37.5 meters of brown pelagic clay possibly deposited in the early Miocene; Unit 2, 9.5 meters of calcareous pelagic clay deposited in the late middle to early late Oligocene; Unit 3, 38 meters of polymictic conglomerate and breccia; Unit 4, 2.1 meters of altered variegated fine tuff; and Unit 5, 25.9 meters which can be further divided into two volcaniclastic breccia sub-units separated by a tuff sub-unit. Nannofossils throughout the interval encompassed by Units 3 through 5 indicate an age range of early late to middle Oligocene. The upper part of the sedimentary sequence was deposited well below the carbonate compensation depth (CCD), whereas the lower part was deposited close to the CCD. Because Site 447 is situated on the sedimentary apron west of the Palau-Kyushu Ridge, tuffs within the lower 47 meters of the middle Oligocene sedimentary sequence probably were derived from that source. Within volcaniclastic breccias, however, basaltic clasts occur with increasing size, abundance, and freshness down-section and appear to have been derived locally from the igneous basement.

The underlying tholeiitic basalts consist of six major petrographic units, several of which are subdivisible into individual cooling units that commonly have pillow lava tops and massive flow bottoms. From the top downward the units are: Unit 6, 18.5 meters of plagioclase-phyric flows and pillow lavas; Unit 7, 9.5 meters of plagioclase-phyric pillow lavas; Unit 8, 44.0 meters of plagioclase-clinopyroxene-olivine-phyric pillow lavas (the bases of massive flows of these lavas are doleritic); Unit 9, a 9.0-meter aphyric to olivine-spinel-phyric flow; Unit 10, 15.0 meters of olivine-plagioclase-clinopyroxene-phyric pillow lavas; Unit 11, 87.5 meters of plagioclase-olivine-spinel-phyric pillow lavas. The lower 14.5 meters of Unit 11 contain plagioclase and spinel megacrysts and anorthositic cumulate xenoliths.

BACKGROUND AND OBJECTIVES

Because both the age and origin of the West Philippine Basin are in question, the principal objectives at Site 447 were to drill through a thin sediment cover as far as possible into basement to seek evidence regarding the age and origin of this marginal basin.

Magnetic lineation patterns are often the best indicators of the timing of ocean-crust generation. However, within marginal basins, identification of magnetic lineation patterns and correlation of these lineations with the geomagnetic reversal time scale has proven to be difficult, even though the general age of these basins is commonly indicated by data from nearby DSDP sites and evidence from adjacent islands.

Previous deep-sea drilling suggests, for example, that the West Philippine Basin (Fig. 1) was formed during the early Tertiary. Two holes had previously been drilled at Site 290 in the West Philippine Basin during DSDP Leg 31. The deeper of the two, Hole 290, was positioned at 17°44.85′N, 133°28.08′E, about 35 km south and east of Site 447 (Fig. 1). The units as described down-hole in Hole 290 include 90 meters of Quaternary to upper Pliocene brown silt-rich clays; 49 meters of upper Oligocene nannofossil ooze (the juxtaposition of these two units suggests subsidence of the West Philippine Basin below the CCD); 80 meters of lower Oligocene or upper Eocene volcanic silts; and an upper Eocene or lower Oligocene basal volcanic breccia. The two basal volcanic units are thought to have been derived from the Palau-Kyushu Ridge. The basal

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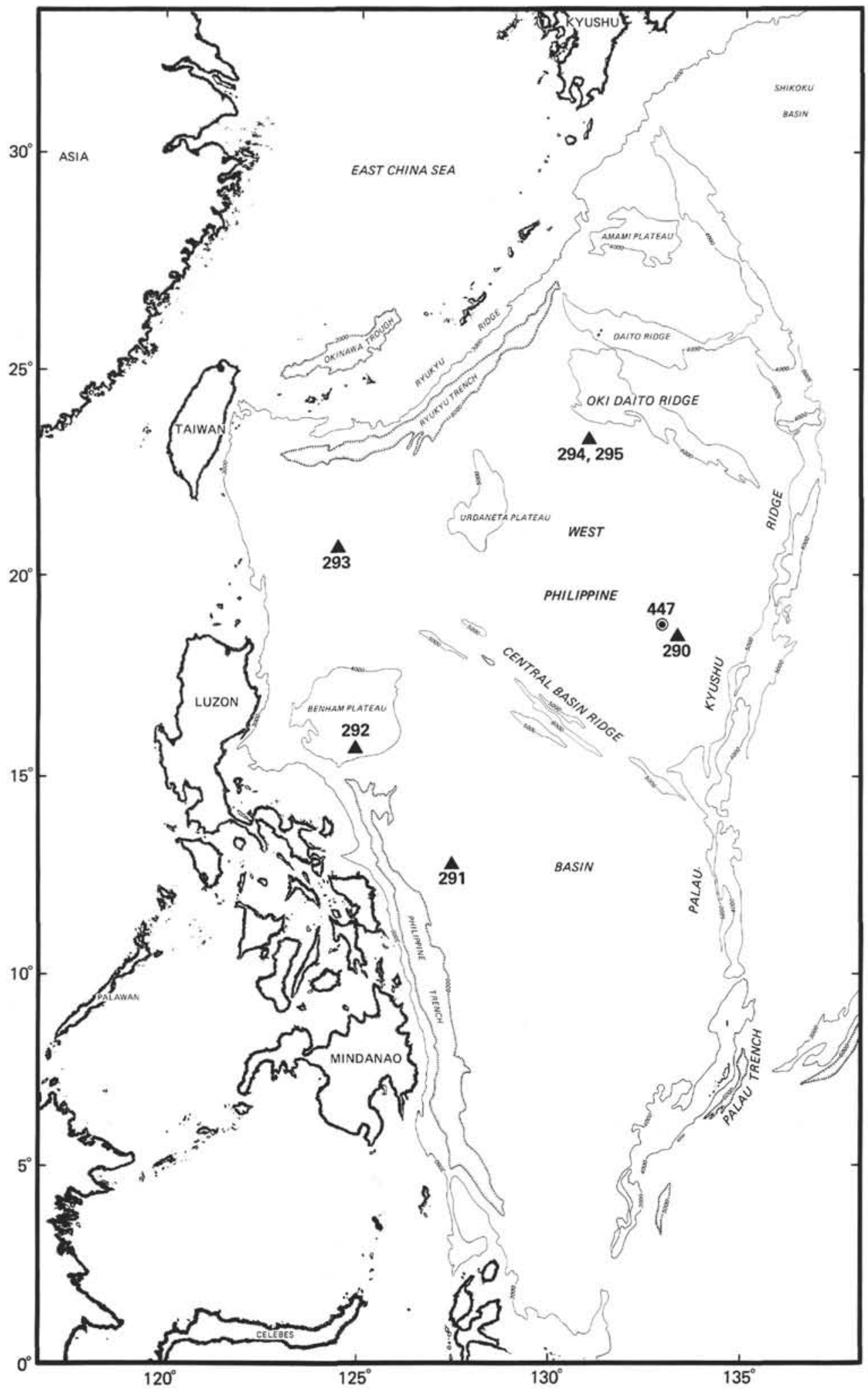

Figure 1. Location of Site 447 and geographic features of the West Philippine Basin and vicinity that are discussed in the text. (The concentric point locates Site 447 and the triangles locate other DSDP Sites.)

breccia, possibly formed by slumping from a local topographic high, contains basalt clasts in a nannofossil-bearing matrix that indicates a minimum age of late Eocene for the basement, which itself was not actually reached (Karig, 1975).

In accord with these data, the results of recent magnetic surveys also suggest an early Tertiary origin, probably by spreading from the Central Basin Ridge. Louden (1976) has mapped west-northwest trending magnetic lineations south of the Central Basin Ridge, which he identified as Anomalies 18 through 21 (~ −45 to −52 m.y.). Magnetic lineations trending west-northwest recently mapped north of the Central Basin Ridge (Watts et al., 1977, Fig. 6), appear oblique to the strike of the Palau-Kyushu Ridge and the active Mariana arc-trench system (Fig. 1).

Site surveys undertaken by Lamont-Doherty Geological Observatory (L-DGO) and Scripps Institution of Oceanography (SIO) indicate that water depths average about 6000 meters in the Site 447 area. A general increase in water depth, a lessening of basement relief, and a slight increase in sediment thickness in a north-northeast direction suggest an increase of basement age in this direction (Fig. 2). The magnetic lineations reported by Watts et al. (1977) are parallel to bathymetric trends striking west-northwest; such magnetic and bathymetric orientations suggest spreading in a north-northeast direction, perhaps from a spreading center to the south-southwest. L-DGO Site Survey magnetic profiles also clearly parallel the trend of local topography (Fig. 3).

Because depth to basement in the West Philippine Basin is much greater than to the accreted sea floor of similar age in the main ocean basins, it has been suggested that the geomagnetic data might be interpreted better in terms of the Mesozoic geomagnetic time scale (Ben-Avraham et al., 1972). Thus, the lineations previously mapped both north and south of the Central Basin Ridge could be variously interpreted as representing either one or both limbs of a Mesozoic or Early Tertiary spreading system.

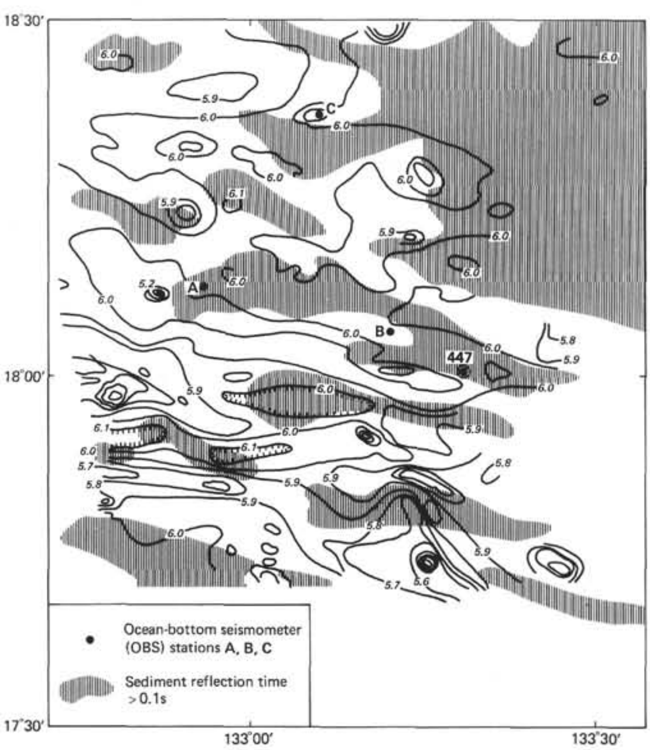

Figure 2. Bathymetry and sediment thickness near Site 447 (L-DGO Site Survey data). (Water depth is contoured in intervals of 0.1 km; shaded sections indicate areas underlain by greater than 0.1 s reflection time of sediment.)

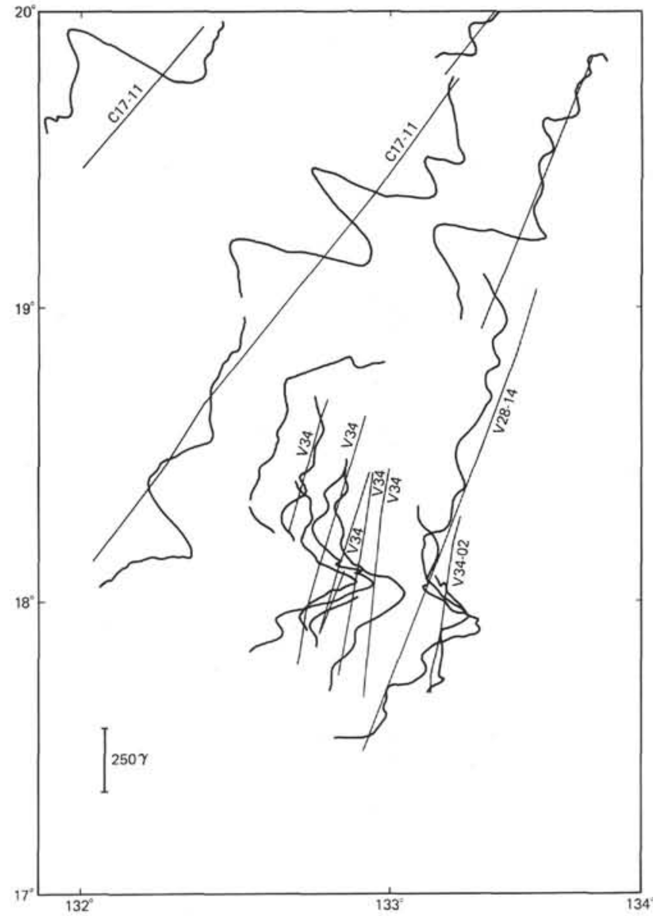

Figure 3. Magnetic-anomaly profiles in the vicinity of Site 447 (L-DGO Site Survey data).

To complicate matters further, reconnaissance seismic-refraction studies in the Philippine Sea have indicated that most of the basin floor is underlain by a 3.5-km/s acoustic basement layer, possibly Early Tertiary flows, capping a much older oceanic crust. The numerous intrusive basaltic units encountered in the sedimentary column at Holes 442–444 of the Northern Philippine transect (Leg 58, Klein, Kobayashi et al., in press) emphasize the need for caution in making indirect interpretations of basement age within marginal basins.

Site 447, therefore, was intentionally located in the eastern part of the West Philippine Basin where the 3.5-km/s capping layer is either very thin or absent. L-DGO Site Survey data also confirm the absence of the 3.5-km/s basement layer at this site (Langseth and Mrozowski, this volume).

In order to encounter fewer drilling difficulties, Site 447 was also located farther from the volcanic-debris source of the Palau-Kyushu Ridge than was Site 290. The seismic-reflection profile recorded during the L-DGO 447 Site Survey (Fig. 4) shows an irregular sediment thickness that exceeds 0.3-s reflection time in structural depressions in a block-faulted basement.

Taking all these factors into account, a single-bit hole was planned to penetrate the 200 meters of surface sediment (Fig. 2) and to drill as far as possible into the 5.2-km/s basement to test for entrapment of old crust of unknown origin.

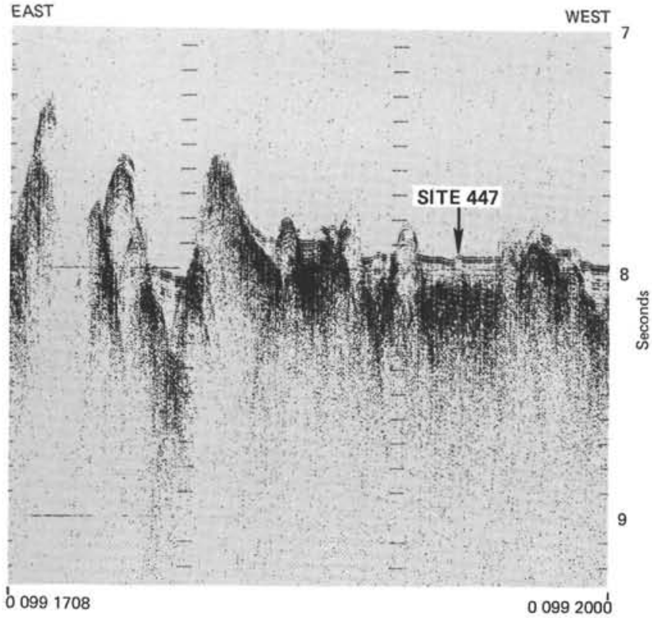

Figure 4. Seismic-reflection profile recorded during preliminary site surveys for Site 447 (L-DGO Site Survey data: *Vema* cruise 34-02, JD 099, 1977; note the profile is from east [left] to west [right]).

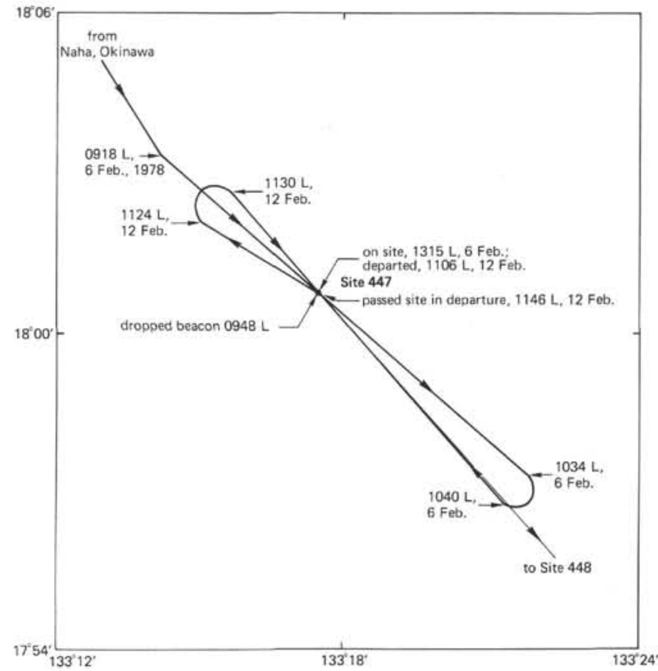

Figure 5. Track of the *Glomar Challenger* during approach and departure from Site 477. (The black circle marks the position of the beacon.)

OPERATIONS

At 0818 Local Time (L), 3 February 1978, the *Glomar Challenger* departed Naha, Okinawa bound for Site 447 in the West Philippine Sea. After leaving the harbor entrance and crossing the 200-meter contour, the *Challenger* slowed to deploy the underway geophysical equipment. At 1045 L, with all equipment streamed, speed was increased to 9.2 knots and a course of 147° was set for Site 447.

Situated in the eastern sector of the West Philippine Basin, Site 447 had been selected on the basis of geophysical site survey data (L-DGO) collected earlier on the *Vema* and the *Conrad*. Three days out of Okinawa the *Challenger* approached the site from the northwest, on a course of 127° (Fig. 5). The reflection profile being taken by the *Challenger* so closely resembled the profile obtained earlier by the *Vema* that a decision was made to drop the beacon on the initial pass over the site. At 0948, 6 February a 13.5-kHz double-life beacon was dropped as the ship crossed Site 447.

Between 1130 L and 1315 L, underway survey equipment was retrieved and the vessel was positioned over the site. A standard F94CK drill bit was selected and a standard bottom-hole assembly was rigged. From 1315 L, 6 February, to 0145 L, 7 February, the bottom-hole assembly and drill string were run to the sea floor, strapping the pipe in the process. Sea floor was felt at 6021 meters below sea level compared to 6022 meters determined by the 12-kHz PDR. The hole was spudded in at 0145 L, and a mud-line punch core was recovered. Because the core catcher was jammed with manganese nodules, only a trace of sediment was recovered. In order to resample the same interval, a new hole was begun, designated 447A.

After recovery of the punch core from Hole 447A, the core catchers of Cores 2 and 3 were fouled with the sand line protective coating, resulting in a lack of recovery in Core 2 and a low recovery in Core 3. A total of five cores were cut in soft sediment before more indurated sediments were encountered in Cores 6 through 11. In Core 12, the sediment was well indurated, and at the bottom of Core 13 basalt basement was recovered from 113 meters sub-bottom.

From 113.0 meters to 270.5 meters sub-bottom, 20 cores were cut in basalt (Cores 14 through 33). Between Cores 17 and 18, the bit was briefly plugged, which necessitated pumping down the core barrel with the center bit attached in order to dislodge the obstruction. Torquing-up occurred and circulation was lost toward the end of cutting of Core 33. Little core was recovered, which was essentially jammed in the core catcher, and several sections were filled with coarse, sand-sized cuttings thought to have caved from above (which apparently caused the torquing-up and loss of circulation). After pulling out nine joints of pipe, circulation was recovered; the pipe was run back and the hole cleaned out to total depth and flushed with drilling mud.

Cores 34 to 36 were cut between 270.5 and 293.0 meters sub-bottom (Table 1). Progressive reduction of core diameter in Cores 35 and 36 indicated progressive bit failure, and after repeated torquing-up during the cutting of Core 37, drilling was terminated at 296.5 meters sub-bottom in tholeiitic basalt.

During the drilling operations, a short, wide-angle reflection sonobouy profile was obtained to aid in correlation of seismic-reflection profiles with the drilling

Table 1. Coring summary, Holes 447 and 447A.

Core No.	Date (February, 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 (%)
Hole 447							
1	7	0305	6031.0-6040.0	0.0- 9.0	9.0	0.4	4.4
Hole 447A							
1	7	0447	6031.0-6040.0	0.0- 9.0	9.0	8.0	88.3
2	7	0634	6040.0-6049.5	9.0- 18.5	9.5	0.0	0.0
3	7	0824	6049.5-6059.0	18.5- 28.0	9.5	1.0	10.7
4	7	1009	6059.0-6068.5	28.0- 37.5	9.5	6.7	70.2
5	7	1204	6068.5-6078.0	37.0- 47.5	9.5	9.6	104.0
6	7	1405	6078.0-6087.5	47.0- 56.5	9.5	9.7	101.7
7	7	1625	6087.5-6097.0	56.0- 66.0	9.5	9.6	100.8
8	7	1823	6097.0-6106.5	66.0- 75.5	9.5	1.8	19.5
9	7	2025	6106.5-6116.0	75.5- 85.0	9.5	3.2	33.3
10	7	2210	6116.0-6125.5	85.0- 94.5	9.5	3.1	32.9
11	8	0008	6125.5-6129.0	94.5- 98.0	3.5	0.9	25.7
12	8	0225	6129.0-6135.0	98.0-104.0	6.0	3.5	58.3
13	8	0512	6135.0-6144.0	104.0-113.0	9.0	0.8	8.9
14	8	0750	6144.0-6153.0	113.0-122.0	9.0	4.6	51.1
15	8	1052	6153.0-6162.0	122.0-131.0	9.0	4.4	48.9
16	8	1404	6162.0-6171.0	131.0-140.0	9.0	1.9	21.2
17	8	1652	6171.0-6180.0	140.0-149.0	9.0	3.9	43.3
18	8	2340	6180.0-6183.0	149.0-152.0	3.0	3.0	100.0
19	9	0244	6183.0-6189.0	152.0-158.0	6.0	3.2	53.3
20	9	0605	6189.0-6198.0	158.0-167.0	9.0	4.0	44.4
21	9	0928	6198.0-6207.0	167.0-176.0	9.0	5.9	65.6
22	9	1218	6207.0-6211.0	176.0-180.0	4.0	3.3	82.5
23	9	1610	6211.0-6216.0	180.0-185.0	5.0	4.4	88.0
24	9	2014	6216.0-6222.0	185.0-191.0	6.0	3.3	55.0
25	10	0155	6222.5-6229.5	191.0-198.5	7.5	4.7	62.7
26	10	0528	6229.5-6238.5	198.5-207.5	9.0	5.1	56.7
27	10	0845	6238.5-6247.5	207.5-216.5	9.0	2.8	31.1
28	10	1214	6247.5-6256.5	216.5-225.5	9.0	3.4	37.8
29	10	1622	6256.5-6265.5	225.5-234.5	9.0	5.8	64.4
30	10	2020	6265.5-6274.5	234.5-243.5	9.0	7.0	77.8
31	10	2345	2674.5-6283.5	243.5-252.5	9.0	4.5	50.0
32	11	0338	6283.5-6292.5	252.5-261.5	9.0	4.2	46.7
33	11	0658	6292.5-6301.5	261.5-270.5	9.0	0.3	3.3
34	11	1124	6301.5-6306.0	270.5-275.0	4.5	2.7	60.0
35	11	1509	6306.0-6315.0	275.0-284.0	9.0	8.0	88.9
36	11	2022	6315.0-6324.0	284.0-293.0	9.0	5.7	63.3
37	12	1015	6324.0-6327.5	293.0-296.5	3.5	0.9	25.7
Total					296.5	155.0	52.3

results. At 1103 L, 12 February 1978, the ship departed Site 447, and a short seismic-reflection survey was completed across the beacon en route to Site 448.

SEDIMENTARY LITHOLOGY

Lying above the basaltic basement at Site 447 are 113 meters of lower Miocene to middle Oligocene sedimentary and volcaniclastic rocks separable into five lithologically distinct units (see Fig. 6).

Unit 1 is 37.5 meters thick and consists of pelagic clay. Dark brown in Core 1, Section 1, the clay grades downward to dark reddish brown in Core 3. The clay appears as alternating brown and yellowish red layers 40 to 95 cm thick in Core 4. These color changes probably are caused by variations in the content of micronodules and amorphous iron-oxide aggregates, neither component of which exceeds 10% in smear slides. The zeolite content systematically increases down-core, from traces at the top to 10% at the base of the unit. The entire core is structureless except for rare, scattered lumps and patches of slightly more indurated, yellowish, presumably less iron-rich material a few mm across. Unit 1 is almost devoid of fossils except for fish teeth, which indicate that the unit is lower Miocene.

Unit 2, 9.5 meters thick, occurs only in Core 5; contacts with overlying and underlying units were not recovered. The unit is a calcareous pelagic clay, dark yellow-brown at the top and grading down-core through yellow-brown to light yellow-brown at its base. This color change probably reflects a subtle decrease in micronodule and amorphous iron content. The sediment in Section 1 contains 2% micronodules and 3% amorphous iron oxides; these constituents decrease downhole to 1% and a trace, respectively, in Section 6.

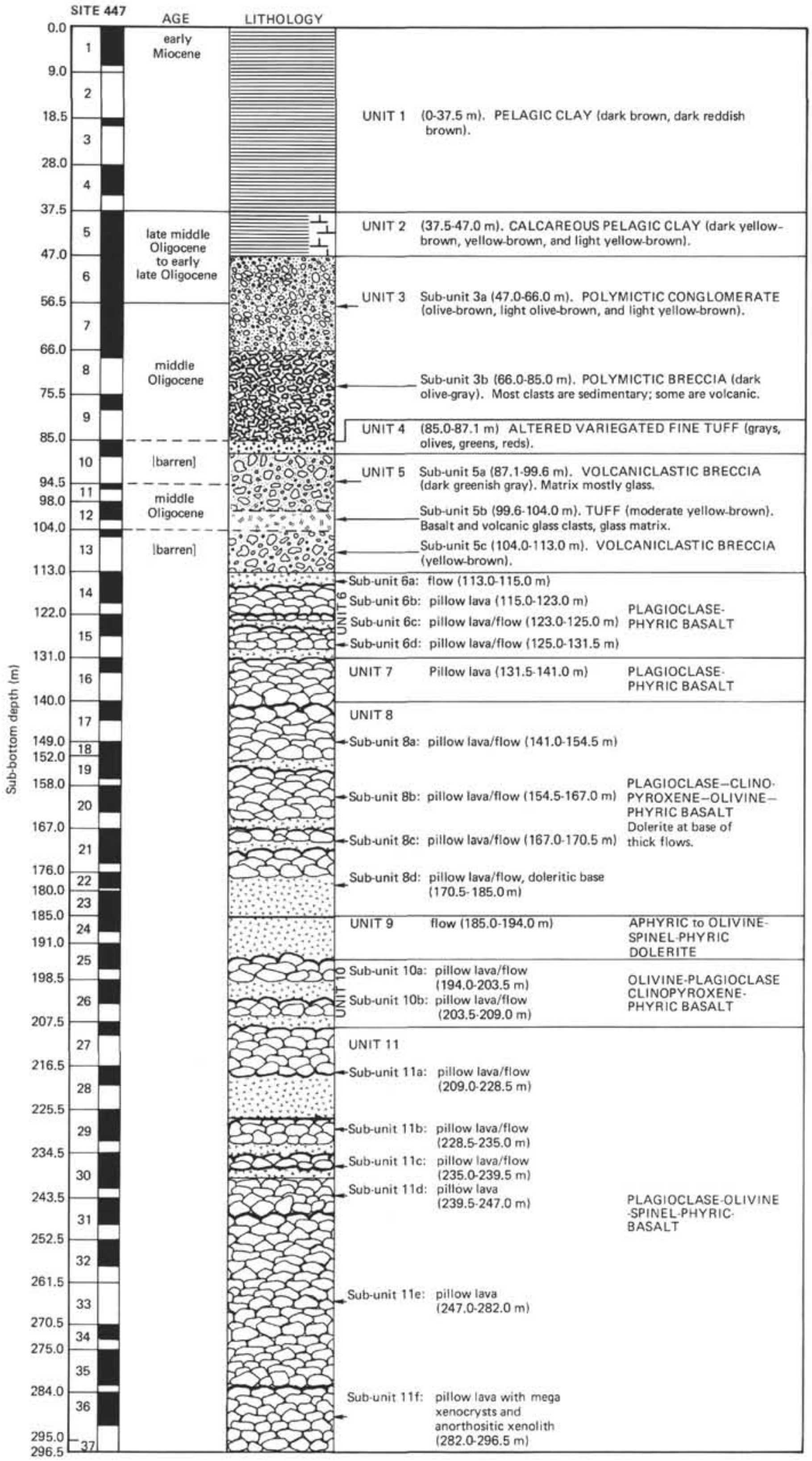

Figure 6. Lithology, age, and core recovery at Site 447. (Heavier lines on pillow tops indicate top of a pillow lava unit or sub-unit. Pillowed massive flows are abbreviated as "pillow lava/flow." Dashed lines in the age column indicate borders of barren intervals. Core recovery is indicated by the solid symbol. Lithologic symbols are summarized in the Introduction [this volume].)

However, the basal 3 meters of the unit are marked at 10- to 20-cm intervals by 0.5- to 1-cm round, dark blebs containing about 10% micronodules and about 40% amorphous iron oxides.

Unit 3, 38 meters thick, includes a polymictic conglomerate and a polymictic breccia recovered from Cores 6 through 9. As in Unit 2, the upper and lower contacts were not recovered.

Sub-unit 3a, the uppermost 19 meters of Unit 3, is a polymictic conglomerate, olive-brown in color, grading down through light olive-brown to light yellowish brown. The matrix and some of the clasts are composed of semilithified calcareous pelagic clay. Clasts of pumice and brown, deeply weathered basalt also occur. The clasts are predominantly rounded and increase in average size down-core from 0.2 to 0.5 cm to about 1 to 2 cm. The clast:matrix ratio varies from about 1:7 in the top 2 meters of the sub-unit to about 1:1 in the rest of the core. Compositionally, the matrix is dominated by clay minerals with small amounts of volcanic glass and fine carbonate. Deeply etched coccoliths are present throughout the sub-unit; nannofossils are less common in its lower part and most of the carbonate is recrystallized.

In the upper part of the sub-unit, drilling disturbance was moderate to intense, disaggregating most of the conglomerate except for a few 2-cm-thick pieces. In the lower part of the sub-unit, where an increase in lithification occurs, some of the conglomerate consists of coherent pieces up to 10 cm thick. The coherent pieces contain manganiferous patches and dendrites, and the tops of some of the pieces are marked by thin manganiferous films. There is therefore some suggestion that drilling deformation was controlled partly by lithification processes involving manganiferous sediments.

Sub-unit 3b, the lowermost 19 meters of Unit 3, is a polymictic breccia recovered from Cores 8 and 9. Its contacts with overlying and underlying units were not recovered; its top is placed at the top of Core 8 and its bottom in the core catcher of Core 9. The breccia is dark olive-gray to dark greenish gray. The clast:matrix ratio ranges between about 3:2 and 3:1, tending to increase down-core. Clasts range in size from 0.1 to 5.5 cm, averaging about 1 cm in diameter. Mudstone fragments dominate the clasts, although volcanic clasts become more important down-core. The sedimentary clasts are moderately rounded to well rounded, whereas the igneous fragments typically are more angular. The matrix is a calcareous pelagic clay.

Unit 4 is the top 2.1 meters of Core 10. The lower contact with Unit 5 is sharp. Unit 4 is an altered fine tuff, variegated in shades of gray, brown, olive, olive-gray, and grayish green, in layers 8 to 40 cm thick. Light and dark mottling varies from slight to intense. The sediment contains smectite, phillipsite, and potassium feldspar. The alteration paragenesis is dealt with by Sartori and Tomadin (this volume).

Unit 5, 25.9 meters thick (Cores 10 through 13), is divided into three sub-units: in the upper part, Sub-unit 5a is a grayish green volcaniclastic breccia with a tuff layer near its top; in the middle, Sub-unit 5b is a light yellowish brown tuff; and in the lower part, Sub-unit 5c is a light yellowish brown volcaniclastic breccia.

Sub-unit 5a, 12.5 meters thick, has a greenish black tuff layer 59 cm thick near its top. Elsewhere the sub-unit consists of angular clasts of fresh and weathered basalt in a matrix of amorphous, very fine volcanic glass with minor recrystallized carbonate and coccolith remnants. The clast:matrix ratio is about 3:1. This sub-unit has a disturbed contact with Sub-unit 5b.

Sub-unit 5b consists of 4.4 meters of tuff. Near the top, the tuff contains mostly very coarse sand-size clasts, grading down-core through coarse sand into coarse and medium sand at the base of the sub-unit. The clasts are angular, irregularly shaped, and rarely larger than 2 mm in diameter, although fragments as coarse as 7 cm are present. Almost all the clasts are of volcanic origin; weathered reddish brown basalt comprises from 40 to 75% of the clasts, volcanic glass and pumice from 25 to 60%, and vesicular basalt with zeolite-filled amygdules typically about 10%. In places the clasts display moderate sorting, and the platy or prismatic grains are oriented parallel to bedding. The clast:matrix ratio is about 7:3. The matrix is mainly clay- and silt-sized glass fragments. Rare ghosts of coccoliths and other carbonate grains comprise less than 5% of the matrix. About 10% is authigenic zeolite, which outlines cavities with acicular, radiating clear crystals and is also rarely associated with carbonate particles.

Sub-unit 5c, 9.0 meters thick, is a light yellow-brown volcaniclastic breccia containing massive and zeolitized vesicular basalt fragments, mostly consisting of reddish brown weathered spherulitic glass. The clasts are angular and irregularly shaped, with average diameters of about 1 cm, although some fragments are larger than the 6.6-cm diameter of the core. The clast:matrix ratio is about 3:1; the matrix is a carbonate-rich volcanic glass with some clay. Approximately 5% of the intergranular spaces are filled with clear zeolites mainly bordering the margins of some glass clasts.

The contact between basal Sub-unit 5c and the underlying basalt was sampled in the core catcher of Core 13. Unfortunately, during recovery of the core most of the core-catcher contents fell out on deck, so the pieces may be out of sequence. As reconstructed, the upper 10 cm of the core catcher contain a plagioclase-phyric basalt cobble; the next 7 cm (the volcaniclastic breccia of Sub-unit 5c and the lower part of the core catcher) contain basalt from igneous basement.

Variations in the texture of the sedimentary units recovered from Hole 447A provide clues to the tectonic history of the site. Unit 5 is primarily a clastic suite of volcanic lithologies. Sub-unit 5c, overlying the basalt, is essentially a basal conglomerate, except that the clasts are predominantly angular rather than rounded. Sub-unit 5b and the lower part of Sub-unit 5a constitute an upward-coarsening trend indicating a tectonic rise of volcanic provenance during the middle Oligocene. Culmination of this coarsening trend is represented by the sample from the core catcher of Core 11. Subsequently, another middle Oligocene pulse of tectonism resulted in both uplift of the site as well as deposition of the breccias of Unit 3. This time, however, provenance consisted of both volcanic and sedimentary carbonate rocks. With advancing time, the breccia clasts became dominated almost entirely by chalk lithologies. Culmination of this second tectonic event reasonably can be assumed to have occurred before the site had finished accumulating its coarse clastics. Because the tuffs of Unit 4 may have been deposited over a very short period by a sudden pulse of volcanic activity from the Palau-Kyushu Ridge, deposition of coarse clastics of Units 5 and 3 may be related to the same tectonic events, interrupted briefly by an influx of fresh volcaniclastic debris. In either case, the uplifted site accumulated nannofossil ooze above the CCD in the late Oligocene before subsiding through the CCD in the early Miocene, after which subsidence continued until modern depths were attained. During this latter subsidence the uppermost 37.5 meters of pelagic clay were deposited (Unit 1). The lack of volcanic components in this unit is notable and indicates that the Palau-Kyushu Ridge has remained volcanically inactive since the early Miocene.

BIOSTRATIGRAPHY

In Hole 447A 113 meters of sediments, believed to be a continuous sequence, were cored (Fig. 6). However, the continuity of the sequence in Unit 1 can be debated; this is discussed in detail in the Accumulation Rates section of this report. Lithologic Unit 1 (0–37.5 m), a noncalcareous, dark brown to dark reddish brown, pelagic clay, contains only ichthyoliths (Samples 447-1,CC and 447A-1,CC). On the basis of these fossils, this particular level is tentatively assigned to the lower Miocene. Lithologic Unit 2 (37.5–47.0 m) consists of calcareous pelagic clay that grades downward into coarser sediments of Units 3 to 5 (47.0–113.0 m), including polymictic conglomerates and volcaniclastic breccias with interbedded tuff. With the exception of Core 10 (85.0–94.5 m), nannofossils occur throughout this sequence and indicate an interval from the middle Oligocene to the early late Oligocene. Radiolarians and foraminifers are extremely rare, the former giving no clues as to age and the latter indicating the Eocene-Oligocene (displaced ?) in Core 7. Diatoms and silicoflagellates were not found.

The upper part of the sedimentary column in Hole 447A is closely similar to that at Hole 290, cored during DSDP Leg 31. In both holes unfossiliferous brown zeolitic clays, which are twice as thick at Hole 290 as at Hole 447A, are underlain by calcareous sediments with the calcareous nannoplankton Zone NP 24 (*Sphenolithus distentus* Zone) at the top, grading downward into Zone NP 23 (*S. predistentus* Zone). Core 12 of Hole 447A may actually be equivalent to part of Core 6 in Hole 290. At Hole 290 the oldest fossil occurrence seems to indicate the late Eocene or early Oligocene, but there is a discrepancy between the nannoplankton and radiolarian age determinations (Karig, Ingle, et al., 1975). In Hole 447A, displaced lower Oligocene nannofossils are noted throughout the middle Oligocene section, suggesting a continuous input of eroded material from lower Oligocene sediments. This might well apply also to Hole 290, where continuous mixing with upper-Eocene radiolarian clays displaced from a nearby source is suspected.

Foraminifers

All samples from Site 447 are barren or nearly barren of foraminifers. One specimen of the benthic species, *Cassidulina subglobosa*, and one arenaceous tube-like foraminifer were observed in the core-catcher material from Core 6. In Sample 447A-7,CC three poorly preserved planktonic specimens (*Pseudohastigerina micra?* [1], *Globigerina* spp. [2]) were found. The presence of *P. micra* (if in place) suggests that this is an Oligocene or Eocene sample. The core-catcher material from Core 11 contained one specimen of *Globigerina* sp.

Calcareous Nannoplankton

Lithologic Unit 1 (Cores 1–4) is barren of calcareous nannoplankton, but calcareous nannofossils are present from the top of Core 5 down to Core 12 (37.5–104.0 m), with the exception of Core 10 (85.0–94.5 m). The assemblages in most cases are poorly preserved and the specimens heavily etched. In Cores 5 and 6 *Sphenolithus ciperoensis* is present together with *S. distentus, S. predistentus, Coccolithus abisectus*, and *Dictyococcites dictyodus*, indicating the Oligocene calcareous nannoplankton Zone NP 24 (*S. distentus* Zone). The same assemblage is present in Cores 7 to 12, except for *S. ciperoensis*, and consequently is placed in calcareous nannoplankton Zone NP 23 (*S. predistentus* Zone). *C. abisectus*, which first occurs at about the same level as *S. ciperoensis* elsewhere, and which is taken as a substitute species for defining the base of Zone NP 24 in high latitude areas (Müller, 1970), was found in all samples down to Sample 12,CC. A similar occurrence of these two species was noted by Ellis (1975) at the nearby Site 290 as well as at Site 296. The use of *C. abisectus* as a substitute species has to be reinvestigated. In several samples, with maxima in Samples 447A-5,CC and -9,CC, *Reticulofenestra umbilica* as well as rare *Cyclococcolithus formosus* and *Braarudosphaera bigelowi*, probably displaced from lower Oligocene deposits, have been found. This indicates continuous erosion in an adjacent area during this time.

Radiolarians

Radiolarians are extremely rare in the sedimentary units recovered from Hole 447A. The few specimens (all are Cenozoic spumellarians) found in the core catchers of Cores 6, 7, and 9 are either nondiagnostic or too fragmentary for positive identification.

Ichthyoliths

Because of the lack of traditional planktonic fossils in the brown pelagic clays of Unit 1 of Holes 447 and 447A, we made an on-board attempt to determine ages by means of fish teeth, which were present in quantities sufficient for study in the core catchers of Cores 1 of Holes 447 and 447A. Owing to the lack of expertise of the shipboard scientists, the identifications were preliminary; nevertheless, using the compilation of Doyle et al. (1974), we identified specimens of ten different subtypes. Five of the forms range throughout much of the Cenozoic, but three forms range from the Eocene to the Miocene (*Curved triangle pointed margin, Flexed triangle 102–112, Flexed narrow triangle 120–128*), and the other two (*Triangle short wing* and *Triangle medium wing*), restrict the ages even further, as they have not been recorded in earlier reports (Dengler et al., 1975; Doyle et al., 1974) in sediments younger than the early Miocene.

Given the present state of knowledge of fish debris, the stratigraphic resolution that can be achieved using such data is certainly less precise than that possible with more traditional fossils. On the basis of the above findings, however, it is reasonable to suggest an age of at least the early Miocene for the bottoms of Cores 1 of Holes 447 and 447A.

PALEOENVIRONMENT

Core 1 of Hole 447, and Cores 1 through 4 of Hole 447A are barren of calcareous nannofossils and foraminifers, suggesting deposition possibly near the present-day water depth of about 6000 meters and certainly below the CCD. The CCD in the Philippine Sea today seems to lie somewhere between 4000 and 4500 meters (Ujiie, 1975). Poorly preserved calcareous nannofossils are present from the top of Core 5 to Core 12 of Hole 447A. Rare, often poorly preserved foraminifers occur sporadically throughout this interval (noted in Cores 6, 7, and 11). The data thus indicate that Cores 5 to 12 were deposited at depths shallower than Cores 1 through 4, probably near to the CCD.

ACCUMULATION RATES

Five depositional units (ranging from nearly barren brown pelagic clay to coarse volcaniclastic breccia) were identified in the sedimentary sequence recovered from Hole 447A above the basalt. In such a section, markedly different accumulation rates are to be expected, but unfortunately, close estimates of these rates cannot be provided because of indefinite biostratigraphic boundaries or datum planes. At 9.0 meters sub-bottom in Hole 447A the sediments may be as old as the early Miocene (based on ichthyoliths). In contrast, the lower 104.0 meters of sediment range in age, at most, from about 29 to 33 m.y.

The typical pelagic brown clay of Unit 1 must have accumulated at a fairly uniform, slow rate. A minimum accumulation rate for Unit 1 is 2 m/m.y., assuming that it is as old as 15 m.y. at a horizon 9.0 meters down-hole (Core 1,CC) and that Unit 2 (37.5–47.0 m) ends at about 29 m.y. (early late Oligocene). This sedimentation rate is in accordance with rates registered elsewhere for such barren, deep-sea clays. Yet extrapolation of this rate to the surface of the sediment layer leads to untenable results. Thus if a complete middle Miocene to Quaternary section was indeed recovered in Core 1 (Hole 447A), then a considerably lower rate is required to account for these 9.0 meters. Alternatively, parts of this younger section must be missing or the Miocene fish teeth in the core catcher of Core 1 are reworked. If the latter is true, and if a complete lower upper Oligocene to Quaternary sequence was recovered in Cores 1 through 4, an average sediment accumulation rate of 1.3 m/m.y. results, which is still comparable to rates determined in other areas of similar depositional environments.

Whereas Unit 1 is at least of sufficient uniformity to warrant one average sedimentation rate, the other six units—all deposited during a probable maximum of 4 m.y.—definitely cannot have been accumulated at the same sedimentation rate. It is probably safe to assume that most if not virtually all of these 4 m.y. may have elapsed during deposition of the 9.5-meter-thick Unit 2, because it represents typical, slow, deep-sea sedimentation. The tuffs of Unit 4 probably represent a rapid deposition of volcanic pyroclastic debris, interrupting coarse sedimentation of Units 5 and 3, which presumably typify rapid accumulations caused by a sudden influx of sediment resulting from tectonic events.

REGIONAL STRATIGRAPHIC SYNTHESIS

Four DSDP holes have been drilled in the Western Philippine Basin between the Oki Daito Ridge, to the north, and the Central Basin Ridge, to the south (Fig. 1). Three of the holes, 290, 294, and 295, were drilled on Leg 31 (Karig, Ingle, et al., 1975); the fourth, 447, was drilled on the present Leg 59 (Fig. 7).

At Hole 447, we penetrated 113 meters of sediment before encountering basaltic basement. The first 25.9 meters of sedimentation consist of middle Oligocene volcaniclastic breccia interbedded with tuff. The volcaniclastic breccia is overlain by a variegated altered fine tuff, in turn overlain by a middle Oligocene polymictic breccia and a middle to lower upper Oligocene polymictic conglomerate, which are situated below a calcareous pelagic clay (totaling 49.6 m). Following deposition of the calcareous pelagic clay, carbonate sedimentation ceased, and 37.5 meters of dark-brown pelagic clay were deposited, in part, during the early Miocene.

The altered fine tuff, the upper 7.4 meters of the volcaniclastic breccia, and the basal 9 meters of breccia above the basaltic basement are barren of microfossils. The breccia and tuff between these barren zones contain nannofossils of the middle Oligocene (see Fig. 7).

The presence of two sedimentary layers containing nannofossils separated by a barren sub-unit cannot be attributed to either tectonic uplifts through the CCD or fluctuations of the CCD itself, because nearly instantaneous influxes of ashes or volcaniclastic breccias may so dilute the fossil record that the sediments appear barren. Also the pore waters created during low-temperature reactions of sea water with fresh igneous rocks may cause solution of calcareous fossils.

At Site 290, approximately 35 km to the south and east of Site 447, 255 meters of sediment were penetrated but basement was not contacted. The oldest sediment at this site is a lower-Oligocene or upper Eocene volcanic conglomerate (33 m), very similar to the volcaniclastic breccia at Site 447. Overlying the conglomerate are 83 meters of lower-Oligocene ash-rich variegated clay, similar to the unit of altered tuff found at Site 447. The succeeding 49 meters are upper-Oligocene ash- and radi-

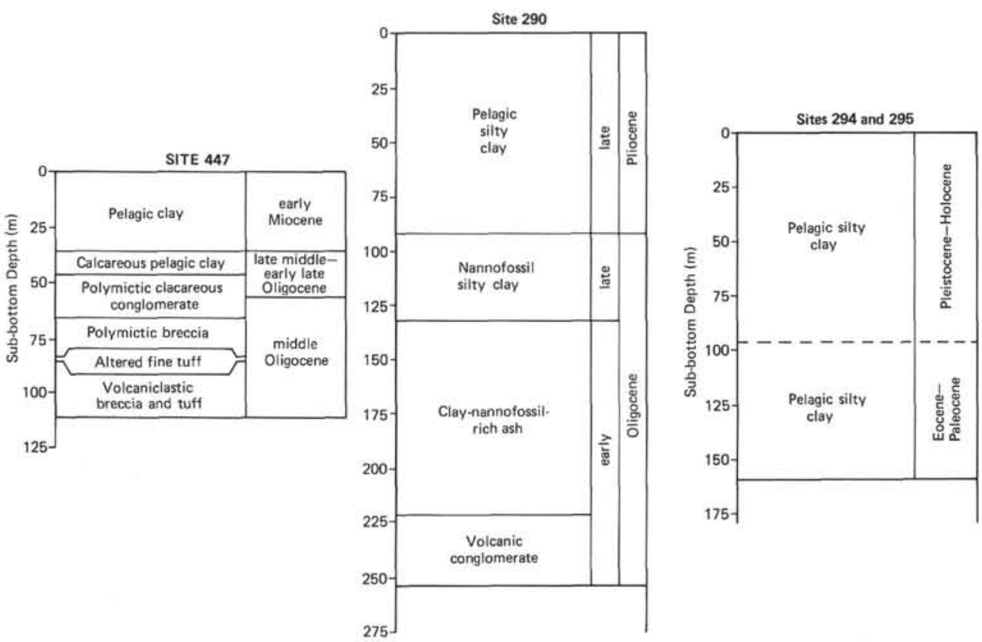

Figure 7. Summaries of stratigraphic sections encountered at Sites 447, 290, 294, and 295 within the northern part of the West Philippine Basin. (Thicknesses are in meters sub-bottom.)

olarian-bearing silty clay that is rich in nannofossils. Carbonate sediments are absent above this level, which is overlain by 90 meters of upper-Pliocene dark yellow-brown silty clay.

The combined Holes 294 and 295 had a maximum penetration of 158 meters in sediment. Initial deposition at this site consists of approximately 60.5 meters of dark reddish brown (ferruginous) silty clay with a minimum age of Paleocene-Eocene. This is capped by approximately 97.5 meters of Pleistocene-Holocene moderate brown silty clay.

The sediments from Sites 290 and 447 can be expected to reflect similar depositional histories because they are both situated on the sedimentary apron of the western flank of the Palau-Kyushu Ridge in nearly identical water depths (Site 447 at 6019 m, Site 290 at 6071 m). However, their distance from the ridge varies; Site 447 is slightly farther from the provenance (Palau-Kyushu Ridge) than is Site 290. A volcaniclastic breccia was deposited over both locations in the early to middle Oligocene. Both sites were near or above the CCD through the late Oligocene; after this period, sedimentation changed from carbonates to pelagic clay (early Miocene at Site 447) and to pelagic silty clay (late Pliocene at Site 290) when both sites fell below the CCD.

The appearance of lower Oligocene volcaniclastic breccias at Sites 290 and 447 may be related to tectonic events associated with the initiation of subduction along the Palau-Kyushu Ridge. Vertical movement associated with subduction tectonics apparently persisted throughout the Oligocene, with the exception of minor fluctuations, maintaining the sites above the CCD. After this time the sites fell below the CCD, either because of subsidence of the back-arc region following cessation of subduction or normal basin subsidence with age. The lack of Miocene sediments at Site 290 could indicate nondeposition or erosion due either to bottom currents or local tectonic adjustments.

The Oki Daito Ridge is the primary provenance for Sites 294 and 295 sedimentation and is not affected by the same tectonic processes that controlled sedimentation at Sites 290 and 447. Sites 294 and 295 remained below the CCD during their entire sedimentary history, accumulating pelagic clays and tephra. Their basal Eocene or Paleocene pelagic silty clay may represent the initial sediment type deposited at Sites 290 and 447 before disruption by tectonism.

ORGANIC GEOCHEMISTRY

Four gas shows observed in Site 447 cores (Sections 5-3, 6-3, 6-4, and 7-4) were sampled and analyzed by procedures described in the Introduction (this volume). In each gas-chromatograph analysis, hydrocarbon bases were absent, although minor amounts of CO_2 were detected. The absence of methane suggests that biogenic gaseous hydrocarbons have not been generated or preserved in significant quantities in this sedimentary environment and that the sediments themselves are of low thermal maturity and/or low in organic matter.

Twenty samples were investigated for organic carbon and nitrogen contents (see the Introduction to this volume for the procedures used). The results of these investigations are given in Table 2 and are plotted against depth in Figure 8. Only minor amounts of organic carbon were found in each of the sedimentary units, with mean values between 0.1 and 0.3 wt. % of the carbonate-free sediment. No depth trend is discernible within any of the lithologic units or the sedimentary sequence as a whole. These low values probably reflect

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

Lithologic Unit or Sub-unit	Sample (intervals in cm)	Organic Carbon (wt. %)	Nitrogen (wt. %)	C:N (atomic ratio)
1	1-1, 50-51	0.13	0.017	8.9
		0.18	0.037	5.7
		0.15	0.028	6.3
1	1-1, 51-52	0.21	0.033	7.5
		0.16	0.031	6.1
		0.15	0.028	6.3
1	1-2, 58-59	0.25	0.032	9.1
		0.20	0.025	9.4
		0.20	0.030	7.8
1	1-3, 50-51	0.12	0.023	6.1
		0.12	0.023	6.1
		0.12	0.021	6.1
1	1-4, 50-51	0.10	0.020	5.9
		0.11	0.023	5.6
		0.10	0.015	7.8
1	1-5, 50-51	0.13	0.017	8.9
		0.17	0.024	8.3
		0.10	0.012	9.7
1	4-1, 80-81	0.12	0.027	5.1
		0.12	0.031	4.6
		0.13	0.031	4.9
1	4-2, 68-69	0.22	0.022	11.7
		0.25	0.024	11.7
		0.21	0.021	11.7
1	4-3, 73-74	0.12	0.014	10.1
		0.11	0.017	7.6
		0.09	0.012	8.8
1	4-4, 51-52	0.24	0.028	10.1
		0.26	0.031	9.8
		0.32	0.030	12.5
1	4-5, 46-47	0.15	0.028	6.3
		0.16	0.027	6.9
		0.11	0.021	6.1
2	5-2, 48-49	0.13	0.009	16.8
		0.15	0.012	14.6
		0.10	0.009	13.0
2	5-3, 64-65	0.13	0.007	21.8
		0.13	0.008	19.1
		0.11	0.004	32.2
2	5-5, 33-34	0.30	0.011	31.8
		0.28	0.017	19.2
		0.35	0.015	27.3
2	5-5, 34-35	0.23	0.009	29.8
		0.20	0.007	33.5
		0.36	0.017	24.8
3a	6-1, 102-103	0.11	0.005	25.7
		0.10	0.004	29.3
		0.15	0.007	19.2
3a	7-3, 138-139	0.22	0.009	28.5
		0.15	0.005	35.1
		0.26	0.009	33.7
4	10-1, 28-31	0.15	0.009	19.5
		0.16	0.010	18.7
		0.18	0.012	17.6
4	10-2, 31-33	0.19	0.012	18.5
		0.15	0.012	14.6
		0.14	0.009	18.3
5a	10-2, 103-104	0.25	0.007	41.8
		0.27	0.005	63.2
		0.18	0.004	52.7

depositional conditions not conducive to the preservation of organic matter, such as oxic sedimentation and very low sediment accumulation rates, low productivity, or the sudden influx of volcanic debris. The nitrogen content of the pelagic clays of Unit 1 is higher (average 0.02%) than those of the underlying calcareous pelagic clays, polymictic conglomerates and breccias, altered tuffs, and volcaniclastic breccias of Units 2, 3, 4, and 5 (average 0.01%); this possibly reflects particle-size differences between these lithologies, because nitrogen is often concentrated in sediments of finer grain size. No uniform depth or diagenetic trend is observed for the C:N ratio, whose mean values range from 5 to 52.

Methods used for the 20 Rock Eval analyses are given in the Introduction (this volume). A summary of the results from the Rock Eval analyses is given in Table 3. In qualitative terms two significant aspects regarding the state of the organic matter are shown by these analyses. First, anomalously large and irregular S_2 responses for samples from Units 1 and 4, maximizing at 550°C, cannot be attributed to highly mature organic matter or to pipe-dope contamination. In contrast, pipe-dope sampled from the Core 2 core-catcher sample has a broad S_1 peak and only a minor S_2 response. The appearance of similar anomalous S_2 peaks from analyses of analogous clay-rich lithologies at Sites 449 and 450 suggests that this S_2 response may arise from an as yet undefined interaction of unconsolidated clay with organic matter or from the clay itself. Second, the calcareous lithologies of Unit 1 and Sub-unit 3a give minimal S_1 and S_2 responses, indicating their lack of pyrolyzable organic matter. The high value of the S_3 peak for Unit 2 samples can be attributed to a contribution from inorganic CO_2 not wholly excluded in such carbonate-rich lithologies.

The low amounts of organic carbon throughout Site 447 have limited the possible scope of the organic geochemical analyses. In addition, the presence of pipe-dope contamination in several cores (notably, the core catcher of Core 2) complicates interpretation of the hydrocarbon analysis.

INORGANIC CHEMISTRY OF INTERSTITIAL WATER

Samples for interstitial-water studies were taken from Sections 447A-4-3 and -6-5. Analytical techniques are given in the Introduction (this volume). Figure 9 presents data for inorganic parameters measured. (IAPSO standard and a surface sea-water sample are shown for comparison.) The collection and investigation of only two samples precluded detailed evaluation of diagenetic trends.

IGNEOUS PETROGRAPHY

Basaltic basement was encountered at a depth of 133 meters sub-bottom; after penetrating 183.5 meters of tholeiitic flows and pillow basalts, the maximum depth of 296.5 meters was reached. As a result of good drilling conditions (60% basalt core recovery), long uninterrupted cores were obtained. Observations of preserved glassy margins of pillows and flows made it possible to measure accurately flow and pillow dimensions. About 28 meters of middle-Oligocene volcaniclastic breccias and tuffs overlie this basement section. The basalts are subdivided into six major units based on hand-specimen lithology and thin-section petrography (see Fig. 6). Many of these major petrographic units are composed of several well-defined eruptive cooling units.

Three categories of eruptive cooling units exist: single lava flows composed of massive basalt, sometimes with ophitic textures in the center; pillow lava flows; and pil-

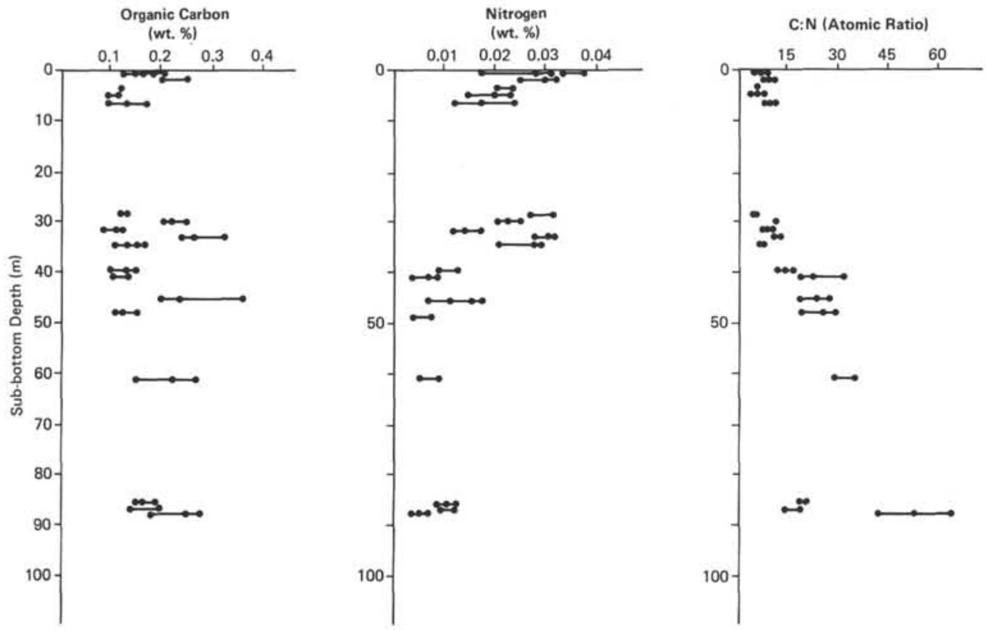

Figure 8. Results of organic carbon and nitrogen analyses of sediment samples versus depth in sub-bottom meters.

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

Lithologic Unit or Sub-unit	No. of Samples	Free Hydrocarbon (S_1)	Bound Hydrocarbon (S_2)	CO_2 from Kerogen (S_3)
1	11	+	+ + +	+
2	4	+	–	+ +
3a	2	+	+	+
4	2	+	+ + +	+
5a	1	+	+	+

Note: – = undetectable, + = minor, + + = moderate, and + + + = major relative amounts.

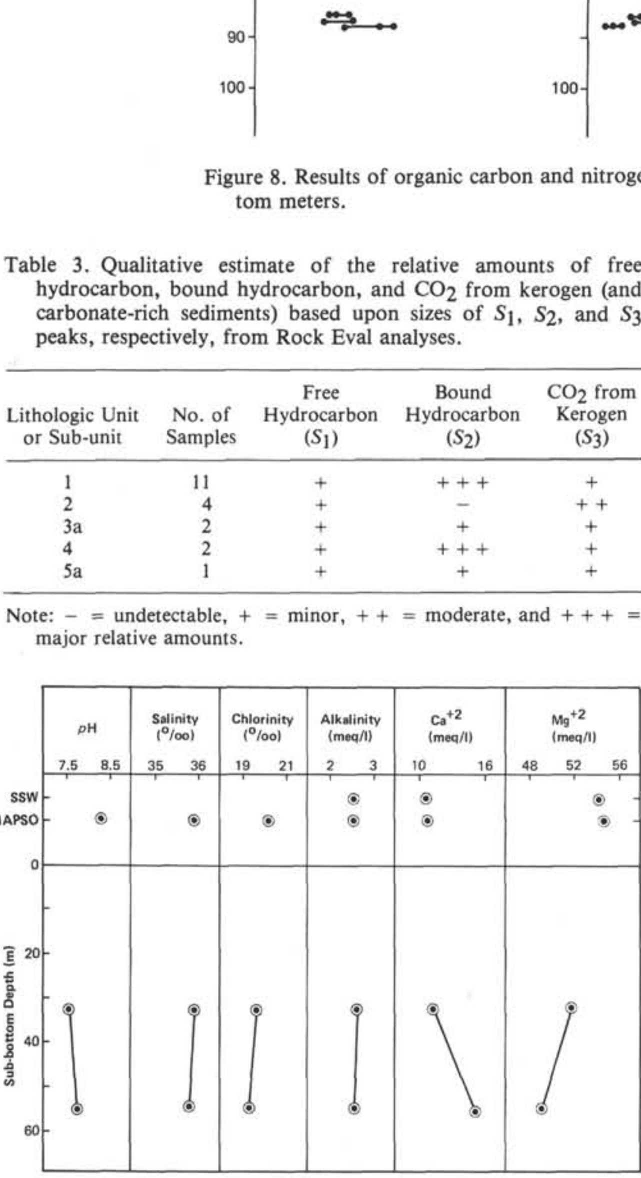

Figure 9. Results of analyses of interstitial water samples versus depth in sub-bottom meters. Values for *p*H, salinity, chorinity, alkalinity, and Ca- and Mg-ion concentrations in millimoles per liter are plotted. (IAPSO standard and a surface sea water sample are shown for comparison.)

lowed massive flows composed of upper pillow lavas underlain by a massive flow. Two eruptive units of the single lava flow type are distinguished (Sub-unit 6a and Unit 9). Sub-unit 6a is a massive basalt flow 2 meters thick, and Unit 9 is a massive basalt flow 9.5 meters thick with doleritic affinities in its interior.

There are five units of pillow lava flows from 7 to 35 meters thick. These cooling units may be composed of smaller cooling units, but further subdivision cannot be made with available evidence. The pillows themselves range in diameter from 0.25 meters to 1.5 meters and average 0.5 meters.

Many eruptive units composed of an upper layer of pillow lava (1.0–12.0 m thick, averaging 5.2 m) that grades into a lower massive flow base (1.0–7.5 m thick, averaging 3.6 m) have been identified as pillowed massive flows. These compound flows are from 2 to 19 meters thick, and the pillowed portion comprises an average of 60% of each unit. The rhythmic sequence of pillow lava–massive flow is a striking feature of the lithology of Hole 447A. Of the 18 probable cooling units, 11 are of this compound type. We consider each pillowed unit and the underlying massive flow to constitute a single eruptive unit, rather than two separate flows, in much the same manner that autobreccia is part of an underlying massive subaerial flow.

An area of intense brecciation occurs within the lava pile at a sub-basement depth of 114 meters (227 m sub-bottom). The zone of brecciation cuts the core at an angle of approximately 65° and is about 0.6 meters thick (true). The occurrence of this brecciated zone is interpreted as a minor fault with rather limited movement (<1 m).

The deepest basalts recovered (Sub-unit 11f) contain xenoliths of anorthositic cumulates and xenocrysts of resorbed gabbroic plagioclase and spinel, both of which are clearly out of equilibrium with the melt. Seismic data have shown that Layer 2 is abnormally thin in the region of Hole 447A. The appearance of cumulate inclusions and xenocrysts suggests that the basalts of Sub-unit 11f may contain phases carried from cumulate magma chambers from Layer 3.

As discussed in the petrology chapters (this volume), the basalts are chemically and mineralogically indistinguishable from mid-ocean ridge (MOR) tholeiitic basalts. The basalts are subdivided on the basis of phenocryst content as follows:

1) aphyric to olivine-spinel-phyric—Unit 9
2) plagioclase-phyric—Units 6, 7
3) plagioclase-olivine-spinel-phyric—Unit 11
4) plagioclase-clinopyroxene-olivine-phyric—Unit 8
5) olivine-plagioclase-clinopyroxene-phyric—Unit 10.

The majority of the pillow lavas have prominent, usually fresh, glassy rims. The glassy rims vary from 1 mm to 2 cm in width and grade through hyalopilitic into variolitic basalt toward the pillow interior. The cores of the pillows are fine-grained, intersertal to ophitic in texture, but are rarely more than 75% crystalline except in the largest pillows. Pillows composed of porphyritic basalt commonly show gravity settling of phenocrysts, notably olivine.

Interpillow glass breccias are common. These glass breccias are composed of shards and fragments, which may be fresh or altered to either palagonite or green, concentrically banded smectites. The breccias are cemented and commonly veined with secondary carbonate and zeolite minerals.

The massive basalt flows, usually between 75 and 100% crystalline, have textures that range from intersertal, through pilotaxitic, to strongly ophitic. Grain size varies from fine to medium-grained.

Most of the basalts from Hole 447A show extensive low-temperature alteration. Only very rarely is fresh olivine observed and only as relict cores. Olivine alters chiefly to a rusty-brown acicular aggregate of smectite and Fe oxides, readily visible in hand specimen. Interstitial glass alters to a similar aggregate of brown smectites; however, pillow margin glass is commonly altered to green smectites. Plagioclase is only rarely altered, and, except in cases of extreme alteration, pyroxene remains fresh.

Vesicles within the basalts are rare (in most cases less than a few per cent of the rock) and commonly are partially or completely filled with brown smectites, green smectites, carbonates, and, in some cases, with zeolites.

Pillowed basalts show the greatest contrast in degree of alteration. Usually at least some of the glass remains fresh, whereas the hyalopilitic or variolitic material adjacent to the margin is commonly oxidized to an extremely altered, mottled pale-brown basalt. The cores of the pillows contain the freshest basalts except for remnants of quenched basaltic glass on the margins. Veins and cavities of calcite, zeolites (phillipsite), sulfides, and rare quartz are present, especially as filling of radial cooling fractures within the pillow basalts. Brown zones of oxidized basalts have formed adjacent to these veins. Least-altered crystalline basalts are found in fracture-free parts of the coarsest zones of massive flows. No high-temperature alteration minerals (e.g., chlorite, epidote, or actinolite) have been observed, and all the alteration and veining described are considered to be of low-temperature origin.

In the following petrographic descriptions, the abundance of phenocrysts and groundmass constituents are given as percentages of the whole rock (for example, 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 (for example, 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%]).

Unit 6 (113.0–131.5 m sub-bottom) is composed of 18.5 meters of plagioclase-phyric tholeiitic basalts and can be divided into four sub-units.

Sub-unit 6a is a massive plagioclase-phyric basalt flow about 2 meters thick, gray, fine-grained, with sparse spherical vesicles (5%, 0.5–5 mm) filled with carbonates, sometimes rimmed with yellowish green smectite. Two per cent plagioclase phenocrysts (2 mm, $\sim An_{75}$) and less than 2% plagioclase glomerocrysts are present in the rock. The subophitic to almost holocrystalline ophitic groundmass is composed of plagioclase laths (50%, ~0.5 mm long, $\sim An_{68}$), granular plumose clinopyroxene (45%, 0.2 mm) between plagioclase laths, and magnetite (5%, 0.01 mm granular crystals). Small grains of olivine (0.1 mm) may have been replaced completely by smectite and carbonate minerals. The flow is crisscrossed by several generations of veins (1–2 mm thick) filled mainly with carbonate minerals.

Sub-unit 6b consists of 8 meters of plagioclase-phyric pillow basalt similar in petrography to Sub-unit 6a. The rock varies in texture from almost glassy on the margins of pillows to holocrystalline ophitic in the interior. Pillows are crossed by rare, small (1–2 mm), fine-grained dikes of the same mineralogic composition as the host pillow; these may be segregation veins filter pressed out of crushed pillows. The pillows are also cut by veins (0.5–1 mm) filled mainly by carbonates. Scattered vesicles, which are mostly spherical, range in size from 0.05 to 0.1 mm and make up only 3% of the rock; these are partially or completely infilled with carbonates rimmed by smectite. Sparse glomerocrysts of plagioclase (1 mm) occur. The inner parts of pillows show a subophitic groundmass. The groundmass consists of plagioclase laths (45%, ~0.8 mm in length), clinopyroxene (45%), olivine (3%, completely replaced with clays and carbonates), magnetite euhedra (2%), and alteration products (5%). The latter mainly consist of carbonates, clays (after olivine and some clinopyroxene), and hematite (after magnetite).

Sub-units 6c and 6d are petrographically similar and consist of pillowed massive flows of plagioclase-phyric basalts (2 m and 6.5 m thick, respectively). Massive basaltic flows and the interior of pillows are approximately 80 to 85% crystalline, gray in color, fine-grained, with frequent pale-brown mottling and brown patches along cracks (due mainly to alteration of groundmass). Only about 3% blocky plagioclase glomerocrysts are present in both sub-units. Thin veins (0.5 mm–1 mm) are filled with carbonates and zeolites. Vesicles (3%, 0.1 mm) appear to be largely empty or partially infilled with carbonates, zeolites, and smectites. Scattered irregular vugs are lined with zeolites. The groundmass is characterized by a subophitic texture and consists of plagioclase laths (50%, 0.8 m), granular clinopyroxene (44%, 0.2 to 0.4 mm), olivine (3%, completely replaced with clays), magnetite (3%, 0.02 mm), and alteration products (carbonate, clays, and smectite—which replaces olivine—intergranular glass, and some pyroxene and plagioclase).

Unit 7 (131.5–141.0 m sub-bottom) consists of 9.5 meters of plagioclase-phyric tholeiitic pillow basalt. As in the basalts of the previous unit, the inner parts of the pillows are about 80% crystalline, fine-grained, and characterized by subophitic texture and low vesicularity (3%). Only sparse plagioclase phenocrysts exist. Vesicles are filled with smectite and carbonate. Rarely, the basalt becomes somewhat coarse and approaches dolerite; otherwise, it is very uniform. The groundmass consists of plagioclase laths (50%, 1 mm, $\sim An_{68}$), euhedral clinopyroxene (35%), pseudomorphs of olivine (10%, 0.25 mm), and magnetite and alteration products (5%). Olivine and glass are replaced completely with aggregates of clay, carbonate, and smectite. Pyroxene and plagioclase have undergone relatively slight alteration.

Unit 8 (141.0–185.0 m sub-bottom) is divided into four pillowed massive flow cooling units. The basalts belonging to this unit are plagioclase-clinopyroxene-olivine-phyric tholeiites.

Sub-unit 8a, 13.5 meters thick, is composed of a 1.4-meter-thick massive flow overlain by 12.1 meters of pillow basalt. The basalts contain up to 20% phenocrysts consisting of euhedral to subhedral olivine ($\sim$50%, 0.9–1.0 mm, pseudomorphed by brown smectite and sometimes carbonate and zeolite), and glomerocrysts of plagioclase ($\sim$50%, 1–2 mm, An_{70-85}). The groundmass is hyalopilitic and variolitic to subophitic with up to 80% glass, depending on the position within the pillowed massive flow. Plagioclase, clinopyroxene, and glass are the dominant groundmass minerals with subordinant magnetite. Vesicles are usually less than 1% of the groundmass and lined with either calcite and zeolites or dark olive smectite.

Sub-unit 8b is 12.5 meters thick and consists of a 2.5-meter thick massive flow overlain by 10.0 meters of pillow basalt. The groundmass is hyalopilitic to subophitic and contains only slightly more than 5% phenocrysts consisting of glomerocrysts of plagioclase ($\sim$80%, 1.5 mm) and olivine ($\sim$20%, 0.6 mm, altered to carbonate and smectite).

Sub-unit 8c is 3.5 meters thick and consists of a 1.5-meter massive flow overlain by 2.0 meters of pillow basalts, which are similar to those described above, except that they contain less than 10% phenocrysts, consisting of plagioclase (<50%, <1 mm) and olivine (50%, 1–2 mm, replaced by iddingsite), and have a groundmass very rich in glass. Figure 10A shows variolitic nucleation around microphenocrysts in the glass of a pillow margin.

Sub-unit 8d is 14.5 meters thick and consists of an 8.0-meter-thick massive doleritic flow that grades upward into 6.5 meters of pillow basalts. The latter contains about 2% phenocrysts of olivine and plagioclase (An_{74}), similar to those in Sub-units 8a to 8c. Groundmass textures range from hyalopilitic through variolitic to pilotaxitic (Fig. 10B). The dolerite contains less than 5% phenocrysts consisting of plagioclase (60%, An_{64-73}, 1-cm-long glomerocrysts) and olivine (<40%, <0.5mm, pseudomorphed by carbonate, smectite, or zeolite). The groundmass is subophitic (grain size about 1 mm); dominant minerals are plagioclase (An_{65}), clinopyroxene, and titanomagnetite. There is slight alteration of pyroxene to smectite.

Unit 9 (185.0 to 194.0 meters sub-bottom) is 9.0 meters thick and consists of aphyric to sparsely olivine-spinel-phyric, fine- to medium-grained, gray, almost holocrystalline dolerite. The texture is ophitic to subophitic (near the base) as shown in Figure 10C. The vesicularity is low and ranges from 0–2% with vesicles (0.05 mm) partially filled with green smectite. Veins are absent except near the base of the unit. Thin sections indicate a groundmass composition of plagioclase (50%, An_{72}), clinopyroxene (45%), and magnetite (5%). The dolerites are fresh and have undergone only slight secondary alteration. Near the base of Unit 9, olivine phenocrysts appear and gradually increase in quantity downward toward the boundary with Unit 10.

Unit 10 (194.0–209.0 m sub-bottom) is 15.0 meters thick and consists of olivine-plagioclase-clinopyroxene-phyric tholeiitic basalts. It can be divided into two sub-units.

Sub-unit 10a is 9.5 meters thick and is a pillowed massive basalt flow. These pillows have fine-grained, extremely altered tops and bottoms rimmed with completely altered glass. The glass is mainly replaced with yellowish green smectite. Inner parts of the pillows are coarser and consist of crystallized basalt with phenocrysts and microphenocrysts of olivine, plagioclase, and clinopyroxene. Scattered vesicles (2%, 0.05 mm) are filled with brown smectite. Pillows are veined by fine-grained aggregates of carbonates and zeolites. A thin section from a pillow core indicates sparse phenocrysts and microphenocrysts of olivine, plagioclase, clinopyroxene (50%), magnetite, and products of groundmass alteration (5%).

Sub-unit 10b is 5.5 meters thick and consists of a pillowed massive olivine-plagioclase-clinopyroxene-phyric basalt, with an ophitic to subophitic groundmass. The latter is composed of plagioclase (50%), clinopyroxene (50%), and opaques and alteration products (5%).

Unit 11 (209.0–296.5 m sub-bottom) is 87.5 meters thick and consists of plagioclase-olivine-phyric tholeiitic basalts. It is subdivided into five pillowed massive flow units and one basalt pillow lava unit.

Sub-unit 11a is 19.5 meters thick and comprises a 9.0-meter basal flow overlain by 10.5 meters of pillowed massive basalts, which contain 5% phenocrysts con-

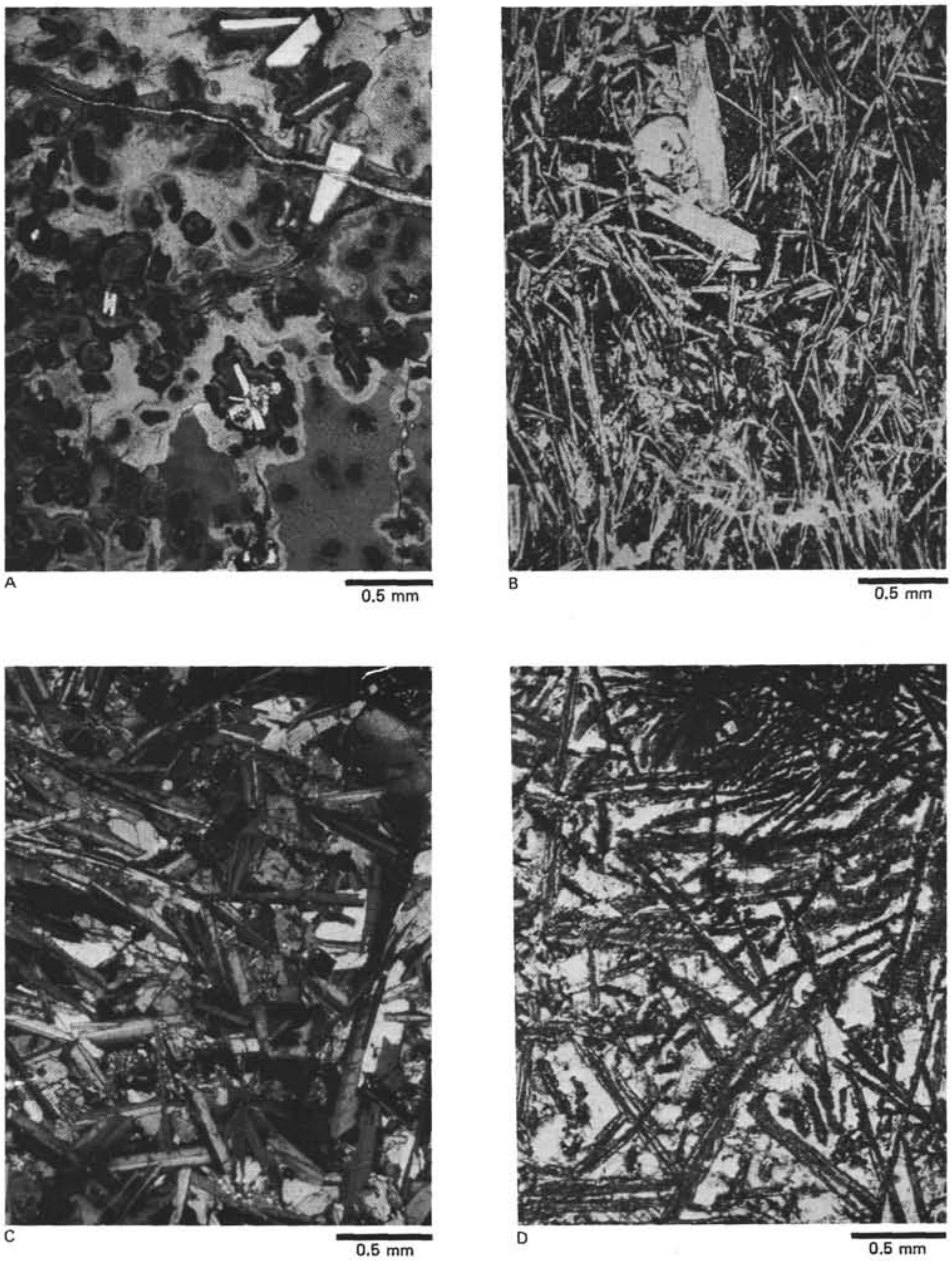

Figure 10. A. Variolitic growths nucleating around microphenocrysts during the initial stages of devitrification of fresh glass from a pillow margin of Sub-unit 8c. (A thin radial fracture is filled with calcite—Section 447A-21-1, [Piece 11]; plane polarized light; bar is 0.5 mm long.) B. Plagioclase phenocrysts in a flow-banded hyalopilitic groundmass composed of plagioclase microlites and altered glass. (Center of pillow from near the top of Sub-unit 8d—Section 447A-21-4, [Piece 3]; plane polarized light; bar is 0.5 mm long.) C. Ophitic dolerite from massive flow base of Unit 9. (Section 447A-24-2 [Piece 2e]; cross polarized light; bar is 0.5 mm long.) D. "Anti-ophitic" texture from a clast of hyalopilitic basalt contained in a zone of brecciation in Unit 11a. (This texture is characterized by the occurrence of lath-like or plumose clinopyroxene crystals that are commonly slightly curved. These crystals are subpoikilophitically enclosed by plagioclase, creating the antithesis of ophitic texture—Section 447A-29-1, [Piece 2a]; plane polarized light; bar is 0.5 mm long.)

sisting of euhedral olivine (50%, microphenocrysts to 1.5 mm, pseudomorphed by green and gray smectite), subhedral plagioclase (50%, 0.5 to 2 mm, partly or wholly altered to zeolites and pale-green smectite), and rare clinopyroxene (0.5 mm, altered). A few translucent brown chrome spinel microphenocrysts occur. The groundmass displays a complete range of textures, depending on the degree of quenching (glassy, hyalopilitic, variolitic, intersertal, subophitic, and pilotaxitic). Groundmass minerals include plagioclase ($\sim An_{67}$), clinopyroxene, and titanomagnetite. Vesicles make up less than 5% of the total rock and are infilled with carbonate and smectite.

Within this cooling unit is a 0.6-meter-wide breccia, which may represent a fault zone as previously discussed. The breccia clasts display a very wide range in texture, including the inverse of an ophitic texture, or an "anti-ophitic" texture, characterized by thin laths of clinopyroxene set in a plagioclase matrix (Fig. 10D). This texture occurs at the edge of a normal glassy zone adjacent to a vein of calcite. It is doubtful that it is related to the calcite vein, because no evidence of high-temperature alteration exists.

Sub-unit 11b is 6.5 meters thick and consists of a 5.0-meter massive flow overlain by 1.5 meters of pillow basalt similar to those described from Sub-unit 11a. These basalts of Sub-unit 11b contain phenocrysts of olivine, plagioclase, rare clinopyroxene, and chrome spinel set in a variolitic groundmass.

Sub-unit 11c is 4.5 meters thick and consists of a 1.5-meter massive flow overlain by 3.0 meters of pillow basalt. In hand specimen, it is similar to Sub-units 11a and 11b, containing 10% phenocrysts of altered olivine and plagioclase set in an ophitic or fine-grained ophitic groundmass.

Sub-unit 11d is 7.5 meters thick and is composed entirely of pillow basalts containing 7% phenocrysts of anhedral olivine (30%, 1 mm, completely altered) and subhedral plagioclase (70%, 0.5–0.7 mm, partially altered) set in an intersertal to pilotaxitic groundmass composed of plagioclase (An_{70}) and plumose clinopyroxene. Rare octohedra of chrome spinel occur in the glass. Spherical vesicles lined with zeolite and smectite form 3% of the rock.

Sub-unit 11e is 35.0 meters thick, is generally rather uniform, and consists of plagioclase-olivine-phyric pillow basalts. The inner parts of the pillows have phenocrysts of olivine and plagioclase with sparse glomerocrysts in a fine-grained matrix. Olivine is observed only as pseudomorphs replaced with smectite, calcite, clay, and zeolites. The groundmass is subophitic and is composed of plagioclase laths (45%, 0.5 mm, $\sim An_{69}$), plumose clinopyroxene (35%, 0.02 mm) crystallized between the plagioclase laths, completely altered olivine (10%, 0.1–0.2 mm), opaques (5%), and glass and alteration products (5%). Pillows enriched with either plagioclase or olivine phenocrysts are commonly observed. It is noteworthy that basalts of the lower part of the unit contain small (0.2 mm) resorbed, euhedral xenocrysts of spinel; these spinels are included in olivine and in the glassy matrix (the spinels are almost completely absent in the middle and upper parts of the unit). Peripheral zones of pillows are characterized by hyalopilitic to variolitic textures. The groundmass contains phenocrysts of plagioclase and olivine and microphenocrysts of clinopyroxene and plagioclase. Most of the marginal glassy rims of pillows are completely altered and replaced with green smectite. Examples of local interpillow autobrecciation of glassy rims are common. Fragments of glass and fine-grained basalts on pillow peripheries are cemented with a fine-grained mass of zeolites and carbonates. Pillows contain rare, scattered, spherical vesicles (1–2%, 0.2–0.3 mm), most of which are completely filled zeolites, carbonates, and smectites.

Sub-unit 11f is at least 14.5 meters thick and is the deepest penetration in Hole 447A (total depth = 296.5 m sub-bottom). It is a plagioclase-olivine-tholeiitic basalt that appears identical to Sub-unit 11e except for the occurrence of an anorthositic cumulate xenolith and plagioclase and spinel xenocrysts. The basalts contain about 10% phenocrysts of anhedral olivine (10%, 1–2 mm, pseudomorphed by brown smectite and zeolite), euhedral plagioclase (<90%, 1.2 mm), and translucent, brown octahedra of chrome spinel (0.2 mm). The chrome spinel occurs as microphenocryst inclusions both in glass and olivine pseudomorphs. The groundmass is 80 to 100% crystalline, subophitic, often with plumose clinopyroxene.

The xenocrysts of anhedral gabbroic plagioclase (0.5–2 cm in diameter) are extremely well rounded, probably because of magmatic corrosion. They also have large anhedral inclusions of brown chrome spinel (0.5–3 mm diameter), suggesting the gabbroic origin. Isolated xenocrysts of spinel show strong disequilibrium with the host basalt (strongly corroded outline with deep embayments). The small xenolith of a fine-grained (~5 mm) anorthositic cumulate occurs near the base of the unit. The cumulate texture of the plagioclase probably suggests that this xenolith was part of the cumulate portion of a gabbroic magma chamber.

METAMORPHIC PETROGRAPHY

Although extensive alteration of basaltic flows and pillow lavas occurs at glassy boundaries and within brecciated portions of the units, only low-temperature alteration phases exist; unambiguous petrographic evidence of either hydrothermal metamorphism of the rocks or high-temperature hydrothermal vein formation is not found. The presence of phillipsite in veins with calcite cannot be taken as an indicator of zeolite-grade metamorphism, because authigenic phillipsite forms at sediment-column ambient temperatures during sediment diagenesis.

CONTACT RELATIONS AND STRATIGRAPHY

The Igneous/Sedimentary Contact

Igneous/sedimentary contacts and stratigraphic relations in Hole 447A are difficult to interpret. Within the lower 47 meters of the middle Oligocene sedimentary sequence (Sub-unit 3b–Unit 5), basaltic clasts occur with increasing abundance, size, and freshness down-section. In the lower 26 meters of this sequence (Unit 5), volcanic glass is abundant in the matrix of sedimentary rocks. In the lowest meter above the igneous contact, 5-cm-diameter clasts similar to the uppermost basalt flow are found. Because these clasts are brecciated, highly angular pieces of basalt, they were probably derived as talus associated with local fault scarps. Two interpretations are possible. The first is that the basalt basement is only slightly older than the overlying middle Oligocene sediments. This hypothesis suggests that shortly after extrusion of basalts along the spreading-center axis, local tectonic activity, associated with the accreting plate margin or transform faulting, shed fault-scarp debris on the basalt flow. This interpretation necessitates that the basaltic basement is of the middle Oligocene (about 32 m.y.); such a hypothesis is in conflict with the plate-tectonic reconstruction of Hilde et al. (1976) and with the magnetic-age estimates of Louden (1976), both of which posit that the age of the basement at Hole 447A is roughly 50 m.y. Still another objection to basaltic basement being only slightly older than the overlying middle Oligocene sediments is the absence of a source of numerous sedimentary clasts in the overlying polymicitic breccia of Unit 3b. Note the discussion on Accumulation Rates in this report in which the breccias are thought to accumulate over a very short peroid of time.

The second interpretation of the contact resolves inconsistencies in the first but creates new problems: If basaltic basement is approximately 50 m.y. old, then a mechanism is required first to strip off sediments that accumulated between 50 and 30 m.y. ago and then to deposit a tectonic igneous breccia on that resulting erosion surface. These tectonic events must occur in old ocean crust. Resolution of this problem may be found by superimposing back-arc tectonics on the West Philippine Basin when the Palau-Kyushu Ridge became a subduction zone in the late Eocene (Hilde et al., 1976). Although the effects of arc formation on the edge of a trapped marginal basin are unknown, it is probable that enough vertical tectonism was felt close to the Palau-Kyushu Ridge to strip off older sediments and subsequently to deposit middle-Oligocene breccias on the older basement by local fault movements. Distinction between these two interpretations has not been established by radiometric dating of the basement rocks, because alteration effects could not be removed (see Sutter and Snee, this volume). Perhaps more definitive magnetic-anomaly identification may resolve the age of the West Philippine Basin.

The Distinction between Extrusive Units

Identification of extrusive cooling units within a volcanic sequence is difficult when the units include pillow lavas, even if the glassy margins of the cooling units are preserved. The glassy margins between two pillows within a pillow-lava cooling unit have the same physical characteristics as do the glassy margins between two massive flow cooling units and the glassy margins between two pillow lava cooling units. Apparently, alteration by sea-water migration along glassy boundaries affects pillow contacts within a cooling unit in the same manner as it affects exterior contacts of the entire cooling unit. A logical boundary to use as stratigraphic marker between extrusive cooling units is the glassy base of a massive flow unit. If this stratigraphic marker is used, three types of extrusive cooling units are recognized: (1) a single massive flow unit (for example, Unit 9); (2) a pillow lava flow sequence with no apparent lithologic breaks (for example, Sub-unit 11e); and (3) a sequence of pillows that are so lithologically similar to an underlying flow that they appear to have formed as one extrusive cooling unit (for example, Sub-units 8a–8d). These are called pillowed massive flows.

No major problems are associated with recognition of single massive-flow units as long as the glassy contact is preserved. A problem does exist with the second category of extrusive cooling unit. A pillow lava flow sequence of similar lithologies cannot be subdivided into individual igneous extrusive events, and thus only a minimum number of cooling units are recognized. Problems also exist in recognition of the third type of extrusive cooling unit, the pillowed massive flow. The pillowed massive flow in a subaqueous environment is somewhat analogous to the autobrecciated flow in the subaerial environment. If this analogy holds, then a problem exists in the subaqueous case because some of the autobrecciated rind of subaerial flows is overrun by the flow itself in a "tractor-tread" fashion, which creates a thin layer of autobreccia at the flow base in addition to the thick autobreccia at the flow top. Thus, a subaqueous flow may also incorporate some of its pillow lava top under the advancing flow front. Obviously, a distinction between pillows of this "tractor-tread" origin and pillows from an underlying, petrographically similar cooling unit cannot be made in the drill core. For this reason, the base of a pillowed massive flow cooling unit is arbitrarily defined at the glassy base of the flow. Notwithstanding, this definition of a flow boundary still allows intelligent petrologic sampling of major extrusive cooling units and therefore justifies use of this arbitrary demarcation between units.

Fortunately, recovery of basalt core in Hole 447A was unusually high, preserving many of the critical glass contacts; of 183.5 meters cored, over 100 meters (nearly 60%) were recovered. Therefore, thick massive flow units (for example, Unit 9) can be distinguished by glassy bases as extrusive cooling units rather than as sills or dikes, even though the centers of these flows have a doleritic character (crystals greater than 1 mm in diameter with ophitic textures). In contrast, an intrusive cooling unit would not have glassy tops and bottoms.

PILLOW LAVAS

The pillows within the lavas of Hole 447A show the following zones from their outer crust to their interiors: a black to dark-green glass zone commonly 5 cm thick; a brownish gray to gray variolitic zone, 5 to 10 cm thick; a pale-brown to dark-brown transition zone up to 20 cm thick; and a dark-gray to dark-green crystalline interior. Glass zones are indicators of pillow boundaries and may be present on the tops of the pillows (upper glass zones), on the bottoms (lower glass zones), or on both, depending upon core recovery and mode of pillow formation (Table 4). We recognize more pillows with upper glass zones than those with lower glass zones. With rare exception, pillow lavas break into drill-core pieces at glass junctions; thus, it is not clear whether the absence of lower glass zones is a function of (1) drilling physics or (2) pillow lava formation. During drilling, the tops and bottoms of core pieces usually form, respectively, ball and socket joints; the tops are convex up and the bot-

Table 4. Number of pillows found in core recovered in Hole 447A.

Unit	UG	LG	ULG	Total
1	9[a] (3)[b]	2 (0)	4 (4)	15 (7)
2	1 (1)	0 (0)	1 (1)	2 (2)
3	21 (12)	6 (2)	8 (8)	35 (22)
4	0 (0)	1 (0)	0 (0)	1 (0)
5	6 (1)	2 (0)	1 (1)	9 (2)
6	16 (6)	6 (1)	10 (10)	32 (17)
7	8 (3)	3 (3)	15 (15)	26 (21)
8	8 (5)	3 (2)	12 (12)	23 (19)
Total	69 (31) 48%	23 (8) 16%	51 (51) 36%	143 (90)

Note: UG = upper glass zone; LG = lower glass zone; and ULG = upper and lower glass zone.
[a] cm
[b] The number in parentheses is the number of pillows used for size estimation.

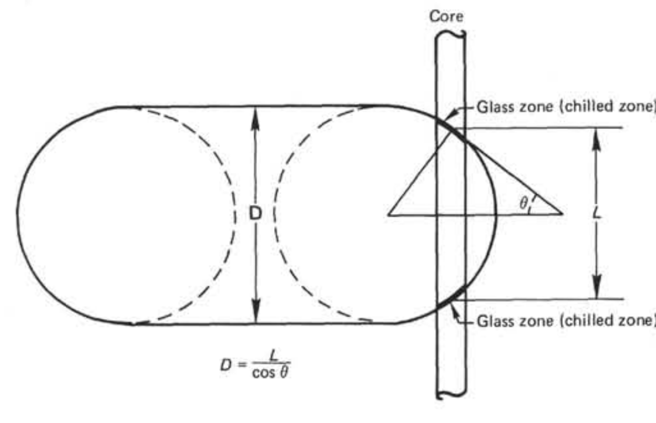

Figure 11. The assumed relative dimensions of pillows. (Estimates of the diameters [D] of pillows are based upon the measured distance [L] between the chilled zones in the drill core and the angle [θ] formed by the tangent to the chilled zone and the horizontal. The angle θ is the measured dip of the glassy margins.)

Table 5. Mean minimum diameter of pillows.

Unit	UG	LG	ULG	Mean
1	38[a] (3)[b]	—	42.5 (4)	40.5 (7)
2	45 (1)	—	40 (1)	42.5 (2)
3	36 (12)	25 (2)	58 (8)	40.5 (22)
4	—	—	—	—
5	45 (1)	—	25 (1)	35.0 (2)
6	41 (6)	60 (1)	66.5 (10)	56.5 (17)
7	68 (3)	60 (3)	45.4 (15)	51.0 (21)
8	29 (5)	65 (2)	30 (12)	30.0 (19)
Mean	39.7 (31)	44.4 (8)	47.1 (51)	44.0 (90)

Note: UG = upper glass zone; LG = lower glass zone; and ULG = upper and lower glass zone.
[a] cm
[b] The number in parentheses indicates the number of pillows used for size estimation.

toms are concave down. The concave-down pieces of core have probably lost bottom chips, resulting in fewer glass bottoms relative to glass tops. If drilling physics is not responsible for the bias toward more glassy tops than bottoms, then perhaps the phenomenon is caused by a difference between formation of pillow tops and bottoms. The observed ratio of upper glass to lower glass zones is 3:1. In well-preserved cores, three types of boundary relationships between neighboring pillows can be observed: upper pillow glass in contact with lower pillow glass; upper pillow glass in contact with lower pillow variolitic zone or marginal transition zone; and upper pillow variolitic zone or transition zone in contact with lower pillow glass. The reason for the absence of the lower glass zone on some pillows is uncertain, but perhaps either the lower pillow was still hot when the upper pillow formed or exposure to sea-water cooling was insufficient to chill the pillow bottoms adequately and preserve glass.

We measured the distance between both the horizontal and inclined upper and lower pillow margins in well-preserved cores recovered from Hole 447A. Many glass margins, however, were found to be inclined to the drill-core axis. If it is assumed that recovered fragments are correctly oriented, these inclined margins can be used in the size estimates. Assuming the pillows possessed parallel upper and lower surfaces and assuming the drill core penetrated the pillow off center and thus the true thickness D in Figure 11 was not recovered, the measured distance L represents an apparent thickness less than the true thickness of the pillow. The total of 90 measured pillows (Table 5) gives a mean minimum thickness of 44 cm; the modal thickness is 30 cm, with a total range in thickness of from 10 to 140 cm (Fig. 12). Assuming the pillow to be the two half spheres of diameter D and to have flat upper and lower surfaces as drawn in Figure 11, the attitude of the glassy layers can be used to solve the equation $D = L/\cos\theta$, in which L is the distance between the chilled margins and θ the angle of dip relative to the drill-core axis.

We measured several pillows in well-recovered cores (<80%) for the parameters L and θ, and the results (Table 6) show that the mean diameter was increased by an average of 25% over the minimum thickness reported in Table 5. These data suggest that the average diameter of the pillows in Hole 447A is 55 cm.

A similar study was made at Hole 417A, where mean minimum thicknesses were estimated using the assumptions already outlined. The diameters of pillows in Hole 417A, however, were calculated from measurements of the radial fractures preserved in the pillow margins, a feature more characteristic of the pillows from Hole 417A than from Hole 447A. The pillows at 417A have a mean minimum thickness of 66 cm and a mean diameter of 92 cm, which is significantly greater than the results obtained from Hole 447A (Donnelly, Francheteau, et al., in press).

PALEOMAGNETISM

A seafloor magnetic-anomaly study of the Southern Philippine Sea by Louden (1976) suggests that the ocean crust in the vicinity of Site 447 was formed on the northern flank of an east-west oriented north-south spreading center during Cenozoic times. Figure 13 is a summary of regional magnetic studies in the Philippine Sea (Watts et al., 1977; Louden, 1976; Tomoda et al., 1975;

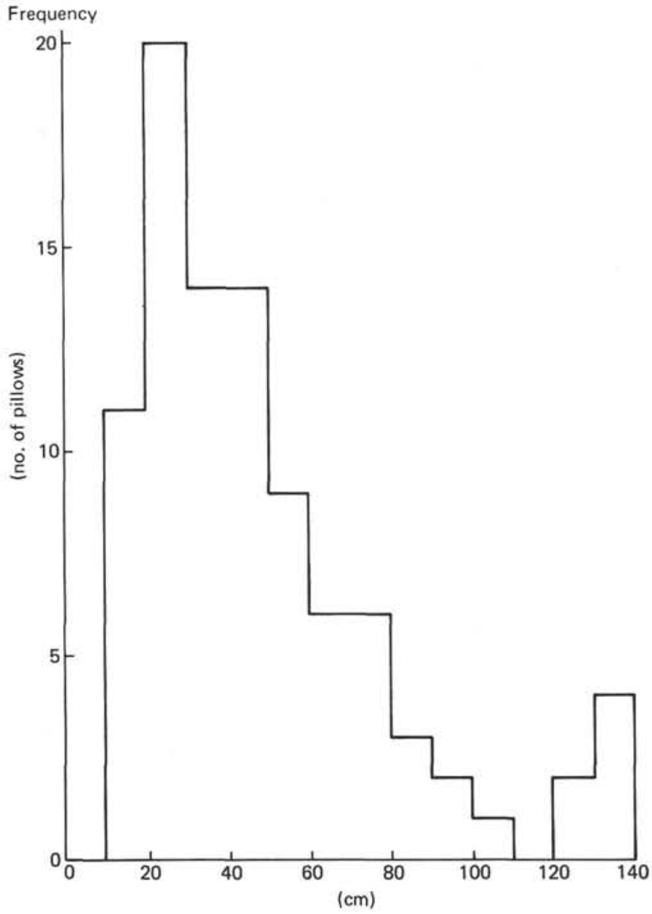

Figure 12. Frequency distribution of the measured minimum diameter of pillows.

Table 6. Calculated size of pillows.

L (cm)	θ (°)	D (cm)	$\frac{D}{L}$
20	20	21.3	1.06
20	45	28.3	1.41
75	30	86.6	1.15
75	0	75.0	1.00
25	15	25.9	1.04
25	20	26.6	1.06
30	20	31.9	1.06
60	20	63.9	1.06
40	25	44.1	1.10
45	10	45.7	1.02
50	45	70.7	1.41
20	15	20.7	1.04
28	45	39.6	1.41
28	30	32.3	1.15
20	50	31.1	1.56
20	60	40.0	2.00
135	30	155.9	1.15
100	50	155.6	1.56
100	50	155.6	1.56
			1.25 = Average

Note: See Figure 11 for explanation of dimensions θ, D, and L of pillows.

Mrozowski and Hayes, 1979). Based upon these studies, we should expect low or equatorial paleolatitudes (inclinations) from samples at the site. This indeed is what we observed.

Only five paleomagnetic samples were collected from the sediment column at the site, owing to poor consolidation and/or drilling disturbance of the sediments. The samples consisted of 2.5 × 2.5-cm cylindrical cores on which the natural remanent magnetization (NRM) was measured on board ship using a Digico magnetometer and later remeasured on a cryogenic magnetometer. Samples were collected from brown clays (447A-5-2, 76), a lithology characterized by unstable paleomagnetic results (Foster, 1972), and from altered variegated fine tuffs (447A-10-1, 105). However, the sample from Core 5 appeared to display stable magnetization and give reliable inclination data; the sample from Core 10 gave anomalously high inclinations (45–47°). A coarse-grained conglomerate with clasts up to 1 cm (Sample 447A-6-7, 39), chosen to conduct a sedimentary-conglomerate test for stable magnetization, proved unusual. A conglomerate consists of randomly oriented clasts; thus total magnetization of the sample should reflect the random orientation of its constituent parts, resulting in an anomalous magnetic direction (reflected by the inclination). In this particular case, the results displayed the expected field inclination, suggesting that the conglomerate had been remagnetized subsequent to deposition.

The NRM of 50 basalt samples was also measured on board the *Glomar Challenger*. The samples consisted of 2.5 × 2.5 cm oriented minicores. Alternating field demagnetization studies were also conducted and details of these studies are discussed elsewhere (see Keating and Herrero, this volume). In general, the experiments showed that these samples are directionally stable after cleaning to 1000 Oe. Intensities, however, drop to roughly 20% after demagnetization to 1000 Oe.

The results of NRM measurements are given in Table 7. In general, the paleoinclinations are shallow and appear to be consistent with the seafloor magnetic studies of Louden (1976). Sub-units 11a through 11d appear to be an exception, showing steeper inclinations (mean inclination = 51.5°). The mean inclination for all other basalt cooling units is 13.8°. The paleolatitude calculated for this site (all samples) based upon the mean is 10.5°.

No attempt has been made to determine polarity histories for these rocks. The pillow basalts cooled in low paleolatitudes, and if a normal secular variation is considered, it would be sufficient to scatter inclinations, giving the appearance of multiple field reversals. Because the apparent reversals cannot be separated from the true field reversals, it becomes impossible to determine an accurate polarity sequence.

PHYSICAL PROPERTIES

Measurements of physical properties of pelagic clay, ooze, chalks, volcaniclastic rocks, and basalts cored at Site 447 include sonic velocity (horizontal and vertical), wet-bulk density, water content, porosity, and acoustic

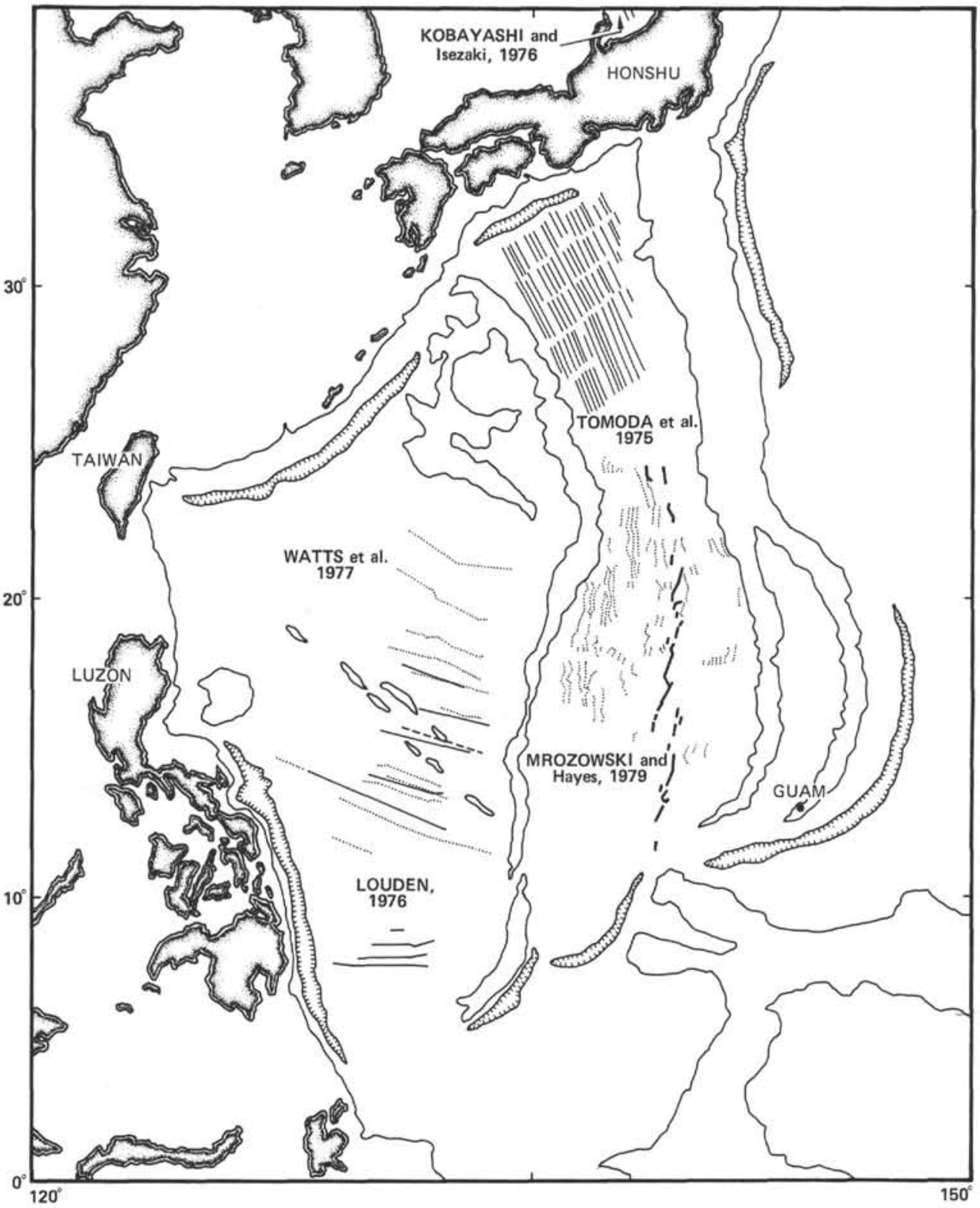

Figure 13. Magnetic-anomaly patterns in the West Philippine Basin (Watts et al., 1977; Louden, 1976), the Shikoku Basin (Tomoda et al., 1975), and the Parece Vela Basin (Mrozowski and Hayes, 1979).

impedance. Methods and procedures for the measurement and determination of physical properties on board the *Glomar Challenger* have been previously described by Boyce (1976) and are briefly summarized in the Introduction (this volume). The results are listed in Table 8 and shown graphically in Figure 14.

Whereas drilling disturbances in the first 47 meters (Cores 1-5) precluded reliable sonic-velocity measurements, velocities were measured on selected samples between 47 and 295 meters sub-bottom (Cores 6-36). Between 0 and approximately 110 meters sub-bottom, apparent wet-bulk density was obtained by the continuous analog GRAPE method; from 110 to 295 meters, special 2-minute GRAPE measurements had to be obtained from individual samples. In order to facilitate comparison, in Figure 14, densities determined by the GRAPE method (using a grain density of 2.75 g/cm^3) are plotted along with those determined by the gravimetric method. Water content and porosity were determined for only a few samples between 47 and 104 meters sub-bottom (Cores 6-12).

Sonic velocities increase with depth and lithification, ranging from 1.95 km/s to 2.52 km/s in Cores 6 through 10. A slight anistropy between vertical velocities (measured perpendicular to bedding) and horizontal velocities (measured parallel to bedding) was also observed. A large increase in sonic velocity occurs between the bottom of Core 10 and the top of Core 14 (94.5-113 m, sub-bottom). Velocities of 4.59 and 3.59 km/s characterized the volcaniclastic breccia and tuff, respectively. In the basalt encountered below Core 13, sonic velocities range from <4 to >6 km/s. The lowest velocities are associated with pillow basalt layers and intensely fractured and weathered zones: the highest

Table 7. NRM results for Hole 447A.

Lithologic Unit or Sub-unit (mean inclination in °)	Sample (core-section, depth in interval in cm)	Depth (m)	Inclination (°)	Declination (°)	Intensity (emu/cm^3)
	5-2, 76	39.26	−13.88	210.78	0.1041×10^{-3}
	6-7, 39	56.39	−0.83	296.87	0.1337×10^{-3}
	10-1, 105	86.05	45.66	37.08	0.1126×10^{-3}
	10-2, 49	86.99	53.92	229.86	0.1648×10^{-3}
	10-2, 121	87.71	−73.60	164.80	0.3420×10^{-4}
	14-1, 39	113.39	−13.00	39.50	0.3573×10^{-4}
	14-1, 90	113.90	6.16	71.29	0.3146×10^{-3}
	14-2, 53	115.03	14.10	264.60	0.1721×10^{-3}
	14-2, 107	115.57	−14.60	87.40	0.1424×10^{-3}
	14-2, 123	113.73	−3.19	94.11	0.2736×10^{-1}
	14-3, 29	116.29	−13.80	39.80	0.2384×10^{-4}
6 (9.5)	14-3, 64	116.64	−1.20	286.10	0.5216×10^{-4}
	14-3, 88	116.88	−8.10	89.80	0.1736×10^{-4}
	15-1, 58	122.58	2.00	146.80	0.2024×10^{-4}
	15-2, 72	124.22	6.00	182.80	0.3912×10^{-4}
	15-2, 130	124.80	−4.13	157.76	0.3936×10^{-2}
	15-4, 5	126.55	−9.5	89.90	0.2023×10^{-3}
	16-1, 11	131.11	−28.70	359.00	0.2500×10^{-4}
7 (10.2)	16-2, 24	132.74	10.90	147.40	0.7672×10^{-3}
	17-1, 31	140.31	−9.50	83.20	0.3911×10^{-3}
	17-3, 89	143.89	−5.30	87.10	0.3228×10^{-1}
	18-2, 98	151.48	−5.11	254.54	0.1004×10^{-2}
	18-3, 20	152.20	−76.00	248.30	0.5320×10^{-4}
	19-2, 113	154.63	−1.69	351.67	0.2203×10^{-2}
	19-3, 40	155.40	−4.07	255.76	0.3240×10^{-2}
	19-3, 122	156.22	−0.16	53.86	0.2018×10^{-2}
	20-1, 76	158.76	−15.04	72.90	0.3054×10^{-2}
8 (14.5)	20-2, 115	160.65	−7.06	55.91	0.2989×10^{-2}
	20-3, 48	161.48	59.00	290.10	0.3840×10^{-3}
	21-1, 10	167.10	−8.14	115.37	0.2602×10^{-2}
	21-1, 73	167.73	−15.58	176.81	0.2738×10^{-2}
	21-2, 109	169.59	−8.60	342.10	0.2546×10^{-2}
	21-4, 110	172.60	−11.37	48.20	0.2844×10^{-2}
	21-5, 71	173.71	−2.73	160.89	0.2117×10^{-2}
	22-1, 83	176.83	−9.51	55.46	0.3172×10^{-2}
	22-3, 19	179.19	−8.07	264.85	0.7064×10^{-2}
	23-1, 5	180.05	−11.11	138.50	0.3080×10^{-2}
	24-2, 76	187.26	13.19	19.26	0.6052×10^{-2}
9 (14.8)	25-1, 92	191.92	16.62	203.61	0.3367×10^{-2}
	25-3, 8	194.08	−2.00	0.10	0.4230×10^{-2}
10 (17.6)	26-1, 67	199.17	14.68	121.02	0.3479×10^{-2}
	26-3, 50	202.00	0.65	348.22	0.2035×10^{-2}
	26-3, 78	202.28	5.84	114.13	0.2239
	27-1, 76	208.26	−65.20	194.00	0.2319×10^{-1}
	28-1, 76	217.26	53.16	206.36	0.1730×10^{-2}
	29-2, 74	227.74	48.36	233.64	0.1734×10^{-2}
11a–11d (51.5)	29-4, 93	230.93	48.06	93.14	0.2425×10^{-2}
	29-5, 8	231.58	46.06	72.57	0.8849×10^{-3}
	30-1, 53	235.03	−64.40	308.80	0.6267×10^{-3}
	30-4, 70	239.70	49.31	315.67	0.2382×10^{-2}
	31-3, 142	247.92	19.70	205.80	0.2975×10^{-3}
	31-4, 17	248.17	25.20	128.17	0.4388×10^{-2}
11e (18.5)	32-1, 103	253.53	20.62	153.25	0.3095×10^{-2}
	32-3, 5	255.55	19.32	328.41	0.3585×10^{-2}
	34-1, 59	271.09	−15.34	135.87	0.3795×10^{-2}
	34-2, 109	273.09	−11.17	248.27	0.2842×10^{-2}

velocities are correlated with dense basalt flows and fresh basalt. The highest values of >6.0 km/s were measured in a coarse-grained basalt (dolerite) flow in Sections 24-3 and 25-1.

Down-core in the poorly lithified polymictic breccia conglomerate, water content ranges from 48% to 31%, whereas porosity ranges from 70% to 53%. A large increase in wet-bulk densities occurs between Cores 10 and 14 in the volcaniclastic breccia and tuff. In the basalts, the values range from around 2.6 g/cm^3 in altered areas to more than 2.9 g/cm^3 in fresh zones.

GEOPHYSICS

Although much has been written on the origin of the seafloor in the South Philippine Sea, the geophysical data that have provided the basis for much of the past speculation have been, in reality, very sparse. Recently, some researchers have proposed an early Tertiary or older age for the formation of the West Philippine Basin by seafloor spreading, based on the magnetic-anomaly pattern (Louden, 1976; Watts et al., 1977). Although Watanabe et al. (1977) note that sample size and distribution are not ideal, they report that average heat-flow values appear to be significantly higher than that predicted for a basin this age (as young as 41 m.y. [Louden, 1976] or older than 50 m.y. [Karig, 1975]). Likewise, the reported heat flow is significantly higher than would be expected for the great depth of the West Philippine Basin, approximately 6000 m below sea level (Sclater et al., 1976). And finally, Seekins and Teng (1977) have concluded, based on surface-wave analysis, that the lithosphere under the entire South Philippine Sea is thin, "on the order of 30 km," and is underlain by a low-velocity mantle.

Karig (1974) has also suggested that the crust in the West Philippine Basin is thin. Seismic-refraction measurements reported by Murauchi et al. (1968), however, do not seem to suggest abnormally thin crust in the South Philippine Sea region. Reversed refraction lines in the South Philippine Sea are rare and, in particular, those located in the West Philippine Basin are not as suggestive of thin crust as those from other parts of the South Philippine Sea. The seismic-refraction data do indicate, however, a widespread, almost ubiquitous 3.5-km/s, low-velocity Layer 2a. In fact, the apparent absence of this layer in one area ultimately determined the location of Site 447 (see Background and Objectives, this chapter).

As was mentioned earlier, the close resemblance of the reflection profile recorded on board the *Glomar Challenger* (during the approach to the drill site) to the profile taken during the L-DGO Site Survey enabled deployment of the beacon on the *Challenger's* initial pass over the drill site. That profile (shown in Fig. 4) reveals a somewhat nonuniform or variable sediment distribution, with transparent sediments ranging in thickness from less than 0.1 s to more than 0.3 s reflection time, effectively attenuating the relief of a block-faulted basement through infilling of fault valleys. The sediment thus appears to be accumulating or ponding in elongated basement lows trending west-northwest (Fig. 2).

Correlation of drilling results with the reflection profile taken across Site 447 is shown in Figure 15. Sediment thickness of slightly more than 0.1 s reflection time is observed in the vicinity of the site. Although several weak reflectors may be present above acoustic basement, the only reflection that can be identified with any certainty and correlated with the drilling results is the strong low-frequency reflection occurring at 0.12 s reflection time, thought to be caused by basaltic basement. This interpretation gives an average velocity of 1.8 km/s for the sediment, which seems reasonable, based on estimated velocities for the upper half of the sedimentary column and the measured velocities in the lower half of the column at Site 447.

Table 8. Physical properties of sediments and igneous rocks from Hole 447A.

Sample (hole-core-section)	Sub-bottom Depth (m)	Sonic Velocity			Wet-Bulk Density			Water Content (%)	Poros-ity (%)	Calcu-lated Grain Density (g/cm^3)	Acoustic Impedance [$\times 10^5$ g/(cm^{2}s)]
		Horizontal		Vertical	Gravi-metric (g/cm^3)	Continuous GRAPE (section averages) (g/cm^3)[b]	Special 2-min GRAPE (g/cm^3)[b]				
447A-1-1	0.75	—	—	—	—	1.23	—	—	—	—	—
447A-1-2	2.25	—	—	—	—	1.23	—	—	—	—	—
447A-1-3	3.75	—	—	—	—	1.27	—	—	—	—	—
447A-1-4	5.25	—	—	—	—	1.23	—	—	—	—	—
447A-1-5	6.75	—	—	—	—	1.19	—	—	—	—	—
447A-1-6	8.25	—	—	—	—	1.16	—	—	—	—	—
447A-4-1	28.75	—	—	—	—	1.26	—	—	—	—	—
447A-4-2	30.25	—	—	—	—	1.31	—	—	—	—	—
447A-4-3	31.75	—	—	—	—	1.33	—	—	—	—	—
447A-4-4	33.25	—	—	—	—	1.30	—	—	—	—	—
447A-4-5	34.75	—	—	—	—	1.33	—	—	—	—	—
447A-5-1	38.25	—	—	—	—	1.23	—	—	—	—	—
447A-5-2	39.75	—	—	—	—	1.25	—	—	—	—	—
447A-5-3	41.25	—	—	—	—	1.30	—	—	—	—	—
447A-5-4	42.75	—	—	—	—	1.30	—	—	—	—	—
447A-5-5	44.25	—	—	—	—	1.30	—	—	—	—	—
447A-5-6	45.75	—	—	—	—	1.31	—	—	—	—	—
447A-6-1	47.75	—	—	—	—	1.34	—	—	—	—	—
447A-6-2	49.25	—	—	—	—	1.30	—	—	—	—	—
447A-6-3	50.75	—	—	—	—	1.31	—	—	—	—	—
447A-6-4	51.90	1.950	—	—	—	—	—	—	—	—	—
447A-6-4	52.25	—	—	—	—	1.32	—	—	—	—	—
447A-6-5	53.75	—	—	—	—	1.32	—	—	—	—	—
447A-6-6	54.90	1.996	—	1.976	—	—	—	—	—	—	2.85
447A-6-6	54.91	—	—	—	1.444	—	1.449	46.30	66.84	2.339	—
447A-6-6	55.25	—	—	—	—	1.37	—	—	—	—	—
447A-6-6	55.44	—	—	—	1.446	—	—	47.35	68.47	2.414	—
447A-6-7	56.75	—	—	—	—	1.41	—	—	—	—	—
447A-7-1	57.20	2.102	—	2.070	—	—	—	—	—	—	3.06
447A-7-1	57.21	—	—	—	1.457	—	1.461	48.15	70.17	2.533	—
447A-7-1	57.25	—	—	—	—	1.45	—	—	—	—	—
447A-7-2	58.75	—	—	—	—	1.45	—	—	—	—	—
447A-7-3	60.25	—	—	—	—	1.47	—	—	—	—	—
447A-7-4	61.75	—	—	—	—	1.48	—	—	—	—	—
447A-7-5	63.25	—	—	—	—	1.49	—	—	—	—	—
447A-7-6	64.75	—	—	—	—	1.51	—	—	—	—	—
447A-8-1	66.05	2.366	—	2.315	—	—	—	—	—	—	—
447A-8-1	66.07	—	—	—	—	—	1.572	—	—	—	—
447A-9-2	77.42	2.485	—	2.445	1.734	—	—	31.10	53.92	2.595	4.31
447A-9-2	77.43	—	—	—	—	—	1.363	—	—	—	—
447A-10-2	87.45	2.517	—	2.444	—	—	—	—	—	—	4.09
447A-10-2	87.46	—	—	—	—	—	1.628	—	—	—	—
447A-10-2	87.47	—	—	—	1.625	—	—	38.00	61.74	2.632	—
447A-12-1	98.69	4.598	—	4.214	—	—	—	—	—	—	—
447A-12-1	98.70	—	—	—	—	—	2.295	—	—	—	—
447A-12-2	100.25	—	—	—	—	1.76	—	—	—	—	—
447A-12-2	100.78	3.595	—	3.626	—	—	—	—	—	—	—
447A-12-2	100.80	—	—	—	—	—	2.171	—	—	—	—
447A-12-3	101.75	—	—	—	—	1.78	—	—	—	—	—
447A-14-1	113.75	—	—	—	—	2.23	—	—	—	—	—
447A-14-1	113.92	—	—	—	2.773	—	—	—	—	—	—
447A-14-1	113.93	—	5.452[a]	—	—	—	—	—	—	—	15.12
447A-14-1	113.94	—	—	—	2.758	—	—	—	—	—	—
447A-14-1	113.95	—	—	—	—	—	2.744	—	—	—	—
447A-15-2	124.76	—	5.108[a]	—	—	—	—	—	—	—	—
447A-15-2	124.78	—	—	—	2.667	—	2.781	—	—	—	—
447A-16-1	132.13	—	4.141[a]	—	—	—	—	—	—	—	—
447A-16-1	132.18	—	—	—	—	—	2.887	—	—	—	—
447A-16-2	132.67	—	5.596[a]	—	—	—	—	—	—	—	—
447A-16-2	132.72	—	—	—	—	—	3.033	—	—	—	—
447A-17-1	140.07	—	5.308[a]	—	—	—	—	—	—	—	—
447A-17-1	140.11	—	—	—	—	—	3.041	—	—	—	—

Table 8. (Continued).

Sample (hole-core-section)	Sub-bottom Depth (m)	Sonic Velocity Horizontal		Vertical	Wet-Bulk Density Gravimetric (g/cm³)	Continuous GRAPE (section averages) (g/cm³)[b]	Special 2-min GRAPE (g/cm³)[b]	Water Content (%)	Porosity (%)	Calculated Grain Density (g/cm³)	Acoustic Impedance [× 10^5 g/(cm²s)]
447A-17-2	141.50	—	5.255[a]	—	—	—	—	—	—	—	—
447A-17-2	141.53	—	—	—	—	—	3.018	—	—	—	—
447A-17-3	144.28	—	5.377[a]	—	—	—	—	—	—	—	—
447A-17-3	144.31	—	—	—	—	—	3.106	—	—	—	—
447A-18-1	149.99	—	5.605[a]	—	—	—	—	—	—	—	—
447A-18-1	150.03	—	—	—	—	—	2.785	—	—	—	—
447A-18-2	151.04	—	5.112[a]	—	—	—	—	—	—	—	—
447A-18-2	151.06	—	—	—	—	—	2.704	—	—	—	—
447A-19-1	152.53	—	5.333[a]	—	—	—	—	—	—	—	—
447A-19-1	152.56	—	—	—	—	—	3.993	—	—	—	—
447A-19-2	154.65	—	5.699[a]	—	—	—	—	—	—	—	—
447A-19-2	154.70	—	—	—	—	—	2.916	—	—	—	—
447A-19-3	156.21	—	—	—	—	—	2.614	—	—	—	—
447A-20-1	158.43	—	5.289[a]	—	—	—	—	—	—	—	—
447A-20-1	158.50	—	—	—	—	—	3.179	—	—	—	—
447A-20-2	160.84	—	4.602[a]	—	—	—	—	—	—	—	—
447A-20-2	160.88	—	—	—	—	—	2.870	—	—	—	—
447A-20-3	161.96	—	3.795[a]	—	—	—	—	—	—	—	—
447A-20-3	162.00	—	—	—	—	—	3.061	—	—	—	—
447A-21-1	167.07	—	—	—	—	—	3.097	—	—	—	—
447A-21-2	168.61	—	4.571[a]	—	—	—	—	—	—	—	—
447A-21-2	168.67	—	—	—	—	—	3.133	—	—	—	—
447A-21-2	169.40	—	5.177[a]	—	—	—	—	—	—	—	—
447A-21-2	169.45	—	—	—	—	—	3.073	—	—	—	—
447A-21-3	171.43	—	4.558[a]	—	—	—	—	—	—	—	—
447A-21-3	171.47	—	—	—	—	—	2.720	—	—	—	—
447A-21-4	172.70	—	5.244[a]	—	—	—	—	—	—	—	—
447A-21-4	172.78	—	—	—	—	—	3.059	—	—	—	—
447A-21-5	173.02	—	4.674[a]	—	—	—	—	—	—	—	—
447A-21-5	173.09	—	—	—	—	—	2.980	—	—	—	—
447A-22-1	176.39	—	4.761[a]	—	—	—	—	—	—	—	—
447A-22-1	176.42	—	—	—	—	—	2.955	—	—	—	—
447A-22-2	177.91	—	4.717[a]	—	—	—	—	—	—	—	—
447A-22-2	177.96	—	—	—	—	—	2.905	—	—	—	—
447A-23-1	180.21	—	5.671[a]	—	—	—	—	—	—	—	—
447A-23-1	180.25	—	—	—	—	—	3.156	—	—	—	—
447A-24-3	188.42	—	6.311[a]	—	—	—	—	—	—	—	—
447A-25-1	191.38	—	—	—	2.907	—	—	—	—	—	—
447A-25-1	191.49	—	5.957[a]	—	—	—	—	—	—	—	—
447A-25-1	191.54	—	—	—	—	—	2.833	—	—	—	—
447A-25-2	192.80	—	5.406[a]	—	—	—	—	—	—	—	—
447A-25-2	192.88	—	—	—	—	—	2.896	—	—	—	—
447A-25-2	193.29	—	4.965[a]	—	—	—	—	—	—	—	—
447A-25-3	194.07	—	5.130[a]	—	—	—	—	—	—	—	—
447A-26-1	199.42	—	4.129[a]	—	—	—	—	—	—	—	—
447A-26-1	199.48	—	—	—	—	—	2.973	—	—	—	—
447A-26-2	200.72	—	4.146[a]	—	—	—	—	—	—	—	—
447A-26-2	200.76	—	—	—	—	—	2.640	—	—	—	—
447A-26-3	201.92	—	4.433[a]	—	—	—	—	—	—	—	—
447A-26-3	201.95	—	—	—	—	—	2.838	—	—	—	—
447A-26-4	203.30	—	—	—	—	—	2.950	—	—	—	—
447A-26-4	203.56	—	4.511[a]	—	—	—	—	—	—	—	—
447A-26-4	203.91	—	—	—	—	—	2.618	—	—	—	—
447A-27-1	207.85	—	5.107[a]	—	—	—	—	—	—	—	—
447A-27-1	207.93	—	—	—	—	—	2.998	—	—	—	—
447A-27-2	209.57	—	4.712[a]	—	—	—	—	—	—	—	—
447A-27-2	209.61	—	—	—	—	—	2.923	—	—	—	—
447A-28-1	217.76	—	5.043[a]	—	—	—	—	—	—	—	—
447A-28-1	217.79	—	—	—	—	—	2.675	—	—	—	—
447A-28-2	218.78	—	4.751[a]	—	—	—	—	—	—	—	—
447A-28-2	218.83	—	—	—	—	—	2.913	—	—	—	—
447A-29-2	227.74	—	5.220[a]	—	—	—	—	—	—	—	—

Table 8. (Continued).

Sample (hole-core-section)	Sub-bottom Depth (m)	Sonic Velocity Horizontal		Sonic Velocity Vertical	Wet-Bulk Density Gravimetric (g/cm^3)	Wet-Bulk Density Continuous GRAPE (section averages) (g/cm^3)[b]	Wet-Bulk Density Special 2-min GRAPE (g/cm^3)[b]	Water Content (%)	Porosity (%)	Calculated Grain Density (g/cm^3)	Acoustic Impedance [$\times 10^5$ g/(cm^{2}s)]
447A-29-4	230.93	—	5.591[a]	—	—	—	—	—	—	—	—
447A-29-4	230.94	—	—	—	—	—	2.807	—	—	—	—
447A-30-1	235.03	—	5.215[a]	—	—	—	—	—	—	—	—
447A-30-1	235.05	—	—	—	—	—	2.735	—	—	—	—
447A-30-4	239.70	—	5.012[a]	—	—	—	—	—	—	—	—
447A-30-4	239.71	—	—	—	—	—	2.336	—	—	—	—
447A-31-3	247.92	—	5.320[a]	—	—	—	—	—	—	—	—
447A-31-3	247.93	—	—	—	—	—	2.765	—	—	—	—
447A-31-4	248.17	—	5.496[a]	—	—	—	—	—	—	—	—
447A-31-4	248.18	—	—	—	—	—	2.841	—	—	—	—
447A-32-1	253.00	—	4.887[a]	—	—	—	—	—	—	—	—
447A-32-1	253.04	—	—	—	—	—	2.704	—	—	—	—
447A-32-3	255.77	—	5.428[a]	—	—	—	—	—	—	—	—
447A-32-3	255.81	—	—	—	—	—	2.663	—	—	—	—
447A-34-1	271.62	—	—	—	—	—	2.996	—	—	—	—
447A-34-2	272.22	—	—	—	—	—	2.956	—	—	—	—
447A-34-1	273.13	—	5.047[a]	—	—	—	—	—	—	—	—
447A-35-2	279.56	—	—	—	—	—	2.854	—	—	—	—
447A-35-5	281.95	—	—	—	—	—	2.645	—	—	—	—
447A-36-3	288.31	—	4.985[a]	—	—	—	—	—	—	—	13.61
447A-36-3	288.32	—	—	—	2.730	—	2.669	—	—	—	—

[a] Basalt average velocity.
[b] Based on an assumed grain density of 2.75 g/cm^3.

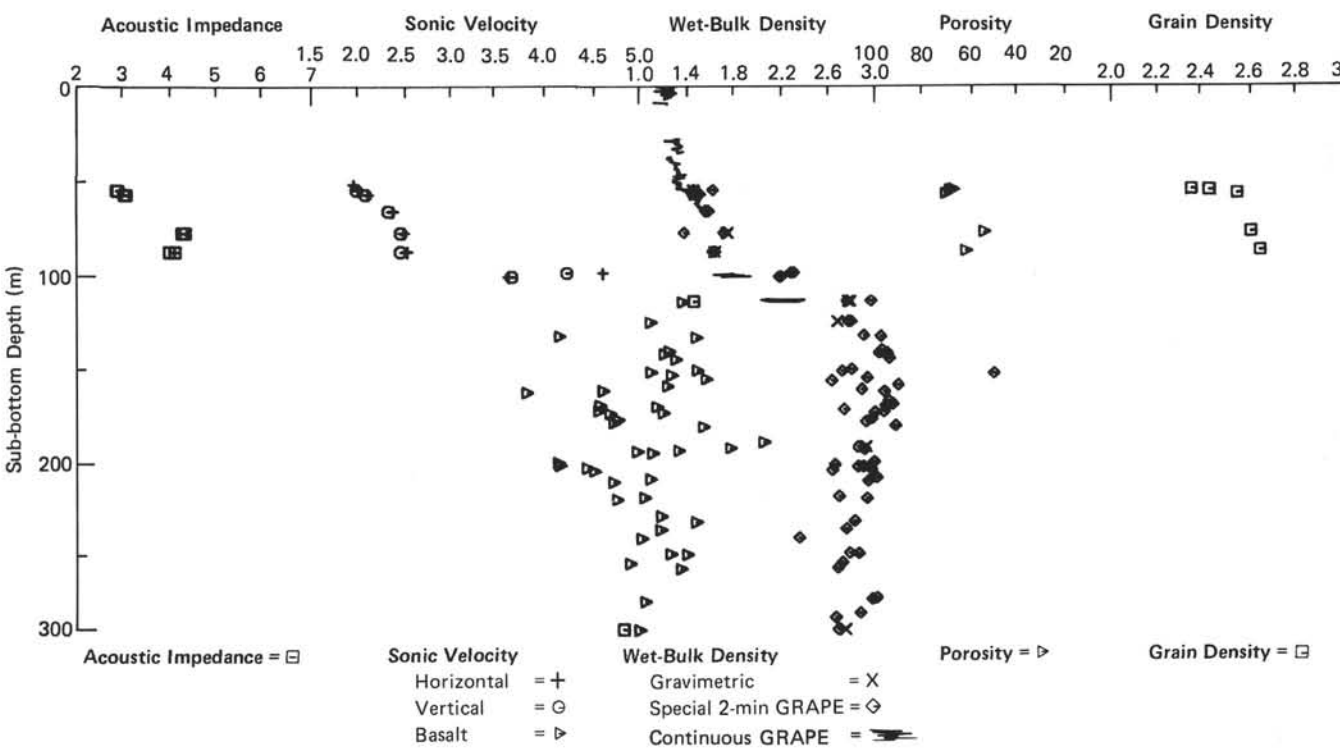

Figure 14. Physical properties of sedimentary and igneous rocks from Hole 447A plotted versus sub-bottom depth in meters. Acoustic impedance is the product of velocity and bulk density. Sonic-velocity measurements include horizontal and vertical velocity of sediments and average velocity of basalts. 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.

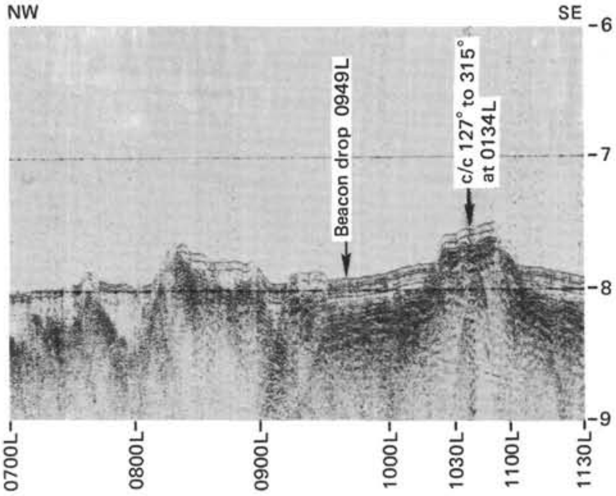

Figure 15. Seismic-reflection profile across Site 447 recorded on board the *Glomar Challenger* during approach to the site.

SUMMARY AND CONCLUSIONS

Site 447 at 18°00.88′N and 133°17.37′E was chosen with the objective of determining the nature and age of the West Philippine Basin basement. Continuous coring resulted in a total recovery of 155 meters out of 296.5 meters drilled. Sediments were cored to a depth of 113 meters, at which point igneous basement was encountered. Basement was penetrated and cored another 183.5 meters to a total depth of 296.5 meters sub-bottom. The sedimentary section is lithologically divided into five lithologic units that range from the early Miocene to the middle Oligocene. The basement section is divided into six extrusive units based upon phenocryst assemblages.

The sedimentary section consists of:

Unit 1 (0–37.5 m), lower Miocene, dark-brown pelagic clay.

Unit 2 (37.5–47.0 m), upper middle to lower upper Oligocene, yellow-brown calcareous pelagic clay.

Unit 3 (47.0–85.0 m), incorporating two sub-units:

Sub-unit 3a (47.0–66.0 m), middle to lower upper Oligocene, olive-brown to light yellow-brown polymictic conglomerate; and

Sub-unit 3b (66.0–85.0 m), middle Oligocene, dark olive-gray polymictic breccia.

Unit 4 (85.0–87.1 m), barren, variegated gray, brown, and olive altered fine tuff.

Unit 5 (87.1–113.0 m), incorporating three sub-units:

Sub-unit 5a (87.1–99.6 m), middle Oligocene, grayish green volcaniclastic breccia with a tuff layer near its top;

Sub-unit 5b (99.6–104.0 m), middle Oligocene, yellowish brown tuff; and

Sub-unit 5c (104.0–113.0 m), barren, yellow-brown volcaniclastic breccia.

The basement consists of:

Unit 6 (113.0–131.0 m), plagioclase-phyric tholeiitic basalts incorporating four sub-units representing individual cooling units:

Sub-unit 6a (113.0–115.0 m), massive basalt flow;

Sub-unit 6b (115.0–123.0 m), pillow lava basalt flow;

Sub-unit 6c (123.0–125.0 m), pillowed massive basalt flow; and

Sub-unit 6d (125.0–131.5 m), pillowed massive basalt flow.

Unit 7 (131.5–141.0 m), plagioclase-phyric pillow lava basalt flow

Unit 8 (141.0–185.0 m), plagioclase-clinopyroxene-olivine-phyric tholeiitic basalt incorporating four sub-units representing individual cooling units:

Sub-unit 8a (141.0–154.5 m), pillowed massive basalt flow;

Sub-unit 8b (154.5–167.0 m), pillowed massive basalt flow;

Sub-unit 8c (167.0–170.5 m), pillowed massive basalt flow; and

Sub-unit 8d (170.5–185.0 m), pillowed massive basalt flow with a doleritic base.

Unit 9 (185.0–194.0 m), aphyric to olivine-spinel-phyric massive doleritic flow.

Unit 10 (194.0–209.0 m), plagioclase-olivine-clinopyroxene-phyric tholeiitic basalt incorporating two sub-units representing individual cooling units:

Sub-unit 10a (194–203.5 m), pillowed massive basalt flow; and

Sub-unit 10b (203.5–209.0 m), pillowed massive basalt flow with a doleritic base.

Unit 11 (209.0–296.5 m), plagioclase-olivine-spinel-phyric tholeiitic basalt incorporating six sub-units representing individual cooling units:

Sub-unit 11a (209.0–228.5 m), pillowed massive basalt flow;

Sub-unit 11b (228.5–235.0 m), pillowed massive basalt flow;

Sub-unit 11c (235.0–239.5 m), pillowed massive basalt flow;

Sub-unit 11d (239.5–247.0 m), pillow lava basalt flow;

Sub-unit 11e (247.0–282.0 m), pillow lava basalt flow; and

Sub-unit 11f (282.0–296.5 m), pillow lava basalt flow with large gabbroic xenocrysts and an anorthositic cumulate xenolith.

Based on ichthyoliths (fish teeth), sediments in the core catchers of Core 1 in both Holes 447 and 447A have been identified as dating from the early Miocene. Although they are fairly abundant and well preserved in Core 1 of 447A, ichthyoliths are rare lower in the dark brown pelagic clay of Unit 1. Unit 2 is assigned to the late middle to early late Oligocene based upon nannoplanktons of Zone NP 24. Sub-unit 3a is assigned to the middle to early late Oligocene based upon nannoplanktons of both Zones NP 23 and NP 24. Sub-unit 3b through Unit 5 are assigned to the middle Oligocene based only upon nannoplanktons of Zone NP 23. Except for the barren intervals between 85.0 and 94.5 meters (Unit 4 and upper Sub-unit 5a) and between 104.0 and 113.0 meters (Sub-unit 5c), the specimens are poorly preserved and heavily etched. No diatoms or silicoflagellates were found in Hole 447A samples. Extremely rare radiolarians were found but were too nondiagnostic or too fragmentary for positive identification. In core-catcher samples collected at the bases of Units 5 and 2, displaced, rare, lower Oligocene nannoplankton were identified within middle to lower upper Oligocene strata, indicating probable erosion of older deposits. Because nannoplanktons can readily be retransported great distances after erosion, the provenance of eroded older deposits is speculative.

Accumulation rates during deposition of the 37.5 meters of the brown pelagic clay were low; if the early Miocene estimation is correct, then a minimum rate of about 2 m/m.y. is reasonable for Unit 1. Between 37.5 meters and 113.0 meters sub-bottom, obviously one continuous rate of deposition cannot be derived within clays, conglomerates, breccias, and tuffs, particularly with only one nannoplankton zone boundary (NP 23/24). In fact, some of these units may have been deposited essentially instantaneously relative to geologic rates. It is probable that the rates of accumulation for the breccias and tuffs of Units 3, 4, and 5 were far greater than those for the calcareous pelagic clays of Unit 2. Furthermore, it is possible that one or more stratigraphic breaks exist in Site 447 even though no positive evidence for a hiatus was found. Because the age of the upper portion of Core 1 has not been established with any degree of certainty, it is possible that one or more unidentified stratigraphic breaks may exist in the section. Likewise, a hiatus may exist at the igneous basement/sedimentary contact.

Because the core catcher of Core 1 in Hole 447 contained abundant ferromanganese nodules and crusts and the tops of cores in Hole 447A commonly had ferromanganese nodules that probably had fallen from the surface during drilling, a ferromanganese-nodule pavement is inferred for this area. Down-core in the dark brown pelagic clay of Unit 1, the zeolite content increases systematically from traces to 10%. Color changes are mainly the result of variations in abundance (up to 10%) of ferromanganese micronodules and iron-oxide aggregates. A decrease (5% to trace) of ferromanganese micronodules and iron-oxide down-core in Unit 2 also results in color changes (from dark yellow-brown at the top to light yellow-brown at the base). Although the top of Sub-unit 3a contains the uppermost volcanic debris, consisting of highly altered pumice or basalt clasts and glass fragments mixed with roughly equal parts of nannofossil chalk and clay minerals, the bottom of Sub-unit 3b contains only rare volcanic debris and is composed of more than 50% clay. Within the polymictic breccia of Sub-unit 3b, an increase in volcanic and sedimentary clasts occurs down-core, with rounded sedimentary clasts dominating near the base of the unit. In the highly altered, variegated fine tuffs of Unit 4, ferromanganese micronodules comprise 10% of the unit, and clay minerals, zeolite, and potassium feldspar comprise the rest of the material. In Unit 5, the uppermost sub-unit (5a) has a greenish black tuff near its top, whereas its lower part consists of angular, fresh to weathered basalt clasts in a fine-grained matrix of glass (73%) and carbonate (27%). The middle sub-unit (5b) shows an upward coarsening from medium-grained sands at the base to coarser sands to angular gravel at the top. The lowermost sub-unit (5c) consists of very angular basaltic clasts, some greater than the 6.6-cm core diameter. A weathered zone was absent from the top of the igneous basement. The basalt at the contact between igneous basement and the overlying Sub-unit 5c breccias does not contain evidence of distinctive weathering.

Excellent core recovery of the basalts, including glassy margins, makes it possible to recognize three types of flows or cooling units: (1) single massive flows; (2) pillow lava flows, which may consist of one or more cooling units; and (3) pillowed massive flows with pillow lava tops and massive flow bases. Massive flows are between 2 and 9.5 meters thick, and average 6 meters thick. Individual pillows vary between 0.1 and 1.4 meters thick and average 0.55 meters thick.

Both the phenocryst mineralogy and the X-ray fluorescence (XRF) data indicate that these basalts are all indistinguishable from tholeiitic mid-ocean ridge basalts. The presence of gabbroic xenocrysts and the anorthositic cumulate xenolith in the basal unit cored suggests that these inclusions were removed from a lower cumulate magma chamber by repeated pulses of fresh magma injection.

No evidence for hydrothermal metamorphism or hydrothermal vein formation exists in the basalts. However, low-temperature alteration of basaltic rocks is common. Radial cooling fractures are filled with veins of brown and green smectites, carbonates, and zeolites. Vesicles are also filled with these minerals, and the altered groundmass and phenocrysts exhibit this mineral suite.

Structural deformation at Site 447 is indicated by a 1.5-meter-thick fault zone that cuts through Unit 9 at approximately a 60° dip. Although the central part of the zone consists of rubble, the margins show distinct high-angle fracture patterns suggestive of extensional faulting, which is in turn suggestive of block faulting of basement rocks.

The average paleolatitude calculated for this site is 10.5°; thus either a 7.5° or a 28.5° northward migration is suggested, depending upon whether a north or south paleolatitude position for the West Philippine Basin is proposed. No polarity histories can be attempted at these low latitudes because apparent reversals (due to normal secular variations) and true reversals cannot be distinguished.

As would be expected, seismic velocities increase with depth and lithification. Velocities increase from 1.95 km/s to 2.52 km/s between Cores 6 and 10. Below Core 10, velocities reach values of 3.59 and 4.59 km/s in the tuffs and volcaniclastic breccias. Within the basement, velocities range from <4 to >6.0 km/s, with lower values characterizing pillow basalts, fractured zones, and weathered horizons and higher values characterizing doleritic bases of fresh massive flows.

From the relationships discussed earlier, the sequence of events at Site 447 from oldest to youngest can be summarized as follows:

1) Tholeiitic flows and pillow lavas formed the basement of the West Philippine Basin at Site 447 in or prior to the middle Oligocene.

2) Between the time of accumulation of the lavas and the present, the region migrated from either 10.5° south or 10.5° north to 18° north.

3) Coarse volcaniclastic breccias and tuffs of Sub-units 5c and 5b were deposited below or close to the CCD. Local tectonism is indicated by the deposition of angular basaltic clasts of Sub-unit 5c, which are very similar to the underlying basalts; these breccias are similar to those observed in talus from fault scarps along modern mid-ocean ridge rift-valley walls. An upward coarsening began in the tuffs of Sub-unit 5b and ended in the volcaniclastic breccias of the lower part of Sub-unit 5a; this may indicate a renewal or second period of tectonic uplift.

4) Sediments of the upper part of Sub-unit 5a became finer upward and were interrupted by the deposition of the fine altered tuffs of Unit 4. A possible interpretation may be a temporary slackening in local tectonism coinciding with a pulse of arc volcanism.

5) A coarsening of sediments occurred again during deposition of Sub-unit 3b. At this time, rounded sedimentary clasts began to appear and gradually became dominant over angular volcanic clasts. Also at this time, reworked lower-Oligocene nannoplankton were mixed with middle-Oligocene fauna. This suggests that more distant and older sedimentary rocks were being eroded. Apparently the site of deposition was at this point above the CCD and remained above the CCD throughout deposition of Sub-unit 3a and Unit 2.

6) Volcanic contribution from the arc to the sediments of Site 447 decreased during deposition of Sub-unit 3a. Thus by the late middle Oligocene to the early late Oligocene, both volcanic influence on and tectonic control of sedimentation ceased.

7) A quiescent period of deep-water accumulation of calcareous pelagic clay took place during the late Oligocene deposition of Unit 2.

8) In the Miocene, submergence of the region again below the CCD, restricted sediment accumulation to a zeolitic brown pelagic clay.

9) Further restriction occurred sometime between early Miocene and Recent, as is indicated by the development of the ferromanganese-nodule pavement near the top of Unit 1.

After the completion of drilling at Site 447, new constraints on the type and timing of the geodynamic processes involved in the formation of the West Philippine Basin were evident. For example, a continuous sequence of uninterrupted normal oceanic tholeiitic basalt flows and pillow lavas with no intervening sediments is consonant with development of a normal oceanic type of basement. No evidence for the occurrence of any sills, dikes, or subsediment flows within the sedimentary sequence was observed. If no significant hiatus exists between formation and sediment accumulation, then the age of the igneous basement beneath the middle Oligocene sediments would be close to middle Oligocene. On the other hand, if a significant hiatus exists, then igneous basement could be much older. The presence of lower Oligocene reworked fossils, possibly derived from a distant source, requires that older sediment existed somewhere in the region prior to the deposition of the middle-Oligocene breccias. Similarly, Eocene reworked fossils were reported to have been derived from a source nearby DSDP Site 290 (Karig, Ingle, et al., 1975). The presence of locally derived middle Oligocene volcaniclastic breccias and polymictic sedimentary conglomerates and breccias containing reworked fossils requires a nearby source of sediment during several periods of tectonism. The presence of volcanic-arc type of debris deposited during the middle to early late Oligocene requires active arc volcanism in the vicinity.

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SITE 447 HOLE CORE 1 CORED INTERVAL: 0.0-9.0 m

AGE	BIOSTR. ZONE: NANNOS	BIOSTR. ZONE: FORAMS	BIOSTR. ZONE: RADS	FOSSIL CHARACT.: FOSSIL	FOSSIL CHARACT.: ABUNDANCE	FOSSIL CHARACT.: PRESERV.	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE
Early Miocene?				I	C	G	1		Mn, Pu	OO OO		*
							CC	0.5				
							1	1.0				
							2					
							3					
							4					

LITHOLOGIC DESCRIPTION

1.5 cm piece of subangular pumice

Total recovery from Hole 447 consists of one 26-cm section and 20 cm of Core-Catcher sample.

Section 1 consists primarily of angular fragments of black (2.5Y 2/0) manganese crust 0.3 to 1.5 cm in size. It also includes:

a) 6 manganese nodules, rounded, 1.5 to 2.0 cm in diameter
b) pumice fragments, yellowish brown (10YR 5/4), 2 cm maximum dimension. irregularly shaped, subrounded edges, altered to clay.

No mud is present, presumably because it was washed out during retrieval.

The Core-Catcher sample consists primarily of very soft dark brown (10YR 3.5/3) pelagic clay with several black (2.5Y 2/0) manganese nodules, subspherical, 1 to 4 cm diameter (mostly 1.5 to 2 cm), and some pumice as in Section 1, 8 to 25 mm in diameter.

SMEAR SLIDE SUMMARY

	CC
TEXTURE:	
Sand	0
Silt	20
Clay	80
TOTAL DETRITAL	84
COMPOSITION:	
Quartz	2
Mica	TR
Clay minerals	81
Volcanic glass	1
Zeolites	TR
Amorph Fe agg.	15
Fish remains	1

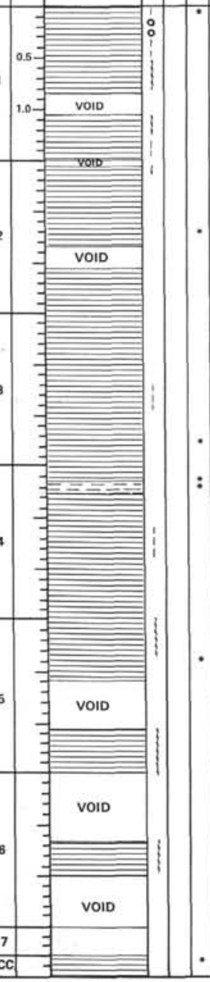
Information on core description sheets, for ALL sites, represents field notes taken aboard ship under time pressure. Some of this information has been refined in accord with post-cruise findings, but production schedules prohibit definitive correlation of these sheets with subsequent findings. Thus the reader should be alerted to the occasional ambiguity or discrepancy.

SITE 447 HOLE A CORE 1 CORED INTERVAL: 0.0-9.0 m (Hole deviation of 0.8° at 198.5 m)

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

Fossil characters: N, F — – (top of Section 1); N, F — – (Section 4); I, C, G (CC)

Sections: 1, 2, 3, 4, 5, 6, 7, CC



LITHOLOGIC DESCRIPTION

10YR 4/3

PELAGIC CLAY, dark brown, from 10YR 4/3 in Sections 1 and 2 to 10YR 3/3 in lower portions of the core. Few scattered 1 to 1.5 cm lumps of more indurated yellow (10YR 6/6) clay, the difference in color presumably due to lower content of amorphous iron oxide aggregates. The only stratification is in Section 4

10YR 4/3
Few small (1-3 mm) lumps of 10YR 7/6

SMEAR SLIDE SUMMARY

	1-10 (D)	2-75 (D)	3-130 (D)	4-21 (D)	5-47 (D)	CC (D)
TEXTURE:						
Sand	0	0	0	0	0	0
Silt	15	20	20	20	5	15
Clay	85	80	80	80	95	85
TOTAL DETRITAL	92	85	80	80	95	85
COMPOSITION:						
Quartz	1	1	TR	TR	–	1
Clay	91	84	80	80	95	84
Volcanic glass	TR	–	–	–	–	TR
Micronodules	–	TR	TR	8	1	–
Zeolites	1	5	8	2	TR	4
Amorph Fe agg.	7	10	10	10	3	10
Fish remains	TR	TR	2	TR	1	1

10YR 3/3
Few small lumps of 10YR 7/6

brown-yellow (10Y 6/6) mud; sharp ctcts above and below
black (10YR 2.5/1)
10YR 3/2

90-91 cm, thin layer of light gray (10YR 7/1) silica

Dominant color: 10YR 3/3

Few yellow-brown (10YR 5/6) lumps; relict pumice?

GRAIN-SIZE:
3-108 (0.1, 29.4, 70.5)

CARBON/CARBONATE:
3-100 (0.1, 0.0, 0.1)

Dominant color: 10YR 3/3

At 82-85 cm irregular, long patch 10YR 5/6; relict pumice?

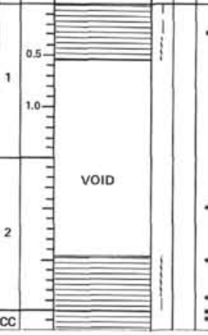
NOTE: Hole 447A, Core 2, 9.0-18.5 m: NO RECOVERY. The core barrel accumulated drilling pipe grease which clogged the Core-Catcher. A sample of the grease was taken by organic geochemist for analysis of contaminants.

SITE 447 HOLE A CORE 3 CORED INTERVAL: 18.5-28.0 m

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

Fossil characters: I, F, G (CC)

Sections: 1, 2, CC



LITHOLOGIC DESCRIPTION

Smear of drill pipe grease

PELAGIC CLAY, dark reddish brown (5YR 2.5/3) with common streaks and approximately 3 mm lumps of slightly more indurated yellowish red (5YR 4/6) material containing less (~1%) micronodules and iron oxide aggregates (see Core-Catcher smear slide).

7.5YR 4/6 patch approximately 1 cm in diameter

Stretched 5 cm long mottle, 5YR 3/3

5YR 2.5/3

SMEAR SLIDE SUMMARY

	1-35 (D)	2-101 (D)	2-141.5 (D)	CC (D)	CC (M)
TEXTURE:					
Sand	0	0	0	0	–
Silt	15	20	15	15	–
Clay	85	80	85	85	98
TOTAL DETRITAL	85	80	85	85	–
COMPOSITION:					
Quartz	TR	–	–	–	–
Clay	85	80	85	85	–
Micronodules	5	8	5	1	1
Zeolites	1	1	4	10	–
Amorph Fe agg.	8	10	5	3	–
Fish remains	1	1	1	1	1

SITE 447 HOLE A CORE 4 CORED INTERVAL: 28.0-37.5 m

AGE	BIOSTR. ZONE (NANNOS / FORAMS / RADS)	FOSSIL CHARACT. (FOSSIL / ABUNDANCE / PRESERV.)	SECTION	METERS	GRAPHIC LITHOLOGY
		N – –; F – –; N – –; F – –	1	0.5; 1.0	Mn; VOID
		N – –; F – –	2		
		N – –; F – –	3		
		N – –; F – –	4		
		N – –	5		
			CC		

LITHOLOGIC DESCRIPTION

Top 10 cm loose Mn nodules, almost certainly dropped in from top of hole.

7.5YR 4/4

5YR 3/2

PELAGIC CLAY, 40 to 95 cm alternations of 7.5YR 4/4 and 5YR 3/2. Streaky admixtures of these two principal colors where the core is severely disturbed. Local small patches and mottles are lighter colored due to lesser contents of amorphous iron oxide aggregates and micronodules.

(7.5YR 4/4, 0.8 x 3 cm stretched mottle)
Disturbed streaky admixture of 7.5YR 4/4 and 5YR 3/2.

5YR 3/2

Streaky admixture, mostly 5YR 3/2; rest 7.5YR 4/4

1.5 cm lump of altered volcanic glass, yellow (5Y 6/8)

5YR 3/2 with streaks of 7.5YR 4/4

Whole core sampled

2.2 cm indurated layer, 10YR 5/4

Deformed layer of 5Y 6/8

VOID

7.5YR 4/4

Streaky admixture of 7.5YR 4/2 and 5YR 3/2

Chunky admixture of 7.5YR 4/2 and 5YR 3/2

SMEAR SLIDE SUMMARY

	1-30 (D)	1-60 (D)	2-60 (D)	3-60 (D)	4-75 (D)
TEXTURE:					
Sand	TR	–	–	5	1
Silt	10	20	20	17	25
Clay	90	80	80	78	74
TOTAL DETRITAL	90	80	80	78	78
COMPOSITION:					
Quartz	–	–	–	–	TR
Feldspar	–	–	–	–	1
Clay minerals	90	80	80	78	77
Micronodules	2	2	TR	2	TR
Zeolites	3	10	8	10	10
Amorph Fe agg.	5	8	10	10	10
Fish remains	TR	TR	2	6	2

Smear Slides (Minor): 3-25, 4-35, 4-65

GRAIN-SIZE:
3-92 (0.3, 21.5, 78.2)

CARBON/CARBONATE:
3-91 (0.0, 0.2, 0.1)

SITE 447 HOLE A CORE 5 CORED INTERVAL: 37.5-47.0 m

AGE	BIOSTR. ZONE (NANNOS / FORAMS / RADS)	FOSSIL CHARACT. (FOSSIL / ABUNDANCE / PRESERV.)	SECTION	METERS	GRAPHIC LITHOLOGY
Late middle to early late Oligocene	NP 24	N C P; N C P; F – –	1	0.5; 1.0	
		F – –	2		
		F – –	3		
		F – –	4		
		F – –	5		
		F – –	6		VOID
		F – –; R R M	7		
		N C P	CC		

LITHOLOGIC DESCRIPTION

VOID
10YR 4/3 volcanic ash

10YR 4/3

CALCAREOUS PELAGIC CLAY, dark yellow-brown in top half of core, grading down through yellow-brown in Section 5 to light yellow-brown in bottom of core. This color change is due to a systematic decrease in amorphous ferruginous aggregate and micronodule content. However, Section 6 has several scattered 0.5 to 1 cm diameter manganese and iron-rich concentrations.

2.5Y 5/6 nannofossil ooze

10YR 4/3

10YR 4/4

Disturbed vertically streaked admixture of 10YR 4/4 and 1.5Y 5/6

10YR 4/4

10YR 5/4

SMEAR SLIDE SUMMARY

	1-75 (D)	2-75 (D)	5-62 (D)	6-94 (D)
TEXTURE:				
Sand	0	0	5	0
Silt	80	75	85	80
Clay	20	25	20	20
TOTAL DETRITAL	15	20	15	20
COMPOSITION:				
Clay minerals	15	20	15	20
Micronodules	2	2	1	1
Zeolites	–	–	–	1
Amorph Fe agg.	3	3	1	TR
Nannofossils	80	75	82	78
Fish remains	TR	–	–	–

Smear Slides (Minor): 1-5, 3-45, 5-30, 6-80

GRAIN-SIZE:
2-102 (0.0, 47.6, 52.3)

CARBON/CARBONATE:
2-99 (0.1, 13.0, 1.7)

MAGNETIC SAMPLE: 2-76

SITE 447 HOLE A CORE 6 CORED INTERVAL: 47.0-56.5 m

AGE	BIOSTR. ZONE: NANNOS	FOSSIL	ABUNDANCE	PRESERV.	SECTION
Late middle to early late Oligocene	NP 24	N F	C –	P –	1
					2
		N F	C –	P –	3
		F	–	–	4
		F	–	–	5
		F	–	–	6
		F R	– R	– G	7
		F N	R C	M M	CC

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY

DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | LITHOLOGIC SAMPLE

LITHOLOGIC DESCRIPTION

General color 2.5Y 4/4

NANNOFOSSIL CHALK-BRECCIA, olive brown in the top section, light olive brown in the rest of the core. Section 1 is best characterized texturally as a microbreccia, with typical clast sizes of 2 to 5 mm. The percentage of clasts varies from 5 to 15%. Section 2 is texturally transitional; the clast sizes increase down-core so the texture in Section 3 and the rest of the core is a proper pebble breccia. All but a few of the clasts are nannofossil chalk; several clasts of altered pumice were smear-slided, and a few brownish yellow clasts of deeply weathered basalt are also found.

Drilling deformation is moderate to intense, disaggregating most of the breccia. Each section contains several 2 to 7 cm thick pieces which have retained their cohesion during drilling.

General color 2.5Y 5/4

SMEAR SLIDE SUMMARY

	1-5 (M)	1-7 (D)	2-60 (M)	2-85 (D)	3-8 (M)	3-12 (M)	3-29 (M)	3-91 (M)	4-70 (M)	4-120 (M)	4-130 (M)
TEXTURE:											
Sand	30	35	25	0	10	50	0	0	2	2	1
Silt	50	50	50	50	90	50	90	90	88	96	89
Clay	20	25	25	50	0	0	10	10	10	2	10
TOTAL DETRITAL	43	55	69	52	98	0	85	89	80	97	94
COMPOSITION:											
Quartz	5	1	–	2	–	–	–	–	TR	–	–
Feldspar	3	TR	–	–	–	–	TR	–	TR	–	–
Heavy minerals	5	TR	–	–	3	–	–	TR	1	2	2
Clay minerals	–	–	25	50	–	–	–	TR	TR	1	–
Lithic frags.	–	34	44	–	–	–	–	–	–	–	–
Volcanic glass	30	20	–	–	95	–	85	89	80	94	92
Micronodules	–	2	TR	1	–	–	–	–	–	–	–
Zeolites	40	TR	1	1	2	3	5	10	3	3	5
Amorph Fe agg.	10	3	TR	TR	–	97	5	1	1	–	TR
Foraminifers				1							
Nannofossils	7	40	40	45	–	–	5	–	15	–	1
Fish remains	–	–	–	TR	–	–	–	–	TR	–	–

GRAIN-SIZE:
1-73 (2.5, 66.8, 30.7)
6-73 (1.8, 64.8, 33.4)

MAGNETIC SAMPLE: 7-39

PHYSICAL PROPERTIES:	Section 4 40-42 cm	Section 6 40-42 cm	Section 6 94-96 cm
$\overline{V}p$ (km/s)			
parallel to beds	1.95	1.99	–
vertical to beds	–	1.97	–
Wet bulk density	–	1.44	1.45
Porosity (%)	–	66.8	68.5
Grain density	–	2.34	2.41

SITE 447 HOLE A CORE 7 CORED INTERVAL: 56.5-66.0 m

AGE	BIOSTR. ZONE: NANNOS	FOSSIL	ABUNDANCE	PRESERV.	SECTION
Middle Oligocene	NP 23	N F	C R	P P	1
		F	–	–	2
		F	R	P	3
		F	R	P	4
		F	R	P	5
		F	–	–	6
		R F	R R	M P	7
		N	F	P	CC

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY

DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | LITHOLOGIC SAMPLE

LITHOLOGIC DESCRIPTION

At 42 and 45 cm: Mn films
Mn patches
Mn patches and dendroids
Mn dendroids
Mn patches

MICROCRYSTALLINE CARBONATE CHALK-BRECCIA. Textural equivalent of Core 6 but with the carbonate component largely microcrystallized; light yellow-brown (2.5Y 6/4); intensely to moderately fractured by drilling. Approximately 80 to 90% of the material has disaggregated by the drill, and 10 to 20% occurs as coherent pieces of breccia 2 to 10 cm thick. There is some suggestion that the variable resistance to drilling deformation is controlled in part by original lithification: the coherent pieces contain manganiferous patches and dendroids and the tops of some coherent pieces are marked by thin manganiferous films, as detailed in Section 1. Similar occurrences mark the entire core.

SMEAR SLIDE SUMMARY

	1-41 (D)	3-92 (D)	5-102 (D)	7-7 (D)
TEXTURE:				
Sand	3	5	2	5
Silt	20	20	15	10
Clay	80	75	83	85
TOTAL DETRITAL COMPOSITION:	61	45	51	50
Quartz	1	TR	TR	TR
Feldspar	–	TR	TR	TR
Mica	–	–	–	TR
Clay	60	45	50	50
Volcanic glass	–	–	1	–
Zeolites	1	1	1	1
Carbonate unspec.	35	51	45	48
Nannofossils	2	3	3	1
Fish remains	–	TR	–	–

GRAIN-SIZE:
4-70 (5.8, 65.3, 29.0)

CARBON/CARBONATE:
4-73 (0.1, 2.6, 0.5)

PHYSICAL PROPERTIES:	Section 1 70-72 cm
$\overline{V}p$ (km/s)	
parallel to beds	2.10
vertical to beds	2.07
Wet bulk density	1.46
Porosity (%)	70.2
Grain density	2.53

SITE 447 HOLE A CORE 8 CORED INTERVAL: 66.0-75.5 m

AGE	BIOSTR. ZONE: NANNOS	BIOSTR. ZONE: FORAMS	BIOSTR. ZONE: RADS	FOSSIL CHARACT.: FOSSIL	FOSSIL CHARACT.: ABUNDANCE	FOSSIL CHARACT.: PRESERV.	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE
Middle Oligocene	NP 23						1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0	VOID			
				N	C	P	CC					

LITHOLOGIC DESCRIPTION

POLYMICTIC BRECCIA, dark olive gray (5Y 3.5/2). The clasts are primarily microcrystalline carbonate chalk (50-55%), mudstone and siltstone (15-20%), plagioclase fragments (5-10%, zeolite fragments (5-10%), basalt fragments (5-10%), and glass fragments (5-10%). The sedimentary clasts are moderately to well rounded whereas the igneous clasts are angular. Clasts comprise approximately 60% of the rock, the 40% matrix being described from smear slides as a marly chalk. Most of the core is missing, and the recovered section consists primarily of drilling breccia.

SMEAR SLIDE SUMMARY

	1-8 (D)	1-12 (M)	6-12 (D)	6-42 (D)	6-124 (D)
TEXTURE:					
Sand	40	0	5	2	0
Silt	20	90	20	20	60
Clay	40	10	75	78	40
TOTAL DETRITAL	45	100	45	38	54
COMPOSITION:					
Quartz	TR	TR	TR	TR	TR
Feldspar	5	TR	TR	–	TR
Mica	–	–	TR	–	–
Heavy minerals	TR	TR	–	–	–
Clay minerals	45	–	45	38	54
Volcanic glass	–	100	–	–	–
Amorph Fe agg.	1	–	–	2	–
Zeolites	–	–	1	–	–
Carbonate unspec.	49	–	52	45	43
Nannofossils	–	–	2	15	3
Radiolaria	–	–	TR	–	–
Sponge spicules	–	–	TR	–	–

PHYSICAL PROPERTIES:

	Section 1 5-8 cm
$\overline{V}p$ (km/s)	
parallel to beds	2.36
vertical to beds	2.31

SITE 447 HOLE A CORE 9 CORED INTERVAL: 75.5-85.0 m

AGE	BIOSTR. ZONE: NANNOS	BIOSTR. ZONE: FORAMS	BIOSTR. ZONE: RADS	FOSSIL CHARACT.: FOSSIL	FOSSIL CHARACT.: ABUNDANCE	FOSSIL CHARACT.: PRESERV.	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE
Middle Oligocene	NP 23			N	F	P	1, 2	0.5, 1.0				T, T
				R	R	P						
				N	F	P	CC					

LITHOLOGIC DESCRIPTION

POLYMICTIC BRECCIA, dark greenish gray (5GY 4/1), well indurated, moderately disturbed by drilling.

Clasts range in size from 1 to 55 mm, averaging 8 to 10 mm, and are typically elongate. Roundness is moderate to good for sedimentary clasts; those derived from volcanic provenance are angular to subangular. The clasts comprise approximately 70 to 80% of the rock, and are summarized in the table below.

From smear slides, the matrix is described as marly chalk, texturally 5% sand (forams), 30% silt and 65% clay. Approximately 60% is made up of nannofossils and foraminifers, recrystallized locally to microcrystalline carbonate. The remaining 40% is mainly clay and amorphous iron oxides. Locally, authigenic feldspar crystals up to 2 mm occur both in the matrix and in clasts.

Lithologic type of clasts:

Coccolith limestone, chalk	light greenish gray (5G 8/1)	25%
Mudstone, marly chalk	greenish gray (5G 6/1)	15%
Fresh basalt fragments	greenish black	20%
Deeply weathered basalt	brownish yellow (10YR 6/4)	10%
Volcanic glass	greenish black	20%
Quartz, feldspar fragments		5%

SMEAR SLIDE SUMMARY

	1-7 (D)	1-76 (D)	1-133 (M)	1-125 (D)
TEXTURE:				
Sand	–	–	–	–
Silt	5	5	90	15
Clay	95	95	10	85
TOTAL DETRITAL	40	34	86	20
COMPOSITION:				
Quartz	–	TR	–	–
Feldspar	1	TR	–	TR
Clay minerals	39	34	6	20
Volcanic glass	–	–	80	–
Amorph Fe agg.	–	–	1	–
Zeolites	TR	–	7	–
Carbonate unspec.	55	58	5	75
Nannofossils	5	8	1	5
Fish remains	–	–	–	TR

GRAIN-SIZE:
2-43 (5.2, 53.1, 41.7)

PHYSICAL PROPERTIES:

	Section 2 42-43 cm
$\overline{V}p$ (km/s)	
parallel to beds	2.48
vertical to beds	2.44
Wet bulk density	1.73
Porosity (%)	53.9
Grain density	2.59

SITE 447 HOLE A CORE 10 CORED INTERVAL: 85.0-94.5 m

AGE	BIOSTR. ZONE: NANNOS	FORAMS	RADS	FOSSIL CHARACT.: FOSSIL	ABUNDANCE	PRESERV.	SECTION	METERS
Middle Oligocene	NP 23			N	–	–	1	0.5, 1.0
				F	–	–	2	
							CC	

GRAPHIC LITHOLOGY

DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / LITHOLOGIC SAMPLE

LITHOLOGIC DESCRIPTION

Gray (5Y 5/1), slightly mottled

Brown (7.5YR 5/2) with minor dark yellowish brown.

Olive (5Y 4/3)

Dark gray (5Y 4/1), moderately to intensely mottled, very dark gray or black 60 to 76 cm.

Reddish brown, slightly mottled black (5YR 5/4 with 5YR 2/1 mottling).

Olive gray (5Y 5/2), intensely mottled at 120 to 122 cm with slightly paler or darker colors.

Olive (5Y 5.5/3), intensely mottled, with a 2-cm blue (5B 6/2) patch.

Olive gray (5Y 5/2), unmottled.

Grayish green (10GY 5/2), slightly mottled in the upper portion, intensely mottled from 52 to 62 cm. Sharp basal contact.

VOLCANICLASTIC BRECCIA, greenish gray (5G 6/1), angular to subrounded clasts principally of volcanic origin, maximum dimensions 3 cm. Sharp basal contact, 26 cm thick.

VITRIC TUFF, greenish black (5GY 2/1), coarser layers 1 and 1.5 cm thick, dark greenish gray (5G 4/1), at 90 to 91 and 104-111 cm, 59 cm thick.

Same **VOLCANICLASTIC BRECCIA,** greenish gray (5G 4/1), as at 60 to 86 cm in this section.

Uppermost unit, 212 cm thick is **FINE TUFF**, hydrothermally altered, variegated clays as detailed; will need shorebased XRM for proper identification.

Core-Catcher: same breccias as above.

SMEAR SLIDE SUMMARY

	1-34	1-62	1-95	1-140	2-84	2-140
TEXTURE:						
Sand	0	0	0	0	0	0
Silt	5	5	5	15	–	35
Clay	95	95	95	85	–	60
TOTAL DETRITAL	91	95	93	95	90	91
COMPOSITION:						
Quartz	2	2	2	2	10	–
Feldspar	–	–	–	–	25	–
Clay	89	93	90	83	45	5
Volcanic glass	–	–	1	10	–	86
Micronodules	6	5	5	1	–	–
Zeolites	TR	TR	1	4	–	10
Amorph Fe agg.	–	–	1	–	10	–
Nannofossils	3	–	–	TR	–	–

CARBON/CARBONATE:
2-92 (0.0, 0.1, 0.1)

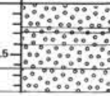
MAGNETIC SAMPLE: 1-105 2-49 2-121

PHYSICAL PROPERTIES:	Section 2 95-97 cm
$\overline{V}p$ (km/s)	
parallel to beds	2.51
vertical to beds	2.44
Wet bulk density	1.63
Porosity (%)	61.7
Grain density	2.63

SITE 447 HOLE A CORE 11 CORED INTERVAL: 94.5-98.0 m

AGE	BIOSTR. ZONE: NANNOS	FORAMS	RADS	FOSSIL CHARACT.: FOSSIL	ABUNDANCE	PRESERV.	SECTION	METERS
Middle Oligocene	NP 23			N	C	P		
				F	R	P		0.5
				F	R	M		
				N	C	PM	CC	

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / LITHOLOGIC SAMPLE

LITHOLOGIC DESCRIPTION

Drilling breccia; clasts 5GY 2/1, 5Y 6/3, 10YR 3/4

Drilling breccia of volcaniclastic breccia: 5GY 2/1; pieces 2 to 6 cm thick

5GY 2/1

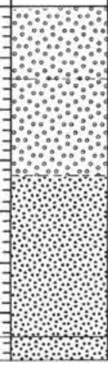
VOLCANICLASTIC BRECCIA as in Core 10. Clasts are well sorted, ranging from 0.5 to 2 cm in the disaggregated interval from 28 to 44 cm; maximum dimensions are normally about 1 cm in the coherent pieces at the top and bottom of the recovered core. The matrix requires shorebased XRM for proper identification. It is greenish black (5GY 2/1), with some interlayers of pale olive (5Y 6/3) volcanic tuff and dark yellowish brown (10YR 3/4) metal-rich clays (smear slides 1-34 and 1-41). present as small (0.5 to 2 cm) randomly mixed fragments among the drilling breccia in the interval from 28 to 44 cm.

SMEAR SLIDE SUMMARY

	1-34 (M)	1-41 (M)
TOTAL DETRITAL	79	60
COMPOSITION:		
Quartz	5	2
Feldspar	–	5
Heavy minerals	–	1
Clay minerals	64	–
Volcanic glass	10	47
Micronodules	15	–
Amorph Fe agg.	–	5
Zeolites	5	–
Microcryst. carb.	–	40
Nannofossils	1	–

SITE 447 HOLE A CORE 12 CORED INTERVAL: 98.0-104.0 m

AGE	BIOSTR. ZONE: NANNOS	FORAMS	RADS	FOSSIL CHARACT.: FOSSIL	ABUNDANCE	PRESERV.	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	
Middle Oligocene	NP 23						1	0.5, 1.0				•, T, •, T, •	5B 5/1; 10Y 4/2, minor 2.5YR 3/2
							2					T, T, T	10YR 5/4
							3					T	
				N	R	P	CC					T	



LITHOLOGIC DESCRIPTION

VOLCANICLASTIC BRECCIA 160 cm thick, medium bluish gray (5B 5/1) at the top and grayish olive (10Y 4/2) with minor dusky red (1.5YR 3/2) in the lower part of the core. Clasts are angular and irregularly shaped, normally 0.5 to 5 cm in size; a few clasts are larger than the 6.6 cm core liner. Most clasts are weathered basalt. Interclast spaces are filled with amorphous very fine-grained volcanic glass (73%), recrystallized carbonate (25%) and coccoliths (2%). The clast/matrix ratio is about 3/1. This unit has a disturbed contact with the underlying **TUFF**, 162 cm thick, moderate yellowish brown (10YR 5/4) gravel to very coarse sand clasts in the lower half of Section 1, grade downcore from light yellowish brown very coarse and coarse to medium-to-coarse in the lower part of the core, defining a general downward-fining ("inverted") size grading. The clasts are angular, irregularly shaped, and rarely larger than 2 mm although clasts up to 7 cm long are present. Almost all the clasts are volcanic in origin: weathered basalt (40 to 75%), glass (25 to 60%), and vesicular basalt (10%) with zeolite-filled amygdules. In places the clasts display moderate sorting, inverted graded bedding, and elongation of platy and prismatic grains parallel to bedding. The clast/matrix ratio is about 7/3. The matrix is mostly clay- and silt-sized glass fragments with rare ghosts of coccoliths and other carbonate (<5%). About 10% is authigenic silica, outlining cavities with acicular, radiating, clear crystals and occurring as rare overgrowths on carbonate particles.

SMEAR SLIDE SUMMARY

	1-5 (M)	1-76 (M)	1-127 (M)
TOTAL DETRITAL	68		
COMPOSITION:			
Quartz	2	Andesitic basalt clast	Andesitic basalt clast
Feldspar	5		
Heavy mingerals	TR		
Clay minerals	30		
Volcanic glass	33		
Amorph Fe agg.	2		
Zeolites	30		

CARBON/CARBONATE:
2-132 (0.0, 1.1, 0.2)

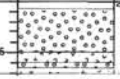
MAGNETIC SAMPLE:
CC-10 CC-100

BULK ANALYSIS:	1-138
SiO_2	49.0
TiO_2	0.85
Al_2O_3	15.7
Fe_2O_3	1.17
FeO	7.72
MnO	0.16
MgO	8.37
CaO	12.93
Na_2O	2.25
K_2O	0.39
P_2O_5	0.06

PHYSICAL PROPERTIES:	Section 1 69-71 cm	Section 2 128-131 cm
$\bar{V}p$ (km/s)		
parallel to beds	4.59	3.59
vertical to beds	4.21	3.62

SITE 447 HOLE A CORE 13 CORED INTERVAL: 104.0-113.0 m

AGE	BIOSTR. ZONE: NANNOS	FORAMS	RADS	FOSSIL CHARACT.: FOSSIL	ABUNDANCE	PRESERV.	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE
							1	0.5				•, T
							CC					

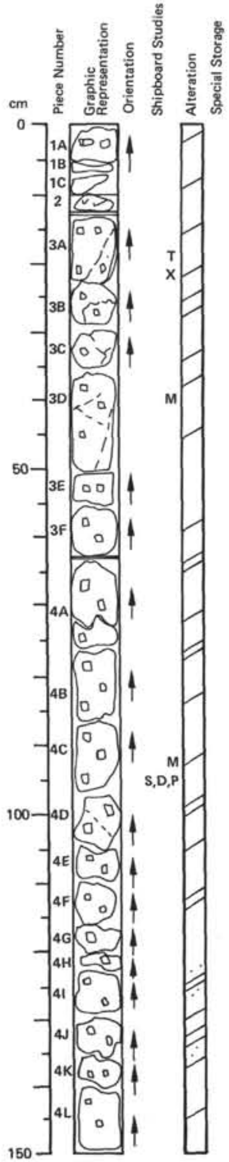


LITHOLOGIC DESCRIPTION

All 50 cm of Section 1 and the 10 to 17 cm interval of the Core-Catcher is **VOLCANICLASTIC BRECCIA**, light yellow-brown with structureless spherulitic glass, massive and zeolitized vesicular basalt fragments, most of them weathered reddish brown (7.5YR 6/6). The clasts are angular and irregularly shaped, the average dimension is about 1 cm, but fragments larger than the liner do sometimes occur. The clast/matrix ratio is about 3/1. The matrix is microcrystalline carbonate (45%), clay (35%), volcanic glass fragments (20%). Intergranular space (5%) is filled by clear silica cement, mainly bordering the margins of some glass clasts.

The top 10 cm and lowest 14 cm of the Core-Catcher is plagioclase-phyric **BASALT**, black and fresh or deeply weathered to a light yellowish brown (10YR 6/4). The lowest piece has a 2 mm thick upper glass rind and 2 to 3 mm calcite fracture fillings.

NOTE: During recovery of the core most of the Core-Catcher contents fell out on deck, so the pieces may well be out of proper stratigraphic sequence.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE				HOLE	CORE		SECT.
5	9	4	4	7		A	1	4	1

Depth: 113.0 to 114.5 m

Visual Description

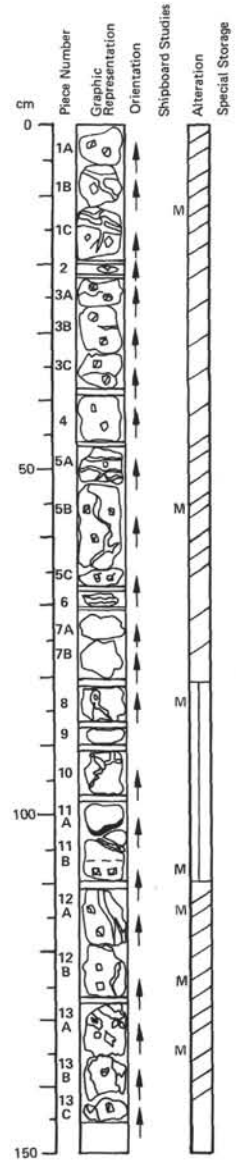
Plagioclase-phyric, tholeiitic basalt flow, gray (7.5R 5/0); groundmass texture varies from hyalopilitic to subophitic; plagioclase euhedral and subhedral, clinopyroxene euhedral to anhedral; minor titanomagnetite; several generations of carbonate veins.

Thin Section Description

Location: 18-20 cm, flow interior
Texture: subophitic
Phenocrysts: 2%; plagioclase An_{75}, 2 mm, mostly glomerocrysts
Groundmass: >93%; plagioclase 50%, An_{69}, 0.5 mm, laths; clinopyroxene 45%, 0.2 mm, plumose intergrowth with plagioclase, not in laths; magnetite/ilmenite 5%, 0.01 mm; olivine(?), 0.1 mm, replaced with smectite and carbonate.
Vesicles: spheres 5%, 0.2-0.5 mm, smectite rims
Alteration: slight; carbonate and clays replace olivine and some plagioclase.

Shipboard Data

Physical Properties:	93-97 cm
$\overline{V}p$ (km/s)	
parallel to beds	5.38
vertical to beds	5.51
Wet bulk density	2.77
Porosity (%)	—
Acoustic impedance	—



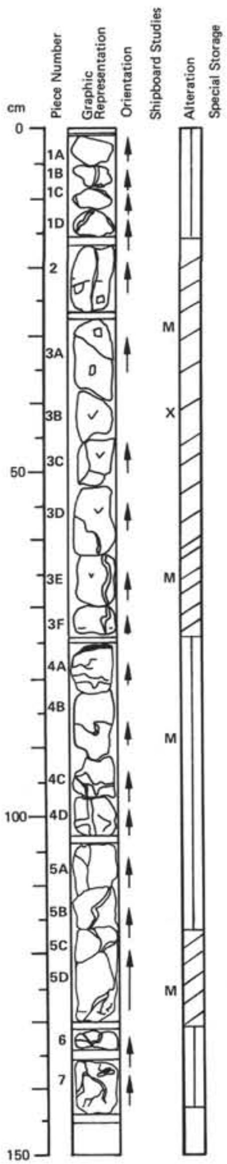
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE				HOLE	CORE		SECT.
5	9	4	4	7		A	1	4	2

Depth: 114.5 to 116.0 m

Visual Description

0-80 cm: basalt flow as in Section 14-1.
80-145 cm: plagioclase-phyric, tholeiitic pillow basalt, gray (7.5R 5/0), slightly altered. Glassy chilled margin, 80-103 cm. Mainly holocrystaline, fine-grained, from hyalopilitic to subophitic and microphyric; sparse microphenocrysts (1.0-1.5 mm) of plagioclase and rare olivine (?). Numerous, 1-10 mm wide dikes of same composition, along contacts of which the host rock is slightly altered.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

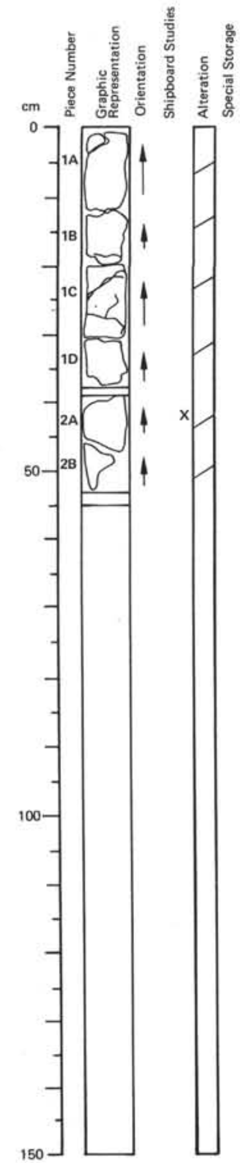
LEG	SITE	HOLE	CORE	SECT.
59	447	A	14	3

Depth: 116.0 to 117.5 m

Visual Description
As in Section 14-2.

Shipboard Data

Bulk Analysis:	**41 cm**
SiO_2	47.7
TiO_2	1.09
Al_2O_3	16.4
Fe_2O_3	1.29
FeO	8.52
MnO	0.19
MgO	6.76
CaO	12.19
Na_2O	2.60
K_2O	0.45
P_2O_5	0.07

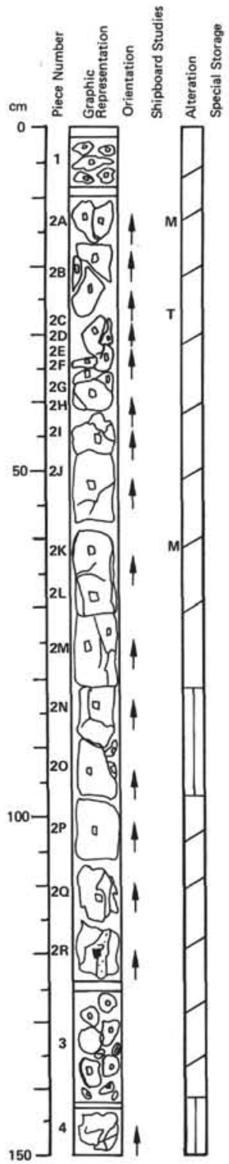


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	14	4

Depth: 117.5 to 118.0 m

Visual Description
As in Section 14-2; inner part of flow.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	15	1

Depth: 122.0 to 123.5 m

Visual Description

0-100 cm: as in Sections 14-3, 14-4; glassy base.

100-150 cm: plagioclase-phyric, tholeiitic basalt, pillowed massive flow, gray (7.5YR 5/0), slightly altered. Texture holocrystalline, fine-grained, diabasic; microphenocrysts (1.5-2 mm) of plagioclase and clinopyroxene locally form glomerocrysts.

Thin Section Description

Location: 26-29 cm, flow interior

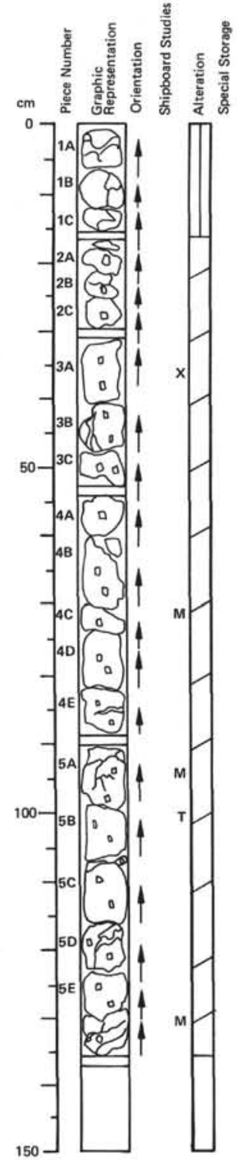
Texture: subophitic

Phenocrysts: < 2%; plagioclase, 1 mm, blocky, in glomerocrysts

Groundmass: > 95%; plagioclase 50%, 0.8 mm, in laths; clinopyroxene 44%, 0.2-0.4 mm, slightly plumose between plagioclase laths; olivine < 3%, 0.1 mm, replaced with clays; magnetite and ilmenite present

Vesicles: 3%, 0.1 mm, with smectite rims

Alteration: ~5% of rock; carbonate (rare) and clays replace olivine and clinopyroxene. Hematite present in olivine and magnetite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	15	2

Depth: 123.5 to 125.0 m

Visual Description

Plagioclase-phyric, tholeiitic basalt, pillowed massive flow as in Section 15-1.

Thin Section Description

Location: 98-100 cm, flow interior

Texture: subophitic

Phenocrysts: < 3%; plagioclase, blocky crystals in glomerocrysts

Groundmass: > 97%; plagioclase 50%, An_{78}, 1.0 mm, elongate laths; clinopyroxene 45%; magnetite and ilmenite < 5%

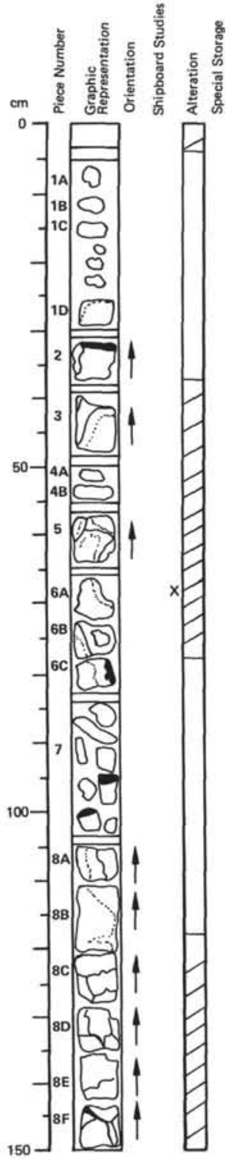
Vesicles: spherical, < 1%, 0.3-0.5 mm, filled with smectite and red cubes (?hematite alteration of pyrite)

Alteration: 10%, carbonate replacing clinopyroxene and some plagioclase; clays replacing clinopyroxene

Shipboard Data

Bulk Analysis:	**35 cm**
SiO_2	47.8
TiO_2	1.95
Al_2O_3	16.3
Fe_2O_3	1.27
FeO	8.41
MnO	0.19
MgO	6.71
CaO	11.51
Na_2O	2.75
K_2O	0.50
P_2O_5	0.08

Physical Properties:	**126-129 cm**
$\overline{V}p$ (km/s)	
parallel to beds	4.83
vertical to beds	5.38
Wet bulk density	2.66



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	15	3

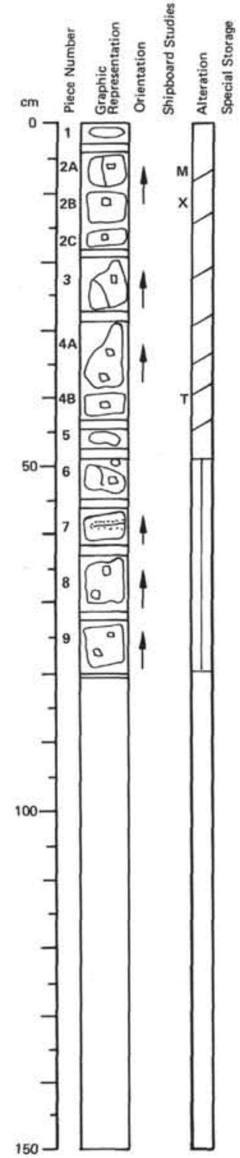
Depth: 125.0 to 126.5 m

Visual Description

Sparsely plagioclase-phyric, tholeiitic basalt, pillowed massive flow, pale gray, fine- to very fine-grained, granular to subophitic; rare phenocrysts of plagioclase in 0-30 cm interval; scattered vesicles 0.5-1.0 mm, empty to filled with calcite or zeolites. Strongly altered at 30-37 cm and 82-105 cm, buff colored, with thin glassy rinds, veined with quartz(?) and zeolites. Fragments of altered glass and green, concentrically banded smectite at 30-37 cm and 65-80 cm.

Shipboard Data

Bulk Analysis:	69 cm
SiO_2	48.5
TiO_2	0.87
Al_2O_3	16.0
Fe_2O_3	1.21
FeO	8.00
MnO	0.18
MgO	7.58
CaO	12.47
Na_2O	2.36
K_2O	0.53
P_2O_5	0.07



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	15	4

Depth: 126.5 to 127.3 m

Visual Description

Sparsely plagioclase-phyric, tholeiitic basalt, pillowed massive flow as in Section 15-3; fine-grained with irregular patches of brown glassy groundmass. Rare vesicles, <0.5 mm, at top of section, becoming numerous and ~1 mm at 4-18 cm. Vesicles empty or lined with blue zeolite and smectite. Scattered plagioclase phenocrysts, 1-2 mm in latter interval.

Thin Section Description

Location: 38-41 cm, flow interior

Texture: hyalopilitic

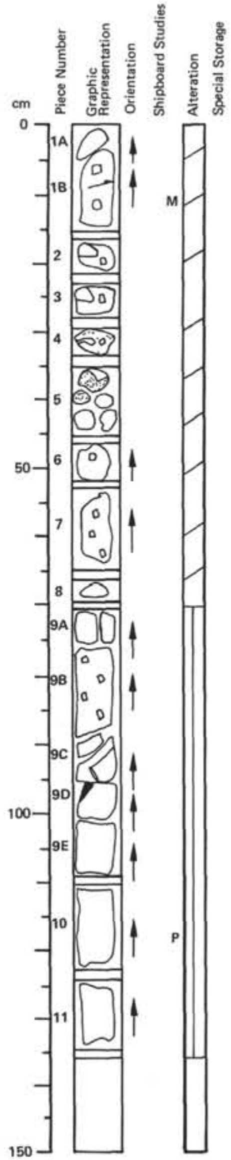
Phenocrysts: < 1%; plagioclase, 0.8-1.0 mm

Groundmass:> 92%; plagioclase 50%, An_{64}, 0.5-0.7 mm; clinopyroxene 45%, 0.2-0.4 mm; magnetite and ilmenite 5%

Vesicles: spherical to oblate, 7%, 0.5-1.5 mm, evenly distributed, with smectite rims and with magnetite rhombs and carbonate centers

Shipboard Data

Bulk Analysis:	13 cm
SiO_2	47.8
TiO_2	1.00
Al_2O_3	15.9
Fe_2O_3	1.26
FeO	8.32
MnO	0.18
MgO	8.82
CaO	10.96
Na_2O	2.68
K_2O	0.38
P_2O_5	0.02



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	16	1

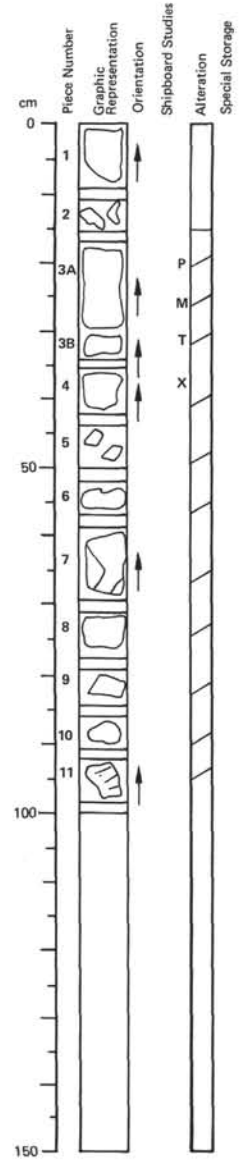
Depth: 131.0 to 132.5 m

Visual Description

Tholeiitic basalt as in Section 15-4 in interval 0-70 cm. From 70-135 cm, aphyric to plagioclase-phyric, tholeiitic pillow basalt; texture is coarser, 75% crystalline, ophitic with common glassy groundmass altered to brown clay, some veining.

Shipboard Data

Physical Properties:	**113-123 cm**
$\overline{V}p$ (km/s)	
parallel to beds	4.14



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	16	2

Depth: 132.5 to 133.5 m

Visual Description

Aphyric to plagioclase-phyric, tholeiitic, pillow basalt as in Section 16-1, alteration slight.

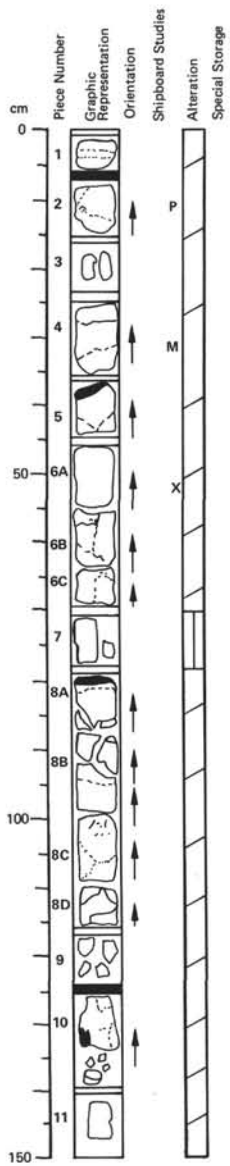
Thin Section Description

Location: 32-34 cm, flow interior
Texture: ophitic
Phenocrysts: none
Groundmass: plagioclase 50%, An_{68}, 1 mm, in curved laths; clinopyroxene 35%, 1 mm, some altered; olivine ~10%, 0.25 mm, altered to carbonate and green smectite; magnetite and ilmenite ~5%
Vesicles: none
Alteration: olivine replaced by clay and carbonate; some clinopyroxene replaced by clay

Shipboard Data

Bulk Analysis:	**37 cm**
SiO_2	47.5
TiO_2	0.99
Al_2O_3	15.4
Fe_2O_3	1.19
FeO	7.88
MnO	0.16
MgO	8.63
CaO	11.96
Na_2O	2.48
K_2O	0.51
P_2O_5	0.07

Physical Properties:	**17-28 cm**
$\overline{V}p$ (km/s)	
parallel to beds	5.59



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	17	1

Depth: 140.0 to 141.5 m

Visual Description

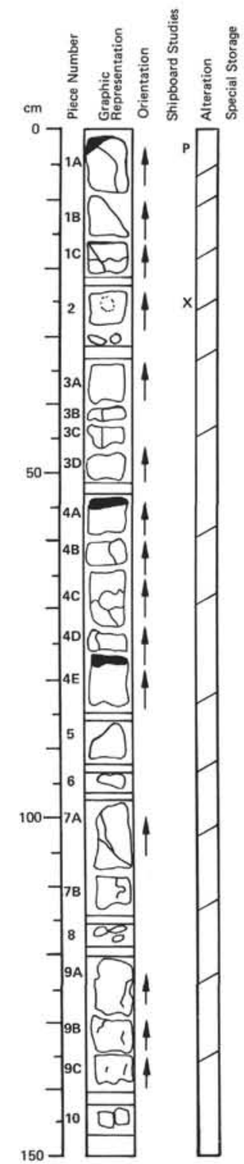
Aphyric to plagioclase-phyric, tholeiitic basalt as in Section 16-2, with numerous veins of zeolite and calcite to 125 cm.

From 125-150 cm, the basalt is plagioclase-olivine-phyric, tholeiitic basalt, pillowed massive flow, light gray, containing glomerocrysts of plagioclase and olivine, 1-3 mm, in very fine matrix. Glassy rinds present.

Shipboard Data

Bulk Analysis:	**52 cm**
SiO_2	48.6
TiO_2	1.05
Al_2O_3	16.1
Fe_2O_3	1.25
FeO	8.25
MnO	0.16
MgO	7.02
CaO	12.22
Na_2O	2.77
K_2O	0.45
P_2O_5	0.08

Physical Properties:	**7-15 cm**
$\overline{V}p$ (km/s)	
parallel to beds	5.30



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	17	2

Depth: 141.5 to 143.0 m

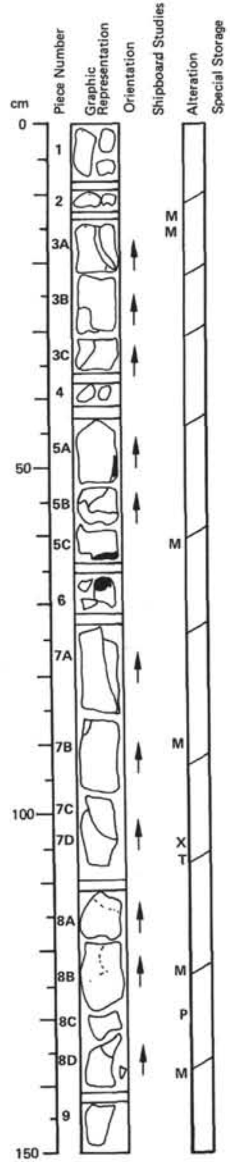
Visual Description

Plagioclase-olivine-phyric, tholeiitic basalt (as in base of Core 17-1), uniformly very fine-grained, light gray, nonvesicular, with numerous veins of calcite or zeolite, and with common chilled glassy pillow margins. Glomerocrysts of plagioclase and clinopyroxene and isolated (10%) 1-2 mm phenocrysts of iddingsite(?) after olivine.

Shipboard Data

Bulk Analysis:	**25 cm**
SiO_2	50.0
TiO_2	1.44
Al_2O_3	14.2
Fe_2O_3	1.33
FeO	8.81
MnO	0.17
MgO	7.67
CaO	11.37
Na_2O	2.66
K_2O	0.41
P_2O_5	0.06

Physical Properties:	**0-6 cm**
$\overline{V}p$ (km/s)	
parallel beds	5.17
vertical beds	5.33



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	17	3

Depth: 143.0 to 144.5 m

Visual Description

Plagioclase-clinopyroxene-phyric basalt as in Section 17-2 becoming less porphyritic towards base of section.

Thin Section Description

Location: 105-107 cm, flow interior

Texture: subvariolitic to subophitic

Phenocrysts: 15%; plagioclase 60%, An_{80}, 1 mm, in glomerocrysts with clinopyroxene, and in blocky crystals; clinopyroxene 40%, 1 mm

Groundmass: >84%; plagioclase 10%, 0.4 mm, lath microcrysts; olivine 2%, 0.1 mm skeletal microcrysts; plumose intergrowths of very fine plagioclase and clinopyroxene, 80%; glass 8%

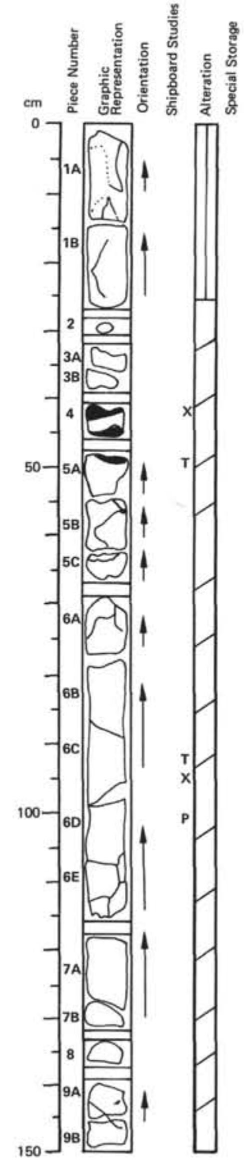
Vesicles: <1%, spherical, 0.05 mm with green smectite rims

Alteration: fresh, unaltered

Shipboard Data

Bulk Analysis:	**105 cm**
SiO_2	50.4
TiO_2	1.42
Al_2O_3	14.3
Fe_2O_3	1.23
FeO	8.13
MnO	0.17
MgO	8.08
CaO	11.86
Na_2O	2.68
K_2O	0.57
P_2O_5	0.10

Physical Properties:	**128-134 cm**
$\bar{V}p$ (km/s)	
parallel to beds	5.37



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	18	1

Depth: 149.0 to 150.5 m

Visual Description

Plagioclase-clinopyroxene-olivine-phyric, tholeiitic basalt (as in Section 17-3); fine-grained almost holocrystalline, pale gray; scattered phenocrysts of plagioclase, in places glomerocrysts, and brown euhedral pseudomorphs after olivine; patchy brown alteration. Vesicles common, 1-2 mm, filled with green smectite and/or zeolite. Occasional glassy rinds. Numerous veins of dark olive smectite and zeolite.

Thin Section Description

Location: 47-49 cm, next to glassy margin

Texture: variolitic

Phenocrysts: 9%; plagioclase 60%, 1.5 mm, clinopyroxene 30%, 0.8 mm; olivine 10%, 0.8 mm, completely altered

Groundmass: 90%; plagioclase 5%, An_{60}, 0.4 mm, very thin laths; clinopyroxene 10%, 0.3 mm; magnetite and ilmenite 3%, >0.02 mm; mostly variolitic 85%

Vesicles: 1%, 0.1-0.3 mm, spherical

Alteration: essentially fresh

Thin Section Description

Location: 82-94 cm, flow interior

Texture: hyalophilitic

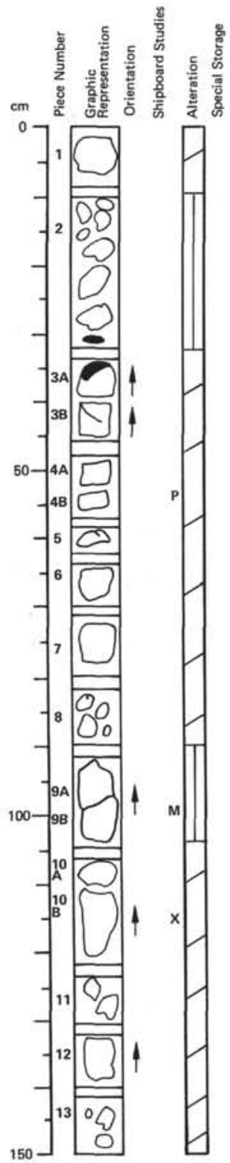
Phenocrysts: 10%; plagioclase 35%, An_{85}, 1.5 mm, glomerocrysts with clinopyroxene twins; clinopyroxene 65%, 1.5-2.0 mm

Groundmass: 90%; plagioclase 50%, An_{72}, 0.5 mm plumose in graphic intergrowths with clinopyroxene 35%, 0.2 mm; magnetite and ilmenite 5%; glass 10%, interstitial.

Alteration: fresh

Shipboard Data

Physical Properties:	**99-107 cm**
$\bar{V}p$ (km/s)	
parallel to beds	5.60



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	18	2

Depth: 150.5 to 152.0 m

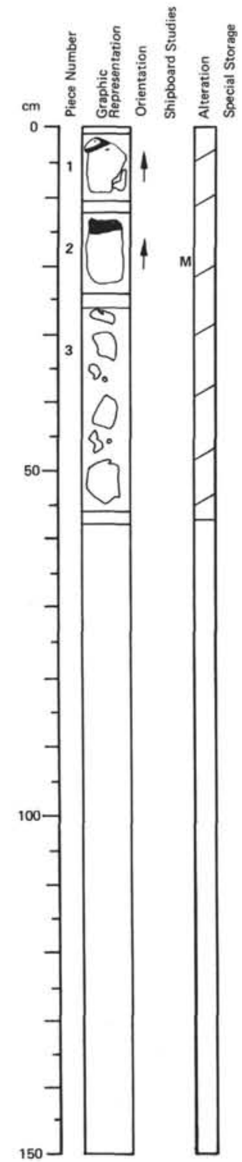
Visual Description

Plagioclase-clinopyroxene-olivine-phyric, tholeiitic basalt as in Section 18-1; two flow units.

Shipboard Data

Bulk Analysis:	116 cm
SiO_2	50.7
TiO_2	1.41
Al_2O_3	14.6
Fe_2O_3	1.24
FeO	8.20
MnO	0.15
MgO	8.24
CaO	12.01
Na_2O	2.67
K_2O	0.39
P_2O_5	0.10

Physical Properties:	54-58 cm
$\overline{V}p$ (km/s)	
parallel to beds	5.11
vertical to beds	—
Wet bulk density	3.08



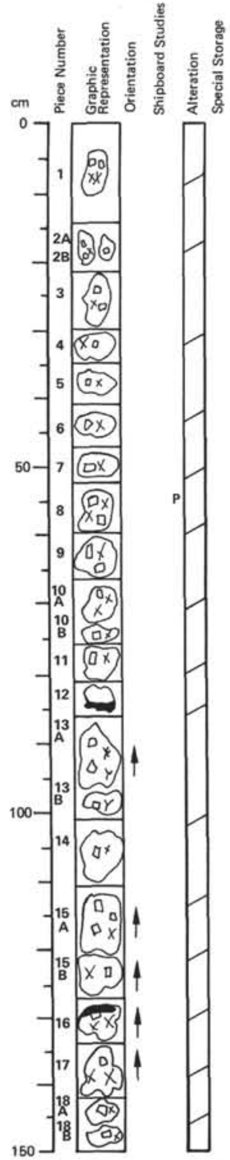
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	18	3

Depth: 152.0 to 153.5 m

Visual Description

Plagioclase-clinopyroxene-olivine-phyric, tholeiitic basalt flow as in Sections 18-1 and 18-2.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	19	1

Depth: 153.5 to 155.0 m

Visual Description

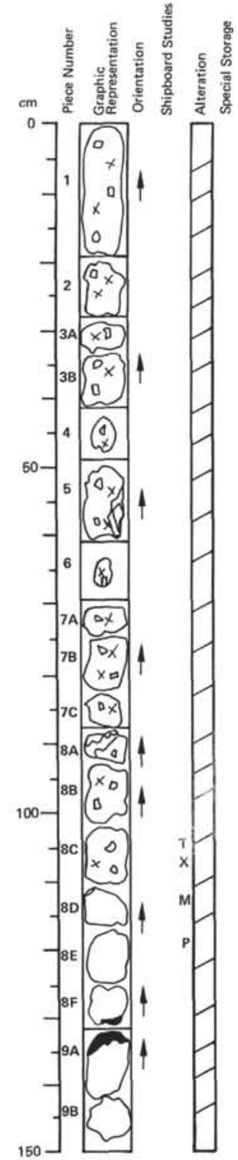
Plagioclase-clinopyroxene-olivine-phyric, tholeiitic basalt flow; gray (5YR 6/0), fine-grained, 90% crystalline; phenocrysts and microphenocrysts of plagioclase and clinopyroxene ~1 mm; frequent glomerocrysts, 2-3 mm. Scattered vugs, ~1 mm, partially or fully infilled with smectite and zeolites. Alteration occurs along fractures.

Glassy rims at 81-85 cm.

From 127-150 cm, basalt is aphyric, fine-grained, strongly altered, and contains glassy rim.

Shipboard Data

Physical Properties:	**53-59 cm**
$\bar{V}$p (km/s)	
parallel to beds	5.33



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	19	2

Depth: 155.0-156.5 m

Visual Description

Plagioclase-clinopyroxene-olivine-phyric, tholeiitic basalt as in Section 19-1, in interval 0-125 cm; pale gray with brown mottling (altered glass). Texture subophitic to hyalopilitic; rare phenocrysts and microphenocrysts of plagioclase, olivine and clinopyroxene. Rare vesicles, ~1 mm infilled partially or fully with calcite, smectite, zeolites.

From 125-150 cm, tholeiitic basalt pillowed flow.

Thin Section Description

Location: 103-105 cm

Texture: hyalopilitic

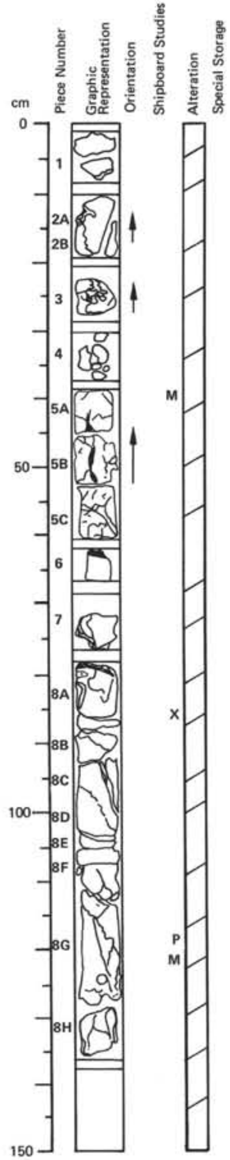
Phenocrysts: 5%; plagioclase 60%, An_{76}, 1.5 mm in glomerocrysts; clinopyroxene 30%, 2.5 mm; olivine ~10%, 1.0 mm altered to smectite and calcite

Groundmass: 95%; plagioclase 50%, 0.5-0.8 mm; clinopyroxene 40%, 0.15 mm; magnetite and ilmenite 10%

Alteration: olivine completely replaced by clays and carbonate; rare replacement of plagioclase with carbonate

Shipboard Data

Physical Properties:	**115-124 cm**
$\bar{V}$p (km/s)	
parallel to beds	5.69



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	19	3

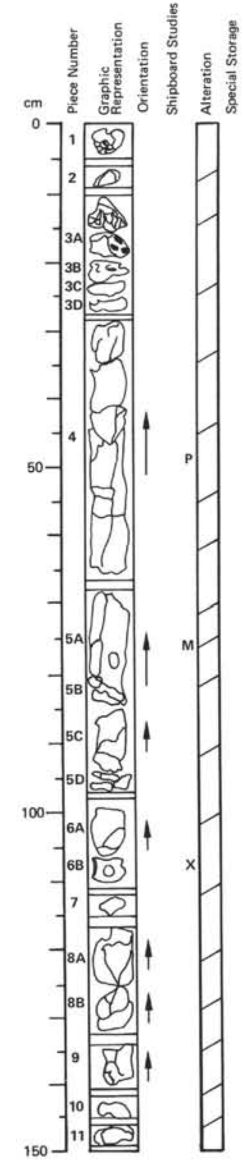
Depth: 156.5 to 158.0 m

Visual Description

Tholeiitic pillowed basalt, same as Section 19-2, fine-grained, pale gray, mottled. Doleritic at base of flows. Groundmass subophitic with <0.5 mm prismatic plagioclase, olivine and elinopyroxene phenocrysts, and altered glassy groundmass (10-15%). Scattered vesicles filled with smectite, carbonate and zeolite. Carbonate and zeolite veins. Chilled glassy margins between 60 and 85 cm interval.

Shipboard Data

Bulk Analysis:	**84 cm**
SiO_2	48.2
TiO_2	1.27
Al_2O_3	15.3
Fe_2O_3	1.49
FeO	9.86
MnO	0.13
MgO	5.72
CaO	11.10
Na_2O	2.41
K_2O	1.12
P_2O_5	0.11



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	20	1

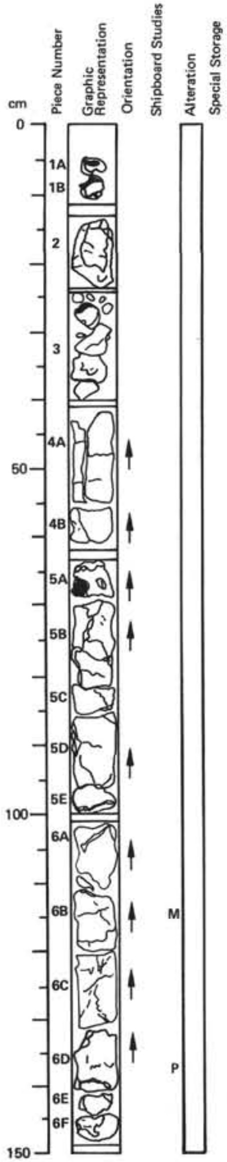
Depth: 158.0 to 159.5 m

Visual Description

Tholeiitic basalt as in Section 19-3.
From 0-25 cm, chilled pillow margin.
From 117-150 cm extremely altered wtih glassy rims.

Shipboard Data

Physical Properties:	**43-57 cm**
$\bar{V}p$ (km/s)	
parallel to beds	5.28



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	20	2

Depth: 159.5 to 161.0 m

Visual Description

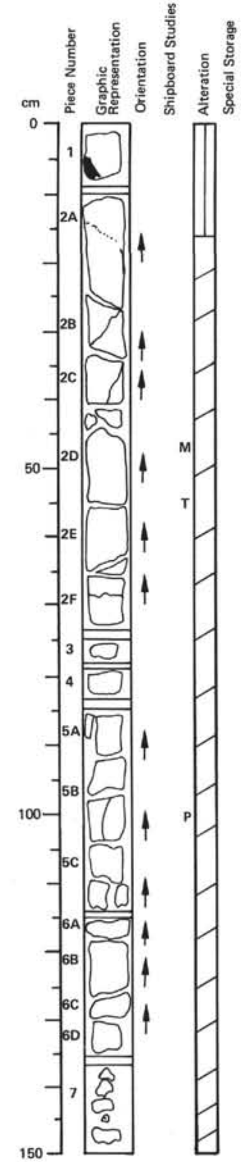
Tholeiitic basalt as in Section 20-1.

From 0-40 cm, extremely altered as in basalt Section 20-1. Underlain by fine-grained, gray (7.5YR 5/0) basalt with subophitic texture. Veins and filled vesicles of carbonate, smectite and zeolite. From 132-150 cm, extremely altered as in top of section.

Flow units doleritic at base.

Shipboard Data

Physical Properties:	**134-142 cm**	
$\overline{V}p$ (km/s)		
parallel to beds	4.60	



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	20	3

Depth: 161.0 to 162.5 m

Visual Description

Sparsely phyric, tholeiitic basalt as in Sections 20-1 and 20-2, fine-grained, gray (N5), with subophitic texture and mottled due to altered glassy groundmass. Rare vesicles filled with smectite. Occasional zeolite/carbonate veins. Glassy margin at top of section.

Thin Section Description

Location: 54-56 cm, flow interior

Texture: subophitic to hyalopilitic

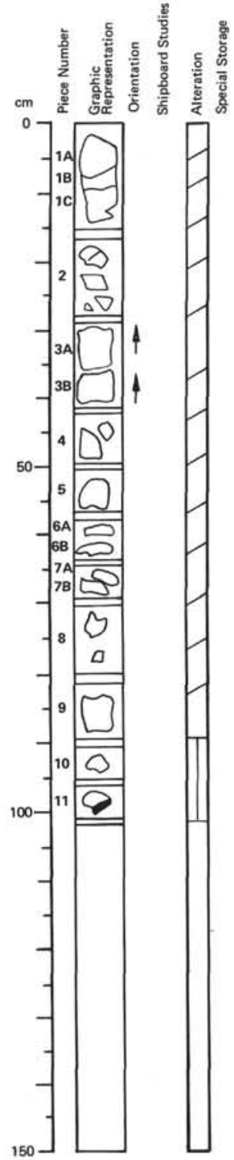
Phenocrysts: <5%; plagioclase 90%, 1.5 mm in glomerocrysts; olivine, 0.6 mm as pseudomorphs of smectite; clinopyroxene, 0.4 mm, rare

Groundmass: >95%; plagioclase 50%, An_{70}, 0.35 mm; clinopyroxene 40%, 0.15 mm; magnetite and ilmenite 10%, 0.02 mm

Alteration: olivine phenocrysts altered to clays and carbonate

Shipboard Data

Physical Properties:	**96-103 cm**
$\overline{V}p$ (km/s)	
parallel to beds	3.79



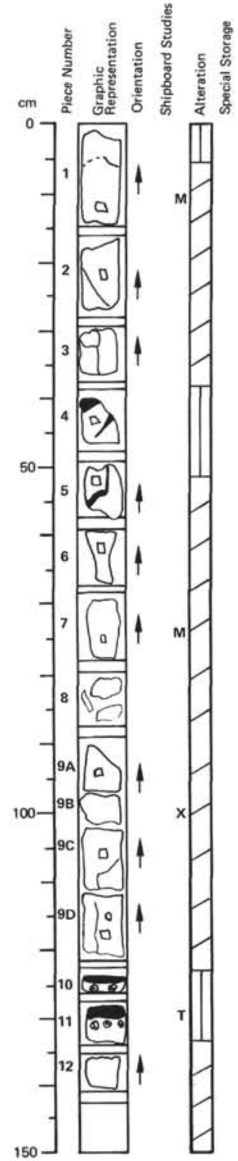
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	20	4

Depth: 162.5 to 164.0 m

Visual Description

Sparsely phyric tholeiitic basalt as in Sections 20-1, 20-2, and 20-3.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	21	1

Depth: 167.0 to 168.5 m

Visual Description

Plagioclase-clinopyroxene-olivine-phyric tholeiitic, pillowed massive basalt flow with several glassy margins. Groundmass fine-grained, ophitic(?), 85% crystalline with irregular areas of glassy groundmass. Subhedral phenocrysts of olivine 5%, 1-2 mm, replaced by rusty brown iddingsite. Sparse phenocrysts of plagioclase <5%, <1 mm. Glassy rinds contain green palagonite shards. Zeolite veining.

Thin Section Description

Location: 128-130 cm, glassy margin

Texture: glassy to variolitic

Phenocrysts: plagioclase <2%, An$_{68(?)}$, 0.4 mm, blocky; olivine rare, altered; clinopyroxene 0.1-0.4 mm, less abundant than plagioclase

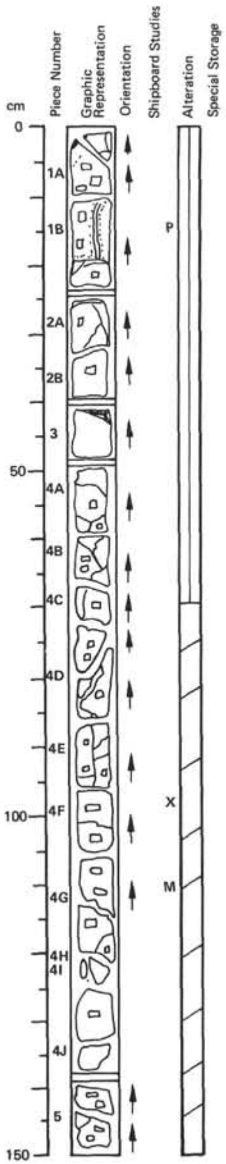
Groundmass: 98%; devitrified variolitic glass accounts for 90% of rock and consists of variolitic intergrowths with plagioclase, olivine and clinopyroxene centers

Alteration: essentially fresh

Shipboard Data

Bulk Analysis:	**99 cm**
SiO_2	49.0
TiO_2	1.12
Al_2O_3	14.8
Fe_2O_3	1.36
FeO	9.00
MnO	0.16
MgO	6.86
CaO	12.38
Na_2O	2.41
K_2O	0.64
P_2O_5	0.09

Physical Properties:	**0-14 cm**
$\bar{V}p$ (km/s)	
parallel to beds	5.36
vertical to beds	—
Wet bulk density	2.80



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	21	2

Depth: 168.5 to 190.0 m

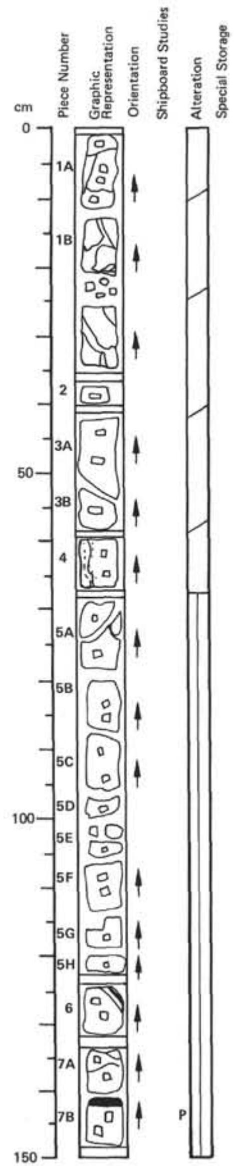
Visual Description

Plagioclase-clinopyroxene-olivine-phyric basalt, with glass rinds, as in Section 21-1. More massive and coarser textured towards base. Glomerocrysts of olivine, 1-3 mm, altered to iddingsite, and of plagioclase. Groundmass aphanitic/ophitic. Uppermost 70 cm extremely altered. Calcite/zeolite veins common.

Shipboard Data

Bulk Analysis:	99 cm
SiO_2	49.0
TiO_2	1.10
Al_2O_3	15.1
Fe_2O_3	1.32
FeO	8.72
MnO	0.16
MgO	7.06
CaO	12.11
Na_2O	2.57
K_2O	0.57
P_2O_5	0.08

Physical Properties:	11-22 cm	90-100 cm
$\bar{V}p$ (km/s)		
parallel to beds	4.57	5.17



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	21	3

Depth: 170.0 to 171.5 m

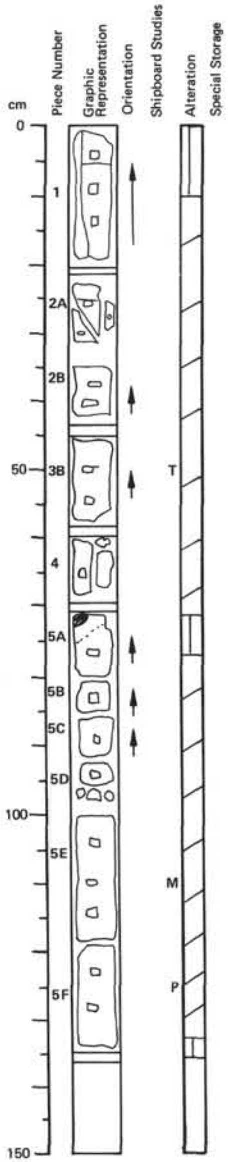
Visual Description

Plagioclase-clinopyroxene-olivine-tholeiitic basalt in interval 0-67 cm, as in Sections 21-1 and 21-2. Flow base.

From 67-150 cm, pillowed massive flow, tholeiitic phyric basalt much as above but much more altered. Common glassy margins.

Shipboard Data

Physical Properties:	143-150 cm
$\bar{V}p$ (km/s)	
parallel to beds	4.55



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	21	4

Depth: 171.5 to 173.0 m

Visual Description

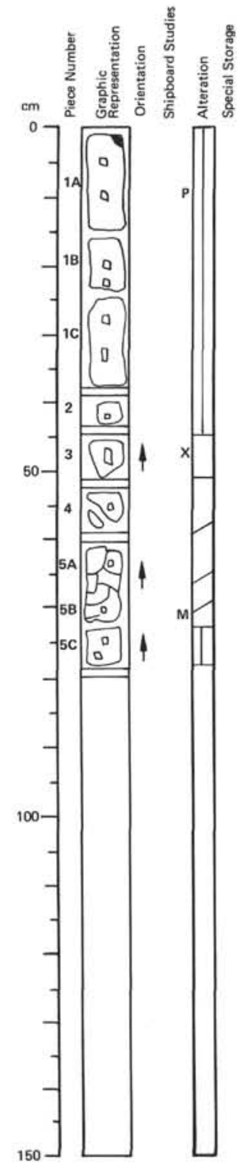
Plagioclase-clinopyroxene-olivine-phyric, tholeiitic basalt as in base of Section 21-3. Groundmass almost holocrystalline.

Thin Section Description

Location: 51-54 cm, flow interior
Texture: trachytic to pilotaxitic
Phenocrysts: ~2%; plagioclase, clinopyroxene and olivine, 1 mm, altered to clays and carbonate
Groundmass: ~98%; plagioclase 45%, 0.4 mm in blades; clinopyroxene 40%, plumose with plagioclase between plagioclase laths; olivine 10%, 0.04 mm, completely altered; magnetite and ilmenite 5%, <0.01 mm
Alteration: olivine and some plagioclase altered to clays and carbonate

Shipboard Data

Physical Properties:	**120-135 cm**
$\overline{V}p$ (km/s)	
parallel to beds	5.24



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	21	5

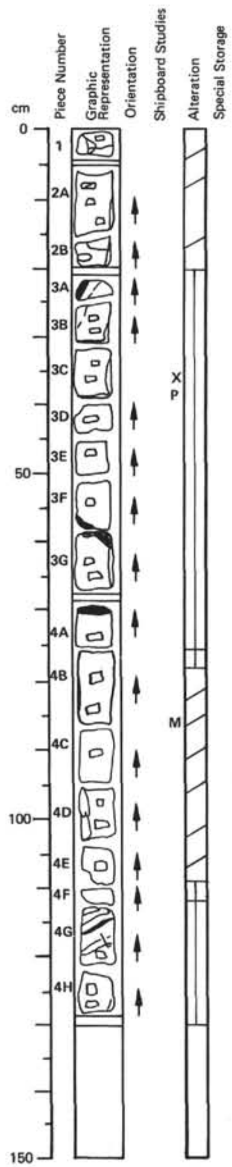
Depth: 173.0 to 173.8 m

Visual Description

Phyric basalt as in Section 21-4.

Shipboard Data

Physical Properties:	**2-15 cm**
$\overline{V}p$ (km/s)	
parallel to beds	4.67



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE		CORE		SECT.
5	9	4	4	7	A		2	2	1

Depth: 176.0 to 177.5 m

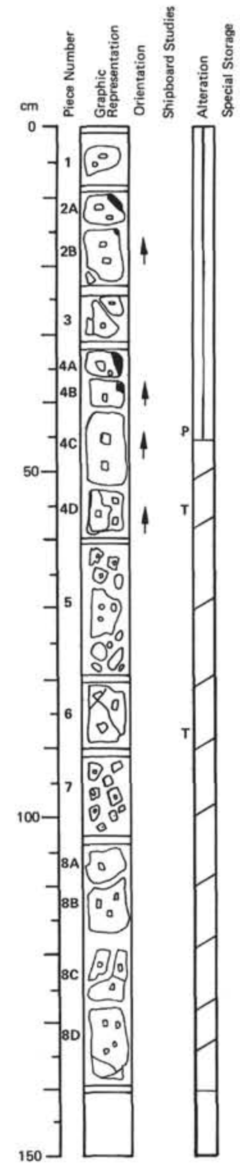
Visual Description

Phyric basalt flow as in Section 21-5. Aphanitic to very fine ophitic, 80% crystalline with phenocrysts of altered olivine < 5%, euhedral 1-2 mm, in glomerocrysts. Abundant glassy rinds.

Shipboard Data

Bulk Analysis:	34 cm
SiO_2	48.2
TiO_2	1.14
Al_2O_3	14.7
Fe_2O_3	1.38
FeO	9.14
MnO	0.16
MgO	6.17
CaO	12.85
Na_2O	2.24
K_2O	0.99
P_2O_5	0.19

Physical Properties:	30-44 cm
$\overline{V}p$ (km/s)	
parallel to beds	4.70
vertical to beds	4.81



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE		CORE		SECT.
5	9	4	4	7	A		2	2	2

Depth: 177.5 to 179.0 m

Visual Description

Plagioclase-clinopyroxene-olivine-phyric pillow basalt as in Section 22-1. Phenocrysts disappear toward base of section.

Thin Section Description

Location: 56-58 cm, flow interior

Texture: subvariolitic

Phenocrysts: 3%, plagioclase, An_{74}, 0.5 mm; clinopyroxene, rare; olivine, altered.

Groundmass: 97%; plagioclase 30%, 0.1 mm; and 60% plumose intergrowths of clinopyroxene and plagioclase; magnetite and ilmenite ~7%, 0.005 mm

Alteration: plagioclase altered to carbonate; green smectite in scattered patches in groundmass; some iron oxides

Thin Section Description

Location: 87-90 cm, flow interior

Texture: hyalopilitic

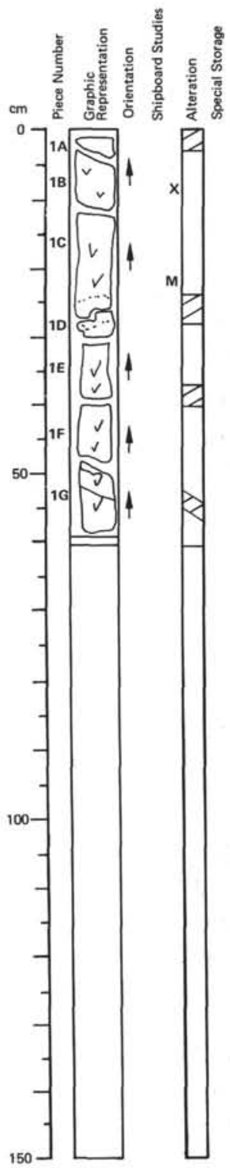
Phenocrysts: 5%; plagioclase, An_{80}, 0.2-0.4 mm, more abundant than olivine, 0.6 mm, altered except for remnant centers

Groundmass: 95%; plagioclase 50%, < 0.2 mm; clinopyroxene 45%; < 0.02 mm

Alteration: olivine altered to yellow and green smectites

Shipboard Data

Physical Properties:	41-51 cm
$\overline{V}p$ (km/s)	
parallel to beds	4.71



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	22	3

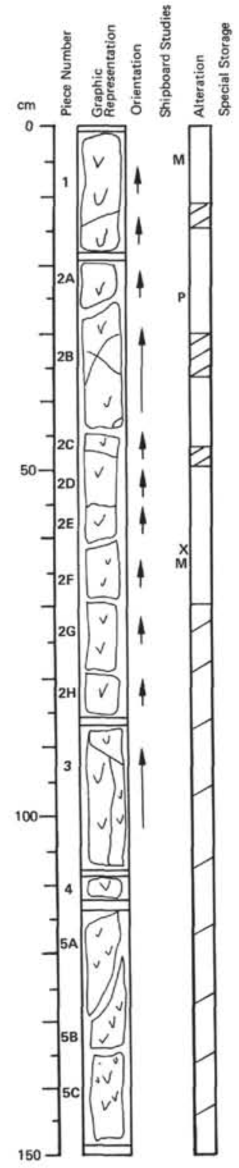
Depth: 179.0 to 179.6 m

Visual Description

Plagioclase-clinopyroxene-olivine-phyric basalt as in Sections 22-1 and 22-2, becoming fine-grained dolerite downwards; fresh, with rare phenocrysts of plagioclase < 5% of the rock, 0.5 mm, laths and clinopyroxene <5% of the rock, ~ 0.2 mm, subhedral. Groundmass holocrystaline, ophitic; fractures altered.

Shipboard Data

Bulk Analysis:	9 cm
SiO_2	50.6
TiO_2	1.13
Al_2O_3	14.5
Fe_2O_3	1.22
FeO	8.08
MnO	0.18
MgO	9.13
CaO	12.07
Na_2O	2.67
K_2O	0.06
P_2O_5	0.08



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	23	1

Depth: 180.0 to 181.5 m

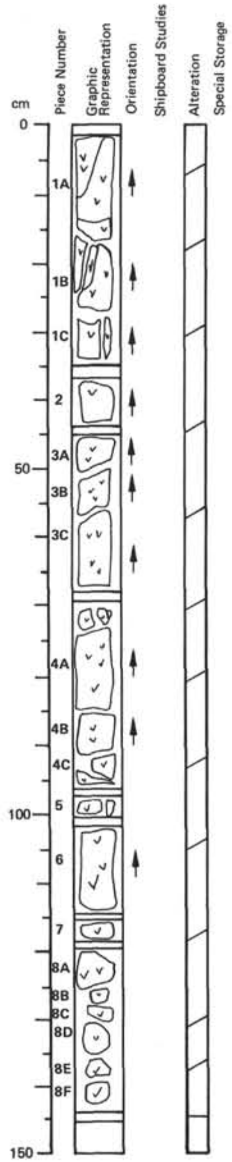
Visual Description

Fine-grained dolerite as in Section 22-3.

Shipboard Data

Bulk Analysis:	63 cm
SiO_2	50.1
TiO_2	1.16
Al_2O_3	14.7
Fe_2O_3	1.26
FeO	8.32
MnO	0.17
MgO	9.32
CaO	11.52
Na_2O	2.68
K_2O	0.06
P_2O_5	0.08

Physical Properties:	21-28 cm
$\overline{V}p$ (km/s)	
parallel to beds	5.67



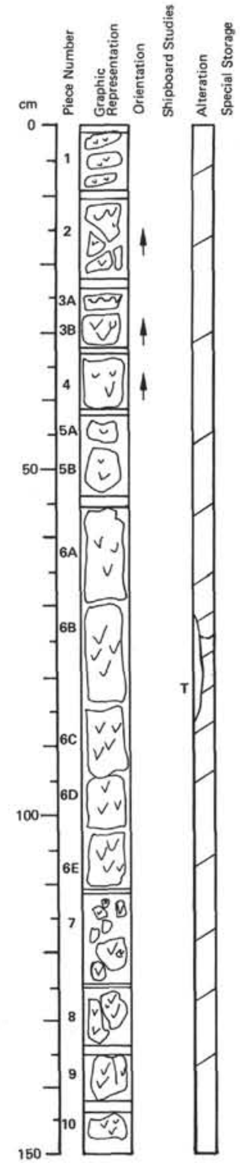
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE		CORE		SECT.	
5	9	4	4	7	A		2	3		2

Depth: 181.5 to 183.0 m

Visual Description

Fine-grained dolerite as in Section 23-1. Clinopyroxene and plagioclase phenocrysts 0.5-1 mm.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE		CORE		SECT.	
5	9	4	4	7	A		2	3		3

Depth: 183.0 to 184.5 m

Visual Description

Fine-grained dolerite as in Sections 23-1 and 23-2. Appearance of olivine phenocrysts that increase in quantity toward base.

Thin Section Description

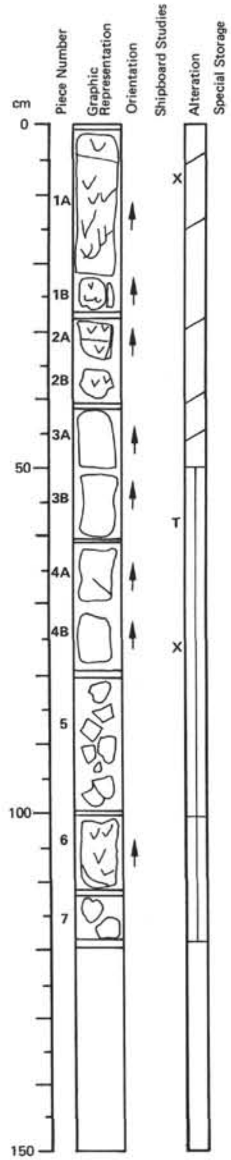
Location: 81-83 cm, flow interior

Texture: subophitic

Phenocrysts: 5%, plagioclase, $An_{64}{}^{+}{}_{(?)}$, 2 mm; clinopyroxene, 1 mm

Groundmass: 95%; plagioclase 50%, An_{67}, < 1 mm, in plumose intergrowths with clinopyroxene; clinopyroxene 45%, <1 mm; magnetite and ilmenite 5%

Alteration: slight; clays replace clinopyroxene



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	23	4

Depth: 184.5 to 185.0 m*

Visual Description

Fine-grained dolerite as in previous cores, becoming finer grained towards base of flow (100 cm) where there is also an increase in phenocryst abundance – ?gravity settling of crystals. Alteration increases toward base of flow.

From 100-120 cm, a new flow unit of aphyric basalt.

Thin Section Description

Location: 57-59 cm, flow interior

Texture: subophitic

Phenocrysts: 10%; plagioclase 60%, An_{73}, 1 mm laths; clinopyroxene 30%, 0.5 mm; olivine 10%, 0.5 mm. About 20% of all phenocrysts are glomerocrysts, 2 mm long.

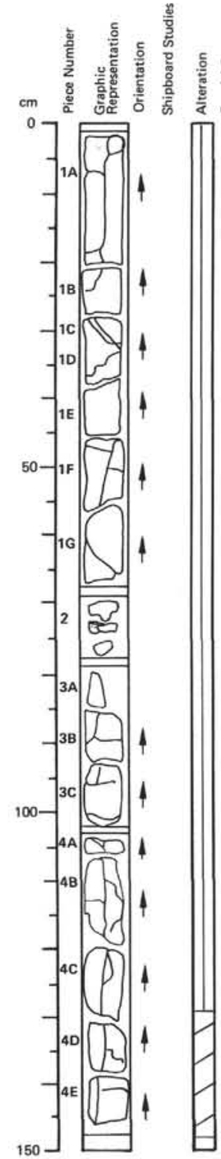
Groundmass: 90%; plagioclase 50%, An_{64}, 0.2 mm; clinopyroxene 40%, 0.04 mm; magnetite and ilmenite 10%, 0.01 mm; no olivine

Alteration: olivine replaced by clays and carbonates

Shipboard Data

Bulk Analysis:	**76 cm**
SiO_2	48.0
TiO_2	1.05
Al_2O_3	14.8
Fe_2O_3	1.33
FeO	8.77
MnO	0.18
MgO	6.86
CaO	12.66
Na_2O	2.36
K_2O	0.59
P_2O_5	0.08

*Note that although the total length of the interval drilled for Core 23 is only 5.0 meters, the length of cored rock with spacers takes up 5.7 meters, making Section 4 1.2 meters long instead of 0.5 meters long.



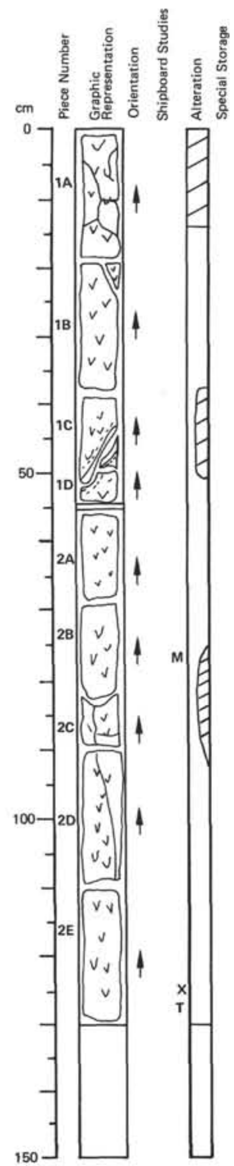
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	24	1

Depth: 185.0 to 186.5 m

Visual Description

Aphyric to sparsely olivine-spinel-phyric, tholeiitic basalt flow. Alteration strong at top, less towards base. Pronounced zeolite veining parallel to core length.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	24	2

Depth: 186.5 to 188.0 m

Visual Description

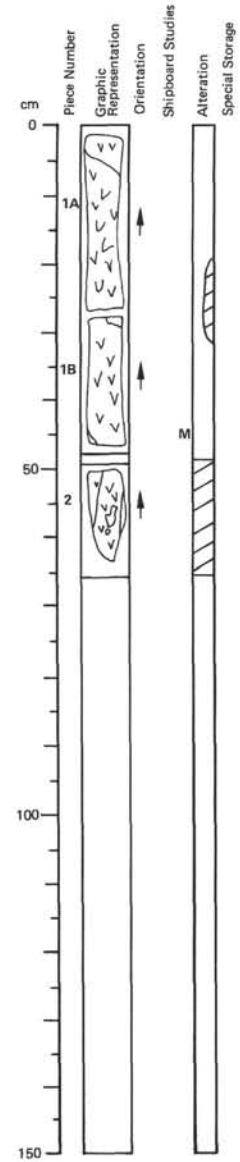
Aphyric to olivine-spinel-phyric, tholeiitic basalt as in Section 24-1. Fine- to medium-grained. Rare plagioclase phenocrysts in holocrystalline, ophitic groundmass.

Thin Section Description

Location: 127-129 cm, flow interior
Texture: ophitic to subophitic
Phenocrysts: none
Groundmass: 100%; plagioclase 50%, An_{72}, 1 mm; clinopyroxene 45%, 1 mm; magnetite and ilmenite 5%, 0.05 mm
Alteration: nearly fresh, some replacement of clinopyroxene with clays.

Shipboard Data

Bulk Analysis:	**126 cm**
SiO_2	47.2
TiO_2	0.83
Al_2O_3	15.7
Fe_2O_3	1.16
FeO	7.67
MnO	0.16
MgO	11.61
CaO	11.67
Na_2O	2.34
K_2O	0.05
P_2O_5	0.05



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	24	3

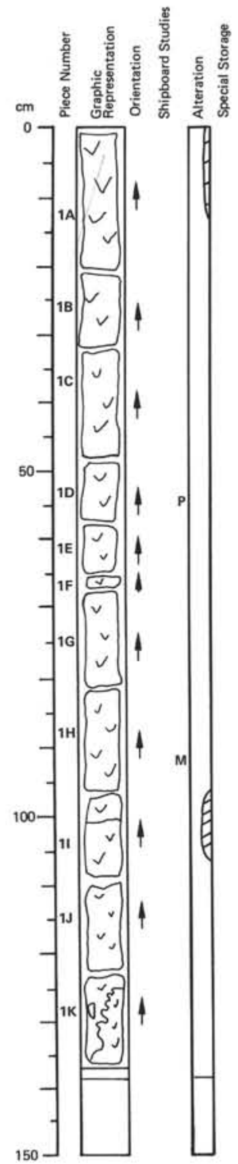
Depth: 188.0 to 188.6 m

Visual Description

Aphyric tholeiitic basalt flow as in Section 24-2.

Shipboard Data

Physical Properties:	**42-45 cm**
parallel to beds	—
vertical to beds	6.31



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	25	1

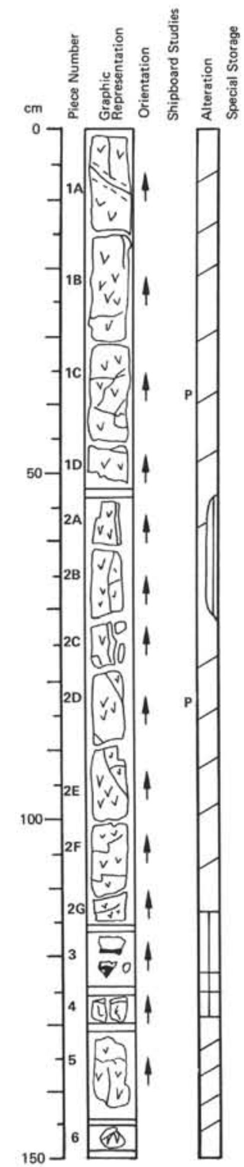
Depth: 191.0 to 192.5 m

Visual Description

Aphyric to sparsely olivine-spinel-phyric tholeiitic basalt as in Sections 24-1, 24-2, and 24-3. Rare plagioclase laths. Rock very fresh and unveined.

Shipboard Data

Physical Properties:	**49-58 cm**
$\overline{V}p$ (km/s)	
parallel to beds	5.95
vertical to beds	—
Wet bulk density	2.91



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	25	2

Depth: 192.5 to 194.0 m

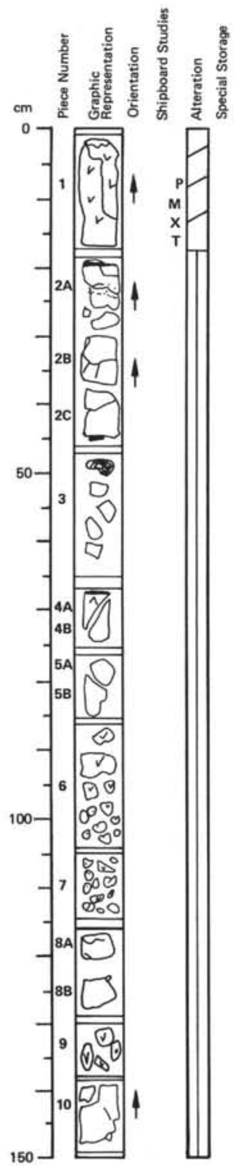
Visual Description

Tholeiitic basalt as in Section 25-1 becoming doleritic and altered toward base of flow unit (125 cm) wherein olivine phenocrysts are common. Zeolite and calcite veins common towards base.

From 125-150 cm, underlying flow unit similar to that above with extreme alteration and glassy margin.

Shipboard Data

Physical Properties:	**30-40 cm**	**78-89 cm**
$\overline{V}p$ (km/s)		
parallel to beds	5.406	4.87
vertical to beds	—	5.11



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	25	3

Depth: 194.0 to 195.5 m

Visual Description

Olivine-plagioclase-clinopyroxene-phyric tholeiitic basalt, pillowed massive flows

From 0-17 cm, fine-grained sparsely olivine-phyric basalt. Below 17 cm, a pillowed sequence of extremely altered, fine-grained to glassy basalt with fresh, black, glassy rims. Contains scattered phenocrysts of euhedral to subhedral olivine < 1% of the rock, ~ 1 mm, altered to brown iddingsite; sparse phenocrysts of dark green to black clinopyroxene, < 0.5 mm, and rare laths of plagioclase are present.

Thin Section Description

Location: 12-14 cm, flow interior

Texture: hyalopilitic

Phenocrysts: none seen in thin section

Groundmass: 98%; plagioclase 40%, 0.5 mm, laths; clinopyroxene 55%, finely plumose with plagioclase; magnetite and ilmenite 5%, 0.02-0.05 mm

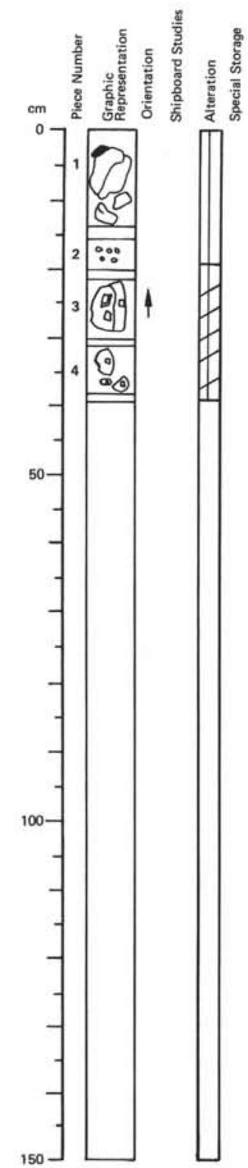
Vesicles: 2%, 0.05 mm, irregular, filled with brown smectite

Alteration: 10% of rock is altered to brown smectite; glassy interstices between plagioclase laths are altered.

Shipboard Data

Bulk Analysis:	**10 cm**
SiO_2	47.5
TiO_2	0.91
Al_2O_3	16.9
Fe_2O_3	1.22
FeO	8.02
MnO	0.19
MgO	7.47
CaO	12.20
Na_2O	2.52
K_2O	0.58
P_2O_5	0.05

Physical Properties:	**7-10 cm**
$\overline{V}p$ (km/s)	
parallel to beds	5.21
vertical to beds	5.04



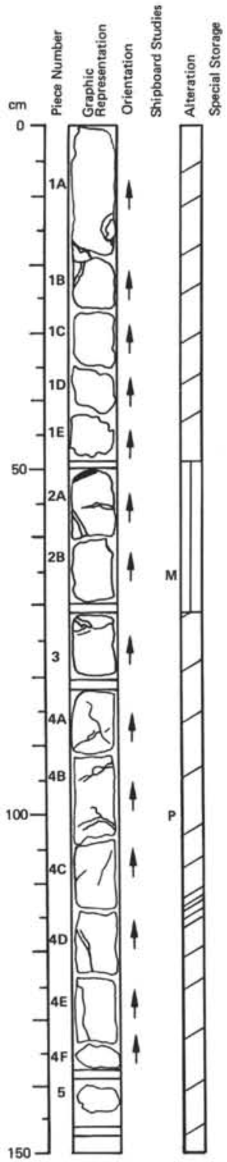
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	25	4

Depth: 195.5 to 195.9 m

Visual Description

Olivine-plagioclase-clinopyroxene-phyric tholeiite as in Section 25-3.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	26	1

Depth: 198.5 to 200.0 m

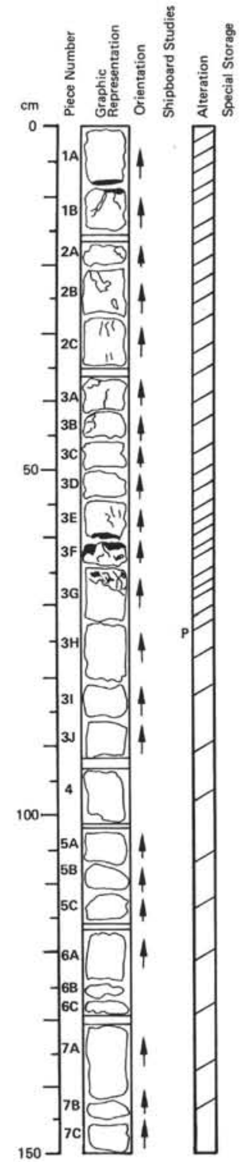
Visual Description

Tholeiite as in Sections 25-3 and 25-4; mostly aphyric but locally microphyric. Veins (0.5 mm) of zeolites and rare zeolite-filled vesicles.

From 50-70 cm extremely altered with thin (0.7 mm) rim of glass completely altered to smectite.

Shipboard Data

Physical Properties:	**92-104 cm**
$\overline{V}p$ (km/s)	
parallel to beds	4.12



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	26	2

Depth: 200.0 to 201.5 m

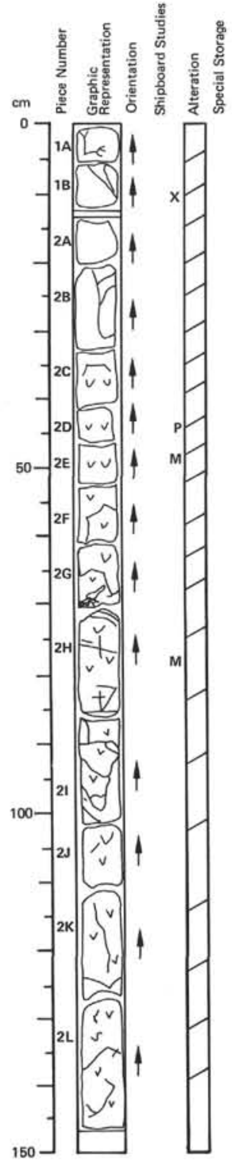
Visual Description

Tholeiite as in Section 26-1.

From 60-70 cm, top of underlying pillow with 3.0-3.5 cm glassy margin containing <0.5 mm fragments of completely altered, fine-grained basalt in completely replaced (smectite) volcanic glass.

Shipboard Data

Physical Properties:	**72-80 cm**
$\overline{V}p$ (km/s)	
parallel to beds	4.14



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	26	3

Depth: 201.5 to 203.0 m

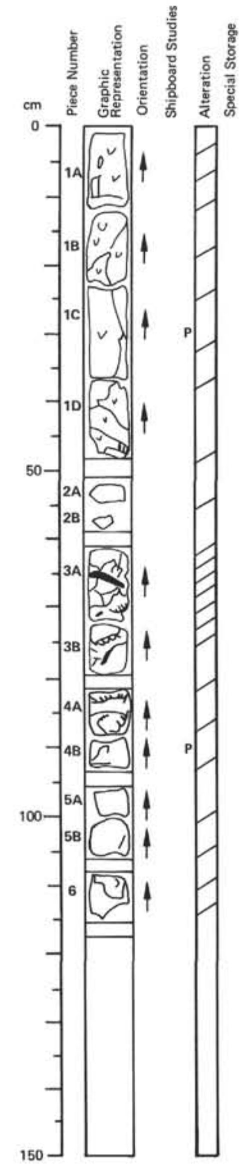
Visual Description

Tholeiite as in Sections 26-1 and 26-2; gray (7.5YR 6/0) with pale brown altered patches; 80% crystallized; veined (0.3-0.5 mm) with carbonates and zeolites.

Interval 2C through 2E is sparsely microphyric, almost holocrystalline; groundmass ophitic to subophitic with intergranular altered glass.

Shipboard Data

Physical Properties:	**42-47 cm**
$\bar{V}p$ (km/s)	
parallel to beds	4.35
vertical to beds	4.51



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	26	4

Depth: 203.0 to 318.0 m

Visual Description

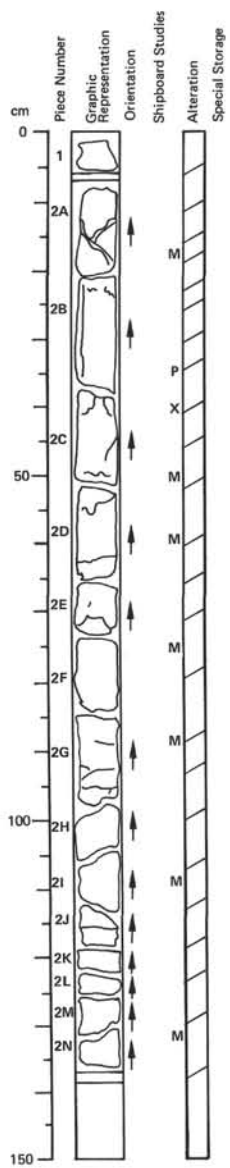
Tholeiite as in Sections 26-1, 26-2, and 26-3, from 0-60 cm.

From 60-115 cm, fine-grained, olivine-plagioclase-clinopyroxene-phyric tholeiitic basalt, pillowed massive flow.

Segments 3A through 3B are aphyric with glassy rim, 1-3 cm, totally replaced with green, zonal smectite and veined with carbonates and zeolites, <0.5 mm.

Shipboard Data

Physical Properties:	**23-37 cm**	**89-93 cm**
$\bar{V}p$ (km/s)		
parallel to beds	4.79	—
vertical to beds	—	4.23



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	27	1

Depth: 207.5 to 208.8 m

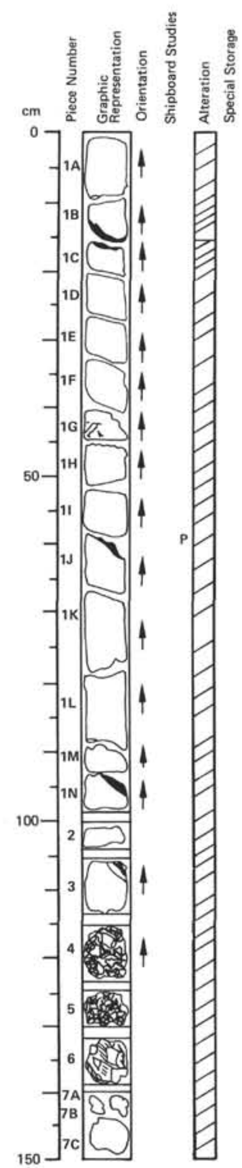
Visual Description

Olivine-plagioclase-clinopyroxene-phyric tholeiite as in lower part of Section 26-4.

Shipboard Data

Bulk Analysis:	**41 cm**
SiO_2	47.2
TiO_2	0.87
Al_2O_3	17.0
Fe_2O_3	1.20
FeO	7.92
MnO	0.17
MgO	8.51
CaO	11.70
Na_2O	2.50
K_2O	0.46
P_2O_5	0.05

Physical Properties:	**35-50 cm**
$\overline{V}p$ (km/s)	
parallel to beds	5.10



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	27	2

Depth: 208.8 to 210.30 m

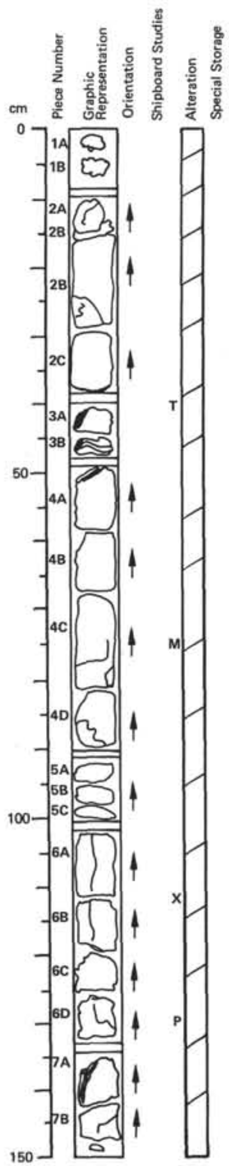
Visual Description

Top 15 cm as in Section 27-1.

From 27-150 cm, plagioclase-olivine-spinel-phyric tholeiitic basalt, pillowed massive flow. Several glassy margins.

Shipboard Data

Physical Properties:	**57-65 cm**
$\overline{V}p$ (km/s)	
parallel to beds	4.71



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	28	1

Depth: 216.5 to 218.0 m

Visual Description

Plagioclase-olivine-spinel-phyric tholeiite as in Core 27; sparsely phyric up section. Pillow margins in segments 3A-3B and 7A.

Thin Section Description

Location: 41-43 cm, glassy margin

Texture: glassy to variolitic with trachytic alignment of plagioclase laths

Phenocrysts: 4%; 1.5 mm, microcrysts in glass and in phenocrysts; clinopyroxene, none apparent but may be altered microcrysts in glass; olivine, microcrysts in glass and in phenocrysts, mostly replaced in variolitic zone but fresh in glass; spinel as microcrysts in glass; trace of pyrite-decorated spherules 0.08 mm

Groundmass: 95%; plagioclase 20%, 0.7 mm; glass 80%, devitrified and fresh

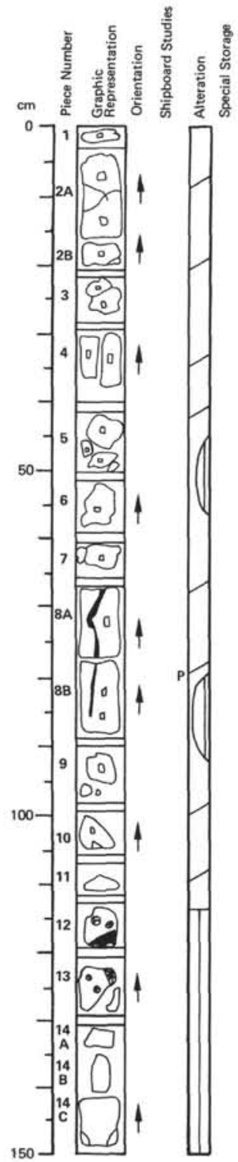
Vesicles: 1%, 1 mm, spherical, with smectite linings

Alteration: green and gray smectite replacing olivine and some plagioclase; phillipsite on glass edge

Shipboard Data

Bulk Analysis:	**112 cm**
SiO_2	48.8
TiO_2	1.01
Al_2O_3	15.3
Fe_2O_3	1.27
FeO	8.39
MnO	0.17
MgO	7.51
CaO	12.17
Na_2O	2.17
K_2O	1.03
P_2O_5	0.11

Physical Properties:	**126-132 cm**
$\overline{V}p$ (km/s)	
parallel to beds	5.04



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	28	2

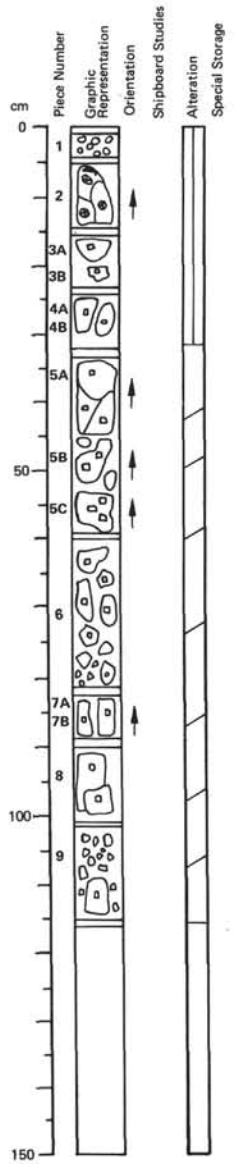
Depth: 218.0 to 219.5 m

Visual Description

Phyric tholeiitic basalt as in Section 28-1. Groundmass ~80%, holocrystalline, aphanitic to finely ophitic; variolitic near glassy margins. Scattered vesicles <1 mm, partly filled with green smectite. Olivine phenocrysts entirely altered to iddingsite, up to 2 mm, 5-10% of rock. Plagioclase in thin 2 mm laths.

Shipboard Data

Physical Properties:	**78-88 cm**
$\overline{V}p$ (km/s)	
parallel to beds	4.75



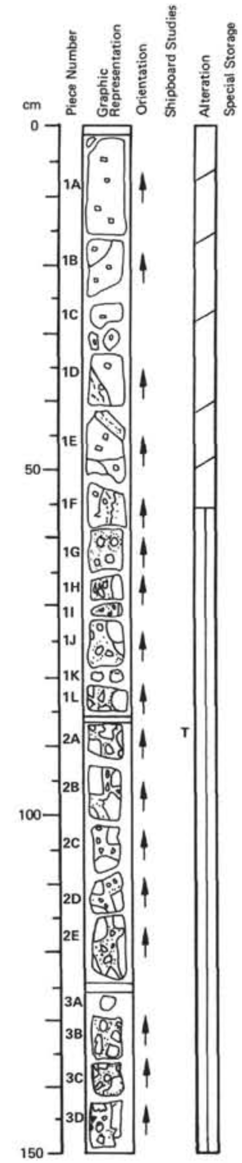
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	28	3

Depth: 219.5 to 220.7 m

Visual Description

Phyric tholeiitic basalt as in Sections 28-1 and 28-2.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	29	1

Depth: 225.5 to 227.0 m

Visual Description

Phyric tholeiitic basalt as in Sections 28-1, 28-2 and 28-3 in upper 55 cm; more vesicular. Below 55 cm, basalt fault breccia. Angular clasts, 0.5-5 cm, averaging ~2 cm, consisting of olivine-plagioclase-phyric basalt cemented with carbonate and zeolites.

Thin Section Description

Location: 88-90 cm

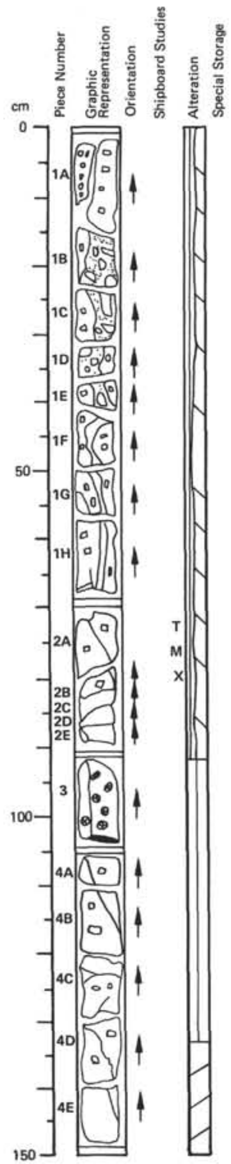
Texture: hyalophilitic and variolitic clasts

Phenocrysts: in clasts; olivine highly altered; plagioclase 0.5-1 mm, altered; clinopyroxene, highly altered.

Groundmass: of clasts of three types: 1) hyalopilitic and antiophitic, swallowtail clinopyroxene, 0.8 mm in plagioclase matrix; 2) hyalopilitic with plagioclase laths 1 mm in clinopyroxene matrix; and 3) variolitic with 0.35 mm plagioclase laths in typical rapid quench texture of pillows.

Vesicles: 0.8 mm

Alteration: calcite veins with zeolites (phillipsite?).



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	29	2

Depth: 227.0 to 228.5 m

Visual Description

Basalt fault breccia in upper 50 cm as in Section 29-1.

From 50-105 cm: plagioclase-olivine-spinel-phyric tholeiitic basalt as in Section 28-3. Becomes variolitic towards glassy base.

From 105-150 cm, fine-grained, subvariolitic, plagioclase-olivine-spinel-phyric tholeiite.

Thin Section Description

Location: 71-73 cm, flow interior

Texture: porphyritic to subophitic

Phenocrysts: 4-5%; olivine 50-60%, 1.0-1.5 mm, euhedral pseudomorphs; plagioclase 40-50%, ~1-2 mm, subhedral, completely altered

Groundmass: >90%; plagioclase 50%, An_{67}, <1 mm, elongate laths; clinopyroxene 30%, 0.1-0.2 mm, plumose; olivine ~3-5%, 0.1 mm, anhedral, completely replaced by smectite and iddingsite; magnetite/ilmenite, 3-5%, 0.1 mm, anhedral, replaced by limonite; glass 5-7%

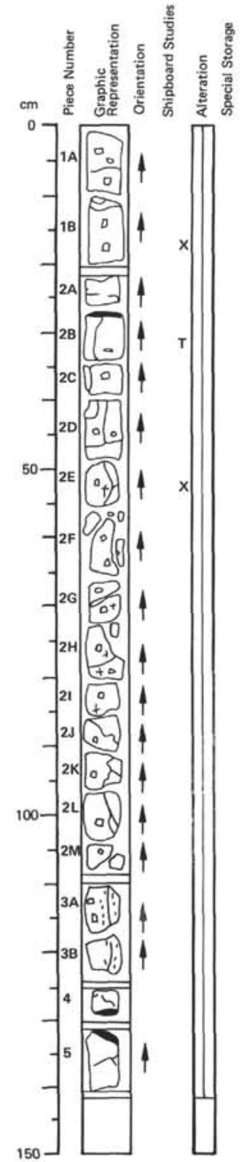
Vesicles: 3-5%, 0.4-0.5 mm, spheroidal, filled with smectite, zeolites, carbonates

Alteration: carbonate veins 2-3%; clays and zeolites altering glass and olivine

Shipboard Data

Bulk Analysis:	80 cm
SiO_2	49.2
TiO_2	0.94
Al_2O_3	15.7
Fe_2O_3	1.19
FeO	7.88
MnO	0.17
MgO	8.55
CaO	12.44
Na_2O	2.31
K_2O	0.44
P_2O_5	0.08

Physical Properties:	74-76 cm
$\overline{V}p$ (km/s)	
parallel to beds	5.15
vertical to beds	5.28



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	29	3

Depth: 228.5 to 230.0 m

Visual Description

0-20 cm: plagioclase-olivine-spinel-phyric tholeiite flow as in basal 45 cm of Section 29-2.

20-125 cm: pyroxene-olivine-plagioclase-phyric basalt pillowed massive flow. Very fine-grained aphanitic groundmass, variolitic near chilled contacts. Pyroxene phenocrysts dark green, subhedral, < 10% of the rock, 1-2 mm concentrated near top of unit. Plagioclase 1-2 mm, rare. Olivine, altered to iddingsite, concentrated in basal 10-20 cm of unit.

125-150 cm: plagioclase-olivine-phyric basalt with variolitic texture.

Thin Section Description

Location: 32-33 cm

Texture: variolitic (some glomerocrysts)

Phenocrysts: 15%; olivine, 1.2 mm highly resorbed, replaced by zeolites and smectite; plagioclase, 0.5 mm, blocky; clinopyroxene, 0.35 mm, spinel, trace

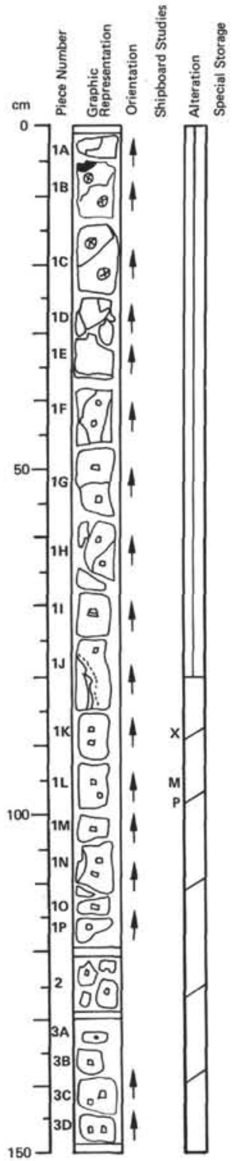
Groundmass: 82%; plagioclase 10%, 0.25 mm, very thin laths; glass 90%, plumose intergrowth of clinopyroxene and plagioclase

Vesicles: 3%, 0.05-1 mm, spheroidal and irregular, coated or filled with zeolites and clays

Alteration: all phenocrysts; carbonate most common in plagioclase

Shipboard Data

Bulk Analysis:	15 cm	51 cm
SiO_2	48.9	48.6
TiO_2	0.92	0.95
Al_2O_3	15.1	15.6
Fe_2O_3	1.23	1.23
FeO	8.11	8.13
MnO	0.17	0.16
MgO	8.08	6.57
CaO	13.13	12.69
Na_2O	2.27	2.21
K_2O	0.57	1.14
P_2O_5	0.09	0.10



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	29	4

Depth: 230.0 to 231.5 m

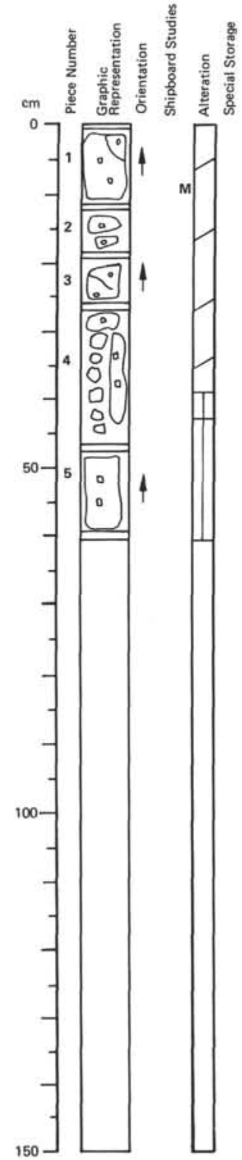
Visual Description

Plagioclase-olivine-phyric basalt with variolitic texture, as in bottom 25 cm of Section 29-3. Olivine, 1-2 mm, <5% of the rock, altered to iddingsite. Plagioclase laths rare.

Shipboard Data

Bulk Analysis:	**86 cm**
SiO_2	48.7
TiO_2	0.93
Al_2O_3	15.3
Fe_2O_3	1.18
FeO	7.78
MnO	0.16
MgO	8.04
CaO	12.94
Na_2O	2.29
K_2O	0.53
P_2O_5	0.09

Physical Properties:	**93-95 cm**
$\overline{V}p$ (km/s)	
parallel to beds	—
vertical to beds	5.59



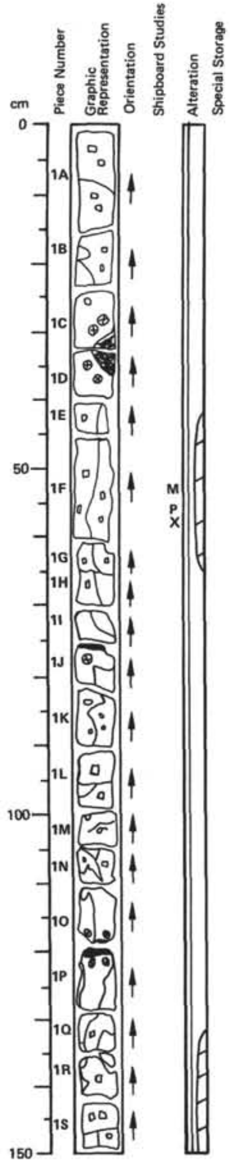
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	29	5

Depth: 231.5 to 232.1 m

Visual Description

Plagioclase-olivine-phyric tholeiitic basalt as in Section 29-4. Scattered vesicles, <5%, ~1 mm, mainly filled with blue zeolite or dark green smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	30	1

Depth: 234.5 to 236.0 m

Visual Description

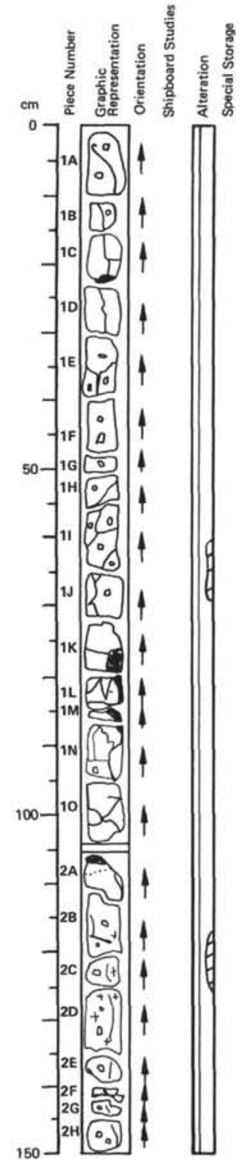
0-33 cm: as in Section 29-5.

33-150 cm: plagioclase-olivine-spinel-phyric tholeiitic basalt, pillowed massive flow. Olivine phenocrysts altered to iddingsite, concentrated towards lower and mid part of pillows. Plagioclase laths rare. Groundmass ~70% crystalline, aphanitic; variolitic near chilled rinds. Highly altered.

Shipboard Data

Bulk Analysis:	**55 cm**
SiO_2	48.6
TiO_2	0.89
Al_2O_3	14.9
Fe_2O_3	1.19
FeO	7.86
MnO	0.16
MgO	8.13
CaO	13.89
Na_2O	2.15
K_2O	0.62
P_2O_5	0.09

Physical Properties:	**53-56 cm**
$\overline{V}p$ (km/s)	
parallel to beds	---
vertical to beds	5.21



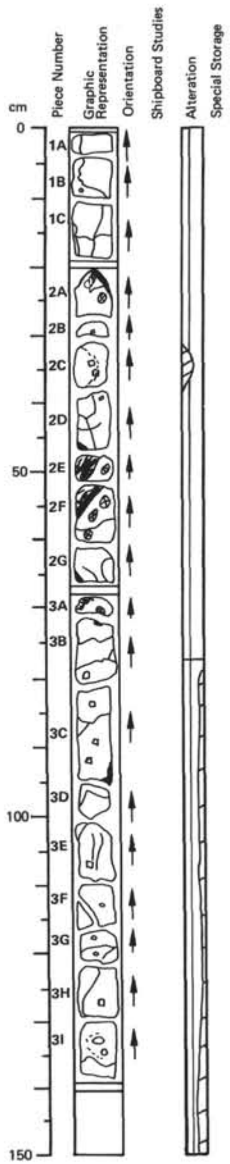
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	30	2

Depth: 236.0 to 237.5 m

Visual Description

Continuation of plagioclase-olivine-spinel-phyric tholeiitic basalt in Section 30-1; some clinopyroxene. Pillows strongly altered near rims. Glass is fresh except for outermost palagonite portion. Abundant interpillow zeolites and carbonate.



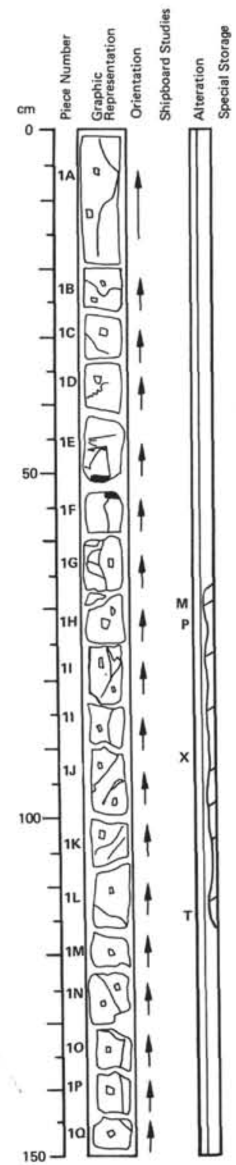
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.
5	9	4	4	7	A	3	0	3

Depth: 237.5 to 239.0 m

Visual Description

Continuation of plagioclase-olivine-spinel-phyric tholeiitic basalt as in Section 30-2. Generally non-vesicular.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.
5	9	4	4	7	A	3	0	4

Depth: 239.0 to 240.5 m

Visual Description

From 0-50 cm, plagioclase-olivine-spinel-phyric tholeiitic basalt as in Section 30-3. Pillow units up to 1 meter.

From 50-150 cm, plagioclase-olivine-spinel-phyric tholeiitic basalt, pillow lava flow.

Thin Section Description

Location: 116-119 cm, pillow interior

Texture: microphyric

Phenocrysts: <8%, olivine 25%, ~1 mm, irregular shape, completely altered; plagioclase 65%, 0.5-0.7 mm, subhedral, completely altered; spinel 10%, <0.01 mm, in glass

Groundmass: 90%; plagioclase 50%, An_{70}, 0.1 mm, elongate laths; clinopyroxene 40%, 0.02 mm, plumose segregation; olivine 2-3%, ~0.01 mm, completely altered; magnetite and ilmenite 2-3%, <0.01 mm; glass 5%, altered

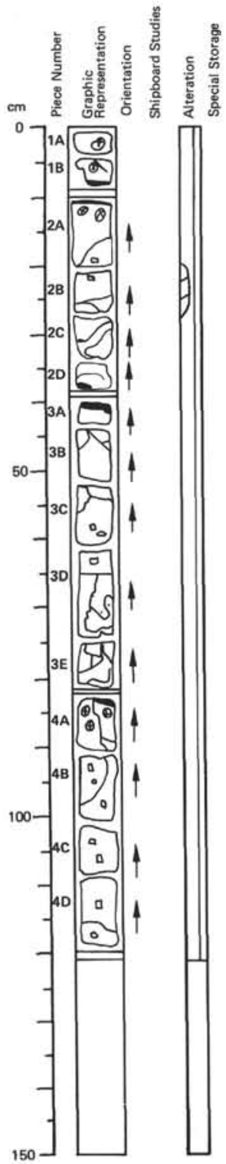
Vesicles: 2%, 0.5 mm, spheroidal, filled with smectite and zeolites

Alteration: carbonate 2-3%, in veins and vesicles; clays and zeolites 5%, replacing plagioclase olivine and glass

Shipboard Data

Bulk Analysis:	**91 cm**
SiO_2	49.4
TiO_2	0.89
Al_2O_3	15.2
Fe_2O_3	1.16
FeO	7.65
MnO	0.16
MgO	9.23
CaO	12.66
Na_2O	2.37
K_2O	0.48
P_2O_5	0.07

Physical Properties:	**70-72 cm**
$\overline{V}p$ (km/s)	
parallel to beds	—
vertical to beds	5.01



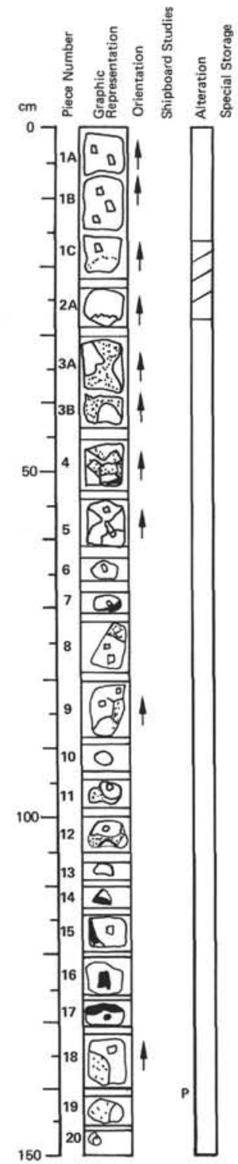
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	30	5

Depth: 240.5 to 241.7 m

Visual Description

Plagioclase-olivine-spinel-phyric basalt, aphanitic to variolitic, as in Section 30-4. Pillows up to 0.5 m.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

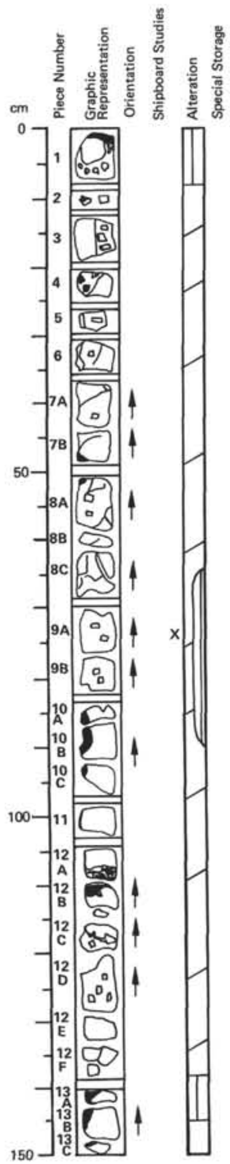
LEG	SITE	HOLE	CORE	SECT.
59	447	A	31	1

Depth: 243.5 to 245.0 m

Visual Description

0-30 cm: plagioclase-olivine-spinel-phyric basalt as in Section 30-5.

30-150 cm: pillow breccia clasts of plagioclase-olivine-spinel-phyric, aphanitic basalt set in a matrix of calcite, quartz and zeolites. Autobrecciation(?).



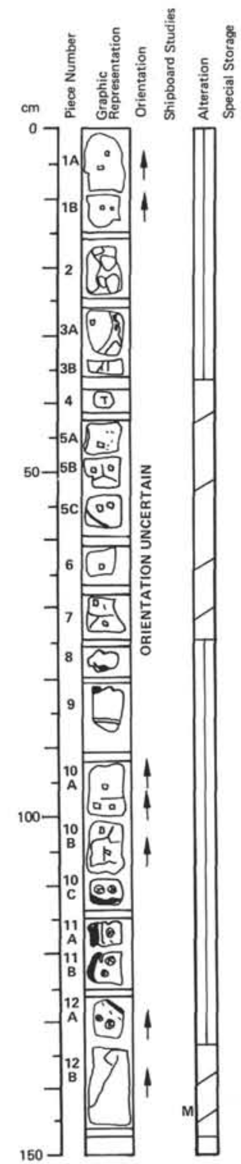
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE		HOLE	CORE		SECT.
5	9	4	4	7	A	3	1	2

Depth: 245.0 to 246.5 m

Visual Description

Pillow breccia as in Section 31-1. Olivine phenocrysts (pseudomorphs). More abundant, 10-15% of the rock.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE		HOLE	CORE		SECT.
5	9	4	4	7	A	3	1	3

Depth: 246.5 to 248.0 m

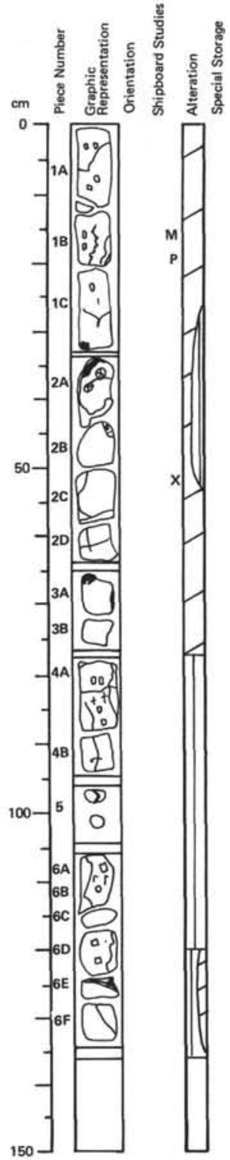
Visual Description

0-37 cm: pillow breccia as in Section 31-2.

37-150 cm: plagioclase-olivine-spinel-phyric tholeiitic basalt, pillow lava flow, similar to clasts in previous breccia unit, but plagioclase phenocrysts up to 10% and olivine phenocrysts <10% of the rock.

Shipboard Data

Physical Properties:	142-144 cm
$\overline{V}p$ (km/s)	
parallel to beds	—
vertical to beds	5.32



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	31	4

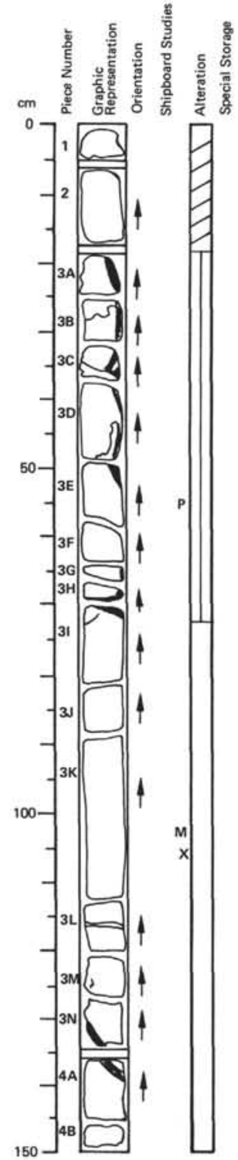
Depth: 248.0 to 249.3 m

Visual Description

Plagioclase-olivine-spinel-phyric tholeiitic basalt as in Section 31-3, with dark green clinopyroxene phenocrysts common in lower half of core. Groundmass ~70% crystalline, aphanitic to variolitic, strongly altered near pillow margins which are abundant. Scattered vesicles lined or filled with blue smectite. Common interpillow carbonate and zeolites.

Shipboard Data

Physical Properties:	**17-19 cm**
$\overline{V}p$ (km/s)	
parallel to beds	—
vertical to beds	5.49



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	32	1

Depth: 252.5 to 254.0 m

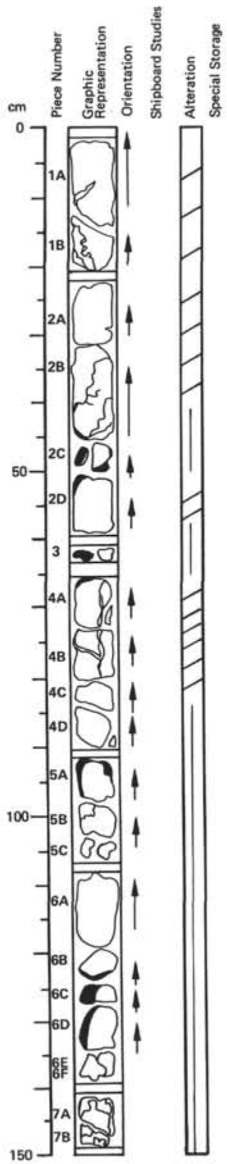
Visual Description

Plagioclase-olivine-spinel-phyric tholeiitic basalt as in Section 31-4.

Shipboard Data

Bulk Analysis:	**107 cm**
SiO_2	49.0
TiO_2	0.79
Al_2O_3	15.8
Fe_2O_3	1.14
FeO	7.52
MnO	0.17
MgO	8.63
CaO	13.31
Na_2O	2.12
K_2O	0.34
P_2O_5	0.05

Physical Properties:	**50-58 cm**
$\overline{V}p$ (km/s)	
parallel to beds	4.88



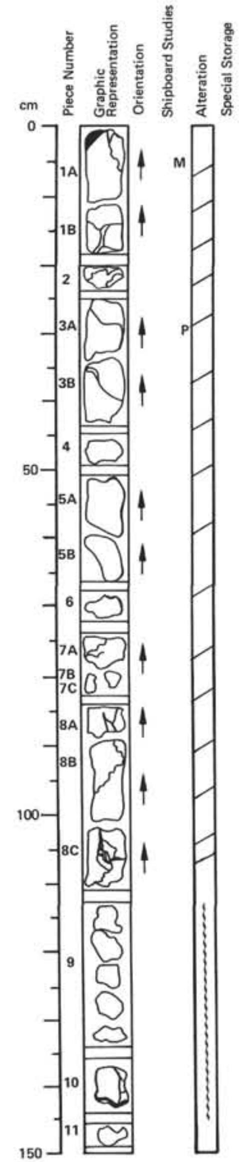
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	32	2

Depth: 254.0 to 255.5 m

Visual Description

Plagioclase-olivine-spinel-phyric tholeiitic basalt as in Section 32-1.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	32	3

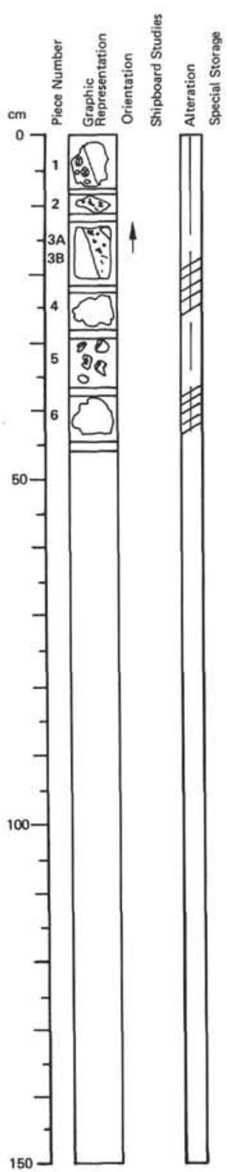
Depth: 255.5 to 257.0 m

Visual Description

Plagioclase-olivine-spinel-phyric tholeiitic basalt as in Section 32-3.

Shipboard Data

Physical Properties:	**27-35 cm**
$\overline{V}p$ (km/s)	
parallel to beds	5.42



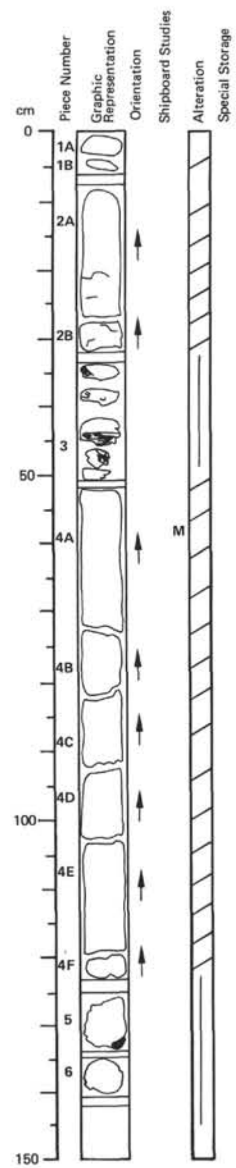
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	33	CC

Depth: 261.5 to 261.9 cm

Visual Description

Plagioclase-olivine-spinel-phyric tholeiitic basalt as in Section 32-3. Glassy margins brecciated.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

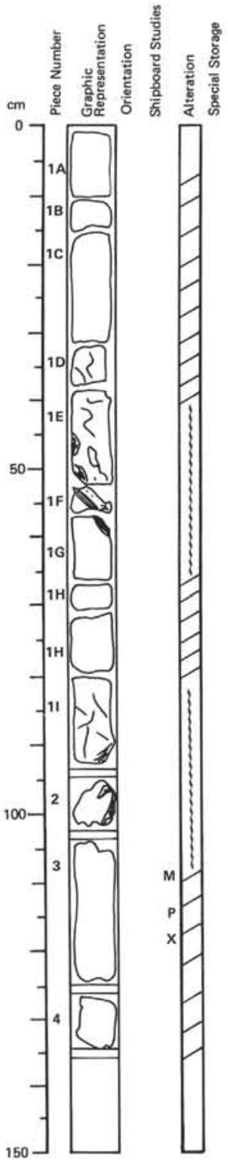
LEG	SITE	HOLE	CORE	SECT.
59	447	A	34	1

Depth: 270.5 to 272.0 m

Visual Description

Plagioclase-olivine-spinel-phyric tholeiitic basalt as in Section 33,CC.

Phenocrysts of plagioclase, 15%, 1-2 mm. Microphenocrysts of olivine and ? clinopyroxene. Groundmass subophitic. Scattered vesicles filled with zeolites and carbonates which are also present in thin, 0.5 mm veins. Patches of rock highly altered.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	34	2

Depth: 272.0 to 273.5 m

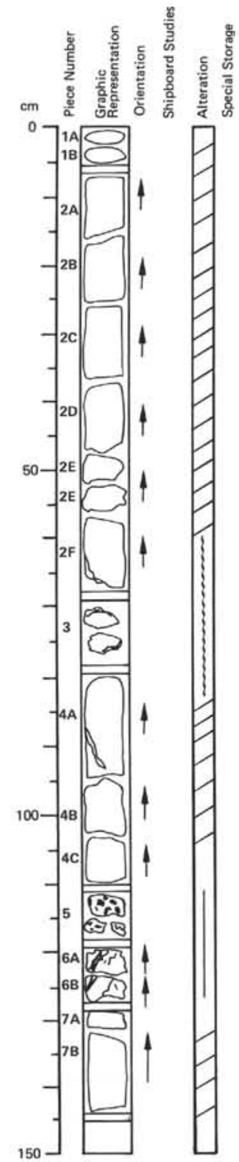
Visual Description

Plagioclase-olivine-spinel-phyric tholeiitic basalt as in Section 34-1.

Shipboard Data

Bulk Analysis:	**119 cm**
SiO_2	48.7
TiO_2	0.90
Al_2O_3	16.2
Fe_2O_3	1.26
FeO	8.31
MnO	0.17
MgO	6.86
CaO	12.91
Na_2O	2.32
K_2O	0.58
P_2O_5	0.07

Physical Properties:	**113-115 cm**
$\overline{V}p$ (km/s)	
parallel to beds	—
vertical to beds	5.04



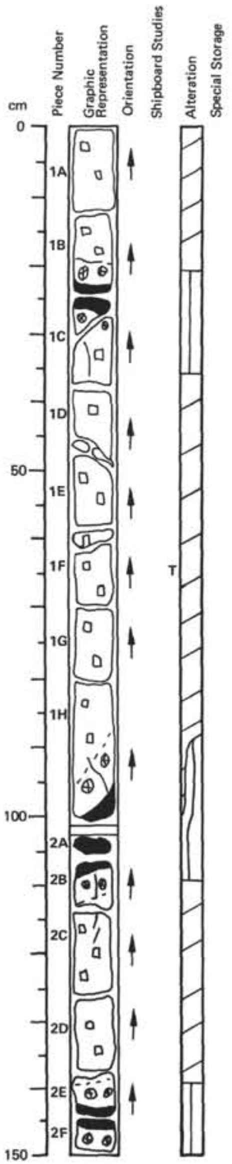
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	35	1

Depth: 275.0 to 276.5 m

Visual Description

Plagioclase-olivine-spinel-phyric tholeiitic basalt as in Section 34-2. Inner parts of pillows 70-80% crystalline with microphenocrysts of clinopyroxene. Groundmass subophitic to vitrophyric at pillow margins, enriched in glassy groundmass. Pillows alternately enriched in olivine and plagioclase phenocrysts.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	35	2

Depth: 276.5 to 278.0 m

Visual Description

Plagioclase-olivine-spinel-phyric tholeiitic basalt as in Section 35-1. Plagioclase phenocrysts 1-3 mm, euhedral,altered. Olivine phenocrysts 1-2 mm, altered to iddingsite. Groundmass 75% crystalline, variolitic near chilled margins.

Thin Section Description

Location: 66-68 cm, pillow interior

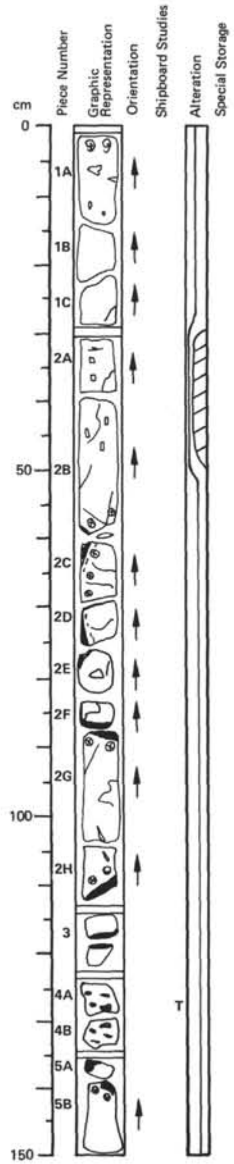
Texture: porphyritic with subophitic groundmass

Phenocrysts: <20%; plagioclase 40%, An_{76}, 1-3 mm, euhedral, highly altered; olivine 50%, 2 mm, subhedral, completely altered; spinel, trace

Groundmass: >80%; plagioclase 40%, An_{69}, 0.5 mm, elongate laths; clinopyroxene 35%, <0.02 mm, plumose segregations; olivine 15%, 0.1-0.2 mm, irregular, completely altered; magnetite/ilmenite 5%, < 0.01; glass 2-3%, altered completely.

Vesicles: none

Alteration: carbonate veins 5%; clays, zeolites replacing olivine, plagioclase glass



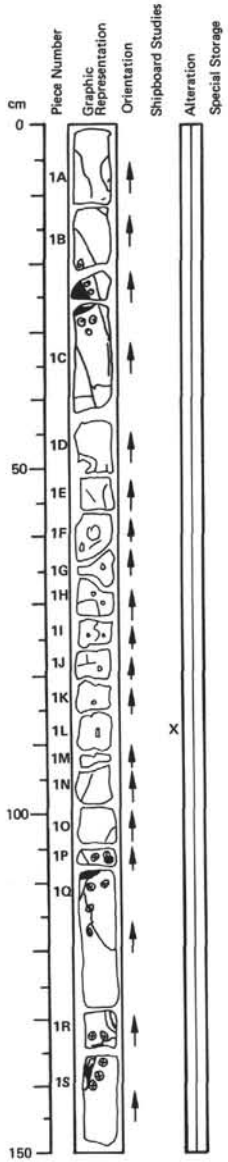
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	35	3

Depth: 278.0 to 279.5 m

Visual Description

Plagioclase-olivine-spinel-phyric tholeiitic basalt as in Section 35-2. Slight brecciation 90-150 cm. Pieces 4A, B, altered glass breccia.



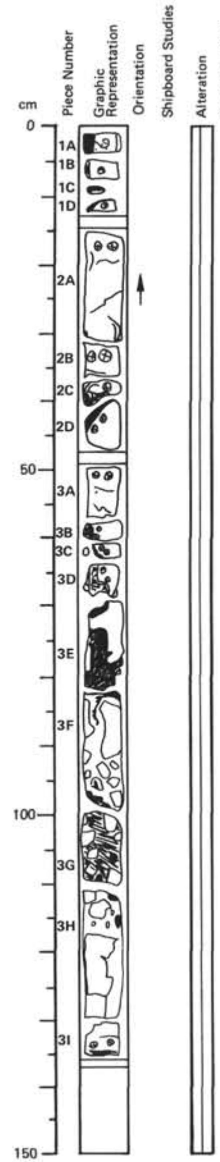
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	35	4

Depth: 279.5 to 281.0 m

Visual Description

Plagioclase-olivine-spinel-phyric tholeiitic basalt as in Section 35-3. Plagioclase-phenocrysts 10% of rock, 1-3 mm, glomeromorphic, slightly altered. Olivine 5-10% of rock, 1-2 mm, altered to brown smectite. Groundmass 75% crystalline, aphanitic to variolitic.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

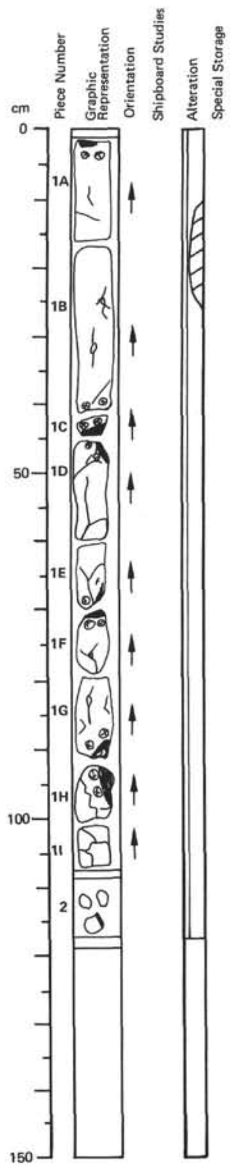
LEG	SITE	HOLE	CORE	SECT.
59	447	A	35	5

Depth: 281.0 to 282.5 m

Visual Description

0-100 cm: plagioclase-olivine-spinel-phyric tholeiitic basalt as in Section 35-4.

100-150 cm: as above but bearing xenocrysts (5-10 mm) of rounded (corroded or abraded) plagioclase, pillow lava flow.



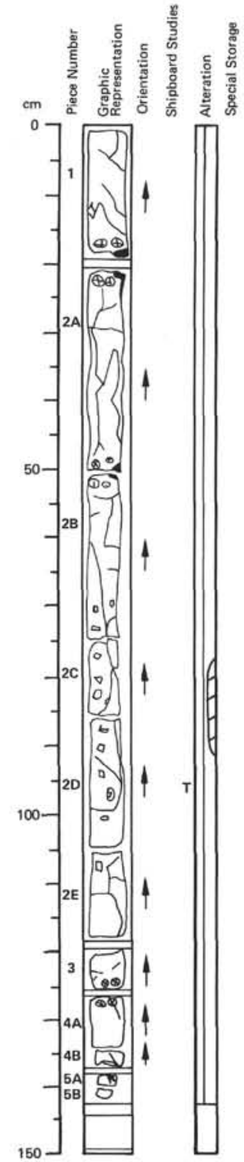
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	35	6

Depth: 282.5 to 283.7 m

Visual Description

Plagioclase-olivine-spinel-phyric tholeiitic basalt, bearing plagioclase xenocrysts as in lower part of Section 35-5.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	36	1

Depth: 284.0 to 285.5 m

Visual Description

Plagioclase-spinel-phyric tholeiitic basalt as in Section 35-6 bearing xenocrysts of plagioclase (in interval 20-120 cm they are up to 1 cm diameter).

Thin Section Description

Location: 95-97 cm

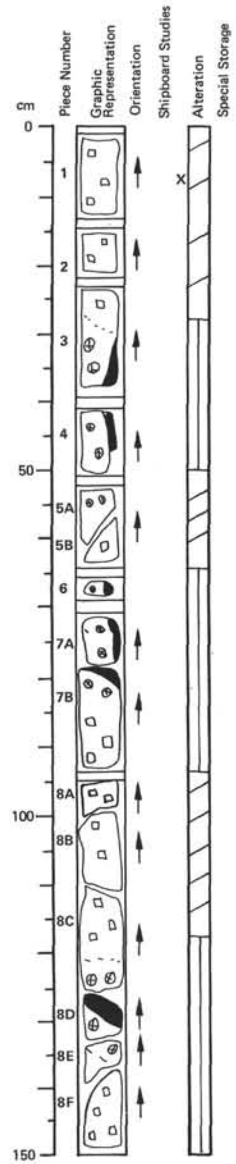
Texture: porphyritic with subophitic groundmass

Phenocrysts: 6-8%; plagioclase 80-90%, 1-2 mm, euhedral, megacrysts 0.5 x 1 cm; olivine 10-20%, 1-2 mm, anhedral, pseudomorphs; spinel, rare, 0.2 mm, euhedral, as inclusions in plagioclase megacrysts

Groundmass: 92-94%; plagioclase 50%, <0.8 mm, elongate laths; clinopyroxene 40%, 0.01 mm, plumose segregations, magnetite/ilmenite 4%, <0.01 mm; glass 6%

Vesicles: none

Alteration: carbonates, clays and zeolites replace olivine, plagioclase and glass



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	36	2

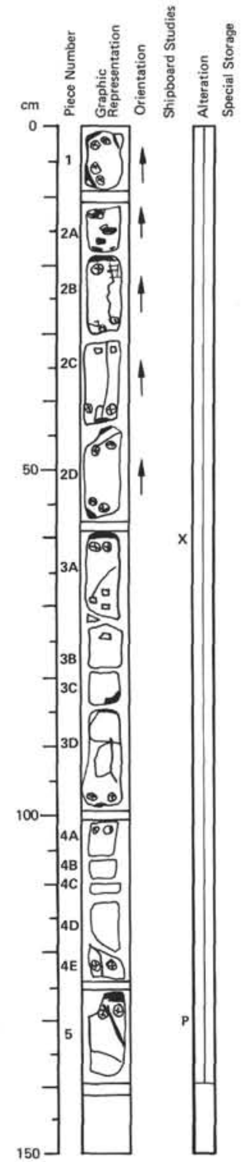
Depth: 285.5 to 287.0 m

Visual Description

Plagioclase-olivine-spinel-phyric tholeiitic basalt, as in Section 36-1. Plagioclase xenocrysts up to 1 cm.

Shipboard Data

Bulk Analysis:	**4 cm**
SiO_2	48.7
TiO_2	1.07
Al_2O_3	16.3
Fe_2O_3	1.28
FeO	8.47
MnO	0.19
MgO	6.78
CaO	12.41
Na_2O	2.84
K_2O	0.39
P_2O_5	0.07



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	36	3

Depth: 287.0 to 288.5 m

Visual Description

Plagioclase-olivine-spinel-phyric tholeiitic basalt in Section 36-2.

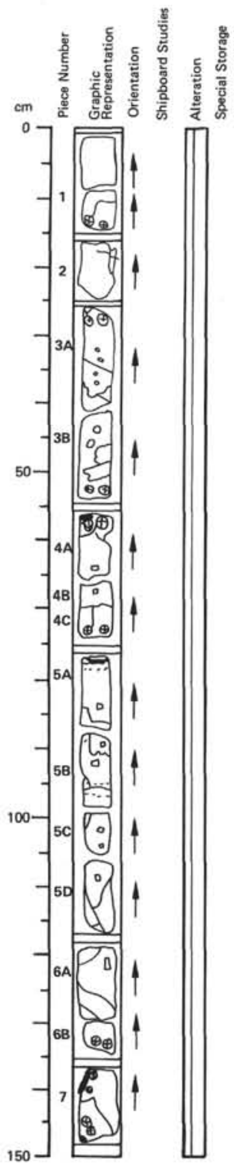
Piece 2A is a pillow glass breccia.

Pieces 3A-3D contain xenoliths up to 4 cm diameter of fresh, coarse crystalline cumulate anorthosite; crystals 3-5 mm in size. Also 2-4 mm xenocrysts of fresh to partly altered plagioclase.

Shipboard Data

Bulk Analysis:	**62 cm**
SiO_2	47.8
TiO_2	0.98
Al_2O_3	16.0
Fe_2O_3	1.35
FeO	8.90
MnO	0.17
MgO	6.63
CaO	11.47
Na_2O	2.24
K_2O	1.12
P_2O_5	0.06

Physical Properties:	**131-133 cm**
$\bar{V}p$ (km/s)	
parallel to beds	4.95
vertical to beds	5.01
Wet bulk density	2.73



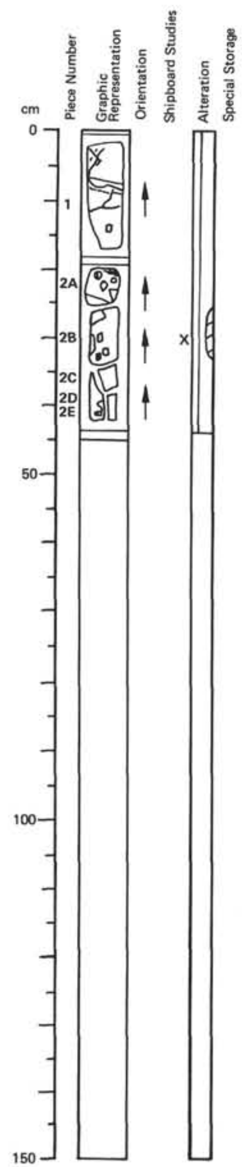
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.
5	9	4	4	7	A	3	6	4

Depth: 288.5 to 290.0 m

Visual Description

Plagioclase-olivine-spinel-phyric tholeiitic basalt containing plagioclase xenocrysts, 1-5 mm, as in Section 36-2.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.
5	9	4	4	7	A	3	6	5

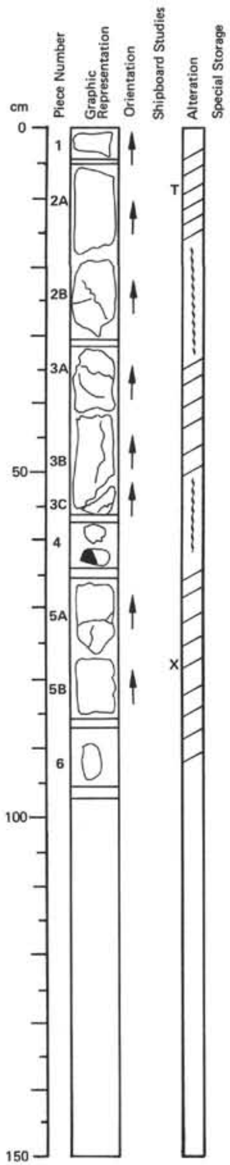
Depth: 290.0 to 290.4 m

Visual Description

Plagioclase-olivine-spinel-phyric tholeiitic basalt; xenocrysts, as in Section 36-4.

Shipboard Data

Bulk Analysis:	**29 cm**
SiO_2	48.1
TiO_2	0.90
Al_2O_3	15.6
Fe_2O_3	1.27
FeO	8.36
MnO	0.16
MgO	7.04
CaO	13.07
Na_2O	2.25
K_2O	0.59
P_2O_5	0.06



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
59	447	A	37	1

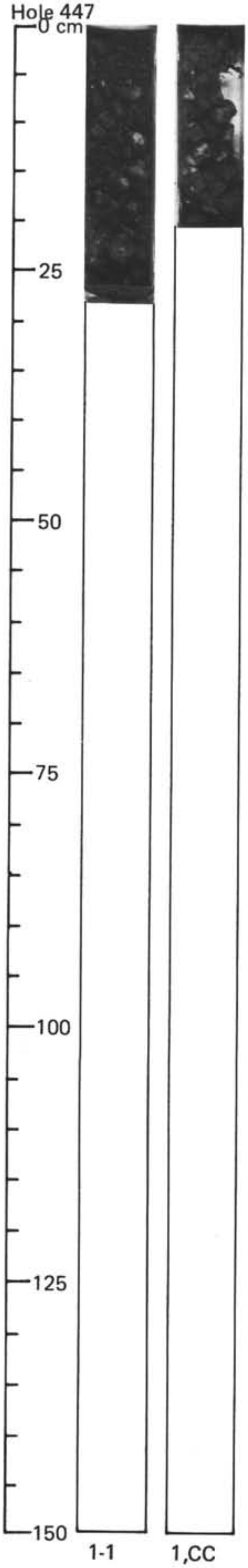
Depth: 293.0 to 294.0 m

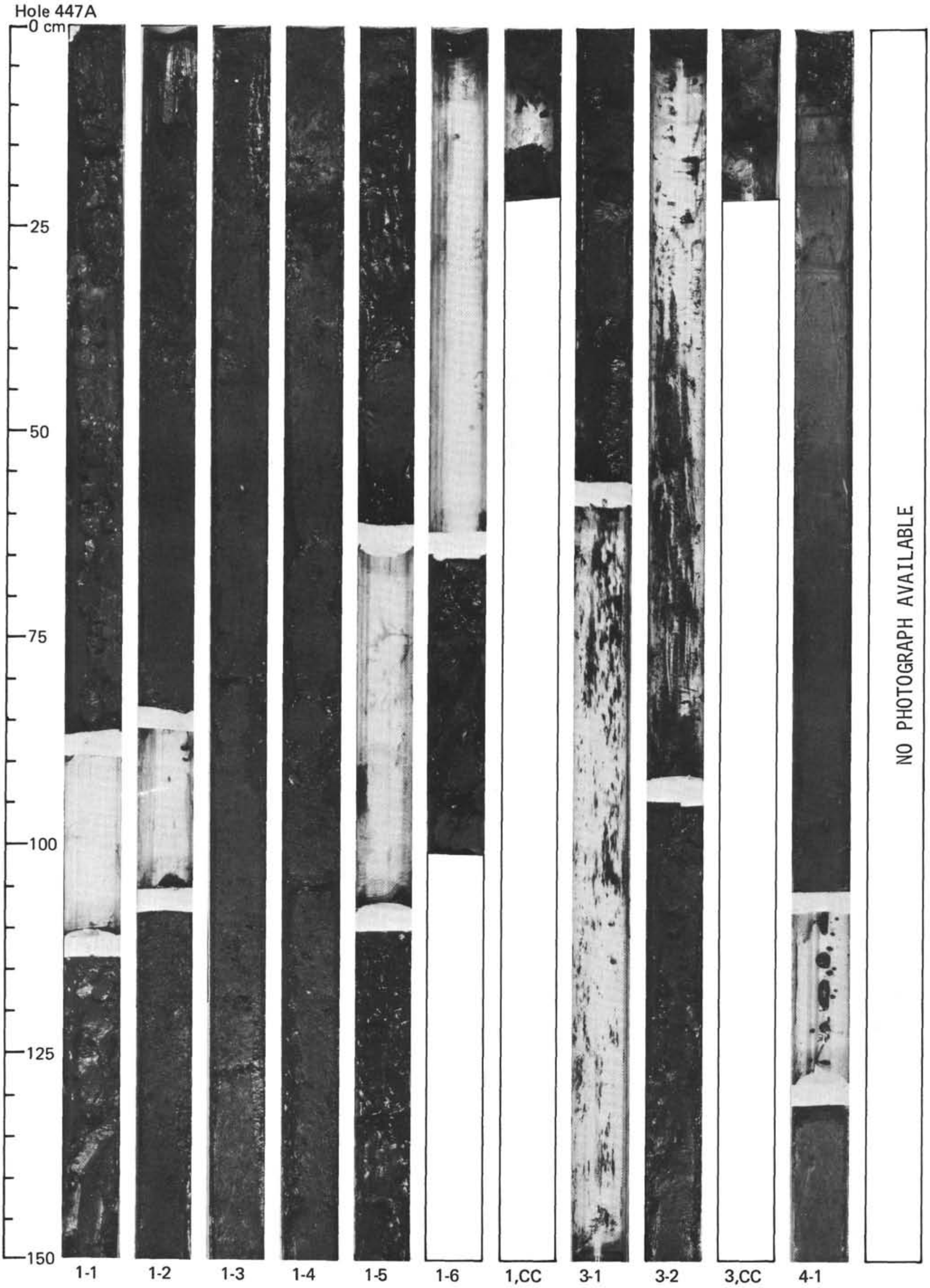
Visual Description

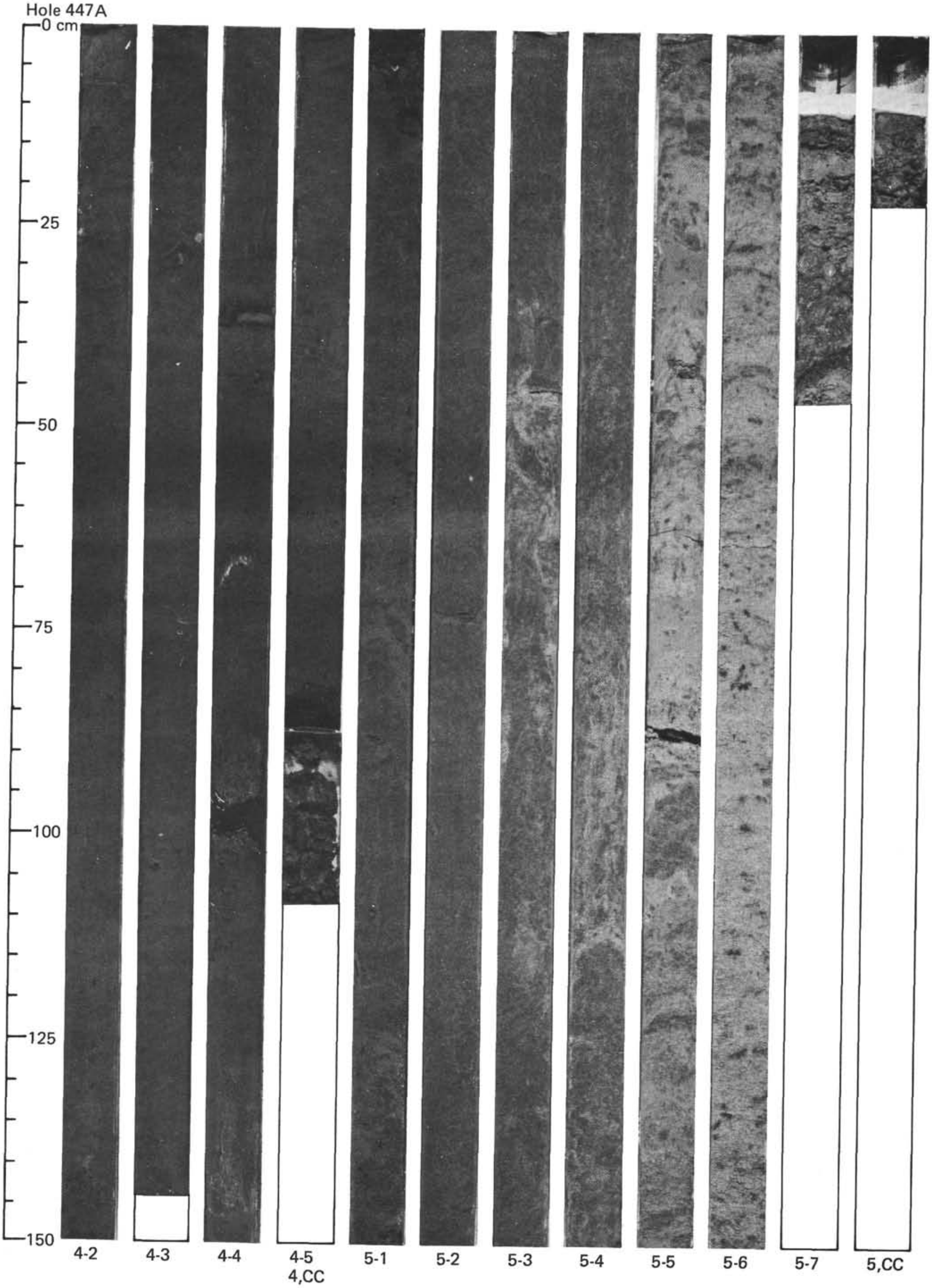
Plagioclase-olivine-spinel-phyric tholeiitic basalt as in Section 36-5. Plagioclase xenocrysts up to 1 cm.

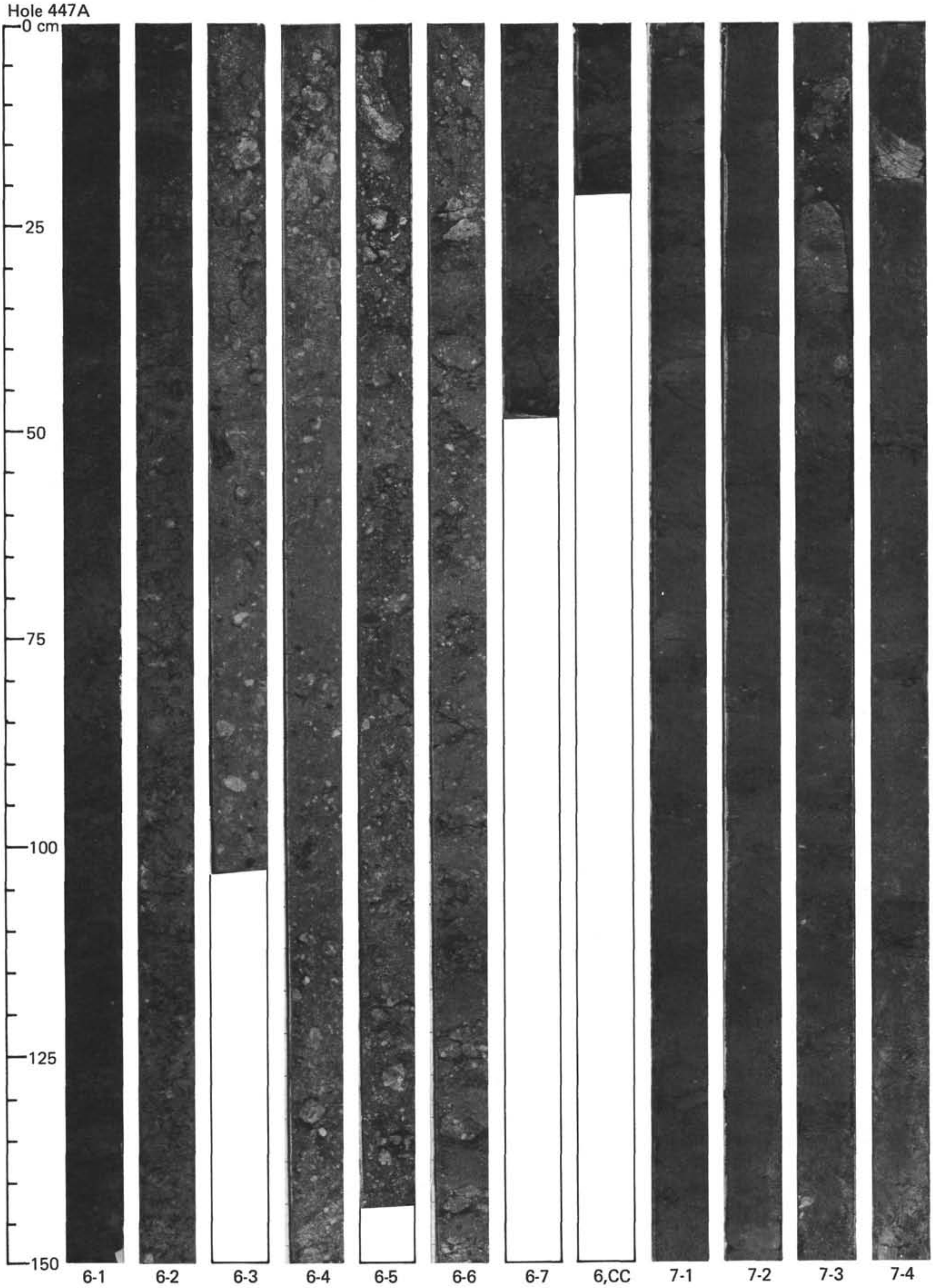
Shipboard Data

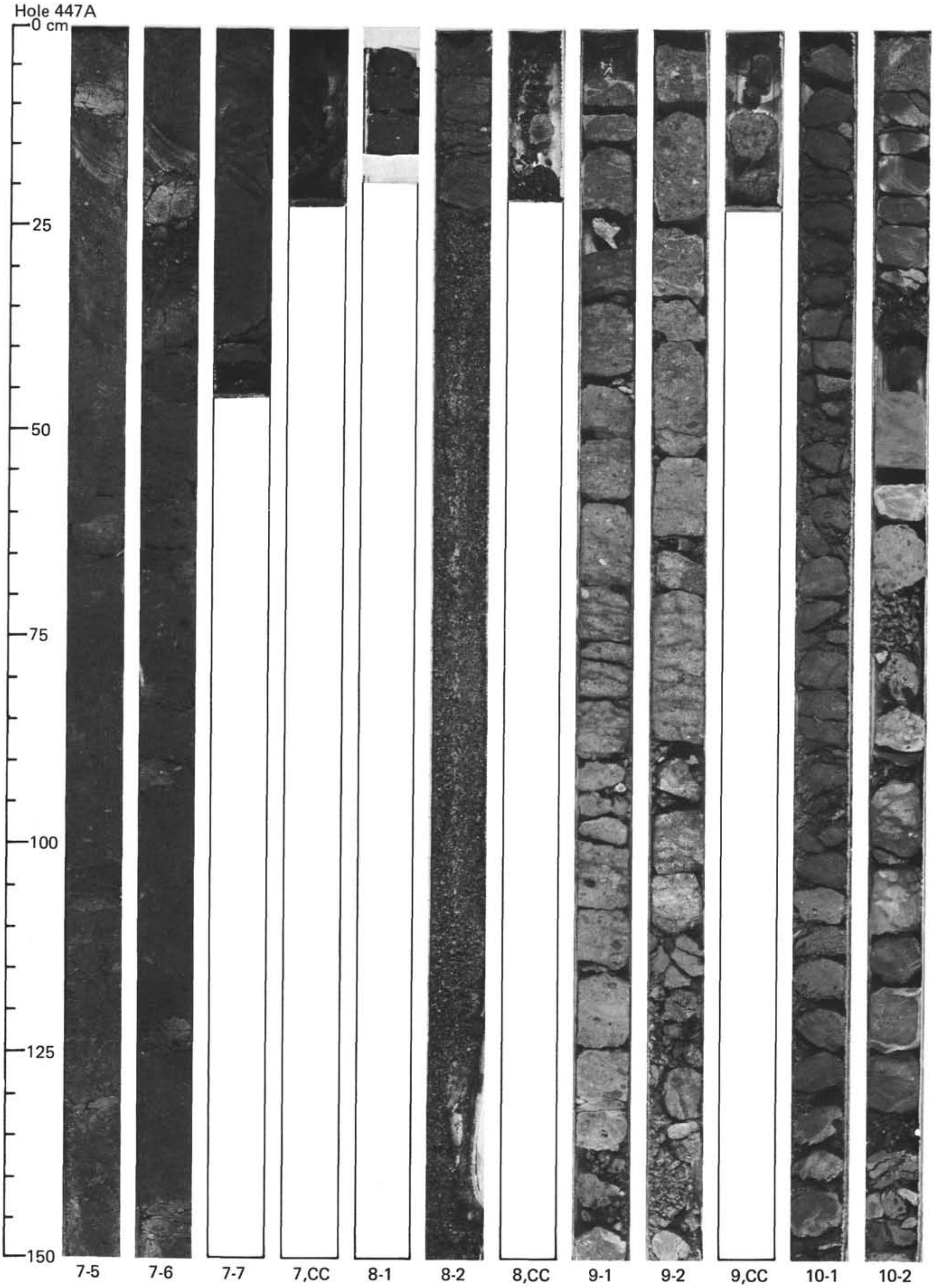
Bulk Analysis:	**80 cm**
SiO_2	47.7
TiO_2	0.92
Al_2O_3	15.9
Fe_2O_3	1.29
FeO	8.51
MnO	0.17
MgO	6.10
CaO	12.64
Na_2O	2.15
K_2O	1.14
P_2O_5	0.09

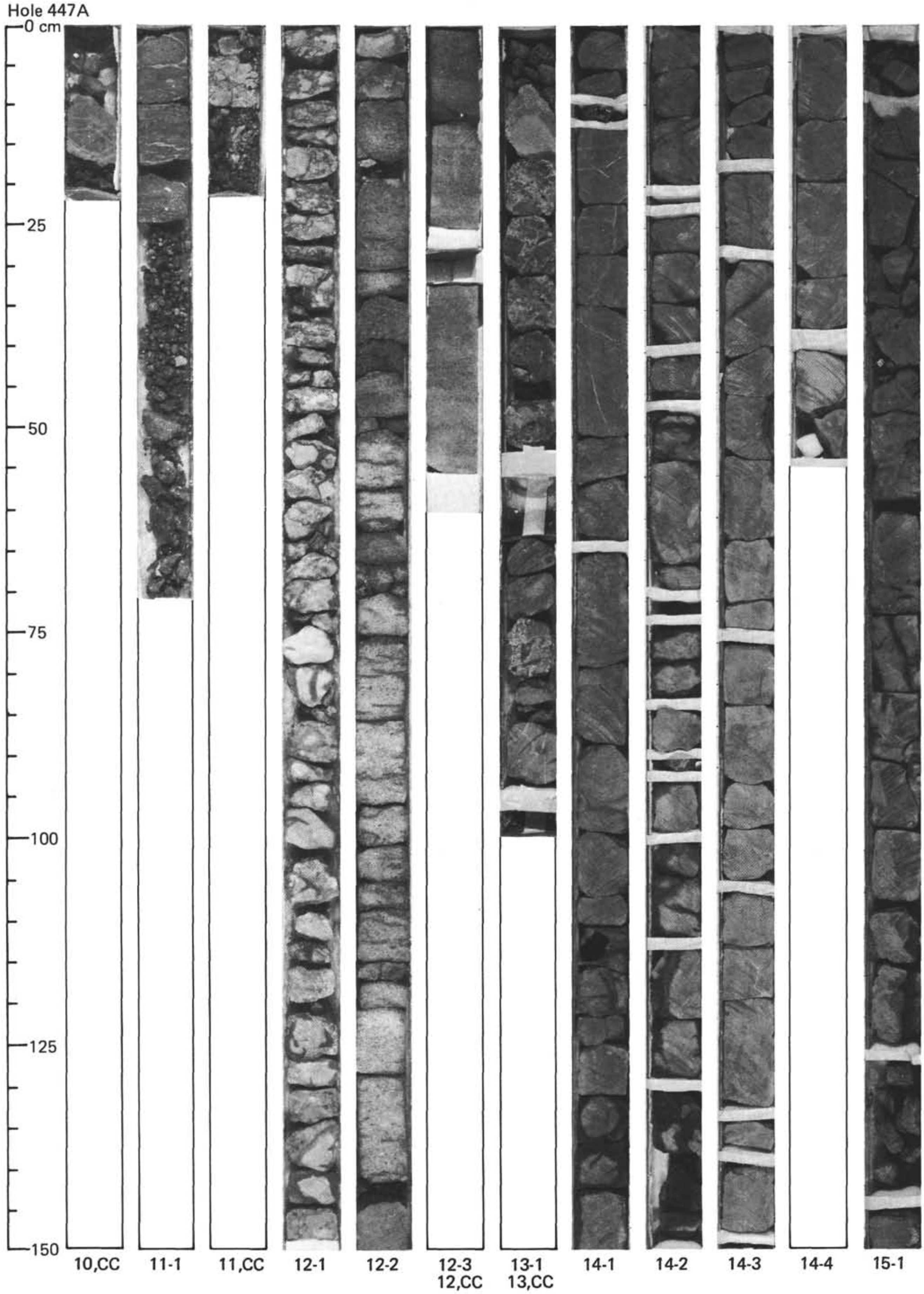

Hole 447
0 cm
25
50
75
100
125
150
1-1
1,CC

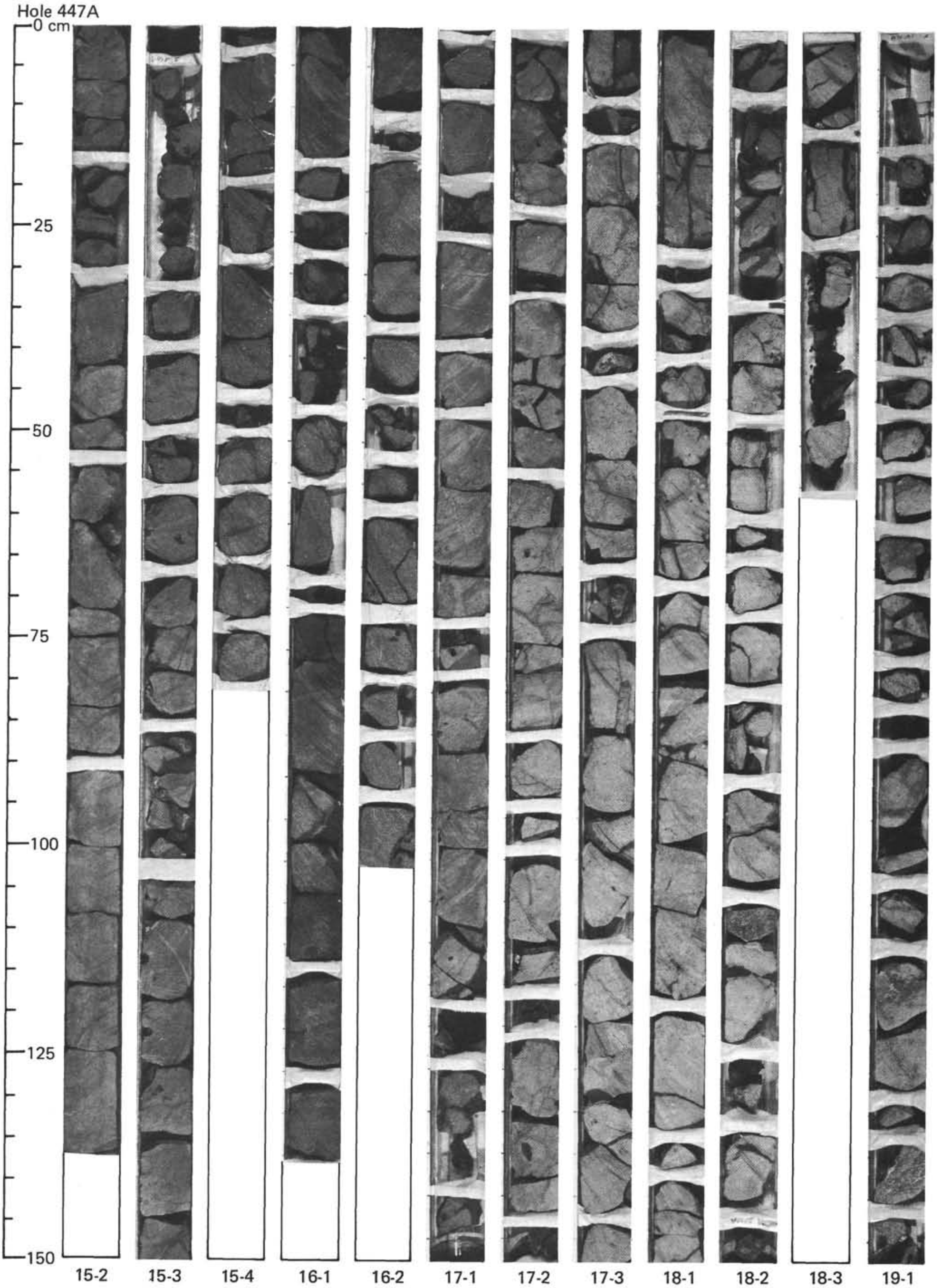

Hole 447A
0 cm
25
50
75
100
125
150
1-1
1-2
1-3
1-4
1-5
1-6
1,CC
3-1
3-2
3,CC
4-1
NO PHOTOGRAPH AVAILABLE

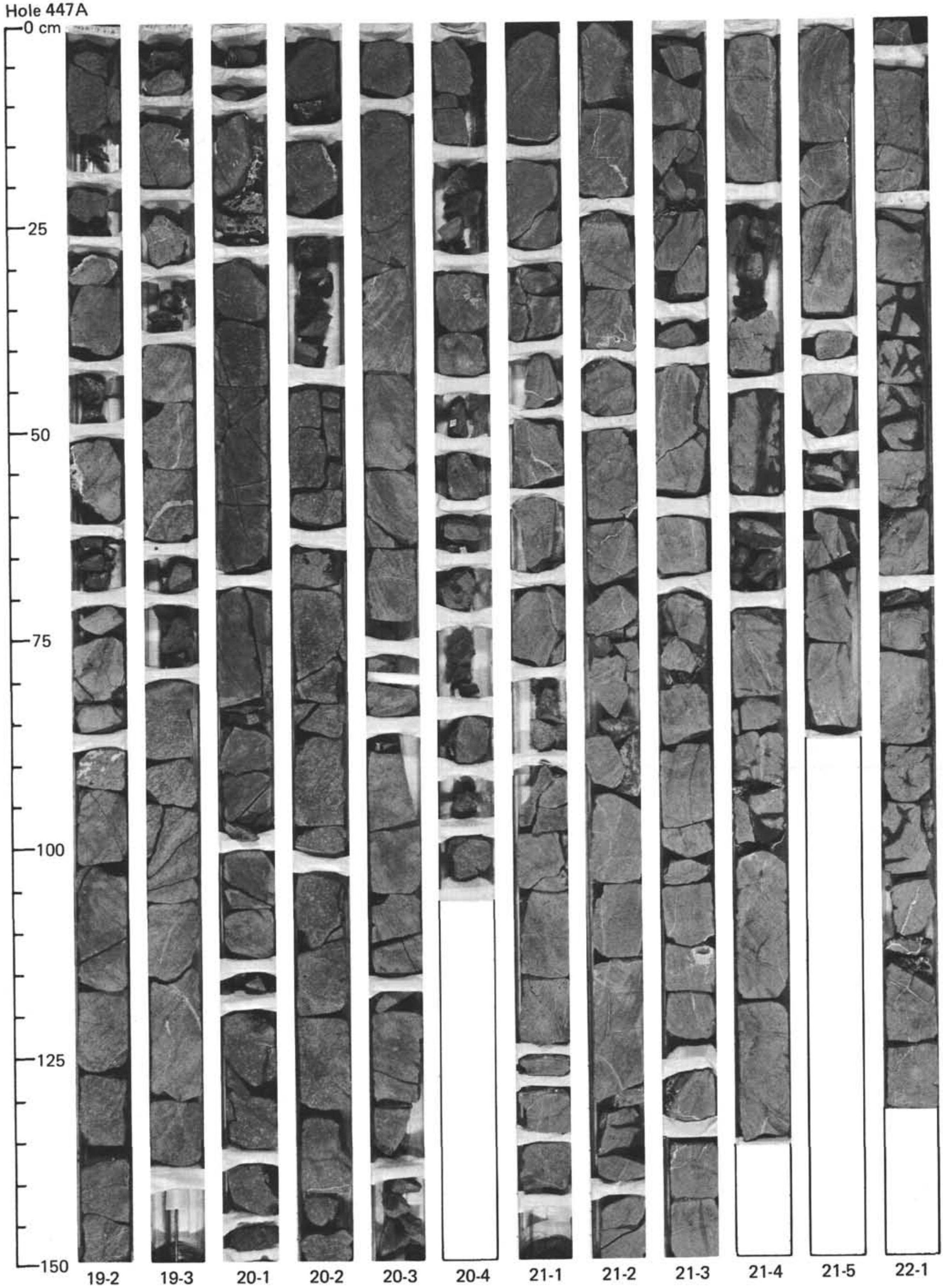

Hole 447A
0 cm
25
50
75
100
125
150
4-2
4-3
4-4
4-5
4,CC
5-1
5-2
5-3
5-4
5-5
5-6
5-7
5,CC

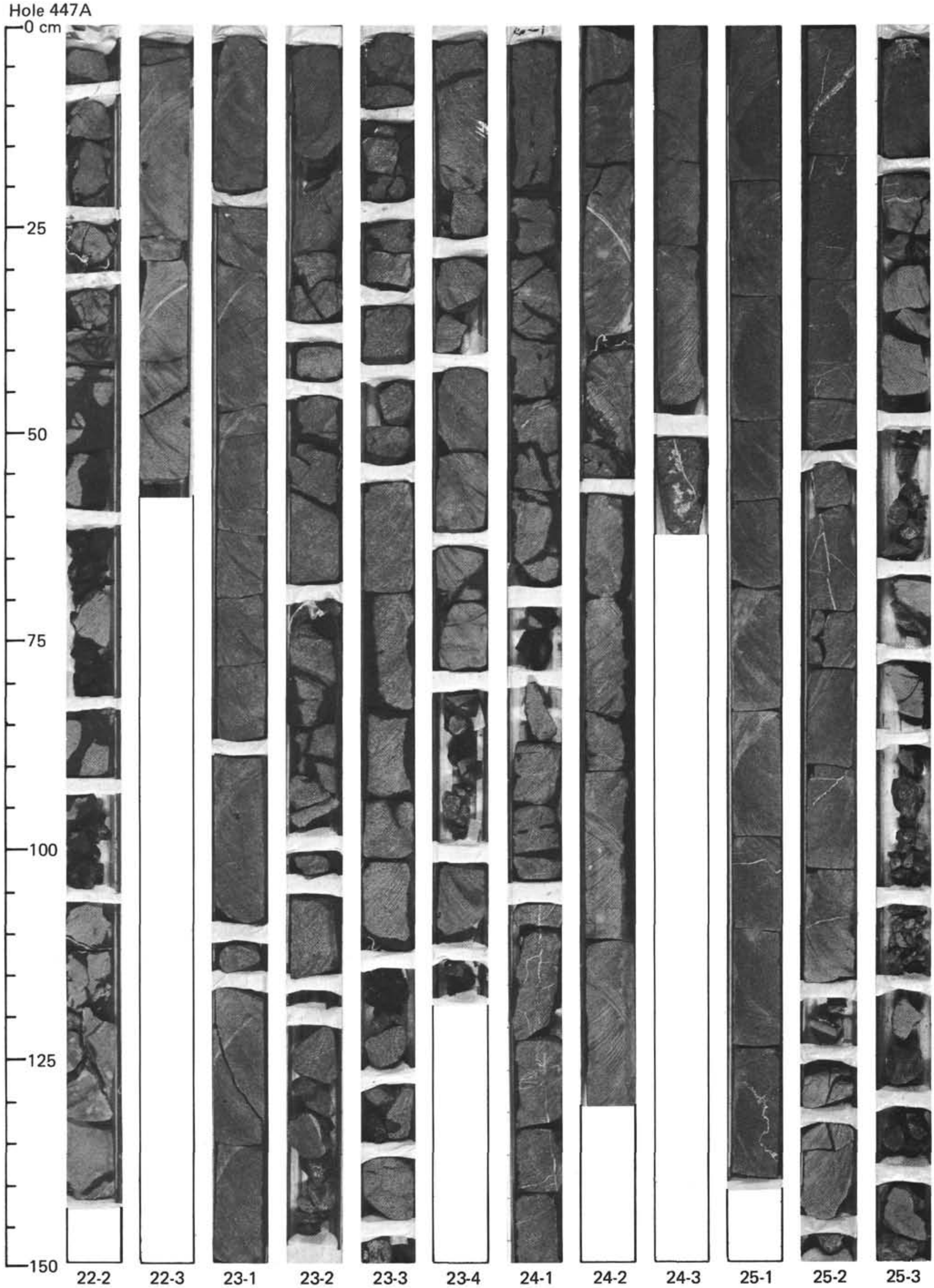

Hole 447A
0 cm
25
50
75
100
125
150
6-1
6-2
6-3
6-4
6-5
6-6
6-7
6,CC
7-1
7-2
7-3
7-4

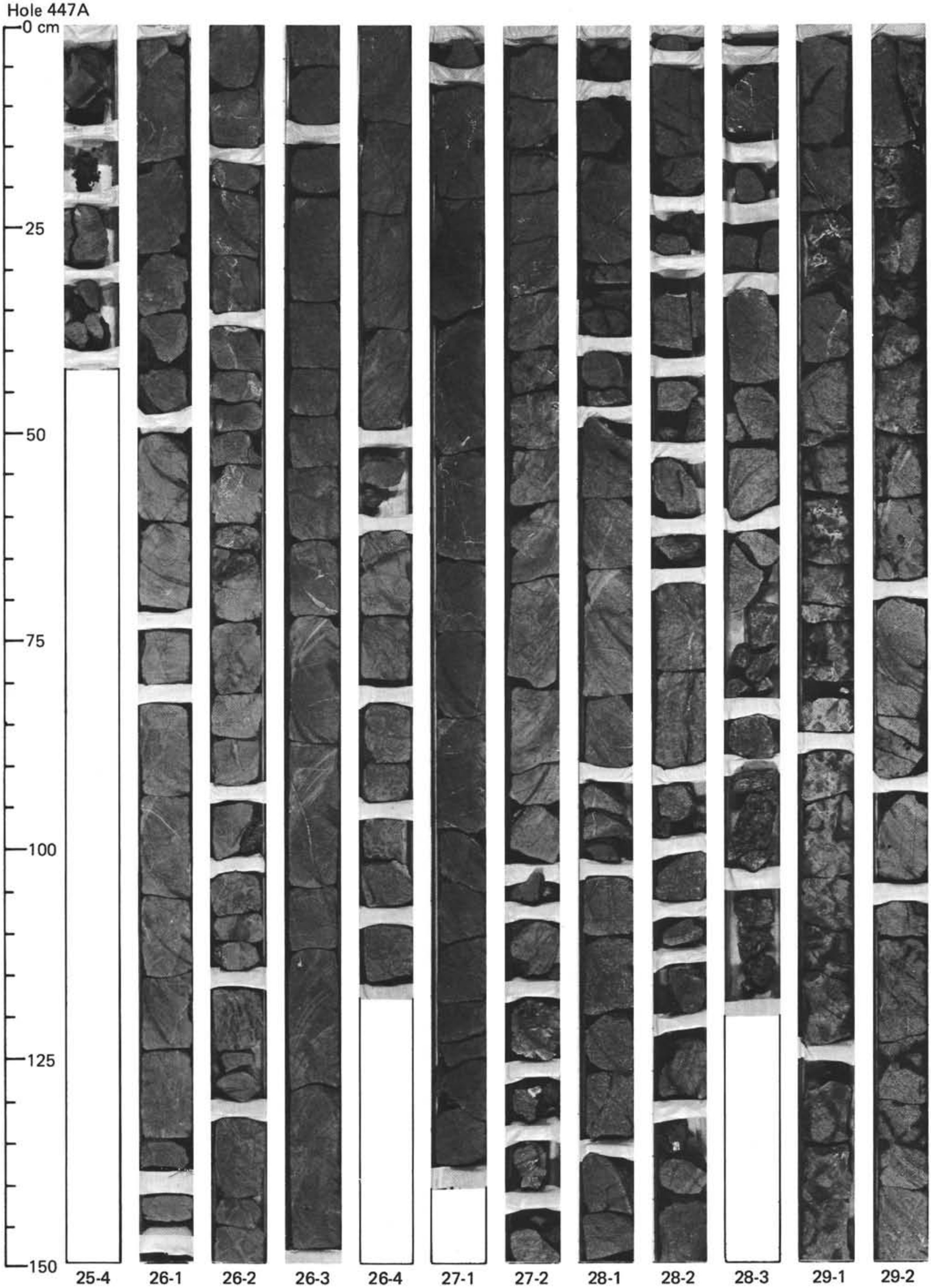

Hole 447A
0 cm
25
50
75
100
125
150
7-5
7-6
7-7
7,CC
8-1
8-2
8,CC
9-1
9-2
9,CC
10-1
10-2

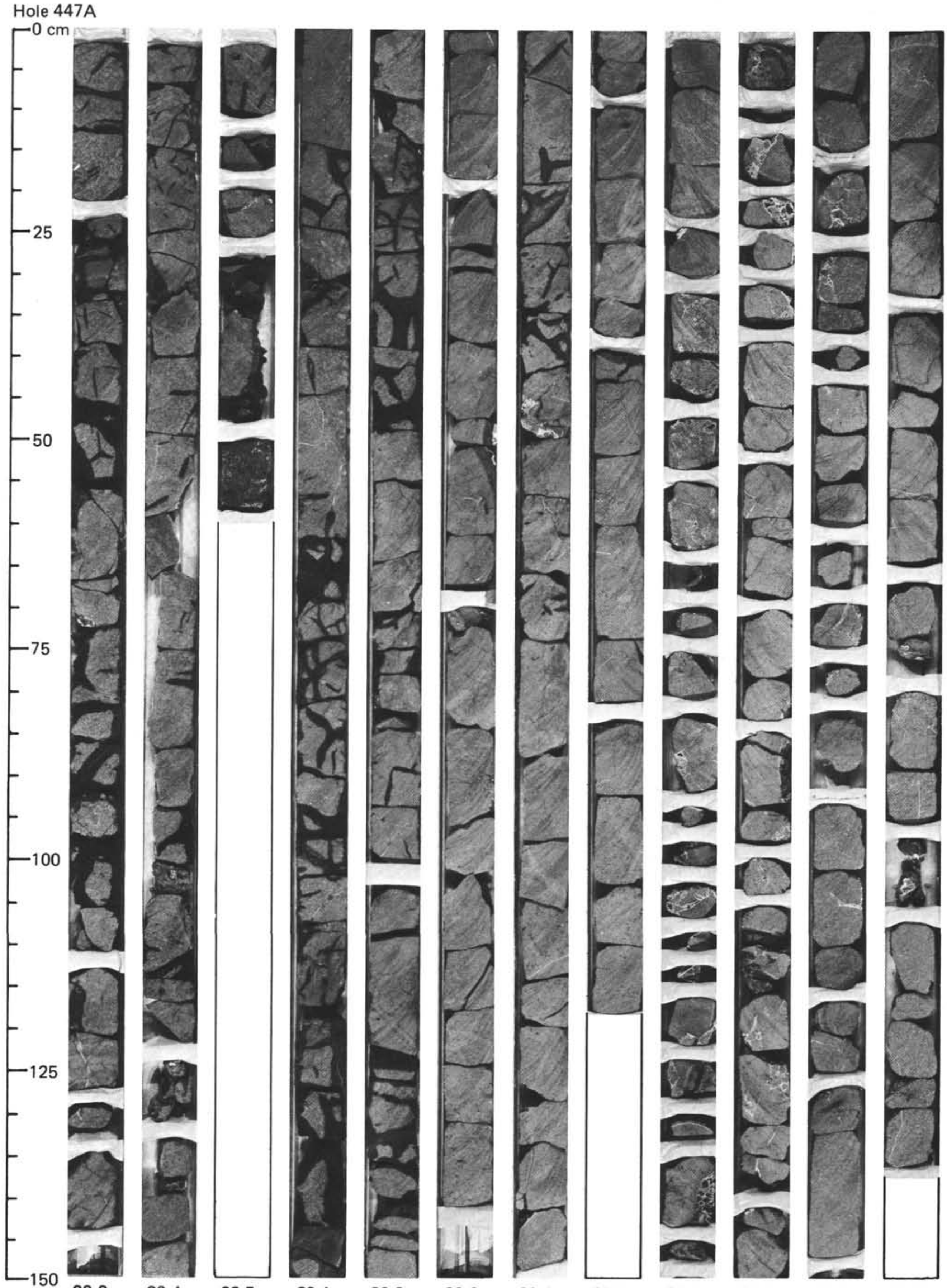

Hole 447A
0 cm
25
50
75
100
125
150
10,CC
11-1
11,CC
12-1
12-2
12-3
12,CC
13-1
13,CC
14-1
14-2
14-3
14-4
15-1

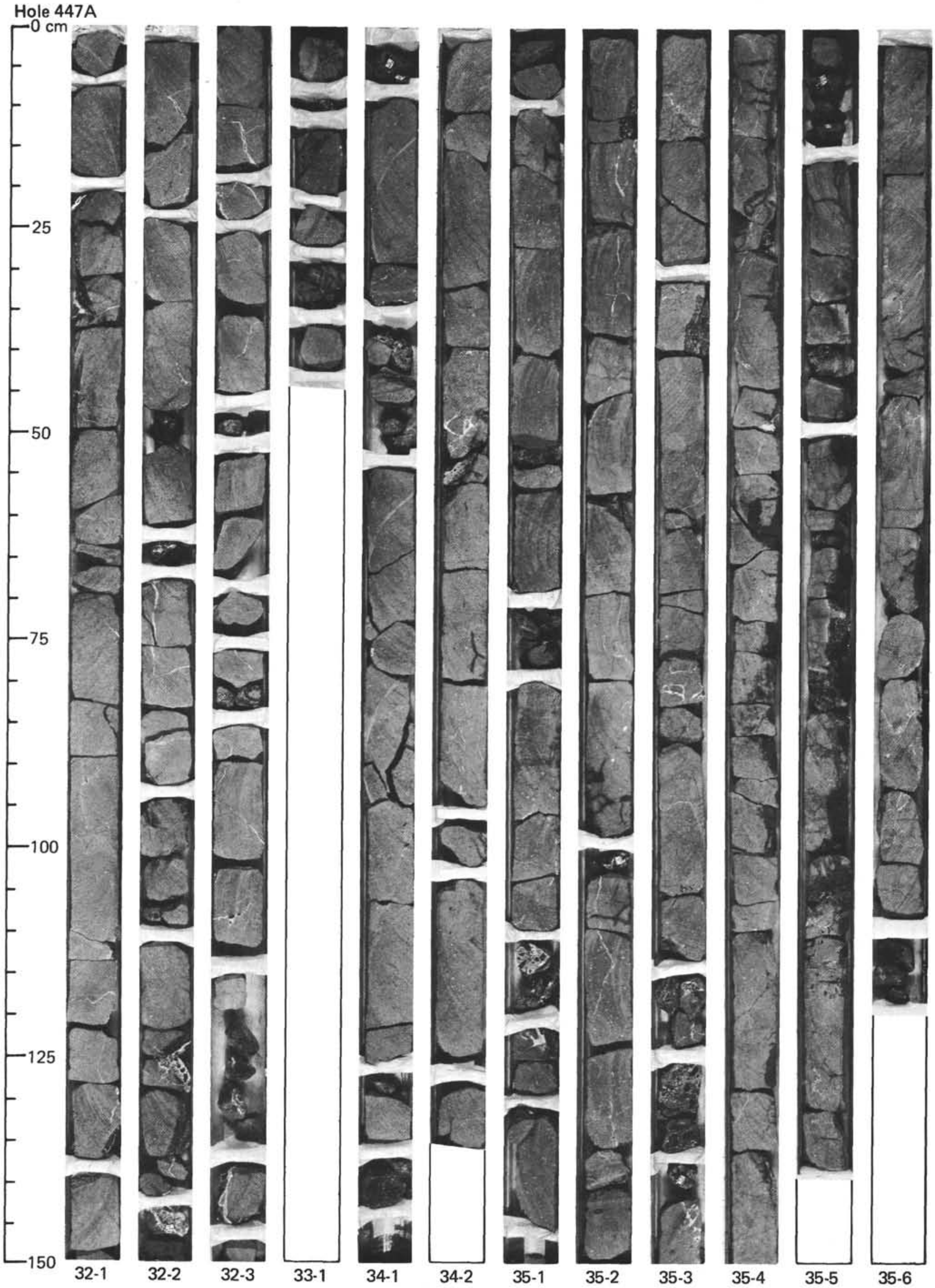

Hole 447A
0 cm
25
50
75
100
125
150
15-2
15-3
15-4
16-1
16-2
17-1
17-2
17-3
18-1
18-2
18-3
19-1

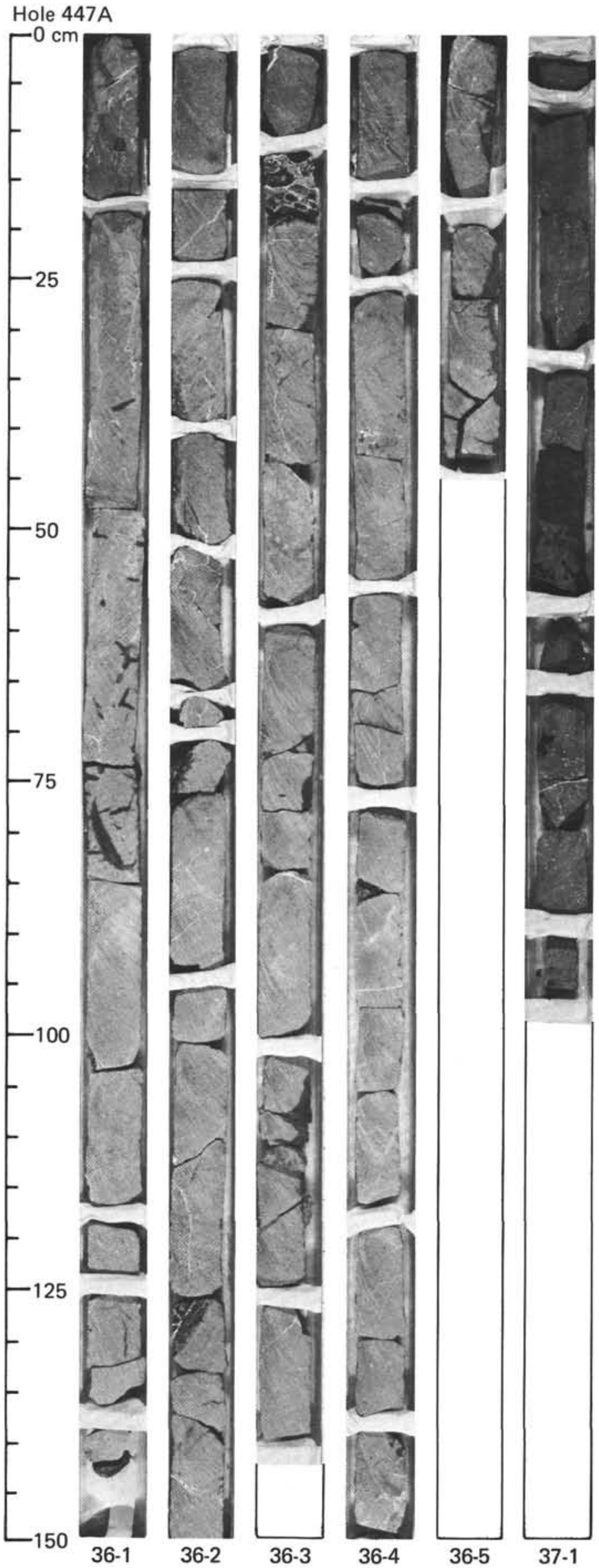

Hole 447A
0 cm
25
50
75
100
125
150
19-2
19-3
20-1
20-2
20-3
20-4
21-1
21-2
21-3
21-4
21-5
22-1


Hole 447A
0 cm
25
50
75
100
125
150
22-2
22-3
23-1
23-2
23-3
23-4
24-1
24-2
24-3
25-1
25-2
25-3


Hole 447A
0 cm
25
50
75
100
125
150
25-4
26-1
26-2
26-3
26-4
27-1
27-2
28-1
28-2
28-3
29-1
29-2


Hole 447A
0 cm
25
50
75
100
125
150
29-3
29-4
29-5
30-1
30-2
30-3
30-4
30-5
31-1
31-2
31-3
31-4


Hole 447A
0 cm
25
50
75
100
125
150
32-1
32-2
32-3
33-1
34-1
34-2
35-1
35-2
35-3
35-4
35-5
35-6


Hole 447A
0 cm
25
50
75
100
125
150
36-1
36-2
36-3
36-4
36-5
37-1