2. SITE 417

Shipboard Scientific Parties[1]

SITE DATA — HOLE 417

Date Occupied: 2 December, 1976

Date Departed: 3 December, 1976

Time on Hole: 21 hours, 45 minutes

Position: 25°06.63'N; 68°02.48'W

Water Depth (sea level): 5468 corrected meters, echo sounding

Water Depth (rig floor): 5478 corrected meters, echo sounding

Bottom Felt at: 5478.2 meters, drill pipe

Penetration (m): 113

Number of Cores: 1

Total Length of Cored Section (m): 8.5

Total Core Recovered (m): 3.6

Percentage Core Recovery: 42

Oldest Sediment Cored:
Depth sub-bottom (m): 3.6
Nature: Brown pelagic clay
Chronostratigraphic unit: Quaternary

Principal Results: Hole 417 was drilled as a pilot hole for Site 417. After a single core was taken to determine the mudline, the hole was washed to a depth of 113 meters to establish the casing depth.

SITE DATA — HOLE 417A

Date Occupied: 3 December, 1976

Date Departed: 10 December, 1976

Time on Hole: 6 days, 22 hours, 45 minutes

Position: 25°06.63'N; 68°02.48'W

Water Depth (sea level): 5468 corrected meters, echo sounding

Water Depth (rig floor): 5478 corrected meters, echo sounding

Bottom Felt at: 5478.2 meters, drill pipe

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Penetration (m): 417

Number of Cores: 46

Total Length of Cored Section (m): 417
In sediment: 208
In igneous rocks: 209

Total Core Recovered (m): 249.5
In sediment: 121
In igneous rocks: 128.5

Percentage Core Recovery: 59.8
In sediment: 58
In igneous rocks: 61

Oldest Sediment Cored:
Depth sub-bottom (m): 189–198.5
Nature: Clay (with sand?)
Chronostratigraphic unit: Late Cretaceous
Measured velocity (km/s): 1.6

Basement:
Depth sub-bottom (m): 208
Nature: Basalt lavas and breccias
Velocity range (km/s): 4–6

Principal Results: Site 417 was located at the southern end of the Bermuda Rise immediately north of the Vema Gap. The site lies on anomaly *M*0 in oceanic crust formed during the Cretaceous (Aptian through Albian) period. The nearest fracture zones lie 10 to 40 nautical miles to the north and south, respectively.

Hole 417A was drilled and cored continuously to 417 meters sub-bottom. The sedimentary sequence consists from the top down of 9 meters of Quaternary brown pelagic clay with reworked nannofossils and foraminifers, 97 meters of unfossiliferous brown clay with sparse rhyolitic ash, 17 meters of barren zeolitic clay, 38 meters of middle Eocene radiolarian zeolitic clay and ooze, and 39 meters of Upper Cretaceous multicolored zeolitic clay. There is an hiatus of unknown duration in the lower sedimentary section between the middle Eocene and Upper Cretaceous sections.

The basement is composed of a relatively uniform, high-calcium, high-aluminum, low-magnesium, plagioclase-rich oceanic basalt. The section consists of 15 pillow basalt units separated by breccia, with a massive basalt unit at least 10 meters thick near the base of the sequence. Fractures and interpillow voids are completely sealed by secondary minerals including smectite, calcite, analcime, natrolite, and hematite. The upper 180 meters of basalt is pervasively altered; only the massive basalt near the base of the section is relatively fresh. Magnetization is strong, uniform, and reversed with an inclination of $-22°$ as predicted by the drill site location on anomaly *M*0. Recovery of both interpillow material and basalt permits calculation of a formational velocity of 4.7 km/s assuming no cracks. Enigmatic rounded pebbles and cobbles of basalt recovered above and possibly within basement are probably artifacts of the drilling process.

The igneous sequence in Hole 417A suggests rapid emplacement during a single phase of magmatic activity from the same parental material and subsequent alteration from the top down. The basaltic pile was apparently exposed to sea water for as long as 30 m.y. before being sealed off by impermeable brown clay. The rocks recovered provide an excellent suite to study progressive alteration in oceanic rocks.

SITE DATA — HOLE 417B

Date Occupied: 25 December, 1976

Date Departed: 28 December, 1976

Time on Hole: 3 days, 3 hours, 30 minutes

Position: 25°06.69′N; 68°02.82′W

Water Depth (sea level): 5482 corrected meters, echo sounding

Water Depth (rig floor): 5492 corrected meters, echo sounding

Bottom Felt at: 5489 meters, drill pipe

Penetration (m): 25

Number of Cores: 1

Total Length of Cored Section (m): 5.5

Total Core Recovered (m): 5.2

Percentage Core Recovery: 95

Oldest Sediment Cored:
Depth sub-bottom (m): 5.5
Nature: Brown pelagic clay
Chronostratigraphic unit: Quaternary

Principal Results: Hole 417B was drilled as a pilot hole for Hole 417D. After a single core was taken to determine the mudline, the hole was washed to a depth of 25 meters to establish the casing depth.

SITE DATA — HOLE 417C

Hole not drilled owing to mechanical problems.

SITE DATA — HOLE 417D

Date Occupied:
Leg 51: 30 December, 1976
Leg 52: 24 January, 1977

Date Departed:
Leg 51: 15 January, 1977
Leg 52: 10 February, 1977

Time on Hole:
Leg 51: 17 days, 22 hours, 45 minutes
Leg 52: 30 days, 9 hours, 30 minutes
Final: 48 days, 8 hours, 15 minutes

Position: Latitude: 25°06.69′N; Longitude: 68°02.81′W

Water Depth (sea level): 5482 corrected meters, echo sounding

Water Depth (rig floor): 5492 corrected meters, echo sounding

Bottom Felt at: 5489 meters, drill pipe

Penetration (m):
Leg 51: 532.5
Leg 52: 176
Final: 708.5

Number of Cores:
Leg 51: 47
Leg 52: 22
Final: 69

Sediment Cored (m):
Leg 51: 176.6
Leg 52: 0
Final: 176.6

Sediment Recovered (m):
Leg 51: 57.6
Leg 52: 0
Final: 57.6

Percentage Sediment Recovery:
Leg 51: 32.6
Leg 52: —
Final: 32.6

Basalt Cored (m):
Leg 51: 189.5
Leg 52: 176
Final: 365.5

Basalt Recovered (m):
Leg 51: 145.8
Leg 52: 117.4
Final: 263.2

Percentage Basalt Recovery:
Leg 51: 76.9
Leg 52: 66.7
Final: 72.0

Total Length of Cored Section (m):
Leg 51: 336.1
Leg 52: 176
Final: 542.1

Total Core Recovered (m):
Leg 51: 203.4
Leg 52: 117.4
Final: 320.8

Oldest Sediment Cored:
Depth sub-bottom (m): 343
Nature: Nannofossil chalk
Chronostratigraphic unit: Lower Aptian
Measured velocity (km/s): 1.8

Basement:
Depth sub-bottom (m): 343
Nature: Basalt
Velocity range (km/s): 4.5–6.1

Principal Results: The sediments drilled in Hole 417D are identical to those in Hole 417A but include a 130-meter-thick Cretaceous section not seen in Hole 417A consisting of a barren, multicolored clay unit and a fossiliferous (early Aptian?) black and green claystone with conspicuous pyrite, phosphate, and organic matter. This unit corresponds to the "black clay" seen at numerous Atlantic sites. Interbedded with this unit is a cyclic radiolarian-sandstone-/claystone turbidite sequence. At the base of the section is a thin unit of nannofossil chalk.

The basement section drilled consists of 365.5 meters of pillow basalts and interlayered massive basalts (the latter cut by dikes near the base of the hole) which were subdivided into 14 lithologic units on the basis of texture and mineralogy. All of the basalts are plagioclase-phyric with subordinate phenocrysts of olivine and/or clinopyroxene. Although very similar to Hole 417A, there are three main differences between the two sections:

a) Pillow breccias are more abundant in Hole 417A.

b) Limestone sediments and calcite are much more developed in Hole 417D.

c) The basalt in Hole 417D is chemically similar to that at Hole 417A (high Ca, Al, low Mg) but much less altered. Fresh glass is abundant in the upper part of Hole 417D, while K_2O is much less abundant than in Hole 417A suggesting a shorter exposure to sea water. XFR data for the freshest aphyric basalts resemble analyzed basalt glass from the MAR rift valley at 22 to 23°N on the Mid-Atlantic Ridge and are similar to many basalts recovered at Sites 395 and 396. A typical anhydrous analysis for aphyric basalt (Sample 417D-64-4, 87–89 cm) gives 50.3 per cent SiO_2, 1.66 per cent TiO_2, 14.4 per cent Al_2O_3, 10.8 per cent FeO, 7.69 per cent MgO, 11.9 per cent CaO, and 0.01 per cent K_2O. Loss on ignition is 1.10 per cent, H_2O is 0.56 per cent, and CO_2 is 0.06 per cent. Very low values for K_2O in the freshest samples suggest these are "normal" LIL-element depleted basalts, while TiO_2 in the range of 1.3 to 1.7 per cent and Fe/(Fe + Mg) averaging about 0.45 indicate somewhat differentiated compositions.

Stable NRM inclinations in the upper levels of the hole are anomalously steep (−60°), but they decrease with depth to values consistent with the extrapolated paleolatitude of the site (−25°). This may be because of either secular variation or tectonic rotation. The NRM of the massive basalts is notably lower in amplitude than that of the pillow basalts and opposite in polarity to anomaly *M*0, while the pillow basalts are magnetized in the same sense as anomaly *M*0.

Measured sonic velocities (V_p) range from 4.5 to 6.1 km/s and average 5.4 km/s. A comparison of this value with the formation velocity (4.8 km/s) obtained in the same hole by downhole logging and the oblique seismic experiment suggests that the crust still contains numerous water-filled cracks and voids despite partial infilling by the products of alteration.

The fossil age of the oldest sediments and the results of fission-track dating on the basaltic glasses confirm the extrapolated age for magnetic anomaly *M*0 proposed by Larson and Hilde (1975). The absolute age of 108 m.y. for early Aptian provides an important datum for the Cretaceous time scale and appears to confirm the Phanerozoic time scale (Geological Society of London, 1964). This result is also important because it confirms the surge in spreading rates during the late Mesozoic (Larson and Pitman, 1972, 1975; Baldwin et al., 1974; and Berggren et al., 1975).

BACKGROUND AND OBJECTIVES

Introduction

Since the beginning of the Deep Sea Drilling Project in 1968, numerous holes have been drilled to shallow depths in the oceanic basement, and several deep penetration attempts have been made in young crust in order to determine the nature of the crustal material which underlies the ocean basins (Table 1).

The rationale for this effort is that without direct sampling, our assumptions about the composition and structure of the oceanic crust are based almost entirely on analogy with on-land exposures of supposed oceanic crust, or on the gross acoustic layering shown by marine seismic refraction. A deep hole in the oceanic crust is thus needed to substantiate these assumptions and to ascertain whether the refracting horizons represent primary lithologic differences, changes in physical properties, or alteration/metamorphic fronts. Deep crustal penetration can also provide information on the short-term persistence of the geochemical characteristics of basalt magma at a given site of extrusion. Similarly, a knowledge of deep basement stratigraphy might shed

TABLE 1
DSDP Holes Penetrating More Than 20 Meters of Basalt

Leg	Hole	Penetration (m)	Estimated Age (m.y.)
24	235	29	60
24	236	22	60
24	238	80	30
26	254	46	15
26	257	64	110
27	259	38	110
27	261	48	140
30	286	57	45
31	292	76	40
33	317	34	120
34	319	59	15
37	332A	333	3.5
37	332B	583	3.5
37	333A	300	3.5
37	334	100	10
37	335	100	20
38	336	31	60
45	395	90	7
45	395A	580	7
45	396	96	10
46	396B	256	10
49	407	–	–
49	408	–	–
49	409	240	2.3
49	410	47	10
49	410A	52	10
49	411	45	1
49	412A	131	1.6
49	413	39.5	3.5

light on eruptive mechanisms and on the balance between intrusive and extrusive igneous activity in the formation of new oceanic lithosphere.

The main objective of Legs 51 through 53 was to drill a deep hole using multiple re-entry in old Atlantic crust where it was hoped that drilling conditions would permit deeper penetration than had been achieved to date in young crust. As in earlier attempts, the primary scientific objective was to reconstruct the history and evolution of the crust from the structure and stratigraphy, composition, magnetic behavior, and physical properties of a thick section through the crust. By drilling in old crust and comparing the results with those obtained in young crusts at sites drilled on Legs 37, 45, 46, and 49, it was anticipated that vein mineralogy and changes in composition might elucidate the nature of aging processes in the crust — whether by progressive low-grade metamorphism or by episode alteration. Additionally, the chemical composition, including minor elements, might be compared to look for mantle heterogeneity and long-period geochemical variations associated with the Mid-Atlantic Ridge.

A secondary objective of the legs was to investigate the thick Cretaceous through Tertiary sediment section in the western Atlantic. Earlier sites in the area (e.g., Sites 101, 105, 186, and 182) found dominantly sublysocline clay-rich sections in the Tertiary and Upper Cretaceous, grading downward to more carbonate-rich Middle and Lower Cretaceous strata. Features of special interest at these earlier sites included sedimentary hiatuses in the Paleogene and Upper Cretaceous, mineralogically interesting Paleogene and Upper Cretaceous clays with abundant zeolites and local metalliferous mineralization, and a variably organic "euxinic" Middle Cretaceous section. Since the Neogene section at these sites had only been spot-cored, however, a complete section was needed to examine the transition from siliceous Pacific-type sedimentation to non-siliceous, younger sedimentation which resulted from the gradual emergence of the Central American isthmus.

A final objective of Legs 51 through 53 was to date the *M*0 anomaly in order to determine the end of the Cretaceous normal interval, to provide a datum for the absolute time scale, and to test the validity of the proposed surge in spreading rates during the late Mesozoic (Larson and Hilde, 1975). It was also of interest in this connection to study basalts of this age to try to determine why the amplitudes of some Cretaceous anomalies are so large. Would basalts erupted into stagnant, organic muds during the Aptian, for example, have anomalously reduced alteration minerals?

Site Location

The deep crustal site originally selected to meet these objectives was located between 30° to 30°30′N, and 66° to 66°30′W, at a depth of 4900 to 5000 meters, about 220 nautical miles south-southwest of Bermuda, near the multichannel seismic reflection and magnetic line run by the Digicon Company for IPOD. The site was located on the Mesozoic magnetic anomaly *M*0, which has an inferred approximate age of 109 m.y. according to the Cretaceous magnetic time scale of Larson and Hilde (1975). Another site located close to the Digicon line southwest of Bermuda on the Mesozoic magnetic lineation *M*17 (137.5 m.y.) had also been considered, but was rejected after the Paleoenvironment Panel pointed out the value of examining oceanic crust emplaced during the deposition of the Albian through Aptian black clays or shales encountered during Legs 11, 14, 40, 41, and 47.

At a late stage it was decided to move the site at least 5° to the south because of unfavorable weather predictions for the original area. A survey was run two months prior to the departure of Leg 51 with the NAVOCEANO vessel *Lynch*. The data were made available in record time by Hartley Hoskins at Woods Hole, with additional data provided by the Site Survey Management at Lamont-Doherty Geological Observatory.

The site finally chosen was the more southerly of two surveyed by *Lynch* around 25°N, 68°W at a depth of about 5500 meters (Figure 1). The *Lynch* seismic reflection records suggested that the area was covered with 400 to 900 meters of sediment with a fair degree of basement relief. The site lies on *M*0, the youngest of the *M* (or Keathley) sequence of anomalies which are also the

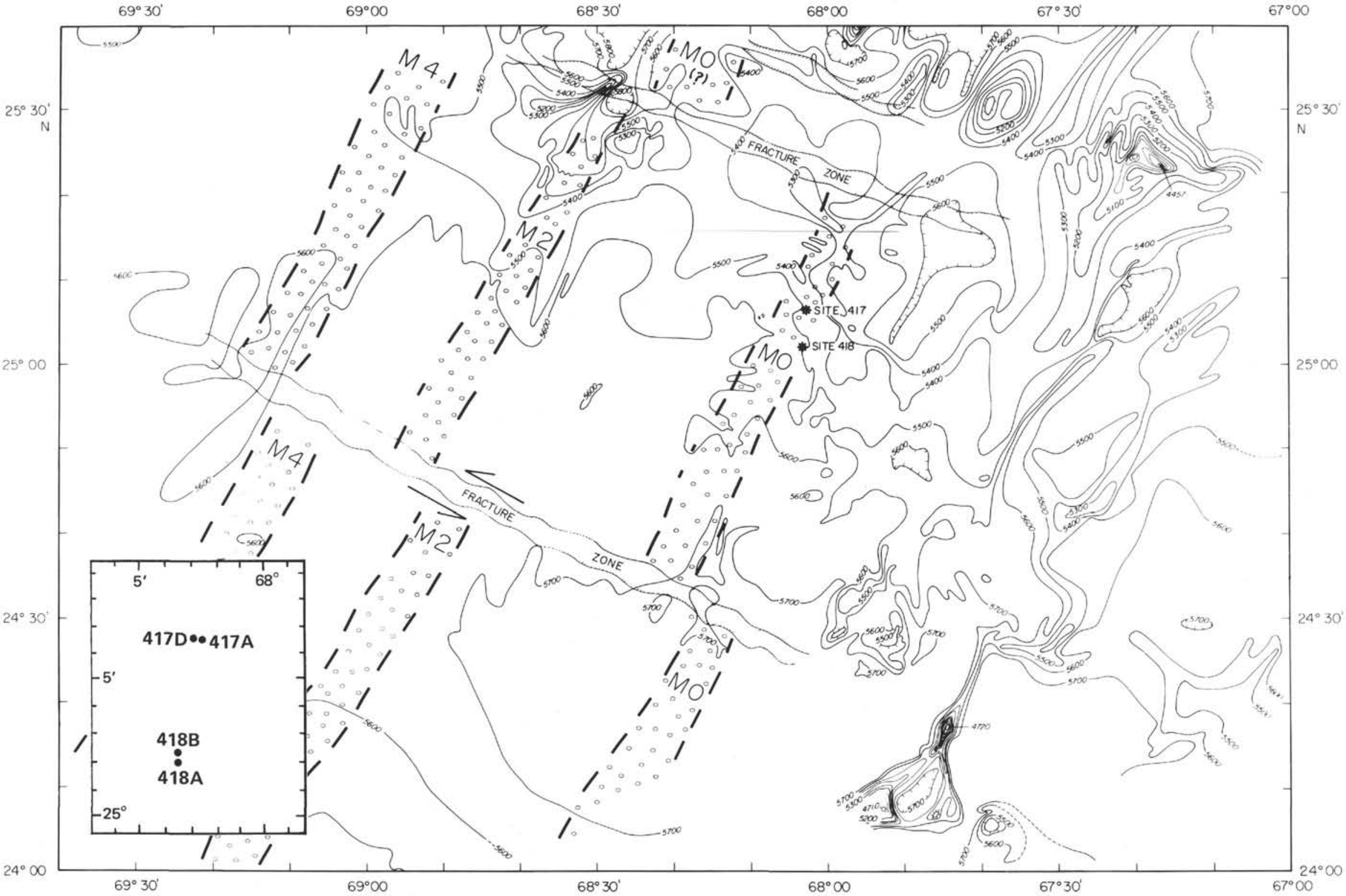

Figure 1. *Bathymetric map of the sites drilled on Legs 51 through 53 (Rabinowitz et al., this volume). Soundings are corrected for velocity of sound in sea water. Contour interval 100 meters. The magnetic blocks responsible for anomalies* M0 *(negative polarity),* M2, *and* M4 *(positive polarity) are shown. The fracture zone locations are drawn on the basis of the magnetic anomalies.*

largest Mesozoic anomalies (Bermuda Discontinuity of Vogt et al., 1971a), possibly owing to a more magnetized source, or to a greater thickness of basalt over an area 50 km wide as suggested by Vogt et al. (1971b). The *M*0/*M*1 anomalies continue with a slight dextral offset north of the New England seamounts into the *J* anomaly which shows great amplitude, as recognized early by Heezen et al. (1959), and is associated with a large ridge with a westward facing scarp more than 500 to 1000 meters high. Attempts at drilling into the *J* Anomaly Ridge during Leg 43 at Site 383, where the ridge is buried under the Sohm Abyssal Plain, were not successful but a reefal assemblage at Site 384 on the nearby Two-Bit Ridge revealed that more than 4000 meters of subsidence has taken place within the last 105 m.y. The proximity of the site to the Newfoundland Ridge and Newfoundland fracture zone may be partly responsible for this large vertical motion. It is interesting to note that the island of Bermuda is just to the east of anomaly *M*0 (Schouten and Klitgord, 1977) and that in the original site area two ridges, one with a maximum relief of 1.2 km, lie near *M*0. Thus at the time of emplacement of *M*0 crust or at a later time, which may be contemporaneous with the uplift of the Bermuda Rise itself, there were large topographic anomalies.

Site 417 lies between the (Great) Abaco fracture zone to the south and the Blake fracture zone to the north on the southernmost portion of the Bermuda Rise immediately to the north of Vema Gap (Vogt and Johnson, 1971). The Bermuda Rise is a broad topographic high with a relief of about 1.3 km, approximately elliptical in shape, 2000 by 1000 km in extent. On this broad gentle arch, horizon *A* (the mid-Eocene reflector) rises nearly a kilometer above the depth at which it is found under the young turbidites of the three adjacent abyssal plains which border the Bermuda Rise (Sohm to the north and northeast, Hatteras to the west, and Nares to the south and southeast). Whereas the northwest half of the Rise has a considerable cover of sediment, the southeast half is devoid of continuous sediment cover. On the eastern part of the Bermuda Rise are a number of scarps descending to the more normal basin (Heezen et al., 1959). Contrary to the view of Ewing et al. (1969), it is not clear that the abyssal plains once extended over what is now the rise, because no obvious turbidites have been found in DSDP cores.

The Bermuda Rise is difficult to understand within the framework of plate tectonics, as are other mid-plate rises like Shatsky, Manihiki, and Hess. The elevation of the Bermuda Rise is probably fairly youthful and may be contemporaneous with the Oligocene volcanism of Bermuda (Reynolds and Aumento, 1974). The Rise is roughly divided in half on the basis of magnetic patterns. The western half is associated with the Keathley or *M* sequence of linear anomalies, while the eastern half belongs to the Cretaceous Quiet Zone. Schouten and Klitgord (1977) have convincingly demonstrated that at least the crust underlying the western half of the Bermuda Rise has been produced in an accretion zone.

The morphologic map of the southern part of the Bermuda Rise from Vogt and Johnson (1971) places the site in broader perspective (Figure 2). The southern fracture zone of Figure 1 lies in the northern part of the Vema Gap, the abyssal passage connecting the Hatteras abyssal plain and the Nares abyssal plain and is defined approximately by the 3000-fathom contour near 24°N 68°W in Figure 2. The fracture zone immediately to the north of Site 417 is marked by the 2900-meter contour trending west-northwest-east-southeast in Figure 2. The Abaco fracture zone cuts the northern limit of the Antilles Outer Ridge in the lower left-hand corner of the map (Figure 2), and the Blake fracture zone is the zone of rough fabric going through 27°N 66°W. Thus, the large fracture zones are spaced about 450 km apart, but the average width of crustal strips unaffected by fracture zone tectonics is about 100 km. The sites of Legs 51 through 53 were located within such a strip in an area of well-defined magnetic lineations in an attempt to drill as "typical" a section of ocean crust as possible. A long seismic reflection profile (Figure 3; R/V *Conrad,* 1903) going approximately through Site 417 and a point at 24°N 67°W shows the setting of Site 417 and the basement roughness in the drilled area .

The results of linear inversion of the magnetic anomaly profile recorded during the *Lynch* survey at the latitude of Site 417 are shown in Figure 4 (H. Schouton, personal communication). It is clear from the inversion that the magnetic anomaly *M*0 of reversed polarity is displaced to the east of the crust with negative magnetization by about 7 km. The inversion results suggested that the best strategy for drilling in the reversely magnetized source block for *M*0 was to locate the ship in the portion of the magnetic anomaly profile with a steep gradient lying to the west of the magnetic minimum. The magnetic anomaly, or rather the total intensity of the magnetic field, was plotted during the initial approach to the site along north-northeast-south-southwest corridor formed by *Lynch* lines E and F. We noted that, although *Glomar Challenger* was constantly over the *M*0 source block, slight course alterations would make us go rapidly "uphill" or "downhill" on the steep slope of the magnetic field to the west of the magnetic minimum. In order to ascertain the exact position of the beacon on the steep gradient, we had to establish a magnetic profile normal to the magnetic lineation (Figure 4). This careful exercise was useful because it enabled us to locate Site 417 close to the center of the narrow *M*0 block with reversed polarity.

Unpublished sonobuoy refraction data from Lamont-Doherty Geological Observatory in the immediate vicinity of Site 417 show a velocity of about 6.0 km/s at a depth of about 0.25 s below acoustic basement (P. D. Rabinowitz and R. L. Larson, personal communication, 1976). Such a velocity is appropriate to Layer 2C

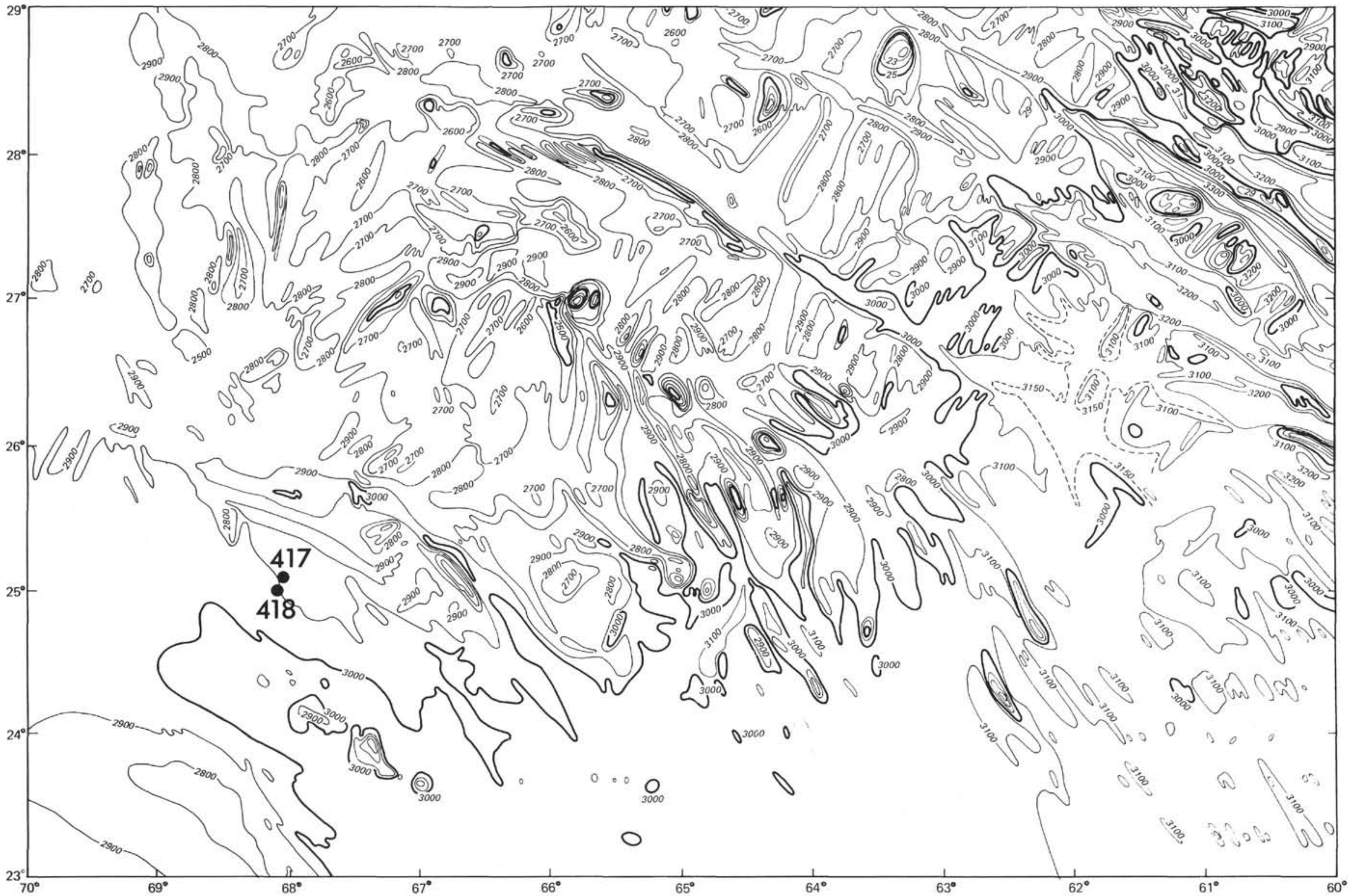

Figure 2. *Bathymetric map of the southern part of the Bermuda Rise (Vogt and Johnson, 1971). Depths are in units of 1/400-s travel time (nominal fathoms). Fracture zones are delineated by linear deeps striking N 60°W. Sites 417 and 418 are shown about 80 km north of the axis of Vema Gap.*

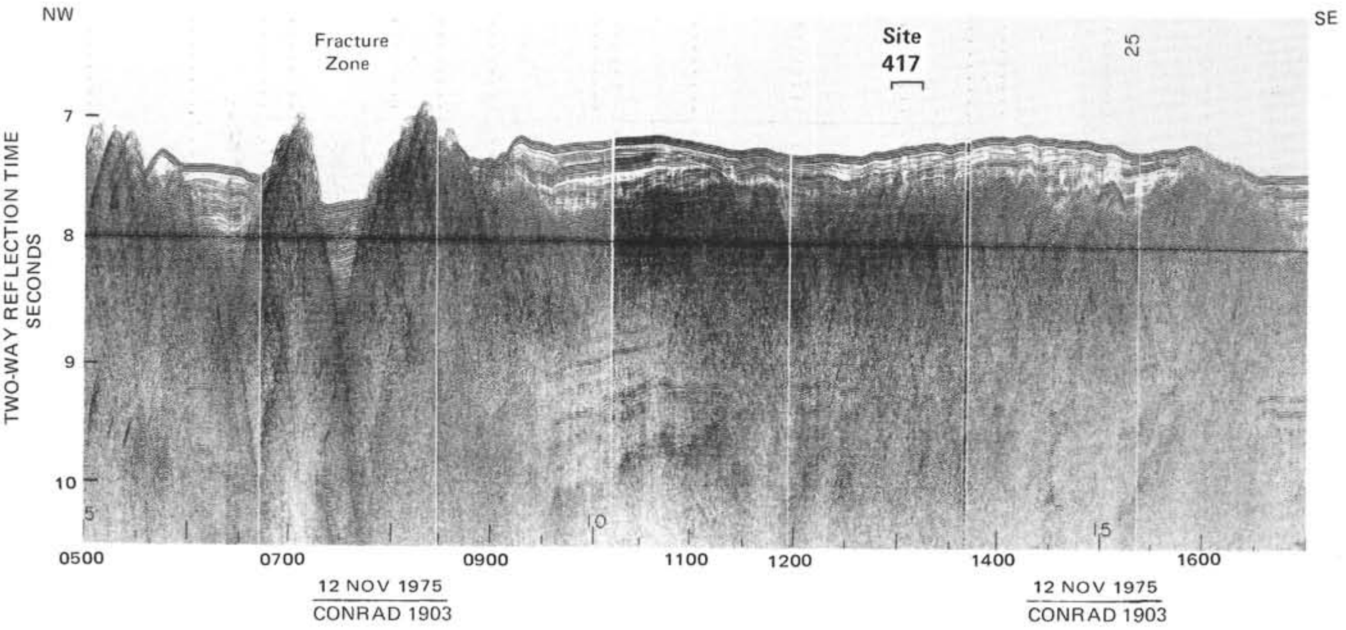

Figure 3. *Seismic reflection profiler record collected aboard R/V* Robert D. Conrad *cruise 1903 (Rabinowitz et al., this volume). Airgun sound source. Vertical scale in seconds of two-way reflection time. Horizontal scale is given in time along ship's track. One hour represents about 10 km. Course is approximately 150°, thus profile is oblique to both fracture zone and magnetic lineations.*

of Houtz and Ewing (1976). The velocity for the uppermost level of the basement was not determined prior to drilling.

OPERATIONS

Under Way to Holes 417 and 417A

The *Glomar Challenger* left San Juan, Puerto Rico, at 1740 hours (2140Z) on 30 November, 1976, after two days of delays due to malfunction of the dynamic positioning system. Underway data acquisition was commenced at 1814 hours.

The course set upon leaving San Juan was 339°, and the speed was about 9.5 knots. The first trench abyssal plain was crossed at 2015 hours at a depth of 7082 meters, and the axis of maximum depth of the Puerto Rico Trench was crossed at 0240 hours on 1 December at a depth of 8157 meters. The *Challenger* traversed the Antilles Outer Ridge and followed the southern boundary of the Vema Gap near the westernmost confines of the Nares abyssal plain. At 1050 hours, the course was changed to 032° to enable a long seismic reflection profile to be made along the strike of magnetic anomaly *M*0. The ship traversed the Vema Gap almost normal to its axis and slowed down at 1245 hours to about 8 knots (170/170 rpm) in order to improve the quality of the seismic reflection records. The base information for Site 417 was the *Lynch* survey, conducted in September 1976 by Hartley Hoskins, and additional information from surveys conducted by Lamont-Doherty Geological Observatory provided by Phil Rabinowitz. Prior to departure, Hans Schouten had provided the results of his inversion of the magnetic profiles on *Lynch* lines A, D, and E (Figure 4). This enabled us to locate the site over the crustal block responsible for anomaly *M*0 — the prime target of drilling. The long line to the northeast, which was started at 1050, was originally intended to be run at constant speed and heading between *Lynch* lines E and F. A strong set of 220° to 230° at 1.2 knots was responsible for the frequent course changes during the approach to the site (Figure 5).

An SSQ41A sonobuoy was dropped in the water at 1400, but the run was unsuccessful because the sonobuoy proved unreliable. The original intent was to conduct a seismic survey with the Bolt 300-in.^{3} air gun, since the *Lynch* seismic records had not been considered adequate by the JOIDES Site Survey Panel. The large air gun could not be operated above 800 psi at a 10-s repetition rate with the two RIX compressors on the *Glomar Challenger*. Since the 120-in.^{3} configuration did not improve on the quality of the *Lynch* record, it was decided not to survey extensively. Careful monitoring of the magnetic data enabled us to be certain that the drill site would be in *M*0 crust. The long line was run in the corridor formed by *Lynch* lines E and F until we arrived in the immediate vicinity of the *Conrad* 1903 line which showed somewhat clearer basement (Figure 3). The 13.5-kHz acoustic beacon was dropped at 1810 about 10 nautical miles to the south of the northern fracture zone in the *Lynch* survey area (Figure 6) over a reasonably thick sedimentary sequence consisting of two transparent units separated by a strong reflector. The northwest line then was continued until 1830, when the course was changed to 227°. It was changed again at 1932 to 115° in order to have a second magnetic and aseismic line across the beacon site. This line was needed to confirm the

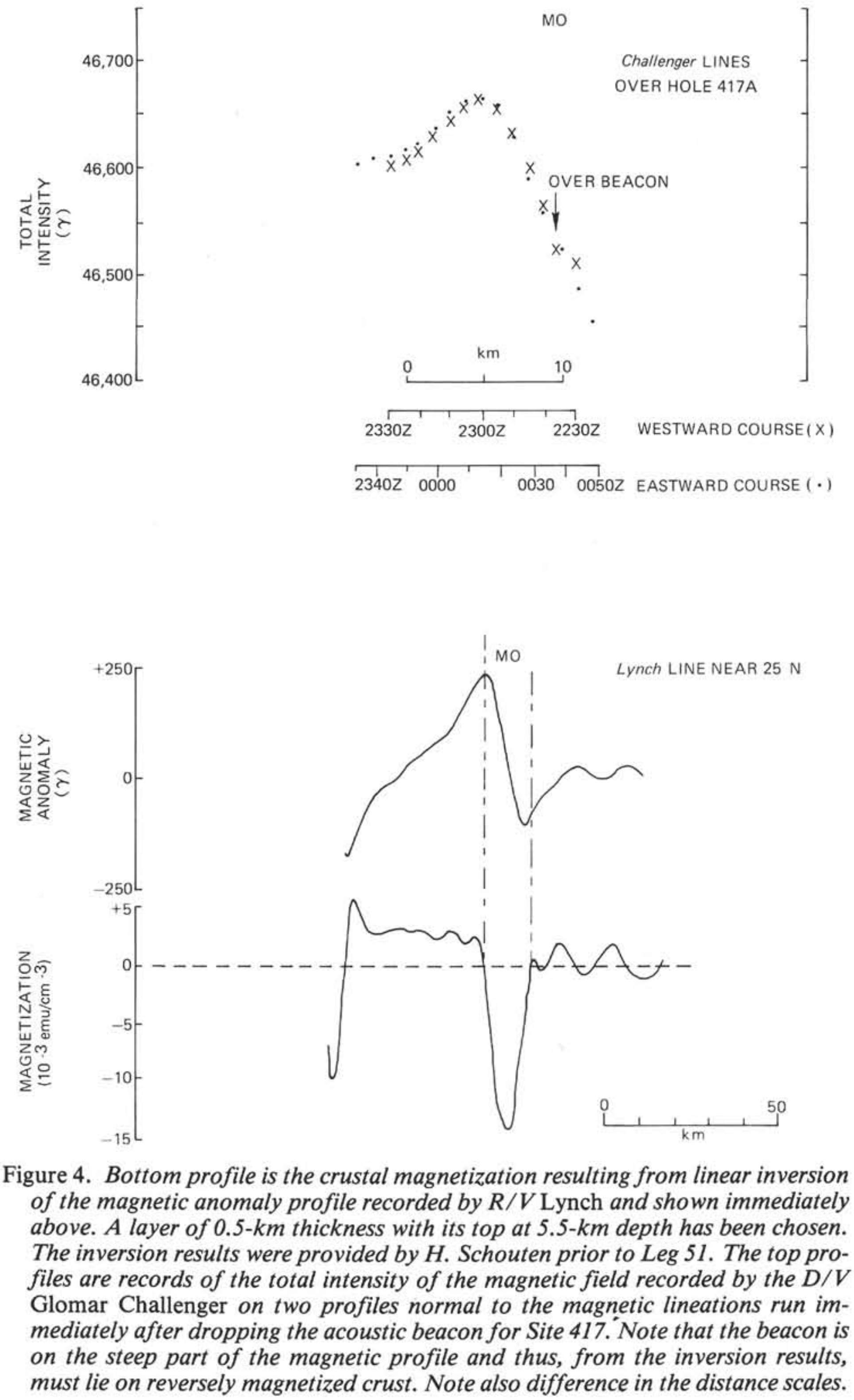

Figure 4. *Bottom profile is the crustal magnetization resulting from linear inversion of the magnetic anomaly profile recorded by R/V* Lynch *and shown immediately above. A layer of 0.5-km thickness with its top at 5.5-km depth has been chosen. The inversion results were provided by H. Schouten prior to Leg 51. The top profiles are records of the total intensity of the magnetic field recorded by the D/V* Glomar Challenger *on two profiles normal to the magnetic lineations run immediately after dropping the acoustic beacon for Site 417. Note that the beacon is on the steep part of the magnetic profile and thus, from the inversion results, must lie on reversely magnetized crust. Note also difference in the distance scales.*

location of the site over the steep western line of the negative anomaly. The latter was predicted by magnetic models to lie over a crustal block striking about 25° and formed at a low paleolatitude during the Cretaceous. Even the sediments appeared to thin and an enigmatic reflector in the shape of a basement high was seen right under the beacon (Figure 7) as it was passed again at 2038. We decided to drill a pilot hole here, because the site was clearly on anomaly *M*0 and well away from fracture zones. The line to the east-southeast was continued until 2050 (0050Z), when the underway geophysical equipment was retrieved. The *Challenger* then

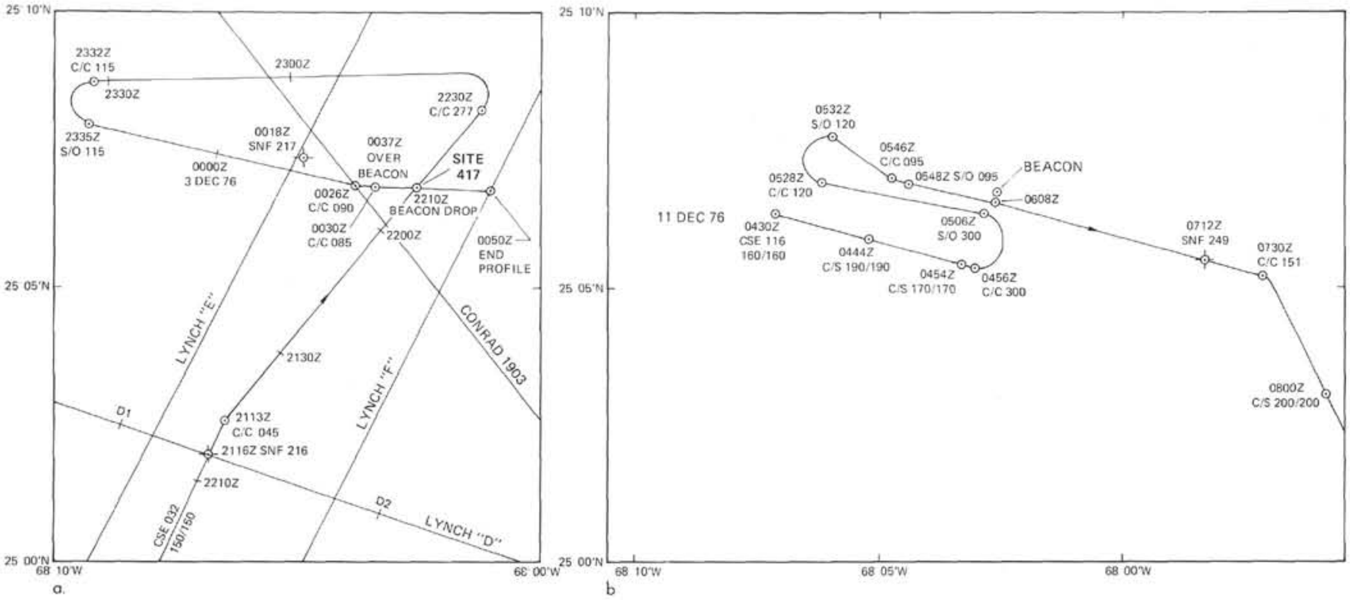

Figure 5. *Approach* (a) *and departure* (b), *Site 417, Leg 51, by the* Glomar Challenger.

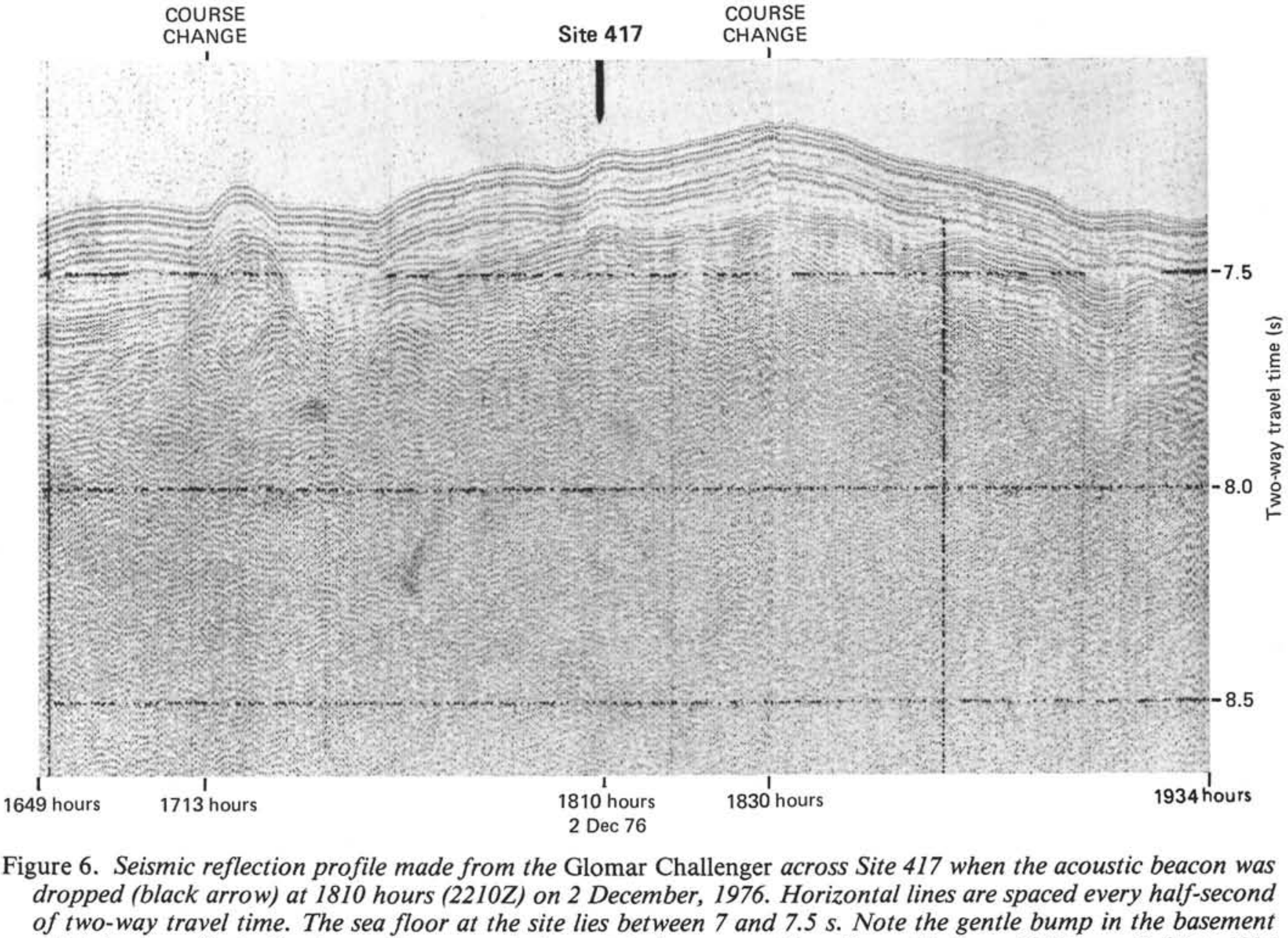

Figure 6. *Seismic reflection profile made from the* Glomar Challenger *across Site 417 when the acoustic beacon was dropped (black arrow) at 1810 hours (2210Z) on 2 December, 1976. Horizontal lines are spaced every half-second of two-way travel time. The sea floor at the site lies between 7 and 7.5 s. Note the gentle bump in the basement which is also reflected in the sea-floor morphology at the beacon position. Record is from 1649 hours* (left) *to 1934 hours* (right). *The reversal of the mean slope of the sea floor corresponds to a change of course at 1830 hours (2230Z) (see Figure 5 for location).*

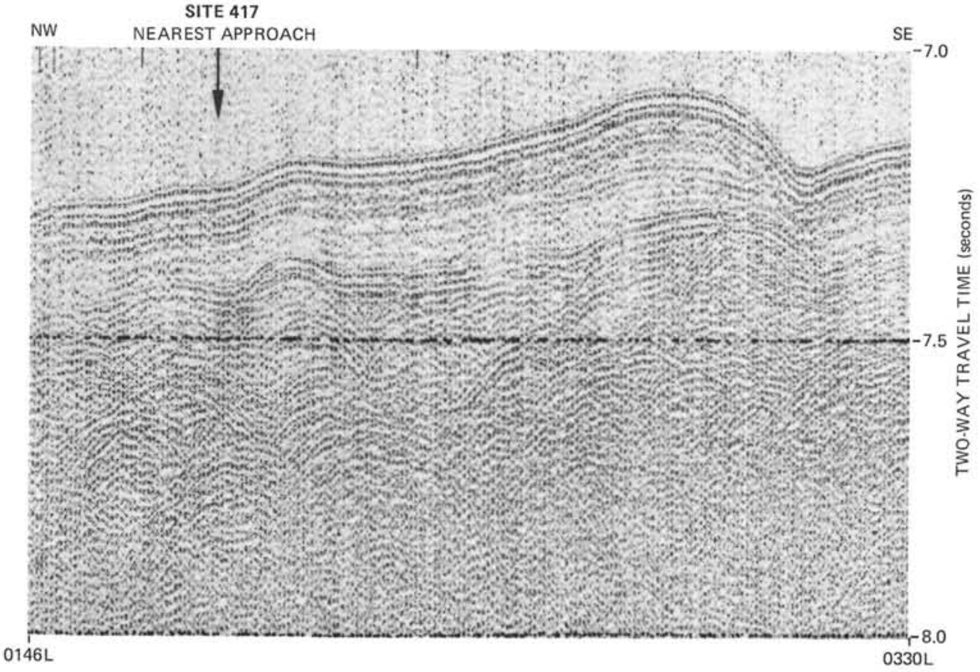

Figure 7. *Seismic reflection profile made from the* Glomar Challenger *just to the south of Site 417 when leaving the area on a line normal to the magnetic lineations. The seismic profile record shown runs from 0146 hours (0527Z) to about 0330 hours on 11 December, 1976 on an approximate heading of 095° (see Figure 5 for location). The arrow marks the location where the ship was 1000 feet south of the Site 417 beacon. Horizontal lines are spaced every half-second of two-way travel time. The sea floor lies between 7 and 7.5 s.*

homed on the beacon to prepare for drilling operations at Site 417.

At Holes 417 and 417A

At 2225 we were ready to magnaflux the drill collars and run in the hole. At 2350, the bottom-hole assembly was made up and we prepared to run pipe. The two-way travel time to the sea floor at Site 417 as read on the 12-kHz record while hovering over the beacon was 7.2 s (uncorrected). The corrected depth below the rig floor was estimated to be 5478 meters.

The first and only core at Hole 417 was on deck at 1613 with 3.6 meters of recovery, but with an indication that 8.5 meters of sediment had been cored (Table 2). The mudline was established officially at 5478.2 meters below the rig floor, in close agreement with the PDR estimate.

At 1730 we started jetting the pipe with no rotation and only mild circulation in order to determine casing depth. Firm sediment was felt at 5581 meters below the rig floor. At 1800, the string was pulled out of the hole and a request was made that Hole 417A be offset at least 500 feet from the site of washing a jetting in order to preserve the upper part of the sediments at Hole 417A.

Hole 417A was offset 500 feet to the south and 500 feet to the east of the beacon where Hole 417 had been drilled. This was accomplished at 2015, and the first core from Hole 417A was on deck at 2113. After the sixth core was retrieved, an attempt at measuring sediment temperature was made at a depth of 56 meters below sea floor using the downhole temperature instrument. Four additional sediment temperature measurements were made at 84.5, 113.0, 141.5 and 169.5 meters sub-bottom, but the measurements are not usable.

While cutting Core 47, at 0655 on 10 December, a fire was reported in the forward thruster room. Both drive shafts of the forward thruster were bent and out of their coupling box. The drill string had to be pulled out as fast as possible, while the *Glomar Challenger* was being held in manual mode over the hole in a Force 8 sea. The mudline was cleared at 0815, and by 1900 all of the drill pipe was on deck. During the recovery, the bit release must have been activated because both the drill bit and core barrel were lost. Since the ship could no longer maintain station, it was necessary to return to San Juan for repairs.

Under Way to San Juan

At 2347 another beacon (16 kHz) was dropped as close as possible to the first to ensure that return to the site would be possible. At 0030 on 11 December, we began steaming on a course of 116° to stream the magnetometer, air gun, and hydrophone array. At 0056 we turned to 300°, and at 0106 we passed 3000 feet abeam of the beacon which lay to our north. At 0146 we changed course to 095° in order to make a long profile over the beacon in an east-southeasterly direction and complete the profile started while approaching the site

TABLE 2
Coring Summary, Site 417

Core	Date	Time	Depth From Drill Floor (m)	Depth Below Sea Floor (m)	Length Cored (m)	Length Recovered (m)	Recovery (%)
				Leg 51			
Hole 417							
1	12/3/76	1613	5478.2-5486.7	0.00-8.5	8.5	3.61	42
Hole 417A							
1	12/3/76	2113	5478.2-5486.7	0.0-8.5	8.5	8.6	101
2	12/3/76	2320	5486.7-5496.2	8.5-18.0	9.5	5.1	54
3	12/4/76	0055	5496.1-5505.7	18.0-27.5	9.5	8.3	87
4	12/4/76	0225	5505.7-5515.2	27.5-37.0	9.5	0.0	0
5	12/4/76	0350	5515.2-5524.7	37.0-46.5	9.5	1.7	18
6	12/4/76	0530	5524.7-5534.2	46.5-56.0	9.5	8.2	86
7	12/4/76	0815	5534.2-5543.7	56.0-65.5	9.5	0.0	0
8	12/4/76	0945	5543.7-5553.2	65.5-75.0	9.5	6.8	72
9	12/4/76	1115	5553.2-5562.7	75.0-84.5	9.5	6.9	73
10	12/4/76	1416	5562.7-5572.2	84.5-94.0	9.5	5.3	56
11	12/4/76	1545	5572.2-5581.7	94.0-103.5	9.5	7.6	80
12	12/4/76	1714	5581.7-5591.2	103.5-113.0	9.5	5.9	62
13	12/4/76	2022	5591.2-5600.7	113.0-122.5	9.5	8.2	86
14	12/4/76	2158	5600.7-5610.2	122.5-132.0	9.5	5.9	62
15	12/4/76	0249	5610.2-5619.7	132.0-141.5	9.5	4.5	47
16	12/5/76	0730	5619.7-5629.2	141.5-151.0	9.5	9.2	97
17	12/5/76	0910	5629.1-5638.7	151.0-160.5	9.5	1.6	17
18	12/5/76	1238	5638.7-5648.2	160.5-170.0	9.5	6.1	64
19	12/5/76	1431	5648.2-5657.7	170.0-179.5	9.5	8.5	89
20	12/5/76	1802	5657.7-5667.7	179.5-189.0	9.5	7.1	75
21	12/6/76	0715	5667.2-5676.7	189.0-198.5	9.5	3.6	38
22	12/6/76	0920	5676.7-5686.2	198.5-208.0	9.5	1.3	14
23	12/6/76	1150	5686.2-5695.7	208.0-217.5	9.5	0.75	8
24	12/6/76	1535	5695.7-5705.2	217.5-227.0	9.5	5.71	60
25	12/6/76	1858	5705.2-5714.7	227.0-236.5	9.5	1.114	12
26	12/6/76	2202	5714.7-5724.2	236.5-246.0	9.5	6.15	65
27	12/7/76	0057	5724.2-5733.7	246.0-255.5	9.5	1.5	16
28	12/7/76	0445	5733.7-5743.2	255.5-265.0	9.5	6.34	67
29	12/7/76	0910	5743.2-5752.7	265.0-274.5	9.5	7.3	77
30	12/7/76	1244	5752.7-5762.5	274.5-284.0	9.5	6.31	66
31	12/7/76	1620	5762.2-5771.7	284.0-293.5	9.5	6.87	72
32	12/7/76	2002	5771.7-5781.2	293.5-303.0	9.5	5.9	62
33	12/8/76	0001	5781.2-5790.7	303.0-312.5	9.5	5.8	61
34	12/8/76	0328	5790.7-5800.2	312.5-322.0	9.5	6.8	72
35	12/8/76	0800	5800.2-5809.7	322.0-331.5	9.5	6.7	71
36	12/8/76	1142	5809.7-5819.2	331.5-341.0	9.5	7.17	75
37	12/8/76	1453	5819.2-5826.7	341.0-348.5	7.5	5.7	76
38	12/8/76	1908	5826.7-5835.56	348.5-357.36	8.86	8.86	100
39	12/8/76	2154	5835.56-5841.7	357.36-363.5	6.14	4.75	77
40	12/9/76	0053	5841.7-5847.7	363.5-369.5	6.0	5.04	84
41	12/9/76	0515	5847.7-5857.2	369.5-379.0	9.5	7.68	81
42	12/9/76	1015	5857.2-5866.7	379.0-388.5	9.5	8.5	89
43	12/9/76	1607	5866.7-5872.7	388.5-394.5	6.0	5.59	93
44	12/9/76	1940	5872.7-5876.95	394.5-398.75	4.25	4.25	100
45	12/10/76	0028	5876.95-5885.7	398.75-407.5	8.75	0.0	0
46	12/10/76	0506	5885.7-5895.2	407.5-417.0	9.5	3.4	36
Hole 417B							
1	12/26/76	1000	5489.0-5494.5	0.0-5.5	5.5	5.20	94.5

TABLE 2 – *Continued*

Core	Date	Time	Depth From Drill Floor (m)	Depth Below Sea Floor (m)	Length Cored (m)	Length Recovered (m)	Recovery (%)
Hole 417C							
	12/29/76	Hole was not cored					
Hole 417D							
1	12/31/76	1805	5489.0–5496.5	0.0–7.5	7.5	5.53	73.7
2	1/1/77	0120	5489.0–5614.4	0.0–125.4	Wash	(2.68)	–
3	1/1/77	0330	5614.4–5624.0	125.4–135.0	9.6	0.20	2.1
4	1/1/77	0555	5624.0–5633.5	135.0–144.5	9.5	0.00	0
5	1/1/77	0900	5633.5–5681.0	144.5–192.0	Wash	(0.89)	–
6	1/1/77	1045	5681.0–5690.5	192.0–201.5	9.5	0.00	0
7	1/1/77	1315	5690.5–5700.1	201.5–211.1	9.6	3.20	33.3
8	1/1/77	1535	5700.1–5709.5	211.1–220.5	9.4	0.90	9.5
9	1/1/77	1745	5709.5–5718.9	220.5–229.9	9.4	2.70	28.7
10	1/1/77	2040	5718.9–5728.2	229.9–239.2	9.3	4.60	49.5
11	1/1/77	2325	5728.2–5736.6	239.2–247.6	8.4	0.40	4.8
		Washed one meter					
12	1/2/77	0130	5737.6–5747.2	248.6–258.2	9.6	6.26	65.2
13	1/2/77	0350	5747.2–5756.7	258.2–267.7	9.5	2.03	21.4
14	1/2/77	0600	5756.7–5766.3	267.7–277.3	9.6	7.77	80.9
15	1/2/77	0830	5766.3–5775.8	277.3–286.8	9.5	2.33	24.5
16	1/2/77	1030	5775.8–5785.3	286.8–296.3	9.5	1.20	12.6
17	1/2/77	1245	5785.3–5794.9	296.3–305.9	9.6	6.36	66.3
18	1/2/77	1514	5794.9–5804.4	305.9–315.4	9.5	3.10	32.6
19	1/2/77	1750	5804.4–5814.0	315.4–325.0	9.6	3.00	31.3
20	1/2/77	2030	5814.0–5823.5	325.0–334.5	9.5	3.06	32.2
21	1/2/77	2320	5823.5–5833.0	334.5–344.0	9.5	5.14	54.1
22	1/3/77	0545	5833.0–5842.5	344.0–353.5	9.5	6.60	69.5
23	1/3/77	1105	5842.5–5846.1	353.5–357.1	3.6	0.23	5.6
24	1/3/77	1315	5846.1–5246.3	357.1–357.3	0.2	0.16	100
25	1/3/77	1730	5846.3–5846.5	357.3–357.5	0.2	0.20	100
	1/4/77	Pulled out of hole and made first re-entry					
26	1/5/77	0720	5846.5–5855.6	357.5–366.6	9.1	7.27	79.9
27	1/5/77	1145	5855.6–5864.7	366.6–375.7	9.1	7.38	81.1
28	1/5/77	1715	5864.7–5873.8	375.7–384.8	9.1	8.40	92.3
29	1/5/77	2205	5873.8–5882.9	384.8–393.9	9.1	7.95	87.4
30	1/6/77	0700	5882.9–5892.0	393.9–403.0	9.1	8.75	96.2
31	1/6/77	1135	5892.0–5901.1	403.0–412.1	9.1	6.15	67.6
32	1/6/77	1625	5901.1–5910.1	412.1–421.1	9.0	7.90	87.8
33	1/6/77	2045	5910.1–5918.5	421.1–429.5	8.4	6.85	81.5
34	1/7/77	0415	5918.5–5926.8	429.5–437.8	8.3	8.34	100
35	1/7/77	0920	5926.8–5934.5	437.8–445.5	7.7	7.70	100
36	1/7/77	1725	5934.5–5940.0	445.5–451.0	5.5	5.52	100
37	1/7/77	2250	5940.0–5947.3	451.0–458.3	7.3	7.32	100
38	1/8/77	0335	5947.3–5953.7	458.3–464.7	6.4	6.36	100
39	1/8/77	1900	5953.7–5960.0	464.7–471.0	6.3	6.33	100
	1/8/77	Pulled out of hole					
	1/9/77	Made second re-entry and performed downhole measurements					
	1/12/77	Made third re-entry					
40	1/13/77	0355	5960.0–5964.6	471.0–475.6	4.6	3.33	72.4
41	1/13/77	0920	5964.6–5973.7	475.6–484.7	9.1	9.10	100
42	1/13/77	1425	5973.7–5982.8	484.7–493.8	9.1	7.49	82.3
43	1/13/77	2015	5982.8–5991.9	493.8–502.9	9.1	8.50	93.4
44	1/14/77	0050	5991.9–6001.0	502.9–512.0	9.1	5.30	58.2
45	1/14/77	0600	6001.0–6010.1	512.0–521.1	9.1	2.51	27.6
46	1/14/77	1140	6010.1–6019.2	521.1–530.2	9.1	0.00	0
47	1/14/77	1445	6019.2–6021.5	530.2–532.5	2.3	0.00	0

TABLE 2 – *Continued*

Core	Date	Time	Depth From Drill Floor (m)	Depth Below Sea Floor (m)	Length Cored (m)	Length Recovered (m)	Recovery (%)
				Leg 52			
Hole 417D							
48	1/25/77	1627	6021.5-6028.0	532.5-539.0	6.5	3.28	50.5
49	1/25/77	2037	6028.0-6034.0	539.0-545.0	6.0	3.45	57.5
50	1/27/77	2341	6034.0-6037.5	545.0-548.5	3.5	2.29	65.6
51	1/28/77	0551	6037.5-6047.0	548.5-588.0	9.5	0.12	1.3
52	1/28/77	1140	6047.0-6056.5	558.0-567.5	9.5	9.01	94.8
53	1/28/77	1624	6056.5-6066.0	567.5-577.0	9.5	2.50	26.3
54	1/28/77	2148	6066.0-6075.5	577.0-586.5	9.5	8.07	84.9
55	1/29/77	0323	6075.5-6085.0	586.5-596.0	9.5	5.59	58.8
56	1/29/77	0818	6085.0-6094.5	596.0-605.5	9.5	0.43	5.0
57	1/29/77	1411	6094.5-6104.0	605.5-615.0	9.5	5.0	52.6
58	1/29/77	1935	6104.0-6113.0	615.0-624.0	9.0	5.23	58.1
59	1/30/77	0102	6113.0-6122.0	624.0-633.0	9.0	7.91	87.9
60	1/30/77	0740	6122.0-6128.0	633.0-639.0	6.0	7.18	120
61	1/31/77	1632	6128.0-6131.0	639.0-642.0	3.0	0.85	28.3
62	1/31/77	2128	6131.0-6140.0	642.0-651.0	9.0	9.0	100
63	2/1/77	0148	6140.0-6149.0	651.0-660.0	9.0	7.6	84.4
64	2/1/77	0600	6149.0-6158.0	660.0-669.0	9.0	7.61	84.5
65	2/1/77	0920	6158.0-6167.0	669.0-678.0	9.0	7.24	80.4
66	2/1/77	1338	6167.0-6176.0	678.0-687.0	9.0	7.10	79.0
67	2/1/77	1808	6176.0-6185.0	687.0-696.0	9.0	8.48	95.2
68	2/2/77	0200	6185.0-6194.0	696.0-705.0	9.0	7.70	85.6
69	2/2/77	1622	6194.0-6197.5	705.0-708.5	3.5	1.77	50.6

on 2 December (Figure 5). At 0208 we passed 1000 feet to the south of the beacon and continued this line until 0332 at approximately 8 knots (170/170 rpm). We changed course to 151° at 9.5 knots (200/200 rpm) and continued to the southeast in order to examine the transition between the Bermuda Rise and the Vema Gap. The line was run obliquely across the Vema Gap and the Nares abyssal plain. A long profile was started at 123°N at right angle to the strike of the Puerto Rico Trench crossing the Antilles Outer Ridge. The *Glomar Challenger* arrived in San Juan, Puerto Rico at 0724 on 13 December for a scheduled crew change and unscheduled repairs.

Under Way to Holes 417B, 417C, and 417D

The *Glomar Challenger* left San Juan harbor on the morning of 22 December and spent the day testing its repaired bow thrusters at the beacon dropped on 28 November, about five miles north of San Juan. Upon completion of these tests, the ship proceeded directly to the vicinity of Hole 417A, surveying along the route with the magnetometer and a tandem arrangement of the 20- and 80-in.^{3} air guns.

At 2217 on 24 December (arrow on Figure 8), the ship passed over the 16-kHz beacon dropped near Hole 417A just after midnight on 11 December when leaving the site. In an effort to improve knowledge of the basement topography, we surveyed the areas of the basement high drilled at Hole 417A. A strong current produced set and drift of about 210° and two knots, respectively. Long intervals without reliable satellite fixes and a forced maneuver due to an approaching vessel caused considerable delay to the planned Christmas Eve survey. At 0500 on 25 December, the air gun and magnetometer gear were brought on board and the ship was positioned over the beacon at 0630. A quick check determined that the 16-kHz beacon was approximately 530 feet to the west-southwest of the 13.5-kHz beacon used for Hole 417A.

At Holes 417B, 417C, and 417D

A mudline determination was made at Hole 417B, 100 feet west of the 16-kHz beacon. At 5485 meters below the rig floor, the core barrel came back empty. A 5.3-meter core was brought up from 5494.5 meters below the rig floor, establishing the mudline depth at 5489 meters below the rig floor, six meters deeper than the depth derived from the EDO and PDR.

The operational prospectus for the deep re-entry hole included a prior casing test. The washing test at Hole 417A suggested that as much as 100 meters of casing could be washed in, but the test at Hole 417B showed that only 25 meters of casing would penetrate the sediment without rotation. The drill string and casing were then recovered at 0645 on 27 December and, after a 15-hour wait for the weather to improve, the cone for Hole 417C was assembled.

No offset was applied from the 16-kHz beacon for this Hole 417C. At 1000 on 28 December the re-entry cone was keelhauled, hung below the moon pool, and 25 meters of 16-in. casing was run in and fastened with a latch. The bottom-hole assembly with an F94 bit was run in and latched, and the cone was released at 1430. While running in the drill string that evening, Paul Lines, a derrickman, was severely injured when he fell

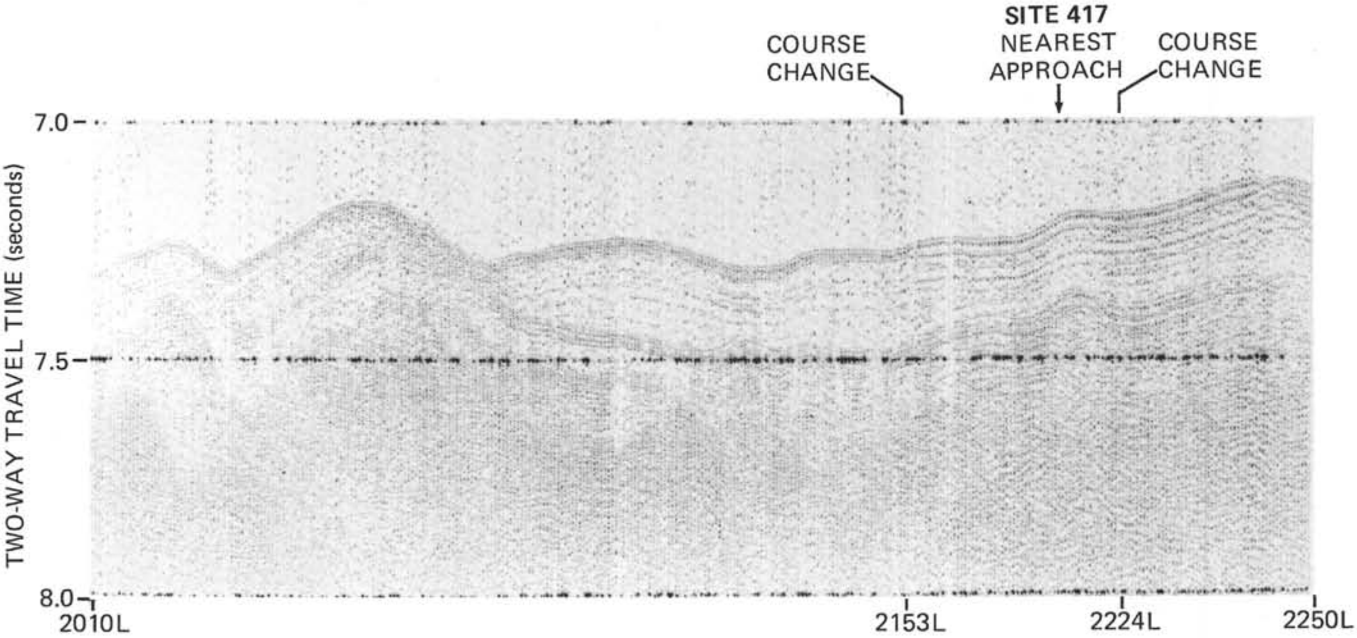

Figure 8. *Seismic reflection profile made from the* Glomar Challenger *on approach to Site 417 when returning from Puerto Rico. The record runs from 2010 hours on 24 December, 1976* (left) *to 2250 hours* (right). *Horizontal lines are spaced every half-second of two-way travel time. The sea floor depth lies between 7 and 7.5 s. The arrow marks the position of the ship when the acoustic beacon of Site 417 laid 600 feet abeam on port side. The heading from 2010 hours to 2153 hours (first c/c) is 348° and then 072° to 2224 hours (second c/c), where it changes to 060° until the end of the record. The 072° profile south of the beacon shows that the hill (Site 417) has also acquired relief on this traverse.*

from the pipe racker to the main deck. A decision was made to set the cone as quickly as possible, and then trip the drill string to the surface in order to return him to San Juan. A Coast Guard rescue helicopter arrived at the ship, and took him immediately to Grand Turk Island.

Shortly after this incident, a shifting tool was run in to release the cone, but the tool was unable to get past the bumper sub. We suspected that the cone had broken away from the rest of the drill string at the bumper sub during the protracted maneuver of trying to wash in the casing. Therefore, we pulled two stands of drill string, verified that the cone was no longer attached, and retrieved the drill string and severed bottom-hole assembly.

Having lost a cone, casing, coring assembly, and other hardware, we then made preparations to set a second cone. Because the more recent (and considerably louder) 16-kHz beacon was located to the west of the original beacon, we decided to move 1000 feet west of this second beacon. We thus minimized the effect of the first (13.5-kHz) beacon should we have to drop a third (13.5-kHz) beacon in the event the second (16-kHz) beacon ceased to function prematurely.

At 2130 on 30 December, we offset 1000 feet west of the beacon, rigged and keelhauled a new cone with 22 meters of casing, and began to make up the bottom-hole assembly. Hole 417D was spudded at 1645 on 31 December, and the cone was washed in and released at 2100. A mudline core verified a rig floor water depth of 5489 meters corresponding to a sea-level water depth of 5479 meters. The PDR depth was 5492 meters corrected to the rig floor, or a water depth of 5482 meters.

After taking the mudline core we drilled, according to plan, to 125.4 meters sub-bottom using a core barrel instead of a center bit. Before cutting the next core, we retrieved the core barrel and labeled its contents "Core 2." Core 3 then recovered a trace of clay, and Core 4 a core barrel full of water. The next drilled interval — 145.5 to 192 meters — was labeled Core 5.

Beginning with Core 6, the hole was cored continuously and uneventfully. After Core 11, a deviation survey run with the Eastman tool showed a hole deviation of 0.5° from the vertical.

We recorded a vertical incidence reflection record from 1441 to 1607 on 1 January, using an SSQ23 sonobuoy tethered 1100 feet from the ship and a 20-in.^{3} air gun hanging from a large rubber float. From these data, the basement was estimated to lie about 310 to 400 meters below the mudline. The basalt was penetrated at 343 meters (Core 21) sub-bottom (5832 m), after which coring proceeded more slowly. Cores 23, 24, and 25 cut slowly (average 17.3 min/m) and had minimal recovery — only pebbles in the core liner. The cause of the difficulty proved to be a broken flapper valve, which lay across the entrance to the core barrel and prevented cored rock from entering. A second Eastman survey at 5833 meters (after Core 22) had shown a deviation of 0.5 from the vertical.

After changing bits, the drill string was run back in the hole. Re-entry was accomplished at 2200 on 4 January after a 40-minute scan at an offset of 1060 feet west and 40 feet north of the 16-kHz beacon. The heave compensator was picked up at 2300, and drilling was started at the new offset. A malfunction of the heave compensator caused it to be set back at 2245 on 5 January.

The 26th core was brought up at 0720 on 5 January. Although 7.3 meters was recovered, the drill pipe measurement for the base of this core was one meter shallower than for the bottom of Core 25. The discrepancy of at least 8.3 meters was not easily explained but apparently resulted from a ship positioning error.

Coring continued smoothly through Core 39, after which the hole was filled with mud and the drill string was tripped a second time, arriving on deck at 0915 on 8 January. The bit had rotated 39.9 hours in basalt, and was retired in order to avoid the risk of losing the hole through bit failure. The last core cut was 5.85 cm in diameter and evenly cylindrical. An Eastman survey in Core 35 showed a deviation from the vertical of 0.5°.

After the second bit, we decided to log the hole so that at least one set of usable logs could be obtained. Accordingly, we rigged for logging. The second reentry, at 1612 on 9 January, required five and one-half hours and three stabs. Part of the problem was attributable to positioning and part to the fact that the end of the drill string was unusually light, allowing it to move excessively.

The first logging run, beginning at 1900 on 9 January, was made with the high-resolution temperature (HRT) logging tool. The run failed when the tool lodged in the wall of the hole, and the cable became badly tangled. On retrieval of the tool, we saw that 185 meters of cable had to be cut.

We then rigged a combined borehole-compensated (BHC) sonic velocity, natural gamma ray (GR), and caliper (CAL) tool and ran this in at 0500 on 10 January. The caliper was working only intermittently during the rigging, and only part of the time in the hole.

The second logging run was unsuccessful; the tool could not penetrate a clay bridge two meters below the drill pipe. Accordingly, the tool was retrieved and the pipe was tripped to the bottom, which it found at 5937 meters DPM. Evidently the hole had acquired 28 meters of fill in the interim. The pipe was raised to 5515 meters (20 m below the mudline) or just below the 16-inch casing shoe, and the tool was run again. This time the tool penetrated to 5565 meters after passing bridges at 5525 and 5537 meters. The BHC–GR–CAL tool was sent down at 1445 on 10 January. With the pipe now at 140 meters sub-bottom, the tool was successfully lowered to the bottom of the hole which had in the meantime raised to 5925 meters due to caving. Since we had to provide 140 meters of protective pipe at the top of the hole and had lost another 40 meters at the bottom owing to fill, we could only log 296 meters of the 476 meters penetrated. However, this interval included 90 meters of basalt, the basalt/sediment contact, and the entire Cretaceous section. Despite these efforts the first successful logging run came to naught, for the film had jammed. The run was repeated successfully, however, and the tool was retrieved at 0015 on 11 January. The log was good, except for the intermittent caliper.

The third logging run with the Compensated Neutron Porosity Log (CNL) Compensated Formation Density Tool (FDC), and the gamma ray (GR) Log nearly ended disastrously. After being run in the hole at 0300 on 11 January, a strand of the logging wire detached at the line wiper and instantly made a huge "rat's nest" on the deck. Then, because of the difficulty of penetrating bridges, the tool was repeatedly raised and dropped. This action enabled the tool to reach the bottom of the hole (still at 5925 m), but apparently caused the excentralizer arm (a spring steel strap) to break off. Now we had a 45-cm piece of steel in the hole. The log was run up the hole to 5601.5 meters by raising the pipe and appeared to be usable in the sediment but questionable in basalt. The tool was brought to the surface at 1000 on 11 January.

The last log run was the combined Dual Induction–Laterolog–8–Gamma Ray log. It was lowered at 1110 immediately after the CNL–FDC–GR tool was retrieved and reached a depth of 5915 meters, after which it was raised to 5600 meters. The log was successful, and the tool was retrieved at 1415 on 11 January. The pipe was then pulled out of the hole and retrieved on deck at 0015 on 12 January.

The pipe was then run in the hole at 0015 on 12 January with an F94 bit and a bottom-hole assembly that included three bumper subs. The third re-entry was accomplished on the first stab after a three-hour scan, the offsets having been changed from 50 north, 1000 west to 640 north, 600 west. A modified temperature probe was allowed to free fall in the core barrel in an attempt to record the water temperature of the core as the string was made up following re-entry. When the tool was later retrieved, it was found that because of a loose battery package, a wire had broken upon impact with the water about 10 meters below the rig floor and that the forced free fall (five strokes of pump pressure) produced no more damage to the tool after a fall of 5.5 km. No measurements were recorded. The new terminal depth of the hole was sensed at 5960 meters, instead of 5965.2 meters (Core 39).

Six cores were taken with good recovery and with drilling time averaging 21.4 minutes/meter. The seventh core (46) had no recovery, and damage to the end of the core barrel suggested that the flapper valve had once again broken when the core barrel latched. Another short core (47) was attempted to confirm the diagnosis. When the core barrel came up empty, we decided to pull out of the hole. Because another two members of the drilling crew had suffered incapacitating injuries in the meantime, the captain and drilling superintendent decided to terminate the leg two days early. The drill string was then tripped to the surface, reaching the deck at

0230 on 15 January. The flapper valve was found whole, although it had been dented.

Under Way to San Juan

Before leaving the hole, a 13.5-kHz beacon was dropped and located about 1500 feet west of the cone. We streamed the geophysical gear and began a brief survey of the site on a course of 285°, made a Williamson turn and crossed the site at 105°, turned to 317° and then crossed the site again on a course of 195°. After the survey was completed at 0530, the *Challenger* continued to San Juan to terminate the leg and rendezvous with the Leg 52 scientific party, arriving at dawn on 17 January.

Under Way to Hole 417D, Leg 52

The *Glomar Challenger* left San Juan on the morning of 21 January, 1977 and spent the day in a test of its bow thrusters and associated circuitry. Upon completion of these tests the *Challenger* was under way at 0815Z on 22 January. The ship proceeded directly to the vicinity of Hole 417D, surveying en route with the magnetometer and the 80- and 120-in.^{3} air guns.

At 1107, 24 January, the ship passed over the 13.5-kHz beacon dropped by Leg 51 when they left the site. At 1122, 24 January, the gear was brought aboard and the ship positioned itself over the beacon at 1337. The water depth was 5480 meters, or 5490 meters corrected to the rig floor.

At Hole 417D

At 1337, 24 January, the *Glomar Challenger* positioned itself over the 13.5-kHz beacon at Hole 417D, and the drill pipe was lowered beginning at 1400Z. At 0100, 25 January, pipe had been lowered to 5474 meters, and at 0215 the EDO scanning tool was run in. Cone scanning began at 0505, and the cone was located at 0653. After a series of positioning-testing maneuvers by the *Challenger,* the cone was relocated at 0818, and at 0858 the cone was stabbed. The pipe was lowered to 5502 meters, and re-entry number 1 was verified at 1030Z.

Coring began with Core 48 at 6021 meters. A second core was taken, Core 49, before operations were shut down at 2105 because of positioning problems caused by the bow thrusters. At 2130 the pipe was pulled, and at 2300Z the pipe was cleared of the mudline. From 0800, 26 January, to 2100, repairs and positioning tests were made and completed. At 2200, the pipe was again lowered. After the bit reached the bottom at 0730, 27 January, the EDO scanning tool was lowered for a second re-entry attempt. After a 2-hour, 10-minute scan, the cone was located and stabbed at 1658. The remaining pipe was lowered to a depth of 6034 meters, and cutting for Core 50 was begun at 2125.

Coring operations proceeded routinely until 30 January, when the pipe was pulled for a bit change at 0750 after 41 hours and 20 minutes of rotation. At 1045, while the pipe was on the way to the surface, another 16-kHz beacon was dropped to ensure relocation of the hole and cone. At 1750, the bit was on the rig floor. Along with the bit change, tests were made on the ship-positioning system, and magnaflux tests were performed on the drill pup joint and saver sub. Following these tests, the bottom-hole assembly was made up and the pipe was run in the hole at 2000 on 30 January.

At 0520 on 31 January, the EDO scanning tool was run in the pipe in order to prepare for re-entry. The cone was spotted at 0759, and at 0815 the cone was stabbed successfully. At 0816 the EDO tool was run out, after which the pipe was lowered to the bottom of the hole and the drill string makeup was completed with the addition of the Bowen sub and heave compensator.

Between 30 January and 10 February, Cores 61 through 68 were retrieved. The hole depth was 639 meters at the start of Core 61 and 705 meters following Core 68, while the total depth following Core 68 was 6194 meters. Following the recovery of Core 68, we decided to change the bit since the core diameter had decreased to 5.2 cm after 19 hours, 38 minutes of rotation. Following a single shot (directional survey) to determine the deviation of the hole, the pipe was pulled at 0200 on 2 February and arrived on deck at 1430.

At 1600, the pipe was lowered again, reaching 5474 meters at 2330. The cone was stabbed at 0923 on 3 February and re-entry number 4 was verified at 1042.

Drilling for Core 69 began at a depth of 6194 meters (705 m sub-bottom). While coring Core 70, a 45,000-lb weight loss was noticed by the drillers and attributed to the loss of the bottom-hole assembly. At 1810 on 3 February the pipe was accordingly again pulled. The entire bottom-hole assembly had broken off 17 inches above the base of the last section of heavy wall pipe. The drill stem was made up again to include "fishing tools," in the hope of clamping onto the broken section at the bottom of the hole.

A new drill string with the "fishing tool" was run in at 1300 on 4 February. At 2228, the EDO tool was run in to a depth of 5481 meters. At 0650 on 5 February, the cone was stabbed and at 0810, the re-entry was verified and the pipe lowered to a depth of 6092 meters sub-bottom to search for the broken drill stem. Re-entry time was 5 hours, 44 minutes.

After re-entry was verified, the pipe was lowered to the top of the broken bottom-hole assembly and "fishing" was begun. After 40 minutes it was decided to pull the drill pipe and examine the "fishing" tool to ascertain if it was still operative. Accordingly, the pipe was pulled and the tool was on deck at 2400 on 6 February. The decision was made to make another attempt to recover the broken pipe. The pipe and attached tool were thus lowered at 0920 on 6 February. At 1316, the pipe reached 5468 meters and another re-entry attempt was begun, the cone being stabbed at 1353 or 37 minutes later. At 1410, the Schlumberger cable broke as the EDO tool was being pulled out. About 4000 meters of cable and the EDO tool remained in the pipe. At 1505, a spearing tool was sent down to retrieve the cable, but on pulling the sand line to the drill we discovered that the spear had also broken off.

At 1710 the pipe was pulled and at 1940 the broken cable was located after 46 stands of pipe had been removed. The Schlumberger cable reel was changed, the pipe was lowered to 5473 meters, and at 0546 the EDO tool was sent down for another re-entry attempt (No. 7).

A malfunction in the EDO tool necessitated pulling the tool at 1000 on 7 February. At 1115 the tool reached the rig floor. The new tool was exchanged and at 1202 the pipe was lowered to 5480 meters. After a two-hour, 26-minute search the cone was stabbed at 1738. However, when additional pipe was lowered, it was determined that the re-entry had not been successful.

Re-entry attempt No. 9 began at 1958 on 7 February, and at 2342 the EDO tool failed completely. On reaching the rig floor at 0050 on 8 February, the EDO extenders were found to be missing. Another tool was made up and lowered at 0146. This tool also failed as the search was being conducted for the cone. Upon reaching the rig floor it was found that the entire EDO sensor unit was missing. Lack of further extenders for the re-entry tool necessitated the decision to pull the pipe.

Two further attempts were made to re-enter the cone at Hole 417D on 9 February, using a modified device to hold the EDO tool with short extenders. After both attempts failed, the tool was pulled at 2115 on 9 February in order to move to Site 418 to set a new cone for a second deep-penetration attempt. After the pipe was pulled, the *Challenger* left Site 417 to drill at Site 418 for several weeks before returning to Hole 417D on 3 March to conduct the oblique seismic experiment.

Oblique Seismic Experiment and Return to San Juan

It was originally planned to run the oblique seismic experiment in Hole 417D upon completion of the deep-penetration attempt. Although the loss of the bottom-hole assembly in Hole 417D prevented running the experiment in the lowest 100 meters of the drill hole, it was possible to perform the experiment in the open portion of the hole from 344 meters sub-bottom to the top of the broken off bottom hole assembly at approximately 603 meters sub-bottom. The experiment was thus attempted from the *Glomar Challenger* in Hole 417D from 3 through 5 March, 1977.

After positioning over the beacon and re-entering the hole, an instrument package consisting of a variable-gain three-component geophone and a fixed-gain vertical component geophone was lowered through the end of the pipe and clamped to the walls of the hole 228 meters into basement. Explosive charges were then set off at the surface at two-minute (½-km) intervals along a cross with the *Glomar Challenger* at the center; each arm of the cross was 12 km long. After shooting had been completed, the north-south line was repeated with the instrument package 8 meters into basement.

All experimental equipment, recording devices, and associated electronics were set up on the *Glomar Challenger.* The explosive charges were set off from the *Virginia key,* a 65-foot T-boat operated by the National Oceanic and Atmospheric Administration. Personnel from the Natural Environment Research Council (U.K.), the Woods Hole Oceanographic Institution, and Scripps Institution of Oceanography were on the *Virginia Key* for the experiment. After its completion, the personnel were transferred to the *Glomar Challenger* and the ship left for San Juan to terminate the leg and rendezvous with the Leg 53 scientific party.

Core Recovery

During the course of drilling at Site 417, 44 basement cores containing a total of 128.5 meters of basalt were recovered in Hole 417A and 47 cores containing 263.2 meters of basalt were recovered in Hole 417D. The total basement penetration in the two holes was 209 and 365.5 meters, respectively, for a recovery of 61 and 72 per cent. Although such high recovery is normally a blessing, we often recovered more than we drilled and occasionally recovered basalt from intervals which we had previously drilled, especially after re-entry.

Aside from cavings which cannot adequately explain the problem, there are two possible causes for this discrepancy: (1) the reported drilling interval for each core is measured in terms of drill string length, not hole depth. If the ship moves laterally, the drill string will be pulled partly out of the hole. The size of this error could be 3 to 5 meters. (2) The position of the bumper subs is not known accurately during drilling, especially in heavy seas, and since each bumper sub has a stroke of 1.5 meters, this uncertainty could introduce an error of as much as 3 to 4.5 meters.

Whatever the cause, we occasionally had to adjust the depth and recovery figures slightly to reduce the recovery to 100 per cent and to reconcile apparent overlaps in coring. To reduce the recovery in any given core, we assumed that the bumper subs had closed partly during the drilling of the next higher core. We thus adjusted the cored interval upward from the core with over-recovery, allowing a maximum of 100 per cent recovery in successive cores, until we reached a core whose adjusted recovery was less than 100 per cent. Thus, the cores with their partial contents can themselves be likened to a string of bumper subs that close upward from the bottom.

To reconcile overlapping core after re-entry, we assumed that the shallower depth to the bottom of the hole observed after re-entry is necessarily more nearly correct than the deeper penetrated depth recorded prior to pulling out of the hole. The reason for this is that the drill string hangs nearly vertical at re-entry, whereas later it can be dragged partly out of the hole during excursions, both known and unsuspected. The correction principle is the same: the offending cores are telescoped upward as before until no overlap remains and no core has more than 100 per cent recovery.

SEDIMENT LITHOSTRATIGRAPHY

Introduction

Site 417 is located just to the north of the Vema Gap, the abyssal passage that connects the Hatteras and Nares abyssal plains. The site also lies near the southern extremity of the Bermuda Rise (see Figure 1), along the *M*0 magnetic anomaly (Hole 417A). The sediment sections encountered in Holes 417, 417A, 417B, and 417D were subdivided into eight major lithological units (see Table 3 composite stratigraphy; Figure 9). Sediments recovered at these sites are similar to those found on previous western Atlantic legs: nearly barren Tertiary clays (but with a radiolarian-rich middle Eocene section) resting on zeolitic multicolored Upper Cretaceous clays overlying green, gray, and black Middle Cretaceous claystones, nannofossil marls and chalks, and radiolarian sandstones. A thin, finely laminated chalk immediately above the basalt in Hole 417D yielded lower Aptian nannofossils, which gives an extrapolated age for the *M*0 magnetic anomaly of about 114 m.y. (van Hinte, 1976). Holes 417 and 417B were mudline cores included in Unit I and Hole 417C was a wash-down without recovery in order to set the cone. Hole 417A, a pilot hole located on a buried basement knoll, reached highly altered basalt basement at 208 meters depth sub-bottom, after continuously coring 24 cores. The recovery rate averaged 60 per cent, although sediments in most cores were highly deformed. Hole 417D was located 450 meters west-northwest and 13 meters deeper than Hole 417A, over a buried basement depression. Surprisingly, we penetrated 130 meters of sediment not seen in Hole 417A, hitting fresh glassy basalt at 343 meters sub-bottom.[2] After four spot cores, Hole 417D was continuously cored from 192 meters to basement. A total of 57.8 meters or 33 per cent was recovered. The results imply that by moving to Hole 417D, we had traversed over a basement slope in excess of 16°. New lithologies included black carbonaceous and phosphate-rich clays, limestones, cherts, zeolite-rich clays (locally bleached), radiolarian turbidites, and nannofossil chalks. Recovery was very poor in the Cenozoic clays but improved somewhat in the Upper Cretaceous mudstones (35%). Disturbance below Core 6 in Hole 417D was usually only moderate, although some zones showed "drill biscuit effects" (e.g., Sections 417D-19-1 and 21-4) with softened sediment injected upward along the inner core liner wall. Basal basaltic sands encountered in Hole 417A were not found in Hole 417D

TABLE 3
Sedimentary Lithologic Units From Site 417

Unit	Lithology/Comments	Chronostratigraphic Unit	Holes 417 and 417A			Holes 417B and 417D		
			Depth (m)	Thickness (m)	Core/Section/Interval	Depth (m)	Thickness (m)	Core/Section/Interval
I	Brown pelagic clay with Nannofossil ooze horizons	Early Quaternary	0-8.5	8.5	417-1, 417A-1, 417B-1	0-9.5	9.5	417B-1, 417D-1
II	Yellow brown to pale brown pelagic clay. Includes some blue ash	Middle Miocene to (?) late Eocene	8.5-105.7	97.2	417A-2 to 417A-12-2, 70 cm	–	–	(washed 7.5-125 m)
III	Dark brown zeolitic clay	?	105.7-122.5	16.8	417A-12-2, 70 cm to 417A-13-3	?122.0-136.0	14	417D-3
IV	Dark brown radiolarian ooze to clay	Middle Eocene	122.5-160.5	38	417A-13-4 to 417A-18-7	?136.0-178.0	42	417D-4 (washed 144.5 to 192.0 m)
	IVa Zeolitic		122.5-136.5		417A-13-4 to 417A-15-3			
	IVb Non-zeolitic		136.5-151.0		417A-15-4 to 417A-16, CC			
	IVc Zeolitic		151.0-160.5		417A-17			
V	Multicolored zeolite clay	Late Cretaceous	160.5-149.5	39	417A-18-1 to 417A-21, CC	178.0-279.5	101.5	417D-6-1 to 417D-15-2, 60cm
	Va Pale and dark yellow-brown, slightly zeolitic		160.5-179.5	19	417A-18-1 to 417A-19, CC	178.0-212.0	34	417D-6-1 to 417D-8, CC
	Vb Yellow-browns and pale green zeolite-rich		179.5-199.5[a]	20	417A-20-1 to 417A-22-1, 100 cm	212-275.0	63	417D-8, CC to 417D-14-4
	Vc Transition		Basalt Rubble[b]			275.0-279.5	4.5	417D-14-5 to 417D-15-2, 60cm
VI	Green to black organic claystone marl and nannofossil chalk including radiolarian sands, pyrite, chert, dolomite, and phosphate	Early Cenomanian to Albian				279.5-325.8	46.3	417D-15-2, 60cm to 417D-19, CC
VII	Cyclic radiolarian sand to marl to claystone	Early Albian to late aptian				325.0-338.6	13.6	417D-20-1 to 417D-21-3, 140cm
	VIIa Pale to dark brown and pale green						11.3	417D-20-1 to 417D-21-2, 60 cm
	VIIb Green and black with nannofossil chalk and chert						2.3	417D-21-2, 60cm to 417D-21-3, 140cm
VIII	Olive-gray, clayey nannofossil chalk	Early Aptian				338.6-339.5[a] (343[b])	0.9	417D-21-3, 140cm to 417D-21-4, 60cm
IX	Glassy basalt with interpillow limestone					Below 343[c]		

[a] Basement according to position in core of the first basalt encountered.

[b] Drilling in Hole 417A encountered altered pillow basalt basement. Driller's records indicate a basement contact at 208 meters sub-bottom. The top of basalt Cores 417A-23 and 24 contains, respectively, 40 cm and 20 cm of a drill breccia with basalt rubble, sand, and overlying clay.

[c] Coring indicated basalt at 339.3 meters sub-bottom and driller's records at 343 meters. Checking with the logging tools, however, showed the sediment basalt interface located at 340 meters sub-bottom.

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[2] DSDP formal practice assigns partially recovered sediments to the top part of the core barrel, whereas the depth reported for basalt was measured by the driller. This creates a slight gap not meant to imply that there is not stratigraphic continuity.

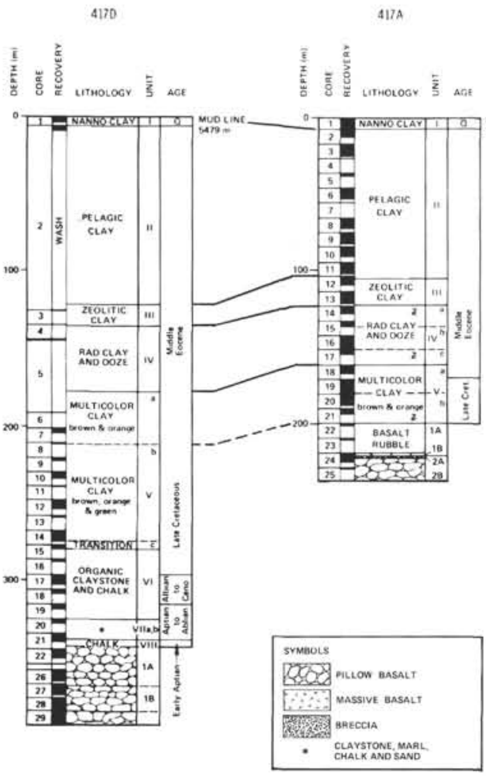


Figure 9. *Correlation of sediment lithology from Hole 417A to Hole 417D. The base of Hole 417A is approximately equivalent to Section 417D-8-2.*

and are treated separately. Otherwise, the lithologies from these holes have been correlated and combined into the stratigraphic scheme given in Table 3.

Description of Lithologic Units

The main criteria for selecting sediment units include color changes, the presence of zeolites and carbonates, the abundance of radiolarians, and the presence of black clay. Where possible, we strived for uniform units that correlate with the sections described during DSDP Legs 11 and 43.

Unit I, Brown Pelagic Clay — Quaternary

The uppermost unit was recovered in Core 1 in Holes 417A, 417B, and 417D, and ranges from 0 to 9.5 meters. The sediments are dominantly a very fine grained homogeneous, brown soft pelagic clay with little structure and a very low carbonate content. Colors vary gradationally from dark yellow brown (10YR 4/4) to brown (10YR 4/3) to very dark brown (10YR 2/2). The sediments contain 60 to 85 per cent clay, up to 30 per cent silt, and minor amounts of quartz, feldspar, and opaques including rutile and Fe-Mn micronodules. In some coarse fractions, foraminifers are common, but most contain fish debris and Fe-Mn micronodules along with minor quartz, opaques, and scarce radiolarians.

Drilling disturbance has homogenized most of the unit, but in Sections 417D-1-3 and 4, more or less well preserved intercalated bands of yellowish brown (10YR 5/4) to light yellow-brown (10YR 6/4) foraminifer-nannofossil ooze persist. In these zones, foraminifers are scarce to common. Calcium carbonate was notably absent in all samples except one nannofossil-rich clay, which contained 37 per cent $CaCO_3$ (Sample 417A-1-1, 59-61 cm). The pelagic muds of Unit I are widespread in the western Atlantic Ocean and were deposited near or below the CCD. The boundary of Unit I is placed at the bottom of Core 417A-1.

Unit II, Brown Pelagic Clay

This unit was not cored in Hole 417D, but washings from residues in the core barrel contained fragments suggesting its presence. In Hole 417A, Unit II extends from 9.5 meters to 105.7 meters. The sediments are yellow brown (10YR 5/4) to brown (10YR 4/3), dark brown (10YR 3/3), or pale brown (10YR 6/3) clays. The colors lighten with depth and become very pale in Cores 417A-10 to 12. In Section 417A-12-2, 70 cm there is an abrupt change to dark brown, marking the base of Unit II. Bedding and structures are generally obliterated by drilling disturbances, but mottling suggests that thin light and dark bands are common. Scattered in Cores 417A-5 to 10 are blebs of light blue-gray (5G 6/1) to greenish gray (5B 7/1 to 6/1) and light pale green (10G 8/2) clay. In Intervals 417A-5-3, 52 to 65 cm and 417A-8-1, 12 to 20 cm, discrete, pale blue beds of volcanic ash occur which are rich in phillipsite.

Unit II is barren of calcareous or siliceous microfossils. Ichthyoliths (Kozarek, this volume) were used to estimate a range from middle Miocene to middle Eocene. The sediments are composed largely of clay minerals with scattered amounts of feldspar (3%) quartz, and terrigenous heavy minerals. Fe-Mn micronodules are rare and tend to be concentrated in a few discrete bands (i.e., Section 417A-8-1). The smear slide composition remains uniform throughout Unit II, except in the rare ash beds which contain up to 45 per cent phillipsite. The silt to clay ratio is approximately 1:9. Color variations correspond to varying amounts of micronodules and ferruginous material. Coarse fractions are dominated by fish debris and Fe-Mn micronodules. A rhodochrosite-dolomite assemblage was recovered from Section 417A-9-2 to Section 417A-13-1. Downward these carbonate crystals change from stubby rhombic shapes to elongate cigar-like, expanded rhombs. Some are dark gray and manganese-coated or replaced, but most are tan and translucent (see Borella and Adelseck, this volume).

Unit III, Dark Brown Zeolitic Clay

Dark mottled clays from Section 417A-12-2 to Section 417A-13-6 were designated Unit III. In Hole 417A, the unit is 16 meters thick but in Hole 417D it is only represented by a few traces in the core catcher. The upper contact is delineated by a sharp color boundary, marking the onset of zeolites. The lower boundary is defined by the appearance of abundant radiolarians and is less precise. Colors are dark brown (10YR 3/3), dark gray brown (10YR 4/2), very dark gray brown (10YR 3/2) to dark yellow brown (10YR 4/4) streaked with light yellow brown (10YR 6/4) to very pale brown

(10YR 7/4). The unit is highly deformed, but is firm in comparison to the two previous units. Bedding may have been present on a centimeter scale. Rare spots of light blue volcanic ash (5B 7/1) are present in some of the sections. The ratio of silt to clay is approximately 1:4. Both the dark clay and less abundant lighter clay commonly exceed 15 to 30 per cent zeolite (clinoptilolite), with the zeolites being more abundant in the lighter bands. Some of the zeolites show a tendency to concentrate in small clusters. The coarse fractions contain abundant micronodules and fish debris plus a few elongate and rounded rhodochrosite grains and scarce radiolarians. No calcite was detected.

Unit IV, Radiolarian Clay and Ooze

This unit is 45 to 50 meters thick and includes Section 417A-13-6 through Core 417A-18; the upper and lower contacts are transitional. The sediments are predominantly a very dark gray-brown (10YR 4/2), brown (10YR 5/3), to yellow-brown (10YR 5/4) clay to radiolarian ooze. Throughout this unit there are intervals of pale brown (10YR 6/3) to light yellow-brown (10YR 6/4) gritty-radiolarian-rich clays. The sediments are highly disturbed, but firm, and show some evidence of initial layering and burrow mottling.

Unit IV can be divided into three subgroups based on the abundance of radiolarians and zeolites (Table 3). The radiolarians are initially scarce (Unit IVa), but become very abundant from Section 417A-14-2 to Core 417A-16 in Unit IVb and finally toward the base of Unit IVc. Zeolites are very common at first, but decrease from Section 417A-14-2 to Core 16, and then increase again in Core 17.

Many of the radiolarians are fragile, lacy orosphaeroid types. Other siliceous forms include sponge spicules and silicoflagellates. Radiolarians dominate the coarse fraction in Sub-unit IVb (85%); fish debris and micronodules dominate in the others. We found no traces of carbonates, nor were chert fragments recovered.

Unit V, Multicolored Pelagic Clay — Upper Cretaceous

This unit is 101 meters thick. The sediment section in Hole 417A ended on a basalt hill while still in onlapping sediments from Unit V. The top part is defined from Hole 417A, Cores 18 to 21. These were correlated with Hole 417D, and the bottom section of Unit V was defined by Cores 417D-6 to Section 15-2. The name "multicolored" was selected to correspond to similar sediments at Site 105, although most colors are variations of light to dark yellow- or red-brown and pale green.

Unit V is subdivided into two sub-units and a transition zone based on significant changes in the cyclic color variations and the amount of zeolites. They are described as follows:

Sub-unit Va:	Clay, slightly zeolitic, dark and light yellow-brown; 178 to 212 meters in Hole 417D.
Sub-unit Vb:	Cyclic pale green and yellow-brown, highly zeolitic clay; 212 to 275 meters in Hole 417D.
Sub-unit Vc:	Transition zone; 275 to 279.5 meters in Hole 417D.

Sub-Unit Va

This sub-unit includes Cores 417A-18 and 19 and 417D-7 and 8. The non-zeolitic portion of Sub-unit Va was found only in the core-catcher in Core 417D-6, whereas in Hole 417A it was about 20 meters thick. Note, that in Hole 417D the multicolored Unit V was possibly cored deeper than at Hole 417A. Sub-unit Va consists of interlayered dark to moderate yellow-brown (10YR 5-6/4, 4/2), dark gray-brown (10YR 4/2), grayish orange (10YR 7/4), yellowish red (5YR 5/6), and light brown clay to zeolitic clay in a dominantly (80%) dark yellow-brown clay to zeolite-rich clay. The clay is firm to stiff and moderately to highly disturbed. Color interlayers still discernible are on a scale of 0.5 to 3 cm in thickness. Minor dark zones and Fe/Mn laminations occur in Core 417D-8-1, 81–112 cm. Contacts are sharp to transitional. Within the color bands, sediments appear homogeneous, are very fine grained, and have a waxy feel. There is no clear evidence of redeposition. These beds and patches of dusky to light red claystone set in a gray brown mudstone are common in 417A-18 and 19. The contact with overlying clays is disturbed. The onset of zeolites parallels a change from very dark to lighter brown hues in Section 417A-20-1, where scattered blebs of blue-gray volcanic ash also occur. Components are dominantly pelagic muds or clays with traces of zeolites and fish debris. Laminations are present in some sections because of Fe/Mn micronodule concentrations. The transition from Fe/Mn zones to dark clay is commonly marked by a thin transitional zone, 1 to 3 mm thick, with a speckled or burrowed character. One indistinctly burrowed bed occurs in the interval 417D-8-1, 81–112 cm. Black, Fe/Mn-rich, wavy laminations outline flattened and flared burrows (Figure 10). These imply that the greater part of Unit V is bioturbated.

The composition of all beds is fairly uniform, with 60 to 95 per cent clay minerals. Zeolites ranging from 1 to 25 per cent are commonly concentrated in pale or orange bands, but overall tend to increase with depth. Other minor components include fish debris (2%), quartz (4%), K-feldspar (2%), and assorted heavy minerals (e.g., rutile and anatase). Fine-grained, brown carbonate (siderite?) occurs very sporadically — for example, in one black interlayer from Sample 417D-6, CC. Otherwise, the unit is devoid of calcareous components. Manganite needles are common in darker gray-brown zones. Darker banding is caused by varying proportions of Fe-Mn grains and micronodules, whereas lighter zones contain amorphous ferruginous material. These differences may reflect variations in sedimentation rates. Coarse fractions contain mostly micronodules and fish debris along with some very poorly preserved radiolarian molds.

Clay and basalt rubble were encountered in Hole 417A, Cores 22 to 24, 198.5 to 217 meters. Basalt was cored in Section 417A-22-1, but yellow-brown sands

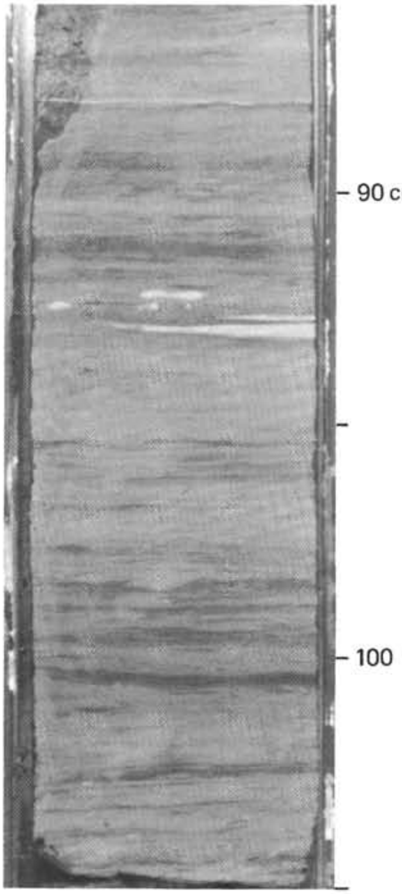


Figure 10. *Interval 417D-8-1, 85 to 104 cm. Yellow-brown clay with dark Fe/Mn-rich laminations consisting of flattened burrows (Unit Va).*

and clay were also recovered at the top of the basalt Cores 417A-23 and 24. Initially scattered radiolarian molds, some bedding, and partially graded structures implied a possible sedimentary origin. Later investigations, however, confirm that these are probably drill breccias comprising particles of highly weathered basalt pillows mixed with the multicolored pelagic clay.

Sub-Unit Vb

This sub-unit is 65 meters thick, encompasses Cores 417A-20 to 22, and Sample 417D-8, CC to Core 417D-15, and shows a cyclic interlayering of yellow-brown (10YR 5/6) and dark yellow-brown (10YR 5/4) zeolite clays (70 to 80%) with minor intercalations (18 to 25%) of pale blue-green, very zeolitic silts to clay. Thin bands of each lithology are mostly homogeneous and non-calcareous, although a few show laminations. Contact boundaries are gradational, mottled, and diffuse to sharp. Most sections from Hole 417D contain only slightly disturbed stiff clay. The three cores from Hole 417A (Cores 20, 21, and 22), in the upper part of this zone, however, are so badly disturbed that the description is based on the correlative sections from Hole 417D. These pelagic clays are compact and hard, but they can still be cut with a cheese cutter. In some instances, for example Sample 417D-11, CC, we recovered hardened claystone. From Cores 417D-9 to 12, brownish hues are distinctly paler than in Sub-unit Va, and in Core 12, they change to slightly stronger reddish hues. Greenish bands are ½-to-3-cm thick and appear to be a result of post-depositional reduction. Commonly, these blue-green bands have thin white laminae of silt-size zeolite crystals in their centers. Bleaching extends roughly equal distances laterally, which suggests some fluid movement along these beds. Grading is not apparent in any of the beds.

Because of the consistently high zeolite (clinoptilolite) percentages, ranging from 20 to over 60 per cent, Sub-unit Vb is designated a zeolite claystone rather than zeolitic clay. Zeolites impart a silt to fine-sand texture to otherwise very fine grained clay; they appear to be slightly more prevalent in the greenish bands. Minor lithologies in this unit include dark gray-brown (10YR 3/2) zeolitic clay with black Fe/Mn stringers (e.g., Sections 417D-9-1, and 13-1, and 417D-10-2) and one 6-mm black manganese pebble. An unusual, 1-cm-thick white-bleached, low-birefringent clay bed occurs at Section 417D-12-4, 101 cm.

The composition of the dominant brown and pale green clays is fairly uniform throughout. Clay minerals dominate, and biogenic components and carbonates are absent, with the exception of some fish debris and radiolarian molds in coarse fractions. Zeolites are common to abundant as 8-to-10-μm, ragged to subhedral clinoptilolite grains, although in some cases, large, blocky or pinacoidal (40-μm) clinoptilolite crystals occur.

Sporadic opal-CT appears as a new constituent below Core 417D-12, comprising up to 5 per cent of some beds. Rutile, anatase, scattered euhedral apatite, and other heavy minerals occur throughout. Carbonates are limited to sparse occurrences of a 2-to-4-μm brown, rhombic carbonate. A thin section of a particularly hard claystone in Sample 417D-11, CC showed that the sediments were probably originally rich in radiolarians, but that most of the tests have been replaced or molded by zeolites.

Sub-Unit Vc

In the last 4.5 meters of the multicolored zeolite clay from Section 417D-14-5 to Section 417D-15-2, 60 cm (275.0 to 279.5 m), the number of green clay interlayers increases and the sediments are distinctly more lithified and brittle. The first cherts encountered were a fine-grained, porcellantiic gray-brown nodule at Section 417D-15-1, 10 cm and brown porcellanitic beds at the base in Section 417-15-2, 60 cm.

Unit VI, Green to Black Organic Claystone, Marls, and Chalk

Unit VI is 46 meters thick in Hole 417D, ranges from 279.5 to 325.8 meters and includes a heterogeneous combination of interlayered lithologies. Beginning with brown porcellanites at the base of Core 417D-15, the unit extends through Sample 417D-19, CC. Important characteristics are the reappearance of calcareous nannofossils and the appearance of interlayers of black organic clay. The lithologies can be broadly categorized into the following four general types which are interlayered in varying amounts:

(1) Green claystone, partly zeolitic, phosphatic, or dolomitic (63%) at the top of the unit. Core 16 shows a dramatic color and composition contrast with Core 15. Sediments are pale blue-green (5BG 7/2) to greenish gray claystone, with bands and laminations of slightly darker hues. Pale to colorless clay minerals are the dominant constituent (50%). Clinoptilolite continues to be abundant (20 to 25%) in Core 16 but dwindles below Sample 417D-17, CC. Cores 417D-16 and part of 17 contain a considerable portion of scattered, dolomite rhombs (10 to 15% and up to 30%). These are 10 to 60 μm across and commonly show a rhombic seed core. Phosphate fish debris(?) occurs within black laminae and appears in smear slides as large (10-to-100-μm) brownish flakes, splinters, chips, and fragments. One black lamina at Core 417D-16-1, 77 cm, consists of more than 70 per cent phosphate. Pyrite is disseminated as tiny bronze crystals surrounded by green alteration products. One brownish black, vitreous chert nodule (Sample 417D-16), CC) with a patina of white porcellanite includes laminae of pyrite-like sulfide.

(2) Black, organic, pyritic, and phosphatic clay (25 to 36%). Firm to crumbly black (5YR 2/1) clay interlayers become an important lithology in Cores 417D-17 through -19, and again in Core 21 (Sub-unit VIIb). The beds range from 0.5 to 40 cm in thickness and commonly show faint laminations. Contacts with gray-green clays to marls are sharp to transitional, and the two colors are somewhat cyclic. Dark clay is rarely burrowed and usually shows some microlaminations (e.g., Section 417D-19-1, 110 cm; Figure 11), but transitional gray-green clay commonly shows some chondrites or fucoid-type burrows with dark fillings. Most mineral grains have a coat of organic material. The main constituents of the black clays are clay minerals (20 to 70%), opaques (e.g., organic + pyrite, 25%), dolomite (?) (up to 50%), radiolarian molds (8%), fish remains (10%), and minor traces of K-feldspar, quartz, heavy minerals, mica, and micarb. Moderately well-preserved nannofossils may comprise up to 10 per cent of many beds. Euhedral authigenic sphalerite was found as a rare component in some pyrite-rich layers. Pyrite also occurs as pods and large nodules (e.g., Samples 417D-17, CC; 19, CC, and 19-2, 16-25 cm; Figure 12). Our few total-carbon determinations show up to 3.5 per cent organic carbon in the richest layers. Carbonate bomb determination ranged up to 8 per cent $CaCO_3$ in black clay samples.

(3) Nannofossil chalks and marls (20 to 30%). Dark gray-brown, pale blue-green, light brown, pinkish gray, and light gray nannofossil chalks to marls are interspersed in Core 417D-17, diminish in Core 417D-18 and are rather common in Core 417D-19 where they occur with pale green nannolimestones. One limestone bed shows well-developed microfaulting (Figure 13). Some

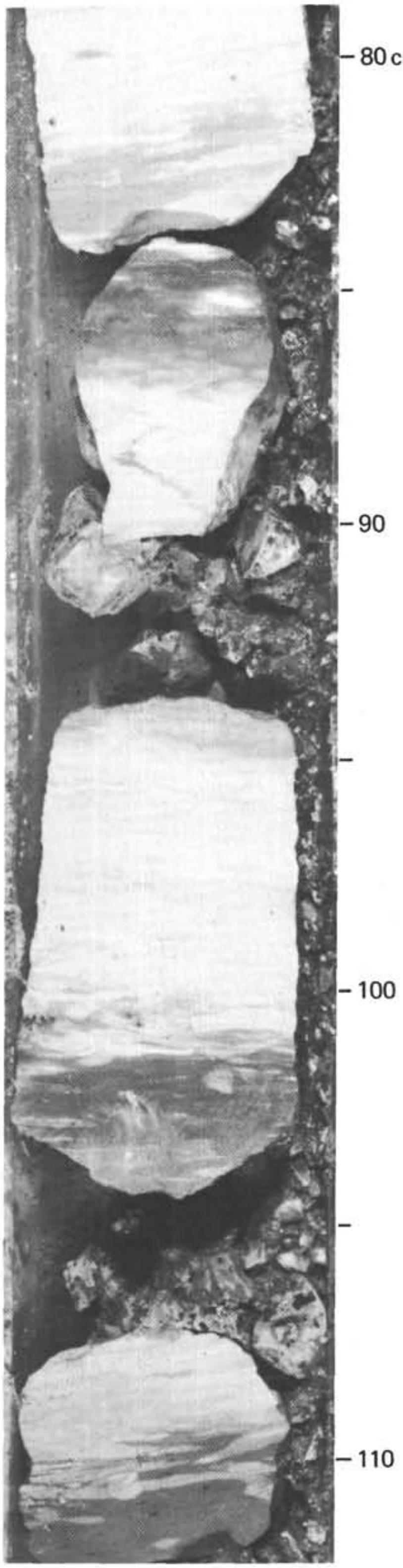


Figure 11. *Interval 417D-19-1, 79 to 112 cm. Depositional cycles in dark green to black clay, showing burrowing in lighter colored material (Unit VI).*

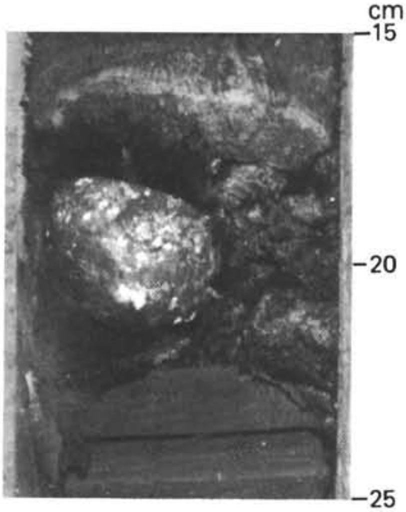


Figure 12. *Interval 417D-19-2, 15 to 25 cm. Pyrite nodule in black clay (Unit VI).*

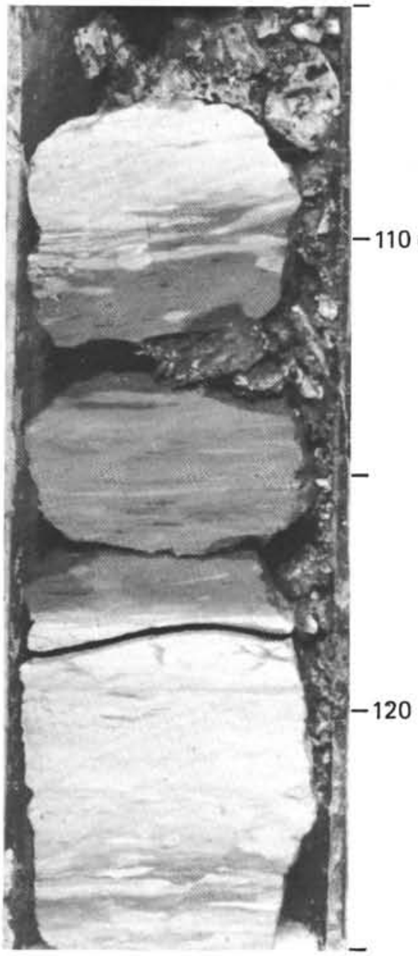


Figure 13. *Interval 417D-19-2, 105 to 125 cm. Burrowing in limestones interlayered with black clay (Unit VI). Note the conjugate sets of normal micro faults in the lower piece.*

darker olive layers have submillimeter laminations consisting of stringers of white specks. Chalk beds are centimeter to decimeter in scale and mostly burrow-mottled. Rare layers show an exponential decrease in burrowing with depth suggestive of redeposition or cyclic development (Figure 13). Many contacts are transitional with gray-black or green clay. The dominant constituents of these beds are nannofossils and nannofossil debris (75 to 95%), with minor clay, radiolarian molds, foraminifers, dolomite, quartz, heavy minerals, and opaques. Carbonate contents vary from 0 to 30 per cent.

(4) Radiolarian sands. Several of the black layers and some green represent concentrations of dark gray, sandy radiolarians (e.g., Samples 417D-17-1, 121-122 cm and 417D-17-3, 137 cm). Radiolarians are replaced and infilled by chalcedony. Faint laminations in these beds may indicate current winnowing.

Unit VII, Cyclic Radiolarian Sandstone to Marl to Claystone

This unit, which is marked at the top by an abrupt color change to cyclic reddish brown and pastel green hues, begins at 325 meters sub-bottom at the top of Section 417D-20 and extends 13.6 meters down to Section 417D-21-3, 140 cm. The unit has been divided into two sub-units on the basis of color and composition as follows:

Sub-unit VIIa:	Brown marlstone to claystone with layers of blue-green radiolarian sand or siltstone; 325-336.3 meters in Hole 417D.
Sub-unit VIIb:	Green to black claystone with interlayered nannochalk and chert; 336.3-338.6 meters in Hole 417D.

Sub-Unit VIIa

This sub-unit consists of two related lithologies. The dominant (80%) is brown (7.5YR 5) to red-brown (5YR 4/4) marlstone to claystone. This lithology alternates with 0.5- to 3-cm bands of pale blue-green (5BG 7/2) calcareous radiolarian sand or siltstone (10 to 15%). Minor amounts of brown, yellow-brown, and brownish black chert occur. Sedimentary structures suggest that the red and green sediments are part of a decimeter-scale cyclic unit which may include redeposited material. These include vague parallel lamination in the pale green beds and faint burrow-mottling in the red-brown layers. Imperfect grading occurs but is very rarely prominent. The green bands are mostly coarser grained radiolarian sands while the red-brown bands are fine to coarse. The pale green coloration has a secondary diagenetic origin, since the color boundaries cross-cut bedding. A cycle begins (e.g., Sample 417D-20-1, 130-140 cm; Figure 14) with (1) a coarse radiolarian sand to clayey sand, although a thin clay band might also mark the base. Some wispy laminations are usually present. Commonly, this part of the bed is bleached pale blue-green. This is followed by (2) a more homogeneous silty clay or nannofossil marl with a few floating radiolarian tests. (3) Faintly darker burrow mottles appear and in-

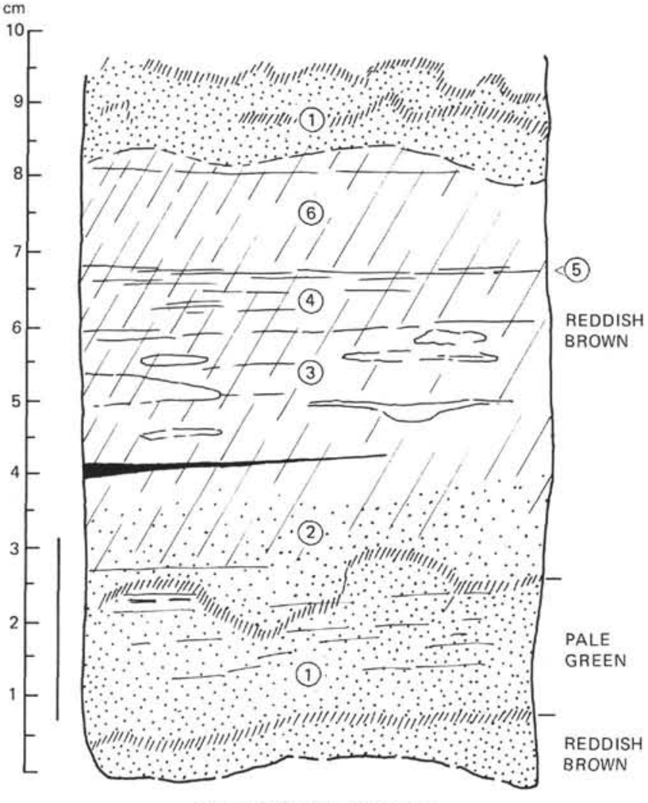


Figure 14. *Interval 417D-20-1, 130 to 140 cm. Idealized redeposition cycle (see text); textures developed in redeposited radiolarian sands to claystones (Unit VII).*

crease upward, until (4) there is a pervasively burrowed, homogeneous brown clay showing slightly lighter hues. (5) In rare cases (e.g., Sample 417D-20-2, 115 cm), this is followed by a thin, fine lutite cap of white clay. The final part (6) is a dark, homogeneous, dark red-brown, normal pelagic clay. We counted 23 to 25 such cycles in Core 417D-20; they become thinner, less frequent and more calcareous at the top of Core 417D-20. If these cyclic beds represented wafted redeposited material from a discrete current pulse, they would also show some separation of the three components — clay, nannofossils, and radiolarians. Smear slides from different red-brown areas vary in composition, containing nannofossils (10 to 40%), clay (30 to 80%), and minor quartz, K-feldspar(?), heavy minerals (apatite), fish debris, and micas. Greenish layers comprise up to 60 per cent chalcedony or opal from poorly preserved radiolarian molds, along with nannofossils, micarb (10 to 20%), and clay (~10%).

Sub-Unit VIIb

We designated a 2.3-meter layer of green to black interlayered organic clay and marls, which occurs at the base of Unit VII between Sections 417D-21-2, 60 cm, and 21-3, 140 cm, a sub-unit of Unit VII, because it more closely resembles Unit VI. The dominant lithology is greenish black (5GY 2/2) to black (N2) phosphatic, dolomitic organic, pyritic claystone. They are faintly bedded on a centimeter scale, and in some places millimeter laminations are visible. Two 1-cm-thick beds of granular pyrite occur. Clay minerals are dominant; nannofossils, radiolarians, and quartz are scarce to common. A trace of sphalerite was noted. Organic carbon in three samples ranged from 1.5 to 3.5 per cent. Calcareous nannofossils are scarce to common, and the carbonate content from bomb measurements ranges from 0 to 4.5 per cent.

Interlayered at the top of Section 417D-21-3 are several cycles of light gray-green and pale green nannofossil marl. These very light colored chalk cycles are completely burrowed and topped by a bright green clay. Chalks bear both radiolarians and foraminifers. Other components possibly include K-feldspar. A thick (1 to 5 cm) replacement chert bed occurs in the 417D-21-2, 108-143 cm interval. Blue-green chalcedony also occurs, with floating, replaced, and chalcedony-infilled radiolarians (see Figure 15). This bed may represent the silicified coarse part of a locally redeposited volcanogenic sediment. In one smear slide from black clay, there were chips of fresh basaltic glass.

Unit VIII, Olive Gray, Clayey Nannofossil Chalk

This thin unit forms a new and distinct lithology that directly overlies basement at Hole 417D between 338.6 to 339.5 meters. It has been partially broken down into biscuits by drilling. These olive-gray chalks show broad, faint color banding, but the most conspicuous feature is the presence of tiny submillimeter streaks and laminations which may be the result of quiet sedimentation in an area devoid of turbating fauna (Figure 16). The constituents are dominated by moderately well preserved nannofossils and nannofossil debris (75 to 95%). Carbonate bomb analysis showed 40 to 80 per cent $CaCO_3$. A few scattered pyrite grains indicate reducing conditions. Other trace minerals include quartz, K-feldspar, chlorite (?), and some cristobalite. One large, unaltered, calcitic belemnite guard was recovered from Section 417D-21-3, 105 cm, and placed in the archive half of the core for later study.

The first basalts encountered in Sample 417D-21, CC and in the base of Section 417D-21-4 were broken, altered pieces from plagioclase phyric basalt. We did not recover any supra-basement rubble in this hole. Pockets and pods of recrystallized pelagic calcareous ooze occur between fresh-looking basalt pillows. These limestones are homogenous to layered, in some cases retaining pink coloration although most are green. That they were initially soft is shown by parallel layering defined by rows of tiny volcanic clasts. In thin sections, some ghosted foraminifers occur as well as calcite-replaced, spheroidal radiolarians. Calcite crystals from 4 to 100 microns across occur as anhedral, intergrown grains. In some intervals a low birefringent carbonate shows a growth texture which may indicate rapid decay of a thermal growth regime (see McKenzie and Kelts, this volume).

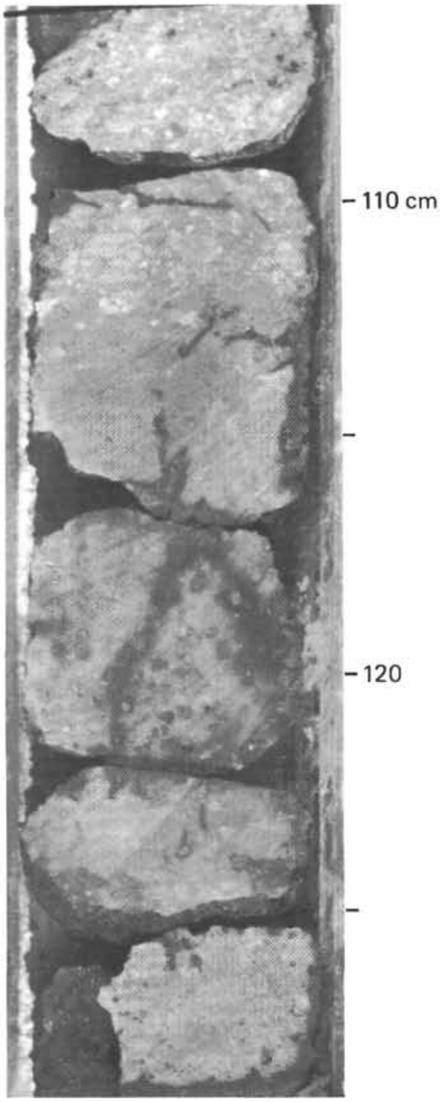


Figure 15. *Interval 417D-21-2, 105 to 127 cm. Gray chert layer with large volcanogenic clasts at the base of Unit VII. Clasts consist of bright green to golden yellow, redeposited fragments in a silica matrix.*

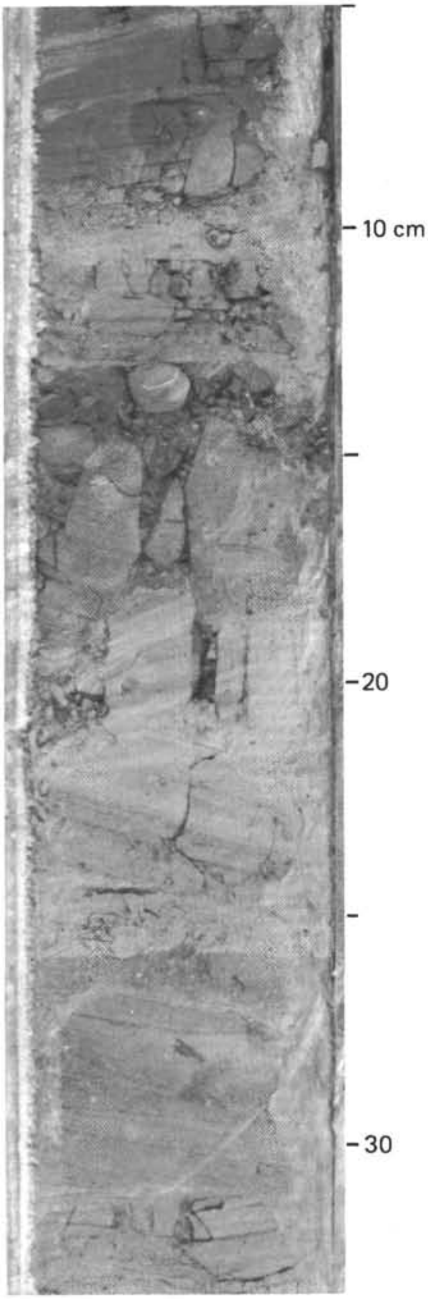


Figure 16. *Interval 417D-21-4, 5 to 33 cm. Olive-gray nannofossil chalk overlying basalt. Note the fine laminations and white striations suggestive of quiet bottom-water conditions (Unit VIII).*

BIOSTRATIGRAPHY

Foraminifers

Holes 417A and B

Planktonic foraminifers were recovered only from the first core in Hole 417A. In this interval the assemblage includes many solution-resistant as well as solution-susceptible forms. The solution-susceptible forms such as *Globigerinoides ruber, Orbulina universa, Globigerinella aequilateralis, Globigerina rubescens,* and *globigerinoides sacculifer* exhibit varying degrees of destructive solution. Among the solution-resistant species present, *Pulleniatina obliquiloculata, Sphaeroidinella dehiscens,* and *Globorotalia tumida* are numerically dominant. The presence in this interval of *Globigerina calida* and *Globigerina digitata* suggests a late Quaternary age. In the same interval, however, *Globorotalia truncatulinoides* is dominantly dextrally (right) coiled, implying an early Quaternary or late Pleistocene age. This apparent contradiction of evidence for the age dictates a simple designation of "Quaternary."

The present-day CCD level is well below the drill depth for this site, and we see a veneer of brown clays developing there today in response to this level. Further study into the mixing of these tropical Quaternary microfossils may also shed light on why calcareous assemblages are developing here.

Other intervals at this site in the zeolite clays, Eocene clay ooze, or Upper Cretaceous clays did not bear planktonic foraminifers. In the Upper Cretaceous interval several species of benthic foraminifers were noted, but the lack of an existing systhesis of benthic foraminiferal biostratigraphy precluded their use here.

Core 417B-1 contains a sparse fauna consisting of the following species: *Globigerina bulloides, G. digitata, G. quinqueloba, Globigerinella aequilateralis, Globigerinita glutinata, Globigerinoides conglobatus, G. ruber, G. sacculifer, Globorotalia truncatulinoides, Neogloboquadrina dutertrei, Neogloboquadrina pachyderma, Orbulina universa,* and *Sphaeroidinella dehiscens.* Much of the calcium carbonate in this core has been removed by dissolution, and consequently the planktonic foraminiferal faunas are dominated by solution-resistant species. The presence of *Globorotalia truncatulinoides* indicates a Quaternary age for Core 417B-1.

Hole 417D

Planktonic foraminifers were recovered at this site only in Cores 1, 17, 20, and 21. Faunas are well preserved, except in some intervals of Core 1 where the calcium carbonate has been partially dissolved. Core 1 bears a diverse warm water, Quaternary assemblage including: *Candeina nitida, Globigerina bulloides, G. digitata, G. falconensis, G. quinqueloba, Globigerinella aequilateralis, Globigerinita glutinata, Globigerinoides conglobatus, G. ruber, G. sacculifer, Neogloboquadrina dutertrei, and Neogloboquadrina pachyderma.* Core 17 bears planktonic foraminifers only in the upper part of Section 1 and the lower portion of Section 2. The assemblage here consists of: *Clavihedbergella moremani, Clavihedbergella simplex, Globigerinelloides bentonensis, Hedbergella amabilis, Hedbergella delroiensis, Hedbergella planispira, Hedbergella yezoana, Rotalipora ticincusis,* and *Schackoina cenomania.* This assemblage indicates a middle Cenomanian age. The stratigraphic position ranges from uppermost Albian to lower Cenomanian.

Foraminifers in Core 20 were found only in the upper part of Section 2.

Planktonic foraminiferal faunas recovered from Sections 21-3 and 4 are dominated by very small globigerinaceans. One of the species present, *Hedbergella similis,* places the sample in the lower Aptian stage.

Radiolarians

Hole 417A

Well-preserved Eocene radiolarians in the interval from Core 14 through Core 17 permitted the precise zonation of this silica-rich portion of the sequence.

Core 14 in its entirety is assigned to the *Podocyrtis Chalara* Zone. This is a range zone and, although the zonal species is never common, it occurs consistently throughout the core. Also common in this interval are the species *Podocyrtis mitra, P. papalis, Lithocyclia ocellus, Lithochytris vespertilio, Cycladophora hispida, Sethochytris triconiscus,* and *Eusyringium fistuligerum.*

Core 15 is assigned to the *Podocyrtis mitra* Zone. This is a partial-range zone defined at its base by the evolutionary first occurrence of *P. mitra* and at its top by the evolutionary first occurrence of *P. chalara.* Common species in the *P. mitra* Zone in Hole 417A are *Theocampe mongolfieri, Lithochytris vespertilio, Podocyrtis papalis, Thyrsocyrtis rhizodon, T. triacantha, and Cycladophora hispida.*

Core 16 is assigned to the *Podocyrtis ampla* Zone. This is a partial-range zone defined at its base by the evolutionary first appearance of *P. ampla* and at its top by the first appearance of *P. mitra.*

Poorly preserved radiolarian species of the genus *Dictyomitra* occur in scattered intervals from Core 18 to the radiolarian ooze in Cores 20 and 21. Below this interval, a single sandy interbed in Section 24-1 bears radiolarians identical to those in the interval above. These scattered occurrences are characterized by the conical multisegmented nasselarian forms common to Upper Cretaceous radiolarian assemblages elsewhere. Included in these assemblages are several species of spheroidal forms resembling *Acaeniotyle umbilicata,* drop-shaped forms similar to *Dictyomitra excellens,* and cruciform specimens resembling *Crucella espartoensis.*

Hole 417D

Radiolarians are absent from Hole 417B and from Cores 417D-1, 16, and 18 but are present in most other samples from Hole 417D. They are poorly preserved throughout most of the sedimentary section.

Radiolarians in Cores 2 and 3 have been replaced by zeolite, and consequently are very poorly preserved. A single specimen of *Podocyrtis mitra* is present in Sample 417D-2, CC, indicating a middle Eocene age, but it is possible that this specimen had been reworked.

Section 5-1 contains an abundance of well-preserved radiolarians, including the following age-diagnostic species: *Cycladophora hispida, Eusyringium fistuligerum, Lithochytris vespertilio, Lithocyclia ocellus* gp., *Lychnocanoma babylonis* gp., *Podocyrtis mitra, P. papalis, P. sinuosa, Sethochytris triconiscus, Theocampe mongolfieri, Thyrosocyrtis rhizodon,* and *T. triacantha.* This fauna and a similar one in Sample 417D-5, CC are assigned to the middle part of the middle Eocene (*Podocyrtis mitra* Zone). This occurrence is identical to that in Core 417A-15. Sediments recovered in Core 6 consist of a small amount of brown clay in the core catcher, which bears scarce specimens of middle Eocene radiolarians from the *Podocyrtis mitra* Zone. Because of the long interval between the base of Core 6 and the known position of the *P. mitra* Zone in Section 5-1, the sediments in Sample 6, CC apparently are not *in situ.*

Cretaceous radiolarians are present in most samples from Core 7 through Core 21. These microfossils are usually poorly preserved because of replacement by zeolite, but preservation is moderate in a few samples in which the siliceous skeletons have not been replaced. In the interval of intense zeolite alteration, only a few species of radiolarians have retained their siliceous skeletons. The faunas throughout this interval are nearly uniform, with fluctuations in diversity closely allied with fluctuations in degree of preservation. Cores 19, 20, and 21 contain radiolarians which have not undergone alteration to zeolite. Despite the lack of alteration, these faunas are not well preserved and species diversity is unchanged from that in the zeolitized faunas. The nearly uniform species composition from Cores 7 through 21 precluded biostratigraphic subdivision of this interval. Principal components of the faunas include: *Acaenio umbilicata, Amphibrachium*(?) sp., *Crucella espartoensis, Dictyomitra excellens, D.* (?) *lacimula, D. torquata*(?), *Gongylothorax verbeeki, Rhopalodictyum* sp., *Spongosaturnalis* cf. *S. lateralis, S.* cr. *S. amplissima*, and *Theocampe* sp.

Calcareous Nannofossils

Site 417

Calcreous nannofossils were recovered from Core 1 at both Holes 417B and 417D, and from Cores 17 through 21 at Hole 417D. At Hole 417D very rare specimens of a single species, *Watznaueria barnesae*, were recovered also from Cores 5 through 16 and from Core 22. No great significance can be attached to this single species except perhaps that it probably signifies a Cretaceous age, although it should be noted that this species is the most commonly redeposited Cretaceous form.

The calcareous nannofossil assemblage in Core 1 at Holes 417B and 417D contains primarily Pleistocene elements, as is the case also at Holes 417 and 417A, and includes *Gephyrocapsa oceanica, Helicosphaera carteri, Ceratolithus cristatus, Cyclococcolithus leptoporus, Cyclococcolithus macintyrei, Geophyrocapsa* spp., *Pseudoemiliania lacemosa* as well as *Thoracosphaera heimi, Thoracosphaeria saxea, Scyphosphaera globulosa*, and *Rhabdothorax* cf. *generus*. These last four species are generally associated with hemipelagic sediments, and it is, therefore, reasonable to infer that they, along with the other calcareous material, have been displaced to this area, for example by a turbidity current (see also Holes 417 and 417A).

The calcareous nanofossils from Cores 17 through 21 at Hole 417D are associated with the dark colored claystone, clayey nannofossil chalk, and limestone that make up a large part of the Early and "mid" Cretaceous sediment. The assemblage at any one level may vary considerably in diversity (number of species present) and in preservation of specimens. Most assemblages are dominated by one or a few solution-resistant species, most prominent among them being *Watznaueria barnesae, Manivitella pemmatoidea, Cretarhabdus surirellus (= Cretarhabdus crenulatus), Cruciellipsis chiastia, Parhabdolithus asper, Parhabdolithus embergeri, Lithastrinus floralis*, and *Lithraphidites carniolensis*. All assemblages are to some degree residual, and the large amount of fragmentation in samples with greatest diversity indicates that far more of the coccolith have been destroyed by solution than were preserved.

The age of the fossiliferous interval at Hole 417D extends from late Albian (possibly Cenomanian) in Core 17, to early Albian to late Aptian in Cores 20 and 21, to early Aptian at the base of Core 21. Key indicators are as follows: *Eiffellithus turriseiffeli* and *Prediscosphaera cretacea* throughout Section 17-1 indicate that this level is no older than late Albian; the absence of the above two species but continued presence of *Lithastrinus floralis* in Cores 21 and 22 to about midway through Section 3 indicates an age span of early Albian to late Aptian. It is possible that the early Albian is represented by a more or less barren or very sparsely fossiliferous interval between Cores 17 and 20, and that the interval including Cores 20 and 21 is entirely Aptian in age. However, the assemblages lack definitive elements and it is not possible to preclude an early Albian age for this level. The lowest sample in Section 21-3 lacks *Lithastrinus floralis*, although the assemblage is well preserved and diverse. This absence can, therefore, be best explained by assigning an early Aptian age to this level and the less fossiliferous samples immediately below it.

Ichthyoliths

One of the fundamental problems of Sites 417 and 418 with respect to biostratigraphy was the thick sequences of brown clays completely lacking in calcareous or siliceous microfossils. Although we were able to recover well-preserved radiolarians from short intervals in each site, much of the upper half of each hole was difficult to date above the Cretaceous.

The biostratigraphic scheme for fossil fish debris of "ichthyoliths" proposed by Riedel, Doyle, and Kennedy is even now still tentative but nonetheless useful for picking epochs in the Tertiary. Some problems with post-depositional displacement of sediments (probably by turbidity currents) remain to be sorted out. In particular, the ages yielded by ichthyolith stratigraphy occasionally differ from those derived from study of radiolarians, foraminifers, and nannofossils. That in a few cases the latter three groups are in agreement, whereas the ichthyoliths are much older, suggests a physical sorting process during displacement.

Hole 417A

Well-preserved, but sparse, ichthyoliths were recovered from all cores at this hole, except Cores 3, 4, 7, 13, 14, and 17. Core 1 is Quaternary, in agreement with data from other microfossil groups. Section 2-2 is assigned to the middle Miocene on the basis of overlapping ranges of *Long triangle stepped margin* and an undescribed subtype of *Wide triangle*. Ichthyoliths from Section 2-3 to Core 5 are assigned to the interval from late Oligocene to middle Miocene.

Section 6-1 bears both *Short triangle stepped margin* and a persistent Oligocene form of a3/bl or *Polygonal cavity long rays* (undescribed) and is assigned to the late Oligocene. Section 8-1 marks the highest stratigraphic occurrence of *Two curved triangle long base* and is assigned to the early Oligocene.

The initial appearance of the subtypes *Plain ellipse, Skewed four or five peaks* and *Three equal peaks flared base* in the interval from Section 8-4 to Section 9-3 indicates a late Eocene to early Oligocene age for this interval.

Section 9-4 to Section 10-1 is assigned to the late Eocene by the initial appearance of *Small dendritic many radiating lines* and *Large with numerous lines.*.

Section 10-2 to Core 15 is assigned to the middle Eocene to late Eocene by the initial appearance of *Rounded apex triangle, Flexed narrow triangle 120-128, Curved triangle pointed margin ends,* and *Skewed four or five peaks.*.

Assignment of Cores 16 through 20 is impossible for the lack of a stratigraphic synthesis of lower Paleogene ichthyoliths.

Hole 417B

Recovery from this hole consisted of only one core in which well-preserved ichthyoliths are present in notable quantities.

Although other microfossil groups indicate a Quaternary age for the core, ichthyolith data clearly suggest a much older interval: middle Miocene to late Miocene.

Sections 1-2, 3, and 4 are suggestive of the above Miocene interval by the presence of *Triangle pointed margin ends, Triangle medium wing,* and *Polygonal cavity* (an undescribed form of a3/bl). Core 1 core catcher bears a middle Miocene ichthyolith fauna characterized by the mutual occurrence of *Long triangle stepped margin* and *Short side peak differentiated margin.*

Hole 417D

The very sparse faunas of ichthyoliths recorded throughout this hole preclude precise correlations based on this microfossil group. The paucity of ichthyoliths here could be attributed to either insufficient sample volume or rapid depositional history diluting the ichthyolith microfossil assemblage.

The occurrences of *Triangle pointed margin ends* and *Triangle short wing* in Section 1-2 and Sample 1, CC suggest a middle Miocene age for the interval, but the simultaneous occurrence in these samples of the Pliocene form *Triangle hooked margin* indicates that the forms may be reworked.

In Section 2-2, the presence of *Asymmetrical peak wide depression* suggests that this level cannot be younger than middle Miocene. Similarly, the occurrence of *Kite-shaped elongate prominence* and *Plain lanceolate* in Core 5 correlations indicate that this level cannot be younger than late Oligocene.

PHYSICAL PROPERTIES OF SEDIMENTS

Measurements of wet-bulk density, compressional wave velocity (*Vp*), shear strength, water content, and porosity were made throughout the cored sediment intervals in Holes 417A and 417D. Our objective was to find out how physical properties change with depth and to make comparisons with both the results of logging in Hole 417D and the seismic reflection record over the site. These data, together with computed values of grain density and acoustic impedance, are presented as a function of sub-bottom depth in Table 4 and Figure 17 for Hole 417A, and in Table 5 and Figure 18 for Holes 417B and 417D. Values of sediment thermal conductivity and thermal resistivity measured in Hole 417A are presented in Table 6 and Figure 17.

Since Hole 417D was drilled at a distance of only 450 meters from Hole 417A, and was continuously cored (in the sediments) only between 192 and 343 meters sub-bottom, whereas Hole 417A was cored between 0 and 211 meters sub-bottom, for the purposes of discussion the cored sediment interval in Hole 417D may be considered a downward continuation of Hole 417A. It should be borne in mind, however, that the physical properties observed in the deeper levels of such a composite column will only apply where the Aptian to Late Cretaceous section is actually present.

Wet-Bulk Density and Grain Density

The values of wet-bulk density presented in Figures 17 and 18 were obtained at room temperature and pressure by either the syringe or the two-minute GRAPE technique described by Boyce (1973). Also shown for comparison are semi-continuous estimates of wet-bulk density obtained by the continuous GRAPE technique and values of grain density computed from mineral abundances determined by Muller from XRD analysis (this volume). Of the two techniques for measuring wet-bulk density of discrete samples, the syringe technique is considered the less accurate (±5%) owing to distortion during laboratory sampling. When corrected, as here, for measured, rather than assumed values of sediment grain density, the two-minute and continuous GRAPE techniques are considered accurate to ±2 per cent and ±5 per cent, respectively.

Syringe values of sediment wet-bulk density obtained for Holes 417A and 417D increase slowly with depth from approximately 1.65 g/cm^3 near the top of the column to about 1.75 g/cm^3 at a sub-bottom depth of 315 meters in Hole 417D. The only significant departures from this trend are near the mudline where densities as low as 1.44 g/gm^3 are observed; at 100 meters, where densities as high as 1.92 g/cm^3 are briefly encountered; and near the base of the column in Hole 417D between 315 and 340 meters, where densities increase rapidly to values as high as 2.12 g/cm^3. Excluding the low-density samples at the top of the column (Core 1 in Holes 417A and 417D), the mean sediment density for the column is 1.71 g/cm^3. Wet-bulk density values obtained by the two-minute and continuous GRAPE techniques display the same trend of slowly increasing density with depth. Quite strikingly, the grain density ranges narrowly between 2.55 and 2.65 g/cm^3 with a mean of 2.60 g/cm^3 throughout this same interval. The only departure from this trend is again toward the base of the column in Cores 17 through 21 in Hole 417D, where the grain density increases to values as high as 2.79 g/gm^3 in response

TABLE 4
Physical Properties of Sediment, Hole 417A

Sample (Core-Section, Interval in cm)	Density		P-Wave Velocity (km/s)	Acoustic[a] Impedance (×10^{5}g/cm^2-s)		Shear Strength (tons/ft^2)	Water Content (% wet weight)	Porosity[a] (vol. %)
	Wet-Bulk (g/cm^3)[a]	Grain (g/cm^3)[b]						
1-1, 70-73	–	–	–	–	–	0.04	–	–
1, 79-81	1.51	–	–	–	–	–	47.5	71.9
2, 118-121	–	–	–	–	–	0.06	–	–
3, 13-14	1.45	–	–	–	–	–	46.2	67.1
3, 16-20	–	–	–	–	–	0.05	–	–
4, 65-67	–	–	1.49	(2.29)	2.26	–	–	–
4, 68-71	–	–	–	–	–	0.08	–	–
4, 75	(1.54)	–	–	–	–	–	–	(68.0)
4, 144-150	1.52	–	–	–	–	–	47.7	72.5
5, 30-32	–	2.63	–	–	–	–	–	–
5, 64-67	–	–	–	–	–	0.08	–	–
5, 90-91	1.52	–	–	–	–	–	47.3	71.9
6, 15-17	–	–	–	–	–	0.05	–	–
2-1, 86-87	1.59	–	–	–	–	–	48.1	76.8
1, 112-116	–	–	–	–	–	0.08	–	–
2, 135-140	–	–	–	–	–	0.08	–	–
3, –[c]	–	2.63	–	–	–	–	–	–
3, 75	(1.59)	–	–	–	–	–	–	(65.0)
3, 75-77	–	–	1.50	(2.39)	2.51	–	–	–
3, 90-94	–	–	–	–	–	0.14	–	–
3, 113-114	1.67	–	–	–	–	–	47.6	78.6
3-1, 104-106	–	–	–	–	–	0.14	–	–
1, 109-110	1.68	–	–	–	–	–	45.2	75.9
2, 129-131	–	–	–	–	–	0.09	–	–
3, 50-51	1.68	–	–	–	–	–	45.1	75.5
3, 119-121	–	–	–	–	–	0.15	–	–
4, 60-62	–	–	1.50	–	–	–	–	–
4, 87-89	–	–	1.50	–	–	–	–	–
4, 113-115	–	–	1.52	–	–	–	–	–
4, 119-121	–	–	–	–	–	0.14	–	–
4, 140-142	–	–	1.51	(2.43)	2.48	–	–	–
5, –[c]	–	2.61	–	–	–	–	–	–
5, 26-27	1.64	–	–	–	–	–	45.8	75.2
5, 75	(1.61)	–	–	–	–	–	–	(63.0)
5-1, 40-41	1.71	–	–	–	–	–	44.3	75.6
1, 52-55	–	–	–	–	–	0.26	–	–
2, 14-16	–	–	–	–	–	0.23	–	–
2, 53-55	–	–	1.50	–	2.55	–	–	–
6-1, 26-30	–	–	–	–	–	0.15	–	–
1, 52-53	1.70	–	–	–	–	–	45.3	77.1
2, 37-39	–	–	–	–	–	0.27	–	–
3, 32-35	–	–	1.49	(2.29)	2.46	–	–	–
3, 46-47	1.67	–	–	–	–	–	44.9	74.2
3. 118-120	–	–	–	–	–	0.14	–	–
4, 67-69	–	–	–	–	–	0.19	–	–
4, 70-71	1.69	–	–	–	–	–	43.9	74.4
5, –[c]	–	2.62	–	–	–	–	–	–
5, 120-122	–	–	–	–	–	0.13	–	–
5, 144-150	1.51	–	–	–	–	–	52.2	78.9
6, 45	(1.54)	–	–	–	–	–	–	(68.0)
7, 12-14	–	–	–	–	–	0.16	–	–
8-1, 94-95	1.62	–	–	–	–	–	37.0	60.0
1, 95-100	–	–	–	–	–	0.28	–	–
2, 107-109	–	–	–	–	–	0.16	–	–
3, –[c]	–	2.61	–	–	–	–	–	–
3, 48-49	1.67	–	–	–	–	–	43.1	71.9
3, 55-57	–	–	–	–	–	0.25	–	–
3, 90	(1.59)	–	–	–	–	–	–	(64.0)
3, 110-113	–	–	1.51	(2.40)	2.52	–	–	–
5, 7-9	–	–	–	–	–	0.50	–	–

TABLE 4 – *Continued*

Sample (Core-Section, Interval in cm)	Density		*P*-Wave Velocity (km/s)	Acoustic[a] Impedance ($\times 10^5$g/cm^2-s)		Shear Strength (tons/ft^2)	Water Content (% wet weight)	Porosity[a] (vol. %)
	Wet-Bulk (g/cm^3)[a]	Grain (g/cm^3)[b]						
9-1, 67-68	1.66	–	–	–	–	–	46.5	77.0
1, 89-91	–	–	–	–	–	0.40	–	–
2, 37-39	–	–	–	–	–	0.56	–	–
3, 33-35	–	–	–	–	–	0.26	–	–
3, 38-39	1.73	–	–	–	–	–	41.2	71.3
3, 75-77	–	–	1.52	(2.46)	2.63	–	–	–
4, 75	(1.62)	–	–	–	–	–	–	(62.0)
4, 103-105	–	–	–	–	–	0.33	–	–
5, –[c]	–	2.61	–	–	–	–	–	–
5, 19-20	1.65	–	–	–	–	–	45.6	75.3
5, 33-35	–	–	–	–	–	0.26	–	–
10-1, 28-30	–	–	–	–	–	0.31	–	–
2, 75	(1.66)	–	–	–	–	–	–	(60.0)
2, 88-90	–	–	–	–	–	0.53	–	–
3, –[c]	–	2.63	–	–	–	–	–	–
3, 10-12	–	–	–	–	–	0.70	–	–
3, 39-40	1.62	–	–	–	–	–	42.7	69.1
3, 50-53	–	–	1.54	(2.56)	2.49	–	–	–
4, 25-27	–	–	–	–	–	0.64	–	–
11-1, 34-36	–	–	–	–	–	0.65	–	–
1, 36-37	1.91	–	–	–	–	–	38.2	73.3
2, 25-27	–	–	–	–	–	0.80	–	–
3, 20-22	–	–	–	–	–	0.91	–	–
3, 78-79	1.82	–	–	–	–	–	39.3	71.4
4, 75	(1.68)	–	–	–	–	–	–	(58.0)
4, 75-78	–	–	1.54	(2.59)	2.80	–	–	–
4, 130-132	–	–	–	–	–	0.92	–	–
4, 144-150	1.84	–	–	–	–	–	40.0	73.7
5, –[c]	–	2.59	–	–	–	–	–	–
5, 45-47	–	–	–	–	–	0.75	–	–
5, 66-67	1.68	–	–	–	–	–	42.0	70.8
12-1, 8-10	–	–	–	–	–	0.53	–	–
1, 95-96	1.75	–	–	–	–	–	41.2	72.0
2, 113-115	–	–	–	–	–	0.83	–	–
3, –[c]	–	2.56	–	–	–	–	–	–
3, 75-77	–	–	–	–	–	0.88	–	–
3, 90-93	–	–	1.54	(2.56)	2.70	–	–	–
4, 44-46	–	–	–	–	–	0.69	–	–
4, 100	(1.66)	–	–	–	–	–	–	(59.0)
13-1, 4-6	–	–	–	–	–	0.53	–	–
2, 116-118	–	–	–	–	–	0.92	–	–
3, 14-15	–	–	–	–	–	1.05	–	–
3, 35-36	1.71	–	–	–	–	–	39.9	68.4
4, 36-38	–	–	1.57	(2.43)	2.68	–	–	–
5, –[c]	–	2.58	–	–	–	–	–	–
5, 66-67	1.55	–	–	–	–	–	55.2	85.7
5, 74-76	–	–	–	–	–	0.20	–	–
5, 75	(1.55)	–	–	–	–	–	–	(66.0)
14-1, 92-94	–	–	–	–	–	1.30	–	–
2, 55-56	1.75	–	–	–	–	–	39.9	69.9
2, 70-72	–	–	–	–	–	0.78	–	–
3, –[c]	–	2.56	–	–	–	–	–	–
3, 65-67	–	–	–	–	–	0.73	–	–
3, 67-70	–	–	1.58	(2.53)	2.50	–	–	–
3, 75	(1.60)	–	–	–	–	–	–	(62.0)
3, 80-81	1.58	–	–	–	–	–	44.0	69.4
4, 9-11	–	–	–	–	–	0.88	–	–

TABLE 4 – *Continued*

Sample (Core-Section, Interval in cm)	Density Wet-Bulk (g/cm^3)[a]	Density Grain (g/cm^3)[b]	*P*-Wave Velocity (km/s)	Acoustic[a] Impedance ($\times 10^5$g/cm^2-s)		Shear Strength (tons/ft^2)	Water Content (% wet weight)	Porosity[a] (vol. %)
15-1, 8-9	1.67	–	–	–	–	–	47.0	78.7
1, 38-40	–	–	–	–	–	0.15	–	–
2, 10-12	–	–	1.54	(2.60)	2.57	–	–	–
2, 58-60	–	–	–	–	–	0.20	–	–
2, 120-122	–	–	1.54	–	–	–	–	–
3, –[c]	–	2.55	–	–	–	–	–	–
3, 26-27	1.64	–	–	–	–	–	42.0	69.1
3, 75	(1.69)	–	–	–	–	–	–	(56.0)
3, 117-119	–	–	–	–	–	0.63	–	–
4, 54-56	–	–	–	–	–	0.43	–	–
16-1, 83-85	–	–	–	–	–	0.70	–	–
2, 88-90	–	–	–	–	–	0.63	–	–
3, –[c]	–	2.56	–	–	–	–	–	–
3, 57-58	1.75	–	–	–	–	–	41.2	71.7
3, 68-70	–	–	–	–	–	0.80	–	–
4, 77-78	–	–	–	–	–	0.65	–	–
5, 69-70	1.75	–	–	–	–	–	40.6	71.1
5, 90-92	–	–	–	–	–	0.46	–	–
6, 21-22	–	–	–	–	–	0.63	–	–
6, 82-85	–	–	1.61	(2.72)	2.82	–	–	–
7, 0-6	1.74	–	–	–	–	–	40.5	70.7
7, 20	(1.69)	–	–	–	–	–	–	(57.0)
7, 28-30	–	–	–	–	–	0.33	–	–
18-1, 84-86	–	–	–	–	–	0.88	–	–
2, 99-100	1.73	–	–	–	–	–	42.0	72.8
2, 100-102	–	–	–	–	–	1.28	–	–
3, –[c]	–	2.63	–	–	–	–	–	–
3, 15-16	1.83	–	–	–	–	–	35.0	63.9
3, 24-27	–	–	1.55	–	–	–	–	–
3, 75	(1.57)	–	–	–	–	–	–	(66.0)
19-1, 84-86	–	–	–	–	–	1.30	–	–
2, 56-58	–	–	–	–	–	1.25	–	–
3, –[c]	–	2.61	–	–	–	–	–	–
3, 10-12	–	–	–	–	–	1.38	–	–
3, 24-25	1.57	–	–	–	–	–	31.8	49.9
3, 51-54	–	–	1.59	(2.64)	2.50	–	–	–
4, 27-29	–	–	–	–	–	1.20	–	–
4, 75	(1.66)	–	–	–	–	–	–	(60.0)
6, 10-12	–	–	–	–	–	0.40	–	–
20-1, 21-23	–	–	–	–	–	1.23	–	–
1, 24-25	1.78	–	–	–	–	–	35.1	62.5
2, 39-42	–	–	1.54	(2.53)	2.74	–	–	–
2, 67-69	–	–	–	–	–	0.49	–	–
5, –[c]	–	2.63	–	–	–	–	–	–
5, 74-75	1.75	–	–	–	–	–	37.3	65.2
5, 75	(1.64)	–	–	–	–	–	–	(62.0)
21-1, 60-61	1.78	–	–	–	–	–	38.9	69.1
1, 75-76	–	–	–	–	–	0.28	–	–
2, 30	(1.64)	–	–	–	–	–	–	(61.0)
2, 53-55	–	–	1.62	(2.66)	2.84	–	–	–
2, 70-72	–	–	–	–	–	0.55	–	–
3, –[c]	–	2.60	–	–	–	–	–	–
3, 0-10	1.75	–	–	–	–	–	41.6	72.7
3, 11-12	1.71	–	–	–	–	–	41.4	70.9
3, 23-25	–	–	–	–	–	0.14	–	–

[a] GRAPE values in parentheses.

[b] From XRD.

[c] Position within section not documented.

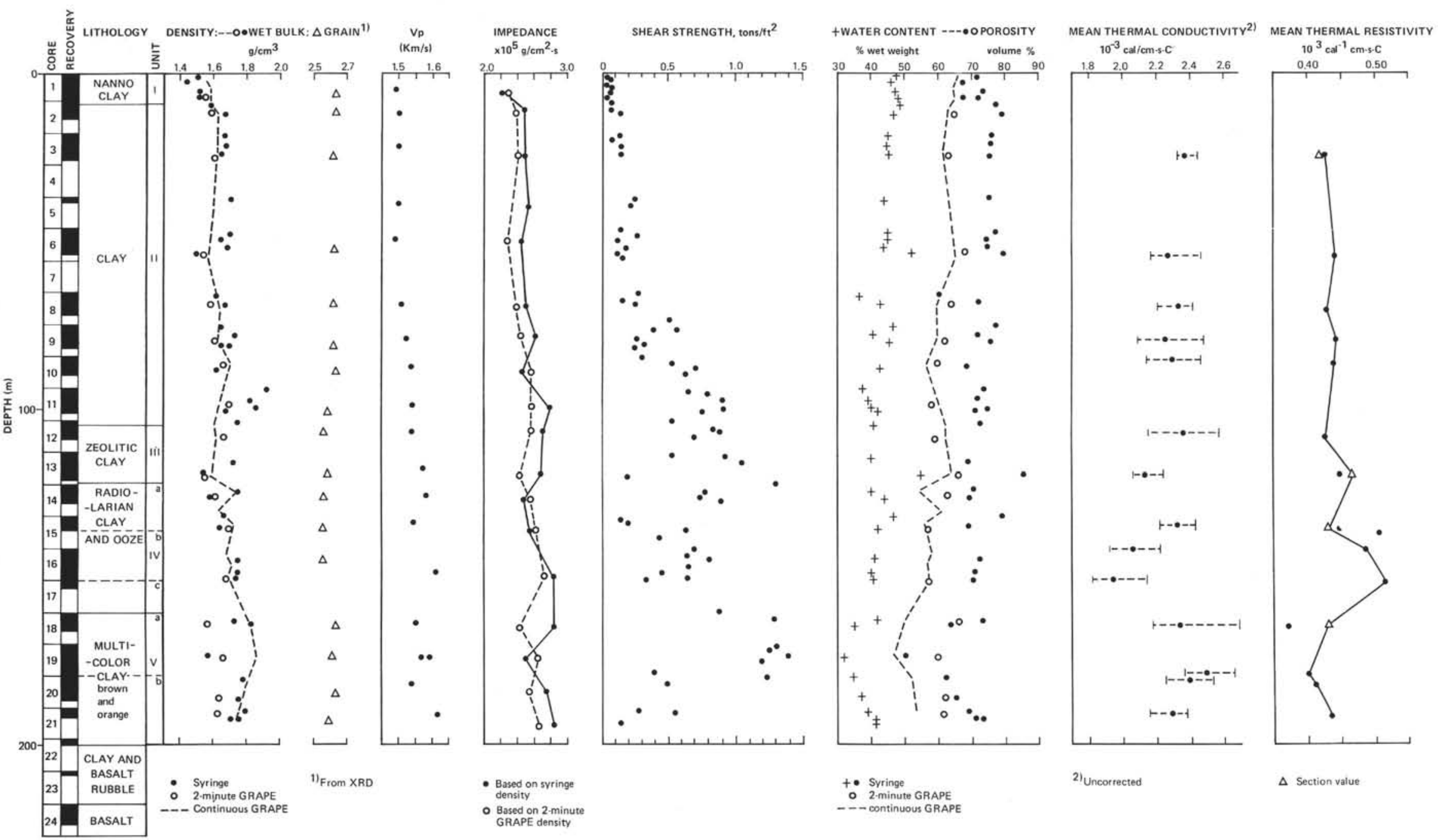


Figure 17. *Hole 417A: sediment physical properties.*

TABLE 5
Physical Properties of Sediment, Holes 417B and D

Sample (Hole-Core-Section, Interval in cm)	Density		*P*-Wave Velocity[b] (km/s)		Acoustic Impedance[b] ($\times 10^5$g/cm^2-s)		Shear Strength (tons/ft^2)	Water Content (% wet weight)	Porosity (vol. %)
	Wet-Bulk (g/cm^3)	Grain[a] (g/cm^3)							
417B-1-3, 120-123	1.54	–	–	–	–	–	0.05	52.4	80.6
4, 40-43	–	–	–	–	–	–	0.04	–	–
4, 50-53	–	–	–	–	–	–	0.05	–	–
417D-1-3, 144-145	1.57	–	–	–	–	–	–	44.4	69.4
4, 81-85	–	–	–	–	–	–	0.06	–	–
7-2, –[c]	–	2.55	–	–	–	–	–	–	–
2, 120-121	1.71	–	1.60(⊥)	–	2.74(⊥)	–	–	34.5	59.0
2, 131-133	–	–	–	–	–	–	1.55	–	–
8-1, –[c]	–	2.55	–	–	–	–	–	–	–
1, 99-102	–	–	1.66(⊥)	–	–	–	–	–	–
9-1, –[c]	–	2.62	–	–	–	–	–	–	–
1, 61-64	–	–	1.61(⊥)	–	2.53(⊥)	–	–	–	–
1, 84-85	1.57	–	–	–	–	–	–	33.1	52.1
1, 112-14	–	–	–	–	–	–	1.23	–	–
10-1, 89-90	1.76, 1.89	–	–	–	–	–	–	29.2	47.3, 54.5
1, 92-94	–	–	–	–	–	–	1.78	–	–
2, –[c]	–	2.62	–	–	–	–	–	–	–
2, 45-48	–	–	1.62(⊥)	–	2.85(⊥)	–	–	–	–
2, 110-112	–	–	–	–	–	–	2.03	–	–
3, 63-64	1.63	–	–	–	–	–	–	34.6	56.2
3, 120-122	–	–	–	–	–	–	1.78	–	–
11-1, 71-74	1.66	–	1.73(⊥)	1.69(II)	2.87(⊥)	2.81(II)	–	35.8	59.5
12-2, –[c]	–	2.58	–	–	–	–	–	–	–
2, 19-20	1.40	–	–	–	–	–	–	9.9	13.9
2, 90-92	–	–	–	–	–	–	1.08	–	–
3, 79-81	–	–	–	–	–	–	1.24	–	–
3, 107-108	1.76	–	–	–	–	–	–	31.4	54.1
4, 19-22	–	–	1.63(⊥)	–	–	–	–	–	–
13-1, –[c]	–	2.58	–	–	–	–	–	–	–
1, 70-71	1.90	–	–	–	–	–	–	27.8	52.8
1, 79-82	–	–	1.66(⊥)	–	3.15(⊥)	–	–	–	–
1, 87-89	–	–	–	–	–	–	1.85	–	–
2, 30-32	–	–	–	–	–	–	1.58	–	–
14-1, 15-16	1.76	–	–	–	–	–	–	29.3	51.5
1, 57-59	–	–	–	–	–	–	1.93	–	–
2, 105-106	1.73	–	–	–	–	–	–	30.3	52.2
2, 111-113	–	–	–	–	–	–	2.10	–	–
3, –[c]	–	2.59	–	–	–	–	–	–	–
3, 88-89	1.76	–	–	–	–	–	–	29.9	52.8
3, 108-110	–	–	–	–	–	–	1.80	–	–
4, 30-31	1.80	–	–	–	–	–	–	29.5	53.0
4, 104-107	–	–	1.65(⊥)	–	2.97(⊥)	–	–	–	–
4, 112-114	–	–	–	–	–	–	1.55	–	–
5, 11-13	–	–	–	–	–	–	1.55	–	–
5, 106-107	1.66	–	–	–	–	–	–	29.3	48.7
15-1, 43-45	–	2.57	–	–	–	–	–	–	–
1, 115-116	1.90	–	–	–	–	–	–	34.5	65.5
1, 142-145	–	–	1.61(⊥)	–	3.06(⊥)	–	–	–	–
2, 26-29	1.77	–	2.04(⊥)	1.74(II)	3.61(⊥)	3.08(II)	–	30.5	53.9
16-1, –[c]	–	2.61	–	–	–	–	–	–	–
1, 34-36	–	–	–	–	–	–	2.30	–	–
1, 69-72	–	–	1.66(⊥)	–	–	–	–	–	–
17-2, 50-53	1.71	–	1.66(⊥)	–	2.84(⊥)	–	–	34.7	59.5
2, 91-93	–	–	–	–	–	–	2.08	–	–
3, –[c]	–	2.66	–	–	–	–	–	–	–
3, 141-143	–	–	–	–	–	–	1.60	–	–
18-1, 72-75	1.64	–	1.73(⊥)	–	2.84(⊥)	–	–	34.2	55.9
2, –[c]	–	2.69	–	–	–	–	–	–	–
2, 63-64	–	–	–	–	–	–	1.65	–	–
19-1, –[c]	–	2.73	–	–	–	–	–	–	–
1, 41-43	1.99	–	2.05(⊥)	1.98(II)	4.08(⊥)	3.94(II)	–	28.6	57.0
20-2, –[c]	–	2.73	–	–	–	–	–	–	–
2, 113-115	2.12	–	2.25(⊥)	2.01(II)	4.77(⊥)	4.26(II)	–	18.3	38.8
21-2, –[c]	–	2.79	–	–	–	–	–	–	–
2, 77-79	1.97	–	1.85(⊥)	1.72(II)	3.64(⊥)	3.39(II)	–	24.8	48.8
4, –[c]	–	2.70	–	–	–	–	–	–	–

[a] From XRD.

[b] ⊥,II: Propagation direction perpendicular and parallel, respectively, to long axis of core.

[c] Position within section not documented.

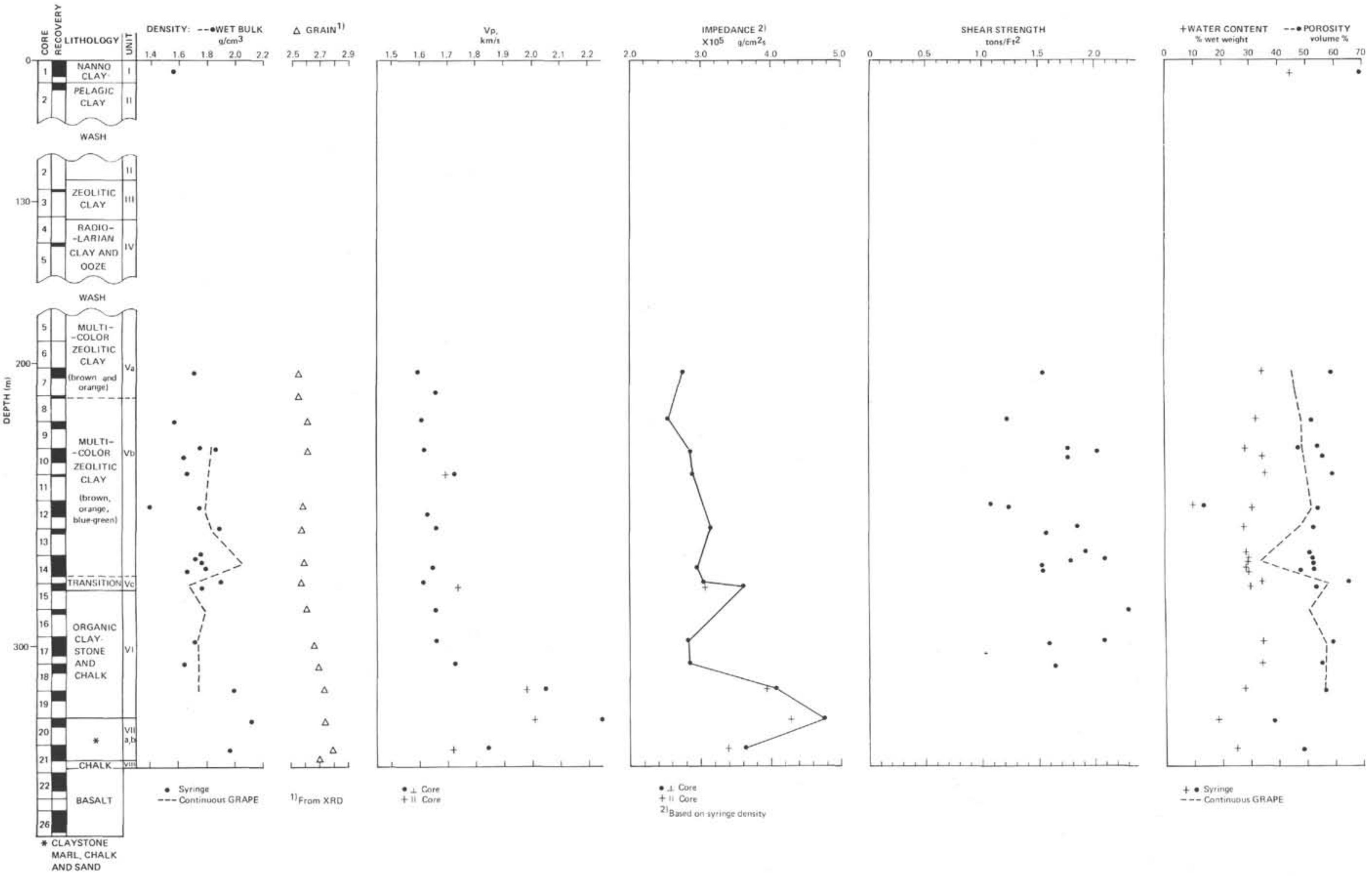


Figure 18. *Hole 417D: sediment physical properties.*

TABLE 6
Thermal Conductivity and Thermal Resistivity of Sediment, Hole 417A[a]

Sample (Core-Section, Interval in cm)	Mean Thermal Conductivity $\left(\frac{\text{cal}}{10^3\text{-cm-s-}^\circ\text{C}}\right)$	Mean Thermal Resistivity $\left(\frac{10^3\text{-cm-s-}^\circ\text{C}}{\text{cal}}\right)$	*n*	Mean Conductivity to Base of Section $\left(\frac{\text{cal}}{10^3\text{-cm-s-}^\circ\text{C}}\right)$	Mean Resistivity to Base of Section $\left(\frac{10^3\text{-cm-s-}^\circ\text{C}}{\text{cal}}\right)$	*n*	Mean Conductivity per Lithologic Unit $\left(\frac{\text{cal}}{10^3\text{-cm-s-}^\circ\text{C}}\right)$	*n*	Lithologic Unit
3-5, 30-120	2.37 ± 0.043	0.421 ± 0.008	4	2.37 ± 0.043	0.42 ± 0.008	4	2.30 ± 0.104	26	Unit II Clay
6-6, 30-130	2.28 ± 0.119	0.440 ± 0.023	4	2.32 ± 0.104	0.43 ± 0.019	8			
8-4, 25-125	2.33 ± 0.075	0.428 ± 0.014	5	2.33 ± 0.094	0.43 ± 0.017	13			
9-4, 10-135	2.26 ± 0.116	0.442 ± 0.023	6	2.31 ± 0.106	0.43 ± 0.020	19			
10-2, 20-140	2.28 ± 0.086	0.439 ± 0.017	7	2.30 ± 0.102	0.43 ± 0.019	26			
12-4, 20-120	2.35 ± 0.122	0.425 ± 0.022	6	2.31 ± 0.108	0.43 ± 0.020	32	2.26 ± 0.146	10	Unit III Zeolitic clay
13-5, 30-120	2.14 ± 0.076	0.466 ± 0.017	4	2.29 ± 0.117	0.44 ± 0.022	36			
15-3, 30-120	2.32 ± 0.084	0.431 ± 0.016	4	2.29 ± 0.115	0.44 ± 0.022	40	2.09 ± 0.179	13	Unit IV Radiolarian clay and ooze
16-1, 30-120	2.06 ± 0.103	0.486 ± 0.024	4	2.27 ± 0.135	0.44 ± 0.026	44			
17-1, 20-120	1.95 ± 0.103	0.513 ± 0.027	5	2.23 ± 0.171	0.45 ± 0.034	49			
18-3, 20-105	2.33 ± 0.180	0.429 ± 0.033	5	2.24 ± 0.174	0.45 ± 0.034	54	2.37 ± 0.143	19	Unit V Multicolor clay
19-6, 25-100	2.49 ± 0.112	0.401 ± 0.018	4	2.26 ± 0.181	0.44 ± 0.036	58			
20-2, 25-100	2.40 ± 0.016	0.417 ± 0.018	4	2.27 ± 0.181	0.44 ± 0.035	62			
21-2, 10-135	2.30 ± 0.074	0.435 ± 0.014	6	2.27 ± 0.175	0.44 ± 0.034	68			

[a] Uncorrected for *in situ* pressure and pressure.

to the appearance of relatively high-density calcite, dolomite, and mixed-layer clays in the section.

Compressional Wave Velocity

The values of compressional wave velocity shown in Figures 17 and 18 were obtained at room temperature and at zero pore and confining pressure, using the Hamilton Frame Velocimeter (Boyce, 1973). In most cases, the velocity was measured perpendicular to the long axis of the core through the core liner. In several instances, particularly near the base of the column where the sediments were more lithified, it was possible to remove coherent samples from the liner for measurement of Vp both parallel and perpendicular.

The values of compressional wave velocity in Holes 417A and 417D increase slowly with depth from approximately 1.50 km/s near the mudline to about 1.65 km/s at a depth of 300 meters sub-bottom. At levels below 300 meters and in one sample at 280 meters, velocities increase sharply to values as high as 2.25 km/s in the horizontal propagation direction in response to the presence of carbonates and mixed-layer clays. Where coherent samples could be taken for the study of seismic anisotropy, Vp is always slow parallel to the core, i.e., perpendicular to bedding. This is consistent with the observation that the slow, or (001) axis in phyllosilicates (Alexandrov and Ryzhova, 1961) tends to lie perpendicular to bedding in compacted sediments.

Acoustic Impedance

As expected, the computed values of acoustic impedance shown in Figures 17 and 18 increase slowly with increasing sediment density and compressional wave velocity to a depth of about 280 meters. Although acoustic reflectors are clearly present in this interval in the seismic reflection profiles for Site 417, none can be discerned from laboratory acoustic impedance data because of drilling disturbance. Below this interval, however, the presence of sharp impedance contrasts associated with the clay to claystone transition in Unit V and the open to mixed-layer clay transition within Unit VI suggest the presence of acoustic reflectors at 280 and 310 meters in Hole 417D. An additional reflector marking the sediment/basalt transition will also be present at 211 and 343 meters, respectively, in Holes 417A and 417D.

Shear Strength

The values of sediment shear strength given in Figures 17 and 18 were obtained at room temperature and zero pore and confining pressure, using a Torvane meter with its axis of rotation aligned parallel to bedding in order to minimize biasing owing to foliation. The shear strength values observed by this means at Site 417 are very low throughout the upper part of the column, ranging from 0.04 tons/ft^2 at the mudline to approximately 0.25 tons/ft^2 at 75 meters. However, they increase rapidly with depth between 75 to 310 meters to as high as 2.3 tons/ft^2 in Unit VI. Below the open to mixed–layer clay transition at 310 meters, the sediments were too stiff for measurements to be continued. Although scatter in the data below 75 meters and both distortion and diapirism in the core itself indicate drilling disturbance, casing suction tests conducted in Hole 417D tend to confirm laboratory measurements of shear strength for the upper levels of the column. This suggests that the discontinuities in shear strength behavior observed at 75 and 310 meters loosely reflect *in situ* changes.

Water Content and Porosity

The water content and porosity of the sediments at Site 417 were determined by the syringe technique supplemented by two-minute and continuous GRAPE determinations of porosity. As discussed above in conjunction with measurements of wet-bulk density, the syringe technique is considered accurate to ±5 per cent, while the two-minute GRAPE technique, when corrected for grain density, is accurate to ±2 per cent. As can be seen in Figures 17 and 18, the porosity of the sediments as measured by the syringe technique decreases with considerable scatter from a high of about 77 per cent near the top of the column to a low of approximately 50 per cent near the base of the sediments in Hole 417D. The only significant departure from this trend is again in the basal sediments below 310 meters, where porosities as low as 38 per cent are encountered. Where GRAPE data are available, a trend parallel to, but lower than the syringe data by approximately 11 per cent, is observed. As expected, the syringe water content trend at Site 417 mimics the porosity trend, with values decreasing with depth from 47 per cent near the mudline to approximately 25 per cent near the base of the column in Hole 417D.

Thermal Conductivity

The thermal conductivity of the sediments in Hole 417A was determined onboard the *Glomar Challenger* using the heated needle-probe technique of von Herzen and Maxwell (1959). Between four and seven measurements spaced 20 to 30 cm apart were made in one section per core in 14 cores for a total of 68 measurements, each with an estimated accuracy of ±4 per cent. The choice of the section to be measured was influenced by the position of five downhole temperature measurements which unfortunately were unsuccessful. All measurements were made after the cores had equilibrated to room temperature; none has been corrected for *in situ* pressure and temperature since the latter is not accurately known.

For a core in which the thermal conductivity varies along its length, the appropriate mean value for heat-flow determinations is the reciprocal of the mean thermal resistivity (i.e., the harmonic mean) along the core rather than the arithmetic mean of the thermal conductivity. The harmonic mean, $\bar{K}$, and the mean thermal resistivity, $\bar{R}$, presented for each core, each lithologic unit, and as a function of depth in Table 6, were accordingly determined from the relation

$$\bar{K} = [\overset{1}{}_{N}(\Sigma^{N}{}_{i} + 1/K_{i})]^{-1} = [\bar{R}]^{-1}$$

$$\propto_{k} = \propto_{R}/\bar{R}^{2},$$

where ∝ is the standard deviation.

The mean and range of the thermal conductivity, together with the mean thermal resistivity for each core section, are shown as a function of depth in Figure 17. Although there is considerable scatter in the data induced, apparently, by variations in drilling disturbance (the range of values tends to be smallest in the upper 70 meters where the core has been homogenized), the trend of the standard deviation shows that the population is non-random. The mean thermal conductivity per section ranges widely from a low of 1.95 $\pm 0.103 \times 10^{-3}$ cal/cm-s-°C between 140 and 150 meters sub-bottom to a high of 2.49 $\pm 0.112 \times 10^{-3}$ cal/cm-s-°C between 160 to 180 meters sub-bottom about a mean for the hole of 2.27 $\pm 0.175 \times 10^{-3}$ cal/cm-s-°C. An inspection of Table 6 suggests that these fluctuations are related in part to changes in composition: the thermal conductivities of the clay and zeolitic clay of Units II and III are similar, while that of the middle Eocene radiolarian clay and ooze (Unit IV) and the Upper Cretaceous multicolored clay (Unit V) are distinctly low ($\bar{K} = 2.09 \pm 0.179 \times 10^{-3}$ cal/cm-s-°C) and high ($\bar{K} = 2.37 \pm 0.143 \times 10^{-3}$ cal/cm-s-°C), respectively. As expected, the running average of thermal conductivity and thermal resistivity values down the hole shows a slight decrease in thermal conductivity with depth reflecting the low-conductivity interval between 140 and 150 meters.

The thermal conductivity values in Hole 417A straddle the 2.25×10^{-3} cal/cm-s-°C value which defines the boundary between regions with normal and higher than normal thermal conductivity according to Langseth and von Herzen (1970). It is interesting that areas of clay deposition are usually marked by fairly low thermal conductivity, whereas abyssal turbidite or biogenous carbonate sands usually have high thermal conductivity. Except for Unit IV, the values reported here are distinctly higher than either those calculated by Langseth and von Herzen (1970) for the brown clays in the Pacific or those previously reported by the same authors for the region of Site 417 (2.09×10^{-3} cal/cm-s-°C for 11 stations in the area 20° to 30°N, 65° to 70°W). Since the area of Site 47 is very close to a high-conductivity region to the north of the Puerto Rico, Hispaniola, Cuba, and part of the Caribbean (see Figure 2 in Langseth and von Herzen, 1970), a slight modifiction of the boundary may be appropriate.

Conclusions

Although many of the physical properties of sediments discussed display expected trends with depth, it must be borne in mind that all but the basal sediments in Hole 417D were strongly to profoundly disturbed by drilling. Since the physical properties of unconsolidated to semiconsolidated sediments, such as those drilled at Site 417, are extremely sensitive to packing (and thus disturbance), the physical property values presented in Tables 4 and 6 are two steps removed from *in situ* values and must be rgarded as only qualitative. Under these circumstances, only the coarsest physical-property discontinuities are likely to survive. Of these, only three appear in Figure 17 and 18 above the sediment/basement transition: (1) a shear strength gradient inflection at approximately 70 meters; (2) a weak impedance contrast associated with the clay/claystone transition at about 280 meters in Hole 417D; and (3) a strong impedance contrast at 310 meters marking a transition from open to mixed-layer clays. Of these discontinuities, the two clay transitions are the most intriguing in that they appear to have accured at an anomalously low overburden pressure. This suggests that part of the sediment column has been removed or tht the base of the column has either been heated from below or clogged with chemical filtrates from above owing to the passage of sea water through the basal sediments into the downwelling limb of a crustal hydrothermal cell.

PALEOMAGNETISM, HOLE 417D

A paleomagnetic study was attempted for the lower sedimentry sequence of Hole 417D (from Section 7-2 to 21-3), whenever undisturbed layering was suitable for sampling. A total of 45 samples were subjected to a demagnetization treatment (40 AF demagnetizations and five thermodemagnetizations) to determine the direction of the primary remanent magnetization (PRM). No conclusions could be drawn from the thermodemagnetization because the samples dried out and disintegrated upon heating; therefore, only AF demagnetization results will be considered here.

The intensities of the natural remanent magnetization (NRM) usually are between $10^{/5}$ and 10^{-4} emu/cm^3 but drop drastically from the onset of the AF demagnetization, given median destructive field values (MDF) of less than 100 Oe for half of the sample collection. Demagnetization curves displaying such a rapid decrease at low alternating fields are generally characteristic of the presence of a large viscous remanent magnetization (VRM) component of low coercivity. As a matter of fact, viscosity tests performed on two samples showed that the VRM acquired in an 8.2-Oe steady field during 35 hours was about 20 times higher than the initial NRM and could be easily erased by alternating fields up to 100 Oe. Since the VRM increases linearly with the applied field, this would be equivalent to a VRM of about the same intensity as the NRM if the experiments were made in the Earth's magnetic field (0.46 Oe at the drilling site).

Together with the drop in intensity, a pronounced instability of remanent magnetization direction upon demagnetization is observed, which is further evidence of the presence of parasitic magnetization component(s). The question arises as to whether the secondary component is always and only a VRM acquired *in situ* or at least in part also an erratic remanent magnetization acquired during the demagnetization process.

In many cases a regular trend is observed from initial positive toward negative NRM directions at the final steps of the AF demagnetization. However, the change in polarity is generally not accompanied by a significant change in relative declination, making it difficult to conclude that in all cases the NRM is composed of a normally directed VRM superimposed on a reversed PRM. Furthermore, the negative inclination values are usually reached only at the very end of the demagnetization when the remaining remanent magnetization is less than 10 per cent of the initial NRM; i.e., when more than 90 per cent of the magnetic minerals carrying the remanence are unlocked and thus able to acquire a new magnetization in any stray field that may be present. We are led to the conclusion that a spurious remanent magnetization component has been acquired during the demagnetization, probably an anhysteretic remanent magnetization (ARM). Such an ARM is known to increase with increasing alternating field and to be generated preferentially along the demagnetizing coil axis; it is thus essentially overprinted on the last demagnetized component when the three sample components are demagnetized one after the other without tumbling the sample. In this case, the Z-axis which corresponds to the vertical axis of the main core was always demagnetized third, and the regular trend toward negative z values observed for all the samples is consistent with an ARM component acquired along this axis.

Except for a few specimens, the presence of parasitic magnetization components is obvious in most of the sediment samples from Hole 417D. Both VRM and ARM can be overprinted onto the PRM and there is no unequivocal criterion to decide whether the VRM has been totally erased by the AF treatment, nor if the ARM, when present, is large relative to the remaining PRM. Because it would be meaningless as matters stand, no attempt was made to draw any conclusions concerning the paleomagnetism of the sediments in Hole 417D.

GEOCHEMISTRY OF SEDIMENTS

Dissolved Gases

Although the sediments at Hole 417A showed no obvious signs of organic matter, samples were analyzed for dissolved gases throughout. Small amounts of carbon dioxide were found in each core barrel down to Core 12; however, no quantitative determinations were made.

Chromatographic analyses of samples from three cores — Cores 6, 11, and 13 — show that only negligible amounts of the lighter hydrocarbons — C_2,C_3,C_4, C_5, or C_6 — are present. Three additional samples from Cores 417A-1 and 6 revealed no detectable amounts of these hydrocarbons at all.

Interstitial Water Chemistry

The relevant data are given in Table 7 as well as in Figure 19. The main observation at this site is the gradual decrease in alkalinity to about 150 meters, the increase in dissolved calcium, and the decrease in dissolved magnesium to the greatest depth reached in the sediments — i.e., to just a few meters above the basalts. Concentration gradients in calcium and magnesium in Hole 417A are very similar to those in Hole 417D, and these elements are linearly correlated with $\Delta Ca/\Delta Mg = -1.43$ ($r^2 = 0.96$). These concentration gradients can best be interpreted in terms of diffusional transport through the sediments between the basalts and the overlying ocean. After the sediment cover has caused par-

TABLE 7
Interstitial Water Data, Site 417

Sample (Hole-Core-Section, Interval in cm)	Depth (m)	pH	Alkalinity (meq/1)	Salinity (°/oo)	Cl^- (°/oo)	Ca^{+2} (m moles/l)	Mg^{+2} (m moles/l)
417A-1-4, 144-150	8.5	7.5	2.85	34.9	19.2	11.0	55.9
6-5, 144-150	56.0	7.3	2.28	36.3	19.8	13.6	50.7
11-4, 144-150	103.5	7.5	1.52	36.0	19.6	19.6	46.6
16-7, 0-6	151.0	6.8	1.03	36.0	19.7	24.2	43.9
21-3, 0-10	198.5	7.1	1.40	36.0	19.8	27.4	43.6
417B-1-3, 144-150	4.5	7.5	3.12	36.0	19.2	11.6	50.5
417D-1-3, 144-150	4.5	7.5	2.65	37.4	19.3	10.7	51.4
8-1, 138-145	212.5	6.8	1.14	36.3	19.9	30.1	40.9
12-3, 144-150	252.2	6.9	1.28	36.0	19.5	34.2	44.9
17-1, 144-150	305.9	7.4	1.17	36.8	19.9	37.3	35.3

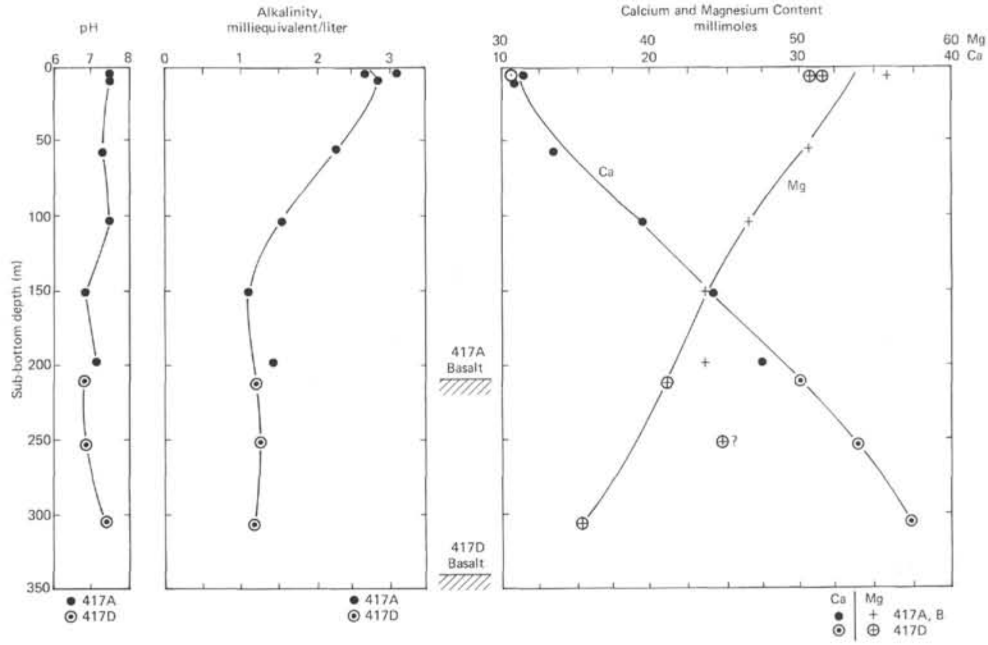


Figure 19. *Interstitial water chemistry, Site 417.*

tially closed chemical conditions, basalt alteration leads to the uptake of magnesium from the ocean with a concomitant release of calcium.

Pyrolysis–Fluorometry

A pyrolytic-fluorometric examination for heavier organic species was made for sediments from Cores 417A-1 through 16. The color of the trichloroethane after extraction of the pyrolytic residues was clear, indicating minimal amounts of heavier organics.

Calcium Carbonate Bomb

Hole 417A

The sediments of Hole 417A were deposited in very deep water (nearly 6 km at present). Consequently, the absence of calcium carbonate throughout is not unexpected. Only one sample — a nannofossil-rich clay from Section 417A-1-1 — yielded detectable $CaCO_3$, while 36 additional samples through Core 417A-18 did not. The presence of calcium carbonate in one sample is attributed to relatively rapid deposition and burial. Sediments moving from Hatteras abyssal plain to the Nares abyssal plain would pass through the vicinity of the Vema Gap, a very short distance from this site and at nearly the same depth of water. Thus, some occurrences of relatively rapidly deposited materials are to be expected. The mixed nature of the nannofossil flora from this sample is consistent with such reworking.

Hole 417D

Twenty-six samples were analyzed for calcium carbonate, using the bomb. Seven were analyzed in conjunction with organic carbon determinations and four of these weighed less than one gram; therefore, the results are less precise. The results are tabulated in Table 8 and are present on the core barrel forms accompanying this chapter. The non-calcareous nature of Unit 5 (Cores 417D-14 and 15), sporadic $CaCO_3$ values of Unit VI (Cores 417D-16, 17, 18, and 19), Unit VII (Cores

TABLE 8

$CaCO_3$ (Bomb) and Reduced Carbon Determinations, Hole 417D

Sample (Core-Section, Interval in cm)	$CaCO_3$	Reduced Carbon	Lithology
14-3, 140-141	0	–[b]	Clay
14-5, 21-22	0	–[b]	Clay
15-1, 72-73	0	–[b]	Clay
15-2, 28-30	0	–[b]	Clay
16-1, 42-43	2[a]	0.1	Green claystone
16-1, 106-107	6	–[b]	Green claystone
17-1, 40-41	43	–[b]	(Minor) light gray nannofossil-rich bed
17-1, 46-47	1[a]	0.5	Black clay
17-3, 57-58	53	–[b]	Gray brown nannofossil-rich clay
17-3, 85-88	33[a]	2.6	Dark grayish brown clay
17-3, 133-134	0[a]	2.4	(Minor) grayish brown phosphate bed
18-2, 68-69	8	–[b]	Dark gray clay
18-2, 91-92	7	–[b]	Pale blue green clay
19-1, 94-95	3	–[b]	Black laminated clay
19-2, 2-3	0	3.5	Black pyritic clay
19-2, 106-108	2	–[b]	Dark green claystone
20-1, 61-62	1	–[b]	Reddish brown claystone
20-2, 24-25	1	–[b]	Reddish brown claystone
20-2, 126-127	11	–[b]	Pale green radiolarian sand
21-1, 54-55	1	–[b]	Reddish brown clay
21-2, 29-30	1	–[b]	Reddish brown clay
21-3, 21-22	43	–[b]	Pale green marl
21-3, 78-79	0	1.5	Black organic clay
21-3, 87-88	15	3.1	Black organic clay
21-3, 144-145	82	–[b]	Olive-gray nannofossil chalk

[a] Indicates underweight sample; low precision.
[b] Not determined.

417D-20; Core 417D-21, Sections 1 and 2), and higher $CaCO_3$ values of Unit VIII (Core 417D-21, Section 3) are immediately evident. The few organic carbon analyses run show values far lower than the maxima reported for this lithology from Sites 386 and 387.

Shore-based studies of calcium carbonate and organic carbon are presented in the Appendix.

IGNEOUS PETROGRAPHY

Hole 417A

We encountered basaltic ocean crust at 211 meters sub-bottom and cored until equipment failure took place at 417 meters, penetrating 206 meters of which 128.5 meters (62%) was recovered. The rocks were dominantly pillow lavas, with lesser amounts of hyaloclastic breccia (13%) and one massive, coarse-grained basaltic layer (9%). The entire section had been severely affected by an apparently low-temperature alteration; therefore, many conclusions regarding original mineralogy and texture may be best drawn by comparison with nearby Hole 417D. The present description will concentrate on those mineralogical and textural details that are comparable to those of Hole 417D, and on the description of the alteration itself.

Figure 20 and Table 9 show the lithologic subdivision of Hole 417A. Nineteen units have been distinguished; these are approximately equivalent to separate extrusive events, except that some units might well contain more than one extrusive/intrusive (cooling) event. Units are generally separated by supra-flow hyaloclastic breccias, but where these breccias are very thick (1m or more) they are enumerated as distinct units. Subdivisions are based on physical breaks within the units, such as hyaloclastic flow boundaries near the top of flows, or on appearance within an otherwise texturally uniform unit of altered zones or other evidence of discrete extrusive/intrusive events. Lower recovery in three intervals makes the designation of units somewhat less certain. Unit 2B, a pillow basalt spanning Cores 24 to the top of 26, is largely unrecovered, and its designation as a single unit is based on putative identification of three separate portions of its top, middle, and base. A gap between Units 5 and 6A was left undesignated because of dissimilarity of the recovered rock on either side. The massive basalt of Unit 18B has a large gap in the middle. The continuity of this unit is based on the similarity of the coarse doleritic texture across the gap. However, a possibility exists that the lowest portion of Unit 18B in the top of Core 46 could be a 40-cm piece which was drilled in Core 44 but was recovered in the lower breccia of Core 46 (Core 45 had no recovery).

Primary Mineralogy

In spite of the extensive alteration of these rocks, the original phenocryst assemblages can be seen to be fairly uniform. In the shallower samples, most of the phenocrysts are more or less pseudomorphed (plagioclase by K-feldspar, zeolites, and clay minerals; and olivine by "iddingsite," clay minerals, calcite, and iron hydroxide), but in deeper, less altered cores fresh plagioclase and clinopyroxene are relatively common. The opaque oxides appear to have largely escaped alteration; they will be described and discussed elsewhere. The upper 90 meters (Units 1 through 12) has plagioclase phenocrysts with or without pseudomorphed olivine; clinopyroxene phenocrysts are rare, and the groundmass consists of plagioclase, clinopyroxene, and opaque oxides. Spinel was not found. The lower units (Units 13 through 19) have plagioclase phenocrysts most abundant, with clinopyroxene less common and olivine still less common. Groundmass phases are similar to those in the upper part.

Plagioclase phenocrysts in the upper 12 units range up to 6 mm in length and are commonly zoned, locally showing oscillatory zoning. Microscopic estimates of composition suggest that these are in the range labradorite-andesine. In the lower seven units, the cores of the plagioclase phenocrysts range through the bytownite interval, with rims in the labradorite interval (An_{90-56}). Groundmass plagioclase spans a similar range (An_{83-53}). Plagioclase phenocrysts locally contain abundant tiny inclusions of devitrified glass (Plate 1, Figure 1).

Olivine in the upper units occurs entirely as pseudomorphs (Plate 1, Figure 2). In the lower part of the hole, olivine pseudomorphs are very scarce. Fresh grains are found in the coarse-grained ophitic basalt of Unit 18B.

Clinopyroxene is found unaltered as a groundmass phase in Unit 8 and below, and as a phenocryst in Unit 13 and below (except for very rare occurrences of fresh clinopyroxene in rocks as shallow as Unit 2B. Its composition (Unit 16C) is diopsidic to sub-calcic augite

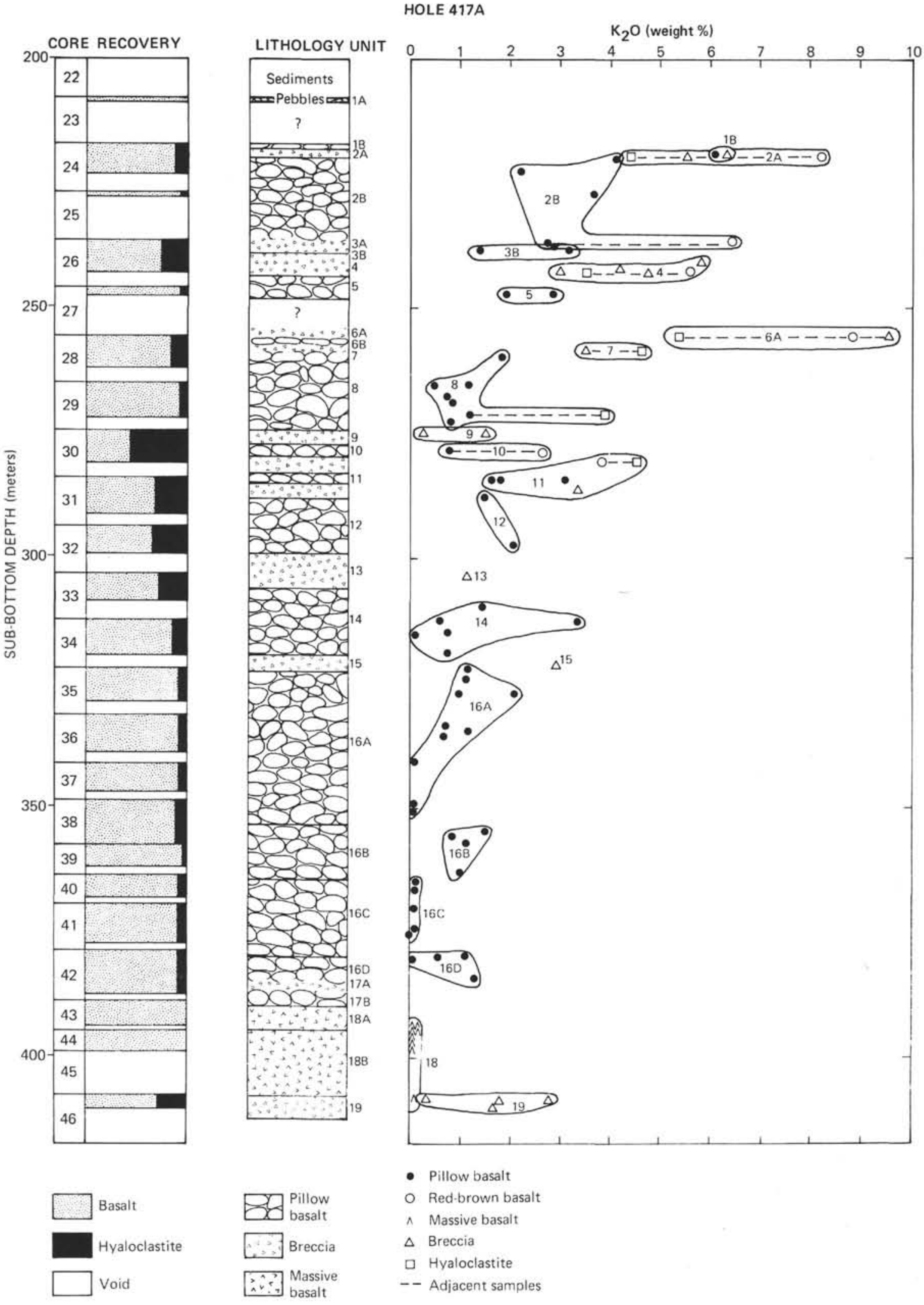


Figure 20. *Diagram showing* (left) *recovery and fraction of basalt (stippled) and hyaloclastite (black) in each core;* (center) *lithologic units;* (right) *K_2O values (water-free in pillow basalts, massive basalt, basalt fragments from breccias, altered basalt, and hyaloclastite. Closely spaced samples connected; sampled from same unit encircled.*

TABLE 9
Basement Lithologic Units, Hole 417A

Unit	Top[a] (m)	Base[a] (m)	Thickness (m)	Type Cooling Unit	Phenocryst Assemblage	Sample (Core-Section, Interval in cm)
1A	208.0	208.8	0.8	Pebbles	Plag–Oliv	22 23-1, 80
1B	217.5	218.8	1.3	Pillow basalt	Plag–Oliv	24-1, 0 to 24-1, 130
2A	218.8	220.1	1.3	Breccia	Plag–Oliv	24-1, 130 to 24-2, 110
2B	220.1	237.2	17.2	Pillow basalt	Plag–Oliv	24-2, 110 to 26-1, 75
3A	237.3	237.5	0.2	Breccia (thin)	Plag–Oliv	26-1, 75 to 26-1, 95
3B	237.5	238.8	1.3	Pillow basalt	Plag–Oliv	26-1, 95 to 26-2, 75
4	238.8	243.4	4.6	Breccia	Plag–Oliv	26-2, 75 to 26-5, 85
		(includes 0.5 m of basalt between 240.6-241.2 m in Core 26-3, 105 cm to 26-4, 15 cm)				
5	243.4	255.5	12.1	Pillow basalt	Plag–Oliv	26-5, 85 to 28-1, 0
6A	255.5	255.9	0.4	Breccia	Plag–Oliv	28-1, 0 to 28-1, 40
6B	255.9	257.4	1.5	Pillow basalt	Plag–Oliv	28-1, 40 to 28-2, 35
7	257.4	258.5	1.1	Breccia	Plag–Oliv	28-2, 35 to 28-2, 150
8	258.5	274.5	16.0	Pillow basalt	Plag–Oliv	28-3, 0 to 29-7, 45
9	274.5	277.2	2.7	Breccia	Plag–Oliv	30-1, 0 to 30-2, 115
10	277.5	279.8	2.3	Pillow basalt	Plag–Oliv	30-3, 0 to 30-4, 75
11	279.8	288.0	8.2	Breccia	Plag–Oliv	30-4, 75 to 31-3, 100
		(includes 1.0 m of basalt between 282.9-284.8 m in Cores 30-6, 90 to 31-1, 75)				
12	288.0	298.8	10.8	Pillow basalt	Plag–Oliv ± Cpx	31-3, 100 to 32-4, 80
13	298.8	306.1	7.3	Breccia	Plag–Cpx–Oliv	32-4, 80 to 33-3, 50
		(includes .7 m of basalt between 303.0-303.7 m in Core 33-1, 0 cm to 33-1, 70 cm)				
14	306.1	319.5	13.4	Pillow basalt	Plag–Cpx–Oliv	33-3, 5 to 34-5, 100
15	319.5	322.7	3.2	Breccia	Plag–Cpx–Oliv	34-5, 100 to 35-1, 65
16A	322.7	353.6	30.9	Pillow basalt	Plag–Cpx–Oliv	35-1, 65 to 38-5, 80
16B	353.5	364.3	10.8	Pillow basalt	Plag–Cpx–Oliv	38-5, 80 to 40-1, 90
16C	364.3	379.7	15.4	Pillow basalt	Plag–Cpx–Oliv	40-1, 90 to 42-1, 75
16D	379.7	385.6	5.9	Pillow basalt	Plag–Cpx–Oliv	42-1, 75 to 42-5, 105
17A	385.6	385.7	0.1	Breccia	Plag–Cpx–Oliv	42-5, 105 to 42-5, 125
17B	385.7	389.9	4.2	Pillow basalt	Plag–Cpx–Oliv	42-6, 0 to 43-2, 0
18A	389.9	394.7	4.8	Massive basalt	Plag–Cpx–Oliv	43-2, 0 to 44-1, 25
18B	394.8	407.9	13.1	Massive basalt	Plag–Cpx–Oliv	44-1, 25 to 46-1, 40
		(includes thin veined unit in Core 44-1, 25 cm to 44-1, 40 cm)				
19	407.9	412.8	4.9	Breccia	Plag–Cpx–Oliv	46-1, 40 to 46-4, 80

[a] Depths corrected for spacers.

($En_{43\text{-}51}$, $Wo_{37\text{-}44}$, $Fs_{7\text{-}17}$), becoming more iron-rich in the groundmass ($En_{38\text{-}46}$, $Wo_{27\text{-}46}$, $Fs_{15\text{-}29}$). Other analyses show a higher Fs content in later crystals.

Clinopyroxene occurs as pseudomorphed grains in the shallower flows, as sub-rounded to completely rounded grains dominantly in the lower flows, and as plumose and skeletal groundmass crystal aggregates (Plate 1, Figures 3 and 4) throughout (but altered in shallower flows). In the coarse basalt of Unit 18, clinopyroxene occurs as ophitic intergrowths with plagioclase (Plate 2, Figures 1 and 2) and as curved, coarse, fan-like plumose groundmass crystals.

Macroscopic Texture

Most of the section recovered consists of pillow basalts, with minor hyaloclastic breccia (13%) and a single massive basalt comprising 9 per cent.

The pillow basalts are characterized by curved pillow margins (Plate 3, Figure 1), radial fractures, a very fine grained selvage with a sharp decrease in grain size of the plagioclase phenocrysts, and solid pillow centers. Where the size of the pillows can be inferred from a reconstruction based on the radial fractures, we find that most pillows are in the size range 30 to 50 cm, with a few more than a meter in size. In addition to the radial fractures, most basalts are cut by sequential, later calcite-filled fractures (Plate 3, Figure 2). In many cases, fractured basalt displaced several millimeters across these fractures can be "fit back together" by inspection of cut surfaces. In no instance did the fracturing in this hole appear to represent later tectonic movements, and no slickensides or crushing were seen.

The hyaloclastic breccias, comprising a conspicuous minor portion of the section drilled at this site, are difficult to characterize texturally, but are highly crumbly, green materials consisting of highly altered glassy basalt debris. They are a crowded mass of fragments of millimeter to centimeter size and are dominantly remnants of thin, curved spalled shells of pillow margins (Plate 4, Figure 1). Angular, equant basalt fragments occur also. The process of alteration evidently resulted in an expansion through hydration such that the pieces have swelled together to reduce the original pore space to a very low value. However, the original porosity is not easily determined. Perlitic structures are common in the more equant fragments (Plate 4, Figures 1 and 2). The bright green color of the hyaloclastite is largely due to green smectite and fades rapidly upon partial drying to a dull grayish yellow color. The breccias contain on the average about 50 per cent brownish basalt fragments, ranging from centimeter-size, angular fragments to more rounded, 10- to 20-cm, isolated pillows or fragments (Plate 4, Figures 3 and 4). Still larger fragments appear to be larger isolated pillows of thin flow tongues. flow tongues.

Microscopic Texture

In general, the basalts range from hyalopilitic to intersertal (Plate 1, Figures 1 and 2). Original glass is completely devitrified and commonly further altered in all samples. Plagioclase appears to have been the first crystallized phenocryst, followed by olivine. In the lower units, clinopyroxene crystallized after plagioclase but before olivine. Plagioclase is generally the dominant phenocryst species, ranging up to 15 per cent. Mafic phenocrysts range up to 15 per cent, but almost all cases are subordinate to plagioclase.

Clinopyroxene phenocrysts commonly, and plagioclase phenocrysts less commonly, show distinctive rounding suggestive of resorption. In extreme cases clinopyroxene phenocrysts are completely rounded, with no identifiable crystal growth faces remaining. Plagioclase phenocrysts show interruptions in growth, with rounding followed by overgrowths developing later euhedral forms. The textures are better developed in the basalts of Hole 417D and are discussed more fully elsewhere.

Quench textures are well developed throughout. The best examples include swallow-tail (i.e., skeletal) terminations on plagioclase crystals (Plate 1, Figure 3); sheaf-like, skeletal, and plumose clinopyroxenes (Plate 1, Figures 3 and 4); skeletal olivine (Plate 1, Figure 1), and octahedral dendrites of titanomagnetite.

Vesicles are found throughout the recovered sequence and are invariably filled with secondary minerals (q.v.). In the massive basalt of Unit 18 are several good examples of shrinkage (segregation) vesicles (Plate 5, Figures 1 and 2). These vesicles show the distinctive two-stage filling, with the larger outline representing an early volume of the separated vapor phase and the inner outline showing the size to which this phase had contracted before final solidification. The space between the outer and inner vesicle wall is occupied by fine-grained basalt which squeezed through the outer vesicle wall during contraction of the vapor phase. Smith (1967) interpreted this as resulting from a submarine basalt moving during solidification down a slope, and thus undergoing an increase in ambient pressure. Donnelly (1972) suggested that a larger change in the specific volume of water during cooling would occur at a fixed higher ambient water pressure, and that the occurrence of shrinkage vesicles should be an indication of an abyssal marine environment. In the present case, they are found only in the thicker basalts which might also be presumed to have solidified over a large temperature range, thus increasing the amount of shrinkage possible.

The massive basalt of Unit 18 shows a subophitic to ophitic texture indicative of slow cooling, though there are no obvious indications that this unit is intrusive. In the lower part of this unit, clinopyroxene grains a few millimeters in size enclose plagioclase crystals from 0.5 to more than 1 millimeter long, and fine-grained groundmass is wholly lacking.

Alteration Mineralogy

Calcite is one of the most widely distributed alteration products, occurring in all but the thinnest fractures, in vesicles, and replacing several phenocryst species, as well as being disseminated in the groundmass. It is untwinned (i.e., unstrained). In one deeper specimen (Core 36, Unit 16A), rhombic subhedral crystals of aragonite were found replacing plagioclase phenocrysts.

The second group of ubiquitous alteration products consists of a variety of clay minerals, including what is called "palagonite," "smectite," and "celadonite." No sharp distinction between these species can be detected, but X-ray diffraction and microprobe analyses show there are at least two distinct chemical-mineralogical tendencies in the decomposition of original glassy basalt to produce these substances. The first tendency produces a silica-rich material, with a corresponding uptake of approximately twice as much Mg as Fe. Little K is absorbed, and the final product includes much of what has been called "brown smectite." X-ray patterns include only those of smectite. This material is birefringent in larger domains, and neutral, brownish, or yellowish in color. The second tendency produces a bright green material enriched in Si and K; and the Fe increased about twice as much as Mg. Some of these samples show both smectite and mica X-ray patterns, but all show some smectite pattern. Because their chemical analysis generally shows a mixed dioctahedral-trioctahedral composition, and also on the basis of X-ray characteristics, we presume that this material represents the fixation of Si, Fe, and K during decomposition of the basalt. This material may form as interlayers in an original smectite (Hower, 1961) and tends towards a theoretical K-Fe-Si mica mineral, as postulated by Foster (1968). Varying degrees of crystallinity and of development of this interlayer are expressed in different degrees of perfection of the mica pattern in X-ray diffraction analysis. The nomenclature of the two series is unsatisfactory; we suggest that the two chemical-mineralogical tendencies be labeled "smectite" and "protoceladonite," but we have no confidence that intermediate tendencies might not eventually be found to be common.

K-feldspar is a widespread alteration mineral in the upper, potassium-enriched units of this hole. It is poorly characterized optically and generally occurs as a polycrystalline replacement of plagioclase phenocrysts. Although probably widespread in the groundmass, it has not been optically identified there.

Several species of zeolite minerals have been identified, but their parageneses are still poorly understood. Analcime is widespread, occurring from Cores 26 through 46. Where it can be identified optically, it occurs as vein fillings and lining vug walls — in the latter case, as sharply euhedral crystal aggregates. Natrolite is present in vugs, where it has been positively identified in Core 39. It occurs as elongate prisms, generally with analcime (Plate 5, Figure 3). X-ray diffraction analysis indicates it might be more widespread, but other positive determinations have not been made. The composition is very nearly ideal for the species. Chabazite has been identified by X-ray diffraction and microprobe in Cores 26, 28, 30, and 35, and in Core 38, where it replaces plagioclase.

Phillipsite has been identified in Cores 28 and 36 by X-ray diffraction and microprobe. The probed samples have a partial composition close to (K_2, Na) Al_5Si_{11}, which is more siliceous and lower in Ca and Na than examples from the literature. One occurrence of this mineral was as glassy crystals lining a vug wall.

Opaque minerals include abundant ?geothite, which has not been well characterized, but is evidently the dominant form of iron in the highly oxidized, shallow basalt samples. Pyrite is not common, but has been identified in the lower cores (Cores 38 through 44). The highly oxidized nature of the shallow samples precludes the occurrence of sulfide minerals. Native copper is present as thin vein-filling films in Core 24, where its occurrence is consistent with the very high ferric/ferrous ratio of this part of the core. Polycrystalline aggregates of "iddingsite" are found in olivine phenocrysts.

Lithologic Units

Unit 1

This unit (Cores 22 through Section 24-1, 130 cm; 208 to 218.8) is a poorly recovered rubble of basalt fragments (Sub-unit 1A; Cores 22 and 23; 208 to 208.8 m) overlying a lithologically similar, highly altered pillow basalt (Sub-unit 1B; Cores 24-1, 0 to 130 cm; 217.5 to 218.8 meters). The rubble of Sub-unit 1A consists of pebbles up to 8 cm in diameter which are more or less rounded and polished. It is not possible to determine how much of their shape might be original, but some of the pebbles have been shaped, if not cut, as a result of drilling. There has been no positive identification (through weathered rinds) of an original lag rubble. The pillow basalt of Sub-unit 1B is a highly altered grayish pillow basalt with conspicuous 1-cm, brownish altered pillow margins. The basalt contains 3 to 10 per cent altered plagioclase phenocrysts (with some fresh remnant plagioclase) and a few per cent of highly altered mafic phenocrysts. Native copper occurs as very thin films on fractures.

Unit 2

This unit (Section 24-1, 130 cm to Section 26-1, 75 cm; 218.8 to 237.3 m) consists of an upper hyaloclastic breccia (Sub-unit 2A, to Section 24-2, 110 cm; 220.1 m) overlying an altered pillow basalt (Sub-unit 2b). The breccia is deep green and contains abundant small, irregular, angular to rounded brownish basalt fragments, many of which appear to be small isolated pillows of approximately 10 to 20 cm in diameter. These basalt fragments are highly altered with 10 per cent plagioclase phenocrysts and 2 to 5 per cent altered mafic phenocrysts, at least some of which are olivine pseudomorphs. The pillow basalt is a highly altered grayish rock, marginally brown, of which only short sections of the top, middle, and base were recovered. It contains 20 per cent highly altered plagioclase phenocrysts and 2 to 5 per cent altered mafic phenocrysts, including olivine pseudomorphs. The shallowest relatively fresh basalt, with fresh plagioclase and clinopyroxene, occurs in this unit as a scarce component.

Unit 3

This unit (Section 26-1, 75 cm to Section 26-2, 75 cm; 237.3 to 238.8 m) consists of a green hyaloclastic breccia (Sub-unit 3A, to Section 26-1, 95 cm; 237.5 m) overlying a pillow bsalt (Sub-unit 3B). The hyaloclastic breccia contains small (a few cm) basalt fragments and has abundant calcite veins. The pillow basalt has 2 to 5 per cent plagioclase phenocrysts, 5 per cent altered mafic phenocrysts, and 3 per cent small vesicles. Small fresh plagioclase and clinopyroxene phenocrysts occur.

Unit 4

This unit (Section 26-2, 75 cm to Section 26-5, 85 cm; 238.8 to 243.4 m) is a green hyaloclastic breccia with brown-margined, gray altered basalt fragments. In the central part (Section 26-3, 105 cm to Section 26-4, 15 cm; 240.6 to 241.2 m) is a 60-cm section of basalt which is either a very large fragment of a pillow or a thin flow tongue. This basalt has 5 to 10 per cent plagioclase phenocrysts to 1.5 mm and up to 10 per cent clinopyroxene phenocrysts up to 3 mm.

Unit 5

This unit (Section 26-5, 85 cm to Section 27-2, 35 cm; 243.4 to 247.9 m) is a poorly recovered, grayish altered basalt with less conspicuous brownish altered pillow margins than were seen in shallower basalts. The basalt consists of 5 to 15 per cent altered plagioclase phenocrysts and 1 to 5 per cent pseudomorphed olivine phenocrysts with minor clinopyroxene phenocrysts.

Unit 6

This unit (Section 28-1, 0 cm to Section 28-2, 35 cm; 255.5 to 257.4 m) consists of a green hyaloclastic breccia (Sub-unit 6A, to Section 28-1, 50 cm; 255.9 m) with irregular fragments of altered basalt overlying a brown-margined, grayish altered pillow basalt (Sub-unit 6B). This basalt is highly fractured and veined, and has a 15-cm section with abundant hyaloclastic breccia in the central portion. The basalt has 5 to 15 per cent altered plagioclase phenocrysts to 5 mm and 5 per cent pseudomorphed mafic phenocrysts.

Unit 7

This unit (Section 28-2, 35 cm to Section 28-2, 150 cm; 257.4 to 258.5 m) is a hyaloclastic breccia with altered, rounded basalt fragments and extensive calcite veining.

Unit 8

This unit (Section 28-3, 0 cm to Section 29-7, 45 cm; 258.5 to 274.5 m) is an altered, grayish, brown-margined pillow basalt, with large pillows (to 90 cm). This basalt has more restricted brownish marginal coloration than in shallower units. Interpillow hyaloclastite is scarce. The basalt has 5 to 15 per cent plagioclase phenocrysts up to 5 mm and up to 5 per cent altered mafic phenocrysts, including some recognizable clinopyroxene.

Unit 9

This unit (Section 30-1, 0 cm to Section 30-2, 115 cm; 274.5 to 277.2 m) is a green hyaloclastic breccia with rounded basalt fragments. Relatively little calcite veining is present.

Unit 10

This unit (Section 30-3, 0 cm to Section 30-4, 75 cm; 277.5 to 279.8 mm) is a grayish altered pilow basalt with 10 per cent plagioclase phenocrysts up to 3mm and 5 to 15 per cent mafic phenocrysts up to 2 mm. The mafic/plagioclase phenocryst ratio is higher than that for shallower basalts.

Unit 11

This unit (Section 30-4, 75 cm to Section 31-3, 100 cm; 279.7 to 288.0 m) is a greenish hyaloclastic breccia with rounded, irregular, grayish altered basalt fragments. Minor calcite veining occurs. A thin grayish altered basalt, possibly a thin flow, occurs from Section 30-6, 90 cm to Section 31-1, 75 cm (282.9 to 284.8 m). This basalt has 7 to 15 per cent plagioclase phenocrysts up to 4 mm and 5 per cent mafic phenocrysts up to 1 mm.

Unit 12

This unit (Section 31-3, 100 cm to Section 32-4, 80 cm; 288.0 to 298.8 m) is a grayish altered pillow basalt with conspicuous marginal brown color of the pillow margins. It has 2 to 25 per cent plagioclase phenocrysts up to 4 mm and 3 to 15 per cent mafic phenocrysts up to 2 mm. The phenocryst content is extremely variable in this unit.

Unit 13

This unit (Section 32-4, 80 cm to Section 33-3, 5 cm; 298.8 to 306.1 m) is a green hyaloclastic breccia with rounded, irregular basalt fragments. This breccia differs from shallower breccias in that the basalt fragments show very limited brown coloration. A thin basalt (Section 33-1, 0 to 70 cm; 303.0 to 303.7 m) has 15 per cent plagioclase phenocrysts up to 3 mm, 1 per cent olivine pseudomorphs up to 1 mm, and 5 per cent clinopyroxene phenocrysts up to 2 mm.

Unit 14

This unit (Section 33-3, 5 cm to Section 34-5, 100 cm; 306.1 to 391.5 m) is a grayish altered pillow basalt with very limited marginal brown coloration and scarce interpillow hyaloclastic breccia. The apparent pillow size increases in downward direction to nearly 1 meter. There are 5 to 20 per cent plagioclase phenocrysts (many quite fresh) up to 8 mm, 2 to 5 per cent olivine pseudomorphs 1 to 3 mm, and up to 2 per cent clinopyroxene phenocrysts 1 to 3 mm.

Unit 15

This unit (Section 34-5, 100 cm to Section 35-1, 65 cm; 319.5 to 322.7 m) is a greenish hyaloclastite breccia with grayish, rounded, irregular basalt fragments slightly marginally colored with brown, and with moderate calcite veining.

Unit 16

This unit (Section 35-1, 65 cm to Section 42-5, 105 cm; 322.7 to 385.6 m) is a thick, relatively fresh pillow basalt sequence divided into four sub-units, which might represent individual flows. These flows all have 10 to 20 per cent plagioclase phenocrysts up to 12 mm, 1 to 5 per cent clinopyroxene phenocrysts 2 to 5 mm, and 0 to 8 per cent olivine pseudomorphs 2 to 5 mm. Vesicles are small and scarce. Sub-unit 16A (Section 35-1, 65 cm to Section 38-5, 80 cm; 322.7 to 353.6 m) is a grayish pillow basalt with marginal brown coloration. The sub-unit is separated from the next lower one by a thin hyaloclastic breccia zone, and by a sharp increase in K_2O across the boundary. Sub-unit 16B (Section 38-5, 80 cm to Section 40-1, 90 cm; 353.6 to 364.3 m) is a grayish pillow basalt with minor marginal brown coloration. Olivine does not exceed 2 per cent in this sub-unit, which is separated from the next lower one by a thin breccia zone. Sub-unit 16C (Section 40-1, 90 cm to Section 42-1, 75 cm; 364.3 to 379.7 m) is a grayish pillow basalt with the most consistently low values of K_2O of any pillow basalt in this hole. It does not appear conspicuously fresher in color than the other sub-units, however, it is separated from the next lower sub-unit by a slightly weathered zone and by a jump in the K_2O values in downward direction. Sub-unit 16D (Section 42-1, 75 cm to Section 42-5, 105 cm; 379.7 to 385.6 m) is a grayish pillow basalt similar to the other sub-units, except for slightly more conspicuous calcite veining.

Unit 17

This unit (Section 42-5, 105 cm to Section 43-1, 130 cm; 385.6 to 389.7 m) consists of an upper sub-unit (Sub-unit 17A, to Section 42-5, 125 cm; 385.7 m) of green hyaloclastic breccia with angular basalt fragments, which was poorly recovered, and a lower sub-unit (Sub-unit 17B) of grayish pillow basalt with marginal brown coloration, minor interpillow hyaloclastite, and calcite veining. It has 7 to 15 per cent plagioclase phenocrysts 3 to 5 mm, more abundant and larger in the lower part; 10 per cent clinopyroxene phenocrysts up to 3 mm, and no olivine pseudomorphs in the upper part, and 10 per cent unidentified mafic pseudomorphs up to 0.5 per mm in the lower part.

Unit 18

This unit (Section 43-2, 0 cm to Section 46-1, 40 cm; 389.9 to 407.9 m) is subdivided into sub-units 18A and 18B at Section 44-1, 25 cm (394.7 m), where a slightly brecciated horizon was noted. This unit is a massive basalt with porphyritic-subophitic texture in the upper part grading downward into a coarse ophitic, doleritic texture. Failure to recover material from Core 45, and the recovery of a 40-cm piece of the base of this unit in the top of Core 46, which was texturally indistinguishable from the lowest piece of Core 44, raises the possibility that this unit is much thinner than designated. The coarse granularity, even near the top of this unit, stands in sharp contrast to any other basalt recovered in this hole and demands a sharply contrasting explanation as to its origin. Although slow static cooling is indicated, it is not clear whether this unit might represent a very shallow intrusive or a ponded lava "lake." A few shrinkage vesicles were noted. These had outer portions filled with fine-grained basalt and inner portions filled with calcite. The shrinkage was about one half. The upper portion of this unit is more texturally variable than the lower, and the discontinuities in granularity suggest some sort of limited fragmentation during emplacement of a dominantly plastic melt. The upper part of the unit consists of 15 per cent plagioclase phenocrysts to 3 mm, and 7 to 10 per cent clinopyroxene phenocrysts to 0.3 mm. These frequently occur in glomeroporphyritic clumps set in a holocrystalline groundmass lacking quench features. At the base, the rock is more uniformly crystalline with 50 per cent plagioclase 7 to 10 mm, 35 to 40 per cent clinopyroxene to 3 mm, some olivine pseudomorphs about 1 mm, and some fresh olivine crystals (with marginal serpentinization) up to 5 mm. The texture is doleritic-ophitic near the base.

Unit 19

This unit (Section 46-1, 40 cm to Section 46-4, 80 cm; 407.9 to 412.8 m) is a greenish hyaloclastic breccia which contrasts with shallower breccias in its darker color, in the very scarce marginal brown color of the grayish basalt fragments, and its abundant calcite veining. The basalt fragments have 20 per cent plagioclase phenocrysts to 3 mm, and 5 per cent olivine pseudomorphs and clinopyroxene phenocrysts to 2 mm. This unit is further distinguished by its high ferrous/ferric ratio (see discussion on rock chemistry in later chapter), and has abundant disseminated analcime.

Hole 417D

We encountered acoustic basement at a depth of 343 meters sub-bottom and cored to 708.5 meters. Recovery averaged 72 per cent in the basement section, 263 meters of basalt being recovered from the 365.5-meter interval. The recovered material is mostly pillow basalt with lesser massive basalt and pillow breccia. Small amounts of fine-grained sediment are associated with many breccias. Fourteen stratigraphic units have been defined, based on cooling characteristics and phenocryst mineralogy (Figure 21, Table 10). Pillowed basalts and associated breccias comprise about 65 per cent and massive units about 35 per cent of the recovered material. A discordant intrusive body near the base of the hole is interpreted as a dike; apart from this, all but one contact between units is interpreted as depositional. The one exception is a fault of unknown displacement separating Units 4 and 5.

Nearly all the recovered basalts are porphyritic, with 5 to 20 per cent phenocrysts, chiefly plagioclase and olivine. Clinopyroxene phenocrysts are present in several units, but they rarely exceed 2 per cent of the rock and are usually small and rounded. Groundmass textures range from fine-grained quench in the pillow basalts to medium-grained subophitic in some of the massive units.

Except for the uppermost 2 meters, the basalts are generally weakly to moderately altered. Some fresh glass persists throughout the section, and secondary minerals are largely confined to vesicles and veins. Vesicles are mainly filled with calcite and smectite; veins and vugs are filled with calcite, smectite, quartz, and pyrite.

Olivine is altered to smectite or calcite, except in fresh glass selvages, but other phenocrysts are typically fresh. Some plagioclase phenocrysts exhibit incipient alteration to brown smectite and authigenic K-feldspar.

Lithologic Units

Unit 1

This unit is a 64.5-meter-thick sequence of pillow basalt which has been divided into three sub-units on the basis of several sedimentary interbeds. The top of the unit coincides with the top of the basement section at 343 meters sub-bottom. The basalt/sediment contact was poorly recovered, but no evidence of baking or recrystallization was found in the nannofossil chalk directly above the basalt, and the contact is interpreted as depositional. A 10-cm-thick carbonate layer at the top of Section 31-4 separates Unit 1 from the underlying pillow basalts of Unit 2.

Unit 1A is about 25 meters thick, extending from the top of basement to Section 27-1, 75 cm. Neither the upper nor the lower contact has a glassy selvage, but glassy pillow rinds are common throughout the unit. Small masses of limestone occur between many pillows, and some of these contain fragments of fresh or altered sideromelane. Minor basalt breccia in Core 22 consists largely of fragmented pillow rinds.

A glass selvage against limestone marks the upper contact of Unit 1B at Section 27-1, 82 cm. The lower contact at the base of Core 28 is placed at the top of a small limestone inclusion. The 17.4-meter-thick unit is composed largely of pillow basalt with minor broken pillow breccia. Small masses of limestone, often containing glass chips or fragments, lie between many of the pillows.

Unit 1C is a 22.7-meter-thick sequence of pillow basalt, petrographically similar to Unit 2B. The upper contact at the top of Core 29 is chilled against a small mass of limestone, as is the lower contact at the top of Section 31-4. Notable limestone layers or inclusions also occur at Section 30-5 (65 to 80 cm and 87 to 103 cm), Section 31-1 (30 to 50 cm), and Section 31-2 (132 to 148 cm).

The basalts of Unit 1 are moderately phyric with 10 to 20 per cent phenocrysts, chiefly plagioclase and

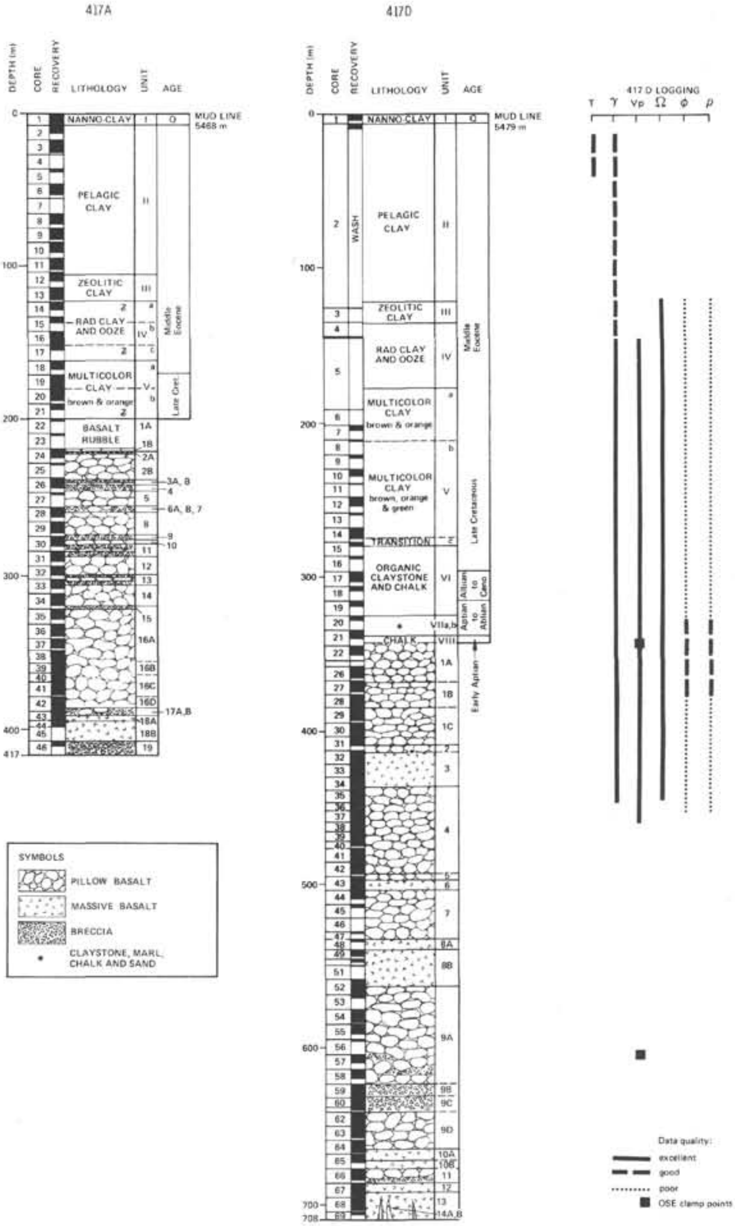


Figure 21. *Basement and sediment stratigraphy, Holes 417A and 417D. Also shown are the intervals logged in Hole 417D.*

olivine. The plagioclase occurs in euhedral to subhedral crystals up to 8 mm long, some of which form larger glomerocrysts. In the upper part of the unit (to the bottom of Core 25), olivine phenocrysts comprise up to 2 per cent of the rock; below Core 25 they make up about 2 to 5 per cent. Olivine phenocrysts are single euhedral crystals seriate in size with groundmass crystals, ranging up to 3 mm across. Rounded clinopyroxene phenocrysts or "xenocrysts" make up about 1 per cent of Unit 1A. In general, the phenocryst content, particularly of plagioclase and clinopyroxene, increases in downward direction in the unit. In addition, many pillows also exhibit systematic phenocryst variations, being highly phyric in the centers and sparsely phyric in the rims.

Groundmass textures are fine-grained to glassy, typically with quench features such as acicular plagioclase microlites and radiating sheaves of poorly crystallized clinopyroxene. Granular magnetite forms about 5 per cent and skeletal olivine crystals 1 to 2 per cent of most specimens.

The upper 2 meters of Unit 1 is moderately to highly altered; the remainder is weakly altered. Vesicles make up less than 1 per cent of the rock and are filled with smectite and calcite, as are scattered veins and fractures. Glass selvages are partly altered to smectite, but most still contain some fresh glass. Olivine is always replaced by smectite or calcite, except in fresh glass selvages. Some plagioclase crystals are incipiently altered to smec-

TABLE 10
Basement Lithologic Units, Hole 417D

Unit/ Sub-Unit	Top[a] (m)	Base[a] (m)	Thickness (m)	Type Cooling Unit	Phenocryst Assemblage	Sample (Core-Section, Interval in cm)
1A	343	367.3	24.3	Pillow basalt	Plag–Oliv	21CC, 46 to 27-1, 75
1B	367.3	384.8	17.5	Pillow basalt	Plag–Oliv–(Cpx)	37-1, 75 to 28-7, 98
1C	384.8	407.5	22.7	Pillow basalt	Plag–Oliv–(Cpx)	29-1, 0 to 31-3, 148
2	407.5	412.8	5.3	Pillow basalt	Plag–Oliv–(Cpx)	31-4, 0 to 32-1, 66
3	412.8	435.4	22.6	Massive basalt	Plag–Cpx–Oliv	32-1, 66 to 34-5, 112
4	435.4	488.4	53.0	Pillow basalt	Plag–Oliv–Cpx	34-5, 112 to 42-3, 75
5	488.4	495.0	6.6	Pillow basalt	Plag–Oliv–Cpx	42-3, 75 to 43-1, 127
6	495.0	500.6	5.6	Massive basalt	Plag–Oliv–Cpx	43-1, 127 to 43-5, 127
7	500.6	538.0	37.4	Pillow basalt	Plag–Oliv–Cpx	43-5, 127 to 47CC
8A	538.0	539.0	1.0	Massive basalt	Plag–Cpx–Oliv	48-5, 0 to 48-7, 98
8B	539.0	562.5	23.5	Massive basalt	Plag–Cpx–Oliv	49-1, 0 to 52-4, 27
9A	562.5	624.0	61.5	Pillow basalt and breccia	Plag–Cpx–Oliv	52-4, 27 to 58-5, 28
9B	624.0	533.0	9.0	Breccia	Plag–Cpx–Oliv	59-1, 0 to 59-7, 37
9C	633.0	642.0	9.0	Breccia	Plag–Cpx–Oliv	60-1, 0 to 61-1, 93
9D	642.0	665.8	23.8	Pillow basalt	Plag–Oliv–(Cpx)	62-1, 0 to 64-4, 127
10A	665.8	672.6	6.8	Massive basalt	Plag–Oliv	64-4, 127 to 65-3, 64
10B	672.6	678.0	5.4	Massive basalt	Plag–Oliv	65-3, 64 to 65-6, 92
11	678.0	687.0	9.0	Pillow basalt	Plag–Oliv	66-1, 0 to 66-6, 76
12	687.0	694.1	7.1	Massive basalt	Plag–Oliv	67-1, 0 to 67-6, 35
13	694.1	708.5	14.4	Massive basalt	Plag–(Oliv)	67-6, 35 to 69-2, 38
14A				Basalt dike	Plag–Oliv–Cpx	68-1, 120 to 68-2, 55
14B				Basalt dike	Plag–Oliv–Cpx	68-4, 5 to 68-4, 49

[a] Depths corrected for spacers.

tite and K-feldspar, particularly in Core 28. Clinopyroxene is always fresh, except in the upper 2 meters of the unit where it is partly altered to calcite and smectite.

Unit 2

Highly plagioclase-olivine-clinopyroxene-phyric pillow basalt makes up Unit 2. This is distinguished from Unit 1 by having a higher content of olivine and clinopyroxene phenocrysts. The underlying basalts of Unit 3 are massive. Inclined glassy selvages mark both the upper contact at Section 31-4, 10 cm, and the lower contact at Section 32-1, 66 cm. The unit is 5.2 meters thick.

The phenocryst content of these basalts shows considerable variation within individual pillows, generally being highest in the pillow centers. Plagioclase phenocrysts average about 15 per cent, range from 10 to 25 per cent, and form euhedral to subhedral crystals up to 10 mm long, occurring either singly or in glomerophyric clots with clinopyroxene. Altered olivine phenocrysts average about 5 per cent of the rock; they are euhedral to subhedral and range up to 5 mm across. Clinopyroxene crystals occur as anhedral, subophitic intergrowths with plagioclase or as individual rounded and corroded crystals up to 3 mm across.

The groundmass is typically a quenched mixture of acicular plagioclase microlites, skeletal olivine crystals, granular magnetite, and poorly crystallized clinopyroxene with minor interstitial glass.

Smectite and carbonate-filled veins are common throughout the unit, and these account for most of the secondary minerals. Vesicles are small and sparse, rarely exceeding 1 per cent of the rock; these are also filled with smectite. Olivine is the only altered phenocryst phase, being replaced by smectite and lesser calcite. Fresh glass persists throughout the unit, but most glassy selvages exhibit at least minor alteration to smectite.

Unit 3

A 17.6-meter-thick sequence of massive basalt makes up Unit 3. A chilled margin marks the upper contact at Section 32-1, 66 cm. No glassy selvage was recovered from the basal contact at Section 34-5, 112 cm, but the grain size of the lower 20 cm of the unit decreases rapidly in downward direction, indicating a definite cooling break. No internal cooling breaks were observed or inferred in the unit. A highly vesicular zone about 2 meters thick occurs near the top of Section 32-3.

The massive basalts of Unit 3 are mineralogically similar to the overlying pillow basalts of Unit 2, except for a somewhat higher proportion of clinopyroxene phenocrysts. Plagioclase phenocrysts vary from 10 to 20 per cent and average 15 per cent. Most of these are subhedral crystals, up to 8 mm long, which are uniformly distributed through the rock. A few crystals are intergrown with clinopyroxene in subophitic clots. Olivine phenocrysts, completely altered to smectite, average about 3 per cent of the rock but range up to 20 per cent in the lower half-meter of the unit. Here, the crystals are oriented with their long axis approximately horizontal, probably as a result of settling from higher in the unit. The olivine crystals are seriate in size, ranging up to 3 mm in most of the unit, and up to 5 mm in the lower half-meter. Anhedral clinopyroxene crystals, intergrown with plagioclase, make up 5 to 10 per cent of the rock. Rounded megacrysts of clinopyroxene occurring in many of the pillow basalts are absent here.

Groundmass textures range from fine-grained quench near the margins to medium-grained subophitic elsewhere. However, some interstitial glass occurs even in the coarsest-grained specimens, giving rise to a characteristic "ophimottled" texture.

Except for the presence of numerous smectite- and calcite-filled veins, the basalts of Unit 3 are relatively fresh. Vesicles, which are common only in the upper part of the unit, are largely filled with smectite and calcite. Olivine crystals are completely altered to smectite throughout the unit, but other phenocrysts are fresh.

Unit 4

This unit is a 52.8-meter-thick sequence of pillow basalt and subordinate broken pillow breccia. A glassy selvage marks the top of the sequence at Section 34-5, 115 cm, and a fault may mark the base at Section 42-3, 75 cm. The underlying pillow basalts of Unit 5 are petrographically similar to those of Unit 4, and the postulated fault probably is not a major feature. However, because the nature and possible magnitude of displacement are unknown, this horizon was designated as a unit boundary. The breccias in this unit generally fill interstices between pillows and represent fragmented pillow rinds. Thin limestone layers are present in Sections 35-4, 37-3, and 38-2. Several of these contain small angular sideromelane fragments, either fresh or altered to smectite.

Most of the basalts in this unit are moderately to highly phyric with 15 to 25 per cent phenocrysts. However, the phenocryst content varies widely within individual pillows, and nearly aphyric zones occur in Section 37-6; 38-2, 5, and 6; and 39-2 and 3. In all specimens, plagioclase makes up the bulk of the phenocrysts, average about 15 per cent. Individual crystals are euhedral to subhedral and up to 10 mm long. Olivine, pseudomorphed by smectite, makes up 5 to 10 per cent of the uppermost basalts but is generally less than 5 per cent below Section 36-4. The olivine phenocrysts are typically euhedral, and seriate in size up to 8 mm. Clinopyroxene phenocrysts are more abundant in Unit 4 than in either Units 1 or 2, averaging about 3 to 5 per cent of the rock. They occur either as single, rounded and corroded, crystals or as irregular subophitic intergrowths with plagioclase.

Unit 5

This unit is a 7.1-meter-thick sequence of pillow basalt separated from the overlying pillow basalts of Unit 4 by a possible fault at Section 42-3, 75 cm. The lower contact is at Section 43-1, 127 cm, at the top of the massive basalt of Unit 6.

The basalts of Unit 5 are sparsely to moderately phyric with large variations in phenocryst content within individual pillows. Plagioclase phenocrysts range from 1 to 10 per cent, olivine phenocrysts from 1 to 7 per cent, and clinopyroxene phenocrysts from 0 to 5 per cent. The plagioclase crystals are euhedral to subhedral, up to 10 mm long and typically fresh. Olivine crystals, pseudomorphed by smectite, have a maximum diameter of about 5 mm and are euhedral. Most of the clinopyroxene occurs as subophitic intergrowths with plagioclase; individual, rounded megacrysts are rare. Groundmass textures range from glassy to very fine grained quench. Typically, acicular plagioclase microlites and small skeletal olivine crystals are surrounded by radiating sheaves of clinopyroxene and subordinate granular magnetite.

Alteration is slight, except for the presence of scattered veins filled with smectite and calcite. Vesicles comprise 1 to 3 per cent of most specimens and are also filled with smectite and calcite. Smectite also replaces olivine and some glass.

Unit 6

This unit is made up of moderately phyric massive basalt and extends from Section 43-1, 127 cm, to Section 43-5, 127 cm; it is 6.1 meters thick. Fine-grained zones occur at both the upper and lower margins, but no glass selvages were recovered and no internal cooling breaks were observed or inferred.

These basalts are sparsely to moderately phyric with a phenocryst content varying from about 10 per cent in the upper part to 3 per cent in the lower part. Plagioclase, which ranges from 2 to 10 per cent, typically forms subhedral prisms up to 5 mm long. Olivine and clinopyroxene each make up from 1 to 3 per cent. Olivine occurs in euhedral crystals, up to 3 mm long, always replaced by smectite. Clinopyroxene forms anhedral, subophitic intergrowths with plagioclase and is most abundant in the coarsest parts of the unit. The groundmass ranges from fine-grained, intersertal near the margins, to medium-grained, subophitic in the center. Some interstitial glass is present even in the coarsest-grained specimens, resulting in an "ophimottled" texture.

Alteration is generally weak, and secondary minerals are largely confined to veins and vesicles, both of which are filled with smectite and calcite. Vesicles are somewhat larger and more abundant in this unit than in the overlying pillow basalts of Unit 5. Olivine crystals are always replaced by smectite, but other phenocrysts are fresh.

Unit 7

This unit consists of a pillow basalt sequence extending from Section 43-5, 127 cm, to the base of Core 47. Only 9.6 meters of basalt was recovered from this 31.4-meter-thick interval, and recovery in Cores 46 and 47 was zero. Hence, the lower contact could be anywhere between 514.5 and 532.5 meters sub-bottom, its placement at the base of Core 47 being arbitrary. A glass selvage marks the upper contact with the massive basalt of Unit 6; the lower contact was not recovered.

Phenocrysts of plagioclase average about 8 per cent, olivine about 4 per cent, and clinopyroxene about 3 per cent of these basalts. Variations in phenocryst content are largely within individual pillows, with pillow margins being the most phyric. The plagioclase crystals occur as subhedral prisms up to 10 mm long, which occur singly or in glomerophyric clusters with clinopyroxene. Olivine crystals are euhedral to subhedral, up to 5 mm long, and are completely replaced by smectite except in fresh glass selvages. Clinopyroxene typically forms subophitic intergrowths with plagioclase, only rarely forming rounded megacrysts. The groundmass ranges from glassy to fine-grained and typically exhibits quench textures. Basalts in the interval from Section 44-1, 85 cm, to Section 44-2, 43 cm, are somewhat more crystalline than in pillows of comparable size elsewhere in the unit. The crystalline groundmass consists of acicular plagioclase microlites, skeletal olivine crystals, granular magnetite, and poorly crystallized clinopyroxene with variable percentages of interstitial glass.

Below Section 44-5, the basalts are highly fractured with many smectite-filled veins. Elsewhere the rock is only weakly altered. Some fresh glass persists in most pillow rinds, and olivine is the only commonly altered phenocryst phase. Smectite- and carbonate-filled vesicles average about 1 to 2 per cent, but locally may be up to 5 per cent of the rock.

Unit 8

The interval from the top of Core 48 to Section 52-4, 27 cm, is included in Unit 8, which consists of medium- to coarse-grained, moderately phyric massive basalt. No cooling breaks or major lithologic discontinuities were observed, although the unit can be divided into two sub-units (A and B), based on differences in grain size between Cores 48 and 49. The upper contact of Unit 8, which must be present somewhere in Cores 46 or 47, was not recovered. The lower contact in Section 52-4, is marked by a small glass selvage.

Sub-unit 8A, confined to Core 48, consists of a single lithologic unit of highly phyric, "ophimottled" basalt. Glassy selvages are absent, whereas they are abundant in the next higher basalts, the pillow basalts of Unit 7. A 2-cm-wide zone of fine-grained basalt at Section 48-7, 54 to 56 cm, is continuous with the tachylytic groundmass of the "ophimottled" basalt and is interpreted as a vein formed during cooling and solidification of the host rock.

Sub-unit 8B, which occurs in Cores 49 through 52, varies from moderately to highly phyric basalt. It is similar to Sub-unit 8A, but is separated from it by a fine-grained zone which presumably lies just below an unrecovered contact between the two units. "Ophimottled" texture is less well defined than in Sub-unit 8A, and the groundmass of Sub-unit 8B commonly contains more glass. Grain size decreases in downward direction, starting at about 562 meters sub-bottom depth, and the base of the unit is chilled to a glass and molded around the intricate glassy margin of the uppermost pillow Unit 9. Small breccia zones in Core 49 are interpreted as being due to post-solidification deformation owing to cooling or compaction. The breccias consist of small fragments separated by thin veins of green smectite. Most pieces fit closely with one another, indicating little relative movement.

The basalts of Unit 8 are moderately phyric, with about 15 per cent phenocrysts of plagioclase, olivine, and clinopyroxene. Plagioclase phenocrysts make up about 10 per cent, olivine about 3 per cent, and clinopyroxene about 2 per cent of the rock. All of the phenocrysts are seriate in size with plagioclase less than 5 mm, and olivine and clinopyroxene less than 3 mm. Olivine forms individual crystals, but plagioclase and clinopyroxene are typically intergrown in medium- to coarse-grained clots with an ophitic to subophitic texture. These clots are set in a glassy to fine-grained quenched groundmass, resulting in the characteristic "ophimottled" texture.

Alteration in these basalts is weak but pervasive. Green smectite is the principal secondary mineral; it occurs in pseudomorphs after olivine, in sparse vesicles and veinlets, and in the groundmass where it replaces glass. Carbonate forms small veinlets commonly rimmed with smectite, and also replaces olivine. A few veins show minor oxidation with development of brown iron hydroxides which stain the pre-existing smectite and carbonate. Zeolite was observed in one thin section (Section 48-7, 85 cm), where it fills small vesicles. Minor secondary pyrite is present in a few veinlets.

Unit 9

This unit, about 103 meters thick, extends from Section 52-4, 27 cm, to Section 64-4, 127 cm. It consists of a complex sequence of pillow basalt and related breccia of relatively uniform, moderately to highly phyric basalt. It can be divided into four sub-units based on dominant lithologic character, but contacts between most of the sub-units are gradational and often they are placed arbitrarily at core boundaries.

Sub-unit 9A is about 61.5 meters thick and consists of about 90 per cent pillow basalt and 10 per cent broken-pillow breccia. Its top is sharply defined below the massive basalt of Unit 8 in Section 52-4, and its base is taken as the bottom of Core 58. Broken-pillow breccia is increasingly abundant from Section 57-3 downward and comprises nearly 30 per cent of the lower 2 meters of Core 58.

Sub-unit 9B, 9.0 meters thick and confined to Core 59, is dominantly broken-pillow breccia. This breccia makes up 50 per cent of the upper meter of Core 59 and increases in downward direction to 100 per cent within another meter. The breccia contains many fragments of glassy pillow rinds and is clearly derived from broken pillows. Individual fragments range from a few millimeters to about 3 cm and are highly angular. The breccia is poorly sorted and has no trace of bedding, indicating little or no reworking. The ratio of glassy to nonglassy material decreases in downward direction, however, and clasts of fine-grained basalt greatly predominate in the lower meter of Core 59.

Sub-unit 9C is composed of about 9 meters of lithic basalt breccia of uncertain origin. Its top is taken arbitrarily as the top of Core 60, and its base is assumed to be the bottom of Core 61. The breccia of Sub-unit 9C has a much higher clast-to-matrix ratio than that of the pillow breccia of Sub-unit 9B. The lower half-meter of Core 60 consists of hyaloclastite breccia, with angular sand-size sideromelane, plagioclase, and basalt fragments in a fine-grained matrix. The hyaloclastite breccia grades upward into the lithic breccia of Sub-unit 9C. The breccias of Sub-units 9B and 9C may have been derived from underlying pillowed or massive flows, either during eruption or subsequently as talus or slump debris. The glassy detritus in the lower half-meter of the unit is probably derived from pillow rinds or margins of massive flows.

Sub-unit 9D is a 23.5-meter-thick sequence of pillow basalt with very little associated breccia. Its top is defined arbitrarily as the top of Core 62 and its base occurs at Section 64-4, 127 cm. A pillow with a moderately phyric margin and a sparsely phyric to aphyric interior forms the lower 55 cm of the unit.

The lithologic assemblage represented by Unit 9 probably resulted from several related eruptions. All of the rocks of the unit are similar mineralogically, being seriate porphyritic with 10 to 15 per cent of phenocrysts. Differences in phenocryst content are related largely to differential accumulation within single pillows rather than gross changes throughout the unit. Phenocryst ratios vary from 6:2:2 to 6:2:4 plagioclase, olivine, clinopyroxene. Plagioclase ranges in size to 5 mm, olivine and clinopyroxene to 2 mm. Clinopyroxene crystals usually occur as glomerocrysts with plagioclase, but some single, rounded crystals are present. Groundmass textures range from intersertal to glassy, and generally show signs of quenching.

Alteration in Unit 9 differs little from that in Unit 8, except for an increased sulfide content. The extent of alteration is directly related to the extent of fracturing and is most intense in the matrix of breccias in Sub-units 9B and 9C. Here, presumably glassy material has been completely altered to smectite and minor carbonate. Sparse vesicles are also filled with these minerals. Olivine in the only commonly altered primary phase, being replaced by smectite, except in fresh glass selvages. Most selvages contain some fresh glass; the rest is replaced by smectite. Sulfide, probably pyrite, is more abundant in Unit 9 than in Unit 8. It occurs in veinlets, replaces olivine, and forms irregular patches disseminated throughout the groundmass, particularly in the medium- and coarse-grained pillows. Some sulfide clusters are several millimeters across. The sulfide is closely associated with smectite and appears to increase irregularly down the section.

Unit 10

Unit 10, 12.5 meters thick, consists of at least one, and probably two, cooling units of moderately to highly phyric, massive basalt. An upper glassy selvage is preserved in Section 64-4, 127 cm. The base of the unit was not recovered and is defined arbitrarily as the base of Core 65. The unit is divided into two sub-units (A and B) on the basis of a thin breccia zone. The sub-units differ primarily in phenocryst proportion and percentage of vesicles.

Sub-unit 10A is 7.8 meters thick, extending from the top of the unit to Section 65-3, 64 cm; its base was not recovered. The rock is moderately phyric with about 15 per cent phenocrysts. Plagioclase phenocrysts form subhedral prisms up to 8 mm long and make up about 10 per cent of the rock. Olivine makes up to 4 to 5 per cent and occurs in euhedral crystals up to 2 mm long; it is completely replaced by smectite, which also fills sparse vesicles and veinlets.

Sub-unit 10B extends about 4.7 meters from Section 65-3, 64 cm, to the bottom of Core 65. The upper 10 cm of the unit is brecciated; the rest is massive and nonvesicular. The breccia at the top of the unit consists of angular fragments of crystalline basalt separated by thin veins of smectite. The unit has a glassy lateral margin in Section 65-4, 76-97 cm, which dips at about 80 degrees. The basalts of Sub-unit 10B are generally medium-grained, but they are fine-grained near the lateral margin and in the lower 30 cm of Section 65-3, possibly near an unrecovered lateral margin.

These basalts contain about 10 per cent plagioclase phenocrysts and 3 per cent olivine phenocrysts. The plagioclase crystals are subhedral and range up to 6 mm in length. Olivine pseudomorphs are euhedral and up to 2 mm long. The phenocrysts are set in a glassy to cryptocrystalline groundmass with characteristic quench textures. Olivine crystals and most glass selvages are replaced by smectite; other minerals are fresh. Sparse smectite-filled vesicles are scattered throughout the unit.

The origin of Unit 10 is uncertain. The glassy lateral margin on Sub-unit 10B suggests a dike, but this could also be the chilled snout of a flow, perhaps where it grades into a carapace of pillows. This glassy zone could also conceivably reflect cooling by water penetrating along a cooling joint. The breccia at the top of the unit could be related to forceful intrusion, flow brecciation, or a fault. The smectite between the fragments is slickensided, suggesting some movement, but the individual fragments show no pervasive shearing.

Unit 11

This unit is a 9-meter-thick sequence of fine-grained, moderately to highly phyric pillow basalt recovered only in Core 66. Its base was not recovered and is taken arbitrarily as the bottom of this core. A minor amount of broken-pillow breccia occurs toward the base of the unit.

Plagioclase and olivine phenocrysts combined make up 10 to 15 per cent of the rock. Plagioclase occurs as subhedral crystals up to 8 mm long; olivine as euhedral crystals up to 3 mm. Olivine is replaced by smectite, except in fresh glass selvages. Clinopyroxene does not form individual phenocrysts, but it sometimes occurs in glomerophyric clots with plagioclase. Vesicles are up to 2 per cent of the rock and range to 0.5 mm in diameter. These are filled with smectite and calcite, as are sparse veins. Glass selvages are partly altered to smectite.

Unit 12

This unit is a single cooling unit, 6.1 meters thick, of sparsely vesicular, moderately phyric massive basalt. Its unrecovered top is defined arbitrarily as the top of Core 67, and its fine-grained base occurs at Section 67-6, 35 cm, where it overlies the petrographically distinct basalt of Unit 13.

Phenocrysts in Unit 12 total between 10 and 15 per cent by volume and consist largely of plagioclase with lesser olivine and minor clinopyroxene. Plagioclase and clinopyroxene phenocrysts typically occur in subophitic clots up to 8 mm across. Olivine forms single euhedral crystals up to 5 mm, which are completely replaced by smectite. Groundmass textures are mostly medium-grained, although patches of glass remain. Fine-grained to glassy margins occur at the top and bottom of the unit, and a fine-grained segregation vein, which grades into the medium-grained rock, occurs at Section 67-5, 114-116 cm. Alteration in this unit is similar to that in adjacent units. Sparse vesicles and veinlets are filled with smectite and calcite, and some glass is altered to smectite.

Unit 13

This unit is a single cooling unit of medium- to coarse-grained massive basalt. It extends from Section 67-6, 35 cm, to the bottom of the hole at Section 69-2, 38 cm, and is about 15 meters thick. The uppermost 50 cm is rather vesicular (2 to 3%), but the contact with Unit 12 was not recovered. Plagioclase phenocrysts make up about 8 per cent by volume and range in size from 5 to 15 mm. The largest crystals are rounded, highly zoned, and are probably xenocrysts. Some of these have small sulfide inclusions. Unlike other units in this hole, Unit 13 is completely crystalline with a subophitic to ophitic groundmass texture. Minor interstitial material intergrown with apatite appears to be alkali feldspar. This material appears to be optically continuous with the plagioclase laths and to represent a late-stage crystallization product. Much of the material is characterized by a patchy texture, perhaps related to exsolution of K and Na phases. Olivine is rare and is always replaced by smectite. Complete crystallization of the groundmass has produced relatively large magnetite crystals up to 0.5 mm across. Smectite is irregularly distributed and is locally intergrown with minor pyrite.

This unit is tentatively interpreted as a thick flow, but neither contact was recovered; its holocrystalline groundmass is also consistent with an origin as a sill. However, the paleomagnetic inclinations of this unit are consistent with the rocks above, suggesting nearly simultaneous emplacement.

Unit 14

This unit consists of two narrow basalt dikes cutting Unit 13. One dike occurs between Section 68-1, 120 cm, and Section 68-2, 48 cm; and the second lies between 2 and 25 cm in Section 68-4. The two occurrences could be part of the same dike, but they are not connected in the core; hence, they are designated Sub-units 14A and 14B, respectively. Steeply dipping glassy margins, contrasting lithologies, and lack of textural variation in the host rock defined the discordant relationships between Units 14 and 13. The dikes are lithologically similar to Unit 8 through Sub-unit 9C, but their paleomagnetic inclinations suggest that they could be related only to Unit 12 through the lower part of Sub-unit 9D.

The dike rock is a plagioclase–olivine–clinopyroxene-phyric basalt with a fine-grained, holocrystalline groundmass. No vesicles are present. Proportions and percentages of phenocrysts vary considerably because of flow segregation. Phenocrysts range from 5 to 30 per cent in proportions from 6:2:2 to 6:3:1 plagioclase, olivine, clinopyroxene. Rounded clinopyroxene is common, ranging in size to 4 mm. Plagioclase crystals range up to 6 mm in size, and altered olivine crystals, in highly skeletal forms, to 4 mm. Plagioclase–clinopyroxene clots often attain sizes in excess of 10 mm. A breccia occurs between the dike and the host rock at Section 68-2, 30 to 50 cm. It consists of angular fragments of coarse-grained host rock and glassy dike rock in a palagonite–smectite matrix. Some of the glass is still fresh.

STRUCTURAL FEATURES

The very high recovery of basalt at these holes allow us to draw conclusions about the original aspect of the basalt in far greater detail than was possible with previous deeply drilled sites, with much lower recovery rates. The division into lithologic units itself is more convincing here, because of a high rate of recovery of lithologic contacts.

The bulk of the basalt at both sites is pillowed basalts. The pillow margins are highly recognizable, and quite typical of what are seen in other basalt sequences. At both holes, fewer pillow bottoms were recovered (at Hole 417A,127 upper, 95 lateral, and 75 lower contacts; and at Hole 417D,179 upper, 87 lateral, and 111 lower contacts). If this observation is valid, its explanation eludes us. It is possible, but not immediately clear, that the process of drilling might favor the recovery of a pillow margin drilled from outside in rather than vice versa. In the absence of additional information, we cannot pursue this problem further. An estimate of the size of the pillows was made for both holes at this site. The basic method for this size determination begins with the premise that most pillows are not drilled through the center, and that the vertical distance traversed is somewhat less than the vertical thickness of the pillow. An attempt to reconstruct the pillow by projecting the radial fractures inward, and assuming that they intersect at the medial plane, showed that the medial diameter determined for Hole 417A was 40 cm, with the maximum size 150 cm (few pillows thicker than 50 cm were found). Another method for this site was to count the total number of pillows in the recovered pillow basalt section (170 to 280 in 92) and determine an average by dividing the two figures. This method yields 33 to 54 cm as the mean vertical thickness, which is in accord with the geometric reconstruction method.

Because of paleomagnetically inferred post-eruptive tilting of the upper part of Hole 417, we made an attempt to identify structural features recovered in the drilled section which might support or argue against the inferred tilt. Assuming that the pillowed basalts of Holes 417A and 417D were once identical, a variety of observations were made and conclusions drawn. These concern (1) differing apparent thickness of the pillows, (2) tilting as inferred from the distribution of the angles of pillow margins, (3) the character of included limestones at Hole 417D, and (4) the attitude of joints in the massive basalts.

The apparent thickness of the pillows differed at the two holes, with the median thickness at Hole 417D being about 55 cm (36 measurements) as compared with 40 cm at Hole 417A (42 measurements). If the pillows are horizontally flattened and approximately planar units, then this size discrepancy corresponds to about 40° tilt at Hole 417D. The larger amount of hyaloclastite at Hole 417A, however, indicates that the original eruptive environment might have differed sufficiently as to permit an original pillow thickness difference independent of tilting.

Histograms of the observed angles of the pillow margins may be the strongest supporting evidence for tilting. The observed margins at Hole 417D clearly peak between 25° and 40°, while the peak at Hole 417A is less than 15°. If there were a difference in original pillow aspect (more flattened at Hole 417A, more spherical at Hole 417D), we might except histograms of different form, with the peak of Hole 417A being sharper than that of Hole 417D. However, there appears to be a shift in the peak rather than a simple change in peak width, and we conclude that tilting is indicated. An additional possibility is that the eruption of the lava might have produced inclined pillows by flowing down a slope. In such a case, the angles observed would represent no subsequent tilt at all.

The observation of tilting of limestone is based on a single example, Interval 417D-31-4, 0 to 15 cm (Figure 22), which shows stratification now inclined nearly 55°. Assuming that this stratification might have been as steep at 20°, nearly 35° of tilt is indicated.

The observation of joints in the massive basalt units is based similarly on too few examples to be completely convincing. If massive basalts cool statically either as lava ponds or as shallow sills, then we might expect their upper surfaces to be sub-horizontal, and cooling fractures to propagate downward at right angles to the isothermal surface. A massive basalt recovered at Hole 417D from Section 32-1, 70 cm to Section 34-5, 112 cm had 15 measurable fractures, whose mean inclination was about 40° from the vertical. A much larger population of calcite-filled fractures, many of which are probably much younger, had 40 per cent of their inclination less than 15° from the vertical, but a secondary maximum (15%) near 40°.

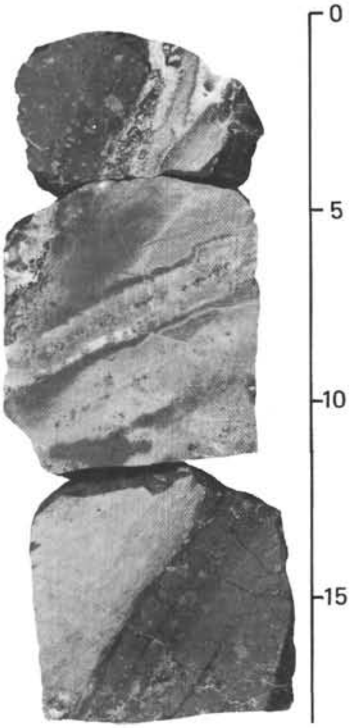


Figure 22. *Close-up photo showing tilted limestone Interval 417D-31-4, 0 to 15 cm.)*

Of these observations, we would put some weight on the angles of pillows margins, but little or no weight on the other observations, either because of the assumptions involved or because of the small number of observations.

The inference of tilting, however, leaves completely unanswered the explanation for such tilting. At Hole 417D, the paleomagnetic inclinations appear to change to the "untilted" shallow values abruptly below a zone at Core 44. This zone shows brecciation of a type not observed in shallower samples, with some slickensiding. Although this breccia might be related to cooling processes, it could also be shallow tectonic and was not seen in other samples. If we infer tilting, then we must consider two mechanisms. The first involves rotation around a horizontal or sub-horizontal axis accompanying some sort of gravity faulting. Such tilting is well known in landsliding, but examples from materials as competent as basalt are not known. A second possibility is that the tilting is constructional, and results when an oversteepened layer of lava sheets breaks away and slumps downward. The tilt, then, is a sort of angle of repose of coherent units tens of meters thick. In either case, the breccia zone could be interpreted as a very shallow fault breccia.

In summary, we would point out that high fractions of recovered rock lead to the possibility of structural inference of some interest, but that the present observations must be interpreted only with considerable caution. The coincidence of inferred tilt through paleomagnetic analysis and our structural analysis would appear to support the latter approaches, but we are not able to satisfy numerous criteria for this interpretation.

BASALT CHEMISTRY AND MAGMATIC VARIATION

Introduction

Both Leg 51 and Leg 52 produced routine shipboard X-ray fluorescence analyses for SiO_2, Al_2O_3, total Fe as FeO*, MgO, CaO, K_2O, and TiO_2, using a shipboard geochemical lab made available by CNEXO. A CHN analyzer was used to determine H_2O and CO_2. Small rock cores or chips were washed in distilled water, crushed, and ground to less than 60 μm in an agate mortar, and dried at 110°C. The rock powder was then ignited at 1050°C and weighed; this figure is reported as "loss on ignition," and should represent mainly H_2O and CO_2 lost from the sample. A 550-mg aliquot was then mixed with lithium borate and fused to a glass disk at 1050°C. The disk was re-fused, as necessary, to assure homogeneity. A cathode tube ray at 50 kv was used for excitation, and conventional rock standards were used for calibration. An additional aliquot of the rock powder dried at 110°C was used for H_2O and CO_2 analysis. These analyses were also calibrated against conventional greenstone standards. In addition, DSDP standards prepared from Leg 37 samples were run on Leg 52 as an additional check on the accuracy of the analytical procedures. Comparison of the Leg 52 analyses of the Leg 37 rocks with the USGS values determined for these same samples (Table 11) provides an empirical indication of the accuracy of the data. As the same equipment, standards, and methods were used on all three legs, the data should be comparable.

All analyses were corrected for the added carbonate observed in thin section by subtracting the amount of CaO required to combine with CO_2 as $CaCO_3$. Data were then normalized to a sum of 97 weight per cent to allow for omission of Na_2O, MnO, and P_2O_5 in the analyses. Values for these oxides may be estimated by comparison with shore-based analyses completed subsequently on similar material, in order to facilitate computation of CIPW norms. For purposes of the discussion in this section, only data representing the freshest rock samples are considered in order to establish the primary magmatic characteristics of the basalts. These "fresh" analyses were chosen on the basis of the following criteria, imposed prior to normalization of the sums:

$K_2O \leq 0.10$ weight per cent;
$H_2O \leq 1.25$ weight per cent;
and $CO_2 \leq 0.40$ weight per cent.

At Site 417, Leg 51, basalt from the 206 meters of basement penetrated at Hole 417A was recovered and analyzed. Much of this basalt was extensively altered; of the 31 samples analyzed, only six pass the chemical "screen" for freshness (Table 12). At Hole 417D, Legs 51 and 52, a total of 366 meters of basement was penetrated; of the 66 samples analyzed on the two legs, 29 samples passed the "screen" (Table 13).

Chemical Variation

The data cover a fairly wide range of compositions, as exemplified by the range in TiO_2 (1.14 to 1.67%), FeO* (8.6 to 11.1%), and Al_2O_3 (14.5 to 18.2%). The chemical data from Holes 417A and 417D (Table 14) do not show any obvious division into distinct compositional groups, in contrast to those obtained subsequently in Hole 418A. This is made clear in plots of FeO versus TiO_2 (Fig. 23) and Al_2O_3 versus TiO_2 (Fig. 24), and of Al_2O_3 versus (FeO* + MgO) (Fig. 25). There is considerable scatter among the data in these plots, with a fairly strong negative correlation (r −0.75) between Al_2O_3 and (FeO* + MgO). Considerable overlap exists between the data fields from Holes 417A and 417D, suggesting that the weathered basalt sequence penetrated at Hole 417A was originally similar to that represented in the upper part of Hole 417D.

Petrographic criteria may be used to subdivide the basalt data from Site 417D into three groups. The divisions are based on the nature of the phenocryst assemblage and have stratigraphic continuity. Lithologic Unit 1, characterized by a two-phase plagioclase–olivine phenocryst assemblage, is not represented by analyses passing our criteria for "fresh" basalt. Units 2 through 9C are characterized by a three-phase olivine–plagioclase–pyroxene phenocryst assemblage. Units 9D through 12 are characterized by a two-phase olivine–plagioclase phenocryst assemblage, while Unit 13 contains only a single-phase (plagioclase) phenocryst assemblage. Two dikes and an aphyric basalt represent the other distinctive lithologies. Carbonate-corrected averages of these major lithologic groups, the aphyric basalt, and two dikes with their CIPW norms are given in Table 15. The normative compositions suggest that, compared with the aphyric basalt, all of the phyric varieties are relatively enriched in plagioclase; in some, olivine enrichment is implied as well, in general agreement with petrographic observations. Overall, the differences are not large, suggesting that significant amounts of crystal cumulates in the phyric basalts are of local, rather than general, importance.

The aphyric basalt lies close to the high-TiO_2, low-Al_2O_3 end of the data distribution, and may represent a typical magmatic liquid at this site. One of the two dikes plots with the basalts, which it also resembles in its three-phase phenocryst assemblage. The second dike is exceptional in its very high Al_2O_3, but appears to lie on the trend of the data set as a whole (Figures 23 through 25), and it shows no obvious alteration effects. Petrographic observations show that the three-phase phenocryst assemblage in these dikes, which is dominated by plagioclase, ranges from about 5 to 30 per cent by volume. Thus, the compositional differences between them and, by implication, the differences in the whole suite of basalts, might be the result of differences in the amount of accumulation of phenocrysts. The role of crystal cumulates, and of the possible additional, more subtle effects of variations in the liquids enclosing these cumulates, are considered in more detail in several of the shore-based studies.

TABLE 11
Comparison of USGS and Leg 52 Analyses for DSDP Leg 37 Standard Samples

Sample (Hole-Core-Section)	332A-8-2		332A-40-2		332B-3-4		332B-35-2	
Oxide	USGS	Leg 52	USGS	Leg 52	USGS	Leg 52	USGS	Leg 52
SiO_2	51.6	51.5	49.2	49.1	48.9	48.4	47.6	47.2
Al_2O_3	14.8	14.4	18.0	17.1	20.4	20.6	12.8	12.5
FeO*	9.90	9.90	6.41	6.30	5.85	5.73	9.10	9.49
MgO	7.29	7.34	9.53	9.60	7.72	8.03	18.2	18.6
CaO	12.1	12.3	14.3	14.6	14.9	14.9	9.30	9.31
K20	0.32	0.31	0.12	0.11	0.05	0.04	0.19	0.17
TiO_2	1.18	1.13	0.57	0.55	0.41	0.41	0.47	0.47
CO_2	0.11	0.09	0.96	0.98	0.09	0.04	2.37	2.16

TABLE 12
Shipboard X-ray Fluorescence Analyses of Basalts From Hole 417A[a]

Sample (Core-Section, Interval in cm)	37-1, 31-34	38-3, 46-49	41-1, 103-105	42-2, 20-22	43-5, 22-25	44-1, 12-15
SiO_2	49.2	49.0	49.5	49.7	49.8	49.1
TiO_2	1.32	1.36	1.41	1.53	1.41	1.47
Al_2O_3	16.9	18.2	17.1	17.7	16.5	16.5
FeO*	9.83	8.64	9.56	8.72	10.06	10.59
MgO	6.87	6.22	6.30	6.29	6.43	6.49
CaO	12.8	13.6	13.2	13.1	12.7	12.8
(Na_2O)	(2.35)	(2.35)	(2.25)	(2.30)	(2.25)	(2.25)
K_2O	0.03	0.00	0.00	0.01	0.02	0.04

[a]Values for Na_2O are estimates based on comparison with shore-based analyses of similar material. All data are carbonate-corrected and screened to exclude altered samples (see text).

PHYSICAL PROPERTIES OF BASEMENT ROCKS

Measurements of wet-bulk density, compressional wave velocity, and porosity were made at closely spaced intervals in the basement rocks recovered in Holes 417A and 417D for comparison with geophysical studies conducted in the vicinity of the site, with the results of downhole logging and with shipboard studies of petrology, geochemistry and rock magnetism conducted on the recovered material. The data are tabulated in Tables 15 and 16 and, together with computed values of grain density and acoustic impedance, core recovery statistics and section-by-section estimates of the relative abundance of altered interstitial material and limestone, are plotted as a function of sub-bottom depth in Figures 26 and 27. The presence of interstitial material in intervals of no apparent recovery arises from estimating the abundance of such material after spacers have been placed in the core liners.

Since density, velocity, and porosity measurements are sensitive to water content, samples were selected for physical property studies and stored in sea water as soon as possible after the cores had been received on deck. Each sample was cut to the form of a right cylinder one inch in diameter by approximately one inch long with polished ends and an orientation mark indicating the vertical direction. A complete set of measurements was then made on each sample to allow close intercorrelation of the physical properties. Grain density and acoustic impedance values were then calculated from the above measurements.

Wet-Bulk Density

The values of wet-bulk density reported in Tables 15 and 16 and shown in Figures 26 and 27 were obtained by the immersion technique (double weighing) on closely spaced, water-saturated samples from all levels of both holes. The samples from Hole 417A and Cores 22 through 45 from Hole 417D were weighed in distilled water, whereas those from Hole 417D, Cores 48 through 69, were weighed in salt water (ϱ = 1.025 g/cm^3) in an attempt to prevent contamination of the immersion medium by salt from the samples themselves. Because of the motion of the ship, the reproducibility of any single measurement was ±0.1 g. The accuracy of the wet-bulk density measurements is thus about ±1 per cent.

Additional measurements of wet-bulk density were made on the samples from Holes 417D, Cores 48 through 69, using the GRAPE 2-minute counting procedure outlined by Boyce (1973). By daily calibration against standards of known density, we estimate that the values obtained by this technique in Tables 15 and 16 are accurate to ±2 per cent.

In comparing the wet-bulk densities obtained by both methods (Figure 28), the GRAPE method gives values that are consistently 0.8 per cent higher than gravimetric determinations and being indirect and more prone to

TABLE 13
Shipboard X-ray Fluorescence Analyses of Basalts From Hole 417D[a]

Sample (Core-Section, Interval in cm)	SiO_2	TiO_2	Al_2O_3	FeO*	MgO	CaO	K_2O	Lithologic Unit	Phenocryst Assemblage
27-3, 43-45	50.3	1.46	17.4	9.14	5.88	12.8	0.04	1B	Plag–Oliv–Cpx
28-4, 102-104	50.0	1.28	17.4	9.18	6.31	12.8	0.04	1B	Plag–Oliv–Cpx
32-1, 96-98	50.6	1.44	17.2	9.73	5.80	12.2	0.06	3	Plag–Oliv–Cpx
32-6, 60-62	51.6	1.51	17.0	9.10	5.92	11.8	0.07	3	Plag–Oliv–Cpx
35-4, 3-9	49.5	1.40	17.4	9.30	6.47	12.5	0.04	4	Plag–Oliv–Cpx
37-5, 116-119	49.7	1.48	17.1	9.75	6.79	12.0	0.06	4	Plag–Oliv–Cpx
30-3, 39-42	50.1	1.51	15.0	10.8	7.15	12.4	0.03	4	Plag–Oliv–Cpx
40-1, 114-117	49.6	1.39	17.5	9.22	6.55	12.5	0.04	4	Plag–Oliv–Cpx
41-5, 43-52	50.0	1.16	17.1	8.98	6.84	12.9	0.01	4	Plag–Oliv–Cpx
42-3, 121-127	50.1	1.15	16.9	9.07	6.37	13.4	0.04	5	Plag–Oliv–Cpx
43-1, 78-81	50.0	1.60	16.0	10.4	6.79	12.2	0.07	5	Plag–Oliv–Cpx
43-6, 13-15	50.0	1.56	16.2	10.4	6.94	11.8	0.04	7	Plag–Oliv–Cpx
48-7, 84-86	49.9	1.53	16.4	9.63	7.17	12.4	0.01	8A	Plag–Oliv–Cpx
49-2, 20-22	50.5	1.67	16.7	9.26	7.34	11.4	0.09	8B	Plag–Oliv–Cpx
52-2, 41-43	50.1	1.40	14.8	10.7	7.31	12.5	0.03	8B	Plag–Oliv–Cpx
52-5, 73-75	49.7	1.62	15.9	10.7	6.36	12.6	0.02	9A	Plag–Oliv–Cpx
55-4, 96-98	49.3	1.51	15.2	11.1	6.77	13.0	0.01	9A	Plag–Oliv–Cpx
63-2, 66-68	50.3	1.46	14.8	9.82	5.42	13.2	0.01	9D	Plag–Oliv
64-4, 87-89	50.5	1.66	14.5	10.8	7.69	11.8	0.01	9D	(Aphyric)
64-6, 15-17	50.0	1.39	16.4	9.77	6.63	12.8	0.01	10A	Plag–Oliv
65-4, 114-116	49.5	1.36	16.5	10.1	6.94	12.6	0.01	10B	Plag–Oliv
65-6, 37-39	49.6	1.14	17.2	9.12	7.23	12.7	0.01	10B	Plag–Oliv
66-3, 44-46	50.1	1.35	16.3	9.83	6.65	12.8	0.01	11	Plag–Oliv
67-2, 29-31	49.7	1.33	16.3	9.95	6.97	12.9	0.01	12	Plag–Oliv
67-5, 33-35	49.4	1.34	16.4	10.1	7.03	12.7	0.01	12	Plag–Oliv
67-7, 35-37	50.8	1.42	16.1	9.50	6.36	12.9	0.01	13	Plag
68-2, 48-50	48.6	0.92	22.2	7.27	5.24	12.7	0.06	14A	(Dike)
68-3, 92-94	50.9	1.64	15.2	10.4	6.82	12.0	0.04	13	Plag
68-4, 18-20	49.9	1.50	15.4	10.4	7.02	12.4	0.01	14B	(Dike)

[a] All data are carbonate-corrected, normalized to 97 per cent, and screened to exclude altered samples (see text).

TABLE 14
Shipboard X-Ray Fluorescence Analyses and CIPW Norms, Hole 417D, by Petrographic Type[a]

Type	Three-Phase	Two-Phase	One-Phase	Aphyric	High-Al Dike	Three-Phase Dike
SiO_2	50.1	49.8	50.9	50.5	48.6	49.9
TiO_2	1.45	1.34	1.53	1.66	.92	1.50
Al_2O_3	16.5	16.3	15.7	14.5	22.2	15.4
FeO*	9.79	9.81	9.95	10.8	7.27	10.8
MgO	6.63	6.70	6.59	7.69	5.24	7.02
(MnO)	(0.15)	(0.15)	(0.15)	(0.15)	(0.15)	(0.15)
CaO	12.4	12.8	12.5	11.8	12.7	12.4
(Na_2O)	(2.33)	(2.28)	(2.32)	(2.45)	(2.50)	(2.30)
K_2O	0.04	0.01	0.03	0.01	0.06	0.01
(P_2O_5)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
N	17	7	2	1	1	1
			CIPW Norms			
Or	0.24	0.06	0.18	0.06	0.35	0.06
Ab	19.7	19.3	19.6	20.7	21.2	19.5
An	34.5	34.2	32.3	28.5	49.2	31.7
Di	22.0	23.7	24.1	24.3	10.9	24.2
Hy	16.6	14.3	20.2	17.6	6.17	15.5
Ol	3.65	4.99	0.23	5.10	9.99	5.62
Il	2.75	2.54	2.91	3.15	1.75	2.85
Ap	0.24	0.24	0.24	0.24	0.24	0.24

[a] Averages of data in Table 14. MnO, Na_2O, and P_2O_5 are estimates based on shore-based analyses of similar material.

systematic error, we shall instead use the gravimetric results throughout the following discussions. The GRAPE results, however, would not materially change the results or conclusions.

As can be seen in Figure 26, the basalts in Hole 417A increase in wet-bulk density with depth from a minimum of about 2.4 g/cm^3 in the altered basalts near the basalt/sediment contact to about 2.85 g/cm^3 toward the base of the hole. Properties of the basalts in Hole 417D, however (Figure 27), are quite different: their densities average 2.8 g/cm^3 and show no trend of increasing with depth, suggesting that the column is relatively fresh throughout. Strongly altered interstitial material found between pillows and in breccias in both holes has an average wet-bulk density of 2.2 g/cm^3 in Hole 417A (two measurements) and 2.5 g/cm^3 in Hole 417D (four measurements).

Sonic Velocity

The values of compressional wave velocity presented in Tables 15 and 16 and in Figures 26 and 27 were obtained on water-saturated samples at room temperature and pressure, using the Hamilton Frame Velocimeter (Boyce, 1973). The samples examined at each level were selected to be representative of the core and section from which the samples were taken. Thus, the majority of the samples were relatively fresh basalts from pillow and flow interiors and glassy to weathered basalts from pillow and flow margins. In addition, a small number of critical samples were taken of the interstitial material found between pillows and in veins and breccias. The velocity measurements were made for propagation

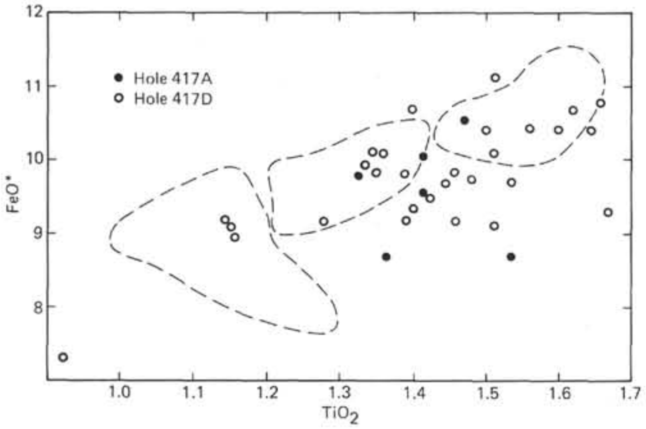


Figure 23. *Weight percentage of FeO* versus TiO_2. Dashed lines enclose fields of the three major composition groups recognized at Site 418.*

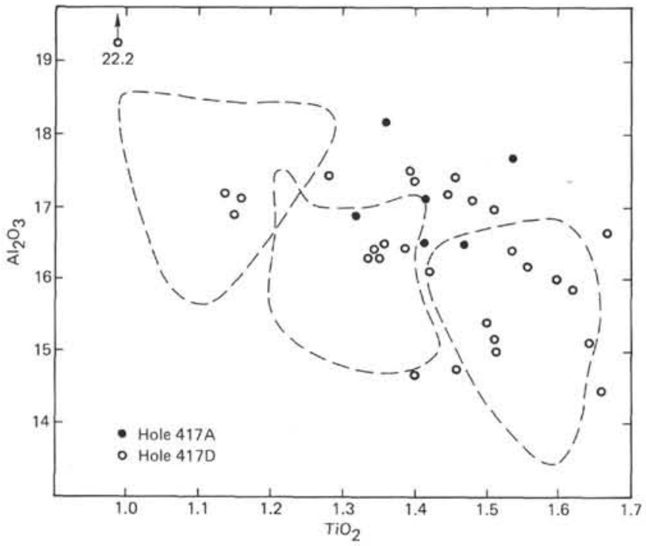


Figure 24. *Weight percentage of Al_2O_3 versus TiO_2. Dashed lines enclose fields of the three major composition groups recognized at Site 418.*

directions perpendicular to the core axis throughout both holes. In addition, a number of measurements were made parallel to the core in the lower levels of Hole 417D to check for seismic anisotropy. Through calibration checks against standards of known velocity and thickness, it is estimated that the measurements are accurate to ±1 per cent.

The basalts in Hole 417A increase sharply in velocity from a low of 3.79 km/s near the top of the basement to values exceeding 5.80 km/s near the base of the hole, suggesting a decrease in alteration with depth. As can be seen in Figure 26, the only significant departures from this trend are found in highly altered breccia zones where measured velocities average 2.88 km/s (two measurements).

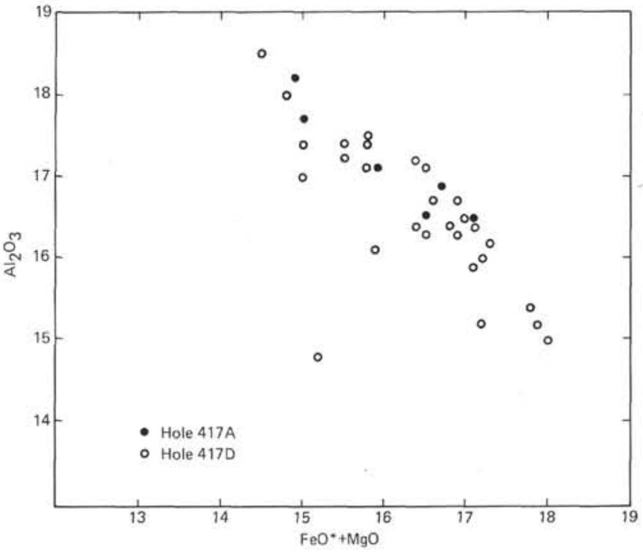


Figure 25. *Weight percentage of Al_2O_3 versus (FeO^* + MgO).*

TABLE 15
Physical Properties of Basement, Hole 417A

Sample (Hole-Core-Section, Interval in cm)	Density Wet-Bulk (g/cm^3)	Density Grain[a] (g/cm^3)	*P*-Wave Velocity (km/s)	Acoustic Impedance (×10^5 g/cm^2-s)	Porosity[a] (vol. %)
417A-24-1, 114-116	2.44	2.96	3.79	9.2	27.4
24-2, 54-56[b]	2.20	–	2.87	6.3	56.0
25-1, 126-128	2.57	2.94	4.63	11.9	19.1
26-1, 23-25	2.65	2.91	4.81	12.7	13.9
27-1, 49-51	2.74	2.92	5.01	13.7	10.1
28-6, 71-73	2.75	2.91	5.04	13.9	8.3
29-4, 55-57	2.76	2.93	5.27	14.5	9.0
30-4, 63-65	2.81	2.96	5.27	14.8	7.5
31-2, 39-41[b]	2.19	–	2.89	6.3	51.7
32-4, 21-23	2.67	2.93	4.87	13.0	13.4
33-5, 18-20	2.71	2.94	5.07	13.7	11.8
34-3, 135-137	2.78	2.92	5.40	15.0	7.6
35-3, 3-5	2.77	2.91	5.44	15.1	7.2
36-2, 67-69	2.84	2.97	5.48	15.6	6.5
37-1, 55-57	2.88	2.99	5.74	16.5	5.6
38-4, 11-13	2.82	2.94	5.30	14.9	8.9
39-3, 43-45	2.76	2.94	5.37	14.8	9.3
40-5, 45-47	2.80	2.98	5.36	15.0	8.8
41-6, 9-11	2.86	2.95	5.80	16.6	4.6
42-6, 4-6	2.72	2.90	5.06	13.8	9.8
43-2, 112-114	2.75	2.91	5.12	14.1	8.4
44-3, 68-70[c]	2.93	3.00	5.80	17.0	3.5
46-4, 43-45	2.71	2.85	5.29	14.3	7.6

[a] Corrected for drying to t = ∞ at 70°C in a vacuum.
[b] Smectite filling.
[c] Massive basalt.

The basalts in Hole 417D, on the other hand, range rather narrowly in velocity from 4.56 to 6.20 km/s and average about 5.5 km/s. There is a slight, but irregular trend of increasing velocity with depth from approximately 5.4 km/s near the basalt/sediment contact to greater than 5.8 km/s near the base of the hole. Although pronounced weathered zones displaying low velocities are present in the column (for example, between Units 2 and 3 at 410 meters sub-bottom and within the pillow basalts of Units 4 and 9*d*), there is no strong trend of decreasing velocity near the top of the

TABLE 16
Physical Properties of Basement, Hole 417D

Sample (Core-Section, Interval in cm)	Density				*P*-Wave Velocity (km/s)				Acoustic[f] Impedance ($\times 10^5$g/cm^2-s)		Porosity[a] (vol. %)
	Wet-Bulk[a] (g/cm^3)		Grain[a] (g/cm^3)		∥	⊥	⊥	Mean			
22-1, 136-139	2.80	–	2.95	–	–	5.38	–	–	15.1	–	7.7
6, 104-107	2.83	–	2.95	–	–	5.40	–	–	15.3	–	6.2
26-1, 84-87	2.77	–	2.96	–	–	5.25	–	–	14.5	–	9.4
4, 72-75	2.80	–	2.94	–	–	5.46	–	–	15.3	–	7.3
27-1, 111-113	2.83	–	2.96	–	–	5.56	–	–	15.7	–	6.4
4, 30-33	2.77	–	2.97	–	–	5.16	–	–	14.3	–	10.1
28-2, 44-46	2.79	–	2.94	–	–	5.41	–	–	15.1	–	7.5
5, 14-16[b]	–	–	–	–	–	5.88	–	–	–	–	–
5, 110-112	2.80	–	2.95	–	–	5.35	–	–	15.0	–	7.9
7, 37-39	2.81	–	2.93	–	–	5.52	–	–	15.1	–	6.1
29-1, 80-82	2.72	–	2.91	–	–	5.02	–	–	13.7	–	10.1
4, 134-136	2.72	–	2.90	–	–	5.20	–	–	14.1	–	9.4
30-1, 112-114	2.86	–	2.95	–	–	5.67	–	–	16.2	–	4.7
5, 118-121	2.74	–	2.93	–	–	5.18	–	–	14.2	–	9.7
31-1, 136-138	2.68	–	2.84	–	–	5.07	–	–	13.6	–	8.8
3, 67-69	2.75	–	2.92	–	–	5.18	–	–	14.2	–	8.8
5, 12-14	2.52	–	2.75	–	–	4.56	–	–	11.5	–	13.2
32-2, 58-61[c]	2.76	–	2.92	–	–	5.04	–	–	13.9	–	8.3
5, 113-116[c]	2.90	–	2.96	–	–	5.79	–	–	16.8	–	3.0
33-2, 137-139[c]	2.86	–	2.93	–	–	5.65	–	–	16.2	–	3.6
5, 4-6[c]	2.87	–	2.93	–	–	5.67	–	–	16.3	–	3.3
34-2, 51-53[c]	2.89	–	2.94	–	–	5.87	–	–	17.0	–	2.7
6, 39-41	2.83	–	2.91	–	–	5.66	–	–	16.0	–	4.6
35-2, 42-45	2.77	–	2.91	–	–	5.31	–	–	14.7	–	7.2
5, 141-143	2.85	–	2.91	–	–	5.67	–	–	16.2	–	4.1
36-1, 115-117	2.84	–	2.93	–	–	5.64	–	–	16.0	–	4.8
4, 51-53	2.84	–	2.94	–	–	5.58	–	–	15.8	–	5.0
37-2, 64-66	2.80	–	2.91	–	–	5.51	–	–	15.4	–	6.0
5, 20-22	2.79	–	2.88	–	–	5.50	–	–	15.3	–	4.8
38-2, 122-124	2.67	–	2.93	–	–	5.79	–	–	15.5	–	3.5
2, 127-129	2.79	–	2.89	–	–	–	–	–	–	–	5.4
4, 80-82	2.89	–	2.95	–	–	5.71	–	–	16.5	–	3.5
5, 4-6[d]	–	–	–	–	–	3.83	–	–	–	–	–
39-1, 130-132[d]	2.38	–	–	–	–	3.67	–	–	8.7	–	–
4, 84-86	2.86	–	2.93	–	–	5.85	–	–	16.7	–	3.4
40-1, 82-84	2.77	–	2.96	–	–	5.46	–	–	15.1	–	9.5
41-2, 20-22	2.82	–	2.98	–	–	5.80	–	–	16.4	–	8.0
5, 87-89	2.74	–	2.85	–	–	5.97	–	–	16.4	–	5.5
42-2, 131-133	2.72	–	2.95	–	–	5.30	–	–	14.4	–	11.6
5, 131-133	2.84	–	3.01	–	–	5.56	–	–	15.8	–	8.4
43-2, 106-108[c]	2.84	–	2.98	–	–	5.61	–	–	15.9	–	7.0
4, 140-142[c]	2.89	–	3.02	–	–	5.72	–	–	16.5	–	6.5
44-1, 139-141	2.76	–	3.00	–	–	5.08	–	–	14.0	–	11.6
3, 80-82	2.89	–	3.02	–	–	5.79	–	–	16.7	–	6.7
45-2, 26-28	2.79	–	3.00	–	–	5.27	–	–	14.7	–	10.9
48-5, 96-99[c]	–	(2.74)	–	5.31	–	5.25	5.19	5.25	–	–	–
5, 100-102[c]	2.76	(2.79)	2.92	5.15	–	5.26	5.19	5.20	14.4	–	8.3
6, 54-57[c]	2.73	(2.81)	3.09	4.89	–	4.88	–	4.89	13.4	–	11.6
49-1, 59-61[c]	2.74	(2.72)	2.88	5.05	–	5.12	5.02	5.06	13.9	–	7.7
2, 43-45[c]	2.78	(2.82)	2.94	5.04	–	5.13	5.04	5.07	14.1	–	8.3
3, 32-34[c]	2.82	(2.81)	2.92	5.46	–	5.35	5.47	5.43	15.3	–	5.4
50-1, 81-83[c]	2.87	(2.86)	2.97	5.53	–	5.64	–	5.59	16.0	–	5.1
2, 83-85[c]	2.84	(2.84)	–	5.69	–	5.49	5.52	5.57	15.8	–	–
2, 93-95[c]	2.89	(2.93)	2.99	5.64	–	5.79	5.58	5.67	16.4	–	5.0
52-1, 80-82[c]	2.91	(2.89)	2.98	5.96	–	5.88	5.82	5.89	17.4	–	3.3
2, 113-115[c]	2.92	(2.92)	–	5.96	–	6.00	5.94	5.97	17.4	–	–
3, 77-79[c]	2.93	(2.93)	2.99	5.99	–	6.07	5.96	6.01	17.6	–	2.8
4, 125-127	2.83	(2.85)	–	5.46	–	5.43	5.43	5.44	15.4	–	–
5, 96-98	2.83	(2.87)	2.95	5.46	–	5.43	–	5.45	15.4	–	6.3
53-1, 10-13	2.82	(2.90)	2.94	5.60	–	5.50	–	5.55	15.7	–	5.8
2, 82-84	2.85	(2.88)	–	5.54	–	5.60	5.49	5.54	15.8	–	–

TABLE 16 – *Continued*

Sample (Core-Section, Interval in cm)	Density				P-Wave Velocity (km/s)				Acoustic[f] Impedance ($\times 10^5$g/cm^2-s)		Porosity[a] (vol. %)
	Wet-Bulk[c] (g/cm^3)		Grain[a] (g/cm^3)		∥	⊥	⊥	Mean			
54-1, 30-32	2.75	(2.75)	2.96	5.03	–	5.02	–	5.03	13.8	–	10.8
2, 39-41	2.77	(2.83)	2.90	5.42	–	5.47	5.41	5.43	15.0	–	7.3
3, 71-73	2.86	(2.87)	3.00	5.57	–	5.54	5.55	5.55	15.9	–	6.7
4, 98-100	2.86	(2.87)	–	5.80	–	5.71	–	5.76	16.5	–	–
5, 97-99	2.90	(2.92)	2.96	5.88	–	5.88	–	5.88	17.1	–	3.1
6, 41-43	2.85	–	2.97	5.58	–	5.64	–	5.61	16.0	–	5.9
55-1, 128-131	2.86	(2.89)	2.98	5.57	–	5.49	5.53	5.53	15.8	–	6.0
1, 131-133	–	(2.91)	–	5.55	–	5.56	–	5.56	–	–	–
3, 73-76	2.86	(2.91)	2.98	5.50	–	5.56	–	5.53	15.8	–	6.2
4, 43-46	–	(2.89)	–	5.76	–	5.66	–	5.71	–	–	–
5, 41-44	2.85	(2.90)	2.96	5.56	–	5.42	–	5.49	15.7	–	5.8
57-1, 96-98	2.82	(2.87)	2.97	5.35	–	5.50	5.35	5.40	15.2	–	7.7
2, 26-29	2.73	(2.69)	2.91	–	5.23	5.22	–	5.26	5.24	14.3	9.0
58-1, 64-66	2.77	(2.80)	2.98	–	5.15	5.14	–	–	5.15	14.3	10.3
2, 64-66	2.74	(2.77)	2.93	–	5.17	4.93	–	5.00	5.03	13.8	10.2
3, 99-101	2.68	(2.71)	–	–	4.76	4.70	–	4.74	4.73	12.7	–
5, 17-19	2.69	(2.71)	2.91	–	4.83	4.94	–	4.82	4.86	13.1	11.3
59-2, 10-12	2.78	(2.79)	2.94	–	5.27	5.25	–	–	5.26	14.6	8.1
3, 7-9	2.80	(2.81)	–	–	5.47	5.55	–	5.49	5.50	15.4	–
4, 11-13	2.83	(2.87)	2.95	–	5.66	5.80	–	5.73	5.73	16.2	5.8
6, 101-103[d]	2.53	(2.52)	2.92	–	4.16	4.24	–	4.22	4.21	10.7	20.3
60-1, 32-35	2.65	(2.69)	2.87	–	5.12	5.10	–	–	5.10	13.5	11.5
2, 37-39	2.77	(2.83)	–	–	5.39	5.39	–	–	5.39	14.9	–
3, 47-49	2.82	(2.85)	–	–	5.42	5.51	–	5.35	5.43	15.3	–
5, 57-59[d]	2.54	(2.50)	2.91	–	4.32	4.26	–	4.01	4.20	10.7	19.1
61-1, 20-23	2.79	(2.80)	2.95	–	5.42	5.50	–	–	5.46	15.2	8.6
62-2, 33-37	2.77	(2.78)	2.91	–	5.45	5.52	–	–	5.49	15.2	7.4
4, 142-145	2.88	(2.85)	2.97	–	5.85	6.02	–	6.02	5.96	17.2	4.8
6, 96-99	2.78	(2.85)	2.94	–	5.37	5.38	–	–	5.38	15.0	8.4
63-1, 75-78	2.86	(2.88)	2.95	–	5.90	6.00	–	5.93	5.94	17.0	4.6
3, 48-51	2.51	(2.55)	2.94	–	–	4.82	–	–	–	12.1	22.2
5, 6-9	2.76	(2.79)	2.96	–	5.31	5.28	–	–	5.30	14.6	10.1
64-1, 30-33	2.74	(2.78)	2.93	–	5.23	5.13	–	5.25	5.20	14.3	10.0
3, 99-102	2.78	(2.84)	2.93	–	5.33	5.45	–	–	5.39	15.0	7.8
5, 9-12[c]	2.72	(2.76)	2.90	–	5.27	5.35	–	5.30	5.31	14.4	9.4
65-2, 7-9[c]	2.87	(2.88)	2.97	–	5.84	6.00	–	5.94	5.93	17.0	5.2
4, 15-18[c]	2.86	(2.92)	2.96	–	5.91	6.00	–	5.97	5.96	17.1	5.2
6, 37-39	2.78	(2.78)	2.95	–	5.70	5.81	–	5.66	5.72	15.9	8.5
66-3, 35-38	2.86	(2.88)	–	–	5.91	5.98	–	5.93	5.94	16.9	–
6, 30-33[d]	2.43	(2.39)	2.81	–	4.52	4.52	–	4.56	4.53	11.0	20.5
67-1, 42-45	2.88	(2.89)	2.96	–	5.89	5.94	–	–	5.92	17.1	4.0
3, 132-134	2.80	(2.81)	2.93	–	5.62	5.72	–	5.68	5.67	15.9	6.6
5, 33-35	2.86	(2.92)	2.95	–	5.87	5.99	–	5.96	5.94	17.0	4.9
7, 7-9	2.83	(2.89)	2.94	–	5.61	5.49	–	5.68	5.59	15.8	5.8
68-1, 7-10[c]	2.82	(2.83)	2.95	–	5.81	5.88	–	5.84	5.84	16.5	6.5
2, 46-48[c]	–	–	–	–	5.21	5.39	–	5.22	5.23	–	–
5, 11-13[c]	2.89	(2.92)	2.98	–	5.97	5.97	–	–	5.97	17.3	4.6
6, 62-65[c]	2.89	(2.92)	2.98	–	6.14	6.20	–	6.06	6.13	17.7	4.1
69-1, 62-64[c]	2.92	(2.95)	2.98	–	6.06	6.16	–	6.08	6.10	17.8	2.9

[a] Cores 22 through 45 corrected for drying to t=∞ at 70°C in a vacuum. Cores 48 through 69 heated for 24 hours at 110°C in a vacuum.

[b] Limestone filling.

[c] Massive basalt.

[d] Smectite filling.

[e] GRAPE values in parenthesis.

[f] Based on gravimetric density data and Vp⊥ or mean.

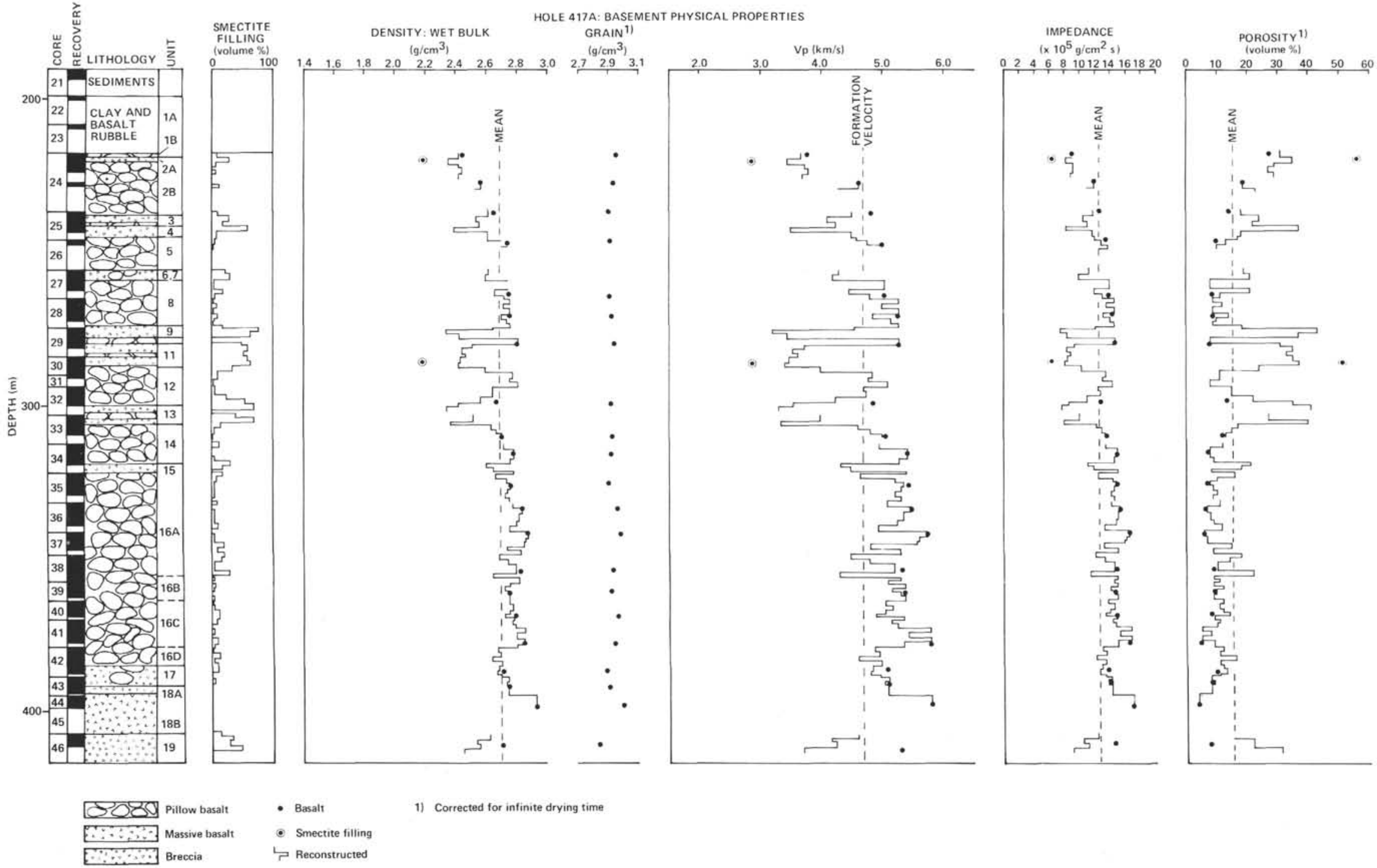


Figure 26. *Hole 417A basement physical properties.*

basement in response to weathering comparable to that observed in Hole 417A. In fact, it is striking that the measured velocities from Hole 417D are generally higher than those in Hole 417A at all levels. Measured velocities in the interstitial material found between pillows also tend to be higher than in Hole 417A; the velocity of the altered material in Hole 417D averages 3.75 km/s (two measurements), while that of the limestone (one measurement) is 5.88 km/s.

Porosity

The porosities reported in Table 15 and 16 for Hole 417A and Cores 22 through 45 in Hole 417D were obtained by heating each sample to 70°C in a vacuum desiccator for periods ranging from 1 to 11 days. Each value was then calculated from the difference between the initial wet-bulk density and the final dry-bulk density determined by plotting the data as a function of time and projecting to $t = \infty$. The data reported for Cores 48 through 69 in Hole 417D were obtained from density measurements before and after heating in air to 110°C for 24 hours.

The porosities measured in Hole 417A tend to be extremely high ($>25\%$) in the weathered basalts at the top of the column, but they decrease rapidly with depth, reaching stable values of approximately 7 to 8 per cent at sub-basement depths greater than 35 meters. The only significant departures from such values are observed in a thin weathered zone at about 300 meters sub-bottom, where the porosity of one sample reaches nearly 14 per cent, and in two samples from below 365 meters (one from the massive basalts of Unit 18), where porosities lower than 4 per cent are encountered. The porosities of the interstitial material found in breccias and between pillows locally reach values as high as 56 per cent.

The porosities in Hole 417D range, for the most part, between 2 and 10 per cent, with higher values (20%) occurring in restricted zones of altered basalt and in interstitial fillings. As in Hole 417A, the massive basalts tend to display the lowest porosities. In contrast to Hole 417A, however, the basalts in Hole 417D have relatively low porosities near the sediment contact and display no pronounced trend of decreasing porosity with depth.

Grain Density

The grain density data shown in Table 15 and 16 and in Figures 26 and 27 were computed from the forementioned wet-bulk density and porosity data. Since the trends of wet-bulk density and porosity shown are roughly mirror images, it is to be expected that the grain densities will remain relatively constant with depth. This is indeed the case: for the most part, they range from 2.90 to 3.00 g/cm^3 and show little variation with depth.

Acoustic Impedance

The values of acoustic impedance presented in Tables 15 and 16 were computed from the forementioned density and velocity values for comparison with surface and deep-towed seismic reflection profiles conducted in the vicinity of the site. As can be seen in Figures 26 and 27, the acoustic impedances in Hole 417A increase from about 9.0×10^5 g/cm^2 s in the weathered basalts near the sediment/basalt contact to values of 14 to 16 $\times 10^5$ g/cm^2 s near the base of the hole, while the values in Hole 417D range, for the most part, between 14 and 16 $\times 10^5$ g/cm^2 s throughout the hole. The only significant departures from either trend are in the massive basalts, where values as high as 17×10^5 g/cm^2 s are common, and in the interstitial material found in breccias and between pillows, where the values range between 6 and 11 $\times 10^5$ g/cm^2 s.

Formation Properties

One of the most striking results of the drilling conducted at Site 417 was the nearly complete recovery, not only of massive flow material, but of complete pillows in a matrix of interstitial material composed of altered glass and limestone. From a knowledge of the density of both this interstitial material and the basalts and their relative abundance as a function of depth, it is possible to reconstruct a synthetic density versus depth profile for each hole from the relationship

$$\rho_s = x_b\rho_b + x_{sm}\rho_{sm} + x_{ls}\rho_{ls} \qquad (1)$$

where ρ_s is the mean density of the depth interval under consideration; x_b, x_{sm}, and x_{ls} are the respective volumetric fractions of basalt, interstitial clay (smectite), and limestone in the interval; ρ_{sm} is the mean density of smectite in the hole (2.20 and 2.40 g/cm^3 in Holes 417A and 417D, respectively), and ρ_{ls} is the density of limestone (2.7 g/cm^3).

By analogy, velocity, impedance, and porosity profiles may be determined as a function of depth from the relations

$$V_{p_s} = \left[\frac{x_b}{V_{p_s}} + \frac{x_{sm}}{V_{p_{sm}}} + \frac{x_{ls}}{V_{p_{ls}}}\right]^{-1} \qquad (2)$$

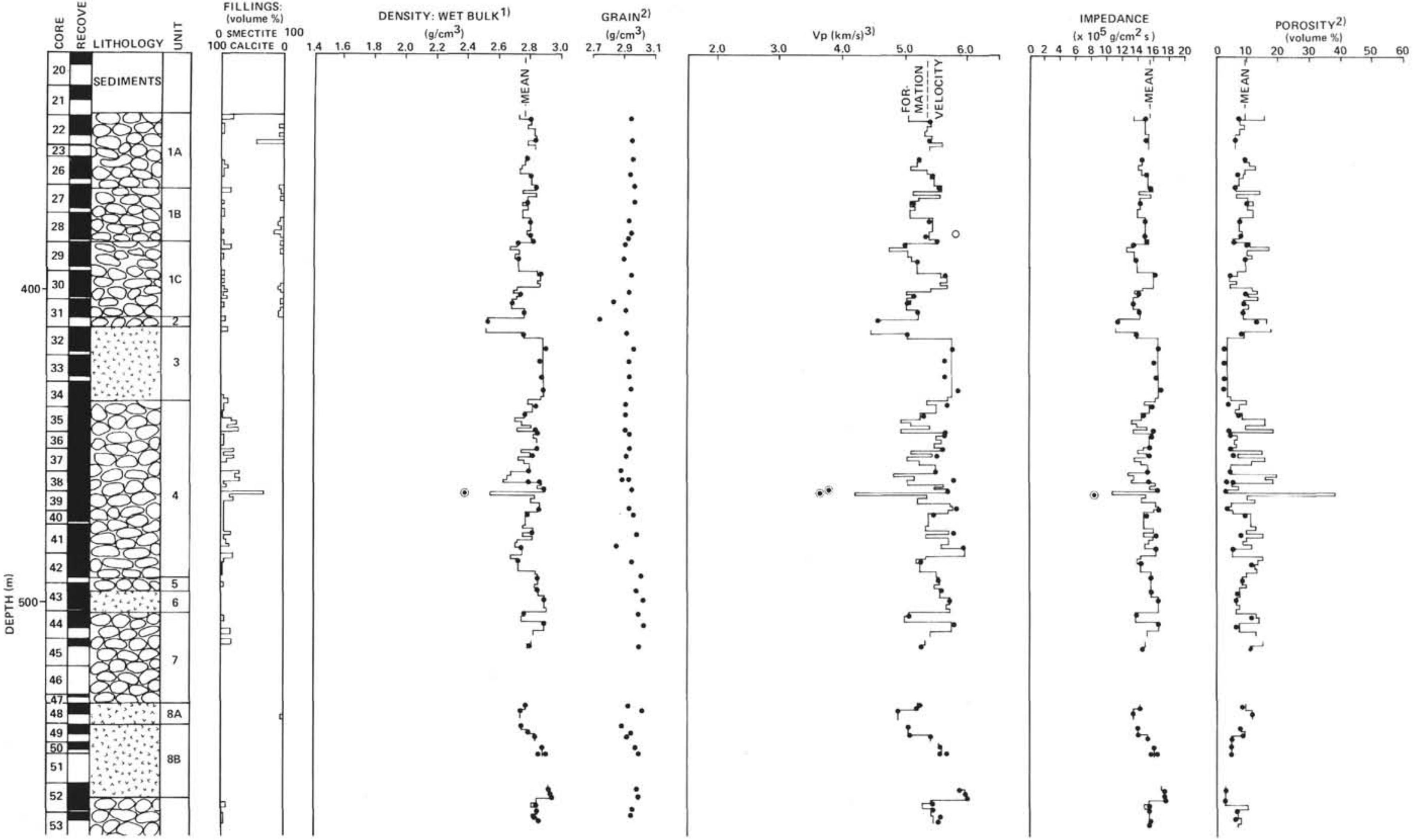
$$Z_s = (V_{p_s})(\rho_s) \qquad (3)$$

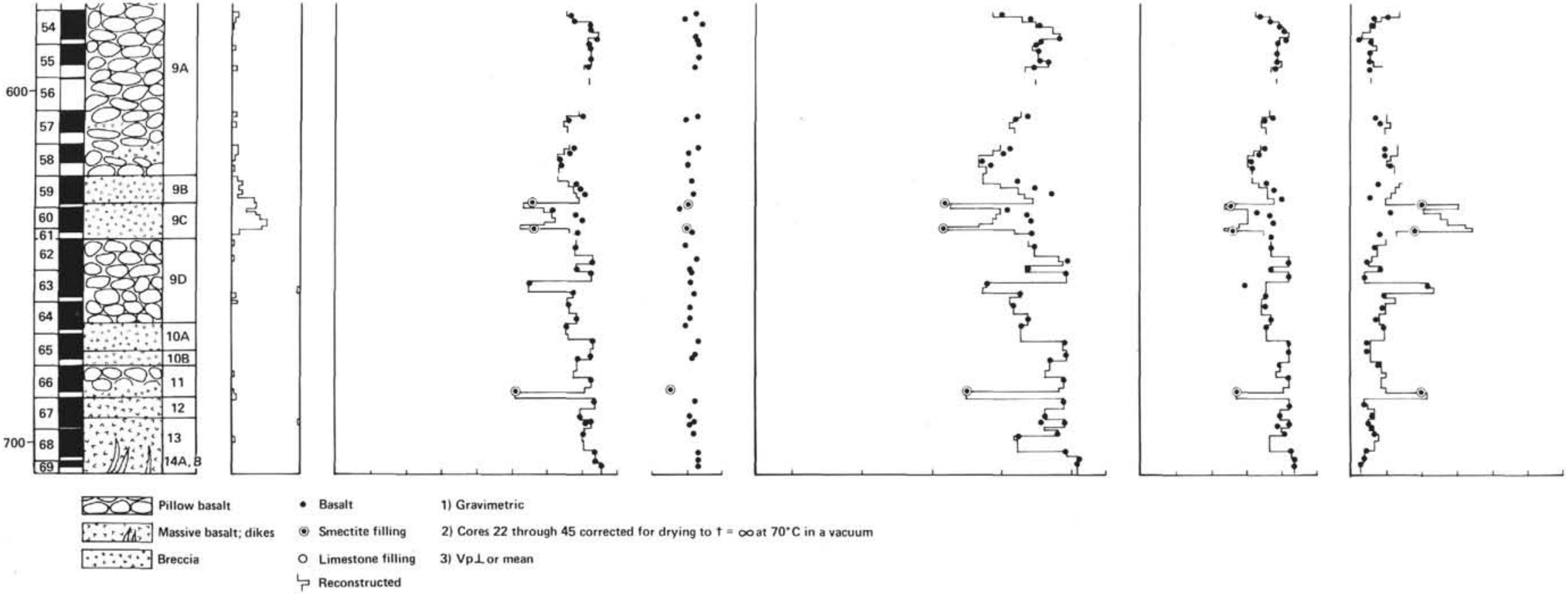
and

$$\phi_s = x_b\phi_b + x_{sm}\phi_{sm} + x_{ls}\phi_{ls}, \qquad (4)$$

where V_{Ps}, V_{Pb}, V_{Psm}, and V_{Pls}, are, respectively, the compressional wave velocity of the interval in question, the nearest measured velocity in basalt, the mean smectite velocity in the hole (2.9 and 3.8 km/s in Holes 417A and D, respectively), and the velocity of limestone (5.9 km/s); Z_s is the acoustic impedance of the interval; and ϕ_s, ϕ_b, ϕ_{sm}, and ϕ_{ls} are, respectively, the porosity of the interval, the nearest measured porosity value in basalt, the mean porosity of smectite (54%), and the porosity of limestone (equated to that of the nearest basalt). The profiles shown in Figures 26 and 27 were calculated on a section-by-section basis — that is, in 1.5-meter-long increments roughly equivalent to the sensor spacing in downhole logging tools. Since, for the purposes of

HOLE 417D: BASEMENT PHYSICAL PROPERTIES





1) Gravimetric

2) Cores 22 through 45 corrected for drying to t = ∞ at 70°C in a vacuum

3) Vp⊥ or mean

Figure 27. *Hole 417D basement physical properties.*

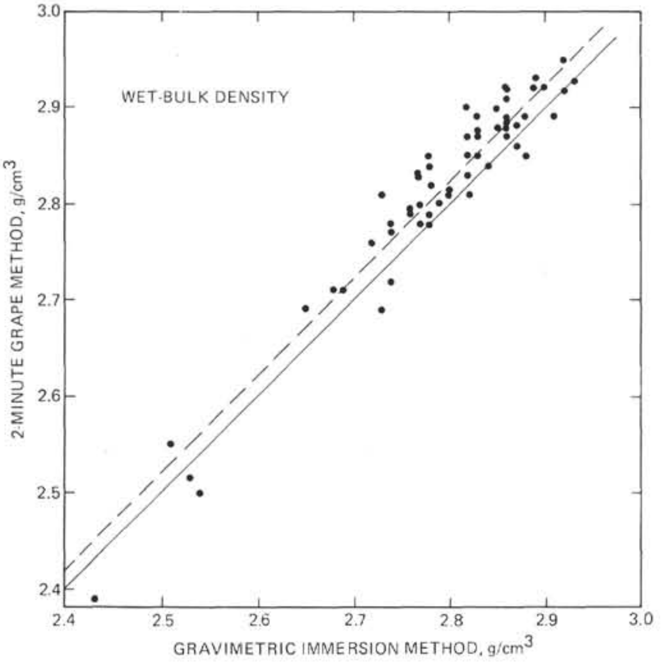


Figure 28. *Comparison of wet-bulk density values obtained by the 2-minute GRAPE and immersion methods. Dotted line represents least-squares fit to the data.*

calculation, the formation was considered to be crack-free, the velocities, densities, and impedances shown will be maximum values and the porosities will be minimum values.

A comparison between these profiles and the laboratory measurements upon which they are based indicates that the density and velocity measurements do not represent formation properties but rather maximum density and porosity envelopes for each hole, while the porosity values represent minimum envelopes. The discrepancy between laboratory values and formation properties can be substantial, particularly in zones of strong alteration. For example, the formation velocities of Units 4, 9, and 13 in Hole 417A are considerably lower than the laboratory velocities of samples which bracket these units above and below.

It is also clear in Figues 26 and 27 that many (but not all) of the units distinguished on lithologic grounds can be delineated on the basis of physical properties as well. For example, in Hole 417A, Units 1 and 2 can be clearly distinguished from Units 3 and 4, 5 through 8, 9 through 11, 12, 13, 14 through 18, and 19, while in Hole 417D, Units 1 and 2 can be distinguishd from Units 3, 4, 5 through 9B, 9C, 9D through 11, and 12 through 14. Among these subdivisions, the breccias are notable for their high smectite content (locally greater than 50% by volume) and consequent high porosity, low density, and low velocity, while the massive basalts display low porosities, high densities, and high velocities beneath a strongly altered, low-velocity cap formed by prolonged interaction with sea water at elevated temperatures. Not unexpectedly, the physical properties of the pillow basalts tend to range irregularly between these two extremes. Although the forementioned units can be distinguished in terms of physical properties, it is unlikely that many can be detected geophysically. The only likely exceptions are the breccias, which may be detectable as sub-basement reflectors because of their low acoustic impedances.

Conclusions

Although the average formation porosity in Hole 417A is higher than in Hole 417D, while the formation density and velocity (computed from transit times) are lower (see Table 17), it is clear from a comparison of Figures 26 and 27 that the formation properties near the base of Hole 417A are nearly identical to those in Hole 417D. Since the age and lithology of the holes are virtually identical, the differences in physical properties can be attributed to differences in alteration because of varying exposure to sea water. Hole 417D, located in a topographic depression, was buried in sediments almost immediately after its formation in late Aptian times, whereas the basement in Hole 417A was exposed as a small knoll until its eventual burial during the Late Cretaceous.

The consequences of such variations in alteration are important for understanding the geophysical behavior of Layer 2. The velocity structures of the two holes, for example, are strikingly different: Hole 417A displays a marked velocity gradient with a compressional wave velocity of 4.2 km/s near the base, while Hole 417D has a relatively uniform velocity of approximately 5.4 km/s throughout. Although the velocity structures in both holes are consistent with that of Layer 2B, Site 417 nonetheless provides considerable evidence of lateral heterogeneity in the upper levels of Layer 2.

BASEMENT PALEOMAGNETISM

Paleomagnetic measurements on a series of 71 basalt samples onboard the *Glomar Challenger* were supplemented by shore-based work on another 42 samples from Hole 417A (Bleil and Smith, this volume). The shipboard paleomagnetic data are given in Levi et al. (this volume), and a summary of the complete set of paleomagnetic results is shown in Table 18. For Hole 417D, a total of 142 measurements were made onboard the *Glomar Challenger* during Legs 51 (85 measurements) and 52 (57 measurements). Bleil and Smith (this volume) studied an additional set of 131 samples from

TABLE 17
Formation Properties, Site 417[a]

Hole	Interstitial Fillings (vol. %)	Wet-Bulk Density (g/cm^3)	Formation Velocity (km/s)	Acoustic Impedance ($\times 10^5$ g/cm^3-s)	Porosity (vol. %)
417A	13.2[b]	2.69	4.68	12.6	15.4
417D	5.7[c]	2.77	5.35	14.8	9.6

[a] Assuming no cracks.
[b] Smectite
[c] 5.0 per cent smectite, 0.7 per cent limestone.

TABLE 18
Summary of Paleomagnetic Results for Basement Rocks, Hole 417A[a]

Sample (Core-Section, Interval in cm)	Depth (m)	Lithological Unit	Magnetic Unit	I_{STABLE}	J_{NRM} ($\times 10^{-3}$emu/cm^3)	SUS ($\times 10^{-3}$emu/cm^{3}Oe)	Q	MDF
24-1, 70 to 24-1, 130	218.20–218.80	1	1	–28.0±7.8	0.589±0.165	0.672±0.062	2.0±0.7	–
24-2, 90 to 26-1, 75	219.90–237.25	2	2	–20.0±3.8	5.95±0.89	0.371±0.038	35.7±5.6	292±32
26-1, 95 to 26-2, 75	237.45–238.75	3	3	–19.0±3.5	3.11±0.77	0.522±0.022	12.8±2.8	217±9
26-3, 90 to 26-4, 25	240.40–241.25	4						
26-5, 85 to 27-2, 35	243.35–247.85	5	4	–23.6±1.5	5.77±0.68	0.645±0.040	22.7±2.5	196±16
28-2, 45 to 29-7, 45	255.95–274.45	6						
30-3, 00 to 30-4, 70	277.50–279.70	7	?					
30-6, 85 to 31-1, 50	282.85–284.50	8	?					
31-3, 100 to 32-4, 80	288.00–298.80	9						
33-1, 00 to 33-1, 70	303.00–303.70	10	?					
33-3, 05 to 34-5, 100	306.05–319.50	11	5	–19.1±1.8	16.4±6.6	1.18±0.13	29.4±11.8	123±7
34-6, 25 to 38-5, 60	320.25–353.45	12A	6	–23.5±0.9	7.24±1.45	0.548±0.107	33.9±2.4	228±17
38-5, 105 to 40-1, 80	353.79–364.21	12B	7	–14.9±2.3	3.64±0.82	0.400±0.060	21.5±4.5	240±29
40-2, 35 to 42-7, 75	365.15–387.87	12C	8	–22.4±1.4	14.9±2.7	0.723±0.200	31.1±2.8	159±19
42-7, 75 to 43-1, 130	387.87–389.70	13	(9)	–21.5	6.54	1.23	11.6	160
43-2, 00 to 43-2, 105	389.88–390.85	14	(10)	–24.8	5.38	0.396	29.5	203
43-2, 105 to 44-1, 40	390.85–395.72	15	11A	–22.2±1.6	23.9±3.7	2.09±0.16	28.3±6.9	109±10
44-2, 00 to 46-1, 00	395.81–407.50		11B	–30.0	3.62+0.41	2.72+0.14	2.9+0.4	65
46-1, 00 to 46-4, 80	407.50–412.80	16	12	–16.1	3.84+2.28	1.47+0.01	4.0+2.6	175+25

[a] Mean values for magnetic units defined on basis of lithologic units, some combined or subdivided on magnetic evidence. From Bleil and Smith, this volume.

Hole 417D, including 33 samples from the part of the hole drilled during Leg 52. A paleomagnetic synthesis of the 216 samples from Hole 417D studied by Bleil and Smith (this volume) is shown in Table 19. The average magnetic properties of rocks from Holes 417A and D are compared with those from other DSDP holes in Table 20.

The basement rocks differ in magnetic properties both between massive flows and pillow lavas and between the two holes. The pillow lavas have cation-deficient quenched skeletal titanomagnetites (titanomaghemites) as primary magnetic minerals. The titanomagnetite grains are small and their content average 0.5 to 1 per cent by volume. In contrast, the massive flows have Ti-rich titanomagnetites with a variable degree of cation deficiency as main carriers of magnetization. The grains are larger and more abundant (0.7 to 5.4% by volume) than in the pillow lavas. Sulfide minerals are common and ilmenite occurs in small (quantities in the massive flows.

The pillow lava magnetic minerals are more oxidized than those of the massive flows, and the Curie temperatures of the pillow lavas (340 to 380°C) are distinctly higher than those of the massive flows (200 to 330°C). The preferential weathering of pillow lavas is probably due to the greater density of pathways for sea water in the commonly heterogeneous pillow pile.

The magnetic properties of the basement rocks of Hole 417A show evidence of only limited paleosecular field variation and therefore a very short period for the emplacement of the Hole 417A lava sequence. In contrast, there are profounder differences both in the secular field variation and the magnetic properties of Hole 417D.

Another difference is that the magnetic minerals are smaller in size and less abundant in Hole 417A than in Hole 417D. Further, the NRM intensity, initial susceptibility, Koenigsberger ratio, and magnetic viscosity for the pillow lava sample differ in the two holes, whereas of these parameters only the initial susceptibility is the same in the massive flows of the two holes. The freshest titanomgnetites have been found in the massive units of the severely altered Hole 417A.

At Site 417 the magnetic minerals exhibit a high degree of low-temperature oxidation. The exceptionally large values of NRM intensity as compared with the intensity in other DSDP holes (Table 20) or even to that of young crust, can be explained by a larger percentage by volume of magnetic minerals than at other sites, Hole 417D having the greatest abundance of magnetic oxides. The exceptionally high amount of magnetic minerals in the basaltic rocks can explain the large amplitude of the *M*0 magnetic anomaly.

No titanomagnetite alteration products such as patches of rutile or anatase granules indicative of high (250 to 300°C) temperatures have been found. Therefore, no evidence exists for a thermal event at higher temperature than 250°C having occurred after the basaltic extrusion (Plasse, this volume; Bleil and Smith, this volume).

Hole 417A

On the basis of a preliminary division of Hole 417A into lithologic units, Bleil and Smith (this volume) defined 13 magnetic units; however little variation in magnetic properties is apparent in the drilled sequence (Table 18). The mean stable inclination of −22.3° is consistent with the reversed polarity of the *M*0 block and with the inferred low paleolatitude (10 to 20°N) for

TABLE 19
Summary of Paleomagnetic Results of Basement Rocks, Hole 417D[a]

Sample (Core-Section, Interval in cm)	Sub-Basement Depth (m)	Lithological Unit	Magnetic Unit	I_{STABLE}[b]	J_{NRM}[c] ($\times 10^{-3}$emu/cm^3)	SUS[d] ($\times 10^{-3}$emu/cm^{3}Oe)	Q[e]	MDF[f]
21, CC to 22-2, 115	339.40–346.65		1A	-76.9±1.5	21.3±3.0	1.79±0.29	28.0±6.6	174±9
22-4, 00 to 26-6, 20	348.50–365.05		1B	-60.1±3.0	13.4±0.8	1.78±0.18	18.3±2.9	159±14
26-6, 20 to 28-3, 145	365.05–379.75	1	1C	-72.6±1.3	11.4±1.3	1.09±0.21	27.0±3.4	229±28
28-4, 00 to 28-5, 150	379.80–382.53		1D	-63.2±1.3	10.0±1.2	0.968±0.227	24.8±3.7	161±24
28-6, 05 to 29-3, 75	382.57–388.21		1E	-68.6±1.1	6.87±1.35	1.25±0.19	14.8±2.8	179±31
29-3, 75 to 31-3, 150	388.21–407.50		1F	-63.2±2.3	8.89±1.01	1.18±0.19	21.8 2.8	240±32
31-4, 20 to 32-1, 70	407.70–412.79	2	2	-70.7±2.6	6.70±1.47	1.06±0.23	17.1±3.3	198±39
32-1, 70 to 34-5, 115	412.79–435.43	3	3	-64.0±1.4	4.61±1.03	2.33±0.06	7.7±2.9	130±27
34-5, 115 to 37-5, 125	435.43–456.66		4A	-65.9±2.1	12.6±1.3	0.976±0.157	36.8±6.9	154±14
37-7, 00 to 38-3, 85	458.02–461.26		4B	-71.6±1.0	15.6±6.0	0.504±0.081	67.1±28.2	239±68
38-5, 95 to 38-6, 75	463.65–464.65	?	4C	-42.9±9.0	15.0±3.3	1.60±0.39	20.6±1.2	161±12
39-1, 00 to 39-3, 105	464.70–467.86		4D	-72.1±1.0	9.41±3.39	2.42±0.27	12.4±5.6	185
39-4, 00 to 40-2, 150	468.21–474.00	4	4E	-65.6±1.1	11.3±1.6	1.35±0.23	19.8±4.1	199±38
40-3, 00 to 41-6, 25	474.00–482.11		4F	-74.5±1.3	9.43±1.34	1.56±0.33	16.8±3.5	165±24
41-6, 85 to 41-8, 35	482.61–484.70		4G	-55.0±0.3	28.1±7.3	1.09±0.06	55.7±11.9	114
42-1, 00 to 42-2, 150	484.70–487.64		4H	-72.2±1.5	3.41±1.50	0.982±0.195	7.2±1.8	165±41
42-3, 00 to 42-4, 85	487.64–489.94		4I	-58.9±1.4	8.37±2.10	2.07±0.24	9.0±2.2	95±6
42-4, 90 to 42-4, 145	489.99–490.53		4K	-72.2±3.5	16.9±2.7	1.62±0.24	22.7±0.3	111±6
42-5, 35 to 43-1, 140	490.92–495.10	5[g]	5	-30.1±2.9	8.08±2.81	2.51±0.17	8.3±3.4	105±10
43-2, 00 to 43-5, 125	495.20–500.54	6	6	-21.4±4.9	4.03±0.63	2.95±0.08	2.8±0.4	69±16
43-6, 125 to 45-2, 145	501.94–514.95	7	7	-29.7±3.0	5.24±0.81	2.62±0.13	4.9±1.2	108±11

[a] Mean values for magnetic units defined on basis of lithologic units, some subdivided on magnetic evidence (from Bleil and Smith, this volume). These values are arithmetric averages; unit weight given to individual samples; errors are standard deviation from the mean.

[b] I_{STABLE} = Stable inclinations as resulting from an AF demagnetization analysis.

[c] J_{NRM} = Intensity of natural remanent magnetization in emu/cm^3 ≅ Gauss (× 10^{-3}).

[d] SUS = Initial susceptibility in emu/cm^3. Oe ≅ Gauss/Oe (× 10^{-3}).

[e] Q = Koenigsberger ratio, present ambient field F=0.46 Oe.

[f] MDF = Median destructive field in Oe.

[g] Note added in proof: the boundary between lithologic Units 4 and 5 has been revised to lie at Section 42-3, 75 cm.

TABLE 20
Mean Values of Magnetic Properties of Basement Rocks, Site 417[a]

	Arithmetric Mean		Geometric Mean		Geometric Mean
	Hole 417A	Hole 417D	Hole 417A	Hole 417D	Other DSDP Holes
J_{NRM}[b] ($\times 10^{-3}$emu/cm^3)	9.43±9.47 N=112	9.22±6.25 N=159	6.53±2.38 N=112	6.93±2.46 N=159	1-3
SUS[c] ($\times 10^{-3}$emu/cm^{3}Oe)	0.94±0.76 N=106	1.80±0.83 N=205	0.70±2.15 N=106	1.52±1.97 N=205	0.2-2
Q[d]	26.8±17.3 N=105	18.2±18.5 N=158	20.5±2.4 N=105	11.4±2.9 N=158	2-40
v[e] (%)	4.1±8.1 N=41	10.6±15.5 N=120	1.0±5.9 N=41	4.5±4.1 N=120	

[a] Unit weight given to individual samples; errors listed are standard deviations of the mean. From Smith and Bleil, this volume.

[b] J_{NRM} = Intensity of natural remanent magnetization.

[c] SUS = Initial susceptibility.

[d] Q = Koenigsberger ratio.

[e] v = Viscosity coefficient according to Thellier and Thellier (1959).

this part of the North American plate in the Early Cretaceous. There is some concern, however, that the non-dipole components of the Earth's magnetic field may not have been cancelled if the emplacement of the lavas at this hole hav been too rapid. The NRM intensity of the basement section to be used for magnetic anomaly modeling is 7.32 × 10^{-3} emu/cm^3, which is in the range of intensities commonly used to match observed magnetic anomalies when assuming a source layer of about 500 meters in thickness.

Hole 417D

The basement section of this hole has been divided into 21 magnetic units (Table 19) on the basis of directional changes in the magnetization. The NRM intensity decreases regularly in the pillow pile overlying the massive lithologic/magnetic Unit 3. The most important division is at about 480 meters sub-bottom depth, with steep stable inclinations averaging −66.1 ± 8.3° found only above this level. In the lower part of the hole (below Section 42-4) a mean value for the sample inclination of −27.4 ± 9.2° is close to the mean inclination for Hole 417A. We note that a fault may be present at the base of Unit 4 at Section 42-3. The difference in inclination may be explained if the upper part of the basaltic pile at Hole 417D was emplaced at a time of atypical Earth magnetic field configuration. This seems improbable and an explanation in terms of tectonic rotation of the upper part of the pile by at least 40° about an east–west axis has been proposed by the Leg 51 party. Additional paleomagnetic evidence for ruling out an excursion of the Earth's field has been provided by the results at Site 418, during Leg 53.

The integrated intensity of magnetization of the entire column at Hole 417D, taking into account the various thicknesses and lithologies, is 8.7×10^{-3} emu/cm^3, about 90 per cent of which is due to pillow lavas. Some of the samples show a positive NRM inclination (Appendix II), but they occur in thin units of weakly magnetized rocks so that the effective magnetization vector is still compatible with a block of reversed polarity of less than 1 km in thickness.

CORRELATION OF SEISMIC REFLECTION PROFILES WITH DRILLING RESULTS

The survey for Site 417 conducted by the *Lynch* in September 1976 and the additional *Conrad* 1903 line showed that the area is characterized by a "rolling hills"type of bottom topography and variable sediment thickness controlled by highs and lows in a fairly irregular basement. In the vicinity of *M*0, the average sediment cover is about 500 to 600 meters thick and basement relief is 200 to 500 meters (Rabinowitz et al., this volume). It was not possible to construct a meaningful sediment isopach map, because the survey line spacing is too wide compared to the wavelength of the basement topography and because the basement interface is not always easy to define on the seismic records.

Hole 417A

The beacon for this hole was dropped at 1810 (2210Z) on the incoming southwest to northeast profile parallel to the strike of the *M*0 source block (Figure 29). A second seismic profile on a mean heading of 097 was made over this beacon (Figure 30) before starting the drilling operations. The outgoing airgun signal consists of multiple pulses over an interval of 0.07 to 0.08 s. The pattern of these pulses tends to be mirrored in the first bottom returns, producing a set of apparent reflecting horizons that undulate in harmony with bottom topography. This pattern is broken where deeper reflectors project upward close to the sea floor.

We recognize four seismic horizons in the profile shown in Figure 30. The horizon 4 is the boundary between acoustic stratigraphy showing discernable layering and the underlying diffuse reverberation. Horizon 4, or basement, is found at 0.24 s below the sea floor. This sediment cover corresponds to an average sea floor to basement sediment velocity of 1.76 km/s. This is rather high compared with the laboratory values of compressional wave velocity, which increase from 1.50 km/s at the mudline to about 1.65 km/s at a depth of 300 meters sub-bottom in Hole 417D. The first hard reflector (reflector 1) lies at the uniform depth of about 0.1 s below the sea floor. The way in which this reflector matches the bottom topography is consistent with the pelagic nature of the overlying sediments. Reflector 1 falls midway into a section of brown pelagic clay (Unit II); we correlate it with a change in induration at 80 meters. The third prominent reflector is horizon 3, which marks the top of an acoustically layered sediment package which pinches and swells to basement topography. Reflector 3 occurs at 0.175 s below the sea floor and is correlated with the top of the multicolored pelagic clay (Unit V), Late Cretaceous in age. This correlation corresponds to an average velocity of 1.83 km/s from the sea floor to the top of the multicolored clay. Reflector 2 has been marked in Figure 30 but is not obvious as it is partially masked by the strong bubble pulse train of reflector 1.

Depths of reflectors and interval velocities are as follows:

Reflector	Two-Way Time Below Sea Floor (s)	Depth (m)	Interval Velocity (km/s)		
0	0	0	1.5	1.8	1.8
1	0.105	80	2.3		
3	0.175	160	1.6		
4	0.240	211			

We note in Figure 29 that Hole 417A is on the southwestern flank of a small basement high. With the average sediment velocity of 1.8 km/s, the top of the hill on the incoming profile (Figure 29) would have 170 meters of sediments, whereas the bottom about 4 km to the southwest would be covered by about 400 meters of sediment. Taking into account the water depth, the maximum relief of the hill is about 280 meters and the mean slope is 4°.

Hole 417D

This hole was drilled with an offset of about 300 meters west of the 16-kHz beacon which had been dropped after leaving Hole 417A, about 160 meters west-southwest of the original Hole 417A beacon. Thus Hole 417D is located about 450 meters almost due west (285°) from Hole 417A and the general sedimentary setting is therefore similar. At Hole 417D a 343-meter sedimentary section was drilled, the top 160 meters of which was equivalent to the Hole 417A section. Because of the large gradients in sediment thickness or basement depth, it is essential to have a seismic profile passing directly over the hole. This is lacking for Hole 417D. The profile of Leg 51 for 24 and 25 December was run on a course of 072° and passed about 200 meters south of the 16-kHz beacon. When, on Leg 52 we reoccupied Hole 417D was reoccupied on Leg 52 on 24 January, a line was run from south-southeast to north-northwest over the 13.5-kHz beacon. Finally, when Hole 417D was abandoned, a short line was made on a course of 189° from one mile north of Site 417 to one mile south of Site 418. In order to correlate the drilled lithologic section to seismic data, we must rely upon the results of a tethered sonobuoy experiment conducted at Hole 417D during Leg 51.

Calm seas, favorable currents, and good weather enabled tethering a SSQ23 sonobuoy aft of the ship at Hole 417D while drilling progressed. The 20-in^3 air gun firing at 1500 psi was suspended from a buoy 3.3 meters subsurface. In two separate experiments the sonobuoy was tethered at 400 meters (2 January) and 250 meters (11 January), and the hydrophone was about 20 meters

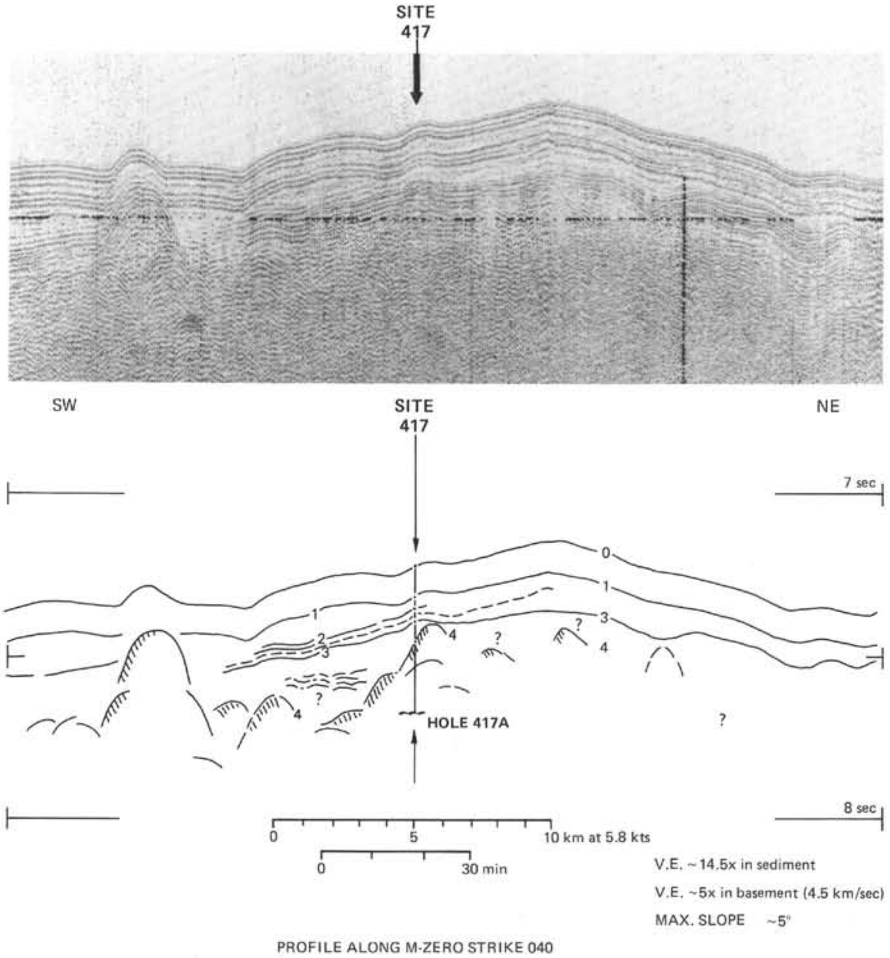


Figure 29. *Interpretation of seismic profiler record from the* Glomar Challenger *(top), showing location of Hole 417A on uppermost southwestern flank of a small basement high. The reflectors are numbered according to scheme of Figure 30. The black arrow on the original record corresponds to the arrow on the interpretative profile.*

subsurface. A section of the best record (at filter settings 40 to 160 Hz) made on 11 January is used in the following.

The correlation of the lithologic section with the stationary seismic reflection record is shown in Figure 31. Owing to the strongly reverberating bubble pulse train picked up by the single sonobuoy hydrophone and the high probability of (undetectable) side reflections, the stationary reflection record has a more layered appearance than warranted. A strong train of three heavy lines at 0.460 sub-bottom was initially thought to represent basement, but the average velocity of the sedimentary column would be too small. Although seven reflectors were tentatively outlined on the ship during Leg 51, only three of these can be resolved with some confidence. These prominent reflectors are at 0.413 s (reflector 7 in Figure 3), at 0.18 to 0.20 s (reflectors 2 and 3 in Figure 31), and at 0.366 s (reflector 6 in Figure 31). The reflector at 0.413 s marks the top of the igneous section found at 333 meters below the sea floor in the sonic log. The mean velocity of the sediments would thus be about 1.6 km/s. The reflector at 0.2 s is very prominent and underlies a generally transparent zone. By analogy with Hole 417A, it probably marks the top of the multicolored pelagic clay (Unit V), which was not cored at this hole but corresponds to a prominent peak in the sonic log velocity at 156 meters. The interval velocity of the upper transparent pelagic layer would thus be 1.55 km/s. This strong reflector dubbed "KAPPA" by the Leg 51 shipboard party, may correspond to horizon A* (Ewing and Ewing, 1970). The third prominent reflector at 0.366 s below sea floor is correlated with the top of the organic claystone (Unit VI) at around 286 meters.

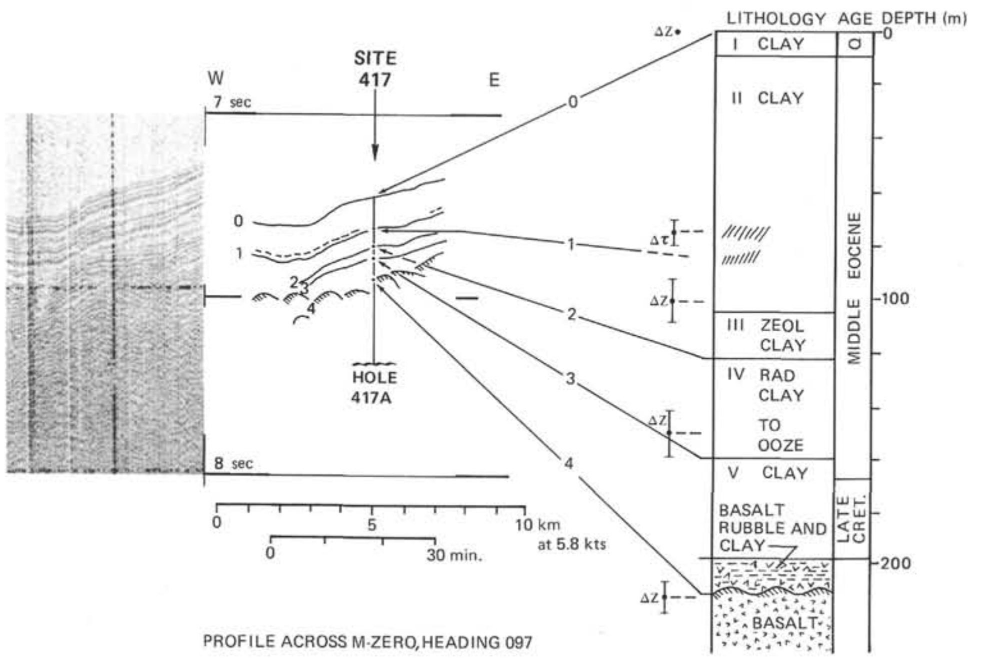


Figure 30. *Interpretation* (middle) *of seismic profiler record* (left) *made from the* Glomar Challenger *on an eastbound course over Hole 417A and correlation with lithologic units* (right). *The small vertical bars to the left of the lithologic section represent shear strength (Δτ) or impedance contrasts* (ΔZ] *seen in the laboratory measurements of the physical properties of the sediment cores.*

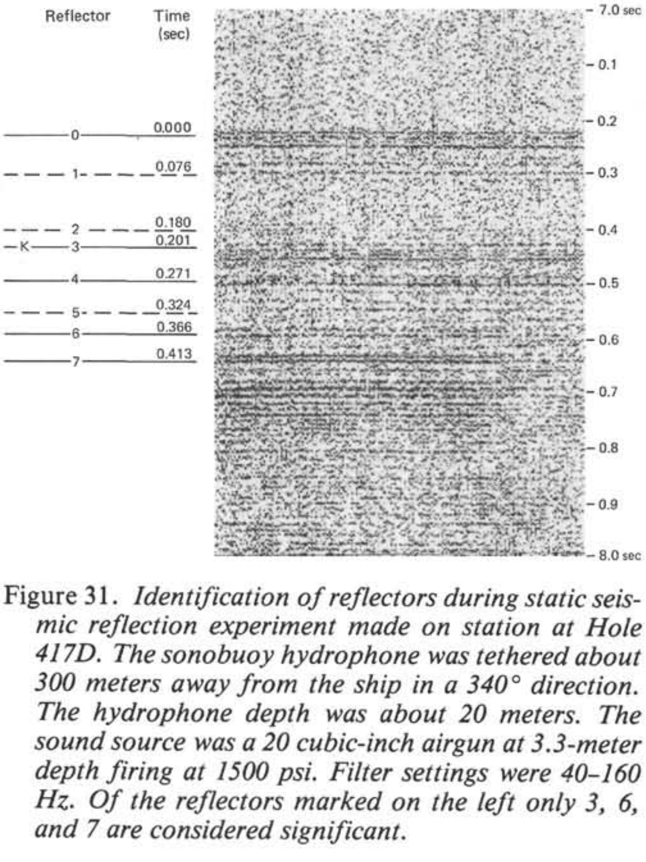


Figure 31. *Identification of reflectors during static seismic reflection experiment made on station at Hole 417D. The sonobuoy hydrophone was tethered about 300 meters away from the ship in a 340° direction. The hydrophone depth was about 20 meters. The sound source was a 20 cubic-inch airgun at 3.3-meter depth firing at 1500 psi. Filter settings were 40–160 Hz. Of the reflectors marked on the left only 3, 6, and 7 are considered significant.*

Depths of reflectors and interval velocities are as follows:

Reflector	Two-Way Time Below Sea Floor (s)	Depth (m)	Interval Velocity (km/s)	
0	0	0		
			1.55	
3	0.20	156		
			1.60	1.6
6	0.366	286		
			2.0	
7	0.413	333		

SUMMARY AND CONCLUSIONS

Site 417 was selected as a multiple re-entry site in old oceanic crust in the western Atlantic. Our primary objective there was to sample a deep section of old crust for comparison with younger crustal rocks drilled on previous legs. Studies of variations in alteration, basalt composition, basement lithology, and physical properties as a function of age were of prime interest.

Five holes were drilled at Site 417 on Legs 51 and 52 from December 1976 to February 1977. The two major holes — Holes 417A and D — were drilled about 450 meters apart. Hole 417A penetrated near the top of a small basement high; Hole 417D lies near the base of the hill. Each hole was continuously cored; a depth of 417.0 meters was reached in Hole 417A and 708.5 meters in Hole 417D. Core recovery average 45 per cent in the sedimentary section and 68 per cent in basement. Basement recovery averaged over 90 per cent in some intervals, providing an excellent sample of oceanic crust.

Sediments

A 211-meter-thick sedimentary sequence was cored in Hole 417A, whereas Hole 417D penetrated 343 meters of sediment, including a Lower Cretaceous section not encountered in Hole 417A. Uppermost Quaternary sediments are brown pelagic clay with some layers of nannofossil ooze. The Tertiary section, ranging from middle Miocene to middle Eocene consists of dark brown, generally nonfossiliferous, zeolitic clays at least 152 meters thick. Radiolarian-rich clays occur in the middle Eocene section. Upper Cretaceous sediments are dark yellow-brown to pale green zeolitic clays that overlie greenish gray to black, Middle Cretaceous claystones, nannofossil marls and chalks, and radiolarian sandstones. The Lower Cretaceous section penetrated by Hole 417D comprises a sequence of alternating brown, green, and black claystones, marl, and radiolarian sand with minor chalk and chert. An olive-gray, clayey nannofossil chalk lies directly above basement.

The entire cored section consists of pelagic sediments — chiefly clays with minor nannofossil and radiolarian oozes. No hemipelagic or shallow water deposits were found, although some of the radiolarian sands may be turbidites. Average sedimentation rates were low, ranging from about 2.5 meters/m.y. for the Cretaceous through middle Eocene section to about 3.5 meters/m.y. for the rest of the Cenozoic. The general absence of calcareous fossils in the Cenozoic sediments suggests deposition below the CCD. The Lower Cretaceous sediments probably reflect deposition under fluctuating oxidizing and euxinic conditions. The black, pyrite-rich mudstones suggest euxinic bottom water conditions, whereas the marls and chalks suggest oxidizing conditions. Basement topography at Site 417, as indicated by the variable sediment thickness, had a relief of several hundred meters and the euxinic conditions probably resulted from restricted bottom water circulation in closed basins. The intercalated radiolarian sands may represent redeposition of radiolarian debris originally laid down on basement highs. The alternating oxidizing and euxinic conditions may reflect periodic flushing of the closed basins with oxygenated water.

Basement Rocks

Basement was penetrated to a depth of 206 meters in Hole 417a and 365.5 meters in Hole 417D. Recovery was unusually high in both holes, averaging 62 per cent in Hole A and 72 per cent in Hole D. With very few exceptions some material was recovered from each core, and in several intervals recovery exceeded 95 per cent.

Nineteen lithologic units were recognized in Hole 417A and 14 in Hole 417D, based largely on variations in lithology and phenocryst assemblage. In Hole 417A the basalt is dominantly pillowed, with one massive unit 15 to 25 meters thick near the base. In Hole 417D, massive units make up 25 per cent of the section. Hyaloclastite and other breccias are associated with the pillow sequences in both holes, but they make up a relatively small part of the section.

Pillow sequences are up to 65 meters thick and are recognized by the presence of numerous glassy rinds, quench textures, and radial fractures. Gently dipping upper and lower margins predominate, suggesting that the pillows are flattened and elongate. Upper margins were recovered more frequently than lower margins, probably because of more frequent disintegration of the basal selvages during drilling. Spacing of glassy selvages indicates an average pillow diameter along the vertical axis of about 0.5 meters.

Several types of breccias are recognized, usually associated with the pillow complexes. Small patches of hyaloclastic breccia composed of glass chips and fragments are common between pillows. These result from spalling of glass from the rinds during growth of the pillows. More voluminous are broken-pillow breccias composed of pillow fragments. These grade into both pillow sequences and lithic basalt breccias. None of the breccias is bedded and all fragments are angular and poorly sorted, indicating little or no reworking of the material. Gradational contacts between these breccias and pillowed flows suggest that the breccias formed by fracturing of pillow lava during or shortly after eruption. However, some of the breccias, particularly the lithic varieties, could represent later accumulations of rubble or talus along steep flow fronts or fault scraps.

The massive units interlayered with the pillow lavas and breccias range from 6 to 30 meters in thickness. They are usually coarser grained than the pillow basalts and lack internal glassy selvages, although most have selvages at the upper and lower contacts. These units are interpreted as thick, massive flows based on their contact relationships, textures, compositions, and magnetic characteristics. Basal contacts are typically molded around the underlying pillows, suggesting a depositional rather than intrusive relationship. Overlying pillows appear to have been emplaced on top of the massive units rather than intruded by them, and there is no observable contact metamorphism or baking at the contacts. Textures in the massive units are "ophimottled," in which subophitic clots of plagioclase and clinopyroxene are set in a glassy matrix. The persistence of a glassy groundmass even in the center of the thick units indicates rapid cooling of the lava and suggests an extrusive origin. Finally, the massive units are chemically similar to the pillow lavas, and stable magnetic inclinations either match those of adjacent pillows or conform to a trend interpreted as being due to secular variation. These relationships strongly imply that the massive units formed as flows rather than later intrusions. Analogy with observed subaerial eruptions suggests a rapid eruption rate with ponding of the lava in small sea-floor basins.

Two narrow dikes were identified near the base of Hole 417D. Each is about 20 cm wide, with nearly vertical glassy margins that cross-cut the massive host rock.

Most of the basalts at Site 417 are porphyritic. In Hole 417D, the uppermost part of the section (lithologic Unit 1) has a phenocryst assemblage consisting of plagioclase + olivine; rocks in the interval between Units 2 and 9C have a three-phase assemblage containing polagioclase + clinopyroxene + olivine, and those between Units 9D and 12 contain olivine + plagioclase. Intense alteration has obscured the primary mineralogy in Hole 417A, but again most of the rocks are porphyritic with plagioclase ± olivine as the most common phenocryst assemblage. Olivine is generally less abundant in the lower units, and clinopyroxene appears as a phenocryst phase in the lower eight units. In addition to the phenocrysts, large, partly resorbed megacrysts of clinopyroxene and plagioclase are common in the rocks from both holes. Compositions of these megacrysts are more magnesian and more calcic than the host basalts, suggesting crystallization from more primitive liquids. The disequilibrium textures could result from mixing of primitive and evolved magmas or by thermal convection in a cooling magma chamber.

Fresh basalts at Site 417 exhibit a fairly wide range of chemical compositions but do not fall into distinct compositional groups. The average composition is a slightly fractionated basalt compared with some mid-ocean ridge tholeiites, but it is similar to modern basalts being erupted along the Mid-Atlantic Ridge at this latitude. Downhole variations are minor but correspond reasonably well with petrographic subdivisions of the core. One of the dikes in Hole 417D is compositionally similar to pillow basalts higher in the section; the other is a high-alumina variety not represented in any of the extrusive units. The one aphyric basalt at this site has relatively high TiO_2 and low Al_2O_3 and may represent a typical magmatic liquid. Compared with the aphyric basalt, the phyric rocks are relatively enriched in normative plagioclase and olivine, in general agreement with the petrographic data. The observed chemical variability in fresh basalts is compatible with minor crystal fractionation plus phenocryst redistribution durng eruption and emplcement.

Hole 417A is unique among basement holes drilled thus far in terms of alteration. Surprisingly, Hole 417D, drilled only 450 meters away, penetrated a relatively fresh basement section containing abundant fresh glass. The rocks in Hole 417A are various shades of red, brown, green, and yellow, and contain a wide variety of secondary minerals. Alteration is most intense in glassy interpillow breccias which are now mixtures of smectite/celadonite, analcime, phillipsite, and calcite. Glassy groundmass material is also highly altered to smectite and calcite. Plagioclase phenocrysts are altered to K-feldspar and smectite, and olivine to smectite/chlorite. Clinopyroxene is the least altered, being partly replaced by smectite/chlorite. Other secondary minerals identified include natrolite, chalcedony, pyrite, and iron hydroxide.

Alteration in this hole is mostly restricted to glassy pillow rinds, and many crystalline rocks are relatively fresh. Glass is partially replaced by smectite and calcite along with some phillipsite. Olivine and interstitial glass are always altered to smectite/chlorite, but plagioclase and clinopyroxene are usually fresh. In the crystalline rocks, most secondary minerals occur in vesicles, vugs, and fractures. In both holes the intensity of alteration decreases in downward direction, and rocks at the bottom of the section are fresh.

The relatively fresh character of the basalts at Hole 417D indicates that the crust was sealed off from circulating sea water at a fairly early stage of evolution. At Hole 417A, the basement apparently remained in contact with sea water for about 30 m.y., judging from the missing sediment interval. This permitted extensive sea water/basalt interaction as indicated by very high values of K_2O, H_2O, and Fe_2O_3/FeO. Oxygen isotope studies suggest that the alteration took place at temperatures no higher than about 20°C.

Paleomagnetism

Site 417 is located on negative magnetic anomaly *M*0, which has an age of approximately 108 m.y. The paleolatitude for the site is about 14.8° and the paleoinclination about 28° (Schouten, 1976). Measured magnetic inclinations in Hole 417A average about 22° and show relatively little scatter. Polarity is reversed as predicted, and the remanent magnetization is strong and stable despite the high degree of alteration. In Hole 417D, the upper 150 meters of basement has a stable inclination averaging −65°, significantly steeper than the average paleoinclination for the site. Below 150 meters, the mean inclination is −27°, with individual values ranging from −54° to −19°. Little agreement exists as to the origin of the anomalously steep inclinations in Hole 417D. Paleomagnetists on Leg 51 believe the upper 150 meters is tilted or rotated, but the Leg 52 shipboard party mostly favor secular variation to explain the inclinations. The close correlation between paleomagnetic units and lithologic and chemical units suggests that the inclinations developed during crustal construction within the median rift. However, until independent means are found to measure tilting, the argument of rotation versus secular variation cannot be resolved.

Physical Properties

While the physical properties of the basalts from Hole 417A are characteristic of extremely altered basalt, measured sonic velocities in the relatively fresh basalts of Hole 417D range from 4.21 to 5.97 km/s, with a mean of 5.47 km/s. The lowest values are from highly altered pillow basalts and pillow breccias, and the highest from fresh massive flows. There is a slight but irregular increase in velocity in the upper 150 meters in Hole 417D; below this level no trends were observed. The coherent nature of the crust at this site suggests that the *in situ* seismic velocities are higher at Site 417 than at younger sites such as Site 332. This suggestion is confirmed by both the downhole logging and oblique seismic experiments, which indicate that the formation velocity at the top of Layer 2 in Hole 417D is 4.8 km/s. Since this value is typical of Layer 2B, it is clear that the increase in compressional wave velocity with age observed in refraction data for the top of Layer 2 is caused by the infilling of cracks and voids by the products of alteration.

REFERENCES

Alexandrov, K. S. and Ryzhova, T. V., 1961. Elastic properties of rock-forming minerals, 2, layered silicates, *Bulletin Acad. Sci. U. S. S. R. Geophys. Ser. English Trans.*, v. 11, p. 871-875.

Baldwin, B., Coney, P. J., and Dickinson, W. R., 1974. Dilemma of a Cretaceous time scale and rates of sea-floor spreading, *Geology,* v. 2, p. 267–270.

Berggren, W. A., van Hinte, J. E., McKenzie, D. P., and Sclater, J. G., 1975. World-wide correlation of Mesozoic magnetic anomalies and its implications: discussion, *Geol. Soc. Amer. Bull.*, v. 86, p. 267-269.

Boyce, R. E., 1973. Appendix I. Physical property methods. *In* Edgar, N. T., Saunders, J. B., et al., *Initial Reports of the Deep Sea Drilling Project*, v. 15: Washington (U. S. Government Printing Office), p. 1115-1128.

Donnelly, T. W., 1972. Deep-water, shallow-water, and subaerial island-arc vulcanism: an example from the Virgin Islands. *In* Shagam et al. (Ed.), Studies in earth and space sciences, *Geol. Soc. of America Memoir,* v. 132, p. 401–414.

Ewing, M. and Ewing, J., 1970. Seismic reflection. *In* Maxwell, A. E. (Ed.), *The sea*: New York (Wiley).

Ewing, M., Worzel, J. L., et al., 1969. *Initial Reports of the Deep Sea Drilling Project*, v. 1: Washington (U. S. Government Printing Office).

Foster, M. D., 1969. Studies of celadonite and glauconite, *U. S. Geol. Survey Prof. Paper*, 614-F.

Geological Society of London, 1964. Geological Society Phanerozoic time scale, *Geol. Soc. London Quart. J.,* v. 120, p. 260–262.

Heezen, B. C., Tharp, M., and Ewing, M., 1959. The floors of the oceans I, *The North Atlantic Geol. Soc. Spec. Paper,* 65, 122.

Houtz, R. and Ewing, J., 1976. Upper crustal structure as a function of plate age, *J. Geophys. Res.*, v. 81, p. 2490-2498.

Hower, J., 1961. Some factors concerning the nature and origin of glauconite, *Am. Mineralogist*, v. 46, p. 313-334.

Langseth, M. G., Jr., and von Herzen, R. I., 1970. Heat flow through the floor of the world oceans. *In* A. E. Maxwell (Ed). *The sea*: New York (Wiley), Part I, p. 299–352.

Larson, R. L. and Hilde, T. W. C., 1975. A revised time scale of magnetic reversals for the Early Cretaceous and Late Jurassic, *Journal of Geophys. Res.,* v. 80, p. 2586–2594.

Larson, R. L. and Pitman, W. C., III, 1972. World-wide correlation of Mesozoic magnetic anomalies and its implications, *Geol. Soc. Amer. Bull.*, v. 83, p. 3645-3662.

________, 1975. World-wide correlation of Mesozoic magnetic anomalies and its implications: reply, *Geol. Soc. Amer. Bull.*, v. 86, p. 270-272.

Reynolds, P. H. and Aumento, F., 1974. Deep Drill 1972. Potassium-argon dating of the Bermuda drill core, *Can. J. Earth. Sci.*, v. 11, p. 1269-1273.

Schouten, H., 1976. Paleolatitudes and synthetic anomaly pattern of *M0* DSDP sites proposed in the western North Atlantic. *In* Hoskins, H. and Groman, R. C. (Eds.), *Informal report of surveys at IPOD Sites At2.2 and AT2.3*; Woods Hole Oceanographic Institution, Woods Hole, Appendix 2.

Schouten, H. and Klitgord, K., 1977. Mesozoic magnetic anomalies, western North Atlantic, *USGS Misc. Field Studies Map MF-915.*

Smith, R. E., 1967. Segregation vesicles in basaltic lava, *Am. J. Sci.*, v. 265, p. 696-713.

Thellier, E. and Thellier, O., 1959. Sur l'intensité du champ magnétique terrestre dans le passé historique et géologique, *Ann. Geóphys.*, v. 15, pp. 285-376.

van Hinte, J. E., 1976. A Cretaceous time scale, *AAPG Bull.,* v. 60, p. 498-516.

Vogt, P. R., Anderson, C. N., and Bracey, D. R., 1971b. Mesozoic magnetic anomalies, sea-floor spreading and geomagnetic reversals in the southwestern North Atlantic, *J. Geophys. Res.*, v. 76, p. 4796-4823.

Vogt, P. R. and Johnson, G. L., 1971. The morphology of the Bermuda Rise, *Deep Sea Research,* v. 18, p. 605–617.

Vogt, P. R., Johnson, G. L., Holcombe, T. L., Gilg, J. G., and Avery, O. E., 1971a. Episodes of sea-floor spreading recorded by the North Atlantic basement, *Techtonophysics,* v. 12, p. 211–234.

von Herzen, R. and Maxwell, A. E., 1959. The measurement of thermal conductivity of deep-sea sediments by a needle-probe method, *J. Geophys. Res.*, v. 64, p. 1557-1563.

APPENDIX

Chert Thin-Section Descriptions

Sample 417D-11, CC: Light Brown, Hard Claystone Nodule

Texture: very fine grained microcrystalline and ferruginous matrix (80%) with "floating" blebs and round, clear spherules of 100 to 200 υm size (20%). A clear mineral also fills the flaser zone commonly flanking both sides of a spherule. Wavy dark ferruginous laminations intertwine around radiolarians. Most radiolarians are round forms, but scattered Dictyomitrid outlines occur. The radiolarians appear replaced and infilled in a random pattern with stubby to blocky, length-slow clinoptilolite.

Sample 417D-15, CC: Porcellanite: Brown to Light Brown-Black Specked, Laminated Clast

Matrix is a homogeneous, very fine grained microlitic chert, comprising intermeshed clay and opaline silica phases (<2 to 3μm). Approximately 30 per cent round radiolarian molds (100 to 200 μm) are scattered randomly as relicts in the matrix. Laminations are straight and result from ferruginous zoning. Most of the matrix is opal-CT, although many radiolarians show radial chalcedony fillings.

Sample 417D-19, CC: Light Gray to Gray Porcellanite

This chunk is zoned with a central dark gray band (0.7 cm) and lighter gray near the edges as a result of different amounts of silica replacement. The matrix is a uniform, fine-grained (2 to 4 μm) microcrystalline opal-CT(?). Some large relict radiolarian spheroids occur. The walls are partially or completely replaced and voids infilled with chalcedony. A few relict radiolarians occur as brownish to black (pyrite) coated skeletons showing delicate wall structures and even small spines.

Sample 417D-19 CC: Clayey Nannofossil Limestone, Reddish Brown Burrowed and Laminated

In thin section, the matrix comprises fine micrite and poorly preserved nannofossils, homgeneous. Some burrows and round splotches (radiolarians?) are now filled with a mosaic of chalcedony.

Sample 417D-21-2, 125-128 cm: Dark Gray Chert With Yellowish Brown Volcanic Clasts

The matrix is a very fine grained chalcedony with densely spaced, sand-sized radiolarian molds which are infilled with radial chalcedony (length-fast). Numerous large (2- to 5-mm) rounded angular, green clay and brown, angular palagonite clasts are floating in the matrix. The devitrified shards are commonly infilled with spherulitic clays and, in some spots, chalcedony. Delicate protrusions preserved on these shards suggest that their transport distance was short.

Sample 417D-21-2, 137-139 cm: Dark Gray Chert With Gray-Green to Blue-Green Volcanogenic Clasts

The matrix is as above — a mosaic of chalcedony with dark opaque strings and numerous radiolarian molds. The volcanic clasts are rounded to subangular and form a framework texture. Most are homogeneous green clay, although some relict volcanogenic textures are observed. There is a faint preferred orientation. Radiolarian molds range from 0.075 to 0.200 mm and volcanic grains at 0.3 to 3.5 mm. Opaque stringers in the matrix seem organic and it is possible that these cherts are silica-replaced, coarse beds redeposited in a black clay environment.

PLATE 1

Figure 1	Photomicrograph (Sample 417A-43-1, 54-62 cm) showing plagioclase phenocryst with zonally arranged devitrified glass inclusions. Note skeletal plagioclase in the devitrified hyalopilitic groundmass. Plain light, base of photo 2.5 mm.
Figure 2	Photomicrograph (Sample 417A-37-3, 70-73 cm) showing skeletal pseudomorph after olivine (center), plagioclase phenocrysts, and skeletal plagioclase laths in altered hyalopilitic groundmass. Polarized light, base of photo 2.5 mm.
Figure 3	Photomicrograph (Sample 417A-38-3, 46-49 cm) showing quenched plumose clinopyroxene, plagioclase, and titanomagnetite. Plain light, base of photo 0.6 mm.
Figure 4	Photomicrograph (Sample 417A-38-3, 46-49 cm) showing skeletal clinopyroxene. Partially polarized light, base of photo 0.6 mm.

PLATE 1

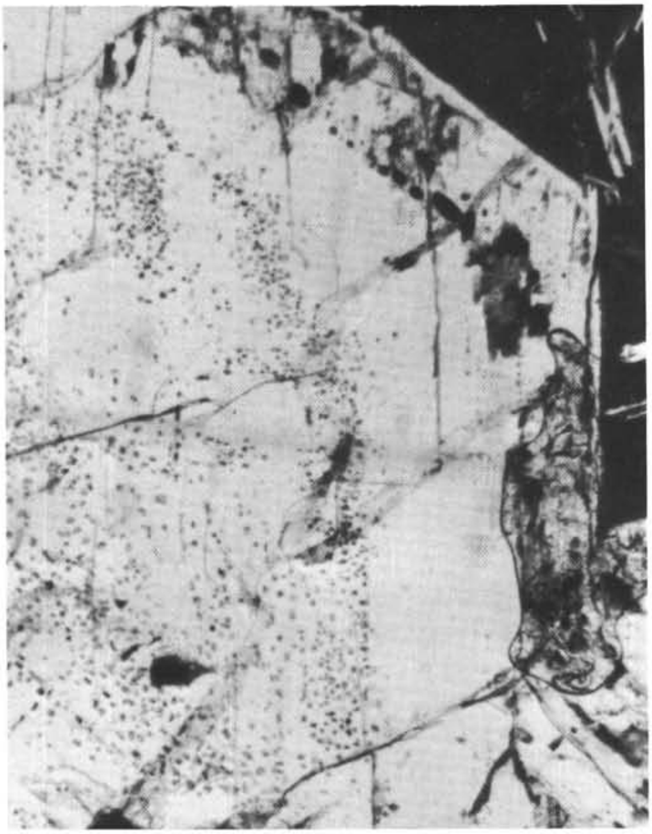


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PLATE 2

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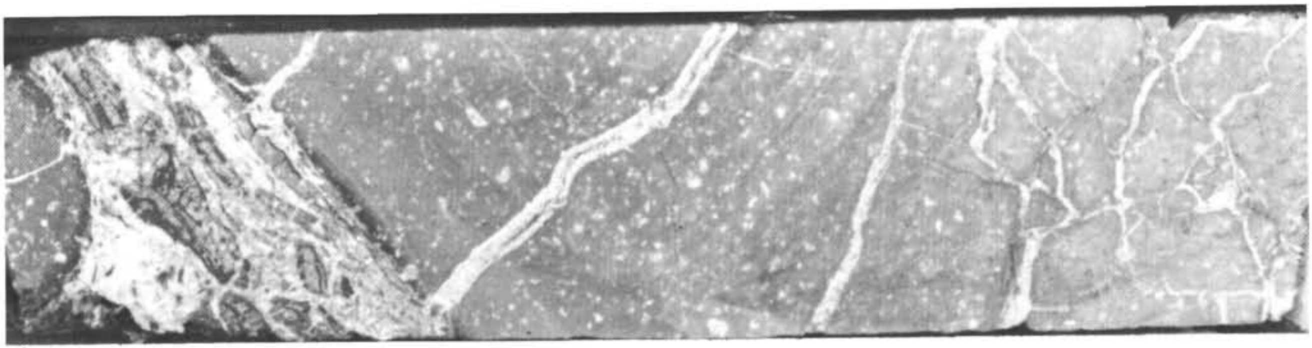
Figure 1 Photomicrograph (Sample 417A-43-5, 22-25 cm) showing ophitically intergrown clinopyroxene and plagioclase in massive basalt of Unit 18. Partially polarized light, base of photo 2.5 mm.

Figure 2 Photomicrograph (Sample 417A-44-3, 9-11 cm) showing subophitically intergrown clinopyroxene and plagioclase in massive basalt of Unit 18. Plain light, base of photo 2.5 mm.

PLATE 3



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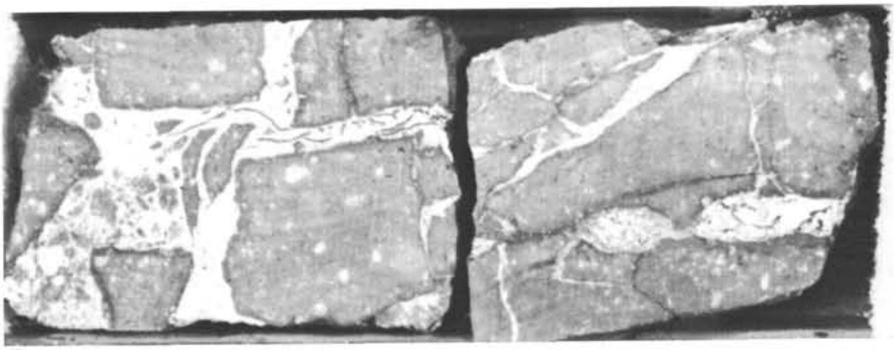


2

Figure 1 Section of basalt (Interval 417A-24-2, 100 to 126 cm) showing curved pillow margin with quenched texture (note smaller plagioclase phenocrysts) and color contrast. The center of the pillow is gray while the margin is light brown in hand specimen (here pale gray). Note the radial fractures and the interpillow hyaloclastic breccia.

Figure 2 Section of basalt (Interval 417A-24-2, 35 to 50 cm) showing strong sequential fracturing, with calcite-filled veins. Here the fragments of basalt can be more or less "fit together" across the fractures, showing limited lateral displacement.

PLATE 4

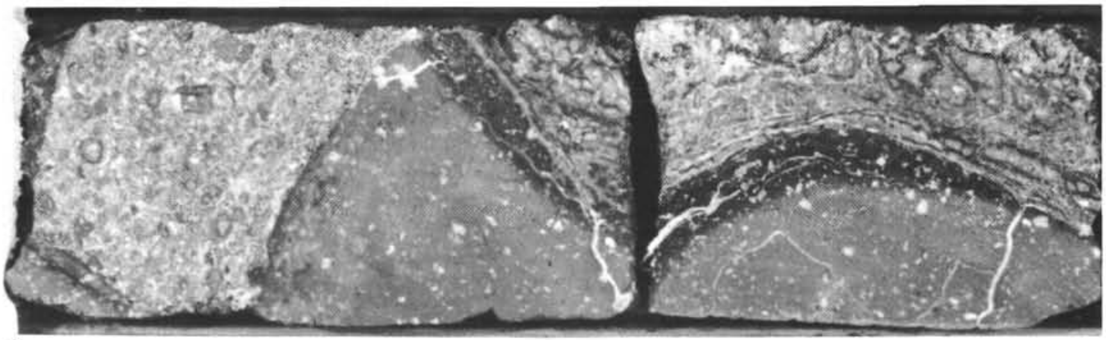
Figure 1. Section of basalt (Interval 417A-24-2, 59 to 80 cm) showing smaller pillow fragments and abundant interpillow hyaloclastic breccia. The central part of the figure shows the exfoliation of marginal glassy spalls and their alteration through hydration and swelling into the hyaloclastite. Many of the smaller, angular glassy basalt fragments have developed perlitic structures. The left margin of the photo shows a pillow which had been broken open after solidification and the pieces displaced relative to each other so that the hyaloclastite now penetrates into the interior of the pillow.

Figure 2 Section of hyaloclastitic basalt (Interval 417A-24-2, 23 to 25 cm) showing an exceptionally clear example of exfiliation leading to a type of perlitic structure in a fragment within the hyaloclastitie. Large altered plagioclase phenocrysts are visibe in the basalt.

Figure 3 Section of hyaloclastitic basalt (Interval 417A-24-2, 0 to 11 cm) showing the exfoliation of the margins of small pillows. One small fragment is radially fractured.

Figure 4 Section of hyaloclastitic basalt (Interval 417A-24-1, 133 to 144 cm) showing the contorted margin of a small, isolated (?) pillow and interpillow hyaloclastitic breccia. This fragment has very thin copper-filled fractures (not visible in photo).

PLATE 4



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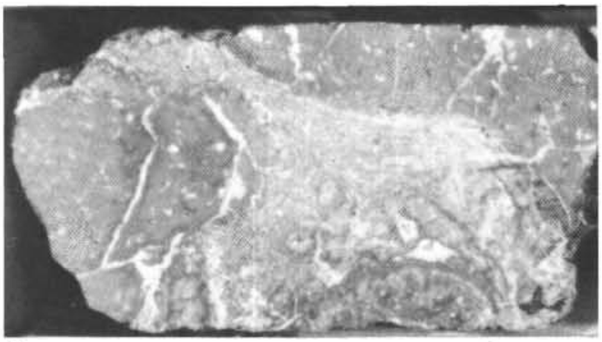

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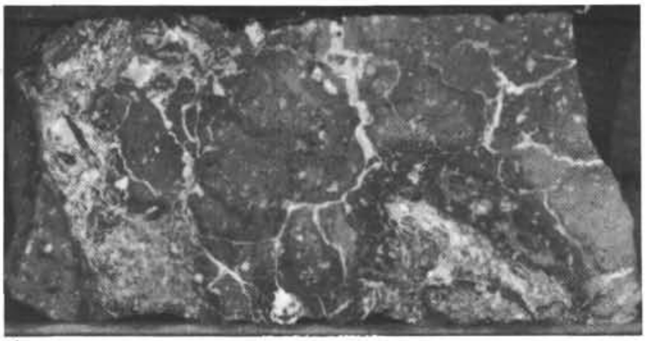
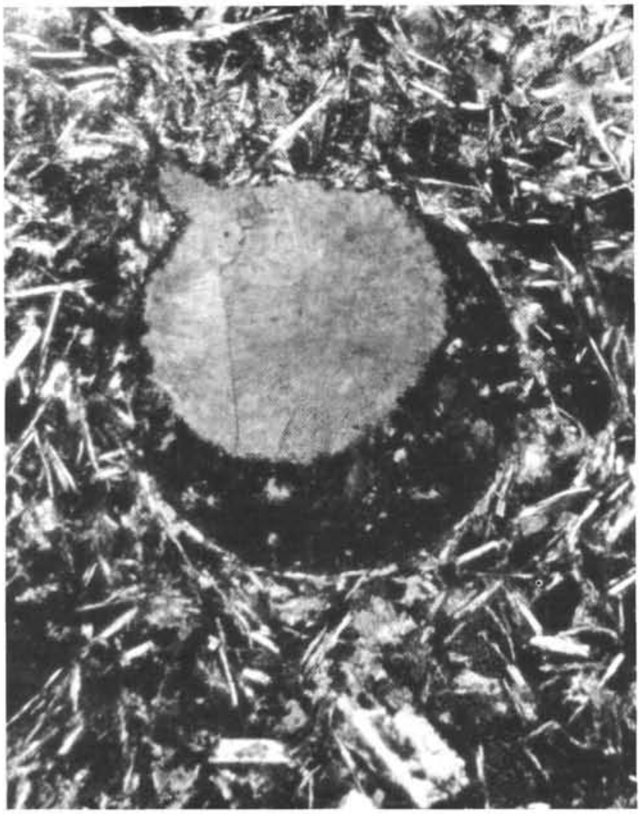


4

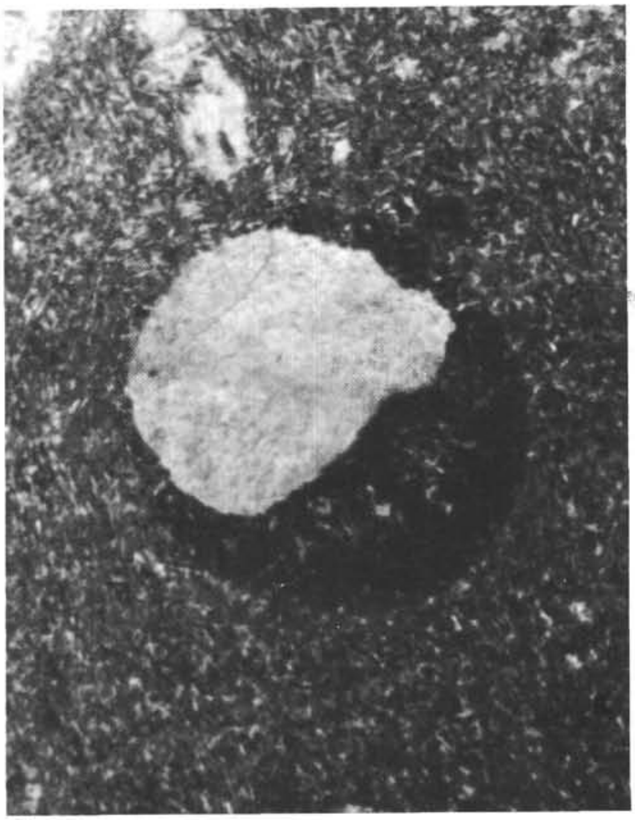
PLATE 5

Figure 1	Photomicrograph (Sample 417A-28-5, 17-19 cm) showing shrinkage vesicle in a medium-grained intersertal basalt. Plain light, base of photo 2.5 mm.
Figure 2	Photomicrograph (Sample 417A-31-1, 8-10 cm) showing shrinkage vesicle in fine-grained intersertal groundmass. Plain light, base of photo 2.5 mm.
Figure 3	Close-up photo showing analcime and prismatic natrolite crystals lining a large vug (Section 417A-39-3, Piece 36).

PLATE 5



1

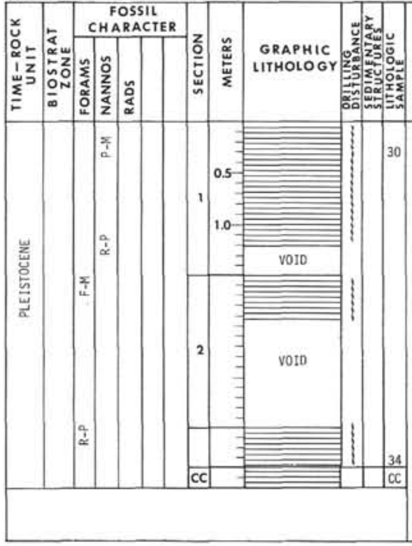


2

3

CORE DESCRIPTIONS, SITE 417[1]

SITE 417 **HOLE** **CORE** 1 **CORED INTERVAL:** 0.0-8.5 m



LITHOLOGIC DESCRIPTION

10YR 4/4

NANNOFOSSIL-BEARING CLAY
Highly disturbed, brown to dark brown, dark yellowish brown (10YR 4/4, 10YR 4/3); completely homogeneous.

<u>Nanno-bearing Clay</u>

Smears: Average of 3

71%	clay min.
10%	nannofossils
TR%	fish debris
4%	qtz.
5%	feld.
1%	zeolite
5%	accessory heavies
3%	ferruginous blebs
1%	palagonite

10YR 4/4

<u>Grain Size</u>

10YR 4/3

<u>3-4</u>
0.2% sand
10.4% silt
89.4% clay

<u>Carbon, Carbon-Carbonate</u>

3-2 (0.3, 0.1, 1)

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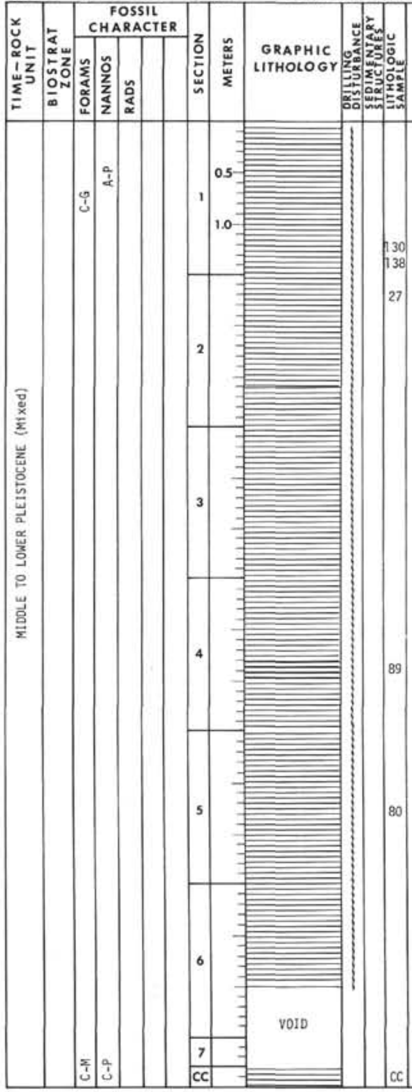
[1] Information on core description sheets represents field notes taken aboard ship under time pressure. Some of this information has been refined in accord with postcruise findings, but production schedules prohibit definitive correlation of these sheets with subsequent findings. Thus the reader should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

SITE 417 HOLE A CORE 1 CORED INTERVAL: 0.0-8.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL-BEARING CLAY
Highly disturbed, dark yellowish brown (10YR 4/4) with minor yellowish brown (10YR 5/4) clay; color boundaries are diffuse.

Nanno-bearing Clay

Smears: Average of 6

82% clay min.
6% nannofossils
1% forams
1% fish debris
2% qtz.
2% feld.
TR% zeolites?
2% accessory heavies
3% ferruginous blebs
1% palagonite

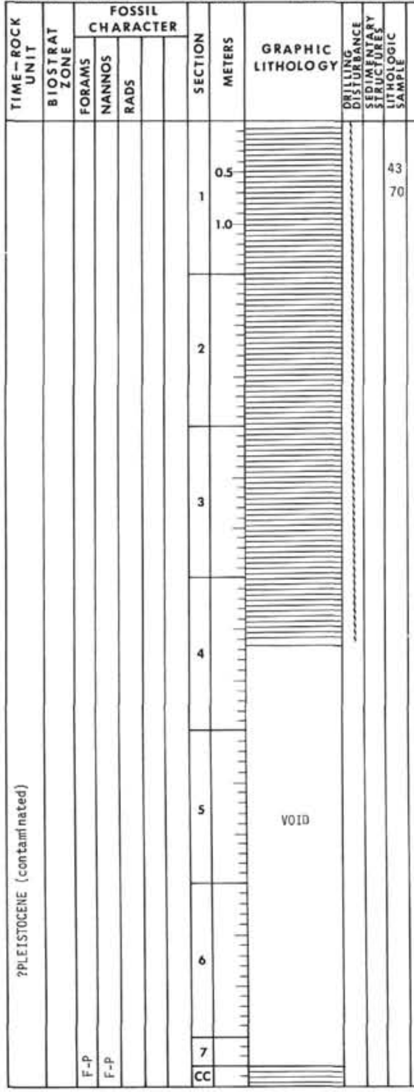
CO_3 Bomb Results

1-1, 59-37%
1-1, 136- 0%
1-3, 83- 0%
1-5, 82- 0%

Carbon, Carbon-Carbonate

1-71 (4.4, 0.1, 36)
3-80 (0.2, 0.1, 1)
5-80 (0.1, 0.1, 0)

SITE 417 HOLE A CORE 2 CORED INTERVAL: 8.5-18.0 m



LITHOLOGIC DESCRIPTION

10YR 4/3

CLAY
Highly disturbed, brown to dark brown (10YR 4/3, 10YR 3/3) streaked with light yellowish brown (10YR 6/4); light spots: Section 3, 30-40 cm, 93-110 cm; and 127-131 cm.

Smears: Average of 2

10YR 3/3

84% clay min.
2% nannofossils
1% fish debris
5% qtz.
3% feld.
2% accessory heavies
2% ferruginous blebs
TR% dolomite

10YR 4/3

CO_3 Bomb Results

2-1, 80-0%
2-3, 116-0%

Grain Size

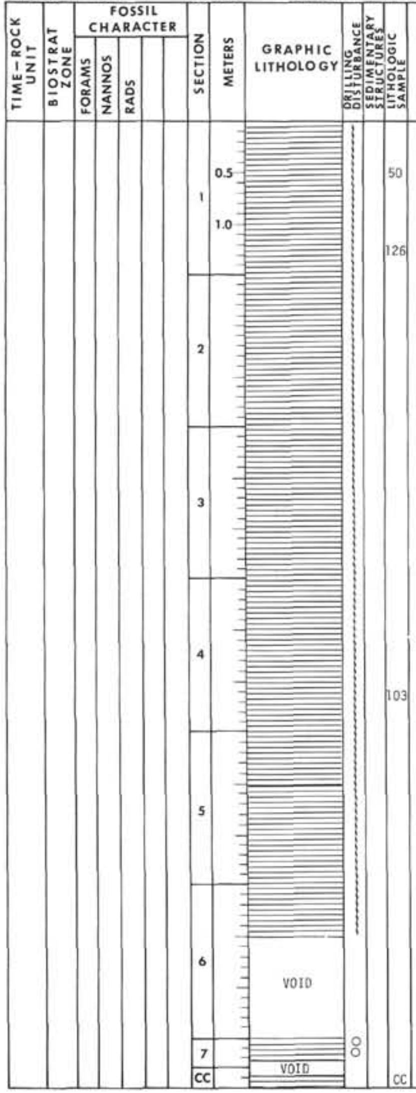
1-70
0.0% sand
7.5% silt
92.5% clay

10YR 4/3

Carbon, Carbon-Carbonate

1-77 (0.1, 0.1, 0)
3-120 (0.1, 0.1, 0)

SITE 417 HOLE A CORE 3 CORED INTERVAL: 18.0-27.5 m



LITHOLOGIC DESCRIPTION

10YR 4/3
to
10YR 4/4

CLAY
Highly deformed, dark brown, brown, dark yellowish brown (10YR 4/4, 10YR 4/3) with streaks of lighter colors (yellowish brown [10YR 5/4, 10YR 4/4]) representing highly disturbed bedding.

Smears: Average of 4

88% clay min.
1% fish debris
3% qtz.
2% feld.
5% accessory heavies
TR% ferruginous
1% Fe-Mn nodules
TR% dolomite

10YR 4/3
to
10YR 4/4

<u>CO₃ Bomb Results</u>

3-1, 103-0%
3-3, 41-0%

10YR 4/3
to
10YR 4/4

Grain Size

1-39
0% sand
6% silt
94% clay

Carbon, Carbon-Carbonate

1-100 (0.1, 0.1, 0)
3-34 (0.1, 0.1, 0)
5-30 (0.1, 0.1, 0)

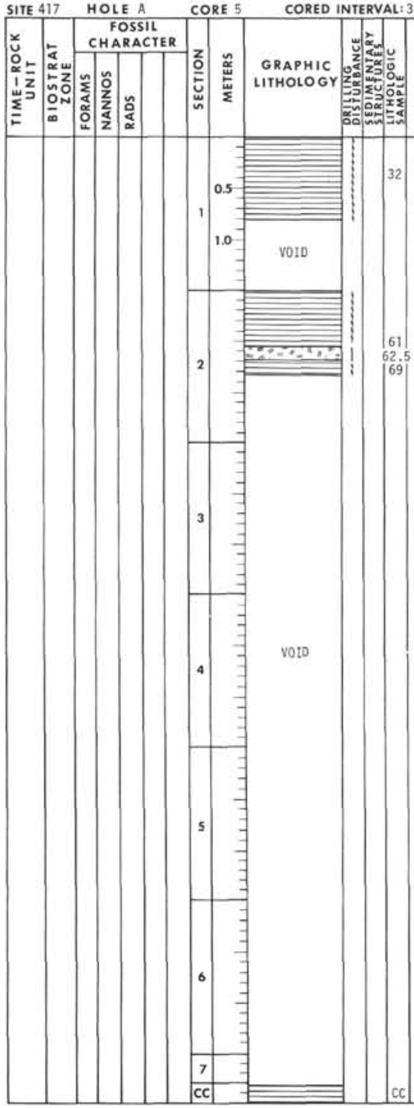
10YR 4/3
to
10YR 4/4

10YR 4/3

10YR 4/3

NO RECOVERY IN CORE 4

SITE 417 HOLE A CORE 5 CORED INTERVAL: 37.0-46.5 m



LITHOLOGIC DESCRIPTION

10YR 5/3

CLAY
Highly disturbed, brown, yellowish brown, light yellowish brown (10YR 5/3, 10YR 5/4, 10YR 6/4). Sharp contact between color zones in Section 2 at 15 cm.

VOLCANIC ASH: Section 2, 56-70 cm. Light blue gray to greenish gray, thinly banded with medium gray (5B 7/1 to 58 6/1) zeolitic clay.

10YR 5/4
to
10YR 6/4

Major Lithology

Smears: Average of 2

92% clay min.
TR% fish debris
4% qtz.
1% feld.
1% zeolites
2% accessory heavies
TR% ferriginous blebs
TR% clear glass

10YR 6/4

Minor Lithology

Smears: Average of 3, Sect. 2, 61, 62.5, 69 cm

70% clay min.
5% qtz.
7% feld.
15% zeolites (phillipsite)
TR% palagonite
2% clear glass
1% biotite
TR% zircon

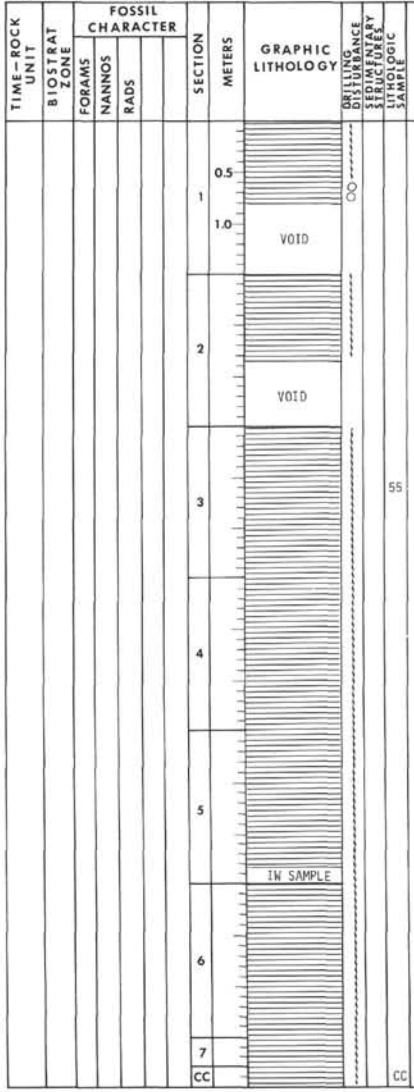
Grain Size

1-18
0.0% sand
7.3% silt
92.7% clay

Carbon, Carbon-Carbonate

1-26 (0.1, 0.1, 0)

SITE 417 **HOLE** A **CORE** 6 **CORED INTERVAL:** 46.5-56.0 m



LITHOLOGIC DESCRIPTION

10YR 5/4
10YR 6/4
10YR 5/4

10YR 5/4
to
10YR 6/4

10YR 5/4
to
10YR 6/4

10YR 5/4
to
10YR 6/4

10YR 5/4
to
10YR 6/4

10YR 3/3
to
10YR 4/3

CC 10YR 5/4

CLAY
Highly deformed, dominantly yellowish brown, dark yellowish brown, dark brown to brown (10YR 5/4, 10YR 6/4, 10YR 3/3, 10YR 4/3); light mottles occur with sharp boundaries, pale brown (10YR 6/3) more conspicuous in lower sections.

VOLCANIC ASH: Spot in Section 3, 55 cm, light pale green (10G 8/2).

Major Lithology

Smear: CC

93% clay min.
5% qtz.
2% ferruginous blebs

Minor Lithology

Smear: 1-55

30% clay min.
10% qtz.
10% feld.
40% zeolites
10% altered volcanics

CO_3 Bomb Results

5-1, 63-0%
6-1, 49-0%
6-3, 27-0%
6-4, 39-0%
6-5, 50-0%

Grain Size

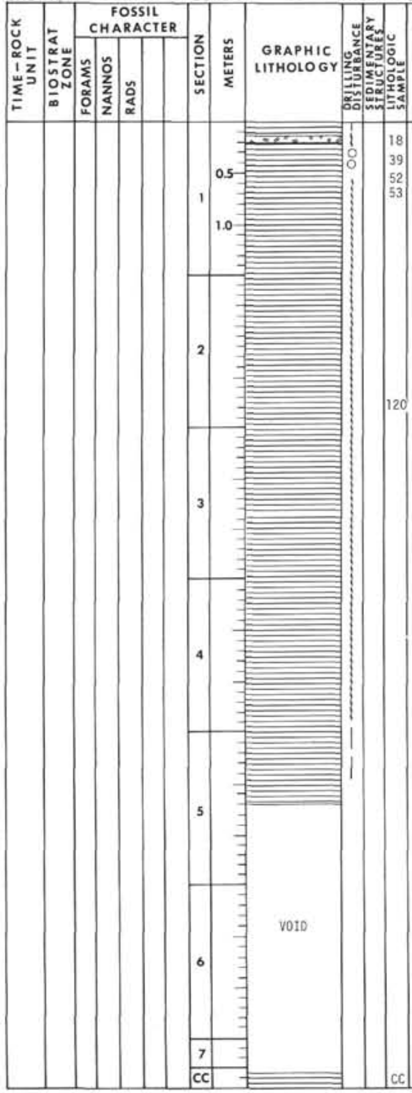
1-46
0.1% sand
6.3% silt
93.6% clay

Carbon, Carbon-Carbonate

1-38 (0.1, 0.1, 0)
3-10 (0.1, 0.1, 0)
4-36 (0.1, 0.1, 0)
5-59 (0.1, 0.1, 0)

NO RECOVERY IN CORE 7

SITE 417 **HOLE** A **CORE** 8 **CORED INTERVAL:** 65.5-75.0 m



LITHOLOGIC DESCRIPTION

10YR 4/4
10YR 5/4
10YR 3/2

10YR 4/4
10YR 5/4

10YR 5/4
10YR 6/4

10YR 5/4
10YR 6/4

10YR 5/3

10YR 5/4
10YR 6/4

CLAY
Highly disturbed; dominantly dark yellow brown, yellow brown, light yellow brown, brown (10YR 4/4, 10YR 5/4, 10YR 6/4, 10YR 5/3) streaked with light brown and light yellow brown (10YR 5/4, 10YR 6/4) layers; minor lithology: very dark gray-brown clay in Section 1, 25-50 cm; ASH: spots of greenish-gray (5G 6/1) clay throughout Sections 1 and 4; bed in Section 1, 15-20 cm; moderately disturbed in Section 5; streaking suggest lamination on 1 cm scale.

Major Lithology

Smears: Average of 4

76% clay min.
TR% fish debris
3% qtz.
2% feld.
1% zeolites
5% accessory heavies
10% ferruginous blebs
TR% Fe-Mn nodules
4% palagonite
1% clear glass

Minor Lithology

Smears:

1-18	1-56
60% clay min.	84% clay min.
5% feld.	2% qtz.
10% zeolites	2% feld.
25% clear glass	2% zeolite
	5% accessory heavies
	5% ferruginous blebs

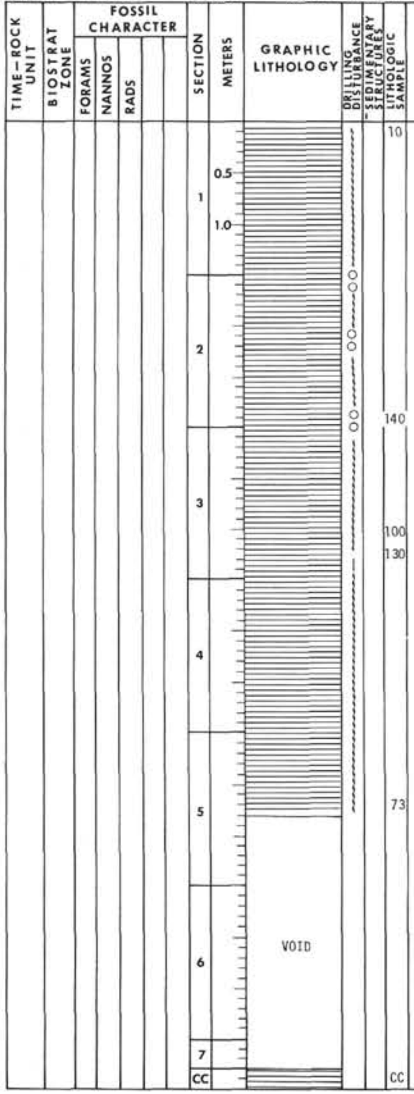
CO_3 Bomb Results

8-1, 91-0%
8-3, 52-0%
8-5, 32-0%

Carbon, Carbon-Carbonate

1-89 (0.1, 0.1, 0)
3-50 (0.1, 0.1, 0)
5-30 (0.1, 0.1, 0)

SITE 417 HOLE A CORE 9 CORED INTERVAL: 75.0-84.5 m



LITHOLOGIC DESCRIPTION

10YR 5/3
10YR 5/4
10YR 3/2
10YR 7/3
10YR 6/3
10YR 6/3
10YR 5/3
10YR 6/3
10YR 6/3

CLAY
Highly disturbed; dominantly pale colors; brown, yellow brown, very pale brown, pale brown (10YR 5/3, 10YR 5/4, 10YR 7/3, 10YR 6/3) streaked with very dark grayish brown, dark brown, dark grayish brown, and brown (10YR 3/2, 10YR 3/3, 10YR 4/2, 10YR 5/3). Colors subequal in Section 1, pale dominant in lower sections. ASH: spots in Section 4 at 120 and 130 cm, olive (5Y 5/3).

Major Lithology

Smears: Average of 5

95% clay min.
TR% qtz.
TR% feld.
1% zeolites
1% accessory heavies
2% ferruginous blebs
1% Fe-Mn nodules

CO_3 Bomb Results

9-1, 75-0%
9-3, 42-0%
9-5, 23-0%

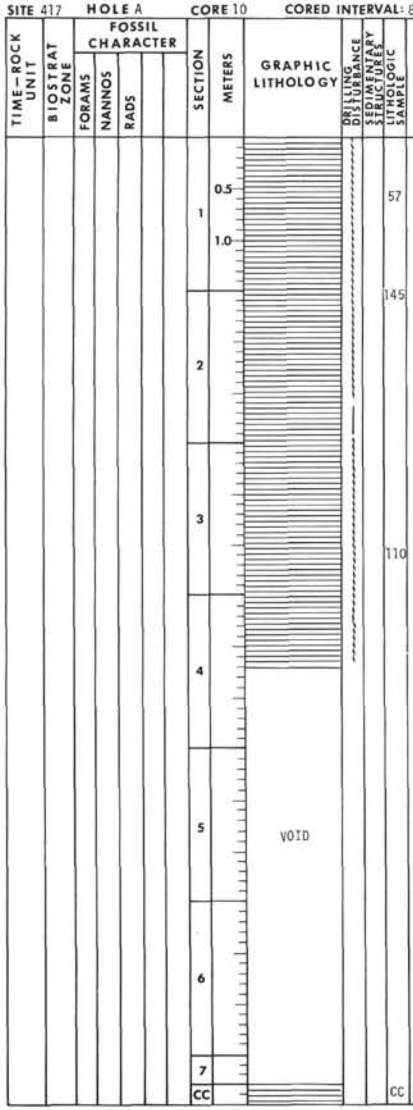
Grain Size

1-70
0.2% sand
3.7% silt
96.1% clay

Carbon, Carbon-Carbonate

1-73 (0.1, 0.1, 0)
3-40 (0.1, 0.1, 0)
5-20 (0.1, 0.1, 0)

SITE 417 HOLE A CORE 10 CORED INTERVAL: 84.5-94.0 m



LITHOLOGIC DESCRIPTION

10YR 6/3
to
10YR 5/3
10YR 6/4
10YR 5/3
10YR 6/4
10YR 5/3

CLAY
Highly disturbed; brown yellow, brown, light yellowish brown (10YR 6/3, 10YR 5/3, 10YR 6/4); streaked with dark brown to brown and dark grayish brown (10YR 4/3, 10YR 4/2); volcanic ash spots in Section 1, largest at 60 and 130 cm, light olive gray (5Y 6/2); less deformed in lower part of Section 2; dark streaks show suggestion of stratification on scale of 1 to 5 cm. Fe-Mn micronodules concentrated in Section 1, 94 and 115 cm.

Major Lithology

Smears: Average of 3

84% clay min.
12% K-feldspar
2% zeolites
1% accessory heavies

Minor Lithology

Smear: 1-57

84% clay min.
2% zeolites
3% accessory heavies
3% biotite

CO_3 Bomb Results

10-1, 45-0%
10-3, 42-0%

Grain Size

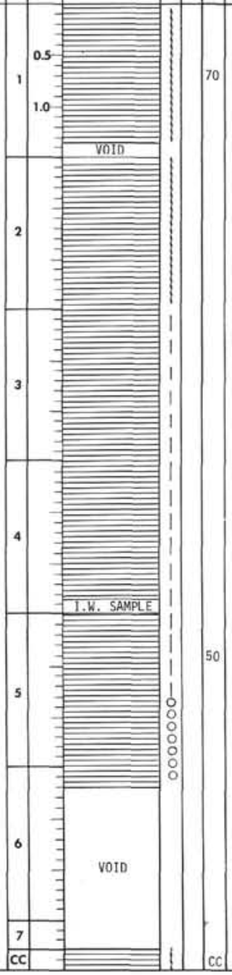
1-40
0.4% sand
3.5% silt
96.1% clay

Carbon, Carbon-Carbonate

1-43 (0.1, 0.1, 0)
3-40 (0.3, 0.1, 1)

SITE 417 HOLE A CORE 11 CORED INTERVAL: 94.0-103.5 m

TIME-ROCK UNIT | BIOSTRAT ZONE | FOSSIL CHARACTER: FORAMS, NANNOS, RADS | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | LITHOLOGIC SAMPLE | LITHOLOGIC DESCRIPTION



10YR 6/3

10YR 5/3

10YR 6/3

10YR 6/3
10YR 6/4

10YR 5/3

10YR 6/3

10YR 6/4

10YR 6/3

10YR 6/3

10YR 6/3

CLAY
Highly disturbed, mainly pale brown (10YR 6/3). Also brown, light yellow brown (10YR 5/3, 10YR 6/4) streaked and mottled in Sections 3-6 with light yellowish brown (10YR 5/3 in subequal amounts; color contacts in Section3: mottled at 31 and 42 cm; sharp at 96 cm.

Major Lithology

Smears: Average of 2

84% clay min.
1% qtz.
5% K-feldspar
1% unspecified feld.
2% accessory heavies
6% ferruginous blebs
3% palagonite
TR% dolomite and rhodochrosite

CO_3 Bomb Results

11-1, 42-0%
11-3, 85-0%

Grain Size

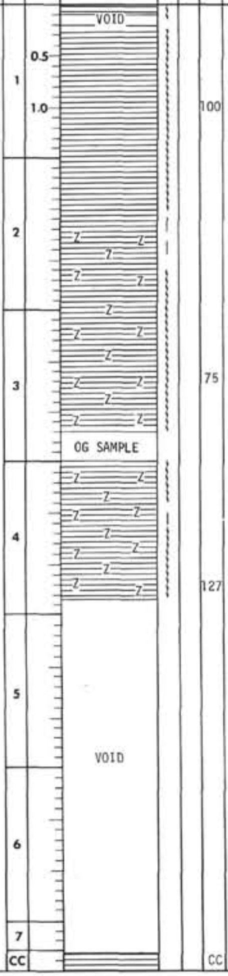
1-40	3-80	5-62
1.0% sand	1.5% sand	0.9% sand
4.2% silt	4.4% silt	5.2% silt
94.8% clay	94.1% clay	93.9% clay

Carbon, Carbon-Carbonate

1-41 (0.2, 0.1, 1)
3-34 (0.2, 0.1, 1)
5-64 (0.1, 0.1, 0)

SITE 417 HOLE A CORE 12 CORED INTERVAL: 103.5-113.0 m

TIME-ROCK UNIT | BIOSTRAT ZONE | FOSSIL CHARACTER: FORAMS, NANNOS, RADS | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | LITHOLOGIC SAMPLE | LITHOLOGIC DESCRIPTION



10YR 5/3

10YR 3/2

10YR 3/2

10YR 4/2

CLAY in Section 1 and top of Section 2, with ZEOLITIC CLAY in lower part of Section 2, and Sections 3 and 4 contact reasonably abrupt; CLAY is highly disturbed, brown (10YR 5/3) with diffuse streaks of paler clay. ASH spot in Section 1, 34.5 and 39 cm.

ZEOLITIC CLAY below Section 2, 70 cm, is highly to moderately disturbed, very dark grayish brown, mottled with brown clay (10YR 5/3) throughout. This clay resembles clay of upper unit. Becomes dark yellow brown (10YR 4/2) with pods of lighter pale brown (10YR 7/4) in Section 4.

CLAY (Major lithology)

Smear: 1-100

80% clay min.
10% K-feldspar
3% accessory heavies
2% ferruginous
TR% dolomite and rhodochrosite

ZEOLITIC CLAY (Major lithology)

Smears: Average of 4

75% clay min.
3% qtz.
5% K-feldspar
11% zeolites
2% accessory heavies
2% ferruginous
1% Fe-Mn nodules
TR% dolomite and rhodochrosite

CO_3 Bomb Results

12-1, 96-0%
12-3, 34-0%

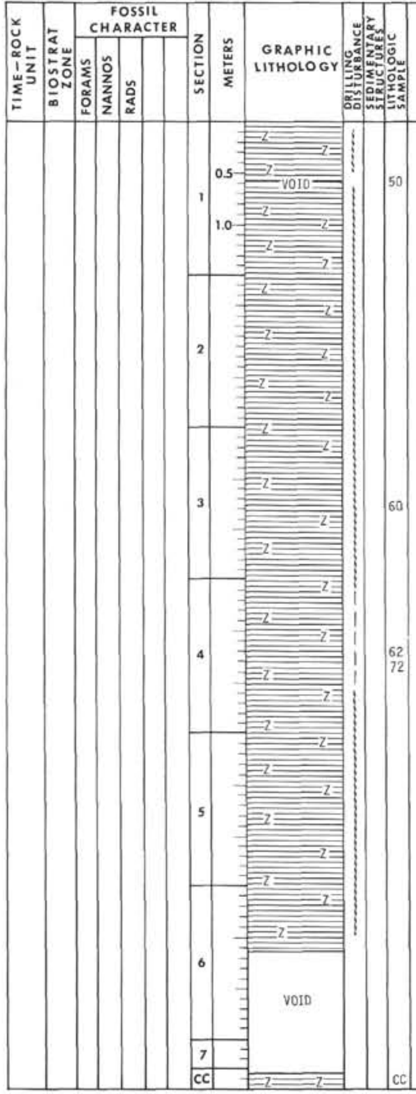
Grain Size

1-4
0.7% sand
3.6% silt
95.7% clay

Carbon, Carbon-Carbonate

1-95 (0.3, 0.1, 2)
3-33 (0.1, 0.1, 0)

SITE 417 HOLE A CORE 13 CORED INTERVAL: 113.0 - 122.5 m



LITHOLOGIC DESCRIPTION

10YR 3/3
10YR 4/2
10YR 4/3
10YR 3/2
10YR 3/2
10YR 4/2
2.5Y 4/4

ZEOLITIC CLAY, highly deformed, firm; dark brown, dark grayish brown, brown to dark brown, very dark grayish brown, dark yellow brown (10YR 3/3, 10YR 4/2, 10YR 4/3, 10YR 3/2) with light yellow brown, and grayish orange (10YR 6/4, 10YR 7/4) streaks.

Spots of light bluish (5B 7/1) volcanic ash in Sections 1 and 2. Light streaks are apparently diffuse laminationsion on a 1 cm scale in top of Section 4. Core Catcher has olive brown clay (2.5Y 4/4).

Major Lithology

Smears: Average of 4

61% clay min.
1% qtz.
1% K-feldspar
32% zeolites
2% accessory heavies
1% ferruginous blebs
TR% Fe-Mn nodules

Minor Lithology

Smear: 4-72

49% clay min.
2% qtz.
2% feld.
45% zeolites
1% accessory heavies
1% ferruginous blebs

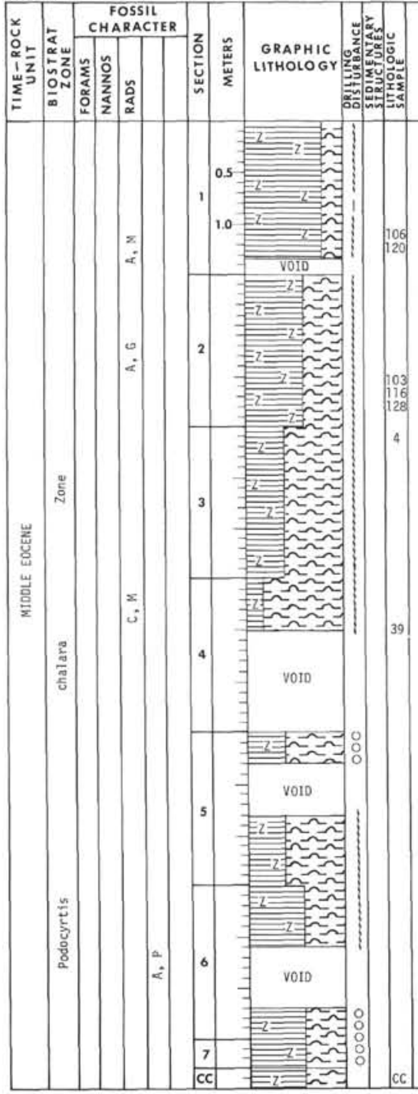
CO_3 Bomb Results

3-30
0.1% sand
1.3% silt
98.6% clay

Carbon, Carbon-Carbonate

3-32 (0.0, 0.1, 0)
5-80 (0.1, 0.1, 0)

SITE 417 HOLE A CORE 14 CORED INTERVAL: 122.5-132.0 m



LITHOLOGIC DESCRIPTION

10YR 3/2
10YR 3/2 to 10YR 4/3
10YR 4/2
10YR 5/2
10YR 5/3
10YR 4/2
10YR 5/2

RADIOLARIAN RICH SILICEOUS ZEOLITIC CLAY with beds of RADIOLARIAN OOZE, highly disturbed, firm.

Dominant lithology: very dark grayish brown, yellow brown, dark grayish brown, dark yellow brown clay (10YR 3/2, 10YR 4/3, 10YR 5/2, 10YR 5/3, and 10YR 4/2).

Beds of RADIOLARIAN OOZE, gritty, are pale brown, light yellow brown, medium yellow brown (10YR 6/3, 10YR 5/3, 10YR 7/4, 10YR 6/4).

Small spots of reddish yellow (7.5YR 5/4 to 7.5YR 7/4) clay occur..

Major Lithology

Smears: Average of 8

52% clay min.
28% radiolaria
4% sponge spicules
2% silicoflagellates
1% qtz.
1% feld.
10% zeolites
1% accessory heavies
1% ferruginous blebs

CO_3 Bomb Results

14-2, 53-0%
14-3, 72-0%

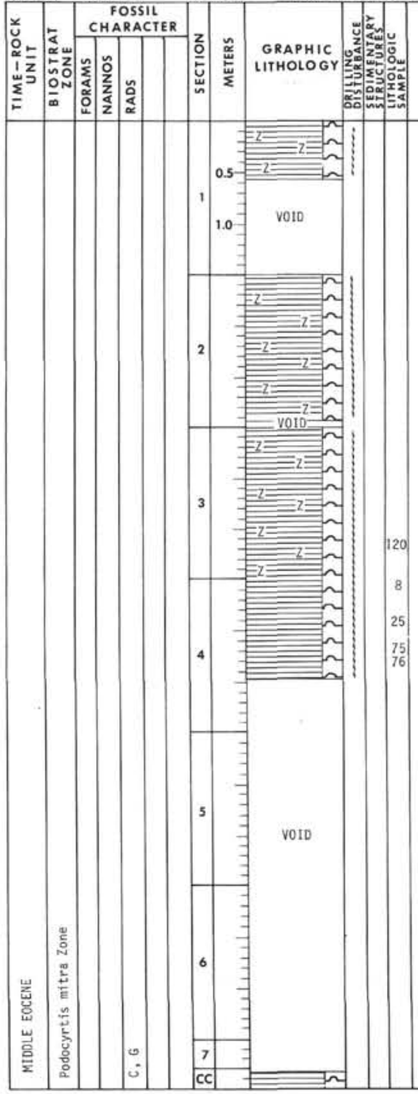
Grain Size

2-50
2.4% sand
14.2% silt
83.5% clay

Carbon, Carbon-Carbonate

2-52 (0.1, 0.1, 0)

SITE 417 **HOLE** A **CORE** 15 **CORED INTERVAL:** 132.0-141.5 m



LITHOLOGIC DESCRIPTION

5Y 4/4

5Y 5/3

10YR 5/3
10YR 3/3
and 4/3

10YR 3/3

RADIOLARIAN-BEARING SILICEOUS ZEOLITIC CLAY (Sections 1-3) highly disturbed, firm. Dominant lithology: olive to brown (5Y 4/4 and 5Y 5/3 to 10YR 5/3).

Irregularly streaked with very pale brown (10YR 7/4), yellowish orange (10YR 7/6), dusky yellow brown (10YR 3/7), light yellowish brown (10YR 6/4). Sharp contacts in Section 3 at 10 and 40 cm. Transitional lithology between 10 and 40 cm is dark brown siliceous zeolitic clay. Below 40 cm is a dark brown (10YR 3/3) siliceous zeolitic clay. Zeolite far less prominant in Section 4. Light streaks are gritty and contain more radiolaria.

Zeolite-rich (Major lithology)

Smear: 3-120

43%	clay min.
10%	radiolaria
5%	sponge spicules
5%	qtz.
2%	feld.
25%	zeolites

Zeolite-poor (Major lithology)

Smears: Average of 5

56%	clay min.
28%	radiolaria
6%	sponge spicules
2%	silicoflagellates
2%	qtz.
5%	feld.
TR%	accessory heavies
TR%	ferruginous blebs

CO_3 Bomb Results

15-1, 77-0%
15-3, 30-0%

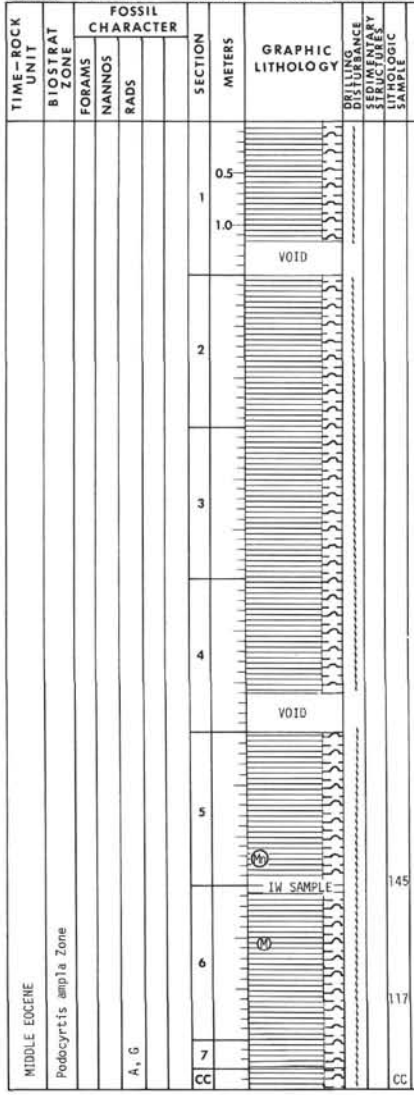
Grain Size

1-19
2.1% sand
11.5% silt
86.5% clay

Carbon, Carbon-Carbonate

1-21 (0.1, 0.1, 0)
3-28 (0.1, 0.1, 0)

SITE 417 **HOLE** A **CORE** 16 **CORED INTERVAL:** 141.5-151.0 m



LITHOLOGIC DESCRIPTION

10YR 5/3

10YR 4/2
to
10YR 7/4

10YR 4/2

10YR 5/3

10YR 6/4

10YR 4/2

118

SILICEOUS CLAY with minor RADIOLARIAN OOZE. Highly disturbed, firm. Dominant lithology: brown, yellow brown, dark yellow brown, grayish orange (10YR 5/3, 10YR 4/2, 10YR 7/4, 10YR 6/4) clay. Minor lithology, as streaks and mottles in major lithology; grayish orange, yellow brown, light yellow brown (10YR 7/4, 10YR 2/2, 10YR 6/4) clayey radiolarian ooze. Reddish yellow (5YR 6/6) clay spots in Section 6, 46 cm. Manganese micronodules in Section 5, 120 cm. Magnetic micronodule in Section 6, 120 cm.

Major Lithology

Smears: Average of 2

60%	clay min.
25%	radiolaria
7%	sponge spicules
2%	qtz.
2%	feld.
4%	ferruginous blebs

Minor Lithology

Smear: 5-145

53%	clay min.
10%	radiolaria
3%	sponge spicules
2%	qtz.
2%	feld.
30%	manganite

CO_3 Bomb Results

16-1, 83-0%
16-3, 8-0%
16-5, 58-0%

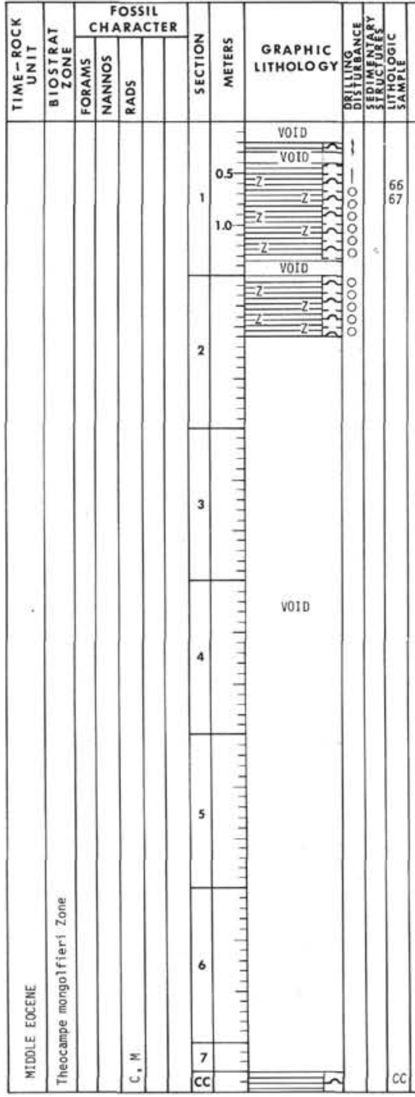
Grain Size

1-78
2.7% sand
28.2% silt
69.1% clay

Carbon, Carbon-Carbonate

1-81 (0.0, 0.1, 0)
3-66 (0.1, 0.1, 0)
5-62 (0.1, 0.1, 0)

SITE 417 **HOLE** A **CORE** 17 **CORED INTERVAL:** 151.0-160.5 m



LITHOLOGIC DESCRIPTION

10YR 4/3

10YR 4/3

RADIOLARIAN-BEARING ZEOLITIC CLAY brown to dark brown (10YR 4/3), highly disturbed, firm. Minor lithology: yellowish red (5YR 5/6) clay, forming a large pod in Section 1, 40-57 cm, and streaks and spots elsewhere. Tiny spots of greenish clay. Rare chert chips throughout.

Major Lithology

Smears: Average of 2

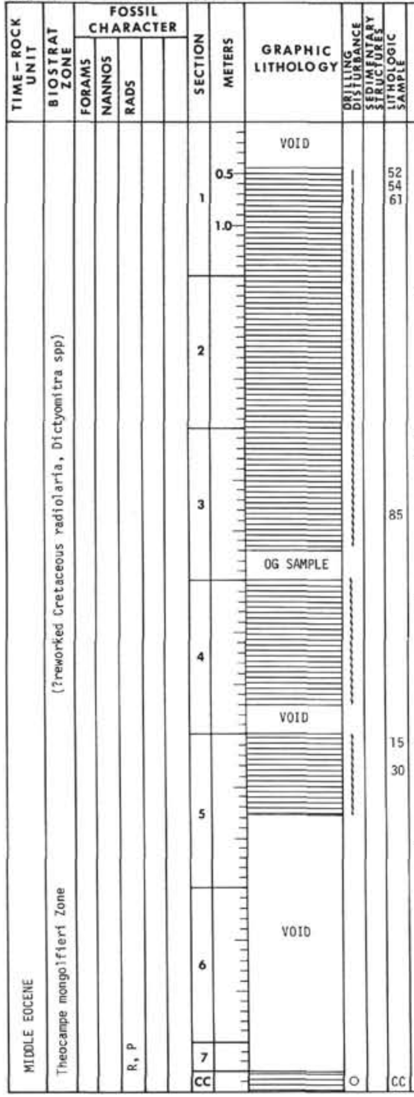
91% clay min.
1% radiolaria
2% qtz.
2% feld.
4% ferruginous blebs

Minor Lithology

Smears: 1-66, 1-67

80% clay min.
5% qtz.
3% plagioclase feld.
3% K-feldspar
5% zeolites
1% accessory heavies
TR% ferruginous blebs
2% clear volcanic glass

SITE 417 **HOLE** A **CORE** 18 **CORED INTERVAL:** 160.5-170.0 m



LITHOLOGIC DESCRIPTION

10YR 4/2
10YR 6/3

10YR 3/2

10YR 4/2
10YR 5/4

10YR 4/2

10YR 3/3

10YR 3/3

CLAY
Dominantly dark grayish brown, dark brown, very dark grayish brown, and pale brown (10YR 4/2, 10YR 3/3, 10YR 3/2, and 10YR 6/3); moderately to highly deformed, firm. Streaked with reddish brown (5YR 5/4), reddish yellow (5YR 6/6), pale brown (10YR 6/3), grayish orange (10YR 7/4) and orange brown (5YR 7/4) clay, the streaks approximating obscure stratification in Section 2. Rare pods of light blue Volcanic Ash (5B 7/6) in Section 3, 85 cm. Sharp boundaries separating three major lithologies at top of Section 1: dark grayish brown (10YR 4/2), 43-57 cm; pale brown (10YR 6/3), 57-64 cm; dark grayish brown (10YR 4/2) 64-150 cm.

Smears: Average of 7

79% clay min.
TR% radiolaria
TR% fish debris
7% qtz.
3% K-feldspar
6% unspecified feld.
2% zeolites
1% accessory heavies
1% ferruginous blebs
1% altered volcanics
TR% biotite

Minor Lithology

Smear: 5-5

62% clay min.
5% qtz.
15% K-feldspar
TR% hornblende
5% feld.
TR% pyroxene
5% zeolites
1% Fe-Mn nodules
3% ferruginous
2% palagonite
2% altered volcanics

Coarse Fraction: forams, radiolaria, fish debris, phosphatic micronodules

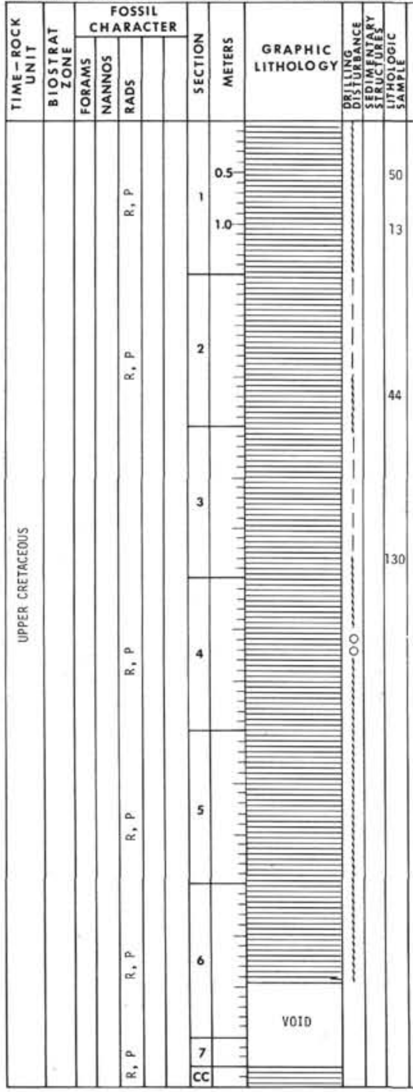
CO_3 Bomb Results

18-1, 97-0%

Carbon, Carbon-Carbonate

1-96 (0.1, 0.1, 0)
3-107 (0.1, 0.1, 0)

SITE 417 HOLE A CORE 19 CORED INTERVAL: 170.0-179.5 m



LITHOLOGIC DESCRIPTION

10YR 3/2
10YR 4/2

CLAY
Multicolored; highly to moderately deformed, firm.

Dominant lithology: very dark grayish brown to dark grayish brown and dark brown (10YR 3/2 to 10YR 4/2 and 4/3).

10YR 3/2

Streaked with brown (10YR 5/3) to light brown (10YR 6/2). Mottles of brown (7.5YR 5/3) in Section 3, 20-30 cm, 65-75 cm. Spots of pale olive (5Y 6/3) VOLCANIC ASH in Section 1, 90-100 cm.

Smears: Average of 4

84% clay min.
7% qtz.
6% K-feldspar
1% zeolites
2% accessory heavies
TR% ferruginous blebs
TR% chert
TR% mica

10YR 4/2
10YR 5/4

Grain Size

1-30
0.0% sand
9.6% silt
90.4% clay

10YR 3/2
10YR 4/2

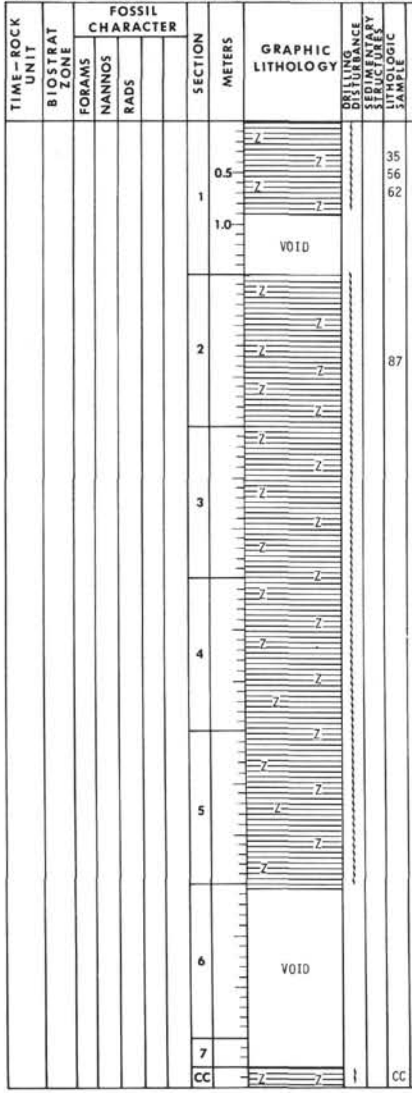
Carbon, Carbon-Carbonate

1-32 (0.1, 0.1, 0)
3-20 (0.1, 0.1, 0)
5-81 (0.1, 0.1, 0)

10YR 4/3

10YR 4/2

SITE 417 HOLE A CORE 20 CORED INTERVAL: 179.5-189.0 m



LITHOLOGIC DESCRIPTION

10YR 3/1

ZEOLITIC CLAY
Multicolored; highly disturbed, firm.

Dominant lithology: very dark gray to moderate yellow brown (10YR 3/1 to 10YR 4/4 and 4/2) clay, streaked with (1) yellowish brown to light brown (10YR 5/4 to 5YR 6/4) and, (2) yellowish red (7.5YR 5/6), Section 1, 56 cm. Pods of pale blue (5B 6/2) Volcanic Ash in Section 1, 62 cm.

10YR 4/4
10YR 4/2

ZEOLITIC CLAY (Major lithology)

Smears: Average of 3

76% clay min.
1% fish debris
7% qtz.
4% K-feldspar
9% zeolites
1% accessory heavies
1% ferruginous blebs
1% Fe-Mn nodules

10YR 3/1

VOLCANIC ASH (Minor lithology)

Smear: 1-56

53% clay min.
5% qtz.
4% K-feldspar
35% zeolites
1% accessory heavies
TR% ferruginous blebs
2% altered volcanics

10YR 3/1

Grain Size

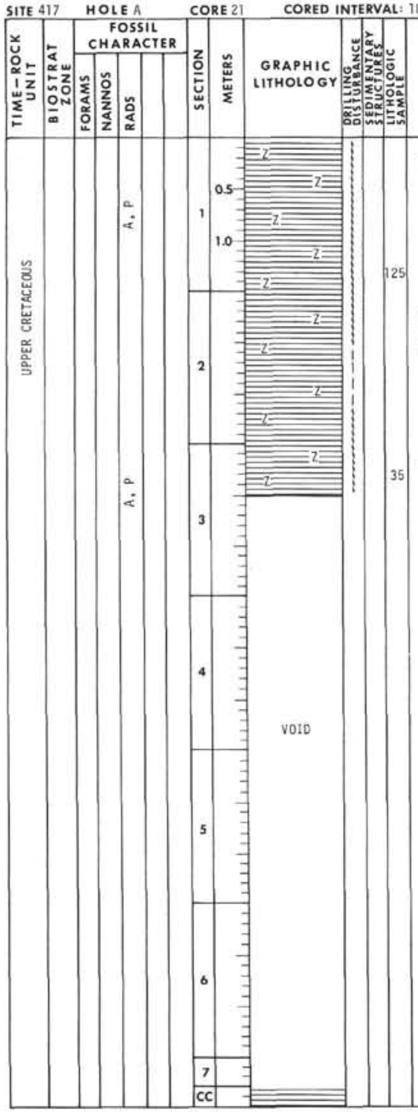
1-28
0.0% sand
25.7% silt
74.3% clay

10YR 3/1

Carbon, Carbon-Carbonate

1-20 (0.1, 0.1, 0)
3-40 (0.1, 0.1, 0)
5-70 (0.1, 0.1, 0)

SITE 417 **HOLE** A **CORE** 21 **CORED INTERVAL:** 189.0-198.5 m



LITHOLOGIC DESCRIPTION

10YR 3/2

ZEOLITIC CLAY
Multicolored; highly disturbed, firm. Dominantly dark brown yellowish to yellowish brown streaked with (1) very light brown (10YR 6/3) to pale yellow brown (10YR 6/2), (2) light to strong brown (5YR 5/4 to 5YR 6/4), (3) dark yellowish brown (10YR 2/2) spots (Section 1, 52 cm). In Section 2 additional major lithology is light brown to yellowish brown (7.5YR 6/4 to 10YR 5/4).

10YR 3/2
to
10YR 5/4

Gritty zeolitic spots (pale yellow orange, 10YR 7/6 to very pale brown (10YR 7/4) occur in Section 1, 55-125 cm; Section 2, 60-70 and 105-110 cm.

Rare bluish to olive spots (altered VOLCANIC ASH) (5B 7/2 to 5Y 5/3) occur especially in Section 2, 20-30 cm; Section 3, 34 cm.

10YR 3/2

ZEOLITIC CLAY (Major lithology)

Smear: CC

73%	clay min.
5%	qtz.
3%	K-feldspar
15%	zeolites
2%	ferruginous blebs
2%	Fe-Mn nodules

VOLCANIC ASH (Minor lithology)

Smears: 1-125, 3-35

52%	clay min.
1%	qtz.
45%	zeolites
1%	ferruginous blebs
1%	accessory heavies

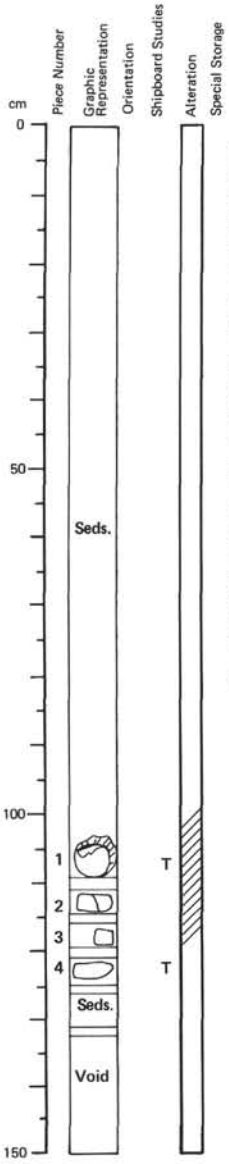
Grain Size

1-96

0.2%	sand
25.2%	silt
74.6%	clay

Carbon, Carbon-Carbonate

1-53 (0.1, 0.1, 0)



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	22	1

Visual Description

0-104, 125-132 cm intervals: dark brown clay (described under sediments).

Pieces 1-4: strongly altered, sparsely phyric basalt cobbles. Basalt dark gray, altered to yellow-gray, yellow-brown near margins; margins of piece 1 altered to blue-gray to blue-green clay. Groundmass aphanitic to hyalopilitic. Plagioclase phenocrysts 10%, <3 mm, completely replaced by calcite and zeolites; olivine phenocrysts completely replaced by smectite and celadonite 1-2%, ≤2 mm. Vesicles 1-2%, ≤3 mm, filled either by green smectite or by white zeolite needles around a calcite core. Veins filled by calcite.

Thin Section Description

Location: basalt fragment, 107 cm

Texture: porphyritic, hyalopilitic

Phenocrysts: altered olivine 2-5%, 1-2 mm, idiomorphic; altered plagioclase, An ≤65, ≤3 mm, idiomorphic with oscillatory zoning

Groundmass: olivine pseudomorphs(?); skeletal plagioclase microlites, An 33, 15%, 0.03-1 mm; plumose clinopyroxene pseudomorphs, 5-10%; altered glass 50%; hematite 10-20%

Vesicles: 1%, 0.05-0.5 mm, filled by smectite ± celadonite, round, occationally compound

Alteration: plagioclase altered to clay and zeolites (analcite); olivine completely altered to iddingsite; glass devitrified, altered to smectite

Thin Section Description

Location: 123 cm

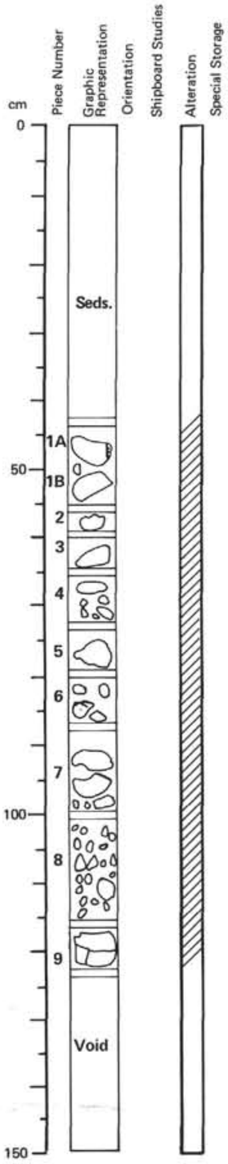
Texture: porphyritic, hyalopilitic

Phenocrysts: altered olivine 1-2%, 3-8 mm, idiomorphic; plagioclase An >50, 15%, 0.5-3.0 mm; altered clinopyroxene <1%, 0.1-0.3 mm

Groundmass: skeletal plagioclase microlites 20%, 0.1-0.5 mm; plumose clinopyroxene pseudomorphs 25-30%, 0.2-0.7 mm; altered glass 30-40%

Vesicles: <1%, 0.2 mm, filled by smectite ± celadonite, round

Alteration: plagioclase phenocrysts altered to clay, zeolites(?); clinopyroxene altered to smectite; olivine replaced by smectite, opaques; glass devitrified, altered to palagonite(?)



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	23	1

Visual Description

0-43 cm interval: clay (described under sediments).

Pieces 1-9: altered plagioclase-phyric basalt fragments, many with fine-grained, aphyric chilled margins. Basalt dark gray, altered to yellow-brown near cracks and margins. Groundmass aphanitic to microlitic. Plagioclase phenocrysts 3-10%, ≤4 mm, replaced by calcite and zeolites(?) ± clay; mafic phenocrysts replaced by smectite ± celadonite(?) 2%, <2 mm. Veins filled by smectite. Piece 1A contains a thin Mn crust and traces of palagonite.

SITE 417 **HOLE** A **CORE** 24 **CORED INTERVAL:** 217.5-227.0 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FOSSIL CHARACTER					SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
		FORAMS	NANNOS	RADS									
UPPER CRETACEOUS				R, P			1	0.5 1.0					
							2						
							3						
							4						
							5						
							6		VOID				
							7						
							CC						

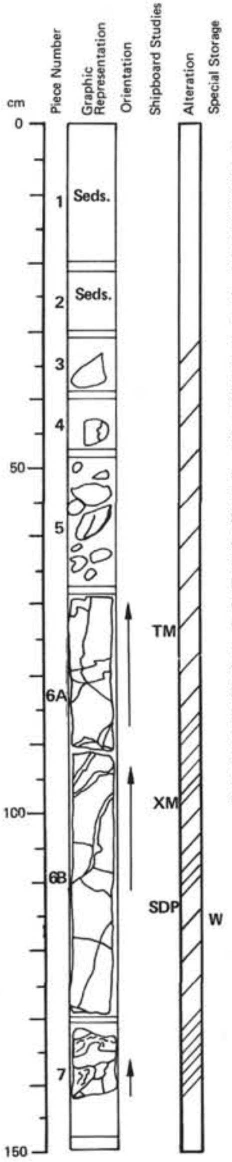
7.5YR 4/4

CLAYEY TO SILTY SAND
Unconsolidated, coarse to medium grained, brown to dark brown (7.5 YR 4/4), occurred on top of the basalt; probably largely drill cuttings, but contained Cretaceous radiolarians.

Basalt described under igneous rocks.

Grain Size

1-11
20.0% sand
19.9% silt
60.2% clay



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

0-30 cm interval: clayey to silty sand (described under sediments).

30-150 cm interval: strongly altered plagioclase-phyric basalt with minor palagonite breccia. Basalt dark gray, altered to yellow-green or pale brown near margins and along numerous cracks and veins. Alteration often one-sided along veins filled by calcite. Plagioclase phenocrysts 10%, ≤3 mm. Local vesicles filled by calcite, smectite and zeolites. Breccia composed of strongly altered basalt fragments (locally auto-brecciated) in a matrix of clear green palagonite, smectite, celadonite and zeolites. Breccia in piece 7 contains native copper.

Thin Section Description

Location: pillow interior, 76 cm

Texture: porphyritic

Phenocrysts: altered plagioclase 10-15%

Groundmass: clay and smectite 65%: magnetite 10-15%

Vesicles: 2-3%, filled by calcite and celadonite

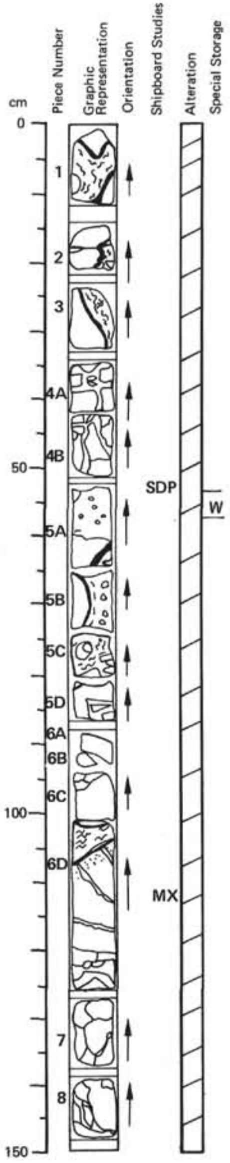
Alteration: plagioclase completely altered to clay, kspar and zeolites(?); glass devitrified, altered in part to clay

Shipboard Data

Bulk Analysis:	99-101 cm
SiO_2	54.19
Al_2O_3	20.64
Fe_2O_3	10.19
MgO	3.06
CaO	2.66
Na_2O	1.56
K_2O	6.38
TiO_2	1.80
P_2O_5	0.35
MnO	0.12
LOI	4.75
H_2O^+	4.19
H_2O^-	N.D.
CO_2	0.80

Magnetic Data:	75-77 cm	99-101 cm
NRM Intensity (emu/cc)	0.423×10^{-3}	0.736×10^{-3}
NRM Inclination	-8.9°	-22.0°
Stable Inclination	-35.8°	-20.9°

Physical Property Data:	114-117 cm
$\overline{V}p$ (km/sec)	3.79
Porosity (%)	16.74
Wet Bulk Density (g/cc)	2.44
Grain Density (g/cc)	2.73



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

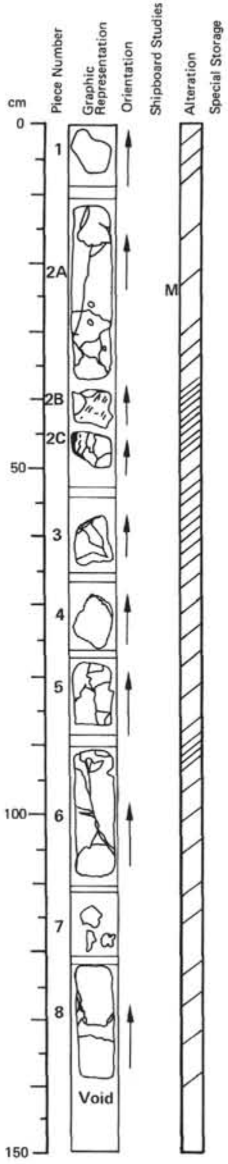
Plagioclase-phyric pillow basalt with palagonite breccia. Basalt dark gray with margins altered to gray-brown, yellow-brown or yellow to a depth of 15 mm; outermost rims dark gray. Groundmass microlitic to aphanitic. Plagioclase phenocrysts ≤10%, ≤4 mm. No mafic phenocrysts or vesicles. Veins filled by calcite, clay and zeolites. In piece 4, the margins of the veins are stained by hematite and fragments of green material are present in the veins. Breccia consists of basalt fragments and glass altered to banded green material. Minor red alteration products also present.

Shipboard Data

Bulk Analysis:	119-115 cm
SiO_2	51.86
Al_2O_3	19.97
Fe_2O_3	11.92
MgO	3.33
CaO	5.52
Na_2O	2.05
K_2O	4.26
TiO_2	1.69
P_2O_5	0.31
MnO	0.16
LOI	3.75
H_2O^+	3.56
H_2O^-	N.D.
CO_2	0.43

Magnetic Data:	113-115 cm
NRM Intensity (emu/cc)	6.837×10^{-3}
NRM Inclination	-15.6°
Stable Inclination	-21.4°

Physical Property Data:	54-56 cm
$\overline{V}p$ (km/sec)	2.87
Porosity (%)	34.2
Wet Bulk Density (g/cc)	2.20
Grain Density (g/cc)	2.83



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

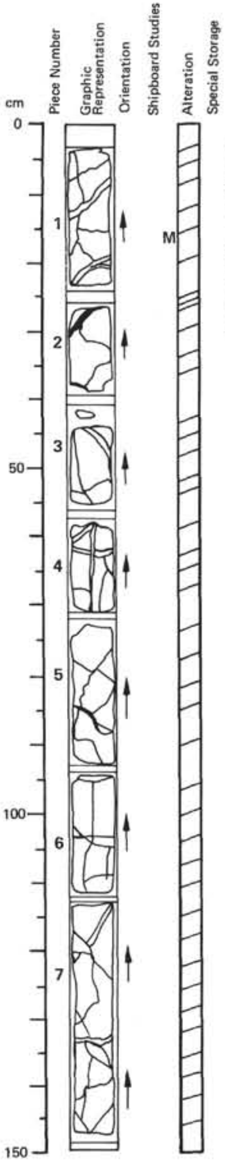
LEG	SITE	HOLE	CORE	SECT.
51	417	A	24	3

Visual Description

Plagioclase-phyric pillow basalt. Basalt dark gray; altered to light gray-brown or yellow-brown; margins dark gray to a depth of 2-3 mm. Groundmass microlitic to aphanitic. Plagioclase phenocrysts < 10%, < 2 mm. No mafic phenocrysts or vesicles are present except in piece 8 where both are present in small amounts (< 2% and < 1% respectively). Thin (1-2 mm) veinlets filled by calcite + clay and zeolites(?) are present in pieces 2C, 3, 5, 6 and 8. In piece 5, the calcite-filled veins have pale, 10-20 mm wide alteration halos. In piece 6, some of the veinlets have black rims. Pieces 2B and C also contain breccias composed of fragments of palagonitized glass, smectite and zeolite(?) cemented by calcite. The fragments tend to be elongate parallel to basalt chill margins.

Shipboard Data

Magnetic Data:	21-23 cm
NRM Intensity (emu/cc)	6.762×10^{-3}
NRM Inclination	-27.3°
Stable Inclination	-26.6°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	24	4

Visual Description

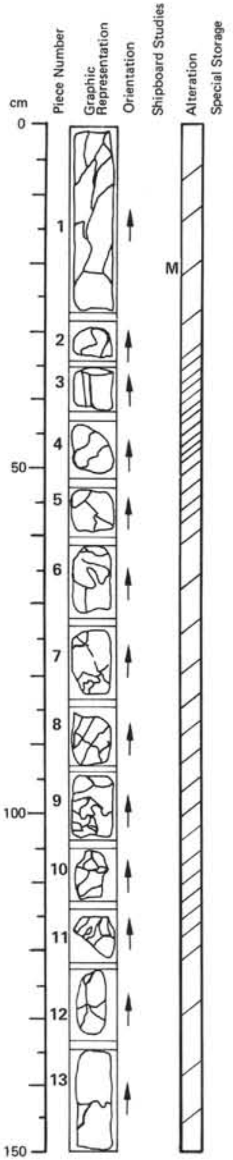
Altered plagioclase-phyric pillow basalt. Groundmass dark gray; altered to gray-brown, yellow-brown and dark brown in 2 cm thick alteration halos along veins, chill margins. Groundmass microlitic. Plagioclase phenocrysts < 10%, < 4 mm; mafic phenocrysts < 5%, < 1 mm. Veinlets filled by calcite ±clay and hematite(?). Piece 2 composed in part, of palagonite breccia.

Shipboard Data

Magnetic Data:	18-20 cm
NRM Intensity (emu/cc)	8.090×10^{-3}
NRM Inclination	-16.2°
Stable Inclination	-16.2°

VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	24	5



Visual Description

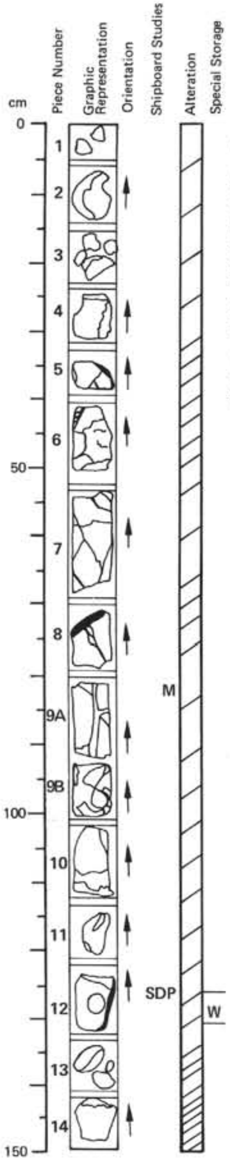
Plagioclase-phyric pillow basalt. Groundmass dark gray; altered to green, gray-brown, yellow-brown and dark brown in patches and halos (2 cm wide) along veins and chill margins. Groundmass microlitic to aphanitic. Plagioclase phenocrysts < 10%, <2 mm; mafic phenocrysts < 10%, <3 mm. Veins filled by calcite ± hematite(?) form local intrusion microbreccias. Pieces 8, 9 and 10 are moderately altered and 3, 4 and 5 strongly altered.

Shipboard Data

Magnetic Data:	22-25 cm
NRM Intensity (emu/cc)	2.518×10^{-3}
NRM Inclination	-19.6°
Stable Inclination	-18.7°

VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	25	1

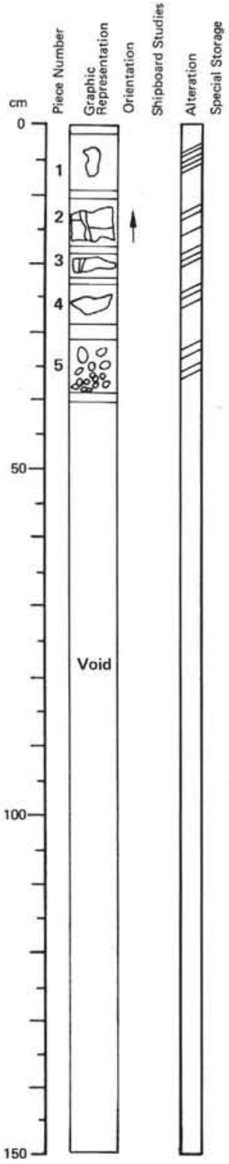


Visual Description

Pieces 1-4, 7, 9 and 11: Altered, highly fractured plagioclase-phyric pillow basalt. Gray groundmass altered to yellow-brown and brown along chill margins. Plagioclase phenocrysts ≤ 10%, ≤3 mm; mafic phenocrysts <5%, ≤1 mm. Pieces 5, 6, 8, 10, 12, 13 and 14: nearly aphyric basalt chill margins. Light yellow-gray. Plagioclase and mafic phenocrysts extremely small. Thin, calcite-filled veins are common; in the aphyric samples, these tend to be perpendicular to chill margins and to be lined with hematite(?) or red-brown smectite(?). Veins in piece 9A are filled by calcite and green smectite. Pieces 3 and 14 are composed in part, of palagonite; piece 14 is strongly zoned with bands of green palagonite, celadonite(?) and smectite (hematite?).

Shipboard Data

Magnetic Data:	82-85 cm
NRM Intensity (emu/cc)	6.819×10^{-3}
NRM Inclination	-31.0°
Stable Inclination	-30.8°

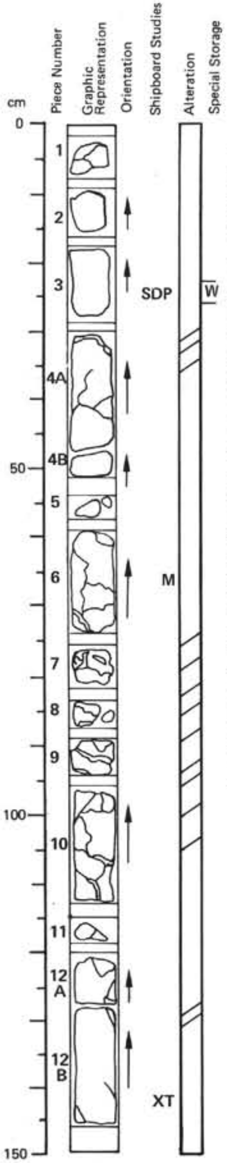


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	25	2

Visual Description

Piece 1. Brown to green palagonite cut by red veinlet. Pieces 2-5: altered phyric pillow basalt. Dark gray groundmass altered to gray-green, gray-brown and yellow-brown. Both plagioclase and mafic phenocrysts are present, the latter altered to smectite. A thin calcite-filled vein is present in piece 2.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	26	1

Visual Description

Phyric pillow basalt with chilled margins and interpillow breccia. Basalt gray, altered to gray-brown along pillow margins. Groundmass microlitic to aphanitic. Mafic phenocrysts (clinopyroxene and olivine replaced by smectite) <5%; plagioclase phenocrysts 2-5%. Calcite-filled veins common. Breccia composed of basalt clasts partially altered to palagonite and smectite in a banded green matrix of palagonite smectite, hematite and zeolites(?).

Thin Section Description

Location: pillow interior, 141 cm

Texture: hyalopilitic

Phenocrysts: altered plagioclase, An >40, 1%, 0.5 mm, euhedral, zoned

Groundmass: plagioclase laths 35%, 0.3 mm, occassionally skeletal; colorless clinopyroxene 20-25%, 0.1 mm, prismatic; magnetite 20-25%, 0.2 mm, idiomorphic; altered glass 10%; minor calcite

Vesicles: 1-2%, 0.3 mm, round, filled by calcite and minor smectite, celadonite

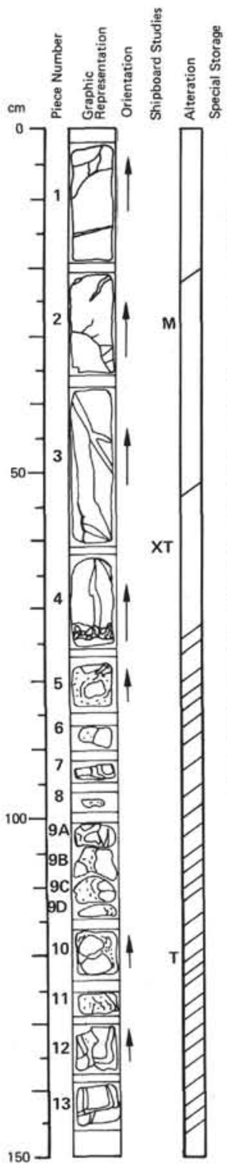
Alteration: plagioclase replaced by calcite, clay and zeolites; glass altered to palagonite, celadonite (?); zeolites, celadonite and calcite present in veins

Shipboard Data

Bulk Analysis: 140-143 cm	
SiO_2	48.64
Al_2O_3	15.90
Fe_2O_3	13.35
MgO	6.58
CaO	8.08
Na_2O	1.69
K_2O	2.89
TiO_2	1.87
P_2O_5	0.17
MnO	0.20
LOI	4.35
H_2O^+	3.34
H_2O^-	N.D.
CO_2	0.73

Magnetic Data:	64-67 cm
NRM Intensity (emu/cc)	3.812×10^{-3}
NRM Inclination	- 8.0°
Stable Inclination	- 8.4°

Physical Property Data:	23-25 cm
$\overline{V}p$ (km/sec)	4.81
Porosity (%)	8.46
Wet Bulk Density (g/cc)	2.65
Grain Density (g/cc)	2.80



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	A	2 6	2

Visual Description

Phyric pillow basalt with palagonite breccia. Interval from 0-70 cm probably represents a single pillow with a chilled lower margin. Basalt gray, altered to gray-brown along margins. Groundmass microlitic to aphanitic. Altered mafic phenocrysts 5-10/, < 1 mm; plagioclase phenocrysts common inpieces 12, 13, variably altered to clay, zeolites. Glass altered to smectite. Veins filled by calcite, smectite and hematite. Breccia composed of altered plagioclase-phyric basalt in a cemented matrix of palagonite, smectite, zeolites, celadonite(?), calcite and hematite or limonite(?).

Thin Section Description

Location: 60 cm, close to chill margin

Texture: hyalopilitic

Phenocrysts: euhedral plagioclase laths 1%, 0.2-0.6 mm

Groundmass: plagioclase microlites 25-30%, 0.1 mm; magnetite (and ilmenite?) 10%, <0.1 mm; devitrified glass 60-65%

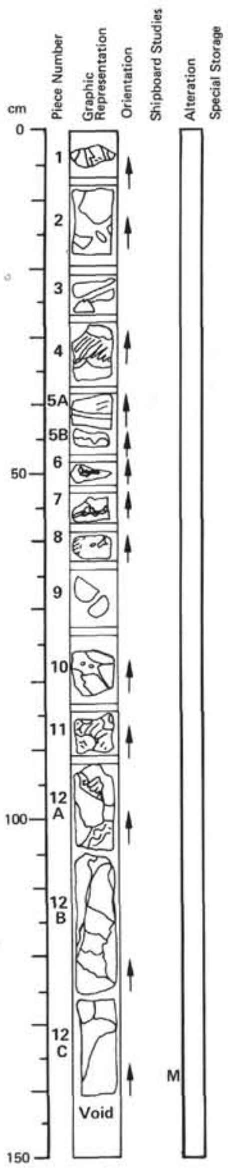
Vesicles: <1%, 0.2 mm, round, filled by celadonite

Alteration: Glass altered to palagonite, zeolites, celadonite

Shipboard Data

Bulk Analysis:	58-61 cm
SiO_2	47.70
Al_2O_3	16.85
Fe_2O_3	14.71
MgO	5.41
CaO	6.68
Na_2O	1.81
K_2O	3.19
TiO_2	1.92
P_2O_5	0.17
MnO	0.22
LOI	3.20
H_2O^+	3.48
H_2O^-	N.D.
CO_2	0.28

Magnetic Data:	26-29 cm
NRM Intensity (emu/cc)	2.824×10^{-3}
NRM Inclination	-20.5°
Stable Inclination	-21.2°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

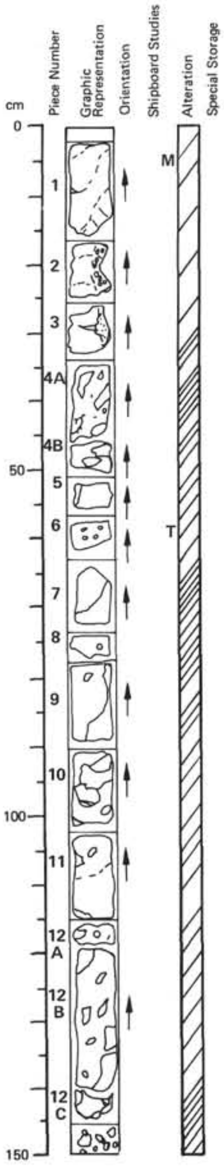
LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	A	2 6	3

Visual Description

Pieces 1-11: Altered plagioclase-phyric pillow basalt in matrix of green palagonite breccia. Basalt gray, altered in patches to yellow-brown; margins slightly hematized. Groundmass microlitic to aphanitic. Plagioclase phenocrysts 10%, <2 mm; mafic phenocrysts <5%, <2 mm. Vesicles and vugs, the latter ranging up to 10 mm in length, are common (<10%) in pieces 6 and 8-10; these are partly or entirely filled by opal, smectite, calcite and zeolites(?) in varying combinations but usually with opal linings and a calcite core. In larger vugs, opal is present as small (0.2 mm), blue-gray spheres. Veinlets in pieces 1 and 6 filled by calcite, smectite. Breccia composed of small fragments of altered basalt in a matrix of palagonite, smectite, calcite, celadonite(?) and minor hematite(?). Piece 12: fractured, phyric basalt. Gray to gray-violet; altered to yellow-brown along veins. Mafic phenocrysts 15%, <1.5 mm; plagioclase phenocrysts <5%, <0.5 mm.

Shipboard Data

Magnetic Data:	137-140 cm
NRM Intensity (emu/cc)	5.223×10^{-3}
NRM Inclination	-13.7°
Stable Inclination	-14.4°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

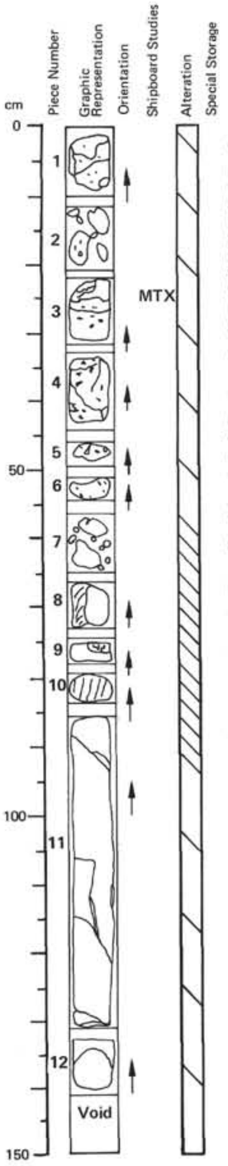
LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	A	2 6	4

Visual Description

Altered pyroxene- and plagioclase-phyric pillow basalt with hyaloclastic(?) breccia. Basalt altered to yellow-brown. Groundmass microlitic. Pyroxene phenocrysts ≤10%, ≤3 mm; plagioclase phenocrysts 5-10%, <1.5 mm, largely replaced by kspar and clay. Amygdules filled by smectite, calcite and zeolites (analcite, celadonite?); calcite-filled vesicles locally coalesce to form network veins (pieces 7-9). Veins filled by calcite, smectite; calcite-filled veins in piece 1 locally micro-brecciated. Breccia composed of highly altered basalt fragments displaying spheroidal weathering in a green matrix of palagonite, smectite, calcite, zeolites(?) and hematite(?).

Shipboard Data

Magnetic Data:	5-8 cm
NRM Intensity (emu/cc)	2.010×10^{-3}
NRM Inclination	+ .9°
Stable Inclination	- 3.3°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	A	2 6	5

Visual Description

Pieces 1-6: phyric pillow basalt. Dark gray, altered to gray-violet, yellow-brown. Groundmass microlitic to aphanitic. Mafic phenocrysts (replaced by smectite) 10%, ≤0.5 mm; plagioclase phenocrysts 5-10%, <0.5 mm. Amygdules calcite, smectite-filled, increase in size from 1-2 mm in piece 1 to ≤10 mm in pieces 4-6. Veinlets filled by calcite and smectite(?).

Pieces 7-10: Volcanoclastic breccia composed of altered fragments of basalt in a green matrix of palagonite, smectite, calcite and minor hematite. Calcite present in veins. Hematite present in veins and along outermost surface of basalt fragments. Piece 9 contains a large inclusion of celadonite.

Pieces 11 and 12: phyric basalt. Gray, altered to yellow-brown near chill margin. Plagioclase phenocrysts 15%, <7 mm; mafic phenocrysts 10%, <2 mm. Veinlets filled by calcite.

Thin Section Description

Location: near chilled margin, 29 cm

Texture: porphyritic

Phenocrysts: altered olivine <10%, 1 mm, euhedral; altered plagioclase 10%, 3 mm, euhedral; altered clinopyroxene 2%, 1 mm, euhedral

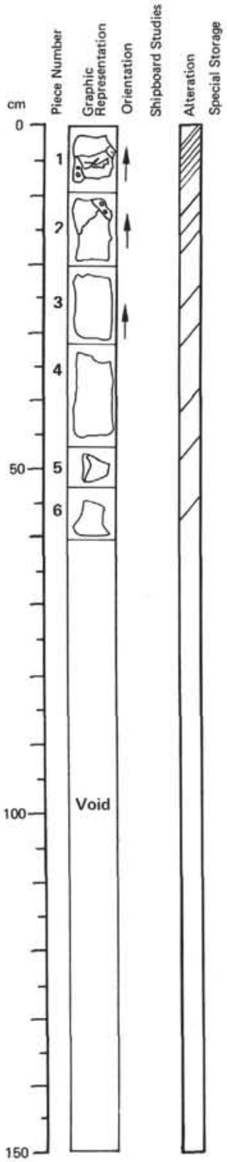
Groundmass: partially altered plagioclase 10%, 0.2 mm, tabular; altered glass >70%

Vesicles: <1%, round, filled by smectite

Alteration: plagioclase largely altered to kspar and clay; clinopyroxene replaced by smectite; olivine phenocrysts completely replaced by smectite and iddingsite(?)

Shipboard Data

Bulk Analysis:	28-30 cm	Magnetic Data:	28-30 cm
SiO_2	49.86	NRM Intensity (emu/cc)	4.819×10^{-3}
Al_2O_3	19.13	NRM Inclination	-24.2°
Fe_2O_3	12.06	Stable Inclination	-24.5°
MgO	4.79		
CaO	7.68		
Na_2O	2.11		
K_2O	3.03		
TiO_2	1.61		
P_2O_5	0.27		
MnO	0.14		
LOI	5.45		
H_2O^+	3.54		
H_2O^-	N.D.		
CO_2	0.83		

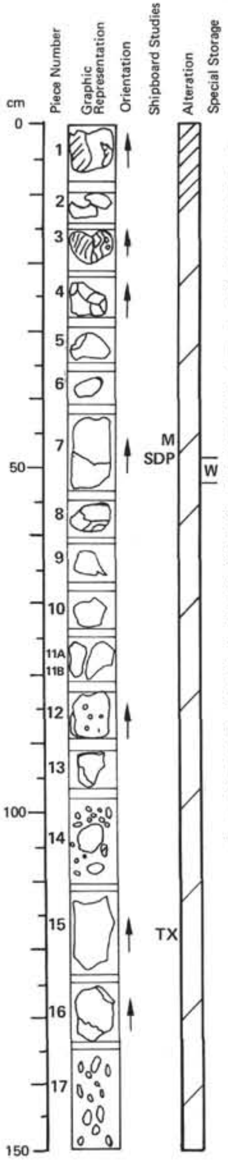


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	A		2	6		6

Visual Description

Porphyritic pillow basalt with minor breccia. Pyroxene phenocrysts (replaced by smectite) 15%, 1-4 mm; olivine(?) phenocrysts (replaced by iddingsite?) 1-2%, 1-2 mm; plagioclase microphenocrysts <2%, <1 mm. Piece 1 is fine-grained, but by calcite veins. Pieces 2-6 are more coarse-grained and contain 1-3 mm calcite-filled amygdules.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Altered phyric pillow basalt with minor palagonite breccia. Basalt dark gray, altered to yellow-brown, red-brown along contacts with breccia. Mafic phenocrysts (replaced by smectite) 15%, <2 mm in piece 1 but increase downward to 20-25%, <4-5 mm in piece 15; plagioclase (partially replaced by calcite, clay) subordinate. Amygdules present throughout, also increase in size and quantity downward to nearly 5 mm and 25% in piece 15; these are filled by smectite (celadonite?) ± an inner core of calcite and zeolites. Phenocrysts and amygdules decrease in piece 16. Calcite veinlets are present in piece 7. Breccia in pieces 1-6 composed of fragments of altered basalt in green matrix of palagonite, smectite, celadonite(?) and calcite cut by a network of hematite or red smectite(?). The matrix in piece 3 is banded in green and violet.

Thin Section Description

Location: pillow interior, 119 cm

Texture: porphyritic, hyaloophitic

Phenocrysts: altered olivine(?) 1-2%, 0.5 mm, euhedral; altered plagioclase 5-10%, 3 mm, euhedral; clinopyroxene 1-2%, 1 mm, euhedral

Groundmass: plagioclase 30%, 0.4 mm, long, tabular; granular clinopyroxene 10%, <0.1 mm, partially altered; devitrified glass 60%

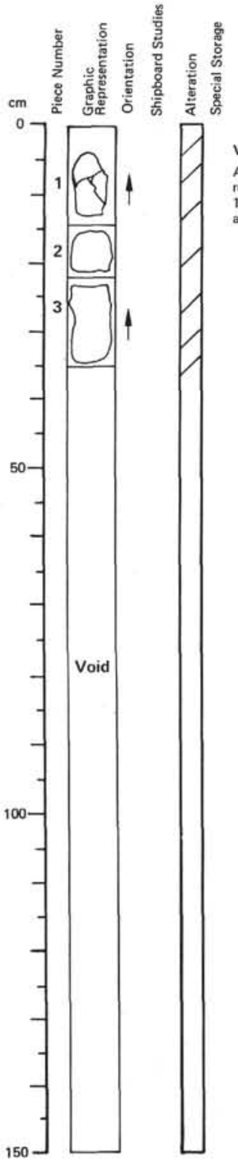
Alteration: plagioclase partially replaced by calcite and albite or kspar; olivine, clinopyroxene replaced by clay

Shipboard Data

Bulk Analysis: 118-120 cm	
SiO_2	50.91
Al_2O_3	19.81
Fe_2O_3	9.95
MgO	4.10
CaO	9.91
Na_2O	2.12
K_2O	2.89
TiO_2	1.58
P_2O_5	0.16
MnO	0.14
LOI	5.75
H_2O^+	2.09
H_2O^-	N.D.
CO_2	1.10

Magnetic Data:	45-48 cm
NRM Intensity (emu/cc)	7.068×10^{-3}
NRM Inclination	-26.1°
Stable Inclination	-26.2°

Physical Property Data:	49-51 cm
$\overline{V}p$ (km/sec)	5.01
Porosity (%)	6.23
Wet Bulk Density (g/cc)	2.74
Grain Density (g/cc)	2.85

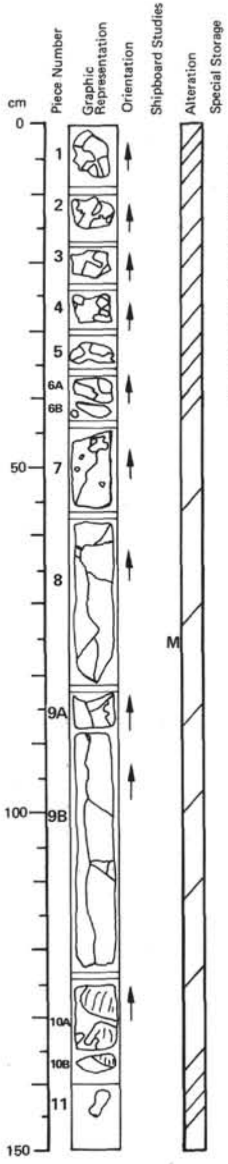


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	27	2

Visual Description

Altered plagioclase-phyric basalt. Groundmass microlitic. Plagioclase phenocrysts (partially replaced by calcite, clay) 10%, <3 mm; mafic phenocrysts (olivine replaced by iddingsite?) 1-2%. Vesicles <4 mm filled by calcite, smectite. Veins filled by calcite (piece 1). Phenocryst and groundmass grain size variable.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

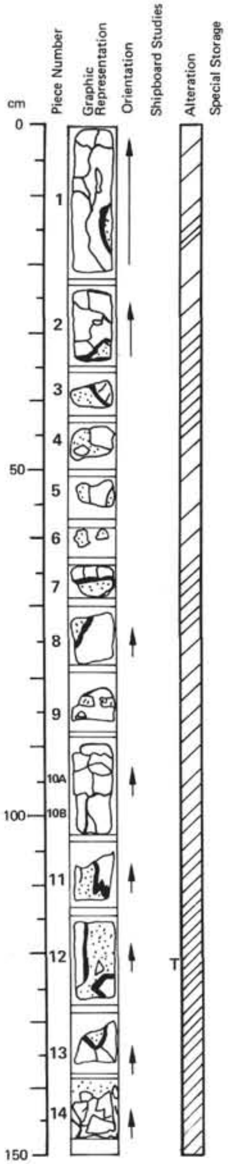
LEG	SITE	HOLE	CORE	SECT.
51	417	A	28	1

Visual Description

Pieces 1-6, 10, 11: altered phyric basalt in breccia. Basalt fragments altered to yellow-gray, gray-brown and yellow-brown; contact with breccia altered red-brown. Plagioclase phenocrysts 10%, <1 mm; mafic phenocrysts (pyroxene, olivine replaced by smectite) 5%, <0.3 mm. Breccia matrix composed of green palagonite and smectite, celadonite(?), calcite, minor hematite. Veinlets filled by calcite. Pieces 7-9: single pillow with chill margins at 45 and 130 cm; composed of light gray phyric basalt altered to yellow-gray in piece 7. Mafic minerals replaced by smectite 10%, <3 mm; plagioclase phenocrysts 5%, <2 mm. Amygdules <5 mm in pieces 7, 9 filled by smectite, celadonite(?) and calcite. Veinlets filled by calcite, smectite.

Shipboard Data

Magentic Data:	75-77 cm
NRM Intensity (emu/cc)	1.284×10^{-3}
NRM Inclination	-30.5°
Stable Inclination	-31.1°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	28	2

Visual Description

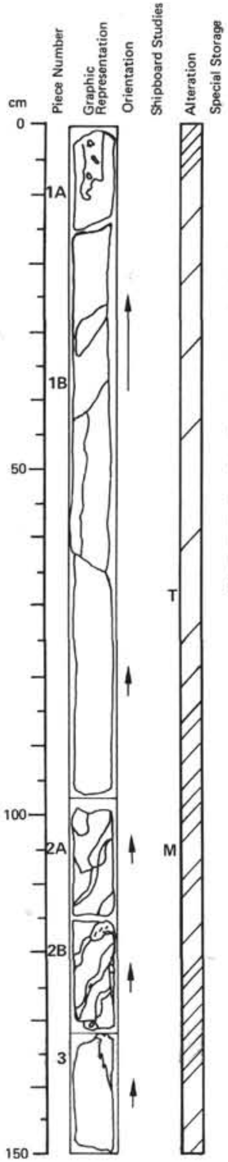
Pieces 1-14: Altered plagioclase-phyric pillow basalt fragments cemented by green palagonite matrix. Basalt altered to yellow-brown and brown along margins. Plagioclase phenocrysts 5-10%, <2 mm. Local amygdules < 10%, <5 mm, filled by calcite, smectite. Calcite veins abundant. Matrix composed of small brown basalt fragments and particles of green, spheroidally-zoned palagonite and smectite after glass, cemented by calcite, and hematite. Basalts surfaces in contact with calcite (pieces 8 and 9) do not show brown alteration.

Thin Section Description

Location: volcanic breccia matrix, 123 cm

Texture: breccia

Groundmass: palagonite and smectite 70%; orthoclase (Or 85) after plagioclase 10%; limonite 5-10%; hematite 5-7%; calcite 5%



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	28	3

Visual Description

Plagioclase-phyric pillow basalt with minor interpillow breccia. Intervals 0-95, 98-130 and 132-150 each represent individual pillows or parts of pillows. The first two are chilled on both top and bottom with minor breccia at either end. The pillows are oxidized near the margins. Plagioclase phenocrysts range in size from 5-6 mm in the centers of pillows to 1-2 mm at either end. Mafic phenocrysts are subordinate. Amygdules rare in centers of pillows, but increase outward, especially toward tops where they may reach 5 mm in diameter. Amygdules filled by smectite. Veins in piece 2 filled by calcite. Breccia composed of altered basalt clasts in green matrix of smectite, palagonite, calcite and hematite.

Thin Section Description

Location: pillow interior, 70 cm

Texture: porphyritic, hyalopilitic

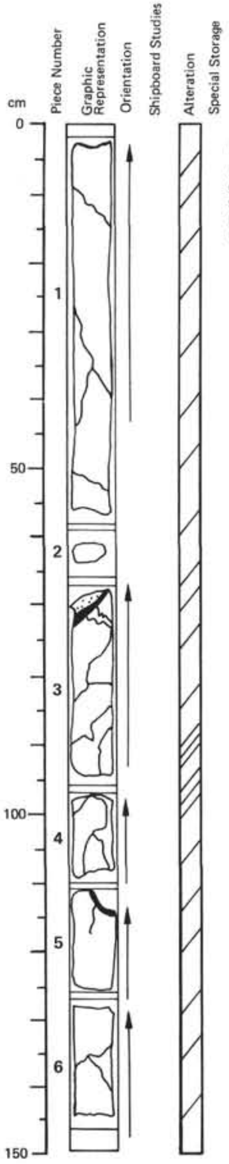
Phenocrysts: altered olivine 1%, 0.5 mm, euhedral; plagioclase 20%, 1-3 mm, euhedral with rims replaced by kspar, adularia or albite and cores replaced by clay

Groundmass: altered olivine(?) 1%, 0.2 mm; plagioclase laths 35%, 0.5 mm, An 40; fresh to altered clinopyroxene 20-25%; altered magnetite 10-15%; devitrified glass 5%; calcite 1%

Alteration: plagioclase altered to clay and Kspar; olivine completely replaced by smectite; glass altered to smectite, palagonite and celadonite (< 1%)

Shipboard Data

Magnetic Data:	103-106 cm
NRM Intensity (emu/cc)	9.503×10^{-3}
NRM Inclination	-17.3°
Stable Inclination	-20.6°

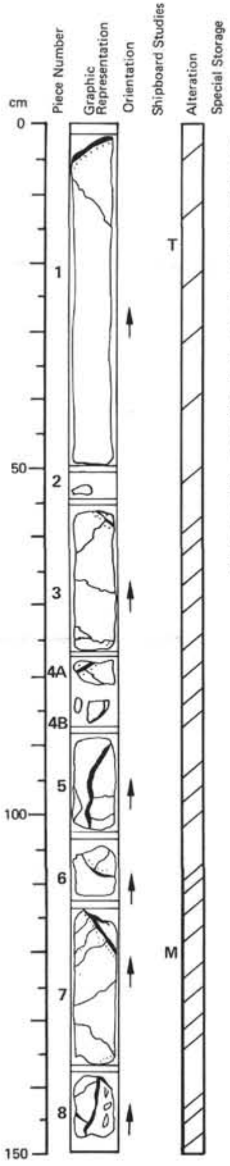


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	28	4

Visual Description

Phyric basalt pillows with chill margins and minor green breccia. Basalts gray with 1-2 cm yellow-gray alteration halo along margins; halo brown adjacent to margin. Plagioclase phenocrysts strongly altered to smectite, calcite ± zeolites 10-15%, ≤5 mm; mafic phenocrysts (smectite after pyroxene) <5%, ≤2 mm. Vesicles abundant, 10%, ≤6 mm. Calcite veins thin (1 mm) and uncommon.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	28	5

Visual Description

Plagioclase-phyric basalt pillows with chill margins and cemented interpillow breccia. Basalt dark gray, altered to pale brown near margins, but rim (3 mm thick) remains gray. Groundmass microlitic to aphantic. Plagioclase phenocrysts partially replaced by calcite, 10%, ≤5 mm; mafic phenocrysts replaced by smectite 5%, <2 mm. Locally amygdules <1% filled by smectite, calcite and/or zeolites. Veinlets of calcite tend to be perpendicular to chill margins. Breccia consists of small, altered basalt clasts in matrix of green palagonite and smectite coated by hematite and cemented by calcite.

Thin Section Description

Location: pillow interior, 18 cm

Texture: porphyritic, hyaloophitic.

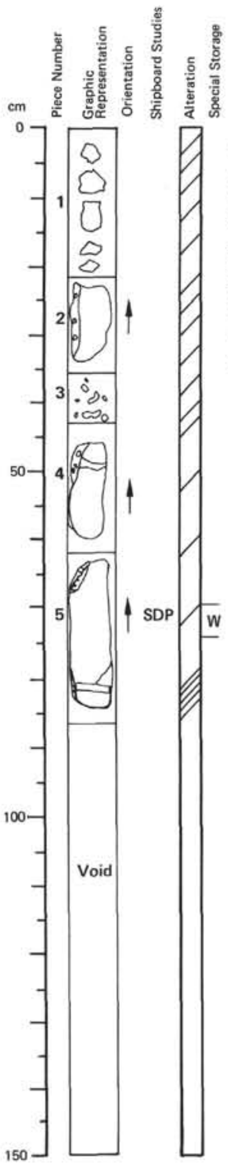
Phenocrysts: altered olivine 1%, 1 mm, euhedral; altered plagioclase 10%, 5 mm, euhedral; altered clinopyroxene 1%, 1 mm, euhedral.

Groundmass: plagioclase 20%, 0.5 mm; tabular; granular clinopyroxene 5%, 0.2 mm; devitrified glass 50-60%.

Alteration: plagioclase phenocrysts partially replaced by calcite and clay; olivine and clinopyroxene phenocrysts completely replaced by smectite.

Shipboard Data

Magnetic Data:	119-121 cm
NRM Intensity (emu/cc)	10.770×10^{-3}
NRM Inclination	-29.9°
Stable Inclination	-30.2°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

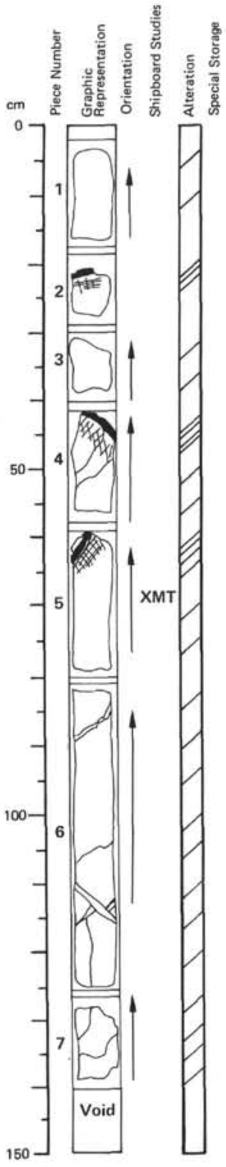
LEG	SITE	HOLE	CORE	SECT.
51	417	A	28	6

Visual Description

Altered plagioclase- and pyroxene-phyric pillow basalt with pillow margins and interpillow breccia. Groundmass microlitic, grain size decreases toward margins in pieces 2, 4 and 5. Amygdules <6 mm in diameter. Breccia composed of altered basalt clasts in a matrix of green smectite, calcite and zeolites. Calcite-filled veins are present in pieces 4 and 5.

Shipboard Data

Physical Property Data:	71-73 cm
$\overline{V}p$ (km/sec)	5.04
Porosity (%)	5.0
Wet Bulk Density (g/cc)	2.75
Grain Density (g/cc)	2.84



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	29	1

Visual Description

Plagioclase-phyric pillow basalt with chill margins. Basalt dark gray, altered to yellow-brown in 1-2 cm thick halo along chill margin; outermost 1-2 mm altered dark brown. Plagioclase phenocrysts strongly altered (to clay, zeolites?) 15%, <1 mm, decrease in size and number toward margins. Amygdules scarce, small (1-3 mm), filled by calcite, celadonite? Thin calcite-filled veins present but scarce. Traces of green interpillow breccia present along margins.

Thin Section Description

Location: pillow interior, 73 cm

Texture: porphyritic, sub-ophitic

Phenocrysts: zoned plagioclase 15-20%, 1-6 mm, An 53-63, euhedral.

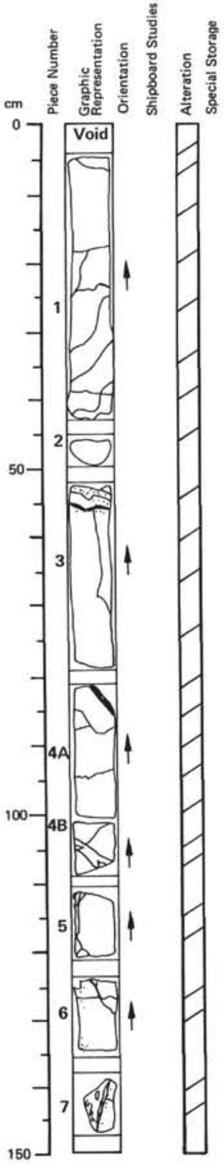
Groundmass: plagioclase laths 35%, 1.5 mm, An 45-50, occassionally skeletal; clinopyroxene 25%, $2V_z = 55°$; magnetite 15%; celadonite 2%; calcite 1%.

Alteration: plagioclase replaced by clay (1-2%) and kspar (1%).

Shipboard Data

Bulk Analysis:	72-74 cm
SiO_2	49.75
Al_2O_3	17.90
Fe_2O_3	8.93
MgO	5.49
CaO	12.53
Na_2O	2.10
K_2O	1.16
TiO_2	1.48
P_2O_5	0.12
MnO	0.16
LOI	2.25
H_2O^+	1.69
H_2O^-	N.D.
CO_2	1.28

Magnetic Data:	72-74 cm
NRM Intensity (emu/cc)	3.566×10^{-3}
NRM Inclination	-23.2°
Stable Inclination	-23.2°

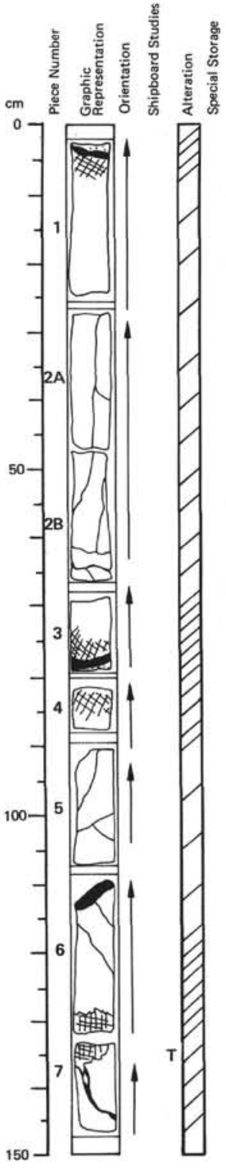


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	29	2

Visual Description

Phyric basalt pillows with chill margins and minor interpillow breccia. Basalt dark gray, grades to pale brown, dark brown at chilled surface. Plagioclase phenocrysts 10%, <6 mm, increase in size downward; mafic phenocrysts 5%, <2 mm. Veins filled by calcite. Breccia composed of altered basalt fragments in green matrix of palagonite, smectite and celadonite(?) cemented by calcite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	29	3

Visual Description

Plagioclase-phyric basalt pillows with chilled margins and traces of interpillow breccia. Basalt dark gray, grades to yellow-brown within 2 cm of margin and to dark brown within 2 mm of margin. Plagioclase phenocrysts completely altered to zeolites(?), 15%, <6 mm; clinopyroxene and olivine phenocrysts altered to smectite, 5-10%. Phenocrysts decrease in size (to <1 mm) and number near margins; groundmass grain sizes show a complimentary variation. Calcite-filled veins rare. Traces of green interpillow breccia coat pillow margins. A large cavity between 128-135 cm is filled by dark green to black smectite(?).

Thin Section Description

Location: next to chilled margin, 5 cm

Texture: porphyritic

Phenocrysts: plagioclase 20%, 1-4 mm, An 60, euhedral with oscillatory zoning, cores occasionally contain high refractive index inclusions.

Groundmass: plagioclase laths 30%, 0.1-1.0 mm, An 45; stubby clinopyroxene (augite?) prisms 25-30%, 0.1 mm, 2V > +40; octahedral magnetite dendrites 15%, <0.2 mm; calcite 2%; smectite and celadonite 1%.

Vesicles: 1%; irregular with glauconite fillings.

Alteration: plagioclase replaced by calcite (1-2%) and clay (2%).

Thin Section Description

Location: chilled margin, 135 cm

Texture: porphyritic, hyaloophitic

Phenocrysts: altered olivine 2%, 1 mm, euhedral; partially altered plagioclase 15%, 4 mm, An >68; euhedral; altered clinopyroxene 5%, 2 mm, euhedral.

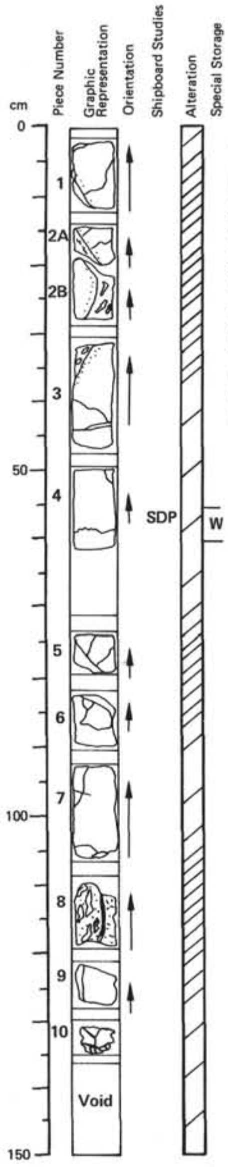
Groundmass: plagioclase 20%, 0.2 mm, tabular; granular to subhedral clinopyroxene 10%, 0.1 mm; euhedral to dendritic magnetite 2%, 0.01 mm; devitrified glass 50%.

Alteration: plagioclase phenocrysts largely replaced by calcite and clay; clinopyroxene phenocrysts completely replaced by smectite; olivine phenocrysts completely replaced by calcite.

Shipboard Data

Bulk Analysis:	4-7 cm
SiO_2	49.79
Al_2O_3	17.64
Fe_2O_3	9.48
MgO	5.32
CaO	12.39
Na_2O	2.43
K_2O	0.70
TiO_2	1.42
P_2O_5	0.14
MnO	0.17
LOI	1.85
H_2O^+	1.48
H_2O^-	N.D.
CO_2	0.51

Magnetic Data:	4-6 cm
NRM Intensity (emu/cc)	6.434×10^{-3}
NRM Inclination	-25.0°
Stable Inclination	-26.3°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

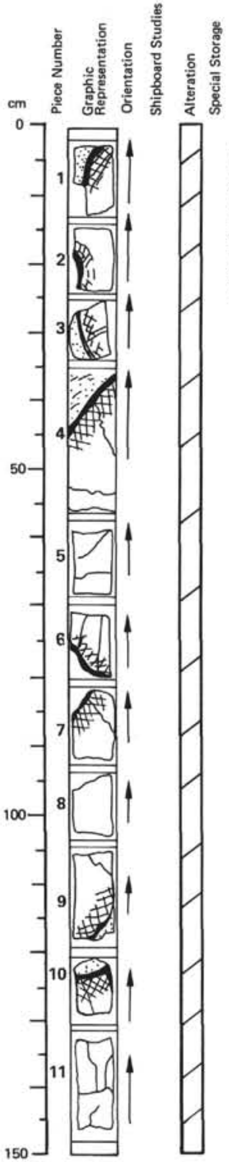
LEG	SITE	HOLE	CORE	SECT.
51	417	A	29	4

Visual Description

Phyric basalt pillows with chilled margins and cemented interpillow breccia. Basalt dark gray, altered to yellow-brown near margins and to dark brown within 3 mm of margin. Plagioclase phenocrysts partially altered to calcite, clay, 10%, ≤2 mm; mafic phenocrysts replaced by smectite 5%, ≤2 mm. Plagioclase phenocrysts increase in size to as much as 5 mm (ave. 2 mm) in pillow interiors (piece 4). Thin (≤1 mm) calcite-filled veinlets present. Aggregates of zeolite(?) crystals are found in cavities and on chilled basalt surfaces in piece 9. Breccia composed of highly altered basalt fragments in a green to red-brown matrix of palagonite, smectite, celadonite(?) and hematite cemented by calcite.

Shipboard Data

Physical Property Data:	55-57 cm
$\overline{V}p$ (km/sec)	5.27
Porosity (%)	5.5
Wet Bulk Density (g/cc)	2.76
Grain Density (g/cc)	2.86

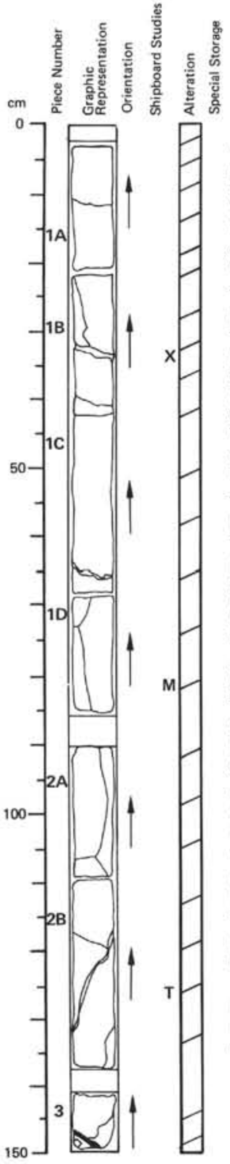


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	29	5

Visual Description

Plagioclase-phyric pillow basalt with chill margins and minor interpillow breccia. Intervals 0-35, 35-80, 80-120 and 120-150 represent individual pillows or parts of pillows. Basalt gray, altered to yellow-brown and finally to dark brown within 2 cm and 2 mm, respectively, of margins adjacent to green breccia. Plagioclase phenocrysts strongly altered to zeolites(?) 15%, ≤6 mm. Phenocrysts decrease in size and number, groundmass becomes aphanitic near margins. Amygdules scarce, filled with non-calcareous white material. Calcite veins normal to pillow margins. Pieces 1, 3, 4, 9 and 10 contain interpillow breccias composed of green to brown smectite, palagonite and minor hematite in the form of delicate, elongate shards parallel to pillow margins. In the samples, cracks normal to the margin are filled by green to brown palagonitic material and/or calcite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	29	6

Visual Description

Phyric basalt pillows with chilled margins, trace of interpillow breccia. Top 85 cm continuous(?) with bottom of previous sections. Interval from 90-150 cm probably represents one pillow. Basalt dark gray, altered to light gray near pillow margins in pieces 1D and 3. In pillow interiors (pieces 1B, 2B), groundmass is microlitic with plagioclase phenocrysts (partially altered to clay, calcite) 10%, <6 mm; mafic phenocrysts (altered to smectite and iddingsite?) <5%, <2 mm. Phenocrysts decrease in size and number, groundmass grades to aphanitic near pillow margins. Calcite-filled veins up to 3 mm wide are common. Piece 3 contains traces of green, cemented interpillow breccia.

Thin Section Description

Location: pillow interior, 34 cm

Texture: prophyritic, hyaloophitic-intersertal.

Phenocrysts: altered olivine 1%, 0.3 mm, euhedral; zoned plagioclase 10%, 0.3-4 mm, partially altered, euhedral.

Groundmass: plagioclase 30%, 0.5 mm, tabular; granular to subhedral clinopyroxene 30%, 0.2 mm; dendritic magnetite 2%, 0.01 mm; devitrified glass 30%.

Vesicles: 1%, 0.1 mm, filled by clay, round.

Alteration: plagioclase phenocrysts partly altered to clay; olivine phenocrysts completely altered to iddingsite; groundmass hematized.

Thin Section Description

Location: pillow interior, 128 cm

Texture: porphyritic, hyaloophitic-intersertal.

Phenocrysts: altered olivine 10%, 0.5 mm, euhedral; altered plagioclase 5%, 1 mm, euhedral; euhedral clinopyroxene 2%, 0.5 mm.

Groundmass: plagioclase 30%, 0.3 mm, tabular; granular to subhedral clinopyroxene 30%, 0.1 mm; euhedral magnetite 5%, 0.03 mm; devitrified glass 30%.

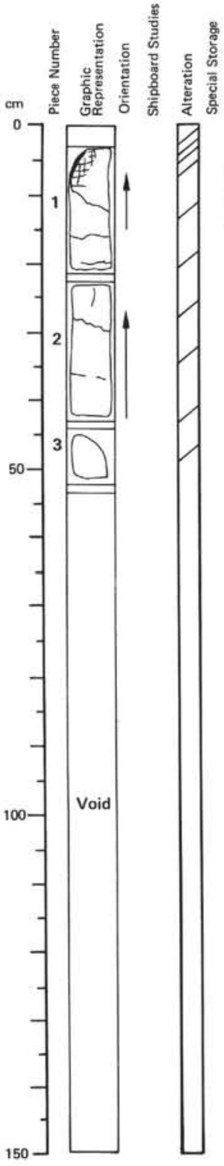
Vesicles: scarce, filled by calcite.

Alteration: plagioclase phenocrysts replaced by calcite, clay and hematite(?); clinopyroxene phenocrysts replaced by calcite and smectite; olivine phenocrysts completely replaced by iddingsite; groundmass hematized.

Shipboard Data

Bulk Analysis:	30-32 cm
SiO_2	48.94
Al_2O_3	17.76
Fe_2O_3	9.90
MgO	5.44
CaO	12.77
Na_2O	2.18
K_2O	0.80
TiO_2	1.43
P_2O_5	0.11
MnO	0.16
LOI	3.50
H_2O^+	1.85
H_2O^-	N.D.
CO_2	1.33

Magnetic Data:	83-85 cm
NRM Intensity (emu/cc)	6.165×10^{-3}
NRM Inclination	-16.3°
Stable Inclination	-18.6°

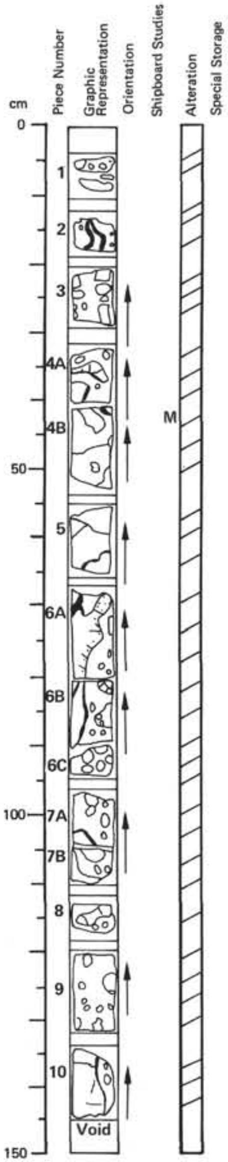


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	29	7

Visual Description

Plagioclase-phyric pillow basalt with chill margin. Basalt gray, altered to yellow-gray and to green and dark brown within 1 cm and 1 mm, respectively, of margin. Groundmass aphanitic near margin (0-25 cm), microlitic in pillow interior (below 25 cm). Plagioclase phenocrysts 10-15%, <5 mm, strongly altered to zeolites(?). Amygdules scarce, filled with non-calcareous, white material. Piece 1 contains a small number of calcite-filled veins normal to the chill margin.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

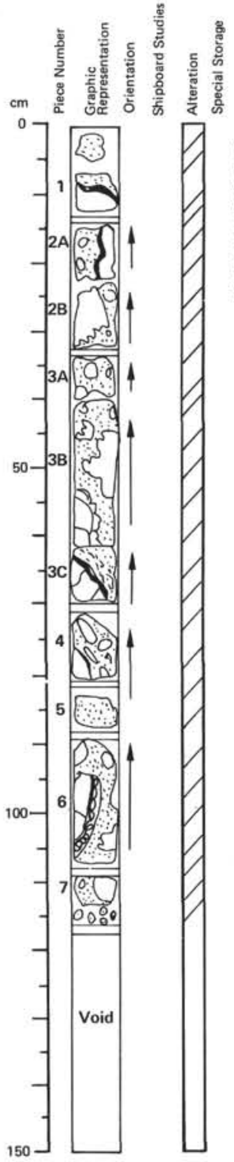
LEG	SITE	HOLE	CORE	SECT.
51	417	A	30	1

Visual Description

Volcanic breccia containing strongly altered basalt fragments in a green palagonite matrix. Basalt gray; altered near margins to pale brown and brown with a 2 mm thick dark brown crust. Groundmass aphanitic. Plagioclase phenocrysts (largely replaced) 10%, <2 mm; mafic phenocrysts (also replaced) 5%, <2 mm. Veins and cavities filled by calcite. Basalt fragments are rounded and exhibit cracked chill margins. Matrix composed of glass fragments completely altered to palagonite in a fine-grained self-matrix.

Shipboard Data

Magnetic Data:	44-47 cm
NRM Intensity (emu/cc)	5.980×10^{-3}
NRM Inclination	-19.5°
Stable Inclination	-20.1°

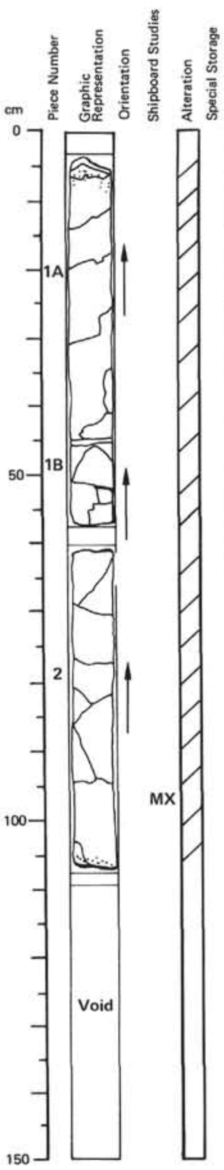


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	30	2

Visual Description

Volcanic breccia containing strongly altered basalt fragments in a green palagonite matrix. Basalt yellow-brown with a 2 mm thick dark brown crust. Groundmass aphanitic. Plagioclase phenocrysts (altered to clay) <10%, <1 mm. Calcite-filled amygdules and cavities (<1 cm) present but uncommon. Basalt fragments rounded, exhibit chilled margins. Original glass completely altered to palagonite. Elongate green palagonite shards are being detached from basalt fragments parallel to their margins. All transitions visible from palagonite rims still attached to the basalt to shards entirely separated from "mother" pillow. Detached shards in self-matrix of finely granulated (1-2 mm) palagonite fragments cemented by calcite. Larger fragments have thin brown margins, perlitic internal structure.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	30	3

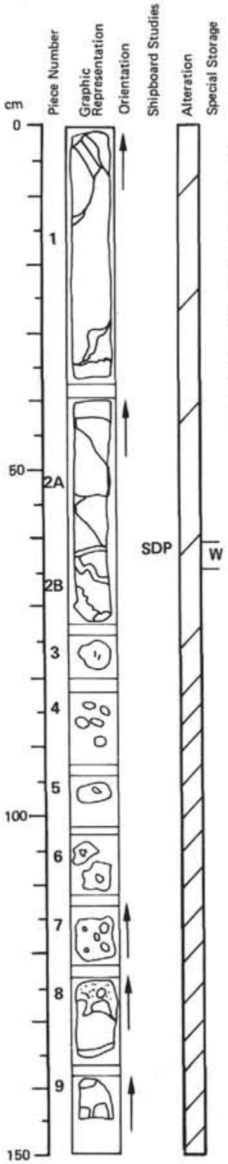
Visual Description

Phyric pillow basalt with chilled margins at 5, 60 and 105 cm. Basalt dark gray, altered to gray-brown within 2 to 10 cm of margins and to dark brown within 1 cm of rim. Plagioclase phenocrysts 10%, <5 mm (ave. 2 mm); mafic phenocrysts 5%, <2 mm. Calcite-filled veins common. Traces of green palagonite breccia are found at top of piece 1A.

Shipboard Data

Bulk Analysis:	92-95 cm
SiO_2	48.94
Al_2O_3	16.88
Fe_2O_3	11.24
MgO	5.63
CaO	12.15
Na_2O	2.28
K_2O	0.72
TiO_2	1.41
P_2O_5	N.D.
MnO	0.17
LOI	2.60
H_2O^+	1.69
H_2O^-	N.D.
CO_2	0.65

Magnetic Data:	92-95 cm
NRM Intensity (emu/cc)	10.010×10^{-3}
NRM Inclination	-13.1°
Stable Inclination	-17.6°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

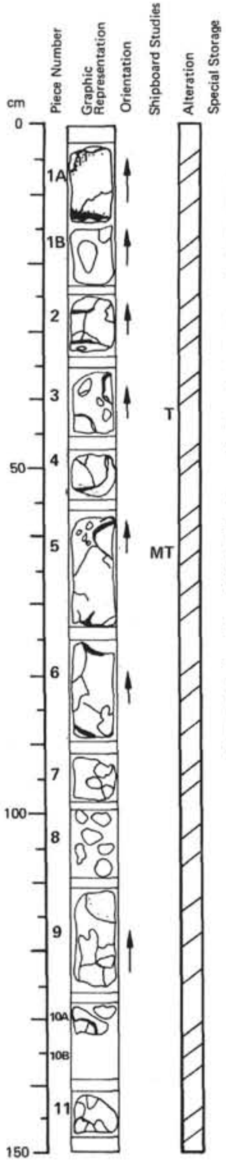
LEG	SITE	HOLE	CORE	SECT.
51	417	A	30	4

Visual Description

Phyric pillow basalt with palagonite breccia. Basalt gray, altered to yellow-brown near margins and to brown within 2-3 mm of pillow rims. Glass entirely palagonitized. Plagioclase phenocrysts (partially replaced by clay) 10%, <3 mm; mafic phenocrysts 15%, <0.5 mm. Veins filled by calcite, celadonite(?) and soft yellow-brown material; veins normal to pillow margin in piece 1 filled by calcite. Breccia in pieces 3-9 composed of altered basalt clasts in a green matrix of palagonite, smectite, celadonite(?) and calcite. Phenocryst in large basalt fragment in piece 8 entirely replaced by gray-green to white clay mineral. Chill margin in piece 8 contains small amygdules filled by zeolites and clay.

Shipboard Data

Physical Property Data:	63-65 cm
$\overline{V}p$ (km/sec)	5.27
Porosity (%)	4.6
Wet Bulk Density (g/cc)	2.81
Grain Density (g/cc)	2.90



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	30	5

Visual Description

Altered phyric pillow basalt fragments in palagonite breccia. Basalt dark gray, grades to yellow-brown and pale brown toward margins; 2 mm thick outer crust gray to dark brown. Fragments have rounded, chilled margins with many calcite-filled cracks. Groundmass devitrified. Plagioclase phenocrysts replaced by clays and K-feldspar, 10%, ≤2 mm; mafic phenocrysts (olivine replaced by iddingsite, celadonite) 3%, <7 mm. Breccia abundant, composed of altered basalt fragments in a green matrix of palagonitized glass fragments, smectite and calcite.

Thin Section Description

Location: chilled margin, 43 cm

Texture: porphyritic, hyalopilitic

Phenocrysts: altered olivine 3-5%, 0.7 mm; altered plagioclase 15%, 6 mm, euhedral.

Groundmass: plagioclase laths 10%, 0.5 mm, An 60; magnetite 5%; devitrified glass 50-60%.

Vesicles: 5-8%, 1-1.5 mm, filled by smectite and celadonite, round to irregular.

Alteration: plagioclase phenocrysts completely altered to clay and kspar; olivine phenocrysts completely replaced by celadonite(?); glass replaced by smectite, palagonite and celadonite(?).

Thin Section Description

Location: near chilled margin, 63 cm

Texture: porphyritic, hyalopilitic.

Phenocrysts: altered olivine 1%, 0.5-1 mm, idiomorphic; altered plagioclase 10%, 3-5 mm, idiomorphic.

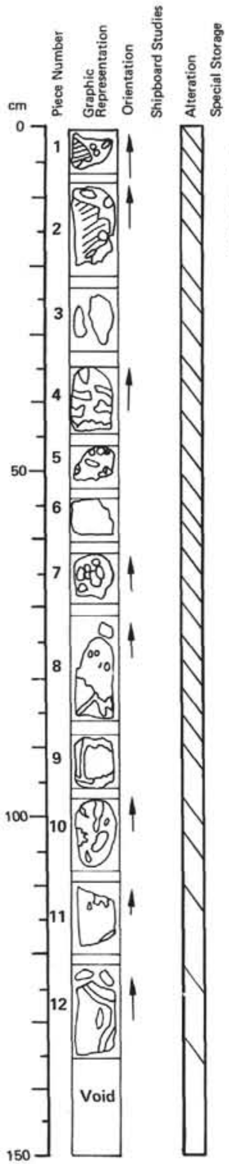
Groundmass: plagioclase microlites 50%, 0.1-0.3 mm; altered glass 40%; traces of magnetite and hematite.

Vesicles: 1-2%, 0.5 mm, filled by smectite, rounded, often coalesced.

Alteration: plagioclase phenocrysts completely replaced by clay and analcite; olivine phenocrysts completely replaced by smectite and iddingsite.

Shipboard Data

Magnetic Data:	61-64 cm
NRM Intensity (emu/cc)	15.143×10^{-3}
NRM Inclination	-28.3°
Stable Inclination	-28.5°

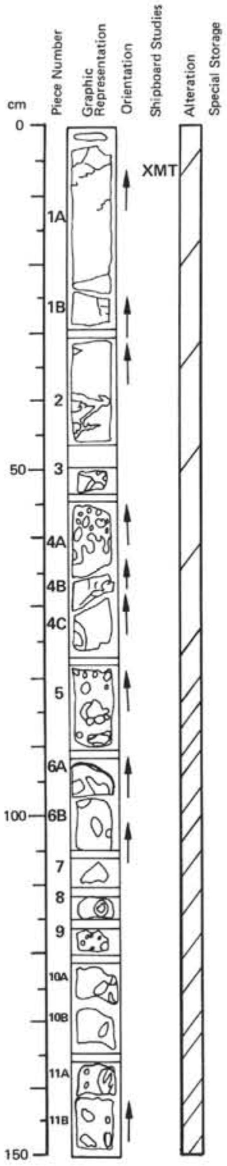


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	30	6

Visual Description

Volcanic breccia containing fragments of altered phyric basalt in a palagonitic hyaloclastite matrix. Basalt fragments altered to yellow gray, yellow-brown with dark red-brown rims. Plagioclase phenocrysts 10-15%, ≤4 mm, completely replaced by white to gray-green clays. Small amygdules filled by clay, calcite and zeolites. Large amygdule in piece 2 filled by a white zeolite having lamellar crystals. Pieces 9 and 12 contain calcite-filled veins. Green breccia matrix composed of palagonite, smectite and celadonite(?) cemented by calcite. Glass completely palagonitized.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	31	1

Visual Description

Phyric pillow basalt with hyaloclastite breccia. Basalt predominant in pieces 1, 2, 4B and 4C. Basalt gray with a pink cast due to initial hematization, altered to yellow-brown near margins. Glass completely palagonitized. Plagioclase phenocrysts 7-10%, ≤2 mm, altered to clay; mafic phenocrysts 5%, ≤3 mm. Veinlets filled by calcite, smectite. Breccia composed of altered basalt fragments in a matrix of calcite (piece 3) or a green matrix of palagonite, smectite, calcite and hematite (pieces 4A, 5-11). Basalt fragments in pieces 4-11 often have hematite rims. Amygdules and phenocrysts are abundant in pieces 5-11, but small in size (10%, ≤1 mm).

Thin Section Description

Location: near chilled margin, 9 cm

Texture: porphyritic, locally pilotaxitic

Phenocrysts: altered plagioclase 15-20%, 0.5-2.5 mm

Groundmass: plagioclase 35-45%, 0.4 mm; clinopyroxene 30%, 0.05-0.1 mm; magnetite 10%, 0.05-0.1 mm; smectite 5%.

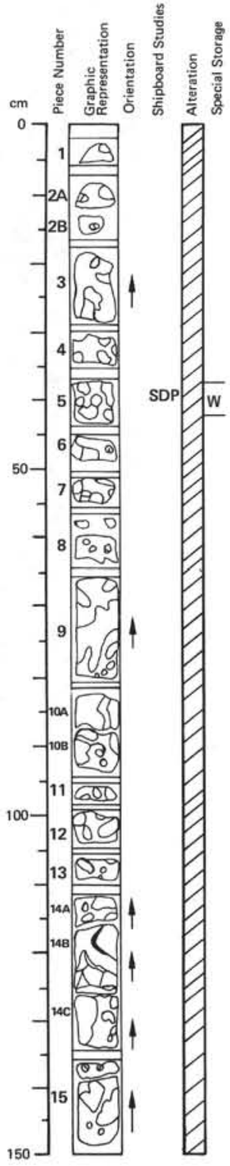
Vesicles: 1-2%, 1-2 mm, filled by celadonite with a calcite core.

Alteration: plagioclase phenocrysts completely replaced by calcite, clay, zeolites and kspar; traces of olivine(?) replaced by smectite.

Shipboard Data

Bulk Analysis:	8-10 cm
SiO_2	48.59
Al_2O_3	17.65
Fe_2O_3	9.69
MgO	5.11
CaO	11.48
Na_2O	2.21
K_2O	1.64
TiO_2	1.51
P_2O_5	0.22
MnO	0.12
LOI	4.90
H_2O^+	N.D.
H_2O^-	2.46
CO_2	1.60

Magnetic Data:	8-10 cm
NRM Intensity (emu/cc)	2.094×10^{-3}
NRM Inclination	-20.5°
Stable Inclination	-20.8°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

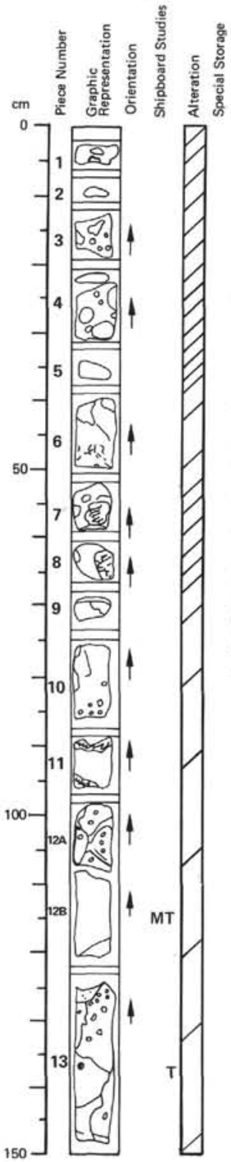
LEG	SITE	HOLE	CORE	SECT.
51	417	A	31	2

Visual Description

Volcanic breccia composed of angular to rounded fragments of phyric basalt altered in whole or in part to palagonite in a self-matrix of palagonite. Basalt fragments pale brown with chilled margins and a glassy groundmass partially replaced by calcite. Plagioclase phenocrysts 10%, ≤2 mm; mafic phenocrysts minor. Rounded fragments almost entirely altered to green or brown palagonite. Matrix composed of fine grains of green smectite and palagonite cemented by calcite.

Shipboard Data

Physical Property Data:	39-41 cm
$\overline{V}p$ (km/sec)	2.89
Porosity (%)	31.6
Wet Bulk Density (g/cc)	2.19
Grain Density (g/cc)	2.75



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	31	3

Visual Description

Pieces 1-5, 7 and 8 consist of volcanic breccia composed of fragments of basalt, most of which are completely altered to palagonite, in a green self-matrix of palagonite, smectite, celadonite(?), calcite and zeolites. Some fragments strongly hematized. Pieces 6 and 9-13 consist of phyric basalt pillows with traces of interpillow breccia. Basalt gray-violet, altered to yellow brown near margins and to dark brown along boundaries with breccia. Groundmass aphanitic to microcrystalline. Plagioclase phenocrysts 10%, <1.5 mm; mafic phenocrysts 15%, <1 mm. Amygdules <3 mm, filled by smectite, yellow to white zeolites and minor calcite. Veinlets filled by calcite, zeolites, minor clay; groundmass next to calcite-filled veinlets unaltered (gray). Piece 11 composed largely of calcite. Groundmass in pieces 12 and 13 rich in tiny crystals of magnetite(?).

Thin Section Description

Location: pillow interior, 118 cm

Texture: porphyritic

Phenocrysts: altered plagioclase 10%, 0.5-1.0 mm, zoned with An 82 core and an An 70 rim, tabular; altered clinopyroxene 3%, 0.3-0.5 mm, prismatic.

Groundmass: plagioclase 10%, 0.1-0.2 mm, An 60, tabular; altered clinopyroxene 2%, 0.1 mm, prismatic; devitrified glass 75%.

Vesicles: 3%, 0.2-0.4 mm, irregular, filled by smectite.

Alteration: plagioclase replaced by montmorillonite and zeolites; clinopyroxene completely replaced by montmorillonite.

Thin Section Description

Location: pillow interior, 140 cm

Texture: porphyritic

Phenocrysts: altered olivine $<1\%$, 0.2 mm, euhedral; altered plagioclase 15%, 1-3 mm, tabular; clinopyroxene $<1\%$, 0.5 mm, prismatic, $2V_z = 60°$.

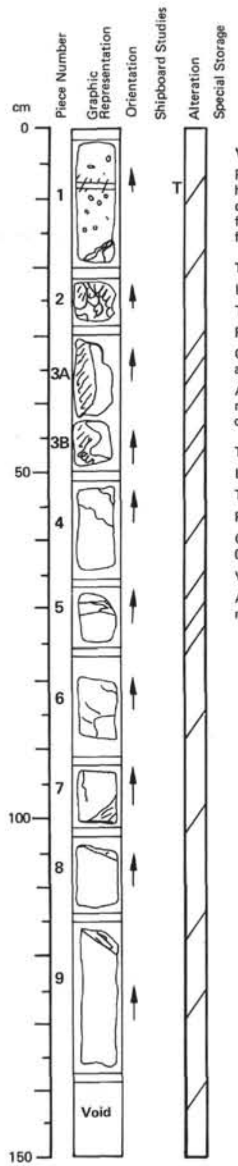
Groundmass: plagioclase 15%, 0.1-0.2 mm, An 60, tabular; anhedral clinopyroxene 15%, 0.1-0.2 mm; devitrified glass 50%.

Vesicles: 2%, 0.2-0.5 mm, filled by smectite, round to irregular.

Alteration: plagioclase phenocrysts largely replaced by montmorillonite and zeolites; olivine phenocrysts completely replaced by smectite; smectite also in groundmass and in veins with calcite.

Shipboard Data

Magnetic Data:	117-120 cm
NRM Intensity (emu/cc)	7.510×10^{-3}
NRM Inclination	-20.0°
Stable Inclination	-20.3°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	31	4

Visual Description

Phyric basalt pillows with minor interpillow breccia. Basalt gray with a pink cast due to initial hematization, altered locally to yellow-gray along margins, veins. Groundmass aphanitic to microcrystalline. Plagioclase phenocrysts 10%, <4 mm; mafic phenocrysts 15%, <0.5 mm. Amygdules filled by clay, celadonite? and quartz. Veinlets filled by calcite. Interpillow breccia composed of fragments of basalt altered to palagonite and smectite in a matrix of calcite.

Thin Section Description

Location: pillow interior, 10 cm

Texture: porphyritic

Phenocrysts: altered plagioclase 10%, 2-5 mm, tabular; prismatic clinopyroxene 1%, 1 mm.

Groundmass: tabular plagioclase 20%, 0.2 mm; altered clinopyroxene 10%, 0.1 mm, anhedral; altered magnetite 5%, 0.2 mm, anhedral; altered glass 55%.

Alteration: plagioclase phenocrysts largely replaced by calcite and clay; clinopyroxene partly replaced by calcite; magnetite completely replaced by leucoxene; groundmass hematized, contains disseminated calcite.

Thin Section Description

Location: pillow interior, 13 cm

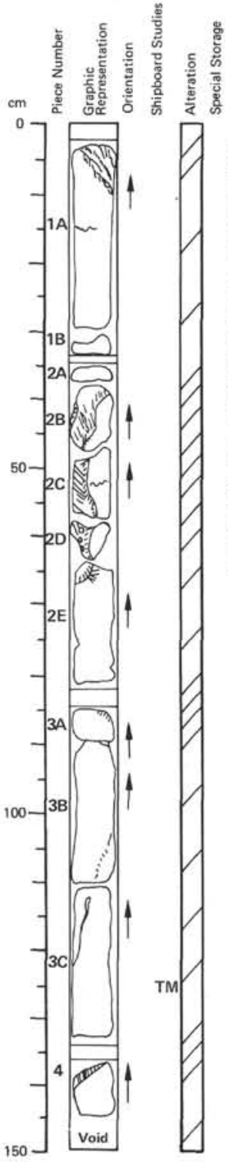
Texture: porphyritic, hyalopilitic.

Phenocrysts: altered olivine 5%, 0.8 mm; altered plagioclase 10-15%, <4 mm, An 70-75.

Groundmass: olivine 10-15%, 0.1 mm; plagioclase 20-25%, 0.2-0.3 mm, An 40; clinopyroxene 20%, 0.05 mm; magnetite 15-20%, 0.01 mm.

Vesicles: 1-2%, <1 mm, filled by celadonite ± smectite or calcite.

Alteration: olivine completely replaced by celadonite ± smectite; plagioclase phenocrysts partly replaced by calcite and clay.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	31	5

Visual Description

Phyric basalt pillows with minor interpillow breccia. Basalt gray-violet, altered to gray-brown along cracks and yellow-brown near margins; pillow rims altered red-brown against breccia. Groundmass aphanitic to microcrystalline. Plagioclase phenocrysts 15%, <4 mm; mafic phenocrysts 15%, <2 mm. Minor zeolites. Veinlets filled by calcite. Breccia composed of elongate fragments of basalt alligned parallel to pillow rims in a green matrix of palagonite, smectite, celadonite(?), hematite and minor calcite.

Thin Section Description

Location: pillow interior, 124 cm

Texture: porphyritic, hyaloophitic

Phenocrysts: altered olivine 1%, 0.5 mm, euhedral; altered plagioclase 15%, 0.5-4 mm, euhedral; altered clinopyroxene 3%, 1 mm, euhedral.

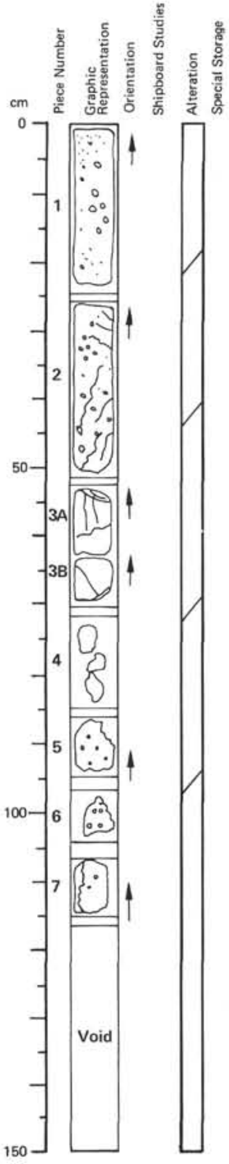
Groundmass: plagioclase 15%, 0.1 mm, tabular; granular to subhedral clinopyroxene 30%, 0.05 mm, partly altered; dendritic to euhedral magnetite 10%, 0.01 mm; devitrified glass 20%.

Vesicles: 1%, 0.01 mm, filled by clay.

Alteration: olivine phenocrysts completely replaced by iddingsite(?); plagioclase and clinopyroxene partially replaced by calcite and clay; groundmass contains desseminated calcite.

Shipboard Data

Magnetic Data:	123-126 cm
NRM Intensity (emu/cc)	2.706×10^{-3}
NRM Inclination	-15.7°
Stable Inclination	-17.4°

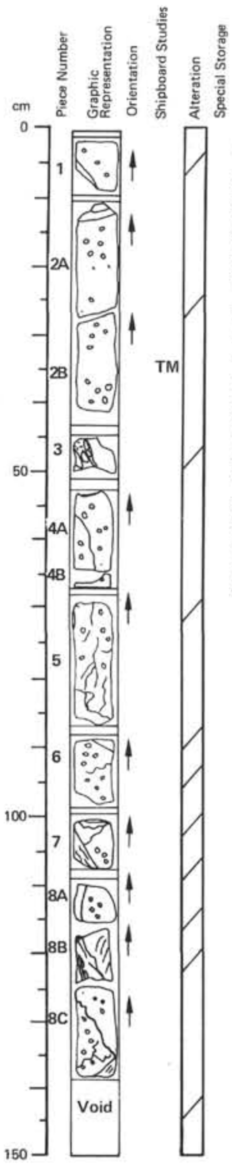


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	31	6

Visual Description

Phyric pillow basalt. Basalt gray-violet, altered to yellow-brown near margins. Groundmass aphanitic to microcrystalline. Plagioclase phenocrysts <15%, <4 mm; mafic phenocrysts <20%, <1 mm. Veinlets filled by calcite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Phyric basalt pillows with interpillow breccia. Basalt gray violet, altered to gray-brown, yellow brown along margins and cracks. Groundmass aphanitic to microcrystalline. Plagioclase phenocrysts 10%, increase in size from <2 mm in piece 1 to <4 mm in pieces 4-9; mafic phenocrysts increase in abundance from 3-5% in piece 1 to 10% in pieces 4-9. Veinlets filled by calcite ± green and brown smectite(?). Veinlet in piece 3 contains quartz(?). Pieces 1-3, 7 and 8 contain interpillow breccia composed of elongate fragments of altered basalt oriented subparallel to pillow margins in a light yellow-green matrix of smectite, calcite and zeolites(?). Cracks in breccia contain iron oxides. Piece 8B contains pure inclusions of a soft, pale yellow-green mineral.

Thin Section Description

Location: pillow interior, 37 cm

Texture: porphyritic, hyalopilitic

Phenocrysts: altered olivine(?) 1-2%; altered plagioclase 20%, <3 mm.

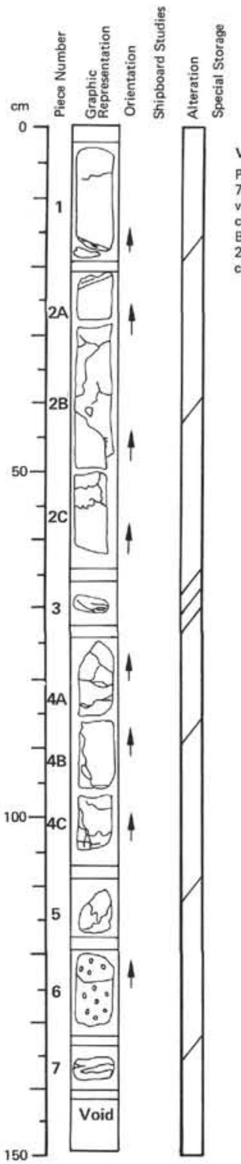
Groundmass: altered olivine 5%, 0.05 mm; plagioclase 15%, 0.2 mm, An 55, often skeletal; clinopyroxene 10%; magnetite 15-20%; devitrified, altered glass 20-30%; calcite (in veins) <1%.

Vesicles: <1%, filled by celadonite and clay ± smectite, calcite.

Alteration: olivine replaced by celadonite + smectite; plagioclase replaced by clay; glass altered to clay and celadonite(?).

Shipboard Data

Magnetic Data:	35-38 cm
NRM Intensity (emu/cc)	6.208×10^{-3}
NRM Inclination	-24.3°
Stable Inclination	-25.1°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

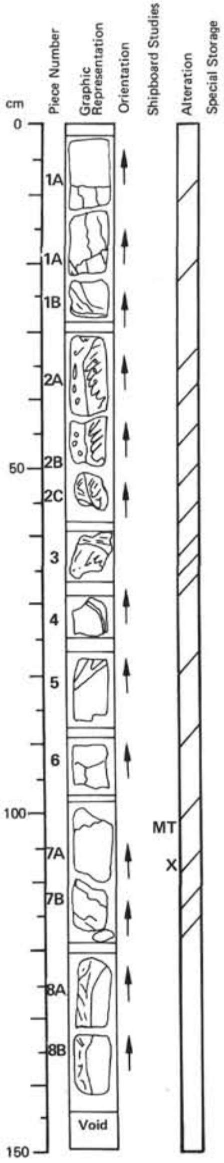
LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	A	3 2	2

Visual Description

Phyric basalt pillows with pillow margins and traces of interpillow breccia. Intervals 0-20, 20-70, 70-110, 110-135 each represent individual pillows or parts of pillows. Basalt in pieces 1-4 gray-violet, altered to yellow-brown near margins. Groundmass aphanitic to microcrystalline. Plagioclase phenocrysts 10%, <2 mm; mafic phenocrysts 15%, <0.5 mm. Veinlets filled by calcite. Basalt in pieces 5 and 6 gray, altered to light gray-brown near margins. Plagioclase phenocrysts 25%, <3 mm. Piece 7 consists of interpillow breccia composed of altered basalt fragments in a calcite matrix.

VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	32	3



Visual Description

Phyric pillow basalt with pillow margins and interpillow breccia. Basalt gray, altered to light gray-brown, yellow-brown near margins. Pillow rims brown immediately adjacent to breccia. Groundmass aphanitic to microcrystalline. Plagioclase phenocrysts range from 2%, <1 mm (piece 7) to 10%, <3 mm (pieces 1-6 and 8), while mafic phenocrysts range from 2-3%, <0.1 mm to 10%, <1 mm over the same interval. Veinlets filled by calcite ±green or brown smectite(?). Piece 5 contains smectite-filled vesicles. Breccia in pieces 1, 2, 3 and 8 composed of elongate yellow-green fragments of altered basalt (originally glass?) oriented subparallel to pillow margins in a matrix of calcite and analcime(?).

Thin Section Description

Location: pillow interior, 104 cm

Texture: porphyritic, hyaloophitic

Phenocrysts: altered olivine 2%, 1 mm, euhedral; plagioclase 15%, 4 mm, euhedral.

Groundmass: plagioclase 20%, 0.1 mm, tabular; altered clinopyroxene 30%; devitrified glass 30%.

Vesicles: <1%, 0.1 mm, filled by clay, round.

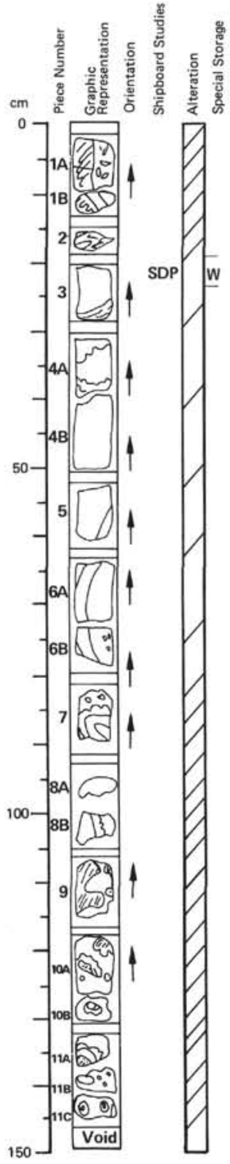
Alteration: plagioclase partially replaced by calcite and clay; olivine phenocrysts completely replaced; glass partially replaced by clay.

Shipboard Data

Bulk Analysis: 105-108 cm		Magnetic Data:	103-105 cm
SiO_2	52.54	NRM Intensity (emu/cc)	3.595×10^{-3}
Al_2O_3	19.61	NRM Inclination	-24.3°
Fe_2O_3	9.74	Stable Inclination	-25.1°
MgO	4.21		
CaO	9.74		
Na_2O	3.46		
K_2O	2.14		
TiO_2	1.68		
P_2O_5	0.32		
MnO	0.13		
LOI	3.75		
H_2O^+	4.24		
H_2O^-	N.D.		
CO_2	2.06		

VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	32	4



Visual Description

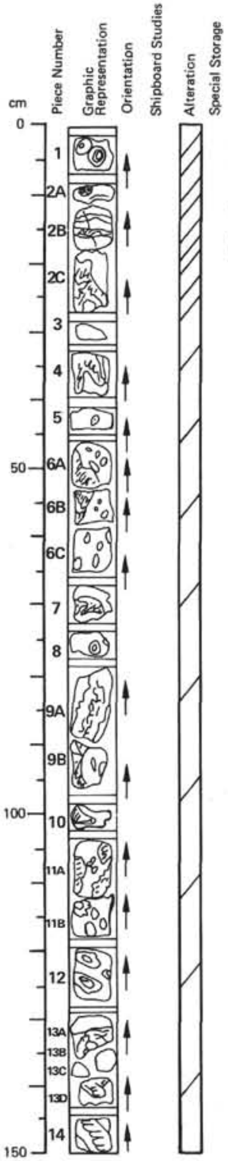
Phyric pillow basalt with well-preserved chilled margins and volcanic breccia. Basalt gray-violet; pillow margins, fragments altered to yellow-brown with brown hematized rims. Groundmass aphanitic to microcrystalline. Plagioclase phenocrysts 10-15%, <3 mm; mafic phenocrysts abundant in pieces 4 and 5 (15%, <0.3 mm), limited to pillow margins in piece 6. Veinlets filled by calcite +light yellow or dark green smectite(?). Breccia composed of light green, elongate fragments of altered basalt often attached or oriented subparallel to pillow margins, in a green to light red-brown matrix of smectite. This breccia is cut in piece 2 by a vein filled by yellow-green clay, calcite and zeolites(?). A large grain of analcime(?) is present in piece 7.

Shipboard Data

Physical Property Data:	21-23 cm
$\overline{V}p$ (km/sec)	4.87
Porosity (%)	8.2
Wet Bulk Density (g/cc)	2.67
Grain Density (g/cc)	2.82

VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	32	5

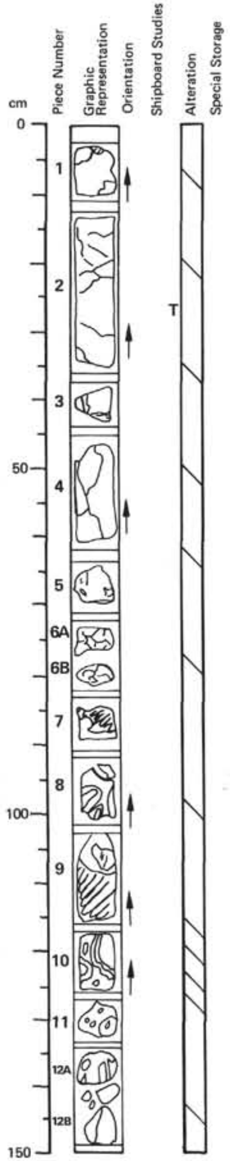


Visual Description

Volcanic breccia composed of altered fragments of phyric basalt in a green palagonite matrix. Basalt fragments gray, altered to yellow-gray; smaller fragments concentrically zoned with brown cores and green rims altered to palagonite. Groundmass aphanitic. Plagioclase phenocrysts 5%, ≤1.5 mm; mafic phenocrysts ≤3%, ≤0.4 mm. Pieces 9-14 contain tiny vesicles. Veinlets filled by calcite. Breccia matrix yellow green to dark green, composed of palagonite, smectite, celadonite(?), analcime and hematite.

VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	33	1



Visual Description

Phyric pillow basalt (0-70 cm) with volcanic breccia (70-150 cm). Basalt gray-violet, altered to gray-brown along calcite-filled veins, yellow-brown near margins. Groundmass aphanitic to microcrystalline. Plagioclase phenocrysts ≤15%, ≤3 mm; clinopyroxene phenocrysts 5%, ≤2 mm, olivine phenocrysts 1%, ≤1 mm. Breccia composed of fragments of basalt altered in part to palagonite in a green matrix of smectite, palagonite, celadonite and calcite. Pillow margins and breccia both contain hematite.

Thin Section Description

Location: pillow interior, 27 cm

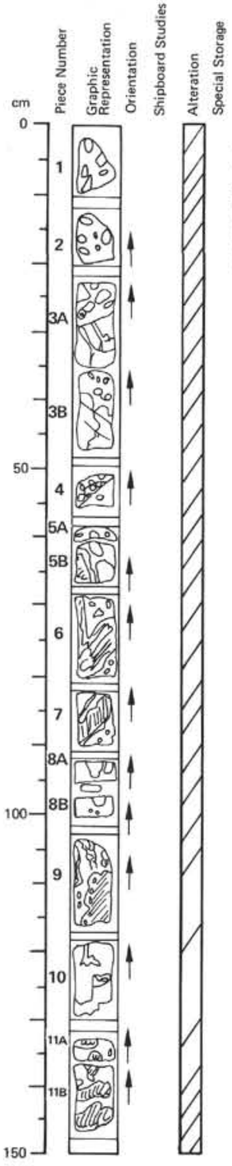
Texture: porphyritic, hyaloophitic

Phenocrysts: altered olivine 5%, 1 mm, euhedral; altered plagioclase 15%, 0.5-3 mm, euhedral; altered clinopyroxene 5%, 2 mm, euhedral.

Groundmass: plagioclase 20%, tabular; undifferentiated groundmass 40%, includes devitrified glass, altered olivine(?) and altered clinopyroxene(?); magnetite 10%, dendritic, anhedral, euhedral.

Vesicles: trace, 0.5 mm, filled by clay

Alteration: olivine and clinopyroxene completely replaced by calcite and clay; plagioclase phenocrysts partially replaced by calcite and clay; veins filled by calcite and zeolites.

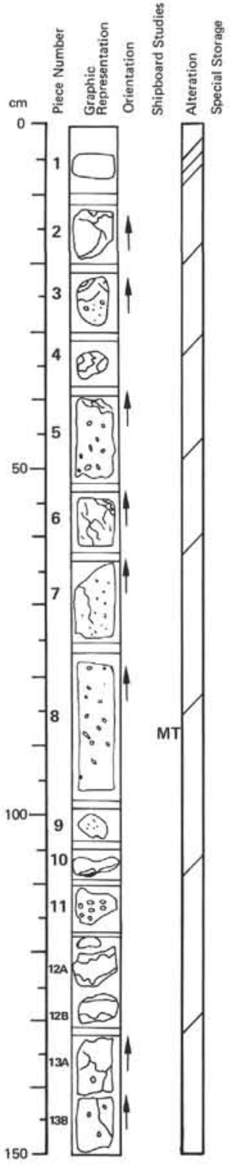


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Volcanic breccia composed of strongly to completely altered phyric basalt fragments (20%) in a green palagonite self-matrix (80%). Basalt yellow brown; smaller fragments zoned with light brown to green cores and brown to dark green rims cut by thin veins of hematite. Groundmass aphanitic. Plagioclase phenocrysts 5%, <1 mm; mafic phenocrysts 2%, <0.5 mm; phenocrysts in smaller fragments completely altered. Vesicles filled by calcite, smectite. Veinlets filled by zeolites (analcime?) and blue-green smectite (piece 3A) or by calcite (piece 3B). Dark green matrix composed of smectite, palagonite, calcite, zeolites(?) and shards of altered basalt.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Phyric pillow basalt with traces of interpillow breccia. Basalt groundmass light gray, altered to yellow-gray, gray-violet with yellow-brown, partially hematized pillow margins. Groundmass aphantiic to microcrystalline. Plagioclase phenocrysts 10-20%, <5 mm; piece 8 also contains phenocrysts of olivine (5%, <3 mm) and clinopyroxene (2%, <2 mm); pillow margins in pieces 6, 7, 9 and 11 nearly aphyric. Vesicles 5%, <1 mm. Veins filled by calcite, smectite. Breccia composed of altered basalt fragments in a green matrix of smectite, palagonite(?), zeolites and hematite.

Thin Section Description

Location: pillow interior, 85 cm

Texture: porphyritic, intersertal

Phenocrysts: altered olivine 5%, 3 mm, subhedral to euhedral; zoned plagioclase 20%, 1-4 mm, euhedral, relatively fresh; altered clinopyroxene 2%, 2 mm, euhedral.

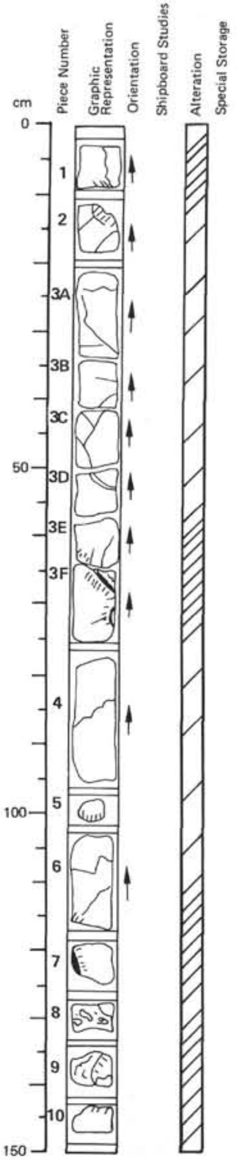
Groundmass: plagioclase 20%, 0.2 mm, tabular; clinopyroxene 30%, <0.1 mm, anhedral to subhedral; magnetite 5%, 0.01 mm, euhedral, dendritic; altered glass 10%.

Vesicles: trace, 0.5-0.8 mm, filled by clay.

Alteration: olivine phenocrysts completely replaced by calcite, clay and smectite; clinopyroxene phenocrysts completely replaced by calcite and clay; glass altered to clay and zeolites.

Shipboard Data

Magnetic Data:	84-87 cm
NRM Intensity (emu/cc)	13.505
NRM Inclination	-19.2°
Stable Inclination	-19.4°

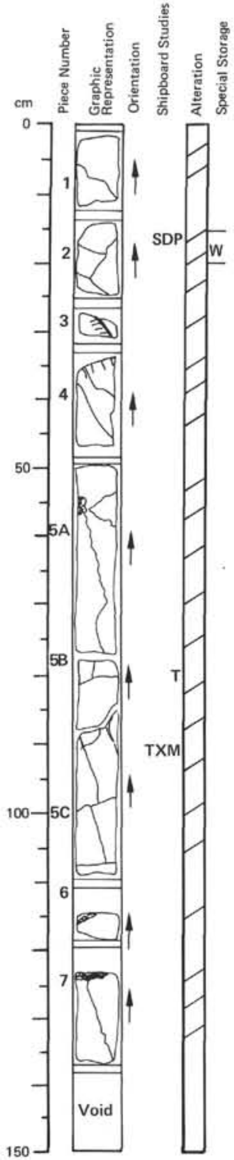


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Phyric pillow basalt with minor interpillow breccia. Basalt dark gray, altered to pale brown near margins, dark brown along hematized rims. Groundmass aphanitic to microcrystalline. Plagioclase phenocrysts 10%, ≤5 mm; mafic phenocrysts <1%, ≤1 mm. Veins filled by calcite. Breccia composed of fragments of altered basalt in a matrix of calcite, smectite and palagonite(?).



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Phyric to sparsely phyric pillow basalt with traces of interpillow breccia. Basalt gray-brown with an aphanitic to microcrystalline groundmass. Plagioclase phenocryst 5-20%, ≤5 mm; clinopyroxene phenocrysts ≤5%, ≤3 mm; olivine phenocrysts ≤5%, ≤0.5 mm. 0-8 and 80-88 cm intervals sparsely phyric. Vesicles 1%, <1%. Cavities at 54 and 119 cm lined by calcite, zeolites, filled by dark green smectite. Breccia composed of altered basalt fragments in a matrix of calcite, smectite and palagonite(?).

Thin Section Description

Location: pillow interior, 84 cm

Texture: porphyritic, hyaloophitic

Phenocrysts: altered olivine 2%, 1 mm, euhedral; altered plagioclase 20%, 4 mm, euhedral; partly altered clinopyroxene <5%, 2 mm, euhedral to subhedral.

Groundmass: altered olivine 10%, 0.05 mm, euhedral to subhedral; plagioclase 20%, 0.2 mm, tabular; granular to subhedral clinopyroxene 25%, 0.05 mm, relatively fresh; dendritic magnetite 5%, 0.02 mm; devitrified glass <10%.

Vesicles: trace, 0.2-0.6 mm, filled by clay, smectite, round.

Alteration: clinopyroxene phenocrysts altered to clay and smectite; olivine and glass altered to clay; veins filled by calcite and smectite.

Thin Section Description

Location: pillow interior, 92 cm

Texture: porphyritic, hyaloophitic

Phenocrysts: altered olivine 5%, 0.5 mm, euhedral; plagioclase 20%, 0.5-4 mm, euhedral to subhedral; altered clinopyroxene 5%, 3 mm, euhedral to subhedral.

Groundmass: altered olivine 10%, 0.02 mm; plagioclase 20%, 0.2 mm, tabular; altered clinopyroxene 20%, 0.02 mm, granular; dendritic magnetite 5%, <0.01 mm; devitrified glass 10%.

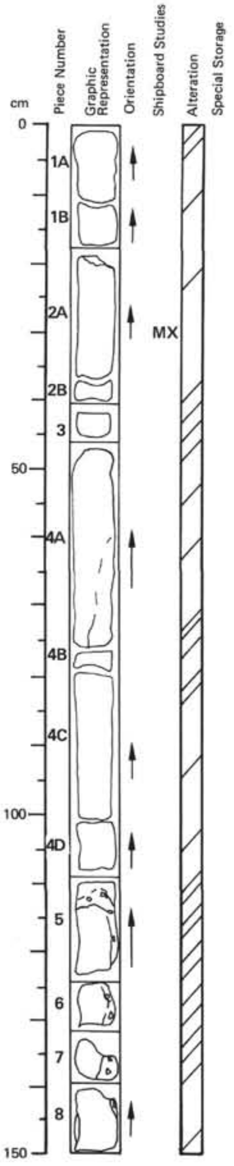
Alteration: olivine completely replaced by iddingsite, clay and smectite; clinopyroxene largely replaced by smectite; plagioclase phenocrysts partly replaced by calcite; glass altered to clay.

Shipboard Data

Bulk Analysis:	90-93 cm
SiO_2	50.20
Al_2O_3	18.15
Fe_2O_3	7.78
MgO	5.45
CaO	12.92
Na_2O	3.46
K_2O	1.43
TiO_2	1.54
P_2O_5	0.12
MnO	0.15
LOI	3.35
H_2O^+	1.60
H_2O^-	N.D.
CO_2	1.36

Magnetic Data:	90-93 cm
NRM Intensity (emu/cc)	9.691×10^{-3}
NRM Inclination	-22.3°
Stable Inclination	-21.8°

Physical Property Data:	18-20 cm
Vp (km/sec)	5.07
Porosity (%)	7.2
Wet Bulk Density (g/cc)	2.71
Grain Density (g/cc)	2.84



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

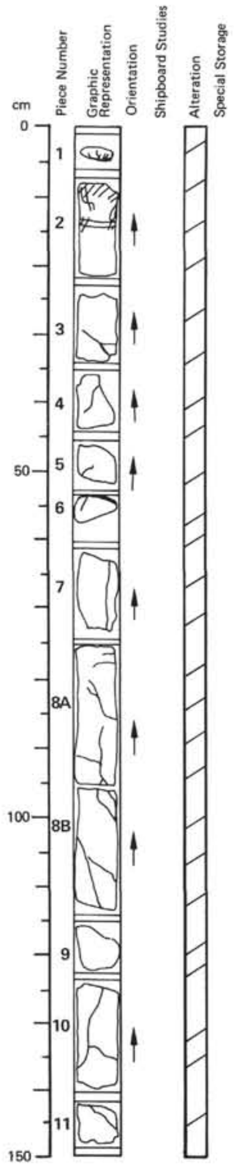
Visual Description

Phyric pillow basalt with minor interpillow breccia. Groundmass aphanitic to microcrystalline. Pieces 1-3, fine to very fine-grained, with mafic phenocrysts (at least some of which are pseudomorphs after olivine) >plagioclase phenocrysts. Pieces 4-8, plagioclase phenocrysts <8 mm, mafic phenocrysts <1 mm. Pieces 5-8 are moderately to highly altered and contain breccia composed of elongate fragments of altered basalt aligned parallel to pillow margins in a green matrix of smectite, palagonite(?), celadonite and calcite. Veins filled by calcite, smectite.

Shipboard Data

Bulk Analysis: 28-31 cm	
SiO_2	49.23
Al_2O_3	16.54
Fe_2O_3	10.89
MgO	6.09
CaO	12.45
Na_2O	2.35
K_2O	0.59
TiO_2	1.41
P_2O_5	0.10
MnO	0.15
LOI	1.15
H_2O^+	1.06
H_2O^-	N.D.
CO_2	0.37

Magnetic Data:	28-31 cm
NRM Intensity (emu/cc)	6.674×10^{-3}
NRM Inclination	-19.8°
Stable Inclination	-19.9°

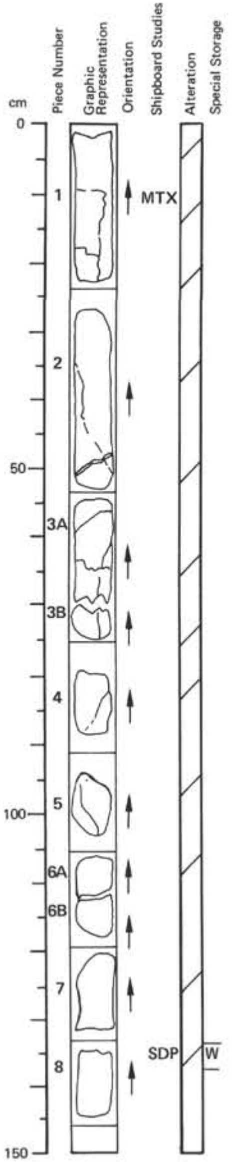


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Phyric pillow basalt. Basalt dark gray, locally altered to pale brown near hematized pillow margins. Groundmass aphanitic to microcrystalline. Plagioclase phenocrysts 5-20%, 3-8 mm; clinopyroxene phenocrysts <3%, <2 mm; olivine phenocrysts <2%, <2 mm. Piece 2 contains flattened vesicles. Veins filled by calcite and locally by sulfides (piece 8).



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Altered phyric pillow basalt. Groundmass aphanitic. Plagioclase phenocrysts 5-10%, <5 mm; altered olivine phenocrysts <3%, 1 mm; clinopyroxene phenocryst 1%, 1 mm. Veins filled by calcite. Piece 8 contains vesicles lined with analcite(?).

Thin Section Description

Location: near chilled margin, 12 cm

Texture: porphyritic, variolitic

Phenocrysts: altered olivine 3%, euhedral; plagioclase 20%, 1-5 mm, euhedral to anhedral; altered clinopyroxene 1%, anhedral.

Groundmass: plagioclase 30%, 0.1 mm, euhedral to subhedral; clinopyroxene 30%, 0.1 mm, anhedral to subhedral; magnetite 10%, 0.01 mm, euhedral, dendritic; devitrified glass 5-50%.

Vesicles: trace, 0.2 mm, filled by clay, round.

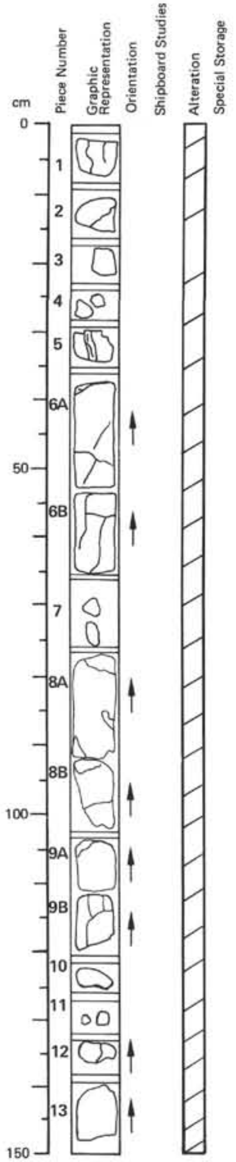
Alteration: olivine and clinopyroxene phenocrysts replaced by clay.

Shipboard Data

Bulk Analysis: 10-13 cm	
SiO_2	49.66
Al_2O_3	17.07
Fe_2O_3	10.19
MgO	7.05
CaO	13.41
Na_2O	2.41
K_2O	0.76
TiO_2	1.42
P_2O_5	0.12
MnO	0.23
LOI	2.30
H_2O^+	1.02
H_2O^-	N.D.
CO_2	0.68

Magnetic Data:	10-13 cm
NRM Intensity (emu/cc)	9.202×10^{-3}
NRM Inclination	-22.8°
Stable Inclination	-23.0°

Physical Property Data:	135-137 cm
$\overline{V}p$ (km/sec)	5.40
Porosity (%)	4.7
Wet Bulk Density (g/cc)	2.78
Grain Density (g/cc)	2.86

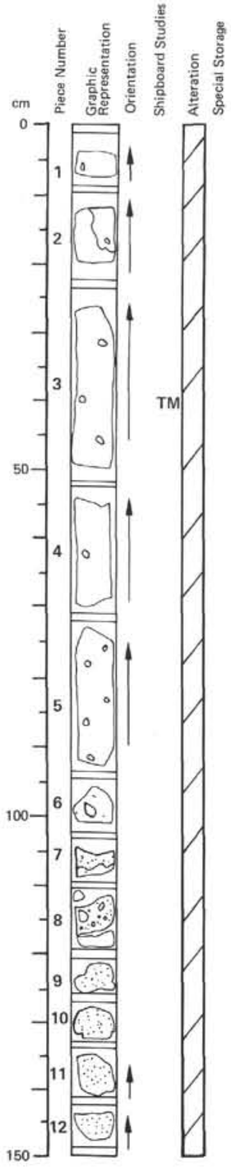


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Phyric pillow basalt. Groundmass gray. Plagioclase phenocrysts 10%, <5 mm; olivine phenocrysts <3%, <2 mm; clinopyroxene phenocrysts 2%, <2 mm. Veins filled by calcite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Phyric pillow basalt (pieces 1-6) underlain by hyaloclastite breccia (pieces 7-12). Basalt gray, altered to yellow-gray along scarce calcite-filled veins. Plagioclase phenocrysts altered to analcite(?), opal(?) and white fibrous zeolites < 12%, < 2 mm; olivine phenocrysts altered to iddingsite < 3%, < 3 mm; clinopyroxene phenocrysts altered to smectite(?) 3%. Amygdules filled by calcite, analcite, zeolites < 10%, < 1 cm, locally coalesce (as in piece 6) to form filled cavities < 2 cm across. Breccia composed of fragments of green palagonitic glass in a finely granulated (1 mm grain size) self-matrix cemented by calcite, hematite. Each fragment has a spherulitic structure composed of delicate, concentric alteration zones surrounding a core of brown residual glass. Spherules separated from the larger basalt fragments appear to have been progressively granulated in the matrix. Relict plagioclase phenocrysts are present (5%, < 2 mm) in the palagonite fragments.

Thin Section Description

Location: pillow interior, 42 cm

Texture: porphyritic, ophitic

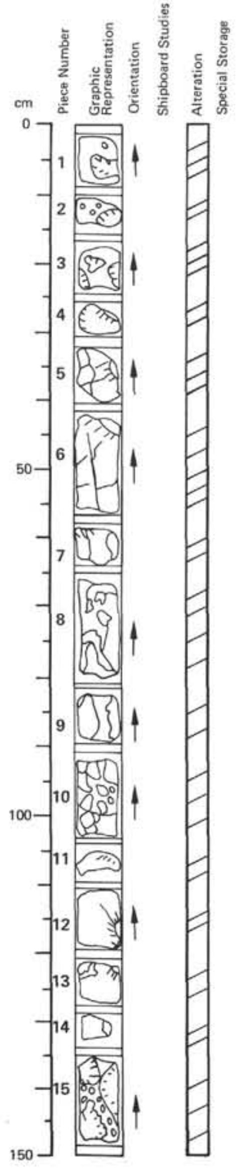
Phenocrysts: altered olivine 2%, 0.5-1 mm, euhedral; partly altered plagioclase 20%, 1-3 mm, euhedral; altered clinopyroxene 5%, 0.5-2 mm, euhedral.

Groundmass: olivine < 10%, 0.1 mm; plagioclase 20%, 0.3 mm, tabular; clinopyroxene 30%, 0.1 mm, granular, subhedral to anhedral; magnetite 10%, 0.05 mm, euhedral.

Alteration: plagioclase partly replaced by clay; clinopyroxene replaced by smectite.

Shipboard Data

Magnetic Data:	40-43 cm
NRM Intensity (emu/cc)	$.281 \times 10^{-3}$
NRM Inclination	+52.8°
Stable Inclination	-24.2°

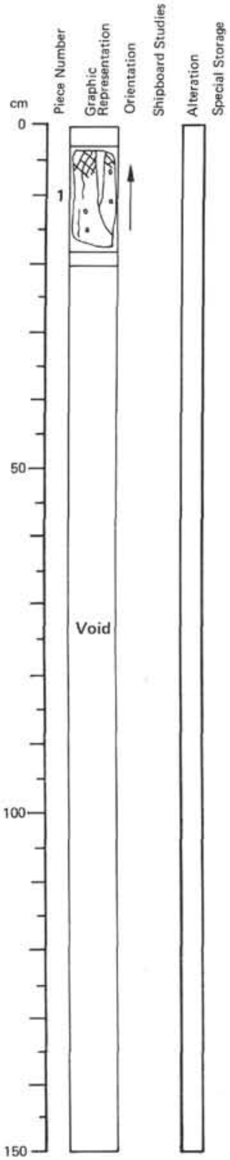


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	A	3 4	6

Visual Description

Altered phyric pillow basalt with volcanic breccia. Basalt gray, altered to yellow-brown near margins. Groundmass aphanitic to microcrystalline. Altered plagioclase phenocrysts 10%, < 5 mm; mafic phenocrysts 5%, < 2 mm, largely replaced by smectite. Vesicles < 1%, filled by smectite. Veins filled by calcite. Breccia composed of fragments of basalt in a matrix of smectite and palagonite(?).

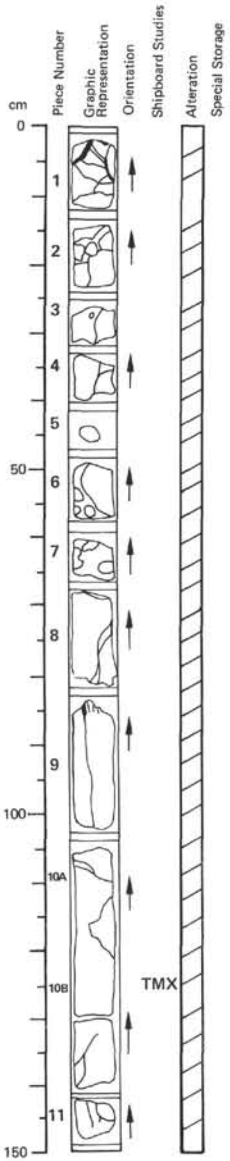


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Altered phyric pillow basalt with chilled margin between 0-7 cm. Basalt gray, altered to yellow-gray near margin. Groundmass microcrystalline. Plagioclase phenocrysts largely replaced by white alteration mineral, small to absent in margin, but increase to 5%, <3 mm in base of piece 1; olivine phenocrysts (replaced by iddingsite) and clinopyroxene phenocrysts (replaced by dark green smectite) similarly increase to 5%, <2 mm and 1%, <2 mm, respectively. Amygdules 5-8%, <1 cm, filled by calcite, analcite and zeolites. Calcite-filled veins normal to the margin are present in the top of piece 1.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Altered phyric pillow basalt with chilled margins and volcanic breccia. Basalt gray, altered to pale brown, dark brown along hematized margins. Groundmass aphanitic to microcrystalline. Altered plagioclase phenocrysts 10%, <3 mm in piece 1-7, increase to <7 mm in pieces 8-11; mafic phenocrysts replaced by smectite, iddingsite 3%, <2 mm. Rounded to elongate vesicles ≤1%, <1 mm; piece 3 contains a 4 mm-long flattened vesicle the long axis of which dips 60° with respect to the core. Veins <4 mm wide, filled by calcite, smectite. Breccia composed of fragments of altered basalt in a fine-grained, green matrix of smectite, palagonite(?) and calcite.

Thin Section Description

Location: pillow interior, 127 cm

Texture: porphyritic, hyalopilitic

Phenocrysts: altered plagioclase 15%, < 6 mm, An 70, glomeroporphyritic; augitic clinopyroxene 2-3%, 5 mm, elongate.

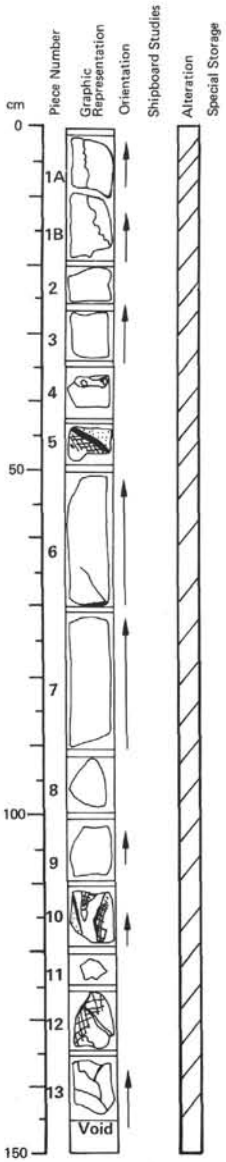
Groundmass: plagioclase 25%, 0.5 mm, An 53; clinopyroxene 45%; magnetite 10-15%; calcite *(in veins)* 1%.

Vesicles: 2-3%, 0.8 mm, filled by calcite

Alteration: plagioclase partially replaced by calcite.

Shipboard Data

Bulk Analysis: 125-128 cm		Magnetic Data:	125-128 cm
SiO_2	47.97	NRM Intensity (emu/cc)	5.429×10^{-3}
Al_2O_3	19.44	NRM Inclination	-20.7°
Fe_2O_3	6.38	Stable Inclination	-20.5°
MgO	3.57		
CaO	18.53		
Na_2O	2.19		
K_2O	1.20		
TiO_2	1.53		
P_2O_5	0.12		
MnO	0.13		
LOI	7.45		
H_2O^+	1.13		
H_2O^-	N.D.		
CO_2	1.69		

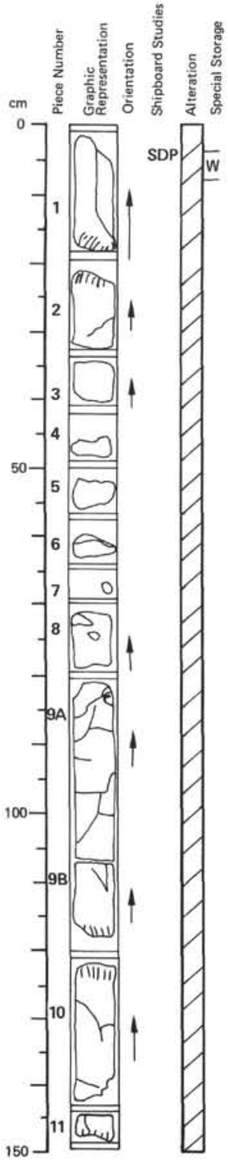


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Altered phyric pillow basalt with chilled margins and minor interpillow palagonite breccia. Basalt gray to yellow-gray; altered to yellow-brown and dark brown within 2 cm and 2 mm, respectively, of margins against breccia. Groundmass aphanitic to microcrystalline. Plagioclase phenocrysts 10%, <3 mm, largely replaced by zeolites; olivine phenocrysts replaced by red-brown iddingsite 5%, ≤4 mm; laths of clinopyroxene replaced by dark green smectite 3%, ≤2 mm. Amygdules 10%, ≤6 mm, often concentrically lined with zeolites, analcite, calcite and smectite(?). Calcite-filled veins. Breccia (pieces 5, 10, 12) composed of delicate, elongate palagonite fragments aligned parallel to pillow margins in a fine-grained green self-matrix. The larger fragments display concentric alteration zones.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

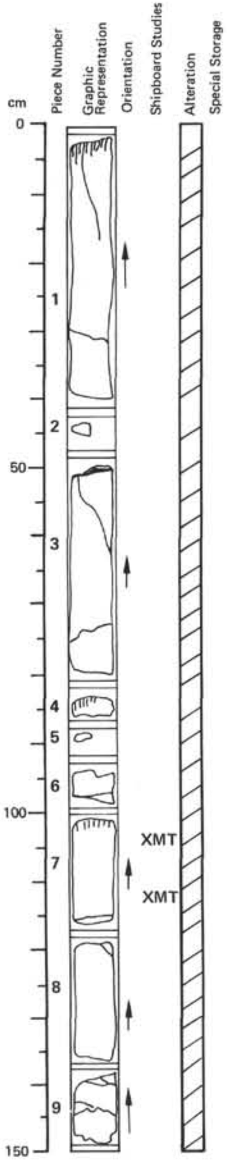
LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	A	3	5		3

Visual Description

Altered phyric pillow basalt. Basalt gray to gray-brown with an aphanitic groundmass. Altered plagioclase phenocrysts 10%, ≤4 mm in pieces 1-7, ≤12 mm in pieces 8-10; clinopyroxene phenocrysts ≤5%, ≤3 mm; olivine phenocrysts ≤3%, ≤3 mm; phenocrysts largely replaced. Vesicles <1%. Veins filled by calcite and smectite(?). Pieces 6 and 8 contain large (1.5-2.5 cm) cavities filled by transparent white zeolites(?) on a yellow-green lining.

Shipboard Data

Physical Property Data:	3-5 cm
$\bar{V}$p (km/sec)	5.44
Porosity (%)	4.4
Wet Bulk Density (g/cc)	2.77
Grain Density (g/cc)	2.85



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	35	4

Visual Description

Altered phyric pillow basalt. Basalt dark gray with an aphanitic to microcrystalline groundmass. Altered plagioclase phenocrysts 10%, <8 mm in pieces 1-8, ≤3 mm in piece 9; mafic phenocrysts 3%, ≤2 mm, entirely replaced by alteration products. Vesicles 1%, ≤1 mm. Veins filled by calcite and *smectite(?)*.

Thin Section Description

Location: near chilled margin, 102 cm

Texture: porphyritic

Phenocrysts: olivine <1%, 2 mm, anhedral; zoned plagioclase 15%, 0.5-5.0 mm, An 76-84, tabular, partly altered; clinopyroxene 1%, 0.3-2.0 mm, prismatic.

Groundmass: plagioclase 2-3%, <0.1 mm, prismatic; altered glass 80%.

Vesicles: 2%, 0.1-0.2 mm, filled by smectite with an opaque core, round.

Alteration: plagioclase partly replaced by montmorillonite and zeolites; clinopyroxene replaced by montmorillonite.

Thin Section Description

Location: pillow interior, 112 cm

Texture: porphyritic

Phenocrysts: altered olivine <1%, 0.2-0.5 mm, euhedral; altered plagioclase 10%, 0.3-1.5 mm, tabular with liquid inclusions; fresh clinopyroxene 2%, 0.1-1.0 mm, prismatic.

Groundmass: plagioclase 25%, 0.1-0.5 mm, An 50-55, tabular; altered clinopyroxene 3-5%, 0.1 mm, anhedral; altered glass 60%.

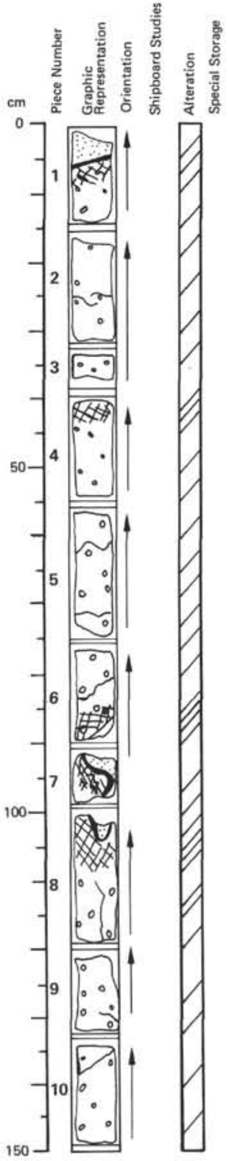
Alteration: plagioclase partly replaced by calcite and montmorillonite; clinopyroxene partly replaced by calcite and smectite; olivine and glass replaced by montmorillonite.

Shipboard Data

Bulk Analysis:

	100-103 cm	111-113 cm
SiO_2	49.40	49.11
Al_2O_3	17.97	17.76
Fe_2O_3	13.18	10.39
MgO	3.57	4.21
CaO	7.67	13.32
Na_2O	3.97	2.54
K_2O	2.04	0.98
TiO_2	1.65	1.44
P_2O_5	0.32	0.20
MnO	0.11	0.15
LOI	5.10	3.60
H_2O^+	4.29	1.86
H_2O^-	N.D.	N.D.
CO_2	0.31	1.28

Magnetic Data:	100-103 cm	111-113 cm
NRM Intensity (emu/cc)	9.131×10^{-3}	5.600×10^{-3}
NRM Inclination	-26.2°	-28.3°
Stable Inclination	-26.0°	-28.3°

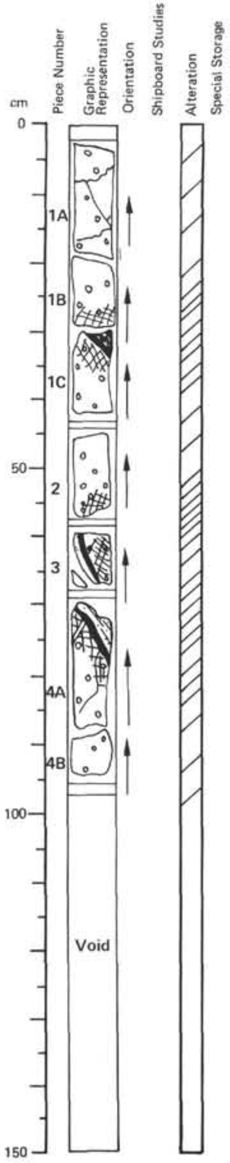


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	35	5

Visual Description

Altered phyric pillow basalt with chilled margins and traces of interpillow breccia. Basalt gray, altered to yellow-brown and dark brown within 2 cm and 2 mm, respectively, of margins against breccia. Groundmass aphanitic to microcrystalline. Plagioclase phenocrysts 10%, ≤4 mm, largely replaced by zeolites(?); iddingsite after phenocrysts of olivine 5%, ≤4 mm; black clinopyroxene laths 5%, <3 mm. Amygdules 10%, 1-6 mm, often concentrically lined with calcite, analcite, zeolites and smectite(?). Minor calcite-filled veins. Breccia (pieces 1, 7 and 8) composed of delicate, elongate fragments of palagonite aligned parallel to pillow margins in a green, fine-grained (<1 mm) self-matrix containing both palagonite and smectite. The larger (1 cm) fragments display delicate, concentric alteration zones.

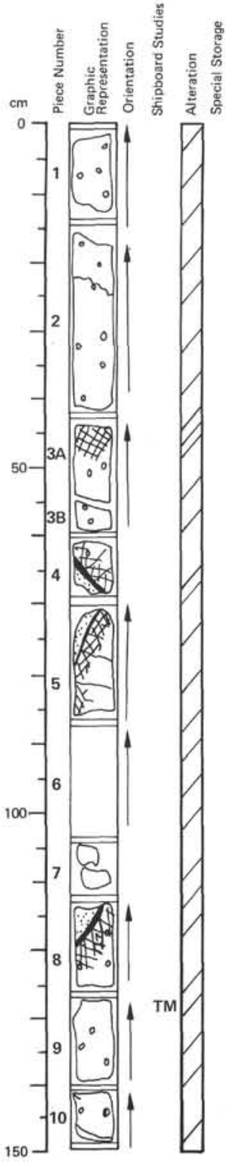


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	A		3 5		6

Visual Description

Altered phyric basalt pillows with chilled margins and minor interpillow breccia. Intervals 0-31, 31-70 and 70-96 cm each represent individual pillows or parts of pillows bounded by hematized chill margins. Basalt gray, altered to yellow-brown and dark brown within 2 cm and 2 mm, respectively, of margins against breccia. Groundmass aphanitic to microcrystalline. Plagioclase phenocrysts 10%, 5 mm, largely replaced by zeolites(?); altered black clinopyroxene laths <5%, <3 mm; iddingsite after phenocrysts of olivine <1%, <5 mm. Amygdules 5-8%, 1-6 mm, often concentrically lined with calcite, analcite, zeolites and smectite(?). Minor calcite-filled veins normal to pillow margins. Breccia (pieces 1C, 3 and 4A) composed of fragments of palagonite aligned parallel to pillow margins in a matrix of smectite and palagonite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	A		3 6		1

Visual Description

Altered phyric basalt pillows with chilled margins and minor interpillow breccia. Intervals 0-70, 70-103 and 113-150 each represent individual pillows or parts of pillows bounded by hematized chill margins. Basalt gray to slightly yellow-gray, altered to yellow and dark brown within 2 cm and 2 mm, respectively of margins against breccia. Groundmass aphanitic to microlitic, contains disseminated hematite. Plagioclase phenocrysts 10%, <5 mm, largely replaced by zeolites(?) and calcite; olivine phenocrysts replaced by iddingsite 4%, <5 mm; black clinopyroxene laths altered to smectite 1%. Scarce amygdules filled by smectite, calcite and zeolites. Minor calcite-filled veins normal to pillow margins. Breccia (in pieces 4-6, 8 and 10) composed of elongate fragments of palagonite aligned parallel to pillow margins in a green matrix of smectite, calcite, hematite and analcite(?).

Thin Section Description

Location: pillow interior, 130 cm

Texture: porphyritic, hyalopilitic to intersertal

Phenocrysts: altered olivine 1-3%, 0.9 mm; altered plagioclase 10%, <3 mm, An 70

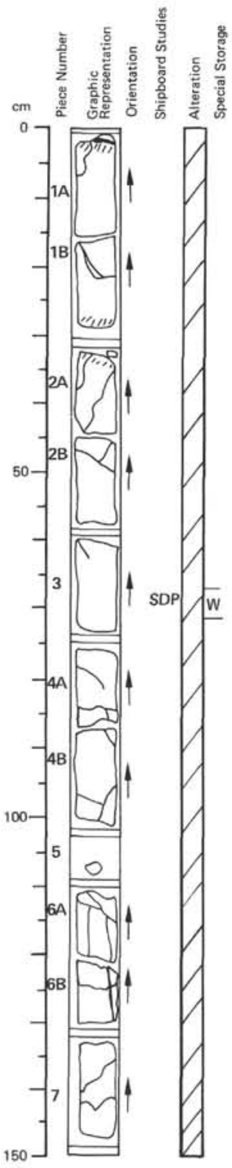
Groundmass: altered olivine 5-10%, 0.1 mm; plagioclase 15-20%, 0.3 mm, An 53, occasionally skeletal; clinopyroxene 20-25%, 0.1 mm, quenched, locally skeletal with ladder structures; magnetite 10-15%; devitrified glass 20-25%.

Vesicles: 1-2%, filled by calcite and saponite, round.

Alteration: plagioclase partially replaced by calcite, clay and zeolites; olivine and glass replaced by clay and smectite.

Shipboard Data

Magnetic Data:	129-132 cm
NRM Intensity (emu/cc)	5.912×10^{-3}
NRM Inclination	-32.8°
Stable Inclination	-33.1°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

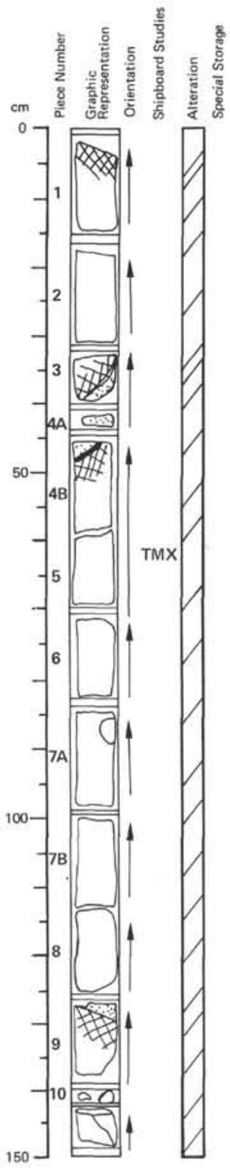
LEG	SITE	HOLE	CORE	SECT.
51	417	A	36	2

Visual Description

Altered phyric pillow basalt with infrequent chilled margins. Basalt dark gray, altered to pale brown near margin; pillow rims gray to dark gray-brown. Groundmass microlitic. Plagioclase phenocrysts 10%, <3 mm, partially altered; olivine phenocrysts completely altered to iddingsite <1%, <2 mm; clinopyroxene phenocrysts altered to smectite(?) 3%, <2 mm. Minor veins *filled by calcite, smectite.*

Shipboard Data

Physical Property Data:	67-69 cm
$\bar{V}p$ (km/sec)	5.48
Porosity (%)	4.0
Wet Bulk Density (g/cc)	2.84
Grain Density (g/cc)	2.92



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	36	3

Visual Description

Altered phyric pillow basalt with chilled margins and minor interpillow breccia. Basalt gray, altered to yellow-gray and dark brown within 2 cm and 2 mm, respectively, of margins against breccia. Groundmass aphanitic. Plagioclase phenocrysts 15%, <5 mm, largely altered to zeolites (?); olivine phenocrysts replaced by iddingsite 4-5%, <5 mm; altered black clinopyroxene phenocrysts <1%, <5 mm. Calcite-filled amygdules scarce to absent. Minor calcite-filled veins. Breccia (in pieces 3, 4A and 8) composed of elongate palagonite fragments (<2-3 cm) aligned parallel to pillow margins in a green, fine-grained (<1 mm) self-matrix of palagonite, smectite, calcite and hematite. Green smectite abundant as interstitial filling between pillows in pieces 3 and 4A.

Thin Section Description

Location: pillow interior, 64 cm

Texture: porphyritic, intersertal

Phenocrysts: altered olivine 5%, 2 mm, euhedral; altered plagioclase 20%, 3 mm, euhedral; altered clinopyroxene 5%.

Groundmass: altered olivine <5%; plagioclase 20%, 0.4 mm, tabular; clinopyroxene 20%, 0.1 mm, anhedral to granular; magnetite 5%, 0.03, euhedral; altered glass <15%.

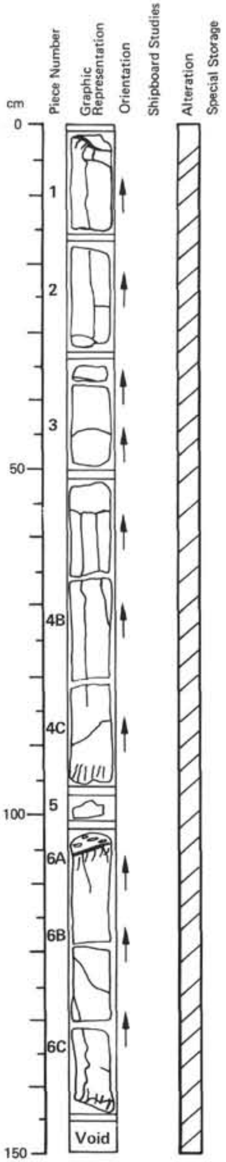
Vesicles: trace, 0.1 mm, filled by smectite, round.

Alteration: olivine replaced by calcite, zeolites and smectite; clinopyroxene replaced by calcite and smectite; plagioclase partly altered to clay.

Shipboard Data

Bulk Analysis: 63-65 cm	
SiO_2	48.90
Al_2O_3	17.54
Fe_2O_3	10.63
MgO	5.53
CaO	12.57
Na_2O	2.31
K_2O	0.78
TiO_2	1.47
P_2O_5	0.15
MnO	0.15
LOI	2.20
H_2O^+	1.76
H_2O^-	N.D.
CO_2	0.86

Magnetic Data:	63-65 cm
NRM Intensity (emu/cc)	2.111×10^{-3}
NRM Inclination	−22.1°
Stable Inclination	−24.7°

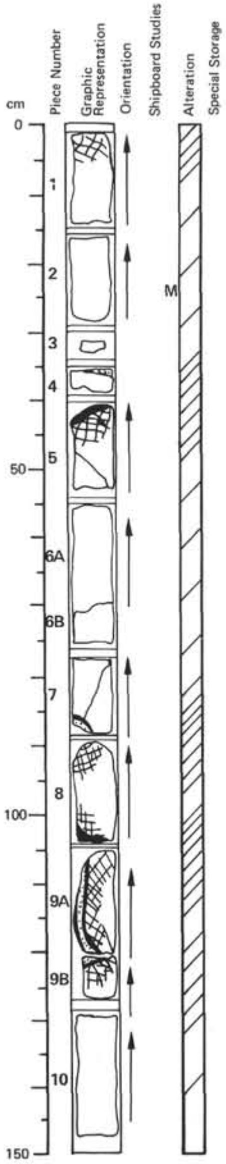


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	36	4

Visual Description

Altered phyric basalt pillows with chilled margins and minor interpillow breccia. Intervals 0-100 and 100-145 cm each represent individual pillows or parts of pillows. Basalt gray altered to yellow brown near margins. Groundmass aphanitic to microlitic, contains disseminated hematite. Plagioclase phenocrysts 10%, <6 mm, partially altered to zeolites(?) and clay; olivine phenocrysts altered to iddingsite 3%, <4 mm; clinopyroxene phenocrysts altered to smectite 2%, <2 mm. Calcite-filled vesicles 1%. Scarce calcite-filled veins. White cavity filling between 131-137 cm. Breccia (in pieces 1 and 6A) composed of elongate fragments of altered basalt aligned parallel to pillow margins in a matrix of smectite, palagonite and calcite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

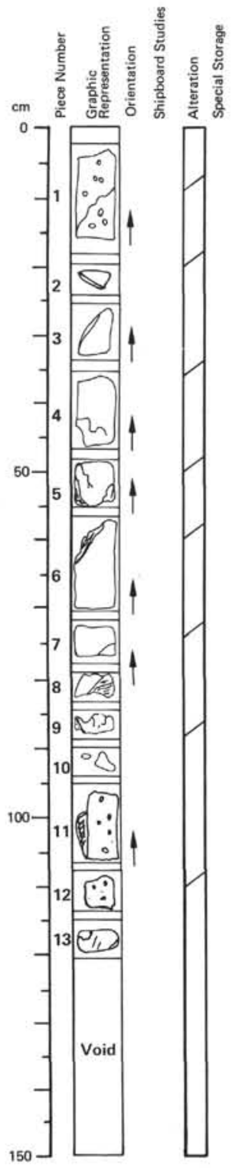
LEG	SITE	HOLE	CORE	SECT.
51	417	A	36	5

Visual Description

Altered phyric pillow basalt with chilled margins and minor interpillow hyaloclastite breccia. Basalt gray, altered to yellow gray and dark brown within 2 cm and 2 mm, respectively, of chilled margins. Groundmass aphanitic to microlitic, contains disseminated hematite. Plagioclase phenocrysts largely altered to clay, zeolites 15%, <8 mm; iddingsite after phenocrysts of olivine 5-8%, <5 mm; black laths of clinopyroxene altered to smectite(?) <2%, <3 mm. Amygdules very scarce, filled by calcite or smectite. Minor calcite-filled veins. Breccia (in pieces 4, 7 and 9A) composed of elongate (<2 cm) palagonite fragments aligned parallel to pillow margins in a green, fine-grained (<1 mm) matrix consisting of palagonite shards, smectite, calcite and hematite.

Shipboard Data

Magnetic Data:	24-27 cm
NRM Intensity (emu/cc)	8.845×10^{-3}
NRM Inclination	-24.0°
Stable Inclination	-23.2°

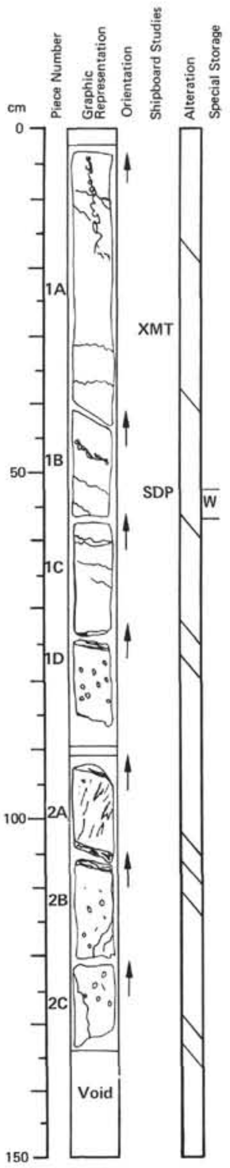


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	A	3	6		6

Visual Description

Altered phyric pillow basalt with chilled margins and interpillow breccia. Basalt gray to gray-violet, altered to gray-brown near margins. Groundmass aphanitic. Plagioclase phenocrysts partly to completely altered to clay, zeolites(?) 10-15%, <5 mm, rarely 1 cm (piece 9); olivine phenocrysts replaced by iddingsite <2%, <1 mm; dark green clinopyroxene phenocrysts 10%, <0.3 mm, rarely 6-8 mm (piece 11). Veins filled by calcite and hematite. Breccia composed of elongate green fragments of basaltic glass(?) altered to palagonite in a banded matrix of calcite and blue-green smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Altered phyric pillow basalt with pillow margins and traces of interpillow breccia. Basalt dark gray; pieces 1D and 2 altered to gray-violet with yellow-gray margins. Groundmass aphanitic to microlitic. Plagioclase phenocrysts 5-10%, <8 mm, partially to completely altered to clay, zeolites(?); clinopyroxene phenocrysts 20%, <5 mm, partially to completely altered to smectite; pieces 1D and 2 contain olivine phenocrysts replaced by iddingsite 1%, <3 mm. Phenocrysts partially altered in pieces 1A-1C, completely altered in pieces 1D and 2. Veins filled by calcite and smectite. Piece 2A contains numerous calcite-filled tension(?) cracks normal to pillow margin.

Thin Section Description

Location: pillow interior, 32 cm

Texture: porphyritic, ophitic

Phenocrysts: altered olivine 5%, 0.3-1.0 mm, subhedral; plagioclase 20%, 1-3 mm, euhedral to anhedral; clinopyroxene 5%, 1-2 mm, euhedral to subhedral.

Groundmass: altered olivine 5%, 0.1 mm, anhedral; plagioclase 20%, 0.1 mm, tabular; clinopyroxene 30%, 0.5 mm, anhedral; magnetite 5%, 0.02 mm, euhedral; altered glass 5%.

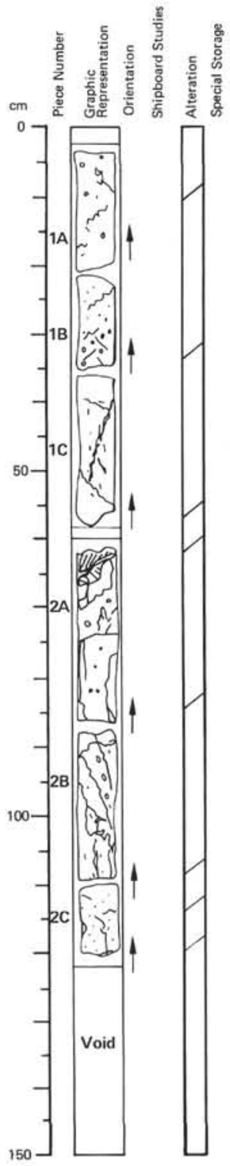
Alteration: olivine and glass partly altered to smectite; groundmass contains disseminated calcite.

Shipboard Data

Bulk Analysis: 31-34 cm	
SiO_2	48.74
Al_2O_3	16.75
Fe_2O_3	10.81
MgO	6.80
CaO	13.16
Na_2O	2.01
K_2O	0.03
TiO_2	1.31
P_2O_5	0.14
MnO	0.16
LOI	0.30
H_2O^+	0.77
H_2O^-	N.D.
CO_2	0.37

Magnetic Data:	31-34 cm
NRM Intensity (emu/cc)	19.476×10^{-3}
NRM Inclination	-12.2°
Stable Inclination	-12.9°

Physical Property Data:	
$\bar{V}p$ (km/sec)	5.74
Porosity (%)	3.4
Wet Bulk Density (g/cc)	2.88
Grain Density (g/cc)	2.94

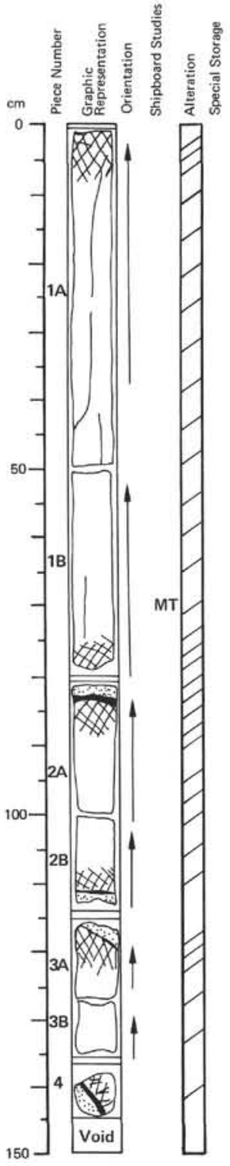


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	37	2

Visual Description

Altered phyric basalt with a gray to gray-brown, aphanitic groundmass. Plagioclase phenocrysts 10-20%, <3 mm, occasionally as large as 7 mm (piece 2A), altered to clay; dark green clinopyroxene phenocrysts partially altered to smectite 20%, <0.5 mm; olivine phenocrysts replaced by iddingsite 1%, <2 mm. Veinlets filled by calcite, brown smectite(?).



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	37	3

Visual Description

Altered phyric basalt pillows with chilled margins and minor interpillow hyaloclastite breccia. Intervals 0-80, 80-115 and 115-145 cm represent individual pillows or parts of pillows bounded by chilled margins. Basalt gray, altered to yellow-gray and dark brown within 5 cm and 2 mm, respectively, of margins against breccia. Groundmass aphanitic to microlitic. Plagioclase phenocrysts 15%, <8 mm, altered to zeolites, clay and calcite; olivine phenocrysts replaced by iddingsite 8%, <5 mm; black augitic clinopyroxene laths <5%, <4 mm. Amygdules scarce, <1 mm, filled by calcite, smectite. Veins filled by calcite. Breccia (in pieces 2, 3A and 4) composed of elongate, green palagonite fragments aligned parallel to pillow margins in a fine-grained (<1 mm) self-matrix of palagonite and smectite cemented by calcite and hematite.

Thin Section Description

Location: pillow interior, 72 cm

Texture: porphyritic, hyalopilitic

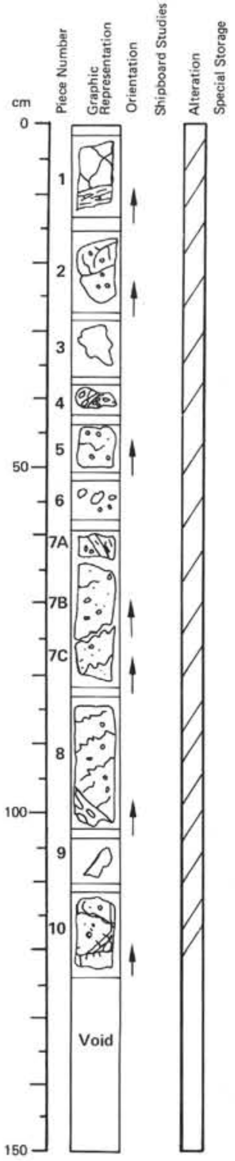
Phenocrysts: altered olivine 2-3%, 0.5-4.0 mm, idiomorphic; zoned plagioclase 10%, 0.7-4.0 mm, altered, idiomorphic; fresh clinopyroxene 1-2%, 1 mm, idiomorphic, occasional twinning.

Groundmass: plagioclase microlites 50%, 0.1-0.3 mm, skeletal; plumose clinopyroxene 5%; magnetite and hematite 30%; clinopyroxene, magnetite and hematite interstitial between plagioclase microlites.

Alteration: plagioclase replaced by calcite, clay and analcite; olivine replaced by calcite and iddingsite.

Shipboard Data

Magnetic Data:	70-73 cm
NRM Intensity (emu/cc)	6.516×10^{-3}
NRM Inclination	-20.6°
Stable Inclination	-20.5°

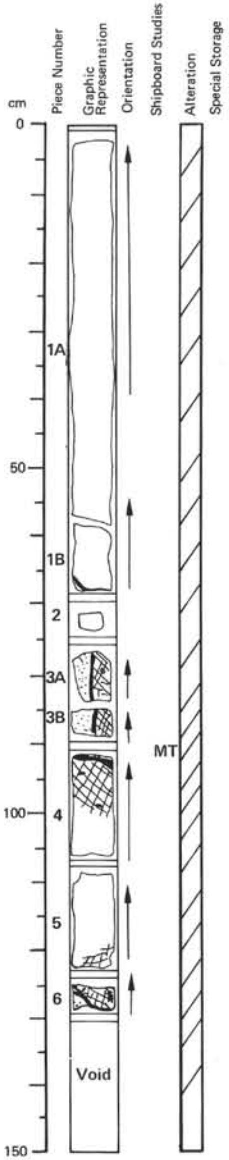


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	37	4

Visual Description

Altered phyric pillow basalt with chilled margins and interpillow breccia. Basalt altered to yellow-brown with a dark brown rim along margins against breccia. Groundmass aphanitic. Plagioclase phenocrysts 10-15%, <5 mm, partially altered to clays; clinopyroxene phenocrysts 5-10%, <1.5 mm. Veins normal to pillow margins, filled by calcite. Breccia composed of pale yellow-green fragments of altered basaltic glass, elongate parallel to pillow margins in a green to blue-green matrix of smectite, palagonite and calcite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	37	5

Visual Description

Altered phyric pillow basalt with pillow margins and interpillow hyaloclastite breccia. Basalt gray, altered to yellow-gray and dark brown within 3 cm and 2 mm respectively, of margins against breccia. Groundmass aphanitic. Plagioglase phenocrysts 15-20%, <8 mm, replaced by calcite, clay and zeolites(?); olivine phenocrysts replaced by iddingsite, calcite 5-8%, <5 mm; black augitic clinopyroxene laths 2-4%, <4 mm. Amygdules scarce, <1 mm, filled by calcite, smectite. Minor calcite-filled veins. Breccia (in pieces 3, 4 and 6) composed of elongate, green palagonite fragments aligned parallel to pillow margins in a fine-grained (<1 mm) self-matrix of palagonite and smectite cemented by calcite and hematite.

Thin Section Description

Location: near chilled margin, 95 cm

Texture: prophyritic, hyaloophitic

Phenocrysts: altered olivine 3%, 0.5-2 mm, euhedral; plagioclase 20%, 6 mm, euhedral; altered clinopyroxene 5%, 1 mm, euhedral.

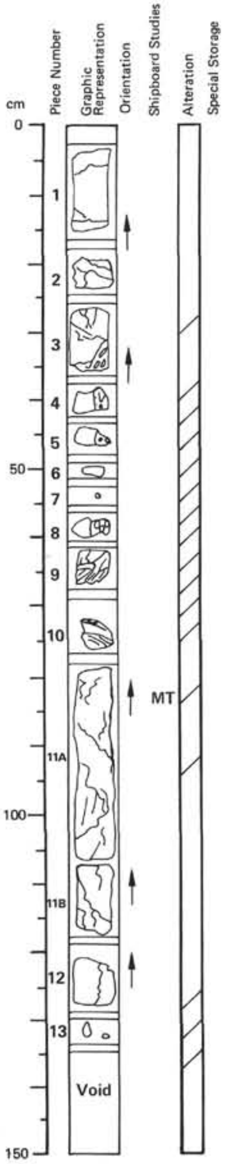
Groundmass: plagioclase 15%, 0.2 mm, tabular, skeletal; altered clinopyroxene or olivine(?) 1%, 0.1 mm; devitrified glass 60%.

Vesicles: trace, 0.05 mm, filled by chlorite

Alteration: olivine phenocrysts replaced by iddingsite; clinopyroxene phenocrysts replaced by calcite; groundmass clinopyroxene, olivine replaced by smectite.

Shipboard Data

Magnetic Data:	93-96 cm
NRM Intensity (emu/cc)	4.859×10^{-3}
NRM Inclination	-23.1°
Stable Inclination	-23.3°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	38	1

Visual Description

Altered phyric pillow basalt with chilled margins and palagonitic interpillow breccia. Basalt dark gray, altered to gray-violet, gray-brown, yellow-brown or brown depending on degree of alteration and proximity to margins. Groundmass aphanitic. Plagioclase phenocrysts 20%, <9 mm, fresh in piece 1, largely replaced by zeolites or clay(?) in pieces 2-6 and 8-12; pyroxene phenocrysts 15%, <2 mm, replaced by calcite or smectite. Veins filled by fine- to coarse-grained calcite; pillow margins locally cut by randomly oriented fractures. Breccia in pieces 3-5, 7-10, and 13 consists of pale yellow-green fragments of altered basaltic glass in a banded green to brown self-matrix composed of palagonite, smectite and calcite.

Thin Section Description

Location: pillow interior, 85 cm

Texture: porphyritic, hyalopilitic

Phenocrysts: altered olivine 1-2%, 0.4 mm; plagioclase 20%, 5.5 mm, An 65; clinopyroxene 3-5%, 2.5 mm, twinned.

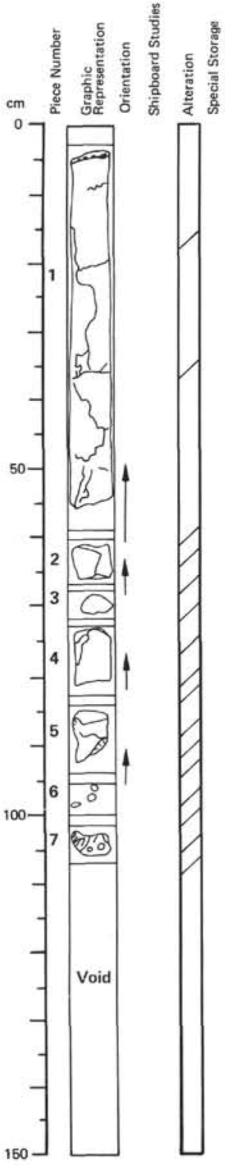
Groundmass: olivine 5-10%, 0.05 mm; plagioclase 15-20%, 0.4 mm, An 60, often skeletal; clinopyroxene 15%, 0.03; magnetite 5-10%; devitrified glass 25%; calcite in veins.

Vesicles: 1-5%, 0.4 mm, filled by calcite.

Alteration: plagioclase partly replaced by calcite; olivine completely replaced by iddingsite, smectite and celadonite.

Shipboard Data

Magnetic Data:	84-87 cm
NRM Intensity (emu/cc)	5.670×10^{-3}
NRM Inclination	-23.7°
Stable Inclination	-24.5°

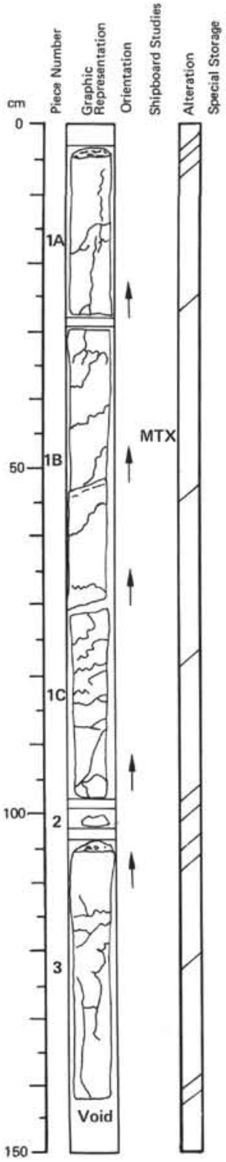


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	38	2

Visual Description

Altered phyric pillow basalt with chilled margins and minor interpillow breccia. Basalt dark gray to gray violet, altered to gray-brown, yellow-brown and red-brown near margins. Groundmass aphanitic to microlitic. Plagioclase phenocrysts 20-25%, <4 mm, altered to clay and zeolites(?); clinopyroxene phenocrysts 5-10%, <1 mm; olivine phenocrysts 1%, <1.5 mm, replaced by iddingsite. Veins filled by calcite. Breccia composed of light yellow-green fragments of altered basaltic glass in a banded self-matrix of palagonite, smectite, calcite and hematite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	A	3 8	3

Visual Description

Altered phyric pillow basalt with chilled margins and traces of interpillow breccia. Basalt dark gray, altered to yellow-brown near margins. Groundmass aphanitic to microlitic. Plagioclase phenocrysts 15%, <3 mm, partially altered to clay; clinopyroxene phenocrysts 15%, <1 mm; olivine phenocrysts completely replaced by iddingsite 1%, <2 mm. Calcite-filled veins common. Piece 1B contains pyrite-filled veins. Breccia in pieces 1A, 2 and 3 composed of fragments of pale yellow-green altered basaltic glass in a banded green matrix of palagonite, smectite and calcite.

Thin Section Description

Location: pillow interior, 47 cm

Texture: porphyritic, ophitic

Phenocrysts: altered olivine 3%, 1 mm, euhedral to subhedral; zoned plagioclase 20%, 1-3 mm, euhedral; clinopyroxene 3%, 3 mm, subhedral.

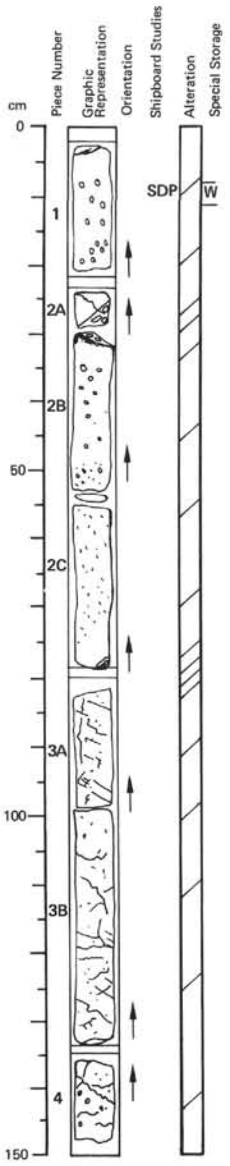
Groundmass: plagioclase 30%, 0.2, tabular; clinopyroxene 20%, 0.1 mm, granular to tabular; dendritic magnetite 5%, 0.02 mm; devitrified glass 5%.

Alteration: olivine replaced by smectite.

Shipboard Data

Bulk Analysis: 46-49 cm	
SiO_2	48.62
Al_2O_3	18.02
Fe_2O_3	9.52
MgO	6.17
CaO	14.12
Na_2O	2.02
K_2O	0
TiO_2	1.35
P_2O_5	0.12
MnO	0.19
LOI	0.70
H_2O^+	0.82
H_2O^-	N.D.
CO_2	0.54

Magnetic Data:	46-49 cm
NRM Intensity (emu/cc)	23.865×10^{-3}
NRM Inclination	-20.8°
Stable Inclination	-16.8°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

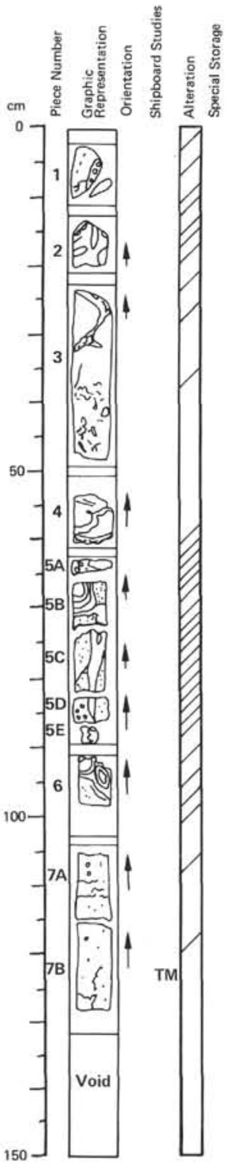
LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	A	3 8	4

Visual Description

Altered phyric basalt pillows with chilled margins and minor interpillow breccia. Basalt gray to gray-violet, altered to yellow-brown near margins. Groundmass aphanitic. Plagioclase phenocrysts 15%, <3 mm, partially altered to clay and zeolites(?); clinopyroxene phenocrysts 10%, <1 mm. Phenocrysts locally concentrated in flow bands subparallel to pillow margins. Veins and microfractures filled by calcite. Vesicles filled by smectite. Breccia in pieces 1 and 2 composed of pale green fragments of altered basaltic glass in a banded green to brown matrix of palagonite, smectite and calcite.

Shipboard Data

Physical Property Data:	11-13 cm
$\overline{V}$p (km/sec)	5.30
Porosity (%)	5.4
Wet Bulk Density (g/cc)	2.82
Grain Density (g/cc)	2.87



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	A	3 8	5

Visual Description

Altered phyric pillow basalt with aphyric chilled margins in a cemented interpillow breccia. Basalt altered to yellow-brown and red-brown. Groundmass aphanitic. Plagioclase phenocrysts 10%, <3 mm, altered to zeolites and clay; clinopyroxene 5%, <0.4 mm. Sealed by large veins of calcite and pale green smectite. Breccia in pieces 1-3, 5 and 6 composed of elongate, pale yellow-green fragments of altered basaltic glass, either randomly oriented or aligned parallel to pillow margins, in a banded green matrix of palagonite, smectite and calcite. Vesicles filled by clay, zeolites and calcite are present in both basalt and breccia shards.

Thin Section Description

Location: pillow interior, 123 cm

Texture: porphyritic, ophitic

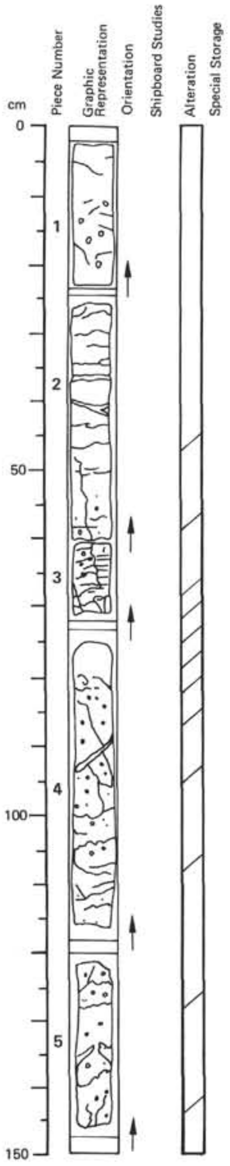
Phenocrysts: altered olivine 3%, 2 mm, euhedral; plagioclase 20%, 1-4 mm, euhedral; clinopyroxene 3%, 1 mm, euhedral.

Groundmass: altered olivine <10%; plagioclase 30%, 0.2 mm, tabular; granular clinopyroxene 20%, 0.05 mm; magnetite 5%, 0.02 mm; devitrified glass <5%; calcite in veins.

Alteration: olivine phenocrysts replaced by calcite.

Shipboard Data

Magnetic Data:	122-124 cm
NRM Intensity (emu/cc)	2.933×10^{-3}
NRM Inclination	-14.8°
Stable Inclination	-15.1°

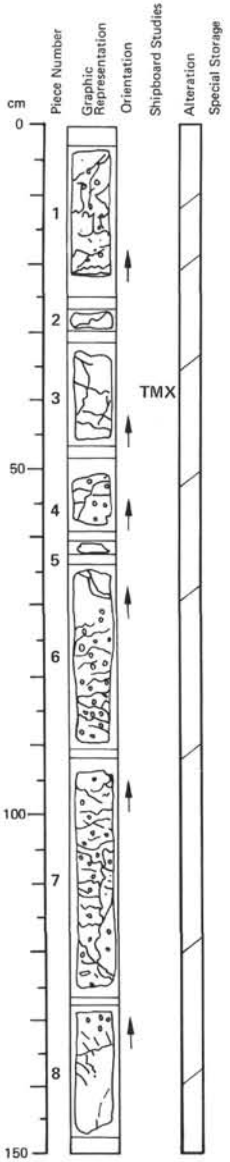


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	A	3 8	6

Visual Description

Altered phyric basalt with a gray microlitic groundmass altered to gray-brown along cracks. Plagioclase phenocrysts 15%, <7 mm, partially altered to clay; clinopyroxene phenocrysts 10-15%, <4 mm. Calcite-filled veins common; in pieces 2 and 3 these are strongly aligned normal to the core axis.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	A	3 8	7

Visual Description

Altered phyric basalt with a gray, aphanitic groundmass. Plagioclase phenocrysts partially groundmass. Plagioclase phenocrysts partially altered to clay and analcite(?) <3 mm in pieces 3 and 8, 15-20% in pieces 1, 2 and 4-7; clinopyroxene phenocrysts 15%, <0.2 mm, present in pieces 1, 2 and 4-7. Veins filled by calcite and analcite(?); between 70-110 cm, these are aligned normal to the core axis.

Thin Section Description

Location: pillow interior, 37 cm

Texture: porphyritic, ophitic

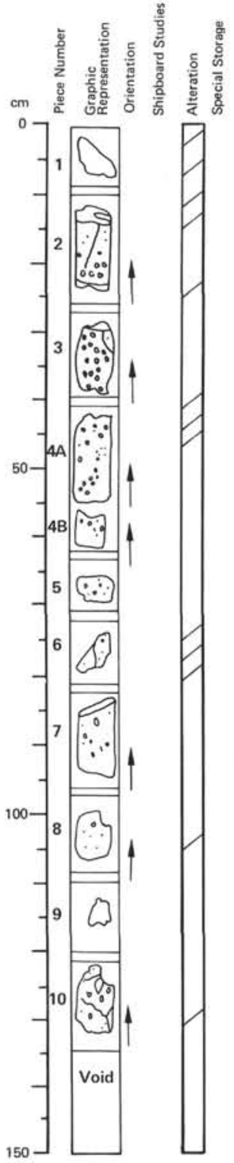
Phenocrysts: altered olivine 3%, 2 mm, euhedral; altered plagioclase 10%, 3%, euhedral; altered clinopyroxene 10%, 2 mm, euhedral.

Groundmass: altered olivine 10%, 0.1 mm, euhedral; plagioclase 30%, 0.3 mm, tabular; anhedral clinopyroxene 25%, 0.1 mm; dendritic to euhedral magnetite 5%, 0.02 mm; devitrified glass <5%.

Alteration: plagioclase phenocrysts partly altered to clay; olivine replaced by smectite.

Shipboard Data

Bulk Analysis: 35-38 cm		Magnetic Data:	35-38 cm
SiO_2	49.67	NRM Intensity	.855 x 10^{-3}
Al_2O_3	17.39	NRM Inclination	-18.3°
Fe_2O_3	10.69	Stable Inclination	-20.0°
MgO	5.38		
CaO	11.60		
Na_2O	2.62		
K_2O	0.83		
TiO_2	1.50		
P_2O_5	0.27		
MnO	0.15		
LOI	3.35		
H_2O^+	0.68		
H_2O^-	N.D.		
CO_2	0.80		

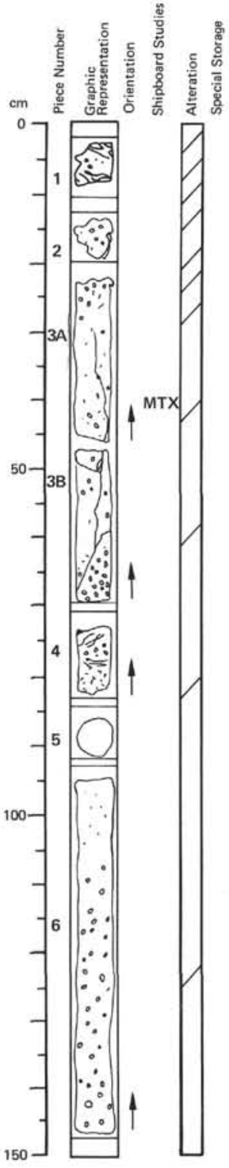


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	A	3 8	8

Visual Description

Altered phyric pillow basalt with chilled margins and minor interpillow breccia. Basalt gray-violet, altered to yellow-brown near margins, red-brown against breccia. Groundmass aphanitic. plagioclase phenocrysts partly altered to clay and analcite(?) 10-20%, <3 mm; clinopyroxene phenocrysts 15%, <0.5 mm. Veins filled by calcite or analcite. Breccia composed of pale yellow-green, partially hematized fragments of altered basaltic glass in a banded pale to yellow-green matrix of palagonite, smectite, calcite and hematite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Phyric basalt, altered to yellow-brown in pieces 1 and 2 but gray and increasingly fresh in pieces 3-6. Basalt locally aphyric, hematized in vicinity of cracks (piece 4). Groundmass microlitic, contains disseminated hematite. Plagioclase phenocrysts 20-25%, <5 mm, partly altered to white clay(?); clinopyroxene 5%, <0.4 mm; olivine phenocrysts <1%, <1 mm, completely altered. Pieces 1 and 5 contain veins filled by calcite and analcite ± natrolite(?).

Thin Section Description

Location: pillow interior, 38 cm

Texture: porphyritic, intersertal

Phenocrysts: altered olivine 1-2%, 0.5-4.0 mm, idiomorphic; altered plagioclase 10%, 0.8-2.5 mm, idiomorphic.

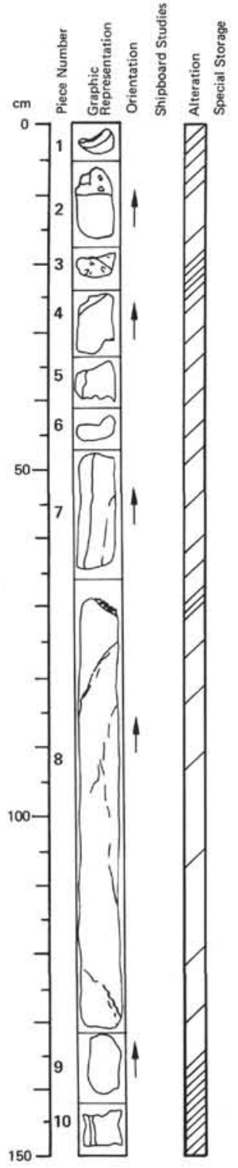
Groundmass: altered plagioclase microlites 50%, 0.2-0.5 mm; fresh augitic clinopyroxene 15%, 0.2-0.4 mm, interstitial between microlites; magnetite 5%; undifferentiated altered groundmass 15%.

Vesicles: <1%, <1 mm, filled by calcite.

Alteration: olivine replaced by calcite; groundmass contains smectite and disseminated hematite.

Shipboard Data

Bulk Analysis: 37-40 cm		Magnetic Data:	37-40 cm
SiO_2	49.16	NRM Intensity (emu/cc)	5.199×10^{-3}
Al_2O_3	17.60	NRM Inclination	-20.1°
Fe_2O_3	11.54	Stable Inclination	-20.6°
MgO	4.59		
CaO	11.55		
Na_2O	2.64		
K_2O	1.15		
TiO_2	1.52		
P_2O_5	0.26		
MnO	0.13		
LOI	1.70		
H_2O^+	2.64		
H_2O^-	N.D.		
CO_2	1.10		

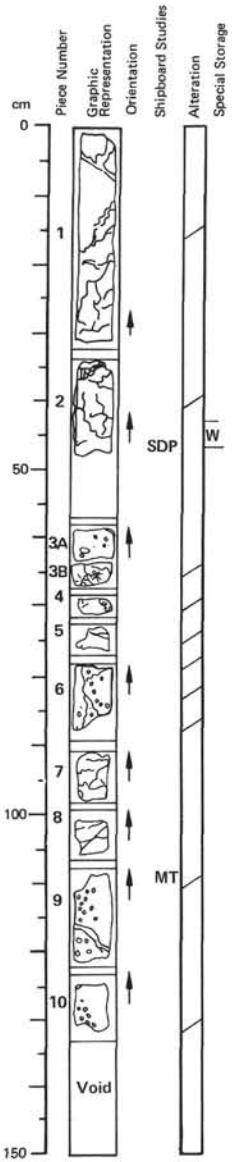


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Altered phyric basalt. Groundmass microlitic, contains disseminated hematite. Plagioclase phenocrysts 5-10%, <8 mm, partially replaced by clay, calcite and analcite; olivine phenocrysts 1-2%, <3 mm, completely replaced. Piece 7 amygdaloidal. Veins filled by smectite (pieces 1 and 2) or by celadonite, analcite and natrolite ± calcite (piece 3). Piece 8 contains a vein filled with large analcite crystals.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	39	3

Visual Description

Altered phyric to aphyric basalt, locally fractured. Basalt gray, altered to yellow-gray, yellow-brown along veins. Groundmass microlitic. Plagioclase phenocrysts 20%, <3 mm, altered to clay, analcite; clinopyroxene phenocrysts 5-7%, <0.2 mm. Veins filled by pale green smectite and calcite (pieces 1-3A) or by crystals of analcite and natrolite (pieces 3B-5).

Thin Section Description

Location: pillow interior, 111 cm

Texture: porphyritic, intersertal

Phenocrysts: altered olivine, trace, 2 mm, idiomorphic; altered plagioclase 10%, 1-2.5 mm, idiomorphic.

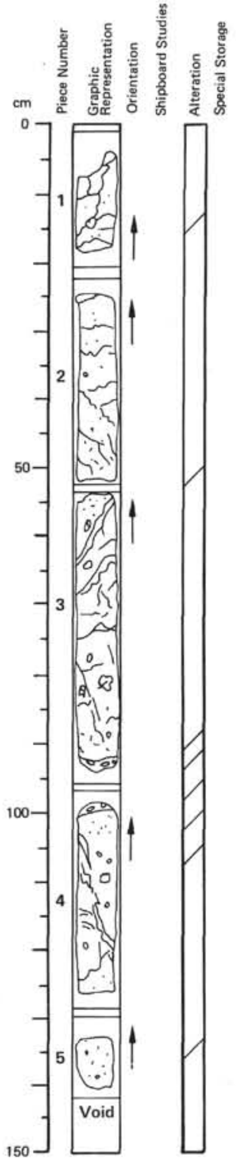
Groundmass: altered plagioclase microlites 50%, 0.1-0.5 mm; fresh augitic clinopyroxene microlites 20%, 0.1-0.4 mm; undifferentiated altered groundmass 20%.

Vesicles: 1%, 1 mm, crescentic calcite fillings.

Alteration: plagioclase replaced by calcite, clay and natrolite; olivine replaced by calcite and clay.

Shipboard Data

Magnetic Data:	109-112 cm
NRM Intensity (emu/cc)	1.794×10^{-3}
NRM Inclination	-9.3°
Stable Inclination	-9.3°
Physical Property Data:	43-45 cm
$\bar{V}p$ (km/sec)	5.37
Porosity (%)	5.7
Wet Bulk Density (g/cc)	2.76
Grain Density (g/cc)	2.87

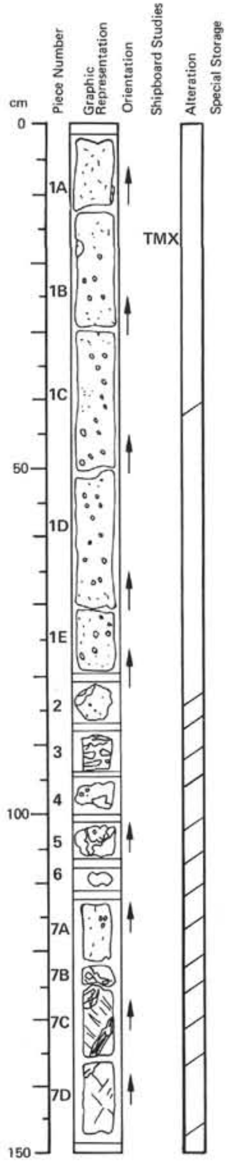


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	39	4

Visual Description

Altered phyric pillow basalt with chilled margins and traces of interpillow breccia between 92-98 cm. Basalt gray, altered to yellow-brown near margins. Groundmass microlitic. Plagioclase phenocrysts partially altered to clay 15-20%, <5 mm in pieces 1, 2 and 5, <12 mm in pieces 3 and 4; clinopyroxene phenocrysts 7%, <0.2 mm. Veins filled by brown smectite and calcite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE			SECT.
5	1	4	1	7	A		4	0	1

Visual Description

Altered phyric basalt with chilled margins and minor breccia. Basalt gray, altered to yellow-brown in pieces 2, 4-7C and the top of 7D. Groundmass microlitic. Plagioclase phenocrysts 15%, <7 mm, partially replaced by clay, analcite; clinopyroxene phenocrysts 10%, <0.5 mm. Veins filled by brown smectite and analcite. Piece 1B contains a small analcite-filled vug. Breccia composed of yellow to yellow-brown fragments of altered basalt or basaltic glass cut by veins of hematite in a banded matrix of calcite, analcite and black shards of relatively fresh glass (piece 3) or of green palagonite, smectite, calcite and hematite (pieces 7B and 7C).

Thin Section Description

Location: pillow interior, 15 cm

Texture: porphyritic, intersertal

Phenocrysts: altered olivine <1%, 1 mm, idiomorphic; plagioclase 15%, 1-5 mm, idiomorphic; fresh clinopyroxene <1%, 1 mm, twinned, rounded and corroded.

Groundmass: plagioclase 40%; interstitial clinopyroxene 5%; undifferentiated, altered groundmass 40%.

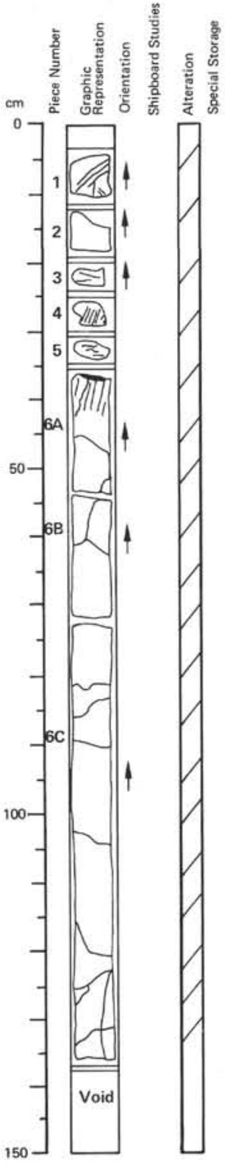
Vesicles: <1%, <0.5 mm, filled by calcite and smectite.

Alteration: plagioclase phenocrysts partly replaced by calcite, montmorillonite, analcite and natrolite; olivine phenocrysts replaced by calcite.

Shipboard Data

Bulk Analysis: 14-17 cm	
SiO_2	48.67
Al_2O_3	18.35
Fe_2O_3	9.54
MgO	4.40
CaO	13.30
Na_2O	3.28
K_2O	0.99
TiO_2	1.57
P_2O_5	0.18
MnO	0.13
LOI	5.25
H_2O^+	4.24
H_2O^-	N.D.
CO_2	2.06

Magnetic Data:	14-17 cm
NRM Intensity (emu/cc)	6.7000×10^{-3}
NRM Inclination	-24.5°
Stable Inclination	-25.1°

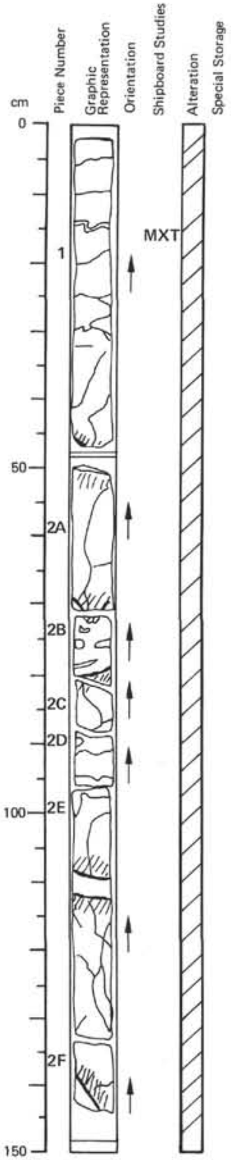


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE			SECT.
5	1	4	1	7	A		4	0	2

Visual Description

Altered phyric basalt with a chilled margin at the top of piece 6A and traces of interpillow or interflow breccia in piece 5. Basalt dark gray with a microlitic groundmass, altered to pale brown in piece 4 and to pale yellow-brown near aphanitic margin in piece 6A. Plagioclase phenocrysts 10%, <7 mm, largely replaced; altered clinopyroxene phenocrysts 2-3%, <3 mm; olivine phenocrysts replaced by iddingsite, <2%, <2 mm. Calcite and smectite-filled vesicles 1%. Veins filled by calcite and dark green smectite. Breccia in piece 5 composed of fragments of basalt altered to palagonite(?) in a green self-matrix of palagonite, red-brown smectite or hematite and calcite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	A		4	0	3

Visual Description

Altered phyric pillow basalt with chilled margins and minor interpillow breccia. Intervals 0-48, 48-71, 78-100 and 110-143 represent individual pillow or parts of pillows bounded by thick, glassy margins. Basalt gray with a microlitic groundmass, altered to yellow-brown near margins. Plagioclase phenocrysts 10%, <6 mm, partly altered to clay; altered clinopyroxene phenocrysts 2%, <3 mm; olivine phenocrysts 2%, <2 mm, completely replaced. Veins, cavity fillings 2B, 2E and 2F) composed of calcite, smectite and zeolites.

Thin Section Description

Location: pillow interior, 18 cm

Texture: porphyritic, hyaloophitic

Phenocrysts: plagioclase 20%, 6 mm, euhedral

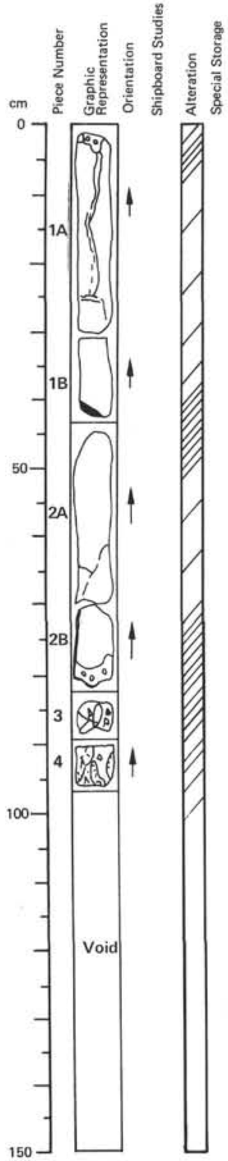
Groundmass: plagioclase 20%, 0.1 mm, tabular; clinopyroxene 10%, 0.03 mm, granular to anhedral; devitrified glass 45%

Vesicles: trace, 0.03 mm, filled by clay.

Shipboard Data

Bulk Analysis: 17-19 cm	
SiO_2	48.75
Al_2O_3	17.73
Fe_2O_3	8.87
MgO	6.51
CaO	14.41
Na_2O	2.30
K_2O	0.07
TiO_2	1.27
P_2O_5	0.12
MnO	0.19
LOI	2.05
H_2O^+	0.90
H_2O^-	N.D.
CO_2	0.94

Magnetic Data:	17-19 cm
NRM Intensity (emu/cc)	16.114×10^{-3}
NRM Inclination	-23.1°
Stable Inclination	-23.7°

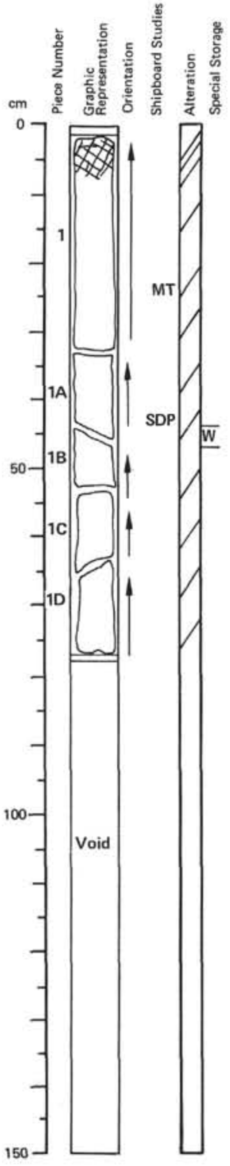


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	A		4	0	4

Visual Description

Altered phyric pillow basalt with chilled margin between 70-75 cm and interpillow breccia between 0-3 and 75-95 cm. Groundmass microlitic. Plagioclase phenocrysts with cores preferentially altered to calcite, zeolites; olivine phenocrysts replaced by iddingsite 5-10%, 1-3 mm. Veins filled by calcite. Breccia composed of clasts of basaltic glass altered to palagonite in a matrix of smectite, celadonite, calcite and zeolites. Clasts in pieces 3 and 4 are aligned parallel to margins.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	40	5

Visual Description

Altered phyric basalt with a chilled margin at the top of piece 1. Basalt gray, altered to yellow-gray near margin. Groundmass microlitic. Plagioclase phenocrysts 15-20%, <1 cm, partially replaced by calcite, analcite(?); olivine phenocrysts replaced by iddingsite and calcite 3-4%, <3 mm; black augitic clinopyroxene laths 1-2%, <3 mm. Small (<1 mm) vesicles filled by calcite or smectite. Veins filled by calcite, celadonite.

Thin Section Description

Location: near chilled margin, 27 cm

Texture: porphyritic, hyaloophitic

Phenocrysts: altered olivine 2%, 1 mm, subhedral; plagioclase 25%, 1-4 mm, euhedral; clinopyroxene 3%, 0.1-1 mm, euhedral to subhedral.

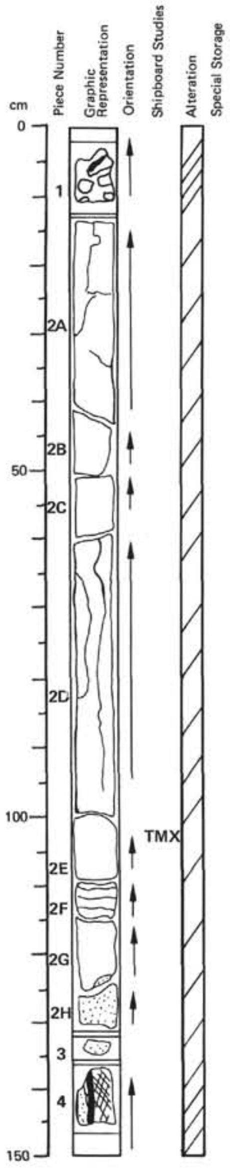
Groundmass: plagioclase 10%, 0.4 mm, skeletal needles, tabular; devitrified glass 60%.

Vesicles: trace, 1 mm, filled by smectite, clay.

Alteration: olivine replaced by smectite, clay; veins filled by calcite, smectite and hematite.

Shipboard Data

Magnetic Data:	26-28 cm
NRM Intensity	25.415×10^{-3}
NRM Inclination	-18.1°
Stable Inclination	-17.9°
Physical Property Data:	45-47 cm
Vp (km/sec)	5.37
Porosity (%)	5.4
Wet Bulk Density (g/cc)	2.80
Grain Density (g/cc)	2.91



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	41	1

Visual Description

Altered phyric pillow basalt with a chilled margin in piece 4 and interpillow breccia in pieces 1, 2H and 3. Basalt gray, altered to yellow-gray and brown within 3 cm and 2mm, respectively, of margin against breccia. Groundmass microlitic. Plagioclase phenocrysts 20%, <1 cm, partially altered to smectite 2-3%, <4 mm; olivine phenocrysts replaced by iddingsite, calcite 1%, <3 mm. Vesicles filled by calcite, smectite <1%, <1 mm. Veins filled by calcite, smectite and pyrite. Breccia consists of yellow-brown to green fragments of altered basalt in a fine-grained, banded green matrix composed of palagonite and smectite cemented by calcite.

Thin Section Description

Location: pillow interior, 104 cm

Texture: porphyritic, hyaloophitic

Phenocrysts: altered olivine 10%, 1-4 mm, euhedral; plagioclase 20%, 1-5 mm, euhedral to subhedral; clinopyroxene 5%, 1-3 mm, subhedral

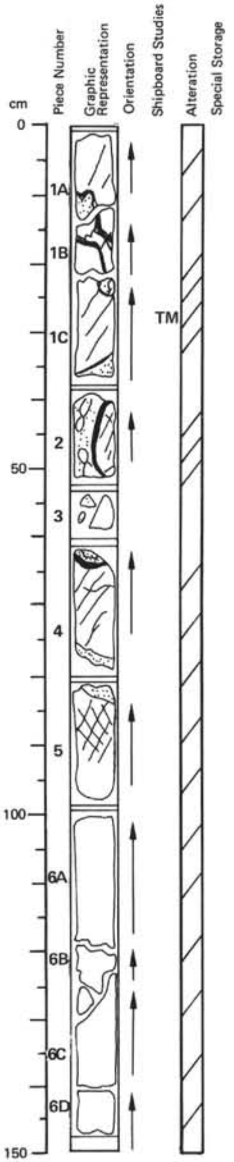
Groundmass: skeletal plagioclase 20%, 1 mm; clinopyroxene 20%, 0.5 mm, anhedral; magnetite 5%, 0.02 mm, euhedral; devitrified glass 20%.

Alteration: olivine replaced by clay and smectite; glass altered to clay.

Shipboard Data

Bulk Analysis: 103-105 cm	
SiO_2	49.28
Al_2O_3	16.97
Fe_2O_3	10.57
MgO	6.27
CaO	13.47
Na_2O	2.33
K_2O	0
TiO_2	1.40
P_2O_5	0.12
MnO	0.19
LOI	0.75
H_2O^+	0.77
H_2O^-	N.D.
CO_2	0.30

Magnetic Data:	103-105 cm
NRM Intensity (emu/cc)	12.652×10^{-3}
NRM Inclination	-11.8°
Stable Inclination	-17.9°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	41	2

Visual Description

Altered phyric pillow basalt with chilled margins against interpillow breccia in pieces 1-5. Basalt gray in piece 6, altered to yellow-brown near margins in pieces 1-5. Groundmass microlitic Plagioclase phenocrysts 15-20%, <5 mm, largely replaced by calcite and analcite; olivine phenocrysts replaced by iddingsite 4-5%, <5 mm; laths of augitic clinopyroxene 2-3%, <5 mm, partly altered to smectite. Scarce vesicles filled by calcite or smectite <1 mm. Veins filled by calcite. Breccia in pieces 1 and 3-5 composed of elongate fragments of palagonite aligned parallel to pillow margins in a green, fine-grained (<1 mm) self-matrix of palagonite and smectite cemented by calcite and hematite. The breccia in piece 2 is composed of altered basalt fragments a calcite-rich matrix.

Thin Section Description

Location: near chilled margin, 29 cm

Texture: porphyritic, hyaloophitic

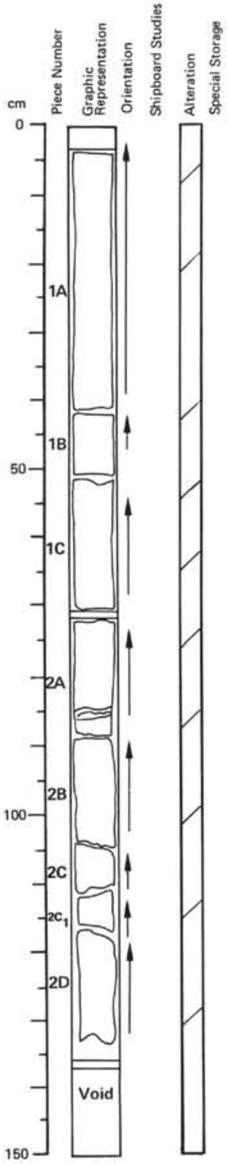
Phenocrysts: altered olivine 1%, euhedral; plagioclase 25%, 1-5 mm, euhedral; clinopyroxene 3%, rounded, partially resorbed.

Groundmass: skeletal plagioclase 20%, 0.5 mm; devitrified glass 50%

Alteration: olivine replaced by clay; glass altered to clay with disseminated hematite; veins filled by calcite, zeolites and sericite(?).

Shipboard Data

Magnetic Data:	28-30 cm
NRM Intensity (emu/cc)	6.774×10^{-3}
NRM Inclination	-29.8°
Stable Inclination	-29.3°

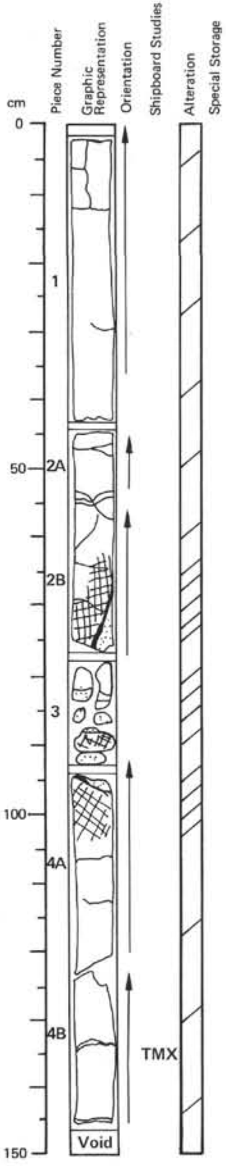


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	41	3

Visual Description

Weakly altered phyric basalt with a gray, intersertal groundmass. Plagioclase phenocrysts 20%, <1 cm, partly replaced by calcite, analcite and zeolites(?); augitic clinopyroxene laths 4-5%, <4 mm; olivine phenocrysts (in piece 2D) 3-4%, <5 mm, replaced by iddingsite and calcite. Vesicles uncommon and small (<1 mm), filled by calcite and smectite. Veins filled by calcite and smectite or by pyrite (piece 2A).



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Altered phyric pillow basalt with chilled margins against palagonitic interpillow breccia in pieces 2B and 4A. Basalt gray, altered to yellow-gray near margins; fragments in piece 3 altered to brown against breccia. Groundmass microlitic. Plagioclase phenocrysts 15-20%, <5 mm, altered to clay; augitic clinopyroxene laths 3-4%, <4 mm, partly altered to smectite; iddingsite pseudomorphs after olivine in piece 2B, 5%, <5 mm. Vesicles scarce, 1-2 mm, filled by calcite or smectite. Veins filled by calcite. Breccia composed of elongate fragments of palagonite in a banded green matrix of palagonite and smectite cemented by calcite.

Thin Section Description

Location: pillow interior, 137 cm

Texture: porphyritic, ophitic

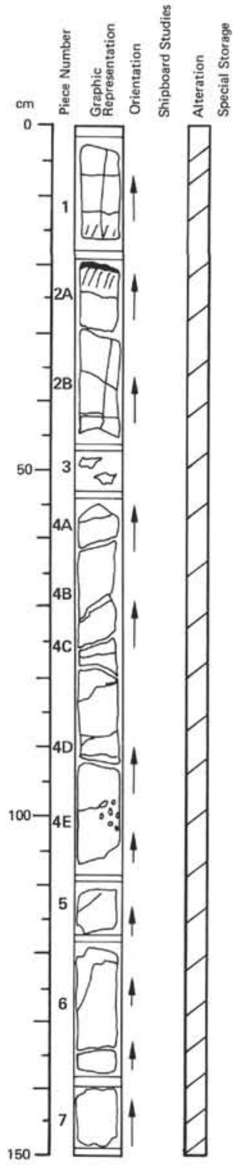
Phenocrysts: altered olivine 5%, 0.5 mm, euhedral to subhedral; plagioclase 20%, 1-3 mm, euhedral, clinopyroxene 5%, 2 mm, euhedral.

Groundmass: olivine <5%; plagioclase 20%, 0.1-0.5 mm, skeletal, tabular; dendritic magnetite 5%, 0.02 mm; glass <5%.

Alteration: olivine replaced by clay.

Shipboard Data

Bulk Analysis: 136-139 cm		Magnetic Data:	136-139 cm
SiO_2	49.61	NRM Intensity (emu/cc)	37.592×10^{-3}
Al_2O_3	17.39	NRM Inclination	-24.8°
Fe_2O_3	9.94	Stable Inclination	-25.3°
MgO	5.37		
CaO	13.89		
Na_2O	1.97		
K_2O	0		
TiO_2	1.49		
P_2O_5	0.10		
MnO	0.20		
LOI	1.55		
H_2O^+	0.86		
H_2O^-	N.D.		
CO_2	0.52		

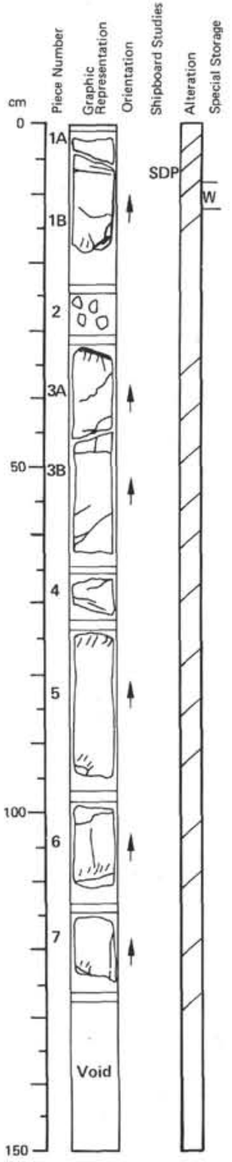


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Altered phyric pillow basalt with glassy chilled margins between 15-25 cm. Groundmass microlitic. Altered plagioclase phenocrysts 20%, <3 mm in pieces 1-4D, <10 mm in pieces 4E-7; altered clinopyroxene phenocrysts 5%, <2 mm; olivine phenocrysts completely replaced by iddingsite 2%, <1 mm. Veins filled by calcite, dark green smectite and sulfides. Piece 4E contains irregular smectite-filled vugs.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

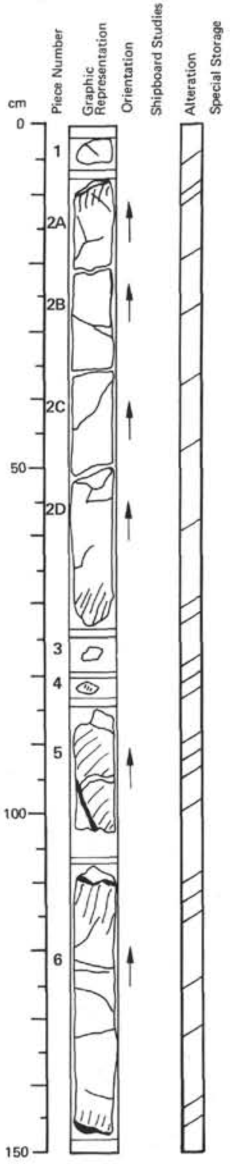
LEG	SITE	HOLE	CORE	SECT.
51	417	A	41	6

Visual Description

Weakly altered phyric pillow basalt with chilled margins at the top of pieces 3A and 5 and at the bottom of pieces 1B and 5-7. Piece 2 contains traces of interpillow breccia. Groundmass microlitic with aphanitic to glassy margins. Plagioclase phenocrysts 20%, <6 mm, partly altered to clay; olivine phenocrysts 10%, <3 mm, completely replaced by iddingsite. Veins filled by calcite and zeolites. Breccia in piece 2 contains calcite and zeolites.

Shipboard Data

Physical Property Data:	9-11 cm
$\bar{V}p$ (km/sec)	5.80
Porosity (%)	2.8
Wet Bulk Density (g/cc)	2.86
Grain Density (g/cc)	2.92

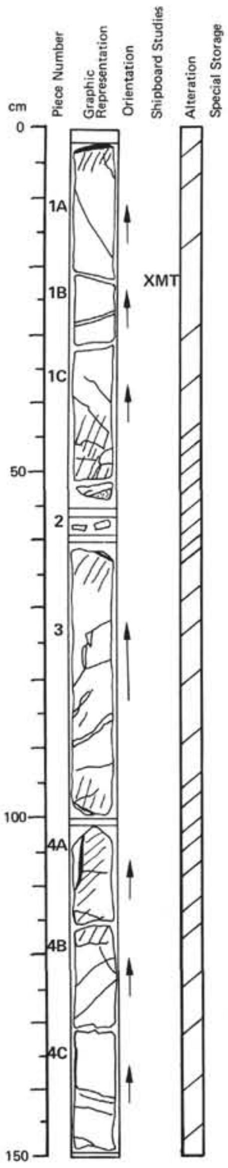


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	42	1

Visual Description

Altered phyric basalt pillows with chilled margins in piece 5 and the top and bottom of pieces 2 and 6. Piece 3 is composed of interpillow breccia. Basalt gray, altered to yellow-brown with a 2 mm-thick dark brown crest along margins. Groundmass crystalline, grades to microcrystalline, aphanitic and finally glassy toward margins. Plagioclase phenocrysts 20%, <1 cm; olivine phenocrysts replaced by iddingsite 5%, <4 mm. Veins filled by calcite and dark green smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Altered phyric basalt pillows . Intervals 0-55, 55-100 and 100-150 cm represent individual pillows or parts of pillows bounded by chilled margins. Groundmass crystalline with aphanitic margins. Altered plagioclase phenocrysts 20%, < 10 mm; altered olivine phenocrysts 5%, <4 mm. Veins and vesicles (the latter common between 27-30 cm) filled by calcite and smectite.

Thin Section Description

Location: pillow interior, 21 cm

Texture: porphyritic, hyaloophitic

Phenocrysts: altered olivine 5%, 0.5-1.0 mm, euhedral; plagioclase 20%, 1-4 mm, euhedral; clinopyroxene 20%, 1-2 mm, rounded, glomeroporphyritic with plagioclase.

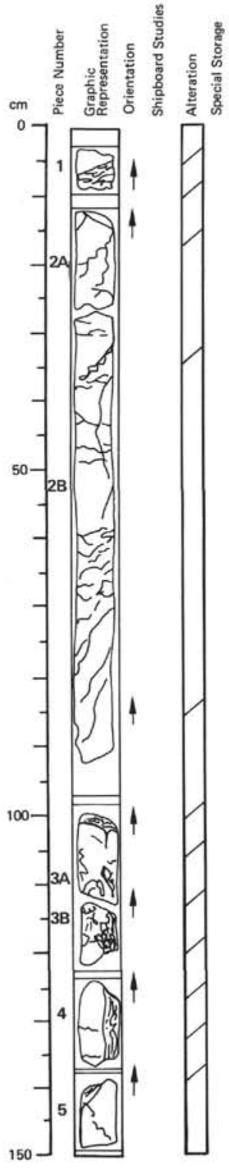
Groundmass: plagioclase 20%, 0.5 mm, dendritic to tabular; clinopyroxene 20%, 0.1 mm, granular to prismatic; magnetite 5%, 0.02 mm, dendritic, euhedral; devitrified glass 10%.

Alteration: olivine replaced by clay.

Shipboard Data

Bulk Analysis: 20-22 cm	
SiO_2	49.66
Al_2O_3	17.65
Fe_2O_3	9.68
MgO	6.28
CaO	13.43
Na_2O	2.07
K_2O	0.01
TiO_2	1.53
P_2O_5	0.15
MnO	0.20
LOI	1.00
H_2O^+	0.94
H_2O^-	N.D.
CO_2	0.28

Magnetic Data:	20-22 cm
NRM Intensity (emu/cc)	23.962×10^{-3}
NRM Inclination	-18.2°
Stable Inclination	-22.0°

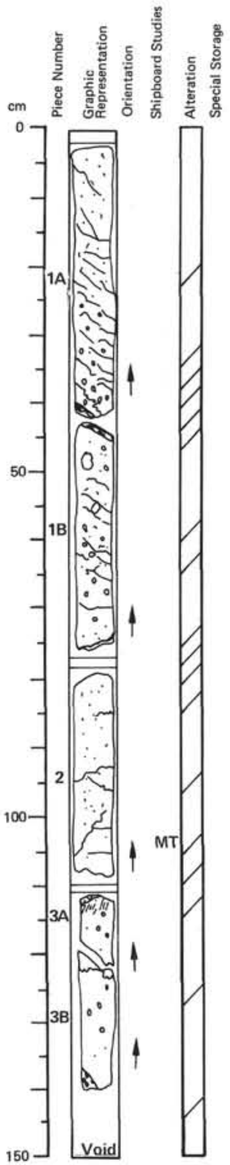


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Altered phyric pillow basalt with chilled margins and minor interpillow breccia. Basalt in piece 3 fractured, cemented by calcite. Basalt gray-violet, altered to yellow-brown near margins. Altered plagioclase phenocrysts 10-15%, <3 mm; altered mafic phenocrysts 5-7%, <0.4 mm. Calcite-filled veins common. Breccia in pieces 1 and 3-5 consists of small, pale green fragments of basaltic glass altered to palagonite, the larger of which are aligned subparallel to pillow margins, in a green matrix of smectite, celadonite and palagonite cemented by veins of calcite and hematite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	42	4

Visual Description

Altered phyric basalt pillows. Intervals 0-42, 42-75, 75-110 and 110-140 represent individual pillows bounded by locally aphyric, 2 cm-wide chilled margins. Basalt gray to gray-violet, altered to yellow-brown or light gray-brown near margins. Altered plagioclase phenocrysts range from 0.5-1.0 mm near margins to <10 mm in pillow interiors; altered mafic phenocrysts 7%, <1 mm. Veins filled by calcite.

Thin Section Description

Location: near chilled margin, 104 cm

Texture: porphyritic, variolitic

Phenocrysts: altered olivine 10%, 0.5-1.0 mm, euhedral; plagioclase 20%, 0.5-2.0 mm, euhedral, some showing overgrowth on partially resorbed grains; clinopyroxene <5%, 0.5-1.0 mm, partially resorbed.

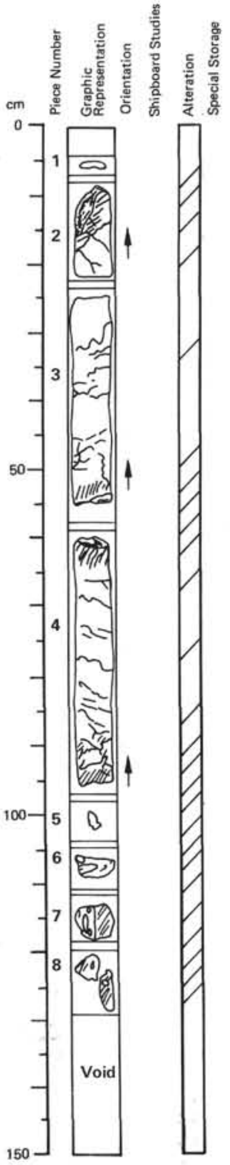
Groundmass: plagioclase 10%, 0.3 mm, skeletal laths, tabular; devitrified glass 55%.

Vesicles: trace, 0.1-1 mm, filled by calcite, smectite.

Alteration: olivine replaced by iddingsite, clay and calcite; glass altered to clay with disseminated hematite.

Shipboard Data

Magnetic Data:	103-106 cm
NRM Intensity (emu/cc)	7.059×10^{-3}
NRM Inclination	-23.6°
Stable Inclination	-22.9°

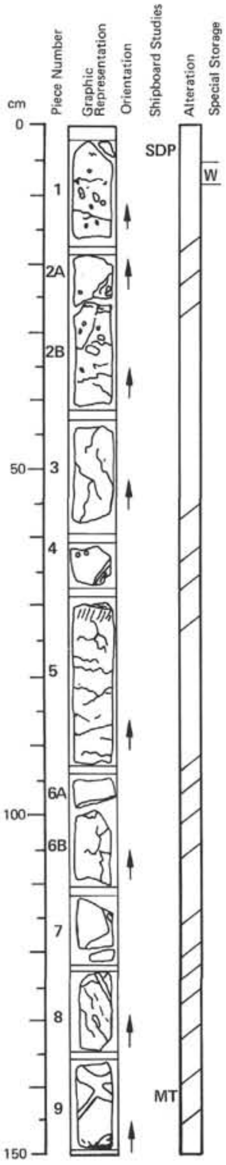


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	42	5

Visual Description

Altered phyric basalt pillows with chilled margins and minor interpillow breccia. Intervals 8-55 and 55-95 represent individual pillows bounded by chilled margins. Basalt gray, altered to gray-violet, yellow-brown along veinlets and margins. Altered plagioclase phenocrysts 20%, <3 mm; altered clinopyroxene phenocrysts 10%, <1 mm; olivine phenocrysts replaced by iddingsite 1%, <1 mm. Veins filled by calcite. Breccia in pieces 1, 6 and 7 consists of yellow-brown to yellow-green fragments of altered basalt (the latter altered to palagonite) in a green matrix of palagonite fragments cemented by smectite and calcite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE			SECT.
5	1	4	1	7	A		4	2	6

Visual Description

Altered phyric basalt with chilled margins and minor breccia in pieces 2A, 4 and 7-9. Pieces 1-4 and 8: basalt gray-brown; altered plagioclase phenocrysts 15%, <5 mm; altered mafic phenocrysts 10%, <0.4 mm. Pieces 5-7 and 9: basalt gray-violet, locally (piece 6A) altered to yellow-brown; plagioclase phenocrysts rare; altered mafic phenocrysts 20-25%, <3 mm. Veins filled by calcite ± analcite. Breccia composed of green fragments of basaltic glass altered to palagonite in a matrix of calcite and analcite.

Thin Section Description

Location: near chilled margin, 145 cm

Texture: porphyritic, variolitic

Phenocrysts: altered olivine 1%, 0.5 mm, euehdral; altered plagioclase phenocrysts 20%, 1-3 mm, euhedral; clinopyroxene 3%, 3 mm, partially resorbed.

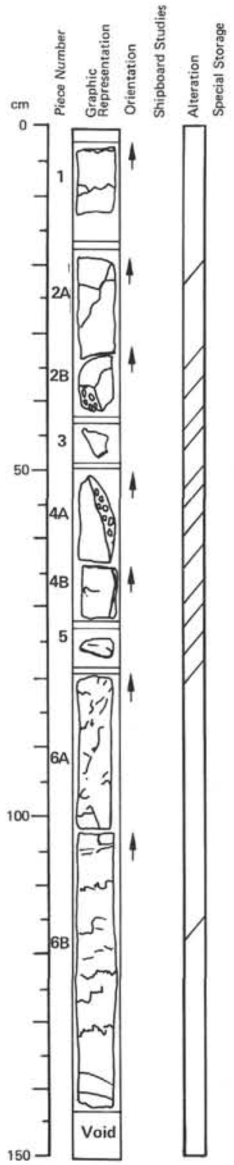
Groundmass: skeletal plagioclase laths 20%, 0.5 mm; altered clinopyroxene and olivine 20%; devitrified glass <35%.

Vesicles: trace, 0.05 mm, filled by smectite, clay and hematite.

Alteration: plagioclase largely altered to clay; olivine replaced by clay, smectite and hematite; veins filled by smectite; groundmass contains disseminated hematite.

Shipboard Data

Magnetic Data:	143-146 cm
NRM Intensity (emu/cc)	5.396×10^{-3}
NRM Inclination	-17.9°
Stable Inclination	-17.8°
Physical Property Data:	4-6 cm
$\overline{V}p$ (km/sec)	5.06
Porosity (%)	6.0
Wet Bulk Density (g/cc)	2.72
Grain Density (g/cc)	2.83

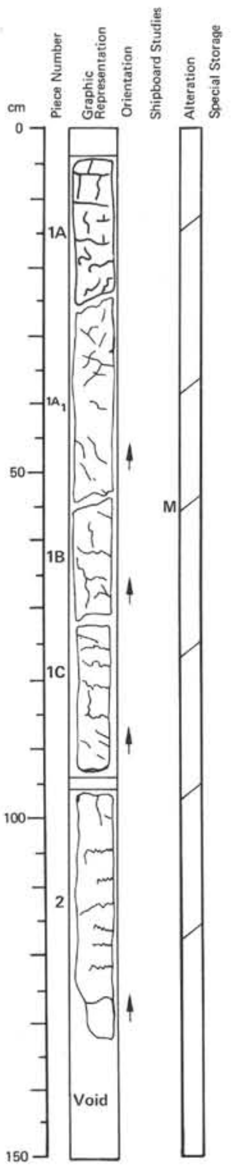


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Altered pyroxene-phyric pillow basalt with chilled margins and minor breccia in pieces 2B, 4 and 5. Basalt gray to gray-violet, altered to yellow-brown near margins. Pyroxene phenocrysts altered to smectite 25%, <2 mm; plagioclase phenocrysts rare except at the base of piece 6B; altered olivine phenocrysts(?) 1%, <1 mm. Veins filled by calcite. Breccia composed of green palagonite fragments in a matrix of calcite and green smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

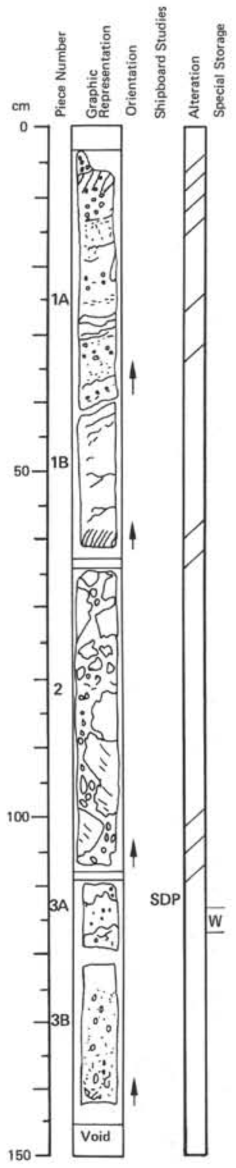
LEG	SITE	HOLE	CORE	SECT.
51	417	A	43	1

Visual Description

Massive phyric basalt with a gray, holocrystalline groundmass. Plagioclase phenocrysts 7%, ≤5 mm; mafic phenocrysts 10%, ≤3 mm. Mafic phenocrysts in piece 2 composed in part (1-2%) of olivine. Veins filled by calcite ± green to brown smectite.

Shipboard Data

Magnetic Data:	59-62 cm
NRM Intensity (emu/cc)	6.390×10^{-3}
NRM Inclination	-21.0°
Stable Inclination	-21.5°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

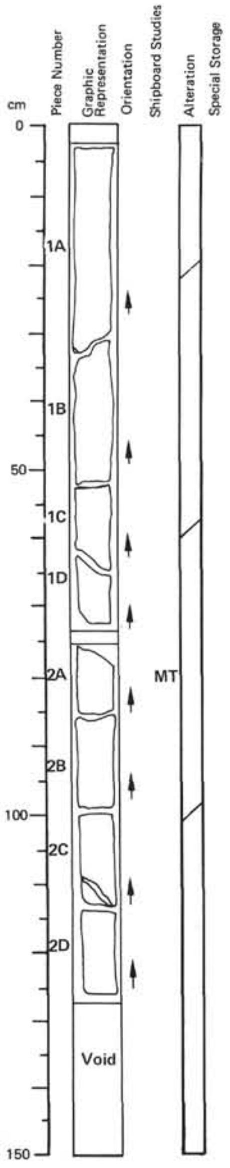
LEG	SITE	HOLE	CORE	SECT.
51	417	A	43	2

Visual Description

Piece 1 consists of a single phyric basalt pillow or thin flow with strongly altered margins and prominent flow banding. The rest of the section represents a massive phyric basalt unit, the top of which (piece 2) consists of a coarse breccia composed of large angular basalt fragments in a basalt matrix, both cut by calcite veins. Basalt gray-violet, altered to yellow-brown or gray-brown along veins and pillow margins. Groundmass aphanitic at the top and bottom of piece 1 and in piece 3A. Plagioclase phenocrysts irregularly distributed, 15%, ≤4 mm; mafic phenocrysts 7-10%, ≤0.5 mm. Veins in piece 3 filled by calcite, smectite and hematite.

Shipboard Data

Physical Property Data:	112-114 cm
$\overline{V}p$ (km/sec)	5.12
Porosity (%)	5.14
Wet Bulk Density (g/cc)	2.75
Grain Density (g/cc)	2.84



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Massive phyric basalt, grading downward through dolerite. Groundmass gray, increasingly coarse-grained with depth, locally glomeroporphyritic. Plagioclase phenocrysts 15-20%, ≤4 mm in piece 1A, decrease with depth to 7% in piece 2; piece 1 contains clinopyroxene and olivine phenocrysts, the latter replaced by smectite, 10-20%, ≤1 mm. Veins filled by calcite ±green to brown smectite.

Thin Section Description

Location: flow interior, 82 cm

Texture: porphyritic, ophitic

Phenocrysts: plagioclase 15-20%, 2-5 mm, zoned An 73-86, tabular, glomerophyric.

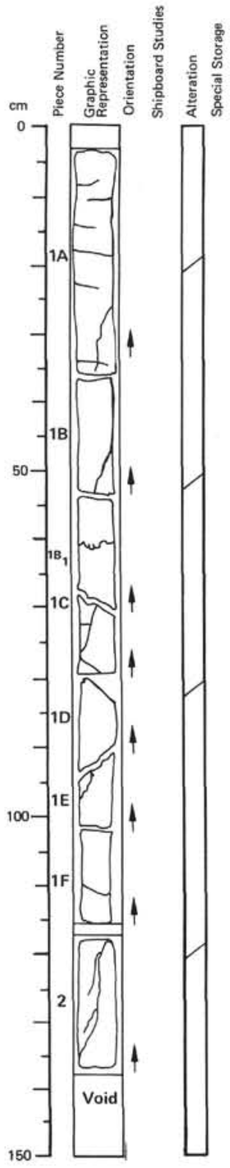
Groundmass: plagioclase 35%, 0.3-0.5 mm, An 68, tabular; clinopyroxene 25%, 0.1-0.2 mm, anhedral; altered magnetite 10%, 0.2 mm, anhedral; altered glass 10%.

Vesicles: 2-4%, 0.5-1.0 mm, round, filled by celadonite(?).

Alteration: institial glass completely altered to clay (celadonite?); magnetite completely altered.

Shipboard Data

Magnetic Data:	80-83 cm
NRM Intensity (emu/cc)	19.701×10^{-3}
NRM Inclination	-12.4°
Stable Inclination	-14.7°

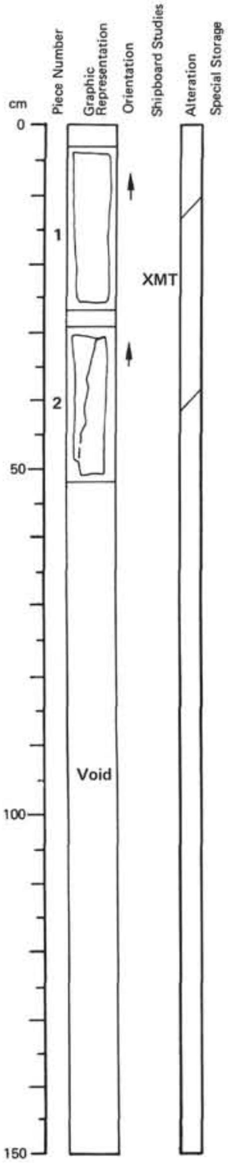


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Massive dolerite with a gray, sparsely-phyric holocrystalline groundmass which increases in grain size from fine- to medium-grained with depth. Plagioclase phenocrysts <5%, <2 mm; clinopyroxene and olivine phenocrysts, the latter replaced by smectite <2%, <2 mm. Veins filled by calcite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Massive, sparsely-phyric dolerite with a gray, fine- to medium-grained, holocrystalline groundmass. Labradorite phenocrysts 3%, <6 mm; mafic phenocrysts composed of clinopyroxene and olivine, the latter replaced by smectite.

Thin Section Description

Location: flow interior, 24 cm

Texture: porphyritic, subophitic

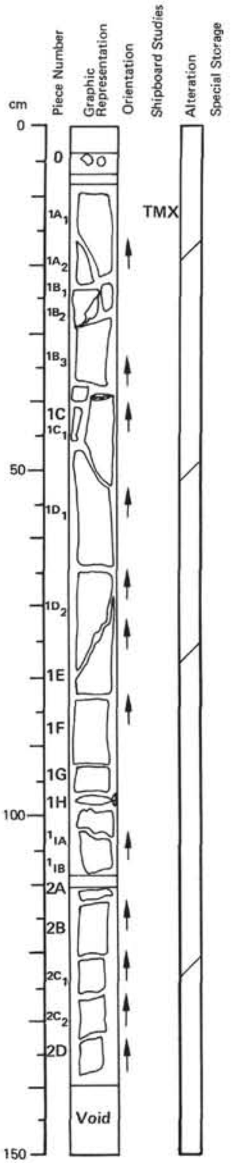
Phenocrysts: fresh zoned plagioclase 10%, 2-5 mm, An >66, tabular.

Groundmass: altered olivine 1%, 0.3-0.4 mm, euhedral; fresh plagioclase microlites 50%, 0.3-1.0 mm, An >45; clinopyroxene (Ti-augite) 30%, 0.5 mm, intergranular to poikilitic; magnetite 5%, 0.1-0.3 mm; devitrified glass 1-2%.

Alteration: olivine replaced by clay and smectite; plagioclase shows incipient alteration to clay.

Shipboard Data

Bulk Analysis: 22-25 cm		Magnetic Data:	22-25 cm
SiO_2	49.64	NRM Intensity (emu/cc)	23.650×10^{-3}
Al_2O_3	16.47	NRM Inclination	-25.3°
Fe_2O_3	11.13	Stable Inclination	-25.6°
MgO	6.41		
CaO	12.69		
Na_2O	2.28		
K_2O	0.02		
TiO_2	1.41		
P_2O_5	0.11		
MnO	0.17		
LOI	0.75		
H_2O^+	0.74		
H_2O^-	N.D.		
CO_2	0.03		



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Massive, locally plagioclase-phyric dolerite with a gray, holocrystalline groundmass which increases in grain size from fine- to medium-grained with depth. Plagioclase phenocrysts 5%, <4 mm; groundmass contains plagioclase, clinopyroxene and minor olivine, the latter replaced by smectite. Veins filled by smectite and calcite +pyrite. Interval between 25-35 cm contains smectite and natrolite(?). Three well-rounded pebbles at top of section altered to pale brown, yellow-brown or olive-gray.

Thin Section Description

Location: flow interior, 13 cm

Texture: porphyritic, ophitic

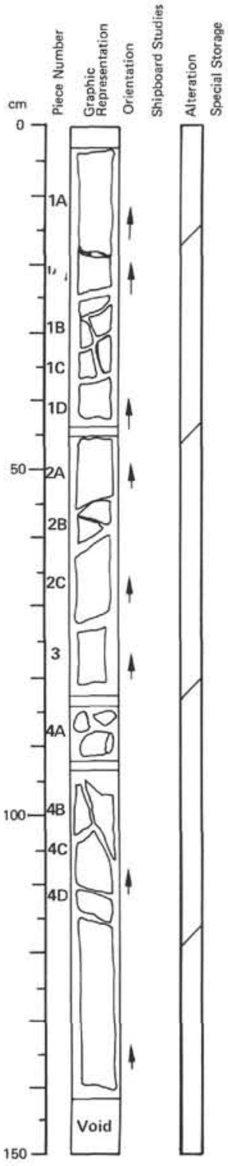
Phenocrysts: olivine 3%, 1 mm, euhedral; plagioclase 20%, 1-2 mm, euhedral to anhedral, glomeroporphyritic; clinopyroxene 3%, 1%, euhedral.

Groundmass: olivine 5%, 0.1 mm, subhedral to euhedral; plagioclase 20%, 0.7 mm; subhedral to euhedral, prismatic; clinopyroxene 30%, 0.7 mm, granular, anhedral, tabular; euhedral magnetite 10%, 0.1 mm; altered glass <5%.

Alteration: olivine replaced by smectite.

Shipboard Data

Bulk Analysis: 12-15 cm		Magnetic Data:	12-15 cm
SiO_2	48.15	NRM Intensity (emu/cc)	25.115×10^{-3}
Al_2O_3	16.23	NRM Inclination	-21.8°
Fe_2O_3	11.56	Stable Inclination	-22.8°
MgO	6.37		
CaO	12.59		
Na_2O	2.22		
K_2O	0.04		
TiO_2	1.44		
P_2O_5	0.13		
MnO	0.17		
LOI	0.30		
H_2O^+	0.77		
H_2O^-	N.D.		
CO_2	0.03		

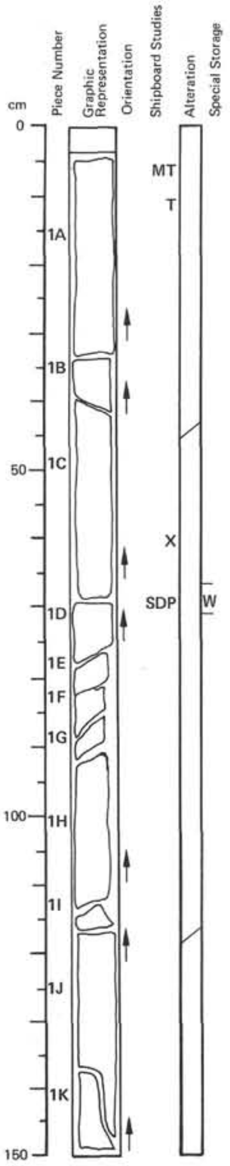


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	44	2

Visual Description

Massive, locally phyric dolerite with a gray, holocrystalline groundmass which increases in grain size from fine- to medium-grained with depth. Plagioclase phenocrysts 1-3%, <4 mm; groundmass contains plagioclase, clinopyroxene and minor olivine, the latter replaced by smectite. Veins filled by calcite; large vein between 95-105 cm filled by calcite, smectite and pyrite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	44	3

Visual Description

Massive, locally plagioclase-phyric dolerite with a gray, medium-grained groundmass which increases in grain size with depth. Plagioclase phenocrysts 2%, <7 mm; groundmass contains plagioclase, clinopyroxene and minor olivine, the latter replaced by smectite. Veins in pieces 1E, 1J and 1K filled by dark green smectite and pyrite ± calcite.

Thin Section Description

Location: flow interior, 6 cm

Texture: ophitic

Phenocrysts: fresh plagioclase 2%, 2-5 mm, zoned with An 55-60 cores and An 35 rims, idiomorphic.

Groundmass: altered olivine(?) 1%, 0.3 mm; plagioclase 50%, 0.2-1.0 mm, An 50, idiomorphic; clinopyroxene (Ti-augite) 40%, 0.1-0.2 mm, poikilitic, light pink; magnetite 5%.

Alteration: olivine(?) completely altered to hematite and smectite.

Thin Section Description

Location: flow interior, 10 cm

Texture: porphyritic, ophitic

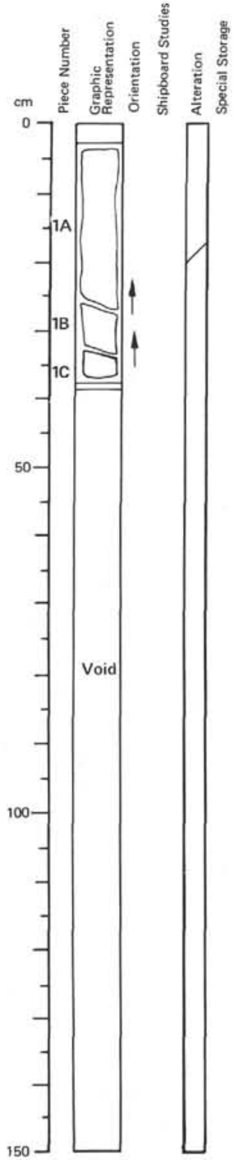
Phenocrysts: plagioclase 25%, 2 mm, subhedral to anhedral, tabular; clinopyroxene 25%, 2 mm, anhedral, plagioclase inclusions common.

Groundmass: altered olivine <5%, anhedral; plagioclase 15%, 0.05 mm, anhedral to subhedral; clinopyroxene 15%, 0.02 mm, anhedral; magnetite 10%, 0.05 mm, euhedral to anhedral, devitrified glass <5%.

Alteration: olivine altered to clay

Shipboard Data

Bulk Analysis: 58-68 cm		Magnetic Data:	8-11 cm
SiO_2	49.73	NRM Intensity (emu/cc)	3.517×10^{-3}
Al_2O_3	16.02	NRM Inclination	-19.9°
Fe_2O_3	11.08	Stable Inclination	-30.5°
MgO	6.92		
CaO	12.47	Physical Property Data:	68-70 cm
Na_2O	2.33	$\overline{V}p$ (km/sec)	5.80
K_2O	0.08	Porosity (%)	2.16
TiO_2	1.45	Wet Bulk Density (g/cc)	2.93
P_2O_5	0.12	Grain Density (g/cc)	2.97
MnO	0.18		
LOI	0.25		
H_2O^+	N.D.		
H_2O^-	N.D.		
CO_2	N.D.		

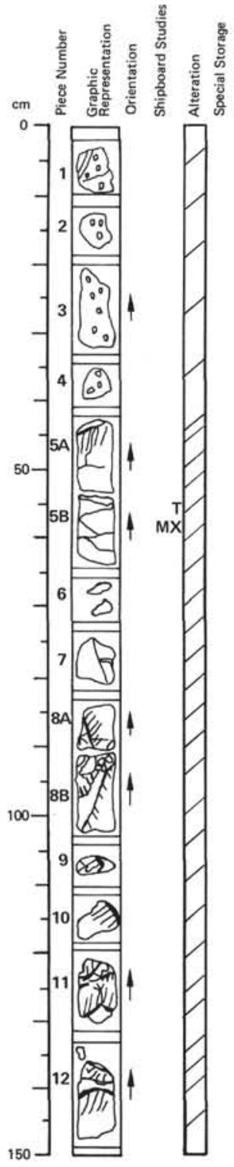


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	44	4

Visual Description

Massive dolerite with a gray, medium-grained groundmass composed of plagioclase, clinopyroxene and minor olivine, the latter replaced by smectite. Groundmass contains irregular patches of calcite and smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	46	1

Visual Description

Pieces 1-4: massive, locally phyric dolerite with a fresh, medium-grained groundmass. Plagioclase phenocrysts 30%, <7 mm; clinopyroxene phenocrysts 20%, <3 mm. Groundmass contains plagioclase, clinopyroxene and fresh olivine. Pieces 5-12: altered phyric pillow basalt with chilled margins and intrusion(?) breccia. Basalt groundmass in both pillows and breccia fragments aphanitic to microlitic. Plagioclase phenocrysts 10%, <3 mm; mafic phenocrysts (clinopyroxene and olivine) 3%, <2 mm; phenocrysts in breccia strongly altered. Breccia matrix composed of calcite (locally scalenohedral) and green smectite. Veins filled by calcite and smectite.

Thin Section Description

Location: pillow interior, 57 cm

Texture: porphyritic, variolitic

Phenocrysts: plagioclase 5%, 0.5 mm, euhedral;clinopyroxene 2%,0.5 mm, partially resorbed.

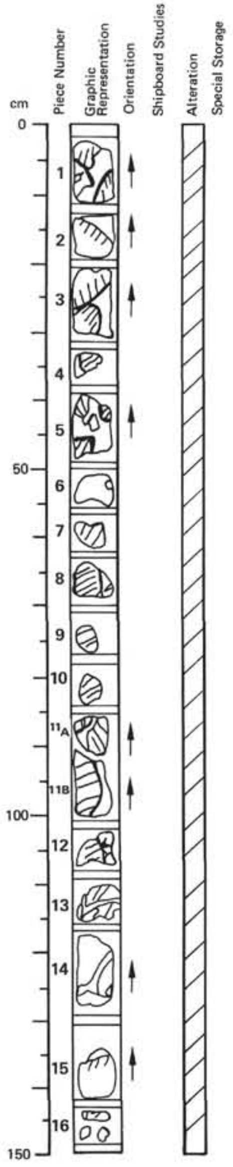
Groundmass: skeletal plagioclase laths 20%, 0.4 mm; granular clinopyroxene 20%, 0.2 mm; devitrified glass 50%.

Alteration: veins filled by calcite, smectite and hematite.

Shipboard Data

Bulk Analysis: 56-59 cm	
SiO_2	48.70
Al_2O_3	15.92
Fe_2O_3	11.23
MgO	6.46
CaO	13.85
Na_2O	1.93
K_2O	0.22
TiO_2	1.44
P_2O_5	0.12
MnO	0.21
LOI	2.20
H_2O^+	1.31
H_2O^-	N.D.
CO_2	1.05

Mangetic Data:	56-59 cm
NRM Intensity (emu/cc)	5.963×10^{-3}
NRM Inclination	-14.8°
Stable Inclination	-15.7°

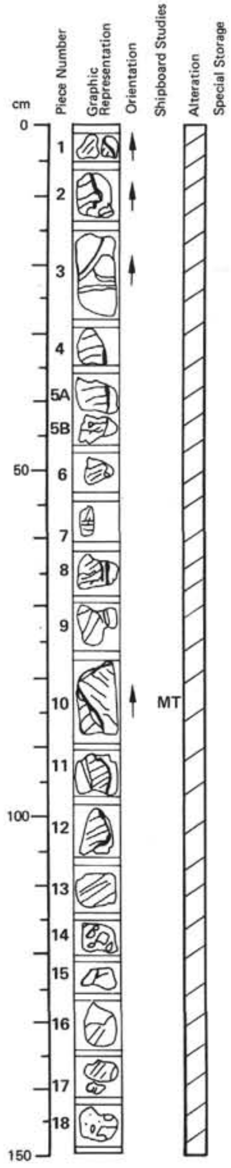


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	46	2

Visual Description

Volcanic breccia composed of phyric pillow basalt fragments, often with chilled margins, in a matrix of calcite and green smectite. Basalt groundmass microcrystalline, locally glassy. Plagioclase phenocrysts 20%, <3 mm; mafic phenocrysts 5%, <2 mm. Calcite in matrix locally coarsely crystalline.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	46	3

Visual Description

Volcanic breccia composed of chilled, phyric pillow basalt fragments, often with strongly altered margins, in a matrix of calcite and green smectite. Basalt groundmass microcrystalline to aphanitic. Plagioclase phenocrysts 20%, <4 mm; mafic phenocrysts 5%, <2 mm.

Thin Section Description

Location: near chilled margin, 84 cm

Texture: porphyritic, variolitic

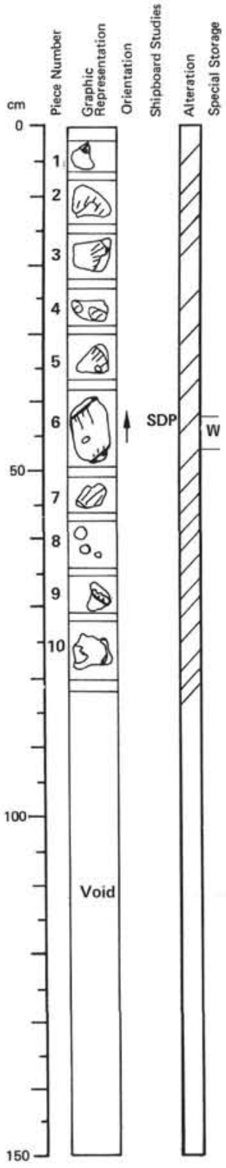
Phenocrysts: altered olivine 3%, 0.5 mm, euhedral; altered plagioclase 15%, 1-2 mm, euhedral; altered clinopyroxene 3%, 0.5 mm, euhedral.

Groundmass: plagioclase laths 20%, 0.2 mm; altered olivine or clinopyroxene 20%, 0.05 mm, anhedral to granular; dendritic magnetite 10%, 0.03 mm; devitrified glass.

Alteration: plagioclase replaced by smectite and zeolites; olivine and clinopyroxene replaced by smectite.

Shipboard Data

Magnetic Data:	82-85 cm
NRM Intensity (emu/cc)	1.526×10^{-3}
NRM Inclination	-31.8°
Stable Inclination	-39.3°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	A	46	4

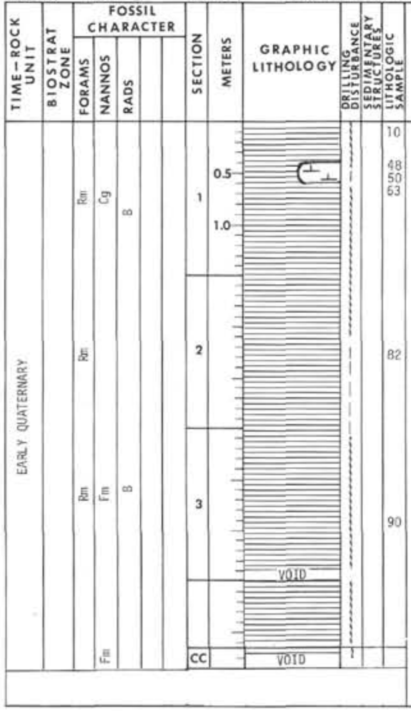
Visual Description

Volcanic breccia composed of phyric pillow basalt fragments, often with strongly altered chilled margins, in a matrix of calcite and green smectite. Basalt groundmass aphanitic to microcrystalline. Plagioclase phenocrysts 10%, <2 mm; clinopyroxene phenocrysts 5-10%, <1 mm. Calcite-filled vesicles 10%, <8 mm. Piece 10 contains a large cavity filled by calcite and zeolites.

Shipboard Data

Physical Property Data:	43-45 cm
$\overline{V}p$ (km/sec)	5.29
Porosity (%)	4.67
Wet Bulk Density (g/cc)	2.71
Grain Density (g/cc)	2.79

SITE 417 **HOLE** B **CORE** 1 **CORED INTERVAL:** 0.0-5.2 m



LITHOLOGIC DESCRIPTION

10YR 4/4
10YR 5/4

NANNOFOSSIL BEARING CLAY highly to moderately disturbed, dark yellowish brown to yellowish brown (10YR 4/4, 10YR 5/4).

Nannofossil bearing Clay (Major Lithology)

Smears: 1-48, 1-50, 1-63, 3-90

10YR 4/4

75% clay min.
8% qtz.
2% feld.
11% heavies and opaques
2% micarb
1% nannofossil
1% fish remains
TR% biotite, chlorite

Nanno Marl (Minor Lithology)

Smears: 1-10, 1-50

10YR 4/4

24% clay min.
8% qtz.
1% feld.
8% heavies and opaques
4% micarb
5% foraminifera
50% nannofossil

Volcanic(?) Ash (Minor Lithology)

Smear: 2-82

10YR 4/4

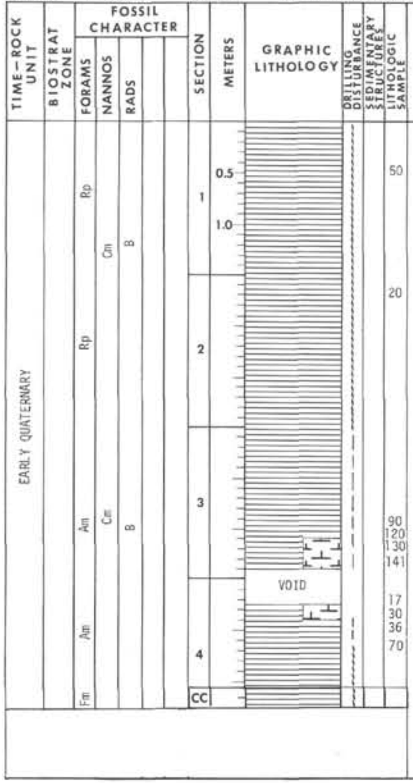
70% clay min.
15% zeolites
15% chert(?)

10YR 4/3

Carbon, Carbon-Carbonate

1-30 (0.3, 0.1, 1)
1-80 (0.2, 0.1, 1)

SITE 417 **HOLE** D **CORE** 1 **CORED INTERVAL:** 0.0-7.5 m



LITHOLOGIC DESCRIPTION

10YR 4/3

NANNOFOSSIL BEARING CLAY and NANNO MARL. Moderately to highly disturbed, brown (10YR 4/3) grading to light yellowish brown (10YR 6/4) in the marl zone.

Nanno-bearing Clay/Nanno Marl (Major Lithology)

Smears: Average of 6

79% clay min.
2% fish remains
2% micarb
6% qtz.
1% feld.
2% zeolites

Marl (Minor Lithology)

Smears: Average of 5

10YR 4/3

42% clay min.
7% forams
37% nannofossils
2% micarb
6% qtz.
6% heavies and opaques
TR% fish remains, volcanic glass

10YR 5/4

CORE 2 REPRESENTS THE DRILLED INTERVAL BETWEEN 7.5 AND 125.4 m. THE 2.5 METERS OF RECOVERED SEDIMENT HAS BEEN PRESERVED BUT WAS NOT DESCRIBED.

Grain Size

10YR 4/3

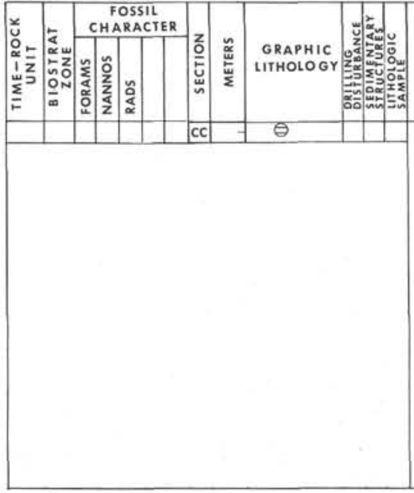
1-3
0.0% sand
9.4% silt
90.5% clay

10YR 4/3

Carbon, Carbon-Carbonate

3-19 (0.2, 0.1, 1)
3-123 (1.8, 0.1, 15)

SITE 417 **HOLE** D **CORE** 2 & 3 **CORED INTERVAL:** 125.4-135.0 m



LITHOLOGIC DESCRIPTION

Recovery consisted only of:

Lump of clay in CC:

Smears: Average of 2

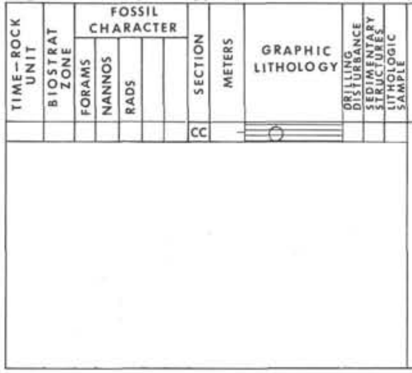
67% clay min.
4% qtz.
1% mica
25% clinoptilolite
3% heavies and opaques

CORE 4: NO RECOVERY.

CORE 5: REPRESENTS THE DRILLED INTERVAL BETWEEN 144.5 and 192 m. THE 0.9 m OF RECOVERED SEDIMENT HAS BEEN PRESERVED BUT WAS NOT DESCRIBED.

Section 1, and CC
M. Eocene
P. mitra Zone
Rads - Ag

SITE 417 **HOLE** D **CORE** 6 **CORED INTERVAL:** 192.0-201.5 m



LITHOLOGIC DESCRIPTION

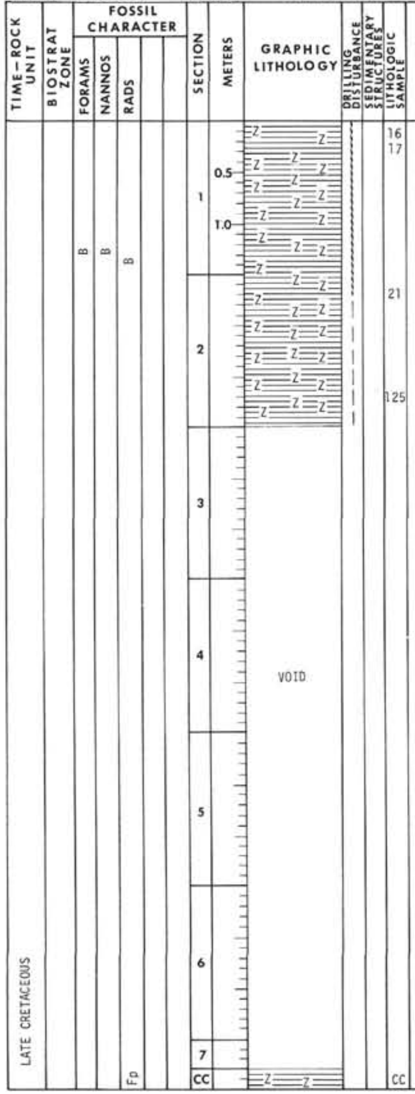
The only recovery consisted of:

Lump of clay in the CC:

Smears: Average of 2

63% clay min.
1% fish remains
5% micarb
8% qtz.
4% plagioclase
1% feld.
2% mica
1% clinoptilolite
10% heavies and opaques
5% dolomite(?)

SITE 417 **HOLE** D **CORE** 7 **CORED INTERVAL:** 201.5-211.1 m



LITHOLOGIC DESCRIPTION

10YR 5/4

ZEOLITIC CLAY
Highly to moderately disturbed, firm, moderate yellowish brown to dark yellow brown (10YR 5/4, 10YR 4/2-2/2) with layers 1-3 cm thick of grayish orange (10YR 7/4) in Section 2 at 20, 60, 130 cm. There is a diffuse banding of ?Fe/Mn at tops of grayish orange bands in Section 2.

10YR 4/2-2/2

Zeolitic Clay (Major Lithology)

Smears: Average of 3

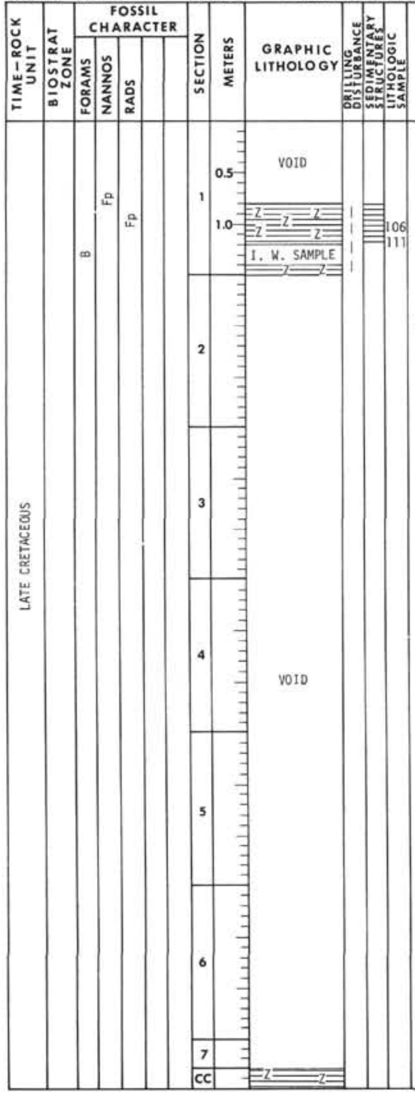
71% clay min.
1% nannofossils
2% fish remains
4% qtz.
2% feld.
15% clinoptilolite
6% heavies and opaques
TR% forams, mica, ?dolomite

Grayish orange bands (Minor Lithology)

Smears: Average of 2

74% clay min.
2% fish remains
6% qtz.
3% feld.
7% clinoptilolite
8% heavies and opaques

SITE 417 **HOLE** D **CORE** 8 **CORED INTERVAL:** 211.1-220.5 m



LITHOLOGIC DESCRIPTION

10YR 3/3

10YR 4/4

ZEOLITIC CLAY firm, slightly disturbed, brown (10YR 3/3) (81-112 cm) and yellowish brown (10YR 4/4) (112-136 cm); laminated on 1 mm scale with black (10YR 3/1) clay. Black layers decrease in thickness and abundance downward.

10YR 4/2
with
10YR 6/5

Core Catcher sample is interlayered on scale of 1-3 cm; yellowish orange (10YR 6/5) with dark yellowish brown (10YR 4/2); thin sandy layer at base.

Zeolitic Clay (Major Lithology)

Smears: Average of 2

82% clay min.
6% qtz.
12% clinoptilolite

Dark bands (Minor Lithology)

Smears: Average of 2

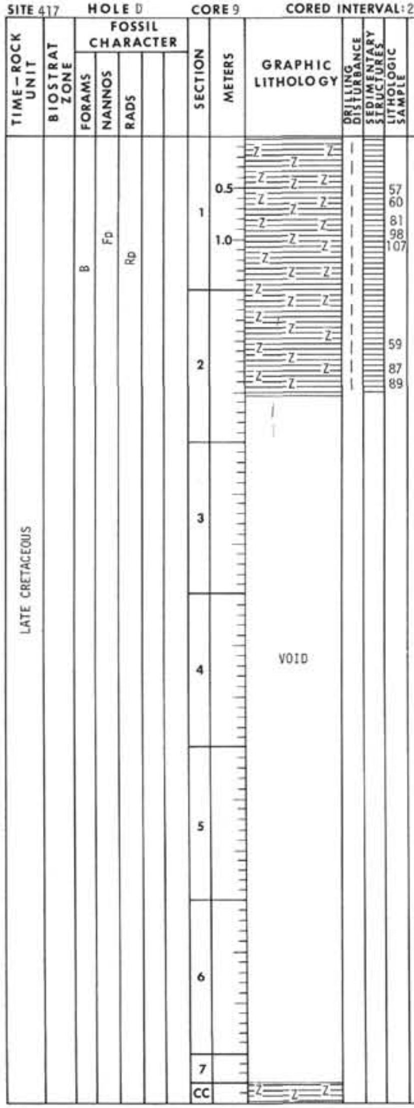
57% clay min.
5% qtz.
1% plagioclase
31% clinoptilolite
6% heavies and opaques

Sandy layer (Minor Lithology)

Smears: CC

50% clay min.
50% clinoptilolite

SITE 417 HOLE D CORE 9 CORED INTERVAL: 220.5-229.9 m



LITHOLOGIC DESCRIPTION

10YR 5/6
with minor
10YR 3/2

and

10YR 5/6
with minor
5BG 3/2

ZEOLITIC CLAY
Firm, slightly disturbed; dominantly (66%) yellowish brown (10YR 5/6) interlayered with pale blue green (5BG 7/2) on scale of 1-5 cm; layering apparently secondary. Very dark grayish brown (10YR 3/2) zone from 56-73 m in Section 1; slightly silty throughout.

Zeolitic Clay, brown color (Major Lithology)

Smears: Average of 4

67% clay min.
1% fish remains
2% qtz.
1% plagioclase
1% feld.
26% clinoptilolite
1% heavies and opaques
1% volc. glass
TR% rads, mica

Pale blue green color (Minor Lithology)

Smears: Average of 5

55% clay min.
1% qtz.
44% clinoptilolite
TR% plagioclase, mica, volc. glass

Dark spots and laminae (Minor Lithology)

Smears: Average of 2

75% clay min.
20% clinoptilolite
5% heavies and opaques

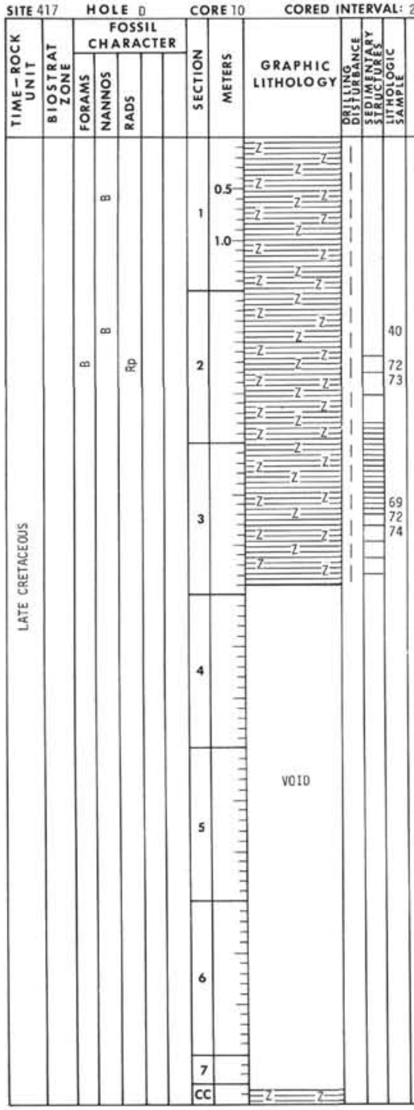
Grain Size

1-28
0.4% sand
29.8% silt
69.9% clay

Carbon, Carbon-Carbonate

1-74 (0.1, 0.1, 0)
2-52 (0.1, 0.1, 0)

SITE 417 HOLE D CORE 10 CORED INTERVAL: 229.9-239.2 m



LITHOLOGIC DESCRIPTION

10YR 5/6

ZEOLITIC CLAY
Firm, slightly disturbed, dominantly yellowish brown (10YR 5/6) with 3% layers on scale of 1 cm of pale blue green (5BG 7/2) silty clay which are slightly graded. Some black laminae.

ZEOLITIC CLAY (Major Lithology)

10YR 5/6
with minor
5BG 7/2

Smears: Average of 7

77% clay min.
1% fish remains
2% qtz.
1% plagioclase
18% clinoptilolite
1% ?cristobalite
TR% heavies and opaques, mica

10YR 5/6
with minor
5BG 7/2

Green color, silty (Minor Lithology)

Smear: 3-74

50% clay min.
50% clinoptilolite
TR% nannofossils

Gray sediment (Minor Lithology)

Smear: 2-72

70% clay min.
5% clinoptilolite
25% opaques

Mn micronodule (Minor Lithology)

Smear: Section 2

40% clay min.
2% fish remains
10% clinoptilolite
48% opaques

Black Sediment (Minor Lithology)

Smear: 2-73

76% clay min.
2% fish remains
22% clinoptilolite

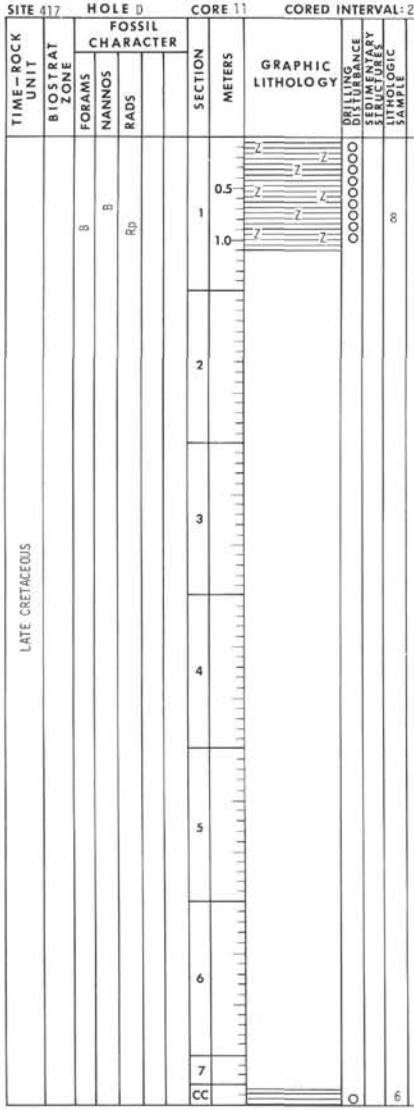
Grain Size

1-54
0.6% sand
14.8% silt
84.7% clay

Carbon, Carbon-Carbonate

1-88 (0.1, 0.1, 0)
3-11 (0.1, 0.1, 0)
3-66 (0.1, 0.1, 0)

SITE 417 **HOLE** D **CORE** 11 **CORED INTERVAL:** 239.2-247.6 m



LITHOLOGIC DESCRIPTION

ZEOLITIC CLAY and CLAYSTONE
Highly disturbed, drilling breccia; dominantly brown to yellowish brown (7.5YR 5/4, 10YR 5/4) clay and claystone with pieces of pale blue green (5BG 7/2) claystone.

ZEOLITIC CLAY (Major Lithology)

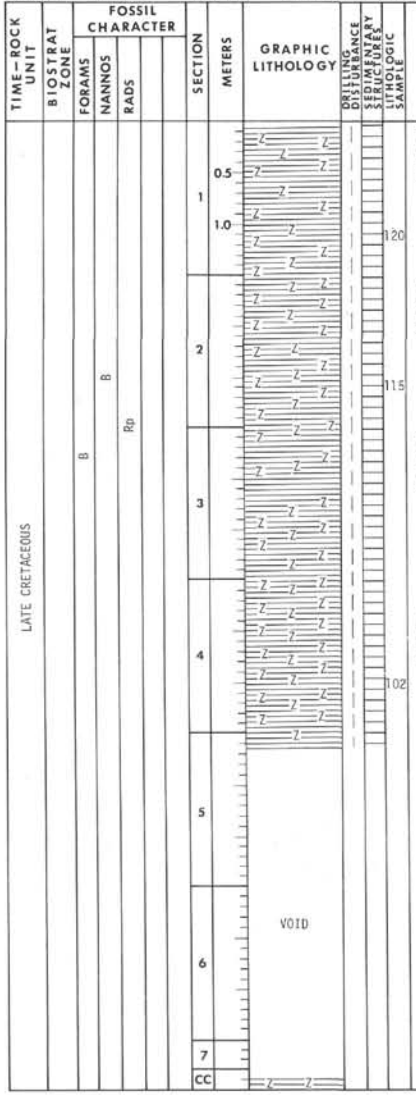
Smears: Average of 2

71% clay min.
28% clinoptilolite
1% heavies and opaques
TR% plagioclase, chlorite

Carbon, Carbon-Carbonate

1-54 (0.1, 0.1, 0)

SITE 417 **HOLE** D **CORE** 12 **CORED INTERVAL:** 248.6-258.2 m



LITHOLOGIC DESCRIPTION

7.5YR 5/6
with
minor
5BG 7/2

ZEOLITIC CLAY
Firm, slightly disturbed/ dark brown to brown (7.5YR 5/6, 7.5YR 5/6) clay with interlayered 23% pale blue green (5BG 7/2) on a scale of 1/2 to 5 cm.

Zeolitic Clay (Major Lithology)

Smears: Average of 2

7.5YR 5/4
with
minor
5BG 7/2

69% clay min.
5% qtz.
18% clinoptilolite
8% heavies and opaques
TR% apatite, mica

Pale blue green sediment (Minor Lithology)

Smears: Average of 2

67% clay min.
5% qtz.
4% plagioclase
24% clinoptilolite
TR% feld., mica

7.5YR 5/4
with
minor
5BG 7/2

White bed (Minor Lithology)

Smear: 4-102

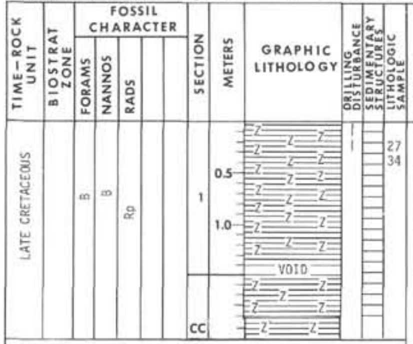
96% clay min.
3% clinoptilolite
1% (?)dolomite
TR% qtz., plagioclase

7.5YR 5/6
with
minor
5BG 7/2

Carbon, Carbon-Carbonate

3-19 (0.1, 0.1, 0)

SITE 417 **HOLE** D **CORE** 13 **CORED INTERVAL:** 258.2-267.7 m



LITHOLOGIC DESCRIPTION

5YR 5/6
to
7.5YR 5/6
with
minor
5BG 7/2
and
5YR 2/1

ZEOLITIC CLAY
Very firm, only slightly disturbed in places; dominantly brown (5YR 5/6 to 7.5YR 5/6) interlayered with 12% pale blue green (5BG 7/2) on scale of 1/2 to 4 cm and 4% brownish black (5YR 2/1) on similar scale. Five thin zones of black laminae (5YR 2/2) in Section 2, 10-20 cm.

ZEOLITIC CLAY (Major Lithology)

Smear: 1-27

68% clay min.
30% clinoptilolite
2% plagioclase
TR% qtz., mica

Dark gray sediment (Minor Lithology)

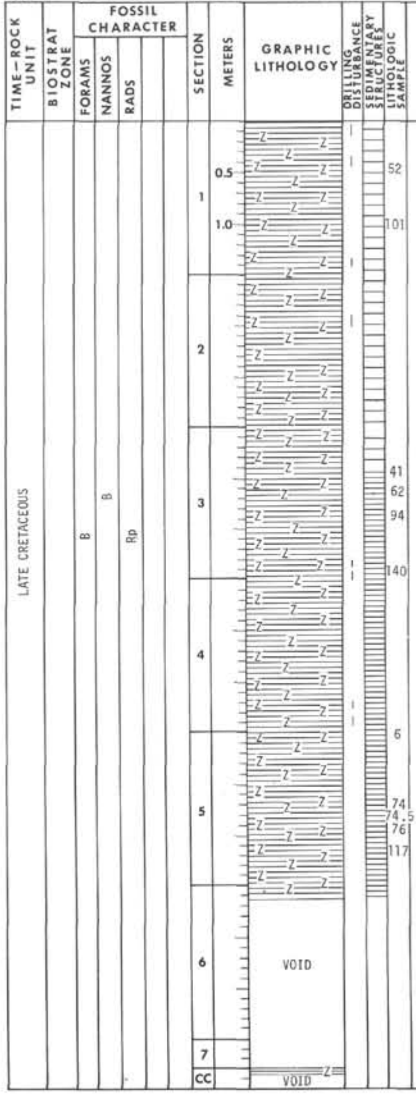
Smear: 1-34

72% clay min.
10% clinoptilolite
15% heavies and opaques
3% (?)siderite/rhodochrosite

Carbon, Carbon-Carbonate

1-5 (0.1, 0.1, 0)
2-20 (0.1, 0.1, 0)

SITE 417 **HOLE** D **CORE** 14 **CORED INTERVAL:** 267.7-277.3 m



LITHOLOGIC DESCRIPTION

10YR 5/4

10YR 5/4
to
7.5YR 5/4

7.5YR 7/6
with
minor
5BG 7/2

7.5YR 5/6
with
minor
5BG 7/2

7.5YR 5/4
to
10YR 4/3

ZEOLITIC CLAY
Very firm, slightly disturbed; dominantly moderate yellowish brown and strong brown (10YR 5/4, 7.5YR 5/6) with 14% bluish beds, mainly pale blue green (5BG 7/2), but also including pale blue green (5BG 6/2), dusky yellowish green (5GY 5/2), and grayish green (10GY 5/2). Minor beds of light grayish orange (10YR 7/4), pale brown (10YR 6/3), light brownish gray (10YR 6/2) and olive brown (2.5Y 4/4); bedding on a scale of 1/2 to 6 cm.

ZEOLITIC CLAY (Major Lithology)

Smears: Average of 7

66% clay min.
2% radiolaria
1% fish remains
1% micarb
2% qtz.
1% feld.
21% clinoptilolite
3% heavies and opaques
TR% apatite, mica

Sandy laminae (Minor Lithology)

Smears: 3-41, 3-62

24% clay min.
72% clinoptilolite
2% heavies and opaques
2% micarb

Pale blue green sediment (Minor Lithology)

Smears: Average of 5

49% clay min.
1% qtz.
45% clinoptilolite
4% heavies and opaques
1% fish remains

Olive brown sediment (Minor Lithology)

Smear: 5-6

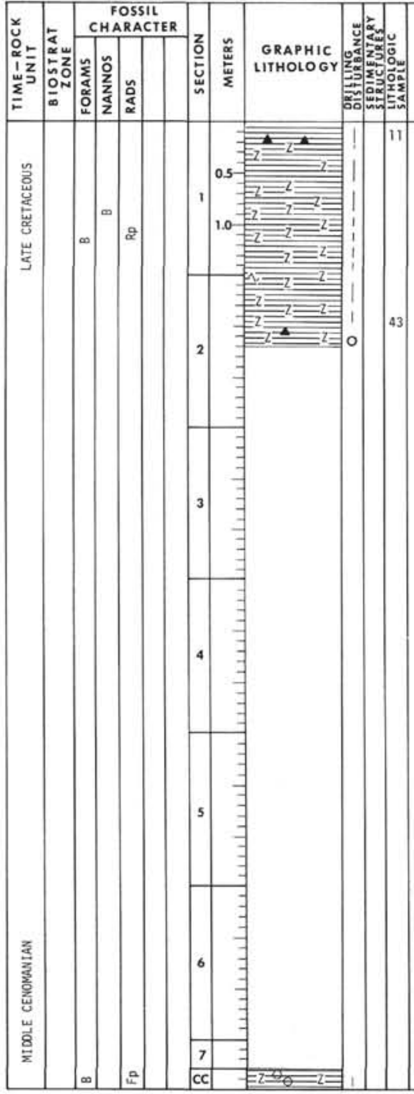
48% clay min.
50% clinoptilolite
2% heavies and opaques

$CaCO_3$ Bomb: 3-140 = 0%
5-21 = 0%

Carbon, Carbon-Carbonate

1-40 (0.1, 0.1, 0)
3-143 (0.1, 0.1, 0)
5-20 (0.1, 0.1, 0)

SITE 417 HOLE D CORE 15 CORED INTERVAL: 277.3-286.8 m



LITHOLOGIC DESCRIPTION

7.5YR 4/4
to
10YR 5/2

ZEOLITIC CLAY
Very firm, slightly to moderately disturbed; 70% grayish brown (10YR 5/2), 20% brown (7.5YR 4/4) and 5% grayish blue green (5BG 5/2), layered on a scale of 1-2 cm. Sediment irregularly lithified; a great deal is claystone.

<u>Zeolitic Clay</u> (Major Lithology)

Smear: 2-43

7.5YR 4/4
to
10YR 5/2

40% clay min.
57% clinoptilolite
3% heavies and opaques

$CaCO_3$ Bomb: 1-72% = 0%
2-28% = 0%

Smear: brown claystone

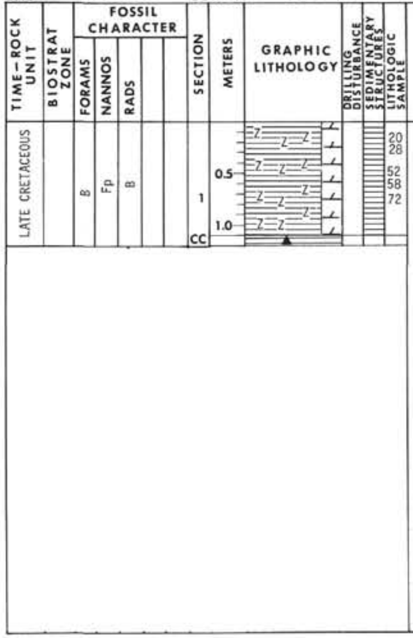
35% clay min.
65% clinoptilolite

ZEOLITIC CLAYSTONE
Lithified, disturbed, laminated; olive gray to grayish brown (5Y 5/2, 10YR 5/2), brown (10YR 5/3), and brown and blue green (7.5YR 5/2 and 5BG 6/2).

<u>Carbon, Carbon-Carbonate</u>

1-74 (0.1, 0.1, 0)
2-36 (0.1, 0.1, 0)

SITE 417 HOLE D CORE 16 CORED INTERVAL: 286.8-296.3 m



LITHOLOGIC DESCRIPTION

ZEOLITIC, (?)DOLOMITIC, PHOSPHATIC CLAYSTONE
Hard, undisturbed; pale blue green (5BG 7/2) laminated with darker shades (5BG 6/2 to 5BG 3/2) and black (5BG 2/2); scattered pyrite crystals.

<u>Claystone</u> (Major Lithology)

Smears: Average of 5

52% clay min.
20% clinoptilolite
25% dolomite
3% heavies and opaques
(largely pyrite)

<u>Black laminae</u> (Minor Lithology)

Smear: 1-77

25% clay min.
5% dolomite
70% fish remains

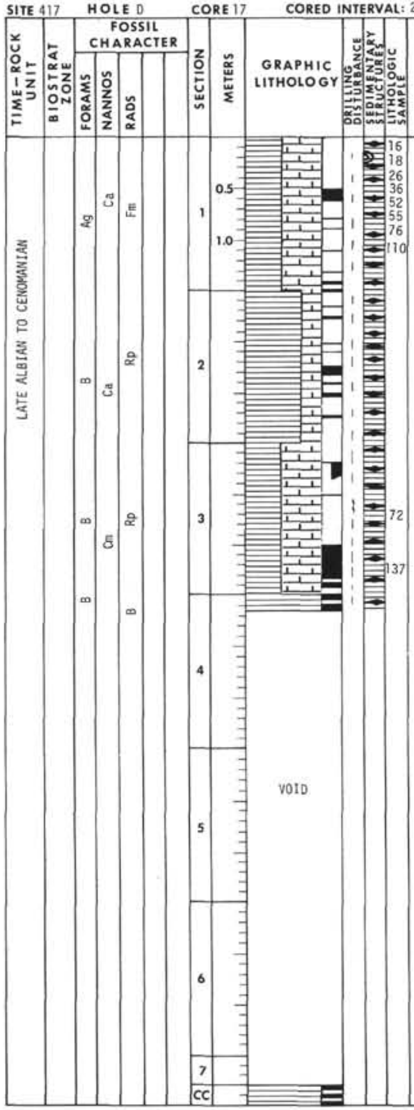
The Core Catcher contains a chalcedonic, brown/black lustrous chert with procellanite layer adhering to one side, and with sulfide crystals.

$CaCO_3$ Bomb: 1-106 = 6%
1-42 = 2%

<u>Carbon, Carbon-Carbonate</u>

1-105 (0.4, 0.2, 2)

SITE 417 **HOLE** D **CORE** 17 **CORED INTERVAL:** 296.3-305.9 m



LITHOLOGIC DESCRIPTION

INTERLAYERED (I) CLAYSTONE: (II)PHOSPHATIC, (?)DOLOMITIC ORGANIC PYRITIC CLAYSTONE; (III)CLAYEY NANNOFOSSIL CHALK; (IV)RADIOLARIAN- and FORAM-BEARING NANNOFOSSIL CHALK. All sediments hard, slightly brecciated by drilling.

NOTE: Position of black, organic layers shown by markings in right-hand column. Entire section interlayered on scale of 1-15 cm and further laminated on a mm scale. Minor lithologies include: yellow "sand" in CC with 65% clay, 5% fish remains, 28% clinoptilolite, and 2% heavies and opaques; sphalerite noted in CC.

I: (27%) - grayish, bluish green (5BG 5/2-5/1) gradational contact, mottled with II and, rarely, with IV. Burrowed, not calcareous.

Smear: 1-36

84% clay min.
10% nannofossils
5% (?)dolomite
1% micarb

II: (36%) - black to very dark gray, finely laminated (2.5Y 2.5-3/0), lustrous, crumbly, slightly calcareous.

Smears: Average of 2

18% clay min.
4% nannofossils
8% radiolaria molds
10% fish remains
1% micarb
29% (?)dolomite
5% qtz.
25% heavy and opaque (mainly pyrite)
TR% mica, apatite
TR% sphalerite

$CaCO_3$ Bomb: 3-140 = 7%

III: (30%) - very dark gray brown, dark gray (2.5Y 3/2, 2.5Y 4/0) laminated with light gray (2.5Y 0/0).

Smears: Average of 4

20% clay min.
74% nannofossils
2% foraminifera
1% micarb
1% (?)dolomite
2% heavies and opaques
TR% fish remains

IV: (7%) - whitish to light gray (5Y 6/1) mottled and laminated.

Smears: Average of 3

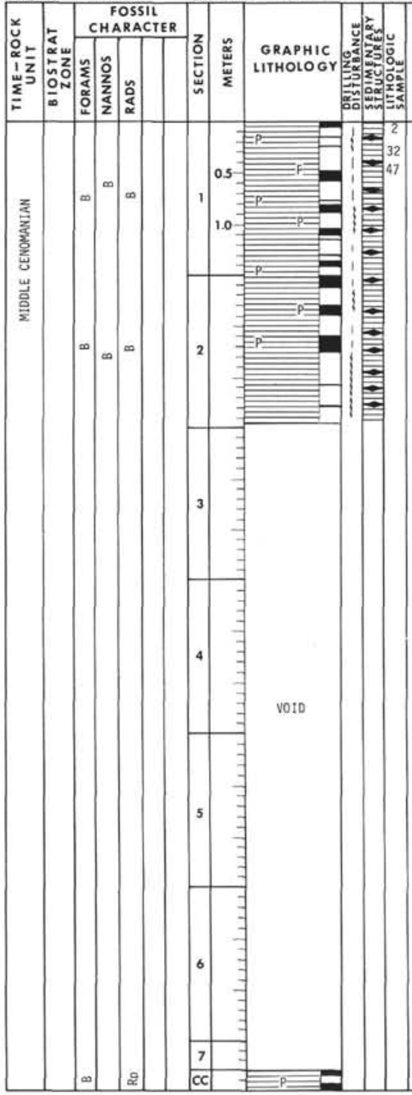
2% clay min.
43% nannofossils
7% foraminifera
10% radiolarian molds
32% micarb
2% (?)dolomite
1% apatite

$CaCO_3$ Bomb:
1- 40 = 43%
1- 46 = 1%
3- 57 = 53%
3- 85 = 33%
3-133 = 0%

Carbon, Carbon-Carbonate

1-90 (5.9, 1.6, 36)
4-5 (6.4, 5.5, 8)

SITE 417 **HOLE** D **CORE** 18 **CORED INTERVAL:** 305.9-315.4 m



LITHOLOGIC DESCRIPTION

INTERLAYERED (I)CLAYSTONE; (II)PHOSPHATIC, (?)DOLOMITIC PYRITIC CLAYSTONE. Hard, brecciated by drilling.

NOTE: Position of black, organic layers shown by markings in right-hand column. Entire section interlayered on a scale of 1-15 cm and further laminated on a mm scale.

I: (69%) - pale blue green to grayish blue; green (5BG 7-5/2); contacts sharp on top, gradational on bottom; burrowed, including "Chondrites"; noncalcareous.

Smear: 1-2

93% clay min.
5% pyrite
2% fish remains

$CaCO_3$ Bomb: 2-91 = 7%

II: (31%) - black to brownish black (5YR 2/1); faint laminae present but not common; burrows not common. Pods of pyrite present.

$CaCO_3$ Bomb: 2-68 = 8%
2-9 = 7%

Pyrite Pod (Minor Lithology)

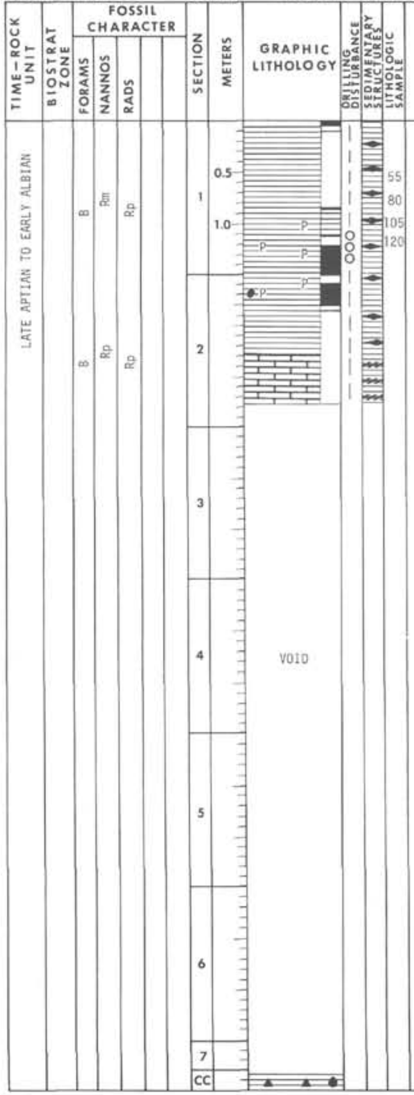
Smear: 1-47

5% feld.
2% fish remains
93% pyrite
TR% sphalerite

Carbon, Carbon-Carbonate

1-57 (0.1, 0.1, 0)
2-70 (2.3, 2.1, 2)

SITE 417 HOLE D CORE 19 CORED INTERVAL: 315.4-325.0 m



LITHOLOGIC DESCRIPTION

INTERLAYERED (I)CLAYSTONE; (II)PHOSPHATIC, (?)DOLOMITIC, PYRITIC CLAYSTONE; (IV) RADIOLARIAN- and FORAM-BEARING NANNOFOSSIL LIMESTONE. Hard, locally brecciated by drilling.

NOTE: Position of black, organic layers shown by markings in right-hand column.

I: (60%) - grayish blue green (5BG 5/2) to dusky blue green (5BG 3/2); laminated, burrowed throughout.

Smears: Average of 2

86% clay min.
10% nannofossils
2% (?)dolomite
2% heavies and opaques
TR% feld., mica

II: (26%) - black, finely laminated, with pyrite.

Smear: 1-105

7% clay min.
5% fish remains
2% mica
3% clinoptilolite
28% heavies and opaques

$CaCO_3$ Bomb: 1-94 = 3%
2-3 = 0%

IV: (14%) - pinkish gray (7.5YR 7/2), light brown (7.5YR 6/4), pale or grayish blue green (5BG 7-5/2); color laminated and burrowed, with micro-faults; contacts sharp.

Smear: 2-120

20% nannofossils
80% micarb
TR% qtz., heavies and opaques

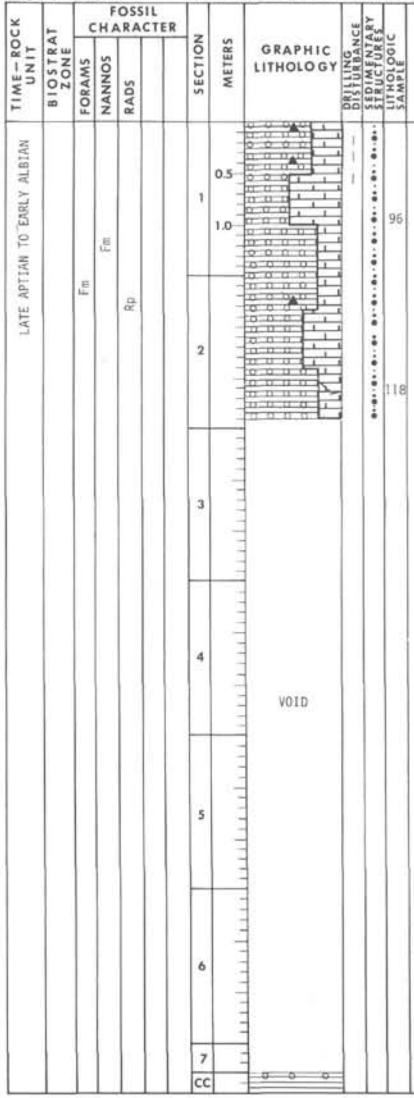
A pyrite nodule, 4x3x6 cm, occurs in Section 2, 19 cm and two pieces of chert and 1 pyrite nodule (3x5x1 cm) found in the Core Catcher.

$CaCO_3$ Bomb: Clay parting in IV, 2-106 = 2%

Carbon, Carbon-Carbonate

1-16 (0.1, 0.1, 0)
1-134 (4.6, 0.4, 35)

SITE 417 HOLE D CORE 20 CORED INTERVAL: 325.0-334.5 m



LITHOLOGIC DESCRIPTION

7.5YR 5/4
to
5YR 4/4
with
minor
5BG 7/2

CYCLIC RADIOLARIAN SANDSTONE to CLAYSTONE and NANNO CHALK. Hard, somewhat brecciated by drilling in part silicified (chert).

Sediment consists of turbidite cycles, but with imperfectly displayed size grading. Basal contact is sharp, with sand-sized radiolarian molds; commonly pale blue green (5BG 7/2). Grades upward to brown (7.5YR 5/4), burrowed claystone to reddish brown (5YR 4/4) homogeneous claystone at top. Cycles average 12 cm in thickness. Blue color at base is irregular, occasionally absent, and apparently secondary. A few of the coarser beds have been silicified to a dark yellowish brown (10YR 4/4) chert.

Coarser sand

Smear: 2-118

10% clay min.
20% nannos
60% radiolarian molds
10% micarb

Claystones

Smears: Average of 2

39% clay min.
34% nannofossils
14% micarb
11% feld.
2% heavies and opaques
TR% fish remains, plagioclase, chlorite, clinoptilolite, apatite

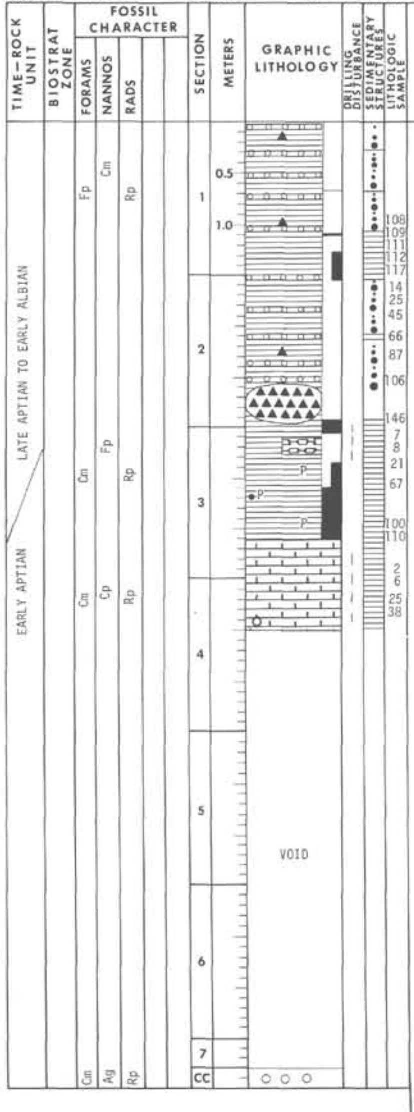
$CaCO_3$ Bomb: fine grained portions 2-24 = 1%
2-126 = 11%
1-61 = 1%

Core Catcher contains angular, very soft pebble of a celadonitic alteration product of basalt.

Carbon, Carbon-Carbonate

1-19 (8.5, 0.0, 70)
1-42 (7.3, 0.0, 61)
2-21 (3.7, 0.0, 31)

SITE 417 HOLE D CORE 21 CORED INTERVAL: 334.5 - 352.5 m



LITHOLOGIC DESCRIPTION

Core consists of four lithological groups, with lithologies repeated in part in groups A and C.

A. (Section 1, Section 2 to 108 cm) CYCLIC RADIOLARIAN SANDSTONE to CLAYSTONE with minor interbedded (I)CLAYSTONE, and (II)PHOSPHATIC, (?)DOLOMITIC, ORGANIC, PYRITIC CLAYSTONE. Hard, slightly brecciated by drilling. Radiolarian sandstone/claystone (70%) is dark reddish brown (5YR 3/3) to brownish gray (5YR 4/1).

Fine grained - Smear: 1-117

95% clay min.

5% heavies and opaques

Coarse grained - Smears: Average of 4

57% clay min.
1% nannofossils
32% radiolarian molds
5% micarb

2% celadonite
2% feld.
1% heavies and opaques

I: (20%) - greenish gray (5G 5/2-10G 4/2), laminated.

Smears: Average of 3

78% clay min.
19% feld.

3% heavies and opaques

II: (10%) - black and olive gray (5Y 4/1).

Smears: Average of 3

52% clay min.
4% nannofossils
2% radiolaria
1% fish remains
9% cristobalite

6% feld.
2% mica
2% heavies and opaques
9% pyrite
6% organic

B. (Section 2, 108-143 cm) CHERT layer, medium gray (N4) with bluish gray green (5BG /2) angular mm scale clasts of celandonitic debris. Clasts altered to golden, shimmering color in center of layer.

C. (Section 2, 143 - Section 3, 110 cm) Interlayered lithologies, (IV)RADIOLARIA- and FORAM-BEARING NANNOFOSSIL CHALK. Lithologies I (15%) and II (65%) described above. IV (20%) light greenish gray (5G 8/1), greenish gray (5G 6/1) and dark green gray (10G 4/2) laminated, burrowed, moderately disturbed by drilling. Sphalerite found in pod of pyrite at 3-100.

Smears: Average of 3

2% clay min.

98% nannofossils

CaCO$_3$ Bomb: Section 3-21 = 43%

1-54 = 1%
1-29 = 1%
3-21 = 43%

D. (Section 3, 110 cm to Section 4, 50 cm) CLAYEY NANNOFOSSIL CHALK, hard, highly brecciated by drilling, olive gray greenish gray, drab olive gray (5Y 4/1, 5Y 6/1, N6), finely and evenly laminated on a mm scale. Contains belemnite in 3-139 cm. Basalt pebble at 4-49.

Smears: Average of 5

18% clay min.
69% nannofossils
8% micarb

1% celadonite
4% heavies and opaques

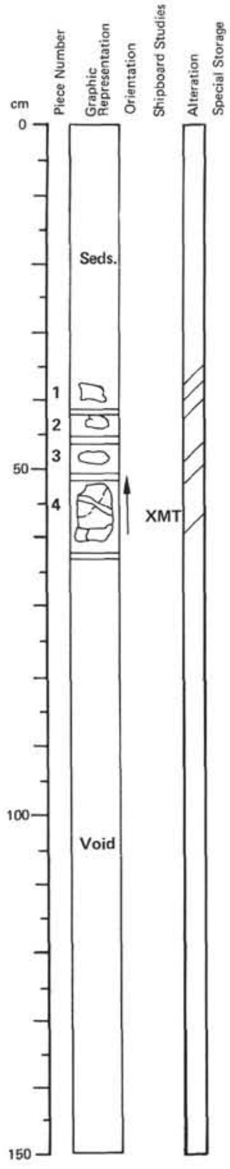
TR% feld., chlorite, cristobalite

CaCO$_3$ Bomb: Section 3-144 = 82%

3- 78 = 0%
3- 87 = 15%
3-144 = 82%

Carbon, Carbon-Carbonate

2-99 (0.1, 0.1, 0)
3-78 (1.9, 1.3, 5)
4-26 (10.5, 0.8, 80)



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	21	4

Visual Description

0-37 cm interval: clayey nanno chalk (described under sediments).

37-62 cm interval: altered plagioclase-phyric basalt. Basalt gray with an alteration halo along veins and margins. Plagioclase phenocrysts <2 mm. Vesicles <4 mm. Veins filled by calcite with inclusions of smectite.

Thin Section Description

Location: 57 cm

Texture: porphyritic

Phenocrysts: altered olivine 2-5%, 2 mm; altered plagioclase 15-20% <5 mm, euhedral.

Groundmass: olivine 5%, 0.1-0.2 mm; plagioclase 30%, 0.3-0.5 mm, microlitic, locally skeletal; altered clinopyroxene 25%, 0.1-0.2 mm, sheaves; magnetite <5%, 0.05-0.1 mm, dendritic; traces of alkali feldspar; sulfides <1%.

Vesicles: 1%, 0.3 mm, round, shrinkage.

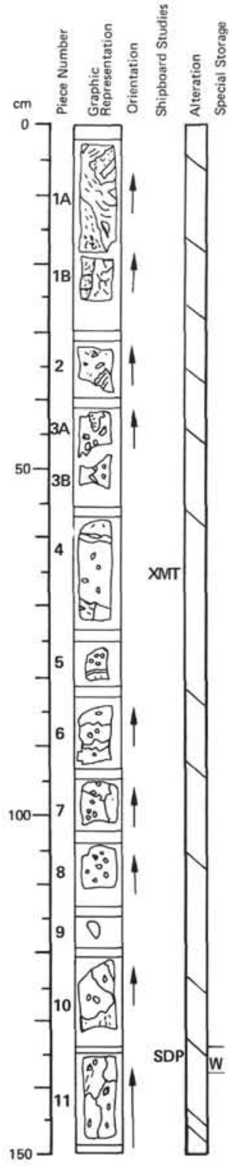
Alteration: olivine replaced by calcite, green smectite; plagioclase partially replaced by kspar, zeolites(?); veins filled by clay.

Shipboard Data

Bulk Analysis: 57 cm

SiO_2	50.29
Al_2O_3	19.84
Fe_2O_3	10.53
MgO	5.22
CaO	9.01
Na_2O	N.D.
K_2O	1.31
TiO_2	1.99
P_2O_5	N.D.
MnO	N.D.
LOI	4.25
H_2O^+	2.43
H_2O^-	N.D.
CO_2	1.37

Magnetic Data:	57 cm
NRM Intensity (emu/cc)	15.489×10^{-3}
NRM Inclination	-79.2°
Stable Inclination	-79.2°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	22	1

Visual Description

Moderately phyric basalt and basalt breccia. Basalt dark gray with light gray-brown chilled margins in pieces 1-3a. Groundmass microlitic. Plagioclase phenocrysts 5-10%, increase in size from <2 mm in piece 1 to <5 mm in pieces 10 and 11, partly replaced by clay(?) or calcite in pieces 1-3, extremely fresh in pieces 4-11; fresh clinopyroxene phenocrysts <10%, <1 mm, partly replaced by green smectite and calcite. Veins filled by calcite and yellow-green to dark green smectite. Pieces 10, 11 contain disseminated calcite. Breccia in pieces 1-3a composed of fragments of basalt and altered glass in a banded matrix of green, yellow-green and blue-green smectite with minor pyrite and veins of calicte; smaller fragments often concentrically zoned, completely replaced by smectite ± calcite. Interpillow breccia in piece 4 composed of calcite spheres and angular shards of devitrified glass in a fine-grained mosaic matrix of calcite, green smectite and celadonite. Glass shards, basalt rimmed by coarse-grained (1 mm) spar calcite.

Thin Section Description

Location: pillow interior, 65 cm

Texture: porphyritic

Phenocrysts: olivine 2-5%, 0.5 mm; plagioclase 10-15%, 2-3 mm, An 65-85, euhedral, locally glomeroporphyritic.

Groundmass: olivine(?) 1-2%; plagioclase 40%, 0.5 mm, An >40, locally skeletal; clinopyroxene 30% quenched; magnetite, 1-5% ,quenched.

Vesicles: 1-2%, shrinkage.

Alteration: olivine replaced by calcite; plagioclase replaced by calcite, clay and kspar; veins and vesicles filled with calcite and celadonite.

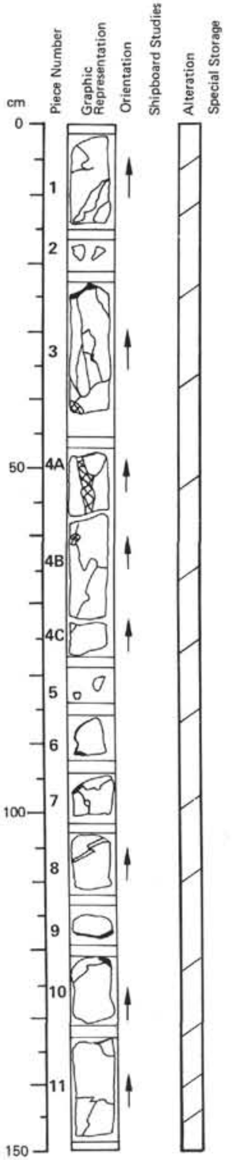
Shipboard Data

Bulk Analysis: 53-67 cm

SiO_2	50.68
Al_2O_3	18.55
Fe_2O_3	12.74
MgO	5.02
CaO	9.50
Na_2O	3.16
K_2O	1.59
TiO_2	1.77
P_2O_5	0.22
MnO	0.10
LOI	1.55
H_2O^+	1.59
H_2O^-	N.D.
CO_2	1.33

Magnetic Data:	63-67 cm
NRM Intensity (emu/cc)	25.527×10^{-3}
NRM Inclination	-73.6°
Stable Inclination	-74.0°

Physical Property Data:	136-139 cm
$\bar{V}p$ (km/sec)	5.38
Porosity (%)	7.02
Wet Bulk Density (g/cc)	2.80
Grain Density (g/cc)	2.94

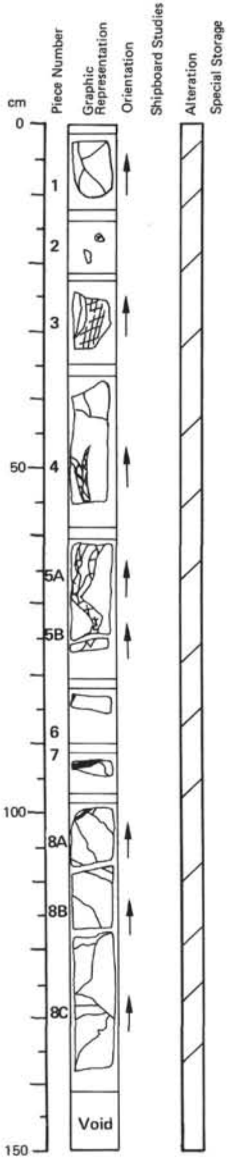


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	D	2 2	2

Visual Description

Phyric pillow basalt with chilled margins in pieces 3, 6, 7, 9 and 10 and traces of fresh glass in piece 6. Basalt dark gray with an aphanitic to intersertal groundmass. Euhedral plagioclase phenocrysts 10-15%, <5 mm, partially replaced by calcite; mafic phenocrysts <2%, <1 mm, replaced by green or pale brown secondary minerals. Vesicles <0.5 mm, filled by calcite and green smectite. Veins filled by calcite ±green smectite, sulfides. Piece 3 contains radial cooling cracks.

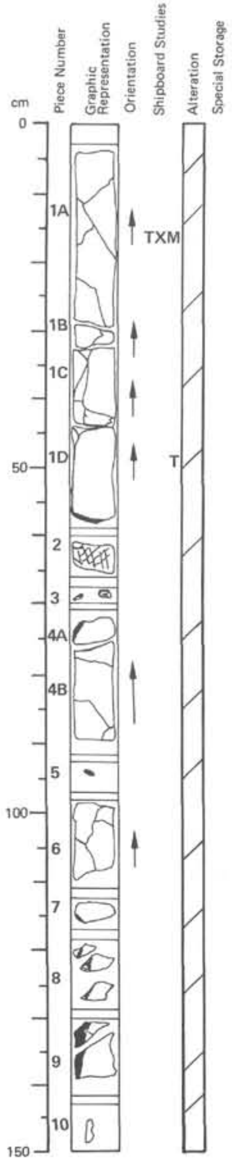


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Phyric pillow basalt with chilled margins and fresh to partially devitrified glass in pieces 3, 7 and 8. Basalt dark gray with an aphanitic to intersertal groundmass. Euhedral plagioclase phenocrysts 20%, <5 mm; mafic phenocrysts <2%, replaced by green to pale brown secondary minerals; euhedral mafic phenocrysts (olivine?) in piece 4 replaced by calcite and pale brown iddingsite(?). Veins filled by calcite ±dark green smectite, sulfides. Glassy margin in piece 3 20 mm thick, coated with dark gray film against calcite-cemented interpillow filling.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	22	4

Visual Description

Phyric pillow basalt with chilled margins (pieces 1D, 4A and 7-9, traces of fresh glass (pieces 2, 3, 5) and interpillow limestone (piece 2). Basalt dark gray with an aphanitic to intersertal groundmass. Euhedral plagioclase phenocrysts 20%, <8 mm, fresh to partially replaced by calcite; mafic phenocrysts <2%. Calcite-filled vesicles <1 mm. Veins filled by calcite, sulfides and green smectite.

Thin Section Description

Location: pillow interior 20 cm

Texture: porphyritic, intersertal

Phenocrysts: olivine 5-6%, <4 mm; plagioclase 10%, <4 mm, An 72; clinopyroxene, 0.1%, 0.3 mm

Groundmass: olivine 5%; plagioclase 35-40%, 0.7 mm, An 60, locally skeletal; clinopyroxene 40%; magnetite, 1-4%; sulfides <1%.

Vesicles: 1-2%, 0.2 mm, round, shrinkage.

Alteration: olivine replaced by clay; vesicles filled by clay.

Thin Section Description

Location: glassy margin, 47 cm

Texture: hyaloporphyritic

Phenocrysts: plagioclase 10%, 4 mm, An 55-70; clinopyroxene <1%, 0.5 mm

Groundmass: olivine 1-2%, 0.1-0.3 mm; plagioclase 5-15%, 0.2 mm, skeletal with fibrous sheaves; glass 70%, devitrified from margin; calcite 2-3%; celadonite 2-3%.

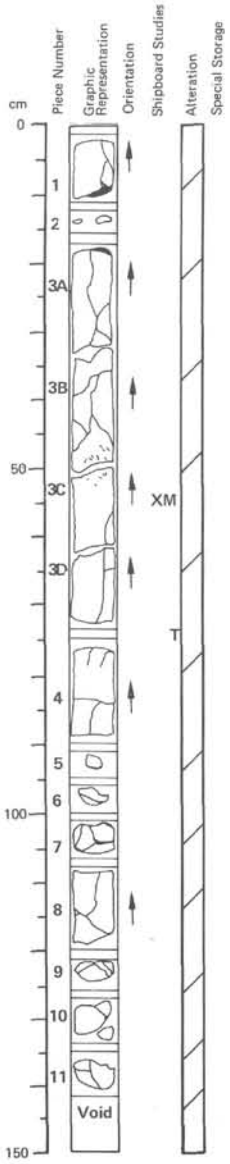
Vesicles: 1-2%, round.

Alteration: olivine replaced by calcite and iddingsite; veins and vesicles filled with calcite and celadonite.

Shipboard Data

Bulk Analysis: 18-21 cm	
SiO_2	48.77
Al_2O_3	16.32
Fe_2O_3	10.65
MgO	7.13
CaO	12.81
Na_2O	2.52
K_2O	0.06
TiO_2	1.41
P_2O_5	0.10
MnO	0.21
LOI	1.55
H_2O^+	1.21
H_2O^-	N.D.
CO_2	0.75

Magnetic Data:	18-21 cm
NRM Intensity (emu/cc)	10.223×10^{-3}
NRM Inclination	-58.6°
Stable Inclination	-63.1°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	22	5

Visual Description

Plagioclase-phyric pillow basalt with glassy chilled margins (pieces 1, 3A and 3D) and fragments of interpillow limestone (pieces 2, 6 and 11). 0-10 and 17-71 cm intervals represent individual pillows or parts of pillows with chilled margins and porphyritic, crystalline interiors. Basalt dark gray with an aphanitic to intersertal groundmass. Euhedral plagioclase phenocrysts 20%, <7 mm; long black tabular mafic phenocrysts rare. Veins, rare vesicles filled with calcite, green smectite.

Thin Section Description

Location: pillow interior, 68 cm

Texture: porphyritic

Phenocrysts: plagioclase 15%, <3.5 mm, An 85

Groundmass: plagioclase 40%, 0.5 mm, An >50, skeletal; clinopyroxene 40%, quenched; magnetite 1-3%; celadonite 1-3%

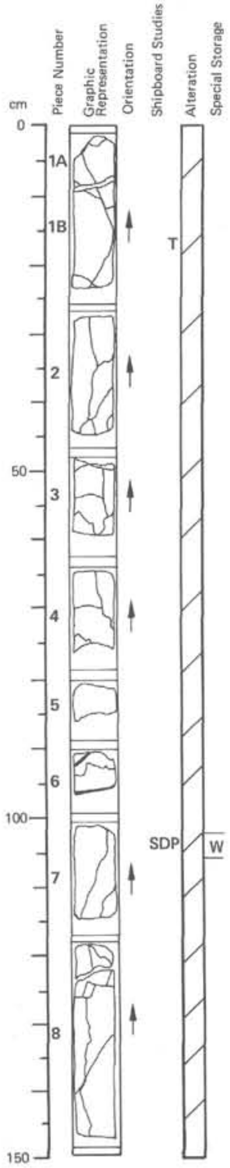
Vesicles: 1%, 0.2 mm, round

Alteration: vesicles filled by calcite

Shipboard Data

Bulk Analysis: 57-60 cm	
SiO_2	48.85
Al_2O_3	16.39
Fe_2O_3	10.80
MgO	6.37
CaO	13.46
Na_2O	2.06
K_2O	0.09
TiO_2	1.41
P_2O_5	0.12
MnO	0.19
LOI	2.30
H_2O^+	0.76
H_2O^-	N.D.
CO_2	1.03

Magnetic Data:	57-60 cm
NRM Intensity (emu/cc)	11.794×10^{-3}
NRM Inclination	-61.4°
Stable Inclination	-67.6°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	D	2 2	6

Visual Description

Dark gray phyric basalt with an intersertal groundmass. Euhedral plagioclase phenocrysts 15-20%, *<7 mm (rarely to 12 mm); mafic phenocrysts <2%, <1 mm, replaced either by green* smectite or by calcite and pale brown secondary mineral; euhedral olivine phenocrysts in piece 8, <1 mm, completely replaced by iddingsite(?) and green smectite. Vesicles common in pieces 7 and 8, <0.3 mm, filled by calcite or green smectite. Veins filled by calcite, green smectite.

Thin Section Description

Location: pillow interior, 20 cm

Texture: porphyritic

Phenocrysts: olivine 3%, <1 mm, euhedral; plagioclase 15%, 2 mm, euhedral

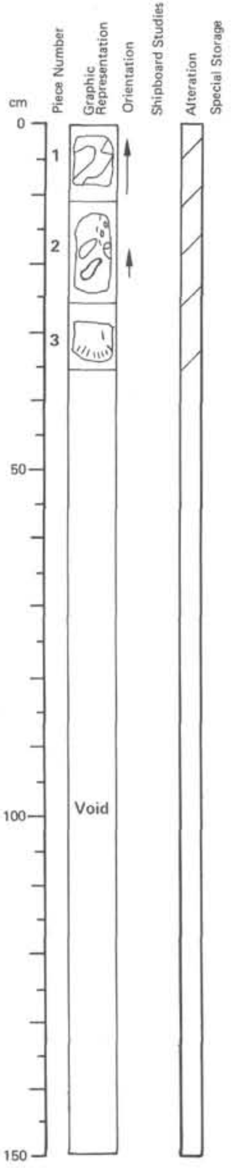
Groundmass: olivine 5%, 0.04 mm, euhedral-subhedral; plagioclase 40%, 0.5 mm, prismatic; clinopyroxene 30%, 0.2 mm, anhedral, quenched; magnetite 5%, 0.01 mm, quenched; glass <5%.

Vesicles: 1%, <0.5 mm, round.

Alteration: olivine replaced by calcite and clay; veins and vesicles filled with calcite and clay.

Shipboard Data

Physical Property Data:	104-107 cm
$\overline{V}$p (km/sec)	5.40
Wet Bulk Density (g/cc)	2.83
Grain Density (g/cc)	2.92

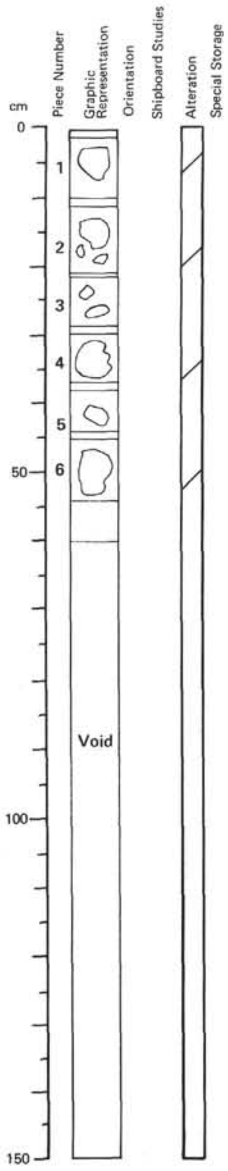


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	D	2 2	7

Visual Description

Phyric pillow basalt with fresh glassy chilled margins (piece 3) and interpillow limestone (piece 2). Plagioclase phenocrysts variably altered to clay; *clinopyroxene(?) phenocrysts <2 mm;* altered olivine phenocrysts 1 mm. Shrinkage vesicles and minor sulfides present in piece 3. Veins filled by calcite. Limestone in piece 2 contains green smectite and fragments of altered glass.

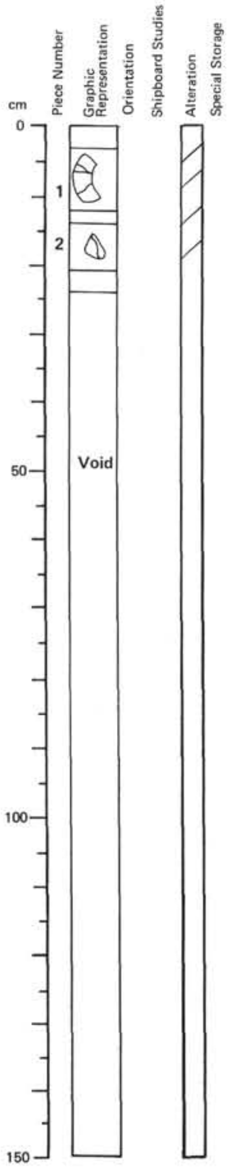


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	23	1

Visual Description

Altered plagioclase-phyric basalt. Basalt gray with an intersertal groundmass. Plagioclase phenocrysts 15%, <5 mm, replaced by calcite and dark green smectite. Calcite-filled vesicles rare, <1 mm. Veins filled by calcite.

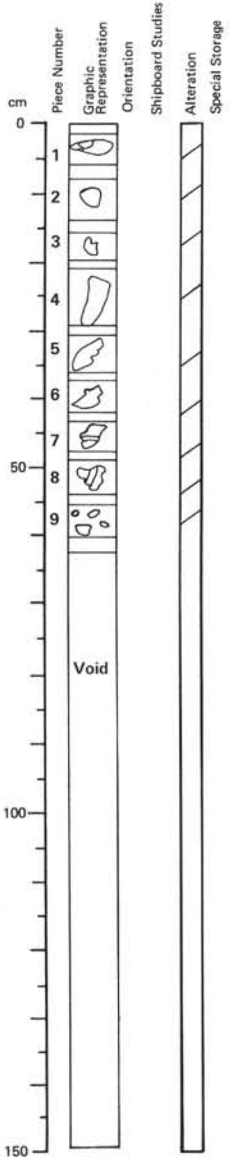


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	24	1

Visual Description

Plagioclase-phyric basalt. Basalt gray with an intersertal groundmass. Euhedral plagioclase phenocrysts 10-15%, <3 mm, partly replaced by calcite. Vesicles common, <0.5 mm, filled by calcite, green smectite and pyrite(?). Veins filled by calcite.

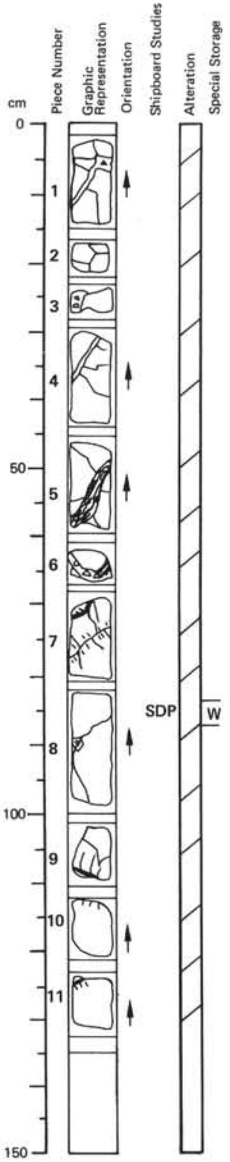


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	25	1

Visual Description

Dark gray, phyric basalt. Euhedral plagioclase phenocrysts 10-15%, ≤5 mm; mafic phenocrysts <2%, 3 mm, replaced by green smectite ± calcite. Calcite-filled vesicles 1%, ≤0.5 mm. Veins filled by calcite and green smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

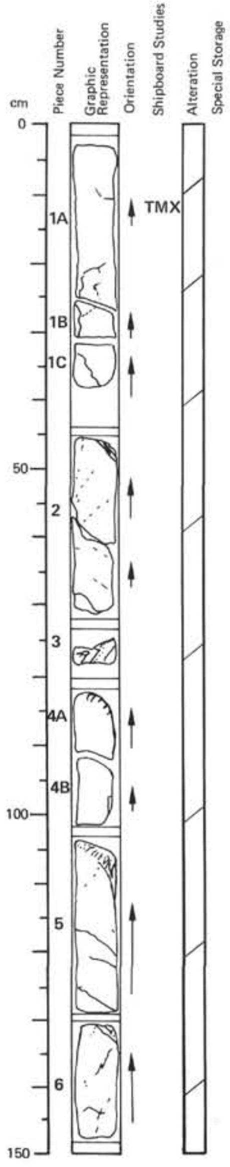
LEG	SITE	HOLE	CORE	SECT.
51	417	D	26	1

Visual Description

Moderately altered phyric pillow basalt with 1-2 cm thick chilled glassy margins (pieces 5 and 6) and traces of breccia (piece 6). Basalt dark gray, altered to gray-brown within 5 mm of cracks and joints. Groundmass aphanitic to crystalline. Euhedral to subhedral plagioclase phenocrysts 20%, ≤6 mm, partially replaced by calcite; euhedral olivine phenocrysts 5%, ≤2 mm, completely replaced by green smectite. Vesicles <1%, <0.5 mm, filled by calcite, green smectite. Veins filled by calcite, green smectite. Basalt in piece 7 contains multiple chill surfaces, two of which are internal.

Shipboard Data

Physical Property Data:	84-87 cm
$\overline{V}p$ (km/sec)	5.25
Porosity (%)	8.68
Wet Bulk Density (g/cc)	2.77
Grain Density (g/cc)	2.94



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	26	2

Visual Description

Phyric pillow basalt with glassy chilled margins (pieces 2, 4a, 5 and 6), well-developed radial cracks (piece 2) and minor breccia (piece 3). Groundmass intersertal to hyalopilitic. Plagioclase phenocrysts 10%; mafic phenocrysts in piece 1 2-4%, <3 mm, partially altered, 5-7% altered olivine in pieces 2 and 4-6. Vesicles 3-5%, filled by calcite and celadonite(?). Veins filled by calcite. Breccia in piece 3 composed of small shards of glass in a matrix of smectite, celadonite(?) and calcite cut by calcite-filled veins. Pice 1 continuous with preceeding section.

Thin Section Description

Location: pillow interior, 10 cm

Texture: porphyritic

Phenocryst: olivine 5%, 1.5 mm; plagioclase 15%, ≤6 mm, An 85-55.

Groundmass: olivine 5%; plagioclase 35-40%, 0.5 mm, An ≤60, skeletal; clinopyroxene 30%, 0.2 mm; magnetite 5%, 0.01 mm; sulfides <1%, 0.1 mm

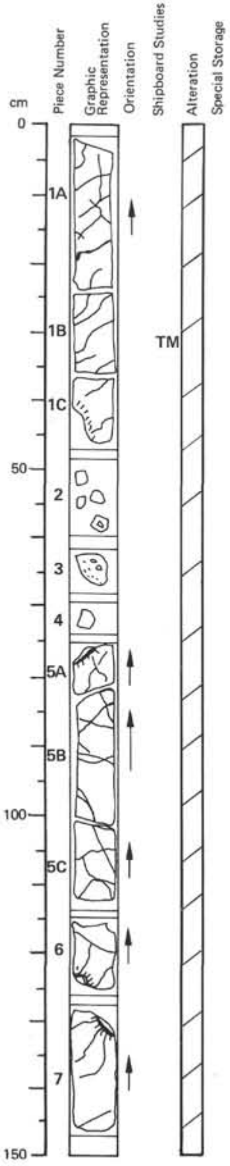
Vesicles: 2%.

Alteration: olivine replaced by calcite and iddingsite; veins and vesicles filled with calcite and celadonite.

Shipboard Data

Bulk Analysis: 9-12 cm	
SiO_2	49.03
Al_2O_3	16.45
Fe_2O_3	10.78
MgO	6.22
CaO	13.41
Na_2O	2.62
K_2O	0.25
TiO_2	1.49
P_2O_5	0.12
MnO	0.15
LOI	2.15
H_2O^+	1.52
H_2O^-	N.D.
CO_2	1.39

Magnetic Data:	9-12 cm
NRM Intensity (emu/cc)	15.812×10^{-3}
NRM Inclination	-66.1°
Stable Inclination	-65.9°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	26	3

Visual Description

Phyric pillow basalt with fresh glassy chilled margins (pieces 1C, 5A, 6 and 7) and minor breccia (pieces 2-4). Groundmass crystalline. Euhedral plagioclase phenocrysts 20%, ≤6 mm; olivine phenocrysts 2-5%, ≤2 mm, replaced by green smectite, calcite. Vesicles 2%, filled by calcite, zeolites, calcite, green smectite and pyrite(?). Breccia in pieces 2-4 composed of glass fragments in a matrix of calcite and green smectite.

Thin Section Description

Location: 30 cm

Texture: porphyritic to glomeroporphyritic

Phenocrysts: olivine 5-7%, ≤1 mm; plagioclase 15-20%, <4 mm, An 55

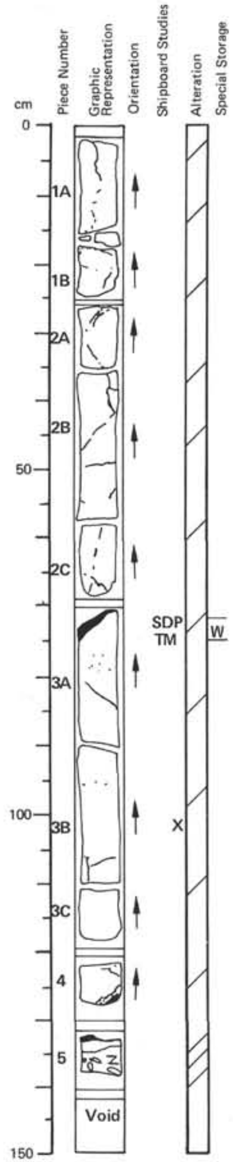
Groundmass: olivine 10%; plagioclase 35%, 0.1-0.5 mm, An 45; clinopyroxene 25-30%, 0.05-0.2 mm, skeletal with some plumose and sheaf structures; magnetite 1-3%.

Vesicles: shrinkage.

Alteration: olivine replaced by clay; veins and vesicles filled with calcite and clay.

Shipboard Data

Magnetic Data:	28-31 cm
NRM Intensity (emu/cc)	15.958×10^{-3}
NRM Inclination	-64.9°
Stable Inclination	-65.3°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	26	4

Visual Description

Phyric pillow basalt with glassy chilled margins (pieces 3A, 4 and 5) and minor interpillow limestone breccia. Groundmass aphanitic to holocrystalline. Plagioclase phenocrysts 5-10%; olivine phenocrysts 5-10%, replaced by calcite, green smectite. Calcite-filled veins common. Piece 5 consists of shards of calcite, green smectite and altered glass in a banded self-matrix of calcite and green smectite.

Thin Section Description

Location: next to glassy margin, 76 cm

Texture: porphyritic

Phenocryst: olivine 5-10%, 0.2-1.0 mm; plagioclase 10-15%, <4.5 mm, An 45

Groundmass: olivine 15%; plagioclase 30-40%; clinopyroxene 30-35%, magnetite <1%

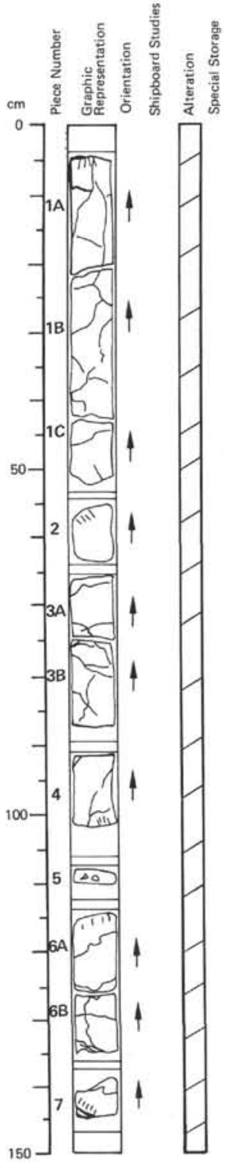
Vesicles: 1-2%, shrinkage.

Alteration: olivine replaced by iddingsite; veins and vesicles filled with calcite, celadonite and clay

Shipboard Data

Bulk Analysis: 75-77 cm	
SiO_2	49.16
Al_2O_3	16.64
Fe_2O_3	11.26
MgO	6.55
CaO	12.06
Na_2O	2.60
K_2O	0.13
TiO_2	1.53
P_2O_5	0.13
MnO	0.18
LOI	0.90
H_2O^+	1.60
H_2O^-	N.D.
CO_2	0.44

Magnetic Data:	75-77 cm
NRM Intensity (emu/cc)	9.916×10^{-3}
NRM Inclination	-45.2°
Stable Inclination	-47.4°
Physical Property Data:	72-75 cm
$\overline{V}p$ (km/sec)	5.46
Porosity (%)	6.74
Wet Bulk Density (g/cc)	2.80
Grain Density (g/cc)	2.93

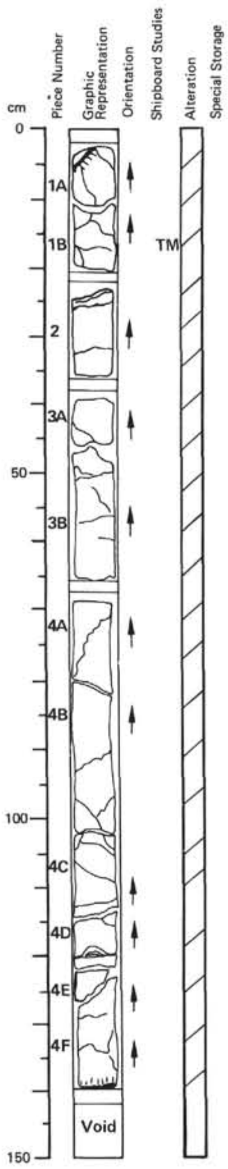


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	26	5

Visual Description

Moderately altered phyric basalt pillows with traces of interpillow breccia (piece 5). 0-53, 53-102, 114-115 cm intervals represent individual pillows bounded by aphanitic to glassy chilled margins. Basalt dark gray, altered to pale brown or gray-green near margins. Groundmass aphanitic to crystalline. Euhedral plagioclase phenocrysts 20%, <8 mm; euhedral olivine phenocrysts 2%, <2 mm, replaced by green smectite. Vesicles 3%, filled by calcite, green smectite. Veins filled by calcite, green smectite and zeolites. Breccia in piece 5 composed of fragments of glass in a matrix of calcite and green smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	26	6

Visual Description

Phyric pillow basalt with fresh to partially devitrified glassy chilled margins (pieces 1A and 4F). Basalt dark gray with an aphanitic to crystalline groundmass. Euhedral plagioclase phenocrysts 20%, <7 mm; euhedral to skeletal olivine phenocrysts 3-5%, 1-3 mm, replaced by green smectite and calcite. Vesicles <2%, filled with green smectite, calcite. Veins filled by green smectite, calcite and zeolites.

Thin Section Description

Location: pillow interior, 17 cm

Texture: porphyritic

Phenocrysts: plagioclase15%, 3 mm, An 65

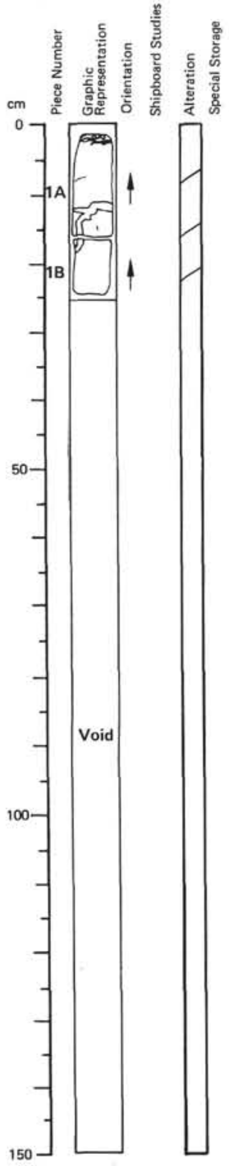
Groundmass: olivine 10%; plagioclase 35%, 0.5-1.0 mm, skeletal and in sheaves; clinopyroxene 35%, 0.5 mm, sheaves; magnetite <1%

Vesicles: 2%

Alteration: vesicles filled by calcite and clay

Shipboard Data

Magnetic Data:	16-18 cm
NRM Intensity (emu/cc)	12.679×10^{-3}
NRM Inclination	-60.2°
Stable Inclination	-61.8°

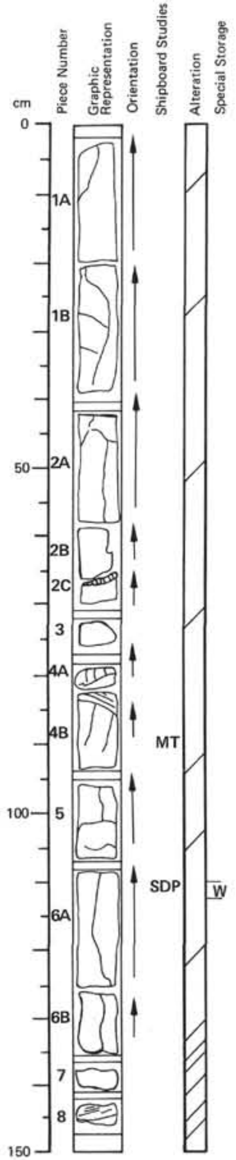


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	26	7

Visual Description

Phyric pillow basalt with glassy chilled margin (piece 1A). Groundmass aphanitic to holocrystalline. Plagioclase phenocrysts 10%, <7 mm; altered olivine phenocrysts <5%, 1-2 mm. Veins filled by calcite and celadonite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	27	1

Visual Description

Phyric pillow basalt with thick glassy chilled margins (pieces 4B and 8) and minor interpillow sediments (pieces 4A, 4B and 8). Basalt dark gray with an aphanitic to holocrystalline groundmass. Plagioclase phenocrysts 15-20%, <5 mm; mafic phenocrysts 3-4%, <5 mm. Vesicles scarce, <1 mm, round, filled with calcite. Veins common, filled with calcite and green smectite. Sediments in piece 4A composed of white to pink limestone with small shards of glass. Sediments in contact with chilled margins in pieces 4B and 8 composed of palagonite fragments in a matrix of calcite.

Thin Section Description

Location: next to glassy margin, 86 cm

Texture: porphyritic

Phenocrysts: olivine 5%, <2 mm; plagioclase 7-10%, <4 mm, An 60

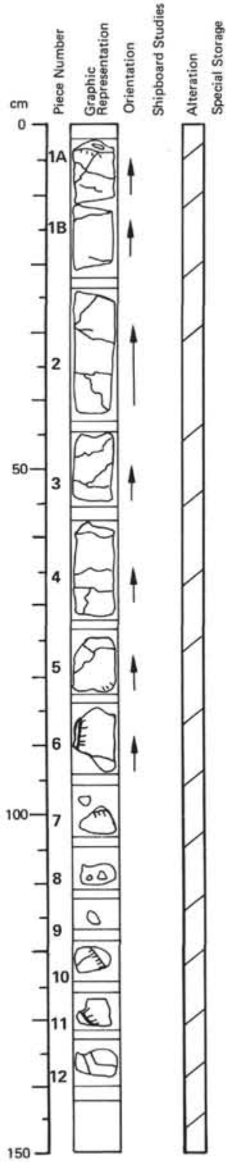
Groundmass: olivine 5-10%; plagioclase 30%, 0.5 mm; clinopyroxene 10-25%; magnetite <1%; glass 15-30%, devitrified

Vesicles: 2-5%, round

Alteration: olivine replaced by calcite; veins and vesicles filled with celadonite, calcite and clay

Shipboard Data

Magnetic Data:	85-87 cm
NRM Intensity (emu/cc)	10.696 x 10^{-3}
NRM Inclination	-73.0°
Stable Inclination	-71.8°
Physical Property Data:	111-113 cm
$\overline{V}p$ (km/sec)	5.56
Porosity (%)	5.76
Wet Bulk Density (g/cc)	2.83
Grain Density (g/cc)	2.94

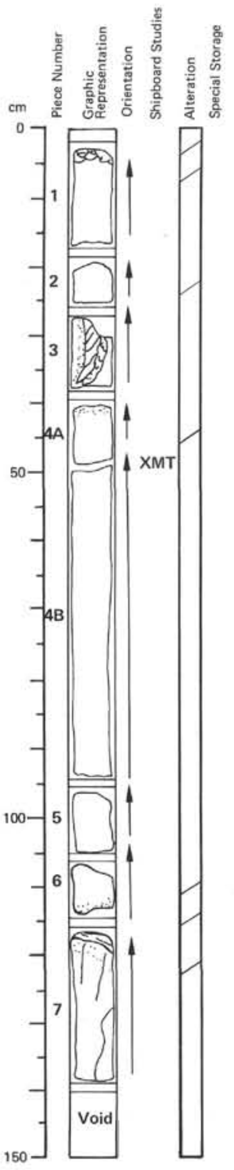


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	27	2

Visual Description

Phyric pillow basalt with chilled margins (pieces 1A, 5, 6, 10 and 11) and traces of interpillow breccia (pieces 1, 8 and 9). Basalt dark gray, locally altered to pale brown. Groundmass aphanitic to crystalline. Euhedral plagioclase phenocrysts 20%, <6 mm; euhedral to subhedral olivine phenocrysts 3%, <2 mm, replaced by green smectite. Vesicles <0.5 mm, filled with calcite, green smectite. Veins filled by green smectite, calcite and zeolites. Interpillow breccia composed of glass shards in a matrix of green smectite and calcite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	27	3

Visual Description

Phyric pillow basalt with glassy chilled margins (pieces 1, 3, 4A, 6 and 7) and traces of interpillow limestone (piece 3). 39-115 and 115-140 cm intervals represent individual pillows or parts of pillows bounded by chilled margins. Basalt dark gray with an aphanitic to holocrystalline groundmass. Plagioclase phenocrysts 20%, <5 mm; olivine phenocrysts 5%, <5 mm, replaced by green smectite. Scarce vesicles and calcite-filled veins. Piece 3 contains and exfoliated glassy chilled margin in a limestone matrix.

Thin Section Description

Location: next to glassy margin, 44 cm

Texture: porphyritic

Phenocrysts: olivine 4-6%, <2 mm; plagioclase 10-15%, <5 mm, An 55, glass inclusions; clinopyroxene <1% 1.2 mm, subhedral

Groundmass: olivine 5-10%; plagioclase 20-25%; clinopyroxene 10-20%; magnetite <1%; glass 30-35%, devitrified

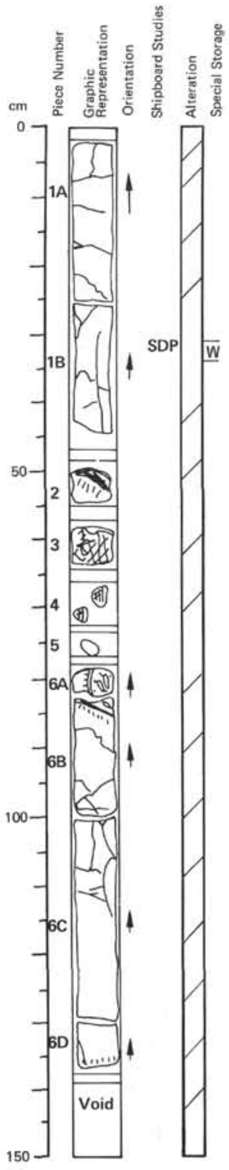
Vesicles: 3-5%

Alteration: olivine replaced by calcite and clay; veins and vesicles filled with calcite and analcite

Shipboard Data

Bulk Analysis: 43-45 cm	
SiO_2	49.79
Al_2O_3	17.17
Fe_2O_3	10.04
MgO	5.82
CaO	13.75
Na_2O	2.45
K_2O	0.04
TiO_2	1.44
P_2O_5	N.D.
MnO	0.15
LOI	0.11
H_2O^+	0.89
H_2O^-	N.D.
CO_2	0.74

Magnetic Data:	43-45 cm
NRM Intensity (emu/cc)	14.759×10^{-3}
NRM Inclination	-78.2°
Stable Inclination	-77.8°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

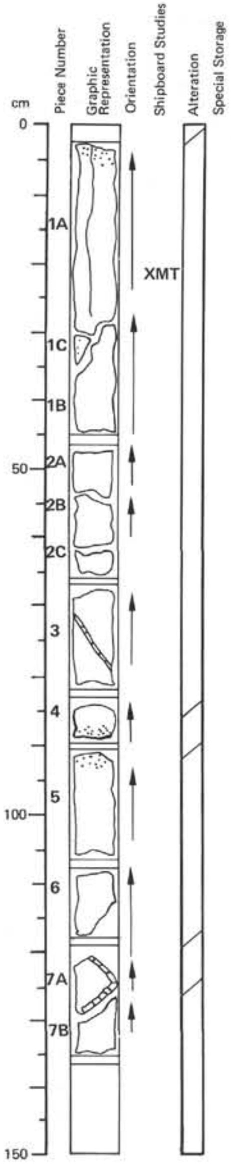
LEG	SITE	HOLE	CORE	SECT.
51	417	D	27	4

Visual Description

Phyric basalt pillows with chilled margins (pieces 2, 6A, 6B and 6D) and interpillow breccia (pieces 2-4, 6A and 6B). Basalt dark gray, locally altered to gray-brown. Groundmass aphanitic to crystalline. Euhedral plagioclase phenocrysts 20%, ≤7 mm; euhedral to subhedral olivine phenocrysts 5%, ≤3 mm, replaced by green smectite and calcite. Vesicles filled with green smectite, calcite. Veins filled by calcite, green smectite and zeolites. Interpillow breccia composed of glass shards in a matrix of zeolites, calcite and green smectite.

Shipboard Data

Physical Property Data:	30-33 cm
$\overline{V}p$ (km/sec)	5.16
Porosity (%)	9.38
Wet Bulk Density (g/cc)	2.77
Grain Density (g/cc)	2.96



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	27	5

Visual Description

Phyric pillow basalt with chilled glassy margins (pieces 1A, 4 and 5). Basalt dark gray with an aphanitic to holocrystalline groundmass. Altered plagioclase phenocrysts 20%, <8 mm; mafic phenocrysts (olivine ± clinopyroxene) 2-3%, <5 mm, replaced by green smectite. Calcite-filled vesicles scarce, <1 mm. Veins filled by calcite.

Thin Section Description

Location: pillow interior, 25 cm

Texture: porphyritic

Phenocrysts: olivine 5-10%, <2-5 mm; plagioclase 15%, <4.0 mm, An 60-65, zoned with glass inclusions; clinopyroxene <1%, 0.3 mm

Groundmass: olivine 10%, 0.05-0.2 mm; plagioclase 30%, <1.0 mm, skeletal; clinopyroxene 30%, <0.7 mm, skeletal, plumose with sheaf structures; magnetite 1-3%, 0.05-0.1 mm; glass <3%, devitrified

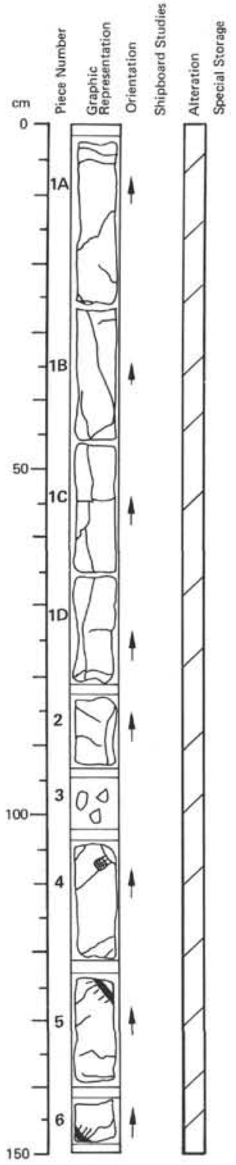
Vesicles: 1-3%

Alteration: olivine replaced by calcite, clay and iddingsite; vesicles filled by calcite and opal(?).

Shipboard Data

Bulk Analysis: 25-27 cm	
SiO_2	49.34
Al_2O_3	17.27
Fe_2O_3	9.97
MgO	6.38
CaO	13.48
Na_2O	2.35
K_2O	0.03
TiO_2	1.36
P_2O_5	0.11
MnO	0.15
LOI	1.95
H_2O^+	0.79
H_2O^-	N.D.
CO_2	0.82

Magnetic Data:	25-27 cm
NRM Intensity (emu/cc)	16.248×10^{-3}
NRM Inclination	-67.6°
Stable Inclination	-66.1°

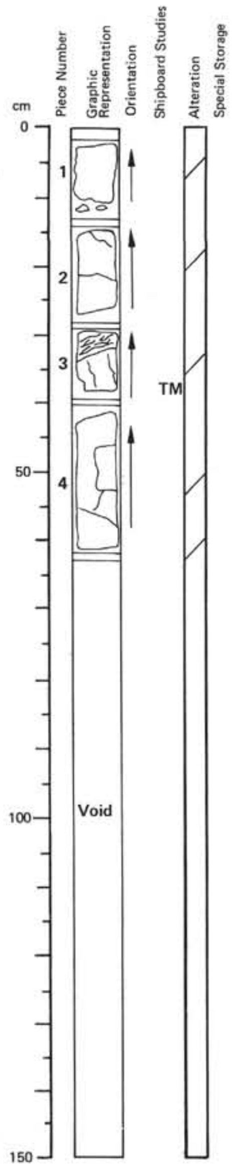


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	27	6

Visual Description

Phyric pillow basalt with glassy chilled margins (pieces 5 and 6) and traces of interpillow breccia (pieces 5 and 6). Basalt dark gray with an aphanitic to crystalline groundmass. Euhedral plagioclase phenocrysts 20%, <9 mm; euhedral olivine phenocrysts 5%, <3 mm, replaced by green smectite. Vesicles filled by green smectite. Veins filled by green smectite and calcite. Interpillow breccia composed of fragments of glass partially altered to green smectite or palagonite(?) in a matrix of calcite and zeolites.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	27	7

Visual Description

Phyric pillow basalt with glassy chilled margins (pieces 2 and 3) and interpillow breccia (pieces 2 and 3). Basalt dark gray with an aphanitic to crystalline groundmass. Altered plagioclase phenocrysts 20%, <8 mm; olivine phenocrysts 2%, <5 mm, replaced by green smectite. Vesicles scarce. Veins normal to pillow margins, filled by calcite. The 1 cm-thick glassy margin in piece 3, composed of hyaloclastite shards cemented by calcite, is partially detached from the underlying pillow.

Thin Section Description

Location: next to glassy margin, 32 cm

Texture: porphyritic

Phenocrysts: plagioclase 15-20%, 3-5 mm, An 85, some partially resorbed; clinopyroxene megacrysts <1%, 0.3 mm, anhedral, partially resorbed

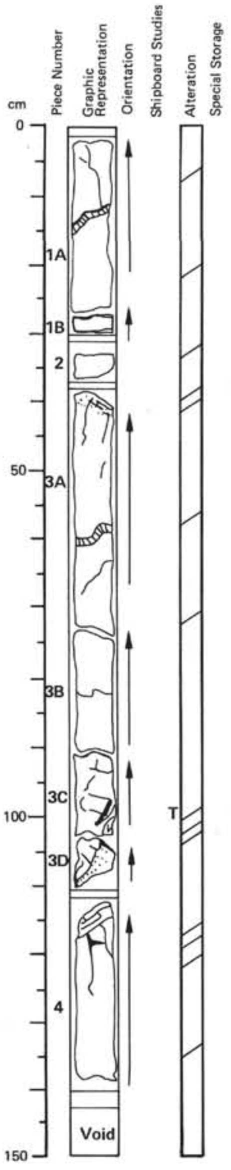
Groundmass: plagioclase 25%, 0.5 mm; magnetite <0.5%; glass 50%, devitrified

Vesicles: 3-4%, round

Alteration: vesicles filled by calcite, celadonite

Shipboard Data

Magnetic Data:	30-33 cm
NRM Intensity (emu/cc)	9.082×10^{-3}
NRM Inclination	-70.9°
Stable Inclination	-69.8°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	28	1

Visual Description

Phyric basalt pillows with 1-2 cm thick glassy chilled margins (pieces 2, 3A, 3C, 3D and 4) and minor interpillow breccia (pieces 3C-4). 0-37, 37-110 and 110-140 cm intervals represent individual pillows or parts of pillows bounded by chilled margins. Basalt dark gray with an aphanitic to crystalline groundmass. Plagioclase phenocrysts 20%, <10 mm; olivine phenocrysts <1%, replaced by green smectite. Vesicles scarce, <1 mm, filled with green smectite. Veins common normal to pillow margins, filled by calcite, minor pyrite.

Thin Section Description

Location: 103 cm

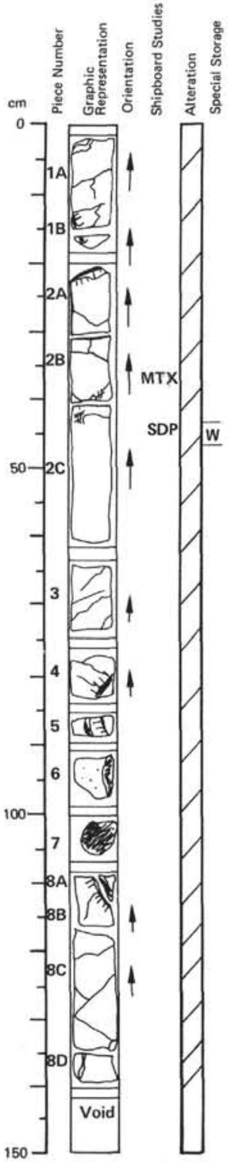
Texture: glomeroporphyritic, intersertal

Phenocrysts: olivine 5%, <3.5 mm, plagioclase 15-20%, An 55, glass inclusions; clinopyroxene 1-2%, 0.5 mm, 2V >50°, glomerocrysts with olivine and plagioclase

Groundmass: olivine 10%; plagioclase 35%; clinopyroxene 20-25%, skeletal, plumose; magnetite 2-4%, dendritic; sulfides 1%, 1 mm, irregular

Vesicles: 5-7%

Alteration: olivine replaced by calcite and iddingsite; vesicles filled by calcite



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	28	2

Visual Description

Phyric basalt pillows with glassy chilled margins (pieces 1A, 1B, 2A and 4-8B), interpillow breccia (pieces 4-8B) and interpillow limestone (piece 6). 0-20, 20-90 and 105-140 represent individual pillows or parts of pillows bounded by chilled margins. Basalt dark gray, altered to gray-brown along veins. Groundmass aphanitic to hyalopilitic near pillow margins, microlitic in pillow interiors. Euhedral plagioclase phenocrysts 20%, < 12 mm; olivine phenocrysts 5%, < 2 mm, replaced by calcite and green smectite. Vesicles and veins filled with calcite and green smectite. Breccia composed of fragments of glass partially altered to palagonite(?) or green smectite in a matrix of calcite and zeolites. Fine-grained limestone in piece 6 composed of calcite and green smectite.

Thin Section Description

Location: pillow interior, 38 cm

Texture: porphyritic

Phenocrysts: olivine <0.2%, <1 mm, idiomorphic; plagioclase 15%, 2-5 mm, idiomorphic, zoned

Groundmass: plagioclase microlites 40%, 0.1-0.5 mm; augitic clinopyroxene 30%, 0.2-0.5 mm, interstitial; titanomagnetite 15%, <0.2 mm

Vesicles: <1%, <1 mm

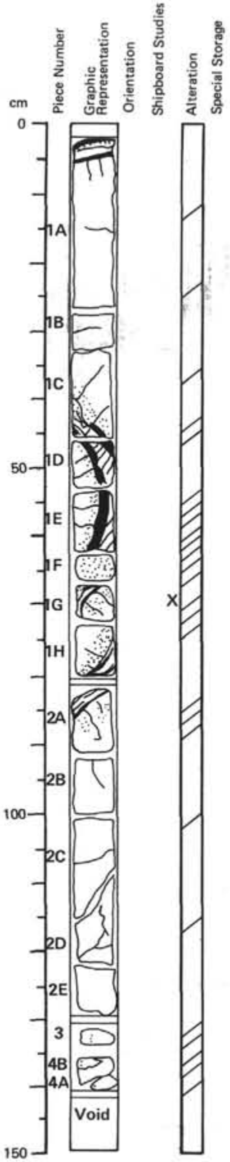
Alteration: calcite and clay pseudomorphs after olivine

Shipboard Data

Bulk Analysis: 37-39 cm	
SiO_2	49.37
Al_2O_3	17.36
Fe_2O_3	10.45
MgO	6.07
CaO	14.08
Na_2O	2.55
K_2O	0.14
TiO_2	1.42
P_2O_5	0.13
MnO	0.16
LOI	1.00
H_2O^+	0.79
H_2O	N.D.
CO_2	1.21

Magnetic Data:	37-39 cm
NRM Intensity (emu/cc)	16.915×10^{-3}
NRM Inclination	-71.6°
Stable Inclination	-71.0°

Physical Property Data:	44-46 cm
$\bar{V}p$ (km/sec)	5.41
Porosity (%)	6.99
Wet Bulk Density (g/cc)	2.79
Grain Density (g/cc)	2.93



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	28	3

Visual Description

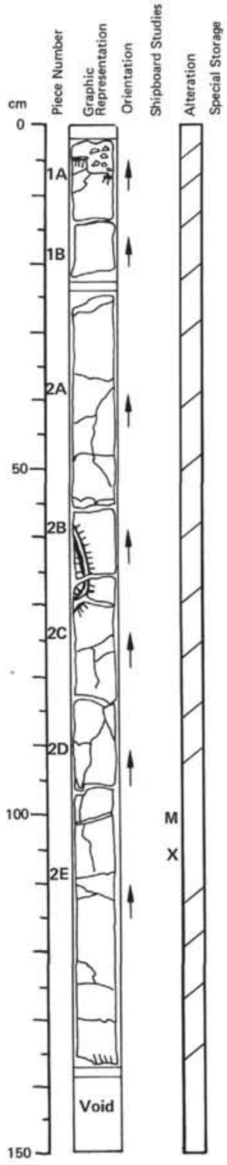
Phyric basalt pillows with 1-2 cm thick, aphyric chilled margins (pieces 1A, 1C-2A) and 0.5-1.0 cm thick glassy rims (pieces 1A, 1C-1E and 1G-2A) against interpillow limestone (pieces 1A, 1D and 4). 0-45, 45-65, 65-80 and 80-140 cm intervals represent individual pillows or parts of pillows bounded by chilled margins. Basalt dark gray with aphanitic to hyalopilitic chilled margins and microlitic pillow interiors. Altered plagioclase phenocrysts 15%, <8 mm; olivine phenocrysts 1-2%, <5 mm, replaced by green smectite. Vesicles scarce. Veins common normal to glassy margins, filled with calcite, green smectite celadonite(?) and minor pyrite. Glassy rims locally detached from adjacent pillows, partially replaced by green smectite, palagonite(?) and calcite. Fine-grained, white to gray-green interpillow limestone composed of calcite and green smectite with occasional shards of glass.

Shipboard Data

Bulk Analysis: 66-68 cm	
SiO_2	50.95
Al_2O_3	16.31
Fe_2O_3	11.92
MgO	6.16
CaO	9.98
Na_2O	2.33
K_2O	1.04
TiO_2	1.39
P_2O_5	0.07
MnO	0.11
LOI	3.45
H_2O^+	3.00
H_2O^-	N.D.
CO_2	1.38

VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	28	4



Visual Description

Phyric basalt pillow with glassy chilled margins (pieces 1A, 2B and 2C) and minor interpillow limestone and limestone breccia (piece 1A). 0-135 cm interval represents one pillow bounded by chilled margins (including a lateral margin between 55-70 cm). Basalt dark gray with an aphanitic to microlitic groundmass. Euhedral plagioclase phenocrysts 20%, <3 mm, occasionally to 15 mm with Carlsbad twins; euhedral olivine phenocrysts <5%, <2 mm, replaced by green smectite. Veins filled by calcite ± green smectite. Interpillow breccia in piece 1A composed of fragments of glass partially altered to palagonite(?) or green smectite in a fine-grained matrix of calcite and green smectite.

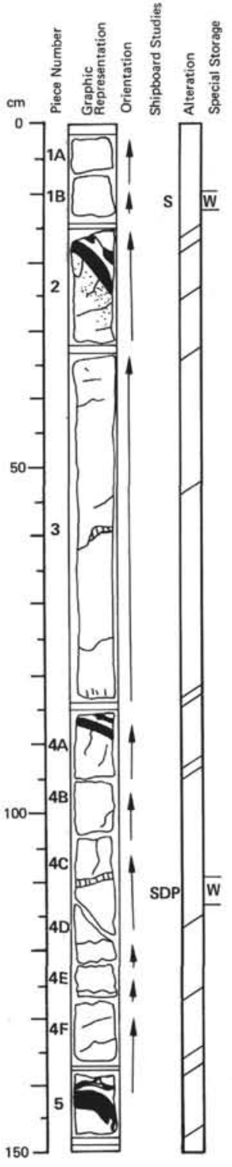
Shipboard Data

Bulk Analysis: 102-104 cm	
SiO_2	49.34
Al_2O_3	17.15
Fe_2O_3	10.05
MgO	6.23
CaO	14.52
Na_2O	2.27
K_2O	0.04
TiO_2	1.27
P_2O_5	0.11
MnO	0.16
LOI	1.25
H_2O^+	0.76
H_2O^-	N.D.
CO_2	1.30

Magnetic Data:	102-104 cm
NRM Intensity (emu/cc)	10.244×10^{-3}
NRM Inclination	-54.8°
Stable Inclination	-63.1°

VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	28	5

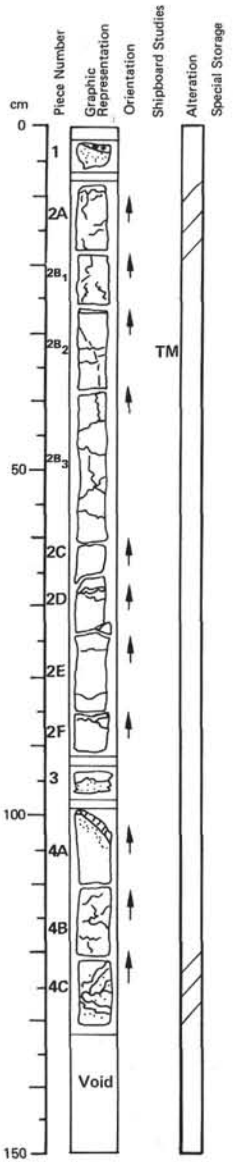


Visual Description

Phyric basalt pillows with well-developed glassy chilled margins (pieces 2, 4A and 5) against interpillow limestone (pieces 1A, 1B, 2, 4A and 5). 15-85, 85-135 and 140-150 cm intervals represent individual pillows or parts of pillows bounded by chilled margins. Basalt dark gray with an aphanitic to microlitic groundmass. Altered plagioclase phenocrysts 20-25%, ≤10 mm; olivine phenocrysts 2-3%, ≤5 mm, replaced by green smectite. Veins common normal to glassy margins, filled by calcite and celadonite(?). Gray-green interpillow limestone layered to massive, composed of fine-grained calcite and green smectite with occasional shards of glass partially replaced by calcite, green smectite and palagonite(?).

Shipboard Data

Physical Property Data:	14-16 cm	110-112 cm
$\overline{V}p$ (km/sec)	5.88	5.35
Porosity (%)		7.34
Wet Bulk Density (g/cc)		2.80
Grain Density (g/cc)		2.94



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	28	6

Visual Description

Phyric basalt pillows with chilled margins (pieces 2A, 2F, 4A and 4C) and interpillow limestone (pieces 1 and 3). 8-92 and 99-130 cm intervals represent individual pillows. Chilled pillow margins locally display 0.5-1.0 cm thick, sparsely phyric, slightly brecciated glassy rims containing fragments of dark gray basalt and 3% plagioclase phenocrysts (<2 mm). These are underlain by a 3 mm thick zone containing spheres of devitrified glass. Pillow interiors dark gray with a microlitic groundmass, altered to light gray, gray-brown or brown near veins in pieces 2A and 4C. Plagioclase phenocrysts 7-15%, ≤5 mm, partially replaced by clay, calcite; clinopyroxene phenocrysts 3-5%, ≤2 mm; olivine phenocrysts <1%, ≤1 mm, partially replaced by green smectite. Veins filled by calcite, green smectite. Fine-grained, gray-green to pink interpillow limestone finely layered to massive, composed of calcite and green smectite with occasional shards of glass partially replaced by calcite, green smectite and palagonite(?).

Thin Section Description

Location: pillow interior, 32 cm

Texture: porphyritic, intersertal

Phenocrysts:olivine <0.5%, <1 mm, idiomorphic; plagioclase 15%, 2-6 mm, idiomorphic, strongly zoned.

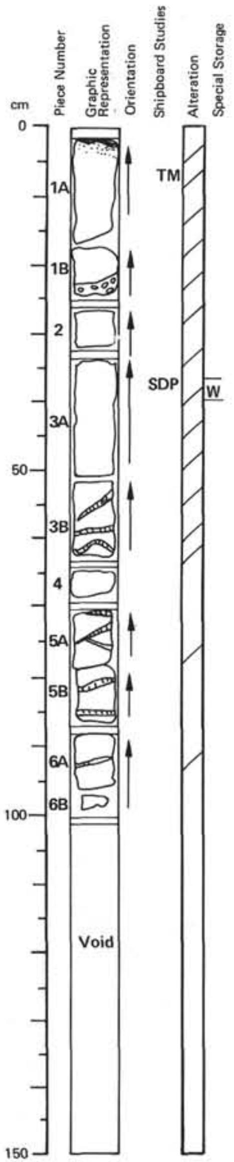
Groundmass: plagioclase 40%, 0.5-2 mm, plumose; clinopyroxene 35%; titanomagnetite 10%

Vesicles: <0.5%, <0.05 mm, round

Alteration: calcite pseudomorphs after olivine; plagioclase replaced by calcite; veins filled with celadonite; vesicles filled by calcite.

Shipboard Data

Magnetic Data:	30-33 cm
NRM Intensity (emu/cc)	6.332×10^{-3}
NRM Inclination	-62.5°
Stable Inclination	-68.2°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	28	7

Visual Description

Altered phyric pillow basalt with chilled margins (piece 1A) and minor breccia (piece 1B). Basalt dark gray, strongly oxidized to shades of brown and orange in pieces 1-3B. Groundmass aphanitic to microlitic. Altered plagioclase phenocrysts 15-20%, ≤5 mm; mafic phenocrysts 2-3%, ≤5 mm, replaced by green smectite. Numerous wide veins filled by calcite ±hematite and green smectite. Breccia composed of basalt fragments in a calcite matrix.

Thin Section Description

Location: next to glassy margin, 6 cm

Texture: porphyritic

Phenocrysts: olivine 2-3%, 1-2 mm, idiomorphic; plagioclase 15% 1-5 mm, idiomorphic, glass inclusions

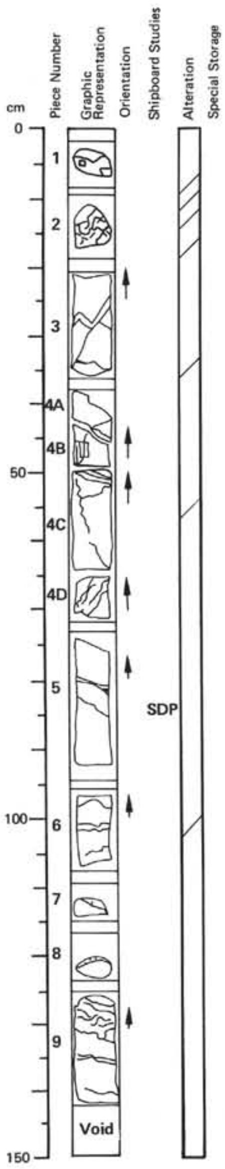
Groundmass: plagioclase microlites 40%, 0.1-0.5 mm; interstitial clinopyroxene 20%, 0.3-0.5 mm, quenched, plumose; titanomagnetite 20%, interstitial

Vesicles: <1%, <1 mm, round

Alteration: calcite pseudomorphs after olivine; plagioclase phenocrysts partially replaced by calcite; vesicles filled by calcite

Shipboard Data

Magnetic Data:	5-7 cm
NRM Intensity (emu/cc)	6.813×10^{-3}
NRM Inclination	-70.0°
Stable Inclination	-69.2°
Physical Property Data:	37-39 cm
$\bar{V}p$ (km/sec)	5.52
Porosity (%)	5.37
Wet Bulk Density (g/cc)	2.81
Grain Density (g/cc)	2.91



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

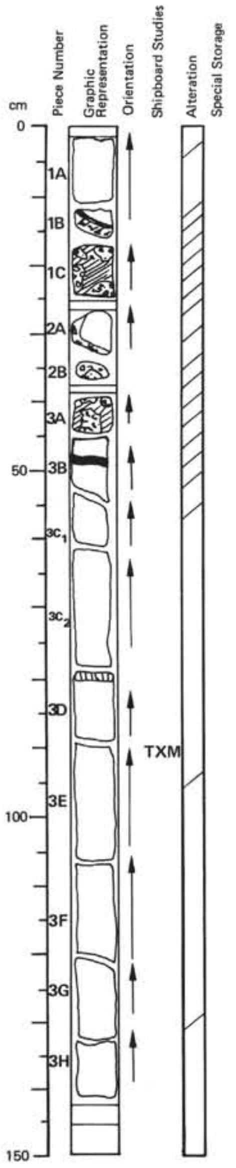
LEG	SITE	HOLE	CORE	SECT.
51	417	D	29	1

Visual Description

Moderately altered phyric pillow basalt with glassy chilled margins (pieces 2, 4D and 7) and minor breccia (pieces 1, 2 and 4D). 10-65, 70-105 and 120-140 cm intervals represent individual pillows. Basalt dark gray, altered to light gray, light brown, red-brown or brown near margins or veins in pieces 2 and 6. Groundmass hyalopilitic near margins, microlitic in pillow interiors. Plagioclase phenocrysts 10%, <5 mm, occasionally to 18 mm, partially replaced by calcite and clay; clinopyroxene phenocrysts <5%, <2 mm, partly replaced by calcite, green smectite; olivine phenocrysts <1%, ≤1 mm, partially replaced by calcite, green smectite. Veins filled by calcite ±green smectite; veins in piece 2 also contain yellow to pink secondary minerals. Breccia composed of fragments of glass replaced by calcite, green smectite, and palagonite(?) in a calcite matrix.

Shipboard Data

Physical Property Data:	80-82 cm
$\overline{V}p$ (km/sec)	5.02
Porosity (%)	7.70
Wet Bulk Density (g/cc)	2.72
Grain Density (g/cc)	2.86



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	29	2

Visual Description

Phyric basalt pillows with chilled glassy margins (pieces 1B and 3B) and hyaloclastite breccia (pieces 1B-3B). 0-13 and 48-140 cm intervals represent individual pillows. Basalt dark gray, with an aphanitic to hyalopilitic groundmass near margins and a microlitic groundmass in pillow interiors. Plagioclase phenocrysts 20%, ≤10 mm, partly replaced by calcite and clay; olivine (and pyroxene?) phenocrysts 5%, <5 mm. Veins filled by calcite and minor pyrite. Breccia in pieces 1B-3B composed of fragments of basalt and basaltic glass in a dark fine-grained matrix of green smectite. Glass in breccia and pillow margins replaced along cracks by calcite, green smectite and palagonite(?).

Thin Section Description

Location: pillow interior, 85 cm

Texture: porphyritic

Phenocrysts: olivine 2-3%, 1-3 mm, idiomorphic; plagioclase 10-15%, 2-6 mm, idiomorphic, zoned; clinopyroxene <0.5%, 1 mm, anhedral

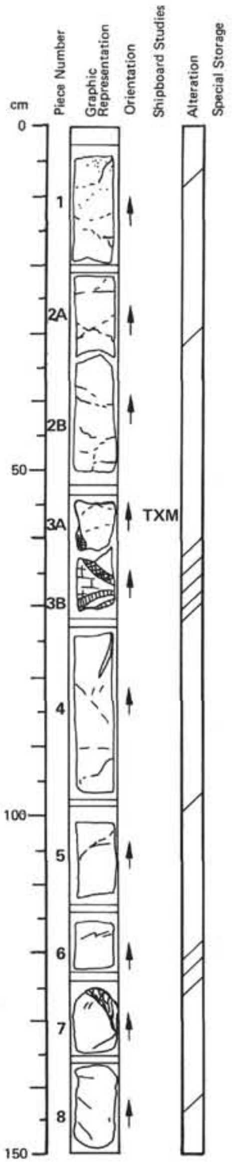
Groundmass: plagioclase 40%, 0.2-1 mm, skeletal; augitic clinopyroxene 20%, 0.2-0.5 mm, interstitial; titanomagnetite 15%, 0.3 mm, granular; glass 5%, interstitial, devitrified

Vesicles: <1%, <1 mm, round

Alteration: olivine replaced by calcite, celadonite and clay; vesicles filled by calcite

Shipboard Data

Bulk Analysis: 83-86 cm		Magnetic Data:	83-86 cm
SiO_2	50.85	NRM Intensity (emu/cc)	10.789×10^{-3}
Al_2O_3	17.54	NRM Inclination	-64.3°
Fe_2O_3	9.70	Stable Inclination	-66.3°
MgO	5.44		
CaO	13.00		
Na_2O	2.44		
K_2O	0.04		
TiO_2	1.39		
P_2O_5	0.11		
MnO	0.14		
LOI	0.75		
H_2O^+	1.14		
H_2O^-	N.D.		
CO_2	0.20		



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	29	3

Visual Description

Phyric basalt pillows with glassy chilled margins (pieces 1, 3 and 6-8), radial cracks (pieces 6-8) and interpillow limestone (piece 3B). 0-65, 65-125 and 125-150 cm intervals represent individual pillows bounded by chilled margins. Basalt dark gray with an aphanitic to hyalopilitic groundmass near margins and a microlitic groundmass in pillow interiors. Plagioclase phenocrysts 10-15%, <5 mm; olivine (± clinopyroxene) phenocrysts 3-5%, 1-3 mm. Groundmass in piece 2 contains disseminated sulfides. Veins filled by calcite. Interpillow limestone composed of calcite and minor green smectite. Glass adjacent to sediments and veins partially replaced by calcite, green smectite and palagonite(?).

Thin Section Description

Location: next to glassy margin, 58 cm

Texture: porphyritic

Phenocrysts: olivine 3-4%, 1-3 mm, idiomorphic; plagioclase 8%, 2-4 mm, idiomorphic, zoned; clinopyroxene <1%, 1-2 mm, anhedral

Groundmass: plagioclase microlites 50%, 0.2-0.6 mm, skeletal; clinopyroxene 15%, plumose or radiating; titanomagnetite 10%; hemitite 10%

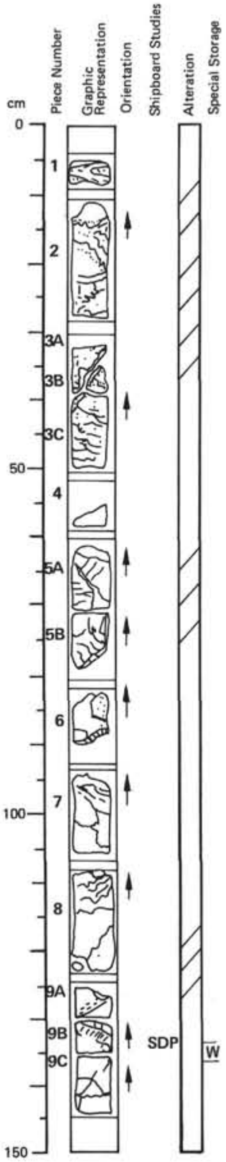
Vesicles: <1%, <1 mm, round

Alteration: olivine replaced by calcite or by clay and iron oxides; vesicles replaced by calcite and clay

Shipboard Data

Bulk Analysis: 57-60 cm	
SiO_2	50.00
Al_2O_3	17.25
Fe_2O_3	10.33
MgO	5.65
CaO	13.66
Na_2O	2.16
K_2O	0.04
TiO_2	1.39
P_2O_5	0.13
MnO	0.15
LOI	1.80
H_2O^+	0.82
H_2O^-	N.D.
CO_2	0.59

Magnetic Data:	57-60 cm
NRM Intensity (emu/cc)	11.769×10^{-3}
NRM Inclination	-70.9°
Stable Inclination	-70.3°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

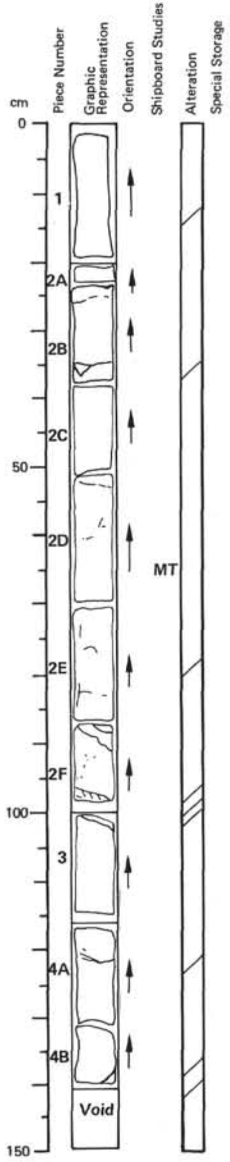
LEG	SITE	HOLE	CORE	SECT.
51	417	D	29	4

Visual Description

Phyric pillow basalt with glassy chilled margins (pieces 2-7, 9A and 9B) and cemented pillow breccia (pieces 1-3A, 6, 9A and 9B). Basalt dark gray, altered to yellow-brown along veins. Groundmass hyalopilitic to microlitic. Plagioclase phenocrysts 10-15%, <7 mm, partly replaced by calcite, clay; clinopyroxene phenocrysts 1%, <2 mm, partly replaced by calcite, green smectite; olivine phenocrysts <1%, <1 mm. Veins filled by calcite ± small shards of glass, locally normal to margins. Breccia composed of fragments of basalt and fractured glass in a matrix of calcite and green smectite. Basalt fragments altered to green smectite and palagonite(?) along veins, fractures and contacts with breccia.

Shipboard Data

Physical Property Data:	134-136 cm
$\overline{V}p$ (km/sec)	5.20
Porosity (%)	8.48
Wet Bulk Density (g/cc)	2.72
Grain Density (g/cc)	2.88



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Phyric basalt pillows with glassy chilled margins (pieces 2E, 2F and 4B). 0-100 and 100-140 cm intervals represent individual pillows or parts of pillows. Basalt dark gray with a hyalopilitic to microlitic groundmass. Plagioclase phenocrysts 10-15%, ≤10 mm; olivine phenocrysts 3-7%, ≤2 mm, partly replaced by calcite; clinopyroxene phenocrysts 2%, ≤2 mm. Veins filled by calcite.

Thin Section Description

Location: pillow interior, 65 cm

Texture: ophitic

Phenocrysts: olivine 2%, 1 mm, euhedral; plagioclase 20%, 4 mm, euhedral to subhedral; clinopyroxene, 0.5%, 1 mm, partially resorbed.

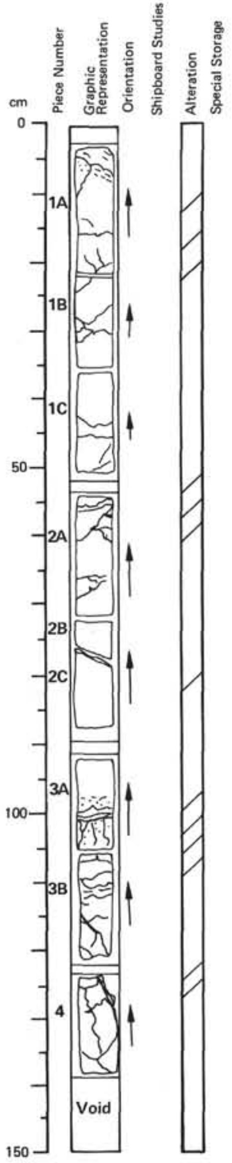
Groundmass: plagioclase 30%, 1 mm, prismatic; clinopyroxene 30%, 0.5 mm, anhedral; magnetite 5%, euhedral and dendritic; glass <5%

Vesicles: round

Alteration: glass and part of plagioclase replaced by clay; vesicles filled by calcite and clay

Shipboard Data

Magnetic Data:	64-67 cm
NRM Intensity (emu/cc)	5.601×10^{-3}
NRM Inclination	-54.7°
Stable Inclination	-64.0°

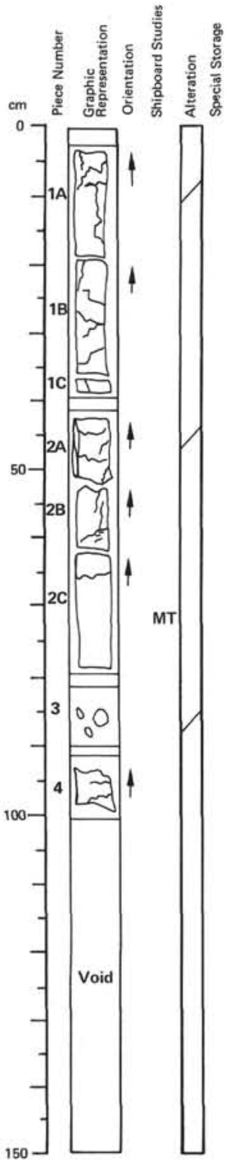


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	D		2	9	6

Visual Description

Phyric basalt pillows with glassy chilled margins (pieces 1A and 3A) and interpillow limestone (piece 1A). 5-100 and 100-140 cm intervals represent individual pillows or parts of pillows. Basalt dark gray with a hyalopilitic to microlitic groundmass. Plagioclase phenocrysts 20%, ≤5 mm, fresh to partly replaced by calcite; clinopyroxene and olivine phenocrysts 2-5%, 1-3 mm and <1%, ≤1 mm respectively, replaced by calcite. Veins filled by calcite. Interpillow limestone finely layered, composed of calcite, minor green smectite. Well-preserved chilled margin in piece 1A displays a 6-7 mm rim of green, devitrified glass in contact with the sediments. This is underlain, in turn, by a 15 mm thick layer of fresh black glass and a 2 mm thick, light gray zone marking the transition to the sparsely phyric to microlitic basalt of the pillow interior. The devitrified to fresh glass transition is marked by a thin zone of fractured glass. Glass along veins and sediment contacts partially replaced by calcite, green smectite and palagonite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	29	7

Visual Description

Phyric, dark gray basalt with a microlitic groundmass. Plagioclase phenocrysts 15%, <3 mm, fresh to partially replaced by calcite; clinopyroxene and olivine phenocrysts 1-2%, <2 mm, replaced by green smectite. Veins filled by calcite, green smectite and pyrite.

Thin Section Description

Location: pillow interior, 72 cm

Texture: porphyritic, intersertal

Phenocrysts: olivine 1%, 1 mm, idiomorphic; plagioclase 15%, 2-5 mm, An 60, idiomorphic, zoned margins

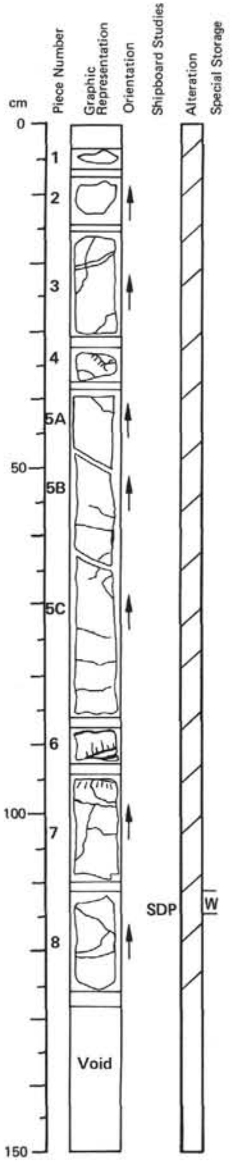
Groundmass: plagioclase laths 40%, 0.2-2 mm; augitic clinopyroxene 35% intergranular, sometimes poikilitic; titano magnetite 5-10%, 0.2-0.3 mm; glass 1-2%, interstitial

Vesicles: 1%, <1 mm, round

Alteration: olivine replaced by calcite or by clay and celadonite; vesicles replaced by calcite and celadonite

Shipboard Data

Magnetic Data:	70-73 cm
NRM Intensity (emu/cc)	9.171×10^{-3}
NRM Inclination	-42.5°
Stable Inclination	-64.3°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

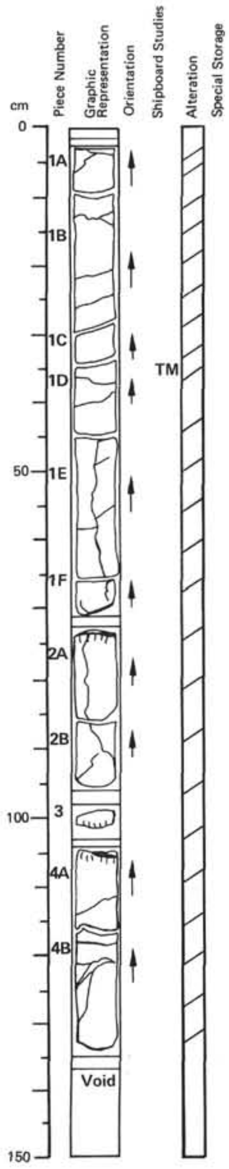
LEG	SITE	HOLE	CORE	SECT.
51	417	D	30	1

Visual Description

Phyric basalt pillows with 10 mm thick, chilled glassy margins (pieces 4, 6 and 7) and traces of interpillow breccia (pieces 1, 4 and 6). 30-92 and 94-130 cm intervals represent individual pillows or parts of pillows. Basalt dark gray, altered to gray brown along veins. Groundmass aphanitic to crystalline. Euhedral plagioclase phenocrysts 30%, 6 mm, partially replaced by green smectite; euhedral olivine phenocrysts 5%, 2 mm, completely replaced by iddingsite, green smectite and calcite. Phenocrysts show evidence of crystal settling. Vesicles < 1%, 0.5 mm, filled by green smectite. Veins filled by calcite and green smectite; veins in piece 2 have analcite linings and iron hydroxide (goethite) cores. Interpillow breccia composed of shards of glass in a matrix of calcite and green smectite.

Shipboard Data

Physical Property Data:	112-114 cm
$\overline{V}$p (km/sec)	5.67
Porosity (%)	4.32
Wet Bulk Density (g/cc)	2.86
Grain Density (g/cc)	2.94



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	30	2

Visual Description

Phyric basalt pillows with 15 mm thick, glassy chilled margins (pieces 1F, 2A, 3 and 4) delineating individual pillows or parts of pillows between 0-71, 72-101 and 102-132 cm. Basalt dark gray, altered to gray-brown near margins. Groundmass aphanitic to crystalline. Euhedral plagioclase phenocrysts <30%, <6 mm; euhedral olivine phenocrysts <10%, <2 mm, replaced by green smectite. Increase in size of plagioclase phenocrysts and increase in abundance of olivine phenocrysts (from 0 to 10%) with depth within individual pillows suggests crystal settling. Vesicles 2%, filled by calcite, green smectite. Veins filled by calcite, green smectite and zeolites.

Thin Section Description

Location: 38 cm, pillow interior

Texture: hyaloophitic, porphyritic

Phenocrysts: olivine 3%, 0.5 mm, euhedral; plagioclase 20%, 2 mm, euhedral-subhedral; clinopyroxene <0.5%, 0.2 mm, as partially resorbed inclusions in plagioclase

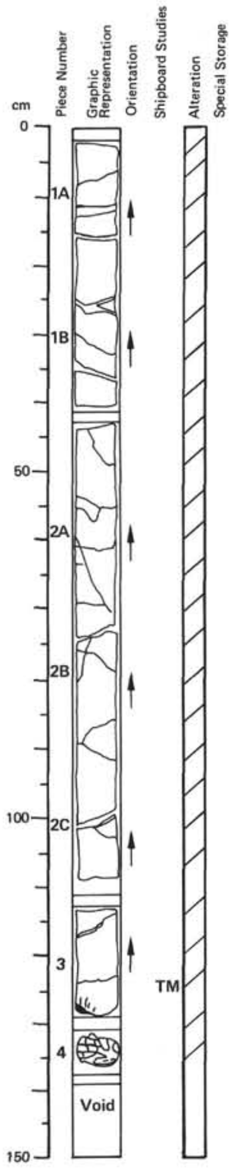
Groundmass: olivine 10%, <0.2 mm, euhedral; plagioclase 30%, <0.5 mm, tabular, quenched; clinopyroxene 30%, <0.5 mm, quenched; magnetite 5%, quenched, dendritic; glass <5%

Vesicles: none

Alteration: veins filled with calcite, aragonite, zeolites and hematite

Shipboard Data

Magnetic Data:	36-39 cm
NRM Intensity (emu/cc)	6.301×10^{-3}
NRM Inclination	-64.2°
Stable Inclination	-64.0°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	30	3

Visual Description

Phyric pillow basalt with chilled margin (piece 3) and minor interpillow breccia. 0-130 cm interval represents part of an individual pillow. Basalt dark gray with an aphanitic groundmass. Euhedral plagioclase phenocrysts 10-30%, <8 mm with occasional megacrysts to 12 mm, locally replaced by calcite and zeolites; euhedral olivine phenocrysts 1-10%, <2 mm, completely replaced by green smectite. Vesicles 3%, filled by green smectite, calcite and zeolites. Veins filled by calcite and green smectite. Breccia in piece 4 composed of elongate fragments of basaltic glass in a calcite matrix cut by veins of sparry calcite, zeolites and clay.

Thin Section Description

Location: 125 cm, next to glassy margin

Texture: hyaloophitic, variolitic

Phenocrysts: plagioclase 15%, 2 mm, euhedral, partially resorbed; clinopyroxene 2%, 0.5 mm, partially resorbed

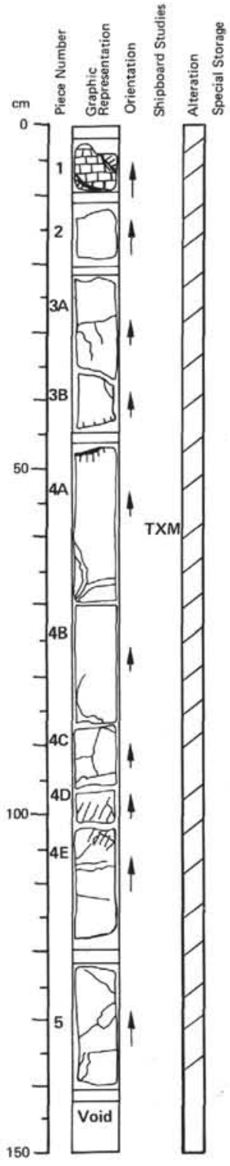
Groundmass: plagioclase 10%, 0.5 mm, tabular; clinopyroxene 5%, 0.3 mm, quenched; glass >60%, devitrified

Vesicles: none

Alteration: veins and vesicles filled with calcite and clay; plagioclase partially altered to calcite

Shipboard Data

Magnetic Data:	123-126 cm
NRM Intensity (emu/cc)	8.400×10^{-3}
NRM Inclination	-68.1°
Stable Inclination	-67.4°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	30	4

Visual Description

Phyric basalt pillows with chilled margins (pieces 1, 3B, 4A, 4D and 4E) and minor interpillow limestone breccia. 5-45, 45-102 and 102-140 cm intervals represent individual pillows or parts of pillows. Basalt dark gray with an aphanitic to crystalline groundmass. Euhedral plagioclase phenocrysts 30%, 5-10 mm, fresh to partially replaced by green smectite; olivine phenocrysts <1%, completely replaced by green smectite. Calcite-filled vesicles <1%. Veins filled by calcite, green smectite. Interpillow breccia composed of fragments of basalt and basaltic glass partially altered to green smectite and palagonite(?) in a calcite matrix.

Thin Section Description

Location: 58 cm, pillow interior

Texture: intersertal

Phenocrysts: olivine 5%, 1.5 mm, euhedral; plagioclase 20%, 4 mm, euhedral; clinopyroxene 0.5%, 1 mm, partially resorbed.

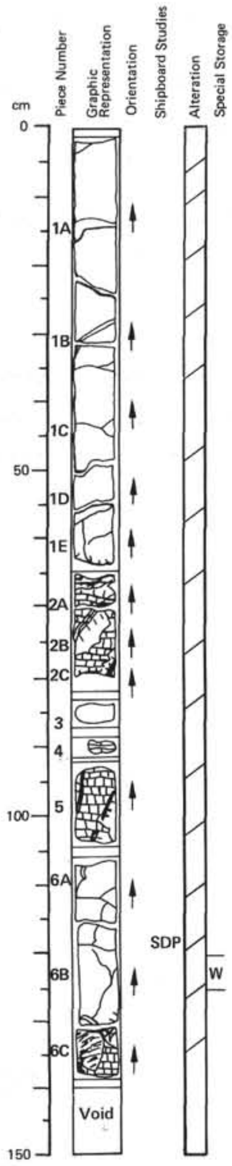
Groundmass: olivine 5%, euhedral-subhedral; plagioclase 30%, 1 mm, prismatic, quenched; clinopyroxene 30%, 0.5 mm, quenched; magnetite, 5%, euhedral-dendritic.

Vesicles: filled by calcite

Alteration: olivine replaced by clay

Shipboard Data

Bulk Analysis: 57-60 cm		Magnetic Data:	57-60 cm
SiO_2	49.14	NRM Intensity (emu/cc)	11.130×10^{-3}
Al_2O_3	17.09	NRM Inclination	-65.6°
Fe_2O_3	10.53	Stable Inclination	-65.6°
MgO	5.54		
CaO	13.19		
Na_2O	2.45		
K_2O	0.17		
TiO_2	1.41		
P_2O_5	0.12		
MnO	0.14		
LOI	1.90		
H_2O^+	1.06		
H_2O^-	N.D.		
CO_2	1.01		



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

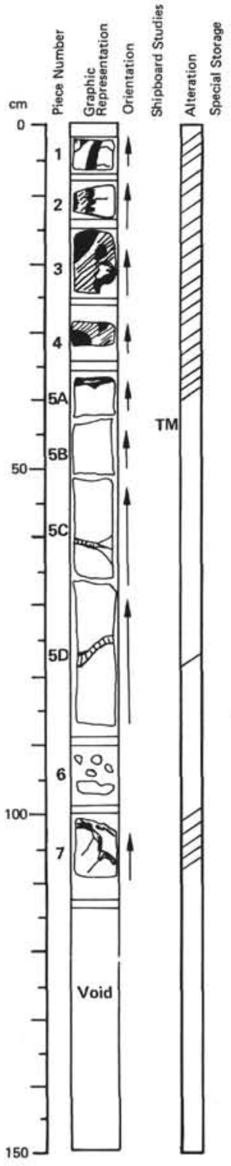
LEG	SITE	HOLE	CORE	SECT.
51	417	D	30	5

Visual Description

Phyric pillow basalt with chilled margins (pieces 1E, 2A, 2B, 5, 6B and 6C) and interpillow limestone (pieces 2, 4, 5 and 6C). Basalt dark gray with an aphanitic to crystalline groundmass. Euhedral plagioclase phenocrysts 30%, 4 mm; euhedral olivine phenocrysts 5%, 3 mm, completely altered to green smectite. Veins filled by calcite and green smectite. Spaces between pillows filled by recrystallized calcite or by a mixture of calcite and green smectite with smectite and fragments of glass along pillow margins. Piece 4 contains analcite.

Shipboard Data

Physical Property Data:	118-121 cm
$\overline{V}p$ (km/sec)	5.18
Porosity (%)	8.51
Wet Bulk Density (g/cc)	2.74
Grain Density (g/cc)	2.91



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	30	6

Visual Description

Phyric pillow basalt with chilled glassy margins (pieces 5A and 7) and volcanic breccia (pieces 1-4). Basalt dark gray, altered to gray-brown within 1 cm of margins. Groundmass aphanitic to crystalline. Altered plagioclase phenocrysts 20%, <5 mm; clinopyroxene phenocrysts 2-3%, <5 mm; olivine phenocrysts 1%, replaced by green smectite. Veins abundant, filled by calcite, green smectite. Breccia composed of fragments of basaltic glass and phyric basalt with glassy margins in a white to green matrix of calcite and green smectite.

Thin Section Description

Location: 46 cm, next to glassy margin

Texture: hyaloophitic

Phenocrysts: olivine 2%, 1 mm, euhedral; plagioclase 20%, 4 mm, euhedral; clinopyroxene 0.5%, 0.5 mm, partially resorbed

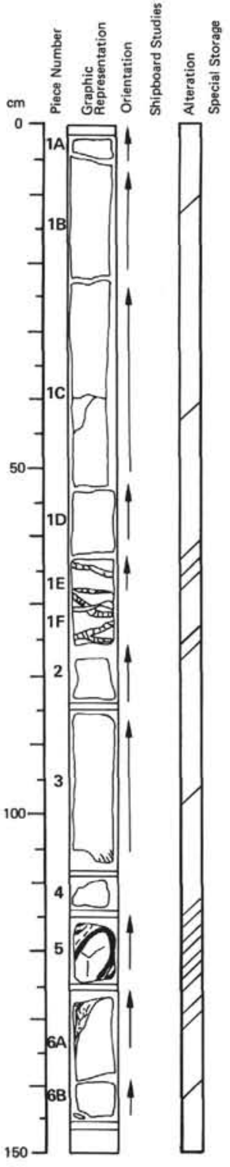
Groundmass: plagioclase 10%, 0.5 mm, quenched; clinopyroxene 20%, 0.5 mm, quenched; glass 50%, devitrified

Vesicles: 2%, 0.2 mm, filled by calcite and clay

Alteration: veins and vesicles filled with calcite

Shipboard Data

Magnetic Data:	45-48 cm
NRM Intensity (emu/cc)	6.394×10^{-3}
NRM Inclination	-75.2°
Stable Inclination	-73.1°

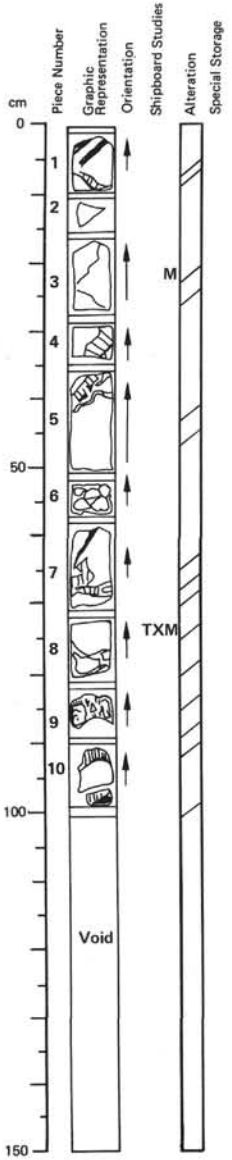


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	30	7

Visual Description

Phyric pillow basalt with glassy chilled margins (pieces 3, 5 and 6A) and minor hyaloclastite breccia (pieces 5 and 6A). Basalt dark gray with an aphanitic to intersertal texture. Altered plagioclase phenocrysts 20-25%; euhedral clinopyroxene phenocrysts 5%, <5 mm; olivine phenocrysts 2%, <5 mm, replaced by calcite, green smectite. Veins abundant, <6 mm wide, filled by calcite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	30	8

Visual Description

Phyric pillow basalt with chilled glassy margins (pieces 1, 5 and 7) and hyaloclastite breccia in a dark green, fine-grained matrix (pieces 1, 6, 7, 9 and 10). Basalt dark gray with an aphanitic to fine-grained, crystalline matrix. Altered, euhedral plagioclase phenocrysts 25%, < 10 mm; mafic (olivine?) phenocrysts 1%, <3 mm, replaced by green smectite. Veins and cavities filled by coarse-grained calcite (pieces 1, 4, 5 and 7).

Thin Section Description

Location: 72 cm, next to glassy margin

Texture: hyaloophitic

Phenocrysts: olivine 5%, 1 mm, euhedral; plagioclase 20%, 2 mm, euhedral, partially resorbed; clinopyroxene 3%, 0.5 mm, partially resorbed.

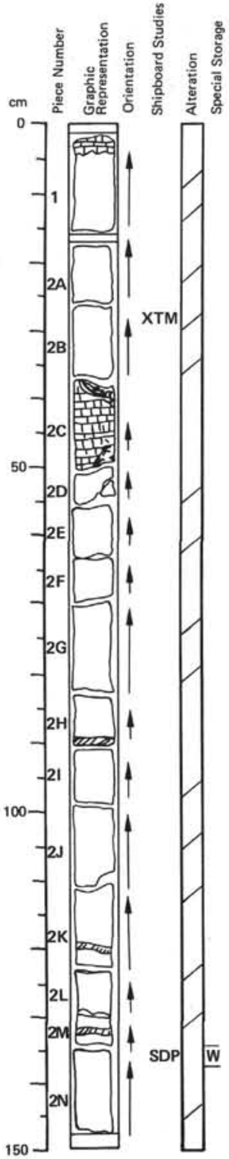
Groundmass: olivine 5%; plagioclase 20%, 0.5 mm, quenched, prismatic with swallow tail crystals; clinopyroxene 20%, quenched; magnetite 5%; glass 20%, fresh to partially devitrified.

Vesicles: round, filled with clay

Alteration: olivine replaced by clay

Shipboard Data

Bulk Analysis: 70-73 cm		Magnetic Data:	70-73 cm
SiO_2	50.42	NRM Intensity (emu/cc)	8.593×10^{-3}
Al_2O_3	18.16	NRM Inclination	-52.3°
Fe_2O_3	9.73	Stable Inclination	-53.7°
MgO	5.50		
CaO	11.17		
Na_2O	2.49		
K_2O	0.40		
TiO_2	1.54		
P_2O_5	0.13		
MnO	0.09		
LOI	1.50		
H_2O^+	1.25		
H_2O^-	N.D.		
CO_2	0.33		



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	31	1

Visual Description

Plagioclase-phyric pillow basalt with brecciated glassy margins (piece 2) and gray-green, fine-grained interpillow limestone (pieces 1 and 2C). Basalt dark gray with an aphanitic to halocrystalline groundmass. Altered euhedral plagioclase phenocrysts 25%, < 10 mm; mafic phenocrysts rare. Veins numerous, filled by calcite and green smectite. Limestone composed of calcite with green smectite and shard of glass ± celadonite.

Thin Section Description

Location: 30 cm, pillow interior

Texture: porphyritic

Phenocrysts: olivine 2%, 2-3 mm, idiomorphic; plagioclase 10%, 2-4 mm, idiomorphic; clinopyroxene < 1%, 1-2 mm, corroded

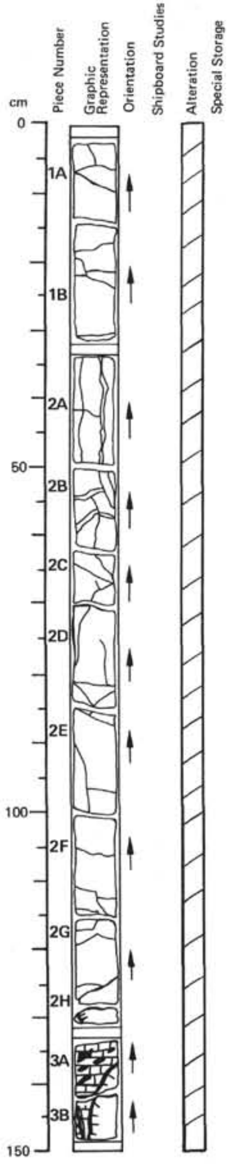
Groundmass: plagioclase 40%, 0.2-1 mm, hollow and skeletal; clinopyroxene 20%, plumose; magnetite, hematite and altered glass 30%, subopaque

Vesicles: 1%, < 1 mm, filled by calcite and clay, some shrinkage vesicles

Alteration: olivine replaced by calcite, clay and celadonite

Shipboard Data

Bulk Analysis: 29-31 cm		Magnetic Data:	29-31 cm
SiO_2	49.01	NRM Intensity (emu/cc)	11.847×10^{-3}
Al_2O_3	17.04	NRM Inclination	-73.4°
Fe_2O_3	11.75	Stable Inclination	-73.3°
MgO	5.11		
CaO	11.86	Physical Property Data:	136-138 cm
Na_2O	2.41	$\overline{V}p$ (km/sec)	5.07
K_2O	0.84	Porosity (%)	8.8
TiO_2	1.39	Wet Bulk Density (g/cc)	2.68
P_2O_5	0.13	Grain Density (g/cc)	2.84
MnO	0.10		
LOI	2.85		
H_2O^+	1.86		
H_2O^-	N.D.		
CO_2	1.25		

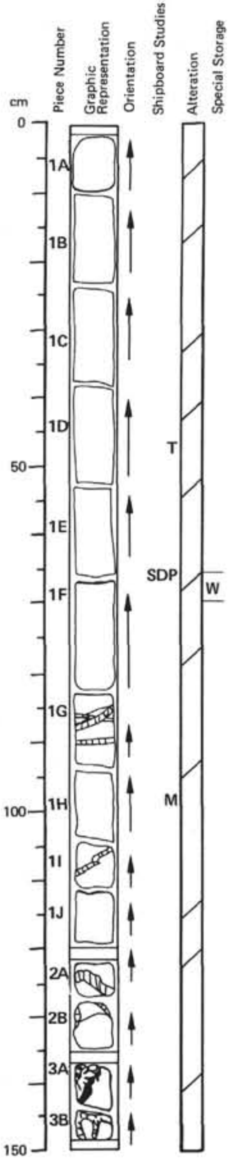


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	31	2

Visual Description

Phyric pillow basalt with chilled margins (pieces 2H and 3) and interpillow limestone breccia (piece 3). 0-130 and 135-150 cm intervals represent parts of individual pillows. Basalt dark gray, locally altered to gray-brown. Groundmass aphanitic to crystalline. Euhedral plagioclase phenocrysts 25%, <5 mm, fresh to partially replaced by green smectite; euhedral olivine phenocrysts 2-5%, 1-3 mm, replaced by green smectite; anhedral clinopyroxene(?) phenocrysts <1%, 0.5 mm. Veins filled by calcite, green smectite and quartz (piece 3). Breccia composed of fragments of glass partially altered to green smectite in a calcite matrix.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	31	3

Visual Description

Phyric pillow basalt with glassy chilled margins (piece 3A) and minor intercalated limestone composed of calcite and minor green smectite (pieces 2 and 3). Basalt dark gray with an aphanitic to crystalline groundmass. Altered euhedral plagioclase phenocrysts 20%, < 10 mm; dark green mafic phenocrysts 2%, < 15 mm. Veins common, <5 mm wide, filled by calcite, green smectite. Basalt in contact with fine-grained, gray-green limestone in pieces 2A and 2B displays no chilled margins. Basalt in piece 3 displays glassy chilled margins in contact with limestone containing coarse-grained sparry calcite.

Thin Section Description

Location: 46 cm, pillow interior

Texture: intersertal

Phenocrysts: olivine 3%, 2 mm; euhedral; plagioclase 20%, 3 mm, euhedral-subhedral; clinopyroxene 0.5%, 1 mm, partially resorbed

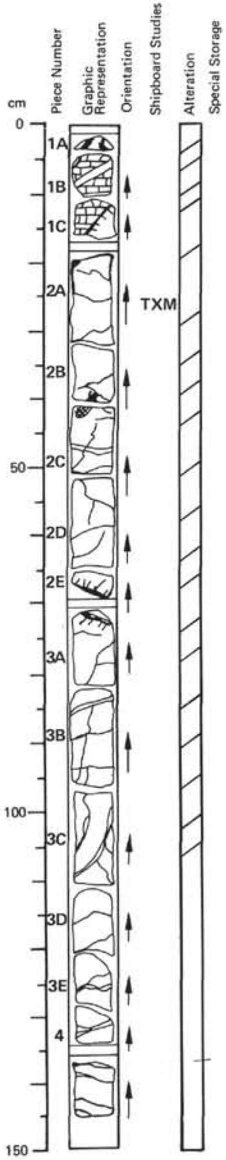
Groundmass: plagioclase 30%, 1 mm, prismatic; clinopyroxene 30%, 0.5 mm. Anhedral; magnetite 5%, 0.02 mm, prismatic-dendritic; glass <5% .

Vesicles: filled by calcite

Alteration: olivine replaced by calcite and clay; glass replaced by clay

Shipboard Data

Magnetic Data:	95-98 cm
NRM Intensity (emu/cc)	10.300×10^{-3}
NRM Inclination	-54.8°
Stable Inclination	-57.3°
Physical Property Data:	67-69 cm
$\overline{V}$p (km/sec)	5.18
Porosity (%)	6.8
Wet Bulk Density (g/cc)	2.75
Grain Density (g/cc)	2.87



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	D	3	1		4

Visual Description

Phyric basalt pillows with chilled glassy margins (pieces 1C, 2E and 3A) and a well-preserved interval of interpillow (interlayered?) limestone (piece 1). 10-70 and 70-145 cm intervals represent individual pillows. Basalt dark gray, altered to pale brown or red-brown in pieces 3C-4. Groundmass aphanitic to crystalline, often microlitic. Euhedral plagioclase phenocrysts 25%, <5 mm; olivine phenocrysts 3%, <1 mm, replaced by green smectite; anhedral clinopyroxene phenocrysts rare. Veins common, filled by calcite, green smectite. Pieces 2B and 2C contain a large filled cavity. Limestone in pieces 1A-1C composed of calcite and minor green clay cut, in piece 1B, by a vein of the same material. Sediments bounded above and below by chilled pillow margins, the upper of which is fragmented and entrained in the sediments next to the margin while the lower is hydrated against the sediments. Limestone may separate two distinct flows.

Thin Section Description

Location: 28 cm, next to glassy margin

Texture: porphyritic

Phenocrysts: olivine 1%, 1-2 mm, idiomorphic; plagioclase 15%, 1-2 mm, idiomorphic, zoned; augitic clinopyroxene <1%, 2-3 mm, rounded.

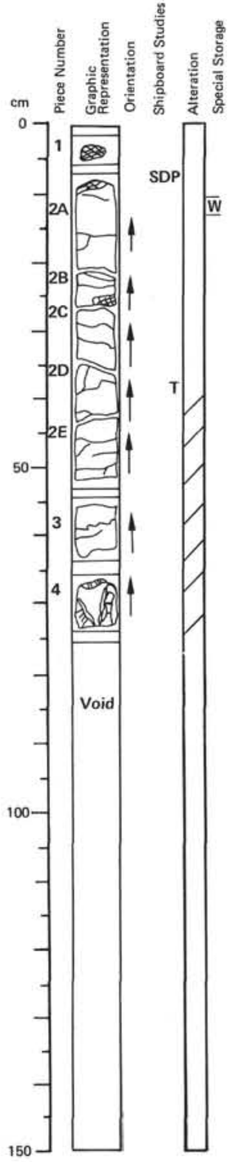
Groundmass: plagioclase 35%, <1 mm, hollow, skeletal; clinopyroxene 15%, plumose; titanomagnetite 20%, <0.3 mm, skeletal; glass 15%, devitrified; calcite vein, 5 mm wide contains glassy shards

Vesicles: <1%, <0.3 mm, round, shrinkage, filled by clay

Alteration: olivine replaced by calcite

Shipboard Data

Bulk Analysis: 27-29 cm		Magnetic Data:	27-29 cm
SiO_2	49.76	NRM Intensity (emu/cc)	13.755×10^{-3}
Al_2O_3	17.36	NRM Inclination	-71.0°
Fe_2O_3	10.42	Stable Inclination	-70.4°
MgO	5.70		
CaO	13.14		
Na_2O	2.42		
K_2O	0.18		
TiO_2	1.43		
P_2O_5	0.11		
MnO	0.15		
LOI	0.85		
H_2O^+	1.79		
H_2O^-	N.D.		
CO_2	0.53		



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	D	3	1		5

Visual Description

Phyric pillow basalt with chilled margins and well-preserved interpillow fillings (piece 4). Basalt dark gray with an aphanitic to crystalline, often microlitic groundmass. Euhedral plagioclase phenocrysts 25%, 4 mm, partially replaced by green smectite; euhedral olivine phenocrysts 5%, 2 mm, replaced by green smectite. Veins filled by calcite. Piece 1 consists entirely of white secondary minerals. Interpillow filling in piece 4 composed of green smectite. Chilled margins in piece 4 devitrified, partially replaced by green smectite.

Thin Section Description

Location: 41 cm, pillow interior

Texture: hyaloophitic

Phenocrysts: olivine 1%, 2 mm, euhedral; plagioclase 15%, 1-4 mm, euhedral, fresh; clinopyroxene 1%, 2 mm, 2V = 50°, partially resorbed

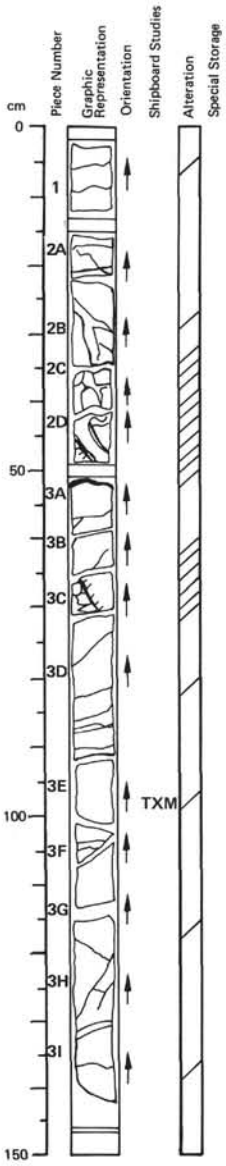
Groundmass: olivine 5%, 0.1 mm; plagioclase 25%, 0.5 mm, quenched; clinopyroxene 40%, 0.3 mm, quenched; glass

Vesicles: none

Alteration: olivine and glass replaced by clay

Shipboard Data

Physical Property Data:	12-14 cm
$\overline{V}p$ (km/sec)	4.56
Porosity (%)	10.2
Wet Bulk Density (g/cc)	2.52
Grain Density (g/cc)	2.69



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	32	1

Visual Description

0-70 cm: phyric pillow basalt and pillow breccia (pieces 2B-2D and 3C) with chilled margins (pieces 2D, 3A and 3C). Basalt dark gray with an aphanitic to holocrystalline, often microlitic groundmass. Euhedral plagioclase phenocrysts 25%, < 10 mm; euhedral olivine phenocrysts 5%, <2 mm, replaced by green smectite. Veins and rare vesicles filled by calcite.

Breccia composed of angular clasts and fragments of basalt and glass in a matrix of calcite and green smectite. Fragments of glass and basalt and surfaces of larger clasts devitrified, partially replaced by green smectite. Breccia matrix in contact with basalt along both holocrystalline and aphanitic surfaces.

70-140 cm: massive phyric basalt with a chilled margin in the top of piece 3D. Basalt gray with an aphanitic groundmass near the margin and an intersertal to subophitic groundmass which increases in grain size with depth between 75-140 cm. Euhedral plagioclase phenocrysts 15%, 5 mm; anhedral clinopyroxene phenocrysts <5%; olivine phenocrysts replaced by green smectite. Minor calcite-filled veins.

Thin Section Description

Location: 95 cm, marginal part of massive basalt

Texture: ophitic, porphyritic

Phenocrysts: olivine 2%, 0.3 mm, euhedral-anhedral; plagioclase 15%, 3 mm, euhedral-subhedral; clinopyroxene 2%, 0.5 mm, partially resorbed

Groundmass: olivine 10%, 0.2 mm, euhedral; plagioclase 20%, 0.8 mm, tabular, quenched; clinopyroxene 35%, 0.5 mm, anhedral, quenched; magnetite 5%, 0.02 mm, granular, quenched

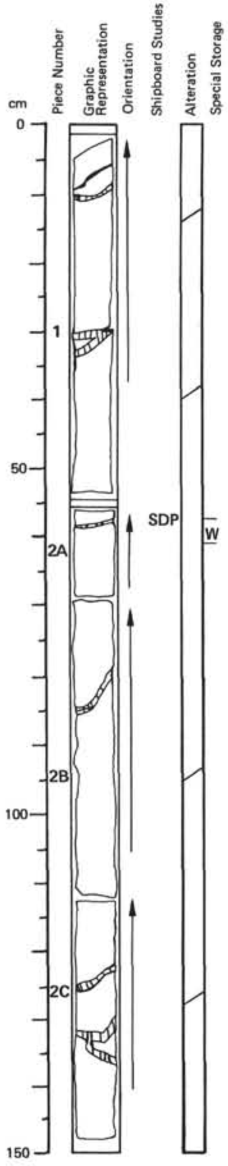
Vesicles: none

Alteration: olivine replaced by clay

Shipboard Data

Bulk Analysis: 96-98 cm	
SiO_2	50.53
Al_2O_3	17.17
Fe_2O_3	10.80
MgO	5.79
CaO	12.54
Na_2O	2.34
K_2O	0.06
TiO_2	1.44
P_2O_5	0.12
MnO	0.15
LOI	0.25
H_2O^+	0.94
H_2O^-	N.D.
CO_2	0.22

Magnetic Data:	96-98 cm
NRM Intensity (emu/cc)	2.738×10^{-3}
NRM Inclination	- 4.1°
Stable Inclination	-55.6°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

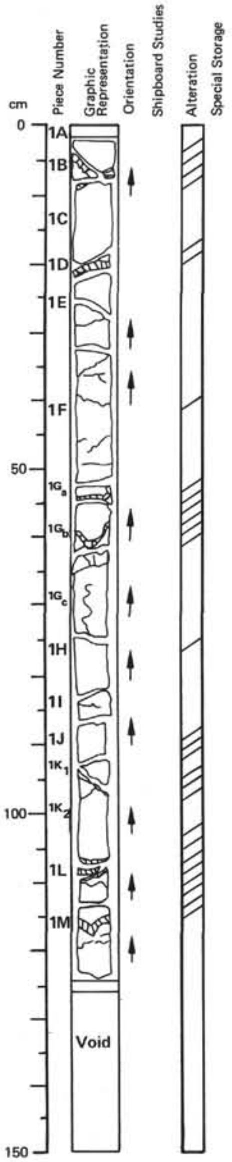
LEG	SITE	HOLE	CORE	SECT.
51	417	D	32	2

Visual Description

Massive, moderately phyric basalt with a gray, subophitic groundmass containing plagioclase microlites in augite, disseminated calcite and minor pyrite. Piece 1 continuous with piece 3I of previous section. Plagioclase phenocrysts 10%, 2-3 mm. Vesicles common, filled by calcite or green smectite (+pyrite) or zoned with green smectite linings and cores of calcite. Basalt zoned on basis of vesicle fillings. Veins filled by calcite and green smectite.

Shipboard Data

Physical Property Data:	58-61 cm
$\overline{V}p$ (km/sec)	5.04
Porosity (%)	2.3
Wet Bulk Density (g/cc)	6.5
Grain Density (g/cc)	2.76

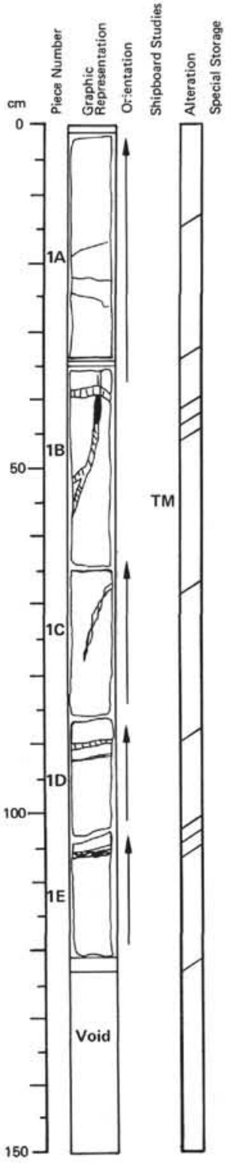


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	32	3

Visual Description

Massive, slightly phyric basalt with a gray, subophitic groundmass containing plagioclase microlites in augite. Plagioclase phenocrysts 5-7%, <7 mm; clinopyroxene phenocrysts 3%, 1-2 mm; olivine phenocrysts <1%, <0.5 mm, replaced by green smectite. Vesicles <2%, 0.5-1.0 mm, filled by calcite. Veins filled by calcite and green to brown smectite. Groundmass along veins locally contains disseminated sulfides.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	32	4

Visual Description

Massive plagioclase-phyric basalt with a gray, subophitic groundmass containing plagioclase microlites in augite and disseminated pyrite. Euhedral plagioclase phenocrysts 10-15%, <5 mm. 0-20 cm interval contains a small number of vesicles filled by calcite and green smectite. Veins filled by green smectite followed by calcite.

Thin Section Description

Location: 57 cm

Texture: porphyritic, subophitic

Phenocrysts: olivine 2-3%, 1 mm, idiomorphic; plagioclase 10%, 2-3 mm, An 60, idiomorphic with zoned margins and glassy inclusions

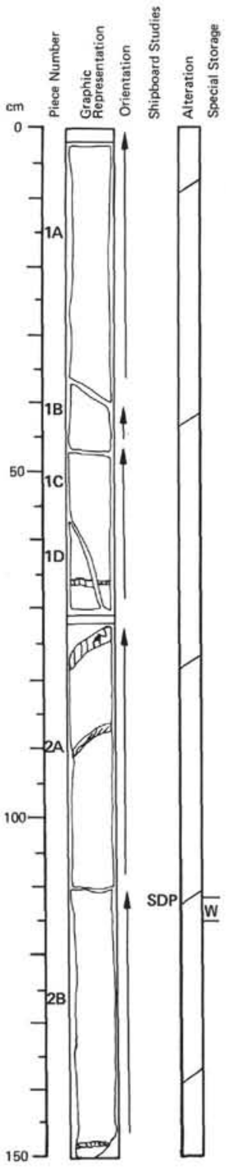
Groundmass: plagioclase laths 40%, 0.5-1 mm, 0.2 mm; augitic clinopyroxene 40%, 0.5-1 mm, intergranular; titanomagnetite 5%, 0.2 mm; interstitial clay 2-3%

Vesicles: none

Alteration: olivine replaced by calcite, clay and celadonite

Shipboard Data

Magnetic Data:	56-58 cm
NRM intensity (emu/cc)	4.560×10^{-3}
NRM Inclination	- 7.7°
Stable Inclination	-62.1°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

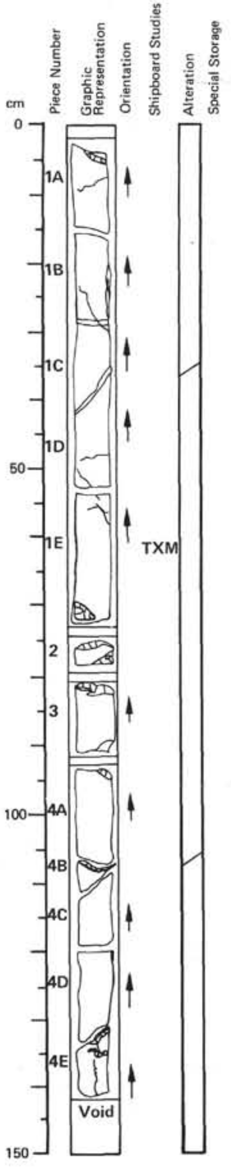
LEG	SITE	HOLE	CORE	SECT.
51	417	D	32	5

Visual Description

Massive plagioclase-phyric basalt with a gray, subophitic groundmass containing plagioclase microlites in augite. Euhedral plagioclase phenocrysts 15%, <5 mm, slightly altered. Veins, rare vesicles filled by calcite, green smectite.

Shipboard Data

Physical Property Data:	113-116 cm
$\overline{V}$p (km/sec)	5.79
Porosity (%)	2.3
Wet Bulk Density (g/cc)	2.9
Grain Density (g/cc)	2.95



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	32	6

Visual Description

Massive, phyric basalt with a gray, subophitic groundmass containing minor disseminated calcite and pyrite. Basalt displays 1-2 cm wide, dark green to yellow-brown, zoned alteration haloes along veins due to partial replacement by calcite and green to brown smectite. Plagioclase phenocrysts 15%, <5 mm; augitic clinopyroxene phenocrysts 7%, <1 mm, partially replaced by green smectite; olivine phenocrysts <1%, <0.5 mm, completely replaced by green smectite. Veins filled by calcite ±white clay.

Thin Section Description

Location: 60 cm, flow interior

Texture: ophitic

Phenocrysts: plagioclase 15%, 4 mm, euhedral-subhedral

Groundmass: olivine 10%, 0.2 mm, euhedral; plagioclase 30%, 1 mm, prismatic; clinopyroxene 30%, 0.4 mm, anhedral; magnetite 5%, 0.1 mm, granular-tabular; glass 5%

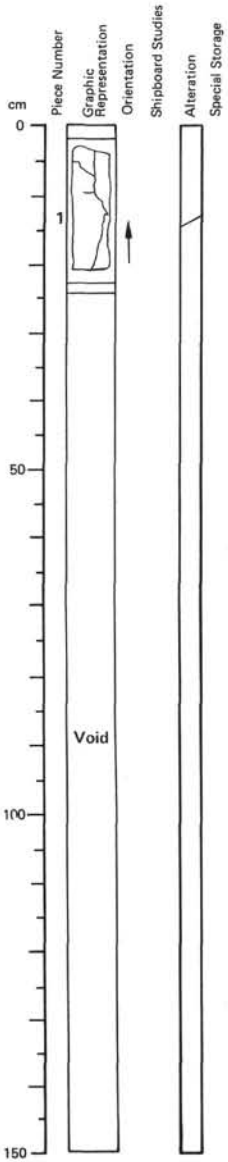
Vesicles: none

Alteration: olivine and glass replaced by clay

Shipboard Data

Bulk Analysis:	60-62 cm
SiO_2	51.01
Al_2O_3	16.78
Fe_2O_3	10.01
MgO	5.85
CaO	12.33
Na_2O	2.39
K_2O	0.13
TiO_2	1.49
P_2O_5	0.10
MnO	0.12
LOI	0.60
H_2O^+	0.79
H_2O^-	N.D.
CO_2	0.43

Magnetic Data:	60-62 cm
NRM Intensity (emu/cc)	7.022×10^{-3}
NRM Inclination	+50.9°
Stable Inclination	-65.8°

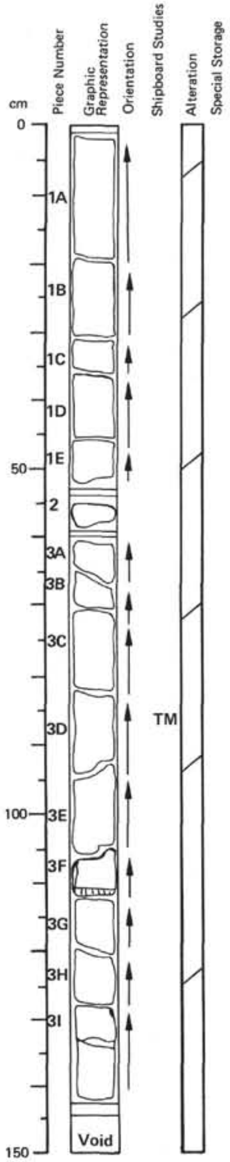


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	32	7

Visual Description

Massive, phyric basalt with a gray, subophitic groundmass. Basalt altered to gray-green or yellow-brown along veins due to partial replacement by calcite and green to brown smectite. Plagioclase phenocrysts 5-7%, <4 mm, slightly altered; clinopyroxene phenocrysts 10%, <0.5 mm, fresh to partially replaced by green smectite. Veins filled by green to brown smectite, minor calcite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	33	1

Visual Description

Massive, plagioclase-phyric basalt with a gray, subophitic groundmass containing plagioclase microlites in augite ± olivine and minor opaques. Euhedral plagioclase phenocrysts 15%, <4 mm, slightly altered. Veins scarce, filled by calcite.

Thin Section Description

Location: 85 cm, massive basalt

Texture: ophitic, porphyritic

Phenocrysts: plagioclase 10%, 3 mm, euhedral-subhedral; clinopyroxene 2%, 2 mm; subhedral-anhedral

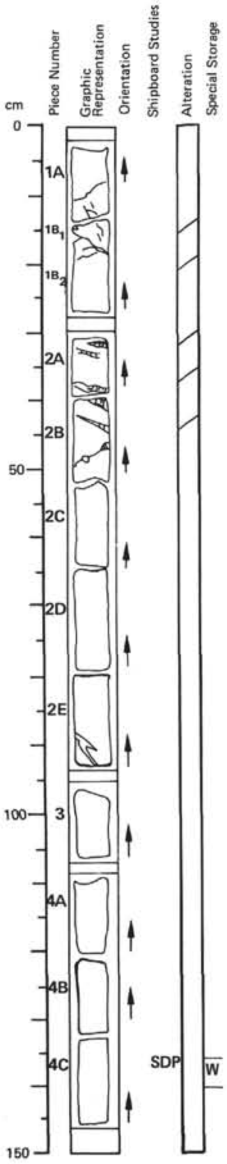
Groundmass: olivine 10%, 0.2 mm, euhedral-subhedral; plagioclase 30%, 0.5 mm, anhedral-subhedral; clinopyroxene 30%, 0.5 mm, anhedral-subhedral; magnetite 3%, 0.05 mm, anhedral

Vesicles: none

Alteration: olivine replaced by clay

Shipboard Data

Magnetic Data:	84-86 cm
NRM Intensity (emu/cc)	5.066×10^{-3}
NRM Inclination	+46.9°
Stable Inclination	-66.1°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

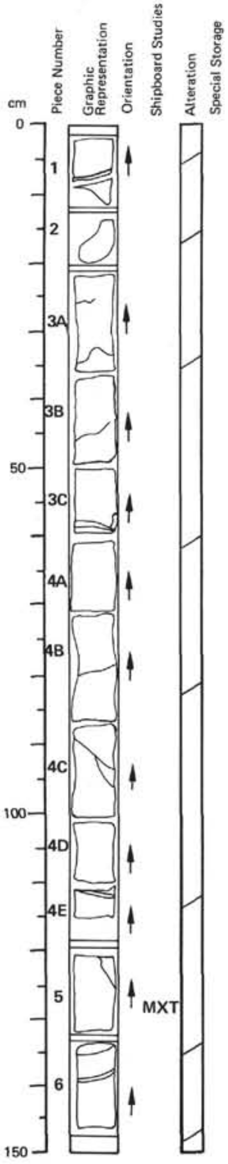
LEG	SITE	HOLE	CORE	SECT.
51	417	D	33	2

Visual Description

Massive, phyric basalt with a gray, holocrystalline groundmass composed of plagioclase, clinopyroxene and minor olivine with traces of interstitial calcite and sulfides. Basalt altered to light yellow-brown along veins; piece 2E displays a thick, light green to brown, zoned alteration halo along veins due to partial replacement of groundmass by green to brown smectite. Plagioclase phenocrysts 15%, <10 mm; clinopyroxene phenocrysts 10%, <0.5 mm, partially replaced by green smectite. Veins filled by calcite and green to yellow-green or brown smectite.

Shipboard Data

Physical Property Data:	137-139 cm
$\bar{V}p$ (km/sec)	5.65
Porosity (%)	2.8
Wet Bulk Density (g/cc)	2.86
Grain Density (g/cc)	2.92



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	33	3

Visual Description

Massive, phyric basalt with a gray, medium-grained, subophitic groundmass composed of plagioclase and clinopyroxene ±olivine and minor oxides. Plagioclase phenocrysts <10%, <7 mm, partly replaced by zeolites(?); altered olivine phenocrysts <1%, 1-2 mm. Veins filled by calcite and green smectite.

Thin Section Description

Location: 130 cm, massive basalt

Texture: ophitic, porphyritic

Phenocrysts: plagioclase 10%, 6 mm, subhedral; clinopyroxene 10%, 2 mm, anhedral

Groundmass: olivine 10%, 0.2 mm; plagioclase 30%, 2 mm, euhedral-subhedral; clinopyroxene 30%, 0.5 mm, anhedral; magnetite 3%, 0.1 mm, euhedral-subhedral

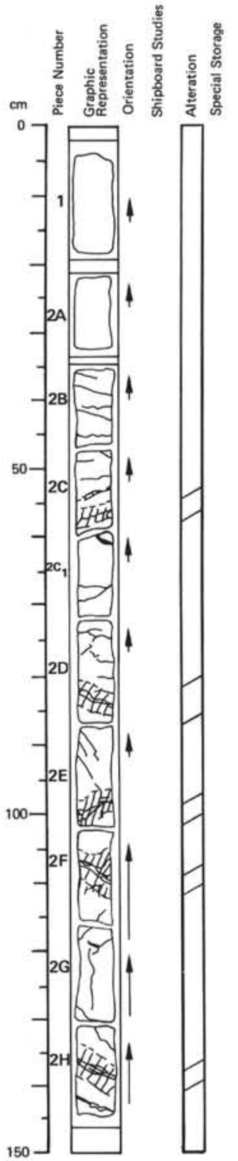
Vesicles: none

Alteration: olivine replaced by clay

Shipboard Data

Bulk Analysis: 128-131 cm	
SiO_2	49.42
Al_2O_3	16.62
Fe_2O_3	10.92
MgO	6.16
CaO	12.47
Na_2O	2.01
K_2O	0.12
TiO_2	1.36
P_2O_5	0.12
MnO	0.15
LOI	0.60
H_2O^+	0.53
H_2O^-	N.D.
CO_2	0.10

Magnetic Data:	128-131 cm
NRM Intensity (emu/cc)	3.703×10^{-3}
NRM Inclination	+79.7
Stable Inclination	-59.4°

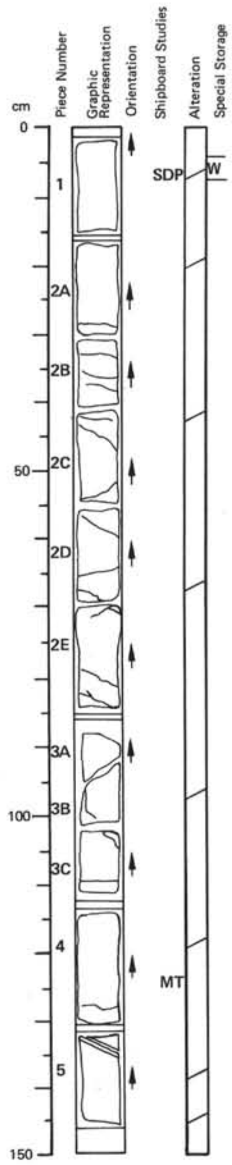


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	D	3 3	4

Visual Description

Massive, phyric basalt with a gray, subophitic groundmass containing minor olivine and traces of disseminated calcite. Basalt displays yellow-brown or green to brown, zoned alteration haloes along veins due to partial replacement of groundmass by green to brown smectite. Plagioclase phenocrysts 15%, ≤8 mm, clinopyroxene phenocrysts 15-20%, ≤1 mm, partially replaced by green smectite. Veins filled by green to brown smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	D	3 3	5

Visual Description

Massive phyric basalt with a gray, medium-grained, holocrystalline groundmass containing plagioclase, abundant olivine (20%), clinopyroxene and minor sulfides and oxides. Plagioclase phenocrysts 15-20%; olivine and clinopyroxene microphenocrysts common. Olivine largely replaced by calcite and iddingsite in pieces 1-4, but relatively fresh in piece 5. Veins filled by calcite and green smectite.

Thin Section Description

Location: 123 cm, massive basalt

Texture: ophitic, porphyritic

Phenocrysts: plagioclase 20%, 3 mm, euhedral-subhedral

Groundmass: olivine 10%, 0.2 mm, euhedral; plagioclase 30%, 1 mm, euhedral, tabular; clinopyroxene 30%, 0.5 mm, subhedral-anhedral; magnetite 0.1 mm

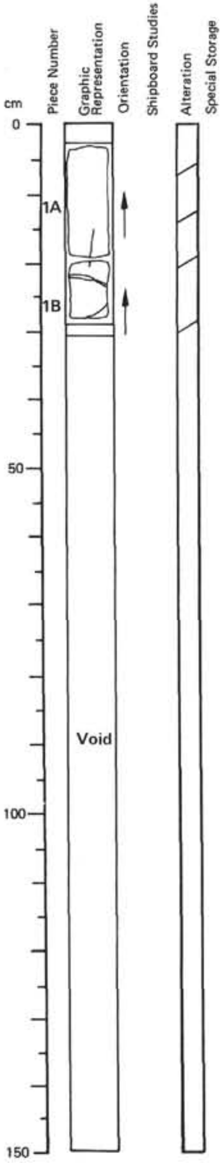
Vesicles: none

Alteration: olivine and plagioclase replaced by clay

Shipboard Data

Magnetic Data:	122-124 cm
NRM Intensity (emu/cc)	1.622×10^{-3}
NRM Inclination	+49.6°
Stable Inclination	-60.7°

Physical Property Data:	4-6 cm
$\overline{V}p$ (km/sec)	5.67
Porosity (%)	2.4
Wet Bulk Density (g/cc)	2.87
Grain Density (g/cc)	2.92

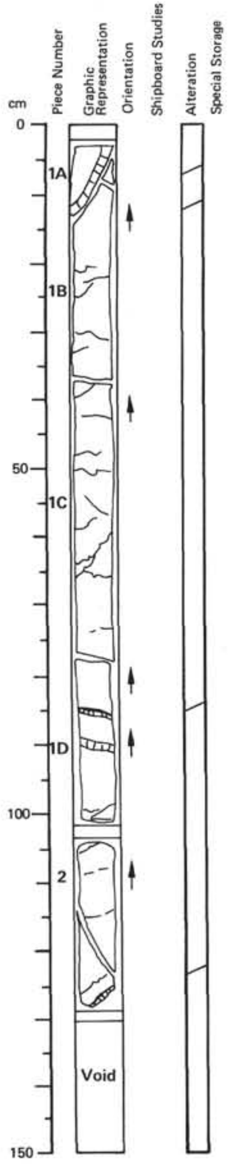


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	D	3 3	6

Visual Description

Massive phyric basalt with a gray, holocrystalline groundmass composed of plagioclase (30-40%), clinopyroxene (25%) and iddingsite after olivine (20-30%). Plagioclase phenocrysts 15%, <7 mm, partially altered. Veins filled by calcite and green smectite.

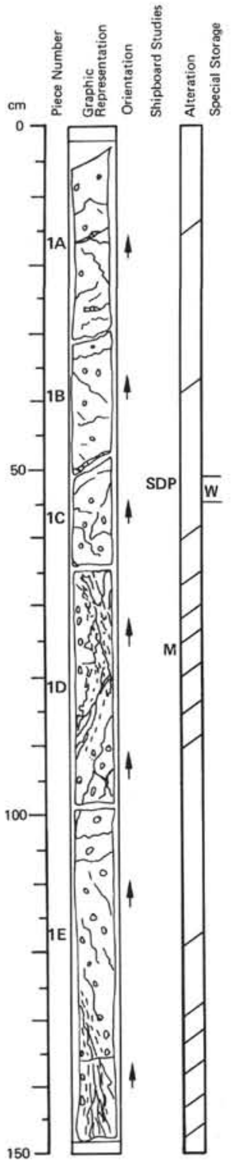


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	D	3 4	1

Visual Description

Massive, phyric basalt with a gray, subophitic groundmass. Basalt altered to green or brown along veins due to partial replacement by green to brown smectite. Plagioclase phenocrysts 7%, <4 mm, fresh to partially replaced by calcite; clinopyroxene phenocrysts 5%, <1 mm, fresh to partially replaced by green smectite; olivine phenocrysts <3%, <0.5 mm, replaced by green smectite or serpentine(?). Vesicles scarce, filled by calcite. Veins filled by dark green to brown smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

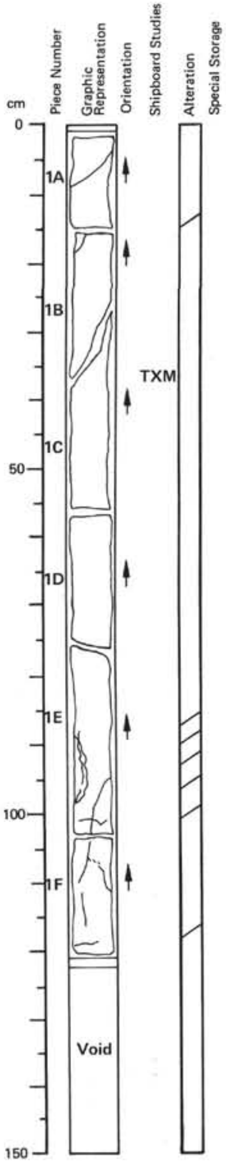
Visual Description

Massive, phyric basalt with a gray, coarse-grained, subophitic groundmass containing traces of disseminated sulfides. Fine-grained, moderately phyric basalt along veins in pieces 1D and 1E altered to gray-green and brown due to partial replacement by calcite and green to brown smectite. Plagioclase phenocrysts 10%, <4 mm; clinopyroxene phenocrysts 8-10%, <2 mm; olivine phenocrysts 1%, <0.5 mm, replaced by green smectite. Veins filled by calcite and green to yellow-brown or brown smectite.

Shipboard Data

Magnetic Data:	77-80 cm
NRM Intensity (emu/cc)	2.572×10^{-3}
NRM Inclination	+70.1°
Stable Inclination	-59.5°

Physical Property Data:	51-53 cm
$\overline{V}$p (km/sec)	5.87
Porosity (%)	2.1
Wet Bulk Density (g/cc)	2.89
Grain Density (g/cc)	2.93



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	D	3 4	3

Visual Description

Massive, phyric basalt with a gray, medium-grained subophitic groundmass containing plagioclase, clinopyroxene and olivine. Plagioclase phenocrysts <5 mm; olivine phenocrysts locally abundant, <3 mm, replaced by iddingsite and calcite. Veins filled by calcite ±green smectite.

Thin Section Description

Location: 38 cm, massive basalt

Texture: ophitic, porphyritic

Phenocrysts: plagioclase 20%, 4 mm, euhedral-subhedral

Groundmass: olivine 10%, 0.02 mm, euhedral; plagioclase 30%, 1 mm, euhedral, prismatic; clinopyroxene 30%, 0.5 mm, euhedral-anhedral, partially quenched; magnetite 5%, 0.01 mm, euhedral, dendritic

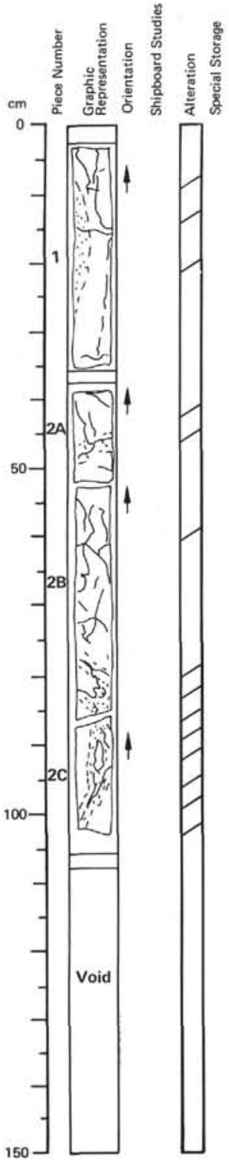
Vesicles: filled by calcite and clay

Alteration: olivine replaced by calcite and clay

Shipboard Data

Bulk Analysis: 37-40 cm	
SiO_2	49.44
Al_2O_3	16.67
Fe_2O_3	9.50
MgO	5.31
CaO	15.52
Na_2O	2.20
K_2O	0.13
TiO_2	1.36
P_2O_5	0.12
MnO	0.16
LOI	2.85
H_2O^+	0.50
H_2O^-	N.D.
CO_2	2.34

Magnetic Data:	37-40 cm
NRM Intensity (emu/cc)	2.059×10^{-3}
NRM Inclination	+16.3°
Stable Inclination	-58.3°

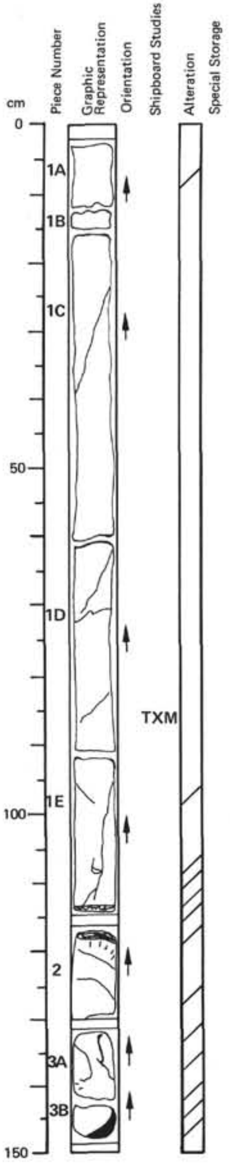


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	D	3 4	4

Visual Description

Massive, phyric basalt with a gray, coarse-grained subophitic groundmass. Basalt along curved fracture sets in pieces 1, 2B and 2C locally fine- to medium-grained, altered green to yellow brown due to partial replacement of groundmass by calcite, green to brown smectite and minor sulfides. Plagioclase phenocrysts 20%, 5-7 mm, partially replaced along fractures by calcite and clay; clinopyroxene phenocrysts 15%, <2 mm, partially replaced along fractures by green smectite and iron hydroxides(?); olivine phenocrysts 1-2%, <0.5 mm, replaced by green smectite. Veins filled by calcite and green to brown smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	D	3 4	5

Visual Description

0-113 cm interval: Massive, phyric basalt with a glassy chilled margin at the base of piece 1E. Basalt gray with a medium- to coarse-grained, subophitic groundmass containing plagioclase, olivine and clinopyroxene; piece 1E increasingly fine-grained, altered toward margin. Plagioclase phenocrysts 15-20%; olivine phenocrysts replaced by iddingsite and calcite, partially aligned with long axis subperpendicular to core axis due to crystal settling(?). Veins filled by calcite and green smectite.

113-150 cm interval: Phyric basalt pillow with glassy chilled margins (pieces 2 and 3B) and minor pillow breccia (piece 3B). Plagioclase phenocrysts 15-20%; olivine phneocrysts 5-10%. Veins filled by calcite and green to brown smectite. Breccia in piece 3B composed of fragments of basalt in a matrix of green smectite.

Thin Section Description

Location: 85 cm, 28 cm from bottom margin of chilled zone

Texture: porphyritic, intersertal

Phenocrysts: olivine 1-2%, 2-3 mm, idiomorphic; plagioclase 10%, 3-8 mm, idiomorphic

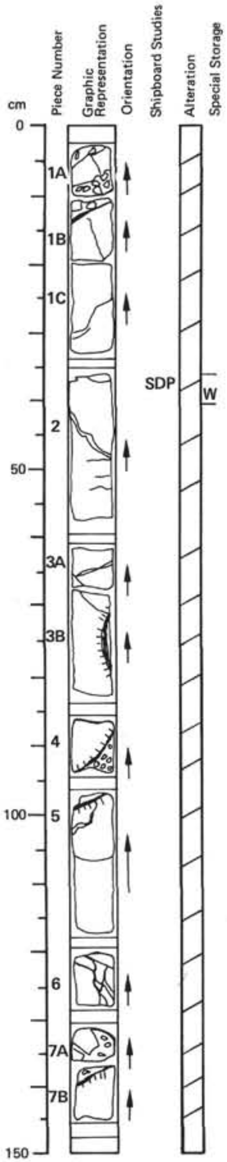
Groundmass: plagioclase 50%, microlites 0.2-0.8 mm, euhedral laths 2-4 mm; augitic clinopyroxene 35%, 0.3-4.0 mm, intergranular, radiating; titanomagnetite 5% 0.2-0.5 mm; interstitial calcite and clay

Vesicles: none

Alteration: olivine replaced by calcite and clay

Shipboard Data

Bulk Analysis: 83-86 cm		Magnetic Data:	83-86 cm
SiO_2	48.76	NRM Intensity (emu/cc)	9.863×10^{-3}
Al_2O_3	16.79	NRM Inclination	-48.9°
Fe_2O_3	11.03	Stable Inclination	-56.6°
MgO	5.75		
CaO	13.57		
Na_2O	2.07		
K_2O	0.14		
TiO_2	1.45		
P_2O_5	0.15		
MnO	0.16		
LOI	1.00		
H_2O^+	1.13		
H_2O^-	N.D.		
CO_2	1.14		



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

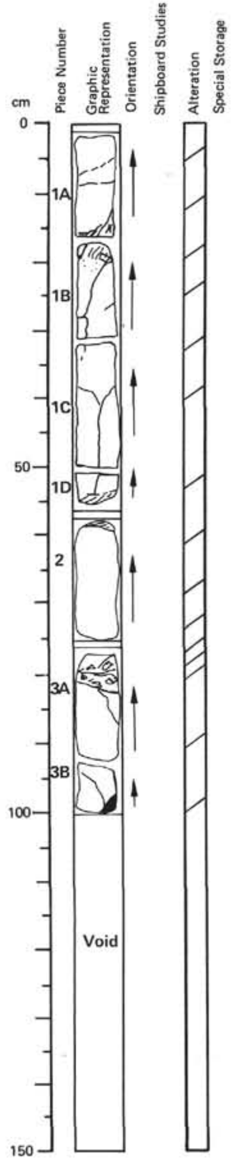
LEG	SITE	HOLE	CORE	SECT.
51	417	D	34	6

Visual Description

Phyric pillow basalt with locally glassy chilled margins (pieces 1B, 3B-5 and 7B) and interpillow breccia (pieces 1A, 1B, 4 and 6-7B). Basalt gray with an aphanitic groundmass. Glass partially replaced by green smectite. Euhedral plagioclase phenocrysts 10-15%, locally 30% (pieces 1C and 2), <5 mm; euhedral olivine phenocrysts 5-10%, 3 mm, replaced by green smectite; euhedral to subhedral clinopyroxene phenocrysts <3%, 1 mm. Vesicles and veins filled by calcite and green smectite. Breccia composed of fragments of basalt and altered glass in a matrix of green smectite and calcite.

Shipboard Data

Physical Property Data:	39-41 cm
$\bar{V}p$ (km/sec)	5.66
Porosity (%)	3.5
Wet Bulk Density (g/cc)	2.83
Grain Density (g/cc)	2.89

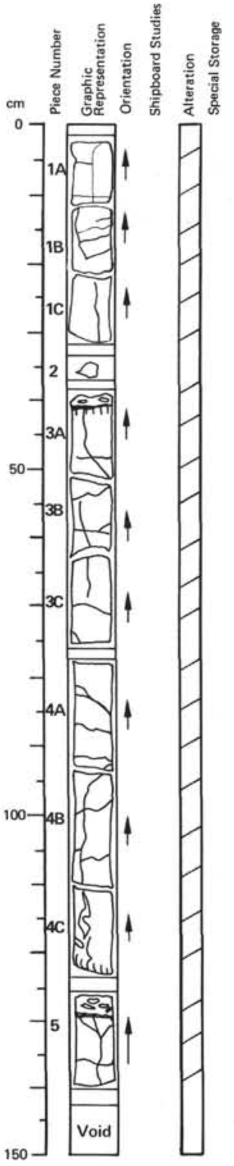


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	34	7

Visual Description

Phyric basalt pillows with glassy chilled margins (pieces 1A, 1B, 1D, 2 and 3B) and traces of interpillow breccia. Basalt gray with an aphanitic groundmass. Plagioclase phenocrysts 10-15%, <7 mm; olivine phenocrysts 10%, <5 mm, replaced by iddingsite and green smectite; olivine phenocrysts > plagioclase phenocrysts near chilled margins. Veins and vesicles filled by calcite.

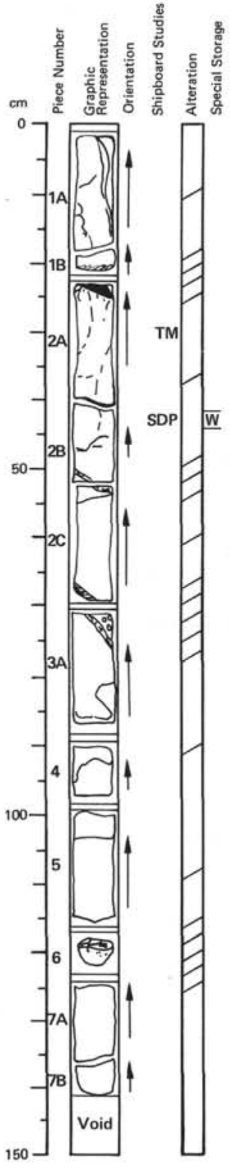


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	D	3 5	1

Visual Description

Phyric pillow basalt with locally glassy chilled margins (pieces 3A, 4C and 5) and minor inter-pillow breccia (pieces 3A and 5). 40-125 cm interval represents a complete pillow. Basalt gray with an aphanitic to crystalline groundmass. Euhedral plagioclase phenocrysts 10-20%, <4 mm; euhedral olivine phenocrysts 2-10%, 3 mm, replaced by green smectite; clinopyroxene <1%, locally as inclusions in plagioclase. Plagioclase and olivine phenocrysts tend to be more abundant near the top and bottom, respectively, of individual pillows. Glass partially devitrified, altered to green smectite. Vesicles filled by calcite. Veins filled by calcite, green smectite and zeolites.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Phyric, gray pillow basalt with glassy margins (pieces 1B, 2A, 2C, 3A and 6) and traces of inter-pillow breccia. 0-21 and 21-70 cm intervals represent individual pillows or parts of pillows bounded by chilled margins. Groundmass varies from aphanitic near margins to intersertal in pillow interiors. Plagioclase phenocrysts 10%, ≤5 mm; olivine phenocrysts 10%, ≤5 mm, replaced by iddingsite and calcite. Olivine phenocrysts tend to be more abundant than plagioclase near margins. Vesicles 1-2%, filled by calcite ± celadonite. Veins filled by calcite ± green smectite.

Thin Section Description

Location: 31 cm, next to glassy margin

Texture: porphyritic

Phenocrysts: olivine 1-2%, 2-6 mm, idiomorphic; plagioclase 15%, 3-10 mm, idiomorphic, zoned with devitrified glass inclusions; augite <1%, 2-3 mm

Groundmass: plagioclase microlites 50%, 0.1-0.5 mm, skeletal, hollow; augite 25%, interstitial, plumose, quenched; magnetite 5%, <0.1-0.2 mm; interstitial smectite 5%

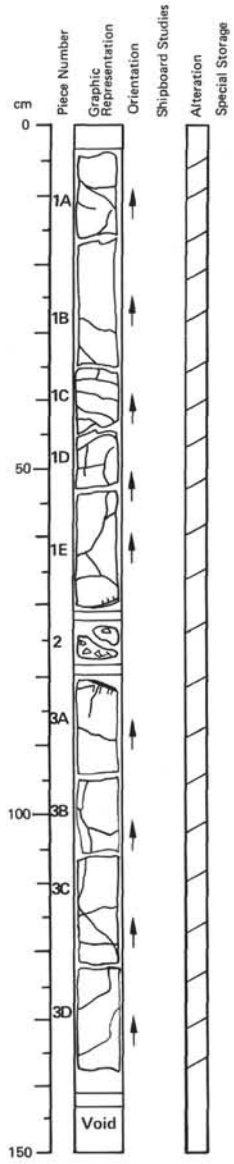
Vesicles: none

Alteration: calcite and iron oxide pseudomorphs after olivine. Veins filled by calcite, celadonite and iron oxides

Shipboard Data

Magnetic Data:	30-33 cm
NRM Intensity (emu/cc)	10.261×10^{-3}
NRM Inclination	-67.8°
Stable Inclination	-67.0°

Physical Property Data:	42-45 cm
$\overline{V}p$ (km/sec)	5.31
Porosity (%)	5.6
Wet Bulk Density (g/cc)	2.77
Grain Density (g/cc)	2.87

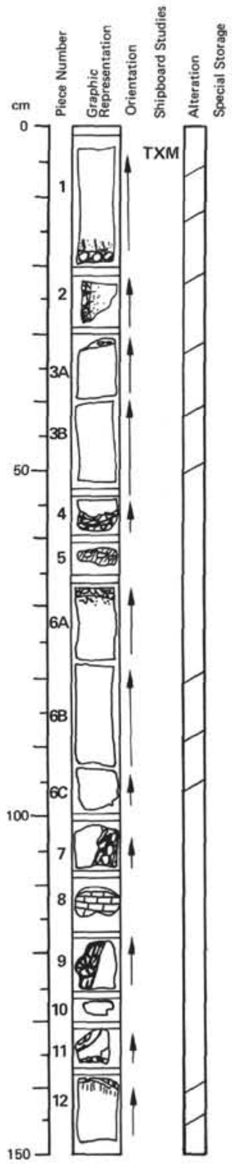


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	D	3	5		3

Visual Description

Phyric pillow basalt with locally glassy chilled margins (pieces 1E and 3A) and traces of interpillow breccia (piece 2). 0-70 and 80-140 cm intervals represent parts of individual pillows *bounded by chilled margins. Basalt gray with an aphanitic groundmass. Euhedral plagioclase* phenocrysts 5-30%, <6 mm; olivine phenocrysts 1-5%, locally 15%, <2 mm, replaced by green smectite. Phenocrysts locally variable with plagioclase and olivine tending to concentrate at the top and bottom, respectively, of individual pillows. Vesicles <1%, <0.5% mm, filled by calcite and green smectite. Veins filled by calcite, green smectite and zeolites. Breccia in piece 2 composed of fragments basalt and glass partially replaced by green smectite in a self-matrix of green smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	D	3	5		4

Visual Description

Phyric pillow basalt with glassy chilled margins (pieces 1-3A, 4, 6A, 7, 9, 11 and 12), hyaloclastite breccia (pieces 7 and 9) and minor interpillow limestone (pieces 8 and 11). Basalt gray with an aphanitic groundmass. Altered, euhedral plagioclase phenocrysts 15-20%, <5 mm; olivine phenocrysts 5-8%, <5 mm, replaced by green smectite and calcite. Vesicles 1-2%, <1 mm, filled by zeolites and green smectite. Minor veins filled by calcite and zeolites(?). Interpillow breccia composed of fragments of black glass partially altered to palagonite in a matrix of dark green smectite and minor calcite. Fine-grained interpillow limestone contains numerous shards of green, devitrified glass.

Thin Section Description

Location: 5 cm, pillow interior

Texture: porphyritic

Phenocrysts: olivine 2-3%, 1-4 mm, idiomorphic; plagioclase 15%, 2-3 mm, idiomorphic, zoned with glass inclusions; augite <1%, 1-3 mm, partially resorbed

Groundmass: plagioclase microlites 45%, 0.2-0.5 mm, hollow, quenched; clinopyroxene 30%, 0.2-0.5 mm, plumose, quenched, intergranular; magnetite 5%, 0.2 mm; interstitial smectite 2-3%

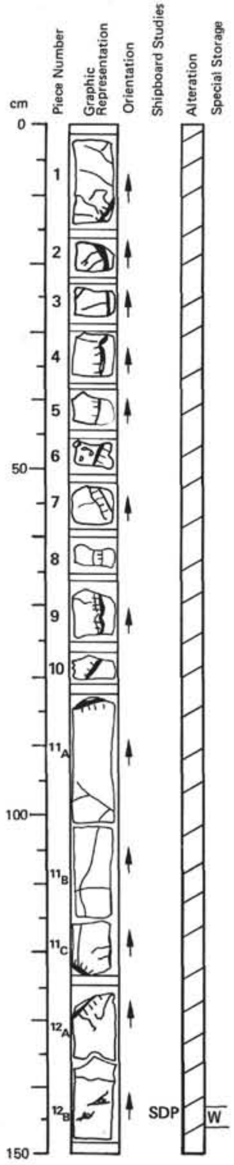
Vesicles: <1%, 1 mm, round, filled with calcite and clay

Alteration: serpentine pseudomorphs after olivine

Shipboard Data

Bulk Analysis: 36-79 cm	
SiO_2	49.33
Al_2O_3	17.23
Fe_2O_3	10.22
MgO	6.40
CaO	12.66
Na_2O	2.00
K_2O	0.04
TiO_2	1.39
P_2O_5	0.11
MnO	0.16
LOI	0.25
H_2O^+	3.12
H_2O^-	N.D.
CO_2	0.96

Magnetic Data:	3-6 cm
NRM Intensity (emu/cc)	9.452×10^{-3}
NRM Inclination	-50.3°
Stable Inclination	-53.6°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

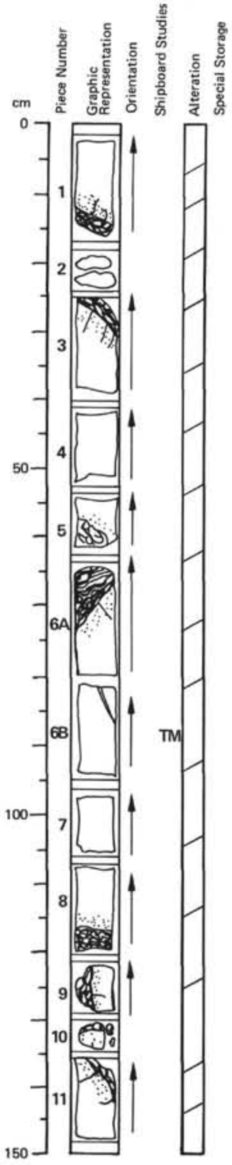
LEG	SITE	HOLE	CORE	SECT.
51	417	D	35	5

Visual Description

Phyric pillow basalt with chilled margins (pieces 1-11A, 11C and 12A) and interpillow breccia (pieces 2-10). 82-125 and 125-150 cm intervals represent individual pillows or parts of pillows bounded by chilled margins. Basalt gray with an aphanitic to crystalline groundmass. Euhedral plagioclase phenocrysts 15-20%, <10 mm; euhedral olivine phenocrysts 5%, <3 mm, replaced by iddingsite, green smectite and calcite. Plagioclase phenocrysts tend to be concentrated toward tops of individual pillows. Veins and vesicles filled by calcite and green smectite. Matrix composed of fragments of glass altered to green smectite in a self-matrix of green smectite.

Shipboard Data

Physical Property Data:	141-143 cm
$\overline{V}p$ (km/sec)	5.67
Porosity (%)	3.2
Wet Bulk Density (g/cc)	2.83
Grain Density (g/cc)	2.90



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	35	6

Visual Description

Phyric pillow basalt with cemented hyaloclastite margins (pieces 1-3, 5, 6A, and 8-11) and minor dark green, fine-grained interpillow fillings (piece 6A). Basalt gray with an aphanitic groundmass. Chilled margins zoned with an outer, partially exfoliated rim composed of fragments of glass 50% altered to green palagonite in a matrix of green smectite underlain by a 2-3 cm wide zone of aphanitic, moderately phyric basalt. Altered, euhedral plagioclase phenocrysts 15-20%, <5 mm; euhedral olivine phenocrysts 5%, <5 mm, replaced by green smectite and minor calcite. Vesicles 1%, <1 mm, filled with green smectite and calcite. Minor veins filled by calcite and green smectite.

Thin Section Description

Location: 88 cm, pillow interior

Texture: porphyritic

Phenocrysts: olivine 1-2%, 1-2 mm, idiomorphic; plagioclase 10%, 2-4 mm, idiomorphic, zoned; augite <1%, 1-2 mm, partially resorbed

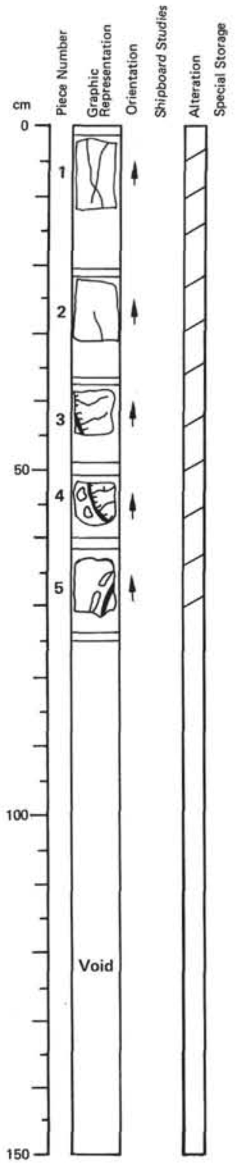
Groundmass: plagioclase microlites 40%, hollow, skeletal; clinopyroxene 45%, plumose, radiating and curved, quenched; titanomagnetite 3-5%, 0.2-0.3 mm; clay 1-2%; interstitial calcite <1%

Vesicles: <1%, 1 mm, round, filled by calcite

Alteration: calcite, clay and serpentine pseudomorphs after olivine

Shipboard Data

Magnetic Data:	87-90 cm
NRM Intensity (emu/cc)	21.395×10^{-3}
NRM Inclination	-66.8°
Stable Inclination	-67.5°

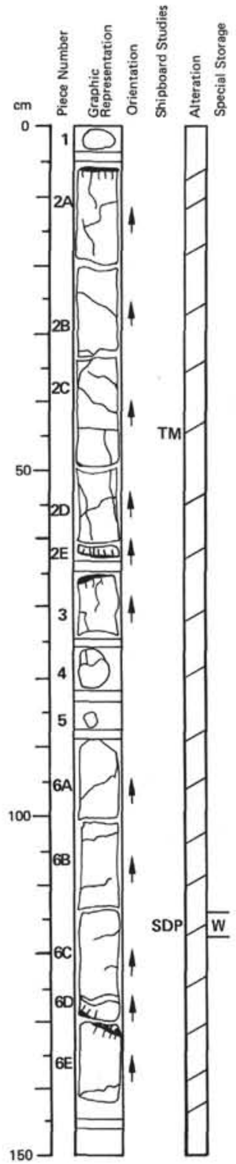


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	D	3 5	7

Visual Description

Phyric pillow basalt with chilled margins (pieces 3-5) and interpillow breccia (pieces 3-5). Basalt gray with an aphanitic groundmass. Euhedral plagioclase phenocrysts 20%, <6 mm; euhedral olivine phenocrysts 5%, <2 mm, replaced by green smectite. Vesicles and veins filled by calcite and green smectite. Interpillow breccia composed of fragments of basalt and basaltic glass altered to green smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	D	3 6	1

Visual Description

Phyric basalt pillows with chilled margins (pieces 2A, 2E, 3, 6D and 6E). 5-63, 63-130 and 130-145 cm intervals represent individual pillows or parts of pillows bounded by chilled margins. Chert pebble (piece 1) probably from sediments above basement. Basalt pale reddish-gray with an aphanitic groundmass. Euhedral plagioclase phenocrysts 20%, <4 mm; euhedral olivine phenocrysts 5%, <3 mm, replaced by green smectite and calcite; euhedral to subhedral clinopyroxene 3-5%, <2 mm. Olivine and clinopyroxene phenocrysts tend to concentrate near the base of each pillow. Veins filled with calcite and green smectite. Glass largely devitrified.

Thin Section Description

Location: 45 cm, pillow interior

Texture: porphyritic

Phenocrysts: olivine 2-3%, 1-5 mm, idiomorphic; plagioclase 15%, 2-4 mm, idiomorphic, zoned; augite 1-2%, 1-2 mm, rounded

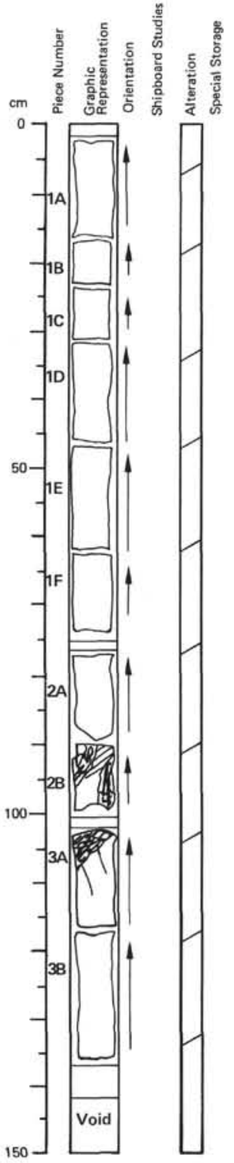
Groundmass: plagioclase microlites 35%, 0.2-0.6 mm, hollow; augite 40%, 0.3-0.6 mm, plumose, curved, intergranular; magnetite 5%, 0.1-0.3, granular; interstitial clay 3-4%

Vesicles: <1%, 1 mm, round, filled by calcite

Alteration: serpentine pseudomorphs after olivine

Shipboard Data

Magnetic Data:	46-48 cm
NRM Intensity (emu/cc)	7.325×10^{-3}
NRM Inclination	-54.7°
Stable Inclination	-69.5°
Physical Property Data:	115-117 cm
$\bar{V}p$ (km/sec)	5.64
Porosity (%)	3.7
Wet Bulk Density (g/cc)	2.84
Grain Density (g/cc)	2.91

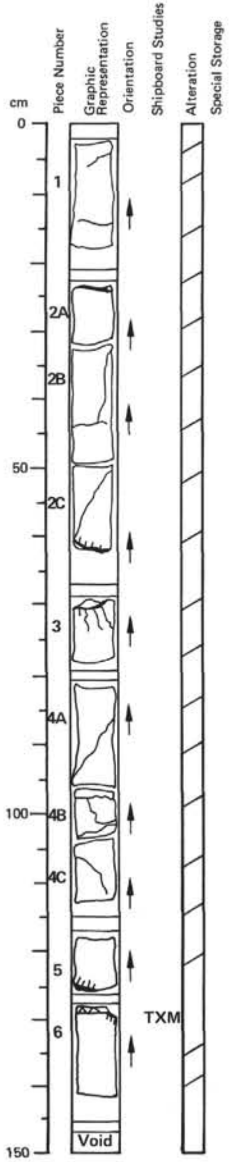


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	36	2

Visual Description

Phyric basalt pillows with cemented hyaloclastite margins (pieces 2B and 3A) and minor dark green, fine-grained interpillow fillings (pieces 2B and 3A). Basalt dark gray with an aphanitic groundmass. Euhedral plagioclase phenocrysts 15%, <5 mm; euhedral olivine phenocrysts 8%, <8 mm, replaced by green smectite and celadonite(?); elongate augite phenocrysts 5%, <8 mm, (100) twins common. Vesicles 3-4%, 1 mm, filled with calcite, zeolites, green smectite and minor sulfides; coalesced vesicles form cavities <1 cm. Veins filled by calcite, minor sulfides. Hyaloclastite margins in pieces 2B and 3A composed of fragments of black glass in a matrix of dark green smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	36	3

Visual Description

Phyric pillow basalt with chilled margins (pieces 1, 2A, 2C, 3, 5 and 6) and traces of calcite-cemented breccia (piece 6). 0-20, 20-65, 65-125 and 125-141 cm intervals represent individual pillows or parts of pillows bounded by chilled margins. Basalt gray with an aphanitic groundmass. Euhedral plagioclase phenocrysts 15-20%, <4 mm; euhedral clinopyroxene phenocrysts 5%, <2 mm; euhedral olivine phenocrysts 5%, <2 mm, replaced by green smectite. Plagioclase phenocrysts tend to concentrate near the top of each pillow, while olivine and clinopyroxene phenocrysts concentrate near the base. Vesicles filled by green smectite and calcite. Veins filled by calcite, zeolites, green smectite and pyrite. Glass largely devitrified or altered to green smectite.

Thin Section Description

Location: 131 cm, next to glassy margin

Texture: porphyritic

Phenocrysts: olivine 2-3%, 1-3 mm, idiomorphic; plagioclase 15%, 2-5 mm, idiomorphic, zoned with numerous glass inclusions; clinopyroxene 1-2%, 2-4 mm, partially resorbed, polkilitic

Groundmass: plagioclase microlites 20%, 0.1-0.4 mm, hollow, skeletal; magnetite 5%, <0.2 mm; devitrified glass 55%

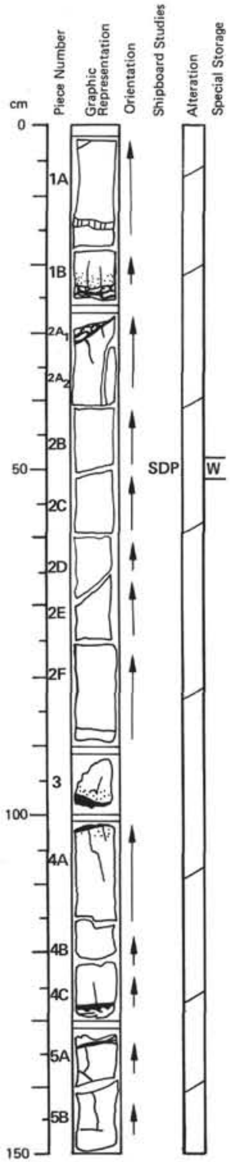
Vesicles: 1%, 0.5-2 mm, round, filled by calcite

Alteration: calcite and clay pseudomorphs after olivine

Shipboard Data

Bulk Analysis: 130-132 cm	
SiO_2	49.57
Al_2O_3	16.74
Fe_2O_3	11.04
MgO	5.94
CaO	14.07
Na_2O	2.08
K_2O	0.27
TiO_2	1.40
P_2O_5	0.13
MnO	0.19
LOI	0.65
H_2O^+	N.D.
H_2O^-	N.D.
CO_2	N.D.

Magnetic Data:	130-132 cm
NRM Intensity (emu/cc)	15.077×10^{-3}
NRM Inclination	-68.0°
Stable Inclination	-69.7°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

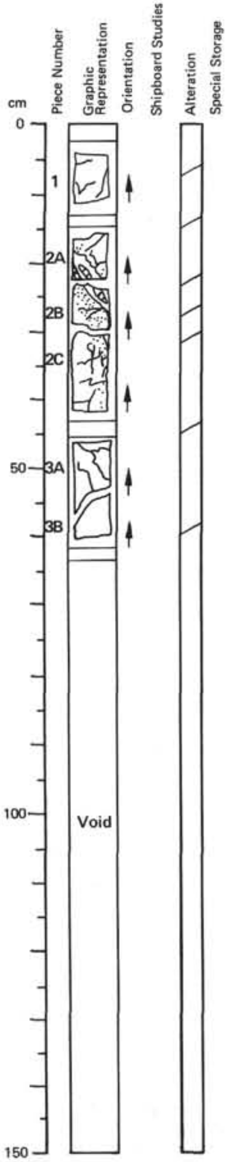
LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	D	3	6		4

Visual Description

Phyric basalt pillows with fragmented glassy margins (pieces 1B, 2A, 3, 4A, 4C and 5A). 0-25, 25-100, 100-130 and 130-150 cm intervals represent individual pillows or parts of pillows bounded by chilled margins. Pillow interiors dark gray with a microlitic groundmass; chilled margins zoned with an outer, partially exfoliated rim composed of fragmented glass underlain by a 2-3 cm wide zone of moderately phyric, dark brown altered basalt with an aphanitic groundmass. Euhedral plagioclase phenocrysts 10-15%, <6 mm; euhedral olivine phenocrysts 4-8%, <4 mm, replaced by green smectite and ccladonite(?); augite phenocrysts 1-2%, 2-3 mm. Vesicles 1-2%, 1 mm, filled with calcite or green smectite, some zoned with calcite cores and lining of green smectite. Veins filled by green smectite and disseminated pyrite.

Shipboard Data

Physical Property Data:	51-53 cm
$\overline{V}$p (km/sec)	5.58
Porosity (%)	3.9
Wet Bulk Density (g/cc)	2.84
Grain Density (g/cc)	2.92

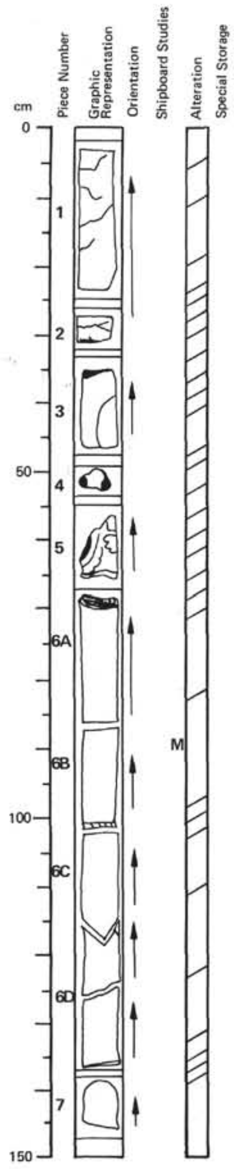


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	D	3	6		5

Visual Description

Phyric, gray pillow basalt with altered, sparsely phyric margins (piece 2). 0-23 and 23-60 cm intervals represent individual pillows bounded by chilled margins. Groundmass ranges from aphanitic in pillow margins to microlitic or subophitic in pillow interiors. Plagioclase phenocrysts 7-20%, <8 mm, partially replaced along margins by calcite and green smectite(?); clinopyroxene phenocrysts 2-7%, <3 mm, partially replaced by green smectite; olivine phenocrysts 1-3%, <2 mm, replaced by calcite, green smectite and iron hydroxides. Groundmass contains minor disseminated sulfides. Glassy margins devitrified along veins, partially replaced by green smectite and calcite. Veins normal to pillow margins, filled by calcite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

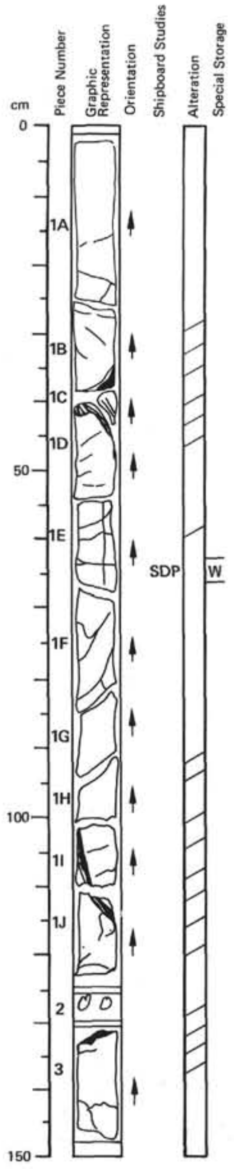
LEG	SITE	HOLE	CORE	SECT.
51	417	D	37	1

Visual Description

Phyric basalt pillows with chilled glassy margins (pieces 2-6A and 7), minor interpillow breccia (pieces 3-5) and minor interpillow sediments (piece 5). 0-32 and 70-136 cm intervals represent individual pillows or parts of pillows bounded by chilled margins. Basalt gray with an aphanitic to subophitic groundmass containing traces of disseminated calcite. Plagioclase phenocrysts 20%, <4 mm, partially replaced by calcite; augite phenocrysts 7%, <3 mm; olivine phenocrysts <1%, <2 mm, replaced by green smectite. Vesicles 2%, <0.3 mm, filled with calcite. Thin veins filled by calcite and brown smectite. Glassy margins partially devitrified, replaced by gray to green smectite and calcite. Fine-grained, weakly layered interpillow sediments in piece 5 composed of calcite and green smectite, contain elongate shards of dark green devitrified glass aligned subparallel to pillow margins.

Shipboard Data

Magnetic Data:	90-93 cm
NRM Intensity (emu/cc)	8.503×10^{-3}
NRM Inclination	-50.7°
Stable Inclination	-61.4°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

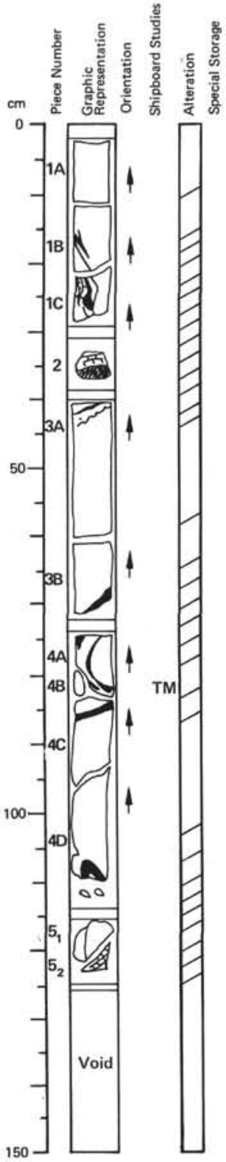
LEG	SITE	HOLE	CORE	SECT.
51	417	D	37	2

Visual Description

Phyric pillow basalt with chilled glassy margins (pieces 1B-1D, 1I, 1J and 3). 0-40, 40-110, 110-125 and 130-150 cm intervals represent individual pillows or parts of pillows bounded by chilled margins. Basalt gray with an aphanitic to microlitic groundmass. Plagioclase phenocrysts 10%, <7 mm; augite phenocrysts 5%, <5 mm; olivine phenocrysts 5%, <7 mm, replaced by iddingsite and calcite. Vesicles 1-2%, filled with calcite, green smectite and/or celadonite. Veins filled by celadonite and/or calcite.

Shipboard Data

Physical Property Data:	64-66 cm
$\overline{V}p$ (km/sec)	5.51
Porosity (%)	4.6
Wet Bulk Density (g/cc)	2.80
Grain Density (g/cc)	2.89



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	37	3

Visual Description

Phyric pillow basalt with chilled glassy margins (pieces 1B, 1C, 3 and 4) and minor interpillow limestone (pieces 2 and 5). 0-30, 40-72, 72-82 and 82-110 cm intervals represent individual pillows or parts of pillows bounded by chilled margins. Basalt gray with an aphanitic to microlitic to subophitic groundmass. Plagioclase phenocrysts 15%, <9 mm, weakly altered; augite phenocrysts 1-2%, <2 mm, weakly altered; olivine phenocrysts <1%, <2 mm, replaced by green smectite. Rare vesicles filled by calcite. Veins filled by calcite and brown smectite. Glassy margins partially devitrified, partially replaced by green smectite and calcite. Fine-grained, layered interpillow limestone, light to dark green or blue-green, composed of calcite and green smectite with shards of altered glass.

Thin Section Description

Location: 90 cm, next to glassy margin

Texture: porphyritic, variolitic

Phenocrysts: olivine 3%, 0.7 mm, euhedral; plagioclase 15%, 2 mm, euhedral; clinopyroxene 3%, 0.7 mm, partially resorbed

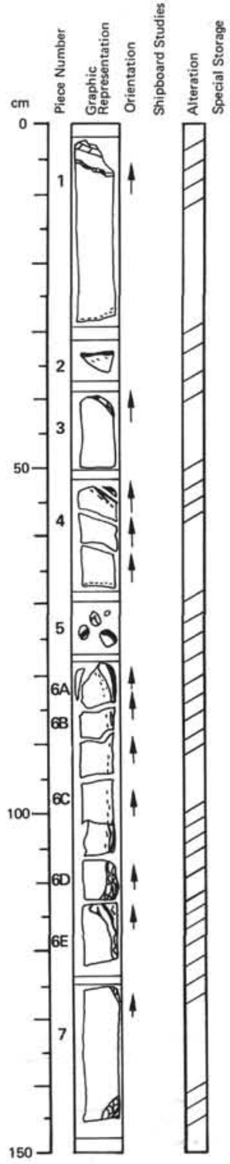
Groundmass: plagioclase 5%, 0.1 mm, prismatic, partially quenched; clinopyroxene >20%, 0.05 mm, quenched; magnetite <5%, <0.01 mm, dendritic; glass >30%

Vesicles: round, filled by calcite and clay

Alteration: olivine replaced by calcite; groundmass replaced by brown microcrystalline material

Shipboard Data

Magnetic Data:	88-91 cm
NRM Intensity (emu/cc)	11.100×10^{-3}
NRM Inclination	-74.5°
Stable Inclination	-74.1°

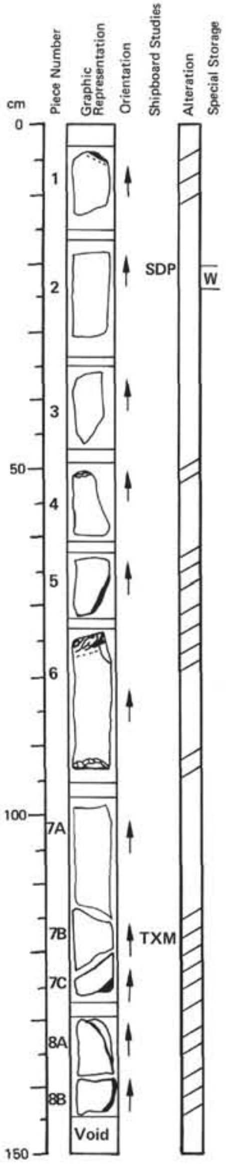


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	37	4

Visual Description

Phyric pillow basalt with nearly aphyric chilled glassy margins (pieces 1-7) and traces of interpillow limestone (piece 1). Basalt gray with an aphanitic to hyalopilitic groundmass in pieces 1-6C and an aphanitic to subophitic groundmass in pieces 6D-7. Plagioclase phenocrysts range from 7%, <0.8 mm near margins to 15%, <5 mm in pillow interiors; olivine phenocrysts absent near margins, increase to 1%, <1 mm in pillow interiors; augite phenocrysts 5-7%, <2 mm. Piece 1 anomalously rich in augite and olivine phenocrysts (10%, <5 mm and 1-2%, <3 mm, respectively) and poor in plagioclase phenocrysts (2%, <3 mm). Plagioclase, augite and olivine partly to completely replaced by green smectite. Glassy margins partially devitrified, replaced by green smectite and calcite. Minor veins filled by calcite. Fine-grained interpillow limestone composed of calcite and green smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	37	5

Visual Description

Phyric pillow basalt with glassy chilled margins (pieces 1, 4-6 and 7C-8B). 73-127 and 127-145 cm intervals represent individual pillows bounded by chilled margins. Basalt gray with an aphanitic to microlitic groundmass. Plagioclase phenocrysts ≤25%, ≤8 mm, locally ≤2 mm, replaced by green smectite. Piece 7 anomalously rich in augite phenocrysts (10%, ≤3 mm). Chilled margins sparsely phyric in piece 6, locally devitrified, replaced by green smectite and calcite. Veins filled by calcite.

Thin Section Description

Location: 117 cm, next to glassy margin

Texture: porphyritic

Phenocrysts: olivine 5%, 1 mm, euhedral; plagioclase 15%, 2 mm, euhedral-subhedral; clinopyroxene 5%, 1 mm, partially resorbed

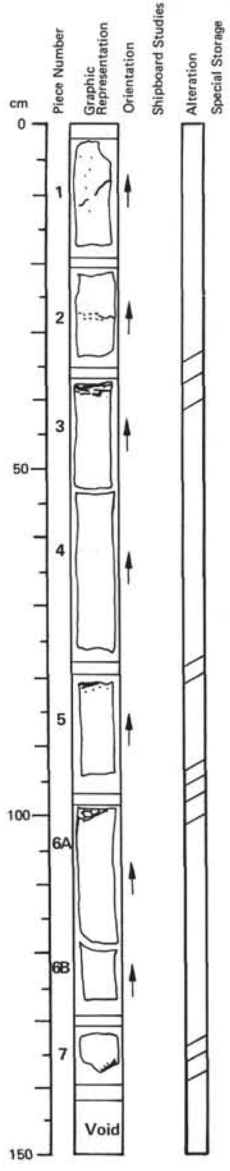
Groundmass: olivine 5%, 0.02 mm, euhedral; plagioclase 20%, 0.1 mm, euhedral; clinopyroxene 30%, 0.05 mm, quenched; magnetite <5%, 0.01 mm, dendritic; devitrified glass <10%

Vesicles: none

Alteration: olivine replaced by calcite and clay

Shipboard Data

Bulk Analysis: 116-119 cm		Magnetic Data:	116-119 cm
SiO_2	49.37	NRM Intensity (emu/cc)	16.340×10^{-3}
Al_2O_3	17.01	NRM inclination	-63.2°
Fe_2O_3	10.75	Stable Inclination	-63.4°
MgO	6.75		
CaO	12.84	Physical Property Data:	20-22 cm
Na_2O	2.31	$\overline{V}p$ (km/sec)	5.50
K_2O	0.06	Porosity (%)	3.7
TiO_2	1.47	Wet Bulk Density (g/cc)	2.79
P_2O_5	0.13	Grain Density (g/cc)	2.86
MnO	0.19		
LOI	1.35		
H_2O^+	0.75		
H_2O^-	N.D.		
CO_2	0.61		

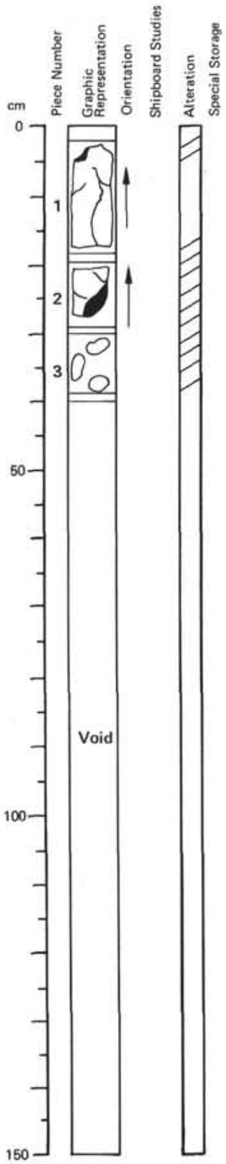


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	37	6

Visual Description

Phyric to slightly phyric pillow basalt with glassy chilled margins (pieces 3, 5, 6A and 7) and traces of interpillow limestone (piece 6A). Basalt gray with an aphanitic to microlitic, locally subophitic groundmass. Plagioclase phenocrysts 3-15%, 1-5 mm, range from nearly absent in chilled margin of piece 3 to quite abundant in pieces with a subophitic groundmass (pieces 1, 2, 5 and 7); clinopyroxene phenocrysts 3-5%, 2-3 mm, locally ≤7 mm (piece 1), replaced by green smectite; olivine phenocrysts 1%, 2-3 mm, replaced by green smectite. Piece 5 anomalously rich in clinopyroxene phenocrysts (7-10%, 2-3 mm). Vesicles ≤3%, 0.3 mm locally coalesced to form large vugs (pieces 4 and 6A), filled with calcite, green smectite and white clay. Veins filled by green smectite, calcite and pyrite.

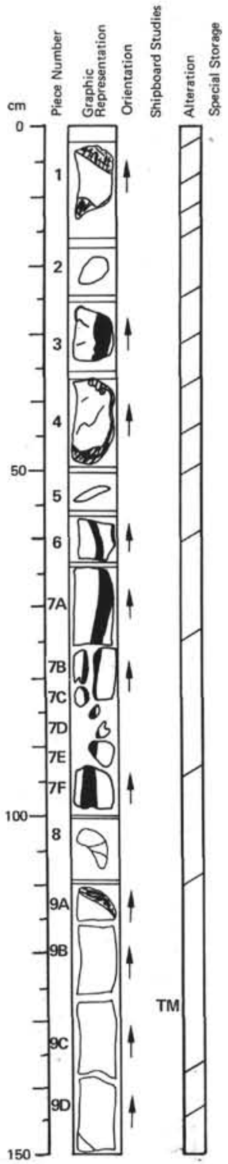


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	37	7

Visual Description

Phyric pillow basalt with glassy chilled margins (pieces 1 and 2). Basalt gray with an aphanitic to microlitic groundmass. Plagioclase phenocrysts 10-15%, <10 mm; olivine phenocrysts 5-7%, ≤1 mm, altered to iddingsite; clinopyroxene phenocrysts 3-5%, <3 mm. Veins common near margins, filled by calcite, green smectite and celadonite(?).



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	38	1

Visual Description

Phyric pillow basalt with glassy chilled margins (pieces 1 and 3-9A) and minor interpillow hyaloclastite breccia (pieces 1, 6 and 8). Basalt gray with an aphanitic to variolitic groundmass along pillow margins and a microlitic groundmass in pillow interiors. Plagioclase phenocrysts 15%, <4 mm; augite phenocrysts 5-10%, 1-2 mm; olivine phenocrysts 5%, 1-2 mm, replaced by green smectite and calcite. Veins filled by calcite, green smectite and pyrite. Hyaloclastic breccia composed of fragments of basalt and devitrified glass partially replaced by palagonite, green smectite and calcite in a matrix of calcite and green smectite.

Thin Section Description

Location: 130 cm, pillow interior

Texture: porphyritic

Phenocrysts: olivine 3%, 0.5 mm, euhedral; plagioclase 20%, 3 mm, euhedral to subhedral; clinopyroxene 5%, 1 mm, partially resorbed

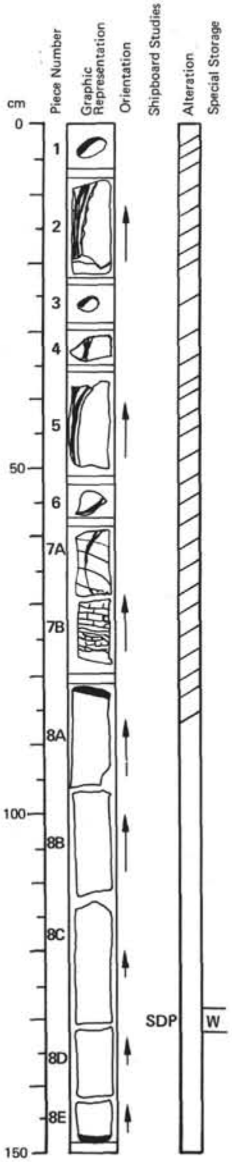
Groundmass: olivine 5%, 0.05 mm, euhedral to subhedral; plagioclase 20%, 0.1 mm, euhedral, tabular; clinopyroxene 30%, 0.05 mm; magnetite 5%, 0.01 mm, dendritic; devitrified glass <10%

Vesicles: 0.01 mm, filled by green smectite

Alteration: olivine replaced by green smectite

Shipboard Data

Magnetic Data:	129-132 cm
NRM Intensity (emu/cc)	16.501×10^{-3}
NRM Inclination	-66.4°
Stable Inclination	-71.6°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

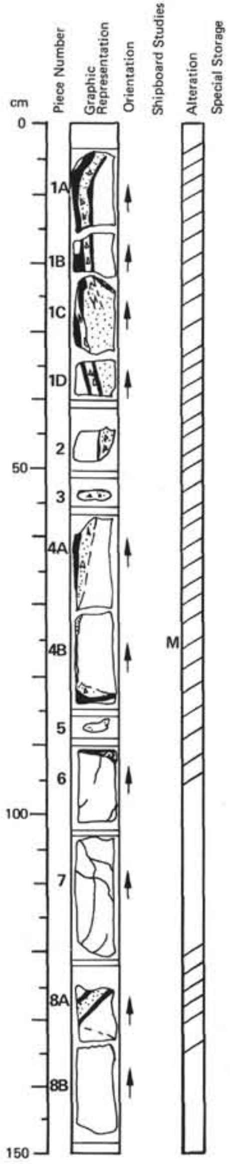
LEG	SITE	HOLE	CORE	SECT.
51	417	D	38	2

Visual Description

Phyric pillow basalt with aphyric, glassy chilled margins (pieces 1-6, 8A and 8E) and minor interpillow limestone (pieces 7A and 7B). Basalt gray with an aphanitic groundmass along pillow margins and a microlitic to subophitic groundmass in pillow interiors. Plagioclase phenocrysts 1-15%, <5 mm; clinopyroxene phenocrysts 2-10%, <3 mm, replaced by green smectite; olivine phenocrysts <1%, <0.5 mm, replaced by green smectite. Phenocrysts variable from pillow margins to interiors and from pillow to pillow with margins tending to be aphyric or rich in clinopyroxene and interiors rich in plagioclase. Vesicles <3%, <2 mm, filled by calcite and green smectite. Veins filled by green smectite and calcite. Glassy margins partially devitrified, replaced by green smectite and calcite. Interpillow limestone in piece 7 crudely layered with a brown upper layer composed of fragments of devitrified glass altered to green smectite in a matrix of calcite and brown to green smectite underlain by a 2-3 cm thick layer of calcite and dark green smectite.

Shipboard Data

Physical Property Data:	122-124 cm	127-129 cm
$\overline{V}$p (km/sec)	5.79	N.D.
Porosity (%)	3.0	4.1
Wet Bulk Density (g/cc)	2.67	2.79
Grain Density (g/cc)	2.91	2.86



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

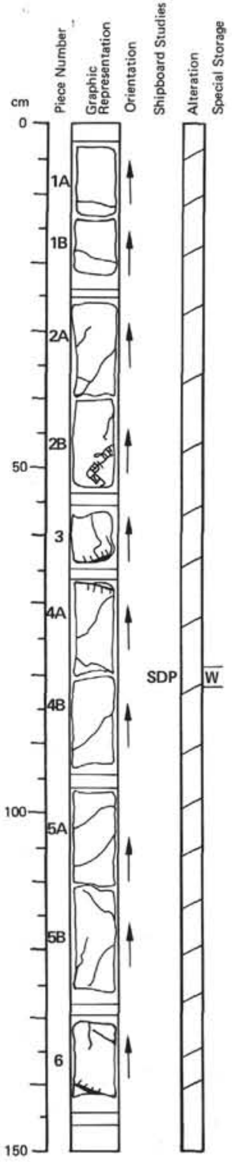
LEG	SITE	HOLE	CORE	SECT.
51	417	D	38	3

Visual Description

Phyric pillow basalt with altered margins (pieces 1-6 and 8A) and palagonite breccia (pieces 1-6 and 8A). Basalt gray with an aphanitic to microlitic groundmass. Plagioclase phenocrysts 15%, < 10 mm; clinopyroxene phenocrysts 5-10%, <5 mm; olivine phenocrysts 1-2%, locally to 5%, replaced by green smectite. Glass largely replaced by dark green smectite, palagonite and calcite. Palagonite breccia composed of strongly altered pillow margin fragments in a locally colliform matrix of calcite and green smectite.

Shipboard Data

Magnetic Data:	76-79 cm
NRM Intensity (emu/cc)	30.983×10^{-3}
NRM Inclination	-70.7°
Stable Inclination	-69.2°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

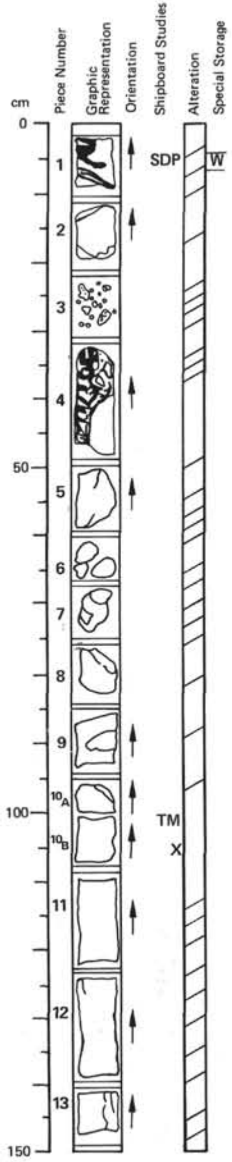
LEG	SITE	HOLE	CORE	SECT.
51	417	D	38	4

Visual Description

Phyric pillow basalt with partially altered glassy margins (pieces 3, 4A and 6). 0-65 and 65-140 cm intervals represent individual pillows or parts of pillows bounded by chilled margins. Basalt gray with an aphanitic to crystalline groundmass. Euhedral to subhedral plagioclase phenocrysts 20%, <7 mm; subhedral clinopyroxene phenocrysts 5%, 3 mm; anhedral olivine phenocrysts 2%, 2 mm, replaced by green smectite. Glass partially devitrified, replaced by green smectite. Veins filled by calcite, green smectite and zeolites.

Shipboard Data

Physical Property Data:	80-82 cm
$\overline{V}p$ (km/sec)	5.71
Porosity (%)	2.7
Wet Bulk Density (g/cc)	2.89
Grain Density (g/cc)	2.94



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	38	5

Visual Description

Phyric to sparsely phyric pillow basalt with chilled margins (pieces 5, 8, 9 and 10) and altered hyaloclastite breccia (pieces 1-10A). Basalt gray with an aphanitic to microlitic groundmass. Plagioclase phenocrysts 20%, <8 mm; olivine phenocrysts 5%, <2 mm, replaced by green smectite; augite phenocrysts 5%, <2 mm. Glass devitrified, replaced by calcite and green smectite. Breccia composed of angular clasts of altered basalt, devitrified glass and palagonite(?) in a matrix of dark green smectite and calcite. Veins filled by green smectite.

Thin Section Description

Location: 104 cm, pillow interior

Texture: microcrystalline

Phenocrysts: olivine 1%, <0.5 mm, euhedral; plagioclase 30%, <0.5 mm, euhedral; clinopyroxene <0.5%, <1 mm, partially resorbed

Groundmass: olivine <10%, <0.01 mm; plagioclase 20%, 0.03 mm, tabular; clinopyroxene 30%, <0.01 mm, anhedral; magnetite <5%, <0.005 mm, dendritic; devitrified glass <10%

Vesicles: filled by green smectite

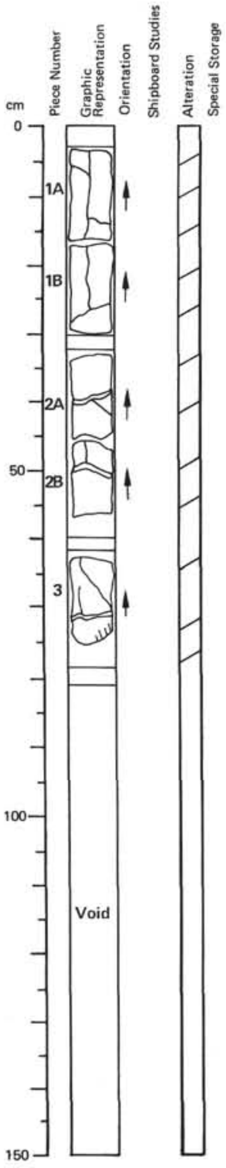
Alteration: olivine replaced by green smectite. Veins filled by green smectite.

Shipboard Data

Bulk Analysis: 106-107 cm	
SiO_2	49.10
Al_2O_3	14.69
Fe_2O_3	14.28
MgO	6.32
CaO	10.83
Na_2O	N.D.
K_2O	0.68
TiO_2	1.71
P_2O_5	N.D.
MnO	N.D.
LOI	0.85
H_2O^+	1.34
H_2O^-	N.D.
CO_2	0.18

Magnetic Data:	102-105 cm
NRM Intensity (emu/cc)	8.096×10^{-3}
NRM Inclination	-40.5°
Stable Inclination	-43.6°

Physical Property Data:	4-6 cm
$\overline{V}p$ (km/sec)	3.83

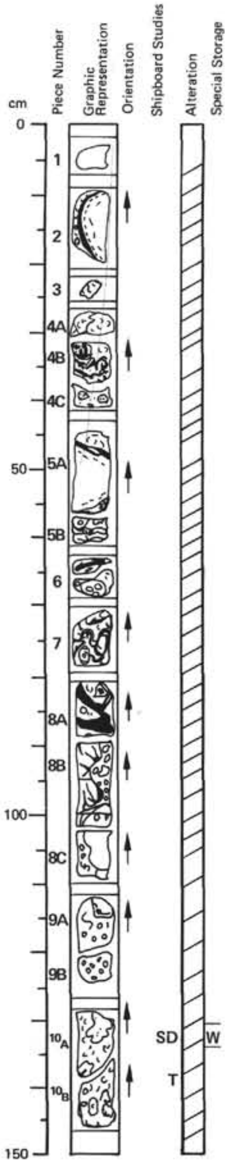


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	38	6

Visual Description

Phyric to sparsely phyric pillow basalt with an altered margin at the base of piece 3. 0-75 cm interval represents part of an individual pillow bounded by chilled margins. Basalt gray with an aphanitic to crystalline groundmass. Euhedral plagioclase phenocrysts 20%, <6 mm, euhedral clinopyroxene phenocrysts 10%, ≤5 mm. Clinopyroxene phenocrysts tend to be concentrated near margin in piece 3 and adjacent to interval aphyric zone in piece 2B. Vesicles filled with zeolites, green smectite and calcite. Veins filled by calcite and green smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	39	1

Visual Description

Volcanic breccia composed of pillow basalt fragments, often with glassy chilled margins or with devitrified margins partially replaced by green smectite, in a matrix of calcite, green smectite and devitrified glass replaced by calcite and green smectite. Basalt gray with an aphanitic to microlitic groundmass. Plagioclase phenocrysts 7%, <3 mm, fresh to weakly altered; augite phenocrysts 2-3%, <2 mm, partly replaced by green smectite; olivine phenocrysts <1%, ≤1 mm, completely replaced by green smectite and calcite. Veins filled by green smectite.

Thin Section Description

Location: 138 cm, hyaloclastite breccia

Texture: brecciated

Phenocrysts: olivine <1%, 1 mm, euhedral; plagioclase 2-3%, 1-2 mm, euhedral with numerous glass inclusions; augite 1%, as partially resorbed megacrysts or in clusters with plagioclase

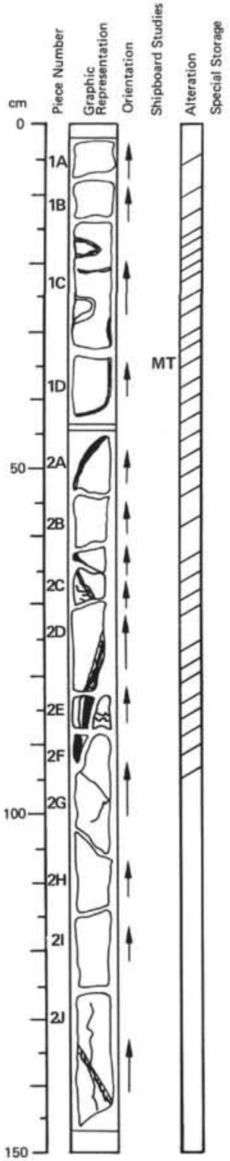
Groundmass: plagioclase microlites 1-2%; concentric layers of pale green glass and fibrous green palagonite 95%; minor calcite

Vesicles: none

Alteration: olivine replaced by green smectite

Shipboard Data

Physical Property Data:	130-132 cm
$\overline{V}p$ (km/sec)	3.67
Wet Bulk Density (g/cc)	2.38



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

0-22 cm: volcanic breccia composed of fragments of basalt with chilled to glassy margins in a matrix of calcite, green smectite and devitrified glass.
22-95 cm: phyric basalt with glassy chilled margins partially replaced by green smectite and calcite (pieces 2A and 2C-2F). Basalt gray with an aphanitic to microlitic groundmass. Plagioclase phenocrysts < 10%, <9 mm; augite phenocrysts <7%, <2 mm, partly replaced by green smectite and calcite, common along pillow margins; olivine phenocrysts <1%, <2 mm, completely replaced by green smectite. Veins filled with green smectite. Piece 1C contains a large calcite-filled vug with a lining of dark green smectite.
95-150 cm: aphyric to sparsely phyric; basalt with a gray, aphanitic groundmass containing microphenocrysts of clinopyroxene. Vesicles 2%, <0.3 mm; fillings alternate between calcite and green smectite with depth. Piece 2J contains a sharp, steeply inclined transition (dip = 60°) between a zone of calcite vesicle fillings and an underlying zone with green smectite fillings. Veins filled with calcite or green to brown smectite.

Thin Section Description

Location: 37 cm, next to glassy margin

Texture: porphyritic

Phenocrysts: olivine 5-7%, <4 mm; plagioclase 10-15%, <4 mm, An 70-75; clinopyroxene 3%, <3 mm, 2 $V_z > 50°$, rounded with sector zoning and wavy extinction, occurs as isolated crystals or with plagioclase in glomerocrysts

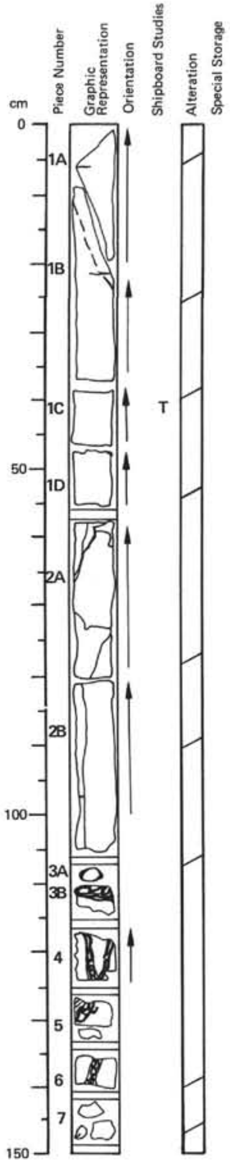
Groundmass: plagioclase 10%, 0.2 mm, skeletal; devitrified glass 70%

Vesicles: 1%, <0.4 mm, filled by calcite

Alteration: olivine replaced by calcite and clay

Shipboard Data

Magnetic Data:	35-38 cm
NRM Intensity (emu/cc)	18.758×10^{-3}
NRM Inclination	-72.6°
Stable Inclination	-72.2°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Aphyric to phyric basalt with minor volcanic breccia in pieces 3A-7. Basalt gray with a microlitic groundmass. 25-45 and 95-105 cm intervals phyric with plagioclase phenocrysts < 10%, <4 mm; mafic phenocrysts (olivine and clinopyroxene) < 10%, <4 mm; olivine phenocrysts replaced by green smectite. 0-25 cm and 45-95 cm intervals contain small vesicles (< 1 mm) with calcite or green smectite fillings. 0-25 cm interval displays a sharp, steeply inclined transition, parallel to a major crack, between a zone of green smectite fillings and an underlying zone with calcite fillings; 45-95 cm interval contains only calcite-filled vesicles. Breccia in pieces 3A-7 composed of fragments of pillow basalt with hyaloclastite margins and shards of glass partially replaced by palagonite, green smectite and calcite in a matrix of green smectite and calcite.

Thin Section Description

Location: 40 cm, flow interior

Texture: porphyritic, intergranular

Phenocrysts: olivine 3-5%, <1.5 mm; plagioclase 15%, <3 mm, An 60; clinopyroxene 1%, 1 mm, wavy extinction

Groundmass: olivine 5%, 0.1 mm; plagioclase 30%, 0.2 mm, An 52-60; clinopyroxene 35%, 0.1 mm; magnetite 5-10%, 0.2 mm, partially altered

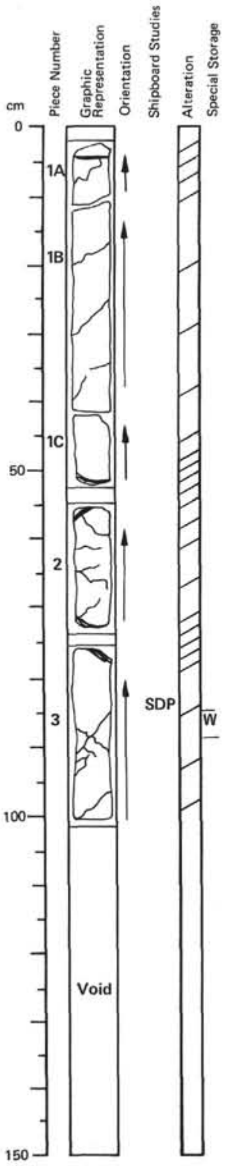
Vesicles: 1-2%, filled with green smectite

Alteration: olivine replaced by green smectite. Veins filled by calcite, vesicles by green smectite

Shipboard Data

Bulk Anaylsis: 39-42 cm

SiO_2	49.64
Al_2O_3	14.83
Fe_2O_3	11.93
MgO	7.08
CaO	12.64
Na_2O	1.96
K_2O	0.03
TiO_2	1.49
P_2O_5	0.19
MnO	0.19
LOI	0.40



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

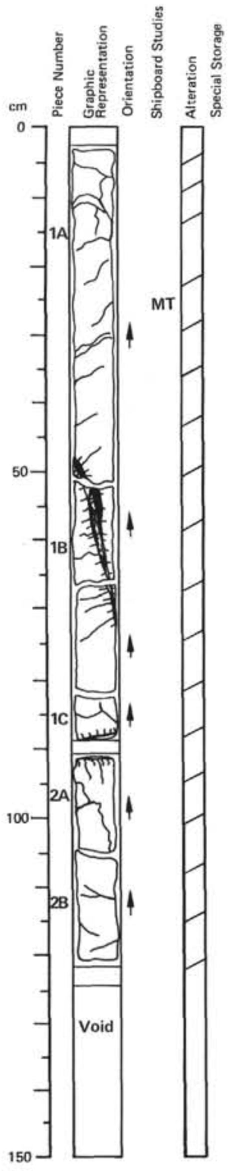
LEG	SITE	HOLE	CORE	SECT.
51	417	D	39	4

Visual Description

Phyric pillow basalt with chilled margins (pieces 1A, 1C, 2 and 3) and traces of interpillow breccia (piece 1A). 0-53, 53-75 and 75-100 cm intervals represent individual pillows or parts of pillows bounded by chilled margins. Basalt gray with an aphanitic to microlitic or locally subophitic groundmass. Plagioclase phenocrysts variable between 3-20%, <6 mm; clinopyroxene phenocrysts 2-7%, <2 mm, partially replaced by green smectite and calcite, common along pillow margins; olivine phenocrysts 1%, <2 mm, replaced by green smectite and calcite. Vesicles 1%, <0.2 mm, locally coalesced to form vugs <7 mm, filled by calcite. Veins filled by calcite and dark green smectite.

Shipboard Data

Physical Property Data:	84-86 cm
$\overline{V}p$ (km/sec)	5.85
Porosity (%)	2.6
Wet Bulk Density (g/cc)	2.86
Grain Density (g/cc)	2.92



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	39	5

Visual Description

Phyric, gray pillow basalt with locally glassy chilled margins (pieces 1 and 2A) and traces of interpillow breccia (piece 1E). 0-60, 60-90 and 90-121 cm intervals represent individual pillows or parts of pillows bounded by chilled margins. Euhedral plagioclase phenocrysts 20%, <8 mm; euhedral clinopyroxene phenocrysts 3-10%, <5 mm, partially replaced by green smectite; euhedral olivine phenocrysts <1%, <2 mm, replaced by iddingsite and green smectite. Glass largely devitrified, replaced by green smectite. Vesicles <2 mm, filled with green smectite, calcite and zeolites(?). Veins filled by calcite and green smectite.

Thin Section Description

Location: 26 cm

Texture: none

Phenocrysts: olivine 2%, 3 mm, prismatic; plagioclase 50%, 1-3 mm, zoned with An 75 cores and An 68 rims, tabular; clinopyroxene 1%, 0.3-0.5 mm, prismatic

Groundmass: plagioclase 15%, <0.75 mm, An 43, tabular, quenched; clinopyroxene 25%, 0.25 mm, spherulitic, quenched; magnetite 7%, 0.05 mm

Vesicles: none

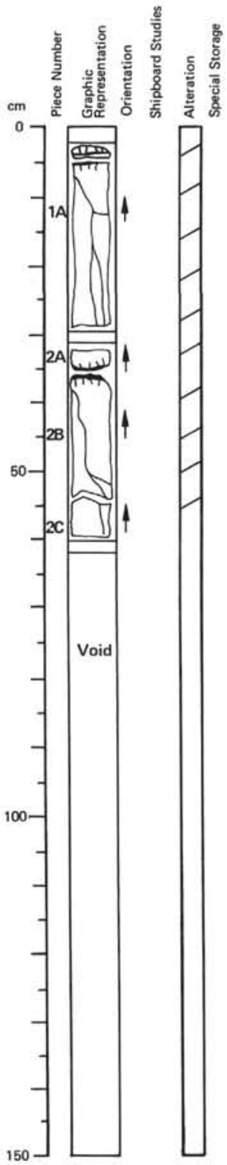
Alteration: olivine replaced by calcite. Veins filled by calcite.

Shipboard Data

Magnetic Data:	25-27 cm
NRM Intensity (emu/cc)	16.300×10^{-3}
NRM Inclination	-63.8°
Stable Inclination	-64.5°

VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	39	6

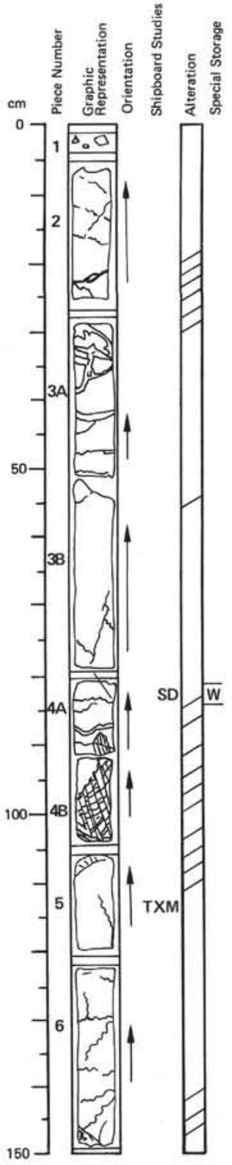


Visual Description

Phyric basalt pillows with haloclastite margins. 0-35 and 35-60 cm intervals represent individual pillows or parts of pillows bounded by chilled margins. Basalt groundmass dark gray. Euhedral plagioclase phenocrysts 20%, <5 mm; euhedral clinopyroxene phenocrysts 5%, <4 mm; olivine phenocrysts 5%, completely replaced by green smectite and calcite. Vesicles <1 mm, filled with calcite. Veins filled by calcite and green smectite.

VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	40	1



Visual Description

Phyric to sparsely phyric pillow basalt with altered chilled margins (pieces 4B, 5 and 6). 0-105 and 105-150 cm intervals represent individual pillows or parts of pillows bounded by chilled margins. Basalt gray, locally altered to yellow-brown along fractured pillow margins (pieces 4A and 4B). Groundmass aphanitic to microlitic or fine-grained. Plagioclase phenocrysts 3-25%, 2-7 mm; clinopyroxene phenocrysts 1-3%, 1.5-4 mm; olivine phenocrysts 1-15%, <5 mm, replaced by dark green smectite or by montmorillonite and calcite. Phenocrysts extremely variable with plagioclase tending to be concentrated in pieces 4 and 6 (near lower pillow margins) while olivine and clinopyroxene are concentrated in pieces 3A, 3B, 5 and 6. Glass partially devitrified, replaced by green smectite, montmorillonite, palagonite(?) and calcite. Vesicles filled by calcite or green smectite, range from 0-2%, <1.5 mm, locally coalesce to form calcite-filled vugs (piece 2). Veins filled by calcite and/or green smectite ± pyrite, locally perpendicular to margins (piece 4). Light brown, finely-layered chert (piece 1) probably from sediment overlying basement.

Thin Section Description

Location: 115 cm, pillow interior

Texture: phyric, microlitic

Phenocrysts: olivine 3%, 0.25-0.50 mm, prismatic; fresh plagioclase 25%, 0.25-0.50 mm, An 68-60, normally zoned; clinopyroxene <1%, 0.25-1.00 mm, prismatic

Groundmass: plagioclase 7%, 0.02-0.25 mm, An 55, tabular, quenched; clinopyroxene 54%, 0.1-0.2 mm, spherulitic, quenched; magnetite 10%, 0.05-0.1 mm

Vesicles: none

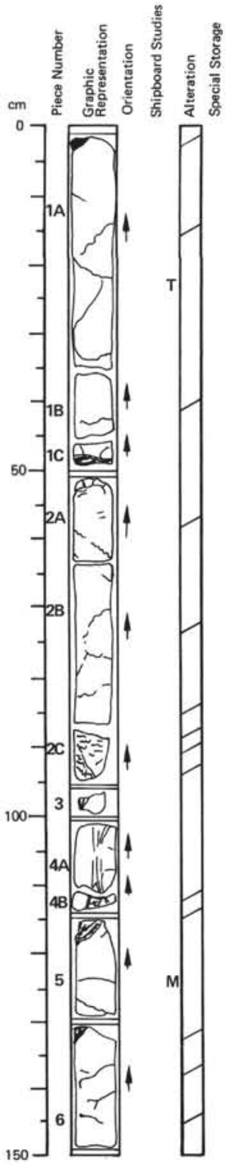
Alteration: calcite 4%, in veins and as pseudomorphs after olivine

Shipboard Data

Bulk Analysis: 114-117 cm	
SiO_2	48.68
Al_2O_3	17.02
Fe_2O_3	9.99
MgO	6.39
CaO	13.70
Na_2O	2.11
K_2O	0.04
TiO_2	1.36
P_2O_5	0.18
MnO	0.18
LOI	1.30
H_2O^+	.65
H_2O^-	N.D.
CO_2	1.06

Magnetic Data:	114-117 cm
NRM Intensity (emu/cc)	11.687×10^{-3}
NRM Inclination	-67.2°

Physical Property Data:	82-84 cm
$\bar{V}p$ (km/sec)	5.46
Wet Bulk Density (g/cc)	2.77



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	40	2

Visual Description

Phyric pillow basalt with glassy chilled margins (pieces 1A, 1C, 2A, and 3-5). Basalt gray with a variolitic groundmass. Plagioclase phenocrysts 10-15%; clinopyroxene phenocrysts 1-5%, <0.5 mm; olivine phenocrysts 5-7%, <3 mm, replaced by iddingsite ± calcite. Mafic phenocrysts tend to be concentrated near margins. Veins and vesicles filled by calcite.

Thin Section Description

Location: 25 cm, next to glassy margin

Texture: porphyritic, subvariolitic

Phenocrysts: olivine 5-6%, 0.5 mm; plagioclase 10-15%, 0.4 mm, An 65, contains devitrified glass inclusions; clinopyroxene 3-4%, 0.3-2 mm, 2V = 55°, zoned

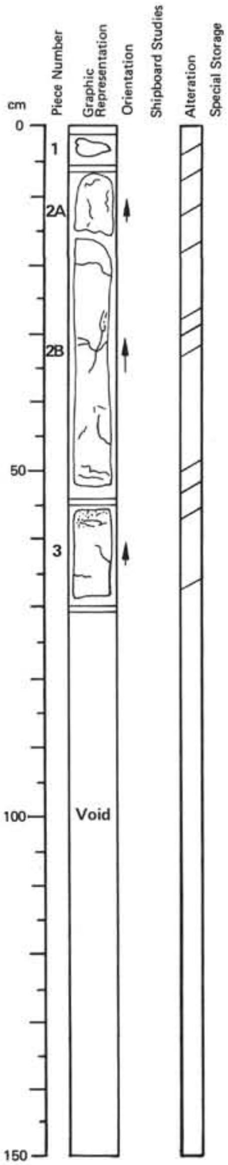
Groundmass: olivine 5%, 0.05-0.1 mm; plagioclase 30-35%, 0.2-0.3 mm, skeletal; clinopyroxene 35-40%, 0.1 mm, skeletal with plumose sprays; magnetite 1-2%, 0.02 mm

Vesicles: 1-2%, filled by celadonite

Alteration: olivine replaced by calcite, iddingsite and clay

Shipboard Data

Magnetic Data:	124-127 cm
NRM Intensity (emu/cc)	15.532×10^{-3}
NRM Inclination	−70.2°
Stable Inclination	−69.3°

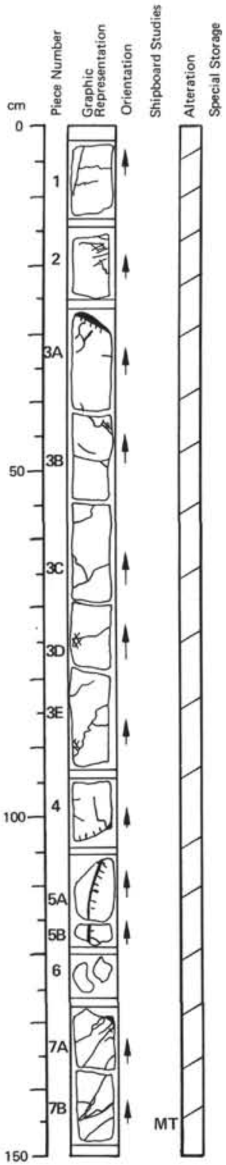


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	40	3

Visual Description

Phyric pillow basalt with altered margins (piece 2A). Basalt gray with an aphanitic groundmass. Plagioclase phenocrysts 10-15%; clinopyroxene phenocrysts 2-3%; olivine phenocrysts 5-7%, <5 mm, replaced by green smectite. Glass replaced by green smectite and palagonite(?). Veins and vesicles filled by clay and calcite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE			SECT.	
5	1	4	1	7	D		4	1		1

Visual Description

Phyric pillow basalt with devitrified margins (pieces 3A, 4, 5 and 7A) and minor interpillow breccia (piece 5). Basalt gray with a crystalline groundmass. Euhedral plagioclase phenocrysts 15%, <5 mm; euhedral to subhedral clinpyroxene phenocrysts 5%, <2 mm, increase to 15% in piece 3D; olivine phenocrysts rare. Mafic phenocrysts and devitrified glass partially to completely replaced by green smectite and calcite. Calcite-filled vesicles <1%, <0.5 mm. Veins filled by calcite and green smectite. Cavity in piece 3D filled by zeolites. Breccia in piece 5 composed of glass fragments replaced by green smectite in a matrix of calcite, green smectite and zeolites.

Thin Section Description

Location: 145 cm, next to glassy margin

Texture: porphyritic

Phenocrysts: olivine 5%, 2 mm, euhedral; plagioclase 20%, 3 mm, euhedral; clinopyroxene 2%, 1 mm, partially resorbed

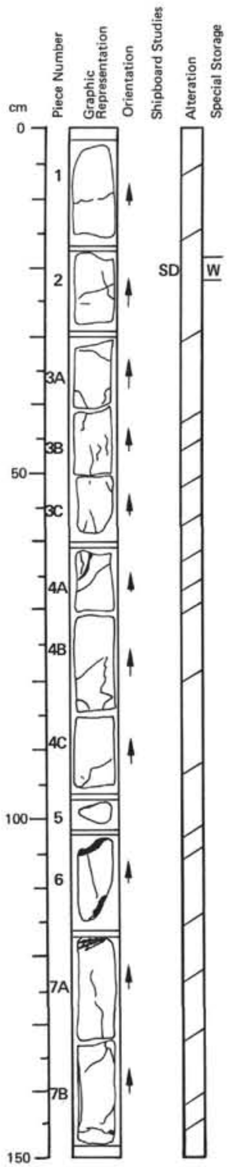
Groundmass: olivine 5%, 0.2 mm, subhedral; plagioclase 20%, 0.3 mm, quenched; clinopyroxene 30%, 0.2 mm, quenched; magnetite 5%, 0.05 mm; glass <5% , devitrified

Vesicles: 3%, filled by calcite

Alteration: olivine replaced by zeolites and clay

Shipboard Data

Magnetic Data:	144-146 cm
NRM Intensity (emu/cc)	9.366×10^{-3}
NRM Inclination	-71.8°
Stable Inclination	-73.0°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

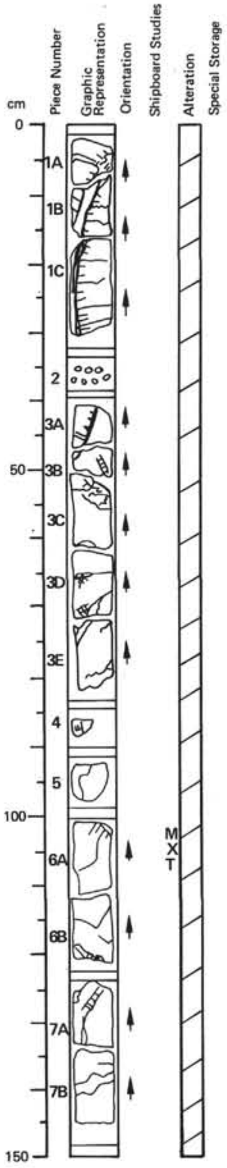
LEG		SITE			HOLE	CORE			SECT.	
5	1	4	1	7	D		4	1		2

Visual Description

Phyric to sparsely phyric pillow basalt with altered chilled margins (pieces 4A, 6 and 7A) and traces of breccia (piece 4A). Basalt gray with aphanitic to variolitic margins. Plagioclase phenocrysts 10%; olivine phenocrysts 5-8%, common in pieces 3C and 4C, replaced by iddingsite ±calcite; pyroxene phenocrysts 1% , increase to 3-5%, 0.3 mm in piece 3. Vesicles 1-2%, increase to 5% in piece 4B, filled by calcite and green smectite. Veins filled by calcite and green smectite. Breccia in piece 4A composed of fragments of strongly altered glass. Piece 4B contains a small sulfide globule. Pillow margins in piece 6 and 7A dip, respectively, at an angle of 27° and 32° to the horizontal.

Shipboard Data

Physical Property Data:	20-22 cm
$\bar{V}p$ (km/sec)	5.80
Wet Bulk Density (g/cc)	2.82



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	41	3

Visual Description

Altered phyric pillow basalt with strongly altered chilled margins (pieces 1, 3A, 3C and 6A) and minor interpillow breccia (pieces 1, 3A and 3B). Groundmass aphanitic to microlitic, partially replaced by calcite and green smectite. Euhedral plagioclase phenocrysts 20%, 5 mm, partially replaced by calcite; euhedral clinopyroxene phenocrysts 5%, 3 mm, partially replaced by green smectite, calcite; euhedral olivine phenocrysts 1%, 2 mm, completely replaced by iddingsite and green smectite. Glass partially devitrified, largely replaced by green smectite. Vesicles <1%, <0.5 mm, filled with calcite, green smectite. Minor veins filled by calcite, green smectite. Breccia composed of devitrified glass and green smectite.

Thin Section Description

Location: 102 cm, next to glassy margin

Texture: porphyritic

Phenocrysts: olivine 5%, 1 mm, euhedral; plagioclase 15%, 3 mm, euhedral, zones; clinopyroxene 2%, 0.2 mm, partially resorbed

Groundmass: plagioclase 5%, 0.05 mm, quenched; glass 70%, variolitic

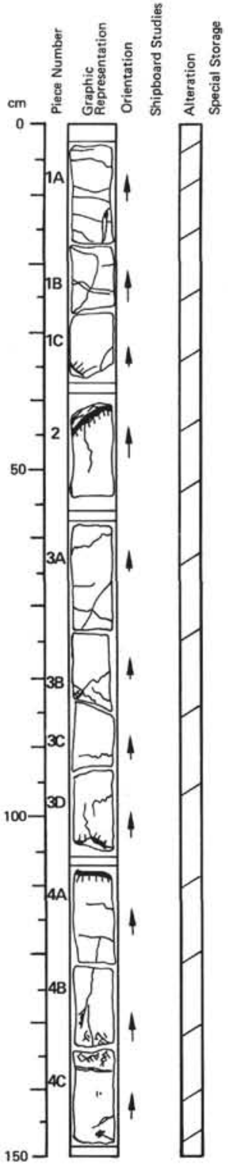
Vesicles: filled by calcite

Alteration: olivine replaced by clay

Shipboard Data

Bulk Analysis: 102-105 cm	
SiO_2	49.90
Al_2O_3	17.61
Fe_2O_3	10.19
MgO	6.57
CaO	10.92
Na_2O	2.84
K_2O	0.21
TiO_2	1.61
P_2O_5	0.17
MnO	0.17
LOI	1.70
H_2O^+	N.D.
H_2O^-	N.D.
CO_2	N.D.

Magnetic Data:	102-105 cm
NRM Intensity (emu/cc)	12.931×10^{-3}
NRM Inclination	-76.9°
Stable Inclination	-77.3°

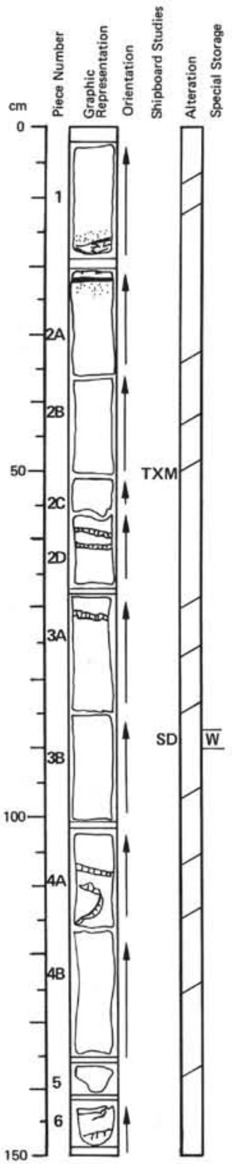


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	41	4

Visual Description

Altered phyric basalt pillows with strongly altered chilled margins (pieces 1C, 2, 3D and 4A). 0-38, 38-105 and 105-150 cm intervals represent individual pillows or parts of pillows bounded by chilled margins. Groundmass aphanitic to crystalline, partially replaced by green smectite, rarely by pyrite. Euhedral plagioclase phenocrysts 15-20%, 4 mm, partially replaced by calcite, green smectite; euhedral clinopyroxene phenocrysts 5%, 3 mm, largely replaced by green smectite; euhedral olivine phenocrysts 1-3%, <2 mm, replaced by green smectite, iddingsite and pyrite; mafic phenocrysts concentrated in piece 4A. Glass completely devitrified, replaced by green smectite. Minor vesicles in pieces 3B, 4B filled with calcite. Veins filled by calcite, zeolites, pyrite and green to brown smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	D		4	1	5

Visual Description

Phyric pillow basalt with glassy chilled margins (pieces 1, 2A and 6) and minor interpillow hyaloclastite breccia (piece 6). Basalt dark gray, altered to gray-brown near margins. Altered euhedral plagioclase phenocrysts 15-20%, <5 mm; euhedral olivine phenocrysts 5-8%, <4 mm, replaced by green smectite and talc(?) or calcite and iddingsite; euhedral pyroxene phenocrysts 2-3%, <3 mm. Calcite-filled vesicles 1-2%, 1-2 mm. Veins filled by calcite, green smectite, minor sulfides. Hyaloclastite breccia in piece 6 composed of shards of glass (altered to palagonite near the margins) in a matrix of calcite and clay.

Thin Section Description

Location: 50 cm, pillow interior

Texture: ophitic

Phenocrysts: olivine 3%, 2 mm, euhedral; plagioclase 25%, 4 mm, euhedral-subhedral; clinopyroxene 5%, 3 mm, anhedral

Groundmass: olivine 5%, 0.1 mm, euhedral-subhedral; plagioclase 20%, 0.5 mm, euhedral; clinopyroxene 35%, 0.2 mm; magnetite 3%, 0.03 mm; glass <5%

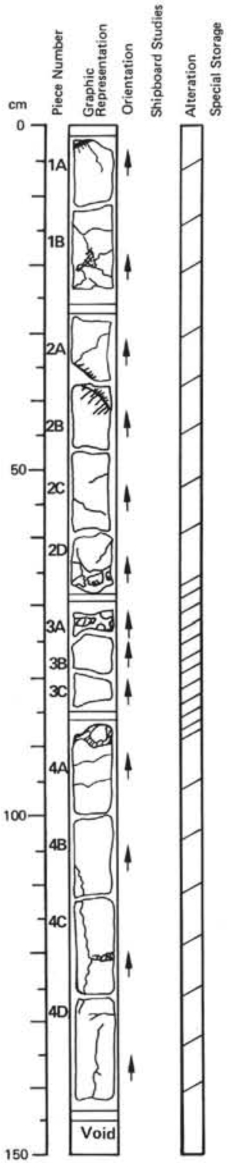
Vesicles: filled by calcite and clay

Alteration: olivine replaced by calcite and clay

Shipboard Data

Bulk Analysis: 50-52 cm	
SiO_2	50.07
Al_2O_3	17.13
Fe_2O_3	9.98
MgO	6.85
CaO	13.60
Na_2O	N.D.
K_2O	0.01
TiO_2	1.16
P_2O_5	N.D.
MnO	N.D.
LOI	0.90
H_2O^+	.67
H_2O^-	N.D.
CO_2	.45

Magnetic Data:	50-52 cm
NRM Intensity (emu/cc)	7.992×10^{-3}
NRM Inclination	−65.1°
Stable Inclination	−71.7°
Physical Property Data:	87-89 cm
$\bar{V}p$ (km/sec)	5.97
Wet Bulk Density (g/cc)	2.74



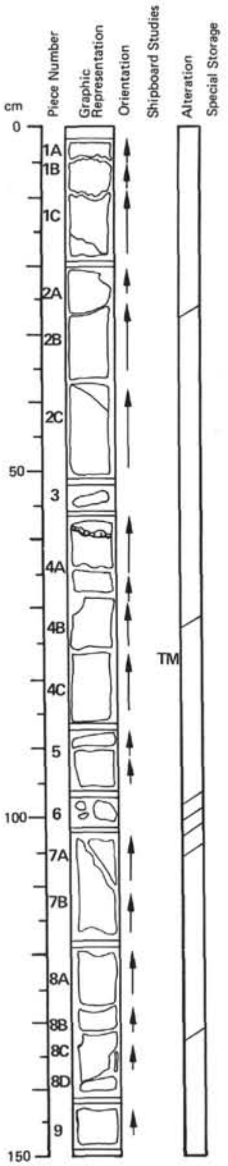
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	D		4	1	6

Visual Description

0-85 cm: phyric pillow basalt with strongly altered chilled margins (pieces 1A, 2A and 2B) and minor breccia (piece 3). Euhedral plagioclase phenocrysts 15%, 4 mm, partially replaced by green smectite; euhedral clinopyroxene phenocrysts 10%, 3 mm, partially replaced by green smectite; euhedral to anhedral olivine phenocrysts 5%, 3 mm, increase to 10%, 4 mm in piece 2D, completely replaced by green smectite, iddingsite and calcite. Rare vesicles filled with calcite. Veins filled with green smectite. Glass devitrified, replaced by green smectite. Large vug in piece 1B filled with calcite and green to brown smectite. Breccia in piece 3 composed of fragments devitrified glass altered to green smectite in a matrix of green to brown smectite, hematite(?) and minor calcite.

83-145 cm: massive, phyric basalt with a fractured, fine-grained margin in piece 4A. Basalt groundmass crystalline. Plagioclase phenocrysts <15%, <4 mm, common in pieces 4B and 4C; altered mafic phenocrysts 5-10%, 3 mm in pieces 4A and 4D, decrease to <1 mm in pieces 4B, 4C. Piece 4C contains vesicles filled by calcite and green smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	41	7

Visual Description

Massive phyric basalt with a dark gray, subophitic groundmass. Altered euhedral plagioclase phenocrysts 15%, <5 mm; euhedral olivine phenocrysts 5%, replaced by green smectite or by opal(?) in association with pyrite; clinopyroxene laths 2%, <6 mm. Minor veins filled by calcite.

Thin Section Description

Location: 76 cm, pillow interior

Texture: hyaloophitic

Phenocrysts: olivine 10%, euhedral-subhedral; plagioclase 25%, 3 mm, euhedral, zoned; clinopyroxene 5%, partially resorbed

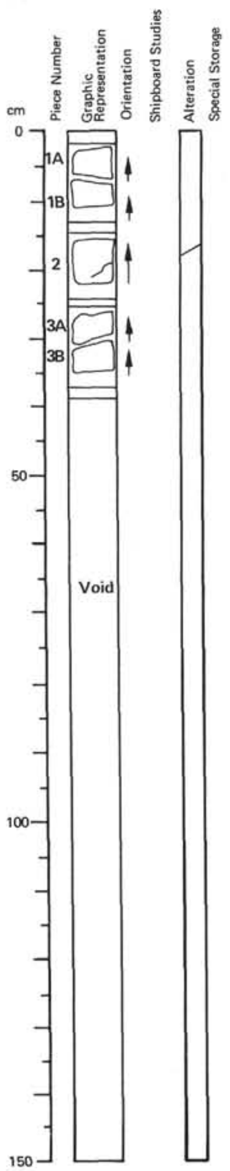
Groundmass: olivine 10%, 0.1 mm, euhedral; plagioclase 20%, 0.5 mm, euhedral; clinopyroxene 30%, 0.2 mm, quenched; magnetite <5%, 0.03 mm, dendritic; glass 10%

Vesicles: <1%, 0.02 mm, filled by clay

Alteration: olivine replaced by clay

Shipboard Data:

Magnetic Data:	76-78 cm
NRM Intensity (emu/cc)	20.325×10^{-3}
NRM Inclination	-51.4°
Stable Inclination	-54.8°

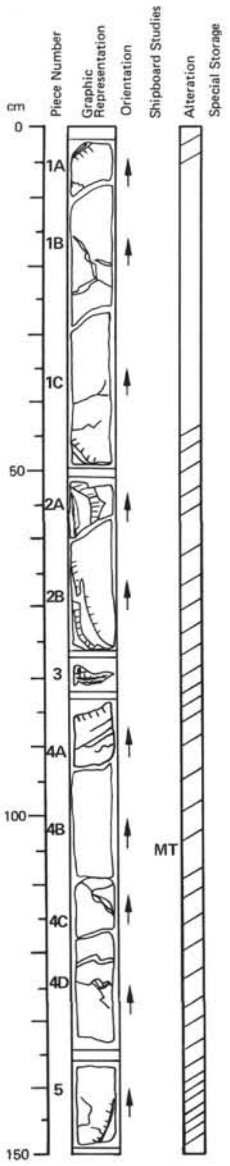


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	41	8

Visual Description

Massive phyric basalt with a dark gray, ophitic groundmass. Euhedral plagioclase phenocrysts 20%, 4 mm; euhedral olivine and clinopyroxene phenocrysts 10%, 3 mm, completely replaced by green smectite and zeolites. Veins filled by green smectite and zeolites.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	D	4 2	1

Visual Description

Altered phyric pillow basalt with strongly altered chilled margins (pieces 1A, 1C, 2, 4A, and 5) and minor interpillow limestone (piece 3). 0-50 and 83-150 cm intervals represent individual pillows bounded by chilled margins. Euhedral plagioclase phenocrysts 20-25%, 4-6 mm; euhedral to partially resorbed clinopyroxene phenocrysts 5%, 4 mm, largely replaced by green smectite and calcite; euhedral olivine phenocrysts 3-5%, 3 mm, completely replaced by green smectite and calcite. Groundmass in pieces 4 and 5 and glass throughout section partially replaced by green smectite. Piece 4D contains a 2 cm-long vug filled by calcite. Veins filled by calcite, green smectite and pyrite. Gray-green interpillow limestone in piece 3 contains fragments of altered glass.

Thin Section Description

Location: 106 cm, pillow interior

Texture: porphyritic

Phenocrysts: olivine 2%, 3 mm, euhedral; plagioclase 30%, 4 mm, euhedral; clinopyroxene 0.5%, 0.5 mm, anhedral

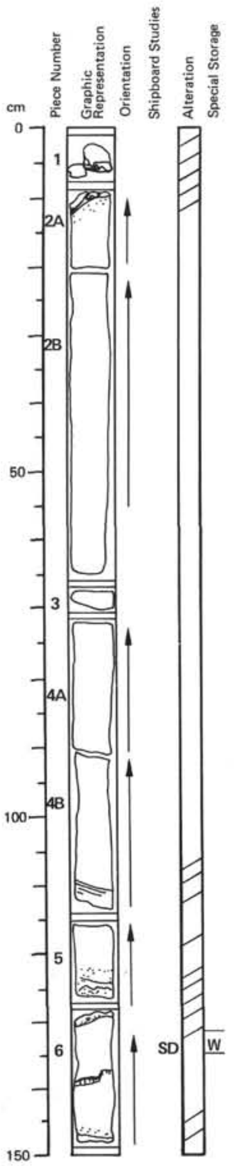
Groundmass: olivine 5%, 0.1 mm, euhedral; plagioclase 20%, 0.5 mm, euhedral, tabular, partially quenched; clinopyroxene 30%, 0.2 mm, euhedral, quenched; magnetite <5%

Vesicles: <1%, <0.5 mm, filled by clay

Alteration: olivine replaced by clay

Shipboard Data

Magnetic Data:	105-107 cm
NRM Intensity (emu/cc)	11.894 x 10^{-3}
NRM Inclination	-68.4°
Stable Inclination	-69.5°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

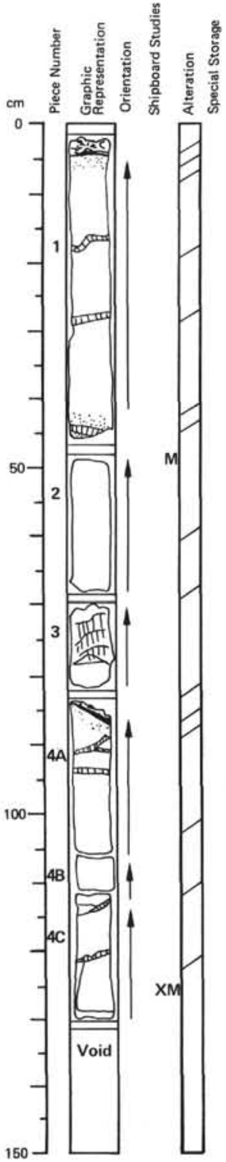
LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	D	4 2	2

Visual Description

Phyric pillow basalt with altered chilled margins (pieces 1, 2A, 4B, 5 and 6). 8-113 and 127-150 cm intervals represent individual pillows bounded by chilled margins. Basalt dark gray, altered to gray-brown along pillow margins. Euhedral plagioclase phenocrysts 20%, <5 mm; partially replaced by calcite and green smectite; euhedral olivine phenocrysts 3-5%, replaced by calcite and iddingsite near pillow margins and by green smectite in pillow interiors; pyroxene laths 2%, <5 mm. Glass largely devitrified, altered to palagonite. Vesicles 1%, 1-2 mm, filled by calcite or green smectite. Minor veins filled by calcite and green smectite.

Shipboard Data

Physical Property Data:	131-133 cm
$\overline{V}p$ (km/sec)	5.30
Wet Bulk Density (g/cc)	2.72



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

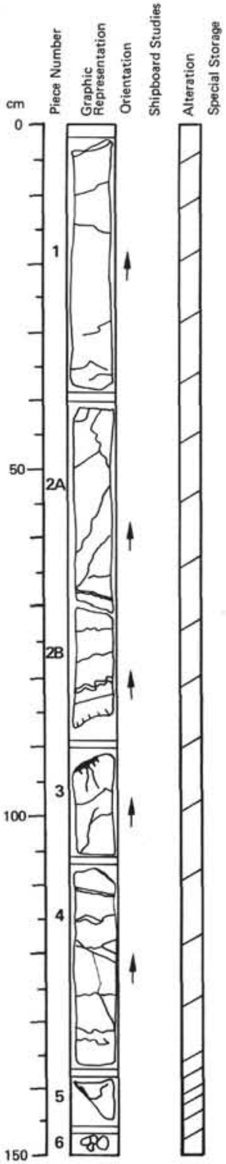
Visual Description

Phyric, dark gray pillow basalt with chilled glassy margins (pieces 1, 3 and 4A). Euhedral plagioclase phenocrysts 15%, < 6 mm; euhedral olivine phenocrysts 2-3%, < 5 mm, replaced by green smectite; pyroxene laths < 1%, < 4 mm. Vesicles 1%, 1-2 mm, filled by calcite or green smectite. Veins filled by calcite, green smectite and sulfides. Piece 3 contains slickensides.

Shipboard Data

Bulk Analysis: 125-127 cm	
SiO_2	50.81
Al_2O_3	17.12
Fe_2O_3	10.22
MgO	6.46
CaO	13.77
Na_2O	2.05
K_2O	0.04
TiO_2	1.17
P_2O_5	0.16
MnO	0.16
LOI	1.25
H_2O^+	.66
H_2O^-	N.D.
CO_2	.13

Magnetic Data:	48-51 cm	125-127 cm
NRM Intensity (emu/cc)	7.935×10^{-3}	3.171×10^{-3}
NRM Inclination	-44.2°	-56.7°
Stable Inclination	-53.5°	-61.8°

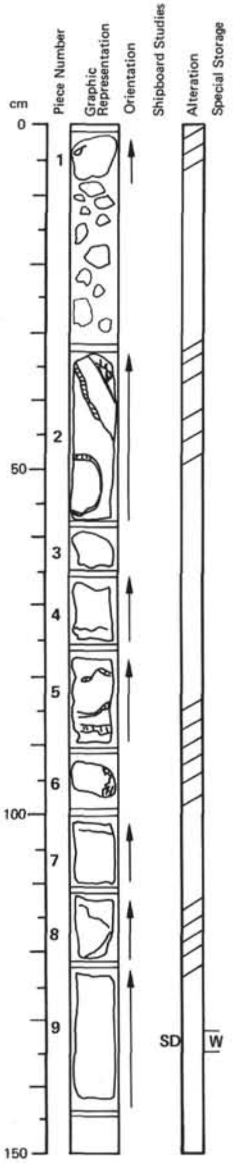


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	D	4	2		4

Visual Description

Phyric pillow basalt with altered margins (pieces 2B, 3 and 5) and traces of breccia (piece 6). Euhedral plagioclase phenocrysts 15%, 4 mm; euhedral to subhedral clinopyroxene phenocrysts 10-15%, 4 mm, partially replaced by green smectite and calcite; euhedral olivine phenocrysts 5%, 3 mm, completely replaced by green smectite and iddingsite; mafic phenocrysts concentrated in 21-34 cm interval. Vesicles filled with calcite and green smectite. Veins filled by calcite and green smectite, + pyrite and zeolites. Glass and groundmass in piece 5 altered to green smectite. Breccia in piece 6 composed of fragments of basalt altered to green to brown smectite (or hematite?) in a matrix of calcite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

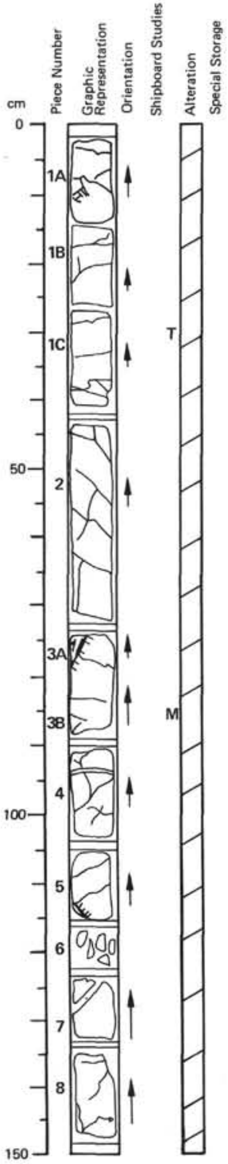
LEG	SITE	HOLE	CORE	SECT.
51	417	D	42	5

Visual Description

Phyric, dark gray pillow basalt with chilled glassy margins (pieces 2 and 8). Euhedral plagioclase phenocrysts 10%, <3 mm; olivine phenocrysts 1%, <3 mm, replaced by green smectite and calcite; clinopyroxene phenocrysts <1%, 2-3 mm. Vesicles 2-3%, 1-3 mm, filled with green smectite and calcite. Minor vesicles filled by calcite and green smectite ± pyrite.

Shipboard Data

Physical Property Data:	131-133 cm
$\overline{V}$p (km/sec)	5.56
Wet Bulk Density (g/cc)	2.84



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	42	6

Visual Description

Phyric pillow basalt with chilled margins in pieces 3A and 5. Groundmass cyrstalline, partially replaced by green smectite and calcite. Euhedral plagioclase phenocrysts 5-10%, <3 mm; euhedral to subhedral clinopyroxene phenocrysts 3%, 2 mm, partially replaced by green smectite; olivine phenocrysts rare, increase to 20% in piece 2, completely replaced by iddingsite. Vesicles 2%, <1 mm, filled with calcite, green smectite and zeolites. Veins calcite, green smectite and pyrite.

Thin Section Description

Location: 21 cm, pillow interior

Texture: ophitic, hyaloophitic

Phenocrysts: olivine 2%, 0.5 mm, euhedral; plagioclase 5%, 4 mm, euhedral; clinopyroxene 2%, 0.5 mm, euhedral

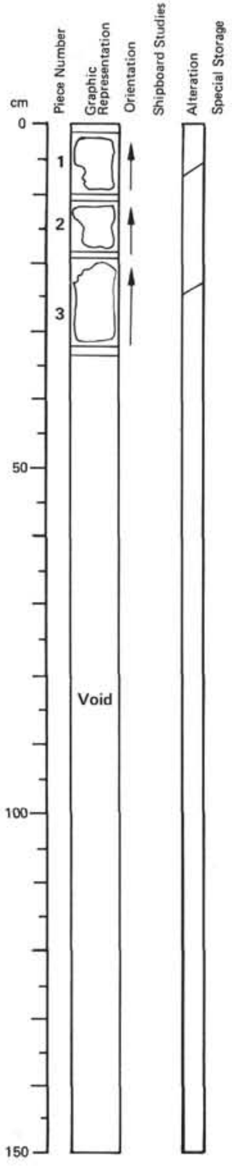
Groundmass: olivine 5-10%, 0.02 mm, euhedral; plagioclase 30%, 0.1 mm, euhedral, prismatic; clinopyroxene 40%, 0.03 mm, euhedral-anhedral, quenched; magnetite <5%, 0.01 mm; glass 5%

Vesicles: 1%, filled by calcite and clay

Alteration: olivine and glass altered

Shipboard Data

Magnetic Data:	86-88 cm
NRM Intensity (emu/cc)	7.045×10^{-3}
NRM Inclination	− 8.7°
Stable Inclination	-31.3°

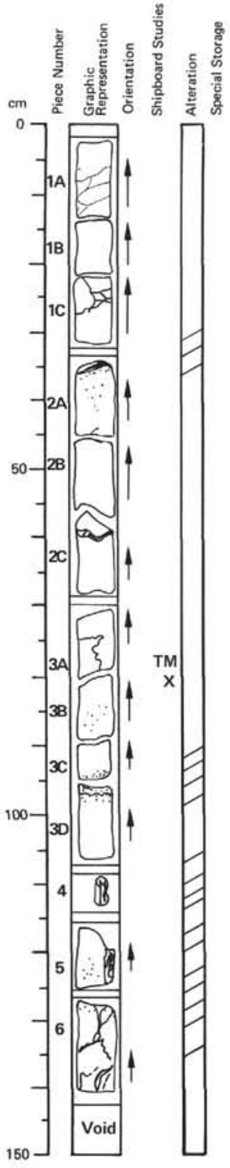


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	D		4 2		7

Visual Description

Dark gray, phyric pillow basalt. Euhedral plagioclase phenocrysts 10%, <3 mm; euhedral olivine phenocrysts 1-2%, <3 mm, replaced by green smectite; clinopyroxene laths 1%, <3 mm. Vesicles 2%, 1-2 mm, filled with calcite and/or green smectite, occasionally lined with sulfides. Minor veins filled with green smectite and/or calcite + sulfides.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	D		4 3		1

Visual Description

Moderately phyric pillow basalt with strongly altered chilled margins (pieces 2A and 3C-5) and traces of interpillow breccia (piece 5). Basalt gray with a fine- to coarse-grained, microlitic to subophitic groundmass. Plagioclase phenocrysts 1-2%, <1.5 mm, increase to 10%, <2 mm in in piece 6, olivine phenocrysts 1-3%, <2 mm, replaced by green smectite and calcite; clinopyroxene phenocrysts 1-2%, <1 mm. Vesicles 1-3%, <0.5 mm, filled with calcite and green smectite. Veins filled by calcite or green smectite. Glass devitrified, replaced by green smectite, palagonite(?) and calcite.

Thin Section Description

Location: 80 cm, next to glassy margin

Texture: porphyritic

Phenocrysts: olivine 5%, 2 mm, euhedral; plagioclase 3%, 2 mm, euhedral; clinopyroxene 2%, 2 mm, partially resorbed

Groundmass: plagioclase 15%, 0.5 mm, quenched; clinopyroxene 20%, 0.3 mm, quenched; magnetite <3%, dendritic; glass 50%, variolitic

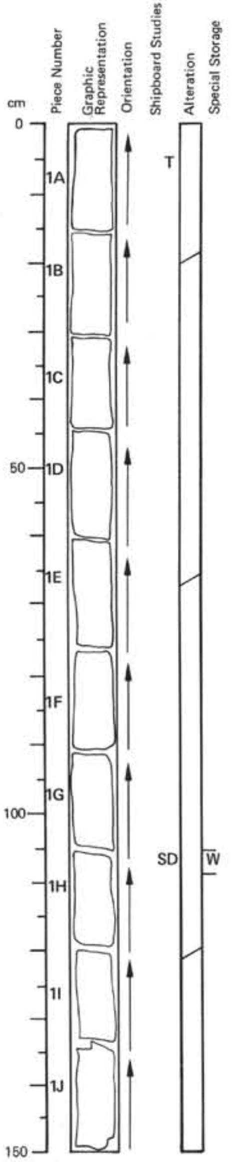
Vesicles: <1%, <0.5 mm, filled by calcite

Alteration: olivine replaced by clay

Shipboard Data

Bulk Analysis: 78-81 cm	
SiO_2	49.38
Al_2O_3	15.75
Fe_2O_3	11.40
MgO	6.71
CaO	12.77
Na_2O	2.14
K_2O	0.07
TiO_2	1.58
P_2O_5	0.19
MnO	0.19
LOI	1.05
H_2O^+	.83
H_2O^-	N.D.
CO_2	.53

Magnetic Data:	78-81 cm
NRM Intensity (emu/cc)	5.714×10^{-3}
NRM Inclination	-11.3°
Stable Inclination	-23.1°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	43	2

Visual Description

Massive phyric basalt with a dark gray, intersertal to subophitic groundmass. Euhedral plagioclase phenocrysts 10%, <3 mm; euhedral olivine phenocrysts 2%, <3 mm, replaced by green smectite; clinopyroxene laths <1%, <3 mm. Vesicles 3-4% in pieces 1A-1D, 1-2% in piece 1D-1J, 1-3 mm, filled by calcite and green smectite. Minor veins filled by calcite and green smectite.

Thin Section Description

Location: 5 cm, pillow interior

Texture: phyric, microlitic

Phenocrysts: olivine 2%, 0.2-0.4 mm, prismatic; plagioclase 15%, 0.2-1.0 mm, An 68-An 63, tabular; clinopyroxene 5%, 0.3-2.0 mm, prismatic

Groundmass: plagioclase 20%, 0.1-0.3 mm, An 53, quenched; clinopyroxene 50%, 0.1 mm, quenched; magnetite 6%, 0.02-0.04 mm, euhedral

Vesicles: <1%, 0.1-0.5 mm, filled by calcite and clay

Alteration: olivine replaced by calcite, clay and serpentine

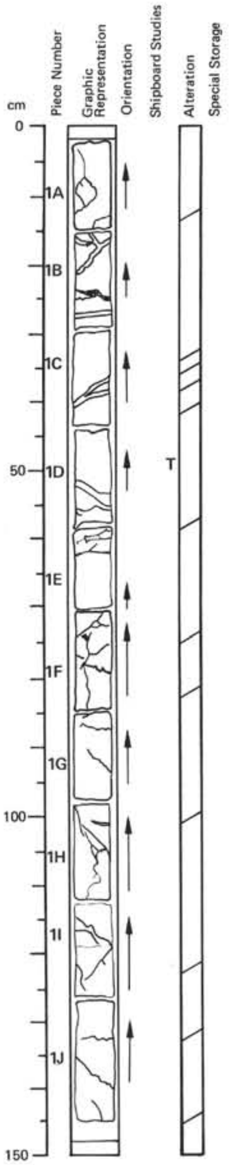
Shipboard Data

Physical Property Data:	106-108 cm
$\bar{V}p$ (km/sec)	5.61
Wet Bulk Density (g/cc)	2.84

Shipboard Data

Bulk Anaylsis: 4-6 cm

SiO_2	49.80
Al_2O_3	16.24
Fe_2O_3	11.68
MgO	6.71
CaO	12.06
Na_2O	2.21
K_2O	0.19
TiO_2	1.60
P_2O_5	0.16
MnO	0.16
LOI	1.10



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	43	3

Visual Description

Sparsely phyric massive basalt with a coarse-grained, subophitic groundmass. Basalt dark gray, altered to greenish-brown along veins filled with green smectite. Plagioclase phenocrysts <1%, <5 mm; olivine phenocrysts <1%, 1-2 mm, replaced by green smectite. Vesicles 2%, <0.5 mm, filled with calcite or green smectite. Veins filled by green smectite and calcite.

Thin Section Description

Location: 50 cm, next to glassy margin

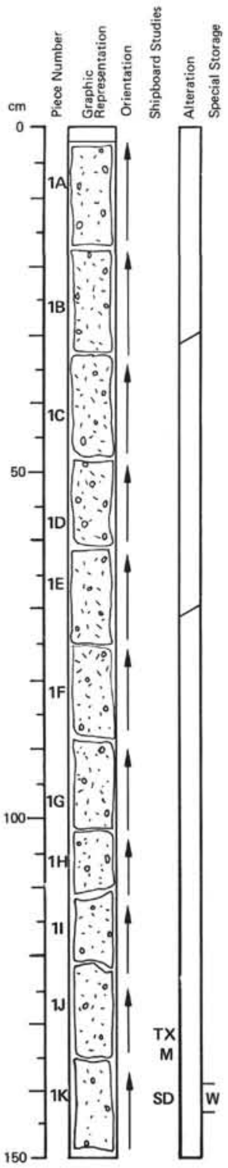
Texture: porphyritic

Phenocrysts: olivine 10%, 3 mm, euhedral; plagioclase 25%, 4 mm, euhedral; clinopyroxene 5%, 4 mm, subhedral

Groundmass: olivine 5%, 0.1 mm; plagioclase 20%, 0.4 mm, prismatic, quenched, clinopryoxene 30%, 0.2 mm, quenched; magnetite <5%, dendritic; glass 20%

Vesicles: <1%, 0.3 mm, filled by calcite

Alteration: olivine replaced by clay



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	43	4

Visual Description

Massive phyric basalt with a dark gray, subophitic groundmass. Euhedral plagioclase phenocrysts 5-8%, <3 mm; olivine phenocrysts <1%, <3 mm, replaced by green smectite; clinopyroxene laths <1%, <10 mm. Calcite-filled vesicles 2%, 1-2 mm. Minor veins filled with calcite and green smectite.

Thin Section Description

Location: 130 cm, interior of massive basalt

Texture: ophitic

Phenocrysts: olivine 5%, 0.5 mm, euhedral; plagioclase 15%, 0.5-3 mm, euheral; clinopyroxene 5%, 0.5 mm, anhedral

Groundmass: olivine 15%, 0.2 mm, euhedral-subhedral; plagioclase 35%, 0.5 mm, prismatic; clinopyroxene 25%, 0.2 mm, anhedral; magnetite <2%, 0.03 mm, dendritic

Vesicles: 1%, 0.02 mm, filled by calcite

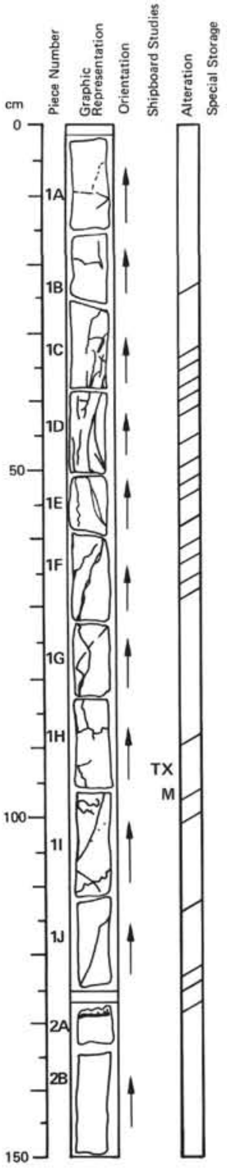
Alteration: olivine replaced by clay

Shipboard Data

Bulk Analysis: 130-132 cm	
SiO_2	49.57
Al_2O_3	15.79
Fe_2O_3	12.25
MgO	6.65
CaO	13.35
Na_2O	2.00
K_2O	0.14
TiO_2	1.49
P_2O_5	0.19
MnO	0.19
LOI	1.15
H_2O^+	.85
H_2O^-	N.D.
CO_2	.72

Magnetic Data:	130-132 cm
NRM Intensity (emu/cc)	2.213×10^{-3}
NRM Inclination	+59.0°
Stable Inclination	-25.3°

Physical Property Data:	140-142 cm
$\overline{V}p$ (km/sec)	5.72
Wet Bulk Density (g/cc)	2.89



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	43	5

Visual Description

0-125 cm: sparsely phyric, massive gray basalt with brown alteration halos along veins filled by green smectite or calcite and pyrite. Groundmass coarse-grained, subophitic in pieces 1A-1H, fine-grained, microlitic in pieces 1I-1J. Plagioclase phenocrysts 2%, <2 mm; olivine phenocrysts 2-5%, <3 mm, replaced by green smectite ± calcite. Veins in pieces 1D-1E gracefully curved.
125-150 cm: phyric pillow basalt with altered chilled margins and traces of breccia (piece 2A). Basalt light gray with an aphanitic to fine-grained, microlitic groundmass. Plagioclase phenocrysts 5%, 1-5 mm, increase in size with depth; olivine phenocrysts 5-7%, <2 mm, replaced by green smectite. Calcite-filled vesicles 3%, <0.3 mm in piece 2B. Veins filled by green smectite. Breccia composed of fragments of devitrified glass replaced by green smectite, palagonite(?) and calcite.

Thin Section Description

Location: 94 cm, interior of massive basalt

Texture: ophitic

Phenocrysts: olivine 5%, 0.3-2 mm, euhedral; plagioclase 10%, 0.5-3 mm, euhedral; clinopyroxene 2%, 0.5 mm, anhedral

Groundmass: olivine 15%, 0.1 mm, euhedral; plagioclase 25-30%, 0.5 mm, prismatic; clinopyroxene 35%, 0.3 mm, anhedral; magnetite <5%, 0.02 mm, dendritic

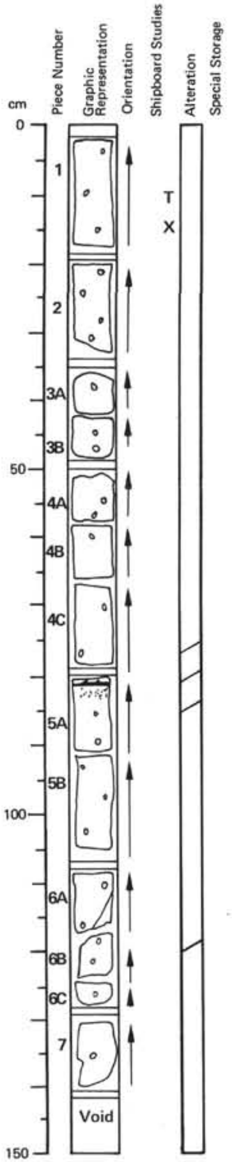
Vesicles: <1%

Alteration: olivine replaced by calcite and clay. Veins filled by calcite.

Shipboard Data

Bulk Analysis: 93-95 cm	
SiO_2	49.65
Al_2O_3	15.55
Fe_2O_3	10.34
MgO	6.10
CaO	15.12
Na_2O	2.13
K_2O	0.21
TiO_2	1.50
P_2O_5	0.18
MnO	0.18
LOI	2.60
H_2O^+	0.61
H_2O^-	N.D.
CO_2	2.43

Magnetic Data:	93-95 cm
NRM Intensity (emu/cc)	5.248×10^{-3}
NRM Inclination	+75.2°
Stable Inclination	-31.2°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE			SECT.
5	1	4	1	7	D		4	3	6

Visual Description

Phyric, dark gray pillow basalt with glassy chilled margins (piece 5A). Altered euhedral plagioclase phenocrysts 7-10%, <5 mm; olivine phenocrysts 3-4%, <10 mm, replaced by green smectite, iddingsite and calcite; altered clinopyroxene laths 3%, <3 mm. Vesicles 2%, 1-3 mm, filled with calcite or green smectite. Minor veins filled by green smectite, calcite.

Thin Section Description

Location: 13 cm, pillow interior

Texture: porphyritic

Phenocrysts: olivine 5%, 0.2-1 mm, euhedral; plagioclase 10%, 0.5-3 mm, euhedral with prismatic micro-phenocrysts; clinopyroxene 3%, 0.2-0.5 mm, anhedral, zoned

Groundmass: olivine <5%, 0.05 mm, euhedral; plagioclase 10%, 0.3 mm, quenched needles; clinopyroxene 20%, 0.05 mm, quenched; glass 50%, devitrified, variolitic

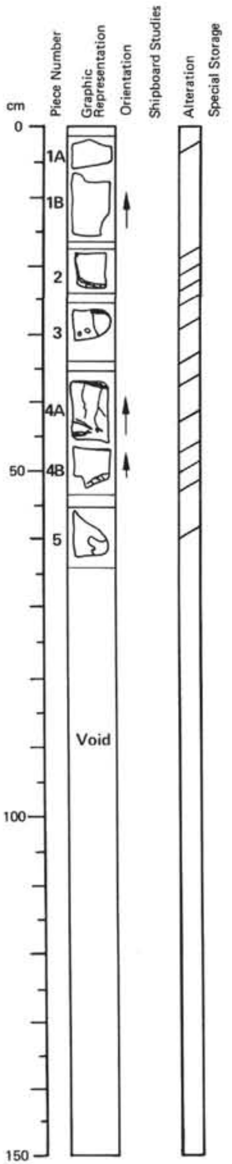
Vesicles: 0.4 mm, filled by clay

Alteration: olivine replaced by calcite and clay. Veins filled by calcite.

Shipboard Data

Bulk Analysis: 13-15 cm

SiO_2	48.83
Al_2O_3	15.75
Fe_2O_3	11.23
MgO	6.77
CaO	12.54
Na_2O	0.04
K_2O	0.04
TiO_2	1.52
P_2O_5	0.19
MnO	0.19
LOI	1.25
H_2O^+	0.82
H_2O^-	N.D.
CO_2	0.71

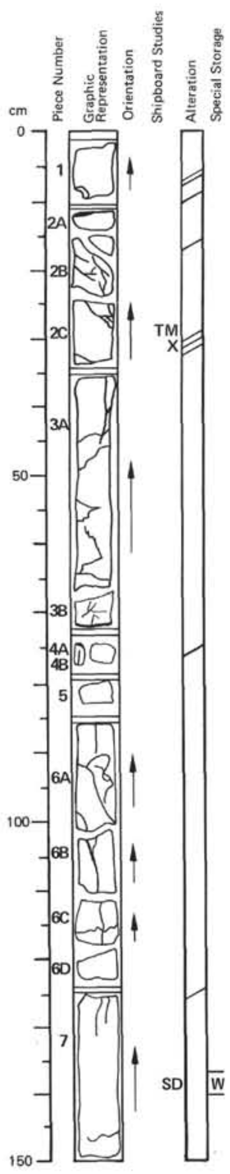


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE			SECT.
5	1	4	1	7	D		4	3	7

Visual Description

Phyric pillow basalt with altered chilled margins (pieces 2 and 4). Basalt gray with an aphanitic to fine-grained, microlitic groundmass. Plagioclase phenocrysts 10%, <2 mm; olivine phenocrysts 10%, <2 mm, replaced by green smectite; clinopyroxene phenocrysts 3%, <1.5 mm. Glass devitrified, replaced by green smectite, palagonite(?) and calcite. Vesicles in pieces 1 and 2, <4%, <0.3 mm, filled by calcite or green smectite. Piece 4A contains a large cavity with a lining of green smectite and a calcite core. Minor veins filled by green smectite. Piece 5 contains slickensides(?) in green smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	D		4	4	1

Visual Description

Phyric basalt with possible chilled margin in piece 6A and traces of hyaloclastite breccia in pieces 1 and 2. Groundmass fine- to medium-grained. Plagioclase phenocrysts 5-10%, <3 mm; olivine phenocrysts 5%, <1 mm, replaced by iddingsite; pyroxene phenocrysts 3-5%, <1 mm. Vesicles 1-2%, filled by calcite and celadonite. Veins common in pieces 1-3 and 6, filled by dark green smectite and calcite.

Thin Section Description

Location: 30 cm, pillow interior

Texture: phyric, microlitic

Phenocrysts: olivine 1%, 0.3-0.6 mm, prismatic; plagioclase 10%, 0.6-5.0 mm, An 80, margins An 70-72, partially sericitized; clinopyroxene 2%, 0.2-0.5 mm, prismatic

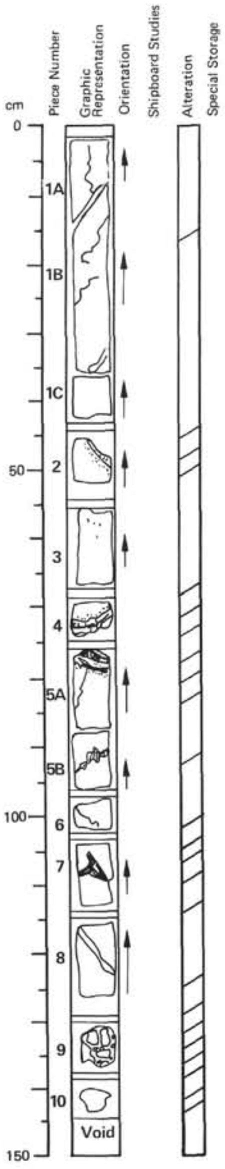
Groundmass: plagioclase 20%, 0.1-0.3 mm, An 65-70, quenched; clinopyroxene 60%, 0.1-0.2 mm, quenched; magnetite 5%, 0.02-0.04 mm

Vesicles: 1%, 0.05-0.8 mm, filled by calcite and clay

Alteration: carbonate 4%, in vesicles, groundmass and pseudomorphs replacing plagioclase, augite and olivine; clays and sericite 3%, in vesicles and pseudomorphs replacing plagioclase, augite, and olivine

Shipboard Data

Bulk Analysis: 28-31 cm		Magnetic Data:	28-31 cm
SiO_2	50.27	NRM Intensity (emu/cc)	2.434 x 10^{-3}
Al_2O_3	17.44	NRM Inclination	+66.5°
Fe_2O_3	10.54	Stable Inclination	−36.9°
MgO	6.83		
CaO	12.60	Physical Property Data:	139-141 cm
Na_2O	2.49	Vp (km/sec)	5.08
K_2O	0.08	Wet Bulk Density (g/cc)	2.76
TiO_2	1.75		
P_2O_5	0.15		
MnO	0.15		
LOI	2.00		
H_2O^+	1.54		
H_2O^-	N.D.		
CO_2	1.02		

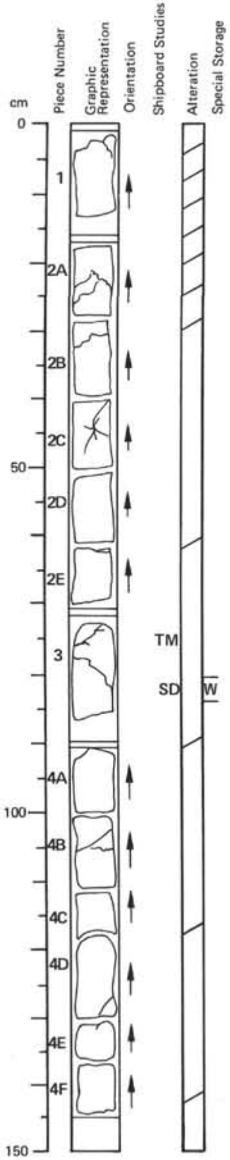


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	D		4	4	2

Visual Description

0-43 cm: sparsely phyric basalt with a coarse-grained, subophitic groundmass which decreases in grain size downward. Plagioclase phenocrysts 2%, <1.5 mm; olivine phenocrysts 3%, <3 mm, replaced by green smectite and calcite; clinopyroxene phenocrysts 1%, <1 mm. Piece 1C contains a small number of large (<4 mm) calcite-filled vesicles. Veins filled by brown to green smectite or by calcite and pyrite. 8-15 cm interval contains slickensides with a dip of 55° and a 45° pitch. 43-145 cm: phyric pillow basalt with altered chilled margins (pieces 2, 4, 5A and 9) and minor interpillow breccia (pieces 4 and 9). Basalt gray, altered to brown along veins filled by green smectite + calcite. Groundmass aphanitic to hyalopilitic along margins, fine- to medium-grained or microlitic in pillow interiors. Plagioclase phenocrysts 5-7%, <2 mm; olivine phenocrysts 7-10%, <3 mm, replaced by green smectite and calcite; clinopyroxene phenocrysts 5%, <1 mm. Minor vesicles in pieces 5-10, <0.3 mm, filled by calcite. Glass replaced by green smectite, palagonite(?) and calcite. Breccia composed of fragments of basalt in a matrix of altered glass.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	D	4 4	3

Visual Description

Sparsely to moderately phyric basalt with chilled margins(?) in pieces 1 and 4F and minor breccia in piece 1. Plagioclase phenocrysts 5-10%, <6 mm; olivine phenocrysts 5-7%, <3 mm, replaced by iddingsite; pyroxene phenocrysts 1-3%, 1 mm. Calcite-filled vesicles 2%. Piece 2A contains a network of interconnected veins filled by calcite and clay. Breccia composed of altered basalt fragments in a matrix of calcite and clay.

Thin Section Description

Location: 80 cm, pillow interior

Texture: porphyritic

Phenocrysts: olivine 5%, 0.5 mm, euhedral; plagioclase 10%, 0.5 mm, euhedral; clinopyroxene 3%, 0.5 mm, subhedral, in aggregates with plagioclase

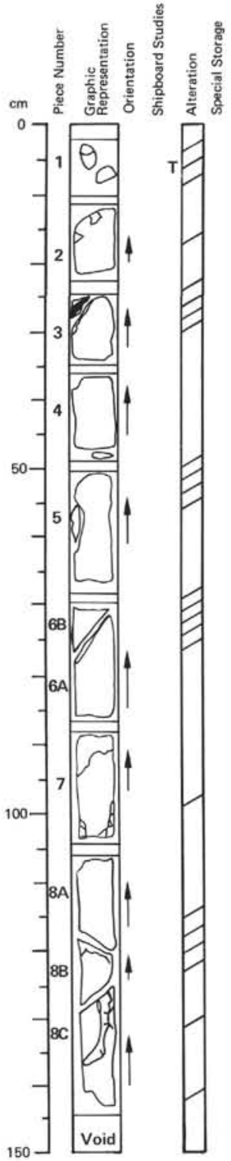
Groundmass: olivine 10%, euhedral; plagioclase 20%, 0.2 mm, euhedral, quenched; clinopyroxene 10%, quenched; magnetite 5%, 0.02 mm, dendritic; glass 40%, devitrified, variolitic

Vesicles: <0.2%

Alteration: olivine replaced by clay

Shipboard Data

Magnetic Data:	78-81 cm
NRM Intensity (emu/cc)	2.608×10^{-3}
NRM Inclination	+42.5°
Stable Inclination	–24.2°
Physical Property Data:	80-82 cm
$\overline{V}$p (km/sec)	5.79
Wet Bulk Density (g/cc)	2.89



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 1	4 1 7	D	4 4	4

Visual Description

Phyric to sparsely phyric pillow basalt with altered chilled margins (pieces 1, 3 and 5). Basalt gray with an aphanitic groundmass along margins and a fine- to medium-grained or microlitic groundmass in pillow interiors. Plagioclase phenocrysts 3%, <2 mm, increase to 15%, <0.5 mm in piece 8; olivine phenocrysts 3%, <2 mm, replaced by green smectite and calcite; augitic clinopyroxene phenocrysts <1%, <1 mm. Calcite-filled vesicles increase in abundance with depth to 5%, <0.6 mm in pieces 5 and 6. Veins filled by green smectite and calcite. Glass devitrified, replaced by green smectite, calcite and palagonite(?). Piece 8A contains slickensides with a 45° pitch.

Thin Section Description

Location: 5 cm, pillow interior

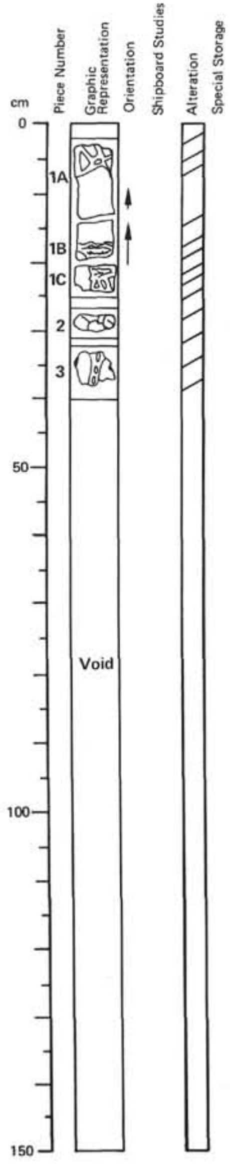
Texture: porphyritic

Phenocrysts: olivine 2%, 0.5 mm, euhedral; plagioclase 20%, 4 mm, euhedral; clinopyroxene 5-7%, 3 mm, subhedral

Groundmass: olivine 20%, 0.02 mm, euhedral; plagioclase 30%, 0.05 mm, euhedral, prismatic, quenched; clinopyroxene 20%, 0.02 mm, quenched; magnetite <5%, 0.02 mm, dendritic

Vesicles: <1%, 0.2 mm, filled by calcite

Alteration: plagioclase and olivine replaced by sericite and clay

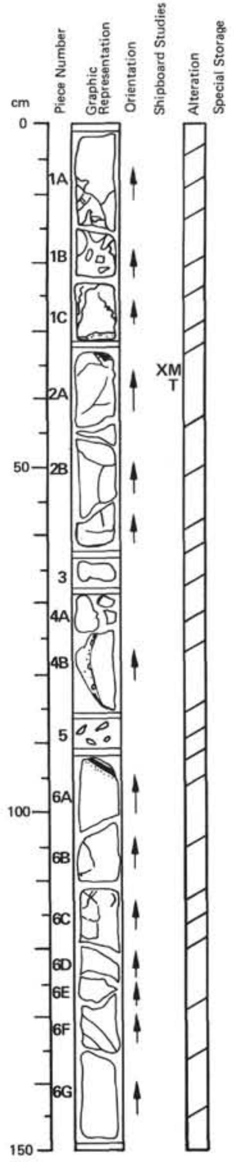


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	44	5

Visual Description

Sparsely phyric, brecciated basalt. Groundmass microlitic to subophitic. Plagioclase phenocrysts 1%, <1.5 mm; olivine phenocrysts 2%, <2 mm, replaced by green smectite; augitic clinopyroxene phenocrysts <1%, <0.5 mm. Calcite-filled vesicles <1%, <0.6 mm. Numerous veins contain fragments of basalt in a matrix of green smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
51	417	D	45	1

Visual Description

Sparsely to moderately phyric pillow basalt with altered, brecciated margins (pieces 1, 2A and 3-6A) and locally brecciated pillow interiors (piece 1) in a matrix of clay and minor calcite. Plagioclase phenocrysts 10%, ≤5 mm; olivine phenocrysts 5%, ≤4 mm; clinopyroxene phenocrysts 2%, 2 mm. Vesicles ≤5%, filled with calcite or green smectite. Shrinkage vesicles indicate tilting. Pieces 6B, 6C and 6F contain large veins and patches filled by calcite and clay. Pieces 2A, 2B and 4B contain slickensides, the latter in devitrified glass.

Thin Section Description

Location: 36 cm, pillow interior

Texture: phyritic, microlitic

Phenocrysts: olivine 2%, 0.2-1.0 mm, prismatic; plagioclase 25%, 0.1-1.0 mm, An 40-45, tabular; clinopyroxene 3%, 0.3-0.6 mm, irregular prismatic

Groundmass: plagioclase 20%, 0.05-0.1 mm, An 36, quenched; clinopyroxene 43%, 0.1 mm, quenched; magnetite 5%, 0.02-0.04 mm

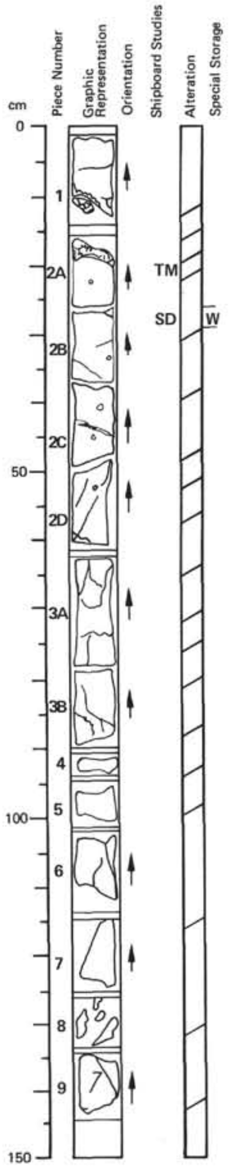
Vesicles: 1%

Alteration: carbonate 2%, in vesicles and pseudomorphs after augite, plagioclase and olivine; clays and sercite 1%, in pseudomorphs after augite, plagioclase and olivine

Shipboard Data

Bulk Analysis: 35-41 cm	
SiO_2	49.16
Al_2O_3	15.89
Fe_2O_3	11.01
MgO	6.18
CaO	12.69
Na_2O	3.01
K_2O	0.15
TiO_2	1.63
P_2O_5	0.15
MnO	0.17
LOI	0.75
H_2O^+	1.39
H_2O^-	N.D.
CO_2	0.90

Magnetic Data:	35-38 cm
NRM Intensity (emu/cc)	9.738×10^{-3}
NRM Inclination	-24.6°
Stable Inclination	-26.6°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	1	4	1	7	D	4	5		2

Visual Description

Sparsely to moderately phyric pillow basalt with brecciated margins in pieces 1 and 2A. Plagioclase phenocrysts 5-10%; olivine phenocrysts 5%, replaced by iddingsite and calcite; pyroxene phenocrysts 1-5%. Vesicles <5%. Numerous veins filled with clay ± calcite. Piece 6 contains a vug with calcite cyrstals and botryoidal growths of green smectite with a refractive index of 1.500-1.510.

Thin Section Description

Location: 17 cm, next to glassy margin

Texture: porphyritic

Phenocrysts: olivine 2%, 0.5 mm, euhedral; plagioclase 15%, 2 mm, euhedral; clinopyroxene 5%, 0.5 mm, partially resorbed, zoned

Groundmass: plagioclase 10%, 0.3 mm, quenched; clinopyroxene 5%, 0.1 mm, quenched; magnetite <5%, dendritic, quenched; glass 70%, devitrified, variolitic

Vesicles: 5%, filled by calcite

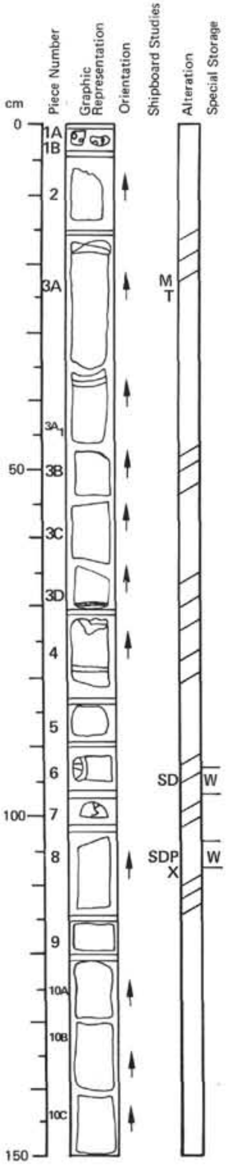
Alteration: plagioclase partially replaced by calcite and sericite. Olivine completely altered.

Shipboard Data

Magnetic Data:	16-19 cm
NRM Intensity (emu/cc)	11.944×10^{-3}
NRM Inclination	-27.7°
Stable Inclination	-31.5°

Physical Property Data:	26-28 cm
$\overline{V}p$ (km/sec)	5.27
Wet Bulk Density (g/cc)	2.79

NOTE: Cores 45-3 through 47-6 = NO RECOVERY and Core 48-1 through 48-4 = CAVINGS.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.
5	2	4	1	7	D	4	8	5

Sections 48-1 through 48-4 filled with cavings from the sediments overlying the basement.

Visual Description

Sparsely phyric, massive basalt with a mottled, dark gray groundmass having a medium- to coarse-grained, subophitic texture. Basalt locally brecciated (pieces 3B, 4 and 6) with a matrix of calcite ±green smectite. Plagioclase phenocrysts <5%, ≤7 mm; olivine phenocrysts ≤5 mm, replaced by green smectite; clinopyroxene phenocrysts ≤5 mm; phenocrysts tend to occur in 3-10 mm wide glomerocrysts. Vesicles 1%, 1-3 mm, filled by calcite or green smectite or by smectite with a core of calcite; some vesicles display crescentic fillings, concave upward, with the axis of symmetry inclined at an angle of 20° to the vertical. Veins filled by calcite or green smectite, by interlayered calcite and green smectite or by calcite with a smectite lining. Veins occasionally offset or truncated by open fractures. Piece 3D contains slickensides in smectite.

Thin Section Description

Location: 22 cm, flow interior

Texture: highly glomerophyric - tachylitic

Phenocrysts: olivine 2%, 0.2-0.6 mm, euhedral; plagioclase 24%, 0.4-1.2 mm, euhedral-subhedral; clinopyroxene 24%, 0.3-0.8 mm, subhedral, subophitic to ophitic clots dominant

Groundmass: olivine 2%, 0.05-0.1 mm, euhedral; plagioclase 15%, 0.01-0.4 mm, euhedral-subhedral; clinopyroxene 15%, 0.005-0.3 mm, euhedral-subhedral; magnetite 5%, 0.005-0.01 mm, irregular, rods; glass 5-10%, tachylitic

Vesicles: 2%, 1 mm, filled by calcite, smectite and zeolites(?); shrinkage vesicles common.

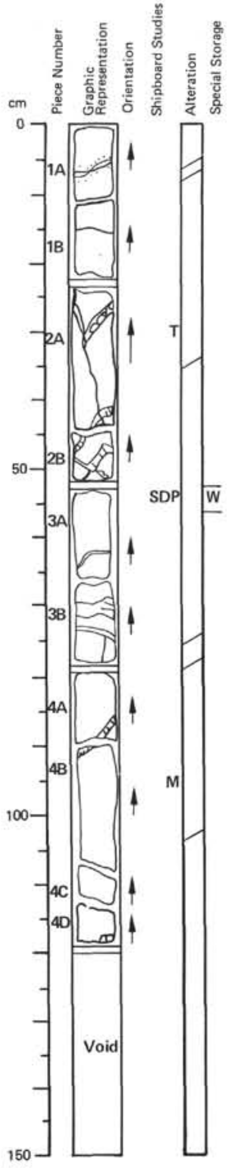
Alteration: olivine, glass and plagioclase partially replaced by calcite and clay

Shipboard Data

Bulk Analysis:	105-107 cm
SiO_2	49.60
Al_2O_3	16.20
Fe_2O_3	8.17
MgO	6.60
CaO	13.40
Na_2O	2.31
K_2O	0.12
TiO_2	1.55
P_2O_5	0.17
MnO	0.15
LOI	2.0
H_2O^+	0.70
H_2O^-	N.D.
CO_2	1.22

Magnetic Data:	21-23 cm
NRM Intensity (emu/cc)	3.56×10^{-3}
NRM Inclination	+17.4°
Stable Inclination	-16.6°

Physical Property Data:	100-102 cm	96-98 cm
$\overline{V}p$ (km/sec)	5.20	5.25
Porosity (%)	8.3	
Wet Bulk Density (g/cc)	2.785	2.74
Grain Density (g/cc)	2.92	



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.
5	2	4	1	7	D	4	8	6

Visual Description

Moderately phyric, massive basalt. Groundmass medium-grained. Plagioclase 35%, phenocrysts <5%, ≤5 mm; altered olivine phenocrysts 5-10%, ≤2 mm. Vesicles 5-10%, ≤2 mm, filled by calcite and green smectite or illite. Vesicles in piece 4C display crescentic fillings, concave upward, with calcite above green smectite. Veins filled with green smectite and calcite. Veins in piece 2A contain calcite and radiating zeolite(?) crystals. Slickensides in pieces 4B and 4C and calcite-filled veins showing vertical extension suggest reverse faulting. Piece 4C contains pyrite.

Thin Section Description

Location: 30 cm, flow interior and calcite vein

Texture: highly phyric, subophitic

Phenocrysts: olivine 5%, 0.5-2 mm, euhedral; plagioclase 25%, 1-3 mm, euhedral, zoned; clinopyroxene 20%, 0.5-1 mm, heteromorphic

Groundmass: plagioclase laths 20%; clinopyroxene 20%, heteromorphic; magnetite 5-10%, euhedral; glass 5%

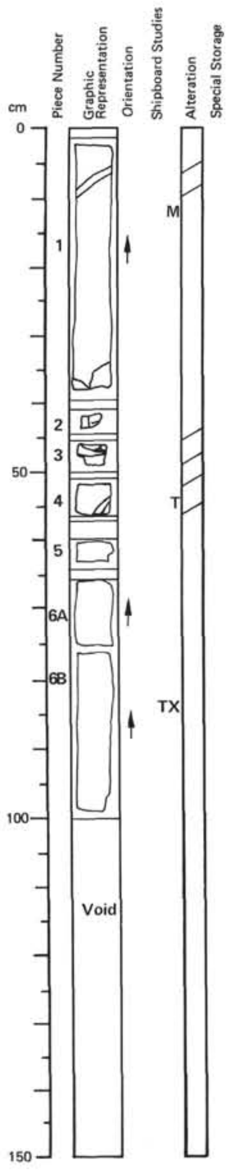
Vesicles: none

Alteration: veins filled by calcite; olivine and glass replaced by clay

Shipboard Data

Magnetic Data:	96-98 cm
NRM Intensity (emu/cc)	2.62
NRM Inclination	+52.3°
Stable Inclination	+ 3.4°

Physical Property Data:	54-56 cm
$\overline{V}p$ (km/sec)	4.89
Porosity (%)	11.6
Wet Bulk Density (g/cc)	2.72
Grain Density (g/cc)	3.09



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 2	4 1 7	D	4 8	7

Visual Description

Sparsely phyric, massive basalt with traces of breccia (piece 4). Groundmass coarse-grained with a mottled intergranular to subophitic texture. Plagioclase phenocrysts <5%, ≤6 mm; olivine phenocrysts 1-2%, ≤4 mm, replaced by green smectite; clinopyroxene phenocrysts 1-2%, ≤4 mm; phenocrysts tend to occur in glomerocrysts ≤10 mm wide. Calcite-filled vesicles 1-2%, 1 mm. Veins filled by calcite or by calcite with a green smectite lining. Basalt in piece 4 fine-grained, non-vesicular adjacent to breccia composed of basalt fragments in a matrix of calcite and green smectite.

Thin Section Description

Location: 54 cm, flow interior

Texture: glomeroporphyritic/aphanitic

Phenocrysts: olivine 0.2-0.5 mm; plagioclase 0.5-4.0 mm; clinopyroxene 0.2-3.0 mm

Groundmass: plagioclase, clinopyroxene and magnetite all cryptocrystalline; section contains a 1.5 cm wide dike containing plagioclase microlites

Vesicles: <1%, 2 mm, round, filled with zeolites and undifferentiated silicates

Alteration: olivine replaced by calcite

Thin Section Description

Location: 85 cm, flow interior

Texture: highly phyric, intersertal, quenched

Phenocrysts: olivine 5%, <1 mm, euhedral; plagioclase 15%, ≤3 mm, euhedral-subhedral, zoned; clinopyroxene 10%, 0.2-0.8 mm, heteromorphic-anhedral

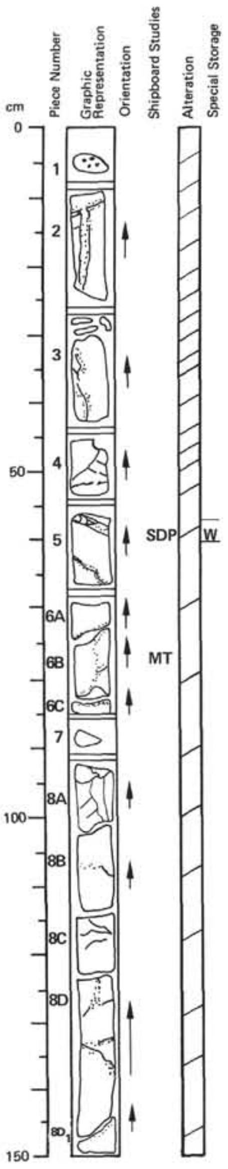
Groundmass: plagioclase 20%, 0.5 mm, skeletal, laths; clinopyroxene 30%, 0.5 mm, plumose, skeletal; magnetite 20%, 0.5 mm, arrow-shaped; glass trace

Vesicles: <1%, 1-2 mm, round, filled by devitrified glass with a clay lining

Alteration: glass and phenocrysts of olivine replaced by clay

Shipboard Data

Bulk Analysis: 84-86 cm		Magnetic Data:	13-15 cm
SiO_2	50.30	NRM Intensity (emu/cc)	4.28×10^{-3}
Al_2O_3	16.50	NRM Inclination	+27.3°
Fe_2O_3	10.82	Stable Inclination	-16.2°
MgO	7.25		
CaO	12.60		
Na_2O	2.25		
K_2O	0.03		
TiO_2	1.54		
P_2O_5	0.15		
MnO	0.19		
LOI	1.90		
H_2O^+	0.90		
H_2O^-	N.D.		
CO_2	0.08		



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Aphyric to sparsely phyric, massive basalt. Groundmass medium-grained, partially replaced by green smectite in pieces 1-4, altered to a depth of 1 cm along veins in pieces 1-8. Plagioclase phenocrysts <5%, <5 mm; olivine phenocrysts <5%, 1-2 mm, replaced by green to brown smectite or iddingsite(?); clinopyroxene phenocrysts <3%, <5 mm. Vesicles <5%, filled by calcite or green smectite. Veins filled with green to brown smectite.

Thin Section Description

Location: 77 cm, flow interior

Texture: ophi-mottled

Phenocrysts: olivine 3%, 0.5 mm, euhedral; plagioclase laths 10%, 0.5-4 mm; clinopyroxene 6%, 0.5-1 mm, subophitic

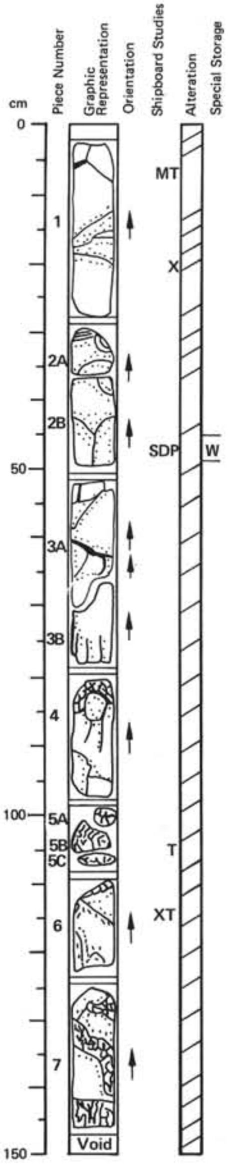
Groundmass: composed of olivine, plagioclase, clinopyroxene, magnetite and glass

Vesicles: <1%, <0.1 mm, filled by smectite and calcite

Alteration: olivine and plagioclase replaced by calcite and clay; veins filled with pyrite and iron oxides.

Shipboard Data

Magnetic Data:	76-78 cm
NRM Intensity (emu/cc)	1.44×10^{-3}
NRM Inclination	+70.9°
Stable Inclination	+12.4°
Physical Property Data:	59-61 cm
$\bar{V}p$ (km/sec)	5.06
Porosity (%)	7.7
Wet Bulk Density (g/cc)	2.73
Grain Density (g/cc)	2.88



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	49	2

Visual Description

Sparsely phyric, massive basalt wtih volcanic breccia in pieces 4-7. Basalt gray, altered to gray brown to a depth of 1 cm along veins and fractures. Groundmass coarse-grained with a mottled, ophitic texture. Plagioclase phenocrysts <5%, <5 mm; augite phenocrysts <3%, <5 mm; olivine(?) phenocrysts <2%, replaced by green to brown smectite or iddingsite(?); plagioclase and augite phenocrysts tend to occur in glomerocrysts. Minor vesicles filled with calcite. Thin veins filled by green to brown smectite. Breccia in pieces 4-7 composed of basalt fragments in a matrix of green smectite and minor calcite. Pieces 2A and 3A contain gouged slickensides.

Thin Section Description

Location: 8 cm, flow interior to flow margin
Texture: intergranular, quenched, glomerophyric
Phenocrysts: olivine 3%, <0.7 mm, euhedral; plagioclase laths 15%, <2 mm, zoned; clinopyroxene 7%, <1 mm, anhedral, mosaic
Groundmass: olivine 10%, intergranular, quenched; plagioclase 13%, intergranular, quenched; clinopyroxene 35%, euehdral; magnetite 2%, 0.005 mm, anhedral; euhedral pyrite 7%, 0.05 mm, in veins
Vesicles: 2%, <1 mm, filled by calcite, zeolites and smectite
Alteration: olivine phenocrysts replaced by calcite and clay; veins filled by calcite and clay; plagioclase replaced by clay.

Location: 106 cm, glassy margin
Texture: intersertal
Phenocrysts: olivine 2%, <1 mm, euhedral; plagioclase laths 9%, <2 mm, zoned; clinopyroxene 4%, <1 mm, anhedral
Groundmass: plagioclase microlites 15%; clinopyroxene 15%, subhedral; magnetite 2%, 0.005 mm, anhedral; glass 45%, devitrified; pyrite 8%, 0.05 mm, subhedral, in veins and elongate grains
Vesicles: none
Alteration: olivine and glass replaced by smectite and minor calcite

Location: 115 cm, flow interior
Texture: highly phyric, intersertal
Phenocrysts: olivine 3%, 0.1-0.8 mm, euhedral; plagioclase 10%, 0.2-2 mm, euhedral-subhedral; clinopyroxene 2%, 0.1-0.5 mm, anhedral-subhedral
Groundmass: 85%, largely and intersertal mat of altered glass and fine-grained (<0.05 mm) plagioclase, clinopyroxene and olivine
Vesicles: none

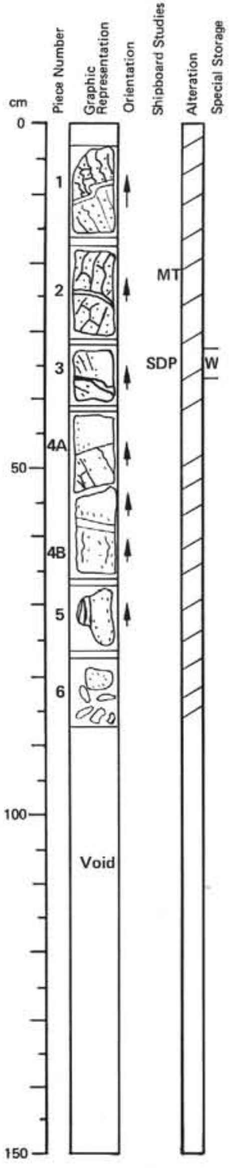
Alteration: olivine glass and plagioclase replaced by calcite, clay and zeolites

Shipboard Data

Bulk Analysis:	20-22 cm	114-116 cm
SiO_2	49.70	51.60
Al_2O_3	16.50	17.70
Fe_2O_3	10.13	9.84
MgO	7.23	6.39
CaO	11.30	10.10
Na_2O	2.44	2.54
K_2O	0.13	0.80
TiO_2	1.65	1.67
P_2O_5	0.17	0.20
MnO	0.12	0.15
LOI	1.6	2.1
H_2O^+	1.15	1.50
H_2O^-	N.D.	N.D.
CO_2	0.07	0.10
Cr	N.D.	N.D.
Ni	N.D.	N.D.
Sr	N.D.	N.D.
Zr	N.D.	N.D.

Magnetic Data:	7-9 cm
NRM Intensity (emu/cc)	0.926×10^{-3}
NRM Inclination	+28.4°
Stable Inclination	-24.6°

Physical Property Data:	43-45 cm
$\overline{V}p$ (km/sec)	5.07
Porosity (%)	8.3
Wet Bulk Density (g/cc)	2.80
Grain Density (g/cc)	2.94



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	49	3

Visual Description

Sparsely phyric, massive basalt with numerous fractures. Basalt gray, altered to gray-brown along veins. Groundmass coarse-grained. Plagioclase phenocrysts <5%, <3 mm; augite phenocrysts <2%, <3 mm; altered olivine phenocrysts <2%, <3 mm; phenocrysts often occur in glomerocrysts. Vesicles rare. Numerous thin veins filled by green smectite and minor calcite; larger veins filled by calcite with a lining of light to dark green or yellow to brown smectite.

Thin Section Description

Location: 21 cm, flow interior to flow margin

Texture: intergranular, quenched, glomerophyric

Phenocrysts: olivine <5%, <1.5 mm, euhedral; plagioclase 15%, <3%, laths with normal, oscillatory, and sector zoning; clinopyroxene 5%, <1.5 mm, euhedral to granular

Groundmass: olivine 10%, seriate, intergranular, quenched; plagioclase 25%, seriate, intergranular, quenched; clinopyroxene 30%, seriate, intergranular, quenched; magnetite 5%, <0.05 mm, euhedral; glass 5%, devitrified

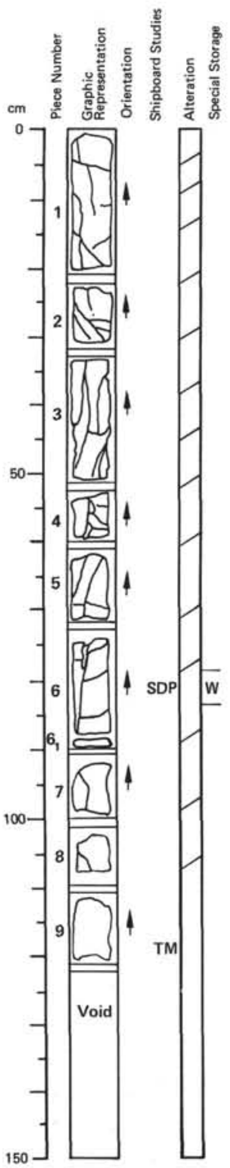
Vesicles: none

Alteration: olivine phenocrysts replaced by calcite and clay. Veins filled by calcite and clay.

Shipboard Data

Magnetic Data:	20-22 cm
NRM Intensity (emu/cc)	2.50×10^{-3}
NRM Inclination	-37.5°
Stable Inclination	-25.0°

Physical Property Data:	32-34 cm
$\overline{V}p$ (km/sec)	5.43
Porosity (%)	5.4
Wet Bulk Density (g/cc)	2.815
Grain Density (g/cc)	2.92



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	50	1

Visual Description

Highly phyric, massive basalt with numerous fractures. Groundmass microlitic, altered to gray-brown. Plagioclase phenocrysts <15% mm, rarely to 8 mm; clinopyroxene phenocrysts 5-10%, <5 mm, rarely to 8 mm; olivine phenocrysts <2 mm, 5%, locally 10-15% (pieces 4-6). Vesicles rare. Numerous veins filled with green to brown smectite, commonly dip 60° to the horizontal. Piece 4 contains horizontal slickensides; piece 5 displays slickensides which dip 65°, pitch 45° and suggest normal and right-lateral components of motion. Piece 9 contains pyrite.

Thin Section Description

Location: 117 cm, flow interior

Texture: glomeroporphyritic, intersertal

Phenocrysts: Olivine 6%, <2.0 mm, euhedral; plagioclase 10%, <3.0 mm, euhedral-subhedral; clinopyroxene 4%, <1.5 mm, anhedral, in clusters with plagioclase

Groundmass: olivine 5%; plagioclase 30%; clinopyroxene 30%, skeletal, subhedral; magnetite 15%

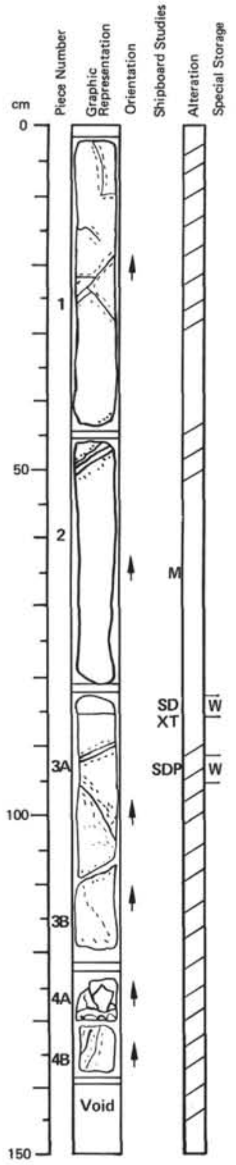
Vesicles: <1%

Alteration: olivine replaced by calcite and clays

Shipboard Data

Magnetic Data: 115-117 cm	115-117 cm
NRM Intensity (emu/cc)	1.85×10^{-3}
NRM Inclination	+36.9°
Stable Inclination	−33.6°

Physical Property Data:	81-83 cm
$\overline{V}p$ (km/sec)	5.59
Porosity (%)	5.1
Wet Bulk Density (g/cc)	2.865
Grain Density (g/cc)	2.97



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	50	2

Visual Description

Highly phyric, massive basalt with traces of breccia in pieces 1 and 4A. Basalt gray, altered to gray-brown to a depth of 10 mm along veins. Groundmass inter-granular to intersertal. Plagioclase phenocrysts 15%, <5 mm; augite phenocrysts 5%, <3 mm; olivine phenocrysts 5%, <3 mm, replaced by smectite or calcite; phenocrysts commonly seriate, tend to occur in glomerocrysts ≤10 mm wide. Vesicles <1%, 1 mm; crescentic fillings common but vary randomly (≤180°) in orientation within single pieces. Veins contain locally complex filling of calcite and smectite, minor breccia and numerous slickensides. Piece 4A contains a brecciated band of aphyric basalt.

Thin Section Description

Location: 89 cm

Texture: Glomeroporphyritic, intersertal to subophitic

Phenocrysts: olivine 5%, <2.0 mm, euhedral; plagioclase 20%, 4 mm, euhedral-subhedral; clinopyroxene 15%, <1.5 mm, anhedral, commonly in subophitic clots

Groundmass: olivine 5%, seriate; plagioclase 25%, seriate, laths and swallow tail aggregates; clinopyroxene 20%, seriate, anhedral; magnetite 5%, euhedral; glass 5%

Vesicles: <1%, <2.0 mm, filled with calcite and smectite

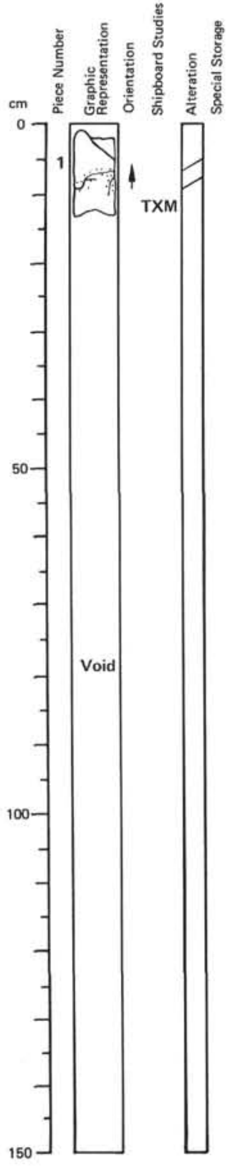
Alteration: olivine replaced by calcite and clays; vesicles filled by calcite and clay

Shipboard Data

Bulk Analysis: 88-90 cm	
SiO_2	50.90
Al_2O_3	15.70
Fe_2O_3	9.84
MgO	6.60
CaO	13.20
Na_2O	2.17
K_2O	0.06
TiO_2	1.56
P_2O_5	0.16
MnO	0.17
LOI	2.6
H_2O^+	0.50
H_2O^-	N.D.
CO_2	1.00

Magnetic Data:	65-67 cm
NRM Intensity (emu/cc)	2.28×10^{-3}
NRM Inclination	+71.8°
Stable Inclination	−16.4°

Physical Property Data:	83-85 cm	93-95 cm
$\overline{V}p$ (km/sec)	5.57	5.67
Porosity (%)		5.0
Wet Bulk Density (g/cc)	2.84	2.905
Grain Density (g/cc)		2.99



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE			SECT.	
5	2	4	1	7	D		5	1	C	C

Visual Description

Sparsely phyric, massive gray basalt with narrow alteration halos along veins. Groundmass holocrystalline, locally aphanitic with plagioclase microphenocrysts. Plagioclase, pyroxene and altered olivine(?) phenocrysts minor; rare, partially resorbed plagioclase megacrysts contain inclusions of euhedral spinel. Veins filled with green smectite and calcite. Sulfides present as rare, anhedral granules.

Thin Section Description

Location: 13 cm, flow interior

Texture: subophitic to intersertal

Phenocrysts: olivine 5%, <1.5 mm, euhedral; plagioclase 25%, <2.0 mm, euhedral laths; clinopyroxene 20%, <1.5, subophitic clots

Groundmass: olivine 5%, seriate; plagioclase 15%, seriate; clinopyroxene 20%, seriate; magnetite 5%, <0.5 mm, euhedral; glass 5%, altered to smectite

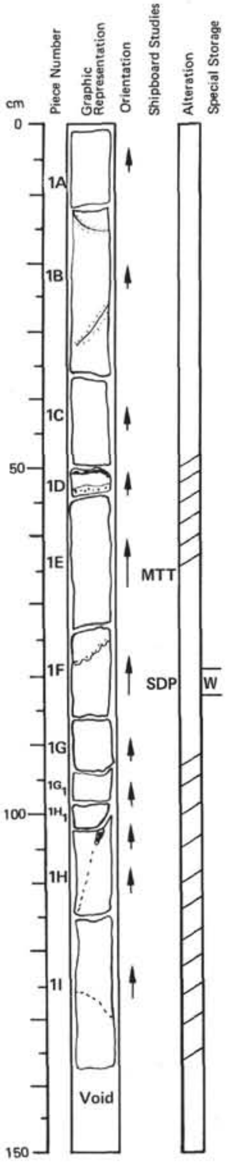
Vesicles: none

Alteration: olivine replaced by calcite and clays; zeolites <1%; iron hydroxides <1%

Shipboard Data

Bulk Analysis: 10-12 cm	
SiO_2	49.40
Al_2O_3	15.50
Fe_2O_3	12.33
MgO	6.78
CaO	12.40
Na_2O	2.08
K_2O	0.26
TiO_2	1.46
P_2O_5	0.16
MnO	0.18
LOI	2.0
H_2O^+	0.93
H_2O^-	N.D.
CO_2	0.07
Cr	N.D.
Ni	N.D.
Sr	N.D.
Zr	N.D.

Magnetic Data:	10-12 cm
NRM Intensity (emu/cc)	1.54×10^{-3}
NRM Inclination	+45.0°
Stable Inclination	−15.6°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	52	1

Visual Description

Moderately to sparsely phyric, massive basalt with an intersertal groundmass. Basalt gray, altered to gray-brown to a depth of 5 mm along veins (pieces 1D, 1E and 1G-1I). Plagioclase phenocrysts 1-5 mm; augite phenocrysts <5 mm; olivine phenocrysts <4 mm, replaced by green smectite and calcite, tend to be concentrated in pieces 1C-1F; phenocrysts commonly seriate. Vesicles rare. Veins filled by calcite and/or green smectite ± sulfides. Sulfides also present as rare, anhedral granules.

Thin Section Description

Location: 65 cm, flow interior

Texture: highly phyric, ophitic

Phenocrysts: olivine 10%, 1 mm, euhedral; plagioclase 25%, 1-3.5 mm, laths; clinopyroxene 25%, 1-2.5 mm

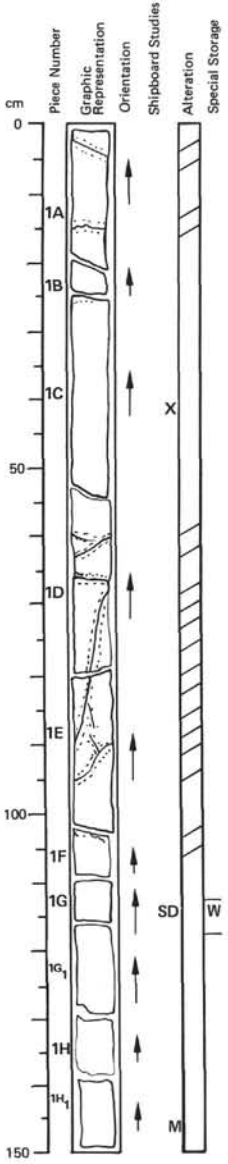
Groundmass: plagioclase 15%, 0.5 mm, laths; magnetite 10%, euhedral; glass 25%

Vesicles: none

Alteration: glass altered to smectite; olivine and pyroxene replaced by clay

Shipboard Data

Magnetic Data:	64-66 cm
NRM Intensity (emu/cc)	4.33×10^{-3}
NRM Inclination	+78.2°
Stable Inclination	− 9.9°
Physical Property Data:	80-82 cm
$\overline{V}$p (km/sec)	5.89
Porosity (%)	3.3
Wet Bulk Density (g/cc)	2.905
Grain Density (g/cc)	2.98



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	52	2

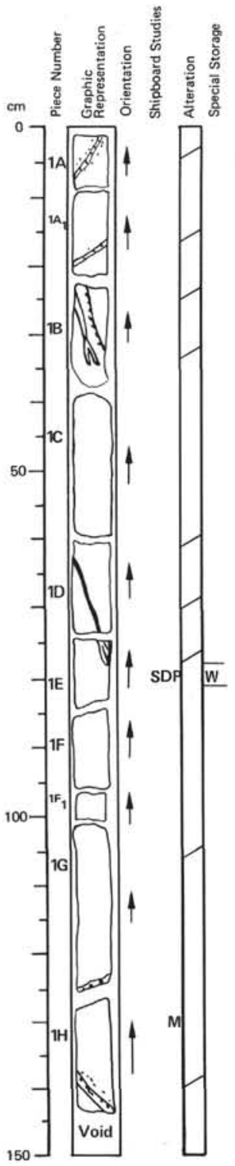
Visual Description

Moderately phyric, massive basalt with a medium- to coarse-grained groundmass. Plagioclase phenocrysts 5%, <5 mm; clinopyroxene phenocrysts 3%; olivine phenocrysts replaced by green smectite, 2-3%, <3 mm, increase to 5-8%, in 19-36, 40-60, 95-98, 112-114 and 128-135 cm intervals; phenocrysts commonly occur in glomerocrysts. Veins steeply dipping, filled by smectite and/or fine to coarsely crystalline calcite. Sulfides present throughout groundmass, concentrated in piece 1A along vein at 16 cm. Section continuous with previous section.

Shipboard Data

Bulk Analysis:	41-43 cm
SiO_2	49.70
Al_2O_3	14.70
Fe_2O_3	11.78
MgO	7.24
CaO	12.50
Na_2O	1.95
K_2O	0.26
TiO_2	1.46
P_2O_5	0.13
MnO	0,17
LOI	2.0
H_2O^+	0.93
H_2O^-	N.D.
CO_2	0.07

Magnetic Data:	144-146 cm
NRM Intensity (emu/cc)	4.06×10^{-3}
NRM Inclination	+36.7°
Stable Inclination	−17.3°
Physical Property Data:	113-115 cm
$\overline{V}$p (km/sec)	5.97
Wet Bulk Density (g/cc)	2.92



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

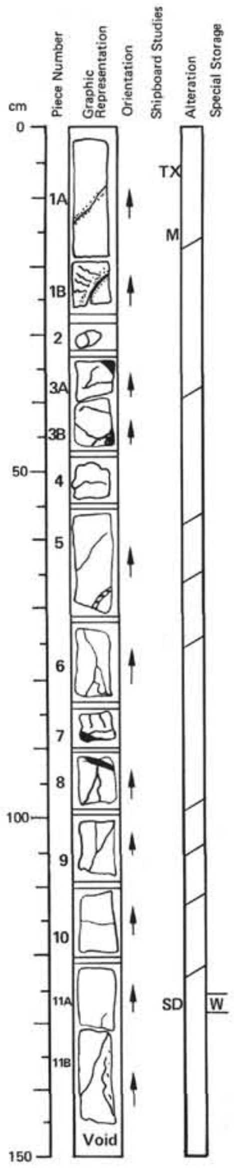
LEG	SITE	HOLE	CORE	SECT.
52	417	D	52	3

Visual Description

Moderately phyric, massive basalt with a fine-grained, aphyric interval between 30-37 cm. Groundmass fine-grained between 108-150 cm, medium-grained with subophitic clots between 0-108 cm. Plagioclase phenocrysts 5-7%, 3-5 mm, locally to 8 mm; clinopyroxene phenocrysts 2-3%, 2-3 mm; olivine phenocrysts 3-4%, <7 mm, replaced by green smectite, concentrated as single crystals or glomerocrysts in 15-21, 49-62 and 118-122 cm intervals, rare between 127-145 cm. Veins filled by calcite, lined with green smectite. Sulfides (pyrite?) disseminated throughout section.

Shipboard Data

Magnetic Data:	131-133 cm
NRM Intensity (emu/cc)	3.92×10^{-3}
NRM Inclination	+71.1°
Stable Inclination	- 8.5°
Physical Property Data:	77-79 cm
$\overline{V}p$ (km/sec)	6.01
Porosity (%)	2.8
Wet Bulk Density (g/cc)	2.93
Grain Density (g/cc)	2.99



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	52	4

Visual Description

0-27 cm: moderately phyric, fine-grained, massive basalt with a chilled glassy margin and minor breccia in piece 1B.

27-150 cm: moderately to highly phyric pillow basalt with chilled glassy margins in pieces 3, 7, and 8. 33-48 cm interval represents a complete pillow bounded by chilled margins. Groundmass fine-grained. Plagioclase phenocrysts <5 mm; clinopyroxene phenocrysts <5 mm; olivine phenocrysts 1-3 mm, <10%; phenocrysts occur singly and in subophitic intergrowths <8 mm across, total 20-35%. Irregular vesicles 10% in piece 10, filled by calcite and green smectite. Veins filled by green smectite and calcite.

Thin Section Description

Location: 8 cm, next to glassy margin

Texture: phyric, intergranular

Phenocrysts: olivine 3%, 0.3-3 mm, euhedral; plagioclase 10%, 1.5-5 mm, euhedral-subhedral; clinopyroxene 2%, 0.1-0.6 mm, subhedral, ophitic-subophitic clots

Groundmass: olivine 2%, 0.02 mm, euhedral; plagioclase 35%, 0.02-0.03 mm, subhedral; clinopyroxene 35%, 0.02-0.03 mm, anhedral; magnetite 3%, 0.02-0.03 mm, dendritic, glass 10%

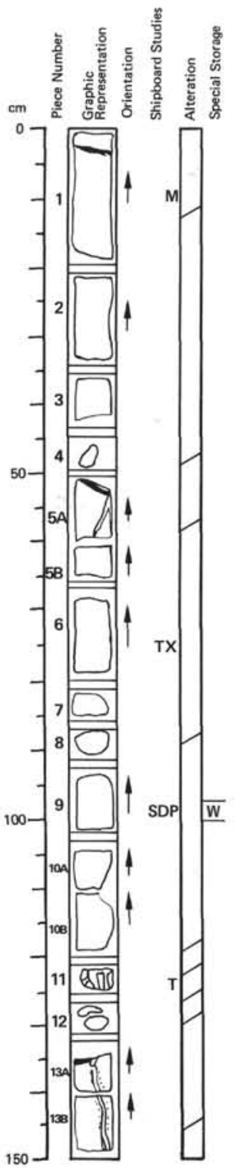
Vesicles: <1%, 1 mm, round, filled by calcite and smectite

Alteration: veins filled by calcite and clay. Olivine and glass replaced by calcite and clay

Shipboard Data

Bulk Analysis: 07-09 cm	
SiO_2	48.20
Al_2O_3	14.80
Fe_2O_3	12.00
MgO	6.96
CaO	13.90
Na_2O	1.93
K_2O	0.28
TiO_2	1.43
P_2O_5	0.16
MnO	0.22
LOI	2.8
H_2O^+	0.80
H_2O^-	N.D.
CO_2	1.44

Magnetic Data:	14-16 cm
NRM Intensity (emu/cc)	4.46×10^{-3}
NRM Inclination	+25.1°
Stable Inclination	- 9.0°
Physical Property Data:	125-127 cm
$\overline{V}p$ (km/sec)	5.44
Wet Bulk Density (g/cc)	2.84



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	52	5

Visual Description

Sparsely to moderately phyric pillow basalt with altered chilled margins in pieces 1, 5A, 10 and 13A and traces of hyaloclastite breccia containing fragments of baked(?) clay (piece 11). Groundmass fine- to medium-grained. Plagioclase phenocrysts <4 mm; clinopyroxene phenocrysts <3 mm; olivine phenocrysts <3 mm, replaced by green smectite ± calcite; phenocrysts occur singly or in subophitic, occasionally stellate, intergrowths <6 mm across, total 10-15%. Veins filled by brown smectite. Chilled margins largely replaced by green smectite and calcite, locally contain traces of fresh glass. Basalt in pieces 2 and 13B contains patches of calcite.

Thin Section Description

Location: 74 cm
Texture: porphyritic - intersertal
Phenocrysts: olivine 2-3%, 0.2-0.5 mm; plagioclase 9%, 0.3-1.5 mm, laths, euhedral - subhedral; clinopyroxene 3-4%, 0.5 mm, intergrowths in plagioclase
Groundmass: plagioclase 35%, <0.1 mm, acicular; clinopyroxene 35%, <0.05 mm, granular; magnetite 10%; glass 5%
Vesicles: <1%, 0.1-0.3 mm, spherical, filled by calcite
Alteration: veins filled with pyrite; glass in groundmass replaced by clay

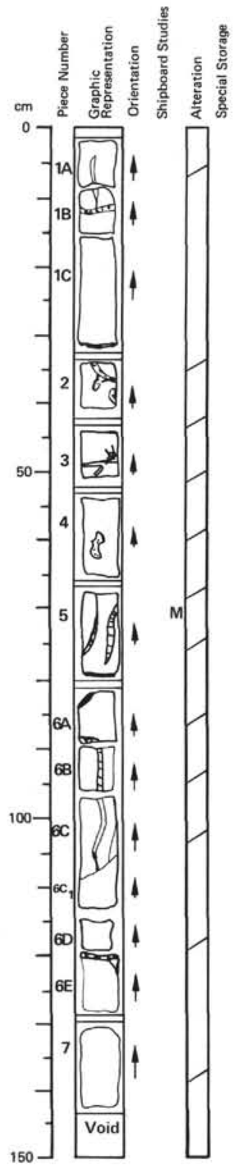
Location: 126 cm, glassy margin
Texture: hyaloophitic
Phenocrysts: olivine <1%; plagioclase 5%, 0.1-1.5 mm, laths; clinopyroxene <1%
Groundmass: glass 95%
Vesicles: none
Alteration: glass replaced by calcite and clay

Shipboard Data

Bulk Analysis: 73-75 cm	
SiO_2	49.30
Al_2O_3	15.80
Fe_2O_3	11.78
MgO	6.30
CaO	12.6
Na_2O	2.08
K_2O	0.08
TiO_2	1.61
P_2O_5	0.16
MnO	0.22
LOI	1.8
H_2O^+	0.86
H_2O^-	N.D.
CO_2	0.12

Magnetic Data:	8-10 cm
NRM Intensity (emu/cc)	14.24×10^{-3}
NRM Inclination	-10.1°
Stable Inclination	-14.3°

Physical Property Data:	96-98 cm
$\overline{V}p$ (km/sec)	5.45
Porosity (%)	6.3
Wet Bulk Density (g/cc)	2.85
Grain Density (g/cc)	2.95



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

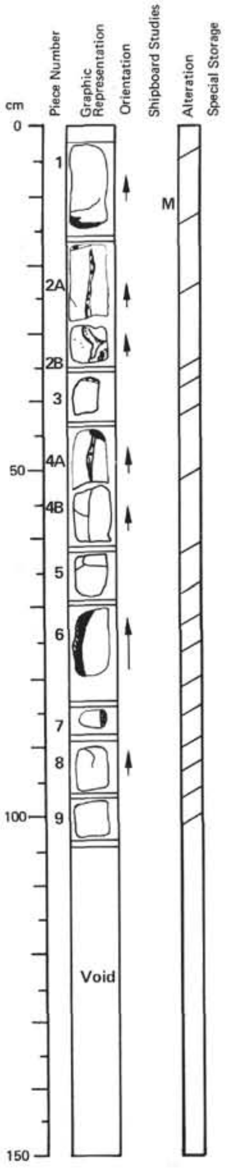
LEG	SITE	HOLE	CORE	SECT.
52	417	D	52	6

Visual Description

Sparsely to moderately phyric pillow basalt with altered chilled margins containing traces of glass in pieces 5 and 6A. Fine- to medium-grained groundmass moderately altered along numerous veins. Plagioclase, clinopyroxene and olivine phenocrysts (the latter replaced by green smectite) tend to occur in intergrowths <5 mm across. Veins filled by calcite, lined with green smectite. Piece 2 contains vugs filled by green smectite and euhedral calcite.

Shipboard Data

Magnetic Data:	69-71 cm
NRM Intensity (emu/cc)	8.73×10^{-3}
NRM Inclination	- 7.6°
Stable Inclination	-12.2°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

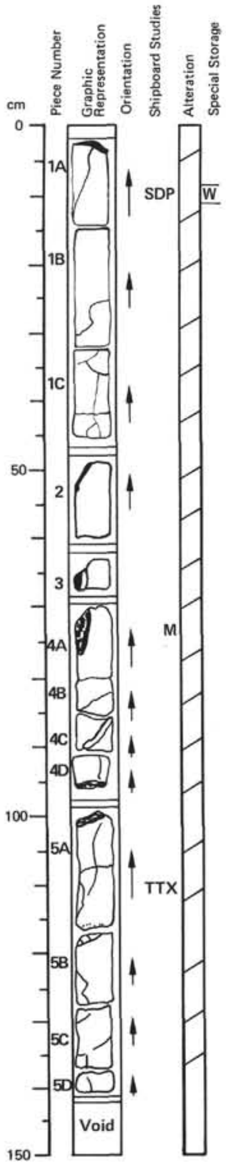
LEG		SITE			HOLE	CORE		SECT.	
5	2	4	1	7	D	5	2		7

Visual Description

Sparsely to moderately phyric pillow basalt with altered chilled margins in pieces 1, 2A, 4A, 6 and 7. Fine-grained groundmass moderately to strongly altered along numerous veins and margins. Plagioclase, clinopyroxene and olivine phenocrysts (the latter replaced by green smectite) 2-5 mm. Piece 2 contains vesicles <2 mm across. Veins <1 cm wide, filled by calcite and green smectite.

Shipboard Data

Magnetic Data:	10-12 cm
NRM Intensity (emu/cc)	17.34×10^{-3}
NRM Inclination	-11.2°
Stable Inclination	-16.2°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Moderately to highly phyric, fine-grained pillow basalt with chilled glassy margins and minor interpillow breccia in pieces 1A, 2, 3, 4A, 4D and 5A. Plagioclase phenocrysts 10-15%, <5 mm; euhedral to anhedral clinopyroxene phenocrysts 10%, <5 mm, often as intergrowths with plagioclase; euhedral olivine phenocrysts 5%, <2 mm, replaced by green smectite. Vesicles 5%, 1-3 mm; the smaller vesicles (1 mm) tend to be filled by calcite or green smectite, while the larger (and more irregular) are filled by calcite and lined by green smectite. Veins filled by calcite.

Thin Section Description

Location: 111 cm, next to glassy margin
Texture: phyric, intersertal, quenched
Phenocrysts: olivine 2%, 2.0 mm, euhedral-subhedral; plagioclase 8%, 4 mm, subhedral; clinopyroxene 4%, 2.0 mm, anhedral
Groundmass: olivine 4%, quenched; plagioclase 25%; clinopyroxene 50%, plumose, magnetite 5%
Vesicles: 2%, 1.0 mm, filled with smectite
Alteration: olivine replaced by calcite and clay

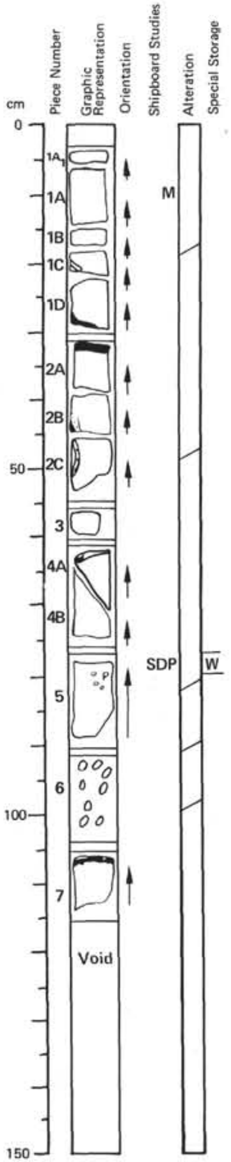
Location: 111 cm, pillow interior
Texture: porphyritic, intersertal, quenched
Phenocrysts: olivine 5%, 0.5-1 mm, euhedral; plagioclase 10%, 1-5 mm, laths, tablets; clinopyroxene 5%, 0.5-1 mm, anhedral
Groundmass: plagioclase 25%, <0.5-1 mm, laths; clinopyroxene 25%, plumose; magnetite 20%, 0.1 mm, euhedral; glass 10%
Vesicles: none
Alteration: olivine and glass replaced by clay

Shipboard Data

Bulk Analysis: 110 cm	
SiO_2	48.60
Al_2O_3	15.50
Fe_2O_3	11.78
MgO	6.34
CaO	13.20
Na_2O	2.28
K_2O	0.37
TiO_2	1.56
P_2O_5	0.14
MnO	0.20
LOI	2.4
H_2O^+	0.95
H_2O^-	N.D.
CO_2	0.95

Magnetic Data:	73-75 cm
NRM Intensity (emu/cc)	12.49×10^{-3}
NRM Inclination	-20.8°
Stable Inclination	-23.5°

Physical Property Data:	10-12 cm
$\bar{V}p$ (km/sec)	5.55
Porosity (%)	5.8
Wet Bulk Density (g/cc)	2.86
Grain Density (g/cc)	2.94



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

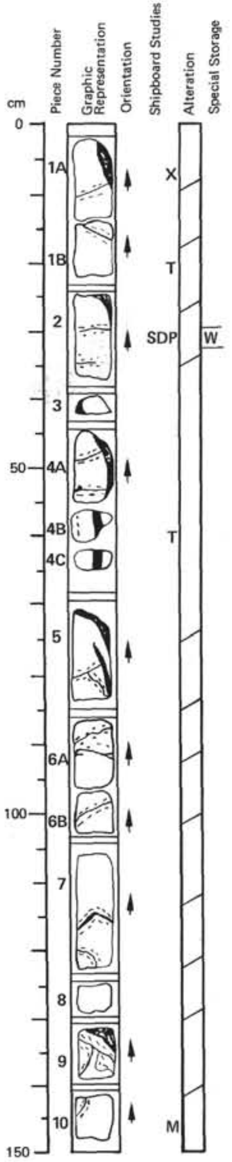
LEG	SITE	HOLE	CORE	SECT.
52	417	D	53	2

Visual Description

Moderately phyric pillow basalt with altered chilled margins in pieces 1D, 2A, 4A and 7 and traces of fresh glass in piece 4A. Groundmass fine-grained to glassy. Plagioclase phenocrysts 4-8%, <2 mm; clinopyroxene phenocrysts 1-2%, present in glomerocrysts with plagioclase; olivine phenocrysts 1-2%, <1 mm, replaced by green smectite. Calcite occurs in patches between 78-82 cm and as possible vesicle fillings in pieces 1B, 1C and 2A. Veins filled by smectite and calcite. Basalt fragments in piece 6 strongly altered.

Shipboard Data

Magnetic Data:	8-10 cm
NRM Intensity (emu/cc)	13.16×10^{-3}
NRM Inclination	-20.3°
Stable Inclination	-22.2°
Physical Property Data:	82-84 cm
$\overline{V}p$ (km/sec)	5.54
Wet Bulk Density (g/cc)	2.865



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	54	1

Visual Description

Moderately to highly phyric pillow basalt with altered chilled margins in pieces 1-5 and 9 and traces of fresh glass in pieces 1, 4A, 5 and 9. Fine-grained groundmass moderately altered with brown alteration halos extending to a depth of 1 cm along veins filled by calcite and lined with brown smectite. Glass largely replaced by green smectite. Plagioclase phenocrysts 10-15%; augite phenocrysts 5%; olivine phenocrysts 5%, replaced by green smectite and calcite(?); phenocrysts commonly occur in subophitic clots <5 mm across. Calcite-filled vesicles common, <0.5 mm. Piece 1 contains a vein filled by sulfides and calcite. Piece 4B contains a large (2 cm) vug filled by olive-green zeolites(?).

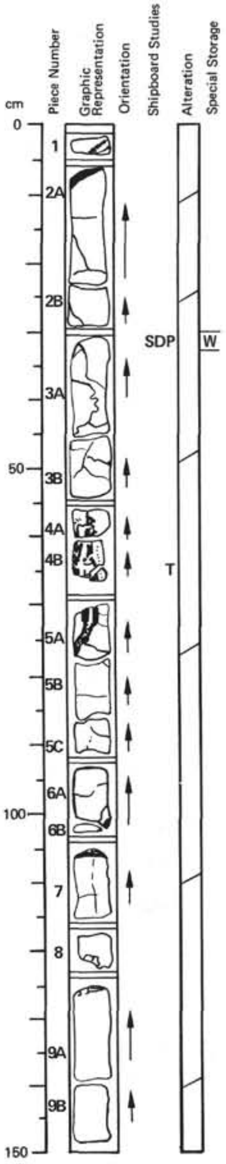
Thin Section Description

Location: 19 cm, pillow interior
Texture: phyric, variolitic
Phenocrysts: olivine 1%, 0.3-0.4 mm, euhedral; plagioclase 6%, 0.6-0.8 mm, euhedral - subhedral; clinopyroxene 3%, 0.3-0.4 mm, subhedral
Groundmass: plagioclase and pyroxene laths in altered glass 88%
Vesicles: 2%, 0.05-1 mm, round, filled by calcite and minor smectite
Alteration: olivine and glass replaced by clay. Clays associated with sulfides

Location: 60 cm, glassy margin
Texture: phyric, glassy
Phenocrysts: plagioclase 5-10%, 0.3-0.5 mm, euhedral; clinopyroxene 5%, 0.3-1 mm, euhedral, oscillatory zoned
Groundmass: glass 85-90%
Vesicles: none
Alteration: veins and interpillow voids filled by clay

Shipboard Data

Bulk Analysis: 7-9 cm		Magnetic Data:	144-146 cm
SiO_2	49.40	NRM Intensity (emu/cc)	25.59×10^{-3}
Al_2O_3	15.70	NRM Inclination	20.9
Fe_2O_3	12.00	Stable Inclination	21.0
MgO	6.41		
CaO	12.50	Physical Property Data:	30-32 cm
Na_2O	2.40	$\overline{V}p$ (km/sec)	5.03
K_2O	0.20	Porosity (%)	10.8
TiO_2	1.59	Wet Bulk Density (g/cc)	2.75
P_2O_5	0.16	Grain Density (g/cc)	2.96
MnO	0.19		
LOI	1.9		
H_2O^+	0.96		
H_2O^-	N.D.		
CO_2	0.44		



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE			SECT.	
5	2	4	1	7	D		5	4		2

Visual Description

Moderately to highly phyric pillow basalt with glassy chilled margins in pieces 1, 2A, 4, 5A, 6 and 7 and interpillow breccia in pieces 4 and 5A. Groundmass aphanitic to fine-grained. Euhedral plagioclase phenocrysts 10-15%, 2-8 mm; euhedral pyroxene phenocrysts 3-5%, <4 mm, commonly with plagioclase in glomerocrysts <8 mm across; euhedral olivine phenocrysts <5%, 1-2 mm, replaced by green smectite. Large (<1 cm) irregular vesicles filled with calcite and dark green smectite; small round vesicles filled by calcite. Piece 8 contains a large (2 cm) calcite-filled vug. Breccia in pieces 4 and 5A composed of fragments of glass replaced by green smectite in a dark brown matrix of altered glass and smectite.

Thin Section Description

Location: 65 cm, glassy margin

Texture: glassy

Phenocrysts: olivine 1%, 0.5 mm, euhedral; plagioclase laths 10%, 0.5-1.5 mm; clinopyroxene 3%, 0.5 mm, intergrown with plagioclase

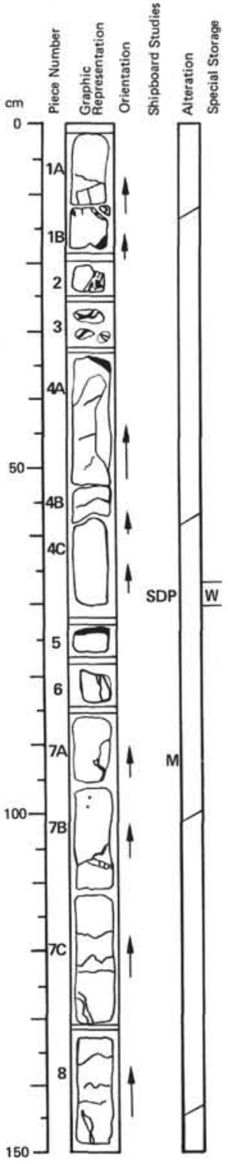
Groundmass: altered glass 85%

Vesicles: *none*

Alteration: glass replaced by smectite and calcite

Shipboard Data

Physical Property Data:	39-41 cm
$\overline{V}$p (km/sec)	5.43
Porosity (%)	7.3
Wet Bulk Density (g/cc)	2.80
Grain Density (g/cc)	2.90



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

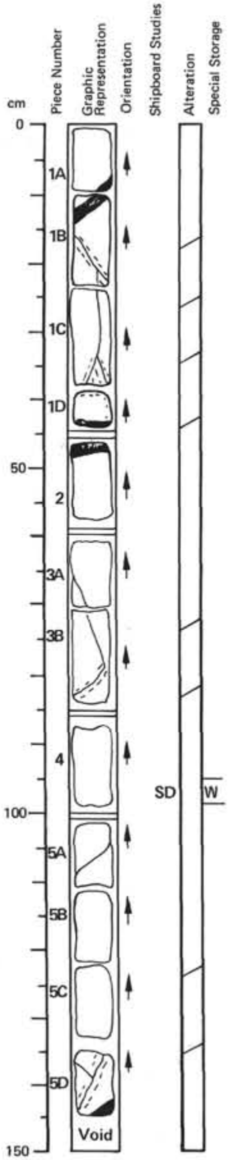
LEG		SITE			HOLE	CORE			SECT.	
5	2	4	1	7	D		5	4		3

Visual Description

Moderately phyric pillow basalt with chilled margins in pieces 1B, 2, 4A and 5, and minor interpillow breccia in piece 3. Groundmass aphanitic to fine-grained. Plagioclase phenocrysts and microlites 5-10%, 5-9 mm and <5%, 2-4 mm respectively; euhedral pyroxene phenocrysts 5-8%, 1-4 mm, commonly with plagioclase in glomerocrysts; olivine phenocrysts <5%, 1-2 mm. Vesicles 1-3%, filled with calcite and dark green smectite. Minor veins filled by calcite and dark green smectite. *Breccia in piece 3 composed of fragments of glass cemented by glass, olive-green smectite(?) and* calcite.

Shipboard Data

Magnetic Data:	92-94 cm
NRM Intensity (emu/cc)	15.22×10^{-3}
NRM Inclination	+ 6.2°
Stable Inclination	+13.9°
Physical Property Data:	71-73 cm
$\overline{V}$p (km/sec)	5.55
Porosity (%)	6.7
Wet Bulk Density (g/cc)	2.865
Grain Density (g/cc)	3.00



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

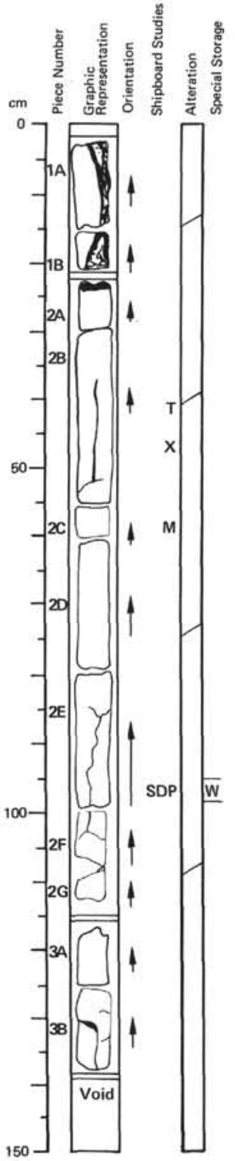
LEG		SITE			HOLE	CORE		SECT.	
5	2	4	1	7	D	5	4		4

Visual Description

Moderately to highly phyric pillow basalt with chilled glassy margins in pieces 1A, 1B, 1D, 2 and 5D. Glass partially replaced by smectite. Plagioclase phenocrysts 10%; augite phenocrysts 5%; olivine phenocrysts 5%, replaced by smectite; phenocrysts tend to occur in subophitic clots <5 mm across. Vesicles common, <.05 mm, filled by calcite, minor smectite. Veins filled by calcite and lined with green to brown smectite. Sulfides present as vein fillings and as small (<.05 mm) disseminated grains.

Shipboard Data

Physical Property Data:	98-100 cm
$\overline{V}$p (km/sec)	5.76
Wet Bulk Density (g/cc)	2.865



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	2	4	1	7	D	5	4		5

Visual Description

Moderately phyric pillow basalt with chilled glassy margins in pieces 1 and 2. 0-22 cm interval represents a complete pillow bounded by well-preserved margins. Groundmass aphanitic to fine-grained. Plagioclase phenocrysts 10%, <1 cm; euhedral ovroxene phenocrysts 3-5%, 2-3 mm, tend to occur in glomerocrysts with plagioclase; olivine phenocrysts <5%. Minor veins filled by calcite and dark green smectite. Large interpillow filling in piece 1 contains calcite and zeolites(?).

Thin Section Description

Location: 42 cm

Texture: intergranular

Phenocrysts: olivine 3%, <2.0 mm, euhedral; plagioclase 6%, <3.0 mm, laths with prominent zoning; clinopyroxene 3%, <2.0 mm

Groundmass: olivine 8%, euhedral; plagioclase laths 35%; clinopyroxene 25%, fibrous bundles; magnetite 5%, <0.02 mm, euhedral; glass 15%, devitrified

Vesicles: 2%, <0.2 mm, filled by smectite with minor calcite

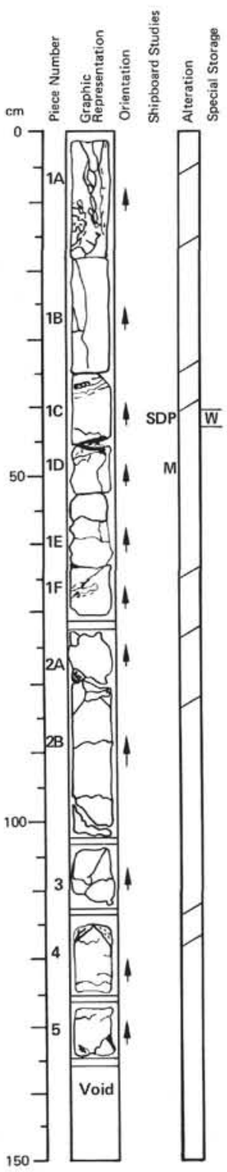
Alteration: calcite <1%, mostly in thin veins; clays replacing olivine 10%; sulfides in veins <1%

Shipboard Data

Bulk Analysis:	42-44 cm
SiO_2	50.80
Al_2O_3	14.70
Fe_2O_3	11.67
MgO	6.48
CaO	12.30
Na_2O	2.54
K_2O	0.03
TiO_2	1.50
P_2O_5	0.15
MnO	0.19
LOI	1.5
H_2O^+	0.73
H_2O^-	N.D.
CO_2	0.12

Magnetic Data:	58-60 cm
NRM Intensity (emu/cc)	19.34×10^{-3}
NRM Inclination	- 0.3°
Stable Inclination	-21.4°

Physical Property Data:	97-99 cm
$\overline{V}$p (km/sec)	5.88
Porosity (%)	3.1
Wet Bulk Density (g/cc)	2.91
Grain Density (g/cc)	2.96



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	54	6

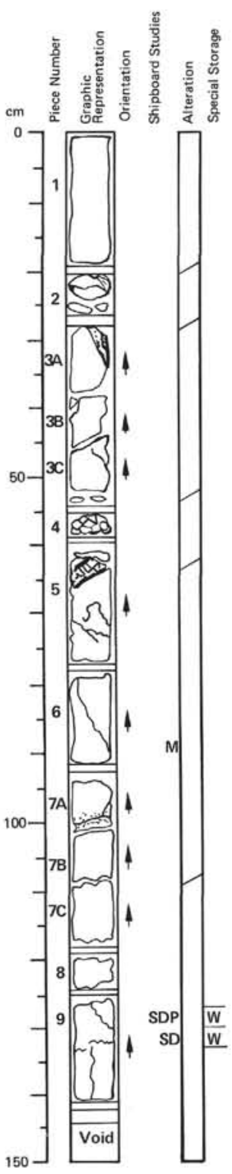
Visual Description

Moderately to highly phyric pillow basalt with chilled glassy margins in pieces 1C and 1D. Groundmass weakly to moderately altered. Plagioclase phenocrysts 10%, ≤6 mm, increase to 15% toward base of section; augite phenocrysts 5%, 2-3 mm; olivine phenocrysts 3-7%, 2-3 mm, replaced by smectite ± calcite. Vesicles 1%, <1 mm, filled by calcite, green smectite and zeolites. Veins filled by calcite and lined with dark green to brown smectite.

Shipboard Data

Magnetic Data:	49-51 cm
NRM Intensity (emu/cc)	34.51×10^{-3}
NRM Inclination	−16.2°
Stable Inclination	−19.2°

Physical Property Data:	41-43 cm
$\bar{V}$p (km/sec)	5.61
Porosity (%)	5.9
Wet Bulk Density (g/cc)	2.85
Grain Density (g/cc)	2.97



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	55	1

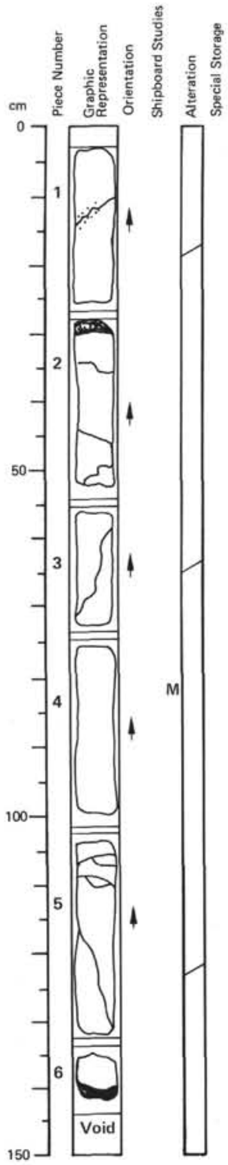
Visual Description

Moderately phyric pillow basalt with minor breccia in pieces 4 and 5 and glassy chilled margins partially replaced by dark green smectite in pieces 2 and 3A. Basalt groundmass composed of plagioclase microlites, pyroxene and altered olivine in a matrix of fresh to altered glass. Glass and olivine in groundmass partially to completely replaced by green smectite. Euhedral plagioclase phenocrysts 8%, <5 mm; anhedral augite phenocrysts 3%, <2 mm; euhedral olivine phenocrysts 2%, <3 mm, replaced by green smectite. Vesicles rare, <1 mm, filled by green to brown smectite and/or calcite. Veins common, ≤1 mm, filled by smectite ± calcite. Breccia in pieces 4 and 5 contains calcite, montmorillonite(?) and green smectite.

Shipboard Data

Magnetic Data:	88-90 cm
NRM Intensity (emu/cc)	17.93×10^{-3}
NRM Inclination	−14.5°
Stable Inclination	−16.8°

Physical Property Data:	128-130 cm	131-133 cm
$\bar{V}$p (km/sec)	5.53	5.56
Porosity (%)	6.0	
Wet Bulk Density (g/cc)	2.875	2.91
Grain Density (g/cc)	2.98	



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

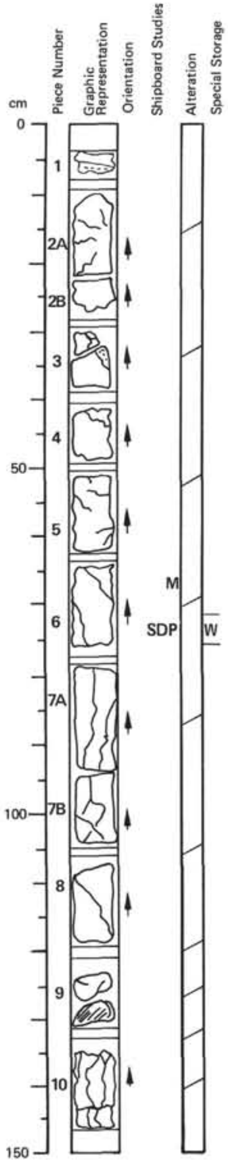
LEG	SITE	HOLE	CORE	SECT.
52	417	D	55	2

Visual Description

Highly phyric, slightly altered pillow basalt with glassy chilled margins in pieces 2 and 6. Groundmass glassy to fine-grained with glomerophyric or subophitic clots. Glass partially replaced by calcite and green smectite. Plagioclase phenocrysts 15%, ≤ 10 mm; subophitic augite clots 5%, ≤7 mm across; olivine phenocrysts 5%, replaced by calcite and smectite. Vesicles common , 0.5 mm, filled by calcite, occasionally by smectite. Sulfides occur as vein fillings and as small (0.5 mm) discrete grains. Piece 5 contains a large complex vein filled by sulfides, calcite and smectite.

Shipboard Data

Magnetic Data:	86-88 cm
NRM Intensity (emu/cc)	19.64×10^{-3}
NRM Inclination	- 2.6°
Stable Inclination	-20.9°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

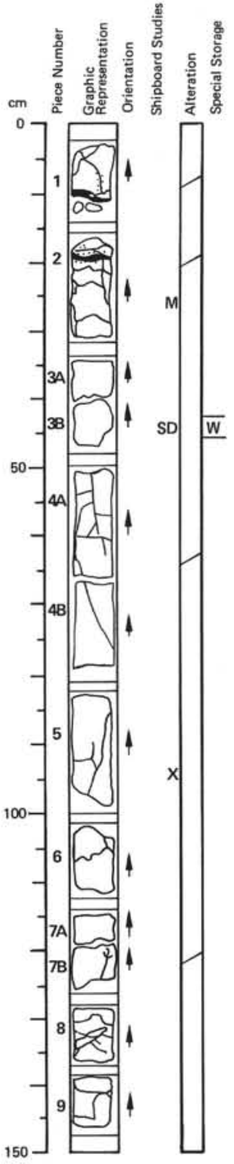
LEG	SITE	HOLE	CORE	SECT.
52	417	D	55	3

Visual Description

Moderately phyric pillow basalt with glassy chilled margins in pieces 1 and 3. Moderately altered groundmass composed of plagioclase microlites, augite and olivine replaced by smectite. Euhedral plagioclase phenocrysts 10%, ≤5 mm, occasionally to 8 mm; anhedral augite phenocrysts 3%, ≤2 mm; euhedral olivine phenocrysts 2%, ≤2 mm, replaced by green smectite. Vesicles <1%, <1 mm, filled by calcite and green to brown smectite. Glassy margins and groundmass locally oxidized along veins filled by green smectite or lined by smectite with a core of calcite.

Shipboard Data

Magnetic Data:	67-69 cm
NRM Intensity (emu/cc)	16.79×10^{-3}
NRM Inclination	+ 2.6°
Stable Inclination	- 9.8°
Physical Property Data:	73-75 cm
$\overline{V}p$ (km/sec)	5.53
Porosity (%)	6.2
Wet Bulk Density (g/cc)	2.885
Grain Density (g/cc)	2.98



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	55	4

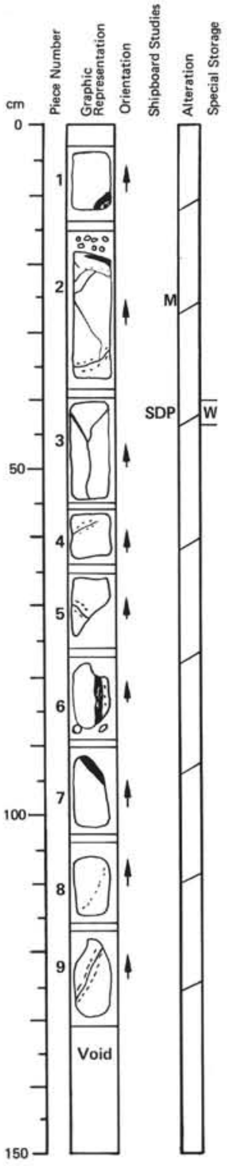
Visual Description

Sparsely phyric pillow basalt with altered glassy margins intermixed with calcite in pieces 1 and 2. Groundmass holocrystalline with occasional glomerocrysts of plagioclase and pyroxene. Euhedral plagioclase, pyroxene and olivine(?) phenocrysts total 15%; pyroxene phenocrysts large (≤7 mm) and abundant in piece 4B. Groundmass relatively fresh even along veins filled with calcite and minor sulfides.

Shipboard Data

Bulk Analysis: 96 cm n	
SiO_2	48.20
Al_2O_3	14.90
Fe_2O_3	12.11
MgO	6.62
CaO	13.20
Na_2O	2.43
K_2O	0.03
TiO_2	1.48
P_2O_5	0.17
MnO	0.21
LOI	1.9
H_2O^+	0.84
H_2O^-	N.D.
CO_2	0.35

Magnetic Data:	28-30 cm
NRM Intensity (emu/cc)	12.52×10^{-3}
NRM Inclination	- 4.5°
Stable Inclination	- 18.3°
Physical Property Data:	43-45 cm
$\overline{V}$p (km/sec)	5.71
Wet Bulk Density (g/cc)	2.89



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

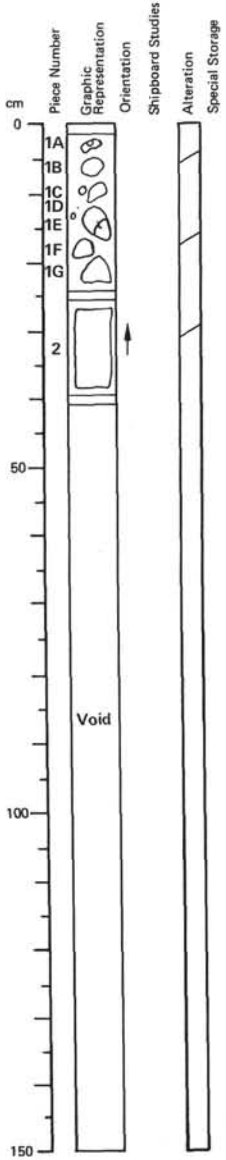
LEG	SITE	HOLE	CORE	SECT.
52	417	D	55	5

Visual Description

Moderately to highly phyric pillow basalt with altered chilled margins in pieces 1, 2, 6 and 7. Groundmass glassy to fine-grained, moderately altered. Plagioclase phenocrysts 7-10%; augite phenocrysts 3-5%; olivine phenocrysts 3-5%, replaced by smectite and minor calcite; phenocrysts <5 mm, usually 1-2 mm, commonly in subophitic glomerocrysts ≤10 mm across. Vesicles common, 0.5 mm, filled by smectite and calcite. Sulfides occur as discrete grains 0.5 mm across. Glass in margins and groundmass largely replaced by smectite.

Shipboard Data

Magnetic Data:	24-26 cm
NRM Intensity (emu/cc)	21.44×10^{-3}
NRM Inclination	-21.0°
Stable Inclination	-24.0°
Physical Property Data:	41-43 cm
$\overline{V}$p (km/sec)	5.49
Porosity (%)	5.8
Wet Bulk Density (g/cc)	2.875
Grain Density (g/cc)	2.96

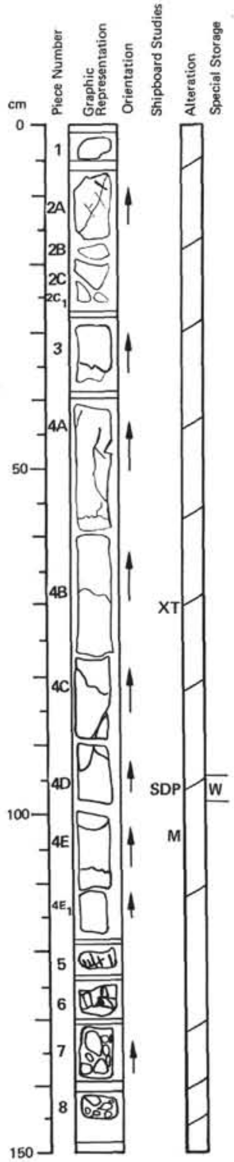


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	56	1

Visual Description

Moderately phyric pillow basalt. Plagioclase, clinopyroxene and olivine phenocrysts tend to occur in glomerophyric clots 2-3 mm across. Veins filled by calcite ± smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	57	1

Visual Description

Sparsely to moderately phyric, fine-grained pillow basalt with a chilled margin in piece 2A and breccia in pieces 7 and 8. Plagioclase phenocrysts and glomerocrysts ≤5 mm; clinopyroxene phenocrysts ≤2 mm; altered olivine phenocrysts ≤4 mm. Piece 1 contains vesicles ≤2 mm across filled with calcite and smectite. Veins common, filled by calcite and green smectite. Breccia in pieces 7 and 8 composed of fragments of basalt in a matrix of green smectite after glass.

Thin Section Description

Location: 69 cm, pillow interior

Texture: subophitic, intersertal

Phenocrysts: olivine 4%, 1.5 mm, euhedral; plagioclase 9%, 2 mm, euhedral-subhedral; clinopyroxene 7%, 1.0 mm, anhedral, subophitic

Groundmass: olivine <1%; plagioclase 30%, swallow-tail laths; clinopyroxene 45%, anhedral, plumose; magnetite 5%.

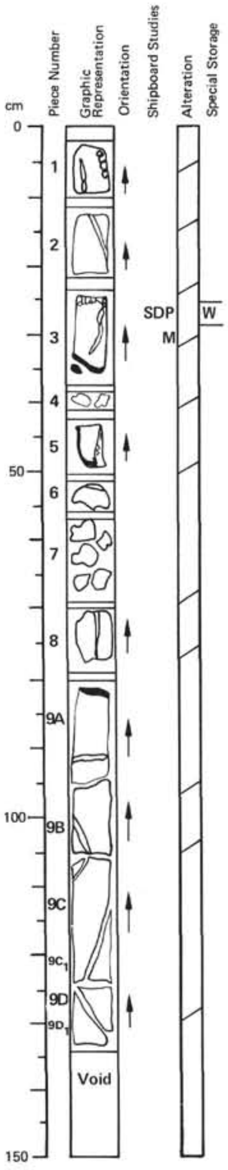
Vesicles: <1%, 1 mm, filled with calcite and smectite

Alteration: olivine replaced by calcite and clays; some veinlets contain sulfides

Shipboard Data

Bulk Analysis: 70 cm	
SiO_2	48.60
Al_2O_3	15.30
Fe_2O_3	12.30
MgO	7.00
CaO	13.9
Na_2O	2.19
K_2O	0.03
TiO_2	1.56
P_2O_5	0.16
MnO	0.20
LOI	1.8
H_2O^+	0.83
H_2O^-	N.D.
CO_2	0.90

Magnetic Data:	101-103 cm
NRM Intensity (emu/cc)	22.46×10^{-3}
NRM Inclination	12.8
Stable Inclination	15.3
Physical Property Data:	96-98 cm
$\overline{V}$p (km/sec)	5.40
Porosity (%)	7.7
Wet Bulk Density (g/cc)	2.845
Grain Density (g/cc)	2.97



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	57	2

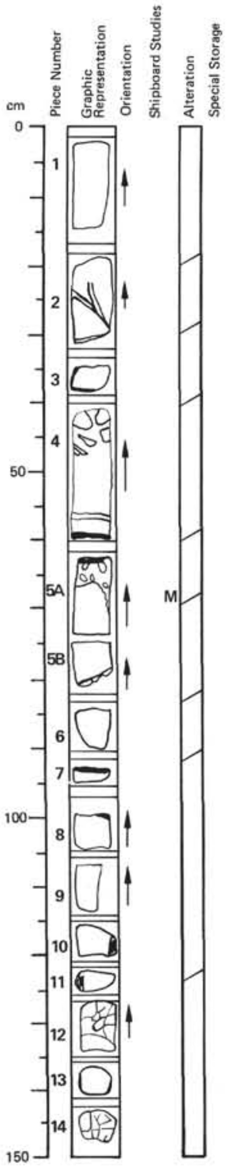
Visual Description

Moderately to highly phyric pillow basalt with altered chilled margins in pieces 3 and 9A and traces of hyaloclastite(?) breccia in pieces 1, 3, and 6. Groundmass aphanitic to fine-grained, increases to medium-grained (small glomerocrysts in a fine-grained matrix) toward pillow interior in piece 9. Glass in pillow margins and groundmass entirely replaced by smectite. Plagioclase phenocrysts 10%, ≤4 mm, usually 2-3 mm; clinopyroxene phenocrysts 4%, occasionally with plagioclase in glomerocrysts or subophitic clots ≤8 mm across; olivine phenocrysts ≤2 mm, 2% , increase to 3-5% in pieces 9B and 9C, replaced by brown to green smectite. Veins filled by brown smectite or by calcite (piece 9B and 9C). Piece 6 contains a calcite-filled vug. Breccia composed of altered basalt fragments in a green smectite matrix derived from sideromelane glass?

Shipboard Data

Magnetic Data:	29-31 cm
NRM Intensity (emu/cc)	12.07×10^{-3}
NRM Inclination	-72.1°
Stable Inclination	-72.1°

Physical Property Data:	26-28 cm
$\overline{V}p$ (km/sec)	5.24
Porosity (%)	9.0
Wet Bulk Density (g/cc)	2.71
Grain Density (g/cc)	2.91



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

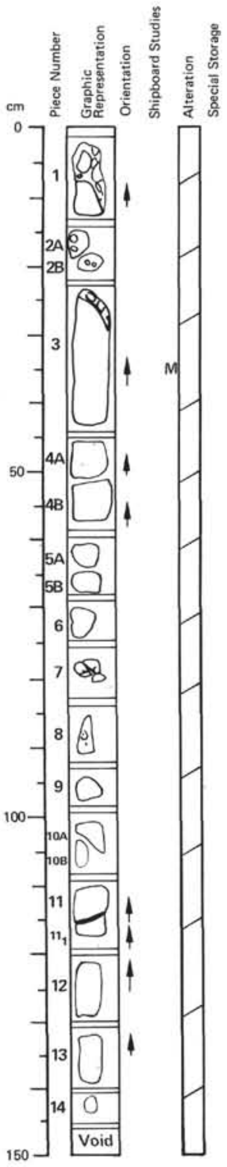
LEG	SITE	HOLE	CORE	SECT.
52	417	D	57	3

Visual Description

Moderately phyric, fine- to medium-grained pillow basalt with altered hyaloclastite breccia in pieces 2-5, 7-12 and 14 and an altered glassy margin(?) in piece 6. Plagioclase and clinopyroxene in glomerocrysts and subophitic clots ≤5 mm across; olivine phenocrysts ≤2 mm, replaced by green smectite and hematite, iddingsite or brown smectite(?). Veins filled by green smectite. Breccia composed of fragments of slightly to moderately altered basalt in a matrix of green smectite and minor calcite.

Shipboard Data

Magnetic Data:	67-69 cm
NRM Intensity (emu/cc)	14.29×10^{-3}
NRM Inclination	-26.2°
Stable Inclination	+26.6°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

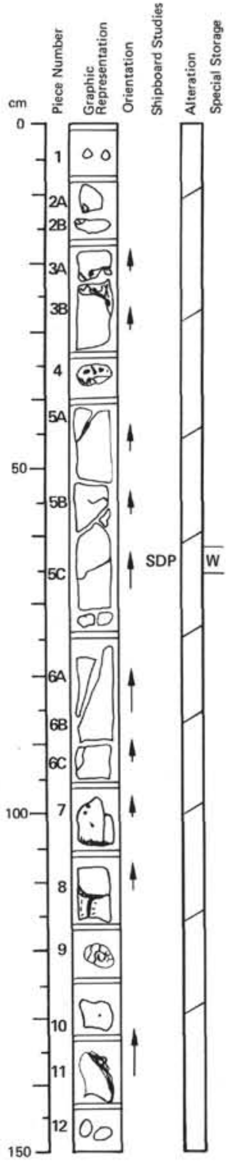
LEG	SITE	HOLE	CORE	SECT.
52	417	D	57	4

Visual Description

Sparsely to moderately phyric pillow basalt with altered hyaloclastite breccia in piece 1. Groundmass fine-grained, moderately altered. Plagioclase phenocrysts and subophitic clots ≤5 mm; clinopyroxene phenocrysts ≤5 mm; olivine phenocrysts ≤7 mm, replaced by calcite and smectite. Numerous veins filled by calcite and green smectite. Breccia composed of basalt fragments cut by veins of green smectite, montmorillonite and calcite in a matrix of calcite and green smectite.

Shipboard Data

Magnetic Data:	34-36 cm
NRM Intensity (emu/cc)	20.03×10^{-3}
NRM Inclination	+62.9°
Stable Inclination	+61.7°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

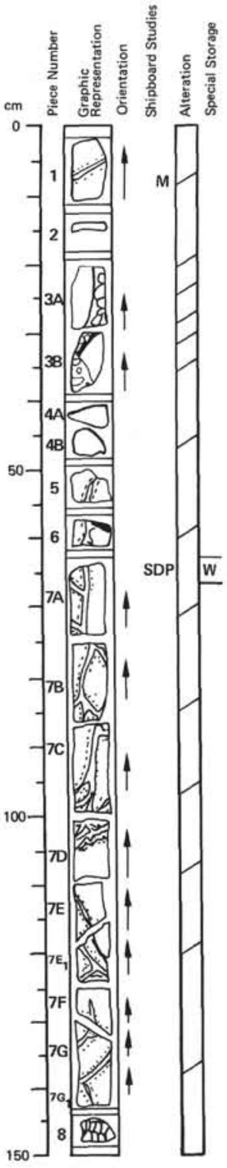
LEG	SITE	HOLE	CORE	SECT.
52	417	D	58	1

Visual Description

Sparsely phyric pillow basalt with glassy chilled margins in pieces 7, 8 and 11 and altered hyaloclastite breccia in pieces 2-4 and 8. Pyroxene phenocrysts <5%, <4 mm, usually <2 mm; plagioclase phenocrysts in rare glomerocrysts with pyroxene; olivine(?) phenocrysts <1 mm, replaced by green smectite. Minor vesicles filled by dark green smectite. Breccia along pillow margins (piece 8) or cutting through pillow interiors (piece 3) composed of coarse (0.5-3.0 cm) fragments of basalt or glass altered to green smectite in a matrix of dark, altered glass.

Shipboard Data

Physical Property Data:	64-66 cm
$\overline{V}p$ (km/sec)	5.15
Porosity (%)	10.3
Wet Bulk Density (g/cc)	2.785
Grain Density (g/cc)	2.98



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

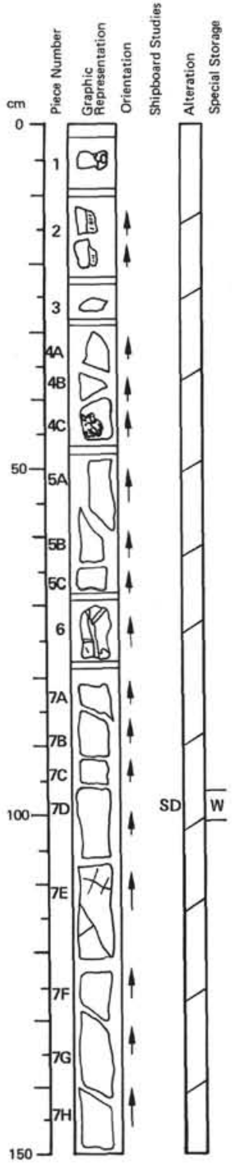
LEG	SITE	HOLE	CORE	SECT.
52	417	D	58	2

Visual Description

Sparsely to moderately phyric pillow basalt with altered chilled margins in pieces 3 and 6 and broken pillow breccia in piece 3. Groundmass aphanitic to medium-grained, oxidized to a depth of 0.5-3.0 mm along veins filled by brown smectite and minor calcite. Subophitic clots and glomerocrysts of plagioclase ± clinopyroxene 10%, 2-3 mm; olivine phenocrysts <1 mm, replaced by green smectite altered to red-brown along oxidized veins. Breccia composed of angular to subrounded fragments of moderately altered or oxidized basalt and glass, 0-20 mm across, in a matrix of dark green to brown smectite and minor calcite. Tabular shards of altered glass aligned subparallel to pillow margins in piece 3 represent exfoliated pillow margins. Piece 8 contains a large calcite-filled vug.

Shipboard Data

Magnetic Data:	8-10 cm
NRM Intensity (emu/cc)	12.49×10^{-3}
NRM Inclination	-79.2°
Stable Inclination	-76.8°
Physical Property Data:	64-66 cm
$\overline{V}$p (km/sec)	5.03
Porosity (%)	10.2
Wet Bulk Density (g/cc)	2.755
Grain Density (g/cc)	2.93



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

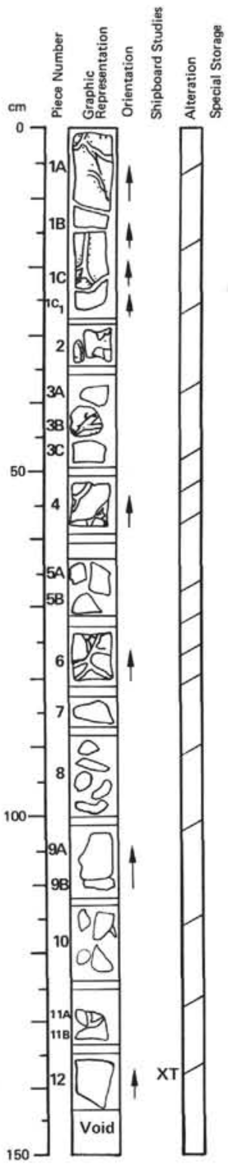
LEG	SITE	HOLE	CORE	SECT.
52	417	D	58	3

Visual Description

Aphyric to sparsely phyric basalt with minor breccia-filled veins in pieces 1, 4C and 5A. Pyroxene phenocrysts <3%, 2-3 mm; altered olivine phenocrysts <1%, 1-2 mm. Minor vesicles filled by calcite. Breccia composed of fragments of basalt and glass altered to green smectite in a matrix of dark altered glass and minor calcite. Pieces 2, 3 and 7 contain veins filled by dark green smectite with well-preserved slickensides indicating strike-slip and normal faulting.

Shipboard Data

Physical Property Data:	99-101 cm
$\overline{V}$p (km/sec)	4.73
Wet Bulk Density (g/cc)	2.695



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	2	4	1	7	D		5 8		4

Visual Description

Moderately phyric, basalt with breccia in pieces 2, 4 and 6. Groundmass medium-grained in piece 1, fine-grained throughout remainder of section. Subophitic clots and glomerocrysts of plagioclase ± clinopyroxene 5-10%, 2 mm; olivine phenocrysts <3%, replaced by green smectite. Smectite vein fillings and smectite after olivine adjacent to veins locally oxidized to red brown. Breccia composed of angular to subrounded fragments of basalt, 1-30 mm across, in a matrix of dark green smectite. Slickensides common along smectite-filled veins. Piece 12 contains irregular vugs, <3 mm across, filled by smectite and an unidentified white zeolite(?).

Thin Section Description

Location: 139 cm

Texture: quenched

Phenocrysts: olivine 5%, 0.2-0.6 mm, euhedral; plagioclase laths 15%, 0.3-4 mm

Groundmass: olivine 1-2%; plagioclase 30%, <0.3 mm, skeletal; clinopyroxene 45%; magnetite 1-2%

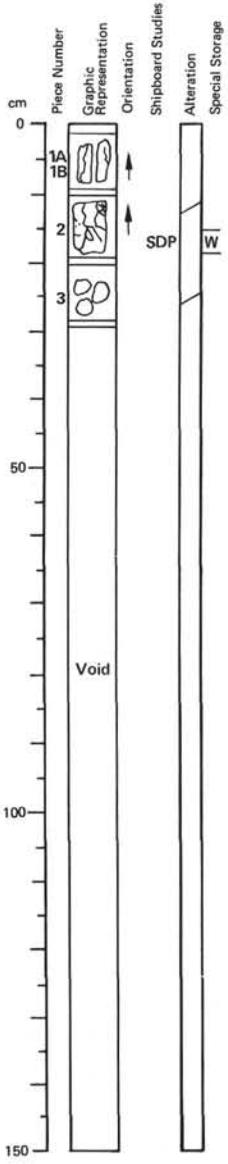
Vesicles: <1%, 0.04-0.1 mm, round, filled with smectite

Alteration: olivine in groundmass replaced by clays. Veins contain clay and iron oxides.

Shipboard Data

Bulk Analysis: 139-141 cm

SiO_2	49.70
Al_2O_3	16.30
Fe_2O_3	10.72
MgO	6.77
CaO	12.40
Na_2O	2.52
K_2O	0.37
TiO_2	1.38
P_2O_5	0.16
MnO	0.15
LOI	2.3
H_2O^+	0.78
H_2O^-	N.D.
CO_2	0.47



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

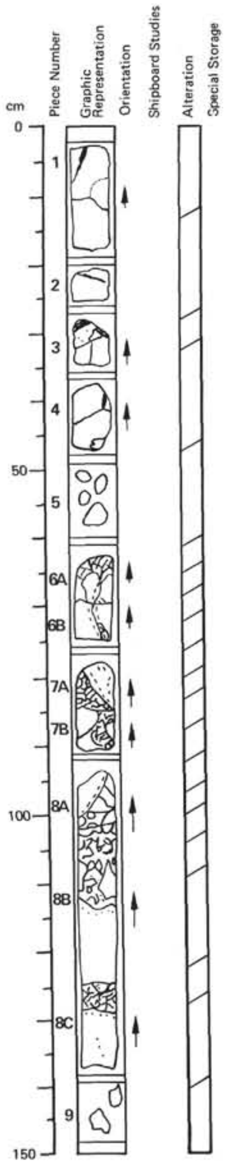
LEG		SITE			HOLE	CORE		SECT.	
5	2	4	1	7	D		5 8		5

Visual Description

Aphyric to sparsely phyric basalt. Rare pyroxene and olivine phenocrysts replaced by green smectite. Veins filled by dark green smectite. Irregular vesicles filled by calcite and dark green smectite.

Shipboard Data

Physical Property Data:	17-19 cm
Vp (km/sec)	4.86
Porosity (%)	11.3
Wet Bulk Density (g/cc)	2.70
Grain Density (g/cc)	2.91

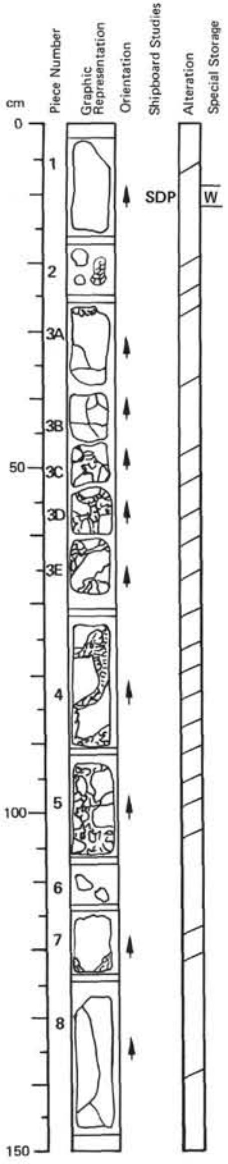


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	59	1

Visual Description

Moderately to highly phyric pillow basalt with a chilled pillow margin completely replaced by green smectite in piece 3 and strongly altered breccia in pieces 6-8. Groundmass ranges from fine-grained in piece 1 to intergranular in piece 8. Plagioclase phenocrysts 10-20%, occur as laths <1 mm across and in subophitic to glomerophyric clots <8 mm across with augite and minor olivine; augite phenocrysts 5%, usually in glomerophyric clots; altered olivine phenocrysts 5%, occasionally in glomerophyric clots, but usually as small (1 mm) euhedral crystals. Vesicles common, <0.5 mm. Veins filled by smectite, locally by calcite (102 cm). Breccia composed of basalt fragments in a matrix of green smectite (oxidized to red, yellow or brown in piece 7) and minor calcite. Slickensides common along smectite-filled veins.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

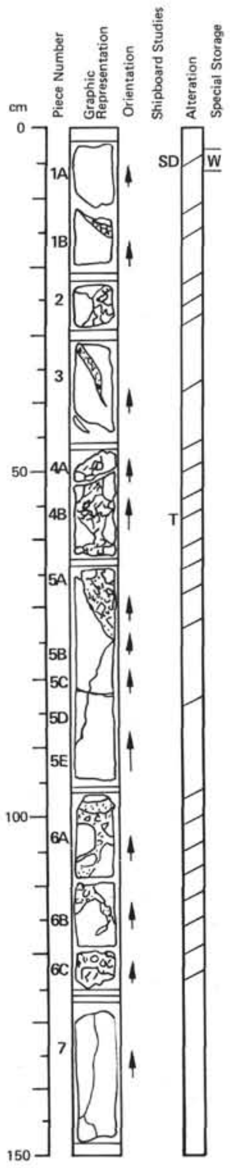
LEG	SITE	HOLE	CORE	SECT.
52	417	D	59	2

Visual Description

Moderately to highly phyric pillow basalt with an altered breccia zone between 50-110 cm and minor brecciation throughout the rest of the section. Groundmass fine- to medium-grained, locally oxidized along veins filled by smectite. Plagioclase phenocrysts 10-20%; augite phenocrysts 5%; altered olivine phenocrysts 5%; phenocrysts <4 mm, tend to occur in subophitic clots, but plagioclase and olivine also occur respectively; as isolated laths and euhedral crystals. Calcite-filled vesicles <2% in pieces 4 and 7. Breccia composed of basalt fragments in a matrix of smectite and minor calcite.

Shipboard Data

Physical Property Data:	10-12 cm
$\overline{V}$p (km/sec)	5.26
Porosity (%)	8.1
Wet Bulk Density (g/cc)	2.785
Grain Density (g/cc)	2.94



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Pieces 1-5A: Sparsely phyric basalt with strongly altered breccia in pieces 1B-5A. Groundmass fine-grained, partially altered to montmorillonite and green to brown smectite. Plagioclase phenocrysts 3%, <3 mm; anhedral augite phenocrysts 1%, <1 mm; euhedral olivine phenocrysts 1%, <1 mm; augite and plagioclase phenocrysts partially replaced and olivine phenocrysts completely replaced by green smectite, montmorillonite and calcite. Vesicles 1%, <1 mm, filled by calcite and smectite. Breccia composed of altered to locally glassy fragments (piece 4B) of basalt in a matrix of dark green smectite.

Pieces 5B-7: Moderately phyric basalt with strongly altered breccia in piece 6. Plagioclase phenocrysts 10%, <5 mm; augite phenocrysts 1-2%; euhedral olivine phenocrysts 1-2%, replaced by smectite, montmorillonite(?) and calcite. Pyrite 3%, occurs as vein fillings and disseminated grains. Breccia composed of small fragments of basalt partially replaced by clay and calcite in a matrix of clay.

Thin Section Description

Location: 58 cm, glassy margin.

Texture: mixed variolitic and intersertal

Phenocrysts: olivine 1 mm; euhedral plagioclase 1.5 mm; subhedral clinopyroxene 1.0 mm

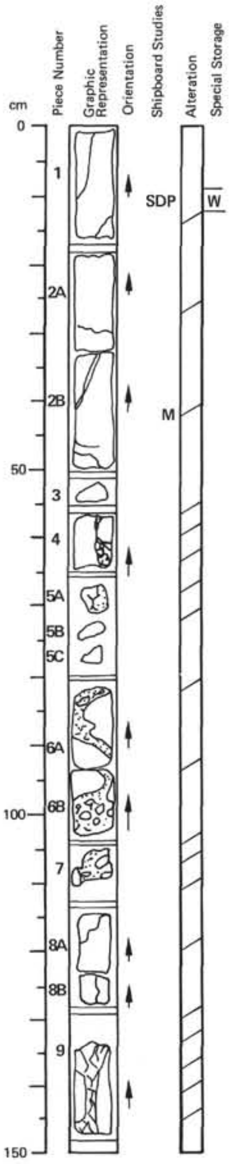
Groundmass: plagioclase 15%, <1 mm; clinopyroxene 10%; clay 70%

Vesicles: none

Alteration: olivine fragments replaced by calcite and smectite. Groundmass largely altered to clay.

Shipboard Data

Physical Property Data:	7-9 cm
$\overline{V}$p (km/sec)	5.50
Wet Bulk Density (g/cc)	2.805



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

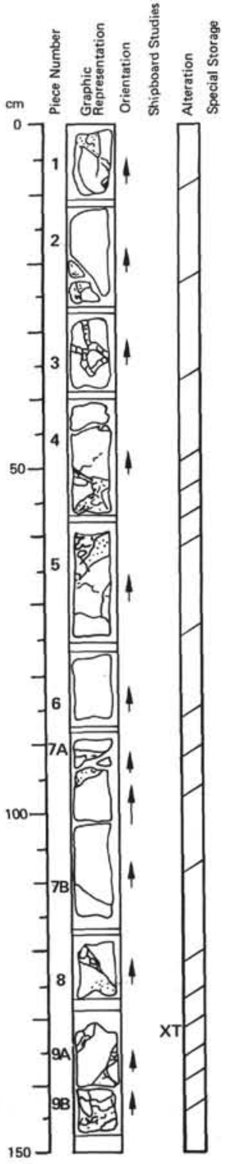
LEG		SITE			HOLE	CORE			SECT.	
5	2	4	1	7	D		5	9		4

Visual Description

Moderately to highly phyric basalt with altered breccia in pieces 4-7. Groundmass fine-grained, partially altered to smectite. Plagioclase phenocrysts 10%, <5 mm; anhedral augite phenocrysts 5%, commonly in glomerocrysts with plagioclase; euhedral olivine phenocrysts 3-5%, <2 mm, replaced by smectite and calcite. Minor vesicles filled with calcite and lined with smectite. Veins filled by calcite and smectite. Breccia in pieces 4-7 composed of sparsely to moderately phyric basalt fragments partially replaced by clay in a locally oxidized clay matrix. Piece 9 strongly fractured with a network of smectite-filled veins.

Shipboard Data

Magnetic Data:	42-44 cm
NRM Intensity (emu/cc)	12.23×10^{-3}
NRM Inclination	75.1
Stable Inclination	77.3
Physical Property Data:	11-13 cm
$\overline{V}$p (km/sec)	5.73
Porosity (%)	5.8
Wet Bulk Density (g/cc)	2.85
Grain Density (g/cc)	2.95



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

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

Visual Description

Sparsely to moderately phyric basalt with altered breccia in pieces 1-5, 7A, 8 and 9. Groundmass moderately altered, locally oxidized along veins filled by smectite. Plagioclase phenocrysts ≤ 10%, <5 mm; subhedral augite phenocrysts <5%, <2 mm; olivine phenocrysts 1-2%, <2 mm, replaced by calcite. Vesicles 1%, 0.5 mm, filled by calcite. Breccia composed of fragments of basalt partially replaced by clay in a matrix of clay and minor calcite.

Thin Section Description

Location: 136 cm

Texture: quenched

Phenocrysts: olivine 3%, 0.1-0.3 mm, euhedral; plagioclase laths 10%, 0.3-1.3 mm; clinopyroxene 2%, intergrown with plagioclase

Groundmass: plagioclase; clinopyroxene, poorly crystallized; devitrified glass

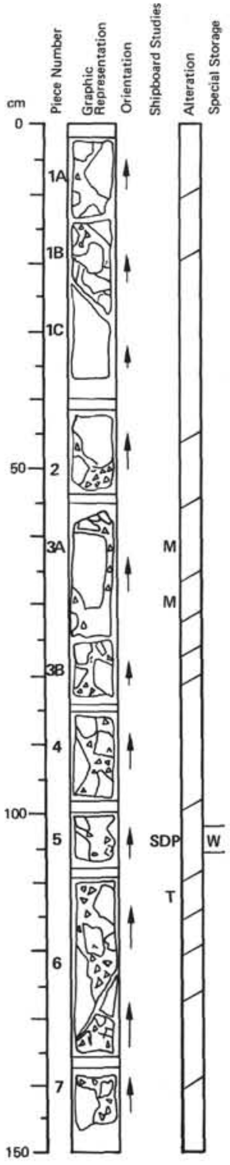
Vesicles: < 1%, 0.15 mm, filled with smectite

Alteration: olivine and plagioclase partially replaced by clay and calcite. Groundmass partially replaced by clay.

Shipboard Data

Bulk Analysis: 136 cm

SiO_2	50.50
Al_2O_3	15.20
Fe_2O_3	13.44
MgO	6.74
CaO	10.70
Na_2O	2.15
K_2O	1.26
TiO_2	1.36
P_2O_5	0.13
MnO	0.16
LOI	3.5
H_2O^+	1.06
H_2O^-	N.D.
CO_2	0.06



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE			SECT.
5	2	4	1	7	D		5	9	6

Visual Description

Basalt breccia composed of angular to subangular fragments of aphanitic to fine-grained, moderately phyric basalt in a matrix of green smectite. Groundmass of basalt fragments relatively fresh to strongly altered, locally oxidized to yellow-brown along margins of smaller fragments (pieces 1B and 3B) and along quenched margins rich in pyroxene phenocrysts. Plagioclase phenocrysts 5%; pyroxene phenocrysts 5%, usually in subophitic clots; rare olivine(?) phenocrysts replaced by brown smectite or iddingsite(?). Pieces 1B, 1C and 6 contain slickensided surfaces in smectite which wrap around larger fragments, suggesting adjustment during compaction.

Thin Section Description

Location: 117 cm

Texture: quenched

Phenocrysts: olivine 3%, 0.2-0.5 mm, euhedral; plagioclase laths 10%, 0.3-1 mm; clinopyroxene <1%, 0.5 mm, subophitic

Groundmass: plagioclase 3-5%, 0.3 mm; glass 80%, partially devitrified

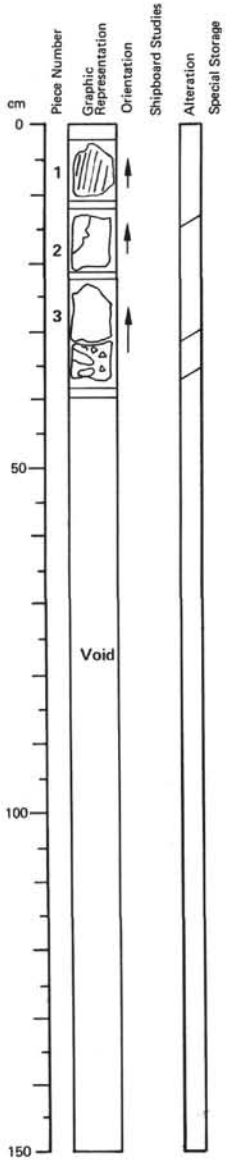
Vesicles: 1%, 0.05 mm, round, filled with smectite

Alteration: olivine replaced by calcite and clay

Shipboard Data

Magnetic Data:	62-64 cm	70-72 cm
NRM Intensity (emu/cc)	9.90×10^{-3}	0.646×10^{-3}
NRM Inclination	+46.2°	-14.3°
Stable Inclination	+43.6°	

Physical Property Data:	101-103 cm
$\bar{V}p$ (km/sec)	4.21
Porosity (%)	20.3
Wet Bulk Density (g/cc)	2.525
Grain Density (g/cc)	2.92

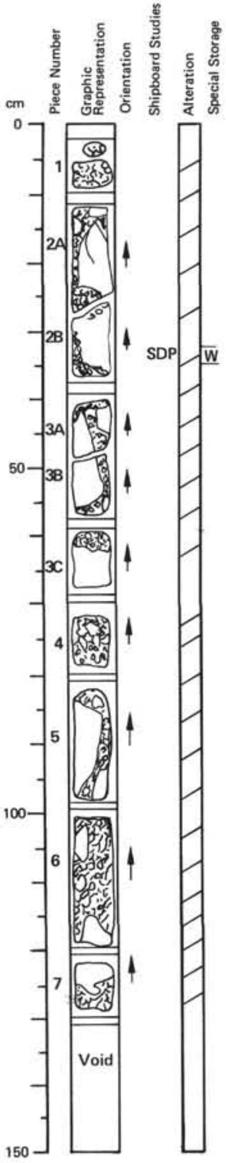


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	59	7

Visual Description

Basalt breccia composed of fragments of moderately phyric basalt in a matrix of green smectite. Groundmass aphanitic to fine-grained, locally oxidized to pinkish gray. Plagioclase and pyroxene phenocrysts total 10%; relative abundance variable in small aphanitic fragments. Pieces 1 and 2 contain vertical slickensides in smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

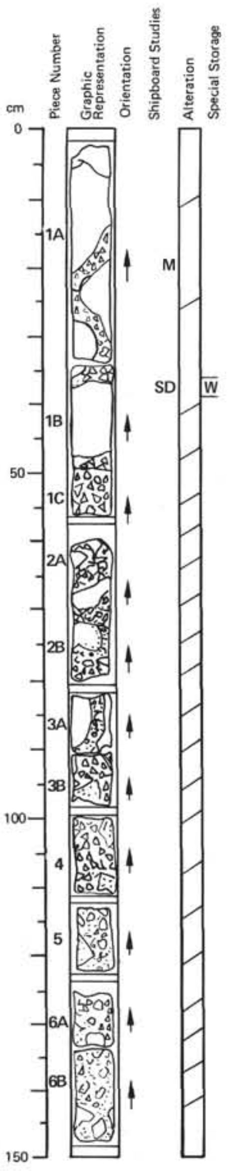
LEG	SITE	HOLE	CORE	SECT.
52	417	D	60	1

Visual Description

Basalt breccia composed of fragments of moderately to highly phyric pillow basalt in a matrix of dark green smectite and calcite. Groundmass fine- to medium-grained; alteration confined to small, fine-grained clasts. Plagioclase phenocrysts 10-15%, <3 mm; augite phenocrysts 5%, <3 mm; olivine phenocrysts 5%, <1.5 mm, replaced by smectite; plagioclase and olivine occur both as euhedral phenocrysts and as glomerocrysts with pyroxene. Calcite is abundant in the matrix at 5, 28, 48, 100 and 120 cm.

Shipboard Data

Physical Property Data:	32-34 cm
$\overline{V}p$ (km/sec)	5.11
Porosity (%)	11.5
Wet Bulk Density (g/cc)	2.67
Grain Density (g/cc)	2.87



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

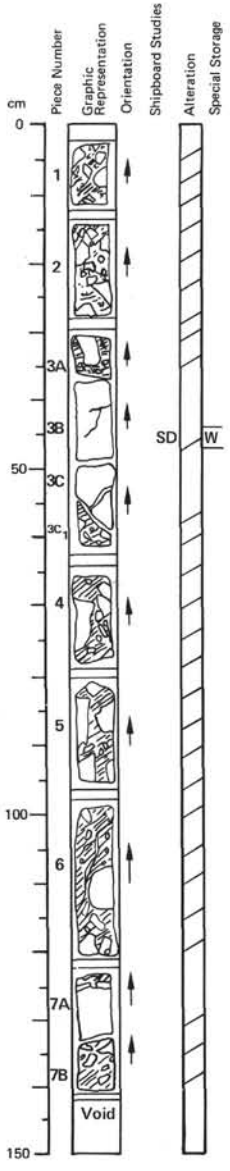
LEG	SITE	HOLE	CORE	SECT.
52	417	D	60	2

Visual Description

Basalt breccia composed of sparsely to highly phyric basalt fragments in a matrix of clay. Groundmass relatively fresh to moderately altered, the smallest clasts being the most altered. Plagioclase phenocrysts 8%, <4 mm; augite phenocrysts 4%, <2 mm, occur as isolated subhedral crystals and in glomercrysts with plagioclase; olivine phenocrysts replaced by smectite and calcite. Thin veins cutting breccia matrix and outlining basalt fragments (pieces 5 and 6A) filled by calcite.

Shipboard Data

Magnetic Data:	18-20 cm
NRM Intensity (emu/cc)	5.12×10^{-3}
NRM Inclination	+74.5°
Stable Inclination	+79.2°
Physical Property Data:	37-39 cm
$\bar{V}p$ (km/sec)	5.39
Wet Bulk Density (g/cc)	2.80



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

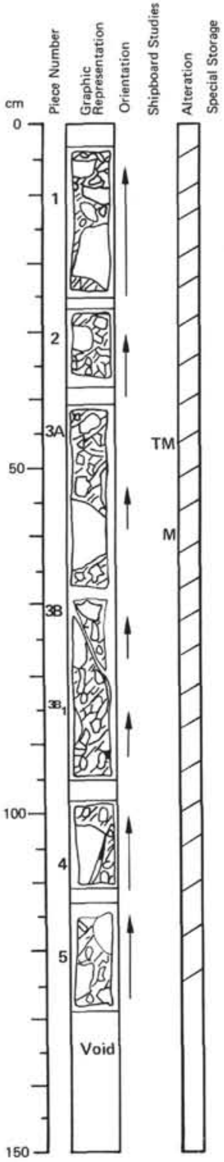
LEG	SITE	HOLE	CORE	SECT.
52	417	D	60	3

Visual Description

Basalt breccia composed of fragments of aphyric to moderately phyric basalt and basaltic glass ranging in size from 1-20 mm in a matrix of dark green smectite mixed with small amounts (<10%) of calcite in pieces 3-7. Groundmass aphanitic to microlitic. Plagioclase phenocrysts 8%, <4 mm; pyroxene phenocrysts 10%, <3 mm. Vesicles 2%, filled by calcite and green smectite. Veins filled by calcite. Pieces 3 and 6 display slickensides, the latter consisting of a normal fault in a calcite vein.

Shipboard Data

Physical Property Data:	47-49 cm
$\bar{V}p$ (km/sec)	5.43
Wet Bulk Density (g/cc)	2.835



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	60	4

Visual Description

Basalt breccia composed of angular to subrounded fragments of moderately phyric basalt, ranging in size from 0.1-90 mm, in a matrix of smectite containing minor calcite and traces of fresh glass. Groundmass fine- to medium-grained. Plagioclase phenocrysts, glomerocrysts of plagioclase and clinopyroxene and phenocrysts of olivine replaced by smectite total 5-10% of basalt and range in size from 1-3 mm. Basalt fragments commonly outlined by calcite-filled veins. Breccia matrix appears to be composed of smectite pseudomorphs after fine shards and spheres of glass or sideromelane sand(?).

Thin Section Description

Location: 47 cm, breccia zone in pillow complex

Texture: brecciated

Phenocrysts: plagioclase, pyroxene and olivine

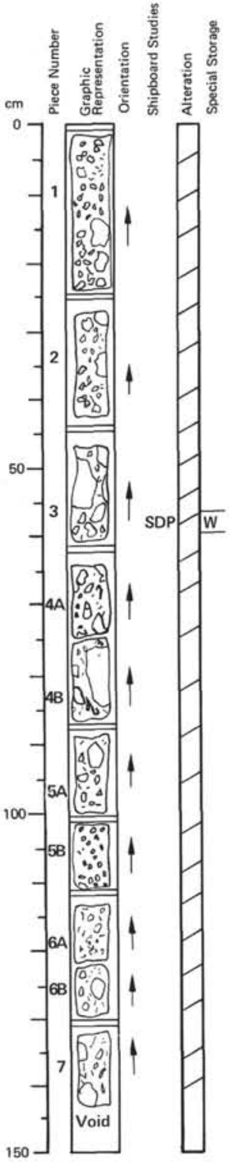
Groundmass: plagioclase 10%, 0.3 mm; altered clinopyroxene and olivine(?); glass

Vesicles: none

Alteration: olivine and glass replaced by calcite and clay

Shipboard Data

Magnetic Data:	46-48 cm	59-61 cm
NRM Intensity (emu/cc)	1.15×10^{-3}	7.04×10^{-3}
NRM Inclination	+53.1°	-10.7°
Stable Inclination	+53.5°	+7.9°



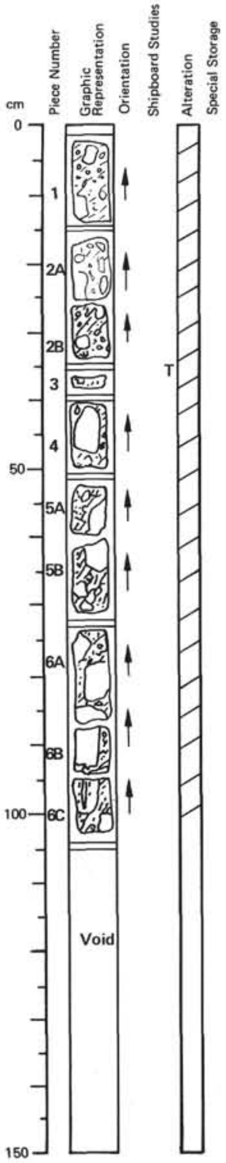
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	60	5

Visual Description

Basalt breccia composed of angular to subrounded fragments of basalt, ranging in size from 0.1-90 mm, in a matrix of smectite containing traces of fresh glass(?). Basalt groundmass fine-grained with an intersertal texture. Plagioclase phenocrysts <3 mm; clinopyroxene phenocrysts <1.5 mm; altered olivine phenocrysts <2 mm; total phenocrysts <5% to >10%. Breccia matrix contains sulfides, cavities lined or filled with smectite (pieces 5-7) and numerous small black spheres of fresh(?) glass toward the base of the section.

Physical Property Data:	**57-59 cm**
$\overline{V}p$ (km/sec)	4.20
Porosity (%)	19.1
Wet Bulk Density (g/cc)	2.52
Grain Density (g/cc)	2.91



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.
5	2	4	1	7	D	6	0	6

Visual Description

Basalt breccia composed of fragments of fine-grained, moderately phyric basalt and fresh basaltic glass in a matrix of smectite. Plagioclase, clinopyroxene and occasional olivine phenocrysts altered to smectite total 5-15% with plagioclase and clinopyroxene occurring predominantly in subophitic clots, <5 mm across, of plagioclase ± clinopyroxene. Calcite-filled veins, subvertical through the larger basalt clasts but diffuse through the matrix, are increasingly common toward the base of the section. Breccia matrix composed of smectite after sideromelane sand(?).

Thin Section Description

Location: 35 cm, breccia

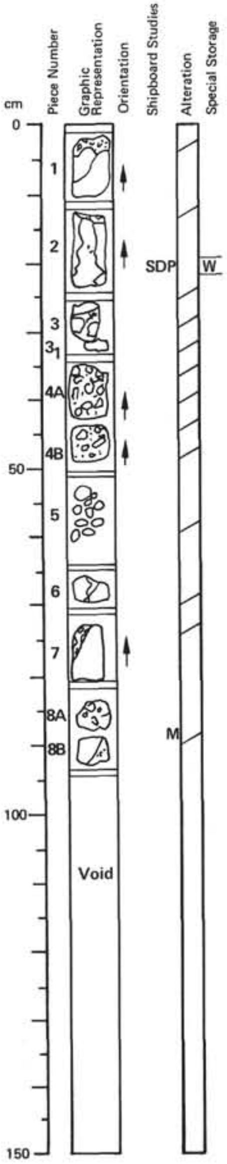
Texture: clastic

Phenocrysts: none

Groundmass: quenched basalt fragments; plagioclase; glass

Vesicles: none

Alteration: glass partially replaced by calcite



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

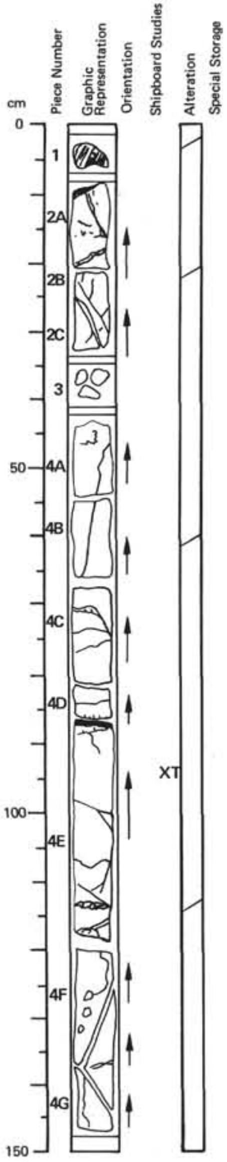
LEG		SITE			HOLE	CORE		SECT.
5	2	4	1	7	D	6	1	1

Visual Description

Basalt breccia composed of fragments of highly phyric basalt, some with glassy chilled margins (pieces 5 and 7), in a matrix of smectite and calcite. Basalt groundmass aphanitic to medium-grained. Phenocrysts consist of plagioclase, clinopyroxene and olivine replaced by smectite; plagioclase and clinopyroxene phenocrysts commonly occur in subophitic clots. Calcite-filled vesicles 1-2%, 0.5-1 mm. Veins and vugs filled by calcite. Sulfides common throughout section.

Shipboard Data

Magnetic Data:	88-90 cm
NRM Intensity (emu/cc)	9.71×10^{-3}
NRM Inclination	+43.3°
Stable Inclination	+36.0°
Physical Property Data:	20-22 cm
$\overline{V}p$ (km/sec)	5.46
Porosity (%)	8.6
Wet Bulk Density (g/cc)	2.795
Grain Density (g/cc)	2.95



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	2	4	1	7	D	6	2		1

Visual Description

Highly phyric pillow basalt with glassy chilled margins in pieces 1, 2A and 4E. Groundmass mottled, aphanitic to microlitic. Euhedral plagioclase phenocrysts 25%, < 10 mm; pyroxene phenocrysts 5%, 2-3 mm; olivine phenocrysts 5-10%, replaced by clay or calcite. Vesicles 1-2%, filled with calcite or dark clay. Vugs and veins filled by calcite, dark clay and pyrite. Piece 1 contains fresh perlitic gray glass, fresh to altered dark glass with plagioclase phenocrysts < 4 mm across and fresh to altered green glass, the former containing numerous pyrite crystals < 1 mm across.

Thin Section Description

Location: 95 cm, pillow interior

Texture: highly phyric, quenched

Phenocrysts: olivine 3%, 0.5-1 mm, euhedral; plagioclase 30%, 1-8 mm, euhedral, zoned with inclusions; clinopyroxene 1%

Groundmass: plagioclase 30%, 0.2-0.5 mm, skeletal; clinopyroxene 20%, 0.2-0.5 mm, plumose; magnetite 5%, 0.1 mm, euhedral; glass 5%; brown clay after plumose pyroxene(?) 10%

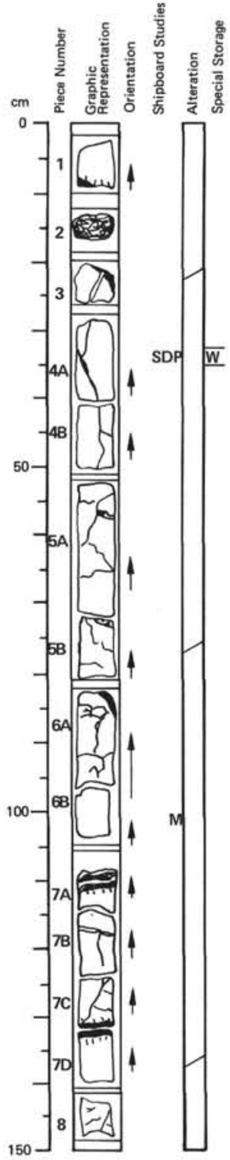
Vesicles: 2%, 0.2-1 mm, filled by clay and calcite

Alteration: olivine replaced by clay

Shipboard Data

Bulk Analysis: 94-96 cm

SiO_2	50.10
Al_2O_3	16.50
Fe_2O_3	11.33
MgO	6.07
CaO	13.80
Na_2O	2.02
K_2O	0.04
TiO_2	1.47
P_2O_5	0.13
MnO	0.19
LOI	1.9
H_2O^+	0.85
H_2O^-	N.D.
CO_2	0.66



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

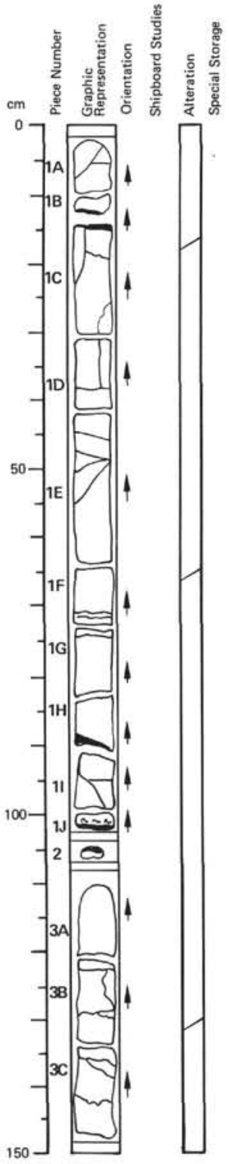
LEG		SITE			HOLE	CORE		SECT.	
5	2	4	1	7	D	6	2		2

Visual Description

Highly phyric pillow basalt with glassy chilled margins in pieces 1-3, 6A, 7A, 7C and 7D. Groundmass mottled. Subhedral plagioclase phenocrysts 15-20%, < 10 mm; pyroxene phenocrysts 5%; altered olivine phenocrysts 5%. Round vesicles 1%, filled by calcite and green smectite. Veins and small vugs filled with calcite, clay and pyrite.

Shipboard Data

Magnetic Data:	101-103 cm
NRM Intensity (emu/cc)	1.38×10^{-3}
NRM Inclination	-19.9°
Stable Inclination	-18.8°
Physical Property Data:	33-35 cm
$\overline{V}p$ (km/sec)	5.49
Porosity (%)	7.4
Wet Bulk Density (g/cc)	2.775
Grain Density (g/cc)	2.91

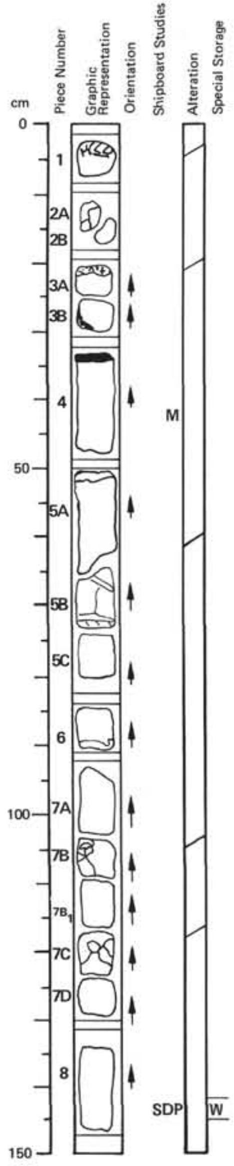


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	62	3

Visual Description

Moderately to highly phyric pillow basalt with glassy chilled margins locally replaced by smectite in pieces 1B, 1C, 1H, 1J and 2. Groundmass mottled with glomerocrysts and patches of glass. Plagioclase phenocrysts 8-10%, <4 mm; augite phenocrysts 2-4%; olivine phenocrysts 2-4%, <2 mm, replaced by smectite; plagioclase and olivine phenocrysts commonly occur, and augite phenocrysts exclusively occur, in glomerocrysts <8 mm across. Vesicles 1-2%, filled by calcite or by calcite with a smectite lining. Veins in pieces 1A, 1F, 3A and 3C filled by smectite, calcite and sulfides. Sulfides also occur as dispersed grains <5 mm across.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

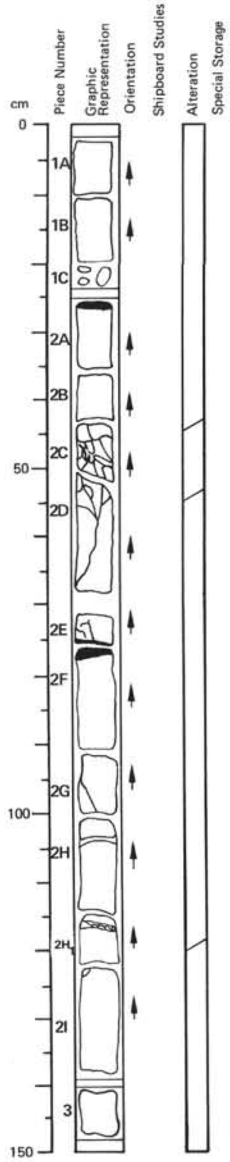
LEG	SITE	HOLE	CORE	SECT.
52	417	D	62	4

Visual Description

Highly phyric pillow basalt with glassy chilled margins in pieces 3B and 4. Groundmass mottled due to presence of glomerocrysts, patches of glass and variations in extent of crystallization. Plagioclase phenocrysts 10%, <4 mm; augite phenocrysts 3%; olivine phenocrysts 3%, <2 mm, replaced by smectite; plagioclase, augite and olivine phenocrysts commonly occur in glomerocrysts <8 mm across but plagioclase and olivine also occur as isolated phenocrysts. Veins filled by smectite, calcite and sulfides. Sulfides also occur as disseminated grains.

Shipboard Data

Magnetic Data:	42-44 cm
NRM Intensity (emu/cc)	9.69×10^{-3}
NRM Inclination	-17.8°
Stable Inclination	-23.5°
Physical Property Data:	142-144 cm
$\bar{V}p$ (km/sec)	5.96
Porosity (%)	4.8
Wet Bulk Density (g/cc)	2.865
Grain Density (g/cc)	2.97

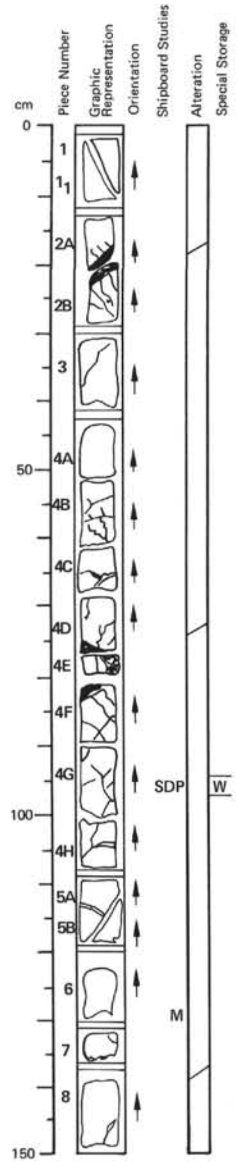


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	62	5

Visual Description

Highly phyric pillow basalt with glassy chilled margins in pieces 2A, 2E and 2F. Groundmass mottled due to presence of glomerocrysts,patches of glass and variations in extent of crystallization. Plagioclase phenocrysts 10%, <4 mm; augite phenocrysts 3%; olivine phenocrysts 3%, <4 mm, replaced by smectite; plagioclase, augite and olivine phenocrysts commonly occur in subophitic glomerocrysts <12 mm across but plagioclase and olivine also occur as isolated phenocrysts. Calcite-filled vesicles 1%. Veins in pieces 2H and $2H_1$ filled by smectite and calcite +sulfides. *Interval between 45-55 cm display incipient brecciaton.*



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

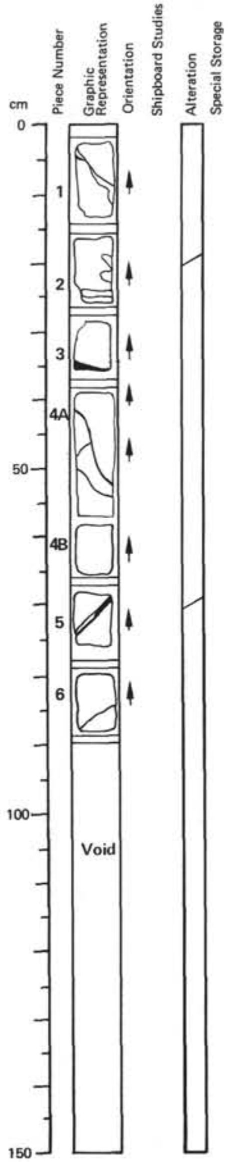
LEG	SITE	HOLE	CORE	SECT.
52	417	D	62	6

Visual Description

Highly phyric basalt pillows with glassy chilled margins in piece 2 and 4D-4F. 0-20, 20-80 and 80-150 cm intervals represent complete pillow or parts of pillows. Groundmass mottled. Plagioclase phenocrysts 15%, <8 mm, commonly in glomerocrysts with pyroxene or as isolated crystals; pyroxene phenocrysts 8%, <5 mm, in glomerocrysts with plagioclase or as isolated crystals; altered olivine phenocrysts 3%, <4 mm. Vesicles 3-5%, 1 mm, filled by calcite and green smectite. Veins filled by clay, calcite and pyrite.

Shipboard Data

Magnetic Data:	128-130 cm
NRM Intensity (emu/cc)	4.71×10^{-3}
NRM Inclination	-23.2°
Stable Inclination	-27.8°
Physical Property Data:	96-98 cm
$\overline{V}p$ (km/sec)	5.38
Porosity (%)	8.4
Wet Bulk Density (g/cc)	2.815
Grain Density (g/cc)	2.94

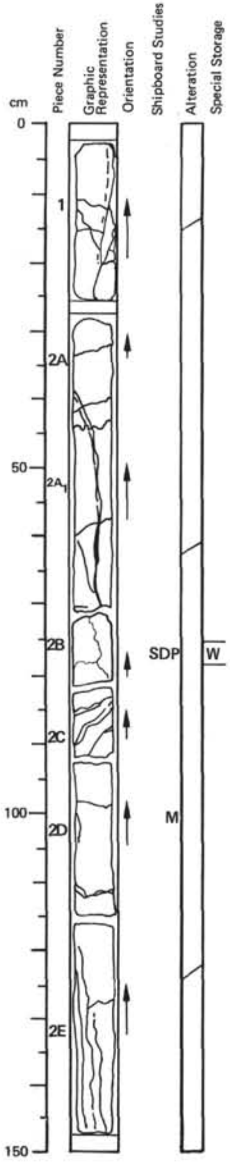


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	62	7

Visual Description

Highly phyric pillow basalt with a glassy chilled margin in piece 3. Groundmass mottled due to presence of subophitic glomerocrysts, patches of glass and variations in extent of crystallization. Plagioclase phenocrysts 10%; augite phenocrysts 3%; olivine phenocrysts 3%, replaced by smectite; augite occurs as isolated phenocrysts, plagioclase and olivine as isolated phenocrysts and glomerocrysts. Piece 6 contains numerous (2%) vesicles filled by calcite or smectite. Sulfides are common throughout section as disseminated grains as large as 8 mm in diameter (piece 2) and in locally complex veins with calcite and smectite (pieces 1 and 5).



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

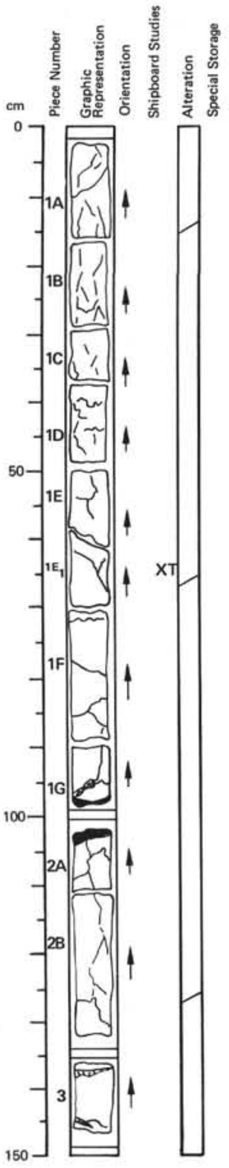
LEG	SITE	HOLE	CORE	SECT.
52	417	D	63	1

Visual Description

Moderately to highly phyric basalt. Groundmass increases in grain size from fine-grained in pieces 1 and 2A to medium- or coarse-grained in pieces $2A_1$-2E. Plagioclase phenocrysts 8-15%, 4-7 mm; augite phenocrysts 1-5%, 1-4 mm; altered olivine phenocrysts 1-5%, 1-8 mm; phenocrysts subhedral to euhedral, increase in size and abundance in pieces $2A_1$-2E. Pieces 1 and 2A contain numerous (3%) vesicles <2 mm across filled by calcite, opal and zeolites. Veins filled by natrolite, by calcite with a lining of dark green smectite containing small (≤1 mm) grains of pyrite, or by calcite and yellow montmorillonite (piece 2C).

Shipboard Data

Magnetic Data:	104-106 cm
NRM Intensity (emu/cc)	8.57×10^{-3}
NRM Inclination	+35.7°
Stable Inclination	-34.5°
Physical Property Data:	75-77 cm
$\bar{V}p$ (km/sec)	5.94
Porosity (%)	4.6
Wet Bulk Density (g/cc)	2.817
Grain Density (g/cc)	2.95



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE			SECT.	
5	2	4	1	7	D		6	3		2

Visual Description

Highly phyric basalt with chilled margins in piece 1G and 2A. Piece 1 represents base of cooling unit described in previous section. Groundmass altered along veins filled by calcite (piece 1) or by calcite and minor sulfides (pieces 2 and 3). Plagioclase and pyroxene phenocrysts common in piece 1, decrease slightly in abundance in pieces 2 and 3; pyroxene phenocrysts concentrated in piece 1F due to crystal settling(?). Pieces 2 and 3 contain numerous (10%) vesicles filled with calcite(?).

Thin Section Description

Location: 65 cm, flow interior

Texture: subophitic

Phenocrysts: olivine 2%, 1 mm, euhedral; plagioclase laths 15%, 1-3 mm; clinopyroxene, 2%, 1-2 mm, anhedral

Groundmass: olivine 10%, 0.1 mm, euhedral; plagioclase 40%, 1.0 mm, euhedral; clinopyroxene 20%, 0.05 mm, anhedral; pyrite 10%

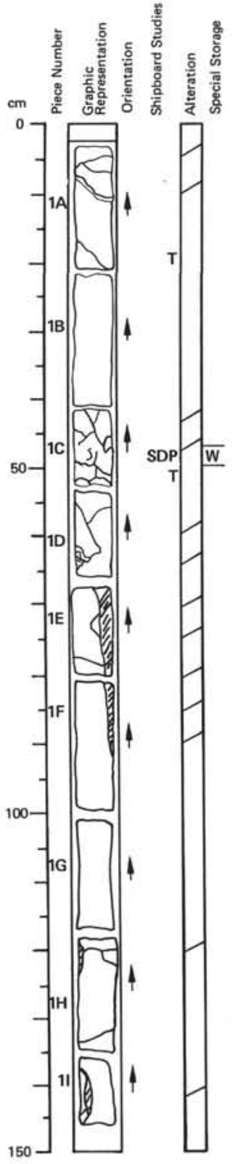
Vesicles: none

Alteration: olivine replaced by clay

Shipboard Data

Bulk Analysis: 64-66 cm

SiO_2	49.30
Al_2O_3	16.50
Fe_2O_3	10.70
MgO	5.31
CaO	13.40
Na_2O	1.93
K_2O	0.03
TiO_2	1.43
P_2O_5	0.15
MnO	0.19
LOI	1.7
H_2O^+	1.01
H_2O^-	N.D.
CO_2	0.38



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE			SECT.	
5	2	4	1	7	D		6	3		3

Visual Description

Highly phyric basalt. Groundmass altered along fractures and veins, increasingly coarse-grained toward center of section. Basalt mottled in appearance due to presence of glomerocrysts, patches of glass and variations in extent of crystallization. Plagioclase phenocrysts 10%, <8 mm; augite phenocrysts 3%; olivine phenocrysts 3%, <4 mm, replaced by smectite; plagioclase, augite and olivine occur commonly as glomerocrysts <10 mm across, less frequently as isolated crystals. Vesicles common (3%) in piece 1. Veins often large (<2 cm across) and complex, with fillings of smectite, calcite and sulfides. Thick veins at 53 and 70-90 cm contain abundant sulfides and quartz(?), respectively.

Thin Section Description

Location: 18 cm

Texture: variolitic

Phenocrysts: plagioclase laths 20%, 1.5-3 mm; clinopyroxene 2%, <1 mm, anhedral

Groundmass: olivine 10%, 0.03 mm; plagioclase 30%, 0.1 mm; clinopyroxene 38%, 0.03 mm; magnetite 5%, 0.01 mm; pyrite 5%, 0.02 mm

Vesicles: <1%, 0.3 mm filled by calcite

Alteration: veins filled by calcite, clay, zeolites and silica

Thin Section Description

Location: 53 cm, next to glassy margin

Texture: intersertal

Phenocrysts: plagioclase laths 10%, <4 mm

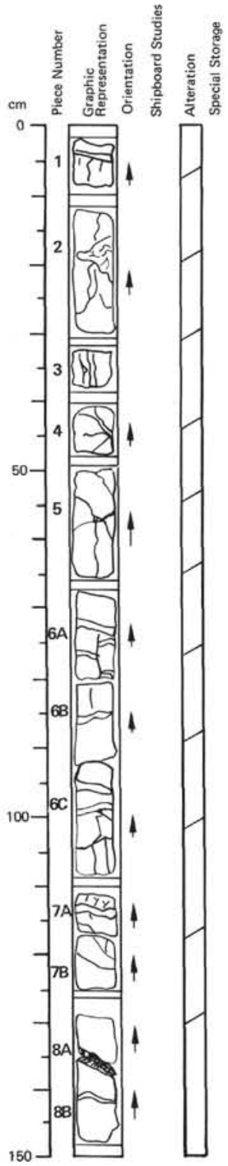
Groundmass: olivine 10%, 0.1 mm; plagioclase 15%, 0.5 mm; clinopyroxene 10%, 0.1 mm; magnetite 5%, 0.02 mm; glass 50%; pyrite <1%

Vesicles: none

Alteration: olivine and glass replaced by clay. Veins filled by smectite, silica and pyrite

Shipboard Data

Physical Property Data:	48-50 cm
$\overline{V}p$ (km/sec)	4.82
Porosity (%)	22.2
Wet Bulk Density (g/cc)	2.53
Grain Density (g/cc)	2.94

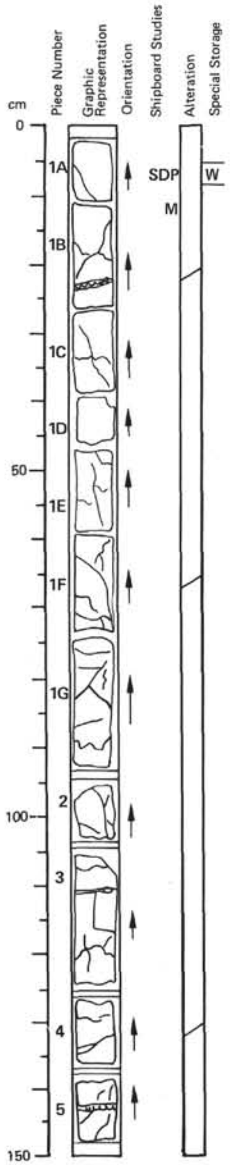


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	63	4

Visual Description

Highly phyric basalt with glassy chilled margins in pieces 8A and 8B. Basalt moderately altered with an aphanitic to fine-grained, groundmass. Plagioclase, augite and altered olivine phenocrysts 15%, 3% and 4%, respectively; augite phenocrysts occur exclusively in glomerocrysts with plagioclase, while plagioclase and olivine occur both in glomerocrysts and as isolated euhedral phenocrysts. Vesicles 1-2%, <2 mm, filled with calcite, opal(?) and zeolites and occasionally lined with pyrite. Veins <2 cm wide, filled by calcite with linings of smectite and inclusions of pyrite and chalcopyrite (piece 5).



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

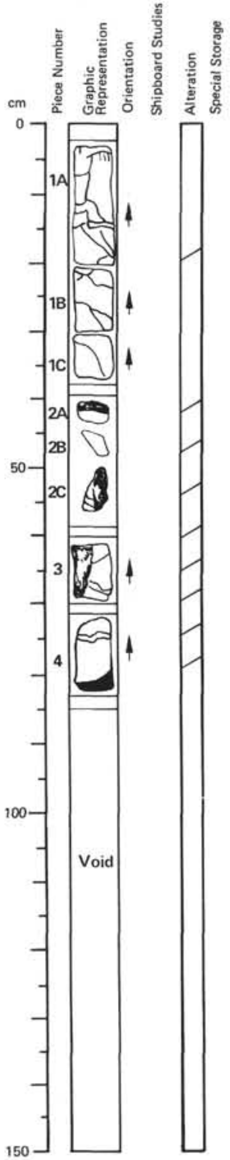
LEG	SITE	HOLE	CORE	SECT.
52	417	D	63	5

Visual Description

Highly phyric basalt. Phenocrysts consist of plagioclase and pyroxene with pyroxene tending to be concentrated in pieces 3 and 4. Vesicles rare below piece 1. Thin veins filled by calcite and sulfides.

Shipboard Data

Magnetic Data:	12-14 cm
NRM Intensity (emu/cc)	22.37×10^{-3}
NRM Inclination	-38.6°
Stable Inclination	-39.9°
Physical Property Data:	6-8 cm
$\bar{V}p$ (km/sec)	5.30
Porosity (%)	10.1
Wet Bulk Density (g/cc)	2.775
Grain Density (g/cc)	2.96

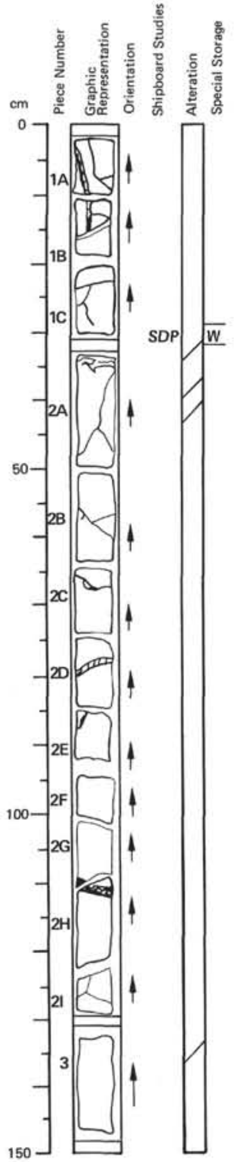


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	63	6

Visual Description

Highly phyric pillow basalt with thick glassy chilled margins in pieces 2A, 2C, 3 and 4. Pillow margins highly phyric, partially (50%) replaced by smectite. Groundmass mottled due to presence of subophitic clots. Plagioclase phenocrysts 10%, < 15 mm; augite phenocrysts 3%, <5 mm; altered olivine phenocrysts 3%, <5 mm. Complex veins filled by smectite, calcite and minor sulfides.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

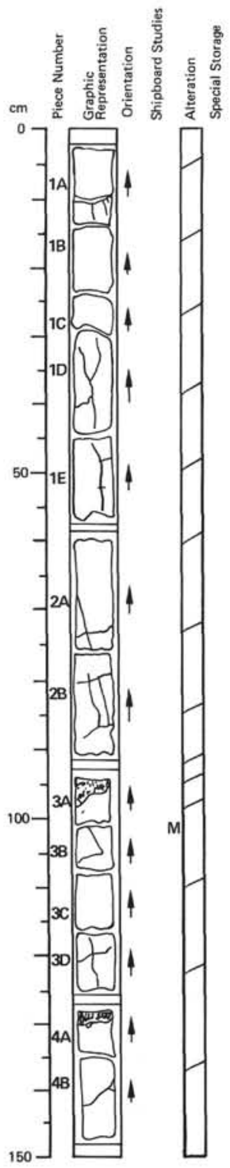
LEG	SITE	HOLE	CORE	SECT.
52	417	D	64	1

Visual Description

Highly phyric pillow basalt with prophyritic, glassy margins in pieces 2G and 2H. Groundmass mottled in appearance due to presence of subophitic glomercrysts, patches of glass and variations in extent of crystallization. Plagioclase phenocrysts 10%, < 15 mm; augite phenocrysts 3%, <5 mm; altered olivine phenocrysts 3%, <5 mm. Calcite-filled vesicles common at top and bottom of section. Complex veins filled by smectite, calcite and sulfides.

Shipboard Data

Physical Property Data:	30-32 cm
$\overline{V}p$ (km/sec)	5.20
Porosity (%)	10.0
Wet Bulk Density (g/cc)	2.76
Grain Density (g/cc)	2.93



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

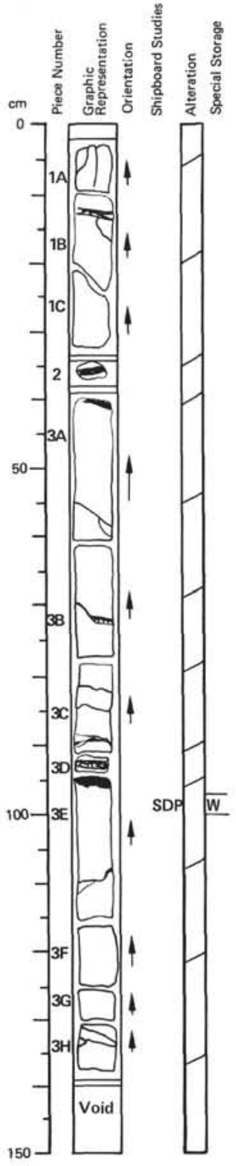
LEG	SITE	HOLE	CORE	SECT.
52	417	D	64	2

Visual Description

Highly phyric pillow basalt with a 2 cm-thick, glassy chilled margin in piece 4A. Groundmass moderately altered. Plagioclase phenocrysts 15%; anhedral augite phenocrysts 3%, commonly in glomerocrysts with plagioclase; altered olivine phenocrysts 2%. Vesicles < 1% in pieces 1-3, increase to 3% in piece 4. Veins filled by pyrite or by calcite with smectite margins containing pyrite grains and crystal < 3 mm across. Piece 3A contains a large filling of montmorillonite with calcite inclusions.

Shipboard Data

Magnetic Data:	102-104 cm
NRM Intensity (emu/cc)	11.63×10^{-3}
NRM Inclination	-25.8°
Stable Inclination	-43.2°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

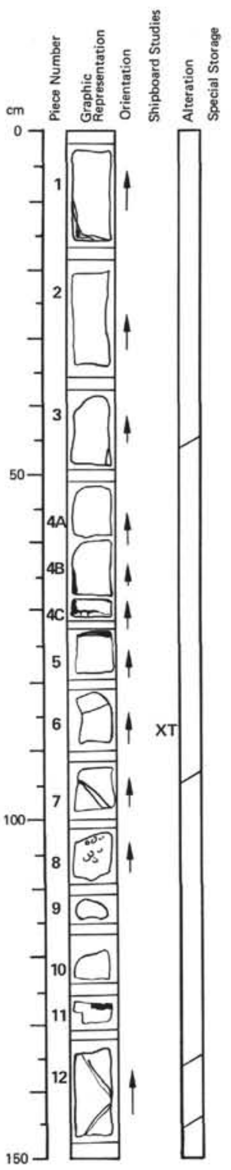
LEG	SITE	HOLE	CORE	SECT.
52	417	D	64	3

Visual Description

Highly phyric pillow basalt with porphyritic, glassy chilled margins in pieces 2, 3A, 3D and 3E. Pillow interiors moderately altered, margins partially (50%) replaced by smectite. Basalt mottled in appearance due to presence of glomerocrysts ≤ 15 mm across, patches of glass and variations in extent of crystallization. Plagioclase phenocrysts 10-15%, ≤ 15 mm; augite phenocrysts 3%; olivine phenocrysts 3%, replaced by smectite. Numerous complex veins filled by calcite, smectite, sulfides and quartz. Piece 3F consists entirely of a large vein filling.

Shipboard Data

Physical Property Data:	99-101 cm
$\overline{V}p$ (km/sec)	5.39
Porosity (%)	7.8
Wet Bulk Density (g/cc)	2.81
Grain Density (g/cc)	2.93



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	64	4

Visual Description

Moderately to highly phyric pillow basalt with chilled glassy margins in pieces 4B-5 and 11; 74-124 cm interval represents an anomalous aphyric pillow with a porphyritic upper margin. Groundmass aphanitic to fine-grained. Plagioclase phenocrysts 10%; clinopyroxene phenocrysts 2-3%, 2-3 mm, commonly with plagioclase in subophitic clots <7 mm across; olivine phenocrysts 2%, 2-3 mm, replaced by smectite and sulfides. Vesicles in pieces 1-4 and 10-12 <1%, <1 mm, filled by calcite and smectite with a lining of pyrite; vesicles in pieces 5-9, 3-5%, filled by smectite. Sulfides occur as vein fillings and as disseminated grains in the groundmass.

Thin Section Description

Location: 88 cm

Texture: tachylytic

Phenocrysts: olivine <1%, <0.2 mm, euhedral, quenched; plagioclase laths <2%, <0.4 mm

Groundmass: plagioclase needles 10%; clinopyroxene 20%, <0.03 mm, fibrous bundles; magnetite 5-10%, <0.03 mm, euhedral; devitrified glass 50%

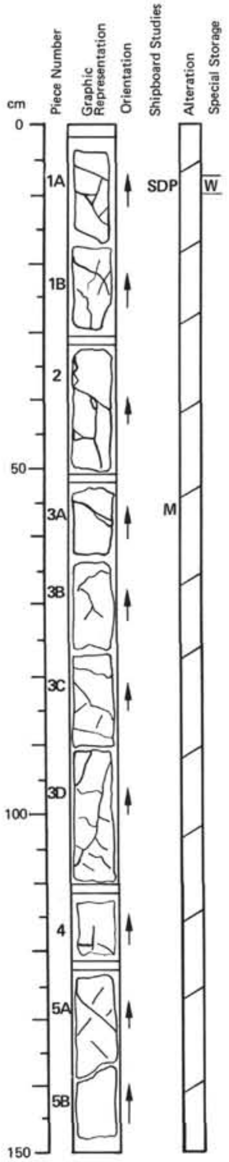
Vesicles: <1%, <0.3 mm spherical with calcite fillings

Alteration: olivine replaced by calcite

Shipboard Data

Bulk Analysis: 87-89 cm

SiO_2	50.30
Al_2O_3	14.40
Fe_2O_3	12.00
MgO	7.69
CaO	11.90
Na_2O	2.13
K_2O	0.04
TiO_2	1.66
P_2O_5	0.16
MnO	0.22
LOI	1.1
H_2O^+	0.56
H_2O^-	N.D.
CO_2	0.06



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	64	5

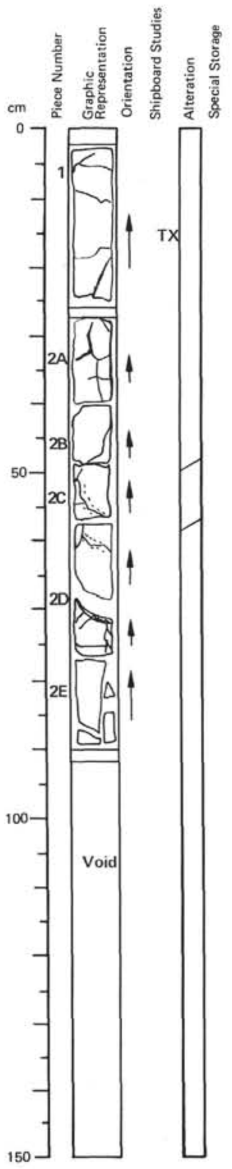
Visual Description

Moderately to highly phyric, massive basalt with a moderately altered, fine-grained groundmass. Plagioclase phenocrysts 10-15%, <6 mm; anhedral augite phenocrysts 3%, <3 mm, in glomerocrysts with plagioclase; euhedral olivine phenocrysts 1-3%, <3 mm, replaced by smectite. Vesicles 1-1.5%, filled by calcite, opal(?), zeolites and smectite. Numerous veins filled by calcite, smectite, montmorillonite and pyrite.

Shipboard Data

Magnetic Data:	56-58 cm
NRM Intensity (emu/cc)	11.82×10^{-3}
NRM Inclination	-38.1°
Stable Inclination	-46.5°

Physical Property Data:	9-11 cm
$\overline{V}p$ (km/sec)	5.31
Porosity (%)	9.4
Wet Bulk Density (g/cc)	2.74
Grain Density (g/cc)	2.90



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	64	6

Visual Description

Moderately phyric, massive basalt with a moderately altered groundmass. Plagioclase and pyroxene phenocrysts total 15% with plagioclase predominating over pyroxene. Vesicles 2-3%, decrease slightly in abundance with depth. Veins filled by calcite, green smectite and minor sulfides.

Thin Section Description

Location: 16 cm, flow interior

Texture: intersertal, quenched

Phenocrysts: olivine 3%, <2 mm, euhedral to skeletal; plagioclase 12%, <5 mm, euhedral laths with altered glass inclusions

Groundmass: plagioclase 35%, seriate laths; clinopyroxene 35%, <0.1 mm; magnetite 5%, <0.05 mm, euhedral; glass 10%

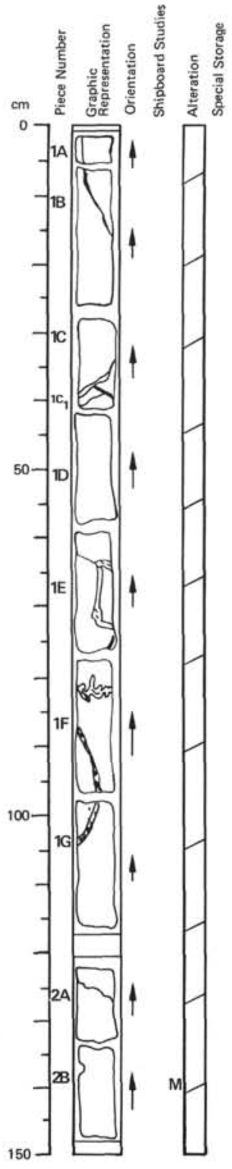
Vesicles: 1%, <1.0 mm, complex 3-phase fillings

Alteration: olivine and glass replaced by calcite and clay

Shipboard Data

Bulk Analysis: 15-17 cm

SiO_2	50.10
Al_2O_3	16.40
Fe_2O_3	10.86
MgO	6.63
CaO	12.90
Na_2O	2.10
K_2O	0.02
TiO_2	1.39
P_2O_5	0.16
MnO	0.18
LOI	1.7
H_2O^+	0.70
H_2O^-	N.D.
CO_2	0.11



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

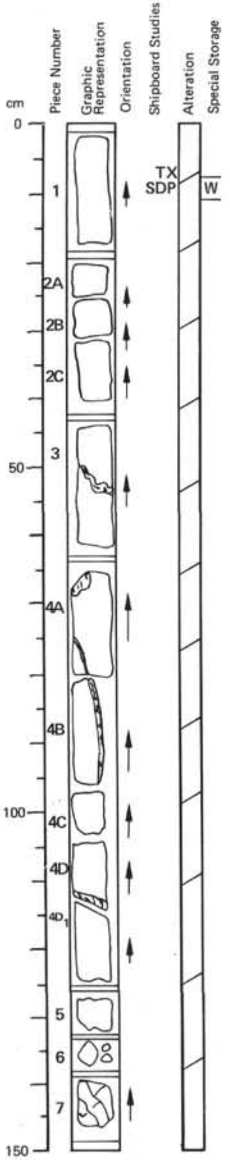
LEG	SITE	HOLE	CORE	SECT.
52	417	D	65	1

Visual Description

Moderately to highly phyric, massive basalt. Basalt moderately altered with a fine-grained, intersertal groundmass containing glomerocrysts of plagioclase and clinopyroxene. Plagioclase and clinopyroxene phenocrysts total 10%, <5 mm and <2 mm, respectively; altered olivine phenocrysts 5%. Vesicles <1 mm, filled with calcite and smectite. Numerous veins filled by calcite , smectite and sulfides. Sulfides also occur as disseminated grains.

Shipboard Data

Magnetic Data:	138-140 cm
NRM Intensity (emu/cc)	5.58 x 10^{-3}
NRM Inclination	+22.1°
Stable Inclination	-46.3°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	2	4	1	7	D	6	5		2

Visual Description

Moderately to highly phyric, massive basalt. Basalt moderately altered with a fine-grained, intersertal groundmass. Plagioclase phenocrysts 10%, <4 mm; clinopyroxene phenocrysts 5%, <2 mm, in glomerocrysts with plagioclase; olivine phenocrysts <5%, replaced by smectite and calcite. Numerous veins filled by smectite, calcite and sulfides. Vesicles filled by calcite and lined by smectite present throughout section, increase to 1-2%, 1-2 mm in pieces 4A-4C.

Thin Section Description

Location: 8 cm, flow interior

Texture: highly phyric, intergranular, quenched

Phenocrysts: olivine 3%, 0.5-3 mm, euhedral, in glomerocrysts with plagioclase; plagioclase 12%, 0.5-4 mm, euehdral to subhedral; clinopyroxene <1%, 1 mm, anhedral, occasionally in rounded megacrysts with plagioclase

Groundmass: olivine 2%, 0.08-1 mm, euhedral; plagioclase 35%, 0.05 mm, euhedral laths; clinopyroxene 35%, 0.05 mm, anhedral-subhedral; magnetite 3%, 0.03 mm; glass 10%

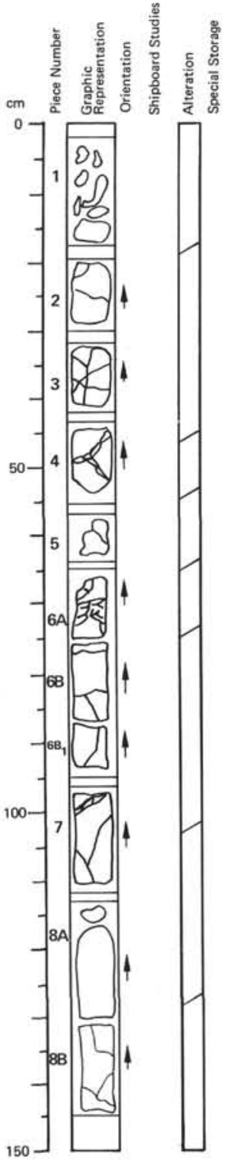
Vesicles: <1%, 0.1 mm, filled by calcite and smectite

Alteration: veins filled by clay; olivine replaced by smectite and calcite; glass replaced by clay

Shipboard Data

Bulk Analysis: 7-9 cm	
SiO_2	50.30
Al_2O_3	16.10
Fe_2O_3	10.83
MgO	6.43
CaO	13.80
Na_2O	1.93
K_2O	0.03
TiO_2	1.87
P_2O_5	0.15
MnO	0.19
LOI	1.8
H_2O^+	0.51
H_2O^-	N.D.
CO_2	0.92

Physical Property Data:	7-9 cm
$\overline{V}p$ (km/sec)	5.93
Porosity (%)	5.2
Wet Bulk Density (g/cc)	2.875
Grain Density (g/cc)	2.97

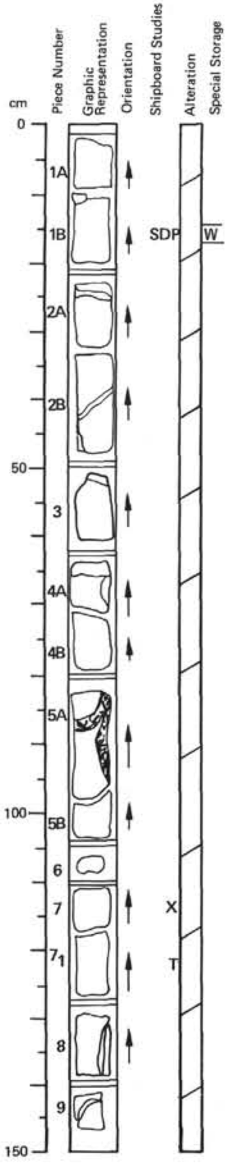


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	2	4	1	7	D	6	5		3

Visual Description

Highly phyric, massive(?) basalt. Groundmass fine-grained, moderately altered along veins. Basalt mottled in appearance due to the uneven distribution of glomerocrysts and phenocrysts and to variations in groundmass texture. Plagioclase phenocrysts 10%, <8 mm, occasionally contain small (0.1 mm) inclusions of fresh glass; augite phenocrysts 3%, commonly in glomerocrysts <5 mm across; olivine phenocrysts 3%, <4 mm, replaced by smectite. Vesicles rare. Veins filled by smectite, or less commonly, by smectite, calcite and sulfides. Piece 6 displays incipient(?) brecciation.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	65	4

Visual Description

Highly phyric, moderately altered pillow(?) basalt with an aphyric chilled margin in piece 5A. Groundmass ranges from fine-grained with an intersertal texture in pieces 1-3 and 56-9 to very fine-grained in pieces 4A-5A near pillow margin. Plagioclase, pyroxene and olivine phenocrysts total 20-25%; plagioclase phenocrysts <5 mm; pyroxene phenocrysts <2 mm, commonly in glomerocrysts with plagioclase; altered olivine phenocrysts <4 mm, locally >5% (piece 2B). Veins filled by smectite, calcite and sulfides.

Thin Section Description

Location: 123 cm, flow interior

Texture: highly phyric, intergranular

Phenocrysts: olivine 3%, 0.5-1.6 mm, euhedral; plagioclase 16%, 1-1.5 mm, euhedral; clinopyroxene 1%, 0.5-0.8, subhedral, commonly in glomerocrysts with plagioclase

Groundmass: olivine 2%, 0.06 mm, euhedral; plagioclase 40%, 0.1 mm, euhedral; clinopyroxene 35%, 0.06-0.08 mm, subhedral; glass and opaques 5%

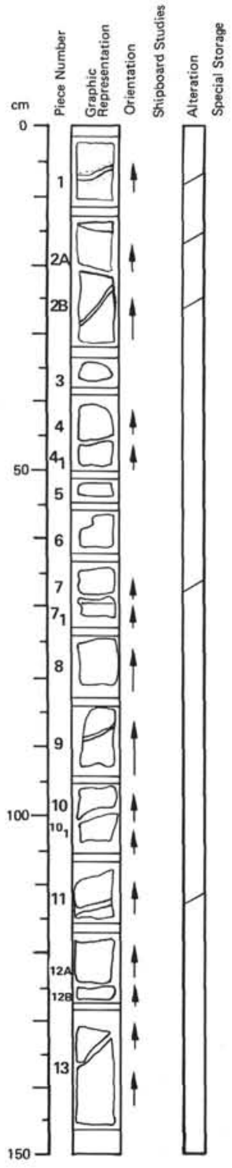
Vesicles: <1%, 0.5 mm, filled by smectite

Alteration: olivine replaced by calcite and smectite; glass replaced by clay

Shipboard Data

Bulk Analysis: 127-129 cm	
SiO_2	49.70
Al_2O_3	16.60
Fe_2O_3	11.22
MgO	6.94
CaO	12.80
Na_2O	2.00
K_2O	0.05
TiO_2	1.36
P_2O_5	0.13
MnO	0.19
LOI	1.5
H_2O^+	0.51
H_2O^-	N.D.
CO_2	0.06

Physical Property Data:	15-17 cm
$\overline{V}p$ (km/sec)	5.96
Porosity (%)	5.2
Wet Bulk Density (g/cc)	2.89
Grain Density (g/cc)	2.96

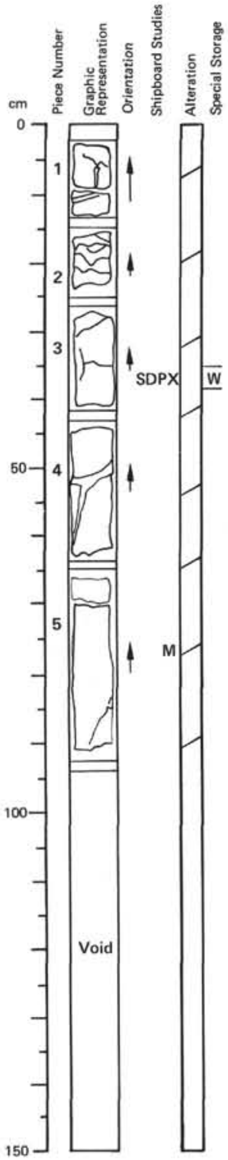


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	65	5

Visual Description

Moderately to highly phyric, massive basalt. Groundmass medium-grained. Plagioclase phenocrysts and glomerocrysts of plagioclase and clinopyroxene total 10-15%, <10 mm across with a mean of 2-3 mm; olivine phenocrysts 2-3%, 1-2 mm, replaced by smectite. Vesicles rare, filled by smectite. Veins filled by dark green smectite, sulfides and minor quartz.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	65	6

Visual Description

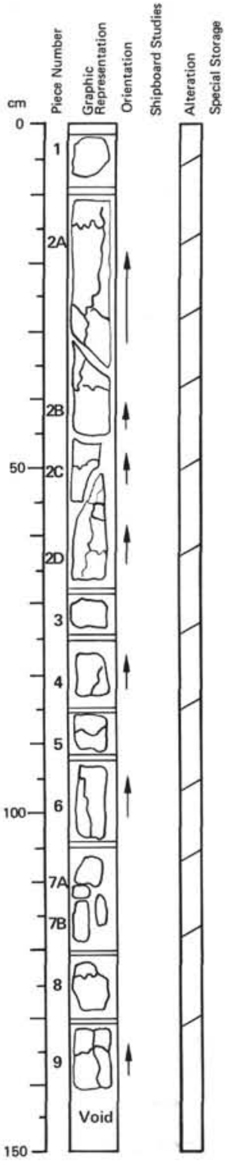
Highly phyric, massive basalt with a moderately altered, coarse-grained groundmass. Plagioclase phenocrysts 10%, ≤7 mm; augite phenocrysts 3%, in glomerocrysts with plagioclase; olivine phenocrysts 5%, ≤5 mm, replaced by smectite. Veins filled by smectite, montmorillonite, calcite and pyrite.

Shipboard Data

Bulk Analysis: 37-39 cm	
SiO_2	48.80
Al_2O_3	16.90
Fe_2O_3	9.97
MgO	7.11
CaO	12.60
Na_2O	1.95
K_2O	0.03
TiO_2	1.12
P_2O_5	0.12
MnO	0.16
LOI	1.7
H_2O^+	1.09
H_2O^-	N.D.
CO_2	0.10

Magnetic Data:	75-77 cm
NRM Intensity (emu/cc)	6.45×10^{-3}
NRM Inclination	+60.2°
Stable Inclination	–54.1°

Physical Property Data:	37-39 cm
$\overline{V}p$ (km/sec)	5.72
Porosity (%)	8.5
Wet Bulk Density (g/cc)	2.78
Grain Density (g/cc)	2.95

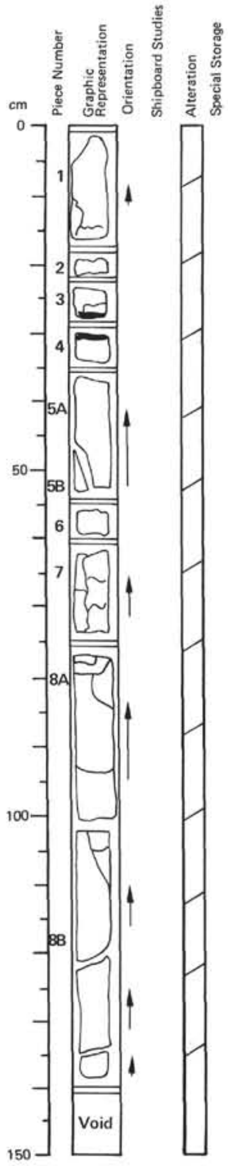


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	66	1

Visual Description

Moderately to highly phyric pillow(?) basalt. Basalt moderately altered with a fine-grained, intersertal groundmass. Plagioclase phenocrysts <5 mm; clinopyroxene phenocrysts < 1.5 mm, in glomerocrysts with plagioclase; olivine phenocrysts <5 mm, replaced by smectite and calcite; phenocrysts total 10-15% in pieces 1-6, increase to 15-20% in pieces 7-9. Vesicles filled by calcite and smectite range in size from 0.5-2.0 mm, increase from 1% in pieces 1-7 to 2% in pieces 8 and 9. Numerous veins filled by smectite, calcite and minor sulfides.

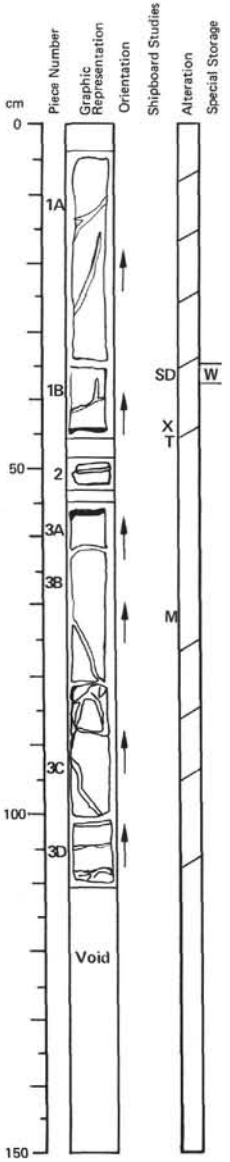


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	66	2

Visual Description

Highly phyric, moderately altered pillow basalt with chilled margins in pieces 3 and 4. Groundmass ranges from fine-grained with an intersertal texture in pieces 1 and 5-8 to very fine-grained or aphanitic in pieces 2-4. Plagioclase, clinopyroxene and olivine phenocrysts total 15-20%; plagioclase <5 mm, occurs as isolated phenocrysts and in glomerocrysts with clinopyroxene; olivine phenocrysts <5 mm, replaced by smectite and calcite. Vesicles filled by calcite and smectite rare in pieces 1-6, increase to 1-2%, in pieces 7 and 8. Numerous veins filled by calcite and smectite. Sulfides common as grains in smectite.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	66	3

Visual Description

Moderately to highly phyric pillow basalt with glassy chilled margins in pieces 1B, 2 and 3A. Basalt moderately altered with a fine- to medium-grained groundmass which decreases in grain size with depth. Plagioclase phenocrysts occur as isolated crystals and in glomerocrysts with clinopyroxene <8 mm across; olivine phenocrysts 2-3%, 1 mm, occasionally in glomerocrysts 2-3 mm across. Calcite-filled vesicles 1-2%, 0.5-1.0 mm in piece 3, absent in pieces 1 and 2. Veins filled by calcite ±quartz(?) or by smectite and sulfides. Piece 3D contains slickensides in smectite with a plunge of 25-30°.

Thin Section Description

Location: 45 cm, pillow interior

Texture: quenched, variolitic

Phenocrysts: olivine 3%, <3 mm, euhedral to skeletal; plagioclase 12%, <5 mm, skeletal laths with many inclusions (including traces of spinel), commonly in glomerocrysts with olivine

Groundmass: plagioclase 30%, seriate skeletal laths; clinopyroxene 40%, <0.05 mm, fibrous to granular; magnetite 5%, <0.02 mm, euhedral; glass 10%

Vesicles: <1%, filled by calcite and clay

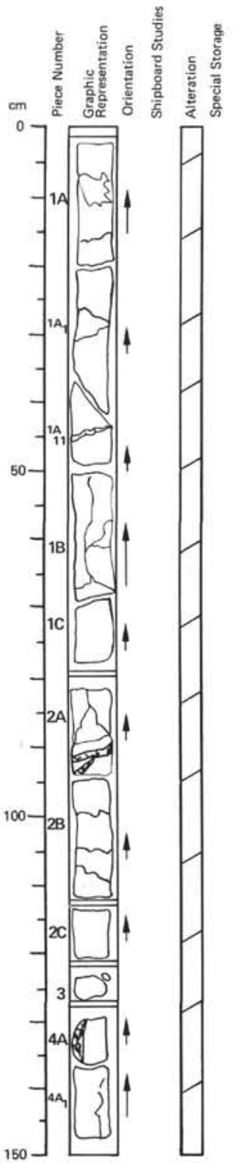
Alteration: olivine and glass replaced by smectite

Shipboard Data

Bulk Analysis: 44-46 cm	
SiO_2	50.60
Al_2O_3	16.50
Fe_2O_3	11.04
MgO	6.72
CaO	12.90
Na_2O	1.98
K_2O	0.03
TiO_2	1.36
P_2O_5	0.20
MnO	0.19
LOI	1.1
H_2O^+	0.78
H_2O^-	N.D.
CO_2	0.03

Magnetic Data:	70-72 cm
NRM Intensity (emu/cc)	4.75×10^{-3}
NRM Inclination	19.9
Stable Inclination	53.7

Physical Property Data:	35-37 cm
$\overline{V}p$ (km/sec)	5.94
Wet Bulk Density (g/cc)	2.87

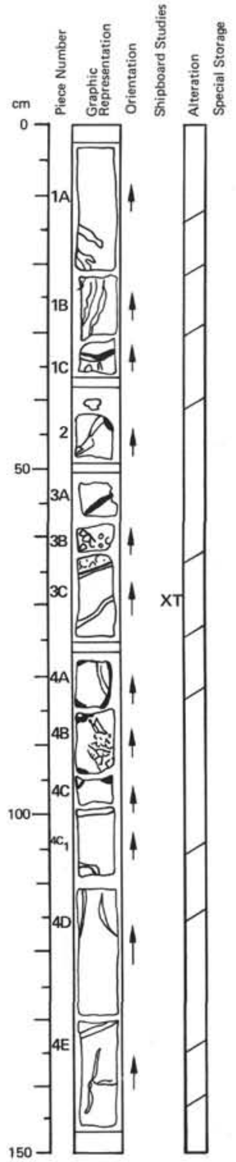


VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	66	4

Visual Description

Highly phyric, moderately altered pillow basalt with a chilled margin in piece 4A. Groundmass fine-grained with an intersertal texture. Plagioclase, clinopyroxene and olivine phenocrysts total 25%; plagioclase phenocrysts ≤5 mm, occur as isolated cyrstals and in glomerocrysts with clinopyroxene; clinopyroxene phenocrysts ≤ 1.5 mm; olivine phenocrysts ≤5 mm, replaced by smectite and calcite. Rare vesicles filled by smectite and calcite. Numerous veins filled by smectite, calcite and sulfides or more rarely, by smectite with a core of calcite. Sulfides occur throughout section as disseminated grains.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	66	5

Visual Description

Moderately to highly phyric pillow basalt with glassy chilled margins in pieces 1C-4C and breccia in pieces 2, 3 and 4B. Groundmass fine-grained. Phenocrysts consist of plagioclase, clinopyroxene and olivine with plagioclase and clinopyroxene commonly occurring in glomerocrysts ≤ 10 mm across. Veins filled by smectite and calcite ± quartz and irregular patches of sulfides. Breccia composed of basalt fragments in a network of smectite veins.

Thin Section Description

Location: 70 cm, pillow interior

Texture: moderately phyric, pilotaxitic(?)

Phenocrysts: olivine <1%, 0.6-1 mm, euhedral; plagioclase 10%, 0.5-4 mm, euhedral-subhedral

Groundmass: olivine 2%; plagioclase, clinopyroxene and magnetite 88%

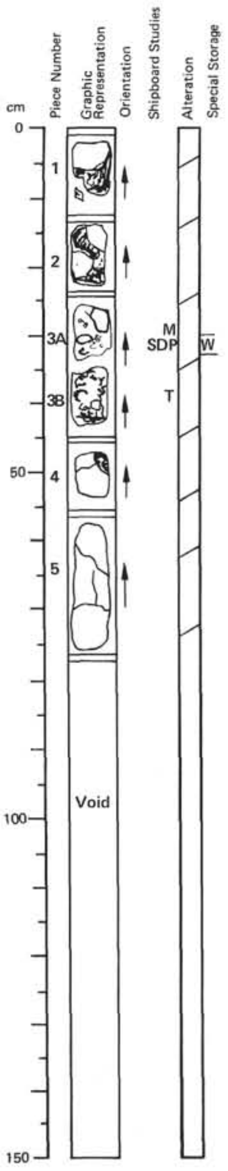
Vesicles: 2%, 0.3-0.5 mm; filled by calcite, smectite and zeolites(?); some filling crescentic

Alteration: olivine replaced by calcite and clay; glass(?) replaced by clay

Shipboard Data

Bulk Analysis: 69-73 cm

SiO_2	49.20
Al_2O_3	17.50
Fe_2O_3	10.08
MgO	5.46
CaO	14.00
Na_2O	2.06
K_2O	0.02
TiO_2	1.37
P_2O_5	0.14
MnO	0.17
LOI	1.9
H_2O^+	1.05
H_2O^-	N.D.
CO_2	0.48



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 2	4 1 7	D	6 6	6

Visual Description

Highly phyric pillow basalt with a chilled glassy margin in piece 4 and a broken pillow breccia containing fragments of fresh glass in pieces 1-3. Groundmass aphanitic to fine-grained with an intersertal texture. Plagioclase, clinopyroxene and olivine phenocrysts total 20%; plagioclase phenocrysts <5 mm; clinopyroxene phenocrysts <2 mm; olivine phenocrysts <3 mm, replaced by smectite and calcite. Numerous veins filled by smectite and calcite. Breccia composed of fragmented glassy pillow margins in a matrix of clay and calcite.

Thin Section Description

Location: 39 cm, hyaloclastite

Texture: glassy, phyric

Phenocrysts: olivine 1%, skeletal; plagioclase 3%, euhedral to skeletal with many glass inclusions

Groundmass: glass 96%, fresh with some palagonite and smectite

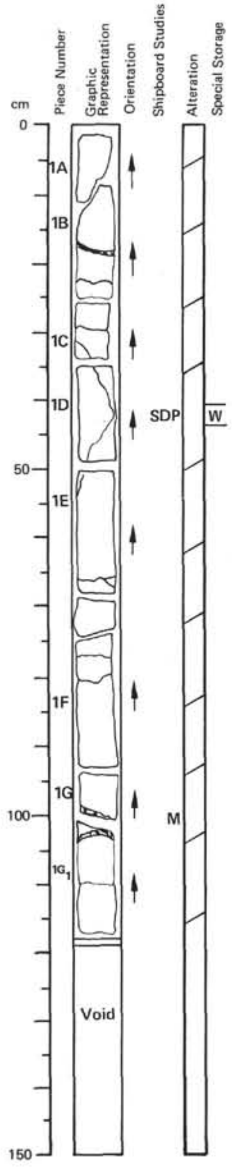
Vesicles: none

Alteration: none

Shipboard Data

Magnetic Data:	29-31 cm
NRM Intensity (emu/cc)	10.04×10^{-3}
NRM Inclination	-81.8°
Stable Inclination	-80.7°

Physical Property Data:	30-32 cm
$\overline{V}p$ (km/sec)	4.53
Porosity (%)	20.5
Wet Bulk Density (g/cc)	2.41
Grain Density (g/cc)	2.81



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 2	4 1 7	D	6 7	1

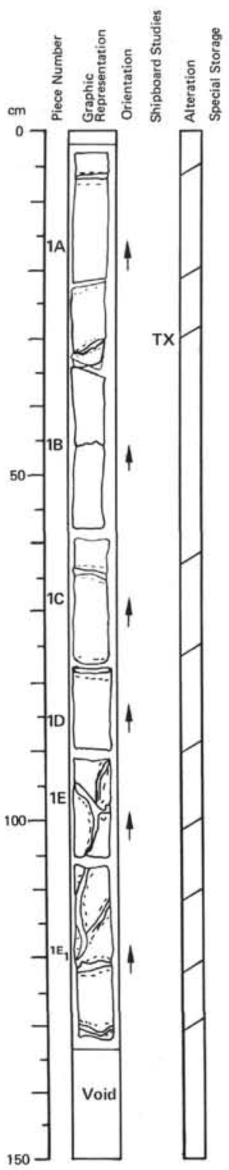
Visual Description

Moderately phyric, massive basalt. Basalt moderately altered with a fine-grained, intersertal groundmass. Plagioclase phenocrysts total 13%; plagioclase phenocrysts <5 mm, occur as isolated crystals and in glomerocrysts with clinopyroxene; clinopyroxene phenocrysts <4 mm; olivine phenocrysts common, <5 mm, replaced by smectite and calcite. Veins filled by smectite with minor calcite and sulfides.

Shipboard Data

Magnetic Data:	112-114 cm
NRM Intensity (emu/cc)	2.72×10^{-3}
NRM Inclination	+55.2°
Stable Inclination	-46.7°

Physical Property Data:	42-44 cm
$\overline{V}p$ (km/sec)	5.92
Porosity (%)	4.0
Wet Bulk Density (g/cc)	2.885
Grain Density (g/cc)	2.96



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	67	2

Visual Description

Highly phyric, massive basalt with a medium-grained groundmass. Plagioclase phenocrysts 12%, <8 mm, occur as isolated crystals and in glomerocrysts with clinopyroxene; clinopyroxene phenocrysts 3%, 0.5-2.0 mm; olivine phenocrysts replaced by smectite 2-3%, 1-2 mm, particularly abundant in pieces 1A, 1B and 1D. Veins filled by calcite, smectite, quartz and sulfides in decreasing order of abundance. Smectite, calcite and sulfides also present as irregular patches in groundmass. Section continuous with Sections 1 and 3.

Thin Section Description

Location: 30 cm, flow interior

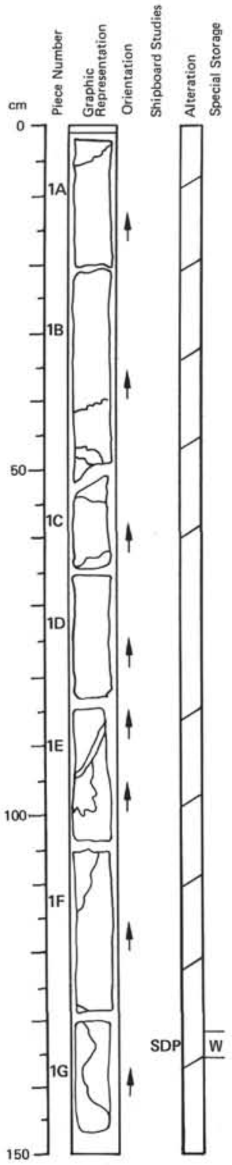
Texture: intersertal

Phenocrysts: olivine 3%, <5 mm, skeletal; zoned plagioclase laths 7%, <5 mm; clinopyroxene <1%, <1 mm, granular, commonly in glomerocrysts

Groundmass: plagioclase 35%, <0.5 mm, elongate microlites; clinopyroxene 40%, <0.1 mm, granular, radiating bundles, magnetite 5%, <0.05 mm, euhedral; glass 10%, devitrified

Vesicles: <1%, <1 mm, filled with devitrified glass and smectite in geopetal structures

Alteration: glass replaced by clay; olivine replaced by clay and traces of silica(?)



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

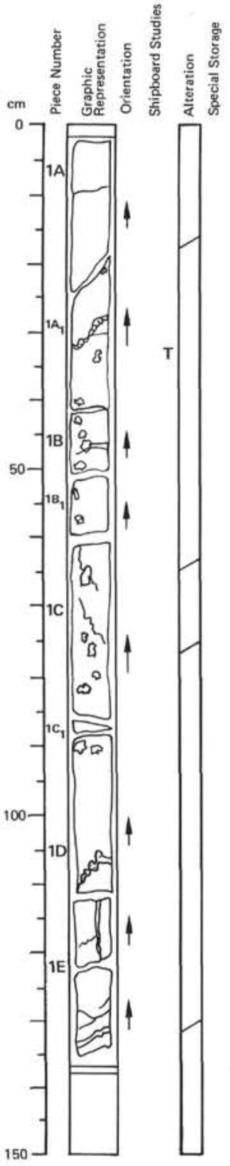
LEG	SITE	HOLE	CORE	SECT.
52	417	D	67	3

Visual Description

Moderately to highly phyric, massive basalt. Basalt moderately altered with a fine-grained, intersertal to holocrystalline groundmass. Plagioclase, clinopyroxene and olivine phenocrysts total 15%; plagioclase phenocrysts <7 mm, occur as isolated crystals and in glomerocrysts with clinopyroxene; euhedral olivine phenocrysts <5 mm, replaced by smectite and calcite, particularly abundant in pieces 1A, 1B, and 1E. Veins filled by smectite, calcite and sulfides. Section continuous with base of Section 2.

Shipboard Data

Physical Property Data:	132-134 cm
$\overline{V}p$ (km/sec)	5.67
Porosity (%)	6.6
Wet Bulk Density (g/cc)	2.805
Grain Density (g/cc)	2.93



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	2	4	1	7	D		6	7	4

Visual Description

Highly phyric, massive basalt with numerous vugs and vesicles distributed unevenly throughout section. Plagioclase phenocrysts 15%, < 15 mm with a mean of 5 mm; altered olivine phenocrysts 5-10%, 2-5 mm; pyroxene phenocrysts <5%. Vesicles and vugs 5-10%, <2 cm, filled by linings of green smectite and cores of calcite, quartz, sulfides and fibrous yellow zeolites(?). Veins filled by smectite and calcite with minor quartz and zeolites. Section continuous with base of Section 3.

Thin Section Description

Location: 32 cm, next to glassy margin

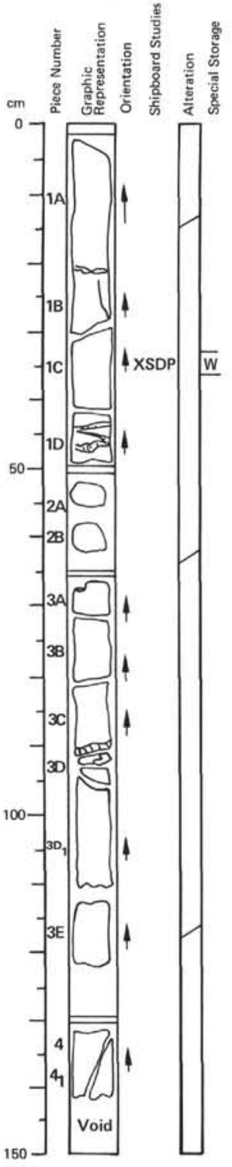
Texture: intersertal

Phenocrysts: olivine 3%, 1 mm, euhedral; plagioclase laths 15%, 5 mm; clinopyroxene 3%, 1 mm, anhedral, commonly in glomerocrysts with plagioclase

Groundmass: olivine 10%; plagioclase 10%; clinopyroxene 40%; magnetite 9%; glass 9%

Vesicles: 1%, up to 3 mm, round to irregular; filled by calcite and smectite

Alteration: olivine replaced by calcite and clay; glass replaced by clay. Veins filled by calcite and clay.



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE		SECT.	
5	2	4	1	7	D		6	7	5

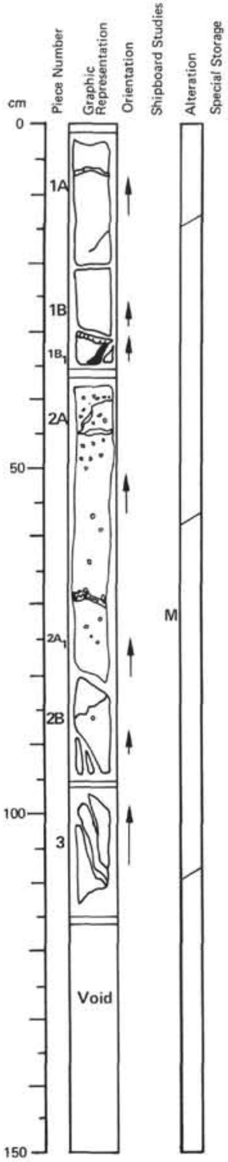
Visual Description

Massive basalt with a moderately phyric, fine-grained groundmass in pieces 2 and 3 and a highly phyric, medium-grained groundmass in pieces 1 and 4. Plagioclase phenocrysts < 15%, < 10 mm; pyroxene phenocrysts <5%, <5 mm; altered olivine phenocrysts 1-7%, 2-8 mm. Vesicles 1%, filled by clay. Veins filled by calcite, clay and sulfides. Section continuous with base of Section 4.

Shipboard Data

Bulk Analysis: 33-35 cm	
SiO_2	49.20
Al_2O_3	16.30
Fe_2O_3	11.22
MgO	7.00
CaO	12.70
Na_2O	1.92
K_2O	0.04
TiO_2	1.34
P_2O_5	0.19
MnO	0.16
LOI	1.4
H_2O^+	0.92
H_2O^-	N.D.
CO_2	0.09

Physical Property Data:	33-35 cm
$\bar{V}p$ (km/sec)	5.94
Porosity (%)	4.9
Wet Bulk Density (g/cc)	2.89
Grain Density (g/cc)	2.95



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	67	6

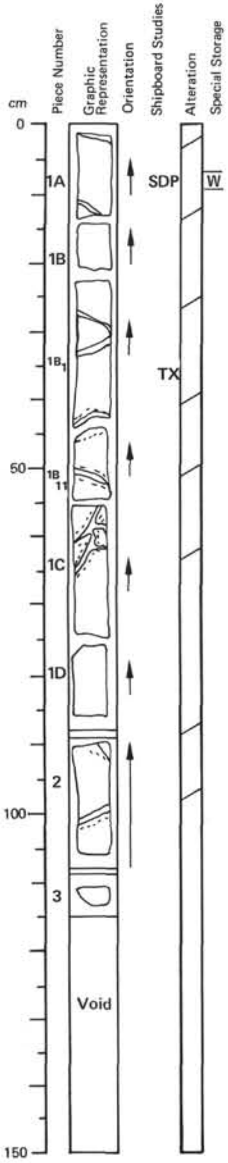
Visual Description

0-35 cm: highly phyric pillow(?) basalt with a chilled margin in pieces 1B and $1B_1$. Plagioclase phenocrysts 15%, < 10 mm; pyroxene phenocrysts to <5%; altered olivine phenocrysts 5%, 5 mm. Veins filled by calcite, zeolites(?) and sulfides.

35-115 cm: sparsely to moderately phyric, massive basalt. Zoned plagioclase phenocrysts 5-7%, <7 mm; pyroxene phenocrysts rare. Vesicles 2-5% in piece 2A, filled with calcite, clay and sulfides. Veins filled by calcite, clay and minor sulfides.

Shipboard Data

Magnetic Data:	72-74 cm
NRM Intensity (emu/cc)	1.67×10^{-3}
NRM Inclination	+42.4°
Stable Inclination	-52.5°



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	67	7

Visual Description

Moderately phyric, massive basalt. Groundmass medium-grained with a granular texture. Plagioclase phenocrysts and glomerocrysts of plagioclase (± clinopyroxene) 10-15%, <8 mm with a mean of 2-3 mm. Vesicles < 1%, 0.5-1.0 mm, filled by calcite, smectite and sulfides. Veins filled by calcite and smectite with minor quartz and sulfides. Sulfides also distributed irregularly throughout groundmass in association with smectite.

Thin Section Description

Location: 36 cm, flow interior

Texture: moderately phyric, subophitic to intergranular

Phenocrysts: plagioclase 10%, 1-5 mm, tablets with inclusions

Groundmass: olivine 3%, 0.1-0.3 mm, euhedral; plagioclase 40%, 0.2-1 mm, euhedral; clinopyroxene 40%, 0.2-1 mm; magnetite 5%, 0.1-0.2 mm, pyrite 0.1%

Vesicles: 0.5%, 1 mm, filled by clay and calcite

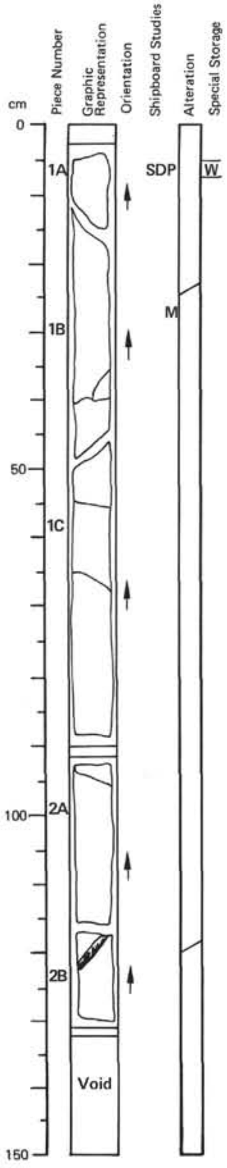
Alteration: olivine glass replaced by calcite and clay; glass replaced by clay

Shipboard Data

Bulk Analysis: 35-37 cm		Physical Property Data:	7-9 cm
SiO_2	50.70	$\overline{V}p$ (km/sec)	5.59
Al_2O_3	16.00	Porosity (%)	5.8
Fe_2O_3	10.53	Wet Bulk Density (g/cc)	2.86
MgO	6.36	Grain Density (g/cc)	2.94
CaO	12.80		
Na_2O	2.07		
K_2O	0.04		
TiO_2	1.42		
P_2O_5	0.20		
MnO	0.14		
LOI	2.0		
H_2O^+	0.47		
H_2O^-	N.D.		
CO_2	0.06		

VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	68	1



Visual Description

0-117 cm: moderately phyric, massive basalt with a coarse-grained (<0.5 mm), crystalline groundmass composed of plagioclase, augite, altered olivine (rare) and magnetite. Zoned plagioclase phenocrysts 5-10%, < 10 mm, commonly with inclusions
117-130 cm: highly phyric basalt dike with an altered glassy margin between 117-123 cm. Dike contact against country rock (basalt described above) well-preserved, steeply inclined. Plagioclase phenocrysts 10%, <4 mm; augite phenocrysts 5%; altered olivine phenocrysts 5%; augite phenocrysts occur exclusively in glomerocrysts < 10 mm across with plagioclase and olivine; plagioclase and olivine also occur as isolated crystals.

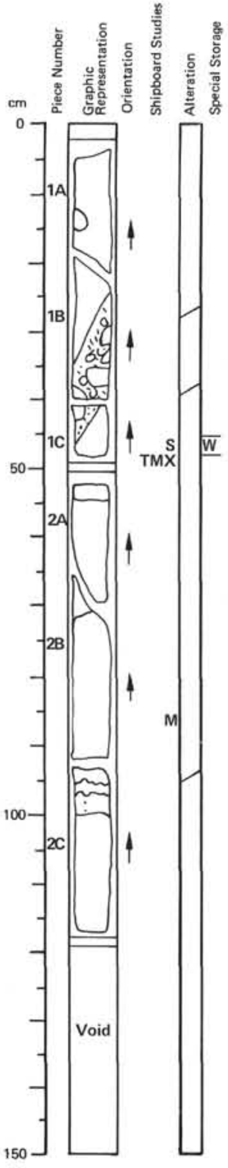
Shipboard Data

Magnetic Data:	27-29 cm
NRM Intensity (emu/cc)	4.91×10^{-3}
NRM Inclination	+73.6°

Physical Property Data:	7-9 cm
$\overline{V}$p (km/sec)	5.84
Porosity (%)	6.54
Wet Bulk Density (g/cc)	2.825
Grain Density (g/cc)	2.95

VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
52	417	D	68	2



Visual Description

0-55 cm: highly phyric, glassy basalt dike with an altered glassy margin at the top of piece 2A and breccia in pieces 1B and 1C. Dike contact against country rock well-preserved, dips at an angle of 75-80°. Plagioclase phenocrysts in dike rock 10%, <6 mm, strongly zoned; altered skeletal olivine phenocrysts < 10%, <4 mm; augite phenocrysts 5%, occur as rounded isolated crystals and in glomerocrysts < 12 mm across with plagioclase and olivine. Breccia composed of fragments of basalt country rock, altered basaltic glass (derived from the dike margins) and palagonite contianing traces of fresh glass.
55-120 cm: moderately phyric, massive basalt with a coarse-grained, crystalline groundmass. Strongly zoned plagioclase phenocrysts 5%, < 10 mm; olivine microphenocrysts 1%. Sulfides present as dispersed grains throughout piece 2.

Thin Section Description

Location: 47 cm, dike

Texture: very fine-grained

Phenocrysts: olivine 5%, < 1 mm, euhedral; plagioclase 35%, <5 mm, occasionally rounded with altered inclusions; clinopyroxene 10%, <2.5 mm, commonly rounded with plagioclase inclusions.

Groundmass: quenched plagioclase laths 20%, <0.02 mm; clinopyroxene 20%, <0.02 mm, quenched fibrous bundles; magnetite 10%, <0.02 mm, quenched, euhedral

Vesicles: none

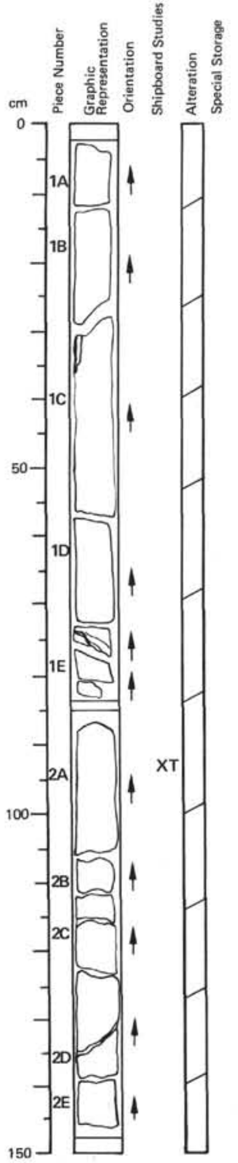
Alteration: olivine replaced by smectite

Shipboard Data

Bulk Analysis: 48-50 cm	
SiO_2	48.30
Al_2O_3	22.00
Fe_2O_3	8.02
MgO	5.20
CaO	12.60
Na_2O	1.94
K_2O	0.06
TiO_2	0.91
P_2O_5	0.09
MnO	0.11
LOI	2.5
H_2O^+	1.17
H_2O^-	N.D.
CO_2	0.03

Magnetic Data:	46-48 cm	84-86 cm
NRM Intensity (emu/cc)	17.12×10^{-3}	2.65×10^{-3}
NRM Inclination	-62.7°	+58.0°
Stable Inclination	-63.5°	

Physical Property Data:	46-48 cm
$\overline{V}$p (km/sec)	5.27



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 2	4 1 7	D	6 8	3

Visual Description

Moderately to highly phyric, massive basalt with a moderately altered, coarse-grained groundmass. Plagioclase phenocrysts 12-18%, occur as small phenocrysts 2-3 mm across and, more rarely, as zoned megacrysts <10 mm across; augite phenocrysts 10%, 2-3 mm; altered euhedral olivine phenocrysts 5%, 2-3 mm. Magnetite common in groundmass. Veins <0.5 mm across, filled by calcite with a smectite lining. Pyrite <1%, 0.2-0.5 mm, occurs as disseminated grains along veins and throughout groundmass.

Thin Section Description

Location: 93 cm, flow interior

Texture: moderately phyric, subophitic

Phenocrysts: plagioclase 8%, 1-10 mm, euhedral with oscillatory zoning

Groundmass: plagioclase 48%, 0.3-0.5 mm, subophitic; clinopyroxene 40%, 0.3-0.5 mm, subophitic; magnetite 3%; apatite, trace

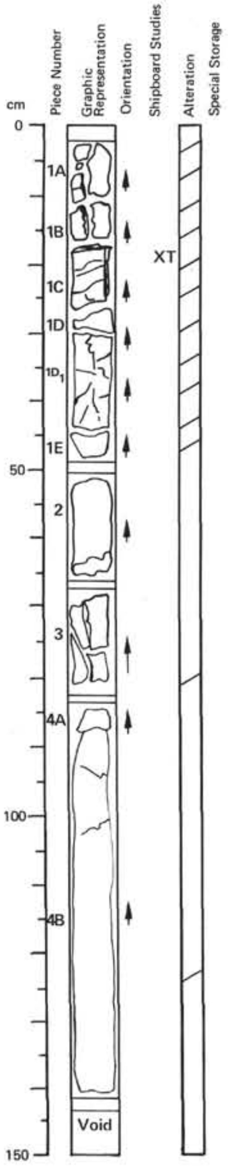
Vesicles: none

Alteration: clinopyroxene replaced by clay

Shipboard Data

Bulk Analysis: 92-94 cm

SiO_2	51.30
Al_2O_3	15.30
Fe_2O_3	11.67
MgO	6.88
CaO	12.10
Na_2O	2.19
K_2O	0.07
TiO_2	1.65
P_2O_5	0.22
MnO	0.15
LOI	1.4
H_2O^+	0.89
H_2O^-	N.D.
CO_2	0.03



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG	SITE	HOLE	CORE	SECT.
5 2	4 1 7	D	6 8	4

Visual Description

Sparsely to highly phyric, massive basalt with an aphanitic to coarse-grained groundmass and altered chilled margins in pieces 1A-1C. Pieces 1A and 1B contain a sharp contact between a highly phyric, coarsely crystalline basalt and a strongly altered, sparsely phyric basalt with an aphanitic to fine-grained groundmass containing occasional phenocrysts of plagioclase, augite and altered olivine. The contact is marked by an altered chilled margin (in the sparsely phyric basalt) and a 5 mm thick vein filled with smectite containing inclusions of altered plagioclase. Pieces 1C-4 represent the upper portion of a massive cooling unit which becomes increasingly coarse-grained and phyric with depth below a 3-4 cm thick chilled margin in piece 1C. Groundmass highly fractured, largely replaced by clay in pieces 1C-1E, moderately altered in pieces 2-4. Plagioclase phenocrysts 8-10%, 3-4 mm in pieces 1C-1E, increase to 15%, <10 mm in pieces 2-4; augite phenocrysts <10%, 1-2 mm, commonly in glomerocrysts with plagioclase; olivine phenocrysts replaced by clay 8-10%, 3-4 mm in pieces 1C-1E, decrease to 1-2 mm in pieces 2-4. Groundmass in pieces 2-4 contains abundant magnetite and occasional crystals of pyrite. Thin veins in pieces 2 and 3 filled by smectite.

Thin Section Description

Location: 19 cm, dike interior

Texture: highly phyric, quenched to intergranular

Phenocrysts: olivine 2%, 1-2 mm, euhedral; plagioclase 15%, 3 mm, euhedral-subhedral; clinopyroxene 3%, 0.5-1 mm, subhedral-anhedral, in rounded megacrysts or in subophitic clots with plagioclase and olivine.

Groundmass: olivine 2%, <0.05 mm; plagioclase 38%, <0.05 mm; clinopyroxene 38%, <0.05 mm; magnetite 2%, <0.05 mm

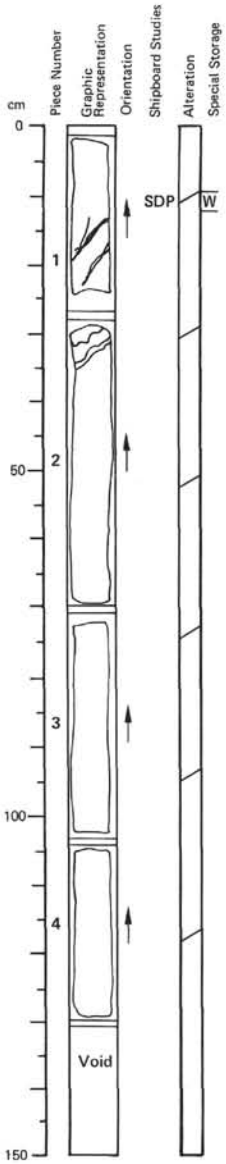
Vesicles: none

Alteration: olivine replaced by smectite and minor pyrite. Veins filled by clay and pyrite.

Shipboard Data

Bulk Analysis: 18-20 cm

SiO_2	50.10
Al_2O_3	15.50
Fe_2O_3	12.00
MgO	7.04
CaO	12.60
Na_2O	8.06
K_2O	0.03
TiO_2	1.50
P_2O_5	0.19
MnO	0.15
LOI	1.0
H_2O^+	0.87
H_2O^-	N.D.
CO_2	0.09



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

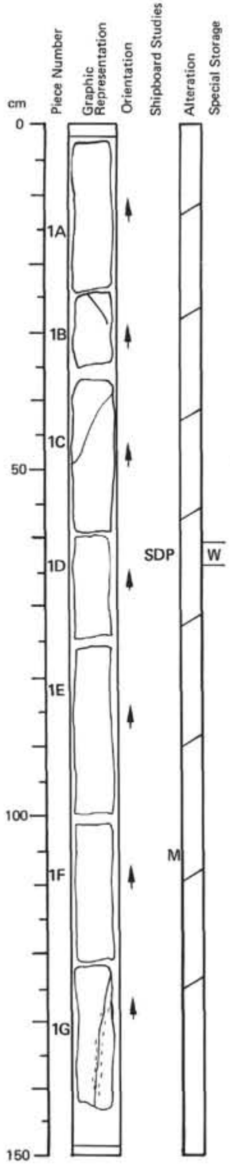
LEG	SITE	HOLE	CORE	SECT.
52	417	D	68	5

Visual Description

Highly phyric, massive basalt. Groundmass partially replaced by smectite. Plagioclase phenocrysts 15%, < 10 mm; augite phenocrysts 10%, < 3 mm; olivine phenocrysts 10%, < 2 mm, replaced by smectite. Magnetite abundant in groundmass as disseminated grains 0.1-0.2 mm across. Veins in pieces 1 and 2 filled by smectite, calcite and occasional grains of pyrite.

Shipboard Data

Physical Property Data:	11-13 cm
$\overline{V}p$ (km/sec)	5.97
Porosity (%)	4.6
Wet Bulk Density (g/cc)	2.90
Grain Density (g/cc)	2.98



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

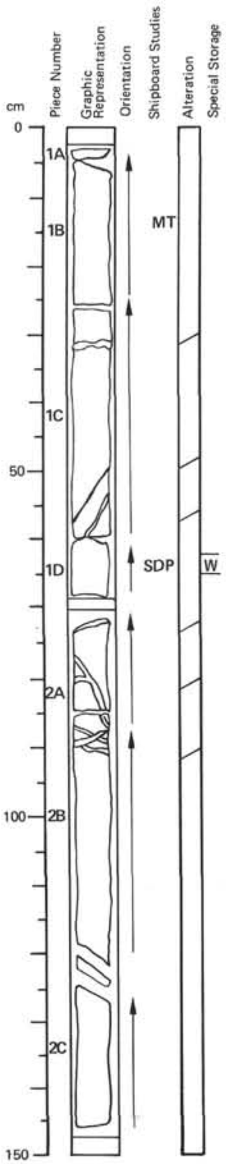
LEG	SITE	HOLE	CORE	SECT.
52	417	D	68	6

Visual Description

Moderately phyric, massive basalt with a doleritic, coarse-grained (0.3-0.8 m) groundmass. Rounded plagioclase phenocrysts 5-10%, 0.5-15 mm, commonly display complex oscillatory zoning, numerous white inclusions and intergrowths with pyroxene microphenocrysts. Groundmass composed of plagioclase, pyroxene, olive-green granules of altered olivine(?), ilmenite(?) and numerous pseudomorphs filled by green or brown smectite(?). Minor veins filled by calcite. Widespread alteration accentuated along veins, appears to be mineral specific, possibly deuteric(?).

Shipboard Data

Magnetic Data:	105-107 cm
NRM Intensity (emu/cc)	5.65×10^{-3}
NRM Inclination	+78.7°
Physical Property Data:	62-64 cm
$\overline{V}p$ (km/sec)	6.13
Porosity (%)	4.1
Wet Bulk Density (g/cc)	2.90
Grain Density (g/cc)	2.98



VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

LEG		SITE			HOLE	CORE			SECT.
5	2	4	1	7	D		6	9	1

Visual Description

Moderately phyric, massive basalt with a holocrystalline, coarse-grained (0.5 mm) groundmass composed of plagioclase, clinopyroxene and fresh(?) olivine. Zoned plagioclase phenocrysts < 10 mm long. Veins filled by calcite or smectite. Sulfides present as disseminated grains throughout veins and groundmass.

Thin Section Description

Location: 13 cm, flow interior

Texture: ophitic

Phenocrysts: olivine 3%, 2 mm, euhedral; plagioclase laths 10%, 5 mm; clinopyroxene 7%, 4 mm, commonly in glomerocrysts with plagioclase

Groundmass: olivine 10%, 0.5 mm; plagioclase 37%, 0.5 mm; clinopyroxene 25%, 0.5 mm; magnetite 8%, 0.5 mm; alkali feldspar < 1%, 0.8 mm; apatite < 1%, as needles in kspar

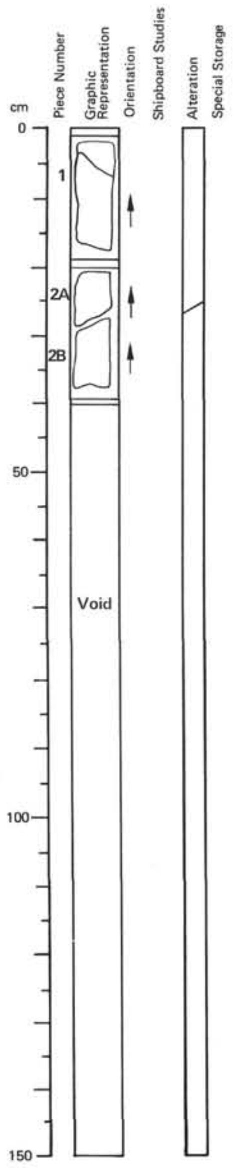
Vesicles: none

Alteration: olivine replaced by clay and calcite; plagioclase and clinopyroxene partially replaced by clay. Thin veins filled by calcite and smectite. Minor pyrite present in clay.

Shipboard Data

Magnetic Data:	12-14 cm
NRM Intensity (emu/cc)	5.44×10^{-3}
NRM Inclination	+72.7°
Stable Inclination	-41.2°

Physical Property Data:	62-64 cm
$\bar{V}p$ (km/sec)	6.10
Porosity (%)	2.9
Wet Bulk Density (g/cc)	2.935
Grain Density (g/cc)	2.98

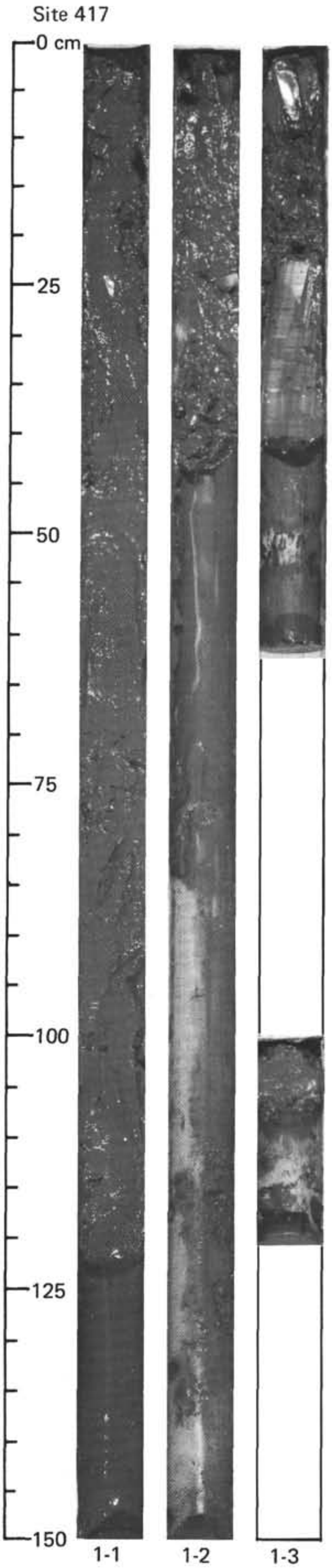


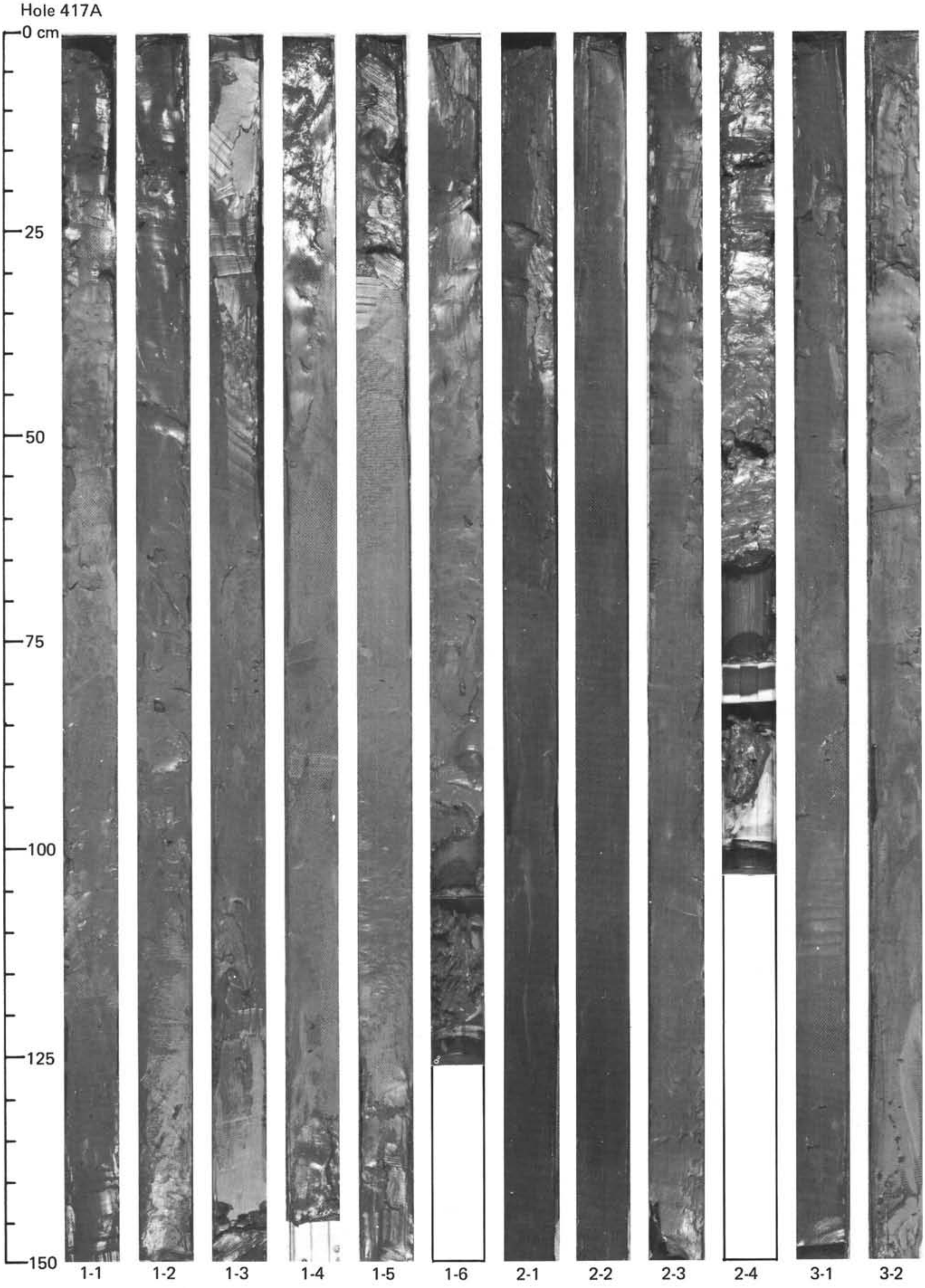
VISUAL CORE DESCRIPTION FOR IGNEOUS ROCKS

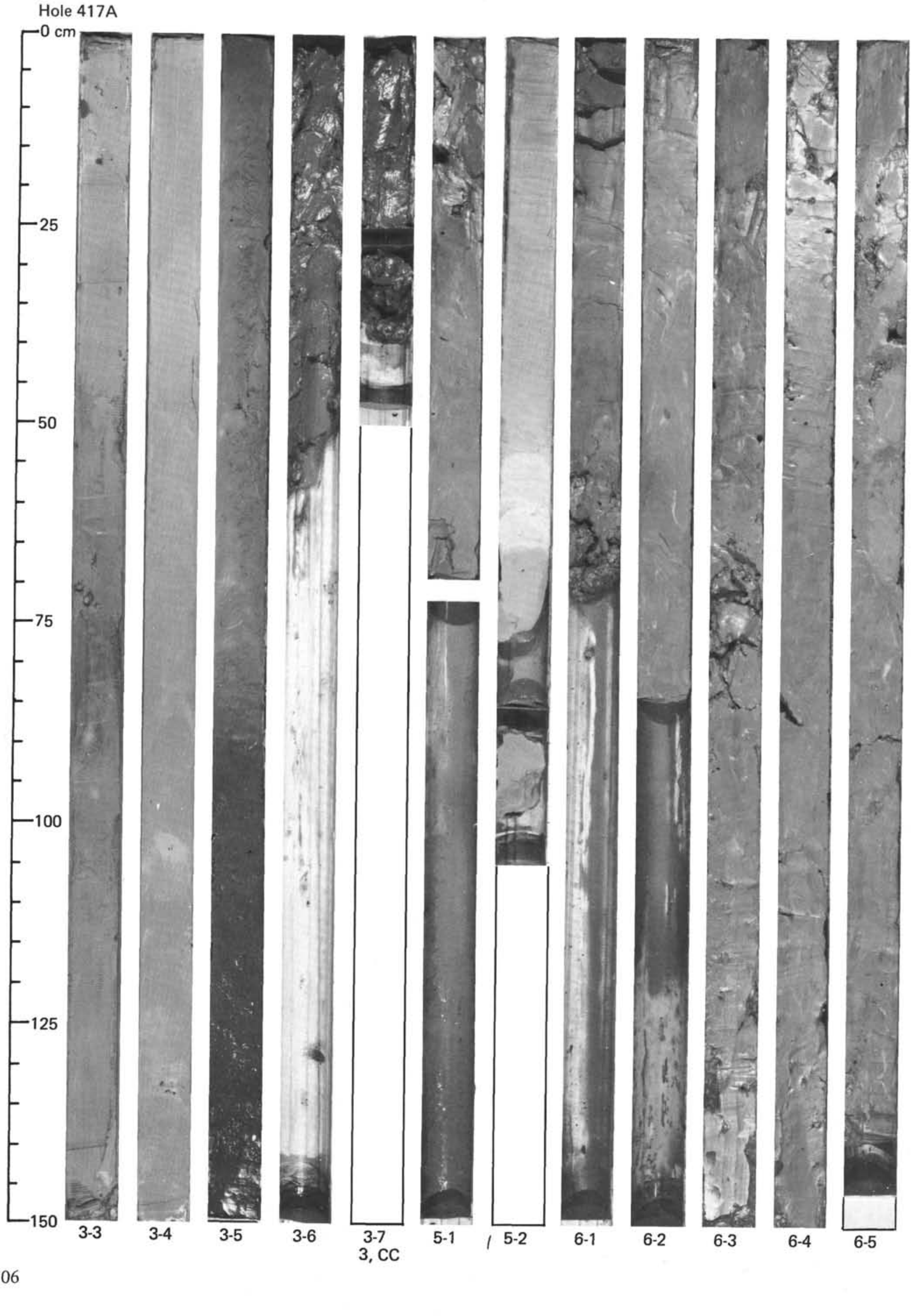
LEG		SITE			HOLE	CORE			SECT.
5	2	4	1	7	D		6	9	2

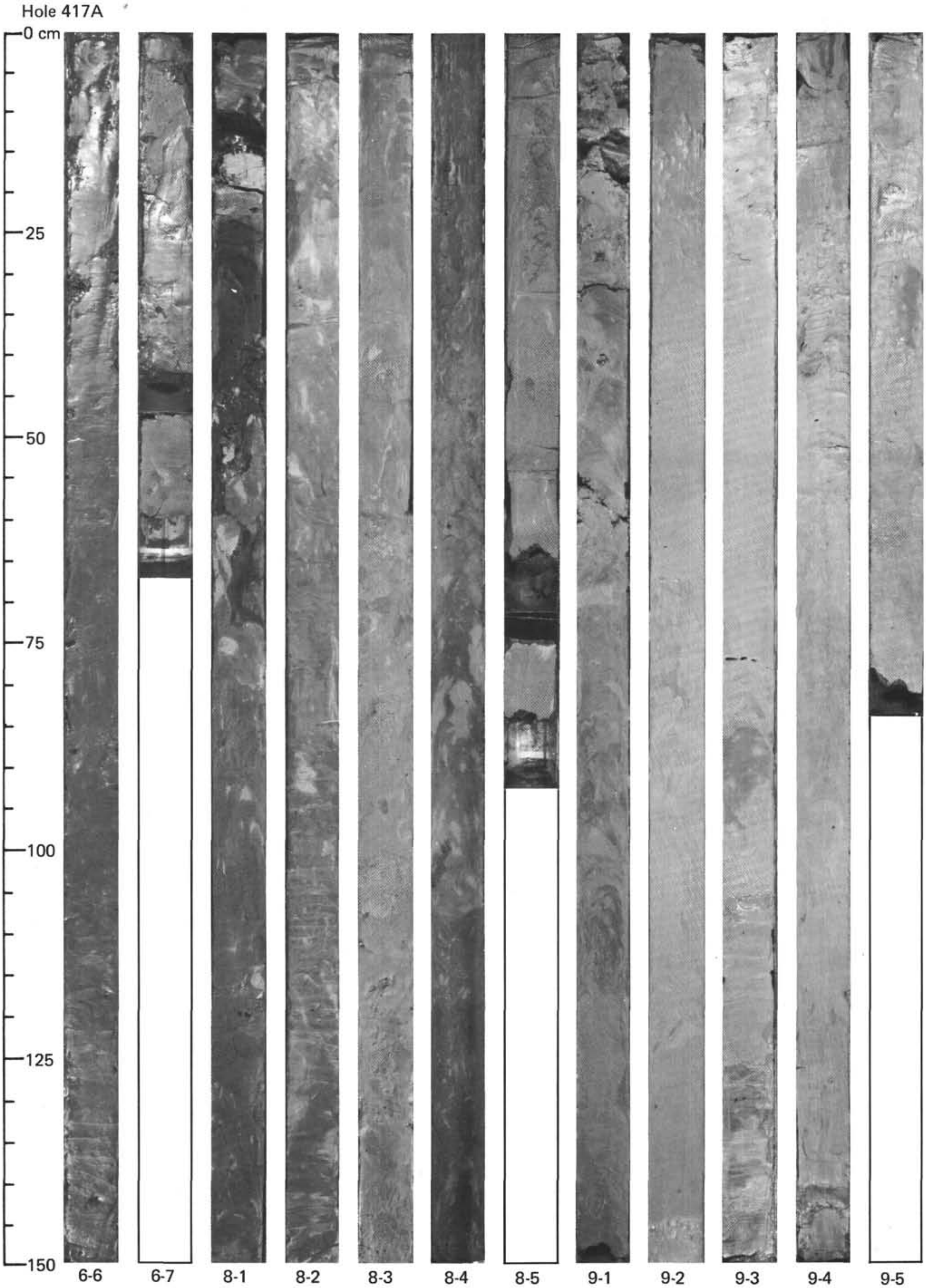
Visual Description

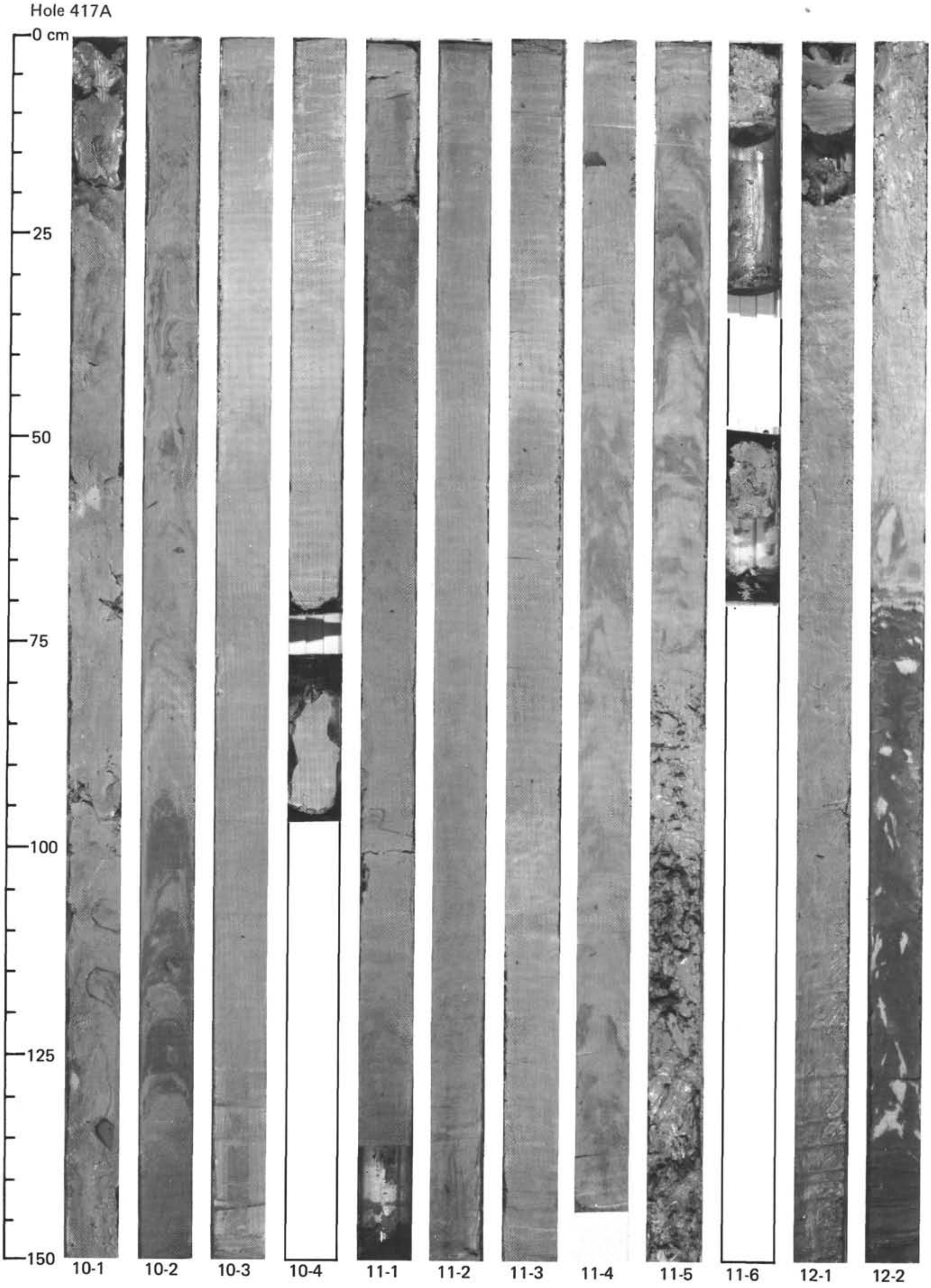
Highly phyric, massive basalt with a coarse-grained (0.5 mm), intersertal to subophitic or holocrystalline groundmass composed of plagioclase, clinopyroxene, partially fresh(?) olivine, magnetite and disseminated sulfides. Zoned plagioclase phenocrysts 15%, < 10 mm; olivine microphenocrysts <0.8 mm. Vein in piece 1 filled by smectite, calcite and sulfides.


Site 417
0 cm
25
50
75
100
125
150
1-1
1-2
1-3

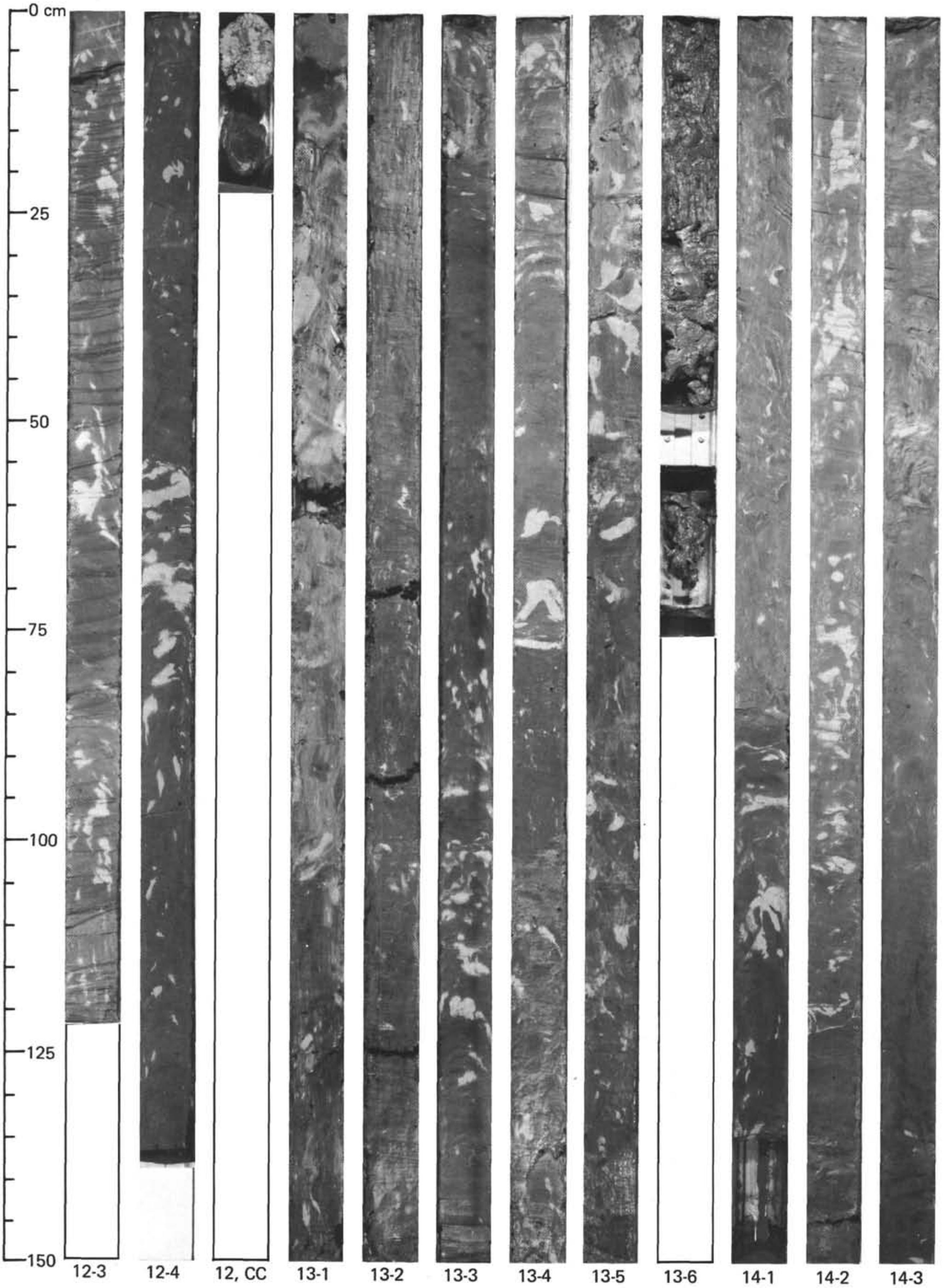

Hole 417A
0 cm
25
50
75
100
125
150
1-1
1-2
1-3
1-4
1-5
1-6
2-1
2-2
2-3
2-4
3-1
3-2

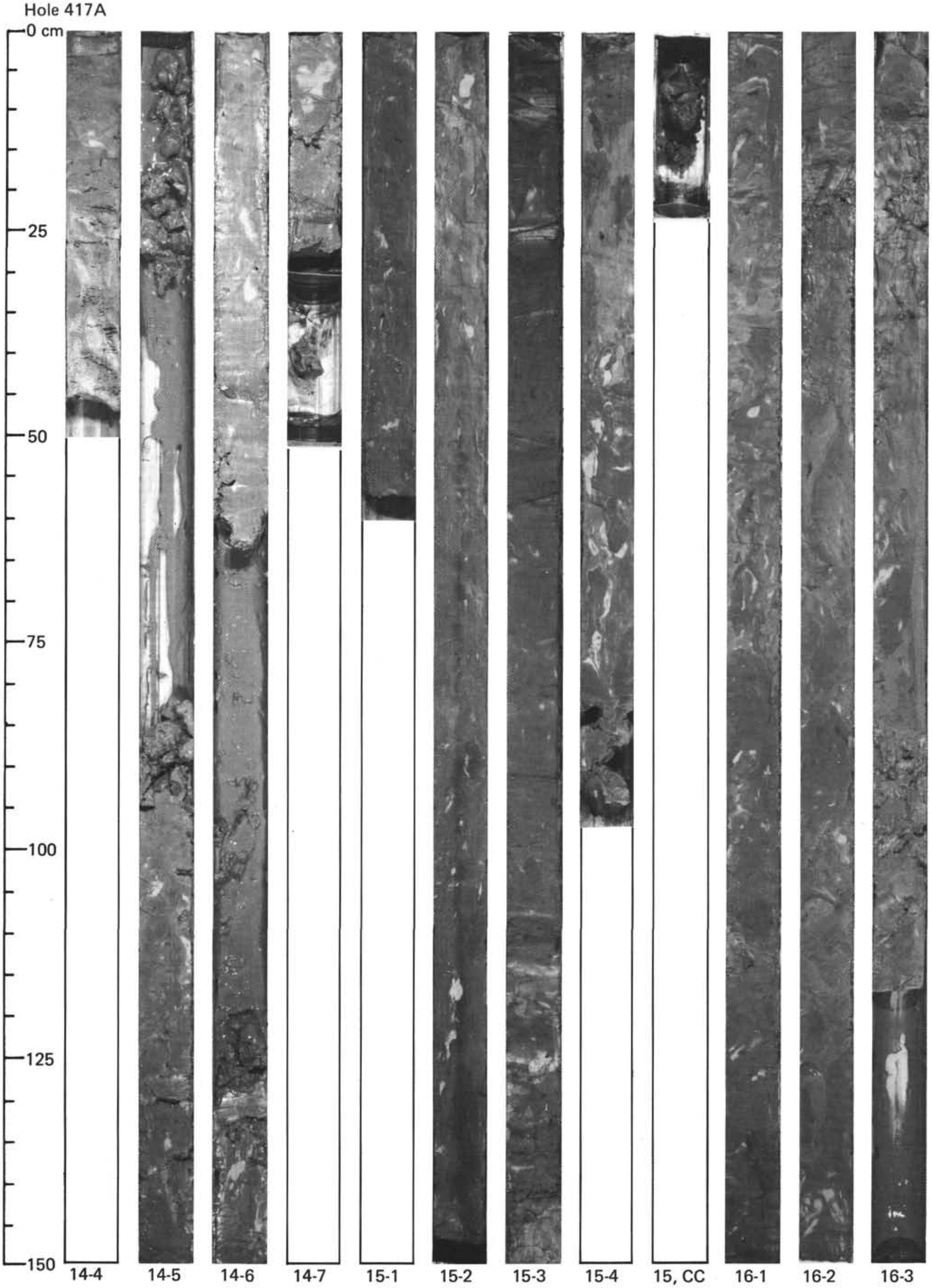

Hole 417A
0 cm
25
50
75
100
125
150
3-3
3-4
3-5
3-6
3-7
3, CC
5-1
5-2
6-1
6-2
6-3
6-4
6-5

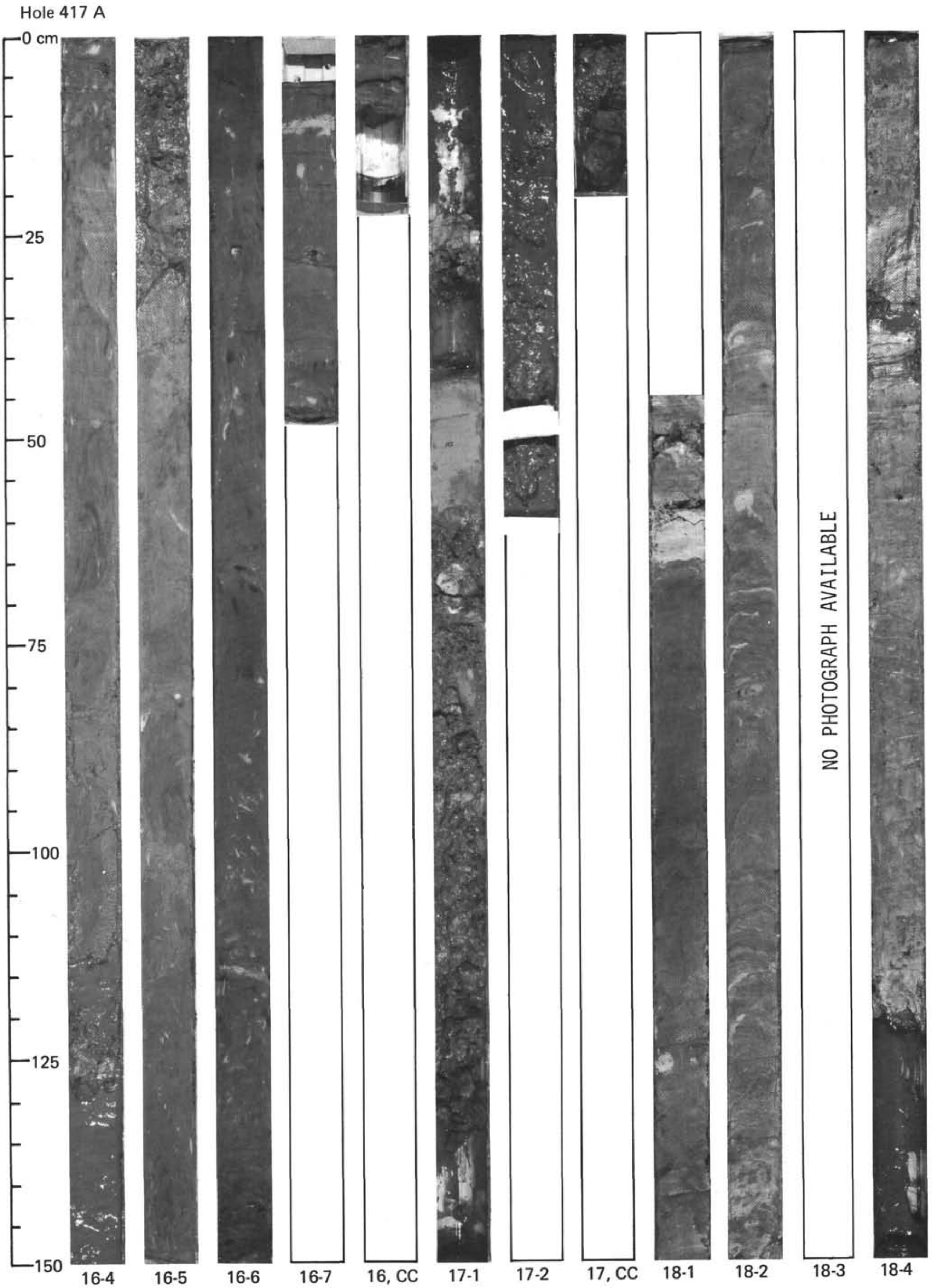

Hole 417A
0 cm
25
50
75
100
125
150
6-6
6-7
8-1
8-2
8-3
8-4
8-5
9-1
9-2
9-3
9-4
9-5

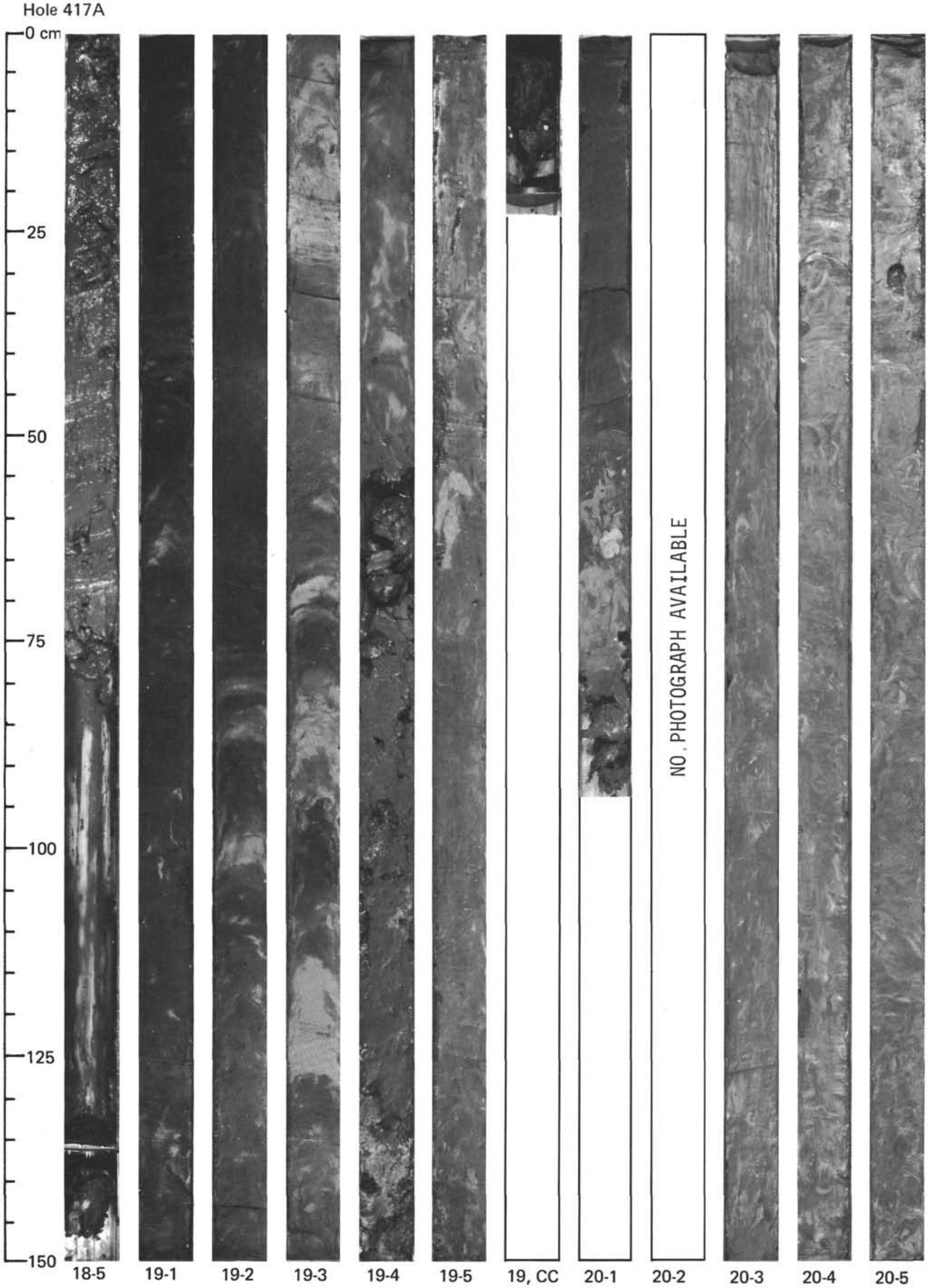

Hole 417A
0 cm
25
50
75
100
125
150
10-1
10-2
10-3
10-4
11-1
11-2
11-3
11-4
11-5
11-6
12-1
12-2

Hole 417A

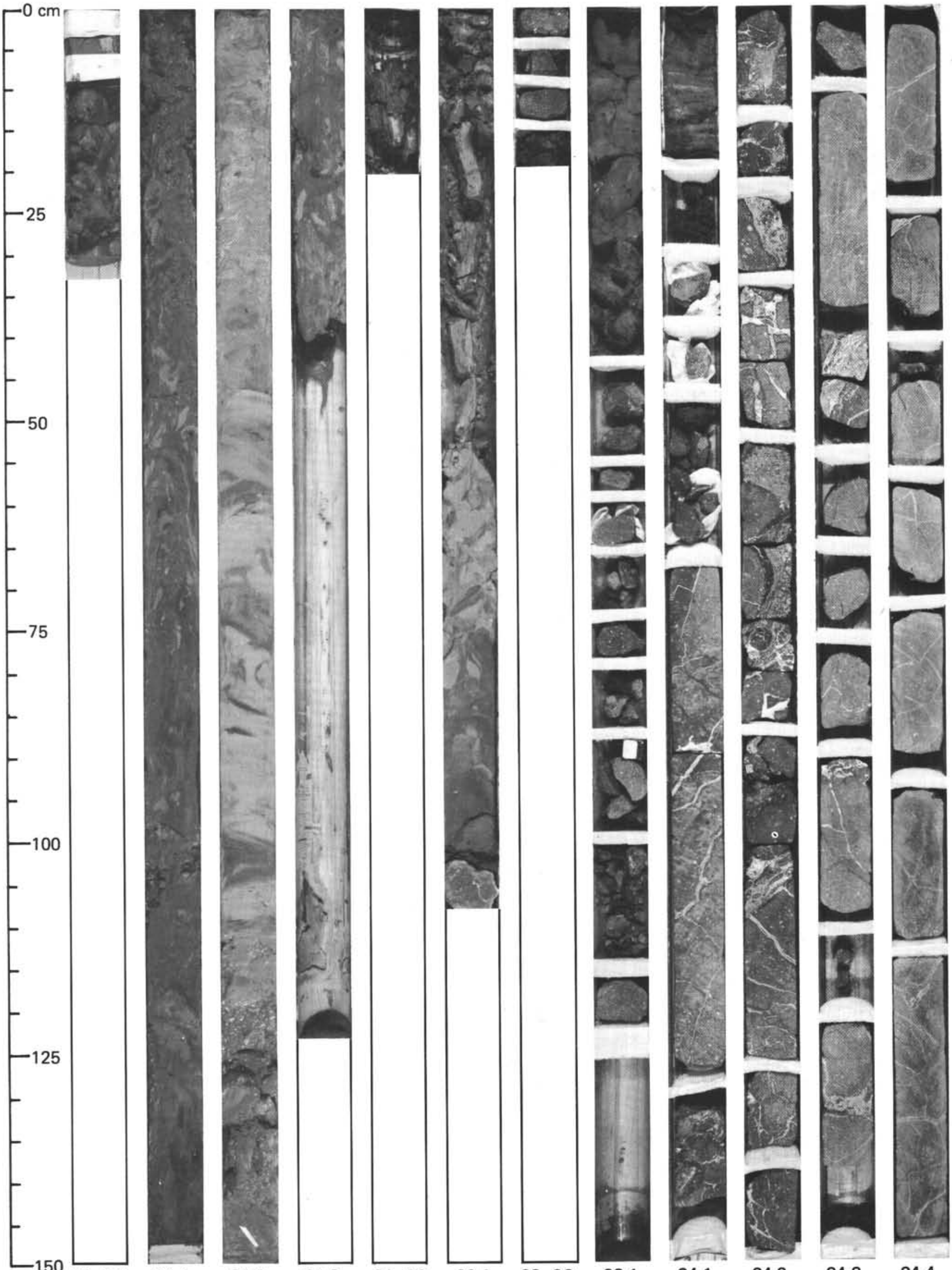

0 cm
25
50
75
100
125
150
12-3
12-4
12, CC
13-1
13-2
13-3
13-4
13-5
13-6
14-1
14-2
14-3


Hole 417A
0 cm
25
50
75
100
125
150
14-4
14-5
14-6
14-7
15-1
15-2
15-3
15-4
15, CC
16-1
16-2
16-3

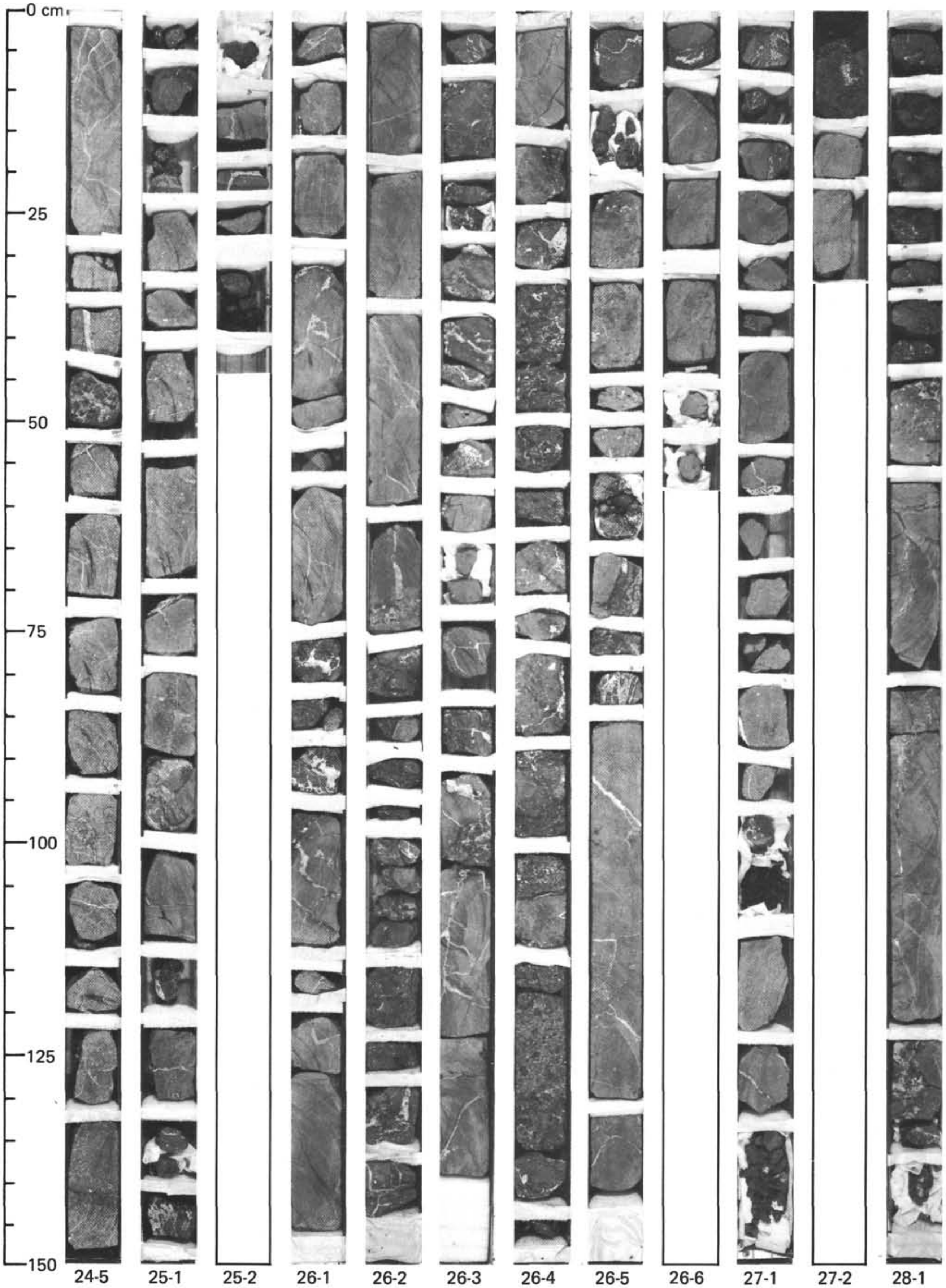

Hole 417 A
0 cm
25
50
75
100
125
150
16-4
16-5
16-6
16-7
16, CC
17-1
17-2
17, CC
18-1
18-2
18-3
18-4
NO PHOTOGRAPH AVAILABLE

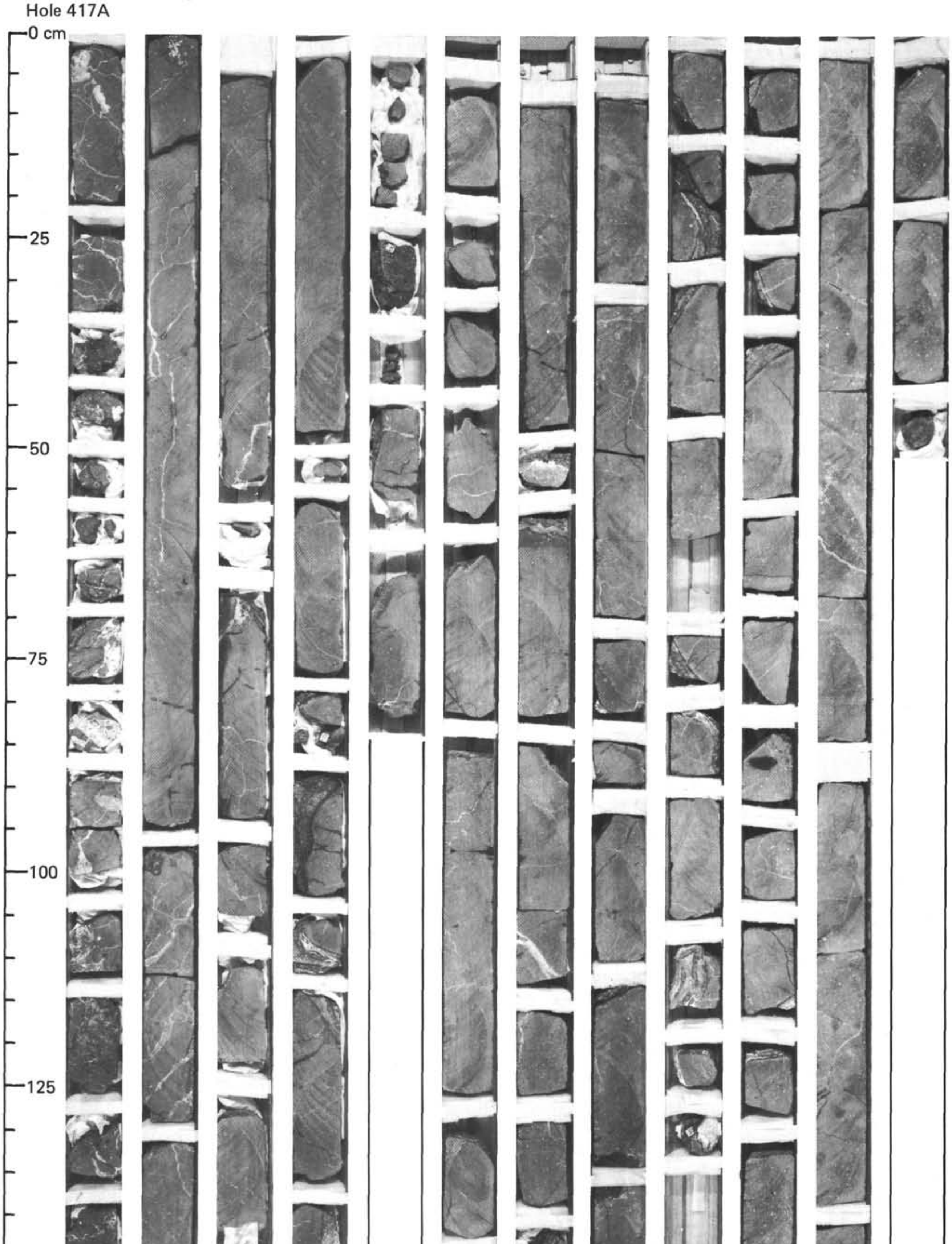

Hole 417A
0 cm
25
50
75
100
125
150
18-5
19-1
19-2
19-3
19-4
19-5
19, CC
20-1
20-2
20-3
20-4
20-5
NO. PHOTOGRAPH AVAILABLE

Hole 417A

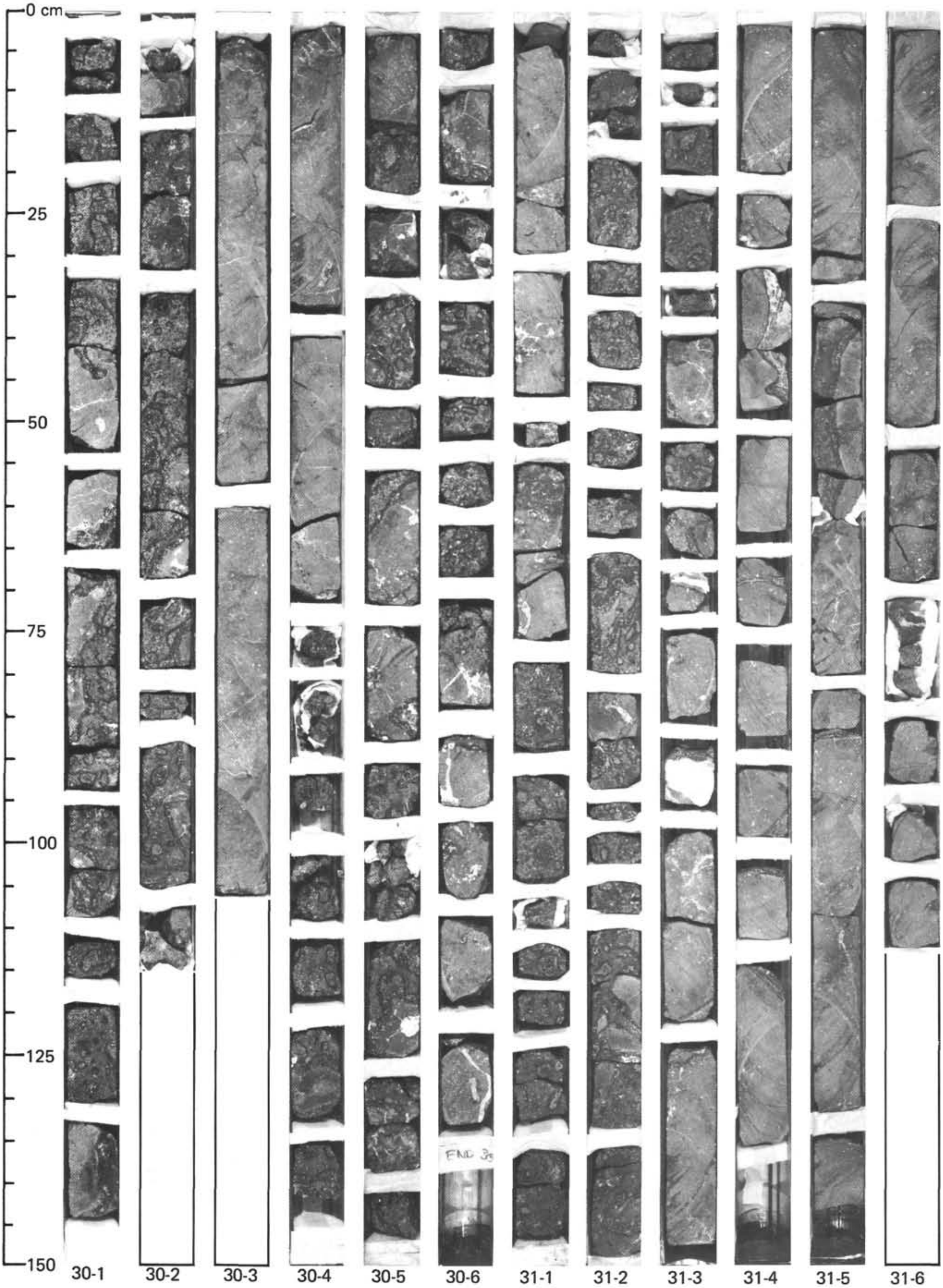

0 cm
25
50
75
100
125
150
20, CC
21-1
21-2
21-3
21, CC
22-1
22, CC
23-1
24-1
24-2
24-3
24-4

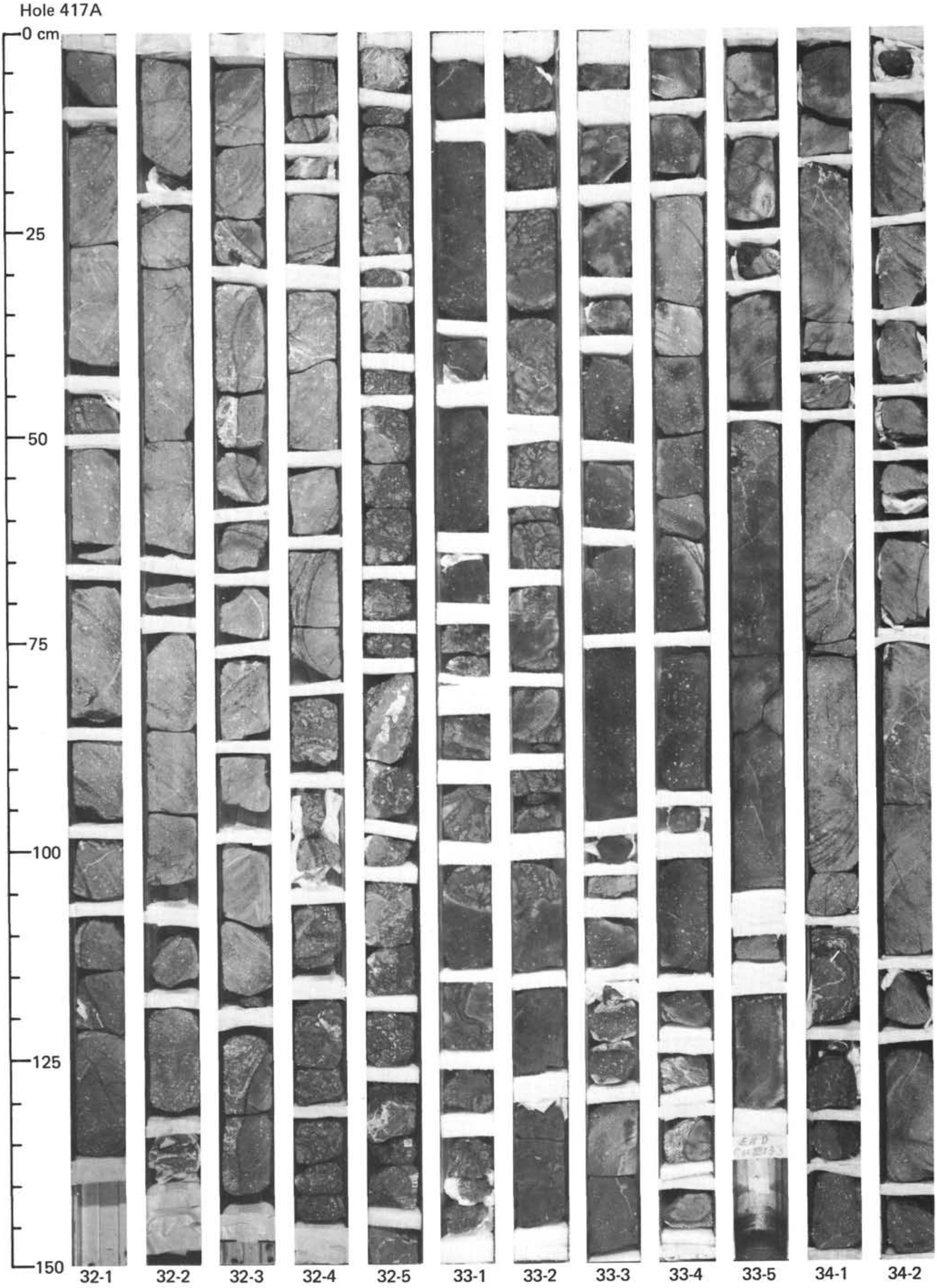
Hole 417A


0 cm
25
50
75
100
125
150
24-5
25-1
25-2
26-1
26-2
26-3
26-4
26-5
26-6
27-1
27-2
28-1

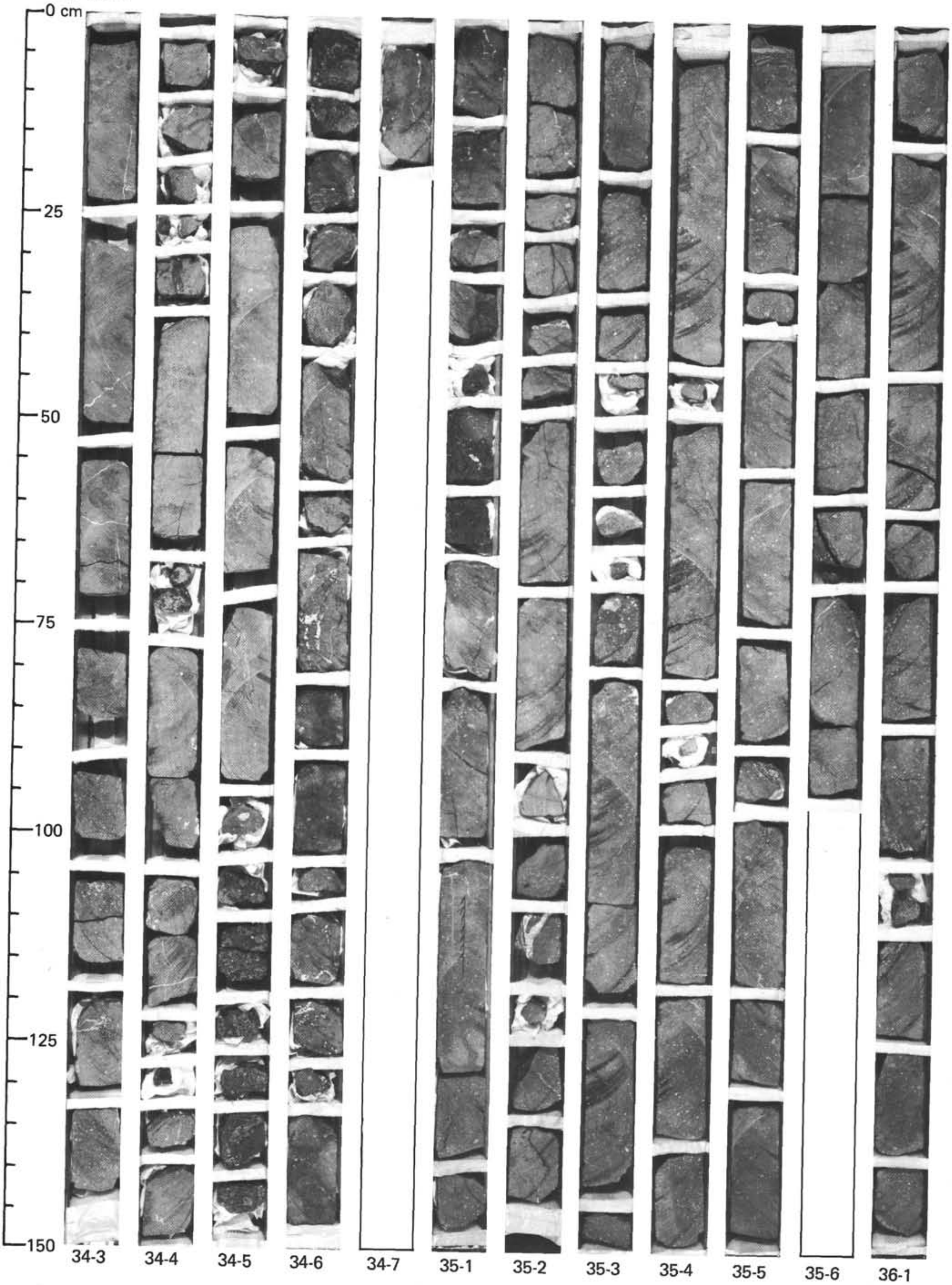

Hole 417A
0 cm
25
50
75
100
125
150
28-2
28-3
28-4
28-5
28-6
29-1
29-2
29-3
29-4
29-5
29-6
29-7

Hole 417A


0 cm
25
50
75
100
125
150
30-1
30-2
30-3
30-4
30-5
30-6
31-1
31-2
31-3
31-4
31-5
31-6
END 3


Hole 417A
0 cm
25
50
75
100
125
150
32-1
32-2
32-3
32-4
32-5
33-1
33-2
33-3
33-4
33-5
34-1
34-2

Hole 417A


0 cm
25
50
75
100
125
150
34-3
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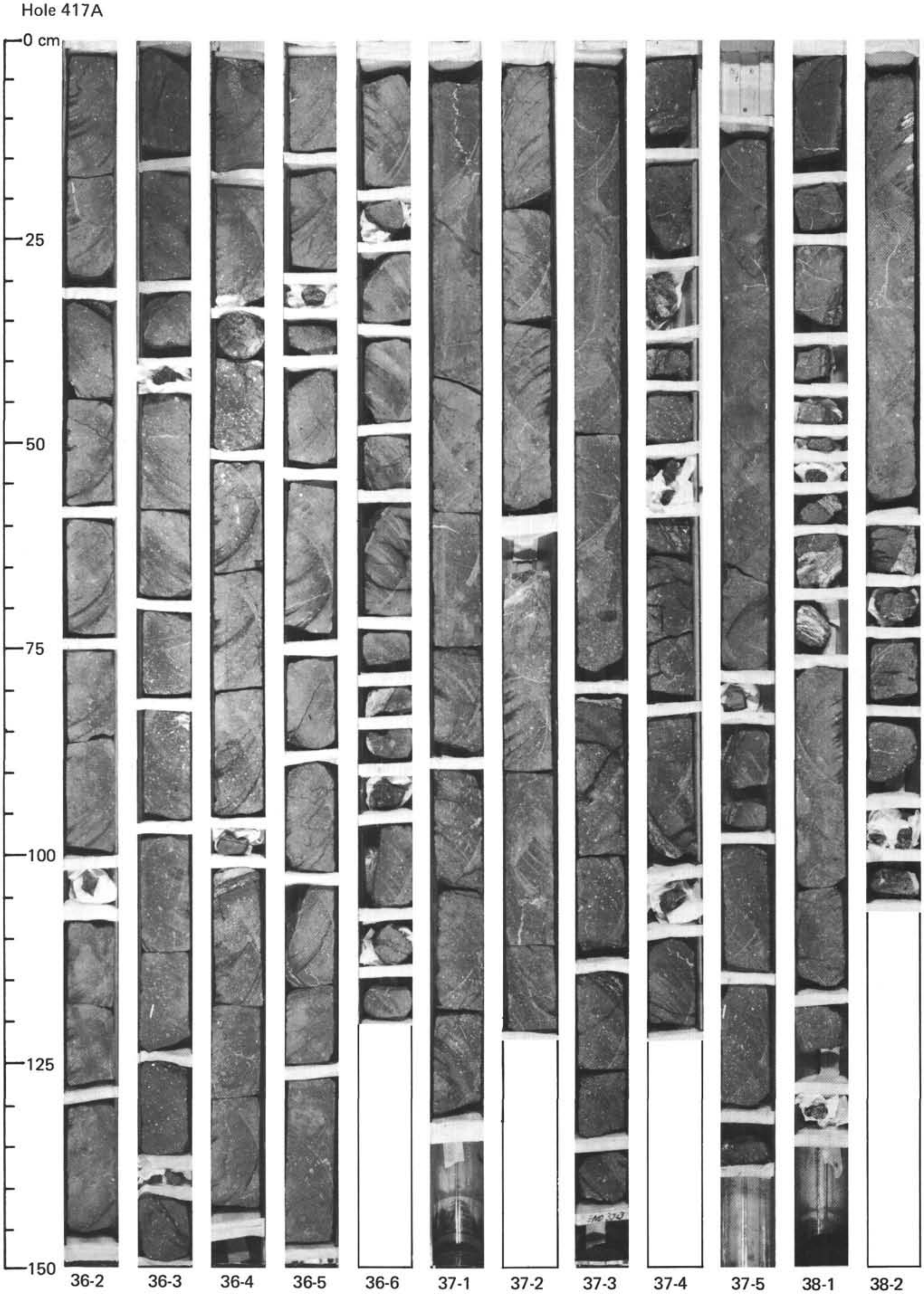
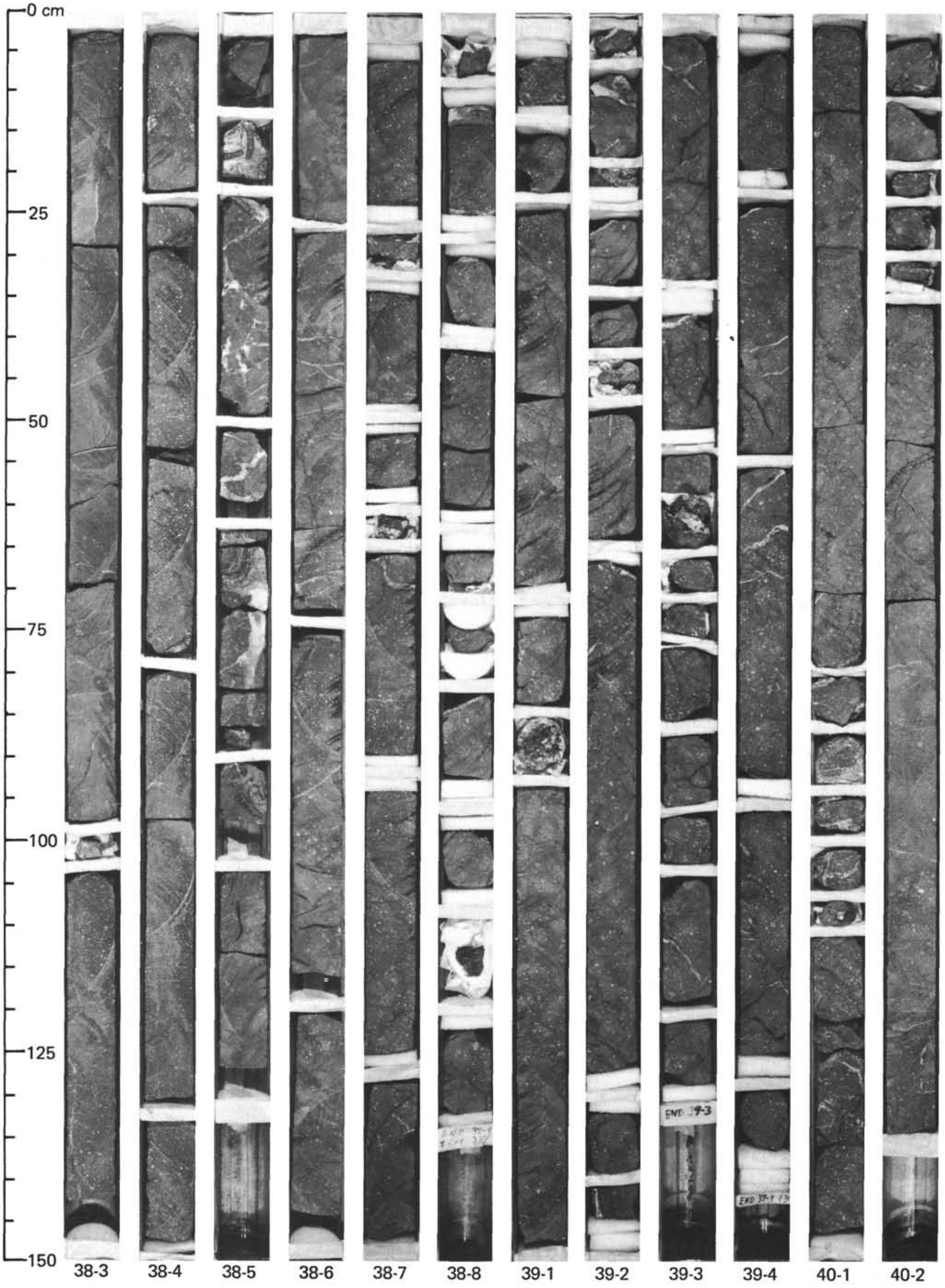
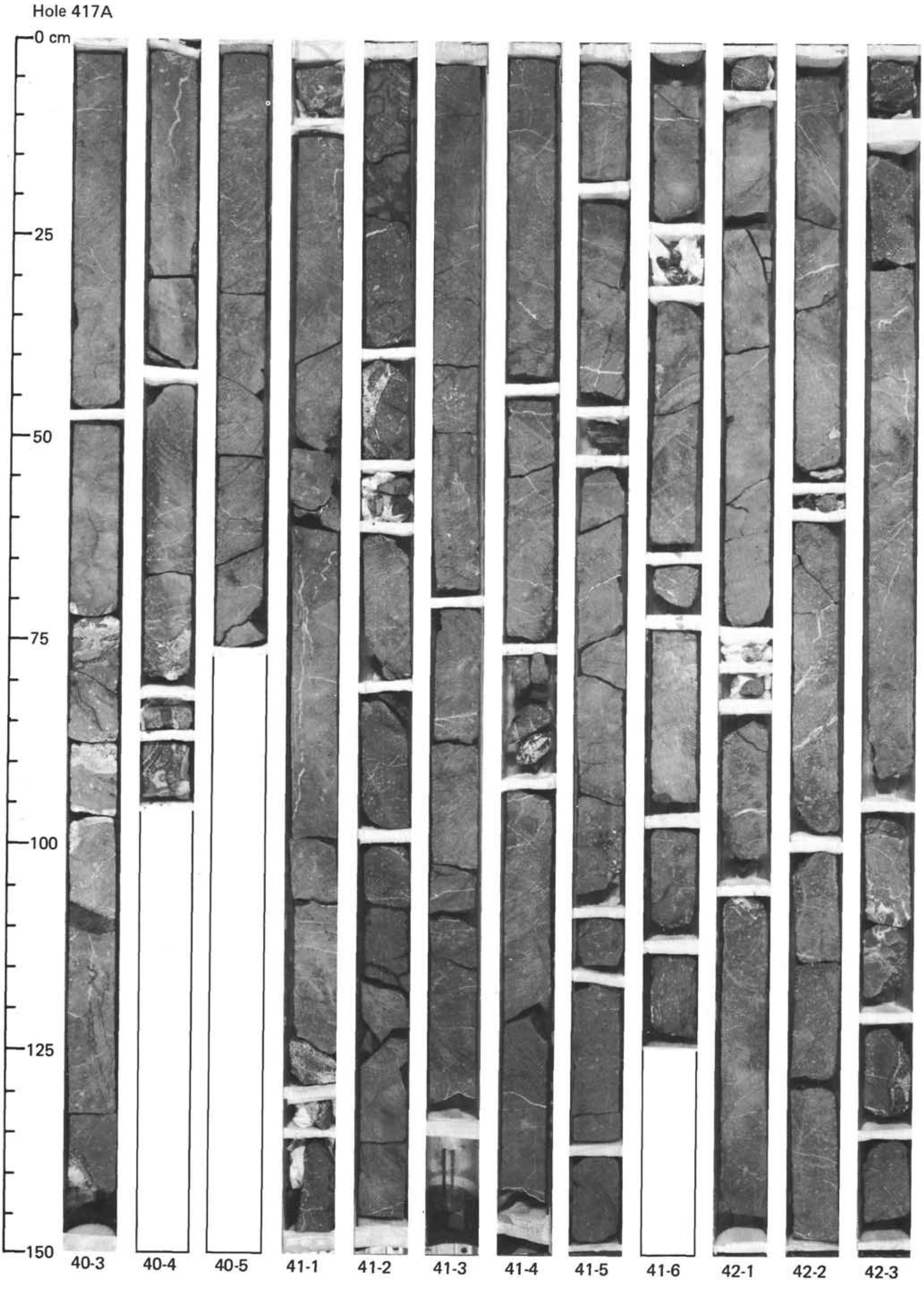
34-5
34-6
34-7
35-1
35-2
35-3
35-4
35-5
35-6
36-1


Hole 417A
0 cm
25
50
75
100
125
150
36-2
36-3
36-4
36-5
36-6
37-1
37-2
37-3
37-4
37-5
38-1
38-2

Hole 417A


0 cm
25
50
75
100
125
150
END 39-3
38-3
38-4
38-5
38-6
38-7
38-8
39-1
39-2
39-3
39-4
40-1
40-2


Hole 417A
0 cm
25
50
75
100
125
150
40-3
40-4
40-5
41-1
41-2
41-3
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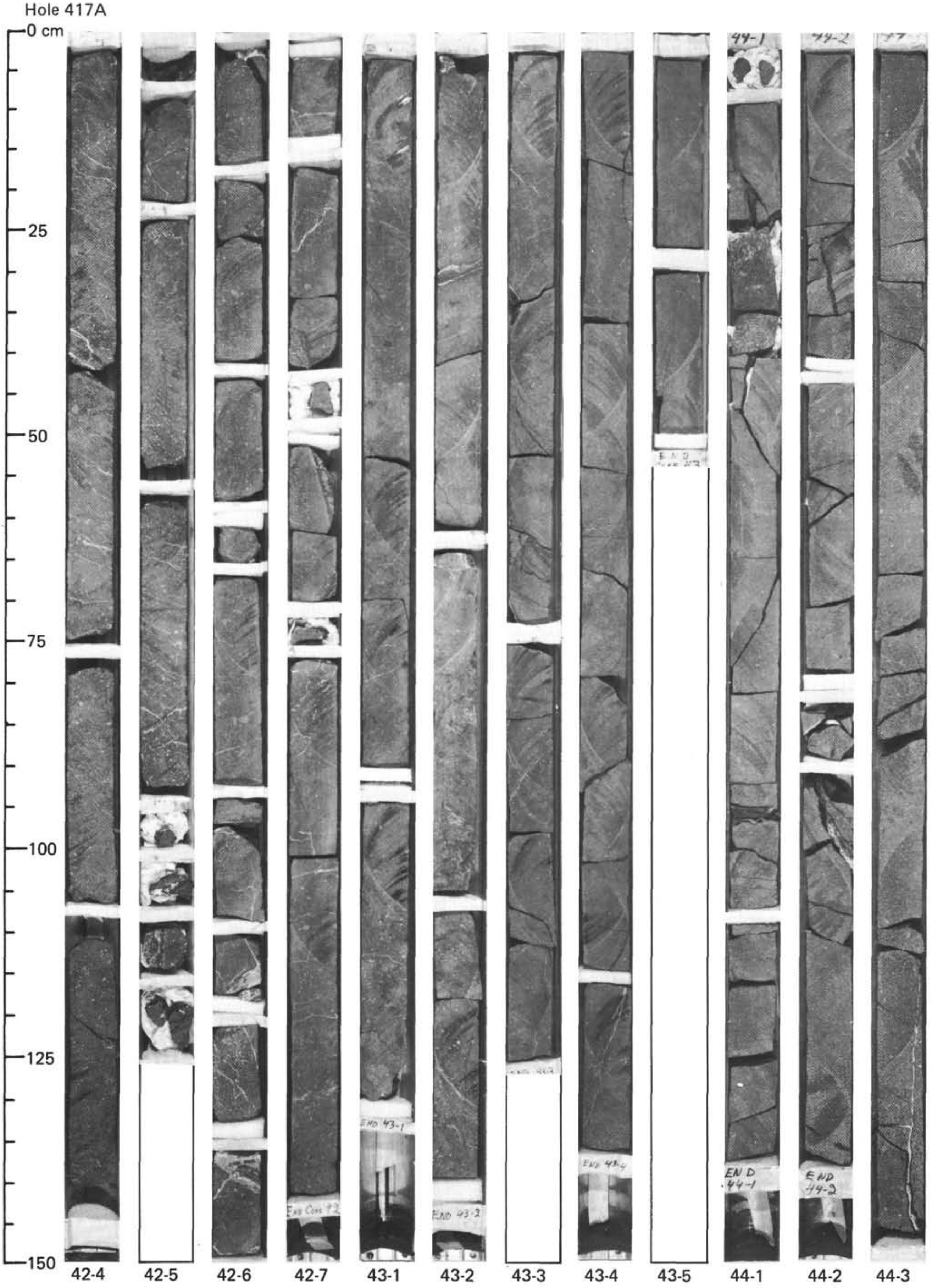
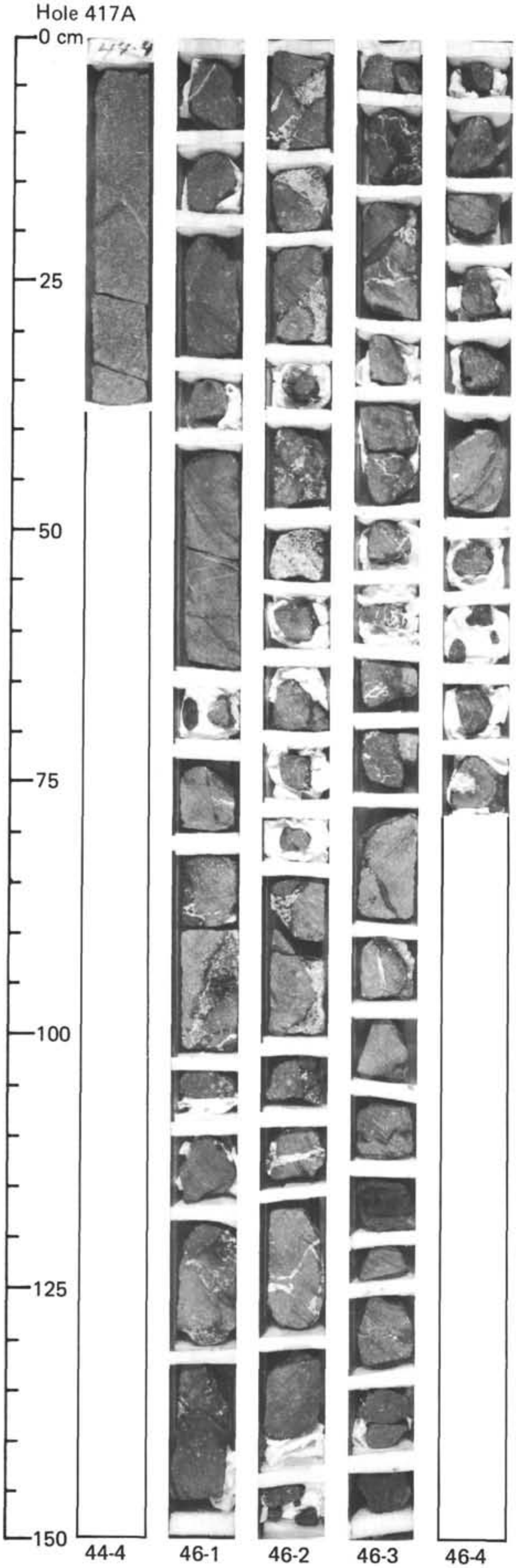
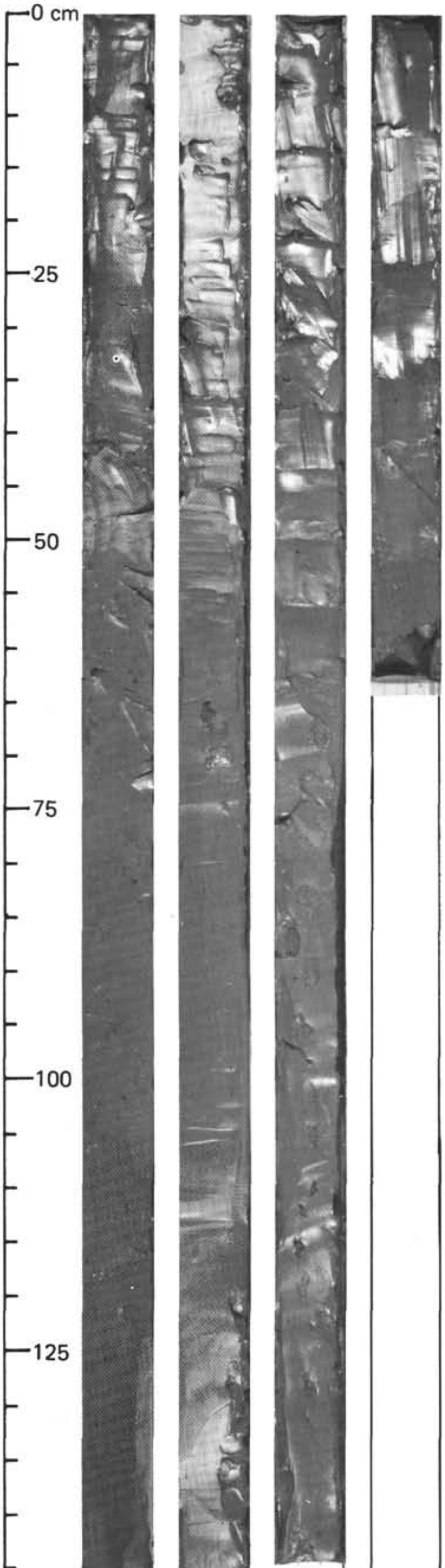
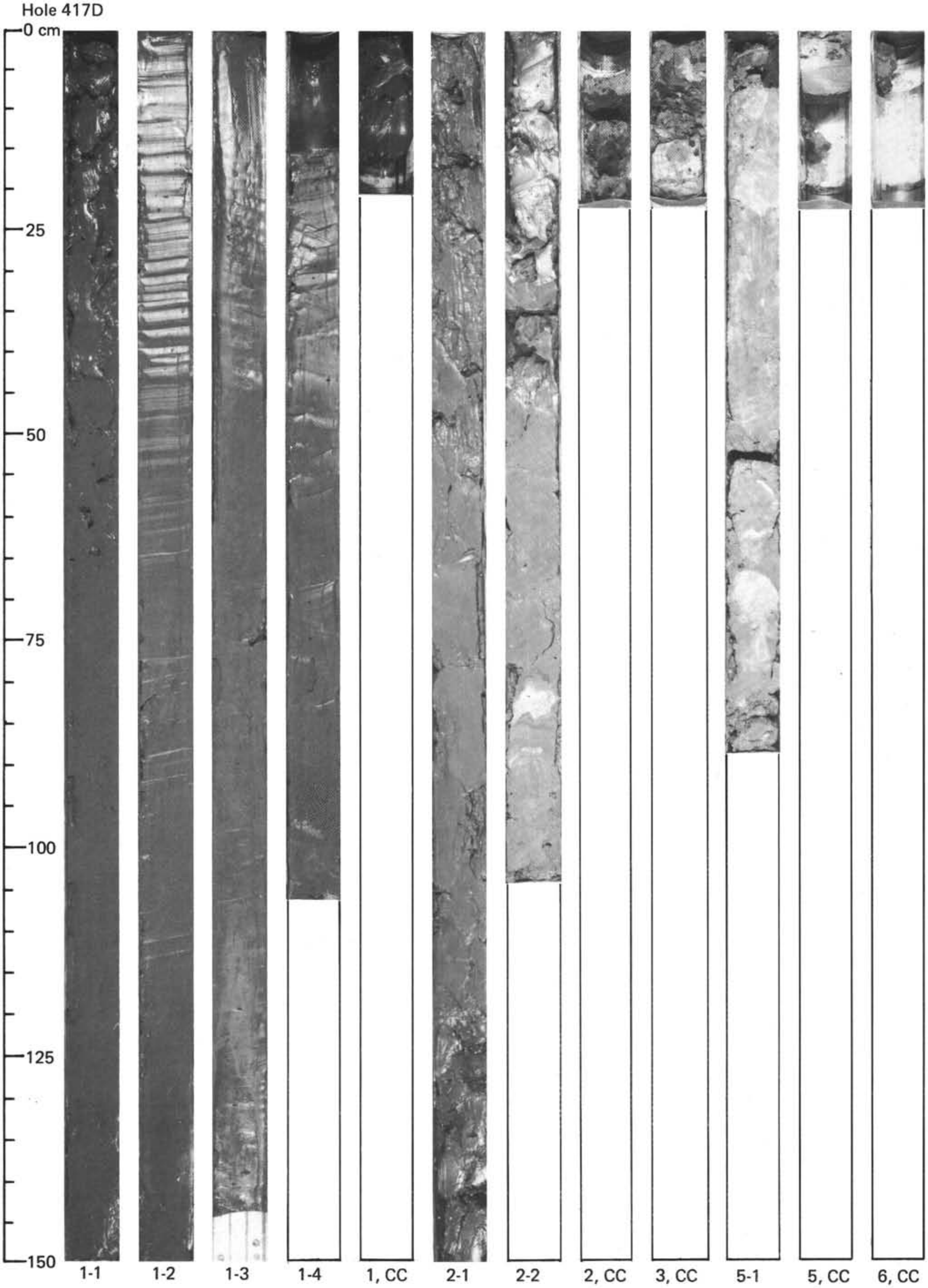
41-6
42-1
42-2
42-3

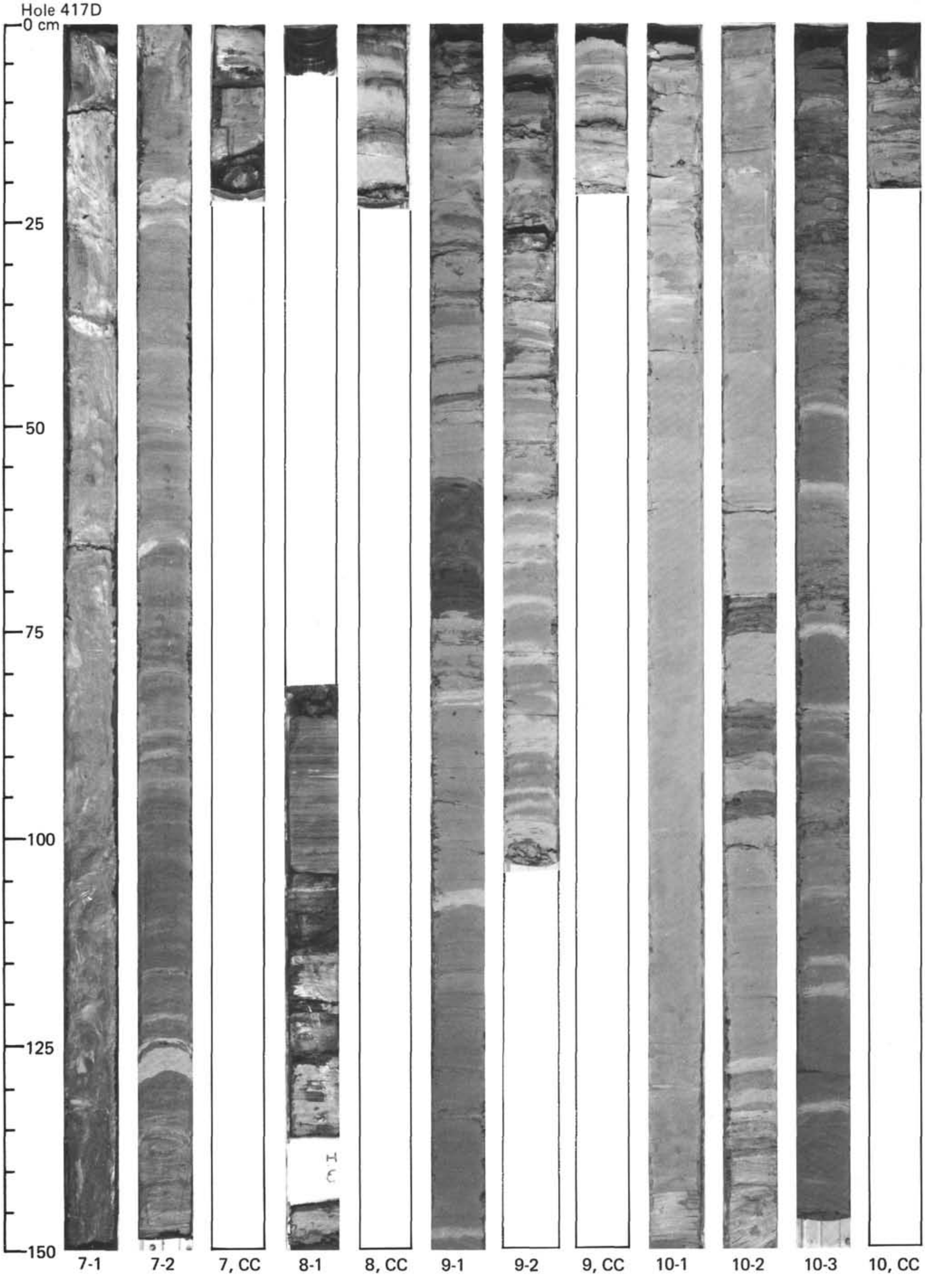

Hole 417A
0 cm
25
50
75
100
125
150
44-1
44-2
END 43-1
END 43-2
End Core 42
END 43-4
END 44-1
END 44-2
42-4
42-5
42-6
42-7
43-1
43-2
43-3
43-4
43-5
44-1
44-2
44-3

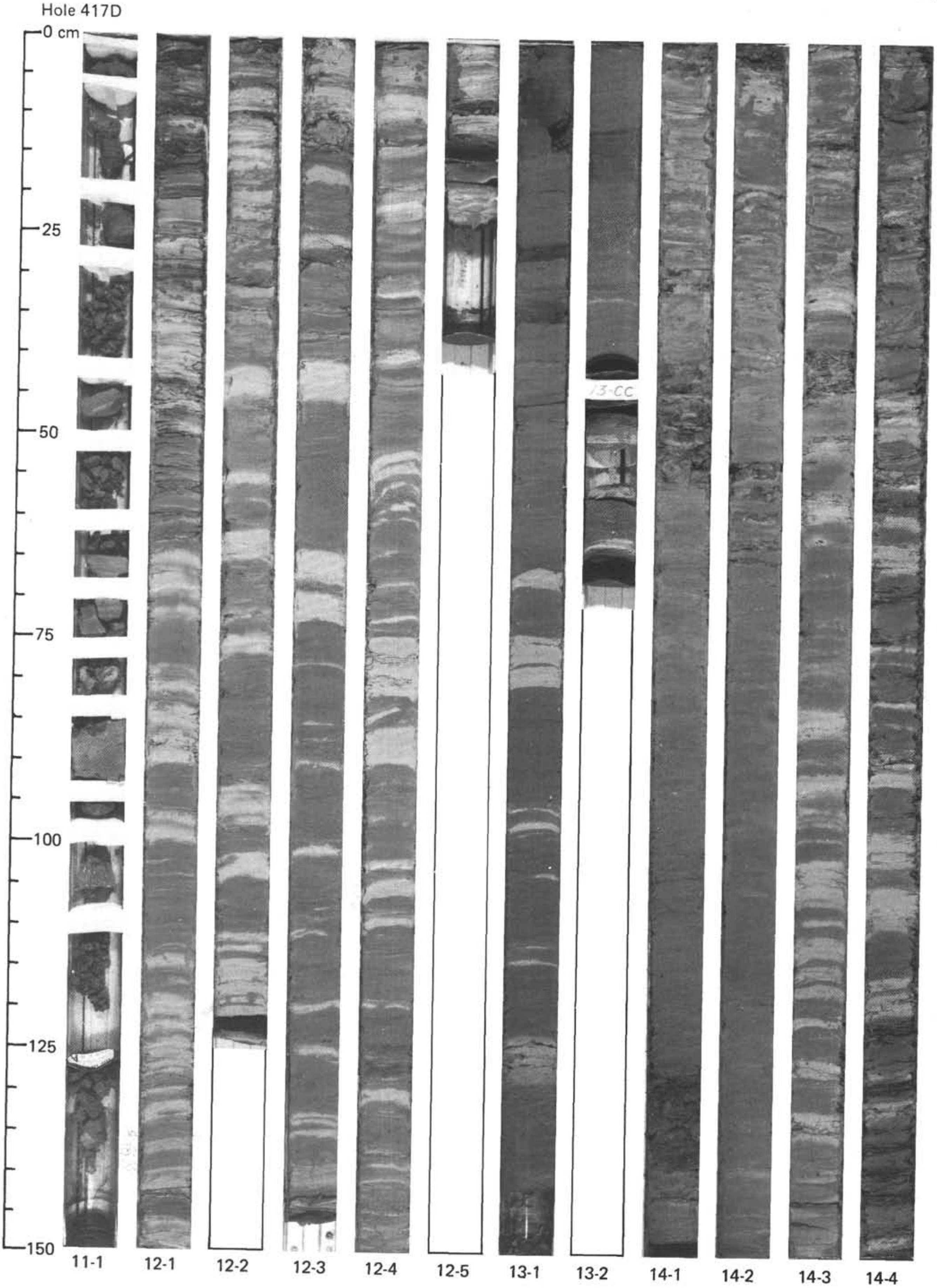

Hole 417A
0 cm
44-4
25
50
75
100
125
150
44-4
46-1
46-2
46-3
46-4

Hole 417B




Hole 417D
0 cm
25
50
75
100
125
150
1-1
1-2
1-3
1-4
1, CC
2-1
2-2
2, CC
3, CC
5-1
5, CC
6, CC


Hole 417D
0 cm
25
50
75
100
125
150
7-1
7-2
7, CC
8-1
8, CC
9-1
9-2
9, CC
10-1
10-2
10-3
10, CC


Hole 417D
0 cm
25
50
75
100
125
150
13-CC
11-1
12-1
12-2
12-3
12-4
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13-1
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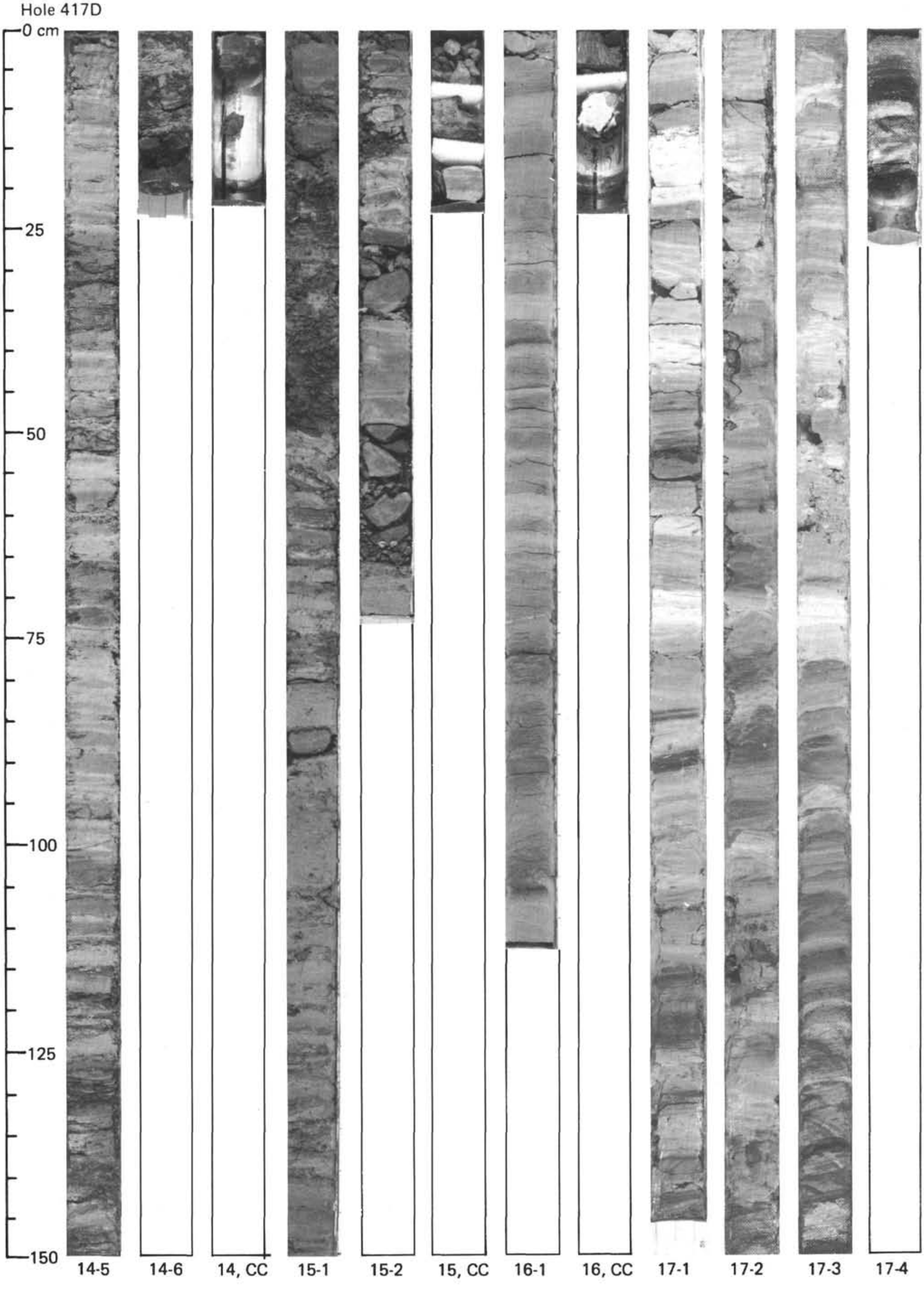
14-2
14-3
14-4


Hole 417D
0 cm
25
50
75
100
125
150
14-5
14-6
14, CC
15-1
15-2
15, CC
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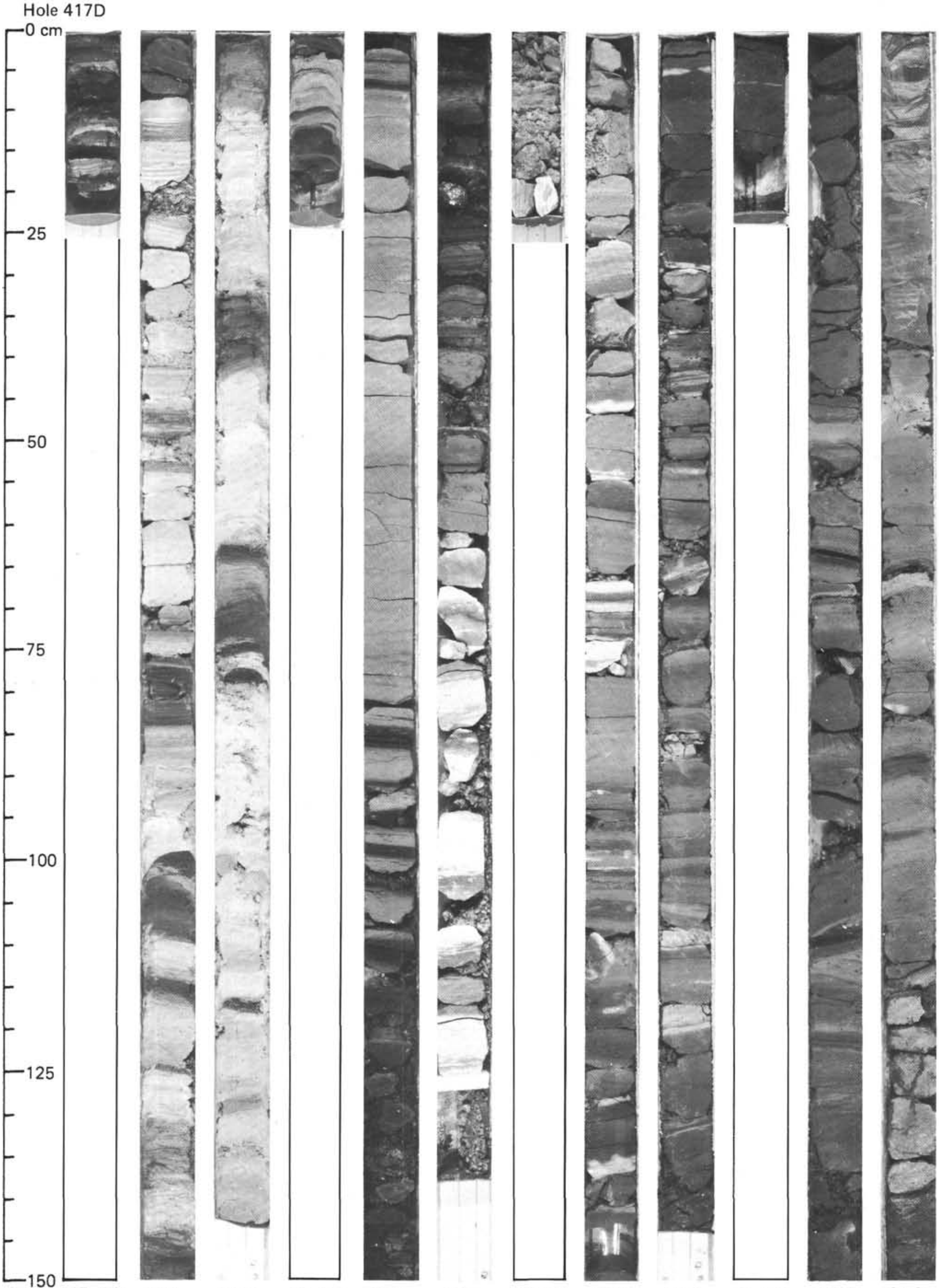
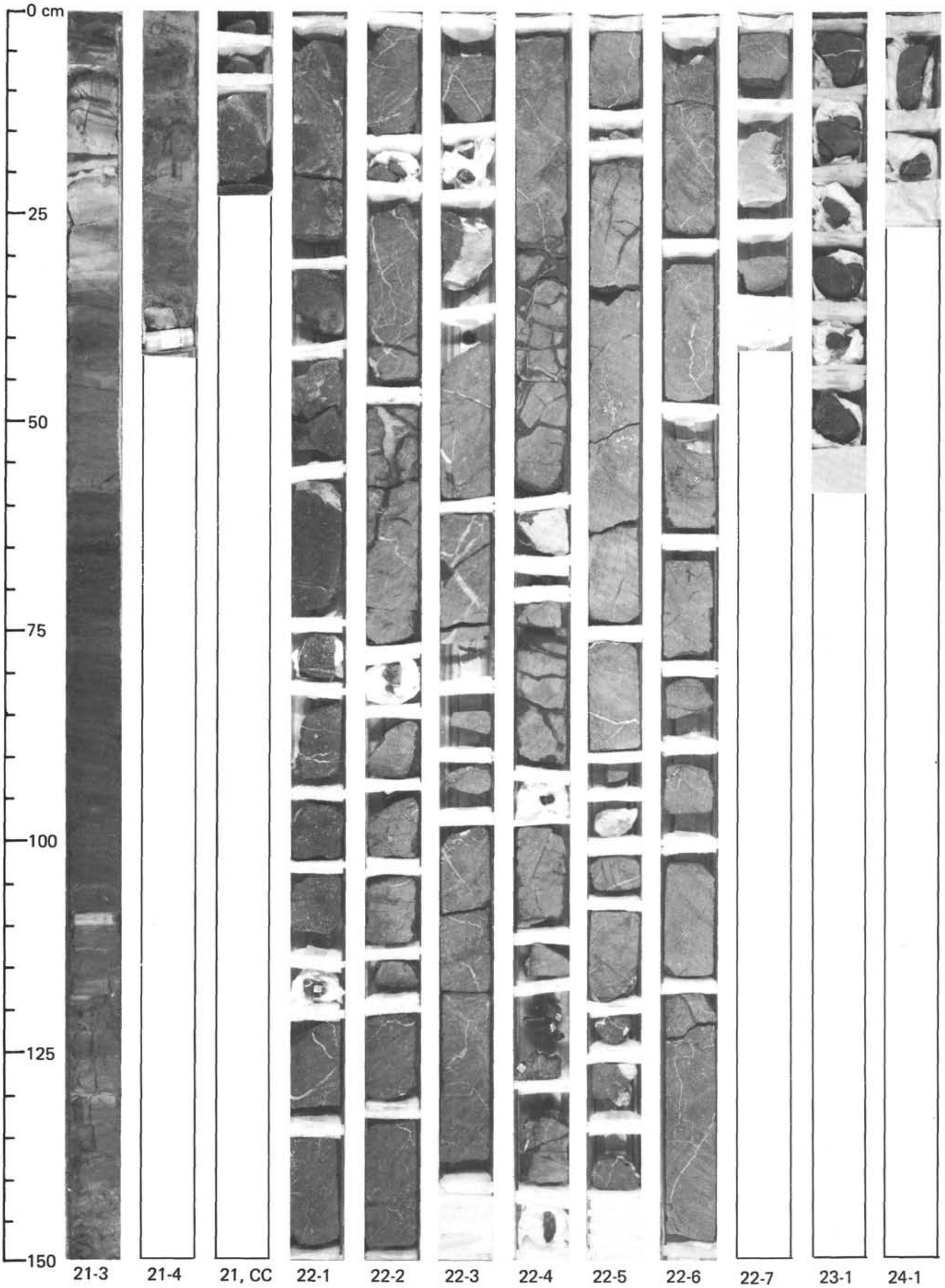
16, CC
17-1
17-2
17-3
17-4


Hole 417D
0 cm
25
50
75
100
125
150
17, CC
18-1
18-2
18, CC
19-1
19-2
19, CC
20-1
20-2
20, CC
21-1
21-2

Hole 417D


0 cm
25
50
75
100
125
150
21-3
21-4
21, CC
22-1
22-2
22-3
22-4
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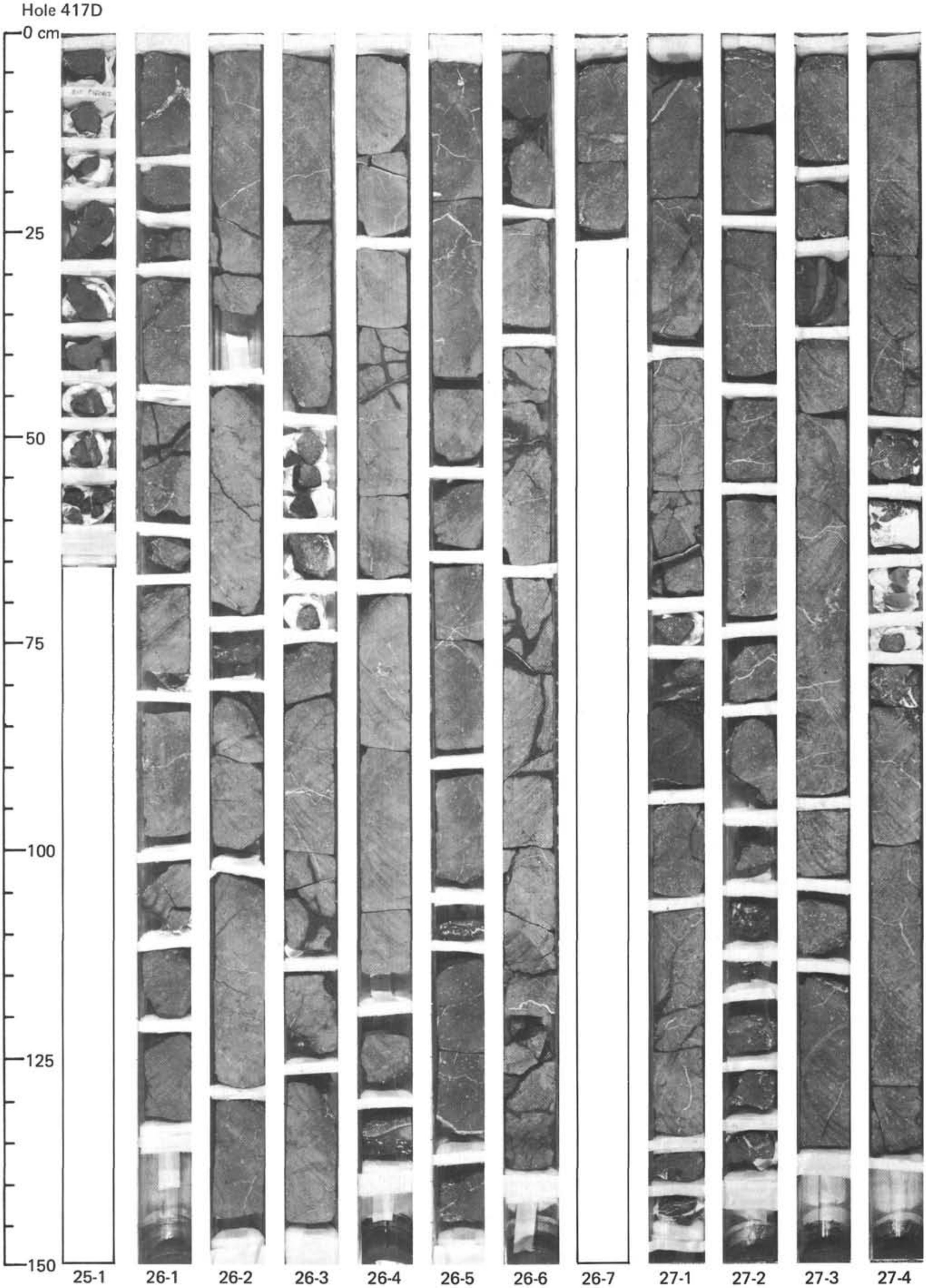
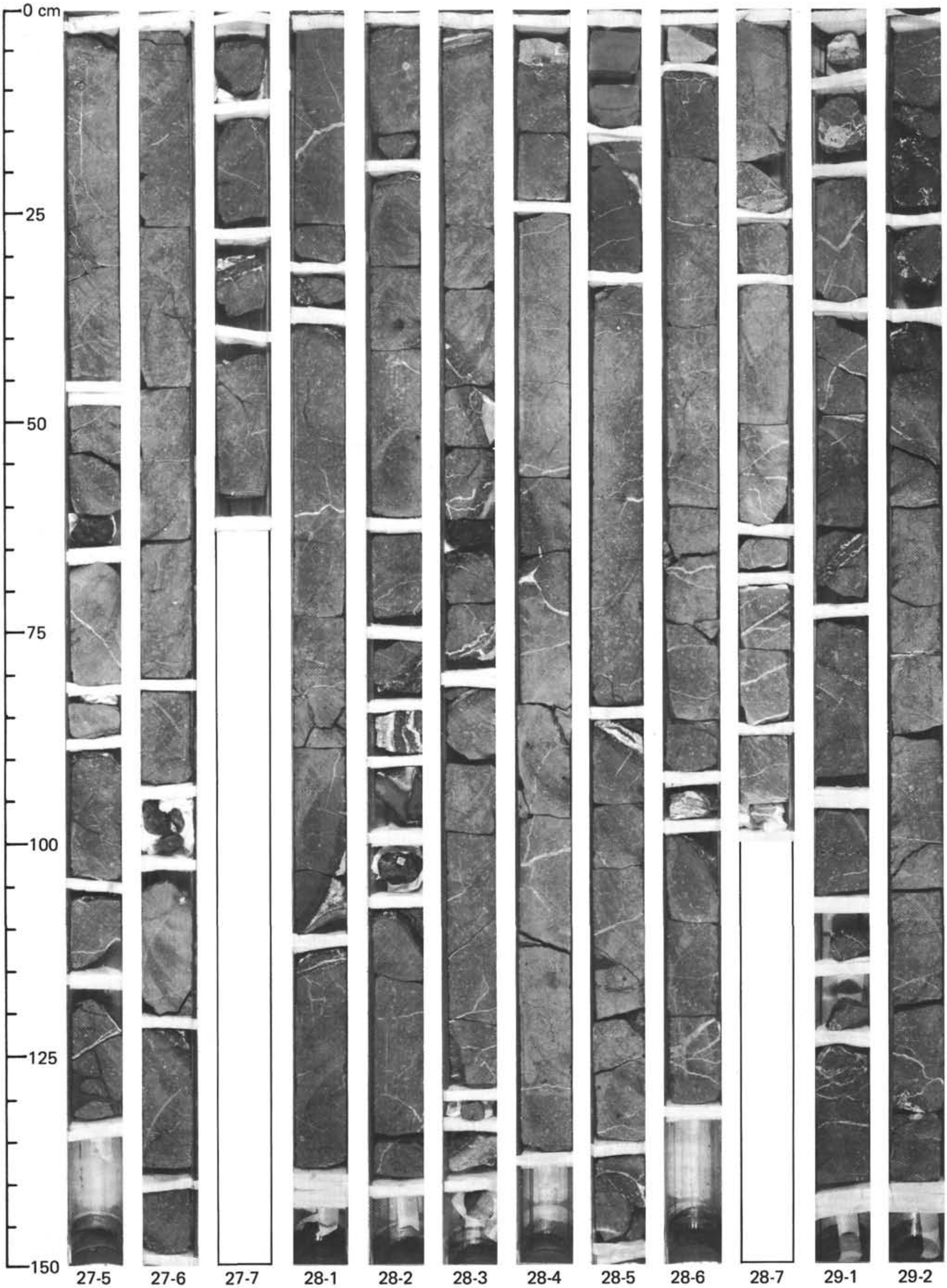
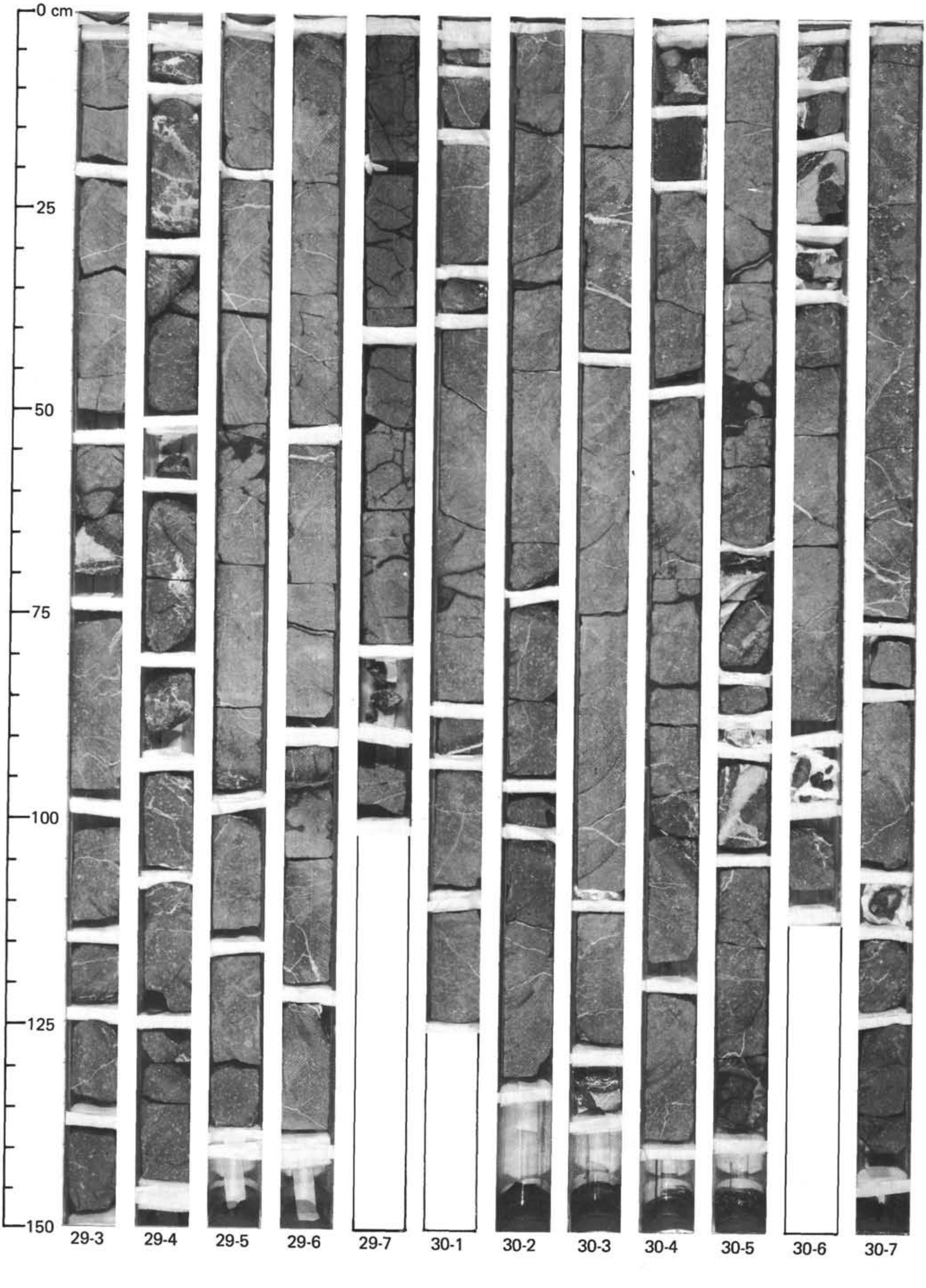
22-6
22-7
23-1
24-1


Hole 417D
0 cm
25
50
75
100
125
150
25-1
26-1
26-2
26-3
26-4
26-5
26-6
26-7
27-1
27-2
27-3
27-4

Hole 417D


0 cm
25
50
75
100
125
150
27-5
27-6
27-7
28-1
28-2
28-3
28-4
28-5
28-6
28-7
29-1
29-2

Hole 417D


0 cm
25
50
75
100
125
150
29-3
29-4
29-5
29-6
29-7
30-1
30-2
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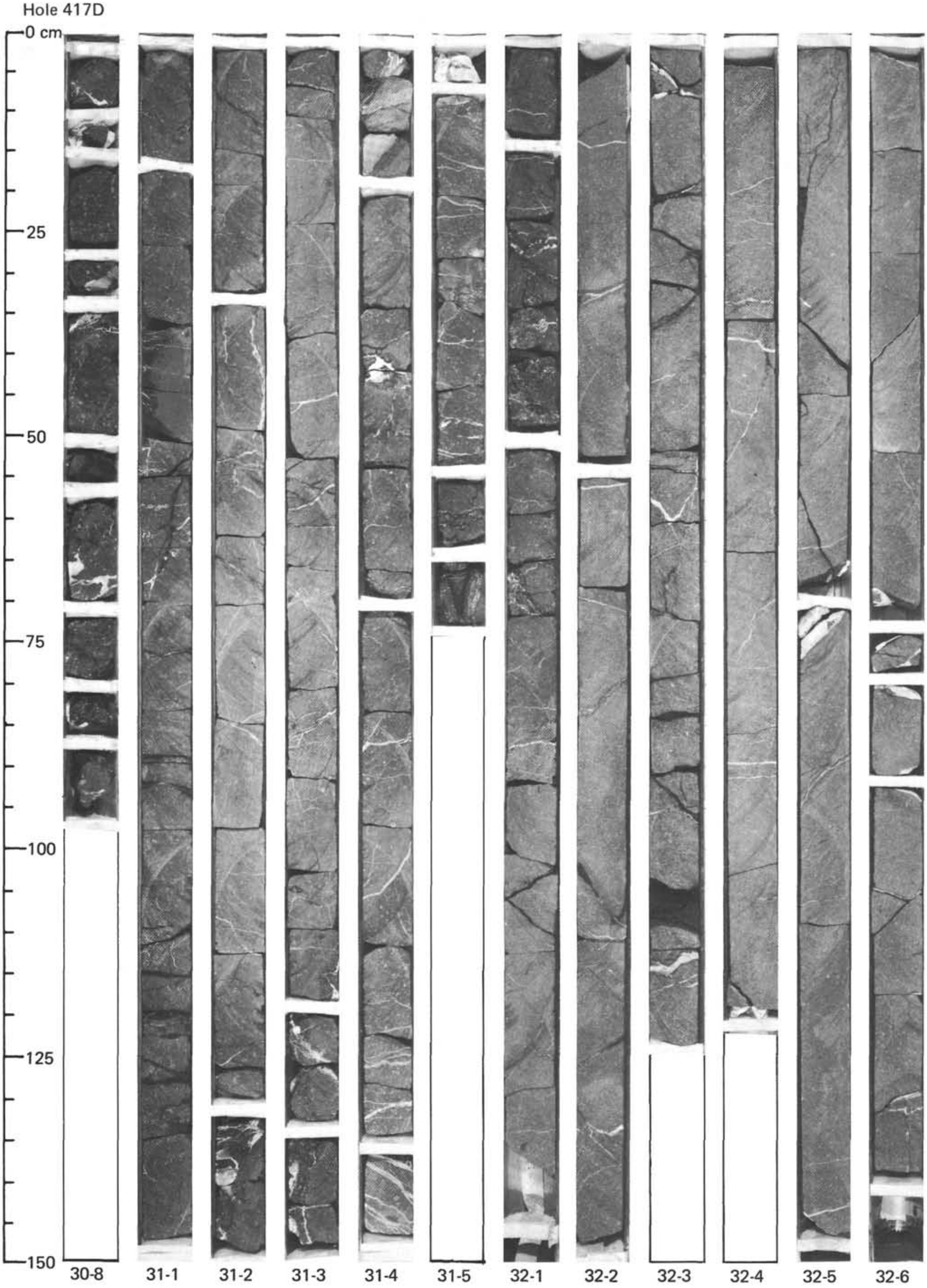
30-4
30-5
30-6
30-7


Hole 417D
0 cm
25
50
75
100
125
150
30-8
31-1
31-2
31-3
31-4
31-5
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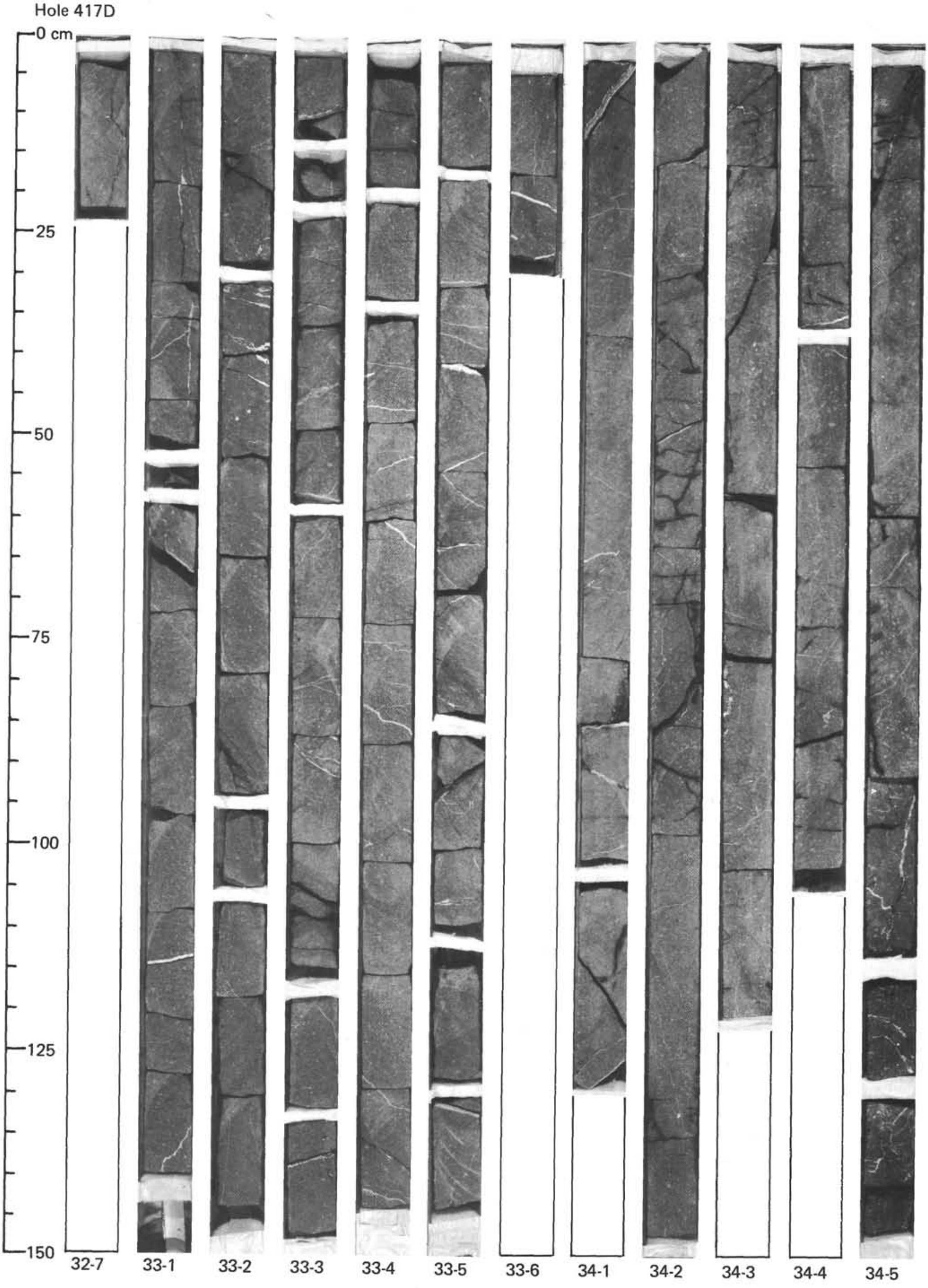
32-2
32-3
32-4
32-5
32-6


Hole 417D
0 cm
25
50
75
100
125
150
32-7
33-1
33-2
33-3
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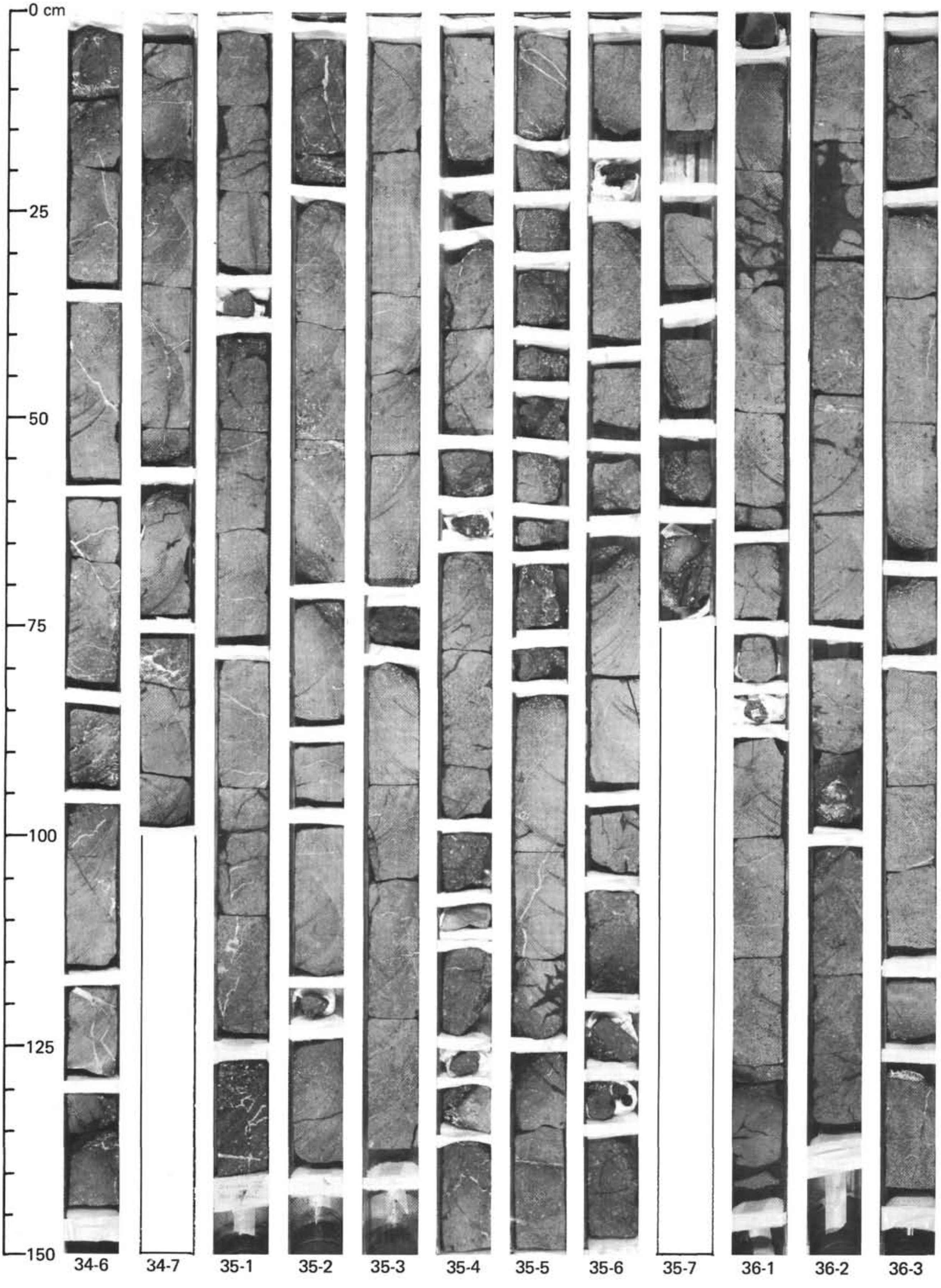
33-6
34-1
34-2
34-3
34-4
34-5

Hole 417D


0 cm
25
50
75
100
125
150
34-6
34-7
35-1
35-2
35-3
35-4
35-5
35-6
35-7
36-1
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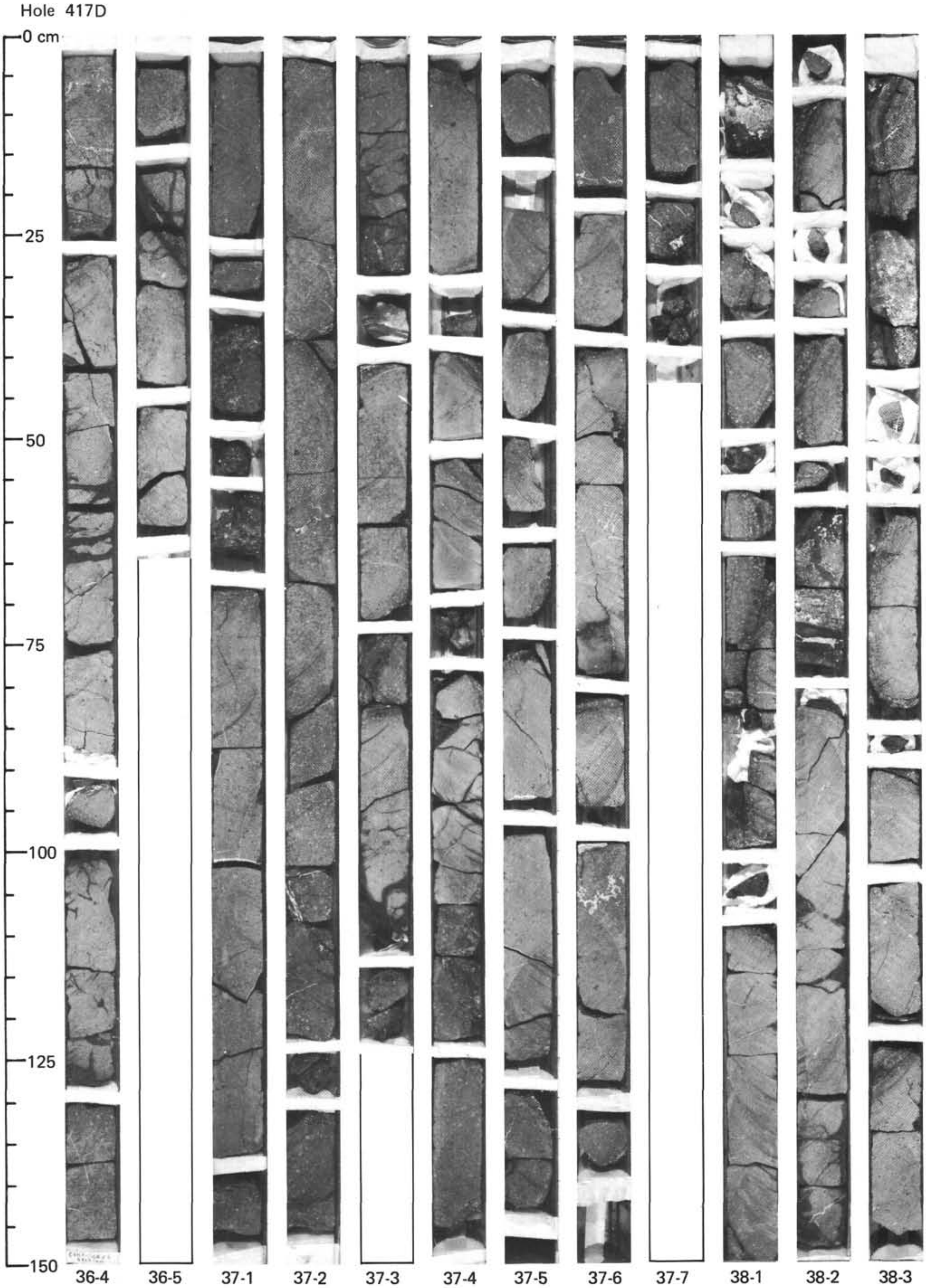
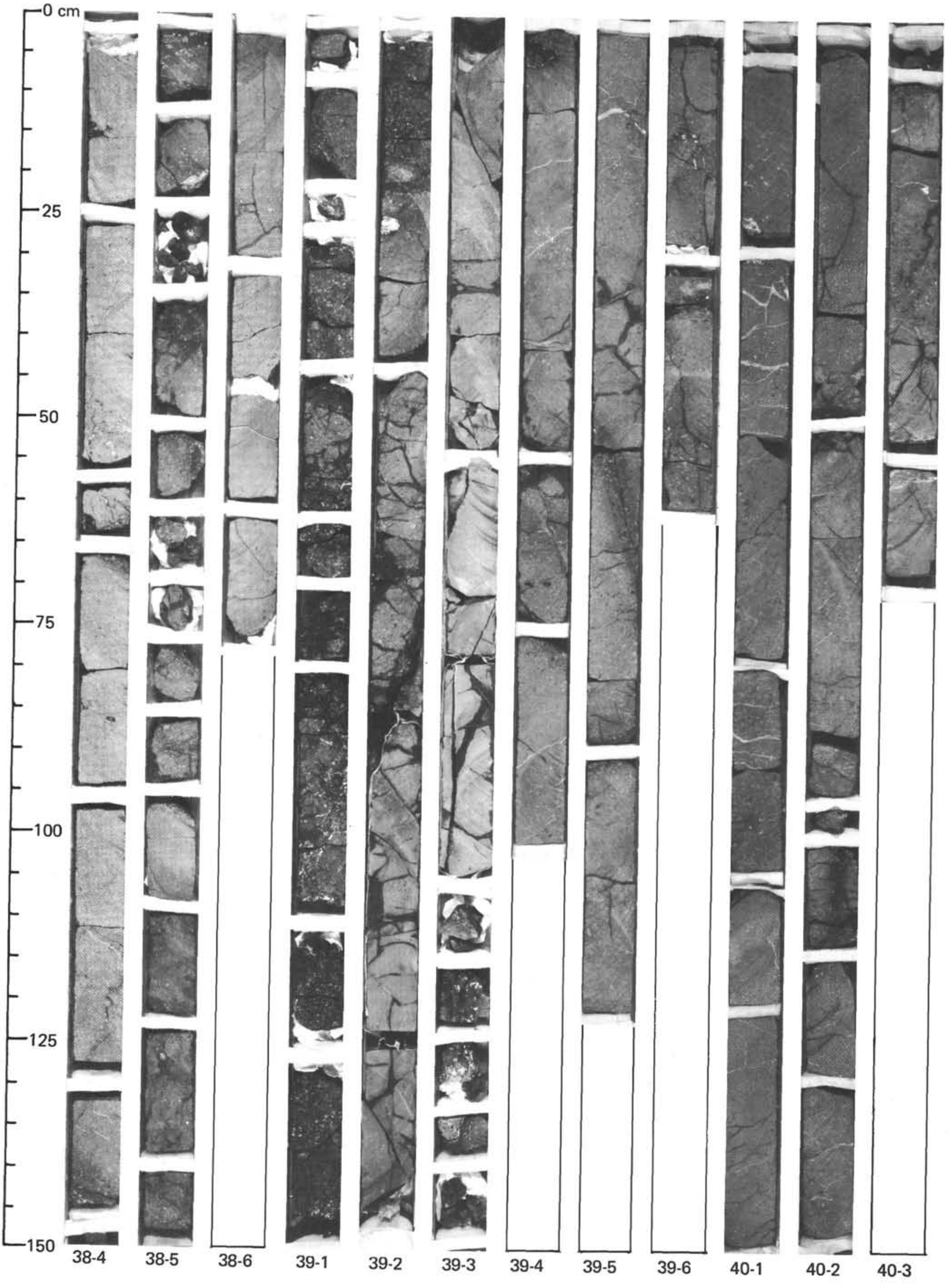
36-3


Hole 417D
0 cm
25
50
75
100
125
150
36-4
36-5
37-1
37-2
37-3
37-4
37-5
37-6
37-7
38-1
38-2
38-3

Hole 417D


0 cm
25
50
75
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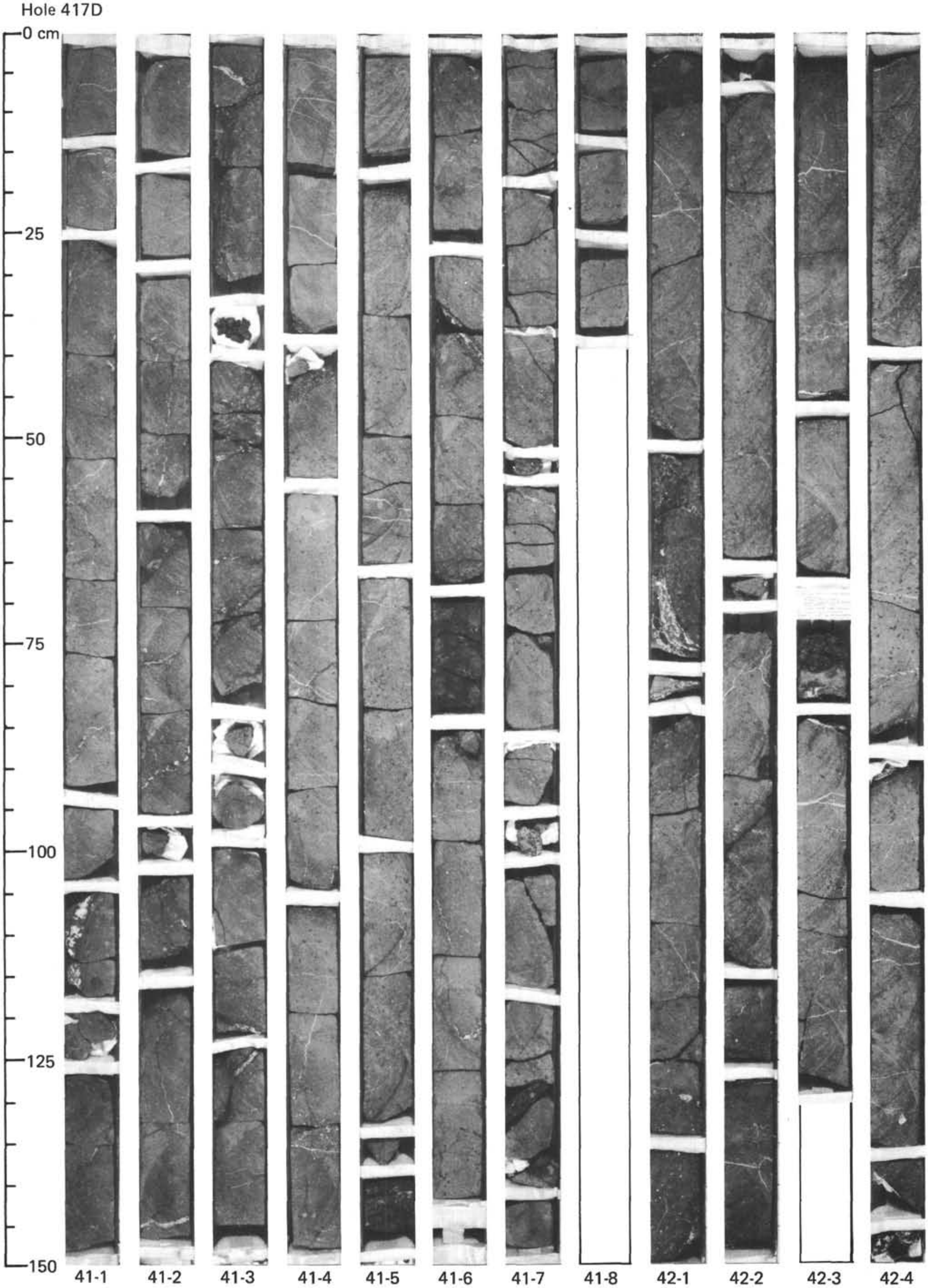
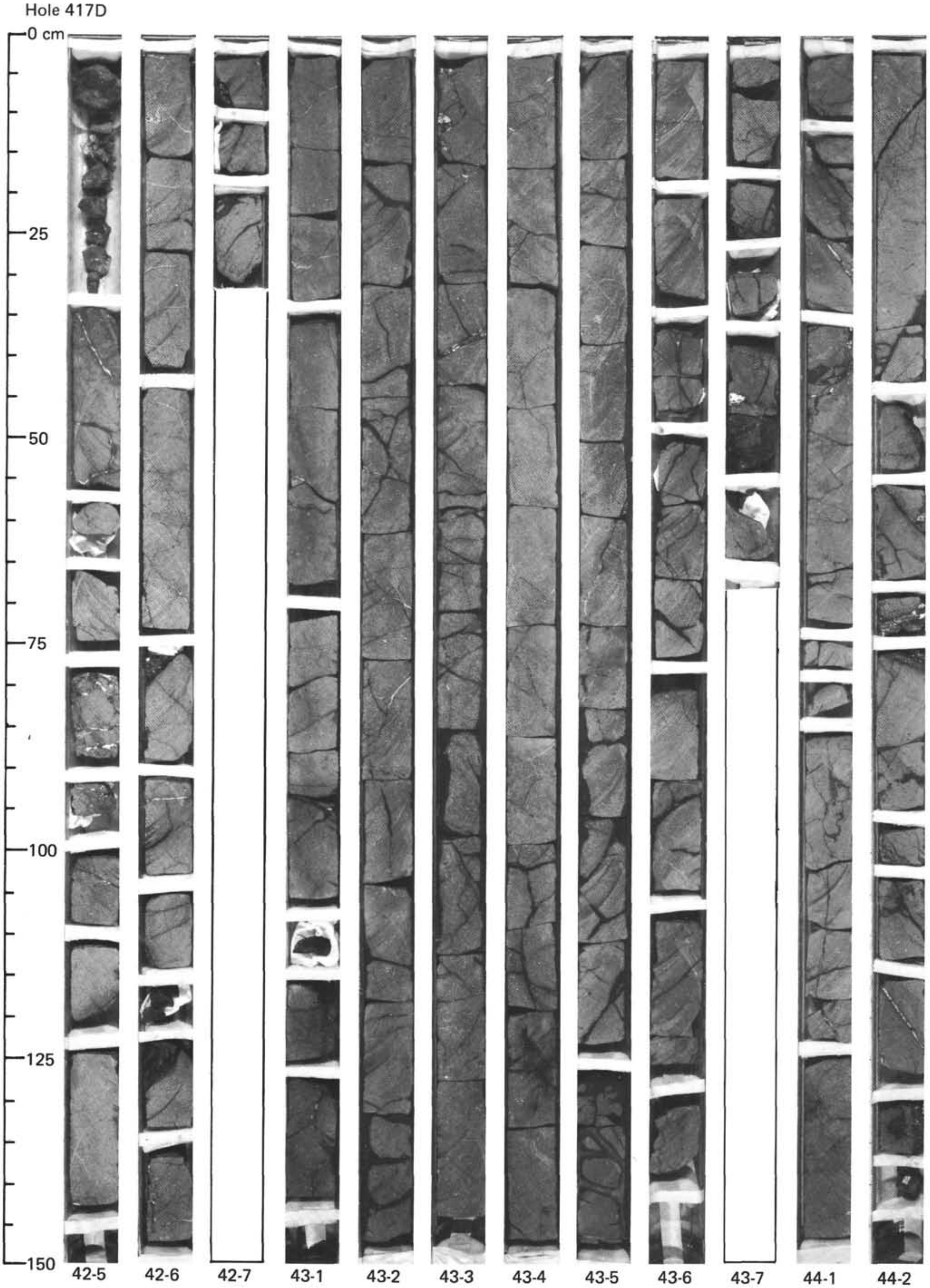
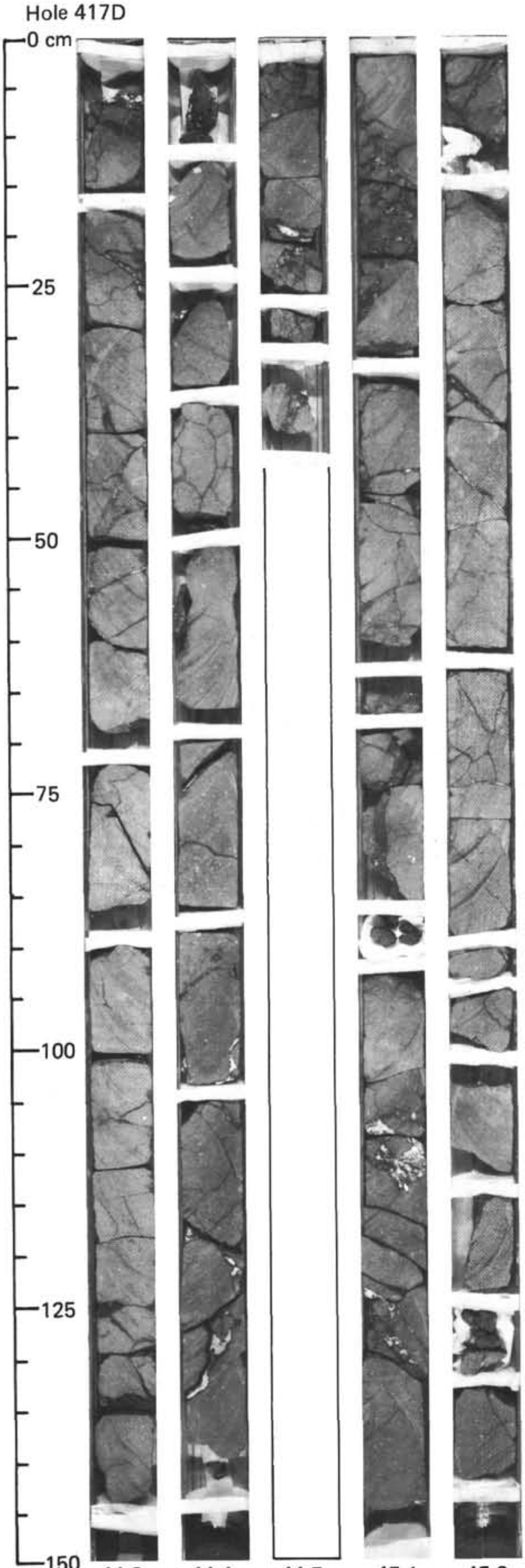
125
150
38-4
38-5
38-6
39-1
39-2
39-3
39-4
39-5
39-6
40-1
40-2
40-3


Hole 417D
0 cm
25
50
75
100
125
150
41-1
41-2
41-3
41-4
41-5
41-6
41-7
41-8
42-1
42-2
42-3
42-4


Hole 417D
0 cm
25
50
75
100
125
150
42-5
42-6
42-7
43-1
43-2
43-3
43-4
43-5
43-6
43-7
44-1
44-2


Hole 417D
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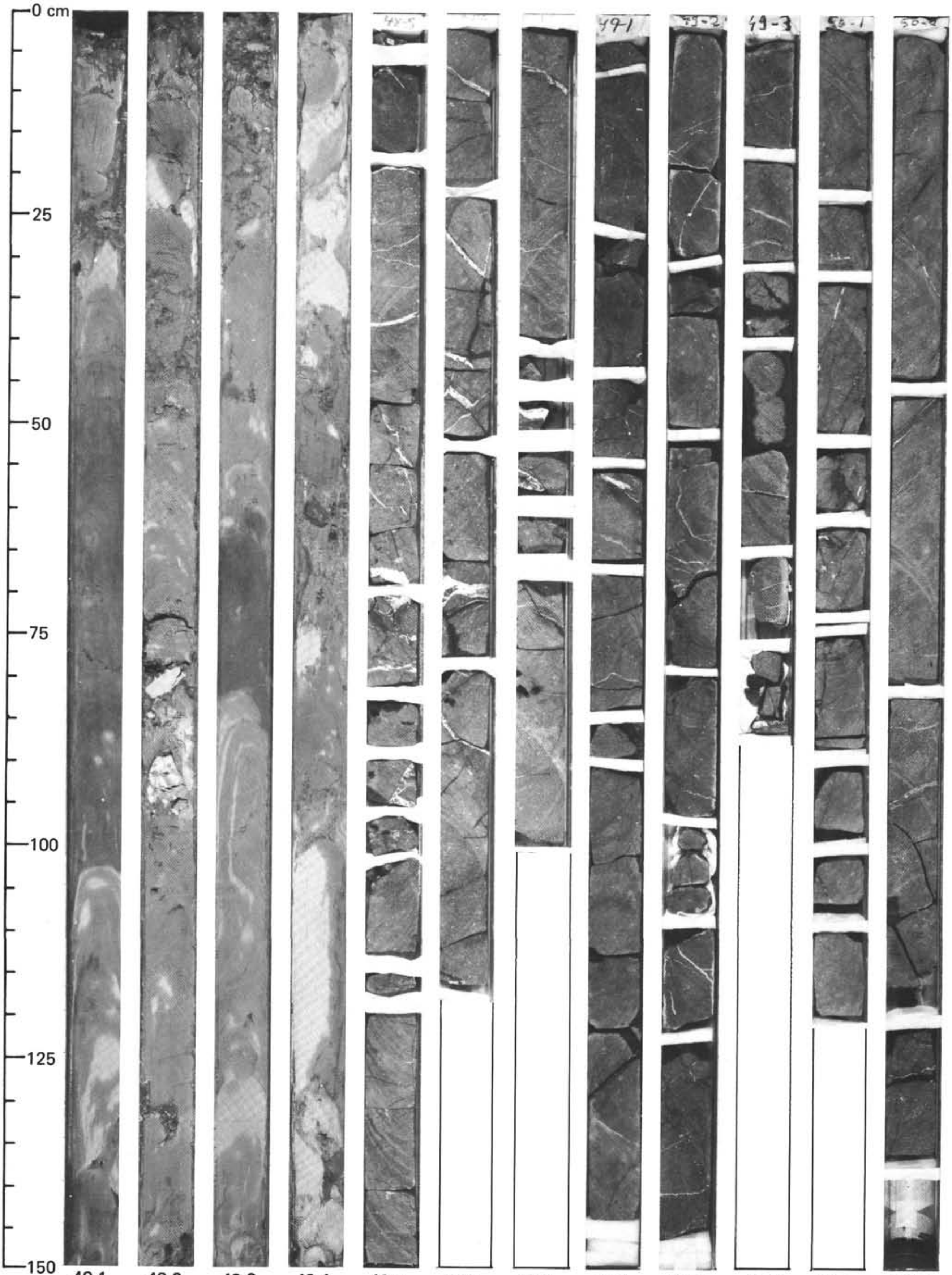
100
125
150
44-3
44-4
44-5
45-1
45-2

Hole 417D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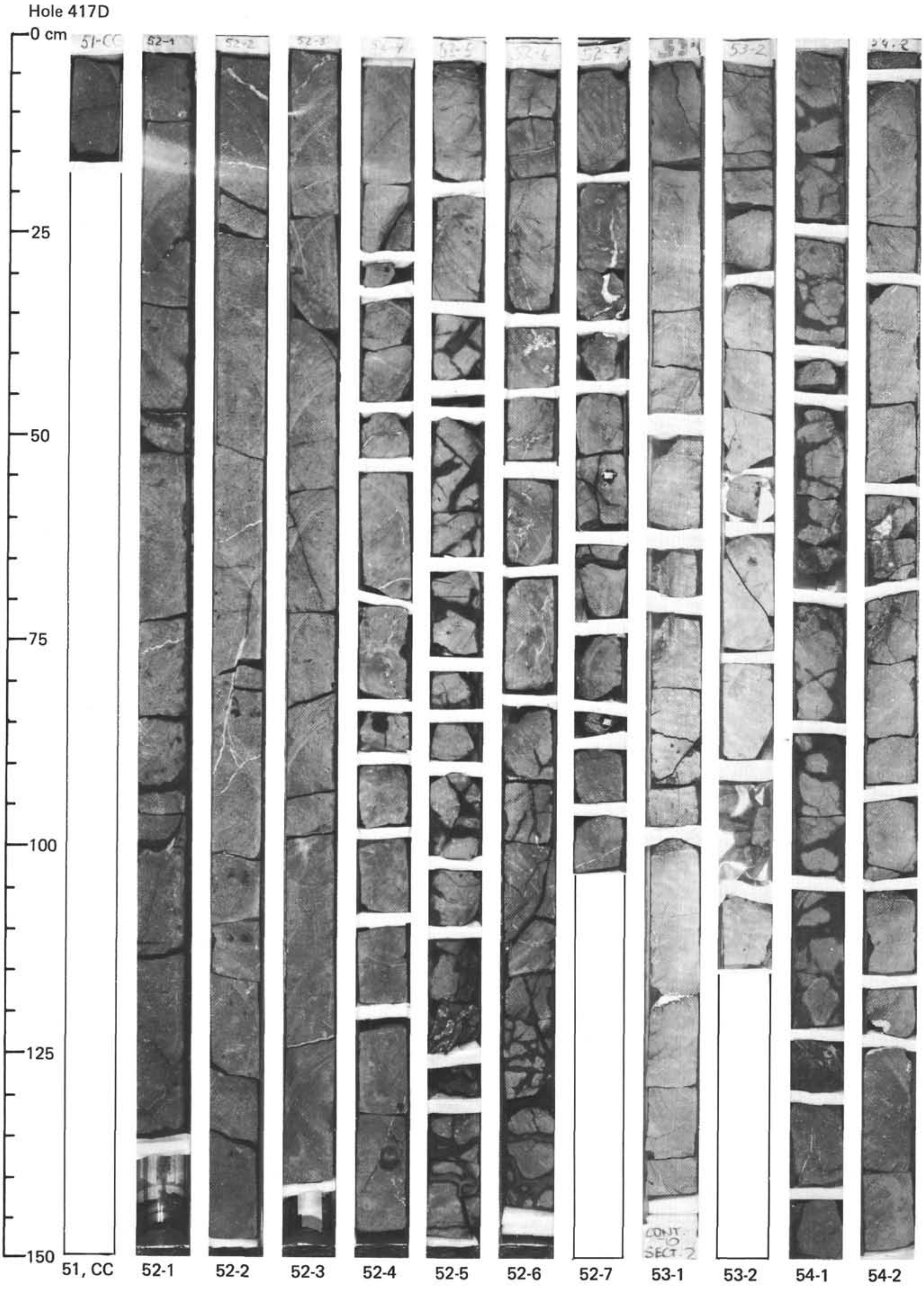
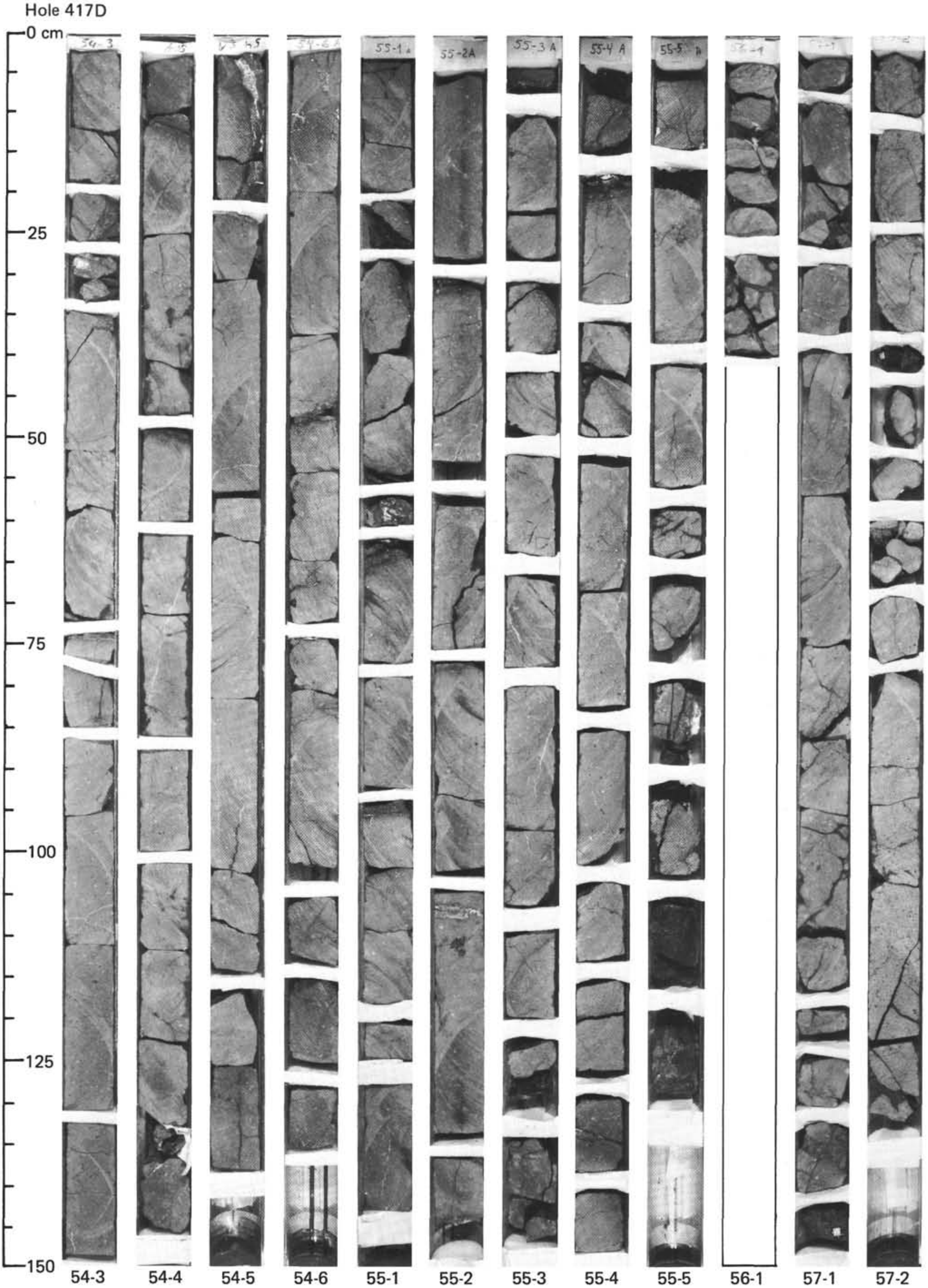
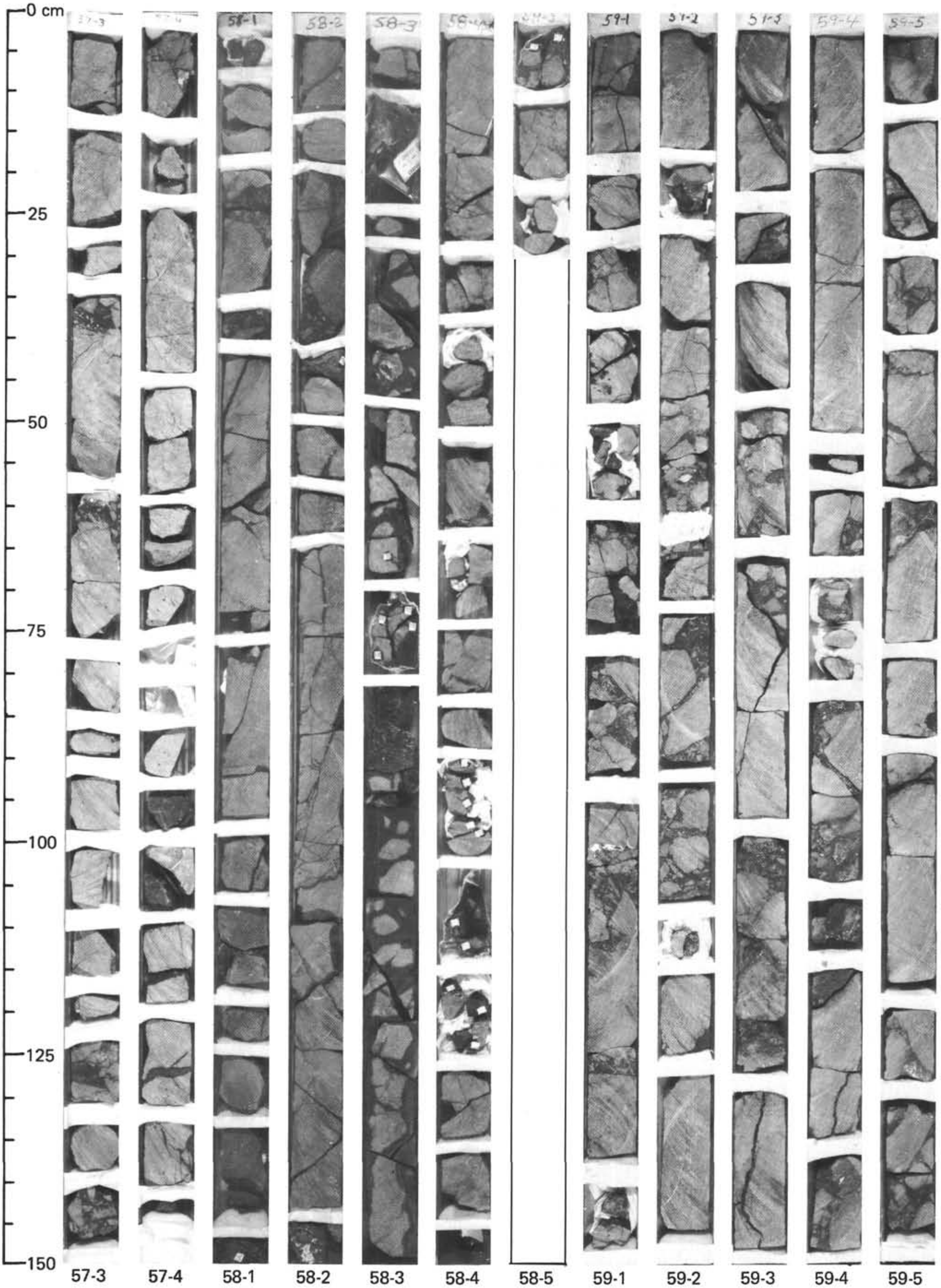
50
75
100
125
150
48-1
48-2
48-3
48-4
48-5
48-6
48-7
49-1
49-2
49-3
50-1
50-2
48-5
49-1
49-2
49-3
50-1
50-2


Hole 417D
0 cm
25
50
75
100
125
150
51, CC
52-1
52-2
52-3
52-4
52-5
52-6
52-7
53-1
53-2
54-1
54-2
CONT. TO SECT. 2


Hole 417D
0 cm
25
50
75
100
125
150
54-3
54-4
54-5
54-6
55-1
55-2
55-3
55-4
55-5
56-1
57-1
57-2

Hole 417D


0 cm
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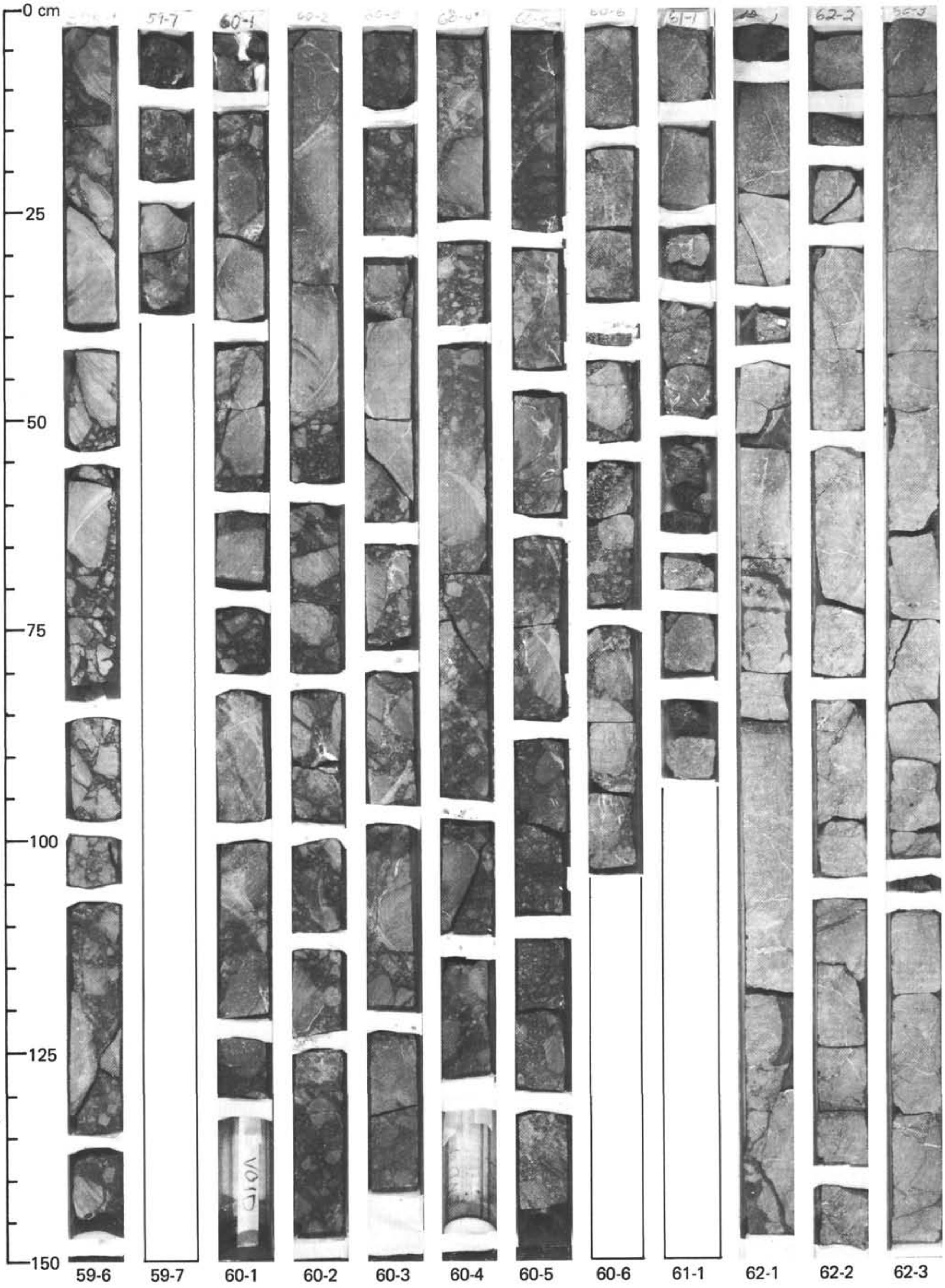
150
57-3
57-4
58-1
58-2
58-3
58-4
58-5
59-1
59-2
59-3
59-4
59-5

Hole 417D


0 cm
25
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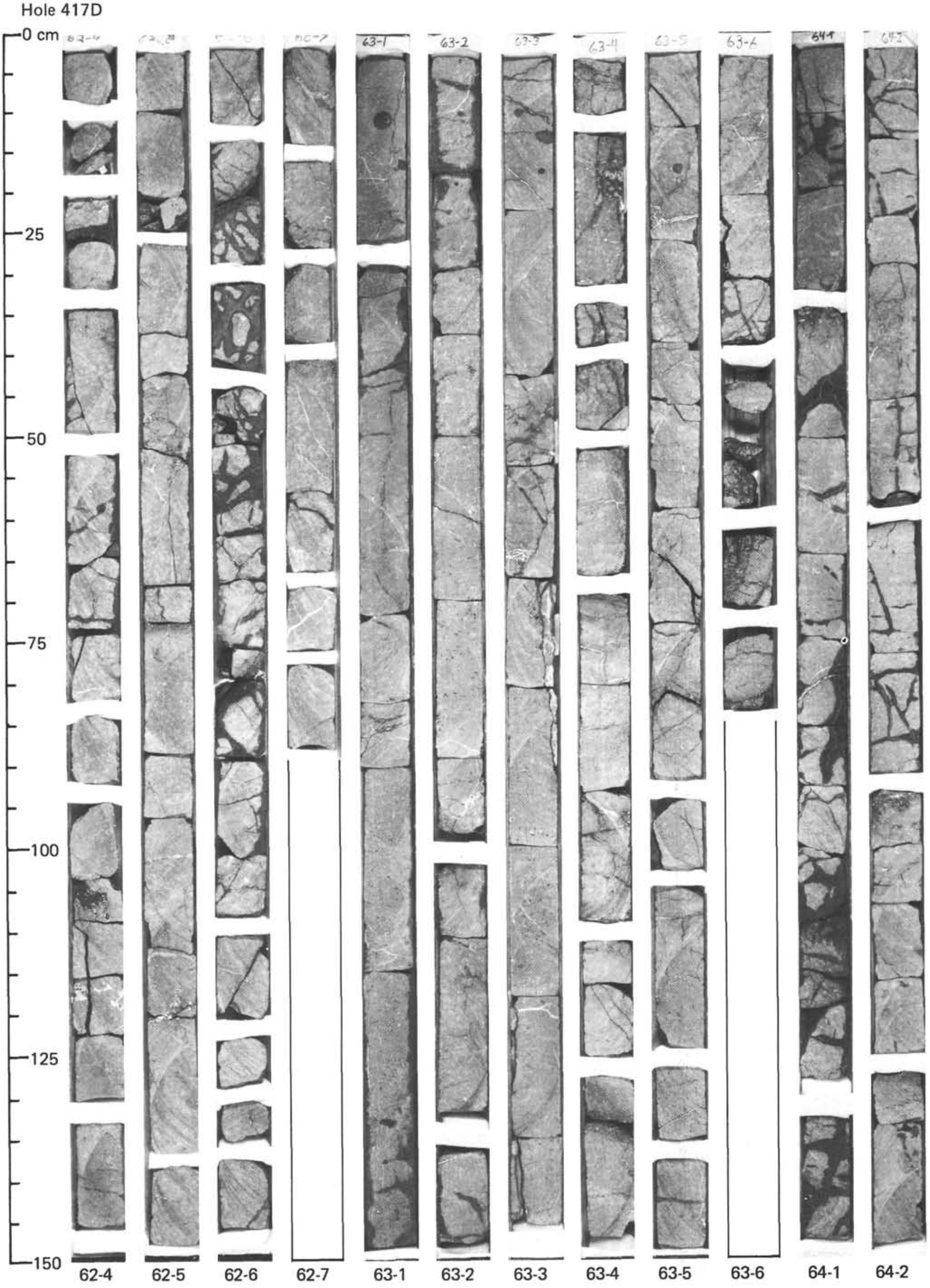
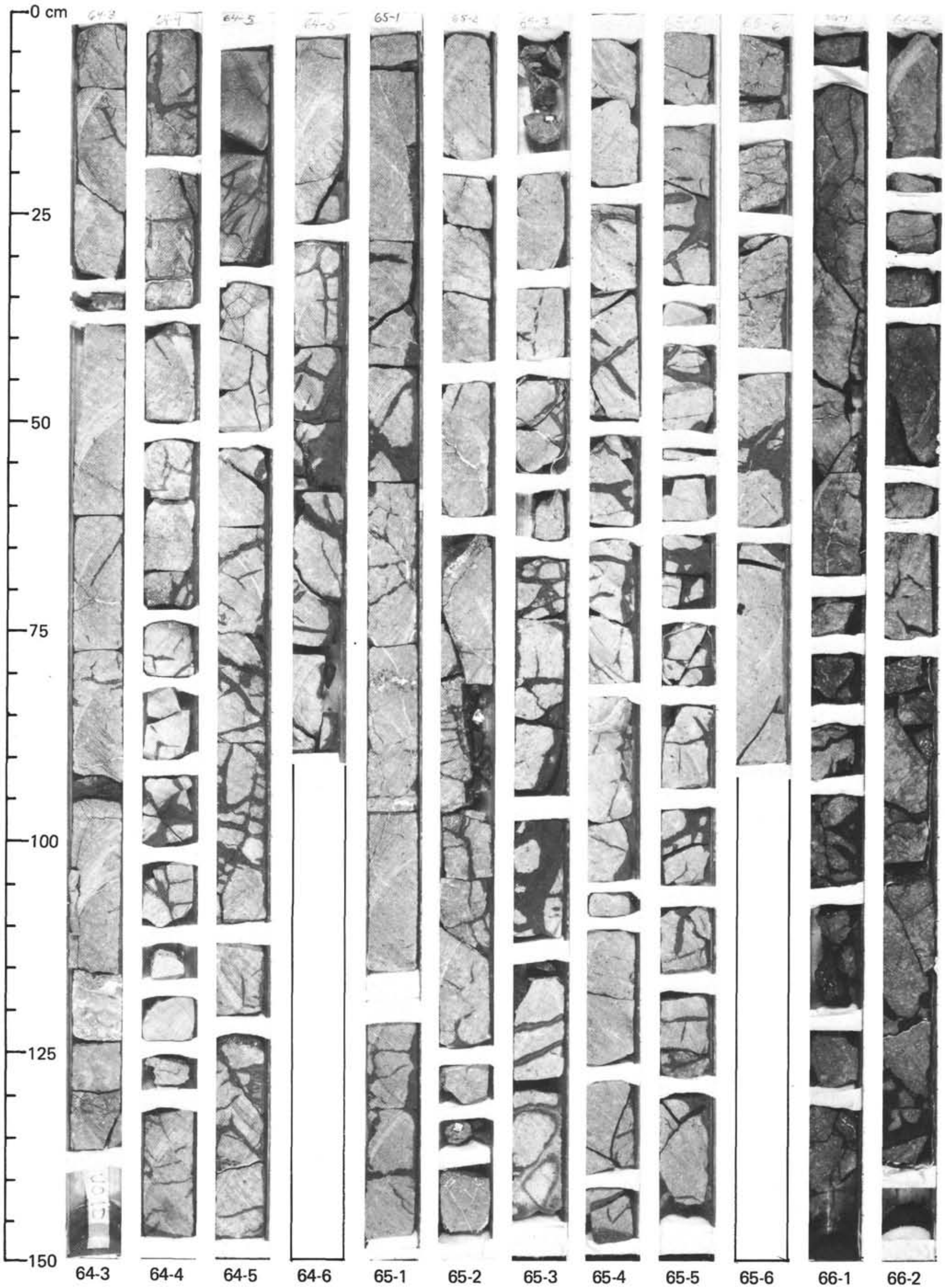
59-6
59-7
60-1
60-2
60-3
60-4
60-5
60-6
61-1
62-1
62-2
62-3
VOID


Hole 417D
0 cm
25
50
75
100
125
150
62-4
62-5
62-6
62-7
63-1
63-2
63-3
63-4
63-5
63-6
64-1
64-2

Hole 417D


0 cm
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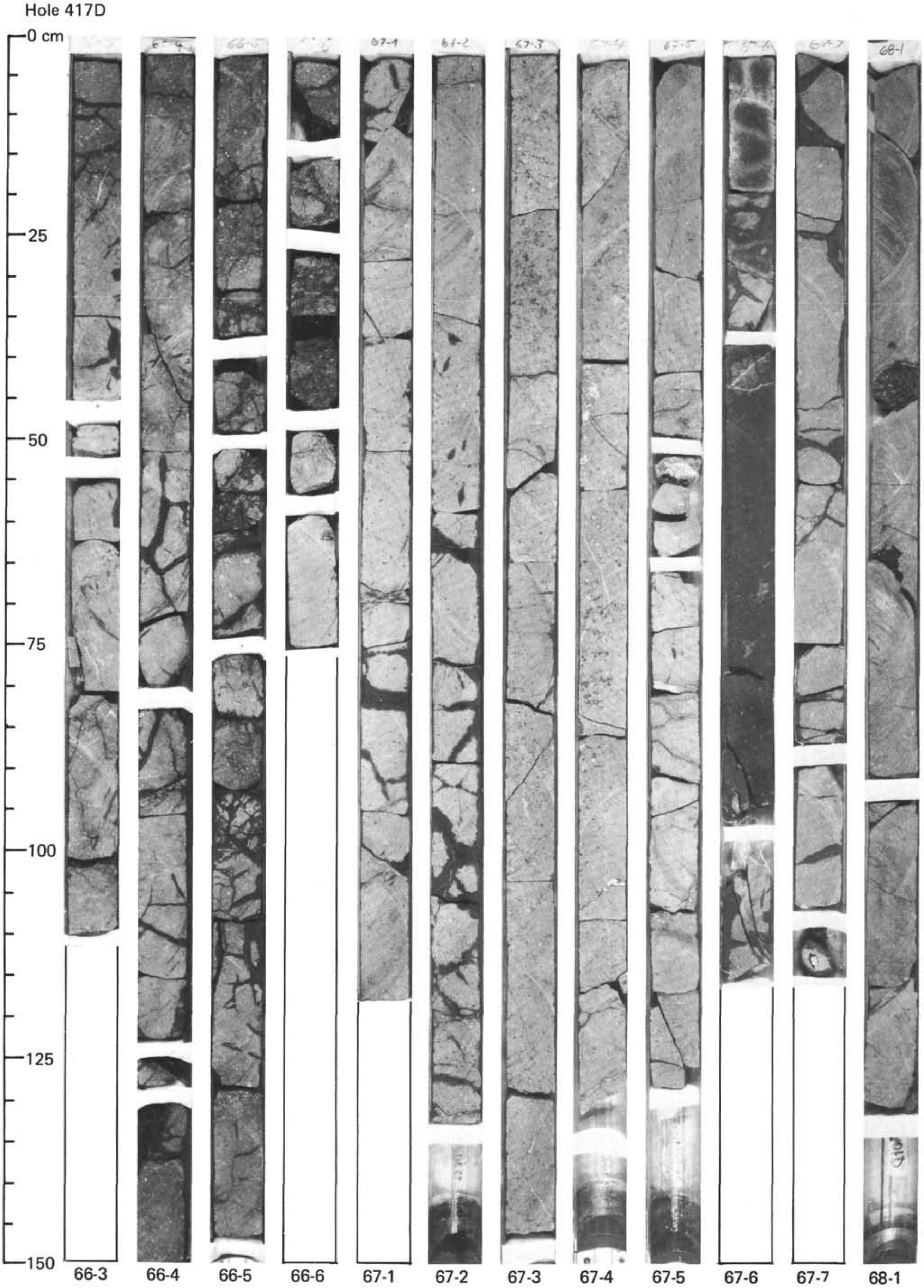
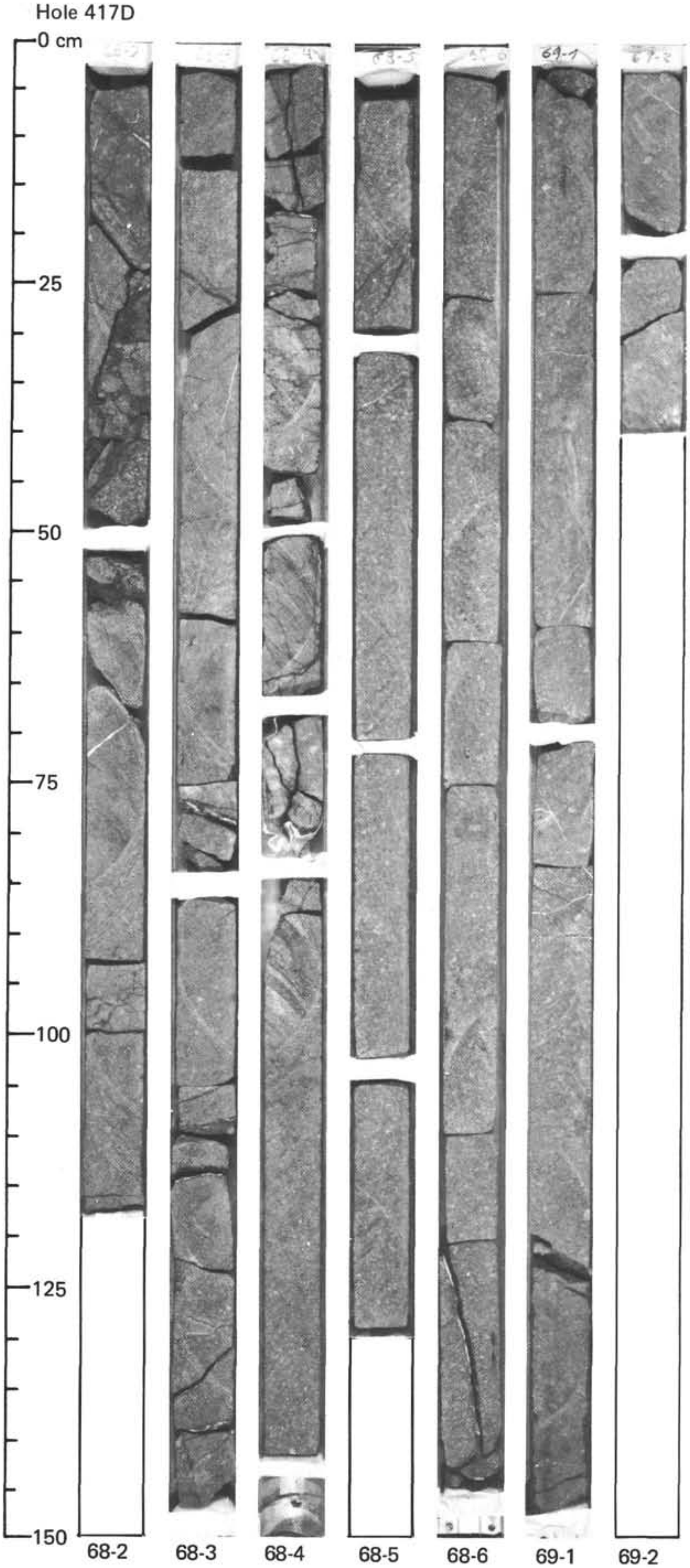
64-3
64-4
64-5
64-6
65-1
65-2
65-3
65-4
65-5
65-6
66-1
66-2


Hole 417D
0 cm
25
50
75
100
125
150
66-3
66-4
66-5
66-6
67-1
67-2
67-3
67-4
67-5
67-6
67-7
68-1


Hole 417D
0 cm
25
50
75
100
125
150
68-2
68-3
68-4
68-5
68-6
69-1
69-2