15. SITE 459: MARIANA FORE-ARC[1]

Shipboard Scientific Party[2]

HOLE 459

Date occupied: 25 April 1978

Date departed: 26 April 1978

Time on hole: 18.4 hrs

Position: 17°51.75′N; 147°18.09′E

Water depth (sea level; corrected m, echo-sounding): 4121

Water depth (rig floor; corrected m, echo-sounding): 4131

Bottom felt (m, drill pipe): 4130

Penetration (m): 3.5

Number of cores: 1

Total length of cored section (m): 3.5

Total core recovered (m): 3.28

Core recovery (%): 94

Oldest sediment cored:
Depth sub-bottom (m): 3.5
Nature: vitric mud
Age: Recent

Principal results: See Hole 459B.

HOLE 459A

Date occupied: 26 April 1978

Date departed: 26 April 1978

Time on hole: 9.0 hrs

Position: 17°51.75′N; 147°18.09′E

Water depth (sea level; corrected m, echo-sounding): 4121

Water depth (rig floor; corrected m, echo-sounding): 4131

Bottom felt (m, drill pipe): 4129.5

Penetration (m): 67

Principal results: See Hole 459B.

HOLE 459B

Date occupied: 26 April 1978

Date departed: 4 May 1978

Time on hole: 192 hrs

Position: 17°51.75′N; 147°18.09′E

Water depth (sea level; corrected m, echo-sounding): 4121

Water depth (rig floor; corrected m, echo-sounding): 4131

Bottom felt (m, drill pipe): 4125.5

Penetration (m): 691.5

Number of cores: 73

Total length of cored section (m): 691.5

Total cored recovered (m): 182.14

Core recovery (%): 26

Oldest sediment cored:
Depth sub-bottom (m): 559
Nature: silicified claystone
Age: pre-late Eocene
Measured velocity (km/s): 1.77

Basement:
Depth sub-bottom (m): 559
Nature: basalt
Velocity range (km/s): 2.7–4.4
Total basement penetration: 132.5

Principal results: Site 459 is located on the eastern edge of a deep sediment pond immediately above (west of) the trench slope break. Hole 459 was abandoned when the lower half of the core barrel containing the mudline core dropped down the drill string and fishing attempts were unsuccessful. Hole 459A, a pilot hole for potential re-entry, was washed down to 87.0 meters; no cores were taken. In Hole 459B, a total of 691.5 meters was cored with a recovery rate of 26%. The upper 559.0 meters are sediments consisting mainly of vitric mud and ooze with ash layers, late to early Pleistocene in age, over a thick pile of turbidites of late Oligocene through middle Miocene age. These in turn overlie middle Eocene to early Oligocene claystones. Hiatuses are recognized for 3.0–10.0, 13.4–14.0, 30.0–34.5, and 40.0–42 Ma. The sedimentary sequence shows that the Site 459 area was subjected to active vertical displacement and tensional stress in the late Oligocene to middle Miocene period.

Below the sediments, 132.5 meters of fine- to medium-grained clinopyroxene-plagioclase pillow basalts, flows, and possible intrusives were cored. Two major chemical types divided into seven subtypes occur, all of them tholeiite and quartz tholeiite in composition. Low contents of TiO_2, Zr, and V despite generally fractionated compositions indicate that these basalts are island arc, rather than abyssal, tholeiites. However, orthopyroxene does not occur in these lavas. Coarser-grained basalts contain quartz–alkali feldspar micrographic intergrowths. The basalts are highly fractured and intensely altered, especially in zones of fractures. Alteration occured in two stages: (1) an oxidative, probably early, and possibly hydrothermal stage in which dioctahedral smectites, celadonite, iron hydroxides, and palygorskite formed as vesicle and vein fillings, and (2) a nonoxidative, probably later stage of intense replacement of groundmass portions of the lavas with trioctahedral smectite and phillipsite. Stage (1) also affected the lowermost sediments, since they too contain palygorskite.

The stable paleomagnetic inclinations of the sediments become shallower deeper in the hole, indicating a northward movement of the site during the Cenozoic. Inclinations in basement are also shallow and of both normal and reversed polarity. Some changes in inclination occur within chemical subtypes, implying faulting of

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the section. Other changes in inclination occur between subtypes, implying that extrusion was over a time period long enough for secular variation of the Earth's magnetic field to occur.

BACKGROUND AND OBJECTIVES

Site 459 (site survey target SP-3C) is located on the eastern margin of the last deep sediment pond on the island arc side of the trench slope break (Figs. 1 and 2). It is one of a series of Leg 60 drill holes (458, 459, and 460/461) designed to investigate the portion of the Mariana arc between the trench axis and the active volcanic arc. The overall background and objectives for this series of holes are discussed in a separate chapter (Mariana arc and fore-arc background and objectives, this volume), and will not be repeated here.

A portion of a reflection seismic record (Fig. 3) obtained during the site selection survey less than 5 km south of Site 459 is an example of the character of the trench-slope break where it demarks the abrupt change from the gentle dip of the fore-arc seafloor to the steep (>9°) dip of the trench wall. The top of the inner wall of the trench, where no acoustic layering is observed, is at about 1125Z time on the reflection profile. We assume the lack of sediment reflections is probably the result of tectonic disturbance of the sediments rather than outcropping of basement, because sonobuoy, OBS, and multichannel seismic velocity determinations near the trench-slope break all indicate a substantial thickness of low-velocity material (about 1 km with velocities less than 3 km/s). Normal faulting is predominant in the seafloor and sub-bottom, suggesting that the region is under tension. To the west, toward the volcanic arc, the sediments appear to thicken over a gradually better-defined and deepening acoustic basement. By 1300Z on Figure 3, apparent sediments are approximately 600 ms (500 m) thick, and the degree of disturbance has lessened to the point where the acoustic basement is well defined and some layering can be observed. This is also the thickest part of the sediments on this particular profile. By 1400Z the acoustic basement shoals to where it seems to crop out on the ocean floor.

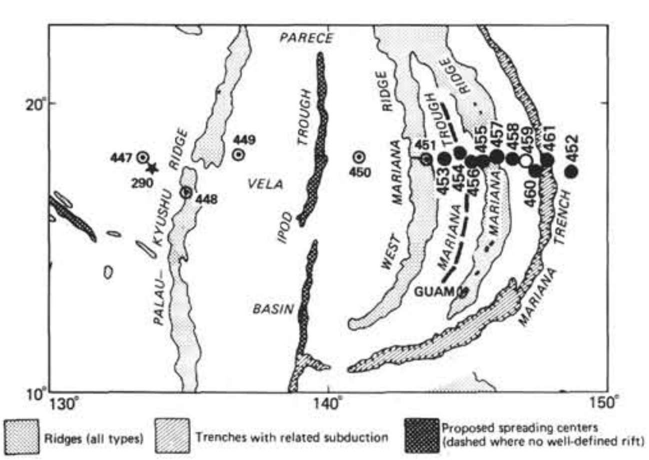

Figure 1. Location of Site 459 (open circle) in the fore-arc region of the Mariana island arc, near the Mariana Trench. Other sites drilled during Leg 60 are shown as closed circles. Sites drilled on Leg 59 are circled dots. Site 290 (Leg 31) is shown by a star.

Another reflection seismic record less than 7 km north of Site 459 (Fig. 4) demonstrates a portion of the trench slope break that has a topographic high rising over 800 meters above the bathymetric trend. No sub-bottom reflectors are observed on the high, which gives it the appearance of an igneous body. However, no magnetic anomalies and only a very subdued gravity anomaly are observed (Hussong and Fryer, this volume). Because these data suggest that the bathymetric high is composed of material with low magnetic susceptibility and low density, it is probably not a volcanic feature.

The primary objectives at Site 459 (SP-3C) were to:

1) determine the nature and origin of the material comprising the acoustic basement at the trench slope break (and, perhaps, by extension the material in the trench-slope break bathymetric high);

2) determine if the wide variety of igneous and metamorphic rocks dredged from lower down the inner wall of the trench (e.g., Dietrich et al., 1978) are derived from the trench slope break;

3) learn, from the recovered sediment, something of the tectonic and volcanic history of the uppermost inner trench wall; and

4) serve as a reference section for comparison with Site 458, on the fore-arc, and Sites 460 and 461, deep on the inner wall of the trench.

OPERATIONS

After a 17-hour stop in Saipan to load supplies, the *Glomar Challenger* sailed at 0615 on 24 April 1978 for Site 459. During transit to Saipan, and during the run back from Saipan to Site 459, all the normal profiling equipment (3.5-kHz and 12-kHz bathymetry, airgun reflection seismic system and magnetometer) were operational.

Site 459 was chosen very near the flank of a bathymetric high on the trench-slope break (see Background and Objectives). The approach to the target area was made from the west, across a sediment-filled basin onto the lower slope of the bathymetric high. The sediment thinned out very quickly as the high was approached, and, although we suspected that there was still adequate sediment to spud in, the difficult drilling conditions encountered previously reinforced our caution and we moved back west to the large sediment-filled basin. When the *Challenger* profile records showed well over 300 meters of sediment, a single life 13.5-kHz beacon was dropped (17°51.7′N, 147°18.1′E) in a PDR depth of 4121 meters at 0604 on 25 April (Fig. 5).

A standard (120-meter) bottom hole assembly was rigged with a 9⅞-inch F93CK bit and the bit release assembly that had just been picked up in Saipan. The drill string was started down at 0730, and we spudded in at a depth of 4120 meters (4130 m below rig floor) at 1400 on 25 April 1978.

The inner barrel containing the mudline core was brought back up to the derrick floor, and the drill pipe was opened to retrieve the core. As the inner barrel was lifted from the drill pipe it came unscrewed in the middle, and the lower half, including the core catcher and liner with the mudline core, dropped back down the drill

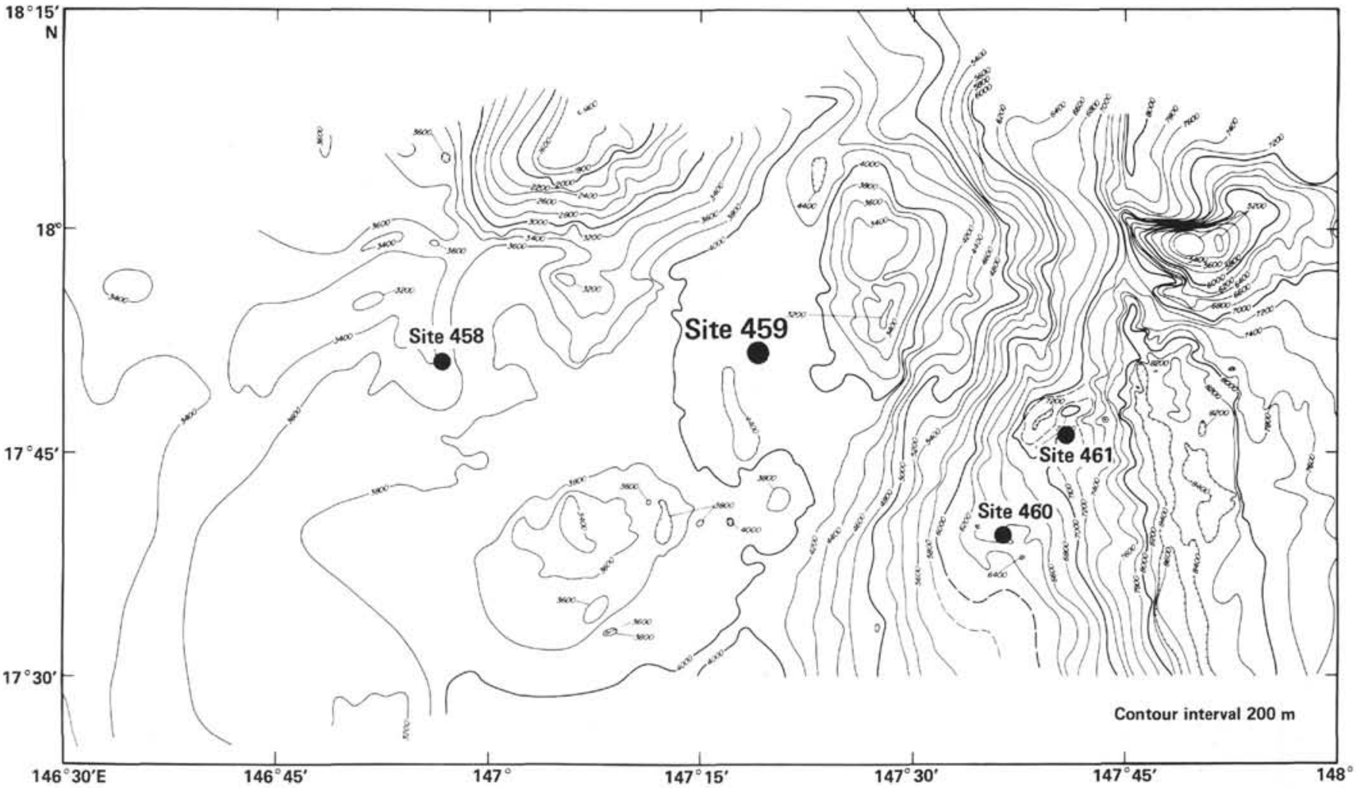

Figure 2. Bathymetry of the Mariana fore-arc region in the vicinity of Site 459 (from Hussong, this volume). Contour interval is in meters.

string. (The expletive simultaneously emitted by the drillers and various bystanders will be left to the reader's imagination.) Two attempts to fish the bottom portion of the inner barrel failed, probably because the plastic core liner was the uppermost object in the hole and was difficult to grasp with the fishing tool. At 1750 the fishing attempts were abandoned and the entire drill string was brought back up. The mudline core was brought aboard in the bottom hole assembly at 0030 on 26 April. The well-traveled 3.28-meter core was the total recovery for Hole 459.

At 0310 the pipe was started back down without moving the ship for Hole 459A. Because this was a potential re-entry site, we conducted 459A as a wash-down pilot hole to determine the length of the casing that would be required for the re-entry cone. Spud-in was at 0726 in 4119.5 meters of water. The bit reached a depth of 87.0 meters after 73 minutes of washing down (the center bit was in place, and no rotation was done). At this time we started back out of the hole, clearing the mudline at 0920 on 26 April 1978.

We offset 50 feet to the east, and Hole 459B was begun by spudding in at 1100 in 4115.5 meters of water (4125.5 meters of pipe below rig floor). The coring summary and drilling rate for all three holes at this site are given in Table 1 and the coring rate for Hole 459B is plotted versus depth in Figure 6. Although plenty of sediment was encountered in Hole 459B, as in the case of Site 458, much of the sediment was quite friable and recovery was erratic and generally low. Approximately 560 meters of sediment and 130 meters of igneous rock were penetrated, with a core recovery rate of 26%.

Three Tokyo T-probe downhole temperature measurements were made at depths of 64.5, 131.0, and 197.5 meters (Uyeda and Horai, this volume). After the second measurement (131 m) the lower 200 feet of sandline had to be cut off because it had been badly kinked during the temperature measurement. This line damage could be the result of one or a combination of three factors: (1) water circulation was turned off while lowering the heat probe to minimize temperature disturbance in the hole; (2) the probe was locked in the bit for a particularly long time; and (3) too much sandline slack may have been let out when the probe locked in the bit. The first two conditions did occur; the third is a possibility. The long measurement duration and shutting down of circulation were two of several variations on the Tokyo T-probe technique that were conducted in order to learn more about temperature disturbance and variation in the hole (Uyeda and Horai, this volume).

The only other problems encountered during drilling were when the overshot filled with line tar and failed to grasp the inner barrel, necessitating two extra core recovery trips. This was as a result of having laid on a new tar-saturated sandline between Sites 458 and 459, so that large amounts of line tar were coming off into the hole.

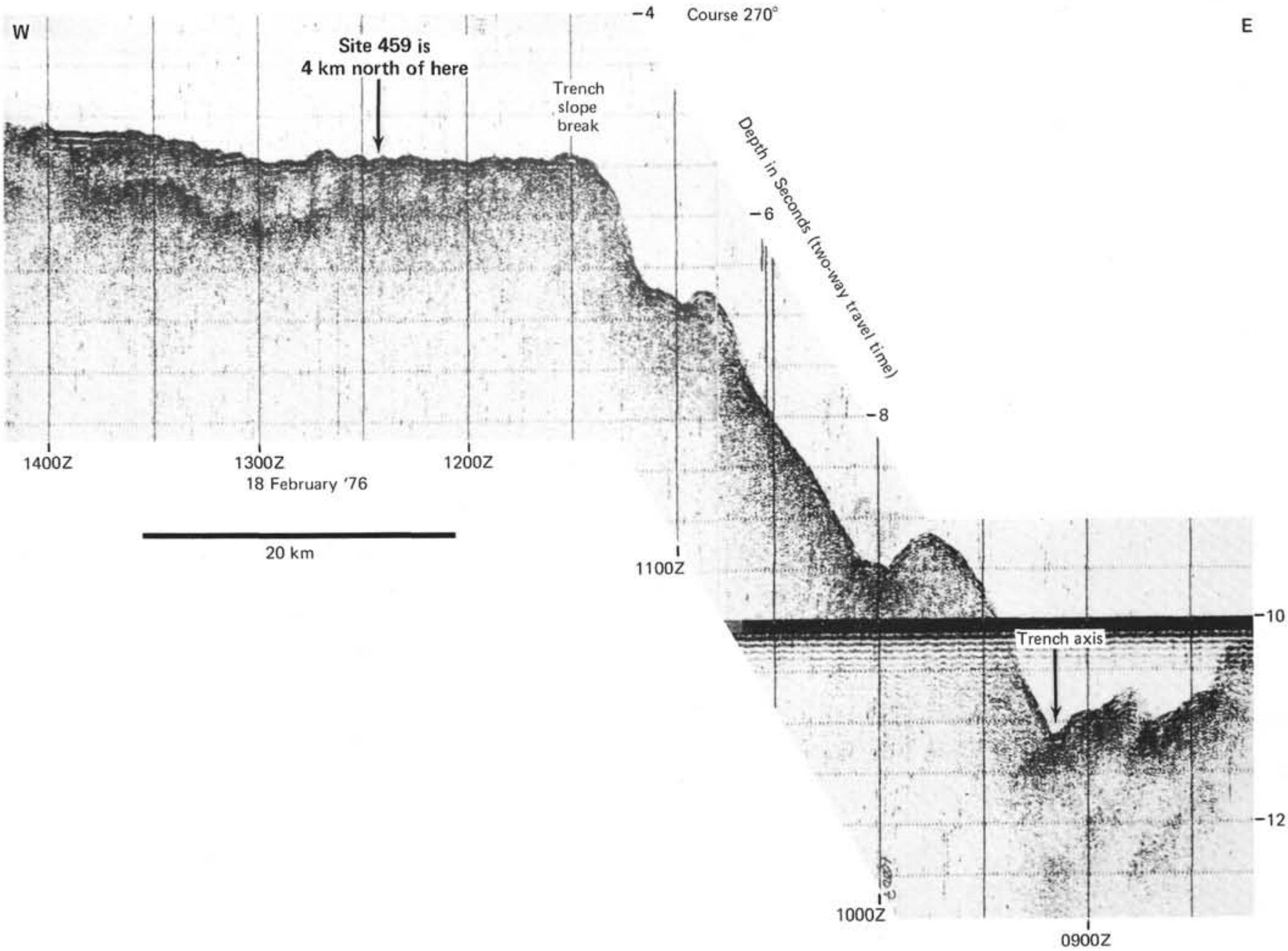

Figure 3. Portion of Hawaii Institute of Geophysics site survey airgun reflection seismic profile obtained on 18 February 1976. Single-channel hydrophone array, filtered 20–80 Hz.

The line tar also showed up in the top of a few core samples, particularly the one taken after the heat flow measurement at 64.5 meters depth.

The ship drifted some 180 feet off station during the cutting of Core 17, owing to the uncompensated addition of an engine to the main drive. This excursion does not seem to have affected the recovery of samples in Core 17.

The heave compensator was installed and used for the cutting of the igneous rock Cores 63 through 73.

During cutting and retrieval of Core 73 the pipe started sticking and torquing owing to caving and infilling, probably from the fractured rock encountered through most of the basement drilling. We decided to abandon further drilling and proceed with logging the hole at this time. The drill string was raised above the sticking level in the hole, and the bit was released at 1753 on 2 May 1978, at a sub-bottom depth of 663 meters. After circulating seawater to clear the hole (mud was not circulated, because the hole has to be full of salt water for the large-scale resistivity experiment [Francis, this volume]), the heave compensator and Bowen unit were set back and the pipe raised to 4244 meters below the rig floor for logging.

The first Gearhart-Owen (GO) logging tool (temperature and gamma-density) was able to go to a depth of only 4646 meters before being stopped (1410 on 2 May) by bridging of the hole. Unfortunately, this blocking was above basement. The second GO run (gamma-sonic and caliper) did not operate properly. The third run (gamma-neutron and laterolog) operated properly but encountered hole bridging at only 4630 meters (2137 on 2 May). The fourth run (gamma-induction) went to only 4611 meters (0245 on 3 May), and the fifth run (repeat of temperature) could go to only 4602 meters (at 0718 on 3 May).

The caving-in of the hole was progressing rapidly, so we rigged the large-scale resistivity experiment (Francis, this volume) rather than try another sonic run. The resistivity experiment lasted from about 0830 to 1757 on 3 May, during which time current was applied at 55 depths for 10 seconds in each polarity. The measurements were apparently successful. Unfortunately, the hole had infilled to 4593 meters by the time this tool reached bottom (1425 local time).

During and just after the large-scale resistivity run the sonic log was repaired and subsequently run to a depth of 4589 meters at 2223 local time. Although the

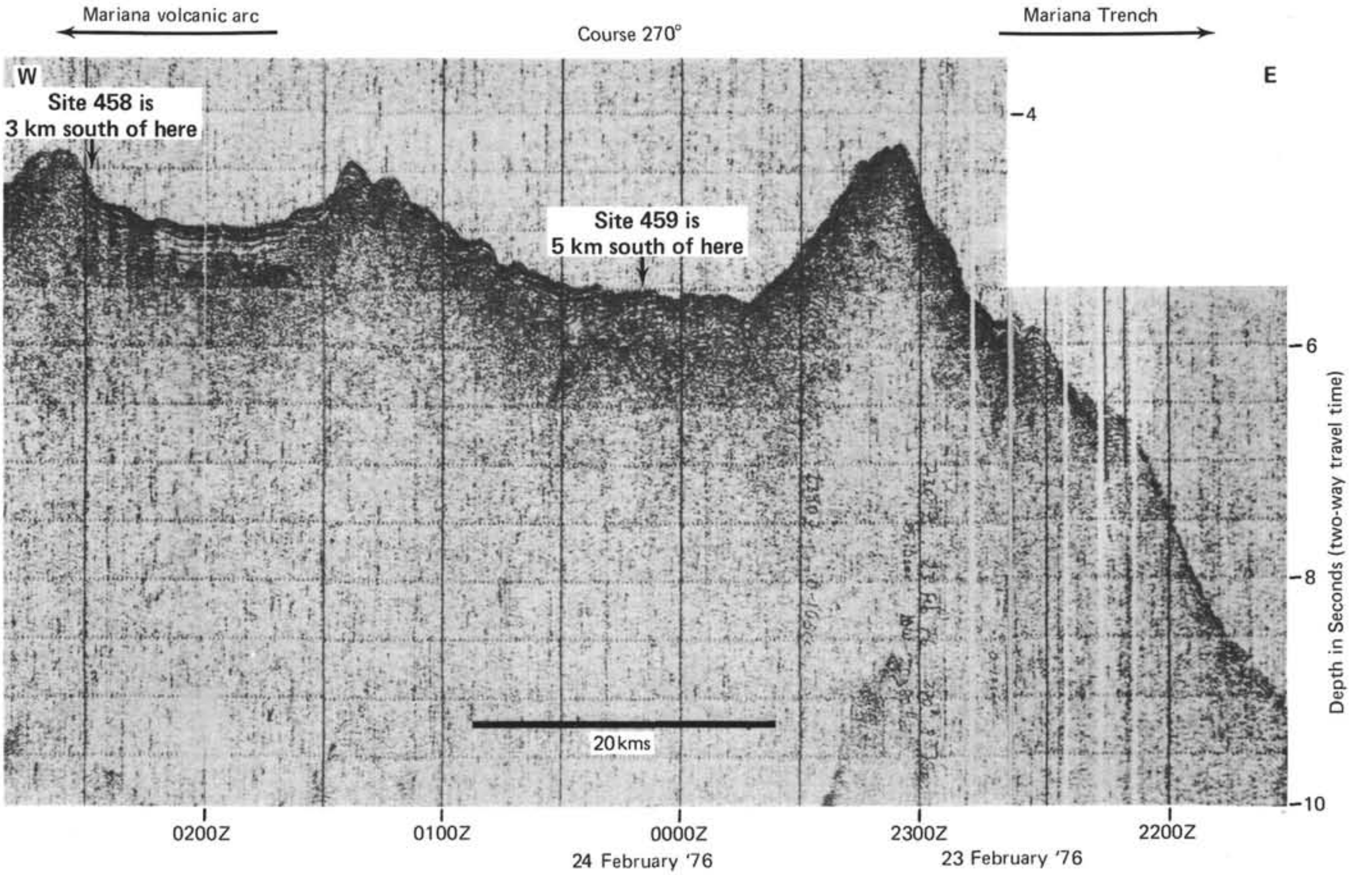

Figure 4. Portion of Hawaii Institute of Geophysics site survey airgun reflection seismic profile obtained on 23-24 February 1976. Single-channel hydrophone array, filtered 20–80 Hz.

sonic tool seemed operational, it behaved erratically and the caliper did not operate, so the measurements are of doubtful quality.

After completion of the logging the drill string was started up at 0200 hrs. and was on deck and secured for transit to the next site at 0930 local time on 4 May 1978.

SEDIMENT LITHOLOGY

At Site 459 (Hole 459B) a 691.5-meter sequence of sediment and igneous rocks was drilled and continuously cored. The total thickness of sediment above the igneous rocks is 559.0 meters. These sediments may be divided into six units, with Unit 3 being further divided into 3 subunits (Fig. 7).

Unit	Core	Thickness (m)	Main Characteristics
1	1–4	36	Siliceous vitric mud and nannofossil vitric ooze
2	5–7	28.5	Hiatuses; vitric mud, nannofossil vitric mud, vitric ash
3	8–57	475	Turbidites; slumping; faulting.
4	58	9.5	Claystone
5	59	9.5	Claystone and cherts
6	60	0.5	Slickensided silicified claystone

Unit I: 36 m; 0–36 m, Cores 1 through 4; late Pleistocene (*Gephyrocapsa oceanica* Zone); 0–0.9 Ma. Dominant lithologies are vitric siliceous and calcareous mud and ooze with muddy to sandy vitric ash layers. The color is mainly dark brown to yellowish brown and is darker in the coarser lithologies. The unit is rich in biogenic sediments. The uppermost 14 meters (Cores 1 and 2) are siliceous with diatoms (up to 75%) and radiolarians (up to 25%). In Cores 3 and 4 nannfossils become predominant (up to 50%) in marly nannofossil ooze. Foraminifers are scarce. Volcaniclastic materials are present either as a minor component in biogenic sediments or as the dominant component in muddy to silty ash layers. They are mainly volcanic glass (25–50%) and feldspars (5–25%). Volcanic glass is generally vesicular, fresh or altered. Clays occur as alteration of volcanic glass and are important components in mud and marly ooze. Reworked pebbles of older claystone and mudstone are common in sandy layers of the two first cores.

The unit is late Pleistocene (*Gephyrocapsa oceanica* Zone, including both the *Ceratolithus cristatus* and *Emiliania ovata* subzones); it bottoms at about 0.9 Ma.

Unit II: 28.5 m; 36–64.5 m, Cores 5 through 7, several possible hiatuses; early Pleistocene–Pliocene?, and early Pliocene–late Miocene; 3.0–10.0 Ma. Between Cores 4 and 8, a condensed sequence with hiatuses is made of vitric mud, marly nannofossil ooze, muddy to sandy crystal, and/or vitric ash. Dominant colors are grayish olive and olive gray.

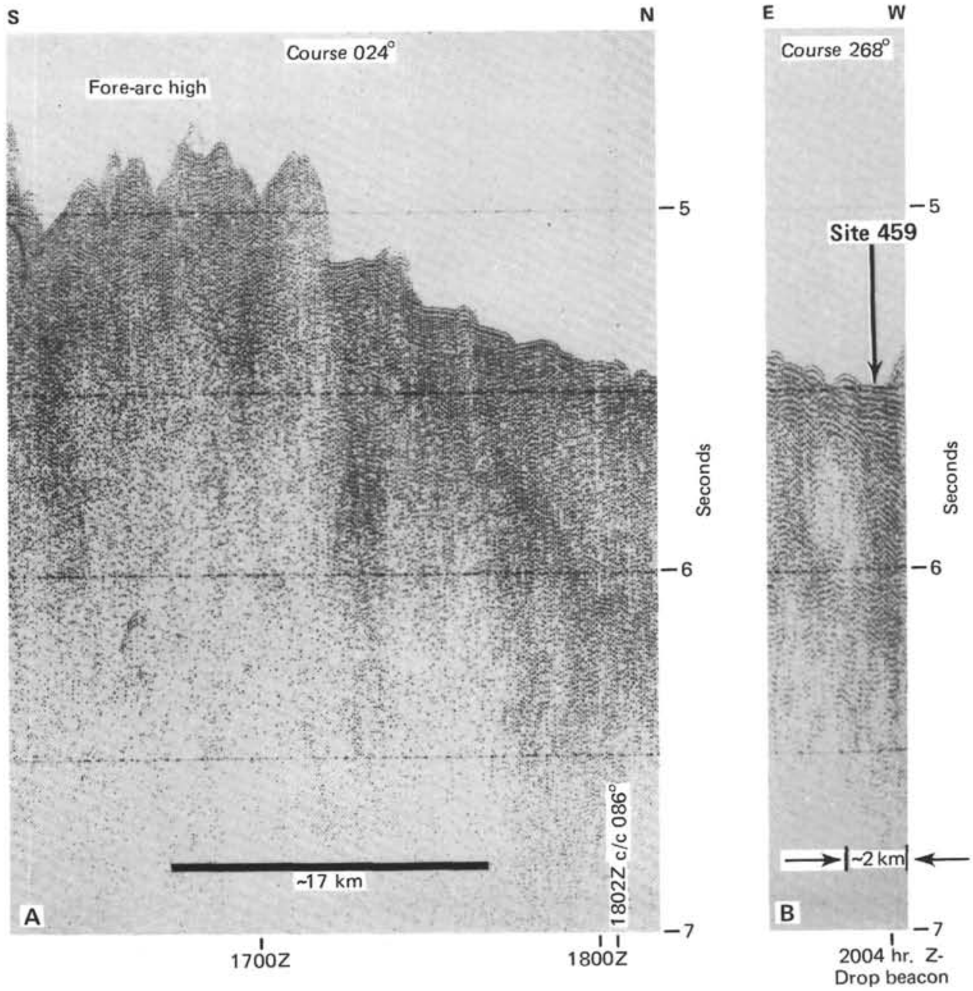

Figure 5. Approach of *Glomar Challenger* to Site 459. Figure 5A crosses a fore-arc high and starts down toward the trench wall east of Site 459. Figure 5B is on course from the east, traversing the trench-slope break to the edge of the fore-arc sediment wedge.

A major and/or a highly condensed sequence is suggested in this unit in the early Pliocene and in late Miocene; Core 5,CC can be placed in the late early Pleistocene *Gephyrocapsa caribbeanica* nannofossil Subzone. Four sections of Core 6 are barren. Sample 459B-6,CC may be assigned to the early late Pliocene *Discoaster tamalis* nannofossil Subzone or older. Only a core catcher sample was recovered from Core 7, and it can be placed in the earliest late Miocene *Ommatartus antipenultimus* radiolarian Zone (7.8 ~9.3? Ma).

Another hiatus, 9.3? ~11 Ma, may also exist between 7,CC and the cores comprising Unit III, because the top of the unit is assigned to the late middle Miocene by the *Catinaster calyculus* nannofossil Subzone (11–12 Ma).

Volcaniclastics are more abundant than in Unit I (15–80%), especially in Core 6. Biogenic components, both calcareous and siliceous, are rare. Nannofossils that may be reworked occur in Core 6. This makes it difficult to establish an exact time scale in this unit.

Unit III: 475 m; 64.5–539.5 m; Cores 8 through 57; middle Miocene through late Oligocene; 11–30 Ma. This unit consists of a thick accumulation of typical turbidites, where the sequences (Bouma sequences or cycles, more or less complete) usually show from top to bottom: (1) burrowed marly chalk or mudstone; (2) massive mudstone; (3) laminated mudstone or siltstone; (4) cross-bedded siltstone; and (5) graded siltstone or sandstone with erosional contacts at the bottom.

Mass flows (turbidite facies) from nearby sources also occur in the lower cores. Slumping occurs commonly throughout the unit. Extensive normal (tensional) faulting is developed throughout, particularly in Cores 26 to 28 (boundary between early and middle Miocene) and 50 to 54 (late Oligocene). Displacement is commonly of a few centimeters or less but can reach 15 cm. Clastic "minidikes," probably the traces of dewatering passages, occur generally at the top of turbidite sequences (Cores 46–57) and crosscut burrows. The openings are tensional in origin and can be filled with over- and underlying coarse-graded sand (sandstone).

This turbiditic Unit III is divided into 3 subunits on the basis of composition and texture:

Subunit IIIA: 161.5 m; 64.5–226 m; Cores 8 through 24; middle Miocene (*Catinaster calyculus* Subzone through *Sphenolithus heteromorphus* Zone); 11–15 Ma. One or more turbidites occur between vitric marly nannofossil chalks and vitric mudstones. The color is dominantly olive gray, with olive black graded or laminated layers (silty and sandy vitric tuff). Volcanic glass (10–70%) is strongly altered; clays, including green clay present all through this subunit, are also a prominent

Table 1. Coring summary, Site 459.

Core	Date (1978)	Time	Depth from Drill Floor (m) Top Bottom	Depth below Seafloor (m) Top Bottom	Length Cored (m)	Length Recovered (m)	Recovery (%)
Hole 459							
1	26 Apr.	0030	4129.5–4133.0	0–3.5	3.5	3.28	93.7
Hole 459A							
0							
Hole 459B							
1	26 Apr.	1153	4125.5–4133.0	0–7.5	7.5	7.1	94.6
2	26 Apr.	1319	4133.0–4142.5	7.5–17.0	9.5	6.66	70.1
3	26 Apr.	1434	4142.5–4152.0	17.0–26.5	9.5	0.05	0.6
4	26 Apr.	1601	4152.0–4161.5	26.5–36.0	9.5	0.26	2.7
5	26 Apr.	1721	4161.5–4171.0	36.0–45.5	9.5	0.57	6.0
6	26 Apr.	1919	4171.0–4180.5	45.5–55.0	9.5	5.87	61.7
7	26 Apr.	2044	4180.5–4190.0	55.0–64.5	9.5	0.08	0.7
8	27 Apr.	0042	4190.0–4199.5	64.5–74.0	9.5	1.62	17.0
9	27 Apr.	0229	4199.5–4209.0	74.0–83.5	9.5	1.24	13.1
10	27 Apr.	0400	4209.0–4218.5	83.5–93.0	9.5	0	0
11	27 Apr.	0602	4218.5–4228.0	93.0–102.5	9.5	2.75	28.9
12	27 Apr.	0723	4228.0–4237.5	102.5–112.0	9.5	0.32	3.4
13	27 Apr.	0854	4237.5–4247.0	112.0–121.5	9.5	0.97	10.2
14	27 Apr.	1013	4247.0–4256.5	121.5–131.0	9.5	1.50	15.7
15	27 Apr.	1446	4256.5–4266.0	131.0–140.5	9.5	3.40	35.7
16	27 Apr.	1610	4266.0–4275.5	140.5–150.0	9.5	0	0
17	27 Apr.	1826	4275.5–4285.0	150.0–159.5	9.5	0.95	10.0
18	27 Apr.	2042	4285.0–4294.5	159.5–169.0	9.5	0	0
19	27 Apr.	2240	4294.5–4304.0	169.0–178.5	9.5	0.60	6.3
20	28 Apr.	0040	4304.0–4313.5	178.5–188.0	9.5	1.14	12.0
21	28 Apr.	0200	4313.5–4323.0	188.0–197.5	9.5	1.37	14.4
22	28 Apr.	0528	4323.0–4332.5	197.5–207.0	9.5	0.80	8.4
23	28 Apr.	0650	4332.5–4342.0	207.0–216.5	9.5	0.03	0.3
24	28 Apr.	0850	4342.0–4351.5	216.5–226.0	9.5	2.85	30.0
25	28 Apr.	1008	4351.5–4361.0	226.0–235.5	9.5	5.03	52.9
26	28 Apr.	1119	4361.0–4370.5	235.5–245.0	9.5	1.5	15.7
27	28 Apr.	1242	4370.5–4380.0	245.0–254.5	9.5	6.62	69.6
28	28 Apr.	1445	4380.0–4389.5	254.5–264.0	9.5	4.70	49.5
29	28 Apr.	1559	4389.5–4399.0	264.0–273.5	9.5	3.48	36.6
30	28 Apr.	1816	4399.0–4408.5	273.5–283.0	9.5	6.22	65.4
31	28 Apr.	1951	4408.5–4418.0	283.0–292.5	9.5	3.06	32.2
32	28 Apr.	2106	4418.0–4427.5	292.5–302.0	9.5	2.46	25.8
33	28 Apr.	2227	4427.5–4437.0	302.0–311.5	9.5	1.56	16.4
34	28 Apr.	2354	4437.0–4446.5	311.5–321.0	9.5	2.27	23.8
35	29 Apr.	0115	4446.5–4456.0	321.0–330.5	9.5	3.38	35.0
36	29 Apr.	0508	4456.0–4465.5	330.5–340.0	9.5	3.30	34.7
37	29 Apr.	0635	4465.5–4475.0	340.0–349.5	9.5	1.79	18.8
38	29 Apr.	0748	4475.0–4484.5	349.5–359.0	9.5	2.49	26.2
39	29 Apr.	0915	4484.5–4494.0	359.0–368.5	9.5	2.87	30.2
40	29 Apr.	1039	4494.0–4503.5	368.5–378.0	9.5	5.77	60.7
41	29 Apr.	1155	4503.5–4513.0	378.0–387.5	9.5	0.15	1.6
42	29 Apr.	1314	4513.0–4522.5	387.5–397.0	9.5	3.34	35.1
43	29 Apr.	1448	4522.5–4532.0	397.0–406.5	9.5	1.5	15.8
44	29 Apr.	1640	4532.0–4541.5	406.5–416.0	9.5	2.36	24.6
45	29 Apr.	1821	4541.5–4551.0	416.0–425.5	9.5	1.05	11.0
46	29 Apr.	1959	4551.0–4560.5	425.5–435.0	9.5	2.94	31.0
47	29 Apr.	2127	4560.5–4570.0	435.0–444.5	9.5	1.32	13.9
48	29 Apr.	2259	4570.0–4579.5	444.5–454.0	9.5	2.05	21.5
49	30 Apr.	0041	4579.5–4589.0	454.0–463.5	9.5	0.73	7.7
50	30 Apr.	0211	4589.0–4598.5	463.5–473.0	9.5	4.55	47.9
51	30 Apr.	0345	4598.5–4608.0	473.0–482.5	9.5	2.30	24.2
52	30 Apr.	0507	4608.0–4617.5	482.5–492.0	9.5	4.04	42.5
53	30 Apr.	0630	4617.5–4627.0	492.0–501.5	9.5	5.28	55.6
54	30 Apr.	0808	4627.0–4636.5	501.5–511.0	9.5	6.61	69.6
55	30 Apr.	0951	4636.5–4646.0	511.0–520.5	9.5	5.65	59.4
56	30 Apr.	1153	4646.0–4655.5	520.5–530.0	9.5	6.32	66.5
57	30 Apr.	1332	4655.5–4665.0	530.0–539.5	9.5	3.90	41.0
58	30 Apr.	1510	4665.0–4674.5	539.5–549.0	9.5	5.0	52.6
59	30 Apr.	1716	4674.5–4684.0	549.0–558.5	9.5	2.45	25.7
60	30 Apr.	1934	4684.0–4693.5	558.5–568.0	9.5	1.69	17.7
61	30 Apr.	2212	4693.5–4703.0	568.0–577.5	9.5	1.50	15.7
62	1 May	0043	4703.0–4712.5	577.5–587.0	9.5	0.73	7.6
63	1 May	0530	4712.5–4722.0	587.0–596.5	9.5	0.75	7.8
64	1 May	0716	4722.0–4731.5	596.5–606.0	9.5	0.67	7.0
65	1 May	1000	4731.5–4741.0	606.0–615.5	9.5	1.65	17.3
66	1 May	1220	4741.0–4750.5	615.5–625.0	9.5	2.57	27.0
67	1 May	1455	4750.5–4760.0	625.0–634.5	9.5	1.95	20.5
68	1 May	1725	4760.0–4769.5	634.5–644.0	9.5	0.45	4.7
69	1 May	2022	4769.5–4779.0	644.0–653.5	9.5	1.76	18.5
70	1 May	2257	4779.0–4788.5	653.5–663.0	9.5	1.58	16.6
71	2 May	0107	4788.5–4798.0	663.0–672.5	9.5	2.79	30.4
72	2 May	0310	4798.0–4807.5	672.5–682.0	9.5	1.50	15.7
73	2 May	0620	4807.5–4817.0	682.0–691.5	9.5	4.35	45.7
					691.5	182.11	26.3

component (40–80%). Calcareous nannofossils usually represent 10 to 30% of the sediments but decrease in abundance downward.

In this subunit a small hiatus may exist in the early middle Miocene. The *Coccolithus miopelagicus* nannofossil Subzone (ca. 0.6 Ma) is missing and the *S. heteromorphus* Zone is rather briefly represented.

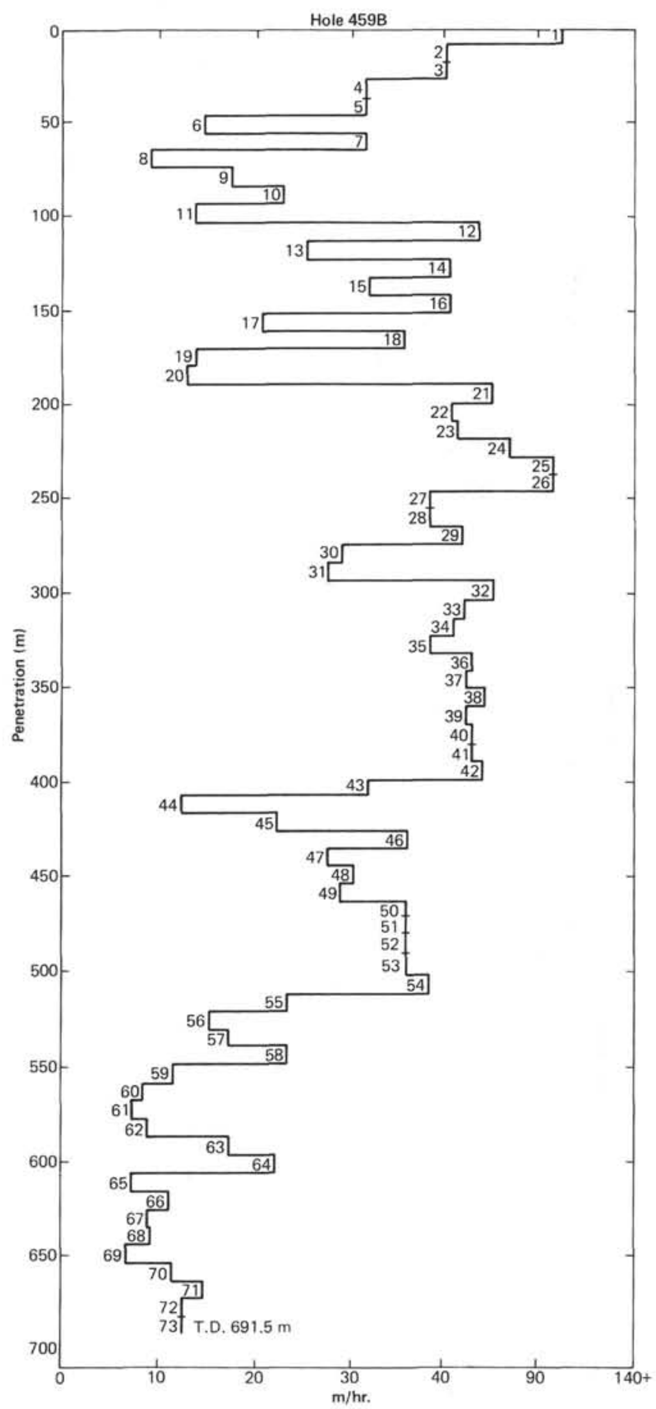

Figure 6. Coring summary, Hole 459B, showing the coring rate per core versus meters of total penetration.

Marly nannofossil chalks decrease (Cores 21–25) and mudstones increase downward through the same interval. Mudstones become dominant below Core 24.

Subunit IIIB: 228 m; 226–454 m; Cores 25 through 48; early Miocene (15–24 Ma). This subunit consists of turbiditic sequences with the following lithologies, from top to bottom in complete turbidites: claystone, mud-

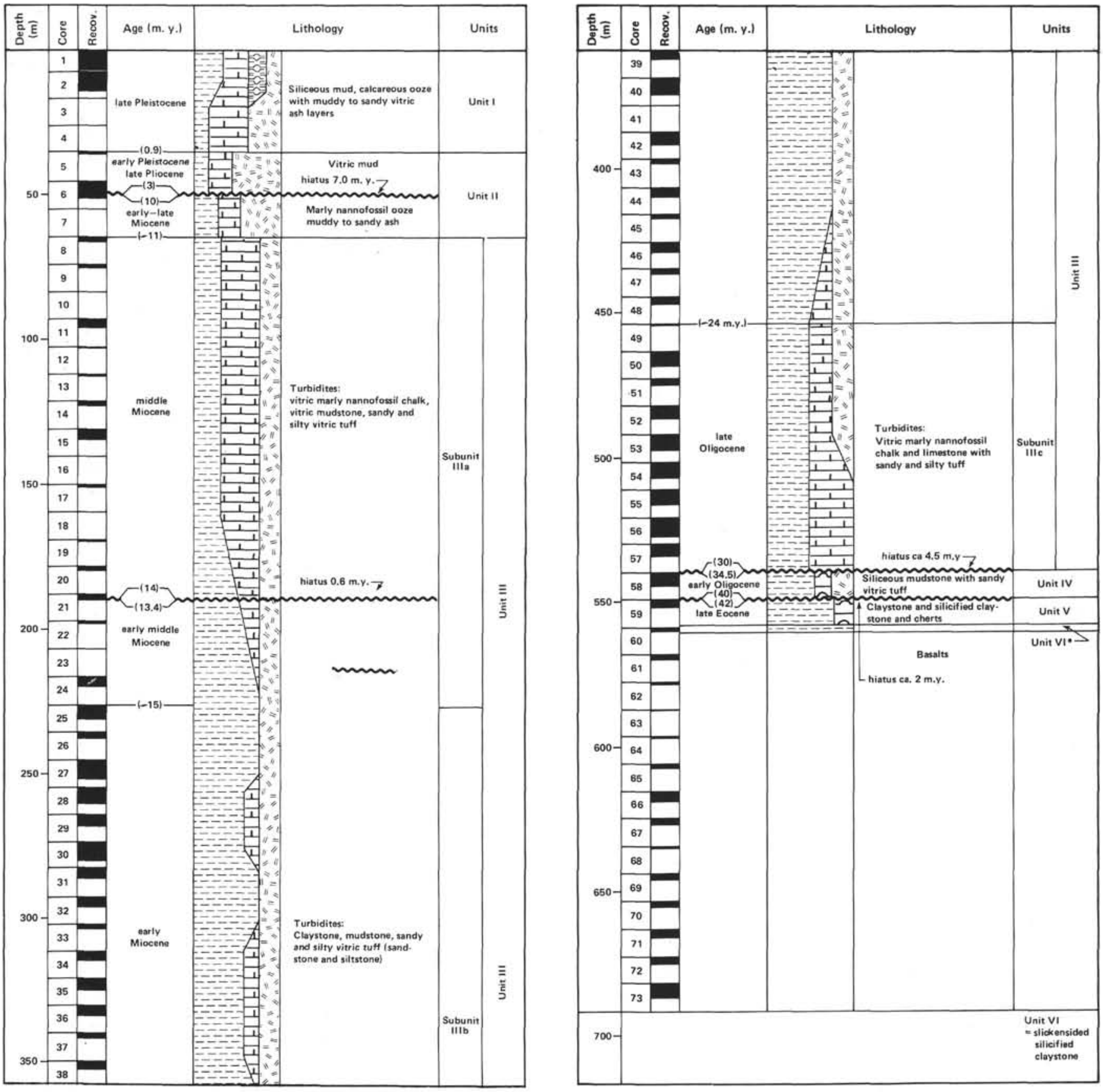

Figure 7. Sediment age, lithology, units, and core recovery versus depth, Hole 459B.

stone, siltstone, and sandstone. Mudstones are contaminated by volcaniclastics, whereas siltstones and sandstones are generally vitric tuffs (more than 50% of ash-size components). Marly nannofossil chalks are rare in the upper part (Cores 25–30), absent in the middle portion, and rare in the lower cores (46–48).

Subunit IIIC: 85.5 m; 454–539.5 m; Cores 49 through 57; late Oligocene; 23–30 Ma. In this subunit, vitric marly nannofossil chalk and limestone increase downward, giving way to calcareous turbidites in Cores 54 to 57. Large foraminifers are commonly reworked in these turbidites (Cores 54, 56, 57). Volcanic glass is very rare (0–3% at the bottom in Cores 55–57) but is increasingly present upward (53 through 49).

Dominant colors are greenish gray, olive gray, and yellowish gray. Core 56, Section 4 contains a dusky brown uniform clay.

Unit IV: 9.5 m; 539.5–549 m; Core 58; early Oligocene to latest Eocene, 34–40 Ma. Absence of a nannofossil zone and a subzone *Sphenolithus predistentus* and *Reticulofenestra hillae*) may indicate a hiatus of ca. 4 m.y. (30–34 Ma) between Units III and IV. Unit IV consists of siliceous claystone and mudstone and silty and sandy vitric tuff organized in graded sequences. Nannofossil limestones are absent; siliceous biogenic components occur (up to 10%). The dominant color is light brown to moderate brown.

Unit V: 9.5 m; 549–558.5 m; Core 59; late Eocene (radiolarian *Podocyrtis chalara* Zone which occupies the early-late Eocene at about 44 Ma). A light brown claystone with several pieces of silicified claystone and grayish brown cherts occurs in Core 59. Smear slides of the claystones contain the following: clay (95%), feldspar (5%), rare radiolarians. A hiatus of over 2 m.y. might occur between *Thyrsocyrtis bromia* radiolarian Zone in Core 58 and the *Podocyrtis charala* radiolarian Zone in Core 59 (40–42 Ma).

Unit VI: 0.5 m; 558.5–559 m; Core 60; pre-late Eocene. In Core 60, the uppermost basement basalts are overlain by 0.5 meters of soft dusky yellowish brown claystone which is silicified and contains very abundant slickensides (produced by drilling? tectonics?). The surface of the first piece of basalt shows a thin slickensided film of the same dusky yellowish brown material. It is therefore not clear whether the sediment contact is depositional, intrusive, or even tectonic in origin. The uppermost basement basalts may be intrusive (see section on Igneous Rocks, Lithology).

BIOSTRATIGRAPHY

Summary

Diverse calcareous nannoplankton and radiolarian assemblages occur throughout most of the sedimentary interval (Cores 1–60) overlying igneous rocks at Site 459 and range in age from late Pleistocene to late Eocene. Several breaks can be seen in the biostratigraphy with major hiatuses occurring in the Pliocene–late Miocene, middle Miocene, early Oligocene, and late Eocene.

Poor recovery and the absence of age-diagnostic nannoplankton species in Cores 6 and 7 make precise zonal determinations impossible, although a discontinuous record is suggested for the early Pleistocene and Pliocene. A minimum gap for the early Pliocene and late Miocene of about 7 m.y. (3.0–10.0 Ma) occurs between Cores 6 and 7.

A nannoplankton subzone representing 0.6 m.y. (13.4–14.0 Ma) is absent between Cores 20 and 21.

Another sizable break occurs between the early and late Oligocene (Cores 57 and 58), representing a minimum of 4.5 m.y. (30.0–34.5 Ma). Still another large gap can be recognized between Cores 58 and 59, since a late Eocene radiolarian assemblage is seen in Core 59. This could represent a minimum of 2.0 m.y. (40.0–42.0 Ma).

Nannoplankton and radiolarian zonations correlate extremely well paleontologically throughout the intervals where both groups occur; however, absolute age determinations vary slightly. This is to be expected when two different zonation schemes are related to absolute time by different methods and subsequently compared. The major exception to zonation agreement is in the early Miocene, where sizable discrepancies are present. This relationship is also evident when a comparison is made between nannoplankton and radiolarian results in the early Miocene at Site 296 (Ellis, 1975; Ling, 1975) as well as other DSDP sites. It would appear that this is due to a major error in zonal age determinations of one or both of the fossil groups.

The major paleontologic breaks agree very closely with changes noted in the lithology at this site.

Nannoplankton

Nannoplankton assemblages throughout the sedimentary interval in Hole 459B range from good to poor preservation and show wide species diversity. They also contain sufficient age-diagnostic forms to indicate that the biostratigraphic sequence is discontinuous.

The Holocene–late Pleistocene *Emiliania huxleyi* Zone is recognized in Core 1 of Hole 459. The following Pleistocene zonation can be recognized in samples from Hole 459B: the *Ceratolithus cristatus* Subzone of the *Gephyrocapsa oceanica* Zone, sections 1 through 4, Core 1; the *Emiliania ovata* Subzone of the *G. oceanica* Zone, Samples 459B-1-5, 90–91 cm through 459B-4,CC; the *Gephyrocapsa caribbeanica* Subzone of the *Crenalithus doronicoides* Zone, Sample 459B-5,CC.

Samples from Sections 1 through 4 of Core 6 are barren. Sample 459B-6,CC contains three rarely occurring species of *Discoaster*. If these are indigenous, then the sample is of early late Pliocene age and the intervening subzones are either missing or represented by the barren interval.

Samples from Cores 8 to 15 are assigned to the late middle Miocene *Discoaster hamatus* Zone because of the presence of the nominate species *D. hamatus*. The presence of *D.* sp. cf. *D. quinqueramus* in Samples 459B-8-1, 90–91 cm; 459B-9,CC; 459B-11-2, 18–19 cm; 459B-11,CC; and 459B-12,CC suggests that these samples may belong in the early late Miocene. (This species is discussed by Bukry, 1973; Howe and Ellis, 1977; Ellis and Lohman, 1979.) However, the total absence of other late Miocene key species indicates that these samples probably belong in the middle Miocene. In that case, considerable section is missing. Nannoplankton zones from early Pliocene (3.0 Ma) to the top of the middle Miocene (11.0 Ma) are absent. However, late Miocene radiolaria are noted in Sample 459B-7,CC. Consequently a hiatus representing about 7.0 m.y. (3.0–10.0 Ma) exists between Samples 459B-6,CC and 459B-7,CC.

The two subzones of the *Discoaster hamatus* Zone, the *Catinaster calcylus* Subzone and the *Helicosphaera carteri* Subzone, can also be identified. The boundary between them occurs between Samples 459B-15-1, 52–53 cm, and 459B-17,CC.

The *Catinaster coalitus* Zone is determined for Samples 459B-19-1,CC top and bottom. Samples from Core 20 can be assigned to the *Discoaster kugleri* Subzone of the *D. exilis* Zone.

The presence of the early middle Miocene *Sphenolithus heteromorphus* Zone assemblage in the two samples of Core 21 (Samples 21-1, 35–36 cm, and 459B-21,CC) suggests that the lower subzone of the overlying *Discoaster exilis* Zone, the *Coccolithus miopelagicus*

Subzone, is missing. This would represent an interval spanning 0.6 m.y. (13.4–14.0 Ma).

The early Miocene–middle Miocene boundary, which corresponds with the boundary between the *Sphenolithus heteromorphus* Zone and the *Helicosphaera ampliaperta* Zone, can be placed between Cores 21 and 22.

The top of the early Miocene *Sphenolithus belemnos* Zone is drawn between Samples 459B-28-1, 42–43 cm, 459B-28-2, 102–103 cm at the first occurrence of *S. heteromorphus*.

The *Discoaster druggii* Subzone of the basal Miocene and late Oligocene *Triquetrorhabdulus carinatus* Zone can be recognized in Samples 459B-35-1, 36–37 cm through 459B-46,CC. A few reworked specimens each of several early Oligocene and/or Eocene species occur in Sample 459B-35,CC near the top of the subzone.

The remaining two lower subzones of the *Triquetrorhabdulus carinatus* Zone cannot be differentiated. Consequently, the Miocene–Oligocene boundary, which coincides with the boundary between these two subzones, cannot be precisely defined. This undifferentiated interval of the *T. carinatus* Zone is present in samples of Cores 47 and 48.

The late Oligocene *Sphenolithus ciperoensis* Zone is recognized in Samples 459B-49-1, 8–9 cm through 459B-54-2, 66–67 cm. The early late Oligocene *Sphenolithus distentus* Zone is determined for Samples 459B-54-3, 83–84 cm through 459B-57,CC.

Sample 459B-58-1, 28–29 cm can be placed in the early Oligocene *Calcidiscus formosa* Subzone of the *Helicosphaera reticulata* Zone. This would indicate a hiatus of at least 4.5 m.y. (30.0–34.5 Ma) between Cores 57 and 58. Although the occurrence range of key age-determining species extends into the Eocene, an Eocene age is not considered for this sample because nannoplankton species limited in the occurrence to the Eocene are not found in association.

Radiolarians

Radiolarians occur at the top of the sedimentary column and at various intervals separated by barren intervals. Preservation and diversity are reasonably good during the Quaternary, part of the middle and early Miocene, and one zone of the Eocene. Nevertheless, many species with stratigraphic importance are lacking.

Quaternary assemblages are abundant only in Core 1 of Holes 459 and 459B, where the *Buccinosphaera invaginata* Zone is represented. In Hole 459B radiolarians are sparse in Cores 2 and 3 and absent in Cores 4 and 5; Core 6 contains only sparse assemblages. None of these lower cores contains age-diagnostic forms.

The core catcher sample of Core 7 contains an assemblage representing the late Miocene *Ommatartus antepenultimus* Zone. Radiolarians are sparse and nondiagnostic in Core 8 and barren in Cores 9 through 14.

In Core 15 assemblages are poorly preserved but contain curved, flat spines of the genus *Oroscena*, which are restricted approximately to the late middle Miocene *Cannartus petterssoni* Zone in DSDP Leg 6 material (Kling, 1971). Samples from Core 20 are above the top of *Calocycletta costata* and in the interval of overlapping *C. laticonus* and *O. antepenultimus* morphotypes and probably are therefore in the *C. petterssoni* Zone.

Core 21 represents the *Dorcadospyris alata* Zone. Cores 22 through the top of Core 24 represent either the same zone or the next earlier *C. costata* Zone, which is clearly recognizable in the rest of Core 24 through the top of Core 25.

The rest of Core 25 through Core 27 belongs to the *Stichocorys wolffii* Zone.

No zone-diagnostic assemblages occur below until the lowest two sediment cores (58 and 59). Core 58 assemblages belong to the latest Eocene *Thyrsocyrtis bromia* Zone. Separated by an hiatus, Core 59 belongs to the late Eocene *Podocyrtis chalara* Zone.

Foraminifers (V. A. Krasheninnikov)

Only rare, poorly preserved foraminifers are present in samples from Site 459. Samples 459-1-1, 44–46 cm and 459B-1-1, 50–52 cm through 459B-2-2, 50–52 cm belong to the undifferentiated Quaternary. Rare benthic forms are present in Samples 459B-20-1, 50–52 cm through 24-2, 91–93 cm. Lower Miocene foraminifers occur in Samples 459B-29-3, 21–23 cm through 459B-43-1, 51–53 cm. Samples 459B-54-1, 81–83 cm through 459B-56-2, 64–66 cm can be assigned to the Oligocene *Globorotalia ciperoensis* Zone and/or the *G. opima* Zone.

ACCUMULATION RATES

For consistency through ages, nannoplankton dates are used for calculation of accumulation rates, except for Lithologic Units IV and V. The accumulation rates are tabulated in Table 2, based on the accumulation curve presented in Figure 8.

The overall rate at Site 459 is higher by a factor of two than that at Site 458, which is geographically nearer to the subaerial detrital source region, the Mariana arc. The difference is easily explained by the abundance of turbidites and occasional mass flows at Site 459 in Lithologic Unit III (see Sediment Synthesis section for discussion).

Table 2. Accumulation rates, Site 459.

Lithologic Unit		Core	Accumulation Rate (kg/cm^2/m.y.)	Duration (Ma)
I		1–4	3.0	0–0.9
II		5–7	2.0	0.9–3.0
				3.0–10.0 Hiatus
		8–20	3.9	10.0–13.4
	A			13.4–14.0 Hiatus
III		21–24	3.2	14.0–24.0
	B	25–48		
	C	49–57	1.9	24.0–30.0
				30.0–34.5 Hiatus
IV		58	?0.2	34.5–?40.0
				?40.0–?42.0 Hiatus
V		59	?1.5	?42.0–?45.0
VI		60	?	

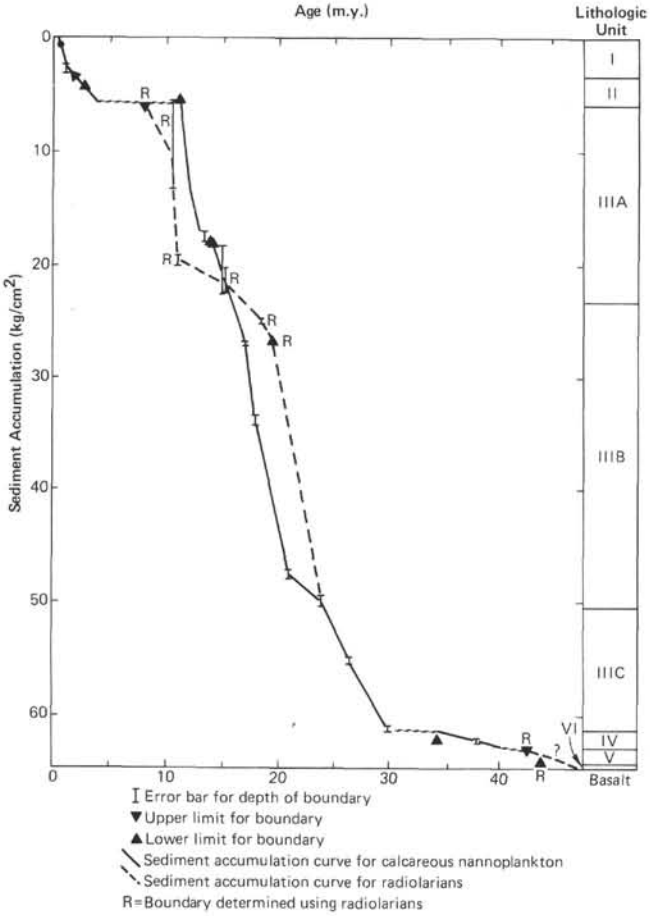

Figure 8. Sediment accumulation (kg/cm^2) versus age, Hole 459B.

Within Unit III, the accumulation rate increases upward from 1.9 to 3.2 $kg/cm^2/m.y.$ at about Cores 47 and 48 near the boundary of Subunits IIIb and IIIc (between Cores 48 and 49). This change apparently corresponds to the the different nature of turbidites in the respective subunits. Limestones and chalks are dominant lithologies in the lower Subunit IIIc with its slower rate, whereas volcaniclastic siltstones and sandstones are dominant lithology in the upper subunit. The still higher sedimentation rate of Subunit IIIa (3.9 $kg/cm^2/m.y.$) may also have resulted from a higher supply rate of volcanic detritus, as shown by the generally upward-increasing abundance of ash in Subunit IIIc.

The rate in the late Pleistocene is unexpectedly high (3 $kg/cm^2/m.y.$). It is 1 $kg/cm^2/m.y.$ at Site 458 during the same period. Because the composition of the late Pleistocene sediments at the two sites does not differ greatly according to smear slide examination (volcanic ash 30-70%, calcareous biogenics; 20-40%, siliceous biogenics 5-15%, detritus 10-30%, at both sites), the higher rate at Site 459 may indicate enhanced biogenic productivity and inflow of volcaniclastics.

Two Neogene hiatuses occur at the same general times at the two sites. The younger is from 3 to 7 Ma at Site 458 and although it ended at the same time at Site 459, it commenced 10 Ma. Middle Miocene hiatuses occur at both sites. They are both short and do not quite coincide. The break at Site 458 is from 12 to 13 Ma and at Site 459 it is from 13.4 to 14 Ma.

SEDIMENT SYNTHESIS

Site 459 is about 157 km eastward of the active Mariana arc axis (Site 457) and about 52.5 km westward of the Mariana trench axis. The site was located on the upper part of the slope of the Mariana Trench, above the trench-slope break. The relative locations of previous sites in the Mariana arc-trench system are shown on Figures 1 and 2. At Site 459 there was some anticipation that the drill might penetrate acoustically opaque sediments belonging to the uppermost imbricate thrust sheets of an accretionary prism.

The 559 meters of sediment at Site 459 are divided into six units and contain several hiatuses, which have already been described. These nondepositional and/or erosional periods might be related to changes in bottom currents and/or to the formation of significant slopes and/or to tectonic instabilities.

The well-developed late Oligocene-early and middle Miocene sediment sequence in Hole 459B indicates downslope sedimentation in a basin. Common slump features and massive flows occurring in the sequence also indicate sediment transport along slopes. The Oligocene-Miocene paleogeography might have been a relatively deep basin at Site 459 with topographic highs or wide drainage areas as sources of clastic materials transported downslope by slumping and turbidity currents.

Comparison with Previous Sites

The sedimentary sequence at Site 459 belongs to the Mariana arc-trench system and is clearly different from the sequence drilled at Site 452 on the Pacific plate, east of the Mariana trench axis.

It is possible to compare the sedimentary evolution through the Cenozoic at Site 459 with that at Site 458, which is located about 31 km to the west, on the same transect:

1) The dominant characteristics of Site 458 are also observed at Site 459, i.e., development of carbonates, similar biogenic components (nannofossil chalks), strong alteration of volcanic debris in older sandstones and siltstones, and the occurrence of reworked material.

2) At Site 459 the series is mostly replaced by turbiditic sedimentation that invaded the sedimentary basin during the late Oligocene and the early and middle Miocene; when detrital turbidites decrease at Site 459, marly nannofossil chalks occur. This happens on quite different scales: at the bottom and at the top of the whole turbiditic sequence (Unit III) marly nannofossil chalks are well expressed, and at the top of individual turbidites burrowed marly nannofossil chalks are generally present.

3) Finally, the leading sedimentation in the basin during the late Oligocene and early Miocene seems to have been biogenic chalk; turbidites are superposed. They episodically invaded a relatively quiet basin. Nevertheless, Site 459 chalks have a high percentage of clay (marly chalks), and mudstones are well developed. On

the other hand, Site 458 had volcaniclastic sandy layers interbedded in chalks, always thin, and without typical and complete turbiditic sequences.

Sites 458 and 459 belonged to the same general paleoceanographic realm during the Cenozoic. Both sites have an island-arc-type igneous basement shown as pre-middle Eocene at Site 459 (quartz dolerite and basalt) and as pre-early Oligocene at Site 458 (high-MgO bronzite andesite and basalt). During the middle–late Eocene and early Oligocene silicified claystone and claystone were deposited, probably as a result of strong alteration (subaerial? submarine?) of island arc volcanic products. The turbidite regime began slowly during the early late Oligocene, first giving calcareous turbidites with reworked large foraminifers (accumulation rate 1.9 kg/cm^2/m.y., Subunit IIIc). In the late Oligocene and the early Miocene, turbidites and slumps became general, and volcaniclastics and clays increased markedly (accumulation rate 3.2 kg/cm^2/m.y., Subunit IIIb). During the middle Miocene (Subunit IIIa) marly nannofossil chalks increased in the turbidite sequence, yet with still higher accumulation rate, 3.9 kg/cm^2/m.y., giving calcareous turbidites. These are generally thinner as individual turbidite sequences and have a finer grain size than the underlying Subunit IIIb.

During the same period, nannofossil chalks and oozes with thin interbedded ash layers were deposited at Site 458.

The sedimentary evolution of Site 458 lacks the major influence of turbidites when compared with Site 459. Therefore the sources for detrital components may be sought, at least partially, to the east (northeast to southeast?) of Site 459. However, western turbidite sources may also be considered, assuming Site 458 was a bathymetric high relative to its surroundings, so that the sediments bypassed the calcareous nonturbiditic sequence existing at Site 458.

Major hiatuses occur during the late Miocene and the early Pliocene (approximately between 10 and 3 Ma at Site 459 and between 3 and 7 Ma at Site 458).

The Plio-Pleistocene sediment lithologies are rather uniform at both sites: vitric siliceous and vitric calcareous mud and ooze with abundant volcaniclastic materials and more abundant siliceous biogenic components in the uppermost sediments. Plio-Pleistocene accumulation rates were higher by a factor of three at Site 459.

Accumulation rates and the thickness of sediments during the Oligocene and Miocene at Site 459 are about two times greater than at Site 458. Dewatering traces, resulting from compaction, are abundant. The accumulation rates and thickness with the overall vertical evolution of turbidites (coarser at the bottom, finer at the top) may indicate that active relative subsidence at Site 459 (or uplift of the source region) occurred during the late Oligocene and early and middle Miocene. Alternatively, the pattern of sediment transport and deposition may have changed. The occurrence of extensive normal faults and clastic minidikes in the sediments of this age, however, implies vertical tectonic movement. Based on the cores and the site survey geophysical profiles (Hussong and Fryer, this volume) near Site 459, the general tectonic regime seems to have been mainly tensional since the late Oligocene in this upper part of the Mariana trench-slope region.

GEOCHEMISTRY

Thirteen samples were taken for porewater chemistry at Site 459, one in Hole 459, the rest in Hole 459B. The results are given in Gieskes and Johnson (this volume). Ca^{2+} increases, and Mg^{2+} decreases steadily to just above basement (559 m sub-bottom), where it is almost entirely depleted. Alkalinity drops sharply in the topmost 50 meters of sediments to a fairly steady range of 0.5 to 1.0 meq/kg. There are modest reversals of the Mg^{2+} and Ca^{2+} gradients just above basement that are evidently a consequence of seawater contamination. The major gradients are evidently produced by reaction of pore fluids with the abundant volcanic glass in the sediments, and perhaps with the basement.

IGNEOUS ROCKS

Lithology

Igneous rocks were cored at Hole 459B from 559 to 691.5 meters sub-bottom. The rocks recovered are mainly fine to medium grained, clinopyroxene–plagioclase basalts. Primarily on the basis of differences in grain size and degree of crystallinity, four lithologic units were delineated within the igneous section (Fig. 9). These are:

Unit 1: 559–587.0 m; Cores 60 through 62. Generally medium-grained aphyric, vesicular ($\bar{x}$ = 20 vol.%), clinopyroxene–plagioclase basalts. Textures range from intersertal to subophitic in all thin sections except Sample 459B-60-1, 44–47 cm), which has a spherulitic texture. Although crystalline phases are generally little altered, the mesostasis of most samples is altered to clays and palygorskite and is often substantially oxidized (Natland and Mahoney, this volume). The fragments recovered in the core contain very few penetrative fractures or veins. Individual pieces are generally bounded by rounded edges, unlike those of the lower cores. The external surfaces of the pieces are commonly free of clay coatings. This unit could represent a relatively thick (i.e., 30 m) lava flow of which the upper contact was not recovered or a sill intruded along the sediment/basement contact.

Unit 2: 587.0–615.5 m; Cores 63 through 65. Fine-grained, sparsely phyric, highly vesicular ($\bar{x}$ = 25 vol. %), clinopyroxene–plagioclase basalts with low (i.e., 10–20 vol.%) degrees of crystallinity. The vesicularity of the thin-sectioned samples ranges from 10 to 35 vol. %. As in Unit 1, the mesostasis in these rocks is largely altered to clay minerals. This alteration extends to the pyroxene microlites as well in the lower portions of the unit. The fracturing observed in Cores 63 and 64 is generally similar to that observed in Unit 1, but Core 65 is highly fractured by drilling. This unit probably represents a sequence of pillowed lavas, even though few pillow rinds were found.

Unit 3: 615.5–644.0 m; Cores 66 through 68. Medium- to coarse-grained, sparsely vesicular, clinopyrox-

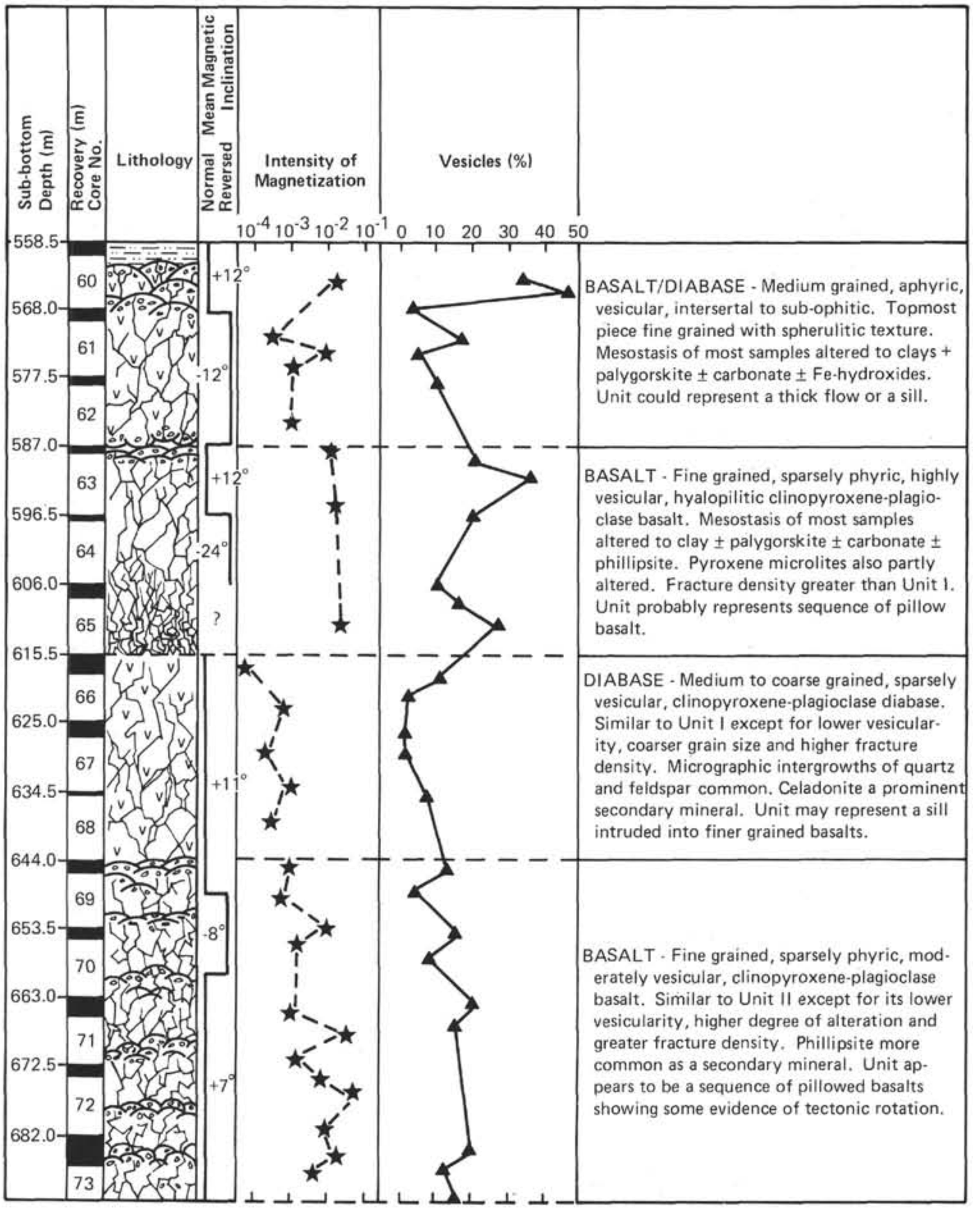

Figure 9. Lithology of igneous basement recovered in Hole 459B. Zones of normal and reversed polarity, intensity of magnetization, and vesicle abundance are also shown.

ene–plagioclase diabase. These rocks are generally similar to those of Unit 1 except for their lower vesicularity (0–10 vol.%), coarser grain size, and higher fracture density. This unit may represent a sill intruded into the finer-grained basalts.

Unit 4: 644.0–691.5 m; Cores 68 through 73. Fine-grained, sparsely phyric, moderately vesicular ($\bar{x}$ = 15 vol.%) clinopyroxene–plagioclase basalt. This unit is similar to Unit 2 except for its lower vesicularity, higher degree of alteration, and greater fracture density. The fracture density increases substantially with depth, and zones of intense fracturing occur at several levels within the unit. This unit also appears to be a sequence of relatively thin flows of pillow basalt.

The mineralogy and textures of the thin-sectioned samples are discussed in detail in the petrography section. Several points of general significance will be discussed here.

An important mineralogic feature of these basalts is their lack of orthopyroxene as a phenocrystic or groundmass phase. This distinguishes them from the volcanic section drilled at Site 458 just 30 km to the west.

Another important feature of these rocks is the occurrence of micrographic intergrowths of quartz and feldspar in the mesostasis of the diabasic rocks in Unit 3. Intergrowths of this type are a common feature of diabase sills and imply a slow cooling history for the body in which they occur. This would suggest Unit 3 is a sill and not a "thick" (i.e., 30-m) flow. Other data also favor a sill interpretation, including (1) the low magnetic intensities of Unit 3 rocks (see Bleil, this volume),

(2) the constancy of grain size with depth within the unit, (3) the restriction of vesicles to the upper and lower portions of the unit, and (4) the lack of chilled (i.e., glassy) flow tops. A pillow fragment found in Core 67, Section 2, appears to have been displaced from higher levels in the hole.

Vesicles occur in most of the basalts at this site. The approximate vesicle volumes in rocks that were thin sectioned are given in Figure 9. Clearly the fine-grained units are more vesicular than the diabasic units. If only the fine-grained flow rocks are considered, vesicularity appears to decrease with depth, although this is obviously only a first-order approximation. The variation in vesicularity within each of the fine-grained flow units suggests the existence of separate flows, each with a vesicular top and a less vesicular interior.

Trains of vesicles are evident in numerous fragments within Units 2 and 4. The orientation of these vesicle trains relative to the vertical plane varies from zero (Core 69, Section 3) to 90° (Core 65, Section 1), often showing angular differences of up to 45° within a single core. If it is assumed that these features formed at near-horizontal orientation, these angles would suggest substantial postdepositional rotation of rocks within the units. At present, the cause and timing of such rotations are not known.

As noted, the fracture densities in the basement rocks cored at this site generally increase with depth. The fractures are generally at high angles to the horizontal plane (50–70°), although in actuality a wide range of angles occur. The fact that the fracture surfaces are generally coated with clays and other secondary minerals, which could only have formed before the rocks were drilled, makes it clear that most of the fractures developed in the larger fragments predate the drilling event. The occurrence in the lower parts of the hole of drilling "rubble" and pea-sized drilling breccias with clay-coated surfaces suggests these rocks were penetratively fractured or strained at some point in their history with the ubiquitous development of clay minerals along the strain directions.

Petrography

Unit 1: Cores 60 through 62

The rocks from the upper portion (from Section 60-1 to the lower part of 60-2) of Unit 1 are fine-grained basalts. They vary in texture from spherulitic to microlitic and intersertal. Although there is some unaltered glass present in the mesostasis, most of it is devitrified or totally altered to brown clays. Plagioclase varies in abundance from 15 to 50% in these rocks and occurs in spherulitic patches or lath-shaped microlites and skeletal crystals. Fe–Ti ore is present in minor amounts as tiny euhedral, or skeletal crystals. The rocks are quite vesicular (3–45%) with small 0.1–4.0 mm), irregular-shaped vesicles scattered throughout the groundmass. These are lined with brown or orange clay minerals and iron hydroxides. In addition, carbonate is present in vesicles in the lower part of Section 60-1 to the middle of 60-2, and zeolites are present in the middle of 60-2.

The grain size of the rocks generally increases with depth in the unit. Diabases occur from the lower part of Section 61-1 through Core 62. Plagioclase is abundant (57–67%) throughout the coarse-grained portion of the unit and occurs as lath-shaped crystals of labradorite. Pyroxene is quite variable in abundance (7–38%) and appears to be augite to subcalcic augite in composition. The pyroxene is slightly zoned with increasing extinction angle toward rims. Fe–Ti oxides occur in minor amounts (1–3%), but individual crystals are as large as 1 mm and are generally skeletal in form (acicular in intersertal patches). The diabases contain some interstitial glass, most of which is either devitrified or totally altered to brown clays. Zeolites are present as small radial patches in vesicles of the diabase in the lower part of Section 61-1. The rocks are generally less vesicular (13–15%) and the vesicles are very small and irregular in shape. The estimate of the volume of vesicles in the rocks may be somewhat low, since most of them are lined with or entirely filled by secondary minerals (brown clays, carbonate, and in one instance zeolite).

Unit 2: Cores 63 through 65

The rocks of Unit 2 are glassy, aphyric basalts. The glass makes up 25 to 90% of the rocks and is generally altered to brown or green smectite, palygorskite, and iron hydroxides (Natland and Mahoney, this volume). The texture of the rocks varies from spherulitic to hyalopilitic with microlites or skeletal laths of acicular plagioclase making up 3 to 20% of the rock and very small granular pyroxene making up 3 to 15% of the rocks. Very minute grains of Fe–Ti oxides (1–3%) are scattered throughout the mesostasis of the rocks. Secondary minerals in these rocks are brown clays and minor zeolites. No carbonate occurs in these rocks. Vesicles make up to 10 to 35% of the rock volume. They are small, less than 1.0 mm and ranging to 5 mm in diameter, and irregular in shape. They are scattered throughout the groundmass and are lined or occasionally completely filled with brown clay and zeolite (zeolite only in Cores 63 and 64). Green clays occur as pseudomorphs after pyroxene in Sample 459B-65-1, 58–60 cm.

Unit 3: Cores 66 through 68

The rocks of this unit are coarser-grained than Unit 2. Although similar petrographically to the diabase of Unit 1, quartz occurs in the diabase of Unit 3. The rocks have subophitic to intersertal texture and contain quartz and alkali feldspar micropegmatitic patches. The rocks contain no phenocrysts and are made up of labradorite (30–60%) and clinopyroxene (10–15%) that ranges from augite to subcalcic augite in composition. The pyroxene grains are zoned slightly with maximum variation in 2V of about 5° (decreasing from about 45 in the cores to 40 in the rims). Fe–Ti oxides vary in abundance from 2 to 7% and occur as small (0.1 mm) euhedral crystals and as larger (up to 0.4 mm) skeletal forms. There are rare needle-like crystals or crystal aggregates of Fe–Ti oxides in the finer-grained portions of the groundmass. These occur most frequently near vesicles. The vesicles in these rocks are sparse (1–15%) and small (0.1–2.0 mm), irregular in shape and scattered throughout the groundmass. As in the previous units the vesicles are lined or completely filled with secondary minerals (blue green celadonite, trioctahedral smectite, mixed layer clays; Natland and Mahoney, this volume). Carbonate is absent. The same secondary minerals are present in the mesostasis (which comprises 10 to 30%) of these rocks, as alteration products of glass. Very small amounts of brown, nearly fresh glass are present in almost all of the thin sections, but generally the mesostasis is completely altered. The grain size of the rocks from the bottom of the unit is slightly less than that of the diabase higher in the unit. The glass content of the sample from Section 68-1, 23 cm is very high (53%), although it is extremely altered. This rock may be close to a cooling boundary of the unit.

Unit 4: Cores 68 through 73

The rocks of Unit 4 are fine-grained aphyric to sparsely microphyric basalt that is heavily altered to clays and zeolite with minor carbonate as vein fillings. The rocks have hyalo-ophitic, hyalopilitic, and intersertal textures. The microphenocrysts, which occur only very rarely in these rocks, are either plagioclase (elongate crystals or labradorite showing some resorption and either normal or oscillatory zoning) or pyroxene (anhedral to subhedral grains). The groundmass of the rocks is composed of lath-shaped and skeletal plagioclase crystals (roughly 30% of the rock volume) and granular pyroxene (20% rock volume). Disseminated throughout the groundmass are small (0.01–0.13 mm) crystals of Fe–Ti oxides, either euhedral or skeletal. Occasionally there are fine needle-like oxides which seem to be concentrated in patches of finer-grained groundmass surrounding vesicles. Generally the vesicles of these rocks are small (0.01–0.5 mm), scattered throughout the groundmass, and irregular in shape. They occasionally show alignment as described in the previous section. The vesicles are commonly lined or filled with dioctahedral smectite (the brown clays occur in Samples 459B-71-1, 30 cm and 459B-71-2, 15 cm), mixed layer clays (Sample 459B-73-1, 6 cm), and phillipsite (Natland and Mahoney, this volume). The phillipsite occurs as radiating patches on the vesicle walls and in the mesostasis of the rocks. Secondary vein fillings in these rocks are primarily clays, but in the upper portion of Sample 459B-71-2 (15 cm) carbonate is present as a vein filling.

The mesostasis of the rocks is composed of abundant glass, most of which is altered to green and brown clays. There is some relatively fresh glass present in some of the rocks, but in general that glass which is not totally altered is at least somewhat devitrified.

Alteration

All of the igneous rocks recovered at Site 459 show some degree of alteration. In general, the extent of alteration depends on the rock texture, since their glassy or devitrified mesostasis is the most unstable component. In some cases the alteration also affects the groundmass microlites, but it very rarely affects the relatively well-developed crystal phases. The degree of fracturing of the rocks is another factor with which the intensity of alteration is positively correlated. The dominant alteration products are clay minerals and palygorskite, although carbonate, phillipsite, Fe-hydroxides, and opal are present locally (Natland and Mahoney, this volume). Palygorskite occurs only in veins.

Clay minerals replace from 10 to 70% of the rock volume and are spread throughout the igneous section. They are green or brown and are predominantly dioctahedral smectites and mixed-layer clays. Colorless varieties were detected only in the uppermost part of Lithologic Unit 1. K-Fe smectites are pale brown and usually associated with Fe-oxyhydroxides. They are more abundant higher in the basement section. Replacing glassy material in the rock mesostasis, clay minerals form chaotic masses and sometimes nearly opaque aggregates when they are intermixed with magnetite, Fe-oxyhydroxides, and remnants of the original minerals or glass. Spherulitic or oolitic textures are characteristic of clay aggregates filling vesicles. The latter are more crystalline and may represent partial recrystallization to mixed-layer clays. A dark green clay appears in pseudomorphs after pyroxene microphenocrysts in thin sections in Sample 459B-65-1, 58–60 cm.

Carbonate occurs within several zones randomly located along the cored interval. Usually it fills the veins and vesicles together with clay minerals and is rarely observed replacing matrix minerals.

Zeolites (mainly phillipsite) are present in low abundance. They usually form small (up to 0.1 mm) radial clusters attached to vesicle walls and are usually covered with rinds of green smectite. They are located mainly in the lower part of the penetrated sequence (Cores 68–71), but phillipsite also occurs in some thin sections above and below this zone.

In the rocks of Unit 3 which have interstitial quartz–feldspar intergrowths, some of the quartz grains are connected with vesicles and the clay aggregates (largely celadonite) filling them. These grains may be considered recrystallized and secondary. Some of the quartz in the mesostasis may also be secondary. Quartz does not occur in other rock types.

In Cores 60 and 61 there are a number of pieces with alteration/oxidation features which resemble Liesegang rings. Their origin is problematic. At several horizons within the cored sequence, tan bands of altered basalt occur which appear to be oxidized/altered equivalents of the olive gray basalts above and below them. Whether or not these bands are related to flow tops or bottoms is not clear.

Igneous Rock Chemistry

Combining the data of Wood et al., Bougault et al., and Sharaskin (all in this volume), the igneous rocks of Hole 459B can be divided into two major chemical types and seven subtypes (Fig. 10). All are basalts with the geochemical characteristics of island arc tholeiites—namely, low TiO_2 (0.67–1.11%) and Zr (36–75 ppm) despite high SiO_2 (51.1–58.6%) and moderate to high enrichment in iron (TFe_2O_3 range 9.83–13.63%). Wood et al. (this volume) observe a depletion in Ta relative to

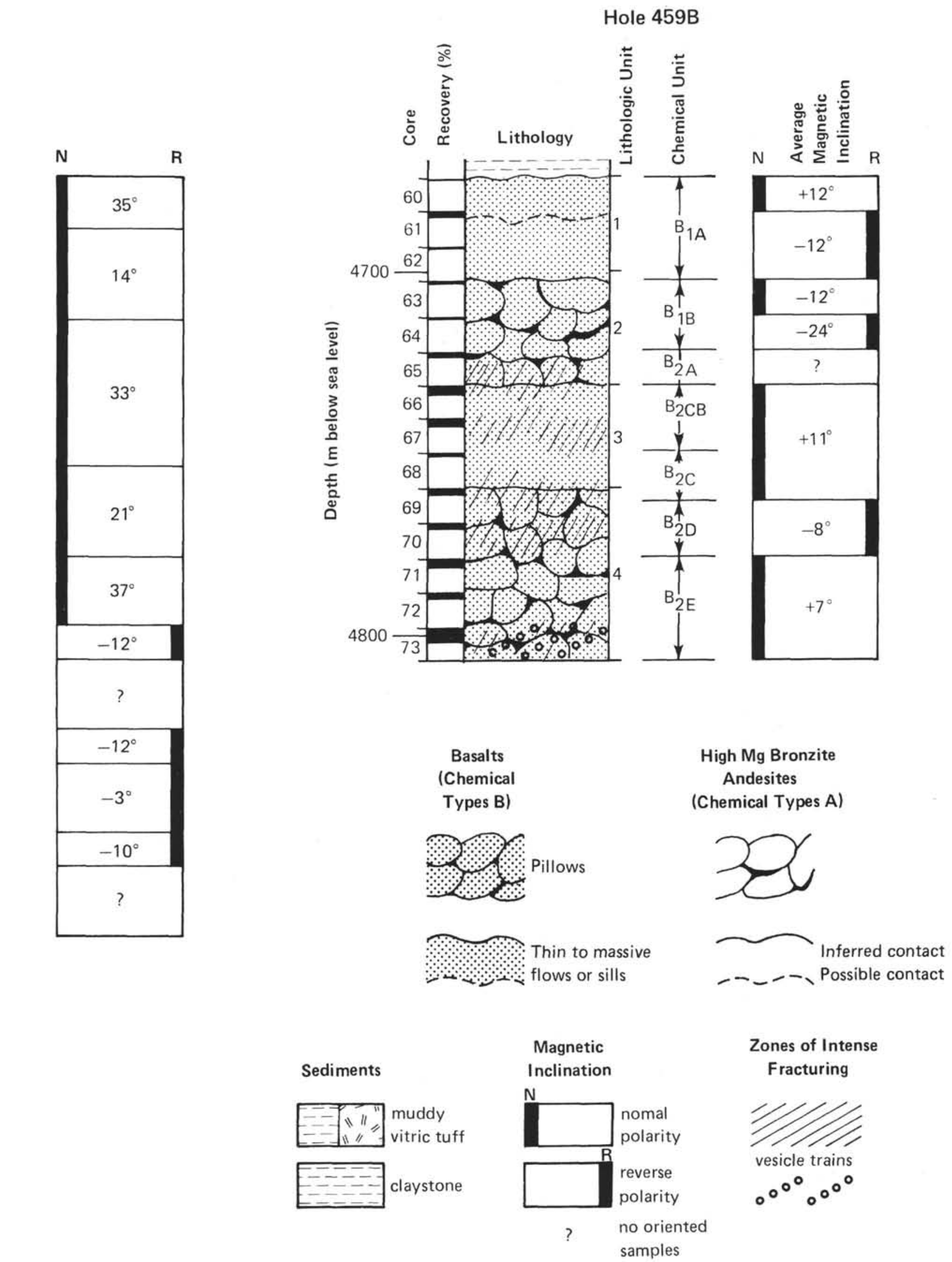

Figure 10. Basement lithologic and chemical stratigraphy, Hole 459B.

La and Th. Despite the low Ti and Zr, Bougault et al. (this volume) observe that these elements and Y are more *enriched* than geochemically similar rare earth elements compared with seafloor basalts. Hickey and Frey (this volume) note the light rare earth element depletion of the basalts and the exceptionally low rare earth element abundances in some of them (2-6 X chondrites) compared with mid-ocean ridge basalts. All of these geochemical features imply that obducted ocean crust from the Pacific Plate was not cored at this site near the eastern edge of the Mariana fore-arc region.

The two major chemical types can be distinguished primarily on the basis of TiO_2 and trace elements. The principal division occurs between Cores 64 and 65, within Lithologic Unit 4 (Fig. 10). Above this division, there are two chemical types, B_{1A} and B_{1B}, both with low TiO_2 contents (0.62–0.83%) and moderately high Ni (43–68 ppm) and Cr (56–159 ppm). Subtype B_{1A} corresponds to Lithologic Unit 1, a single flow or intrusive body 28.5 meters thick. Below Core 64 are five very similar but nevertheless distinct chemical subtypes (B_{2A}–B_{2E}) in increasing order of depth (Fig. 10). Compared with the two B_1 subtypes, these have generally higher TiO_2 (up to 1.21%), and considerably lower Ni (11–24 ppm) and Cr (14–55 ppm). Both principal Types B_1 and B_2 are mostly quartz normative, but Type B_2 basalts include some samples with quite high normative quartz (up to 9.9%). Cores 66 and 67 (Lithologic Unit 3, Chemical Subtype B_{2B}), where samples have high normative quartz, contain rocks with the quartz–alkali feldspar micrographic intergrowths mentioned earlier.

Despite the general contrast between Types B_1 and B_2, which broadly represent a trend of iron, silica, and incompatible trace element enrichment as MgO decreases, the subtypes do not appear to represent a single "liquid" line of descent. Subtype B_{1A}, for example, has 3 to 4% lower MgO than Subtype B_{1B}, despite higher Ni and Cr. It has lower TiO_2 and Zr but higher SiO_2. In fact, it differs very little geochemically from the Type A_2 high-MgO andesites of Site 458, 31 km to the west. Evidently, the same type of compositional and/or melting variations occurred in the mantle source of lavas at both sites, although perhaps to less of an extreme beneath Site 459.

The "fractionated" B_2 subtypes all evidently had parental compositions similar to Subtype B_{1B}, but in these subtypes different levels of TiO_2 and Zr enrichments occur at comparable MgO and Ni abundances. The single sample analyzed of Subtype B_{2A} has the highest TiO_2 and TFe_2O_3 of all Site 459 samples analyzed, yet it has the lowest SiO_2 of all the B_2 subtypes. The simplest interpretation of these variations is that different fractionation trends, and probably slightly but distinctly different parental compositions, were involved. Wood et al. (this volume) argue that a mantle phase such as rutile or sphene retained Ti, Ta, and Nb during melting of magmas parental to these arc tholeiites. But they did not reconcile this with the general relative *enrichment* of Ti (and Zr) compared with rare earth element abundances observed by Bougault et al. (this volume) or with the general highly fractionated compositions of the basalts, which indicate that most do not represent melt compositions. The lavas are highly vesicular and have extremely high intensities of magnetization (Fig. 9). This suggests that conditions of elevated water and oxygen partial pressures may have enhanced the stability of titanomagnetite in the lavas (e.g., Osborne, 1959, 1962). Varying the extent of the fractionation of this mineral along with the primary silicate phases could explain the variable abundances of TiO_2 and SiO_2 among the Type B_2 basalts and perhaps some of the other geochemical "anomalies" of these lavas as well. How early in a fractionation sequence such an effect might occur is difficult to say, but we note that the TiO_2 abundances of the most primitive (highest MgO) Site 459 basalts (Subtype B_{1B}) are *not* particularly lower than in *all* mid-ocean ridge basalts with comparable MgO (e.g., FAMOUS area basalts from the Mid-Atlantic Ridge; Langmuir et al., 1977; Bryan, 1979, and Costa Rica Rift basalts; Srivastava et al., 1980; Fodor et al., 1980; CRRUST, in press).

The effect of alteration on these basalts has been considerable, but the geochemical effects are difficult to evaluate systematically. There are about 50% variations in K_2O and twofold variations in Rb within individual chemical subunits in the upper half of the cored basement section, where oxidative alteration is most prominent. In the lower part of the basement section, these variations are much less marked. The two most prominent secondary minerals in the finer-grained basalts are (1) palygorskite in the upper part of basement and (2) dioctahedral smectite, probably saponite, in the lower part of the hole. Both are Mg-rich secondary minerals. Within chemical subtypes, MgO can vary by as much as 1% by weight, but in some samples, reduced MgO correlates with enrichment in K_2O, implying that K-rich, Mg-poor clay minerals have partially replaced the rock. Needless to say, alteration effects can make quantitative evaluation of primary geochemistry difficult indeed.

PALEOMAGNETISM

We took sediment cores suitable for paleomagnetic study (109 samples from Cores 1–57, Hole 459B), encompassing the last 30 m.y. and obtained a polarity reversal pattern in general agreement with the established paleomagnetic time scale since the early Oligocene. The stable inclination of the sediments is shallower deeper in the hole, indicating a northward movement of the site during the Cenozoic. For the igneous rocks (26 samples) from Hole 459B, there is a clear correspondence between lithologic and magnetic units. The stable inclinations of the igneous rocks are also shallow and of mixed polarity (Fig. 9). For more complete exposition of these points, see Bleil (this volume).

PHYSICAL PROPERTIES

Compressional wave velocity, wet-bulk density, salt-corrected water content, porosity, acoustic impedance, and thermal conductivity were determined for cores recovered from Hole 459B. The measurements are tabulated in Table 3. Velocity–density parameters are plotted against depth in Figure 11.

Table 3. Velocity-density measurements, Site 459.

Sample Core, Section, Interval (cm)	Depth (m)	Sound Velocity (km/s)	GRAPE Wet Bulk Density[a] (g/cm^3)	Wet Water Content[b] (%)	Porosity[c] (%)	Wet Bulk Density[d] (g/cm^3)	Acoustic Impedance $(g/cm^2 s \times 10^5)$	Rock Type
1-1, 105-107	1.05	1.55						Mud
1-2, 85-87	2.35	1.54		45.5	68.9	1.55	2.39	Mud
1-3, 101-103	4.01	1.55		42.6	66.6	1.60	2.48	Mud
1-4, 92-94	5.42	1.56						Mud
1-5, 42-44	6.42	1.57						Mud
2-1, 112-114	8.62	1.55						Mud
2-2, 41-43	9.41	1.56		53.2	75.1	1.45	2.26	Mud
2-3, 30-32	10.80	1.56		52.2	74.6	1.46	2.28	Mud
2-4, 80-82	12.8	1.60	1.42	57.2	77.8	1.39	2.22	Mud
2-5, 20-22	13.7	1.60	1.51	51.5	73.8	1.47	2.35	Mud
6-1, 4-7	45.54	2.02		41.1	65.0	1.62	3.27	Mudstone
6-1, 110-112	46.60	1.59	1.51	50.9	73.7	1.48	2.35	Mud
6-2, 52-54	47.52	1.62	1.52				2.46	Mud
6-3, 70-71	49.20	1.82		42.9	65.3	1.56	2.84	Mudstone
6-3, 106-108	49.56	1.57	1.46	52.8	74.3	1.44	2.26	Mud
6-4, 72-74	50.72	1.66	1.55				2.57	Very stiff mud
8-1, 63-65	65.13	1.52	1.73	39.2	62.7	1.64	2.49	Mud
9-1, 65-66	74.65	1.82		34.1	57.1	1.71	3.11	Mudstone
11-1, 48-50	93.48	1.83	1.68	36.5	60.2	1.69	3.09	Mudstone
11-2, 49-51	94.99	1.87	1.68	36.3	60.5	1.71	3.20	Mudstone
12,CC, 11-12	102.61	1.67	1.79	31.5	54.2	1.76	2.94	Sandy volcanic ash
13-1, 2-4	112.02	1.76	1.62	35.9	58.5	1.67	2.94	Vitric marly chalk
14-1, 37-40	121.87	2.17	1.98				4.30	Vitric mudstone
14-1, 94-96	122.44	1.70	1.59	44.4	68.0	1.57	2.67	Vitric mudstone
15-1, 137-140	132.37	1.76	1.68	37.3	60.5	1.66	2.92	Marly chalk
15-2, 132-135	133.82	1.72						Marly chalk
17-1, 13-17	150.13	1.81	1.75				3.17	Vitric marly chalk
19-1, 11-15	169.11	1.70	1.62				2.75	Mudstone
20-1, 83-84	179.33	1.69	1.66	34.6	58.3	1.73	2.92	Marly chalk
21-1, 19-21	188.19	1.57	1.64	40.6	64.2	1.62	2.54	Chalk
22-1, 37-38	197.87	1.61	1.75	34.0	57.3	1.73	2.79	Marly vitric chalk
24-1, 26-28	216.76	1.66	1.52	43.1	64.9	1.54	2.56	Marly chalk
24-2, 43-45	218.43	1.76	1.73	33.2	56.5	1.74	3.06	Marly chalk
25-1, 15-17	226.15	1.78	1.84	30.6	53.1	1.78	3.17	Vitric mudstone
25,CC, 16-18	230.99	1.75	1.82	31.6	54.0	1.75	3.06	Siltstone
26-1, 15-18	235.65	1.91	1.74	33.0	56.1	1.74	3.32	Vitric marly chalk
27-1, 58-61	245.58	1.85	1.80				3.33	Vitric mudstone
27-5, 28-30	251.28	1.98	1.79	30.5	53.1	1.79	3.54	Marly chalk
28-1, 16-19	254.66	1.95	1.74	36.1	60.2	1.71	3.33	Mudstone
28,CC, 16-19	259.16	2.12	1.85				3.92	Siltstone
29-1, 2-6	264.02	1.97	1.78				3.51	Mudstone
29-2, 7-9	265.57	2.02	1.78	32.4	56.5	1.78	3.60	Mudstone
30-2, 53-56	275.53	1.75	1.59	44.7	68.5	1.57	2.75	Mudstone
30-4, 86-88	278.86	1.81	1.58	45.3	68.8	1.56	2.82	Mudstone
31-1, 56-58	283.56	1.94	1.80	33.8	58.0	1.76	3.41	Vitric mudstone
32-1, 3-9	292.53	1.73	1.66				2.87	Vitric mudstone
32-2, 35-36	294.35	1.79	1.79	32.4	55.1	1.74	3.11	Sandy vitric tuff
33-1, 122-124	303.22	1.84	1.66	33.7	55.7	1.70	3.13	Muddy vitric tuff
34-1, 14-16	311.64	1.83	1.90	23.0	42.5	1.89	3.46	Muddy vitric tuff
34-2, 74-76	313.74	1.80	1.67	35.4	57.1	1.65	2.97	Vitric mudstone
35-1, 11-16	321.11	1.73	1.70				2.94	Vitric mudstone
35-2, 71-73	323.21	1.75	1.68	35.8	57.8	1.65	2.89	Mudstone
36-1, 23-29	330.73	1.81	1.81				3.28	Sandy vitric tuff
36-2, 12-14	332.12	1.77	1.67	37.7	60.0	1.63	2.89	Vitric mudstone
36,CC, 11-13	333.76	1.76	1.78	31.5	53.2	1.73	3.04	Sandy vitric tuff
37-1, 14-16	340.14	1.85	1.73	31.9	53.6	1.72	3.18	Sandy vitric tuff
38-1, 11-13	349.61	1.83	1.74	31.7	53.2	1.72	3.15	Vitric mudstone
39-1, 106-111	360.06	1.73	1.66				2.87	Siltstone
40-1, 7-9	368.57	1.86	1.68	38.5	61.4	1.63	3.03	Mudstone
42-1, 80-82	388.30	1.93	1.81	31.0	53.7	1.77	3.42	Silty vitric tuff
42-2, 37-40	389.37	1.75	1.91	26.2	48.2	1.88	3.29	Sandstone
43-1, 130-132	398.30	1.99		25.6	47.1	1.89	3.76	Siltstone
44-1, 28-30	406.78	1.97		38.7	61.3	1.63	3.21	Mudstone
45-1, 17-19	416.17	2.20		29.6	51.0	1.76	3.87	Vitric mudstone
46-1, 30-33	425.80	1.98	1.73	34.9	58.1	1.71	3.39	Sandstone
47-1, 40-43	435.4	1.74	1.69	36.2	58.9	1.67	2.91	Mudstone
48-1, 80-82	445.30	2.03	1.97	22.9	43.4	1.94	3.94	Vitric marly chalk
49-1, 6-8	454.06	1.88	1.68	37.1	60.9	1.68	3.16	Mudstone
50-1, 137-139	464.87	1.87	1.54	44.4	67.2	1.55	2.90	Mudstone
50,CC, 15-17	467.93	1.76	1.80	30.4	53.5	1.80	3.17	Marly chalk
51-1, 7-9	473.07	1.68	1.64	33.4	54.9	1.68	2.82	Silty chalk
52-1, 22-24	482.72	1.83	1.73	30.4	51.5	1.73	3.17	Vitric marly chalk
52-1, 131-133	483.81	1.73	1.56	43.5	67.2	1.58	2.73	Siliceous claystone
53-1, 63-65	492.63	1.66	1.70	33.3	54.7	1.68	2.79	Vitric siltstone
53-3, 55-57	495.55	1.92	1.75	32.8	54.8	1.71	3.28	Marly chalk
54-1, 143-145	502.93	2.20	1.98	23.9	45.3	1.94	4.27	Marly limestone
55-3, 31-33	514.31	2.42	2.30	12.3	27.4	2.27	5.49	Nanno limestone
55-4, 58-60	516.08	2.24	2.11	18.4	37.4	2.08	4.66	Nanno limestone
56-1, 143-145	521.93	2.41	2.32	12.0	26.8	2.28	5.49	Foram-nanno limestone
56-2, 90-92	522.90	2.36	2.28	14.0	30.3	2.22	5.24	Foram-nanno limestone
56-4, 45-48	525.45	1.83	1.93	26.3	48.8	1.90	3.48	Claystone
56-4, 89-90	525.89	1.82	1.93	26.5	49.2	1.90	3.46	Claystone
57-2, 94-96	532.44	1.75	1.80	32.9	57.0	1.87	3.27	Claystone
57-3, 72-74	533.72	2.22	2.04	20.0	40.0	2.05	4.55	Marly limestone
58-1, 106-108	540.56	1.83	1.52	43.9	65.9	1.54	2.82	Silty mudstone
59-1, 65-66	549.65	3.18	2.11	12.4	25.7	2.13	6.77	Chert
59-1, 134-136	550.34	1.77	1.91	26.4	49.0	1.90	3.36	Claystone
60-1, 124-126	559.74	3.78	2.50	8.6	21.0	2.49	9.41	Basalt
60-2, 30-32	560.30	3.61	2.38	12.4	29.0	2.40	8.66	Basalt
61-1, 99-101	568.99	4.42	2.62	6.3	16.0	2.59	11.4	Basalt
61-2, 65-69	570.15	4.43	2.64				11.7	Basalt
62-1, 46-50	577.96	4.40	2.67				11.7	Basalt
64-1, 28-30	596.78	3.40	2.38	12.7	29.1	2.34	7.96	Basalt

Table 3. (Continued).

Sample Core, Section, Interval (cm)	Depth (m)	Sound Velocity (km/s)	GRAPE Wet Bulk Density[a] (g/cm^3)	Wet Water Content[b] (%)	Porosity[c] (%)	Wet Bulk Density[d] (g/cm^3)	Acoustic Impedance (g/cm^2 s × 10^5)	Rock Type
65-1, 84-86	606.84	2.52	2.14	19.5	40.6	2.13	5.37	Altered basalt
66-1, 45-48	615.95	3.83	2.54	8.2	20.1	2.52	9.65	Basalt
66-2, 61-63	617.61	2.87	2.38	12.7	29.5	2.37	6.80	Altered basalt
67-1, 104-106	626.04	3.72	2.57	7.1	17.8	2.55	9.49	Basalt
68-1, 35-37	634.85	2.73	2.44	10.2	24.0	2.41	6.58	Basalt
69-1, 126-128	645.26	3.45	2.35	12.2	27.6	2.32	8.00	Very altered basalt
69-2, 28-32	645.78	—	2.28					Altered basalt
70-1, 43-45	653.93	3.14	2.33	13.0	29.3	2.31	7.25	Altered basalt
70-1, 89-90	654.39	2.74	2.34	13.6	31.0	2.33	6.38	Very altered basalt
71-1, 75-77	663.75	3.09	2.40	12.9	29.9	2.37	7.32	Altered basalt
71-1, 134-136	664.34	3.29	2.40	11.4	26.6	2.39	7.86	Altered basalt
71-2, 29-31	664.79	3.44	2.43	10.8	25.2	2.39	8.22	Altered basalt
72-1, 26-28	672.76	2.84	2.25	16.7	36.4	2.22	6.30	Very altered basalt
73-1, 6-9	682.06	2.68	2.37				6.35	Altered basalt
73-3, 121-124	686.21	2.69	2.33	15.4	33.9	2.26	6.08	Altered basalt

[a] From 2-min. counts.
[b] Salt-corrected.
[c] Porosity = (salt-corrected wet-water content) × [wet-bulk density (gravimetric)]/1.025.
[d] Gravimetric method.

Sonic Velocity

Sonic velocities for the vertical direction were measured in the Hamilton Frame. The first 8 cores, to 74 meters depth, were unlithified except for some minor bands in Core 6. These minor lithified bands give rise to the spike in the velocity-depth curve at 45 meters. A wide range of rock types was recovered from the lithified part of the sedimentary column, ranging in grain size from claystones to sandstones and in composition from calcareous to siliceous to vitric ash, but predominantly mixtures of these three components. The plot of velocity against depth (Fig. 11), although showing an overall trend of increasing velocity with depth, also shows a large-scale waviness which may be related to comparable changes in composition or grain size. For example, the low velocities encountered at about 200 meters depth were all measured in chalks. However, it is difficult to understand why the small peak in the velocity-depth plot occurs at about 260 meters.

Toward the base of the sedimentary column, from about 500 to 525 meters, limestones were recovered with velocities in the range 2.20 to 2.42 km/s. The only rocks with higher velocities in the sedimentary column were cherts, two thin bands of which were found just above the igneous basement at about 550 meters depth. One of these cherts gave a velocity of 3.18 km/s.

Sonic velocities in the basalts, all of which were altered to some degree, ranged from 2.52 to 4.43 km/s. The overall trend was for the sonic velocity to decrease with depth, probably reflecting the greater degree of alteration of the deeper rocks.

Density, Porosity, and Water Content

Wet bulk densities were determined by 2-minute GRAPE counts on the same parallel-sided chunks for which velocity determinations had previously been made. A proportion of these samples were then subjected to gravimetric measurement of density, water content, and porosity. Although the density-depth plot shows more scatter than the velocity-depth plot, it reflects some of the features of the latter. The shallow peak in the velocities at 260 meters also appears to be present in the density plot. The highest densities in the sedimentary rocks occur in the limestone between 500 and 525 meters sub-bottom. These range from 1.9 to 2.3 g/cm^3. The top part of this limestone formation was reached by the Gearhart-Owen density log, yielding a density of 2.02 g/cm^3 and placing its upper contact at 504.5, 506.0, and 504.2 meters sub-bottom on three consecutive passes of the tool. Subsequent logs failed to reach this depth because the hole was gradually filling up.

The densities of the basalts ranged from 2.1 to 2.6 g/cm^3, showing an overall tendency to decrease with depth (Fig. 11). Sonic velocity and density show a reasonable correlation (Fig. 12), though not so marked as for Hole 458.

The porosities of the basalts ranged from 16 to 41%. The highest porosities were clearly associated with the most altered samples. It is likely that some of this porosity is not real but due to water being driven from clay minerals while drying for 24 hours at 110°C. The best indication of the initial porosity of the basalts is therefore the minimum observed—about 16%.

Thermal Conductivity

Thermal conductivities of both sedimentary and igneous core samples recovered from Hole 459B were measured and a thermal conductivity profile was constructed to a sub-bottom depth of 690 meters. The data show that the increase of sediment thermal conductivity with depth is very gradual—i.e., 0.18 mcal/cm s °C/100 m. Below 511 meters, however, some lithified sediments, mostly limestone, show an unusually high thermal conductivity, an average of 11 samples being 5.32 ± 0.24 mcal/cm s °C. Data also show a remarkable correlation between the thermal conductivity of basement rocks and their lithology. For a detailed synopsis of these results, see Horai (this volume).

Heat Flow

Heat flow estimated from one sediment temperature measurement at 64.5 meters sub-bottom depth in Hole

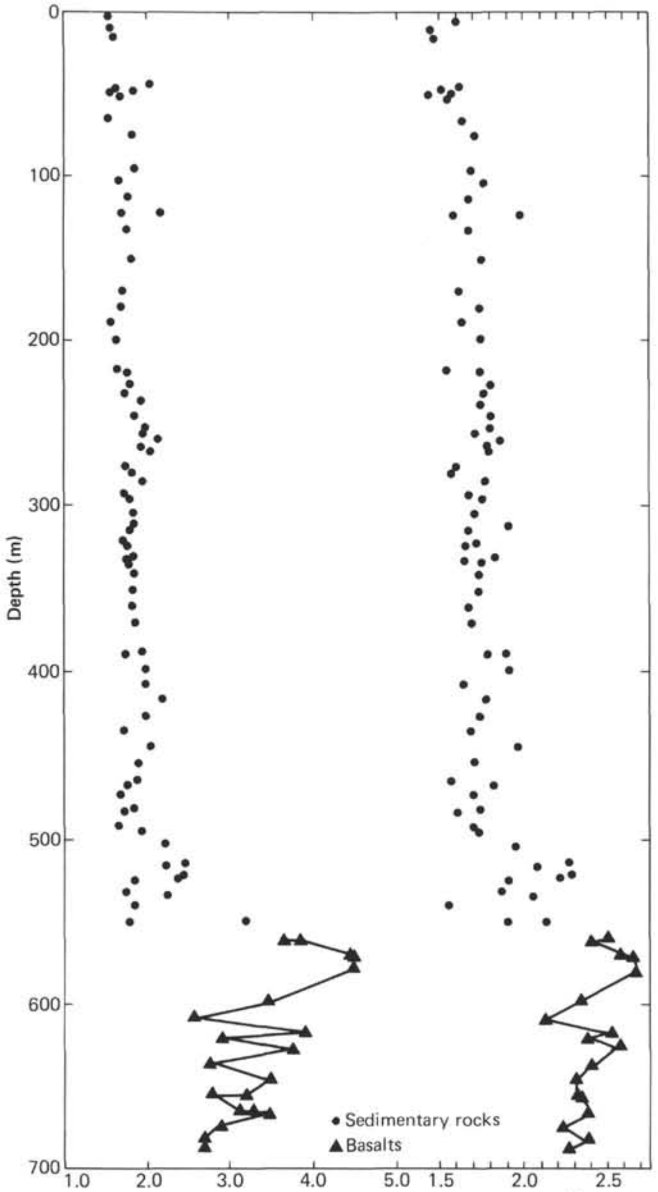

Figure 11. Sonic velocity and density of sedimentary and igneous samples plotted versus depth, Hole 459B.

459B is 0.7 HFU. Owing to a change in recorded temperature during the measurement, however, this value is not very reliable. Water temperature in the hole, measured at various subsequent stages of drilling and during Gearhart-Owen logging, showed the effect of drilling disturbance but could be correlated enough to help substantiate the calculated heat flow value (Uyeda and Horai, this volume).

SUMMARY AND CONCLUSIONS

Site 459 is on the easternmost edge of the thickly sedimented fore-arc basin just above the Mariana trench–slope break. The main objective of drilling at this site was to investigate the sedimentary history of the fore-arc region and the nature of its basement. We hoped also to learn more about the volcanic and tectonic history of the Mariana arc–trench system.

The site was located where the *Glomar Challenger* air-gun profile showed well over 300 meters of sediment. Three holes were drilled at Site 459. The first failed because of mechanical failure, and the second was a washdown pilot hole in the event of re-entry.

A total of 691.5 meters of sediments and igneous rocks was cored in Hole 459B. This included 559 meters of sediments in 6 lithologic units, and 132.5 meters of igneous rocks in 4 lithologic units. The igneous rocks are mainly fine- to medium-grained vesicular clinopyroxene–plagioclase basalts.

Well-developed late Oligocene and early and middle Miocene turbidite sequences attest to rapid sedimentation and significant topographic relief in the area of Site 459 during those epochs. The environment seems to contrast with that near Site 458 (which is 670 m shallower and about 31 km to the west, closer to the Mariana arc). At the latter, nannofossil chalk and oozes with thin ash layers were deposited during the same period. Accumulation rates of sediments during the Oligocene and Miocene at Site 459 are about twice as high as at Site 458.

Sites 458 and 459 belonged to the same general paleoceanographic realm during the Cenozoic. Both have island-arc-type igneous basement which is at least pre-middle Eocene at Site 459 and early Oligocene at Site 458. No substantial turbidites were recovered at Site 458. If the source of the dominant turbidites at Site 459 was the volcanic arc to the east, then one must argue that these turbidites somehow bypassed the intervening Site 458. Alternatively, a much closer source of turbidites may have influenced sedimentation at Site 459. In either case, large relative subsidence of Site 459 or uplift of its turbidite source regions during the late Oligocene as well as in the early and middle Miocene may explain fluctuations in sediment accumulation rate at the site. Extensive normal faulting and clastic minidikes in the cores from the same period further indicate that the fore-arc regional stress pattern was dominantly tensional.

As at Site 458, it is important to note that both the sediments and igneous rocks in Hole 459B show many signs of small-scale disruption (fractures and slickensides). Based on the consistent paleomagnetic trends, a fairly continuous sedimentation history, and the absence of repeated intervals, however, we may discount the occurrence of larger-scale tectonic deformation. What disruption does occur in the sedimentary column (the major hiatuses) seems to correlate between Sites 458 and 459, suggesting that it may be caused by a phenomenon more widespread than local tectonics.

Igneous rocks recovered in Hole 459B consist of pillows, flows, and possible intrusions of arc-related tholeiitic basalt. Two major chemical types comprising seven subtypes were recovered, most of them considerably fractionated from parental compositions. At least one of the subtypes appears to be at least transitional in composition to such high-MgO andesites as those recovered only 31 km away at Site 458. In any case, a spec-

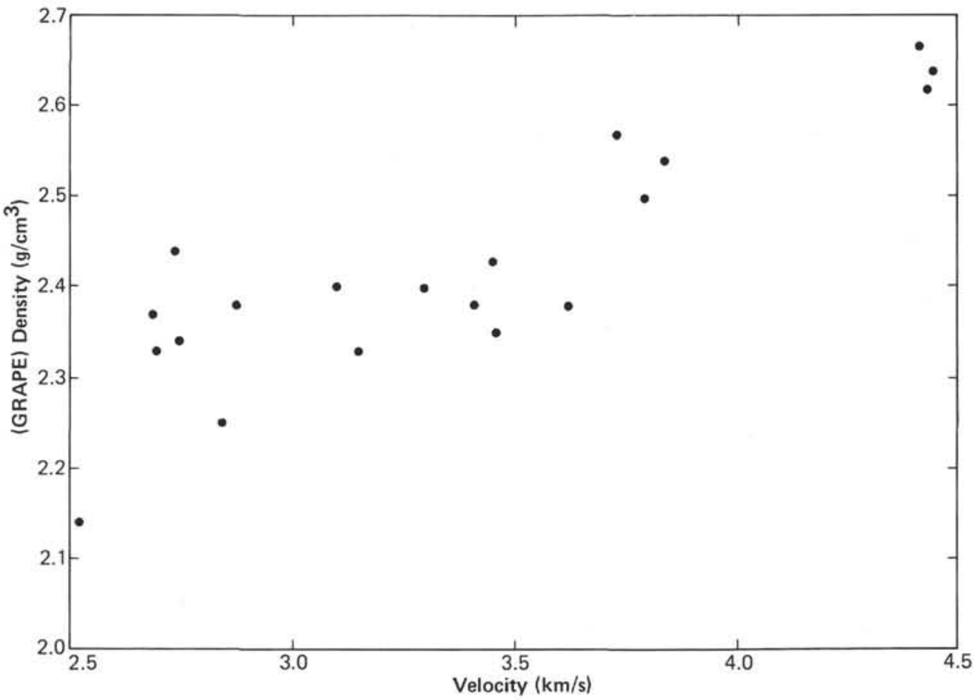

Figure 12. Velocity versus (GRAPE) density of basalt samples, Hole 459B.

trum of differences in parental compositions such as source composition and perhaps depth, phase control, degree of melting, and pathways of shallow fractionation can be inferred from the basalt compositions.

Alteration in basement of Hole 459B is of a type heretofore unobserved either in the deep ocean or on land. The striking feature of the alteration is the abundant development of palygorskite as a vein-filling mineral. It is associated in the cores with celadonite and iron hydroxides and hence probably represents an early, possibly hydrothermal oxidative stage of alteration. Late alteration, concentrated along the zones of intense fracturing, particularly deeper in the hole, was nonoxidative and led to the formation of dioctahedral smectite and phillipsite. Palygorskite also occurs in the lowermost sediments (Desprairies, this volume), which are brown and look oxidized. It probably formed at the same time as the palygorskite in the igneous basement, when there were only a few meters of sediments on the basalts.

Of the reversals that would be expected for the time covered, paleomagnetic measurements in the sediments reveal 32 reversals out of 97, in spite of several hiatuses, core disturbance, and a 36% recovery rate (Bleil, this volume). Inclinations are generally shallower deeper in the hole. Basement rocks, which have an exceptionally wide range in NRM intensity (10^{-5} to 10^{-1} emu/cm^3), have shallow inclinations, implying for Site 459 a lower paleolatitude ($\sim 5°$) at the time of basalt extrusion than at present.

Logging and the large-scale resistivity experiment were successfully conducted in Hole 459B, although caving of sediments prevented these measurements in basement. Heat flow at the site is estimated at 0.7 HFU.

The laboratory-measured sonic velocity of the basement basalts decreased with depth in the 134.5 meters of basement cored, from an average of about 4 km/s to about 3 km/s. The higher-velocity rocks appear to be from massive flows that are less altered than the lower-velocity rocks, which are mostly pillow lavas. As at other sites drilled during Leg 60, the thermal conductivity is very dependent on the lithology and degree of lithification of the sediments and on the vesicularity of the igneous rocks.

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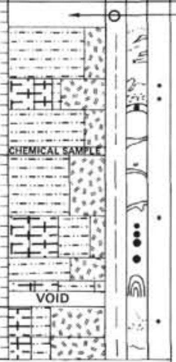
SITE 459 HOLE CORE 1 CORED INTERVAL: 0.0 to 3.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS
Late Pleistocene	*Emiliania huxleyi* (N) / *Buccinosphaera invaginata* (R)		AG	AG	1	0.5, 1.0
	Emiliania ovata (N) / *Collosphaera tuberosa* (R)		AG	CM	2	
					3	
			AG	AG	CC	

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / LITHOLOGIC SAMPLE



LITHOLOGIC DESCRIPTION

Section 1, 0-28 cm: Slurry with rusty iron flakes from pipe.

Olive gray ash (5Y 4/2)

Olive black (5Y 2.5/2) sandy vitric ash
5Y 4/2 grades downward to 5Y 5/3
Dark grayish brown (2.5Y 4/2), mud, silty

Olive black

Very dark grayish brown (2.5Y 3/2) with a black patch
Very dark gray (5Y 3/1)
Dark olive gray (5Y 3/2)
Dark brown (7.5YR 3/2)
2.5Y 4/2
Very dark grayish brown (2.5Y 3/2)

Dark grayish brown (10YR 4/2 and 2.5Y 4/2) ash layers

Mottled with very dark grayish brown (2.5Y 3/2)
Dark brown (10YR 3/3)
Dark yellowish brown (10YR 4/2)

VITRIC SILICEOUS CALCAREOUS MUD with SANDY VITRIC ASH and CALCAREOUS SILTY MUD, olive gray (5Y 4/2) dark grayish brown (2.5Y 4/2), very dark gray (5Y 3/1), dark olive gray (5Y 3/2), and dark brown (7.5YR 3/2) muds interbedded with and grading into thin layers of olive black (2.5Y 3/2) or dark grayish brown (10YR 4/2 and 2.5Y 4/2) sandy vitric ash. Foraminifers visible in 1-90 to 100 cm, 2-60 to 100 cm, and 3 – vitric calcareous silty mud.
Section 1: Three beds of olive black (5Y 2.5/2) sandy vitric ash are between 30 and 60 cm. Another is between 80 and 90 cm, rest is mud.
Section 2: Mostly vitric siliceous calcareous mud. A prominent graded bed is between 60 and 100 cm. Ash interbeds at 17 to 70 cm, 45 to 48 cm, and three close together between 115 and 135 cm, with some foraminifers.
Section 3 and Core-Catcher: Sandy vitric nannofossil mud with traces of foraminifers mottled with darker sandy mud.

SMEAR SLIDE SUMMARY

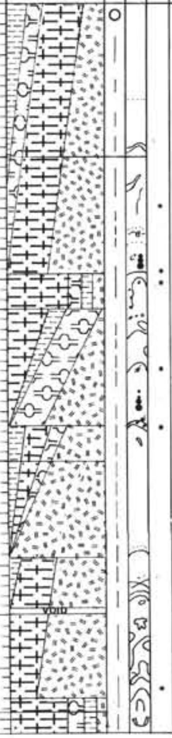
	Sandy vitric ash	Vitric siliceous calcareous mud	Calcareous siliceous mud	Sandy vitric nannofossil mud
	1-84	**1-98**	**2-61**	**3-11**
TEXTURE:				
Sand	70	10	2	30
Silt	30	40	48	20
Clay	–	50	50	50
TOTAL DETRITAL	80	30	40	60
COMPOSITION:				
Feldspar	20	10	+	20
Heavy minerals	10	–	–	–
Clay	–	10	30	20
Volcanic glass	40	10	10	20
Rock fragments	10	–	–	–
Zeolite	–	+	–	–
Carbonate unsp.	5	+	+	10
Foraminifers	–	10	3	+
Nannofossils	10	30	20	30
Diatoms	5	5	2	–
Radiolaria	–	15	25	–
Sponge spicules	–	5	+	–
Opaques	–	5	–	–
Silicoflagellates	–	–	5	–

SITE 459 HOLE B CORE 1 CORED INTERVAL: 0.0 to 7.5 m

TIME-ROCK UNIT: Late Pleistocene

BIOSTRAT ZONE: *Ceratolithus cristatus* (N); *Buccinosphaera invaginata* (R); *Ceratolithus tuberosa* (R); *Emiliania ovata* (N) ?

SECTION	METERS	FORAMS	NANNOS	RADS
1	0.5, 1.0		AG	AM
2			AG	CM
3			B	AG
4			B	AM
5			AM	CM
CC			AM	CG



Dark brown (10YR 3/3) mud, darker downwards

Black (10YR 2.5/1)

Very dark grayish brown (2.5Y 3/2)

Brownish black (5YR 2/1)

Dark brown (10YR 3/3) grades downwards to olive gray (5Y 4/2)

Olive black (5Y 2/1) sandy

Dark yellowish brown (10YR 4/4) mud, darker downwards

Dark yellowish brown (10YR 4/2) with dark sandy patches

10YR 3/3

Dark brown (7.5YR 3/2)

Very dark grayish brown (10YR 3/2)

Pebbles black (10YR 2.5/1)

Very dark grayish brown (10YR 3/2) with a black sandy patch

Darker, silty

Brown to dark brown (10YR 4/2)

Black (10YR 2.5/1) grades to very dark gray (10YR 3/1)

Dark grayish brown (10YR 4/3)

10YR 3/3

10YR 2.5/1 patches sandy to silty

10YR 3/3

10YR 4/4

VITRIC ASH, SILICEOUS CALCAREOUS VITRIC MUD and SILICEOUS VITRIC ASH, dark brown (10YR 4/3 and 10YR 3/3) mud and dark brown (10YR 3/3 to 7.5YR 3/2) siliceous-vitric and crystal-vitric ash with interbeds of thin black (10YR 2.5/1) to very dark gray (10YR 3/1) pebbly or sandy layers. Six major graded sequences occur: 1-0 to 2-118 cm; 2-118 to 3-0 cm; 3-0 to 115 cm; 3-115 to 4-0 cm; 4-0 to 95 cm; and 4-95 to 5-80 cm.

Section 1: Very deformed or soupy at top. A 2 cm black sandy layer is between 150 and 160 cm.

Section 2: Mostly siliceous calcareous vitric mud with sandy layers between 70 and 80 cm (has erosional base), and 115 to 120 cm. A mottled bed with visible foraminifers is between 80 and 120 cm, and three claystone pebbles 2 cm in diameter are between 135 and 150 cm.

Section 3: Siliceous vitric ash grades downward to siliceous vitric crystal ash. A pebbly sandy layer is between 115 and 120 cm.

Section 4: Grades downward to 95 cm where there is a dark silty layer. Below is another graded sequence.

Section 5 and Core-Catcher: Grades downward to 80 cm, but mottled by deformation. A sandy bed is between 60 and 70 cm.

SMEAR SLIDE SUMMARY

	Calcareous siliceous vitric mud	Claystone (Reworked)	Nannofossil ooze
	2-45	2-107	2-125
TEXTURE:			
Sand	–	–	–
Silt	50	5	30
Clay	50	95	70
TOTAL DETRITAL	55	98	25
COMPOSITION:			
Feldspar	5	5	5
Clay	20	90	20
Volcanic glass	25	3	+
Rock fragments	5	–	–
Micronodules	–	1	–
Zeolite	–	1	–
Carbonate unsp.	5	–	10
Foraminifers	–	–	10
Nannofossils	25	–	45
Diatoms	5	–	+
Radiolarians	10	–	10
Sponge spicules	–	–	+
Iron oxides	–	–	–
Palagonite	–	–	–

SMEAR SLIDE SUMMARY

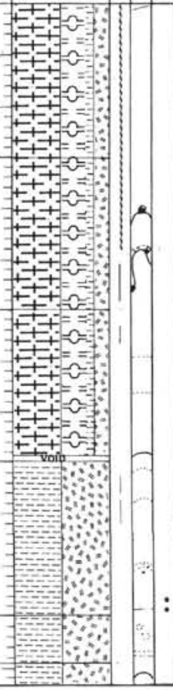
	Siliceous Vitric Ash	Siliceous Vitric Crystal Ash	Vitric Ash
	3-61	3-110	5-64
TEXTURE:			
Sand	3	–	–
Silt	77	40	75
Clay	20	60	25
TOTAL DETRITAL	70	85	100
COMPOSITION:			
Feldspar	20	25	15
Clay	20	55	25
Volcanic glass	30	15	50
Zeolite	+	–	–
Diatoms	10	5	–
Radiolaria	20	10	–
Sponge spicules	–	+	–
Iron oxides	+	–	–
Palagonite	–	–	10

SITE 459 HOLE B CORE 2 CORED INTERVAL: 7.5 to 17.0 m

TIME-ROCK UNIT: Late Pleistocene

BIOSTRAT ZONE: *Emiliania ovata* (N)

SECTION	METERS	FORAMS	NANNOS	RADS
1	0.5, 1.0			FM
2			AM	FM
3				RM
4				B
5				
CC			RP	RM



Very dark grayish brown (10YR 3/2)

Yellowish brown (10YR 5/4) (top)

Brown to dark brown (10YR 4/3) 50 to 60 cm

Top 10YR 4/3 grades to bottom 10YR 5/4

Pebbles 10YR 5/4

10YR 5/4

10YR 4/3

Dark brown (10YR 3/3) grades to 10YR 4/4

VITRIC-SILICEOUS CALCAREOUS MUD and MUDDY VITRIC ASH. A series of 10 to 70 cm generally graded beds, some with visible foraminifers, mostly silty at the base.

Section 1: Mottled and very deformed, silty at the top.

Section 2: Three beds. Mudstone pebbles at base of top at 55, 95 and 130 cm.

Section 3: Generally structureless with < 1% visible foraminifers. Mottles dark grayish brown (2.5Y 4/2) between 45 and 80 cm.

Section 4: Color grades downward to more yellowish tone, but structureless; no visible foraminifers. Small black sandy patch at 103 cm. Firm muddy vitric ash (145 to 150 cm).

Section 5: Brown mud with firmer patches.

Core-Catcher: As above.

SMEAR SLIDE SUMMARY

	Muddy Vitric Ash	Muddy Vitric Ash
	4-135	4-145
TEXTURE:		
Sand	–	–
Silt	40	40
Clay	60	60
TOTAL DETRITAL	100	
COMPOSITION:		
Feldspar	15	10
Clay	60	60
Volcanic glass	25	30
Micronodules	+	–
Carbonate unsp.	–	+

SITE 459 HOLE B CORE 3 CORED INTERVAL: 17.0 to 26.5 m

TIME-ROCK UNIT: Late Pleistocene

BIOSTRAT ZONE: *Emiliania ovata* (N)

SECTION	METERS	FORAMS	NANNOS	RADS
CC			AM	RM
1	0.5, 1.0			
2				

Core-Catcher: **VITRIC MARLY NANNOFOSSIL OOZE,** two pieces of olive black (5Y 2/1).

SMEAR SLIDE SUMMARY

	Vitric Nannofossil Marly Ooze
	CC
TEXTURE:	
Sand	–
Silt	50
Clay	50
COMPOSITION:	
Feldspar	5
Volcanic glass	40
Carbonate unsp.	2
Foraminifers	3
Nannofossils	50

SITE 459 HOLE B CORE 4 CORED INTERVAL: 26.5 to 36.0 m

Time-Rock Unit: Late Pleistocene
Biostrat Zone: *Emiliania ovata* (N)
Fossil Character: Nannos CM, Rads B
Sections: CC, 1, 2 (Meters 0.5, 1.0)

LITHOLOGIC DESCRIPTION

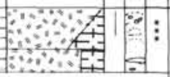
Core-Catcher: VITRIC MARLY NANNOFOSSIL OOZE, olive gray (5Y 3/2) throughout. Foraminifers visible 4.0 cm to 8.0 cm. A firm mud lump at 5 cm. Thin silty brownish black (5YR 2/1) beds as indicated.

SMEAR SLIDE SUMMARY

	Vitric Marly Nannofossil Ooze
	CC-20
TEXTURE:	
Sand	–
Silt	50
Clay	50
TOTAL DETRITAL	55
COMPOSITION:	
Feldspar	10
Clay	10
Volcanic glass	35
Carbonate unsp.	5
Foraminifers	10
Nannofossils	30

SITE 459 HOLE B CORE 5 CORED INTERVAL: 36.0 to 45.5 m

Time-Rock Unit: Early Pleistocene
Biostrat Zone: *Gephyrocapsa caribbeanica* (N)
Fossil Character: Nannos FP, Rads B
Sections: 1, CC



LITHOLOGIC DESCRIPTION

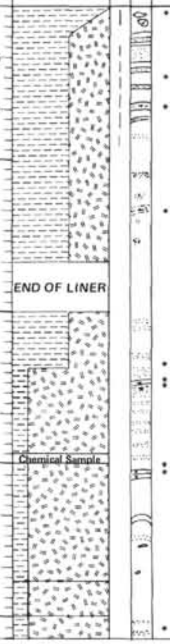
SILTY VITRIC ASH and MUDDY NANNOFOSSIL VITRIC ASH
1-3 to 7 cm: Grayish olive (10Y 4/2), silty vitric ash. Olive black (5Y 2/1) sandy patches.
1-10 to 13 cm: Firmer, grayish olive (10Y 4/2), muddy nannofossil vitric ash lump.
1-13 to 30 cm: Color darkens downwards.
1-30 to 40 cm: Olive gray (5Y 3/2) muddy nannofossil vitric ash.
Core-Catcher: As above, olive black (5Y 2/1) patches.

SMEAR SLIDE SUMMARY

	Silty Vitric Ash	Muddy Nannofossil Vitric Ash	Muddy Nannofossil Vitric Ash
	1-6	1-19	1-30
TEXTURE:			
Sand	10	–	–
Silt	80	60	70
Clay	10	40	30
TOTAL DETRITAL	100	80	70
COMPOSITION:			
Feldspar	10	10	10
Clay	10	20	10
Volcanic glass	80	50	50
Carbonate unsp.	–	+	+
Foraminifers	–	–	5
Nannofossils	–	20	25
Iron hydroxide	–	+	+

SITE 459 HOLE B CORE 6 CORED INTERVAL: 45.5 to 55.0 m

Time-Rock Unit: Pliocene(?)
Fossil Character: Section 1: Nannos B, Rads B; Section 2: Nannos B, Rads FP; Section 3: Nannos B, Rads B; Section 4: Nannos B, Rads FP; CC: Forams RP, Nannos RP
Sections: 1, 2, 3, 4, CC (Meters 0.5, 1.0)



LITHOLOGIC DESCRIPTION

VITRIC MUD and VITRIC ASH
Mostly brown (10YR 5/4). Firmer layers are stippled in structures column.
Sections 1 and 2: Grayish olive (10YR 4/2) breccia at top (slumped down hole?). All the rest is yellowish brown (10YR 5/4). Black spots (~1 mm) in mudstone 1-92 to 95 cm (Mn oxides?). Thicker mud beds have horizontal burrows ~5 mm in diameter.
Sections 3 and 4: Yellowish brown (10YR 5/4) to 67 cm in Section 3; shades of gray and olive gray below, except for sandy and muddy interbeds as shown.
Core-Catcher: As above. Light olive gray (5Y 5/2) with two sandy vitric ash bands olive gray (5Y 3/2).

SMEAR SLIDE SUMMARY

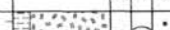
	Vitric Mud	Claystone (Reworked)	Claystone with Nodules	Mud with Opaque Nodules	Clay
	1-70	1-17	1-93	2-45	3-43
TEXTURE:					
Sand	–	–	10	20	2
Silt	5	5	30	10	8
Clay	95	95	60	70	90
TOTAL DETRITAL	100	100	85	85	95
COMPOSITION:					
Feldspar	5	5	15	5	5
Clay	85	95	60	80	90
Volcanic glass	10	+	10	–	–
Micronodules	–	+	15	20	5
Zeolite	–	–	–	–	+
Nannofossils	+	–	–	–	–
Hematite	–	–	+	–	–
Palagonite	–	–	–	–	–

SMEAR SLIDE SUMMARY

	Sandy Vitric Ash	Vitric Mud	Vitric Mud	Silty Vitric Ash	Sandy Vitric Ash
	3-64	3-67	4-3	4-8	CC-13
TEXTURE:					
Sand	70	5	–	20	60
Silt	30	20	15	40	20
Clay	–	75	85	40	20
TOTAL DETRITAL	80	90	95	90	90
COMPOSITION:					
Feldspar	20	10	5	20	20
Clay	–	30	80	40	20
Volcanic glass	60	40	10	30	50
Micronodules	20	5	5	10	10
Zeolite	–	+	+	–	–
Nannofossils	–	5	–	–	+
Hematite	+	–	–	+	–
Palagonite	–	10	+	–	+

SITE 459 HOLE B CORE 7 CORED INTERVAL: 55.0 to 64.5 m

Time-Rock Unit: Late Miocene or Early Pliocene
Fossil Character: Nannos B, Rads FM
Sections: CC, 1, 2 (Meters 0.5, 1.0)



LITHOLOGIC DESCRIPTION

Core-Catcher: MUDDY CRYSTAL VITRIC ASH, firm, dark yellowish brown (10YR 4/2).

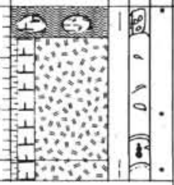
SMEAR SLIDE SUMMARY

	Muddy Vitric Ash
	CC-18
TEXTURE:	
Sand	–
Silt	20
Clay	80
TOTAL DETRITAL	95
COMPOSITION:	
Feldspar	15
Clay	40
Volcanic glass	30
Micronodules	5
Radiolarians	++
Palagonite	+

SITE 459 HOLE B CORE 8 CORED INTERVAL: 64.5 to 74.0 m

TIME-ROCK UNIT: Middle Miocene
BIOSTRAT ZONE: *Catinaster calyculus* (N)

FORAMS	NANNOS	RADS	SECTION	METERS
	AM	RP	1	0.5, 1.0
	AP	RP	CC	



LITHOLOGIC DESCRIPTION

CRYSTAL VITRIC ASH with a graded bed.
1-0 to 30 cm: With grease, thinner diameter, disturbed variable lithology. ?Effect of HEAT FLOW PROBE.
1-30 to 150 cm: Dark yellowish brown (10YR 4/2), CRYSTAL VITRIC ASH with patches and thin beds of silty dusky brown (5YR 2/2) as indicated.
A GRADED BED (14.0 to 14.3 cm), very fine sand to mud, color darkens downwards.
Core-Catcher: Firm mud; moderate brown band, VITRIC ASH between light olive gray (5Y 5/2) and olive gray (5Y 3/2).

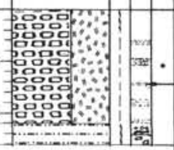
SMEAR SLIDE SUMMARY

	Nannofossil Ooze	Vitric Ash	Vitric Ash
	1-10	1-110	CC-8
TEXTURE:			
Sand	–	5	5
Silt	20	60	55
Clay	80	35	40
TOTAL DETRITAL	64	95	70
COMPOSITION:			
Feldspar	1	20	10
Heavy minerals	1	–	–
Clay	20	25	20
Volcanic glass	5	50	40
Micronodules	–	5	10
Zeolite	–	+	–
Carbonate unsp.	37	–	+
Nannofossils	30	+	10
Radiolarians	1	–	–
Sponge spicules	–	–	+
Palagonite	5	+	10

SITE 459 HOLE B CORE 9 CORED INTERVAL: 74.0 to 83.5 m

TIME-ROCK UNIT: Middle Miocene
BIOSTRAT ZONE: *Catinaster calyculus* (N)

FORAMS	NANNOS	RADS	SECTION	METERS
	AP	B	1	0.5, 1.0
	AP	B	CC	



LITHOLOGIC DESCRIPTION

VITRIC MARLY CALCAREOUS OOZE, color darker than Core 8. Olive gray (5Y 3/2); indurated patches shown by stippling in structures column.
Core-Catcher: Sample very disturbed; soft mudstone fragments.

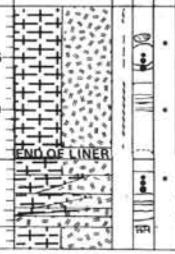
SMEAR SLIDE SUMMARY

	Vitric Marly Calcareous Ooze
	1-55
TEXTURE:	
Sand	–
Silt	10
Clay	90
TOTAL DETRITAL	60
COMPOSITION:	
Feldspar	10
Clay	30
Volcanic glass	20
Carbonate unsp.	20
Nannofossils	20

SITE 459 HOLE B CORE 11 CORED INTERVAL: 93.0 to 102.5 m

TIME-ROCK UNIT: Middle Miocene
BIOSTRAT ZONE: *Catinaster calyculus* (N)

FORAMS	NANNOS	RADS	SECTION	METERS
			1	0.5, 1.0
			2	
	AM	B	CC	



LITHOLOGIC DESCRIPTION

Site 459, Hole B, Core 10, Interval 83.5 to 93.0 m: NO RECOVERY.

VITRIC MARLY NANNOFOSSIL CHALK
Color olive gray (5Y 4/1) to greenish gray (5GY 6/1). Lithification increasing.
Section 1:
0-30 cm: Very deformed and soupy
30-35 cm: Laminated siltstone piece in drilling sand
35-60 cm: Graded bed, finer part is marly nannofossil chalk
40-41 cm: Coarser band, fining upward
41-63 cm: Thinly laminated
59-63 cm: Fining upwards from very fine sandstone to siltstone
63-98 cm: Drilling paste
98-105 cm: Slightly fractured siltstone with 1-2 mm thick hard vitric mudstone at top, grayish black (N2).
105-137 cm: Drilling paste
139-141 cm: Slightly fractured sandstone
Section 2:
0-15 cm: Sand coarsening upward olive gray (5Y 4/1).
15-35 cm: Fining and lighter in color upwards; irregularly laminated greenish gray (5GY 6/1). **VITRIC NANNOFOSSIL CHALK.**
35-55 cm: Finer, lighter upwards olive black (5Y 2/1) to olive gray (5Y 3/2) (top). Bottom 2 cm well-laminated, upper 10 cm not laminated.
55-60 cm: As above, but lower 3 to 4 cm cross-laminated, no upper massive part.
60-71 cm: Olive gray laminated, fractured.
Core-Catcher: Several pieces of mudstone, angular, some laminated.

SMEAR SLIDE SUMMARY

	Marly Nannofossil Chalk	Vitric Mudstone	Vitric Nannofossil Chalk
	1-38	1-98.5	2-20
TEXTURE:			
Sand	–	–	–
Silt	10	30	30
Clay	90	70	70
TOTAL DETRITAL	50	95	22
COMPOSITION:			
Feldspar	8	10	1
Heavy minerals	–	–	2
Clay	40	55	8
Volcanic glass	2	30	10
Micronodules	–	5	–
Zeolite	–	+	–
Carbonate unsp.	20	+	35
Foraminifers	–	–	2
Nannofossils	30	–	40
Radiolarians	–	–	1
Palagonite	–	–	4

SITE 459 **HOLE** B **CORE** 12 **CORED INTERVAL:** 102.5 to 112.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS			SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE
Middle Miocene	*Catinaster calyculus* (N)		AM	B			CC					

LITHOLOGIC DESCRIPTION

Core-Catcher:
GRADED, SANDY ASH TO VITRIC CHALK, grayish olive green throughout unless otherwise noted.
0-10 cm: Fragments as below
10-25 cm: Laminated very fine sandstone
26-28 cm: Olive black (5Y 2/1) fine sandstone, sandy vitric crystal ash
28 cm: Erosion contact
28-35 cm: Siltstone fragments

SMEAR SLIDE SUMMARY

	Vitric Marly Chalk	Sandy Crystal Vitric Ash
	CC-3	CC-27
TEXTURE:		
Sand	5	95
Silt	25	5
Clay	70	–
TOTAL DETRITAL	50	100
COMPOSITION:		
Feldspar	10	40
Heavy minerals	–	9
Clay	20	13
Volcanic glass	15	35
Carbonate unsp.	20	–
Foraminifers	–	+
Nannofossils	30	+
Palagonite	5	3

SITE 459 **HOLE** B **CORE** 13 **CORED INTERVAL:** 112.5 to 121.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS			SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE
Middle Miocene	*Catinaster calyculus* (N)						1	0.5				
			AM	B			CC					

LITHOLOGIC DESCRIPTION

VITRIC MARLY CHALK with TURBIDITE
Section 1:
0-13 cm: Laminated, silty, light olive gray (5Y 5/2)
13-37 cm: Silty
37-58 cm: Sandy, slightly darker than olive gray (5Y 3/2)
58-62 cm: Upward fining silt bed
62-68 cm: As above, alternately sand and silt
68-84 cm: Laminated
Core-Catcher: A mud lump, same as 62-65 cm, slump(?)

SMEAR SLIDE SUMMARY

	Vitric Marly Chalk
	1-7
TEXTURE:	
Sand	–
Silt	20
Clay	80
TOTAL DETRITAL	45
COMPOSITION:	
Feldspar	5
Clay	30
Volcanic glass	10
Carbonate unsp.	30
Nannofossils	25

SITE 459 **HOLE** B **CORE** 14 **CORED INTERVAL:** 121.5 to 131.0 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS			SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE
							1	0.5 1.0				
			B	B								

LITHOLOGIC DESCRIPTION

VITRIC MUDSTONE
Fractured and shattered partly along horizontal laminations, color is olive gray (5Y 3/2) generally.
79-81 cm: Alternating thin layers (up to 5 mm) of light olive gray (5Y 5/2) and dark yellowish brown (ash?) bands
94-103 cm: Mudstone with several spots (burrows?) and two bands of dark yellowish brown (ash?)
105-115 cm: Mudstone with light olive gray (5Y 5/2) burrows(?)

SMEAR SLIDE SUMMARY

	Vitric Mudstone
	1-22
TEXTURE:	
Sand	5
Silt	15
Clay	80
COMPOSITION:	
Feldspar	10
Clay	70
Volcanic glass	20
Micronodules	+
Zeolite	+
Nannofossils	+
Radiolarians	+

SITE 459 **HOLE** B **CORE** 15 **CORED INTERVAL:** 131.0 to 140.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS			SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE
Middle Miocene	*Catinaster calyculus* (N) – *Cannartus petterssoni* (R)?		AM	B			1	0.5 1.0				
			B	RP			2					
							3					
			B	RP			CC					

Chemical Sample

LITHOLOGIC DESCRIPTION

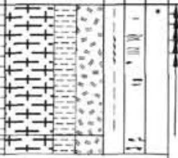
MARLY NANNOFOSSIL CHALK, VITRIC MUDSTONE and SANDY VITRIC TUFF
Sections 1 and 2: Repetitive turbidite sequence, grading from marly nannofossil chalk (fine) through vitric mudstone, to sandy vitric tuff (coarse). About 20 cycles or portions of cycles were recovered. Boundaries are shown to the right of the lithology sample column. The smallest is 1 cm (2-127 to 128 cm) and largest 60 cm (1-105 to 2-15 cm). Colors of typical cycles are: (1) top–grayish olive (10Y 4/2), (2) middle–olive gray (5Y 3/2), (3) bottom–olive black (5Y 2/1).
Section 3 and Core-Catcher: Olive gray (5Y 3/2) mudstone (shattered in Section 3).

SMEAR SLIDE SUMMARY

	Vitric Mudstone	Sandy Vitric Tuff	Marly Nanno-fossil chalk	Marly Nanno-fossil chalk
	1-10	1-25.5	1-50	2-133
TEXTURE:				
Sand	–	50	–	–
Silt	10	30	5	5
Clay	90	20	95	95
TOTAL DETRITAL	95	90	77	–
COMPOSITION:				
Feldspar	10	20	2	5
Clay	75	10	40	35
Volcanic glass	10	60	5	5
Micronodules	5	10	–	–
Carbonate unsp.	–	–	30	35
Nannofossils	–	–	23	20
Radiolarians	+	–	–	–

SITE 459 HOLE B CORE 17 CORED INTERVAL: 150.0 to 159.5 m

TIME-ROCK UNIT: Middle Miocene | BIOSTRAT ZONE: *Helicosphaera carteri* (N) | FOSSIL CHARACTER: FORAMS, NANNOS: RP, AM; RADS: B | SECTION: 1, CC | METERS: 0.5, 1.0



Olive black bands

Small slump structure

Olive black bands

LITHOLOGIC DESCRIPTION

Site 459, Hole B, Core 16, Interval 140.5 to 150.0 m: No Recovery.

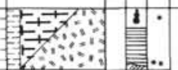
MARLY NANNOFOSSIL CHALK, VITRIC MUDSTONE and SANDY VITRIC TUFF
Same description as Core 16. Six cycles present. Color is mostly olive gray (5Y 3/2).
Core-Catcher: As above. Olive gray (5Y 3/2), small slump structure, and olive black bands.

SMEAR SLIDE SUMMARY

	Vitric Marly Nannofossil Chalk
	1-14
TEXTURE:	
Sand	–
Silt	10
Clay	90
TOTAL DETRITAL	50
COMPOSITION:	
Feldspar	3
Clay	37
Volcanic glass	10
Carbonate unsp.	30
Nannofossils	20

SITE 459 HOLE B CORE 19 CORED INTERVAL: 169.0 to 178.5 m

TIME-ROCK UNIT: Middle Miocene | BIOSTRAT ZONE: *Helicosphaera carteri* (N), *Catinaster coalitus* (N) | FOSSIL CHARACTER: NANNOS: CM, CM; RADS: B, B | SECTION: 1 | METERS: 0.5



LITHOLOGIC DESCRIPTION

Site 459, Hole B, Core 18, Interval 159.0 to 169.0 m: No Recovery

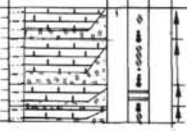
LAMINATED MUDSTONE, SILTY VITRIC TUFF, and SANDY VITRIC TUFF
Two thin graded beds 0 to 5 cm, 5 to 50 cm is massive laminated olive gray (5Y 3/2) mudstone. An erosional contact occurs at 50 cm. Below this, color is grayish brown (5Y 3/2) and the two tuff varieties alternate in cross-beds.

SMEAR SLIDE SUMMARY

	Mudstone	Silty Vitric Tuff	Sandy Vitric Tuff
	1-10	1-55	1-56.5
TEXTURE:			
Sand	–	20	60
Silt	10	60	30
Clay	90	80	10
TOTAL DETRITAL	90	100	100
COMPOSITION:			
Feldspar	10	10	10
Clay	80	20	10
Volcanic glass	+	70	80
Nannofossils	10	–	–
Radiolarians	–	+	–
Opaques	+	–	–

SITE 459 HOLE B CORE 20 CORED INTERVAL: 178.5 to 188.0 m

TIME-ROCK UNIT: Middle Miocene | BIOSTRAT ZONE: *Discoaster kugleri* (N), *Cannartus petterssoni* (R)? | FOSSIL CHARACTER: NANNOS: AM, AM; RADS: CM, CM | SECTION: 1 | METERS: 0.5, 1.0

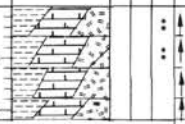


LITHOLOGIC DESCRIPTION

TURBIDITES: NANNOFOSSIL CHALK, VITRIC MARLY NANNOFOSSIL CHALK and SILTY VITRIC TUFF,
burrowed throughout, originally composed of four sequences. Grain size from darker pale grayish brown (5YR 4/2) and coarser at the bottoms, to lighter yellowish brown (10YR 5/2) finer top with olive black (5Y 2/1) sandy bands. Intervals of grade sequences are 12 to 32 cm, 32 to 74 cm, 74 to 95 cm, 95 to 110 cm.

SITE 459 HOLE B CORE 21 CORED INTERVAL: 188.0 to 197.5 m

TIME-ROCK UNIT: Middle Miocene | BIOSTRAT ZONE: *Sphenolithus heteromorphus* (N), *Dorcadospyris alata* (R) | FOSSIL CHARACTER: NANNOS: AM; RADS: CM, CM, AP | SECTION: 1 | METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

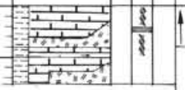
TURBIDITES, NANNOFOSSIL CHALK, MARLY NANNOFOSSIL CHALK, SILTY AND SANDY VITRIC TUFF
Generally as in Cores 17-20, but burrowing is less extensive; a few beds are free of burrows. Upper parts are more burrowed than lower ones. About twelve turbidite sequences identifiable, each from top to bottom consisting of: nannofossil chalk, white, highly burrowed; vitric marly nannofossil chalk; marly vitric nannofossil chalk; sandy or silty vitric tuff (sandstone, siltstone); colors are pale yellowish brown (10YR 6/2), yellowish gray (5Y 7/2), and some olive black bands. Only five sequences are schematically shown with the sense of grading (fining upward) indicated by arrows to the right of the lithology cycle column.

SMEAR SLIDE SUMMARY

	Nannofossil Chalk	Marly Vitric Nannofossil Chalk	Marly Vitric Nannofossil Chalk	Sandy Vitric Tuff
	1-18	1-29	1-48	1-51
TEXTURE:				
Sand	–	–	–	50
Silt	–	20	25	10
Clay	100	80	75	40
TOTAL DETRITAL	20	55	50	75
COMPOSITION:				
Feldspar	–	15	5	20
Heavy minerals	–	–	+	–
Clay	20	25	25	10
Volcanic glass	–	15	20	45
Carbonate unsp.	–	20	–	–
Nannofossils	80	25	50	20
Opaques	–	–	5	5

SITE 459 HOLE B CORE 22 CORED INTERVAL: 197.5 to 207.0 m

TIME-ROCK UNIT: Early Middle Miocene | BIOSTRAT ZONE: *Helicosphaera ampliaperta/Sphenolithus heteromorphus?*, *Dorcadospyris alata–Calocycletta costata* (R) | FOSSIL CHARACTER: NANNOS: AP, AP; RADS: RP | SECTION: 1, CC



LITHOLOGIC DESCRIPTION

TURBIDITES, NANNOFOSSIL CHALK-VITRIC NANNOFOSSIL CHALK and SANDY/SILTY VITRIC TUFF
Section 1: One graded sequence 0 to 45 cm
0-27 cm: Burrowed chalk
27-38 cm: Non-burrowed light olive gray chalk
38-45 cm: Laminated
45-49 cm: Sandstone (dark layer)
45-52 cm: Strongly burrowed chalk
Core-Catcher: Light olive gray chalk and olive black sand bed

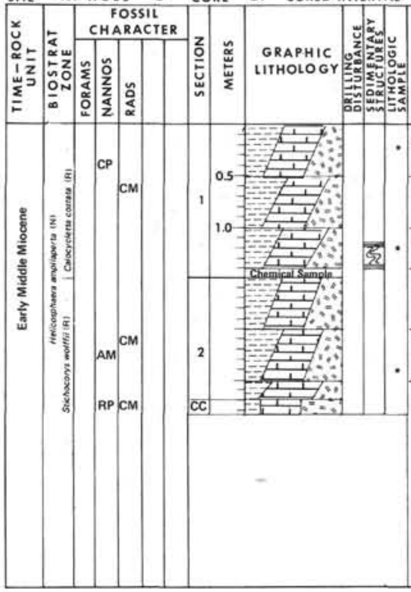
SITE 459 HOLE B CORE 23 CORED INTERVAL: 207.0 to 216.5 m

SECTION: CC

LITHOLOGIC DESCRIPTION

Core-Catcher: Two pieces of olive black **SANDSTONE** (sandy vitric tuff).

SITE 459 HOLE B CORE 24 CORED INTERVAL: 216.5 to 226.0 m

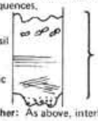


LITHOLOGIC DESCRIPTION

TURBIDITES, MARLY NANNOFOSSIL CHALK and SILTY VITRIC TUFF.

Section 1: Eleven graded sequences (fewer are shown schematically) with marly nannofossil chalk and silty vitric tuff. Color is white (top) grayish yellow green (5GY 7/2), darker olive black (5Y 2/1) at the bottom. Slump between 116 to 140 cm.

Section 2: As above, but more olive black tuff layers; sixteen graded sequences.

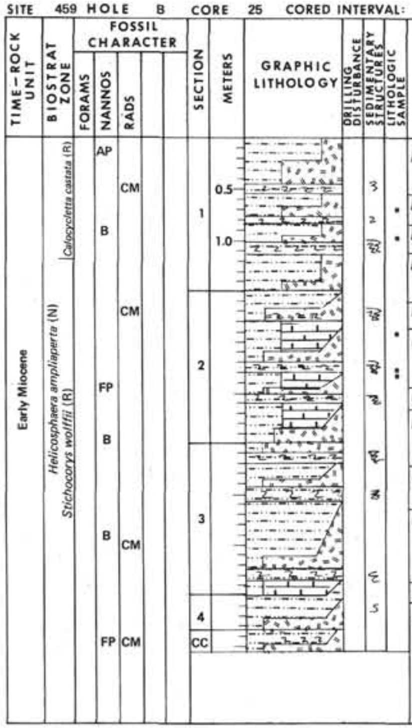


Core-Catcher: As above, interbedded nannofossil chalk and tuff.

SMEAR SLIDE SUMMARY

	Marly Nannofossil Chalk	Silty Vitric Tuff	Marly Nannofossil Chalk
	1-32	2-114	2-94
TEXTURE:			
Sand	–	20	–
Silt	5	50	5
Clay	95	30	95
TOTAL DETRITAL	40	95	–
COMPOSITION:			
Feldspar	–	25	+
Clay	35	20	35
Volcanic glass	5	50	5
Carbonate unsp.	30	–	10
Nannofossils	30	5	50
Radiolarians	–	–	+
Sponge spicules	–	–	+

SITE 459 HOLE B CORE 25 CORED INTERVAL: 226.0 to 235.5 m



LITHOLOGIC DESCRIPTION

TURBIDITES, VITRIC MUDSTONE, VITRIC MARLY NANNOFOSSIL CHALK AND SILTY/SANDY TUFF

Section 1: Overall color between dark yellowish brown (10YR 4/2) and moderate brown (5YR 3/4). Sequence of seventeen graded turbiditic cycles with three slump beds: 45 to 55 cm, 84 to 87 cm, and 105 cm. Bottom of graded beds usually have erosional contacts.

Section 2: As above; semi-lithified graded turbidite sequence. Nineteen cycles; 3 slump beds. Overall color is between light olive gray (5Y 5/2) and brownish gray (YR 4/1).
87 cm: Sandy pumice layer.

Section 3: Overall color between dark yellowish brown (10YR 4/2) and light olive gray (5Y 5/2). Three slumps, eleven graded layers.

Section 4: **0 to 20 cm**—Bioturbated 20 to 30 cm slump in grayish brown siltstone; overall color olive gray.

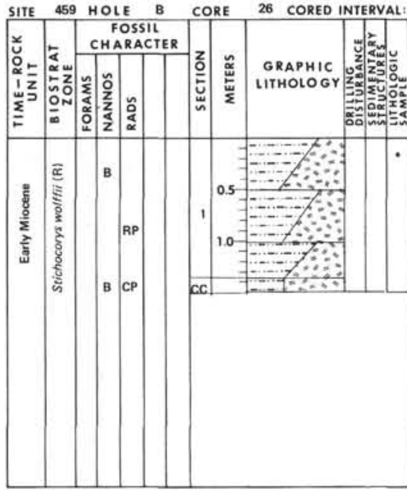
Core-Catcher: As above, erosional boundary at the bottom of grayish brown sandstone.

Remarks: Volcanic glass strongly altered to clays.

SMEAR SLIDE SUMMARY

	Vitric Mudstone	Silty Vitric Tuff	Vitric Mudstone	Silty Vitric Tuff	Vitric Marly Nannofossil Chalk	Sandy Pumice Layer
	1-77	1-99	1-100	2-50	2-85	2-87
TEXTURE:						
Sand	10	–	–	–	–	80
Silt	20	50	10	10	20	10
Clay	70	50	90	90	80	10
TOTAL DETRITAL	100	95	90	100	30	100
COMPOSITION:						
Feldspar	15	5	15	15	–	15
Heavy minerals	–	–	–	–	–	5
Clay	70	40	45	35	20	10
Volcanic glass	15	50	30	50	10	70
Micronodules	+	5	–	–	–	–
Carbonate unsp.	–	–	10	–	10	–
Nannofossils	–	–	–	–	60	–
Diatoms	–	–	–	+	–	–
Radiolarians	+	–	–	+	–	–

SITE 459 HOLE B CORE 26 CORED INTERVAL: 235.5 to 245.0 m



LITHOLOGIC DESCRIPTION

TURBIDITES, VITRIC MUDSTONE and SILTY/SANDY VITRIC TUFF (schematically shown).

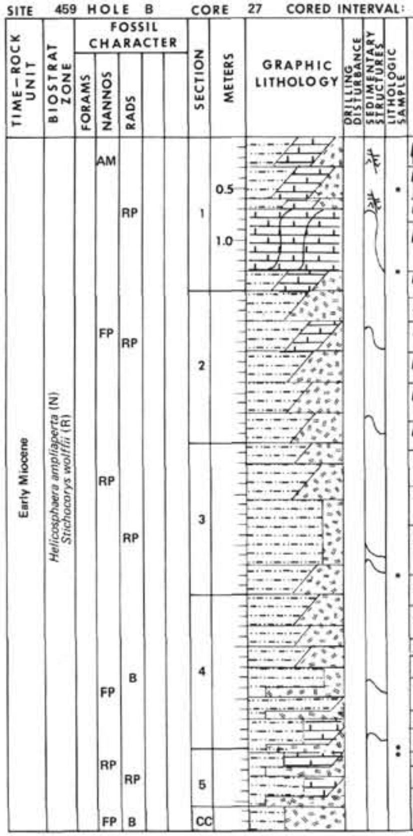
Similar to Core 25; color at the top of each cycle is light olive gray (5Y 5/2). The bottoms are olive gray (5Y 3/2) or brownish black (5YR 2/1). Nine turbiditic sequences occur. Turbidite cycles are only schematically shown; arrows indicate sense of grading (fining upward). Dewatering structures occur from 27 to 30 cm.

Core-Catcher: Probably a part of a slump deposit.

SMEAR SLIDE SUMMARY

	Vitric Mudstone
	1-20
TEXTURE:	
Sand	–
Silt	20
Clay	80
TOTAL DETRITAL	100
COMPOSITION:	
Feldspar	10
Clay	55
Volcanic glass	25
Zeolite	+
Palagonite	10

SITE 459 HOLE B CORE 27 CORED INTERVAL: 245.0 to 254.5 m



LITHOLOGIC DESCRIPTION

TURBIDITES, RARE MARLY NANNOFOSSIL CHALK, VITRIC MUDSTONE and SILTY/SANDY VITRIC TUFF

Section 1: Similar to Core 26.

55 to 130 cm: 75 cm thick slump bed as a major part of a graded bed; overall color is grayish olive (10Y 4/2). Nine graded cycles, faults (normal) 20 to 25 cm, 60 to 70 cm.

Section 2: As above; sequences of silty-sandy graded beds. At their bottom brownish black (5YR 2/1) sandy layers are common. Eighteen sequences in the section (only shown schematically); slumps 40 to 53 cm, 102 to 124 cm.

Section 3: Alternate grayish black (N2) and olive gray (5Y 4/1) to grayish olive (10Y 4/2) vitric mudstone, plus graded beds as above (ten sequences). Zoophycus in 2 mm thick layers (27 cm, 34 cm, 137 cm); slumps 100 to 109 cm, 110 to 125 cm.

Section 4: Graded and cyclic beds of grayish olive green (5GY 3/2) with grayish black (N2) layers at bottom of each cycle. Seven cycles in section, drawn as they occur. Slumps 80 to 90 cm, 130 to 138 cm.

Section 5: As above, but marly nannofossil chalk two cycles, drawn as they occur.

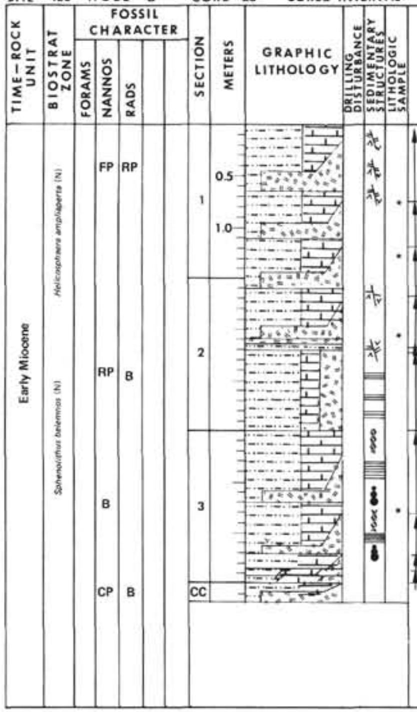
Core-Catcher: Part of slump deposit(?); medium dark gray (N4) siltstone.

Remarks: Clays as result of strong alteration of volcanic glass.

SMEAR SLIDE SUMMARY

	Silty Nannofossil Vitric Mudstone	Vitric Mudstone	Vitric Mudstone	Vitric Mudstone	Marly Nannofossil Chalk
	1-58	1-130	3-130	4-148	5-9
TEXTURE:					
Sand	–	–	–	–	–
Silt	30	30	30	30	10
Clay	70	70	70	70	90
TOTAL DETRITAL	70	100	95	100	80
COMPOSITION:					
Feldspar	5	15	10	5	–
Clay	35	55	65	55	70
Volcanic glass	30	30	20	40	10
Zeolite	–	–	–	+	–
Carbonate unsp.	10	–	5	–	–
Nannofossils	20	–	–	–	20
Radiolarians	–	–	–	–	+

SITE 459 HOLE B CORE 28 CORED INTERVAL: 254.5 to 264.0 m



LITHOLOGIC DESCRIPTION

TURBIDITES WITH INTENSE NORMAL FAULTING. MUDSTONE, VITRIC MUDSTONE, with SANDY/SILTY VITRIC TUFF.

Section 1: As in Core 27, but faults and fractures are abundant; lithification increases. Color is slightly darker olive gray to olive black. Faults mainly nearly vertical (≤4 cm) with opening component. Smaller, irregular fracture or both sides also with opening component. Burrows are all by the faults. Incipient fracturing starts from here and displacements larger upward (110 cm). Graded sand bed 90-140 cm.

Section 2: As above, but no vertical fractures; graded beds only upper half. Burrows only in the lower half; faulting (normal) 10 cm, 65-80 cm. Thirteen graded turbiditic cycles.

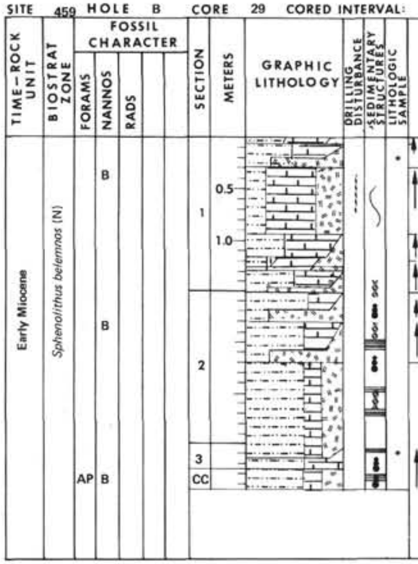
Section 3: Six turbiditic cycles with (from top to bottom): (1) greenish gray chalk, (2) burrowed mudstone, (3) massive mudstone, (4) laminated mudstone/siltstone, (5) cross-bedded siltstone/fine sandstone, (6) graded bedded medium to fine sandstone, olive black (N2), (7) sand layer brownish black. 0 to 21 cm–slump; 0 to 70 cm–3/4/6; 70 to 120 cm–1/2/3/4/5/6; 120 to 135 cm–2/3/4/6; 135 to 142 cm–3/4/7; 142 to 150 cm–3.

Core-Catcher: Graded very fine sandstone to medium sandstone between very dusky red (10R 2/2) and black, faintly laminated siltstone, dark greenish gray (5GY 4/1).

SMEAR SLIDE SUMMARY

	Silty Vitric Tuff	Sandy Vitric Tuff	Vitric Mudstone	Mudstone
	1-79	1-130	2-55	3-77
TEXTURE:				
Sand	20	50	–	30
Silt	70	45	20	70
Clay	10	5	80	10
TOTAL DETRITAL	80	90	70	90
COMPOSITION:				
Feldspar	5	10	5	5
Heavy minerals	+	20	–	5
Clay	5	3	50	75
Volcanic glass	50	55	15	5
Carbonate unsp.	15	5	20	–
Foraminifers	+	1	–	–
Nannofossils	20	1	10	–
Radiolarians	+	–	–	10
Palagonite	5	5	–	–

SITE 459 HOLE B CORE 29 CORED INTERVAL: 264.0 to 273.5 m



LITHOLOGIC DESCRIPTION

TURBIDITES, VITRIC NANNOFOSSIL CHALK and MUDSTONES, WITH SILTY TO SANDY VITRIC TUFF

Section 1: Same as Core 28, but 30-93 cm is grayish green (10GY 5/2), more chalky; four cycles 0 to 10 cm, 10 to 29 cm, 96 to 120 cm, 120 to 127 cm, 127 to 150 cm; mudstone 28 to 50 cm; slump 50 to 96 cm.

Section 2:

0 to 70 cm: Five cycles fining upwards

94 to 150 cm: Burrowed, laminated, or massive mudstone

25 to 30 cm: Massive sandstone

Core-Catcher: Brightly fractured, faintly laminated mudstone, dark olive gray (5Y 3/1)

SMEAR SLIDE SUMMARY

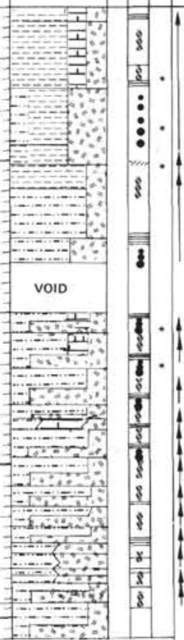
	Mudstone	Vitric Nannofossil Chalk
	1-30	3-4
TEXTURE:		
Sand	–	–
Silt	10	40
Clay	90	60
TOTAL DETRITAL	100	70
COMPOSITION:		
Feldspar	5	+
Clay	85	40
Volcanic glass	10	30
Micronodules	+	–
Carbonate unsp.	–	10
Nannofossils	–	20
Sponge spicules	+	–
Fish remains	+	–

SITE 459 HOLE B CORE 30 CORED INTERVAL: 273.5 to 283.0 m

TIME-ROCK UNIT: Early Miocene
BIOSTRAT ZONE: *Sphenolithus belemnos* (N)
FOSSIL CHARACTER (FORAMS, NANNOS, RADS): Section 1: CP; Section 2: CP; Section 4: B; CC: B B

SECTION: 1, 2, 3, 4, 5, CC — METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / LITHOLOGIC SAMPLE



LITHOLOGIC DESCRIPTION

TURBIDITES throughout; MARLY NANNOFOSSIL CHALK, CLAYSTONE, MUDSTONE WITH SILTY and SANDY VITRIC TUFF LAYERS
Section 1, 0 to 15 cm: Firm drilling breccia
15 to 35 cm: Thick turbidite with sandstone at the bottom; abundant pieces of pumice (white or pale green) 0.5 to 1 cm in diameter, reworked.
10 to 28 cm: Laminated mudstone grayish yellow green (5GY 7/2)
29 to 40 cm: Burrowed
40 to 60 cm: Massive
60 to 64 cm: Burrowed
64 to 75 cm: Laminated
75 to 135 cm: Fine sandstone grading downwards into coarse sandstone
135 to 150 cm: Mudstone and very fine sandstone
Section 2: Two turbidite cycles end of Section 1 plus 0 to 5 cm, 5 to 100 cm
0 to 5 cm: Cross-bedded fine sandstone
5 to 21 cm: Claystone-mudstone, grayish yellow green (5GY 6/2)
21 to 25 cm: Burrowed
25 to 70 cm: Massive
70 to 90 cm: Laminated
90 to 100 cm: Graded coarse sandstone
Section 3: Seven turbidites–0 to 21 cm, 21 to 56 cm, 56 to 91 cm, 91 to 107 cm, 107 to 114 cm, 114 to 145 cm, 145 cm into Section 4, same cycles: burrowed, laminated, graded, as above. Colors are grayish yellow green (5GY 4/2), greenish gray (5GY 6/1), light olive gray (5Y 6/1). Bottom of coarse sandstone with erosional figures.
Section 4: Ten turbidites, as above; 0 to 20 cm, 20 to 40 cm, 40 to 62 cm, 62 to 75 cm, 75 to 83 cm, 83 to 95 cm, 95 to 100 cm, 100 to 103 cm, 103 to 118 cm, 120 to 135 cm, strongly laminated throughout.
Core-Catcher: As above; dusky yellow green and olive black patches and beds
Remarks: Colorless volcanic glass with large pipe vesicles is abundant; green clays

SMEAR SLIDE SUMMARY

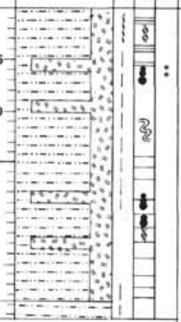
	Marly Nannofossil Chalk	Vitric Mudstone	Claystone	Sandy Vitric Tuff	Silty Vitric Tuff
	1-70	1-129	2-14	3-20	3-55
TEXTURE:					
Sand	0	0	0	60	–
Silt	10	10	10	30	90
Clay	90	90	90	10	10
TOTAL DETRITAL	60	85	100	90	95
COMPOSITION:					
Feldspar	10	15	5	15	5
Clay	50	65	90	10	10
Volcanic glass	–	15	5	65	80
Micronodules	–	–	+	–	5
Zeolite	–	–	+	–	–
Carbonate unsp.	20	15	–	5	–
Foraminifers	–	–	–	–	+
Nannofossils	20	–	–	5	–
Radiolarians	–	–	+	+	+
Fish remains	–	–	+	–	–

SITE 459 HOLE B CORE 31 CORED INTERVAL: 283.0 to 292.5 m

FOSSIL CHARACTER (FORAMS, NANNOS, RADS): Section 2: B; CC: B B

SECTION: 1, 2, CC — METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / LITHOLOGIC SAMPLE



LITHOLOGIC DESCRIPTION

TURBIDITES, VITRIC MUDSTONE, SILTY/SANDY VITRIC TUFF
Similar to Core 30, but recognition of cycles is more difficult due to drilling disturbances, including brittle fractures.
Section 1:
15 to 25 cm: Burrowed and laminated pieces
25 to 36 cm: Sandstone and siltstone (N2)
36 to 54 cm: Burrowed mudstone
54 to 61 cm: Mudstone grading to siltstone downward
61 to 80 cm: Burrowed and laminated
80 to 82 cm: Sandstone, N2
82 to 110 cm: Burrowed and laminated very fine sandstone
110 to 130 cm: Slump
Section 2: As above, brittle fracturing, stronger in the upper half of the section, no layer thicker than 5 cm. Olive gray silt and very fine sandstone dominate.
Core-Catcher: Burrowed mudstone, grayish olive (10Y 4/2) between 0 and 10 cm, fractured between 10 and 15 cm.
Remarks: Mainly colorless volcanic glass in smear slides.

SMEAR SLIDE SUMMARY

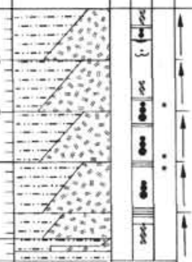
	Vitric Mudstone	Silty Vitric Tuff
	1-58	1-61
TEXTURE:		
Sand	–	20
Silt	40	60
Clay	70	20
TOTAL DETRITAL	95	100
COMPOSITION:		
Feldspar	5	15
Heavy minerals	–	5
Clay	70	20
Volcanic glass	20	60
Carbonate unsp.	5	–
Diatoms	+	–
Radiolarians	+	–
Fish remains	+	–

SITE 459 HOLE B CORE 32 CORED INTERVAL: 292.5 to 302.0 m

FOSSIL CHARACTER (FORAMS, NANNOS, RADS): CC: B B

SECTION: 1, 2, CC — METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / LITHOLOGIC SAMPLE



LITHOLOGIC DESCRIPTION

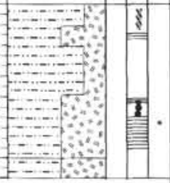
TURBIDITES, VITRIC MUDSTONE WITH SILTY AND SANDY VITRIC TUFF, cycles schematically shown, basal contacts erosional.
Section 1: Turbidite cycles distinct from top to bottom; burrowed, laminated and coarse graded. Nine cycles in Section 1; dewatering cracks 5 to 10 cm. Burrows of Chondrites 20 to 26 cm, 86 to 93 cm, 120 to 126 cm.
Section 2: Five cycles present; colors are grayish olive green (5GY 3/2), grayish yellow green (5GY 7/2), and greenish black (5G 2/1).
Core-Catcher: Erosion contact between two cycles.
Remarks: Foraminifer fragments (probably reworked) at 1 to 40 cm, and 2 to 9 cm; green clay (alteration of volcanic glass).

SMEAR SLIDE SUMMARY

	Silty Vitric Tuff	Sandy Vitric Tuff	Vitric Tuff
	1-98	1-140	2-9
TEXTURE:			
Sand	–	70	20
Silt	50	30	20
Clay	50	–	60
TOTAL DETRITAL	100	90	
COMPOSITION:			
Feldspar	10	15	15
Heavy minerals	5	5	20
Clay	45	70	30
Volcanic glass	40	–	35
Micronodules	+	–	–
Foraminifers	–	10	+
Nannofossils	–	+	–
Radiolarians	–	–	+

SITE 459 HOLE B CORE 33 CORED INTERVAL: 302.0 to 311.5 m

TIME-ROCK UNIT: Early Miocene
BIOSTRAT ZONE: *Sphenolithus belemnos* (N)
FOSSIL CHARACTER: FORAMS — ; NANNOS AM; RADS B
SECTION: 1, CC
METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

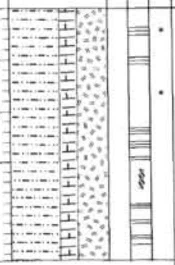
VITRIC MUDSTONE WITH SILTY LAYERS AND MUDDY VITRIC TUFF
Section 1: Color is mainly 5G 5/1 throughout. Coarser darker bands; burrowed 10 to 15 cm and 85 to 95 cm; vitric mudstone 0 to 95 cm; medium sandstone dark greenish gray (5GY 4/1) 95 to 100 cm. Muddy vitric tuff and siltstone, greenish gray (5G 5/1) 110 to 150 cm, faintly laminated. Chondrites 10 to 15 cm.
Core-Catcher: Several lumps of siltstone as above.

SMEAR SLIDE SUMMARY

	Muddy Vitric Tuff 1-110
TEXTURE:	
Sand	–
Silt	40
Clay	60
TOTAL DETRITAL	80
COMPOSITION:	
Feldspar	10
Clay	20
Volcanic glass	50
Carbonate unsp.	+
Nannofossils	20

SITE 459 HOLE B CORE 34 CORED INTERVAL: 311.5 to 321.0 m

TIME-ROCK UNIT: Early Miocene
BIOSTRAT ZONE: *Sphenolithus belemnos* (N)
FOSSIL CHARACTER: FORAMS — ; NANNOS CP; RADS RP
SECTION: 1, 2
METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

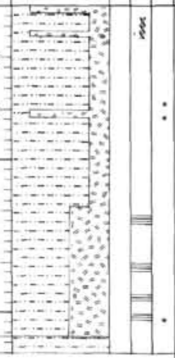
NANNOFOSSIL VITRIC MUDSTONE WITH MUDDY/SILTY VITRIC TUFF LAYERS
Section 1: 0 to 25 cm, brownish gray (5YR 4/1); parallel, horizontal laminations in muddy vitric tuff 25 to 150 cm; greenish gray (5G 5/1) vitric mudstone with nannofossils.
Section 2: 0 to 10 cm, slightly mottled, laminated mudstone; greenish gray (5G 5/1). 0 to 40 cm, light olive gray (5Y 5/1), very fine sandstone, upper few cm burrowed. 40 to 80 cm, slightly laminated.

SMEAR SLIDE SUMMARY

	Muddy Vitric Tuff 1-16	Vitric Mudstone 1-87
TEXTURE:		
Sand	–	–
Silt	40	50
Clay	60	50
TOTAL DETRITAL	100	75
COMPOSITION:		
Feldspar	10	15
Clay	60	30
Volcanic glass	30	30
Micronodules	+	–
Foraminifers	–	5
Nannofossils	–	20

SITE 459 HOLE B CORE 35 CORED INTERVAL: 321.0 to 330.5 m

TIME-ROCK UNIT: Early Miocene
BIOSTRAT ZONE: *Discoaster druggii* (N)
FOSSIL CHARACTER: NANNOS AP, AP, CP; RADS B
SECTION: 1, 2, 3, CC
METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

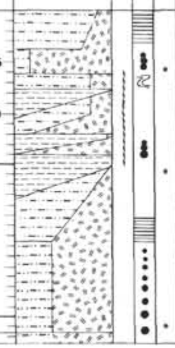
MUDSTONE, SILTSTONE, SANDSTONE (SILTY VITRIC TUFF AND SANDY VITRIC TUFF) LAMINATED.
Section 1: Grayish olive (10Y 4/2) throughout
0 to 6 cm: Mudstone then olive gray (5Y 3/2) sandstone
6 to 25 cm: Siltstone burrowed
25 to 26 cm: Brownish black (5YR 2/1) fine sandstone
26 to 41 cm: Mudstone
41 to 45 cm: Very fine sandstone
45 to 106 cm: Mudstone
106 to 110 cm: Sandstone, grayish red (5R 4/2)
110 to 150 cm: Mudstone
Section 2: Monotonous mudstone, grayish olive (10Y 4/2), slightly laminated
Section 3: Grayish olive (10Y 4/2), silty vitric tuff
Core-Catcher: Very fine sandstone, color as above
Remarks: Volcanic glass strongly altered; abundant vesicles; green clays as result of alteration.

SMEAR SLIDE SUMMARY

	Vitric Mudstone 1-101	Vitric Mudstone 1-114	Silty Vitric Tuff 3-8
TEXTURE:			
Sand	–	–	–
Silt	35	40	55
Clay	65	60	45
TOTAL DETRITAL	70	100	90
COMPOSITION:			
Feldspar	10	10	10
Heavy minerals	–	5	–
Clay	45	55	40
Volcanic glass	25	30	40
Micronodules	–	+	–
Carbonate unsp.	5	–	–
Foraminifers	5	+	5
Nannofossils	25	–	5
Radiolarians	–	+	–

SITE 459 HOLE B CORE 36 CORED INTERVAL: 330.5 to 340.0 m

TIME-ROCK UNIT: Early Miocene
BIOSTRAT ZONE: *Discoaster druggii* (N)
FOSSIL CHARACTER: NANNOS CP; RADS B
SECTION: 1, 2, 3, CC
METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

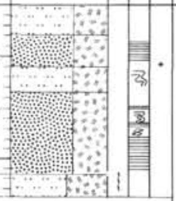
TURBIDITES: CLAYSTONE, VITRIC MUDSTONE, SILTSTONE, SANDSTONE (SILTY AND SANDY VITRIC TUFF; typical sequences of turbidites, slumping.
Section 1: Gray olive (10Y 4/2) throughout; four turbiditic cycles–0 to 60 cm, 75 to 120 cm, 120 to 140 cm; 140 cm through Sections 2 and 3.
0 to 55 cm: Finely laminated, coarser downwards
55 to 60 cm: Sandy vitric tuff
60 to 75 cm: Slump
75 to 120 cm: Claystone to mudstone
120 to 140 cm: Mudstone to fine sand
140 to 150 cm: Mudstone
Section 2: Olive gray (5Y 4/1) throughout. One unit, 150 cm thick from top to bottom is claystone, vitric mudstone, siltstone, and sandstone.
Section 3: End of sandstone, olive gray (5Y 4/1)
Core-Catcher: As above

SMEAR SLIDE SUMMARY

	Sandy Vitric Tuff 1-60	Vitric Mudstone 2-16	Sandy Vitric Tuff 3-9
TEXTURE:			
Sand	50	–	50
Silt	20	30	20
Clay	30	70	30
TOTAL DETRITAL	85	85	–
COMPOSITION:			
Feldspar	10	5	10
Clay	25	40	30
Volcanic glass	60	30	40
Micronodules	+	–	–
Carbonate unsp.	–	10	–
Foraminifers	+	–	+
Nannofossils	15	15	20

SITE 459 HOLE B CORE 37 CORED INTERVAL: 340.0 to 349.5 m

TIME-ROCK UNIT: Early Miocene
BIOSTRAT ZONE: *Discoaster druggii* (N)
FOSSIL CHARACTER: FORAMS, NANNOS, RADS — CP B
SECTION: 1, 2, CC — METERS: 0.5, 1.0
GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / LITHOLOGIC SAMPLE



LITHOLOGIC DESCRIPTION

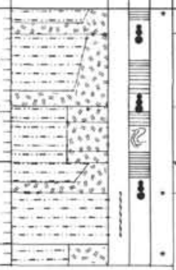
SILTSTONE AND FINE SANDSTONE (SILTY/SANDY VITRIC TUFF), with laminations and slumps.
Section 1: Color grades downward between olive gray (5Y 3/2) and olive black (5Y 2/1).
0 to 30 cm: Massive fine sandstone
30 to 60 cm: Sparsely laminated medium sandstone
60 to 82 cm: Fine sandstones with slump
82 to 150 cm: Laminated medium sandstone with slump
Section 2: As above
Core-Catcher: As above

SMEAR SLIDE SUMMARY

	Silty Vitric Tuff
	1-64
TEXTURE:	
Sand	20
Silt	40
Clay	40
TOTAL DETRITAL	100
COMPOSITION:	
Feldspar	5
Heavy minerals	5
Clay	40
Volcanic glass	50
Foraminifers	+

SITE 459 HOLE B CORE 38 CORED INTERVAL: 349.5 to 359.0 m

TIME-ROCK UNIT: Early Miocene
BIOSTRAT ZONE: *Discoaster druggii* (N)
FOSSIL CHARACTER: FORAMS, NANNOS, RADS — CP; RP B
SECTION: 1, 2, CC — METERS: 0.5, 1.0
GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / LITHOLOGIC SAMPLE



LITHOLOGIC DESCRIPTION

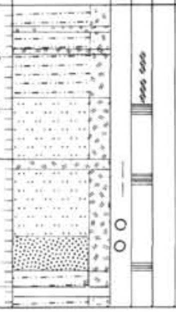
TURBIDITES, MUDSTONE, VITRIC MUDSTONE WITH SILTSTONE AND FINE SANDSTONE (SILTY/SANDY VITRIC TUFF), slump, figures are present.
Section 1: Color olive gray (5Y 3/2 to 5Y 4/2). Several turbiditic sequences–0 to 23 cm, 23 to 95 cm.
0 to 23 cm: Laminated mudstone, vitric mudstone, fine mudstone at the bottom.
23 to 95 cm: Laminated every 2 to 3 cm. Medium sandstone at the bottom
95 to 110 cm: Fine laminated sandstone
110 to 140 cm: Slump in medium sandstone
140 to 150 cm: Siltstone
Section 2: Greenish gray (5G 5/1) to dark greenish gray (5G 4/1) and dark gray (N3). One turbidite between 0 and 30 cm, bottom graded.
30 to 80 cm: Mudstone, deformed by drilling
Core-Catcher: Grayish olive green (5GY 3/2) vitric mudstone, as above

SMEAR SLIDE SUMMARY

	Silty Vitric Tuff	Vitric Mudstone	Vitric Mudstone
	1-10	2-27	CC-10
TEXTURE:			
Sand	–	10	–
Silt	30	50	40
Clay	70	40	60
TOTAL DETRITAL	75	80	
COMPOSITION:	1		
Feldspar	10	10	10
Heavy minerals	5	–	–
Clay	50	30	60
Volcanic glass	20	40	30
Micronodules	+	+	+
Carbonate unsp.	15	10	–
Foraminifers	–	+	+
Nannofossils	10	10	–
Fish remains	–	+	–

SITE 459 HOLE B CORE 39 CORED INTERVAL: 359.0 to 368.5 m

TIME-ROCK UNIT: Early Miocene
BIOSTRAT ZONE: *Discoaster druggii* (N)
FOSSIL CHARACTER: FORAMS, NANNOS, RADS — CP B
SECTION: 1, 2, CC — METERS: 0.5, 1.0
GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / LITHOLOGIC SAMPLE

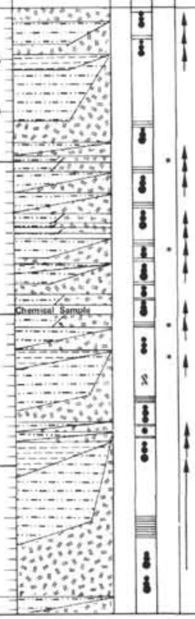


LITHOLOGIC DESCRIPTION

TURBIDITES, MUDSTONE, SILTSTONE, SANDSTONE, with darker bands of SANDY/SILTY VITRIC TUFF;
Section 1:
0 to 70 cm: Thinly laminated siltstone, grayish olive (10Y 4/2) and very fine sandstone with fine sandstone bands, olive black (5Y 2/1)
70 to 90 cm: Mudstone, greenish gray (5G 5/1), laminated and burrowed
90 to 150 cm: Finely laminated silt
Section 2: Grayish olive (10Y 4/2) throughout
0 to 15 cm: Laminated fine sandstone
15 to 75 cm: Faintly laminated siltstone to mudstone
75 to 110 cm: Fine sandstone
110 to 130 cm: Mudstone
Core-Catcher: As above

SITE 459 HOLE B CORE 40 CORED INTERVAL: 368.5 to 378.0 m

TIME-ROCK UNIT: Early Miocene
BIOSTRAT ZONE: *Discoaster druggii* (N)
FOSSIL CHARACTER: FORAMS, NANNOS, RADS — FP B
SECTION: 1, 2, 3, 4, CC — METERS: 0.5, 1.0
GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / LITHOLOGIC SAMPLE



LITHOLOGIC DESCRIPTION

TURBIDITES, CLAYSTONE, MUDSTONE, VITRIC MUDSTONE WITH SILTSTONE TO FINE SANDSTONE (SILTY TO SANDY VITRIC TUFF). Turbiditic sequences very clear from top to bottom: (1) claystone, (2) burrowed mudstone, (3) laminated siltstone, (4) graded siltstone or sandstone. One thick sequence (Sections 3 to 4): 134 cm for other sequences; average thickness is about 20 cm.
Section 1: Dark greenish gray (5G 4/1) between 0 to 15 cm, grayish green (10GY 5/2) from 15 cm to 150 cm.
Five cycles: 0 to 15 cm, 15 to 45 cm, 45 to 130 cm, 130 to 146 cm, 146 to 150 cm.
Section 2: Color grading dusky yellow green (5GY 5/2) top to grayish brown (5YR 3/2) bottom. Color grading associated with size grading (grayish brown, coarser).
Eleven Cycles: 1 to 3 cm, 3 to 10 cm, 10 to 27 cm, 27 to 49 cm, 49 to 60 cm, 60 to 67 cm, 67 to 70 cm, 70 to 75 cm, 75 to 99 cm, 99 to 133 cm, and 133 to 140 cm.
Section 3: Color same as above, between 0 to 105 cm, below 105 cm, grading between dusky yellow green (5GY 5/2) to grayish olive green (5GY 3/2).
Five cycles: (plus the beginning of one large one, extending through Section 4) 0 to 12 cm, 12 to 36 cm, 36 to 105 cm, 105 to 115 cm, 115 to 126 cm, 126 cm to Section 4, 110 cm.
Section 4: Color is olive gray (5Y 3/2) throughout, coarser layers darker. 0 to 110 cm–the end of a cycle beginning in Core 40, Section 3, 126 cm. *110 to 130 cm–a turbiditic cycle.*
Core-Catcher: Pieces of very fine sandstone to siltstone, as above.
Remarks: Volcanic glass with long pipe vesicles.

SMEAR SLIDE SUMMARY

	Silty vitric tuff	Silty vitric tuff	Silty vitric tuff	Claystone
	1-145	2-86	3-8	3-37
TEXTURE:				
Sand	10	10	0	0
Silt	50	50	70	2
Clay	40	40	30	98
TOTAL DETRITAL	100	100	90	
COMPOSITION:				
Feldspar	15	10	10	5
Clay	40	40	30	93
Volcanic glass	45	50	50	+
Micronodules	–	–	10	+
Foraminifers	–	–	+	–
Radiolarians	+	+	–	–
Sponge spicules	–	–	–	+
Fish remains	–	+	–	+

SITE 459 HOLE B CORE 41 CORED INTERVAL: 378.0 to 387.5 m

TIME-ROCK UNIT: Early Miocene
BIOSTRAT ZONE: *Discoaster druggii* (N)
FOSSIL CHARACTER: NANNOS RP; RADS RP
SECTION: CC, 1, 2 — METERS: 0.5, 1.0

LITHOLOGIC DESCRIPTION

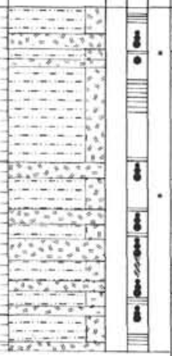
Core-Catcher: VITRIC MUDSTONE, finely laminated, grayish olive (10Y 4/2).

SMEAR SLIDE SUMMARY

	Vitric Mudstone CC-7
TEXTURE:	
Sand	–
Silt	15
Clay	85
TOTAL DETRITAL	95
COMPOSITION:	
Feldspar	5
Clay	80
Volcanic glass	10
Foraminifers	?
Radiolarians	5
Fish remains	+

SITE 459 HOLE B CORE 42 CORED INTERVAL: 387.5 to 397.0 m

TIME-ROCK UNIT: Early Miocene
BIOSTRAT ZONE: *Discoaster druggii* (N)
FOSSIL CHARACTER: NANNOS FB; RADS B
SECTION: 1, 2, 3, CC — METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

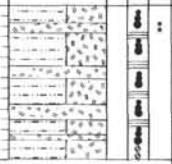
TURBIDITES, CLAYSTONE, MUDSTONE WITH SILTSTONE TO SANDSTONE LAMINATED OR GRADED LAYERS (SILTY TO SANDY VITRIC TUFF)
Section 1: Mainly olive black (5Y 2/1) below 45 cm, grayish olive (10Y 4/2) above.
0 to 45 cm: Laminated sandstone-siltstone, coarser at the bottom.
45 to 50 cm: One cycle siltstone downward, mudstone upwards.
85 to 100 cm: Fine laminated sandstone to coarse medium sandstone.
Section 2: Olive black (5Y 2/1) from 0 to 90 cm; grayish olive (10Y 4/2) below.
0 to 11 cm: Mudstone, very fine sandstone, cross-laminated sandstone.
11 to 50 cm: Mudstone, siltstone
50 to 56 cm: Sandstone, laminated
56 to 90 cm: Siltstone to medium sandstone laminated
110 to 115 cm and **120 to 125 cm:** Burrowed
126 to 128 cm: Sandstone, N3
128 to 138 cm: Claystone
138 to 150 cm: Laminated mudstone, bottom coarser
Section 3:
0 to 25 cm: Massive mudstone to laminated siltstone downward dusky yellow green (5GY 5/2).
Core-Catcher: Semi-consolidated siltstone, grayish olive green (5GY 3/2).

SMEAR SLIDE SUMMARY

	Silty Vitric Tuff 1-50	Claystone 2-30	Silty Vitric Tuff CC
TEXTURE:			
Sand	–	–	20
Silt	70	3	70
Clay	30	97	10
TOTAL DETRITAL	100	100	
COMPOSITION:			
Feldspar	10	3	15
Clay	30	95	10
Volcanic glass	60	2	75
Radiolarians	–	+	+

SITE 459 HOLE B CORE 43 CORED INTERVAL: 397.0 to 406.5 m

TIME-ROCK UNIT: Early Miocene
BIOSTRAT ZONE: *Discoaster druggii* (N)
FOSSIL CHARACTER: NANNOS B; FORAMS RP, NANNOS B
SECTION: 1 — METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

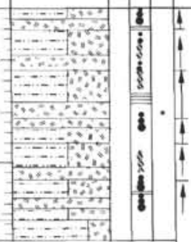
TURBIDITES, VITRIC MUDSTONE WITH SILTSTONE AND SANDSTONE (SILTY/SANDY VITRIC TUFF)
0 to 17 cm: Medium sandstone, olive black (5Y 2/1)
18 to 22 cm: Mudstone, grayish olive (10Y 4/2)
22 to 30 cm: Fine sandstone, olive gray (5Y 3/2)
30 to 65 cm: Laminated, greenish gray (5GY 5/1)
65 to 70 cm: Fine sandstone, olive gray (5Y 3/2)
70 to 80 cm: Graded from sandstone bottom to siltstone, olive gray (top) to olive black (bottom) upwards
80 to 110 cm: Mudstone, dark greenish gray (5G 4/1)
110 to 150 cm: Siltstone, burrowed, olive black laminated, greenish gray (5GY 5/1).
Remarks: Volcanic glass, mainly colorless, green clay as a result of alteration.

SMEAR SLIDE SUMMARY

	Sandy Vitric Tuff 1-17	Silty Vitric Tuff 1-18
TEXTURE:		
Sand	70	10
Silt	20	40
Clay	10	50
TOTAL DETRITAL	100	90
COMPOSITION:		
Feldspar	20	10
Heavy minerals	5	–
Clay	10	30
Volcanic glass	65	45
Carbonate unsp.	–	+
Foraminifers	+	–
Nannofossils	+	10
Opaques	–	5

SITE 459 HOLE B CORE 44 CORED INTERVAL: 406.6 to 416.0 m

FOSSIL CHARACTER: NANNOS B; NANNOS B, RADS B
SECTION: 1, 2, CC — METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

TURBIDITES, MUDSTONE, CRYSTAL, VITRIC MUDSTONE burrowed and laminated, with SANDSTONE-SILTSTONE (SANDY/SILTY VITRIC TUFF) GRADED.
Section 1: Variously colored mudstone, often burrowed with sandy/silty layers graded upwards. Erosional contact at the base of graded sequences. Graded sequences are darker: grayish black (N2), olive black (5Y 2/1), brownish gray (5YR 4/1), dark gray (N3).
Section 2: As above in Section 1; cycles–0 to 5 cm, 5 to 15 cm, 15 to 25 cm, and 25 to 50 cm.
Core-Catcher: As above

SMEAR SLIDE SUMMARY

	Sandy Crystal Mudstone 1-103
TEXTURE:	
Sand	40
Silt	30
Clay	30
TOTAL DETRITAL	
COMPOSITION:	
Feldspar	55
Heavy minerals	10
Clay	30
Opaques	5

SITE 459 HOLE B CORE 45 CORED INTERVAL: 416.0 to 425.5 m

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

Section 1 (0.5, 1.0 m). Fossil character: Nannos B; Nannos B, Rads B.

LITHOLOGIC DESCRIPTION

TURBIDITIC SEQUENCES WITH VITRIC MUDSTONE AND SILTSTONE (SILTY VITRIC TUFF)
Color is generally olive gray (5Y 4/1) with darker N3 to N4.5 silty or sandy layers, graded, laminated. Silty/sandy vitric tuff at 5 to 6 cm, 49 to 51 cm, 55 to 65 cm, 75 to 85 cm. Distinctly graded upwards between 55 and 65 cm and 75 to 85 cm.

SMEAR SLIDE SUMMARY

	Vitric Mudstone
	1-34
TEXTURE:	
Sand	–
Silt	20
Clay	80
COMPOSITION:	
Feldspar	5
Clay	75
Volcanic glass	20
Zeolite	+
Carbonate unsp.	+
Opaques	+

SITE 459 HOLE B CORE 46 CORED INTERVAL: 425.5 to 435.0 m

TIME-ROCK UNIT: Early Miocene | BIOSTRAT ZONE: *Discoaster druggii* (N) | FOSSIL CHARACTER (FORAMS, NANNOS, RADS) | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | LITHOLOGIC SAMPLE

Sections 1, 2, CC (0.5, 1.0 m). Fossil character: Nannos CP, Rads RP (Section 1); Rads RP (Section 2); Nannos AP, Rads B (CC). Chemical sample. VOID.

LITHOLOGIC DESCRIPTION

TURBIDITIC SEQUENCES WITH NANNOFOSSIL CHALK, NANNOFOSSIL VITRIC MUDSTONE, LAMINATED AND GRADED SILTSTONE AND SANDSTONE (SILTY/SANDY VITRIC TUFF). Mudstone and chalk strongly bioturbated. Mini-clastic dikes in the upper part of sequences, formed shortly after burrow formation.

Section 1:
0 to 92.5 cm: Mainly light olive gray (5Y 5/2)
92.5 to 140 cm: Mainly between light olive gray (5Y 5/2) and yellowish gray (5Y 7/2). Frequent intercalations of thin sandy layers, brownish black (5YR 2/1) or dark gray (N3). Blackish red (5Y 2/2) and pale red (10R 6/2) nannofossil vitric mudstone (85 to 90 cm).
Section 2: Mainly olive gray (5Y 4/1). Sandy layers are darker—brownish black (5YR 2/1), pale red (5R 6/2), dusky red (10R 2/2), yellowish brown (10YR 6/2). Sandy layers at 10 cm, 20 to 25 cm, 49 to 51 cm, and 65 to 70 cm (graded bed).
Core-Catcher: Normal faulting; two pieces of step-faulted olive gray to light olive gray mudstone. Upper Piece: Fault planes ~35° dip formed before burrows. Lower Piece: Fault planes approximately vertical, formed after burrows.

SMEAR SLIDE SUMMARY

	Nannofossil Vitric Mudstone	Nannofossil Chalk	Nannofossil Chalk
	1-86	1-93	2-100
TEXTURE:			
Sand	–	–	–
Silt	40	5	5
Clay	60	95	95
TOTAL DETRITAL	85	30	40
COMPOSITION:			
Feldspar	25	5	5
Heavy minerals	5	–	–
Clay	45	20	35
Volcanic glass	10	5	+
Carbonate unsp.	+	10	–
Nannofossils	15	60	60
Radiolarians	–	–	+
Fish remains	–	–	+

SITE 459 HOLE B CORE 47 CORED INTERVAL: 435.0 to 444.5 m

TIME-ROCK UNIT: Late Oligocene or Early Miocene | BIOSTRAT ZONE: *Cyclicargolithus abisectus*/*Discoaster deflandrei* (N) | FOSSIL CHARACTER (FORAMS, NANNOS, RADS) | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | LITHOLOGIC SAMPLE

Section 1 (0.5, 1.0 m). Fossil character: Nannos CM, Rads B; Nannos AM, Rads RP.

LITHOLOGIC DESCRIPTION

VITRIC MARLY NANNOFOSSIL CHALK, turbiditic sequences. Alternate: (1) finely bedded yellowish gray (5Y 6/2): 0 to 35 cm, and 45 to 75 cm; (2) strongly bioturbated darker lithology light olive gray (5Y 5/2)–35 to 45 cm and 75 to 150 cm.

SMEAR SLIDE SUMMARY

	Vitric Marly Nannofossil Chalk
	1-60
TEXTURE:	
Sand	–
Silt	35
Clay	65
TOTAL DETRITAL	60
COMPOSITION:	
Feldspar	10
Clay	35
Volcanic glass	15
Carbonate unsp.	10
Nannofossils	30

SITE 459 HOLE B CORE 48 CORED INTERVAL: 444.5 to 454.0 m

TIME-ROCK UNIT: Late Oligocene or Early Miocene | BIOSTRAT ZONE: *Cyclicargolithus abisectus* or *Discoaster deflandrei* (N) | FOSSIL CHARACTER (FORAMS, NANNOS, RADS) | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | LITHOLOGIC SAMPLE

Sections 1, 2, CC (0.5, 1.0 m). Fossil character: Nannos CP, Rads B (Section 1); Nannos FP, Rads B (CC). VOID.

LITHOLOGIC DESCRIPTION

MARLY NANNOFOSSIL CHALK AND VITRIC MARLY NANNOFOSSIL CHALK, thin laminated, coarser downwards in each sequence.

Section 1:
0 to 35 cm: Thin laminated chalk; coarser downwards, greenish yellow green (5GY 7/2); vertical dewatering structures
35 to 45 cm: Burrowed and darker 5GY 6/2
45 to 50 cm: Laminated
50 to 60 cm: Highly bioturbated olive gray (5Y 3/1 to 5Y 4/1)
60 to 90 cm: Thinly laminated
90 to 150 cm: Bioturbated, alternate 0.5 to 3 cm thick silty to muddy layers.
Section 2:
0 to 5 cm: Burrowed
5 to 10 cm: Laminated
10 to 20 cm: Burrowed
20 to 30 cm: Laminated
30 to 35 cm: Burrowed; color is dark yellowish brown (10YR 4/2–1 to 10 cm); grayish yellow green (5GY 6/2–10 to 40 cm).
Core-Catcher: As above
Remarks: Clay increases upwards; nannofossil chalk decreases upwards; both starting with Core 48.

SMEAR SLIDE SUMMARY

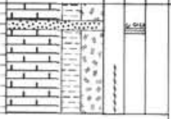
	Marly Chalk	Vitric Marly Nannofossil Chalk
	1-21	1-82
TEXTURE:		
Sand	–	–
Silt	5	20
Clay	95	80
TOTAL DETRITAL	45	60
COMPOSITION:		
Feldspar	?	10
Clay	40	40
Volcanic glass	5	10
Carbonate unsp.	10	10
Nannofossils	45	30

SITE 459 HOLE B CORE 49 CORED INTERVAL: 454.0 to 463.5 m

TIME-ROCK UNIT: Late Oligocene
BIOSTRAT ZONE: *Sphenolithus ciperoensis* (N)

FOSSIL CHARACTER: NANNOS AM; AM, RADS B

SECTION: 1 — METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

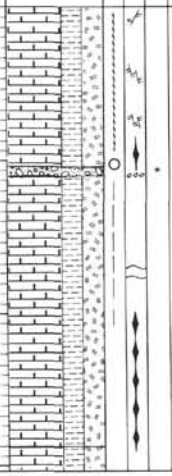
MARLY NANNOFOSSIL CHALK WITH SILTY AND SANDY LAYERS. Color is grayish olive green (5GY 3/2) or slightly lighter. Faintly laminated and vertically diked dewatering structures. Very deformed by drilling between 60 and 110 cm. Laminated between 15 to 35 cm. Coarser layer (diameter of elements 1 to 5 mm) 20 to 30 cm.

SITE 459 HOLE B CORE 50 CORED INTERVAL: 463.5 to 473.0 m

TIME-ROCK UNIT: Late Oligocene
BIOSTRAT ZONE: *Sphenolithus ciperoensis* (N)

FOSSIL CHARACTER: NANNOS CM; B; AM; FORAMS/NANNOS AP, RADS RP

SECTION: 1, 2, 3, CC — METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

MARLY NANNOFOSSIL CHALK WITH SANDSTONE, SILTSTONE AND CONGLOMERATE. Bioturbation and normal faulting throughout.
Section 1: Greenish gray (5GY 6/1) to olive gray (5Y 4/1). Some brownish black sandy layers; normal faults are common, dewatering structures 20 to 26 cm. Drilling disturbance stronger with drilling paste surrounding blocks. Bioturbation and faulting also present (50 to 130 cm). Strongly bioturbated 130 to 150 cm.
Section 2: Strongly bioturbated throughout, olive black (5Y 2/1) to olive gray (5Y 4/1). Frequent N3 sandy layers. Conglomerate at 7 to 12 cm. Reworking: silicified claystone, mudstone, sandy vitric tuff, silty vitric tuff, all in pebbles 0.5 to 3.5 cm in diameter.
Section 3: Strong bioturbation all through the sequence; original layered structure is hardly visible. Colors are light olive gray (5Y 5/2), pale brown (5YR 5/2), pale yellowish brown (10YR 6/2), yellowish gray (5Y 7/2).
Core-Catcher: As above

SMEAR SLIDE SUMMARY

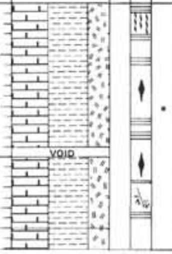
	Sandy Vitric Tuff (Pebbles in Conglomerate)	Silty Vitric Tuff (Pebbles in Conglomerate)
	2-10	2-10
TEXTURE:		
Sand	45	30
Silt	30	50
Clay	25	20
TOTAL DETRITAL	100	100
COMPOSITION:		
Feldspar	15	10
Heavy minerals	–	5
Clay	25	20
Volcanic glass	60	65
Radiolarians	+	–

SITE 459 HOLE B CORE 51 CORED INTERVAL: 473.0 to 482.5 m

TIME-ROCK UNIT: Late Oligocene
BIOSTRAT ZONE: *Sphenolithus ciperoensis* (N)

FOSSIL CHARACTER: FORAMS/NANNOS AP; AP, RADS B

SECTION: 1, 2, CC — METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

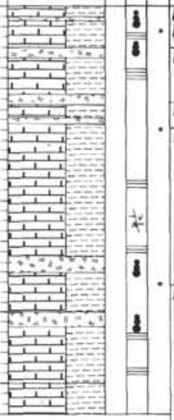
VITRIC MARLY NANNOFOSSIL CHALK, laminated marly nannofossil chalk with small scale erosional boundaries. Color is generally pale olive (10Y 6/2). Mini-faults and mini-dikes throughout.
Section 1:
10 to 20 cm: Dewatering structures and laminated
75 to 90 cm: Bioturbated
135 to 140 cm: Slightly darker than moderate yellowish brown (10YR 5/4)
Section 2: As above
0 to 5 cm: Bioturbated, brownish
5 to 70 cm: Laminated, yellowish gray (5Y 7/2)
Faults common (normal)
Core-Catcher: As above

SMEAR SLIDE SUMMARY

	Vitric Marly Nannofossil Chalk
	1-94
TEXTURE:	
Sand	–
Silt	30
Clay	70
TOTAL DETRITAL	70
COMPOSITION:	
Feldspar	10
Clay	40
Volcanic glass	20
Foraminifers	+
Nannofossils	30
Radiolarians	+
Fish remains	+

SITE 459 **HOLE** B **CORE** 52 **CORED INTERVAL:** 482.5 to 492.0 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	GRAPHIC LITHOLOGY	LITHOLOGIC DESCRIPTION
			AP		1	0.5, 1.0		
			AP		2			
			AP		3			
			B	RP	CC			



LITHOLOGIC DESCRIPTION

MARLY NANNOFOSSIL LIMESTONE, VITRIC MARLY NANNOFOSSIL CHALK, CLAYSTONE with CROSS-LAMINATED AND GRADED SILTY TO SANDY VITRIC TUFF LAYERS (TURBIDITES) IDEAL.

Sequence:

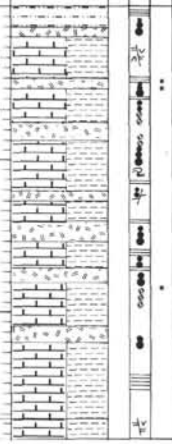
Fracturing and faulting (normal), increasing downward.
Section 1: Six turbiditic sequences, fining upward.
0 to 10 cm: Olive gray (5Y 3/2)
10 to 15 cm: Dusky yellow (5Y 6/4)
15 to 45 cm: 5GY 7/2
45 to 90 cm: 5YR 5/6 to 5GY 7/2 downward
90 to 110 cm: 5GY 7/2
110 to 145 cm: Light (5YR 5/6)
145 to 150 cm: 5YR 5/6
Section 2: One turbiditic sequence between 0 and 110 cm; another begins between 110 and 150 cm.
Section 3: 1 to 15 cm end of previous sequence. Laminated 15 to 45 cm.
Core-Catcher: As above, claystone fractured, light olive gray (5Y 4/2).
Remarks: Claystone seems to be silicified; dewatering microdiking developed in claystone bands in Section 1, 10 to 16 cm, 45 to 49 cm, 90 to 90 cm, 125 to 129 cm, 135 to 139 cm; in Section 2 24 to 28 cm.

SMEAR SLIDE SUMMARY

	Silicified Claystone	Vitric Marly Nannofossil Chalk	Marly Nannofossil Limestone
	1-116	1-18	2-123
TEXTURE:			
Sand	–	–	–
Silt	3	20	5
Clay	97	80	95
TOTAL DETRITAL	96	70	70
COMPOSITION:			
Feldspar	3	5	2
Clay	93	46	65
Volcanic glass	+	15	3
Carbonate unsp.	–	10	–
Nannofossils	4	30	30

SITE 459 **HOLE** B **CORE** 53 **CORED INTERVAL:** 492.0 to 501.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	GRAPHIC LITHOLOGY	LITHOLOGIC DESCRIPTION
Late Oligocene	*Sphenolithus ciperoensis* (N)		AP		1	0.5, 1.0		
					2			
					3			
			AP	B	CC			



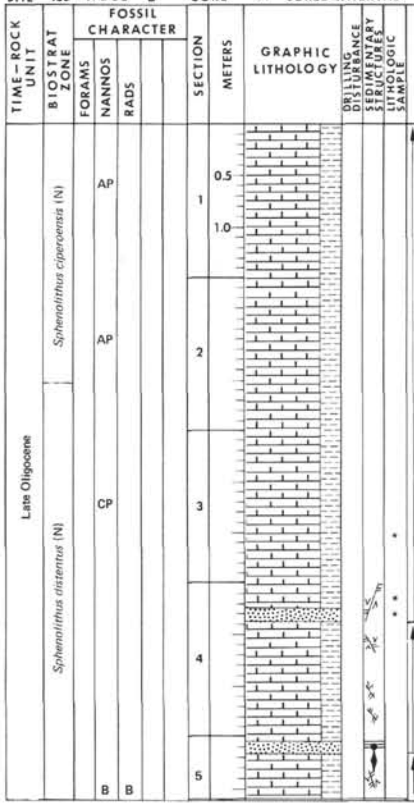
LITHOLOGIC DESCRIPTION

MARLY NANNOFOSSIL CHALK, MUDSTONE WITH SILTY VITRIC LAYERS (SILTSTONE). Normal faulting throughout the core.
Section 1:
0 to 8 cm: Laminated
10 to 23 cm: Mudstone
23 to 26 cm: Fine sandstone, graded
Between **26 and 150 cm:** Several cycles with graded sandstone downward and burrowed mudstone upward. Light olive gray (5Y 5/2) throughout extensive normal faulting.
Section 2: Similar to Section 1, but more sandy layers, brownish black (5YR 2/1) and dark gray (N3). In general, the color is grayish olive (10Y 4/2). Extensive normal faulting throughout.
Section 3: Mudstone predominates olive gray (5Y 4/2). Laminated below 50 cm.
Section 4:
0 to 30 cm: Fine sandstone laminated grayish olive green (5GY 3/2).
30 to 45 cm: Light gray (N7) chalk
45 to 55 cm: Dusky yellow green mudstone, faults and dikes are common
Core-Catcher: Greenish yellow green (5GY 7/2) with layers and patches (burrows?) grayish olive green (5GY 3/2).
Dewatering structures 1-94 to 105 cm; 2-0 to 10 cm, 62 to 65 cm; 3-18 to 22 cm, 42 to 60 cm; 4-12 to 15 cm, 48 to 52 cm.

SMEAR SLIDE SUMMARY

	Silty Vitric Tuff	Marly Nannofossil Chalk	Mudstone
	1-73	1-76	2-123
TEXTURE:			
Sand	–	–	–
Silt	40	2	10
Clay	60	98	90
TOTAL DETRITAL	80	42	100
COMPOSITION:			
Feldspar	10	1	5
Clay	40	40	90
Volcanic glass	30	1	5
Carbonate unsp.	–	20	–
Foraminifers	+	–	–
Nannofossils	20	38	–

SITE 459 HOLE B CORE 54 CORED INTERVAL: 501.5 to 511.0 m



LITHOLOGIC DESCRIPTION

MARLY NANNOFOSSIL CHALK, VITRIC MARLY NANNOFOSSIL CHALK WITH SANDSTONE. Two large graded units: (turbidites) in calcareous sediments. The coarser is graded sandstone with reworked foraminifers and volcaniclastic materials (glass feldspar). Tensional mini-faults are common (normal faults).

Section 1: Upper part of an upward fining unit starting from Section 4 (30 cm-53 cc) might be the uppermost continuation of the same unit. Color is slightly lighter than greenish gray (5G 6/1). Almost uniform but grain-size increases very slightly downwards.

Section 2: Continues from above; slightly coarser

Section 3: Continued from above, greenish gray (5G 5/1). Top is very fine sandstone; bottom fine sandstone with patches throughout. Dusky green grains up to 2 mm across, increasing downwards.

Section 4:

0 to 5 cm: Fine sandstone 5G 5/1

5 to 30 cm: Alternate layers of darker and lighter lithologies

31 cm: Graded sandstone with abundant foraminifers, probably reworked

31 to 51 cm: Laminated color, olive gray (5Y 3/2)

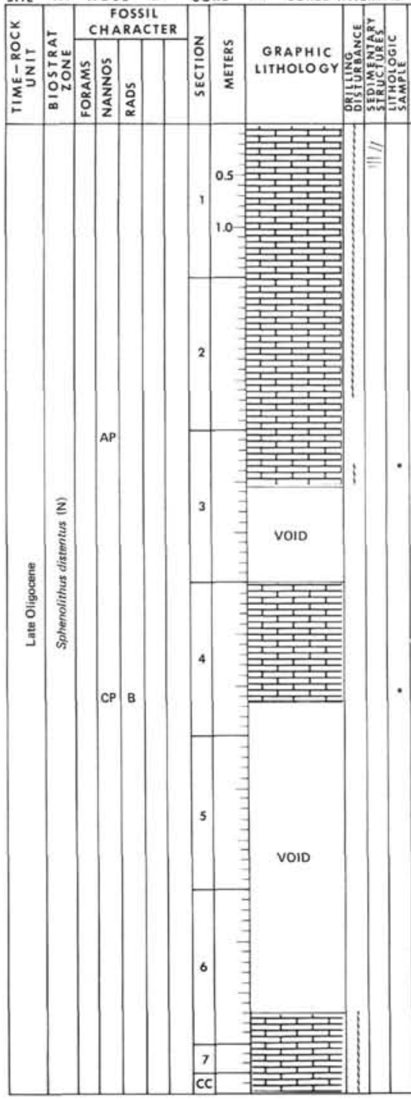
Common tensional mini-faults: (10 to 30 cm, 60 to 110 cm, 115 to 150 cm) displacement 1.5 cm, 3.5 cm, larger than 13 cm.

Section 5: Grayish olive (10Y 4/2); laminated graded sandy layer (0 to 5 cm); bioturbated (5 to 20 cm); laminated and faulted (20 to 30 cm)

SMEAR SLIDE SUMMARY

	Marly Nannofossil Limestone	Sandstone	Marly Nannofossil Limestone
	3-85	4-15	4-31
TEXTURE:			
Sand	–	–	60
Silt	2	30	40
Clay	98	70	–
TOTAL DETRITAL	42	40	100
COMPOSITION:			
Feldspar	2	5	20
Heavy minerals	–	–	5
Clay	30	20	–
Volcanic glass	10	25	25
Carbonate unsp.	+	30	–
Foraminifers	8	10	50
Nannofossils	50	20	1
Diatoms			
Radiolarians			Reworked?
Sponge spicules			
Fish remains		+	

SITE 459 HOLE B CORE 55 CORED INTERVAL: 511.0 to 520.5 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL LIMESTONE AND MARLY NANNOFOSSIL LIMESTONE, to Section 2, 120 cm, drilling breccia highly fractured. From Section 2, 20 cm, nannofossil limestone and marly nannofossil limestone.

Section 1:

0 to 20 cm: 5Y 3/2

20 to 30 cm: Mudstone and sandy mudstone, brownish black (5YR 2/1)

30 to 35 cm: Laminated claystone, pale blue green (5BG 7/2)

35 to 120 cm: Marly chalk and limestone, grayish olive green (5GY 4/2)

120 to 125 cm: Greenish yellow green (5GY 7/2)

125 to 150 cm: Olive gray (5Y 3/2)

Section 2: As above. Above 120 cm either highly fractured or drilling paste. Lithology as the lower 2/3 of Section 1. Grayish olive (10Y 4/2) (mostly).

115 to 150 cm: Massive limestone, grayish yellow green (5GY 3/2)

Section 3: Limestone, grayish yellow green (5GY 7/2)

Section 4: 0 to 10 cm is drilling paste. Clay-size limestone between grayish orange (10YR 7/4) and yellowish gray (5Y 7/2).

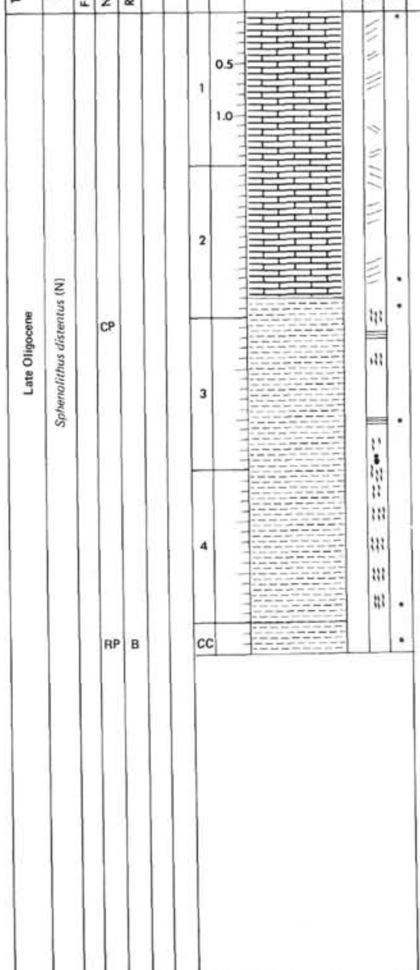
Core-Catcher: All intensely fractured; from 50 to 85 cm color changes abruptly to yellowish gray (5Y 7/2). Lithology as above.

SMEAR SLIDE SUMMARY

	Nannofossil Limestone	Marly Nannofossil Limestone
	3-40	4-100
TEXTURE:		
Sand	–	–
Silt	3	5
Clay	97	95
TOTAL DETRITAL	23	39
COMPOSITION:		
Feldspar	3	2
Clay	20	33
Volcanic glass	–	3
Carbonate unsp.	27	–
Foraminifers	–	2
Nannofossils	50	60

SITE 459 HOLE B CORE 56 CORED INTERVAL: 520.5 to 530.0 m

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



LITHOLOGIC DESCRIPTION

FORAMINIFER-NANNOFOSSIL LIMESTONE and dusky brown **CLAYSTONE; CALCAREOUS TURBIDITES (REWORKED FORAMINIFERS).**

Section 1: Massive limestone, rarely visible mottling throughout, inclined as indicated. Grayish yellow green (5GY 7/2) in color. Slightly coarser downward.

Section 2: Continuation from Section 1 down to 105 cm.

105 to 110 cm: Fine sandstone, graded; medium dark gray (N4).

110 to 150 cm: Brittly fractured dark yellowish brown (10YR 4/2) marly chalk; filled with drilling paste of the same rock.

At 137 cm: Claystone in a thin pale green (10G 6/2) band.

Section 3: Continued from Section 2; microdikes occur at the top of upward fining units (dewatering structures).

1 to 10 cm: Olive gray (5Y 3/2) microdikes

10 to 15 cm: Very light gray, laminated

15 to 30 cm: Olive gray (5Y 4/2)

30 to 36 cm: Laminated

36 to 98 cm: Bioturbated yellowish gray (5Y 7/2)

98 to 100 cm: Laminated siltstone

100 to 120 cm: Microdikes (5RY 4/4)

120 to 150 cm: Bioturbated and laminated downwards, yellowish gray (5Y 7/2)

Section 4: Dusky brown (5YR 2/2) throughout with beds, mottles or patches of moderate brown (5YR 4/4); boundary sharp or gradual; microdiking extensive.

Core-Catcher: As above, claystone

Remarks: Dusky brown color in Section 4 and Core-Catcher. Fragments of foraminifers probably reworked in a turbidite (Section 2, 104 cm). Dewatering microdiking common, especially in Section 4.

SMEAR SLIDE SUMMARY

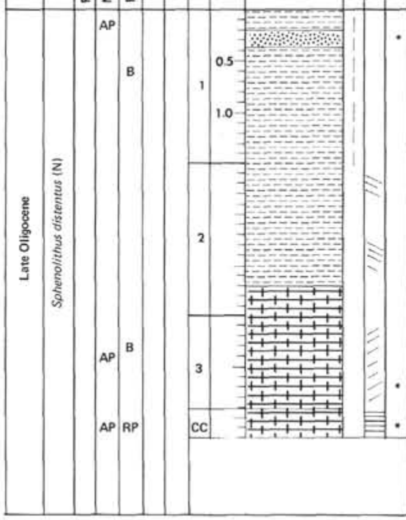
	Foraminifer Nanno-fossil Limestone	Foraminifer Nanno-fossil Limestone	Claystone
	1-10	2-105	2-137
TEXTURE:			
Sand	–	–	–
Silt	5	15	4
Clay	95	85	96
TOTAL DETRITAL	40	20	100
COMPOSITION:			
Feldspar	+	+	2
Clay	40	20	96
Volcanic glass	–	–	2
Carbonate unsp.	+	–	–
Foraminifers	5	25	–
Nannofossils	65	65	–

SMEAR SLIDE SUMMARY

	Crystal Mudstone	Claystone	Claystone
	3-110	4-130	CC-22
TEXTURE:			
Sand	–	–	–
Silt	25	5	5
Clay	75	95	95
TOTAL DETRITAL	100	98	100
COMPOSITION:			
Feldspar	25	8	5
Clay	75	88	95
Volcanic glass	–	2	–
Carbonate unsp.	–	–	–
Foraminifers	–	1	–
Nannofossils	–	1	+

SITE 459 HOLE B CORE 57 CORED INTERVAL: 530.0 to 539.5 m

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



LITHOLOGIC DESCRIPTION

CLAYSTONE, MARLY NANNOFOSSIL CHALK AND MARLY NANNOFOSSIL LIMESTONE with sandy/silty layers. Foraminifers probably reworked in sandstone.

Section 1: Same as in Core 56, Section 4, but the proportion of brownish material increases, especially at 130 to 150 cm, 109 to 113 cm, 70 to 85 cm. A vesicular "basaltic" pebble 4.5 cm in diameter (28 to 31 cm) occurs in greenish yellow green (5GY 7/2) sandstone with foraminifers and nannofossils.

Section 2: Claystone, moderate brown (5YR 4/4)

30 cm: 25° dip

32 to 40 cm: Darker 5YR 3/4

70 to 100 cm: Intercalation of fine sandstone (0.5 cm or less), 20° dip

105 to 110 cm: Darker 5YR 3/4

120 to 150 cm: Highly bioturbated marly chalk between yellowish gray (5Y 7/2) and grayish orange pink (5YR 7/2)

Section 3: Strongly bioturbated marly nannofossil limestone and chalk. Original layering is rarely visible. The inclination of bedding as indicated in the structures column.

Core-Catcher: Yellowish gray (5Y 7/2) with darker bands N5

Remarks: Section 1, 0 to 110 cm is interpreted as a mass flow deposit.

SMEAR SLIDE SUMMARY

	Calcareous Sandstone	Marly Nanno-fossil Limestone	Marly Nannofossil Chalk
	1-27	3-65	CC
TEXTURE:			
Sand	40	–	–
Silt	10	–	2
Clay	50	100	98
TOTAL DETRITAL	50	40	45
COMPOSITION:			
Feldspar	10	–	3
Heavy minerals	–	–	2
Clay	20	40	40
Carbonate unsp.	10	20	–
Foraminifers	30	–	–
Nannofossils	30	40	50

SITE 459 HOLE B CORE 58 CORED INTERVAL: 539.5 to 549.0 m

Time-Rock Unit	Biostrat Zone	Fossil Character (Forams / Nannos / Rads)	Section	Meters
Early Oligocene	*Cyclococcolithus formosus* (N)	AP RP	1	0.5, 1.0
Late Eocene	Indeterminate (N) *Thyrsocyrtis bromia* (R)	RP RP	2	
		B RP	3	
		RP RP	CC	

Limestone

42 cm: Microdikes

Microdikes

Below 83 cm: Brittly fractured drilling paste fills most of the liner

Light olive gray (5Y 5/2) and Grayish olive (10Y 4/2)

Moderate browns (5YR 4/4 and 5YR 3/4)

LITHOLOGIC DESCRIPTION

SILICEOUS MUDSTONE WITH SANDY VITRIC TUFF LAYERS, light brown (5YR 5/6) to moderate brown (5YR 5/6). Lithology changes similar to Core 56, Section 4, and in Core 57, Section 2 (115 cm), but more sandy. Coarser, darker beds stippled, medium light gray (N6). Sandy and silty tuff layers are graded; dusky yellowish brown (10YR 2/2).
Core-Catcher: As above, light brown (5YR 5/6)
Remarks: Section 2, 118 cm to Section 3, 140 cm is interpreted as a mass flow deposit.

SMEAR SLIDE SUMMARY

	Silty Vitric Tuff	Siliceous Mudstone	Sandy Vitric Tuff	Vitric Mudstone	Sandy Vitric Tuff
	1-100	1-103	2-31	2-113	3-80
TEXTURE:					
Sand	10	–	60	–	50
Silt	50	20	40	10	30
Clay	40	80	–	90	20
TOTAL DETRITAL	100	82	100	100	100
COMPOSITION:					
Feldspar	10	5	25	15	10
Heavy minerals	2	–	15	–	5
Clay	40	72	50	75	20
Volcanic glass	48	5	–	10	65
Rock fragments	–	–	10	–	–
Radiolarians	+	8	–	–	–
Sponge spicules	–	10	–	–	–
Fish remains	–	+	–	–	–

SITE 459 HOLE B CORE 59 CORED INTERVAL: 549.0 to 558.5 m

Time-Rock Unit	Biostrat Zone	Fossil Character (Forams / Nannos / Rads)	Section	Meters
Middle/Late Eocene	Indeterminate (N) *Podocyrtis chalara* (R)	B CM	1	0.5, 1.0
		B RP	2	
		RP RP	CC	

LITHOLOGIC DESCRIPTION

CLAYSTONE, light brown (5YR 5/6), softer and coarser between 0 to 110 cm, and firmer and finer between 110 to 150 cm,
65 to 75 cm: Three larger pieces of cherts, grayish brown (5YR 3/2).
90 to 95 cm: Microdikes
125 to 135 cm: Pieces of silicified claystone (5YR 3/2). Colors are moderate brown (5YR 4/4) to light olive gray (5Y 5/2), stippled portion stained to dark gray (N3).
Core-Catcher: Between moderate brown (5YR 4/4) and light olive gray (5Y 5/2). Some bedding planes stained to dark gray (N3 and N4).
Remarks: Radiolaria are present in some levels making them siliceous claystone

SMEAR SLIDE SUMMARY

	Claystone (alternating volcanic glass)
	1-135
TEXTURE:	
Sand	–
Silt	5
Clay	95
TOTAL DETRITAL	100
COMPOSITION:	
Feldspar	5
Heavy minerals	+
Clay	95
Hematite	+

SITE 459 HOLE B CORE 60 CORED INTERVAL: 558.5 to 568.0 m

Time-Rock Unit	Biostrat Zone	Fossil Character (Forams / Nannos / Rads)	Section	Meters
	Indeterminate (N)	RP B / B	1	0.5, 1.0

IGNEOUS ROCKS

LITHOLOGIC DESCRIPTION

SOFT CLAYSTONE
Possibly silicified, dusky yellowish brown (10YR 2/2), slightly lighter below 25 cm. Slickensides, very abundant. Angular pieces of claystone (30 to 40 cm). First sediment on the top of igneous rocks. Piece No. 5: piece of claystone bounded with slickensided face, dark dusky brown (5YR 2/2), and slightly darker.
Remarks: Clays as a result of alteration of volcaniclastic materials.

SMEAR SLIDE SUMMARY

	Claystone (alternating volcaniclastic glass)	Claystone (silicification?)	Claystone (silicification?)
	1-6	1-10	1-25
TEXTURE:			
Sand	–	–	–
Silt	5	2	1
Clay	95	98	99
TOTAL DETRITAL	100	100	100
COMPOSITION:			
Feldspar	5	2	1
Heavy minerals	–	+	–
Clay	95	98	99
Micronodules	–	+	+

Below 50 cm: igneous rock (described on next sheet)

SITE 459 HOLE B CORE 63 CORED INTERVAL: 587.0 to 596.5 m

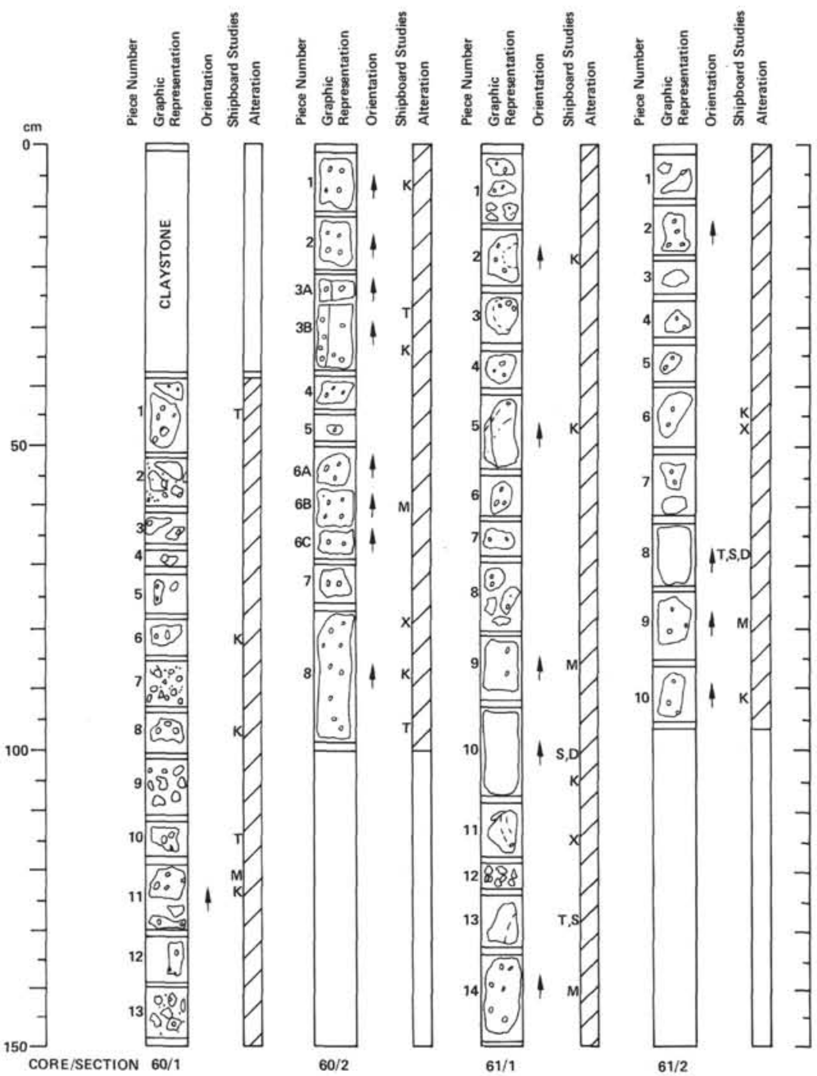
Time-Rock Unit	Biostrat Zone	Fossil Character (Forams / Nannos / Rads)	Section	Meters
		RP	CC	
			1	0.5, 1.0
			2	

LITHOLOGIC DESCRIPTION

Section 1:
1 to 10 cm: Pieces of claystone and nannofossil limestones probably reworked from above during drilling.

SMEAR SLIDE SUMMARY

	Claystone	Nannofossil Limestone
	1-1 to 10	1-1 to 10
TEXTURE:		
Sand	–	–
Silt	2	–
Clay	98	100
TOTAL DETRITAL	99	40
COMPOSITION:		
Feldspar	2	–
Clay	97	40
Nannofossils	–	60
Diatoms	1	–



60-459B-60 4674.0-4683.5 m (558.5-568.0 m, BSF)

Claystone and aphyric basalt

Section 1, 0-40 cm. Claystone.

Section 1, 40-150 cm and Section 2. Fine- to medium-grained, highly vesicular (0.1-3 mm, 30-40%) nearly holocrystalline pervasively altered aphyric basalt. Color is greenish-gray (5Y 5/1) with mesostasis altered to brown clay (oxidized?). Carbonate is present as exterior surface coatings and as vesicle(?) fillings. Some clay on exterior fracture surfaces is pink in color. Apparently, the core is part of a massive flow unit, possibly nearly 30 meters thick.

Thin Section Descriptions

60-1, 44-47 cm. Altered microlitic to spherulitic aphyric basalt. Probable top of large flow or sill. The rock contains about 15% skeletal elongate microlites of plagioclase, about 5% clinopyroxene spherulites (fibrous) and about 2% opaques. There are about 15% irregular vesicles (0.1-0.5 mm). The rest is microcrystalline to glassy mesostasis, generally altered to clays. Texture is quite variable in this thin section (*spherulitic on one side, microlitic on the other*).

60-1, 113-115 cm. Subophitic to intersertal aphyric basalt. The rock contains about 40% plagioclase, 30% clinopyroxene, 3-5% titanomagnetite, 25% vesicles (0.2-0.4 mm), and about 25% altered and devitrified glass. Vesicles are filled with carbonate and perhaps orange-brown oisotropic palagonite. Clays, Fe-hydroxides, and palagonite(?) replace glass as well as material between plagioclase and cpx.

60-2, 28-31 cm. Spherulitic to subophitic/intersertal basalt. The rock contains scattered microphenocrysts of plagioclase (An_{60-70}) and more abundant augite. The groundmass consists of 50% plagioclase, 20% clinopyroxene, and about 1% titanomagnetite (all formed at high undercooling). Devitrified and partly altered glass, and vesicles, divide the rest of the groundmass. Alteration is pervasive to clays and Fe-oxides.

60-2, 96-98 cm. *Intersertal aphyric basalt. The rock contains about 30%* euhedral to skeletal plagioclase (An_{75-70}), 20% granular clinopyroxene ($2V^{-} = 55°$; augite) and cubic to elongate/skeletal titanomagnetite. There are 3% vesicles up to 0.5 mm and irregularly shaped, and 40% mesostasis. The latter is cryptocrystalline but with skeletal plagioclase, skeletal titanomagnetite, and spherulitic clinopyroxene. The mesostasis also contains about 5% carbonate, some clays, and traces of zeolite and Fe-hydroxides.

	J_{NRM}	MDF	Inc.	S	D	Rock Type
60-1, 121-124 cm	4.11×10^{-3}	109+	+13.4	—	—	—
60-1, 124-126 cm	—	—	—	3.78	2.49	Basalt
60-2, 30-32 cm	—	—	—	3.61	2.40	Basalt
60-2, 61-63 cm	32.0×10^{-3}	90	+11.4	—	—	—

60-459B-61 4683.5-4693.0 m (568.0-577.5 m, BSF)

Aphyric basalt

Fine- to medium-grained, vesicular (20-30%, 0.1-1 mm), nearly holocrystalline, fairly massive aphyric basalt. The rocks are prevasively moderately altered. Their mesostasis is altered to brown and apple green clay minerals. Carbonate is present on exterior fracture surfaces and as vesicle fillings. *Several pieces have distinct alteration rinds of browner* (oxidized) material. There are minor veins of yellow-green clay. Section 2 is less vesicular than Section 1, and has greener clays.

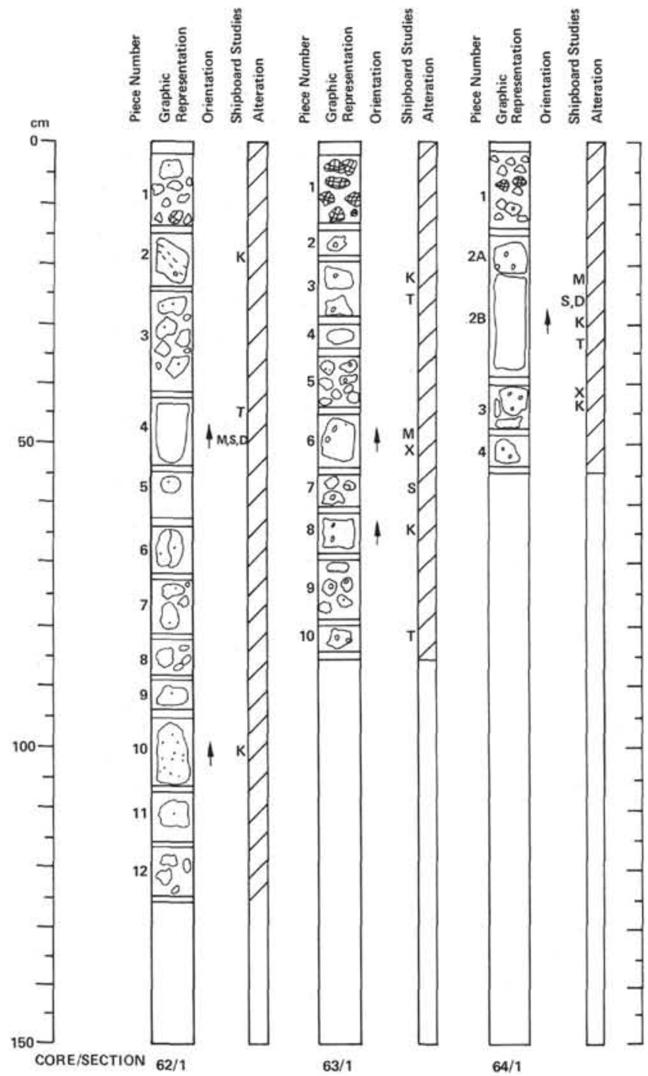
Thin Section Descriptions

61-1, 106-107 cm. Quartz diabase. Texture is subophitic, intergranular, and micropegmatitic. The orck is aphyric. It consists of about 67% plagioclase (0.1-1 mm; An_{50-55}), 7% pigeonite, 3% titanomagnetite, 20% devitrified and altered glass, 1% quartz, and 2% alkali feldspar. The latter forms interstitial micropegmatitic intergrowths with quartz. The rock has about 3% vesicles and 10-15% *alteration minerals, mainly clays in* vesicles and replacing glass. There may also be minor zeolites.

61-1, 126-129 cm. Diabase. This rock is very similar to the one just described, but has less glass (only 10%, again totally shot), no quartz or alkali feldspar, and includes carbonate among its secondary minerals.

61-2, 69-70 cm. Diabase. This rock is similar to the two just described, but has less than 1% clinopyroxene phenocrysts (a single glomerocryst). Plag is An_{70}.

	J_{NRM}	MDF	Inc.	S	D	Rock Type
61-1, 85-87 cm	0.53×10^{-3}	87	− 8.7	—	—	—
61-1, 99-101 cm	—	—	—	4.42	2.59	Basalt
61-1, 140-142 cm	9.60×10^{-3}	90	−10.3	—	—	—
61-2, 65-69 cm	—	—	—	4.43		Basalt
61-2, 81-82 cm	0.721×10^{-3}	123+	−15.4	—	—	—



60-459B-62 **4693.0-4707.5 m (577.5-587.0 m, BSF)**

Aphyric basalt

Fine- to medium-grained moderately altered aphyric basalt. Grain-size is fairly uniform throughout the core, which appears to represent the lower part of a fairly massive flow-sequence at the top of basement at this site. The basalt is greenish-gray (5GY 5/1) to olive gray (5Y 4/2) near oxidization rinds. Several pieces have oxidation rinds as shown by the dotted lines. Clear to blackish green clays line fractures and occur on exterior fracture surfaces. The mesostasis is altered to green and brown clays.

Thin Section Description

62-1, 44-46 cm. Subophitic to interstitial basalt. The rock is aphyric, and contains 57% plagioclase (An_{60}), 15% augite, and 3% skeletal titanomagnetite. There is about 25% altered, devitrified, sometimes spherulitic glass, and 10% irregular vesicles up to 7 mm in size. Clays are 5-10%, and fill vesicles and replace glassy interstitial material.

	J_{NRM}	MDF	Inc.	S	D	Rock Type
62-1, 46-50 cm	—	—	—	4.40	—	Basalt
62-1, 47-49 cm	1.24×10^{-3}	139	−14.5	—	—	—

60-459B-63 **4707.5-4712.0 m (587.0-596.6 m, BSF)**

Claystone (drilling breccia) and aphyric basalt

1-10 cm. Pieces of claystone and nannofossil limestone, probably reworked from above during drilling.

10-125 cm. Fine- to medium-grained aphyric moderately to intensely altered aphyric basalt. Grain-size is finer than in previous cores, and there is less clay alteration of the mesostasis. Some greenish-black clays coat exterior fracture surfaces. Vesicularity varies considerably (3.5%-20%; 0.1-2.0 m). Some pieces have vesicles in almost planar orientation.

Thin Section Descriptions

63-1, 24-27 cm. Hyalopilitic aphyric basalt. About 3% plagioclase microlites, and 5% clinopyroxene cyrstals are set in a partly devitrified and badly altered glassy groundmass. Vesicles comprise 10-15% of the rock (0.2-7 mm) and are round to irregular in shape. Clays and Fe-hydroxides make up 50% of the rock.

63-1, 81-83 cm. Hyalopilitic to intersertal aphyric basalt. The rock consists of about 15% plagioclase, and 10% clinopyroxene microlites, with 3% skeletal titanomagnetite. Vesicles make up about 15% of the rock, and the remainder is a partly devitrified and badly altered mesostasis. Clays make up about 50% of the rock, filling vesicles and replacing mesostasis.

	J_{NRM}	MDF	Inc.	S	D	Rock Type
63-1, 49-51 cm	20.1×10^{-3}	157	+11.7	—	—	—

60-459B-64 **4712.0-4721.5 m (596.6-606.0 m, BSF)**

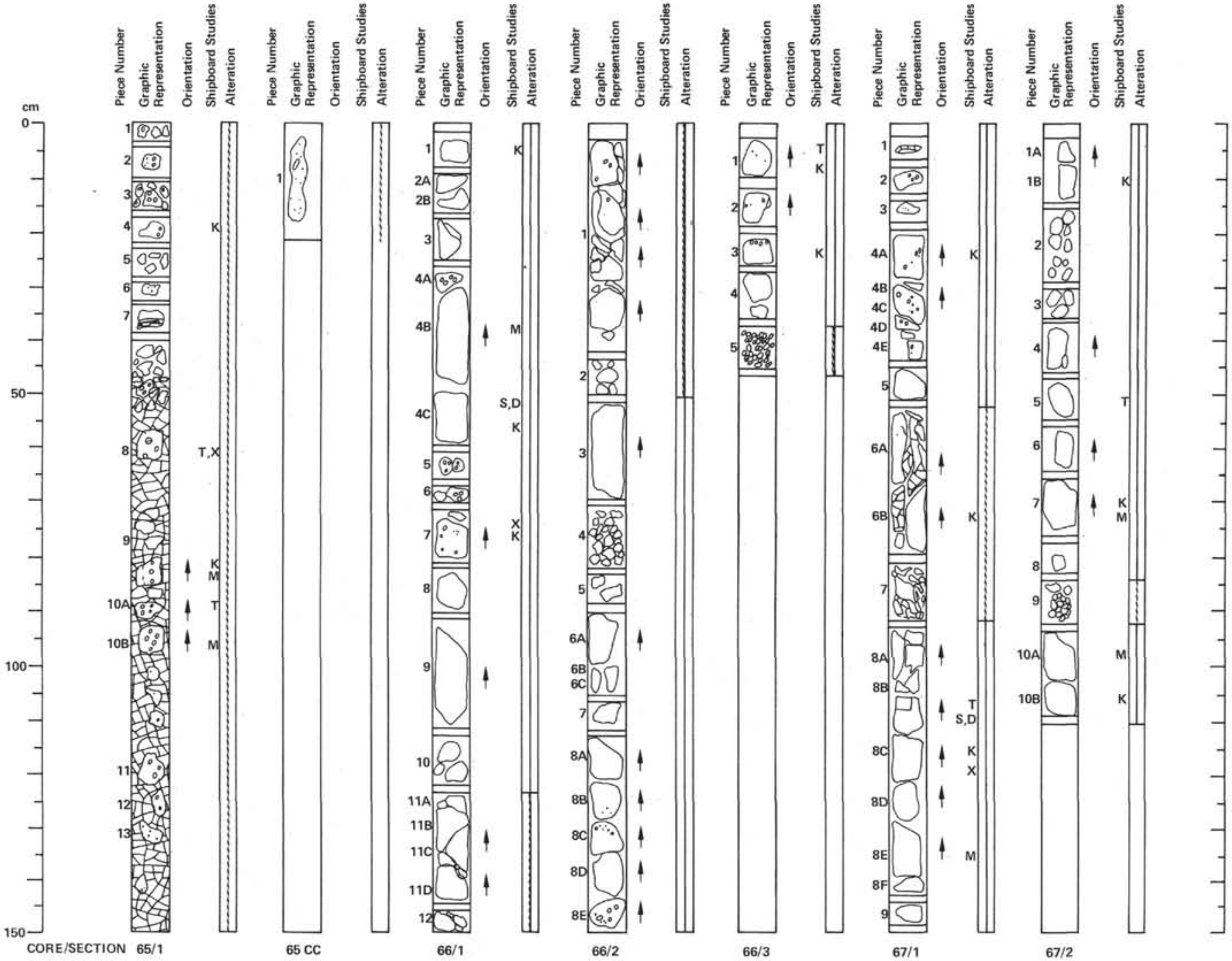
Aphyric basalt

Fine- to medium-grained, aphyric, greenish-gray (5Y 4/1), vesicular (20-30%; 0.1-1 mm), moderately altered basalt. Greenish-black clay is on exterior surfaces of Pieces 3 and 4. The mesostasis is generally very little altered. Several pieces in 1 are sedimentary (reworked from the upper part of the hole). The basalts are not oxidized, nor is there secondary carbonate.

Thin Section Description

64-1, 33-36 cm. Hyalopilitic to intersertal aphyric basalt. The rock consists of about 20% plagioclase, and 10% clinopyroxene microlites, with about 3% titanomagnetite. The rest is vesicles (10%, 0.5-1.5 mm), and altered glass mesostasis. Clays make up between 60 and 70% of the rock.

	J_{NRM}	MDF	Inc.	S	D	Rock Type
64-1, 23-25 cm	35.6×10^{-3}	116	−23.6	—	—	—
64-1, 28-30 cm	—	—	—	3.40	2.34	Basalt



60-459B-65 4721.5-4731.0 m (606.0-615.5 m, BSF)

Aphyric basalt

Intensely altered and highly fractured, fine-grained, aphyric, vesicular (10-40%; 0.1-3.0 mm), olive black (5Y 2/1) to dark greenish-gray (5GY 4/1) basalt. Vesicles are generally lined with green clay, and exterior fracture surfaces are coated with greenish-black to apple green clays. Piece 7 of Section 1, and nearby fractured material, appear to be portions of a highly fractured pillow rind with zeolites in cavities and veins. Pieces 10A-C have vertical vesicle trains with vesicles up to 3 mm in length, and largely filled with greenish-gray clays. The clay content is very high in fractured material.

The Core-Catcher consists of drilling flour made up of greenish-black to dark greenish-gray basaltic material.

Thin Section Descriptions

65-1, 58-60 cm. Hyalopilitic basalt. The rock contains about 1% microphenocrysts of plagioclase and lesser clinopyroxene up to 0.9 mm long, both with euhedral morphology. The groundmass has about 5% microlites of plagioclase, and 3% clinopyroxene. There is about 1-2% titanomagnetite and 10% scattered vesicles up to 5 mm across. The mesostasis is altered and makes up about 90% of the rock. It is replaced by clays (minor chlorite also replaces cpx).

65-1, 88-90 cm. Hyalopilitic aphyric basalt. The rock consists of microlites of plagioclase (20%) and, clinopyroxene (15%) with skeletal titanomagnetite (3%). Vesicles make up 15-20% of the rock, and are 0.05-3.5 mm and irregular in shape. The remainder is a nearly opaque mesostasis; dark brown to brownish-black, with pervasive alteration to clays and Fe-hydroxides.

	J_{NRM}	MDF	Inc.	S	D	Rock Type
65-1, 83-85 cm	42.0×10^{-3}	147	+45.0	—	—	—
65-1, 84-86 cm	—	—	—	2.52	2.13	Alt. basalt

60-459B-66 4731.0-4740.5 m (615.5-625.0 m, BSF)

Aphyric basalt

Dark greenish-gray (5G 4/1) to greenish-black (5G 4/1) aphyric basalt ranging in vesicularity from 1-5%. The rocks are medium-grained throughout but slightly coarser-grained in the lower part of Section 2 (Pieces 8A-E) and in Section 3. There are minor patches of slightly browner color on some pieces. Fracture surfaces on the samples are dark greenish-black (5GY 2/1). Slickenside surfaces are also colored pale gray and white. Fracturing is intense at the bottom of Section 1. Alteration is greatest in the fractured pieces. Vesicles are filled with green or brown clays (similar to matrix clays). Carbonates are absent. The topmost pieces of Section 2 are highly sheared.

Thin Section Description

66-2, 1-7 cm. Subophitic to intersertal diabase. The rock is aphyric, and consists predominantly of plagioclase (An_{70-65}, 55%), clinopyroxene (10%), titanomagnetite (5%), glassy mesostasis (15%), and clay minerals (15%) with traces of quartz and alkali feldspar in micrographic intergrowths. Dendritic ilmenite is a minor interstitial component. Vesicles are 5% of the rock, 0.1-2 mm in diameter, and irregular in shape.

66-3, 3-4 cm. Subophitic, micropegmatitic, intergranular quartz diabase. The rock is aphyric, and consists predominantly of plagioclase (60%), clinopyroxene (pigeonitic, 15%), titanomagnetite (2%), and glass (10%). Quartz (5%) and alkali feldspar (4%) form interstitial micropegmatitic intergrowths. Clays and Fe-hydroxides replace glassy material between micropegmatitic aggregates. The rock has about 3% vesicles up to 2 mm across, forming irregular spaces between crystals.

	J_{NRM}	MDF	Inc.	S	D	Rock Type
66-1, 39-41 cm	6×10^{-6}	—	(+11.1)	—	—	—
66-1, 45-48 cm	—	—	—	3.83	2.52	Basalt
66-2, 61-63 cm	—	—	—	2.87	2.37	Alt. basalt
66-2, 137-139 cm	0.860×10^{-3}	62	(+11.1)	—	—	—

60-459B-67 4740.5-4750.0 m (625.0-634.5 m, BSF)

Aphyric basalt

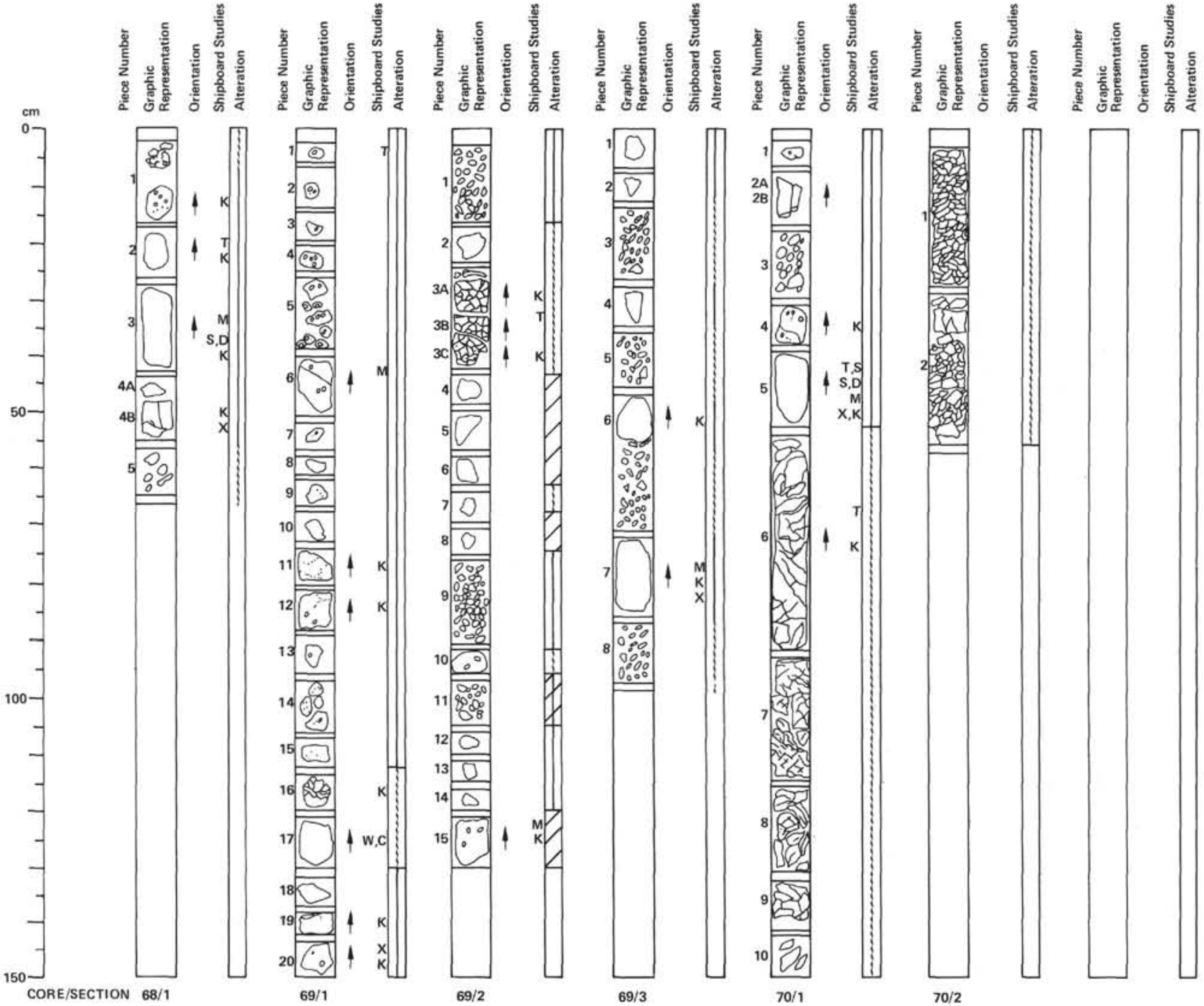
Very fine- to medium-grained, altered aphyric basalt, apparently a pillow sequence. An altered glassy rind is on Section 1, Piece 1. Alteration is intense, to nearly total. Fracture surfaces in the rocks show white to dark greenish-black (5GY 2/1) mineral encrustations, some of them slickensided. There are patches and diffuse bands of brownish-gray (5YR 4/1) discoloration throughout many fragments, particularly near cracks and fractures. Section 2, Piece 5 shows a contact between altered basalt and a clastic fracture filling(?) or more highly altered basaltic material. Alteration in Section 2 includes some to moderate yellowish-brown (10YR 5/4), indicating perhaps a more oxidizing type of alteration.

Thin Section Descriptions

67-1, 106-107 cm. Subophitic to intersertal aphyric diabase. The rock consists of about 50% plagioclase (An_{60-55}), subcalcic augite (10%; 2V+ = 40° or less), titanomagnetite (5%), and devitrified glass (25%) containing skeletal crystallites. There are also rare interstitial micropegmatitic quartz-alkali feldspar intergrowths. There are about 10-15% clay minerals filling vesicles and replacing glass. Vesicles are 5% of the rock, 0.3-1.5 mm across, and irregular in shape.

67-2, 50-54 cm. Subophitic to intersertal aphyric diabase. The rock consists of plagioclase (60%; An_{60-55}), augite (10%), titanomagnetite (5%) and devitrified glass. Some interstitial plagioclase is more sodic than larger crystals, and is associated with micropegmatitic quartz-alkali feldspar intergrowths. The glass is both partially crystallized (tiny dendritic opaques abound), and altered to clays. Clays also fill vesicles, which make up 1-3% of the rock and are up to 1 mm across.

	J_{NRM}	MDF	Inc.	S	D	Rock Type
67-1, 104-106 cm	—	—	—	3.72	2.55	Basalt
67-1, 134-136 cm	0.645×10^{-3}	188+	+11.0	—	—	—
67-2, 71-73 cm	0.983×10^{-3}	128	+ 9.8	—	—	—



60-459B-68 4750.0-4759.5 m (634.5-644.0 m, BSF)

Aphyric basalt

Medium-grained, aphyric, altered, variably vesicular basalt. Vesicle abundance diminishes downcore (Piece 1, ~20%; Piece 2, ~10%; Pieces 3-5, ~5%). Alteration is intense to almost total in rubbly zones. Green clays encrust vesicles and replace matrix materials. Pieces 3-5 are more fractured than 1 and 2. Piece 4A shows slickensides.

Thin Section Description

68-1, 24-26 cm. Intersertal basalt. The rock is aphyric, and consists of about 30% plagioclase (An_{50}), 10% augite, 7% titanomagnetite, and 53% devitrified, totally altered glass. The rock has about 5% vesicles lined with clays and zeolites up to 2 mm across. Clays make up about 35% and zeolites 5% of the rock.

	J_{NRM}	MDF	Inc.	S	D	Rock Type
68-1, 33-35 cm	0.733×10^{-3}	162	+12.9	—	—	—
68-1, 35-37 cm	—	—	—	2.73	2.41	Basalt

60-459B-69 4759.5-4769.0 m (644.0-653.5 m, BSF)

Aphyric basalt

In this core, small fragments of pillows alternate with ighly fractured, rubbly material. The core is moderately to intensely altered throughout. Even on the larger pieces, slickensides occur, hency they are also probably simply parts of the breccia. The rocks are dark greenish-gray (5GY 4/1) with some pieces and patches with olive gray (5Y 4/1) alteration. In Section 1, vesicles are large (~3 mm) through Pieces 1-6, but smaller and occasionally in trains below. Pieces 10 and 15 of Section 2 have larger vesicles (5-8 mm). These are round. Thin carbonate(?) veins occur in these two pieces. Elsewhere, clays predominate. Piece 16 of Section 1 has an altered glassy(?) rind. In Section 3, the rubbly zones are nearly mylonitic. Slickensides occur both on the basalt "lumps" in Section 3, and on small pieces in the rubble zones.

Thin Section Descriptions

69-1, 3-5 cm. Intersertal microphyric basalt. There are traces of plagioclase and clinopyroxene euhedral phenocrysts up to .8 mm, set in a groundmass of smaller plagioclase (25%), augite (10%), titanomagnetite (5%), and altered glass (60%). Vesicles are fairly abundant (10%) and up to 3 mm across. Traces of carbonate occur in the vesicles, and clays and zeolites both line vesicles and replace glass.

69-2, 33-34 cm. Hyalopilitic aphyric basalt. The rock consists of about 20% plagioclase, 15% clinopyroxene, 5% titanomagnetite, and 60% altered glass. Vesicles are 3-5% and up to 1 mm across. Clays replace glass and line vesicles.

	J_{NRM}	MDF	Inc.	S	D	Rock Type
69-1, 44-46 cm	2.05×10^{-3}	218	+12.4	—	—	—
69-1, 126-128 cm	—	—	—	3.45	2.32	v. Alt. basalt
69-2, 28-32 cm	—	—	—	—	—	Alt. basalt
69-2, 125-127 cm	1.20×10^{-3}	307	−12.2	—	—	—
69-3, 79-81 cm	13.2×10^{-3}	132	− 8.9	—	—	—

60-459B-70 4769.0-4778.5 m (653.5-663.0 m, BSF)

Aphyric basalt

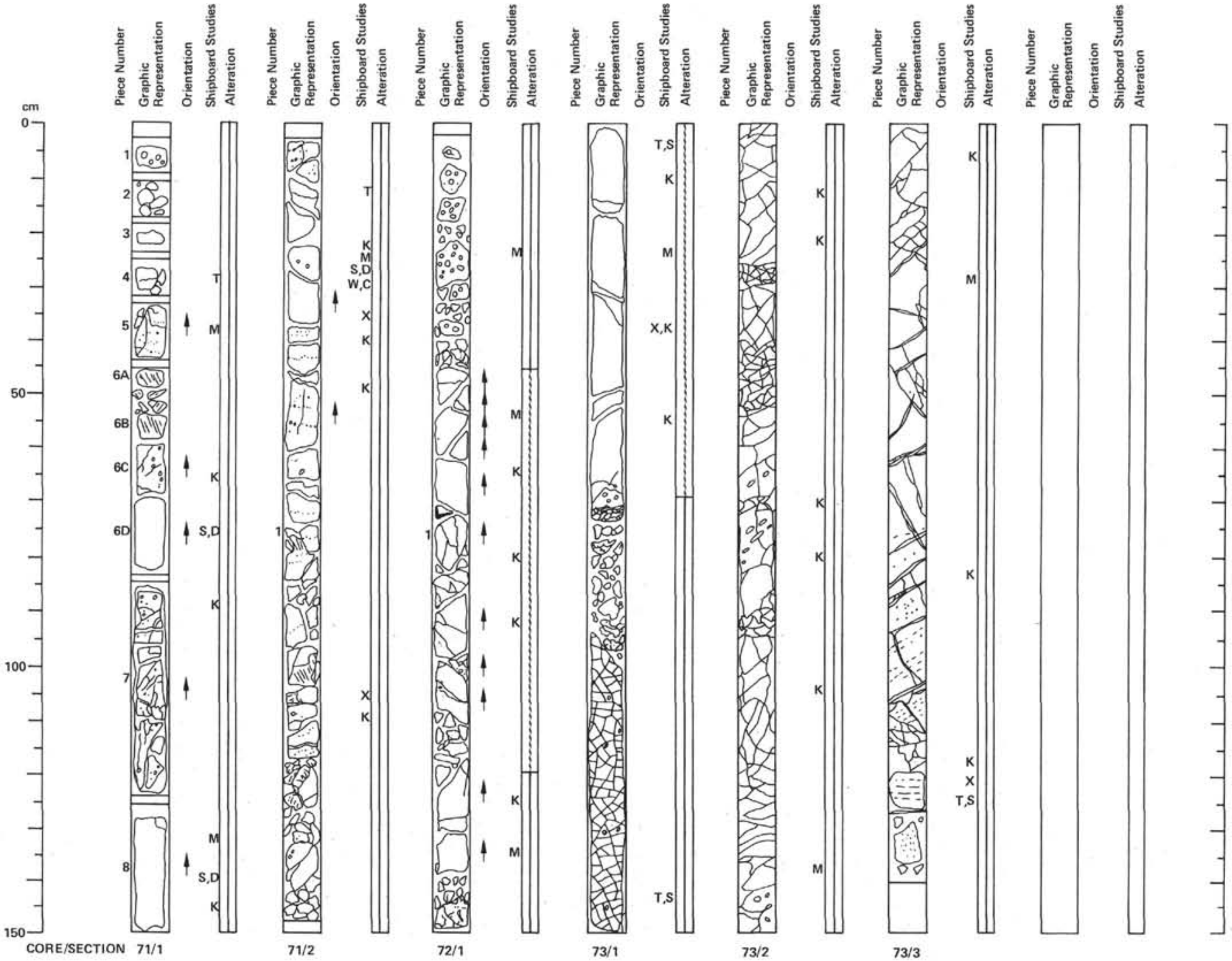
The material in this core is similar to that in Core 69 in that fairly coherent individual pieces alternate with intensely fractured material. The core is intensely to extremely altered (moreso in the fractured materials). Basalts are aphyric, medium bluish-gray (5B 5/1) with diffuse patches of moderate yellowish-brown (10YR 5/4). The latter color is concentrated about fractures in the rock. The basalts are fine-grained, and moderately vesicular (5-10%), with variable vesicle size and shape. Slickensides are abundant in the highly sheared basalts. The color of basalts in Section 2 is darker: greenish-black (5GY 2/1) to olive black (5Y 2/1).

Thin Section Descriptions

70-1, 69-71 cm. Hyalopilitic plagioclase-clinopyroxene microphyric basalt. Plagioclase (2%) and clinopyroxene (1%) microphenocrysts (0.2-0.4 mm) are set in a groundmass of plagioclase (20%), clinopyroxene (15%), titanomagnetite (2%), and altered devitrified glass (50%). Ilmenite needles may also be present. Vesicles form 9% of the rock, and are up to 1 mm across. Clays line vesicles and replace mesostasis.

70-1, 41-42 cm. Intersertal plagioclase-clinopyroxene microphyric basalt. Microphenocrysts of plagioclase (1%) and clinopyroxene (1%) up to 0.4 mm across are set in a groundmass of plagioclase (30%), clinopyroxene (27%), titanomagnetite (2-3%), and altered mesostasis (25%). Vesicles make up 12% of the rock, and are up to 0.5 mm across. They are filled with clays and/or zeolite.

	J_{NRM}	MDF	Inc.	S	D	Rock Type
70-1, 43-45 cm	—	—	—	3.14	2.31	Alt. basalt
70-1, 46-48 cm	3.81×10^{-3}	196	− 3.4	—	—	—
70-1, 89-90 cm	—	—	—	2.74	2.33	v. Alt. basalt



60-459B-71 4778.5-4788.0 m (663.0-672.5 m, BSF)

Aphyric basalt

Dark greenish-gray (5G 4/1), aphyric, vesicular (~10%; ~1 mm), fine-grained, intensively altered and highly fractured (sheared) basalt. The rocks have patches of olive gray discoloration, especially next to cracks, which are lined with green or brown secondary minerals. Vesicles tend to be filled with the same minerals. Slickensides are abundant. In Section 2, there are, in addition to the green clay fracture fillings, some white secondary minerals, and patches of a dark yellowish-brown discoloration (10YR 4/2) around fractures near 128 cm.

Note: pieces in Section 2 were too fractured to remove from the liner and number.

Thin Section Descriptions

71-1, 30-33 cm. Hyalopilitic plagioclase-clinopyroxene sparsely microphyric basalt. The rock contains about 0.5% each of euhedral microphenocrysts of plagioclase (An_{70}) and clinopyroxene up to 1.5 mm in length. These are set in a groundmass of plagioclase microlites (20%), clinopyroxene (10%), titanomagnetite (7%), and altered devitrified glass (63%). Vesicles are 5-7% of the rock and up to 0.5 mm across. They are filled with clay, which also replaces probably 40% of the mesostasis.

71-2, 15-16 cm. Intersertal plagioclase-clinopyroxene sparsely microphyric basalt. Microphenocrysts of plagioclase (1%) and clinopyroxene (1%) up to 0.5 mm across are set in a groundmass of plagioclase (28%), clinopyroxene (20%), titanomagnetite (3%), ilmenite (1%) and brownish devitrified glass (10%). Vesicles up to 0.8 mm make up 15% of the rock. Clays (15%) and zeolites (5%) line vesicles and replace the mesostasis, and carbonate veins make up about 2% of the section.

	J_{NRM}	MDF	Inc.	S	D	Rock Type
71-1, 39-41 cm	3.31×10^{-3}	182	+ 6.1	—	—	—
71-1, 75-77 cm	—	—	—	3.09	2.37	Alt. basalt
71-1, 130-132 cm	6.92×10^{-3}	182	+ 5.3	—	—	—
71-1, 134-136 cm	—	—	—	3.29	2.39	Alt. basalt
71-2, 29-31 cm	—	—	—	3.44	2.39	Alt. basalt
71-2, 30-32 cm	5.82×10^{-3}	161	+ 4.6	—	—	—

60-459B-72 4788.0-4797.5 m (672.5-682.0 m, BSF)

Aphyric basalt

Dark greenish-gray to greenish-black vesicular fine-grained basalt. The rocks are intensively fractured, and can easily be separated along fractures revealing slickensides. Alteration is intense to nearly total. Vesicles are abundant and mainly small (~1 mm; 20%). Larger vesicles (2-5 mm) are rare and concentrated in the upper part of the section (5-45 cm). Some of them are encrusted with a bluish-green clay mineral. Others are empty. The upper (3-50 cm) and lower (120-150 cm) intervals of the core are light olive gray in color, apparently reflectingthe presence of Fe-hydroxides. A patch of this color also occurs between 74 and 85 cm. This interval also contains irregular veins filled with greenish-black clays and carbonate. The lower 10 cm of the core is true basaltic breccia with mylonitized olive gray to bluish-green gray cement.

	J_{NRM}	MDF	Inc.	S	D	Rock Type
72-1, 26-28 cm	—	—	—	2.34	2.22	v. Alt. basalt
72-1, 54-56 cm	11.1×10^{-3}	135	+ 4.9	—	—	—
72-1, 134-136 cm	66.3×10^{-3}	144	+12.6	—	—	—

60-459B-73 4797.5-4807.0 m (682.0-691.5 m, BSF)

Aphyric basalt

Fine- to medium-grained, variably vesicular, intensely altered aphyric basalt. The top 74 cm of Section 1 are fairly massive, with few fractures, grain-size decreasing downward, and an apparent glassy lower margin (now altered). Below this (74-94 cm) is a zone of highly altered hyaloclastite in which angular pieces of vesicular, glassy, and very fine-grained basalt are set in a sheared clay matrix. The rest of Section 1 and all of Section 2 are more intensely fractured than 0-74 cm of Section 1, but like it consists of fine-grained, greenish-black basalt. Trains of irregular vesicles occur between 90 and 110 cm of Section 2, and an olive gray zone of alteration between 128 and 137 cm. Section 3 has fewer fractures than Section 2, most of them inclined, and inclined vesicle trains are abundant between 70 and 138 cm. The vesicle trains parallel fractures, as shown. One direction of fractures makes an angle of 75° to the left edge of the liner, the other approximately 150° (i.e., the angle between the two directions is about 75-80°). Between 110 and 117 cm of Section 3 is another olive gray zone, probably containing Fe-hydroxides. Generally, the groundmass of the basalts is pervasively altered to clay minerals.

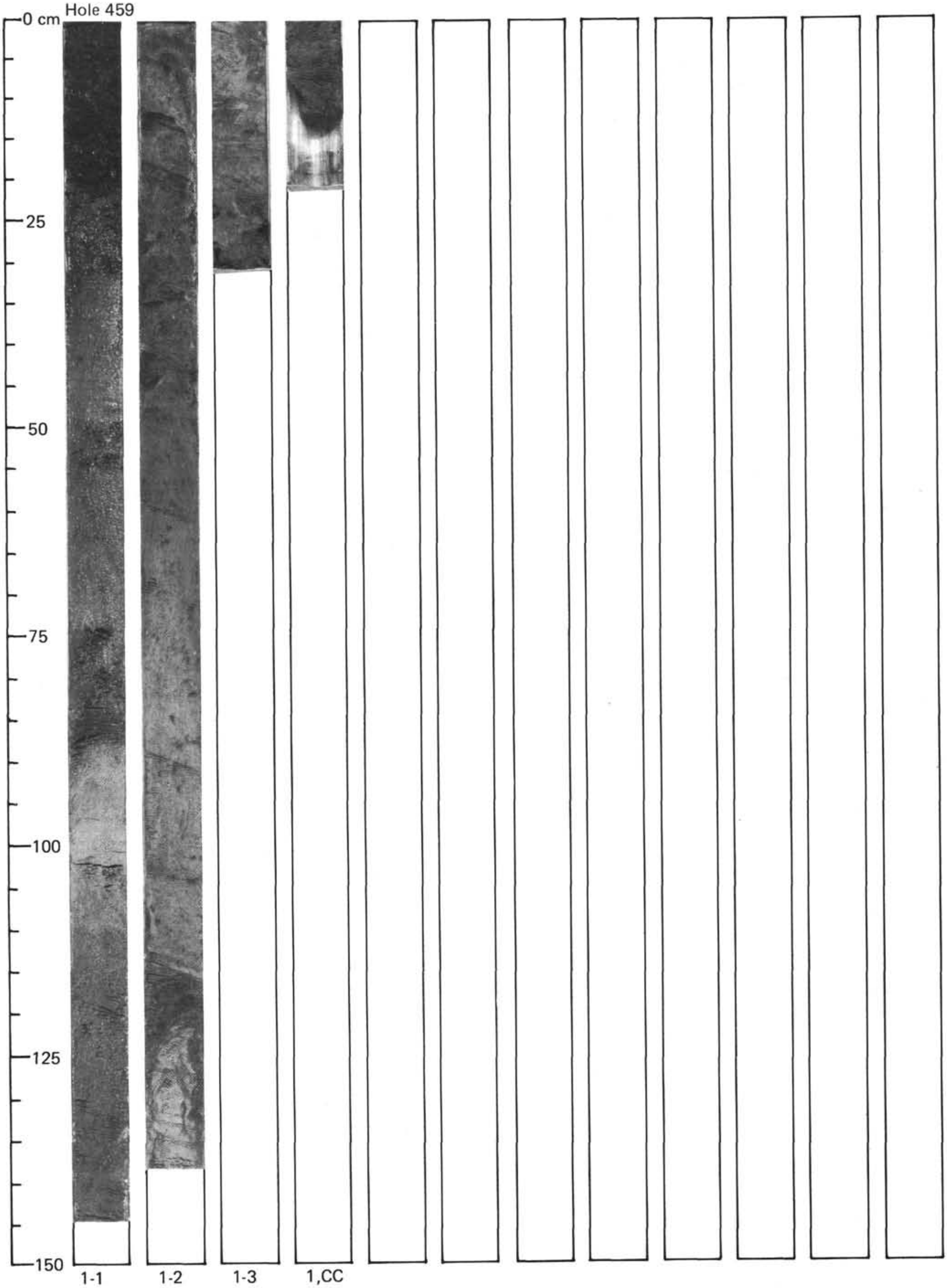
Thin Section Descriptions

73-1, 6-9 cm. Hyalopilitic aphyric basalt. The rock consists of about 30% plagioclase microlites, 15% clinopyroxene, 5% titanomagnetite, and 50% badly altered glass. Vesicles are about 10% of the rock, and up to 0.8 mm across. The main alteration mineral is clay, replacing most of the glass and lining vesicles. Zeolite also fills spherules surrounded by clays.

73-1, 141-144 cm. Hyalophitic sparsely plagioclase microphyric basalt. There are about 1% plagioclase microphenocrysts up to 0.5 mm set in a groundmass of 30% plagioclase laths, 22% clinopyroxene (pigeonitic?), 2% titanomagnetite, and 15% altered glass. Vesicles make up 10% of the rock and are irregular in shape, up to 3 mm long. Clays (20%) partially replace the mesostasis and line vesicles.

73-3, 122-125 cm. Hyalopilitic plagioclase-clinopyroxenesparsely microphyric basalt. Microphenocrysts of plagioclase (2%) and clinopyroxene (1%) up to 0.5 mm long are set in a groundmass of slender plagioclase laths (35%), anhedral clinopyroxene (15%), cubic titanomagnetite (2%) and mostly altered glass (10%). Vesicles make up 10% of the rock and are up to 1.5 mm across. Clays are 25% of the rock and replace mesostasis and line vesicles.

	J_{NRM}	MDF	Inc.	S	D	Rock Type
73-1, 6-9 cm	—	—	—	2.68	—	Alt. basalt
73-1, 25-27 cm	11.2×10^{-3}	158	+13.5	—	—	—
73-2, 139-141 cm	22.0×10^{-3}	143	+ 3,8	—	—	—
73-3, 28-30 cm	7.33×10^{-3}	180	+13.5	—	—	—
73-3, 121-124 cm	—	—	—	2.69	2.26	Alt. basalt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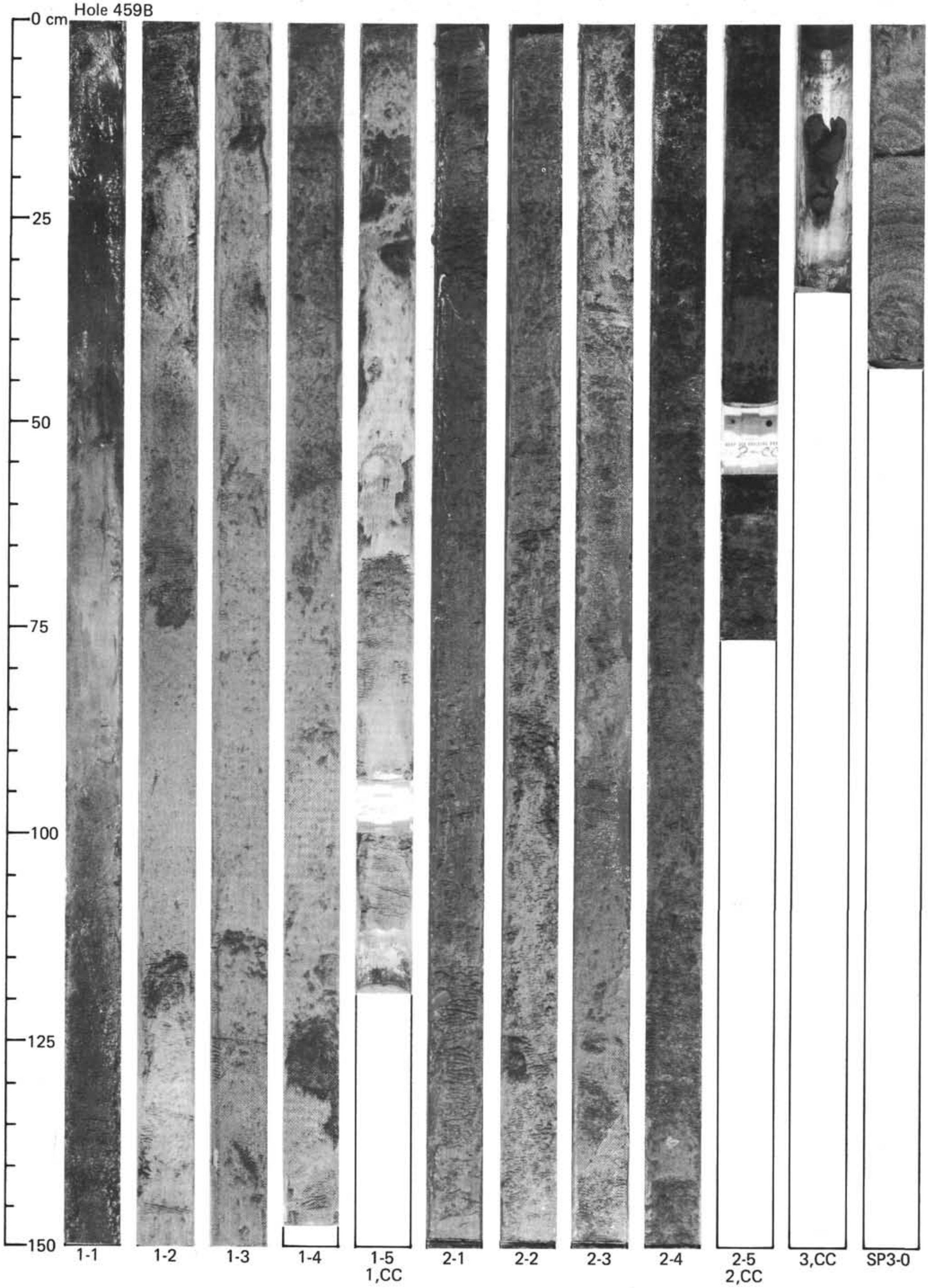
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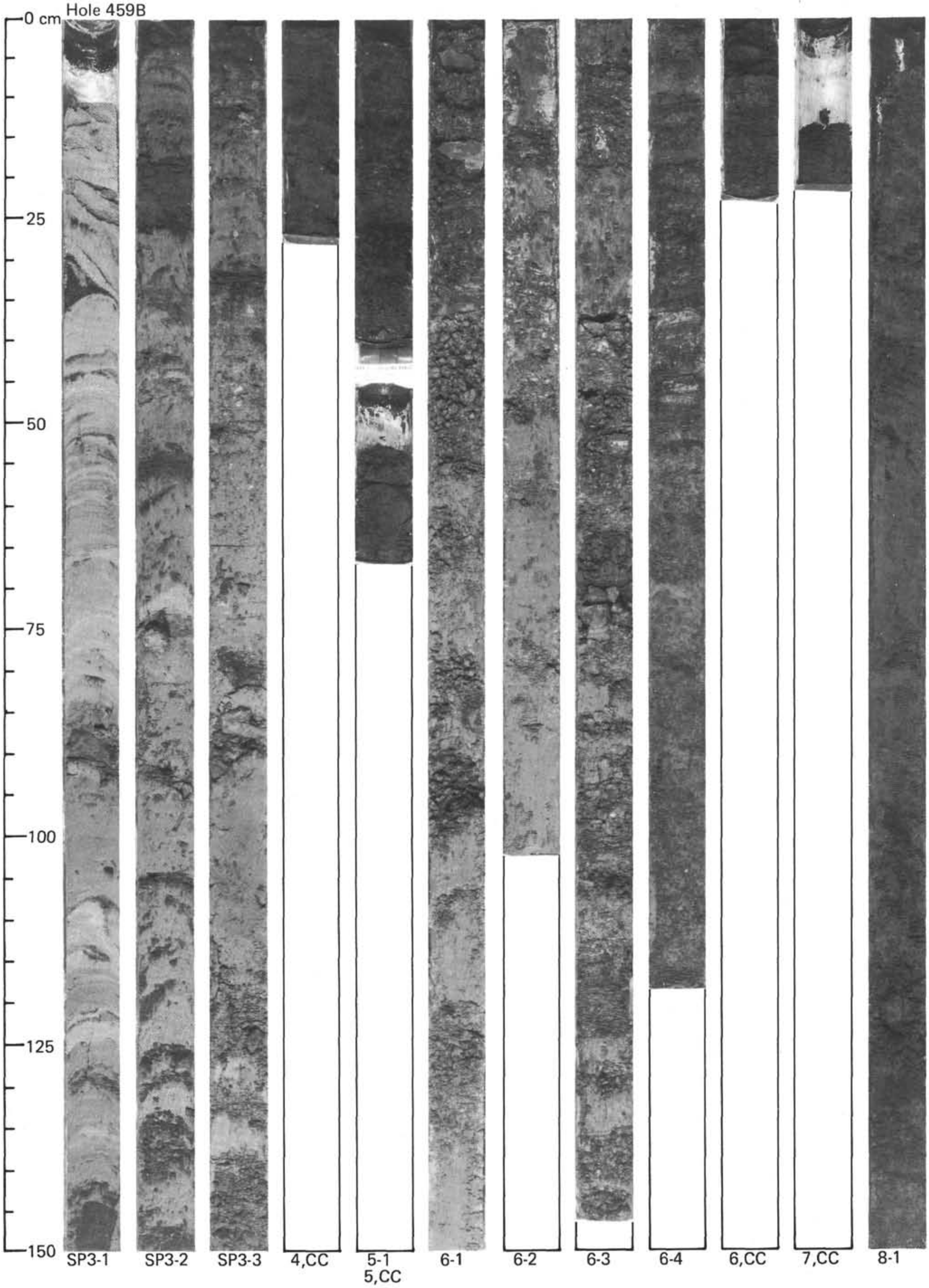
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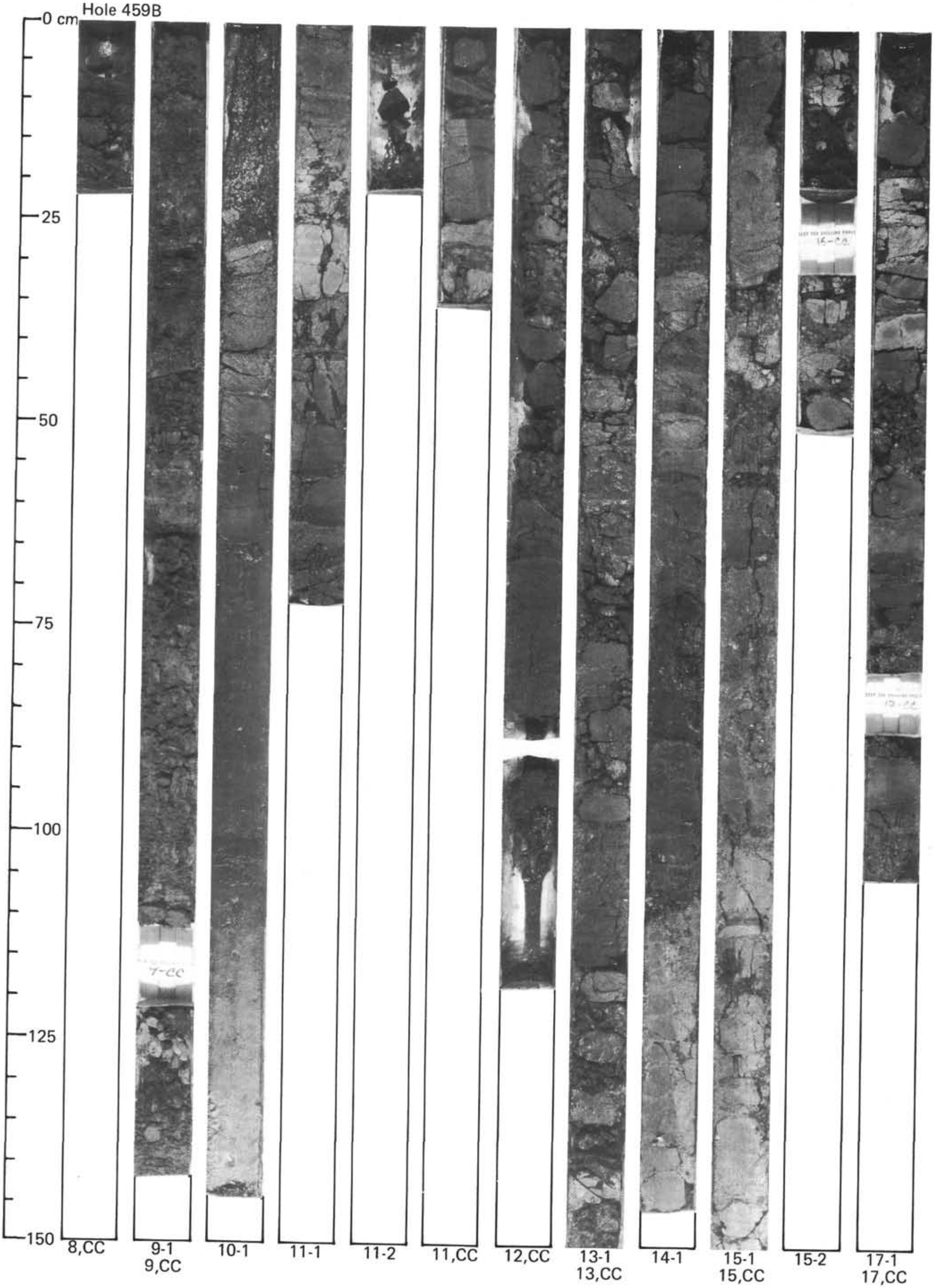
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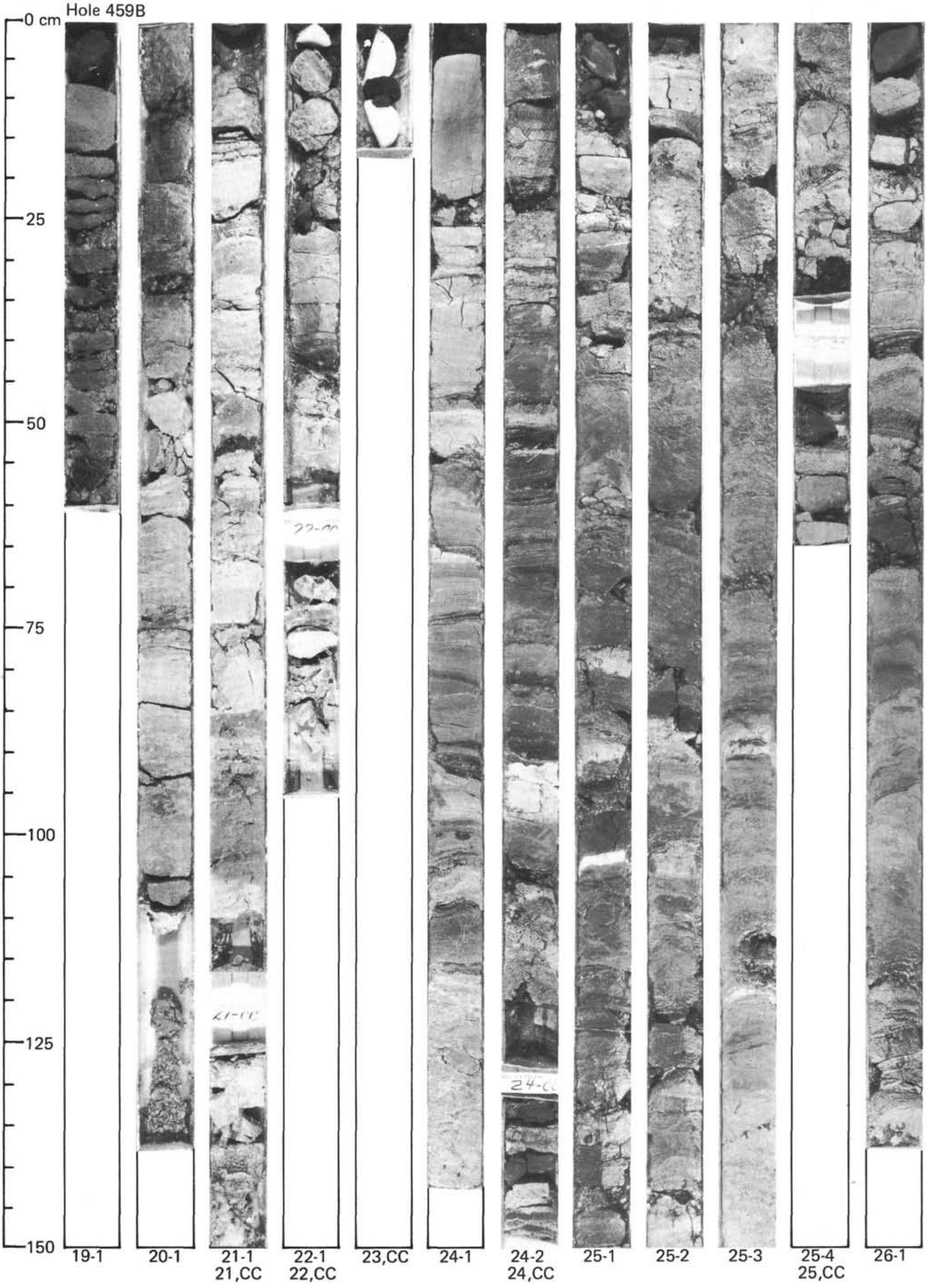
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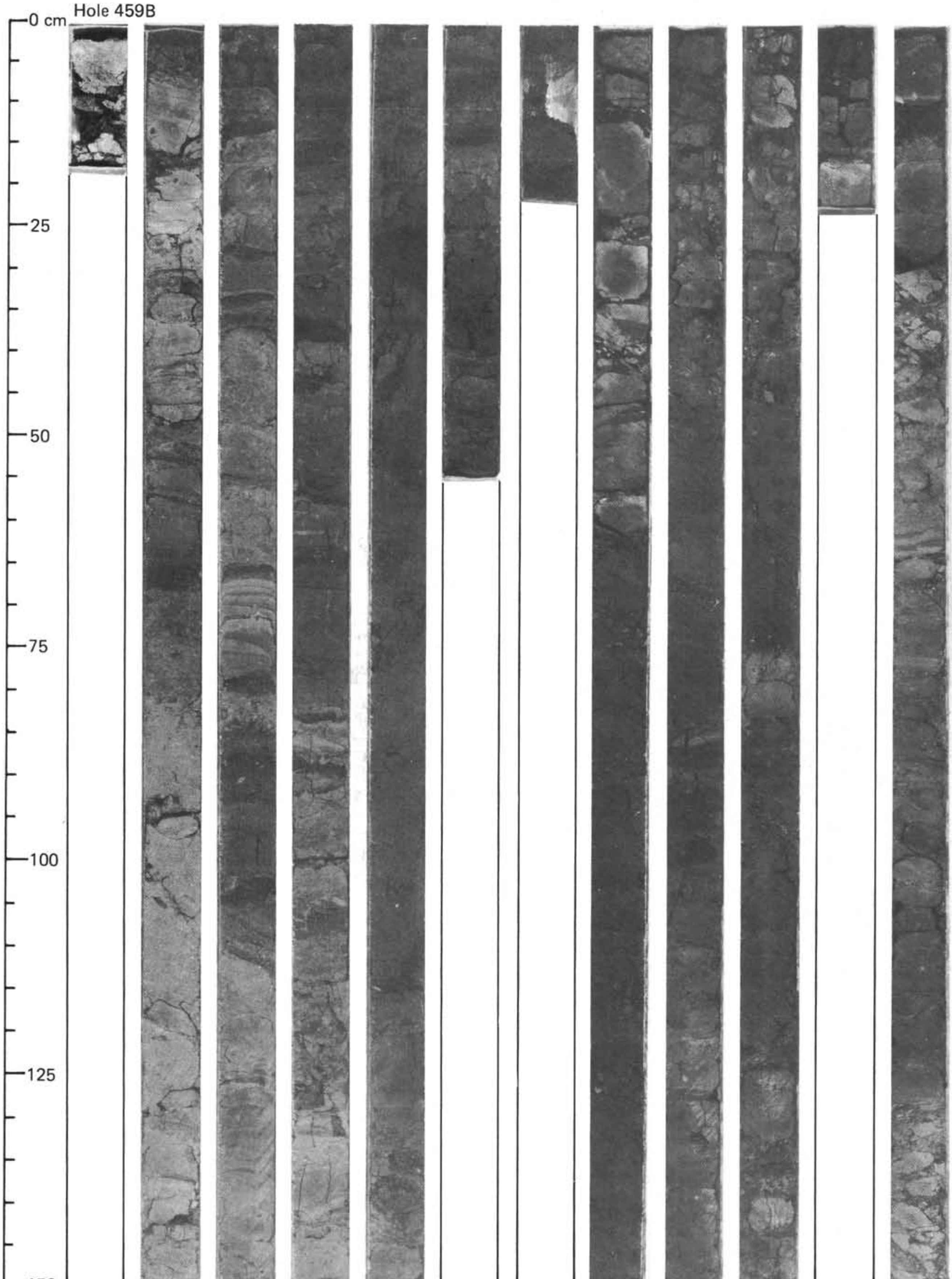
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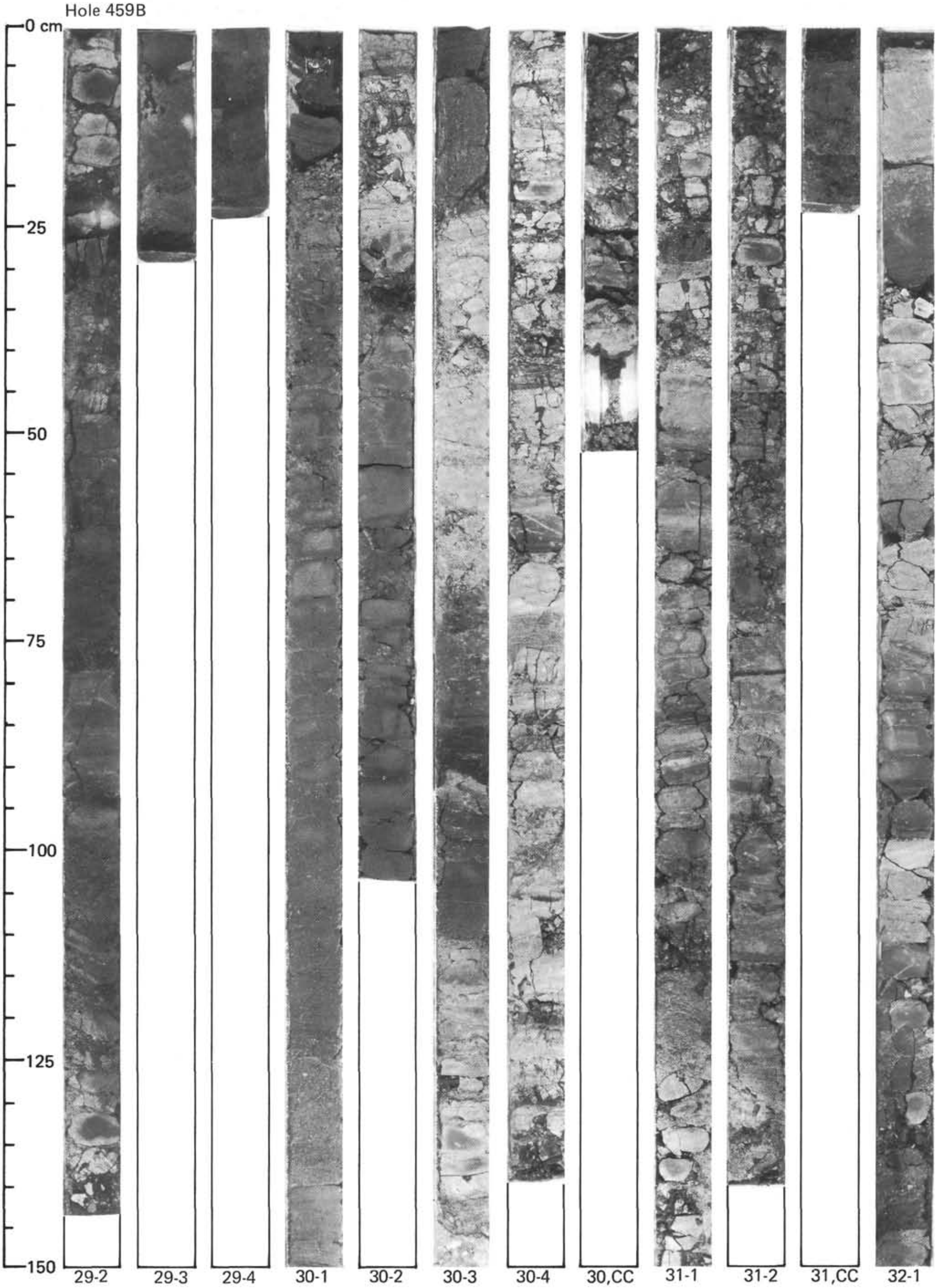
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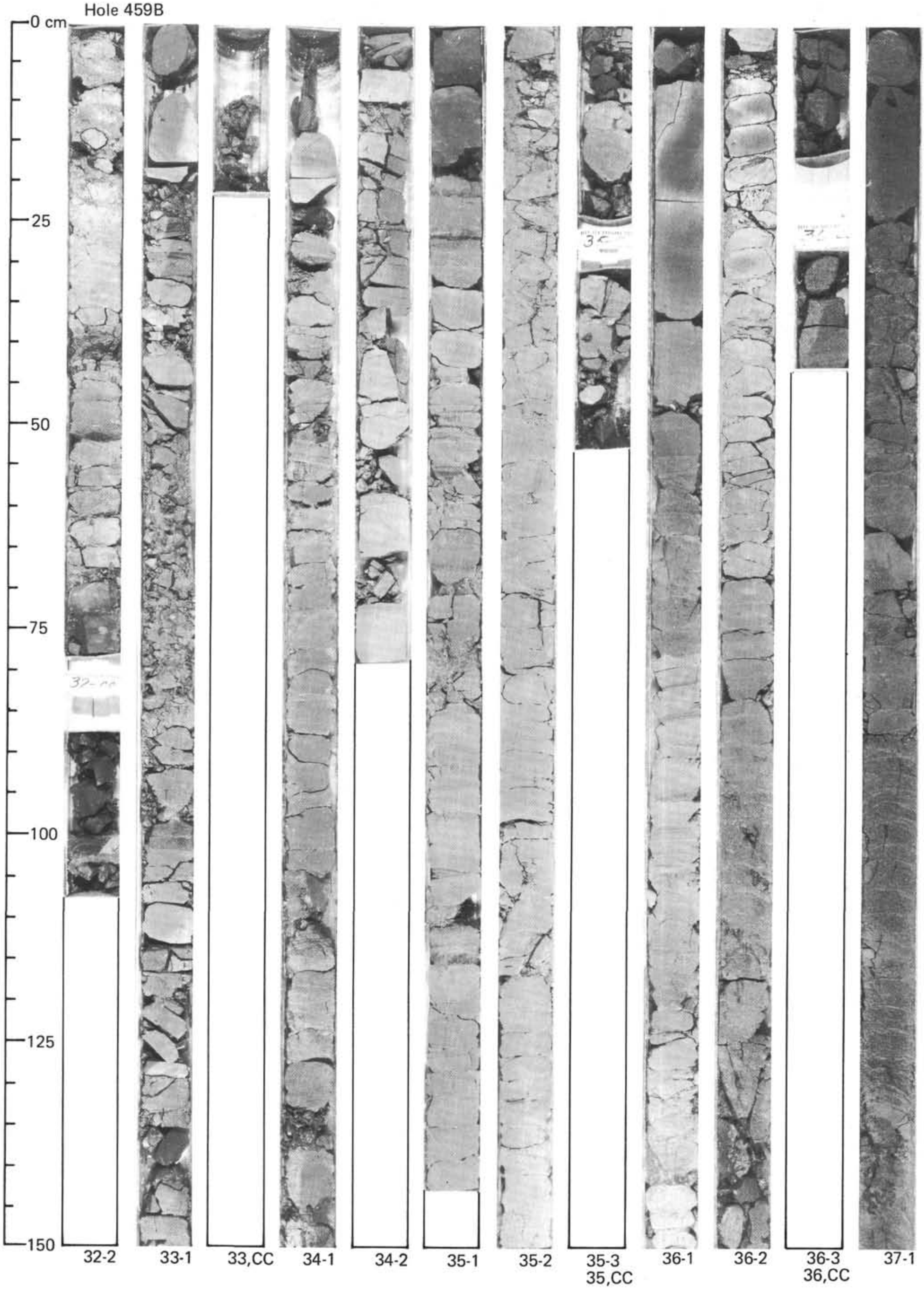
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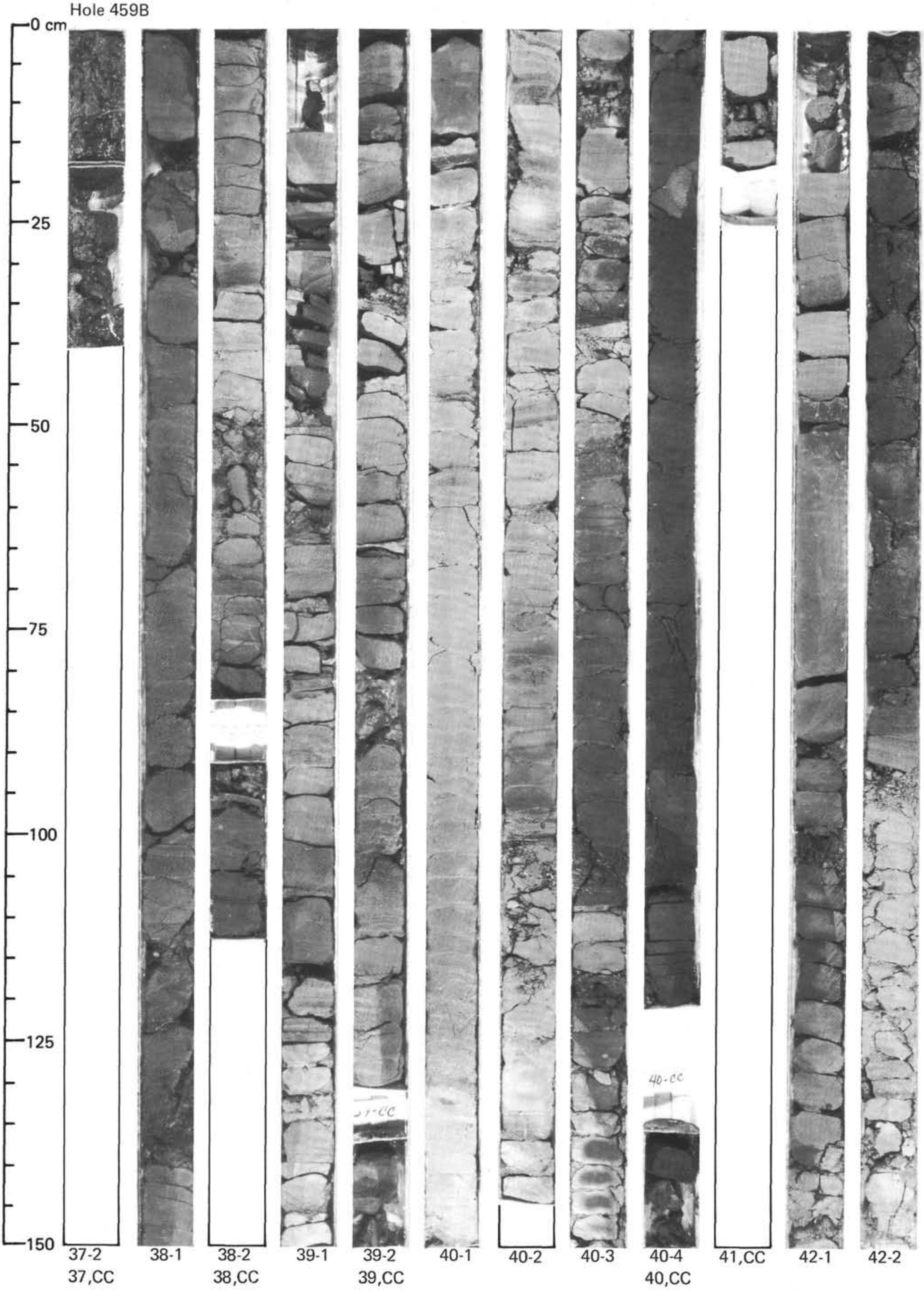
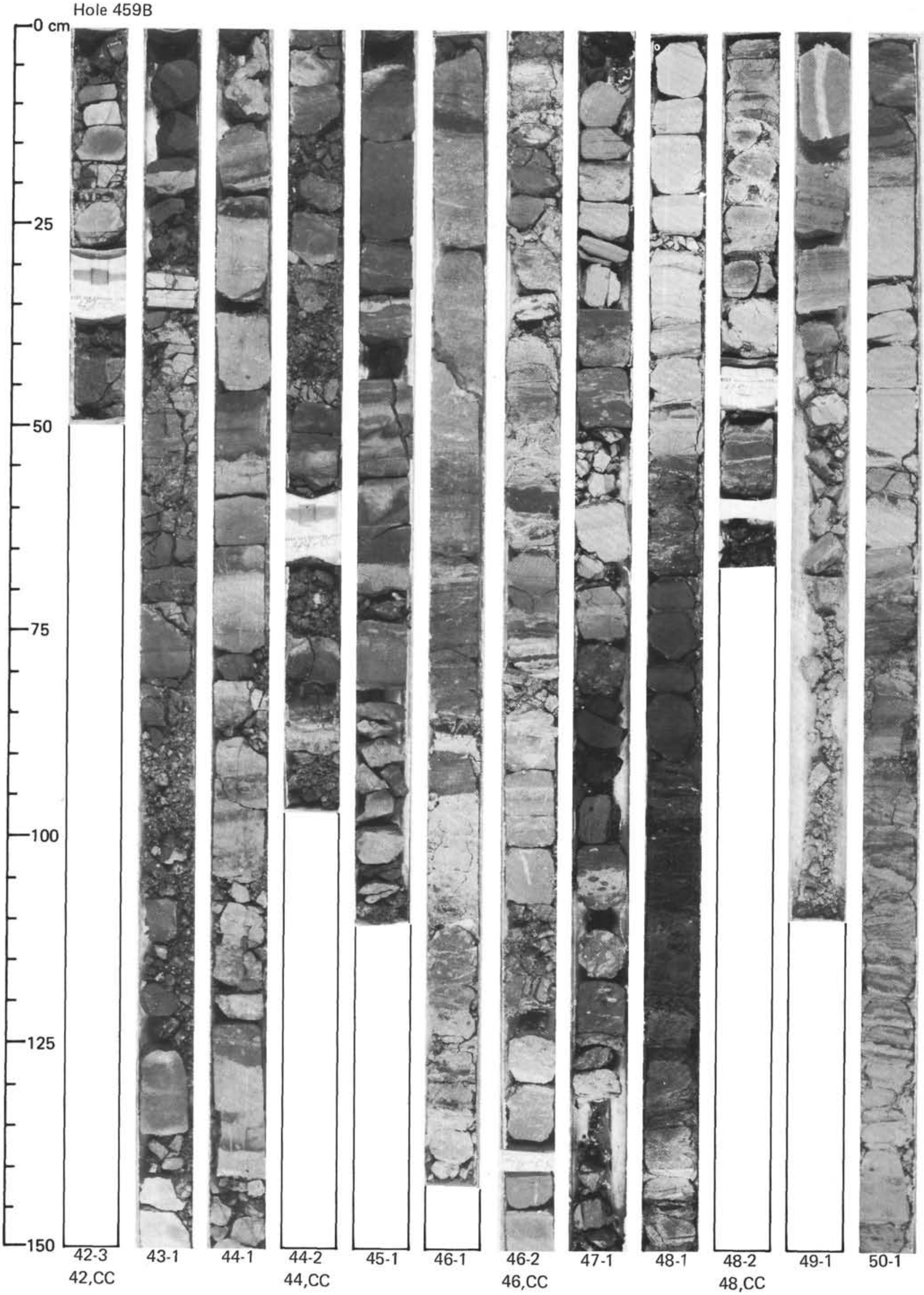
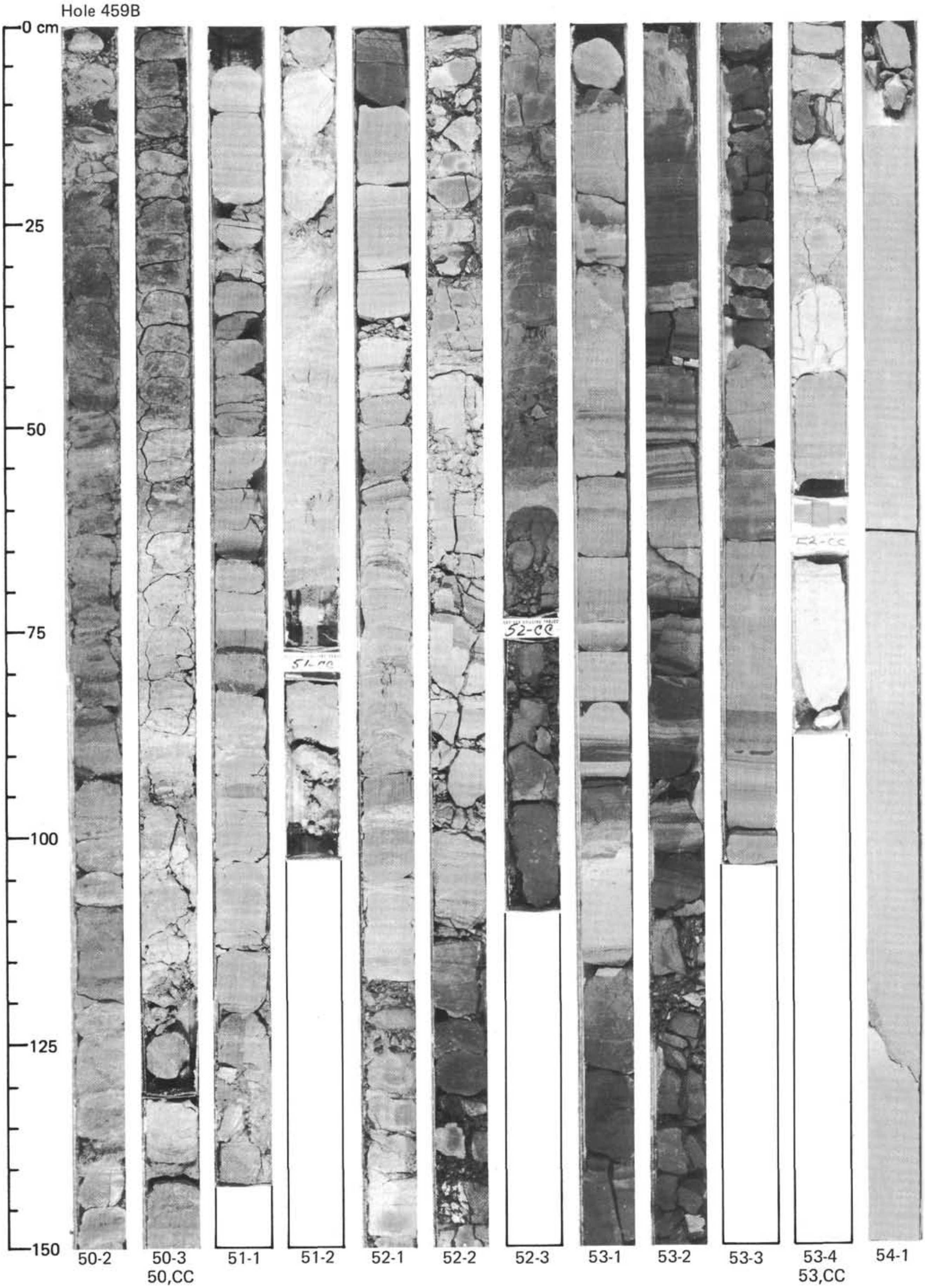
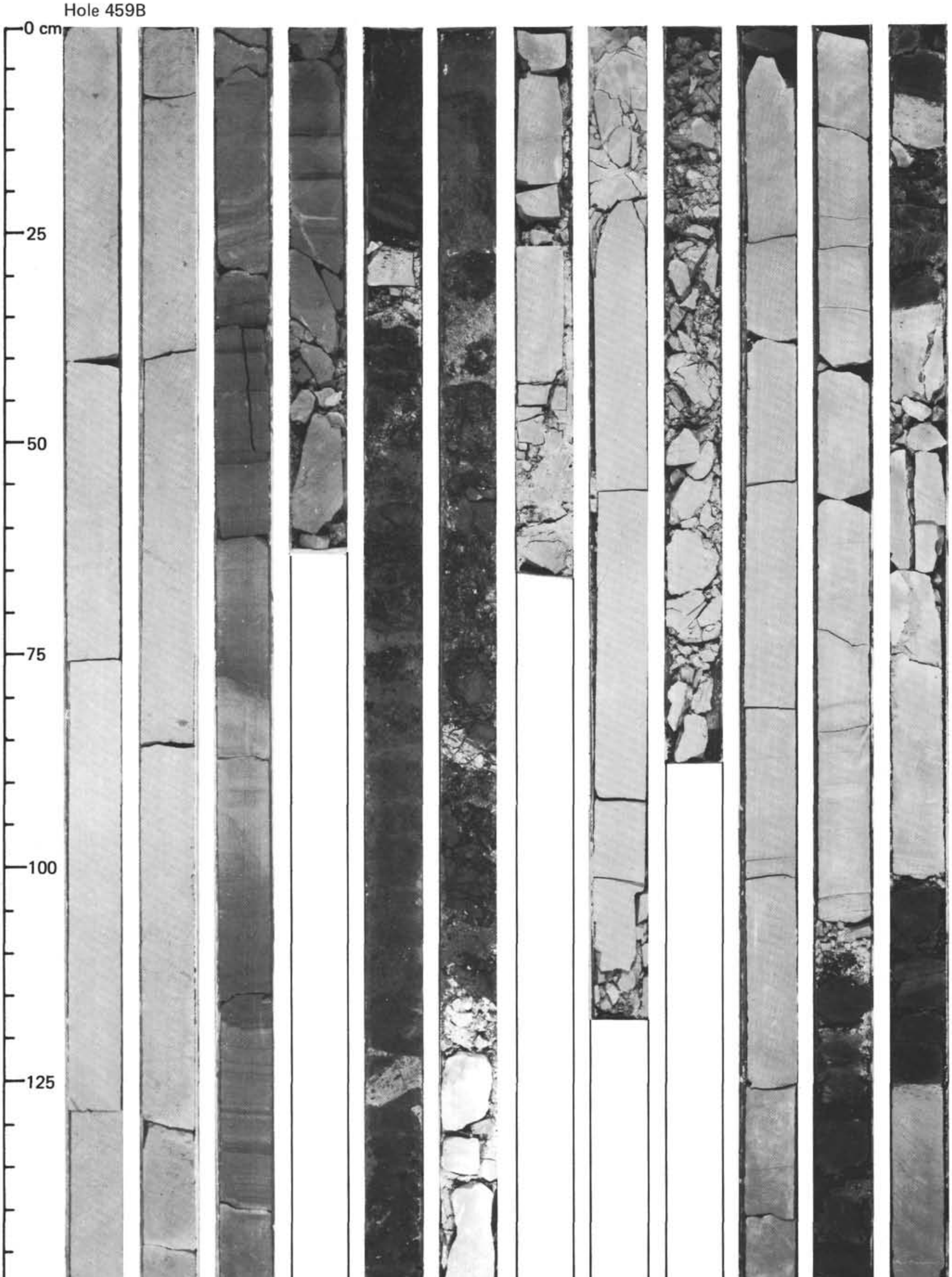
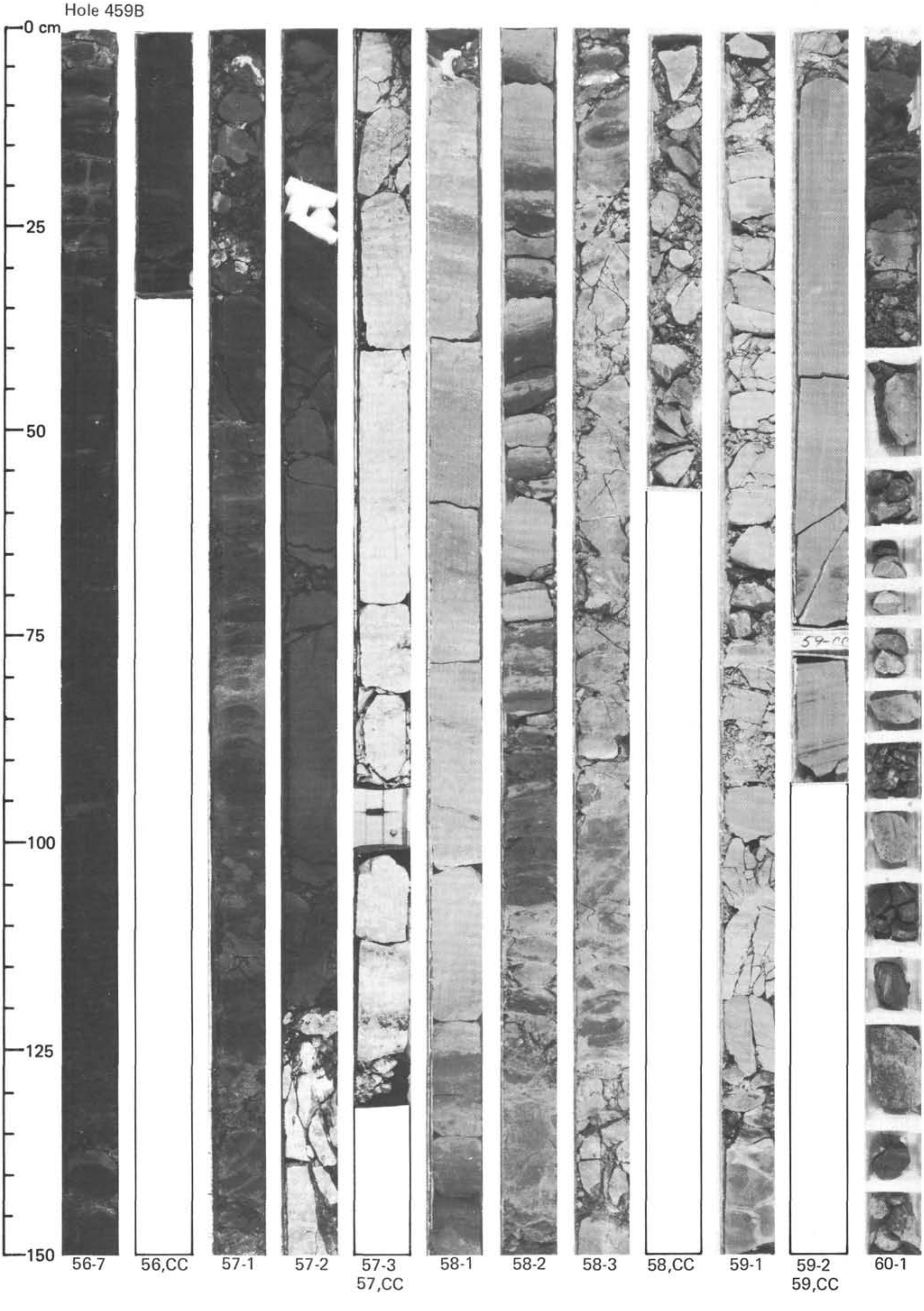
35-3
35,CC
36-1
36-2
36-3
36,CC
37-1

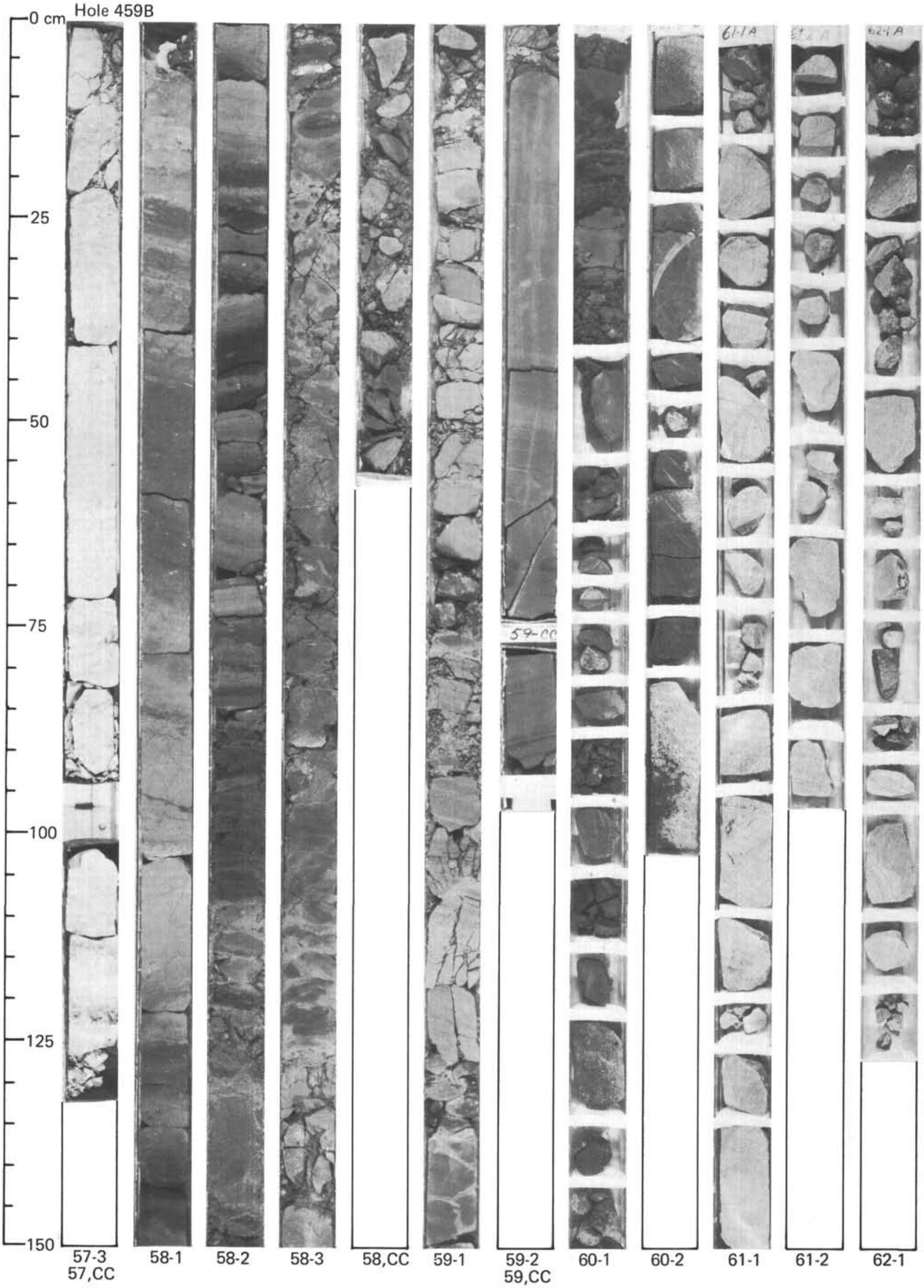

Hole 459B
0 cm
25
50
75
100
125
150
37-2
37,CC
38-1
38-2
38,CC
39-1
39-2
39,CC
40-1
40-2
40-3
40-4
40,CC
41,CC
42-1
42-2

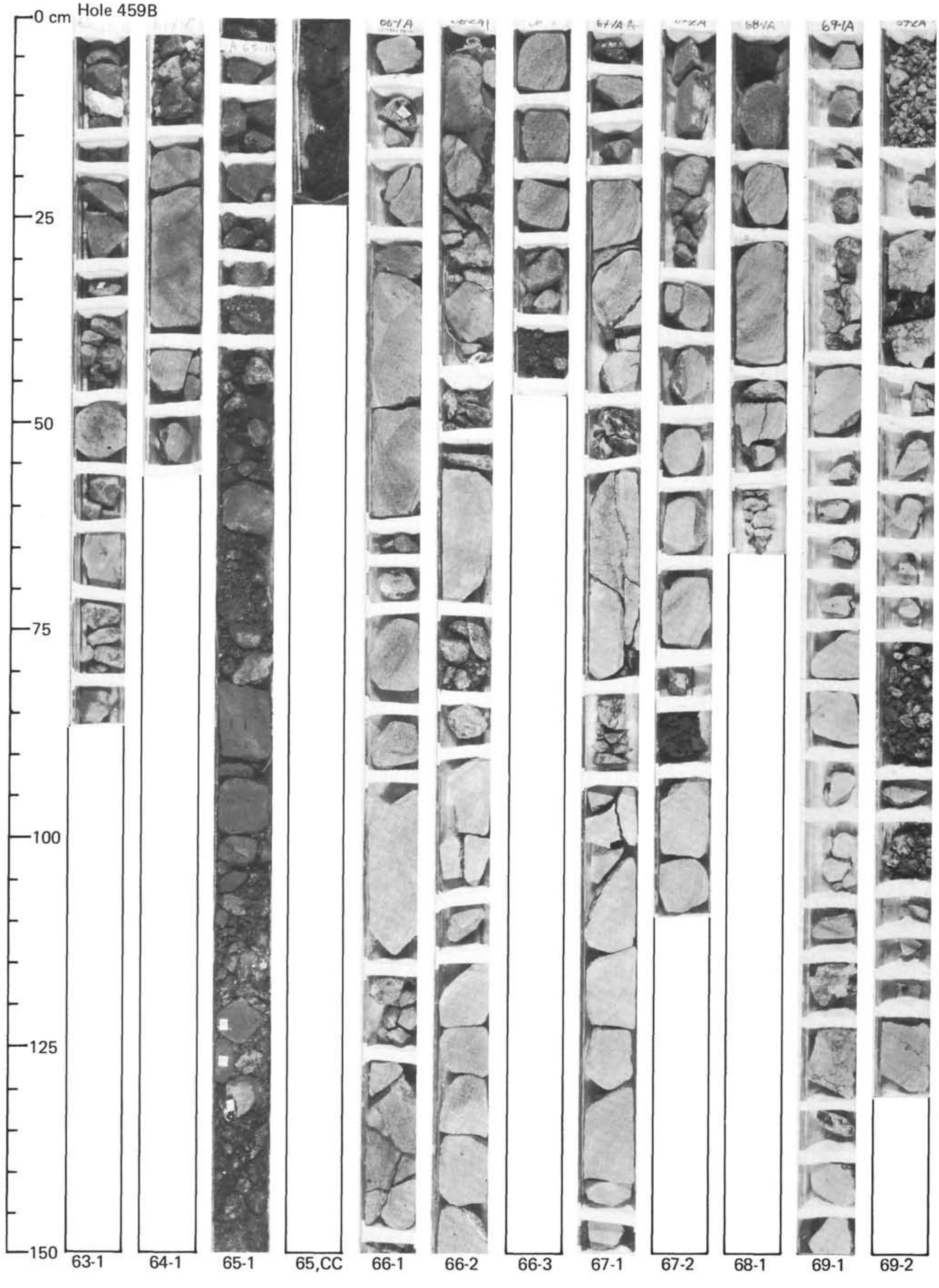

Hole 459B
0 cm
25
50
75
100
125
150
42-3
42,CC
43-1
44-1
44-2
44,CC
45-1
46-1
46-2
46,CC
47-1
48-1
48-2
48,CC
49-1
50-1

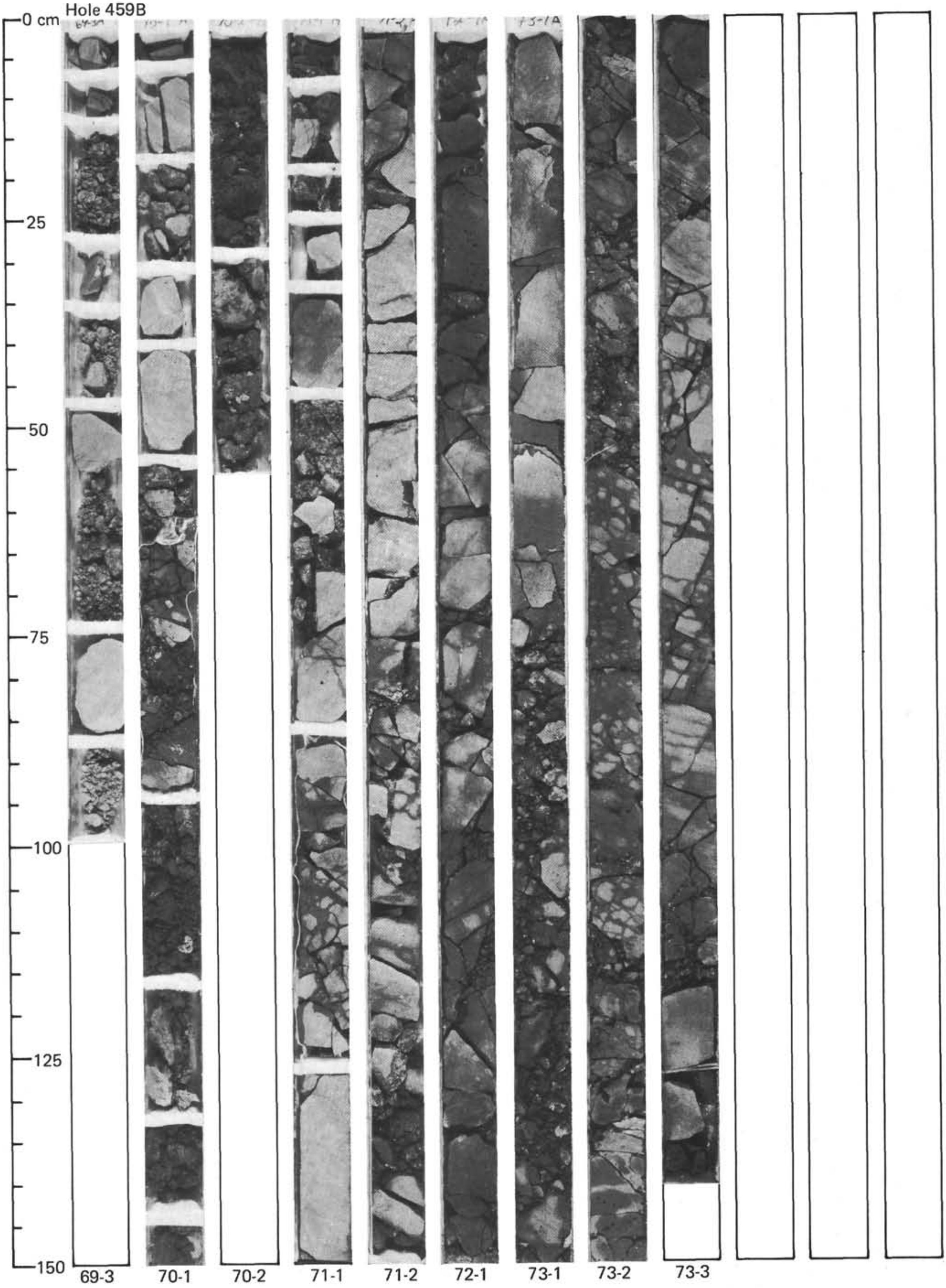

Hole 459B
0 cm
25
50
75
100
125
150
50-2
50-3
50,CC
51-1
51-2
52-1
52-2
52-3
53-1
53-2
53-3
53-4
53,CC
54-1


Hole 459B
0 cm
25
50
75
100
125
150
54-2
54-3
54-4
54-5
55-1
55-2
55-3
55-4
55,CC
56-1
56-2
56-3


Hole 459B
0 cm
25
50
75
100
125
150
56-7
56,CC
57-1
57-2
57-3
57,CC
58-1
58-2
58-3
58,CC
59-1
59-2
59,CC
60-1
59-CC


Hole 459B
0 cm
25
50
75
100
125
150
57-3
57,CC
58-1
58-2
58-3
58,CC
59-1
59-2
59,CC
60-1
60-2
61-1
61-2
62-1
59-CC
61-1 A
62-1 A


0 cm
Hole 459B
25
50
75
100
125
150
63-1
64-1
65-1
65,CC
66-1
66-2
66-3
67-1
67-2
68-1
69-1
69-2


Hole 459B
0 cm
25
50
75
100
125
150
69-3
70-1
70-2
71-1
71-2
72-1
73-1
73-2
73-3