4. SITE 469: BASE OF PATTON ESCARPMENT[1]

Shipboard Scientific Party[2]

HOLE 469

Date occupied: 28 October 1978

Date departed: 31 October 1978

Position: 32°37.00′N, 120°32.90′W

Water depth (sea level; corrected m, echo-sounding): 3790

Bottom felt (m, drill pipe): 3802.5

Penetration (m): 453.5

Number of cores: 51

Total length of cored section (m): 453.5

Total core recovered (m): 178.5

Core recovery (%): 39

Oldest sediment cored:
Depth sub-bottom (m): 390.8
Nature: Metalliferous nannofossil chalk
Chronostratigraphy: Upper lower Miocene (16.5–17.5 m.y. old)

Basement:
Depth sub-bottom (m): 390.8
Nature: Basalt

Principal results: At Site 469 on the foot of Patton Escarpment, a single hole was continuously cored to a total depth of 453.5 meters sub-bottom, the lower 57.5 meters in the basement. Because of a stubborn, unreleasing drill bit, the hole could not be logged. Four lithologic units were recovered: Unit 1 is a 42 meter Quaternary clay with minor foraminifer and nannofossil ooze. Unit 2 is divided into an upper sub-unit deposited in the Pliocene—foraminiferal-nannofossil ooze with local silty clay layers—and a lower sub-unit—foraminifer ooze grading into glauconitic sand and siliceous nannofossil to nannofossil ooze—deposited from the late middle to late Miocene. The two sub-units are separated by a hiatus from about 4.2 to 3.3 m.y. and together span the interval from 42 to 225 meters depth. Two more hiatuses (between 5.7 and 10 m.y. and between 10.8 and 13 m.y., respectively) occur within the lower sub-unit. Unit 3 is silty claystone and tuff in the upper part (225 to 368.5 m deep), an altered diabase sill (Sub-unit 3a—368.5–387 m deep) in the middle, and a nannofossil chalk with metalliferous sediments in the lower part (387 to 390.7 m deep). The sediments above the sill were deposited in the early middle Miocene and those below in the early Miocene. Unit 4 is a very thin (0.1 m) layer of dolomite iron-rich clay deposited in the early Miocene. The basement is microcrystalline pillow basalt with altered glass fragments forming hyaloclastites and rare thin layers of metalliferous sediment within basalt fractures and between pillows.

The sediment accumulation rates are 25 m/m.y. in the upper 80 meters, decreasing to 10 m/m.y. throughout the early Pliocene and late Miocene; in the middle Miocene, rates increased to 30 m/m.y. and in the early Miocene to 60 m/m.y. These high sedimentation rates are similar to those encountered at the previous borderland Sites 467 and 468 (and to those in Monterey Shale in onshore basins) and are related to the influx of terrigenous material at that time. The change from relatively higher to lower sedimentation rates in the late middle Miocene coincides with a major unconformity in the borderland area. At the top of Unit 3, the terrigenous contribution to Site 469 is reduced, which was most probably caused by the isolation of the continental source of sediments, resulting from the formation of intervening borderland basins and ridges in the late middle Miocene. This interpretation also explains the almost nonterrigenous nature of Unit 2 at this site. The middle Miocene volcanogenic sediments in Unit 3 were probably derived from sources such as the nearby San Juan seamount and Patton Ridge. And the presence of andesite and dacite at the edge of the continental shelf suggests that the volcanics are related to the intersection of the East Pacific Rise with the continental margin rather than to island-arc activity. The metalliferous sediments overlying typical ocean-floor pillow basalt with quench texture characterize this as an oceanic-crust site typical of the west flank of the East Pacific Rise. The micropaleontologic age of the basement is estimated to be 17 ± 0.5 m.y.

BACKGROUND AND OBJECTIVES

The asymmetric magnetic-anomaly pattern in the northeast Pacific has been interpreted by McKenzie and Morgan (1969) and Atwater (1970) to indicate the former presence of a trench off western North America that consumed the Farallon plate during the early to mid(?) Tertiary. According to their models, the Farallon–Pacific Ridge first intersected the trench off western North America roughly 30 m.y. ago. Subsequent to this event, a pair of triple junctions migrated in opposite directions away from the intersection. Atwater (1970) concluded that at the time of intersection, subduction ceased between the two triple junctions and strike-slip (transform) faulting began along this segment of the continental margin. These tectonic processes probably played a major role in the structural development of the margin, but field investigators have had only moderate success in correlating geologic events on the margin with predictions based on the plate tectonic models. Discrepancies in the timing between model predictions and actual tectonic events may be due to the rather tenuous identifications of sea-floor magnetic anomalies adjacent to the margin. Here the magnetic signature is obscured because of the greater-than-normal thickness of sediments overlying oceanic basement as well as numerous topographic features, such as the San Juan seamount (Fig. 1).

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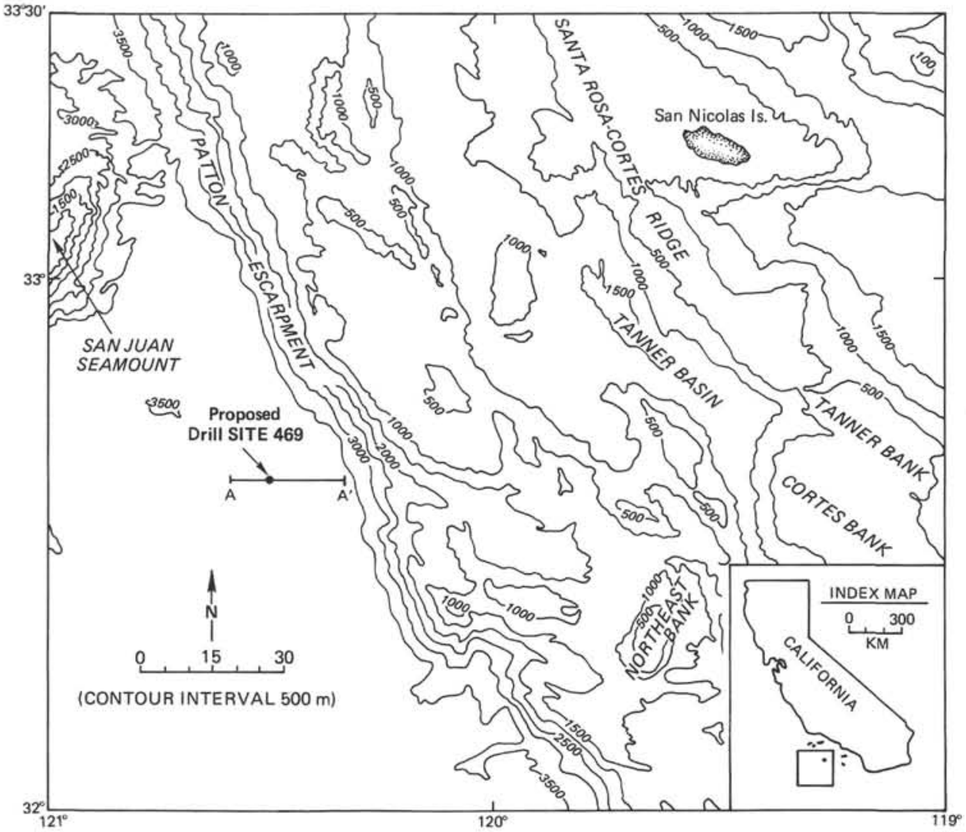

Figure 1. Generalized bathymetric map (in meters) of the outer California Continental Borderland showing position of proposed Site 469 and seismic track line AA'.

The primary objective of Site 469 was to determine the precise time that the Farallon-Pacific Ridge intersected the trench off southern California. In order to accomplish this objective, the proposed site is located on the seaward flank of a sediment-filled trough that lies at the base of the continental slope off the California Continental Borderland (Fig. 2). The seismic profile shown in Figure 3 and the implications of plate tectonic models outlined above suggest that this trough may represent a trench that was active prior to subduction of the Farallon plate. We anticipated that cores recovered from this site would provide data on the age and nature of the sediment within the trough and the age of oceanic basement. Dating of the oceanic crust to determine the time of intersection of the Farallon-Pacific Ridge with the trench would allow us to evaluate the effect of this event on the structural development of the continental margin. Knowing the precise time of intersection would resolve some of the chronologic discrepancies of plate tectonic models with continental-margin and onshore studies. We also expected the estimated 700 meters of Miocene-Pleistocene sediment filling the trough to provide a detailed biogenic siliceous record. In addition, we anticipated a record of calcareous plankton in earlier periods (Miocene-Pliocene), when the site was probably above the carbonate compensation depth (CCD). With both calcareous and siliceous records, the site would provide further insights into the mid-latitude paleoceanographic history of the California Current.

OPERATIONS

The survey for Site 469 involved the use of the 120-cubic-inch air gun to provide enough energy to penetrate the 0.5 s of sedimentary section and reach basement, indicated by a 1976 single-channel line and a 1978 multichannel line (Fig. 3), both run by the USGS vessel *Lee*. The *Glomar Challenger* crossed the Patton Escarpment over the abyssal plain to the west at a cruising speed of 8½ knots (Fig. 4). When speed was reduced to 5½ knots, an excellent air-gun record was obtained, which showed an indistinct basement reflector dipping gently eastward toward the escarpment (Fig. 5). Deeper reflectors seen on this record (and on the multichannel presite survey) turned out to be artifacts of the record, as shown by the coring done at the site. The survey continued beyond the site to a point where the abyssal plain terminated westward against sediment-covered abyssal hills. The *Challenger* returned eastward to the site on its own track, dropped the beacon on the run at 0231 hours (local time)[3] 27 October, and positioned over the site after a Williamson turn (Fig. 4).

The hole was spudded at 1640 hours. Continuous coring was routine, except that the core barrel was retrieved using the drawworks sand line instead of the regular sand line, thereby shortening the time necessary

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[3] Times specified in the text are local times; those in seismic-section figures are Zulu times (Z).

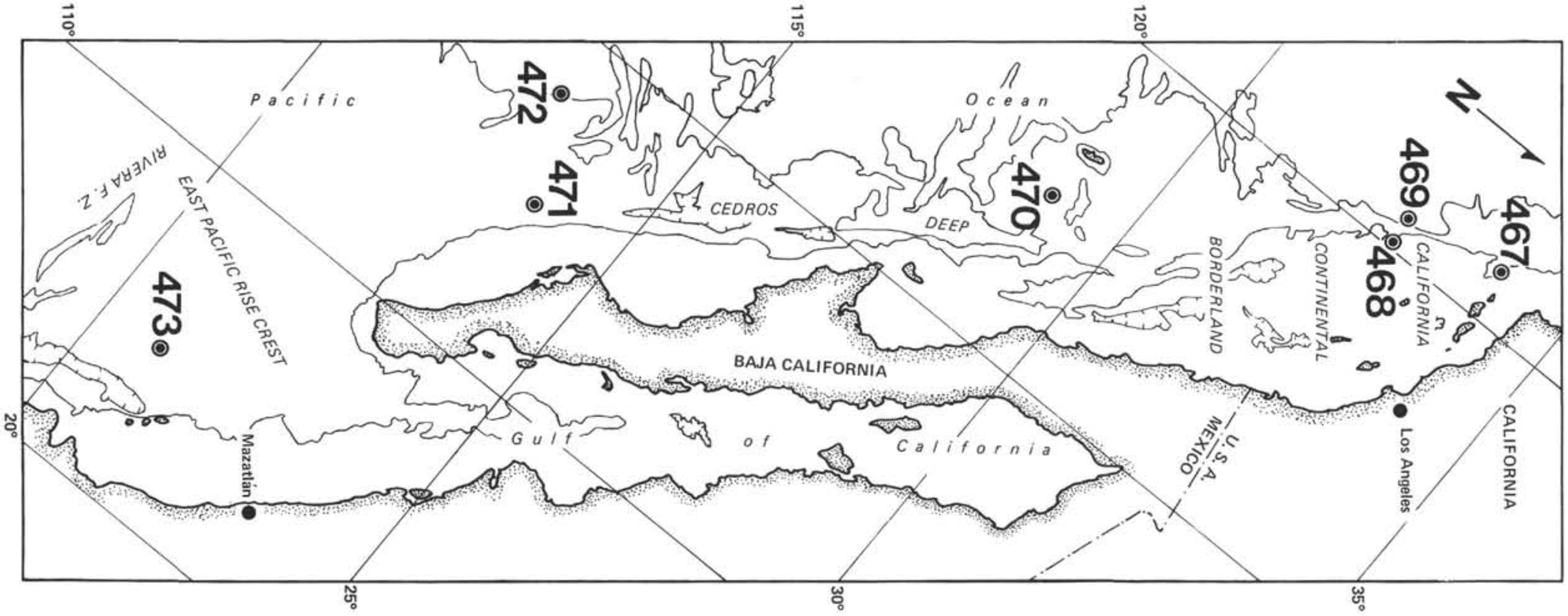

Figure 2. Location of Leg 63 sites.

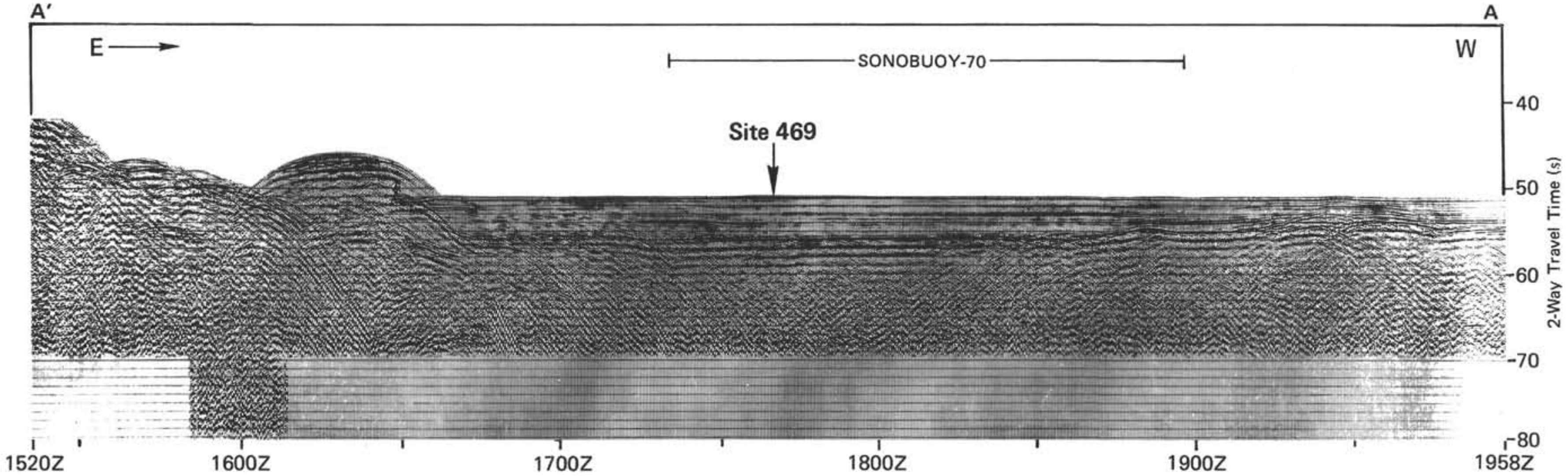

Figure 3. Multichannel seismic-reflection profile AA′ showing proposed position of Site 469 (*S. P. Lee*). (The location of this profile is shown on Fig. 1.)

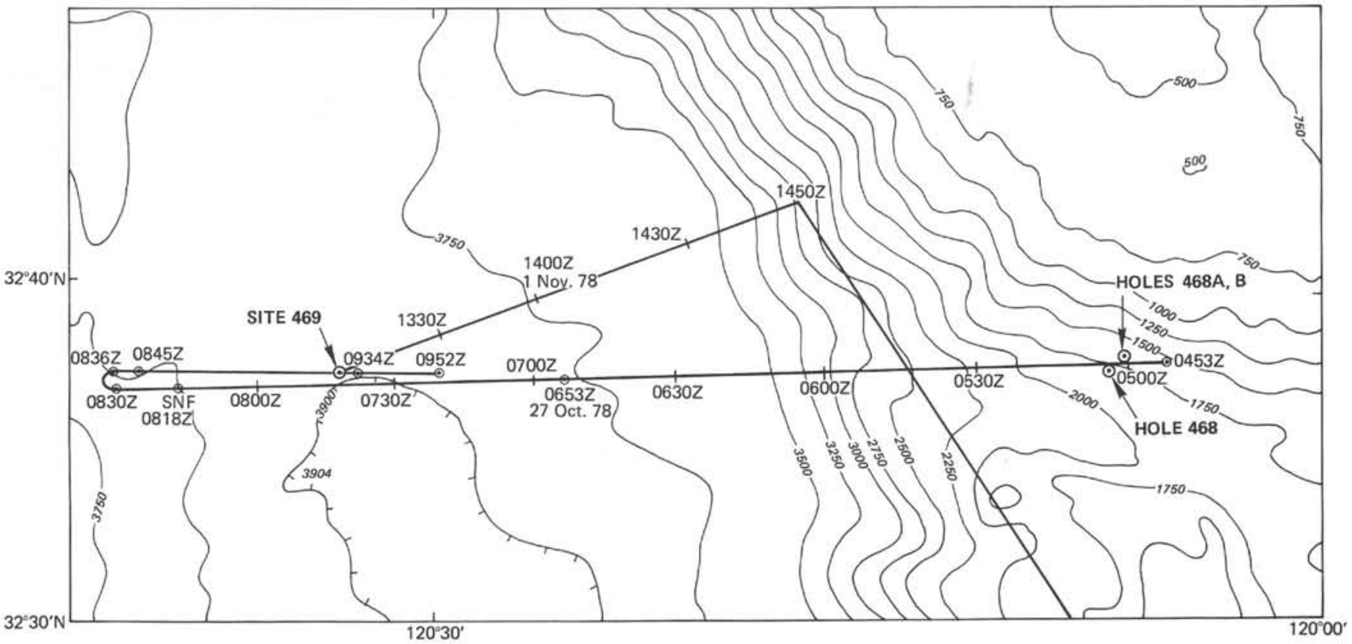

Figure 4. Bathymetric map (in meters) showing the area around Sites 468 and 469 and the seismic lines of the *Glomar Challenger*'s approach to and departure from Site 469.

to retrieve each core barrel. Core recovery was high to a depth of 226 meters (Table 1), where harder sediment required an increase in pump strokes from 5 to 30 spm (strokes per min) and a reduction in core recovery. This drilling break corresponds to the boundary between Lithologic Units 2 and 3 and a sharp change in sediment density and velocity. Low recoveries higher in the section (Cores 16, 17, 19, and 21) cannot be explained by changes in pump pressure or in lithology. Coring times and recoveries were relatively uniform in Unit 3, but a sharp decrease in coring rate occurred with Core 40, which penetrated a diabase sill. Recoveries were high in the sill and in an underlying bed of claystone (Core 43), which was cored at the same rate as was Unit 3. Fractured, altered basalt was reached in Core 44. Coring rates varied from 80 min for Core 46 to 248 min for Core 49. Indications of progressive bit deterioration in basalt included reduced core diameter and ragged torque. The bit began to lock up while coring Core 51, and we terminated coring operations. (We later determined that a cone had been lost on Core 51.)

The hole was flushed with 50 barrels of gel mud followed by 20 barrels of MY-T gel in preparation for logging. The bit-release go-devil was pumped down and pressured up, but the bit did not release. A second go-devil also failed to release the bit, so it was impossible to run open-hole logs. The pipe was pulled, and at 0602 hours on 1 November we were underway for Site 470.

A postsite survey on an east-northeast heading was done at 5½ knots using the 120-cubic-inch air gun in hopes of better defining the geology at the contact between the abyssal plain and the Patton Escarpment, but the basement reflector could be traced only part way to the escarpment (Fig. 6).

LITHOLOGY

Sediments and Sedimentary Rocks

The sedimentary section at Site 469 has been divided into four lithologic units (Table 2; Fig. 7) on the basis of microfossil abundance, mineralogical components, texture, and degree of lithification. These include gray hemipelagic clay (Unit 1), olive green nannofossil and siliceous nannofossil ooze (Unit 2), greenish gray silty claystone (Unit 3), and reddish brown metalliferous sediments (Unit 4). A diabase sill occurs within Unit 3 and is described in the section on igneous rocks.

Unit 1: Hemipelagic Clay (0–42 m)

Unit 1 consists of gray silty clay and minor amounts of calcareous ooze with varying proportions of nannofossils and foraminifers. The clay contains about 12% subangular quartz and feldspar. The nannofossil–foraminiferal ooze in this unit is olive brown to olive gray and varies from 15% to 80% nannofossils and from 10% to 60% foraminifers. The unit contains several patches and layers of glauconitic foraminiferal ooze (12% glauconite, 50% foraminifers). Patches and streaks of pyrite occur throughout. Some microfossils are pyritized. The boundary between Units 1 and 2 is gradational and was chosen on the basis of the relative proportion of calcareous ooze and clay in the cores.

Unit 2: Nannofossil Ooze (42–225 m)

Unit 2 is dominantly biogenic ooze. This unit is pale olive to pale green nannofossil ooze with varying amounts of foraminifers and siliceous microfossils. Minor lithologies include foraminiferal ooze, siliceous clay, and glauconitic foraminiferal ooze containing up

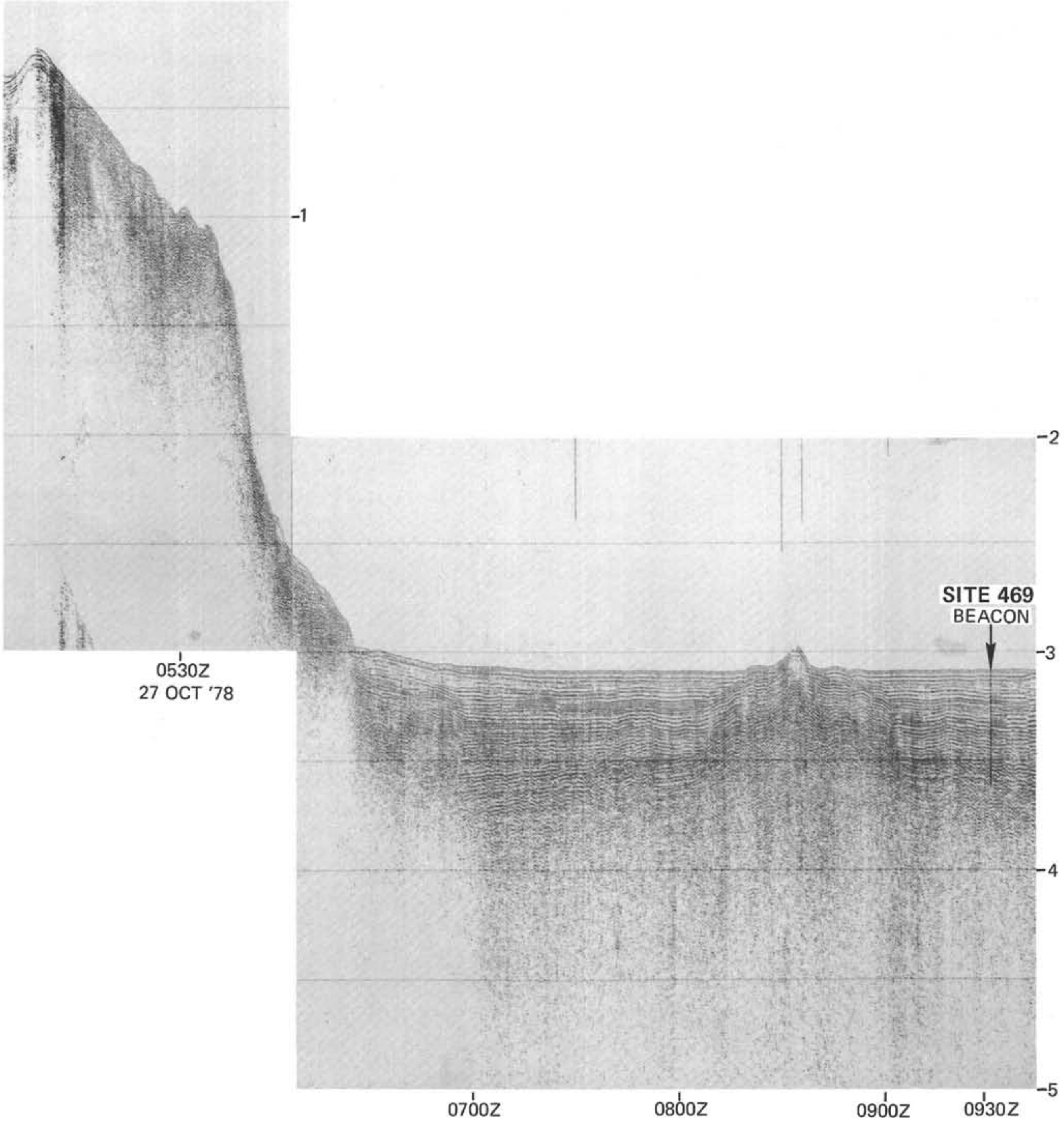

Figure 5. *Glomar Challenger* seismic profile approaching Site 469 (location of profile on Fig. 4).

to 20% glauconite. The unit can be divided into two parts. Sub-unit 2a consists of nannofossil clay and foraminiferal-nannofossil ooze (Section 5-4 through Section 11-1; 42–94 m). Sub-unit 2b consists of nannofossil ooze and siliceous-nannofossil ooze (Section 11-1 through Core 24; 94–225 m).

Sub-unit 2a grades downward from clay-rich sediments (50%–80% clay) containing little silt to carbonate-rich sediments that are dominated by foraminiferal-nannofossil ooze. Core 10 consists of greenish gray silty clay and foraminiferal silt, with up to 30% silt in the nonbiogenic sediment fraction. The silt contains minor amounts of amphibole and glauconite and trace amounts of glaucophane and dolomite. The boundary between Sub-units 2a and 2b was determined on the basis of the marked decrease in silty clay and foraminifer abundance below Core 10.

Sub-unit 2b consists of variegated foraminiferal-nannofossil ooze, siliceous-nannofossil ooze, and nannofossil ooze. The cohesive sediment from Sub-unit 2b

Table 1. Coring summary for Site 469.

Core No.	Date (Oct. 1978)	Time	Depth from Drill Floor (m)	Depth below Sea Floor (m)	Length Cored (m)	Length Recovered (m)	Core Recovered (%)
1	27	1727	3802.5-3810.0	0.0-7.5	7.5	7.09	95
2	27	1830	3810.0-3819.5	7.5-17.0	9.5	4.61	49
3	27	1934	3819.5-3829.0	17.0-26.5	9.5	9.84	100+
4	27	2036	3829.0-3838.5	26.5-36.0	9.5	5.56	59
5	27	2142	3838.5-3848.0	36.0-45.5	9.5	8.37	88
6	27	2245	3848.0-3857.5	45.5-55.0	9.5	9.26	97
7	27	2352	3857.5-3867.0	55.0-64.5	9.5	8.98	95
8	28	0103	3867.0-3876.5	64.5-74.0	9.5	6.82	72
9	28	0212	3876.5-3886.0	74.0-83.5	9.5	2.53	27
10	28	0310	3886.0-3895.5	83.5-93.0	9.5	6.38	67
11	28	0412	3895.5-3905.0	93.0-102.5	9.5	4.48	47
12	28	0522	3905.0-3914.5	102.5-112.0	9.5	9.35	98
13	28	0630	3914.5-3924.0	112.0-121.5	9.5	7.61	80
14	28	0740	3924.0-3933.5	121.5-131.0	9.5	3.22	34
15	28	0840	3933.5-3943.0	131.0-140.5	9.5	2.42	25
16	28	1000	3943.0-3452.5	140.5-150.0	9.5	0.20	2
17	28	1111	3952.5-3962.0	150.0-159.5	9.5	0.70	7
18	28	1255	3962.0-3971.5	159.5-169.0	9.5	4.24	45
19	28	1405	3971.5-3981.0	169.0-178.5	9.5	0.62	7
20	28	1525	3981.0-3990.5	178.5-188.0	9.5	7.15	75
21	28	1630	3990.5-4000.0	188.0-197.5	9.5	0.00	0
22	28	1748	4000.0-4009.5	197.5-207.0	9.5	3.41	36
23	28	1855	4009.5-4019.0	207.0-216.5	9.5	4.70	49
24	28	2005	4019.0-4028.5	216.5-226.0	9.5	8.60	91
25	28	2115	4028.5-4038.0	226.0-235.5	9.5	1.59	17
26	28	2250	4038.0-4047.5	235.5-245.0	9.5	0.04	0.4
27	29	0012	4047.5-4057.0	245.0-254.5	9.5	0.32	3
28	29	0209	4057.0-4066.5	254.5-264.0	9.5	1.09	11
29	29	0335	4066.5-4076.0	264.0-273.5	9.5	0.13	1
30	29	0454	4076.0-4085.5	273.5-283.0	9.5	1.14	12
31	29	0628	4085.5-4095.0	283.0-292.5	9.5	0.37	4
32	29	0815	4095.0-4104.5	292.5-302.0	9.5	1.20	13
33	29	1041	4104.5-4114.0	302.0-311.5	9.5	1.70	18
34	29	1315	4114.0-4123.5	311.5-321.0	9.5	0.34	4
35	29	1506	4123.5-4133.0	321.0-330.5	9.5	1.01	11
36	29	1652	4133.0-4142.5	330.5-340.0	9.5	2.38	25
37	29	1820	4142.5-4152.0	340.0-349.5	9.5	3.14	33
38	29	1958	4152.0-4161.5	349.5-359.0	9.5	2.21	23
39	29	2148	4161.5-4171.0	359.0-368.5	9.5	0.31	3
40	30	0139	4171.0-4174.0	368.5-371.5	3.0	2.34	78
41	30	0508	4174.0-4180.5	371.5-378.0	6.5	4.39	68
42	30	0950	4180.5-4189.5	378.0-387.0	9.0	7.53	84
43	30	1143	4189.5-4198.5	387.0-396.0	9.0	3.85	43
44	30	1650	4198.5-4207.5	396.0-405.0	9.0	2.60	29
45	30	1932	4207.5-4212.5	405.0-410.0	5.0	2.67	53
46	30	2207	4212.5-4216.5	410.0-414.0	4.0	1.83	46
47	31	0200	4216.5-4225.5	414.0-423.0	9.0	3.00	33
48	31	0740	4225.5-4234.5	423.0-432.0	9.0	2.73	30
49	31	1127	4234.5-4243.5	432.0-441.0	9.0	1.35	15
50	31	1500	4243.5-4252.5	441.0-450.0	9.0	1.98	22
51	31	1717	4252.5-4256.0	450.0-453.5	3.5	1.08	31
Total					453.5	178.46	39

has very fine purple and grayish purple laminations and cross-laminations that cut through burrows and surround some of the dark patches that are rich in pyrite; these are probably diagenetic aureoles and pseudolaminae caused by the migration of iron and/or manganese under reducing conditions in the sediment.

The upper portion of Sub-unit 2b contains sequences of greenish gray foraminiferal ooze that grade upward into greenish gray and olive gray siliceous-nannofossil ooze and greenish gray and greenish white nannofossil ooze. The foraminiferal ooze contains up to 20% glauconite and 5% pyrite and some plant debris and phosphate. The siliceous-nannofossil ooze ranges from 10% to 45% siliceous microfossils, principally diatoms and sponge spicules with lesser amounts of radiolarians and silicoflagellates. The siliceous-nannofossil ooze is also rich in pyrite. In the lower portion of Sub-unit 2b, the foraminiferal ooze is sometimes missing and the sequences consist of only siliceous-nannofossil ooze or diatomite grading upward to nannofossil ooze. The thickness of the sequences varies from about 0.5 to 3 meters and averages about 1 meter. There is no visible evidence of graded bedding or sedimentary structures within the sequences. The boundary between Units 2 and 3 is marked by a sharp change in induration from firm, cohesive nannofossil ooze (above) to sediments that are moderately to well indurated and sedimentary rocks with more terrigenous detritus (below).

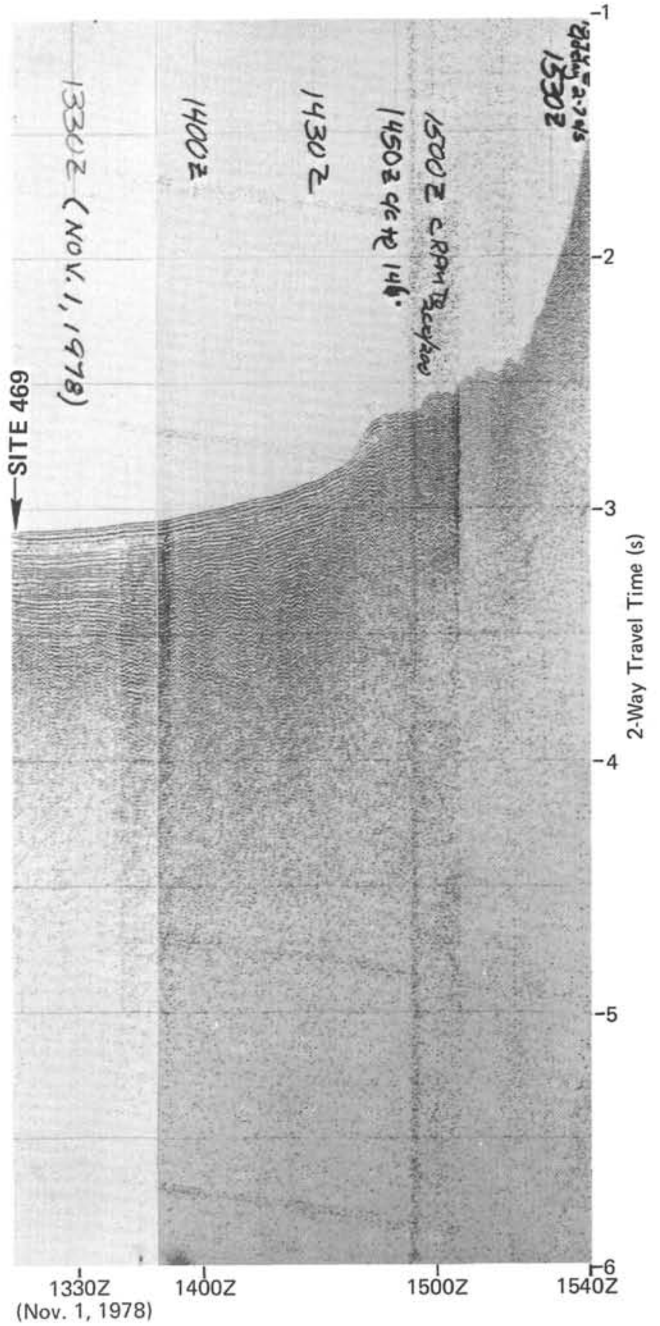

Figure 6. *Glomar Challenger* seismic profile departing Site 469 (location of profile on Fig. 4).

Unit 3: Silty Claystone (225–390.7 m)

The dominant lithology of Unit 3 is greenish gray silty claystone, but the unit is very diverse, also comprising a number of characteristic minor lithologies includ-

Table 2. Summary of lithologic units, Site 469.

Unit or Sub-unit	Cores	Depth below Sea Floor (m)	Chrono-stratigraphy	Lithology
1	Cores 1-5, Section 4	0.0-42.0	Quaternary	Silty clay with minor amounts of nannofossil and foraminiferal ooze.
2a	Core 5, Section 4-Core 11, Section 1	42.0-94.0	Pliocene	Clays, nannofossil, and foraminiferal ooze.
2b	Core 11, Section 1-Core 24	94.0-225.0	upper middle Miocene-upper Miocene	Variegated foraminiferal, glauconitic nannofossil ooze, siliceous-nannofossil ooze, and nannofossil ooze.
3	Cores 25-43, Section 2	225.0-390.7	lower Miocene-lower middle Miocene	Silty claystone and volcaniclastics; minor lithologies: porcellanite, sand, sandstone, nannofossil claystone and chalk, siliceous limestone.
3a	Cores 40-42	368.5-387.0	lower middle Miocene	Diabase sill.
3	Resumes			
4	Core 43, Section 3	390.7-390.8	lower Miocene	Dolomitic iron-rich clay.

ing porcellanite, sand and sandstone, altered vitric and pumiceous tuff, and a matrix-supported volcaniclastic breccia. In addition, there are minor amounts of nannofossil claystone, clayey and siliceous chalk, siliceous dolomite, zeolite-cemented silt, sandstone, and ash. A diabase sill occurs between 368.5 and 387 meters depth. This sill is defined as Sub-unit 3a and is described together with the basalts in the section on igneous rocks.

The sediments and rocks of Unit 3 are generally burrow-mottled and occasionally have lenticular bedding. The diagenetic pseudolaminae found in Unit 2 are commonly present in the silty claystones, chalks, and porcellanites of Unit 3. The claystone has about 15% silt-size quartz, feldspar, and lithic fragments. Glauconite and glaucophane are trace constituents.

The calcareous rocks of this unit are nannofossil claystone and sandstone with some clayey chalk or siliceous chalk. The chalk is greenish gray to light gray and has many features in common with the nannofossil ooze of Unit 2, such as bioturbation, reduction spots, and pseudolaminae. A siliceous dolomite occurs immediately above the diabase sill in the lower part of this unit. Sedimentary structures in the dolomite are similar to those of the siliceous-nannofossil chalk.

Opal-CT (cristobalite) porcellanite is most common in the upper part of Unit 3; only one porcellanite was recovered from below 310 meters. The porcellanite ranges from greenish gray to light gray and has sedimentary structures similar to the siliceous-nannofossil ooze of Sub-unit 2b.

The sand and sandstone of Unit 3 contain subangular quartz (up to 25%), glauconite (up to 15%), feldspar (up to 10%), and lithic fragments, several of which are zeolite-cemented. Some sandstone is graded and contains abundant benthic foraminifers. The sandstone occurs in Cores 27 to 32 (250–300 m), an interval in which many reworked nannofossils were found. A coarse sand of feldspar, altered volcanic rock fragments, glauconite, and basaltic hornblende occurs in Core 43 above basalt basement.

Cores 36 to 39 (330–368.5 m) above the diabase sill contain layers of partially altered vitric and pumiceous tuff, many of which have graded bedding, sharp basal contacts (some with load structures), and gradational upper boundaries. The tuff is bluish gray to dark gray and contains fine silt- to clay-size particles. The thickest tuff layer is 3 meters thick. In general, the tuff is partially altered to green smectite. Some beds contain abundant vitric ash. Dispersed ash is also common in the sediment up to 50 meters above the depth at which the first tuff occurs.

Core 33 contains a volcaniclastic breccia. Two breccia sequences are present. The lower sequence is a breccia of pebble-size fragments of angular basalt, andesite, pumice, and volcanic glass. The clasts also include a few rounded sandstone and limestone pebbles and some rounded, green pebbles that are foliated. Other fragments include mollusk and bryozoan debris. The size of the clasts decreases upward. The matrix of the lower breccia is a siliceous (opal-CT) silty claystone with benthic foraminifers, silt-size angular quartz and feldspar, and a few planktonic foraminifers. The upper breccia sequence is coarse-grained and graded. Most clasts are coarse sand-size, and there are layers of lapilli-size pumice. Clasts include partially altered pumice, volcanic rock fragments, lithic fragments, benthic foraminifers, glauconite, and shell debris. The upper sequence is poorly cemented with opal-CT.

Unit 4: Iron-rich Clay (390.7–390.8 m)

Unit 4 consists of metalliferous sediment. The sediment is a red brown, dolomitic iron-rich clay with a few nannofossils. It contains X-ray amorphous iron-rich material and traces of hematite. Although only a small amount of this sediment was recovered from above the basalt, pieces of red brown lithified metalliferous sediment (Section 469-45-1 [Pieces 7a, b, c and d]) were recovered within the basalt, and the upper 30 meters of basalt contain chert and limestone intercalations as well as numerous veins filled with red brown jasper.

Igneous Rocks

The igneous sequence at Site 469 includes an 18.5-meter-thick diabase sill separated from underlying basaltic rocks by about 5 meters of clayey nannofossil chalk and iron-rich clay (Fig. 8). The diabase is dark green, fine- to medium-grained, and, except near its contacts, is texturally and compositionally uniform throughout. The mineralogic constituents of this diabase include plagioclase, clinopyroxene, brownish green clay, opaque minerals, calcite, zeolites, talc, quartz, and amphibole, in decreasing order of abundance. Intersertal to intergranular textures predominate. Plagioclases are strongly zoned, with labradorite cores and andesine rims. Clinopyroxenes are mostly pale green in plane light; several that have faint pink tints may be titaniferous. In addition, rare, brownish green, pleochroic clinopyroxenes also occur (Sample 469-42-1, 10–14 cm); these have large $X \wedge C$ extinction angles and are probably an iron-rich variety. Brownish green smectite is the most common alteration mineral in the diabase, occurring macroscopically as thin patches or layers and microscopically filling interstices between plagioclase laths and equant pyroxenes. Additional but minor alteration minerals include calcite, talc, mica, amphibole, and an unidentified zeolite.

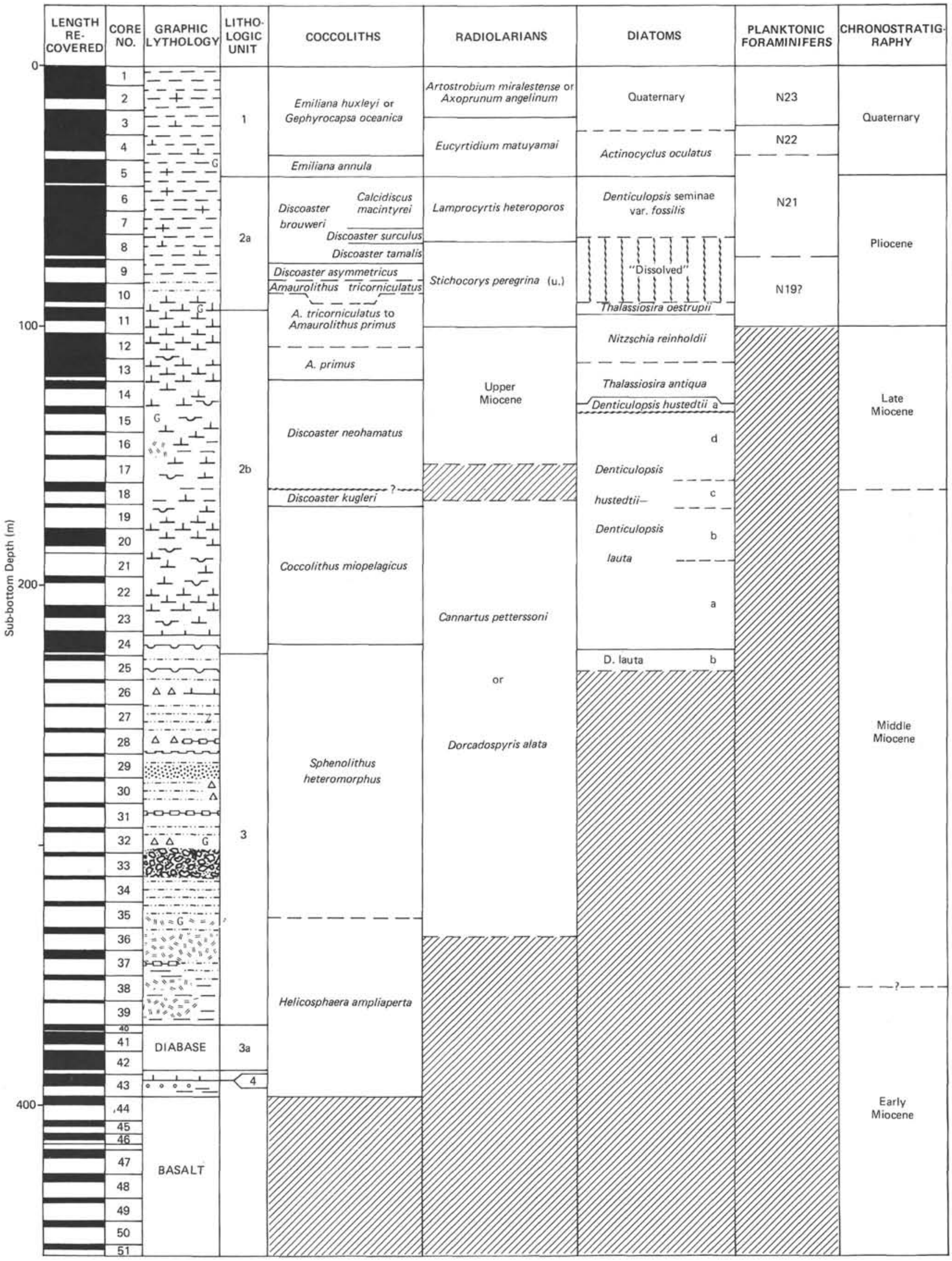

Figure 7. Lithologic and biostratigraphic summary, Site 469.

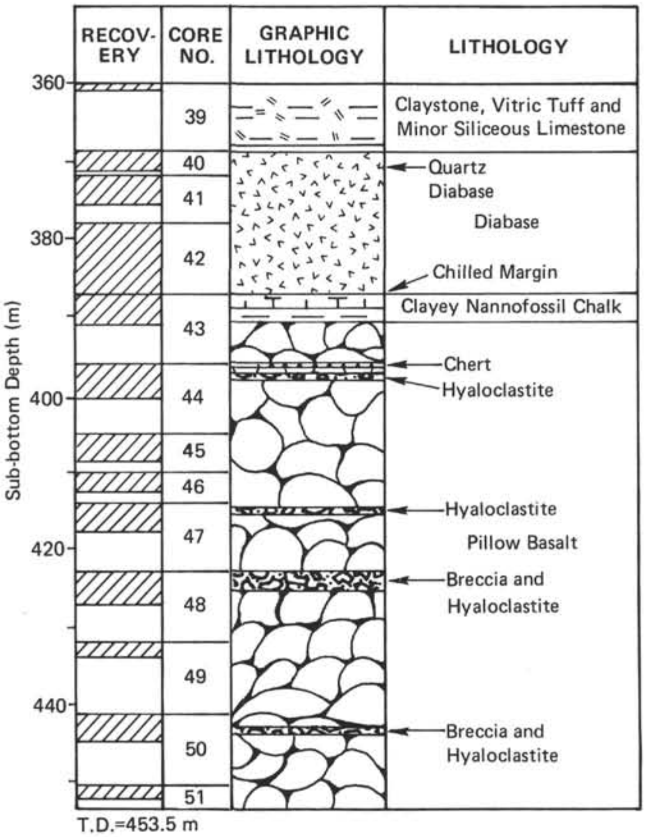

Figure 8. Igneous rock sequence at Site 469.

Interstitial quartz occurs near the top of the sill, suggesting slight differentiation. Grain-size decreases toward the chilled basal contact of the diabase. The diabase changes to aphyric basalt at this chilled contact and consists of skeletal plagioclase microlites, opaque minerals, and trace amounts of clinopyroxene with abundant greenish brown smectite. The texture is subvariolitic.

The basaltic rocks recovered from the basal 62.7 meters at Site 469 include pillow basalts, basaltic breccias, and hyaloclastites. The pillow basalts are gray to dark gray, slightly vesicular, and moderately altered, particularly along common calcite- and green smectite-filled fractures. Most are aphyric with occasional glassy margins (Core 46); some are porphyritic with skeletal microphenocrysts of plagioclase or of plagioclase and clinopyroxene with well developed quench morphology. The plagioclase microphenocrysts are either normally zoned or have homogeneous labradoritic cores enclosed by thin, more sodic rims. Talc-smectite-magnetite pseudomorphs of olivine microphenocrysts occur rarely in these basalts (e.g., Section 43-3, 73 cm). Microscopic textures of these rocks vary from holohyaline to hyalopilitic intersertal and are locally subvariolitic or variolitic.

Angular basalt fragments that are texturally and compositionally similar to the pillow basalts are the major constituents of the basaltic breccias at this site. Clast size ranges from 0.5 to 3.0 cm, and they are most frequently cemented together by calcite or set in a matrix of green smectite. Hyaloclastites occur with these basaltic breccias. Although fresh, brown basaltic glass is still present in some of these hyaloclastites, most consist wholly of green smectite with subordinate calcite cement. These rocks are extremely soft and easily scratched with the fingernail. Shardlike textures and the occasional preservation of brown basaltic glass suggest that these hyaloclastites are alteration products of basaltic glass. The hyaloclastites and basaltic breccias are more common in the lower half of this basaltic sequence.

BIOSTRATIGRAPHY

Upper Quaternary through upper lower Miocene sediment was recovered at Site 469. Coccoliths deposited in the late early Miocene occur in Core 43 in the lower *Helicosphaera ampliaperta* Zone immediately above the basement; radiolarians of probably the same age (*Calocycletta costata* Zone) are present in Sample 469-38,CC. The possibility cannot be excluded, however, that the lower Miocene radiolarians of Core 38 are reworked. Coccoliths, diatoms, and radiolarians generally provide good biostratigraphic zonation of the interval from Cores 1 through 25 (Quaternary through lower middle Miocene). Planktonic foraminifers are abundant in the first nine cores but sparse or absent in the remaining cores. Siliceous microfossils are scarce just below Sample 469-25,CC, yielding only sporadic biostratigraphic data, whereas coccoliths continue downsection (Fig. 9). The oldest sediment of Site 469, intercalated in basalt of Core 45, yielded upper lower Miocene coccoliths.

The Quaternary/Pliocene boundary occurs in Core 5, and the Pliocene/Miocene boundary is placed between Cores 11 and 12. The upper Miocene/middle Miocene boundary occurs between Cores 17 and 19. Placement of the middle Miocene/lower Miocene boundary is uncertain. It could possibly fall within the interval between Cores 38 and 43. Figure 7 summarizes zone assignments for Site 469.

Coccoliths

At Site 469, lower Miocene to upper Quaternary coccolith assemblages are typically abundant, diverse (6 to 12 species recorded for shipboard biostratigraphy), and moderately well preserved. Lower upper Miocene warm-water discoasters—*Discoaster bellus* Bukry and Percival, *D. loeblichii* Bukry, *D. neohamatus* Bukry and Bramlette, and *D. pentaradiatus* Tan—in Cores 13 to 17 distinguish the Site 469 assemblages from cooler-water, less diverse upper Miocene assemblages at Site 467. Although the upper Miocene record is less complete at nearby Site 468, the correlative assemblages are similar to those at Site 469 for the upper Miocene, suggesting a similar oceanographic environment.

Reworked Eocene or Oligocene coccoliths provide evidence of the amount and duration of erosion in the vicinity of Site 469. Displaced Eocene and Oligocene species are sparse in middle and lower Miocene Cores 27, 32 to 39, and 43, common in middle Miocene Cores 28 to 31, and absent in Quaternary to middle Miocene Cores 1 to 26. This distribution is in contrast to Site 467,

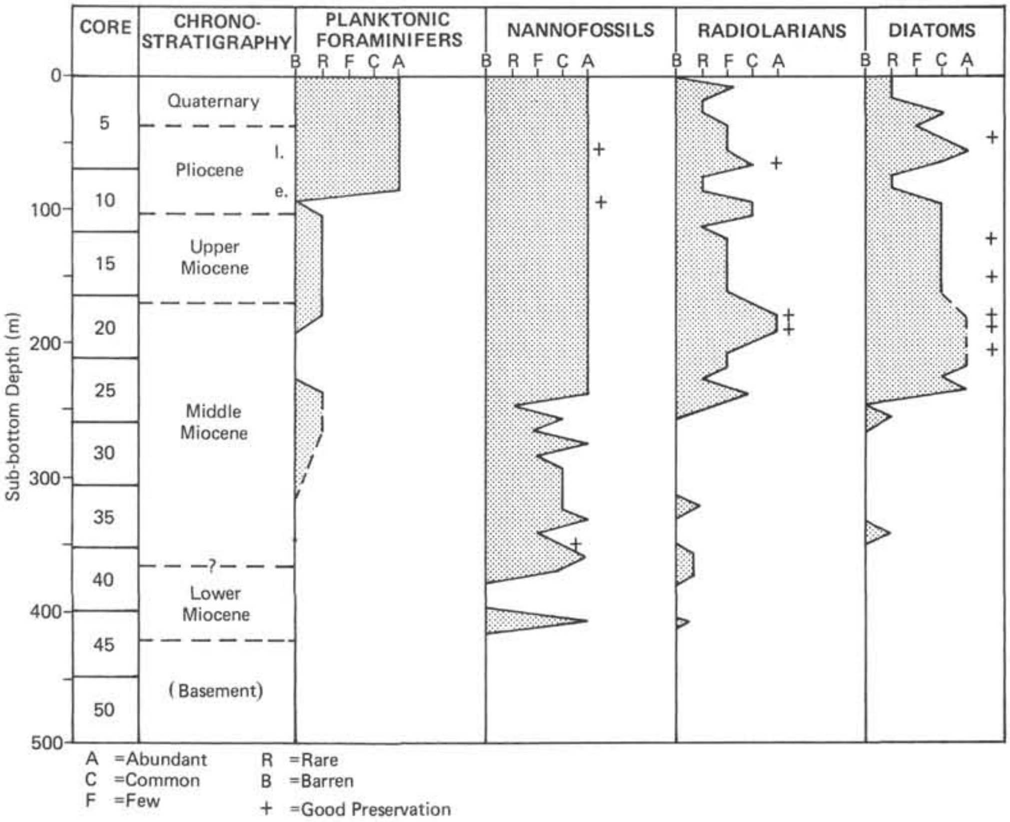

Figure 9. Plots of relative abundances of planktonic microfossils, Site 469.

where reworked Eocene and Oligocene specimens are recorded only from the Pliocene and Quaternary.

The oldest coccoliths from Site 469 are sparse, moderately preserved specimens from a baked, reddish, metalliferous sediment intercalated with basalt in Core 45. A smear slide from Sample 469-45-1, 90–93 cm, contains *Helicosphaera carteri*, which indicates deposition in the early Miocene or later. The oldest sediment above basalt—in Core 43—is assigned to the lower part of the *Helicosphaera ampliaperta* Zone, considered to be upper lower Miocene (Bukry, 1975). An overlap between *Sphenolithus heteromorphus* and *Triquetrorhabdulus milowii* is used to identify the lower part of the *H. ampliaperta* Zone (Bukry, 1971) in Core 43.

A diabase sill in Cores 40 to 42 (368.5 to 387 m) is within the *H. ampliaperta* Zone (approximately 15.5–17.5 m.y.). *S. heteromorphus* Zone (approximately 14–15.5 m.y.) assemblages range from Core 24 to Core 35, providing evidence for a high rate of sedimentation for the middle Miocene. However, four cores from the interval contain sandy sediments with reworked Eocene or Oligocene coccoliths, such as *Chiasmolithus grandis* (Bramlette and Riedel), *Dictyococcites bisectus* (Hay, Mohler, and Wade), *Discoaster barbadiensis* Tan, and *Reticulofenestra umbilica* (Levin).

The middle Miocene *Discoaster exilis* Zone of Core 19 is separated from the upper Miocene *Discoaster neohamatus* Zone (7 to 11 m.y.) in Core 17 by a probable unconformity. After encountering a "sand" during the cutting of Core 18, there was difficulty in retrieving the core barrel. It is apparent from the mixed colors and upper Miocene chronostratigraphy of the pea-sized drill cuttings constituting Core 18 that some contamination occurred. *Discoaster* sp. aff. *D. kugleri* Martini and Bramlette occurs in Core 19 in the upper part of the *D. exilis* Zone. This is the third consecutive site of Leg 63 where short-ranged *D. kugleri* has provided correlation: the other occurrences are in Core 90 at Site 467 and Core 3 at Hole 468B.

Discoaster neohamatus Bukry and Bramlette s. str. is present in Core 15 and represents the northernmost record of this tropical and subtropical species in the eastern Pacific. The *D. neohamatus* Zone—also identified by the use of *D. bellus, D. brouweri* Tan, *D. loeblichii, D. prepentaradiatus* Bukry and Percival, and *Minylitha convallis* Bukry—ranges from Core 14 to Core 17 (121.5 to 159.5 m). Silicoflagellates are especially common and diverse in this interval, suggesting fertile and variable oceanographic conditions.

A paucity of *Ceratolithus, Discoaster quinqueramus* Gartner, and *Triquetrorhabdulus rugosus* Bramlette and Wilcoxon precludes precise placement of the Miocene/Pliocene boundary. *Amaurolithus primus* (Bukry and Percival) ranges through the interval in Cores 10 and 13 and indicates the *Amaurolithus primus* Subzone or *Amaurolithus tricorniculatus* Zone.

The upper nine cores contain a seemingly incomplete upper Pliocene and Quaternary coccolith succession, although the recovered sediment commonly is disturbed by drilling operations. *Discoaster* and *Gephyrocapsa* are sufficiently diverse to permit recognition of low-latitude subzones. However, cool-water *Coccolithus pelagicus* is present throughout the Quaternary and Pliocene and warm-water *Ceratolithus* occurs only at the top of the interval, in the upper *Emiliania ovata* Subzone of Core 3 and in Pliocene Cores 6 and 9. This contrasts with the occurrences of these taxa at the southern end of the California Current in the coring area of DSDP Leg 54 (Bukry, 1980).

Silicoflagellates

Silicoflagellates are well preserved at Site 469 but are common in only a few cores, such as middle Miocene Core 25 and upper Miocene Cores 13 to 17. Middle Miocene Cores 26 to 43 are barren, and silicoflagellates in Pliocene and Quaternary Cores 1 to 9 are sparse.

Taxa indicative of high-, mid-, and low-latitude silicoflagellate zones occur in the richly diversified upper Miocene assemblages of Cores 13 to 17 (112–159.5 m). For example, a count of 200 specimens for Sample 469-15,CC shows *Dictyocha brevispina* (Lemmermann) and *D. pulchella* Bukry predominant over *Dictyocha* sp. (fibuloid) by 8% to 1%; this suggest the low-latitude *Dictyocha brevispina* Zone (Martini, 1971; Bukry and Foster, 1973). *Distephanus pseudocrux* (Schulz) and *D. pseudofibula* (Schulz) total 8% of the population and indicate affinities to the mid-latitude *Distephanus pseudofibula* Zone (Bukry, 1973). Finally, the occurrence in the same sample of 53% *Distephanus speculum speculum* (Ehrenberg), 4% *D. speculum minutus* Bachmann, 4% *D. speculum* s. ampl. (large), 6% *Mesocena circulus* (Ehrenberg), 6% *M. diodon borderlandensis* n. subsp., and 1% *M. diodon nodosa* Bukry indicates the high-latitude *Mesocena circulus* Subzone of the *Distephanus speculum speculum* Zone (Bukry, 1975).

Radiolarians

Abundant to rare middle Miocene through Quaternary radiolarians of poor to good preservation were recovered from Cores 1 through 25 of Site 469. Very rare and poorly preserved lower middle Miocene radiolarians occur sporadically in Cores 30, 35, 36, and 38 above the basement. The dissolved remains of siliceous microfossils in some cores of the lower middle Miocene section at Site 469 suggest that the absence of radiolarians in that region is due to diagenesis rather than to the primary lack of siliceous skeletons.

The Quaternary sediments of Hole 469 yielded radiolarian assemblages containing northeastern Pacific cold-water species as well as less numerous equatorial warm-water species, and Kling's (1973) zonation is applicable. Cores 1 through 3, Section 1 can be assigned to the upper Pleistocene *Axoprunum angelinum* Zone, as indicated by the rare to abundant presence of *Lamprocyrtis haysi* and *L. neoheteroporos* and the absence of *Eucyrtidium matuyamai* and *Lamprocyrtis heteroporos*. The upper Pleistocene interval contains sporadic older radiolarians, such as different species of *Cyrtocapsella, E. matuyamai, L. heteroporos*, and *Stichocorys peregrina*, which must be reworked. Characterized by the rare to common occurrence of *E. matuyamai,* and *L. neoheteroporos* in the upper part, and *L. heteroporos* in the lowermost part, Section 3-2 through Section 5-5 can be placed in the lower Pleistocene *E. matuyamai* Zone.

The presence of few to abundant specimens of *L. heteroporos* and the absence of *E. matuyamai* and *Stichocorys peregrina* indicate the upper Pliocene (*L. heteroporos* Zone) for Sample 469-5,CC through Section 8-1. The association of common to abundant individuals of *L. heteroporos* and rare to common occurrences of *S. peregrina* suggest that Section 8-3 through through Sample 469-11,CC (*S. peregrina* Zone, upper part) were deposited in the early Pliocene. The boundary between Miocene and Pliocene is marked by the sudden and abundant appearance of *L. heteroporos*.

The upper Miocene comprises Section 12-1 through Sample 469-17,CC. The fact that all of this interval contains few to abundant *S. peregrina* but lacks *Ommatartus antepenultimus* and (except for Sample 469-17,CC) *O. penultimus* suggests that the lower part of the upper Miocene succession (*O. antepenultimus* and *O. penultimus* Zones) is partly or totally missing at Hole 469.

Cannartus pettersoni was not found below Core 17. This indicates that the upper middle Miocene *C. petterssoni* Zone is either not represented by sediments or is condensed. Cores 19 through 30 are distinguished by the presence of *Cannartus laticonus, C. mammiferus*, and various species of *Cyrtocapsella, Stichocorys delmontensis, S. wolfii* a.o., which suggest the lower middle Miocene (*Dorcadospyris alata* Zone). The poor assemblages gained from Cores 32 through 36 were probably deposited in the early middle Miocene. As to the ages of Cores 38 and 39, a definite conclusion cannot be drawn. Sample 469-38,CC yields *Cyrtocapsella tetrapera* and *Cannartus violina*. Available evidence suggests that *C. violina* is restricted to the lower Miocene. Consequently, it follows that Samples 469-38,CC and 469-39,CC are either lower middle Miocene, with *C. violina* being reworked, or upper lower Miocene, with *C. violina* as an autochthonous fossil.

According to the radiolarian zonation, the Quaternary and Pliocene seem to be entirely represented at Site 469, perhaps with the exception of the upper Quaternary *Artostrobium miralestense* Zone. Upper and middle Miocene, however, seem to be only incompletely represented by sediments, because the assemblages with *O. penultimus, O. antepenultimus*, and *C. petterssoni* are partly or totally missing. The Pliocene and Quaternary radiolarian zones introduced by Kling (1973) are restricted to the cold-water regions of the North Pacific; they are associated with few specimens of equatorial species in Cores 1 through 8 at Site 469, such as the Pliocene–Quaternary species *Amphirhopalum ypsilon, Ommatartus tetrathalamus, Spongaster tetras*, and *Theocorythium vetulum*. The lower Pliocene and Miocene assemblages are mostly warm-water species, the number of which decreases from Miocene toward the lower Pliocene. The total lack of the equatorial lower middle Miocene *Dorcadospyris alata* may be considered an indicator of cold-water influence.

Diatoms

Abundant to few diatoms occur in the middle Miocene through lower Quaternary sediments at Site 469. Preservation is good to moderate, and the assemblages can readily be zoned.

Samples 469-3,CC through 469-5-5, 70–72 cm are placed in the lower Quaternary *Actinocyclus oculatus* Zone. The presence of *Rhizosolenia matuyamai* in Sample 469-3,CC indicates an age of about 0.93 to 1.0 m.y. (Burckle et al., in press). Deposition in the early Quaternary is supported by the occurrence of *Nitzschia reinholdii* and *Thalassiosira plicata* and the silicoflagellate *Mesocena quadrangula* in the same sample.

Samples 469-5,CC through 469-7,CC are correlated with the upper Pliocene *Denticula seminae* var. *fossilis* Zone on the basis of the presence of *Thalassiosira antiqua* and *Denticula seminae* var. *fossilis* without *Denticula kamtschatica*.

Core 8 through 10 contain rare diatoms that are mostly reworked from the middle Miocene. This interval apparently corresponds with the middle and lower parts of the Pliocene at nearby Site 467, in which diatoms are also rare.

The lower Pliocene *Thalassiosira oestrupii* Zone is represented in Samples 469-11-1, 40–42 cm and 469-11-3, 40–42 cm. The underlying interval from Sample 469-11,CC through Sample 469-13-1, 40–42 cm is assigned to the *Nitzschia reinholdii* Zone, which is mostly upper Miocene. The Miocene/Pliocene boundary is tentatively placed between Cores 11 and 12.

The interval from Sample 469-13-2, 40–42 cm through Sample 469-15-1, 40–42 cm correlates with the upper Miocene *Thalassiosira antiqua* Zone. A possible hiatus separates this zone from the overlying *N. reinholdii* Zone in the upper part of Core 13.

The presence of *Nitzschia porteri* and *Thalassionema hirosakiensis* without younger diatoms in Sample 469-13-2, 40–42 cm indicates an age no younger than about 7.0 m.y. Immediately above, in Sample 469-13-1, 40–42 cm, *Thalassiosira miocenica* indicates an age no older than about 6.0 m.y.

Sample 469-15-2, 40–42 cm contains *Thalassiosira burckliana* without *T. antiqua* and correlates with the upper part of Subzone a of the *Denticula hustedtii* Zone. Sample 469-15,CC contains *Denticula dimorpha, D. lauta*, and *Lithodesmium reynoldsii* and is placed in the *Denticula hustedtii–D. lauta* Zone. The lower part of the *D. hustedtii* Zone appears to have been removed from the interval between these two samples. Glauconitic sand in Section 15-2 is supportive of a hiatus.

The interval from Sample 469-15,CC through Sample 469-24-5, 90–92 cm is assigned to the *Denticula hustedtii–D. lauta* Zone. This interval can be further subdivided into the following subzones: Subzone d (Samples 469-15,CC through 469-17,CC); Subzone c (Sample 469-19-1, 40–42 cm, with Sample 469-19,CC tentatively assigned to this Subzone); Subzone b (Samples 469-20-1, 120–122 cm through 469-20,CC); and Subzone a (Samples 469-22-1, 142–144 cm through 469-24-5, 90–92 cm). Core 18 contains drilling breccia, which represents downhole contamination, and Core 21 contains no sediment. The middle Miocene/upper Miocene boundary is placed in the interval of Core 18 (159.5 to 169 m).

Samples 469-24-6, 82–84 cm through 469-25,CC are correlated with the lower middle Miocene *Denticula lauta* Zone (Subzone b). Diagenetic alteration below this interval removes all but the robust, dissolution-resistant diatoms, so that biostratigraphic subdivision is not possible.

The Quaternary through upper Miocene section at Site 469 (Cores 1–17) contains consistent reworked middle Miocene diatoms. The middle Miocene (Cores 19–25) is almost completely free of reworked diatoms.

Foraminifers

Planktonic foraminifers are abundant in the first nine cores but sparse or absent in the remaining sediment cores recovered at Site 469. Planktonic foraminifer assemblages in all samples show some signs of dissolution.

Globigerina bulloides, Orbulina universa, Globorotalia inflata, and *Neogloboquadrina pachyderma* (s.s.) are common members of the assemblages in Cores 1 through 4, which are assigned to the Quaternary on the basis of nannofossil and diatom data. Abundant representatives of *Neogloboquadrina humerosa* and *N. atlantica* with *Globorotalia inflata* in Cores 5 through 7 suggest that this interval was deposited during the late Pliocene (Zone N21), whereas the occurrence of *Globorotalia puncticulata* in Cores 9 through 11 places these cores in Zone N19. Sparse, poorly preserved planktonic foraminifers encountered below Core 11 are not age diagnostic.

Benthic foraminifers are common in the first 14 cores of Hole 469. Bathyal water depths are indicated by the consistent occurrence of *Pullenia bulloides* and *Uvigerina senticosa*, however, displaced specimens from shallower depths are usually present. Benthic foraminifers are generally sparse and poorly preserved in samples examined from below Core 14.

SEDIMENT ACCUMULATION RATES

The sediment accumulation rate curve (Fig. 10) for Site 469 was constructed from selected diatom (D), radiolarian (R), and coccolith (C) events. The curve shows rates of about 25 m/m.y. for the Quaternary and late Pliocene, 10 m/m.y. for the early Pliocene into the middle Miocene, 30 m/m.y. for the early middle Miocene, and 60 m/m.y. for the early Miocene of Site 469. We detected no significant time gaps in this section.

GEOCHEMICAL MEASUREMENTS

Interstitial Water

Interstitial water was extracted from seven Site 469 samples from 9 to 395 meters sub-bottom depth. The *p*H, salinity, chlorinity, alkalinity, and calcium and magnesium concentrations of the pore water were determined on board using the technique described by Gieskes (1974), with minor modifications. The results are

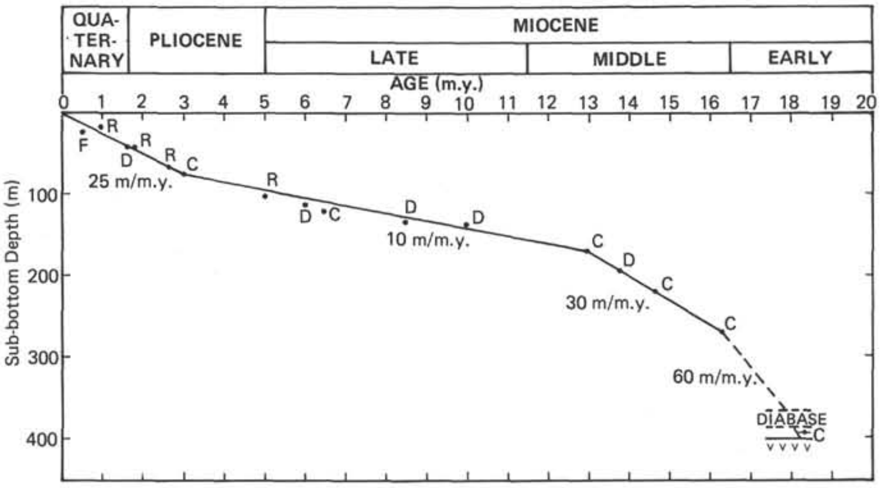

Figure 10. Sediment accumulation rates, Site 469.

shown in Figure 11. Except for the sample at 395 meters depth, calcium and magnesium are well correlated. The concentration versus depth profiles suggest that the gradients in calcium and magnesium are essentially diffusional (McDuff and Gieskes, 1976) and probably result from reactions occurring in the underlying basalt.

Calcium Carbonate Content

The calcium carbonate concentration in samples from Site 469 was determined on board by the carbonate bomb technique. The results of these determinations are included in the core descriptions in this chapter and plotted in Figure 12. The calcium carbonate contents reflect, in a general way, the lithology of the sedimentary units. The calcium carbonate content of the hemipelagic clays of Unit 1 is less than 30%; that of the Unit 2 oozes ranges from 14% to 82%, depending on the proportion of foraminifers and nannofossils in the biogenic ooze. Below 225 meters sub-bottom depth, sediments are moderately to well indurated and are rich in terrigenous detritus. The carbonate content measured in these sediments is very low (2%–11%), but this measurement is probably biased, because the low-carbonate-content silty clay, silt, and sand were less well indurated and therefore easier to sample for carbonate than were the indurated porcellanite, chalk, and limestone. Thin sections of limestone and porcellaneous chalk from this interval contain about 50% microcrystalline calcite. Sediments in the lower part of Unit 3 have structures similar to those in some of the porcellanites and chalky limestones at shallower depths in the unit and contain 23% to 75% $CaCO_3$.

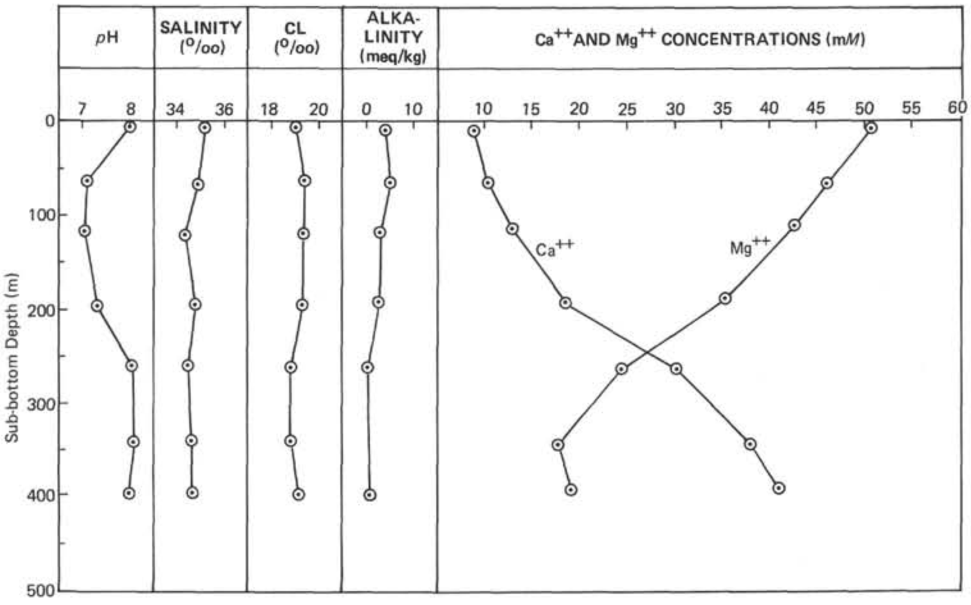

Figure 11. Interstitial water profiles, Site 469.

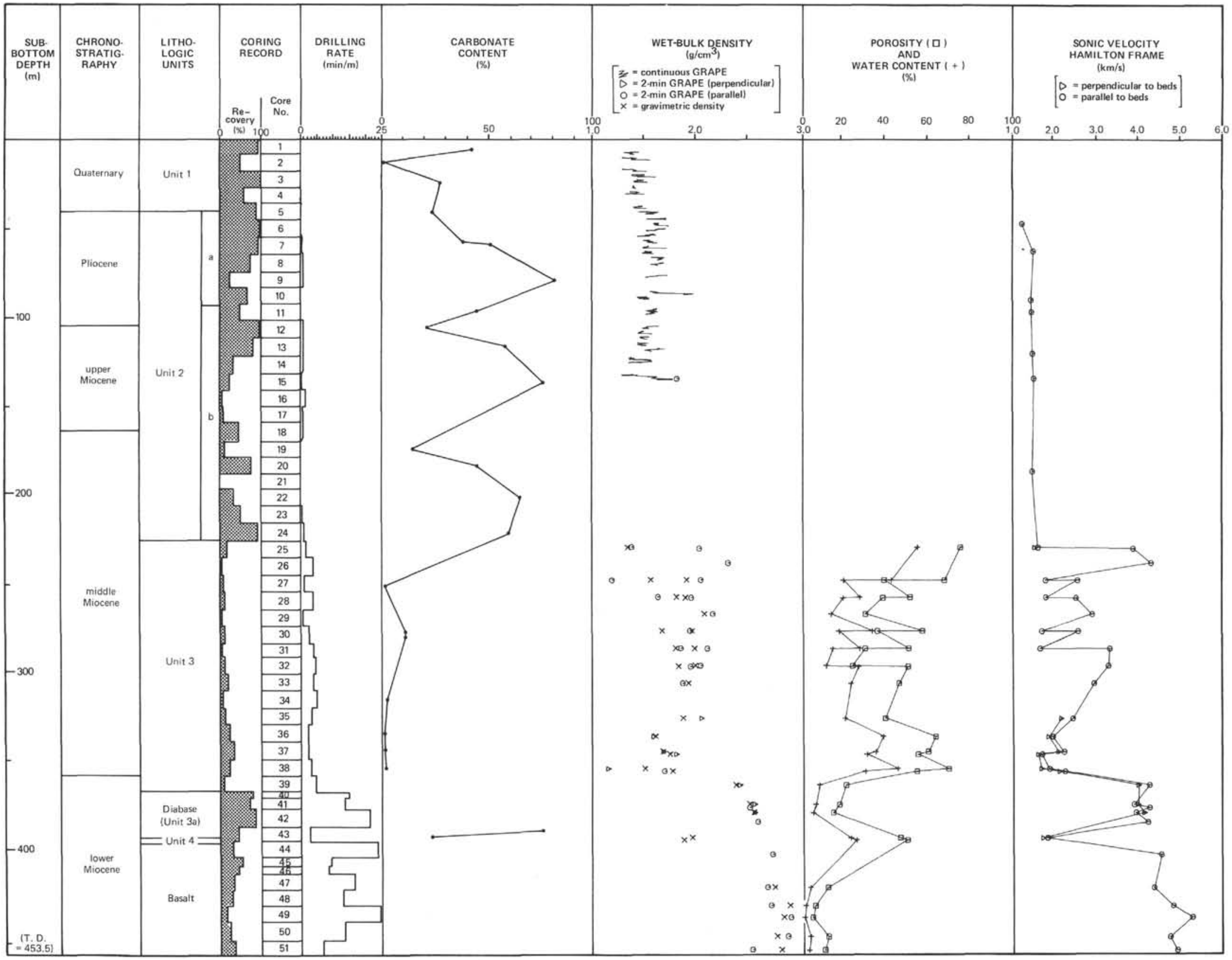

Figure 12. Summary of physical properties, Site 469.

PHYSICAL PROPERTIES

Figure 12 summarizes the physical-properties data at Site 469. The density and sonic velocity of the upper 227 meters of soft clay and nannofossil ooze at Site 469 are nearly constant, averaging 1.60 g/cm^3 and 1.50 km/s, respectively. Near the base of this interval (Core 23, ~210 m), the sediments become slightly more indurated, as indicated by a subtle increase in both density and velocity. A marked increase in both of these parameters at 228 meters corresponds to the shallowest, well indurated (cemented?) calcareous porcellanite (opal-CT). Similar layers of porcellanite alternate with less dense silty claystone in the subjacent interval (228-302 m). This alternation readily explains the variability in the density and velocity profiles at these depths. The density and velocity values of the silica-cemented, graded breccia at the base of this interval (~302 meters, Core 33) resemble the average values for the overlying porcellanite. In contrast, the underlying zone of interbedded claystone and tuff (302-365 m) has density and velocity values indistinguishable from the overlying silty claystone.

A sharp contrast in density and velocity occurs at about 369 meters (base of Core 39), corresponding to a lithologic change from tuff and claystone to a hard, dense siliceous dolomite (Sample 469-39,CC); densities increase from about 1.72 g/cm^3 to 2.57 g/cm^3, respectively, and velocities from 2.11 km/s to 4.09 km/s, respectively. We recovered only a small piece of this dolomite. It is immediately underlain by a diabase sill(?) 18.5 meters thick. The velocity and density of this igneous unit are identical to those of the dolomite, perhaps reflecting thermal alteration of the carbonate.

A low density and velocity interval consisting of nannofossil chalk underlies the diabase. This reversal in density and velocity is followed by another distinct increase in these two parameters corresponding to underlying basalts and altered hyaloclastites. The basalts have an average density of 2.75 g/cm^3 and a sonic velocity of 4.81 km/s. The altered hyaloclastites have a lower density, about 2.3 g/cm^3 (from continuous GRAPE); we made no velocity measurements of these altered rocks. Porosity and water content vary inversely with density throughout the section at Site 469.

Table 3 presents average density and velocity values; on the basis of these values, the impedance contrasts for boundaries between successive lithologies are:

Lithologies	Impedance Contrast
Clay and nannofossil ooze overlying porcellanite	0.49
Porcellanite versus interbedded claystone	0.33
Claystone and tuff overlying diabase	0.49
Nannofossil chalk overlying basalt	0.59

These impedance contrasts suggest that at least three strong reflectors may be detected on seismic profiles: the tops of the porcellanite, diabase, and basalt. In addition, reflectors within the unit of interbedded porcellanite and claystone might also be expected.

Table 3. Average densities and velocities of lithologies recovered at Site 469.

Lithology	Depth Interval (m)	Density (g/cm^3)		Velocity (km/s)	
		Range	Average	Range	Average
Clay and nannofossil ooze	0-228	1.40-1.83	1.60	1.26-1.64	1.50
Calcareous porcellanites	228-302	1.97-2.32	2.11	2.56-4.33	3.28
Silty claystone	238-302	1.59-2.04	1.84	1.64-2.58	1.90
Claystone and tuff	302-365	1.53-2.07	1.72	1.74-2.47	2.11
Dolerite	370-387	2.52-2.60	2.57	3.93-4.18	4.09
Nannofossil chalk	387-390	—	1.80	—	1.88
Basalt[a]	391-T.D.	2.55-2.91	2.75	4.40-5.31	4.81

[a] These data include no measurements of the altered hyaloclastite intercalated with basalt, so the true average velocity of the basalt unit that would be determined from seismic data or from logging information may be lower than given here.

We made only one measurement of shear strength in the sediments recovered at this site. The value is 229 mbar for Core 15 (at a sub-bottom depth of 133 m), a nannofossil ooze. This value is well below Bouma and Moore's (1975) curve relating unconfined shear strength to depth of burial for carbonate ooze; it bears a closer resemblance to their strength values for silty and clayey sand.

The physical-properties data at Site 469 clearly reflect the increase in lithification of sediments at about 210 meters. In addition, abrupt increases in density and porosity occur at about 228 meters, corresponding to the shallowest calcareous porcellanite. Although this layer occurs within the zone of increasing mechanical compaction, it signals the onset of silica diagenesis (i.e., the dissolution of diatom and radiolarian tests and precipitation of the silica as opal-CT). Both groups of siliceous microfossils are absent below about 225 meters. This process cements the sediment and increases its density and velocity. The fluctuations of the density and velocity profiles between 228 and 295 meters apparently reflect variations in the degree of silicification. A diabase sill capped by a siliceous dolomite corresponds to the next sharp increase in density and velocity. Below this is a low density and velocity interval of nannofossil chalk occurs, followed by underlying basalt having high density and velocity. Impedance contrasts of 0.5 to 0.6 indicate that the tops of the porcellanite, diabase, and basalt should be excellent seismic reflectors.

CORRELATION OF REFLECTION PROFILE WITH DRILLING RESULTS

The acoustic stratigraphy in the vicinity of Site 469 is shown on the seismic-reflection profile obtained by the *Glomar Challenger* (Fig. 6). Four distinguishable sequences of reflectors are seen on this record:

1) A sequence of strong, widely spaced, and persistent reflectors about 0.14 s thick at the top of the cored interval.

2) A sequence of closely spaced, very persistent reflectors about 0.06 s thick.

3) Strong, widely spaced reflectors about 0.095 s thick that are similar to the upper sequence of reflectors.

4) A zone of indistinct, discontinuous reflectors about 0.145 s thick.

5) A strong reflector at 0.44 s at the base of the zone of indistinct reflectors.

This sequence of acoustistratigraphic units at Site 469 inferred from the seismic profile is shown in Figure 13. The upper sequence of widely spaced reflectors correlates with Lithologic Units 1, Sub-unit 2a and uppermost Sub-unit 2b, which chiefly consist of Quaternary to upper Miocene clays. The very persistent and closely spaced reflectors correlate with the nannofossil ooze of the rest of Lithologic Sub-unit 2b. The change from closely spaced reflectors in this unit to widely spaced reflectors in the underlying unit at about 0.2 s is correlated with a hiatus in the upper Miocene section. Below this, the indistinct set of reflectors correlates with the change from predominantly pelagic and hemipelagic sediments to the clastic and volcaniclastic sediments (silty claystone, volcanic breccia and sandstone, and tuff) of Lithologic Unit 3. The prominent reflector at 0.44 s is correlated with the diabase sill.

CONCLUSIONS

1. The paleontological age of basement at Site 469 is probably 17 to 18 m.y. and is clearly no older than 18.3 m.y. This is in agreement with the magnetic anomaly age at the site as predicted by Atwater (1970). The age of sediments intercalated between the diabase sill and the underlying pillow basalt cannot be distinguished from that of the sediments immediately overlying the diabase.

2. An altered, homogeneous diabase sill occurs at 368.5 to 387 meters depth. Evidence of its intrusive nature is the decrease in crystal size toward the base of the sill; the top of the unit was not recovered in cores. From 387 to 390.7 meters, the sill is underlain by nannofossil chalk, which is itself underlain by metalliferous sediment and lithified sediment. This is underlain by microcrystalline pillow basalt with altered glass fragments forming hyaloclastite. Fractures in the basalt contain jasper.

3. The lower part of the sedimentary section includes volcaniclastic rocks with graded bedding, parallel lami-

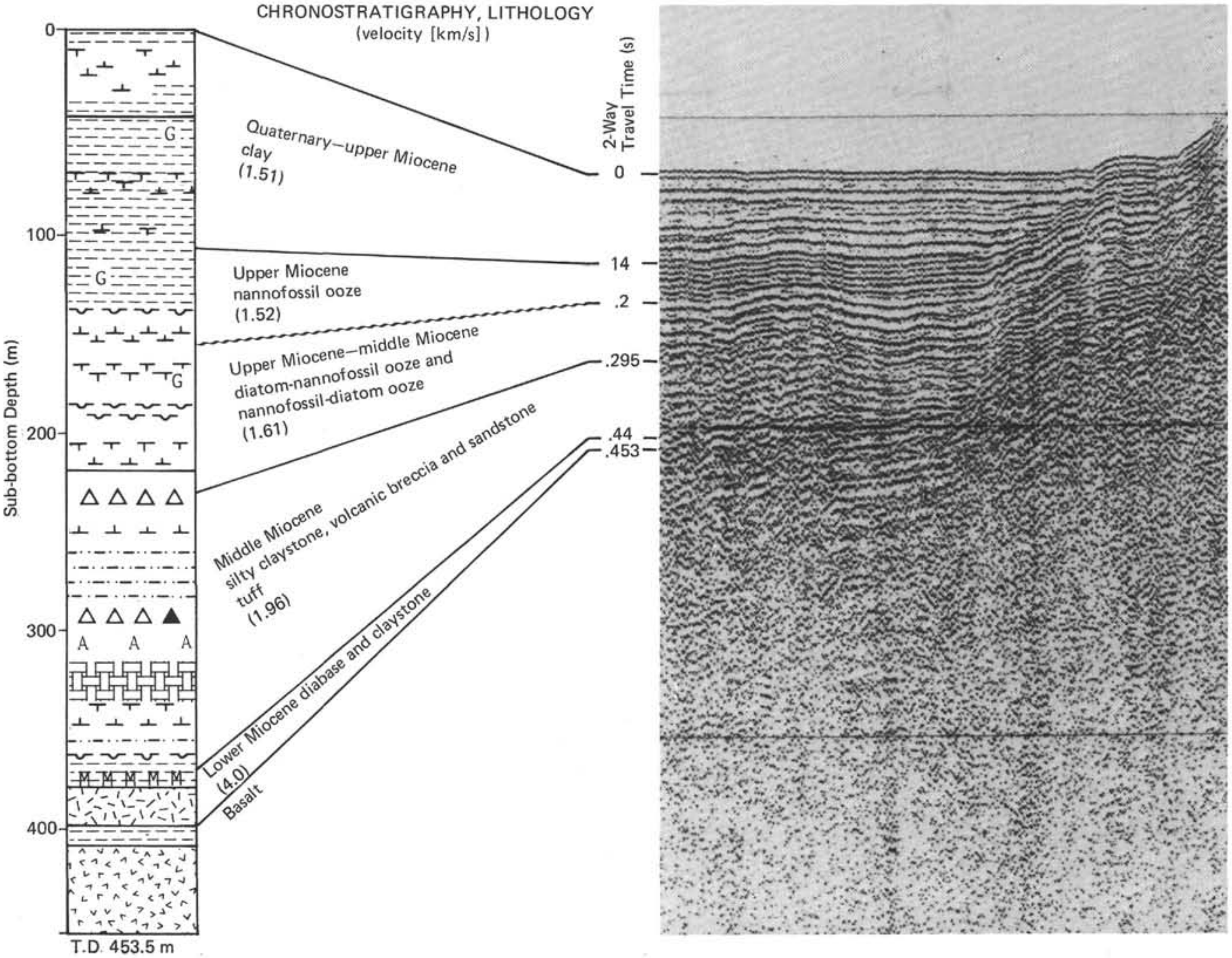

Figure 13. Correlation of *Glomar Challenger* reflection profile with lithologic units, Site 469.

nations, and scour marks; also present are reworked Eocene coccoliths, fragments of shallow-water mollusks, and glauconite. This many reflect uplift and subaerial erosion of the adjacent continental margin as it was met by the ancestral East Pacific Rise crest. The overlying sequence consists mainly of hemipelagic chalk and ooze, probably suggesting subsidence of the margin as the rise crest migrated south. This change is dated as occurring 13 to 15 m.y. ago, on the basis of changes in lithology (and about 13 m.y. on the basis of the decrease in the sedimentation rate upsection).

4. The volcaniclastic breccia is dominated by fragments of basalt and andesite. The volcaniclastic unit thickens eastward toward the continental slope and Site 468, as indicated by the seismic-reflection profiles. Similar volcaniclastic breccias at Site 468 on the upper continental slope suggest that Sites 468 and 469 were close to one another at the time of emplacement of the breccias.

5. The presence of opal-CT below Core 24 suggests that siliceous microfossils were present in the lower part of the hemipelagic sequence prior to diagenesis. Diagenetic trends at this site match similar depth- and temperature-controlled transformations at Sites 467, 468, 471, and 473.

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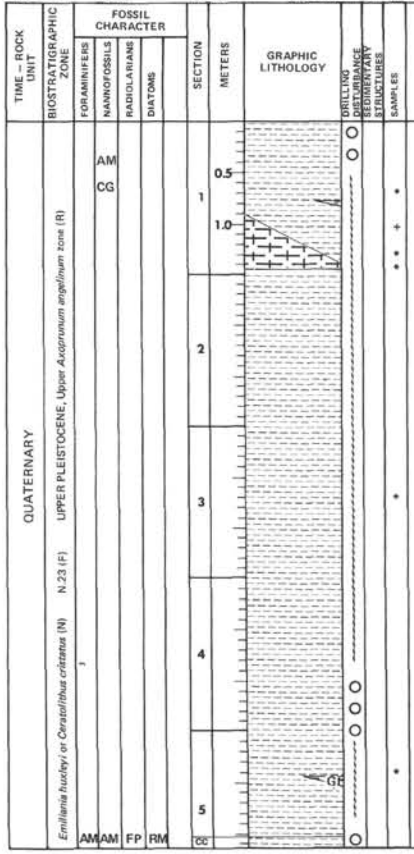
SITE 469 HOLE CORE 1 CORED INTERVAL 0.0–7.5 m



N5

Ash patch

5Y 6/4

N5

Patches of glauconitic foraminifer ooze

LITHOLOGIC DESCRIPTION

CLAY, medium gray (N5) to medium dark gray (N4), mixed by drilling with minor dusky yellow (5Y 6/4) to moderate olive brown (5Y 4/4) **NANNOFOSSIL FORAMINIFERAL OOZE.** Clay has mottled streaks of medium bluish gray **VITRIC ASH** in Sections 2–4. Patch of grayish black (N2) ash in Section 1 composed mostly of brown glass. Patches of **GLAUCONITIC FORAMINIFERAL OOZE** mixed with clay in Section 5.

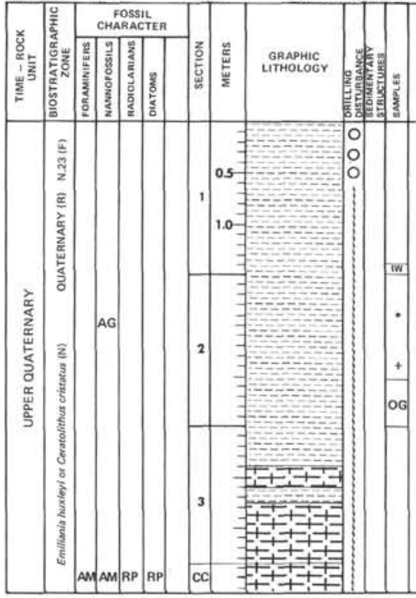
ORGANIC CARBON AND CARBONATE

	1-107
% Organic Carbon	–
% $CaCO_3$	43

SMEAR SLIDE SUMMARY

	1-78 (M)	1-136 (M)	1-148 (D)	3-77 (M)	5-42 (M)
TEXTURE:					
Sand	80	50	–	–	60
Silt	18	10	12	20	10
Clay	2	40	88	80	30
COMPOSITION:					
Quartz	–	3	6	8	6
Feldspar	–	TR	2	4	2
Mica	TR	TR	TR	1	1
Heavy minerals	2	TR	TR	TR	–
Clay	–	4	88	67	4
Volcanic glass	97	TR	TR	15	–
Glauconite	TR	3	TR	–	12
Pyrite	TR	–	TR	4	2
Carbonate unspec.	–	–	2	1	5
Foraminifers	–	60	–	–	50
Calc. Nannofossils	–	30	–	–	15
Diatoms	1	TR	TR	TR	1
Radiolarians	TR	TR	1	–	TR
Silicoflagellates	TR	TR	1	TR	1
Iron oxides	–	–	–	–	1

SITE 469 HOLE CORE 2 CORED INTERVAL 7.5–17.0 m



N5

Patch of nannofossil ooze

N7

N5

N7

LITHOLOGIC DESCRIPTION

CLAY, medium gray (N5), with streaks of medium bluish gray (5B 5/1) **ASH-RICH CLAY.** Light gray (N7) patches and intervals of **FORAMINIFER-NANNOFOSSIL OOZE** common, Section 3. Ooze also contains streaks and small patches of grayish black (N2) vitric ash. Intense drilling deformation.

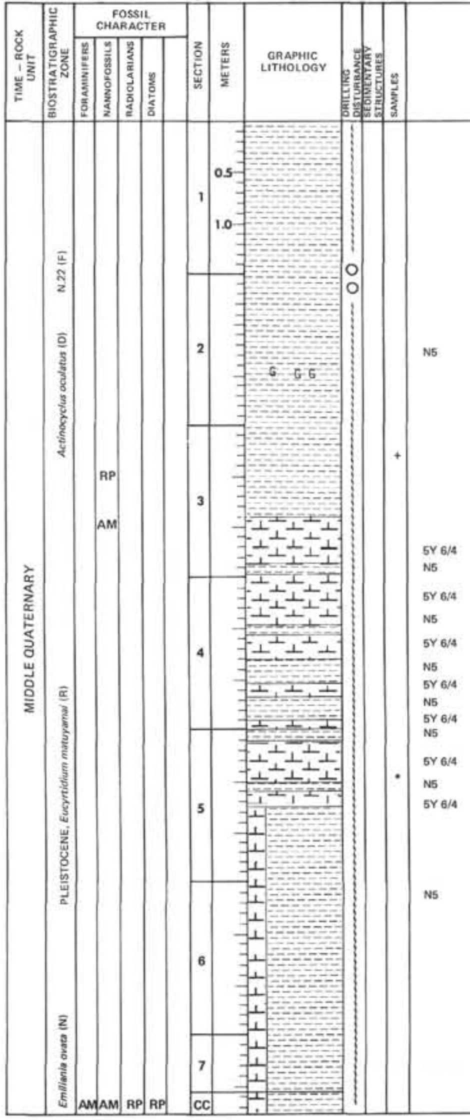
ORGANIC CARBON AND CARBONATE

	2-95
% Organic Carbon	0.73
% $CaCO_3$	1

SMEAR SLIDE SUMMARY

	2-45 (M)
TEXTURE:	
Sand	5
Silt	10
Clay	85
COMPOSITION:	
Quartz	1
Clay	8
Pyrite	1
Carbonate unspec.	10
Foraminifers	10
Calc. Nannofossils	70
Diatoms	TR
Sponge spicules	TR

SITE 469 HOLE CORE 3 CORED INTERVAL 17.0–26.5 m



LITHOLOGIC DESCRIPTION

CLAY, medium gray (N5), mixed by drilling with dusky yellow (5Y 6/4) and olive brown (5Y 4/4) **NANNOFOSSIL OOZE** throughout. Clay contains several patches of **GLAUCONITIC FORAMINIFERAL OOZE** scattered in Sections 1–2. Nannofossil ooze becomes more abundant in base Section 3; still deformed but shows as alternating light zones in darker clay. Clay and ooze mixed in Sections 6–7. Clay also contains scattered pyrite-rich patches and streaks. Contacts between clay and ooze disturbed by drilling.

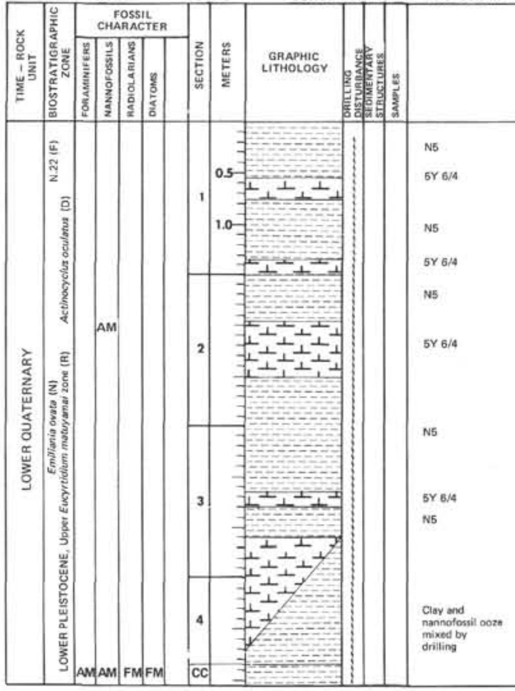
ORGANIC CARBON AND CARBONATE

	3-36
% Organic Carbon	–
% $CaCO_3$	27

SMEAR SLIDE SUMMARY

	5-50 (M)
TEXTURE:	
Sand	–
Silt	10
Clay	90
COMPOSITION:	
Quartz	3
Feldspar	TR
Mica	TR
Heavy minerals	TR
Clay	8
Volcanic glass	TR
Glauconite	TR
Pyrite	TR
Foraminifers	7
Calc. Nannofossils	82

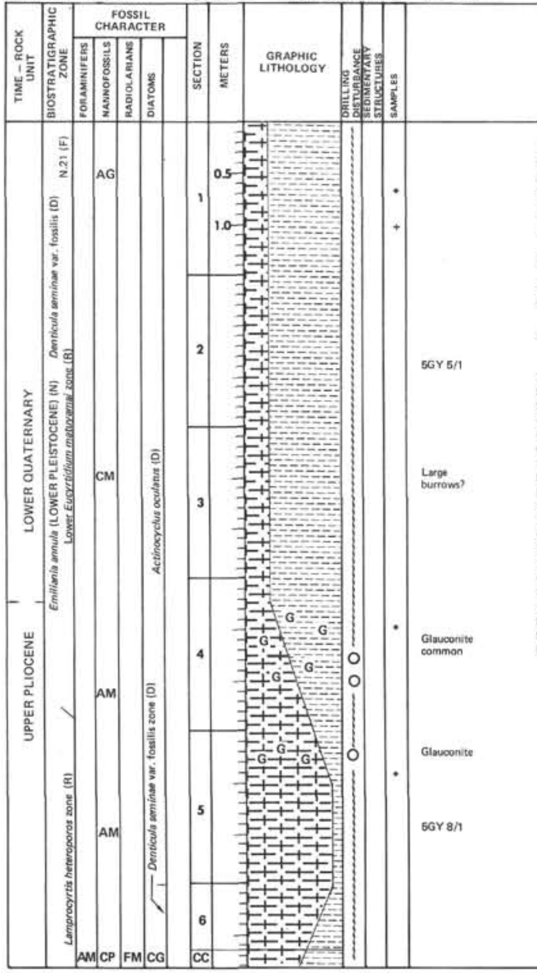
SITE 469 HOLE CORE 4 CORED INTERVAL 26.5–36.0 m



LITHOLOGIC DESCRIPTION

CLAY, medium gray (N5), with zones of dusky yellow (5Y 6/4) to moderate olive brown (5Y 4/4) **NANNOFOSSIL OOZE** mixed by drilling. Streaks and patches of medium bluish gray (5B 5/1) pyrite-rich clay scattered throughout. Intense drilling deformation.

SITE 469 HOLE CORE 5 CORED INTERVAL 36.0–45.5 m



LITHOLOGIC DESCRIPTION

FORAMINIFERA-NANNOFOSSIL CLAY, medium greenish gray (5GY 5/1) with light grayish olive (10Y 4/2) mottled zones corresponding to more nannofossil-rich sediments; Section 5 is mostly light greenish gray (5GY 8/1) **FORAMINIFERA-NANNOFOSSIL OOZE.** Glauconitic intervals in Sections 4 and 5. Scattered small patches of pyrite-rich sediment throughout. Intense drilling deformation.

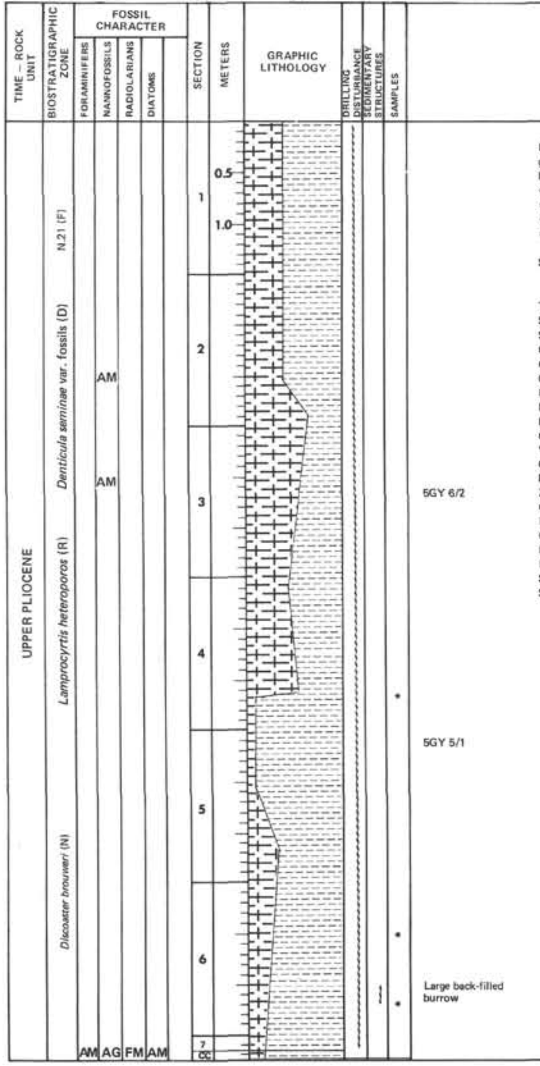
ORGANIC CARBON AND CARBONATE

	1-105
% Organic Carbon	–
% $CaCO_3$	24

SMEAR SLIDE SUMMARY

	1-70 (D)	4-50 (M)	5-47 (D)
TEXTURE:			
Sand	–	50	–
Silt	50	25	25
Clay	50	25	75
COMPOSITION:			
Quartz	2	TR	TR
Feldspar	1	TR	TR
Mica	TR	TR	–
Heavy minerals	–	TR	–
Clay minerals	50	10	5
Volcanic glass	TR	–	TR
Glauconite	TR	2	TR
Pyrite	2	1	1
Foraminifers	20	70	15
Calc. Nannofossils	20	14	70
Diatoms	1	TR	2
Radiolarians	1	TR	TR
Sponge spicules	2	3	5
Silicoflagellates	1	TR	1
Plant debris	TR	–	–

SITE 469 HOLE CORE 6 CORED INTERVAL 45.5–55.0 m



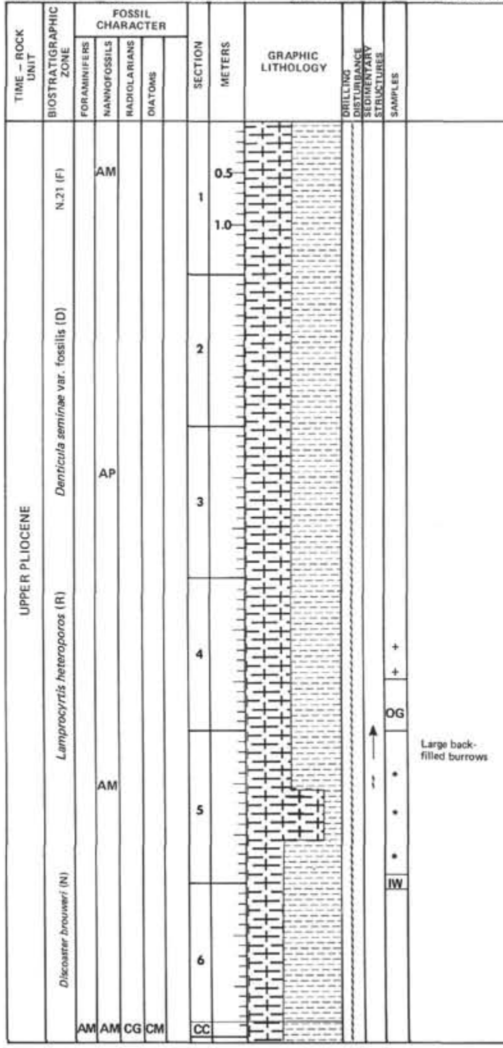
LITHOLOGIC DESCRIPTION

FORAMINIFERA-NANNOFOSSIL CLAY, medium greenish gray (5GY 5/1) to grayish yellow green (5GY 6/2), light colors more nannofossil-rich. Original contacts of clay-rich and more nannofossil-rich sediments obscured by drilling deformation. Diatoms slightly more abundant, base of core. Scattered pyrite-rich patches throughout. Burrows noted in less deformed sediment.

SMEAR SLIDE SUMMARY

	4-120 (D)	6-54 (D)	6-128 (D)
TEXTURE:			
Sand	1	5	–
Silt	4	25	40
Clay	95	70	60
COMPOSITION:			
Quartz	–	TR	5
Feldspar	–	TR	2
Mica	–	TR	TR
Heavy minerals	–	–	TR
Clay	80	50	55
Volcanic glass	–	–	TR
Glauconite	–	–	1
Pyrite	TR	3	3
Zeolite	–	–	TR
Carbonate unspec.	15	–	5
Foraminifers	2	15	3
Calc. Nannofossils	TR	20	5
Diatoms	1	3	8
Radiolarians	2	TR	3
Sponge spicules	–	7	9
Silicoflagellates	1	–	1

SITE 469 HOLE CORE 7 CORED INTERVAL 55.0–64.5 m



LITHOLOGIC DESCRIPTION

FORAMINIFERA-NANNOFOSSIL CLAY, medium greenish gray (5GY 5/1) with greenish gray (5GY 5/2) and light greenish gray (5GY 8/1) streaks and zones that are more nannofossil-rich. Scattered pyrite-rich patches. Large back-filled burrows, top Section 5. Lithologies mixed and homogenized by drilling.

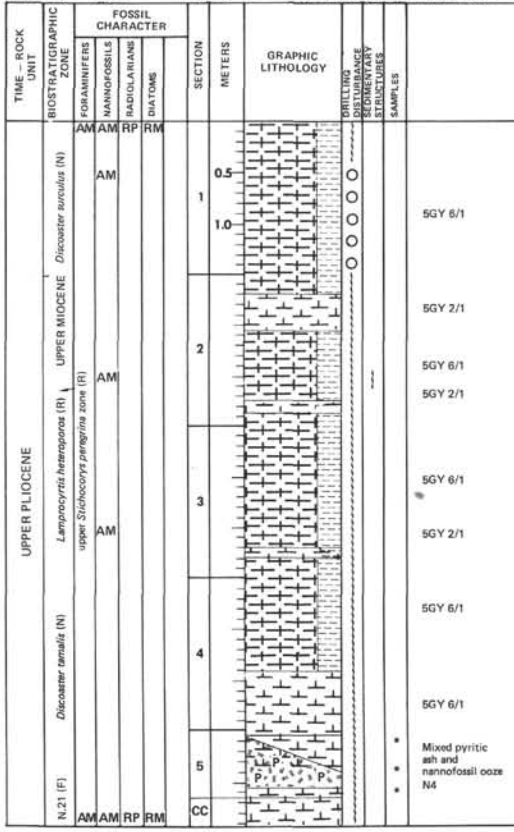
ORGANIC CARBON AND CARBONATE

	4-70	4-97
% Organic Carbon	–	0.55
% $CaCO_3$	38	51

SMEAR SLIDE SUMMARY

	5-45 (D)	5-86 (D)	5-130 (D)
TEXTURE:			
Sand	2	–	10
Silt	38	30	25
Clay	60	70	65
COMPOSITION:			
Quartz	1	TR	5
Feldspar	TR	TR	2
Mica	TR	TR	–
Heavy minerals	TR	TR	1
Clay	10	5	55
Glauconite	1	TR	–
Pyrite	2	1	3
Foraminifers	20	20	20
Calc. Nannofossils	50	65	13
Diatoms	5	2	5
Radiolarians	3	TR	2
Sponge spicules	7	5	3
Silicoflagellates	1	2	1
Plant debris	–	–	TR

SITE 469 HOLE CORE 8 CORED INTERVAL 64.5–74.0 m



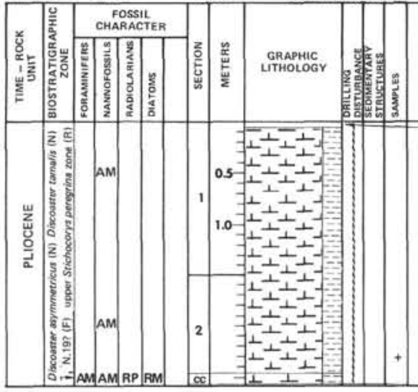
LITHOLOGIC DESCRIPTION

FORAMINIFERA-NANNOFOSSIL CLAY, greenish gray (5GY 6/1), and light greenish gray (5GY 2/1) **CLAYEY NANNOFOSSIL OOZE,** mixed and partly homogenized by drilling. Medium gray (N4) pyritic **VITRIC ASH** partly mixed with overlying ooze, Section 5. Scattered pyrite-rich patches throughout core.

SMEAR SLIDE SUMMARY

	5-14 (D)	5-40 (M)	5-60 (D)
TEXTURE:			
Sand	1	30	–
Silt	29	70	20
Clay	70	–	80
COMPOSITION:			
Quartz	2	5	TR
Feldspar	3	1	TR
Mica	–	–	TR
Heavy minerals	–	TR	1
Clay	12	–	8
Volcanic glass	50	74	–
Glauconite	–	–	TR
Pyrite	3	20	1
Carbonate unspec.	5	–	5
Foraminifers	1	–	10
Calc. Nannofossils	15	–	70
Diatoms	1	–	2
Radiolarians	1	–	1
Sponge spicules	1	–	2
Silicoflagellates	1	–	TR

SITE 469 HOLE CORE 9 CORED INTERVAL 74.0–83.5 m



LITHOLOGIC DESCRIPTION

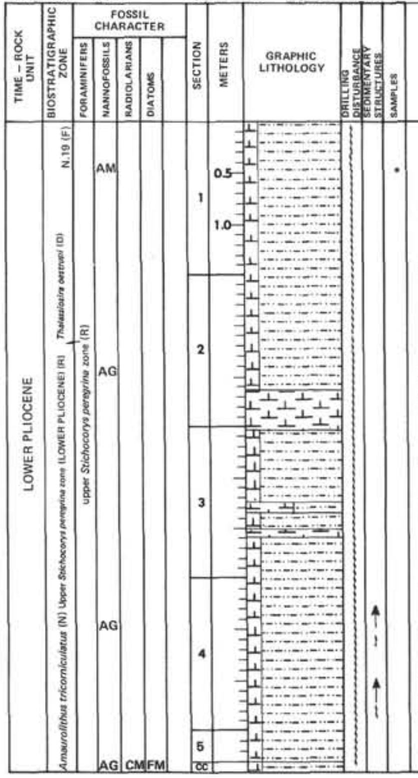
VOID

CLAYEY NANNOFOSSIL OOZE, greenish gray (5GY 6/1) to light greenish gray (5GY 8/1), with scattered pyrite-rich patches. Intense drilling deformation.

ORGANIC CARBON AND CARBONATE

	2-82
% Organic Carbon	–
% $CaCO_3$	82

SITE 469 HOLE CORE 10 CORED INTERVAL 83.5–93.0 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL SILTY CLAY, medium greenish gray (5GY 5/1) and dark yellowish gray (5GY 6/2) with streaks and thin intervals of greenish white (5GY 9/1) **NANNOFOSSIL OOZE** deformed by drilling. Two intervals Section 4 have large back-filled burrows partly filled with glauconite. Scattered pyrite-rich patches throughout.

5GY 5/1

Sharp color change 5GY 9/1

5GY 5/1

Mixed nannofossil ooze and silty clay

5GY 5/1

5GY 6/2

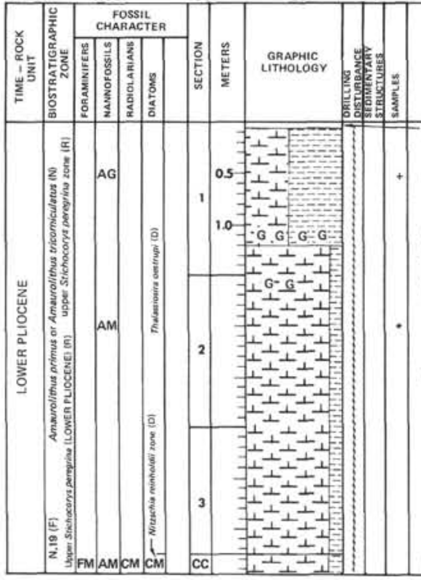
5GY 5/1

Glauconite-filled burrows 5GY 6/2

SMEAR SLIDE SUMMARY

	1-50 (D)
TEXTURE:	
Sand	–
Silt	30
Clay	70
COMPOSITION:	
Quartz	7
Feldspar	5
Mica	TR
Heavy minerals	2
Clay	60
Glauconite	TR
Pyrite	2
Carbonate unspec.	5
Calc. Nannofossils	10
Diatoms	2
Sponge spicules	5
Plant debris	TR
Glaucophene	TR

SITE 469 HOLE CORE 11 CORED INTERVAL 93.0–102.5 m



LITHOLOGIC DESCRIPTION

VOID

5GY 6/1

Common glauconite and foraminifers

Glauconite-rich patch

5GY 9/1

5GY 6/1

NANNOFOSSIL CLAY, greenish gray (5GY 6/1), mottled. Base of clay contains abundant glauconite and foraminifers. Sharp color change to greenish white (5GY 9/1) **CLAYEY NANNOFOSSIL OOZE** at 120 cm Section 1. It is mottled and deformed by drilling. Glauconitic-rich patch (sand-size glauconite) at top Section 2. Color change back to greenish gray in Core-Catcher. Scattered dark pyrite-rich patches throughout.

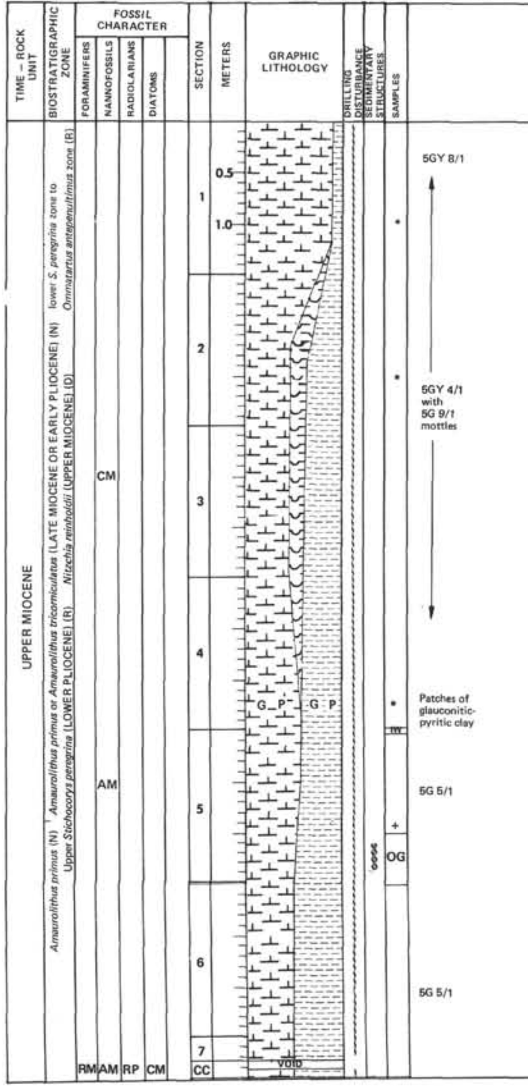
ORGANIC CARBON AND CARBONATE

	1-57
% Organic Carbon	–
% $CaCO_3$	44

SMEAR SLIDE SUMMARY

	2-57 (D)
TEXTURE:	
Sand	–
Silt	5
Clay	95
COMPOSITION:	
Clay	10
Pyrite	10
Calc. Nannofossils	75
Diatoms	TR
Radiolarians	2
Sponge spicules	3

SITE 469 HOLE CORE 12 CORED INTERVAL 102.5–112.0 m



LITHOLOGIC DESCRIPTION

CLAYEY NANNOFOSSIL OOZE, mottled light greenish gray (5GY 8/1), light greenish white (5G 9/1), and greenish gray (5G 5/1), changing to dark greenish gray (5GY 4/1) **DIATOM-NANNOFOSSIL CLAY** with nannofossil ooze mottles in Sections 2 and 3. Diatoms decrease and nannofossils increase again in Section 4. Greenish black (5GY 2/1) glauconite- and pyrite-rich patches 125 cm, Section 4. Pinkish purple pyritic streaks scattered throughout. Core is intensely deformed by drilling.

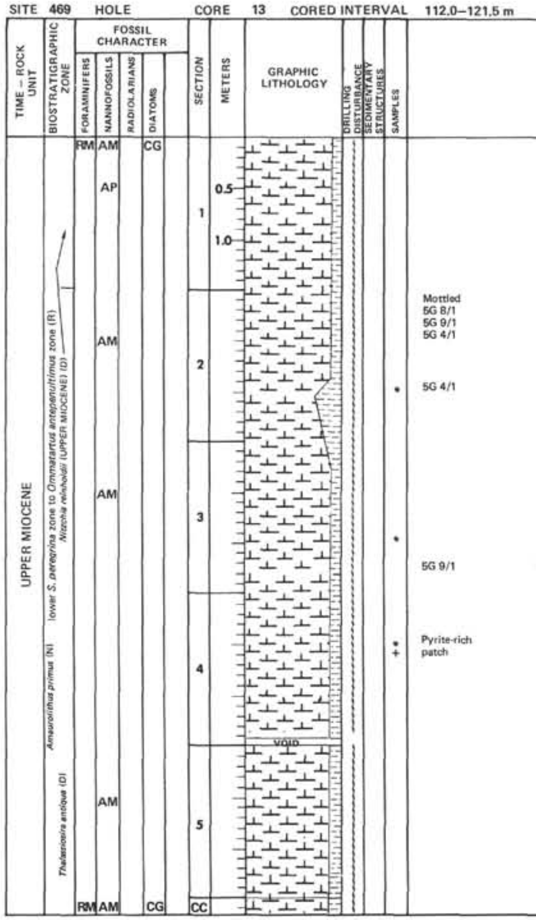
ORGANIC CARBON AND CARBONATE

	5-98
% Organic Carbon	0.42
% $CaCO_3$	21

SMEAR SLIDE SUMMARY

	1-106 (D)	2-100 (D)	4-121 (M)
TEXTURE:			
Sand	–	–	–
Silt	5	10	10
Clay	95	95	90
COMPOSITION:			
Clay	10	35	70
Glauconite	–	–	3
Pyrite	3	TR	5
Carbonate unspec.	–	2	–
Foraminifers	5	3	1
Calc. Nannofossils	80	30	15
Diatoms	–	10	TR
Radiolarians	2	5	1
Sponge spicules	–	TR	3

SITE 469 HOLE CORE 13 CORED INTERVAL 112.0–121.5 m



LITHOLOGIC DESCRIPTION

CLAYEY NANNOFOSSIL OOZE, light greenish gray (5G 8/1) and light greenish white (5G 9/1) to dark greenish gray (5G 4/1), darker colors more clay-rich. Pinkish purple pyritic streaks and patches throughout. Intense drilling deformation.

ORGANIC CARBON AND CARBONATE

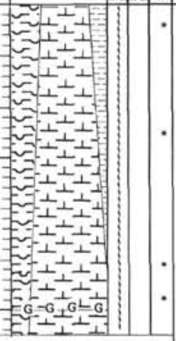
	4-60
% Organic Carbon	–
% $CaCO_3$	58

SMEAR SLIDE SUMMARY

	2-100 (D)	3-100 (D)	4-54 (M)
TEXTURE:			
Sand	–	–	–
Silt	10	10	50
Clay	90	90	50
COMPOSITION:			
Quartz	TR	1	–
Heavy minerals	TR	1	–
Clay	17	15	–
Pyrite	3	–	100
Carbonate unspec.	–	2	–
Foraminifers	1	TR	–
Calc. Nannofossils	70	70	–
Diatoms	3	2	–
Radiolarians	2	3	–
Sponge spicules	2	2	–
Silicoflagellates	TR	1	–

SITE 469 HOLE CORE 14 CORED INTERVAL 121.5–131.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
UPPER MIOCENE	lower *S. peregrina* zone to *Ommatartus antepenultimus* zone (R) *Denticula hustedtii* subzone "a" (D) *Discoaster neorectus* (N) *Thalassiosira antiqua* (D) Lower *Stichocorys peregrina* (R)		CM			1	0.5 1.0
			AM			2	
		RM	AM	FM	CM	CC	



5GY 5/2
and
10GY 5/2

5G 8/1

Distinct color change 5GY 5/2

Foraminifers and glauconite common

LITHOLOGIC DESCRIPTION

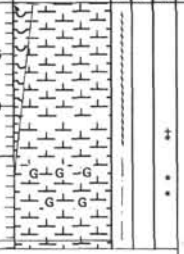
DIATOM-NANNOFOSSIL OOZE, light olive (10Y 5/4) and pale olive (10Y 6/2) to dusky yellow green (5GY 5/2) and grayish green (10GY 5/2). Darker colors, more diatom-rich sediment. Distinct color change base Section 2 separates light colored nannofossil ooze from underlying ooze rich in foraminifers and sand-size glauconite. Scattered pinkish purple and olive black pyrite-rich streaks and patches throughout.

SMEAR SLIDE SUMMARY

	1-23 (D)	1-130 (D)	2-110 (D)	2-148 (M)
TEXTURE:				
Sand	–	–	–	50
Silt	10	10	10	20
Clay	90	90	90	30
COMPOSITION:				
Quartz	–	–	–	8
Mica	–	–	–	8
Clay	23	10	10	5
Volcanic glass	7	–	–	3
Glauconite	–	–	–	20
Carbonate unspec.	–	8	5	–
Foraminifers	1	1	TR	25
Calc. Nannofossils	40	55	60	20
Diatoms	15	20	20	–
Radiolarians	5	5	2	2
Sponge spicules	5	–	2	5
Silicoflagellates	4	1	1	–
Plant debris	–	–	–	5
Glaucophane ?	TR	–	–	–

SITE 469 HOLE CORE 15 CORED INTERVAL 131.0–140.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
UPPER MIOCENE	lower *S. peregrina* zone to *Ommatartus antepenultimus* zone (R) *Denticula hustedtii* subzone "a" (D) *Discoaster neohamatus* (N) *T. antiqua* (D) Lower *Stichocorys peregrina* (R)	RM	AM	FM	CM	1	0.5 1.0
			AM				
			AP				
		RM	AM	FM	CM	2 CC	



5G 7/1

5G 9/1

Glauconite/foraminifer layer
Glauconite/foraminifer
5G 9/1

LITHOLOGIC DESCRIPTION

DIATOM-NANNOFOSSIL OOZE, light greenish gray (5G 7/1) changing down core to light greenish white (5G 9/1) **NANNOFOSSIL OOZE.** Dark greenish gray (5G 4/1) glauconite-foraminifer-rich layer at 23 cm, Section 2. Abundant pinkish purple pyritic streaks throughout.

ORGANIC CARBON AND CARBONATE

	1-130
% Organic Carbon	–
% $CaCO_3$	77

SMEAR SLIDE SUMMARY

	1-137 (D)	2-24 (D)	2-40 (D)
TEXTURE:			
Sand	–	–	30
Silt	10	5	5
Clay	90	95	65
COMPOSITION:			
Heavy minerals	TR	1	–
Clay	10	1	5
Volcanic glass	–	–	8
Glauconite	–	–	5
Pyrite	–	–	TR
Carbonate unspec.	17	–	–
Foraminifers	TR	5	15
Calc. Nannofossils	50	80	50
Diatoms	15	4	5
Radiolarians	4	8	10
Sponge spicules	2	1	2
Silicoflagellates	2	–	3
Plant debris	–	–	TR

SITE 469 HOLE CORE 16 CORED INTERVAL 140.5–150.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
LOWER UPPER MIOCENE	Upper *Discoaster variabilis* zone (N) *Ommatartus penultimus* (?) zone (R) *Denticula hustedtii* – *Denticula lauta* subzone "d" (D) lower *S. peregrina* zone to *Ommatartus antepenultimus* zone (R)		AM	FM	CG	CC	

4 cm long pyritized burrow

LITHOLOGIC DESCRIPTION

CLAYEY NANNOFOSSIL OOZE, greenish gray (5G 6/1) to dark greenish gray (5G 4/1), broken by drilling. Thin olive black (5Y 2/1) layer of **VITRIC ASH** at 16–20 cm. Four cm long pyritized burrow occurs as separate piece in broken nannofossil ooze at 2–5 cm.

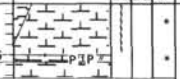
Core-Catcher only.

SMEAR SLIDE SUMMARY

	CC-17 (D)
TEXTURE:	
Sand	10
Silt	55
	35
Quartz	2
Heavy minerals	1
Clay	7
Volcanic glass	90

SITE 469 HOLE CORE 17 CORED INTERVAL 150.0–159.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
LOWER UPPER MIOCENE	*Discoaster bellus* (N) *Ommatartus penultimus* zone (R) *Denticula hustedtii* – *Denticula lauta* subzone "d" (D)		AG			1	0.5
		RM	AM	FM	CM	CC	



5G 8/1 grades to 5G 9/1

Foraminifer-ash-rich layer

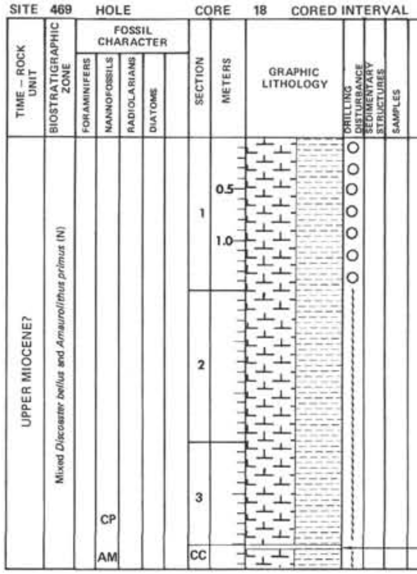
LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, light greenish white (5G 9/1) to light greenish gray (5G 8/1), darker color sediment near top of core more diatom-rich. Common dark gray (N3) streaks and pyritic patches throughout. Dark gray (N3) layer at 52–58 cm pyritized **FORAMINIFER-NANNOFOSSIL OOZE** mixed with abundant **VITRIC ASH.**

SMEAR SLIDE SUMMARY

	1-20 (D)	1-56 (D)
TEXTURE:		
Sand	–	–
Silt	10	40
Clay	90	60
COMPOSITION:		
Quartz	–	2
Feldspar	–	TR
Mica	–	TR
Heavy minrals	–	TR
Clay	10	8
Volcanic glass	–	26
Glauconite	–	2
Pyrite	–	7
Carbonate unspec.	10	–
Foraminifers	3	2
Calc. Nannofossils	65	52
Diatoms	2	2
Radiolarians	8	4
Sponge spicules	2	3
Silicoflagellates	TR	–

SITE 469 HOLE CORE 18 CORED INTERVAL 159.5–169.0 m

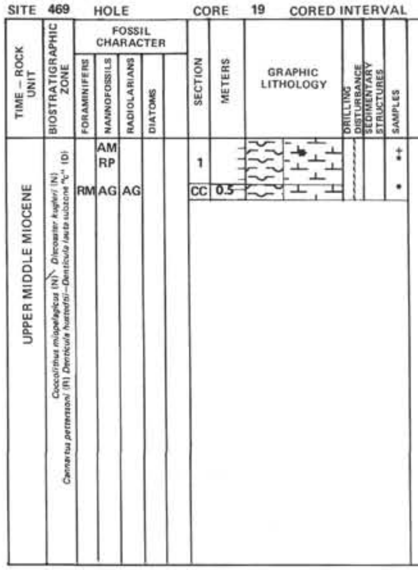


LITHOLOGIC DESCRIPTION

VOID

Drilling breccia of light greenish gray (5GY 8/1) to medium gray (N5) **CLAYEY NANNOFOSSIL OOZE AND NANNOFOSSIL CLAY.**

SITE 469 HOLE CORE 19 CORED INTERVAL 169.0–178.5 m



LITHOLOGIC DESCRIPTION

Andesite(?) clast

DIATOM-NANNOFOSSIL OOZE, light greenish gray (5G 8/1) to greenish gray, ash-rich in parts. Small andesite(?) clast at 10–12 cm. Core becoming firm.

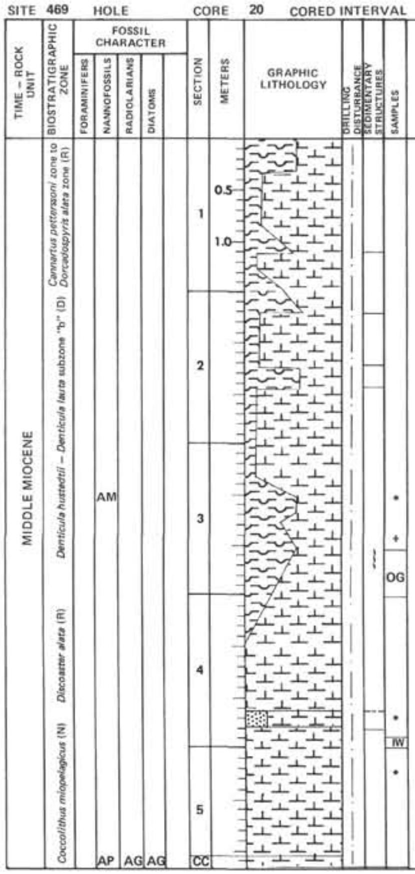
ORGANIC CARBON AND CARBONATE

	1-17
% Organic Carbon	–
% $CaCO_3$	14

SMEAR SLIDE SUMMARY

	1-22 (D)	CC-1 (D)
TEXTURE:		
Sand	2	5
Silt	18	25
Clay	80	75
COMPOSITION:		
Quartz	2	5
Feldspar	1	1
Heavy minerals	TR	TR
Clay	5	5
Volcanic glass	5	15
Calc. Nannofossils	50	40
Diatoms	25	25
Radiolarians	3	2
Sponge spicules	8	6
Silicoflagellates	1	TR

SITE 469 HOLE CORE 20 CORED INTERVAL 178.5–188.0 m



LITHOLOGIC DESCRIPTION

5Y 6/1

N9

5Y 6/1

N9

Sharp color changes
5Y 6/1

N9

Foraminifer-,
glauconite-rich
sandy layer

Interbedded white to very light gray (N8–N9) **NANNOFOSSIL OOZE** and light olive gray (5Y 6/1) **DIATOM-NANNOFOSSIL OOZE.** Abrupt color changes mark base of diatom-rich intervals; upper contacts are gradational over several cm. Possibly burrowed but drilling/cutting disturbance obscures. Olive gray (5Y 4/1) layer 112–126 cm Section 4 consists of foraminifers, sand-size grains of quartz, feldspar, and glauconite mixed with pyrite-rich nannofossil ooze. Sharp color change marks top and base of layer. Scattered pyrite-rich streaks and patches throughout.

ORGANIC CARBON AND CARBONATE

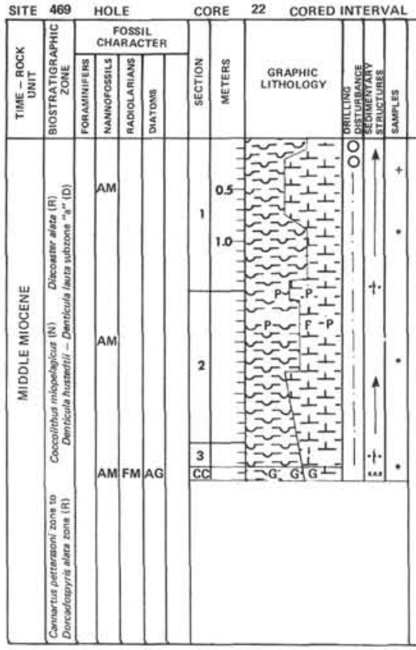
	3-98
% Organic Carbon	0.32
% $CaCO_3$	44

SMEAR SLIDE SUMMARY

	3-59 (D)	4-123 (M)	5-25 (D)
TEXTURE:			
Sand	–	40	–
Silt	40	10	15
Clay	60	50	85
COMPOSITION:			
Quartz	–	10	–
Feldspar	–	5	–
Heavy minerals	TR	TR	TR
Volcanic glass	–	3	–
Glauconite	–	2	–
Pyrite	TR	10	TR
Carbonate unspec.	–	8	4
Foraminifers	2	15	5
Calc. Nannofossils	50	41	80
Diatoms	25	–	5
Radiolarians	TR	–	TR
Sponge spicules	20	5	5
Silicoflagellates	3	–	1

Site 469, Core 21, 188.0–197.5 m: NO RECOVERY.

SITE 469 HOLE CORE 22 CORED INTERVAL 197.5–207.0 m



5GY 8/1

5Y 5/2

Sharp color change

Pyrite-rich layer

Sharp color change

5Y 5/2

Glauconitie, foraminifer-rich sandy layer

LITHOLOGIC DESCRIPTION

Interbedded light olive gray (5Y 5/2) **NANNOFOSSIL-DIATOMACEOUS OOZE** and light greenish gray (5GY 8/1) to very light gray (N8) **DIATOM-NANNOFOSSIL OOZE,** sharp contacts marked by distinct color changes. Some lenticular bedding and abundant indistinct burrows. Several pyrite-rich layers near top Section 2; pinkish purple pyrite-rich patches and streaks scattered throughout. Graded glauconitic, foraminifer-rich sandy layer 5–6 cm in Core-Catcher.

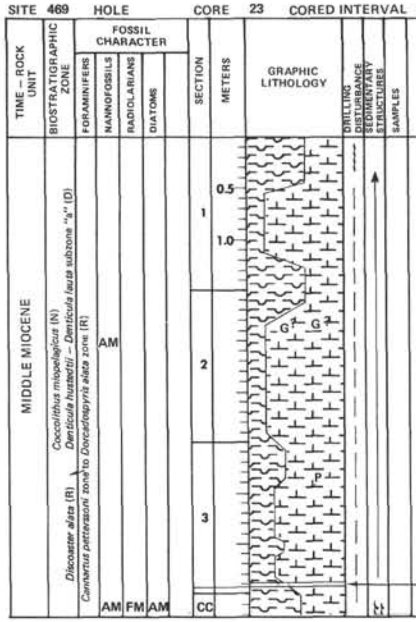
ORGANIC CARBON AND CARBONATE

	1-32
% Organic Carbon	–
% $CaCO_3$	64

SMEAR SLIDE SUMMARY

	1-94 (D)	2-77 (D)	CC-5 (M)
TEXTURE:			
Sand	–	–	40
Silt	45	30	10
Clay	55	70	50
COMPOSITION:			
Quartz	–	–	15
Feldspar	–	–	5
Volcanic glass	TR	TR	5
Glauconite	TR	–	2
Pyrite	1	TR	5
Carbonate unspec.	–	–	5
Foraminifers	–	TR	12
Calc. Nannofossils	50	67	46
Diatoms	41	23	–
Radiolarians	TR	TR	–
Sponge spicules	8	8	5
Silicoflagellates	TR	TR	–

SITE 469 HOLE CORE 23 CORED INTERVAL 207.0–216.5 m



5Y 5/2

5GY 8/1

5Y 5/2

Ash-rich patch

5GY 8/1

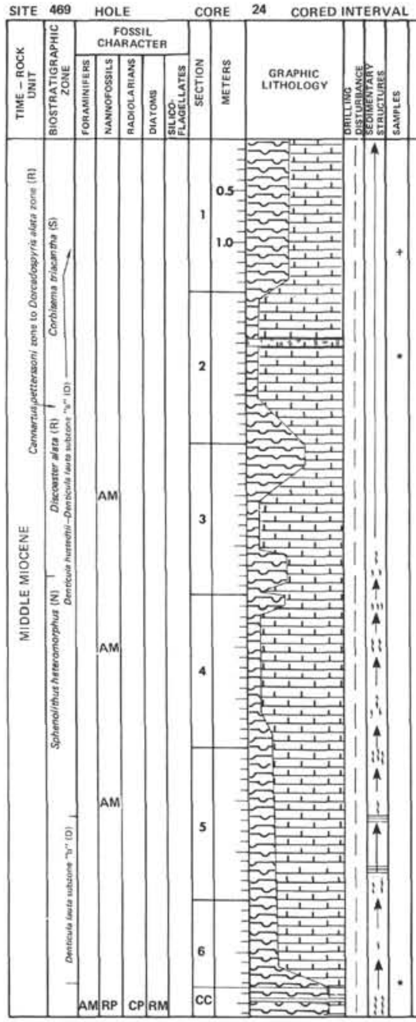
Pyrite-rich patch

VOID

LITHOLOGIC DESCRIPTION

Interbedded light olive gray (5Y 5/2) **NANNOFOSSIL-DIATOMACEOUS OOZE** and light greenish gray (5GY 8/1) to very light gray (N8) **DIATOM-NANNOFOSSIL OOZE,** burrowed with indistinct lenticular bedding throughout. Abundant scattered dark pyrite-rich (manganese?) streaks and patches minor horizontal and subhorizontal purple gray bands. Contacts between dark diatom-rich and light nannofossil-rich ooze are gradational.

SITE 469 HOLE CORE 24 CORED INTERVAL 216.5–226.0 m



5G 6/1

Pyrite/Mn? patch

N8

Ash layer

5G 4/1

Large horizontal back-filled burrow

5G 4/1

N8

5G 6/1

Pyrite/Mn? pseudolaminations

Large horizontal back-filled burrow

Pyrite/Mn? pseudolaminations

Concentric pyrite

LITHOLOGIC DESCRIPTION

DIATOM-NANNOFOSSIL CHALK, very light gray (N8) and light bluish gray (5B 7/1) to greenish gray (5G 6/1), interbedded with greenish gray (5G 6/1) to dark greenish gray (5G 4/1) **NANNOFOSSIL AND CLAYEY DIATOMITE.** Chalk and diatomite burrowed throughout. Burrows in diatomite filled with light colored chalk. Chalk has occasional thin grayish purple (5P 4/2) to pale purple (5P 6/2) pyrite/Mn?-rich pseudolaminations. Thin layer of greenish gray (5GY 6/1) **VITRIC ASH** interbedded with chalk Section 2.

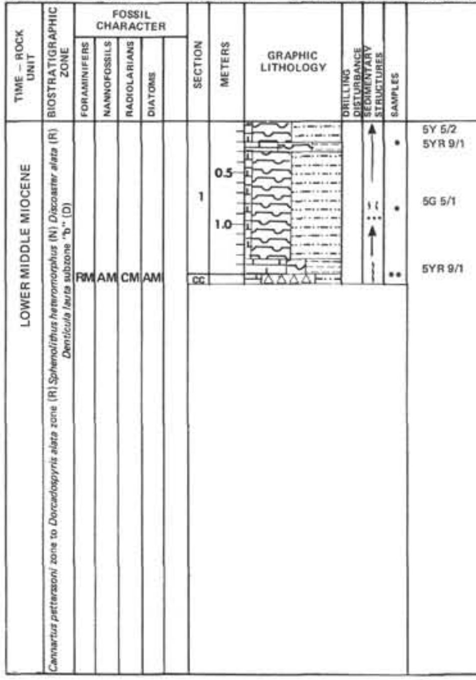
ORGANIC CARBON AND CARBONATE

	1-114
% Organic Carbon	–
% $CaCO_3$	59

SMEAR SLIDE SUMMARY

	2-65 (D)	6-86 (D)
TEXTURE:		
Sand	–	–
Silt	8	82
Clay	92	18
COMPOSITION:		
Quartz	4	4
Mica	–	TR
Clay	–	33
Calc. Nannofossils	–	TR
Diatoms	–	45
Radiolarians	–	6
Sponge spicules	–	12
Silicoflagellates	–	TR

SITE 469 HOLE CORE 25 CORED INTERVAL 226.0–235.5 m



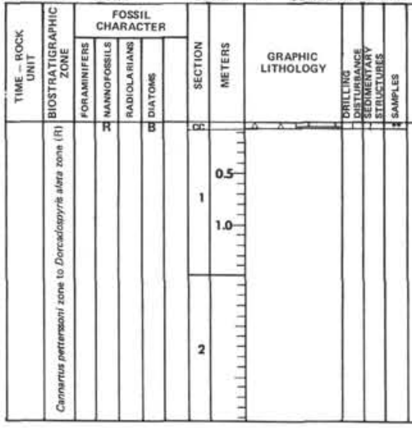
LITHOLOGIC DESCRIPTION

Interbedded light olive gray (5Y 5/2) to medium greenish gray (5G 5/1) **NANNOFOSSIL-DIATOMACEOUS SILTY CLAYSTONE** and pinkish white (5YR 9/1) **DIATOM NANNOFOSSIL CHALK,** burrows common throughout. Burrows filled with chalk in diatom-rich intervals. Chalk interbeds have grayish purple (5P 4/2) and pale purple (5P 6/2) pyrite/Mn?-rich pseudolaminations. Core-Catcher contains few fragments of **NANNOFOSSIL CLAYSTONE** and two larger pieces of dark greenish gray (5GY 4/1) **CALCAREOUS PORCELLANITE.**

SMEAR SLIDE SUMMARY

	1-25 (D)	1-90 (D)	CC-8 (D)	CC-10 (M, T)
TEXTURE:				
Sand	–	–	–	–
Silt	40	50	10	5
Clay	60	50	90	95
COMPOSITION:				
Quartz	10	5	3	TR
Feldspar	4	2	2	–
Mica	2	TR	–	–
Heavy minerals	1	1	–	–
Clay	35	45	70	20
Volcanic glass	1	1	–	–
Glauconite	TR	TR	–	–
Pyrite	1	1	2	2
Zeolite	TR	TR	–	–
Carbonate unspec.	–	3	3	50
Foraminifers	–	TR	–	3
Calc. Nannofossils	25	5	20	–
Diatoms	20	25	–	–
Radiolarians	TR	TR	–	–
Sponge spicules	8	10	–	–
Silicoflagellates	2	2	–	–
Plant debris	1	–	–	–
Opal-CT	–	–	–	25

SITE 469 HOLE CORE 26 CORED INTERVAL 235.5–245.0 m



LITHOLOGIC DESCRIPTION

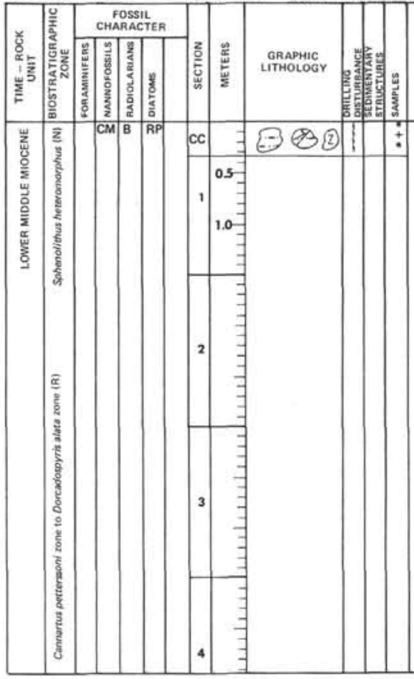
SILICEOUS CHALK, greenish gray (5G 6/1), burrowed with grayish purple pyrite/Mn?-pseudolaminations. Thin Section shows opal-CT and chalcedony fill and replace many foraminifer tests. Opal-CT common in matrix. One echinodum spine noted.

Core-Catcher only.

SMEAR SLIDE SUMMARY

	CC-4 (D)	CC-5 (D, T)
COMPOSITION:		
Quartz	2	1
Heavy minerals	TR	–
Clay	27	15
Glauconite	1	–
Carbonate unspec.	70	50
Foraminifers	–	3
Opal-CT	–	25

SITE 469 HOLE CORE 27 CORED INTERVAL 245.0–254.5 m



LITHOLOGIC DESCRIPTION

Drilling breccia of dark greenish gray (5GY 4/1) **SILTY CLAYSTONE and NANNOFOSSIL SILTY CLAYSTONE,** and medium dark gray (N4) **ZEOLITIC SILTY SANDSTONE.** Claystone has faint mottles but not obviously burrowed. Zeolite (clinoptilolite?) occurs as clear, euhedral and prismatic silt-size crystals.

Core-Catcher only.

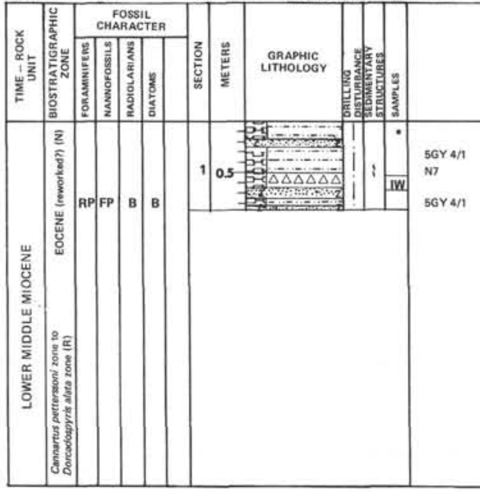
ORGANIC CARBON AND CARBONATE

	CC-15
% Organic Carbon	–
% $CaCO_3$	2

SMEAR SLIDE SUMMARY

	CC-11 (M)	CC-28
TEXTURE:		
Sand	45	–
Silt	40	25
Clay	15	75
COMPOSITION:		
Quartz	25	10
Feldspar	10	5
Mica	TR	–
Heavy minerals	3	2
Clay	20	75
Volcanic glass	5	TR
Glauconite	10	1
Pyrite	–	3
Zeolite	15	–
Carbonate unspec.	2	–
Diatoms	–	1
Sponge spicules	–	3
Plant debris	TR	–
Lithic fragments	10	–

SITE 469 HOLE CORE 28 CORED INTERVAL 254.5–264.0 m



LITHOLOGIC DESCRIPTION

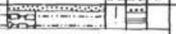
Interbedded dark greenish gray (5GY 4/1) **CALCAREOUS SILTY CLAYSTONE** and dark greenish gray **ZEOLITIC(?) SANDY SILTSTONE.** Claystone has faint lenticular bedding and thin silty layers. Siltstone contains glauconite. Thin light gray (N7) **CALCAREOUS PORCELLANITE** at 51–54 cm is burrowed.

No Core-Catcher.

SMEAR SLIDE SUMMARY

	1-10 (D)
TEXTURE:	
Sand	–
Silt	20
Clay	80
COMPOSITION:	
Quartz	5
Feldspar	2
Clay	60
Glauconite	TR
Pyrite	1
Carbonate unspec.	23
Calc. Nannofossils	2

SITE 469 HOLE CORE 29 CORED INTERVAL 264.0–273.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER				SECTION	METERS	GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES
		FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS			
LOWER MIDDLE MIOCENE	MIDDLE AND UPPER EOCENE (reworked?) mixed with MIDDLE MIOCENE (N) *Cannartus petterssoni* zone to *Dorcadospyris alata* zone (R)		CM	B	B	CC		

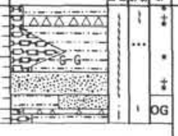
LITHOLOGIC DESCRIPTION

N5
5GY 4/1

SANDSTONE (0–5 cm), medium gray (N5), graded, contains abundant lithic fragments, with less quartz, glauconite, and foraminifers. Fragments of dark greenish gray (5GY 4/1) **CALCAREOUS SILTY CLAYSTONE** below 5 cm contain thin graded silty layers and faint laminations.

Core-Catcher only.

SITE 469 HOLE CORE 30 CORED INTERVAL 273.5–283.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER				SECTION	METERS	GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES
		FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS			
LOWER MIDDLE MIOCENE	*Cannartus petterssoni* zone to *Dorcadospyris alata* zone (R)		AG CP FP	B	B	1	0.5 1.0	

LITHOLOGIC DESCRIPTION

5GY 4/1
Ash and glauconite common

Drilling breccia consisting of dark greenish gray (5GY 4/1) calcareous **SILTY CLAYSTONE, SILTY SANDSTONE, and CALCAREOUS PORCELLANITE.** Claystone is burrowed, contains scattered pyrite-rich streaks and one nannofossil/glauconite/ash-rich interval. Burrows also common in porcellanite. Sandstone contains abundant quartz and feldspar.
No Core-Catcher.

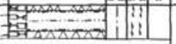
ORGANIC CARBON AND CARBONATE

	1-11	1-79
% Organic Carbon	–	11
% $CaCO_3$	0.42	11

SMEAR SLIDE SUMMARY

	1-6 (D)	1-18 (D)	1-56 (D)	1-80 (D)
TEXTURE:				
Sand	–	–	–	50
Silt	25	30	45	40
Clay	75	70	55	10
COMPOSITION:				
Quartz	10	7	2	40
Feldspar	5	5	1	25
Heavy minerals	2	2	–	3
Clay	75	70	35	10
Volcanic glass	5	–	40	7
Glauconite	1	1	–	3
Pyrite	2	15	2	2
Zeolite	TR	–	–	5
Carbonate unspec.	–	–	15	TR
Foraminifers	–	–	–	–
Calc. Nannofossils	–	–	5	–
Diatoms	–	–	TR	TR
Sponge spicules	–	–	TR	–
Lithic fragments	–	–	–	5

SITE 469 HOLE CORE 31 CORED INTERVAL 283.0–292.5 m

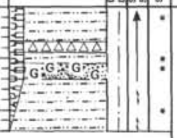
TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER				SECTION	METERS	GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES
		FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS			
LOWER MIDDLE MIOCENE	LOWER OR MIDDLE MIOCENE (with reworked EOCENE-OLIGOCENE) (N) *Cannartus petterssoni* zone to *Dorcadospyris alata* zone (R)		CM	B	B	CC		

LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, dark grayish green (5G 4/1), burrowed with scattered pyrite-rich patches. Top and bottom of core is dark grayish green **CALCAREOUS PORCELLANITE** with abundant burrows and some silty layers. Core broken by drilling.

Core-Catcher only.

SITE 469 HOLE CORE 32 CORED INTERVAL 292.5–302.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER				SECTION	METERS	GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES
		FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS			
LOWER MIDDLE MIOCENE	*Sphenolithus heteromorphus* (N) *Cannartus petterssoni* zone to *Dorcadospyris alata* zone (R)		CM RP CM	B	RP	1	0.5 1.0	

LITHOLOGIC DESCRIPTION

Very small burrows

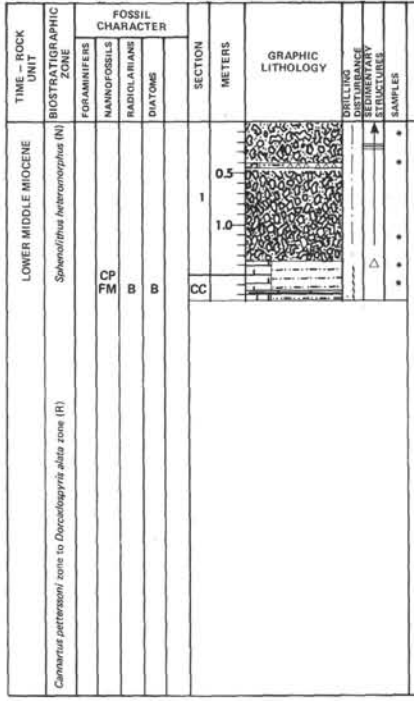
Interbedded(?) dark greenish gray (5G 4/1) to dark gray (N4) **CALCAREOUS SILTY CLAYSTONE AND SANDY SILTSTONE, SILTY CLAYSTONE AND SILTY SANDSTONE, AND CALCAREOUS PORCELLANITE.** Burrows common; filled with lighter colored calcareous sediment. Sandstone and siltstone are glauconitic with some lithic fragments. Core is mainly broken pieces of separate lithologies; nature of contacts unknown.

Core-Catcher only.

SMEAR SLIDE SUMMARY

	1-18 (D)	1-57 (D)	1-66 (D)	1-107 (D)
TEXTURE:				
Sand	7	–	30	–
Silt	23	55	50	25
Clay	70	45	20	75
COMPOSITION:				
Quartz	7	3	20	10
Feldspar	5	2	10	5
Mica	TR	–	–	–
Heavy minerals	2	1	2	1
Clay	60	45	19	75
Volcanic glass	5	25	5	TR
Glauconite	3	TR	7	1
Zeolite	–	5	3	TR
Carbonate unspec.	10	–	10	6
Foraminifers	–	–	10	–
Calc. Nannofossils	5	–	5	–
Diatoms	TR	10	1	–
Radiolarians	TR	1	TR	–
Sponge spicules	–	7	–	–
Lithic fragments	–	–	5	–

SITE 469 HOLE CORE 33 CORED INTERVAL 302.0–311.5 m



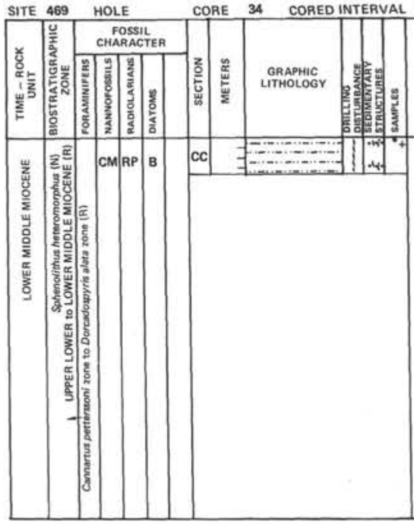
LITHOLOGIC DESCRIPTION

SEDIMENTARY BRECCIA, dark greenish gray (5GY 5/1) with angular clasts of bluish gray (5B 5/1) pumice and very light gray (N8) and black perlitic glass. Porphyritic volcanic rock fragments also common. Fragments of echinoid spines, pectons and bryozoa common near top of core. Maximum clast size in core is ~3 cm. Matrix is opal-CT cemented calcareous clay. Breccia fines upward. Piece of **CALCAREOUS CLAYEY PORCELLANITE** at 42 cm. Base of core contains pieces of dark greenish gray (5GY 4/1) **NANNOFOSSIL CLAYSTONE** and one piece of medium gray (N5) finely crystalline **CLAYEY LIMESTONE.** Core broken into drilling biscuits.

SMEAR SLIDE SUMMARY

	1-14 (D,T)	1-42 (M,T)	1-118 (D)	1-146 (D)	CC-19 (M)
TEXTURE:					
Sand	–	–	–	–	–
Silt	–	30	–	20	20
Clay	–	70	–	80	80
COMPOSITION:					
Quartz	2	8	3	6	–
Feldspar	3	2	1	2	–
Mica	TR	–	–	–	–
Heavy minerals	–	2	–	–	–
Clay	–	50	31	54	4
Palagonite	TR	–	10?	–	–
Glauconite	–	–	–	TR	–
Pyrite	–	–	–	2	3
Carbonate unspec.	2	8	5	18	93
Foraminifers	3	–	4	–	–
Calc. Nannofossils	–	–	–	18	TR
Diatoms	–	(molds)	–	–	–
Volcanic lithic fragments	85	TR	55	–	–
Carbonate skeletal fragments	5	–	–	–	–
Opal-CT	?	30	–	–	–

SITE 469 HOLE CORE 34 CORED INTERVAL 311.5–321.0 m



LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, dark greenish gray (5G 4/1), lenticular bedding and faint burrows. Drilling breccia.

Core-Catcher only.

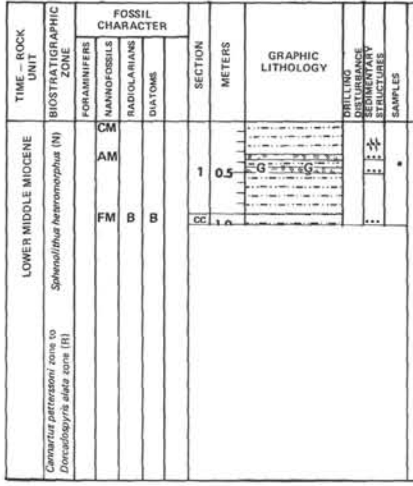
ORGANIC CARBON AND CARBONATE

	1-7
% Organic Carbon	–
% $CaCO_3$	3

SMEAR SLIDE SUMMARY

	1-2 (D)
TEXTURE:	
Sand	10
Silt	30
Clay	60
COMPOSITION:	
Quartz	20
Feldspar	10
Clay	61
Pyrite	4
Carbonate unspec.	3
Foraminifers	1
Sponge spicules	1

SITE 469 HOLE CORE 35 CORED INTERVAL 321.0–330.5 m



LITHOLOGIC DESCRIPTION

5G 4/1
calcareous

5G 2/1

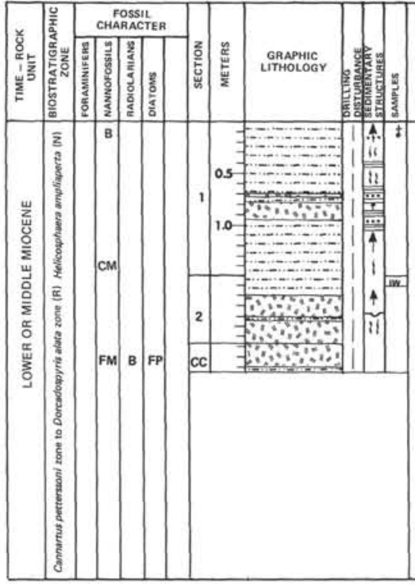
5G 4/1

SILTY CLAYSTONE, dark greenish gray (5G 4/1), some lenticular bedding and scattered burrows. Two thin layers of greenish black (5G 2/1) graded **VITRIC TUFF** composed mainly of glauconitic tubular pumice fragments. Calcareous interval 18–20 cm. Core is broken and fragmented by drilling.

SMEAR SLIDE SUMMARY

	1-48 (M)
TEXTURE:	
Sand	60
Silt	30
Clay	10
COMPOSITION:	
Quartz	2
Feldspar	5
Clay	3
Volcanic glass	74 (pumice)
Glauconite	10
Pyrite	4
Zeolite	1
Calc. Nannofossils	1

SITE 469 HOLE CORE 36 CORED INTERVAL 330.5–340.0 m



LITHOLOGIC DESCRIPTION

Interbedded olive gray (5Y 4/1) to dark greenish gray (5G 4/1) **SILTY CLAYSTONE** and medium dark gray (N4) to medium bluish gray (5B 5/1) **VITRIC TUFF.** Claystone has laminated intervals and zones of lenticular bedding and burrows. Tuff is fine-grained and moderately well sorted. Two upper layers are graded and faintly laminated. Tuff at 20–40 cm, Section 2, has distinct load structures.

ORGANIC CARBON AND CARBONATE

	1-8
% Organic Carbon	–
% $CaCO_3$	2

SMEAR SLIDE SUMMARY

	1-13 (D)
TEXTURE:	
Sand	–
Silt	25
Clay	75
COMPOSITION:	
Quartz	15
Feldspar	8
Mica	2
Heavy minerals	TR
Clay	69
Volcanic glass	2
Pyrite	2
Carbonate unspec.	1
Calc. Nannofossils	1

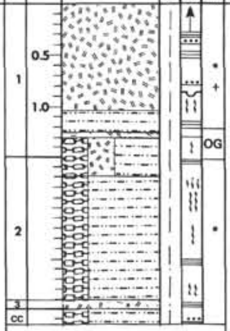
SITE 469 HOLE CORE 37 CORED INTERVAL 340.0–349.5 m

TIME – ROCK UNIT: LOWER OR MIDDLE MIOCENE

BIOSTRATIGRAPHIC ZONE: *Helicosphaera ampliaperta* (N)

FOSSIL CHARACTER

FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
	CM		
	CG	B	B



Large burrows

Interbedded tuff and claystone

LITHOLOGIC DESCRIPTION

Interbedded medium dark gray (N4) to medium bluish gray (5B 5/1) **VITRIC TUFF** and olive gray (5Y 3/2) to dark greenish gray (5G 4/1) **CALCAREOUS SILTY CLAYSTONE.** Tuff unit in upper part Section 1 contains two graded sequences with plane laminations. Tuff and claystone are interbedded top Section 2/base Section 1. Claystone is bioturbated; large burrows filled with lighter colored sediment.

ORGANIC CARBON AND CARBONATE

	1-81
% Organic Carbon	0.29
% $CaCO_3$	2

SMEAR SLIDE SUMMARY

	1-62 (D)	2-73 (D)
TEXTURE:		
Sand	5	–
Silt	70	1
Clay	25	99
COMPOSITION:		
Quartz	5	TR
Feldspar	20	–
Mica	4	–
Clay	–	75
Volcanic glass	66	–
Glauconite	TR	–
Pyrite	4	TR
Carbonate unspec.	–	20
Calc. Nannofossils	–	5
Diatoms	1	–

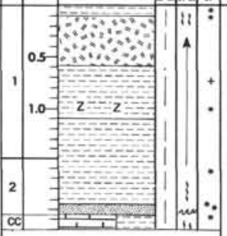
SITE 469 HOLE CORE 38 CORED INTERVAL 349.5–359.0 m

TIME – ROCK UNIT: LOWER OR MIDDLE MIOCENE

BIOSTRATIGRAPHIC ZONE: *Helicosphaera ampliaperta* (N) UPPER LOWER TO LOWER MIDDLE MIOCENE (R)

FOSSIL CHARACTER

FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
	B		
	B		
	RM		
	AM		
	CM		
	FM	RP	B



Large burrow
5B 5/1

5G 4/1

5G 4/1

N4
5GY 5/1

LITHOLOGIC DESCRIPTION

Interbedded medium bluish gray (5B 5/1) **VITRIC TUFF,** dark greenish gray (5G 4/1) **CLAYSTONE AND ZEOLITIC CLAYSTONE,** olive gray (5Y 4/1) to dark gray (N4) **CLAYEY SANDSTONE,** and medium greenish gray (5GY 5/1) **CLAYEY NANNOFOSSIL CHALK.** Tuff is burrowed and contains faint laminations. Claystone is burrow mottled throughout. Sandstone contains contorted laminations. Chalk in Core-Catcher is burrowed and contains scattered pyrite-rich patches.

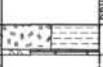
ORGANIC CARBON AND CARBONATE

	1-86
% Organic Carbon	–
% $CaCO_3$	3

SMEAR SLIDE SUMMARY

	1-8 (D)	1-13 (D)	1-102 (D)	2-20 (D)	2-62 (D)	2-56 (D)	CC-8 (D)
TEXTURE:							
Sand	–	–	–	–	10	40	–
Silt	15	55	15	15	60	20	10
Clay	85	45	85	80	30	40	90
COMPOSITION:							
Quartz	5	3	–	10	20	20	3
Feldspar	3	2	–	5	10	10	2
Mica	–	–	–	TR	–	–	–
Heavy minerals	TR	TR	–	1	3	3	TR
Clay	65	30	70	70	22	25	30
Volcanic glass	15	50	TR	–	20	25	–
Glauconite	TR	–	–	TR	TR	TR	–
Pyrite	1	3	TR	2	2	2	1
Zeolite	1	5	20	–	5	5	–
Carbonate unspec.	3	–	–	2	–	TR	20
Foraminifers	–	–	–	TR	2	2	–
Calc. Nannofossils	5	–	–	10	5	–	40
Diatoms	2	–	–	–	–	TR	–
Radiolarians	–	–	–	–	–	–	–
Sponge spicules	TR	–	–	–	5	TR	–
Plant debris	–	–	–	TR	–	–	–
Lithic fragments	–	7	–	–	5	5	–
Glaucophane ?	–	–	–	TR	TR	TR	–

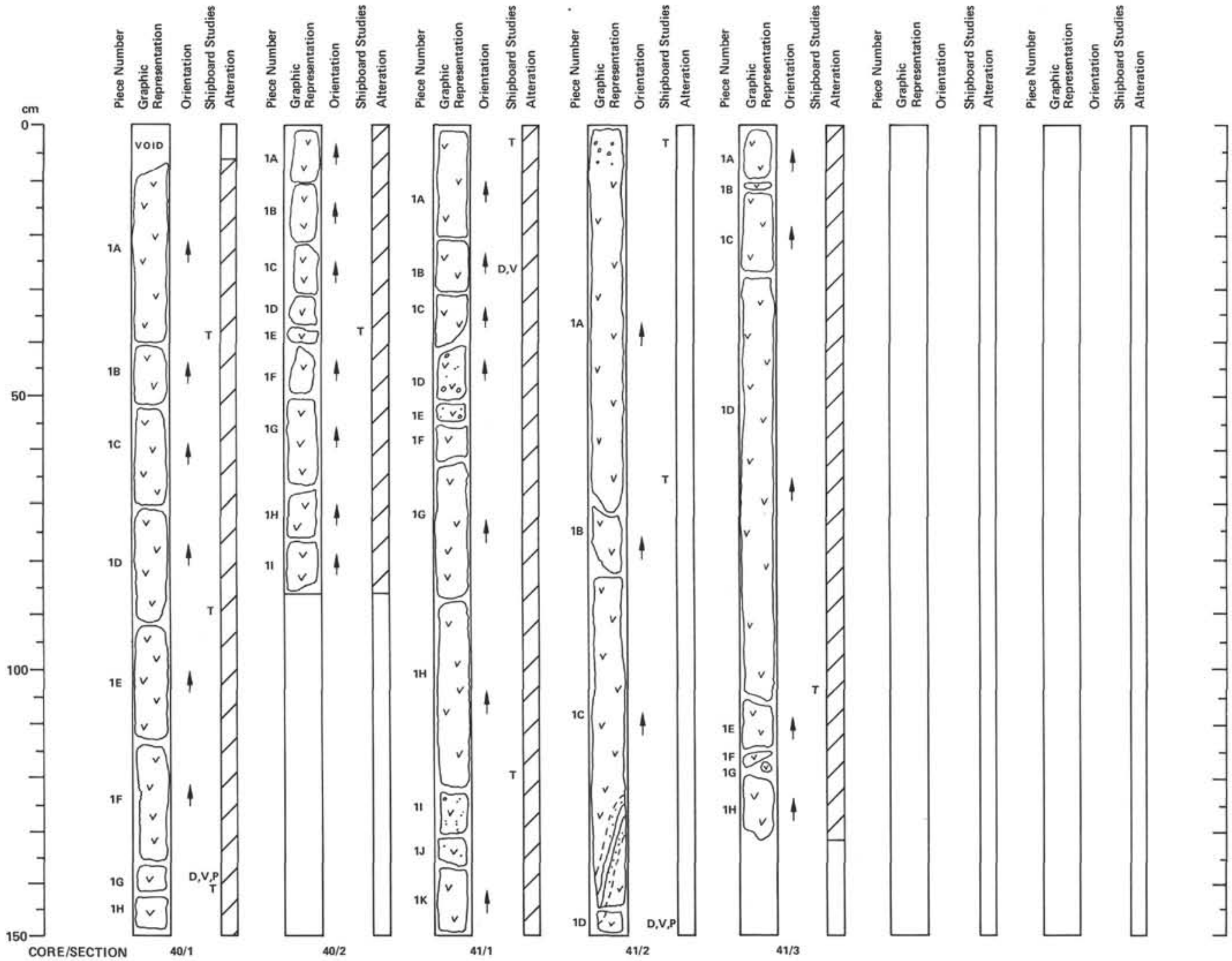
SITE 469 HOLE CORE 39 CORED INTERVAL 359.0–368.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER					SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES		LITHOLOGIC DESCRIPTION
		FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS									
LOWER OR MIDDLE MIOCENE	*Helicosphaera ampliaperta* or *Sphenolithus heteromorphus* (N) UPPER LOWER to LOWER MIDDLE MIOCENE (R) (Unconsolidated material contains Pliocene Discoasters)		CM	RP	B		CC					•	N6	Drilling breccia composed of fragments of **CLAYSTONE and VITRIC TUFF.** Basal 5 cm of core contains intact piece of burrow mottled, medium light gray (N6) **SILICEOUS(?) DOLOMITE.** Limestone has slight porcellaneous texture.
							1	0.5 1.0						
							2							
							3							
							4							

Core-Catcher only.

SMEAR SLIDE SUMMARY

	CC-28 (D)
COMPOSITION:	
Clay	10
Carbonate unspec.	80
Quartz	10


cm
0
50
100
150
CORE/SECTION
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Alteration
VOID
1A
1B
1C
1D
1E
1F
1G
1H
1I
1J
1K
T
D,V
D,V,P
40/1
40/2
41/1
41/2
41/3

SITE 469, CORE 40, SECTIONS 1–2, 368.5–370.9 m

MAJOR ROCK TYPE – DIABASE

Macroscopic Description

Diabase – medium gray, fine- to medium-grained. Homogeneous with scattered alteration patches of green clay up to 2 mm across. No vesicles; calcite-filled voids (1 mm across) occur between 107–117 cm in Section 1.

Thin Section Descriptions

Diabase – Section 1, Piece 1A, 37–41 cm
Texture: intersertal
Phenocrysts: none
Groundmass: plagioclase, 45%, 0.01–1 mm, euhedral-subhedral; clinopyroxene, 30%, 0.05–0.5 mm, euhedral-subhedral; opaques, 7%, 0.05–0.5 mm, anhedral; quartz(?), trace, 0.1 mm, anhedral
Alteration: greenish brown clays (25%) and calcite (TR) between plagioclase and pyroxene crystals

Diabase – Section 1, Piece 1E, 90–92 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase, 45%, 0.05–1 mm, euhedral-anhedral; clinopyroxene, 20%, 0.03–0.4 mm, subhedral-anhedral; opaques, 7%, 0.03–0.3 mm, anhedral; quartz, 2%, 0.3–0.7 mm, anhedral-rounded
Alteration: greenish brown clays (25%) and calcite between plagioclase and pyroxene crystals

Diabase – Section 1, Piece 1H, 143–146 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase, 45%, 0.05–1 mm, euhedral-subhedral; clinopyroxene, 30%, 0.03–0.4 mm, subhedral-anhedral; opaques, 7%, 0.03–0.3 mm, anhedral; quartz, TR, anhedral – associated with clays
Alteration: colorless and greenish brown clays (25%) and calcite (TR) between plagioclase and pyroxene crystals

Diabase – Section 2, Piece 1E, 37–40 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase, 55%, 0.05–1 mm, euhedral-subhedral; clinopyroxene, 25%, 0.01–0.1 mm, anhedral-subhedral; opaques, 4%, 0.01–0.1 mm, anhedral
Alteration: brownish green clay (16%), calcite (TR) and zeolite(?) (TR) between plagioclase and pyroxene crystals

Shipboard Data

Sample	D	V(∥)	V (⊥)	P
Section 1, Piece 1G, 138 cm	2.52	3.98	4.03	19

SITE 469, CORE 41, SECTIONS 1–3, 371.5–375.8 m

MAJOR ROCK TYPE – DIABASE

Macroscopic Description

Diabase – fine- to medium-grained and holocrystalline. Scattered vesicles and calcite-filled voids. Some vesicles up to 2 mm across. Small (~2 mm) patches of green clay also common. A thin (~1.5 cm) fine-grained zone occurs at 120 cm, Section 1; core is also fine-grained between 0–115 cm and 122–135 cm, Section 3. Calcite-filled fracture in Section 2 between 125–145 cm.

Thin Section Descriptions

Diabase – Section 1, Piece 1A, 2–4 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase, 60%, 0.05–1 mm, euhedral-subhedral; clinopyroxene, 15%, 0.01–0.1 mm, anhedral-subhedral; opaques, 4%, 0.01–0.1 mm, anhedral
Vesicles: <1%, <0.2 mm
Alteration: brownish green clay (19%), calcite (2%), and zeolite (TR) between plagioclase and pyroxene crystals

Diabase – Section 1, Piece 1I, 121–124 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase, 40%, 0.3–2 mm, euhedral-subhedral; clinopyroxene, 25%, 0.5–1 mm, anhedral; opaques, 7%, 0.03–0.2 mm, anhedral
Alteration: brownish green clay (25%), calcite (1%) and zeolite (2%) between plagioclase and pyroxene crystals

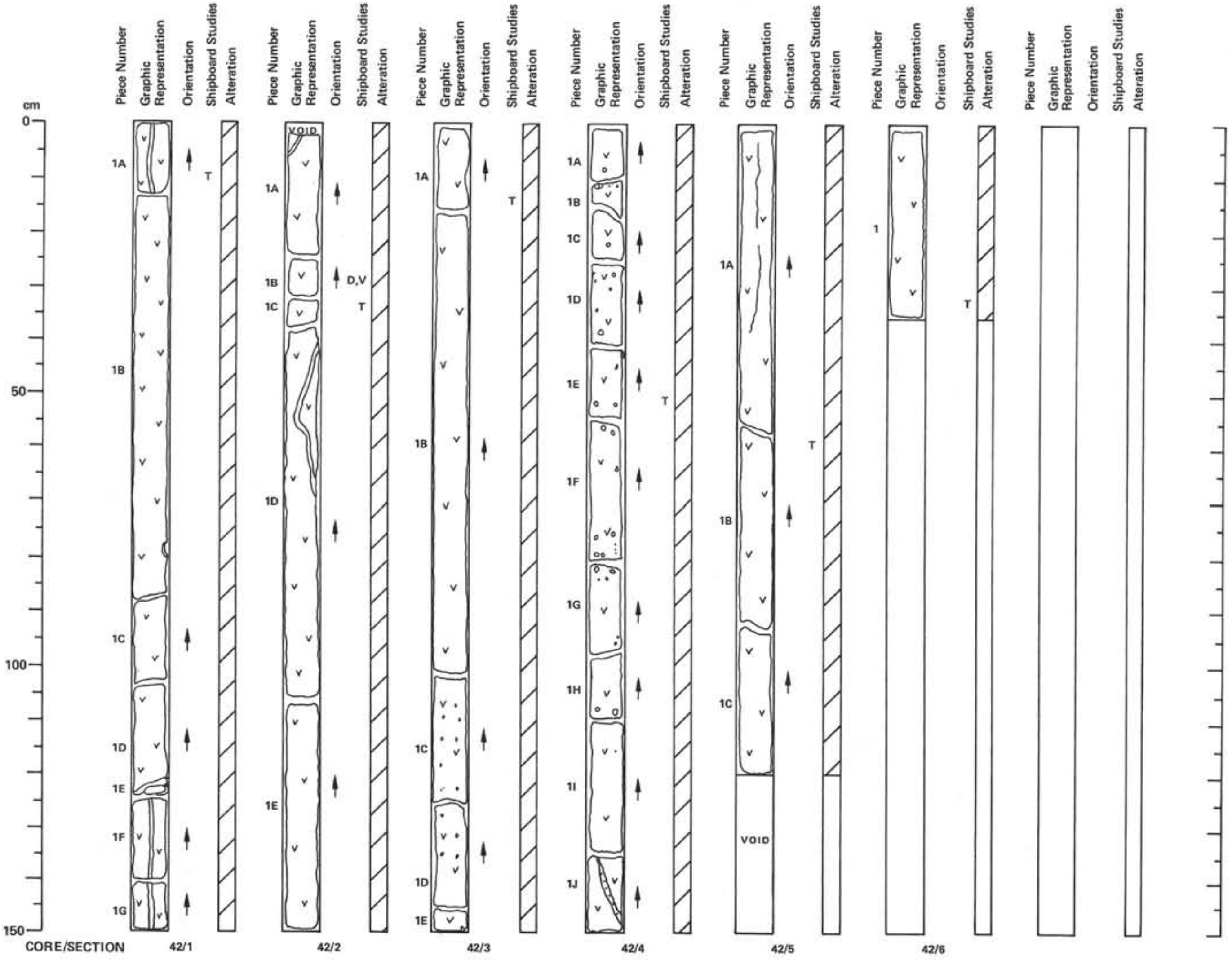
Diabase – Section 2, Piece 1A, 2–4 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase, 40%, 0.1–0.5 cm, euhedral-subhedral; clinopyroxene, 30%, 0.05–0.5 mm, anhedral; opaques, 6%, 0.03–0.2 mm
Alteration: brownish green clay (23%), zeolite (2%), calcite (TR), and talc(?) (TR) between plagioclase and pyroxene crystals

Diabase – Section 2, Piece 1A, 66–69 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase, 40%, 0.1–1 mm, euhedral-subhedral; clinopyroxene, 30%, 0.05–0.2 mm, anhedral; opaques, 6%, 0.03–0.2 mm, anhedral
Alteration: brownish green clay (23%), zeolite (analcime?) (2%), calcite (TR), and talc(?) (TR), between plagioclase and pyroxene crystals

Diabase – Section 3, Piece 1D, 103–106 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase, 40%, 0.1–1 mm, euhedral-subhedral; clinopyroxene (augite), 30%, 0.05–0.2 mm, subhedral-anhedral; opaques, 6%, 0.03–0.2 mm, anhedral
Alteration: brownish green clay (24%), calcite(TR), zeolite (TR), and talc(?) (TR) between plagioclase and pyroxene crystals

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 1, Piece 1B, 24 cm	2.52	4.18	–	–
Section 2, Piece 1D, 148 cm	2.56	–	4.18	16


cm
0
50
100
150
CORE/SECTION
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Alteration
42/1
1A
1B
1C
1D
1E
1F
1G
T
42/2
VOID
1A
1B
1C
1D
1E
D,V
T
42/3
1A
1B
1C
1D
1E
T
42/4
1A
1B
1C
1D
1E
1F
1G
1H
1I
1J
T
42/5
1A
1B
1C
VOID
T
42/6
1
T

SITE 469, CORE 42, SECTIONS 1–6, 378.0–387.3 m

MAJOR ROCK TYPE – DIABASE

Macroscopic Description

Diabase – fine- to medium-grained with scattered small (~2 mm across) patches of green clay alteration throughout. Grain size decreases sightly near base Section 6. Several concentrations of green clay alteration in Section 1 (63–64 cm), Section 2 (51 and 146 cm), and Section 3 (79–80 cm). Calcite-filled voids are common. Fractures (as marked) are filled with calcite or green clay. Pyrite is sometimes associated with the calcite veins. Scattered pyrite crystals occur between 80–90 cm in Section 5.

Thin Section Descriptions

Diabase – Section 1, Piece 1A, 10–14 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase, 40%, 0.1–1 mm, euhedral-anhedral; clinopyroxene (augite – a few grains have green tint at rim), 30%, 0.05–0.5 mm, subhedral-anhedral; opaques, 6%, 0.03–0.2 mm, anhedral; brownish green clinopyroxene (iron-rich augite?), TR, 0.3 mm, subhedral; green amphibole, TR, 0.1 mm, subhedral.
Alteration: brownish green clay (24%), talc(?) (1%), calcite (TR), and zeolite (analcime?) (TR), between plagioclase and pyroxene crystals

Diabase – Section 2, Piece 1C, 32–35 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase, 45%, 0.1–1 mm, euhedral-subhedral; clinopyroxene, 27%, 0.05–0.5 mm, subhedral-anhedral; opaques, 7%, 0.03–0.2 mm, anhedral. Clinopyroxene has slight purple tint.
Alteration: brownish green clay (29%), talc(?) (2%), and calcite (TR) occur between plagioclase and pyroxene crystals

Diabase – Section 3, Piece 1A, 12–15 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase (zoned from labradorite to andesine), 50%, 0.1–1 mm, euhedral-subhedral; clinopyroxene (augite), 30%, 0.05–0.5 mm, subhedral-anhedral; opaques (Fe-Ti oxides?), 8%, 0.03–0.2 mm, anhedral
Alteration: brownish green clay (11%), talc(?) (TR), and calcite (TR) occurs between plagioclase and pyroxene crystals

Diabase – Section 4, Piece 1E, 52–55 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase (zoned labradorite-andesine), 55%, 0.1–1 mm, euhedral-subhedral; clinopyroxene (augite), 20%, 0.05–1 mm, subhedral-anhedral; opaques (Fe-Ti oxides?), 7%, 0.03–0.2 mm, anhedral
Alteration: brownish green clay (18%), calcite (TR), and talc(?) (TR) occurs between plagioclase and pyroxene crystals

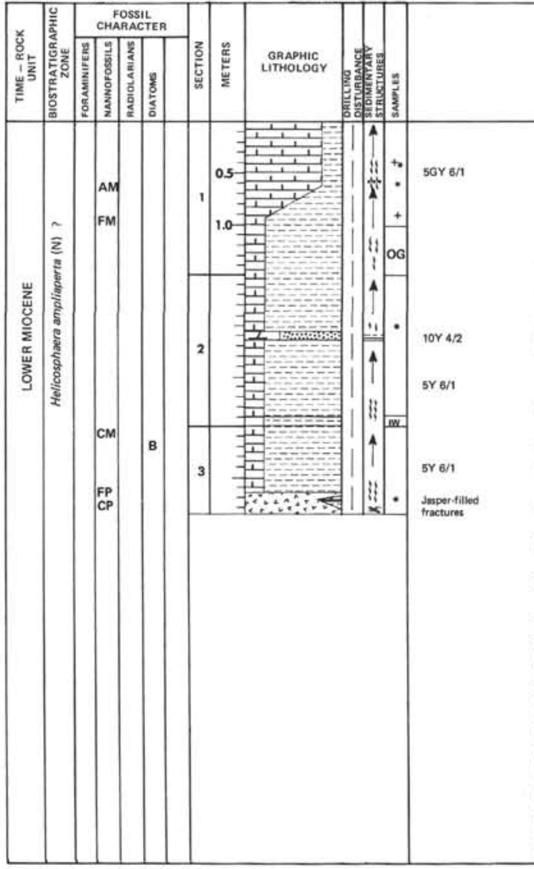
Diabase – Section 5, Piece 1B, 58–61 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase (zoned labradorite-andesine), 55%, 0.1–0.5 mm, euhedral-subhedral; clinopyroxene (augite), 20%, 0.05–0.3 mm, subhedral-anhedral; opaques (Fe-Ti oxide?), 7%, 0.03–0.2 mm, anhedral
Alteration: brownish green clay (16%), calcite (2%), and zeolite (TR) occur between plagioclase and pyroxene crystals

Diabase – Section 6, 30–33 cm
Texture: subvariolitic
Phenocrysts: –
Groundmass: plagioclase, 40%, 0.01–0.3 mm, skeletal-needle; clinopyroxene, TR, 0.01–0.3 mm, skeletal-equant; opaques, 7%
Vesicles: 8%, 0.1–0.3 mm, irregular
Alteration: vesicles are commonly filled with calcite (5%). Some plagioclase and glass(?) between plagioclase crystals altered to brownish green clay (30%) and zeolite (10%).

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 2, Piece 1B, 27–29 cm	2.60	4.26	–	–

SITE 469 HOLE CORE 43 CORED INTERVAL 387.0–396.0 m



LITHOLOGIC DESCRIPTION

CLAYEY NANNOFOSSIL CHALK AND NANNOFOSSIL CLAYSTONE, greenish gray (5GY 6/1) to light olive gray (5Y 6/1), burrowed with some lenticular bedding. Scattered pyrite-rich patches and some pseudolaminations. Thin layer of grayish olive (10Y 4/2) **DOLOMITIC(?) SANDSTONE** in Section 2 has faint laminations and gradational upper contact. **BASALT** at base of core (65–86 cm, Section 3) is fractured and has some glassy rinds. Some fractures filled with reddish brown (10YR 4/6) jasper. Small piece of reddish brown **DOLOMITIC(?) IRON-RICH CLAY** occurs between basalt fragments in Section 3.

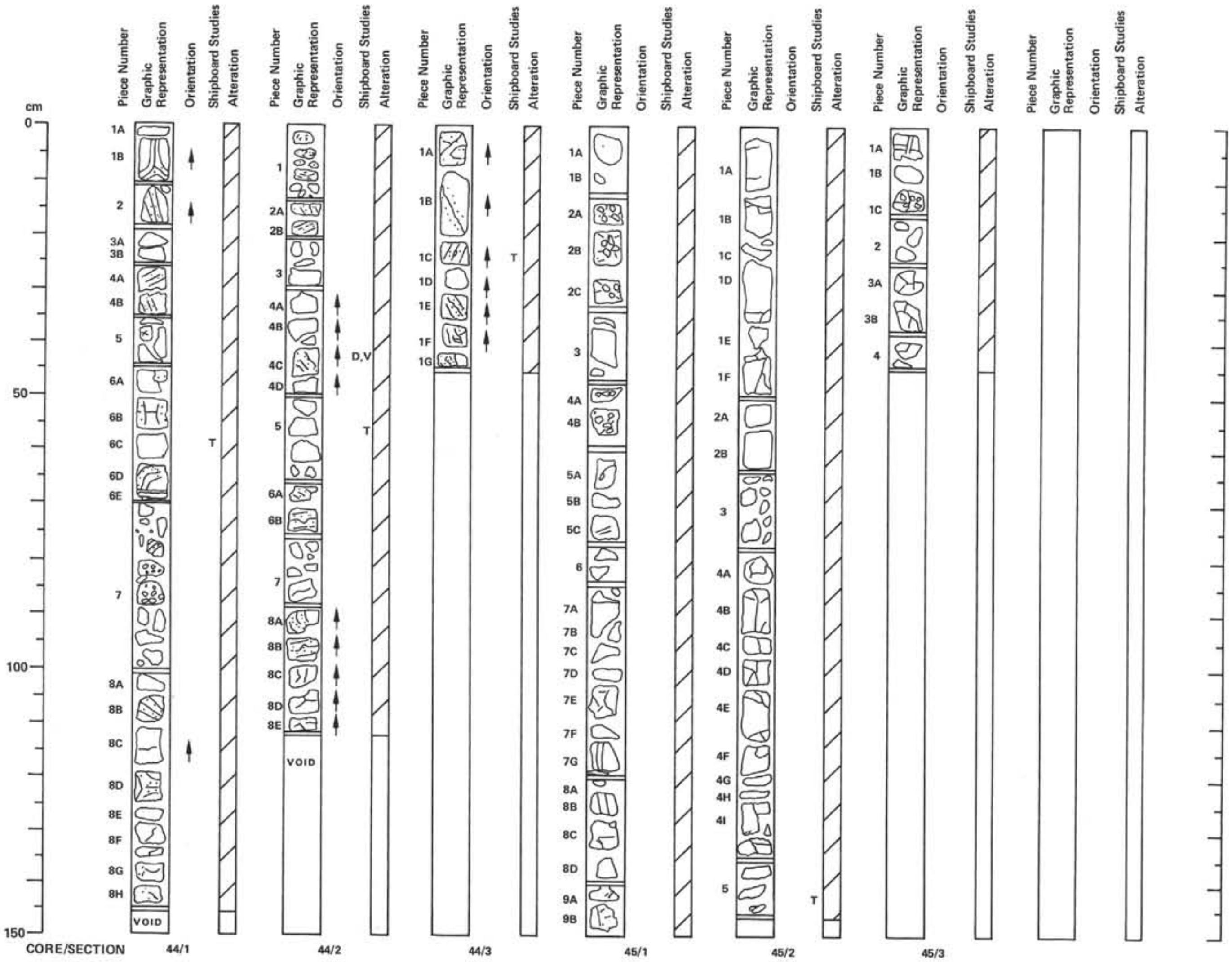
THIN SECTION DESCRIPTION – Basalt (Section 3, 73 cm):
Porphyritic Texture (subvariolitic groundmass)
Phenocrysts:
Plagioclase, 1%, 0.1–0.7 mm, euhedral, skeletal, prismatic;
Olivine (pseudomorphs), 1%, 0.1–0.5 mm, euhedral, altered to talc
Groundmass:
Plagioclase, 30%, 0.01–0.1 mm, euhedral, skeletal needles;
Glass, 63%, devitrified; Opaques, 4%
Vesicles: 1%, 1.0–1.5 mm
Alteration:
Clays, TR, replaces olivine; talc, TR, replaces olivine

ORGANIC CARBON AND CARBONATE

	1-40	1-92
% Organic Carbon	–	1.95(?)
% $CaCO_3$	75	28

SMEAR SLIDE SUMMARY

	1-48 (D)	1-68 (D)	2-59 (M)	3-75 (M)
TEXTURE:				
Sand	–	–	80	–
Silt	6	10	15	2
Clay	94	90	5	98
COMPOSITION:				
Quartz	12	–	30	–
Feldspar	TR	–	35	–
Heavy minerals	TR	–	5	–
Clay	10	40	15	50
Glauconite	–	–	TR	–
Pyrite	–	–	TR	–
Carbonate unspec.	10	30	–	–
Foraminifers	3	–	–	–
Calc. Nannofossils	65	30	–	3
Radiolarians	TR	–	–	–
Dolomite	–	–	15	47
Iron-oxides	–	–	–	2


cm
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CORE/SECTION
Piece Number
Graphic Representation
Orientation
Shipboard Studies
Alteration
44/1
1A 1B 2 3A 3B 4A 4B 5 6A 6B 6C 6D 6E 7 8A 8B 8C 8D 8E 8F 8G 8H
VOID
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44/2
1 2A 2B 3 4A 4B 4C 4D 5 6A 6B 7 8A 8B 8C 8D 8E
VOID
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44/3
1A 1B 1C 1D 1E 1F 1G
T
45/1
1A 1B 2A 2B 2C 3 4A 4B 5A 5B 5C 6 7A 7B 7C 7D 7E 7F 7G 8A 8B 8C 8D 9A 9B
45/2
1A 1B 1C 1D 1E 1F 2A 2B 3 4A 4B 4C 4D 4E 4F 4G 4H 4I 5
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45/3
1A 1B 1C 2 3A 3B 4

SITE 469, CORE 44, SECTION 1–3, 396.0–399.4 m

MAJOR ROCK TYPE – BASALT

MINOR ROCK TYPES – ALTERED HYALOCLASTITE, CHERT

Macroscopic Descriptions

Basalt – aphyric, moderately altered and highly fractured. Several pieces have glassy margins (eg. Pieces 6A–C, Section 1). Fractures are often filled with sparry calcite and/or green clay. Yellowish and greenish gray alteration rinds surround fractures.

Altered Hyaloclastite – pieces of basalt (originally glassy?), completely altered to green clays. Occur as small fragments between basalt at 70–100 cm, Section 1.

Chert – grayish red (5R 4/2), clayey and quartzose (Pieces 3A–B, Section 1).

Thin Section Descriptions

Basalt (glassy margin) – Section 1, Piece 6C, 58–60 cm
Texture: porphyritic with cryptocrystalline groundmass
Phenocrysts: plagioclase, <1%, 1.5 mm, euhedral
Groundmass: glass, 99%, devitrified
Alteration: glass altered to yellowish green clay minerals

Basalt – Section 2, Piece 5, 58–60 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase, 30%, <0.02 mm, laths; clinopyroxene, 15%, <0.01 mm, anhedral granular; altered mesostasis, 35%; opaques, 10%
Vesicles: 10%, 0.1–0.3 mm, circular
Alteration: green clays fill some vesicles and occur as extensive alteration of glassy groundmass

Basalt – Section 3, Piece 1D, 26–28 cm
Texture: intersertal
Phenocrysts: –
Groundmass: plagioclase, 30%, <0.03 mm, laths; clinopyroxene, 30%, <0.02 mm, anhedral and equant; mesostasis, 35%; opaques, TR
Vesicles: 5%, <0.3 mm, circular
Alteration: brownish green clay fills some vesicles

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 2, Piece 4C, 41 cm	2.74	4.58	–	–

SITE 469, CORE 45, SECTIONS 1–3, 405.0–408.5 m

MAJOR ROCK TYPE – BASALT

MINOR ROCK TYPE – BASALTIC BRECCIA, CLAYEY LIMESTONE, CHERT

Macroscopic Descriptions

Basalt – aphyric, moderately altered, and highly fractured. Fractures filled with calcite or reddish brown chert (jasper). Yellowish alteration rinds surround fractures. No glassy margins noted.

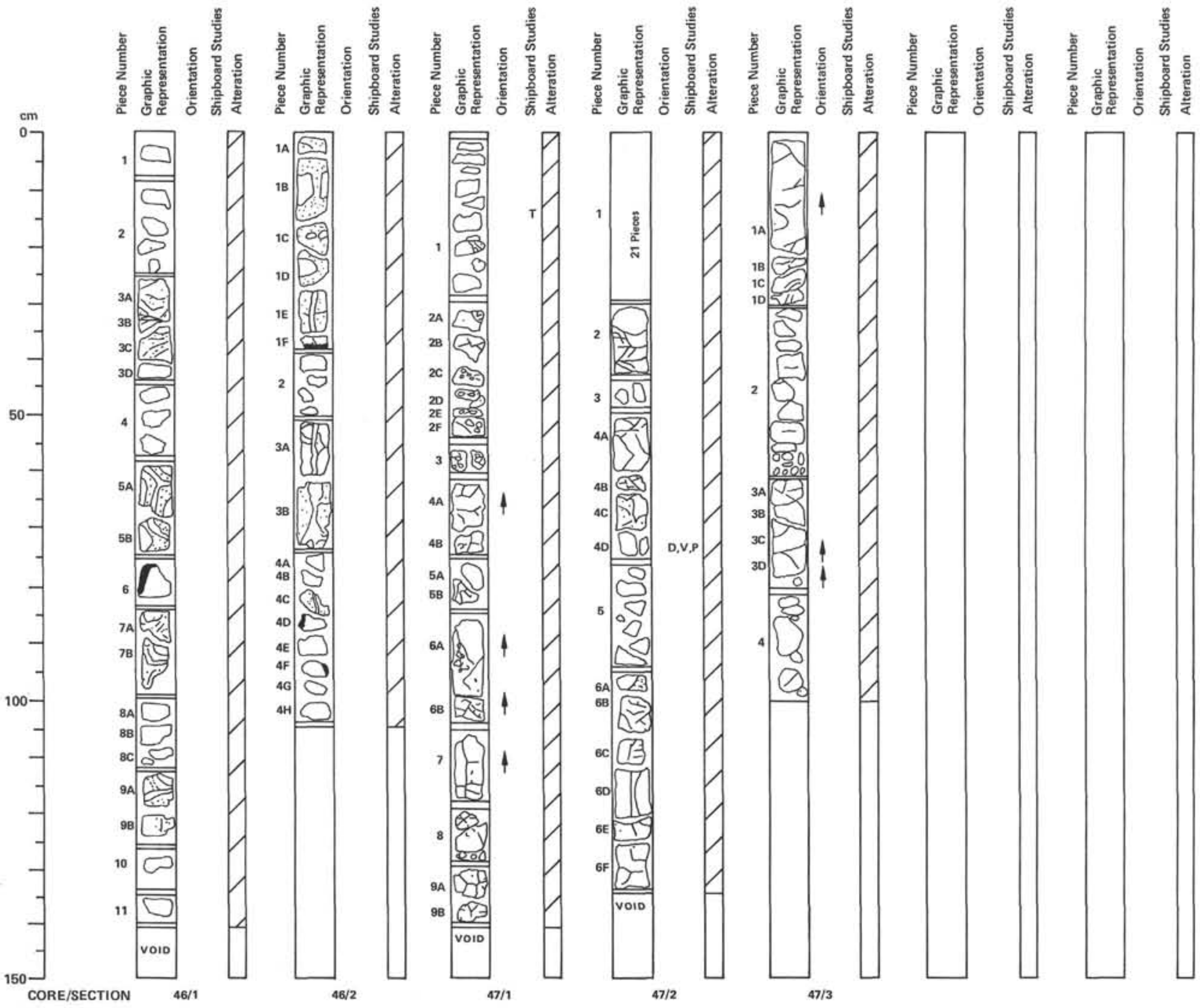
Basaltic Breccia – Pieces 2, 4, and 5A–B in Section 1 are basaltic breccia consisting of angular fragments of aphyric basalt with some palagonite filling spaces between fragments.

Clayey Limestone – Pieces 7A–D in Section 1 are massive, reddish brown clayey limestone. No sedimentary structures.

Chert – Piece 1B in Section 3 is reddish brown chert (spherulitic jasper) cut by small calcite veinlets.

Thin Section Description

Basalt – Section 2, Piece 5, 140–142 cm
Texture: porphyritic with subvariolitic groundmass
Phenocrysts: plagioclase, <1%, 0.5–1 mm, euhedral; clinopyroxene, <1%, 0.5–1 mm, euhedral
Groundmass: plagioclase, 40%, <0.03 mm, skeletal; clinopyroxene, 30%, <0.02 mm, anhedral and equant; mesostasis, 17%; opaques, 10%, <0.02 mm
Vesicles: 3%, <0.2 mm, circular
Alteration: brownish green clay replaces parts of mesostasis and fills some vesicles



SITE 469, CORE 46, SECTIONS 1–2, 410.0–412.5 m

MAJOR ROCK TYPE – BASALT

Macroscopic Description

Basalt – aphyric, moderately altered, and highly fractured. Fractures filled with calcite, red jasper, or green clay and surrounded by yellowish gray alteration rinds. Several pieces (eg. Section 1, Piece 6; Section 2, Pieces 1F, 4d and F) have glassy margins as marked.

SITE 469, CORE 47, SECTIONS 1–3, 414.0–417.5 m

MAJOR ROCK TYPE – BASALT

MINOR ROCK TYPE – ALTERED HYALOCLASTITE

Macroscopic Descriptions

Basalt – aphyric, moderately altered, and highly fractured. Calcite or red jasper fills some fractures; yellowish alterations rinds border fractures. Piece 3A, Section 3, has a glassy margin.

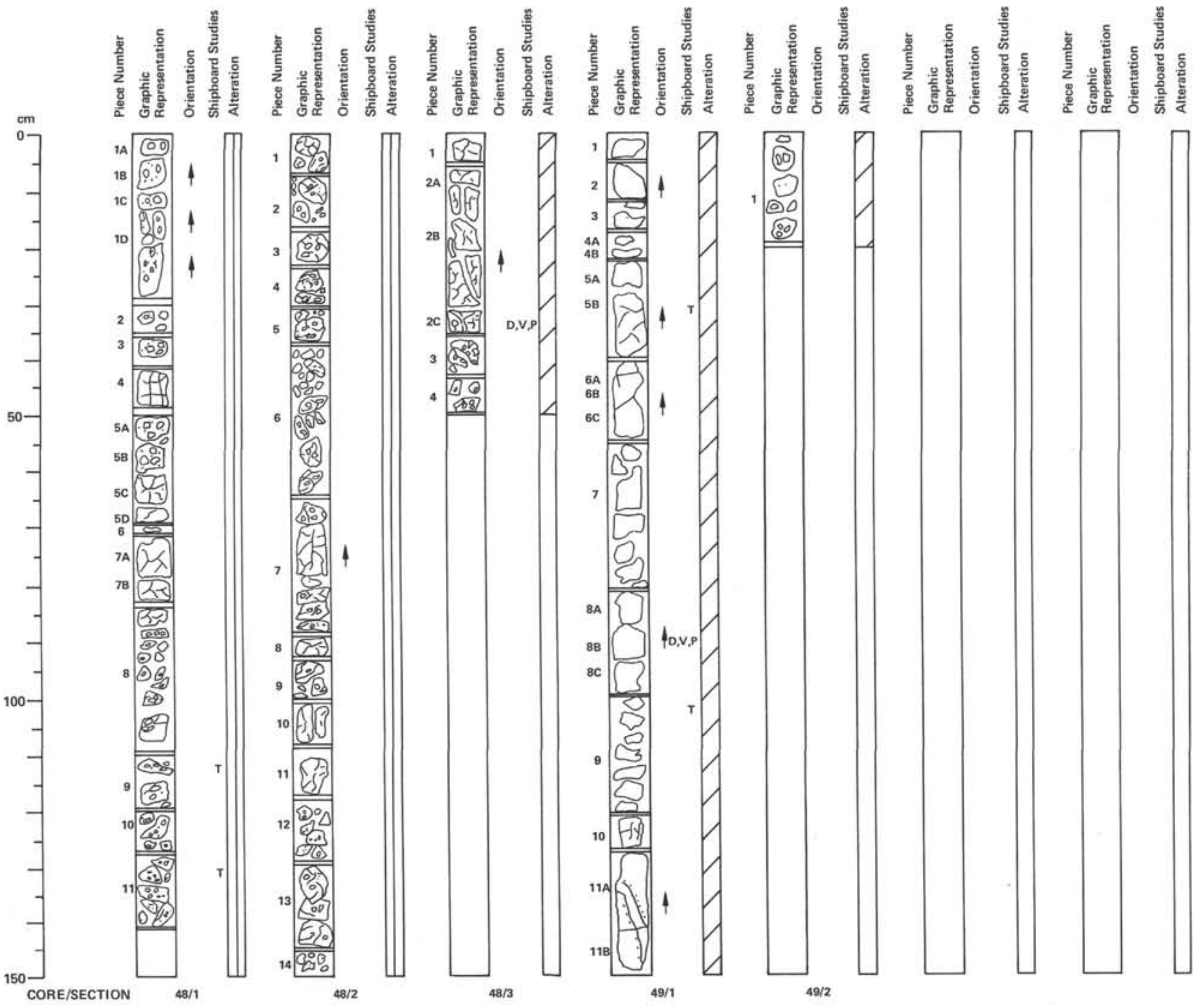
Altered Hyaloclastite – angular fragments of glassy basaltic breccia partially or completely altered to green clay and calcite. Brown basaltic glass preserved in several pieces. Alteration produces soft rock easily scratched with fingernail. Many fragments are concentrically banded. Calcite veins separate basalt and hyaloclastite where they occur in same piece (eg. Piece 2A, Section 1). Hyaloclastite occurs in Section 1, Pieces 2A and 2C–F and in Section 2, several fragments in Piece 1.

Thin Section Description

Basalt – Section 1, Piece 1, 14–18 cm
Texture: marginally porphyritic with variolitic groundmass
Phenocrysts: plagioclase, <1%, 0.2 mm, euhedral
Groundmass: plagioclase, 38%, 0.03–0.1 mm, skeletal needles; clinopyroxene, 35%, 0.03–0.1 mm, skeletal; mesostasis, 15%; opaques, 8%
Vesicles: 4%, 0.06–0.1 mm, circular
Alteration: brownish clays fill some vesicles

Shipboard Data

Sample	D	V (ǁ)	V (⊥)	P
Section 2, Piece 4D, 74 cm	2.76	4.40	–	13



SITE 469, CORE 48, SECTIONS 1–3, 423.0–426.5 m

MAJOR ROCK TYPES – ALTERED HYALOCLASTITE, BASALT

Macroscopic Descriptions

Altered Hyaloclastite – glassy basaltic breccia partially or completely altered to green clay. Altered rock easily scratched with fingernail. Many fragments are concentrically banded (i.e. alteration mimics outline of fragment); other fragments have circular or spherulitic structures with radiaxial patterns. Pieces 4, 5B and 8 in Section 1 still contain some fragments of unaltered basaltic glass. Hyaloclastite marked by breccia symbol (eg. Section 1, Pieces 1–3, 5A–B, part of 8, and 9–11; Section 2, most of Section; Section 3, Piece 4).

Basalt – aphyric, moderately altered, and highly fractured. Some fractures filled with green clay or calcite. Large calcite vein in Section 3, Piece 3. Yellowish gray alteration rind surrounds fractures.

Thin Section Descriptions

Basalt (glassy margin) – Section 1, Piece 9, 113–117 cm
Texture: holohyaline
Phenocrysts: plagioclase, <1%, 0.2–0.3 mm, euhedral
Groundmass: glass, 99%, partly devitrified
Alteration: traces of zeolitic amygdules

Hyaloclastite – Section 1, Piece 11, 130–133 cm
Texture and Composition: breccia composed of angular fragments of basaltic glass (60%) up to several cm across set in an aphanitic matrix (40%). Both fragments and matrix are altered to green clays.

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 3, Piece 2C, 34 cm	2.91	4.85	–	6.9

SITE 469, CORE 49, SECTIONS 1–2, 432.0–433.7 m

MAJOR ROCK TYPE – BASALT

MINOR ROCK TYPE – ALTERED HYALOCLASTITE

Macroscopic Descriptions

Basalt – aphyric to slightly porphyritic, moderately altered, and highly fractured. Glassy margins in Section 1, Piece 8B and 9, as marked. Calcite fills many small fractures; large calcite vein in Piece 11, Section 1. Minor red jasper and green clay in other fractures.

Altered Hyaloclastite – glassy basaltic breccia partially or completely altered to green clay. Identical to hyaloclastite in Core 48. Fragments in Piece 1, Section 2.

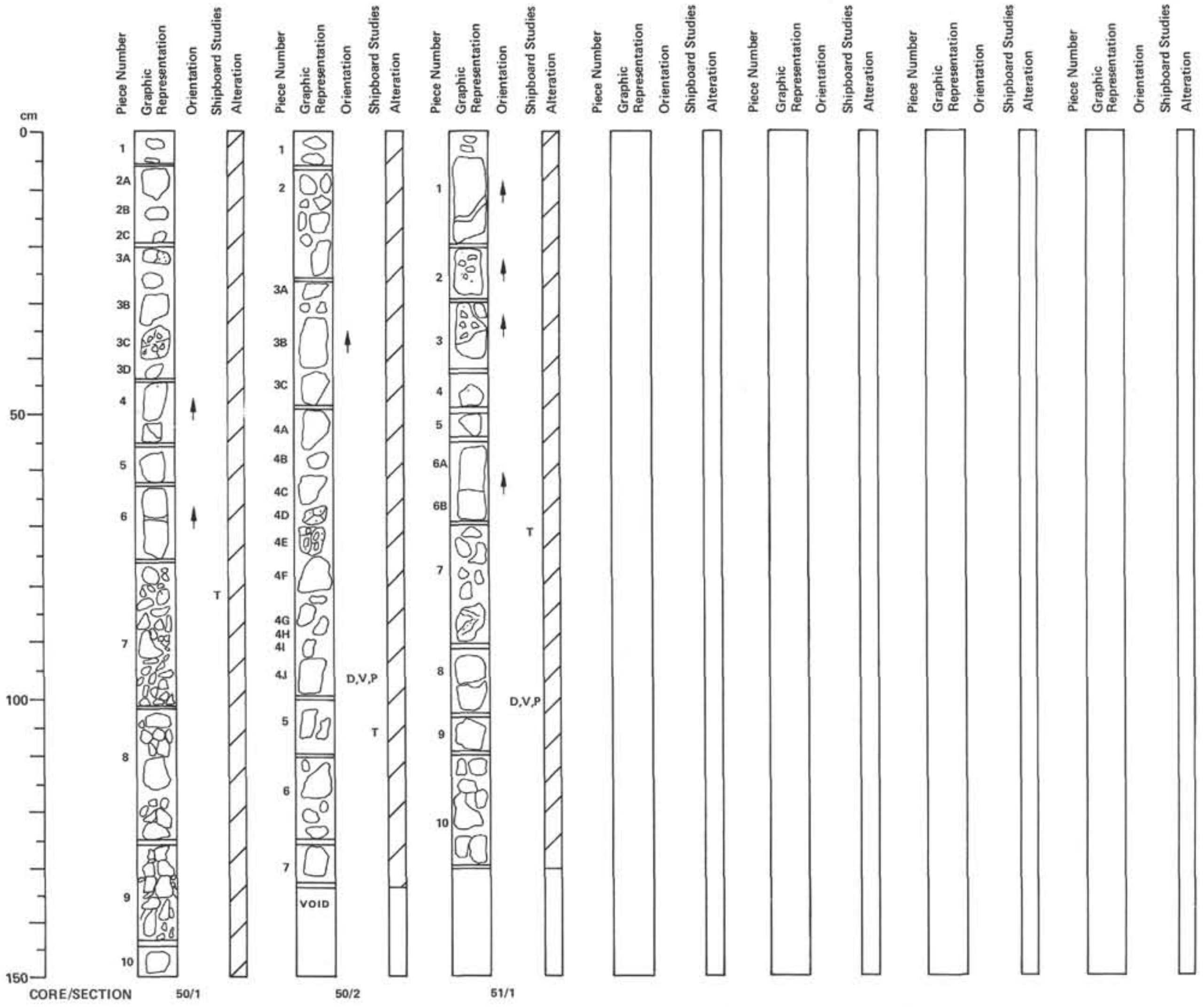
Thin Section Descriptions

Basalt – Section 1, Piece 5B, 32–35 cm
Texture: marginally porphyritic with hyalopilitic groundmass
Phenocrysts: plagioclase, TR, 0.5–1%, euhedral; clinopyroxene, TR, 1–2 mm, subhedral
Groundmass: plagioclase, 20%, <0.1 mm, skeletal; clinopyroxene, 10%, <0.05 mm, skeletal; glass, 57%, devitrified; opaques, 10%.
Vesicles: 3%, 0.5–3 mm
Alteration: brownish green clay fills some vesicles

Basalt (glassy margin) – Piece 9, 103–106 cm
Texture: holohyaline
Phenocrysts: plagioclase, <1%, 0.5–1 mm euhedral
Groundmass: brown glass, 95%, partly devitrified
Alteration: clays occur along fractures in glass

Shipboard Data

Sample	D	V (∥)	V (⊥)	P
Section 1, Piece 8B, 88 cm	2.84	5.31	–	6



SITE 469, CORE 50, SECTIONS 1–2, 441.0–443.6 m

MAJOR ROCK TYPES – BASALT, ALTERED HYALOCLASTITE

Macroscopic Descriptions

Baslat – aphyric, moderately altered, and highly fractured. Pieces 1 and 2 in Section 2 have glassy margins as marked. Calcite and green clay fill some fractures. Yellowish gray alteration rind fills some fractures.

Altered Hyaloclastite – basaltic breccia partially or completely altered to green clay. Interiors of altered fragments are concentrically banded. Angular fragments of fresh basalt and basaltic glass occur in Section 1, Pieces 7–10. Pieces 3A–B in Section 1 and Pieces 4D–E in Section 2 are basaltic breccias (fresh basalt fragments) with a matrix of green clay. Hyaloclastite marked by breccia pattern.

Thin Section Descriptions

Hyaloclastite – Section 1, Piece 7, 80–82 cm
Texture and Composition: breccia consisting of altered basalt fragments (~60%) set in green clay fine-grained matrix. All minerals and glass have been replaced by green clay

Basalt – Section 2, Piece 5, 107–108 cm
Texture: hyalopilitic to subvariolitic
Phenocrysts: –
Groundmass: plagioclase, 35%, <0.1 mm, skeletal; clinopyroxene, 30%, <0.05 mm, skeletal; glass, 33%, devitrified and altered; opaques, 8%, 0.05 mm
Vesicles: 4%, <0.2 mm
Alteration: glassy groundmass is devitrified and partly altered to clays; clays also fill some vesicles

Shipboard Data

Sample	D	$V(\parallel)$	$V(\perp)$	P
Section 2, Piece 4J, 97 cm	2.78	4.78	–	13

SITE 469, CORE 51, SECTION 1, 450.0–451.3 m

MAJOR ROCK TYPE – BASALT

Macroscopic Description

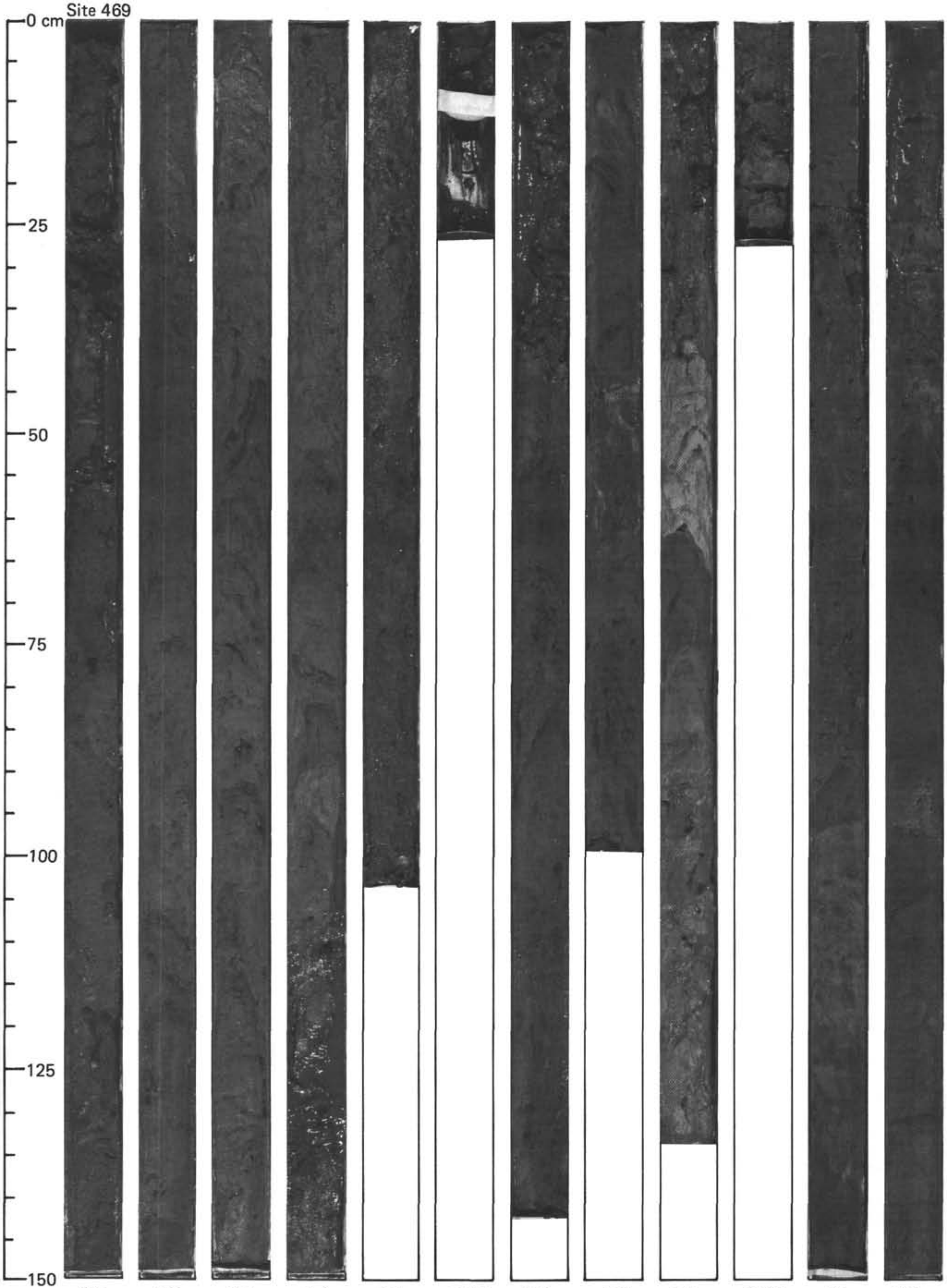
Basalt – aphanitic to slightly phaneritic, moderately altered and fractured. Calcite and green clay fill some fractures in Pieces 1 and 7. Pieces 2 and 3 are basaltic breccias.

Thin Section Description

Basalt – Section 1, Piece 7, 73–75 cm
Texture: variolitic
Phenocrysts: –
Groundmass: plagioclase, 30%, <0.05 mm, skeletal; clinopyroxene, 10%, <0.02 mm, skeletal; glass, 47%, devitrified.
Vesicles: 3%, 0.1–0.2 mm, circular
Alteration: vesicles partly filled with clay

Shipboard Data

Sample	D	$V(\parallel)$	$V(\perp)$	P
Section 1, Piece 8, 101–103 cm	2.82	4.95	–	12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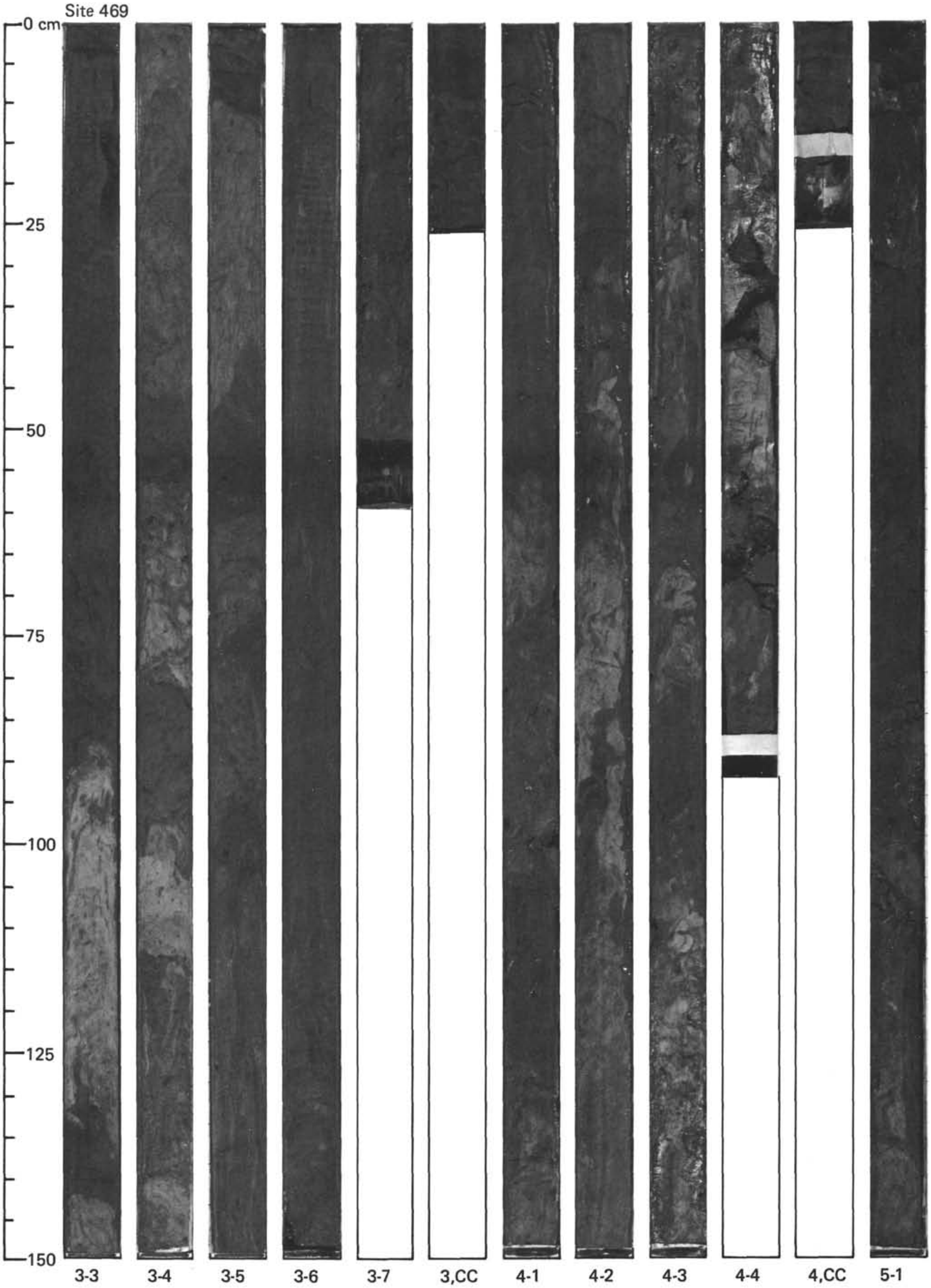
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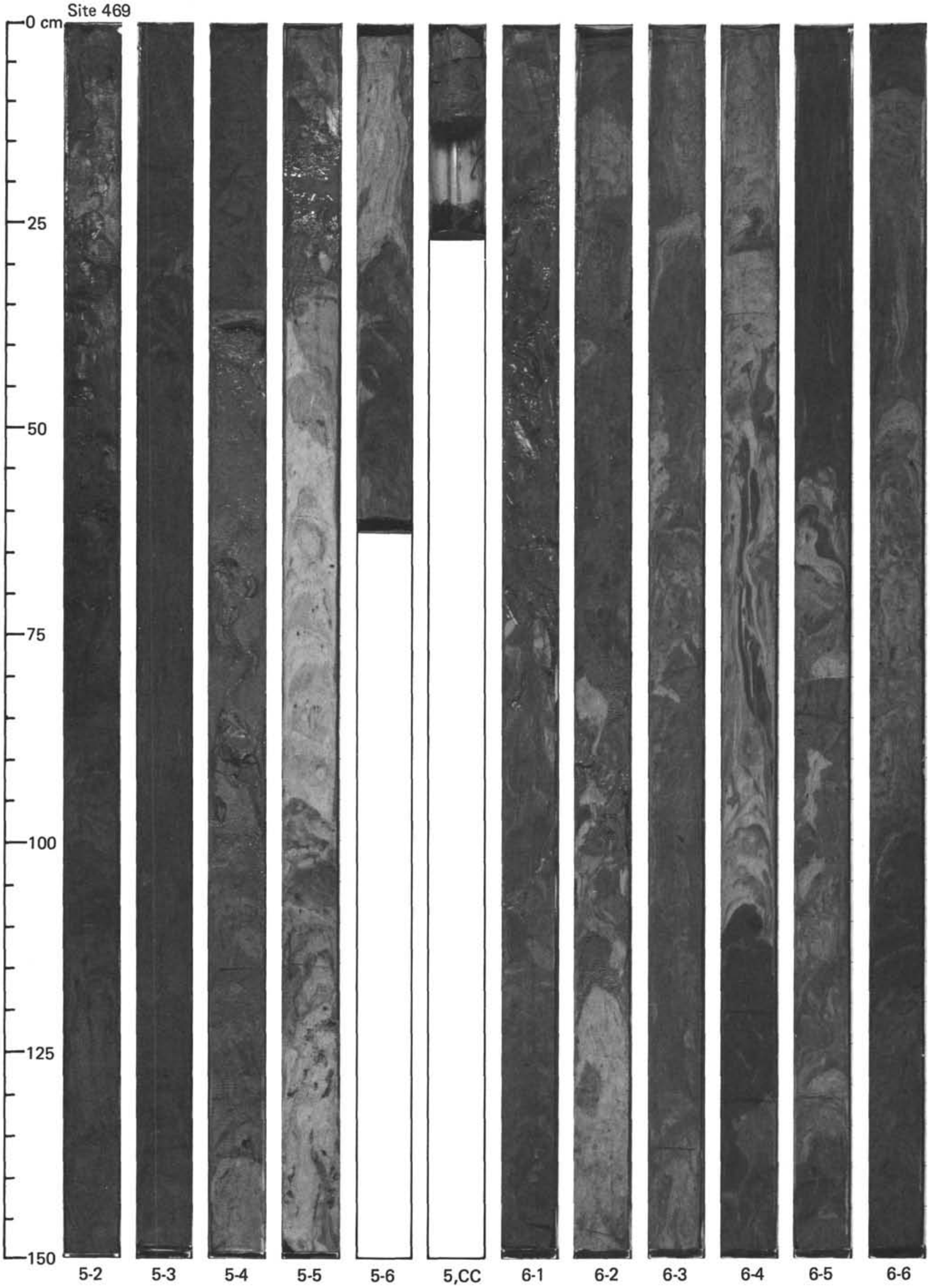
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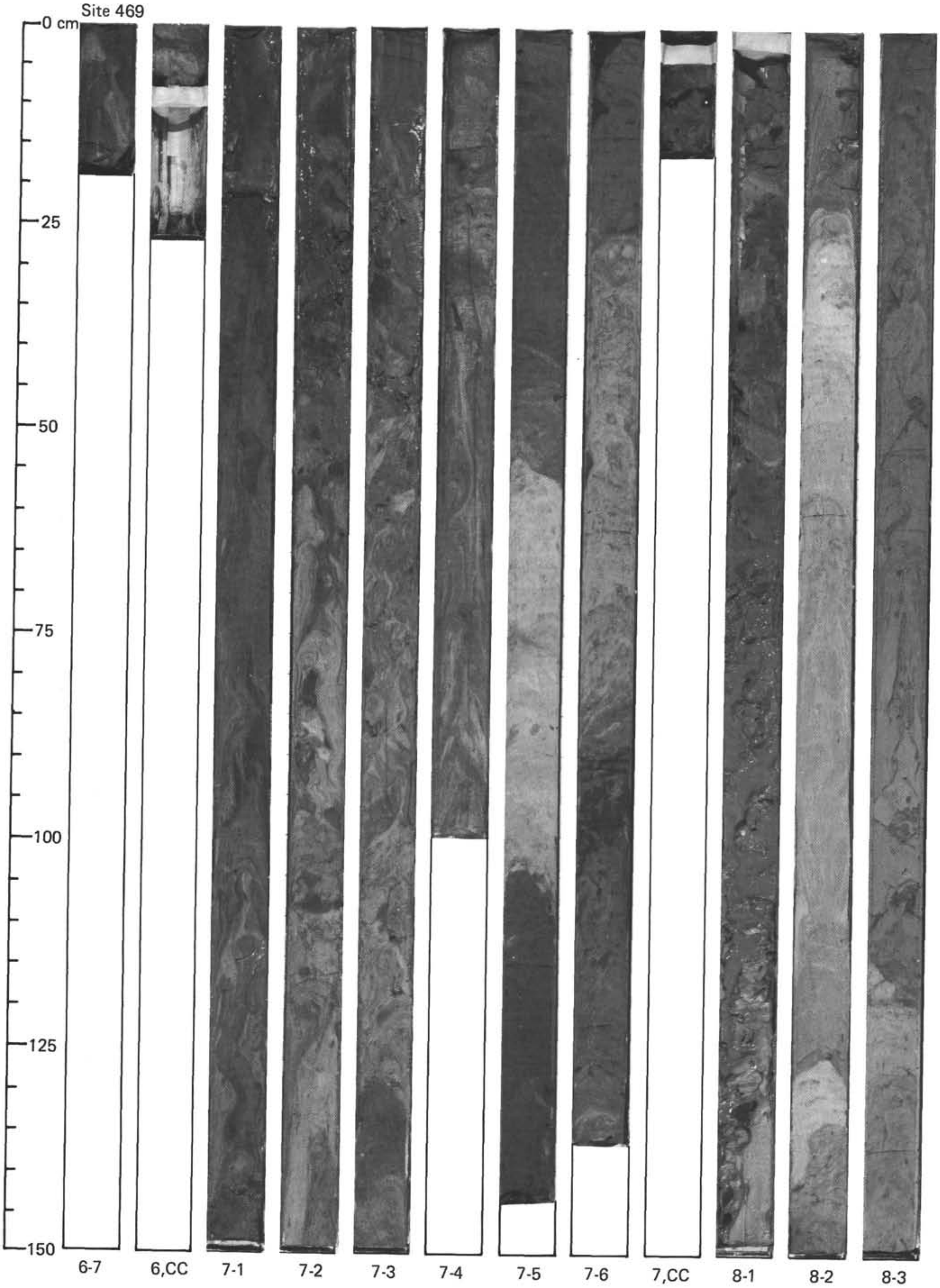
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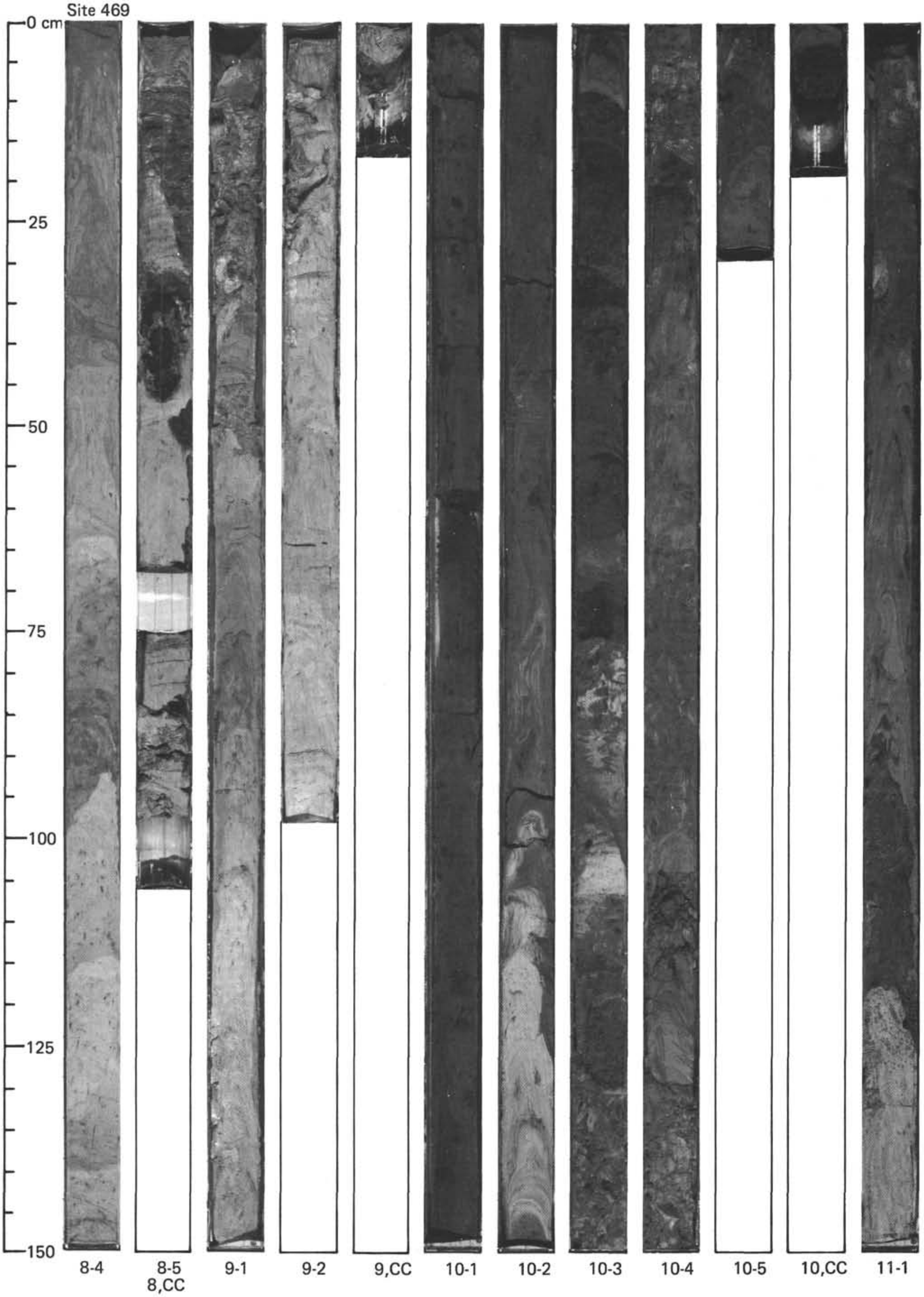
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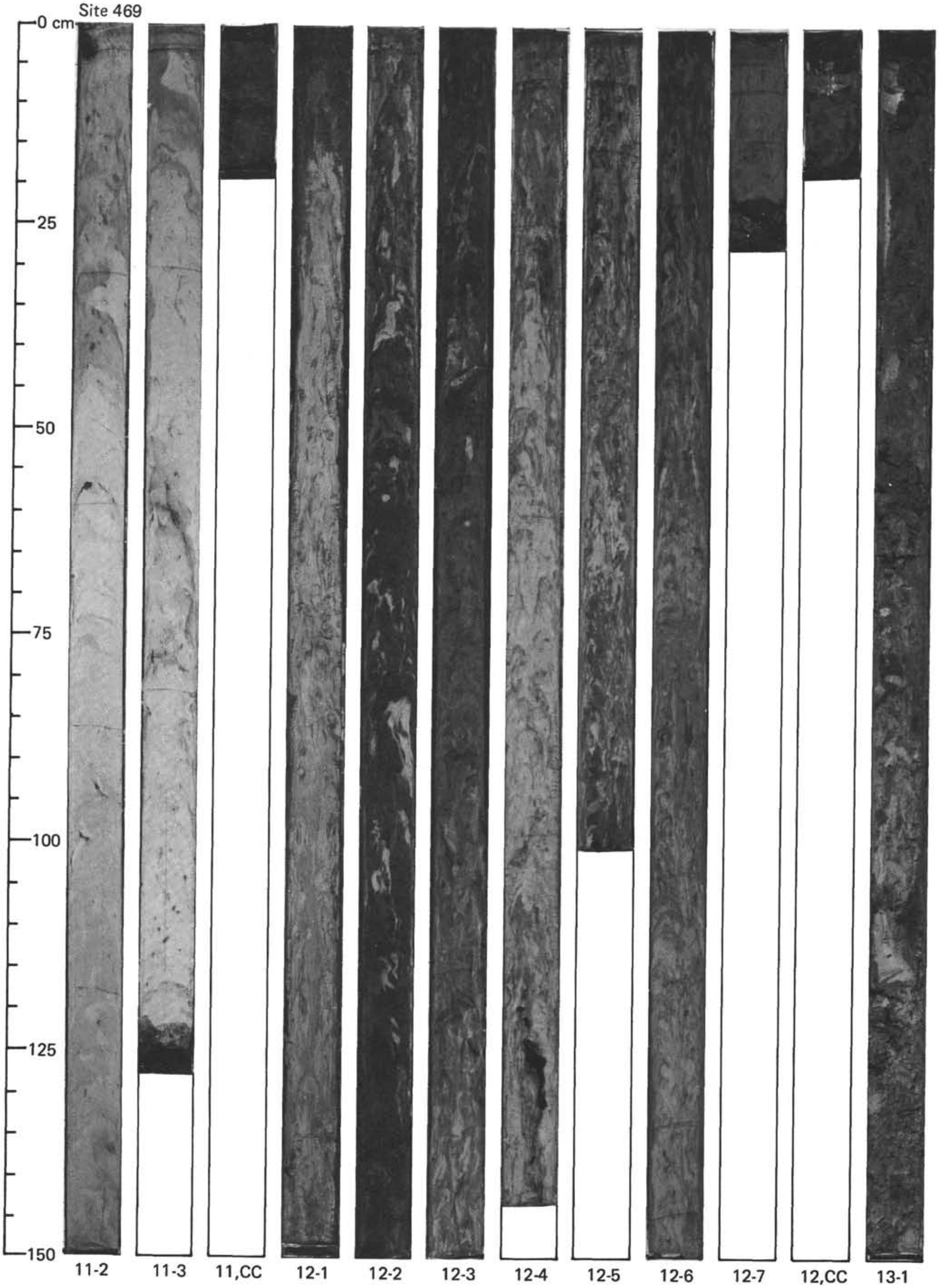
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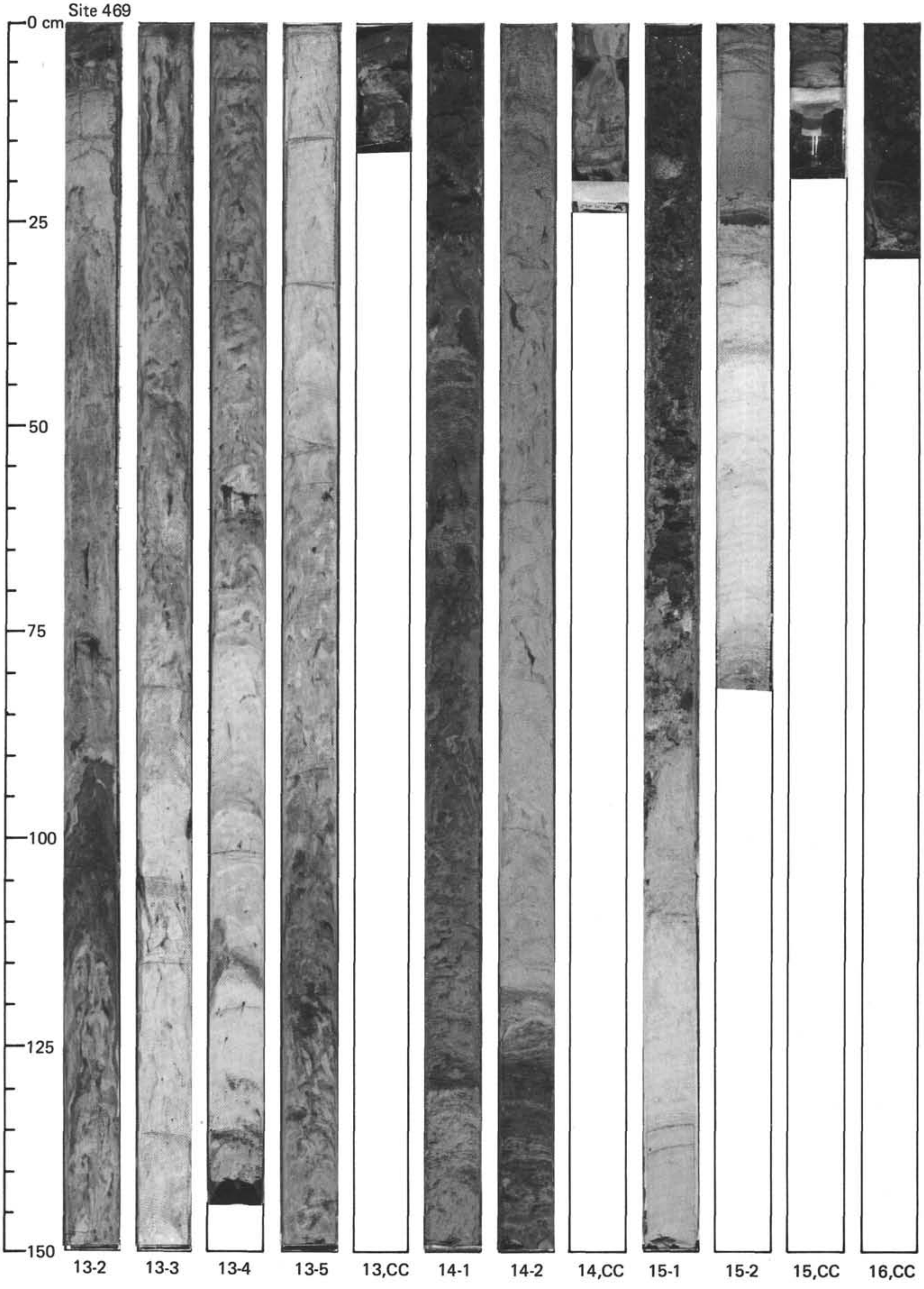
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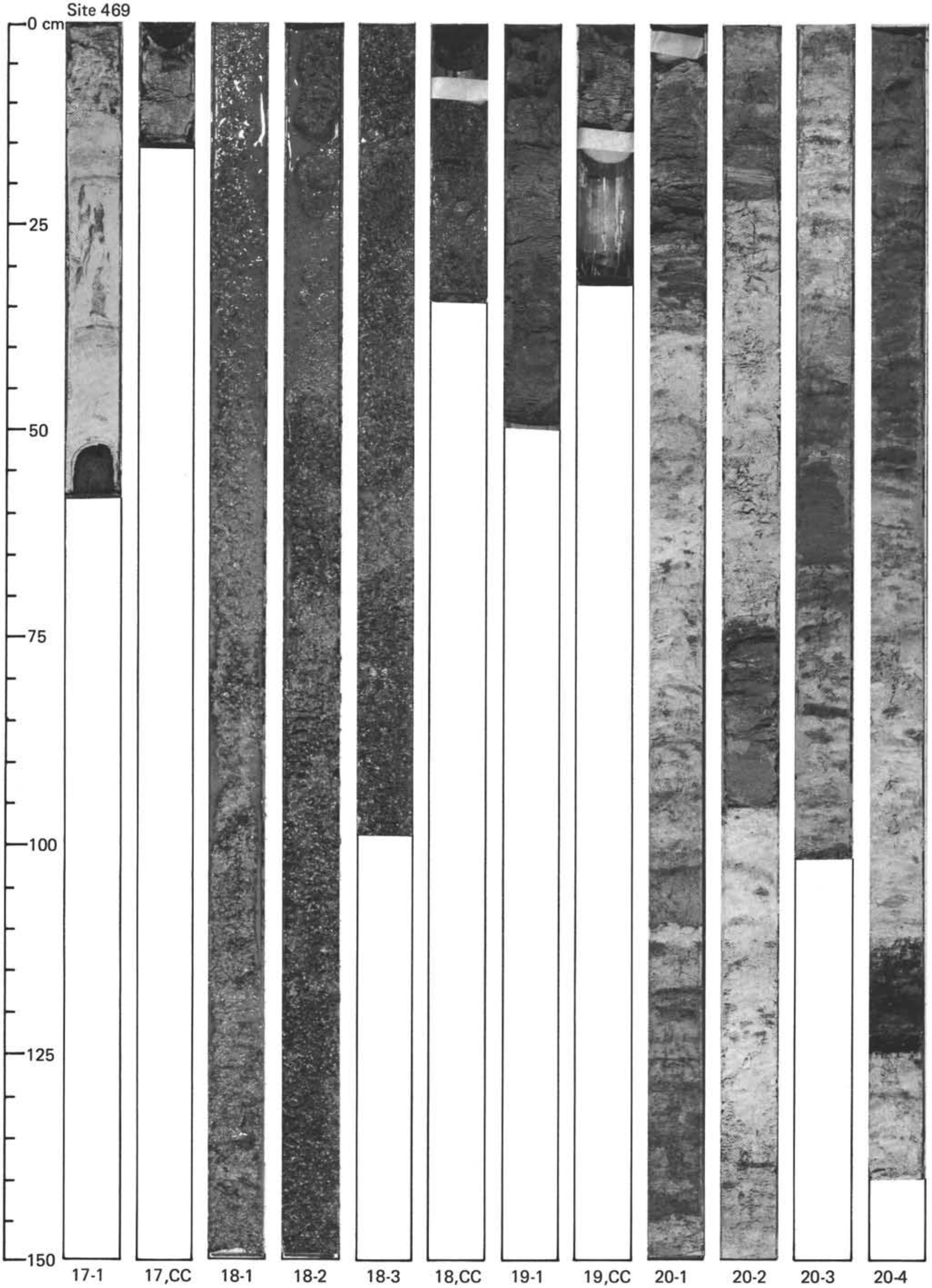
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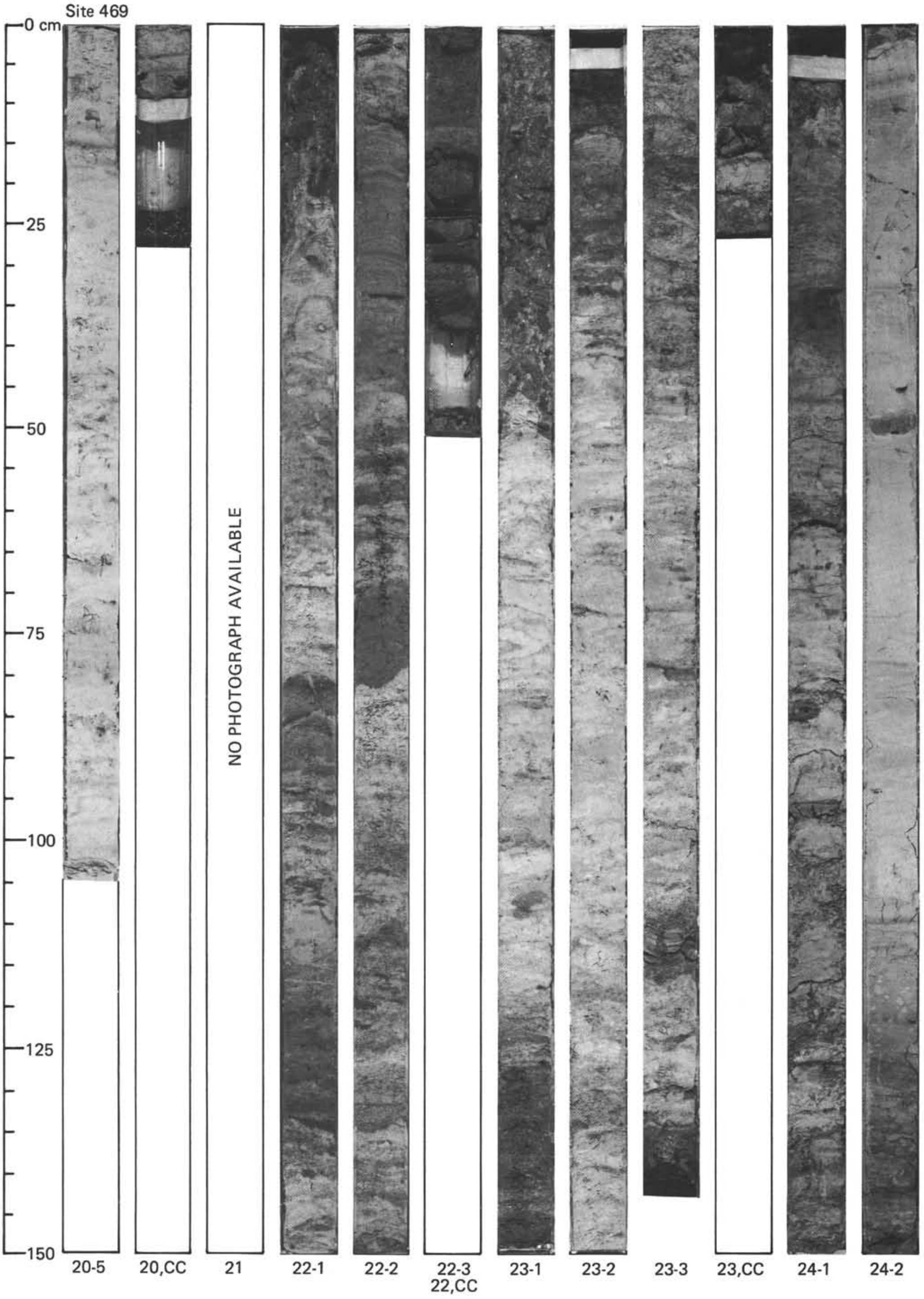
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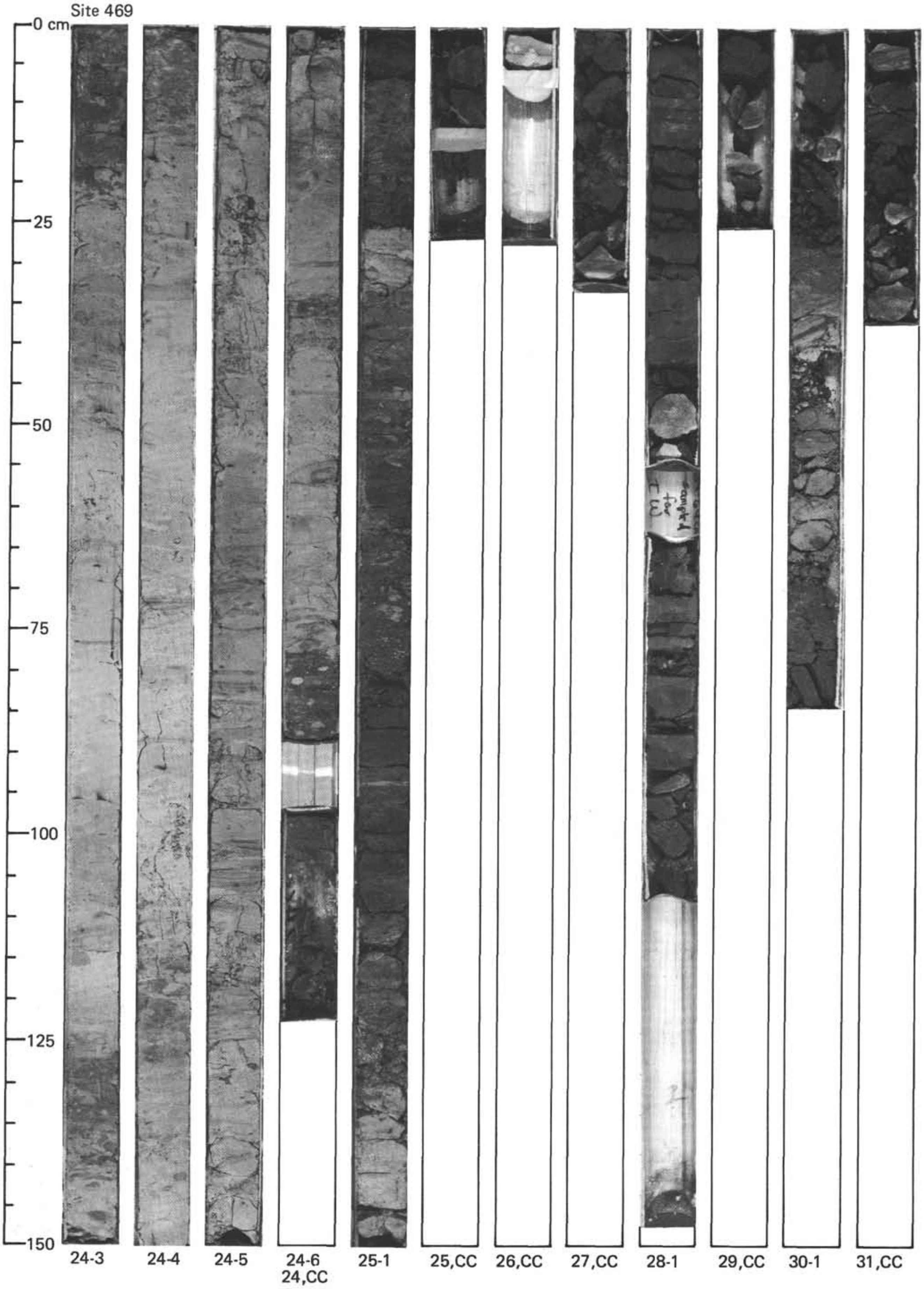
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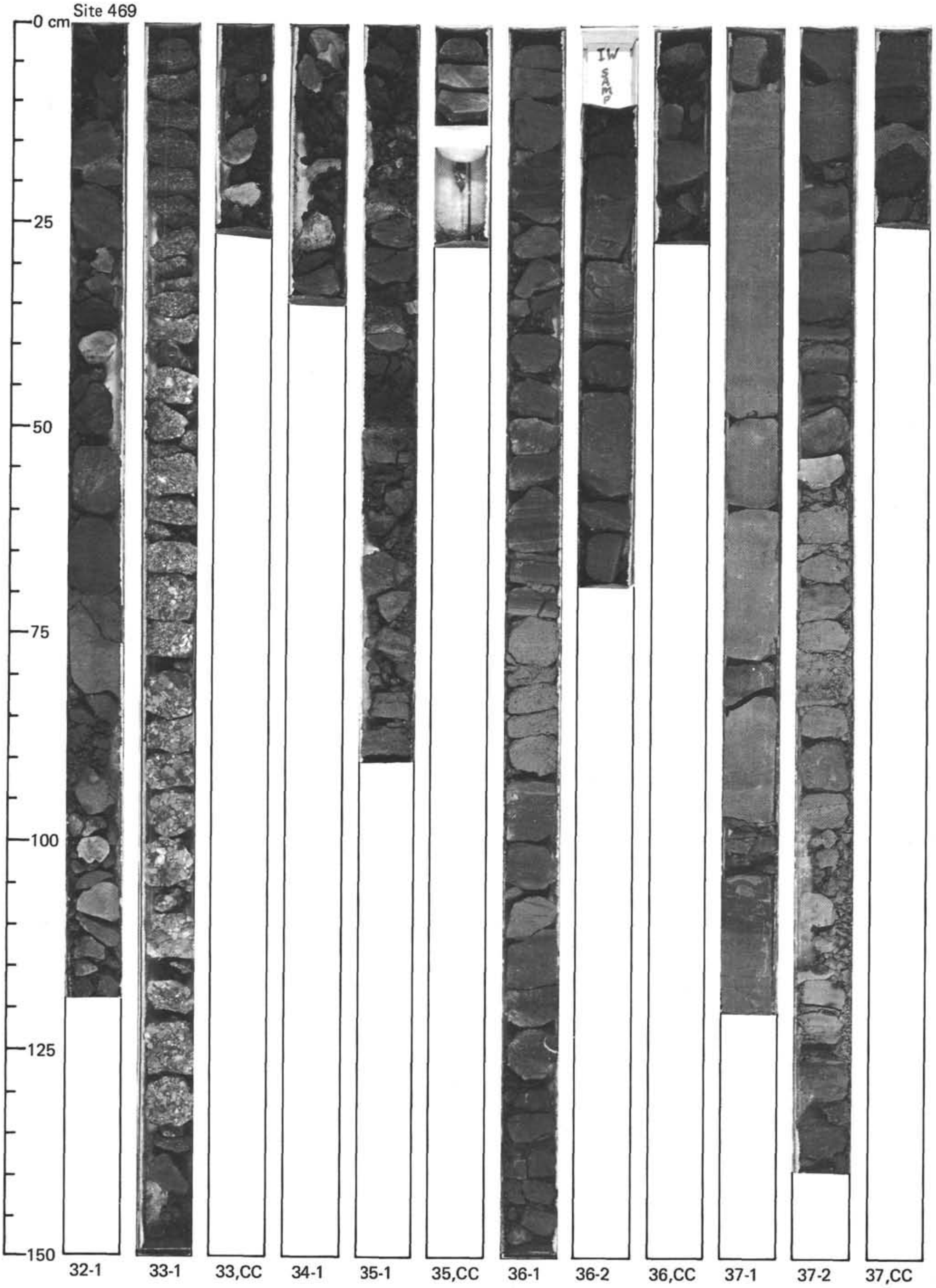
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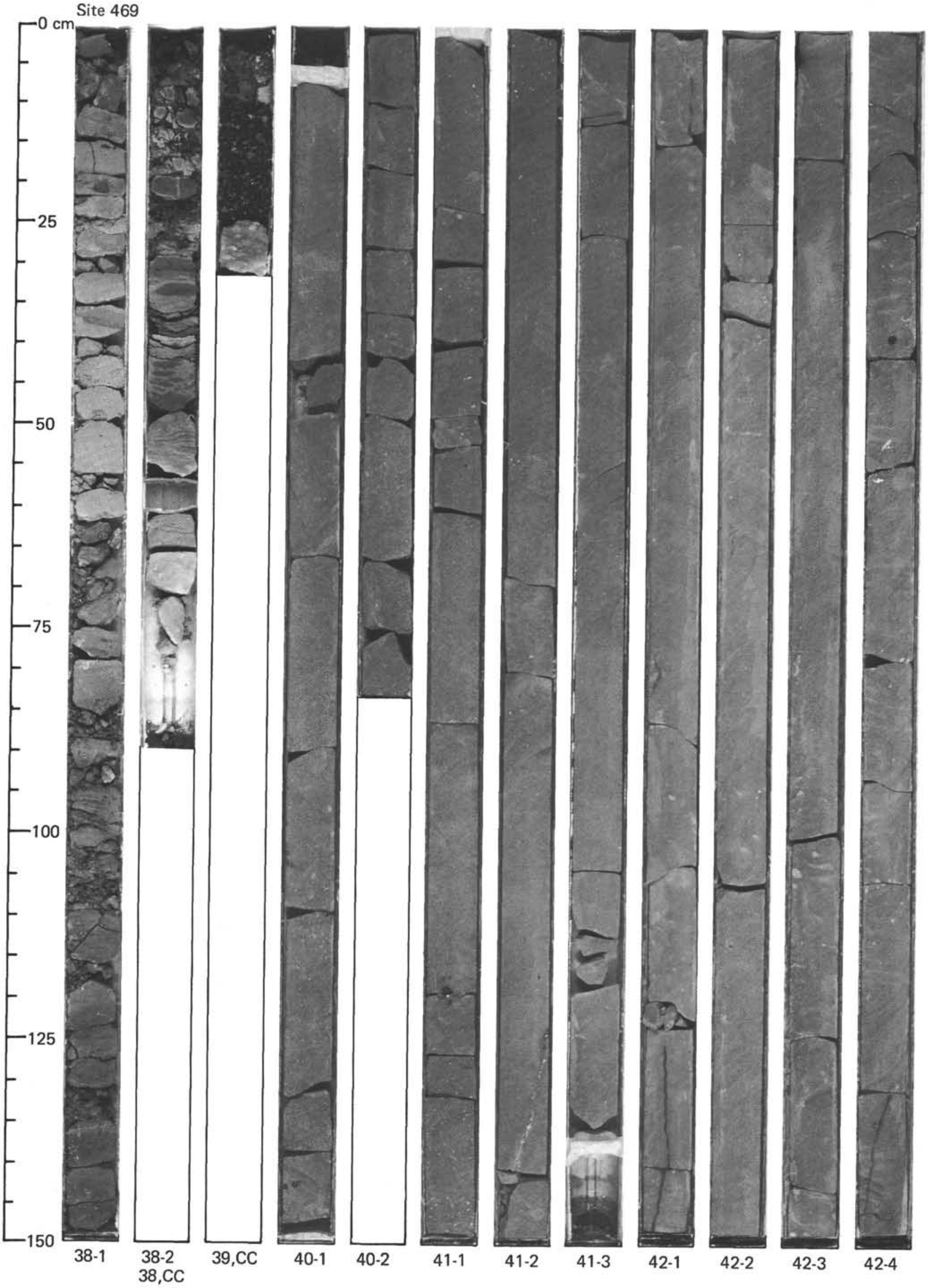
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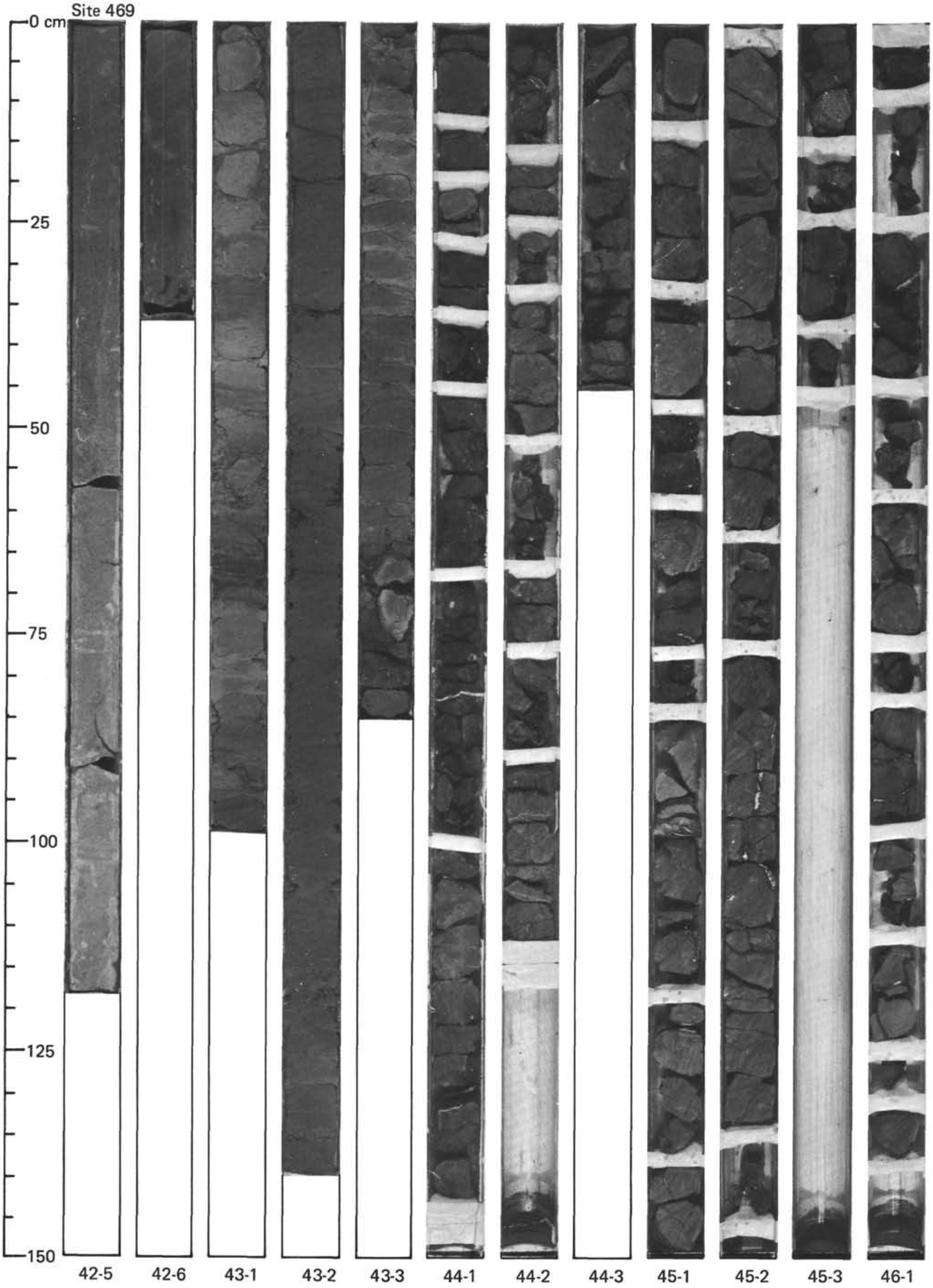
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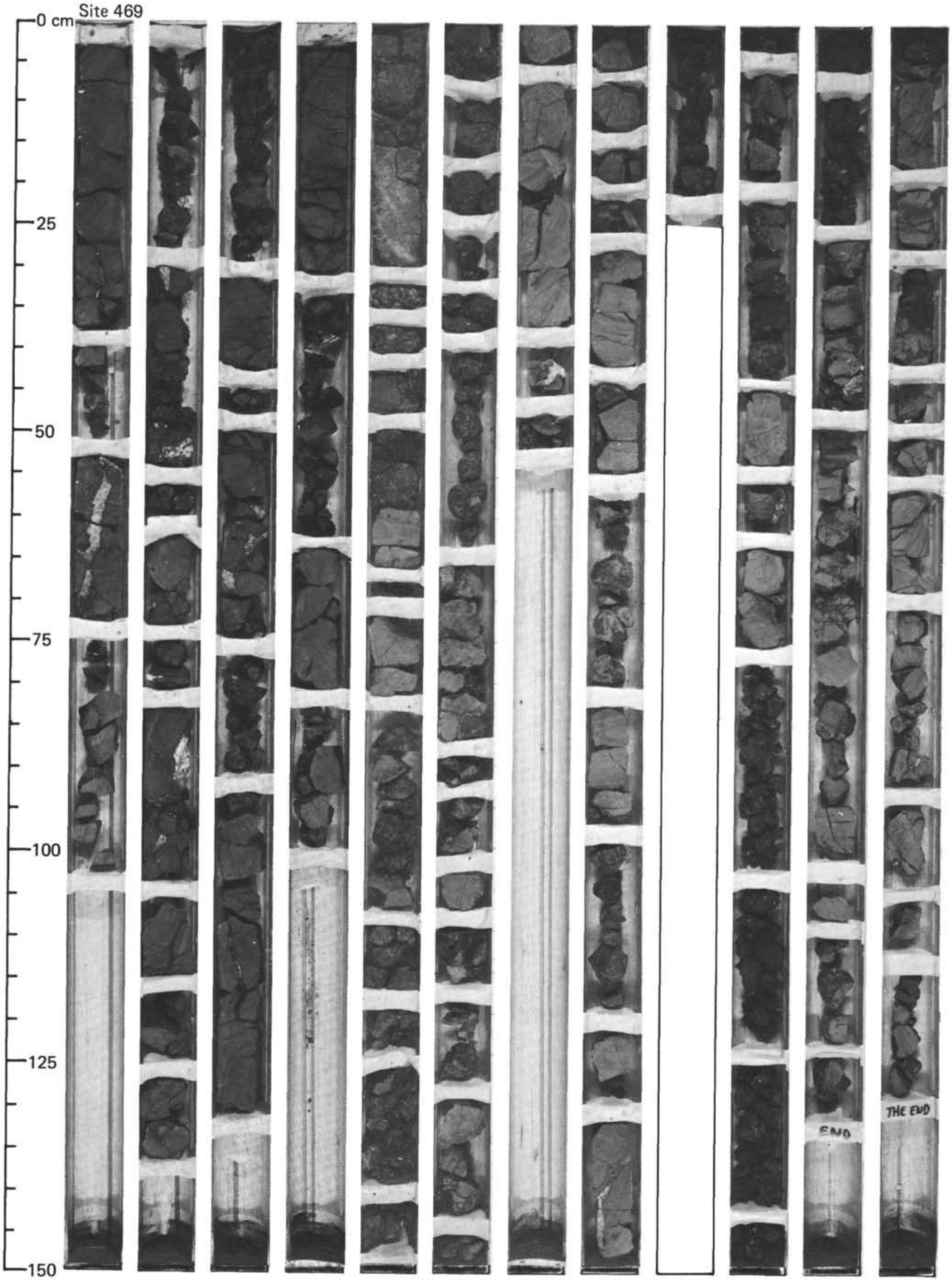
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