7. SITE 570[1]

Shipboard Scientific Party[2]

HOLE 570

Date occupied: 17 February 1982, 0900 hr.

Date departed: 21 February 1982, 1532 hr.

Time on hole: 102 hr., 32 min.

Position: 13°17.12′N; 91°23.57′W

Water depth (sea level; corrected m, echo-sounding): 1698

Water depth (rig floor; corrected m, echo-sounding): 1708

Bottom felt (m, drill pipe): 1718.2

Penetration (m): 401.9

Number of cores: 42

Total length of cored section (m): 398.9

Total core recovered (m): 165.5

Core recovery (%): 41.4

Oldest sediment cored:
Depth sub-bottom (m): 374
Nature: limestones, sandstones, shales
Age: early Eocene
Measured velocity (km/s): 3.994 (sandstones)

Basement:
Depth sub-bottom (m): 374.0–401.9
Nature: serpentinitic mud–serpentinitized peridotite
Velocity range (km/s): 3.601–4.265

Principal results: At Site 570, on the upper slope of the Middle America Trench, drilling penetrated 374 m of sediments overlying a basement of serpentinized peridotites. The sequence recovered is:

Unit I. 0–208 m Pleistocene green mud with layers of sand that are locally thick and pebbly (that is, with Hole 496, the coarsest Pleistocene recovered during Legs 67 and 84 from the Trench to the top of the slope).

Unit II. 208–255 m Pliocene green mud with sand layers.

Unit III. 255–330 m late Miocene green mud with rare horizons of pebbly sand above about 1 m of black sandy and pebbly early Miocene mudstone.

Unit IV. 330–374 m of an early Eocene sequence of light green siliceous limestones, grayish greenish sandstones with volcanic components, and blackish red pebble horizons at the base.

Basement. 374–401.9 m black serpentinized peridotites with horizons of pale blue green serpentinitic mud in the upper 10 m.

The unconformity between early Eocene and late Miocene was recovered in Core 35, at 330 m; it could tentatively be considered two superposed unconformities, the most evident being the late Miocene unconformity, as observed at Site 566, overlying an early Miocene unconformity, as observed at Site 567.

The hole was drilled in a region where the gas hydrate bottom simulating reflector (BSR) is 540 m deep, although the BSR does not occur beneath the site. Gas hydrates were recovered from Core 22 (201.2–210.7 m) to the bottom of the hole in basement: the most spectacular was recovered in Core 27 (249.1–258.8 m) in the form of a complete section of massive white hydrate. Small pieces of gas hydrates were found in each core below Core 27 to basement. As at Site 566, the basement serpentinite contains significant amounts of the heavier hydrocarbons, which prompted us to abandon the hole for safety reasons. The presence of significant gas in serpentinized peridotite both at Sites 566 and 570 may be more than a local accident. If it is a general condition, the gas may have migrated from sediment that underlies an overthrust ophiolite; similarly, sediments underlie overthrusted ophiolites on land in Central America.

A good suite of logs confirms the presence of the massive hydrate at 249 m and indicates a 3- to 4-m-thick body with velocities of more than 3 km/s and densities of about 1 g/cm^3. It shows that only sandy layers with a relatively greater porosity have sufficient hydrate to give an increased velocity despite the presence of visible hydrate in some mud samples.

For the second time since drilling at Site 569, early Eocene (earliest Eocene at 570) was recovered above the basement, which confirms that the tectonic emplacement of the basement is pre-early Eocene, thus perhaps part of the Laramide event in the broad sense of that tectonic period. The results from Site 570 show clearly that the Guatemala margin is constructed of an ophiolitic basement belonging to the continental framework of Central America.

BACKGROUND AND OBJECTIVES

Contours of the Earth's total magnetic field over the landward slope of the Middle America Trench off Guatemala show a concentrated band of high-amplitude anomalies along the upper slope; otherwise the magnetic field is featureless downslope until close to the Trench axis, where the oceanic style of anomalies begins. The band of anomalies has been interpreted as the truncated end of an accreted igneous oceanic basement beneath sediment of the forearc basin (Seely et al., 1974; Ladd et al., 1978; Ibrahim et al., 1979). The objective at Site 570 was to sample the acoustic basement where it is relatively close to the seafloor, has a high magnetic anomaly, and where a sample of the initial sediment to cover the basement might be present. Sampling of the basement on the upper slope was necessary to finish the transect of drill holes into the basement that forms the Central America margin. Sampling the overlying cover was necessary to reconstruct the Tertiary tectonic history of the present convergent margin and its immediate predecessors and tie the marine and onshore geology together.

OPERATIONS

Glomar Challenger departed Site 569 at 0050L (local time), 17 February and steamed 5 hr. to the Site 570 area. From 0540 to 0705L we surveyed to locate the site

[1] von Huene, R., Aubouin, J., et al., *Init Repts. DSDP*, 84: Washington (U.S. Govt. Printing Office).

[2] Roland von Huene (Co-Chief Scientist), U.S. Geological Survey, Menlo Park, California; Jean Aubouin (Co-Chief Scientist), Département de Géotectonique, Université Pierre et Marie Curie, Paris, France; Miriam Baltuck, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, California (present address: Department of Geological Sciences, Tulane University, New Orleans, Louisiana); Robert Arnott, Department of Geology, University of Oxford, Oxford, United Kingdom (present address: Shell International, Holland); Jacques Bourgois, Département de Géotectonique, Université Pierre et Marie Curie, Paris, France; Mark Filewicz, Union Oil Company, Ventura, California; Roger Helm, Institut Für Geologie, Ruhr-Universität Bochum, Bochum, Federal Republic of Germany; Keith A. Kvenvolden, U.S. Geological Survey, Menlo Park, California; Barry Leinert, Hawaii Institute of Geophysics, University of Hawaii, Manoa, Honolulu, Hawaii; Thomas J. McDonald, Department of Oceanography, Texas A&M University, College Station, Texas; Kristin McDougall, U.S. Geological Survey, Menlo Park, California; Yujiro Ogawa, Department of Geology, Kyushu University, Hakozaki, Fukuoka-Shi, Japan; Elliott Taylor, Department of Oceanography, Texas A&M University, College Station, Texas; Barbara Winsborough, Espey, Houston, and Associates, Austin, Texas (present address: Department of Geology, Princeton University, Princeton, New Jersey).

on seismic line GUA-11, and at 0705L a 13.5-kHz beacon was dropped. At 0900L, the ship was in position and the "running in" operation began.

The hole was spudded at 1412L, 17 February, and the first core was recovered at 1455L. Continuous coring followed on 17, 18, and 19 February through a massive gas-hydrated section beginning at 191.5 m below the mud line. Because the depth limit for gas hydrates was calculated at 540 m, drilling proceeded carefully through a hydrated section to the basement of serpentinite, which was recovered from 374 to 401.9 m. The last core in serpentinite came up at 2125L, 19 February, when we stopped drilling in part because of the unexpected presence of large amounts of ethane with a significant amount of heavier hydrocarbon molecules.

From 2125L, 19 February, to 0630L, 20 February, preparations were made for logging, flushing the hole, releasing the bit, and filling the hole with heavy-weight mud.

From 0630L, 20 February to 0800L, 21 February, sonic, sonic waveform, gamma ray, caliper, density, neutron, dual laterolog, and temperature logs were run.

After running out of the hole from 0800 to 1530L, 21 February, *Glomar Challenger* departed Site 570 at 1532L with a short seismic line over Site 570, and was under way to Manzanillo at 1600L.

Table 1 shows the coring summary for Site 570.

LITHOSTRATIGRAPHY

Site 570 is located on the edge of a small bench in the upper slope region of the Middle America Trench, at a depth of 1718 m. The site is 40 km north of the Trench axis, 25 km south of the edge of the shelf, and 70 km south of the coast of Guatemala (Fig. 1).

Forty-two cores were drilled with good recovery to a sub-bottom depth of 402 m. Serpentinite basement was recovered from Cores 39 to 42. The sediments overlying

Table 1. Coring summary, Site 570.

Core no.	Date (Feb. 1982)	Time	Depth from drill floor (m) Top Bottom	Depth below seafloor (m) Top Bottom	Length cored (m)	Length recovered (m)	Recovery (%)
1	17	1455	1718.2–1723.0	0.0–4.8	4.8	4.76	99
2	17	1600	1723.0–1732.7	4.8–14.5	9.7	6.71	69
	17	Drilled	1732.7–1735.7	14.5–17.5	—	—	—
3	17	1659	1735.7–1745.4	17.5–27.2	9.7	9.10	94
4	17	1750	1745.4–1755.0	27.2–36.8	9.6	5.37	56
5	17	1852	1755.0–1764.6	36.8–46.4	9.6	9.19	96
6	17	2008	1764.6–1774.2	46.4–56.0	9.6	9.13	95
7	17	2102	1774.2–1783.9	56.0–65.7	9.7	5.34	55
8	17	2156	1783.9–1793.6	65.7–75.4	9.7	3.83	39
9	17	2246	1793.6–1803.3	75.4–85.1	9.7	2.65	27
10	17	2340	1803.3–1812.9	85.1–94.7	9.6	3.17	33
11	18	0045	1812.9–1822.5	94.7–104.3	9.6	4.83	50
12	18	0134	1822.5–1832.1	104.3–113.9	9.6	0.00	0
13	18	0220	1832.1–1841.8	113.9–123.6	9.7	0.00	0
14	18	0405	1841.8–1851.5	123.6–133.3	9.7	8.02	83
15	18	0450	1851.5–1861.2	133.3–143.0	9.7	3.48	36
16	18	0547	1861.2–1870.9	143.0–152.7	9.7	7.60	78
17	18	0635	1870.9–1880.6	152.7–162.4	9.7	7.15	74
18	18	0725	1880.6–1890.3	162.4–172.1	9.7	2.68	28
19	18	0815	1890.3–1900.0	172.1–181.8	9.7	4.88	50
20	18	0900	1900.0–1909.7	181.8–191.5	9.7	1.90	20
21	18	1008	1909.7–1919.4	191.5–201.2	9.7	3.05	31
22	18	1104	1919.4–1928.9	201.2–210.7	9.5	5.43	57
23	18	1155	1928.9–1938.4	210.7–220.2	9.5	8.19	86
24	18	1249	1938.4–1947.9	220.2–229.7	9.5	5.15	54
25	18	1345	1947.9–1957.6	229.7–239.4	9.7	5.13	53
26	18	1453	1957.6–1967.3	239.4–249.1	9.7	2.60	27
27	18	1600	1967.3–1977.0	249.1–258.8	9.7	1.50	15
28	18	1954	1977.0–1986.6	258.8–268.4	9.6	3.85	40
29	18	2057	1986.6–1996.2	268.4–278.0	9.6	4.33	45
30	18	2221	1996.2–2005.8	278.0–287.6	9.6	3.30	34
31	18	2351	2005.8–2015.4	287.6–297.2	9.6	1.21	13
32	19	0055	2015.4–2025.0	297.2–306.8	9.6	3.13	33
33	19	0200	2025.0–2034.6	306.8–316.4	9.6	0.10	1
34	19	0309	2034.6–2044.2	316.4–326.0	9.6	1.92	20
35	19	0415	2044.2–2053.8	326.0–335.6	9.6	3.89	39
36	19	0540	2053.8–2063.4	335.6–345.8	9.6	1.69	18
37	19	0647	2063.4–2073.0	345.8–354.8	9.6	1.96	20
38	19	0909	2073.0–2082.6	354.8–364.4	9.6	0.70	7
39	19	1200	2082.6–2092.2	364.4–374.0	9.6	1.20	13
40	19	1426	2092.2–2101.5	374.0–383.3	9.3	0.30	3
41	19	1921	2101.5–2110.8	383.3–392.6	9.3	4.88	52
42	19	2125	2110.8–2120.1	392.6–401.9	9.3	1.75	20
Total					398.9	165.05	41

Note: "Drilled" in Time column indicates that recovery was combined with recovery of preceding core, that is, two core lengths were drilled for every instance of recovery.

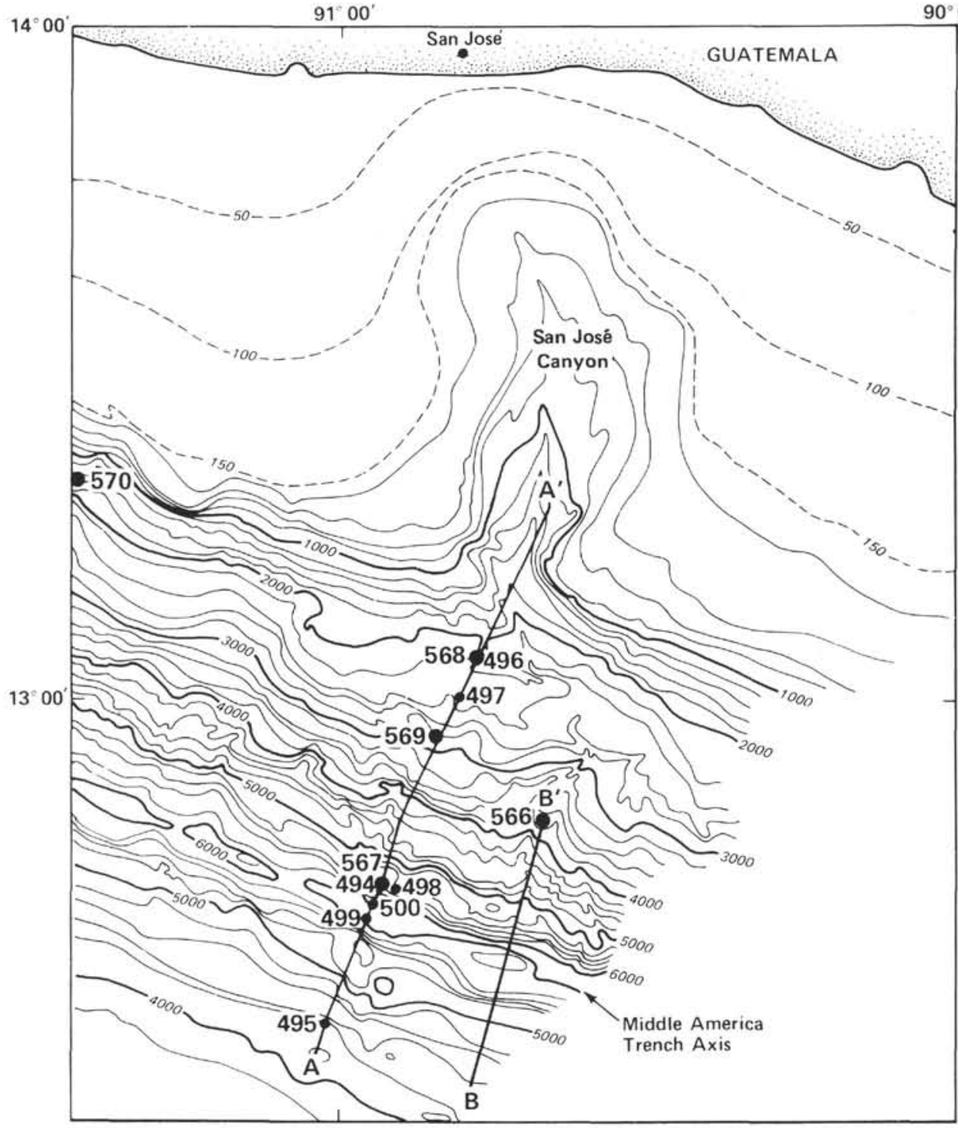


Figure 1. Bathymetry of the Guatemala margin and San José Canyon, showing the UTMSI survey tracks and the location of Legs 67 and 84 sites off Guatemala.

the basement are divided into four units on the basis of lithology, biostratigraphy, and well-log data (see Fig. 2).

Unit I

Unit I comprises Cores 1 to 22, 0 to 208 m sub-bottom depth (Pleistocene) and is subdivided into two subunits on the basis of lithology.

Subunit Ia (Cores 1–14; 0–130 m sub-bottom depth; Pleistocene) comprises massive, olive gray (5Y 3/2) to grayish olive (10Y 4/2) mud that is highly deformed during drilling. The average sand–silt–clay percentages are 12, 28, and 60%, respectively (based on shipboard smear-slide analyses). The major detrital component is clay, although minor amounts of quartz and plagioclase feldspar are present. Siliceous biogenic remains (diatoms, radiolarians, silicoflagellates, and sponge spicules) make up to 5% of the total sediment. Calcareous biogenic remains (foraminifers and calcareous nannofossils) make up to 8% of the total sediment.

Sedimentary structures are quite rare, but finely laminated silty beds, with normal grading, are observed in Cores 2, 4, and 5. Large shell fragments (up to 1 cm in diameter) are found dispersed within the structureless mud throughout this sub unit. Mottling, which results from bioturbation, is common and ranges in color from olive gray (5Y 3/2), pale olive (10Y 6/2), to greenish black (5G 2/1).

Ash layers occur in Cores 1, 2, 6 through 9, and 11. Seventeen distinct layers of ash or muddy ash are discerned, and well-preserved beds commonly display normal grading. The ash varies in color from very light gray (N8), moderate olive brown (5Y 4/4), olive gray (5Y 3/2), to greenish black (5GY 2/1).

Thin, normally graded sand beds up to 40 cm in thickness occur in Cores 1, 2, 6, 7, 10, 11, and 14. Well-log data show that thin sand beds also occur in the unrecovered section between Cores 5 and 6. The sands often contain up to 15% foraminifers and unspecified carbon-

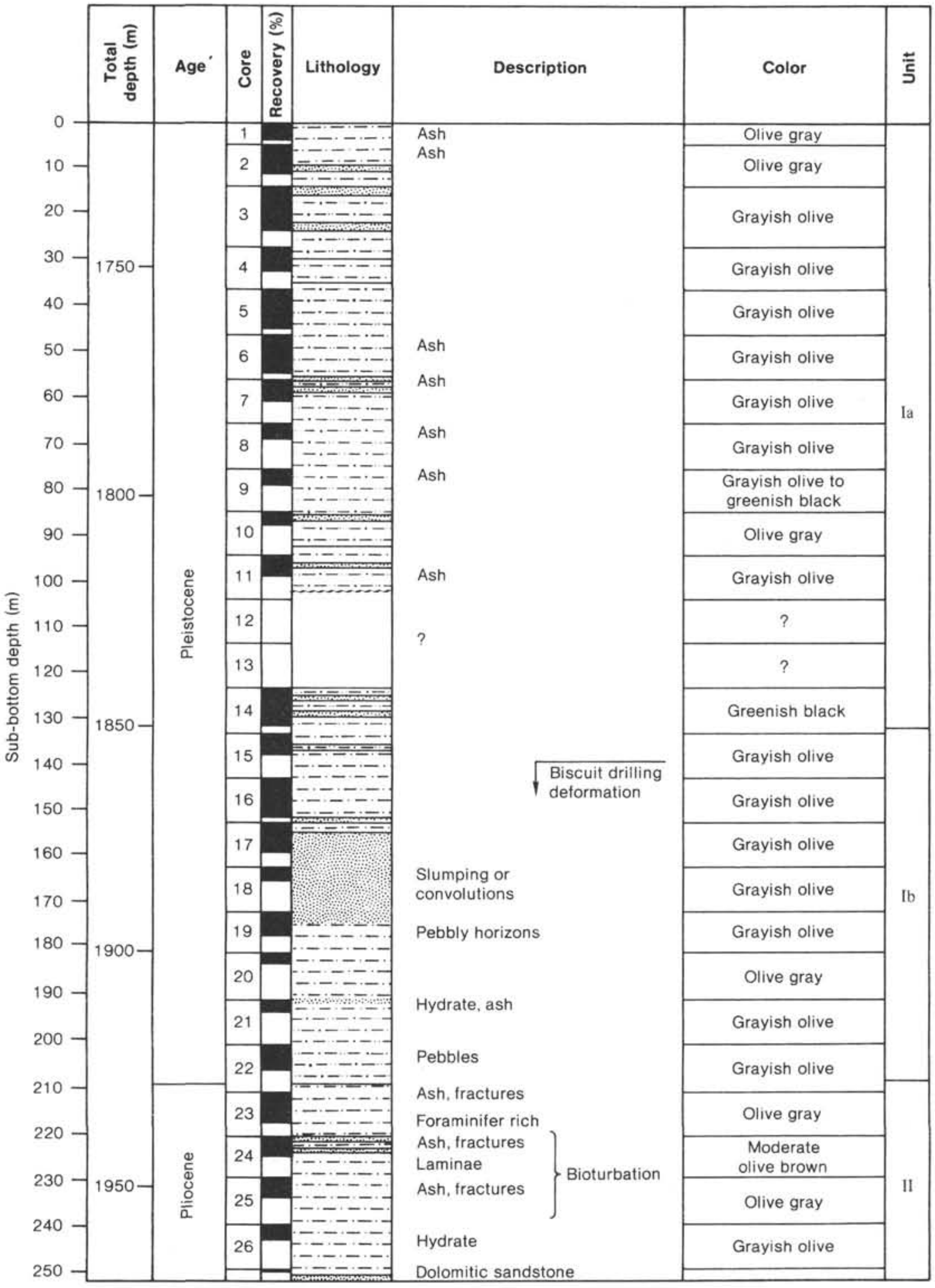


Figure 2. Lithostratigraphic summary at Site 570.

ate detritus. The major detrital components are feldspar, quartz, and volcanic ash, which compose up to 80% of the total sediment.

Subunit Ib (Cores 15–22; 130–208 m sub-bottom depth; Pleistocene) comprises massive grayish olive (10Y 4/2) sandy mud that was highly deformed during drilling, except where it was firm enough to form drilling biscuits (Cores 16–22). The average sand-silt-clay percentages are 24, 16, and 60%, respectively. The finest-grained sediment is in Cores 21 and 22, which contain olive gray mud (5Y 3/2). Calcareous biogenic remains (foraminifers and unspecified carbonate detritus) make up to 8% of the total sediment but locally make up to 20% (Core 18). Siliceous biogenic remains are relatively

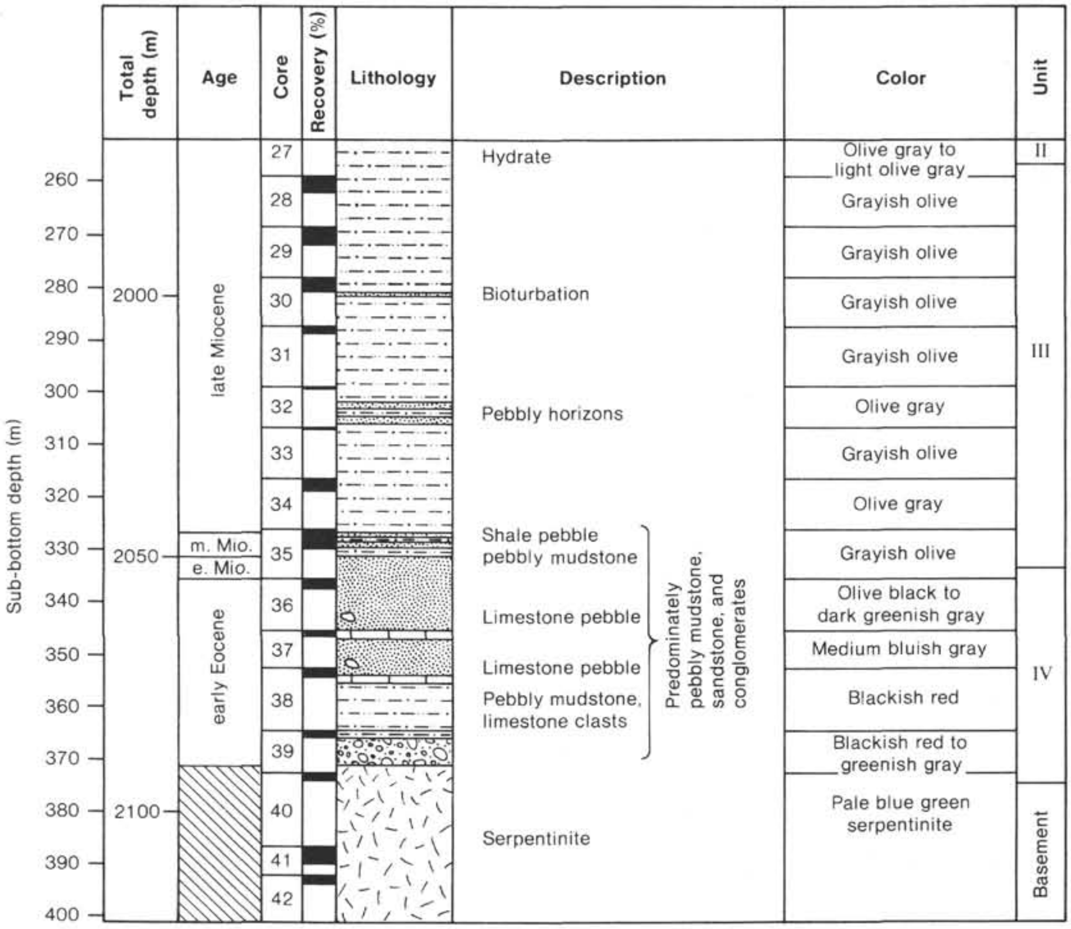


Figure 2. (Continued).

rare compared to Subunit Ia. The major detrital component is clay, although minor amounts of feldspar and volcanic ash are present.

Sedimentary structures are rare, but in Core 18 thin, graded silt laminations up to 10 mm in thickness are highly contorted, with apparent dips varying between 30 and 70°. This horizon of contorted bedding is 70 cm thick and was probably formed by slumping or loading of relatively unconsolidated sediment. Large shell fragments and rounded pumice and soft mud pebbles (up to 1 cm in diameter) are found dispersed within the massive sandy mud. In Core 19 pebble horizons that lack any sand are present. Black (N1) mottling is common throughout this unit and is probably the result of bioturbation.

Grayish olive (10Y 4/2) sand beds occur in Cores 17, 18, and 21. The sand is generally massive and contains dispersed large-rounded pebbles of pumice. Well-log data show that two sand horizons occur between 185 and 190 m sub-bottom. These sands were not recovered in Core 20. Sand recovered contains up to 15% foraminifer and shelly debris. The major detrital components are feldspar, quartz, and volcanic ash, which comprise up to 75% of the total sediment.

Only one light gray (N7) ashy sand was distinguished in this unit (top of Core 21). This ash contained solid gas hydrate.

Unit II

Unit II ranges from Cores 23 to 27, 208 to 255 m sub-bottom depth (early to late Pliocene) and comprises an olive gray (5Y 3/2) to moderate olive brown (5Y 4/4) mudstone. It is distinguished from Unit I by its age and by its hardness. The average sand-silt-clay percentages are 22, 18, and 60%, respectively. Calcareous biogenic remains locally make up to 20% of the total sediment (Core 23, Section 6). The major detrital component is clay, although minor amounts of quartz, plagioclase feldspar, and volcanic glass are present.

Bioturbation is very common (particularly in Core 24 and 25) and may account for the absence of sedimentary structures from Cores 24 to 27. Burrows are sometimes filled with coarse sand or ash. In Core 23, where there is only minor bioturbation, finely laminated silty beds are observed.

Ash layers occur in Cores 22, 23, 25, and 26. Seven distinct layers of ash or muddy ash are discerned, and these range in color from greenish black (5GY 2/1) to very light gray (N8). The ash layers are often graded and contain quartz and feldspar in amounts of up to 20% of the total sediment.

Thin, normally graded sand beds occur in Core 24, and well-log data show that at least two other sand beds are present but were not recovered in Cores 25 and 26. The sand is composed of quartz, feldspar, volcanic ash, and clay. Only minor amounts of siliceous and calcareous biogenic detritus are present.

Several postdepositional deformation features are noted in this unit, including fractures (mainly vertical in orientation) and a strong horizontal scaley fabric (Core 23). Similar features were observed at Sites 568 and 569.

The base of Unit II is marked by a highly fractured and indurated dolomite. Some fractures in the dolomite were filled with solid gas hydrate (Core 27). The rock contains up to 5% quartz and feldspar grains of volcanic origin that float in a dolomite matrix. Solid gas hydrate was also recovered in Cores 26 and 27 immediately above the dolomite. In Core 27 at least 1.05 m of solid gas hydrate were present. Well-log data show that the solid gas hydrate is at least 3 m thick, but it is not known whether this is a continuous layer of broad lateral extent or just a local accumulation.

Unit III

Unit III (Cores 27-35; 255-330 m sub-bottom depth; early to late Miocene) comprises grayish olive (10Y 4/2) mud, mudstone, and shale. Cores 27 to 34 are late Miocene and Core 35 contains a very thin middle and early Miocene section (see Biostratigraphy section). The average sand-silt-clay percentages are 6, 13, and 81%, respectively (based on shipboard smear-slide analyses). Siliceous and calcareous biogenic components make up to 10% of the total composition of the sediment. The major detrital component is clay, although minor amounts of quartz are also present.

The mud, mudstone, and shale are structureless and contain dispersed pumice clasts (Core 29). Original sedimentary structures may have been disrupted by bioturbation, which is recorded in minor amounts throughout the unit and causes olive gray (5Y 3/2) mottling. Postdepositional fracturing is present in Core 29 and is similar to that observed in Unit II (see the description above).

Normally graded sand and pebble beds up to 3 cm thick are present in Cores 30 and 32. The coarsest Miocene sediment is found at the base of Unit III in Core 35 (down to Section 5), where coarse sand beds up to 50 cm thick are interbedded with massive mud containing dispersed clasts of limestone (up to 5 cm in diameter). This is underlain by a conglomerate containing clasts of andesite that commonly display flow textures. The clasts lie within a greenish black (5G 2/1) sand that is mainly composed of plagioclase feldspar (up to 60% of the total sediment) but also contains minor amounts of limestone and andesite rock fragments. The lower Eocene to lower Miocene unconformity lies between Cores 35 and 36.

Solid gas hydrate was found dispersed throughout all of Unit III, particularly within sand and ash beds (Core 32) but also within fractures in the mudstone.

Unit IV

Unit IV comprises (Cores 35 to 39, 330 to 374 m sub-bottom depth (early Eocene). The stratigraphy of Unit IV (Fig. 3) is mainly constructed from well-log data, for recovery was quite poor between Cores 36 and 39. Because the physical properties of sediments recovered correlate well with downhole logging measurements, Figure 3 is probably an accurate record of the rock types present (see Physical Properties section).

The top of Unit IV comprises a 7-m thick sequence of silty mud with at least two very thin sand horizons. This is underlain by a structureless, olive black (5Y 2/1) to dark greenish gray (5G 4/4) sand (Core 36); this sand

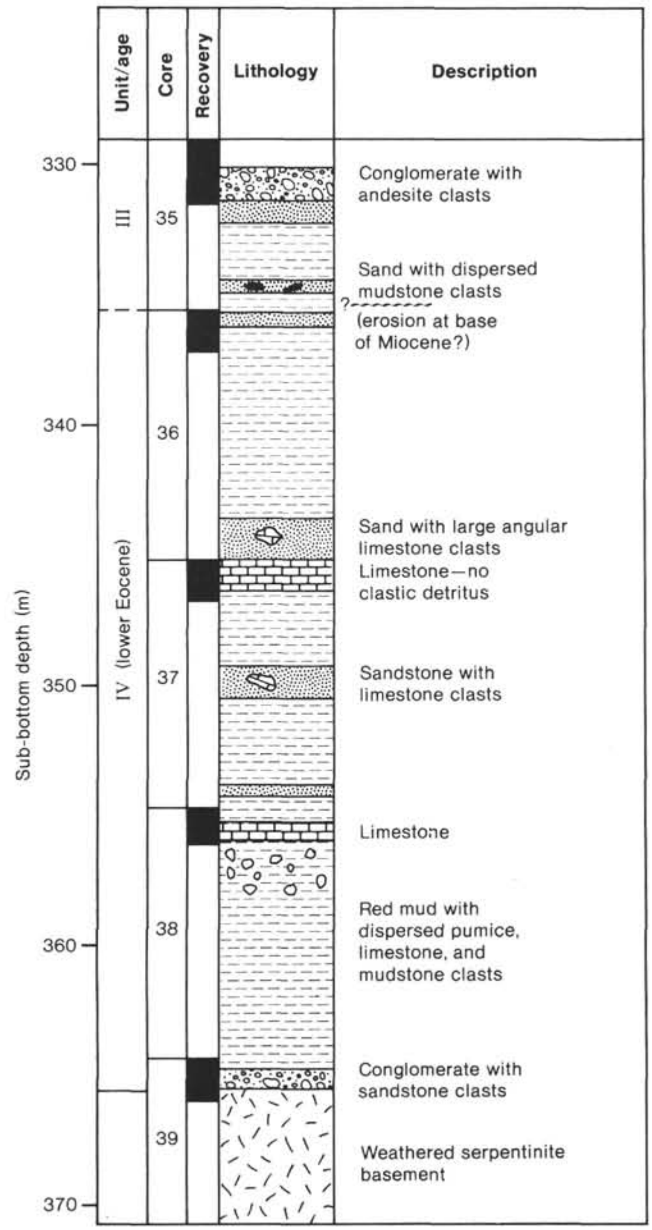


Figure 3. Lithostratigraphic Site 570 Unit IV showing well-log detail of corresponding rock types.

is very rich in plagioclase feldspar (which makes up to 55% of the total sediment).

The sand is immediately underlain by a pale blue green (5BG 6/6) limestone (Core 37). This is mainly composed of calcareous nannofossils and clay, although very small amounts of angular quartz and feldspar are present (up to 5% of the total sediment).

The limestone is underlain by an unrecovered 2-m section of mud, in turn underlain by a very coarse sand (Core 37) rich in feldspar. Pale blue green limestone (5BG 6/6) was recovered beneath this sand and is similar in composition to the limestone in Core 37. Immediately underlying this limestone is a radiolarian-rich-blackish red (5R 2/2) to grayish black (N2) mudstone. This contains dispersed clasts of limestone, pumice, and cemented sandstone. One sandstone clast displays good Bouma T_b and T_c units, demonstrating that it was originally deposited by a turbidity current. Underlying the mudstone is a basal conglomerate (Core 39). This is clast supported and has a coarse sandstone matrix. The clasts are angular and are mainly composed of sandstone with a calcite cement. The conglomerate marks the base of Unit IV, because it immediately overlies serpentinite basement. Solid gas hydrate was dispersed throughout Unit IV.

Basement

The basement rocks recovered at Site 570 (Cores 39–42; 374–402 m sub-bottom depth) are serpentinites. Primary magmatic minerals are now almost completely serpentinized, but some orthopyroxene and chromite grains (1%) are recognized, suggesting that the original peridotite was a harzburgite. Chromite grains show cataclastic textures. The main serpentinite groundmass is composed of lizardite and chrysotile serpentine minerals, which exhibit hourglass to ribbon textures. Euhedral tremolite grains up to 0.5 mm in diameter are dispersed throughout the serpentine groundmass. Tremolite is variably replaced by serpentine. Minor amounts (less than 1%) of talc are present.

The serpentinite is crosscut by many vains of different compositions, but the relationships between different phases of vein intrusion is difficult to discern. Fibrous serpentine, stained with hematite, is a common vein mineral. Chlorite is often present within veins.

The upper part of the serpentinite basement drilled at Site 570 is composed of blue green serpentinitic mud (Cores 39–40). The white mottling of the serpentinite mud is caused by the presence of smectite (probably an alteration product of serpentine).

Conclusions

Site 570 records deposition on the upper slope of the Middle America Trench. Coarse clastic detritus recovered from the Pleistocene and Eocene sections demonstrates that local topographic depressions on the slope can trap sand. Thus not all sand is transported to the Trench through submarine canyons, and coarse clastic detritus cannot be used *per se*, to indicate Trench or canyon sediment.

The stratigraphy at Site 570 shows remarkable thickness changes when compared with other nearby sites on the slope. The Pleistocene section is over 210 m thick at Site 570, whereas at Site 569 it is only 50 m thick. Similarly the lower Miocene is only 1 m thick at Site 570 compared to over 140 m at Site 569. Such thickness changes show that rates of sediment accumulation on the slope of the Middle America Trench are very localized. This is also shown by the position of unconformities or hiatuses at different stratigraphic levels within holes drilled in slope deposits. As an example of this, a reduced lower Miocene succession overlies lower Eocene sediment at Site 570, whereas at Site 560 a thick lower Miocene sequence overlies upper Eocene sediment. Thus while deposition was occurring in one place, nondeposition or erosion was taking place elsewhere.

Unit IV is very important because it indicates that the serpentinite basement was pre-lower Eocene. Many different lithologies are present within the thin Eocene succession (Fig. 3). The predominant facies observed are pebbly mudstones, sand, and conglomerates that record deposition on a slope. Interbedded with these sediments are two limestone horizons that record long periods of slow pelagic sedimentation. These were probably deposited when the main locus of sedimentation switched elsewhere. The Eocene section contains clasts of andesite, sandstone turbidite, and red mudstone. The sandstone turbidite clasts may have been derived from the Cretaceous to Paleocene section that is present in the forearc basin north of Site 570. Benthic foraminifers from sandstones (Core 36) demonstrate that much of the sand was derived from the inner shelf and transported to abyssal depths where most of the mud accumulated (see Biostratigraphy section).

The serpentinite basement at Site 570 demonstrates that the upper slope is underlain by ophiolitic rock. The serpentinite here has been altered at higher temperatures than similar basement recovered at Sites 566 and 567, as shown by the presence of tremolite.

BIOSTRATIGRAPHY

Introduction

Drilling at Site 570 recovered about 360 m of Pleistocene through early Eocene sediments overlying 10 m of undated conglomerate on basement (Fig. 4). Calcareous nannofossils and benthic foraminifers occur in rare to common numbers with variable preservation throughout. Diatoms occur in moderately preserved, variable abundances within the Pleistocene and late Miocene sediments, but are nearly absent in the early Miocene and early Eocene samples.

Section 570-1-2 through Sample 570-23-4, 47 cm are Pleistocene, on the basis of all three studied microfossil disciplines. Low species diversity hampered detailed subdivision of this interval. Samples 570-23-6, 36 cm through 570-25-4, 36 cm are late Pliocene, based on nannofossils and in part on diatoms and benthic foraminifers, whereas 570-25,CC through 570-27-1 (gas hydrate mud matrix in 570-27-1) are early Pliocene, based on nannofossils and benthic foraminifers. In addition, rare late Miocene, possibly reworked diatoms are present throughout this interval. Samples 570-28-1, 43 cm

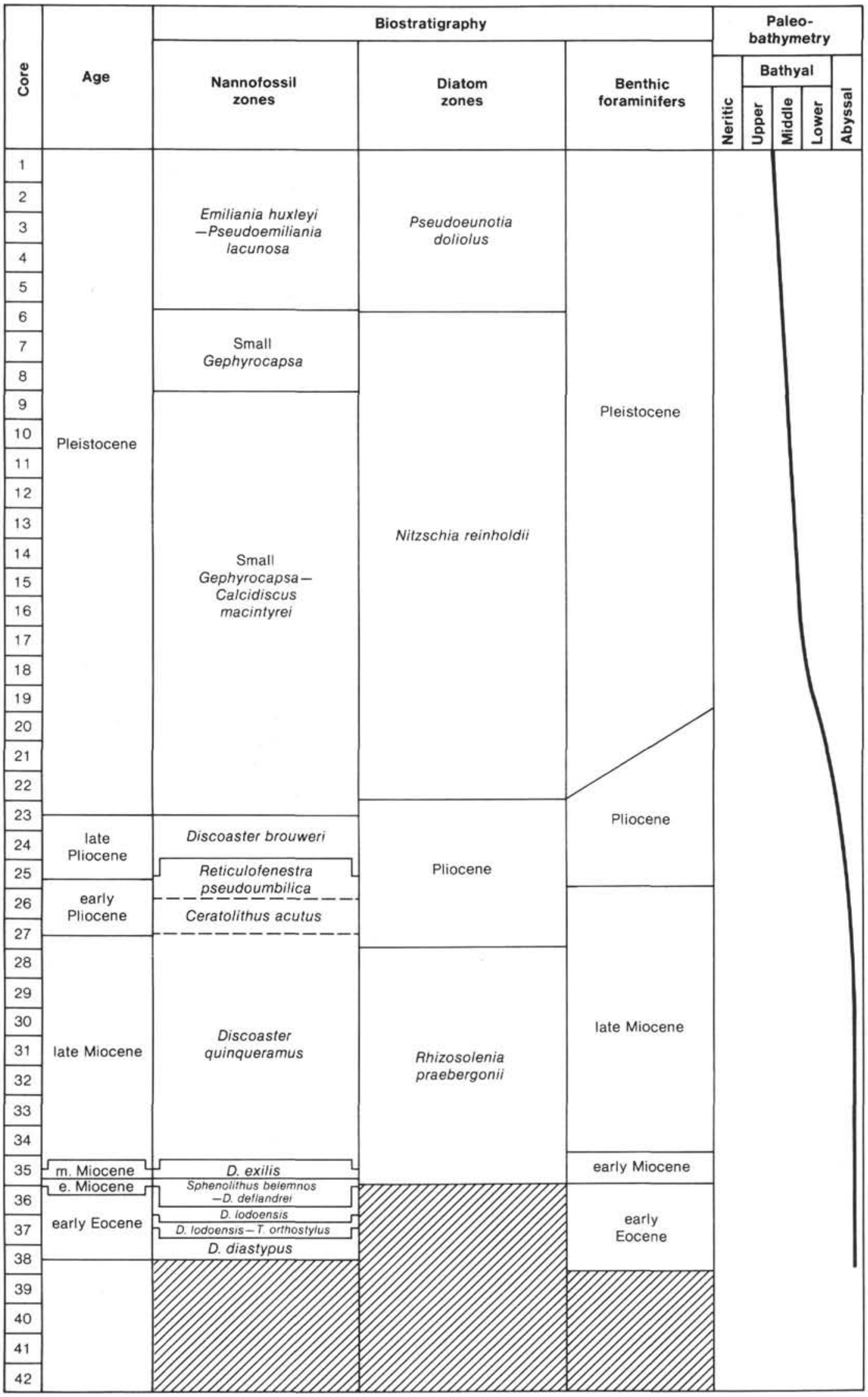


Figure 4. Biostratigraphic and paleoecologic summary, Site 570. Hachures indicate barren intervals.

through 570-35-1, 30 cm (268–327 m sub-bottom depth) are late Miocene, based on all disciplines, whereas 570-35-4, 5 cm through 40 cm is middle Miocene, and the lower part of Core 35 is early Miocene, based on nannofossils and benthic foraminifers.

Both greenish limestones and silty mudstones recovered from 570-36-1, 125 cm through 570-38-1, 55 cm (approximately 340–360 m) are early Eocene, based on nannofossils and benthic foraminifers. Approximately 10 m (less than 1 m recovered) of apparent conglomerate overlying serpentinite basement is barren of age-definitive *in situ* microfossils.

Site 570 benthic foraminiferal assemblages indicate a gradual shallowing from abyssal depths in the early Eocene to upper middle bathyal depths in the late Pleistocene. Early Eocene sands contain a benthic foraminiferal fauna that has been transported from the inner shelf (0–50 m) into abyssal depths below the foraminiferal CCD (calcite compensation depth). The early and late Miocene assemblages suggest deposition occurred in the abyssal biofacies, with transported material primarily from the upper middle and upper bathyal biofacies. During the Pliocene, shallowing continued from the abyssal, going to upper middle bathyal depths by the late Pleistocene. Transported material continues to be from the upper bathyal and outer shelf facies.

Sediment accumulation rates (Fig. 5) vary from 130 m/m.y. to approximately 5.3 m/m.y. for recovered sediments and suggest two hiatuses within the Miocene and a third significant hiatus between early Miocene and early Eocene sediments.

Sedimentation rates for the Pleistocene (1–215 m) are relatively high at 130 m/m.y. Sedimentation rates for Pliocene sediments (216–250 m) decrease dramatically to 13 m/m.y.; a very short hiatus (0.5 m.y.) may exist at the base of this interval and the underlying late Miocene sediments.

Sedimentation rates for the late Miocene (251–327 m) are approximately 47 m/m.y. The base of this interval occurs near Core 35, Section 1, because a short sequence of middle Miocene mudstone is present in 570-35-4 and early Miocene mudstone occurs in 570-35,CC. Two suc-

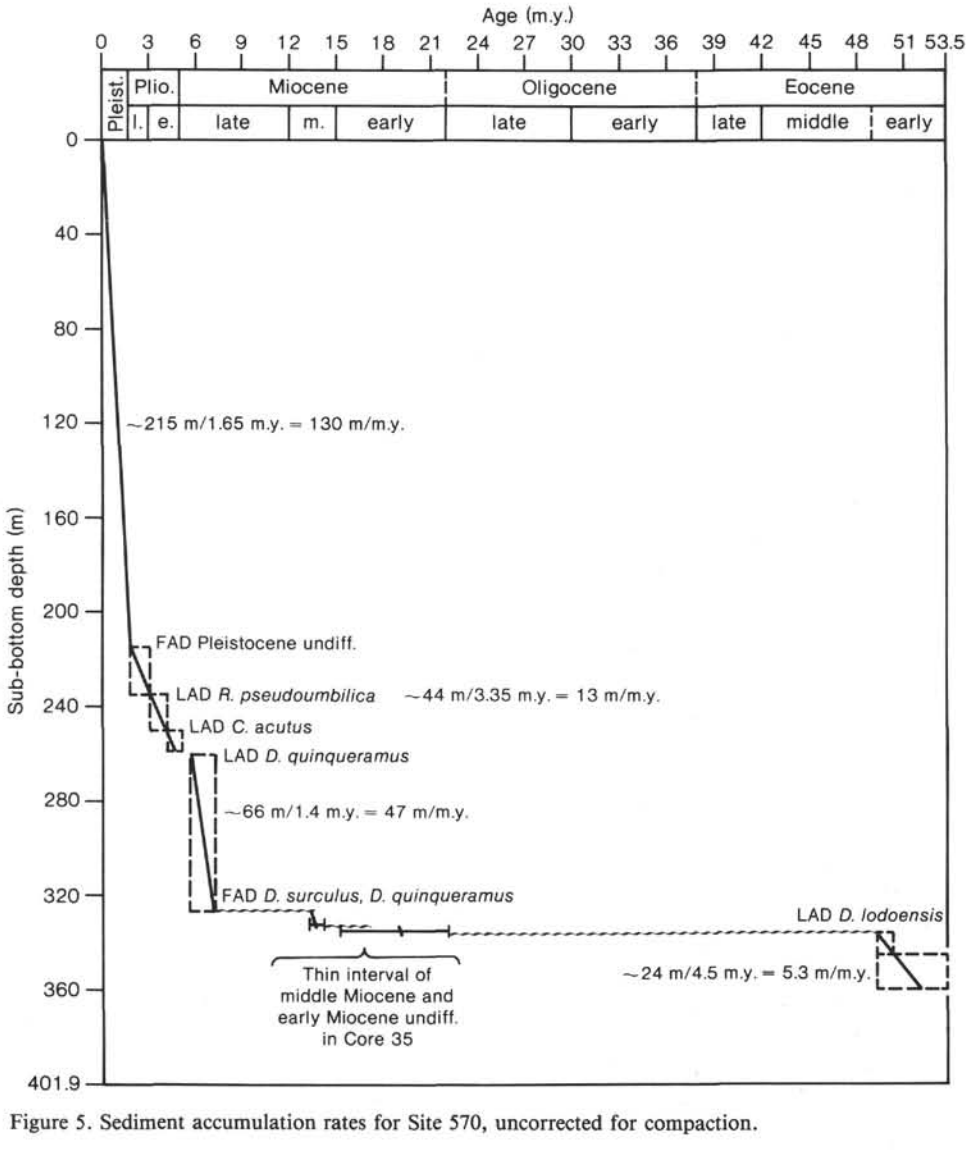


Figure 5. Sediment accumulation rates for Site 570, uncorrected for compaction.

cessive hiatuses of 3 m.y. or more probably separate the late and middle Miocene, and the middle and early Miocene sediments.

The early Miocene mudstone in 570-35,CC directly overlies early Eocene sandy mudstones and limestones (330–360 m), which have an approximate sedimentation rate of 5.3 m/m.y. A hiatus representing at least 27 m.y. is therefore suggested between the early Miocene and early Eocene sediments.

Nannofossils

Pleistocene through early Eocene sediments (Fig. 4) were recovered to a depth of approximately 360 m and contain age-diagnostic nannofossils that overlie 10 m of age-indeterminate conglomerate above 32 m of serpentinite basement.

Calcareous nannofossils are well preserved by nondiverse throughout the Pleistocene mudstones, well preserved and abundant throughout the Pliocene and late Miocene sediments, and marginally preserved in rare to common numbers within the early Eocene sandy mudstones and limestones.

Reworking of Pliocene nannofossils occurs sporadically throughout the Pleistocene and becomes especially prevalent in 570-18,CC. Several Paleocene species were also observed in the early Eocene sediments sampled at 570-36,CC and 570-37-1, 28 cm.

Section 570-1-2 through Sample 570-23-4, 47 cm are Pleistocene. Species diversity is low throughout this interval, and zonal markers such as *Pseudoemiliania lacunosa, Helicosphaera sellii*, and *Calcidiscus macintyrei* occur inconsistently. Small *Gephyrocapsa* spp. become abundant and *Gephyrocapsa oceanica* is absent in 570-6,CC through 570-8,CC, which suggests assignment to the small *Gephyrocapsa* Zone of Gartner (1977). Significant reworking of *D. brouweri* occurs in 570-18,CC.

Samples 570-23-6, 36 cm through 570-25-4, 36 cm are assigned to the late Pliocene *Discoaster brouweri* Zone of Okada and Bukry (1980). They contain *D. brouweri, D. pentaradiatus*, and *Helicosphaera sellii*. Lack of the consistent presence of *Discoaster tamalis* and *Discoaster surculus* restricts further subzonation.

Samples 570-25,CC and 570-26,CC (239.4–249.1 m) are early Pliocene and contain *Reticulofenestra pseudoumbilica, Sphenolithus neoabies, D. brouweri*, and *D. pentaradiatus*, which are indicative of the *Reticulofenestra pseudoumbilica* Zone. Core 27, Section 1 contains silty mud that was interbedded with gas hydrate. The silty mud matrix is assigned to the early Pliocene *Ceratolithus acutus* Zone and contains well-preserved specimens of *C. acutus, Discoaster surculus, S. neoabies, R. pseudoumbilica*, and *D. pentaradiatus*. Fractured siliceous dolomite interbedded with gas hydrate in 570-27,CC (258.8 m) is barren of nannofossils.

Samples 570-28-1, 43 cm through 570-35-1, 30 cm (268–327 m) are late Miocene, contain *Discoaster quinqueramus, D. bergrenni, D. surculus* (large morphotype), and rare *D. loeblichii*, and are assigned to the *Discoaster quinqueramus* Zone.

Silty mud matrix sampled from decomposed hydrates at 570-35-4, 5 cm through 570-35-4, 40 cm, just above a thin conglomerate, contains rare *Discoaster exilis, S. neoabies* and *Discoaster variabilis* s.l., which are indicative of the middle Miocene. Sample 570-35,CC (335.6 m) is early Miocene and contains *Helicosphaera ampliaperta, H. intermedia, Discoaster deflandrei*, and *Reticulofenestra gartneri*.

Sandy mudstone sampled at 570-36-1, 125 cm and 570-36-2, 44 cm also provided the matrix support for a gas hydrate. This interval is early Eocene and contains *Discoaster barbadiensis, D. lodoensis, Tribrachiatus orthostylus*, and *Coccolithus* cf. *crassus*, which are indicative of the *Discoaster lodoensis* Zone. Hard greenish limestone recovered from 570-36,CC (345.2 m) is also early Eocene (*D. lodoensis* Zone) and contains abundant recrystallized specimens of those species present in the softer lithology above, along with *Chiasmolithus solitus, Neococcolithus distentus, Lophodolithus mochloporus*, and others.

Limestone sampled from 570-37-1, 42 cm and 570-38-1, 55 cm (approximately 360 m depth) is also early Eocene but contains *Discoaster diastypus* along with *T. orthostylus* and *Discoaster binodosus* and is assigned to the *Discoaster diastypus* Zone. Rare reworking of several Paleocene species occurs within both the sandy mud and limestone lithologies from 570-36,CC to 570-37-1, 28 cm.

Samples 570-38,CC through 570-39,CC (364.4–374 m) are essentially barren of nannofossils. A soft brown serpentinite-bearing mudstone lithology present in 570-38,CC contains very rare nannofossil specimens of the Cretaceous species *Watznaueria barnesae* and *Micula staurophora* (species which are commonly reworked) mixed with sporadic, long-ranging Tertiary nannofossil species and Miocene foraminifers. Downhole contamination of this sediment is a distinct possibility. Cores 40 through 42 (383.3–401.9 m) recovered serpentinite and are barren of nannofossils.

Diatoms

Diatoms are present in all the sampled intervals at Site 570 down to 570-37,CC. Many of these species, however, are long-ranging or appear as a reworked component of the assemblage.

The Pleistocene (Cores 1 through 22 or 23) is well documented by the continuous presence of the reliable taxon *Pseudoeunotia doliolus*; the occurrence of *Nitzschia reinholdii* beginning at the bottom of Core 6 marks the early part of the Brunhes Event in the middle Pleistocene. The early Pleistocene indicator *Rhizosolenia praebergonii* appears about halfway down the section, at the bottom of Core 8.

We encountered pliocene diatoms beginning at Core 23. These include *Nitzschia jouseae, Thalassiosira convexa, Rossiella tatsunokuchiensis*, and *Hemidiscus ovalis*. Miocene forms, which were reworked in the Pliocene, are *Coscinodiscus vetustissemus* (late Miocene) and *Thalassiosira praeconvexa* (late Miocene). We also observed *Ceratulus pacificus* fragments (late Oligocene).

Thalassiosira convexa (late Miocene to latest Pliocene) continues into Core 31, putting this interval within the late Miocene at the oldest. Additional support for a late

Miocene age in Cores 28 through 32 is the presence of *Coscinodiscus yabei* and *Coscinodiscus temperei* var. *delicata* in this interval.

The late Miocene continues until the first part of Core 35. Characteristic late Miocene species observed in the interval from 570-28 to 570-35,CC were *Actinoptychus biformis, Coscinodiscus excentricus* var. *leasareolatus, Melosira sulcata* var. *siberica*, and *Rouxia naviculoides*. All of these species are absent in the core catcher of Core 35, which is dated as early Miocene on the basis of nannofossils. The next four cores—36 through 39,CC—are barren of diatoms.

Benthic Foraminifers

Benthic foraminifers from Site 570 are abundant, moderately diverse, and well preserved. Pleistocene through early Eocene assemblages are present at this site. Although several major unconformities have removed portions of the sedimentary record, Pleistocene, Pliocene, Miocene, and Eocene assemblages are present. Ecologic analysis indicates continual uplift since the late Miocene, with several abrupt changes associated with the unconformities. Early Miocene, late Miocene, and Pliocene assemblages indicate abyssal (4000 m) depths, whereas the early Pleistocene is in the lower middle bathyal biofacies (1500–2000 m) and the late Pleistocene is in the upper middle bathyal biofacies (500–1500 m).

Pleistocene benthic foraminiferal assemblages (Cores 1 through 22) were not examined in detail, however, the assemblages are similar to the Holocene assemblages off Central America (Smith 1964). Cooler-water species *Cassidulina limbata* and *Cassidulina californica* appear in several samples mixed with warmer water species, indicating probable glacial–interglacial cycles. Pliocene and Miocene benthic species appear in the lower portion of the Pleistocene interval making a Pleistocene or Pliocene age call difficult on the basis of benthic foraminifers. Nannofossils place the early Pleistocene/Pliocene boundary between 570-23-4, 47 cm and 570-23-6, 36 cm. Ecologic analysis of the benthic foraminiferal assemblages indicates a gradual shallowing from the Pliocene/Pleistocene boundary to the present and from the lower middle bathyal biofacies to the upper middle bathyal biofacies. Unconformities in the lower part of this interval are suggested by abrupt faunal changes between 570-18,CC and 570-19,CC and between 570-14,CC and 570-15,CC. Transported material is primarily from the upper bathyal biofacies, with occasional concentrated layers of the outer shelf material.

Pliocene benthic foraminiferal assemblages are not easily differentiated from the Pleistocene assemblages. Assemblages diagnosed as probably Pliocene range from Cores 20 to 25. The upper samples are mixed with Pleistocene benthic foraminiferal species and considered to be Pleistocene based on nannofossils. Miocene species occur sporadically throughout and increase in the lower samples. The Pliocene interpretation is based primarily on changes in dominance of species and is less related to the occurrence of age-diagnostic species. Ecological analysis indicates a continuation of the Pleistocene bathymetric trend, and the Pliocene assemblages are within the lower middle bathyal biofacies. Abyssal and lower bathyal species become more common in the early Pliocene. Transported material is primarily from the upper bathyal biofacies.

Miocene benthic foraminiferal species indicate both late (570-28,CC to 570-34) and early (Core 35) Miocene ages. The first age-diagnostic benthic foraminiferal species appear in Sample 570-35-4, 12–14 cm, which is slightly higher (20 cm) than the first appearance of early Miocene nannofossils. Both the late and early Miocene assemblages were deposited in the abyssal biofacies, with the bulk of the transported material being displaced from the upper bathyal and upper middle bathyal biofacies.

Early Eocene foraminiferal species are present in Cores 36 and 37. The benthic foraminiferal tests are poorly preserved and siliceous, indicating deposition occurred in the abyssal zone and below the foraminiferal CCD. Analysis of the faunas indigenous to the sands indicates that the sands originate in the inner shelf biofacies and contain sparse but definite inner shelf species such as *Amphistegina*. Interbedded shale sequences contain only planktonic foraminifers.

PHYSICAL PROPERTIES

Methods

Techniques described for previous sites of this leg were used for laboratory determination of bulk densities, porosities, and wet-water contents. Compressional or sonic-wave velocities were obtained using the Hamilton-Frame velocimeter, and strength measurements were conducted utilizing both a hand-held Torvane and a Soil Test penetrometer. Thermal conductivity was measured for some samples following the method described.

Results

Index properties, including bulk density, wet-water content, and porosity, are plotted in Figure 6, portraying the downhole changes related to overburden and lithology. The upper 10 to 15 m of sediment show a rapid loss of water an an increase in bulk density, from 1.4 Mg/m^3 for surficial sediment to 1.5 $Mg/^3$ at 12 m. Below this point, the Pleistocene mud section shows very little change with depth except for occurrences of sandier horizons (i.e., 54 and 173 m sub-bottom) and mudstone (221 m). The underlying Pliocene, Miocene, and early Eocene muds follow this trend with little deviation. Within these intervals, however, different lithologies were recovered, presenting characteristics quite different from the mud, as indicated in Figure 6.

Strength measurements yielded both shear and unconfined compression strengths, which are displayed in Figure 7. Several observations can be made, beginning with an overall downhole increase in strength from approximately 0 kPa at subsurface to approximately 350 kPa at 220 m for unconfined compressive strength. Secondly, a large number of cores, especially the uppermost section, show increased strength within the cored interval that is related to the state of disturbance caused by drilling. Finally, the hand-held Torvane measurements of shear strength show much more variability than penetrometer

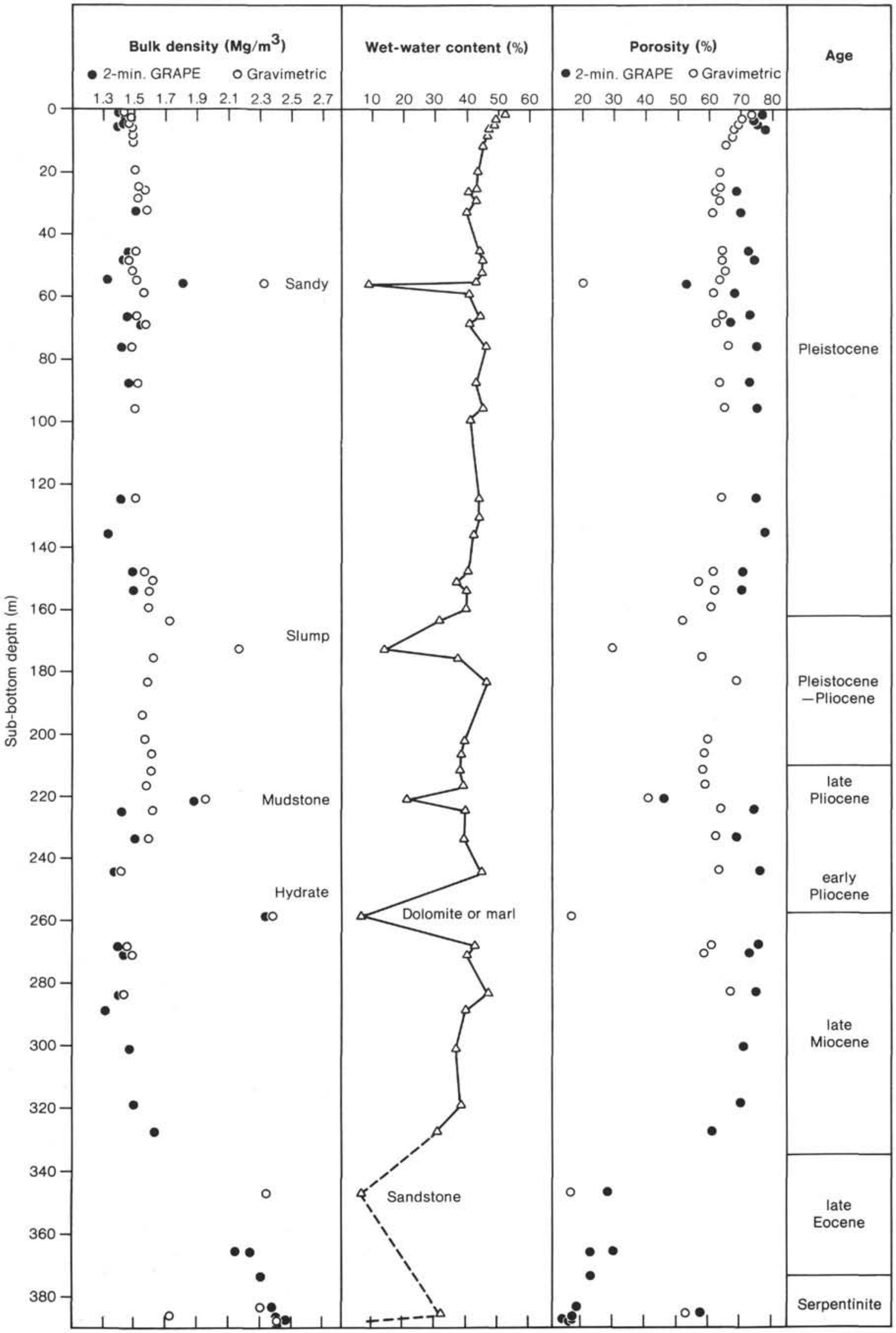


Figure 6. Index properties of cored sediments and rocks at Site 570.

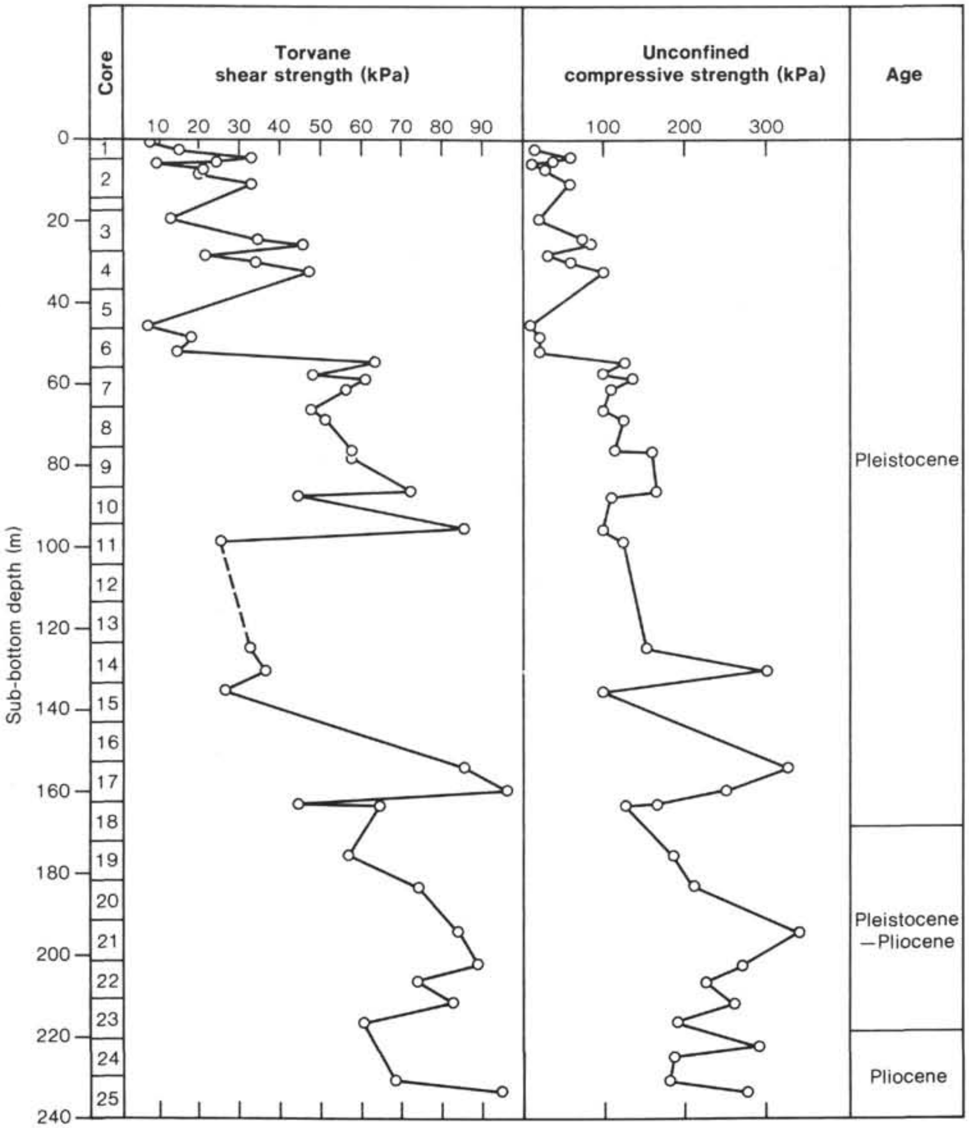


Figure 7. Strength characteristics of Site 570 sediments.

(unconfined compressive strength) tests, which not only stems from the greater sensitivity of this measurement but also from the fact that the shear test involves more sample area and becomes prone to reflecting weakened zones produced from drilling, instead of the less disturbed, "normal" sediment strength. The recovered sediment at this site also contained consistently high amounts of dissolved gas that caused various degrees of sediment disturbance, which may also be reflected in the variable nature of the strength profiles.

Sonic velocities and acoustic impedances were made on numerous samples and are plotted in Figure 8. Velocities for the mud section show an increase downhole from roughly 1.5 km/s to 1.8 km/s in the upper 50 m. Below this depth attenuation from degassing precluded further measurements on mud, thus limiting the remaining velocities to lithified sediments and rock.

Thermal conductivities for a number of samples were obtained using the needle probe on temperature-stabilized samples in the core liner. One sample of serpentinite was also tested, using the flat, half-space probe on a split core section. These data are presented in Table 2 and are not corrected to *in situ* conditions.

Recovery of massive hydrate in Core 27 allowed actual laboratory measurements of sonic velocity and of density via the 2-min. GRAPE technique. Because of the rapid decay of clathrate, sonic velocity determinations were made while the thickness of sample was actually changing, thus requiring two people to do simultaneous readings of sample thickness and delay time. Attenuation within the hydrate was elevated and therefore numerous readings were obtained to gain a statistically valid measurement. The data measured are listed in Table 3.

The average velocity from Table 3, excluding the highest and lowest value, is 2.751 km/s, with a standard deviation of 0.27. The velocities shown have been multiplied by the correction factor for the μs/cm scale used (i.e., 0.9917).

Corrected bulk density for the hydrate recovered is calculated on an average width of sample in the gamma

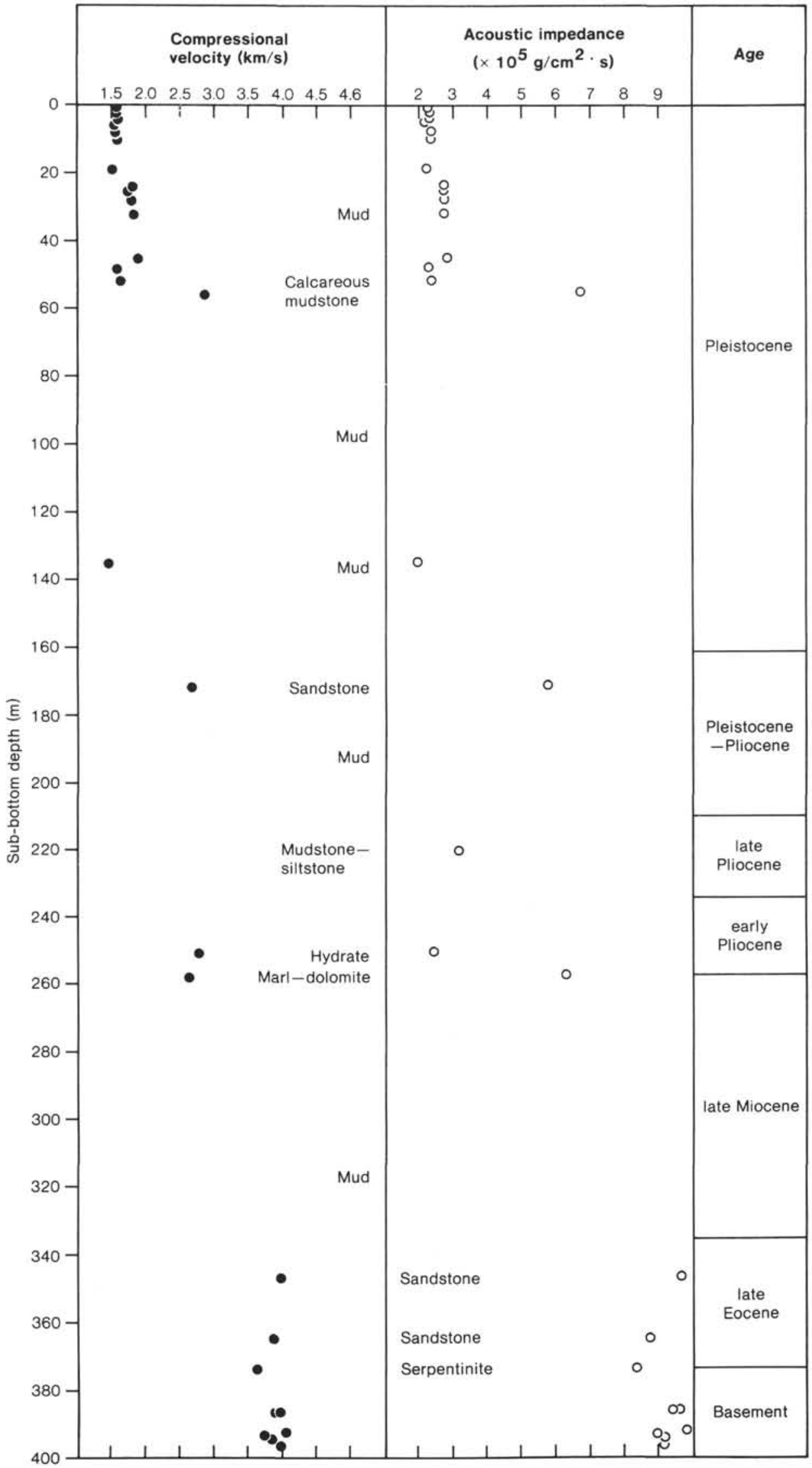


Figure 8. Acoustic character of sediments and rock recovered at Site 570.

Table 2. Thermal conductivity measurements at Site 570.

Sample	Sub-bottom depth (m)	Thermal conductivity (mcal/cm°C s)
570-2,CC	14.40	1.843
570-4,CC	36.70	1.603
570-6-7, 4 cm	55.40	1.557
570-20,CC	191.40	1.843
570-23,CC	220.10	1.975
570-28,CC	268.30	1.202
570-41-3, 63-70 cm (serpentinite)	386.93	5.184

Table 3. Clathrate compressional-wave velocity.

Centimeter delay	μs/cm scale	Delay time (μs)	Distance (cm)	Velocity (km/s)[a]
1.29	2	2.58	0.678	2.606
1.25	2	2.50	0.645	2.559
1.20	2	2.40	0.602	2.488
0.99	2	1.98	0.548	2.745
0.97	2	1.94	0.510	2.607
0.92	2	1.84	0.488	1.630
1.06	2	2.12	0.521	2.437
1.05	2	2.10	0.471	2.224
0.38	2	0.76	0.404	5.272
1.25	2	2.50	0.696	2.761
1.09	2	2.18	0.666	3.030
0.90	2	1.80	0.588	3.240
0.86	2	1.72	0.547	3.154

[a] Corrected velocity.

ray beam of the GRAPE for the two-minute period. Two measurements were made yielding values of 0.873 Mg/m^3 and 0.898 Mg/m^3, which would indicate an open, porous ice structure.

Discussion

The overall lithology at Site 570 is a mud to sandy mud deposited mostly during the Pleistocene. This lithology shows a downhole change in physical properties also characteristic of several nearby sites. The trend is one of more rapidly changing characteristics in the uppermost section (10-15 m), followed by a very gradual and slow consolidation trend for the remaining section. The most outstanding features of the physical properties at this site are the various minor lithologies and the clathrate. Table 4 summarizes some characteristic ranges of properties measured on laboratory samples and allows correlation of lithologies with downhole logging records. Examination of the logs shows good agreement between *in situ* and laboratory determinations of physical properties, which indicates reliability for lithological interpretation in the nonrecovered column.

A final note is made regarding the character of the logged hydrate section and laboratory measurements. Velocities recorded on the sonic log yield ranges between 3.3 and 3.8 km/s, as opposed to the average laboratory measured value of 2.75 km/s, possibly reflecting the effects of degassing and compressibility of the cored material. Also, the density compensated log produces bulk densities of 1.024 to 1.045 Mg/m^3, as opposed to 0.88 Mg/m^3. Again this demonstrates the variation of properties from *in situ* conditions to laboratory conditions. Another consideration regarding causes creating the difference in the data is the amount of incorporated mud in the *in situ* hydrate versus the relatively mud-free chunk used for laboratory measurements.

GEOPHYSICS

Site 570 was selected to sample basement from the upper slope of the Trench. There are no basement ridges above the level of the base of hydrate along the main Guatemalan transect area, making it necessary to select a site elsewhere in the network of seismic lines. Site 570 is about 70 km west of the main transect on a shallow basement target seen in seismic record GUA-11. (GUA-11 is 15 km west of the line published by Seely et al., 1974.) This basement high is associated with a dipolar magnetic anomaly that lies in the main belt of anomalies and has a steep gradient indicating a shallow anomaly-producing body (Fig. 9).

Site 570 is 14 km downslope from the edge of the shelf and 75 km east of the Petrel Well. In seismic record GUA-11 (Fig. 10) the upper 0.3 s thick cover of slope deposits has low relative amplitude and is underlain by a diffracting upper surface of a seismic unit without coherent internal reflections. The sonic log gives velocities of 1.5 to 1.7 km/s in the slope sediment, and 2.4 to 2.7 km/s in the diffracting unit below. The massive hydrate is well located in the seismic record from the logged velocities. This hydrate may correspond to a diffraction. The uncertainty is in the precise location of GUA-11. *Glomar Challenger* records made coming onto and leaving the site suggest a diffracting reflection at the massive hydrate level. However, the hydrate is not associated with any coherent reflections that would suggest a planar body or strata of high velocity material.

Table 4. Range of lithologic physical properties from lab measurements, Site 570.

Lithology	Bulk density (Mg/m3)	Porosity (%)	Sonic velocity (km/s)	Acoustic impedance ($\times$ 10^5 g/cm^2 · s)
Mud	1.331-1.962	41.5-81.2	1.504-1.895	2.164-3.018
Sandstone	2.162-2.412	17.3-30.5	2.673-3.994	5.779-9.634
Dolomite	2.398	17.5	2.625	6.295
Clathrate	0.873-0.898	—	2.224-5.272	1.942-4.734
Serpentinitic mud-serpentinite	1.711-2.467	2.61-57.8	3.601-4.265	8.329-9.905

Note: — indicates not determined.

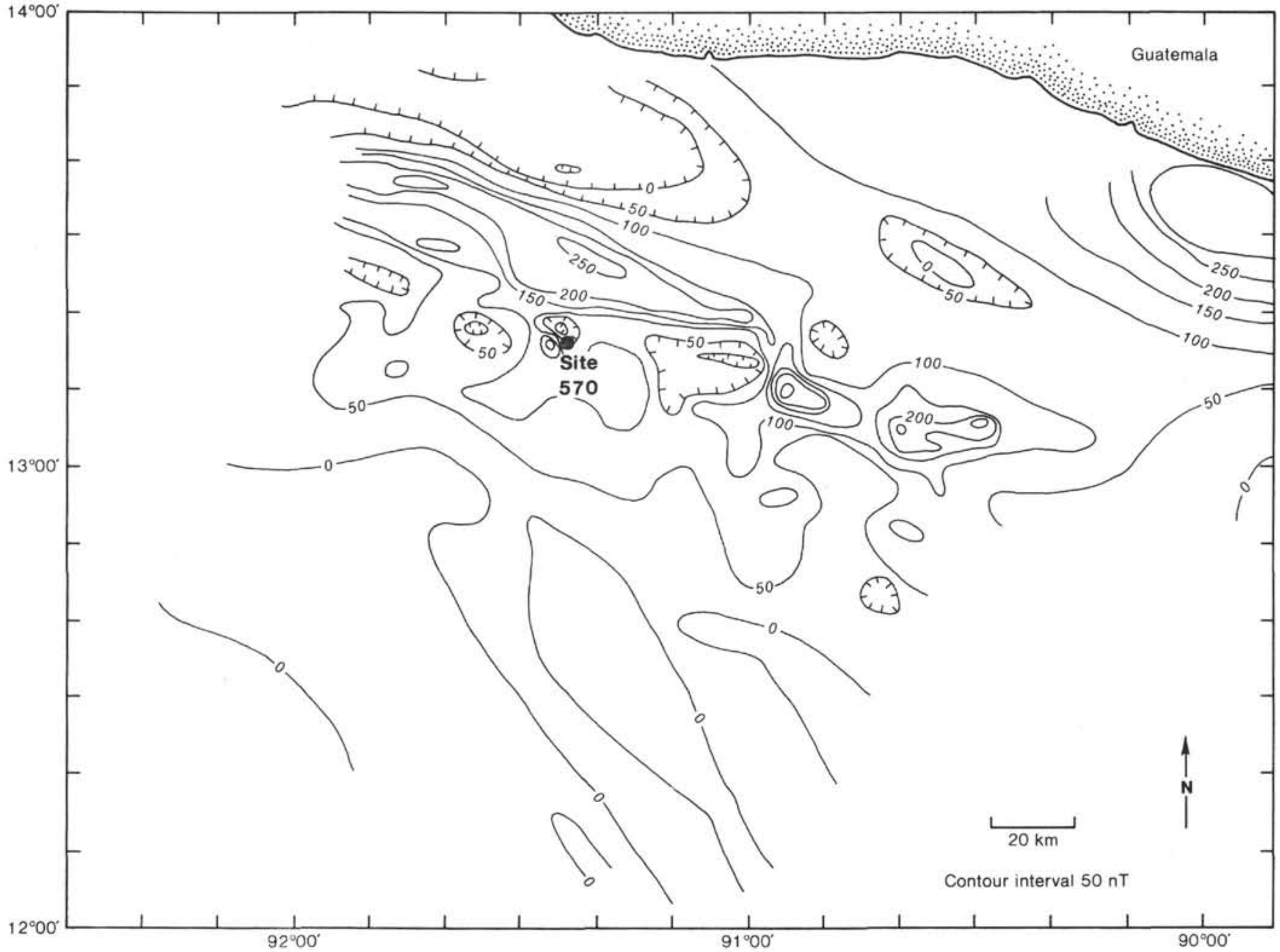


Figure 9. Magnetic anomaly map off Guatemala showing strong dipolar feature associated with the seamount adjacent to Site 570.

Magnetometer measurements made coming on site and departing the site confirmed the steep dipolar anomaly on the magnetic anomaly map made by McMillan (in Ladd et al., 1982). However, the ophiolitic rock recovered at Site 570 has a low magnetic susceptibility, thus the prominent circular topographic peak could be the anomalous source and is perhaps an outcrop of basement or a forearc volcano. Conventional sampling of the peak produced basalt fragments from submarine flows that may be the source of the dipolar anomaly.

A suite of logs including sonic, sonic waveform, density, gamma ray, caliper, neutron porosity, dual laterolog, SP, and temperature were run at this site, however, because this was the last operation prior to going into port, there was insufficient time on board to make a thorough analysis of these data. The logs are of excellent quality because of good hole conditions and they show clearly the massive hydrate, the top of the Eocene limestone and sandstone, and the serpentinite. The Pleistocene, Pliocene, and Miocene mud sections are of uniform velocity, density, porosity, and resistivity, thus providing a clear background for thin limestone and sandstone beds. The massive hydrate is clearly defined and can be separated from the underlying thin dolomite bed (Fig. 11). Sonic velocity and density values from logging are compared with physical properties in the physical properties section. The temperature log, uncorrected for circulation, gives a temperature gradient of about 26°C/km, which agrees well with the gradient of the Petrel Well.

PALEOMAGNETISM

Most of the sediments recovered from this site were too unconsolidated to provide useful paleomagnetic data. An exception was a thin sandstone bed in Core 39. Alternating field demagnetization results for this sample are plotted in Figure 12. This sample maintains a stable reversed inclination in fields up to 175 Oe, at which point the inclination varies erratically, probably because of the acquisition of small anhysteretic remanent magnetizations. The result suggests that the sandstone was deposited at close to its present latitude, provided that it has not been tectonically tilted (an estimate of bedding dip could not be made).

Serpentinites were recovered in Cores 41 and 42. The results of stepwise demagnetizations on three samples from each of these cores are plotted in Figure 13. All of

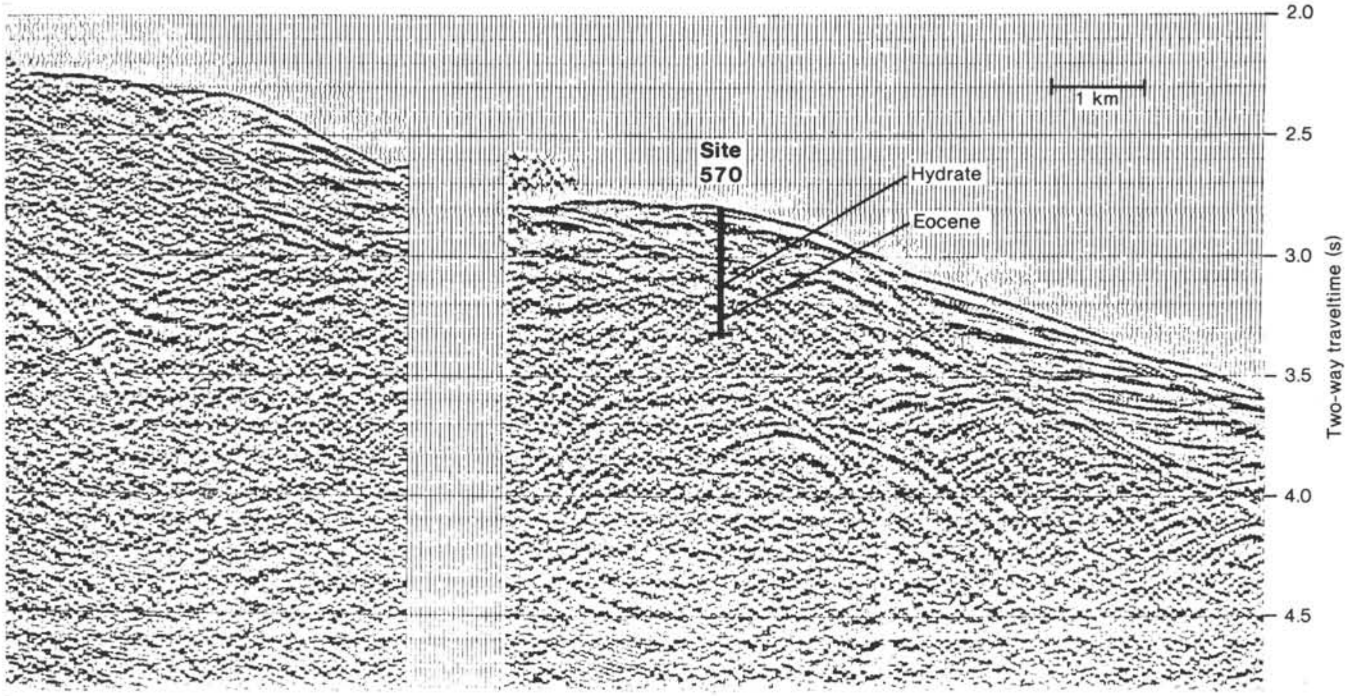


Figure 10. A part of seismic record GUA-11 approximately across Site 570 showing depth of hydrate and Eocene sediment.

the samples from Core 41 show extremely stable behavior, with inclinations that remain in the range 15° to 20° even in fields of 800 Oe. The samples from Core 42 are less stable and have reversed inclinations that stabilize at about −20° for two of the samples and at about +5° for the uppermost Sample 547-42-1, 31 cm. The results suggest that like the sandstone sample, the serpentinites acquired their stable magnetizations at close to their present latitude. However, the variability in their magnetic stability suggests that magnetization of this unit was a multistage process with at least two episodes corresponding to the normal and reversed polarities.

Results of magnetic susceptibility measurements on the samples are shown in Table 5. The Königsberger ratios (Q_n) are quite variable, ranging from 3.6 for the lowest sample (570-42-2, 32 cm) to 0.40 for Sample 570-41-3, 97 cm. The uppermost Sample 570-41-3, 33 cm has the best magnetic properties for producing a magnetic anomaly with a high intensity of magnetization (7.2×10^{-4} emu/cm^3) and a high Königsberger ratio (3.2). It also has a very high magnetic stability (Mean Destructive Field of 650 Oe). However, the average magnetization of the entire sequence of samples is somewhat lower, about 4×10^{-4} emu/cm^3. This, combined with the change in magnetic polarity of the lower samples, implies that the whole sequence would not produce a very large magnetic anomaly.

GEOCHEMISTRY

Because the objective at this site was to sample the rocks of the acoustic basement, a minimum geochemical program was undertaken to monitor routinely the composition of hydrocarbon gases and the chemistry of the interstitial water. This routine program was interrupted when dispersed and then massive gas hydrates were encountered. Sufficient massive gas hydrate (ca. 1.5 m) was recovered at about 250 m sub-bottom to attempt, for the first time, to bring the substance to shore-based laboratories for detailed physical and chemical studies. A second surprising observation was that significant amounts of gas were associated with the serpentinite at the bottom of the hole at 402 m sub-bottom.

Gas Analyses

Vacutainers were used to collect gases from cores; the procedures have been described in detail in the Site 565 report. The following hydrocarbon gases were determined: methane (C_1), ethane (C_2), propane (C_3), isobutane (i-C_4), normal butane (n-C_4), noepentane (neo-C_5), isopentane (i-C_5), and normal pentane (n-C_5). The use of vacutainers requires that sufficient gas be present to be collected within the core liners, preferably in pockets formed as the sediment expands. The first two cores recovered at this site did not develop gas pockets; therefore, gas was sampled through the caps at the lower end of the cores. In these cores, concentrations of hydrocarbon gases were low, with C_1 less than about 12.5% (Table 6). Low concentrations result not only because the absolute amount of hydrocarbons in these cores is small, but also because gas samples taken through the end caps have ample opportunity to become diluted with air. In addition to hydrocarbon gases and CO_2, H_2S was also present in these cores. Thus these cores are from the zone of sulfide reduction, which at this site is very near the sediment/water interface.

Below 17.5 m sub-bottom, most cores containing unconsolidated sediment developed gas pockets while the cores were on deck. Wherever gas pockets could be sampled the amount of C_1 measured was usually greater than 60% (Table 6). Between about 10 and 100 m sub-bot-

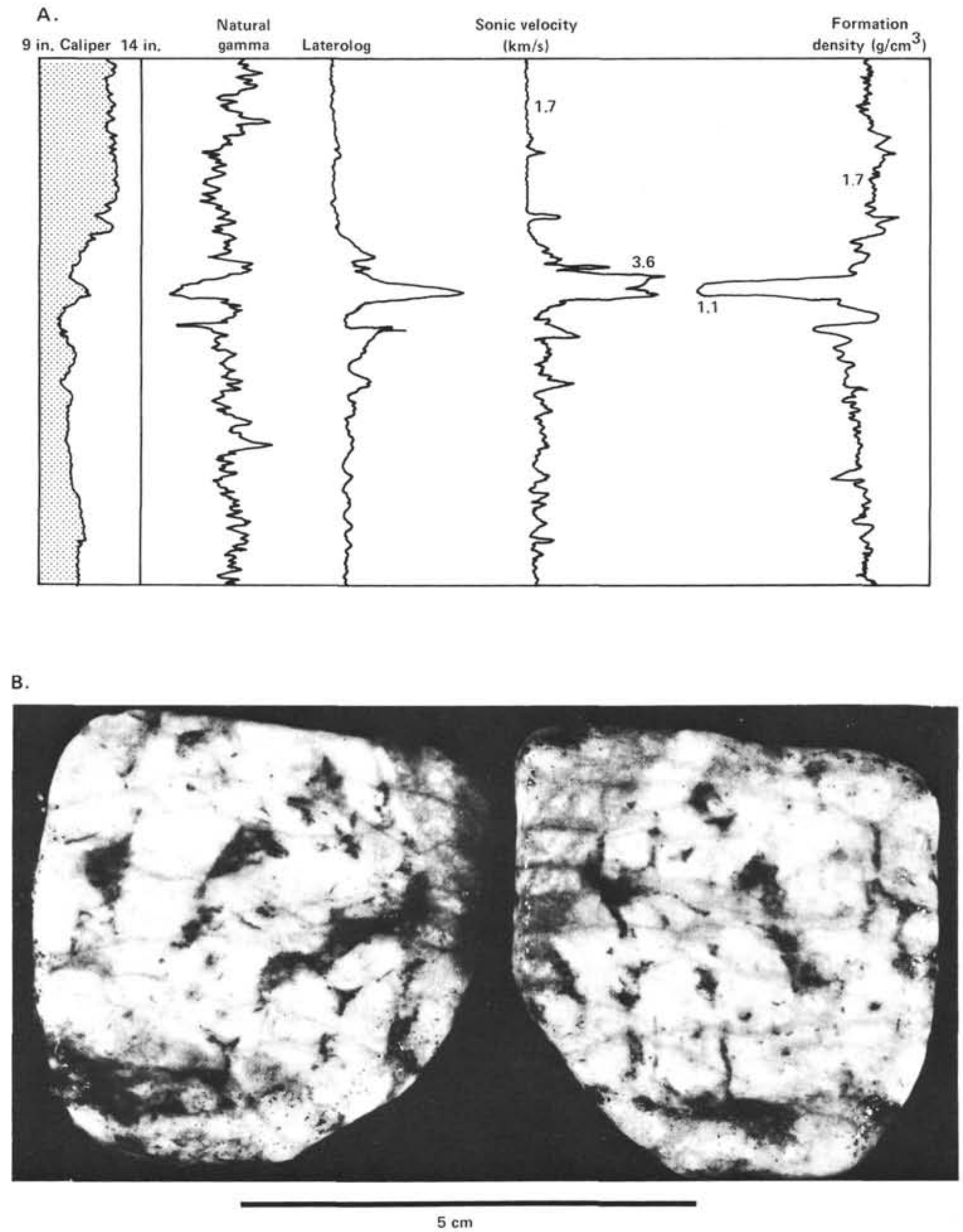


Figure 11. A and B. Photograph of gas hydrate recovered from Site 570 (Section 570-27-1) and logging characteristics of the hydrate layer.

tom, ratios of C_1/C_2 were large, falling in the range between about 50,000 and 92,000 (Fig. 14). These large ratios indicate that the C_1 is a product of microbial alteration of organic matter. In this same interval, higher molecular weight hydrocarbons were present up to C_5 (Table 6).

Between about 100 and 245 m sub-bottom, the C_1/C_2 ratios decreased with depth regularly and exponentially from 92,000 to 410 (Fig. 14). This exponential decrease reflects the early diagenetic production of C_2. The relative distribution of C_2 through C_5 hydrocarbons remained about the same throughout the interval from 100 to 210 m with a distributional pattern similar to that observed for gases in sediments in the interval from 17.5 to 100 m. However, in the interval from 100 to 210 m, the concentrations of the C_2 through C_5 hydrocarbons generally increased. For example, C_2 increased from about 10 to 130 ppm. Gas hydrate occurred as laminations in ash at a sub-bottom depth of 192 m.

Between 205 and 235 m sub-bottom, the relative distribution of C_2 through C_5 hydrocarbons changed and the concentrations of these gases continued to increase, with C_2 reaching about 320 ppm. At the depth of 235 m the C_1/C_2 had decreased to 1800.

In the next lower core (Core 26) the concentration of C_2 through C_5 hydrocarbon gases increased abruptly (Table 6) and the C_1/C_2 ratio decreased to 410 (Fig. 14). The next lower core (Core 27) encountered a massive gas hydrate between about 250 and 255 m sub-bottom. This almost pure gas hydrate was associated with fractured

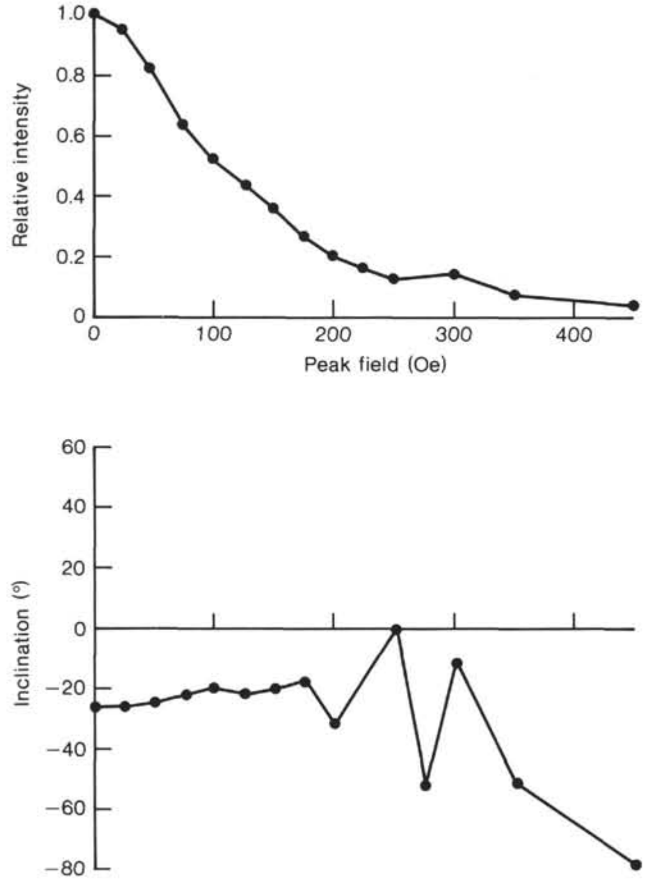


Figure 12. Alternating field demagnetization of a sandstone sample from Site 570 (Sample 570-39-1, 41–43 cm).

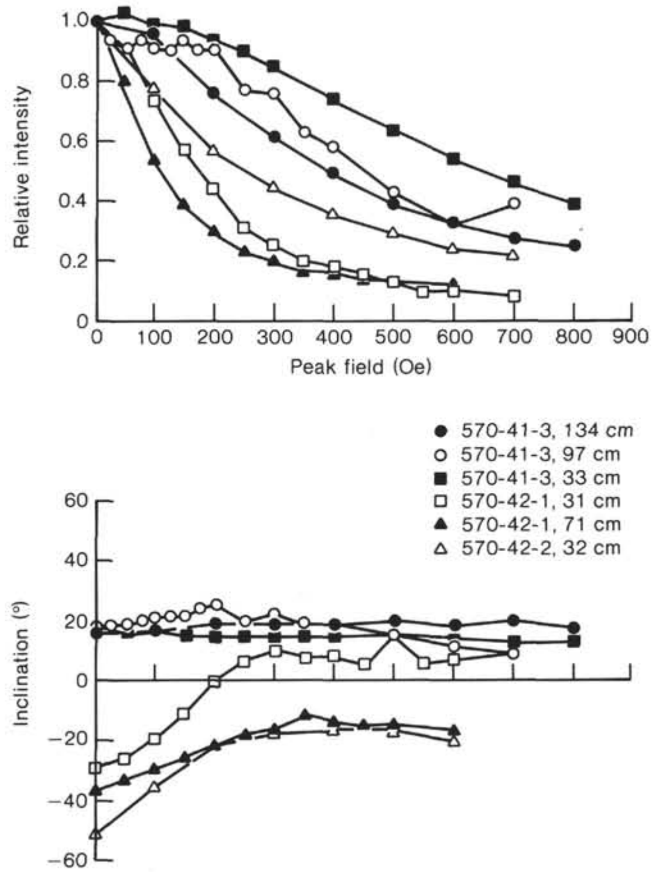


Figure 13. Alternating field demagnetization of serpentinite samples from Site 570.

Table 5. Magnetic properties of igneous rocks from Site 570.

Sample (hole-core-section, cm level)	NRM ($\times 10^{-4}$ emu/cm^3)	Susc. ($\times 10^{-4}$ cm·g·s)	Q_n
570-41-3, 33	7.2	5.6	3.2
570-41-3, 97	1.2	7.5	0.40
570-41-3, 134	1.6	7.2	0.56
570-42-1, 31	4.4	12.0	0.92
570-42-1, 71	6.8	20.0	0.85
570-42-2, 32	3.6	2.5	3.6

dolomite at its base and was located at the unconformity between late Miocene and Pliocene. Cores 28 and 29 also contained pieces of gas hydrate, and the distribution of gases from the cores was similar to that of Core 26. Cores 30 through 37 had visible evidence of gas hydrates. In these cores, however, the amounts of C_3 through C_5 are generally lower than the amounts found in Cores 28 and 29.

The unconsolidated sediment record essentially ended at about 350 m sub-bottom, and gas pockets were no longer available for sampling. The fractured serpentinite below 385 m sub-bottom appeared to be outgassing slightly, and samples of gas were analyzed from Cores 41 and 42. Hydrocarbon gases were present in high concentrations and the C_1/C_2 ratio decreased to 85 in the last core, at which point drilling was terminated. The occurrence of high concentrations of hydrocarbons in the fractured serpentinite at Site 570 is similar to the observations made at Site 566.

Gas Hydrates

Although Site 570 lies within the pressure–temperature stability field for gas hydrates, the finding of extensive gas hydrates was not anticipated here. The first visual evidence of gas hydrate was obtained in Core 21 (about 192 m sub-bottom) in the form of ash laminated with gas hydrate. In Core 26 at 246 m sub-bottom, gas hydrate occurs in fractures of mudstone. Core 27 (249.1–258.8 m) contained 1.05 m of massive gas hydrate, a portion of which is shown in Figure 15. Density and sonic logs later showed that this gas hydrate is about

Table 6. Distribution of hydrocarbon gases at Site 570.

Section (core—section)	Sub-bottom depth (m)	C_1 (%)	C_2 (ppm)	C_3 (ppm)	i-C_4 (ppm)	n-C_4 (ppm)	neo-C_5 (ppm)	i-C_5 (ppm)	n-C_5 (ppm)
1-4	5	—	0.07	0.08	0.10	0.02	0.06	—	—
2-5	11	13	1.40	0.37	0.10	0.03	0.02	—	—
3-6	26	80	8.70	2.20	0.59	0.16	0.04	0.08	—
4-2	30	89	12.00	2.20	0.59	0.10	0.16	0.22	—
5-3	41	84	14.00	2.60	0.76	1.90?	0.09	0.56?	1.00?
6-5	53	89	18.00	3.80	1.00	0.22	0.08	0.36	—
7-4	61	89	16.00	4.30	2.90?	0.48	0.37	0.98	0.08
8-3	69	61	11.00	4.10	1.20	0.31	0.06	1.30	0.08
9-2	78	23	3.10	1.40	0.40	0.10	0.07	0.51	0.04
10-2	88	74	10.00	4.80	1.30	0.32	0.29	2.00	0.15
11-1	96	81	8.80	7.70	1.50	0.41	0.01	1.90	0.11
14-5	130	87	28.00	5.60	0.72	0.26	0.04	0.33	0.12
15-2	136	84	29.00	3.10	2.10	0.16	0.02	0.26	0.05
16-6	151	80	40.00	6.90	0.84	0.31	0.06	0.43	0.13
17-3	157	65	37.00	8.90	0.97	0.46	0.04	0.90	0.08
18-1	164	62	54.00	8.10	1.00	0.40	0.04	1.15	0.05
19-3	176	65	64.00	8.50	0.89	0.39	0.04	1.31	0.07
20-1	183	58	62.00	8.80	0.41	0.25	0.11	0.48	0.29
21-2	193	65	130.00	11.00	1.40	0.43	0.16	0.54	0.09
22-3	205	64	110.00	3.50	0.67	0.17	0.16	0.54	0.03
23-2	214	61	280.00	7.10	1.60	0.40	0.54	1.60	0.21
24-3	224	55	240.00	4.40	0.77	0.21	0.82	0.14	0.03
25-4	235	58	320.00	11.00	1.60	0.84	2.20	0.20	0.18
26-4	246	56	1400.00	400.00	140.00	110.00	5.60	42.00	29.00
28-6	267	71	1700.00	190.00	110.00	86.00	5.70	47.00	12.00
29-4	274	86	1900.00	240.00	130.00	120.00	6.30	62.00	13.00
30-4	284	63	1000.00	110.00	87.00	20.00	3.50	17.00	2.30
31-1	289	75	790.00	12.00	25.00	1.90	1.70	4.40	1.30
32-4	302	69	740.00	9.80	8.10	3.90	0.49	2.20	0.96
34-1	317	80	420.00	2.70	0.34	—	—	—	—
35-2	329	81	690.00	—	0.66	—	0.10	—	0.06
36-1	337	81	810.00	1.10	6.70	0.67	1.20	1.80	0.75
37-1	346	70	930.00	0.14	7.40	1.00	0.82	2.10	0.96
41-2	386	69	3600.00	4800.00	1400.00	170.00	11.00	9.90	11.70
42-1	394	25	3000.00	3400.00	910.00	140.00	8.80	8.60	3.20

Note: – indicates not detected.

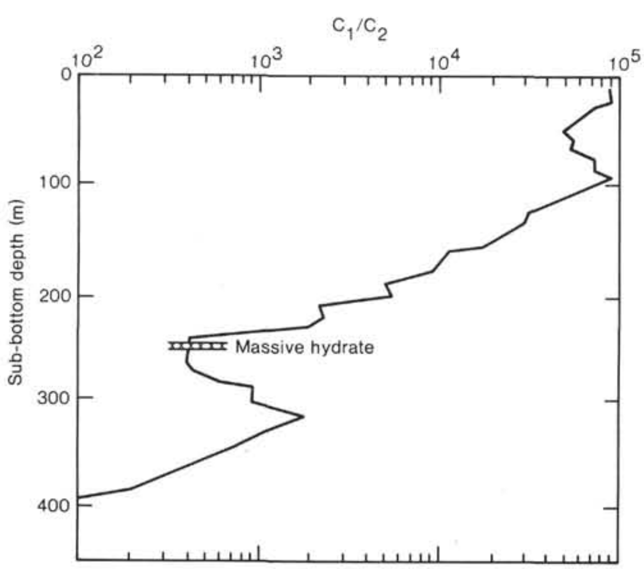


Figure 14. Ratios of methane to ethane (C_1/C_2) with depth at Site 570.

4 m thick (see Geophysics section). Pieces of gas hydrate were also recovered from fractures in mudstone in Cores 28 and 29 (258.8–278.0 m) and visually observed in Cores 30 through 37 (278.0–354.8 m).

The concentrations of hydrocarbon gases collected in a pressure device from decomposed gas hydrates from Cores 21 and 27 are listed as follows:

	Core 21	Core 27
C_1	44%	69%
C_2	390 ppm	1600 ppm
C_3	0.9 ppm	48 ppm
i-C_4	0.7 ppm	22 ppm
n-C_4	0.02 ppm	28 ppm
neo-C_5	—	1 ppm
i-C_5	—	17 ppm
n-C_5	—	8 ppm
i-C_6	—	14 ppm
n-C_6	—	19 ppm

These gas hydrates apparently include mainly C_1 and C_2 because the higher molecular weight hydrocarbons are present in significantly lower amounts. Perhaps the gas hydrates in sediments at this site are mainly Structure I. In Structure I gas hydrates, the cages are only large enough for C_1 and C_2 hydrocarbons (Hand et al., 1974). At Site 570, the C_3 through C_6 hydrocarbons in sediments probably have been excluded from the gas hydrate but may be present in the pore spaces of the sediment associated with the gas hydrate.

Figure 15. Portion of massive gas hydrate in Core 27 (249 m sub-bottom), Site 570.

Samples of the gas hydrate from Cores 21, 27, 28, and 29 were allowed to decompose under controlled conditions in the pressure device from which samples of gas were taken for gas chromatographic analyses. The volumetric ratio resulting from gas hydrate decomposition ranged from about 10 to 42 volumes of C_1 per volume of water. Solubility of C_1 in water at the pressure-temperature conditions in this hole is about 3 volumes of C_1 per volume of water. Therefore, the volumetric ratios obtained during the decomposition of the gas hydrates clearly show that more C_1 was present than could exsolve from water saturated with C_1. The ratios provide strong evidence that the substances sampled were indeed gas hydrates and not ice made of water saturated with C_1.

Interstitial Water Chemistry

Ten sediment samples were taken from which pore water was squeezed. The results from these ten samples provide profiles of interstitial water chemistry from 4.5 to 374 m sub-bottom (Fig. 16).

Of particular interest is the relationship of salinity and chlorinity to the occurrence of gas hydrates. Both salinity and chlorinity decrease slightly from the surface to a sediment depth of 234 m (Fig. 16). Below this depth, however, the decrease in both these measurements is rapid. For example, chlorinity decreases from about 18.5 to 9‰ and salinity from about 32 to 16‰. This rapid decrease takes place in the same interval where massive gas hydrate was discovered at about 250 m and where pieces of gas hydrate were found in fractures in the mudstone below the massive gas hydrate. In addition, water from the decomposed massive gas hydrate was investigated; the water was essentially fresh. Thus, as at Sites 565 and 568, the low values of salinity and chlorinity correlate with the occurrence of gas hydrates and support the conclusions of Hesse and Harrison (1981).

Summary

Although the occurrence of gas hydrates dispersed in sediments of the Middle America Trench had been well documented by the results from Legs 66, 67, and from Sites 565 and 568 of Leg 84, the results from Site 570 show that gas hydrate can occur as massive units. In this case, gas hydrate mixed with some fine-grained sediment occurs at about 250 m sub-bottom as a unit about 4 m thick at an unconformity between the upper Miocene and Pliocene. The gas hydrate includes mainly C_1 and C_2 in its structure, although C_3 through at least C_6 hydrocarbons are present in the system of gas hydrate and sediment.

Surprisingly high concentrations of gaseous hydrocarbons were found in the fractures of the serpentinite at the bottom of the hole at Site 570. C_1/C_2 ratios as low as 85 were measured on gas sampled at the bottom of the hole. This occurrence of hydrocarbon gases in serpentinite is similar to that observed at Site 566.

SUMMARY AND CONCLUSIONS

Site 570 is situated in the upper slope of Middle America Trench off Guatemala, in about 1700 m of water, 40 km upslope and 4300 km above the Trench axis. The site is about 40 km from the Petrel Well reported by Seely (1979). One hole was drilled to 401.9 m, ending in serpentinized peridotite. The sequence recovered is:

Unit I. 0–208 m Pleistocene green mud with sandstone layers that are locally thick and pebbly.

Unit II. 208–255 m Pliocene green mud with sandstone layers.

Unit III. 255–330 m late Miocene green mud with rare horizons of pebbly sandstone above about 1 m of black sandy and pebbly early Miocene mudstones.

Unit IV. 330–374 m of an early Eocene sequence of light green siliceous limestones, grayish greenish sandstones with volcanic components, and blackish red pebble horizons at the base.

Basement. 374-401.9 m, black serpentinized peridotites with horizons of pale blue green serpentinitic mud in the upper 10 m.

The unconformity between early Eocene and late Miocene is between Cores 35 and 36, at about 330 m; it

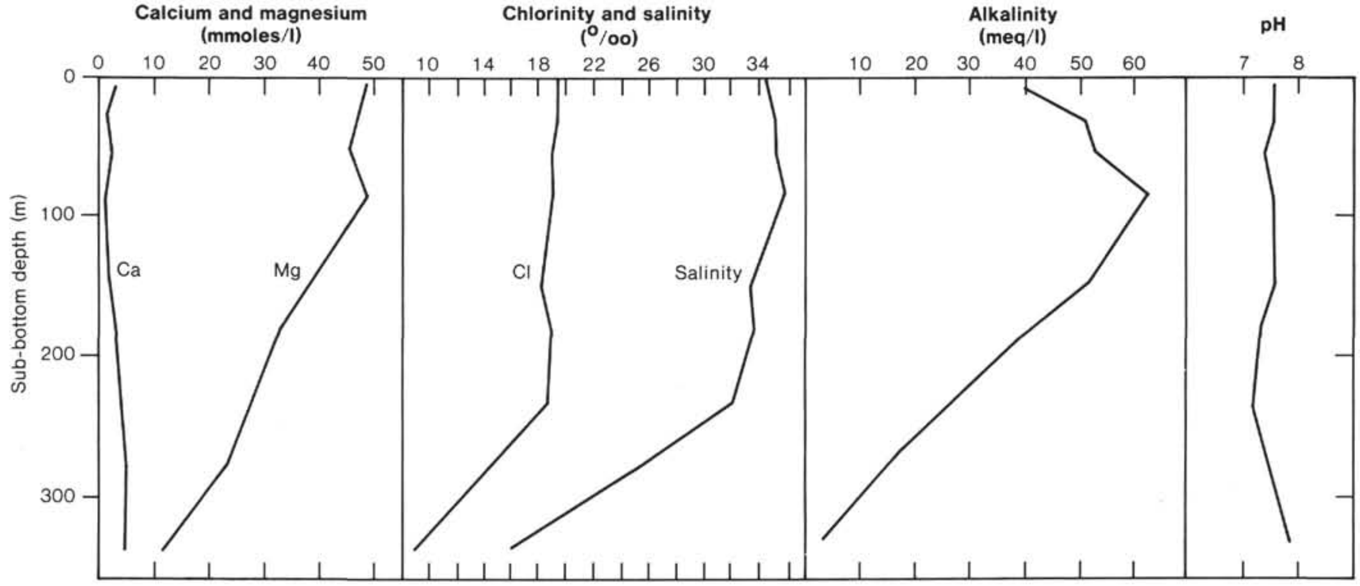


Figure 16. Chemistry of interstitial water, Site 570.

could tentatively be considered two superposed unconformities, the most evident being the late Miocene unconformity, as observed at Site 566, overlying an early Miocene unconformity, as observed at Site 567.

The Pleistocene sequence is the second thickest and the coarsest recovered during Legs 67 and 84 on the slope and in the Trench. This shows that coarse clastic sediment can be trapped in ponded basins on the slope as well as in the trench itself. Coarse clastic sediment is by itself not a lithologic mark of trench sedimentation.

Benthic foraminiferal assemblages at Site 570 indicate a gradual shallowing from abyssal depths in the early Eocene to depths in the upper middle bathyal biofacies by the late Pleistocene. Early Eocene sands contain a benthic foraminiferal fauna that was transported from the inner shelf (0–50 m). Transported material in the Miocene is primarily from the upper middle and upper bathyal biofacies and from the upper bathyal and outer shelf biofacies in the Pliocene and Pleistocene.

The hole was drilled in a region where the base of the zone of gas hydrate was at about 540 m. No bottom simulating reflector (BSR) was seen directly beneath the site. Gas hydrates were recovered from Core 21 (about 192 m) and occurred in sediment from all cores from 246 m to the basement: the most spectacular gas hydrate was recovered in Core 27 (249.1–258.8 m) in the form of a complete section of massive white hydrate. Significant amount of hydrocarbons larger than methane were observed in the serpentinite basement, as at Site 566. The presence of significant amounts of hydrocarbon gases in fractured serpentinite both at Sites 566 and 570 may be more than a local phenomenon, if it is a general condition, the gas may have migrated from sediment underlying an overthrust ophiolite, as has been observed on land in Central America.

A good suite of logs confirms the presence of the massive hydrate at 249 m and indicates a 3- to 4-m-thick body with velocities of more than 3 km/s and densities of about 1 g/cm^3. The logs show that only layers with a relatively greater porosity have sufficient hydrate to give an increased velocity despite the presence of visible hydrate in the mud recovered. The seismic records show no indication of the massive hydrate; no continuous reflection appears in the seismic record at the depth where hydrate is shown by the logs. Below the hydrate the logs indicate zones of high porosity in the serpentinized peridotite zone. The high porosity may help explain the occurrence of gas in ultramafic rock.

All the sites drilled on the slope of Guatemala from downslope (567) to upslope (570) through middle slope (566, 569) entered a basement composed of ophiolitic rock. Again, as at Site 569, early Eocene (at 570, the earliest Eocene) was recovered above this basement, confirming that its tectonic emplacement is pre-early Eocene, thus belonging perhaps in a broad sense to the Laramide event. The results from Site 570 show clearly that the Guatemala margin is constructed of an ophiolitic basement belonging to the continental framework of Central America.

REFERENCES

Gartner, S., 1977. Calcareous nannofossil biostratigraphy and revised zonation of the Pleistocene. *Mar. Micropaleontol.*, 2:1–25.

Hand, J. H., Katz, D. L., and Verma, V. K., 1974. Review of gas hydrates with implications for oceanic sediments. *In* Kaplan, I. R. (Ed.), *Natural Gases in Marine Sediments*: New York (Plenum), pp. 179–194.

Hesse, R., and Harrison, W. E., 1981. Gas hydrates (clathrates) causing pore-water freshening and oxygen isotope fractionation in deep-water sedimentary sections of terrigenous continental margins. *Earth Planet. Sci. Lett.*, 55:453–462.

Ibrahim, A. K., Latham, G. V., and Ladd, J. W., 1979. Seismic refraction and reflection measurements of the Middle America Trench offshore Guatemala. *J. Geophys. Res.*, 84:5643–5649.

Ladd, J. W., Ibrahim, A. K., McMillen, K. J., Latham, G. V., von Huene, R. E., 1982. Interpretation of seismic reflection data of the Middle America Trench offshore Guatemala. *In* Aubouin, J., von Huene, R., et al., *Init. Rept. DSDP*, 67: Washington (U.S. Govt. Printing Office), 675–690.

Ladd, J. W., Ibrahim, A. K., McMillen, K. J., Latham, G. V., von Huene, R. E., et al., 1978. Tectonics of the Middle America Trench offshore Guatemala. *Int. Symp. of the Guatemala 4· February*

Earthquake and Reconstruction Process. Guatemala City, May, 1978 (Vol. 1).

Okada, H., and Bukry, D., 1980. Supplementary modification and introduction of code numbers to the low latitude coccolith biostratigraphic zonation (Bukry, 1973, 1975). *Mar. Microapelontol.*, 5: 321–325.

Seeley, D., 1979. Geophysical investigations of continental slopes and rises. *In* Watkins, J. S., Montadert, L., and Dickerson, P. W. (Eds.), *Geological and Geophysical Investigations of Continental Margins*: Tulsa, Oklahoma, Am. Assoc. Pet. Geol. Mem., 29:245–260.

Seely, D. R., Vail, P. R., and Walton, G. G., 1974. Trench-slope model. *In* Burke, C. A., and Drake, C. L. (Eds.), *The Geology of Continental Margins*: New York (Springer-Verlag), pp. 249–269.

Smith, P. B., 1964. Ecology of benthonic species. *U.S. Geol. Surv. Prof. Paper 429-B*.

SITE 570 HOLE CORE 1 CORED INTERVAL 0.0–4.8 m sub-bottom

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	SECTION	METERS
Pleistocene	*Pseudoemiliania lacunosa–Emiliania huxleyi*	1, 2, 3, 4, CC	0.5, 1.0

GRAPHIC LITHOLOGY

DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

- Dispersed shelly fragments
- Thin laminae
- Thin ashy horizon
- Void

LITHOLOGIC DESCRIPTION

Dominant lithology: sandy mud.

Color: olive gray (5Y 3/2). Structureless.

SMEAR SLIDE SUMMARY (%):

	1, 143	2, 149	CC
Texture:			
Sand	10	23	20
Silt	55	10	10
Clay	35	67	70
Composition:			
Quartz	2	2	4
Feldspar	3	3	3
Heavy minerals	2	1	Tr
Clay and silt	73	76	79
Volcanic glass	15	5	2
Glauconite	–	–	1
Pyrite	2	2	2
Carbonate unspec.	–	4	4
Foraminifers	–	1	Tr
Calc. nannofossil	–	3	3
Diatoms	1	3	1
Radiolarians	–	Tr	Tr
Sponge spicules	2	1	2

CARBONATE BOMB (% $CaCO_3$):
1, 1 cm = 43

SITE 570 HOLE CORE 2 CORED INTERVAL 4.8–14.5 m sub-bottom

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	SECTION	METERS
Pleistocene	*Pseudoemiliania lacunosa–Emiliania huxleyi*	1, 2, 3, 4, 5, CC	0.5, 1.0

GRAPHIC LITHOLOGY

DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

- Muddy ash
- Moderate olive brown (5Y 4/4)
- Very light gray (N8) ash
- Ash
- Very light gray (N8) ash
- Dispersed ash
- Ashy horizon
- Sand with shelly fragments

LITHOLOGIC DESCRIPTION

Dominant lithology: sandy mud.

Color: Olive gray (5Y 3/2).

Faintly laminated in places. Interbedded with ash (see column) and one sand bed. Dispersed shelly fragments throughout.

SMEAR SLIDE SUMMARY (%):

	1, 90	1, 115	1, 147	5, 3	CC
Texture:					
Sand	20	15	70	70	15
Silt	10	10	10	30	10
Clay	70	75	10	–	75
Composition:					
Quartz	1	1	–	3	1
Feldspar	1	3	4	7	3
Mica	Tr	Tr	–	–	Tr
Heavy minerals	1	Tr	4	8	1
Clay	34	73	–	–	74
Volcanic glass	50	5	90	79	5
Glauconite	–	–	–	–	Tr
Pyrite	Tr	2	2	3	1
Carbonate unspec.	3	3	–	–	5
Foraminifers	–	1	–	–	3
Calc. nannofossils	3	5	–	–	2
Diatoms	2	2	–	–	2
Radiolarians	Tr	Tr	–	–	2
Sponge spicules	5	5	–	–	1
Silicoflagellates	Tr	–	–	–	–

SITE 570 HOLE CORE 3 CORED INTERVAL 17.5–27.2 m sub-bottom

TIME – ROCK UNIT | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION

Time – rock unit: Pleistocene

Biostratigraphic zone: *Pseudoemiliania lacunosa–Emiliania huxleyi*

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

Meters: 0.5, 1.0

- Shelly sand layer
- Gastropod shell
- Dispersed sand grains
- Shell fragment
- Shell fragment
- Dispersed sand grains

Dominant lithology: mud. Color: grayish olive (10Y 4/2). Structureless. Dispersed shell fragments.

Minor lithology: sandy mud and sand beds. Color: grayish olive (10Y 4/2). Sand beds are well graded. Sharp bases.

SMEAR SLIDE SUMMARY (%):

	5, 70	6, 30
Texture:		
Sand	5	30
Silt	30	5
Clay	65	65
Composition:		
Quartz	3	2
Feldspar	2	1
Mica	Tr	Tr
Heavy minerals	Tr	–
Clay	78	69
Glauconite	–	Tr
Carbonate unspec.	3	10
Foraminifers	10	12
Calc. nannofossils	Tr	–
Diatoms	Tr	1
Radiolarians	2	3
Sponge spicules	–	2
Silicoflagellates	–	Tr

SITE 570 HOLE CORE 4 CORED INTERVAL 27.2–36.8 m sub-bottom

TIME – ROCK UNIT | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION

Time – rock unit: Pleistocene

Biostratigraphic zone: *Pseudoemiliania lacunosa–Emiliania huxleyi*

Sections: 1, 2, 3, 4, CC

Meters: 0.5, 1.0

- Greenish black (5G 2/1)
- Sandstone in a burrow
- Greenish gray mottling
- Shell fragment

Dominant lithology: sandy mud with occasional sand horizons. Color: grayish olive (10Y 4/2). Some thin laminations. Mainly structureless.

Minor lithology: mud. Color: grayish olive (10Y 4/2). Structureless.

SMEAR SLIDE SUMMARY (%):

	CC
Texture:	
Sand	40
Silt	5
Clay	55
Composition:	
Quartz	15
Feldspar	10
Mica	1
Heavy minerals	Tr
Clay	61
Glauconite	Tr
Carbonate unspec.	2
Foraminifers	2
Diatoms	Tr
Radiolarians	2
Sponge spicules	1
Silicoflagellates	1
Rock fragments	5

SITE 570 HOLE CORE 5 CORED INTERVAL 36.8–46.4 m sub-bottom

TIME – ROCK UNIT: Pleistocene

BIOSTRATIGRAPHIC ZONE: *Pseudoemiliania lacunosa–Emiliania huxleyi*

FOSSIL CHARACTER: FORAMINIFERS | NANNOFOSSILS | RADIOLARIANS | DIATOMS

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY

DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES

LITHOLOGIC DESCRIPTION

- Gastropod shell
- Shelly fragment
- Olive gray (5Y 3/2) ash bed
- Olive gray (5Y 3/2) mottle
- Shell fragment
- Shell fragment
- Large mica flake
- Yellowish gray (5Y 7/2) mottle
- Pale olive (10Y 6/2) mottling
- Light blue gray (5Y 5/2) mottling
- Shell fragment

Dominant lithology: mud. Color: grayish olive (10Y 4/2). Structureless. Some thin laminations in Section 4. Dispersed shell fragments.

SMEAR SLIDE SUMMARY (%):

	2, 114
Texture:	
Sand	15
Silt	35
Clay	50
Composition:	
Quartz	12
Feldspar	10
Mica	Tr
Heavy minerals	Tr
Clay	66
Volcanic glass	2
Glauconite	1
Carbonate unspec.	2
Foraminifers	2
Calc. nannofossils	Tr
Diatoms	Tr
Radiolarians	2
Sponge spicules	1
Silicoflagellates	Tr

SITE 570 HOLE CORE 6 CORED INTERVAL 46.4–56.0 m sub-bottom

TIME – ROCK UNIT: Pleistocene

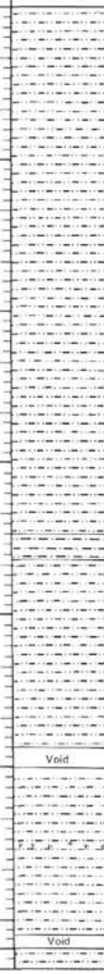
BIOSTRATIGRAPHIC ZONE: Small *Gephyrocapsa*

FOSSIL CHARACTER: FORAMINIFERS | NANNOFOSSILS | RADIOLARIANS | DIATOMS

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES

LITHOLOGIC DESCRIPTION

- Moderate olive brown (5Y 4/4) mottling
- Light olive brown (5Y 5/6) mottle
- Dark greenish yellow (10Y 6/6) mottle
- Light olive brown (5Y 5/6) mottle
- Dusky yellow (5Y 6/4) mottling
- Moderate olive brown (5Y 4/4) mottle
- Shell fragments
- Dusky yellow mottle
- Greenish black (5GY 2/1) ash
- Ash band
- Shell fragments

Dominant lithology: mud. Color: grayish olive (10Y 4/2) to moderate olive brown (5Y 4/4).

Structureless. Some sandier bands and one ash layer. Mottling throughout.

SMEAR SLIDE SUMMARY (%):

	2, 68
Texture:	
Sand	5
Silt	35
Clay	60
Composition:	
Quartz	7
Feldspar	4
Mica	Tr
Clay	80
Glauconite	1
Carbonate unspec.	3
Foraminifers	3
Calc. nannofossils	1
Diatoms	1
Radiolarians	Tr
Sponge spicules	Tr
Silicoflagellates	Tr

SITE 570 HOLE CORE 7 CORED INTERVAL 56.0–65.7 m sub-bottom

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
Pleistocene	Small *Gephyrocapsa*					1	0.5, 1.0	Void			
						2		Void, Void			
						3		Void			*
						4					*
						CC					

LITHOLOGIC DESCRIPTION

- Calcareous sandstone
- Bivalve shell
- Light olive mottling
- Sand
- Shelly graded horizon
- Shelly bed
- Graded olive (5Y 3/2) ash bed
- Shelly bed
- Pale olive (10Y 6/2) mottling
- Pale olive (10Y 6/2) tuff band
- Shell fragments

Dominant lithology: mud. Color: grayish olive (10Y 4/2) to moderate olive brown (5Y 4/4). Structureless.

Minor lithology: sand. Color: grayish olive (10Y 4/2). Massive. Ash bands.

SMEAR SLIDE SUMMARY (%):

	3, 125	4, 22
Texture:		
Sand	60	5
Silt	20	25
Clay	20	70
Composition:		
Quartz	1	15
Feldspar	1	5
Mica	–	Tr
Heavy minerals	–	Tr
Clay	20	70
Volcanic glass	70	1
Glauconite	2	1
Carbonate unspec.	3	3
Forammifers	Tr	1
Calc. nannofossils	Tr	Tr
Diatoms	–	2
Radiolarians	2	1
Sponge spicules	1	1
Silicoflagellates	Tr	Tr

SITE 570 HOLE CORE 8 CORED INTERVAL 65.7–75.4 m sub-bottom

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
Pleistocene	Small *Gephyrocapsa*					1	0.5, 1.0		O O		*
						2		Void			
						3					*
						CC					

LITHOLOGIC DESCRIPTION

- Olive gray ash
- Shelly fragments
- Bivalve shell
- Slightly coarser graded bed
- Shell fragment
- Olive gray mottle
- Dispersed forams

Dominant lithology: mud. Color: grayish olive (10Y 4/2).

Dispersed shell fragments. Mostly structureless except for some ash horizons and mottling.

SMEAR SLIDE SUMMARY (%):

	1, 95	3, 24
Texture:		
Sand	10	30
Silt	30	10
Clay	60	60
Composition:		
Quartz	9	15
Feldspar	6	10
Mica	3	2
Heavy minerals	Tr	Tr
Clay	72	–
Volcanic glass	Tr	Tr
Glauconite	2	2
Carbonate unspec.	2	5
Foraminifers	2	2
Calc. nannofossils	Tr	2
Diatoms	1	1
Radiolarians	2	2
Sponge spicules	1	1
Silicoflagellates	Tr	Tr

SITE 570 HOLE CORE 9 CORED INTERVAL 75.4–85.1 m sub-btottom

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
Pleistocene						1	0.5, 1.0				*
						2					*
						CC					

LITHOLOGIC DESCRIPTION

- Grayish olive
- Olive gray
- Greenish black
- Ash bed

Dominant lithology: mud. Color: grayish olive to 101 cm (Section 1) then distinct color change to greenish black (5G 2/1).

Remnant bedding destroyed by drilling disturbance.

SMEAR SLIDE SUMMARY (%):

	1, 55	2, 74
Texture:		
Sand	5	–
Silt	25	20
Clay	70	80
Composition:		
Quartz	5	5
Feldspar	3	3
Mica	Tr	Tr
Heavy minerals	–	Tr
Clay	84	75
Volcanic glass	–	8
Glauconite	Tr	2
Carbonate unspec.	3	3
Foraminifers	2	1
Calc. nannofossils	Tr	Tr
Diatoms	1	1
Radiolarians	2	2
Sponge spicules	Tr	Tr
Silicoflagellates	Tr	Tr

SITE 570 HOLE CORE 10 CORED INTERVAL 85.1–94.7 m sub-bottom

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
Pleistocene						1 2 CC	0.5 1.0					

Foram rich sandstone

Void

Void

Dominant lithology: mud. Color: olive gray (5Y 3/2) to Section 2 (30 cm) then moderate olive brown (5Y 4/4).

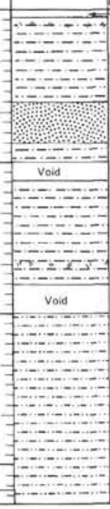
Structureless – except for one thin sandy bed at 95 cm.

SMEAR SLIDE SUMMARY (%):

	1, 18	1, 89	2, 64
Texture:			
Sand	7	30	15
Silt	25	30	15
Clay	68	40	70
Composition:			
Quartz	2	5	2
Feldspar	–	2	2
Heavy minerals	Tr	2	–
Clay	68	40	64
Volcanic glass	1	3	2
Glauconite	1	1	1
Pyrite	1	2	2
Zeolite	1	–	–
Carbonate unspec.	–	10	–
Foraminifers	–	15	10
Calc. nannofossils	5	5	10
Diatoms	10	5	5
Radiolarians	1	3	3
Sponge spicules	1	3	–
Silicoflagellates	2	1	–

SITE 570 HOLE CORE 11 CORED INTERVAL 94.7–104.3 m sub-bottom

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
Pleistocene						1 2 3 4 CC	0.5 1.0					



Void
Olive gray (5Y 3/2) ash

Ash layer

Dominant lithology: i) sandy mud. Color: grayish olive (10Y 4/2). Structureless except for a sand rich horizon. Two thin ash beds present. ii) Mud. Color: grayish olive (10Y 4/2). Structureless.

SMEAR SLIDE SUMMARY (%):

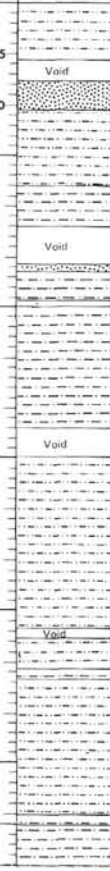
	1, 100
Texture:	
Sand	15
Silt	40
Clay	45
Composition:	
Quartz	5
Feldspar	3
Clay	40
Glauconite	2
Pyrite	2
Zeolite	2
Foraminifers	10
Calc. nannofossils	10
Diatoms	10
Radiolarians	3
Sponge spicules	10
Silicoflagellates	2

Core 12, 104.3–113.9 m sub-bottom: no recovery.

Core 13, 113.9–123.6 m sub-bottom: no recovery.

SITE 570 HOLE CORE 14 CORED INTERVAL 123.6–133.3 m sub-bottom

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
Pleistocene						1 2 3 4 5 6 CC	0.5 1.0					



Pumice clast

Bivalve shell

Dominant lithology: i) mud. Color: greenish black (5GY 2/1) except between 0–55 cm (Section 1) where it is moderate olive brown (5Y 4/4).

Mainly structureless – some banding present.

ii) Sandy mud. Sand. Color: greenish black (5GY 2/1).

Structureless.

SMEAR SLIDE SUMMARY (%):

	1, 132 D	2, 130
Texture:		
Sand	30	12
Silt	40	30
Clay	30	58
Composition:		
Quartz	10	3
Feldspar	7	2
Mica	1	–
Heavy minerals	–	Tr
Clay	30	68
Glauconite	1	–
Pyrite	1	–
Zeolite	2	–
Carbonate unspec.	–	5
Foraminifers	5	3
Calc. nannofossils	3	–
Diatoms	15	5
Radiolarians	3	3
Sponge spicules	5	3
Silicoflagellates	2	–

SITE 570 HOLE CORE 15 CORED INTERVAL 133.3–143.0 m sub-bottom

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
Pleistocene						1	0.5, 1.0	Void				Black (N1) mottling
						2						Black (N1) mottling
						3		Void			*	
						4		Void				Black (N1) mottling
						CC						

Dominant lithology: sandy mud with sand.

Color: grayish olive (10Y 4/2) to olive gray (5Y 3/2).

Structureless except for one sand bed. Mottled black (N1) throughout.

Minor lithology: mud. Color: grayish olive (10Y 4/2).

Structureless.

SMEAR SLIDE SUMMARY (%):

	3, 145
Texture:	
Sand	25
Silt	15
Clay	60
Composition:	
Feldspar	2
Heavy minerals	1
Clay	76
Volcanic glass	5
Glauconite	1
Pyrite	2
Carbonate unspec.	5
Foraminifers	4
Calc. nannofossils	1
Diatoms	1
Radiolarians	Tr
Sponge spicules	2

SITE 570 HOLE CORE 16 CORED INTERVAL 143.0–152.7 m sub-bottom

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
Pleistocene						1	0.5, 1.0				*	← Pyrite rich
						2		Void				
						3		Void, Void				Foraminifer rich sand; Void
						4		Void, Void				
						5						← Pumice fragment
						6						← Pumice fragment
						7						
						CC						

Biscuit fracturing for first time.

Dominant lithology: sandy mud. Color: grayish olive (10Y 4/2).

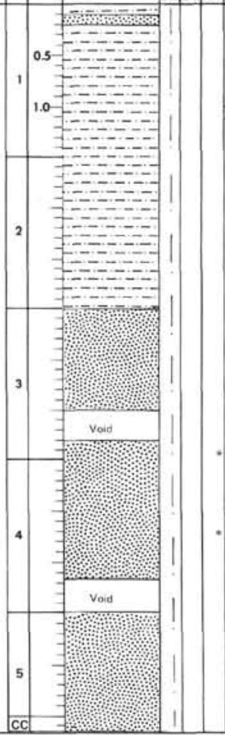
Structureless except for one foraminifer rich bed. Dispersed pumice fragments.

SMEAR SLIDE SUMMARY (%):

	1, 95
Texture:	
Sand	20
Silt	15
Clay	65
Composition:	
Quartz	2
Feldspar	2
Mica	Tr
Heavy minerals	Tr
Clay	71
Volcanic glass	3
Pyrite	1
Carbonate unspec.	10
Foraminifers	2
Calc. nannofossils	1
Diatoms	2
Radiolarians	2
Sponge spicules	2

SITE 570 HOLE CORE 17 CORED INTERVAL 152.7–162.4 m sub-bottom

TIME-ROCK UNIT: Pleistocene



- Pumice
- Shell debris
- Moderate blue green (5BG 4/6) clasts

LITHOLOGIC DESCRIPTION

Dominant lithology: i) sand. Color: grayish olive (10Y 4/2).

Generally massive with dispersed shelly debris throughout.

ii) Sandy mud. Color: grayish olive (10Y 4/2).

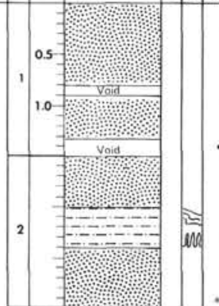
Structureless except for dispersed pumice and shelly fragments.

SMEAR SLIDE SUMMARY (%):

	3, 145	4, 67
Texture:		
Sand	15	30
Silt	10	20
Clay	75	50
Composition:		
Feldspar	4	5
Mica	Tr	–
Heavy minerals	–	3
Clay	77	12
Volcanic glass	3	–
Glauconite	–	70
Carbonate unspec.	5	3
Foraminifers	2	4
Calc. nannofossils	1	2
Diatoms	1	1
Radiolarians	1	–
Sponge spicules	2	–

SITE 570 HOLE CORE 18 CORED INTERVAL 162.4–172.1 m sub-bottom

TIME-ROCK UNIT: Pleistocene



Slumped horizon bedding dips between 30° and 70°

LITHOLOGIC DESCRIPTION

Dominant lithology: sand. Color: grayish olive (10Y 4/2).

Generally structureless except for slumped horizon. Here there is thin laminae up to 10 mm in thickness – highly contorted. Shelly debris dispersed throughout.

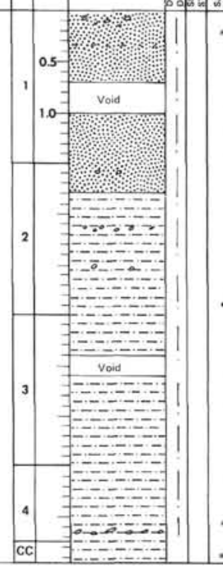
SMEAR SLIDE SUMMARY (%):

	2, 148
Texture:	
Sand	15
Silt	10
Clay	75
Composition:	
Feldspar	5
Mica	1
Heavy minerals	1
Clay	59
Pyrite	3
Carbonate unspec.	25
Foraminifers	2
Calc. nannofossils	1
Diatoms	1
Sponge spicules	1

CARBONATE BOMB (% $CaCO_3$):
1, 145 cm = 25

SITE 570 HOLE CORE 19 CORED INTERVAL 172.1–181.8 m sub-bottom

TIME-ROCK UNIT: possible late Pliocene to Pleistocene



- Volcanic pebbles
- Ash band
- Pebbles
- Volcanic pebbles + black mudstone
- Dispersed pebbles
- Pebble horizon

LITHOLOGIC DESCRIPTION

Dominant lithology: i) sandy mudstone. Color: grayish olive (10Y 4/2). Stringers of pebbles and lots of dispersed sand and shelly fragments.

ii) Sand. Color: grayish olive (10Y 4/2).

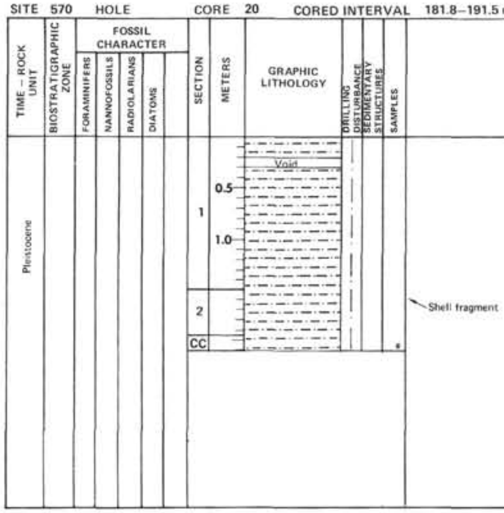
Generally massive except for stringers of pebbles and shelly debris.

SMEAR SLIDE SUMMARY (%):

	1, 26	4, 60	CC
Texture:			
Sand	45	20	5
Silt	10	10	15
Clay	45	70	80
Composition:			
Feldspar	5	2	1
Mica	–	Tr	–
Heavy minerals	4	1	1
Clay	44	57	78
Volcanic glass	35	8	10
Pyrite	2	–	10
Carbonate unspec.	5	25	–
Foraminifers	–	2	–
Calc. nannofossils	Tr	2	–
Diatoms	1	2	–
Radiolarians	1	Tr	–
Sponge spicules	2	1	–

CARBONATE BOMB (% $CaCO_3$):
2, 145 cm = 22

SITE 570 HOLE CORE 20 CORED INTERVAL 181.8–191.5 m sub-bottom



LITHOLOGIC DESCRIPTION

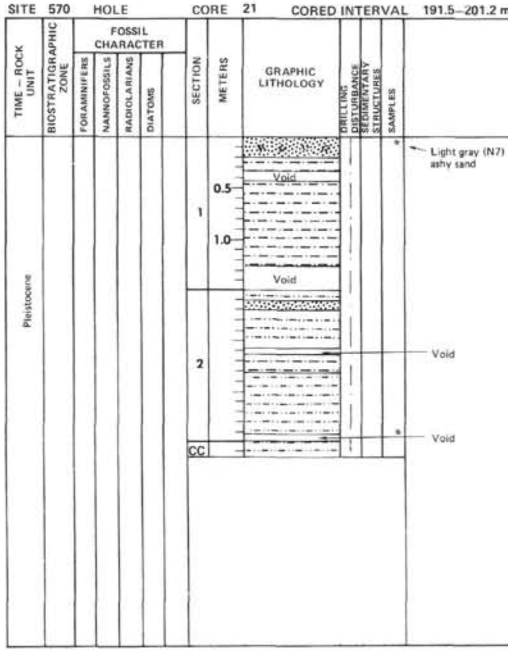
Dominant lithology: sandy mudstone. Color: olive gray (5Y 3/2).

Biscuits common. Quite calcareous in parts. Some greenish clasts. Foraminifer tests common, as well as shell fragments. No sedimentary structures.

SMEAR SLIDE SUMMARY (%):

	CC, 10
Texture:	
Sand	20
Silt	10
Clay	70
Composition:	
Feldspar	5
Heavy minerals	1
Clay	60
Volcanic glass	5
Pyrite	3
Carbonate unspec.	20
Foraminifers	5
Calc. nannofossils	1

SITE 570 HOLE CORE 21 CORED INTERVAL 191.5–201.2 m sub-bottom



LITHOLOGIC DESCRIPTION

Dominant lithology: i) sandy mud. Color: grayish olive (10Y 4/2).

ii) Mud. Color: grayish olive (10Y 4/2).

Interbedding of these lithologies. No sedimentary structures.

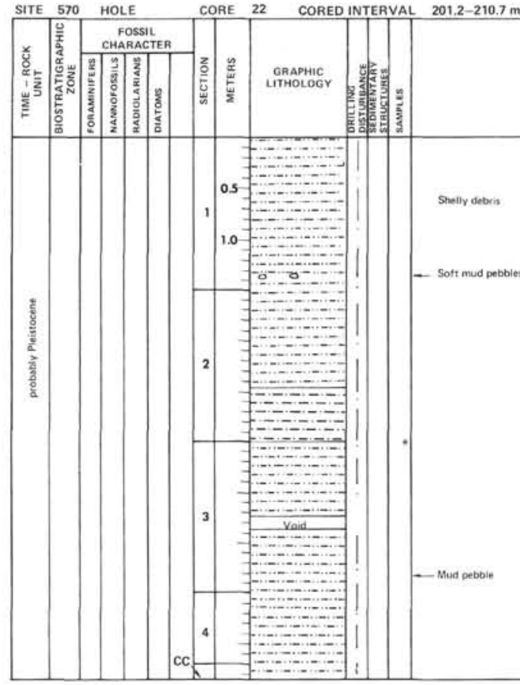
Minor lithology: i) sand. Color: light gray (N7).

Very ashy sand. Contained gas hydrate. Structureless.

SMEAR SLIDE SUMMARY (%):

	1, 2	2, 142
Texture:		
Sand	95	5
Silt	5	20
Clay	–	75
Composition:		
Quartz	15	–
Feldspar	9	–
Mica	3	1
Heavy minerals	10	Tr
Clay	–	85
Volcanic glass	45	–
Pyrite	4	1
Carbonate unspec.	3	12
Foraminifers	5	2
Diatoms	Tr	Tr
Radiolarians	–	Tr
Sponge spicules	–	1
Silicoflagellates	–	Tr

SITE 570 HOLE CORE 22 CORED INTERVAL 201.2–210.7 m sub-bottom



LITHOLOGIC DESCRIPTION

Dominant lithology: mudstone. Color: grayish olive (10Y 4/2).

Structureless except for one or two dispersed mud pebbles. Dispersed shelly debris throughout especially in Section 2 where rock is a sandy mudstone.

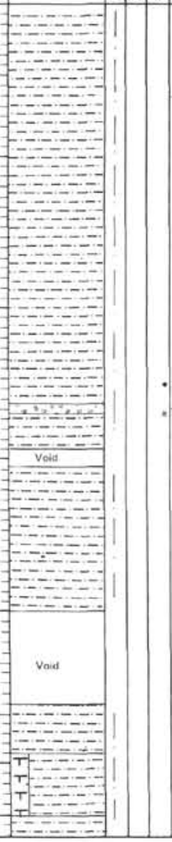
SMEAR SLIDE SUMMARY (%):

	3, 1
Texture:	
Sand	15
Silt	25
Clay	60
Composition:	
Feldspar	1
Mica	1
Heavy minerals	Tr
Clay	89
Volcanic glass	2
Pyrite	2
Zeolite	2
Carbonate unspec.	3
Foraminifers	Tr
Calc. nannofossils	1
Sponge spicules	1

SITE 570 HOLE CORE 23 CORED INTERVAL 210.7–220.2 m sub-bottom

TIME – ROCK UNIT: possibly late Pliocene

BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS | SECTION: 1, 2, 3, 4, 5, 6, CC | METERS: 0.5, 1.0 | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES



Horizontal scaly cleavage

Vertical fractures

Ashy mud

Rich in foraminifera

LITHOLOGIC DESCRIPTION

Dominant lithology: sandy mudstone. Color: olive gray (5Y 3/2).

No sedimentary structures visible. Some ashy horizons and a zone rich in foraminifera. Fracturing and scaliness common at the top of the core.

SMEAR SLIDE SUMMARY (%):

	3, 103
Texture:	
Sand	5
Silt	20
Clay	75
Composition:	
Quartz	1
Feldspar	1
Heavy minerals	1
Clay	68
Volcanic glass	15
Pyrite	1
Carbonate unspec.	8
Foraminifers	1
Calc. nannofossils	2
Diatoms	Tr
Radiolarians	1
Sponge spicules	2
Silicoflagellates	Tr

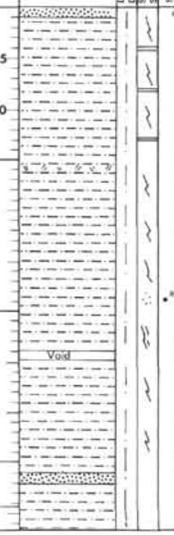
CARBONATE BOMB (% $CaCO_3$):
3, 80 cm = 10

SITE 570 HOLE CORE 24 CORED INTERVAL 220.2–229.7 m sub-bottom

TIME – ROCK UNIT: late Pliocene

BIOSTRATIGRAPHIC ZONE: *Discoaster brouweri*

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS | SECTION: 1, 2, 3, 4, CC | METERS: 0.5, 1.0 | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES



Thin ash band

Fractures – vertical

Sandy burrow

Open fractures vertical and parallel to each other

Oblique fracturing (30%) to horizontal

LITHOLOGIC DESCRIPTION

Dominant lithology: sandy mudstone. Color: moderate olive brown (5Y 4/4).

Thin laminations in Section 1. Lots of bioturbation throughout – concentrates sand sized particles. Fracturing in biscuits (drilling) is original. One thin ash band – otherwise rare.

SMEAR SLIDE SUMMARY (%):

	1, 8	2, 138
Texture:		
Sand	25	20
Silt	25	20
Clay	50	60
Composition:		
Quartz	1	1
Feldspar	3	7
Mica	–	1
Heavy minerals	1	1
Clay	50	70
Volcanic glass	15	5
Pyrite	5	2
Zeolite	15	–
Carbonate unspec.	–	10
Foraminifers	5	2
Calc. nannofossils	1	1
Diatoms	3	Tr
Radiolarians	1	Tr
Sponge spicules	1	1

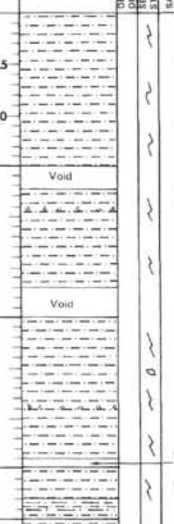
CARBONATE BOMB (% $CaCO_3$):
2, 140 cm = ~5%

SITE 570 HOLE CORE 25 CORED INTERVAL 229.7–239.4 m sub-bottom

TIME – ROCK UNIT: late Pliocene; early Pliocene

BIOSTRATIGRAPHIC ZONE: *Discoaster brouweri*

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS | SECTION: 1, 2, 3, 4, CC | METERS: 0.5, 1.0 | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES



Ashy band

Fracturing

Sandy burrow

Sandy burrow

Ashy band

Void

Blue green (5BG 3/2) mud, 1 cm

LITHOLOGIC DESCRIPTION

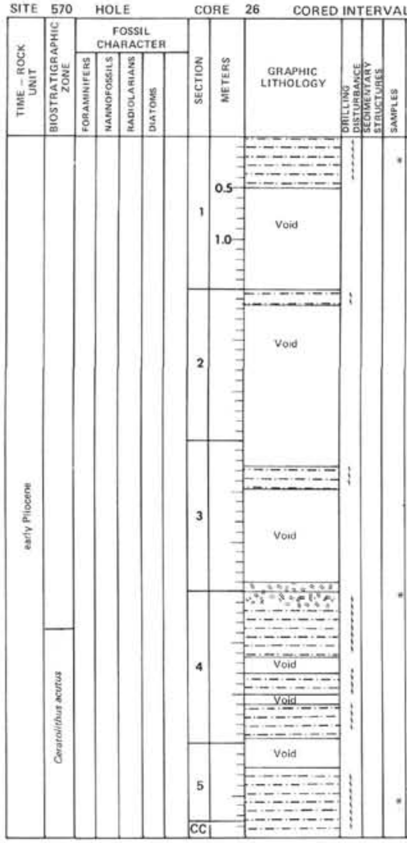
Dominant lithology: sandy mudstone. Color: olive gray (5Y 3/2).

Bioturbation throughout but some remnant ash bands and mudstone band. Fracturing (30° to horizontal) found in Section 2.

SMEAR SLIDE SUMMARY (%):

	3, 133	4, 14
Texture:		
Sand	15	7
Silt	10	30
Clay	75	60
Composition:		
Quartz	4	4
Feldspar	–	4
Mica	–	Tr
Heavy minerals	2	Tr
Clay	82	80
Volcanic glass	2	2
Pyrite	2	2
Carbonate unspec.	5	3
Foraminifers	2	–
Diatoms	Tr	–
Sponge spicules	1	–

SITE 570 HOLE CORE 26 CORED INTERVAL 239.4–249.1 m sub-bottom



LITHOLOGIC DESCRIPTION

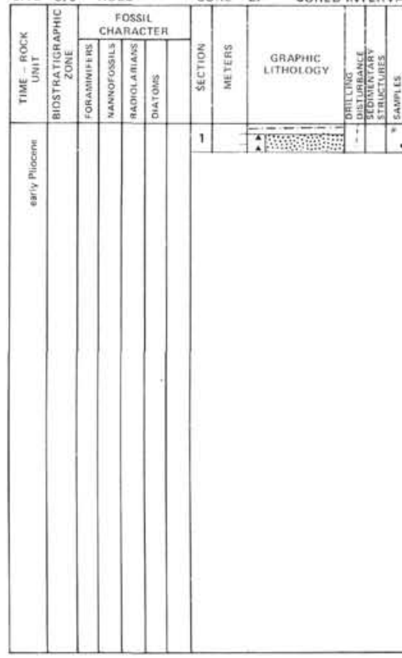
Dominant lithology: sandy mud. Color: grayish olive (10Y 4/2).

Structureless except for some ash beds. Gas hydrate present.

SMEAR SLIDE SUMMARY (%):

	1, 26	4, 5	5, 53
Texture:			
Sand	25	25	45
Silt	15	25	30
Clay	60	50	25
Composition:			
Quartz	1	10	5
Feldspar	5	25	15
Heavy minerals	5	5	8
Clay	60	–	51
Volcanic glass	–	65	–
Pyrite	3	–	3
Carbonate unspec.	15	–	5
Foraminifers	3	–	2
Calc. nannofossils	–	–	Tr
Diatoms	1	–	1
Sponge spicules	2	–	–

SITE 570 HOLE CORE 27 CORED INTERVAL 249.1–258.8 m sub-bottom



LITHOLOGIC DESCRIPTION

Dominant lithology: sandstone. Color: light olive gray (5Y 3/2).

Very hard siliceous rock. Composed of quartz and dolomite. Medium grained. Highly fractured with calcite filling the veins.

The rest of the core is composed of gas hydrate ice.

Minor lithology: sandy mud. Color: olive gray (5Y 3/2). Very soupy – so it is structureless.

SMEAR SLIDE SUMMARY (%):

	1, 5
Texture:	
Sand	30
Silt	25
Clay	45
Composition:	
Quartz	2
Feldspar	8
Heavy minerals	2
Clay	57
Volcanic glass	10
Carbonate unspec.	10
Foraminifers	1
Calc. nannofossils	Tr
Diatoms	Tr
Radiolarians	Tr
Rock fragments	10

CARBONATE BOMB (% $CaCO_3$):
1, 24 cm = 63

SITE 570 HOLE CORE 28 CORED INTERVAL 258.8–268.4 m sub-bottom

TIME-ROCK UNIT: late Miocene

BIOSTRATIGRAPHIC ZONE: *Discoaster quinqueramus*

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY

DRILLING DISTURBANCE, SEDIMENTARY STRUCTURES, SAMPLES

LITHOLOGIC DESCRIPTION

Dominant lithology: mud. Color: grayish olive (10Y 4/2). Structureless. Some dispersed hydrate in veins.

SMEAR SLIDE SUMMARY (%):

	3, 100
Texture:	
Sand	10
Silt	15
Clay	75
Composition:	
Quartz	2
Heavy minerals	1
Clay	65
Volcanic glass	2
Glauconite	3
Pyrite	2
Carbonate unspec.	4
Calc. nannofossils	10
Diatoms	7
Radiolarians	3
Sponge spicules	3
Silicoflagellates	1

SITE 570 HOLE CORE 29 CORED INTERVAL 268.4–278.0 m sub-bottom

TIME-ROCK UNIT: late Miocene

BIOSTRATIGRAPHIC ZONE: *Discoaster quinqueramus*

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS

SECTION: 1, 2, 3, 4, CC

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY

DRILLING DISTURBANCE, SEDIMENTARY STRUCTURES, SAMPLES

Pumice clast

Dark mottle

Fracturing *in situ*

Hydrate

LITHOLOGIC DESCRIPTION

Dominant lithology: mud. Color: grayish olive (10Y 4/2).

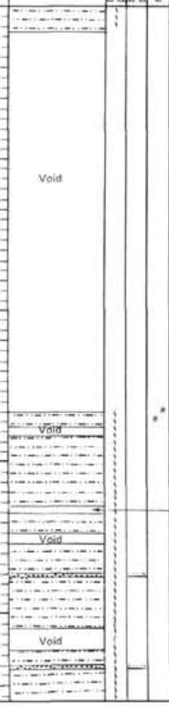
Structureless. Lots of gas bubbles. Dispersed pumice clasts and some fracturing.

SMEAR SLIDE SUMMARY (%):

	3, 100
Texture:	
Sand	5
Silt	10
Clay	85
Composition:	
Quartz	1
Clay	85
Volcanic glass	1
Glauconite	Tr
Pyrite	1
Zeolite	Tr
Carbonate unspec.	5
Calc. nannofossils	2
Diatoms	3
Radiolarians	1
Sponge spicules	1
Silicoflagellates	Tr

SITE 570 HOLE CORE 30 CORED INTERVAL 278.0–287.6 m sub-bottom

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
late Miocene	*Discoaster quinqueramus*					1, 2, 3, 4, 5, CC	0.5, 1.0	Void			* *	



Moderate olive brown (5Y 4/4) mud

Dark brown organic layer

Void

Burrows

Scattered foraminifer

Dominant lithology: mud. Color: grayish olive (10Y 4/2).

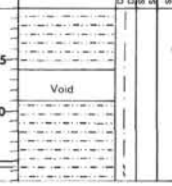
Structureless due to gas disturbance. Some sand horizons. Bioturbation and fracturing.

SMEAR SLIDE SUMMARY (%):

	3, 100	3, 106
Texture:		
Sand	10	2
Silt	20	10
Clay	70	87
Composition:		
Quartz	–	2
Feldspar	–	1
Heavy minerals	–	Tr
Clay	–	87
Volcanic glass	5	3
Glauconite	Tr	–
Pyrite	1	–
Carbonate unspec.	5	2
Calc. nannofossils	5	2
Diatoms	3	2
Radiolarians	2	–
Sponge spicules	2	1
Silicoflagellates	Tr	Tr

SITE 570 HOLE CORE 31 CORED INTERVAL 287.6–299.2 m sub-bottom

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
late Miocene	*Discoaster quinqueramus*					1, 2, CC	0.5, 1.0	Void			*	



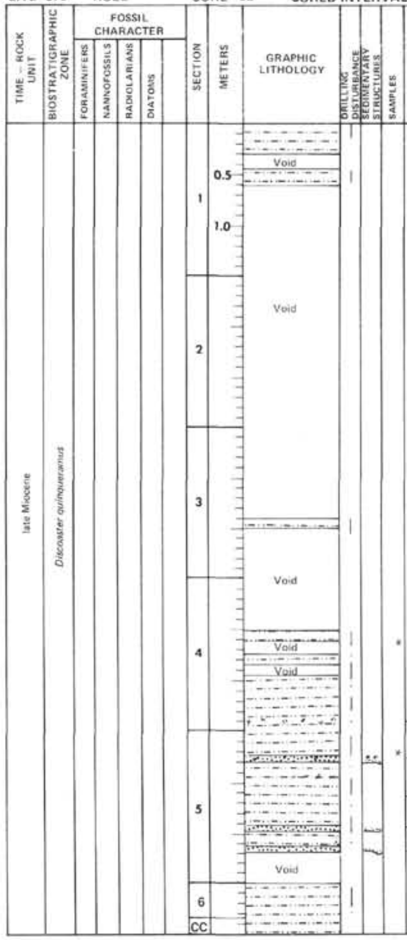
Dominant lithology: mudstone. Color: dusky yellow (5Y 6/4) to grayish olive (10Y 4/2).

Structureless except for olive gray (5Y 3/2) mottling. Gas expansion cracks.

SMEAR SLIDE SUMMARY (%):

	1, 46
Texture:	
Sand	3
Silt	10
Clay	87
Composition:	
Quartz	1
Feldspar	Tr
Mica	87
Volcanic glass	2
Glauconite	Tr
Carbonate unspec.	2
Foraminifers	Tr
Calc. nannofossils	5
Diatoms	2
Radiolarians	1
Sponge spicules	1
Silicoflagellates	Tr

SITE 570 HOLE CORE 32 CORED INTERVAL 297.2–306.8 m sub-bottom



LITHOLOGIC DESCRIPTION

Dominant lithology: mud. Color: olive gray (5Y 3/2) to greenish black (5GY 2/1).

Moderate olive brown (5Y 4/4) mottling. Structureless and gas expansion cracks. One ash layer in Section 4. Dispersed pebbles.

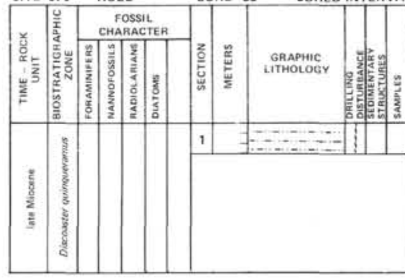
Minor lithology: sand. Color: olive gray (5Y 3/2).

Structureless. Dispersed pebbles within the sands.

SMEAR SLIDE SUMMARY (%):

	4, 80	5, 27
Texture:		
Sand	5	5
Silt	10	15
Clay	85	80
Composition:		
Quartz	2	2
Feldspar	1	1
Heavy minerals	1	1
Clay	85	80
Volcanic glass	2	–
Glauconite	Tr	7
Pyrite	Tr	1
Zeolite	Tr	Tr
Carbonate unspec.	7	5
Foraminifers	Tr	–
Calc. nannofossils	5	1
Diatoms	1	1
Radiolarians	–	Tr
Sponge spicules	1	1
Silicoflagellates	Tr	Tr

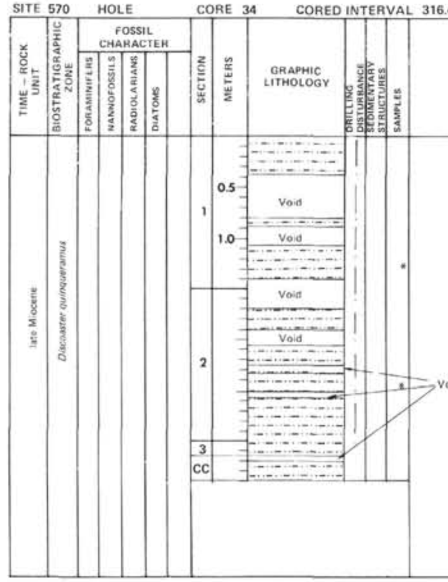
SITE 570 HOLE CORE 33 CORED INTERVAL 306.8–316.4 m sub-bottom



LITHOLOGIC DESCRIPTION

Dominant lithology: mudstone. Color: grayish olive (10Y 4/2).

SITE 570 HOLE CORE 34 CORED INTERVAL 316.4–326.0 m sub-bottom



LITHOLOGIC DESCRIPTION

Dominant lithology: mudstone/shale.

Color: olive gray (5Y 3/2).

Structureless.

SMEAR SLIDE SUMMARY (%):

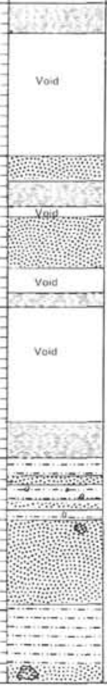
	1, 130	2, 97
Texture:		
Sand	30	5
Silt	30	10
Clay	40	85
Composition:		
Quartz	5	3
Feldspar	5	2
Heavy minerals	3	Tr
Clay	40	83
Volcanic glass	25	4
Glauconite	1	–
Pyrite	Tr	1
Zeolite	Tr	Tr
Carbonate unspec.	7	3
Foraminifers	Tr	Tr
Calc. nannofossils	2	2
Diatoms	Tr	1
Sponge spicules	Tr	1
Lithic fragments	10	–

SITE 570 HOLE CORE 35 CORED INTERVAL 326.0–335.6 m sub-bottom

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	SECTION	METERS
late Miocene	*Discoaster quinqueramus*	1	0.5, 1.0
middle Miocene		2, 3	
early Miocene		4, 5, CC	

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE · SEDIMENTARY STRUCTURES · SAMPLES

Limestone pebble supported by massive mud

Limestone pebble same as above

Large pebble of andesite

Very coarse feldspar rich sand

Sandy mud/sand with shale pebble

LITHOLOGIC DESCRIPTION

Dominant lithology: i) shale. Color: grayish olive (10Y 4/2). Structureless.

ii) Sand. Color: greenish black (5G 2/1). Structureless. Some dispersed clasts including small limestone grains, and andesite clast.

iii) Mudstone. Color: dusky yellow (5Y 6/4) to grayish olive (10Y 4/2).

Usually structureless but contains large dispersed clasts of varying lithologies including limestone.

SMEAR SLIDE SUMMARY (%):

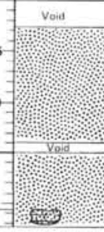
	CC, 10
Texture:	
Sand	30
Silt	20
Clay	50
Composition:	
Quartz	2
Feldspar	10
Mica	5
Heavy minerals	15
Clay	35
Volcanic glass	20
Palagonite	1
Pyrite	10
Diatoms	Tr
Sponge spicules	2

SITE 570 HOLE CORE 36 CORED INTERVAL 335.6–345.2 m sub-bottom

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	SECTION	METERS
early Eocene	probably *Discoaster lodoensis*	1	0.5, 1.0
		2, CC	

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE · SEDIMENTARY STRUCTURES · SAMPLES

Hydrate

Medium bluish gray (5B 5/1)

Large limestone fragment in sand

LITHOLOGIC DESCRIPTION

Dominant lithology: i) sand. Color: olive black (5Y 2/1) to dark greenish gray (5G 4/4) to medium bluish gray (5B 5/1). Structureless. Was full of gas hydrate that has melted. Rich in feldspar.

Minor lithology: limestone. Color: pale blue green (5BG to grayish gray (5GY 6/1).

Structureless. Full of nannofossils.

SMEAR SLIDE SUMMARY (%):

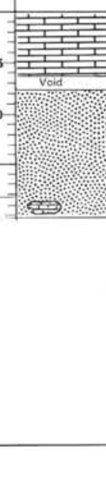
	1, 117	2, 40	CC, 5
Texture:			
Sand	90	70	20
Silt	10	20	80
Clay	–	10	–
Composition:			
Quartz	20	10	–
Feldspar	30	55	–
Mica	5	–	–
Heavy minerals	20	2	–
Clay	–,	10	–
Volcanic glass	10	–	–
Palagonite	3	–	–
Glauconite	Tr	–	–
Pyrite	5	–	–
Carbonate unspec.	5	Tr	20
Calc. nannofossils	–	–	80
Diatoms	–	Tr	–
Radiolarians	Tr	–	–
Sponge spicules	2	–	–
Rock fragments	–	23	–

SITE 570 HOLE CORE 37 CORED INTERVAL 345.2–354.8 m sub-bottom

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	SECTION	METERS
early Eocene	Probably *Discoaster diastypus*	1	0.5, 1.0
		2, CC	

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE · SEDIMENTARY STRUCTURES · SAMPLES

Drilling breccia of limestone also contained sandstone

Small clast in sand is limestone

Limestone (pale blue green – 5BG 6/6)

LITHOLOGIC DESCRIPTION

Dominant lithology: i) sand. Color: medium bluish gray (5B 5/1).

Very coarse sand, structureless.

ii) Limestone. Color: pale blue green (5BG 6/6). Structureless. Lies within a sand of exactly the same composition. No contacts seen but limestone drilling breccia also contains sand. Same limestone also found in Core Catcher.

SMEAR SLIDE SUMMARY (%):

	1, 39	1, 98 M	2, 38
Texture:			
Sand	–	1	70
Silt	5	10	20
Clay	95	98	10
Composition:			
Quartz	Tr	1	7
Feldspar	Tr	1	69
Mica	–	–	Tr
Heavy minerals	–	–	Tr
Clay	40	65	10
Volcanic glass	–	–	16
Carbonate unspec.	3	3	–
Calc. nannofossils	37	30	–
Silicoflagellates	20	–	–

SITE 570 HOLE CORE 38 CORED INTERVAL 354.8–364.4 m sub-bottom

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
early Eocene	*Discoaster diastypus*		B			1	0.5, 1.0	Void	△ △ △ △		* *	Void; Dispersed clasts including sandstone and limestone

Dominant lithology: i) mudstone. Color: blackish red (5R 2/2).

Structureless. Contains clasts of limestone (5BG 6/6) pumice and sandstone. One sandstone clast at the base is up to 5 cm in diameter. It is veined and could contain Bouma T_b T_c units.

ii) Limestone. Color: pale blue green (5BG 6/6). Structureless. Also found as clasts in the mud below.

SMEAR SLIDE SUMMARY (%):

	1, 103	1, 116	1, 127
Texture:			
Sand	1	15	65
Silt	15	20	25
Clay	84	65	10
Composition:			
Quartz	Tr	5	15
Feldspar	1	3	25
Mica	Tr	–	–
Heavy minerals	–	3	5
Clay	92	66	–
Volcanic glass	–	–	10
Glauconite	1	–	–
Pyrite	–	5	3
Carbonate unspec.	3	10	4
Radiolarians	2	8	–

SITE 570 HOLE CORE 39 CORED INTERVAL 364.4–374.0 m sub-bottom

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
			B			1, CC	0.5, 1.0	Void	△ △ △ | |		*	Shale – with scaly fabric; Sandstone supported conglomerate – pebbles of calcareous sand, limestone and mud; Serpentinite

Dominant lithology: i) shale. Color: grayish black (N2). Structureless but with scaly fabric on a lot of the surfaces.

ii) Conglomerate. Contains angular clasts of limestone, sandstone, and mudstone. Sandstone is the predominant clast type. Sandstone clasts have veins.

Minor lithology: serpentinite. Color: dusky blue (5PB 3/2).

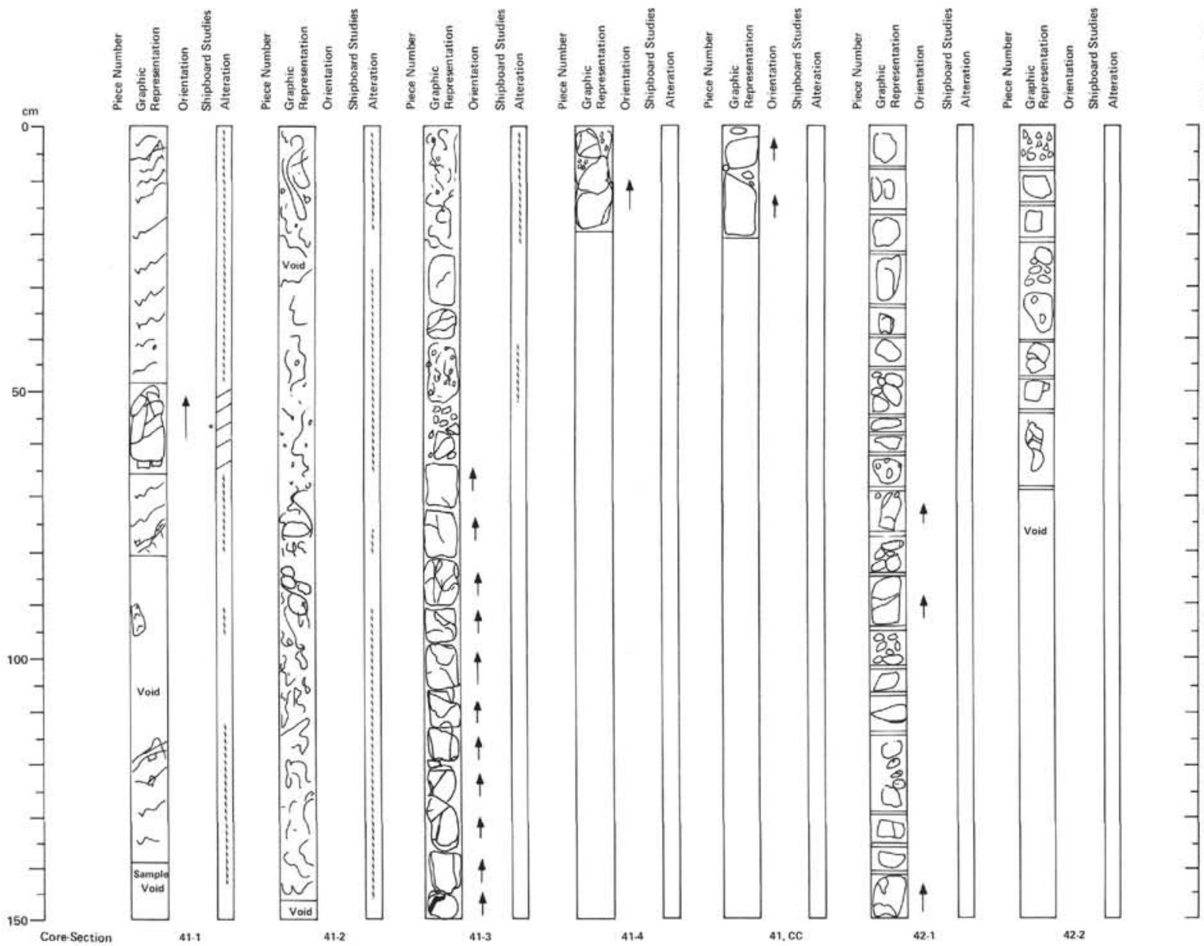
SMEAR SLIDE SUMMARY (%):

	1, 113
Texture:	
Sand	2
Silt	45
Clay	53
Composition:	
Quartz	1
Feldspar	4
Mica	2
Heavy minerals	3
Clay	88
Pyrite	2

SITE 570 HOLE CORE 40 CORED INTERVAL 374.0–387.3 m sub-bottom

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
						1						Sandy mud – downhole contaminant

Dominant lithology: serpentinite. Color: pale blue green (5BG 7/2). Highly sheared.



84-570-41-1 Depth 383.3–392.6 m

0–47 cm: light bluish gray (5B 2/1) serpentinite mud.

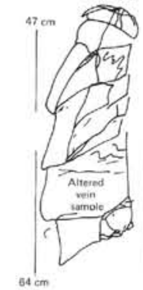
47–64 cm*: broken pieces harder, black serpentinite with blue green veins of serpentinite.

64–82 cm: serpentinite mud with gravel sized clasts of serpentinite.

88–94 cm: serpentinite mud.

115–140 cm: light bluish gray soupy serpentinite mud with gravel-sized pieces of harder serpentinite.

*47–64 cm:



84-570-41-2 Depth 383.3–392.6 m

0–20 cm: serpentinite mud with clasts of serpentinite (black –N3) and greenish yellow (10Y 7/4) and light bluish (5B 7/1) serpentinite mud.

25–147 cm: same as above.

Large clasts of massive serpentinite at 67–71, 74–78, and 83–93 cm.

84-570-41-3 Depth 383.3–392.6 m

0–22 cm: serpentine mud with serpentinite clasts.

22–42 cm: massive serpentinite with veins.

41–51 cm: serpentinite mud with clasts of massive serpentine (drilling).

51–64 cm: serpentinite drilling breccia with larger clasts of serpentinite mud.

64–150 cm: massive serpentinite.

84-570-41-4 Depth 383.3–392.6 m

Massive serpentinite.

84-570-41, CC Depth 383.3–392.6 m

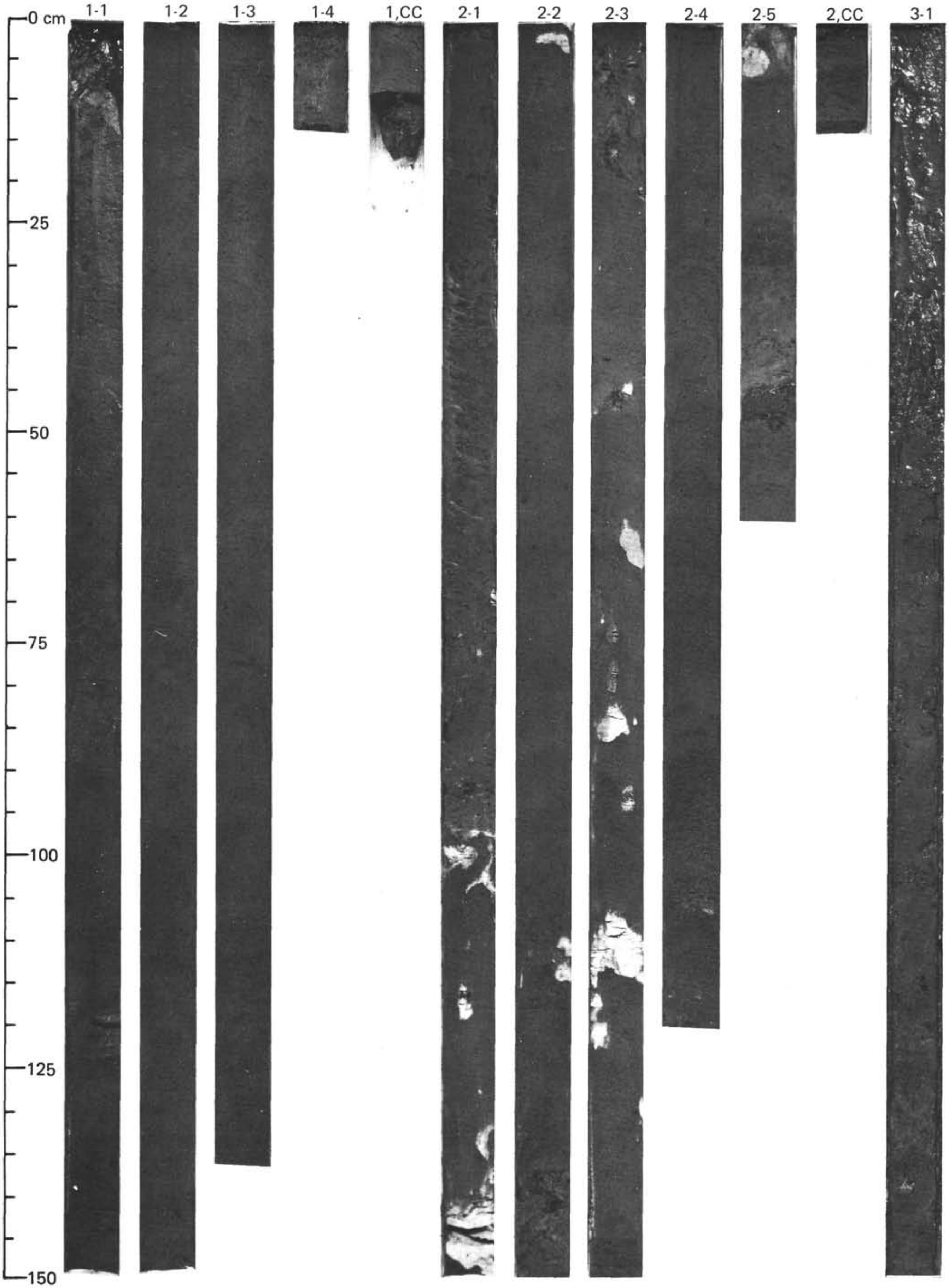
Massive serpentinite.

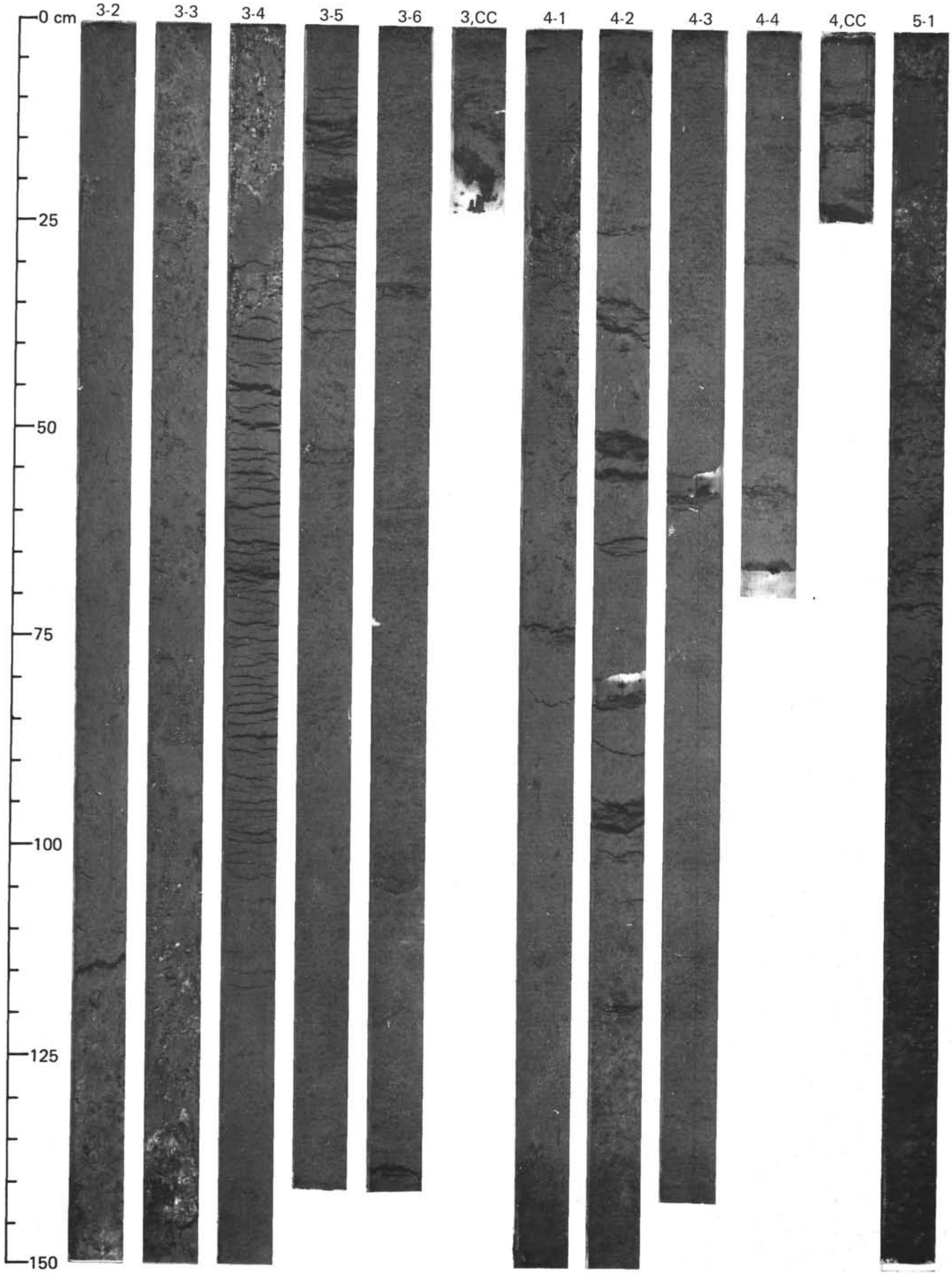
84-570-42-1 Depth 392.6–401.9 m

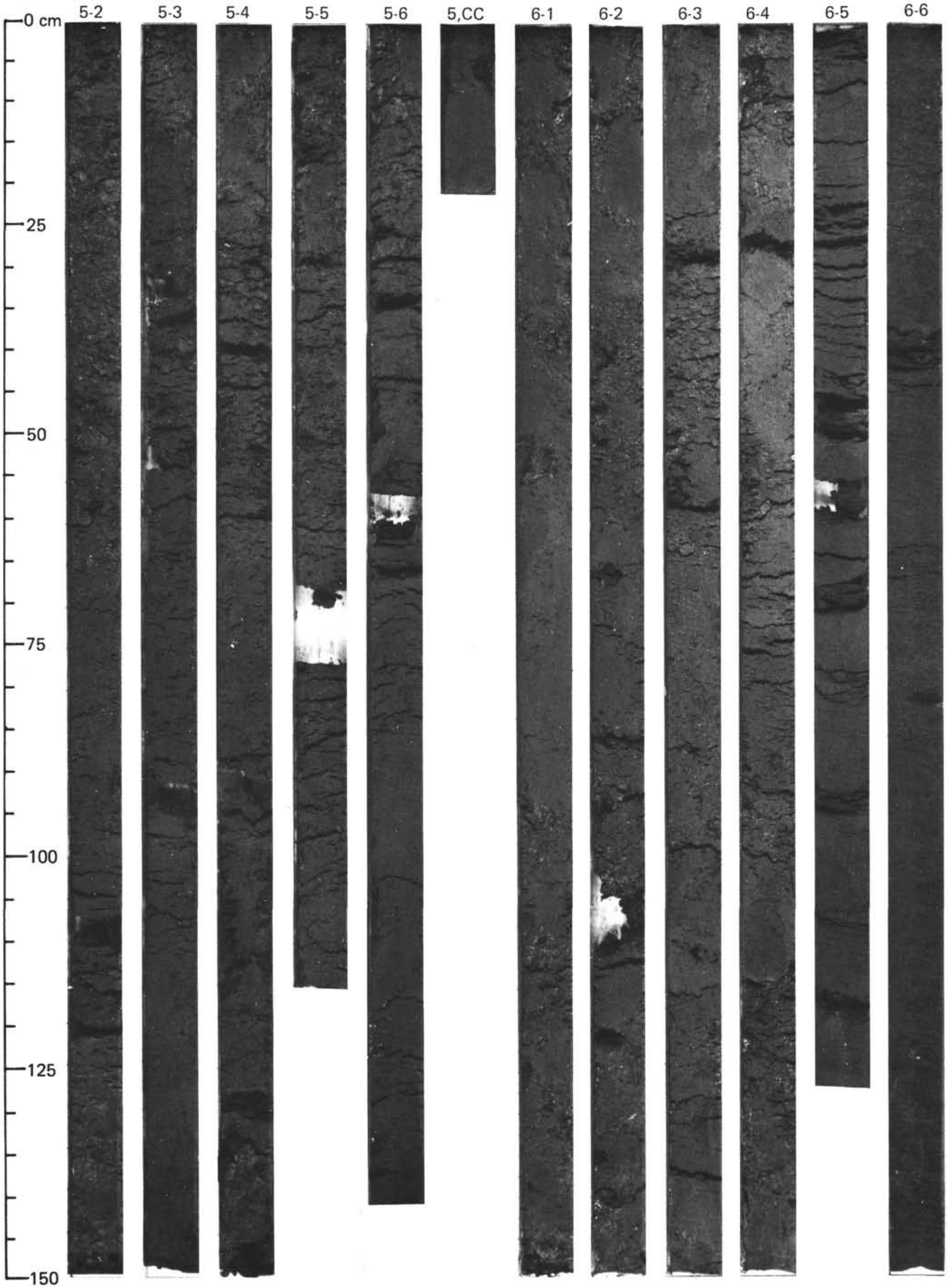
Massive serpentinite with pale green serpentinite veins.

84-570-42-2 Depth 392.6–401.9 m

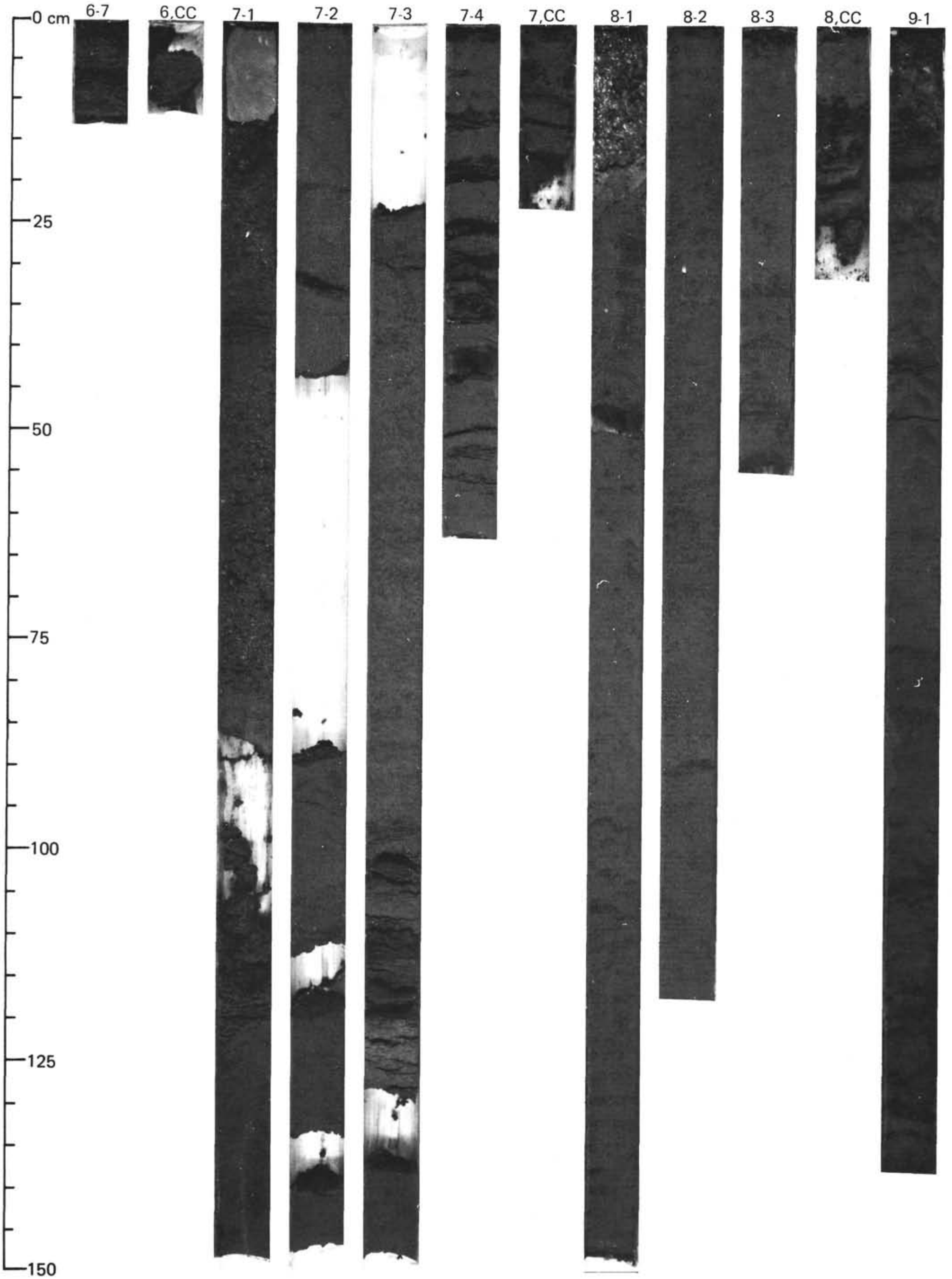
Massive serpentinite with pale green serpentine veins.

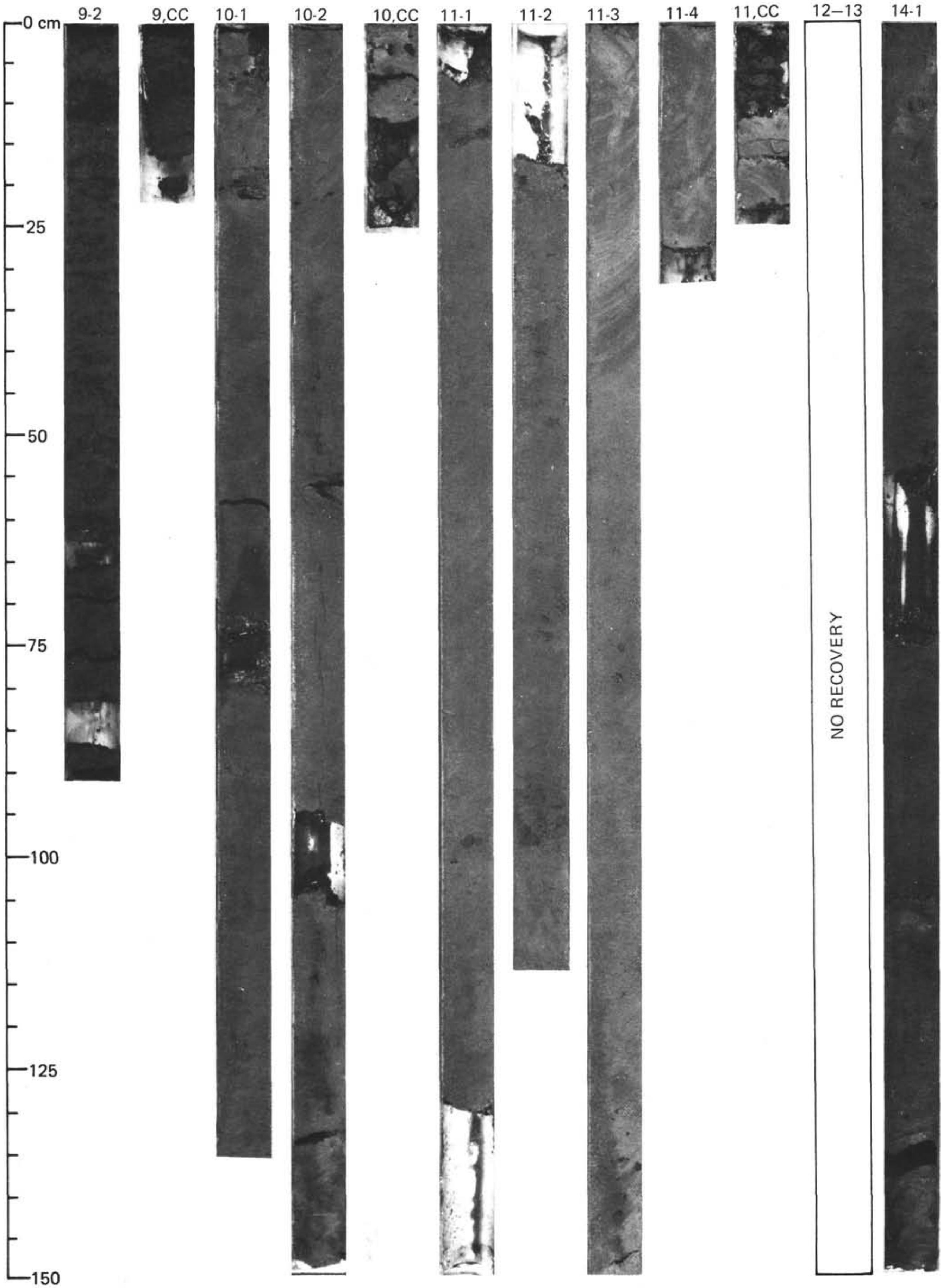

1-1
1-2
1-3
1-4
1,CC
2-1
2-2
2-3
2-4
2-5
2,CC
3-1
0 cm
25
50
75
100
125
150

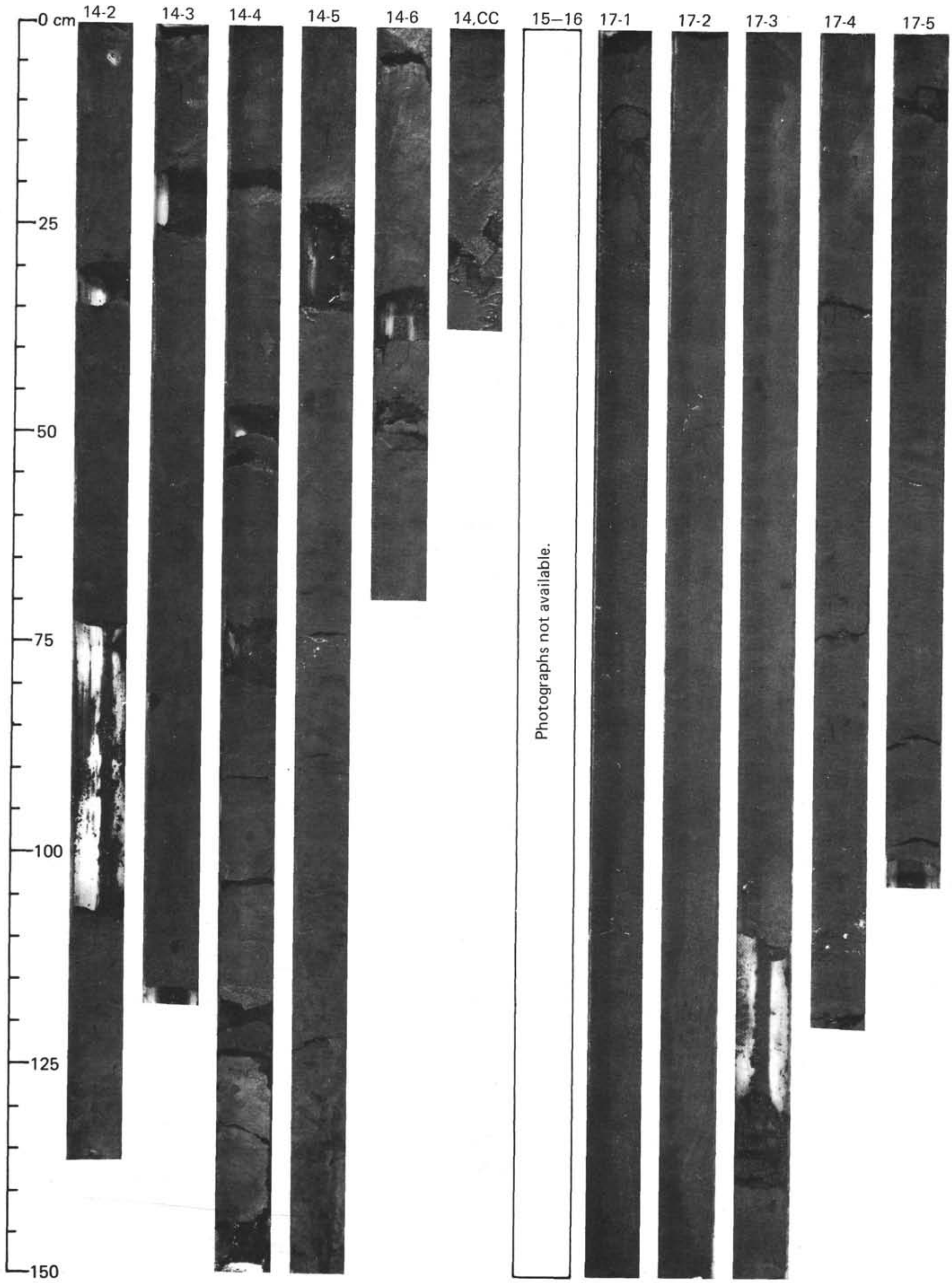

0 cm
25
50
75
100
125
150
3-2
3-3
3-4
3-5
3-6
3,CC
4-1
4-2
4-3
4-4
4,CC
5-1

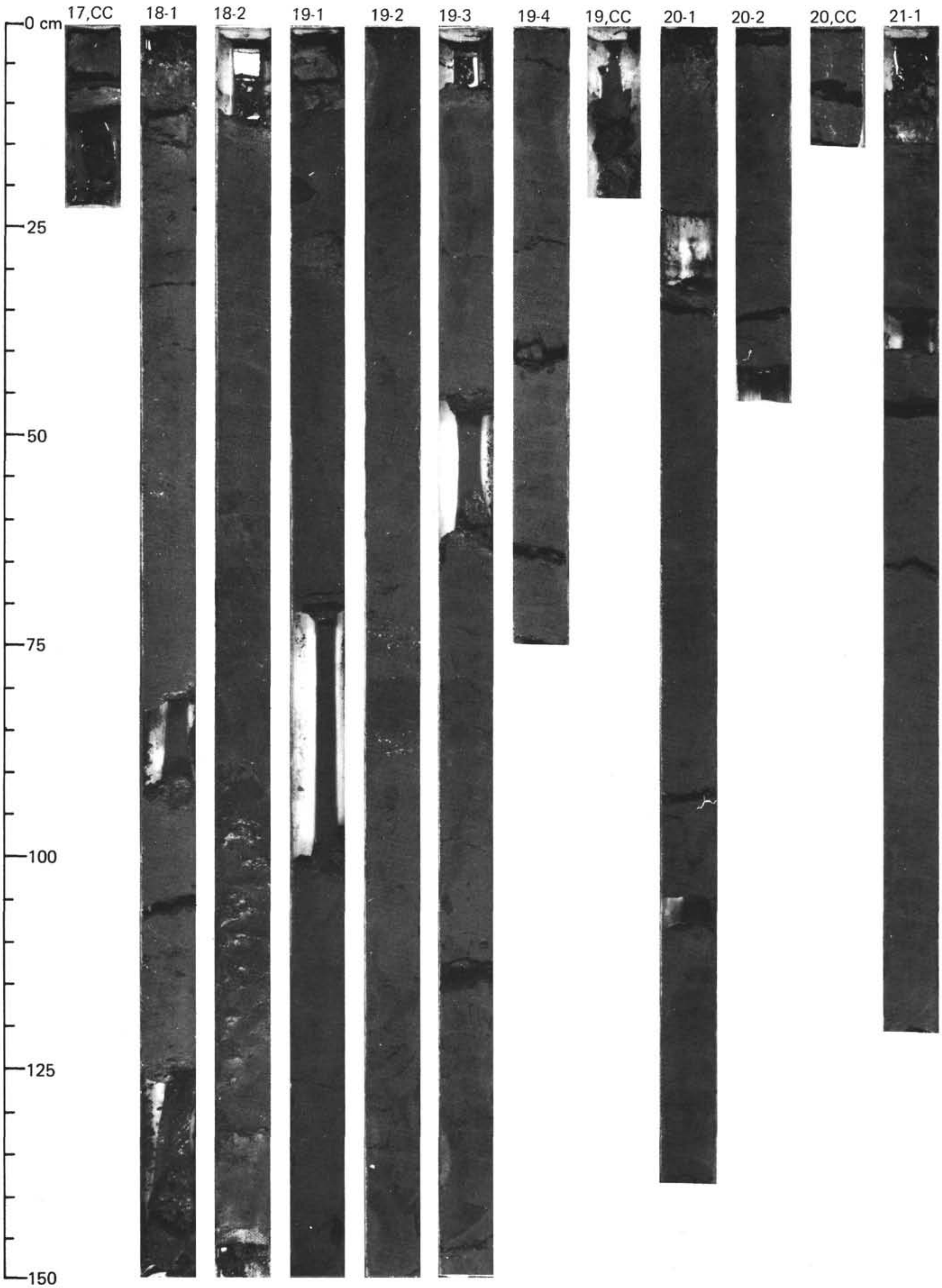


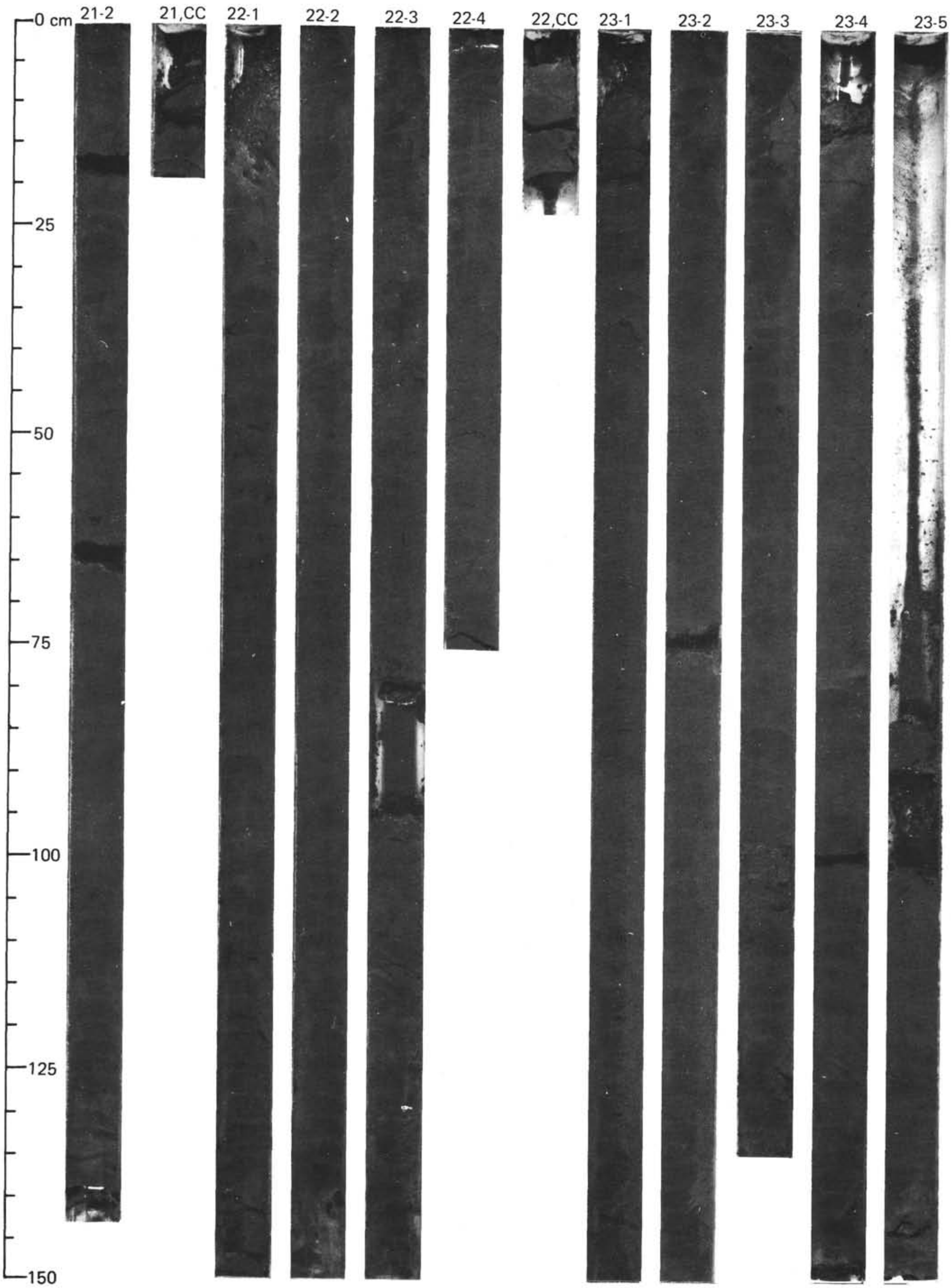
0 cm
25
50
75
100
125
150
5-2
5-3
5-4
5-5
5-6
5,CC
6-1
6-2
6-3
6-4
6-5
6-6

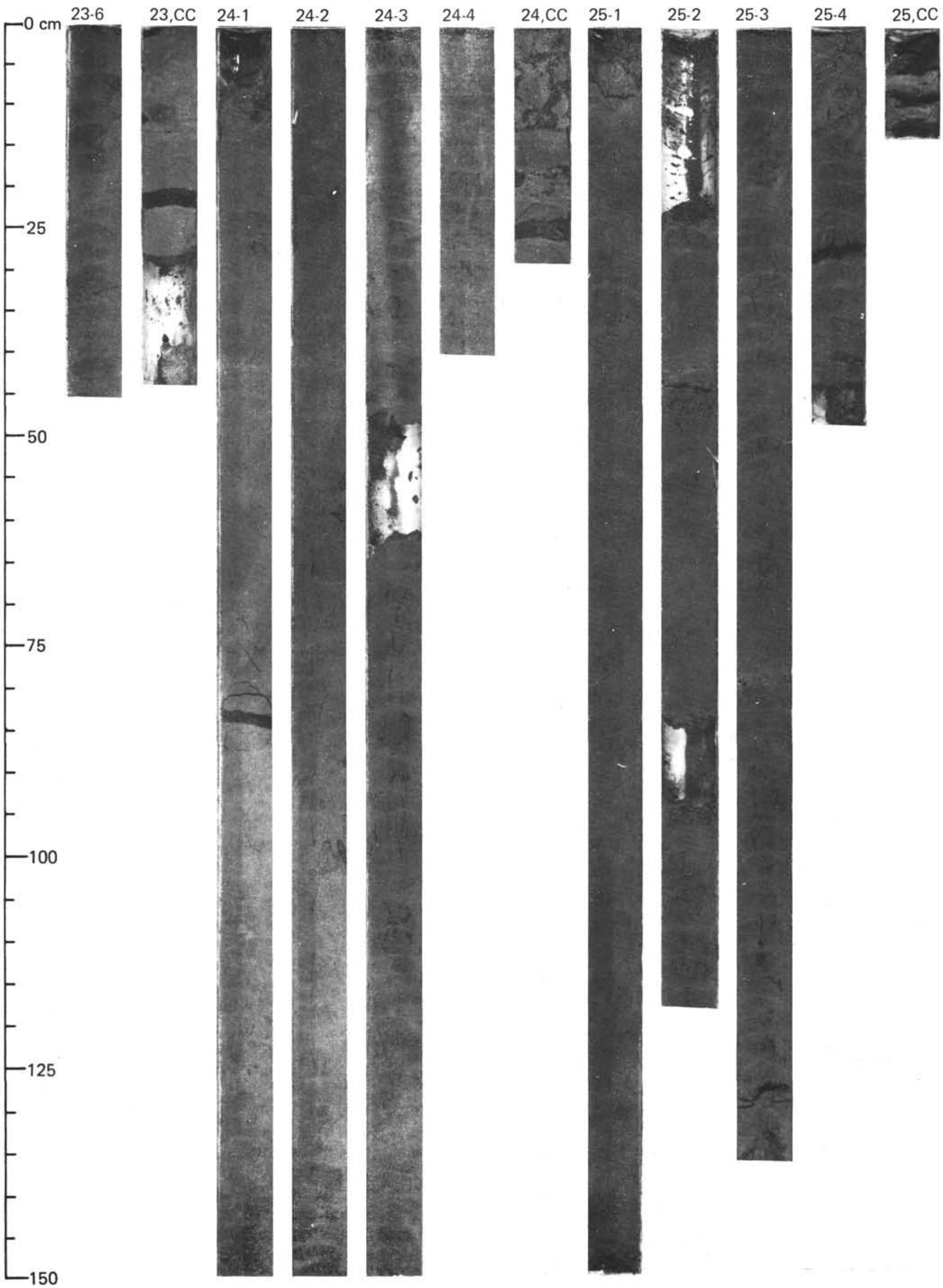

0 cm
25
50
75
100
125
150
6-7
6,CC
7-1
7-2
7-3
7-4
7,CC
8-1
8-2
8-3
8,CC
9-1

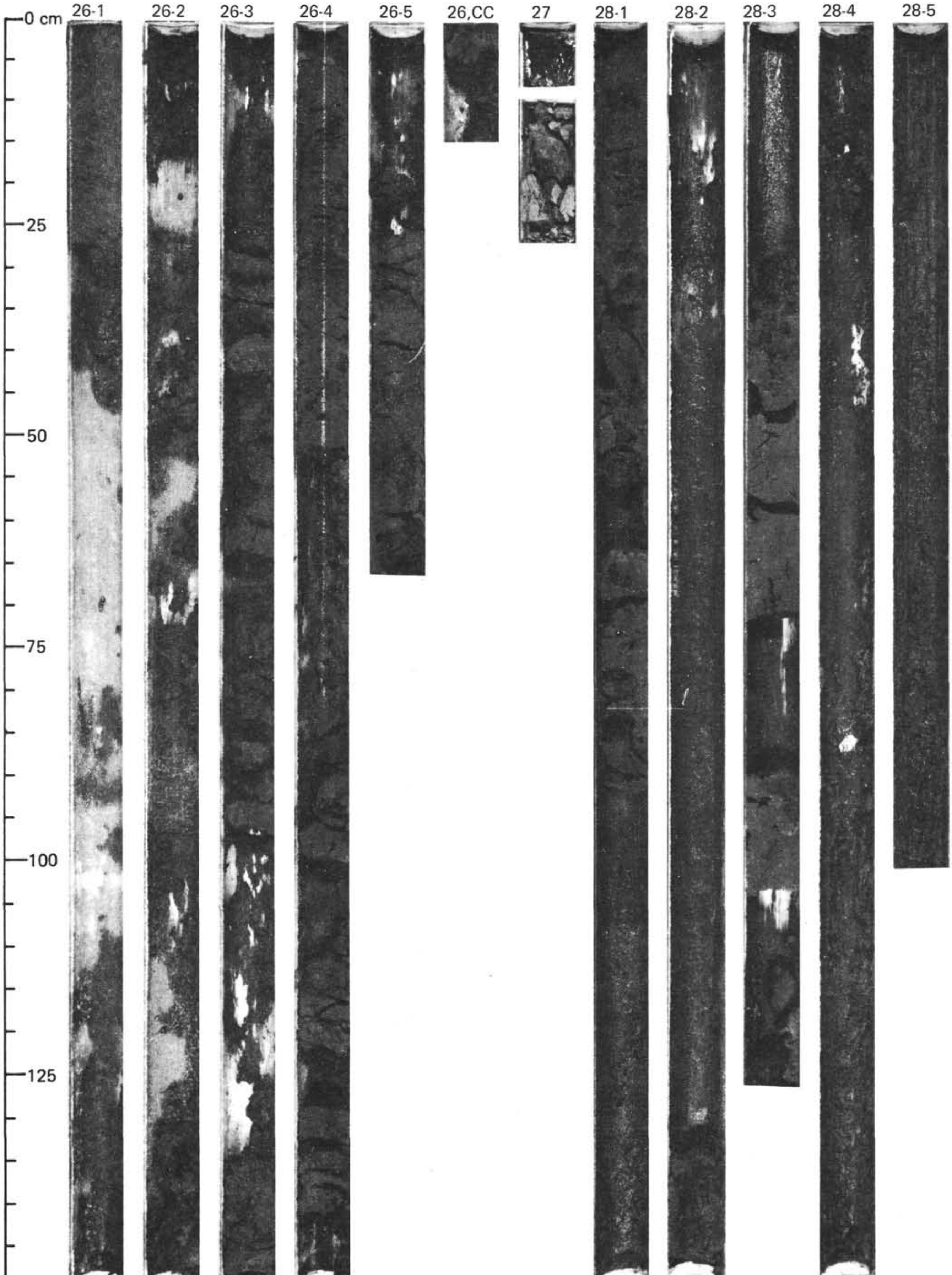

0 cm
25
50
75
100
125
150
9-2
9,CC
10-1
10-2
10,CC
11-1
11-2
11-3
11-4
11,CC
12–13
14-1
NO RECOVERY

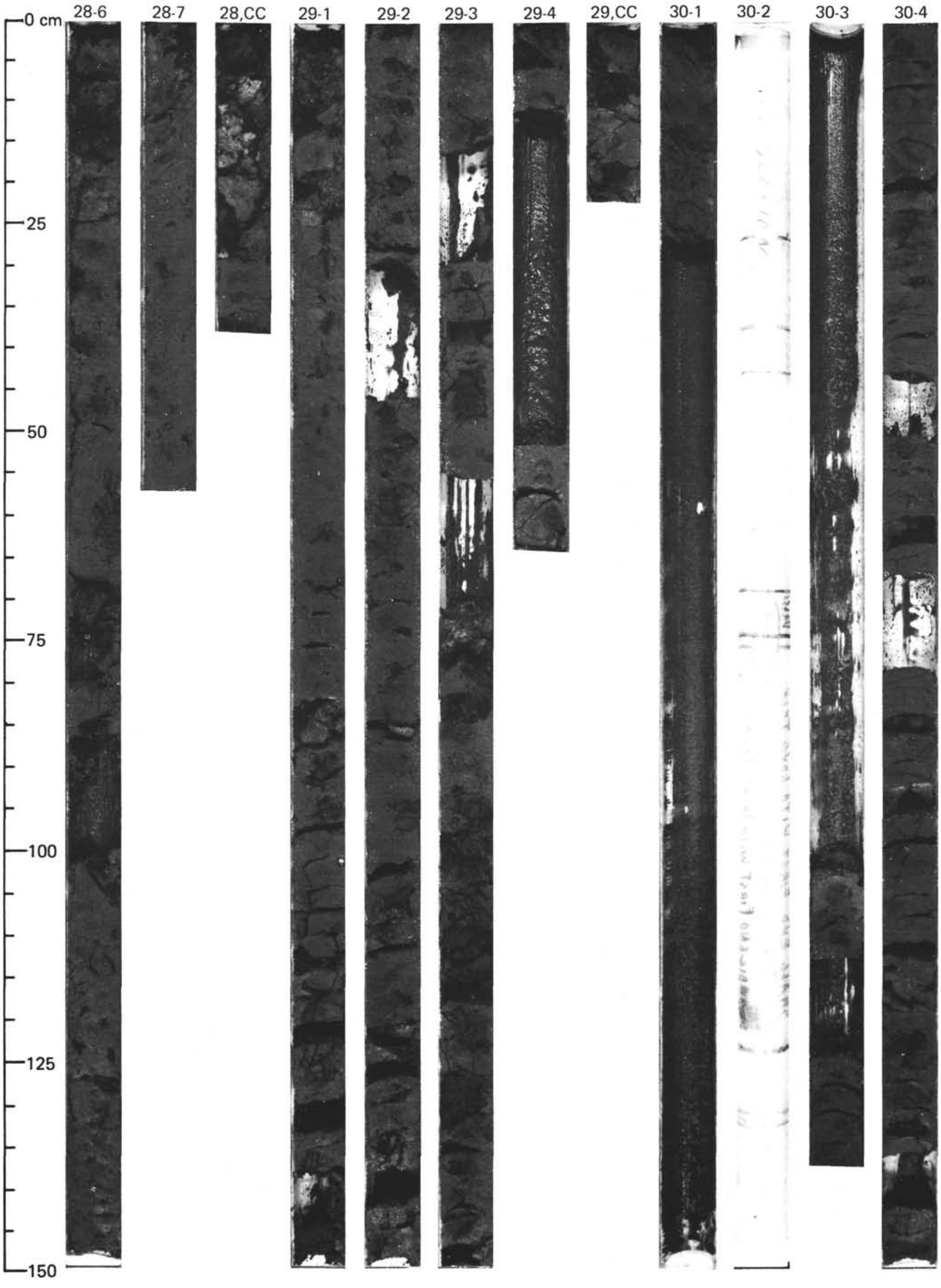

0 cm
25
50
75
100
125
150
14-2
14-3
14-4
14-5
14-6
14,CC
15–16
17-1
17-2
17-3
17-4
17-5
Photographs not available.

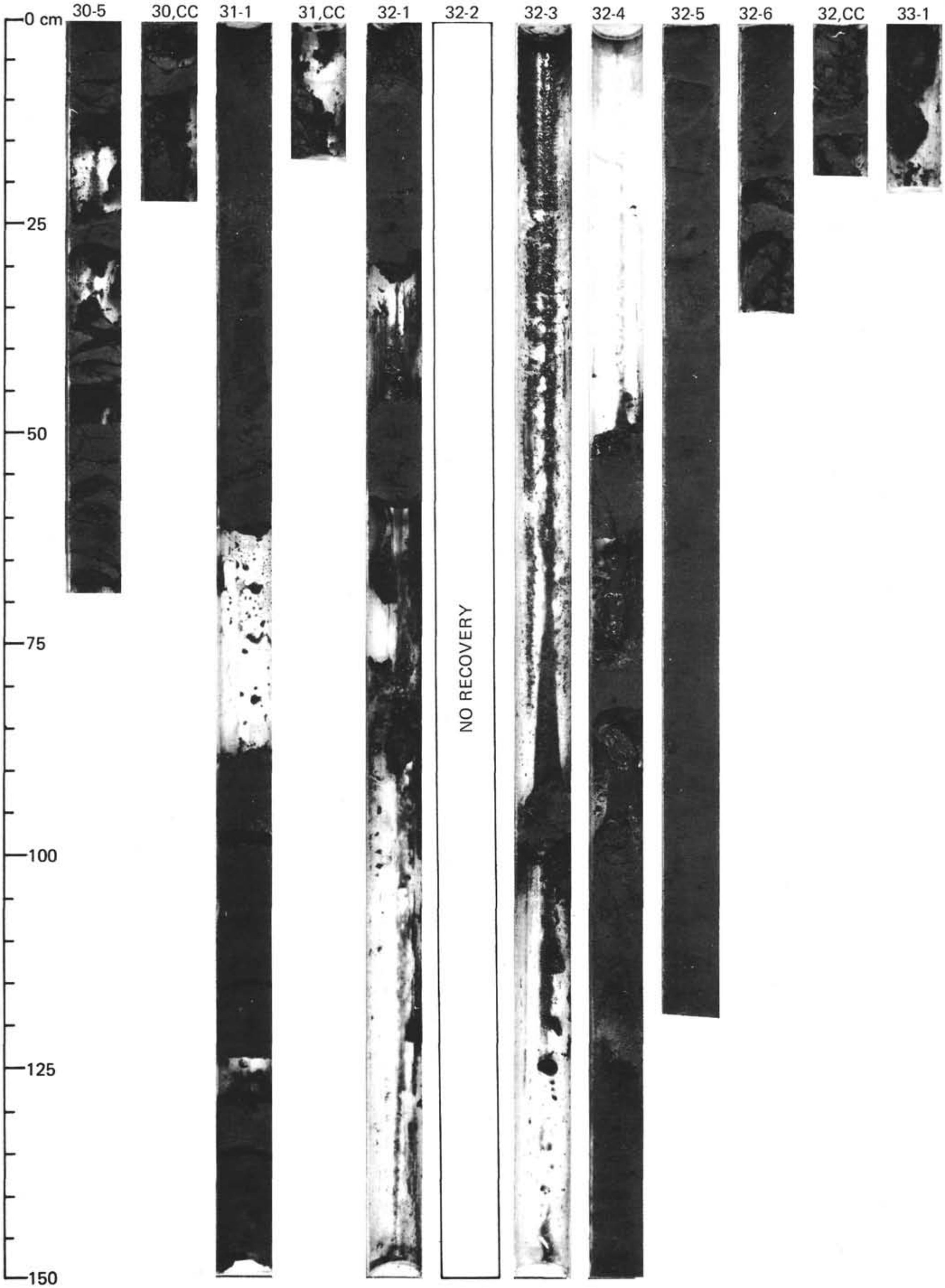

0 cm
25
50
75
100
125
150
17,CC
18-1
18-2
19-1
19-2
19-3
19-4
19,CC
20-1
20-2
20,CC
21-1


0 cm
25
50
75
100
125
150
21-2
21,CC
22-1
22-2
22-3
22-4
22,CC
23-1
23-2
23-3
23-4
23-5


23-6
23,CC
24-1
24-2
24-3
24-4
24,CC
25-1
25-2
25-3
25-4
25,CC
0 cm
25
50
75
100
125
150

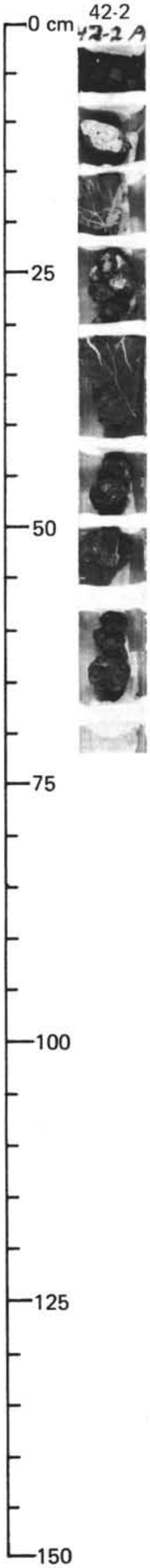

0 cm
25
50
75
100
125
150
26-1
26-2
26-3
26-4
26-5
26,CC
27
28-1
28-2
28-3
28-4
28-5


28-6
28-7
28,CC
29-1
29-2
29-3
29-4
29,CC
30-1
30-2
30-3
30-4
0 cm
25
50
75
100
125
150


0 cm
25
50
75
100
125
150
30-5
30,CC
31-1
31,CC
32-1
32-2
32-3
32-4
32-5
32-6
32,CC
33-1
NO RECOVERY

0 cm
25
50
75
100
125
150
34-1
34-2
34-3
34,CC
35-1
35-2
35-3
35-4
35-5
35,CC
36-1
36-2
36-CC


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


42-2
0 cm
25
50
75
100
125
150