5. SITE 293

The Shipboard Scientific Party[1]

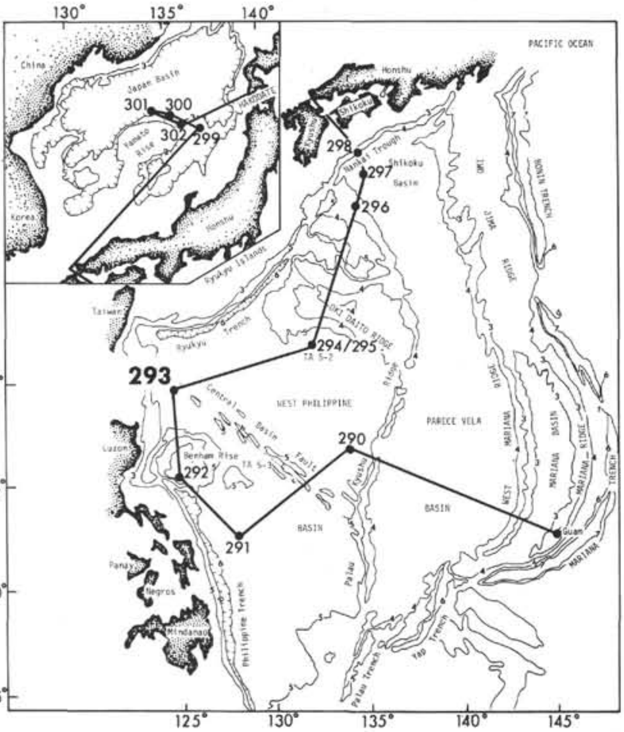


Figure 1. *Location map and* Glomar Challenger *ship track around DSDP Site 293. From map: "Topography of North Pacific," T. E. Chase, H. W. Menard, and J. Mammerickx, Institute Marine Resources, Geol. Data Center, Contour depths in kilometers; scale 1:6,500,000.*

SITE DATA

Position: 20°21.25′N; 124°05.65′E

Water Depth (from sea level): 5599 corrected meters (echo sounding)

Bottom Felt At: 5626 meters (drill pipe)

Penetration: 563.5 meters

Number of Holes: 1

Number of Cores: 23

Total Length of Cored Section: 202.5 meters

Total Core Recovered: 78.6 meters

Percentage of Core Recovery: 38.9%

Oldest Sediment Cored:
Depth below sea floor: 517-547 meters plus
Nature: Basaltic breccia
Age: late mid Miocene

Principal Results: Site 293 was drilled into a thick apron of sediment lying north and east of Luzon and immediately west of Central Basin Fault zone in West Philippine Basin. The stratigraphic column consists of 244 meters of late Pliocene-Pleistocene sand-silt turbidites, 156 meters of Pliocene distal mudstone trubidites, 29 meters of brown mudstone with reworked late-mid Eocene nannofossils overlying 46.5 meters (or more) of Miocene basaltic breccia. This breccia is probably associated with mid-plate faulting within the West Philippine Basin between the latest Eocene(?) and mid Miocene.

BACKGROUND AND OBJECTIVES

Background

The northwest corner of the West Philippine Basin, is a very complex region where the west-facing Luzon arc meets Taiwan and the Ryukyu arc. Trending northwesterly into this corner are the Central Basin Fault, variously described as a very old crustal fracture (Udintsev, 1971); a spreading center (Ben Avraham et al., 1972); and a Tertiary transform fault (Karig, 1973).

It is now reasonably certain that, in the Pliocene, the west-facing Luzon system collided with Taiwan, which was at that time an inactive part of the Ryukyu arc trend. However, the west-facing Luzon system has been active for only a relatively short period of time, prior to which, subduction of the Philippine plate in this region took place along the east side of Luzon in an east-facing arc system. The record of this activity is preserved in rocks of the Sierra Madre Oriental, but the information now available suggests only that this subduction was active in the Paleogene and perhaps earlier.

Previously it was thought that the Central Basin Fault terminated at the Taiwan-Ryukyu junction, but recent recontouring (Karig, 1973) suggested that if projected, it would terminate by abutting the old east-facing subduction zone several hundred kilometers south of the junction.

[1]James C. Ingle, Jr., Stanford University, Stanford California; Daniel E. Karig, Cornell University, Ithaca, New York; Arnold H. Bouma, Texas A & M University, College Station, Texas; C. Howard Ellis, Marathon Oil Company, Littleton, Colorado; Neville S. Haile, University of Malaya, Kuala Lumpur, Malaysia; Itaru Koizumi, Osaka University, Osaka, Japan; Ian MacGregor, University of California at Davis, Davis, California; J. Casey Moore, University of California at Santa Cruz; Santa Cruz, California; Hiroshi Ujiié, National Science Museum of Tokyo, Tokyo, Japan; Teruhiko Watanabe, University of Tokyo, Tokyo, Japan; Stan M. White, California State University at Fresno, Fresno, California; Masashi Yasui, Japan Meteorological Agency, Tokyo, Japan; Hsin Yi Ling, University of Washington, Seattle, Washington.

A substantial sediment apron, constructed as a result of drainage from northern Luzon, has overlapped and buried the northern end of the zone of rough topography associated with the Central Basin Fault and filled the site of the old trench. This apron must, therefore, postdate both subduction and activity on the Central Basin Fault.

Site 293 was located near the distal end of the sediment apron and near the southwest edge of the Central Basin Fault, which in this region appeared to be a broad diffuse band of ridges and troughs (Figures 1-3).

Objectives

It was hoped that a carefully placed hole would date the local basement and the duration of apron formation, and thus constrain the timing of some of the critical events in this region. Site 293 was, of the Philippine Basin sites, the closest to the Central Basin Fault and there was an outside chance that data would be obtained which would bear directly on the period of activity along the fault. If the initiation of the apron formation could be dated, we would also constrain the time at which subduction ceased in the old east Luzon Trench.

OPERATIONS

Presite Survey

This site was originally located using well-navigated *Oceanographer* seismic reflection records, as well as records from the SIO ANTIPODES 4 expedition.

Site 293 was approached along course 355°T on 30 June. Underway seismic records clearly displayed the seaward margins of the turbidite fan. Speed was reduced to 7 knots as the Central Basin Fault zone was crossed along a course of 270°T. A relatively thick portion of the turbidite apron appeared immediately adjacent to the high of the Central Basin Fault. Speed was further reduced to 5.8 knots over apron sediments "ponded" within buried basement ridges and troughs. The overlying sedimentary section was displayed as a highly reflective upper layer (interpreted as turbidites), overlying a transparent layer. After passing across an ever-thickening wedge of apron sediments, it was decided that the most productive drilling site would be adjacent to the Central Basin Fault zone on the flank of a buried basement high (Figures 2, 3, 4).

A course change to course 095°T was made, and the ship proceeded back toward the Central Basin Fault zone (Figure 2). Another course change was made to 095°T with the beacon dropped at 0728 LCT, 1 July, over a "pond" of apron sediments between the Central Basin Fault zone, and an adjacent buried ridge (Figure 3). The first beacon (13 kHz) dropped began to fail during descent, and a second 16-kHz beacon was released. Positioning problems and the beacon failure led to the site being offset 608 meters to the west and down the "basement" slope. The site was also located using data from a successful sonobuoy run prior to drilling.

Drilling Program

The vessel was stabilized over the drilling site and Hole 293 was spudded at 2000 LCT, 1 July in a water depth of 5601 meters (PDR). It was anticipated that the friable turbidite sands might present problems in burying the drill collars; however, no caving was experienced, and an initial punch core retrieved a small sample of sand and silt. In light of the multiple objectives at this site, and the promise of only marginal fossil control, the sedimentary sequence was interval cored to a depth of 516 meters (Core 18) (Table 1).

Core 18 (516-521 m) contained brown mudstone and a very lithified basaltic breccia with an attendant and abrupt increase in drill rate (Figure 5). Continuous coring commenced, and Cores 18-21 (516-544.5 m) also

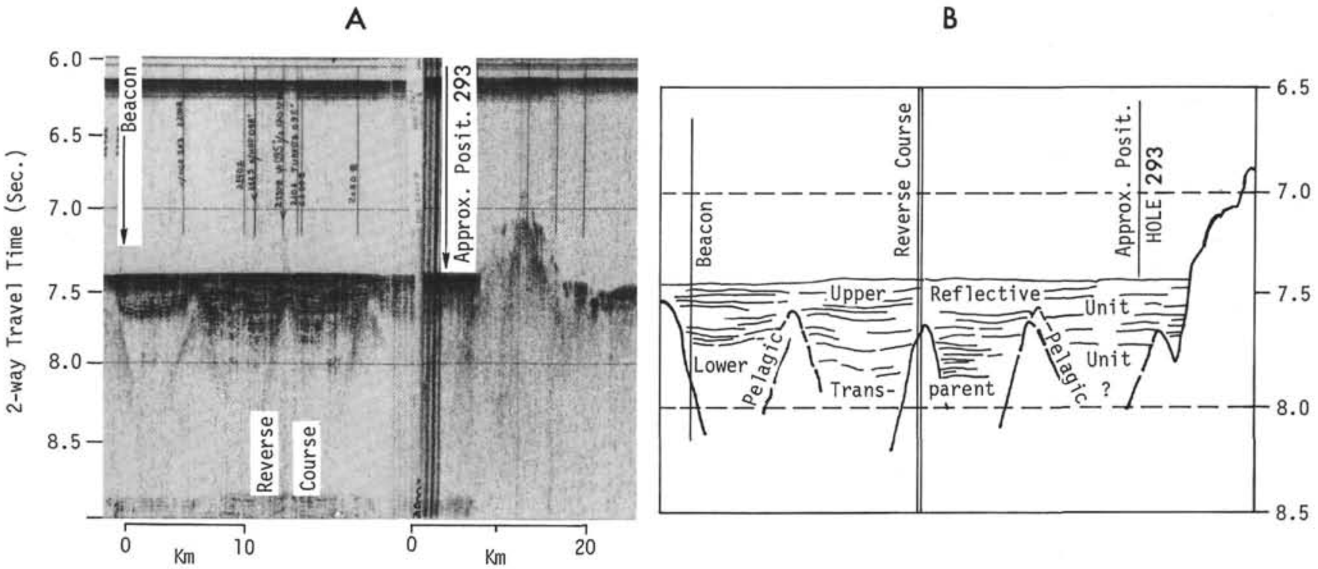


Figure 2. Glomar Challenger *seismic reflection profile (A) and interpretation (B) along approach track to Site 293. The partial cover of pelagic sediment beneath the turbidites shows well on the record.*

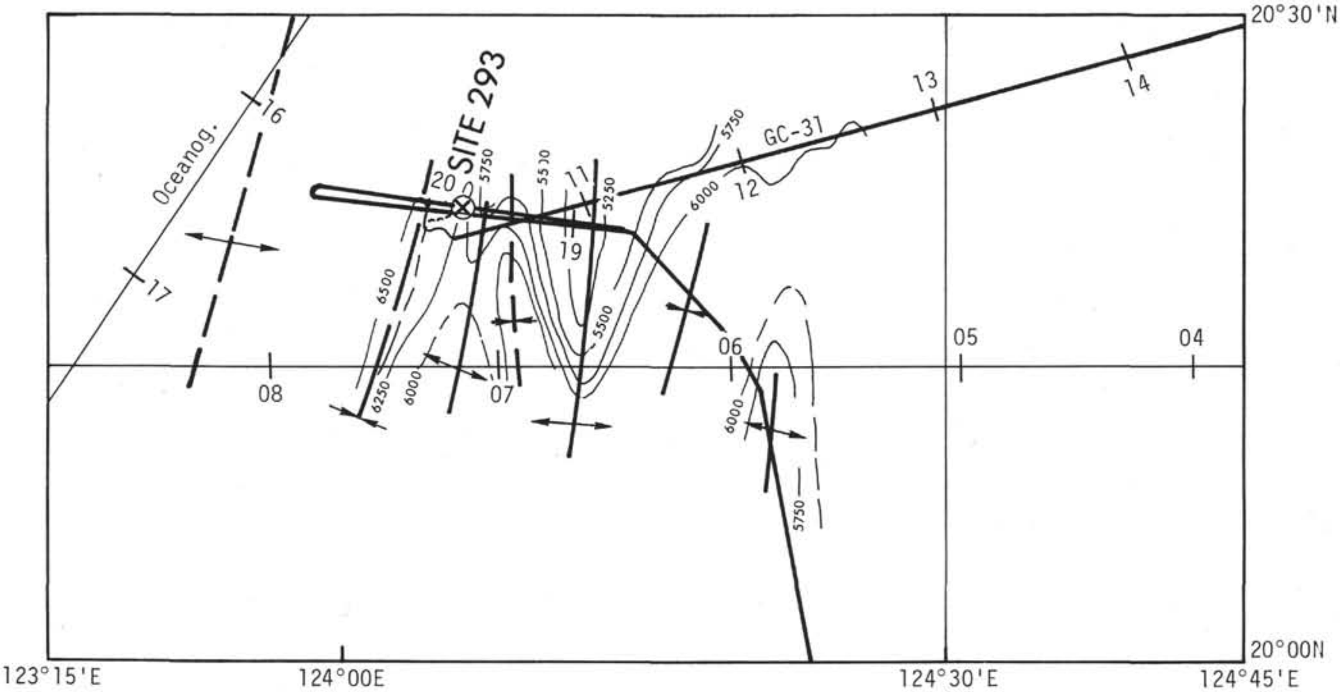


Figure 3. *Basement topography near Site 293. Depths to acoustic basement in meters assuming water velocities given by Matthews tables and a sediment velocity of 1.8 km/sec. Only trends are shown near the intersecting* Oceanographer *tracks because of uncertainty in track adjustment.*

retrieved pieces of the basaltic breccia with poor recovery. Attempts at cutting Cores 22 and 23 proved negative. Finally, stalling, increasing torque, and sticking pipe caused Site 293 to be abandoned at 6144 meters without reaching basalt.

Two attempts were made to obtain sonobuoy records leaving Site 293; however, both attempts failed due to malfunctioning sonobuoys. Figure 4 shows the seismic reflection profile obtained upon leaving Site 293.

LITHOLOGY

The sediment column should be considered as one continuum, but it can be divided into five subunits for descriptive purposes (Table 2 and Figure 5). In general, the sediment section consists of a clay series that gradually became interrupted by silt and later on by sandy silt deposition. The mineralogy indicates that the detrital particles were derived from a volcaniclastic source. Lithologic characteristics of the sequences cored are presented in Figure 6.

Subunit 1A

Only a knife point of material could be collected from the punch core (Core 1) representing the upper 3 meters. The sediment is a sandy silt with feldspar, transparent and opaque heavy minerals, and volcanic glass as main components. The color is dark brown. Since some fossils, ranging in age from Holocene to Cretaceous, were incorporated, it is believed that the source was a volcaniclastic sediment rather than a volcanic one.

The failure to obtain a core indicates either very watery clayey sediment or sandy material. The latter points to a well-sorted deposit that underwent winnowing action by bottom currents. The presence of such currents was also established from the beacon behavior. Although it is unlikely that the entire 3 meters are one sandy silt unit, it is reasonable to assume that the interval consists of many thin "contourite" type deposits, with water-rich clayey sediments in between.

Subunit 1B

This part of the sediment column (Core 2 to Core 7, Section 3) has very fine sand to coarse silt beds incorporated in a clay unit. Graded bedding was not found in most of the beds. The contact between clay and its overlying coarser material is normally more distinct than the contact between the sand/silt and its overlying clay. These layers all have aspects of distal turbidites.

A number of silty sand layers, varying in thickness from 1 to 4 cm, have sharp upper and lower bedding plane contacts. Although substantiating data are lacking, they reveal characteristics of contourites (Bouma and Hollister, 1972; Bouma, 1972, 1973).

The overall sand/clay ratio of this subunit is low in spite of some sand beds being as thick as 30-50 cm. The textural and compositional data from all lithologies of this subunit are presented in Table 3. Colors for the fine-grained sediments vary from dark gray to medium dark gray, and for the coarser grained deposits from dark to very dark greenish-gray.

The wide range in lithologic combinations of the three components sand, silt, and clay has a selective effect on the mineralogy (Table 3). The quartz is slightly coarser than the feldspar in spite of wide scattering. Most of the

TABLE 1
Coring Summary, Site 293

Core	Cored Interval Below Bottom (m)	Cored (m)	Recovered (m)	Recovered (%)	Remarks[a]
1	0.0-3.0	3.0	0.0	0.0	
Wash	3.0-88.5				
2	88.5-98.0	9.5	6.5	68.0	
3	98.0-107.5	9.5	7.0	74.0	
Wash	107.5-145.5				
4	145.5-155.0	9.5	2.2	23.0	
5	155.0-164.5	9.5	5.1	53.0	
Wash	164.5-202.5				30 bbl mud
6	202.5-212.0	9.5	3.0	33.0	
7	212.0-221.5	9.5	6.6	69.0	
Wash	221.5-259.5				
8	259.5-269.0	9.5	2.3	25.0	
9	269.0-278.5	9.5	5.4	57.0	
Wash	278.5-297.5				
10	297.5-307.0	9.5	3.5	37.0	
Wash	307.0-326.0				
11	326.0-335.5	9.5	0.4	4.0	
Wash	335.5-354.5				30 bbl mud
12	354.5-364.0	9.5	9.5	100.	
Wash	364.0-383.0				
13	383.0-392.5	9.5	1.7	18.0	
Wash	392.5-411.5				
14	411.5-421.0	9.5	0.5	5.0	Drilling rate slows through Core 17
Wash	421.0-440.0				
15	440.0-449.5	9.5	6.0	63.0	
Wash	449.5-468.5				30 bbl mud
16	468.5-478.0	9.5	6.9	72.0	
Wash	478.0-497.0				
17	497.0-506.5	9.5	6.6	69.0	
Wash	506.5-516.0				
18	516.0-521.0	5.0	1.4	28.0	Abrupt increase in drilling rate.
19	521.0-525.5	4.5	0.4	4.0	50 bbl mud
20	525.5-535.0	9.5	1.5	12.0	
21	535.0-544.5	9.5	2.3	24.0	
22	544.5-554.0	9.5	0.0	0.0	50 bbl mud
23	554.0-563.5	9.5	0.0	0.0	
Total	563.5	202.5	78.6	38.9	

[a]Figure 5 contains graphs of drilling rates and lithology.

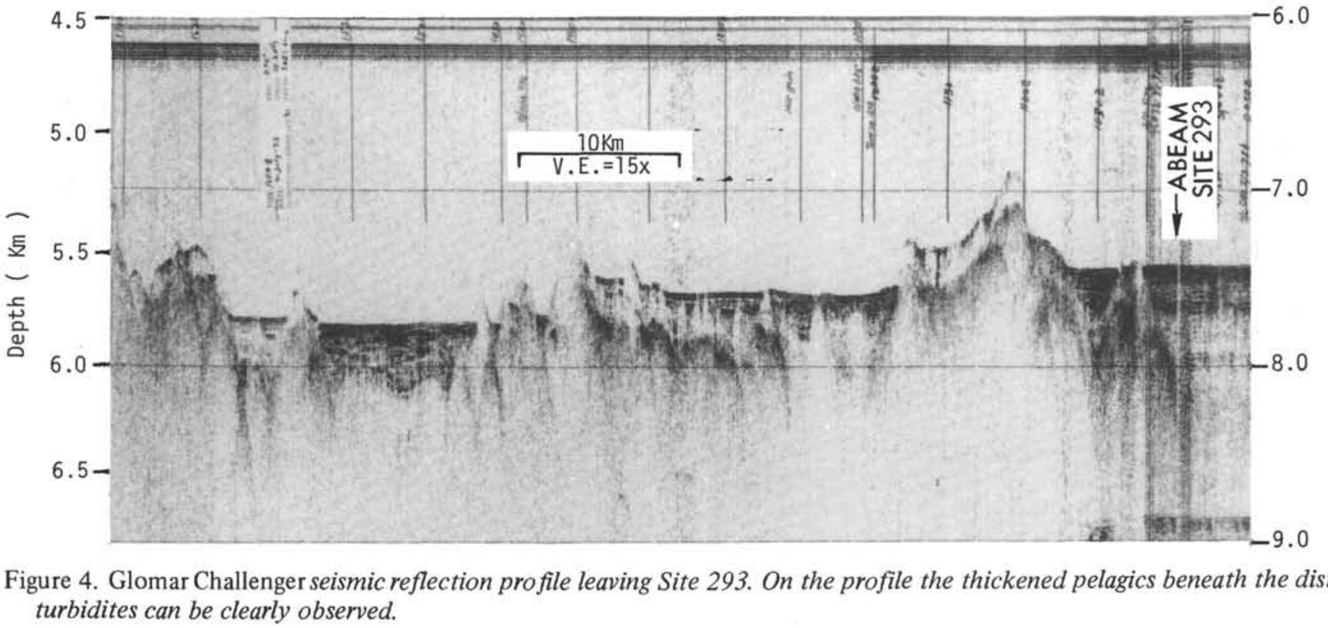


Figure 4. Glomar Challenger *seismic reflection profile leaving Site 293. On the profile the thickened pelagics beneath the distal turbidites can be clearly observed.*

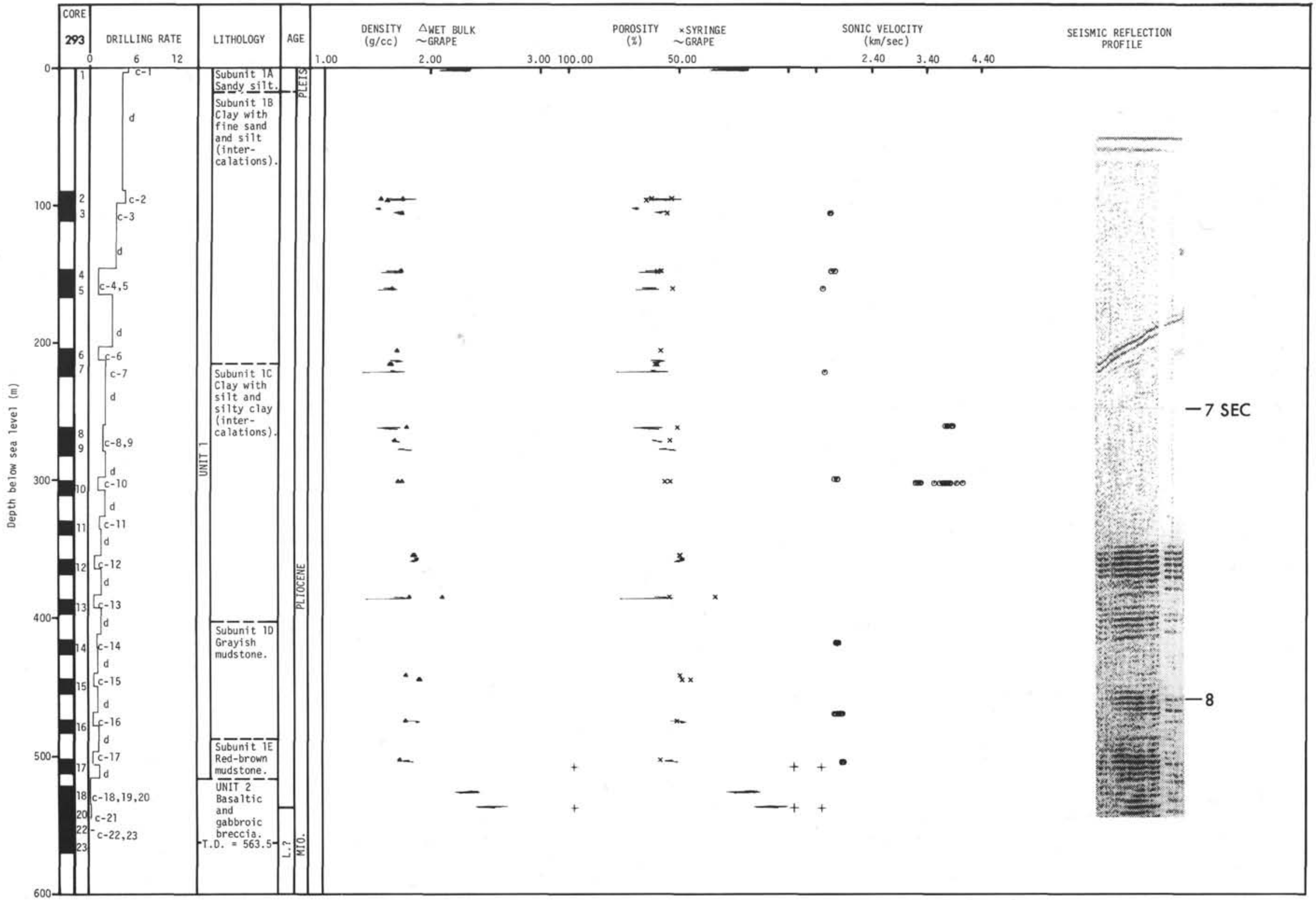


Figure 5. *Hole summary diagram, Site 293.*

TABLE 2
Unit Descriptions, Depths, Thicknesses, and Ages, Site 293

Unit and Descriptions		Depth (m)	Thickness (m)	Age
1A	Sandy silt	0.0–3.0	3.0+	Pleistocene/Holocene
1B	Very fine sand to coarse silt within clay unit	88.5–215.0	126.5	Late Pliocene (?)-Pleistocene
1C	Bedded series of distal turbidites and ash beds	215.0–392.5	177.5	Late Pliocene at 269 to 278.5m
1D	Clay, silty clay, and clayey silt	392.5–478.0	85.5	?
1E	Red and brown claystone	497.0–517.0	20.0	?
2	Tholeiitic basalts, gabbro-breccia	517.0–544.5	27.5?	Late middle Miocene-late Pliocene nannofossils in Core 20 (525.5 m)

TABLE 3
Ranges in Size and Composition for the Different Lithologies of Subunit 1B, Site 293, Based on Smear Slides, Grain Size, and X-Ray Data (in %)

Component	Sandy Silt	Silty Sand	Clayey Sand	Clayey Silt	Silty Clay
Sand	15–40	50	57	5–10	1–15
Silt	40–80	30	17	50–80	20–48
Clay	5–15	20	26	15–45	51–80
Quartz	7–12	–	18	10–30	6–35
Feldspar	17–50	33	40	50	1–50
Heavy minerals	15–50	50	5	10–30	5–25
Opaques	5–10	–	5	10	4–10
Clay minerals	5–25	–	32	13–45	10–65
Volcanic lithics	10–35	–	–	–	0–10
Palagonite	0–10	–	–	0–3	–
Volcanic glass	0–25	2	–	2–22	1–25
Glauconite	1–15	–	–	–	–
Zeolites	0–15	–	–	0–5	10–25
Carbonate	0–1	10	–	–	0–tr
Nannofossils	–	5	tr	0–2	0–tr
Sponge spicules	0–1	–	–	–	0–tr

identified heavy minerals and lithic fragments fall in the silt-sand size range. The presence of glauconite may indicate a shallow-water source area. The heavy minerals consist mainly of amphiboles (green and brown basaltic hornblende, hornblende), pyroxene, chlorite, and hypersthene, which indicates a volcanic origin.

A number of cores from the upper part of this subunit showed gas expansion cracks. Since the gas consisted of methane, it presumably is the result of decaying plant fragments. Only one minor volcanic ash intercalation was found in this subunit, just above the lowest sandy bed. Its composition is comparable to those of the deeper volcanic ash beds.

Subunit 1C

The sediment of this subunit reveals a thin to medium bedded series distinguished by different colors. A small number of thin volcanic ash beds were observed. A fixed pattern of successive colors, presenting a sedimentary cycle or sequence, is depicted in Table 4. The cycle p, q, r is characteristic, although (p) can be missing.

The textural and compositional data of this subunit are given in Table 5. In spite of the wide range in grain sizes, the following tendencies can be noted: quartz occurs mainly as small silt particles; feldspar is very common, and has a wider size range; heavy minerals vary with a mean in the silt class; volcanic glass and palagonite are slightly larger in size than the heavy minerals (hydraulic equivalents); and zeolites fall primarily in the silt class. Chlorite is the main heavy mineral. The amphiboles consist primarily of green and brown-basaltic hornblende. The volcanic ash intercalations reveal a wide range of grain sizes, but vary little in composition. Their feldspar content is high when the silt content is high. The volcanic glass normally is devitrified.

The mineralogy of this subunit indicates volcaniclastic origin. Distal-like turbidites with pelagic green-colored clays were presumably deposited near or below the carbonate compensation depth based on the scarcity or absence of fossils in the clay.

Subunit 1D

The sediment found in Cores 14, 15, and 16 consists of rather hard, homogeneous muds that often break with conchoidal surfaces. The material is too fine to readily display primary sedimentary structures. Some color variations do occur without revealing a cyclic pattern. The three major colors are bluish-gray, olive-gray, and moderate yellowish-brown. A few grayish-blue-green spots are scattered throughout and a few dark laminae, sometimes lenticular, with or without micrograded bedding, were observed. Burrows do occur in many parts of this subunit.

The mineralogy is not too conclusive, but most of the silt grains are detrital in origin, derived from a volcaniclastic source. The deposits can be interpreted as preturbidite sediments, as are often found in flysch areas

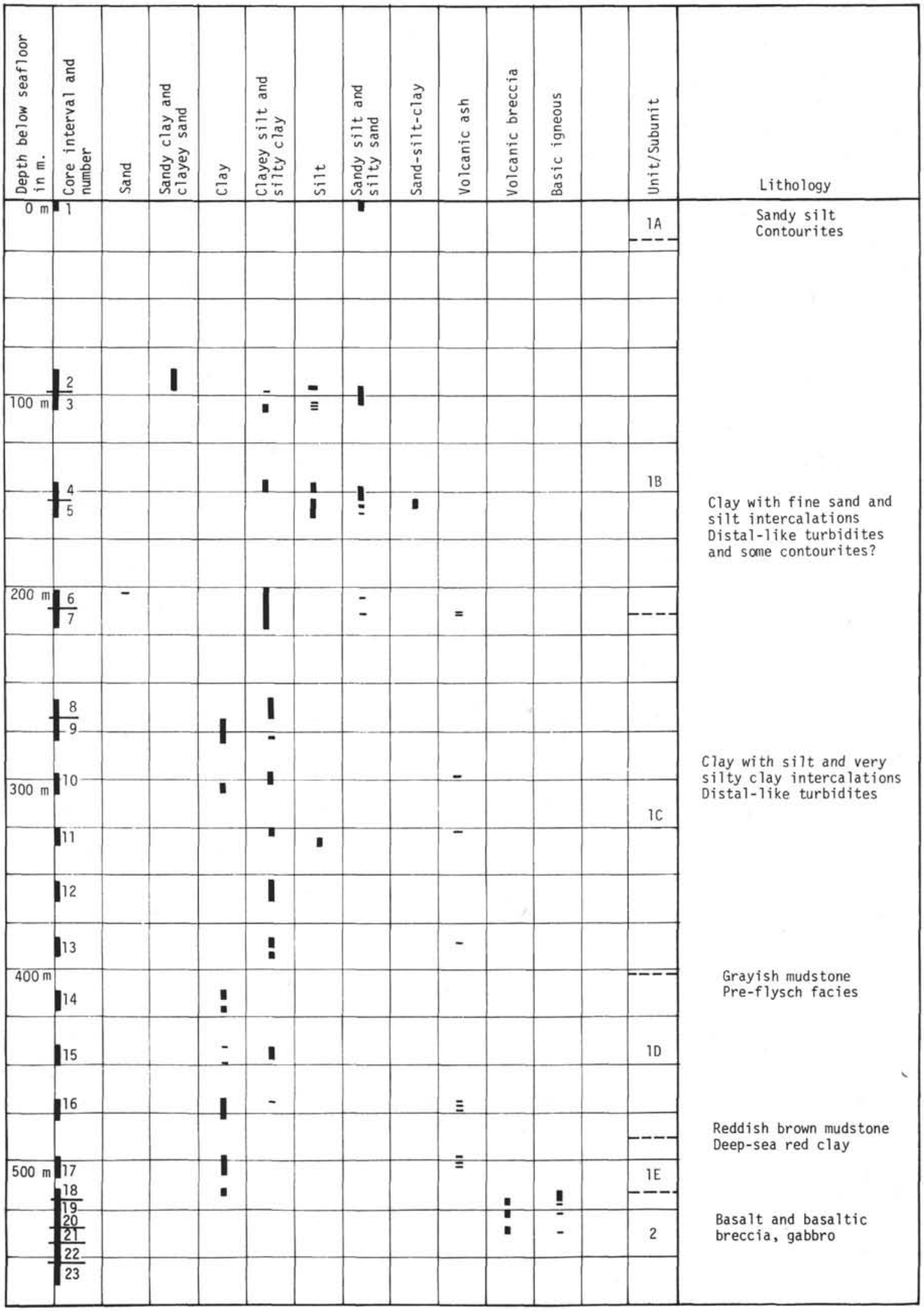


Figure 6. *Lithologic summary, Site 293.*

TABLE 4
Sedimentary Cycle as Observed in Subunit 1C, Site 293

———	Distinct contact
	(r) green clay (5GY 4/1) with or without bioturbation; average thickness ranges from 2-5 cm; hard dry sediment with slightly fattish appearance
·········	indistinct to barely visible contact
	(q) purple brown (5P 3/2) slightly silty clay, 5-15 cm thick except in lower cores where thicknesses range between 3-6 cm; appearance changes from slightly crumbly to slightly fatty in upward direction, along with a faint decrease in silt content
------	Contact visible to distinct, can be absent
	(p) purple greenish gray (5YR 3/1) clayey silt to slightly clayey silt, often with noticeable graded bedding; thickness from 0.1-4 cm; in some cases this division is absent; crumbly appearance
———	Distinct contact

TABLE 5
Ranges in Size and Composition for the Different Lithologies of Subunit 1C, Site 293, Based on Smear Slides, Grain Size, and X-Ray Data (in %)

Component	Clayey Silt	Silty Clay	Clay
Sand	0-1	2-15	0-8
Silt	75-79	15-45	10-12
Clay	20-25	25-80	80-85
Quartz	0-5	10-20	1-5
Feldspar	20-40	0-40	8-20
Heavy minerals	3-10	2-30	2-5
Opaques	0-3	2-5	1-5
Clay minerals	40-63	12-70	55-83
Palagonite	–	0-4	–
Volcanic glass	1-5	1-5	–
Zeolites	0-25	1-25	0-5
Carbonate	–	0-1	0-9
Nannofossils	–	tr -3	–

underlying a turbidite series. Since no paleontological support is available to show the rate of accumulation, the occasional high zeolite content indicates low sedimentation rates.

Subunit 1E

Cores 17 and 18 (upper part of Section 1) contained a claystone, with a variety of red to brown colors: grayish-brown, dark yellow-brown, and very dusky red.

The grain size range is very narrow, and the composition varies little. The clay minerals are often coated with iron oxides. Zones with intensive burrowing and mottling could be observed, as well as a few laminae. A total of 10 ash beds was noted, ranging from a few millimeters to a few centimeters in thickness, and predominantly composed of clay-sized volcanic glass.

The sediment from Core 18 has the characteristics of a deep-sea red clay. This type of deposition became gradually interrupted by detrital clays and some volcanic ashes (Core 17).

Unit 2

This unit is composed of tholeiitic basalts and gabbros, characteristic of deeper levels of the oceanic crust. The metamorphosed, or altered, equivalent of each rock type suggests alteration under low amphibolite, or upper greenschist conditions.

Core 18, Section 1; Core 19, Section 1, 1-138 cm

Ophitic tholeiitic basalt (plagioclase 40%-55%, pyroxene 37%-52%, opaques 5%-8%, amphibole up to 52%, chlorite up to 3%). The shear zones through the basalt are largely brecciated, the pyroxenes are all altered to actinolitic amphiboles, and the texture becomes schistose.

Core 19, Section 1, 138-150 cm; Core 20, Section 1, 0-25 cm

Matrix is moderate yellowish-brown. The breccia is composed of altered basalt and greenschist clasts in a matrix of plagioclase, amphibole, chlorite, and altered opaque mineral fragments in clay-sized groundmass, with minor amounts of zeolite and calcite.

Core 20, Section 1, 25-61 cm

Matrix is moderate reddish-brown. The clasts are of low-grade amphibolite facies rocks of deformed gabbros and basalts. Relict clinopyroxene can be found, but actinolitic amphibole with schistose textures are abundant. The matrix is composed of amphibolite, plagioclase, and oxide mineral fragments in a clay-sized matrix that is rich in goethite, clay minerals, and minor amounts of carbonate.

Core 20, Section 1, 61-103 cm

Matrix is light greenish-gray. Microgabbro clasts are largely altered to amphibole gabbros, and shear zones can be seen in the clasts. Matrix consists of plagioclase, amphibole, and opaque mineral fragments in a clay-sized groundmass.

Core 20, Section 1, 103-150 cm

Coarse-grained gabbro clasts (plagioclase 40%-60%, clinopyroxene 30%-45%, orthopyroxene 5%-20%, amphibole 5%-20%, opaques 0-3%) are subject to varying degrees of alteration to amphibole gabbros or amphibole schists. The matrix is composed of mineral fragments in clay-sized matrix with calcite. The lower 5 cm of this section contained a single fragment of altered greenschist basalt.

Core 21, Section 1; Section 2, 0-73 cm

The matrix is pale to dark yellowish-orange. The clasts (3-15 cm), are composed largely of gabbros (plagioclase 45%-50%, clinopyroxene 30%-44%, orthopyroxene 0-10%, opaques 1-2%). The plagioclase crystals are tabular and occasionally show well-developed parallel orientation, suggestive of cumulate textures. Clinopyroxene crystals are interstitial, while orthopyroxene poikilitically enclose a smaller generation of plagioclase crystals. The clinopyroxene crystals are often partially or largely altered to actinolitic amphibole. Some fragments are sheared. A minor percentage of smaller clasts (1-2 cm) is composed of variolitic basalt, amphibole plagioclase schists, and gabbros that are thoroughly altered to amphibole schists. The matrix is composed of mineral fragments in a groundmass of clay-sized material with abundant calcite.

Core 21, Section 2, 73-86 cm

The matrix is dark to very dark reddish-brown. Clasts of quartz (15%), plagioclase (57%), clinopyroxene (20%), oxide (8%), diorite with well-defined schistose texture (quartz-diorite schist), occur in a groundmass of mineral fragments from diorite in a matrix of chlorite and serpentine.

Core 21, Section 2, 86-150 cm

The matrix is light greenish-gray. Clasts (1-4 cm) of coarse-grained gabbro (plagioclase 60%, clinopyroxene 30%, orthopyroxene 10%), showing tabular plagioclase with well-defined parallelism, large poikilitic orthopyroxene and interstitial clinopyroxene, present a cumulate texture. The matrix is composed of mineral fragments from gabbro clasts in a finer groundmass of clay minerals, chlorite, and minor amounts of calcite.

PHYSICAL PROPERTIES

Bulk Density, Porosity, and Water Content

Overall bulk-density values show a gradual increase (Figure 4) downhole reflecting the gradual consolidation of the sedimentary deposits; porosity values show a complimentary decrease, presumably for the same reasons. A sharp density contrast occurs at the basement contact, where sedimentary rocks (density 1.8-1.9) overlie altered basalt, and basaltic breccia (densities ca 2.6). Densities of individual pieces of basaltic breccia from Core 20, Section 1 range from 2.5 to 2.65 (average 2.60), showing agreement with sectional averages of basement density.

The syringe method of bulk-density and porosity measurements shows a wider scatter than similar data determined by the GRAPE method. This variance is to be expected in nonhomogeneous sediments, since the GRAPE measurements are sectional averages, whereas the syringe data are taken from a point. The downhole values for water content show a poorly defined inverse correlation with GRAPE bulk density (Figure 4).

Vane Shear

Seven vane-shear determinations were made. In general, shear strength increases downhole. The rather gross anomalous values may be due to inconsistencies in measuring technique, or weakening of the samples by drilling fluid. For further discussion, see Bouma and Moore (this volume).

Sonic Velocity

The low degree of consolidation of the sediments cored from the upper 250 meters (Cores 1-9) in Hole 293 prevented accurate sonic-velocity measurements. The sonic attenuation of these sediments is so great that the velocimeter signal was weak or undetectable when propagated through the 3-cm-thick core. The sediments could not be removed from the core liner for direct velocity measurements.

The sediments of Cores 10 to 18 are sufficiently consolidated for direct measurement of sonic velocities in any direction. Sonic-velocity measurements were focused on the detection of possible anisotropy. Two adjacent samples were slabbed parallel and perpendicular to bedding from Cores 10, 14, and 16. Five velocity measurements were made in the central regions of these slabs. Velocities taken parallel to bedding are 15% higher than those taken perpendicular to bedding in a lithified volcanic ash from Core 10. Semilithified clayey sediments of Cores 14 and 16 showed slightly higher velocities perpendicular to bedding, compared to values obtained parallel to bedding. However, significant overlap in the standard deviations of vertical and horizontal readings exist, and their differences may be due to technical error.

A claystone fragment from Core 17 was shaped into a cylindrical sample, approximately 5 cm in diameter and 15 cm long. Sonic-velocity measurements were repeated every 45° across the cylinder, parallel to bedding. Assuming reversible propagation of sound, four measurements were made at each of four locations: 0°, 45°, 90°, and 135° (compass directions are arbitrary since the core was unoriented):

Direction	Sonic Velocity
0°	1.790 ±0.012 km/sec
45°	1.779 ±0.008 km/sec
90°	1.785 ±0.013 km/sec
135°	1.779 ±0.007 km/sec

These data show no hint of horizontal anisotropy in sonic velocity. In Table 6, all the above-quoted values are averaged into one horizontal velocity.

Thermal Conductivity

Thermal-conductivity measurements were carried out mainly to test the instrumentation system. Apparently uniform and undisturbed core sections were selected, with four to five measurements being made on each section. Thermal-conductivity measurements varied up to

TABLE 6
Sonic-Velocity Measurements, Site 293

Sample (Interval in cm)	Hole Depth (m)	Sonic Velocity (km/sec)
8-1, 63	260.1	3.74[a,b] ±0.05
10-1, 140	298.9	1.69[c]
10-3, 133	301.8	3.17[b] ±0.03
10-3, 137	302.2	3.68[c] ±0.10
14-5, 5	417.5	1.68[c] ±0.02
14-5, 6	417.6	1.69[b] ±0.01
16-1, 82	469.3	1.75[b] ±0.02
16-1, 84	469.5	1.68[c] ±0.03
17-5, 142	504.4	1.78[c] ±0.01

[a]Pebble in volcanic ash.

[b]Measured in vertical direction.

[c]Measured in horizontal direction.

0.3×10^{-3} cal/cm sec°C around the mean for a given section (Table 7, Figure 7). Unhomogeneous lithologies, rather than technical errors, apparently account for these variations.

GEOCHEMICAL MEASUREMENTS

Alkalinity, *p*H, and salinity measurements are summarized in Table 8.

Alkalinity

The average alkalinity of the nine samples is 10.0 meg/kg. Seven of these values and the average are all above the surface seawater reference value of 2.59 meg/kg. The highest value (29.23) is found in Unit 1B (Core 2, Section 4) 94.5 meters below the sea floor. A rather sharp drop in values occurs between Cores 8 and 10 (13.29 to 7.72, respectively). Both cores contain a clay with silty to very silty interbeds representing Unit 1C.

pH

*p*H values were all below that of the seawater reference value at the site (8.3 to 8.2). The five punch-in *p*H values averaged 7.55, while nine flow-through values averaged 7.98. The *p*H trends with depth show: lower punch-in values compared to flow-through values from 94.5 to 384.5 meters, and a drop of 8.3 to 7.5 for flow-through *p*H from Core 15 to Core 17. Both cores are in Unit 1E, but Core 15 is a silty claystone, Core 17, a claystone.

Salinity

Nine salinity measurements from Hole 293 averaged 32.7‰. All values were lower than the overlying seawater reference value of 35.2‰. The trend of the salinity values is a general decrease with depth. The lower values occur in the claystones below 384 meters, matching the similar, low values for alkalinity and *p*H.

PALEONTOLOGIC SUMMARY

Introduction

A sedimentary sequence of silts, clays, thick turbidites, and mudstones of turbidity current origin were penetrated above a basaltic breccia and basalt at Site 293. The general paucity of calcareous microfossils suggests that deposition at this site has likely taken place below the calcium carbonate compensation depth

TABLE 7
Thermal Conductivities Measured at Site 293

Sample (Interval in cm)	Hole Depth (m)	Thermal Conductivity in 10^{-3} cal/cm sec°C		
		Needle Probe	Average	From Water Content
7-2, 144-150	89	–		2.30 ±0.14
7-6, 25	221	2.57		
7-6, 50		2.36	2.34	
7-6, 75		2.29		
7-6, 110		2.13		
12-0, 123-133	354			2.73 ±0.17
12-4, 23	360	2.60		
12-4, 50		2.70		
12-4, 75		2.20	2.42	
12-4, 106		2.39		
12-4, 136		2.22		
16-5, 8	476			2.62 ±0.17
16-5, 25		2.47		
16-5, 52		2.51		
16-5, 75		2.10	2.37	
16-5, 100		2.45		
16-5, 125		2.34		

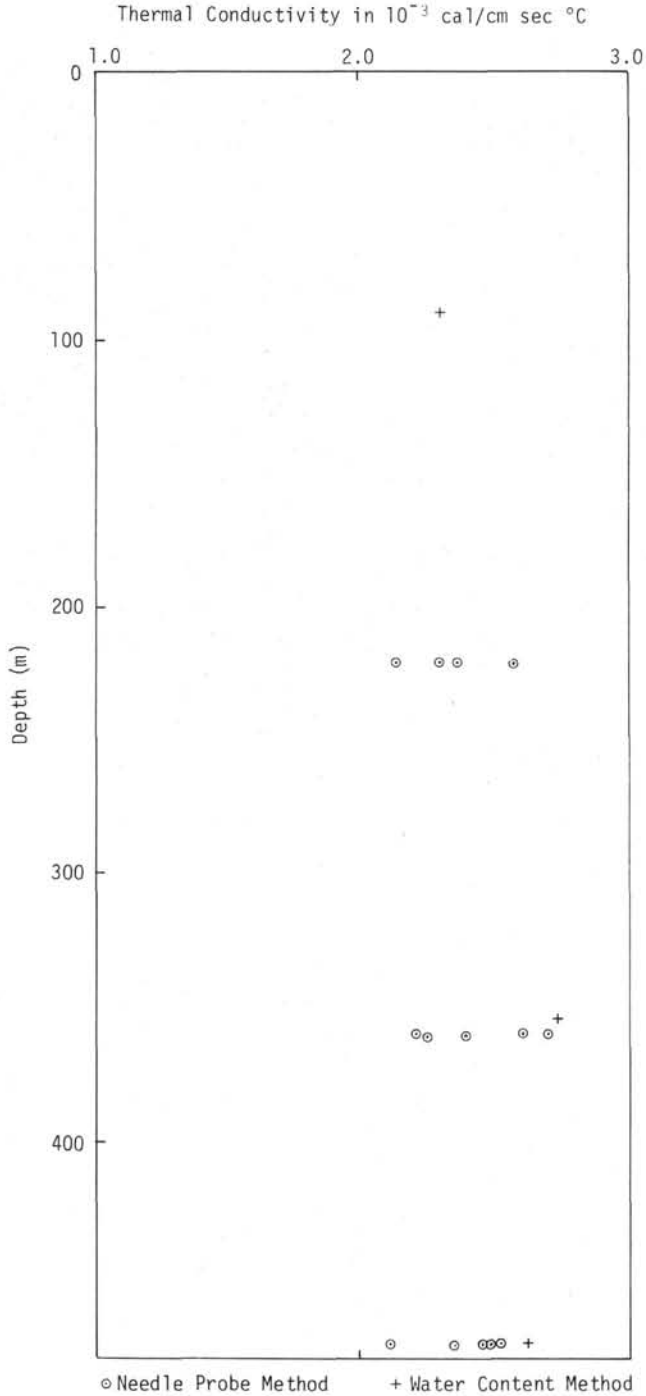


Figure 7. *Thermal-conductivity results, Site 293.*

throughout the time represented. Sparse planktonic foraminifera and calcareous nannofossils were used to recognize Pleistocene and late Pliocene sediments. Calcareous nannofossils provide evidence for a late middle Miocene to late Pliocene age for sediments associated with the basalt and basaltic breccia. Several of the samples studied were found to contain reworked foraminifera and nannofossils ranging in age from the Late Cretaceous to early Pliocene. Radiolarians, diatoms, and silicoflagellates are absent from all samples studied.

A silty sand unit encountered in Core 1 (3 m) contains Holocene(?)-late Pleistocene nannofossils and foraminifera. A sample from the turbidite sequence in Core 3 (106 m) contains Pleistocene nannofossils, and Cores 4, 8, and 9 (155-278.5 m) contain late Pliocene foraminifera and nannofossils.

A few chips of mudstone recovered from the liner of Sample 22, CC (554 m) contain late middle Eocene nannofossils which are interpreted as being a reworked flora. Nannofossils found in the basaltic beccia matrix of Core 20 (525 m) and in mudstone chips recovered from the liner of Sample 23, CC (563 m) are no older than late middle Miocene in age. Numerous other samples throughout the entire cored sequences contain reworked and displaced nannofossils and foraminifera, as clearly recorded by the abraded nature of some of the foraminifera.

Calcareous Nannofossils

The generally very poor state of preservation of the few calcareous nannofossils that were recovered suggests that deposition occurred well below the carbonate compensation depth. Rapid burial can probably best explain the several fairly well-preserved specimens which were recovered from the silty fraction of the turbidite sequence.

The sample from Core 1 contains a Holocene/Pleistocene *Gephyrocapsa* floral assemblage, in addition to reworked late Eocene species. Core 3, Section 5 also contains the Pleistocene genus *Gephyrocapsa*, and if *G. oceanica* (identification is questionable) is present, then this sample is of late Pleistocene age.

Samples from Cores 4 and 7 contain assemblages of indeterminant age. The recovery of *Ceratolithus cristatus* and *Discoaster brouweri* from Core 8, Section 2c and *C. cristatus* from Sample 9, CC places both of these samples in the late Pliocene.

Red claystone samples from immediately above the basaltic breccia in Core 18 contain the Eocene nannofossil species *Reticulofenestra umbilica* together with *Discoaster deflandrei*. A few sediment chips recovered from the liner of Sample 22, CC were found to contain the late middle Eocene nannofossil species *Sphenolithus radians* in association with *Reticulofenestra umbilica* and *Discoaster deflandrei*. The combined occurrence ranges of these three species provide evidence that they represent an age equivalent to the *Discoaster bifax* Subzone of the *Reticulofenestra umbilica* Zone. However, the preservation of this assemblage is extremely poor with the specimens either being badly corroded or heavily overgrown with calcium carbonate, and they occur in quite low abundance. The specimens found in Core 18 occur in small aggregates, giving the impression that they represent small fragments of nannofossil ooze incorporated into the claystone sediment. This, together with their poor state of preservation and the occurrence of younger specimens in samples lower in the section, provides evidence to interpret this assemblage as representing floral reworking into a younger sediment.

TABLE 8
Summary of Shipboard Geochemical Data, Site 293

Sample (Interval in cm)	Depth Below Sea Floor (m)	pH Punch-in	pH Flow-through	Alkalinity (meq/kg)	Salinity (°/₀₀)	Lithologic Unit
Surface seawater reference		8.27	8.18	2.59	35.2	
2-4, 144-150	94.5	7.52	7.85	29.23	34.1	
4-1, 144-150	147.0	7.49	7.84	24.63	33.0	Unit 1B
7-2, 144-150	215.0	7.40	8.00	14.08	33.3	
8-1, 144-150	261.0	–	7.94	13.29	32.4	
10-2, 144-150	301.0	7.70	7.99	7.72	33.0	Unit 1C
12-0, 123-133	354.5	–	8.19	4.69	31.9	
13-1, 144-150	384.5	7.65	8.24	2.75	33.0	
15-3, 144-150	444.5	–	8.32	1.66	31.9	Unit 1E
17-4, 144-150	503.0	–	7.46	1.47	31.6	
Average		7.55	7.98	10.05	32.7	

A sample of the basaltic breccia matrix from Core 20, Section 1 was found to contain *Discoaster brouweri* and *Reticulofenestra pseudoumbilica*. These species are known to range in age from the late middle Miocene to the late Pliocene. The recovery of *Discoaster pentaradiatus* from sediment chips found in the liner of Sample 23, CC further confirms a late middle Miocene to late Pliocene for this lower unit. The other nannofossil occurrences in remaining samples are interpreted as representing reworked assemblages.

Foraminifera

Both planktonic and benthonic foraminifera were recovered from samples of Cores 1 through 7 and Core 9. The fauna consists of very small specimens which occur only rarely in most cases. Sample 8-1, 15-30 cm and core-catcher samples from Cores 10-17 were found to contain small rods of aggregated framboidal pyrite suggesting anoxic bottom condition. This evidence, together with a depth below the carbonate compensation level, may explain the absence of foraminifera in samples below Core 9.

A sequence of graded fine-grained sands to clays immediately overlying a turbidite interval in Core 7, Section 2 was examined for foraminifera. Only the lower, or coarsest, of the four samples (Sample 7-1, 31-32 cm) was found to contain foraminifera. The assemblage consists of juvenile forms of planktonic specimens, and the shallow-water benthonic species *Ammonia beccarii*, *Elphidium* spp., and *Pseudononion japonicum* var. However, all of the specimens are of the same size as the sediment grains in which they occur, suggesting that they were transported along with the other clasts and do not represent a biocoenose.

Where mixed clay and fine-grained sand lithologies occur in faunally productive core-catcher samples, it is suspected that the foraminifera are a component of the sandy portion. Consequently, most of the foraminifera recovered from Site 293 samples are interpreted as being reworked. However, Sample 4, CC, containing *Globorotalia tosaensis*, *Globigerinoides obliquus*, *G. extremus*, *Globorotalia acostaensis humerosa*, and *Pulleniatina obliquiloculata praecursor*, is considered to contain an indigenous fauna of late Pliocene age which can be referred to Zone N21.

It was also noted that a reworked specimen of the Late Cretaceous taxa *Globotruncana* sp. was observed in Sample 1, CC, and the late middle Paleocene species *Globorotalia* sp. cf. *G. angulata* was recovered from Sample 12, CC. No previous occurrences of Paleocene planktonic foraminifera have been reported from the far western Pacific Ocean.

SUMMARY AND INTERPRETATIONS

Summary

Site 293 penetrated a 517-meter sequence of turbidites and mudstones overlying a tectonic breccia basement at the distal end of a sedimentary apron off the northeast flank of Luzon (Figures 2, 3, and 5). The section could not easily be divided into stratigraphic units because of the gradual and subtle transitions in lithology. As a first approximation, the upper 400 meters has been classified as a turbidite sequence, possibly overlain by a surficial contourite subunit, and the lower 117 meters as a pelagic to hemipelagic mudstone. The entire section above basement has been treated as one stratigraphic unit with five subunits (Figure 4).

Subunit 1A (0-20m) is represented by only a trace of sample in one core catcher, but is interpreted as a contourite sequence based on the effects of bottom currents on the beacon. The thickness is rather arbitrarily placed at 20 meters, and the age is Holocene with reworked fossils of late Eocene and Cretaceous age.

Subunit 1B (20-210 m) consists of a series of turbidites, generally of clay to fine sand range, but with some beds of coarse sand containing shell fragments. A terrigenous source is implied by the nature of the detrital grains and by reworked shallow-water benthonic foraminifera. This unit is mostly Pleistocene in age but may be late Pliocene near the base.

Subunit 1C (210-400 m) appears to be a distal turbidite sequence, finer grained than Subunit 1B and interbedded with green clay which is possibly pelagic or hemipelagic. The age is late Pliocene. A reworked Paleocene planktonic foraminifer documents redeposition within this unit. Estimated sedimentation rates (Figure 8) demonstrate these younger units were deposited at twice the rate of underlying Miocene sediments.

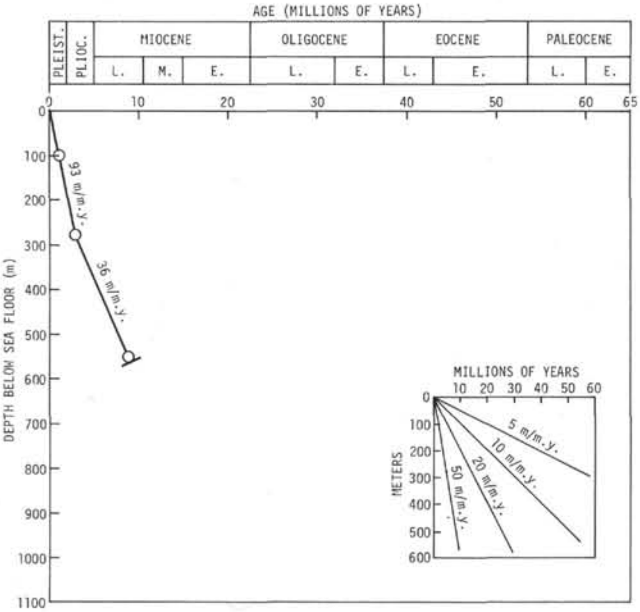


Figure 8. *Estimated rate of sedimentation of Site 293 based on calcareous nannofossil zonation (Ellis, this volume) and time scale of Berggren (1972).*

Subunit 1D (400-478 m) is a multicolored blue-gray, olive-gray, and yellow-brown clay with laminated to homogeneous structure, possibly representing a preturbidite sequence. In all likelihood this unit is terrigenous in origin. It is apparently barren of age-diagnostic fossils.

Subunit 1E (478-517 m) consists of red to brown claystone, probably pelagic in origin, but possibly redeposited in part, as suggested by clusters of late middle Eocene nannofossils. A number of ash beds are also present in this unit. It also lacks diagnostic fossils.

Unit 2, in which the hole bottomed, is a breccia, comprised of igneous rocks ranging from metabasalt to quartz dioritic gneiss. The altered basalt intervals could be flows or large breecia fragments. This lithology could best be interpreted as a fault breccia, but must have slid slightly downhill to incorporate a few late middle Miocene to late Pliocene discoasters. The thickness is unknown, but extends at least from 517 meters to total depth at 563.5 meters.

Interpretations

Although Site 293 was drilled very close to, or perhaps within, the northwestern extension of the Central Basin Fault zone, the abbreviated site survey (Figure 3) indicated that only north-northeast-trending basement structures were present in the area. The crossing of the two *Oceanographer* tracks initially suggested several northwesterly trending troughs. However, the water depths at the track crossing differed by more than 200 meters on the smoothly sloping apron, indicating a serious position error. After the leg 1 *Oceanographer* track was adjusted on the basis of an anomalous velocity interval, the trends near the crossing also became northerly. Post-cruise studies revealed that there were no northwesterly trends due to the Central Basin Fault zone anywhere in the apron area (Karig and Wageman, this volume).

The age of the basement in the area near Site 293 is very likely different than the age of the basement topography. No in situ basaltic material was obtained in the hole, but apparently reworked pelagic sediments above the breccia and the small clots of redeposited nannofossils with ages as old as late Eocene point to a nearby basement of at least that age. A pelagic sequence beneath the apron sediments on some of the basement ridge flanks (Figure 2) but not on others, including the one drilled, can most reasonably be interpreted as a result of faulting and disruption of the basin crust after much of the pelagic cover had been deposited. Because the apron sediments are not faulted (see Figure 4 and Karig and Wageman, this volume), this disruption would have taken place before pelagic sedimentation ceased. The source of the reworked pelagics at Site 293 is most probably the crest of the adjacent ridge, and if so, the local basement would also be late Eocene or older.

The brecciated and metamorphosed igneous rocks at the base of Site 293 imply significant faulting of oceanic basement material. The presence of some of high greenschist to low amphibolite facies rocks obtained at the ocean floor indicates a large but unknown amount of vertical displacement.

Most or all of the metamorphic rocks are constituents of oceanic or marginal basin crust. Although the metadiorites could be attributed to arc activity instead of basaltic differentiation, there is no other evidence suggesting an arc origin.

Inclusion of mid-Miocene to late Pliocene nannofossils in the breccia matrix places an upper limit on the surficial remobilization of the mass, but the faulting may have taken place much earlier. Post-cruise investigations (Karig and Wageman, this volume) suggest that faulting took place in the mid-Tertiary, after accumulation of a partial pelagic cover and before the formation of the apron.

The apron sediments near Site 293 vary from 0 to more than a kilometer in thickness because of the great basement relief, but generally thin to the north and east. Water depths exceed 5.5 km and judging from the noncalcareous nature of the apron sediment column, the basin floor has been below the local CCD since apron initiation.

Extensive survey tracks demonstrate that this apron has been fed by submarine canyons off north and east Luzon (Karig, 1973; Karig and Wageman, this volume), and presently receives most of its material from the Cagayan River and submarine canyon. Analysis of these profiles indicates that previous feeder systems lie to the south of the active channel and they represent earlier drainage of the Cagayan system across the rising Sierra Madre Range (Karig and Wageman, this volume).

On the reflection profiles near Site 293 (Figures 2, 3, and 4), and in most other parts of the apron, the apron sediments are highly reflective near the top and become more transparent downward. Sonobuoy and underway reflection measurements at Site 293, show this upper reflective zone to be about 0.33 sec thick, with an ill-defined transition to transparent sediments beneath.

Very roughly this corresponds to the lithologic transition from sand- and silt-rich turbidites to clay-rich turbidites between 200 and 300 meters.

One question arising from the site and hole data is whether the lower mud-rich section represents general deposition of fine-grained terrigenous sediment over the entire apron, or pre-turbidite deposits, preceding the growth of the turbidite apron. Both piston cores (Laii and Sanko, 1969) and the *Glomar Challenger* profile leaving the site (Figure 4) show that the pelagic sediment deposited just beyond the turbidites are thicker and have a higher silt content than do the brown clays in the center of the Philippine Basin. However, this accounts for a thickening of only a hundred meters or so, and in many of the basement troughs the lower transparent unit of the apron reaches thicknesses exceeding 500 meters. Moreover, reflection profiles across the entire apron show that the upper reflective unit remains about the same thickness and that the transparent unit has a turbidite type geometry in contrast to the thickened pelagics beneath turbides at the edge of the apron. It is more likely that the transition to coarser and more highly reflective apron sediments reflects the marked uplift of Luzon, and resultant enhanced erosion. The late Pliocene date of this transition obtained at Site 293 is identical to the date of uplift obtained by work on Luzon (Christian, 1964; Durkee and Pederson, 1961). The deeper lutite section would then represent the period of time after the trench off eastern Luzon ceased to act as a sediment trap (Karig and Wageman, this volume), and before this pronounced uplift.

Reworked pelagic and benthonic foraminifera in the Pliocene-Recent turbidites, of ages as old as Late Cretaceous, probably come from either Luzon or the Palaui Ridge. Erosion of the presently active submarine canyon into the presumably sedimentary Palaui Ridge may have produced some of these reworked foraminifera. In any case there must have been reasonably deep basins of Late Cretaceous age in the region, possibly now represented as deformed material in an old subduction zone.

REFERENCES

Ben Avraham, Z., Bowin, C., and Segawa, T. 1972. An extinct spreading centre in the Philippine Sea: Naure, v. 240, p. 453-455.

Berggren, W., 1972. A Cenozoic time-scale—some implications for regional geology and paleobiogeography: Lethaia, v. 5, p. 195-215.

Bouma, A.H., 1972. Recent and ancient turbidites and contourites: Gulf Coast Assoc. Geol. Soc. Trans., v. 22, p. 205-221.

_______, 1973. Leveed-channel deposits, turbidites, and contourites in deeper part of Gulf of Mexico: Gulf Coast Assoc. Geol. Soc. Trans., v. 23, p. 368-376.

Bouma, A.H. and Hollister, C.D., 1973. Deep ocean basin sedimentation. *In* Middleton, G.V. and Bouma, A.H. (Cochairmen), Turbidites and deep-water sedimentation: Short course notes Pacific section, SEPM, Anaheim, California, p. 79-118.

Christian, L.B., 1964. Post Oligocene tectonic history of the Cagayan basin, Philippines: Philippine Geol., v. 18, p. 114-147.

Durkee, E.F. and Pederson, S.L., 1961. Geology of Northern Luzon, Philippines: Am. Assoc. Petrol. Geol. Bull., v. 45, p. 137-168.

Karig, D.E., 1973. Plate convergence between the Philippines and the Ryukyu Islands: Marine Geol., v. 14, p. 153-168.

Laii, C. and Sanko, P., 1969. Core analysis and bottom photographs: Marine geophysical survey program 65-67; Area 13, v. 5: Washington (U.S. Naval Oceanographic Office

Udintsev, G.B., 1971. Taiwan-Aiante fault zone as the oldest rift: Pacific Science Congress, 12th, Record of Proc., v. 1, p. 356.

APPENDIX A
Summary of X-Ray, Grain Size, and Carbon-Carbonate Results, Site 293

Section	Sample Depth Below Sea Floor (m)	Lithology	Age	Bulk Sample[a] Major Constituent			2-20µ Fraction (c) Major Constituent			<2µ Fraction (c) Major Constituent			Grain Size			Classification	Carbon Carbonate			Comments
				1	2	3	1	2	3	1	2	3	Sand (%)	Silt (%)	Clay (%)		Total (%)	Organic (%)	CaCo3 (%)	
		Unit 1A Dark Brown Sandy silt	Pleist.- Holocene		Not Sampled for X-Ray, Grain Size or Carbon-Carbonate															
293-2-2	91.3-91.4	Unit 1B	Late	Plag.	Mont.	Quar.	Plag.	Quar.	Mica	Mont.	Plag.	Mica	57.3	16.5	26.2	Clayey Sand	0.3	0.2	0	Amph. in Bulk (2.8%), 2-20µm (2.6%)
293-2-5	94.8	Clay with	Pliocene (?)										11.7	79.3	8.9	Silt				Clin. in 2-20µm and <2µm (2.1%)
293-2-5	95.0	Sandy Silt	–										1.5	86.8	11.7	Silt				
293-2-5	95.1	and Silt	Pleistocene										18.4	73.8	7.8	Sandy Silt				
293-2-5	95.1	Intercalations											1.6	50.8	47.6	Clayey Silt				
293-3-5	105.0																0.4	0.4	1	
293-4-2	147.8			Plag.	Quar.	Mica	Plag.	Quar.	Mica	Mont.	Plag.	Mica	1.1	48.4	50.6	Silty Clay				Amph. in Bulk (5.5%); 2-20µm (4.0%)
293-5-4	160.8			Plag.	Quar.	Mont.	Plag.	Quar.	Pyri.	Mont.	Plag.	Quar.	2.3	75.3	22.3	Silt				Clin. in 2-20µm (1.5%), <2µm (1.4%)
293-6-2	204.3												9.1	69.1	21.9	Clayey Silt				Clin.,Pyri., Amph. in Bulk, 2-20µm
293-6-2	205.0												0.0	43.3	56.7	Silty Clay				Pyri., in <2µm (2.1%)
293-8-2	261.8	Unit 1C	Late	Plag.	Quar.	Mont.	Plag.	Quar.	Mont.	Mont.	Plag.	Quar.	0.1	37.5	62.3	Silty Clay	0.2	0.2	0	Clin., Amph. in Bulk; Amph in 2-20µm
293-9-6	277.5	Clay with	Pliocene	Plag.	Mont.	Quar.	Plag.	Quar.	Mont.	Mont.	Mica	Plag.								Clin. in <2µm
293-9-6	277.6	Silty and very	269 to	Plag.	Quar.	Mont.	Plag.	Quar.	Mont.	Mont.	Plag.	Quar.								Clin., Amph., in Bulk, 2-20µm
293-10-2	299.7	Silty Clay	278 meters										0.4	75.0	24.6	Clayey Silt				Clin. in <2µm
293-10-3	300.9	Intercalations															0.7	0.6	1	Clin., Amph. in Bulk, 2-20µm, Clin. in <2µm
293-15-1	440.3	Unit 1D	?	Plag.	Quar.	Mica	Quar.	Mica	Plag.	Mont.	Mica	Quar.	0.5	27.7	71.8	Silty Clay				
293-15-1	441.0	Grayish		Phil.	Mont.	Plag.	Phil.	Plag.	Mont.	Mont.	Phil.	Plag.	0.9	48.6	50.5	Silty Clay	0.6	0.1	4	Clin. in 2-20µm (1.0%)
293-15-1	441.3	Mudstone		Plag.	Mont.	Quar.	Plag.	Quar.	Mica	Mont.	Mica	Quar.	0.2	23.2	76.6	Clay	0.1	0.1	0	Clin. in Bulk, (1.3%), 2-20µm (1.1%)
293-15-7	449.0																0.2*	0.0*	2*	*Second Sample = 0.1, 0.1, 0
293-16-3	472.3			Mont.	Mica	Quar.	Mica	Quar.	Plag.	Mont.	Mica	Quar.	0.1	11.1	88.8	Clay				
293-17-2	499.3	Unit 1E	?	Mont.	K-Fe.	Mica	Mont.	K-Fe.	Quar.	Mont.	K-Fe.	Quar.								
293-17-3	500.8-500.9	Reddish											0.3	10.4	89.3	Clay	0.1	0.1	0	Goet. abund. (25-65%) in Bulk, 2-20µm and
293-18-1	516.6	brown		K-Fe.	Mica	Mont.	K-Fe.	Quar.	Plag.	Mont.	Quar.	K-Fe.	0.2	18.5	81.3	Clay				<2µm
		mudstone																		

Note: Complete results of X-Ray, Site 293, will be found in Part V, Appendix I. X-ray mineralogical legend on Appendix A, Chapter 2. U-1 Peaks at 9.46Å, 4.16Å, and 2.705Å in Bulk and 2-20µm; trace reported for Sections 293-2-2, 4-2, 5-4, 8-2, 9-6, 9-6.

[a]Two plagioclases were combined for Sections 293-2-2, 4-2, 5-4, 9-6, 15-1 (440.3) and 15-1 (441.3).

Site 293 Hole Core 1 Cored Interval: 0.0-3.0 m

AGE	ZONE	FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
PLEISTOCENE/HOLOCENE	N23	Rq	Fp	B		Core Catcher				CC *	Subunit 1A 5YR 4/1

Color brownish gray (5YR 4/1); material caught between liners of punch core.

VOLCANIC SAND-RICH SILT
Smear: CC

Texture	Composition
80% Silt	40% Feldspar
18% Sand	30% Heavy minerals
2% Clay	20% Opaques
	9% Volcanic glass
	1% Foraminifera
	Tr% Nannofossils

Foraminifera are redeposited; heavy minerals include: green and brown (basaltic) hornblende, chlorite, and pyroxene.

Explanatory notes in chapter 1

Site 293 Hole Core 2 Cored Interval: 88.5-98.0 m

AGE	ZONE	FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
						1	0.5, 1.0	VOID		
						2				* 140
						3		VOID		
						4		GEOCHEM AND CONSOLIDAT. SAMPLES		
						5				* 59
		Fg	B	B		Core Catcher				* CC

LITHOLOGIC DESCRIPTION

Subunit 1B

Core dominately dark gray (N3) to medium dark gray (N4); soupy in Sections 1-4 to firm with slight to intense deformation in Section 5; some dark greenish gray areas (5G 4/1 - 5GY 3/1) in Section 5; burrowing(?) or mottling in Section 5.

N3 + N4

CLAYEY SAND
Smear: 2-140

Texture	Composition
57% Sand	40% Feldspar
26% Clay	32% Clay minerals
17% Silt	18% Quartz
	5% Heavy minerals
	5% Opaques
	Tr% Nannofossils

Heavy minerals mainly amphibole; sand-bearing in Sections 1, 2, 3, and 4.

SANDY SILT (Minor Lith)
Smear: 5-59

Texture	Composition
74% Silt	35% Volcanic lithics
18% Sand	15% Feldspar
8% Clay	15% Heavy minerals
	12% Quartz
	11% Clay minerals
	7% Opaques
	5% Glauconite

Clayey silt / Silty clay — contact

Indistinct graded bedding; amphiboles are the common heavy mineral; some gradation to silty sand.

N3-N4

CLAYEY SILT
Smear: CC

Texture	Composition
50% Silt	45% Feldspar
40% Clay	15% Clay minerals
10% Sand	10% Quartz
	10% Heavy minerals
	10% Opaques
	Tr% Nannofossils

5GY 4/1

5G 4/1 +

Grain Size 2-140
57.3, 16.5, 26.2
Grain Size 5-47
1.5, 86.8, 11.7
Grain Size 5-64
1.6, 50.8, 47.6

Grain Size 5-27
11.7, 79.3, 8.9
Grain Size 5-59
18.4, 73.8, 7.8

N3 + N4

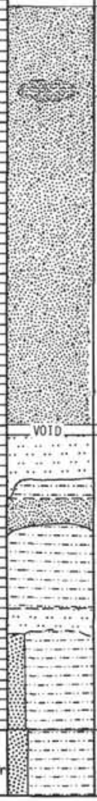
Carbon Carbonate 2-142
0.3, 0.2, 0

X-ray 2-135 (Bulk)
39.4% Plag
20.2% Mont
18.5% Quar
14.1% Mica
3.6% Chlo
2.8% Amph
1.4% Calc

Explanatory notes in chapter 1

Site 293 Hole Core 3 Cored Interval: 98.0-107.5 m

AGE	ZONE	FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE		LITHOLOGIC DESCRIPTION
PLEISTOCENE	Gephyrocapsa caribbeanica or G. oceanica?					1	0.5, 1.0	VOID	o		5GY 4/1	Color dark greenish gray (5GY 4/1); drilling breccia - to Section 4 with a great deal of mixing; deformation moderate through Section 5; turbidite bedding in Section 4 (68-105 cm).
									o		5GY 6/1	
						2			o		5GY 4/1	
						3			o			
			B			4		VOID		* 68	5GY 4/1	
			B									
			Rp			5				* 80	5YR 4/1	
											5GY 4/1	
		Rm		B		Core Catcher				CC *	5GY 4/1	



SILTY SAND

SANDY SILT
Smear: 4-68

Texture	Composition
65% Silt	25% Volcanic lithics or devitrified volcanics
30% Sand	20% Heavy minerals
5% Clay	17% Feldspar
	15% Glauconite
	10% Opaques
	8% Quartz
	5% Clay minerals

SAND-RICH, SILTY CLAY (Minor Lith)
Smears: 5-80, CC

Texture	Composition
55% Clay	25-35% Clay minerals
30% Silt	25-35% Quartz
15% Sand	15-20% Feldspar
	10-25% Heavy minerals
	10% Opaques
	10% Lithics
	5% Volcanic glass
	Tr% Glauconite
	Tr% Micrite

Carbon Carbonate 5-100
0.4, 0.4, 1

Explanatory notes in chapter 1

Site 293 Hole Core 4 Cored Interval: 145.5-155.0 m

AGE	ZONE	FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE		LITHOLOGIC DESCRIPTION
LATE PLIOCENE	N21					1	0.5, 1.0	VOID	o	87 *	5GY 4/1 with 5Y 2/1	Color generally dark greenish gray (5GY 4/1) with thin bands of olive black (5Y 2/1); deformation slight to intense; turbidite bedding - Section 1 (118-130 cm), Section 2.
								GEOCHEM SAMPLE				
			Rp B Rp			2			|	* 88 93 * 137 *	5GY 4/1	
		Ag		B		Core Catcher				CC *		

VOLCANIC-RICH SILTY CLAY
Smears: 1-87, 2-93

Texture	Composition
60% Clay	65% Clay minerals
35% Silt	13-25% Volcanic glass (devit.)
5% Sand	8-10% Heavy minerals
	6-10% Feldspar
	4- 5% Opaques
	Tr% Sponge spicules

VOLCANIC SILTY CLAY
Smear: 2-88

Texture	Composition
51% Clay	50% Feldspar
48% Silt	18% Quartz
1% Sand	10% Clay minerals
	10% Volcanic glass
	5% Heavy minerals
	5% Opaques

Heavy minerals: amphibole, chlorite.

CLAY-RICH SILTY SAND (Minor Lith)
Smear: 2-137

Texture	Composition
50% Sand	50% Heavy minerals
30% Silt	33% Feldspar
20% Clay	10% Micarb
	5% Nannofossils
	2% Volcanic glass

Heavy minerals include: brown and green hornblende, hypersthene and chlorite.

CLAY-RICH SANDY SILT (Minor Lith)
Smear: CC

Texture	Composition
55% Silt	25% Clay minerals
30% Sand	25% Feldspar
15% Clay	17% Quartz
	15% Heavy minerals
	12% Lithics
	5% Opaques
	1% Glauconite, micarb

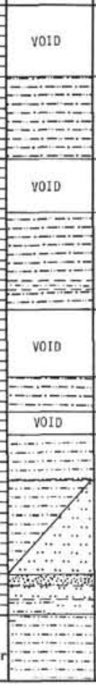
Grain Size 2-81
1.1, 48.4, 50.6

X-ray 2-77 (Bulk)
48.8% Plag
17.8% Quar
15.6% Mica
9.6% Mont
5.5% Amph
2.8% Chlo

Explanatory notes in chapter 1

Site 293 Hole Core 5 Cored Interval: 155.0-164.5 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
						1	0.5, 1.0	VOID	o o o o		5GY 4/1
						2		VOID	o o o o o o o		5GY 4/1
						3		VOID, VOID	| |		5GY 4/1
			B			4			| | | | |	* 117 129 *	5GY 4/1
		Rm		B		Core Catcher				CC *	5GY 4/1



Color dominantly dark greenish gray (5GY 4/1); drilling breccia to Section 3 represents mixture of a turbidite sequence; good turbidite sequence in Section 4.

SANDY SILT
Smear: 4-117

Texture	Composition
50% Silt	50% Heavy minerals
40% Sand	42% Feldspar
10% Clay	5% Volcanic glass
	2% Nannofossils
	1% Sponge spicules

Heavy minerals: brown-green hornblende (50), hypersthene (5), chlorite (5), opaques (15).

CLAY-RICH SILT
Smear: 4-129

Texture	Composition
75% Silt	30% Feldspar
23% Clay	20-30% Heavy minerals
2% Sand	13% Clay minerals
	5% Zeolite
	3% Palagonite
	2% Volcanic glass
	2% Nannofossils

Clayey silt - CC with 55% Silt, 45% Clay, 45% Clay minerals and 22% Volcanic glass.

Grain Size 4-133
2.3, 75.3, 22.3

X-ray 4-128 (Bulk)
50.5% Plag
22.5% Quar
12.9% Mont
4.2% Pyri
4.1% Clin
3.6% Amph
2.2% Chlo

Explanatory notes in chapter 1

Site 293 Hole Core 6 Cored Interval: 202.5-212.0 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
						1	0.5, 1.0		o o o o o o		5GY 4/1
						2			| | | | |	* 100 * 133	
		B	B	B		Core Catcher					

Color dark greenish gray (5GY 4/1) deformation drilling breccia - slight; turbidite sequence in Section 2, starting at 121 cm (distal).

SILTY CLAY
Smear: 2-100

Texture	Composition
50% Clay	55% Clay minerals
45% Silt	15% Feldspar
5% Sand	8% Quartz
	5% Heavy minerals
	5% Opaques
	2% Volcanic glass
	Tr% Nannofossils

SAND-RICH SILT (Minor Lith)
Smear: 2-133

Texture	Composition
80% Silt	50% Feldspar
15% Sand	30% Heavy minerals
5% Clay	10% Palagonite
	5% Volcanic glass

Heavies include: brown hornblende (5), green hornblende (30), chlorite (50), opaques (15).

Grain Size 2-25.5 (Sand bleb)
9.1, 69.1, 21.9

Grain Size 2-100 (Dom. Lithology)
0.0, 43.3, 56.7

Explanatory notes in chapter 1

Site 293 Hole Core 7 Cored Interval: 212.0-221.5 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE		LITHOLOGIC DESCRIPTION
						1	0.5, 1.0	VOID		*31	5GY 4/1	
		B B B Rg	B B B B			2		GEOCHEM SAMPLE		*25, *83, 105*	5GY 4/1; Subunit 1C	
						3		VOID		*59	5GY 4/1	
						4					5GY 4/1	
						5		VOID				
						6		VOID			5GY 4/1; 5GY 4/1	
		Rg	Rp	B		Core Catcher					5Y 2/1	

Core dark greenish gray (5GY 4/1) with varied colored (0.5-3 cm) interbeds of massive clay - silty clay and clayey silt; prominant 0-45 cm (Section 1); in Sections 2, 3, 4 and 6.

SILTY CLAY
Smears: 3-59, 6-59

Texture	Composition
48% Clay	19-40% Clay minerals
40% Silt	20-30% Feldspar
2% Sand	20-25% Zeolite
	10-20% Heavy minerals
	1- 5% Volcanic glass

SILT-RICH CLAY
Smear: 2-25

Texture	Composition
80% Clay	45% Clay minerals
18% Silt	20% Zeolites
2% Sand	20% Quartz
	10% Heavy minerals
	5% Volcanic glass

SANDY SILT (Minor Lith)
Smear: 2-105

Texture	Composition
70% Silt	30% Feldspar
25% Sand	25% Heavy minerals
5% Clay	25% Volcanic glass
	15% Zeolite
	5% Palagonite

Heavy minerals include: green hornblende (10), brown hornblende (25), chlorite (50), pyroxene (5).

CLAY-RICH SILT (Minor Lith)
Smear: 3-45

Texture	Composition
79% Silt	35% Clay minerals
20% Clay	25% Feldspar
1% Sand	20% Heavy minerals
	15% Zeolite
	5% Volcanic glass

Heavy minerals: 80% chlorite, 20% hornblende.

VOLCANIC ASH (Minor Lith)
Smears: 1-31, 2-83

Texture	Composition
90% Silt	82% Volcanic glass
5% Sand	8% Feldspar
5% Clay	5% Heavy minerals
	5% Palagonite

Explanatory notes in chapter 1

Site 293 Hole Core 8 Cored Interval: 259.5-269.0 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE		LITHOLOGIC DESCRIPTION
LATE PLIOCENE	Discoaster brouweri					1	0.5, 1.0	VOID; GEOCHEM SAMPLE			N4	
			Rp			2				*78, *101	N4; 10Y 6/2	
		B	B	B		Core Catcher						

Color medium dark gray (N4); drilling breccia in Sections 1-2, to intense deformation at bottom of Section 2.

SILTY CLAY
Smear: 2-78

Texture	Composition
62% Sand	53% Clay minerals
38% Silt	40% Feldspar
	3% Heavy minerals
	3% Opaques
	1% Volcanic glass

NANNOFOSSIL SILTY CLAY (Minor Lith)
Smear: 2-101

Texture	Composition
70% Clay	30% Clay minerals
25% Silt	25% Auth. carbonate
5% Sand	25% Nannofossils
	10% Feldspar
	10% Heavy minerals

Grain Size 2-77
0.1, 37.5, 62.3

Carbon Carbonate 2-77
0.2, 0.2, 0

X-ray 2-77 (Bulk)
38.7% Plag
21.6% Quar
21.5% Mont
5.9% Chlo
5.4% Clin
5.3% Mica
1.6% Amph

Explanatory notes in chapter 1

Site 293 Hole Core 9 Cored Interval: 269.0-278.5 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS		OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE						1	0.5, 1.0	VOID			
						2					
						3				*30	
						4		VOID			
						5					
						6				*23, *31, *35, *38	
	Discoaster brouweri	Rm	Fg		B	Core Catcher				CC *	

Generally a medium dark gray (N4) with minor purple-blue hues throughout i.e. green (5GY 4/1) purple (5P 3/2) with purple-green (5YR 3/1); *Clay bedding:
1) green: hard - 1-3 cm thick } vague contacts
2) purple: clay-crumbly } between (cyclicity)
3) purple-green: silty, decrease upward = base cycle

CLAY
Smear: 3-30

Texture	Composition
82% Clay	64% Clay minerals
10% Silt	20% Feldspar
8% Sand	9% Auth. Carbonate
	5% Heavy minerals
	1% Quartz
	1% Opaques

N4 (with variations noted above)

SILT-RICH CLAY
Smears: 6-23, 6-35, 6-38

Texture	Composition
75-80% Clay	45-70% Clay minerals
15-25% Silt	25-30% Feldspar
0- 5% Sand	12-20% Quartz
	2- 5% Heavy minerals
	2% Opaques
	1- 2% Zeolite
	1% Auth. carbonate
	Tr% Nannofossils

5GY 4/1

SILTY CLAY
Smears: 6-31, CC

Texture	Composition
50-70% Clay	33-55% Clay minerals
30-40% Silt	25-35% Feldspar
0-10% Sand	5-20% Heavy minerals
	17-20% Quartz
	2- 5% Opaques
	2- 5% Zeolites
	1% Volcanic glass

X-ray 6-105 (Bulk) (purple clay)
33.8% Plag
23.9% Mont
22.2% Quar
8.6% Mica
6.5% Chlo
3.3% Clin
1.8% Amph

N4 (with variations noted above)

X-ray 6-110 (Bulk) (green clay)
50.5% Plag
22.0% Quar
17.3% Mont
4.2% Clin
2.6% Mica
2.1% Chlo
1.3% Amph

N4 (with variations noted above)

5Y 2/1

Explanatory notes in chapter 1

Site 293 Hole Core 10 Cored Interval: 297.5-307.0 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
						1	0.5, 1.0	VOID		*132	
						2		GEOCHEM SAMPLE		*70	
						3					
		B	Rp	B		Core Catcher				CC *	

Dominate color dark green gray (5GY 4/1); slight deformation; some burrowing; layering noted as follows:
1) (5Y 2/1) olive black-purple=silty clay=hemipelagic
2) (5GY 4/1) dark green gray=silty clay distal
3) (5Y 3/1) olive gray-black=clayey silt turbidite
Above interbedded (2-5 cm) thick sequences.

5GY 4/1 – 5GY 5/1

CLAYEY SILT
Smear: 2-70

Texture	Composition
75% Silt	65% Clay minerals
25% Clay	20% Feldspar
	10% Heavy minerals
	5% Quartz

5GY 4/1 with interbeds

VOLCANIC ASH (Minor Lith)
Smear: 1-132

Texture	Composition
90% Clay	90% Devit. ash
10% Silt	6% Feldspar
	2% Opaques
	2% Heavy minerals

5GY 4/1 with interbeds

CLAY (Minor Lith)
Smear: CC

Texture	Composition
85% Clay	60% Clay minerals
10% Silt	15% Feldspar
5% Sand	10% Fe-oxides
	5% Quartz
	3% Heavy minerals
	2% Opaques

5Y 2/1

Grain Size 2-69
0.4, 75.0, 24.6

Carbon Carbonate 3-44
0.7, 0.6, 1

Explanatory notes in chapter 1

Site 293 Hole Core 11 Cored Interval: 326.0-335.5 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
						1	0.5 / 1.0	VOID		*125 *138	5GY 4/1
		B	B	B		Core Catcher				CC *	5Y 2/1 to 5GY 2/1

Color dark greenish gray (5GY 4/1); slight drilling deformation.

SILTY CLAY
Smear: 1-138

Texture	Composition
60% Clay	60% Clay minerals
40% Silt	15% Feldspar
	10% Quartz
	10% Heavy minerals
	5% Opaques

VOLCANIC ASH (Minor Lith)
Smear: 1-125

Texture	Composition
90% Clay	94% Volcanic glass (Devit.)
6% Silt	2% Opaques
4% Sand	2% Feldspar
	1% Heavy minerals
	1% Quartz

CLAY
Smear: CC

Texture	Composition
81% Clay	83% Clay minerals
12% Silt	8% Feldspar
7% Sand	5% Opaques
	2% Quartz
	2% Heavy minerals

Explanatory notes in chapter 1

Site 293 Hole Core 12 Cored Interval: 354.5-364.0 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
						1	0.5 / 1.0			* *101 *105 *108	
						2					
						3					5GY 4/1
						4					cycle colors - 5GY 4/1
						5		VOID			cycle colors - 5GY 4/1
						6		VOID			
		Rp	Rp	B		Core Catcher					5GY 4/1

Color variation of cyclic sedimentation; slight drilling deformation:

Cycle:
- distinct contact
- green clay
- indistinct contact
- 2-5 cm purple brown-silty clay
- visible contact
- 0.5-4 cm purple gray-clayey silt (graded)
- distinct contact
- 2-5 cm green clay

cycle colors: Basic color dark green gray (5GY 4/1).

SILTY CLAY
Smear: 1-101

Texture	Composition
70% Clay	35% Clay minerals
27% Silt	25% Zeolite
3% Sand	20% Heavy minerals
	15% Quartz
	4% Palagonite
	1% Volcanic glass

Heavy minerals: chlorite (70), amphibole (20), opaques (10).

SILTY CLAY
Smears: 1-105, 1-108

Texture	Composition
55-60% Clay	20-30% Heavy minerals
40-45% Silt	40% Feldspar
5-15% Sand	12-25% Clay minerals
	5% Zeolite
	5% Auth. carbonate
	2- 3% Nannofossils
	0- 3% Palagonite
	0- 2% Glass

Heavy minerals: chlorite (60-75), amphibole (5-30), opaques (10-20).

Explanatory notes in chapter 1

Site 293 Hole Core 13 Cored Interval: 383.0-392.5 m

AGE	ZONE	FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
						1	0.5 1.0	VOID GEOCHEM SAMPLE			Color variations: green, purple brown, green. Purple gray = cyclic with green black (5G 2/1) as basic color. Drilling deformation breccia to slight. SILTY CLAY cycle colors
						2		VOID	O O O O		var. colors of cycle 5G 2/1
		B	Rp	B		Core Catcher					5G 2/1

Site 293 Hole Core 14 Cored Interval: 411.5-421.0 m

AGE	ZONE	FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
						1	0.5 1.0	VOID	O O O	* 123	Subunit 1D Generally olive gray (5Y 3/2) with cyclic colors as noted; drilling breccia: approaching claystone induration. SILT-RICH CLAY Smear: 1-123 Texture: 72% Clay, 18% Silt, 10% Sand Composition: 72% Clay minerals, 18% Feldspar, 7% Heavy minerals, 3% Opaques, Tr% Nannofossils 5Y 3/2
		B	B	B		Core Catcher					5Y 2/1

Explanatory notes in chapter 1

Site 293 Hole Core 15 Cored Interval: 440.0-449.5 m

AGE	ZONE	FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
			B B			1	0.5 1.0			* 33 * 103 130 *	5B 4/1 and 5Y 5/1 10YR 5/4 + + scattered green spotting +
						2				* 145	5Y 5/1
			B			3		GEOCHEM SAMPLE		* 90	10YR 5/4 5BG 4/2
			B			4					5GY 4/1 graded beds D-E sequence
		B	B	B		Core Catcher					

Colors variable-bluish gray (5B 4/1), olive gray (5Y 5/1), with areas moderate yellow brown (10YR 5/4), dark green gray (5GY 4/1); laminae and burrows present - very firm.

CLAY (CLAYSTONE)
Smears: 1-130, 2-145, 3-90

Texture	Composition
95% Clay	9-33% Feldspar
5% Silt	7-30% Quartz
	5-60% Zeolite
	2-45% Clay minerals
	1-40% Volcanic glass
	1-10% Auth. carbonate
	1- 2% Heavy minerals, opaques

Smear 1-33 clay with 20% authigenic carbonate.

ZEOLITIC CLAY (Minor Lith)
Smear: 1-103

Texture	Composition
80% Clay	58% Clay minerals
15% Silt	35% Zeolite
5% Sand	5% Quartz, feldspar
	1% Heavy minerals
	1% Volcanic glass

Textures of other smear slides (Sd, St, Cl)
1-33 (3, 28, 69) 2-45 (0, 30, 70)
1-103 (3, 47, 50) 3-90 (4, 35, 61)
1-130 (0, 23, 77)

Grain Size 1-27: 0.5, 27.7, 71.8
Grain Size 1-101: 0.9, 48.6, 50.5

Grain Size 1-130: 0.2, 23.2, 76.6

Carbon Carbonate 1-101: 0.6, 0.1, 4

Carbon Carbonate 1-130: 0.1, 0.1, 0

X-ray 1-27 (Bulk): 29.2% Plag, 26.5% Quar, 21.2% Mica, 17.8% Mont, 5.5% Chlo

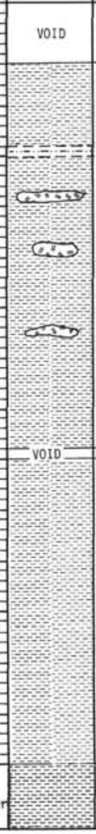
X-ray 1-101 (Bulk): 60.3% Phil, 19.6% Mont, 9.0% Plag, 7.1% Quar, 4.0% Mica

X-ray 1-130 (Bulk): 32.8% Plag, 25.4% Mont, 20.6% Quar, 16.6% Mica, 3.3% Chlo, 1.3% Clin

Explanatory notes in chapter 1

Site 293 Hole Core 16 Cored Interval: 468.5-478.0 m

AGE	ZONE	FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
						1	0.5, 1.0	VOID			
			B								5GY 4/1
			B			2				* 99	5GY 4/1 ↓ grade to ↓ 5Y 4/1
						3				* 80	5Y 4/1 ↓ grade to ↓
			B					VOID			10YR 5/4
			B			4					10YR 5/4
			B			5					10YR 5/4
		B	B	B		Core Catcher				CC *	10YR 4/4



Colors dominately moderate yellow brown (10YR 5/4), dark green gray (5GY 4/1), and olive gray (5Y 4/1) with local thin beds of olive black (5Y 2/1); slight drilling deformation; excellent burrows.

CLAY (CLAYSTONE)
Smears: 3-80, CC

Texture	Composition
90-95% Clay	61% Clay minerals
5-10% Silt	21% Quartz
	12% Feldspar
	4% Opaques
	1% Auth. carbonate
	Tr- 1% Zeolite

VOLCANIC ASH (Minor Lith)
Smear: 2-99

Texture	Composition
90% Silt	64% Volcanic glass
10% Clay	20% Feldspar
	10% Clay minerals
	5% Opaques
	1% Heavy minerals

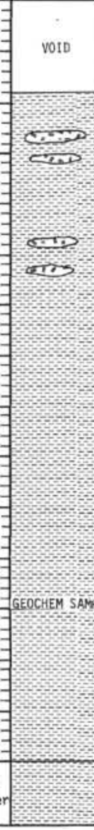
Grain Size 3-79
0.1, 11.1, 88.8

X-ray 3-80 (Bulk)
36.9% Mont
22.9% Mica
22.8% Quar
11.6% Plag
5.7% Chlo

Explanatory notes in chapter 1

Site 293 Hole Core 17 Cored Interval: 497.0-506.5 m

AGE	ZONE	FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
						1	0.5, 1.0	VOID			Subunit 1E
											↑ 10YR 5/4 ↓
			B			2					↓ 10YR 4/2 ↓ 5YR 7/2
			B			3				* 80	↑ 10YR 5/4 ↓
			B			4		GEOCHEM SAMPLE			↓ 10YR 4/2 ↓ ↑ 10YR 5/4 ↓ ↓ 10YR 4/2
			B			5					
		B	Rp	B		Core Catcher				CC *	10YR 5/4



Color ranges from grayish brown (5YR 3/2) to moderate yellow brown (10YR 5/4); other hues moderate brown (5YR 3/4), dark yellow brown (10YR 4/2); burrows intense; interbedding of ash zones in Sections 3-5, plus interbedding noted by color variations in all sections.

CLAY (CLAYSTONE)
Smear: 3-80, CC

Texture	Composition
90% Clay	84% Clay minerals
10% Silt	14% Feldspar
	2% Micarb
	<1% Heavy minerals
	Tr% Zeolite

Grain Size 3-81
0.3, 10.4, 89.3

Carbon Carbonate 3-88
0.1, 0.1, 0

X-ray 3-78 (Bulk)
75.5% Mont
11.8% K-Fe
5.2% Mica
4.6% Quar
2.9% Plag

Explanatory notes in chapter 1

Site 293 Hole Core 18 Cored Interval: 516.0-521.0 m

AGE	ZONE	FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		B	B			1	0.5 1.0			*005 *25 *60 *TS	10R 2/2 Unit 2 5G 6/1
			Rp								
		B	B	B		Core Catcher					

Color: claystone moderate brown (5YR 3/4) to very dusky red (10R 2/2); basalt greenish gray (5G 6/1).

CLAY (CLAYSTONE) - 5YR 3/4 moderate brown
Smear: 1-005

Texture	Composition
95% Clay	93% Clay minerals
5% Silt	5% Quartz, feldspar
	1% Heavy minerals
	1% Zeolite

CLAY (CLAYSTONE) - 10R 2/2 dusky red
Smears: 1-25, 1-60

Texture	Composition
95% Clay	98% Fe-oxides and clay minerals
3% Silt	1% Nannofossils
2% Sand	1% Zeolites
	<1% Quartz, feldspar

BASALT
Thin section: 1-90 - ophitic overgrowth of lath-like plagioclase in groundmass of pale green amphibole altered after clinopyroxene; scattered opaques.

Composition
52% Amphibole
40% Plagioclase (An_{50})
8% Opaques

Grain Size 1-62
0.2, 18.5, 81.3

X-ray 1-59 (Bulk)
28.1% K-Fe
22.5% Mica
21.6% Mont
19.8% Quar
4.9% Chlo
3.2% Plag
A Goet

Explanatory notes in chapter 1

Site 293 Hole Core 19 Cored Interval: 521.0-525.5 m

AGE	ZONE	FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
			B			1	0.5 1.0	VOID		TS * *144 *TS	5G 6/1

BASALT (5G 6/1) - Separate piece at base of section.

BASALT BRECCIA: angular to subangular basalt fragments (1-5 cm) in fine-grained grayish orange (10YR 7/4) matrix; fragments within matrix (1-10 mm); matrix is a silty clay with clay minerals, ferruginous material, amphiboles, feldspar, lithics, and zeolites.

BASALTIC BRECCIA
Thin section: 1-145 - breccia of angular-subangular fragments (1-5 cm) of basalt fine-grained grayish-orange (10YR 7/4) matrix, composed of fragments (1-10 mm) - silty clay (ferruginous) (see smear description 1-144).

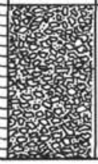
BASALT
Thin section: 1-108 - ophitic intergrowth tabular plagioclase (An_{50-55}%) intergrown with clinopyroxene (37); highler altered scattered opaques (5); zone of mineralization. Rock is altered tholeiitic basalt.

FERRUGINOUS SILTY CLAY
Smears: 1-144 (Matrix)

Texture	Composition
58% Clay	46% Clay minerals
40% Silt	25% Heavy minerals (amphibole)
2% Sand	23% Feldspar
	3% Lithic fragments
	3% Zeolite

Explanatory notes in chapter 1

Site 293 Hole Core 20 Cored Interval: 525.5-535.0 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
LATE MIDDLE MIOCENE-LATE PLIOCENE			Rm B			1	0.5 1.0			* 40 50 * * TS 103 TS 136

LITHOLOGIC DESCRIPTION

IGNEOUS BRECCIA
Four units within core:
i) 0-25 cm - breccia with angular to subangular basalt fragments (up to 10 cm);
ii) 25-61 cm - angular clasts (2-4 cm) in fine-grained matrix; matrix is bimodal with grains (0.2 to 0.8 cm) in fine silty clay; color is moderate red brown (10R 4/6); clast are basalt (angular and micrograbbro);
iii) 61-145 cm - clasts (4-15 cm) of anorthosite gabbro in fine-grained, light greenish gray matrix - matrix is bimodal; and
iv) 145-150 cm - greenish gray (5GY 6/1) basalt fragment.

BRECCIA
ii - clasts of greenschist facies schists of deformed gabbros - in clay size matrix of amphibole, oxide, plagioclase, carbonate and goethite.

iii - coarse gabbro (plagioclase-40, clinopyroxene-30, orthopyroxene-20, amphibole-10) in clay size matrix of carbonate, amphibole, clinopyroxene.

BRECCIA FRAGMENTS
i - Microgabbro
Thin section: 1-103 - euhedral, subhedral plagioclase in groundmass of interstitial clinopyroxene, now altered to amphibole.

Composition
45% Plagioclase (An_{52})
20% Clinopyroxene
35% Amphibole

ii - Gabbro
Thin section: 1-136 - subhedral-anhedral plagioclase intergrown with interstitial clinopyroxene; plagioclase-twinned, zoned; clinopyroxene shows exsolution, partial alteration to amphibole.

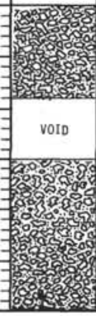
Composition
60% Plagioclase
32% Pyroxene
5% Amphibole
3% Opaques

SANDY SILT MATRIX MATERIAL
Smears: 1-40, 1-50

Texture	Composition
50-60% Silt	40-50% Feldspar
30% Sand	16-55% Heavy minerals (amphibole)
10-20% Clay	20% Fe-oxides
	10-20% Clay minerals
	2- 3% Opaques
	1- 3% Auth. carbonate

Explanatory notes in chapter 1

Site 293 Hole Core 21 Cored Interval: 535.0-544.4 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
			B			1 2	0.5 1.0	 VOID		TS 10 TS TS 110

LITHOLOGIC DESCRIPTION

IGNEOUS BRECCIA

10YR 8/6 — Section 1:
Large (up to 13 cm) clasts of gabbro, angular-subangular anorthosite gabbro, variolitic basalt, hornblende plagioclase schists, and gabbro altered to greenschist Additional descriptions in Lithology Report-Site 293.
Matrix: color yellowish orange (10YR 8/6) with composition and texture as follows:

10YR 6/6 — SILTY SAND
Smear: 1-10

Texture	Composition
50% Sand	54% Feldspar
40% Silt	32% Heavy minerals
10% Clay	10% Clay minerals
	2% Opaques
	2% Auth. carbonate
	Tr% Zeolite

5YR 3/2
5GY 8/1

Heavy minerals: amphiboles, clinopyroxenes.

Section 2:
0-40 cm: coarse grained angular gabbro clasts (1-15 cm) in dark yellow orange (10YR 6/6) matrix

40-80 cm: finer grained (1-3 cm) gabbro clasts in dark yellowish orange matrix

80-89 cm: fine grained gabbro and pyroxene diorite gneiss clasts in grayish brown (5YR 3/2) matrix (clay size) of chlorite

89-150 cm: angular to subangular gabbro clasts (1-5 cm) in light greenish gray (5GY 8/1) matrix of chloritic, serpentine, authigenic carbonate

Additional descriptions in Lithology Report - Site 293.

Matrix: color light greenish gray (5GY 8/1)
SAND-RICH SILT
Smear: 2-110

Texture	Composition
85% Silt	45% Feldspar
10% Sand	40% Heavy minerals
5% Clay	10% Altered pyroxene
	5% Auth. carbonate

Explanatory notes in chapter 1

Site 293 Hole Core 22 Cored Interval: 544.5-554.0 m

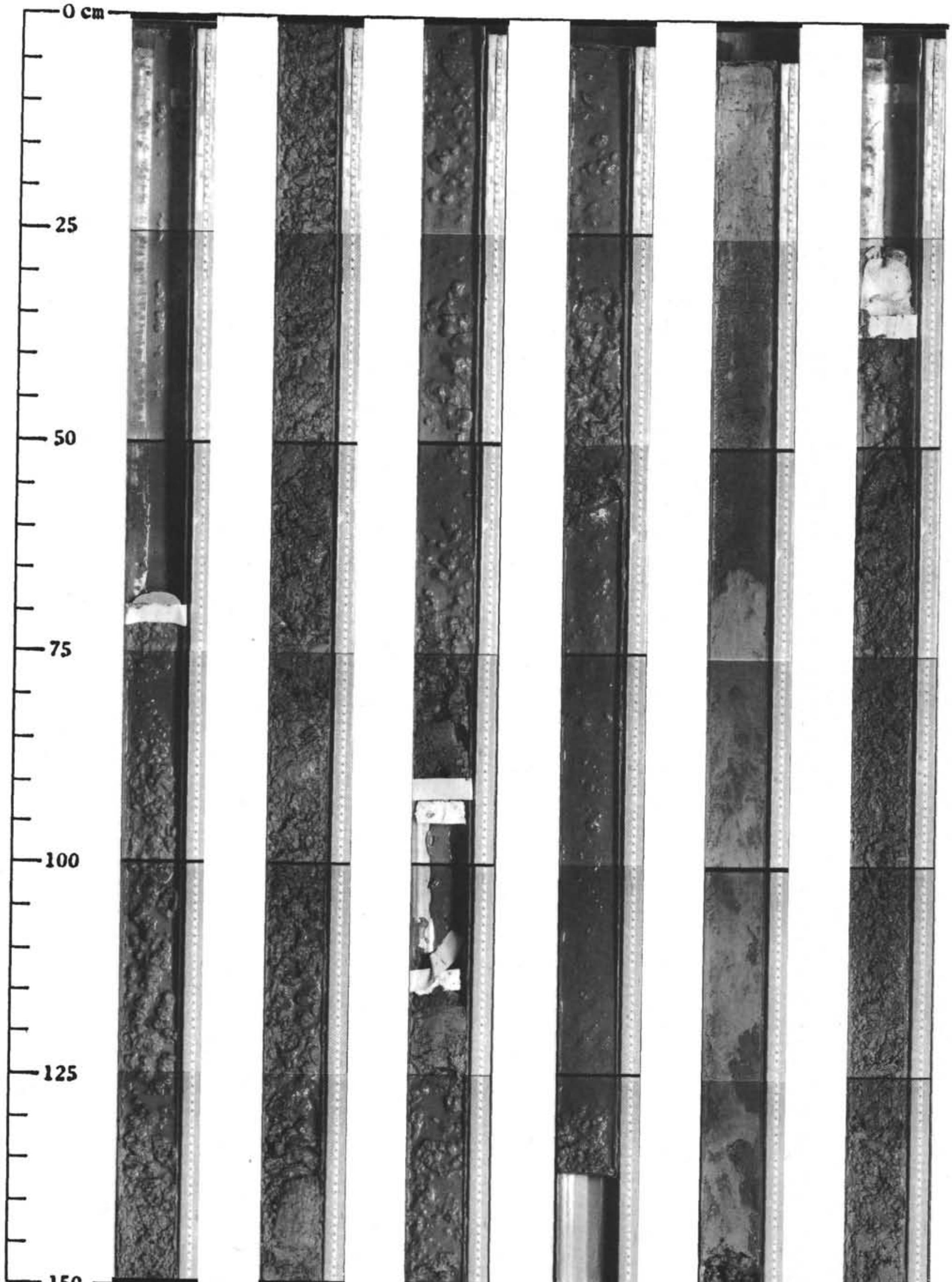
AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
				B							PALEO: A few sediment chips retained on inner lining of core catcher were found to contain few poorly preserved nannofossils.

Explanatory notes in chapter 1

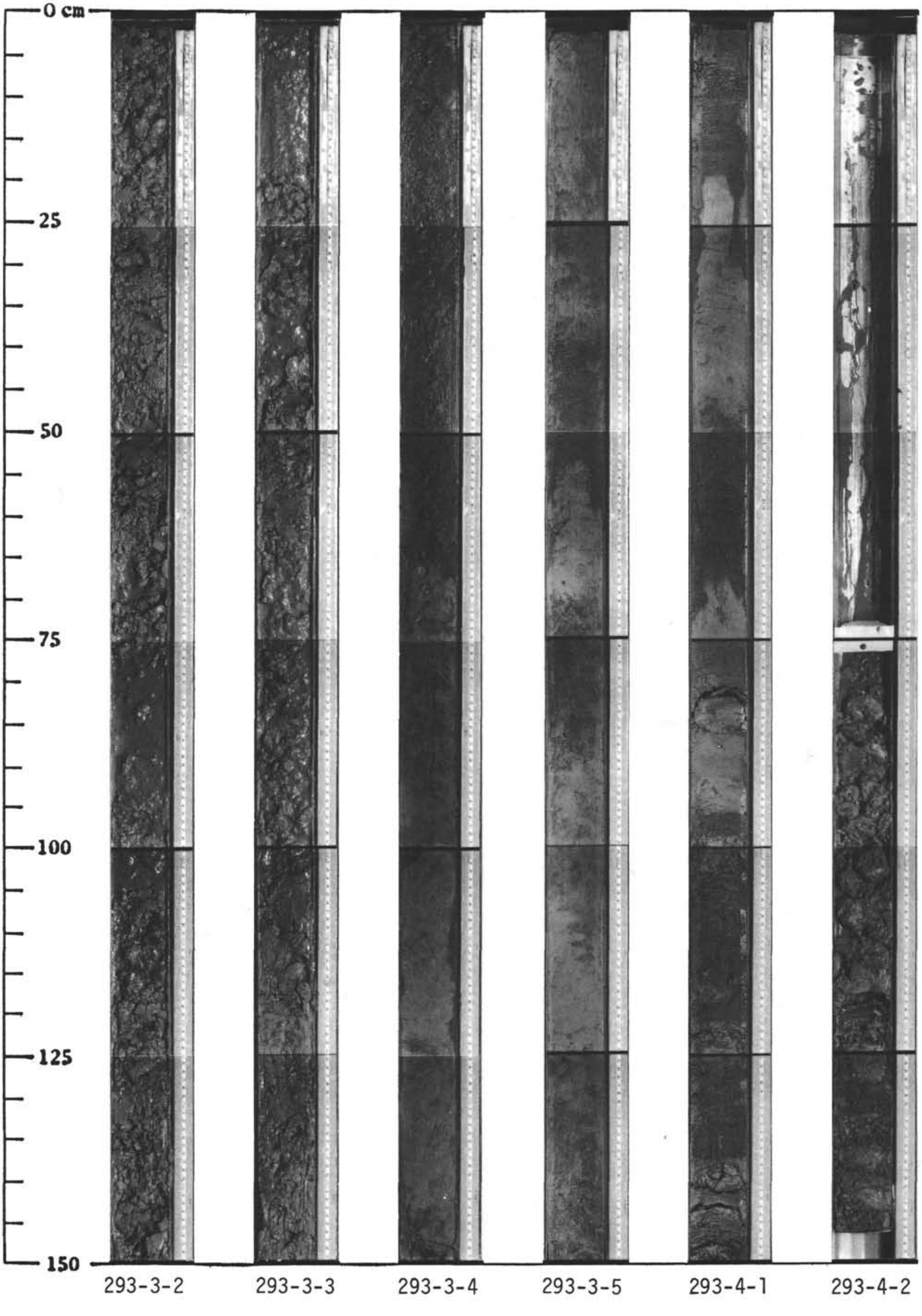
Site 293 Hole Core 23 Cored Interval: 554.0-563.5 m

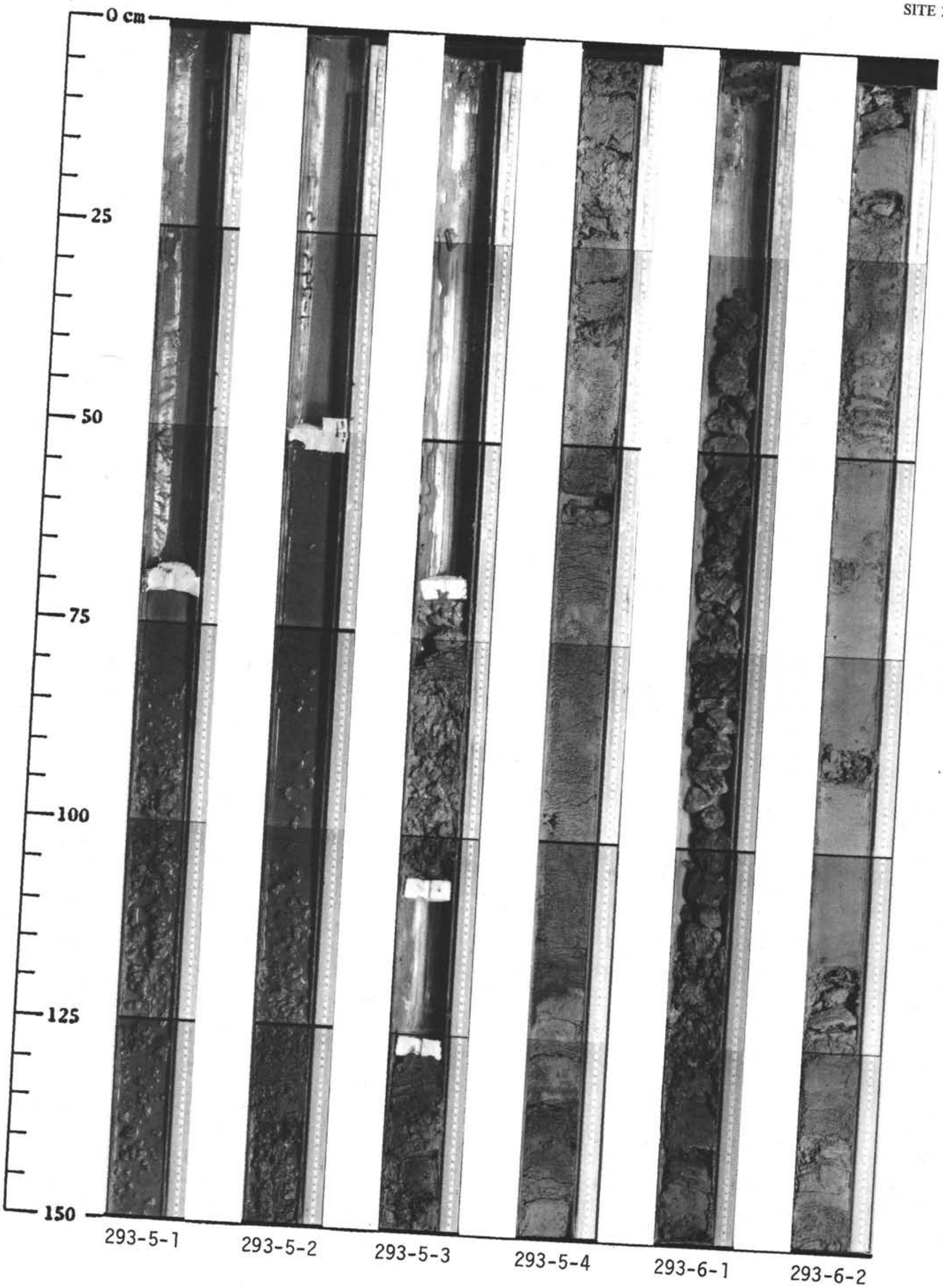
AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIDDLE MIOCENE-LATE PLIOCENE				B							PALEO: A few sediment chips retained on inner lining of core catcher were found to contain rare moderate to well preserved nannofossils.

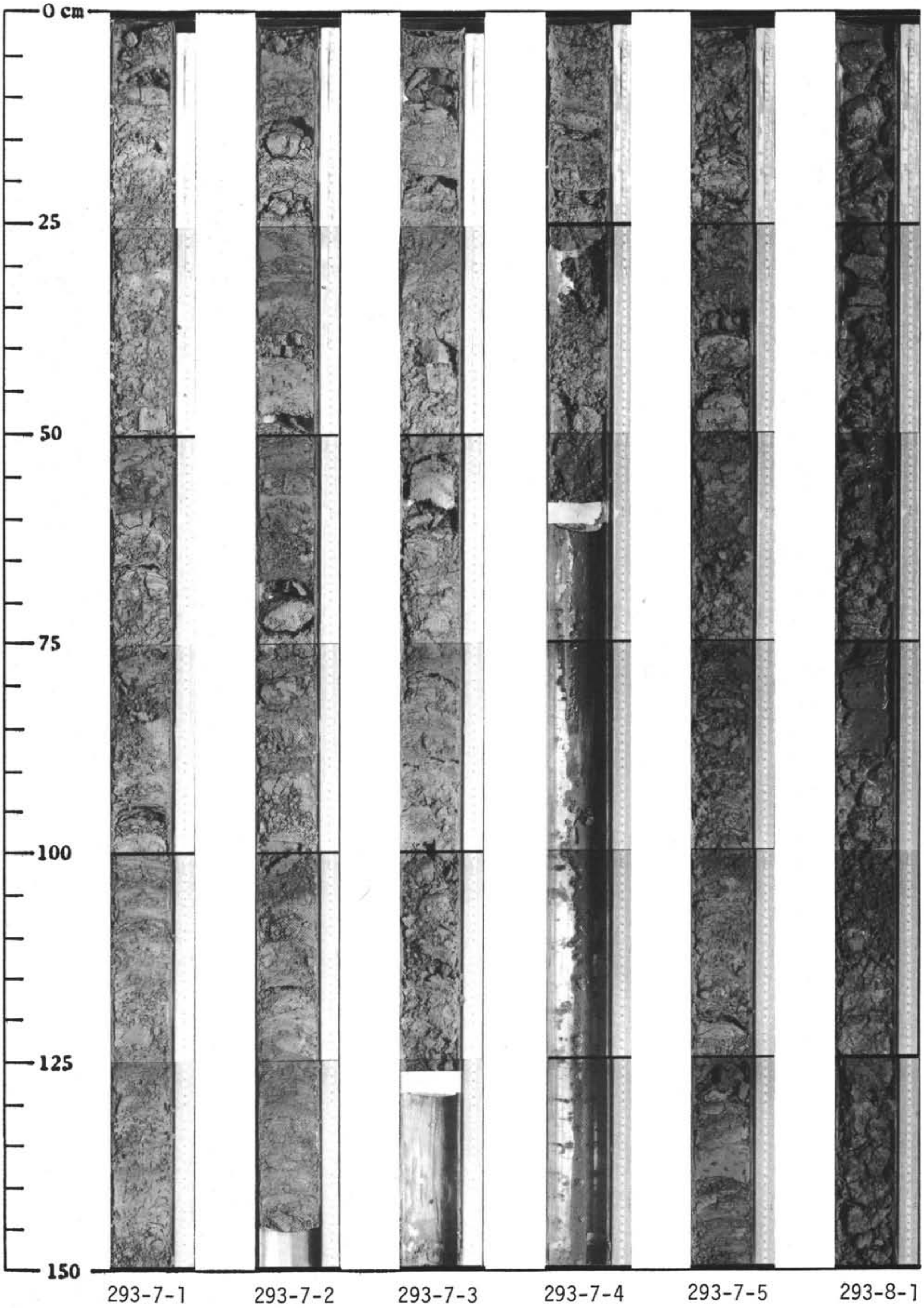
Explanatory notes in chapter 1

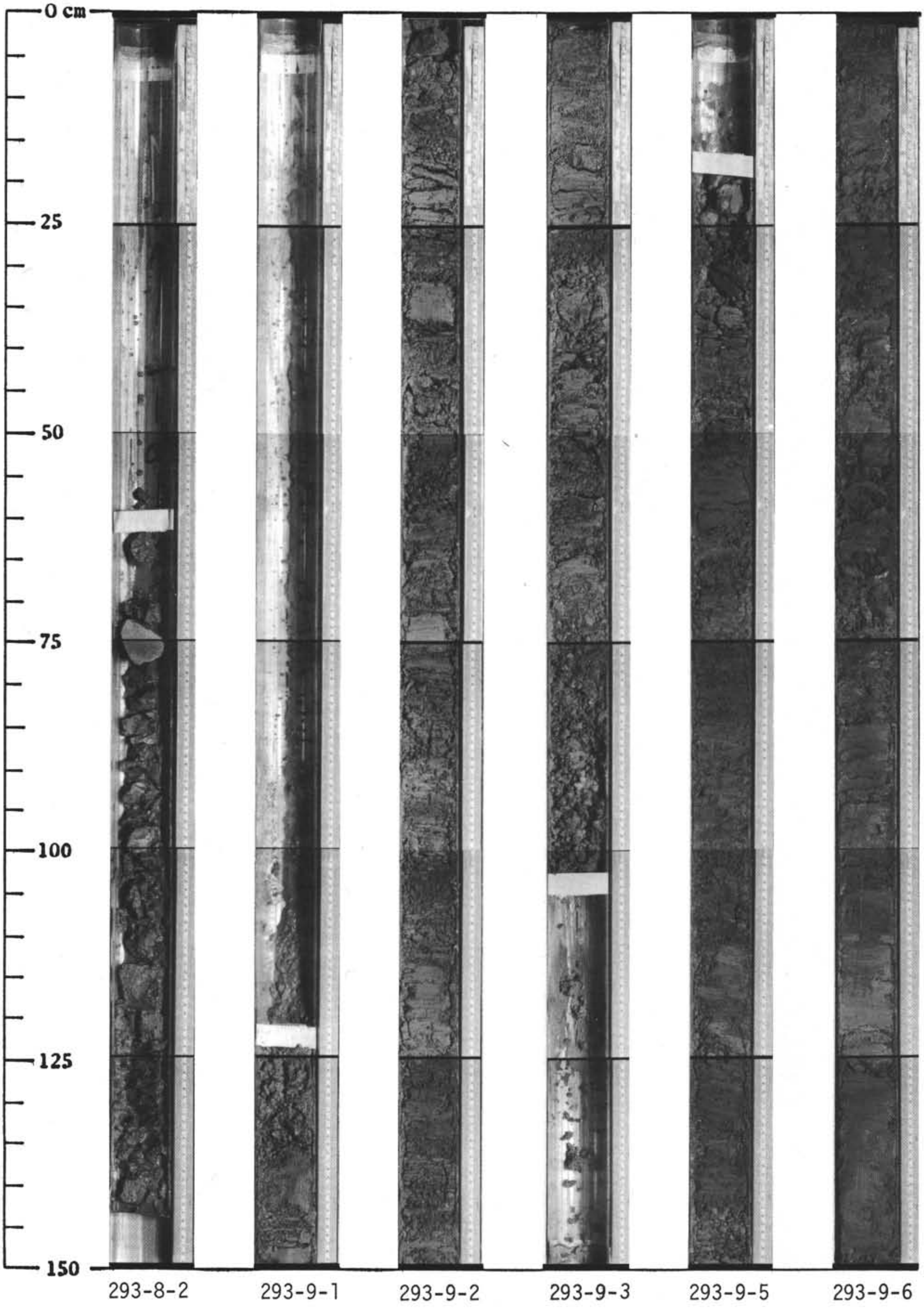


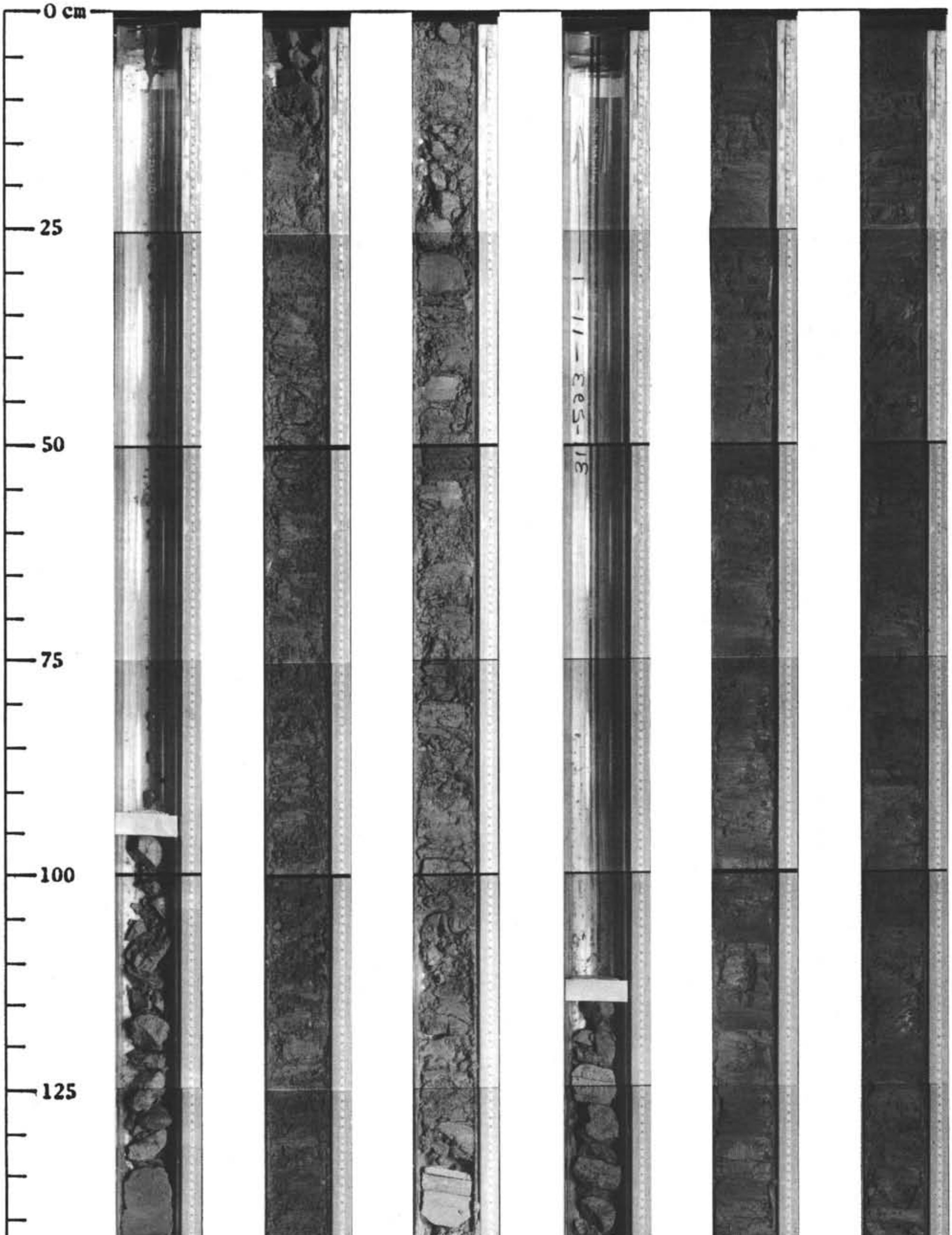
293-2-1 293-2-2 293-2-3 293-2-4 293-2-5 293-3-1


0 cm
25
50
75
100
125
150
293-3-2
293-3-3
293-3-4
293-3-5
293-4-1
293-4-2

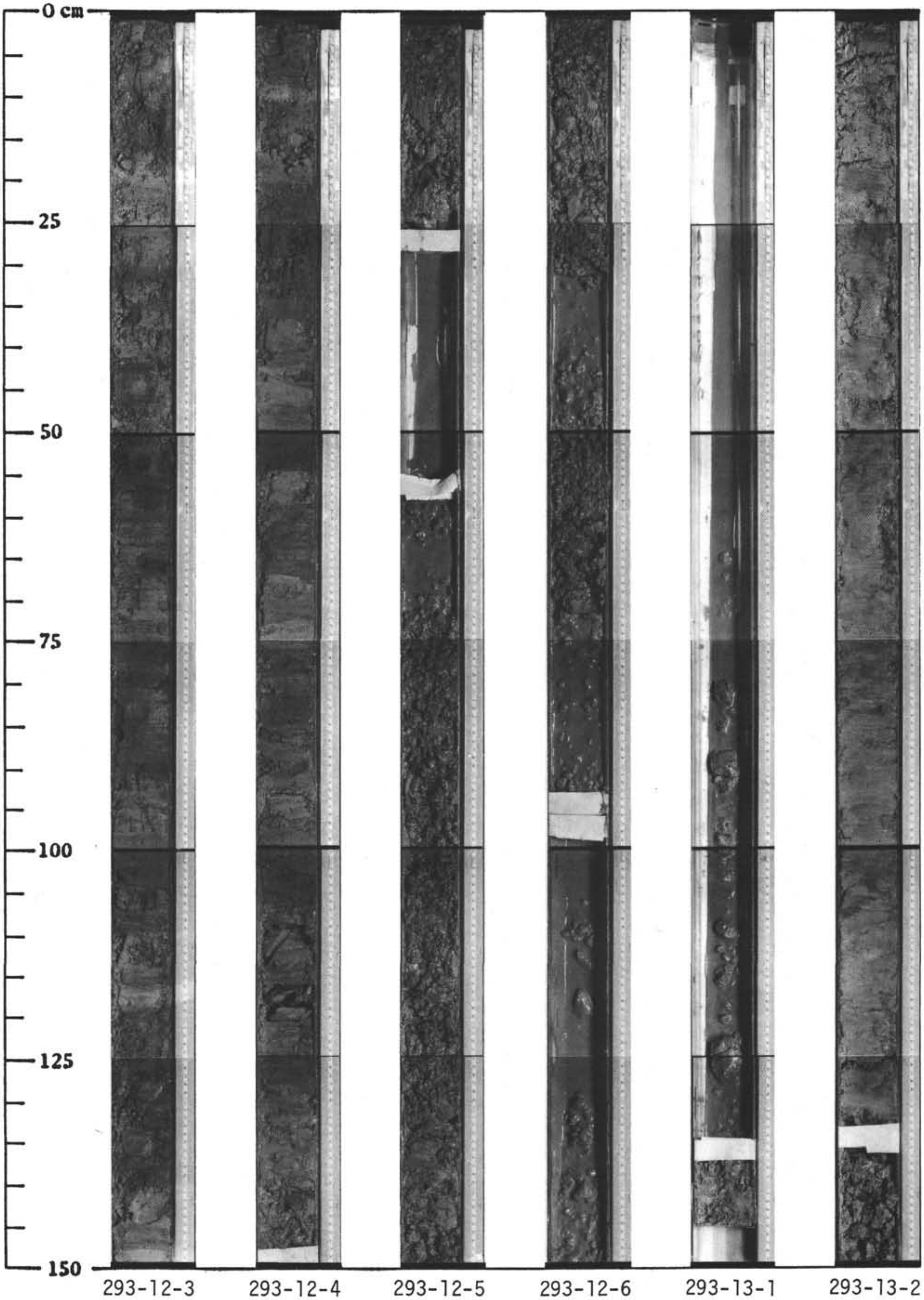

0 cm
25
50
75
100
125
150
293-5-1
293-5-2
293-5-3
293-5-4
293-6-1
293-6-2

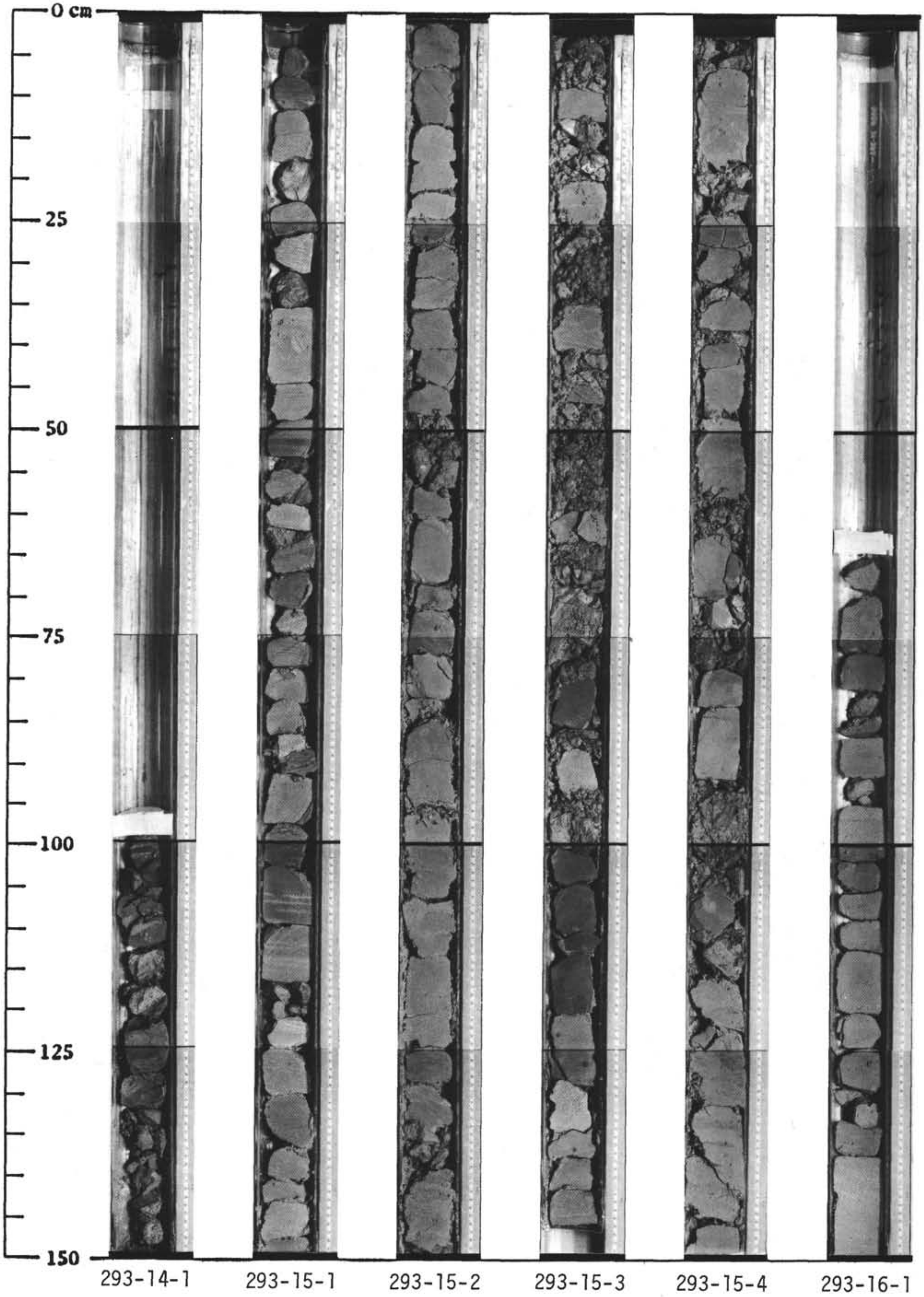

0 cm
25
50
75
100
125
150
293-7-1
293-7-2
293-7-3
293-7-4
293-7-5
293-8-1

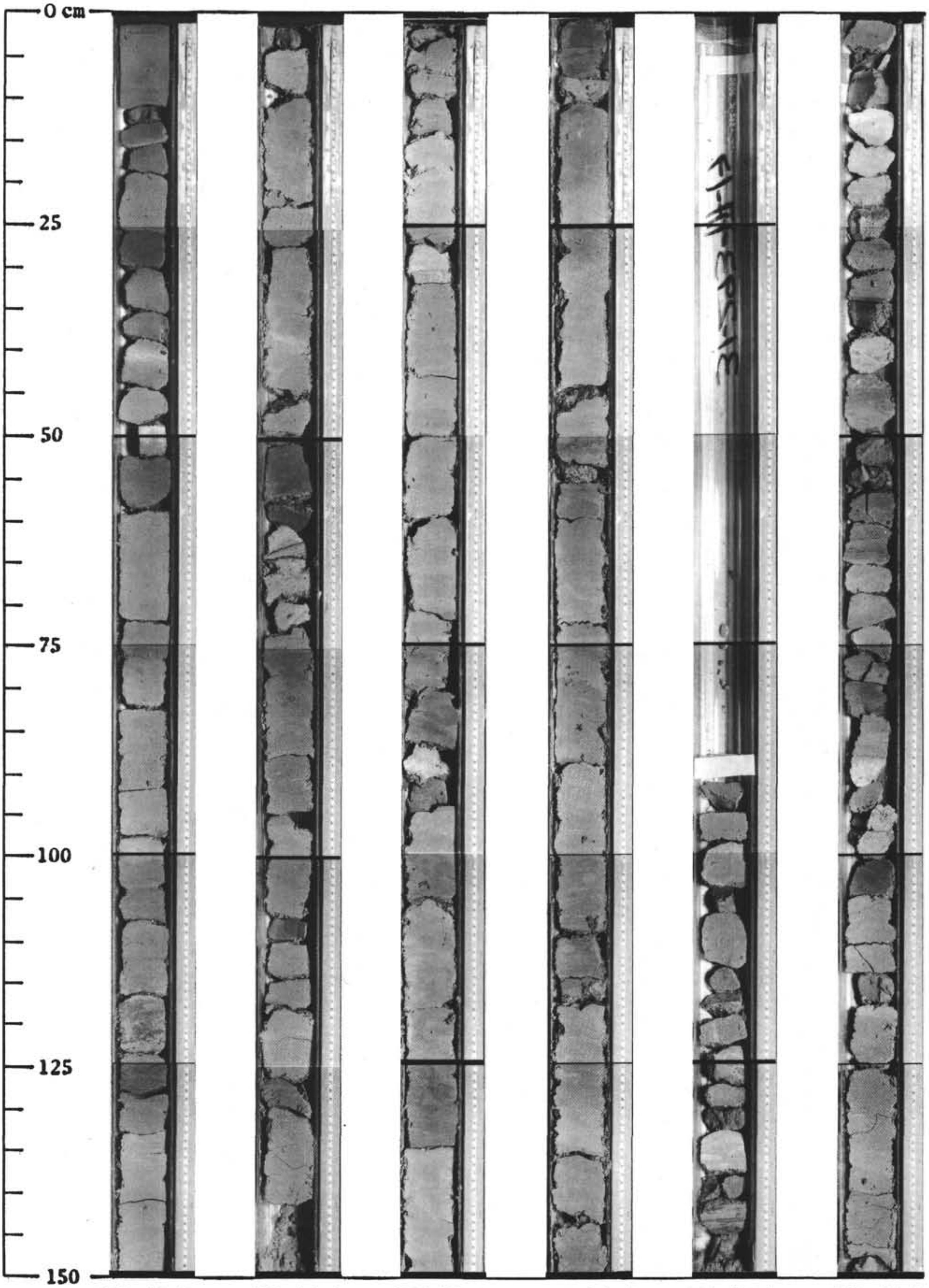

0 cm
25
50
75
100
125
150
293-8-2
293-9-1
293-9-2
293-9-3
293-9-5
293-9-6

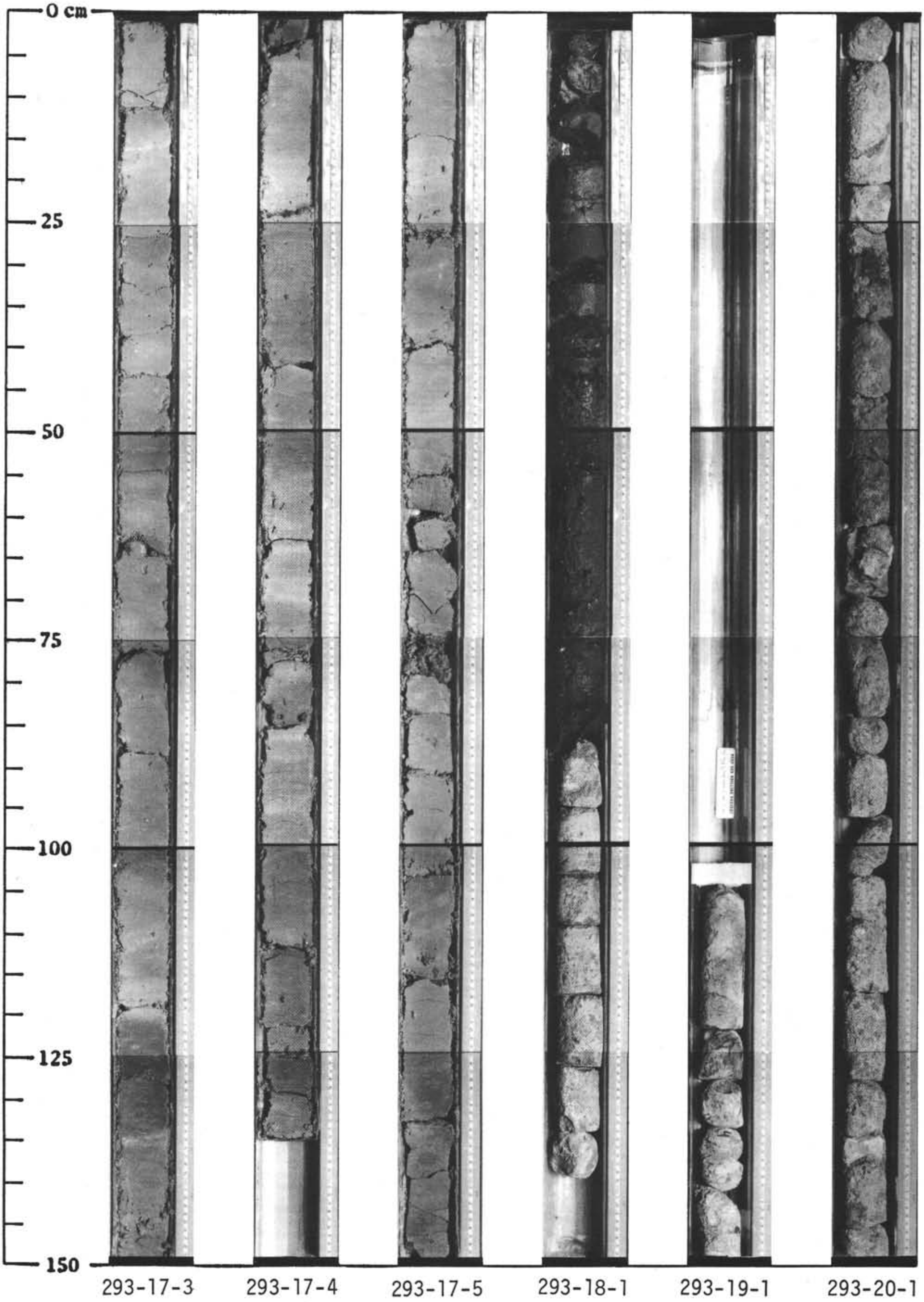


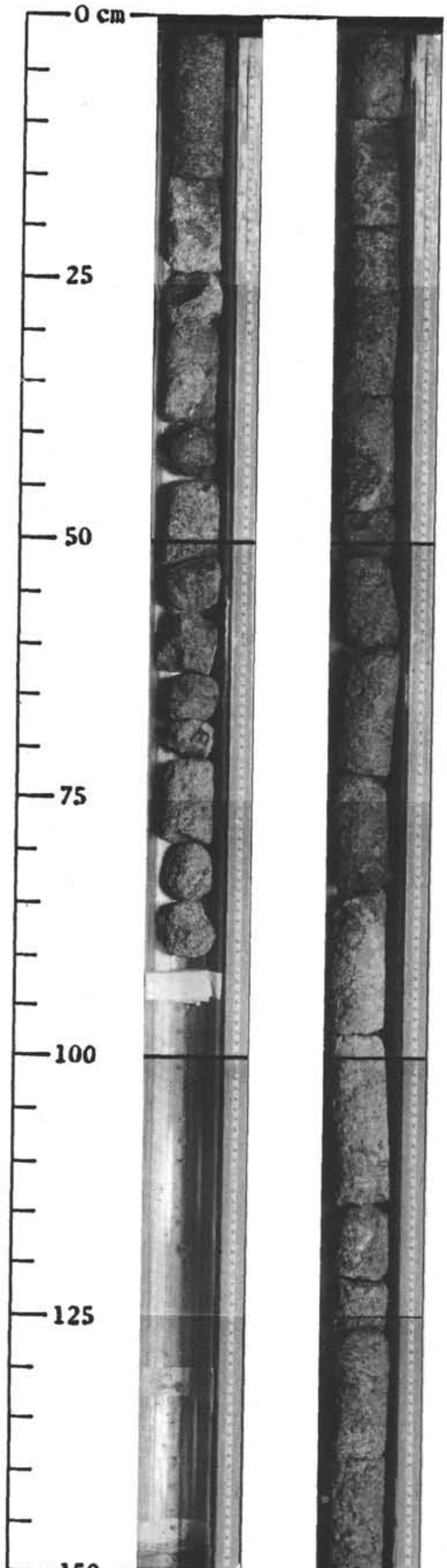
293-10-1 293-10-2 293-10-3 293-11-1 293-12-1 293-12-2


0 cm
25
50
75
100
125
150
293-12-3
293-12-4
293-12-5
293-12-6
293-13-1
293-13-2


0 cm
25
50
75
100
125
150
293-14-1
293-15-1
293-15-2
293-15-3
293-15-4
293-16-1


0 cm
25
50
75
100
125
150
293-16-2
293-16-3
293-16-4
293-16-5
293-17-1
293-17-2


0 cm
25
50
75
100
125
150
293-17-3
293-17-4
293-17-5
293-18-1
293-19-1
293-20-1



293-21-1 293-21-2