8. SITE 153

The Shipboard Scientific Party[1]

Position:
13°58.33′N
72°26.08′W.

Water Depth: 3932 meters.

Penetration: 776 meters.

ABSTRACT

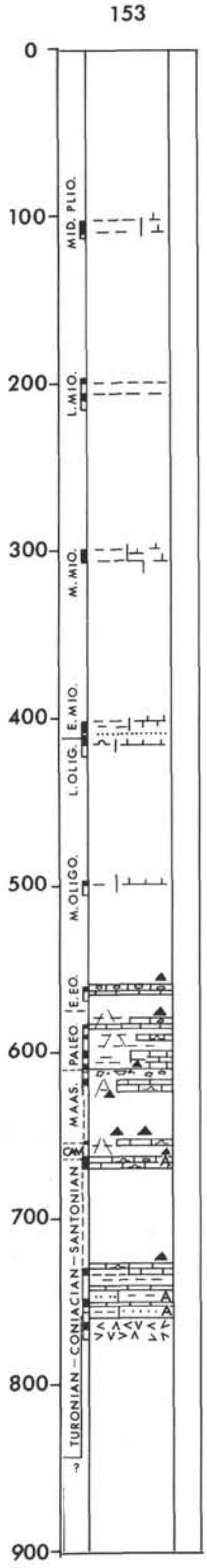
This site is located in the Aruba Gap, between the Beata Ridge and Venezuela where processed reflection data indicate stratified layers below Horizon B″.

Thick soft sediments of Cenozoic age overlie hard, siliceous limestones and cherts of Early Eocene to Cretaceous (Coniacian) age. Horizon A″ marks the interface between these two units. Horizon B″ corresponds to a very fine-grained basalt suggestive of the top of a flow.

The limestone underlying Horizon A″ is irregularly silicified and contains interlayered cherts. Interbeds of carbonaceous, phosphatic, volcanic clay are found in the lower part.

BACKGROUND

Site 153 is located at the southern end of the Beata Ridge, between the ridge and South America (Aruba gap). A seismic refraction line (Edgar et al., 1971, profile 79) which lies over the continental margin and Venezuelan Basin to the east of this site shows a 3.1 and 3.6 km/sec seismic layer thinning and truncating against overlying lower velocity sediment that could be interpreted as pre-Horizon B″ layers and termination at about the Horizon B″ level (Figure 1). A processed seismic reflection line run over the area of the site by Esso Production Research Co. (Figure 2) also shows a wedge of sediment or rock below Horizon B″ truncating seaward. The location of these refraction and reflection lines are shown in Figure 3. The site had originally been selected if drilling to Horizon B″ in the Venezuelan Basin had failed, but the recovery of dolerites from sills made the objective of pre-Horizon B″ cores even more appealing.



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Seismic reflection records were supplied to us by Lamont-Doherty Geological Observatory on completion of a site survey by R/V *Vema. Glomar Challenger* reflection records approaching the site are shown in Figure 4; the track of the vessel is shown in Figure 5. There was a problem deciding on where to place the site—seaward of the oldest truncated layer where the oldest rock may lie close to Horizon B″ or landward where there was the possibility of not encountering igneous rock. The decision was made to drill a hole over the wedge on the assumption that Sites 146 and 150 had achieved essentially all that could be accomplished farther in the basin and we should attempt to sample the sediment wedge.

OBJECTIVES

The objective at this site was to penetrate Horizon B″ into layered rock that, according to seismic data, was truncated seaward and thickened rapidly beneath the continental slope of South America.

OPERATIONS

A recently received profile record from the R/V *Vema* precluded the necessity for detailed site surveying. The ship approached the site at 0800 hours on 23 January and passed near the site on a brief survey in order to find a location where both A″ and B″ were present. After spot coring five intervals of soft sediment above Horizon A″, continuous coring began at 563 meters where the first hard sediment was encountered (Horizon A″). Coring continued (with, however, one core representing 37 and another 64 meters of drilling) until basalt was reached at 766 meters. Poor recovery and loss of time retrieving and returning the barrel led us to core in excess of the normal 9-meter interval. The basalt was cored for an additional 10 meters in the hope of penetrating it, but when the drilling rate indicated that the bit was badly worn, the hole was terminated. The drill string was withdrawn and the ship was underway for Site 154 at 2130 hours on 27 January.

LITHOLOGY

The section above Horizon A″ was spot cored at five intervals. The uppermost core (102-111 m) is of a greenish gray nannoplankton calcareous clay. The next two cores (198-216 m) contain less than 10 percent calcium carbonate and the foraminifera are largely dissolved. The clay is soft and homogeneous. Minor volcanic material at the bottom of Core 1 includes phillipsite, quartz, hornblende, plagioclase, and biotite. In the core catcher of Core 2 is a dispersed turbidite with silt-sized quartz grains, manganese micronodules, bipyramidal quartz, gypsum, and pyritized foraminifera and Radiolaria. In this upper sequence the degree of solution of fossils is greater than in the lower interval.

The next lower core (300-309 m) consists of interbedded clay, similar to the first three cores, and light bluish gray marly calcareous clay, with layers 10 cm or more in thickness. The layering (Figure 6) is disrupted both by abundant burrows and by intense drilling disturbance. The carbonate content of the marly layers is about 50 percent. Foraminifera show the effects of solution. An unusual minor constituent of the clays of Core 4 are minute (less than 10 microns) euhedral crystals of yellow to brown garnet. Dolomite (or siderite) is persistent, but minor.

The downward increase in carbonate marks the next cores which are light bluish gray marly foram-nanno chalk and bluish white nannofossil chalk (403-421 and 499-500 m). The carbonate content varies from 50 to 80 percent. Radiolaria and nannofossils are well preserved, but foraminifera show signs of solution. These sediments are compact but neither indurated nor lithified. Dolomite is scarce; volcanic debris is absent.

A sharp drop in the drilling rate at 555 meters probably identifies Horizon A″. Core 8 was taken at 563 meters and Early Eocene silicified hard limestone and chert were recovered.

Coring below Horizon A″ recovered a greenish gray limestone sequence with irregularly silicified zones and interlayered cherts. Burrowing is well developed. Minor volcanic ash layers consist of montmorillonite with clinoptilolite, biotite, apatite, and zircon. Barite is conspicuous in some of the lower limestones. Radiolaria occur in the upper three cores (9, 10 and 11) and foraminifera and nannofossils are found throughout, although they are generally poorly preserved. In the interval 586 to 609 meters, most of the foraminifera are benthonic forms.

At the Cretaceous-Tertiary boundary (Sample 153-12-1, 113; 611 m), a silicified breccia (Figure 7) somewhat resembling the hardground of Site 151, Core 11, occurs. The fragments of the breccia are separated by calcite-filled veins and have matching boundaries.

In the lower part of the hole (below 730 m), the limestone is interlayered with a carbonaceous, phosphatic, volcanic clay (Figure 8). This clay is olive black and has a variable carbonate content. Fish debris, including complete bones (some of them articulated), is abundant. Minor barite crystals, zeolites, and horizontal chevron burrows (*Zoophycos*) are conspicuous in some zones (see Warme et al. and Maurasse, this volume). Pea-sized nodules of sparry calcite, chalcedony, and significant (1-2%) reduced organic matter are found. Towards the base of the unit, the ash component increases and nearly pure, graded ash beds a few centimeters in thickness are found (Figure 9).

The lower limestones show small-scale, dominantly horizontal burrowing, much of which has been secondarily distorted. Pyrite is scattered throughout, and one concretion several centimeters in diameter was found (Figure 8; Frontispiece). Glauconite streaks are present.

Although the upper contact with the basalt was not recovered, the vitric groundmass and very fine grain size of the uppermost basalt sample suggests that it occurred near the flow top. About three meters of basalt were recovered; it is fresh, sparsely and finely amygdaloidal, and slightly fractured. There is no indication of the basalt being pillowed.

PHYSICAL PROPERTIES

Wet-bulk Density, Water Content, and Porosity

Wet-bulk density and porosity were measured by two methods aboard the *Glomar Challenger*: Gamma Ray Attenuation Porosity Evaluator (GRAPE) and individual sample volume-weight measurements (the sample data are the enclosed dots in the hole and core plots). Water content was determined by weight-weight relationships. In general the precision of these data is ±5 percent. Methods, errors, assumptions, corrections, sediment disturbances, and interpretation precautions are discussed in Appendix I.

Some stiff sediment or rock is cored without plastic flowage of the sample and, since the drill bit has a smaller diameter than the core liner (2.60 in. I.D.), the hard sediment samples also have that smaller diameter, with the remaining space being filled with a drilling slurry or highly disturbed sediment (in some cases air). A problem arises here because a 2.60 inch diameter is used in the density calculations.

Where necessary, the GRAPE data of Site 153 are adjusted (GRAPE corrected diameter [GCD] is the dotted line density and porosity in the core and hole plots) for the smaller diameter of the core. Diameters were generally smaller than 2.60 inches by 9% in Cores 4, 5, and 6; 10% in Cores 13, 16, and 17; 12% in 7, 8, 9, 12, 18, and 19; and 13.5% in Cores 10, 11, and 14. A typical slurry density of 1.1 g/cc was assumed in these calculations. See the Appendix for a discussion and for the equations used for correction.

Only the maximum density trends and minimum porosity trends were recalculated since lesser densities and greater porosities are suspect of being drill-disturbed sediments, smaller diameters, or rock fragments. These adjusted data are only approximations.

Results

Wet-bulk densities at Site 153 from Pliocene clay at 100 meters below bottom to Cretaceous micritic limestone at 760 meters vary from 1.50 g/cc to 2.45 g/cc (67 to 12% porosity) and increase irregularly with increasing depth. Specifically, wet-bulk densities of Pliocene nannofossil clay at 100 meters depth are 1.55 to 1.68 g/cc (68 to 60% porosity) but wet-bulk densities gradually increase to 1.70 to 1.90 g/cc (58 to 47% porosity) in similar Miocene sediments at 300 meters. Densities in Miocene-Oligocene marl and foraminiferal nannofossil chalk at 400 meters depth and Oligocene nannofossil chalk and clay at 500 meters depth are about the same as those sediments at 300 meters, although deeper and older. However, porosities appear to continue to decrease while the wet-bulk density remains constant. This is because of decreasing grain density which is related to the occurrences of radiolarians and sponge spicules.

Eocene-Paleocene micritic limestone (rare nannofossils) from 560 meters to 600 meters have wet-bulk densities of 2.2 g/cc to 1.8 g/cc (13 to 33% porosity). Paleocene-Cretaceous (?) micritic limestone (with minor marl and clay; silica in the lower section) have typical densities of 1.9 g/cc to 2.3 g/cc (31 to 14% porosity), with a range from 1.85 to 2.55 g/cc (45 to effectively 0% porosity ?). The sand overlying the basalt has a density of 2.3 g/cc (33% porosity), while the density of the basalt is about 2.7 g/cc.

In Core 1, a high GRAPE density spike was caused by a pyrite nodule. The Core 3 graph also has a spike which may be a nodule. However, since these rocks were surrounded by sediment, the recorded density is not a true density of the nodules.

Water content samples were collected at a depth of 200 meters from clay, and at 300 meters from marl, with values of 33 percent and 31 percent, respectively.

Sound Velocity

Sound velocity through sediment and rock samples was measured by the Hamilton Frame technique, which is discussed in the Appendix. This method has a precision within ±1.1 percent.

Sound velocity was measured on sediments and rocks which appeared to be physically undisturbed. These velocities were measured parallel to the bedding planes, unless otherwise noted in Table 1, and were measured at laboratory pressures and temperatures (25.4 to 28.5°C).

Results

At Site 153, sound velocities range from 1.57 to 5.63 km/sec, and irregularly increased with increasing depth. Specifically, between 200 and 500 meters, velocities increased from 1.57 to 2.11 km/sec in Miocene calcareous clay, marl, and chalk, and Oligocene nannofossil chalk. Between 609 and 610 meters, Paleocene silicified marl had higher velocities of 2.13 to 2.52 km/sec. Paleocene and Cretaceous limestone from 588 to 620 meters had velocities of 2.02 to 3.26 km/sec with typical velocities within 2.0 to 2.5 km/sec, while the Cretaceous limestones from 620 to 750 meters had greater velocities of 2.45 to 3.79 km/sec with 3.14 to 3.60 km/sec being typical. A similar trend of increasing velocities with increasing depth can be seen in the siliceous limestone velocities. Eocene and Paleocene siliceous limestone from 563 meters to 612 meters has sonic velocities of 2.23 to 3.42 km/sec, while Cretaceous siliceous limestone from 620 to 717 meters have velocities of 3.01 to 4.06 km/sec.

Eocene chert recovered at 563 and 572 meters has sound velocities of 3.90 to 4.50 km/sec, which was low compared to 5.20 to 5.63 km/sec measured through five Cretaceous conchoidally fractured chert fragments from 650 to 700 meters.

Volcanic shale and sandstone above (751 to 754 m) the basalt has sound velocities of 2.38 to 2.50 km/sec, which contrasted with the 4.78 km/sec of the basalt below these sediments.

Natural Gamma Radiation

Natural gamma ray emissions were counted for a period of 1.25 minutes at 7.62 cm (3 in.) intervals along the core, with a counting precision of about ±100 counts. Methods, equipment, error porosity corrections, and sediment disturbance are discussed in the Appendix. The following data were not corrected for varying porosity.

Natural gamma radiation emitted from sediments recovered at Site 153 ranged from 0 to 3200 counts per 1.25 minutes at a 7.62 cm core interval. The Santonian-Coniacian micritic limestone from 728 meters to 770 meters below the sea floor, with organic- and phosphate-rich clastic beds, had the highest emissions of 300 to 3200 counts. The Pliocene-Miocene nannofossil clay, clay, and marl from 100 to 300 meters had intermediate counts of 1300 to 2600 while 200 to 1000 counts were emitted from the Miocene and Oligocene foraminiferal nannofossil chalk

TABLE 1
Hamilton Frame Sonic Velocities, Site 153

Core	Section	Upper Interval[a] (cm)	Depth in Hole (m)	Velocity[b] (m/sec)	Temperature (°C)	Remarks
3	1	32.0	207.32	1574	25.5	Clay.
3	1	114.0	208.14	1624	25.4	Clay.
4	1	0.0	300.00	1631	27.1	Clay, zeolitic.
4	2	40.0	301.90	2074	27.1	Clay, nanno-rich.
4	3	123.0	304.23	1951	27.1	Nanno marl ooze.
5	1	60.0	403.60	1669	26.7	Foram nanno marl.
5	2	85.0	405.35	1693	26.7	Foram nanno chalk, clay-rich.
5	3	85.0	406.85	1823	26.5	Foram nanno chalk, clay-rich.
5	4	52.0	408.02	1841	26.5	Nanno foram marl.
5	4	138.0	408.88	2110	26.5	Foram nanno chalk, clay-rich.
6	1	84.0	412.84	2031	26.5	Nanno chalk, clay-rich.
6	2	143.0	414.93	2102	26.5	Nanno chalk, clay-rich.
7	1	75.0	499.75	2093	25.5	Nanno chalk, clay-rich.
8	1	84.0	563.84	4498	28.0	Chert, calcareous.
8	1	92.0	563.92	2673	28.0	Limestone, silicified.
8	CC	0.0	572.00	3904	(Cold)	Limestone, silicified, velocity measured when core arrived at surface, thus "cold"
8	CC	0.0	572.00	3868	(Cold)	Limestone, silicified.
9	1	90.0	586.90	3204	27.7	Marlstone, silicified.
9	1	110.0	587.10	3175	27.7	Marlstone, silicified, dark.
9	2	33.0	587.83	2593	26.5	Marlstone, slightly silicified.
9	2	90.0	588.40	2496	26.5	Limestone, micritic.
10	1	145.0	592.45	2233	26.7	Marlstone, micritic.
10	2	84.0	593.34	2389	26.3	Claystone, silicified.
10	2	84.0	593.34	2396	26.3	Claystone, silicified.
10	2	143.0	593.93	2083	26.2	Micritic marl.
11	1	88.0	600.88	2165	26.2	Nanno marl.
11	2	96.0	602.46	2110	25.4	Nanno marl.
11	3	42.0	603.42	2285	27.6	Nanno marl.
11	3	139.0	604.39	2653	27.6	Claystone, zeolitic, calcareous.
12	1	70.0	609.70	2026	25.3	Nanno marl.
12	1	90.0	609.90	2830	25.3	Marl, silicified.
12	1	125.0	610.25	2218	25.3	Foram limestone, clay-rich, light.
12	1	125.0	610.25	2131	25.3	Foram limestone, clay-rich, dark.
12	2	27.0	610.77	2528	25.3	Foram limestone, clay-rich.
12	3	0.0	612.00	3425	27.2	Limestone, cherty.
12	3	140.0	613.40	3260	27.0	Limestone, clay-rich.
13	2	13.0	620.63	3602	26.3	Limestone, clay-rich.
13	2	92.0	621.42	3407	26.3	Limestone, clay-rich.
13	4	30.0	623.80	2910	28.5	Limestone, clay-rich.
13	4	83.0	624.33	2455	28.5	Limestone, clay-rich.
14	1	87.0	656.87	5634	27.2	Chert, brownish yellow.
14	1	97.0	656.97	5121	27.2	Chert, brownish gray.
14	1	103.0	657.03	3135	27.2	Limestone
14	1	109.0	657.09	5227	27.2	Chert, reddish brown.
15	1	27.0	667.27	5273	26.8	Chert, gray and tan layers.
15	1	84.0	667.84	5231	26.8	Chert, tan.
15	1	117.0	668.17	3011	26.8	Radiolarian foram limestone, "sandy."
15	1	145.0	668.45	3308	26.8	Radiolarian foram micritic limestone, partly silicified.
15	2	38.0	668.88	3429	26.0	Radiolarian foram micritic limestone, partly silicified.
15	2	100.0	669.50	3639	26.0	Radiolarian foram micritic limestone, partly silicified.
15	3	15.0	670.15	5198	25.8	Chert, gray.
15	3	70.0	670.70	3680	25.8	Radiolarian foram micritic limestone, $\parallel$ to bedding, partly silicified.
15	3	70.0	670.70	3243	25.8	Radiolarian foram micritic limestone, $\perp$ to bedding, partly silicified.
15	3	85.0	670.85	3417	25.8	Micritic limestone, partly silicified, some ash.
15	4	29.0	671.79	3200	25.5	Radiolarian foram micritic limestone, slightly silicified.
15	4	49.0	671.99	4397	25.5	Radiolarian foram micritic limestone, $\parallel$ to bedding, silicified.
15	4	49.0	671.99	4497	25.5	Radiolarian foram micritic limestone, silicified, $\perp$ to bedding.

TABLE 1 – *Continued*

Core	Section	Interval[a] (cm)	Depth in Hole (m)	Velocity (m/sec)	Temperature (°C)	Remarks
15	4	83.0	672.33	4067	25.5	Radiolarian foram micritic limestone, silicified.
16	1	36.0	731.36	3783	25.7	Foram limestone.
16	1	120.0	732.20	3780	25.7	Foram limestone, with burrows.
16	2	95.0	733.45	2720	25.7	Claystone, black, carbonaceous.
16	2	103.0	733.53	3449	25.7	Foram limestone.
18	2	13.0	750.63	3789	27.7	Micritic limestone.
18	2	50.0	751.00	2402	27.7	Shale, black, chloritic.
18	3	28.0	752.28	2434	26.5	Shale, black, chloritic.
18	3	90.0	752.90	2380	26.5	Shale, black, chloritic.
18	4	87.0	754.37	2503	27.4	Sandstone, volcanic, coarse grained.
18	4	102.0	754.52	2387	27.4	Sandstone, volcanic, fine-grained.
20	1	145.0	768.45	4785	27.4	Basalt, fractured.

[a]Upper limit of a 3-cm sample interval.

[b]Velocities were measured parallel to bedding unless noted otherwise.

and marl from 400 meters depth and foraminiferal nannofossil chalk and minor clay from 500 meters depth. The marl and clay emitted the higher counts, while the chalk emitted the lower counts of 200 to 600. Paleocene-Cretaceous micritic limestone with minor marl from 580 to 625 meters emitted counts from 100 to 700 while the Eocene micrite-sparite chalk, at 560 meters, and Cretaceous micritic limestone from 650 to 665 meters, and 770 meters, emitted very low counts of 100. The basalt only emitted 200 to 300 counts.

Penetrometer

Needle penetration tests were conducted at Site 153 with a 1 mm diameter needle. The methods, equipment, and sediment disturbance are discussed in the Appendix.

Penetration tests were performed on Cores 1, 3, and 4 from 100, 200, and 300 meters below the sea floor, where penetration decreased with increasing depth. Penetration into Pliocene nannofossil clay from 100 meters was 4 mm; penetration into Miocene clay at 200 meters depth was 1 to 2 mm; and Miocene clay and marl at 300 meters had penetrations of 1 to 2 mm and less than 1 mm, respectively. Below this depth, penetrations into Miocene foraminiferal chalk were not significant.

BIOSTRATIGRAPHY

Spot cores were taken through the upper part of the sedimentary sequence at this site.

Core 1 (102-111 m) contains rich calcareous planktonic fossils, but lacks radiolarians. It belongs to the *Globigerinoides trilobus fistulosus* Subzone of the *Globorotalia miocenica* Zone (Middle Pliocene). It contains calcareous nannofossils of the *Discoaster surculus* Zone.

Cores 2 and 3 (198-216 m) contain sparse planktonic foraminifera, strongly affected by solution, poor assemblages of calcareous nannofossils consisting almost exclusively of asteroliths, and no radiolarians. These cores probably belong to the *Globorotalia acostaensis* and *Discoaster quinqueramus* zones of the Late Miocene.

Core 4 (300-309 m) contains a good assemblage of the *Globorotalia fohsi fohsi* Zone and abundant but only moderately diverse calcareous nannofossils of the *Sphenolithus heteromorphus* Zone. Like the cores above it at this site, it also lacks radiolarians.

Core 5 (403-412 m) contains a very condensed Middle-Early Miocene sequence reminiscent of those in Core 4 at Site 150 and Core 4 at Site 151. A sample from Section 1 of Core 5 belongs to the *Globorotalia fohsi peripheroronda* Zone, samples from the lower part of Section 3 and upper part of Section 4 the *Globigerinatella insueta* Zone, and the catcher of Core 5 the *Globigerinoides primordius* Zone. The *Praeorbulina glomerosa, Globigerinita stainforthi*, and *Globigerinita dissimilis* zones were not detected but this may simply reflect the sampling interval used. Calcareous nannoplankton through the top of Section 4 of Core 5 belongs to the *Sphenolithus heteromorphus* Zone. A sample from the lower part of Section 4 belongs to the *Sphenolithus belemnos* Zone. The zones which should immediately overlie and underlie the *Sphenolithus belemnos* Zone, the *Helicopontosphaera ampliaperta* and *Discoaster druggi* zones, were not detected, but again this might be due to the sampling interval used. The lower part of Core 5 and Core 6 contain common, moderately to well-preserved (somewhat dissolved) radiolarians of the *Calocycletta virginis* Zone.

Core 6, which is immediately subjacent to Core 5 (412-421 m) contains planktonic foraminifera of the *Globorotalia kugleri* Zone of the Late Oligocene and calcareous nannoplankton of the *Triquetrorhabdulus carinatus* Zone.

Core 7 (499-508 m) contains assemblages of the *Globigerina ampliapertura* and *Sphenolithus predistentus* zones of the Middle Oligocene.

Sediment recovered from the center bit after drilling between Cores 7 and 8 contains *Globorotalia opima opima*, indicating that the *Globorotalia opima opima* Zone is present at this site; it must lie between Cores 6 and 7 (421-499 m).

Core 8 (563-572 m), lies in early Eocene deposits according to the planktonic foraminifera present in a

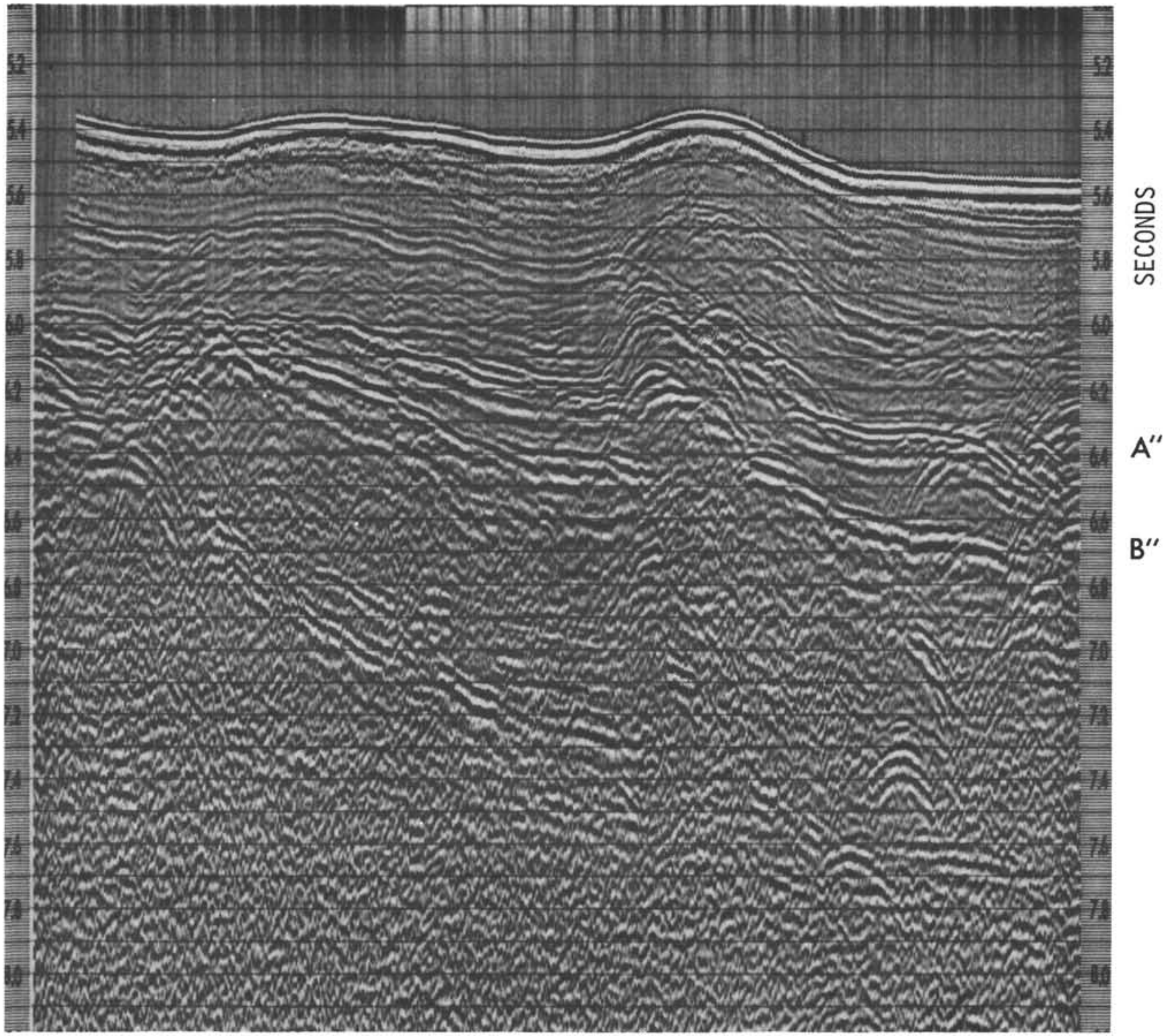


Figure 2. *Processed seismic reflection line extending from the base of the continental slope of South America into the Caribbean Sea showing a thick wedge of possible sediment or volcanic rocks lying below Horizon B″ and thinning seaward. It terminates on the south edge of the Beata Ridge. Track shown on Figure 3. (Courtesy of Esso Production Research Company.)*

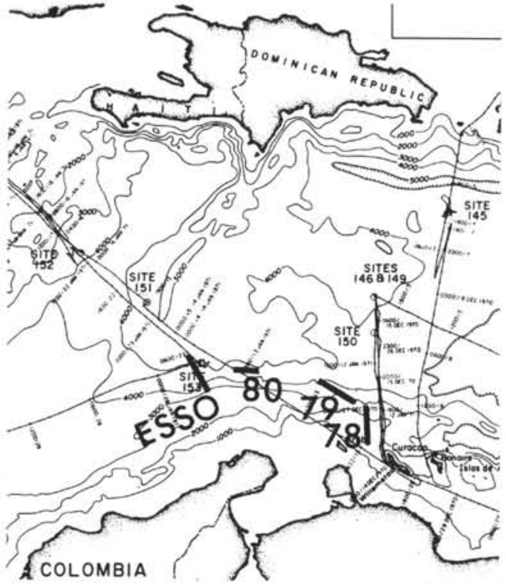


Figure 3. *Chart showing location of refraction profiles of Figure 1 and reflection line of Figure 2.*

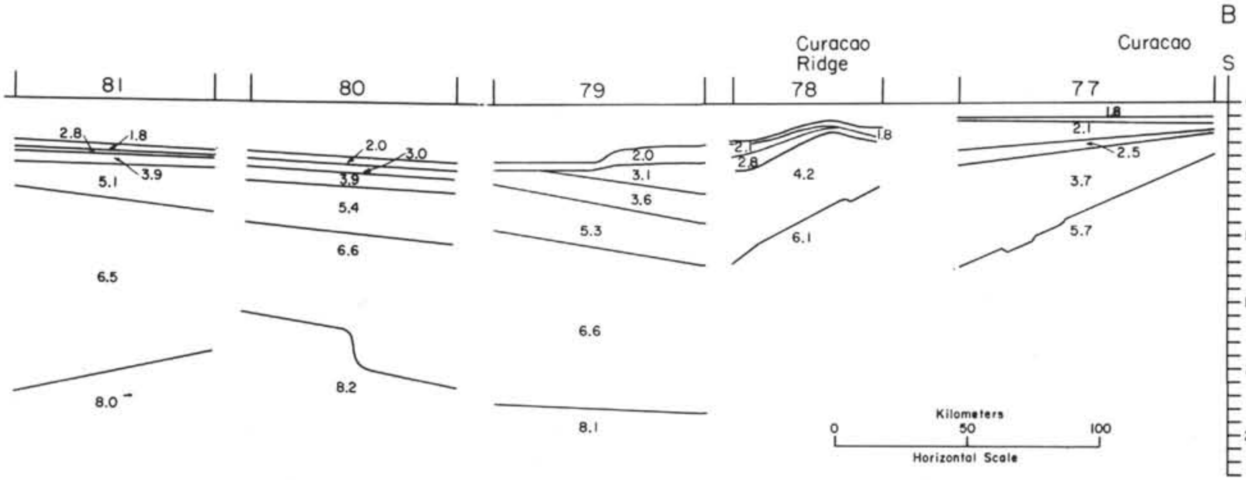


Figure 1. *Seismic refraction profiles shot across the northern continental margin of South America showing the truncation of a wedge of 3.1 and 3.6 km/sec layers in the vicinity of Site 153. Track shown on Figure 3 (Edgar et al., 1971).*

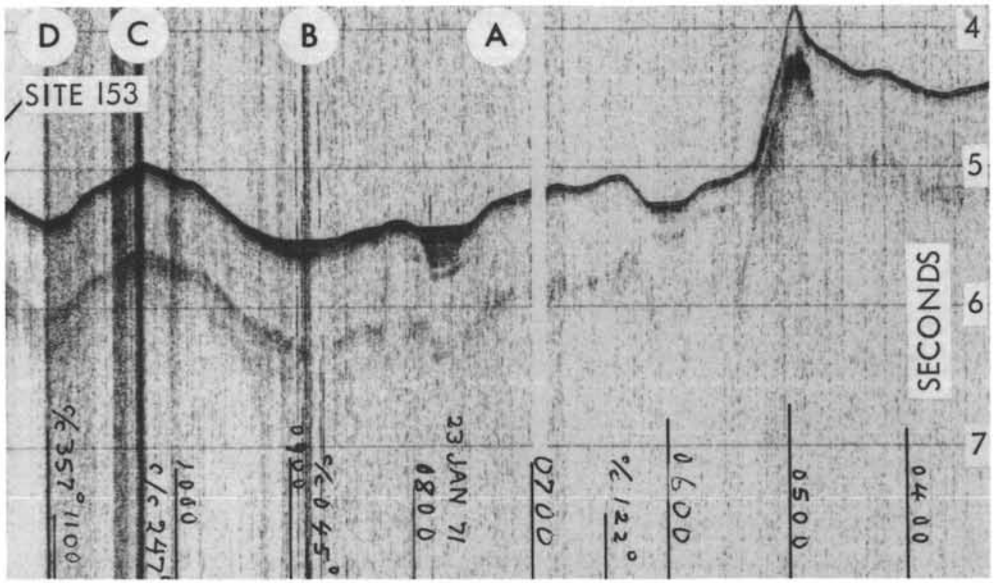


Figure 4. *Profiler record made by* Glomar Challenger *on approach to Site 153. Track shown on Figure 5.*

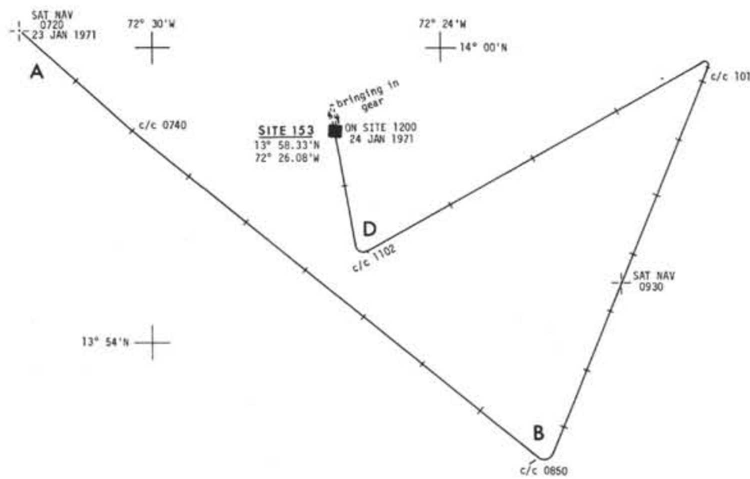


Figure 5. *Track of* Glomar Challenger *on approach to Site 153.*

Figure 6. *Interbedded clay and marly chalk ooze showing intense burrowing (153-4-3, 50-70).*

Figure 7. *Limestone breccia occurring at a hiatus separating Cretaceous and Tertiary limestones (153-12-1, 95-118).*

sample from Section 1; they are indicative of the *Globorotalia formosa formosa* Zone. Calcareous nannofossils are rare in this material and are questionably assigned to the Paleocene *Discoaster gemmeus* Zone, in which case they must be mixed or reworked into the younger Eocene sediment.

Continuous coring was carried out between 586 and 619 meters. Cores 9, 10, and 11 through Section 3 are generally poor in planktonic foraminifera although a few thin layers contain richer assemblages characteristic of the Paleocene *Globorotalia pusilla pusilla* Zone. These cores also contain sparse nannofossils belonging to the *Gasiculithus tympaniformis* Zone.

The catcher sample of Core 11 contains a planktonic foraminiferal assemblage of the *Globorotalia angulata* Zone.

Section 1 of Core 12 (609-619 m) is devoid of planktonic foraminifera to a depth of 90 cm, but does contain calcareous nannofossils of the *Chiasmolithus danicus* Zone. Between 90 and 102 cm is a breccia containing fragments of micrite some of which contain planktonic foraminifera of the *Globigerina eugubina* Zone.

The breccia, which marks the base of the Cenozoic, is underlain by a few centimeters of sediment devoid of plankton fossils, but the lower parts of Core 12 contain globotruncanids of the Maestrichtian *Globotruncana gansseri* and *Globotruncana "tricarinata"* Zones and poor calcareous nannofossils.

Figure 8. *Interbedded limestone and carbonaceous sediment. Note intense burrowing and deformation in some limestone layers. A large pyrite nodule is found in the upper part of the picture (see frontispiece). The carbonaceous layers are rich in fish remains and volcanic debris and contain conspicuous* Zoophycus *burrows (153-16-2, 87-132).*

Figure 9. *Graded beds of basaltic ash immediately above basalt flow (153-19-1, 79-99).*

Core 13 was taken by drilling between 619 and 656 meters and contains assemblages of the *Globotruncana "tricarinata"* Zone.

Core 14 (656-667 m) contained only benthonic foraminifera and rare nannofossils.

Cores 15 and 16 (667-740 m) contain planktonic foraminifera of the *Globotruncana concavata concavata* Zone of the Coniacian.

Core 17 (740-749 m) yielded only a catcher sample with benthonic foraminifera.

Cores 18 and 19 (749-767 m) contain layers with good assemblages of the Late Turonian *Globotruncana schneegansi* Zone and layers devoid of foraminifera. Calcareous nannofossils are rare to absent.

CONCLUSIONS

Although only spot cores were taken above Horizon A″, we can draw several conclusions about this interval. The occurrence of clays in higher intervals and carbonate sediments in the early Miocene indicates that the fluctuation of the depth of calcium carbonate compensation seen at Sites 146/149 and adjacent sites affected this area also. The high accumulation rate of the clay-rich part of the section (around 25 m/m.y.) is noteworthy. Very minor, possibly turbiditic debris of obviously continental origin was found. Very little of the section is volcanic and the high accumulation rates evidently reflect proximity to the South American continent. Possibly in the pre-Pliocene interval, before the Panamanian isthmus was raised, strong surface currents may have carried a large terrigenous clay sediment load to this site.

Beneath the cherts and lithified limestones of Horizon A″, the lower limestone section is presently deeper than the contemporaneous, carbonate-free Paleocene of Site 146, suggesting that there may have been substantial differential vertical movement between the two sites since their deposition or a substantial difference in the type of sediment being deposited at the two areas.

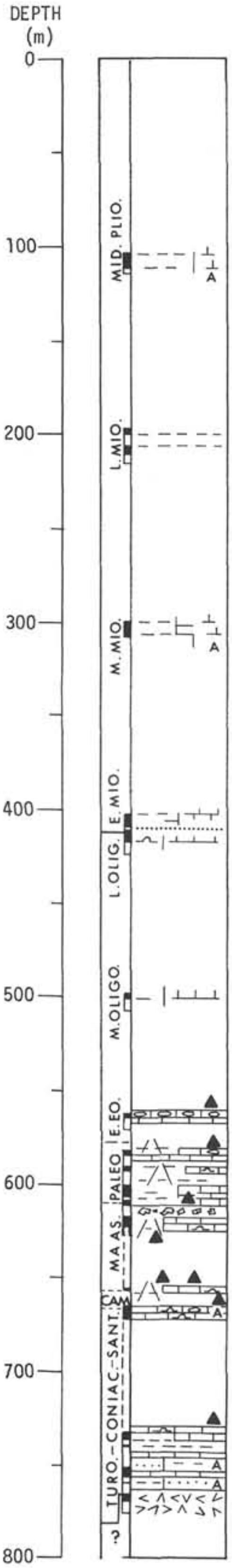
The silicified breccia and chert at the Cretaceous-Tertiary boundary of Core 12 is similar to the ferruginous, siliceous, hardground of Core 11, Site 151. In both cases foraminiferal oozes have been silicified, and later compaction and volume changes may have accounted for local brecciation. Very probably, both are hardgrounds and both represent temporally parallel (if not fully coincidental) epochs of relative shallowing, exposure to moderate bottom currents, and penecontemporaneous silicification.

The interlayering of organic, phosphatic, and volcanic clays with the limestones at the lower part of the section indicates, as at Site 146, the presence of a topographically diverse sea floor, with stagnant low areas in which fish debris and other organic matter accumulated with incomplete decomposition. The occurrence of basaltic ash at this level suggests further that this topographic disruption of the sea floor may have accompanied widespread basaltic eruptions in the central Caribbean.

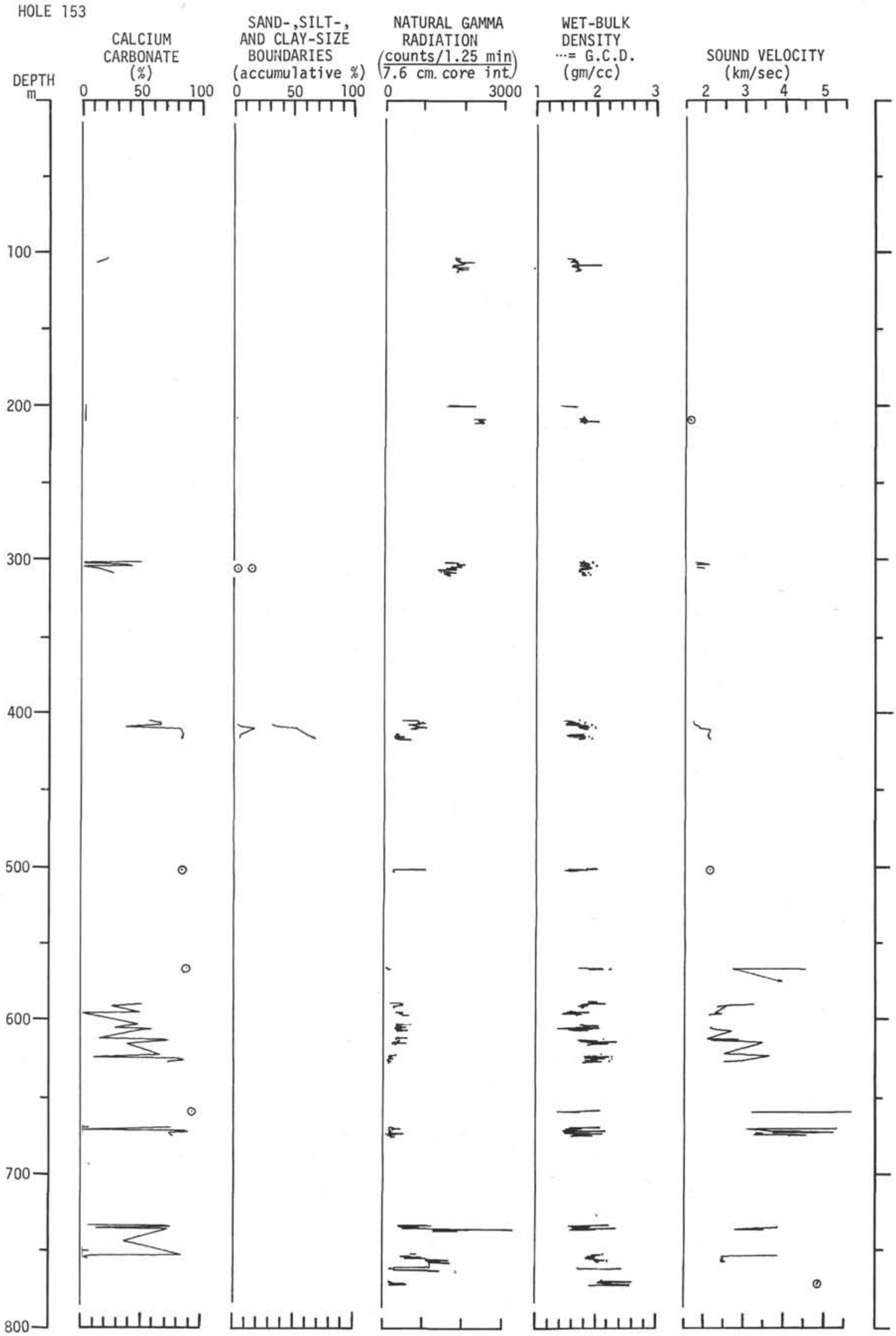
REFERENCE

Edgar, N. T., Ewing, J. I. and Hennion, J., 1971. Seismic refraction and reflection in Caribbean Sea. Am. Assoc. Petrol. Geologists Bull. 55, 833.

SITE 153 — LITHOLOGY



UNITS	SUBUNITS OR DESCRIPTION
UNIT I (0 to 551? m) NANNO CHALK, MARL and CLAY	(0? to 350? m) (Cores 1 to 4) NANNOFOSSIL rich CLAY, CLAY, and NANNOFOSSIL MARL OOZE, greenish gray. ZEOLITE rich zones in Core 4 (300 to 309 m). Volcanic ash layers in Cores 1 (102 to 111 m) and Core 4 (300 to 309 m). (350? to 551? m) CLAY rich FORAM NANNO CHALK, light bluish gray with some nanno foram marl, radiolarian rich nanno chalk, and sandy layers. 551(?) m boundary picked from slight slow down in drilling rate.
UNIT II (551 to 758.90 m) LIMESTONE, MARLSTONE and CHERTS	551? to 758 m Light gray, LIMESTONE and SILICEOUS LIMESTONE, MARLSTONE and SILICEOUS MARLSTONE, and some silicified claystone and calcareous chert. Limestones and marlstones are micritic with rare nannofossils, radiolarians, and sponge spicules. Light olive gray zeolitic zones in Core 11 (600 to 609 m). BRECCIA, LIMESTONE, pale blue green in Core 12 (609 to 619 m). In the lower part of the hole are ash layers, light olive gray to brown, and volcanic clays, silts and sands, greenish black. Organic rich volcanic sediments, olive black, at 730 to 740 m in Core 16.
UNIT III (758.90 to 776 m T.D.) BASALT	BASALT, gray amygdoloidal, with altered chlorite in the cracks.


HOLE 153
DEPTH m
CALCIUM CARBONATE (%)
0 50 100
SAND-,SILT-, AND CLAY-SIZE BOUNDARIES (accumulative %)
0 50 100
NATURAL GAMMA RADIATION (counts/1.25 min / 7.6 cm. core int.)
0 3000
WET-BULK DENSITY ···= G.C.D. (gm/cc)
1 2 3
SOUND VELOCITY (km/sec)
2 3 4 5
100
200
300
400
500
600
700
800

SITE 153 HOLE CORE 1 CORED INTERVAL (m) 102-111

AGE: MIDDLE PLIOCENE

ZONE: FORAM: Globorotalia miocenica (Globigernoides trilobus fistulosus sz); NANNO: Discoaster surculus

SECTION	METERS	LITHOLOGY	PALEO SAMPLE ABUNDANCE PRESERVATION	LITHOLOGIC DESCRIPTION[1]	DEFORMATION
1	0.5	VOID			
1	1.0		F A W N C W	5GY5/1 5GY5/2	III
2	0.5			5GY6/1 plagioclase	III
2	1.0		N C W	5GY4/1	III
3	0.5			10GY4/2 and 5GY6/1	II
3	1.0		N C W F A W		III
4	0.5		N C W	5Y4/1 to 5Y5/2	III
4	1.0			*(replacing a cylindrical burrow)	II
5	0.5			5GY4/1 and 5Y4/1	II
5	1.0		N F M F A W		III
6	0.0		N C W	*	III
6	0.5			5Y4/1	III
6	1.0	VOID	F A W	biotite, hornblende, plagioclase, phillipsite conspicuous	III
CORE CATCHER			F A W N C W		

NANNOPLANKTON CALCAREOUS CLAY; varied in color from greenish gray to grayish olive.

Iron sulfide staining is common and pyrite (indicated by "*") occurs as shell replacements. Pyrite increases slightly with depth. Some carbonate rhombs.

A light olive gray layer in Section 6 contains volcanic debris, rare quartz and chlorite, common zeolites and hornblende.

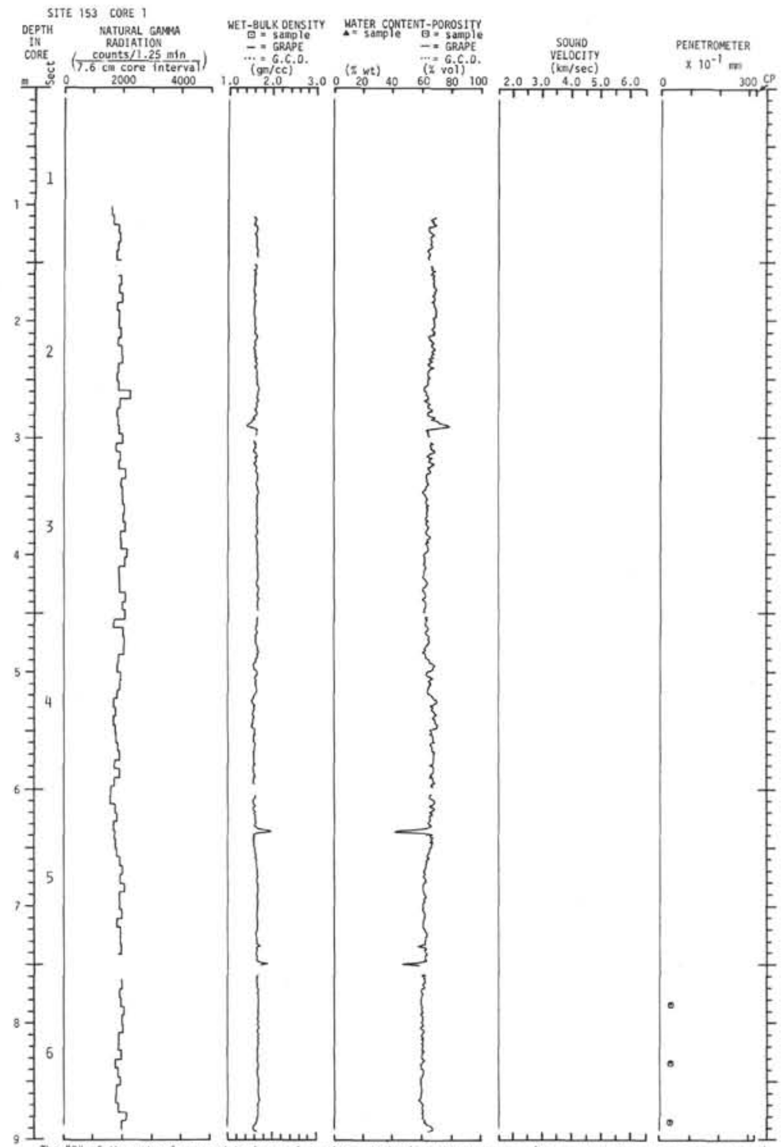
The entire core is disturbed.

Sediment is soft, plastic, and homogeneous.

III. Flow-in: intimate mixture.

CaCO₃ (%) / SAND-SILT-CLAY (accumulative %): 0 50 100

[1]For explanation of symbols, see Chapter 1



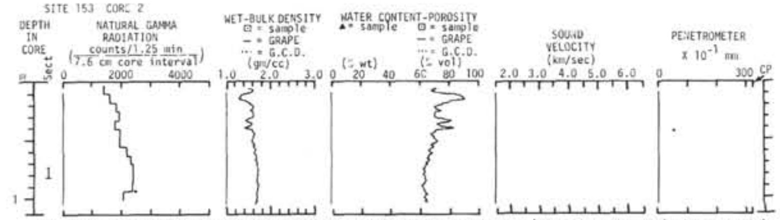
The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1428. This background was subtracted from the data.

SITE 153 HOLE CORE 2 CORED INTERVAL (m) 198-207

AGE	ZONE FORAM	ZONE NANNO	ZONE RAD	SECTION	METERS	LITHOLOGY	LITHO SAMPLE	PALEO SAMPLE ABUNDANCE PRESERVATION	LITHOLOGIC DESCRIPTION[1]	CaCO3 (%) SAND-SILT-CLAY (accumulative %) 0 50 100	DEFORMATION
LATE MIOCENE	Globorotalia acostaensis	Discoaster quinqueramus		1	0.5 1.0			F F M n	5GY4/1 CLAY; drilling breccia (V) with iron sulfide streaking, becomes more compact below 67 cm. No horizontal structures observed.		V
				CORE CATCHER				N R M F C M	Core catcher contains detrital grains of quartz, plagioclase, orthoclase, zoisite, and amphibole. Fish teeth, gypsum micronodules, biotite, and apatite. Radiolaria replaced by pyrite also occur. In addition, X-ray diffraction shows K-feldspar. Analyses of pellets in the core catcher shows the following:		

FE_2O_3	2.0%
MnO	46 %
Ba	22000 ppm
Sr	2000 ppm
Cu	<200 ppm

[1]For explanation of symbols, see Chapter 1

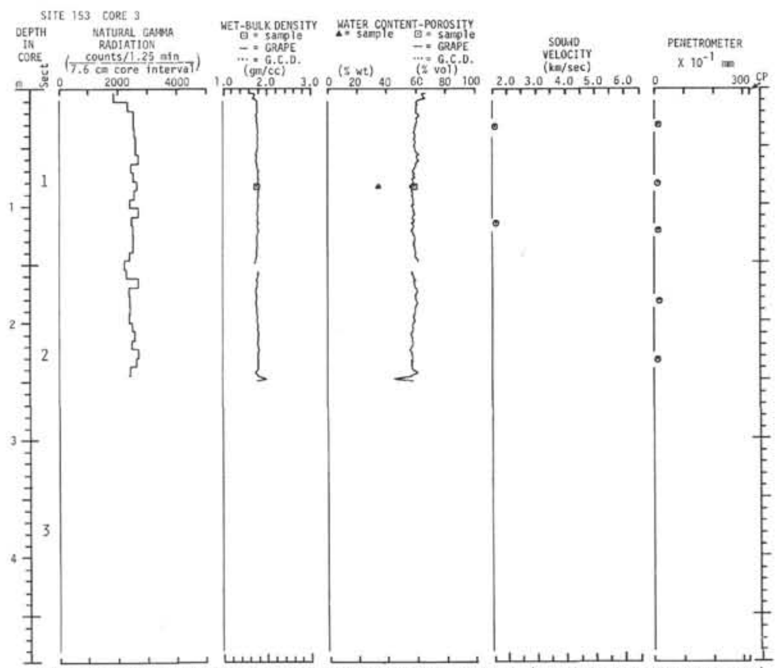


The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1408. This background was subtracted from the data.

SITE 153 HOLE CORE 3 CORED INTERVAL (m) 207-216

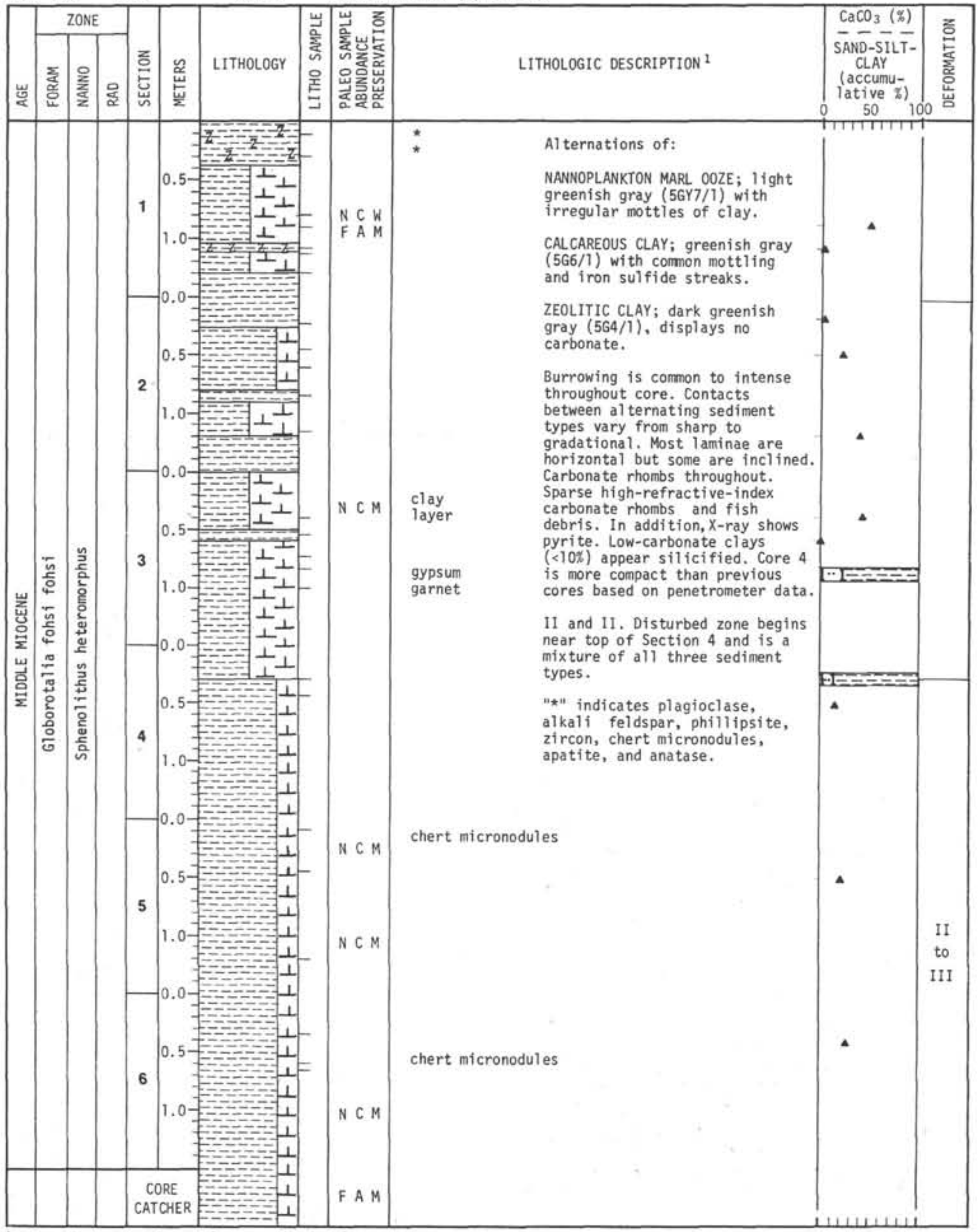
AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGY	LITHO SAMPLE	PALEO SAMPLE ABUNDANCE PRESERVATION	LITHOLOGIC DESCRIPTION [1]	$CaCO_3$ (%) SAND-SILT-CLAY (accumulative %) 0 50 100	DEFORMATION
LATE MIOCENE	Globorotalia acostaensis	Discoaster quinqueramus		1	0.5, 1.0			N R P / F C M; N F P	5GY4/1 CLAY; compact and homogeneous with abundant iron sulfide streaking. Slight mottling occurs. Sediment becomes less compact in Sections 3 and 4 due to disturbance. Pyrite is abundant to common in lower part of Section 1. Sparse plagioclase, scattered carbonate rhombs, and pyrite. In addition, X-ray shows K-feldspar.		
				2	0.0, 0.5, 1.0	VOID		n			III
				3	0.0, 0.5, 1.0, 0.5	VOID		N F P			
				CORE CATCHER				R O / F C M			

[1] For explanation of symbols, see Chapter 1

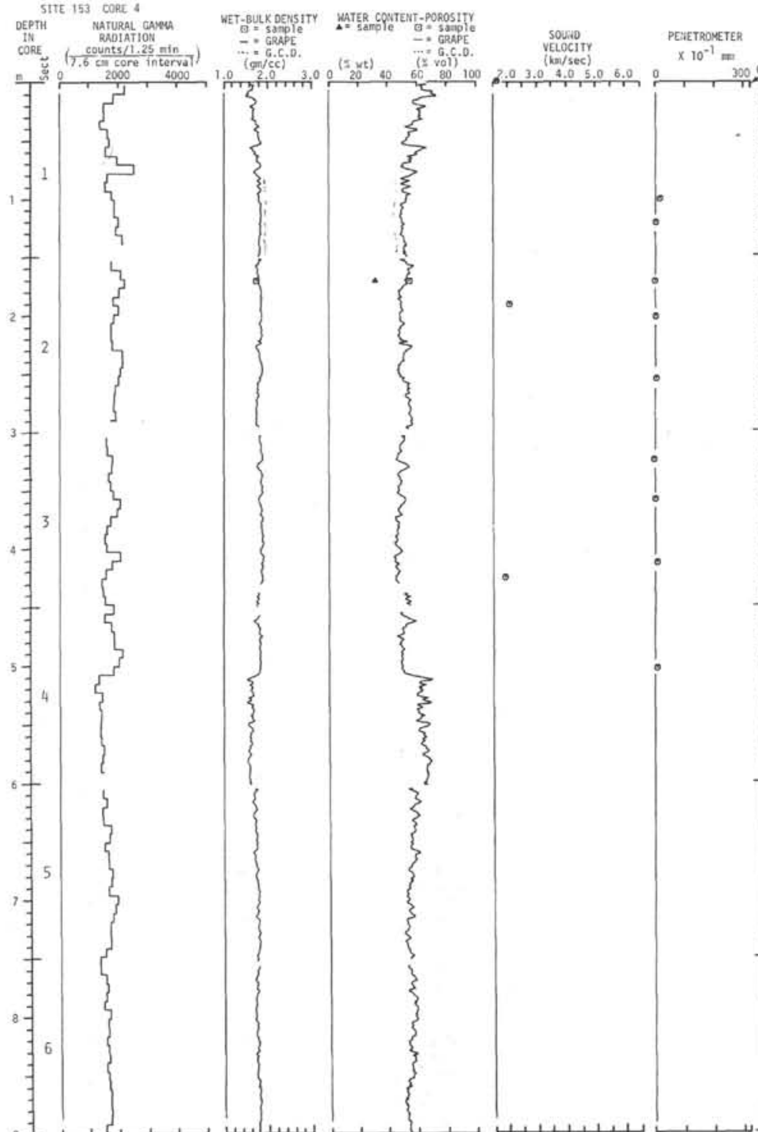


The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1420. This background was subtracted from the data.

SITE 153 HOLE CORE 4 CORED INTERVAL (m) 300-309



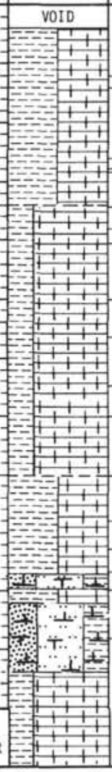
[1]For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1407. This background was subtracted from the data.

SITE 153 HOLE CORE 5 CORED INTERVAL (m) 403-412

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGY	LITHO SAMPLE	PALEO SAMPLE ABUNDANCE PRESERVATION		LITHOLOGIC DESCRIPTION[1]	CaCO3 (%) / SAND-SILT-CLAY (accumulative %) 0 50 100	DEFORMATION
MIDDLE MIOCENE	Globorotalia fohsi peripheroronda	Sphenolithus heteromorphus		1	0.5, 1.0	VOID		R O; F A M; N C W				
EARLY MIOCENE	Globigerinatella insueta			2	0.5, 1.0			N C W; R O; N C W	pyrite			
				3	0.5, 1.0			N C W; R O; N C W; F C M				
		Sphenolithus belemnos ?	* *	4	0.5, 1.0			N C W; F A M; R O; R O; R C M; N C W; R C M				
	*			CORE CATCHER				R C M; F A M				

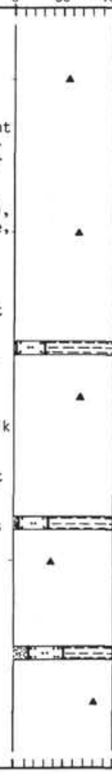


FORAMINIFERAL NANNOPLANKTON MARL to FORMINIFERAL NANNOPLANKTON CHALK; light bluish gray (5B7/1) with infrequent bedding but common mottling. Variation of calcium carbonate alone differentiates the sediment types. Carbonate rhombs throughout. X-ray also shows K-feldspar and pyrite.

Mottles are oval (1 cm diameter), often display internal structure, and appear both parallel and inclined to bedding. Mottling varies from light olive gray (5Y6/1) to olive gray (5Y4/1). Burrowing has mixed all sediment types and the resulting mottles vary greatly in amount of calcium carbonate. Chevron-type burrows occur as in Site 146. Pyrite occurs in some mottles.

Boundaries between marl and chalk are gradational and each generalized unit may contain several alternations of sediment type.

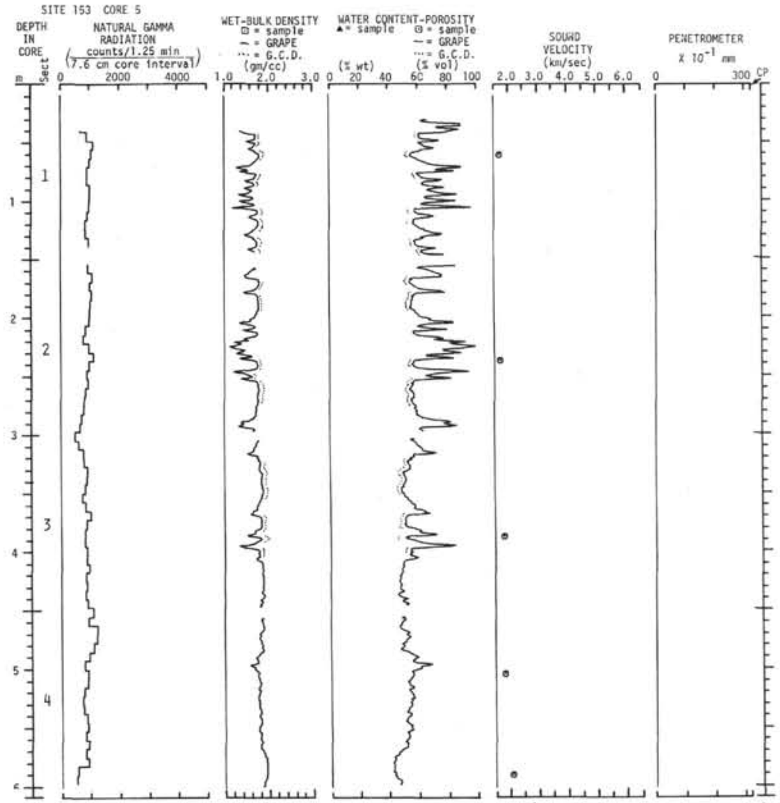
CALCAREOUS SAND-SILT-CLAY occurs in Section 4 and is generally homogeneous except for slight upward grading from 47 to 32 cm. Basal contact of this unit is sharp against underlying chalk.



[1]For explanation of symbols, see Chapter 1

* Globigernoides primordius

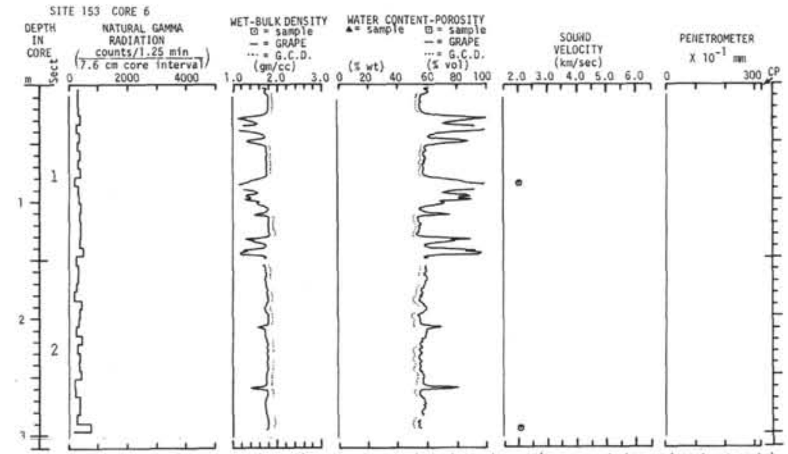
* * Calocycletta virginis



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1396. This background was subtracted from the data.

SITE 153 HOLE CORE 6 CORED INTERVAL (m) 412-421

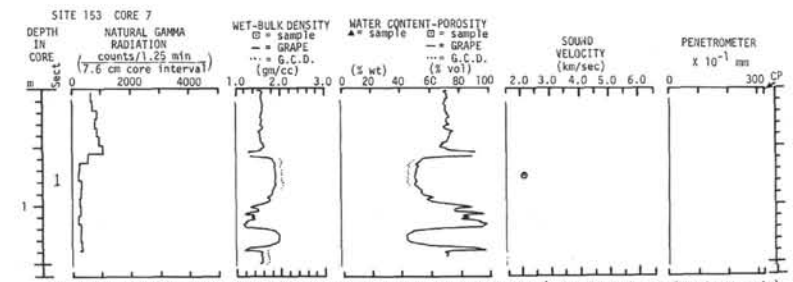
AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGY	LITHO SAMPLE	PALEO SAMPLE ABUNDANCE PRESERVATION	LITHOLOGIC DESCRIPTION[1]	CaCO3 (%) / SAND-SILT-CLAY (accumulative %) 0 50 100	DEFORMATION
LATE OLIGOCENE - EARLY MIOCENE	Globorotalia kugleri	Triquetrorhabdulus carinatus	Calocycletta virginis	1	0.5, 1.0			N C P F A P N C P	NANNOPLANKTON CHALK; bluish white (5B9/1) to light gray (N7) uniform chalk containing nannofossils and micrite with foraminifers, radiolaria, and sponge spicules. Mottling is slight to common and is greenish black (5GY2/1). Core is very compacted and indurated. The acetate peel indicates that the components are unoriented and unsorted, and their chambers are either empty or micrite filled. Sparse plagioclase. X-ray also shows K-feldspar. One blackish red (5R2/2) layer occurs at 43-47 cm in Section 2. The lower boundary is sharp and the upper gradational. Composition is similar to remaining core except for a trace of dolomite.		
				2	0.0, 0.5, 1.0	VOID		R A M N C P N C P			
				CORE CATCHER				R C M			



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1396. This background was subtracted from the data.

SITE 153 HOLE CORE 7 CORED INTERVAL (m) 499-508

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGY	LITHO SAMPLE	PALEO SAMPLE ABUNDANCE PRESERVATION	LITHOLOGIC DESCRIPTION[1]	CaCO3 (%) / SAND-SILT-CLAY (accumulative %) 0 50 100	DEFORMATION
MIDDLE OLIGOCENE	Globigerina ampliapertura	Sphenolithus predistentus	Theocyrtis tuberosa	1	0.5, 1.0			N C M F A M R A M	plagioclase — NANNOPLANKTON CHALK; light bluish gray (5B7/1) mixed with clasts of dark greenish gray (5GY4/1) and greenish gray (5G6/1) noncalcareous clay, from 0-57 cm; the compact nannoplankton chalk (57-150 cm) displays slight to intense (57-76 cm) very dusky purple mottling (5P2/2) containing sulfides. Radiolaria and sponge spicules occur but are not common. Sparse plagioclase. X-ray also shows K-feldspar.	V	
				CORE CATCHER				R A G F A M			

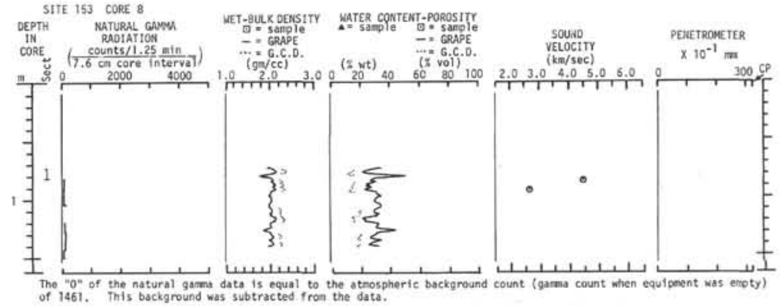


The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1428. This background was subtracted from the data.

[1] For explanation of symbols, see Chapter 1

SITE 153 HOLE CORE 8 CORED INTERVAL (m) 563-572

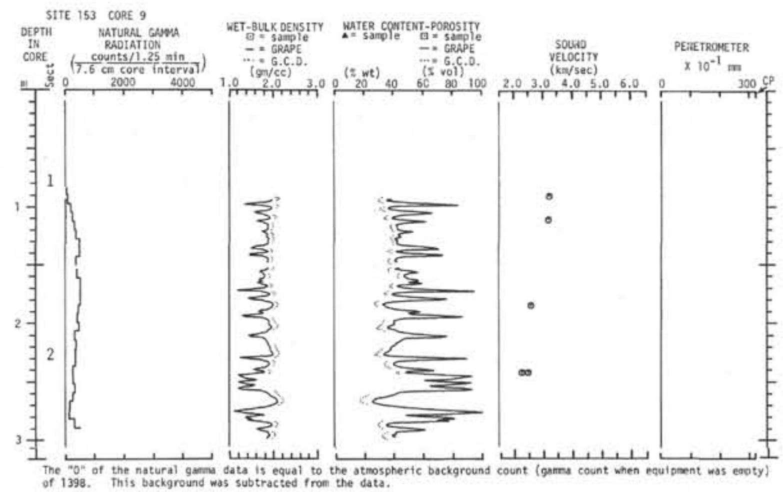
AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGY	LITHO SAMPLE	PALEO SAMPLE ABUNDANCE PRESERVATION	LITHOLOGIC DESCRIPTION[1]	CaCO₃ (%) ---- SAND-SILT-CLAY (accumulative %) 0 50 100	DEFORMATION
EARLY EOCENE	Globorotalia formosa formosa	Discoaster gemmeus		1	0.5 1.0	VOID		N F P F A M	SILICEOUS LIMESTONE, light gray (N8) and laminated, interbedded with light olive gray (5Y6/1) CALCAREOUS CHERT.	▲	
				CORE CATCHER				R O F A M	Foraminiferal test walls are preserved and chambers are empty or filled by matrix. Dolomite is observed. X-ray shows cristobalite. Silicified limestone displays fossil walls all or partly silicified with outlines preserved and chambers filled with silica. Silicified zones are concentrations of small silica lenses with both sharp and gradational contacts to the limestone matrix. Staining indicates calcite content of core catcher material is irregular. Some chert occurs.		



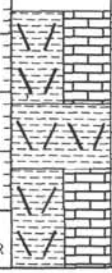
SITE 153 HOLE CORE 9 CORED INTERVAL (m) 586-591

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGY	LITHO SAMPLE	PALEO SAMPLE ABUNDANCE PRESERVATION	LITHOLOGIC DESCRIPTION[1]	CaCO₃ (%) ---- SAND-SILT-CLAY (accumulative %) 0 50 100	DEFORMATION
PALEOCENE	?	Fasciculithus tympaniformis	unzoned	1	0.5 1.0	VOID		F F P N F P F F P R F P F C P	SILICIFIED MARL grading into LIMESTONE. Silicified marl (5GY6/1) has numerous lenticular laminations (1 mm thick) due to burrowing. Several zones of olive gray CHERT (5Y4/1) occur where silicification increases. Grades to very light gray (N8) limestone near 60 cm in Section 2. The limestone displays rare nannofossils and grains of micrite. A trace of dolomite occurs. Carbonate rhombs throughout. X-ray shows cristobalite, clinoptilolite, and barite.	▲	
MIDDLE PALEOCENE	Globorotalia pusilla pusilla			2	0.0 0.5 1.0			F R P N F P R F P		▲	
				CORE CATCHER				F R P R F M			

[1]For explanation of symbols, see Chapter 1



SITE 153 HOLE CORE 10 CORED INTERVAL (m) 591-600

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGY	LITHO SAMPLE	PALEO SAMPLE ABUNDANCE PRESERVATION	LITHOLOGIC DESCRIPTION[1]	$CaCO_3$ (%) / SAND-SILT-CLAY (accumulative %) 0 50 100	DEFORMATION
MIDDLE PALEOCENE	Globorotalia pusilla pusilla (indirectly)	Fasciculithus tympaniformis	unzoned	1	0.5 1.0	VOID					
				2	0.0 0.5 1.0			F F P F R P F R P N F P R F P	pyrite radiolarian molds		VI
				CORE CATCHER				F F P R R M			

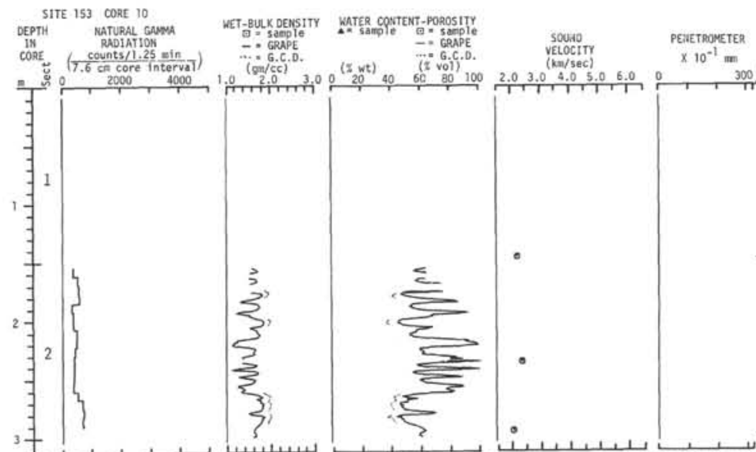
MICRITIC MARL; greenish gray (5GY6/1) to light olive gray (5Y6/1) with minor amounts of nannoplankton, radiolaria, and sponge spicules. Light colored glass, authigenic calcite, and plagioclase also occur. Marl is heavily bioturbated and has lenses (3 cm x 1 cm and smaller) displaying sharp and gradational contacts. Marl grades into underlying unit over ~5 cm at 60 cm in Section 2. Fractures abundant in lower part.

SILICIFIED CLAYSTONE; Light gray olive (5Y5/2), homogeneous, with minor radiolaria, sponge spicules, plagioclase, and quartz. Radiolaria are poorly preserved and filled by opal. Thin section reveals subparallel particle orientation. Common plagioclase, sparse biotite, and chert micronodules. X-ray shows cristobalite, clinoptilolite, and barite. A fracture is surrounded by a 5 mm thick greenish gray (5GY6/1) zone at 100-105 cm. Contact with underlying marl is sharp but marl is crumbly at 115-130 cm in Section 2.

Thin section: slightly calcareous clay with radiolaria "ghosts", and euhedral to anhedral silt sized quartz, plagioclase, and pyrite.

RADIOLARIAN ARGILLACEOUS LIMESTONE; highly bioturbated, with abundant fragmented sponge spicules and fish bones. Radiolaria are replaced by calcite. Matrix contains nannoplankton fragments, clays, and micrite. Concentration of carbonate in the burrows.

[1]For explanation of symbols, see Chapter 1

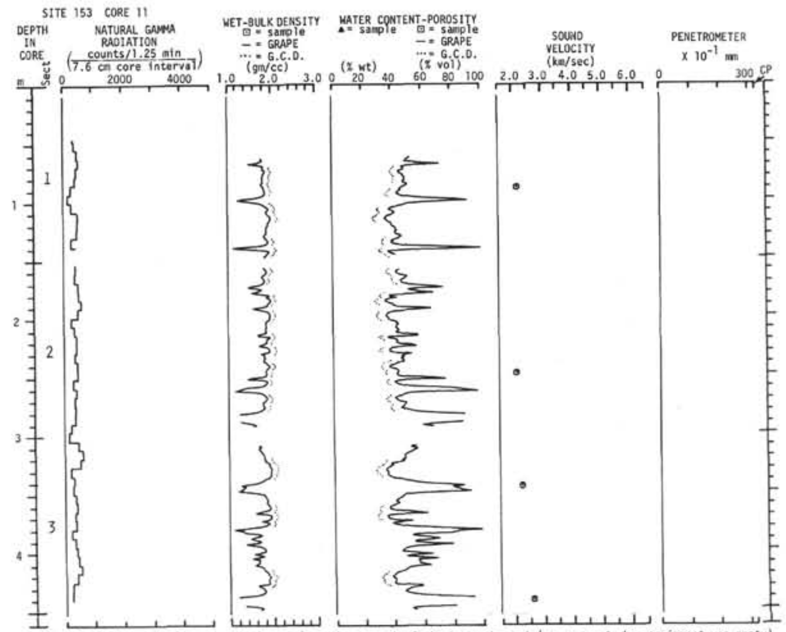


The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1382. This background was subtracted from the data.

SITE 153 HOLE CORE 11 CORED INTERVAL (m) 600-609

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGY	LITHO SAMPLE	PALEO SAMPLE ABUNDANCE PRESERVATION	LITHOLOGIC DESCRIPTION[1]	CaCO3 (%) / SAND-SILT-CLAY (accumulative %) 0 50 100	DEFORMATION
MIDDLE PALEOCENE	Globorotalia pusilla pusilla; 2	Fasciculithus tympaniformis	unzoned	1, 2, 3	0.5, 1.0, 0.0, 0.5, 1.0, 0.0, 0.5, 1.0	VOID		R F M, N F M, F C P, R F M, N F P, F C P, N F P, F A M, F C P, N F P	NANNOPLANKTON MARL and ARGILLACEOUS LIMESTONE; light olive gray (5Y6/1) to light bluish gray (5B7/1) with darker zones of olive gray (5Y4/1). Laminae and lenses are common, parallel to bedding, and most have sharp contacts. Some plagioclase; sparse quartz and clinoptilolite. X-ray also shows cristobalite and barite. Light bluish gray zones seem associated with microfractures. Foraminifers are microspar and spar filled. Nannofossils appear to be partly recrystallized. ZEOLITIC CALCAREOUS CLAY; olive gray (5Y4/1) to light olive gray (5Y6/1), occurs as zones in Section 3. Clinoptilolite is abundant and plagioclase minor. Fractures are green coated with black material. 2. Globorotalia angulata		
				CORE CATCHER				F C M, R F M			

[1]For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1416. This background was subtracted from the data.

SITE 153 HOLE CORE 12 CORED INTERVAL (m) 609-619

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGY	LITHO SAMPLE	PALEO SAMPLE ABUNDANCE PRESERVATION	LITHOLOGIC DESCRIPTION[1]	CaCO3 (%) / SAND-SILT-CLAY (accumulative %) 0 50 100	DEFORMATION
2 / 3	? / 4	5		1	0.5 / 1.0	VOID		F F P / N F M / N F M / F C M / N C M / F F P / F F P / N F M	plagioclase / fine clinoptilolite / plagioclase		
MIDDLE MAASTRICHTIAN	Globotruncana gansseri	?		2	0.0 / 0.5 / 1.0			N C M / F A M			
EARLY MAASTRICHTIAN	Globortruncana "tricarinata"			3	0.0 / 0.5 / 1.0			F A M / F A M / N F M	chert micro-nodules		
				CORE CATCHER				F A M / R O			

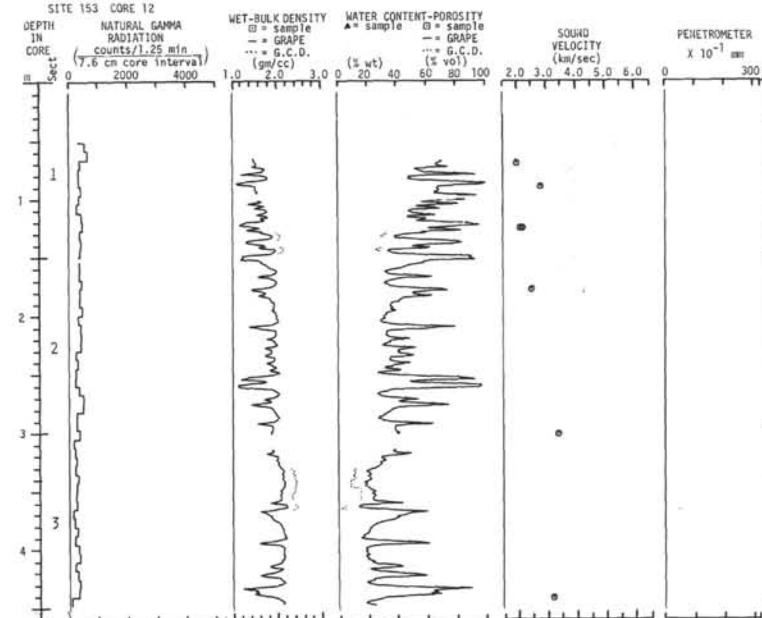
CALCAREOUS CLAY and NANNOPLANKTON MARL; olive gray (5Y4/1) to light olive gray (5Y6/1), intensively mottled and bioturbated. Sparse plagioclase, clinoptilolite, and chert micronodules. X-ray also shows cristobalite and barite. Burrows appear flattened. Clay-rich zones contain abundant clinoptilolite. Pale blue green (5BG7/2) zones around fractures. Sediment types alternate with no well-defined bedding.

LIMESTONE BRECCIA ("hard ground"); variable pale blue green (5BG7/2) to grayish blue green (5BG5/2) silicified marl fragments, micrites, and sparse biomicrites. Highly bioturbated; burrows contain packed foraminiferal biomicrite. The foraminifers are small and chalcedony filled. Also contains authigenic quartz and feldspar. The fractures contain breccia of the same composition cemented by drusy calcite and authigenic sand-sized feldspar. A chert pebble is found on top of the breccia.

FORAMINIFERAL LIMESTONE; light olive gray (N8) the color varying with the amount of calcium carbonate. Packed biomicrite, with foraminifers parallel oriented in some cases and unoriented in others. Rare radiolaria and benthonic foraminifers. Microspar and sparry filling, with a micritic and argillaceous matrix. Moderate to intense bioturbation. A cemented fracture occurs within the limestone (Section 3, 55-80 cm) and contains limestone fragments.

2. EARLY-MIDDLE PALEOCENE
3. EARLY PALEOCENE
4. Globigerina eugubina
5. Cruciplacolithus tenuis

[1] For explanation of symbols, see Chapter 1



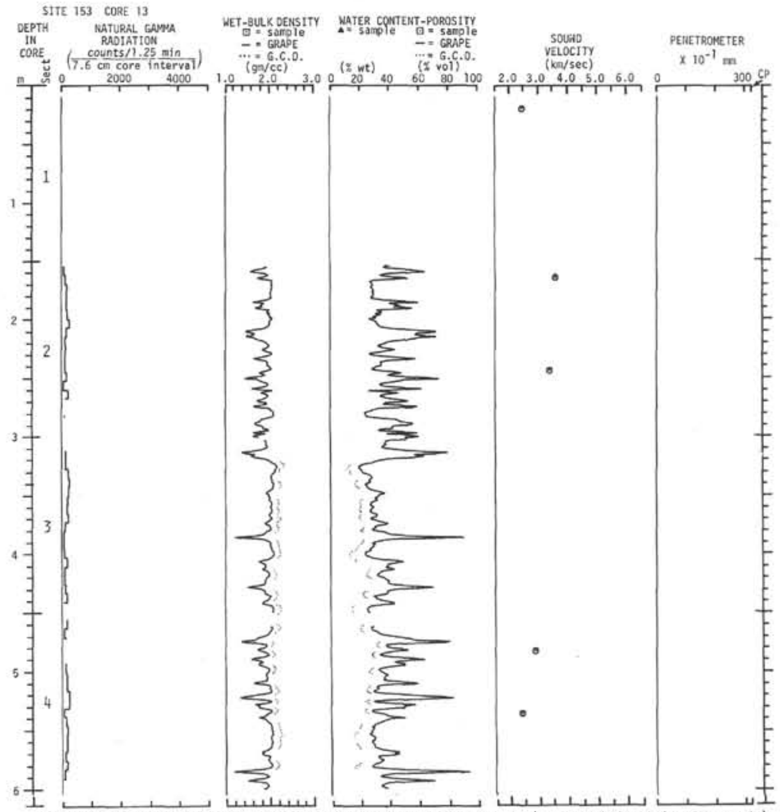
The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1398. This background was subtracted from the data.

SITE 153 HOLE CORE 13 CORED INTERVAL (m) 619-656

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGY	LITHO SAMPLE	PALEO SAMPLE ABUNDANCE PRESERVATION	LITHOLOGIC DESCRIPTION[1]	CaCO3 (%) - - - - SAND-SILT-CLAY (accumulative %) 0 50 100	DEFORMATION
EARLY MAASTRICHTIAN	Globorotruncana "tricarinata"	?		1	0.5 1.0	VOID					
				2	0.5 1.0			F A W	chert micro-nodules; chert micro-nodules		
				3	0.5 1.0			F A W N F P			
				4	0.5 1.0				chert micro-nodules		
				CORE CATCHER				F A M R O			

ARGILLACEOUS LIMESTONE; light bluish gray (5B7/1) to very light gray (N8), some nannoplankton and foraminifera. Lenticular laminae of light olive gray (5Y6/1) form bedding. Dark mottles are siliceous and have abundant micronodules. Acetate peel and thin section suggest a sparse argillaceous biomicrite with foraminifers filled with microspar and sparite. Also contains ostracods and fish scales. Foraminiferal fragments and in situ collapsed foraminifera are oriented parallel to bedding. Matrix is micritic and argillaceous, with rare nannofossils. Bioturbation is moderate to intense resulting in lenticular laminae and mottling. Section 3 displays chevron-type burrows. Entire core displays a complex arrangement of lenses and mottles. Greenish gray (5G6/1) mottling occurs in Section 2 and increases slightly downward. Darker mottles are slightly siliceous and contain micronodules and radiolarian molds. CALCAREOUS CHERT appears in minor amounts and is bluish gray (5B6/1). Some foraminifers and nannofossils are present; silica replaces foraminifers. Greenish gray (5G6/1) zones surround fractures. X-ray shows cristobalite, K-feldspar, clinoptilolite, and barite.

[1]For explanation of symbols, see Chapter 1

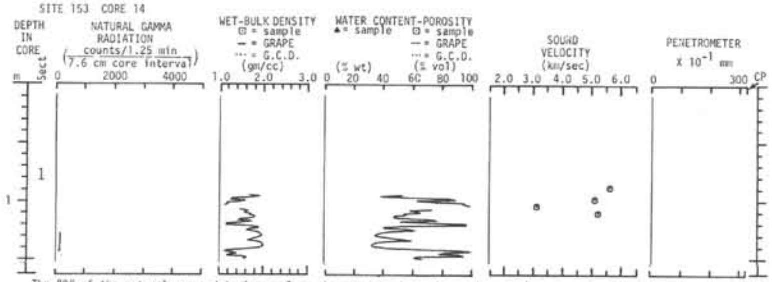


The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1418. This background was subtracted from the data.

SITE 153 HOLE CORE 14 CORED INTERVAL (m) 656-667

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGY	LITHO SAMPLE	PALEO SAMPLE ABUNDANCE PRESERVATION	LITHOLOGIC DESCRIPTION[1]	$CaCO_3$ (%) SAND-SILT-CLAY (accumulative %) 0 50 100	DEFORMATION
CRETACEOUS	?	?		1	0.5 1.0	VOID		F R P N F P	LIMESTONE and CHERT fragments. Limestone is highly banded with argillaceous micrite. Fauna is oriented parallel to bedding and is filled by microspar and sparite. Argillaceous matrix bends around forams indicating compaction. Numerous laminae and lenses occur with both sharp and gradational contacts. Foraminifers, nannofossils, and radiolaria are rare. Some lenses are siliceous and display red molds and micronodules. Chert fragments are brownish gray (5YR6/1) with conchoidal fracture. Calcareous chert with irregular silicified areas of microquartz and ghosts of foraminifers and partially replaced sparite.	▲	
				CORE CATCHER							

[1]For explanation of symbols, see Chapter 1

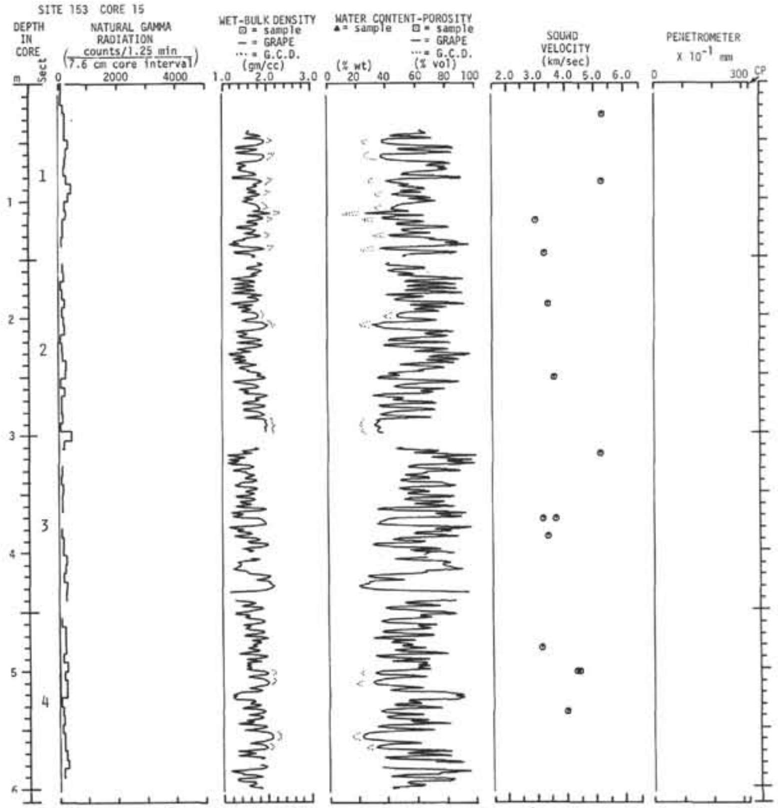


The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1418. This background was subtracted from the data.

SITE 153 HOLE CORE 15 CORED INTERVAL (m) 667-731

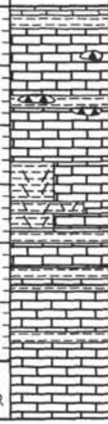
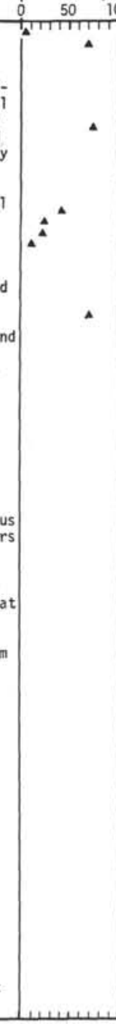
AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGY	LITHO SAMPLE	PALEO SAMPLE ABUNDANCE PRESERVATION	LITHOLOGIC DESCRIPTION[1]	$CaCO_3$ (%) / SAND-SILT-CLAY (accumulative %) 0 50 100	DEFORMATION
CONIACIAN	Globotruncana concavata concavata	?		1	0.5, 1.0	VOID		F C P N R P	SILICEOUS LIMESTONE with CHERT layers. Limestone is very light gray (N8) to light gray (N7) radiolaria foraminiferal biomicrite. Fossils are both oriented parallel to bedding and unoriented. Tests are filled with microspar and sparite while fragments are filled by micritic matrix. Nannofossils are rare. Often micro-cross-laminated with rare microstylolites. Burrowing is slight to moderate throughout and is best observed in darker areas. Slightly friable sandy texture in parts of Section 1. Matrix is often draped over fossils indicating compaction. Slightly silicified, with chalcedony filling in some radiolaria. Radiolarian molds throughout. Chert is light olive gray (5Y5/2) to brownish gray (5YR4/1) and often displays the remains of matrix and fossils of limestone. Chert-limestone contacts are sharp and undulating. At Section 2, 11-14 cm, the radiolarian foraminiferal limestone contains disseminated barite crystals, some also in fractures.		
				2	0.0, 0.5, 1.0				ASH layers occur in all sections. One layer (Section 1, 84 cm) is siliceous clay and ash containing micronodules, feldspar, zircon, hornblende, and apatite. Ash often occurs in burrows.		
				3	0.0, 0.5, 1.0			F C P N R P	"*" indicates plagioclase, alkali feldspar, green hornblende, biotite, apatite, and zircon.		
				4	0.0, 0.5, 1.0				"†" indicates basaltic ash with plagioclase, altered palagonite, and glauconite.		
				CORE CATCHER				F C P R O	X-ray diffraction shows cristobalite, clinoptilolite, and barite.		

[1]For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1445. This background was subtracted from the data.

SITE 153 HOLE CORE 16 CORED INTERVAL (m) 731-740

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGY	LITHO SAMPLE	PALEO SAMPLE ABUNDANCE PRESERVATION	LITHOLOGIC DESCRIPTION[1]	$CaCO_3$ (%) / SAND-SILT-CLAY (accumulative %)	DEFORMATION
CONIACIAN	Globotruncana concavata concavata	?		1	0.5, 1.0				phosphorite; fish debris; organic matter		
				2	0.0, 0.5, 1.0			F C P / N R P	fish debris, glauconite, phosphorite; phosphorite; large pyrite nodules		
				CORE CATCHER				R O / F A M			

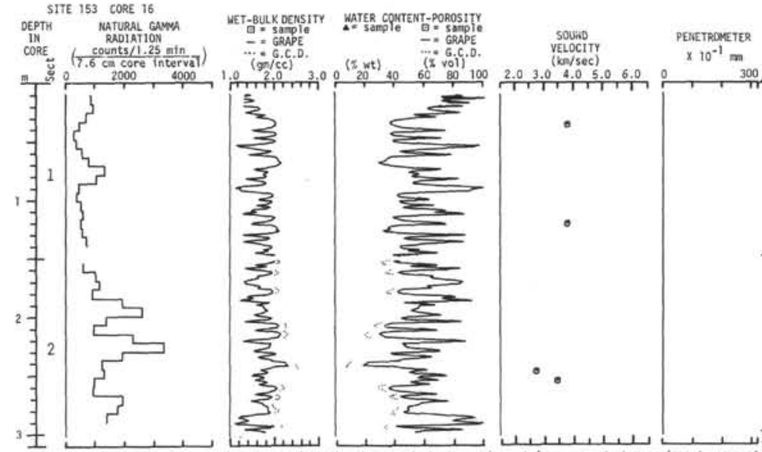
FORAMINIFERAL LIMESTONE interbedded with phosphatic CALCAREOUS CLAYS and VOLCANIC IRON-RICH ORGANIC CLAY. Foraminiferal limestone is predominantly very light gray (N8) with variegated streaks and lenses of olive gray (5Y4/1) and greenish black (5GY2/1). Thin section shows a mottled planktonic foraminiferal biomicrite with argillaceous matrix. Radiolaria and benthic foraminifers are rare. Fossils are filled with sparite and fragments are often concentrated into lenses. Occasionally contains abundant fish debris, scattered plagioclase, barite and basaltic ash. X-ray shows clinoptilolite. Phosphatic calcareous clay is olive black (5Y2/1) and often grades into surrounding limestone. Nodules and fish debris are common. Other clays display altered basaltic ash, chlorite, glauconite. Chert fragments are black to medium dark gray (N4) often thin laminated argillaceous foraminiferal chert. Foraminifers are replaced by chalcedony. Silicified matrix. Nodules of phosphorite, conspicuous barite crystals and fish debris found at Section 2 (68-71 cm).

Analysis of the clay at 68-71 cm in Section 2:

SiO_2	55.9%
Al_2O_3	4.9%
TiO_2	0.45%
Fe_2O_3	2.5%
MgO	0.8%
CaO	8.6%
Na_2O	1.30%
K_2O	0.20%
MnO	0.04%
P_2O_5	0.82%
Ba	1200 ppm
Sr	450 ppm
Cu	200 ppm

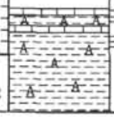
Laminated, bioturbated, RADIOLARIAN FORAMINIFERAL LIMESTONE with barite, plagioclase, fish debris, glauconite and basaltic ash fragments.

[1]For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1420. This background was subtracted from the data.

SITE 153 HOLE CORE 17 CORED INTERVAL (m) 740-749

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGY	LITHO SAMPLE	PALEO SAMPLE ABUNDANCE PRESERVATION	LITHOLOGIC DESCRIPTION[1]	CaCO₃ (%) / SAND-SILT-CLAY (accumulative %) 0 50 100	DEFORMATION
CRETACEOUS				1	0.5 1.0	VOID 		R F P	fish debris	▲	V.I
				CORE CATCHER				F F P			

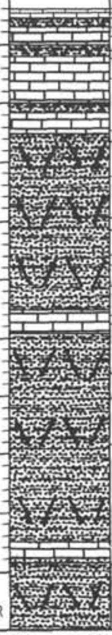
Interbedded MICRITIC LIMESTONE and SILTY VOLCANIC CLAY. Limestone is predominately light gray (N7-N8) and similar to Core 16 limestone. Volcanic clays are predominantly olive black (5Y2/1) and consist of altered basaltic ash with plagioclase, chert micronodules, chlorite, glauconite, clinoptilolite, abundant fish debris, and opal. Some alternation of coarse-fine lenses suggests reworking by currents.

Analysis of the clay at 121-127 cm in Section 1:

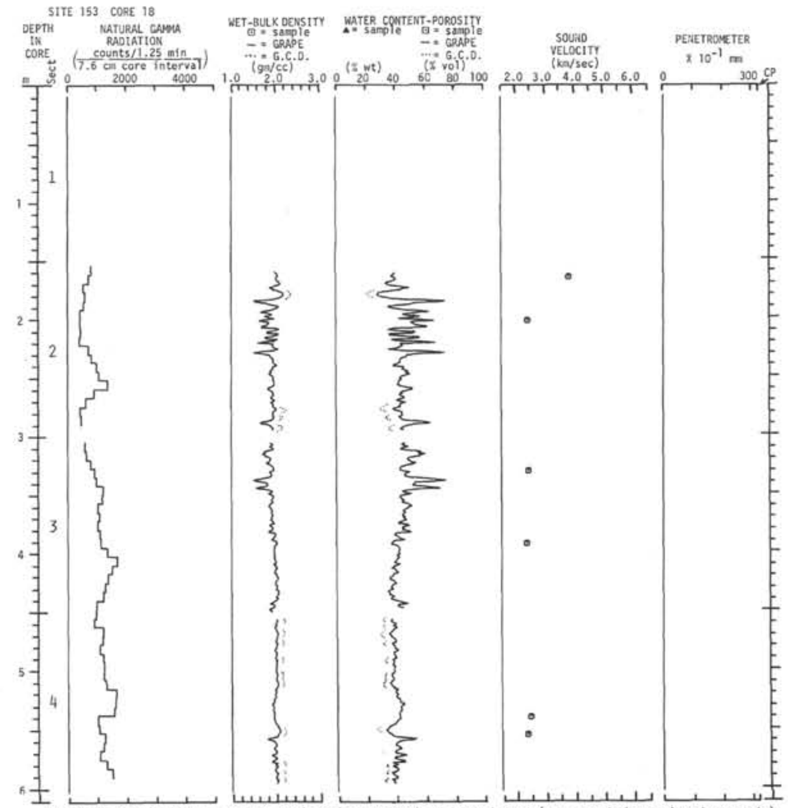
SiO_2	48.7%
Al_2O_3	12.6%
TiO_2	0.85%
Fe_2O_3	8.0%
MgO	5.5%
CaO	7.0%
Na_2O	2.50%
K_2O	0.70%
MnO	0.04%
P_2O_5	0.12%
Ba	1900 ppm
Sr	500 ppm
Cu	110 ppm

[1]For explanation of symbols, Chapter 1

SITE 153 HOLE CORE 18 CORED INTERVAL (m) 749-758

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGY	LITHO SAMPLE	PALEO SAMPLE ABUNDANCE PRESERVATION	LITHOLOGIC DESCRIPTION [1]	CaCO3 (%) / SAND-SILT-CLAY (accumulative %) 0 50 100	DEFORMATION
LATE TURONIAN - CONIACIAN	Globotruncana schneegansi	?		1	0.5 1.0	VOID 		F A M F C P N R P F C M F C P F F P N F P R O F C P N F P N R P f f N F P F R P	MICRITIC LIMESTONE interbedded with VOLCANIC SANDSTONES and SHALES. Limestone is predominately light gray (N7) and olive gray (5Y4/1) with minor nannofossils. Glauconite occurs in dark greenish gray laminae and lenses. Volcanic sands and shales are predominately greenish black (5G2/1) altered basaltic ash. Components include dark devitrified glass, chlorite, plagioclase, clay, and glauconite in varying amounts. Clay and glass are usually dominant. Some zones are slightly calcareous. This lithology displays complex bedding and structures. Graded bedding with sharp bottom contacts and gradational tops is common. Laminae and lenses with both sharp and gradational contacts is common. Graded beds often exceed 2 cm and become coarser and thicker (>10 cm) in Section 4. Flame structures appear in Section 2. All sections of this lithology are multibedded and not uniform as suggested by lithic column.		
				2	0.0 0.5 1.0						
				3	0.0 0.5 1.0						
				4	0.0 0.5 1.0						
				CORE CATCHER							

[1] For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1405. This background was subtracted from the data.

SITE 153 HOLE CORE 19 CORED INTERVAL (m) 758-767

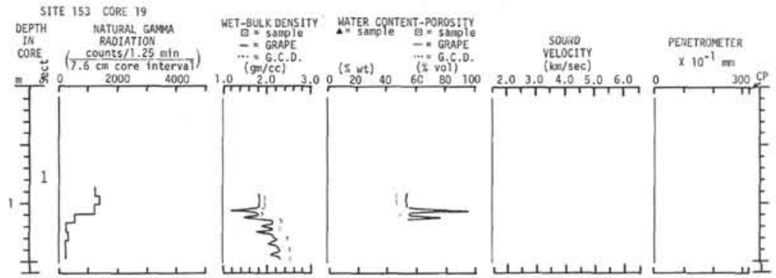
AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGY	LITHO SAMPLE	PALEO SAMPLE ABUNDANCE PRESERVATION	LITHOLOGIC DESCRIPTION[1]	CaCO3 (%) / SAND-SILT-CLAY (accumulative %) 0 50 100	DEFORMATION
LATE TURONIAN	Globotruncana schneegansi	?		1	0.5 / 1.0	VOID		F A M / N F M	radiolarian molds, basaltic ash, plagioclase		
				CORE CATCHER							

VOLCANIC SANDS and BASALT.
Volcanic sands are medium light gray (N6) to dark gray (N3) and strongly bedded. Laminations are 5-50 mm thick and graded. Beds have sharp bottom contacts, grading upward from coarse-medium sand to silt, and burrowing near the upper contacts. Slides suggest an altered basaltic ash with abundant dark devitrified glass and clay. Plagioclase and chert micronodules are rare. Chlorite, glauconite, and radiolaria molds are present.
Basalt is olive black (5Y3/1), fine grained, and sparsely amygdaloidal. Numerous fractures often filled with alteration material (chlorite). Mostly brown glass crowded with oxide and pyroxene microlite bundles. Some plagioclase microlites and pyroxene crystals occur.

X-ray results at 101-107 cm:

Diffuse scattered X-rays	62%
Amorphous scattering	41%
Calcite	58%
Quartz	2%
K-feldspar	6%
Montmorillite	33%
Pyrite	2%

[1]For explanation of symbols, see Chapter 1

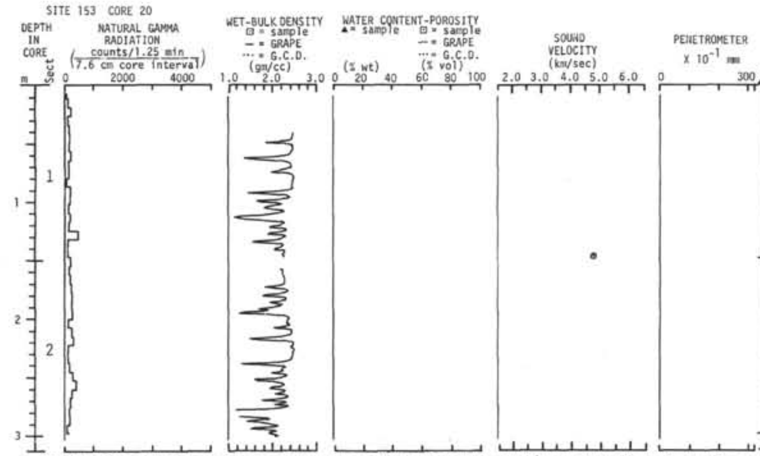


The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1405. This background was subtracted from the data.

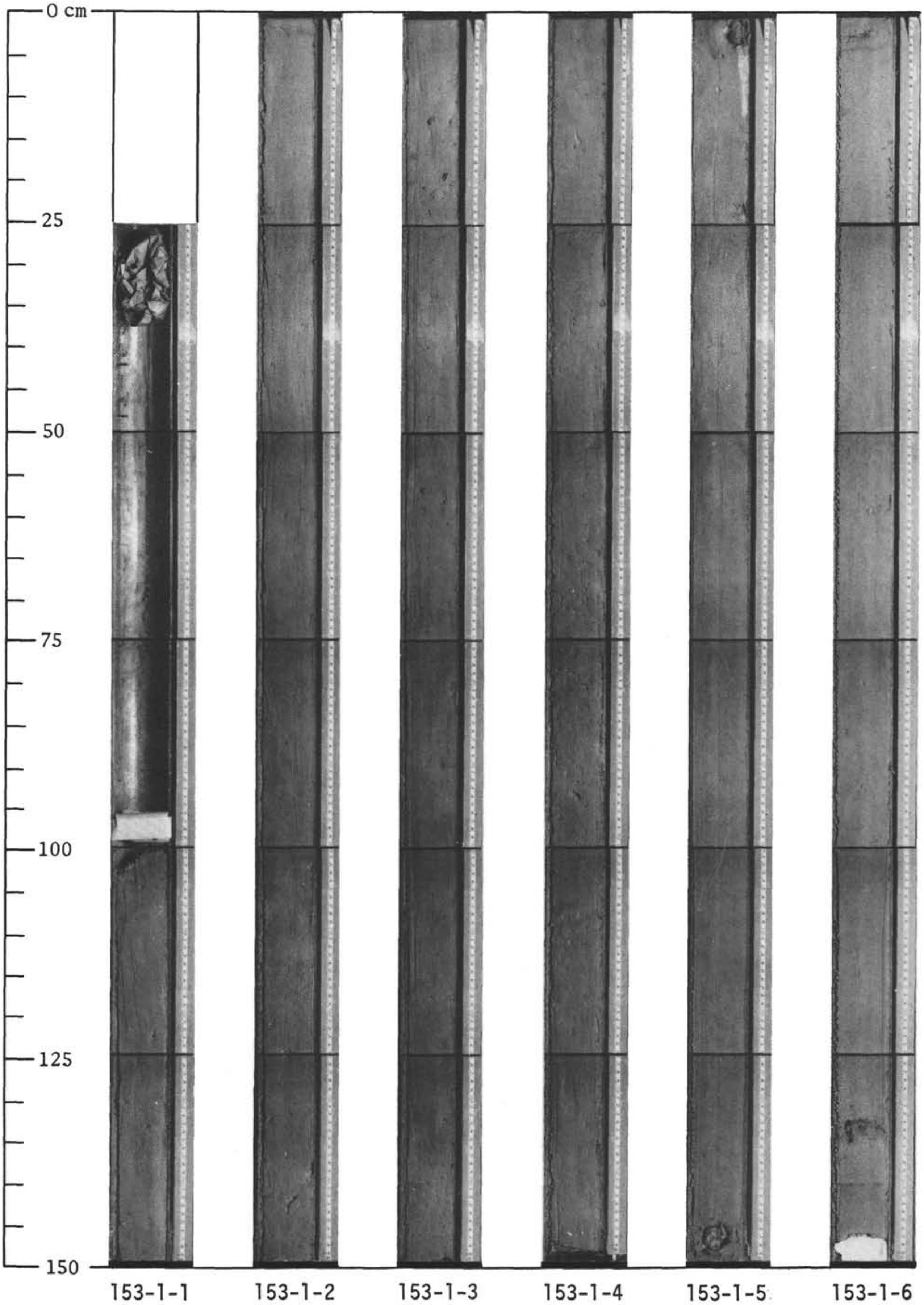
SITE 153 HOLE CORE 20 CORED INTERVAL (m) 767-776

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGY	LITHO SAMPLE	PALEO SAMPLE ABUNDANCE PRESERVATION	LITHOLOGIC DESCRIPTION[1]	$CaCO_3$ (%) / SAND-SILT-CLAY (accumulative %) 0 50 100	DEFORMATION
				1	0.5 1.0	VOID			BASALT: Same description as Core 19.		
				2	0.0 0.5 1.0						
				CORE CATCHER							

[1]For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1366. This background was subtracted from the data.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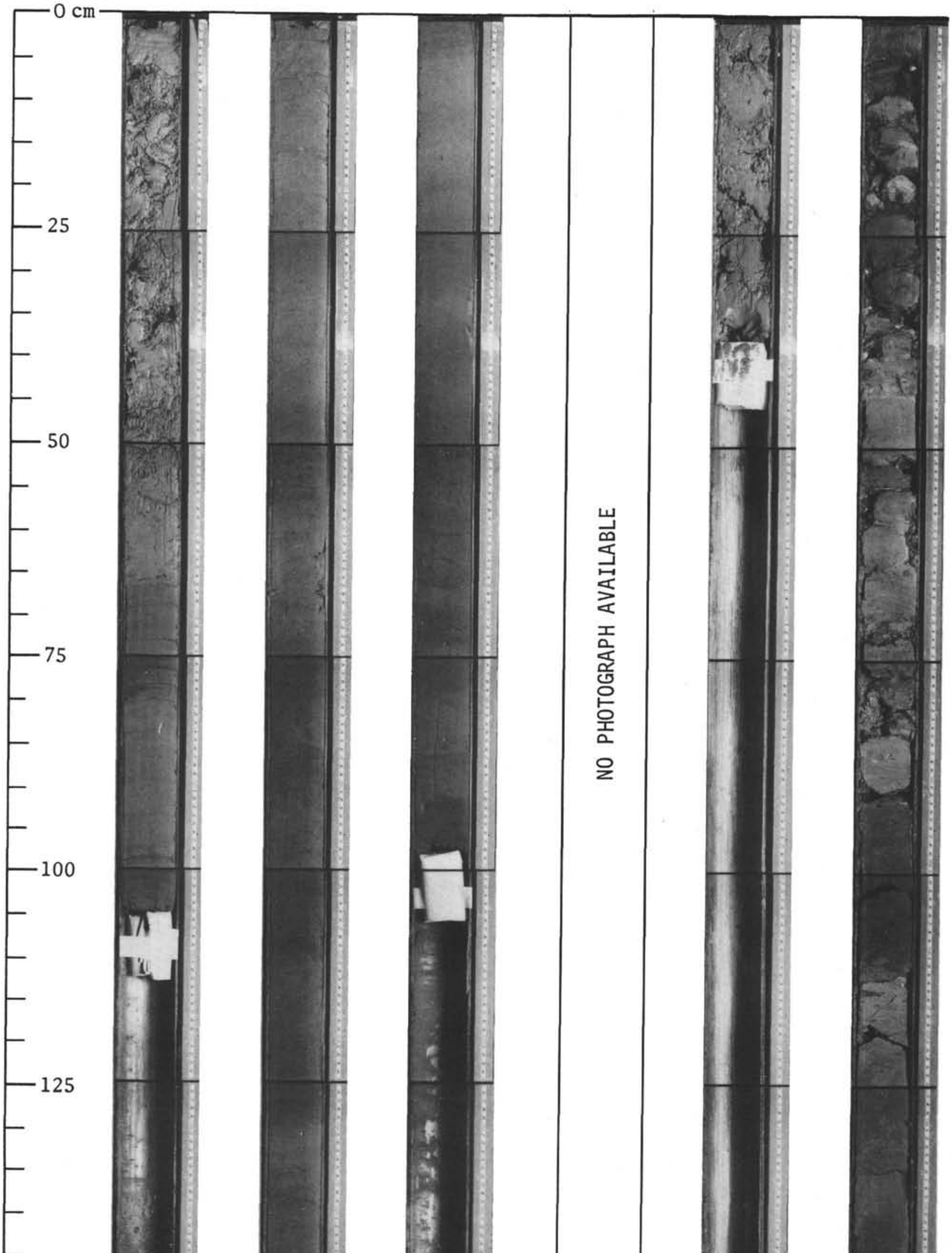
50
75
100
125
150
153-1-1
153-1-2
153-1-3
153-1-4
153-1-5
153-1-6


0 cm
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50
75
100
125
150
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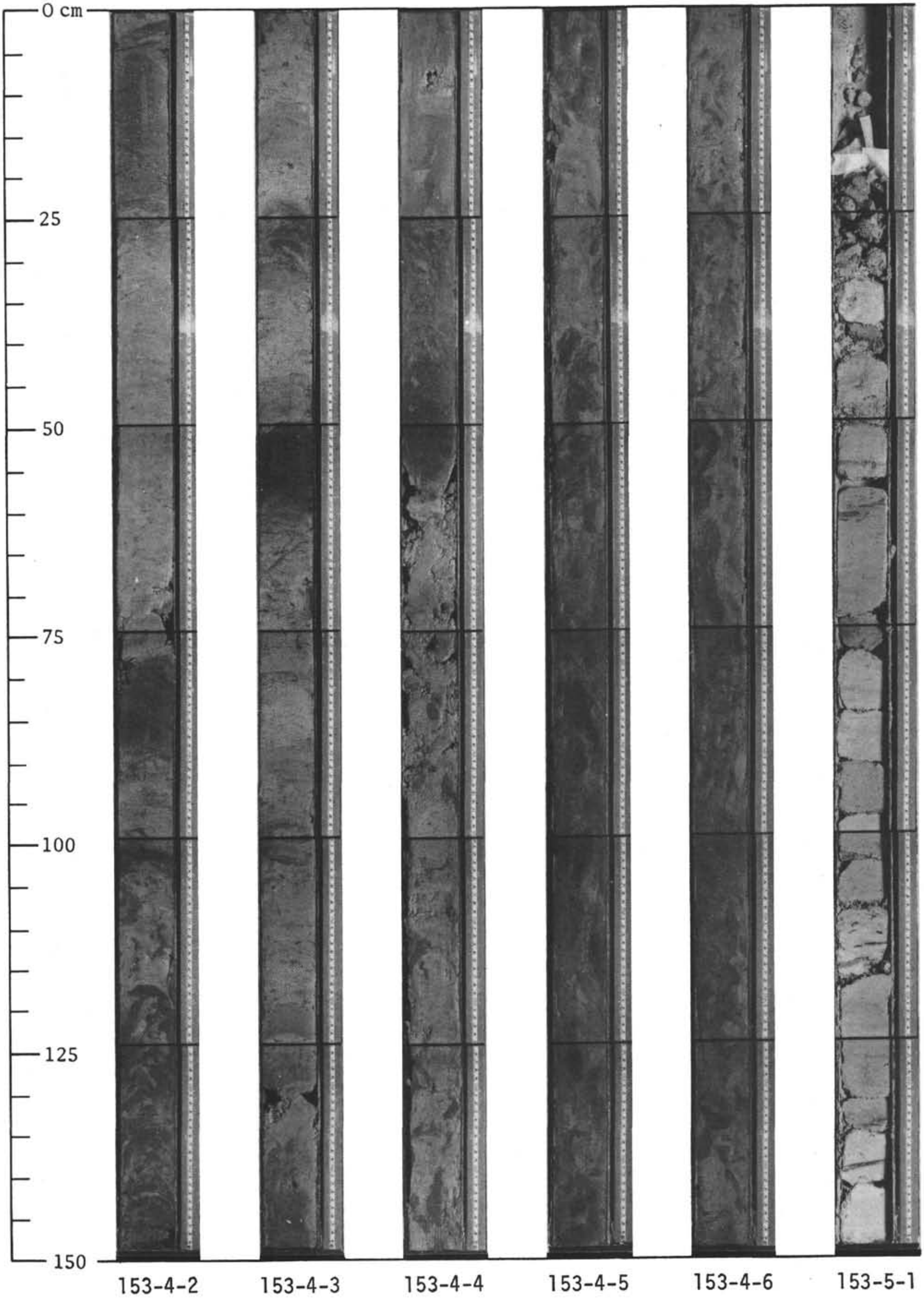
153-2-1
153-3-1
153-3-2
153-3-3
153-3-4
153-4-1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100
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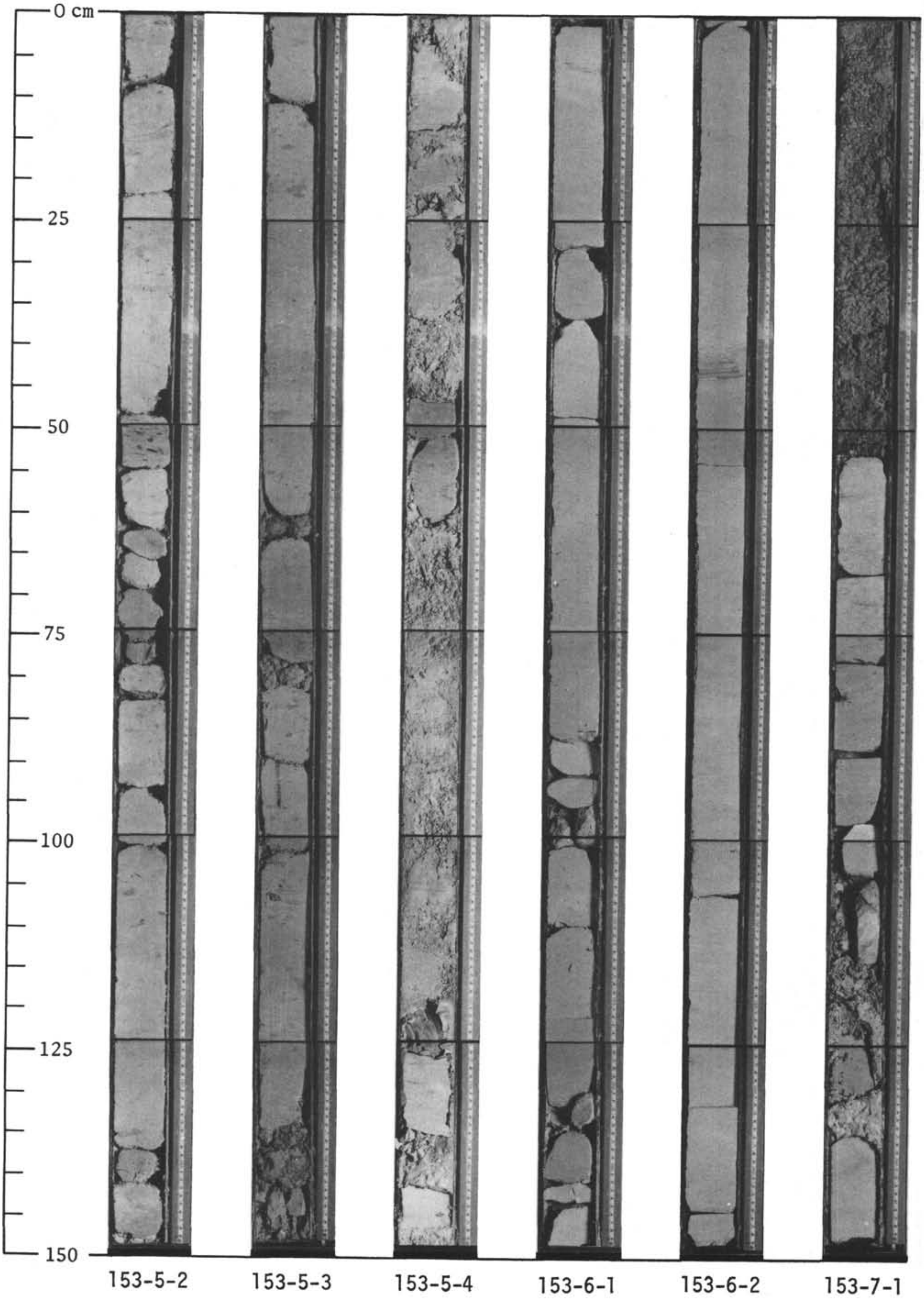
153-5-1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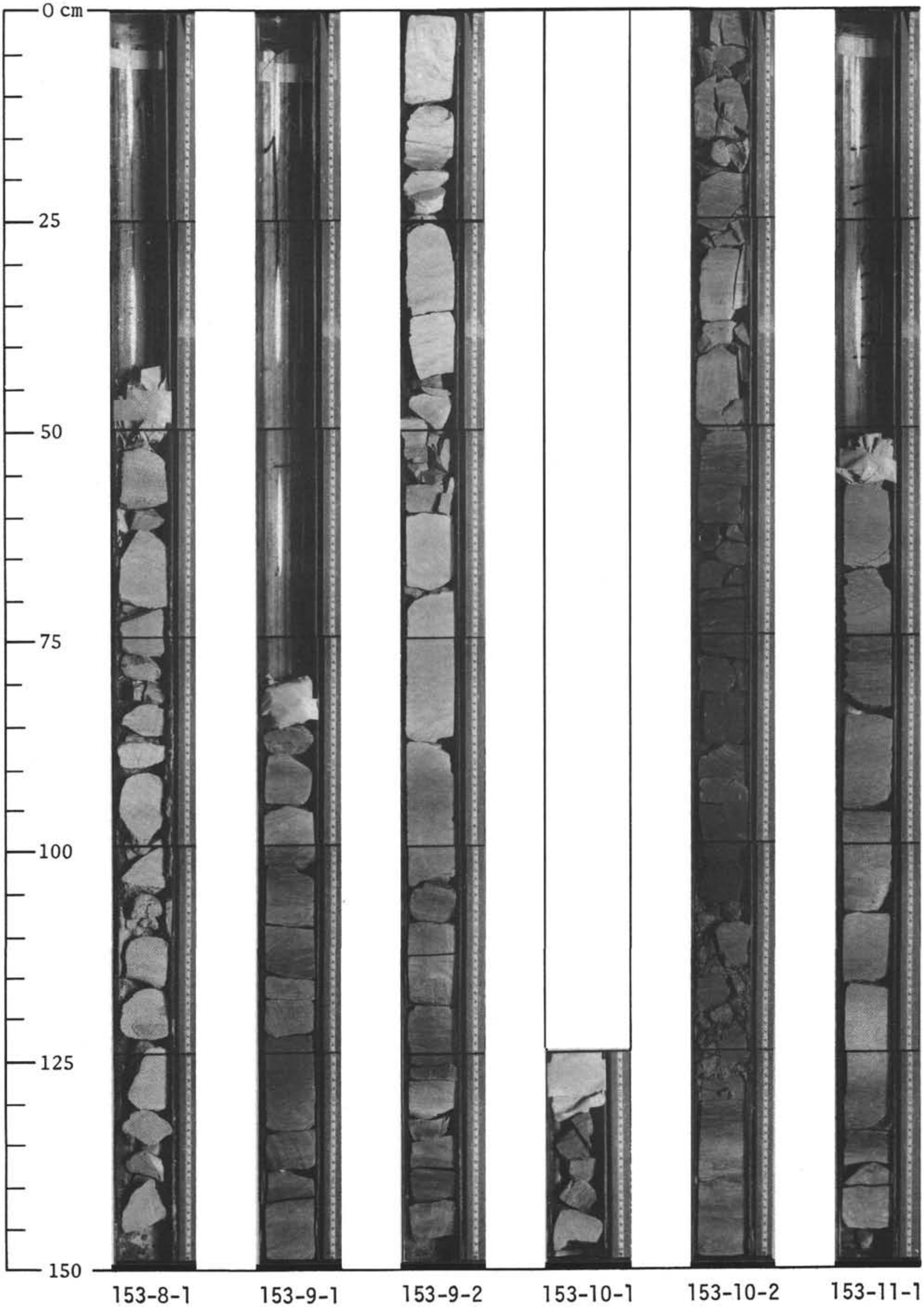
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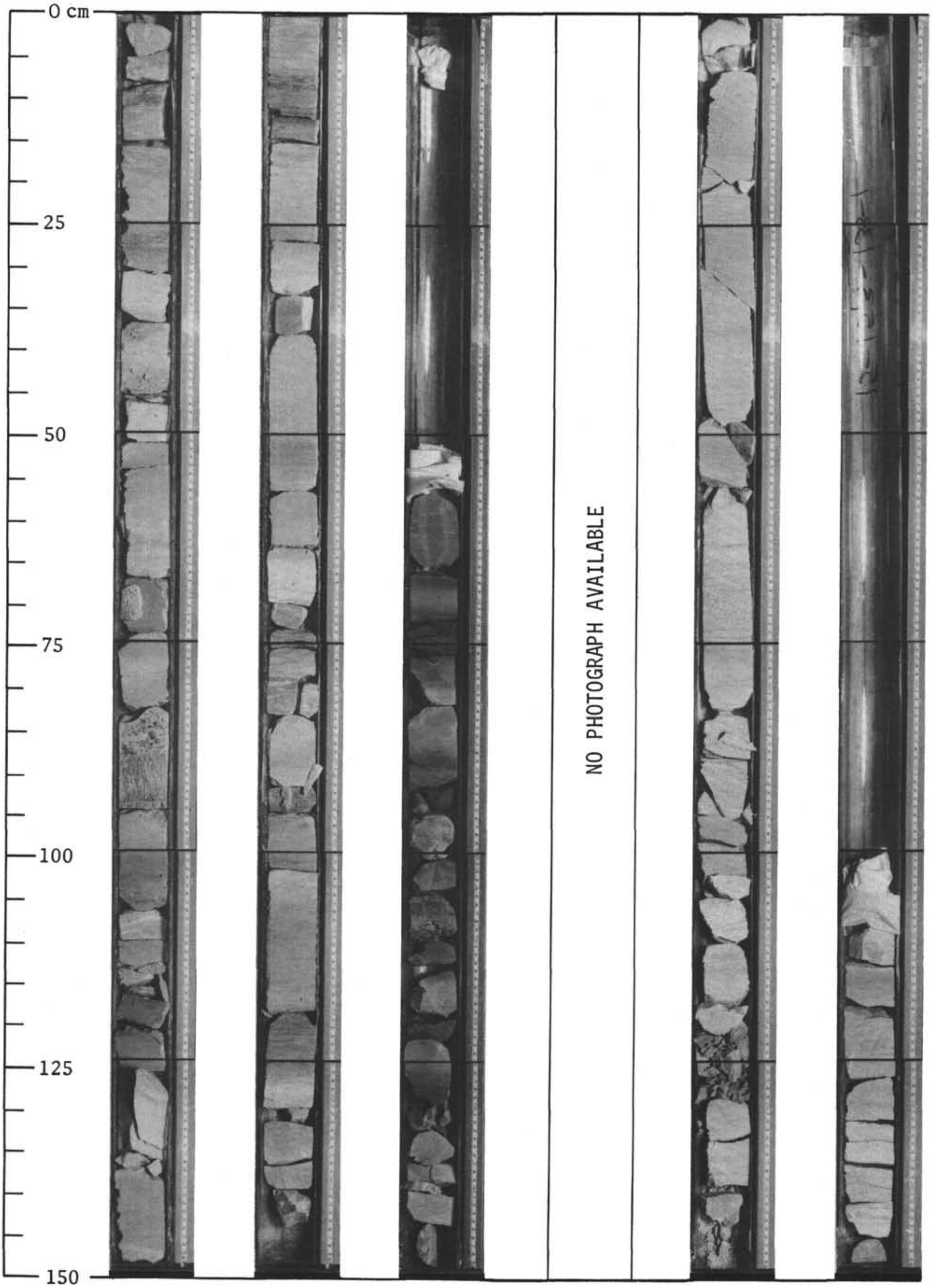
153-10-2
153-11-1



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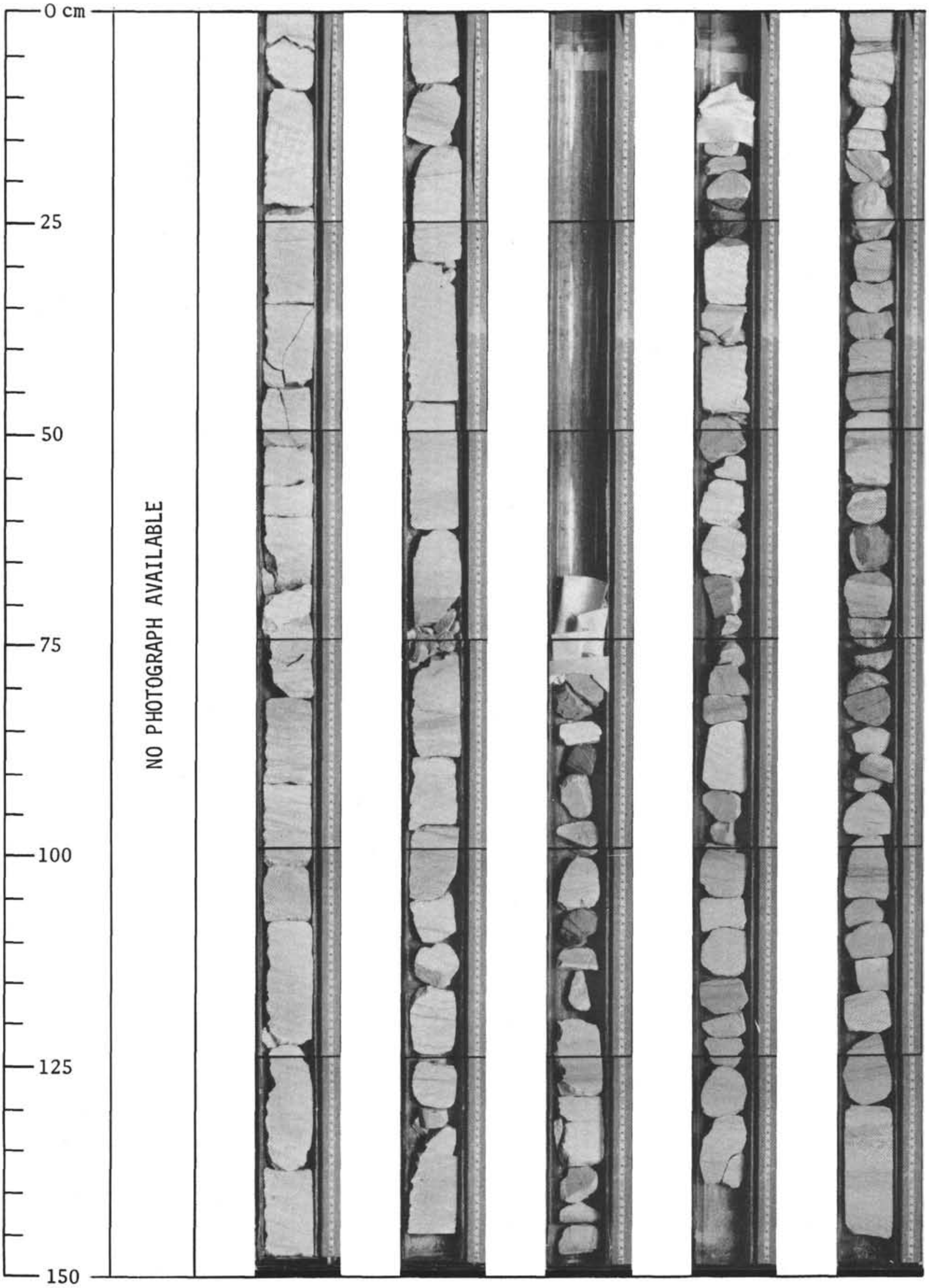
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153-13-4
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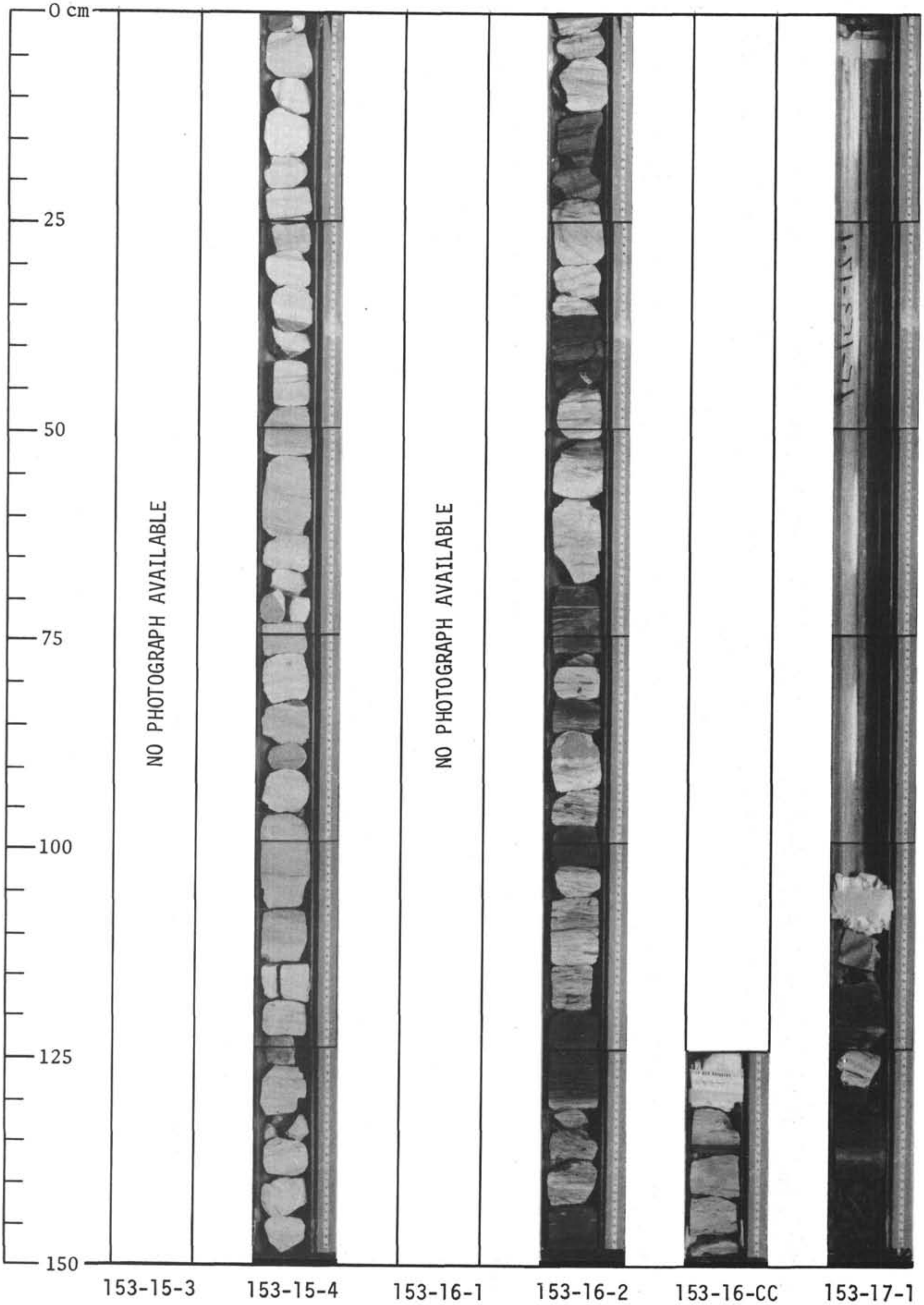
153-15-1
153-15-2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50
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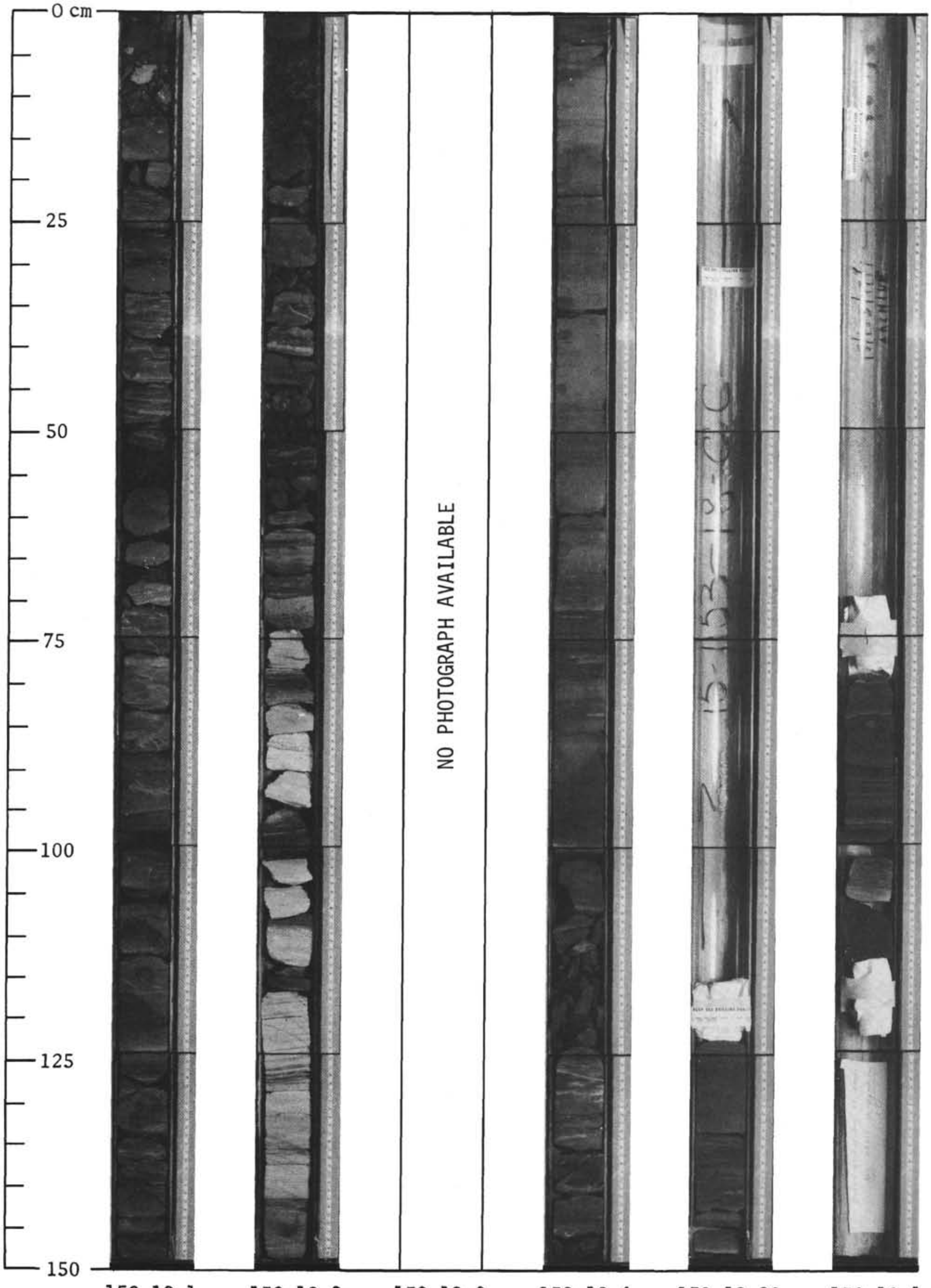
153-15-4
153-16-1
153-16-2
153-16-CC
153-17-1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153-18-1
153-18-2
153-18-3
153-18-4
153-18-CC
153-19-1