2. SITE 155

The Shipboard Scientific Party[1]

SYNOPSIS

Area: Coiba Ridge, eastern equatorial Pacific

Date Occupied: 6-8 February, 1971

Position:
Lat. 06°07.38′N
Long. 81°02.62′W

Water Depth: 2752 meters (corrected)

Penetration: 536 meters

Number of Holes: 1

Number of Cores: 15

Core Recovery: 57.0 meters

Acoustic Basement:
Depth: 0.63 second
Nature: Basalt
Inferred acoustic velocity for sedimentary section: 1650 m/sec

Age of Oldest Sediment: Middle Miocene

The site was continuously cored from 434 meters to total depth. Sidewall cores at 285 meters and 371 meters recovered middle Pliocene nannofossil marl and marl ooze; a sidewall core at 384 meters recovered late Miocene nannofossil marl. The continuously cored section consists of two sediment units and basalt:

434-484 meters – Nannofossil marl and marly clay interbedded with barren, waxy (bentonitic?) claystone, moderately diagenetically altered.
Age: Early late to middle Miocene.

484-519 meters – Nannofossil chalk rich in altered volcanic debris; calcareous microfossils abundant but poorly preserved; siliceous microfossils virtually absent; significant diagenetic alteration; poor recovery, probably many hard layers.
Age: Middle Miocene.

519-536 meters – Basalt, holocrystalline, considerably altered, probably extrusive.

The sedimentation rate for the upper 390 meters was approximately 72 m/m.y., decreasing to 12 m/m.y. for the interval 400-480 meters, and increasing again to about 44 m/m.y. for the basal chalk unit.

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REGIONAL SETTING AND OBJECTIVES

DSDP 155 is located in the northern part of the Panama Basin on the east flank of the Coiba Ridge (Figure 1). The Panama Basin is bordered by the Central and South American continent and by the isostatically compensated Cocos and Carnegie ridges, which enclose a central basin cut by several north-south trending fracture zones. One of these, the Coiba Fracture Zone, divides the Panama Basin into an eastern and a western part. The eastern part is complex, consisting of several high blocks, including the Coiba and Malpelo ridges and intervening rugged basins. The western half contains the young east-west trending Galapagos Rift Zone between the Cocos and Carnegie ridges.

The high blocks in the Panama Basin show some striking similarities. All stand at about the same height above the surrounding terrain, are in isostatic equilibrium, and are bounded by normal faults. All are covered with a relatively thick sedimentary blanket resting, for the most part, on a smooth acoustic basement which differs from the rugged volcanic basement of the demonstrably young volcanic basement elsewhere in the region. On all blocks, the deposits immediately overlying the acoustic basement are finely stratified and resemble the calcareous deposits of the eastern equatorial Pacific elsewhere (Ewing et al., 1968). On the Carnegie Ridge, the entire sedimentary section is stratified in this manner, while on the other ridges a basal stratified unit is overlain, locally unconformably, by alternating stratified and semistratified or transparent sediments that are similar in acoustic signature to the sediment cover of the young, deep parts of the Panama Basin. Thus, stratified sections in the Panama Basin are restricted to the high blocks. In general, seismic reflection studies (van Andel et al., 1971) suggest that the initial depositional history of all major ridges was similar but that the later histories of the Cocos, Malpelo, and Coiba ridges differed significantly from the history of the Carnegie Ridge.

Van Andel et al. (1971) have suggested that all high blocks in the Panama Basin originally formed part of an ancestral east-west trending Carnegie Ridge of unknown origin, located approximately at the latitude of the present Carnegie Ridge. This ridge was subsequently split into a northern and a southern half by the development of the Galapagos Rift. Opening of this rift began in the east at an unknown time and proceeded westward, reaching the block west of the Coiba Fracture Zone approximately 10 m.y. ago. While the southern half of the ridge remained stationary relative to the rest of the area, successive northern segments migrated northward along fracture zones until they descended into and sealed the eastward extension of the Middle America Trench. Thus, deactivation of the trench has proceeded from the area south of Panama to the

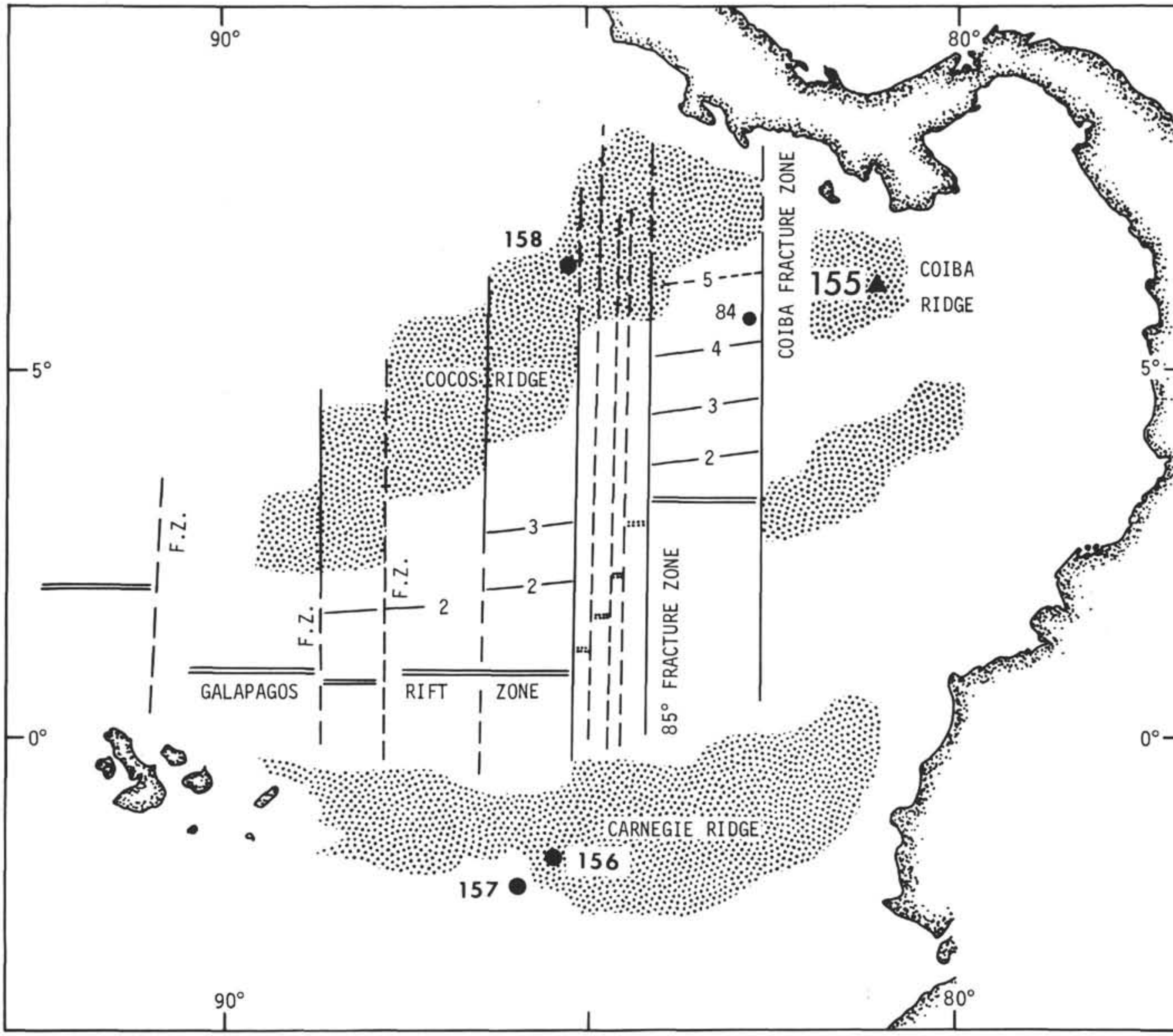


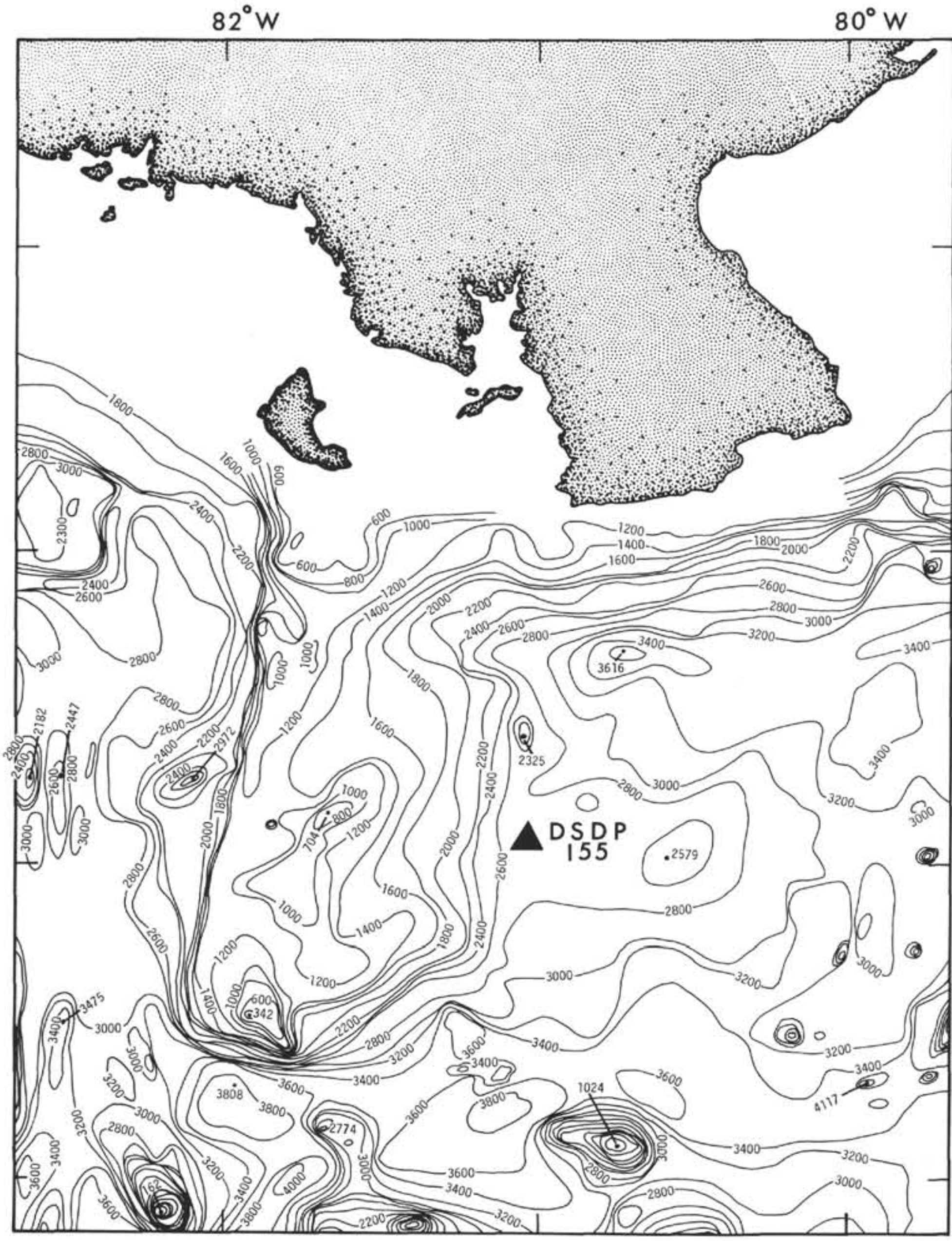
Figure 1. *Tectonic map of the Panama Basin (after van Andel et al., 1971) with locations of drill sites. Numbered contours are magnetic anomalies.*

Coiba Ridge and finally to the northeastern end of the Cocos Ridge. The authors suggested that the uplift of the Isthmus of Panama and the closure of the Central American seaway resulted from isostatic rebound of the plugged subduction zone.

Three sites in the Panama Basin, one each on the Coiba, Carnegie, and Cocos ridges, were chosen by the Pacific Site Selection Panel. These sites were designed to test the hypothesis of van Andel et al. (1971) through comparison of sedimentary sections, basement ages, and depositional histories of the three ridges. In addition, the sites were chosen to determine the late Cenozoic biostratigraphic history of the eastern equatorial Pacific in locations shallow enough to insure preservation of calcareous microfossils. Furthermore, the results from these sites were expected to shed more light on earlier findings of the Deep Sea Drilling Project in this region which suggested that elements of the late Tertiary microfauna might belong to a Caribbean rather than to a Pacific faunal province.

TOPOGRAPHIC AND GEOLOGIC SETTING

The Coiba Ridge is bordered on the west by a steep scarp descending into the Coiba Fracture Zone. In contrast, the eastern slope is gentle and covered with a thick blanket of sediment (Figure 2). The site is located about halfway between the high western edge of the Coiba Ridge and the deep basin that lies along the foot of the continental slope off Panama. The basement of the eastern slope is somewhat undulating. Locally, normal faults that offset the basement down to the east can be recognized. Pinnacles and discontinuous basement ridges locally accompany these faults. The site itself is located in a small depression



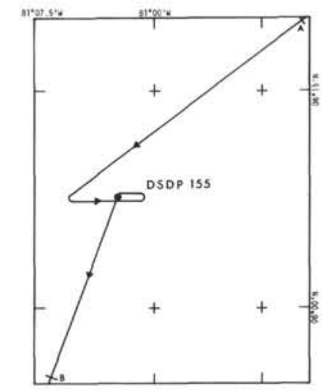


Figure 2. *Location of DSDP 155 on the Coiba Ridge. Depth contours in uncorrected meters after van Andel et al. (1971). Insert: site approach track; A-155 and 155-B are locations of acoustic reflection profiles of Figure 5.*

between the upper part of the slope on the west and largely buried basement ridge trending slightly east of north on the eastern side. The site was surveyed in detail by R/V *Vema* of Lamont-Doherty Geological Observatory in January 1971; a detailed site description is given in Chapter 11 of this volume. Figure 3 shows the distribution of sediment in the area (this volume, Chapter 11) and Figure 4 the topography. The sediment blanket covers a slightly undulating basement of small hills and a few, relatively short ridges which trend in a northeasterly direction. The drill site is located in a depression between basement highs that contains approximately 0.6 sec of sediment.

The sedimentary section of the Coiba Ridge is acoustically quite uniform (Figure 5). The section at DSDP 155 is typical. The acoustic basement, except on rare pinnacles and small ridges, is smooth and strongly reverberating. Its relief conforms quite closely to that of the sea floor. The section consists of an upper zone of transparent or semitransparent sediment with rare faint and discontinuous reflectors. The acoustically semitransparent zone rests on a series of three separate units of stratified material separated by two zones of acoustically transparent deposits. The lowermost stratified section rests directly on acoustic basement. Although the individual zones of the lower stratified portion are not completely continuous, they are present and vary little in thickness over most of the Coiba Ridge. Locally, seismic reflection profiles of the Coiba Ridge show low-angle unconformities near the top of the stratified sequence but none are in evidence near the drill site. The acoustic profile at the drill site is summarized in Table 1, which also gives the assumed correlations between the lithologic section of the hole and the reflectors.

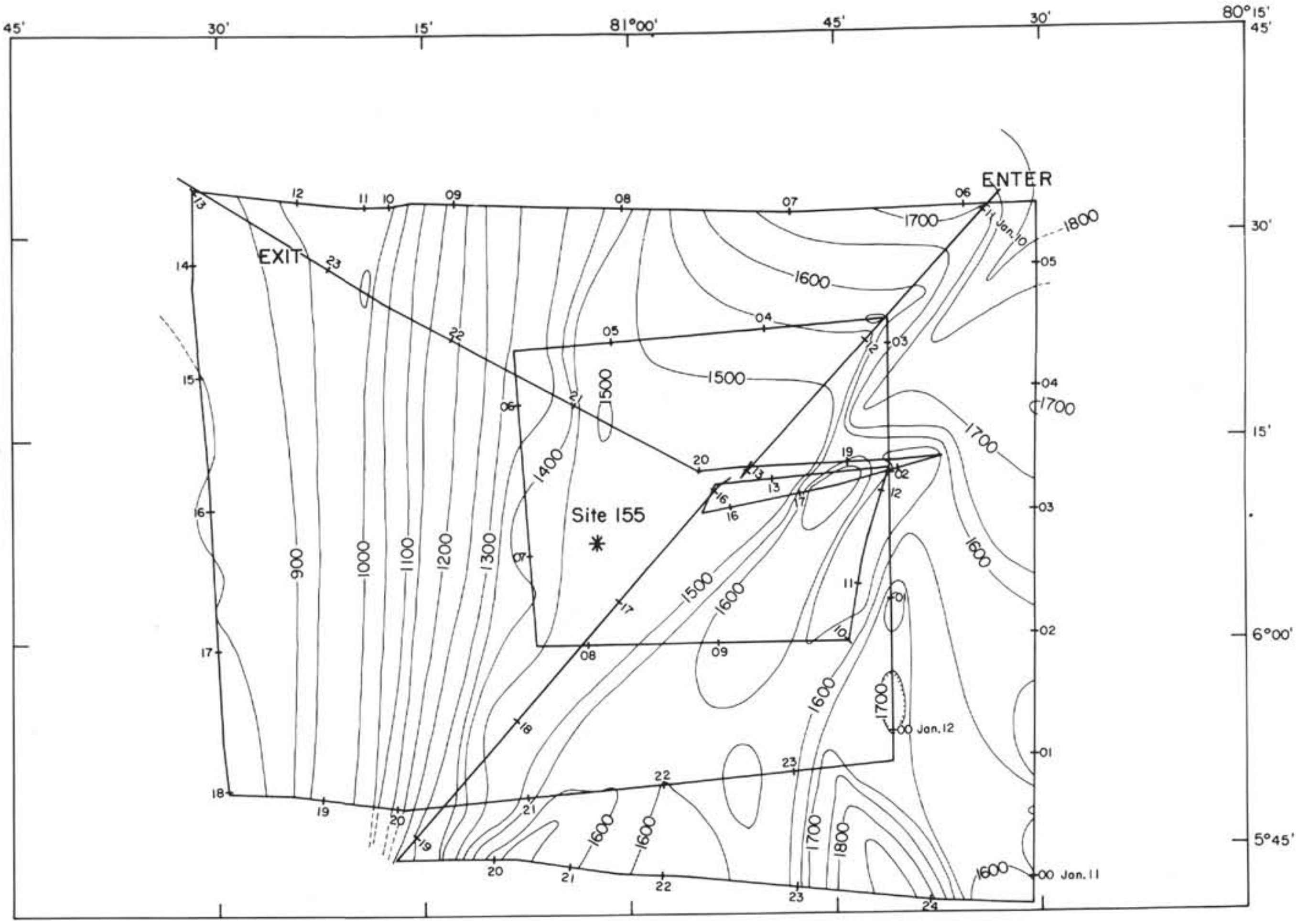


Figure 3. *Sediment thickness in the area of the* Vema *28 site survey around DSDP 155 (after Chapter 11, Figure 2). Sediment thickness in hundreds of meters assuming a velocity of 2 km/sec.*

OPERATIONS

Because a site survey was available (this volume, Chapter 11), the drill site was selected on the basis of a short double pass over the site area (Figure 2). The beacon was dropped at 1100 hours on February 4. A new type of bit, a Smith 10-1/8", 4-cone button bit with shaped inserts performed very satisfactorily and drilled ahead rapidly even in hard claystone and basalt. The section from the surface to 434 meters below the sea floor was drilled. From there, the hole was continuously cored to basement at 519 meters, with two additional cores taken in basement to a total depth of 536 meters. On the way out, three sidewall cores were taken at 384, 371, and 285 meters respectively. A summary of coring operations is given in Table 2.

LITHOLOGY

Four basic sediment units can be distinguished at DSDP 155: (1) mottled nannofossil marl, (2) waxy claystone, (3) mottled marly clay and marl, and (4) nannofossil-foraminiferal chalk. Of these, the first three types are interbedded (Figure 6).

Unit 155-1

Unit 155-1 is an intensely mottled olive and light olive nannofossil marl with mottles that are either lighter than the predominant color and somewhat more calcareous or darker and rich in finely disseminated pyrite. In most beds in this unit, pyritic layers up to a few centimeters in thickness and pyrite nodules 0.5-1.0 cm in diameter are found. The sediments obtained with the sidewall corer at 285, 371, and 384 meters, as well as the upper portion of the cored interval belong to this unit. Its deepest occurrence is at 454.3 meters.

Unit 155-2

Unit 155-2 is a claystone, possibly bentonitic, massive, and quite homogeneous, of a dominant medium greenish gray color which darkens with depth. Individual beds vary in thickness from a few centimeters to a maximum of 5 meters (Figure 6). Since the unit is texturally very homogeneous and quite cohesive, deformation by the coring process is particularly well exhibited. Typically, cores of this lithology consist of 2-6 cm of undisturbed claystone followed by 1-3 cm of thoroughly disturbed material which has flowed around the undisturbed pieces.

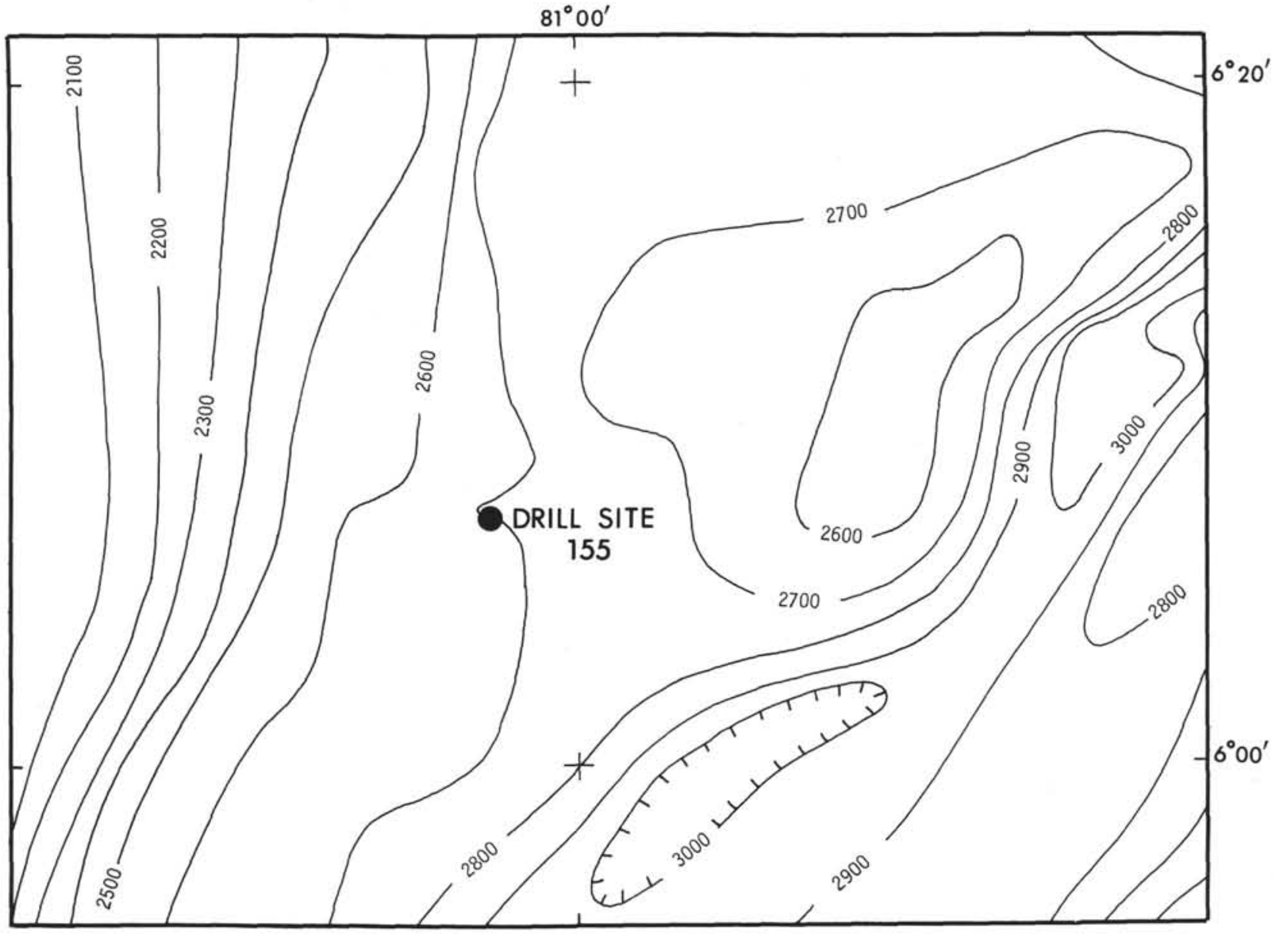


Figure 4. *Bathymetric map of the site survey area around DSDP 155. Depths in uncorrected meters below sea level. Based on data from a site survey by R/V* Vema *(Lamont-Doherty Geological Observatory), and tracks from D/V* Glomar Challenger *and R/V* Yaquina *(Oregon State University).*

Beds of Unit 155-2 alternate with those of 155-1 between 441-466 m. Contacts between 155-2 and other lithologies are generally distinct and marked by layers of fine pyrite and pyrite nodules and, in one case, by disseminated silt-size dolomite rhombs (at 444 m).

Unit 155-3

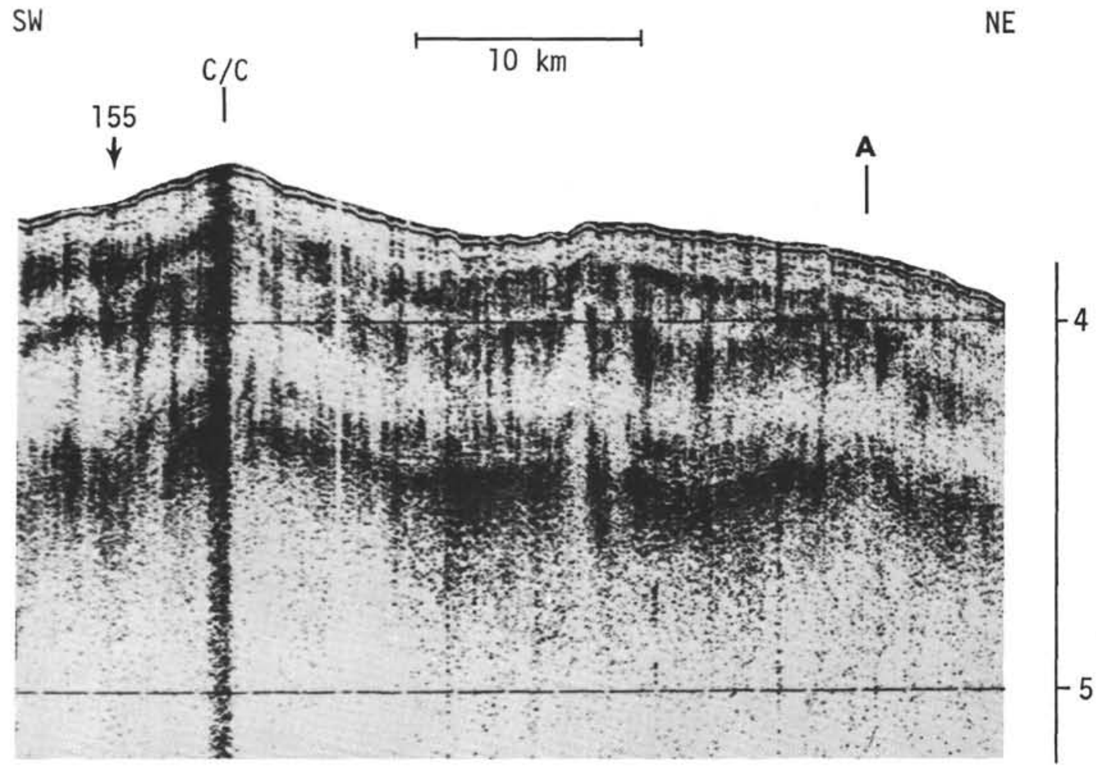
Unit 155-3 grades from marly clay to marl and generally contains less carbonate than 155-1. The sediments are in various shades of olive, gray, and green, and mottling is less pronounced than in 155-1. The lighter colored mottles contain more nannofossils than the matrix; the darker ones contain finely disseminated pyrite. Pyrite nodules and pyrite-rich claystone layers several millimeters to several centimeters in thickness are common. A few veinlets of barite occur in the lower beds. The first occurrence of this type is at 456 meters where it is interbedded with 155-2; it is dominant below 466 meters to its last occurrence at 484 meters.

Unit 155-4

Unit 155-4 is a chalk which underlies 155-3 without interbedding. At the top it contains a few olive gray laminae in a light green unit; downward it grades to light and very light gray. At 490 meters it becomes dolomitic, massive, and well indurated. From this depth down to 500 meters and probably to the contact with basement, the material is again softer, being a chalk-marl, yellowish to olive gray in color. Dark, medium to coarse-grained sand and granules increase in size and abundance downward to about 5 per cent near 500 meters. These grains are clayey aggregates that may be decomposed fragments of basalt and basaltic glass.

Unit 155-5

Basalt was recovered from the catcher of Core 10 at 521 meters. The contact with the chalk was not recovered but is placed at 519 meters based on the reduced drilling rate. The sample is a heavily altered basalt. In Core 11, about 40 cm



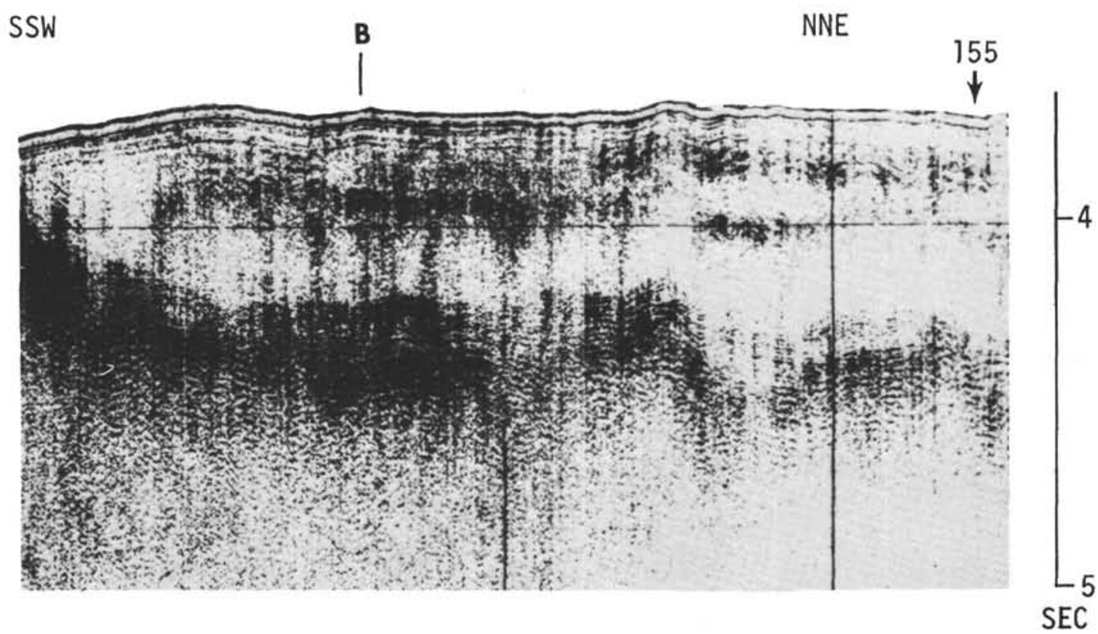


Figure 5. *Acoustic reflection profiles near DSDP 155. Locations on Figure 2. Depths in seconds two-way travel time. Horizontal scale approximate.*

of chalk of Unit 155-4 was recovered in the interval 521-527 meters, underlain by altered basalt. Basalt, and a partly recrystallized limestone fragment in contact with altered glassy basalt were recovered in Core 12. The fresh-appearing basalt above the limestone in Core 12 is, in thin section (155-12-1, 106-107), an extensively altered, holocrystalline, fine-grained augite basalt with doleritic texture. Plagioclase laths are normally zoned from labradorite to andesine. The pyroxene and groundmass are deuterically altered; vugs in the rock are partly filled with carbonate and rimmed with serpentine. The limestone fragment (thin section 155-12-1, 121) is calcitic with relict texture suggesting an original grain size of less than 10 microns. Near the contact with the basalt, the calcite is recrystallized into 500-1000 micron grains. The basalt at the contact is a partly devitrified glass with rare plagioclase

TABLE 1
Comparison of Acoustic Section and Drill Data, DSDP 155

Reflectors	Depth (sec)	Drilling Results	Velocity For Interval (sec)	Velocity (m/sec)	Calculated Depth[a] (m)
Top upper stratified zone	0.10	not cored			82
Top middle stratified zone	0.29	not cored			239
Top lower stratified zone	0.59	485 m top chalk	0.0-0.59	1640	487
Top acoustic basement[b]	0.63[b]	519 m top basalt	0.0-0.63	1650	519

[a]Based on assumed velocity of 1650 m/sec.

[b]Assumed correlations.

TABLE 2
Coring Summary, DSDP 155

Core	Depth Below Sea Level (m)	Depth Below Sea Floor (m)	Cored (cm)	Recovered (cm)	Recovered (%)
1	3186-3195	434-443	900	852	94.7
2	3195-3204	443-452	900	900	100.0
3	3204-3213	452-461	900	900	100.0
4	3213-3222	461-470	900	900	100.0
5	3222-3231	470-479	900	900	100.0
6	3231-3240	479-488	900	546	60.7
7	3240-3249	488-497	900	272	30.2
8	3249-3258	497-506	900	265	29.4
9	3258-3267	506-515	900	CC[a]	0.0
10	3267-3273	515-521	600	CC[a]	0.0
11	3273-3279	521-527	600	75	12.5
12	3279-3288	527-536	900	86	9.6
13	3136	384	sidewall core		
14	3123	371	sidewall core		
14	3037	285	sidewall core		

[a]Core catcher sample only.

laths. Serpentine and other alteration products form veinlets and pseudomorphs after plagioclase and pyroxene. The lowermost basalt (thin section 155-12-1, 134) is a deuterically altered rock consisting of about 40 per cent plagioclase laths in a devitrified groundmass. Serpentine and accessory bowlingite are pseudomorphic after olivine and possibly pyroxene. Areas of groundmass are segregated from areas rich in plagioclase and ferromagnesian pseudomorphs. The plagioclase laths in the crystalline regions show some alignment.

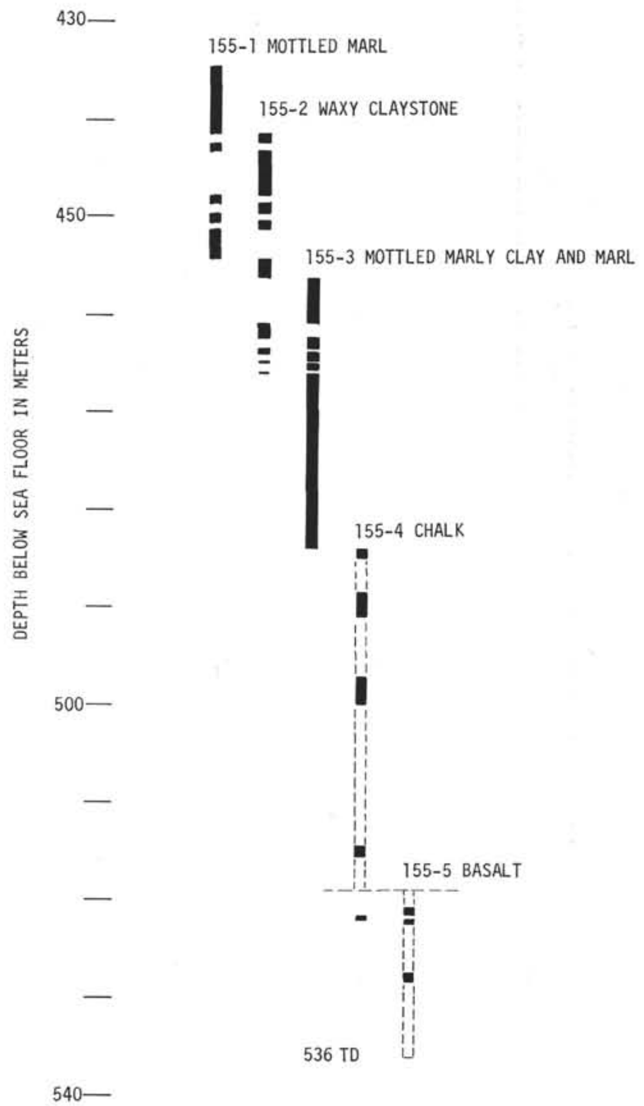


Figure 6. *Sequence of lithologic units at DSDP 155. For explanation see text.*

GEOCHEMISTRY

Interstitial water samples and shipboard observations for DSDP 155 are listed in Table 3.

TABLE 3
Interstitial Water Samples and Shipboard Observations, DSDP 155.

Core	Section	Sampled Interval (cm)	pH	Eh (mv)	Lab. Temp. (°C)	Salinity (‰)	Squeeze Pressure (psi)
1	6	0-6	8.24	158	25.8	29.7	3000
2	6	0-8	7.34	202	26.0	29.7	3000
3	6	0-7	8.53	153	26.3	30.8	3000
4	6	0-7	8.39	139	26.2	30.8	3000
5	6	0-8	8.36	138	26.1	29.7	3000
6	4	0-5	7.68	169	26.3	29.2	3000
7	2	0-5	8.47	160	26.3	30.8	3000
8	CC	0-0	7.49	162	26.1	31.9	2436
9	CC	0-0	7.36	158	26.0	33.0	3000

BIOSTRATIGRAPHY

Foraminifera, coccoliths, and radiolarians occur in most samples from the middle and upper Miocene continuously cored interval of this site (Cores 1-12; 434-536 meters). In addition, three sidewall cores above this section (13-15), and sediment adhering to the bit recovered upper Miocene, Pliocene, and Quaternary. Preservation is generally poor for all fossil groups.

Coccoliths are poorly diversified and solution etched, and many marker species are rare or absent. Especially strong etching was noted in the upper Miocene (Cores 1-5, and sidewall Core 13) and some samples are barren of coccoliths.

Foraminifera likewise show solution effects in the upper part of the section, especially in sidewall Core 15 where the fauna is enriched in solution-resistant *Pulleniatina*. A zone of impoverished foraminiferal faunas, probably due to solution, also straddles the middle-upper Miocene boundary. A corresponding zone of solution was found at Site DSDP 158. The most striking aspect of foraminiferal preservation at this site is diagenetic in origin, and was found throughout the continuously cored section. It comprises deformation of a significant proportion of tests by crushing and/or flattening, and the infilling of tests by silica, and is undoubtedly related to silica mobilization in this part of the section. Similar phenomena were found in the basal portions of DSDP 157 and 158.

Radiolarians are few and poorly preserved; they are not found below 506 meters in the section, and below 470 meters dissolution of silica is so extensive that reliable identification to species level is not possible.

An apparently complete middle and upper Miocene section is present in the continuously cored interval. The sediments immediately overlying basalt belong in the *Globorotalia fohsi fohsi* (foraminiferal) zone and the *Sphenolithus heteromorphus* (nannofossil) zone; the top of the continuously cored section is in the *Globorotalia acostaensis* Zone, basal *Discoaster quinqueramus* Zone, and *Stichocorys peregrina* (radiolarian) Zone. A complete sequence of intervening foraminiferal and nannofossil zones is present.

Sidewall Core 13 recovered sediments of the upper *Globorotalia plesiotumida, Discoaster quinqueramus*, and *Stichocorys peregrina* zones; sidewall Core 14, the *Globorotalia tumida*, (?)*Ceratolithus tricorniculatus*, and *Spongaster pentas* zones; sidewall Core 15, the *Globoquadrina altispira, Reticulofenestra pseudoumbilica*/*Discoaster brouweri,* and *Spongaster pentas* zones; and the bit sample, Quaternary sediment determined by nannofossils to be of the *Gephyrocapsa oceanica* Zone.

By analogy with other Panama Basin sites, a continuous or nearly continuous, thick late Tertiary sequence is probably present at this site.

PHYSICAL PROPERTIES

Bulk Density

GRAPE bulk density reveals a slight increase with depth; however, individual sections display large variations that far exceed the change in the average value per section. This is probably due to sediment disturbance and mixing, and to the presence of pyrite. Exceptionally high bulk densities do indeed correspond to sediments with high concentrations of pyrite which results in erroneous values obviously not representative of the overall bulk density characteristics of the sediment. The effect of a 3-cm diameter nodule on the GRAPE bulk density is seen at approximately 471 meters.

GRAPE bulk densities range from 1.42 g/cc to 2.91 g/cc. However, the average values per section range from 1.58 g/cc to 2.05 g/cc throughout the measured lithologic section. The average value for each 1.5-meter section is considered more reliable than unique point values determined by the GRAPE. Laboratory bulk densities range from a low of 1.54 g/cc to a high of 2.17 g/cc. Densities are relatively high in the upper 434-444 meters in the marl compared to lower values found with depth which occur in the claystone with interbedded marl reflecting the relative increase in fine-grained material between 444-456 meters. This sediment shows varying degrees of deformation with pieces of undisturbed sediment surrounded by a disturbed matrix. Below 456 meters bulk density increases with depth in the predominantly marly clay with interbedded claystone and lower carbonate content than the overlying sediment. Highest bulk densities occur in the chalks from 482-498 meters. A significant decrease occurs at a depth of approximately 500 meters. This low bulk density is characteristic of the chalk-marl which is composed of clay aggregates and possibly decomposed volcanic sand.

Porosity

GRAPE porosities range from as low as zero to as high as 74 per cent. The extremely low values occur where pyrite is present in quantity in the measured sections. The wide range of values does not reflect the general characteristics of the sediment porosities which decrease with depth. Relatively low porosities (average GRAPE value per section) that are observed in the upper 334-344 meters in the marl increase in the claystone between 444-456 meters before decreasing again with depth.

Laboratory porosities show a similar relationship with depth; however, most values differ from those determined by the GRAPE. Porosities range from 32 per cent in the dolomitic chalk at a depth of 498 meters to 69 per cent in the claystone at a depth of 461-464 meters. Relatively high porosities (66 per cent) are found in the claystone between 443 and 452 meters.

Water Content

Water content ranges from 15 per cent in the dolomitic chalk at 498 meters to 45 per cent in the claystone at 463.5 meters. The water-content profile closely follows that of porosity, with an overall decrease with depth. A value of 29 per cent, however, is observed in the chalk-marl at approximately 500 meters. This is the sediment with medium to coarse sand grains and granules which appear to be clay aggregates.

Grain Density

Low average grain densities of 2.49 to 2.54 g/cc occur in the claystone between 444-446 meters. However, higher values are more common, and throughout the lithologic section average about 2.74 g/cc. High average grain densities are probably related to the presence of pyrite, which is common throughout the sequence.

Sonic Velocity

The sonic velocity profile reveals only a slight general increase with depth to maximum velocities below 490 meters. Velocities in sediment have a range of 1.51 to 2.35 km/sec, with an average velocity of about 1.79 dm/sec. The underlying altered basalt has a velocity of 3.75 km/sec.

Natural Gamma Radiation

The average gamma activity per 1.5-meter section is relatively uniform above 456 meters, but increases markedly from 456 meters to about 472 meters. This increase reflects the decrease in carbonate content of the sediment in the interval from 456-482 meters. Below about 472 meters, the activity decreases sharply to about 488 meters and is lowest at approximately 488 to 490 meters. A wide range of activity is observed in a few sections. This undoubtedly reflects variations not only in the relative concentrations of radionuclides, but also in the degree of sediment disturbance.

SUMMARY

The single hole drilled at this site penetrated 519 meters of sediment before entering basalt basement of middle Miocene age. The section above 285 meters was not sampled, but by analogy with Site 84, some 110 miles to the west (Hays et al., 1972), consists of nannofossil chalk ooze rich in calcareous and siliceous microfossils, with abundant volcanic ash. Pleistocene sediment scraped from the bit at DSDP 155 (position in the hole unknown) confirms the similarity to DSDP 84.

Sidewall cores at 285 and 371 meters recovered middle Pliocene and late Miocene nannofossil marl to marl ooze. A third sidewall core at 384 meters is similar, but contains more volcanic debris and markedly less well preserved nannofossils and foraminifera than the section above.

The sedimentation rate for the upper 390 meters or so of the section (based on a zero surface age and the sidewall core ages) is about 70 m/m.y. This contrasts markedly with the value of about 15 m/m.y. for the section from about 390 meters to basalt at 519 meters. The depth of the change in sedimentation rate appears to correlate with the oldest sediments deposited at Site 84.

The continuously cored section from 434 to 536 meters penetrated two sedimentary units and 17 meters of basalt. The upper unit (434 to 484 m), of early late Miocene to middle Miocene age, consists of moderately indurated nannofossil marl and marly clay, usually with corroded or crushed microfossils, interbedded with barren waxy (bentonitic) claystone. The redistribution of opaline silica and the presence of dolomite and barite segregations points to moderately intense diagenesis of this unit. Pyrite is ubiquitous, usually as dispersed grains or stringers at lithologic contacts, but occasionally forming nodules up to 3 cm in diameter. Acoustic velocities of this unit are generally 1.6 to 1.8 km/sec, while GRAPE porosities average 50 to 70 per cent for entire sections. Natural gamma activity is apparently negatively correlated with carbonate content of the sediment (generally 2000 to 3000 counts/7.6 cm/75 sec).

The lowest sedimentary unit (494 to 519 m) of middle Miocene age is a nannofossil chalk, locally dolomitized and rich in altered volcanic debris. Calcareous microfossils are abundant but again are poorly preserved. Siliceous microfossils are virtually absent. Recovery of this unit was poor (probably due to alternating hard and soft layers). The pieces recovered have GRAPE porosities of 30 to 40 per cent, acoustic velocities of 2.0 to 2.7 km/sec, and natural gamma activity some 35 per cent lower than in the overlying unit. Again, diagenesis has noticeably modified the original sediment.

The average acoustic velocity for the full sedimentary section, based on a thickness of 519 meters and 0.64 sec, is 1620 m/sec.

The basalt basement drilled comparatively easily, suggesting considerable alteration. The tendency of matrix minerals to swell in water and the presence of abundant bowlingite in thin sections confirms this suggestion. The rock appears fresh in hand specimen, which, together with the paucity of brown iron oxides in thin section, points to deuteric alteration or alteration under reducing conditions rather than normal oxidizing halmyrolysis. The recovered basalt is mostly holocrystalline. Flow banding and amygdules are visible in some fragments.

Included with the basalt are fragments of recrystallized chalk. The absence of metasomatism in these fragments suggests that the basalt is a flow, rather than an intrusive body. A single acoustic measurement give an unusually low velocity of 3.75 km/sec for the basalt.

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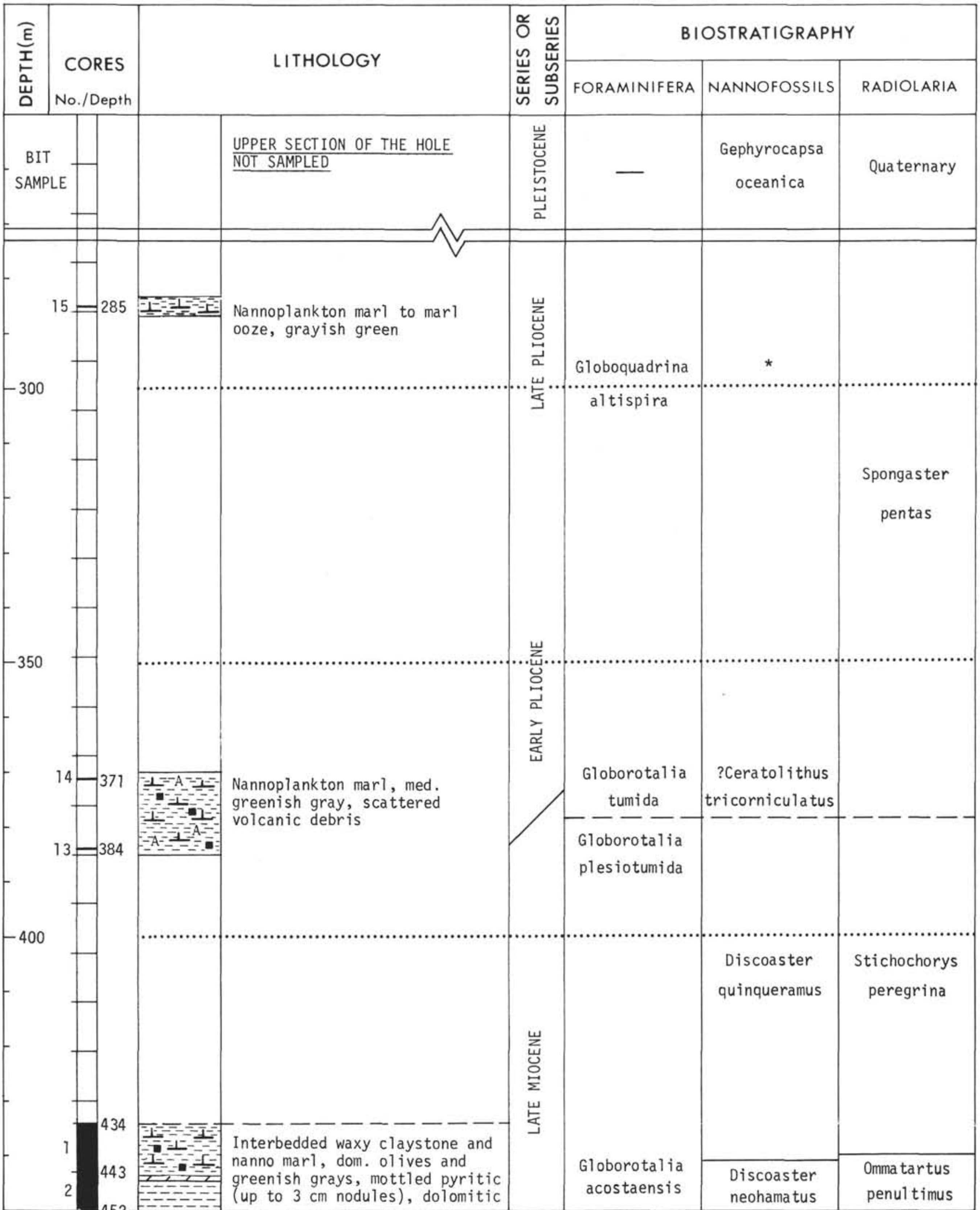


*=Discoaster brouweri and Reticulofenestra pseudoumbilica

Figure 7. *DSDP 155, graphic hole summary. Vertical scale 1 cm = 10 m (1:1000).*

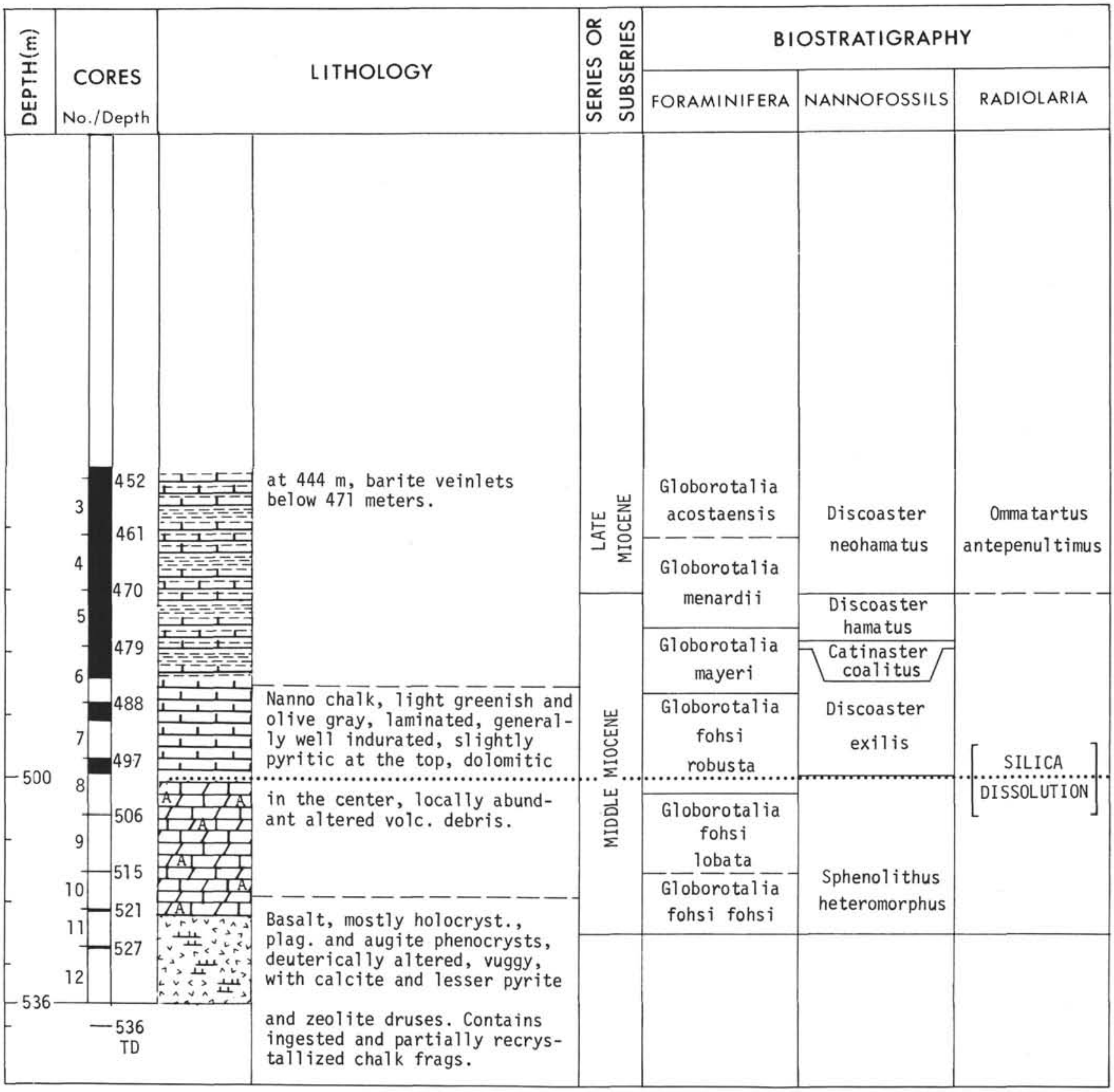
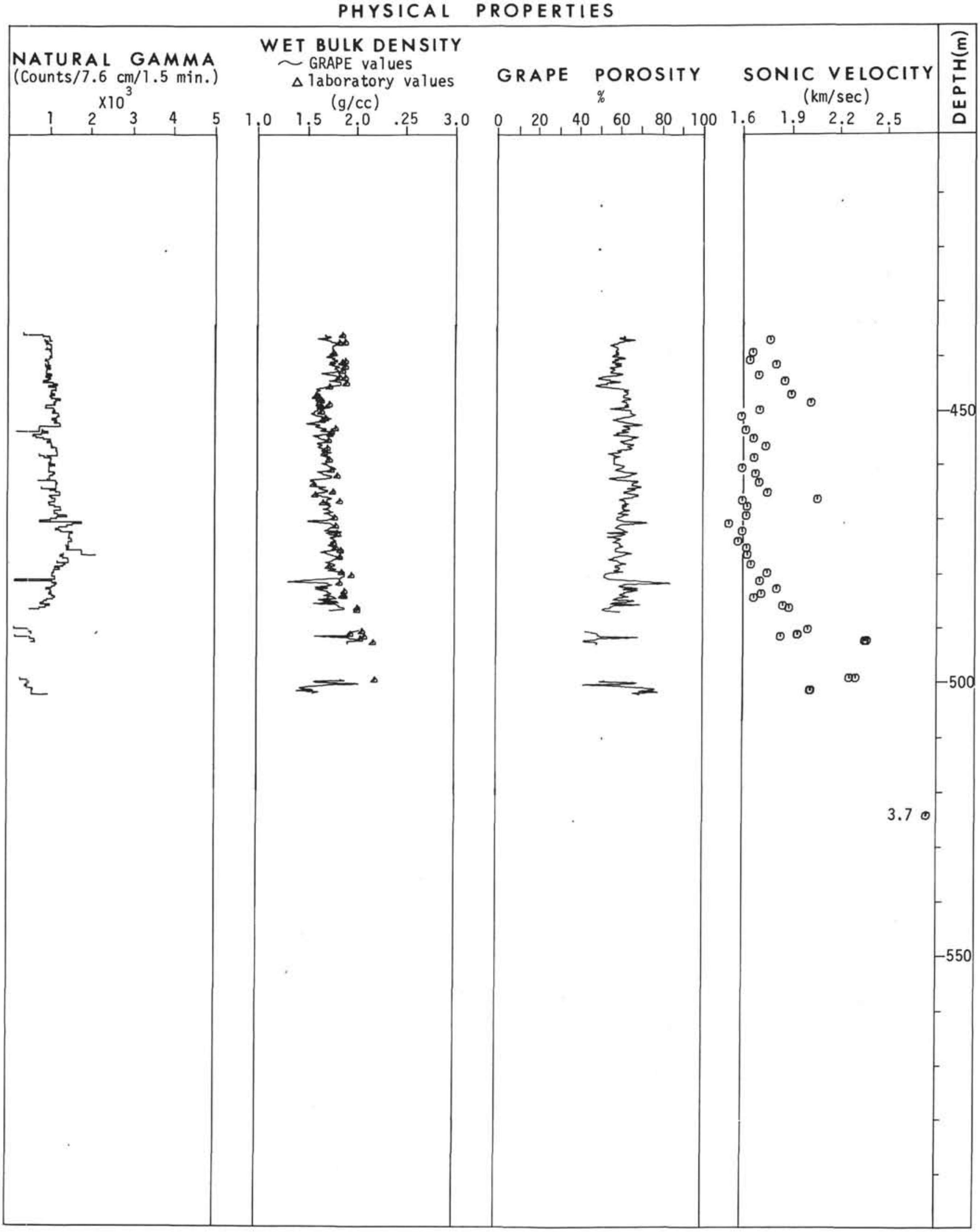


Figure 7. (*Continued*).


PHYSICAL PROPERTIES
NATURAL GAMMA
(Counts/7.6 cm/1.5 min.)
X10^3
1 2 3 4 5
WET BULK DENSITY
GRAPE values
laboratory values
(g/cc)
1.0 1.5 2.0 .25 3.0
GRAPE POROSITY
%
0 20 40 60 80 100
SONIC VELOCITY
(km/sec)
1.6 1.9 2.2 2.5
DEPTH(m)
450
500
550
3.7

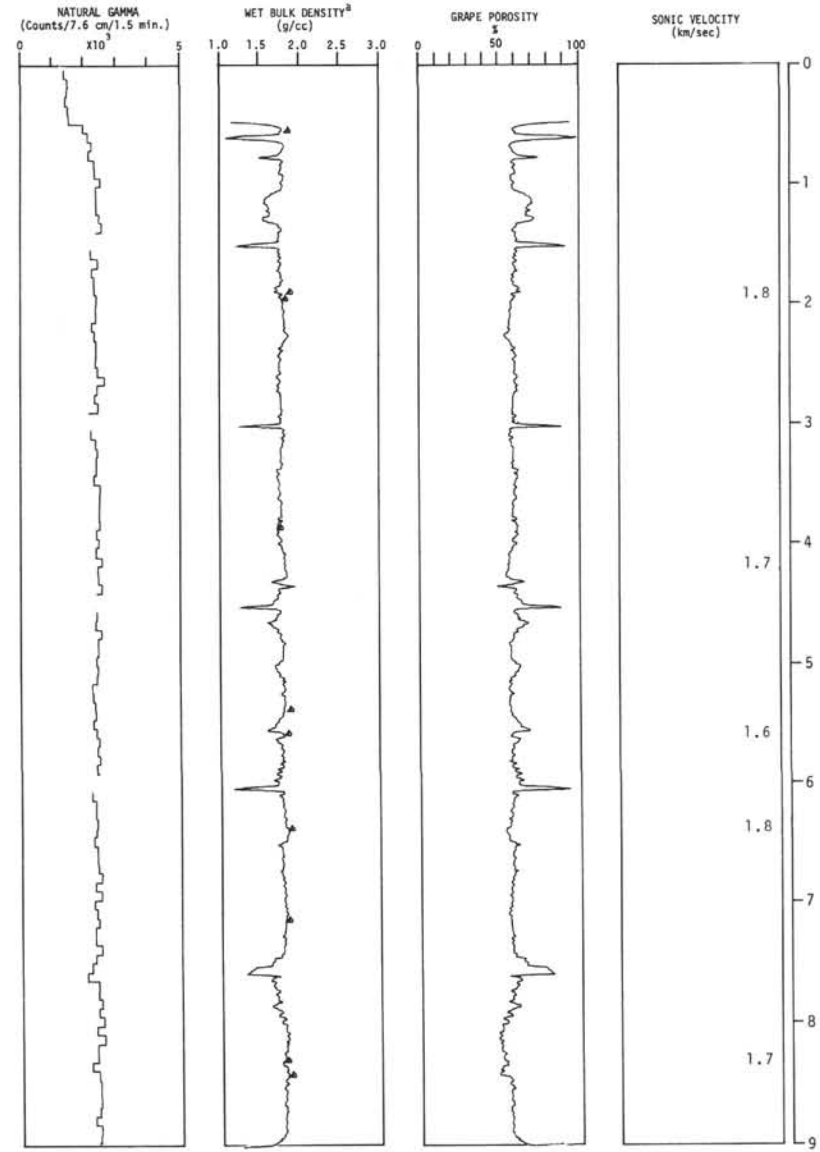
SITE: 155 HOLE: CORE: 1 Cored Interval: 434-443 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
UPPER MIOCENE	*Globorotalia acostaensis*	*Discoaster quinqueramus*	*Stichojeorys peregrina*	0–1.5	1	VOID; marl		* *	NF R	Marl, mottled, olive and light olive gray.			
				1.5–3	2	marl		*					
				3–4.5	3	marl		*		pyritic mudstone 5 cm thick, brownish grayish black, with 0.5 cm pyrite nodule			
				4.5–6	4	marl		*					
		Discoaster neohamatus		6–7.5	5	marl		*		0.5 cm pyrite nodules at contact			
				7.5–9	6	claystone; marl		* * *		Claystone, massive, medium olive gray Marl, olive, mottled with light olive gray burrows.			
					CC	marl			NR		F Pd	F Pd	

% $CaCO_3$: 0 50 100; F M C Pd F P

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



SITE: 155 HOLE: CORE: 2 Cored Interval: 443-452 m

AGE: SERIES: UPPER MIOCENE

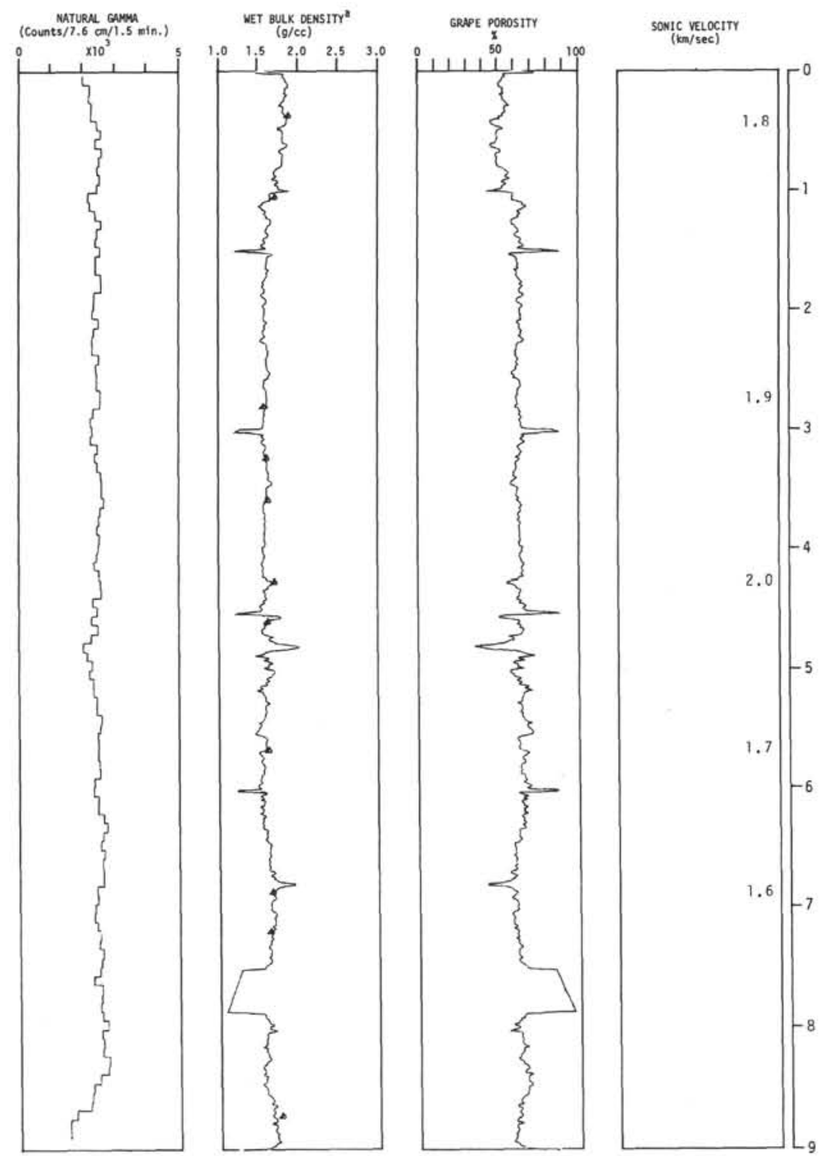
ZONE: Foram: *Globorotalia acostaensis*; Nanno: *Discoaster neohamatus*; Rad: *Omm. penultimus*

DEPTH (Meters)	SECTION	DISTURBANCE	SMEAR SLIDE	PALEO. SAMPLE	DESCRIPTION	MICROFOSSIL Abund/Pres Foram	Nanno	Rad
0	1				Marl, grayish olive mottled with greenish-gray burrows			
					Intercolated grayish olive marl and olive gray claystone			
1			* *		Claystone; dolomitic; very dark greenish gray; with 1 cm pyrite nodules			
			*					
2	2				Claystone; slightly dolomitized at top of unit; medium greenish gray; waxy.			
3–4	3		*					
5	4	N	*		Marl, grayish olive		C M	
					Claystone, waxy, various shades of gray and olive			
6			* * *					
7	5		*		Marl, grayish olive, mottled with lighter shades but less than marls higher in hole.			
		N			Claystone, medium greenish gray		F P	
8	6				0.8 cm thick zone of sand-sized pyrite at contact			
					Marl, grayish olive; mottled with darker and lighter shades			
	CC		*	NF R		F* P	A* M	C P

% $CaCO_3$: 0 50 100

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles

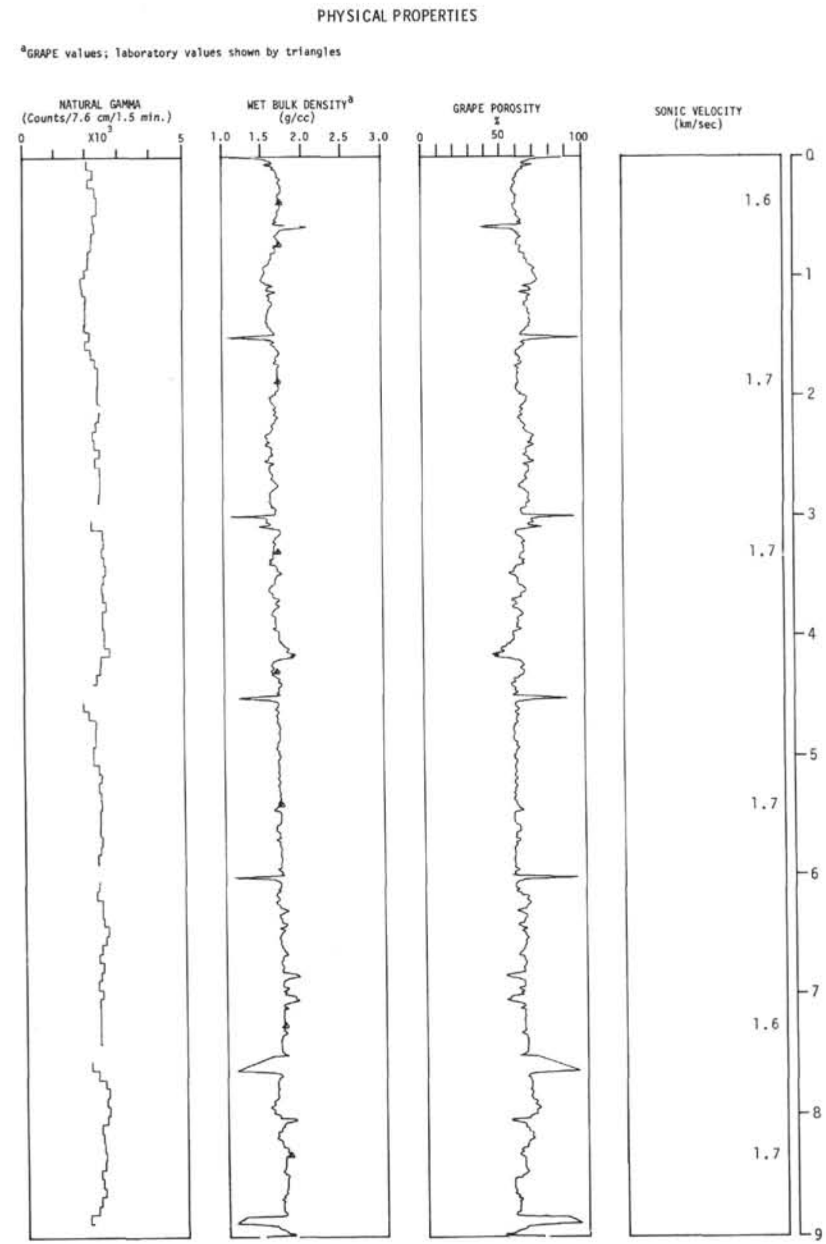


SITE: **155** HOLE: CORE: 3 Cored Interval:

SERIES	AGE / ZONE: Foram	Nanno	Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION
UPPER MIOCENE	*Globorotalia acostaensis*	*Discoaster neohamatus*	*Ommatartus penultimus*	0–1.5	1			*		Marl, variegated olive, grayish olive, and light olive; mottled pyrite nodule; 1 cm dia. pyrite nodule; 1 cm. dia.
				1.5–3.0	2			*		Claystone, greenish gray, massive, waxy
				3.0–4.5	3					At contact, 1 cm thick pyrite-rich layer, with 8 mm diameter nodules
				4.5–6.0	4			* *		Marly clay grading to marl at top and bottom of unit; mottled; predominant colors grayish olive, dark grayish olive and olive green; mottled variously medium olive gray, yellow to light olive gray, medium greenish gray and dark grayish olive.
				6.0–7.5	5			*		
			Omm. antepenult.	7.5–9.0	6			*		Disturbed; voids
					CC				NF R	

MICROFOSSIL Abund/Pres: Foram, Nanno, Rad; % $CaCO_3$ 0, 50, 100; C M F P C P

PHYSICAL PROPERTIES



SITE: 155 HOLE: CORE: 4 Cored Interval: 461-470 m

SERIES: UPPER MIOCENE

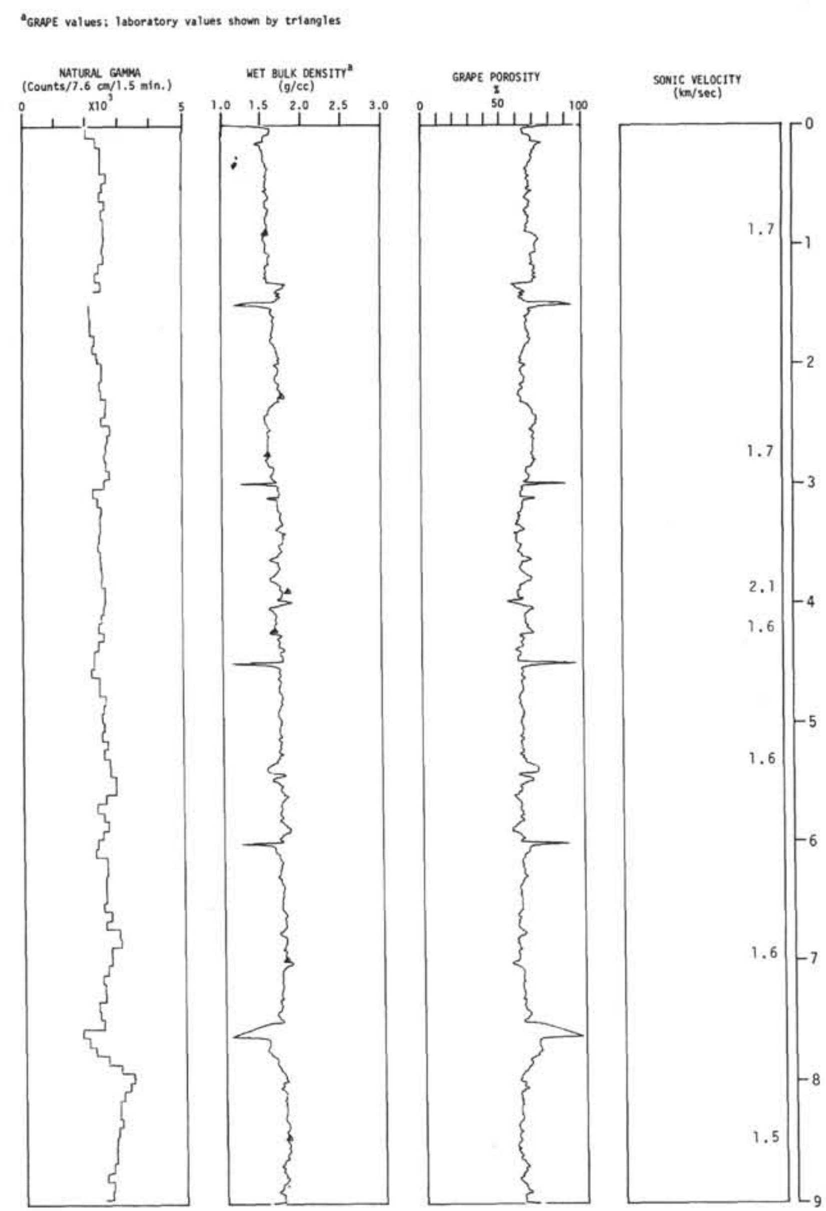
AGE / ZONE: Foram: (?) *Globorotalia menardii/G. acostaensis*; Nanno: *Discoaster neohamatus*; Rad: *Ommatartus antepenultimus*

Sections: 1, 2, 3, 4, 5, 6, CC — Depth (Meters) 0–9

MICROFOSSIL Abund/Pres: top of core: Foram R M, Nanno C M; CC: Rad F P. Paleo. sample: NR (top), R (CC).

DESCRIPTION
Marl, grayish olive
Claystone, waxy, medium greenish gray
dark gray
Marly clay; mottled; grayish olive green grading downward to dusky olive green; mottles lighter and darker shades
intercalated transition (disturbed)
Claystone; medium greenish gray; waxy
Marly clay, greenish olive gray, with olive gray mottles which contain finely disseminated pyrite
Claystone, massive, waxy, dark gray
Marly clay, greenish olive gray; mottled
large olive gray mottled 4 cm thick containing fine pyrite
Claystone, olive gray, massive, waxy
Marly clay, grayish olive green but somewhat lighter at center of unit; dusky yellow green and olive gray mottles
2 mm calcite stringer
pyrite nodule

PHYSICAL PROPERTIES



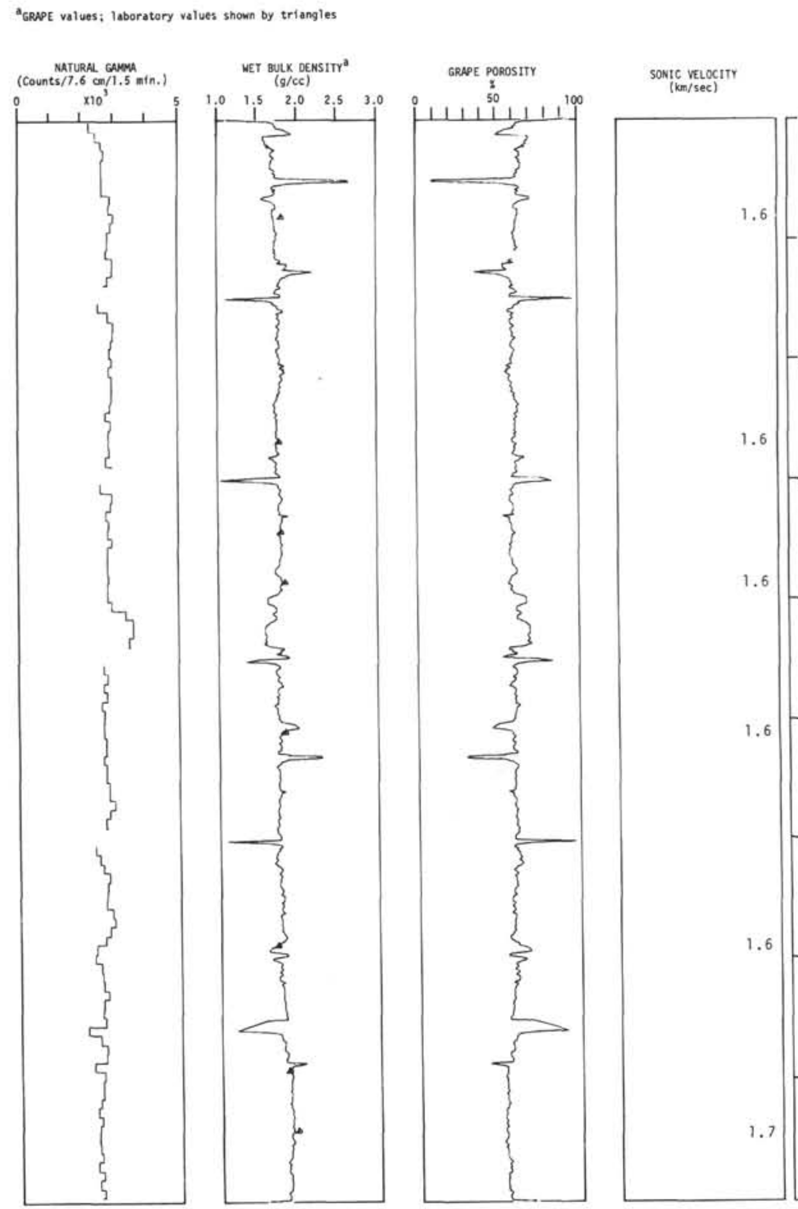
SITE: 155 HOLE: CORE: 5 Cored Interval: 470-479 m

SERIES	Foram zone	Nanno zone	Rad zone	DEPTH (Meters)	SECTION	DESCRIPTION	Foram	Nanno	Rad
MIDDLE MIOCENE	?N.15/N.14	* / *Discoaster hamatus*		0–1.5	1	Nannofossil chalk, light olive gray Top and bottom third: Marly clay, grayish olive green; with olive gray mottles containing fine pyrite. Center of unit is marl, grayish olive, with olive gray and dusky olive green mottles. Gradational changes.			
				1.5–3	2	Pyrite nodule 3 cm in diameter Barite crystals, 2-4 mm, zone 3 cm long		F	P
				3–4.5	3	disturbed transition Claystone, dark greenish gray		F	P
				4.5–6	4	pyritic claystone, dark to dusky yellowish brown, 4 cm thick Marly clay, grayish olive green, mottled olive gray (fine pyrite) Barite veinlets		R	P
				6–7.5	5	pyritic claystone stringers Marl, grayish olive to dusky yellow green gradational with overlying and underlying units pyritic claystone lamina and stringers Marly clay, grayish olive green. Mottled with pyritic dark to dusky yellowish brown claystone		A	M
	Catinaster coalitus			7.5–9	6	2 mm barite stringer at contact Marl, dusky yellow green with grayish olive mottling, grading down into next unit Marly clay, grayish olive green; grayish olive mottles, grading down into next unit Marly, dusky yellow green with lighter mottling			
					CC				

MICROFOSSIL Abund/Pres: C M A P F P; % $CaCO_3$ 0–50–100

*Discoaster neohamatus

PHYSICAL PROPERTIES



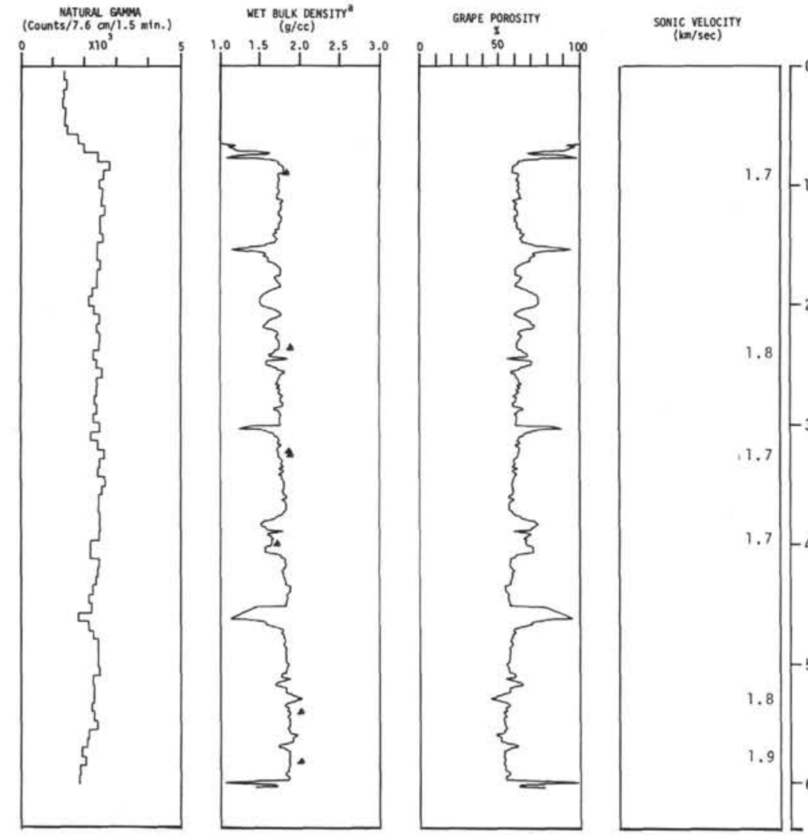
SITE: 155 HOLE: CORE: 6 Cored Interval: 479-488 m

SERIES	AGE ZONE: Foram	AGE ZONE: Nanno	AGE ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad
MIDDLE MIOCENE	*Globorotalia mayeri*	*Discoaster exilis*		0–6	1, 2, 3, 4, CC	VOID		*		Marl, dusky yellow green with lighter mottles Marly clay, grayish olive green, dark yellowish brown pyritic mottles, grading down into next unit Marl, dusky yellow green with lighter mottles Pyritic claystone, dusky yellow brown, olive gray mottles Marly clay, variegated olive gray, dusky yellow green, dark gray, medium greenish gray, with lighter mottles, grading down into next unit Chalk, grayish yellow green with lighter mottles Marly clay, mottled, variegated dusky yellow green, grayish olive green, dark greenish gray. Gradational with overlying and underlying units. Marl, grayish to dusky yellow green, medium greenish gray mottles, gradational with next lower unit. 4 cm thick pyritic claystone layers, medium dark gray. Marly clay, medium olive gray; grades into: Marl, greenish gray and dusky yellow green, with olive gray pyritic mottles. 0.4 cm thick barite stringer Marly claystone, grayish to dusky yellow; thinly laminated with olive gray. 0.5 cm thick barite at contact Chalk, light greenish to greenish gray; few olive gray lamina	A	P	F P

% $CaCO_3$: 0 50 100

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles

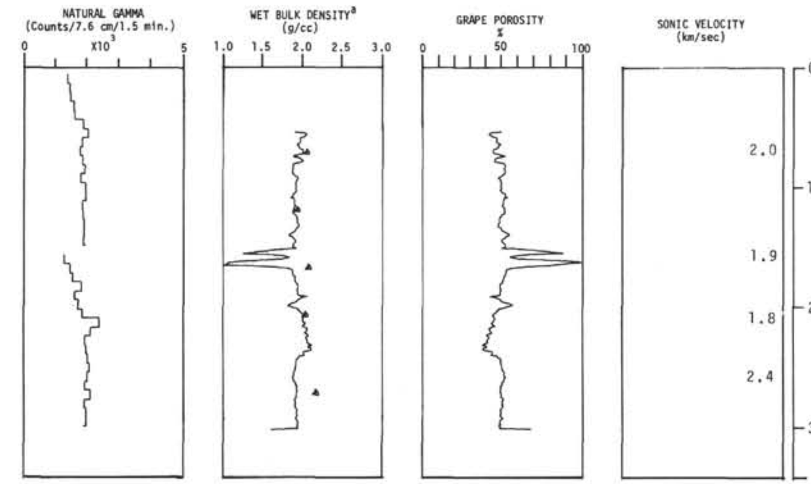


SITE: 155 HOLE: CORE: 7 Cored Interval: 488-497 m

SERIES	AGE / ZONE: Foram	Nanno	Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres (Foram, Nanno, Rad); % $CaCO_3$
MIDDLE MIOCENE	*Globorotalia fohsi robusta*	*Sphenolithus heteromorphus*; *Discoaster exilis*		0–1	1	VOID; chalk				Chalk, grading from light greenish and greenish gray at top to very light to light gray at base of unit. Few disturbed olive gray pyritic laminae. Not mottled.	
				2	2	dolomitic chalk		*		Chalk, dolomitic, massive, well indurated, light olive gray. Numerous silt-sized dolomite rhombs	
					CC				NR		A Pd F P

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles

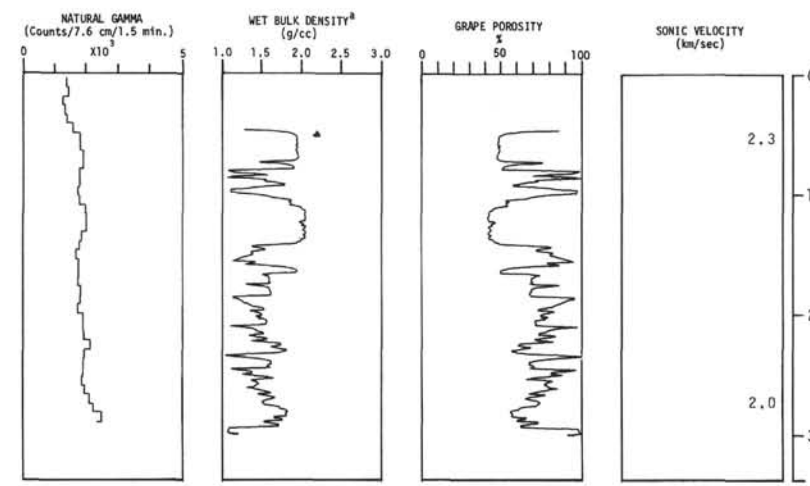


SITE: 155 HOLE: CORE: 8 Cored Interval: 497-506 m

SERIES	AGE / ZONE: Foram	Nanno	Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres (Foram, Nanno, Rad); % $CaCO_3$
MIDDLE MIOCENE	*Globorotalia fohsi robusta*	*Sphenolithus heteromorphus*		0–1	1	VOID; dolomitic chalk		*		Chalk, dolomitic, light olive gray, massive, well indurated.	
								*		Some chalk, but softer; few disturbed laminae. Grades down into next unit.	
				2	2	chalk-marl		* *		Chalk-marl, yellowish to light olive gray. Dark medium to coarse sand grains and granules with aspect of lithic fragments increasing in size and abundance to about 5% at base of section. Smear slides show these to be clay aggregates. Decomposed volcanic sand?	
					CC				NR		A M F P

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



SITE: 155 HOLE: CORE: 9 Cored Interval: 506-515 m

SERIES	AGE – ZONE: Foram	AGE – ZONE: Nanno	AGE – ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad	% $CaCO_3$ (0 – 50 – 100)
MIDDLE MIOCENE	*G. fohsi robusta*	*Sphenolithus heteromorphus*			CC				N P	Chalk ooze, light gray		A P	R P	

SITE: 155 HOLE: CORE: 10 Cored Interval: 515-521 m

SERIES	AGE – ZONE: Foram	AGE – ZONE: Nanno	AGE – ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad	% $CaCO_3$ (0 – 50 – 100)
MIDDLE MIOCENE					CC				N	16-cm diameter altered basalt fragment. 0.5 - 1 cm cavities lined with calcite and pyrite druses		— —		

SITE: 155 HOLE: CORE: 11 Cored Interval: 521-527 m

SERIES	AGE – ZONE: Foram	AGE – ZONE: Nanno	AGE – ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad	% $CaCO_3$ (0 – 50 – 100)
MIDDLE MIOCENE	*G. fohsi fohsi*	*Sphenolithus heteromorphus*		1	1	VOID				Chalk, yellowish gray and light olive gray, 14 fragments 8-2 cm in size		A P		
									N	Basalt, altered diabasic texture, in 5 fragments 7 to 3 cm in size				
					CC					Same fine-grained altered basalt; 3 fragments. One piece partly vesicular with calcite and zeolite		— —		

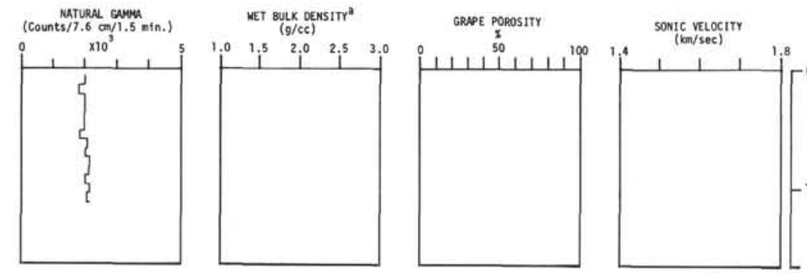
Sonic Velocity (km/sec) 3.8; Depth 1.43 m

SITE: 155 HOLE: CORE: 12 Cored Interval: 527-536 m

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad	% $CaCO_3$ (0, 50, 100)
MIDDLE MIOCENE	|	|	|	1	1	VOID		*** *		*Thin section Altered augite basalt, holocrystalline. 9 fragments 3-8 cm in size. Crystalline limestone, fine grained, with peripheral sliver of altered basalt glass. Single fragment.				
					CC					Altered basalt, 4 fragments 3-10 cm. in size. Altered basalt, fine grained. Zeolite-lined vugs in one of the 4 fragments.		A P		

PHYSICAL PROPERTIES

[a]GRAPE values; laboratory values shown by triangles



SITE: 155 HOLE: SIDEWALL CORE: 13 Cored Interval: 384

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram	Nanno	Rad	% $CaCO_3$ (0, 50, 100)
UPPER MIOCENE	*G. plesiotumida*	*Discoaster quinqueramus*	*Spongaster pentas*		CC			*	NF R	Marl to marl ooze, medium greenish gray.	C M	C M	F P	

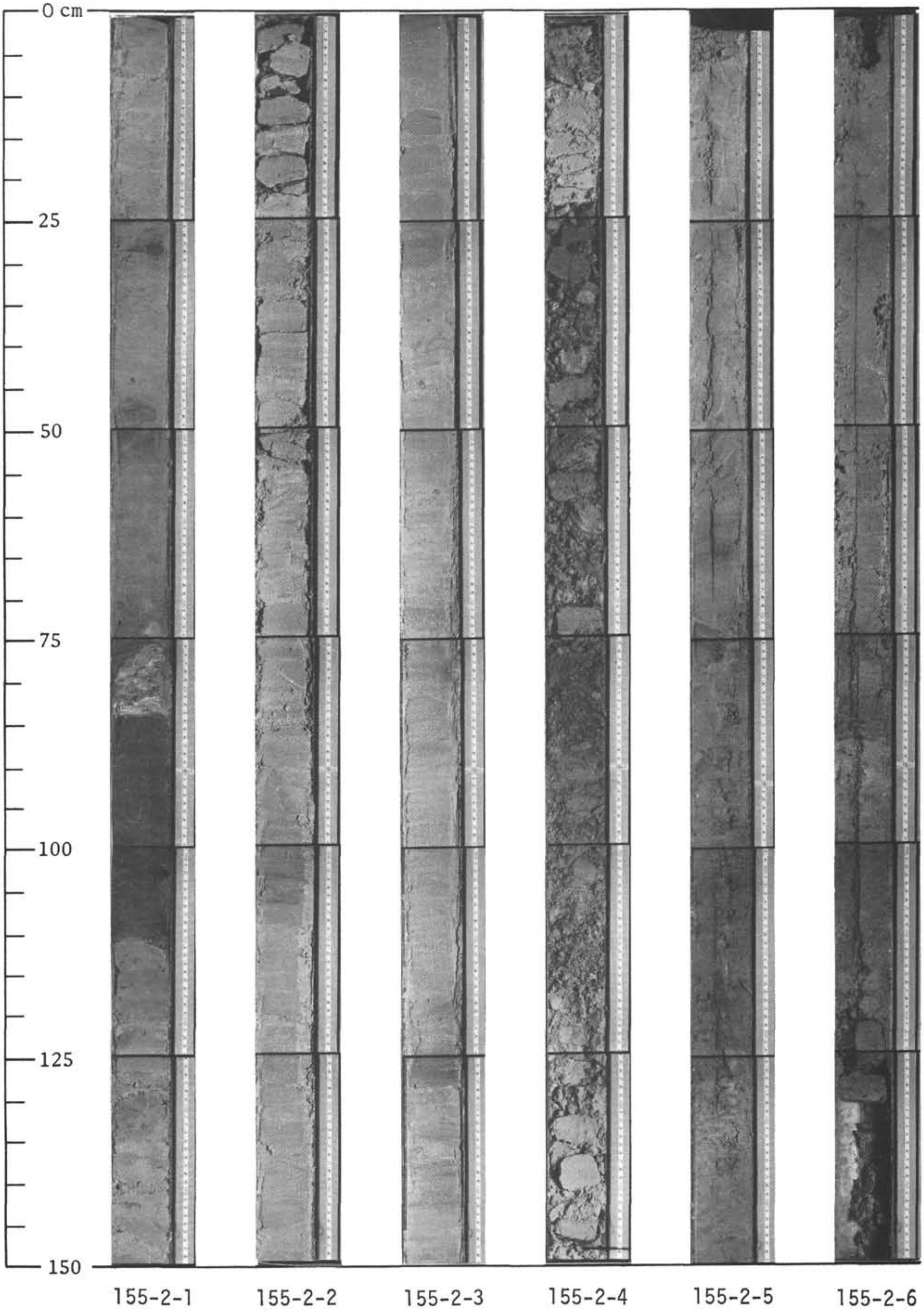
SITE: 155 HOLE: SIDEWALL CORE: 14 Cored Interval: 371

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram		Nanno		Rad	
LOWER PLIOCENE	*G. tumida*	*	*Spongaster pentas*	CC				*	NF R	Marl to marl ooze, medium greenish gray.	C*	M	A	M	F*	P

SITE: 155 HOLE: SIDEWALL CORE: 15 Cored Interval: 285

AGE: SERIES	ZONE: Foram	ZONE: Nanno	ZONE: Rad	DEPTH (Meters)	SECTION	LITHOLOGY	Disturbance	Smear Slide	Paleo. sample	DESCRIPTION	MICROFOSSIL Abund/Pres: Foram		Nanno		Rad	
LOWER PLIOCENE	*G. tumida*	*	*Spongaster pentas*	CC				*	N N N F R	Marl to marl ooze, grayish olive.	R	P	A C C	G P M	C	M

* *Discoaster brouweri and Reticulofenestra pseudoumbilica*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125
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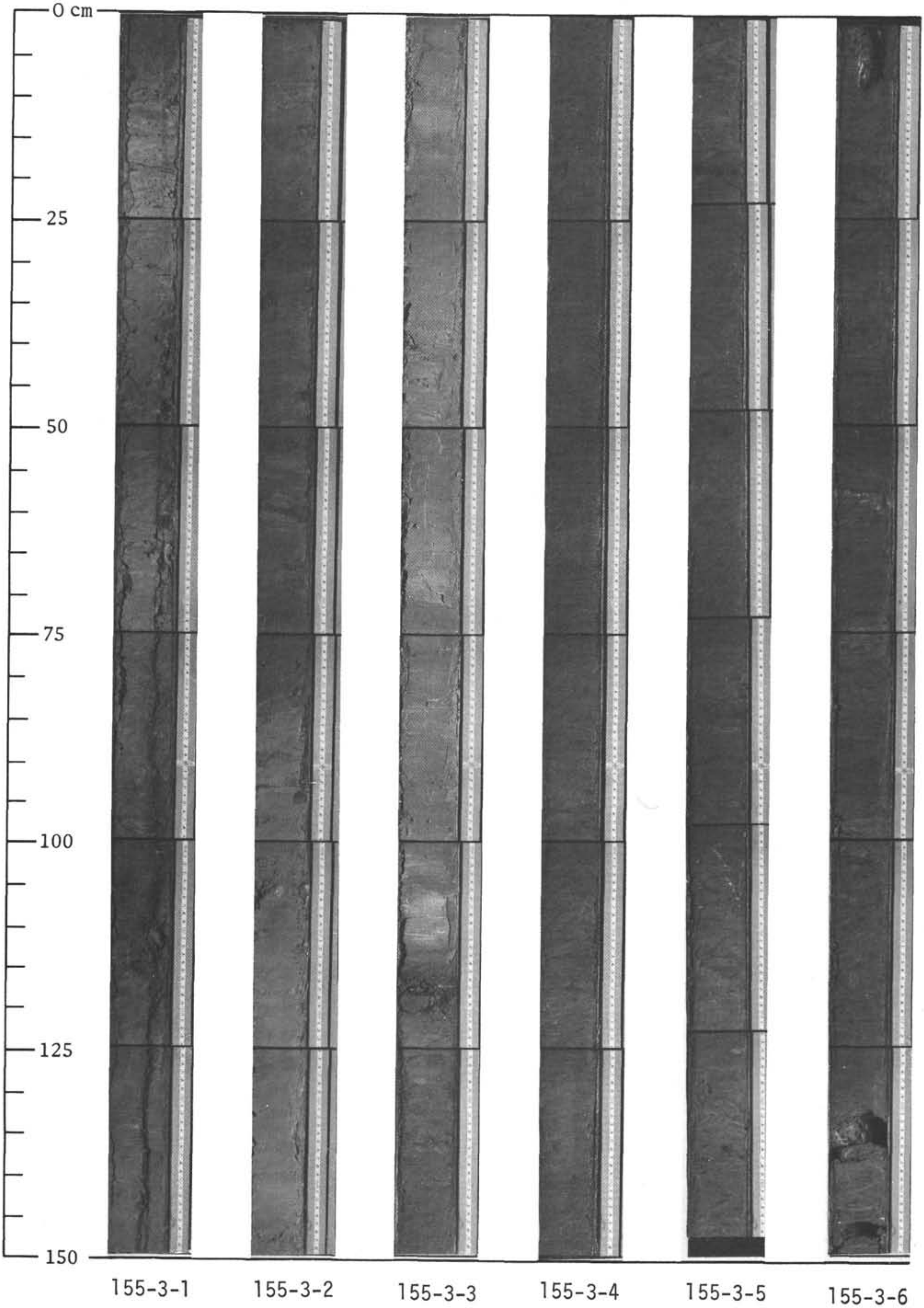
155-2-2
155-2-3
155-2-4
155-2-5
155-2-6


0 cm
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50
75
100
125
150
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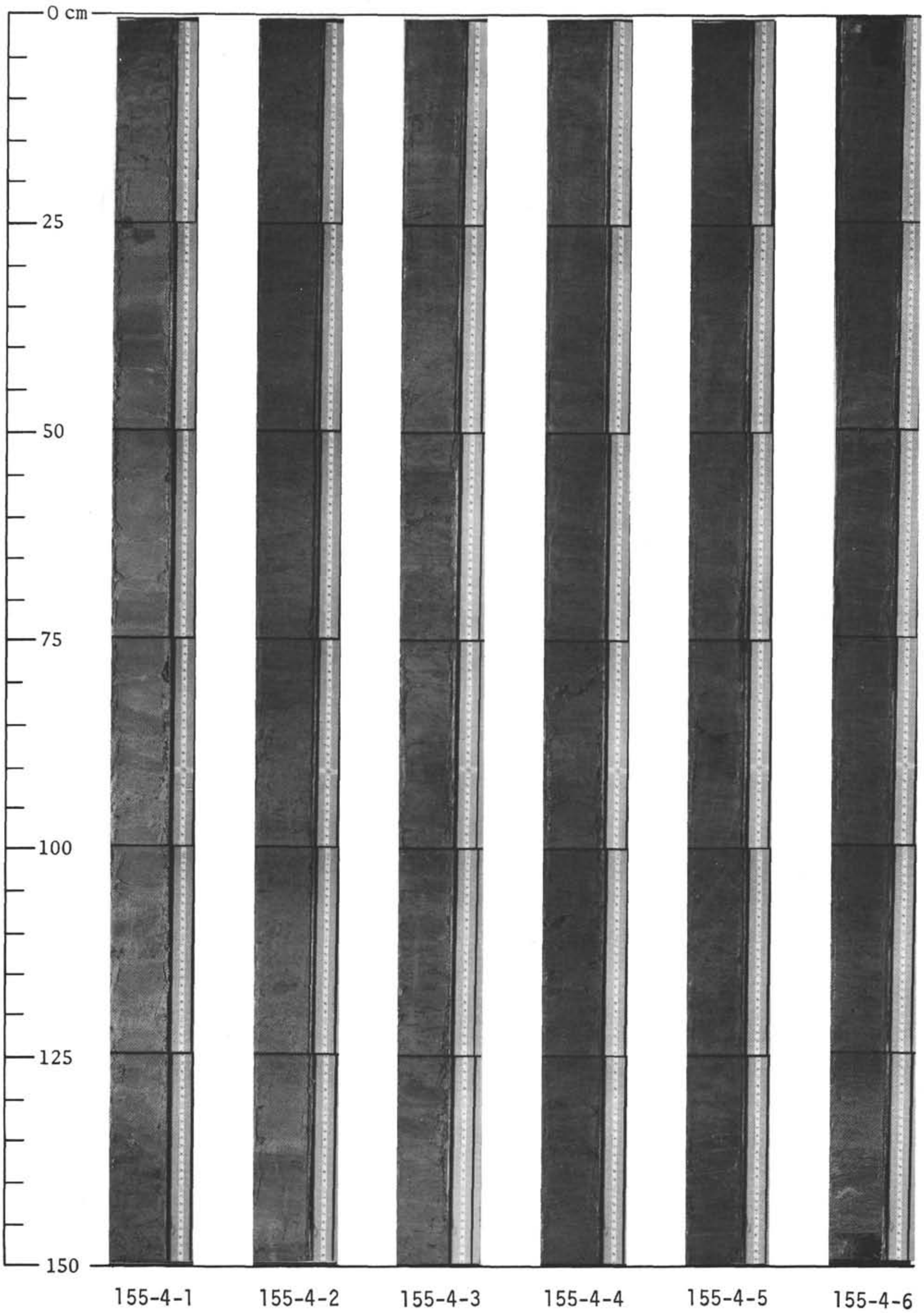
155-3-2
155-3-3
155-3-4
155-3-5
155-3-6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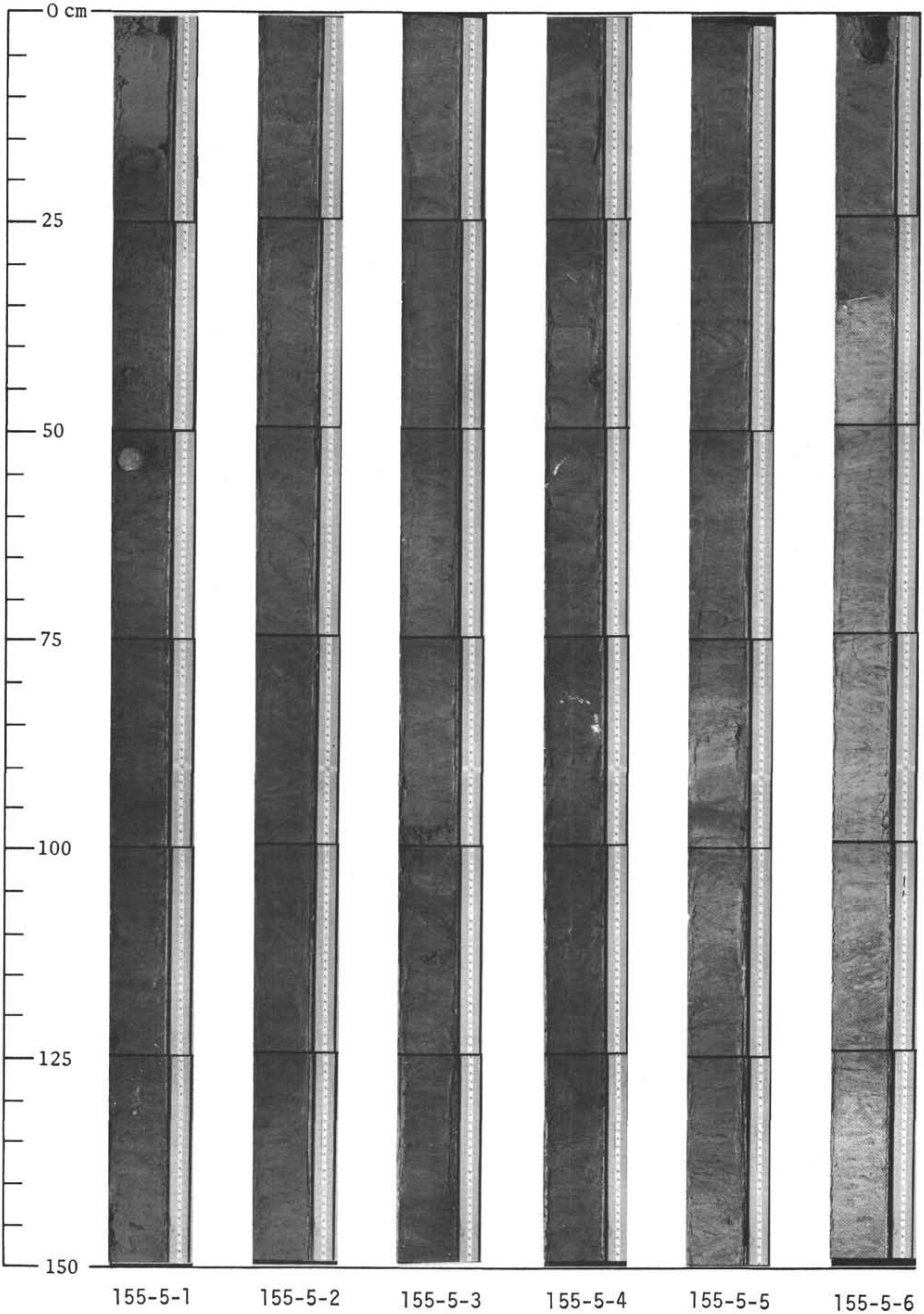
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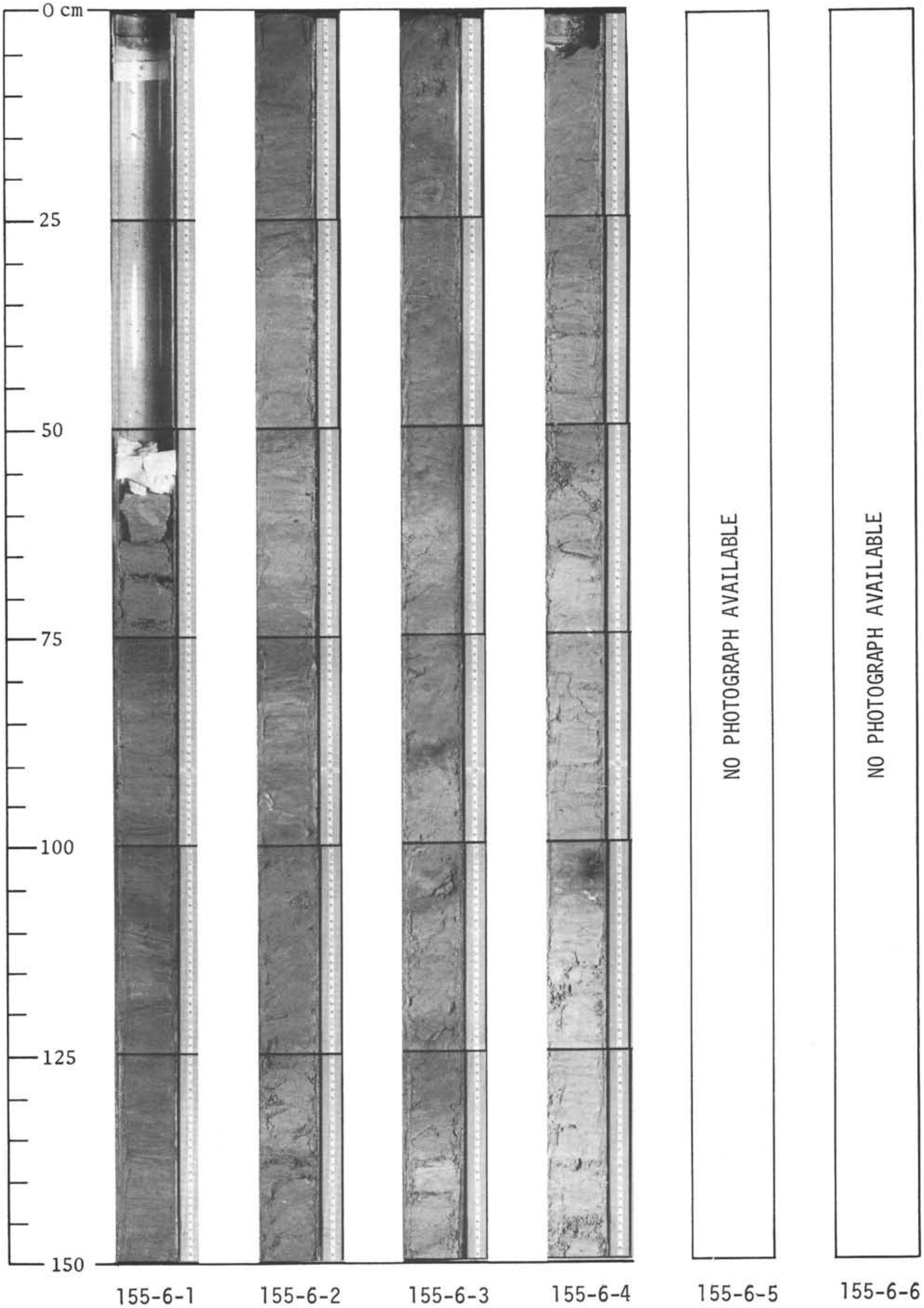
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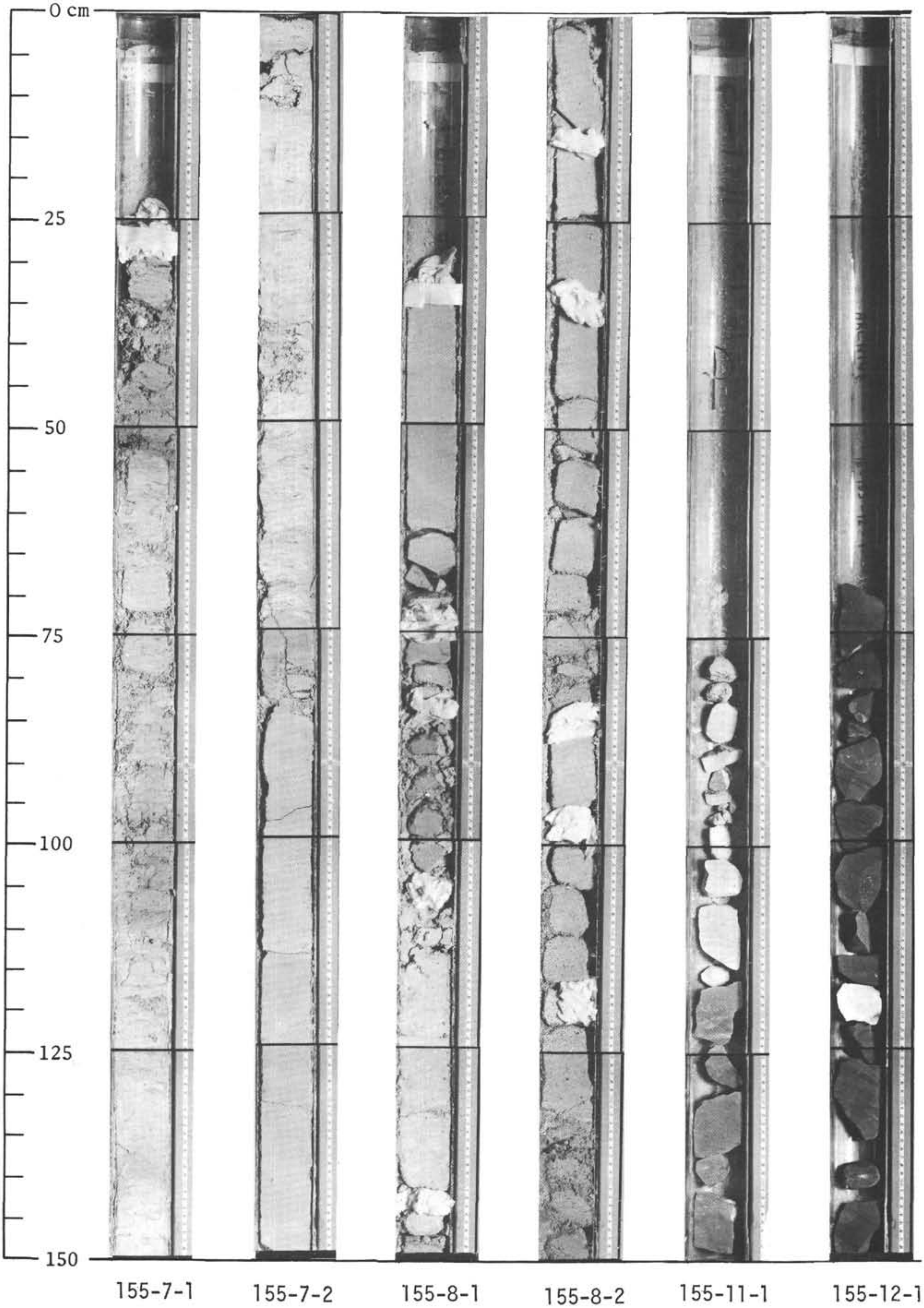
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155-8-1
155-8-2
155-11-1
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