7. SITE 140

The Shipboard Scientific Party[1]

ABSTRACT

Site 140 is situated at the foot of the continental rise about 450 kms west of Cap Blanc, Africa.

About 150 meters of nannoplankton chalk ooze of Pliocene age and younger, and 75 meters of silty clay and diatom ooze of Miocene age overlie, with a pronounced hiatus of 20 to 25 million years, at least 400 meters of Middle Eocene to Upper Cretaceous siliceous clay, shale, and chert with thin silt and sand beds. Dolomite is common to abundant in some silt beds.

The Miocene and older sediments contain an abundance of detrital quartz. Nearly all sediments from this site show evidence of redeposition and have high sedimentation rates.

The first major zone of reflectors on the *Challenger* seismic record can be correlated with the major lithologic changes from calcareous ooze above to silty clay below.

SITE DATA

Time: 1505 October 31, 1970
1410 November 4, 1970

Position: 21° 44.97′N
21° 47.52′W

Water Depth: 15,065 feet
2,380 nominal fathoms
4,483 meters

Total Penetration: 651 meters

Cores Taken: Ten Cores

BACKGROUND, SURVEY, AND OPERATIONS

Site 140 lies at the foot of the continental rise about 450 km west of Cap Blanc in a water depth of about 4500 meters (Figure 1). This site is located at the eastern North Atlantic magnetic quiet zone boundary (See Chapter 27 and map in folder).

A description and photographs of the seismic reflection profiles for Site 140 is included with the account of Site 139 (Chapter 6). An enlargement of the profile at Site 140 is given in the composite diagram as Figure 2.

The morphology of the lower continental rise off West Africa is very smooth. The numerous flat reflecting horizons seen on the seismic reflection profiles (Chapter 6, Figure 2) show no signs of deformation. The reflecting horizons bound thin wedges of sediment which thicken slightly toward the continent. Seismic Sonobuoy measurements (unpublished LDGO data; J Ewing, pers. comm.) indicate that 1.5 to 2.0 km of sediment overlie basement (layer 2). These measurements also indicate that the uppermost 800 meters of sediments have low average seismic velocities of about 1.76 km/sec, whereas the lower 1000 m of sediments have velocities of 2.6 to 3.0 km/sec. These lie on the basement with a velocity of about 5 km/sec. The reflector observed at about 0.6 seconds at Site 139 can be traced southwestward to Site 140, but is only about 0.2 seconds deep there. The reflector is believed to represent a pronounced lithologic change from clayey chalk ooze to mainly silty clay with diatoms. At least two strong reflectors can be seen at Site 140 below the reflector mentioned above. (See Chapter 6, Figure 2.)

Seismic Reflection Data:	*Vema*	*Challenger*
Intermediate Reflectors	0.15 sec	0.17 sec
	0.55 sec	0.60 sec
	0.75 sec	0.80 sec
Basement Reflector	1.60 sec	?

A summary of the drilling and coring operations is given in Figure 3 and Table 1.

BIOSTRATIGRAPHY

General

Calcareous micro- and nannofossils were found only in the uppermost part of this site (Hole 140, Cores 1 and 2, Hole 140A, Core 1). The age diagnostic fossils are listed in Table 2. In 140-1, rich planktonic foraminifera and nannoplankton of Late Pliocene age were found. Middle Miocene planktonic foraminifera and nannoplankton assemblages showing signs of solution were recovered in 140A-1. Early Miocene planktonic foraminifera and nannofossils from 140-2 are even more strongly affected by solution. Abundant diatoms, Radiolaria and displaced shallow-water benthonic foraminifera also occur in this core. In 140A-2, 140-3 and 140-4, only Radiolaria indicative of Middle to Lower Eocene were present. Below a barren interval (140-5, 6), some arenaceous foraminifera

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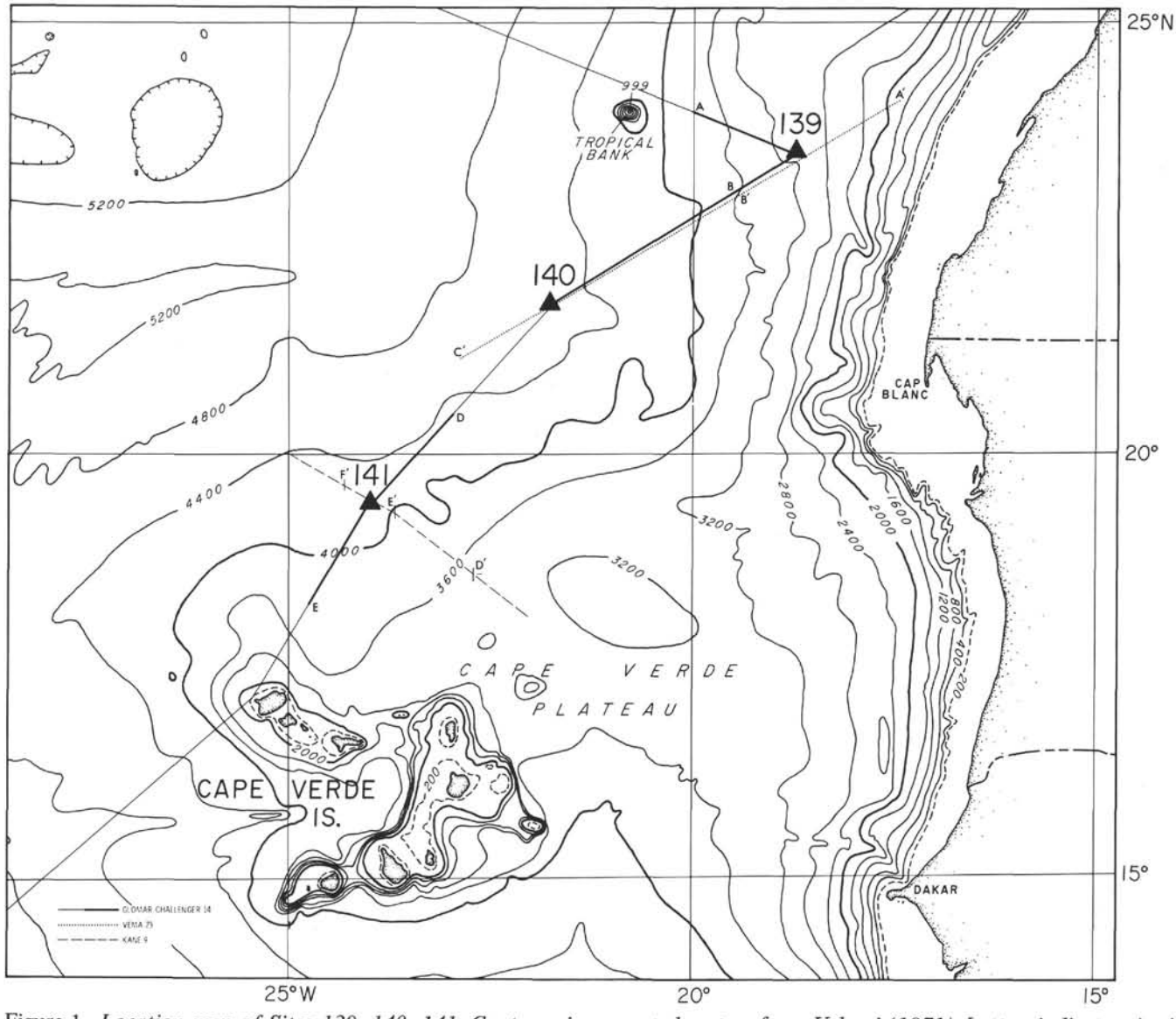

Figure 1. *Location map of Sites 139, 140, 141. Contours in corrected meters from Uchupi (1971). Letters indicate seismic profiles shown in Chapter 6, Figure 2 and Chapter 8, Figure 1.*

indicative of Paleocene to Upper Campanian occur in 140-7 and 8. Radiolaria from 140-8 indicate a Maestrichtian age.

Foraminifera

The Pliocene foraminiferal fauna of Core 1 is of the normal pelagic type. The two following cores (140A-1, 140-2) of Miocene age apparently contain a large proportion of displaced forms. This is especially true for 140A-1, where typical shallow water fossils such as *Ammonia beccarii*, Pararotalia, Elphidium, barnacle plates, and larger mollusk shells, are associated with common planktonic foraminifera. The benthonic association of 140-2 lived probably in somewhat deeper water; it is very similar to that of Core 5 in Site 139. Of the lower cores in Site 140, only Cores 7 and 8 contain some foraminifera. These are of the agglutinated type and most probably indicate deep water below the calcium carbonate compensation level. A Paleocene to Late Campanian age for these two cores is indicated by the presence of *Rzehakina epigonalata.*

Nannoplankton

Core 1 contains rich assemblages of Late Pliocene age. The common occurrence of the four rayed *Discoaster tamalis* in this core is characteristic for the lowermost part of the *Discoaster brouweri* zone. Core 2 yields only etched assemblages of Early Miocene age. *Sphenolithus heteromorphus* and *S. belemnos* occur together with *Helicopontosphaera ampliaperta* throughout the core. Cores 3 through 8 lack calcareous nannoplankton. Core 1 of Hole 140A recovered Middle Miocene nannofossils in a poor state of preservation. Core 2 of Hole 140A does not contain any nannoplankton.

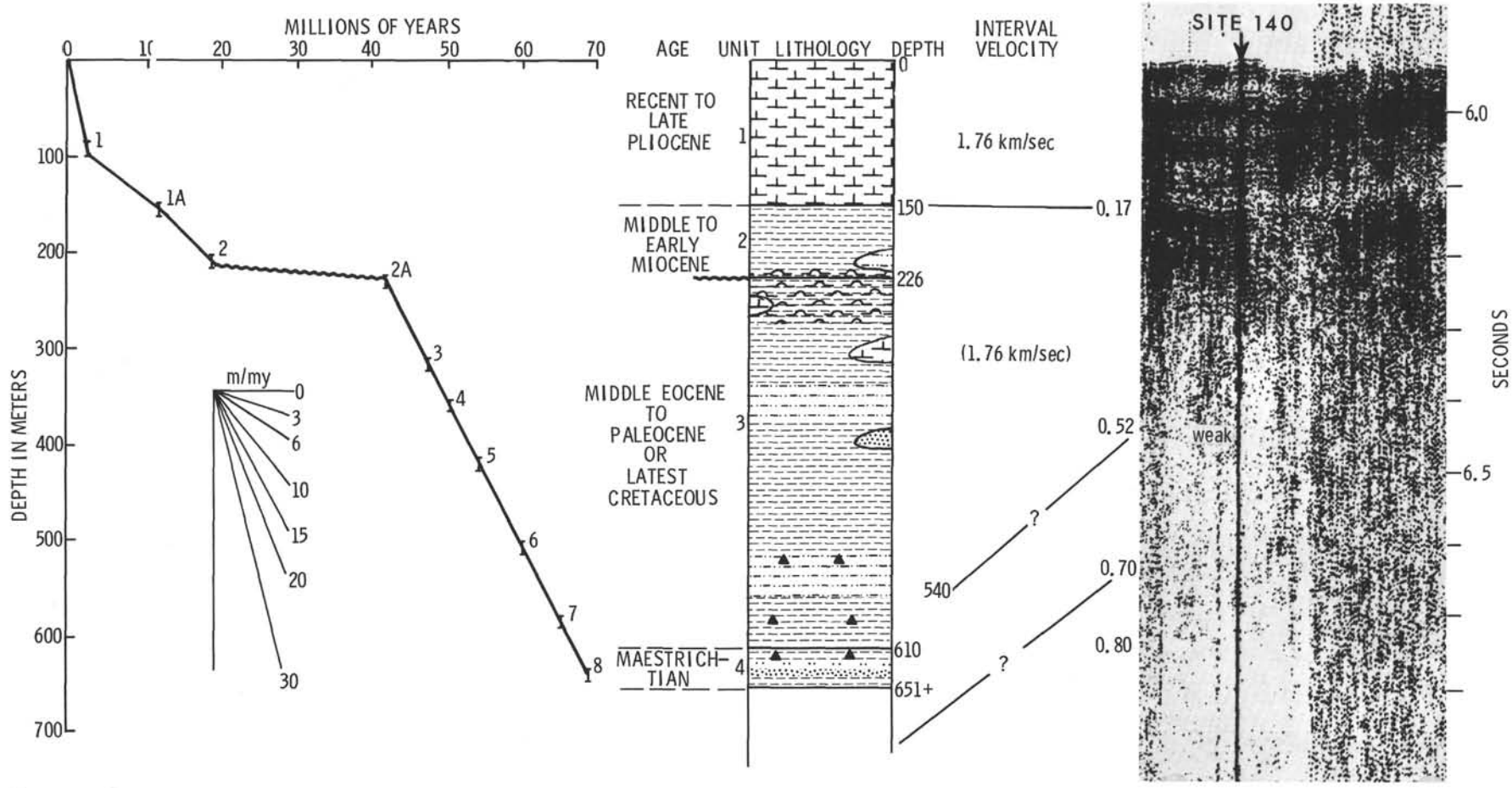

Figure 2. *Geological synthesis at Site 140. Weak reflector at 0.52 second should correlate with subbottom depth of 540 meters if assume average velocity of 1.76 km/sec (see also Figure 2 of Chapter 6).*

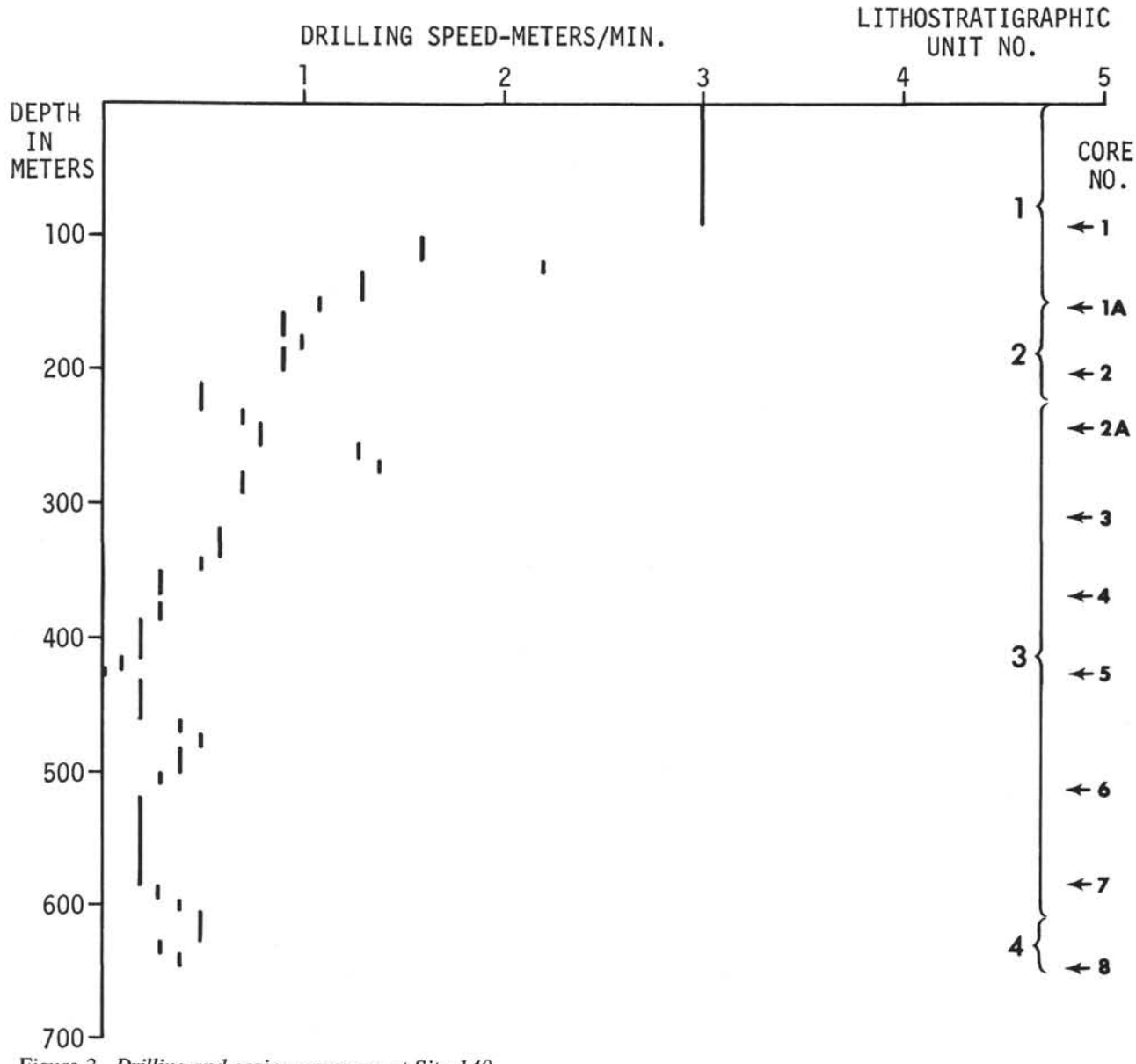

Figure 3. *Drilling and coring summary at Site 140.*

Diatoms

Determinations listed below were made by Hans Schrader.[2]

Hole 140, Core 2:

Very few strongly etched diatoms, no rads, no sponge spicules

Hole, 140, Core 2, Section 1, 116 cm:

Craspedoporus coscinodiscus, Cymatogonia ambioceras, Chaetoceros spores, *Stephanopyxis turris, Melosira sulcata, Denticula lauta, Actinoptychus splendens, Coscinodiscus marginatus*. Rich and well preserved diatom assemblage. Few sponge spicules, Radiolaria and *Silicoflagellatae*.
Age: Miocene

Hole 140, Core 2, Section 2, 126 cm:

Melosira sulcata, Chaetoceros bristles and spores, *Hemiaulus polymorphus, Thalassionema nitzschioides, Actinocyclus* spec. Strongly etched diatom assemblages, only stronger silicified parts of frustules left. Few Radiolaria and sponge spicules.
Age: No age diagnostic species found.

Hole 140, Core 2, Section 2, 94 cm:

Chaetoceros bristles and spores, *Crasperdodiscus coscinodiscus, Coscinodiscus marginatus, Chaetoceros cinctus, Xanthiopyxis oblonga, Rhaphoneis amphiceros, Sceptroneis caduceus, Denticula lauta, Stephanopyxis turris, Actinocyclus ehrenbergi, Navicula spectabilis, Triceratium* spec., *Pseudopyxilla* spec. Diatom ooze with well preserved frustules, few Radiolaria, common *Silicoflagellatae* and few sponge spicules.
Age: Miocene

Hole 140, Core 2, Section 4, 100 cm:

Similar 140-2-2-94.

Hole 140, Core 2, Section 4, 150 cm:

Similar 140-2-2-94.

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TABLE 1
Drilling and Coring Record for Site 140

Description	Interval Below Sea Floor (m)	Core Recovery (m)	Drilling Rate (m/min)
Drill	0-89		3.0
Core 1	89-98	9.0	
Drill	98-117		1.6
	117-126		2.2
	126-146		1.3
	146-155		1.1
	155-173		0.9
	173-183		1.0
	183-201		0.9
Core 2	201-210	9.0	
Drill	210-229		0.5
	229-238		0.7
	238-257		0.8
	257-266		1.3
	266-276		1.4
	276-293		0.7
Core 3	311-318	4.5	
Drill	318-340		0.6
	340-350		0.5
	350-368		0.3
Core 4	368-374	1.4	
Drill	374-387		0.3
	387-406		0.2
	406-415		0.2
	415-425		0.1
	425-427		0.03
Core 5	427-432	0	
Drill	432-462		0.2
	462-472		0.4
	472-482		0.5
	482-491		0.4
	491-501		0.4
	501-510		0.3
Core 6	510-519	1.7	
Drill	519-530		0.2
	530-549		0.2
	549-568		0.2
	568-578		0.2
	578-585		0.2
Core 7	585-587	0.1	
Drill	587-596		0.3
	596-605		0.4
	605-627		0.5
	627-636		0.3
	636-645		0.4
Core 8	645-651	4.1	
Hole 140A	801		
Core 1	150-159	0.7	
Drill	159-235		1.4
Core 2	235-244	8.2	

Hole 140, Core 2, Section 6, 125 cm:
Similar 140-2-2-94.

Hole 140, Core 2, Section 6, 130 cm:
Similar 140-2-2-94 but higher content of coccoliths, clay size particles and diatom species, originated from littoral biocoenosis.

Hole 140, Core 3, 4, 5, 6, 7, 8:
No diatoms, few rads, few sponge spicules.

Hole 140A:
No diatoms, no rads, no sponge spicules.

LITHOSTRATIGRAPHY

Two holes, 140 and 140A, were drilled at Site 140. Coring at Site 140 began at 89 meters below the sea floor in sediments of Early Pliocene age and ended at 651 meters in sediments of Late Cretaceous age. Two general types of lithologies were encountered: chalk to marl oozes; and deep sea clays, largely non-calcareous, with varying amounts of silt. Four lithologic units were recognized.

Unit	Cores	Lithology	Depth Below Sea Floor (m)	Age
1	1	Nannofossil Chalk/marl ooze with forams	0-150	Recent-Late Pliocene (?)
1	1A, 2	Reddish-brown and greenish gray clay w/silt lenses and olive diatom mud/ooze w/nannos	150-226	Middle-Early Miocene
		HIATUS		
3	2A, 3, 4,5,6, 7	Clay similar to Unit 2 w/diatoms and Rads passing down into olive gray silty dolomitic clay w/dark chert beds	226-610	Middle Eocene to Paleocene or latest Cretaceous
4	8	Greenish gray silty zeolitic clay w/sub-arkosic sand beds	610-651+	Maestrichtian

UNIT 1 – Nannofossil Chalk-Marl Ooze (Core 1)

The upper part of the section (Unit 1) consists of nannofossil chalk and marl oozes with 5 to 15 per cent forams. The cored interval, 80 to 89 meters, is of Early Pliocene age, but, on the basis of piston cores in nearby areas (*Vema* cores 23-99 and 23-100) and the drilling records, the unit extends from the sea floor to a depth of 150 meters and appears to be Pliocene to Recent in age. The average sedimentation rate for Unit 1 is about 20 m/my. Drilling rates ranged from 3.0 to 1.6 meters per minute.

UNIT 2 – Clay, Silt, Diatom Mud/Ooze (Cores 1A, 2)

Unit 2 is of Middle Early Miocene age and consists of: brown and greenish gray clays with minor sandy silt lenses and some siliceous fossils (140A Core 1); and darker grayish olive mud and siliceous ooze (diatoms and radiolarians) with a few thin lenses of lighter greenish gray calcareous-siliceous ooze having roughly equal amounts of nannofossils, diatoms, and radiolarians (140 Core 2). Silt-size terrigenous grains are largely quartz with minor degraded micas and a few grains of feldspar. Pyrite is present in the darker beds. The average sedimentation rate for the unit is about 10m/my. Drilling rates ranged from 1.3 to 0.9 meters per minute.

TABLE 2

CORE	DIAGNOSTIC FOSSILS HOLE 140		
	FORAMINIFERA	NANNOPLANKTON	AGE
1	Rich, predominantly planktonic fauna with *Globorotalia miocenica, Gr. pertenuis, Gr. humerosa, Gr. crassaformis* s.l and *Globigerinoides ruber*. The Core Catcher sample contains also *Globorotalia margaritae* (large), *Gr. multicamerata, Globigerina venezuelana,* and *Globoquadrina altispira.* Age: Pliocene, *Globorotalia exilis/Gr. miocenica* Zone for Sections 1 to 5, *Globorotalia margaritae* Zone for the Core Catcher sample.	Rich assemblages of calcareous nannoplankton including *Discoaster browseri, D. tamalis, D. pentaradiatus, D. surculus, Ceratolithus rugosus, Reticulofenestra* cf. *pseudoumbilica* (small). Preservation: E1-01. Zone: *Discoaster browseri.* Age: Late Pliocene	Late Pliocene
2	The assemblage is mainly siliceous (floods of diatoms and common Radiolaria). Benthonic foraminifera *(Lenticulina, Bolivina, Uvigerina, Epistominella, Nonionella, Stilostomella, Gyroidina)* are fairly common. The few planktonic foraminifera include *Catapsydrax dissimilis, Globigerinoides subquadratus, Globorotalia fohsi peripheroronda,* and *Globigerinita* sp. Age: Early Miocene, *Catapsydrax stainforthi* or *Catapsydrax dissimilis* Zone.	Poorly preserved nannoflora including *Helicopontosphaera ampliaperta, Sphenolithus heteromorphus, S. belemnos.* Preservation E_2 to E_3 - 01. Zone: *Helicopontosphaera ampliaperta.* Age: Early Miocene.	Early Miocene
3	None	None	
4	None	None	
5	None	None	
6	None	None	
7	Rare and rather poorly preserved agglutinated foraminifera: *Bathysiphon* sp.,*Pelosina complanata, Spiroplectammina mexiaensis, Trochamminoides irregularis, Rzehakina epigona lata, Glomospira gordialis.* Age: Campanian to Paleocene, *Rzehakina epigona* Zonule.	None	Late Cretaceous to Paleocene
8	Rare agglutinated foraminifera including *Bathysiphon* sp.,*Pelosina complanata, Verneuilinoides* sp., *Trochamminoides irregularis, Clavulina* cf. *arenata, Rzehakina epigona lata,* and *Glomospira gordialis.* Age: Late Cretaceous (Campanian) to Paleocene, *Rzehakina epigona* Zonule.	None	Late Cretaceous to Paleocene

TABLE 2A

CORE	DIAGNOSTIC FOSSILS HOLE 140A		
	FORAMINIFERA	NANNOPLANKTON	AGE
A1	A mixed assemblage of well preserved thin-walled planktonic foraminifera with a benthonic shallow-water fauna. Planktonic species include *Globorotalia cultrata, Gr.* cf. *acostaensis, Gr. obesa, Globigerina praebulloides,* and *Globigerinoides obliquus.* The benthonic assemblage consists of *Pararotalia* spp. (cf. *taiwanica/ozawai), Elphidium* cf. *macellum* and sp., *Ammonia beccarii,* and *Spiroplectammina carinata,* together with common abraded larger shell fragments and a few barnacle plates. Age: Probably Middle to Late Miocene.	Poor heterogeneous assemblage with *Discoaster exilis, D. brouweri, D. pentaradiatus, Reticulofenestra pseudoumbilica.* Age: Middle to Late Miocene.	Middle to Late Miocene
A2	None	No nannoplankton.	

Hiatus

The uncored interval of 25 meters (210-235 meters below sea floor) between Units 2 and 3 spans 20 to 25 million years–Early Miocene to Middle Miocene. The average sedimentation rate, therefore, was less than 1 m/my which indicates the presence of a major hiatus between Late Eocene and Early Miocene.

UNIT 3 – Clay with Siliceous Fossils, Silty Dolomitic Clay, and Chert (Cores 2A, 3, 4, 5, 6, 7)

The upper part of Unit 3 is of Middle Eocene age (Core 2A, 3 and 4) and consists of: 1) brown and greenish gray stiff slightly silty clay with a few thin sand beds; and 2) interbedded greenish gray and olive gray clays. The latter is silty and contains some diatoms and Radiolaria. Zeolites are common to abundant in a few lenses of greenish gray silty sand. The bottom contacts of the olive beds are sharp; the upper contacts gradational. Drilling rates ranged from 1.4 to 0.3 meters per minute.

The lower part of Unit 3 is of questionable Early Eocene (or Late Paleocene) age at the top, and Paleocene or latest Cretaceous age at the bottom. It consists of pale green pyrite-bearing clay with laminae of feldspathic silty sand (140 Core 5), and interbedded greenish gray and olive gray silty clay and silt (Cores 6 and 7). The latter beds resemble the green and olive clays in the upper part of the unit; but in addition, they contain abundant dolomite crystals (comprising as much as 40% of some of the silt beds), and certain of the darker olive beds have been cemented and replaced by silica to form silicified mudstone and chert. Drilling rates were uniformly low, ranging from 0.5 to 0.2 meters per minute. The average sedimentation for Unit 3 is about 15 m/my and appears to be remarkably uniform (see Figure 2).

UNIT 4 – Silty Zeolitic Clay and Arkosic Sand Beds (Core 8)

Sediments of Maestrichtian age were cored from 645 to 651 meters and consist of greenish gray, slightly silty, zeolitic clay with beds of light greenish gray sandy silt to silty sand, and occasional thin beds of fine to medium-grained pinkish gray sand with minor silt and clay. The greenish sands have gradational contacts with the clay; the pinkish sands, which are only a few millimeters thick, have sharp upper and lower contacts. The mineralogy of both sand types is similar consisting of angular to subrounded quartz; 10-20 per cent feldspar (microcline more abundant than sodic plagioclase and sanidine); minor biotite and chlorite; and a suite of heavy minerals including hornblende, zircon, rutile, apatite, tourmaline and topaz. Zeolites are common.

The core catcher of Core 7 contained a piece of hard feldspathic quartz siltstone cemented by silica. The mineralogy resembles that just described for the sands except that muscovite, pyrite, and siliceous spicules were noted among the accessory minerals. Drilling rates in Unit 4 ranged from 0.3 to 0.5 meters per minute.

PHYSICAL AND CHEMICAL PROPERTIES

Penetrometer measurements (mm $\times 10^{-1}$) decrease with depth from about 60 in the ooze of Core 1 to less than 10 in the clays of Core 3 at 320 meters. Below 320 meters, readings are consistently low (5-15).

There are no general trends for either bulk density or porosity as a function of depth (Table 3). A wide scatter of values within single cores represents either drilling disturbances (as in Core 1) or interbedded lithologic units (lower cores). Porosities calculated from water content agree very well with those measured by GRAPE. Measured water content has a small range of values, 37 to 46 per cent; again, no trend with depth is shown.

Natural gamma radiation correlates reasonably well with lithology. Values for Core 1 are uniformly low (100-600) even for nanno ooze. Core 2 (diatom mud) shows counts of 300 to 1200. The siliceous Eocene clays of Cores 2A and 3 range from 900 to 2500. The olive gray clay layers of Core 3 give higher gamma counts than the greenish gray more siliceous layers. Core 4 is also Middle Eocene silty clay, but readings are somewhat lower (range 500-1200).

Lower Eocene-Paleocene (?) interbedded cherts and dolomitic silty clays (Core 6) have rather low values ranging from 400 to 700. Core 8 contains an Upper Cretaceous sequence of alternating clays and sandy silts. Gamma values of 1000 to 1800 characterize this section; the higher values showing a fair correlation with the coarser feldspathic layers.

TABLE 3
Summary of Density, Porosity and Water Content Data for Site 140

			GRAPE			Sediment Sample			
Hole	Core	Section	Depth Below Sea Floor (m)	Density (gm/cc)	Porosity (%)	Depth Below Sea Floor (m)	Water Content (%)	Density (gm/cc)	Porosity (%)
140	1	1	89.75	1.59	63	89.14	37	1.61	59
140	1	2	91.25	1.57	64	90.64	40	1.51	61
140	1	3	92.75	1.61	62	–	–	–	–
140	1	4	94.25	1.56	65	94.50	39	1.55	61
140	1	5	95.75	1.60	62	–	–	–	–
140	1	6	97.25	1.62	61	–	–	–	–
140	2	1	201.75	1.46	58	201.14	44	1.37	61
140	2	2	203.25	1.31	72	––	––	––	–
140	2	3	204.75	1.47	57	204.14	42	1.45	62
140	2	4	206.25	1.50	54	205.57	42	1.41	59
140	2	5	207.75	1.39	64	–	–	–	–
140	2	6	209.25	1.44	59	–	–	–	–
140	3	1	311.75	1.48	58	311.14	42	1.42	59
140	3	2	313.25	1.63	44	312.80	43	1.35	58
140	3	3	314.75	1.58	48	315.33	46	1.44	66
140	3	6	–	–	–	318.64	45	1.44	65
140	4	1	368.75	1.36	66	368.14	39	1.47	57
140	4	3	371.75	1.39	64	371.91	42	1.40	59
140	6	2	512.25	1.35	20	511.51	39	1.23	48
140	8	1	645.75	1.68	52	645.60	27	1.68	46
140	8	2	647.25	1.73	48	647.85	38	1.60	60
140	8	3	648.75	1.72	49	–	–	–	–
140A	1	1	150.75	1.60	66	151.05	33	1.75	57
140A	2	1	235.75	1.69	56	235.78	31	1.72	53
140A	2	2	237.25	1.69	56	236.64	31	1.72	54
140A	2	3	238.75	1.66	58	238.14	25	1.83	46
140A	2	4	240.25	1.67	57	239.64	34	1.72	58
140A	2	5	241.75	1.62	61	241.14	33	1.61	52
140A	2	6	243.25	1.60	62	242.64	38	1.60	61

TABLE 4
Chemical Property Measurements on Samples from Site 140

			Sample Interval (cm)				
Hole	Core	Section	Top	Bottom	pH	Eh	Salinity (‰)
140	1	6	0.0	10.0	7.42	−50	36.3
140	2	6	0.0	10.0	7.50	+104	38.5
140	3	2	0.0	8.0	7.42	+133	41.8
140	4	3	148.0	150.0	7.50	+121	43.4
140	6	CC			7.49	+145	46.2
140	8	2	0.0	4.0	7.54	+143	53.4
140A	2	6	0.0	10.0	7.47	+165	40.7

Sonic velocity measurements made were as follows: 140-4-1, 10 cm, 1.65 km/sec; 140-6-2, 42 cm, 1.66 km/sec; 140-8-1, 110 cm, 1.72 km/sec.

Surface water salinity and pH values at Site 140 were 35.8 ppt and 8.40, respectively. The interstitial water pH values fall in a narrow range (7.42 to 7.40) on the slightly alkaline side which is normal for deep sea sediments. Salinity values, on the other hand, start out with a normal oceanic value of 36.3 ppt at 90 meters and increase regularly with depth to 53.4 ppt at 645 meters (Table 4).

DISCUSSION AND CONCLUSIONS

About 120 to 150 meters of calcareous ooze overlie at least 530 meters of predominantly siliceous clay sediments at Site 140. The calcareous ooze in cores taken from this site, ranges in age from Recent (piston core evidence) to Late Pliocene at 89 to 98 meters (Core 1), thus giving an average sedimentation rate of about 30 m/my. Middle Miocene sediments were recovered at 150 meters (Core 1A) so the 50-meter interval between Cores 1 and 1A represents 9 m.y. which is an average sedimentation rate of ~5 meters/m.y. This average rate is too low for either of the dominant lithologies above or below this interval and therefore a small hiatus may be present.

A major zone of reflections on the *Challenger* record occurs at 0.17 second which, if correlated with the major lithologic change from calcareous ooze above to silty clay below, would give velocities somewhere in the range 1.5 to <1.8 km/sec depending on where the boundary occurs in the interval of 120 to 150 meters. From the drilling rate evidence (Figure 3), the best guess would be to place the boundary close to 150 meters. The sonobuoy data available from this area (see Background this chapter) indicates an average seismic velocity of about 1.76 km/sec for the upper

800 meters of sediment. This reflector at 0.17 second can be traced all the way up the continental rise to Site 139 where it occurs at a depth of 0.55 second and was again tentatively correlated with a similar lithologic change.

Core 1 from Hole 140A (150-159 m) contained non-calcareous clay with sand and silt interbeds. However, 42 meters lower down in Core 2 of Hole 140, thin beds (up to 10 cm) of calcareous material of Early Miocene age (containing an estimated 30% carbonate) are present in a predominantly diatom mud or ooze. This calcareous material (mostly nannoplankton) may have been resedimented from higher up the continental rise if the area of Site 140 was still below the carbonate compensation depth in the Middle Miocene. Foraminifera from Hole 140, Core 2 and Hole 140A, Core 1 show a mixture of pelagic and shallow water species. In addition, the carbonate compensation depth at Site 140 may have deepened again in the Early Miocene so that conditions were favorable for preservation of calcite; fluctuations in water depth are considered unlikely.

From 210 to 235 meters, the sediments in Cores 2 of Hole 140 and 2 of Hole 140A show an increase in age from Early Miocene to Middle Eocene. Unless the Oligocene and Late Eocene is represented by a very condensed sequence (there is no evidence for this at any other Leg 14 sites), there is a hiatus of about 20 million years. Sites 135 and 136 also showed major hiatuses in the Paleogene.

In the Paleogene and possibly latest Cretaceous, clay and silty clay are rhythmically interbedded, and sedimentation was sufficiently slow (15 m/my) to allow moderate burrowing. In the lower part of the Paleogene, (Core 6) cyclic sedimentation is well-developed. The sediment here ranges from a dolomitic silty clay to a clayey dolomite silt. Thin (5-30 mm) chert beds are quite common. In Core 7, similar chert beds occur in dark shale. Minor pyrite occurs throughout the Paleogene sediments. The occurrence of dolomite, cristobalite, montmorillonite, and palygorskite-rich beds, often occurring in cyclic sequences, suggests sudden depositional changes which might tentatively be related to offshore volcanic activity. Subsequently, diagenesis has also been an important factor in the development of these sediments. The siliceous material in the Eocene clays is believed to be redeposited.

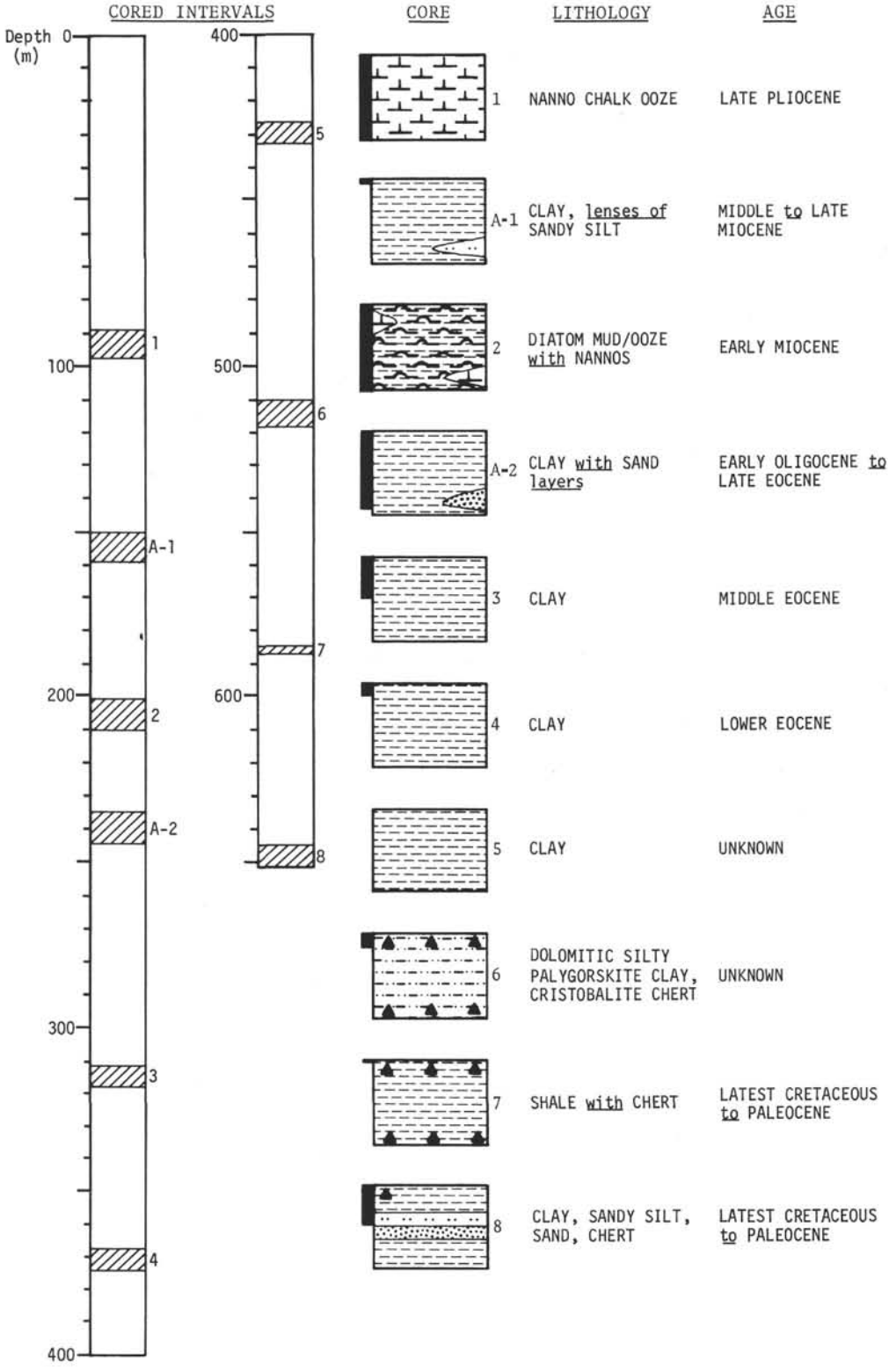
A few thin (<2 cm) sand layers occur in the Middle Eocene sediments (140A Core 2). These are very clean quartzose sands and are probably resedimented beach deposits. An unusual sandy silt layer in Core 3 of Hole 140 contained about 20 per cent zeolite grains and may be partly of volcanic origin.

In the Late Cretaceous (Core 8) clay and silty clay is interbedded with numerous well-sorted feldspathic quartz sands. The sands have a mineral suite suggesting first cycle deposition from a granitic source area (possibly Reguibate Massif—see map in folder).

REFERENCE

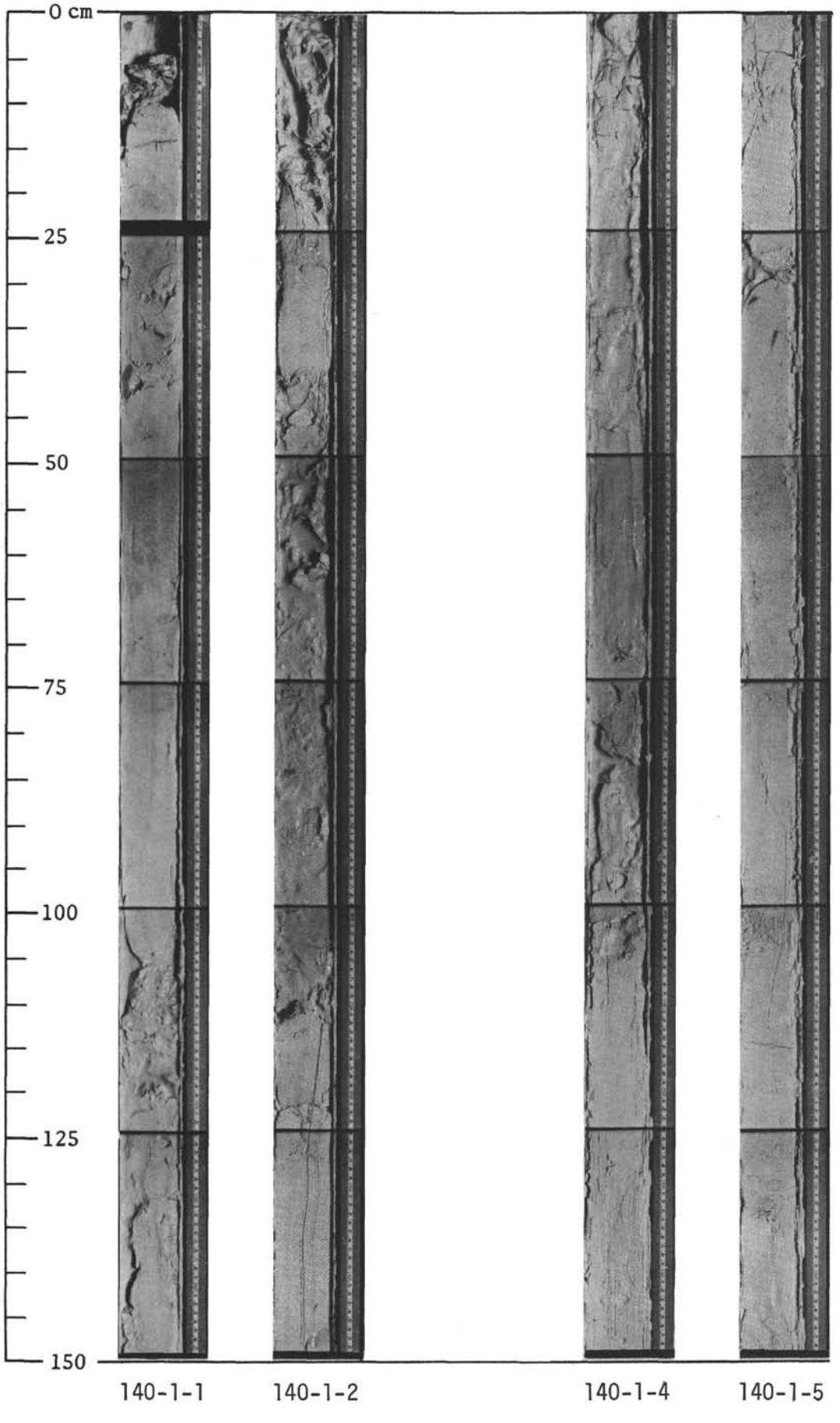
Uchupi, E., 1971. Bathymetric Atlas of the Atlantic, Caribbean, and Gulf of Mexico; Woods Hole Oceanographic Institution, Reference No. 71–72, unpublished manuscript.

SITE 140– SUMMARY



SITE 140 CORE 1 DEPTH (m) 89-98

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE	LITHOLOGIC DESCRIPTION	NATURAL GAMMA RADIATION (COUNTS/7.6 cm/1.5 min; 1000 2000)
LATE PLIOCENE	SECTONS 1-5: *Globorotalia exilis-G. miocenica* CORE CATCHER: *Globorotalia margaritae*	*Discoaster brouweri*		1	0	VOID	30	NANNO CHALK OOZE $CaCO_3$ 87 White to very light yellowish gray (5Y 8/1-2) Smear Slide Average: Nannos 50-50% Clay 20-25% Forams 10-15% Quartz, feldspar, hornblende and biotite 2-4% Crystalline calcite Tr.-5%	
					1		110	20 cm GZ 4-30-66 GZ 10-32-58 $CaCO_3$ 65 Entire core very much disturbed by coring	
				2	2				
				3	3			Section 3 not cut, watery	
				4	4		100	GZ 9-27-64 $CaCO_3$ 98	
				5	6		75	Most coccoliths and forams triturated $CaCO_3$ 92 GZ 2-30-68	
				6	8			Section 6 not cut, watery	
				CC			CC		


0 cm
25
50
75
100
125
150
140-1-1
140-1-2
140-1-4
140-1-5

SITE 140 CORE 2 DEPTH (m) 201-210

AGE	ZONE FORAM	ZONE NANNO	ZONE RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE
EARLY MIOCENE	*Catapsydrax stainforthi* or *C. dissimilis*	*Helicopontosphaera ampliaperta*	*Dorcadospyris alata?*	1	1		
			Calocycletta costata	2	2	VOID	94
				3	3		
				4	4		100
			Calocycletta veneris	5	5		150
				6	6	VOID	
			C. bromia	CC	7		
					8		

LITHOLOGIC DESCRIPTION

QUARTZOSE DIATOM MUD/OOZE — $CaCO_3$ 10
Grayish olive (10Y 4/2); homogenous and firm

Average Composition:

Clay	~40-50%
Diatoms (fragments)	25-35%
Radiolaria, sponge spicules, and dinoflagellates	5-15%
Quartz and feldspar	5-10%
Carbonate (Calcareous nannos >> forams plus fragments)	5-10%
Pyrite and organic material	5%
Chlorite, biotite	Tr.

$CaCO_3$ 8

with thin layers and lenses of

sec.1, 20 cm GZ 19-44-37

DIATOM MUD/OOZE with CALCAREOUS NANNOS
Light greenish gray (5GY 8/1)

Average Composition:

Diatoms (fragments)	25-30%
Calcareous nannos and angular calcite fragments	20-30%
Clay	~30%
Quartz, feldspar, mica and hornblende	3-5%
Radiolarian fragments, sponge spicules and dinoflagellates	2-5%

$CaCO_3$ 8

Coarse Fraction: — $CaCO_3$ 13 $CaCO_3$ 1
Quartz, diatoms, radiolarias, benthonic forams, spicules, glauconite

sec.3, 10 cm GZ 19-44-37

10 cm GZ 18-36-46

Section 5 not cut, watery

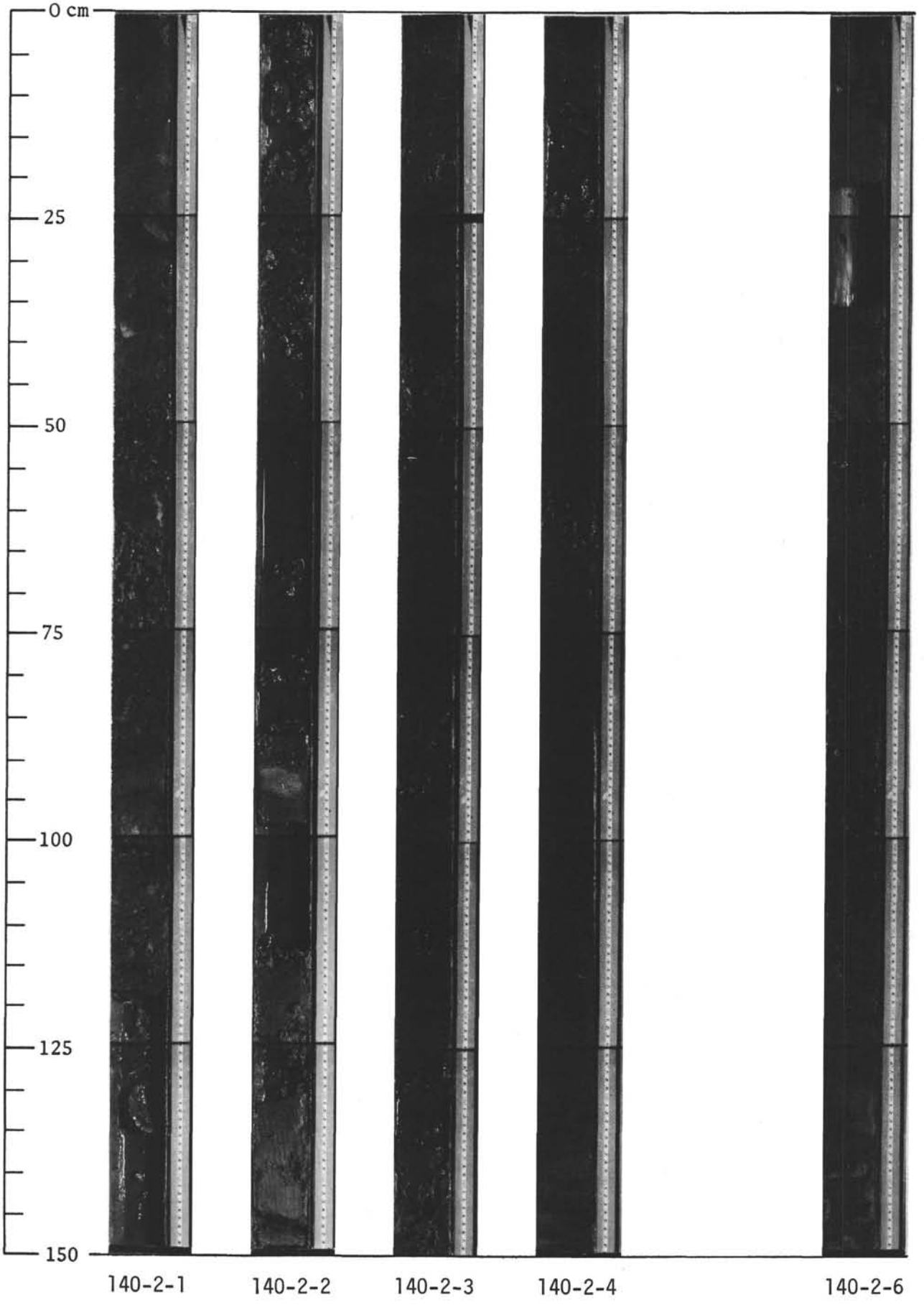
$CaCO_3$ 8

GZ 16-47-37

X-Ray (cc):

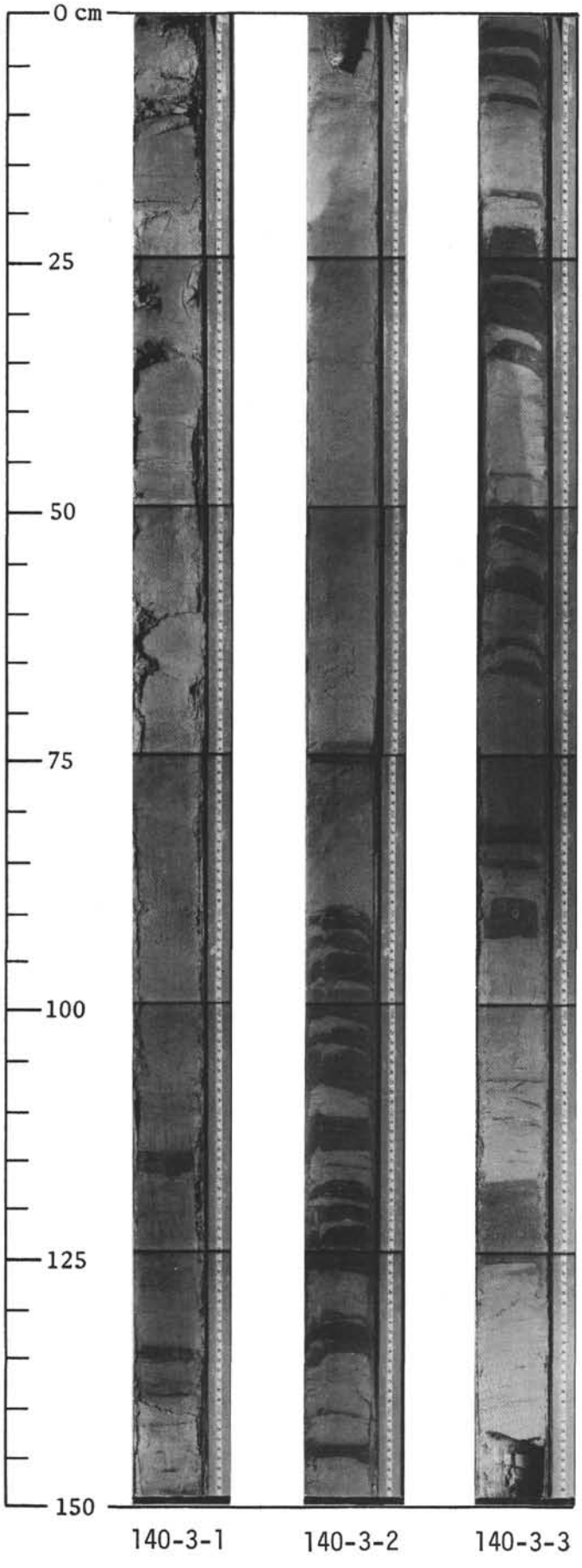
Quartz	A
Mica, montmorillonite, calcite, kaolinite	C
Chlorite, feldspar, pyrite, dolomite	Tr.

NATURAL GAMMA RADIATION
COUNTS/7.6 cm/1.5 min
1000 2000


0 cm
25
50
75
100
125
150
140-2-1
140-2-2
140-2-3
140-2-4
140-2-6

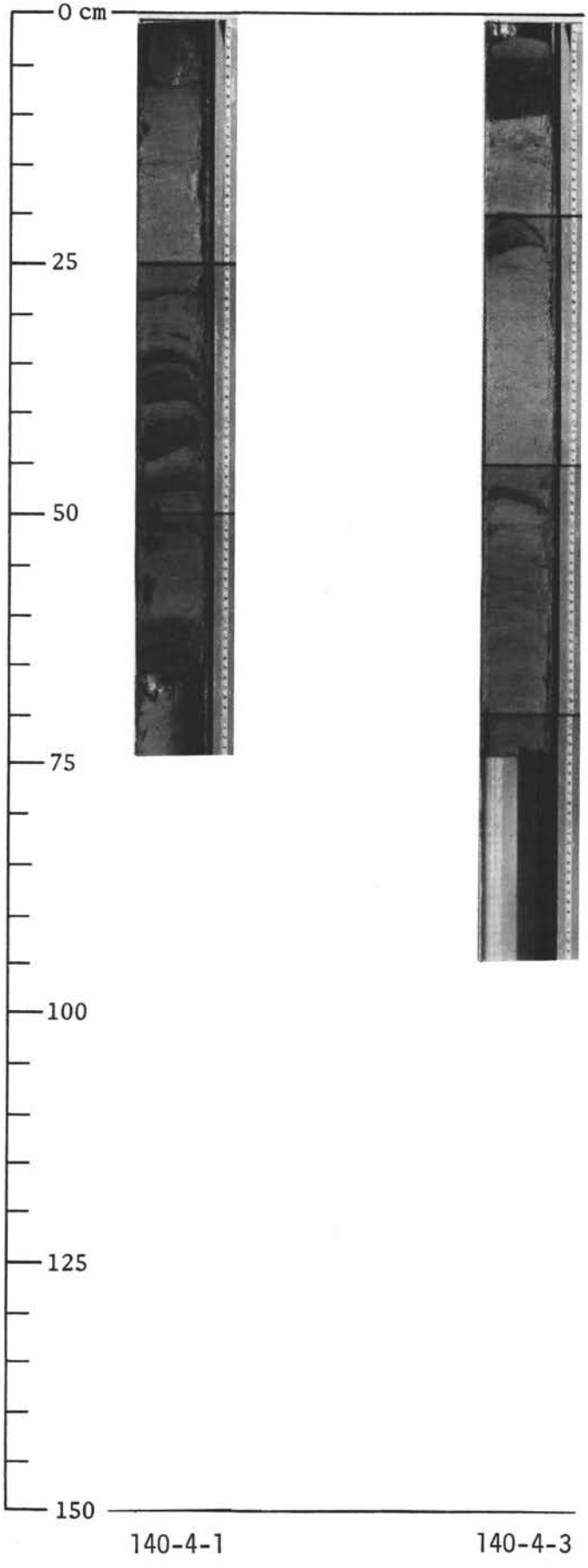
SITE 140 CORE 3 DEPTH (m) 311-318

AGE	ZONE FORAM	ZONE NANNO	ZONE RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE	LITHOLOGIC DESCRIPTION	NATURAL GAMMA RADIATION COUNTS/7.6 cm/1.5 min 1000 2000
MIDDLE EOCENE		*Lamiterium goethema*		1*	1			CLAY $CaCO_3$ 0 Two different colors and slightly different lithologies, intercalated: A) Greenish gray (5G 6/1), slightly siliceous Average Composition: Clay 80-90% Diatom fragments 5-10% Radiolaria and sponge spicules, Tr.-3% Chlorite, biotite Tr. B) Olive gray (5Y 4/1) $CaCO_3$ 0 Average Composition: Clay ~95% Fragments of radiolaria, diatoms, sponge spicules 3% Quartz 2% * See Section Summaries sec.1, 20 cm GZ 0-16-84 sec.2, 40 cm GZ 1-11-88 GZ 0-10-90 $CaCO_3$ 0	
				2*	2				
				3*	3				
				CC	4				


0 cm
25
50
75
100
125
150
140-3-1
140-3-2
140-3-3

SITE 140 CORE 4 DEPTH (m) 368-374

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE	LITHOLOGIC DESCRIPTION	NATURAL GAMMA RADIATION (COUNTS/7.6 cm/1.5 min; 1000, 2000)
MIDDLE OR EARLY EOCENE				*1	1			CLAY $CaCO_3$ 0 Two different colors, intercalated: A) Greenish gray (5G 6/1) Composition: Clay ~85% Quartz 5% Degraded mica 5% B) Olive gray (5Y 4/1) to dark greenish gray (5GY 4/1) Composition: Clay ~95% Quartz 3% Radiolarian fragments <1% Pyroxene, zeolite Tr. sec.1, 10 cm GZ 2-15-83 * See Section Summaries Coarse Fraction: Claystone and sandstone fragments, radiolarias (partially pyritized) $CaCO_3$ 0 100 cm GZ 0-11-89	
				2	2	VOID			
				*3	3				
				CC	4				

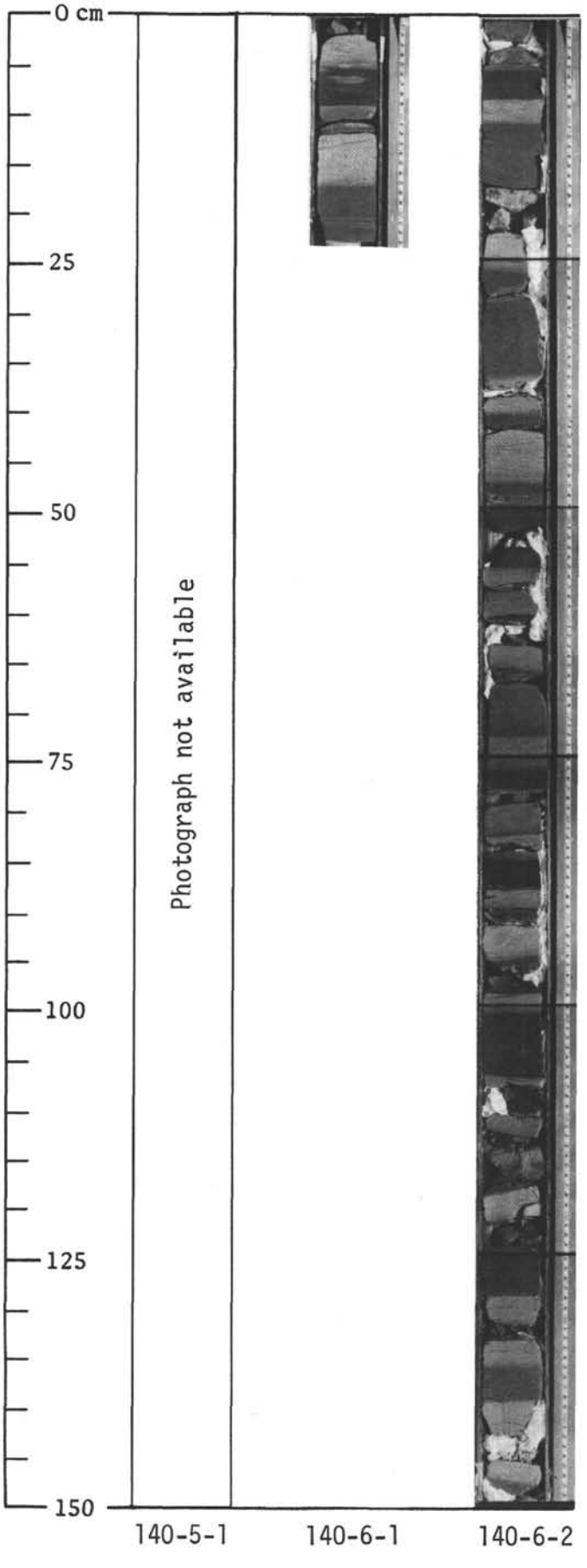

0 cm
25
50
75
100
125
150
140-4-1
140-4-3

SITE 140 CORE 5 DEPTH (m) 427-432

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE	LITHOLOGIC DESCRIPTION	NATURAL GAMMA RADIATION (COUNTS/7.6 cm/1.5 min: 1000, 2000)
UNKNOWN				1 CC		NOT TO SCALE		CLAY Pale green (10G 6/2) Composition: Clay ~97% Quartz 2% Pyrite, hematite 1% Few laminae of SANDY SILT Composition: Quartz 90% Feldspar 8% Heavies (hornblende, rutile, zircon) 2% Local Mn oxide and pyrite concentrations along laminae Core catcher recovery only X-Ray (cc) (CHERT): Disordered Cristobalite A Palygorskite C Quartz Tr.	

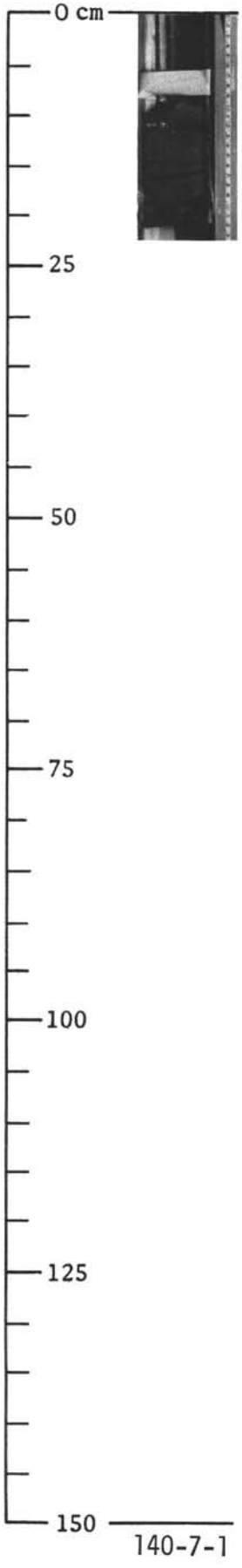
SITE 140 CORE 6 DEPTH (m) 510-519

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE	LITHOLOGIC DESCRIPTION	NATURAL GAMMA RADIATION (COUNTS/7.6 cm/1.5 min: 1000, 2000)
UNKNOWN				1* 2* CC	1 2	VOID		Alternations of: A) DOLOMITIC SILTY CLAY Dusky olive green (5GY 4/2) B) DOLOMITIC SILTY CLAY Bluish gray (5B 7/1) to greenish gray (5G 6/1) C) CHERT Dark olive gray (5Y 3/2) GZ 0-40-60 $CaCO_3$ 16 * See Section Summaries	

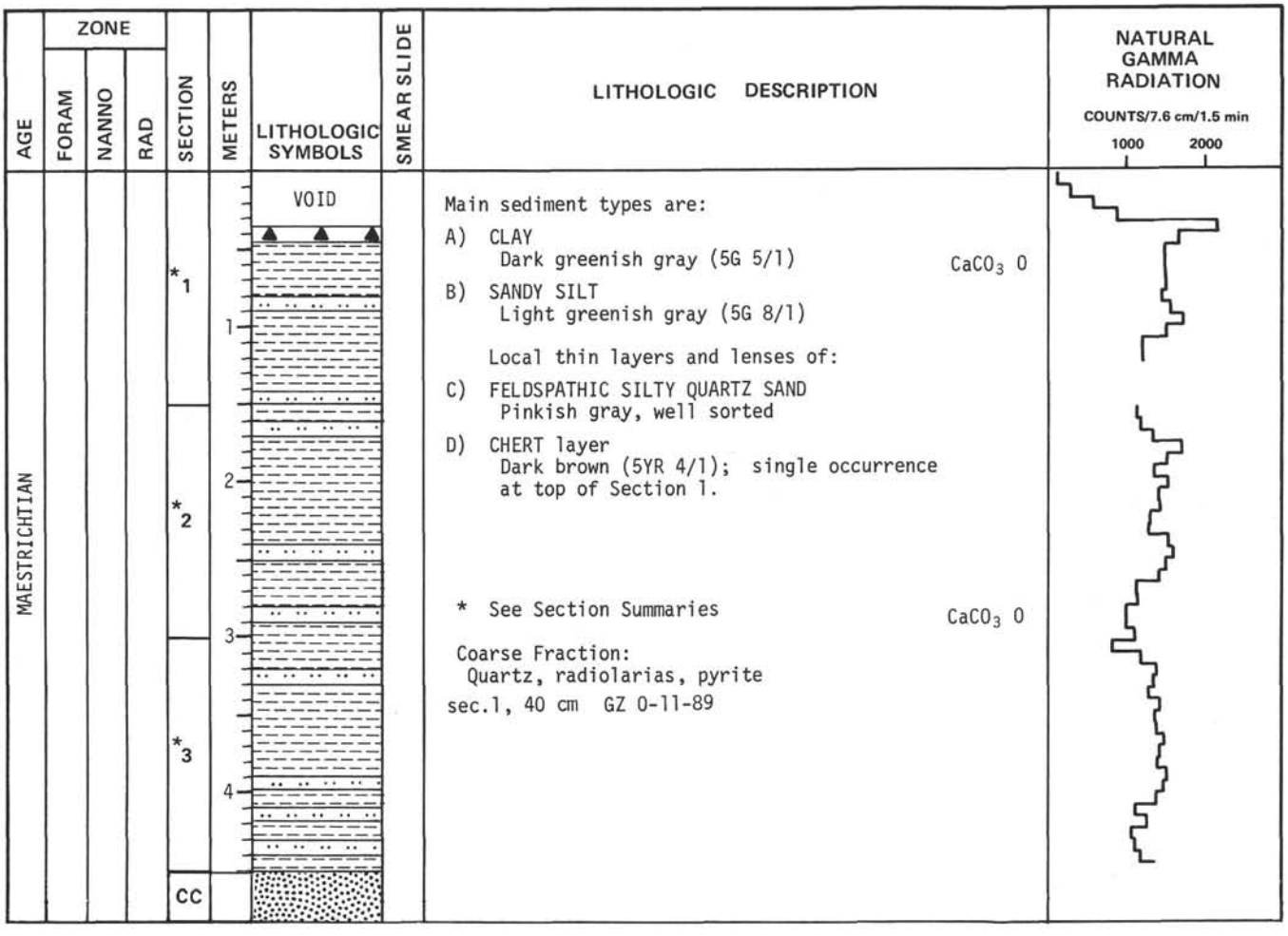

0 cm
25
50
75
100
125
150
Photograph not available
140-5-1
140-6-1
140-6-2

SITE 140 CORE 7 DEPTH (m) 585-587

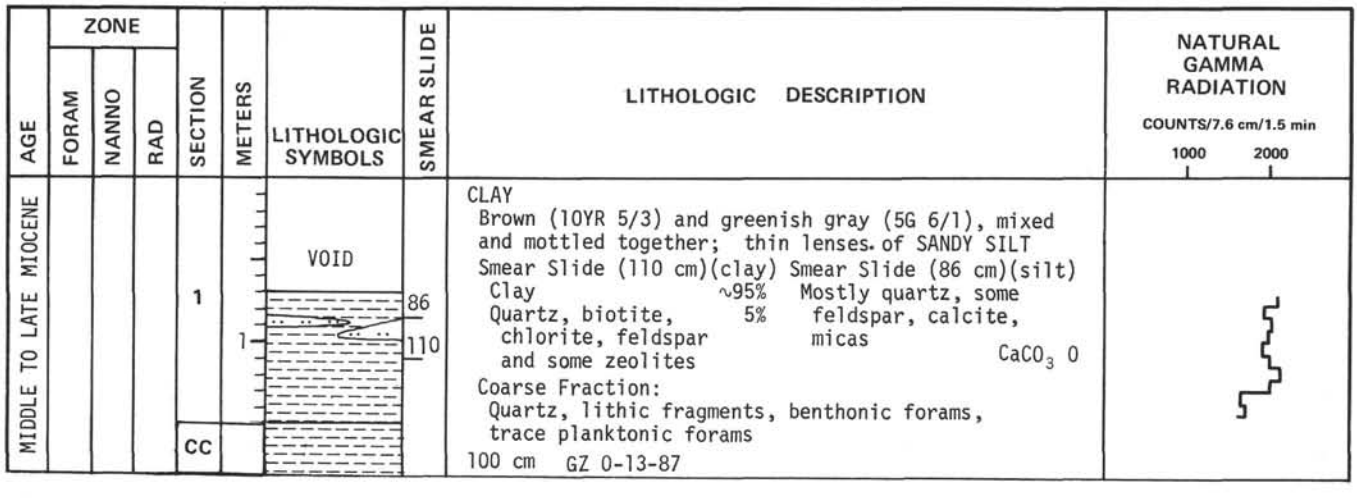
AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE	LITHOLOGIC DESCRIPTION	NATURAL GAMMA RADIATION (COUNTS/7.6 cm/1.5 min: 1000, 2000)
LATEST CRETACEOUS TO (?) PALEOCENE				1 CC				SHALE Greenish black (5GY 2/1) with CHERT Slightly lighter color Smear Slide (cc): Clay (plus altered feldspar?)* 85-90% Quartz 5% Opaque (pyrite?) 3% Feldspar ǂ 2% Chalcedony ǂ Chlorite, biotite, authigenic Tr. carbonate (dolomite or siderite), pyritized radiolarian fragments, hornblende * At least some of the 'clay' may be grains of feldspar altered (partially to fully) to clay in situ, rather than as aggregates of clay minerals deposited as pelagic sediment. ǂ Chalcedony fragments up to 250μ, associated with the lithification to CHERT. X-Ray (cc): Cristobalite, montmorillonite A Quartz C Feldspar, mica, palygorskite, (?) siderite Tr.	

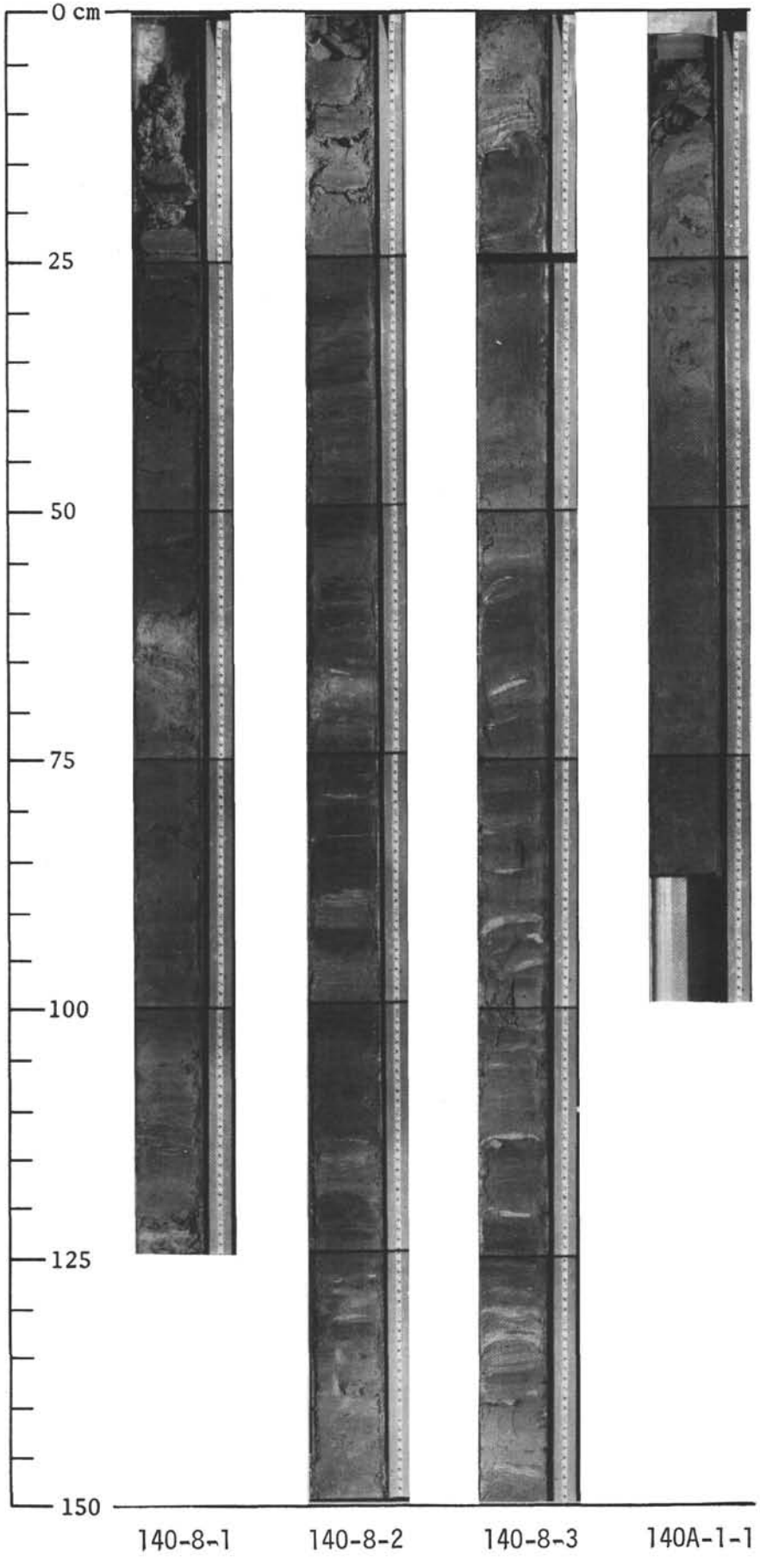

0 cm
25
50
75
100
125
150
140-7-1

SITE 140 CORE 8 DEPTH (m) 645-651

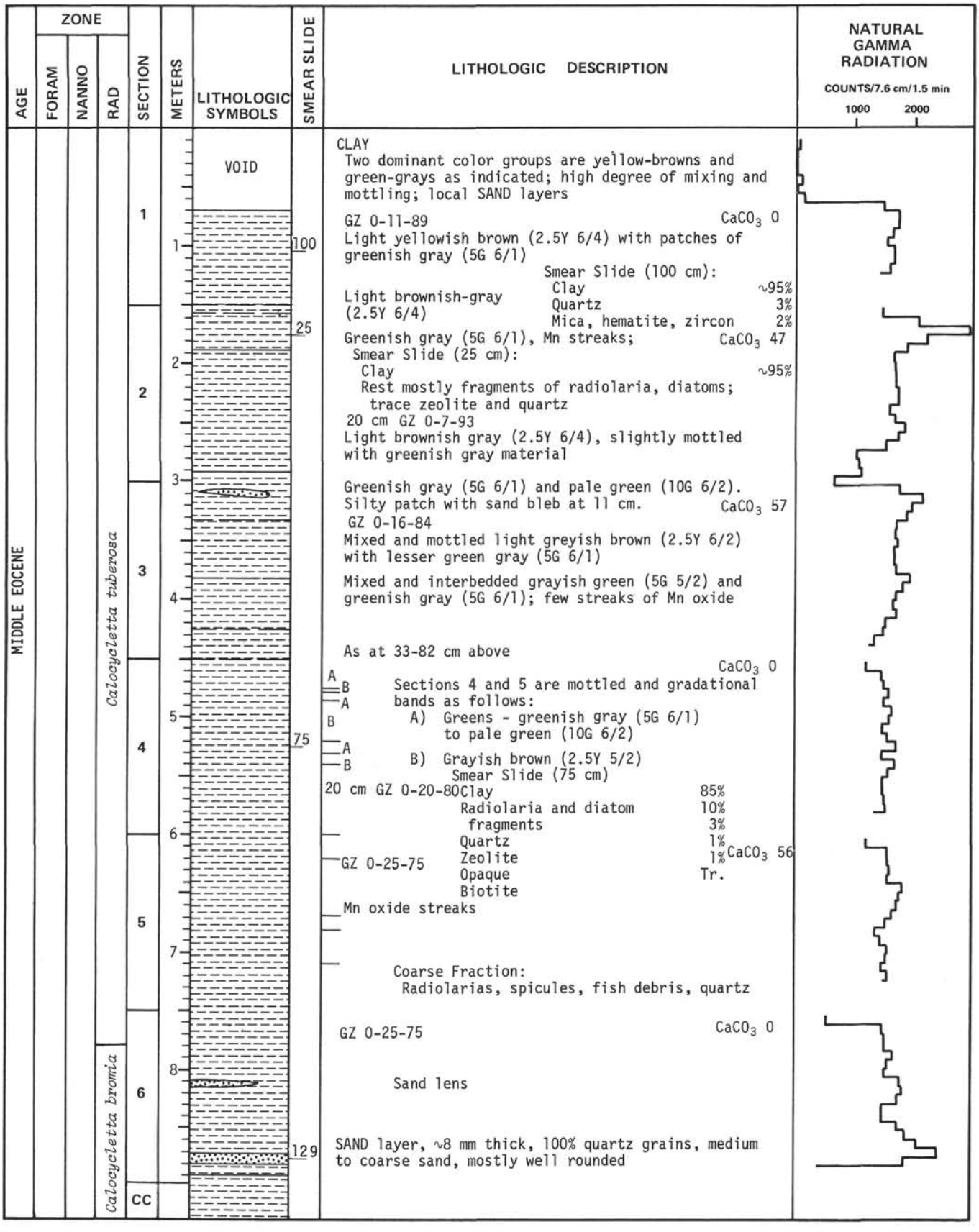


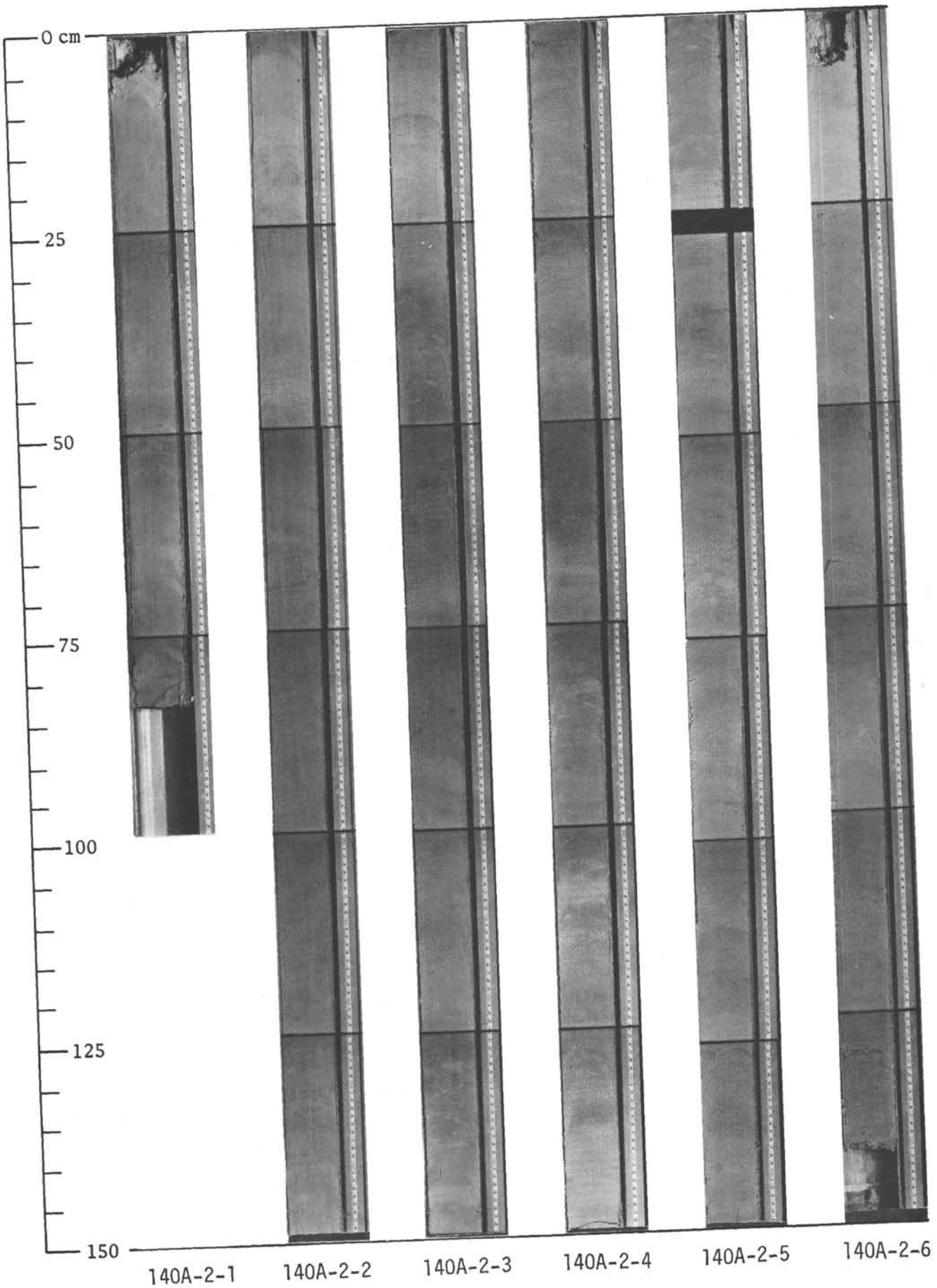
SITE 140A CORE 1 DEPTH (m) 150-159



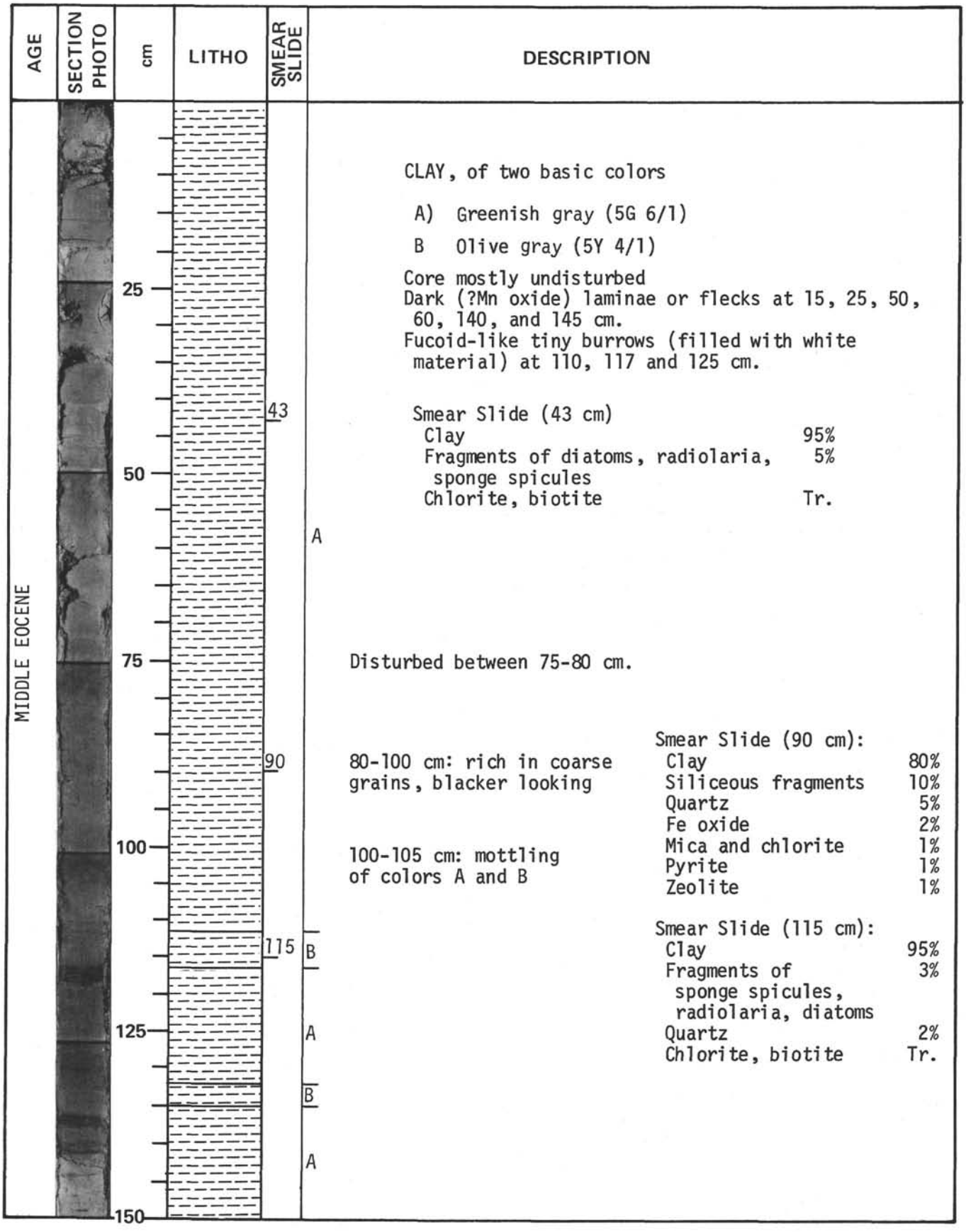

0 cm
25
50
75
100
125
150
140-8-1
140-8-2
140-8-3
140A-1-1

SITE 140A CORE 2 DEPTH (m) 235-244

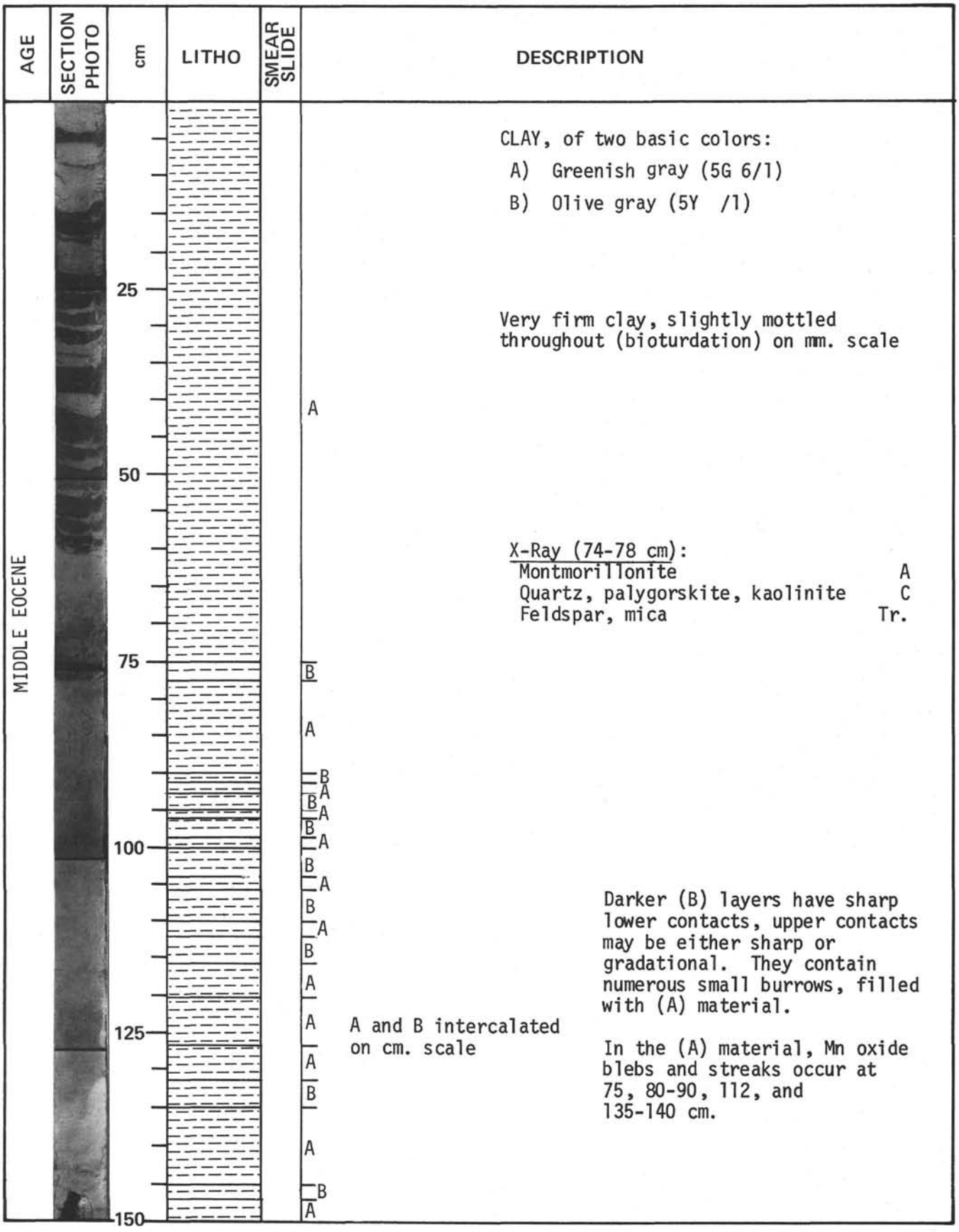



0 cm
25
50
75
100
125
150
140A-2-1
140A-2-2
140A-2-3
140A-2-4
140A-2-5
140A-2-6

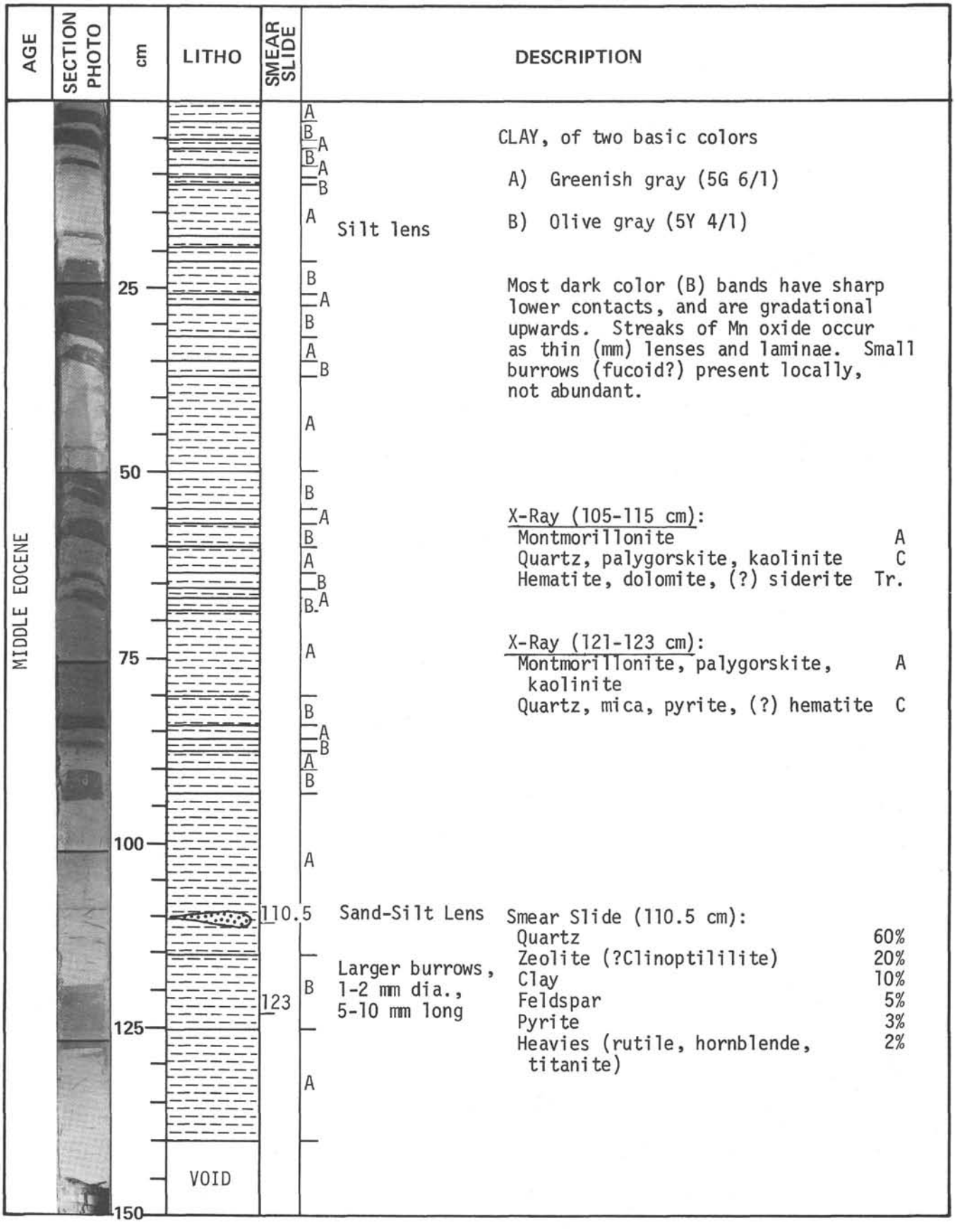
SITE 140 CORE 3 SECTION 1



SITE 140 CORE 3 SECTION 2



SITE 140 CORE 3 SECTION 3



SITE 140 CORE 4 SECTION 1

AGE: MIDDLE OR EARLY EOCENE

cm: 25, 50, 75, 100, 125, 150

LITHO: VOID

SMEAR SLIDE: 25, 65

DESCRIPTION

CLAY, of two different colors, intercalated:

A) Greenish gray (5G 6/1)

B) Olive gray (5Y 4/1)

Lower boundaries of dark layers are generally sharper than upper ones.

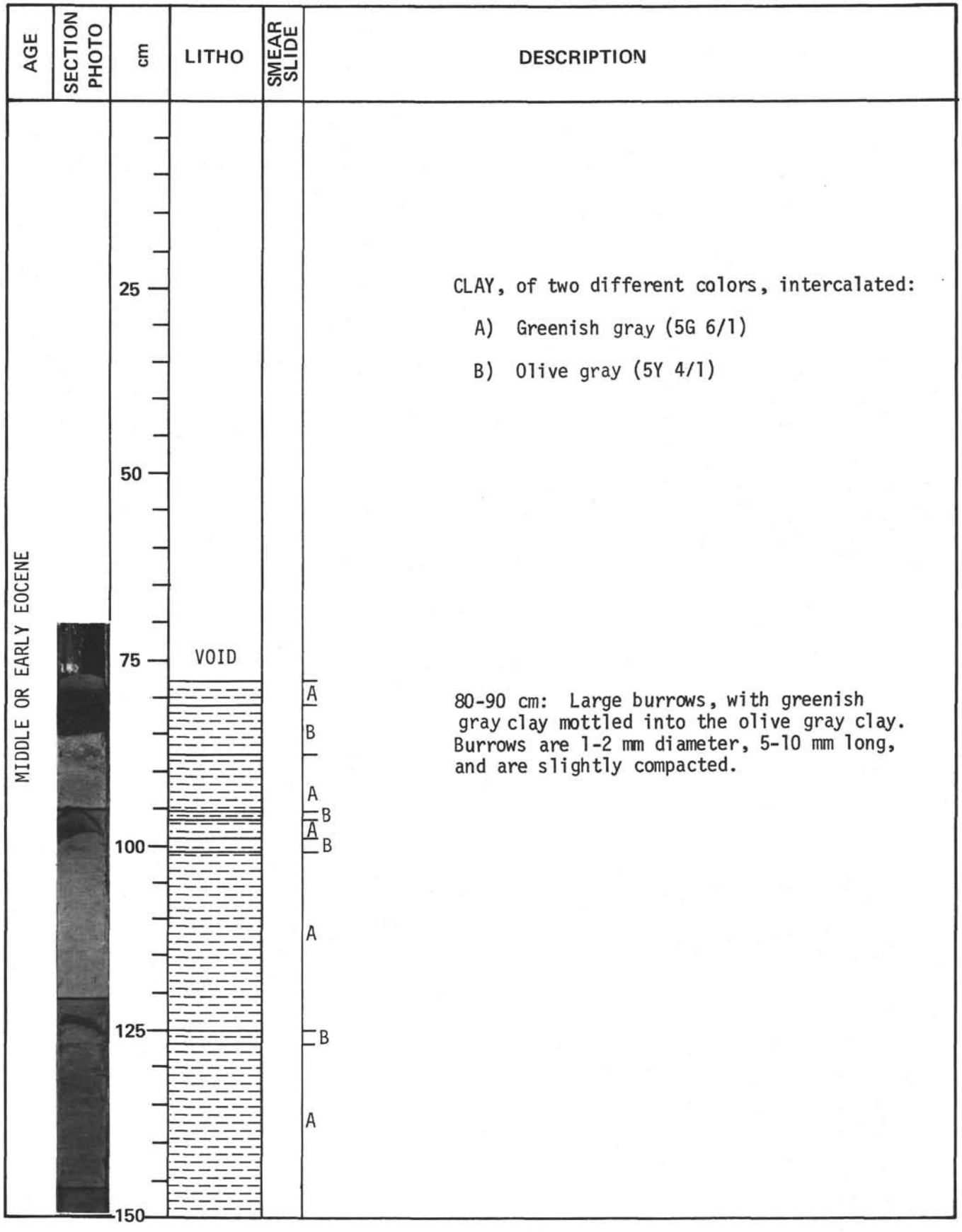
Smear Slide (25 cm):

Clay	≈85%
Quartz	5%
Degraded mica	5%
Chlorite	3%
Pyrite, radiolarian fragments	Tr.

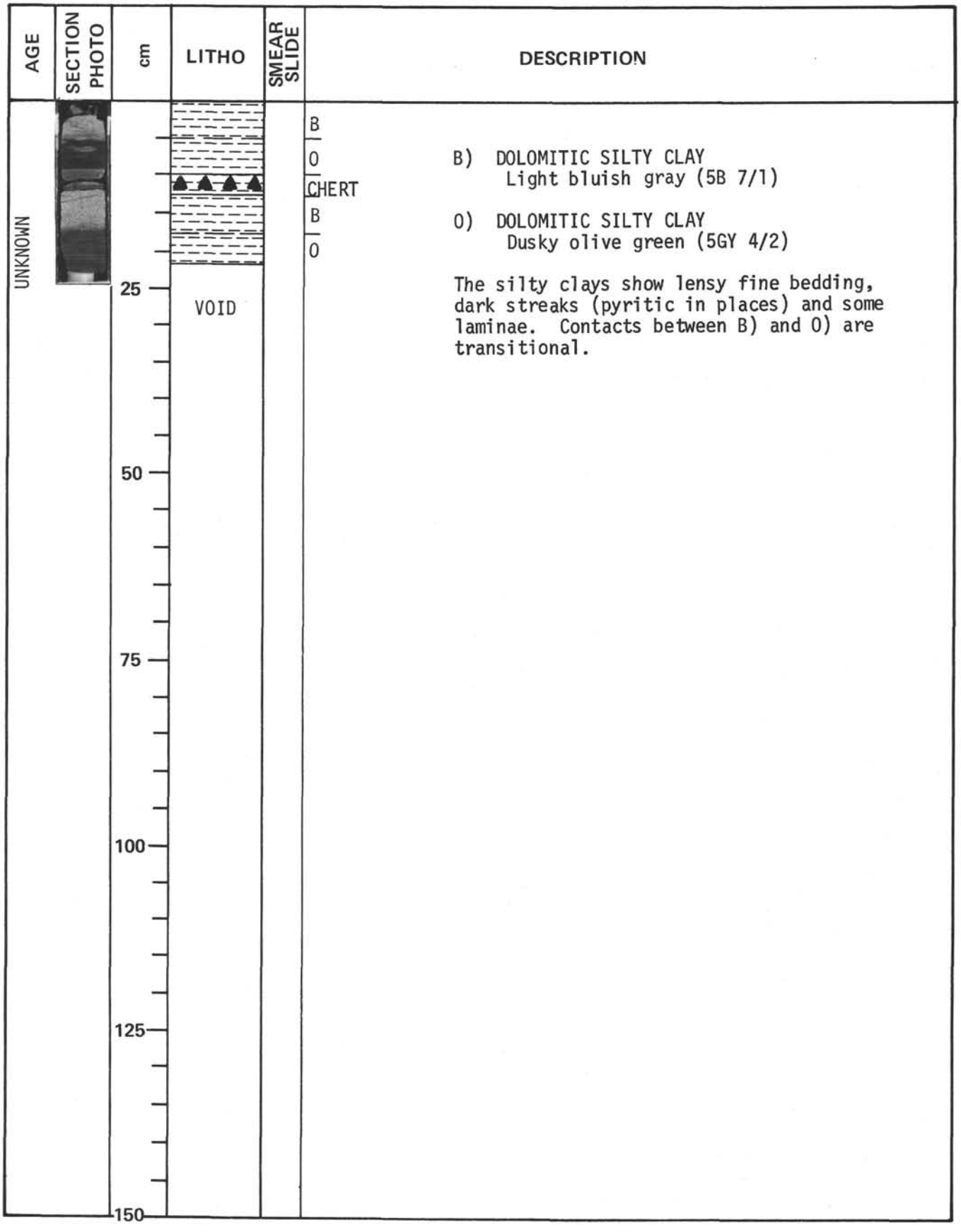
Smear Slide (65 cm):

Clay	≈95%
Quartz	3%
Radiolarian fragments	<1%
Pyrite, zeolite	Tr.

SITE 140 CORE 4 SECTION 3



SITE 140 CORE 6 SECTION 1



SITE 140 CORE 6 SECTION 2

AGE: UNKNOWN

cm: 25, 50, 75, 100, 125, 150

SMEAR SLIDE: 42, 54, 86, 103

B) DOLOMITIC SILTY CLAY
Light bluish gray (5B 7/1)

O) DOLOMITIC SILTY CLAY
Dusky olive green (5GY 4/2)

And mixture of the above two colors where indicated. Dark layers usually have a sharp lower boundary and more transitional (~1 cm) upper boundary. Fissility suggests hidden lamination. Fine streaky to lensy bedding in places.

Smear Slide (42 cm):

Dolomite rhombs*	35%
Clay	65%
Quartz, chlorite	Tr.

*Many have smaller rhombs as nuclei

Smear Slide (54 cm, sand lens):

Quartz	45%
Dolomite rhombs‡	40%
Pyrite	10%
Biotite	5%
Fe oxide, heavies, clay, feldspar, chlorite	Tr.

‡Many with opaque nuclei

X-Ray (84.5 cm):

Cristobalite, palygorskite	A
Quartz, dolomite	C
Feldspar	Tr.

Smear (86 cm):

Clay	~70%
Dolomite rhombs	20%
Quartz	5%
Pyrite (including pyritized radiolarian fragments)	5%

Smear (103 cm):

Clay	~70%
Dolomite rhombs	20%
Quartz	5%
Pyrite (including pyritized radiolarian fragments)	5%

Many dolomite rhombs have dark nuclei

Clay aggregates show some optical continuity

SITE 140 CORE 8 SECTION 1

AGE: MAESTRICHTIAN

cm: 25, 50, 75, 100, 125, 150

LITHO: VOID

SMEAR SLIDE: 57, 93

33-48 cm: CLAY; greenish gray (5G 6/1); fragmented by coring. CHERT layer, dark brown (5YR 4/1) at 43-44 cm.

48-85 cm: CLAY; greenish gray (5G 4/1); very firm, with faint laminations and streaks of slightly lighter color, possibly shallow burrows.

Smear Slide (57 cm):

Clay	~85%
Quartz	10%
Zeolites	4%
Feldspar	1%

85-96 cm: SILTY SAND and SILT; light greenish gray (5G 8/1) to greenish gray (5G 6/1); subarkosic; softer than the clays above and below

Smear Slide (93 cm):

Quartz	70%
Feldspar (microcline > plagioclase)	20%
Clay	~5%
Heavies (hornblende, zircon, rutile, tourmaline, topaz, pyrite)	2%

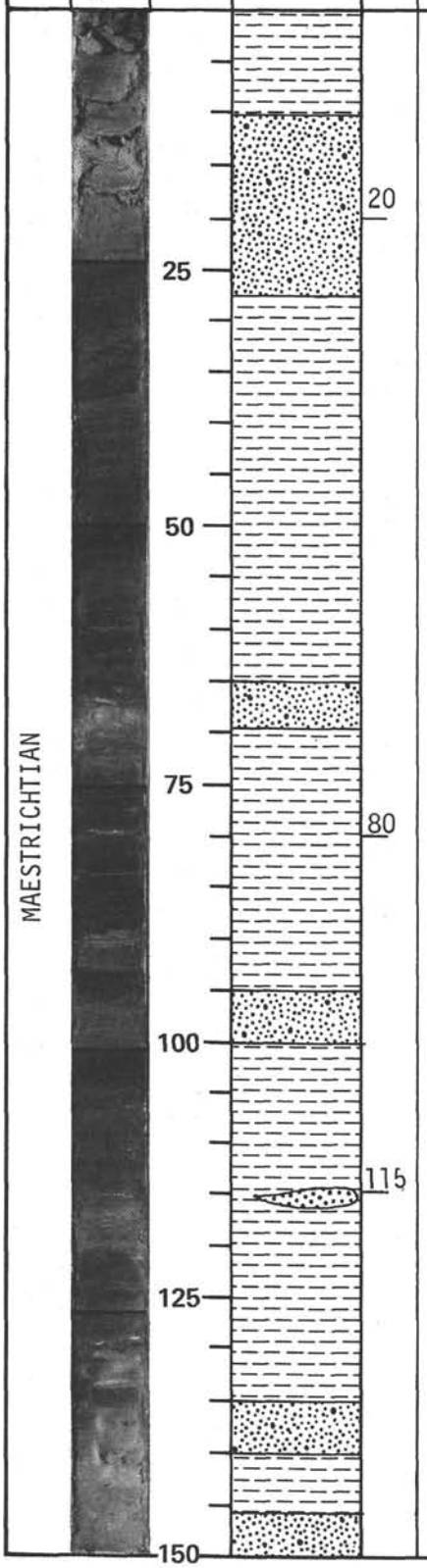
96-147 cm: CLAY; dark greenish gray (5G 4/1) and greenish gray (5G 6/1), interbedded and mixed by burrowing. Also a few white sandy blebs (burrowing?). Gray streak with pyrite at 127 cm.

147-150 cm: SILT; greenish gray, plus a thin (5 mm) bed of SAND; pinkish gray (7.5YR 6/2)

Smear Slide (148 cm):

Quartz	60%
Feldspar (K feldspar > plagioclase; sanidine present	20%
Zeolite	10%
Chlorite plus heavies	2%

SITE 140 CORE 8 SECTION 2



ALTERNATION OF

A) CLAY
Dark greenish gray (5G 5/1) and greenish gray (5G 6/1), colors alternate as thin (millimeters) 'lensy' laminae; very firm

Smear Slide (80 cm):

Clay (as aggregates or degraded minerals)	~90-95%
Zeolites	3%
Quartz	2%
Pyrite	2%
Mica	Tr.

B) SILTY SAND or SANDY SILT
Greenish gray (5G 6/1); subarkosic

Smear Slide (20 cm):

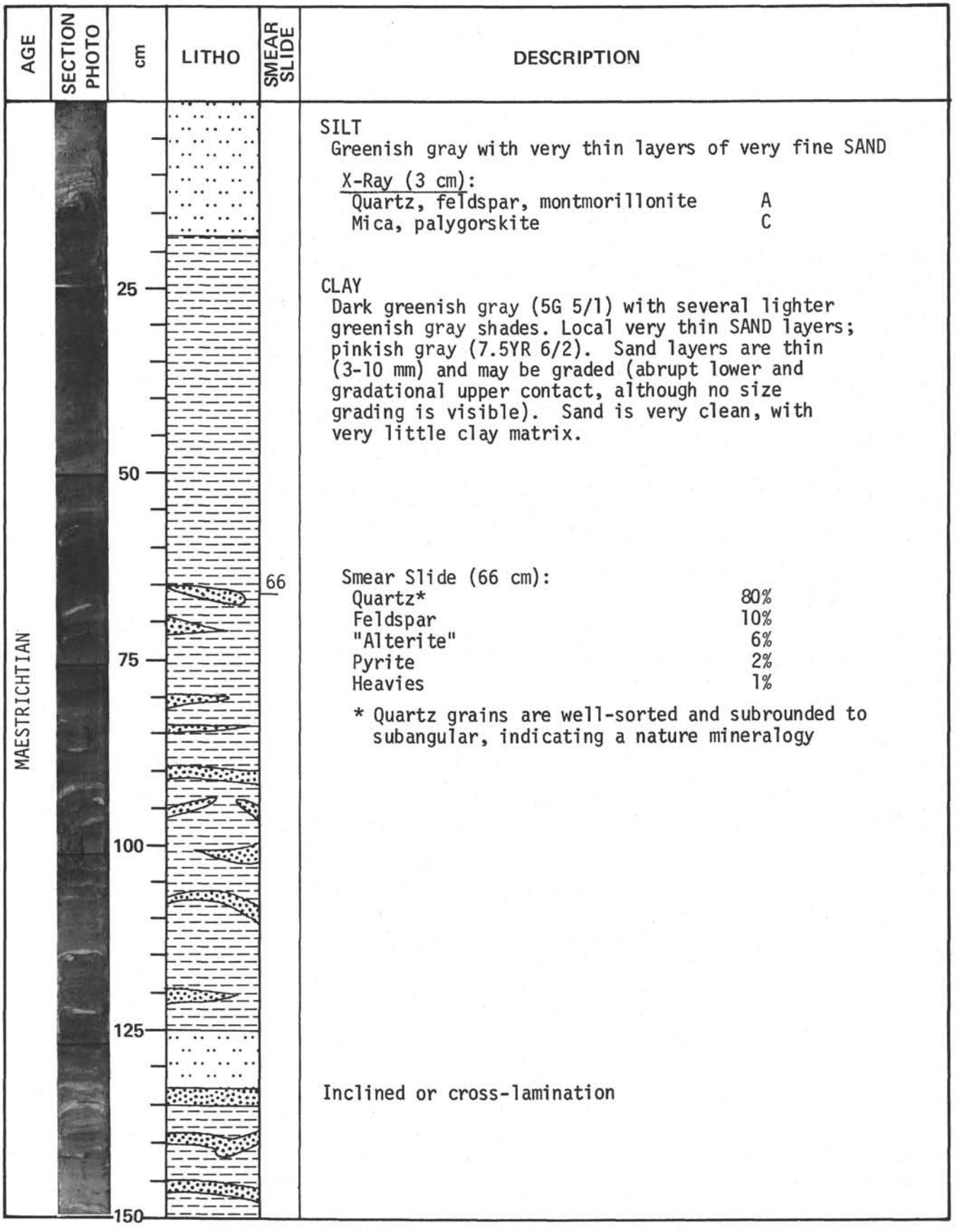
Quartz	60%
Feldspar	20%
Clay	15%
Pyrite	5%
Chlorite, mica, hornblende, zircon	Tr.

Well-developed laminae, ~1 mm. apart

Feldspathic quartz sand lens
Pinkish grey (7.5YR 6/2)
Smear Slide (115 cm):

Quartz	80%
Feldsapr	15%
Glass	3%
Zeolite	1%
Pyrite	1%
Chlorite, mica, hornblende, zircon	Tr.

SITE 140 CORE 8 SECTION 3



SILT
Greenish gray with very thin layers of very fine SAND

X-Ray (3 cm):

Quartz, feldspar, montmorillonite	A
Mica, palygorskite	C

CLAY
Dark greenish gray (5G 5/1) with several lighter greenish gray shades. Local very thin SAND layers; pinkish gray (7.5YR 6/2). Sand layers are thin (3-10 mm) and may be graded (abrupt lower and gradational upper contact, although no size grading is visible). Sand is very clean, with very little clay matrix.

Smear Slide (66 cm):

Quartz*	80%
Feldspar	10%
"Alterite"	6%
Pyrite	2%
Heavies	1%

* Quartz grains are well-sorted and subrounded to subangular, indicating a nature mineralogy

Inclined or cross-lamination