4: SITE 9

The Shipboard Scientific Party[1]

SITE REPORT

Objectives

The Atlantic Advisory Panel proposed that Site 9 should be drilled on the northeastern flank of the Bermuda Rise (lat. 32° 37′ N., long. 59° 10′ W.), which is about 100 miles west of the Sohm Abyssal Plain. The bottom of this region consists of low linear ridges that are roughly parallel and oriented in a northwest-southeasterly direction. Scattered seamounts, some of which have peaks 2000 fathoms (3660 meters) below sea level, arise from the otherwise featureless sea floor between the ridges. The rise is dissected by deep valleys with steep flanks. Towards the east, these valleys are partially filled with turbidites of the Sohm Abyssal Plains.

The primary purpose in drilling Site 9 was to examine a sedimentary column where seismic reflectors were largely absent and to determine the age of sediments overlying acoustical basement in the examination of sea floor spreading. The basement trace is fairly rough (Figure 1), and Horizons A, β, and B have not been detected in the overlying 2600-2800 feet (4760-5120 meters), (0.90 seconds reflection time) of sediment. The upper several hundred feet (0.1-0.2 seconds reflection time) of sediment are acoustically laminated and, on the basis of piston cores, they were expected to represent a calcareous pelagic facies. The underlying sediment is acoustically transparent, except for a single weak reflector at a depth of 2200-2400 feet (4025-4390 meters), (0.75 seconds reflection time) below the sea floor.

Therefore, the following drilling prospectus was drawn up:

1) Attempt continuous coring of the upper acoustically-laminated sediments and the contact with the underlying acoustically-transparent sediment;

2) Attempt discontinuous coring at widely-spaced intervals in the acoustically-transparent sediment above the weak reflector.

3) Attempt to core the weak reflector.

4) Attempt continuous coring of the sediment between the weak reflector and the basement; and,

5) Attempt to core the basement rock.

The available well-logging procedure was to be followed.

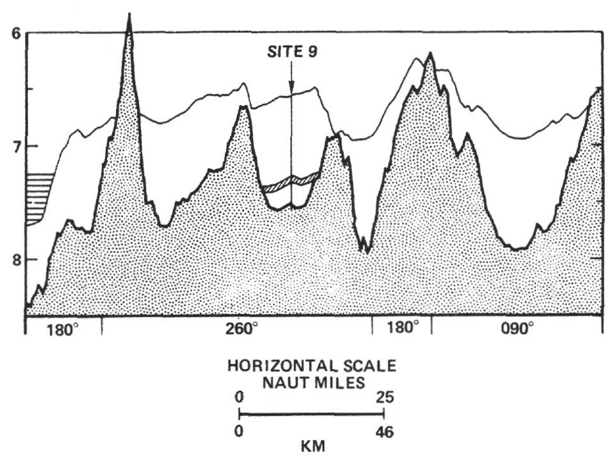

Figure 1. *Line drawing of profiler record across Site 9 made by* Vema *of Lamont-Doherty Geological Observatory showing typical acoustical subbottom features in the region of Site 9.*

Drilling and Coring Log

At 0800 hours, October 21, final positioning for Hole 9 (Figure 2) was achieved at latitude 32° 46.4′ N and longitude 59° 11.7′ W in a water depth of 16,285 feet (4965 meters) (corrected). Figure 3 is a tracing of the seismic record made while on station. Continuous coring procedures were initiated when the tungsten carbide bit reached the sea floor. The reader is referred to Tables 1 and 2 for a summary of coring operations.

The first core barrel was retrieved at 0505, October 22, and was found to be empty except for traces of sediment in the catcher and liner. Apparently, the core had been cut but the soft sediment was not retained by the catcher. Cores 2, 3 and 4 had similar results, and the cause was attributed to the same condition. Quaternary microfossils were present in smear slides that were made from the traces of sediment in Cores 1, 2 and 4.

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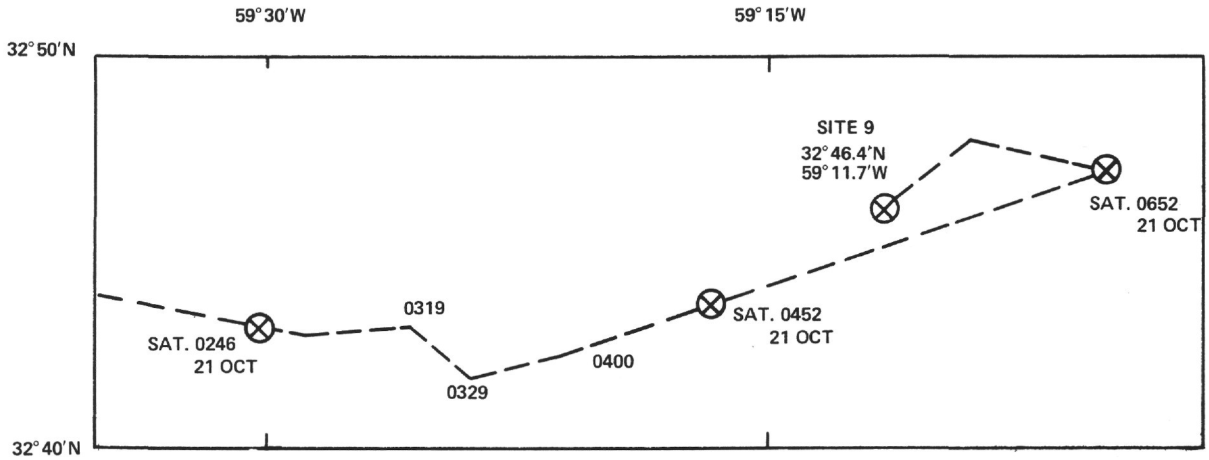


Figure 2. *Chart showing* Glomar Challenger's *approach to Site 9.*

Core 5 was cut from 103 feet (31.4 meters) to 228 feet (69.5 meters), a distance of 125 feet (38.1 meters) in an effort to increase recovery by sediment compaction in the core. This attempt yielded 25 feet (7.6 meters) of highly disturbed sediment. For Core 6, a 30 foot (9.1 meter) core was cut but was lost through the catcher. Because of these adverse conditions, the decision was made to stop continuous coring, and the center bit was replaced. Drilling progressed to 630 feet (192 meters), where the sediments appeared to be more consolidated. Cores 7 through 12 yielded a low recovery of Miocene - Pliocene clay separated by intervals of water trapped in the liner. At 1613 feet (491.6 meters), the power sub failed, and the drill string became stuck in the hole because of the inability to rotate the pipe. After freeing the pipe, the hole was abandoned. Drilling had reached a depth of 2052 feet (625 meters) beneath the ocean floor.

Hole 9A was drilled at the same location and the same beacon, drill string and bit were used, after pulling the drill string to the sea floor.

The intention at Hole 9A was to drill below the total depth of Hole 9 in order to sample older sediment and possibly the basement. For this reason, the first core was not taken until a depth of 2226 feet (678.6 meters) had been reached. The sediment recovered is a hard clay with Eocene cherts and radiolarian ooze. Deformation of the plastic liner caused extreme difficulty in extruding the core. Overheating of the bit appears to have produced this deformation. Several hundred feet of section was drilled before Core 2 was cut, which yielded only one foot of hard clay containing sparse coccoliths, foraminifera and Radiolaria of Upper Cretaceous age. The transparent liner was discolored to a cloudy white and badly deformed in the lower two feet, suggesting that the bit had become overheated. A 30 foot (9.1 meter) core of sediment directly below Core 2 was cut. Core 3, cut immediately below Core 2, contained 7 feet (2.1 meters) of clay. The power sub failed again, the center bit was replaced and drilling progressed by means of the rotary table and kelly. The sea was fairly high (four to six on the Beaufort scale) and the kelly rubbed against the horn, rounding off the corners to a minor degree exponential. As weather conditions deteriorated, the kelly bearing lifted from side to side as the ship rolled. At one time, the kelly bearing jumped out of the table and as a result the mounting pins were bent.

Because deformation of the liner restricted core recovery, the remaining cores at this site were taken without liners and were extruded using a hydraulic pump. The

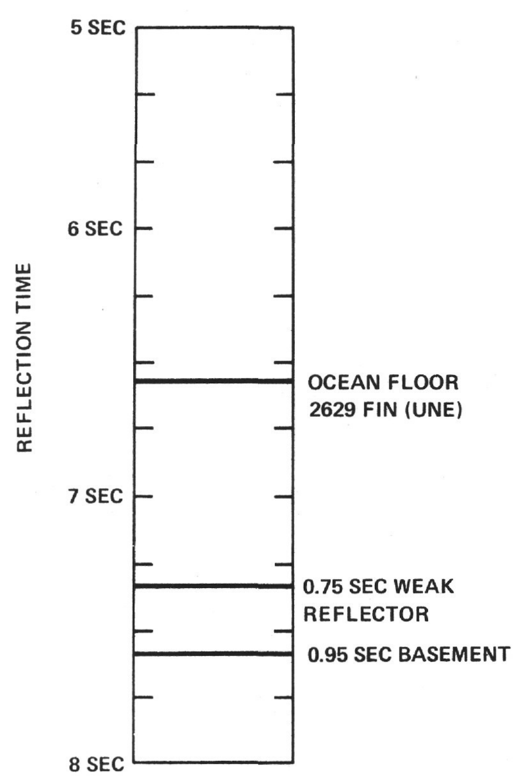


Figure 3. *Line drawing of profiler record made on station by* Glomar Challenger *at Site 9.*

sediments lying close to the basement are very well indurated, which may account for the relatively poor recovery in Cores 4 and 5. Basement rock was encountered beneath red indurated clays at 2740 feet (835.5 meters) and about 200 grams of igneous rock were recovered from the lower portion of Core 6, which was only about 1-foot long. Because of the high risk of damaging or of losing the drill string when in the bottom to the full depth of 2740 feet, or of the hole beginning to collapse, the drill string was raised to a penetration of only 2500 feet before attempting to either recover Core 6 or log the hole.

TABLE 1
Drilling Summary

Hole 9
(lat. 32° 46.4'N., long. 59° 11.7'W.; depth 4981 meters)

Hour/Date Recov.	Core No.	Depth Below Sea Floor		Depth Below Sea Surface		Core Cut		Core Recov.		% Core Recov.	No. Core Sec.
		m	ft	m	4	m	ft	m	ft		
0505		0.0	0	4974	16,316						
22 Oct	1	1.2	4	4982	16,341	7.62	25		0	0	0[a]
0720		1.2	4	4982	16,341						
22 Oct	2	10.4	34	4991	16,371	9.14	30		0	0	0[a]
0858		10.4	34	4991	16,371						
22 Oct	3	19.5	64	5000	16,401	9.14	30		0	0	0[b]
1040		19.5	64	5000	16,401						
22 Oct	4	28.6	94	5009	16,431	9.14	30		0	0	0[c]
1405		31.4	103	5012	16,440						
22 Oct	5	40.5	133	5021	16,470	9.14	30	7.62	25	83	5[d]
1610		69.5	228	5050	16,565						
22 Oct	6	78.6	258	5059	16,595	9.14	30		0	0	0[e]
0045		194.5	638	5175	16,975						
23 Oct	7	203.6	668	5184	17,005	9.14	30	5.79	19	63	4
0310		203.6	668	5184	17,005						
23 Oct	8	212.6	698	5193	17,035	9.14	30	6.10	20	66	6[f]
1330		310.5	989	5282	17,326						
23 Oct	9	310.6	1019	5291	17,356	9.14	30	6.10	20	66	6[g]
1600		310.6	1019	5291	17,356						
23 Oct	10	319.7	1049	5300	17,386	9.14	30	9.14	30	100	6
0030		473.4	1553	5454	17,890						
24 Oct	11	482.5	1583	5463	17,920	9.14	30	0.30	1	3	1[h]
0315		482.5	1583	5463	17,920						
24 Oct	12	491.6	1613	5472	17,900	9.14	30	1.22	4	13	2[i]
						108.16	355	36.27	119	33.5	

Note: Hole 9 was terminated when power sub failed and pipe stuck in hole.

TD = 18,389 feet

TABLE 1–*Continued*

Hole 9A
(lat. 32° 46.4′N., long. 59° 11.7′W.; depth 4981 meters)

Hour/Date Recov.	Core No.	Depth Below Sea Floor m	ft	Depth Below Sea Surface m	ft	Core Cut m	ft	Core Recov. m	ft	% Core Recov.	No. Core Sec.
0040		678.6	2226	5659	18,563						
19 Oct	1	683.2	2241	5664	18,578	4.57	15	2.74	9	60	6[j]
1730		758.2	2487	5739	18,824						
29 Oct	2	764.9	2509	5745	18,846	6.71	22	0.30	1	5	2
2250		764.9	2509	5745	18,846						
29 Oct	3	773.8	2539	5754	18,876	9.14	30	5.18	17	56	4[k]
1100		822.8	2699	5803	19,036						
30 Oct	4	825.9	2707	5806	19,044	2.44	8	0.91	3	30	1[k]
0145		825.9	2707	5806	19,044						
30 Oct	5	834.2	2737	5815	19,074	9.14	30	1.83	6	20	2[k]
0535		834.2	2737	5815	19,074						
30 Oct	6	834.5	2738	5815	19,075	0.30	1	0.30	1	100	0[k]
						32.30	106	11.28	37	34.9	

Note: TD = 19,075 ft

[a]Cores 1 and 2– Smear slides made of mud stuck to liner.
[b]Core 3 – Returned to bottom immediately – no smear taken.
[c]Core 4 – Smear taken.
[d]Core 5 – Very loosely consolidated soft gray, some thin brown beds can be seen through liner (inch) core actually cut from 16,440 - 16,565 feet.
[e]Core 6 – Smear slide.
[f]Core 8 – Thirty feet mixed water and sediment.
[g]Core 9 – Sections 4 and 5 empty – only Sections 1, 2, 3 and 6 preserved.
[h]Core 11 – Soupy mud with lithified sediment jammed in catcher; lost considerable soupy sediment out top of liner during extraction from core barrel.
[i]Core 12 – Sections 1 and 5 exist; water only in Sections 2, 3, 4 and 6.
[j]Core 1 – Material jammed in both 15 foot sections of core with gap of unknown distance between them. Core material was found at top and bottom of core barrel; 3 stages of extruding sediment (with great difficulty) yielded the sections of the lower 15 foot core and although their succession in stratigraphic order is known, their positions within the core are not. The central part of the 30 foot core was empty, but sediment was tightly lodged in the upper part. Core section labelling was as follows: Sec. 1 - 1 ft, 2 - 0 ft (section nonexistent), 3 - 0 ft (section nonexistent), 4 - 2 ft, 5 - 2 ft, 6 - 4 ft.
[k]Cores 3 through 6 – Taken without plastic liner because of damage to liner in Cores 1 and 2 and resulting extrusion problems.

TABLE 2

Coring Rates

Core No.	Drilling Time (hr)	Depth Cored (ft)	Average Coring Rate (ft/hr)	Remarks
Hole 9				
1	0.1	25	250	
2	0.1	30	300	
3	0.1	30	300	
4	0.1	30	300	
5	0.1	30	300	
6	0.1	30	300	
7	0.1	30	300	
8	0.2	30	150	
9	0.3	30	100	
10	0.3	30	100	
11	0.3	30	100	
12	0.5	30	60	
Hole 9A				
1	0.8	15	19	Cherty radiolarian ooze
2	0.9	22	24	Cherty radiolarian ooze
3	0.9	30	33	
4	0.5	10	20	
5	1.0	30	30	
6	0.5	1	2	Basement rock

Summary of Drilling and Coring at Site 9

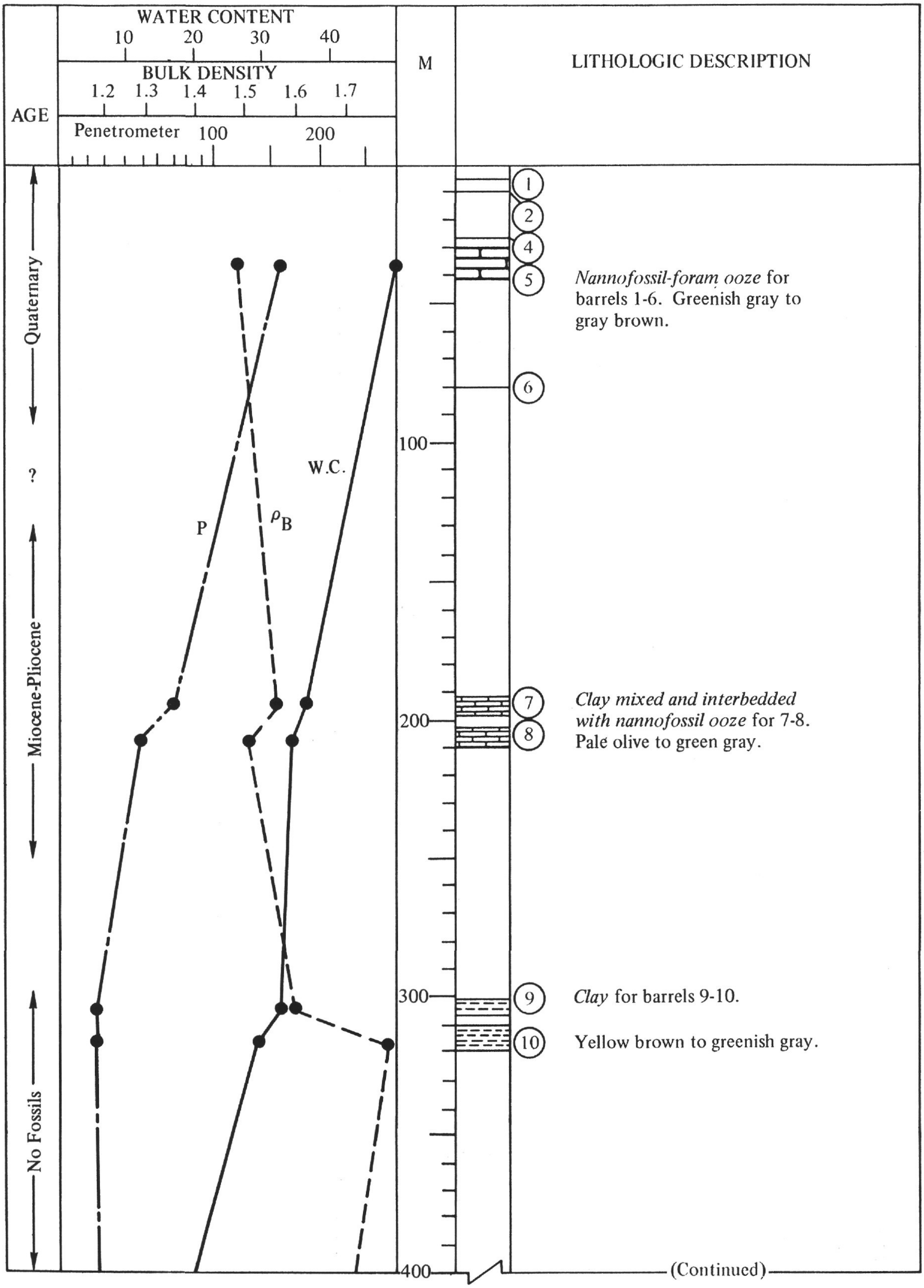


Figure 4. *Summary of drilling and coring at Site 9.*

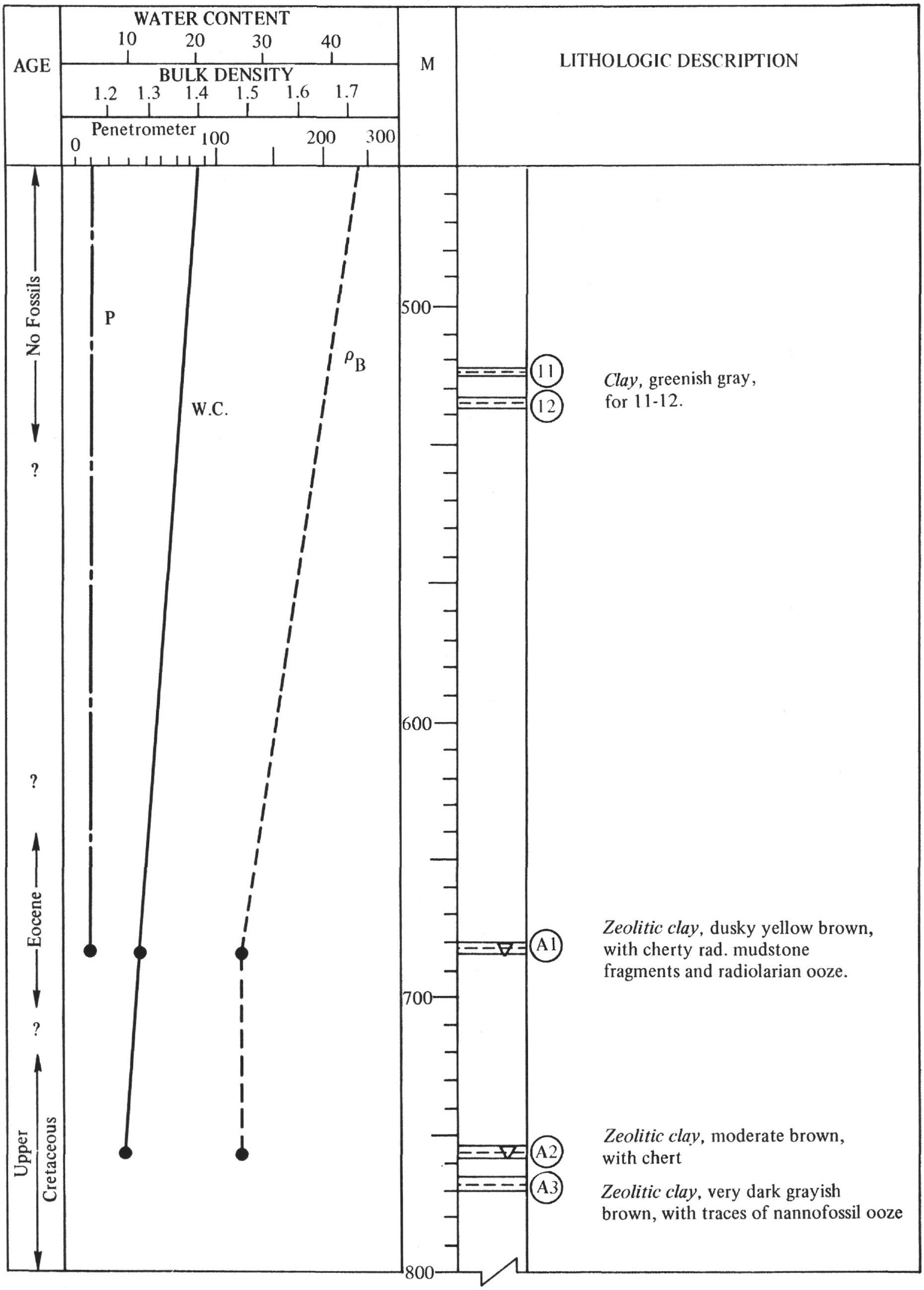


Figure 4. *Continued.*

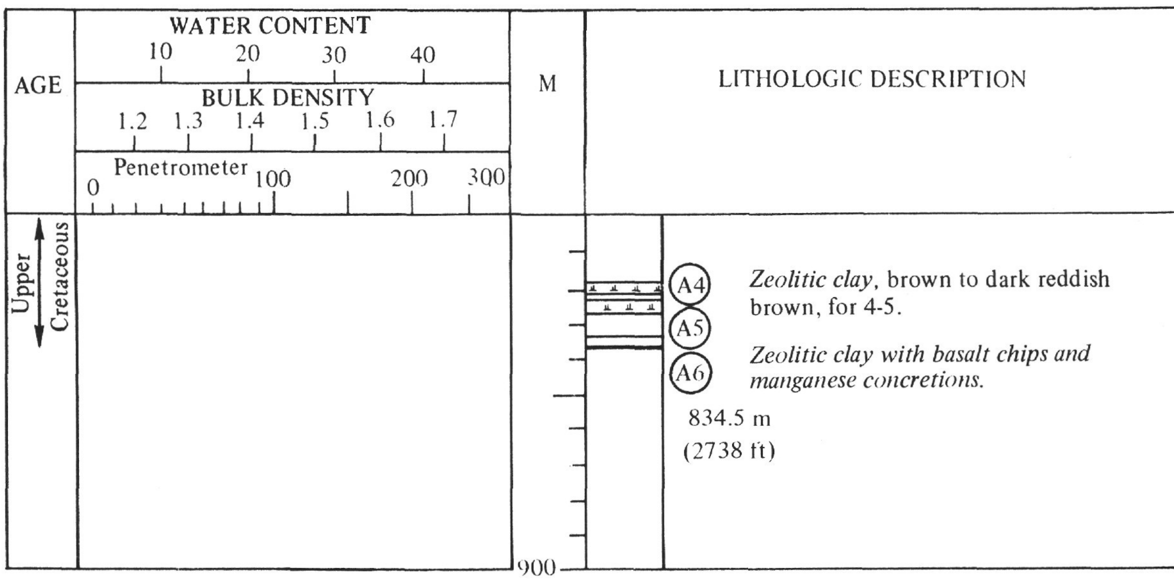


Figure 4. *(Continued)*

The Cores Recovered from Site 9

Figures 5 through 16 are the graphic summaries of the cores recovered at Site 9.

These figures show, for each core:

(1) The stratigraphic age.
(2) The natural gamma radiation
(3) The bulk density, determined by the GRAPE (Gamma Ray Attenuation Porosity Evaluation) equipment
(4) The length of the core in meters measured from the top of the core and the subbottom depth of the top of the cored interval.
(5) The lithology (see key with Chapter 3).
(6) The positions of the tops of each core section.
(7) Some notes on the lithology.

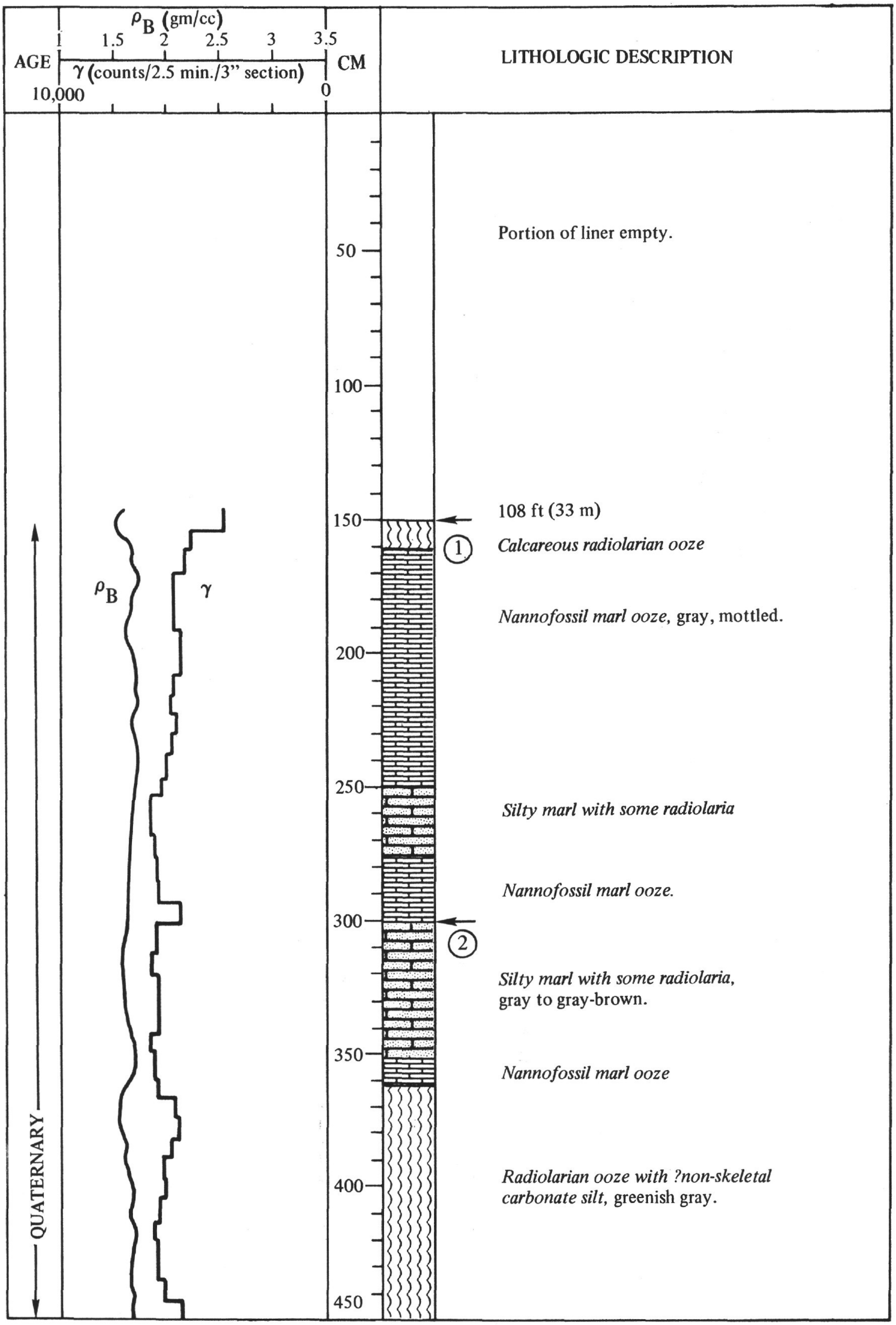


Figure 5. *Hole 9 Core 5.*

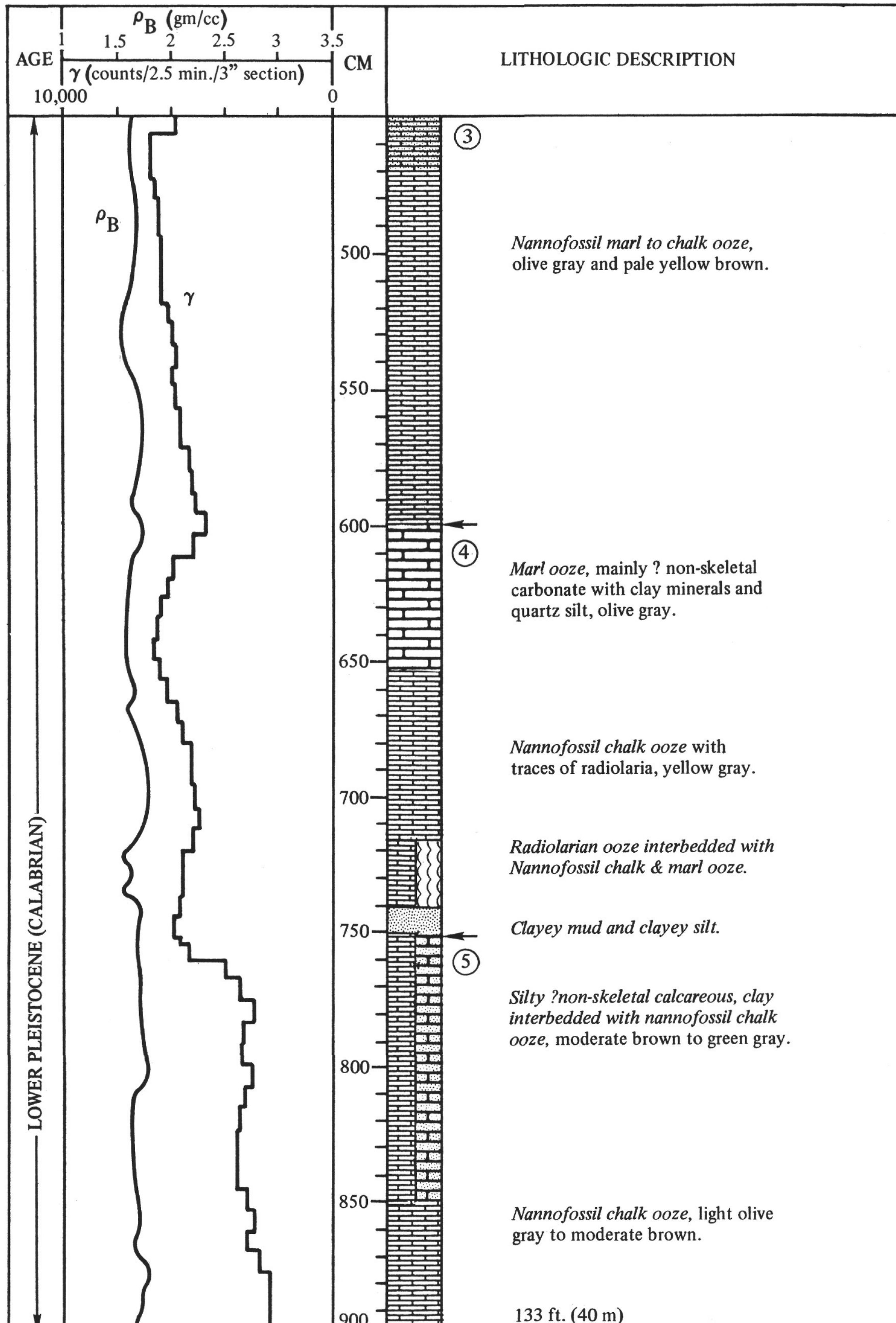


Figure 5. *Continued.*

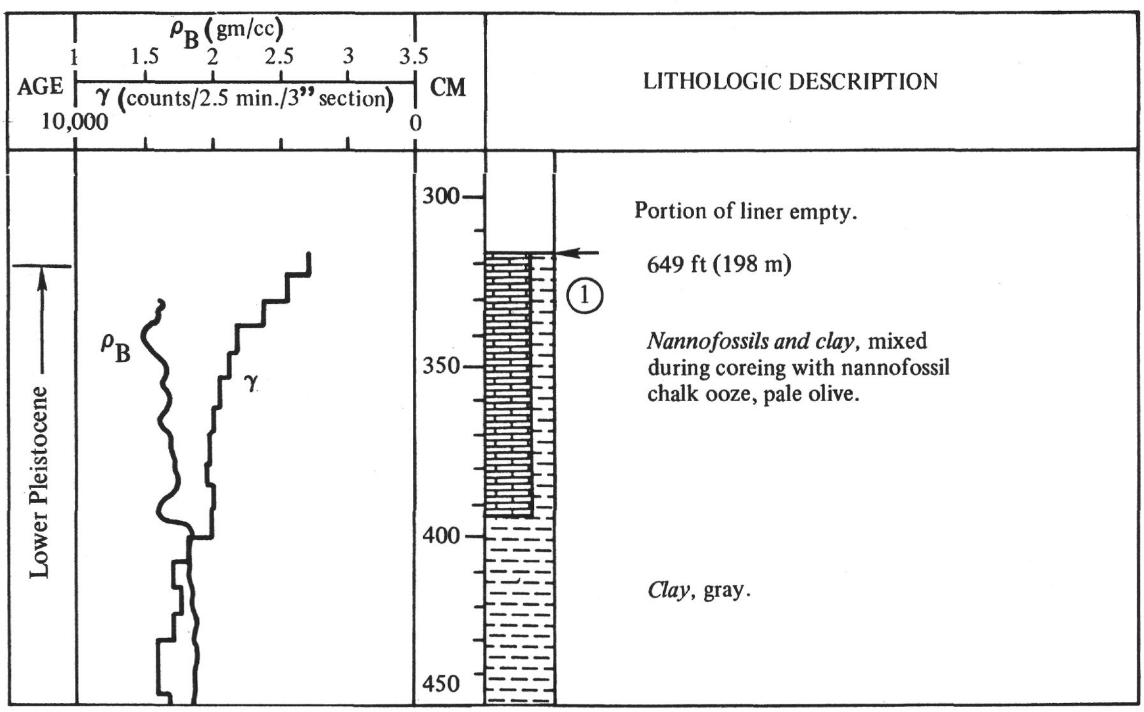


Figure 6. *Hole 9 Core 7.*

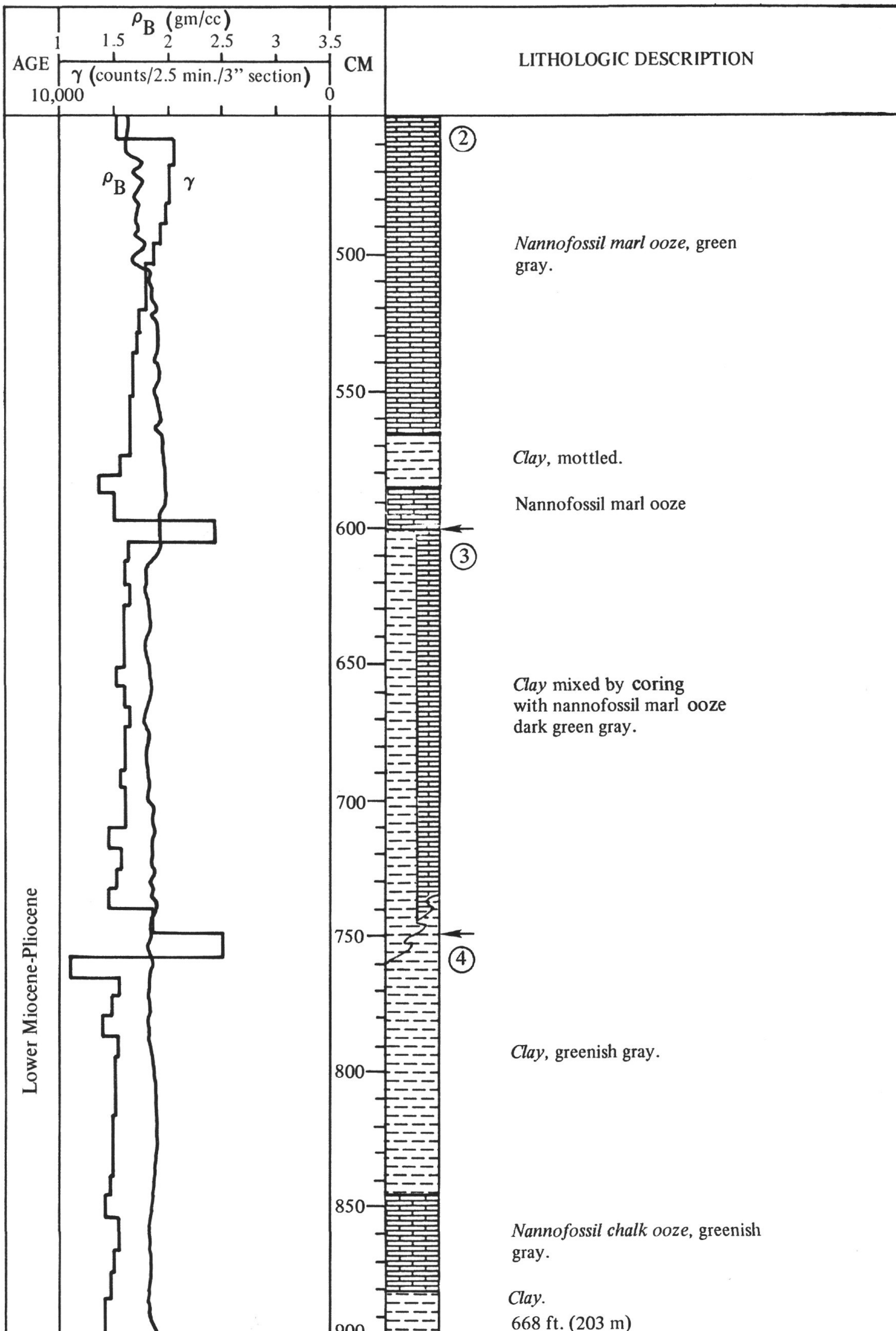


Figure 6. *Continued.*

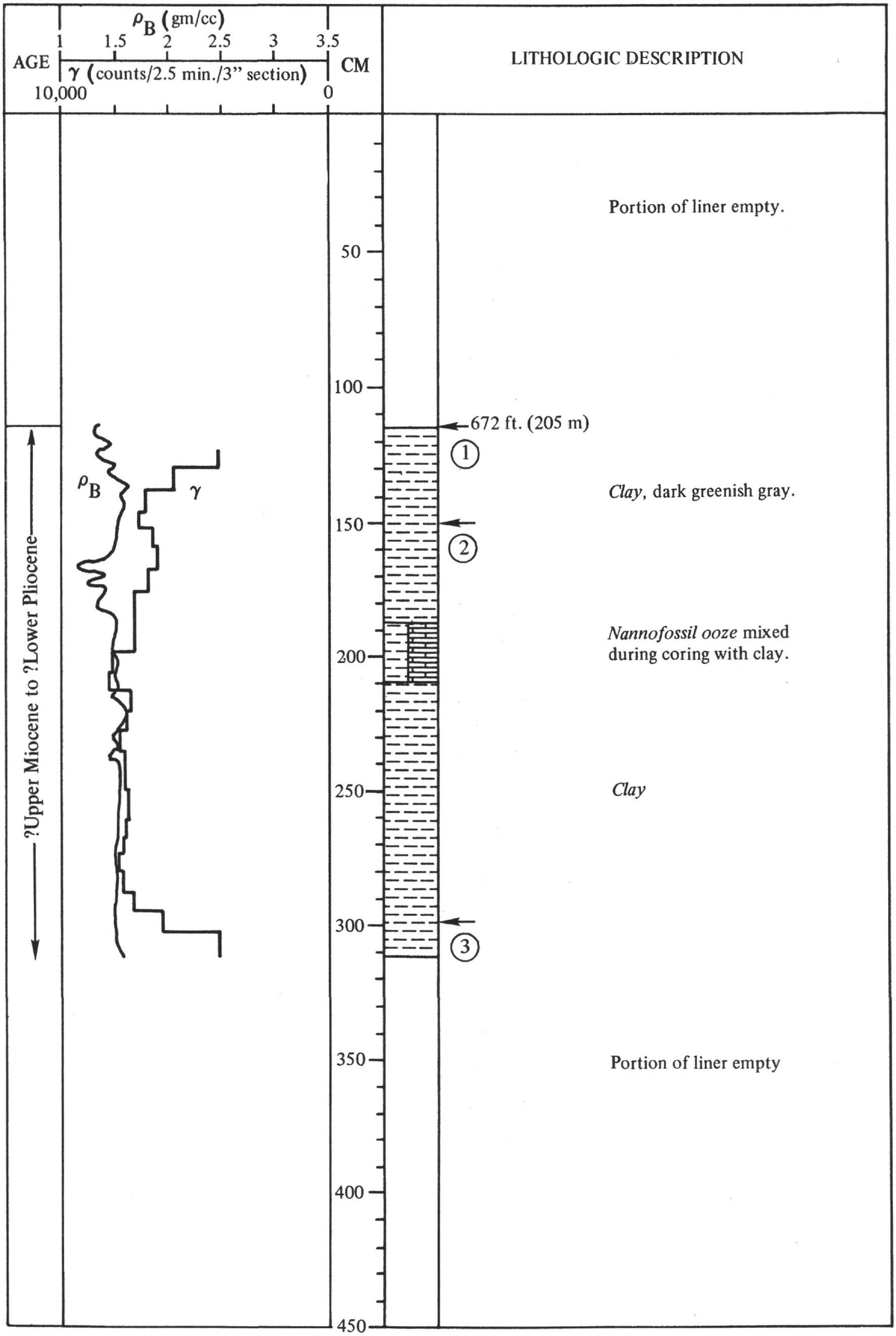


Figure 7. *Hole 9 Core 8.*

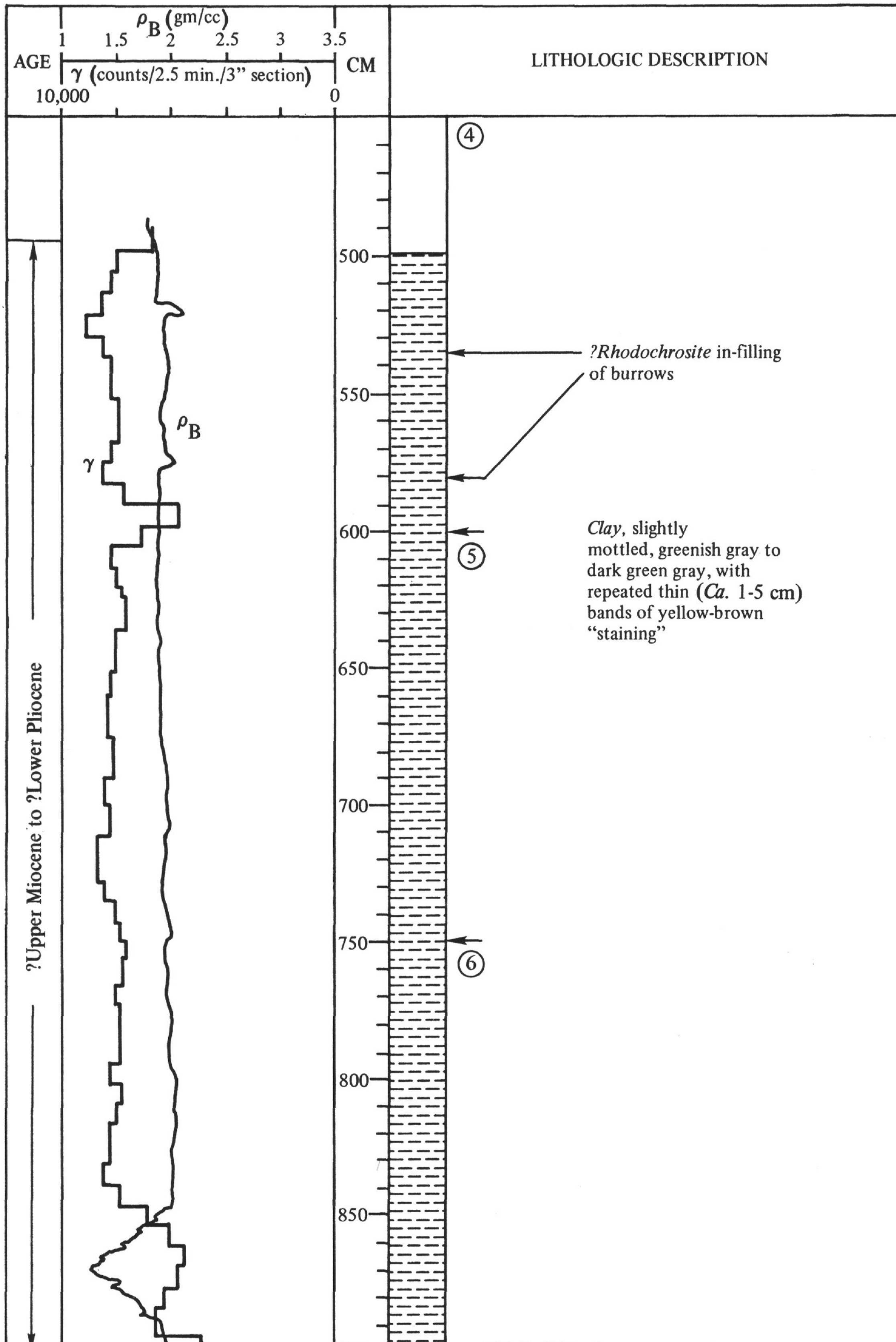


Figure 7. *Continued.*

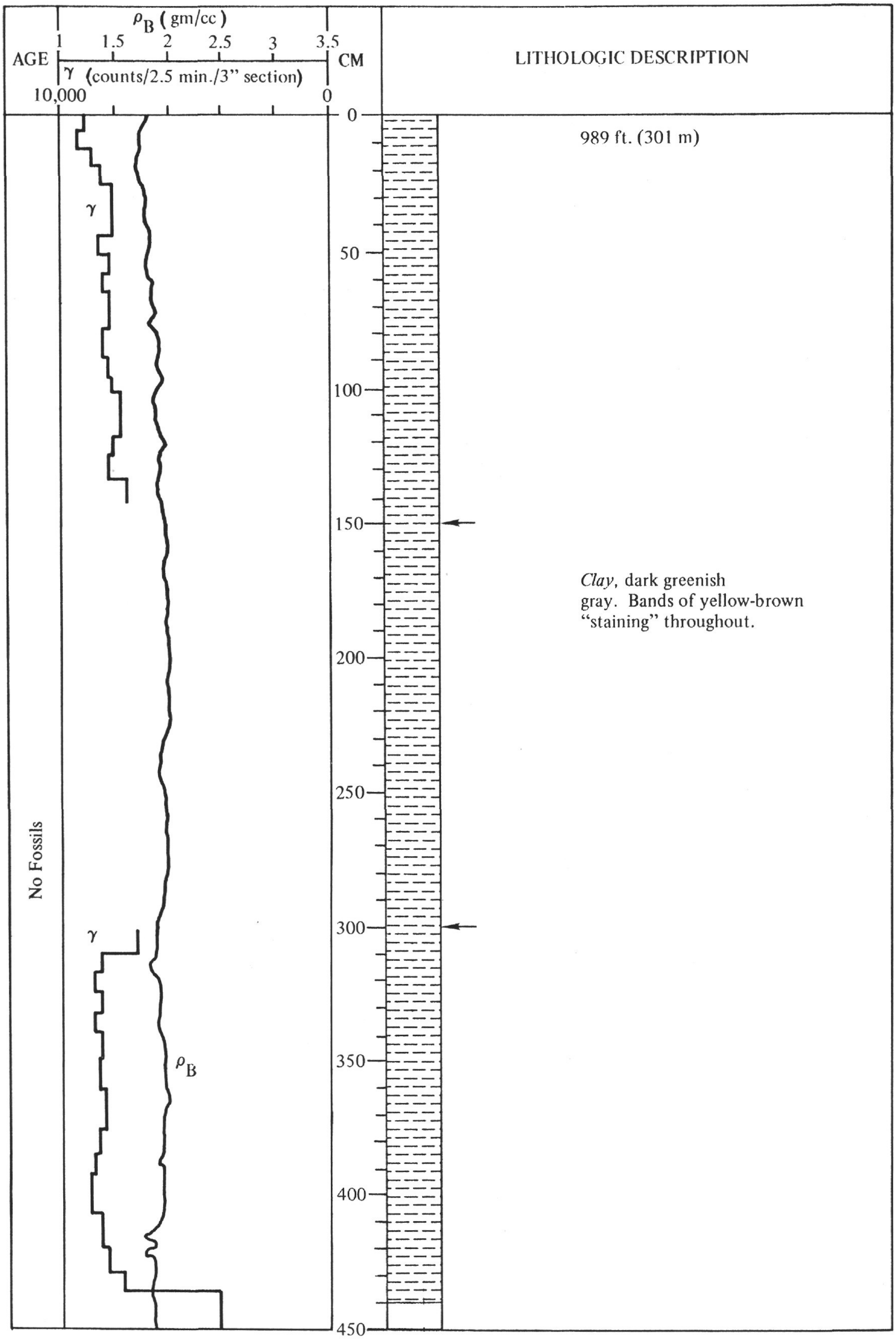


Figure 8. *Hole 9 Core 9.*

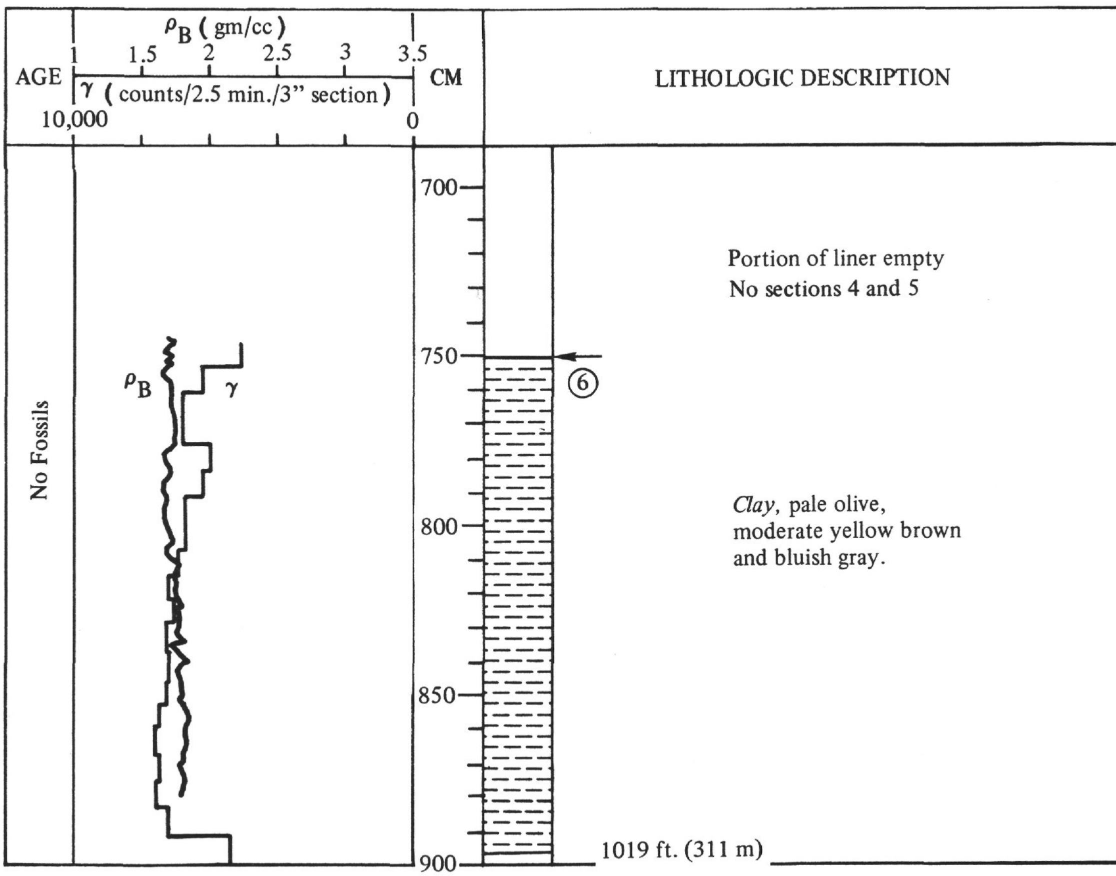


Figure 8. *Continued.*

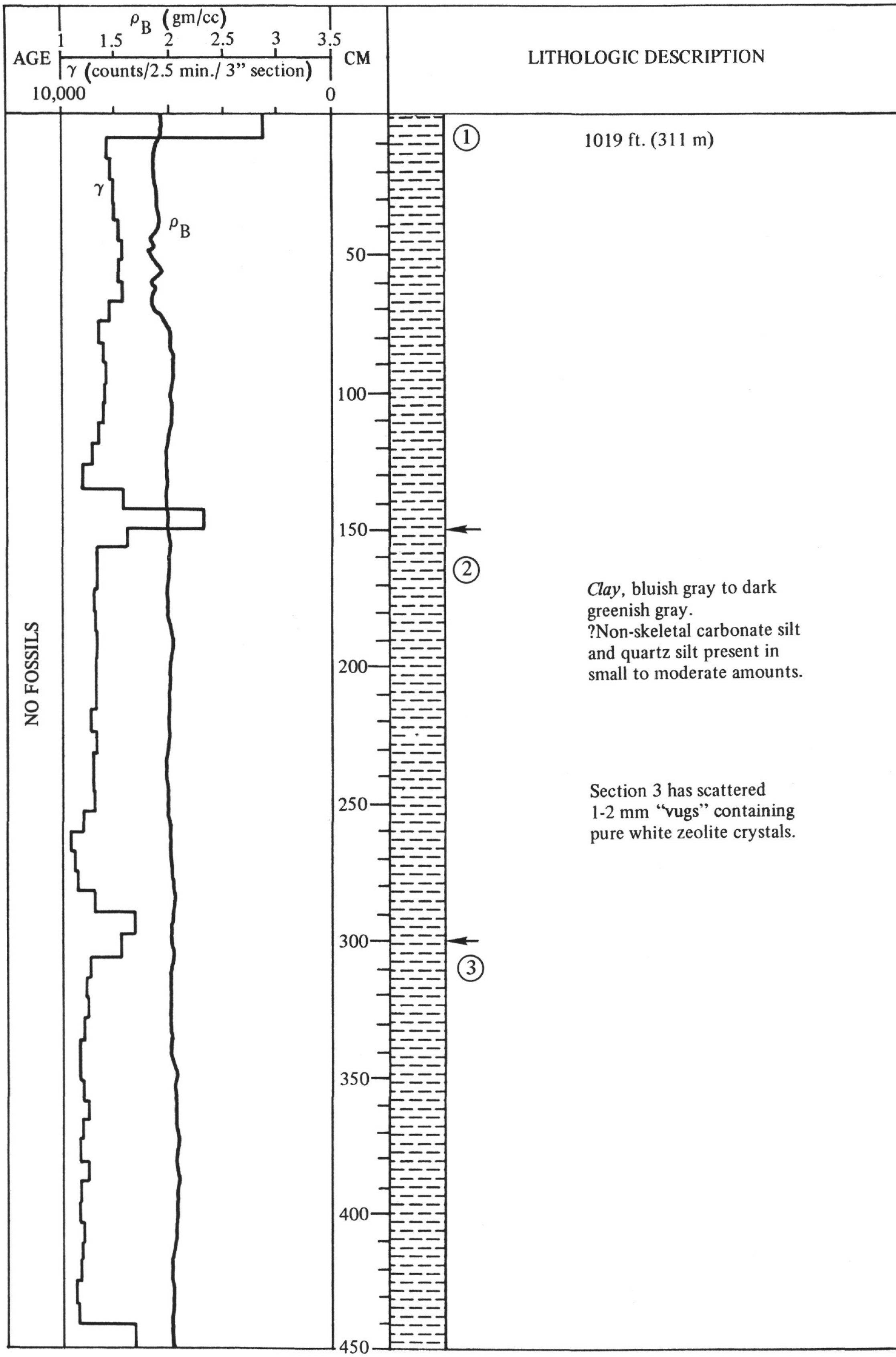


Figure 9. *Hole 9 Core 10.*

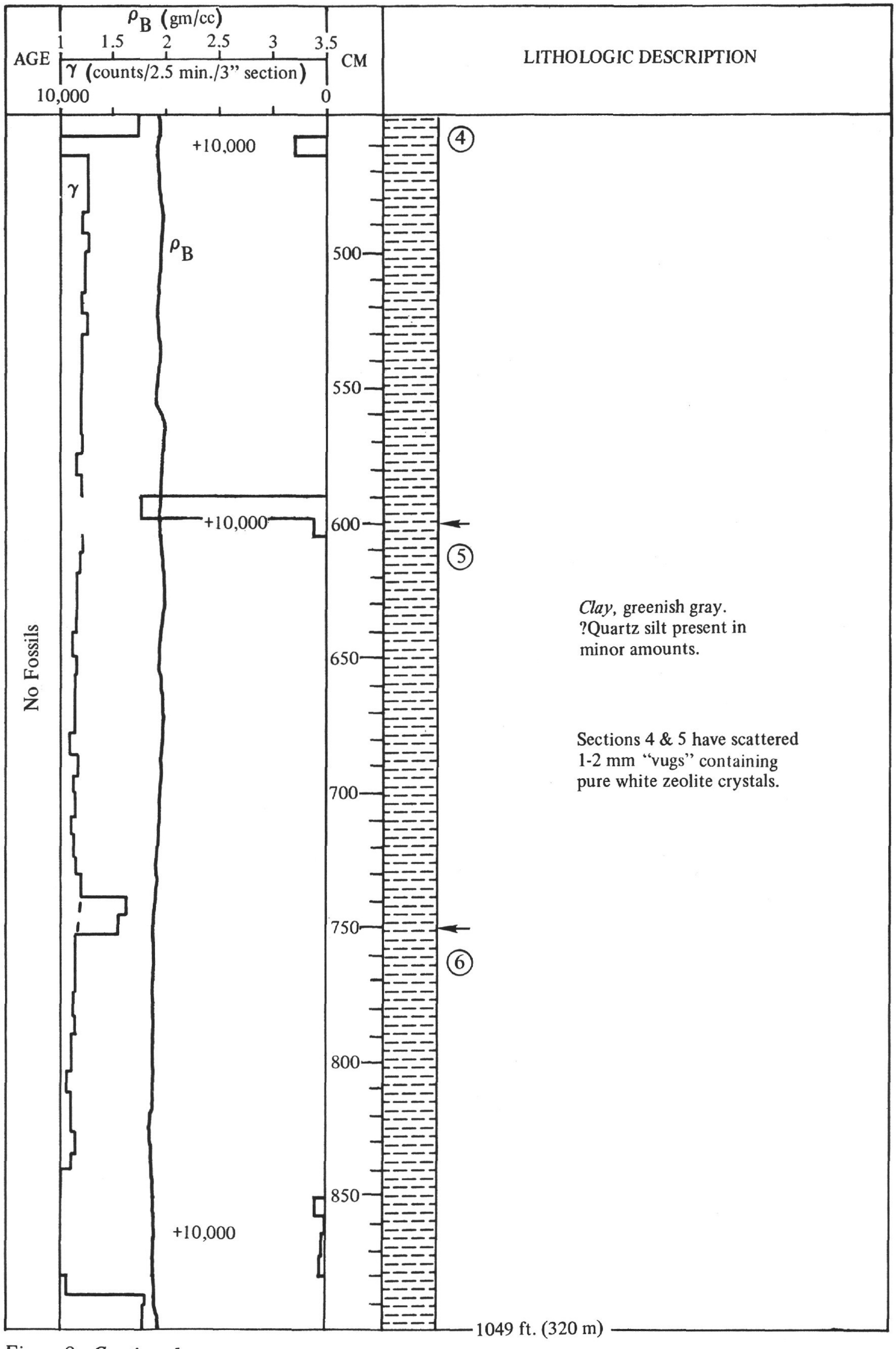
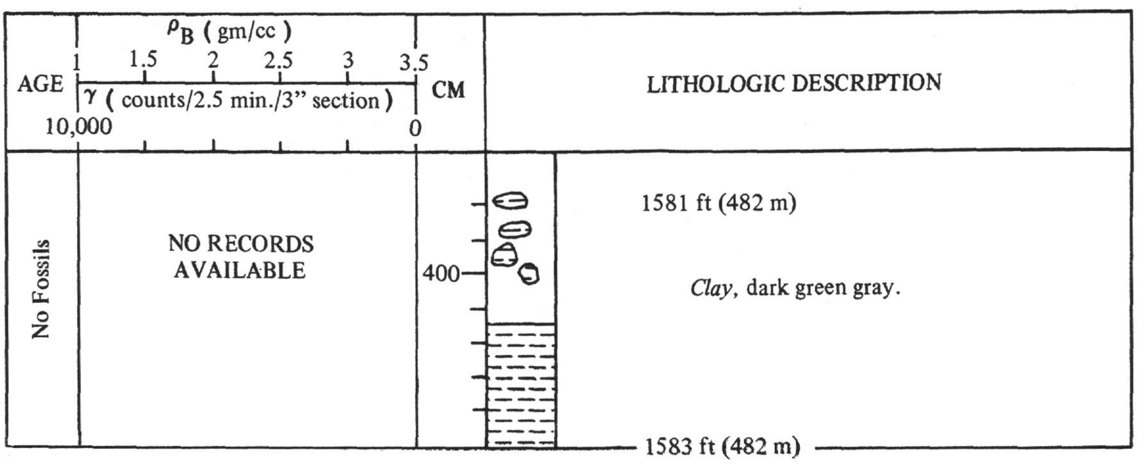


Figure 9. *Continued.*



AGE
ρ_B (gm/cc)
1 1.5 2 2.5 3 3.5
γ (counts/2.5 min./3" section)
10,000 0
CM
LITHOLOGIC DESCRIPTION
No Fossils
NO RECORDS AVAILABLE
400
1581 ft (482 m)
Clay, dark green gray.
1583 ft (482 m)

Figure 10.

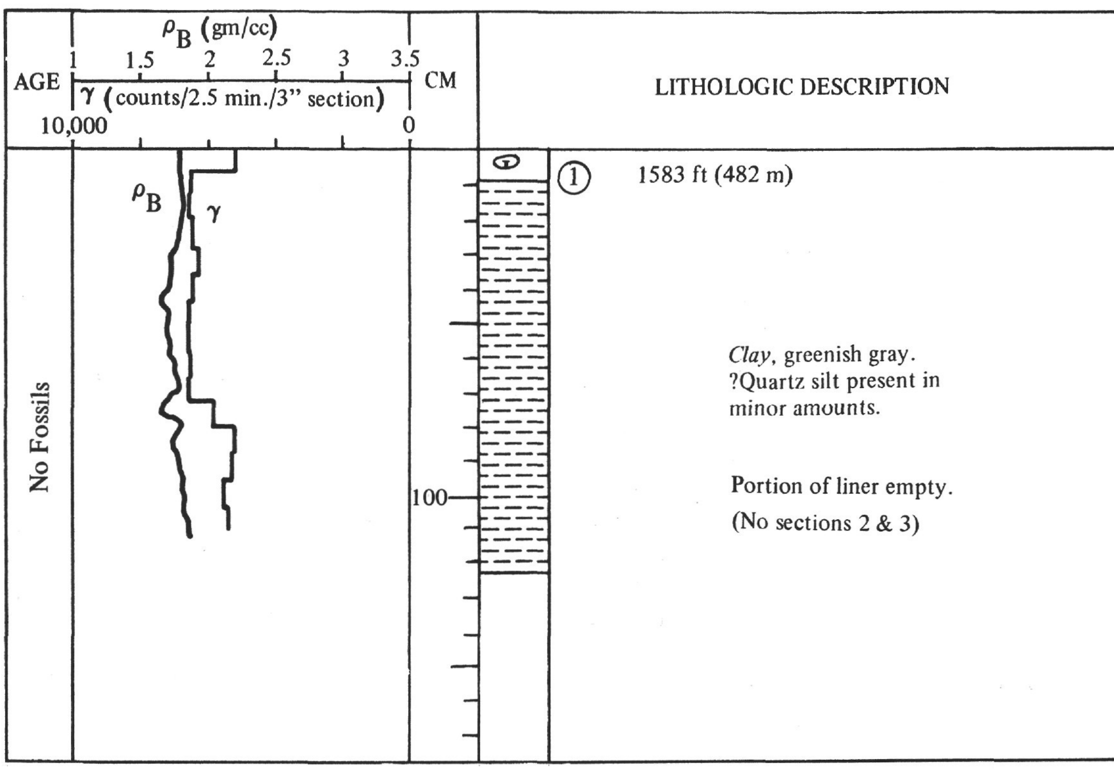


Figure 11. *Hole 9 Core 12.*

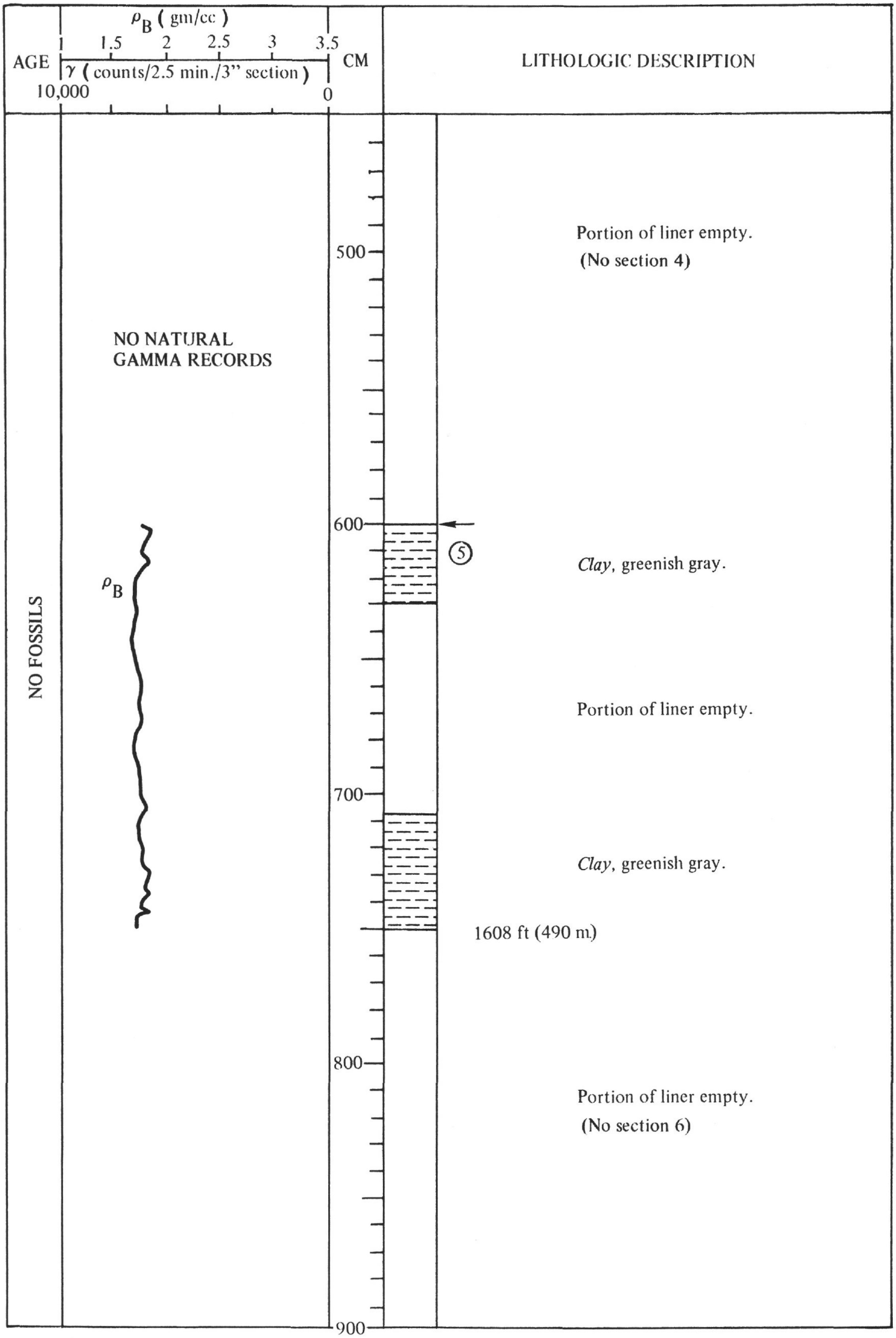


Figure 11. *Continued.*

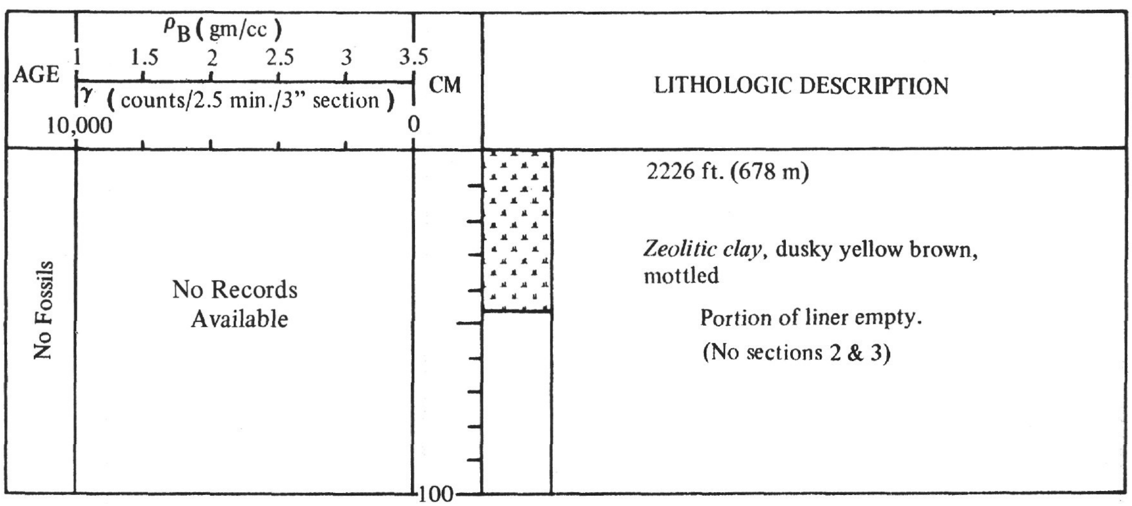


Figure 12. *Hole 9A Core 1.*

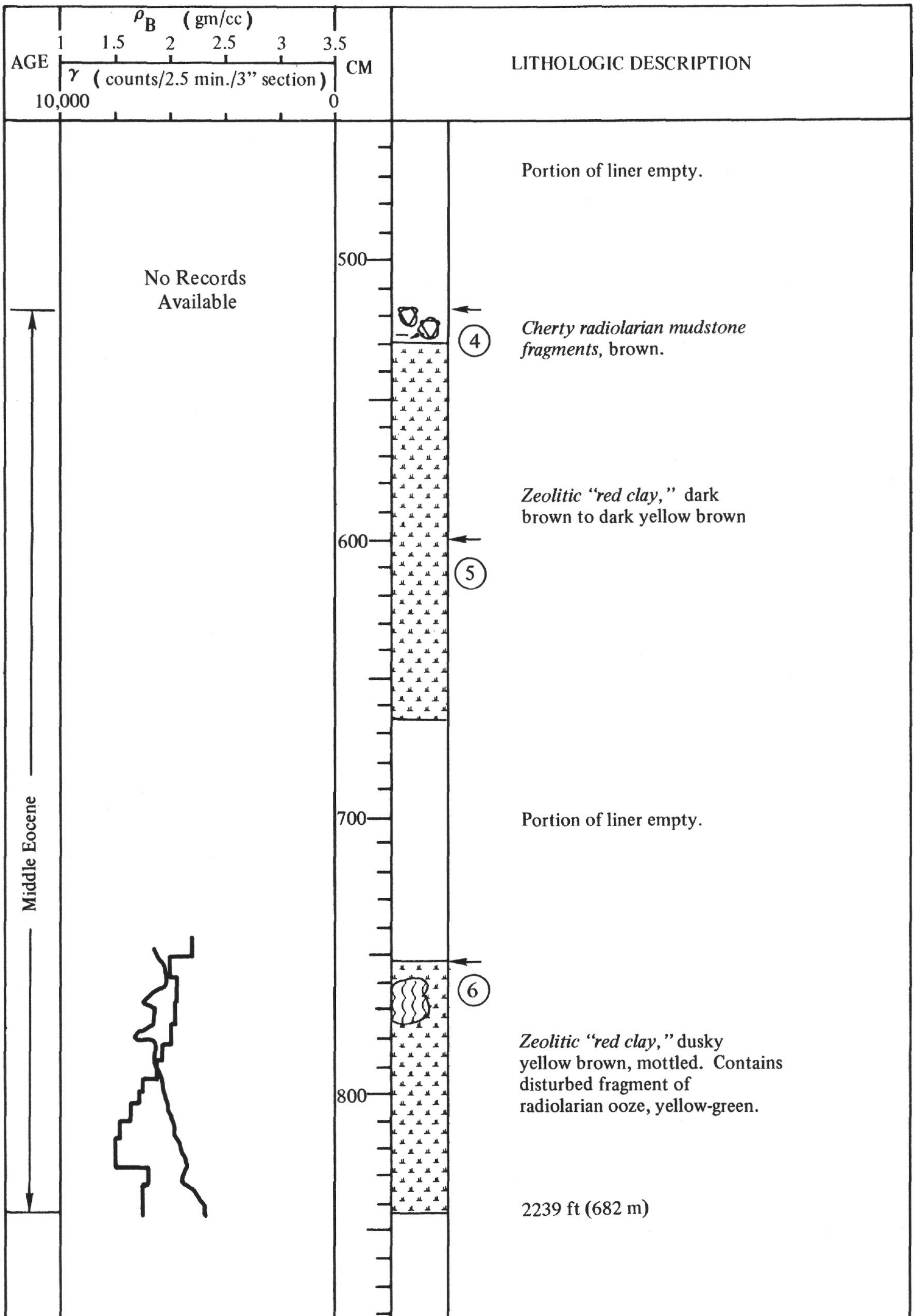


Figure 12. *Continued.*

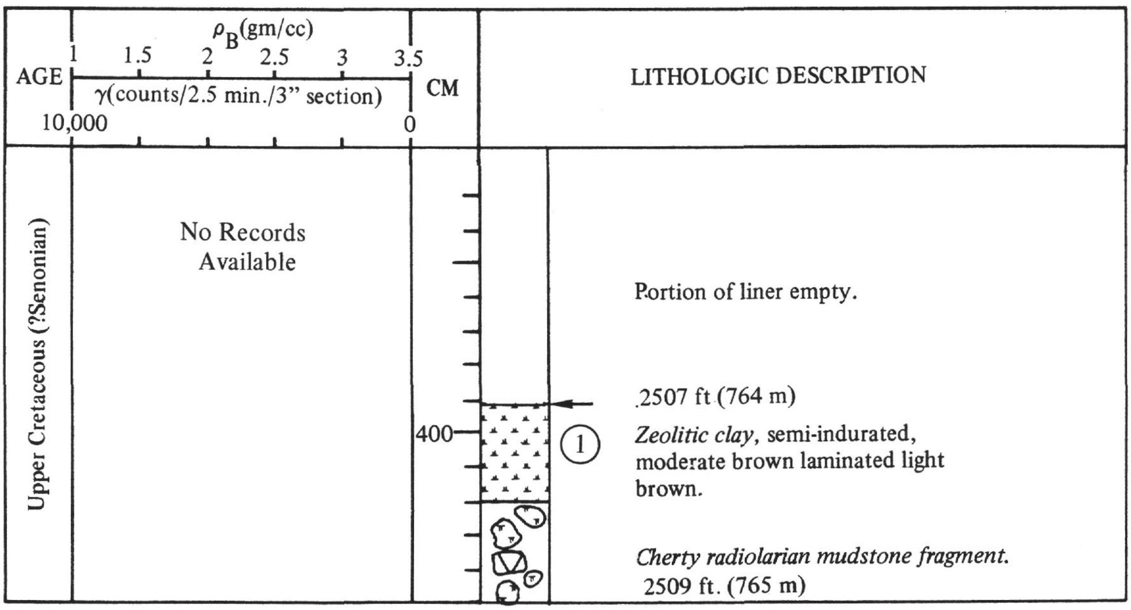


Figure 13. *Hole 9A Core 2.*

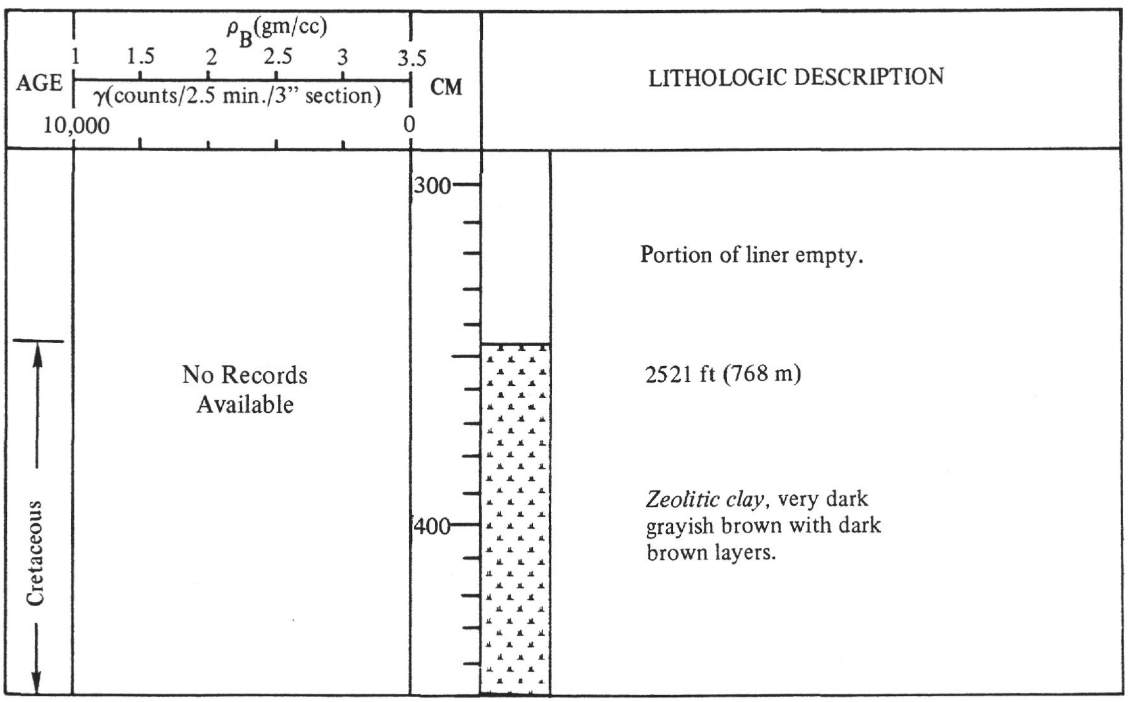


Figure 14. *Hole 9A Core 3.*

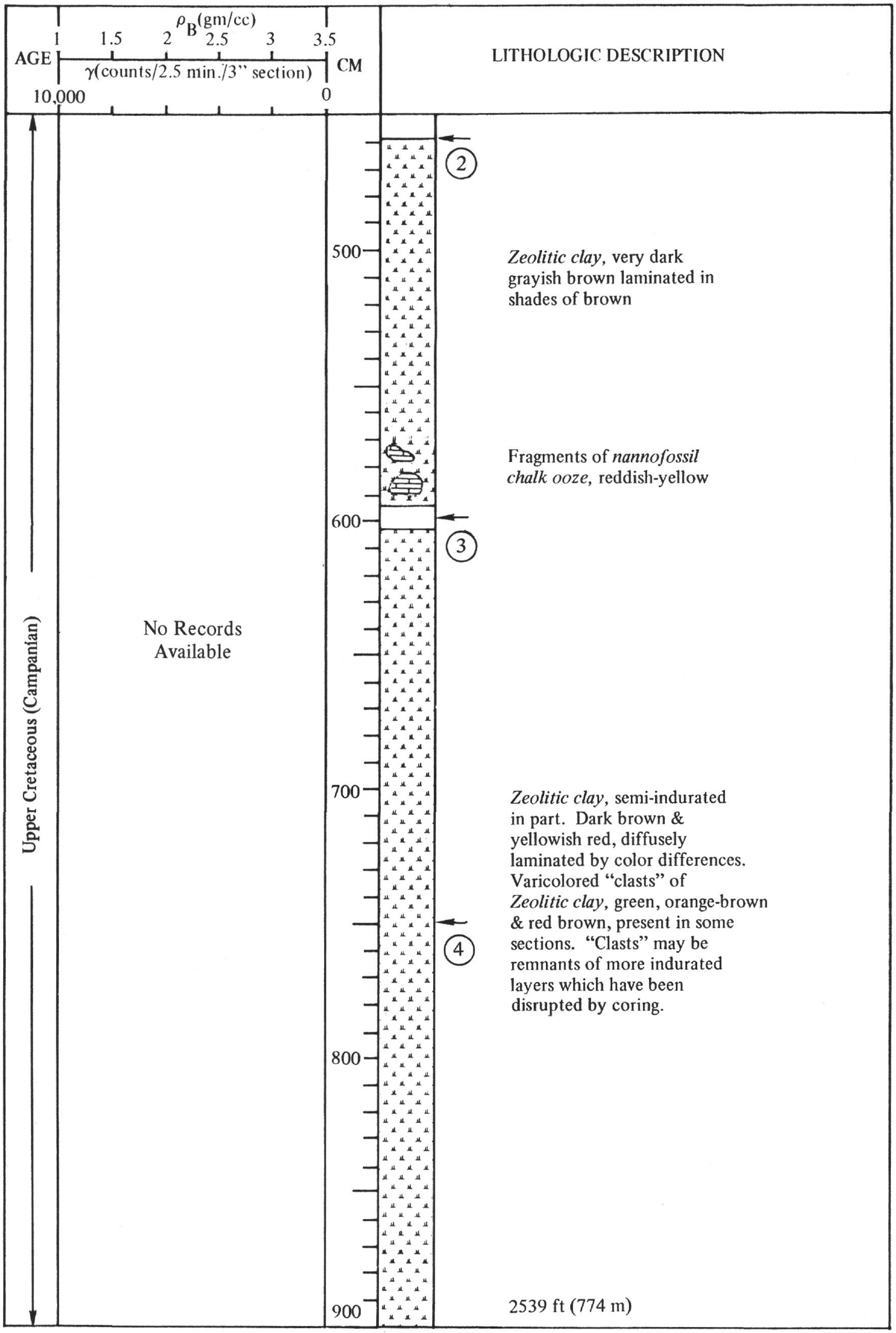


Figure 14. *Continued.*

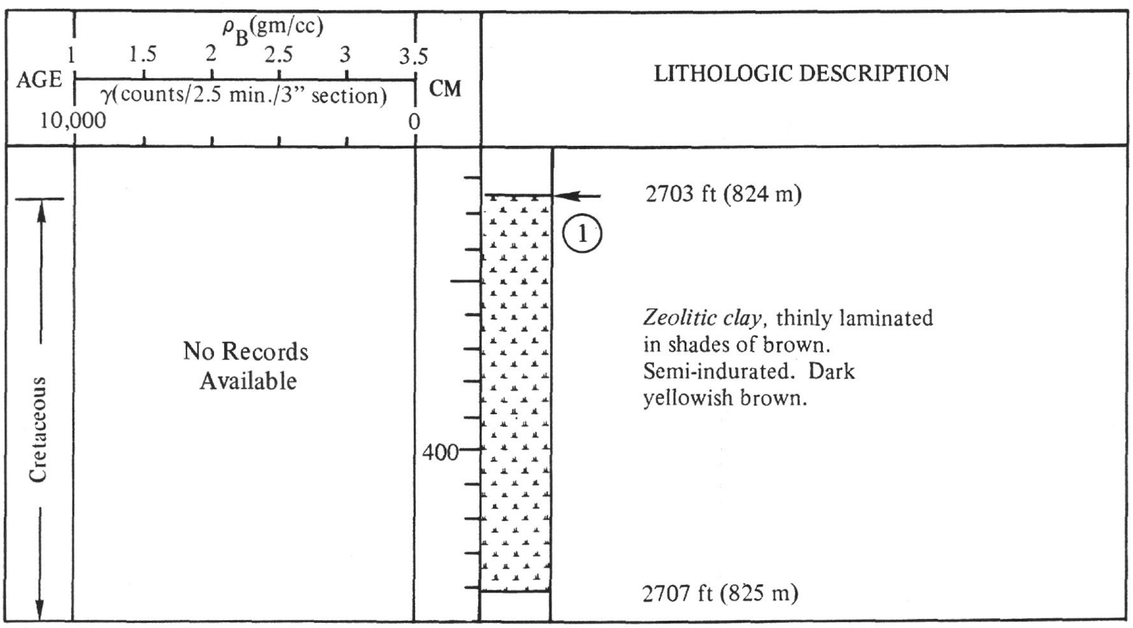


Figure 15. *Hole 9A Core 4.*

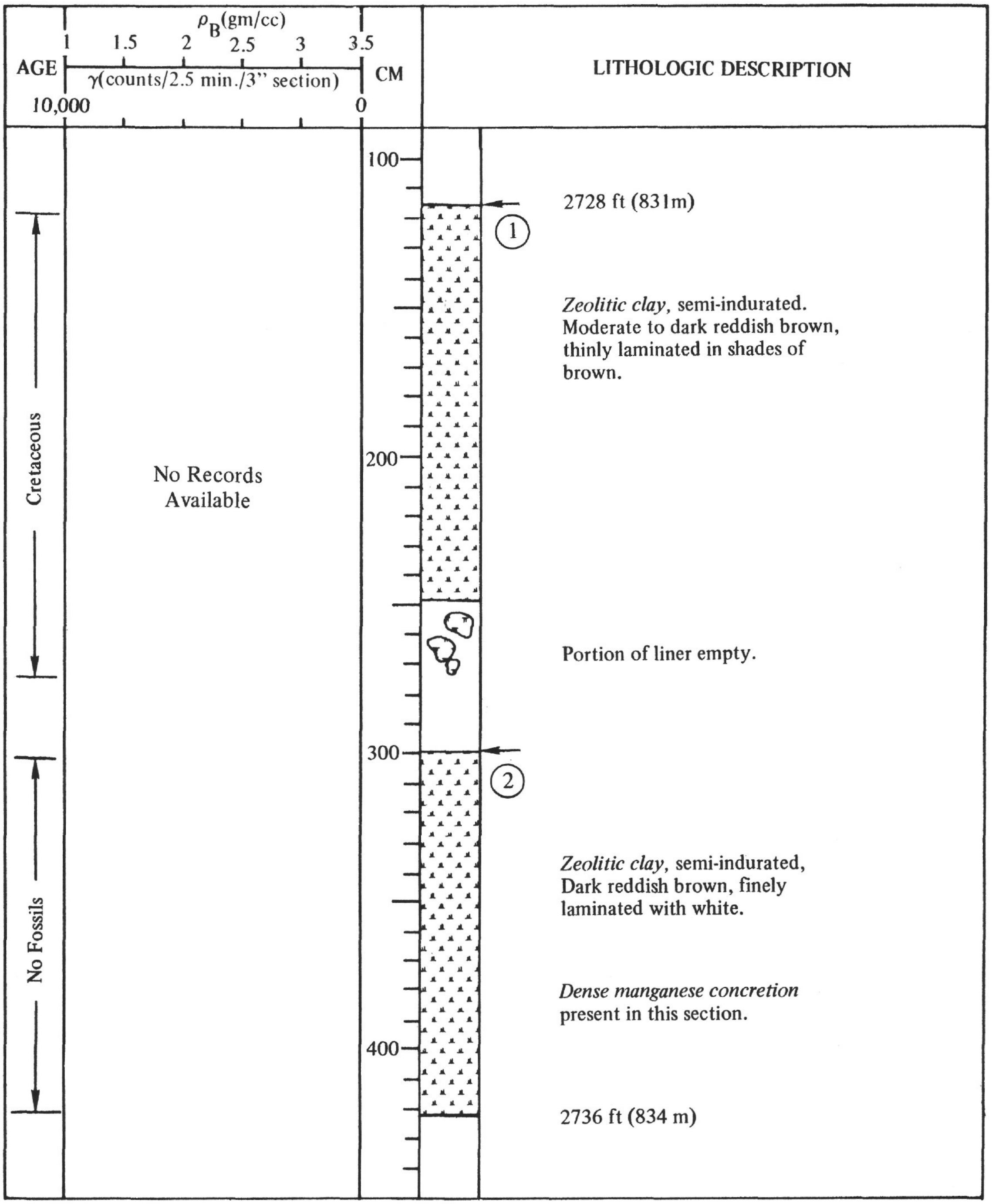


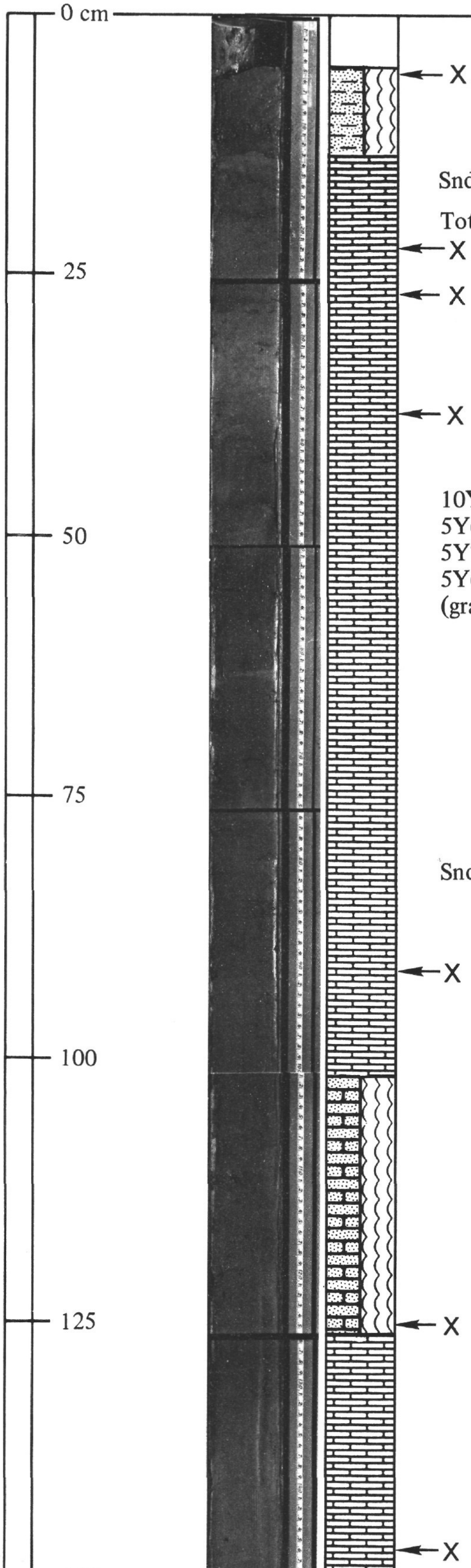
Figure 16. *Hole 9A Core 5.*

The Cores Recovered from Site 9

Figures 17 through 56 show details of the individual core sections of the cores from Site 9.

Each figure shows:

(1) A scale of centimeters from the top of each section.
(2) A photograph of the core section.
(3) The lithology (see key in Chapter 3).
(4) The positions of smear slides (x).
(5) Notes on the lithology, X-ray mineralogy, carbon content, expressed as a percentage of total sediment (see Chapter 9), the water content and the grain size (see Chapter 8). Colors are given with reference to the GSA Rock Color Chart.



5-12 cm: - *Calcareous and Silic. silty clay,*

Clay mins.	55%
Carb. fragments	20%
Rads. diat., spics.	20%

Snd. 0.3, Slt. 25.6, Cl. 74.1

Tot. C. 3.2, Org. C. 0.4, $CaCO_3$ 23.3

X-ray diffraction results (12-14 cm)

Montm.	0.0%
Chlor.	0.0
Mica	13.7
Clin.	0.0
Kao.	10.5
Quartz	18.2
K-feld.	2.9
Plag.	8.8
Calcite	39.3
Dolo.	6.6

10YR5/1 (M)
5Y6/1 (M)
5Y7/1 (M)
5Y6/2 (M)
(gray, mott.)

12-101 cm: - *Nannofossil marl ooze.*

Nannos.	20-85%
Non skel. carb.	7-45%
Clay mins.	5-40%

Snd. 0.2, Slt. 19.6, Cl. 80.2

X-ray diffraction results (80-82 cm)

Montm.	0.0%
Chlor.	0.0
Mica	19.3
Clin.	0.0
Kao.	19.7
Quartz	26.0
K-feld.	6.7
Plag.	14.7
Calcite	7.0
Dolo.	6.6

101-130 cm: - *Marl*

Clay mins.	50%
Non skel. carb.	40%
Rads. etc.	10%
Qtz. silt.	tr.

130-150 cm: - *Nannofossil marl ooze.*

Figure 17. *Hole 9 Core 5 Section 1.*

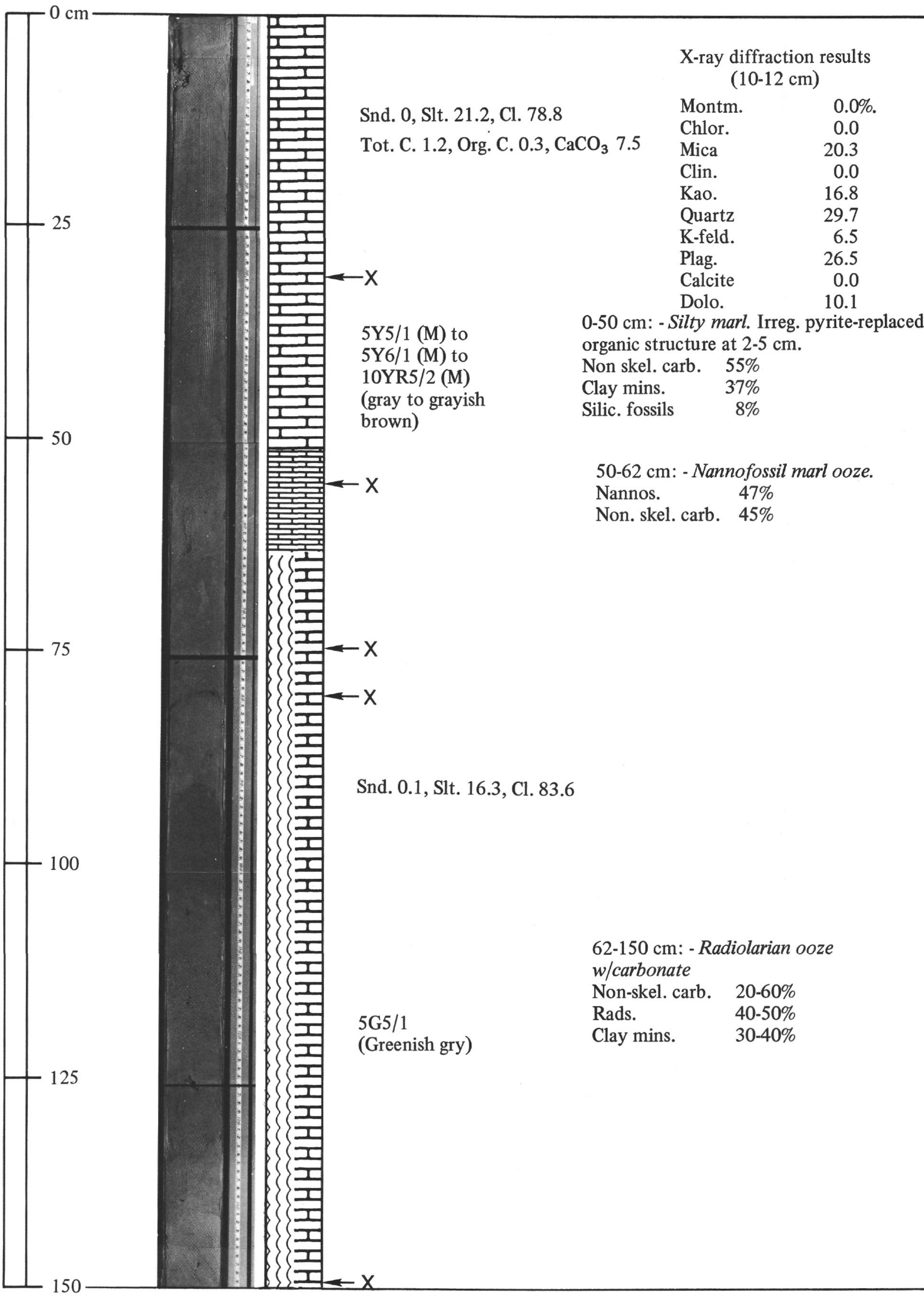


Figure 18. *Hole 9 Core 5 Section 2.*

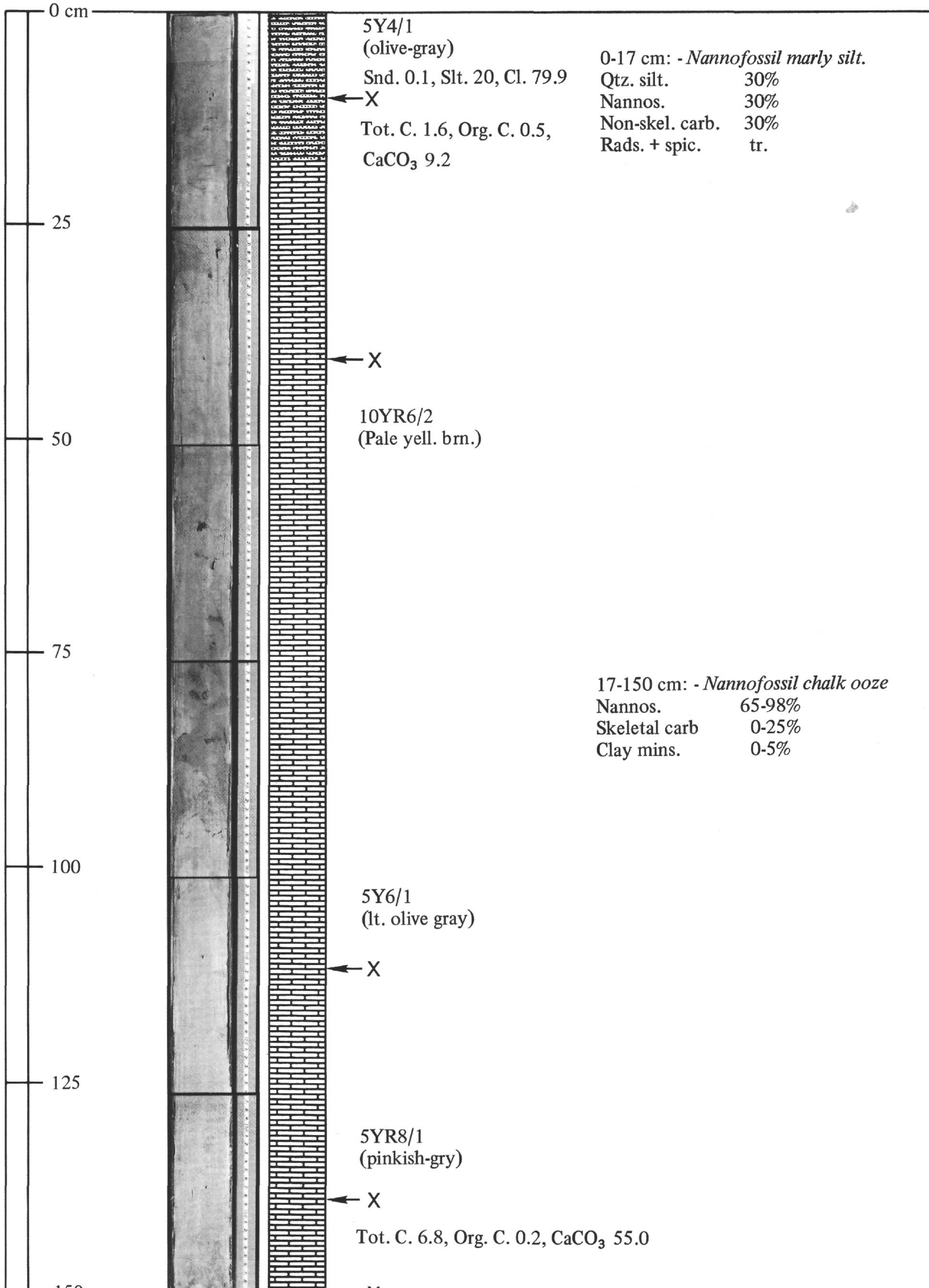


Figure 19. *Hole 9 Core 5 Section 3.*

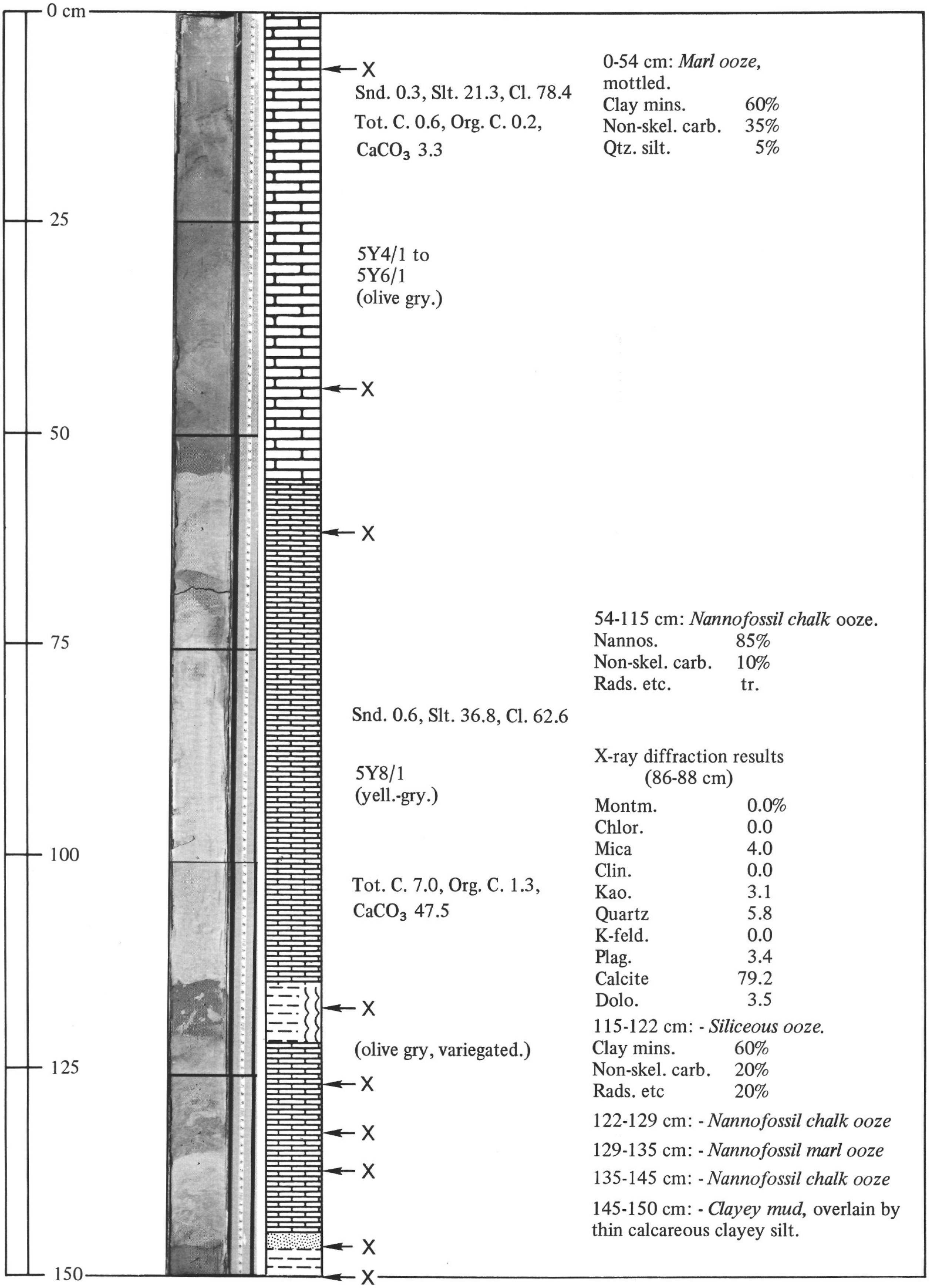
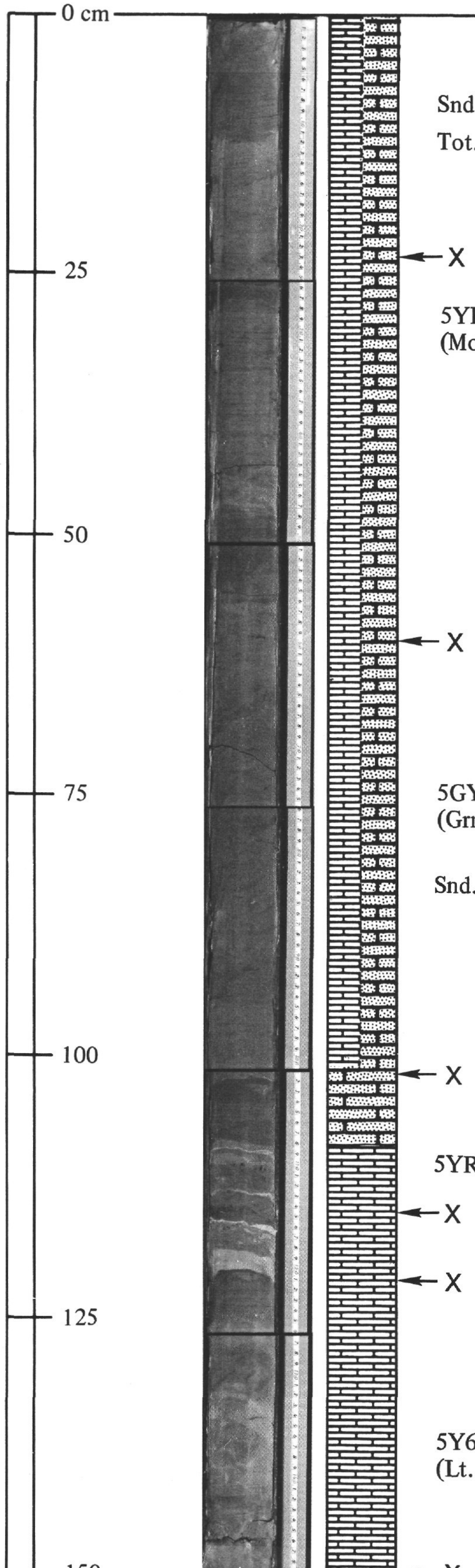


Figure 20. *Hole 9 Core 5 Section 4.*



Snd. 0.0, Slt. 20.4, Cl. 79.6

Tot. C. 9.2, Org. C. 0.4, $CaCO_3$ 73.3

X-ray diffraction results (11-13 cm)

Montm.	0.0%
Chlor.	0.0
Mica	34.0
Clin.	0.0
Kao.	22.8
Quartz	27.6
K-feld.	0.0
Plag.	8.9
Calcite	3.6
Dolo.	3.1

5YR4/1
(Mod. brn.)

0-101 cm: - *Silty calc. clay interbedded w/nannofossil chalk ooze.*

Clay mins.	15-70%
Nannos.	0-75%
Qtz. silt	0-10%
Non-skel. carb.	10-20%

5GY5/1
(Grnsh. gry.)

Snd. 0.6, Slt. 22.3, Cl. 77.1

X-ray diffraction results (86-88 cm)

Montm.	0.0%
Chlor.	0.0
Mica	27.1
Clin.	0.0
Kao.	25.0
Quartz	31.9
Plag.	16.0

101-108 cm: - *Silty calc. clay.*

clay mins.	55%
Non-skel. carb.	40%
Nannos. + qtz. silt	tr.

5YR4/1

108-150 cm: - *Nannofossil chalk ooze.*

Nannos.	75%
Clay mins.	15%
Non-skel. carb.	10%

5Y6/1
(Lt. olive gry.)

Figure 21. *Hole 9 Core 5 Section 5.*

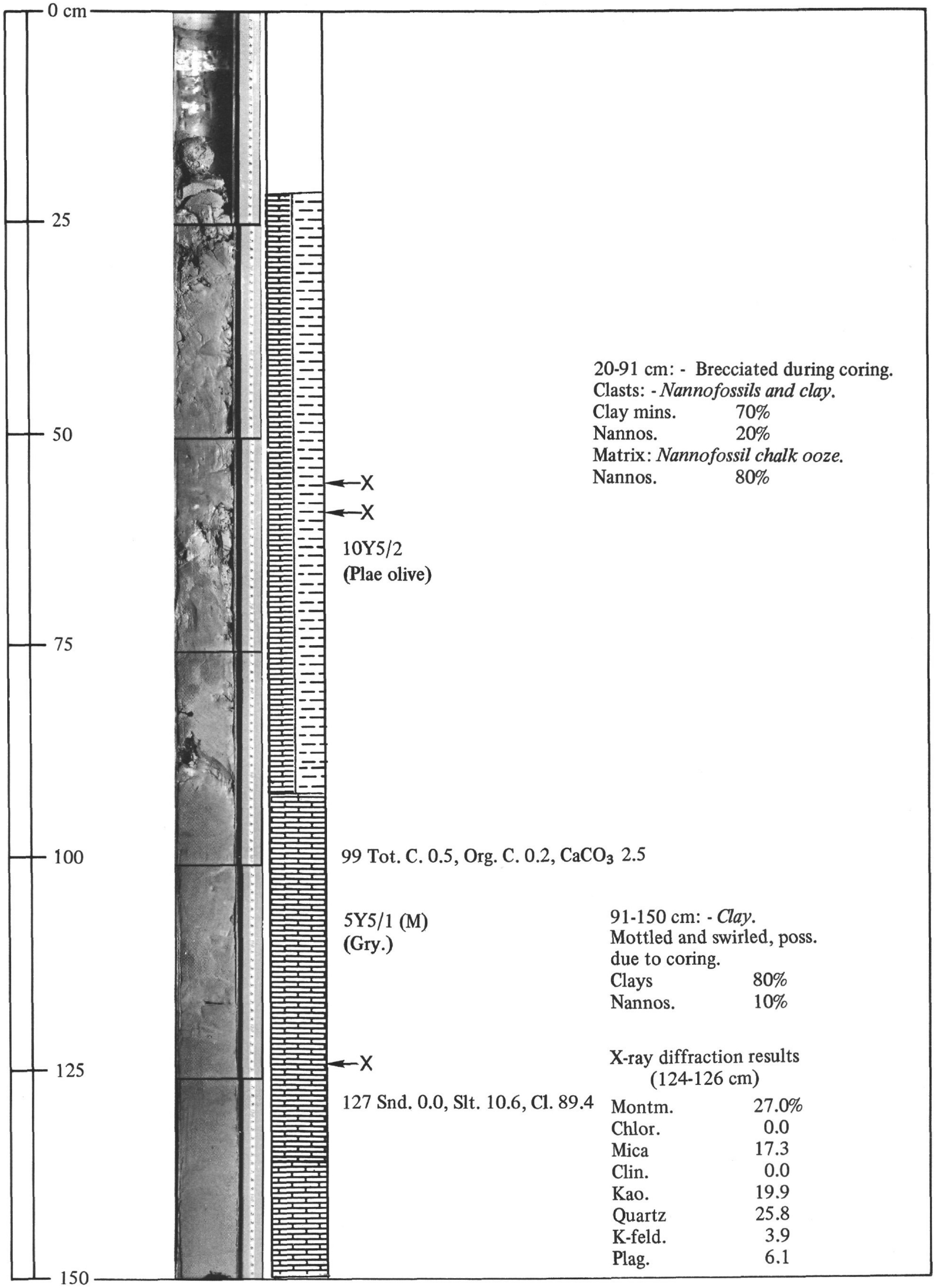


Figure 22. *Hole 9 Core 7 Section 1.*

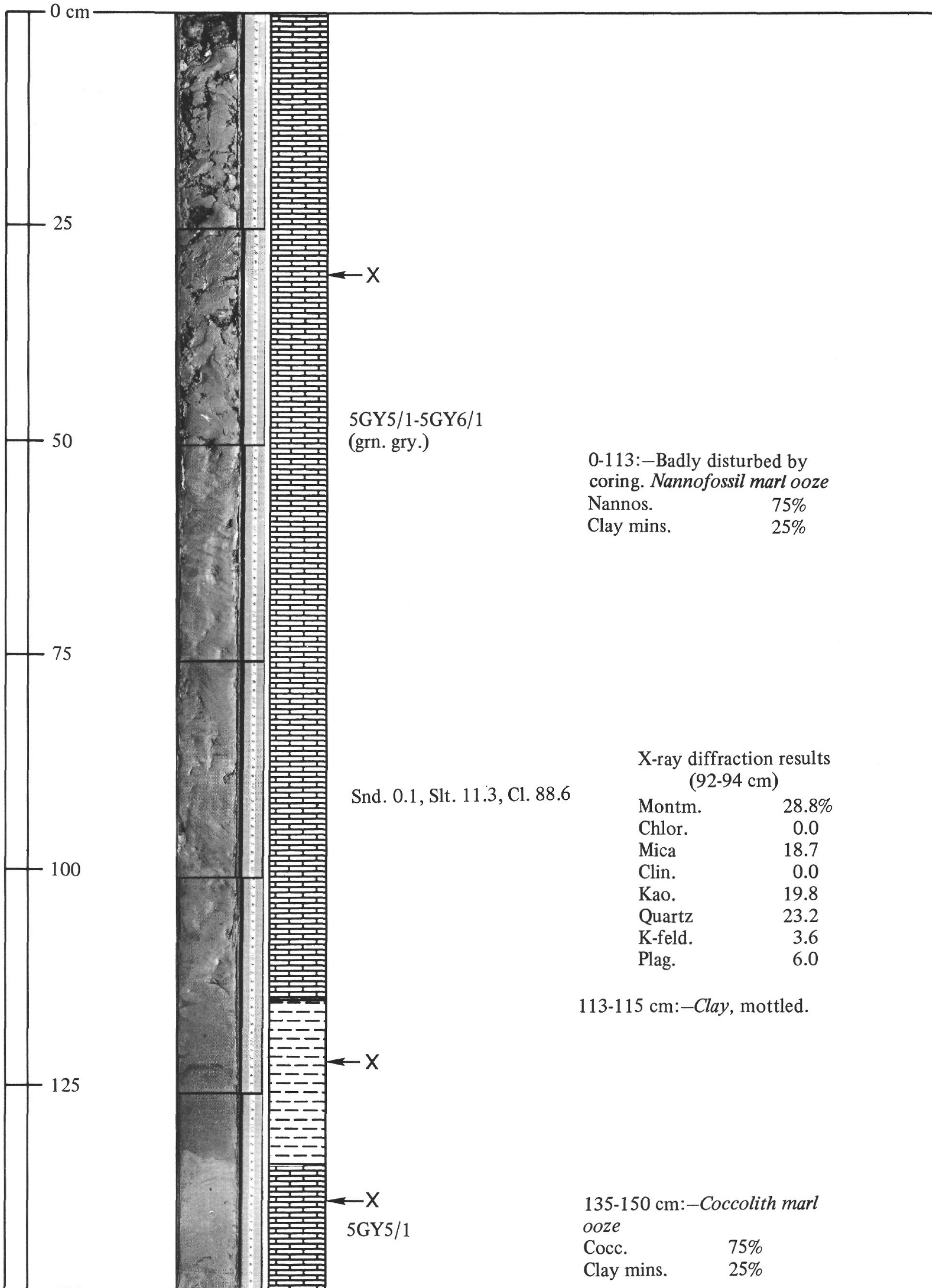


Figure 23. *Hole 9 Core 7 Section 2.*

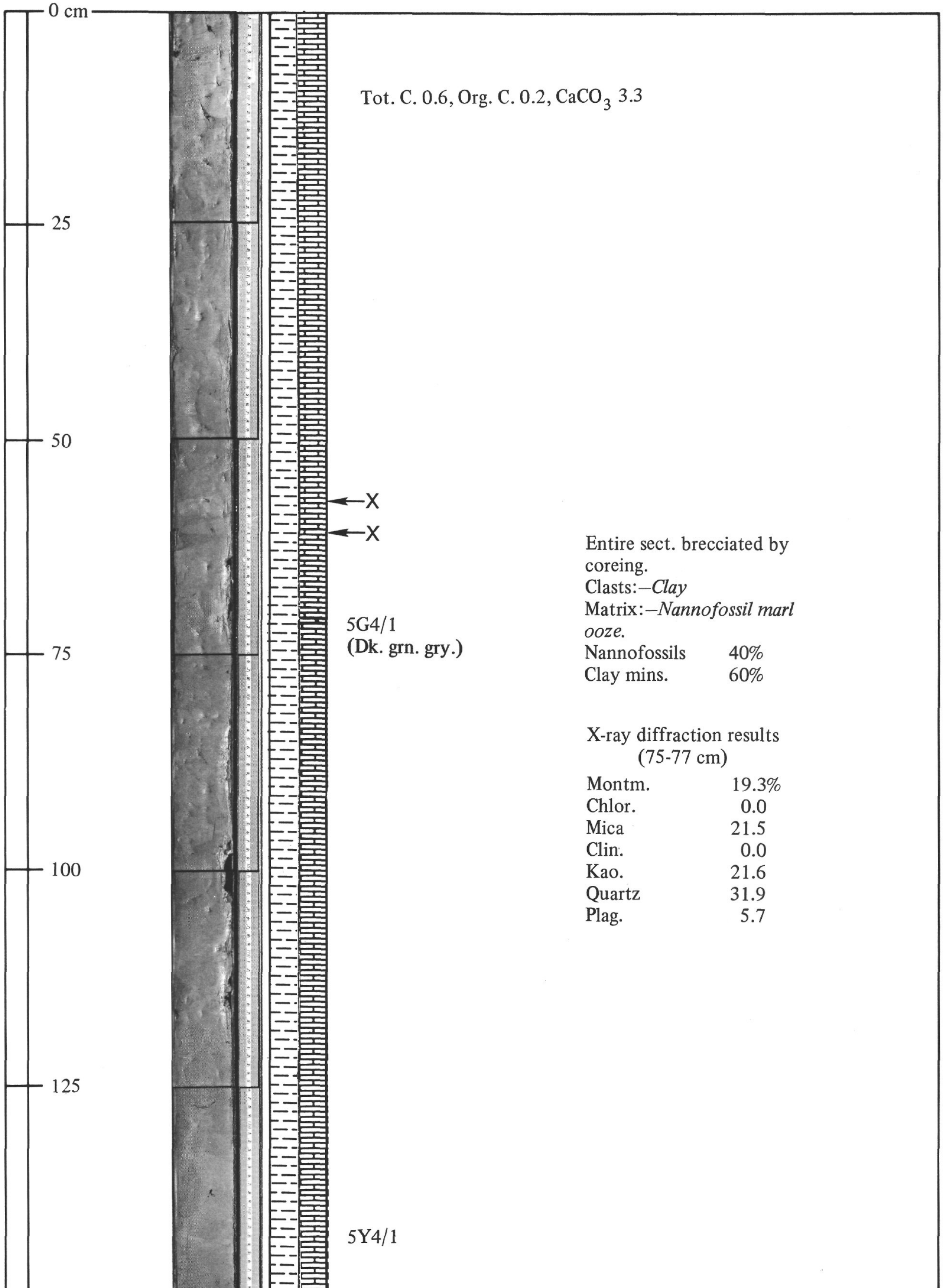


Figure 24. *Hole 9 Core 7 Section 3.*

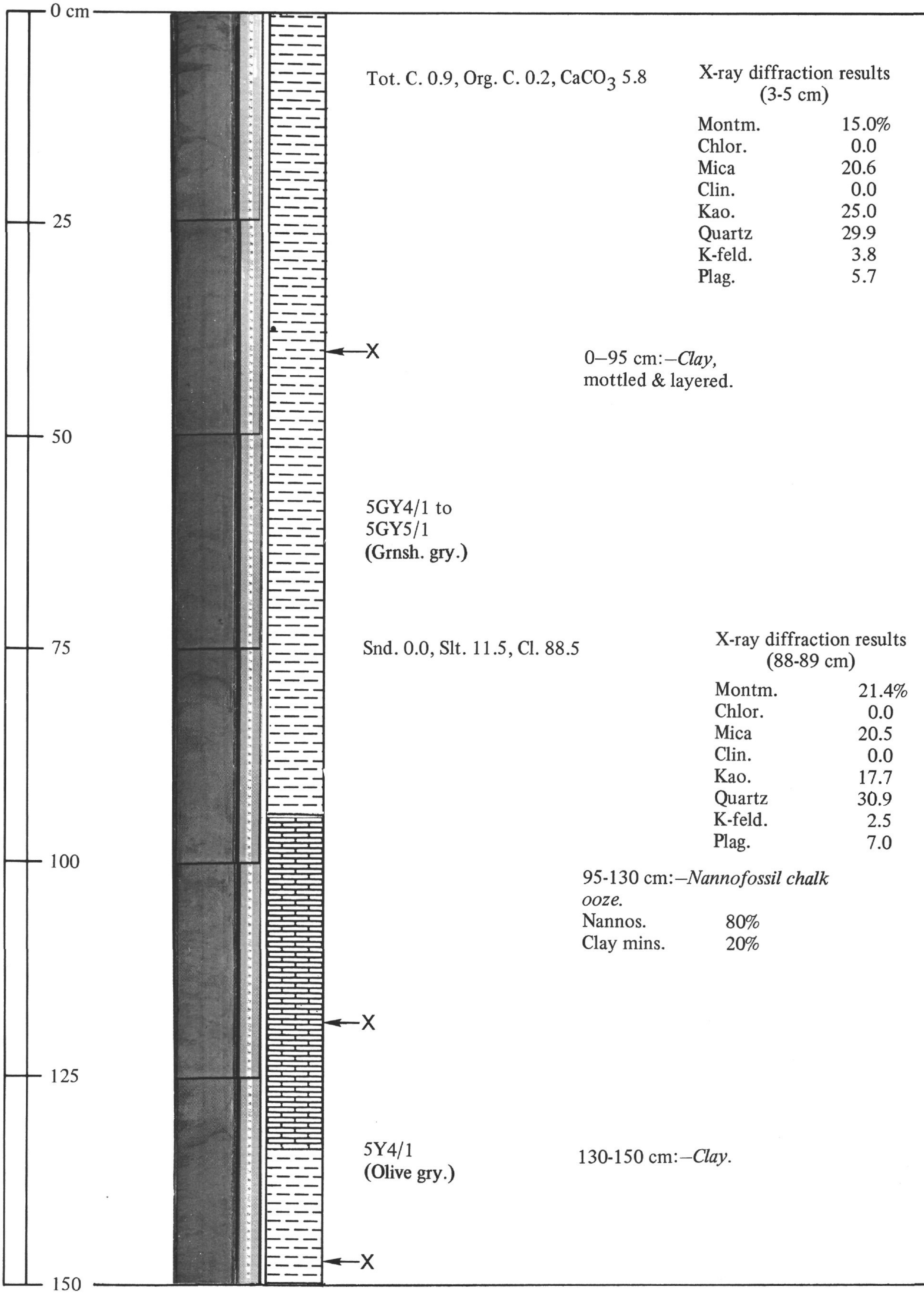


Figure 25. *Hole 9 Core 7 Section 4.*

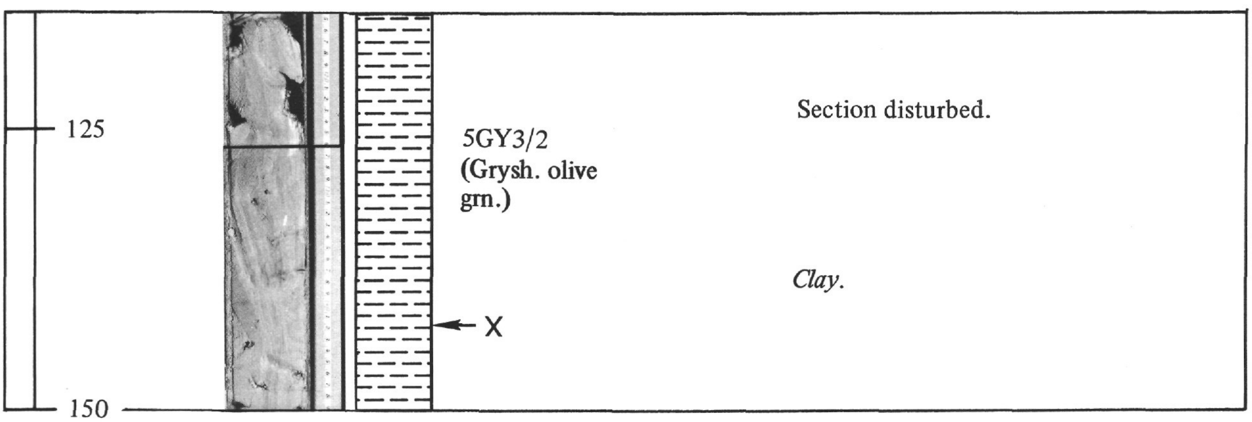
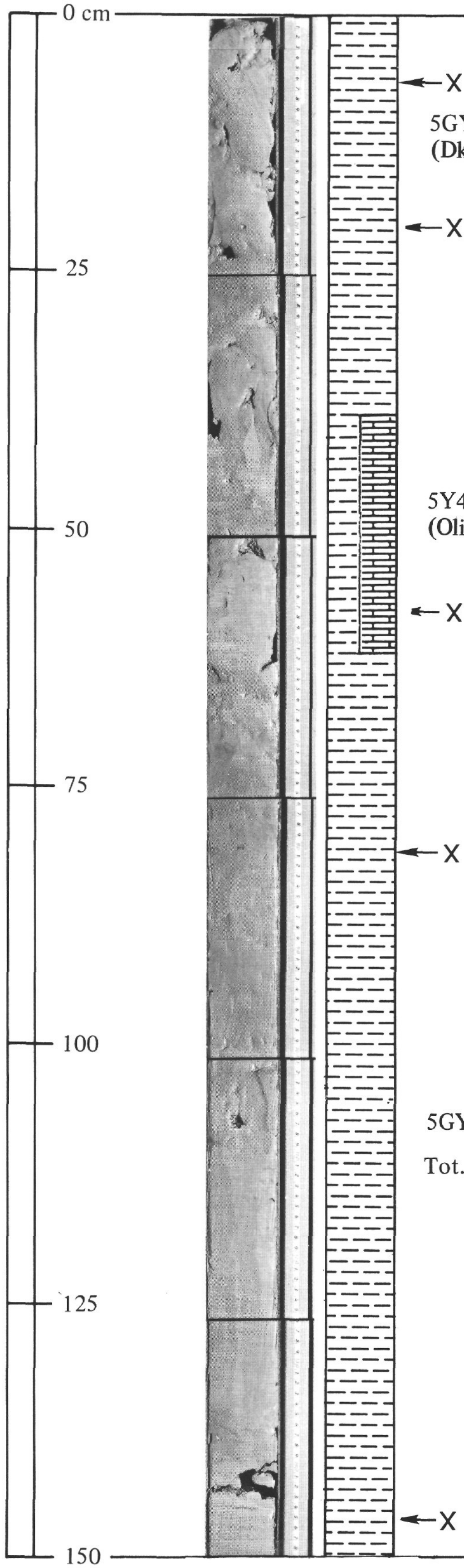


Figure 26. *Hole 9 Core 8 Section 1.*



5GY4/1
(Dk. grnsh. gry.)

5Y4/2
(Olive gry.)

5GY4/1

Tot. C. 0.6, Org. C. 0.3, $CaCO_3$ 2.5

Whole section badly disturbed.
0-38 & 61-150 cm:—
Clay, w/black streaks.

X-ray diffraction results
(16-18 cm)

Montm.	29.7%
Chlor.	0.0
Mica	15.6
Clin.	0.0
Kao.	20.5
Quartz	24.1
K-feld.	3.5
Plag.	6.6

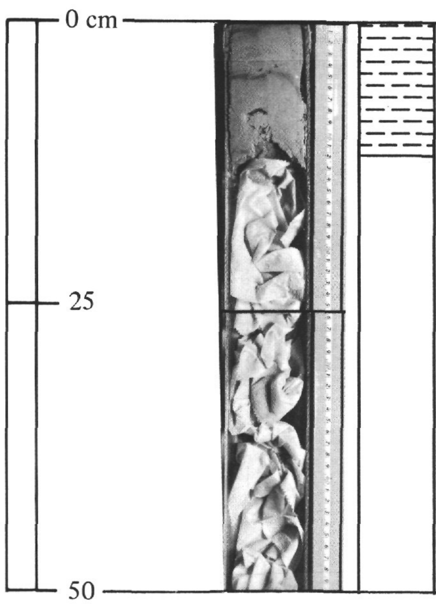
38-61 cm:—*Nannofossil ooze* between clay clasts

Nannos.	60%
Clay mins.	40%

X-ray diffraction results
(69-71 cm)

Montm.	25.2%
Chlor.	0.0
Mica	21.8
Clin.	0.0
Kao.	18.3
Quartz	31.2
Plag.	3.5

Figure 27. *Hole 9 Core 8 Section 2.*



Tot. C. 0.4, Org. C. 0.3, $CaCO_3$ 0.8
5GY4/1
(Dk. grnsh. gry.)

Clay, streaked with black.

X-ray diffraction results
(9-11 cm)

Montm.	34.3%
Chlor.	0.0
Mica	14.9
Clin.	0.0
Kao.	19.9
Quartz	24.1
K-feld.	3.35
Plag.	3.45

Figure 28. *Hole 9 Core 8 Section 3.*

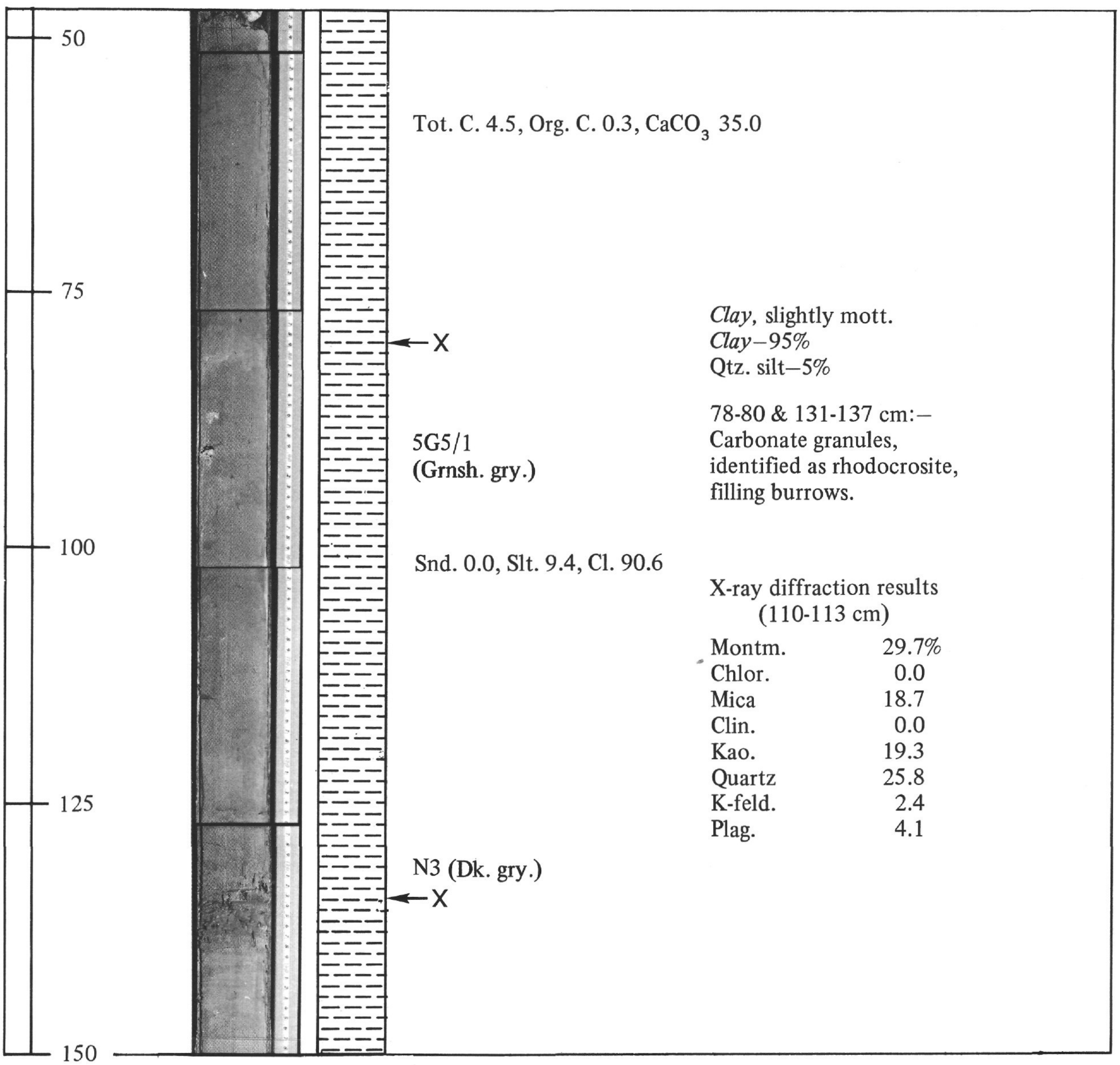
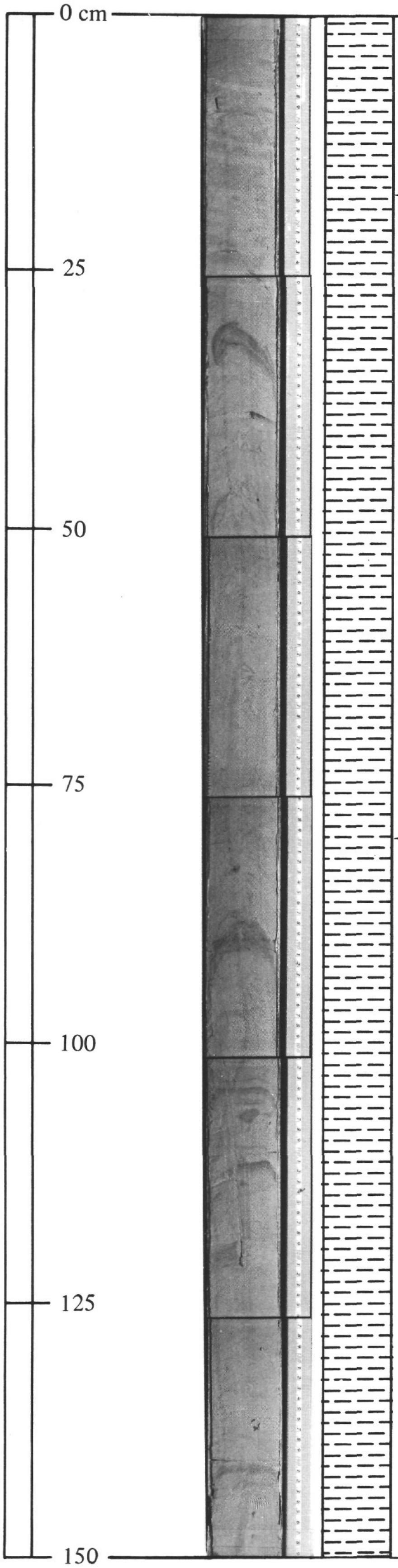


Figure 29. *Hole 9 Core 8 Section 4.*



Tot. C. 0.4, Org. C. 0.3, $CaCO_3$ 0.8

X-ray diffraction results
(6-8 cm)

Snd. 0.0, Slt. 11.1, Cl. 88.9

X

Montm.	32.5%
Chlor.	0.0
Mica	14.2
Clin.	0.0
Kao.	17.0
Quartz	27.1
K-feld.	3.2
Plag.	5.9

X

5GY4/1
(Dk. grnsh. gry.)

Clay, slightly mottled w/
small dk. gry. patches.

Small nodules.

Clay	100%

Bands of yell-brn.
staining throughout.
(10YR5/8 (m))

X

X-ray diffraction results
(70-72 cm)

Montm.	21.3%
Chlor.	0.0
Mica	19.0
Clin.	0.0
Kao.	17.9
Quartz	32.8
K-feld.	4.1
Plag.	4.9

Figure 30. *Hole 9 Core 8 Section 5.*

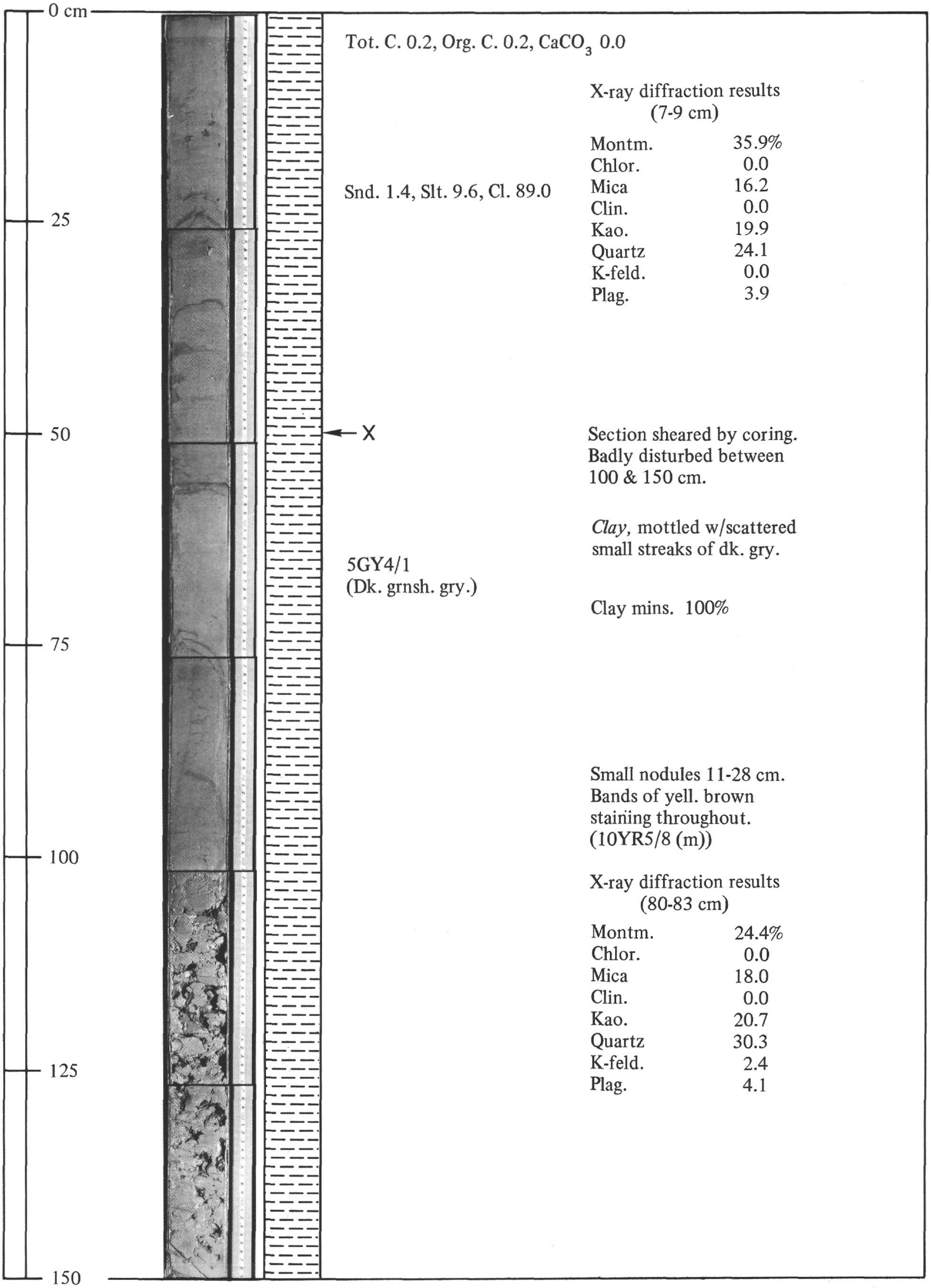


Figure 31. *Hole 9 Core 8 Section 6.*

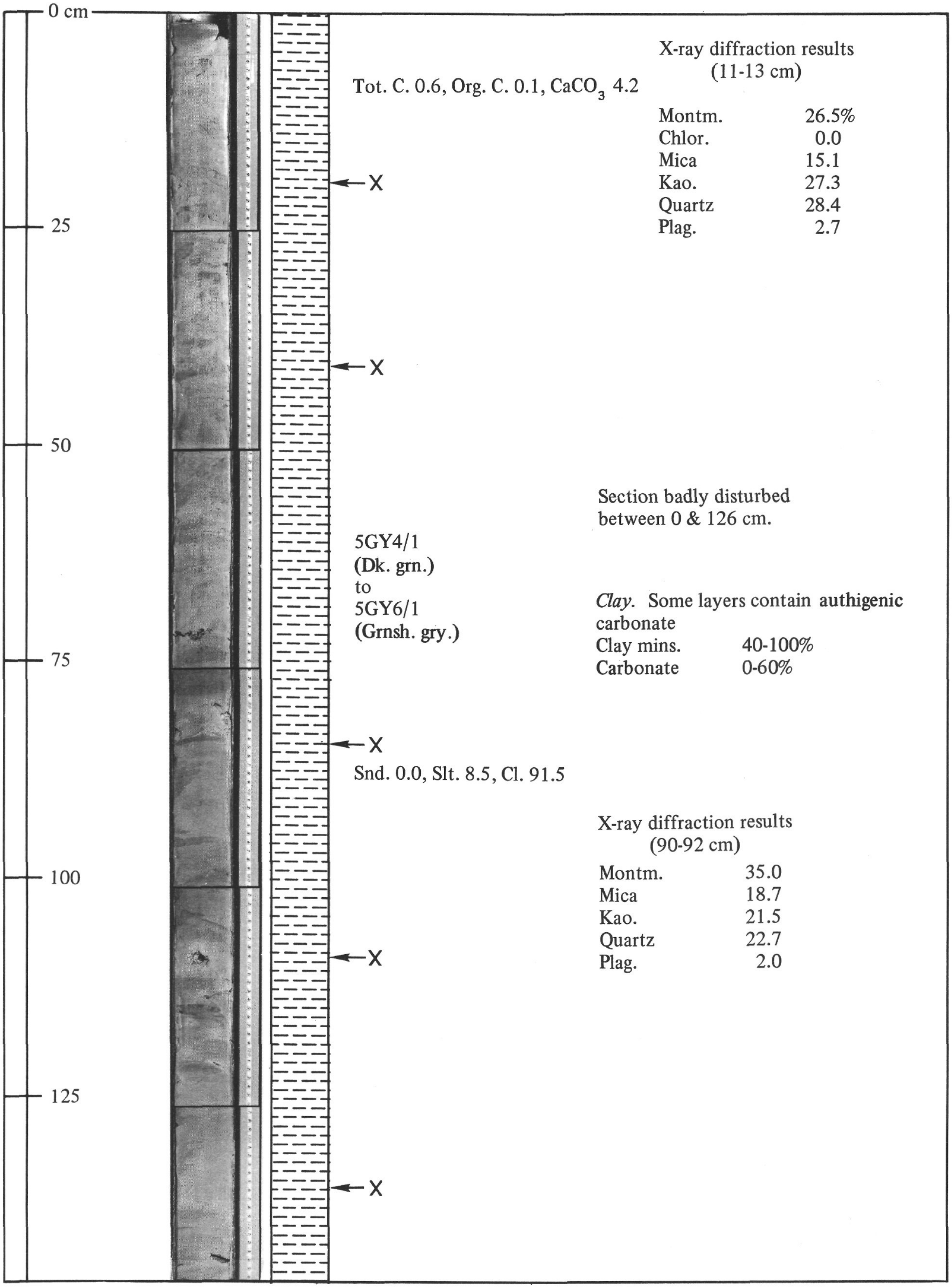


Figure 32. *Hole 9 Core 9 Section 1.*

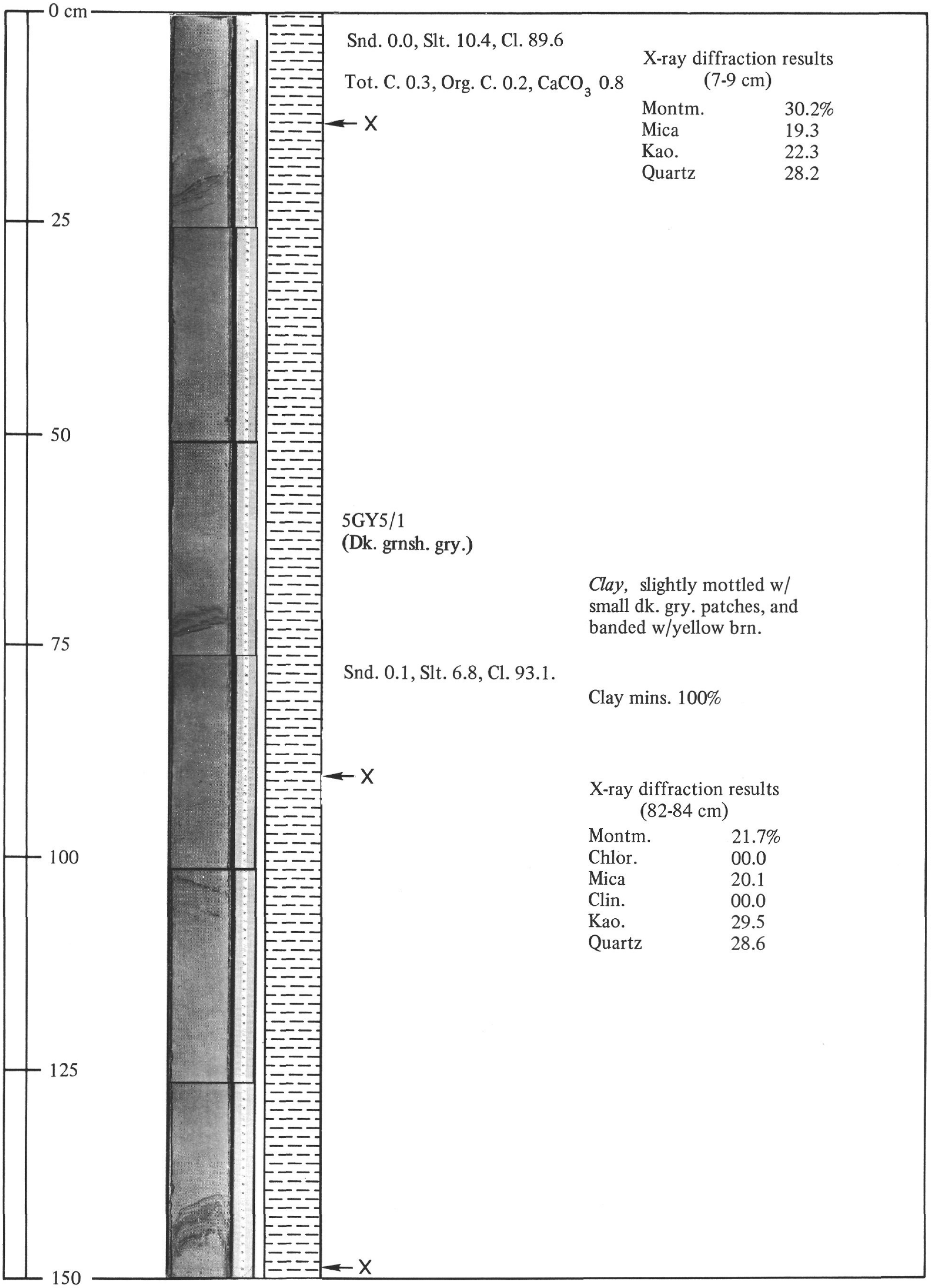


Figure 33. *Hole 9 Core 9 Section 2.*

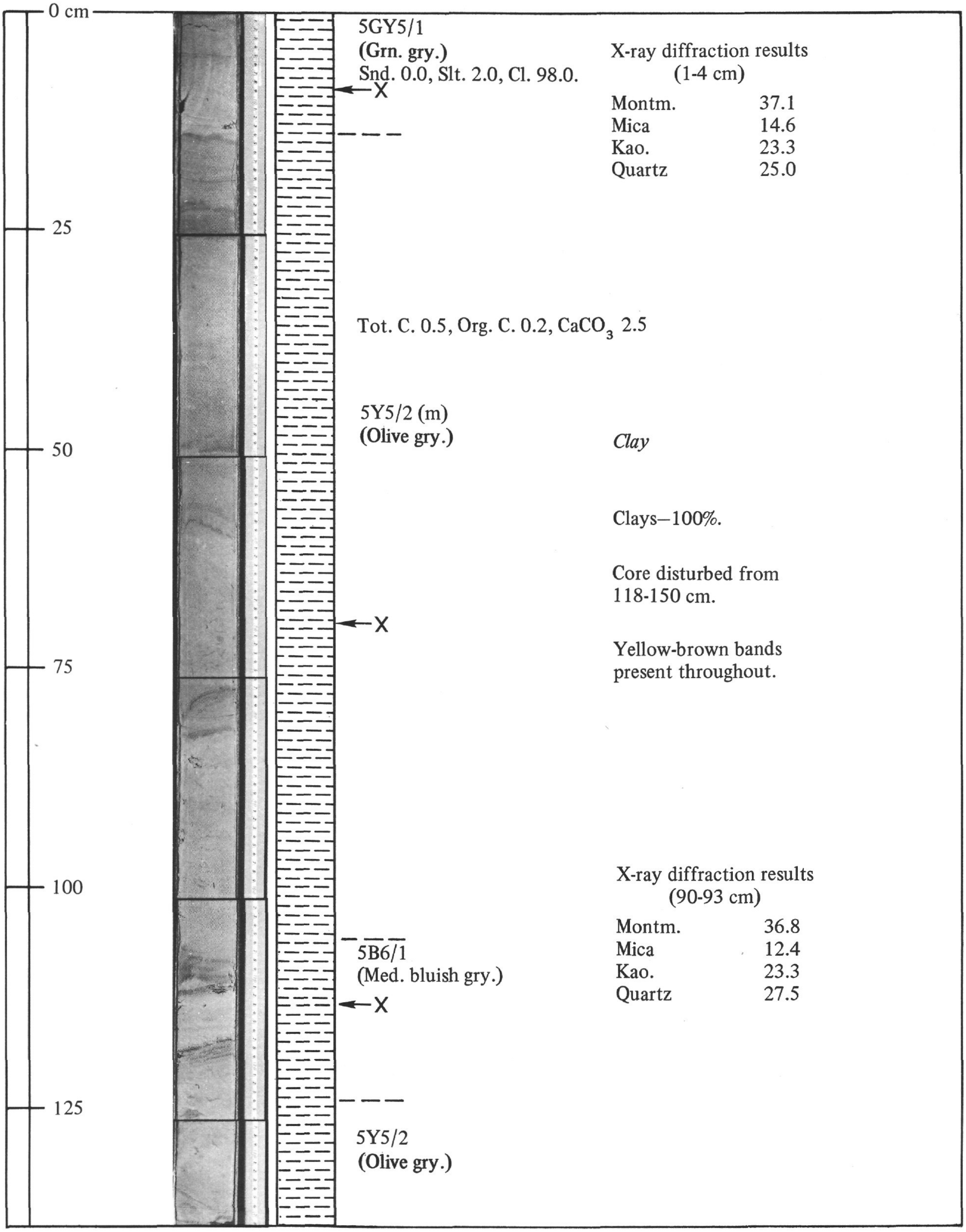


Figure 34. *Hole 9 Core 9 Section 3.*

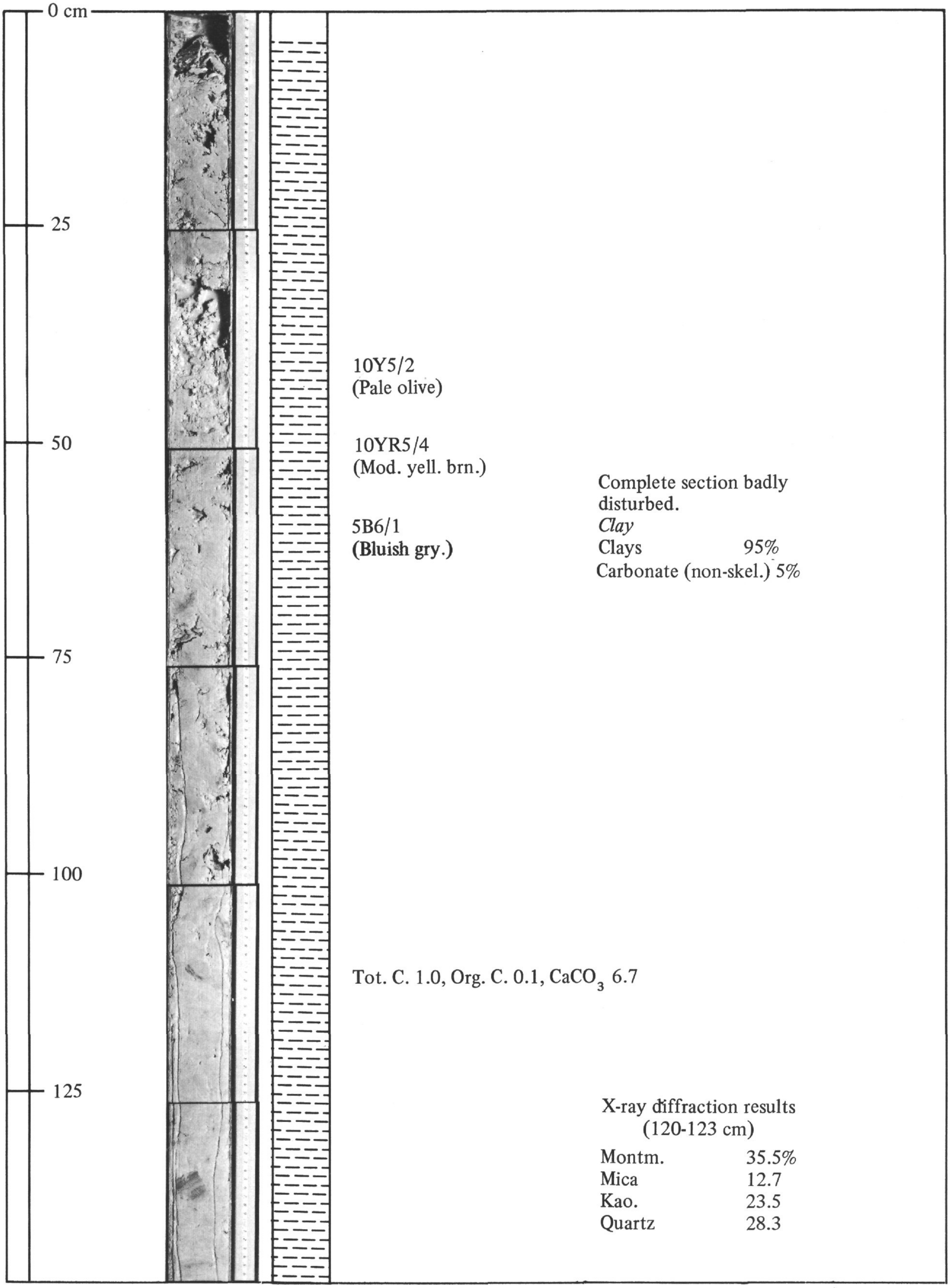


Figure 35. *Hole 9 Core 9 Section 6.*

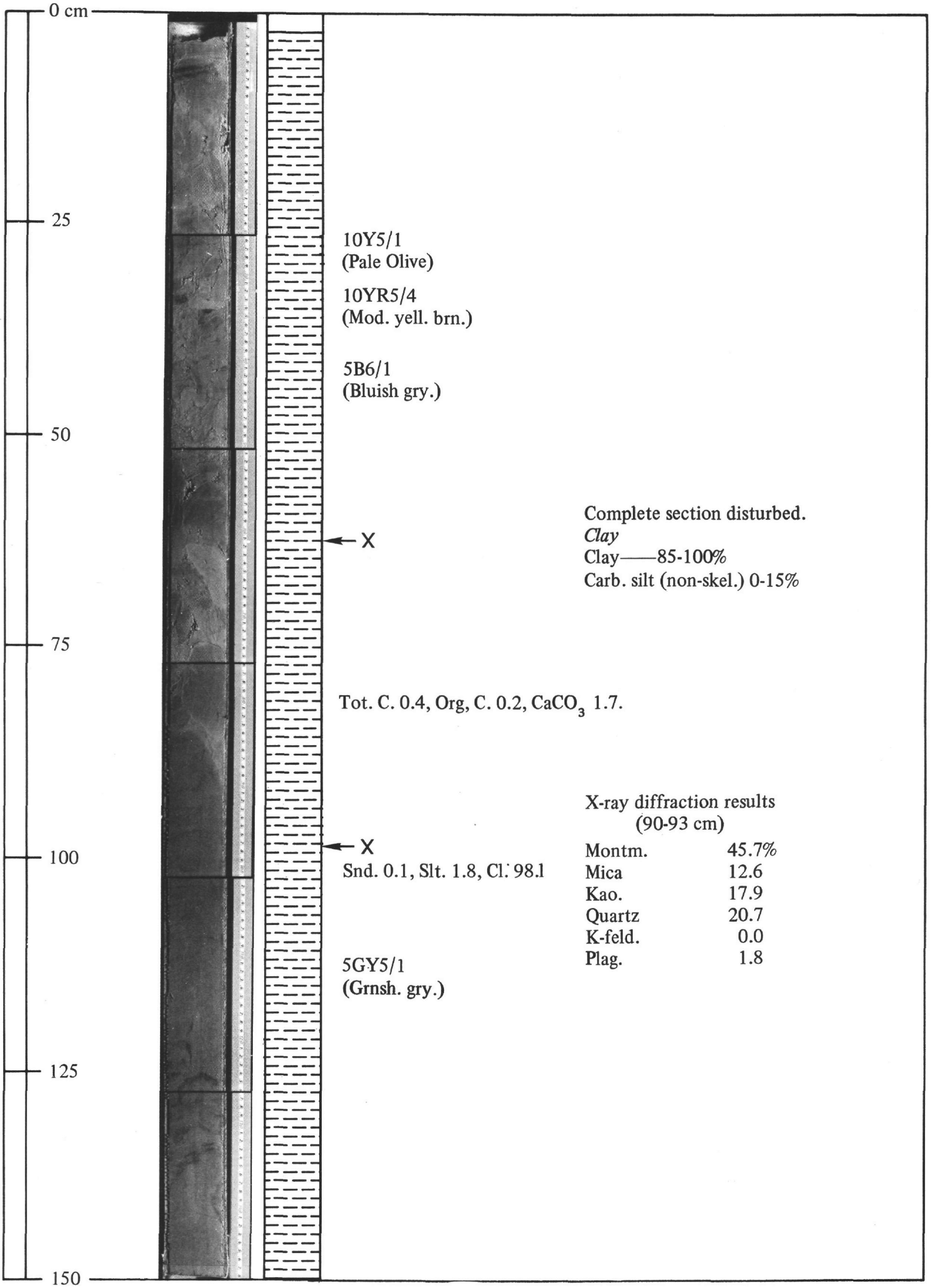


Figure 36. *Hole 9 Core 10 Section 1.*

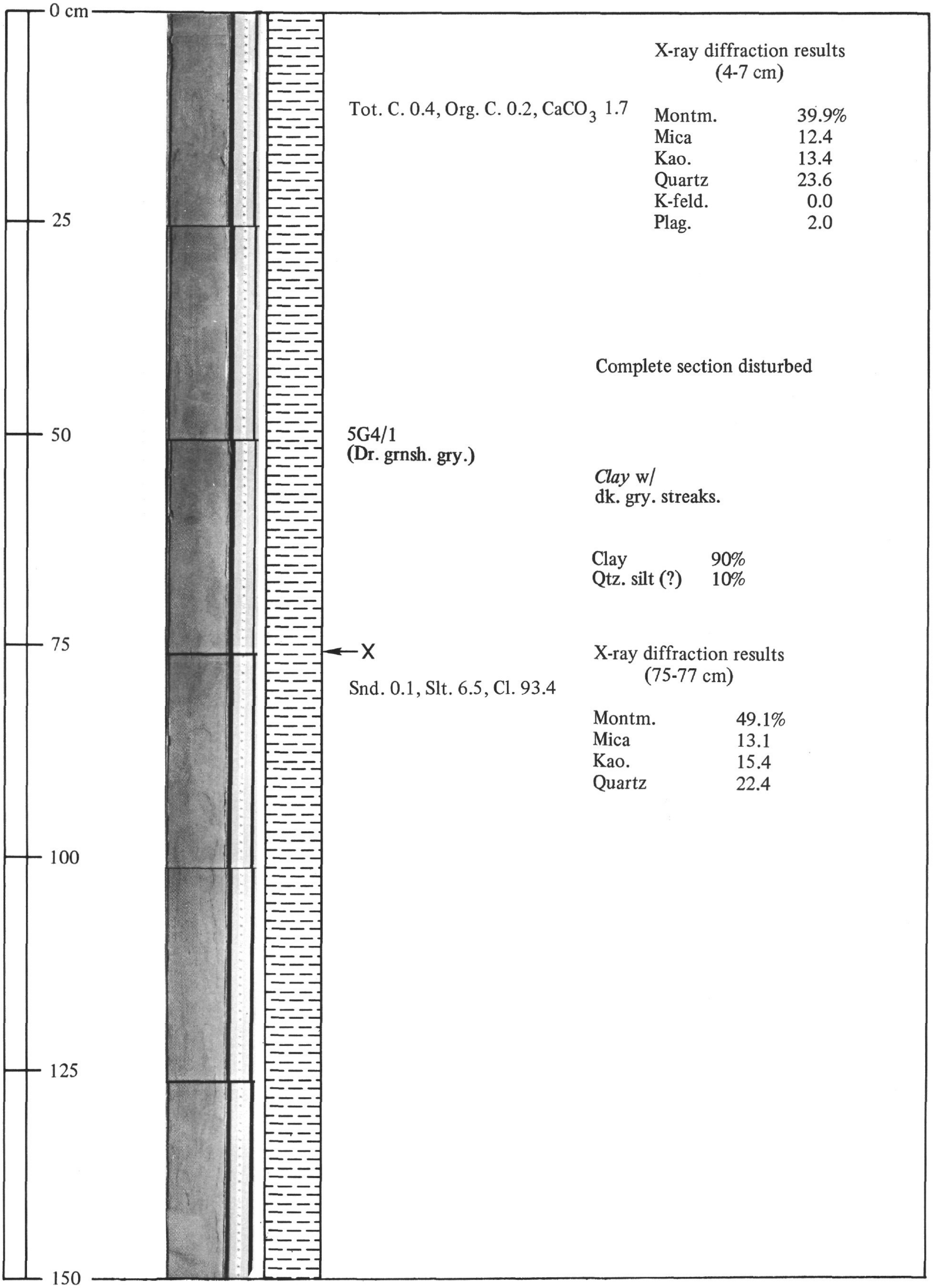


Figure 37. *Hole 9 Core 10 Section 2.*

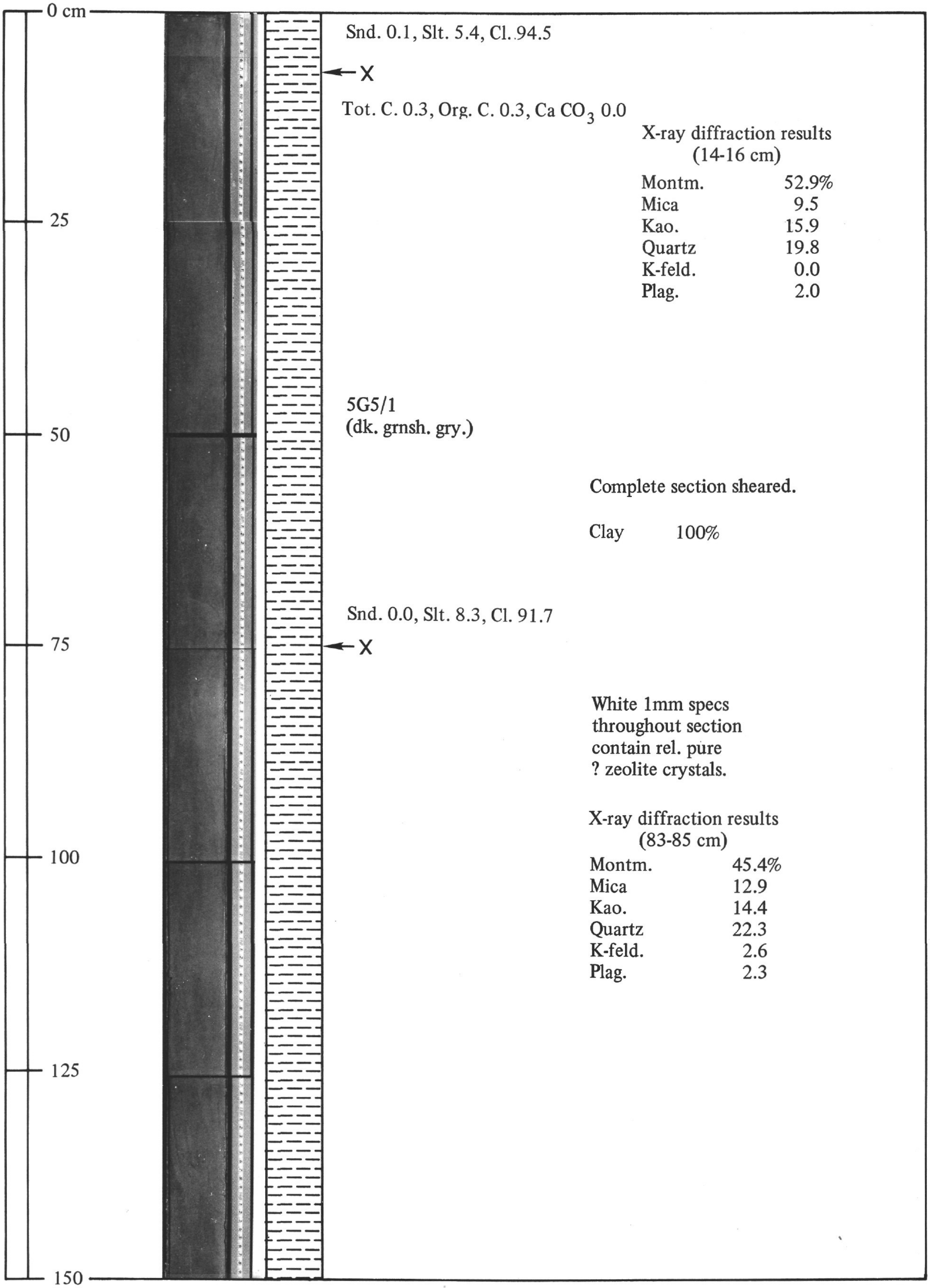
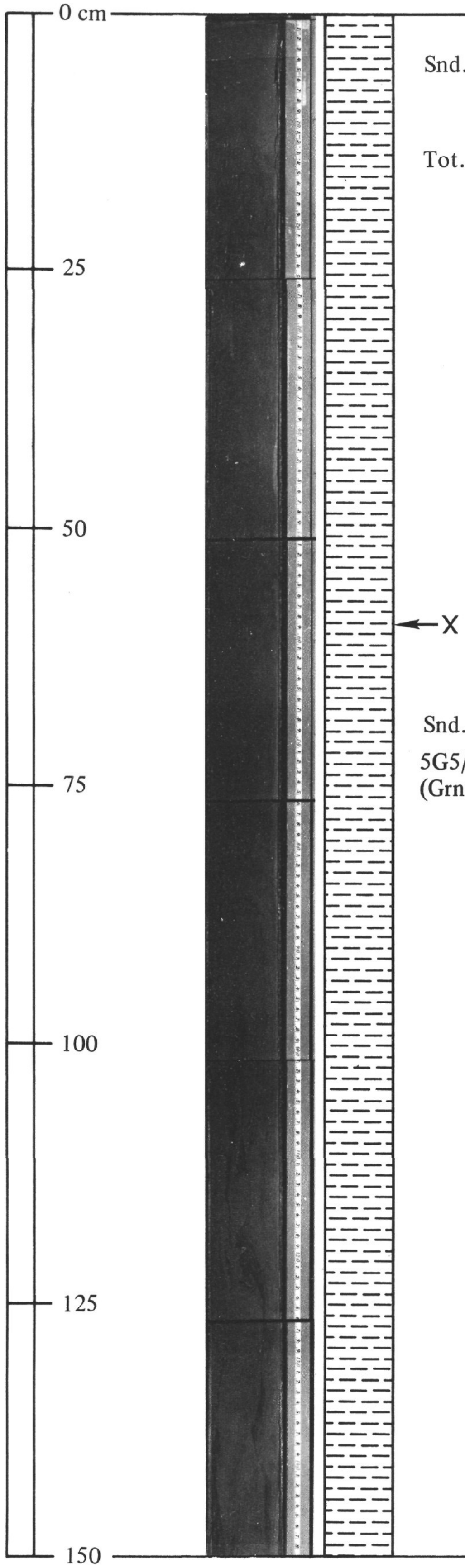


Figure 38. *Hole 9 Core 10 Sectoin 3.*



Snd. 0.0, Slt. 7.6, Cl. 92.4

Tot. C. 0.4, Org. C. 0.2, $CaCO_3$ 1.7

X-ray diffraction results
(10-12 cm)

Montm.	51.2%
Mica	13.6
Kao.	17.6
Quartz	17.6

Section disturbed.

Clay.
Dark gry. streaks.

Clay	100%

Snd. 0.0, Slt. 7.2, Cl. 92.8.

5G5/1
(Grnsh. gry.)

X-ray diffraction results
(72-74 cm)

Montm.	45.1%
Mica	9.8
Kao.	18.3
Quartz	26.8

White 1-2 mm specs throughout section contain pure ? zeolite crystals.

Figure 39. *Hole 9 Core 10 Section 4.*

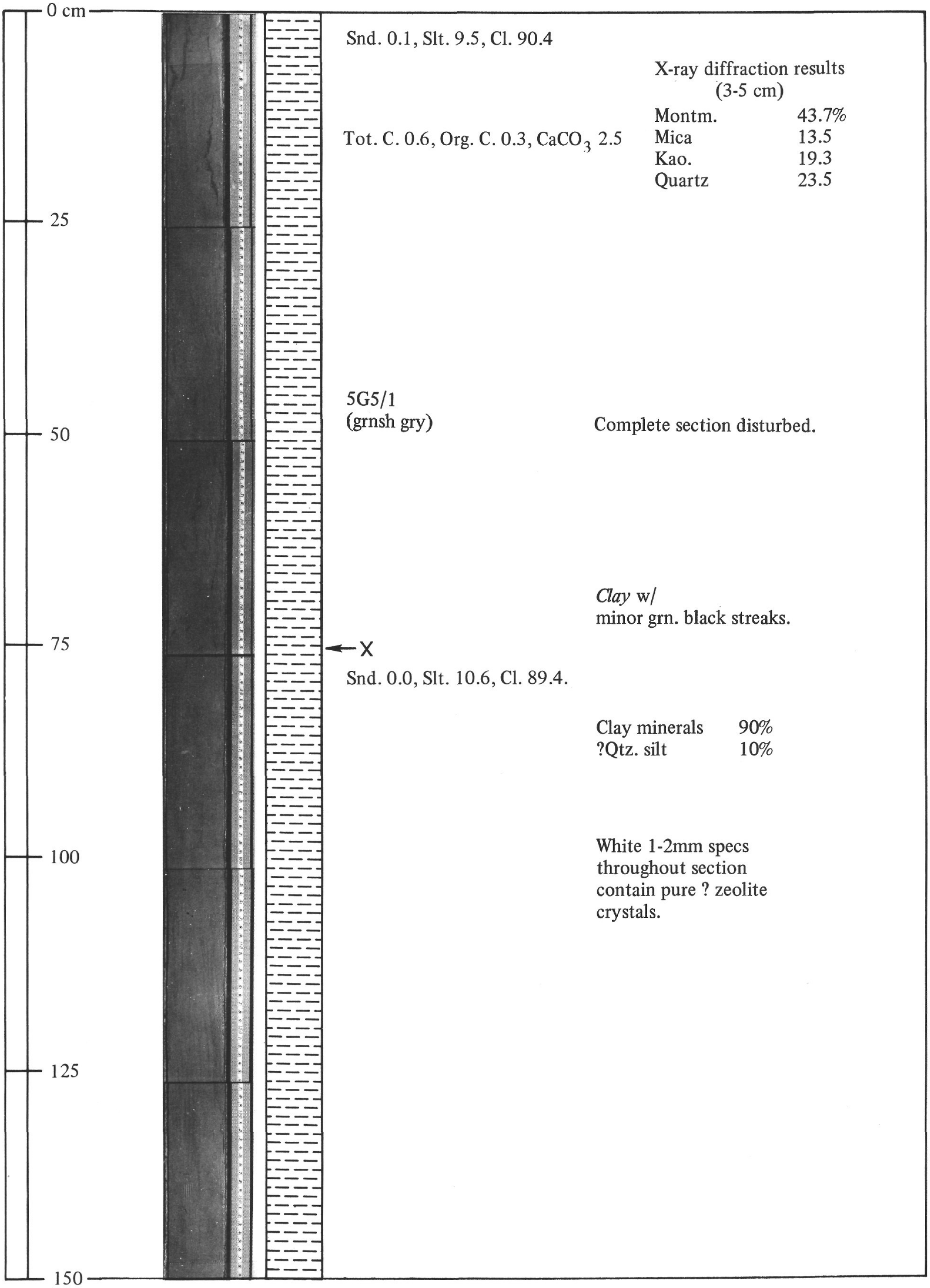


Figure 40. *Hole 9 Core 10 Section 5.*

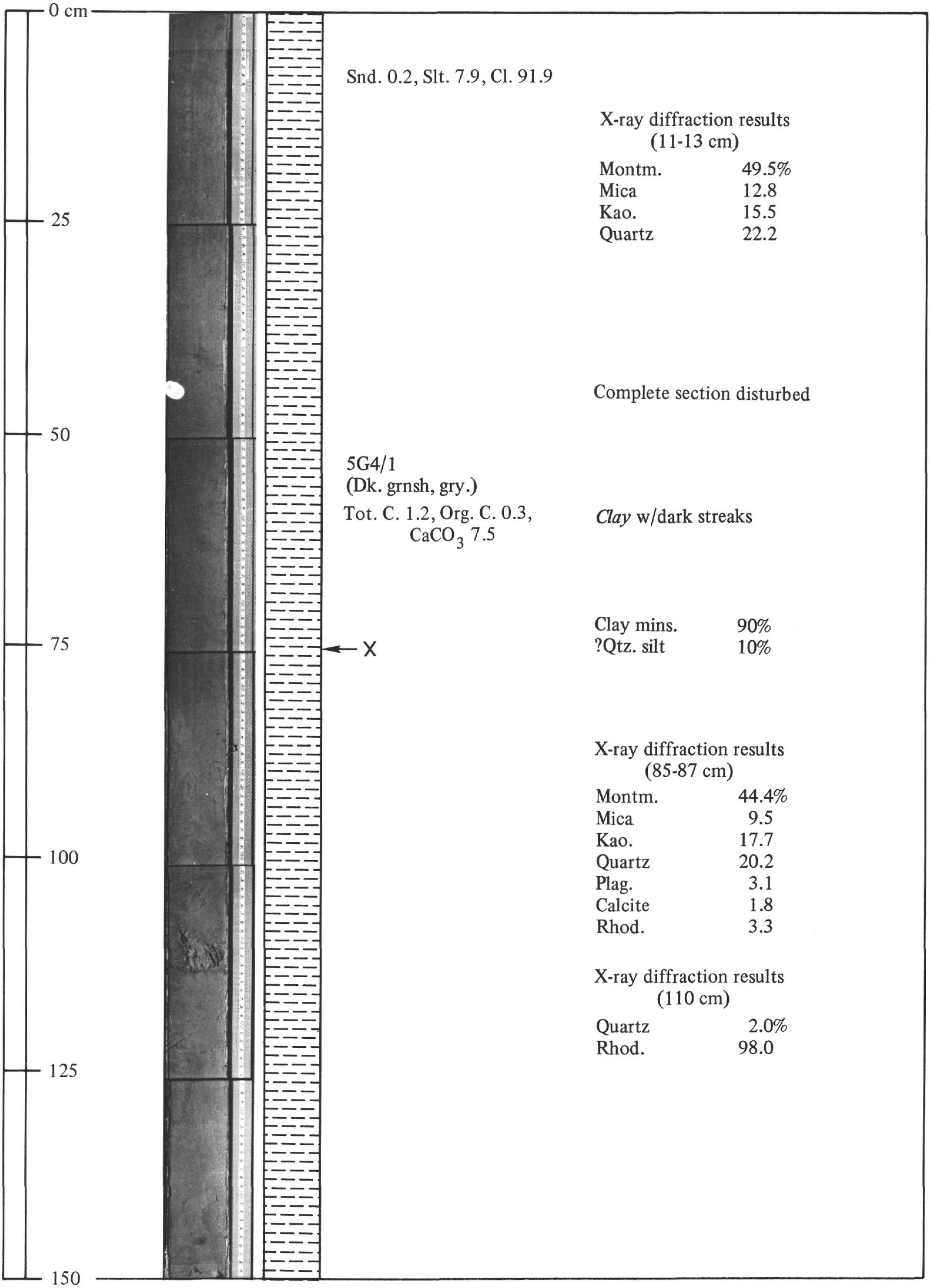


Figure 41. *Hole 9 Core 10 Section 6.*

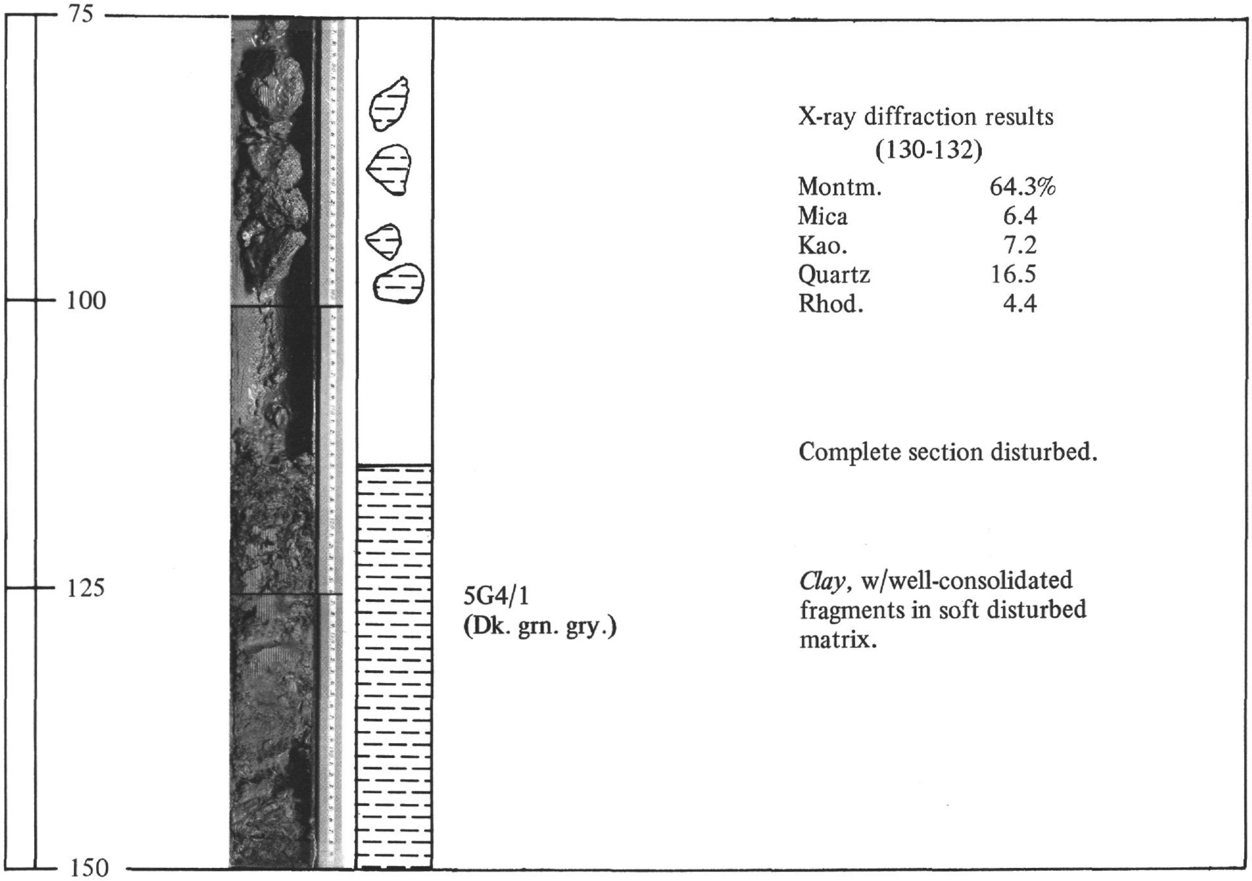


Figure 42. *Hole 9 Core 11 Section 1.*

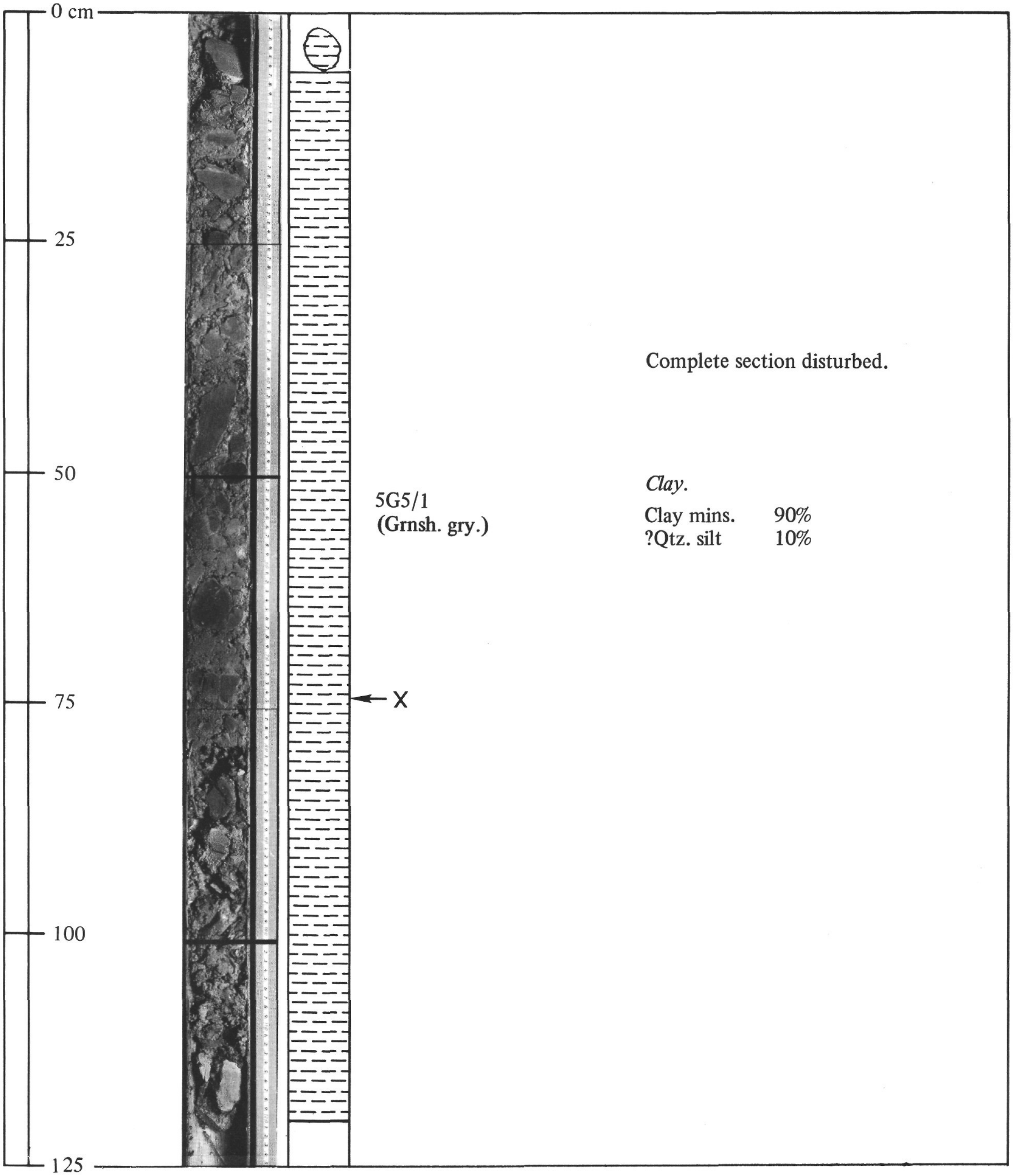


Figure 43. *Hole 9 Core 12 Section 1.*

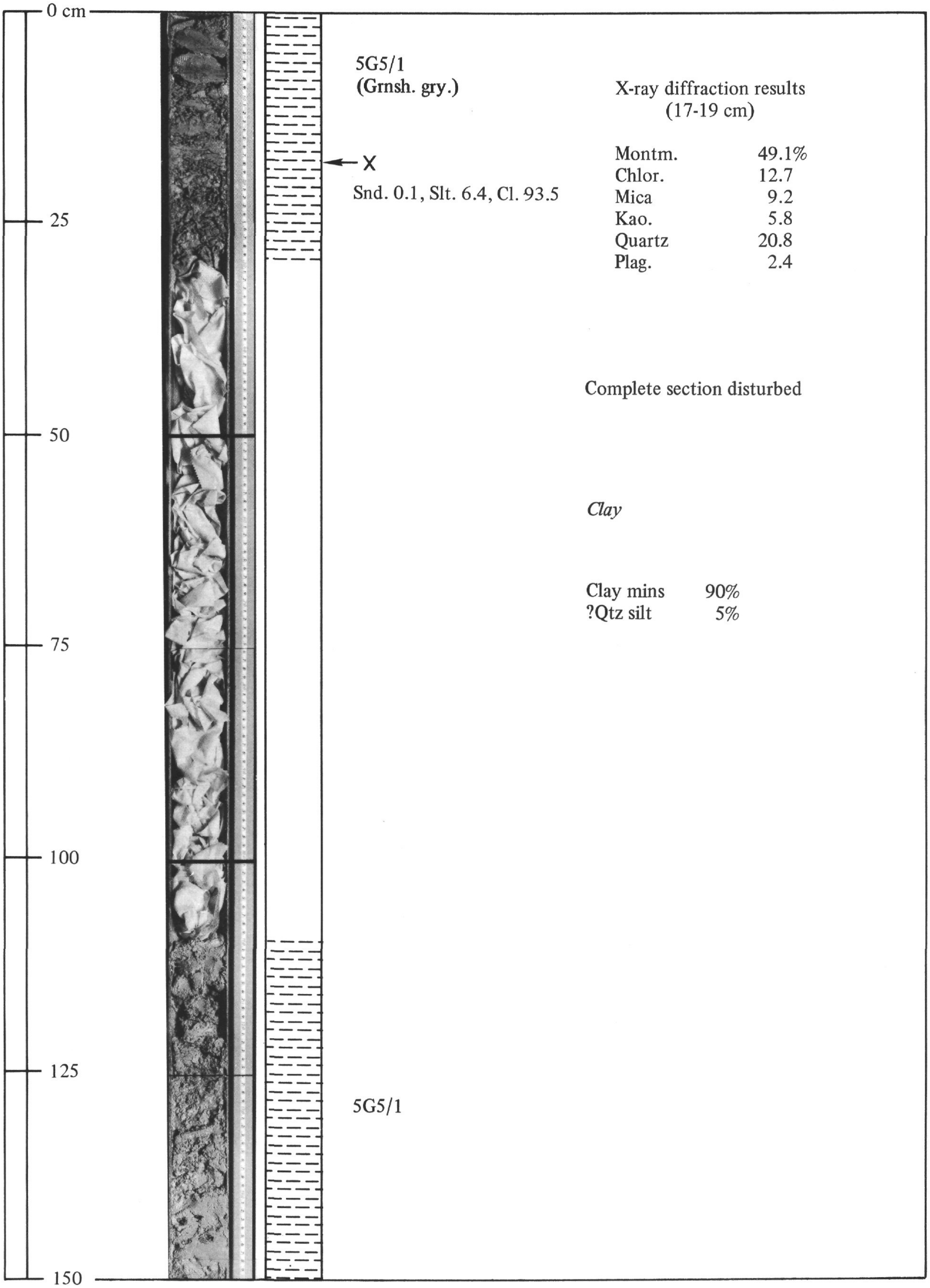


Figure 44. *Hole 9 Core 12 Section 5.*

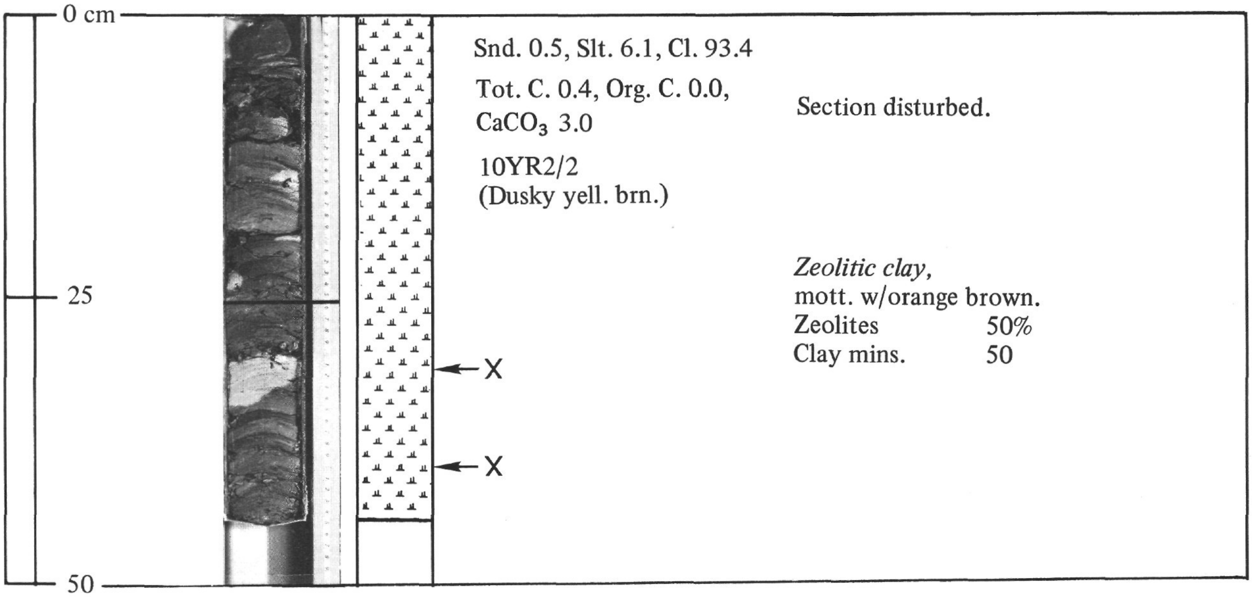


Figure 45. *Hole 9A Core 1 Section 1.*

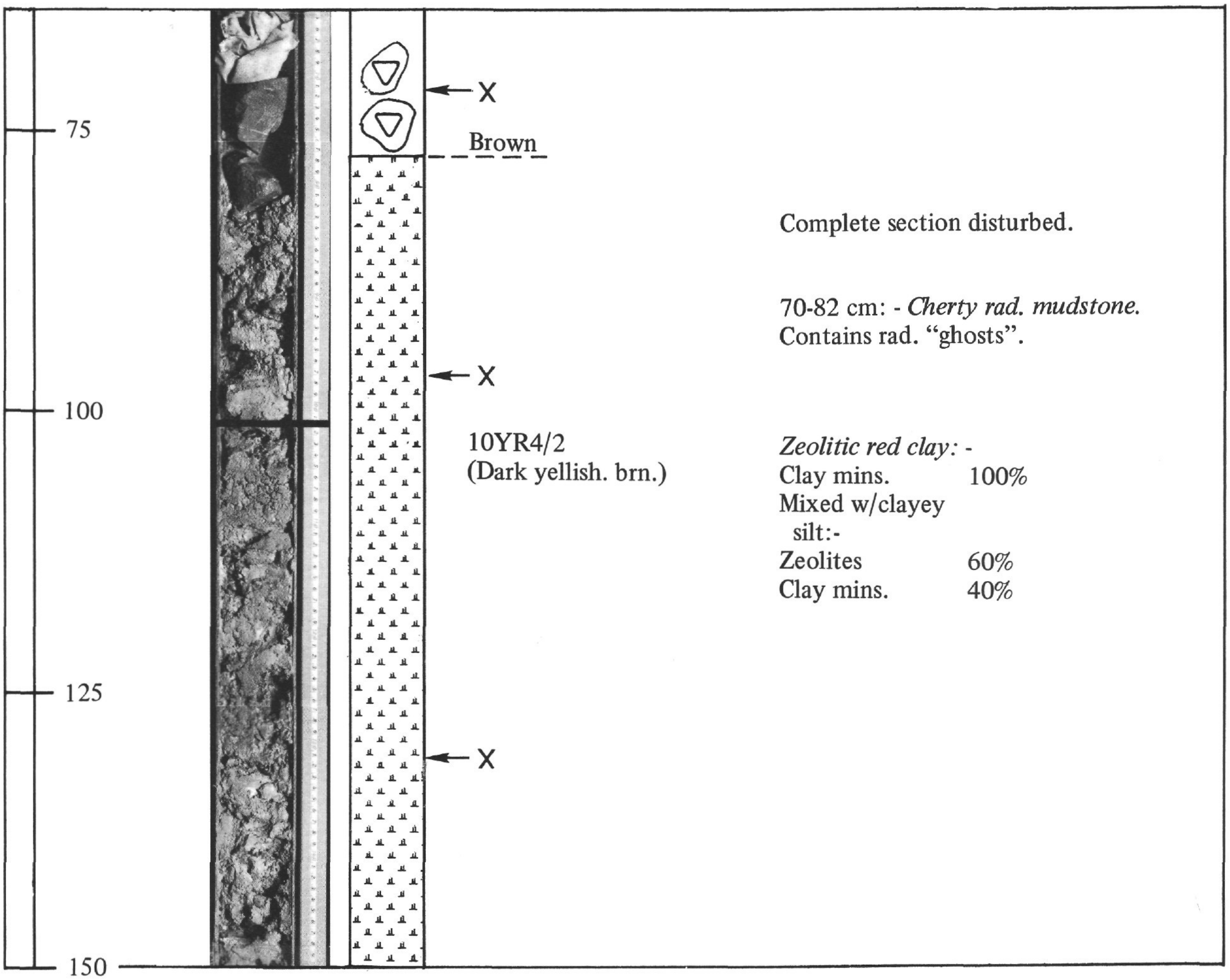


Figure 46. *Hole 9A Core 1 Section 4.*

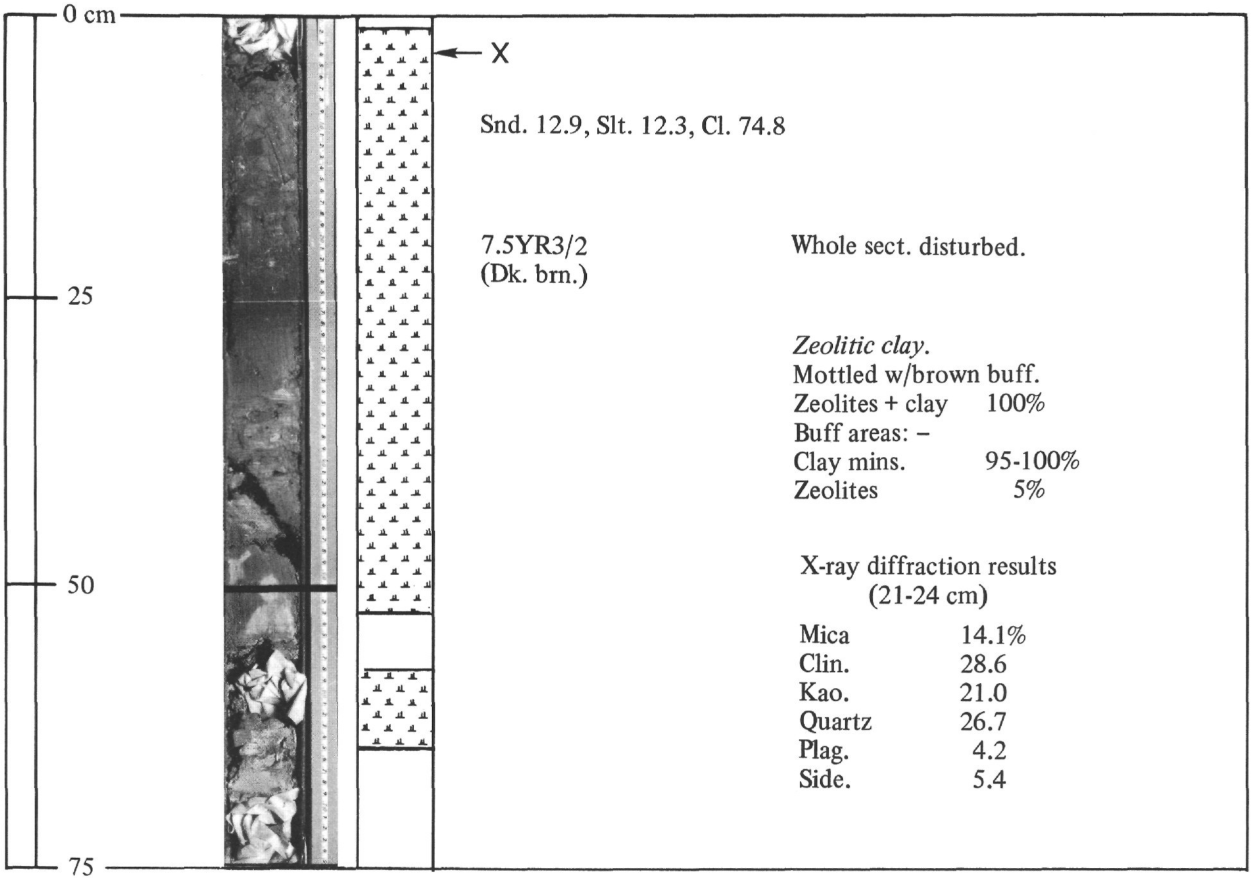


Figure 47. *Hole 9A Core 1 Section 5.*

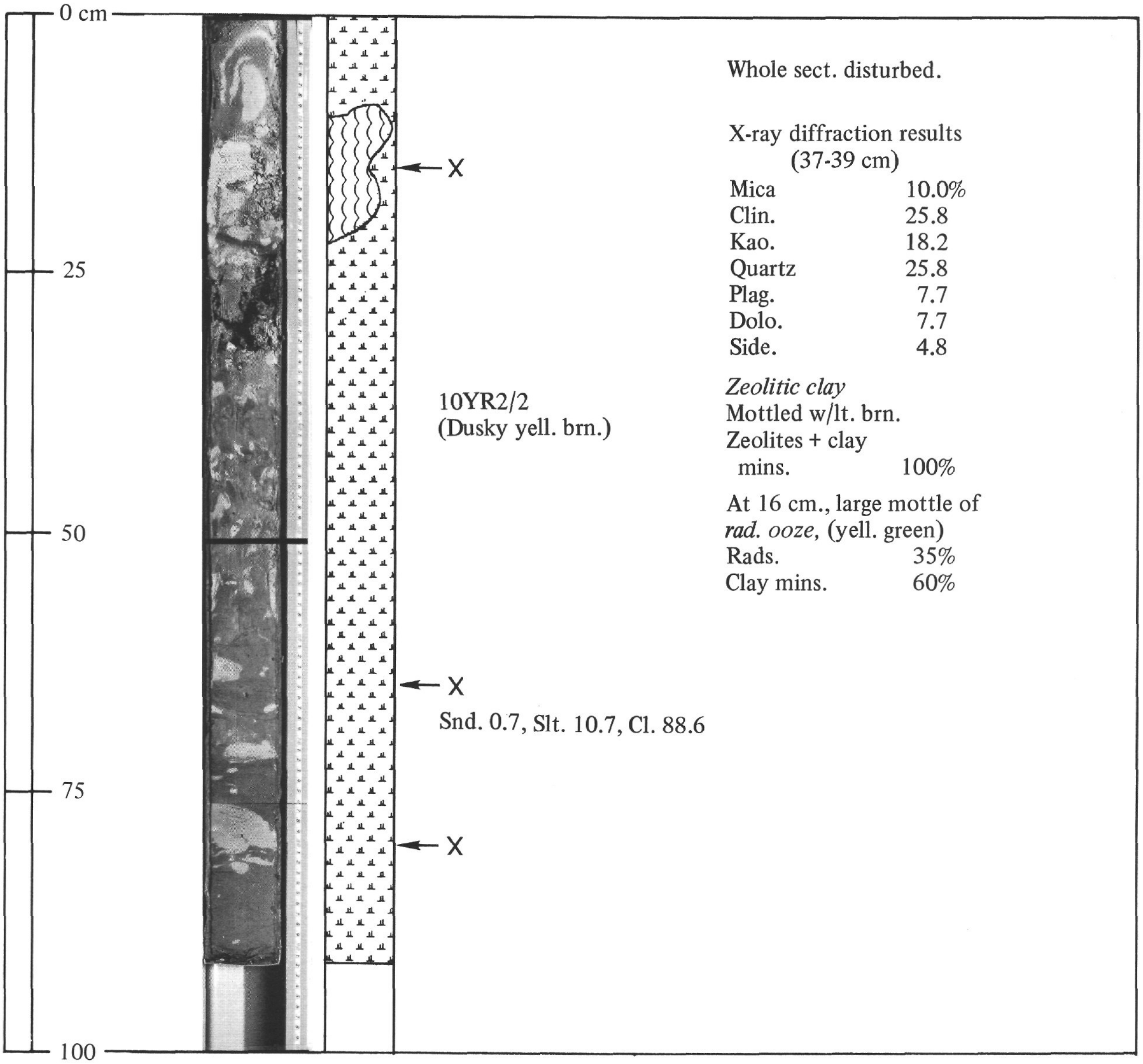


Figure 48. *Hole 9A Core 1 Section 6.*

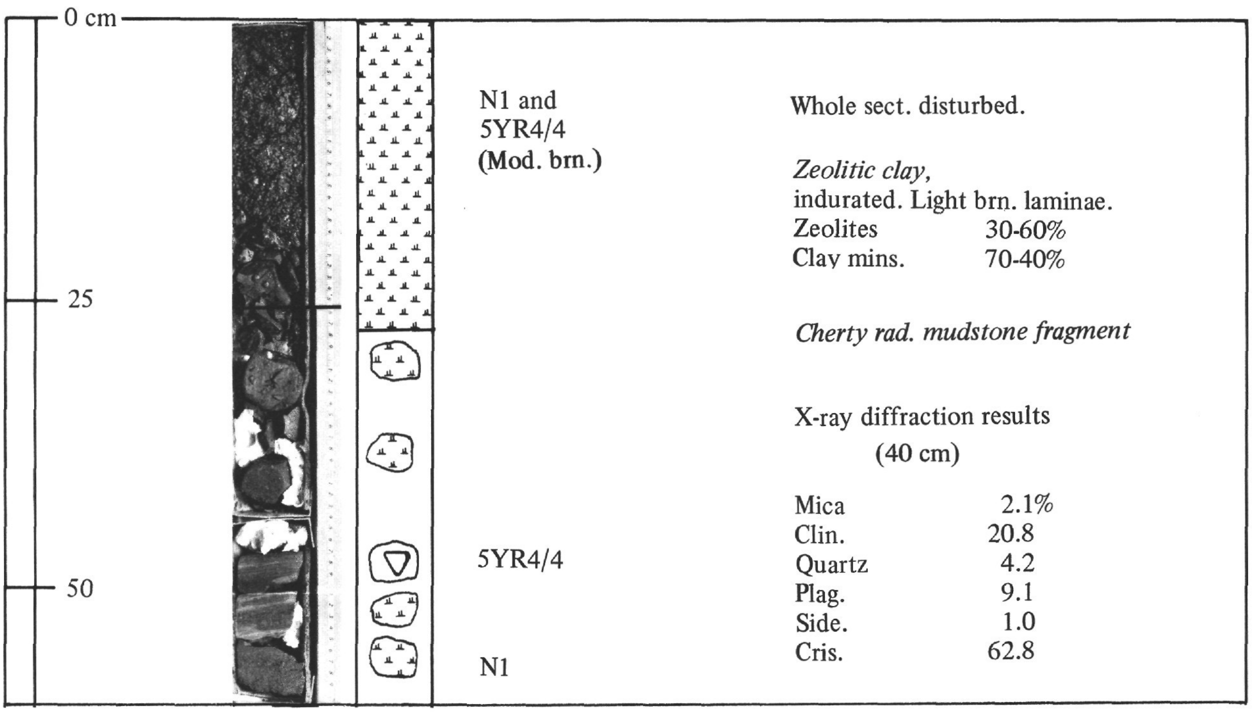
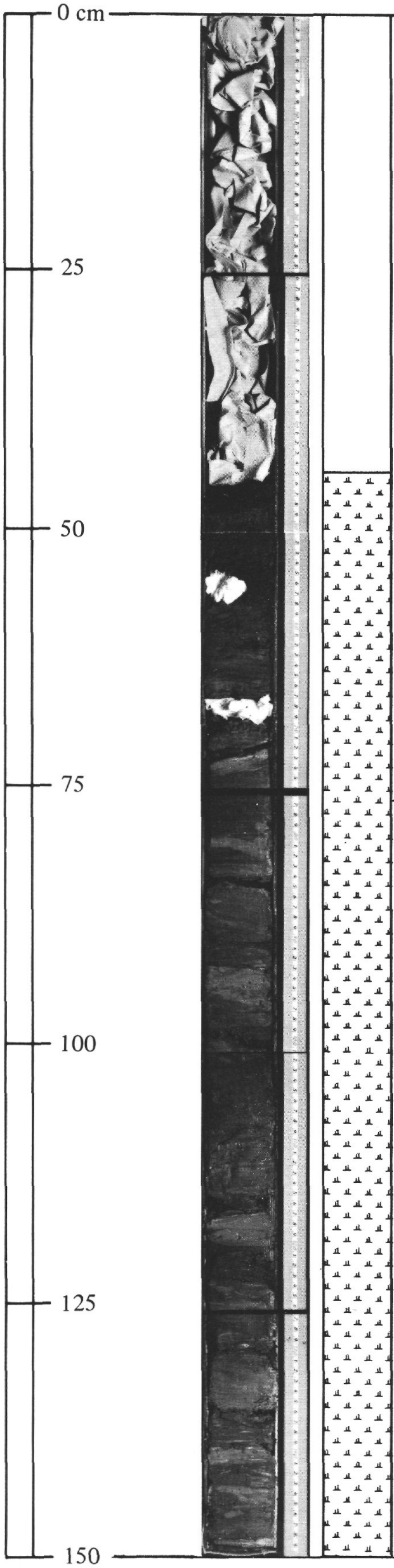


Figure 49. *Hole 9A Core 2 Section 1.*



Sect. somewhat disrupted.

Snd. 0.5, Slt. 18.8,
Cl. 80.7

10YR3/2
(V. dk. grysh. brn.)

Zeolitic clay, with dark brn. layers.

Clay mins.	80%
Zeolites	20%

X-ray diffraction results
(82-84 cm)

Mica	5.6%
Clin.	22.8
Quartz	7.7
K-feld.	2.8
Plag.	2.9
Calcite	2.6
Side.	1.4
Cris.	54.2

X-ray diffraction results
(143-144 cm)

Mica	3.7%
Clin.	26.2
Kao.	6.6
Quartz	6.6
K-feld.	2.4
Plag.	1.9
Side.	1.0
Cris.	56.5

Figure 50. *Hole 9A Core 3 Section 1.*

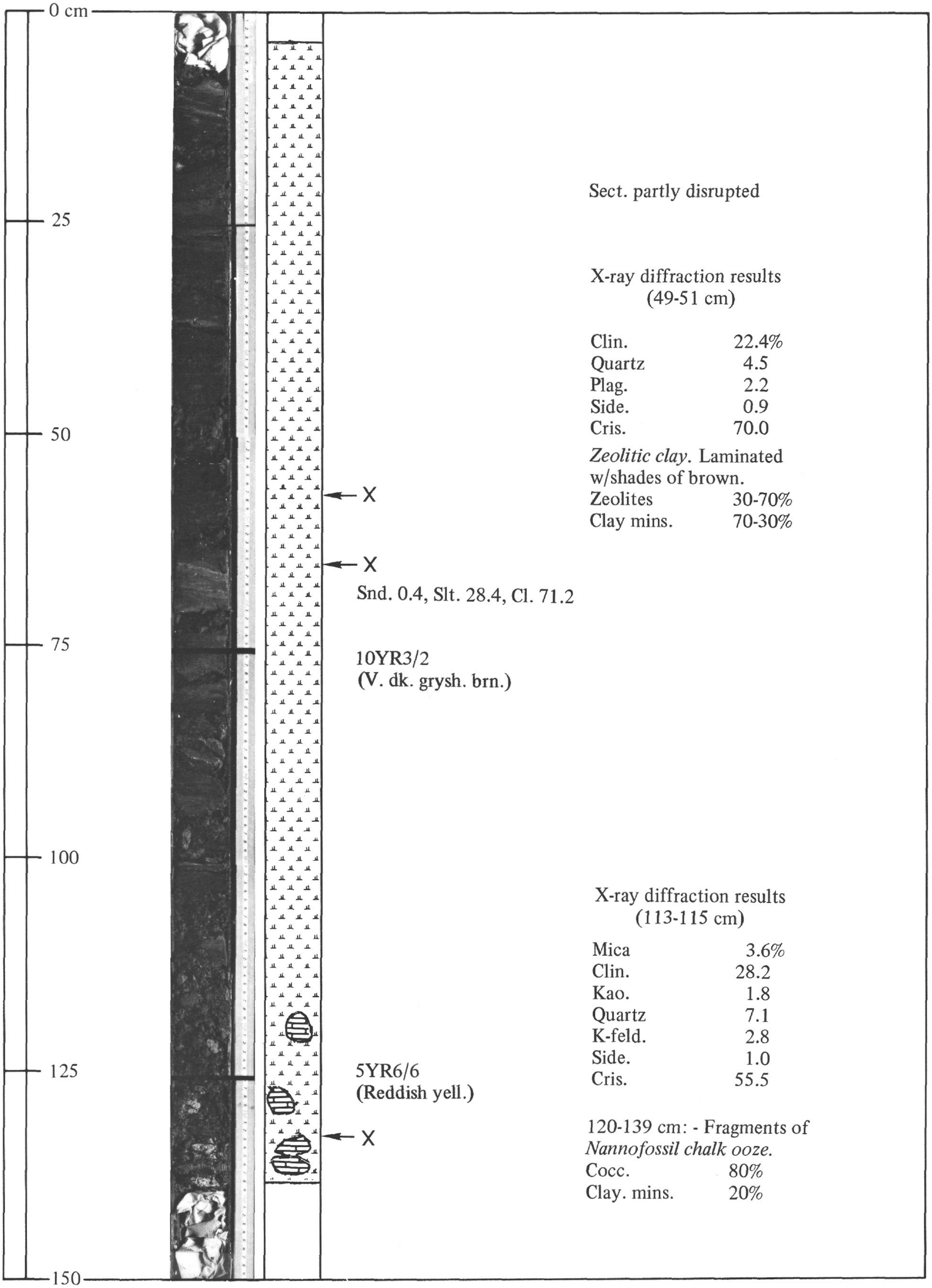
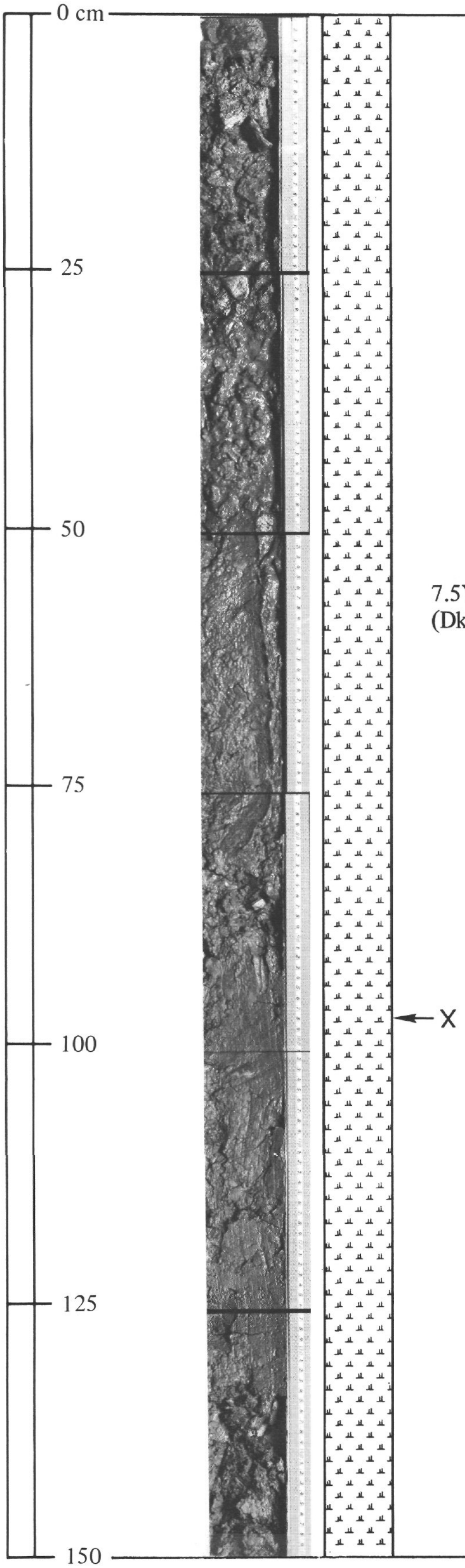


Figure 51. *Hole 9A Core 3 Section 2.*



7.5YR3/2
(Dk. brn.)

X-ray diffraction results
(14-18 cm)

Mica	5.3%
Clin.	42.9
Kao.	2.4
Quartz	10.1
K-feld.	3.5
Plag.	3.0
Rhod.	1.9
Side.	1.9
Cris.	29.0

Whole sect. disturbed.

Zeolitic clay. Semi-indurated in part.

Variecolored "clasts" present: green, orange-brn. and red-brn.

Figure 52. *Hole 9A Core 3 Section 3.*

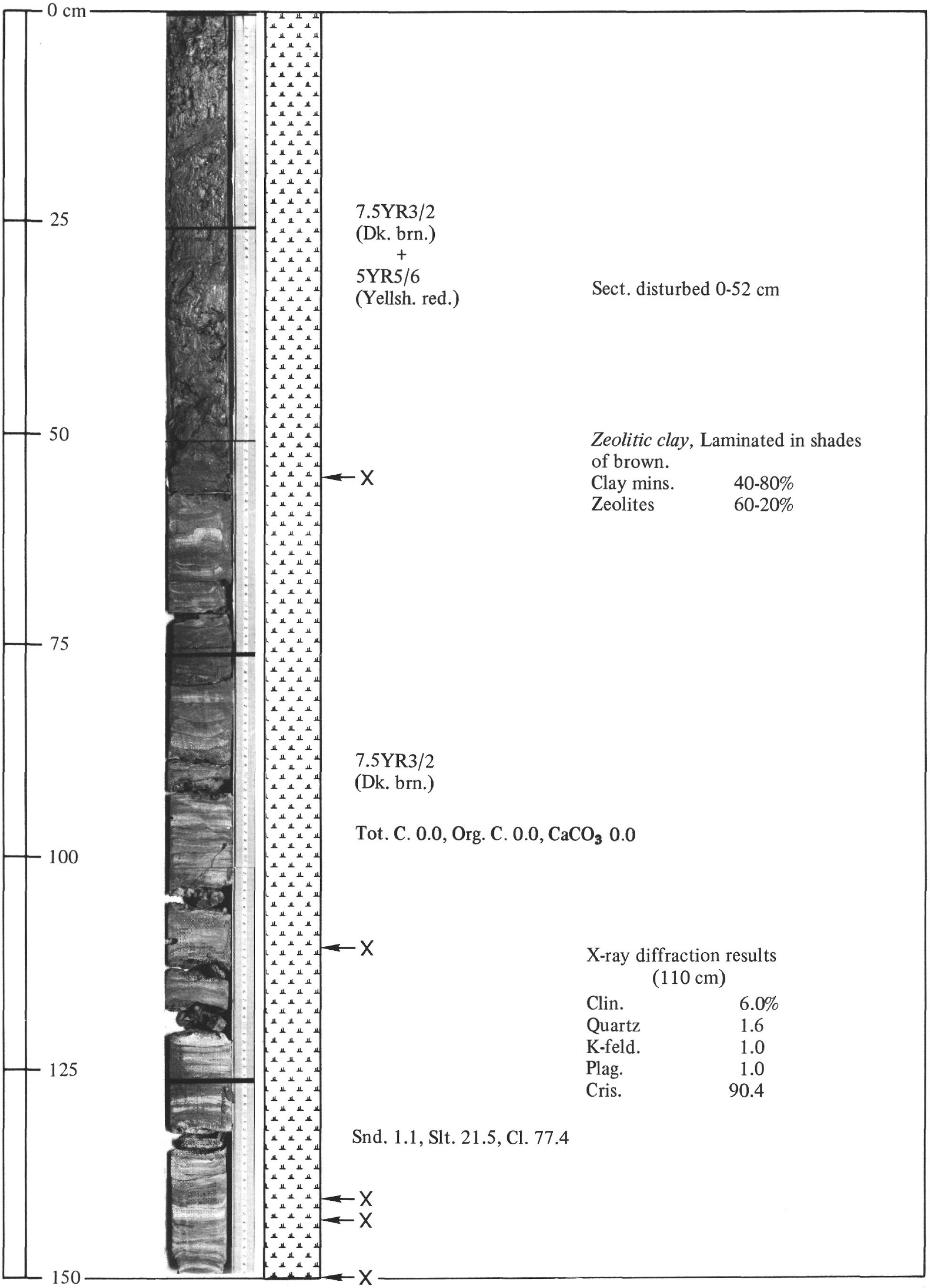
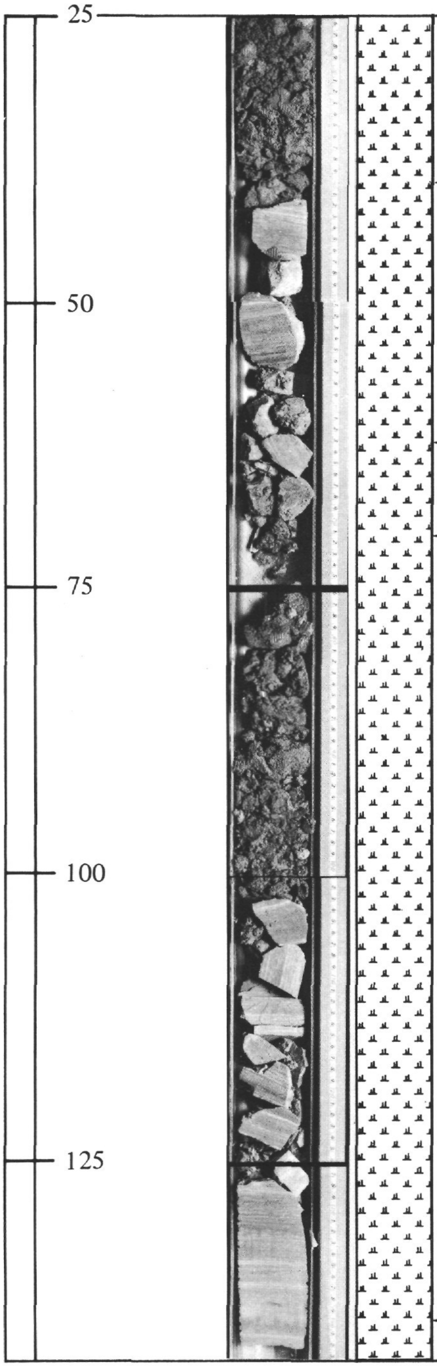


Figure 53. *Hole 9A Core 3 Section 4.*



X
X
X
X

10YR4/2
(Dk. yellsh. brn.)

X-ray diffraction results
(25 cm)

Mica	3.0%
Clin.	24.2
Quartz	7.5
K-feld.	1.6
Plag.	1.6
Cris.	61.5

Sect. disrupted from 25-128 cm.

Zeolitic clay, thinly laminated in shades of brown.

Zeolites	40%
Clay mins.	55%
Qtz. silt	5%

X-ray diffraction results
(114 cm)

Mica	2.0%
Clin.	32.0
Quartz	9.6
K-feld.	0.0
Plag.	2.1
Side.	1.4
Cris.	52.9

Figure 54. *Hole 9A Core 4 Section 1.*

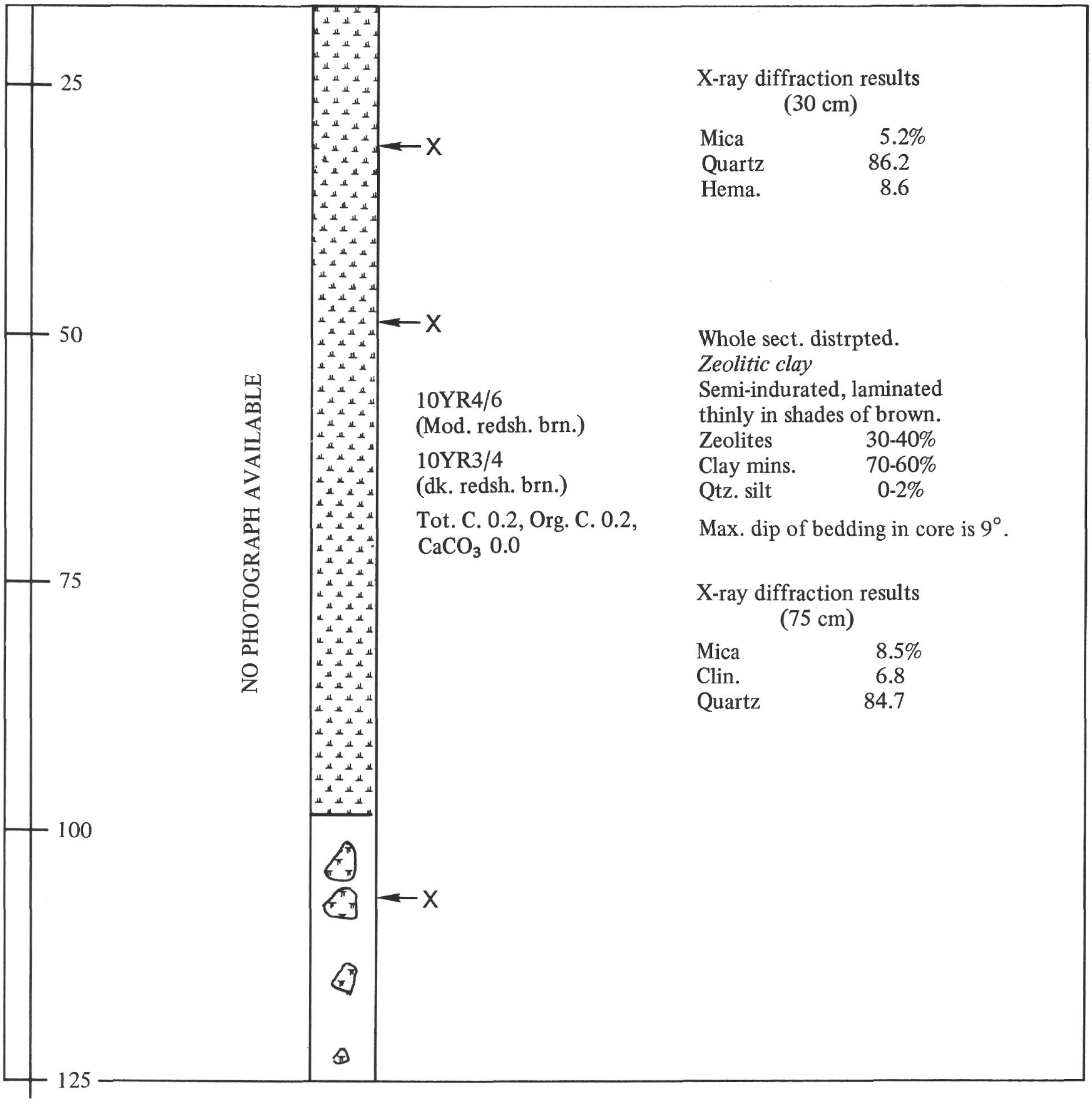
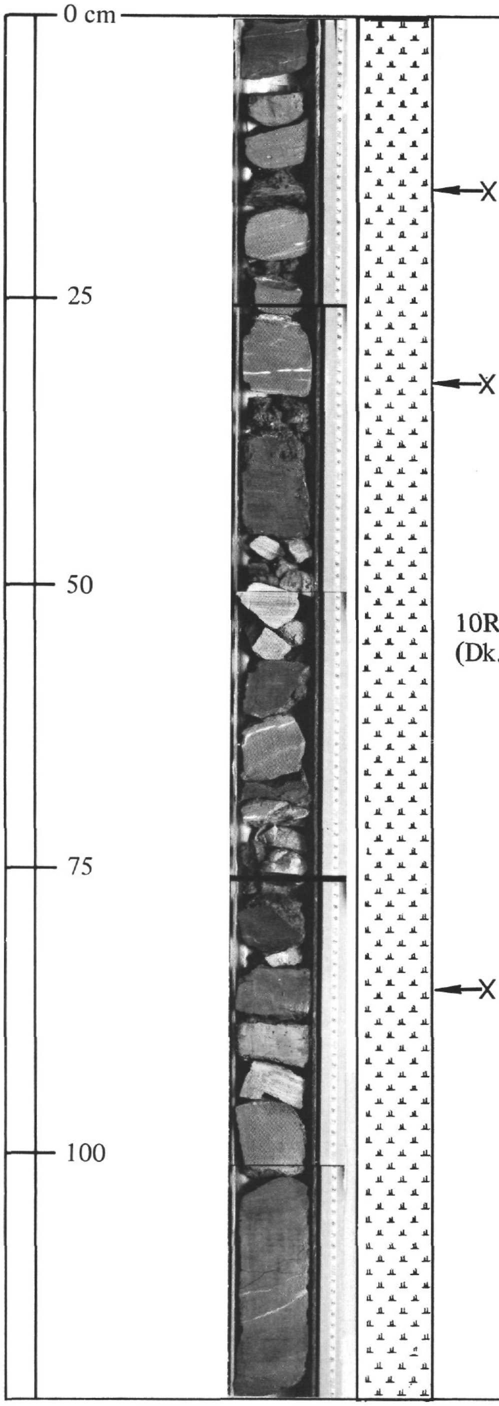


Figure 55. *Hole 9A Core 5 Section 1.*



10R3/4
(Dk. redsh. brn.)

X-ray diffraction results
(34-35 cm)

Mica	4.2%
Quartz	84.1
Hema.	11.7

Whole sect. consists of fragmented sections.

Zeolitic clay, laminated finely w/white Semi-indurated.

X-ray diffraction results
(50-51 cm)

Mica	2.1%
Clin.	21.8
Quartz	7.1
Side.	1.2
Cris.	67.8

Dense 5 cm. dia. manganese concretion in this sect.

Figure 56. *Hole 9A Core 5 Section 2.*

Lithology

Based on limited samples, there are two basic lithologies in the sediments from Holes 9 and 9A. The upper 700 foot (213 meter) section is composed predominantly of calcareous and siliceous oozes and the lower 2040 foot (622 meter) section is largely a non-calcareous, sparsely fossiliferous to non-fossiliferous clay. An examination of washings and cavings from the holes did not indicate the presence of any other varieties of sediment.

The biogenic ooze is Upper Miocene, Pliocene and Quaternary. The beds contain appreciable amounts of silt-sized irregular fragments of dolomite of indeterminate origin. Below 700 feet (213 meters) to a total depth of 2738 feet (835 meters), clayey and indeterminate fine-grained sediments predominate, ranging in age from Upper Miocene to at least as old as Upper Cretaceous. Dolomite fragments occur only sparsely at two or three thin horizons within these clays. Cherty sediments, formerly radiolarian oozes of Eocene Age, occur in poorly developed horizons between about 2200 feet (671 meters) and 2490 feet (759 meters).

Sediments of the uppermost 1600 feet (488 meters) irrespective of mineralogy, are dominantly olive gray to dark grey-green with localized yellow-brown bands. In the interval between about 1600 feet (488 meters) and 2200 feet (761 meters) the dominant hue changes to yellow-brown and red-brown, increasing notably in intensity, to very dark reddish brown in the lowermost 30 feet (9 meters) above basement.

Basement rock is a finely vesiculated glassy basalt, associated with well-indurated sediments. Dense manganese concretions, having botryoidal and dendritic forms, occur within the dark red-brown silty clays immediately overlying the basement. Pure zeolite, clinoptilolite, occurs in small white pockets or segregations (1 to 2 millimeters across) in some sections of the core, in addition to being a major component of the sediments of Hole 9A.

Manganese mineralization and iron enrichment, present in the sediments overlying basement, suggest some form of hydrothermal processes, possibly related to fumarole activity associated with underlying igneous activity. Such activity may have continued during the early stages of sedimentation, thus affecting the deepest sediments.

The chertified Eocene radiolarian ooze occurring between 2200 feet (671 meters) and 2490 feet (759 meters) is mineralogically similar to some of the cherts cored in Hole 8A. Age relationships are also equivalent, within the age resolution of radiolarian fossil remains. Unlike samples from Hole 8A, no terrigenous silt-sized material was noted in Hole 9A in association with the cherty material, although a considerable gap in the sample record exists above the cores containing chert fragments. However, it is of interest to note that this cherty material occurs approximately at the boundary between olive-grey and red-brown sediments, a relationship also observed in earlier holes (Hole 7A, Leg 1).

Physical Measurements

Ship Laboratory Measurements

Natural Gamma-Radiation

Natural gamma radiation varies with depth of burial or degree of compaction of sediment, as well as with mineralogy. The lowest values, on an arbitrary scale, are for the least compacted calcareous cores and are quite low, being about 1200 cpm above background. The small amount of associated siliceous ooze has a slightly higher count, probably indicating a somewhat larger proportion of potassium-bearing detrital minerals. Below the predominantly calcareous sediment, clayey sediments, admixed and interbedded with calcareous material, yield about 2000 cpm above background at a sediment depth of about 650 feet (198 meters). In conjunction with two thin zones of authigenic carbonate, probably rhodochrosite, the gamma activity is somewhat higher than is characteristic for the surrounding material—probably indicating the presence of significant proportions of potassium-bearing zeolites. Below 100 feet (328 meters) in the sediment, compaction and possible increased proportions of potassium-bearing zeolite minerals cause a continuous increase in the count rate from 2120 to 2680 cpm above background. No adequate measurements were made below 1049 feet (319.8 meters) because of broken and incomplete cores.

X-Radiography

The average exposure time required for X-ray photographs to achieve adequate exposure was found to be a qualitative measure of density. Times range from 2.8 seconds more or less smoothly up to about 7.8 seconds with other instrument settings being constant. No notable structures were noted on X-radiographs.

Gamma-Ray Attenuation Porosity Evaluator (GRAPE)

Porosity, as determined by gamma-ray attenuation, showed a smooth reciprocal relationship to density; it decreased downward with increasing density. The only significant reversals in this trend occurred in the depth ranges of interbedded clays and calcareous muds.

The gamma-attenuation traces show detailed relationships to individual beds. In general, the nannofossil cores are more porous than the clayey muds. Conspicuous exceptions to this are two thin beds of authigenic carbonate, in Core 8 which have much lower porosity and higher density.

Typical values of porosity are: 60 to 70 per cent for the upper 200 feet (60.9 meters) of foraminiferal coccolith ooze containing much detritus; 45 to 50 per cent for the clayey muds at about 650 feet (198 meters) and 55 per cent for the calcareous sediments at this depth; 45 per cent for clayey muds at 1000 to 1500 feet (328 to 457 meters), depth of burial; and, 40 to 43 per cent for one determination at about 2500 feet (762 meters). These values from gamma-ray attenuation show a close coherence relationship to values obtained during the water content calculations.

The most significant variation in density is an increase with depth. This variation is smooth and shows few reversals except in Cores 7 and 8 (Hole 9) where clays are intermixed and interbedded with nannofossil-foraminiferal oozes. In the upper 200 feet (60.9 meters), typical values range from 1.46 to 1.63. In the intermediate mixed clays and calcareous muds at about 650 feet (198 meters), values range from 1.62 to 1.81 with the lower values belonging to the more pure calcareous nannofossil oozes and the lowest values to radiolarian-rich ooze. In the deeper clays below 1000 feet (328 meters) densities range generally above 1.8 and increase only slightly with depth to 2487 feet (758 meters), below which no satisfactory determinations are available. Gamma attenuation values are about 7 per cent higher than values calculated from core section weight.

Penetrometer

Needle penetration into the sediments generally decreased downward at this site, as would be expected from general increase in compaction with depth. Penetration was generally bound to be variable in cores that had been disturbed, and is considered a good indication of coring disturbance, where evidence for this is otherwise obscure.

Sonic Velocity

Measurements of sonic velocity at 1 atmosphere pressure by the Winokur method yielded values that were lower than velocities measured *in situ* by combination of seismic profiling and drilling. Averaging of these values for cored intervals gave velocities of 1.49 km/sec at 100 feet (32.8 meters)–(Core 5), 1.55 at 650 feet (198 meters)–Cores 7 and 8, 1.62 at 1000 feet (328 meters)–Cores 9 and 10 and, 1.8 at 2200 feet (670 meters)–Core 1, Hole 9A. No measurements from deeper than this level were possible because the sediment was either broken or not recovered in plastic liners (see Drilling and Coring Log). Values from cored intervals were averaged; these average values were then arbitrarily assigned to depth ranges extending halfway to the adjacent cored interval, except at the top and bottom where the values were extended to the extremities of the section. The depth weighted averaging yielded 1.68 km/sec. This value, determined by a measurement parallel to the bedding, is somewhat below the *in situ* average velocity measured vertically through the section by combination of penetration and seismic profile. The scatter of the data is substantial and probably comes largely from imperfections in the cores and in their contact to the plastic liner material.

Down-Hole Logging

In-pipe gamma-ray, neutron and interval velocity logging were planned for Hole 9A. Because the pipe had a tendency to stick in the hole, no open-hole logging was attempted. In an attempt to reduce the hazard of having the pipe stuck in the hole, the bit was raised to 2429 feet (740 meters) below the ocean floor before in-hole logging.

The gamma-ray neutron log was run from 18,745 feet (5715 meters) to 16,236 feet (4950 meters). The difference of 49 feet (16 meters) between the driller's depth and the logger's depth is unusually great, but the reason is not apparent. The records do not appear to be reliable.

Paleontology and Biostratigraphy – Summary

Nannofossils	Foraminifera	Radiolaria
Hole 9, Core 1: A very small sample was recovered adhering to the core catcher. The sample consisted mainly of late Quaternary coccolithic ooze along with some detrital materials, chiefly calcareous. The following calcareous nannofossils were identified: *Emiliania huxleyi, Gephyrocapsa* spp.; *Ceratolithus* sp., *Umbilicosphaera mirabilis, Um-*	Hole 9, Core 1: Insufficient material recovered for foraminiferal examination.	Hole 9. Core 1: Radiolaria absent.

Nannofossils	Foraminifera	Radiolaria
bellosphaera sp. and *Coccolithus pelagicus.*		
Hole 9, Core 2: A small sample was recovered adhering to the core catcher. The sample consists of a poorly sorted mixture of silt and contains abundant late Quaternary calcareous nannofossils, including *Emiliania huxleyi, Umbellosphaera* sp., *Gephyrocapsa* spp.; *Ceratolithus* sp., and *Coccolithus pelagicus.* Also present are some reworked nannofossils from the Upper Miocene-Pliocene *(Discoaster pentaradiatus)* and Cretaceous *(Eiffellithus turriseiffeli, Arkhangelskiella).*	Hole 9, Core 2: Insufficient material recovered for foraminiferal examination.	Hole 9, Core 2: Rare fragments of Radiolaria and diatoms.
Hole 9, Core 4: A small sample was recovered adhering to the core catcher, and consists mainly of silt and clay-size detrital material including quartz and calcareous debris, and abundant late Quaternary calcareous nannofossils, including *Emiliania huxleyi, Gephyrocapsa* spp.; *Ceratolithus* sp., *Coccolithus pelagicus, Discolithina japonica, Cyclococcolithus leptoporus, Rhadborsphaera clavigera* and *Umbilicosphaera mirabilis.* Also present are some reworked calcareous nannofossils of Tertiary *(Sphenolithus abies, Zygodiscus)* and Cretaceous *(Chiasmolithus)* Age.	Hole 9, Core 4: The core catcher yielded a rich assemblage dominated by planktonic foraminifera; all the species known to be living in the Sargasso Sea are present, including *Globorotalia truncatulinoides* (completely keeled), *G. hirsuta, G. menardii, G. inflata, Pulleniatina obliquiloculata,* and various species of *Globigerinoides,* including *G. ruber* with red tests. Pink tests were also observed in *Globigerina rubescens.* The age of this assemblage, as indicated by the foraminifera, is late Pleistocene; an assignment of Zone N.22 (upper part) or N.23 of Blow's 1968 zonation is suggested.	Hole 9, Core 4: Core catcher contains rare radiolarian and diatom fragments.
Hole 9, Core 5: Calcareous nannofossils are present throughout Core 5, and they may be rare to abundant. The following species were identified indicating a middle and early Quaternary Age: *Gephyrocapsa* spp., *Coccolithus pelagicus, Ceratolithus cristatus, Umbilicosphaera mirabilis, Cyclococcolithus leptoporus, Rhabdosphaera clavigera, Helicopontosphaera carteri, Discolithina japonica* and *"Discolithus" phaseolus* cf. *Coccolithus cricotus,* which is rare or lacking near the top, but becomes more abundant in the lower part of Core 5. The extinction of this species appears to be an excellent	Hole 9, Core 5: Core 5 was studied in some detail and revealed strong variations in the composition of the fauna. Foraminiferal faunas are rich in some levels, poor or even totally absent in others. Benthonic foraminifera are fairly numerous, and in some cases probably displaced (corroded tests of shallow water *Miliolidae,* attached *Cibicides).* Also present in many of the samples considered were large amounts of minute debris of planktonic foraminiferal shells. Certain warm water species living in the Sargasso Sea, and also present in Core 4, are lacking in some Core 5 samples, or are present in smaller	Hole 9, Core 5: The radiolarian fauna recovered from this core is well preserved and composed largely of species endemic to low latitudes (e.g., *Panartus tetrathalamus tatrathalamus* Haeckel, *Pterocanium praetextum praetextum* (Ehrenberg), *Botryocyrtis scutum* (Harting), *Spongaster tetras tetras* Ehrenberg and *Euchitonia* spp.) A few species endemic to middle atitudes can be found (e.g., *Lithocampe* sp., *Spongaster tatras irregularis* Nigrini, *Actinomma medianum* Nigrini and *Eucyrtidium acuminatum* - Ehrenberg) along with rare specimens of one form endemic to subarctic waters *(Styptosphaera? spumacea* Haeckel). All of the above mentioned

Nannofossils	Foraminifera	Radiolaria
marker within the Pleistocene as it is completely lacking in samples above Core 5. Also present at several levels in Core 5 is silt and clay-size detritus, consisting chiefly of calcareous and quartz fragments. Other levels appear to be relatively free of detritus and consist almost entirely of coccolith ooze.	proportions; cool water species do occur in Core 5, thus suggesting some climatic fluctuations. However, no conclusions may be drawn concerning Pleistocene climatic fluctuations because of the way the present core was cut (see operations report). The presence of displaced foraminiferal assemblages is in agreement with the high rate of sedimentation observed for the Pleistocene section and with the unusually large thickness of the interval in which partially keeled specimens of *Globorotalia truncatulinoides* occur (approximately 38 meters). This interval may be referred to the *Globorotalia truncatulinoides* (N.22) partial range zone of Blow.	species are described and illustrated in Nigrini (1967) and Nigrini (in press). Overall a Tropical-Transitional assemblage (Nigrini, in press) is indicated by the radiolarian fauna. Radiolarian abundance decreases towards the bottom of the core. Trilypean Radiolaria are found in small numbers throughout the core and indicate a relatively high rate of sediment accumulation. Orosphaerid fragments are found in the upper part of the core. Diatoms are present throughout and include fragments of *Ethmodiscus rex* (Rattray). Since, in this case, 125 feet (37.5 meters) of sediment had to be cored and packed in the core in order to achieve a 25 foot recovery, the sediments are badly dsiturbed and studies of stratigraphic sequences or fluctuations in the faunal composition would be meaningless.
Hole 9, Core 6: A small sample was recovered adhering to the core catcher, and consisted largely of silt and clay-size debris with calcareous nannofossils being common. The following species are identified: cf. *Coccolithus cricotus, Cyclococcolithus leptoporus, Umbilicosphaera mirabilis, Coccolithus pelagicus, Ceratolithus cristatus, Discoaster brouweri* (very rare) and *Gephyrocapsa* sp. (rare). The presence of abundant cf. *Coccolithus cricotus,* rare *Gephyrocapsa oceanica,* and very rare *Discoaster brouweri*—the last named probably reworked upwards by burrowing organisms—indicates the proximity of the Plio-Pleistocene boundary below Core 6, so that the age assigned to this level very probably should be early Pleistocene.	Hole 9, Core 6: Similar to the lower part of Core 5 The co-occurrence of *Globorotalia truncatulinoides* and *G. tosaensis* indicates a lower Pleistocene Age (early N.22 Zone).	Hole 9, Core 6: Radiolaria absent.
Hole 9, Core 7: Calcareous nannofossils are common to abundant throughout most of Core 7, and indicate a late Miocene to middle Pliocene Age for this interval. The following species were recorded: *Discoaster brouweri, D. surculus, D. pentaradiatus, D. variabilis, D. challengeri, Reticulofenestra pseudoumbilica, Spheno-*	Hole 9, Core 7: Samples from this core yielded very poor and dwarfed foraminiferal faunas which demonstrate unfavorable ecologic conditions, possibly related to excessive depth of deposition. Benthonic foraminifera are present, including *Quinqueloculina* and *Triloculina* with corroded tests. A precise age assign-	Hole 9, Core 7: Radiolaria absent.

Nannofossils	Foraminifera	Radiolaria
tarhabdus sp., *?Cylindralithus gallicus, Ceratolithoides kamptneri, Tetralithus murus.* The last three species indicate a probable Maestrichtian Age for the assemblage however, it appears that the nannofossils in this sample may have been mixed in from some level above Core 2, as no undisturbed nannofossil bearing sediments were identified within the core.	The genera *Heterohelix,* and *Hedbergella* are represented by single specimens with thin shells, sometimes broken. Benthonic foraminifera are as common as (or more common than) the planktonics. The relative abundance of primitive forms with arenaceous tests such as, *Saccamina, Reophax* and *Glomospira* should be pointed out. Similar co-occurrences of primitive arenaceous forms and of planktonic foraminifera belonging to the family *Heterohelicidae,* without *Globotruncana,* are known from some Upper Cretaceous formations of the Italian peninsula which are characterized by low rates of sedimentation and are interpreted as deep-sea deposits.	
Hole 9A, Core 3: A small lump (about 1cc) of reddish sediment included with other disturbed sediment in Section 2 of this core consisted almost entirely of Upper Cretaceous nannofossils, the assemblage being identical to that encountered in Core 2. This lump probably caved in from some level near or above that of Core 2.	Hole 9A, Core 3: No foraminifera present.	Hole 9A, Core 3: Rare, poorly preserved Cretaceous Radiolaria are found throughout the core.
Hole 9A, Core 4: No calcareous nannofossils.	Hole 9A, Core 4: No foraminifera present.	Hole 9A, Core 4: Same as Hole 9A, Core 3.
Hole 9A, Core 5: No calcareous nannofossils.	Hole 9A, Core 5: No foraminifera present.	Hole 9A, Core 5: A sparse and poorly preserved radiolarian fauna similar to that of Cores 3 and 4 is found in Core 5. However, the core catcher sample contains a relatively rich and well-preserved assemblage including a number of species of *Dictyomitra, Pseudoaulophacus* sp., *Theocapsomma* sp., *Gongylothorax verbeeki* (Tan Sin Hok), *Theocampe* sp. and *Hemicryptocapsa* sp. (*?conara* Foreman). Sponge spicules are also in the core catcher sample.
Hole 9A, Core 6: The core catcher of this core yielded a calcareous nannofossil assemblage identical to that of Cores 2 and 3. Doubtless these nannofossils also had their origin as cavings from above the	Hole 9A, Core 6: The core catcher of Core 6 yielded a very poor foraminiferal assemblage similar to that of Core 2, including *Gumbelitria cretacea, Heterohelix globulosa, Hedbergella*	Hole 9A, Core 6: The core catcher contains rare, poorly preserved Cretaceous Radiolaria.

Nannofossils	Foraminifera	Radiolaria
lithus abies, Ceratolithus sp., *Cyclococcolithus leptoporus, C. acquiscutum* and *Helicopontosphaera* sp. The absence of *Ceratolithus tricorniculatus* in all of Core 7 suggests a probable early Pliocene, rather than late Miocene Age for this core.	ment cannot be made on the basis of the foraminifera alone, since the few species identified have a rather wide range. Among the most interesting are *Globigerina nepenthes* which range from the Upper Miocene to the Lower Pliocene, and *Globigerinoides bollii* (Middle Miocene to Pliocene).	
Hole 9, Core 8: Section 2 of Core 8 yielded an excellent assemblage of calcareous nannofossils indicating a late Miocene (Messinian) to early Pliocene Age. The assemblage contains the following species: *Sphenolithus abies, Reticulofenestra pseudoumbilica, Discoaster brouweri, D. surculus, D. pentaradiatus, Cyclococcolithus leptoporus, Ceratolithus rugosus* and *Ceratolithus tricorniculatus.* The last named species, though relatively rare, has the narrowest stratigraphic range of the above species and, therefore, is age definitive for this level.	Hole 9, Core 8: Same as for Hole 9, Core 7.	Hole 9, Core 8: No siliceous microfossils.
Cores taken below this level at Hole 9 are barren of both calcareous and siliceous microfossils.		
Hole 9A, Core 1: Calcareous nannofossils absent.	Hole 9A, Core 1: Foraminifera absent.	Hole 9A, Core 1: An assortment of material was brought up with the center bit prior to the recovery of Core 1. Disaggregation of one fragment of pale green indurated material yielded a rich, well-preserved radiolarian fauna of Eocene Age. At the top of Section 1, Radiolaria are present only as rare fragments; in Section 4 they are more numerous, well-preserved and Eocene in age. In Section 6, a sample was taken from an isolated patch of pale green sediment. The remainder of the section is mottled brown and is poor in Radiolaria, but the pale green sediment yielded a very rich radiolarian fauna of low to Middle Eocene Age.
Hole 9A, Core 2: A sample taken from the core catcher of Core 2 yielded several characteristic Upper Cretaceous nannofossils, including *Arkhangelskiella* sp., *Prediscosphaera cretacea, Micula* sp., *Tetralithus aculeus, Cre-*	Hole 9A, Core 2: The foraminiferal fauna is extremely poor. Planktonic foraminifera are present, but none of them belong to the genus *Globotruncana,* the most important and usually the most common in the Upper Cretaceous.	Hole 9A, Core 2: The catcher sample contains poorly preserved Cretaceous Radiolaria (*Dictyomitra* spp., and members of the families Amphipyndacidae and Pseudoaulophacidae).

Nannofossils	Foraminifera	Radiolaria
level of Core 2, and were mixed with the sediment in the core catcher.	*monmouthensis, Saccammina complanata, Reophax, Ammodiscus, Glomospira, Gyroidinoides nitidus, Globorotalites michelinianus,* and *Gavelinella whitei* indicating a probable Senonian Age.	

PLATE 1

Radiolaria

(All figures X200)

A Unidentified Spumellarian Radiolaria; 2-9A-3-3, 0-3 cm (X21/0).

B Unidentified Spumellarian Radiolaria; 2-9A-3, core catcher (F26/1).

C *Pseudoaulophacus* sp., 2-9A-2, core catcher (K39/3).

D *Gongylothorax· verbeeki* (Tan Sin Hok); 2-9A, core catcher (M38/0).

E *Theocapsomma* sp.; 2-9A-5, core catcher (Y17/1).

F *Hemicryptocapsa* sp.; (?conora Foreman); 2-9A-2, core catcher (H-49/0).

G *Theocampe* sp.; 2-9A-3-2, 78-80 cm (Y20/2).

H *Dictyomitra* sp.; 2-9A-5, core catcher (F40/4).

I *Dictyomitra* sp.; 2-9A-5, core catcher (W40/3).

J *Dictyomitra* sp.; 2-9A-2, core catcher (G51/3).

K *Dictyomitra* sp.; 2-9A-4-1, N133-6 cm (032/2).

L *Dictyomitra* sp.; 2-9A-3-1, 50-2 cm (C35/1).

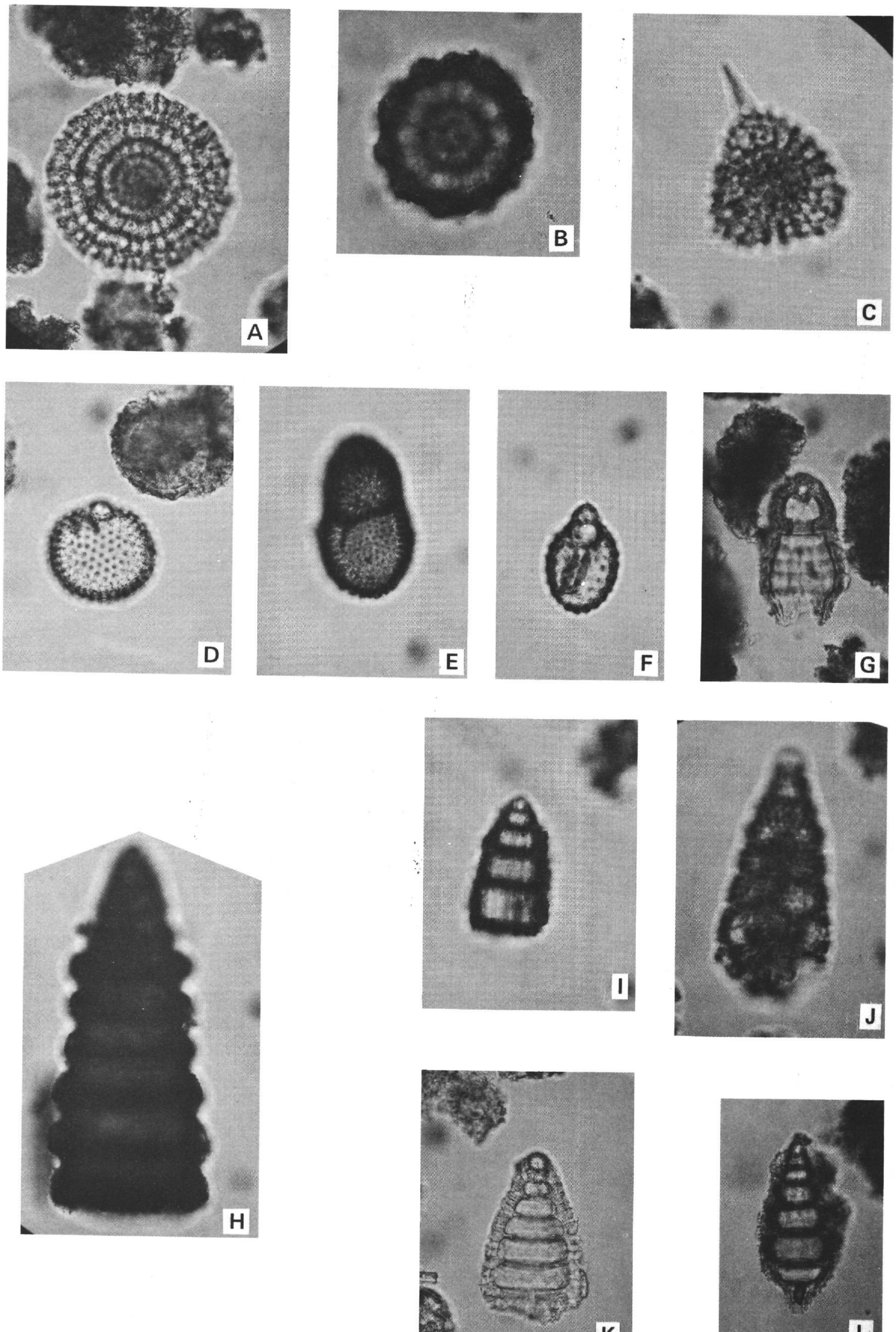


Plate 1.

SUMMARY

Rates of Sediment Accumulation

The reader is referred to the Cruise Leg Synthesis for discussion of the basic assumptions involved in these calculations.

In Holes 9 and 9A four cored intervals allowed the authors to make some calculations concerning the rate of sediment accumulation. They are as follows:

1) Base of Core 6 (Hole 9), near the Pliocene-Pleistoceen boundary; 1.8 m.y. at 78 meters beneath the sea floor.
2) Base of Core 9 (Hole 9), dated as the Miocene-Pliocene boundary; 6 m.y. at 213 meters.
3) Base of Core 1 (Hole 9A), Eocene; 44 m.y. at 683.2 meters.
4) Base of Core 6 (Hole 9A), Senonian; 85 m.y. at 764.9 meters.

(This age is based on a very sparse foraminiferal assemblage.) The calculated rates of sediment accumulation are:

TABLE 3
Rates of Sediment Accumulation

Interval	Cumulative
Pleistocene to Recent: 4.3 cm/1000 yr.	Pleistocene to Recent: 4.3 cm/1000 yr.
Pliocene (basal) to Pleistocene: 3.2 cm/1000 yr.	Pliocene (basal) to Pleistocene: 3.6 cm/1000 yr.
Eocene to basal Pliocene: 1.2 cm/1000 yr:	Eocene to Recent: 1.6 cm/1000 yr.
Upper Cretaceous to Eocene: 0.2 cm/1000 yr.	Upper Cretaceous to Recent: 0.9 cm/1000 yr.

The progressive increase in the rate of sediment accumulation from the Cretaceous to the Recent appears clear both in the interval and cumulative rates.

Discussion

A number of acoustical reflectors were noted in the top 0.1 seconds reflection time of sediment on the *Vema* profiler records of the Hole 9 survey area. These reflectors overlie 0.65 seconds of acoustically transparent sediments and were the objective of the first five coring attempts. Only Core 5 returned with sediment, but it had been so badly disturbed by the coring process that meaningful physical measurements were impossible to make. Rapid lithologic changes, basically between calcareous oozes and clays in Core 5, contrast with the uniform sedimentary composition of the underlying acoustically transparent layer, suggesting that the reflectors are related to these lithologic changes.

The weak reflector observed at 0.75 seconds on profiler records may be a zone of cherty radiolarian ooze. The age of the deepest core taken at Hole 9 is Upper Miocene. The first core of Hole 9A recovered Eocene cherty radiolarian ooze, and the second core recovered fragments of cherty radiolarian ooze in zeolitic Upper Cretaceous sediments. These chert pieces were not similar to the surrounding sediments and may have come from the cored interval.

If a significant chert layer is present above the first core at Hole 9A then the drilling record would certainly have shown a decrease in the rate of penetration. Unfortunately, the particular record which contains this information is missing. The rate at which these two cores at Hole 9A were cut was considerably less than that of any of the overlying sediments of Hole 9 or of some of the underlying Cretaceous (or older) sediments at Hole 9A. Thus, the reflector probably lies between the Miocene and the Eocene and may be the upper surface of a partially silicified layer. Possibly the reflector is correlative with the silicified Eocene Radiolaria deposits which were noted at Sites 7 and 8.

The thick accumulation of acoustically transparent sediment seen on profiler records is composed dominantly of clay. Based on the few cores recovered, it is generally free of calcareous components, except in the upper Cenozoic and Upper Eocene sections. Radiolaria are found rarely in the Quaternary cores and in somewhat greater numbers in the Eocene and Upper Cretaceous cores. These clays and zeolitics may have formed from the alteration of volcanic material that could have originated from seamounts in the area north and northeast of Bermuda. The profiler records at Sites 7, 8 and 10 suggest that these characteristically thick and acoustically transparent sediments are not very extensive to the east, west and south, although they may be present for a considerable distance northward which would suggest that the dominant winds and currents remained fairly constant throughout the period of deposition.

Most of the sediments in the cores taken at Hole 9A have a reddish hue which increases in intensity near the basement where the consolidated clays are brick red. The red color stems from oxidized iron (hematite 11.7 per cent in one sample) which may have originated from iron rich waters that emanated from the basement.

The scientists on Leg 1 identified a major lithologic change in Tertiary sediments on the Bermuda Rise, from turbidites at depth to "red clay" above. The Bermuda Rise is presently too high to receive turbidite deposits from the continental margin, so the transition to red clay was interpreted as the time the rise formed. According to their interpretation, the transition was gradual, commencing in the Middle Eocene and apparently ending at about the Miocene-Pliocene boundary.

There were no turbidites sampled at Hole 9 which could be compared with the Leg 1 data. However, there is a transition in Hole 9 from non-calcareous red clay to foraminiferal calcareous deposits. The deepest sampled calcareous sediments occur at 700 feet (213 meters) and barren red clay at about 1000 feet (305 meters). The next oldest dated sediment (age determined by Radiolaria) is Eocene and occurs at 2200 feet (670 meters). It would appear that the rise uplifted the area at Hole 9 from below to above the carbonate compensation zone during the late Miocene. However, no evidence was noted that would indicate the time at which the uplift was terminated. An alternative explanation would be that the sediment accumulation at Hole 9 raised the floor of the ocean above the compensation depth, thus achieving the same transition without calling on tectonism. An additional complication is that the depth of compensation may ahve fluctuated with time. In reality, all three factors may have played a role in varying degrees to produce the resultant transition.

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APPENDIX – MICROPALEONTOLOGICAL DETERMINATIONS

Lists of Selected Planktonic and Benthonic Foraminifera and Age Determinations by M. B. Cita.

Sample 9-5-1, 40-42 cm (depth unknown, about 69 to 78 meters below the mud line):

Poor foraminiferal fauna. The planktonic species include *Globorotalia truncatulinoides, G. hirsuta, G. inflata, G. crassaformis, G. scitula, Orbulina universa, Globigerinoides ruber, G. trilobus, Globigerina eggeri, G. quinqueloba, Globigerinita glutinata.* The benthonic species include *Quinqueloculina* sp., *Pullenia quinqueloba, Cassidulina oblonga, Nonion* sp., *Eponides umbonatus,* etc.

Age determination: Pleistocene, *Globorotalia truncatulinoides* Zone N.22.

Sample 9-5-1, 83-86 cm (depth unknown, about 69 to 78 meters below the mud line):

Rare foraminifera, including benthonics: *Allomorphina trigona, Cibicides* sp., *Lagena* sp., *Eponides* sp., and planktonics: *Globorotalia truncatulinoides, G. inflata, G. hirsuta, G. acostaensis* (?) *pseudopima, Globigerina quinqueloba, Orbulina universa, Globigerinoides elongatus, G. sacculifer, G. trilobus, G. ruber.*

Age determination: Pleistocene, *Globorotalia truncatulinoides* Zone N.22.

Sample 9-5-1, 120-122 cm (depth unknown, about 69 to 78 meters below the mud line):

Poor foraminiferal fauna including benthonics: *Pullenia, Cibicides, Eponides, Pyrgo,* and planktonics: *Globorotalia truncatulinoides, G.* aff. *tosaensis, G. inflata, Globigerinella aequilateralis.*

Age determination: lower Pleistocene, probably lower part of the *Globorotalia truncatulinoides* Zone N.22.

Sample 9-5-2, 60-62 cm (depth unknown, about 69 to 78 meters below the mud line):

Abundant, minute debris of planktonic foraminifera. Rare entire tests, some of them partly dissolved. *Globorotalia inflata, Globigerina eggeri, Orbulina universa, Globigerinita* spp., dwarfed specimens of *Globigerina quinqueloba* (?). Also present *Triloculina, Quinqueloculina seminulum, Lagena, Cibicides.*

Age determination: probably Pleistocene.

Sample 9-5-3, 37-40 cm (depth unknown, about 69 to 78 meters below the mud line):

Abundant, minute debris of planktonic and rare entire tests including: *Globorotalia truncatulinoides, G. inflata, G. hirsuta, Orbulina universa.* Also present *Allomorphina trigona, Nonion, Eponides, Triloculina, Lagena.*

Age determination: Pleistocene, *Globorotalia truncatulinoides* Zone N.22.

Sample 9-5-3, 120-123 cm (depth unknown about 69 to 78 meters below the mud line):

Abundant broken tests of planktonic foraminifera: *Globorotalia menardii, G. inflata, G. acostaensis* (?) *pseudopima, G. hirsuta, Orbulina universa, Globigerina quinqueloba* (often dwarfed), *Globigerinoides ruber,* etc. Benthonic foraminifera include: *Nonion, Cibicides, Pyrgo, Cassidulina, Eponides umbonatus,* etc.

Age determination: Pleistocene.

Sample 9-5-4, 43-46 cm (depth unknown, about 69 to 78 meters below the mud line):

Numerous broken tests of planktonic foraminifera and very rare entire specimens comprising *Globigerinita glutinata* and *Globigerina* sp. Also present *Gaudryinidae, Pyrgo, Quinqueloculina, Eponides, Cibicides, Pullenia, Lagena.*

Age determination: None.

Sample 9-5-4, 107-110 cm (depth unknown, about 69 to 78 meters below the mud line):

Rich planktonic assemblage with *Globorotalia truncatulinoides, G. tosaensis, G. hirsuta, G. crassaformis, G. inflata,* rare left coiling *Globorotalia menardii, Orbulina universa, Candeina nitida, Globigerinoides conglobatus,*

G. trilobus, G. elongatus, G. ruber, Globigerina quinqueloba, Pulleniatina obliquiloculata obliquiloculata etc.
Age determination: early Pleistocene, lower part of the *Globorotalia truncatulinoides* Zone N.22.

Sample 9-5-5, 50-52 cm (depth unknown, about 69 to 78 meters below the mud line):

Rare assemblage of planktonic foraminifera with *Globorotalia inflata* (dominant species), *G. scitula, Globigerina eggeri, G. quinqueloba, G.* cf. *pachyderma, G. bulloides, Globigerinita glutinata, Globigerinoides ruber, G. trilobus.* Also present rare Ostracods and benthonic foraminifera including *Eponides umbonatus, Cassidulina* sp., *Pyrgo* sp.
Age determination: probably Pleistocene.

Sample 9-5, core catcher (depth probably 69 to 78 meters below the mud line):

Foraminifera fairly abundant, witn many broken tests of planktonic species. *Globorotalia truncatulinoides* (also transitional to *G. tosaensis), G. crassaformis* (common), *G. inflata, G. scitula, Globigerina eggeri, G. bulloides, Globigerinoides elongatus, G. conglobatus, G. trilobus, G. sacculifera, G. ruber* (never with pink tests), *Pulleniatina obliquiloculata obliquiloculata.* Also present rare Ostracoda, *Pullenia quinqueloba, Globocassidulina subglobosa, Virgulina schreibersiana, Lagena* etc.
Age determination: early Pleistocene, lower part of the *Globorotalia truncatulinoides* Zone N.22.

Sample 9-6, core catcher (depth about 78 meters below the mud line):

Assemblage very poor, comprising *Globorotalia truncatulinoides* also transitional to *G. tosaensis, G. crassaformis, G. hirsuta, Globigerinoides ruber* (never with pink tests), *G. trilobus, G. elongatus, Globigerina quinqueloba, G. tetracamerata Globigerinita glutinata.* Also present *Allomorphina trigona, Virgulina, Lagena, Nonion, Eponides.*
Age determination: early Pleistocene, lower part of the *Globorotalia truncatulinoides* Zone N.22.

Sample 9-7-1, 50-52 cm (depth about 195 meters below the mud line):

Assemblage extremely poor, with *Orbulina universa, Globigerina quinqueloba, Globigerinita glutinata* and the benthonics *Allomorphina trigona, Cibicides, Eponides, Pullenia, Cassidulina.*
Age determination: Miocene or younger.

Sample 9-7-2, 135-137 cm (depth about 197 meters below the mud line):

Assemblage very poor, with many broken tests of planktonic foraminifera. *Globigerina nepenthes, G. ciperoensis angustiumbilicata, G. microstoma, Orbulina universa, Globigerinoides ruber.* Among the benthonics are present *Cassidulina, Eponides, Cibicides, Lagena, Pleurostomella, Textularia, Nonion, Pullenia quinqueloba, Allomorphina trigona.*
Age determination: uncertain, due to the scarcity of the fauna, which is not younger than the Lower Pliocene and not older than the Tortonian.

Sample 9-8-2, 58-60 cm (depth about 205 meters below the mud line):

Fauna very poor and strongly affected by solution. Many broken tests of planktonic foraminifera. *Globigerina nepenthes, Globigerinoides bollii, Globigerinoides* sp. Benthonic foraminifera predominant, including *Textularia* spp., *Quinqueloculina, Triloculina, Lagena, Pleurostomella, Cibicides, Eponides, Globocassidulina subglobosa, Allomorphina trigona, Vaginulina,* etc. Small fish teeth also present.
Age determination: Upper Miocene to Lower Pliocene.

Sample 9-8-4, 78-81 cm (depth about 207 meters below the mud line):

Assemblage very poor, including *Globigerina nepenthes, G. bulloides, G. quinqueloba, Globorotalia* aff. *margaritae, Globigerinita glutinata, Globigerinoides ruber.*
Age determination: As above.

Sample 9A-2, core catcher (depth about 760 meters below the mud line):

Extremely rare foraminifera including planktonic species: *Heterohelix globulosa, Hedbergella* sp., and benthonic forms: *Saccamminidae, Reophax* sp., *Glomospira* sp., costate *Nodosariids, Gyroidinoides nitidus, Pullenia jarvisi, Gavelinella* cf. *Whitei, Osangularia cordieriana.*
Age determination: Upper Cretaceous, probably Senonian.

Sample 9A-6, core catcher (about 834.5 meters below the mud line):

Extremely rare foraminifera, including planktonic species *(Gumbelitria cretacea, Heterohelix globulosa, Hedbergella monmouthensis, H. holmdelensis)*, benthonic forms with arenaceous test *(Saccammina complanata, Sorosphaera* sp., *Reophax* sp., *Ammodiscus* sp., *Glomospira* sp.*)*, and with calcitic test (costate Nodosariids, *Gyroidinoides nitidus, Globorotalites michelinianus, Gavelinella whitei, Heterolepa* sp.).
Age determination: Upper Cretaceous, probably Santonian to Campanian.

Calcareous Nannofossil Determinations by S. Gartner.

Sample 9-1, smear from core catcher:

Emiliania huxleyi, Gephyrocapsa sp., *Umbellosphaera* sp., *Umbilicosphaera mirabilis, Ceratolithus cristatus, Coccolithus pelagicus.*
Age determination: late Quaternary.

Sample 9-2, smear from core catcher:

Gephyrocapsa sp., *Emiliania huxleyi, Umbellosphaera* sp., *Ceratolithus cristatus, Coccolithus pelagicus.*
Age determination: late Quaternary.

Sample 9-4, smear from core catcher:

Gephyrocapsa sp., *Emiliania huxleyi, Ceratolithus cristatus, Coccolithus pelagicus, Discolithina japonica, Cyclococcolithus leptoporus, Rhabdosphaera clavigera, Umbilicosphaera mirabilis.*
Age determination: late Quaternary.

Sample 9-5-1, 7 cm:

Gephyrocapsa sp., *Coccolithus pelagicus.*
Age determination: middle Quaternary.

Sample 9-5-1, 16.5 cm:

Same, plus *Ceratolithus cristatus.*
Age determination: middle Quaternary.

Sample 9-5-1, 127-128 cm:

Gephyrocapsa sp., *Coccolithus pelagicus.*
Age determination: middle Quaternary.

Sample 9-5-2, 7-8 cm:

As above.
Age determination: middle Quaternary.

Sample 9-5-2, 124-125 cm:

As above.
Age determination: middle Quaternary.

Sample 9-5-3, 12-13 cm:

As above.
Age determination: middle Quaternary.

Sample 9-5-3, 106-107 cm:

As above.
Age determination: middle Quaternary.

Sample 9-5-4, 40-41 cm:

As above.
Age determination: middle Quaternary.

Sample 9-5-4, 94-95 cm:

As above.
Age determination: middle Quaternary.

Sample 9-5-4, 137-138 cm:

As above.
Age determination: middle Quaternary.

Sample 9-5-5, 19-20 cm:

As above.
Age determination: middle Quaternary.

Sample 9-5-5, 118-119 cm:

Gephyrocapsa sp., *Coccolithus pelagicus,* cf. *Coccolithus cricotus.*
Age determination: early-middle Quaternary.

Sample 9-5-5, core catcher:

Gephyrocapsa oceanica, cf. *Coccolithus cricotus, Umbilicosphaera mirabilis, Cyclococcolithus leptoporus, Rhabdosphaera clavigera, Helicopontosphaera kamptneri, Discolithina japonica, Discolithus phaseolus, Ceratolithus cristatus.*
Age determination: early-middle Quaternary.

Sample 9-6, core catcher:

cf. *Coccolithus cristatus, Cyclococcolithus leptoporus, Umbilicosphaera mirabilis, Coccolithus pelagicus,* cf. *Ceratolithus cristatus, Gephyrocapsa* sp., *Discoaster brouweri* (rare).
Age determination: early-middle Quaternary.

Sample 9-7-1, 48.5-49.5 cm:

Discoaster brouweri, D. surculus, D. pentaradiatus, D. variabilis, Reticulofenestra pseudoumbilica, Sphenolithus abies, Ceratolithus sp., *Cyclococcolithus leptoporus, C. aequiscutum.*
Age determination: early Pliocene.

Sample 9-7-1, 84-85 cm:

As above.
Age determination: early Pliocene.

Sample 9-7-1, 119-120 cm:

Discoaster brouweri, D. variabilis, D. surculus, D. pentaradiatus, Reticulofenestra pseudoumbilica, Sphenolithus abies, Ceratolithus sp.
Age determination: early Pliocene.

Sample 9-7-2, 41-42 cm:

As above.
Age determination: early Pliocene.

Sample 9-7-2, 134-135 cm:

As above.
Age determination: early Pliocene.

Sample 9-7-3, 17-18 cm:

As above.
Age determination: early Pliocene.

Sample 9-7-4, 7-8 cm:

As above.
Age determination: early Pliocene.

Sample 9-7, core catcher:

As above.
Age determination: early Pliocene.

Sample 9-8-2, 53-54 cm:

Sphenolithus abies, Reticulofenestra pseudoumbilica, Discoaster brouweri, D. pentaradiatus, D. surculus, Ceratolithus rugosus, C. tricorniculatus.
Age determination: late Miocene–early Pliocene (probably Messinian).

Sample 9-8-2, 123.5 cm:

As above.
Age determination: late Miocene–early Pliocene.

Sample 9-8 core catcher:

cf. *Reticulofenestra pseudoumbilica,* cf. *Cyclococcolithus leptoporus, Discoaster* sp., *Discoaster surculus.*
Age determination: late Miocene–early Pliocene.

Sample 9-9-2, 14-15 cm:

Barren.

Sample 9-9, core catcher:

Reticulofenestra sp.
Age determination: not determinable.

Sample 9-10, core catcher:

Barren.

Sample 9-11, core catcher:

Barren.

Sample 9-11, core catcher:

Barren.

Sample 9A-2, core catcher:

Cylindralithus gallicus, Ceratolithoides kamptneri, Arkhangelskiella sp., *Prediscosphaera cretacea, Micula* sp., *Cretarhabdus danicus, Tetralithus aculeus, Tetralithus murus, Maslovella barmesae.*
Age determination: probably Maestrichtian.

Sample 9A-3-2, 135 cm:

As above.
Age determination: probably Maestrichtian.

Sample 9A-6, core catcher:

As above.
Age determination: probably Maestrichtian.