9. SITE 190

The Shipboard Scientific Party[1]

SITE DATA

Date Occupied: 22-24 Aug 71.

Position:
55°33.55'N
171°38.42'E.

Water Depth: 3875 meters.

Penetration: 627 meters.

Number of Holes: One.

Number of Cores: 16.

Total Core Recovered: 85 meters.

Acoustic Basement:
Depth: 1.15 seconds
Nature: Unknown
Velocity: Unknown.

Age of Oldest Sediment: Lower-middle Miocene.

Basement: Not reached.

SUMMARY

Site 190 is located in the southwestern Aleutian Basin just east of the southern terminus of the main or northern part of Shirshov Ridge, Bering Sea. The 627-meter thick sediment and sedimentary rock sequence drilled and cored consists of a Holocene through upper Miocene (0-615m) silty clay with variable amounts of diatoms, and diatom ooze with variable amounts of silt and clay overlying an upper to middle (?) Miocene (615-? m) section of mudstone, limestone, and clay. Discrete layers of vitric volcanic ash and thin layers of volcanically derived (?) silt occur throughout the upper Miocene and younger section (0-615 m).

Although Site 190 is located over part of the abyssal floor of the Aleutian Basin, which previous geologic studies and seismic reflection profiles (Ludwig et al., 1971a; 1971b) imply is underlain by a thick (as much as 1000 m) sequence of turbidite beds of late Cenozoic age, the bulk of the cored deposits are not visibly size-graded sand or silt, but rather are silty or clayey diatomaceous layers. However, grain size analyses shows that many of these layers are, in fact, graded units. It can be conjectured that the leveling of the abyssal plain in the vicinity of Site 190 resulted from the deposition of only distal turbidites together with a continual rain of siliceous microorganisms. However, the fact that the site is located over a slight structural dome, across which the acoustically definable turbidite sequence thins, may have, in part, contributed to the general paucity of coarser graded sand and silt layers.

Within the acoustically measured turbidite section (250 m), only the upper 175 meters contain coarse size-graded beds. Presumably this section, which corresponds to the entire Pleistocene, signifies glaciation and glacially lowered sea levels. However, displaced freshwater and littoral diatoms occur to a depth of 200 meters in upper Pliocene diatomaceous and silty beds, and acoustically the turbidite-bearing sequence extends at least 50 meters deeper (see Scholl and Creager, this volume). The silty diatom ooze and diatomaceous silty clay below 375 meters is worm-burrowed and semi-indurated and largely of late late Miocene age. Except for the occurrence of size-graded terrigenous turbidites, the entire diatomaceous section (0-615 m) is similar in age and lithology to Unit A recognized at other (except Site 188) Bering Sea sites. The upper or middle (?) Miocene claystone and limestone recovered below this depth are temporally and lithologically equivalent to Unit B encountered at these sites.

BACKGROUND AND OBJECTIVES

Description

The Aleutian Basin of the Bering Sea, a classical marginal oceanic basin, is floored by a vast abyssal plain occupying nearly all of the deep-water areas north of the Aleutian Ridge. Site 190 is located in about 3800 meters of water near the southwestern corner of the basin. The location is also near the southern terminus of the north-trending Shirshov Ridge (Figure 1).

Seismic reflection profiles reveal that about 1000 meters of stratified deposits underlie the basin floor at Site 190; elsewhere the thickness is considerably greater. At Site 190 an acoustic basement occurs at 1.15 sec below bottom. The overlying deposits appear to include highly reflective silty and possibly sandy turbidite beds forming the upper 250 to 300 meters; an underlying sequence of poorly reflecting pelagic beds about 400 meters thick, a sharp reflector at the base of this sequence, and about 300 to 400 meters of weakly reflecting strata resting on the acoustic basement (Figures 2 and 3) Site 190 is located over a 300- to 400-meter high basement ridge that causes a slight shoaling of the overlying sea floor and a thinning of underlying units, including the turbidite sequence.

[1]David W. Scholl, U.S. Geological Survey, Menlo Park, California; Joe S. Creager, University of Washington, Seattle, Washington; Robert E. Boyce, Scripps Institution of Oceanography, La Jolla, California; Ronald J. Echols, University of Washington, Seattle, Washington; Timothy J. Fullam, Standard Oil Company of California, La Habra, California; John A. Grow, Massachusetts Institute of Technology, Cambridge, Massachusetts; Itaru Koizumi, Osaka University, Osaka, Japan; Homa J. Lee, Naval Civil Engineering Laboratory, Port Hueneme, California; Hsin Yi Ling, University of Washington, Seattle, Washington; Richard J. Stewart, University of Washington, Seattle, Washington; Peter R. Supko, Scripps Institution of Oceanography, La Jolla, California; Thomas R. Worsley, University of Washington, Seattle, Washington.

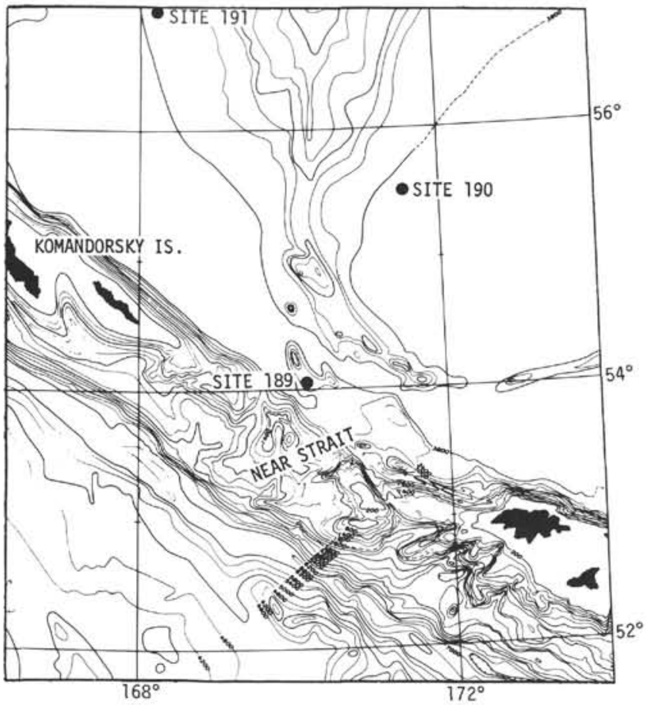


Figure 1. *Base map showing the location of Site 190.*

Objectives

Interest in the textural and sedimentary structures of the turbidites flooding the abyssal depths of the Aleutian Basin and in its general history of sedimentation prompted drilling at Site 190. The age of the base of the turbidite sequence was also to be determined – this in order to bracket the timing of the first glacially(?) lowered sea level and possibly the initial carving of the enormous submarine canyons that cut into the Bering Sea continental slope and outer shelf. Also of interest is the age and composition of the pelagic unit sandwiched between the turbidite sequence and the acoustic basement; it is especially important to know if turbidite beds are interbedded in this sequence. A prominent subbottom reflector at about 0.78 sec, thought to be a silty layer, was to be reached and sampled.

OPERATIONS

Pre- and Post-drilling Survey

Site 190 is located just east of Shirshov Ridge in the Aleutian Basin, Bering Sea, along the track of the reference profile obtained by D.W. Scholl on 25 Aug 70 (Figure 2). The site was approached with a ship's heading of 033°T which was approximately the reciprocal of the heading used in obtaining the reference profile. The air-gun profile obtained during the approach (Figure 3) so closely approximated the reference profile that the beacon was dropped on

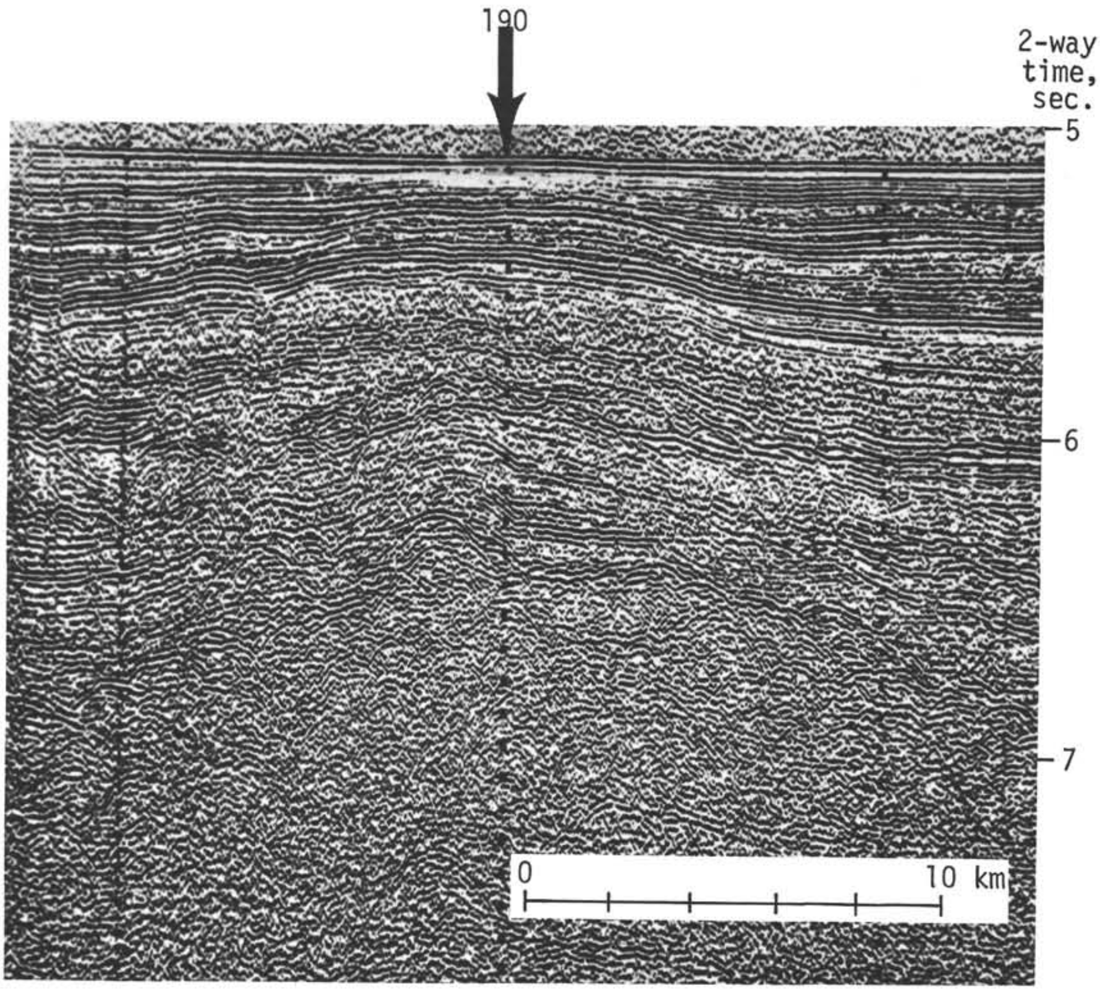


Figure 2. *Site 190 reference seismic reflection profile, obtained by D. W. Scholl, 25 Aug 70.*

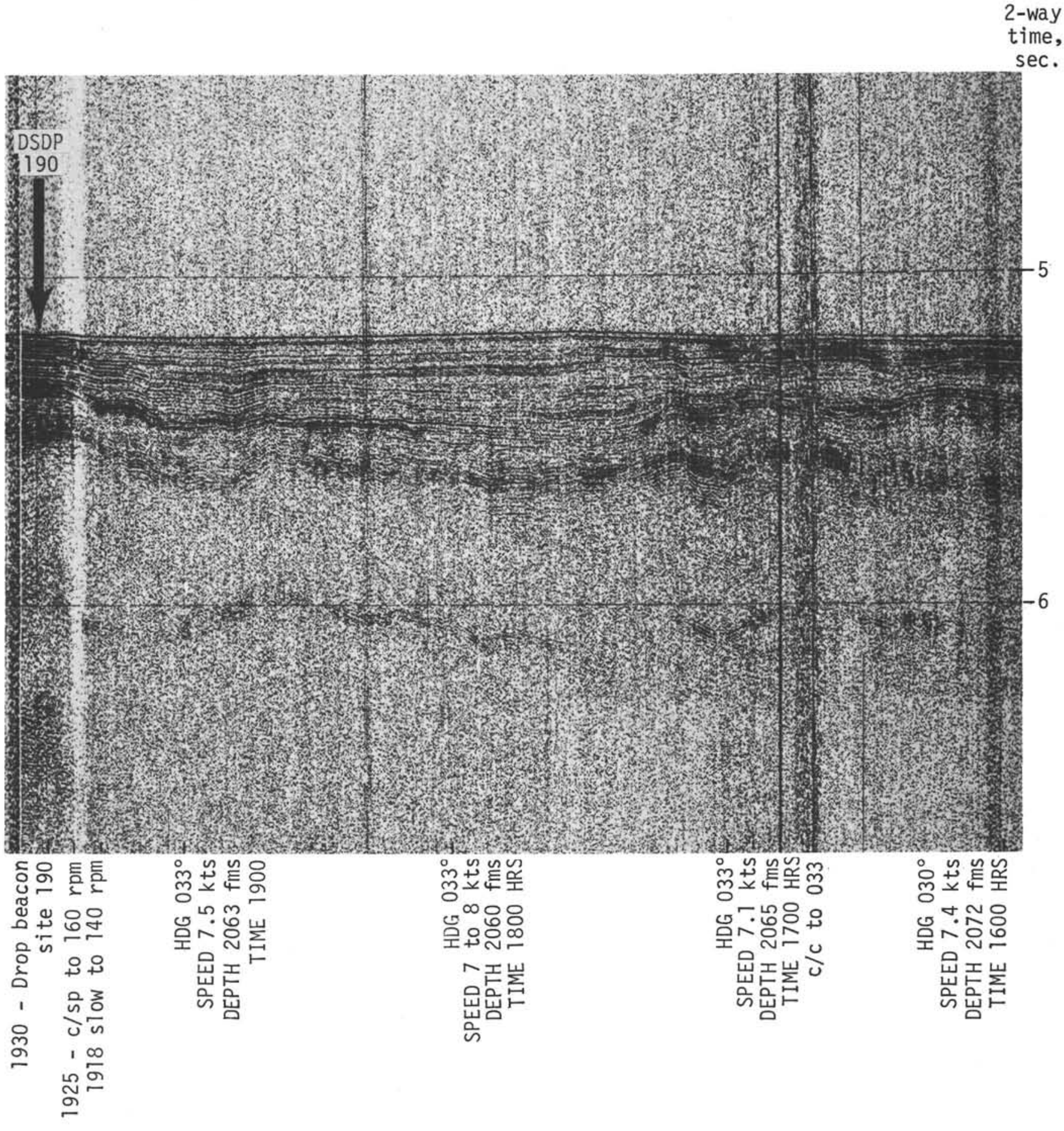


Figure 3. Glomar Challenger *seismic reflection profile obtained on approach to Site 190.*

the fly at 1930 hrs on 22 Aug 71. The finally accepted position is: 55°33.55'N; 171°38.42'E. No post-drilling survey was deemed necessary. A map showing the approach and departure tracks plus the site location is shown in Figure 4.

Drilling Program

Site 190 was occupied from 1930 hrs 22 Aug 71 (beacon away) until 1700 hrs 24 Aug 71 with alternate coring and washing from the sea floor to a subbottom depth of 627 meters. Cores from depths between 609 and 627 meters contained limestone and mudstone which were extremely difficult to core with the core extender and bit assembly being used. These sedimentary rocks correlate well with the last prominent reflector above that considered acoustic basement. Considering the time left for this leg and the difficulty of further drilling or coring, the hole was terminated.

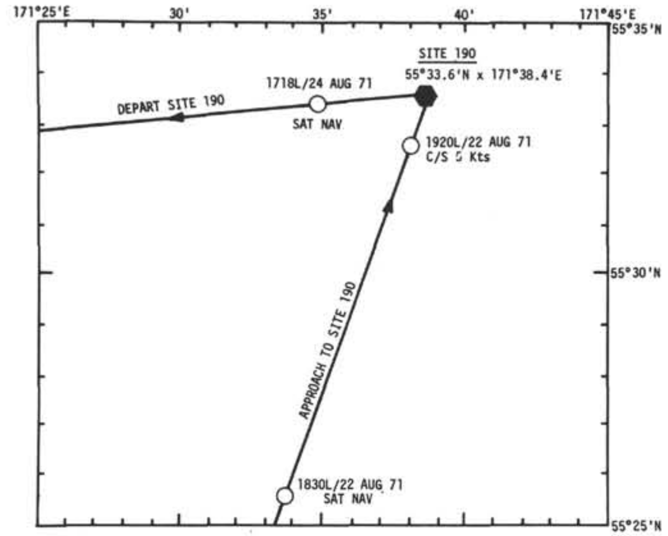


Figure 4. Glomar Challenger *approach and departure tracks, Site 190.*

Using Matthews Tables, the sonic depth of 2060 fms was corrected to 3848 meters, giving a water depth of 3854 meters and a drill-floor depth of 3864 meters. This compares with 3885 meters below drill floor established on the basis of the first core collected which contained sediment with a good oxidized surface. The 3885 meters below drill floor or 3875 meters below sea level is the accepted depth at this site.

No difficulties were encountered in drilling this hole through 609 meters of fine-grained sediment. Drilling rates were approximately 100 meters per hour until the limestone and mudstone was encountered. The core extender and bit assembly being used was not the proper combination for coring or recovery of this hard material. This was understood before the hole was started. A coring summary is given in Table 1.

TABLE 1
Core Summary – Site 190

Core	Cored Interval Below Bottom (m)	Cored (m)	Recovered (m)	Recovered (%)
1	0-6	6	6.0	100.0
2	6-15	9	3.0	33.3
3	15-24	9	4.9	54.4
4	24-33	9	5.8	64.4
5	33-43	10	9.2	92.0
6	43-52	9	7.5	83.3
Wash				
7	75-84	9	7.5	83.3
8	84-93	9	6.3	70.0
Wash				
9	112-121	9	4.5	50.0
Wash				
10	150-159	9	3.9	43.3
Wash				
11	197-206	9	6.3	70.0
Wash				
12	225-234	9	5.5	61.1
Wash				
13	328-337	9	4.5	50.0
Wash				
14	421-430	9	9.2	102.2
Wash				
15	609-618	9	0.9	10.0
16	618-627	9	CC	0.0
		142	85.0	59.9

TABLE 2

Unit	Cores	Depth Below Sea Floor (m)	Lithology	Age
A	1-15	0-615	Diatom silty clay: diatom ooze	Upper Pleistocene to upper Miocene
	1-10	0-175	Diatom-bearing to rich silty clay with several size-graded sands and silts	Upper to lower Pleistocene
	11-13	175-375	Diatom ooze	Pliocene to upper Miocene
	14-15	375-615	Diatom ooze and diatom silty clay semiindurated, burrowed	Upper Miocene
B	16	615-627	Mudstone plus clay and limestone, containing solution-corroded diatoms	Upper Miocene Middle Miocene (limestone pebble)

LITHOSTRATIGRAPHY

The 627-meter Holocene to middle Miocene section at Site 190 consists primarily of greenish gray silty clay with variable amounts of diatoms, and olive gray diatom ooze with variable amounts of silt and clay. The sediments have been divided into two major units based on diatom content and preservation (Table 2). In the upper unit, A (0 to 615 m), diatoms are well preserved and abundant, constituting as much as 95 per cent of the volume of some layers. Sediments in the lower part of Unit A are semi-indurated and burrowed and probably represent a transition to Unit B, even though the diatom content remains high. Unit B (615 to 627 m) consists of mudstone and clay containing only scattered and severely corroded diatom fragments.

Discrete beds of vitric volcanic ash and thin layers of silt occur throughout Unit A. In the Pleistocene portion (Cores 1-10, 0-175 m) of Unit A, the size-graded silt layers are thicker (up to 15 cm) and more numerous than below 175 meters, and are associated with several thick (up to 25 cm) layers of size-graded sand and silt. The size-graded sands and silts are presumably turbidites and, although they do not form the major part of the Site 190 sediment, they could be responsible for the leveling of the late Cenozoic fill over this area of the Aleutian Basin.

Unit A – 0 to 615 Meters

Most of the sediments recovered at Site 190 are interbedded mixtures of diatoms, silt, and clay. Typically, the sediments are olive gray to dark greenish gray diatom-bearing to diatomaceous silty clay, and silt- and clay-bearing diatom ooze. Color variations are associated with slight compositional changes, and, in general, the grayer colored sediments are richer in silt and clay. For the most part, the pelagic and terrigenous components are about equal; however, the number and thickness of diatom ooze layers and the diatom content of the silty clays generally increase toward the bottom of the unit.

A well-developed, oxidized surface layer of diatom ooze, 20 to 25 cm thick, occurs at the sediment-water interface. The colors of the layer range from dark yellowish brown to olive to grayish olive.

Numerous vitric volcanic ash beds occur throughout Unit A. They are typically 5 to 10 cm thick, but attain a maximum thickness of about 50 cm (Core 8, 85 m below bottom). Colors range from very light gray for nearly pure light-colored glass ashes to brownish gray for ashes containing up to 25% silt and/or clay. Also occurring are a few thin streaks of dark-colored crystal ash containing large amounts of feldspar (25%), lithic fragments, altered glass, and unidentified material (40%), in addition to light- and dark-colored glass shards.

The upper part of Unit A (0-175 m) is distinguished by the presence of at least four visibly size-graded sand and silt layers, all about 25 cm thick. (Grading in other sands and silts has been revealed by detailed size analyses. Colors of the graded layers are dusky yellowish brown to olive black.

The lower part of Unit A (375-615 m) is semi-indurated and burrowed. Burrows generally are parallel to bedding, which is horizontal. Numerous thin laminae of olive black volcanic silt containing pyritized diatoms occur in the dominant diatomaceous silty clay and clayey diatom ooze. The core catcher sample from Core 15 at the base of Unit A contains a piece of diatom-bearing limestone which probably was responsible for a drilling break at 609 meters below bottom.

Unit B – 615 to 627 Meters

A single core catcher sample constitutes Unit B. Sediments recovered include two pieces of mudstone, a small piece of limestone with well-preserved middle Miocene diatoms and silicoflagellates, and olive gray clay containing scattered solution-corroded diatoms.

PHYSICAL PROPERTIES

Bulk density, water content, natural gamma radiation, acoustic velocity, thermal conductivity, vane shear strength, and residual negative pore water pressure were measured on the samples obtained. The bulk density was measured with the GRAPE system and calculated from shore laboratory water content testing. Four 6-cm long unsplit sections were obtained for consolidation testing on shore. The GRAPE densities are shown on the core summary sheets. The mean GRAPE densities for the sections tested are shown on the site summary sheet along with the acoustic velocities.

Site 190 is important from a physical-engineering properties point of view because sampling was nearly continuous over the critical first 100 meters, the samples were of relatively good quality, and the sediment was relatively homogeneous. Because of these favorable conditions, the number of consolidation test samples taken at this site was greater than at any other site of this leg. An analysis of the results of these consolidation tests is given in a separate chapter by Lee (this volume).

Bulk Density

The GRAPE density was measured on all sections through Core 14. However, it appears that the results on Core 14 are inaccurate, probably because of inadequate filling of the core liner. Therefore, only results through Core 13 are presented.

As may be seen from the core summary sheets, the small-scale variations in the GRAPE record correlate well with small-scale variations in the lithology. Diatom ooze layers register as low-density zones; ash and sand layers register as high-density zones; diatom clay sections represent medium-density zones. Taking the site as a whole (site summary sheet) the GRAPE density data are quite scattered over the first 50 meters, reflecting the presence of numerous ash and sand layers. The scatter decreases over the next 50 meters, and the general trend of the data is one of gradually increasing density produced by compaction of the diatomaceous clay. From 100 to 200 meters the density decreases somewhat as the diatom content increases. Below 200 meters the density again begins to increase.

There are no sharp breaks in the data. Rather, the density varies gradually over the depth range sampled and reflects gradual changes in lithology.

Acoustic Velocity

The acoustic velocity does not deviate from the range 1.5 to 1.6 km/sec for the entire depth span tested (0 to 425 m). There are, however, important variations in the velocity distribution with depth. Over the first 100 meters the velocity increases from about 1.5 to 1.55 km/sec. It decreases to 1.5 km/sec at 120 meters and then begins to gradually increase again, finally reaching a value of 1.6 km/sec at 425 meters. This reflects the lithologic changes noted in the bulk density section.

Summary

The physical properties indicate a relatively uniform sediment extending to a depth of 425 meters. Both density and acoustic velocity increase to a depth of 100 meters, decrease slightly to 200 meters, and then increase again to 425 meters. The variations are small, but apparently reflect a slight change in sediment type over the range 100 to 200 meters.

PALEONTOLOGY

Correlation with previous sites by means of diatoms and silicoflagellates is good, but Radiolaria decrease in diversity below Core 4 (middle Pleistocene) to a few nondiagnostic, long-ranging species. Core 16 is devoid of fossils with the exception of a limestone pebble containing middle Miocene silicoflagellates and diatoms. Displaced freshwater diatoms were found down through Core 10.

Planktonic foraminifera occur in the Pleistocene section, but are virtually absent below, as at previous sites. Cores

13, 14, and 16 contain an arenaceous fauna. Displaced shelf species are mixed with the typical deep-sea benthic fauna in Core 5.

All sediments are devoid of calcareous nannofossils except nondiagnostic species in Cores 1 and 3 (Pleistocene). The occurrence of planktonic foraminifera in the other Pleistocene cores without nannofossils may be a result of selective exclusion from very cold (less than 1°C) surface water (McIntyre et al., 1972).

Foraminifera

In the Quaternary section, planktonic and calcareous benthic foraminifera fluctuate in abundance from sample to sample. All calcareous tests are absent in some Quaternary samples, which are either barren or have a sparse arenaceous fauna. Only a sparse arenaceous fauna occurs in the surface sediment (the oxidized layer, Core 1).

Late Pliocene samples (from Cores 11 and 12) are barren of foraminifera. Early Pliocene to late Miocene cores contain *Martinottiella communis* (Cores 13, 14, and 16), *Eggerella* sp. (Core 15), and *Cyclammina* sp. (Core 16). Preservation of the arenaceous test of these species is good except in Core 16 where the tests of *Cyclammina* are infilled with an undetermined material and badly deformed by compression. No other species were found. These species also occur in the indurated sediments of Unit B of some previous Bering Sea sites.

Radiolaria and Silicoflagellates

Sediments of Site 190 yield rather good radiolarian and silicoflagellate assemblages. Most of the radiolarian taxa reported in the study of Bering Sea sediments (Ling et al., 1971) were encountered in the uppermost two samples of this site (Table 9, Chapter 28). Both *Eucyrtidium(?) tumidulum* and *Stylacontarium acquilonium* were found in Core 3, the latter species, however, was recovered also in Cores 4 and 6 (questionably in Core 13). Starting from Core 4 downward, species diversity of Radiolaria decreases gradually and consists of long-range forms only. The clayey part of Core 16, the lowest of this site, is completely barren of Radiolaria.

The microfloral succession of silicoflagellates recovered from this site (Table 9, Chapter 27) agrees well with those presented from previous sites.

Although the clayey sediments of Core 16 were barren of silicoflagellates, a limestone pebble caught in the core catcher contains several specimens of *Cannopilus sphaericus* in addition to other Miocene forms. This finding not only marks the first occurrence for this species during this leg, but also constitutes the first record of the species from such a high-latitude area. Occurrence of this form in the section of Newport Beach, California, and the experimental Mohole sediments at Guadalupe site, is limited to the Luisian Stage.

Diatoms

Diatom valves observed from this site are abundant and well preserved and the stratigraphic sequence of diatoms through Core 16 at Site 190 is shown in Table 8, Chapter 30.

Although the clayey sediments of Core 16 in the lowest part of the sequence is barren of diatoms, a limestone pebble included in the sediments contains many well-preserved middle Miocene index species for the northern Circum-Pacific region; they are *Actinocyclus ingens, A. tsugaruensis, Synedra jouseana, Denticula lauta,* and *Kieselavia carina,* etc.

CORRELATION BETWEEN REFLECTION PROFILE AND STRATIGRAPHIC COLUMN

The reflection profile collected by D. W. Scholl, 1970, which was used to select Site 190, is shown in Figure 5 along with the stratigraphic column and physical properties. A sonobuoy reflection profile (wide-angle) taken by the *Glomar Challenger* while on station is shown in Figure 6. The upper 0.40 sec on both records show well-developed internal stratification. This is presumably caused by interbedded diatom ooze and ash layers and rare silt and size-graded turbidite sequences. A zone of more transparent sediments occurs between 0.40 and 0.75 sec, particularly on the sonobuoy profile (Figure 6), and correlates with silty diatom ooze and diatomaceous silty clay lacking silty turbidite layers.

Between 0.75 and 0.80 sec a strong reflector (particularly in Figure 6) can be seen which corresponds to the top of Unit B, the mudstone. Acoustic basement was recorded somewhere between 1.1 and 1.3 sec; its lithology is unknown.

Interval velocities within Unit A, based on the shipboard laboratory measurements, are near 1.6 km/sec; the travel-time solution (i.e., to the top of Unit B) is also between 1.55 and 1.65 km/sec (615 m by either 0.75 or 0.80 sec).

REFERENCES

Ling, H.Y., Stadum, C. and Welch, M., 1971. Polycystine Radiolaria from the Bering Sea surface sediments. Proc. 2nd Intern. Plankt. Conf. Rome. 2, 705.

Ludwig, W.J., Marauchi, J., Den, N., Ewing, M., Hotta, H., Houtz, R.E., Yoshii, T., Asanuma, T., Hagiwara, K., Sato, T. and Ando, S., 1971a. Structure of Bowers Ridge, Bering Sea. J. Geophys. Res. **76** (26), 6250.

Ludwig, W.J., Houtz, R.E. and Ewing, M., 1971b. Sediment distribution in the Bering Sea: Bowers Ridge, Shirshov Ridge, and enclosed basins. J. Geophys. Res. **76** (26), 6367.

McIntyre, A., Ruddiman, W.F. and Jantzen, R., 1972. Southward penetrations of the North Atlantic Polar Front: faunal and floral evidence of large-scale surface water mass movements over the last 225,000 years. Deep-Sea Res. **19**, 61.

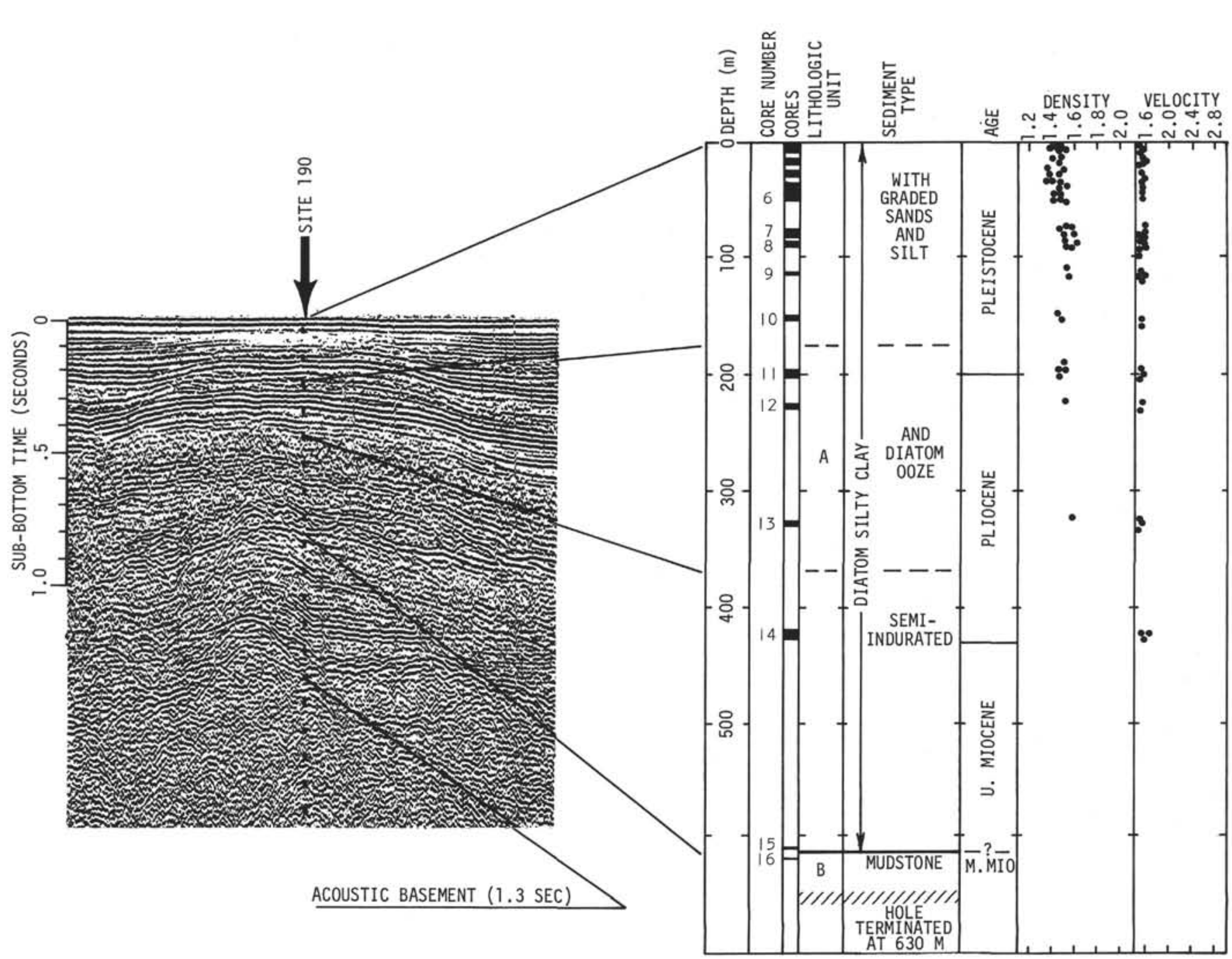


Figure 5. *Correlation of reference seismic reflection profile, physical properties, and lithologic column, Site 190.*

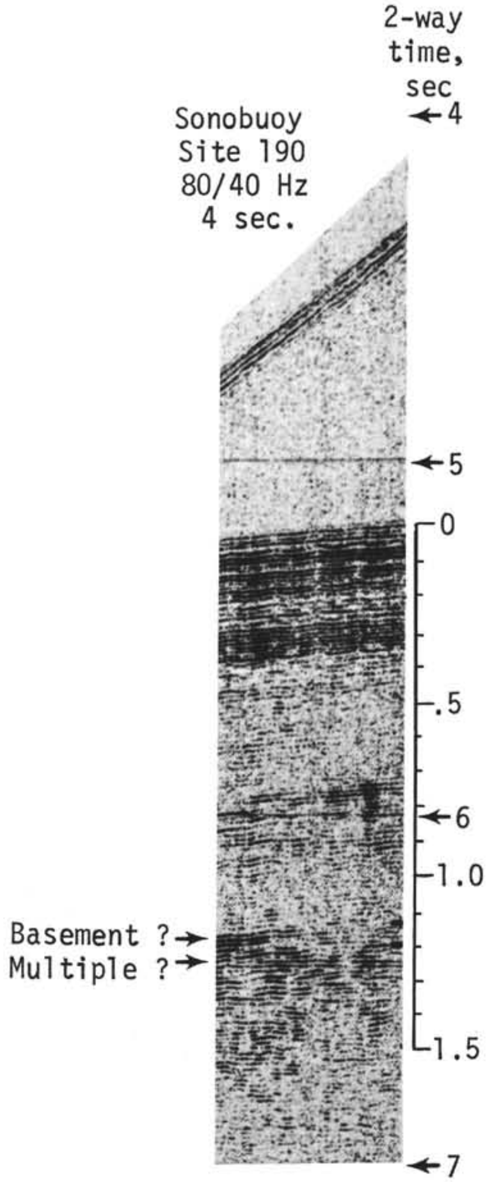
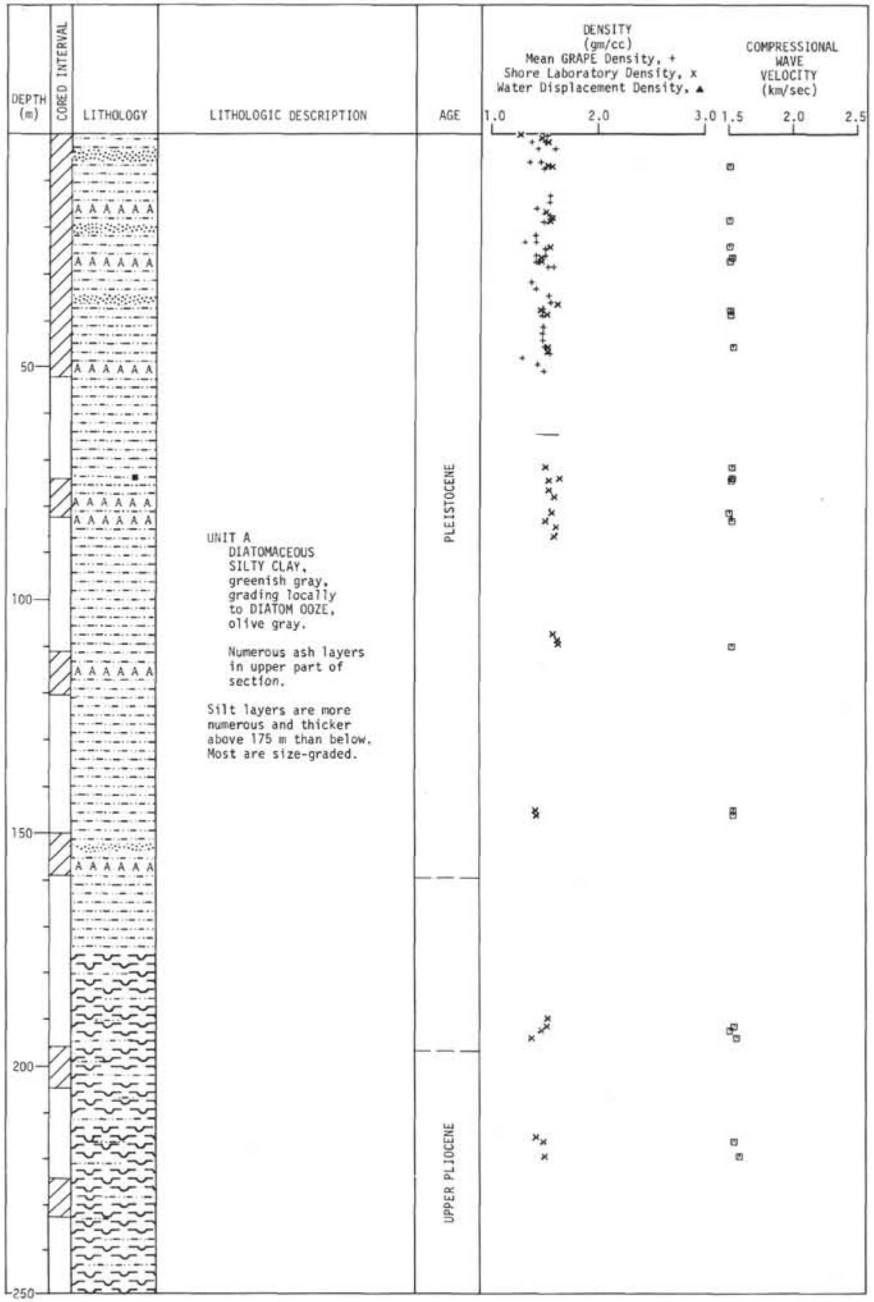


Figure 6. *Sonobuoy profile, Site 190.*

SITE 190



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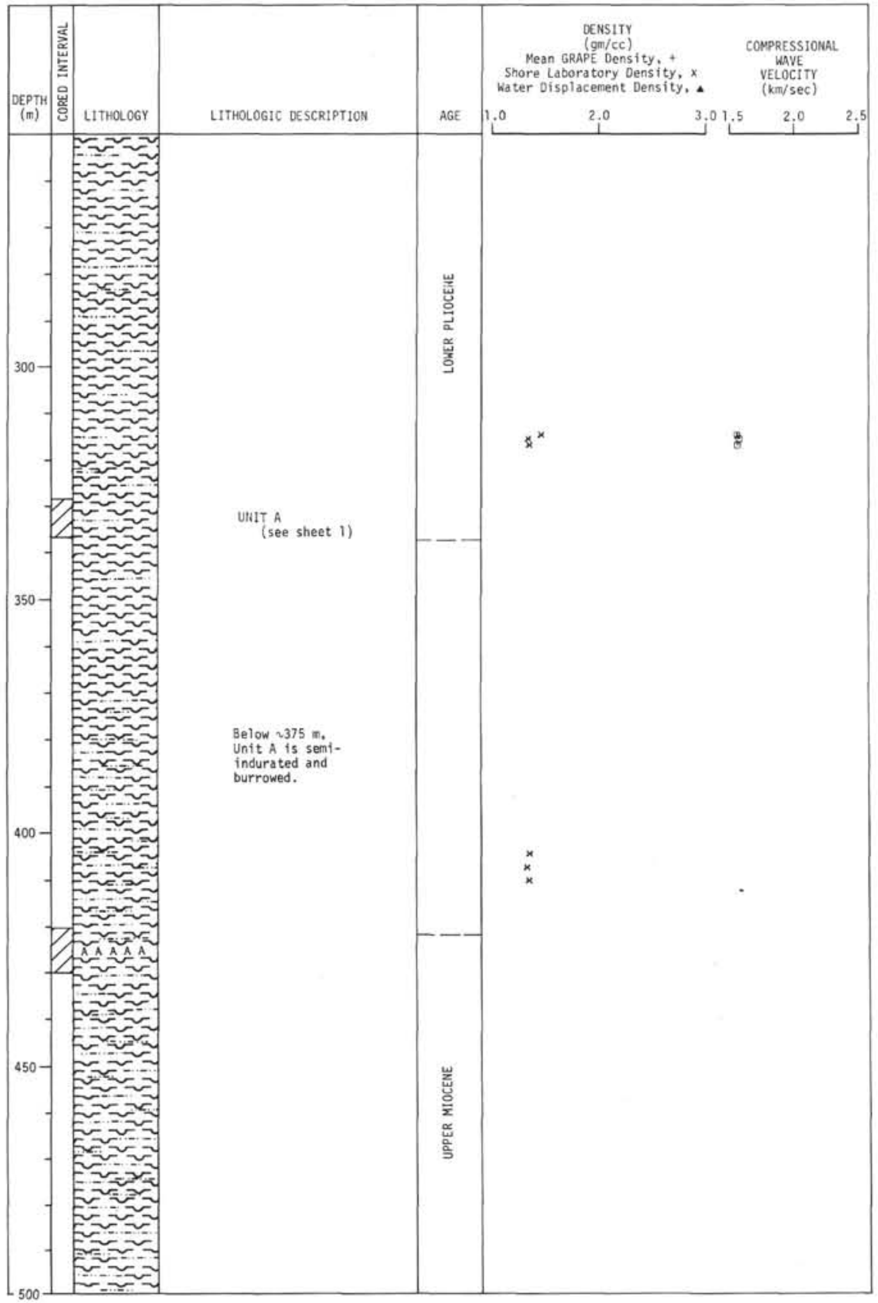
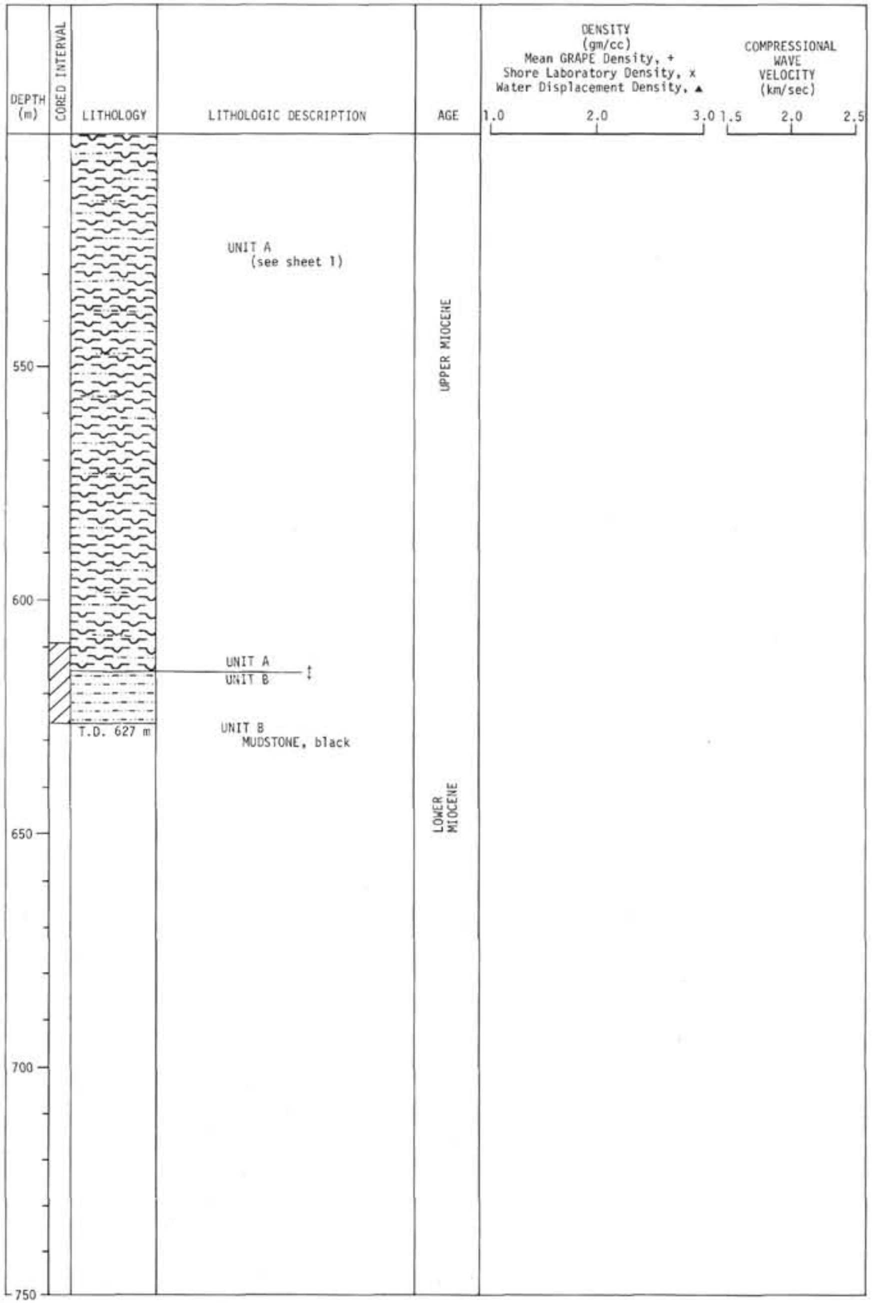


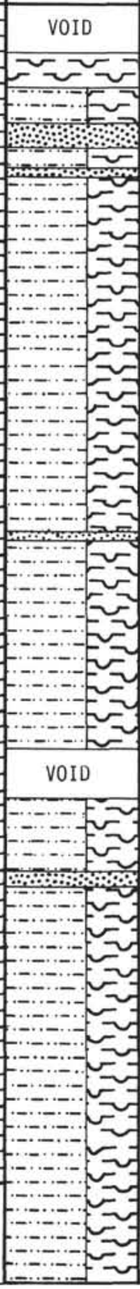
SITE 190



DEPTH (m)
CORED INTERVAL
LITHOLOGY
LITHOLOGIC DESCRIPTION
AGE
DENSITY (gm/cc) Mean GRAPE Density, + Shore Laboratory Density, x Water Displacement Density, ▲
COMPRESSIONAL WAVE VELOCITY (km/sec)
1.0 2.0 3.0
1.5 2.0 2.5
550
600
650
700
750
UNIT A (see sheet 1)
UPPER MIOCENE
UNIT A
UNIT B
T.D. 627 m
UNIT B MUDSTONE, black
LOWER MIOCENE

Site 190 Hole Core 1 Cored Interval: 0-6

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
UPPER PLEISTOCENE	(D) Denticula seminae (S) Distephanus octangulatus	PF BF D R S PF BF	- F A R - F C	G M - P	1	0.5 1.0	VOID		43 52 84 105 130
		PF BF	- R		2				34
		PF BF	F R		3				39 85 125
		PF BF	F R		4		VOID		
		PF BF	C R	M	5				75
		D N R S	A R F R	G M M M	Core Catcher				



LITHOLOGIC DESCRIPTION

oxidized surface layer: DIATOM OOZE (80-95% diatoms)
dark yellow brown (10YR 3/4) - olive (5Y 4/3) - grayish olive (10Y 4/2)

SAND layers, olive black (5Y 2/1), very fine grained

Slide 1-84	Slide 1-105
40% feldspar	40% feldspar
25% pyroxene	15% pyroxene
20% lithics	15% lithics
5% amphibole	10% opaques
10% quartz	5% amphibole
	10% quartz

SILTY SAND, very fine grained
60% feldspar, 5% pyroxene, 5% lithics, 5% opaques, 20% quartz

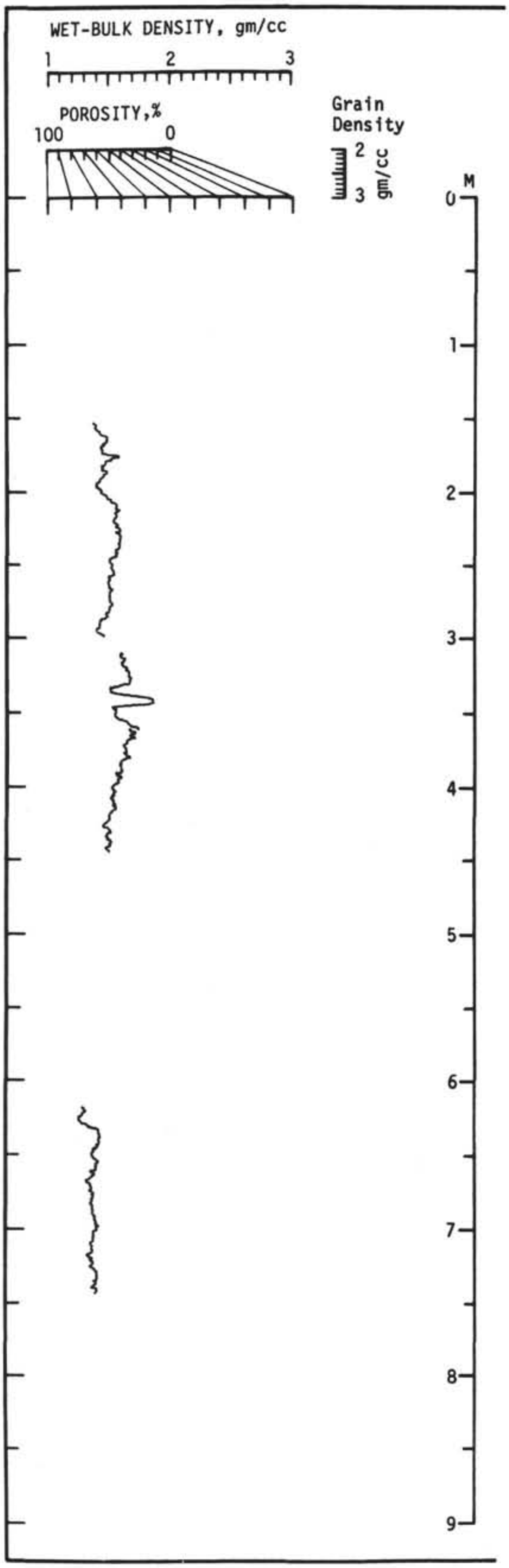
Basic lithology

DIATOM RICH to DIATOMACEOUS SILTY CLAY
olive gray (5Y 3/2)

scattered pods and thin layers of DIATOM OOZE and SAND

SAND

Explanatory notes in Chapter 1


WET-BULK DENSITY, gm/cc
1
2
3
POROSITY,%
100
0
Grain Density
2
3
gm/cc
M
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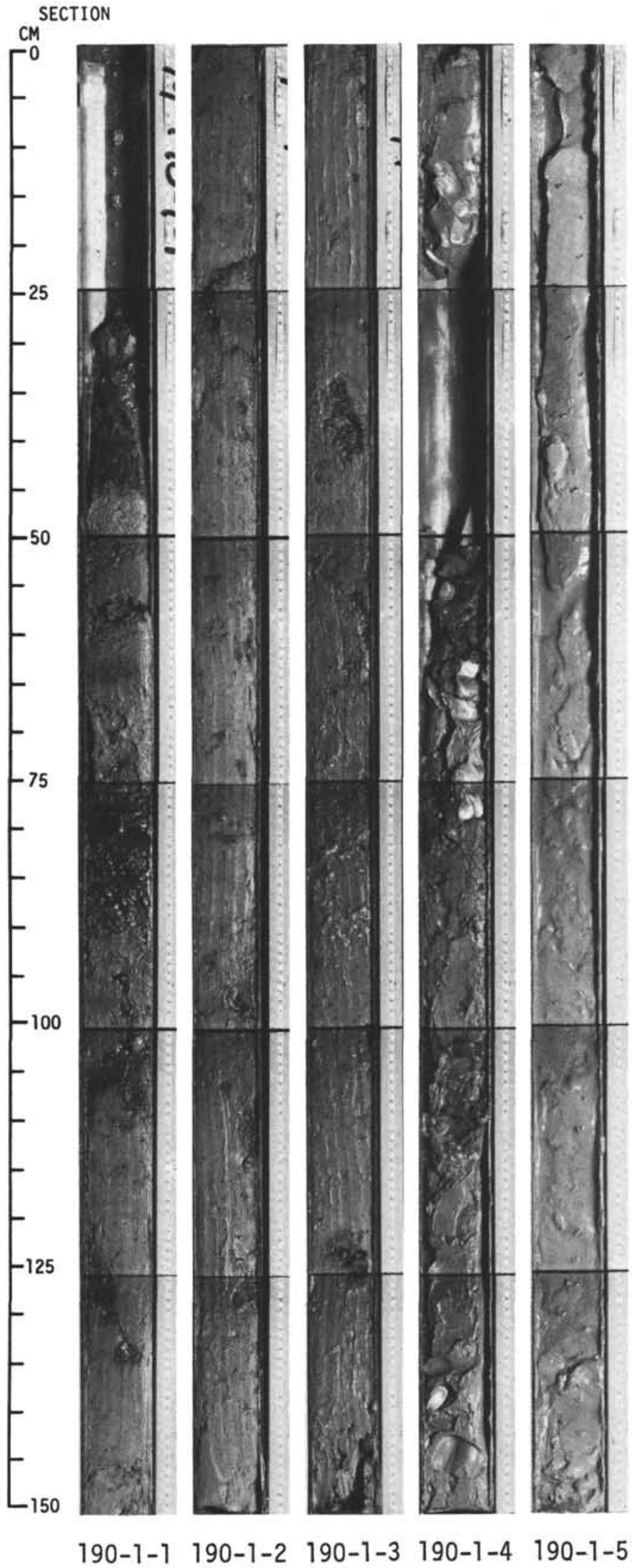
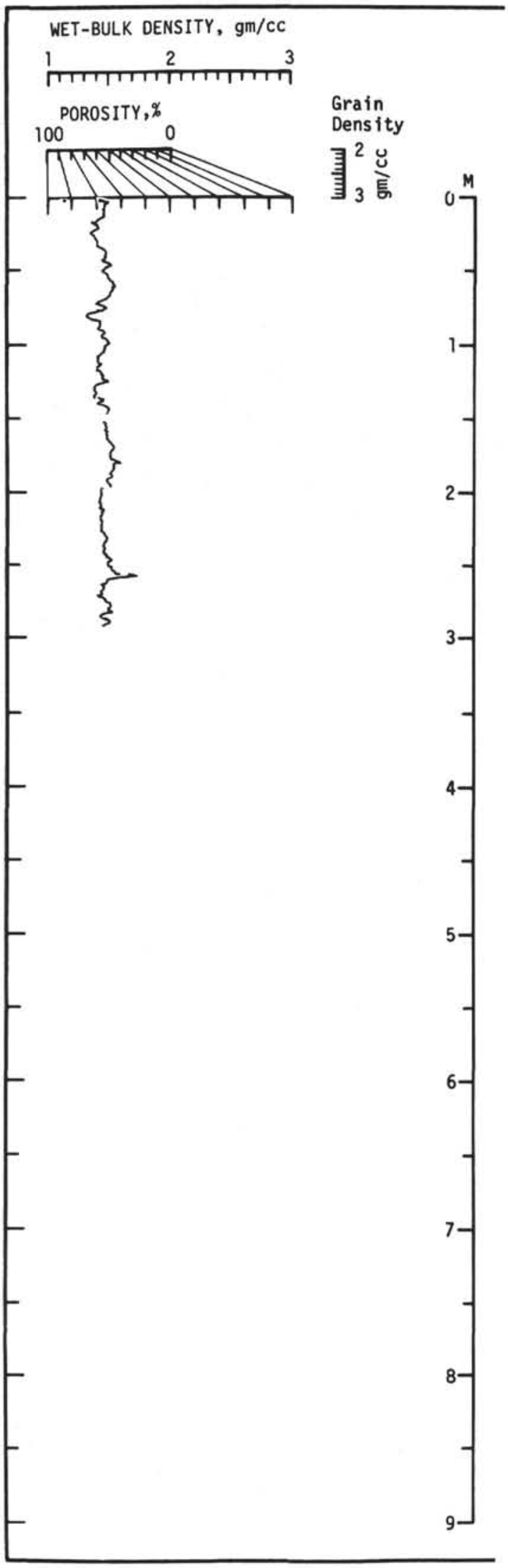
1
2
3
4
5
6
7
8
9


SECTION
CM
0
25
50
75
100
125
150
190-1-1
190-1-2
190-1-3
190-1-4
190-1-5

Site 190 Hole Core 2 Cored Interval: 6-15

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	FOSSIL CHARACTER: ABUND.	FOSSIL CHARACTER: PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
UPPER PLEISTOCENE	(D) *Denticula seminae*	D	A	G	1					
		PF	R	M		0.5			45	Basic lithology DIATOM BEARING SILTY CLAY and DIATOM RICH SANDY CLAYEY SILT olive gray (5Y 3/2)
		BF	-						81	
						1.0				
					2				15	with scattered bands and pods of SAND BEARING SILTY CLAY and 1-4 cm thick layers of SANDY DIATOMACEOUS SILT light olive gray (5Y 5/2)
		PF	-						96	VITRIC ASH very light gray (N8)
		BF	R							
		D	A	G	Core Catcher					VITRIC ASH very light gray (N8)
		N	-	-						
		R	R	M						
		S	R	M						

Explanatory notes in Chapter 1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gm/cc
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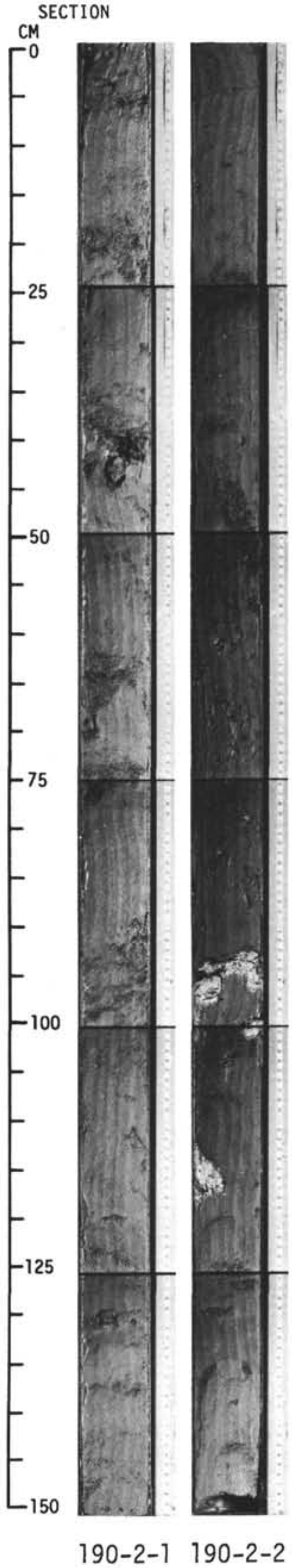
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CM
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75
100
125
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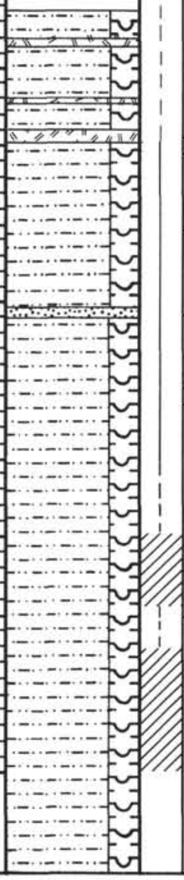
190-2-1
190-2-2

Site 190 Hole Core 3 Cored Interval: 15-24

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
MIDDLE PLEISTOCENE	(D) Rhizosolenia curvirostris (S) Distephanus octonarius	PF BF	R -		1	0.5 1.0	VOID		
		PF BF	- -		2				45 55
		D R S	A R -	G M -					105
		PF BF	- -		3				10 55 65
		PF BF	- -		4				23 50
		D N R S	A R R F	G M M M	Core Catcher				



LITHOLOGIC DESCRIPTION

VITRIC ASH, very light gray (N8) (layer about 2 cm thick)

2 cm VITRIC ASH, olive gray; contains 10-20% clay

VITRIC ASH, olive gray (5Y 3/2), 80-90% glass shards
10-20% clay

SANDY SILT (disturbed layer, about 5 cm thick)

Basic lithology
DIATOM RICH SILTY CLAY
olive gray (5Y 3/2) - dark greenish gray (5GY 4/1)

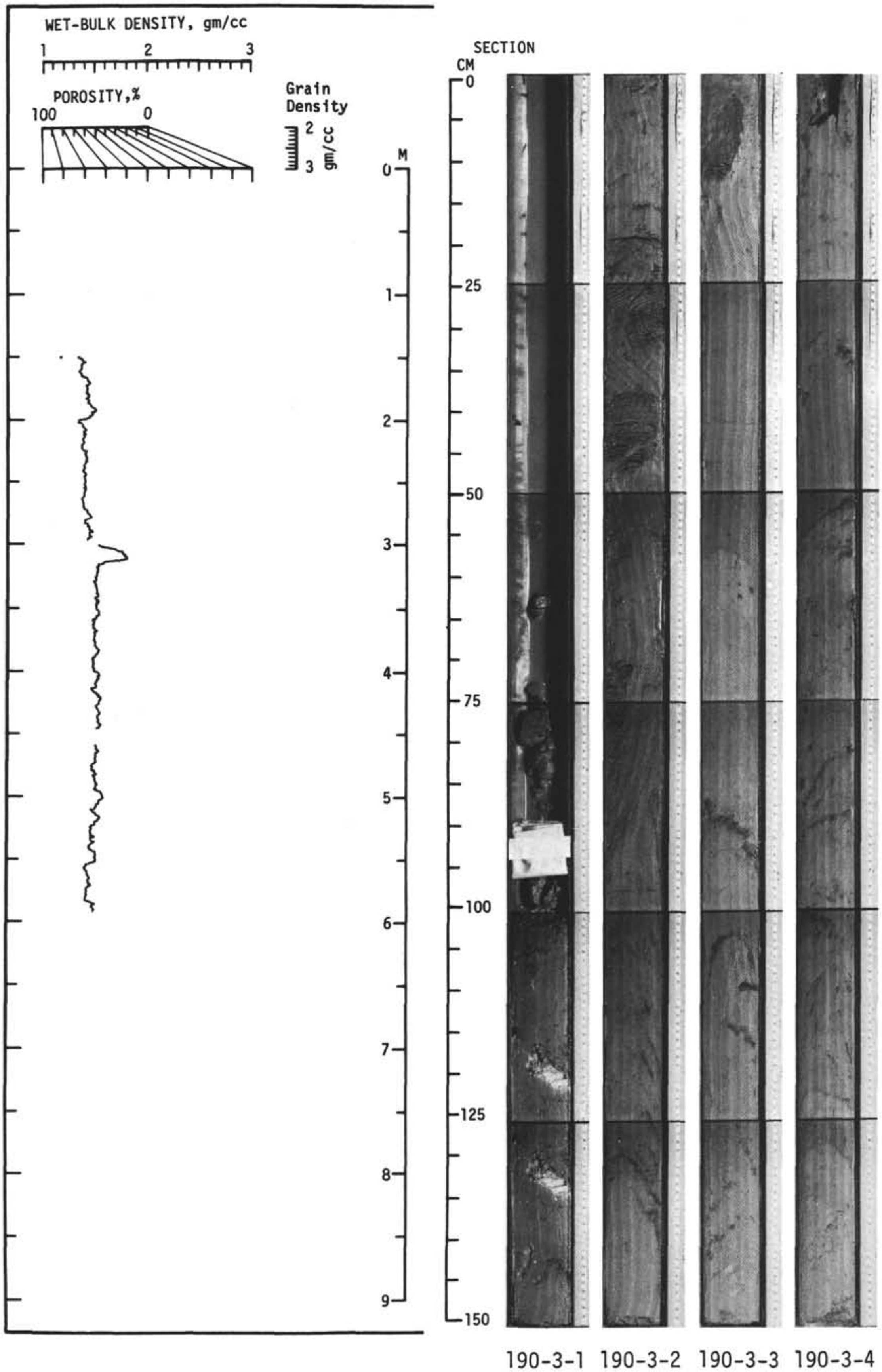
with scattered streaks, pods, and layers of SILT RICH CLAYEY DIATOM OOZE, grayish olive (10Y 4/2), compact SILT BEARING CLAY, dark greenish gray (5GY 4/1 - 2/1), and bands and pods of SILT and SANDY SILT, olive black (5Y 3/1)

Slide 2-55 (diatom ooze layer)
50% diatoms
20% silt
30% clay

Slide 2-105 (basic lith.)
10% diatoms
30% silt
60% clay

Slide 4-23
40% clay
30% feldspar
10% pyroxene
10% glass
5% diatoms
2% opaque

Explanatory notes in Chapter 1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Grain Density
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gm/cc
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8
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SECTION
CM
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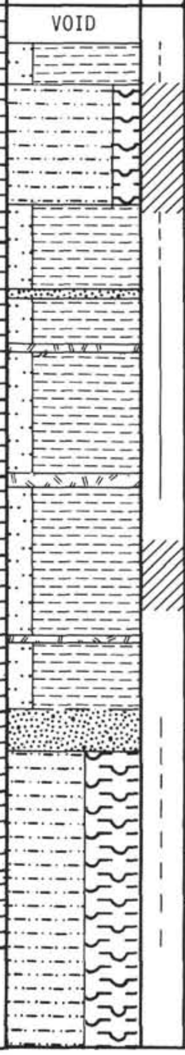
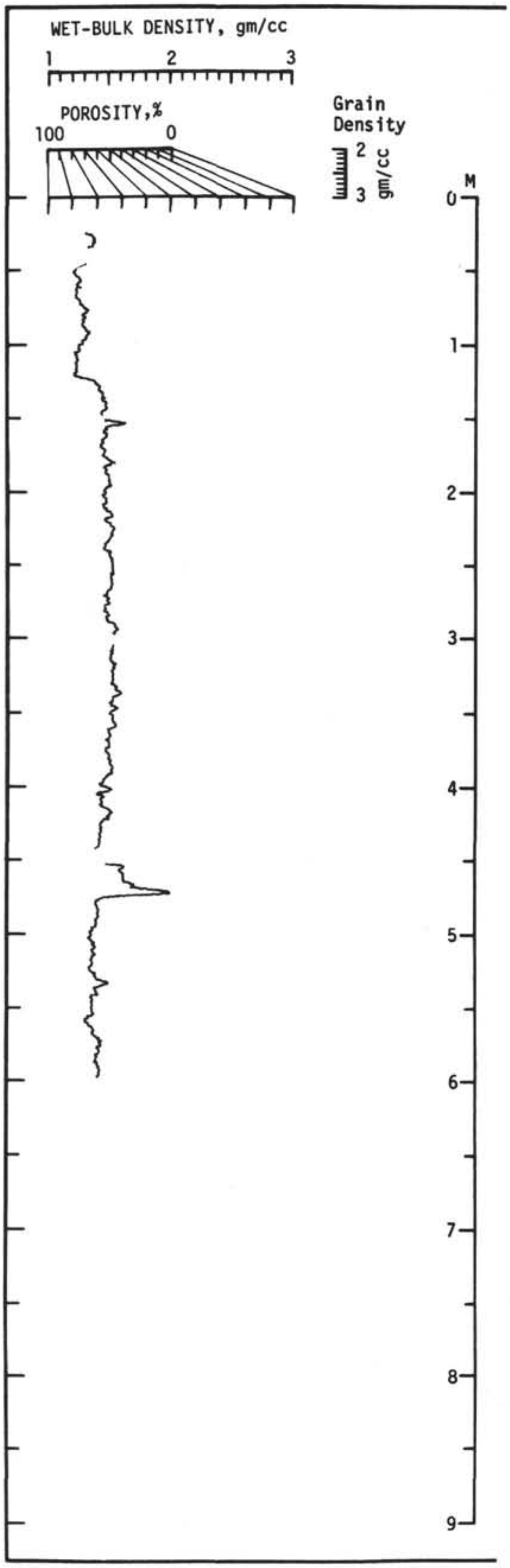
25
50
75
100
125
150
190-3-1
190-3-2
190-3-3
190-3-4

Site 190 Hole Core 4 Cored Interval: 24-33

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE PLEISTOCENE	(D) Rhizosolenia curvirostris (S) Distephanus octonarius	PF BF D R S	- R A F C	G M M	1	0.5 1.0	VOID		-30 80A 80B -140	mixture of DIATOM RICH and DIATOMACEOUS CLAYEY SILT olive gray (5Y 3/1 - 4/1) 10-30% diatoms 30-60% silt 20-40% clay
		PF BF	- R		2				-33 -68 -90	SANDY SILT (irregular pods) ASH DIATOM BEARING SILT RICH CLAY dark greenish gray (5GY 4/1)
		PF BF	- R		3				-75	ASH 3 layers of VITRIC ASH pinkish gray (5YR 8/1) composition range: TR - 5% diatoms 10 - 20% silt 80 - 85% clay ASH
		PF BF	A C	M	4				-10 -89 119 120	SANDY SILT, olive black (5Y 2/1), graded mixtures of DIATOM RICH SILTY CLAY and CLAY BEARING SILTY DIATOM OOZE olive gray (5Y 3/1 - 4/1) thin layers, pods of SANDY SILT, olive black (5Y 2/1)
		D N R S	A - R R	G - M M	Core Catcher					Slide 4-119 55% diatoms 35% silt (feld.pyrox.) 10% clay Slide 4-120 15% diatoms 25% silt 60% clay



Explanatory notes in Chapter 1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gm/cc
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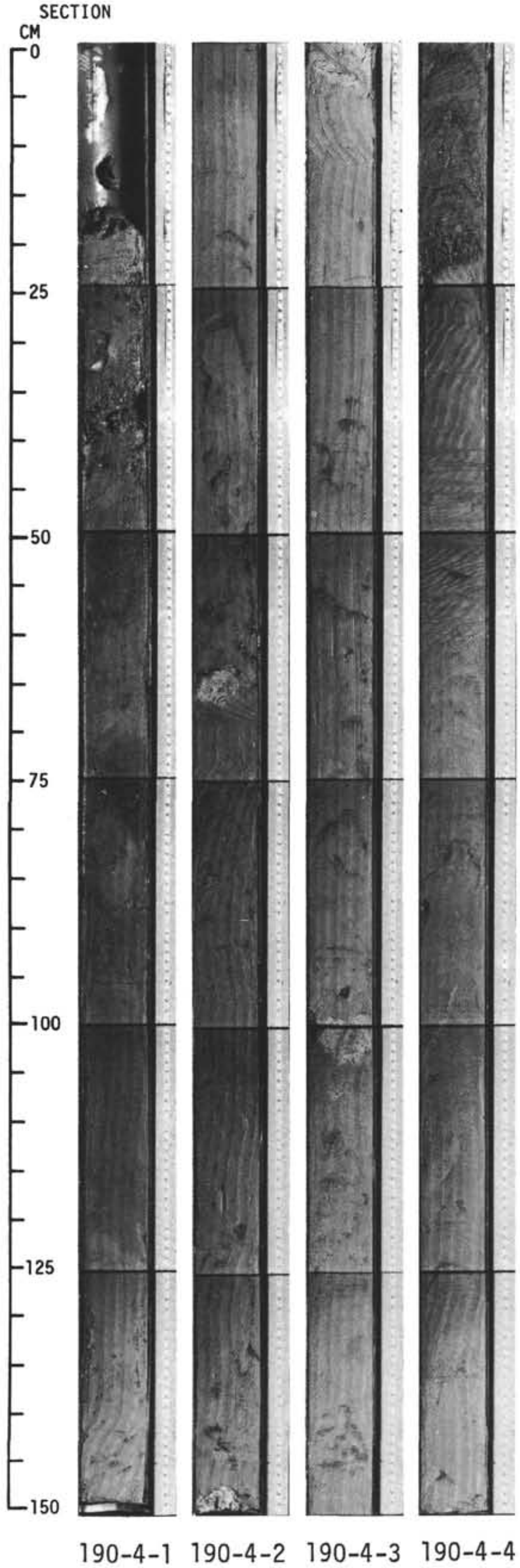
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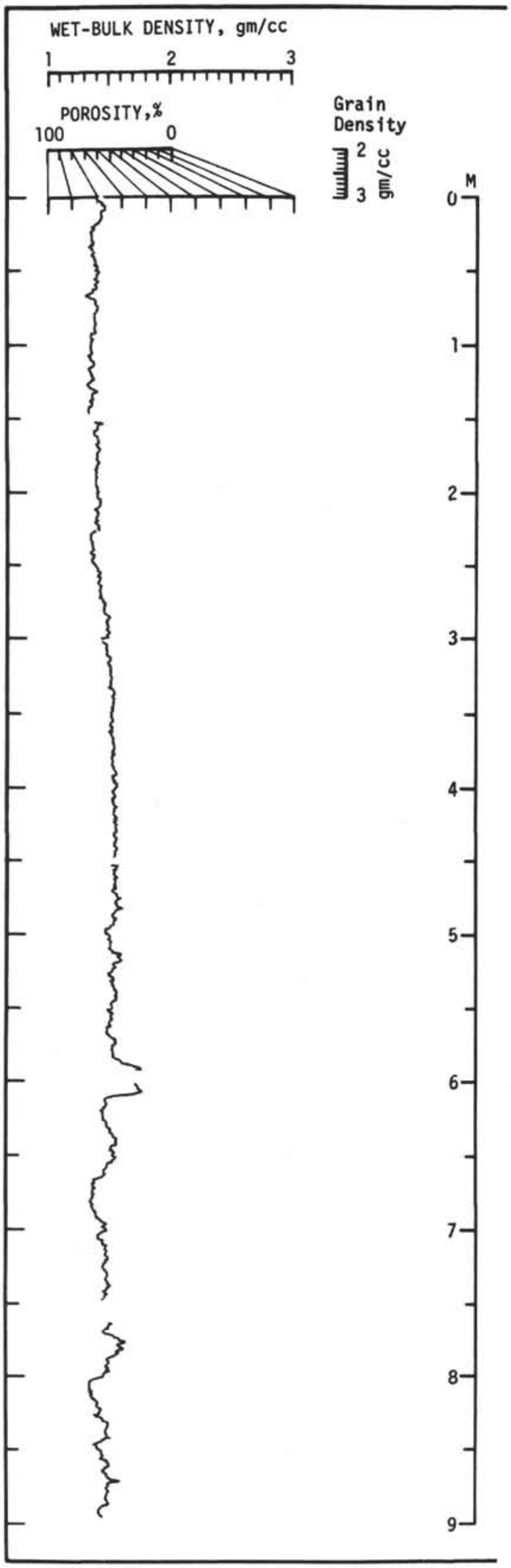
190-4-2
190-4-3
190-4-4

Site 190 Hole Core 5 Cored Interval: 33-43

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE PLEISTOCENE	(D) Rhizosolenia curvirostris (S) Distephanus octonarius	PF BF	F F	P	1	0.5 1.0			-75	DIATOMACEOUS SILTY CLAY dark greenish gray (5GY 4/1) Slide 1-75 40% diatoms 30% silt 30% clay
		PF BF R S	C R R F	M M M	2				-75	SILT RICH DIATOMACEOUS CLAY Slide 2-75 30% diatoms 20% silt 50% clay
		D PF BF	A F R	G P	3				-75	gradational change DIATOM and SILT RICH CLAY Slide 3-75 10% diatoms 20% silt 70% clay
		PF BF	- -		4				-60 -145	SILTY SAND
		PF BF R S	C R R -	M M -	5				-21 -60 -86	SILT RICH CLAYEY DIATOM OOZE light olive gray (5Y 5/2) Slide 5-86 50% diatoms 10% silt 40% clay
		PF BF	- -		6				-30 -95 -120	DIATOM and SILT RICH CLAY dark greenish gray (5GY 4/1) composition range: 5 - 10% diatoms 15 - 20% silt 70 - 80% clay pods and thin layers of SANDY SILT and SILT RICH CLAYEY DIATOM OOZE
		D N R S	A - R R	G - M M	Core Catcher					

Explanatory notes in Chapter 1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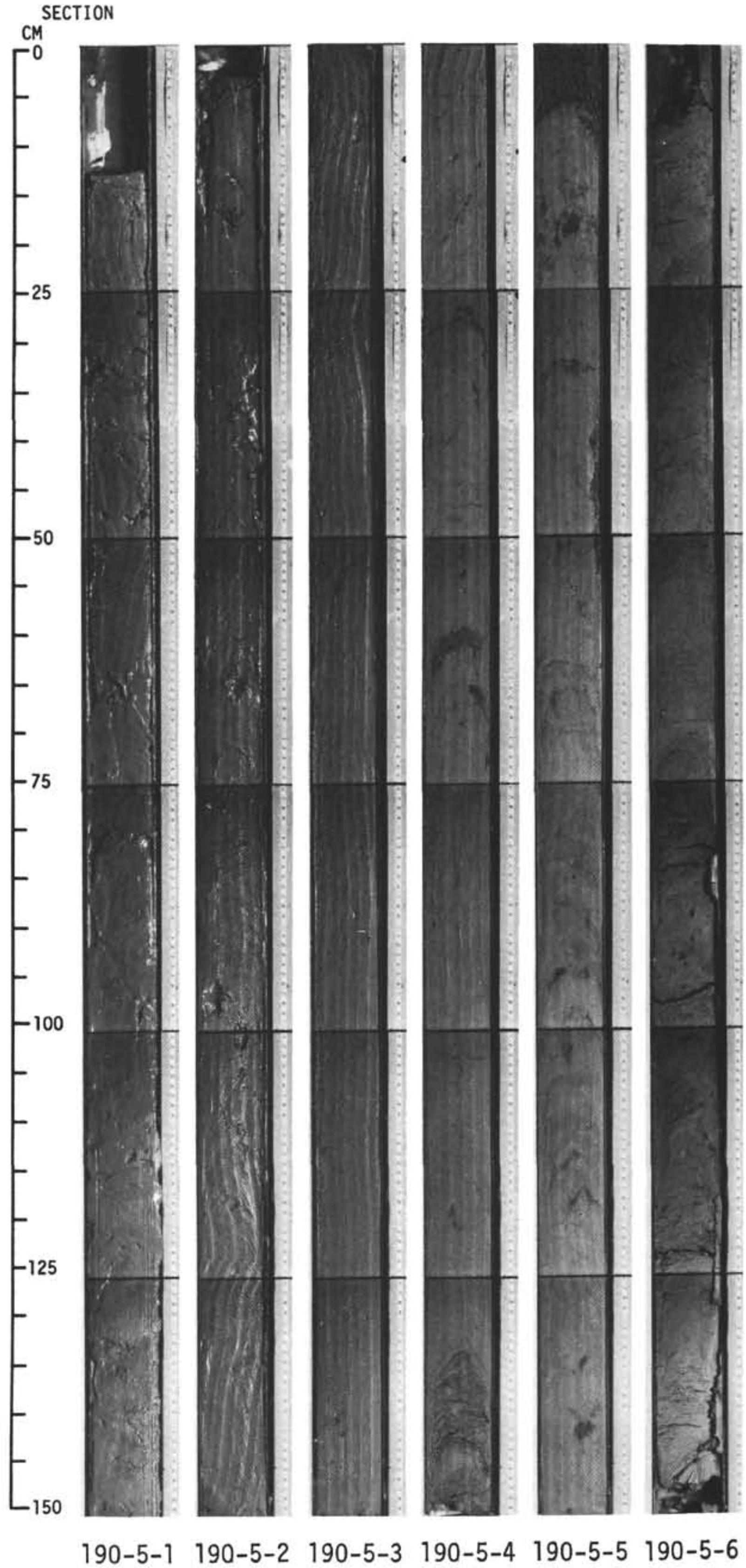
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190-5-5
190-5-6

Site 190 Hole Core 6 Cored Interval: 43-52

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
MIDDLE PLEISTOCENE	(D) Rhizosolenia curvirostris (S) Distephanus octonarius	PF BF	F R	M	1	0.5 1.0			75 128
		PF BF	F R	P	2				
		D R S	A R F	G M M	3				148
		PF BF	C R	P					
		PF BF	- -		4				75 123 140
		PF BF	R R	P	5				74 105 145
		D N R S	A - R R	G - M M	Core Catcher		?—?—?		

LITHOLOGIC DESCRIPTION

Interbedded and mixed by coring:
DIATOM and SILT RICH CLAY
DIATOMACEOUS SILTY CLAY and
SILT RICH CLAYEY DIATOM OOZE
dark greenish gray (5GY 4/1) to
olive gray (5Y 3/2)

Slide 1-75	Slide 1-128
45% diatoms	60% diatoms
10% silt	10% silt
45% clay	30% clay

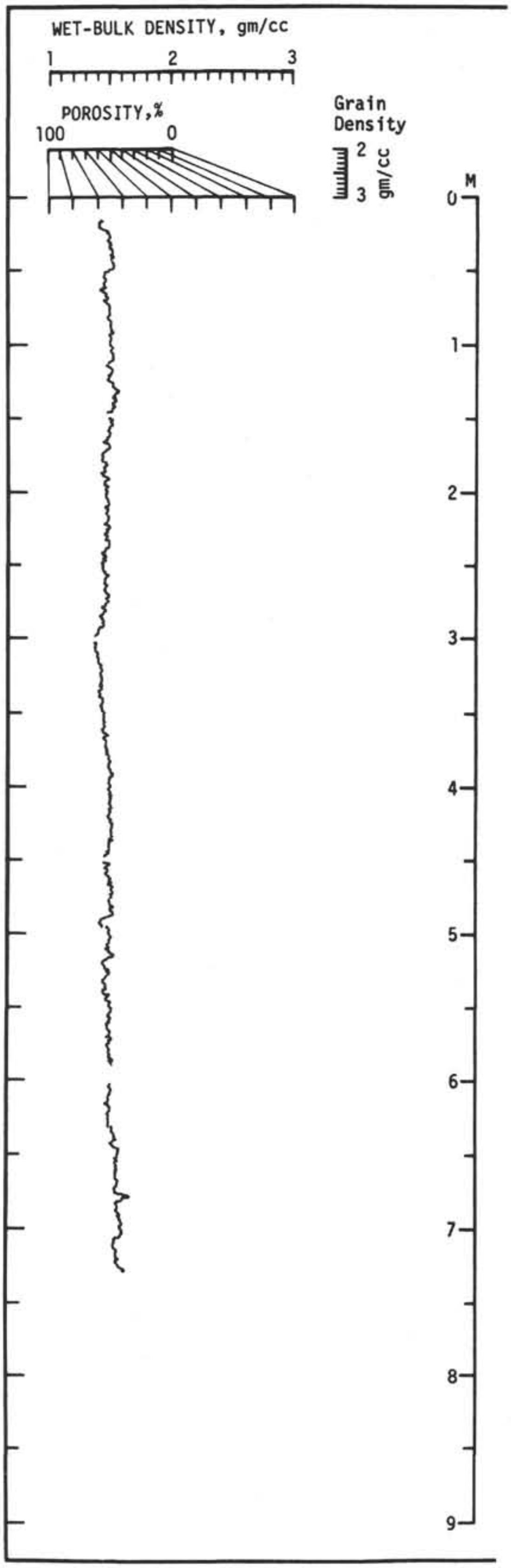
Slide 4-75	Slide 4-123
20% diatoms	40% diatoms
10% silt	20% silt
70% clay	40% clay

1-2 cm SILT layer

VOID

CLAY BEARING VITRIC ASH layers
olive gray (5Y 4/1 - 5/2)
5 - 10% clay
90 - 95% glass shards

Explanatory notes in Chapter 1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gm/cc
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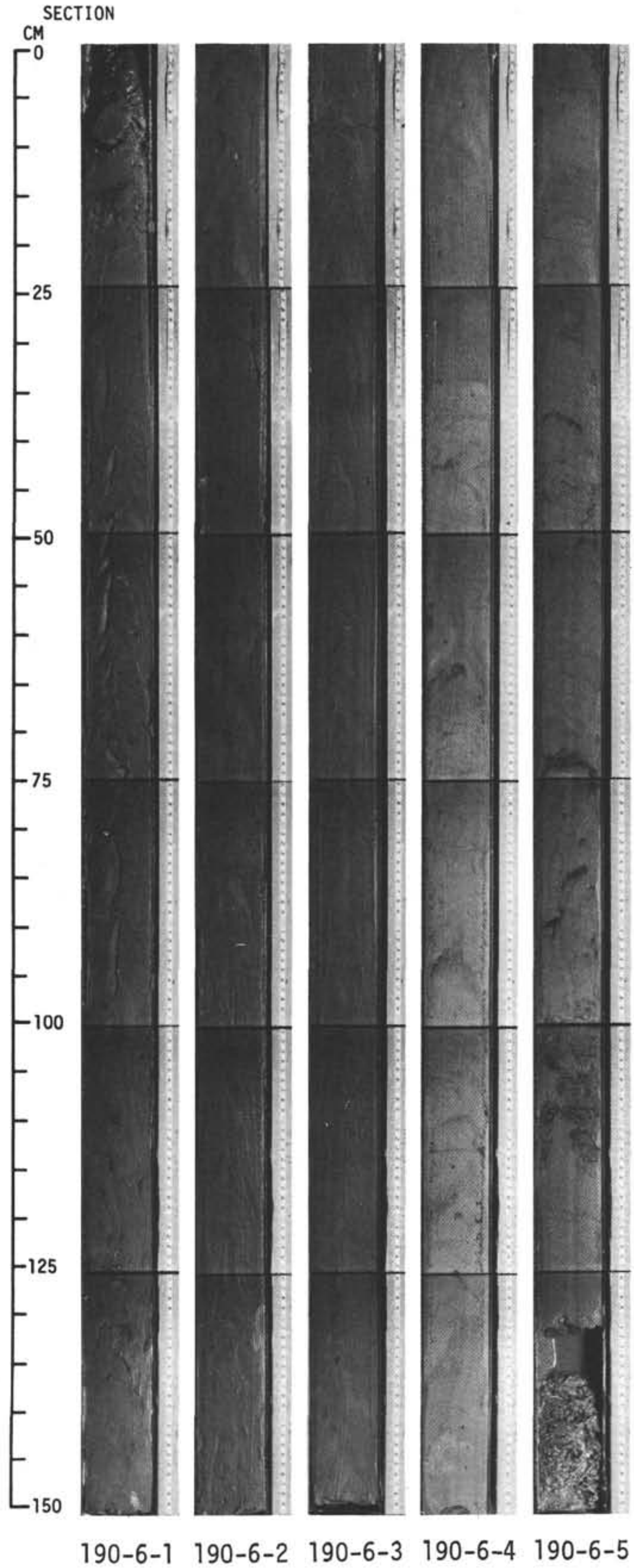
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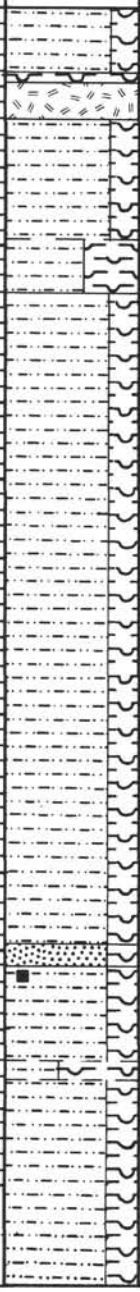
190-6-2
190-6-3
190-6-4
190-6-5

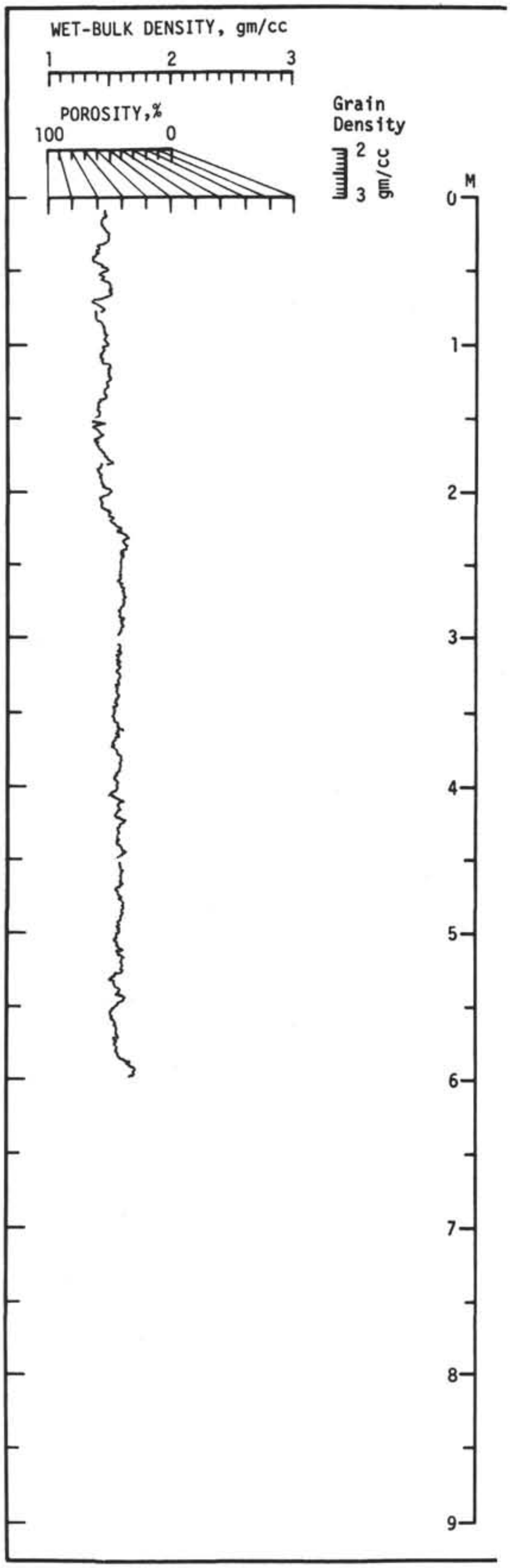
Site 190 Hole Core 7 Cored Interval: 75-84

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE PLEISTOCENE	(D) Rhizosolenia curvirostris; (S) Distephanus octonarius				1	0.5; 1.0			44; 46; 54; 66; 95	DIATOM OOZE, olive gray (5Y 4/2), 95% diatoms SILT and CLAY BEARING VITRIC ASH olive gray (5Y 4/1) to dark yellow brown (10YR 3/2) DIATOMACEOUS CLAYEY SILT (?) olive gray (5Y 4/1)
		PF BF D R S	C F F R R	M - G M M	2				75	Basic lithology DIATOM and SILT RICH CLAY to DIATOM RICH SILTY CLAY dark greenish gray (5GY 4/1) composition range: 10 - 25% diatoms 10 - 30% silt 50 - 70% clay
					3				59; 107	pods, streaks and thin bands of olive black (5Y 3/1) SILT and olive gray DIATOMACEOUS CLAYEY SILT
					4				75; 148	erratic shale fragment, sec. 5, 15 cm
		PF BF	C R	M	5					GLASS and DIATOM RICH SAND, olive gray (5Y 3/2) 25% diatoms, 35% feldspar, 15% lithics, opaque etc. 15% glass, 5% pyroxene and other CARBONATE and SILT BEARING CLAY RICH DIATOM OOZE 65% diatoms 5% silt 10% carbonate 20% clay
					Core Catcher					XR 2-60: 43% amorph., 17% quartz, 13% plag., 21% mica, 5% chlor., 2% mont.

Core Catcher:

	A	G
D		
N	-	-
R	R	M
S	F	M
PF	-	
BF	-	

Explanatory notes in Chapter 1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gm/cc
M
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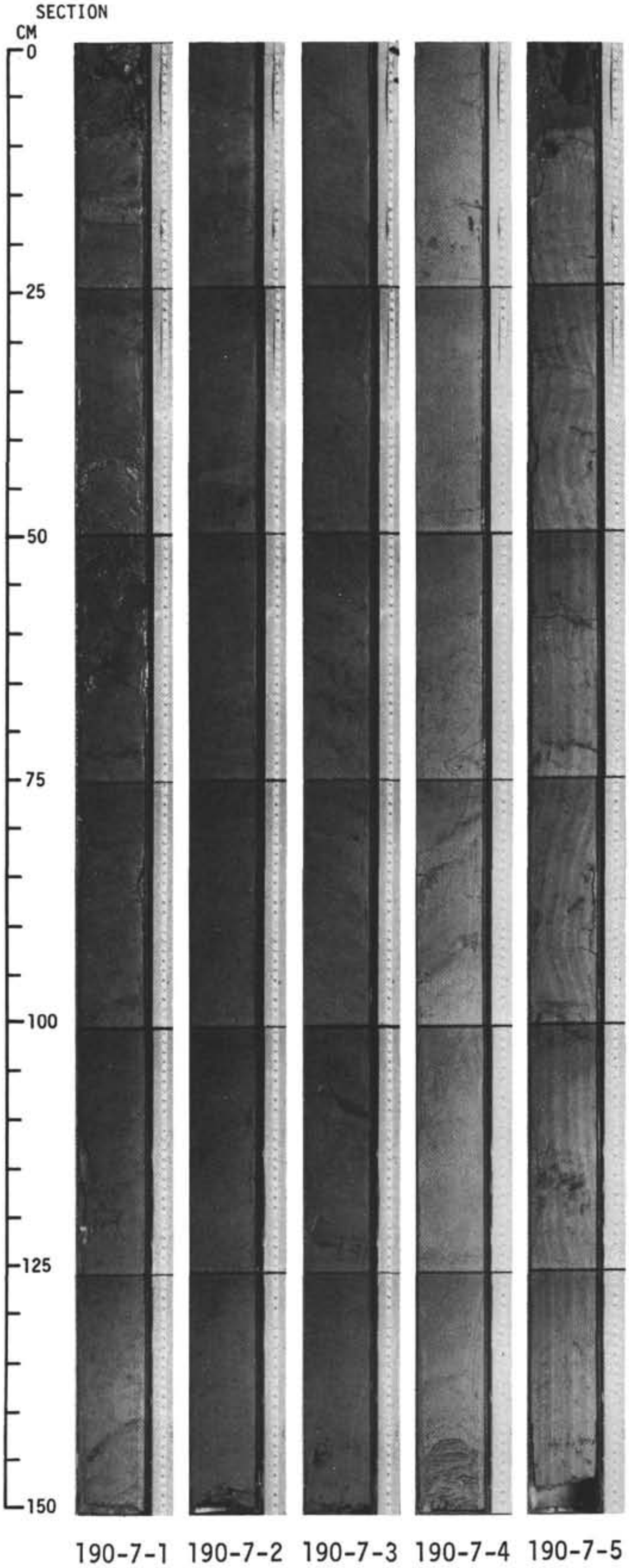
SECTION
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190-7-4
190-7-5

Site 190 Hole Core 8 Cored Interval: 84-93

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
MIDDLE PLEISTOCENE	(D) Rhizosolenia curvirostris	D R S	A R C	G M M	1	0.5 1.0	VOID		
		PF BF	- R		2				130 25 70 100 145
					3				24 84 100 141
					4				
LOWER PLEISTOCENE	(D) Actinocyclus oculatus (S) Dictyocha subarctios				5				46 95
		D N R S	A - R F	G - M M	Core Catcher				

LITHOLOGIC DESCRIPTION

CLAYEY SILT 55% silt, 45% clay
to
DIATOM RICH CLAYEY SILT 10% diatoms, 50% silt, 40% clay
dark greenish gray (5GY 4/1)

VITRIC ASH, olive (5Y 4/3)

SILT and CLAY BEARING DIATOM OOZE
light olive gray (5Y 5/1)
80 - 85% diatoms
5 - 10% silt
10% clay

ASH

CLAY RICH SILTY DIATOM OOZE
greenish gray (5GY 4/1)
60% diatoms
30% silt
10% clay

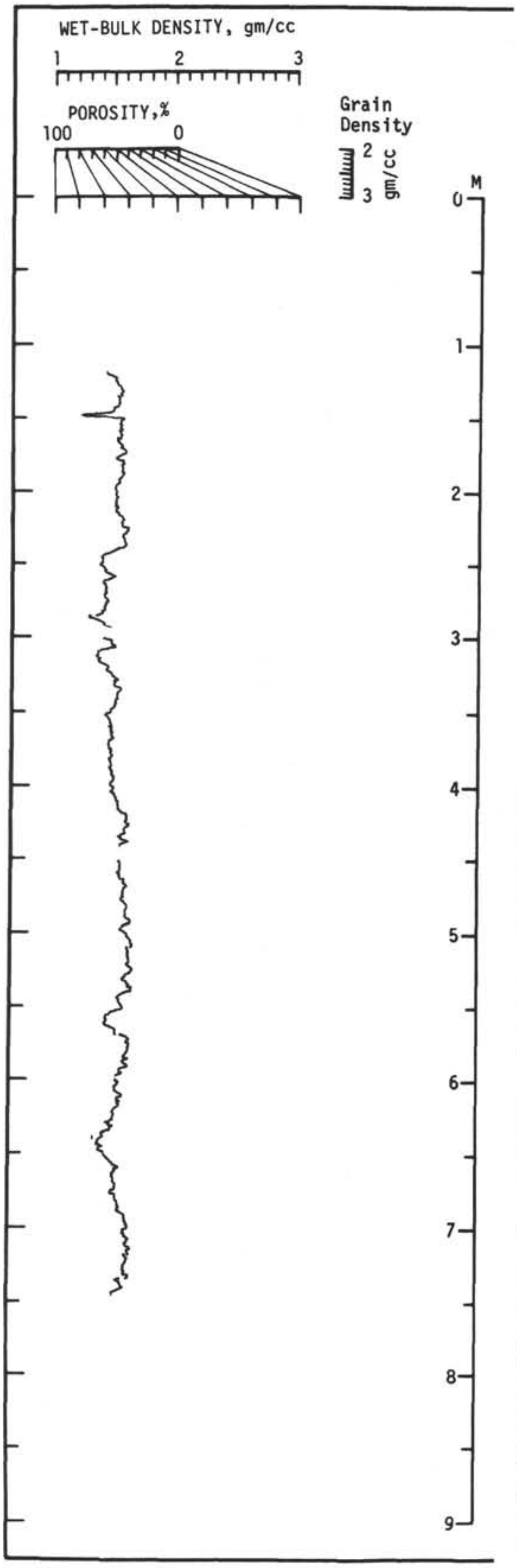
DIATOM OOZE, light olive gray (5Y 5/1)

SILT and CLAY BEARING DIATOM OOZE, grayish olive (10Y 3/2)

DIATOM BEARING SILTY CLAY
olive gray (5Y 3/2) to dk greenish gray (5GY 3/1)

pods, streaks and thin bands of:
dark feldspathic silt and
compact greenish black clay
throughout the core

Explanatory notes in Chapter 1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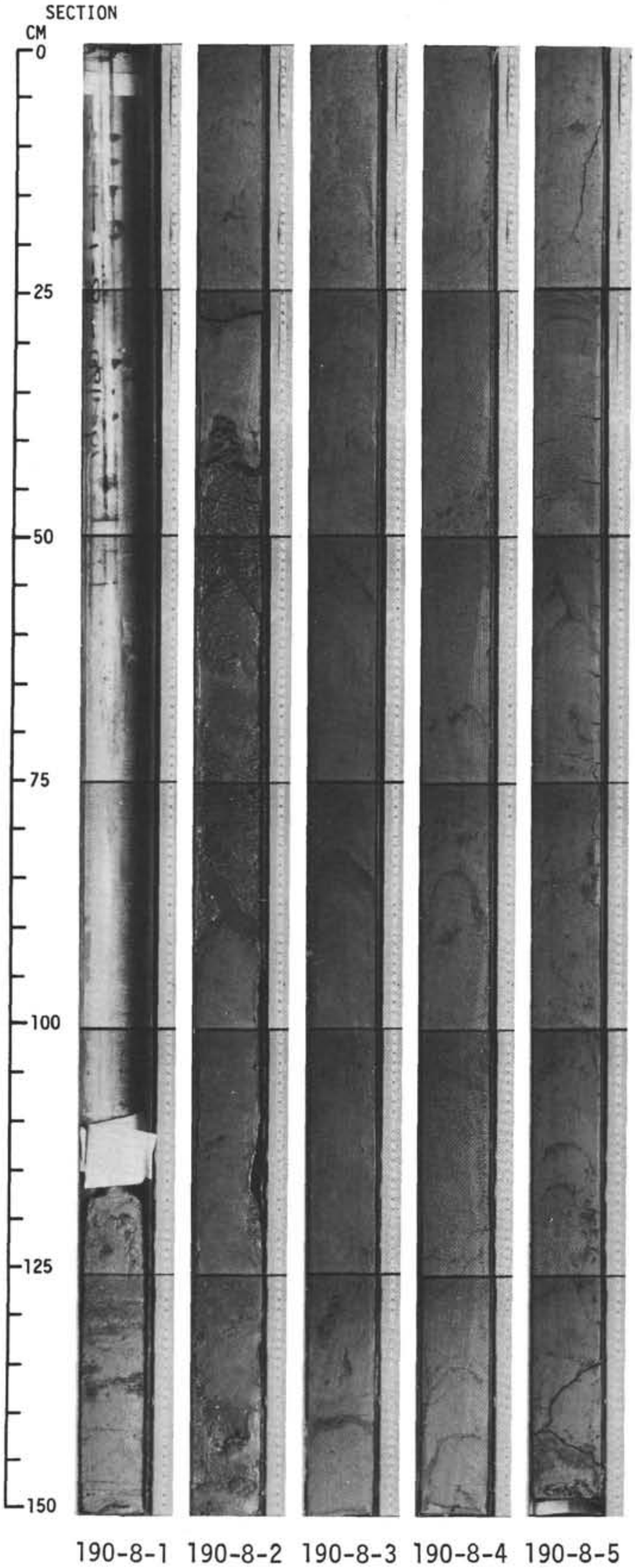
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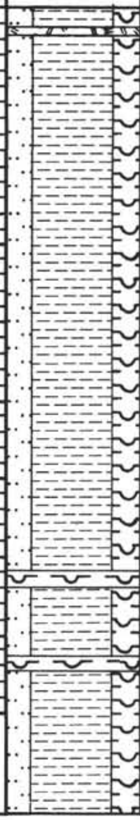
190-8-4
190-8-5

Site 190 Hole Core 9 Cored Interval: 112-121

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
UPPER MIOCENE	(D) Denticulina kamtschatica	D R S PF BF	A R R C -	G M M P	1	0.5 1.0			3 9 12 15 75
					2				
LOWER PLEISTOCENE	(D) Actinocyclus oculatus (S) Dictyocha subarctios	PF BF	- -		3				75
					Core Catcher				

LITHOLOGIC DESCRIPTION

VITRIC ASH olive gray (5Y 4/1) 2 cm layer
- 70% glass shards
- 20% feldspar
- 10% other

Basic lithology:
DIATOM and SILT RICH CLAY
dark greenish gray (5GY 4/1)
- 10 - 25% diatoms
- 5 - 25% silt
- 65 - 75% clay

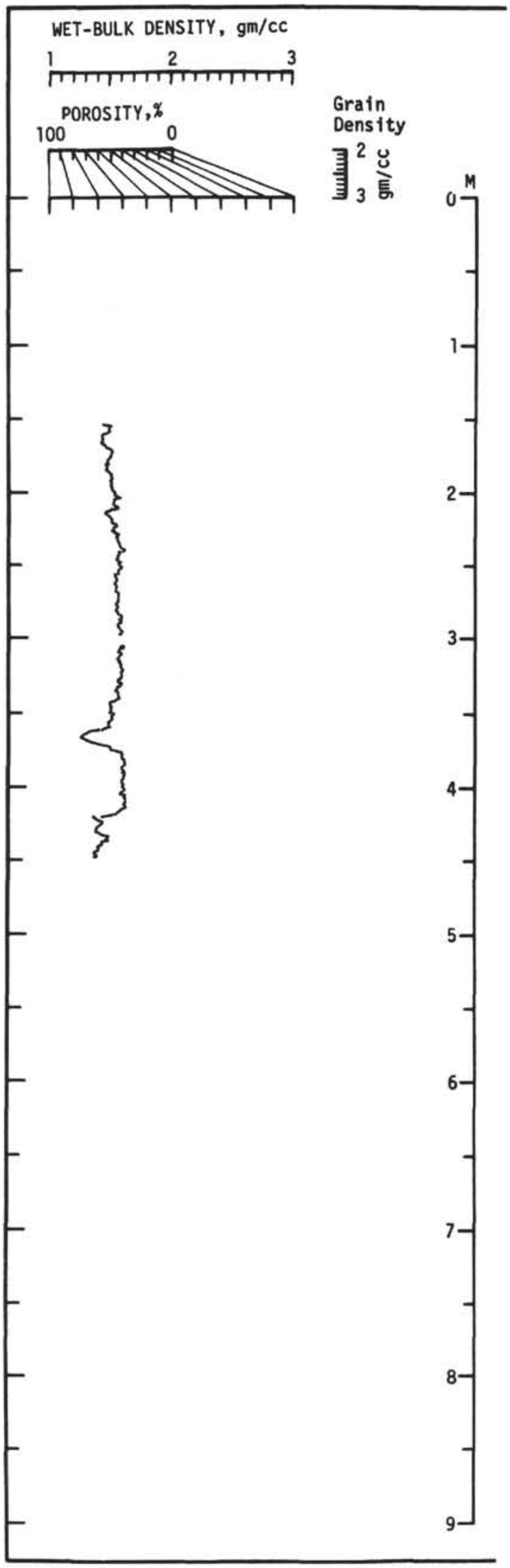
thin interbeds, pods and streaks of:
1) DIATOMACEOUS CLAYEY SILT olive gray (5Y 4/1) 30% diatoms
2) FELDSPATHIC SILT olive black (5Y 2/1)
3) SILT RICH CLAY greenish black (5GY 3/1)

DIATOM OOZE layers, olive gray (5Y 3/1)
- XR 2-30
- 75% amorph.
- 9% quartz
- 4% plag.
- 10% mica
- 2% chlor
- TR mont.

Core Catcher:

D	A	G
N	-	-
R	F	M
S	F	M
PF	R	
BF	R	

Explanatory notes in Chapter 1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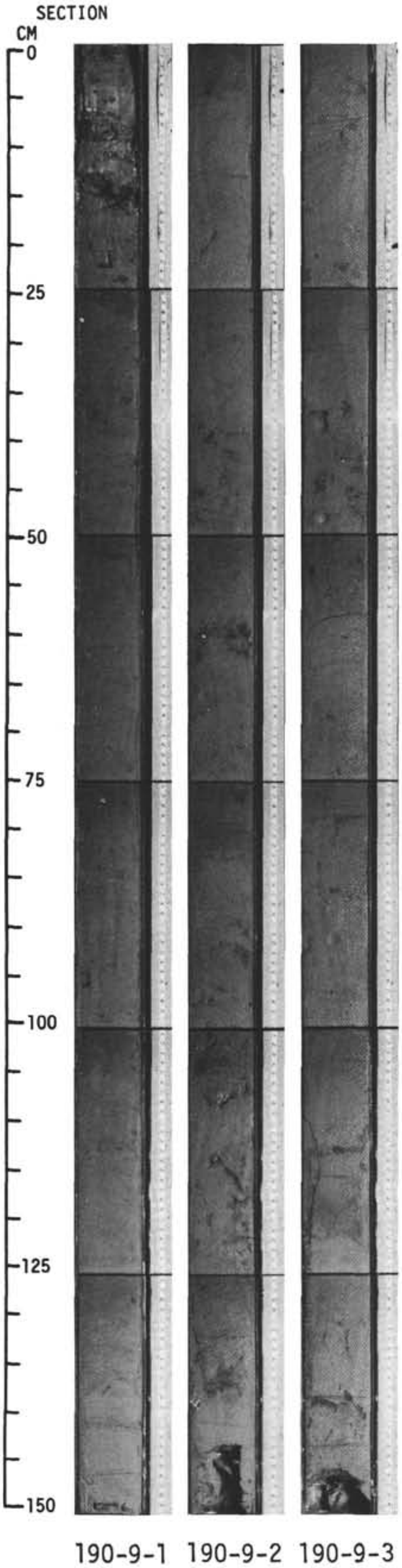
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190-9-3

Site 190 Hole Core 10 Cored Interval:150-159

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	FOSSIL CHARACTER: ABUND.	FOSSIL CHARACTER: PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
LOWER PLEISTOCENE	(D) Actinocyclus oculatus (S) Dictyocha subarctios	R S	R -	M -	1	0.5 1.0	VOID		90 135
		PF BF	- R		2				85 92
					3				12 51 72
		D N R S	A - R R	G - M M	Core Catcher				

LITHOLOGIC DESCRIPTION

Basic lithology (sections 1 and 2)
DIATOMACEOUS SILTY CLAY
olive gray (5Y 3/2)
Slide 1-90
30% diatoms
30% silt
40% clay

SILTY DIATOM OOZE
dark grayish olive (10Y 3/2)
55% diatoms, 45% silt

SILT and CLAY BEARING DIATOM OOZE, grayish olive (10Y 4/2)
FELDSPATHIC SILT, olive black (5Y 2/1)

Slide 2-85
90% diatoms
10% silt, clay

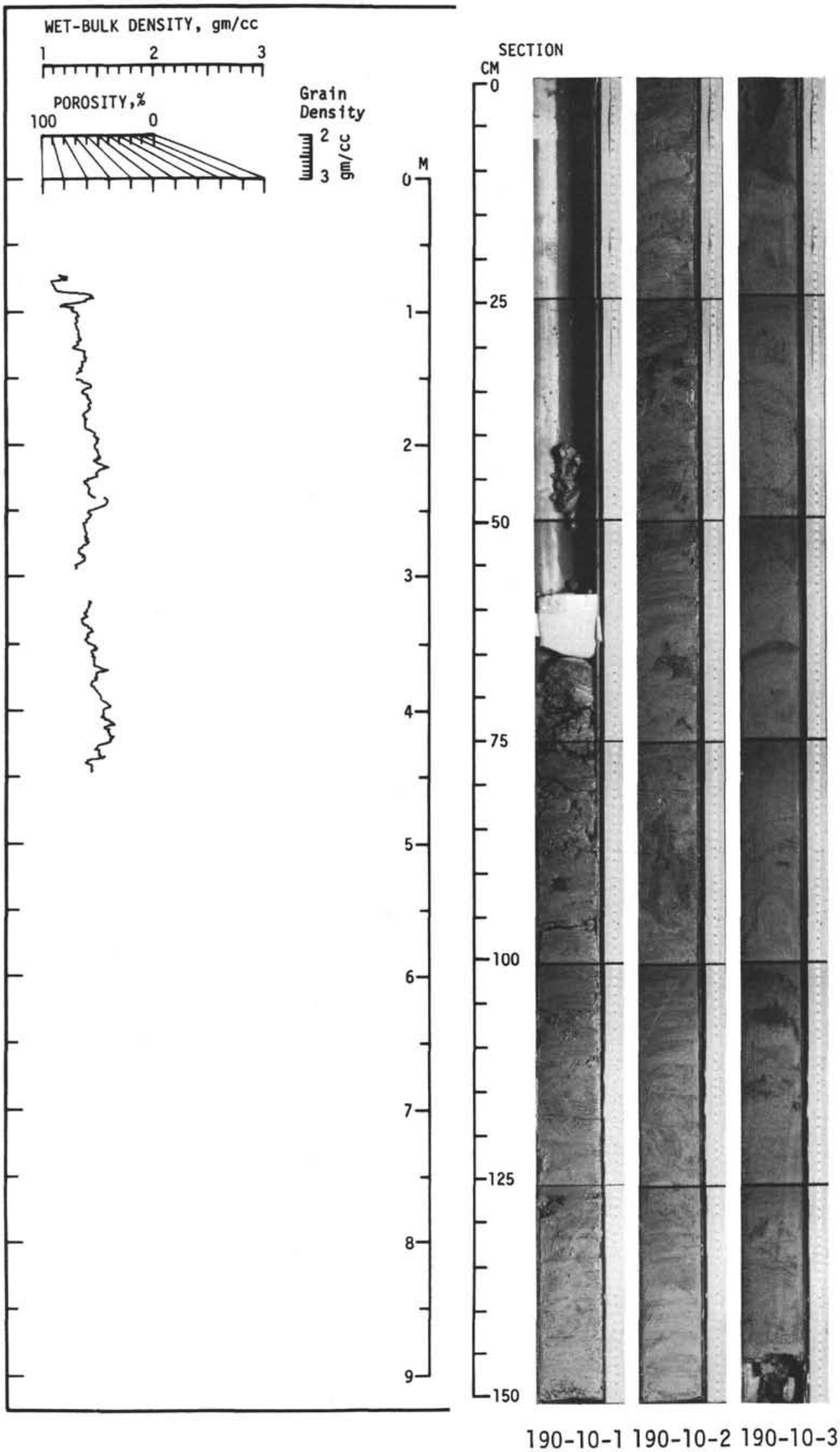
Slide 2-92
3 - 5% diatoms
60% feldspar and qtz(?)
30% pyroxene, other heavy
5% opaques

SILT, graded

VITRIC ASH pod
CLAY RICH SILTY DIATOM OOZE
olive gray (5Y 3/2)
Slide 3-72
50% diatoms
30% silt
20% clay

streaks pods and thin layers of:
FELDSPATHIC SILT and SAND
and compact greenish black (5GY 2/1) CLAY

Explanatory notes in Chapter 1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gm/cc
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SECTION
CM
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75
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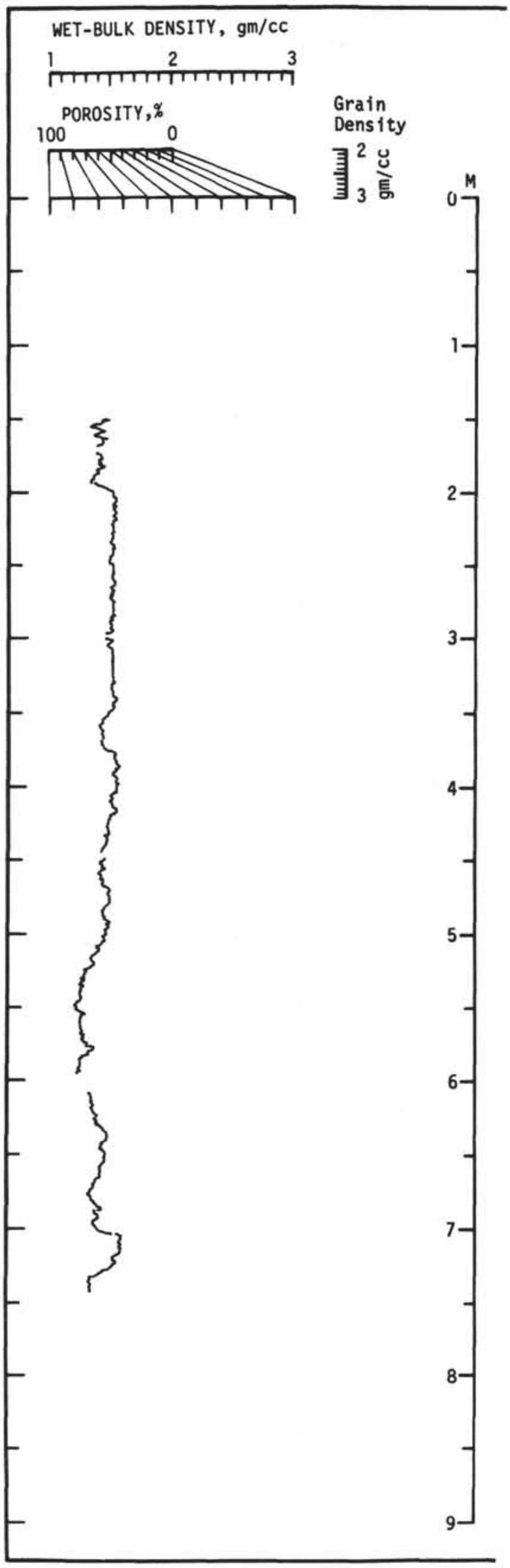
150
190-10-1
190-10-2
190-10-3

Site 190 Hole Core 11 Cored Interval: 197-206

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
UPPER PLIOCENE	(D) Thalassiosira zabelinae (S) Ammodochium rectangulare	D R S	A R C	G M M	1	0.5 1.0	VOID			
					2				75	DIATOM RICH SILTY CLAY dark greenish gray (5GY 4/1) Slide 2-75: 20% diatoms, 40% silt, 40% clay, TR carbonate. Slide 3-75: 20% diatoms, 20% silt, 60% clay
		PF BF D R S	- R C R -	G M -	3				75	
					4				100	gradational zone. SILT and CLAY BEARING DIATOM OOZE olive gray (5Y 4/2) Slide 4-100: 85% diatoms, 5% silt (feldspar), 10% clay
					5				38, 130	VITRIC ASH pods. gradational zone. SILT BEARING CLAYEY DIATOM OOZE dark gray (5Y 4/1) Slide 5-130: 60% diatoms, 10% silt, 30% clay
		D N R S	C - R R	M - M M	Core Catcher					

Explanatory notes in Chapter 1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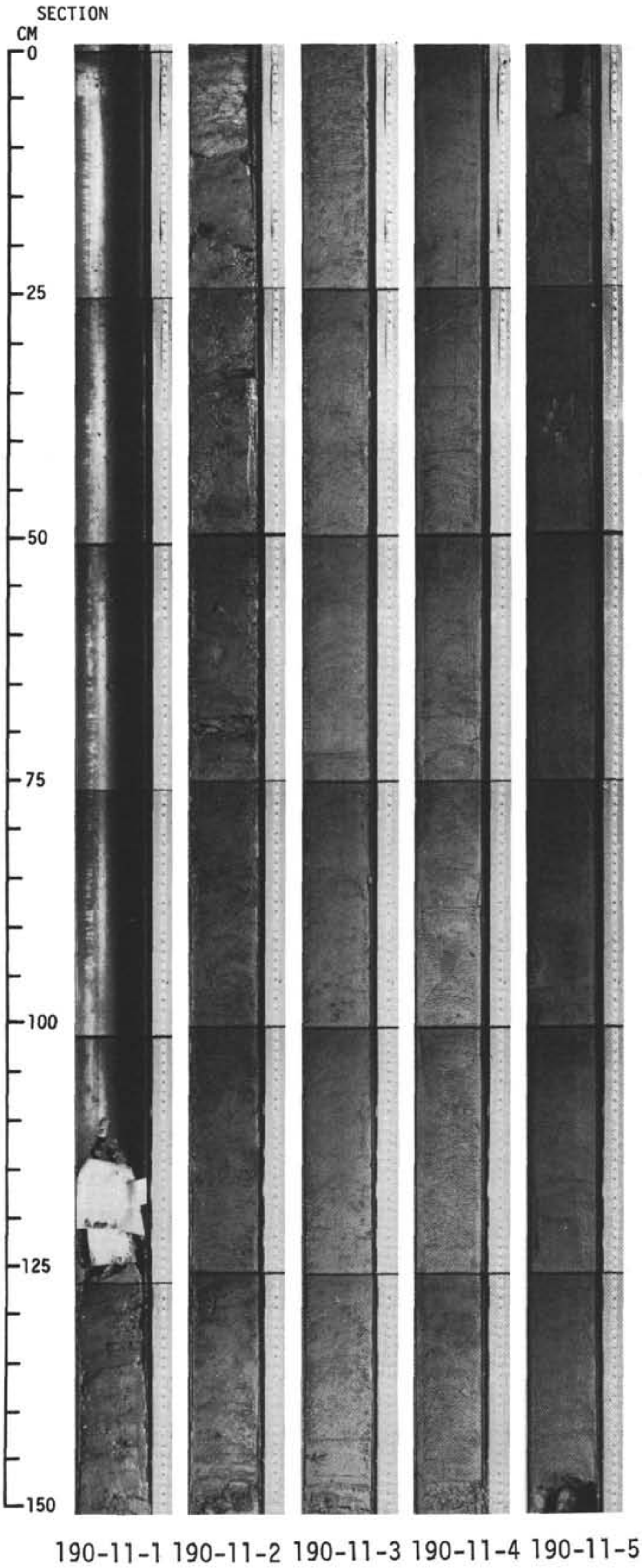
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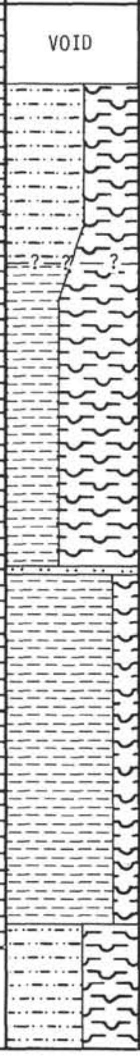
190-11-1 190-11-2 190-11-3 190-11-4 190-11-5

Site 190 Hole Core 12 Cored Interval: 225-234

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
UPPER PLIOCENE	(D) Thalassiosira zabelinae	R S	R C	M M	1	0.5 1.0	VOID		60 64 100
					2				75
		R S PF BF	R - F R	M - M	3				60 80 85
					4				80 145
		D N R S	A - R R	G - M M	Core Catcher				



LITHOLOGIC DESCRIPTION

DIATOMACEOUS SILTY CLAY
with ~5 cm layers of
SILT and CLAY BEARING DIATOM OOZE
dark gray (5Y 4/1) and dark greenish gray (5GY 4/1)

Slide 1-60
30% diatoms
30% silt
40% clay

Slide 1-64
80% diatoms
5 - 10% silt
10 - 15% clay, TR carbonate

SILT BEARING CLAYEY DIATOM OOZE
dark greenish gray (5GY 4/1)

Slide 2-75
50% diatoms
10% silt
40% clay

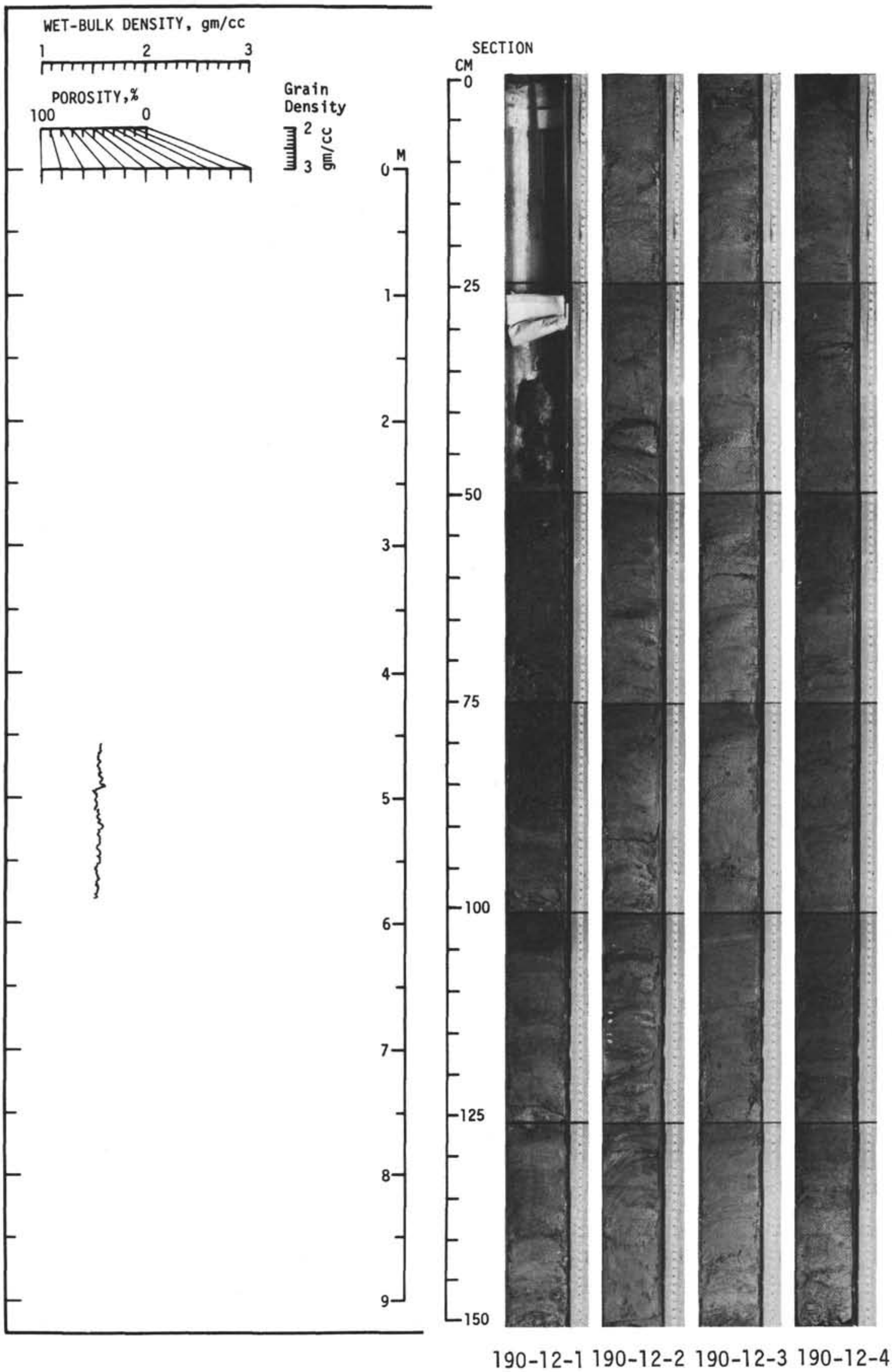
GLASS RICH FELDSPATHIC SILT (1 cm layer)
olive black (5Y 2/1)
Slide 3-60
40% feldspar
20% pyroxene
20% glass shards
10% clay
TR diatoms
10% other

SILT BEARING DIATOM RICH CLAY
dark greenish gray (5GY 4/1)
Slides 3-80 and 4-80
15% diatoms
5% silt
80% clay

XR 2-140
70% amorph.
8% quartz
4% plag.
14% mica
3% chlor.
1% mont.

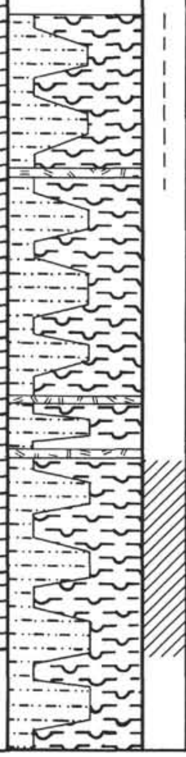
DIATOMACEOUS CLAYEY SILT
olive gray (5Y 4/1)
Slide 4-145
40% diatoms
40% silt
20% clay

Explanatory notes in Chapter 1


WET-BULK DENSITY, gm/cc
1
2
3
POROSITY,%
100
0
Grain
Density
2
3
gm/cc
M
0
1
2
3
4
5
6
7
8
9
SECTION
CM
0
25
50
75
100
125
150
190-12-1 190-12-2 190-12-3 190-12-4

Site 190 Hole Core 13 Cored Interval: 328-337

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
LOWER PLIOCENE	(D) Denticula seminae - D. kamtschatica (S) Cannopilus hemisphaericus	PF BF D R S	- - A - F	G - M	1	0.5 1.0	VOID		-105 -115 -145
					2				-50
					3				-19 -24
					Core Catcher				



LITHOLOGIC DESCRIPTION

Note: interbedding is shown diagrammatically

Basic lithology:

Interbedded (5-20 cm layers)
SILT and CLAY BEARING
DIATOM OOZE to SILT BEARING
CLAY RICH DIATOM OOZE
olive gray (5Y 4/2 - 5/1)

and

DIATOMACEOUS SILTY CLAY
dark greenish gray (5GY 4/1)

VITRIC ASH
light brownish gray (10YR 6/1)

VITRIC ASH
light olive gray (5Y 6/1)

VITRIC ASH
light gray
top is biotite bearing, feldspar rich

Slide 1-105
90% diatoms
10% silt/clay

Slide 1-115
45% diatoms
25% silt
35% clay

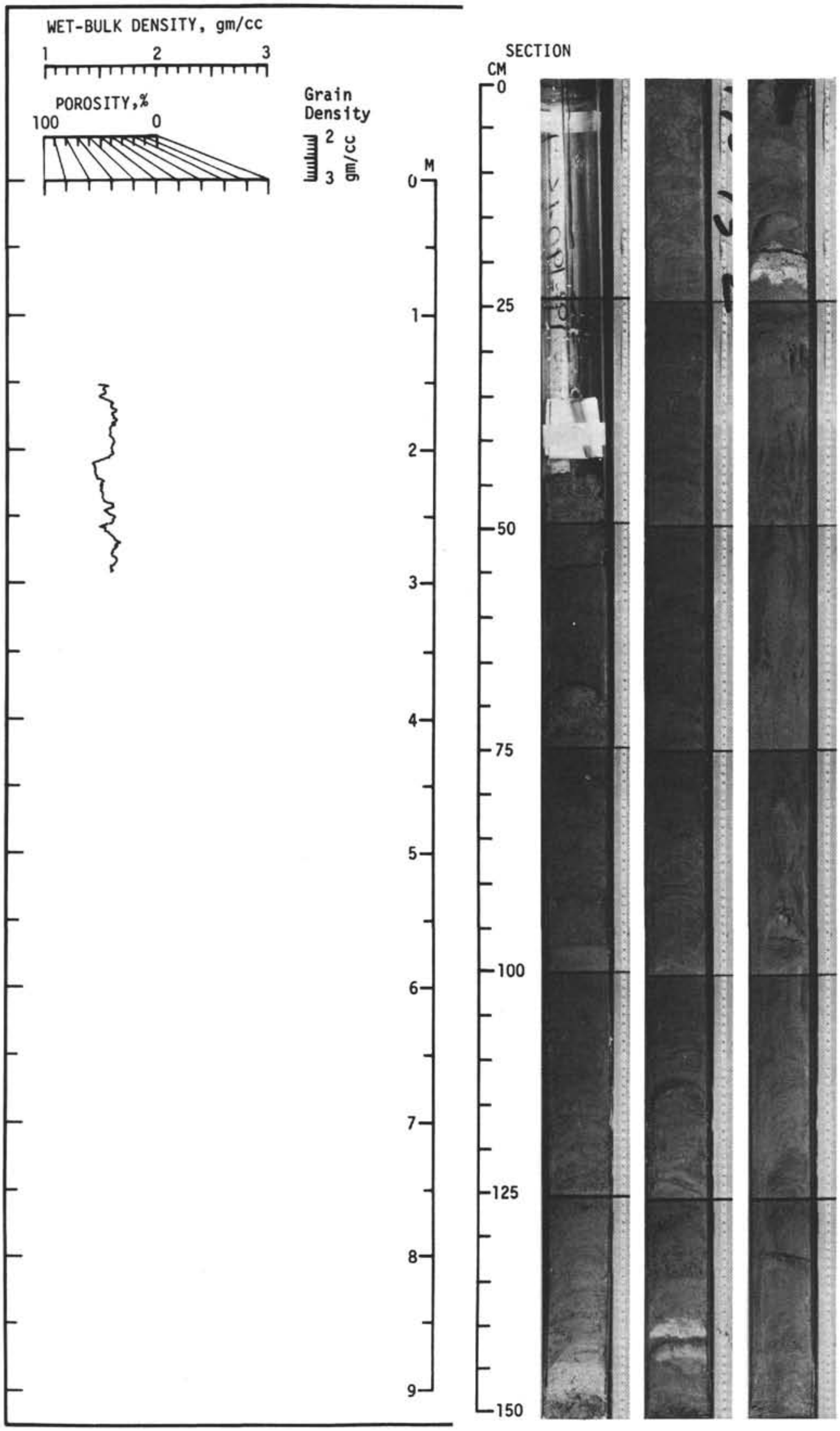
Slide 2-50
75% diatoms
5% silt
20% clay

Core Catcher:

	A	G
D		
N	-	-
R	R	M
S	F	M
PF	-	
BF	F	

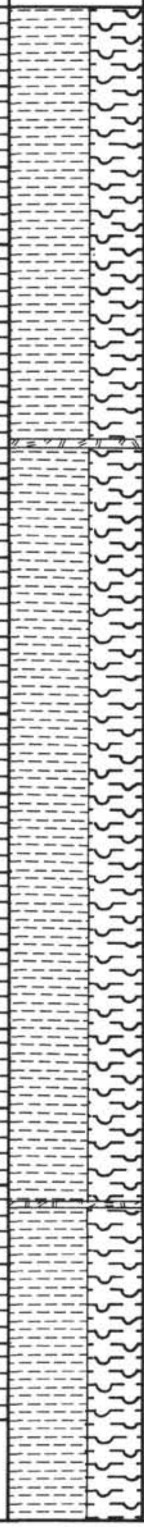
XR 2-60
79% amorph.
6% quartz
4% plag.
8% mica
1% chlor.
2% mont.

Explanatory notes in Chapter 1



190-13-1 190-13-2 190-13-3

Site 190 Hole Core 14 Cored Interval: 421-430

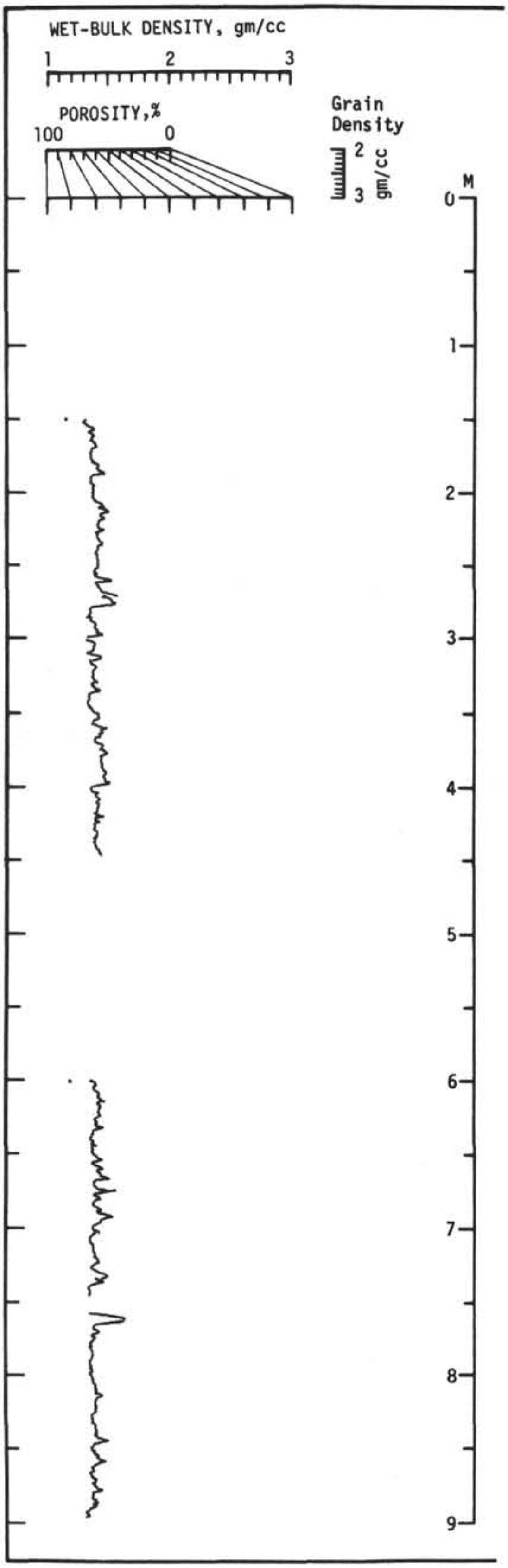
AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
UPPER MIOCENE	(D) Denticula kamtschatica (S) Distephanus speculum var. pentagonus				1	0.5 1.0				
		PF BF D R S	- R A - C	 G - M	2				-111 -128	VITRIC ASH yellowish gray (5Y 8/1)
					3					Basic lithology SILT BEARING DIATOMACEOUS CLAY light olive gray - olive gray (5Y 5/1 - 3/2) various grayer and browner shades semi-indurated, burrowed
		D R S	A - C	G - M	4					numerous thin (<1-4 cm) layers of FELDSPATHIC SILT containing up to 30% pyritized diatoms, olive black (5Y 2/1)
					5				-99 -110	average composition of basic lith. 30% diatoms 10% silt 60% clay
					6				-15	VITRIC ASH brownish gray (5YR 4/1)
					Core Catcher					

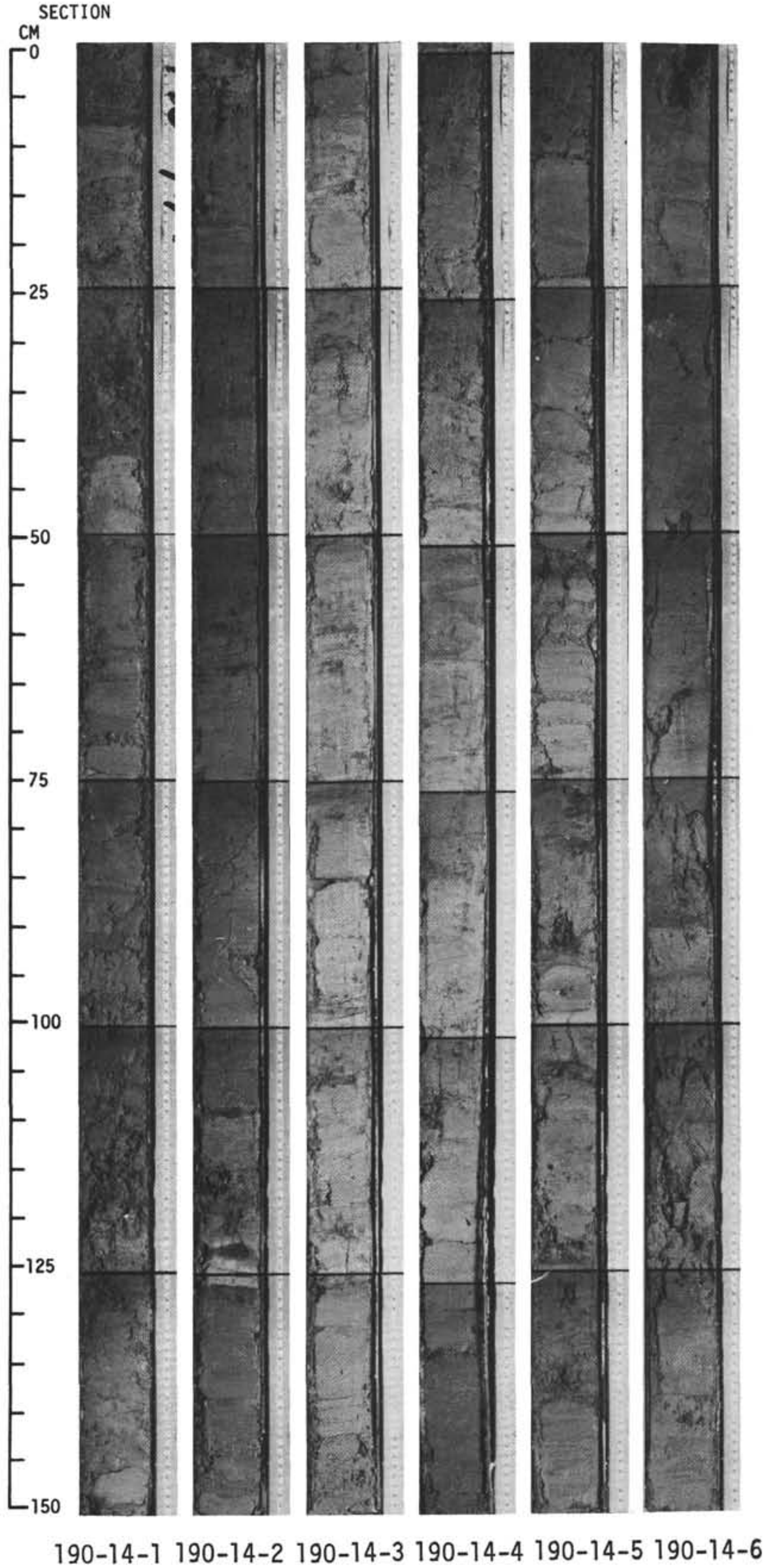
XR 2-130	6-10	
86%	97%	amorph.
4%	1%	quartz
4%	1%	plag.
2%		mica
TR	TR	chlor.
2%	1%	mont.
TR		pyrite
TR		amphib.

Core Catcher:

D	C	G
PF	R	
BF	R	
N	-	-
R	R	M
S	R	M

Explanatory notes in Chapter 1


WET-BULK DENSITY, gm/cc
1
2
3
POROSITY,%
100
0
Grain Density
2
3
gm/cc
M
0
1
2
3
4
5
6
7
8
9


SECTION
CM
0
25
50
75
100
125
150
190-14-1 190-14-2 190-14-3 190-14-4 190-14-5 190-14-6

Site 190 Hole Core 15 Cored Interval: 609-618

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
UPPER MIOCENE	(D) Denticula kamtschatica				1	0.5 1.0	VOID			XR 1-130 64% amorph. 5% quartz 12% plag. 16% mica 2% chlor. CLAYEY DIATOM OOZE olive gray (5Y 4/1) semi-lithified, burrowed VITRIC ASH DIATOM BEARING LIMESTONE light olive gray (5Y 6/1)
					Core Catcher					

Core Catcher:

	D	A	G
N	-	-	
R	R	M	
S	F	M	
PF	-		
BF	R		

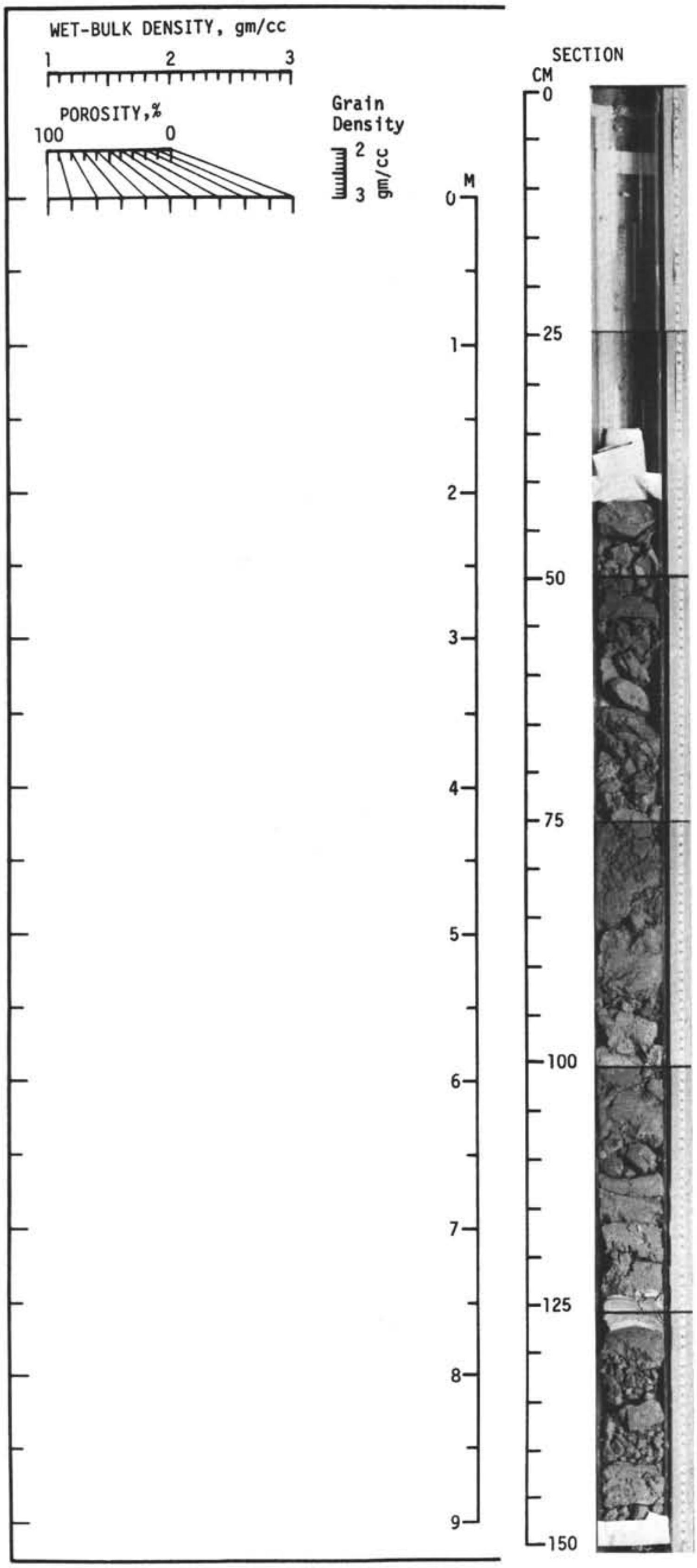
Site 190 Hole Core 16 Cored Interval: 618-627

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					Core Catcher					core catcher sample only: 1) CLAY olive gray (5Y 3/2) contains partially dissolved diatoms 2) 2 pieces of MUDSTONE (~5 cm diam.) 3) LIMESTONE

Core Catcher:

	D	R	M
N	-	-	
R	-	-	
S	-	-	
PF	-		
BF	-		

Explanatory notes in Chapter 1


WET-BULK DENSITY, gm/cc
1 2 3
POROSITY,%
100 0
Grain Density
2
3
gm/cc
M
0
1
2
3
4
5
6
7
8
9
SECTION
CM
0
25
50
75
100
125
150

190-15-1