5. SITE 278

The Shipboard Scientific Party[1]

SITE DATA

Location: Southern Emerald Basin

Position: 56°33.42'S; 160°04.29'E

Water Depth:
PDR, from sea level: 3675 meters
From drill pipe measurement from derrick floor: 3708 meters (adopted)

Dates Occupied: 14-17 March 1973

Depth of Maximum Penetration:
Hole 278: 438.5 meters
Hole 278A: 44 meters

Number of Holes: 2

Number of Cores:
Hole 278: 35
Hole 278A: 2

Total Recovery:
Length:
Hole 278: 277.8 meters
Hole 278A: 7.5 meters
Percentage:
Hole 278: 85
Hole 278A: 39

Age of Oldest Sediment Cored: Middle Oligocene

Summary: Sediments at Site 278 are an almost complete Pleistocene to middle Oligocene sequence of 428 meters of alternating calcareous diatom and radiolarian oozes, and siliceous nannofossil oozes and chalks. Six sedimentary units belong to three general categories; 172 meters of radiolarian-diatom and diatom ooze of late Pliocene to Recent age; 214 meters of alternating siliceous nannofossil ooze and nannofossil-rich siliceous ooze of early Pliocene to earliest Miocene age; and 42 meters of early Oligocene nannofossil chalk with sponge spicules. These fluctuations probably indicate changes in the locations and strength of the Antarctic Convergence. Increased sedimentation rates occur towards the Recent with very low rates for the Oligocene (0.5 cm/1000 years), moderate rates for the Miocene-early Pliocene (1.3 cm/1000 years), and spectacularly high rates in late Pliocene and Pleistocene (7.5 cm/1000 years). Rates reflect increased productivity in region throughout middle and late Cenozoic, probably related to intensification of the Antarctic Convergence. Upward increase in dissolution of calcium carbonate supports this theory. Much of the Pliocene is missing in disconformity. There is a tremendous increase in the amount of quartz grains of ice-rafted origin above this disconformity. The first evidence of glacial marine sediments at this site is of late Miocene (?) age. Excellent radiolarian and diatom biostratigraphy although calcareous microfossils are of varying abundance and preservation. Well-dated middle Oligocene (30 m.y. old) sediments lie directly on pillow basalts.

The Oligocene age of basement will have a profound effect on the inferred plate motions of the Macquarie triple junction.

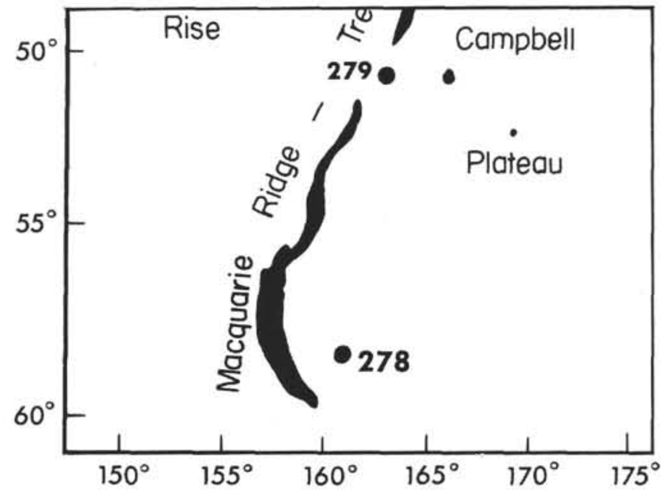

Figure 1. *Location of Site 278, DSDP Leg 29.*

BACKGROUND AND OBJECTIVES

Site 278 was drilled near the junction of the southeast extension of the Macquarie ridge and the Emerald basin in a water depth of 3700 meters (Figures 1 and 2). Due to a lack of clearly lineated magnetic anomalies (possibly due to intense fracturing) the age of the Emerald basin is not known. A short distance to the east of the drill site, the magnetic anomalies have been dated as Upper Cretaceous by Christoffel and Falconer (1972). A short distance to the west, Weissel and Hayes (1972) have dated the anomalies as lower Miocene. Hence the site is between two regions separated by 50-60 m.y. The sediments at the site are delicately layered and have the appearance of layered fine-grained material deposited from gentle bottom currents. A change in the

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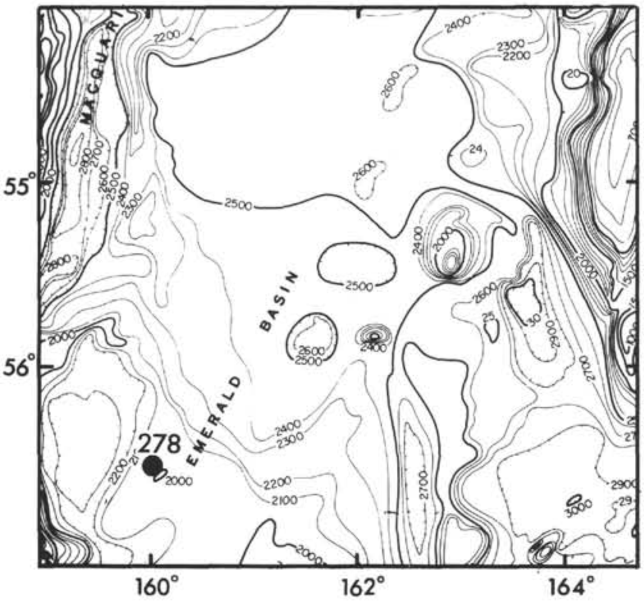

Figure 2. *Bathymetry at Site 278.*

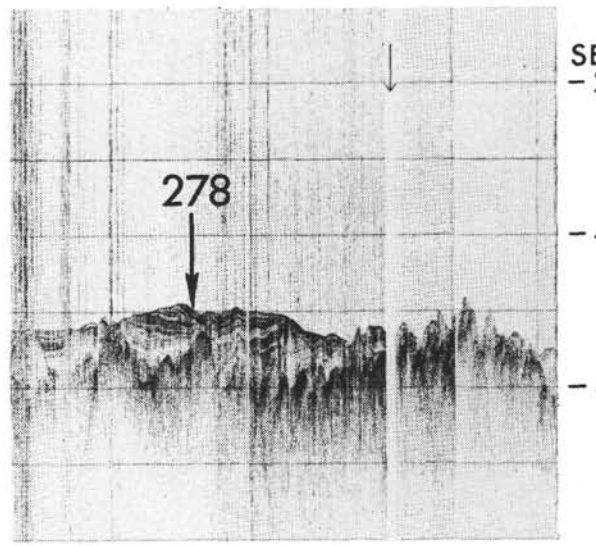

Figure 3. *Profiler section at Site 278.*

current regime seems to have occurred within the section; an unconformity can be seen in Figure 3.

The site was selected because of its present-day position at the Antarctic Convergence. The primary objectives of the site were:

1) To obtain a biostratigraphic sequence at the boundary between Antarctic and subantarctic waters. At a depth of 3600 meters at lat 56°30′S alternations possibly exist between calcareous and siliceous biogenic fractions related to latitudinal movement of the Antarctic Convergence (polar front). Calcareous nannoplankton in the present day do not extend into Antarctic waters (Hasle, 1960), and are also assumed not to have done so in the past. Fluctuations in nannofossils in the core obtained at this relatively shallow site should therefore largely reflect alternations in the Antarctic Convergence.

2) To examine changes in biogenic productivity associated with the Antarctic Convergence. The Antarctic Convergence separates highly siliceous biogenic sediments to the south from more calcareous-rich biogenic sediments to the north. Fluctuations in these components may thus reflect changes in the position of the Antarctic Convergence. Siliceous productivity in the northern Antarctic water-mass region is the highest in the world because of upwelling of nutrient-rich deep water. The history of this productivity will be examined as it relates the evolution of the Antarctic Convergence.

3) To obtain a paleoglacial history of Antarctica for that part of the Cenozoic sequence obtained at Site 278 by examination of ice-rafted debris; the site is within the range of icebergs. During Leg 28 no material older than late Eocene had been obtained. Glacial debris was found in cores as old as Oligocene supporting Oligocene Antarctic glaciation suggested by Margolis and Kennett (1970) and Kennett et al. (1972). Antarctic glaciation of early and middle Eocene age has been suggested by Margolis and Kennett (1970), although the extent of this glaciation is unknown.

4) To determine a history of bottom-water activity at Site 278. It is hoped that this will provide further information on major paleocirculation changes involving deep water in the area. The unconformity shown in Figure 3 at "A" may reflect a fundamental change in bottom water patterns in the region. This may relate to critical structural changes in the Australian-Antarctic oceanic region.

5) To determine age of basement.

OPERATIONS

Site 278 in the Emerald Basin was approached from the north along an *Eltanin*-34 track (Figure 4). The actual site was selected by correlation of sea-floor topography; the beacon was released on the first pass over the site.

With positioning in the manual mode, the hole was spudded in 3708 meters of water in very soft sediment and a mud line core was recovered. The hole was continuously cored from 3809 meters (101 meters penetration) to 4075 meters with very good recoveries on all but two cores which experienced a collapsed liner and a shattered liner. Alternate drilling and coring proceeded to 4103.5 meters where a continuous coring program was followed to a total depth of 4146.5 meters or 438.5 meters of penetration. Basalt was encountered at 4136 meters, cored for 10.5 meters with 4.6 meters recovered. Details of the coring are included in Table 1.

During the coring operations, the computer was repaired and positioning returned to automatic mode. The mud line was cleared and Hole 278A was spudded to core the 95 meter interval which had been washed down in Hole 278. The second coring attempt from 3723.5-3733 meters recovered 1.5 meters of sediment and 10 centimeters of basalt. It was evident that some of the basalt from Core 278-35 had fallen out of the core barrel, and lodged on top of the bit. In an attempt to

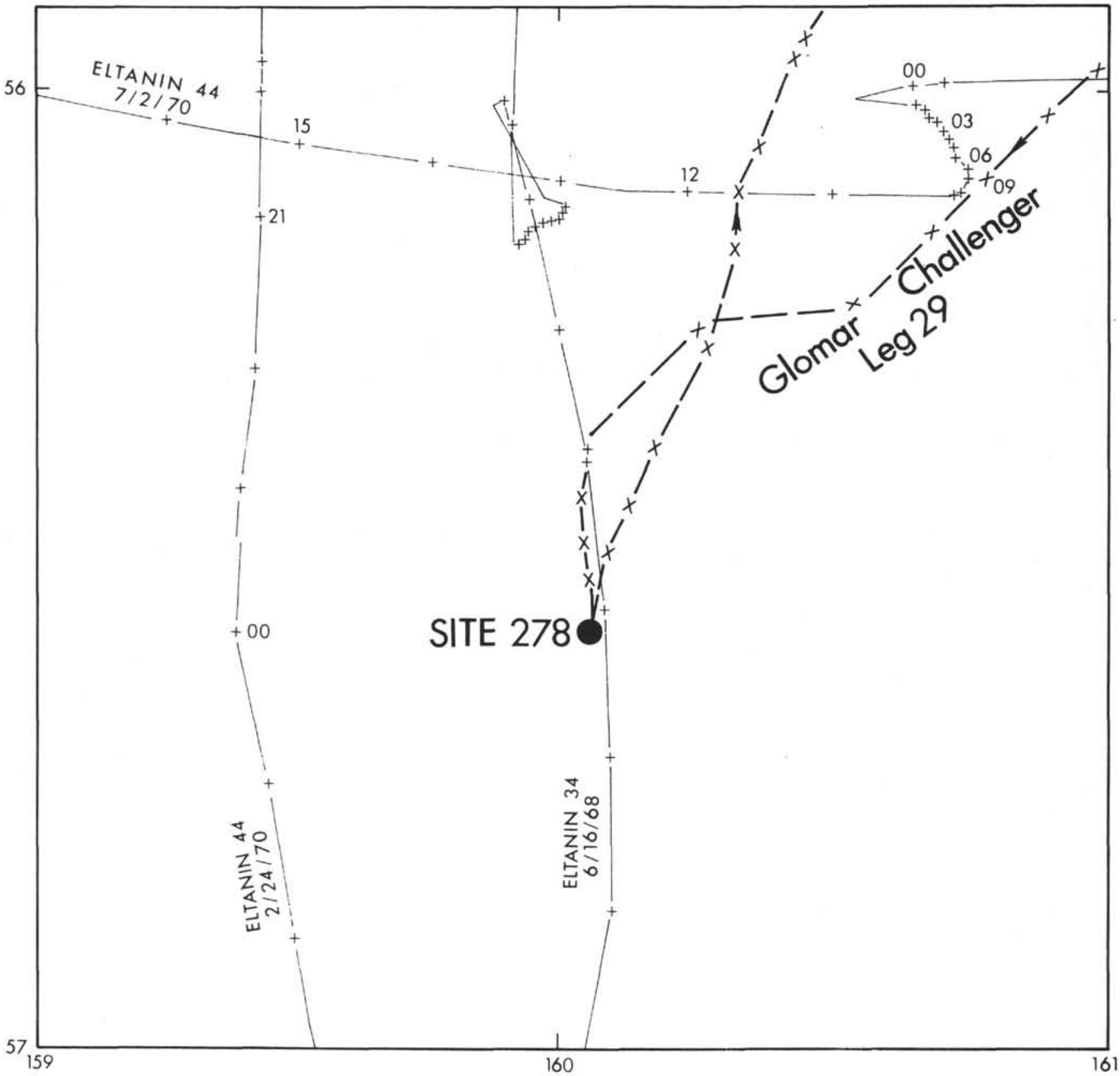

Figure 4. *Track chart.*

clear the bit, an extended core barrel was dropped and the hole cut from 3733-3742.5 meters. Recovery was 6 meters of sediment with several small pieces of basalt. A fourth attempt from 3742.5-3752 meters resulted in recovery of approximately 5 centimeters of basalt and no sediment.

LITHOLOGY

Approximately 428 meters of sediment and 5 meters of basalt were cored at Site 278. The sediment sequence consists of alternating calcareous diatom and radiolarian oozes, and siliceous nannofossil oozes and chalks (Figure 5). Hole 278A was drilled next to Hole 278 in order to recover cores from the upper 100 meters in this area. The lithological units are subdivided as shown in Table 2.

Unit 1

Unit 1 is characterized by a light brownish gray foraminiferal-bearing diatom ooze with alternating distinctly darker layers and gray mottles that contain as much as 20% terrigenous detrital minerals. The detrital material consists of angular quartz grains, rock fragments, and opaque minerals that are of possible ice-rafted origin. These sharply defined, alternating color changes perhaps suggest periods of increased iceberg ac-

TABLE 1
Coring Summary, Site 278

Core	Cored Interval Below Bottom (m)	Cored (m)	Recovery (m)	Recovery (%)
Hole 278				
1	0.0-6.0	6.0	6.0	100
2	101.0-110.5	9.5	9.5	100
3	110.5-120.0	9.5	9.0	95
4	120.0-129.5	9.5	7.5	79
5	129.5-139.0	9.5	9.0	95
6	139.0-148.5	9.5	9.5	100
7	148.5-158.0	9.5	9.3	98
8	158.0-167.5	9.5	9.5	100
9	167.5-177.0	9.5	8.5	90
10	177.0-186.5	9.5	9.0	95
11	186.5-196.0	9.5	8.9	94
12	196.0-205.5	9.5	8.7	92
13	205.5-215.0	9.5	9.5	100
14	215.0-224.5	9.5	9.3	98
15	224.5-234.0	9.5	8.3	87
16	234.0-243.5	9.5	9.5	100
17	243.5-253.0	9.5	8.8	93
18	253.0-262.5	9.5	9.0	95
19	262.5-272.0	9.5	3.5	37
20	272.0-281.5	9.5	9.0	95
21	281.5-291.0	9.5	9.5	100
22	291.0-300.5	9.5	5.9	62
23	300.5-310.0	9.5	9.5	100
24	310.0-319.5	9.5	9.5	100
25	319.5-329.0	9.5	6.6	70
26	329.0-338.5	9.5	9.5	100
27	338.5-348.0	9.5	9.5	100
28	348.0-357.5	9.5	8.6	91
29	357.5-367.0	9.5	9.4	99
30	376.5-386.0	9.5	2.9	31
31	395.5-405.0	9.5	4.1	43
32	405.0-414.5	9.5	9.2	97
33	415.5-424.0	9.5	5.4	57
34	424.0-429.0	5.0	2.5	50
35	429.0-438.5	9.5	4.3	45
Total		324.5	277.7	85
Hole 278A				
1	15.5-25.0	9.5	1.5	16
2	25.0-34.5	9.5	6.0	63
Total		19.0	7.5	39

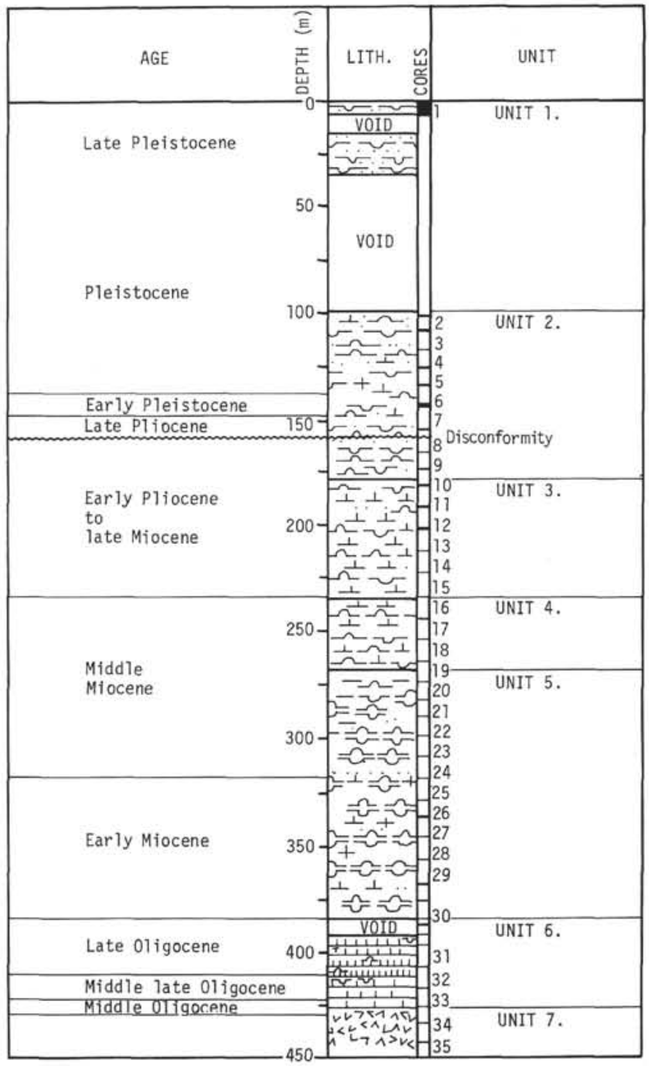

Figure 5. *Stratigraphic sequence at Site 278.*

TABLE 2
Lithologic Summary, Site 278

Unit	Lithology	Subbottom Depth (m)	Unit Thickness (m)
1	Foraminifera and detrital silt-bearing radiolarian-diatom ooze	0-6	6
2	Nannofossil-rich spicule-bearing diatom ooze	100-172	72
3	Siliceous nannofossil ooze	172-236	64
4	Alternating nannofossil-rich siliceous ooze and diatom-rich nannofossil ooze	236-264	28
5	Detrital and nannofossil-bearing radiolarian-diatom ooze, alternating with siliceous ooze	264-386	122
6	Siliceous nannofossil chalk	386-428	42
7	Porphyritic pillow basalt with micritic limestone inclusions in interpillow areas	428-433	5

tivity. However, some of the detrital material may have been transported by bottom currents.

A continuation of this unit can be found in Hole 278A. The sediments in Hole 278A consist of very soupy, light- to medium-gray detrital-bearing calcareous diatom ooze with intense deformation and vertical banding. The sediment is late Pleistocene in age. It contains abundant detrital mineral grains ($\approx$20% of total sediment) which are of possible ice-rafted origin.

Unit 2

Unit 2 is basically a nannofossil/sponge-spicule rich radiolarian and diatom ooze, differing from Unit 1 in having more nannofossils. Locally it contains micromanganese nodules, mica streaks and bands, and varies from light bluish gray to gray with greenish-gray streaks. It is generally soft and has faint mottles. Drilling created spectacular deformation structures.

Unit 3

Unit 3 is a very-pale-brown to white siliceous nannofossil ooze. Siliceous microfossils (diatoms, Radiolaria, and sponge spicules) comprise up to 40% of this unit, and it generally contains less than 10% detrital material. Micromanganese nodules and streaks are also locally abundant, although manganese makes up less than 30% of the sediment. It is soft to stiff in texture, and where undeformed, exhibits slight mottles and burrowing structures.

Unit 4

Unit 4 consists of thin alternating beds of nannofossil-rich siliceous ooze, and diatom-rich nannofossil ooze. The percentages of biogenic calcareous and siliceous materials varies extensively. The unit is generally soft to stiff, mottled, sparsely burrowed, with a low detrital mineral content. Colors range from greenish gray to light bluish gray, with the lighter colors associated with nannofossil-rich zones.

Unit 5

Unit 5 is generally similar to Unit 2, being a siliceous ooze, differing in having less than 10% detrital minerals, and in being more stiffly indurated. It is locally rich in nannofossils, radiolarians, and sponge spicules, as well as some manganese. Toward its base it is semilithified and contains traces of glauconite and silicoflagellates. Volcanic rock fragments (1-4 mm) are also rarely found with angular outlines. Volcanic glass and sanidine are also found with the rock fragments. The color of the sediment varies from bluish gray to greenish gray.

Unit 6

Unit 6 is a light-gray to very-pale-brown siliceous nannofossil chalk which is a semilithified equivalent of Unit 3. It contains appreciably less siliceous material (<10%), exhibits faint mottles, manganese streaks, and micronodules. It is generally non-stratified and contains only a trace of detrital minerals. Volcanic glass and rock fragments are abundant toward the base of the unit.

Unit 7

Unit 7 consists of a porphyritic plagioclase pillow basalt with carbonate and zeolite-filled veins, amygdules, and vesicles. The rims of the pillows are glassy; the glass is palagonitized and contains olivine crystals and feldspar laths. The pyroxenes are broken down. Between the glass rinds are micritic limestone inclusions which are well lithified and contain rare casts of foraminifera. There is no evidence of baking or mineralization of the micritic limestone, although it was probably originally a nannofossil ooze. It was squeezed down between the pillow surfaces or was deposited between the pillows. The deepest basalt cored had a glass rim only on its top surface and may represent a massive flow basalt.

Conclusions

This site is of interest because of its location at the present-day Antarctic Convergence. The fluctuations in lithology from nannofossil ooze to siliceous diatom ooze may indicate changes in the location and strength of the convergence, with the siliceous oozes representing times when the convergence was nearby. The convergence brought nutrient and silica-rich waters to the surface, thereby increasing biological productivity and sedimentation rates. A detailed study in variations in the amount of ice-rafted materials in the sediments is presented in Chapter 30 (this volume). Significant fluctuations in the abundance of glacial marine sediments occur in the Pleistocene and late Pliocene sediments. Lesser amounts occur in the early Pliocene/late Miocene sediments, and no older ice-rafted grains were found at this site.

The siliceous nannofossil chalks which rest on top of the pillow basalt are middle-late Oligocene, establishing a minimum age for the basement in the area.

The oldest (early Miocene) siliceous ooze occurs in Unit 5. These sediments contain more detrital sediments than the underlying chalk, although not as much as the younger sediments at this site. The transition zone of mixed siliceous and calcareous sediments (Unit 4) is mid Miocene and may represent a time during which the Antarctic Convergence repeatedly fluctuated from near its present position to south of it. The middle-late Miocene siliceous nannofossil oozes of Unit 3 may represent a time during which the convergence was south of its present position, possibly being affected by the development of the Macquarie Ridge, or represent a time of weaker upwelling.

Unit 2, a late-Pliocene-Pleistocene siliceous ooze, represents a time when the convergence was located near its present position and of similar intensity. Detrital mineral grains and rock fragments of ice-rafted origin are much more abundant than in underlying strata, and sedimentation rates are also considerably higher. Unit 1 is similar to Unit 2, except that it contains undissolved foraminifera and more ice-rafted material.

Additional notable features of the sequence at Site 278 are the small amounts of glauconite and the abundance of micro-manganese nodules (Chapter 34, this volume) indicating well-oxygenated bottom waters. Also of interest is the absence of any chert in spite of the high silica content of the sediment.

GEOCHEMICAL MEASUREMENTS

Table 3 and Figure 6 summarize the analyses of interstitial waters at Site 278. The *p*H measurements by both punch-in and flow-through methods were all lower than that of the surface seawater reference, except the flow-through reading of 8.25 for Sample 278-22-4, 6-12 cm. The lowest *p*H (6.87) is a punch-in analysis from Sample 278-17-6, 0-6 cm.

Alkalinities were all higher than that of surface seawater reference except in Sample 278-34-3, 75-85 cm which was identical (2.54 meg/kg). High alkalinity measurements of 4.69 meg/kg were found in Cores 2 and 4. Salinity values are all higher than surface seawater, the highest values (35.8 ‰) occurring in Core 278-34, above the basalt, and in Core 278A-2. The basalt may be producing this high value.

BIOSTRATIGRAPHY

This late Pleistocene to mid Oligocene sequence, continuously cored below 101 meters, is of exceptionally high paleontological interest. Most of the sequence yielded very abundant, highly diverse, and well-preserved diatoms, Radiolaria, and silicoflagellates. The sequence is apparently continuous except that much of the Pliocene is missing in an unconformity in Core 278-8, CC.

Besides the siliceous microfossils, this sequence contains highly variable frequencies of poorly preserved and very low diversity calcareous nannofossil and planktonic foraminiferal assemblages. In the middle and, especially, lower parts of the sequence these microfossil groups are abundant, but in the upper part they only form a minor component of the sediment. This pattern results from variations in the degree of calcite dissolution.

The late Neogene ages obtained from the Radiolaria and calcareous nannofossils appear to strongly conflict with those indicated by the planktonic foraminifera. For the purposes of this report the radiolarian age assessments are adopted (Figure 7) because radiolarians are abundant and their succession conforms to the well-known Antarctic zonal scheme of Hays and Opdyke (1967) which has been matched against the paleomagnetic stratigraphy. If subsequent investigations sub-

TABLE 3
Shipboard Geochemical Data, Site 278

Core	Section	Sample Interval Top (m)	Sample Interval Avg. (m)	*p*H Punch-in	*p*H Flow-thru	Alkalinity (meq/kg)	Salinity (‰)	Lithologic Unit
Surface Seawater Reference				7.72	7.92	2.54	34.1	
Hole 278								
1	3	0.0	4.52	–	7.52	3.03	35.5	1
Hole 278A								
2	4	25.0	33.03	7.54	7.44	4.01	35.8	1
2	3	101.0	104.05	7.26	7.52	4.69	35.5	2
5	6	129.5	137.53	7.26	7.30	4.50	35.2	2
8	5	158.0	164.53[a]	7.15	7.22	4.35	35.5	2
12	5	196.0	202.53	6.97	7.10	4.30	35.2	3
17	6	243.5	251.53	6.87	7.21	4.11	35.2	4
22	4	291.0	300.03[b]	7.38	7.68	4.69	35.5	5
27	1	338.5	348.53	7.61	7.54	3.81	35.2	5
32	4	405.0	411.03	7.14	7.08	3.13	35.5	6
34	3	424.0	428.30	–	7.36	2.54	35.8	6
Average				7.20	7.38	3.92	35.4	

[a]Two analyses were run, the second on #50 Whatman filter paper. Values are: Flow-thru *p*H=7.23, Alk=4.35, and S=35.2°/₀₀.

[b]Cold squeeze (4°C) analyses also run. Values are: Flow-thru *p*H=8.25, Alk=2.98, and S=34.6°/₀₀.

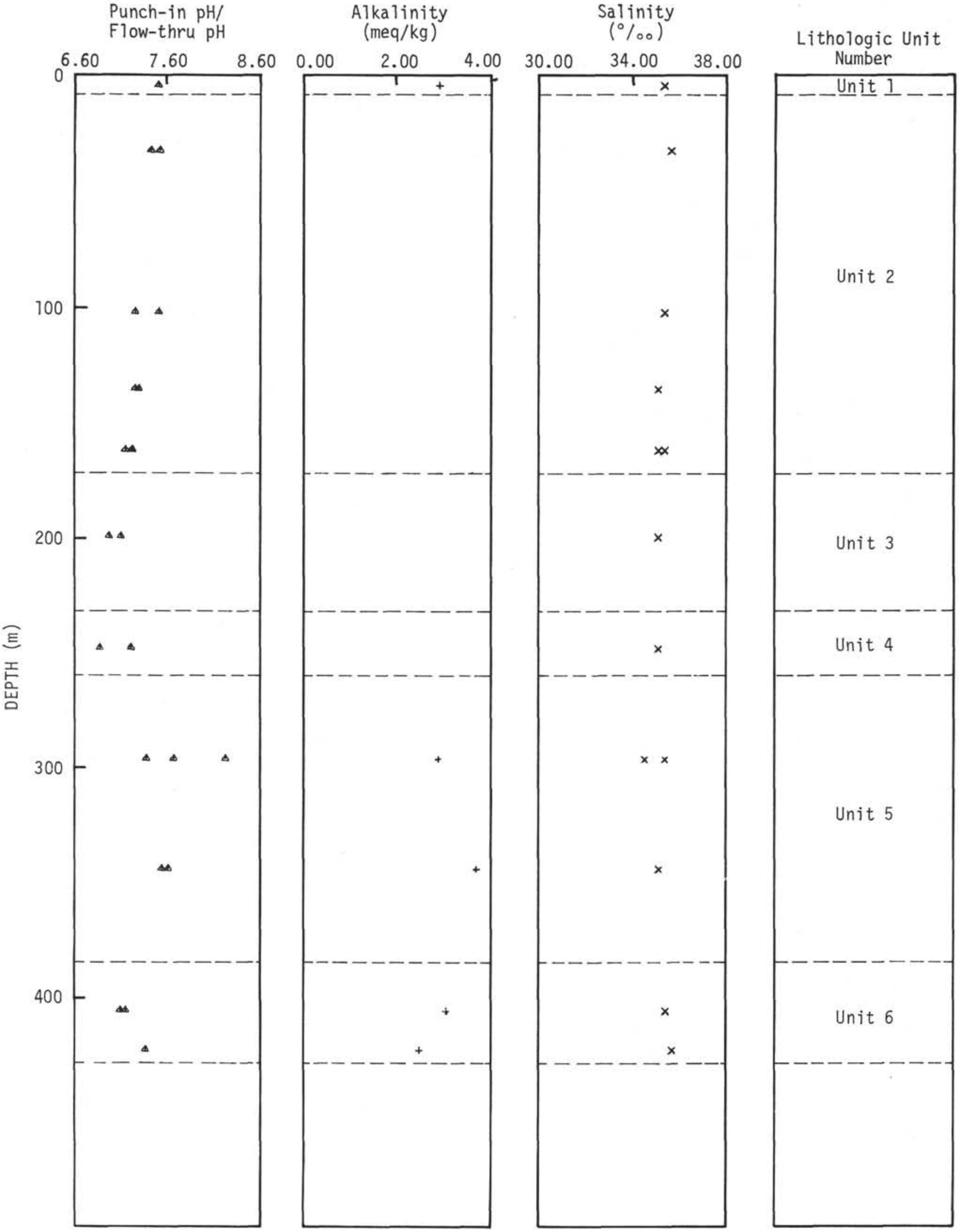

Figure 6. *Shipboard geochemical data versus depth, Site 278.*

stantiate the late Neogene ages adopted here, then it must follow that the planktonic foraminiferal zones are strongly diachronous compared to their occurrence at lower latitudes. One example of this diachronity, the base of *Globorotalia truncatulinoides*, has already been documented by Kennett (1972). The ages adopted for the Miocene and Oligocene intervals are based on the calcareous nannofossils, planktonic foraminifera, and diatoms (Figure 7). All of the microfossil evidence indicates normal oceanic deposition far from land.

Foraminifera

Eight of the 37 samples examined were barren of planktonic foraminifera. Apart from the specimens from Samples 278-31, CC, 278-32, CC, and 278-33, CC, and Sample 1, CC from both holes, the samples showed indications of solution on the foraminiferal tests. Although the original diversity was low due to the high latitude position of the site, the diversity has been lowered further by selective solution of tests. The resultant abundance level in the samples is a false diversity,

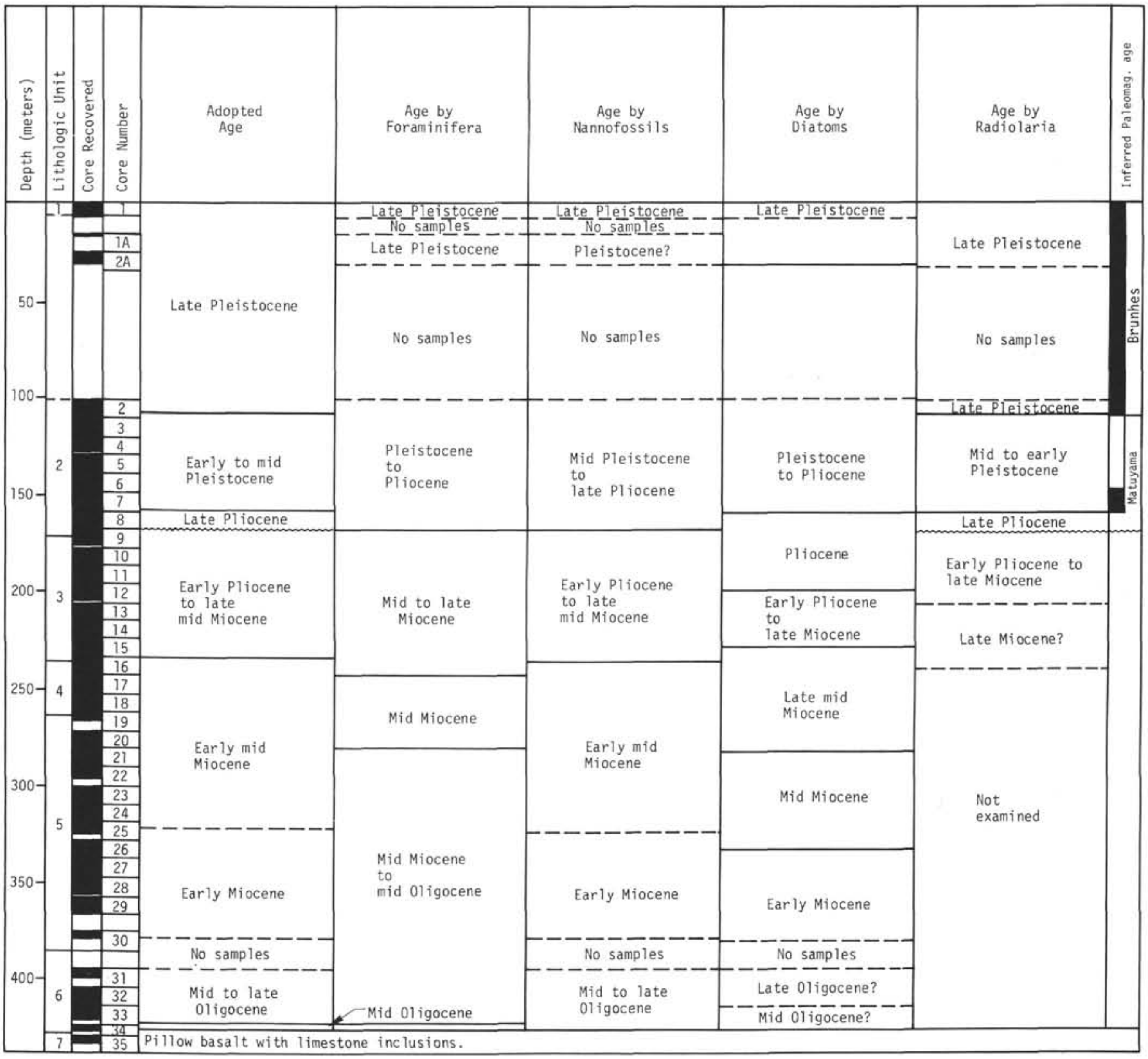

Figure 7. *Biostratigraphy and adopted ages at Site 278.*

and is not truly representative of the original living species. It also follows that the species that remain were subjected to solution, and consequently have relatively high solution-resistant tests.

Evidence exists to show that greater solution occurs within older sediments occurring within the surface layers. In Samples 278-1, CC and 278A-1, CC, there are five to seven species including the thin-walled taxa *Globigerina (G.) bradyi*, and *G. (G.) quinqueloba*. By comparison there are only two species in Samples 278-2, CC and 278A-2, CC, and it is assumed that these faunas have been subjected to longer solution attacks by active bottom water.

From the study of planktonic foraminifera, Site 278 appears to have been at or below the lysocline, apart from the middle Oligocene and earliest part of the early Miocene.

The following seven informal planktonic foraminiferal zones are based on the occurrence of taxa from Holes 278 and 278A. Stratigraphic control for the Pliocene-Pleistocene is based on the work by Kennett (1972) on subantarctic faunas and on the published data of the New Zealand Oligocene-Miocene stratigraphic ranges of taxa by Jenkins (1971).

Globorotalia (G.) truncatulinoides Zone
(Site 278, Core 1, top of Section 1)

Zone definition: The total range of *G. (G.) truncatulinoides*.

Age: Late Pleistocene-Recent.

Remarks: *Globigerina (G.) bradyi, G. (G.) quinqueloba, Globorotalia (G.) truncatulinoides*, and *G. (T.) pachyderma* were found in the zone.

Globorotalia (T.) inflata Zone
(Site 278, Cores 278A-1, 2)

Zone definition: top—initial appearance of *Globorotalia (G.) truncatulinoides*; base—initial appearance of *G. (T.) inflata*.

Age: Mid-Late Pleistocene.

Remarks: *Globigerina (G.) bradyi, G. (G.) bulloides, G. (G.) quinqueloba, Globigerinita glutinata, Globorotalia (T.) inflata*, and *G. (T.) pachyderma* were found in the zone.

Globorotalia (T.) puncticulata Zone
(Site 278, Cores 2-8)

Zone definition: top—initial appearance of *G. (T.) inflata;* base—initial appearance of *G. (T.) puncticulata*.

Age: Pliocene-Pleistocene.

Remarks: *Globigerina (G.) bradyi, G. (G.) bulloides, G. (G.) quinqueloba, Globorotalia (T.) pachyderma, G. (T.) puncticulata*, and *G. (T.) scitula* were found in the zone. The most common species in the zone is the thick-walled left-coiled *G. (T.) pachyderma*.

Globigerina (G.) bulloides Zone
(Site 278, Cores 9-16)

Zone definition: Top—initial appearance of *G. (T.) puncticulata*; base—extinction of *Globorotalia (T.) conica*.

Age: Middle-upper Miocene.

Remarks: Only *G. (G.) bulloides* is recorded.

Globorotalia (T.) conica Zone
(Site 278, Cores 17-20)

Zone definition: The total stratigraphic range of *G. (T.) conica*.

Age: Middle Miocene.

Remarks: *Globigerina (G.) woodi woodi* and *Globorotalia (T.) conica* were recorded in the zone.

Globigerina (G.) woodi Zone
(Site 278, Cores 21-33)

Zone definition: Top—initial appearance of *G. (T.) conica*; base—extinction of *Globigerina (S.) angiporoides angiporoides*.

Age: Middle Oligocene-middle Miocene.

Remarks: *Globigerina* cf. *bulloides, G. (G.) juvenilis, G. (G.) woodi woodi, Globigerinita dissimilis, G. unicava, Globorotalia (T.) nana nana*, and *G. (T.) nana pseudocontinuosa* were recorded in the zone. In Sample 278-33, CC, many of the tests of *G. (G.) woodi woodi* have been replaced by manganese.

Globigerina (S.) angiporoides angiporoides Zone
(Site 278, Core 34)

Zone definition: Top—extinction of *G. (S.) angiporoides angiporoides*; base—undefined but within the range of the zonal fossil.

Age: Middle Oligocene.

Remarks: *G. (S.) angiporoides angiporoides*, and *G. (G.) ciperoensis angustiumbilicata* were found in the zone. The fauna consists almost entirely of the zonal fossil.

Calcareous Nannofossils

Assemblages characteristic of the late Pleistocene to mid or late Oligocene interval were obtained from this biogenic sequence. Calcareous nannofossils are absent or rare to abundant and their preservation is very poor to moderate. Diversity is low in most samples, a predictable result of the high southern latitude of this site. Almost all of the species used by Martini (1971) for zoning the Oligocene to Pleistocene interval are missing. The age assignments given to the cores are based on the few species present (Table 4). This entire sequence appears to have been deposited below the lysocline and many of the nannofloras, notably those characteristic of most of the early Miocene, were undoubtably deposited just above the calcite compensation depth.

The late Pleistocene *Coccolithus pelagicus* Zone occurs in Cores 278-1, 278A-1, and 278A-2. It is at least 31 meters thick, being underlain by a 70-meter-thick uncored interval. Only Core 278-1 has been examined closely; those from Hole 278A were subjected to intense disturbance during drilling. The nannofloras are rare to common, and moderately well preserved, with very low diversities. Taxa more or less consistently present are *Coccolithus pelagicus, Cyclococcolithina leptopora*, questionable *Emiliania huxleyi* (only recognized in Sample 278-1), *Gephyrocapsa* spp. (small), *G.* cf. *oceanica*, and *Helicopontosphaera kamptneri*. Of these *C. leptopora* and *?E. huxleyi* are the most common. *G.* cf. *oceanica* and *H. kamptneri* mainly occur in Sections 2 and 3 of Core 278-1 where the overall nannofloral abundance is highest. This situation presumably results from

TABLE 4
Calcareous Nannofossil Biostratigraphy, Site 278

Age	Zone	Source of Samples
Pleistocene	*C. pelagicus*	Core 1; also Section 278A-1-3
	P. lacunosa	Core 2 to Sample 6-2, 56 cm
Pliocene	*Reticulofenestra pseudoumbilica*	Sample 6-2, 135 cm to Core 15
Late Miocene		
Mid Miocene	*Cyclicargolithus neogammation*	Cores 16-25
Early Miocene	*Discoaster deflandrei*	Cores 25-30
Late Oligocene	*Reticulofenestra bisecta*	Cores 31-34
Mid Oligocene		
		Basalt

a slight depression of the calcite compensation depth relative to this site. The highest and lowest samples examined, 278-1-1, 120 cm, and 278A-2,CC, respectively, appear to have been subjected to a greater degree of dissolution than the intermediate samples.

In 1958 (summer), the surface seawater temperatures above this site were about 2°C (Houtman, 1967, Fig. 2a). Comparison with the south Pacific study of Hasle (1960, 1969) indicates that the calcareous nannoflora living in the photic zone overlying this site probably consists entirely of *E. huxleyi*. The consistent presence of other species in the sediments probably results from either mixing of different life assemblages during the settling process; or highly selective post-depositional dissolution.

The mid Pleistocene to late Pliocene *Pseudoemiliania lacunosa* Zone occurs from the top of Core 278-2 to the base of Core 278-8. It is at least 66 meters thick, overlain by a 70-meter-thick uncored interval. The nannofloras are rare to common, rather poorly preserved, and of low diversity. Small unidentified Prinsiaceae dominate throughout. Common taxa are *C. pelagicus*, *C. leptopora*, and *P. lacunosa* (base at 278-6, CC; early Pleistocene by Radiolaria). Much more rare and sporadic in their occurrence are *G.* spp. (small; base about Sample 278-6-1, 110 cm), *G.* cf. *oceanica* (base in Sample 278-3-1, 110 cm), and *H. kamptneri*. The Prinsiaceae taxon "*Coccolithus*" *minutulus s.l.* occurs in most samples but has not been observed in Core 278-5. The base of this taxon is hard to determine but may be about Sample 278-7-5, 110 cm. *Cyclococcolithina macintyrei* occurs sporadically as high as Sample 278-2-6, 30 cm. Apart from very rare unidentifiable specimens in Sample 278-7-3, 110 cm, the genus *Discoaster* has not been observed in this interval. Consequently it is not possible to determine the position of the Pliocene-Pleistocene boundary by nannofossils in this sequence. The base of this zone coincides with the marked change in the radiolarian faunas, suggesting an unconformity.

The early Pliocene to late mid Miocene *Reticulofenestra pseudoumbilica* Zone occurs from Samples 278-8, CC to 278-15, CC. It is 67 meters thick, and coincides roughly with an interval of siliceous nannofossil ooze. The nannofloras are usually very abundant but of poor preservation and low diversity. Small unidentified Prinsiaceae and *R. pseudoumbilica* overwhelmingly dominate the assemblages. The only other taxon fairly consistently present in this interval is *C. pelagicus s.l.*, which is usually rare. Other taxa very sporadically present include *Coccolithus eopelagicus s.l.*, *Cyclococcolithina leptopora*, *C. macintyrei* (especially Core 278-9), *Discoaster pentaradiatus* (Samples 278-8, CC, and 278-9-1, 110 cm), *D.* sp. indeterminate, *Sphenolithus neoabies* (highest specimen observed is in Sample 278-9-1, 110 cm), and *Thoracosphaera* sp.

The early mid Miocene *Cyclicargolithus neogammation* Zone occurs from Sample 278-16-1, 30 cm, to Sample 278-25-3, 110 cm. It is 90-meters thick and occurs within an interval consisting largely of radiolarian-diatom oozes. The nannofloras are generally more or less common and fairly diverse, but are poorly preserved. *C. pelagicus s.l.*, *C. neogammation*, and small indeterminate Prinsiaceae are fairly common throughout. Other taxa relatively constantly present are *C. eopelagicus s.l.* (especially in Cores 24 and 25), *Discoaster* sp. indeterminate, and *D. variabilis* between Samples 278-17-6 and 278-20, CC. Much more sporadic in their occurrence are *Cyclococcolithina macintyrei*, *Discoaster adamanteus* (Sample 278-20, CC and below), *D.* cf. *bollii* (Samples 278-17, CC to 278-20, CC), *D. challengeri* (Section 278-17-6 to Sample 278-20, CC), *D. deflandrei* group (Section 278-22-1 and below), *D. druggi*? (Sample 278-20, CC and below), *D. exilis* (Section 278-16-6 to Sample 278-18, CC), *Reticulofenestra* sp., and *Sphenolithus moriformis*. The discoasters are usually poorly preserved (overgrown) and battered. They are always rare, and the identifications are based on single-specimen occurrences in several samples. They are considered to be visitors to this high-latitude site. The taxa have stratigraphic ranges elsewhere which are more or less consistent with the age adopted for this interval. A taxon reminiscent of the late Paleogene species *Reticulofenestra bisecta* occurs quite commonly in Core 278-21. A definite specimen was observed in Sample 278-23-3, 53 cm. Three single specimens of the Danian to earliest Miocene genus *Chiasmolithus* were observed in Samples 278-19-3, 13 cm, 278-21-2, 140 cm, and 278-24-4, 110 cm respectively. The uncertainty regarding the exact base of this zone results partly from the different taxonomic concepts of *D. deflandrei* employed by the two investigators, and partly from the rarity of this taxon in this sequence. It is possible that the base of this zone is as high as Sample 278-22-1, 110 cm, certainly it is not lower than the adopted position.

The early Miocene *Discoaster deflandrei* Zone occurs between Samples 278-25-4, 30 cm, and 278-30, CC. It is about 60 meters thick but neither the top nor the base (a 25-meter unsampled interval underlies) can be accurately fixed. Subsequent investigations may well result in this zone being combined with the overlying *C. neogammation* Zone at this site. This interval, which is almost entirely composed of radiolarian-diatom oozes, contains three distinct nannofossil assemblage groupings. The highest, which extends down to Section 278-27-3, contains common, but poorly preserved and low diversity nannofloras. *C. pelagicus s.l., C. neogammation,* and small Prinsiaceae are common and persistent. Consistently present but rare, are *C. eopelagicus s.l.* (Core 25 only), *D. deflandrei,* and *Sphenolithus moriformis.* Other taxa observed are very rare and sporadic *Discoaster* sp. indeterminate, *D. druggi*?, and *D. adamanteus.* The middle nannofossil assemblage grouping occurs between Sections 278-27-4 and 278-29-6. Many of the samples taken from this interval lack calcareous nannofossils but others contain very small, poorly preserved nannofloras consisting mostly of small unidentified Prinsiaceae. Other taxa very sporadically present are *C. pelagicus s.l., C. neogammation,* and *Reticulofenestra* sp. This situation presumably results from the near total dissolution of the nannofloras due to a lowering of the calcite compensation depth at this site. The lower nannofossil assemblage grouping occurs from Samples 278-29, CC to 278-30, CC inclusive. The nannofloras are common but poorly preserved, and of low diversity. Abundant *Reticulofenestra* sp. indeterminate, common *C. pelagicus s.l.,* and fairly common *C. neogammation* occur throughout. The typical high-latitude late-Eocene and Oligocene species *Chiasmolithus altus* occurs in and below Sample 278-30-2, 30 cm. Other very rare taxa sporadically present in this interval are *D. adamanteus, D. deflandrei,* and *S. moriformis.* A single specimen of the mid-Oligocene to early-Miocene taxon *Triquetrorhabdulus carinatus* was observed in Sample 278-30, CC. This interval is considered to be of earliest Miocene age because of the presence of *Chiasmolithus altus* and the absence of *Reticulofenestra bisecta.*

The late- to mid-Oligocene *Reticulofenestra bisecta* Zone occurs from the top of Core 31 to Sample 278-34-3, 110 cm. It is about 33 meters thick, and immediately overlies pillow basalt. The nannofloras are very abundant but poorly preserved and of relatively low diversity. Persistently present are abundant *Reticulofenestra* sp., common *Chiasmolithus altus* aff., *Cyclicargolithus neogammation,* and *Ericsonia ovalis s.l.,* relatively common *Reticulofenestra bisecta* and *R. laevis*?, and rare *Sphenolithus moriformis.* Also present, in low sporadic numbers, are *Coccolithus eopelagicus s.l., Discoaster deflandrei,* and *Thoracosphaera* sp. Single specimens of *Helicopontosphaera recta* (Sample 278-34-1, 12 cm), *Triquetrorhabdulus carinatus* (Sample 278-31-1, 20 cm), and *Zygrhablithus bijugatus* (Sample 278-31-2, 17 cm) were observed. The presence of the planktonic foraminifer *Globigerina angiporoides* at the base of this sequence indicates that most of this zone is of late Oligocene age (Hornibrook and Edwards, 1971).

Diatoms

The assemblages of Site 278 vary greatly in abundance, diversity, and preservation. This situation probably largely reflects the observed lithologic and compaction changes, since the poorest floras occur in the basal nannofossil chalk, and the richest assemblages occur in the upper part of the sequence with siliceous oozes. The highest frequencies of diatoms coincide with the greatest abundance of Radiolaria, silicoflagellates, and sponge spicules. The following age groupings are suggested, and within these age grouping, a number of additional distinctive assemblages can be recognized. All of the taxa encountered in Hole 278 have a marine planktonic habit.

Core 1 (late Pleistocene): This contains abundant cold-water planktonic diatoms *Charcotia actinochilus, Coscinodiscus excentricus* var. *jousei, C. oculus iridis, Fragilariopsis curta, F. lanceolata, F. ritscherii, F. kerguelensis, Shimperiella antarctica, Synedra jouseana, Synedra* sp., *Thalassiothrix longissima,* plus many species still living; considered Pleistocene; preservation excellent.

Cores 2-7 (Pliocene-Pleistocene): Abundance of *Actinocyclus* including the extinct *A. ingens, A. octonarius, A. rothii, A. tsugaruensis, Coscinodiscus tabularis, C. lentiginosus, C. excentricus, C. marginatus, Thalassiosira gracilis,* and relatively few *Nitzschia* and *Denticula* species. Since the *Denticula* and *Nitzschia* species are more abundant in the Miocene and the Pliocene sediments, these samples are considered to be of Pliocene to Pleistocene age. Cores 278-2 to 278-7 contain greater numbers of Centricae and silicoflagellates than the overlying sediments.

Core 8 to Core 11, Section 6 (Pliocene): Very high diversity, essentially similar to those of the overlying interval but also with the highest occurrences of Denticula species: *D. punctata, D. dimorpha, D. hustedtii, D. irregularis, D. kamtschatica,* and *Rhizosolenia bergonii.* Considered to be of slightly older Pliocene age.

Sample 11, CC to Core 14 (late Miocene-early Pliocene): Differs markedly from the overlying intervals, containing the highest known occurrences of *Asteromphalus brookei, A. paroulus, Coscinodinus marginatus, C. oculus-iridis, Actinocyclus oculatus, A. tsugaruensis, A. ingens, Denticula irregularis,* and a distinctive new species. *D. hustedtii* and *D. kamtschatica* abundant with many other taxa; *Denticula punctata, D. lauta, D. dimorpha* still present; *Nitschia jouseae* and *N. miocenica* absent. *Fragilariopsis lanceolata, F. ritcherii, F. curta, F. separanda,* and *F. vanheurckii* first occur in Core 14. This suggests that these assemblages are late Miocene. Centricae abundant with high diversity. *Thalassiothrix* spicules are abundant; fragments are common. The late Miocene radiolarian *Lithromitra lineata* also occurs within this interval.

Cores 15-20 (late mid Miocene): Centricae fewer and diversity decreases downward as with *Denticula* species; increase downward of *Coscinodiscus marginatus, Rhaphoneis dilatata, Actinocyclus, Rhaphoneis sachalinensis, Rhaphidodiscus microtatos; Cosmiodiscus insignis* are abundant in this zone; this suggests the late mid Miocene.

Cores 21-25 (mid Miocene): A decrease in the diversity and in the quality of preservation is evident within Cores 21-23; Cores 24 and 25 have a higher diversity. *Coscinodiscus marginatus, Denticula lauta, Dimi-*

dium falcatum, and *Endyctia robusta* are abundant but all of the other forms are rare. Species not found higher include *Pseudopodosira westii, Rhisosolenia aculeifera, R. curvirostris* var. *inermis,* and *Synedra jouseana* is abundant. The assemblages are typical of the mid Miocene.

Cores 26-30 (early Miocene): A marked change occurs at this interval. Most of the *Rhizosolenia* species and all the *Denticula* species are absent. *Stephanopyxis turris* and *Thalassionema hirosakiensis* are abundant. Highest occurrences of *Coscinodiscus paleaceus, Asteromphalus brookei, A. heptactis, A. parvulus,* and *Bogorovia* sp. Early Miocene seems most likely.

Cores 31 and 32 (late Oligocene?): Number and diversity of diatoms much smaller. The taxa consist of long-ranging species, but these assemblages can be easily separated from those which underlie by the lowest known occurrences of *Synedra. Thalassionema nitzschiodes, T. hirosakiensis,* and especially *Thalassiolbrix longissima* and *Stephanopyxis turris* are abundant. Late Oligocene is suggested.

Cores 33 and 34 (mid Oligocene?): Assemblages markedly different from the overlying, lacking certain typically Neogene diatoms (see above), and containing several forms which are completely new to science. These latter include new species of *Coscinodiscus decrescenoides, Enclyctia burcklei, Macrora stella, Dicladia,* and *?Pyxilla.* Mid Oligocene is tentatively suggested.

Silicoflagellates

Silicoflagellates are rare to common in the samples representing late Oligocene to Pleistocene sediments. The Pleistocene to late Pliocene assemblages are dominated by *Distephanus speculum,* while species of *Dictyocha* are very rare or absent. According to Mandra (1969), this is indicative of low temperatures during deposition, predictable at almost 60°S. However, a complete change of the assemblage occurs in an early Pliocene to late Miocene sample (278-10-1, 110 cm), where the *Dictyocha/Distephanus* ratio is surprisingly high, indicating higher temperatures. In early Pliocene and the Miocene, *Distephanus* and *Mesocena* dominate the assemblages, while *Naviculopsis* becomes common, from the early Miocene on downwards. *Cannopilus* is never common, but occurs in the Pleistocene and late Pliocene (Cores 278-2 to 278-7), and from the mid Miocene to late Oligocene (Cores 278-20 to 278-34). *Cannopilus* also prefers low temperatures (Bukry and Foster, 1973).

Radiolaria

Radiolaria have been examined in Cores 278-1 to 278-12 and Cores 278A-1 to 278A-3. Throughout this interval they are abundant and well preserved, allowing application of the zonation of Hays and Opdyke (1967).

The Quaternary (late Matuyama and Brunhes; t=1.79 m.y. to present) is 157 meters thick, extending from the surface to Section 278-7-6. By far the most dominant form is *Antarctissa denticulata.* Other forms include *A. strelkovi, Spongoplegma antarcticum, Botryopyle antarctica, Lithelius nautiloides,* and *Spongotrochus glacialis.*

The ψ-χ boundary equivalent to the Brunhes-Matuyama paleomagnetic epoch boundary (Hays and Opdyke, 1967), is based on the last appearance of *Pterocanium trilobum* and *Saturnalus circularis.* In Site 278 this level occurs between Samples 278-2-4, 90 cm and 278-2-5, 40 cm.

From Samples 278-7-1, 90 cm to 278-7-6, 140 cm the presence of *Clathrocyclas bicornis* and the absence of *Eucyrtidium calvertense* indicates an age equivalent to the Gilsa Event (t = 1.61-1.79 m.y.B.P.) which is of earliest Pleistocene age. The top of *E. calvertense's* range in Sample 278-7, CC marks the χ-Φ boundary. The lower portion of the Φ zone is apparently removed by an unconformity located between Samples 278-8, CC and 278-9-1 (40 cm). The existence of the unconformity is based on several changes: the abrupt appearance of *A. strelkovi* and *A. denticulata* at the unconformity; the absence of *Pseudocubus vema;* and the presence of *Antarctissa* sp. in sediment immediately below the unconformity.

The presence of *Lychnocaniam grande rugosum* and *Triceraspyris sp.* in Samples 278-9-1, 40 cm to 278-12-6, 86 cm mark the Υ zone which is early-middle Gilbert (t = 3.97-~5.0 m.y.B.P.)

No radiolarian zonal schemes are applicable to the sequence below Sample 278-12, CC. However, the continued presence of *Desmospyris spongiosa* and *E. calvertense* and absence of *L. grande rugosum* and *Triceraspyris* in Samples 278-12, CC to 278-15, CC does suggest a late Miocene age.

SEISMIC DATA

The material at this site represents an isolated pod of pelagic-type sediment, derived from bottom current transport and deposition. The area is well removed from the thick sequence of ponded turbidites in the Solander Trough. The minor mid-Pliocene hiatus of about 2 m.y. at a depth of about 170 meters, seems to correlate with the unconformity at a reflection depth of about 0.2 sec that appears in the profiler section (Figure 3).

SEDIMENTATION RATES

Sedimentation rates for Site 278 are shown in Figure 8. Three distinct episodes of sedimentation and one of non-sedimentation are shown from the middle Oligocene to the Recent. Sedimentation rates were very low (~0.5cm/1000yr) during the Oligocene to early Miocene episode of deposition. From the middle Miocene to early Pliocene sedimentation rates increased to an average of 1.3 cm/1000 yr during deposition of nannofossil-rich siliceous oozes and siliceous-rich nannofossil oozes. After a break in sedimentation during at least the middle Pliocene, a spectacular increase in sedimentation occurred from late Pliocene to Recent, of an average of 7.5 cm/1000 yr. This associated with deposition of diatom-radiolarian ooze.

The dramatic increase in productivity appears to herald the initiation of the high productivity associated with the Antarctic Convergence as it is known today. Alternatively, increased sedimentation rates at Site 278 may be partly related to increased deposition of sediment transported from extensive regions in the south Tasman Sea. This is not the major process as shown by excellent preservation of siliceous biogenic components, and reworking is not extensive. Although the cause of

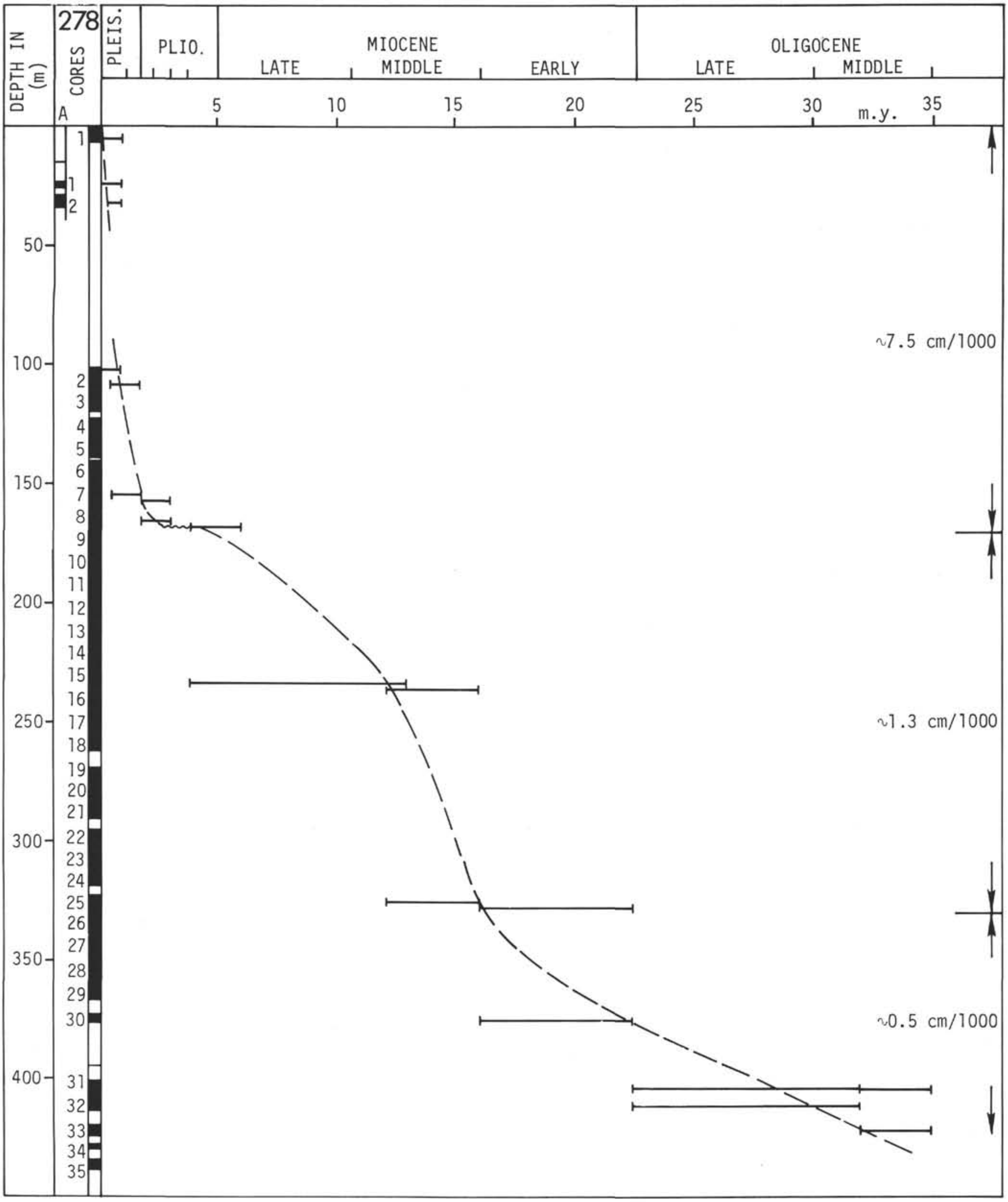

Figure 8. *Sedimentation rate curve at Site 278; ages based on adopted age, (Figure 7).*

increased productivity is unknown it is probably related with more vigorous oceanic overturn, which is related to cooler Pleistocene climates.

Increased sedimentation in two main steps from the Oligocene to the present appears to be related to increased productivity of diatoms. This suggests increased upwelling of nutrient-silica-rich deep water in the Southern Ocean associated with the Antarctic Convergence.

SUMMARY AND CONCLUSIONS

Site 278 was drilled in the southwestern Emerald Basin well away from the flank of the Macquarie Ridge in 3708 meters of water (Figure 1), obtaining 37 cores with total penetration of 438 meters, the basal 5 meters of which consists of pillow basalt.

Six sedimentary units have been distinguished which can be grouped into three broader units as follows: The upper 172 meters consist of late Pleistocene (Recent?) to late Pliocene radiolarian-diatom ooze (Units 1 and 2). This is underlain by 214 meters of early Pliocene to early Miocene alternating siliceous nannofossil ooze and nannofossil-rich siliceous ooze (Units 3 to 5). This is underlain by 42 meters of early Oligocene nannofossil chalk rich in sponge spicules (Unit 6). Rates of sedimentation increase upward in step-like fashion. Sedimentation rates are very low for the Oligocene (0.5 cm/1000 yr), moderate for the Miocene-early Pliocene (1.3 cm/1000 yr), and very high for the late Pliocene and Pleistocene (7.5 cm/1000 yr). Well-dated middle Oligocene (30 m.y. old) nannofossil chalk lies directly on pillow basalt with zeolite-filled veins, amygdules, vesicles, and interpillow micritic limestone layers. The outer surfaces of the pillows are glassy, and the glass is palagonitized. Although the basalt/chalk contact was not recovered, there is no evidence of baking of the limestone or mineralization.

The almost continuous Quaternary to middle Oligocene sequence offers a particularly fine biostratigraphy of well-preserved and abundant diatoms and radiolaria throughout except in the Oligocene where siliceous microfossils other than sponge spicules are rare. The Oligocene contains abundant and moderately diverse assemblages of planktonic foraminifera and calcareous nannofossils. The Neogene calcareous assemblages show much evidence of dissolution. This has reduced the diversity of the calcareous assemblages.

Conclusions

The age difference between basement at Site 277 and basement south of the Campbell plateau, 300 km to the east, is about 50 m.y. This discrepancy calls for an important discontinuity in the sea floor, which is most likely related to the post-mid Eocene tectonic activity that has deformed the western edge of the Campbell plateau. A major fracture zone, and a 600-meter change in sea floor depth are present (see Chapter 42, this volume). The formation of the sea floor at Site 277 is probably contemporaneous with the onset of subsidence (Fleming, 1962) in the Waiau depression in Southland, New Zealand. The depression is located at the head of the Solander Trough-Emerald Basin (see Figure 1, Chapter 44, this volume).

The history of biogenic sedimentation at this site is of particular interest because of its location at the present-day Antarctic Convergence. The fluctuations in lithology from nannofossil ooze to radiolarian-diatom ooze appear to indicate changes in the location and strength of the Antarctic Convergence. The siliceous oozes represent times when the convergence was nearby, thereby increasing productivity and sedimentation rates.

The Oligocene nannofossil chalks reflect deposition initially above, and later slightly below the planktonic foraminiferal lysocline, under fully oceanic conditions. Very low sedimentation rates and the paucity of siliceous biogenic components other than sponge spicules suggest that upwelling was essentially nonexistent in the region. This implies the absence of an Antarctic Convergence at this time. Alternatively, the convergence would need to be squeezed between Site 278 and the Antarctic continent. It is possible that the Antarctic Convergence and the related upwelling did not develop before the beginning of the Neogene due to constricted circulation in the narrow Paleogene passage between Australia and Antarctica.

The Oligocene nannofossil chalks contain abundant sand-size feldspathic glass and sanidine grains, an indication of nearby volcanism. Significant fluctuations in the abundance of ice-rafted quartz sand grains occur in Pleistocene and late Pliocene sediments. Lesser amounts are found in early Pliocene/late Miocene sediments at this site. Ice-rafted grains are absent in all sediments older than late Miocene.

The first siliceous oozes to occur are early Miocene and at these latitudes they probably reflect siliceous productivity associated with the early development of the convergence. Moderately low sedimentation rates indicate, however, that siliceous biogenic productivity was relatively low and upwelling was generally sluggish. Alterations of siliceous-rich and calcium carbonate-rich biogenic sediments in the mid Miocene almost certainly record latitudinal fluctuations of the Antarctic Convergence. The consistent combination of siliceous and carbonate components in the oozes suggests, however, that the convergence did not change position greatly. The relatively fixed position of the convergence probably reflects the influence of the Macquarie Ridge throughout the Neogene. Today the Antarctic Convergence is diverted further south by the Macquarie Ridge.

The considerable increase in siliceous biogenic productivity that began about the middle-late Pliocene and has continued to the present indicates an intensification of upwelling associated with the Antarctic Convergence. The location of Site 278 on the southeastern side of the Macquarie Ridge in an area protected from erosion by the circumpolar current has enabled the deposition of an almost continuous sequence. It is possible that sedimentation rates may also have been increased by sediment deposition by bottom currents at this location during the Plio-Pleistocene.

Large amounts of materials, most probably biogenic are known to have been eroded over extensive areas of the southern Tasman Sea during the Plio-Pleistocene. This material may have been transported by bottom currents associated with circumpolar currents to the southwest Pacific basin via the area immediately south of the Macquarie Ridge, and through two deep east-west channels that cut through the Macquarie Ridge to the north. Some of this transported sediment may have been deposited on the leeward side of the Macquarie Ridge in the area of Site 278 and contributed to the very high sedimentation rate. Minor reworking of biogenic materials into the Plio-Pleistocene indicates some bottom current activity. However, the excellent preservation of the siliceous microfossil assemblages strongly suggests that high productivity is the primary cause of the high Plio-Pleistocene sedimentation rates. This is probably related to a critical development of world-wide glaciation at this time, as recorded by the initiation of ice-rafting in the North Atlantic and a marked increase in bottom-water erosion observed in the south Tasman Sea, the Ross Sea, and the central Pacific. At Site 278 increased dissolution of calcium carbonate from the Oligocene to the present day probably is related to higher bottom-water activity, itself related to the stimulated oceanic circulation.

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APPENDIX A
Summary of X-Ray[a], Grain Size, and Carbon-Carbonate Results, Hole 278

Section	Sample Depth Below Sea Floor (m)	Lithology	Age	Bulk Sample Major Constituent 1	2	3	2-20μ Fraction Major Constituent 1	2	3	<2μ Fraction Major Constituent 1	2	3	Grain Size Sand (%)	Silt (%)	Clay (%)	Classification	Carbon Carbonate Total (%)	Organic (%)	$CaCO_3$ (%)	Comments
278-1-1	1.4	Unit 1 Foraminifera and detrital silt-bearing radiolarian-diatom ooze	Late Pleistocene	Plag.	Calc.	Quar.	Plag.	Quar.	Mica.	Mont.	Plag.	Mica	9.9	60.0	30.1	Clayey silt	2.8	0.1	22	Amph-in bulk, 2-20μ & <2μ Gyps 1M <2μ
278-1-2	2.4-2.7			Plag.	Calc.	Quar.	Plag.	Quar.	Mica.	Mont.	Mica	Plag.	9.1	55.1	35.8	Clayey silt				*Amph-in bulk, 2-20μ and <2μ *2nd sample=9.1, 68.3, 28.5
278-1-4	5.8			Calc.	Plag.	Mica	Plag.	Quar.	Mica.	Mont.	Plag.	Mica								Amph-in bulk and 2-20μ
278-2-4	106.0-106.1	Unit 2 Nannofossil-rich diatom ooze	Late Pliocene to late Pleistocene	Calc.	Mica	Plag.	Quar.	Plag.	K-Fe.	Mont.	Mica	Quar.	1.8	50.2	48.0	Clayey silt	2.7	0.1	21	Amph-in bulk and 2-20μ
278-3-5	117.1			Calc.	Mica	Quar.	–	–	–*	–	–	–*	3.4	44.0	52.6	Silty clay	4.1	0.1	33	*No results available
278-3-5	117.7-117.8			Calc.	Plag.	Quar.	Plag.	Quar.	Mica	Mont.	Mica	Quar.	4.0	50.7	45.4	Clayey silt	3.2	0.1	26	Amph-in bulk, 2-20μ and <2μ
278-6-3	143.1			Plag.	Quar.	Mica	Plag.	Quar.	Mica	Mont.	Mica	Plag.	3.2	50.1	46.6	Clayey silt	3.7	0.1	30	
278-8-2	159.8-159.9																			
278-12-1	196.7-196.8	Unit 3 Siliceous nanno-fossil ooze	Early Pliocene	Calc.	Mica	Quar.	Quar.	Plag.	Mica	Mont.	Mica	Plag.	0.1	25.6	74.3	Silty clay	7.0	0.1	58	Amph-in 2-20μ
278-13-4	210.4			Calc.	Mica	Quar.	Quar.	Plag.	Mica	Mont.	Mica	Quar.	0.1	23.2	76.6	Clay	7.7	0.1	64	Amph-in 2-20μ
278-15-3	228.1			Mica	Quar.	Plag.	Quar.	Plag.	Mica	Mont.	Mica	Quar.								Amph-in 2-20μ
278-16-6	241.8-241.9	Unit 4 Nanno-rich siliceous ooze, diatom-rich nanno ooze	to early	Mica	Quar.	Plag.	Quar.	Plag.	Mica	Mont.	Mica	Quar.	0.2	24.8	74.9	Silty clay	0.7	0.1	5	Amph-in 2-20μ
278-18-6	261.2-261.3			Calc.	Mica	Quar.	Quar.	Plag.	Mica	Mont.	Mica	Quar.	1.7	29.1	69.2	Silty clay	3.7	0.1	30	Amph-in 2-20μ
278-21-6	289.5-289.6	Unit 5 Rad-diatom ooze and siliceous ooze	Miocene	Calc.	Mica	Quar.	Quar.	Plag.	Mica	Mont.	Mica	Quar.	0.3	25.1	74.6	Silty clay	4.3	0.1	35	Amph-in 2-20μ
278-24-5	316.5-316.6			Calc.	Mica	Quar.	Quar.	Plag.	Mica	Mont.	Mica	Quar.	0.4	32.7	66.9	Silty clay	4.2	0.1	34	Amph-in 2-20μ
278-28-2	349.9			Mica	Quar.	Plag.	Quar.	Plag.	Mica	Mica	Mont.	Quar.	0.4	20.8	78.9	Clay	0.8	0.1	6	
278-31-3	399.0	Unit 6 Siliceous nanno-fossil chalk	Middle to late Oligocene	Calc.	Mica	Quar.	Quar.	Mica	Plag.	Mica	Mont.	Quar.	0.6	36.9	62.5	Silty clay	7.6	0.1	63	Gyps-in <2μ
278-34-3	427.1			Calc.	Mica	Mont.	Mica	Quar.	Plag.	Mica	Mont.	Quar.	5.9	43.4	50.7	Silty clay	6.8	0.0	57	Dolo in bulk

Note: * = see comment column.

[a]Complete results of X-ray, Site 278 will be found in Appendix I, Table 4.

[b]Legend in Appendix A, Chapter 2.

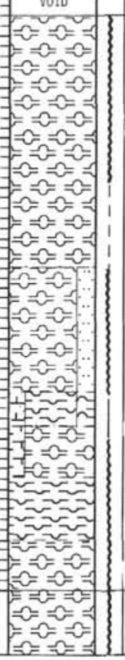
[c]Peaks at 5.76Å, 3.63Å, & 8.12Å among others in bulk fraction for Samples 278-1-1, 1-4, 2-4, 3-5, and 6-3 in amounts of 5.25% for all samples except 6-3, which reports Trace (5%) amounts.

Site 278 Hole Core 1 Cored Interval: 0.0-6.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	LITHO. SAMPLE
LATE PLEISTOCENE	G. (T.) punctuculata ? / G. (G.) truncatulinoides / C. pelagicus / Ψ	F	A	G	1	*75
		N	R	P	1	*135
		N	C	M	2	
		N	C	M	2	
		N	C	M	3	
		N	F	M	3	*130
		F	F	M	4	
		F	C	G	4	*105
		N	R	P	4	*148
		D	A	G	Core Catcher	
		S	F	M	Core Catcher	
		R	A	G	Core Catcher	

METERS: 0.5, 1.0

LITHOLOGY: VOID



LITHOLOGIC DESCRIPTION

Light brownish gray (2.5Y 6/2) FORAM-BEARING RAD DIATOM OOZE with dark gray mottles due to an increase in detritals and mica. Glacial-type quartz grains: this grades into a FORAM AND DETRITAL SILT-BEARING RAD DIATOM OOZE at base of Sec. 1. Other lithologies and color changes noted were: Secs. 2 and 3 darker bands containing detritals are firm and less deformed, while lighter bands are moderately deformed to soupy; grayish brown (2Y 5/2) layer rich in SAND DETRITALS (Sec. 2 85-100 cm); light yellowish brown (2.5Y 6/4) layer, PELAGIC (Sec. 2 100-120 cm) and a grayish brown layer (2Y 5/2) at 120-130 cm, Sec. 2; Sec. 3 contains a light yellowish brown (2.5Y 6/4) DETRITAL SILT-RICH, FORAM-BEARING RAD DIATOM OOZE (0-110 cm) and a grayish brown (2.5Y 5/2) RAD AND NANNO-RICH DIATOM OOZE at 110-140 cm. Sec. 3 (140 cm) to 40 cm in Sec. 4 is a DETRITAL SILT BEARING FORAM RICH RAD DIATOM OOZE: colors noted in Sec. 4 includes: pale yellow (2.5Y 7/4) with a faint mottling, light gray (2.5Y 7/2) and gray (2.5Y 6/0).

SS 3-130		SS 4-105		SS 4-148	
N	-20%	DE	-20%	D	-20%
D	-60%	F	- 2%	R	-50%
R	-15%	N	- 3%	DE	-20%
S	- 3%	D	-60%	S	-10%
F	- 1%	S	-10%		
DE	- 1%	R	- 4%	Sd	-10%
		(angular		ST	-50%
		sand grains)		CL	-40%

X-ray 1-140 (Bulk)
Calc - A Chlo - TR
Quar - P Mont - TR
K-Fe - P Amph - P
Plag - A
Mica - P

X-Ray 2-89 (Bulk)
Calc - A Chlo - TR
Quar - P Mont - TR
K-Fe - P Gyps - TR
Plag - A Amph - TR
Mica - P

X-ray 4-130
Calc - A Chlo - TR
Quar - P Mont - P
Plag - P Amph - TR
Mica - P

Grain Size 1-143 (9.9, 60.0, 30.1)

Grain Size 2-118 (9.1, 55.1, 35.8)

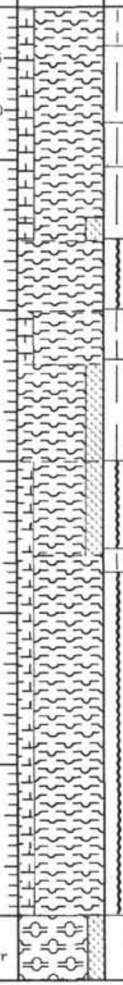
Grain Size 2-121 (9.1, 62.3, 28.5)

Carbon Carbonate 1-142 (2.8, 0.1, 22)

Site 278 Hole Core 2 Cored Interval: 101.0-110.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	LITHO. SAMPLE
LATE PLEISTOCENE		N	C	M	1	
		N	C	P	1	137 *
		N	C	M	2	73 *
	Ψ	N	C	M	2	
		N	C	M	3	
		N	F	P	3	91 *
		N	F	P	4	53 *
	G. (T.) punctuculata / P. lacunosa	N	F	P	4	
EARLY TO MIDDLE PLEISTOCENE		N	C	P	5	
		N	C	P	5	75 *
	X	N	C	P	6	
		N	F	M	6	
		F	M	R	Core Catcher	* CC
		R	A	G	Core Catcher	
		N	F	M	Core Catcher	
		D	C	G	Core Catcher	
		S	R	M	Core Catcher	

METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

Core shows variable lithologies mainly variations of a DIATOM OOZE. Sec. 1 to Sec. 2 (60 cm) NANNO-RICH SPONGE SPICULE bearing DIATOM OOZE (SS 1-137), Sec. 3 (0-50 cm and Sec. 4 (110 cm) through Sec. 6 (SS 5-75): DIATOM-RAD OOZE in core catcher (SS CC). This is spicule-rich. The core also shows color variations: greenish gray (5GY 6/1), grayish green (5G 6/1) Secs. 1, 2, 3, and 6; medium bluish gray (5B 5/1) and light bluish gray (5B 7/1) in Secs. 2, 4, and 6. The colors are slightly to intensely mottled, showing vertical streaks in intensely deformed areas. The deformation ranges from intense (soupy) to slight.

SS 1-137		SS 2-73		SS 3-91		SS 4-53		SS 5-75	
N	-15%	F	-15%	DE	- 5%	DE	- 8%	DE	- 1%
D	-50%	N	-15%	N	- 4%	F	- 5%	M	- 9%
S	-25%	D	-35%	F	- 1%	N	-22%	F	- 5%
DE	- 8%	R	- 5%	D	-80%	D	-40%	N	-25%
(quartz,		S	-15%	S	-10%	R	- 8%	D	-50%
muscovite,		DE	-15%			S	-15%	R	- 2%
biotite,								S	- 8%
chlorite)									

SS CC
G -TR
M -10%
D -30%
R -40%
S -20%

X-ray 4-58 (Bulk)
Calc - M
Quar - P
Plag - P
Mica - P
Chlo - TR
Amph - TR

Grain Size 4-54 (1.8, 50.2, 48.0)

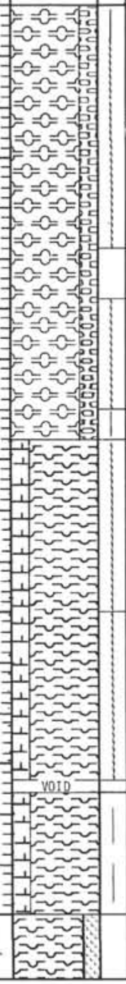
Carbon Carbonate 4-51 (2.7, 0.1, 21)

Explanatory notes in Chapter 1

Site 278 Hole Core 3 Cored Interval: 110.5-120.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS
EARLY TO MIDDLE PLEISTOCENE	G. (T.) puncticulata; P. lacunosa X	N	C	P	1	0.5, 1.0
		N	C	P	2	
		N	F	P	3	
		N	C	P	4	
		N	C	P	5	
		N	C	P	6	
		F R N D S	R A F C R	G G M G G	Core Catcher	

LITHOLOGY



LITHO. SAMPLE: * 127; * CC

LITHOLOGIC DESCRIPTION

Light bluish gray (5B 7/1) with micaceous dark streaks: MICARB-RICH RAD DIATOM OOZE in Sec. 1 to 130 cm in Sec. 3; NANNO-RICH DIATOM OOZE Sec. 3 (130 cm) to Sec. 6 (20 cm) and a SPONGE SPICULE-RICH DIATOM OOZE in CC; deformation is usually intense causing color streaking: colors are light gray (7.5GY 7/0), light bluish gray (5B 7/1), light greenish gray (5G 8/1) and greenish gray (5G 6/1).

SS 1-127		SS CC	
M	-15%	DE	- 2%
F	-10%	CM	- 2%
N	-10%	N	- 3%
D	-30%	D	-75%
R	-25%	R	- 3%
S	-10%	S	-15%

X-ray 5-120 (Bulk)
Calc - M
Quar - TR
Plag - TR
Mica - TR

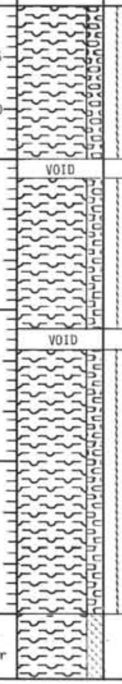
Grain Size 5-124 (3.4, 44.0, 52.6)

Carbon Carbonate 5-127 (4.1, 0.1, 33)

Site 278 Hole Core 4 Cored Interval: 120.0-129.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS
EARLY TO MIDDLE PLEISTOCENE	G. (T.) puncticulata; P. lacunosa X	N	C	M	1	0.5, 1.0
		N	C	M	2	
					3	
					4	
		F R N D S	VR A F C R	M G P M P	Core Catcher	

LITHOLOGY



LITHO. SAMPLE: * CC

LITHOLOGIC DESCRIPTION

Light bluish gray (5B 7/1) MICARB-RICH DIATOM OOZE; the core catcher is SPICULE-RICH (SS CC). The core is highly deformed with a decreasing micarb content down core.

SS CC	
D	-15%
M	-10%
N	- 5%
D	-50%
R	- 2%
S	-18%

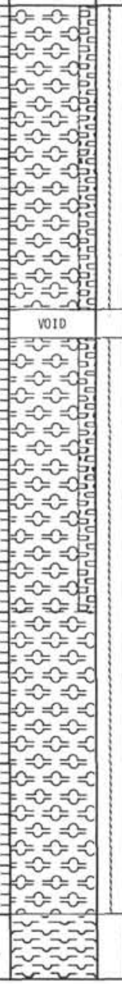
Explanatory notes in Chapter 1

Site 278 Hole Core 5 Cored Interval: 129.5-139.0 m

AGE: EARLY TO MIDDLE PLEISTOCENE

ZONE: G. (T.) puncticulata; P. lacunosa; X

SECTION	FOSSIL	ABUND.	PRES.
1	N	C	P
2	N	F	P
3	N	C	M
4	N	F	P
5	N	F	P
6	N	F	P
Core Catcher	F	VR	M
	R	A	G
	N	R	P
	D	A	M
	S	—	—



LITHO. SAMPLE: * CC

LITHOLOGIC DESCRIPTION

Light bluish gray (5B 7/1) with streaks of light greenish gray and greenish gray (5G 8/1), SPICULE-BEARING MICARB-RICH RAD DIATOM OOZE grading into a MICARB-BEARING RAD/DIATOM OOZE in Sec. 5; and to a SPONGE SPICULE AND MICARB-BEARING DIATOM OOZE in the core catcher: core shows swirling and streaking and is intensely deformed grading into moderate deformation in Secs. 3 through 6.

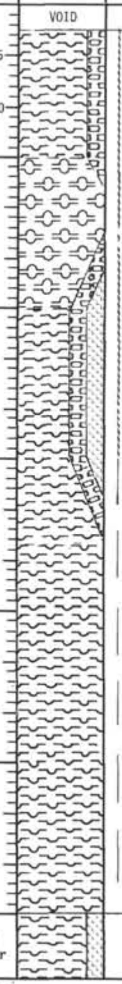
SS CC
DE - 4%
M - 7%
F - 2%
N - 5%
S -10%
D -70%
R - 2%

Site 278 Hole Core 6 Cored Interval: 139.0-148.5 m

AGE: EARLY TO MIDDLE PLEISTOCENE

ZONE: G. (T.) puncticulata; P. lacunosa; X; P. lacunosa

SECTION	FOSSIL	ABUND.	PRES.
1	N	C	P
2	N	C	M
2	N	C	M
3	N	C	M
4	N	F	M
5	N	R	P
6	N	F	P
Core Catcher	F	R	M
	R	A	G
	N	F	M
	D	F	M
	S	F	G



LITHO. SAMPLE: * 135; * CC

LITHOLOGIC DESCRIPTION

Light bluish gray (5B 7/1), medium bluish gray (5B 5/1) to greenish gray streaked MICARB-RICH DIATOM OOZE; intensely deformed varying with moderate deformation throughout the core. Sec. 2 shows excellent color mottling of grayish green and greenish gray colors and is a RAD DIATOM OOZE, with clay blebs and mild bioturbation: it grades into a MICARB/SPONGE SPICULE-RICH DIATOM OOZE in Sec. 3: a dusky yellow green (5GY 5/2) coloration with greeenish gray streaks and intense deformation occurs in Sec. 5.

SS 3-135		SS CC	
Q	-24%	M	- 8%
G	-TR	N	-12%
M	-16%	D	-60%
F	- 2%	R	- 5%
D	-60%	S	-15%
R	-TR	DE	- 5%
S	-12%		

X-ray 3-105 (Bulk)
Calc - A
Quar - P
K-Fe - TR
Plag - P
Mica - P
Chlo - TR
Mont - TR
Amph - TR

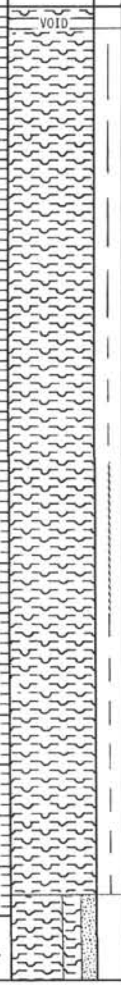
Grain Size 3-108 (4.0, 50.7, 45.4)

Carbon Carbonate 3-110 (3.2, 0.1, 26)

Explanatory notes in Chapter 1

Site 278 Hole Core 7 Cored Interval: 148.5-158.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHO. SAMPLE
EARLY TO MIDDLE PLEISTOCENE	G. (T.) punctiuculata / P. lacunosa	N	F	P	1	0.5, 1.0	
		N	F	P	2		
		N	F	P	3		90 *
		N	F	P	4		
		N	F	P	5		
		N	F	P	6		
PLIOCENE		F R N D S	R A F C R	M G P M P	Core Catcher		* CC



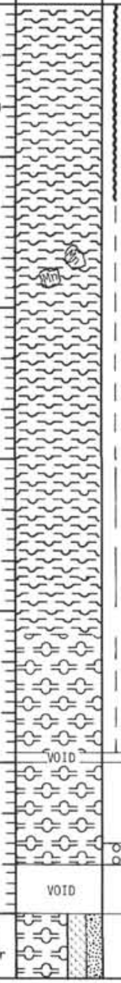
LITHOLOGIC DESCRIPTION

Light bluish gray (5B 7/1) to greenish gray (5B 7/1) DIATOM OOZE, which is generally moderately deformed, although slight and intense deformation does occur: swirled and streaked colorations noted and bioturbated areas occur. The core shows both soft to stiff characteristics: in Secs. 2 and 3 greenish gray (5G 6/1), dusky yellow green (5GY 5/2) to gray (5B 7/1) colors are noted and the core has a stiff to firm induration Sec. 5 is well indurated faintly mottled and laminated, with greenish gray to light greenish gray colors with the colors getting lighter toward the bottom. In Sec. 6 at 130 cm is a contact to a yellowish gray (5Y 8/1), light olive gray (5Y 6/1) RAD AND DETRITAL SILTY SAND-RICH DIATOM OOZE.

SS 3-90		SS CC	
DE	- 4%	DE	-15%
M	- 2%	D	-60%
F	-TR	R	-10%
N	- 3%	S	- 4%
D	-80%	M	- 3%
R	- 4%	F	- 5%
S	- 6%		

Site 278 Hole Core 8 Cored Interval: 158.0-167.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHO. SAMPLE
PLIOCENE	G. (T.) punctiuculata / P. lacunosa / R.p.	N	—	—	1	0.5, 1.0	
		N	—	—	2		105 *
		N	R	P	3		
		N	—	—	4		
		N	—	—	5		
		N	C	P	6		* 77
		N	—	—			
		F R N D S	R A C C R	M G P M P	Core Catcher		



LITHOLOGIC DESCRIPTION

Pale yellow brown (10YR 6/2), greenish gray to light bluish gray (5B 7/1) DIATOM OOZE, becoming SPICULE-RICH (SS 2-105) in Sec. 2. The core shows intense deformation at the top (Sec. 1) becoming firmer (moderate-slight deformation) at the bottom, (Secs. 5-6). Other colors occuring are: light bluish gray (5B 7/1); pale yellow brown with light mottles; and a very pale orange (10YR 8/2) with dark streaks of Mn. in Sec. 2; light brownish gray (10YR 6/2) in faint mottles with greenish gray (5G 6/1) as well as a mixture of 5G 6/1 and 10YR 6/2 in Sec. 3; very pale brown (10YR 7/3) dark streaks and brown (10YR 5/3) to very pale brown with greenish gray streaks in Sec. 4 (100 cm) through Sec. 5: Sec. 5 (30 cm) is a RAD DIATOM OOZE with an incorporated ice-rafted pebble of granite grading into a SILT AND SAND, DETRITAL-RICH SILICEOUS OOZE in Sec. 6 and a SPONGE SPICULE AND SANDY SILT DETRITAL-RICH DIATOM RAD OOZE in the core catcher.

SS 2-105		SS 6-77		SS CC	
DE	- 8%	Q	- 7%	DE	-22%
D	-80%	F	- 5%	M	- 5%
S	-12%	Mi	- 2%	N	- 3%
		HM	- 6%	D	-25%
		DE	-20%	R	-30%
		N	-10%	S	-15%
		D	-30%		
		R	-20%		
		S	-15%		
		Si	- 5%		

X-ray 2-37 (Bulk)
Calc - P
Quar - P
K-Fe - TR
Plag - A
Kaol - TR
Mica - P
Chlo - TR
Mont - P
Amph - TR

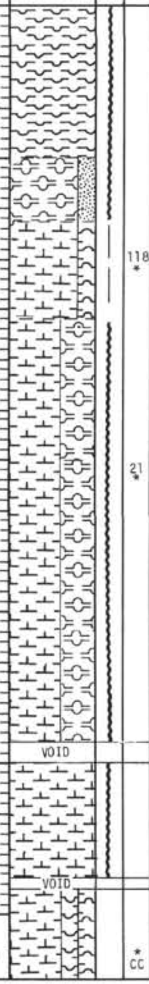
Grain Size 2-34 (3.2, 50.1, 46.6)

Carbon Carbonate 2-40 (3.7, 0.1, 30)

Explanatory notes in Chapter 1
R.p. = R. pseudoumbilica

Site 278 Hole Core 9 Cored Interval: 167.5-177.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
LATE MIOCENE	G. (G.) bulloides; R. pseudoumbilica	N	A	P	1	0.5			
		N	C	P		1.0			
		N	A	P	2				118 *
		N	A	P	3				
		N	A	P	4				21 *
		N	A	P	5		VOID		
		N	A	P	6		VOID		
		F R N D S	R A A C R	M G P M G	Core Catcher				* CC



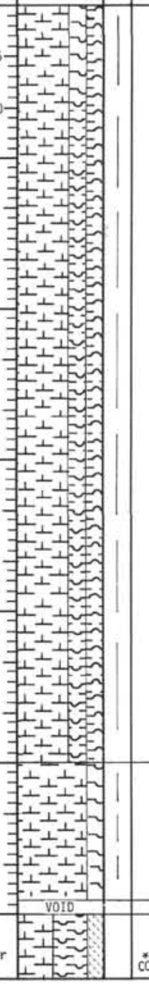
LITHOLOGIC DESCRIPTION

The core consists of a very light brown (10YR 5/3) DIATOM OOZE with white (10YR 8/1) and light gray (10YR 7/2) colors which are swirled and streaked, vertically banded. A SAND AND SILT-RICH SILICEOUS OOZE in Sec. 2 (0-65 cm) grades into a SILICEOUS-RICH NANNO OOZE white (10YR 8/1) at 65 cm in Sec. 2 going to 15 cm in Sec. 3. Sec. 3 (15 cm) is MIXED NANNO + DIATOM OOZE and a very pale brown (10YR 7/3) SILICEOUS NANNO OOZE in Sec. 4 (0-70 cm). Swirled and mixed colors with mild mottling is common. The core is stiff but tends to be deformed intensely. MN micronodule streaks increase in Sec. 5. The core catcher consists of a very pale brown (10YR 7/3) RAD/DIATOM-RICH NANNO OOZE (SS CC).

SS 2-118		SS 4-21		SS CC	
N	-70%	N	-60%	N	-50%
D	- 8%	D	-20%	D	-25%
R	-15%	R	-12%	R	-15%
S	- 7%	S	- 8%	S	-10%
				DE	- 1%

Site 278 Hole Core 10 Cored Interval: 177.0-186.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
LATE PLIOCENE	G. (G.) bulloides; R. pseudoumbilica	N	A	P	1	0.5			
						1.0			
		N	A	P	2				
		N	A	P	3				
		N	A	P	4				
		N	A	P	5				
		N	A	P	6		VOID		
		F R N D S	VR A A C R	M G P M M	Core Catcher				* CC



LITHOLOGIC DESCRIPTION

White (10YR 8/2) stiff induration with a uniform texture DIATOM/RAD-RICH NANNO OOZE, speckled with MN micronodules. Some mixing with a pale yellow brown (10YR 7/2) color occurs as well as some dark streaks of clay and MN in Sec. 3. Sec. 6 consists of a soft to stiff light gray (10YR 7/2) DIATOM-RICH NANNO OOZE and the core catcher is a SPONGE SPICULE-RICH DIATOM NANNO OOZE (SS CC).

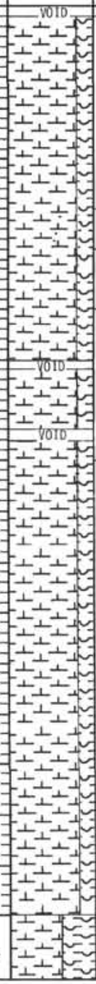
SS CC	
DE	- 1%
N	-45%
D	-30%
R	- 7%
S	-13%

Explanatory notes in Chapter 1

Site 278 Hole Core 11 Cored Interval: 186.5-196.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	DEFORMATION	LITHO. SAMPLE
LATE MIOCENE	G. (G.) bulloides; R. pseudoumbilica	N	A	P	1	0.5; 1.0		
		N	A	P	2			
		N	A	P	3			
		N	A	P	4			
		N	A	P	5			
		N	A	P	6			
		F	VR	M	Core Catcher			* CC
		R	A	G				
		N	A	P				
		D	C	G				
		S	R	M				

LITHOLOGY



LITHOLOGIC DESCRIPTION

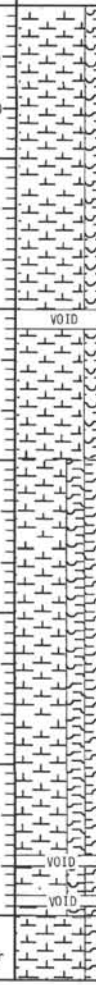
Light gray (10YR 7/1) DIATOM-RICH NANNO OOZE. The core is stiff, in upper sections becoming soft in Sec. 3 and firm again in Secs. 4-6. A mottling of colors occurs with light brownish gray (10YR 7/2) and light gray (10YR 7/1). The core catcher consists of a DIATOM NANNO OOZE (SS CC).

SS CC
N -60%
D -25%
R - 5%
S -10%

Site 278 Hole Core 12 Cored Interval: 196.0-205.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	DEFORMATION	LITHO. SAMPLE
LATE MID MIOCENE TO LATE MIOCENE	G. (G.) bulloides; R. pseudoumbilica	N	A	P	1	0.5; 1.0		
		N	A	P	2			
		N	A	P	3			
		N	A	P	4			
		N	A	P	5			
					6			
		N	A	P	Core Catcher			* CC
		F	VR	M				
		R	A	G				
		N	A	P				
		D	A	G				
		S						

LITHOLOGY



LITHOLOGIC DESCRIPTION

White (5Y 8/1) to very light gray (5Y 7/1). The core is soft to soupy (Sec. 6) and shows a light mottled, swirled texture with colors of light greenish gray (5G 8/1) very light gray (N8) and light bluish gray (5B 7/1). The basic lithology is a DIATOM-RICH NANNO OOZE grading into a RAD AND DIATOM-RICH NANNO OOZE in Sec. 4. The core catcher is a DIATOM-BEARING RAD-RICH NANNO OOZE.

SS CC
D -TR
N -75%
D -10%
R -15%

X-ray 1-75 (Bulk)
Calc - M
Quar - TR
K-Fe - TR
Plag - TR
Mica - P
Chlo - TR

Grain Size 1-73 (0.1, 25.6, 74.3)

Carbon Carbonate 1-71 (7.0, 1.0, 58)

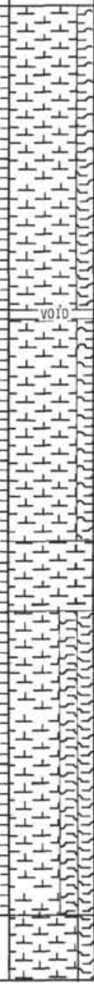
Explanatory notes in Chapter 1

Site 278 Hole Core 13 Cored Interval: 205.5-215.0 m

AGE: LATE MID MIOCENE TO LATE MIOCENE

ZONE: G. (G.) bulloides; R. pseudoumbilica

SECTION	METERS	FOSSIL	ABUND.	PRES.	LITHO. SAMPLE
1	0.5, 1.0				
2		N	A	P	
3		N	A	P	
4		N	A	P	
5		N	A	P	
6		N	A	P	
Core Catcher		F R N D S	VR A A G R	M G P G M	* CC



LITHOLOGIC DESCRIPTION

Light bluish gray (5B 7/1) DIATOM-BEARING RAD-RICH NANNO OOZE; a RAD/DIATOM NANNO OOZE in Secs. 5 and 6 and a DIATOM-RICH NANNO OOZE in core catcher (SS CC). The core is intensely deformed in Secs. 1 and 2, becoming soft to stiff lower in the core. A slight mottling is noteable as well as specks of MN occurring in Sec. 3.

SS CC
DE -TR
N -75%
D - 5%
R - 5%
S - 5%

X-ray 4-44 (Bulk)
Calc - M
Quar - TR
K-Fe - TR
Plag - TR
Mica - TR
Mont - TR

Grain Size 4-41 (0.1, 23.2, 76.6)

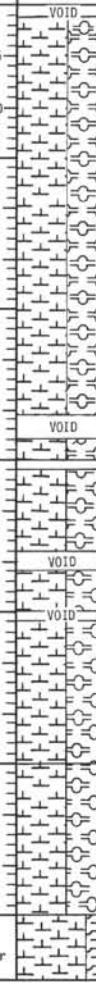
Carbon Carbonate 4-40 (7.7, 0.1, 64)

Site 278 Hole Core 14 Cored Interval: 215.0-224.5 m

AGE: LATE MID MIOCENE TO LATE MIOCENE

ZONE: R. pseudoumbilica

SECTION	METERS	FOSSIL	ABUND.	PRES.	LITHO. SAMPLE
1	0.5, 1.0	N	A	P	
2		N	C	P	
3					
4		N	A	P	
5		N	A	P	
5		N	A	P	
6		N	A	P	
Core Catcher		F R N D S	— A C C R	— G P M M	* CC



LITHOLOGIC DESCRIPTION

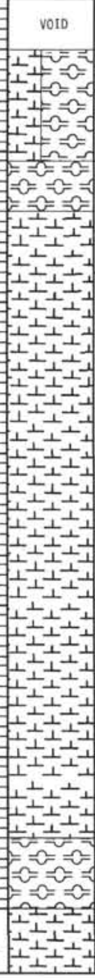
Light bluish gray (5B 7/1) SILICEOUS NANNO OOZE. A micro-diorite(?) pebble occurs at 85 cm Sec. 1. The core is soft with intense deformation (soupy) with a stiffening in Sec. 6. The core lithology in Secs 1, 2 and 3 grades into a light bluish gray (5B 7/1) DIATOM/RAD NANNO OOZE in Secs. 4, 5, and 6; and a DIATOM-RICH NANNO OOZE in the core catcher. Other colors noted with some mottling are greenish gray (5B 6/1) and bluish white (5B 9/1).

SS CC
N -70%
D -15%
R -10%
S - 5%
DE - 1%
(augite, chlorite, biotite)

Explanatory notes in Chapter 1

Site 278 Hole Core 15 Cored Interval: 224.5-234.0 m

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
LATE MID MIOCENE TO LATE MIOCENE	R. pseudoumbilica	N	P	P	1	0.5 / 1.0	VOID		
		N	—	—	2				20 *
		N	—	—	3				
		N	F	P	4				
		N	P	P	5				
		N	C	P	6				
		F R N D S	— A A C R	— G P M P	Core Catcher				* CC



LITHOLOGIC DESCRIPTION

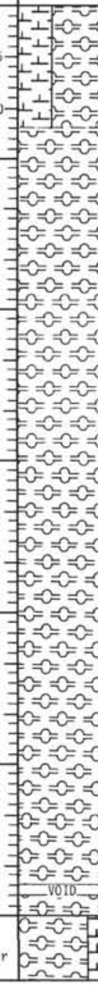
The core is greenish gray (5GY 6/1) RAD/DIATOM NANNO OOZE (Sec. 1) grading into a light olive gray (5Y 6/1) NANNO-BEARING SILICEOUS OOZE (SS 2-20) in Sec. 2 (10-60 cm), and to a pale brown (10YR 6/3), very firm, DIATOM-BEARING NANNO OOZE in Sec. 2 (60 cm) to Sec. 6 (80 cm). Grayish brown (10YR 6/2) colorations and MN specks occur in Secs. 3 and 4. The core is firm in Sec. 6 (80-150 cm) consists of light gray (10YR 7/1) NANNO-BEARING SILICEOUS OOZE and the core catcher is a DIATOM-BEARING NANNO OOZE (SS CC).

SS 2-20		SS CC	
DE	- 3%	DE	-TR
N	-10%	N	-80%
D	-40%	D	-10%
R	-30%	R	- 7%
S	-17%	S	- 3%

X-ray 3-60 (Bulk)
Quar - P
K-Fe - P
Plag - P
Kaol - TR
Mica - A
Chlo - TR
Mont - P

Site 278 Hole Core 16 Cored Interval: 234.0-243.5 m

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
EARLY MID MIOCENE	C. neogammation	N	C	P	1	0.5 / 1.0			
		N	—	—					
		N	A	P	2				
		N	C	P	3				
		N	R	P	4				
		N			5				
		N	C	P	6				
		F	VR	M			VOID		
		N D S	C R	P P	Core Catcher				* CC



LITHOLOGIC DESCRIPTION

Core consists of a yellowish gray (5Y 8/1) very stiff, SILICEOUS NANNO OOZE SILICEOUS OOZE to a NANNO-BEARING SILICEOUS OOZE. Deformation is intense to slight, with intense areas showing color mottling. Color occurrences throughout core include greenish gray (5GY 6/1), light gray (5Y 7/1) and yellow gray (5Y 8/1). The core catcher consists of a light bluish gray (5B 7/1) NANNO-RICH SILICEOUS OOZE.

SS CC	
DE	- 2%
VG	-TR
N	-20%
D	-40%
R	-16%
S	-22%

X-ray 6-36 (Bulk)
Quar - P
K-Fe - P
Plag - P
Kaol - TR
Mica - A
Chlo - TR
Mont - P

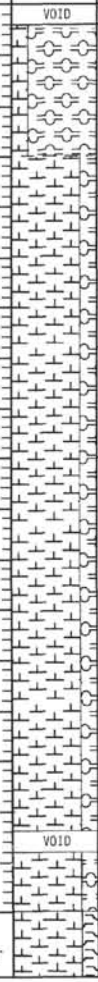
Grain Size 6-33 (0.2, 24.8, 74.9)

Carbon Carbonate 6-30 (0.7, 0.1, 5)

Explanatory notes in Chapter 1

Site 278 Hole Core 17 Cored Interval: 243.5-253.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	LITHO. SAMPLE
EARLY MID MIOCENE	G. (T.) conica; C. neogammation				1 (VOID at top)	
		N	R	P	2	32 *
					3	
		N	F	P	4	
		N			5	
		N	C	P	6 (VOID)	
		F	VR	M		
		N	C	P	Core Catcher	* CC
		D	R	P		
		S	—	—		



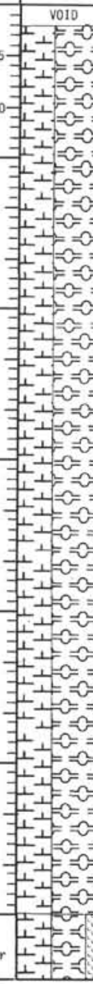
LITHOLOGIC DESCRIPTION

Light bluish gray (5B 7/1) NANNO-RICH SILICEOUS OOZE to a soft SILICEOUS-RICH NANNO OOZE starting in Sec. 2 of a light olive gray (5Y 6/1) color. The core catcher is a stiff DIATOM-RICH NANNO OOZE. Other colors noted are: grayish green (5GY 6/1) in Sec. 3, light gray (10YR 7/2) and greenish gray (5GY 6/1) in Secs. 5 and 6. Intense mottling noted especially in Secs. 5 and 6. Core is soft to stiff in lower portions.

SS 2-32		SS CC	
D	- 1%	DE	- 1%
N	-80%	VG	-TR
D	-10%	N	-70%
R	- 3%	D	-20%
S	- 6%	R	- 4%
		S	- 2%

Site 278 Hole Core 18 Cored Interval: 253.0-262.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	LITHO. SAMPLE
EARLY MID MIOCENE	G. (T.) conica; C. neogammation	N	C	P	1 (VOID at top)	
		N	C	P	2	
		N	C	P	3	
		N	C	P	4	
		N	C	P	5	
		N	C	P	6	
		F	VR	M		
		N	C	P	Core Catcher	* CC
		D	R	P		
		S	R	P		



LITHOLOGIC DESCRIPTION

Yellowish gray (5Y 8/1), with light olive gray streaks and mottles, SILICEOUS NANNO OOZE with a SPONGE SPICULE-RICH NANNO DIATOM OOZE in core catcher. Other colors noted were: light gray (5Y 6/1) and olive gray (10YR 7/1); some intense mottling noted; core is stiff in Sec. 1 to soft with drilling breccia of rounded clasts of clay in Secs. 4-6.

SS CC
DE - 1%
N -40%
D -40%
R - 3%
S -15%

X-ray 6-70 (Bulk)
Calc - A
Quar - P
K-Fe - P
Plag - P
Kaol - TR
Mica - P
Chlo - TR
Mont - TR

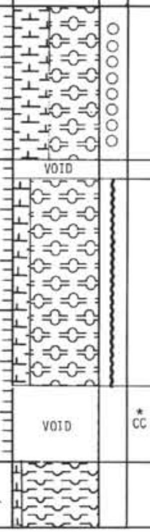
Grain Size 6-67 (1.7, 29.1, 69.2)

Carbon Carbonate 6-65 (3.7, 0.1, 30)

Explanatory notes in Chapter 1

Site 278 Hole Core 19 Cored Interval: 262.5-272.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
EARLY MID MIOCENE	G. (T.) conica; C. neogammation	N	F	P	1	0.5, 1.0			
							VOID		
		N	F	P	2				
		N	C	P					
		N	F	M	3		VOID		* CC
		F	VR	M	Core Catcher				
		N	C	M					
		D	C	M					
		S	–	–					



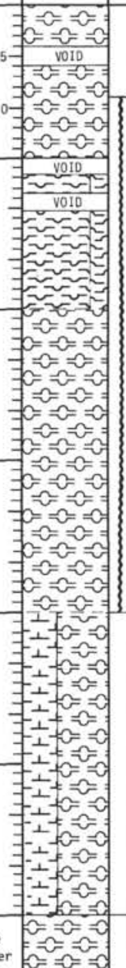
LITHOLOGIC DESCRIPTION

Light gray (5Y 7/2) SILICEOUS NANNO OOZE, a light bluish gray (5B 7/1) NANNO-RICH SILICEOUS OOZE and a NANNO-RICH DIATOM OOZE in the core catcher.

SS CC	
DE	- 1%
N	-20%
D	-60%
R	- 8%
S	-11%

Site 278 Hole Core 20 Cored Interval: 272-281.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
EARLY MID MIOCENE	G. (T.) conica; C. neogammation	N	C	P	1	0.5, 1.0	VOID		* 15
					2		VOID; VOID		
		N	–	–	3				117 *
					4				
		N	A	P	5				66 *; 81 *
		N	A	P	6				
		N	C	P					
		F	VR	M	Core Catcher				* CC
		N	C	P					
		D	C	M					
		S	—	—					



LITHOLOGIC DESCRIPTION

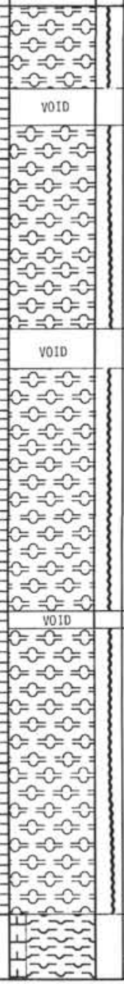
Core consists of dusky yellow green (5GY 5/2) DETRITAL-BEARING RAD DIATOM OOZE (Secs. 1 and 2); light bluish gray (5B 7/1) RAD-RICH DIATOM OOZE (Sec. 2); a DETRITAL STIFF SAND-BEARING SILICEOUS OOZE (with a variety of detrital minerals - brown stained tests) brecciated but semilithified in Sec. 3. Other lithologies are: NANNO-BEARING RAD DIATOM OOZE (Sec. 4), NANNO-BEARING DIATOM OOZE (Sec. 5) grading to a SILICEOUS NANNO OOZE (SS 5-81) and a NANNO-BEARING SILICEOUS OOZE in core catcher (SS CC).

SS 1-15		SS 3-117		SS 5-66		SS 5-81		SS CC	
HM	-Tr	D	-50%	M	- 2%	N	-65%	DE	- 1%
(pyroxene,		R	-20%	N	-10%	D	-25%	N	-10%
chlorite)		S	-20%	D	-60%	R	- 5%	D	-30%
Fd (Plag)	-Tr	DE	-10%	R	-10%	S	- 5%	R	- 8%
Mn	-Tr	(plag.,		S	-17%			S	-50%
Q	-Tr	biotite)							

Explanatory notes in Chapter 1

Site 278 Hole Core 21 Cored Interval: 281.5-291.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
EARLY MID MIOCENE	G. (G.) woodi / C. neogammation				1	0.5 – 1.0	VOID		
		N	A	P	2				
		N	A	M	3		VOID		
		N	A	P	4				
		N	A	P	5		VOID		
		N	A	P	6				
		F N D S	R A C —	M P M —	Core Catcher				* CC



LITHOLOGIC DESCRIPTION

Light bluish gray (5B 7/1) NANNO-BEARING SILICEOUS OOZE with the core catcher consisting of a NANNO-RICH DIATOM OOZE (SS CC). Deformation is intense with drilling breccia (Sec. 4) to an absence of deformation. Soft to stiff with a hard layer in Sec. 2 (60-80 cm). A faint mottling is noted in Sec. 6 as well as an olive gray (5Y 6/2) coloration.

SS CC
N -30%
D -50%
R -10%
S -10%

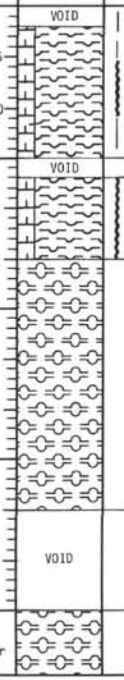
X-ray 6-54 (Bulk)
Calc - A
Quar - P
K-Fe - P
Plag - P
Mica - P
Chlo - TR
Mont - TR

Grain Size 6-51 (0.3, 25.1, 74.6)

Carbon Carbonate 6-57 (4.3, 0.1, 35)

Site 278 Hole Core 22 Cored Interval: 291.0-300.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
EARLY MID MIOCENE	G. (G.) woodi / C. neogammation	N	A	M	1	0.5 – 1.0	VOID		
		N	R	P	2		VOID		
					3				71 *
		N	C	M	4		VOID		
		F N D S	VR C R R	M M P P	Core Catcher				* CC



LITHOLOGIC DESCRIPTION

Light bluish gray (5B 7/1) NANNO-RICH DIATOM OOZE Sec. 1 to 100 cm in Sec. 2; SILICEOUS OOZE (SS 3-71) Sec. 2 (100 cm) to Sec. 4 (50 cm) and NANNO-BEARING SILICEOUS OOZE in core catcher (SS CC). Core is soft to soupy in Secs. 1 and 2 to stiff in Sec. 2 (50 cm) to Sec. 4 (50 cm). Slight mottling and greenish gray (5G 6/1) colors noted in Secs. 2 and 3.

SS 3-71		SS CC	
DE	- 2%	CM	-TR
HM	- 1%	N	-10%
N	-TR	D	-40%
D	-40%	R	-30%
R	-35%	S	-20%
S	-23%		

Explanatory notes in Chapter 1

Site 278 Hole Core 23 Cored Interval: 300.5-310.0 m

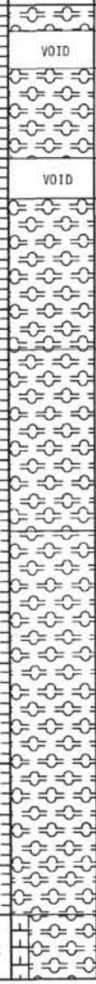
AGE: EARLY MID MIOCENE

ZONE: G. (G.) woodi; C. neogammation

SECTION	FOSSIL	ABUND.	PRES.
1	N	C	P
1	N	C	P
2	N	F	P
2	N	C	P
3	N	F	P
3	N	R	P
4	N	F	P
4	N	R	P
5	N	C	P
5	N	F	P
6	N	C	P
6	N	C	P
Core Catcher	F	VR	M
Core Catcher	N	C	M
Core Catcher	D	C	M
Core Catcher	S	R	P

METERS: 0.5, 1.0

LITHOLOGY



DEFORMATION / LITHO. SAMPLE: * CC

LITHOLOGIC DESCRIPTION

Light bluish gray (5B 7/1) NANNO-BEARING SILICEOUS OOZE, being NANNO-RICH in core catcher. Core is generally firm, with slight mottling. Greenish gray (5G 6/1) colors in Sec. 3 and MN flecks noted in Sec. 4.

SS CC

DE	- 1%
N	-35%
D	-40%
R	-10%
S	-15%

Site 278 Hole Core 24 Cored Interval: 310.0-319.5 m

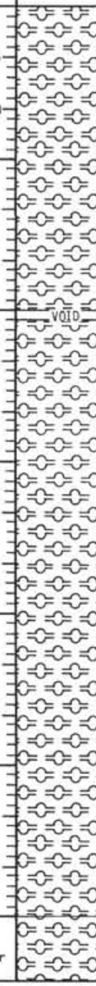
AGE: EARLY MID MIOCENE

ZONE: C. neogammation

SECTION	FOSSIL	ABUND.	PRES.
1	N	C	P
1	N	C	P
2	N	C	P
2	N	A	P
3	N	C	P
3	N	A	P
4	N	C	P
4	N	A	M
5	N	C	P
5	N	F	P
6	N	R	P
6	N	F	P
Core Catcher	F	—	—
Core Catcher	N	R	P
Core Catcher	D	C	M
Core Catcher	S	R	P

METERS: 0.5, 1.0

LITHOLOGY



DEFORMATION / LITHO. SAMPLE: * CC

LITHOLOGIC DESCRIPTION

Light blue gray (5B 7/1) SILICEOUS OOZE (SS CC). Some dark mottles and streaks noted including MN streaks in Sec. 3. Greenish gray (5G 6/1) colors noted in Sec. 5. Core is soft to stiff, and semilithified.

SS CC

DE	- 1%
N	- 2%
D	-70%
R	-10%
S	-15%
Mi	-TR

(muscovite)

X-ray 5-54 (Bulk)

Calc	- A
Quar	- TR
K-Fe	- TR
Plag	- TR
Kaol	- TR
Mica	- P
Chlo	- TR
Mont	- TR

Grain Size 5-51 (0.4, 32.7, 66.9)

Carbon Carbonate 5-58 (4.2, 0.1, 34)

Explanatory notes in Chapter 1

Site 278 Hole Core 25 Cored Interval: 319.5-329.0 m

Age: EARLY MIOCENE

Zone: C. neogammation; G. (G.) woodi; D. deflandrie

SECTION	FOSSIL	ABUND.	PRES.
1 (0.5: VOID)	N	C	P
1	N	F	P
2	N	F	P
2	N	C	P
3	N	F	P
3	N	R	P
4	N	C	P
4	N	F	P
5	N	R	P
5	N	F	P
Core Catcher	F	VR	M
	N	F	P
	D	C	P
	S	R	P

LITHO. SAMPLE: *CC

LITHOLOGIC DESCRIPTION

Greenish gray (5G 6/1) SILICEOUS OOZE, with a RAD-RICH DIATOM OOZE in core catcher (SS CC). Intense MN flecks noted in Sec. 2 and some in Sec. 3. Core is very stiff to semilithified, with faint mottling, streaking and slight or no deformation. Sec. 4 shows a light bluish gray (5B 7/4) coloration.

SS CC

CM	- TR
N	-10%
D	-63%
R	-15%
S	-10%
Si	- 2%

Site 278 Hole Core 26 Cored Interval: 329.0-338.5 m

Age: EARLY MIOCENE

Zone: G. (G.) woodi; D. deflandrie

SECTION	FOSSIL	ABUND.	PRES.
1 (VOID)			
2 (VOID)	N	C	P
2	N	F	P
3	N	C	P
3	N	C	P
4	N	F	P
4	N	R	P
5	N	C	P
5	N	F	P
6	N	C	P
6	N	R	P
Core Catcher	F	VR	M
	N	C	P
	D	C	P
	S	R	P

LITHO. SAMPLE: *CC

LITHOLOGIC DESCRIPTION

Light bluish gray (5B 7/1) SILICEOUS OOZE to a NANNO AND RAD-BEARING DIATOM OOZE Sec. 5 (70 cm) and Sec. 6 and a RAD NANNO-RICH DIATOM OOZE in core catcher. Greenish gray (5G 6/1) coloration noted in Sec. 3. Core deformation is drilling breccia to moderate (Sec. 4) or no deformation Sec. 5 (70 cm) and Sec. 6.

SS CC

N	-20%
D	-53%
R	-15%
S	-10%
G	- 1%

Explanatory notes in Chapter 1

Site 278 Hole Core 27 Cored Interval: 338.5-348.0 m

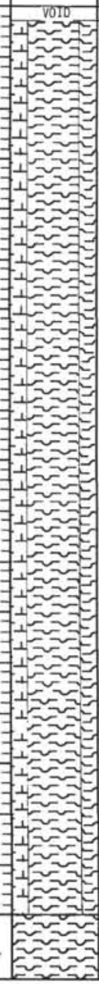
AGE: EARLY MIOCENE

ZONE: D. deflandrei

FOSSIL	ABUND.	PRES.	SECTION
			1
			2
N	R	P	3
N	R	P	4
N	—	—	4
N	—	—	5
N	—	—	6
F	—	—	Core Catcher
N	R	P	Core Catcher
D	C	P	Core Catcher
S	R	P	Core Catcher

METERS: 0.5, 1.0

LITHOLOGY



DEFORMATION | LITHO. SAMPLE: *CC

LITHOLOGIC DESCRIPTION

Light greenish gray (5G 6/1) to medium bluish gray (5B 5/1) RAD AND NANNO-RICH DIATOM OOZE to a DIATOM OOZE in core catcher. Deformation: drilling breccia to intense. Core is stiff in Secs. 4, 5, and 6. Mottling and a light bluish gray (5B 7/1) color noted in Sec. 5.

SS CC
Q - 1%
M - 2%
D -80%
R - 7%
S - 5%
SF - 5%
HM -TR
(chlorite)

Site 278 Hole Core 28 Cored Interval: 348.0-357.5 m

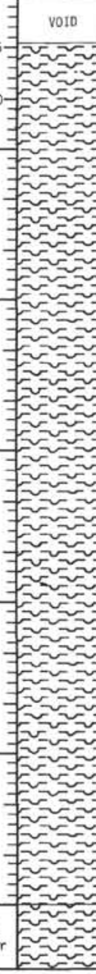
AGE: EARLY MIOCENE

ZONE: D. deflandrei

FOSSIL	ABUND.	PRES.	SECTION
N	R	P	1
N	R	P	1
N	—	—	2
N	—	—	2
N	—	—	3
N	R	P	3
N	—	—	4
N	—	—	4
N	—	—	5
N	—	—	5
N	—	—	6
N	R	P	6
F	—	—	Core Catcher
N	R	P	Core Catcher
D	C	P	Core Catcher
S	R	P	Core Catcher

METERS: 0.5, 1.0

LITHOLOGY



DEFORMATION | LITHO. SAMPLE: *CC

LITHOLOGIC DESCRIPTION

Greenish gray (5G 6/1) RAD-BEARING DIATOM OOZE (SS CC). The core is stiff in Secs. 1, 2, and 5 to semilithified in Secs. 3, 5 and 6. Slight mottle is noticed: layers and streaks of MN occur in Secs. 3 and 6. Deformation is slight, with no noticeable deformation in Secs. 3 and 4.

SS CC
Q -TR
Mi -TR
D -81%
R -10%
S - 5%
SF - 3%
RF -TR

X-ray 2-42 (Bulk)
Quar - P
K-Fe - P
Plag - P
Mica - A
Chlo - TR
Mont - P

Grain Size 2-40 (0.4, 20.8, 78.9)

Carbon Carbonate 2-39 (0.8, 0.1, 6)

Explanatory notes in Chapter 1

Site 278 Hole Core 29 Cored Interval: 357.5-367.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	LITHO. SAMPLE
EARLY MIOCENE	D. deflandrei	N	—	—	1	0.5, 1.0	VOID	
		N	R	P			VOID	
							VOID	
		N	—	—	2			
		N	—	—				
		N	—	—	3			
		N	R	P				
		N	—	—				
					4		VOID	
		N	—	—				
					5		VOID	
							VOID	
		N	—	—	6			
		N	R	P				
		F	—	—				
		N D S	R C F	P M M	Core Catcher			* CC

LITHOLOGIC DESCRIPTION

Light bluish gray (5B 7/1) RAD DIATOM OOZE with a RAD-RICH DIATOM OOZE in core catcher. A moderate mottling is noticed in Sec. 2 (20-80 cm) and Sec. 3 has greenish gray (5G 6/1) colors. Deformation is intense, soupy to moderate, with core becoming stiff to semilithified in Sec. 6.

SS CC
Q -TR
Mi -TR
N -TR
D -70%
R -20%
S - 8%

Site 278 Hole Core 30 Cored Interval: 376.5-386.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	LITHO. SAMPLE
EARLY MIOCENE	D. deflandrei	N	C	P	1	0.5, 1.0		
		N	C	P				
		N	C	P	2			
		N	C	P				
		F	—	—				
		N D S	C C F	P M M	Core Catcher			* CC

LITHOLOGIC DESCRIPTION

Light bluish gray (5B 7/1) semilithified to soft RAD-RICH DIATOM OOZE. Core catcher is a DIATOM-RICH NANNO OOZE.

SS CC
DE -TR
M -TR
N -60%
D -25%
R - 5%
S - 5%

Site 278 Hole Core 31 Cored Interval: 395.5-405.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	LITHO. SAMPLE
MID TO LATE OLIGOCENE	G. (G.) woodi / R. bisecta	N	A	P	1	0.5, 1.0	VOID	
		N	C	P				
		N	A	P	2			
		N	A	P				
		N	A	P	3			
		N	A	M				
		F N D S	R A R R	M M P P	Core Catcher			* CC

LITHOLOGIC DESCRIPTION

Light gray (10YR 7/1) and (10YR 7/2) SPONGE SPICULE RAD-BEARING NANNO-CHALK; lithified, broken by drilling into chunks: some MN staining, some green gray mottles, and color streaking.

SS CC
N -90%
D - 1%
R - 2%
S - 7%

X-ray 3-55 (Bulk)
Calc - M
Quar - TR
K-Fe - TR
Plag - TR
Kaol - TR
Mica - P
Chlo - TR
Mont - TR

Grain Size 3-51 (0.6, 36.9, 62.5)

Carbon Carbonate 3-54 (7.6, 0.1, 63)

Explanatory notes in Chapter 1

Site 278 Hole Core 32 Cored Interval: 405.0-414.5 m

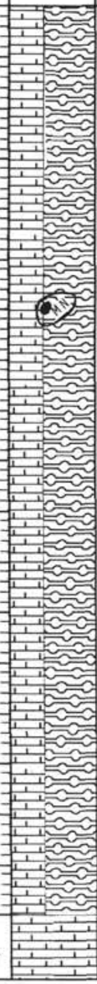
AGE: LATE OLIGOCENE

ZONE: G. (G.) woodi; R. bisecta

SECTION	FOSSIL	ABUND.	PRES.
1	N	A	P
1	N	A	P
2	N	A	P
3	N	A	P
3	N	A	P
4	N	A	P
5	N	A	P
5	N	A	P
6	N	A	P
Core Catcher	F / N / D / S	VR / A / R / —	M / P / M / —

METERS: 0.5, 1.0

LITHOLOGY



LITHO. SAMPLE: * CC

LITHOLOGIC DESCRIPTION

Light gray (10YR 7/1 to 7/2) SILICEOUS NANNO CHALK stiff-firm to semilithified (lithified) and no noticeable deformation; small stains of MN occur and a faint mottling is noticed with the gray colors and very pale brown (10YR 7/3); MN nodules, micronodules and some burrowing was noticed. The burrows include zoophycus type burrows. The core appears to have a massive bedding (non-stratified). The core catcher contains a RAD-BEARING NANNO CHALK.

SS CC
DE -TR
DR(?) -TR
N -95%
R - 5%
S -TR

Site 278 Hole Core 33 Cored Interval: 414.5-424.0 m

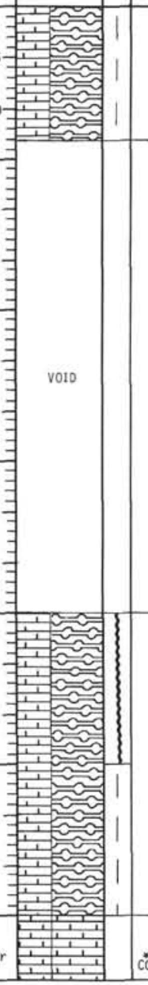
AGE: LATE OLIGOCENE

ZONE: G. (G.) woodi; R. bisecta

SECTION	FOSSIL	ABUND.	PRES.
1	N	A	P
1	N	A	P
5	N	A	P
5	N	A	P
6	N	A	P
6	N	A	P
Core Catcher	F / N / D / S	VR / A / R / —	M / P / P / —

METERS: 0.5, 1.0

LITHOLOGY



LITHO. SAMPLE: * CC

LITHOLOGIC DESCRIPTION

Light gray (10YR 7/2) SILICEOUS NANNO CHALK with MN streaks. The core is very stiff to semilithified, with drilling breccia in Sec. 4. Color in Sec. 6 is a very pale brown (10YR 7/3).

SS CC
N -80%
MN - 1%
F - 2%
R - 5%
S -10%

Explanatory notes in Chapter 1

Site 278 Hole Core 34 Cored Interval: 424.0-429.0 m

AGE: MID OLIGOCENE

ZONE: G. (S.) angiporoides angiporoides; R. bisecta

FOSSIL	ABUND.	PRES.
N	A	P
N	A	M
N	A	P
N	A	M
N	A	P
N	A	P
F	C	P-M
N	A	P

SECTION: 1, 2, 3, Core Catcher

LITHOLOGY: VOID (Sec. 1); VOID (Sec. 2); VOID (Sec. 3)

LITHOLOGIC DESCRIPTION

Very pale brown (10YR 7/3) NANNO CHALK and light gray (10YR 7/1) SILICEOUS NANNO CHALK: deformation is intense to a drilling breccia in Sec. 3. The contact to a PLAGIOCLASE PORPHYRITIC BASALT olive black (5Y 2/1) occurs in Sec. 3 (115 cm). The basalt has black glass rinds (RI 1.598 480/ °SiO_2 of palagonite. Micritic limestone inclusions are light gray (10YR 7/2), with white rare calcite filled amygdules 0.5 mm.

X-ray 3-13 (Bulk)
Calc - M
Dolo - TR
Quar - TR
K-Fe - TR
Plag - TR
Kaol - TR
Mica - P
Chlo - TR
Mont - P

Grain Size 3-11 (5.9, 43.4, 50.7)

Carbon Carbonate 3-10 (6.8, 0.0, 57)

Site 278 Hole Core 35 Cored Interval: 429.0-438.5 m

SECTION: 1, 2, 3, Core Catcher

LITHOLOGIC DESCRIPTION

PLAGIOCLASE PORPHYRITIC BASALT olive black (5Y 2/1) with black palagonite rinds, inclusions of micritic limestone, calcite amygdules and veins, and vesicules. Rock is altered olivine pillow basalt. Feldspar is laboradorite. Some material has been lost between segments so there is no lithologic continuity in core. Basalt has 15% plagioclase euhedra ($\bar{x}$ 2-3 mm), feldspar laths, acicular pyroxene? with iddingsite after olivine and abundant palagonite. The micrite contains forams, is 2 cm thick and is bounded on either side by glass. The micrite believed to be preserved in inter-pillow area. There is no evidence of alteration or baking however. Glass is colorless, contains fresh labradorite phenocrysts and laths and olivine euhedra. Micrite may have been a NANNO OOZE 20 segments occur in Sec. 1, 12 segments in Sec. 2, and in core catcher 9 pieces of basalt were found. 3-5 mm fragments, without glass as described above.

Site 278 Hole A Core 1 Cored Interval: 15.5-25.0 m

AGE: PLEISTOCENE

ZONE: C. pelagicus

FOSSIL	ABUND.	PRES.
F	A	G
R	A	G
N	F	P
D	C	M
S	R	M

SECTION: 1, Core Catcher

LITHOLOGY: VOID

LITHO. SAMPLE: 30 *

LITHOLOGIC DESCRIPTION

Light gray (N7) DETRITAL BEARING CALCAREOUS? DIATOM OOZE. Most of core loss was due to basalt chips caught in core catcher dogs.

SS 1-30
DE - 8%
M - 7%
F - 1%
N - 2%
D - 75%
R - 2%
S - 5%

(Detrital minerals include chlorite, hornblende and quartz)

Site 278 Hole A Core 2 Cored Interval: 25.0-34.5 m

AGE: PLEISTOCENE

ZONE: C. pelagicus

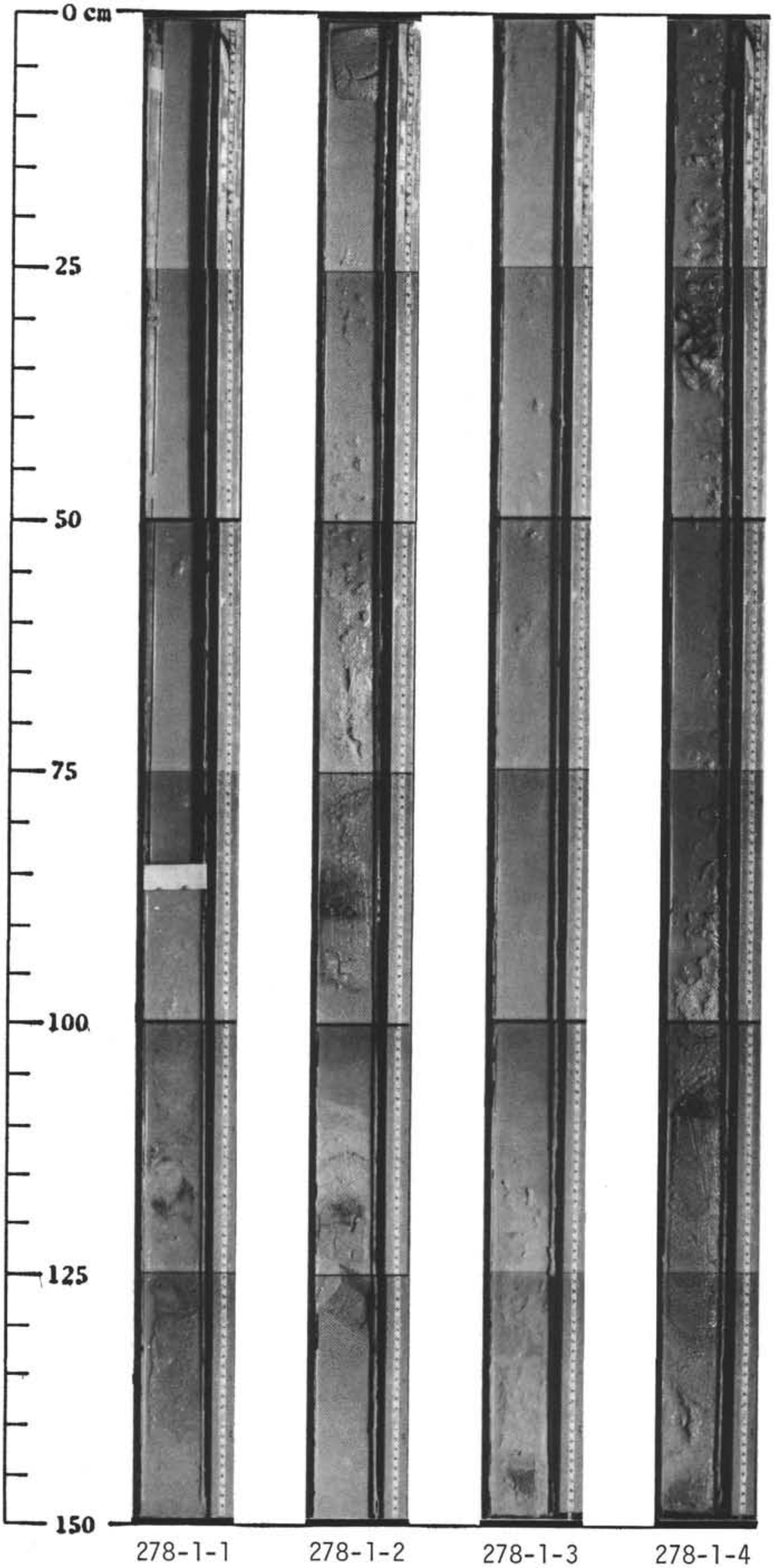
FOSSIL	ABUND.	PRES.
F	C	M
R	A	G
N	F	M
D	A	M
S	F	M

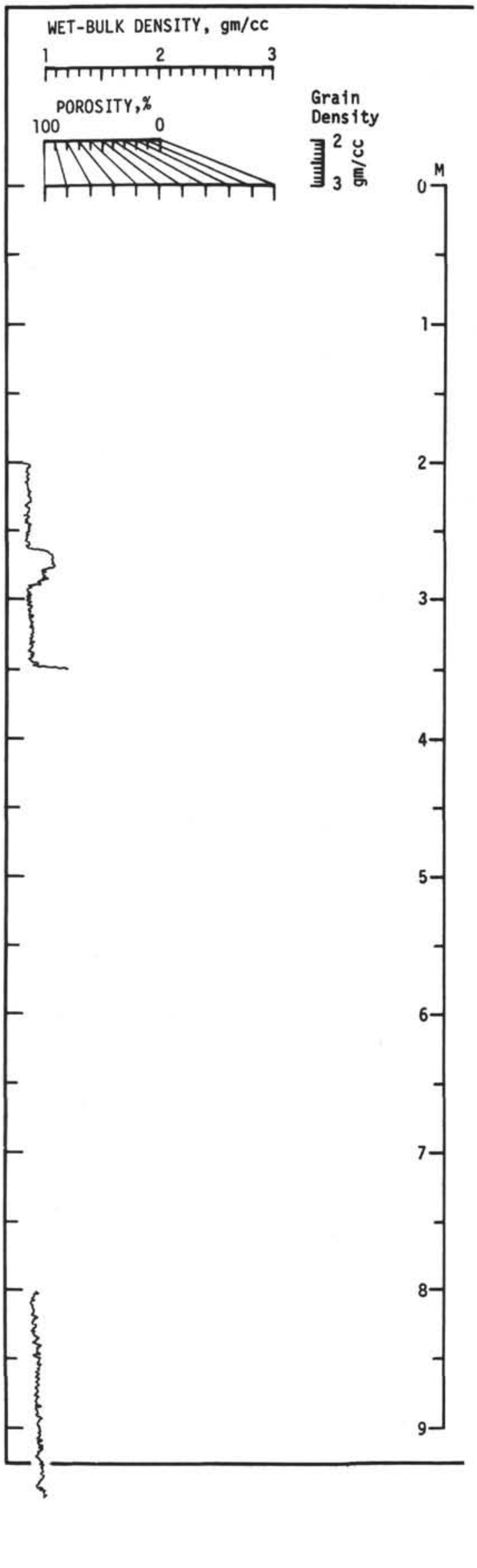
SECTION: 1, 2, 3, 4, Core Catcher

LITHOLOGIC DESCRIPTION

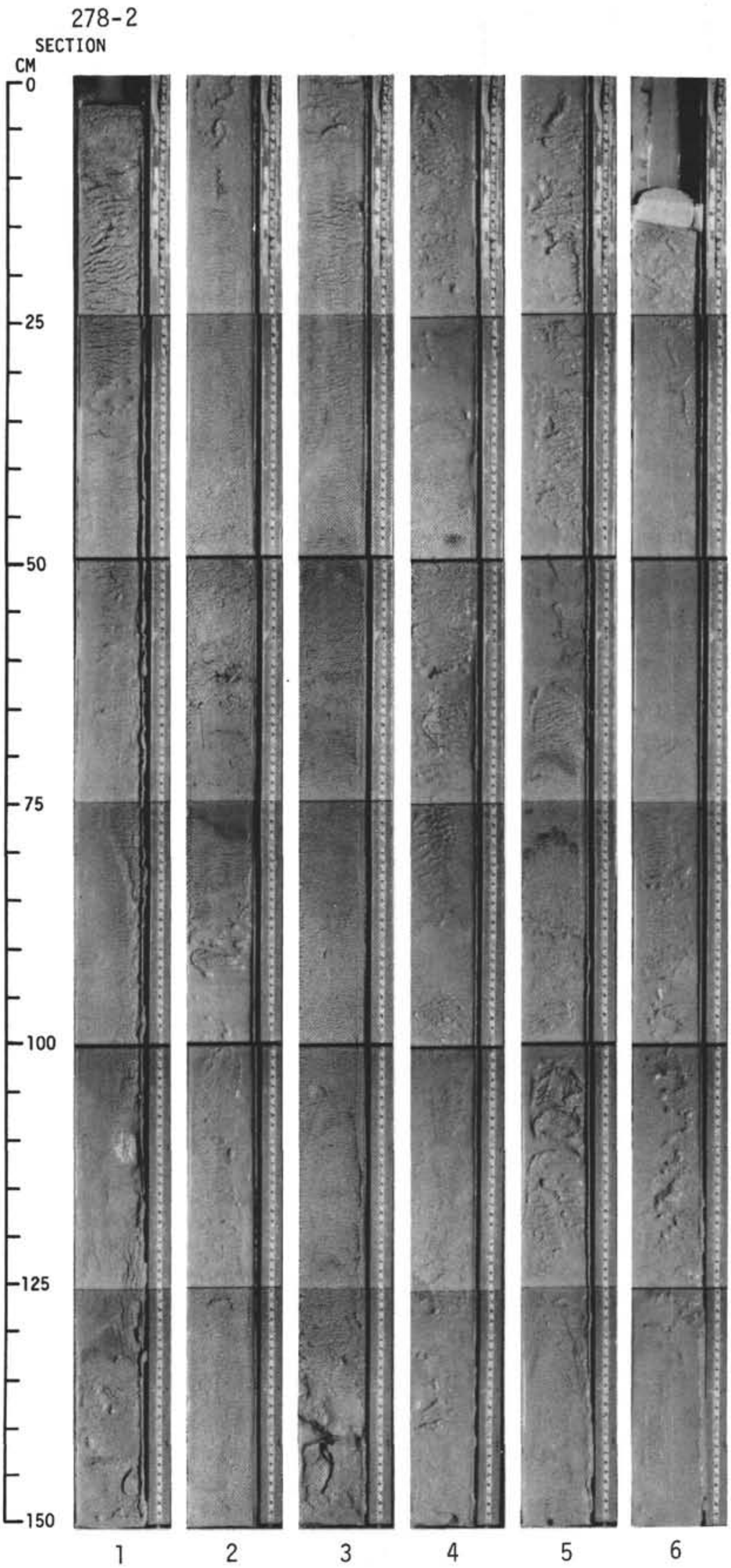
Medium Gray (N5), light gray (N7), DETRITAL BEARING CALCAREOUS DIATOM OOZE. Intense deformation shown by vertical color banding; some soft zones in Sec. 4 and dark greenish gray (5G 4/1) colors.

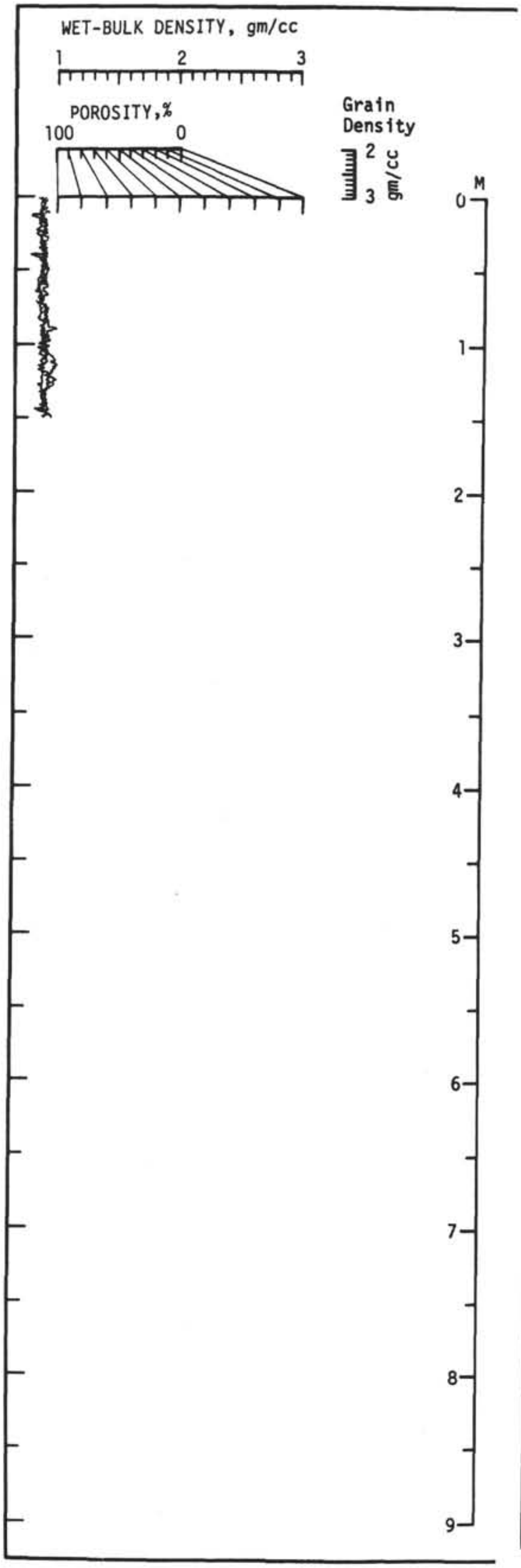
Explanatory notes in Chapter 1


0 cm
25
50
75
100
125
150
278-1-1
278-1-2
278-1-3
278-1-4


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

278-2


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


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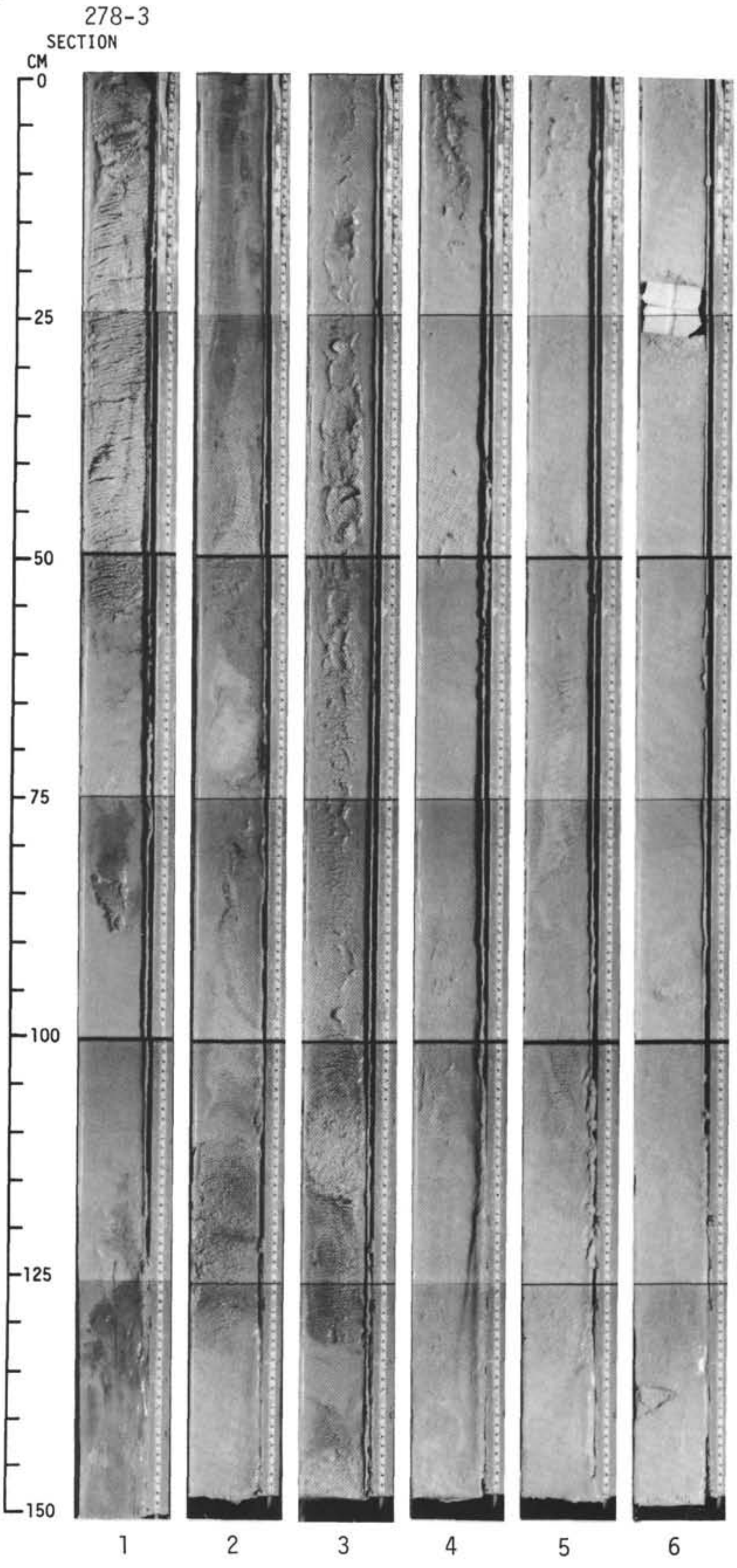
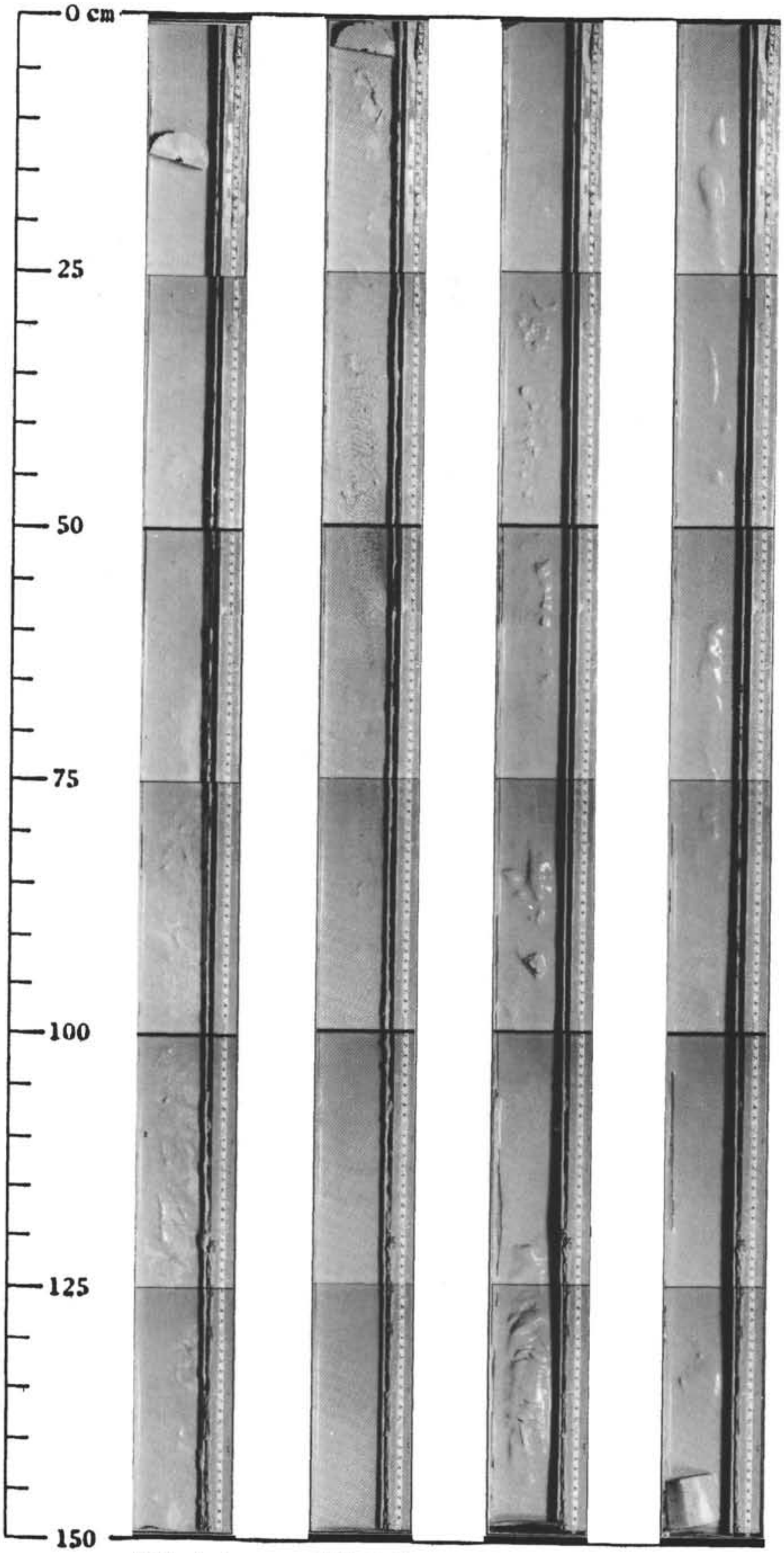
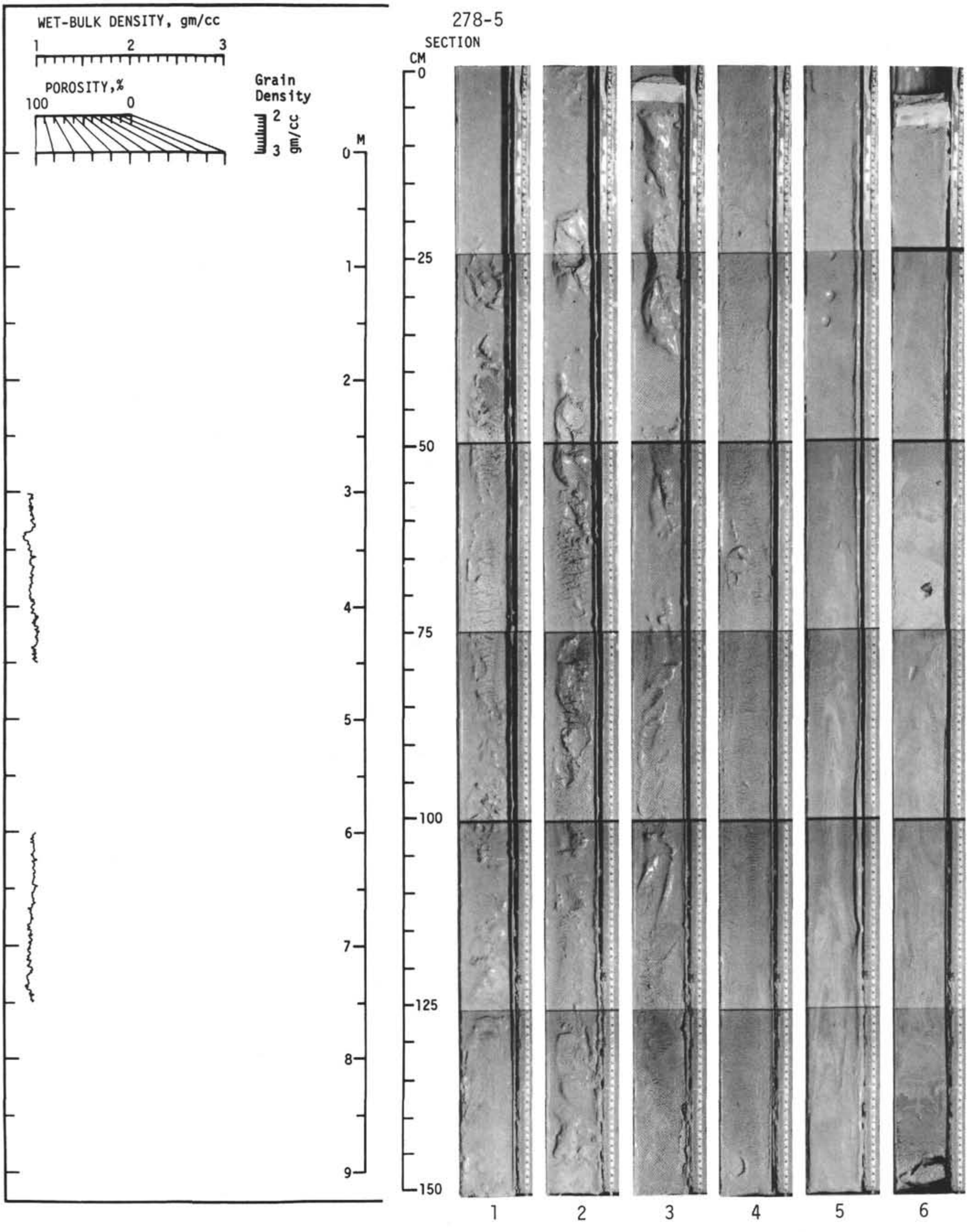
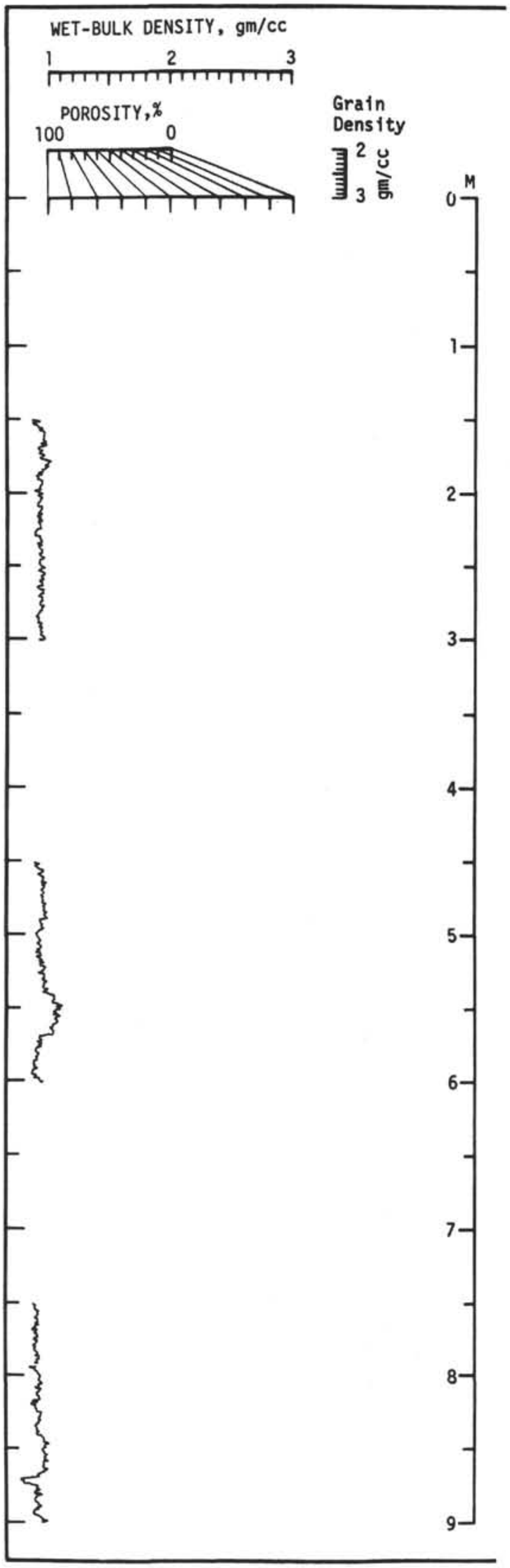
5
6
7
8
9


278-3
SECTION
CM
0
25
50
75
100
125
150
1 2 3 4 5 6



278-4-1 278-4-2 278-4-3 278-4-4


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
278-5
SECTION
CM
0
25
50
75
100
125
150
1
2
3
4
5
6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2
3
POROSITY,%
100
0
Grain Density
2
3
gm/cc
M
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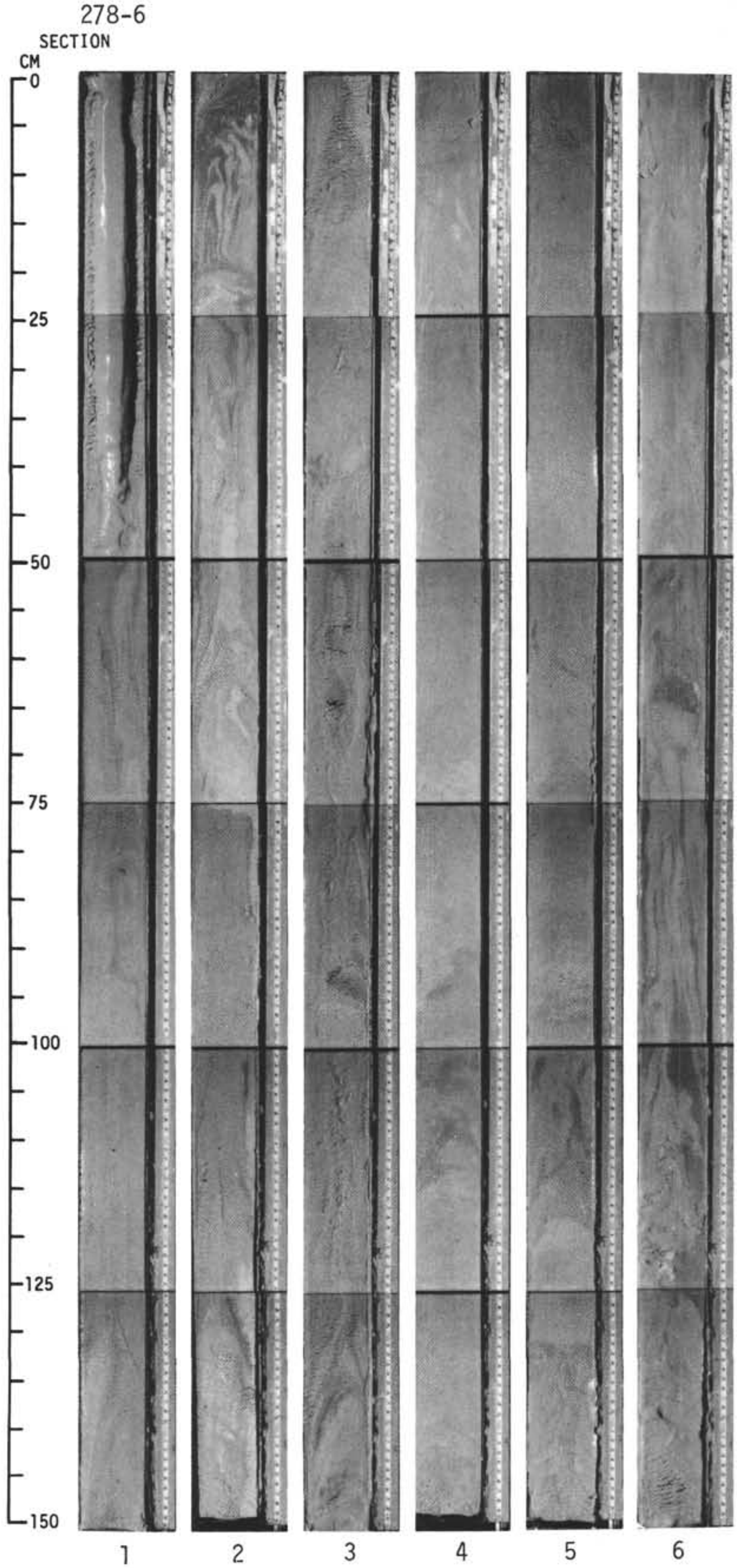
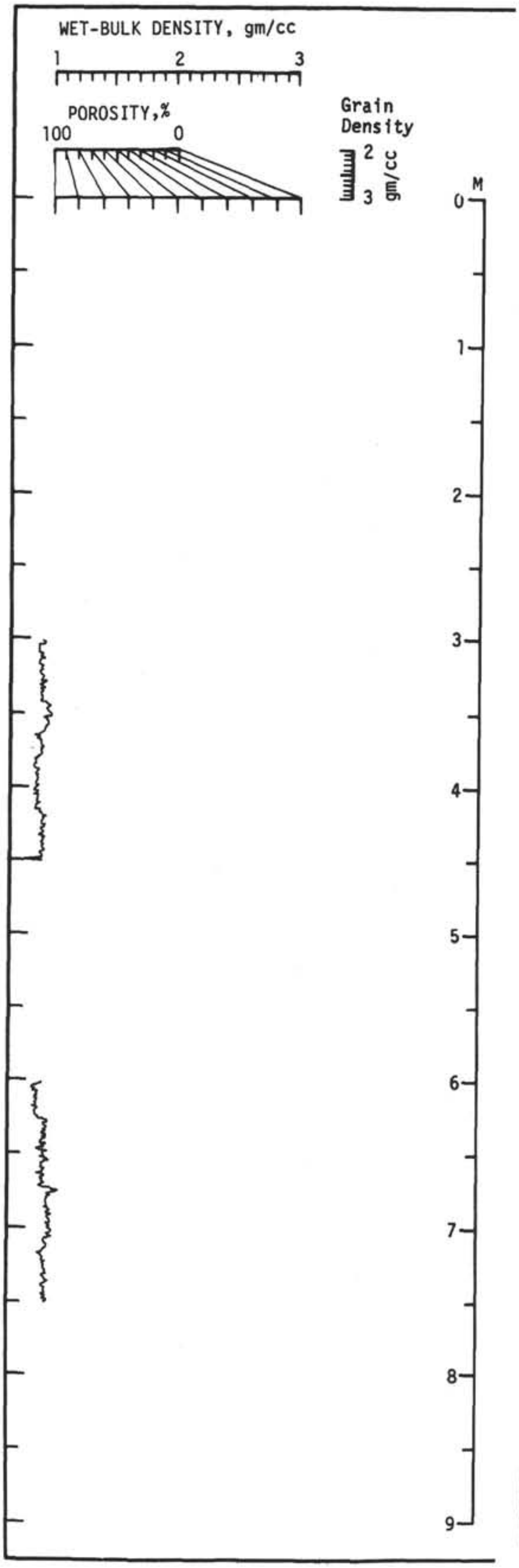
5
6
7
8
9


278-6
SECTION
CM
0
25
50
75
100
125
150
1
2
3
4
5
6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1
2
3
POROSITY,%
100
0
Grain Density
2
3
gm/cc
M
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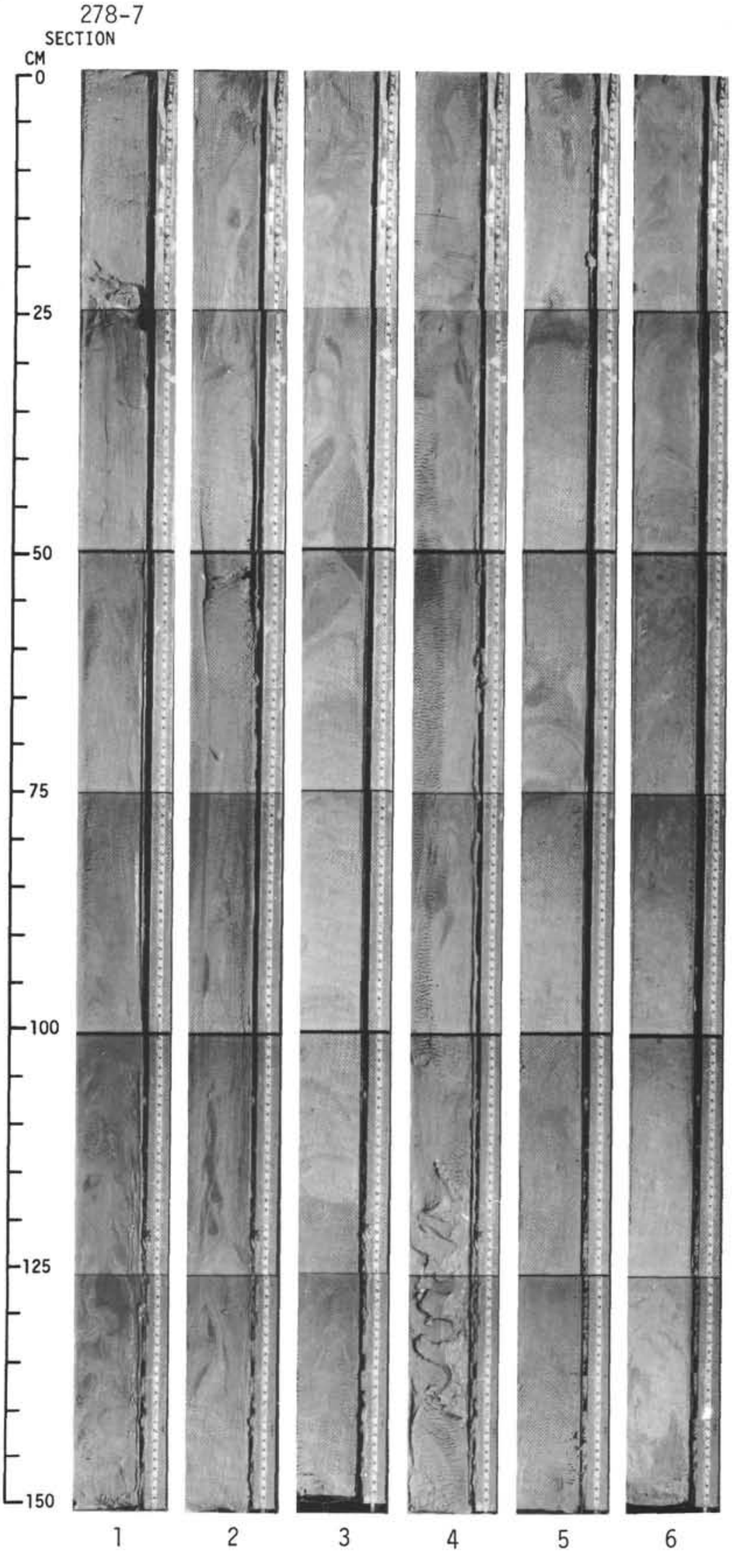
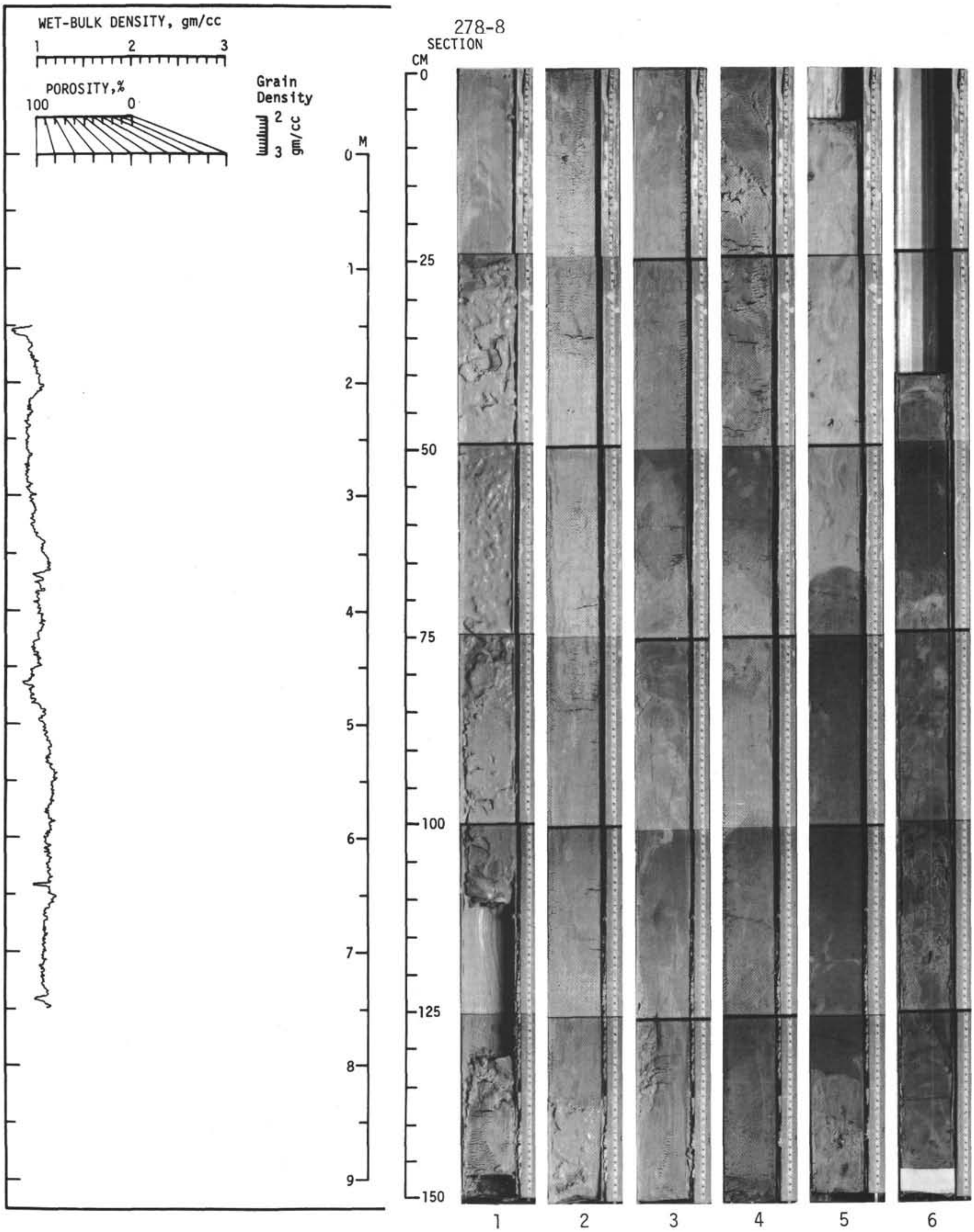
5
6
7
8
9


278-7
SECTION
CM
0
25
50
75
100
125
150
1
2
3
4
5
6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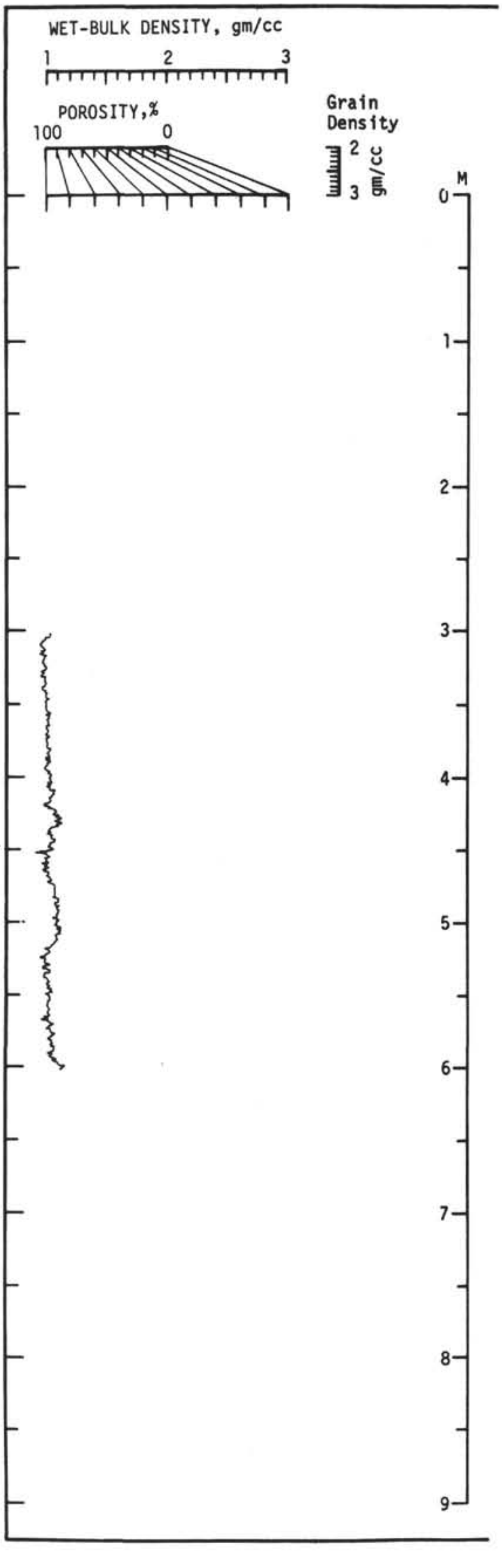
2
3
POROSITY,%
100
0
Grain Density
2
3
gm/cc
M
0
1
2
3
4
5
6
7
8
9
278-8
SECTION
CM
0
25
50
75
100
125
150
1
2
3
4
5
6


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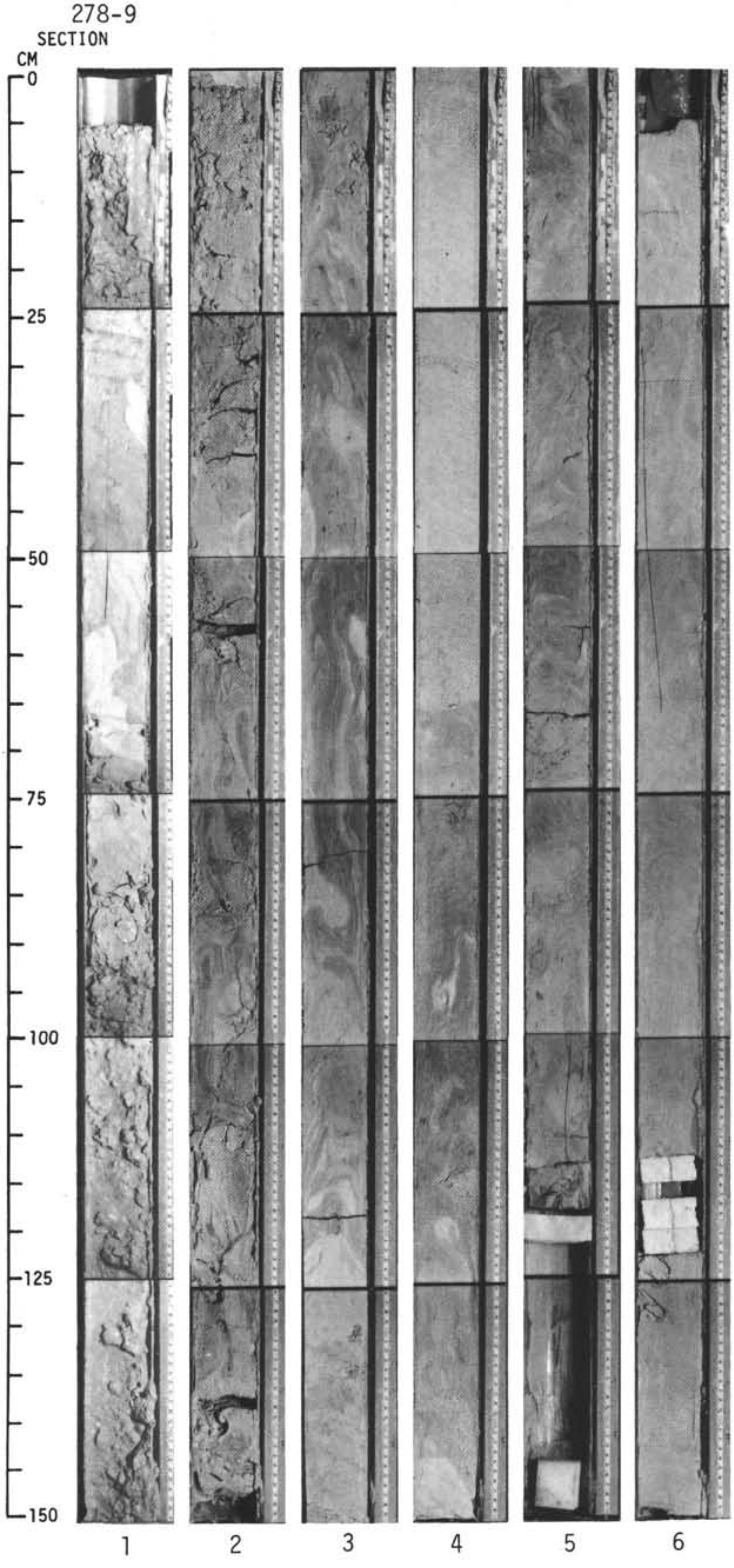
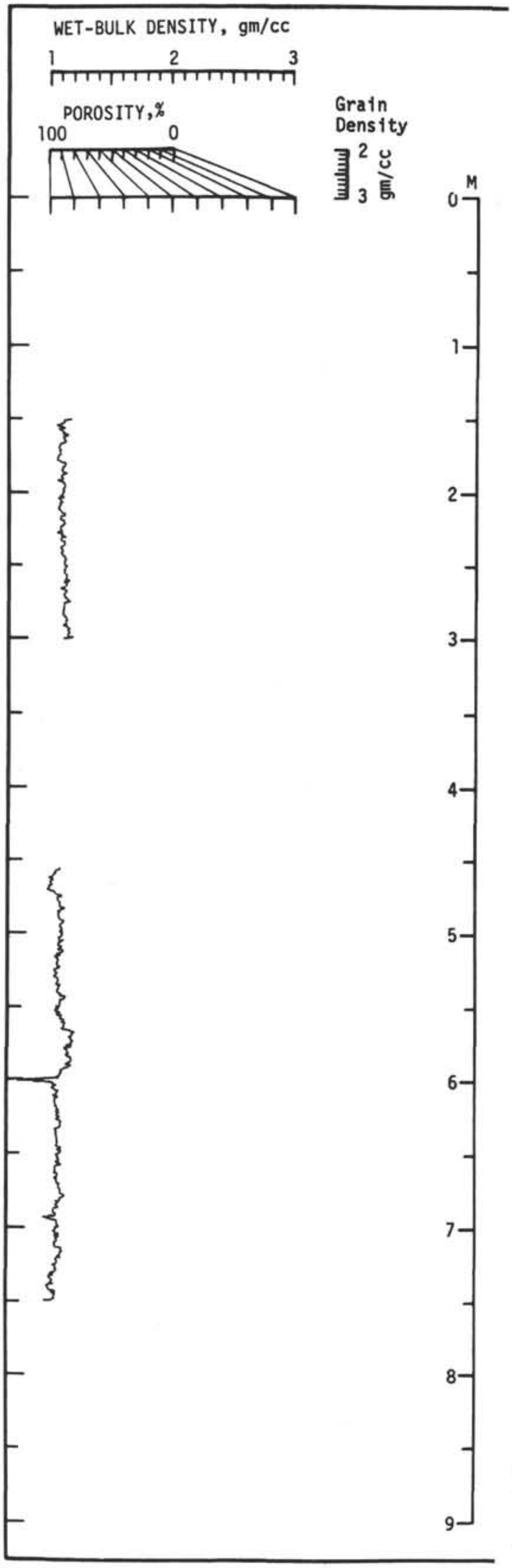
5
6
7
8
9


278-9
SECTION
CM
0
25
50
75
100
125
150
1
2
3
4
5
6


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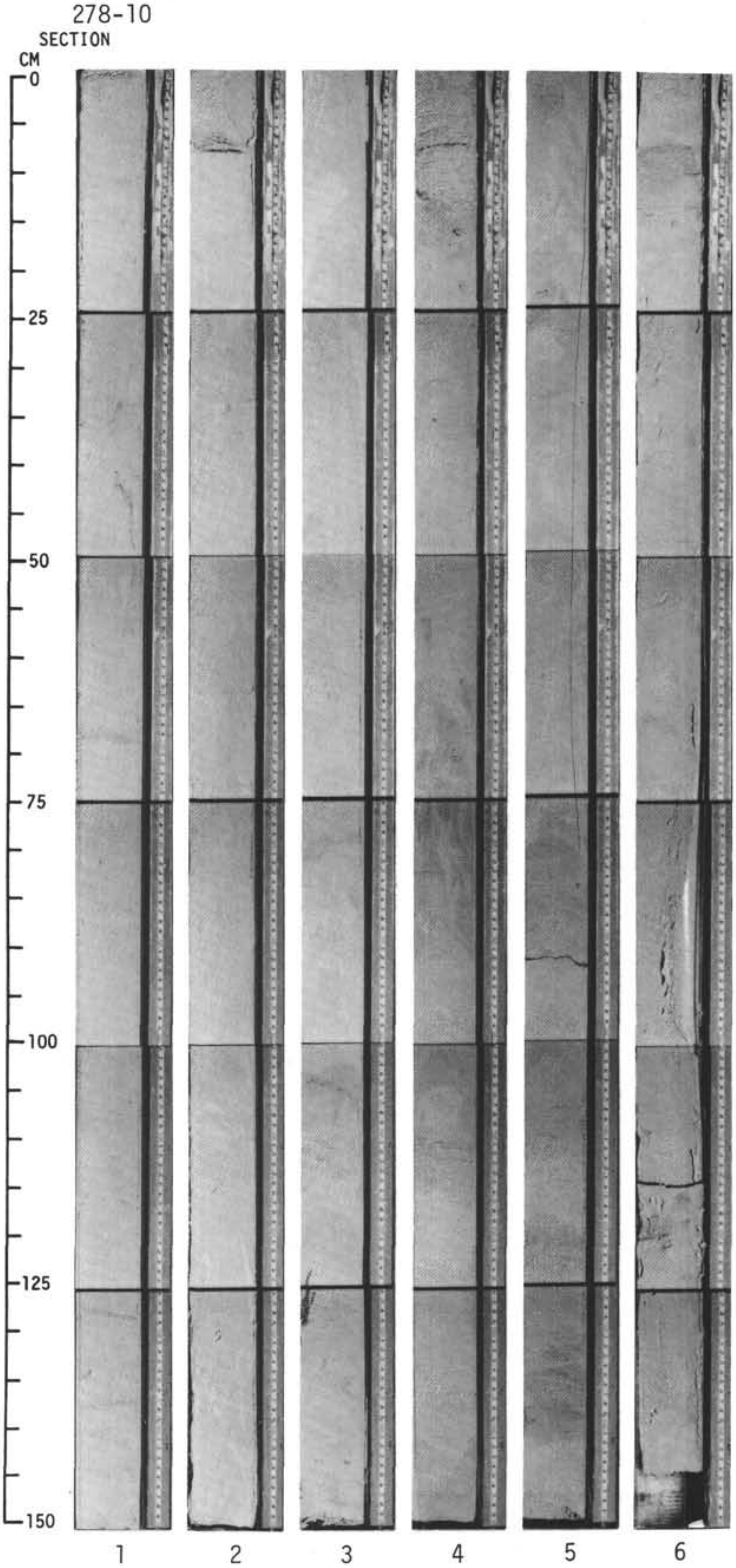
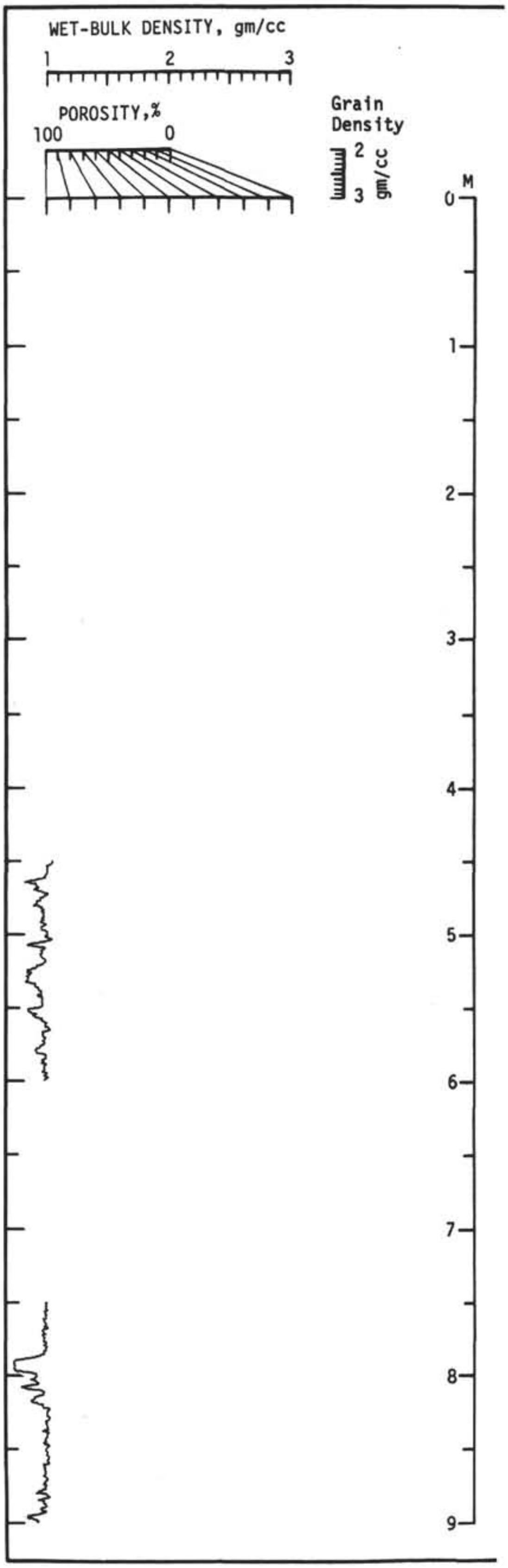
5
6
7
8
9


278-10
SECTION
CM
0
25
50
75
100
125
150
1
2
3
4
5
6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Grain Density
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gm/cc
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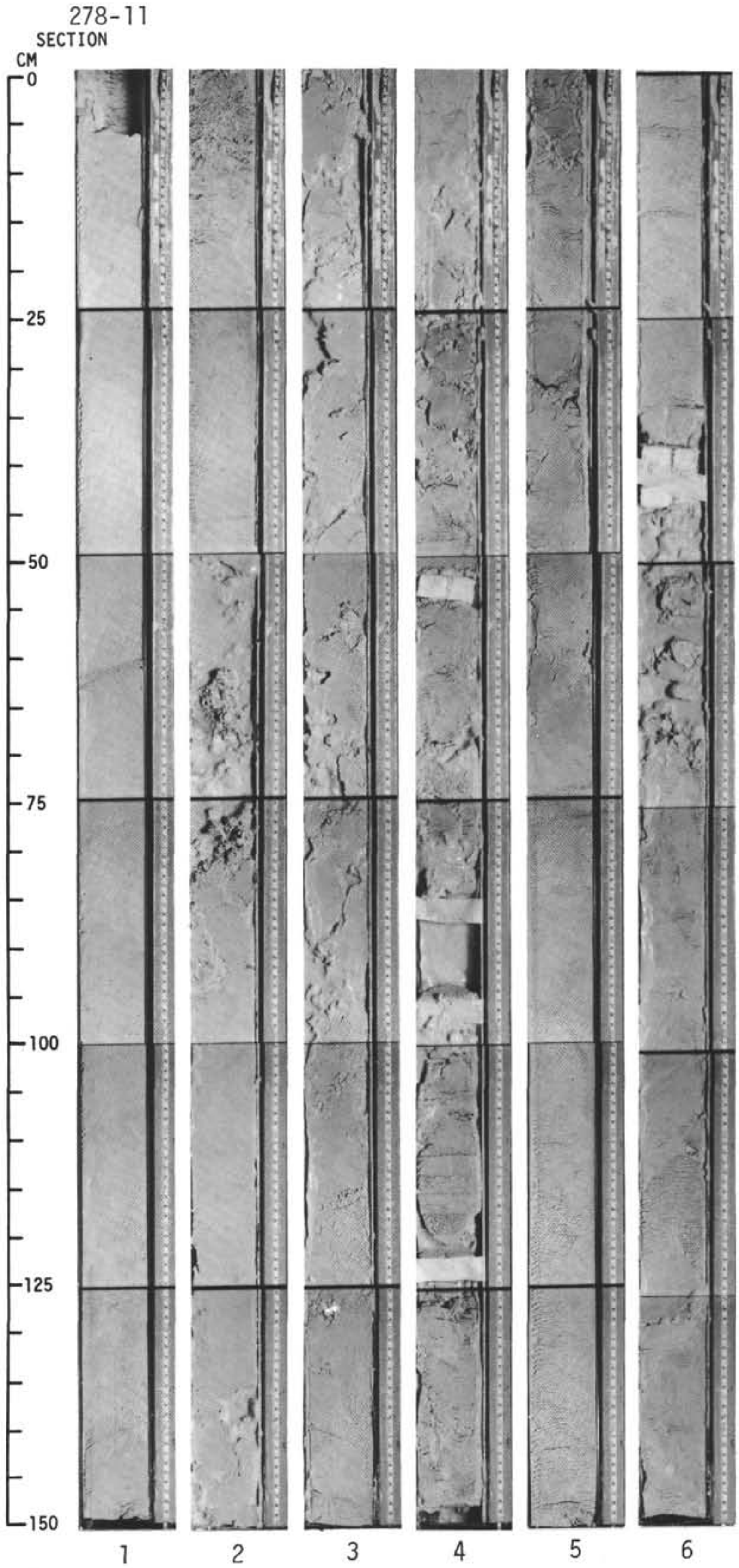
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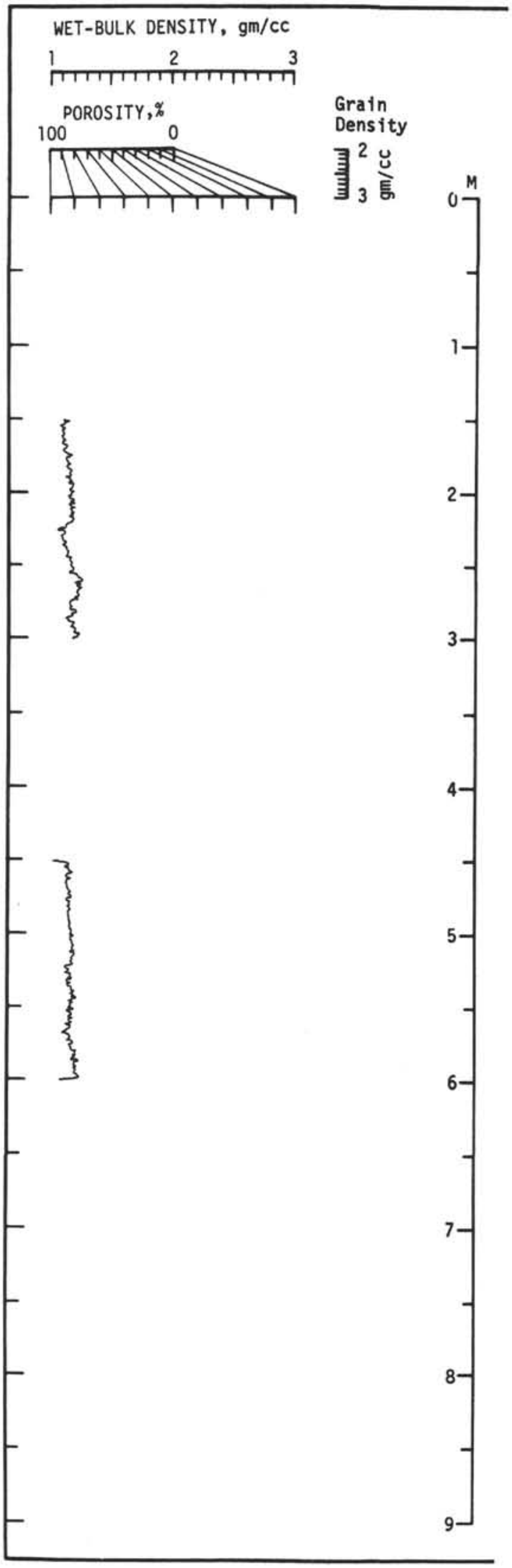
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Grain Density
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gm/cc
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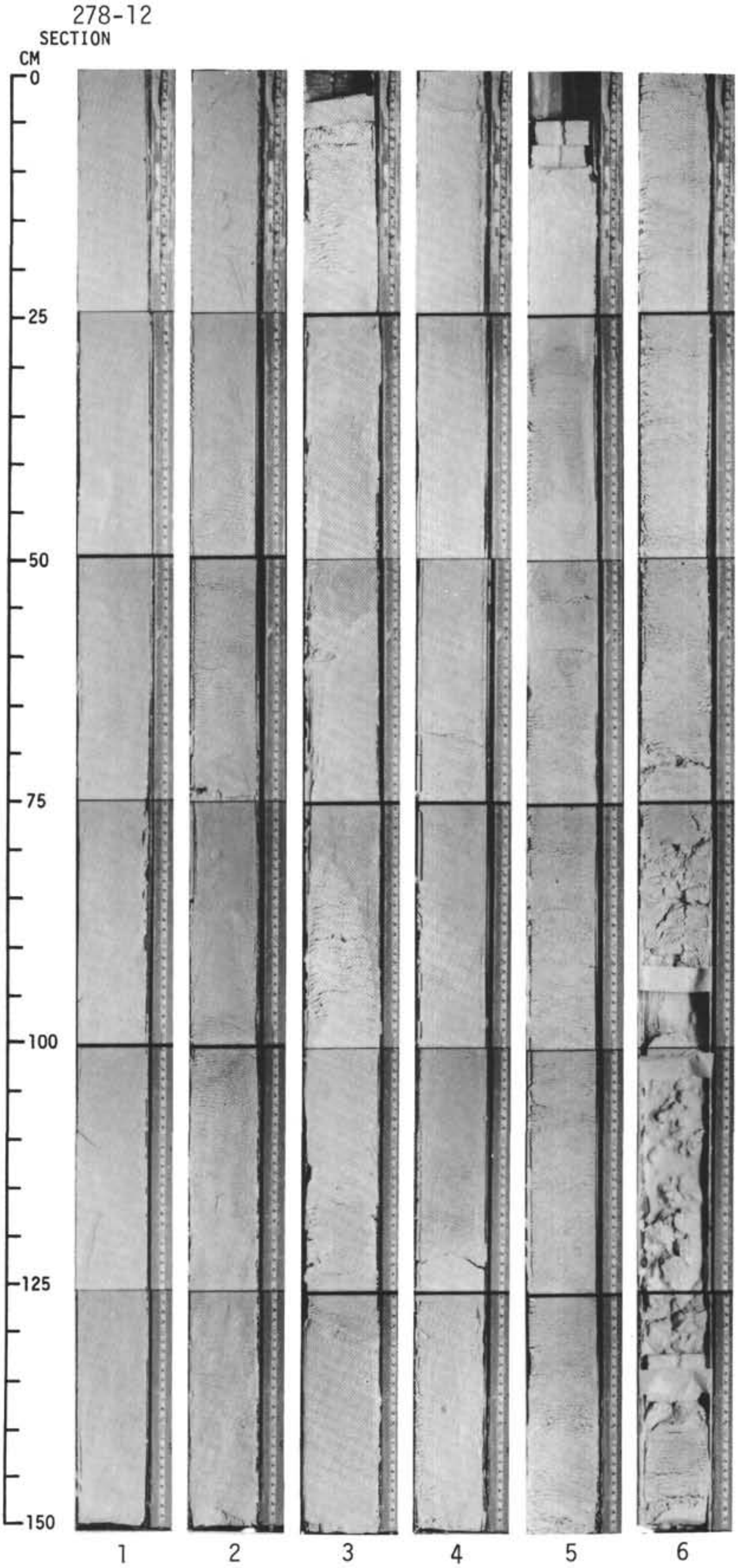
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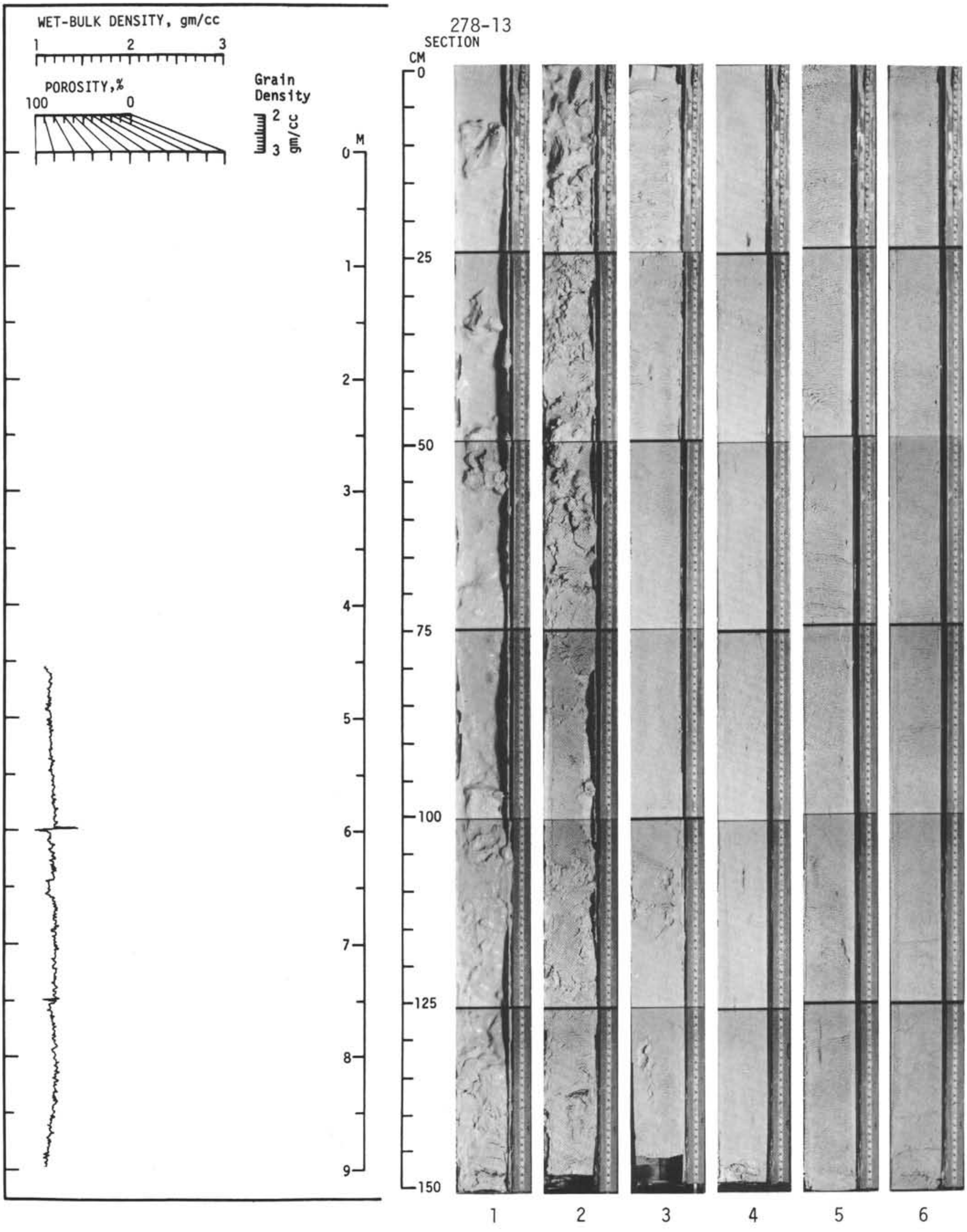
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gm/cc
M
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SECTION
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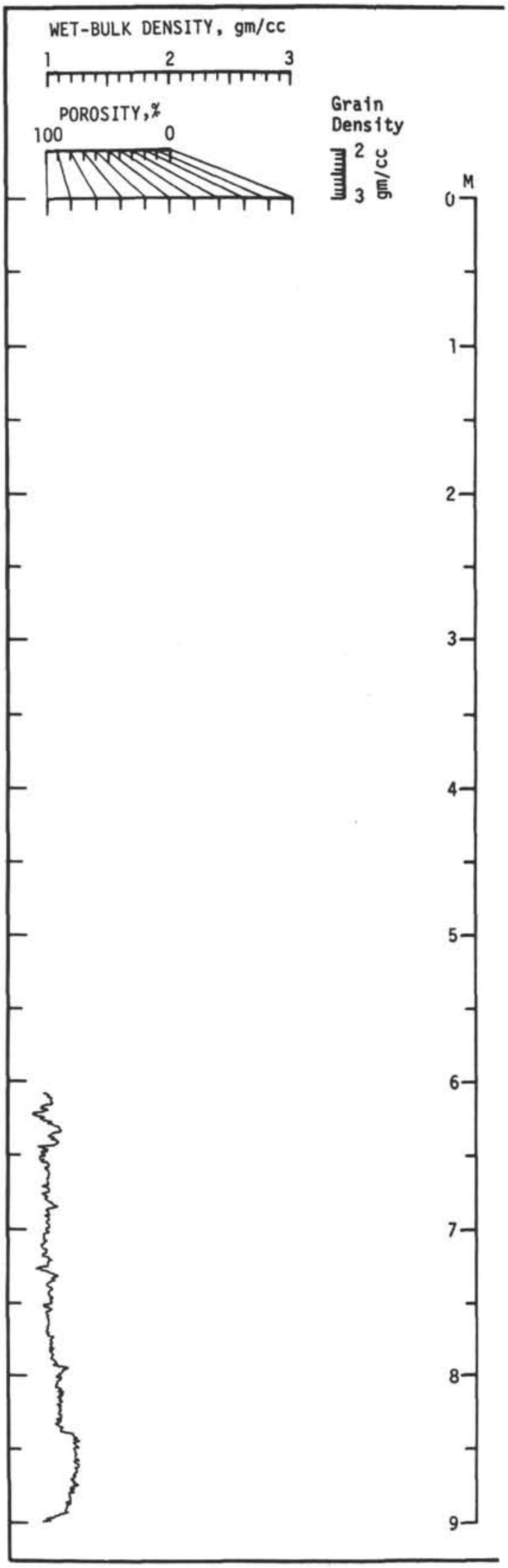
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gm/cc
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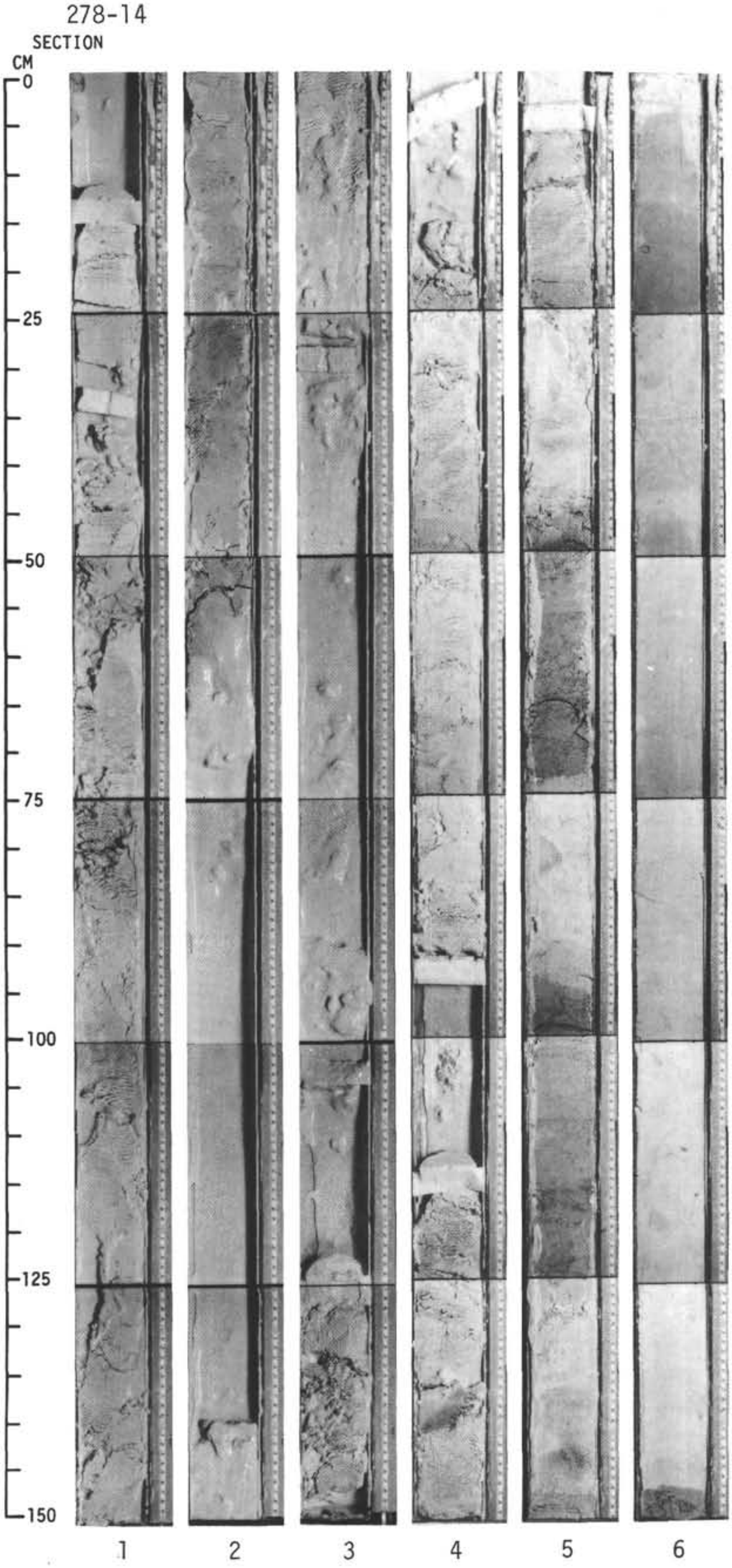
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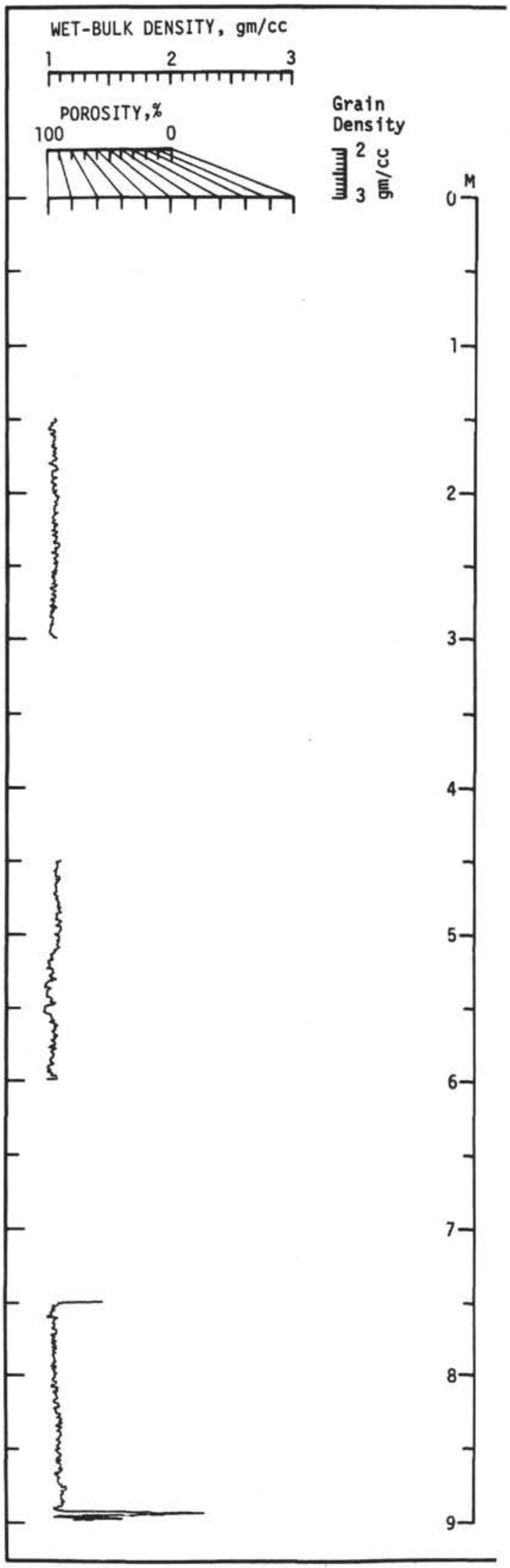

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gm/cc
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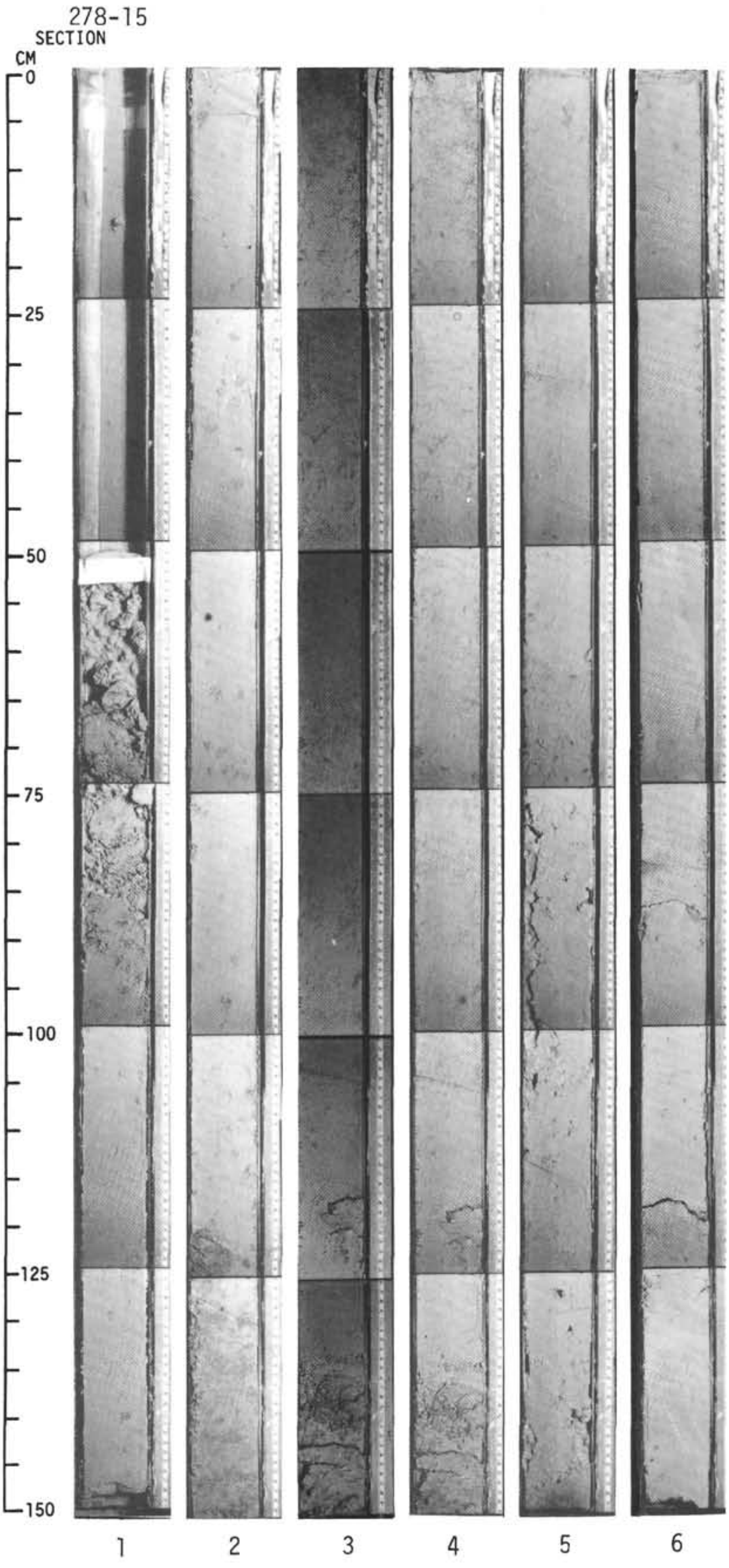

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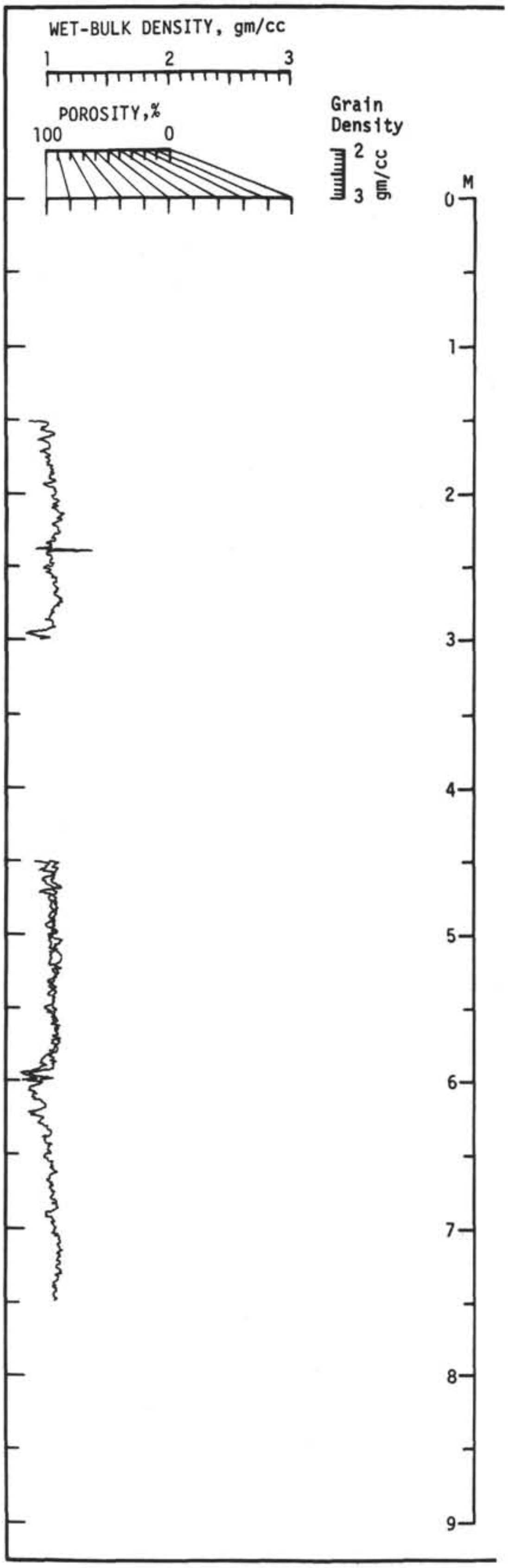
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Density
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gm/cc
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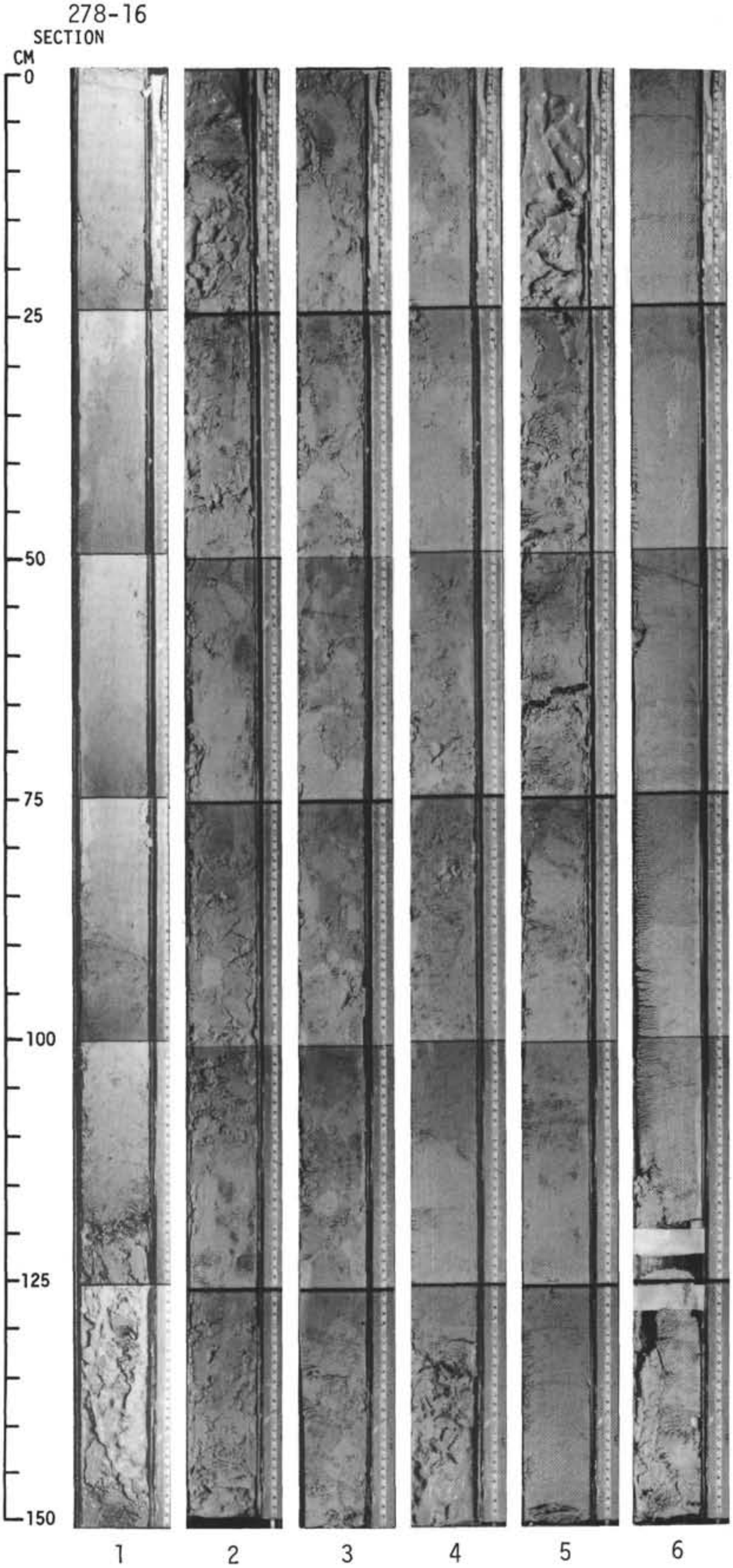
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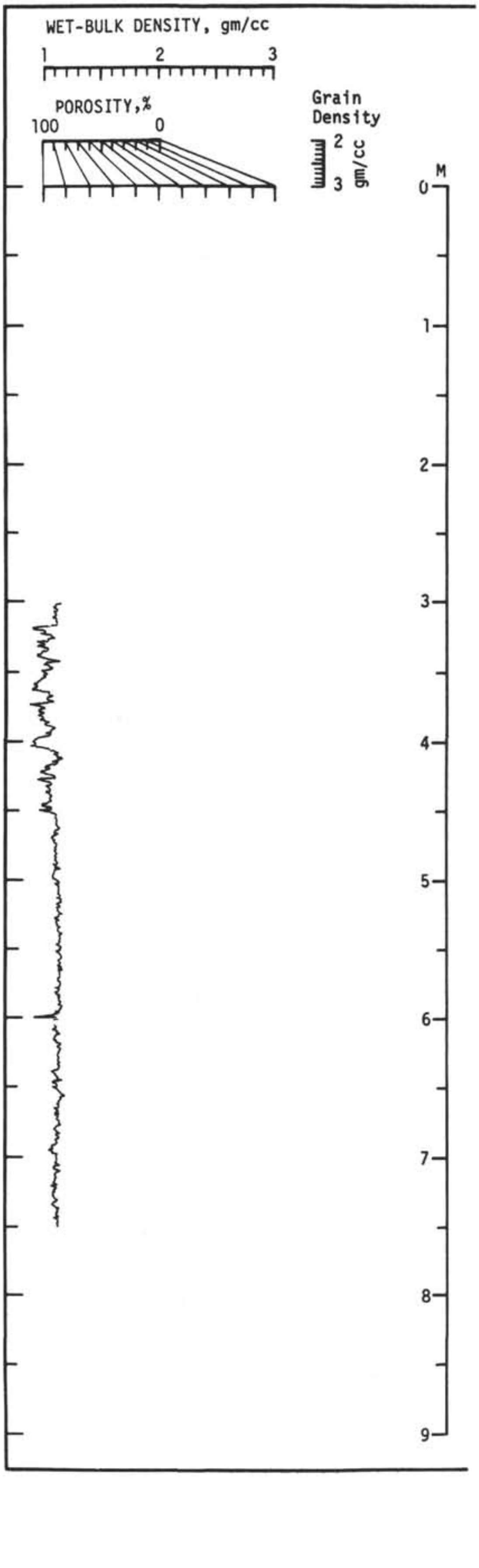
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100
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Grain Density
2
3
gm/cc
M
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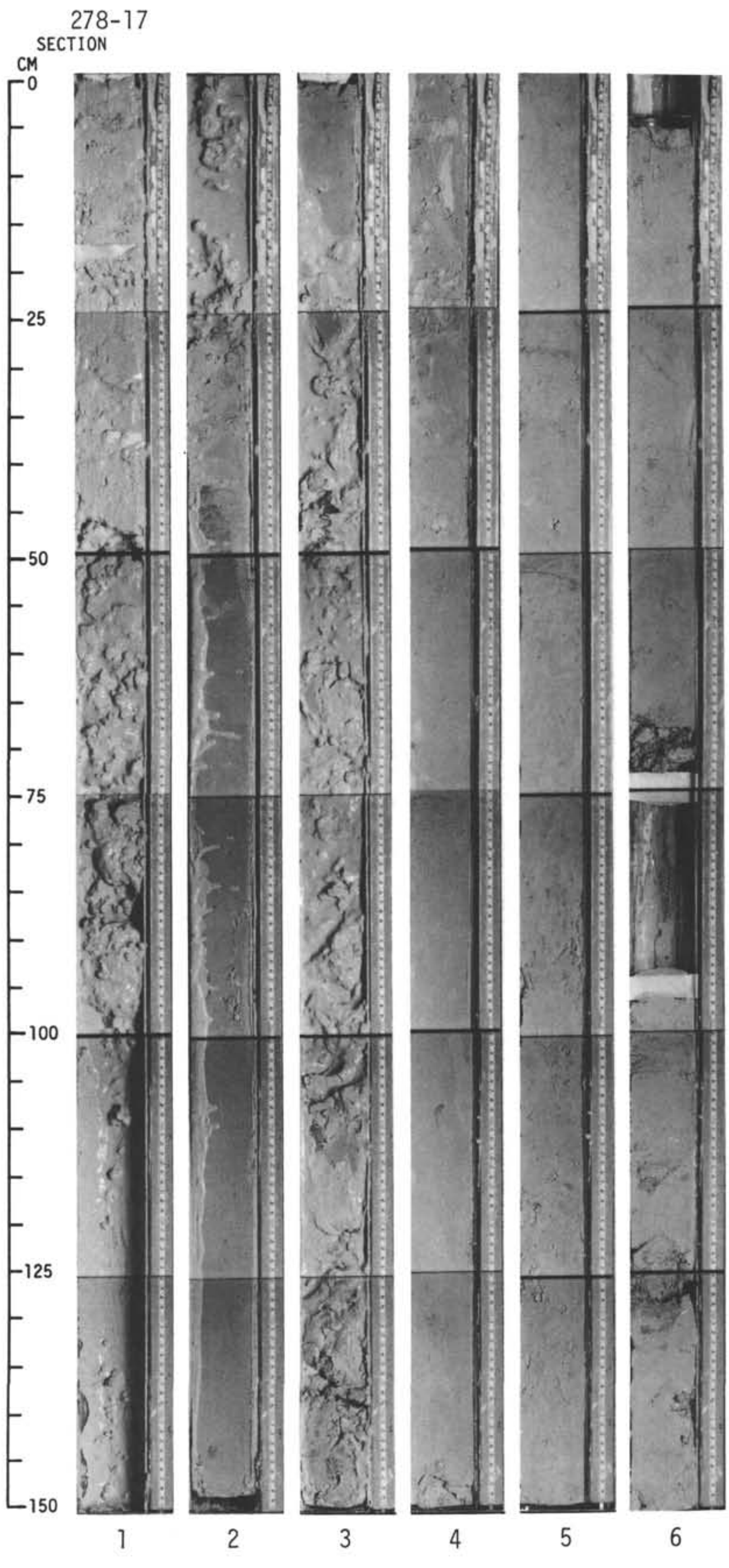
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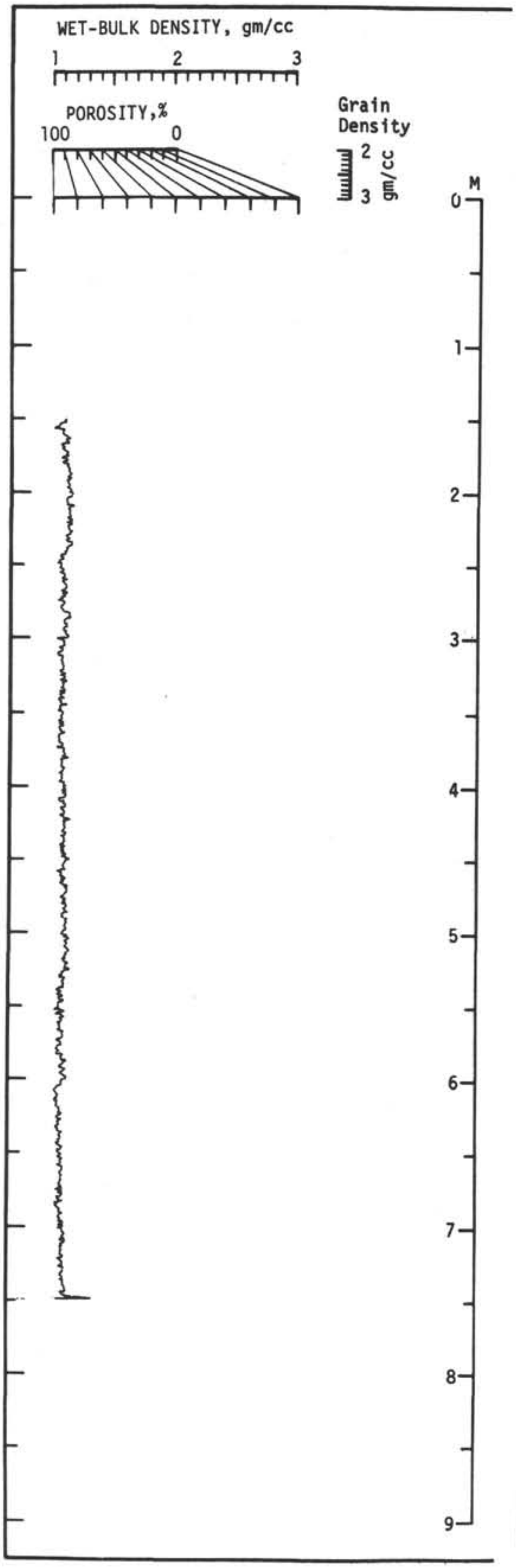
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POROSITY,%
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Grain
Density
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gm/cc
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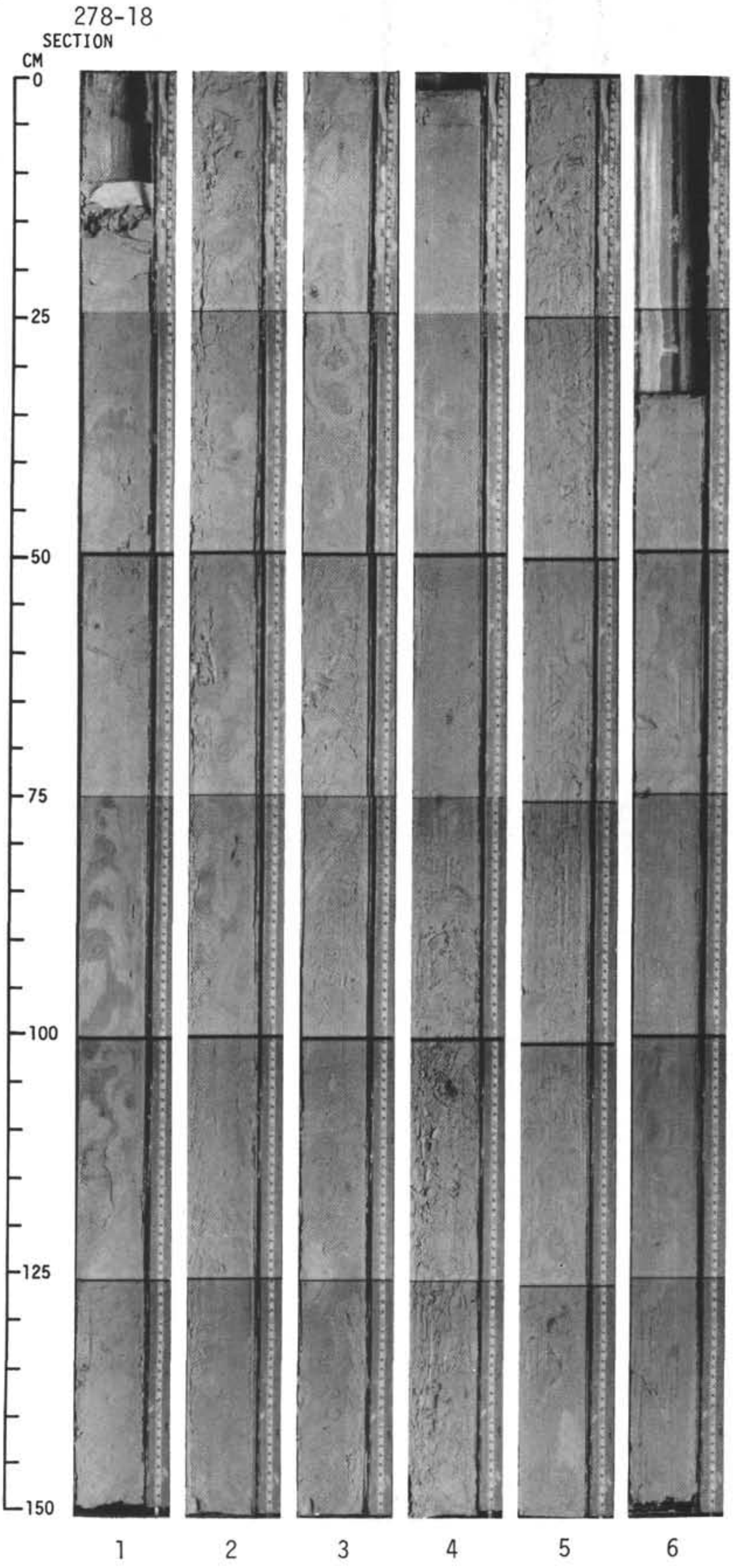
278-18
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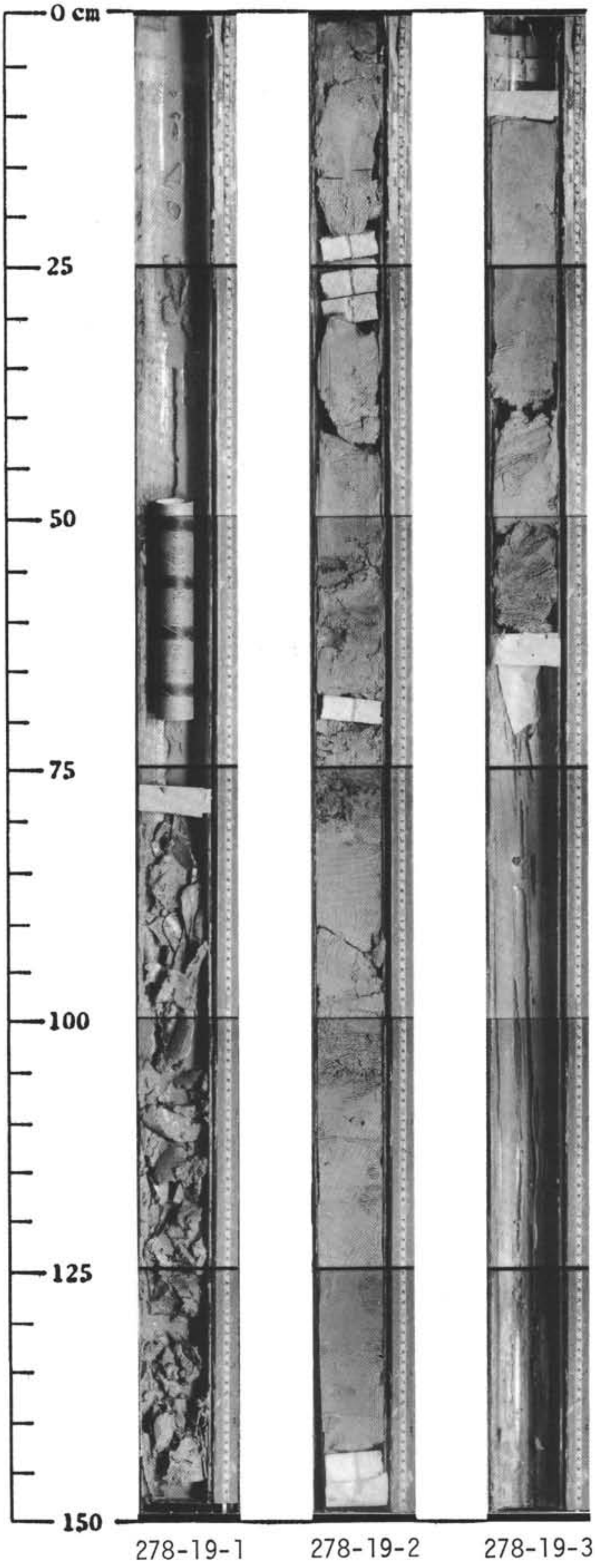
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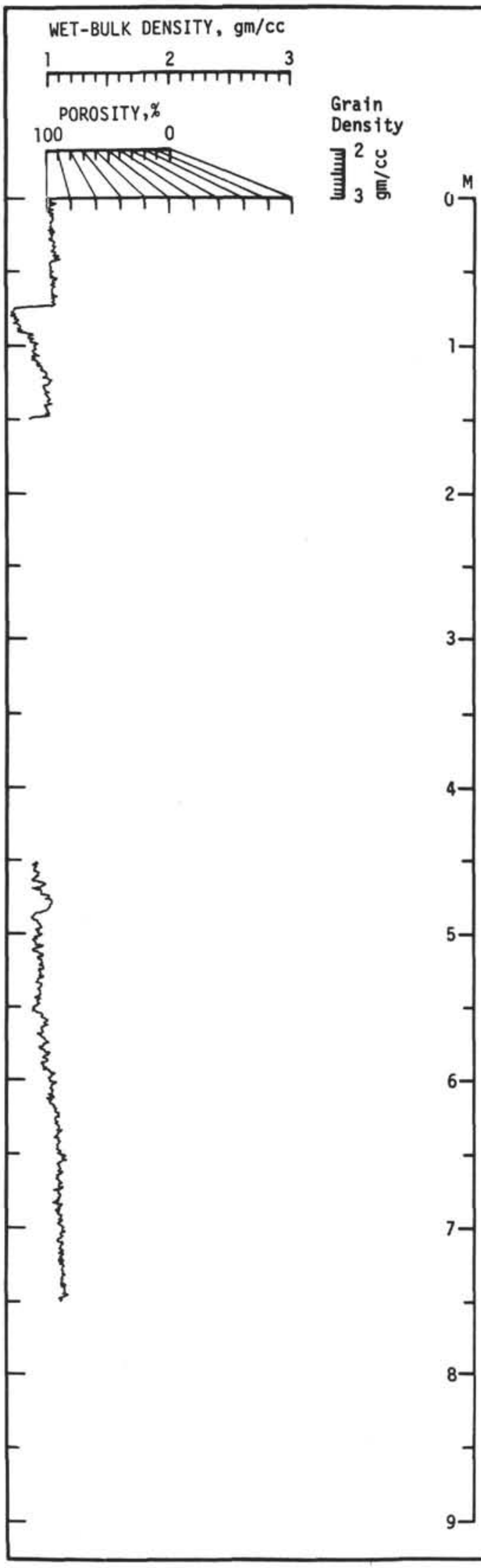
278-19-1
278-19-2
278-19-3



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Grain Density
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3
gm/cc
M
0
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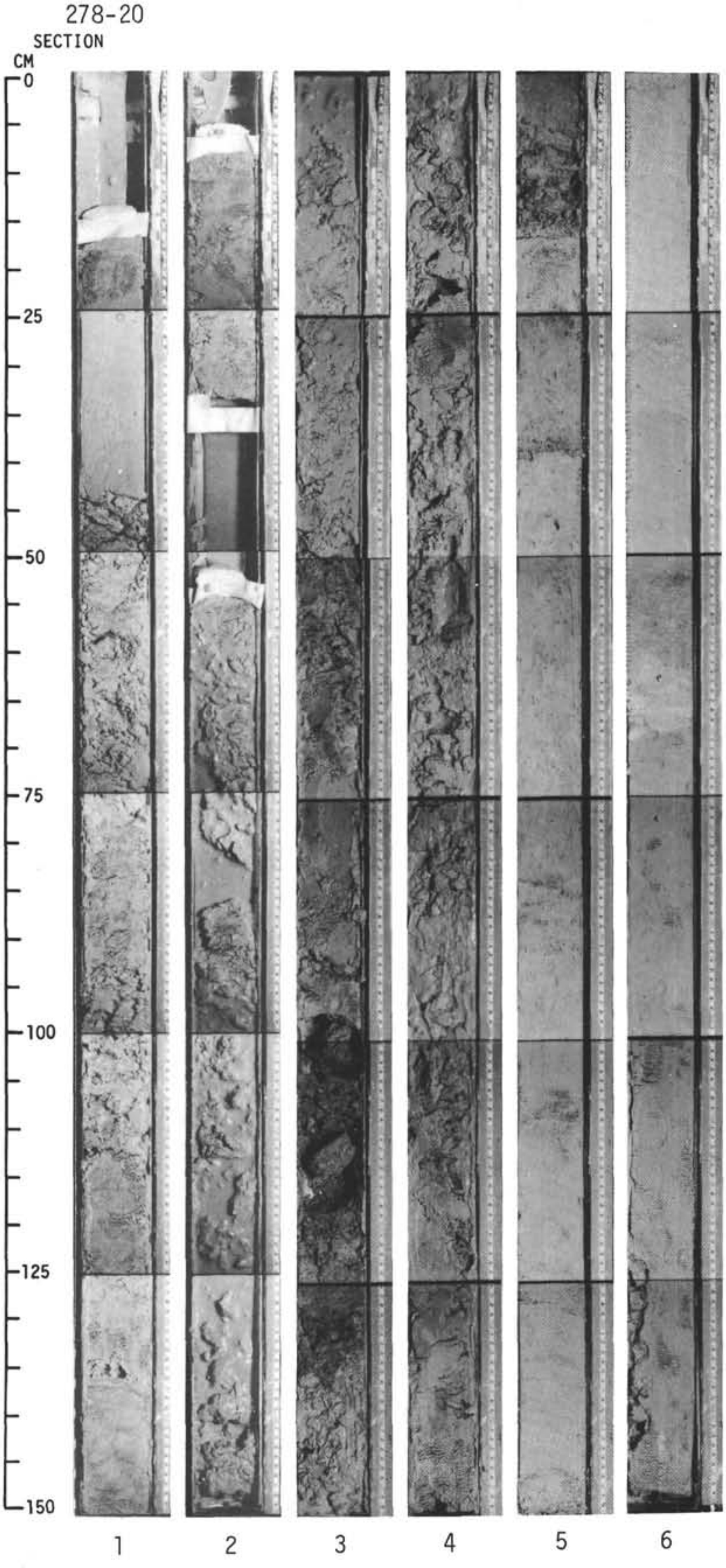

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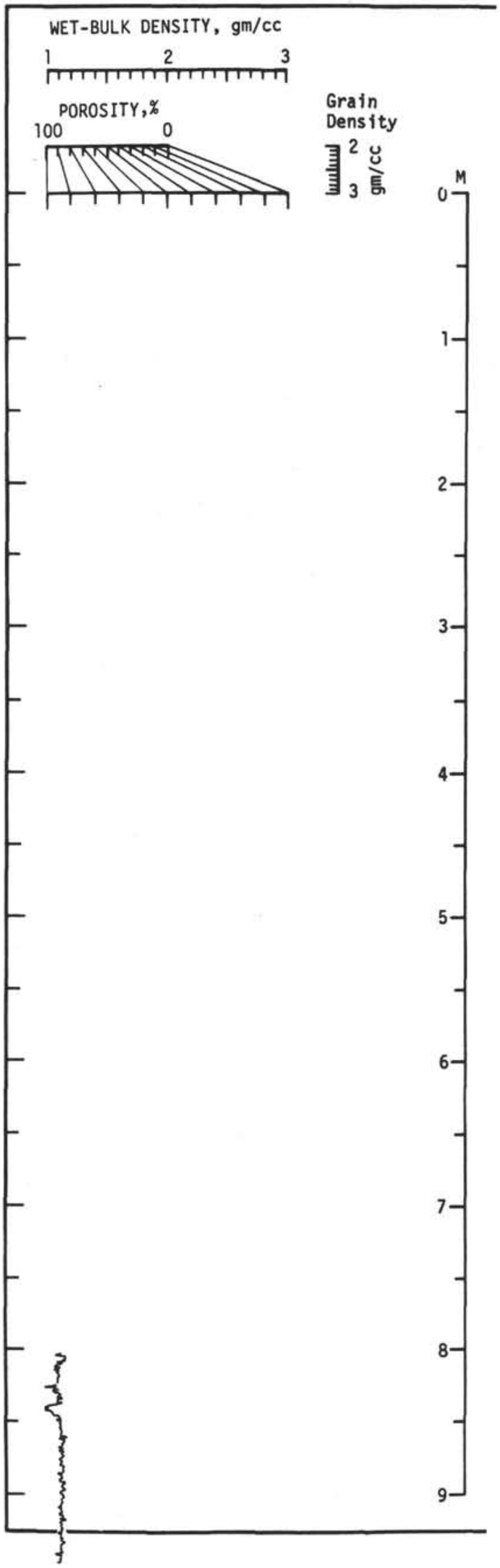
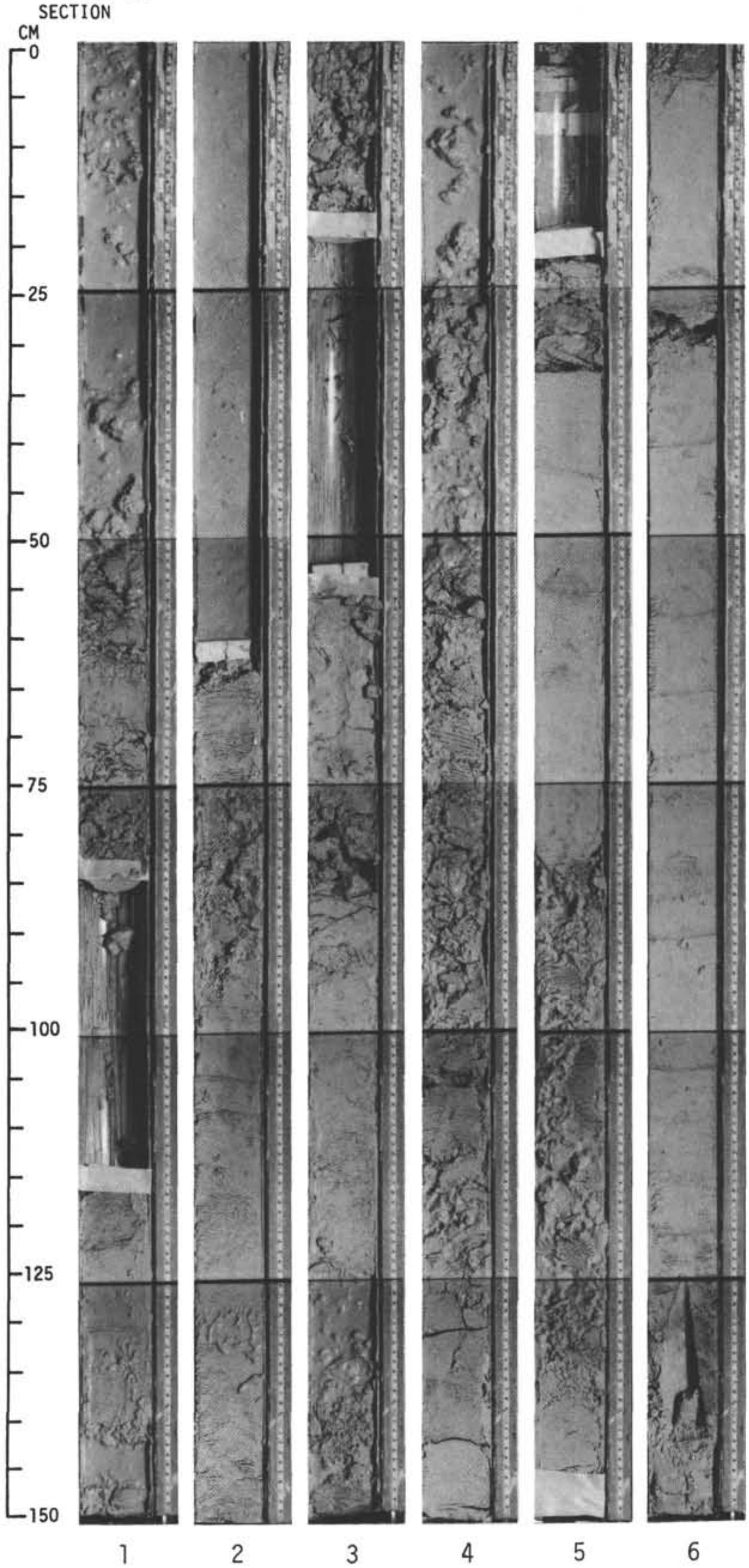
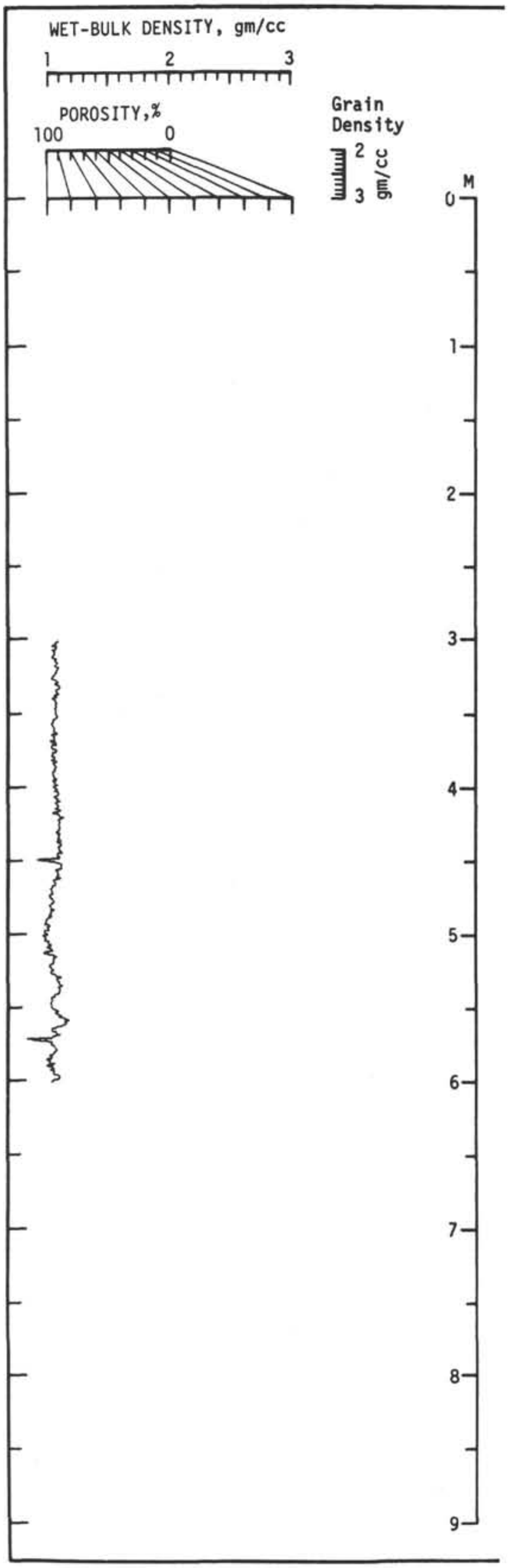


278-21
SECTION



1 2 3 4 5 6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Grain
Density
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gm/cc
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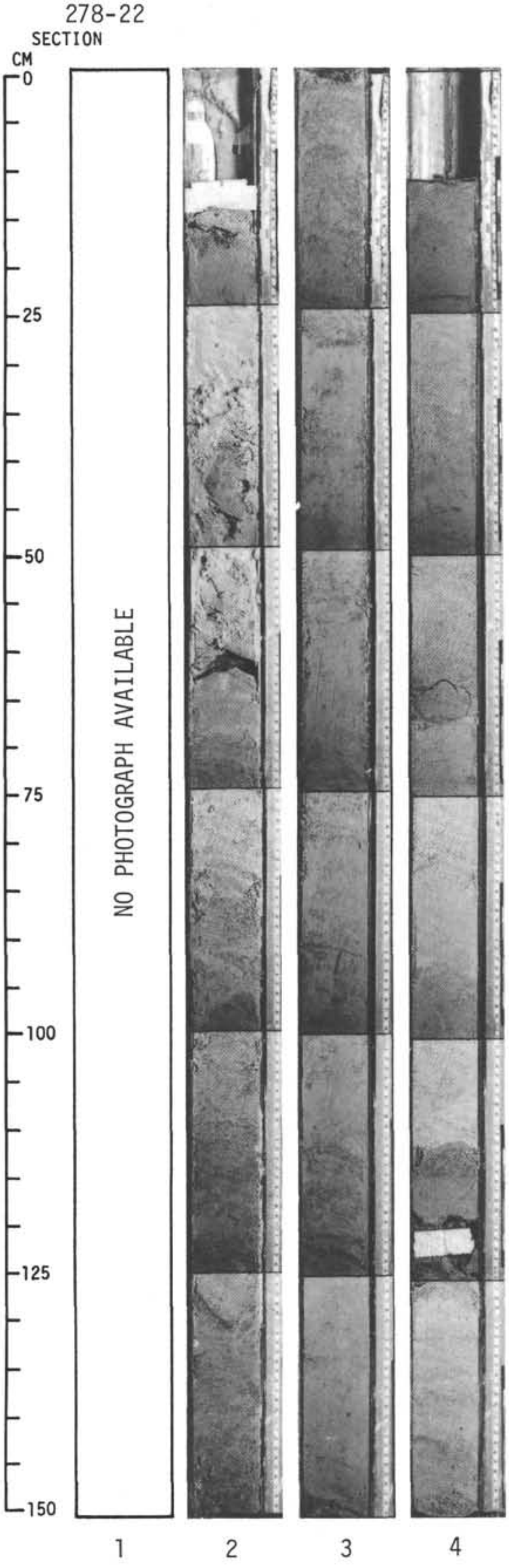
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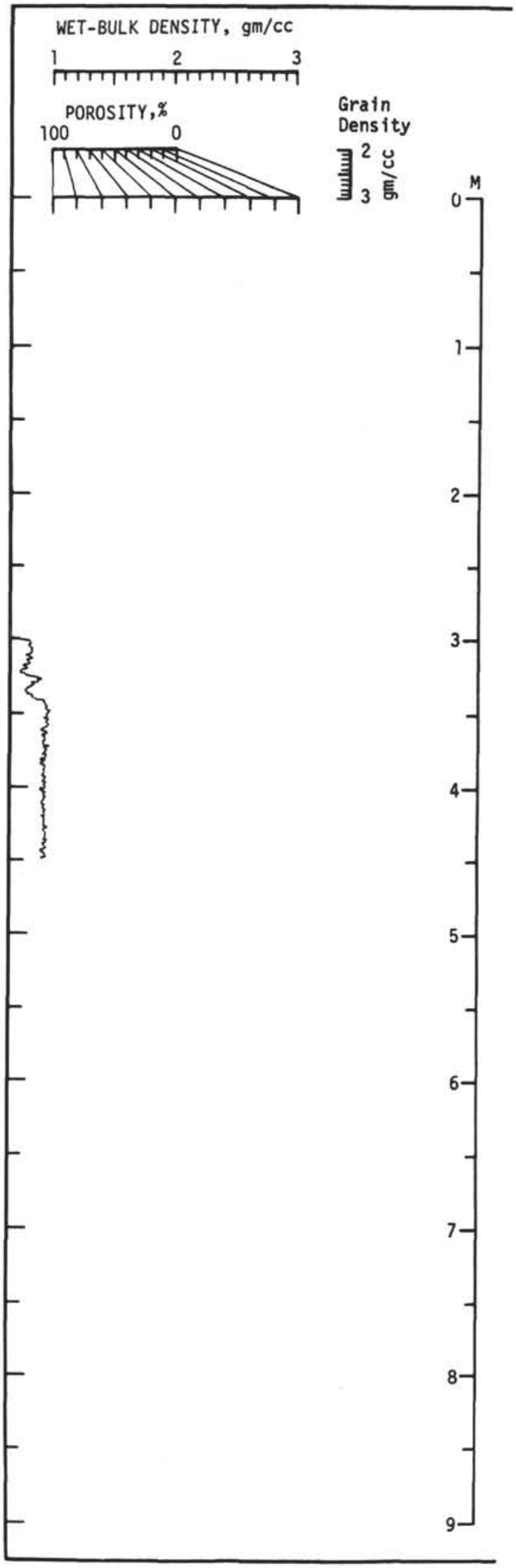
WET-BULK DENSITY, gm/cc
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POROSITY,%
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Grain
Density
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gm/cc
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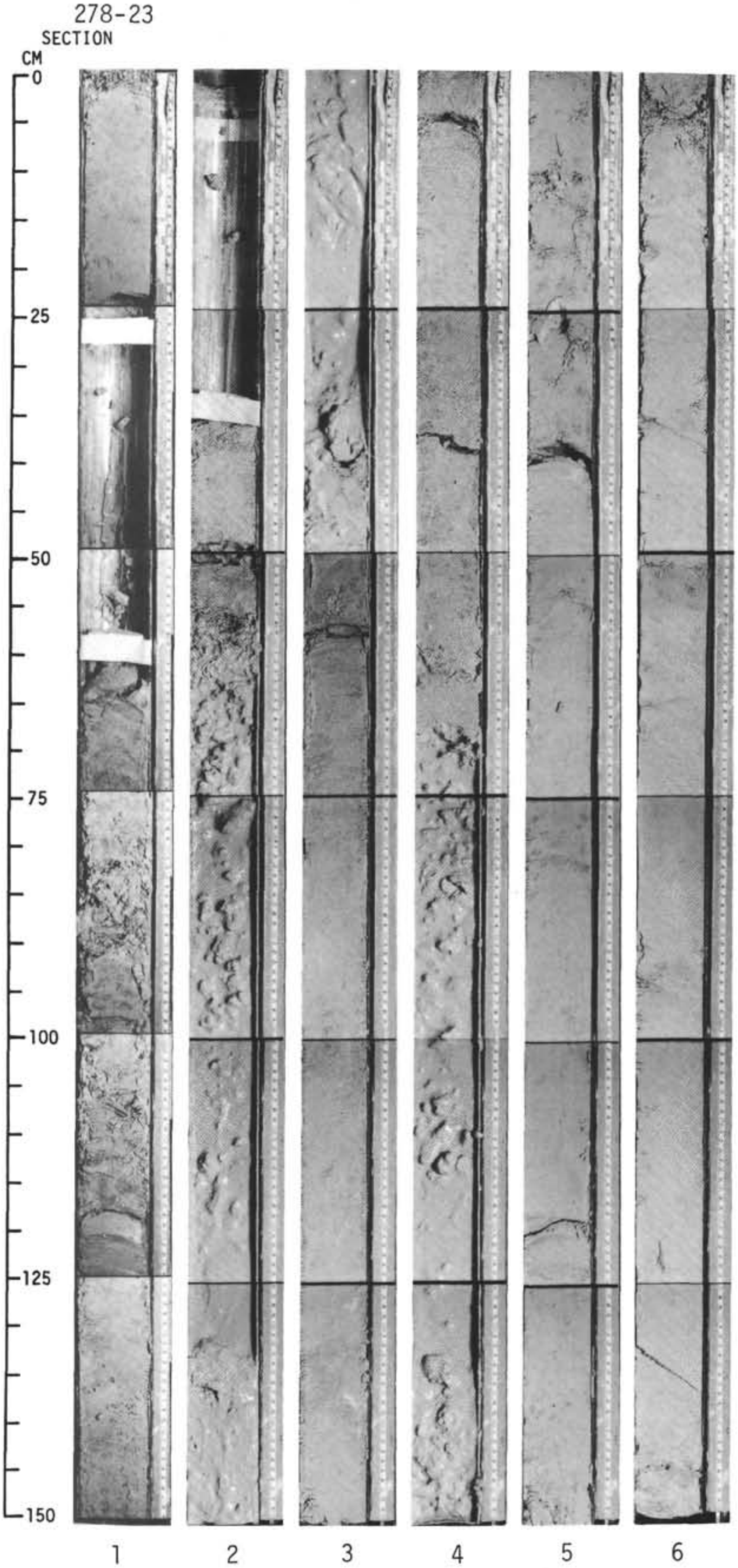
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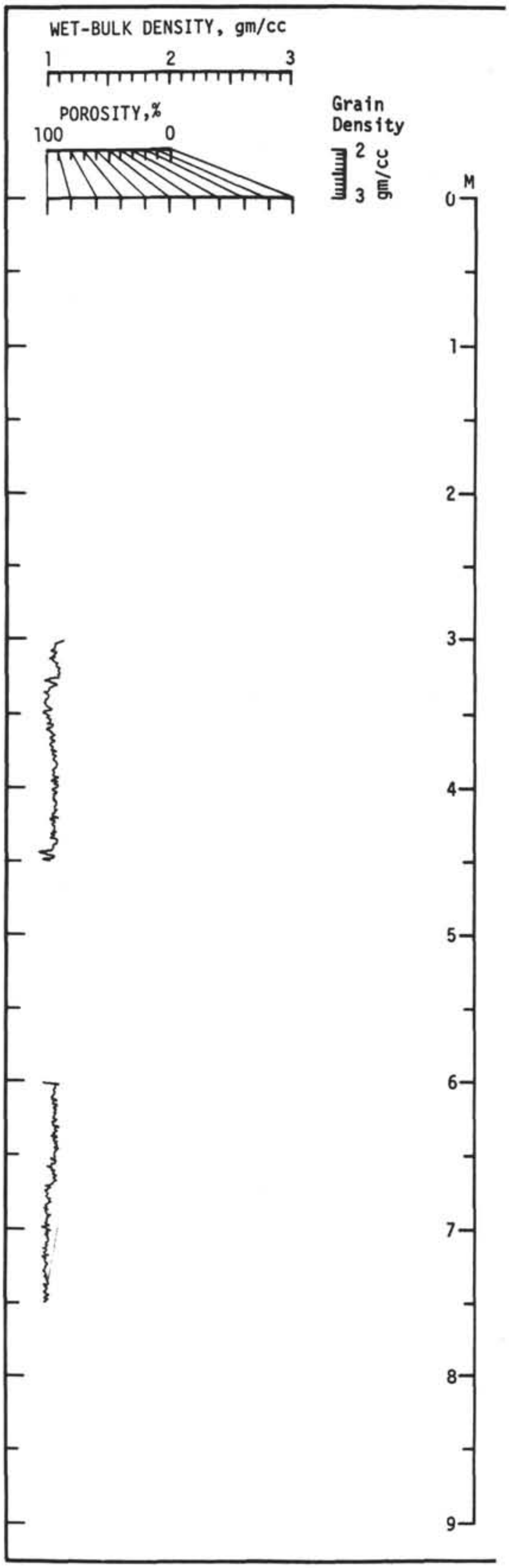
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gm/cc
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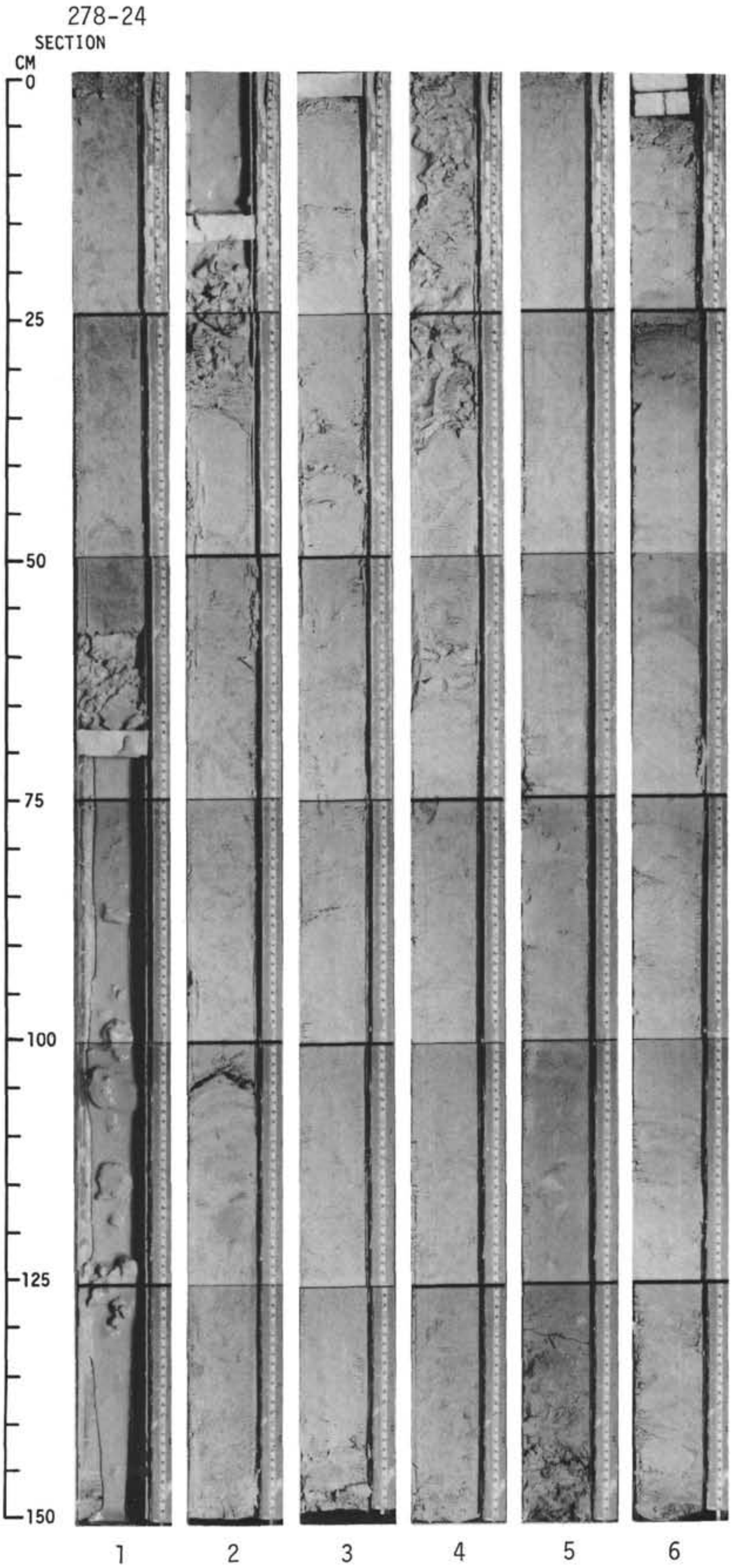
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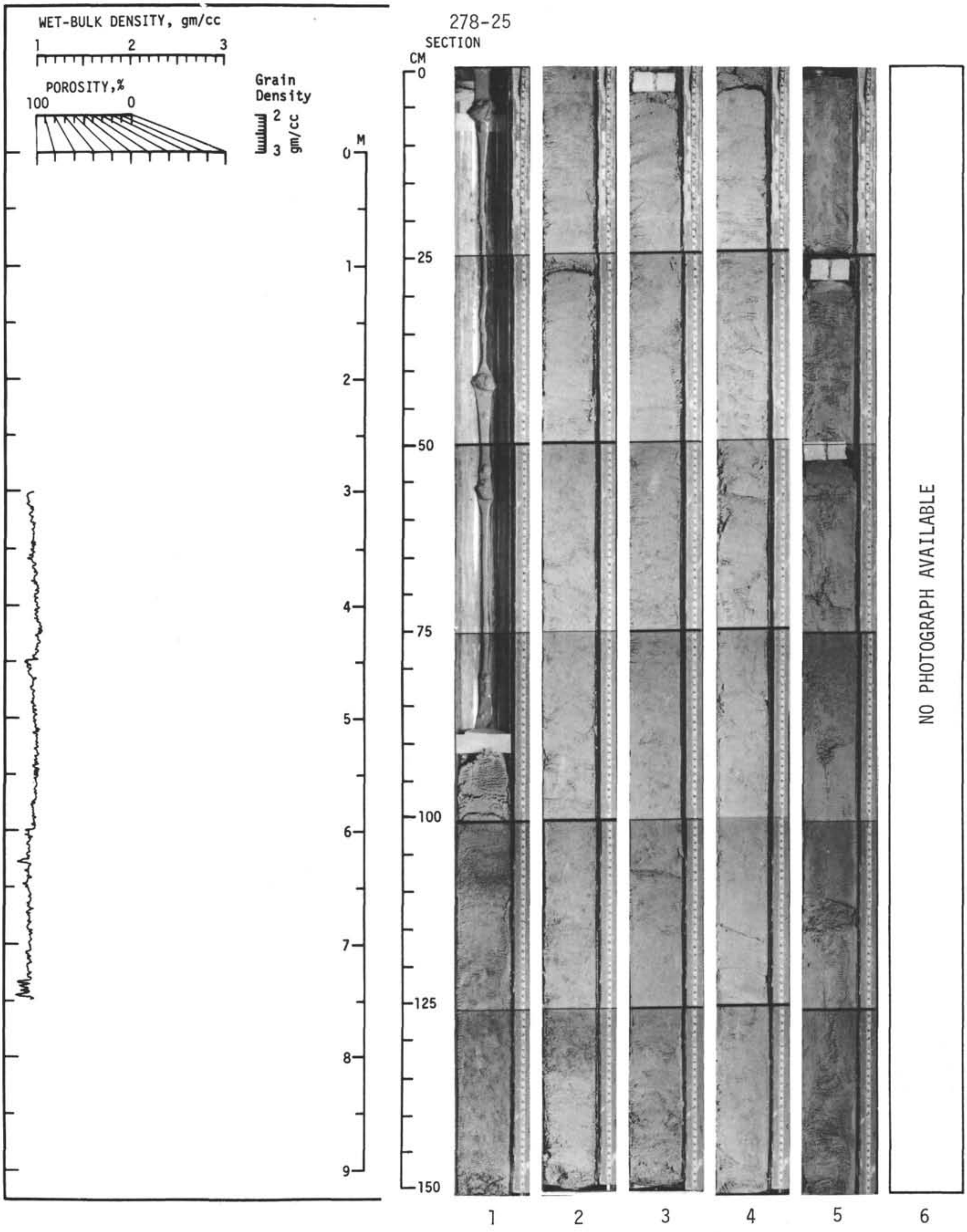
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POROSITY,%
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Grain Density
2 3 gm/cc
M
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278-25
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1 2 3 4 5 6
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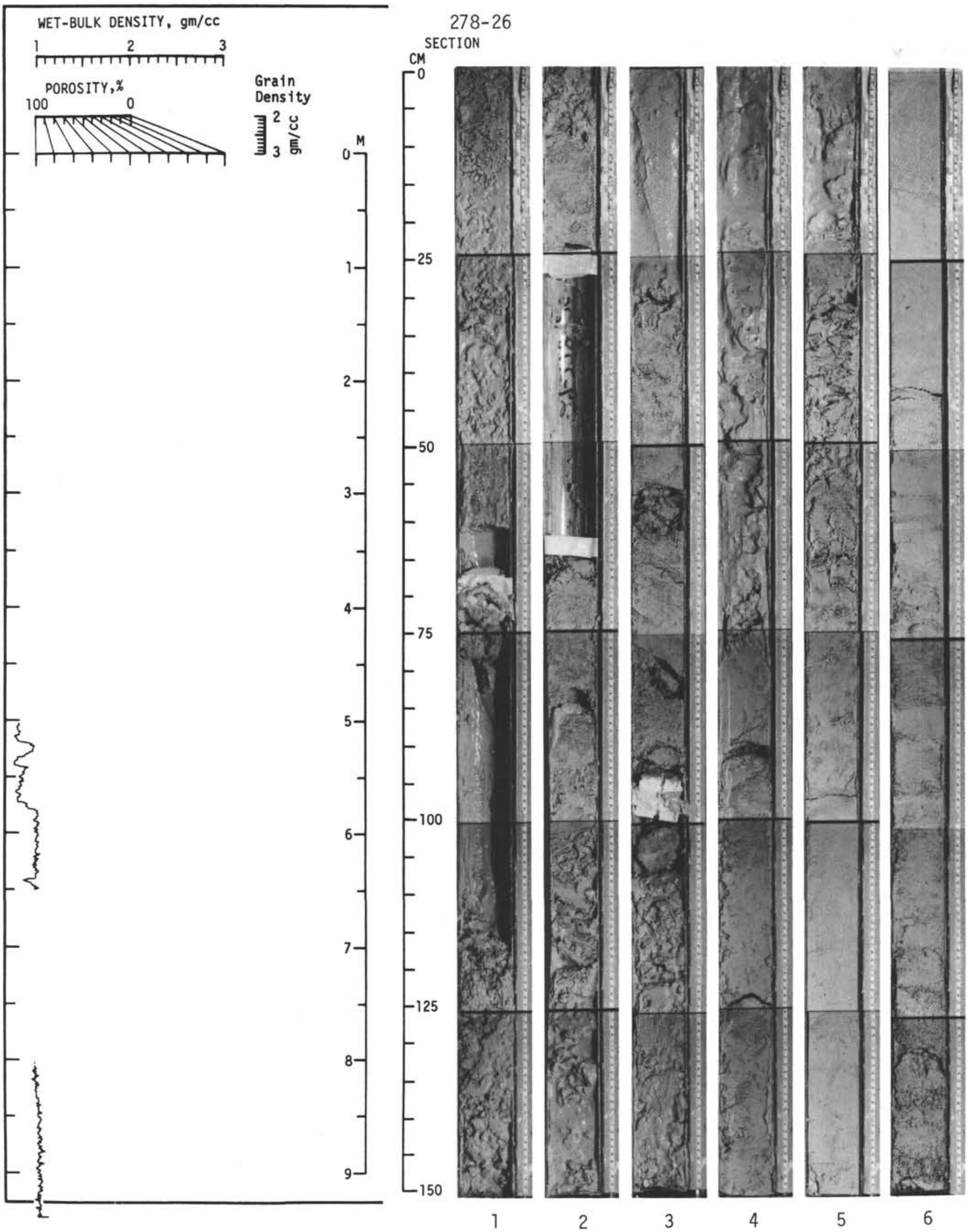
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gm/cc
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SECTION
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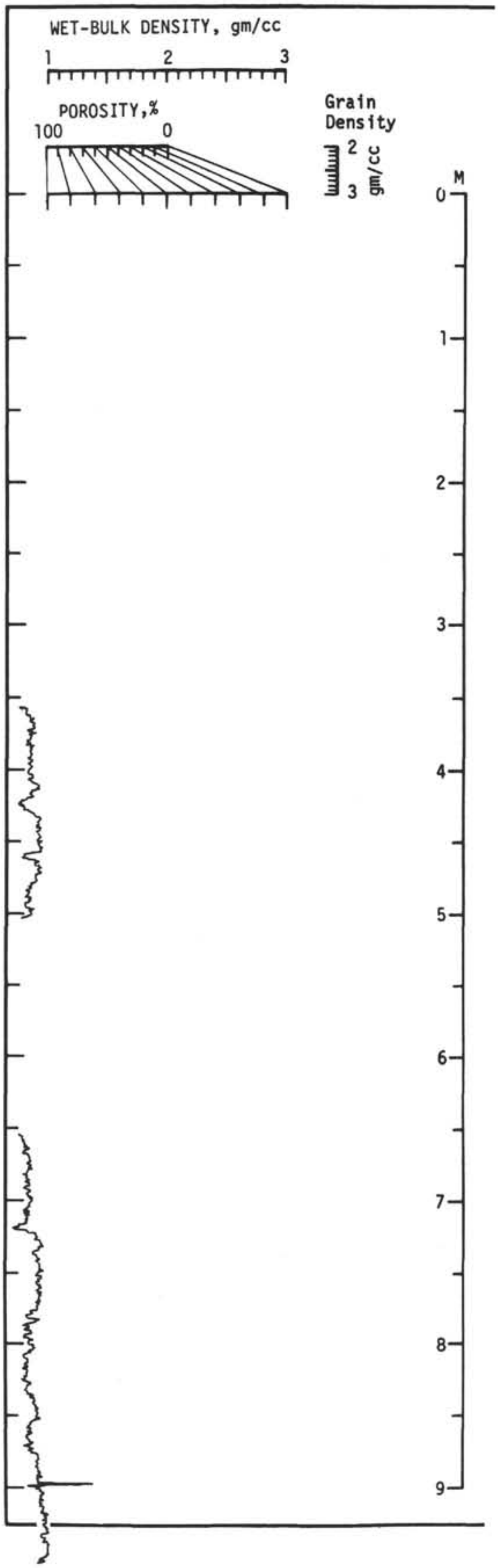
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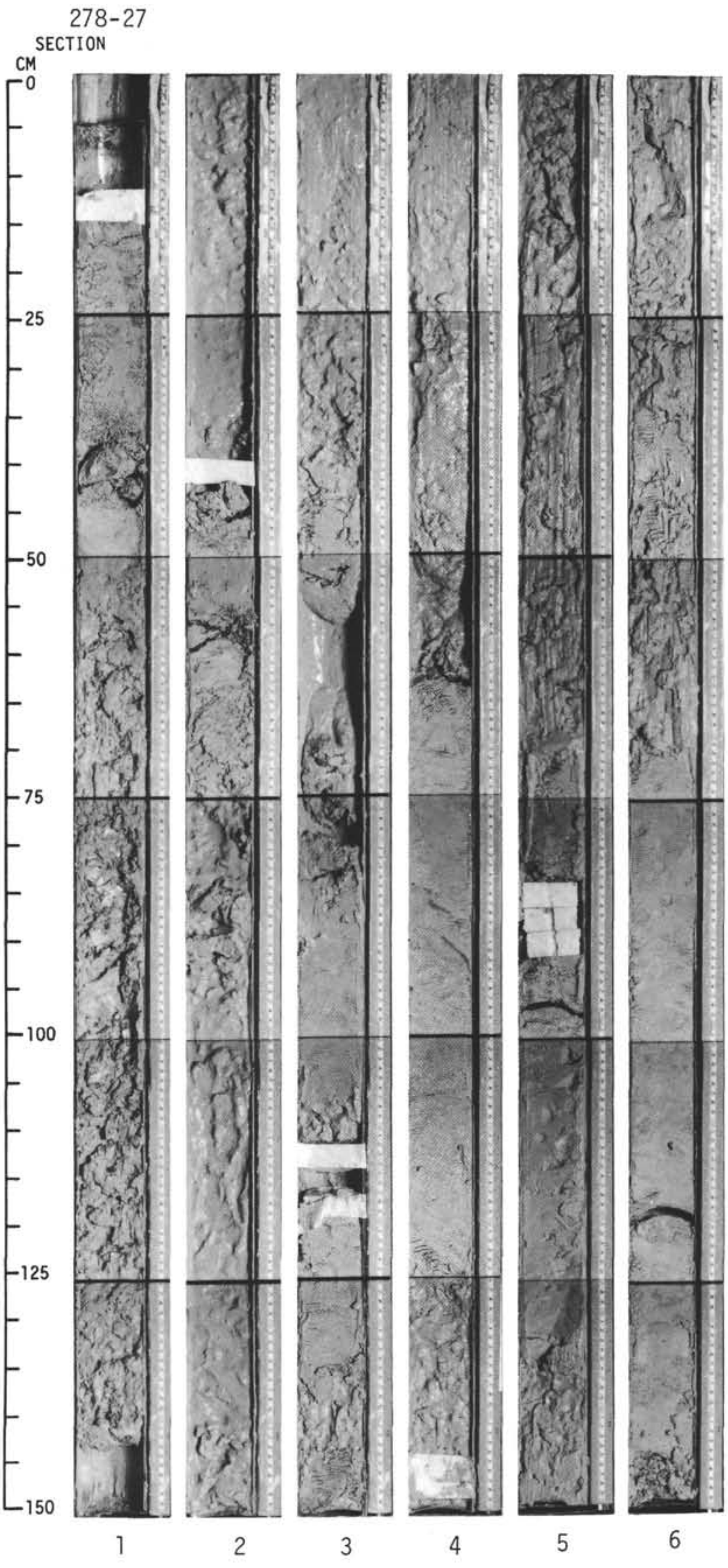
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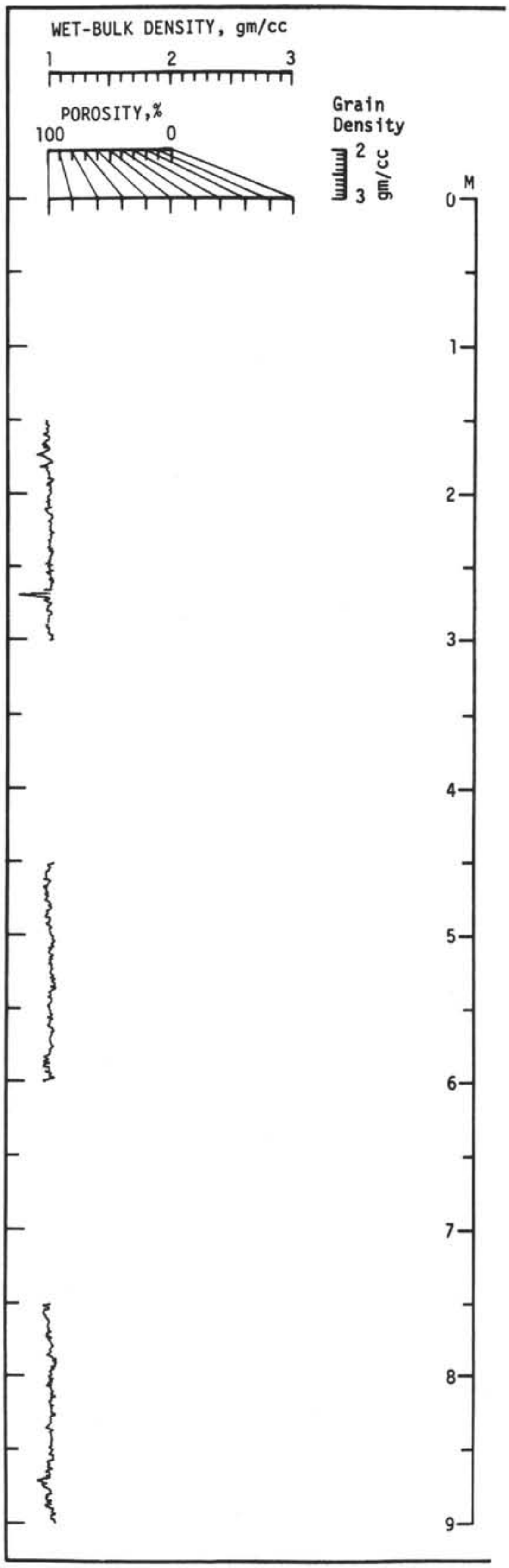
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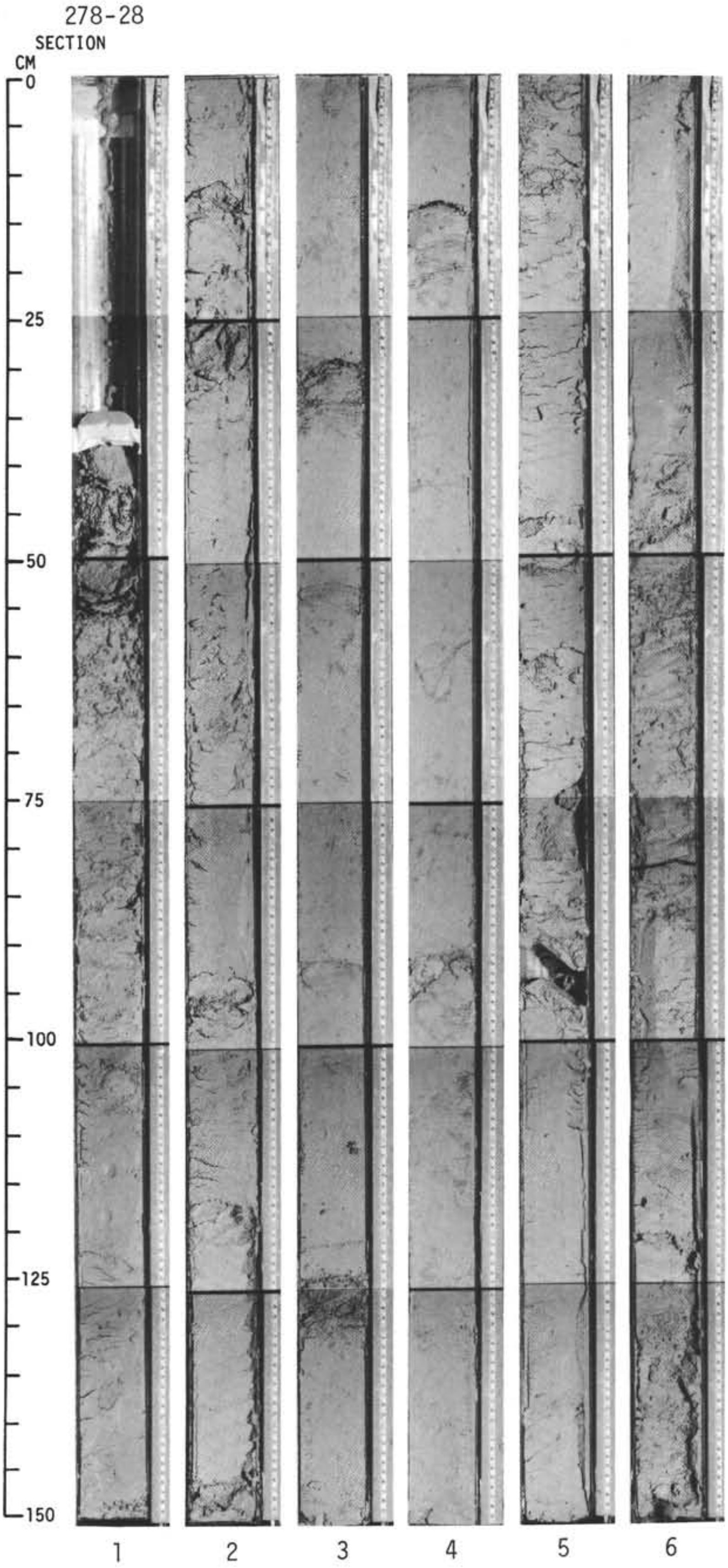
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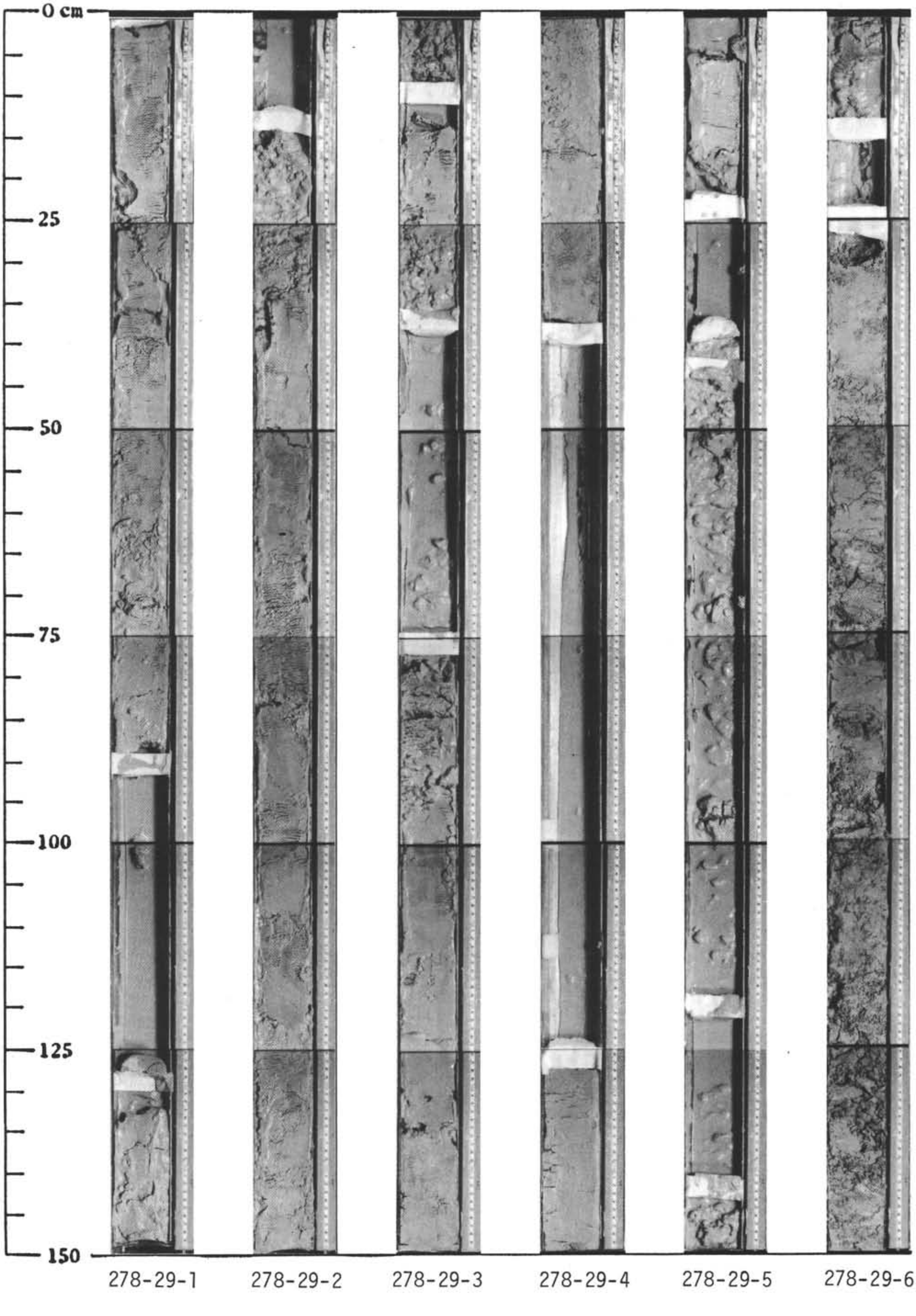
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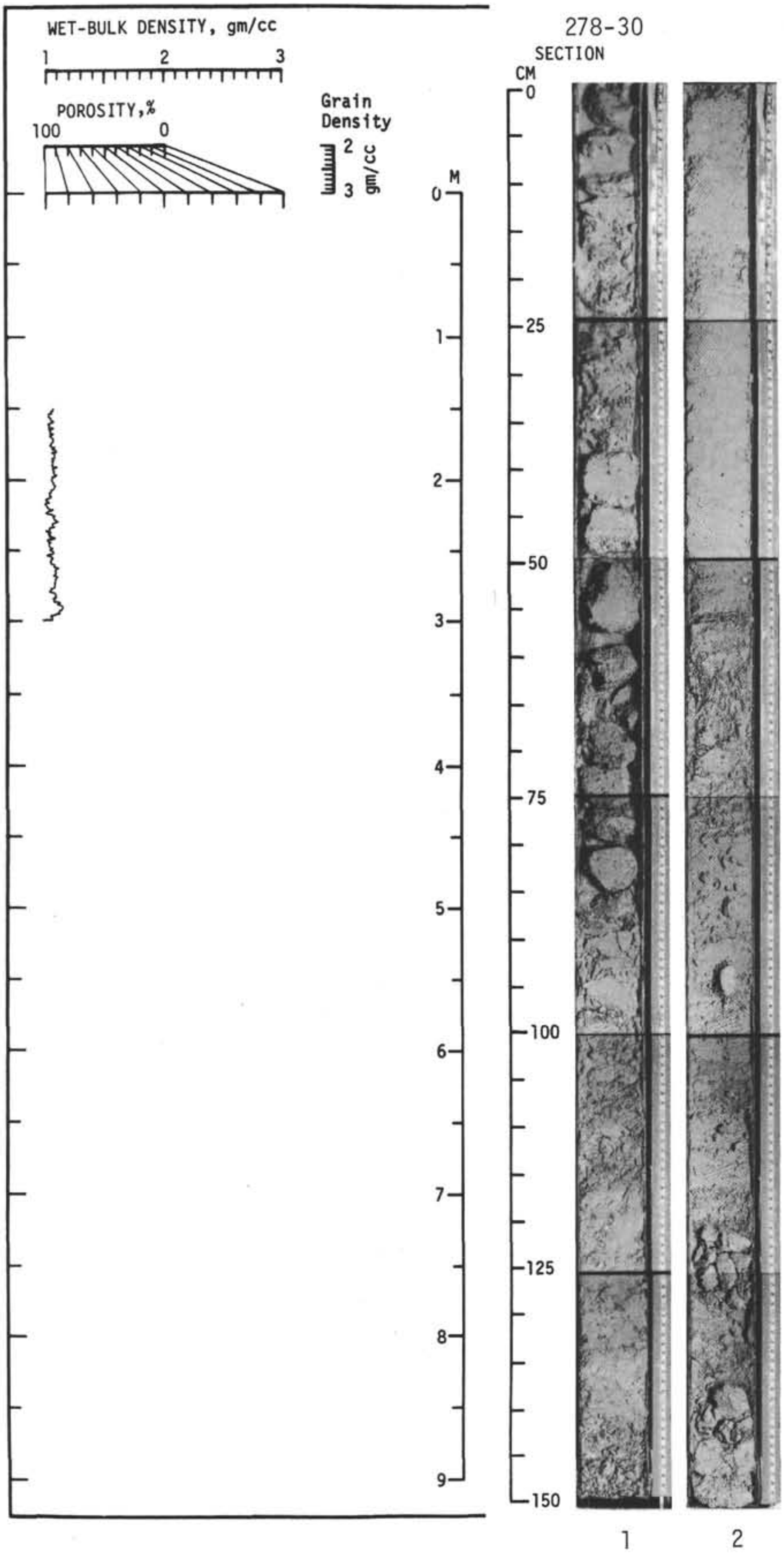
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gm/cc
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278-30
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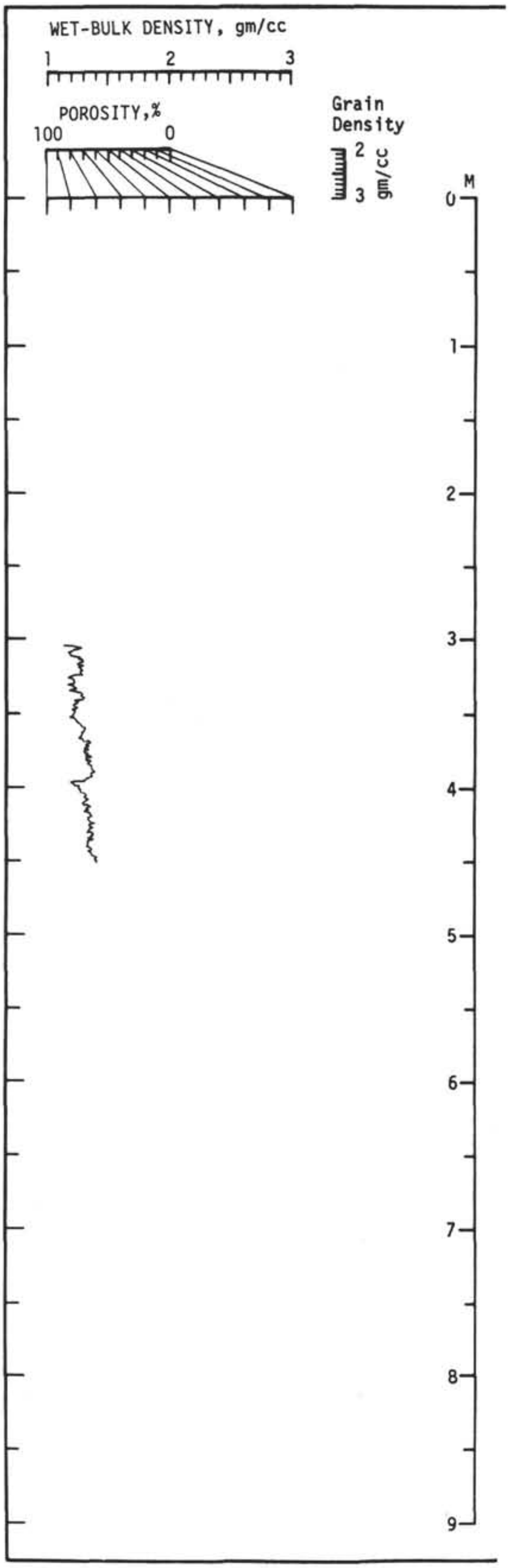
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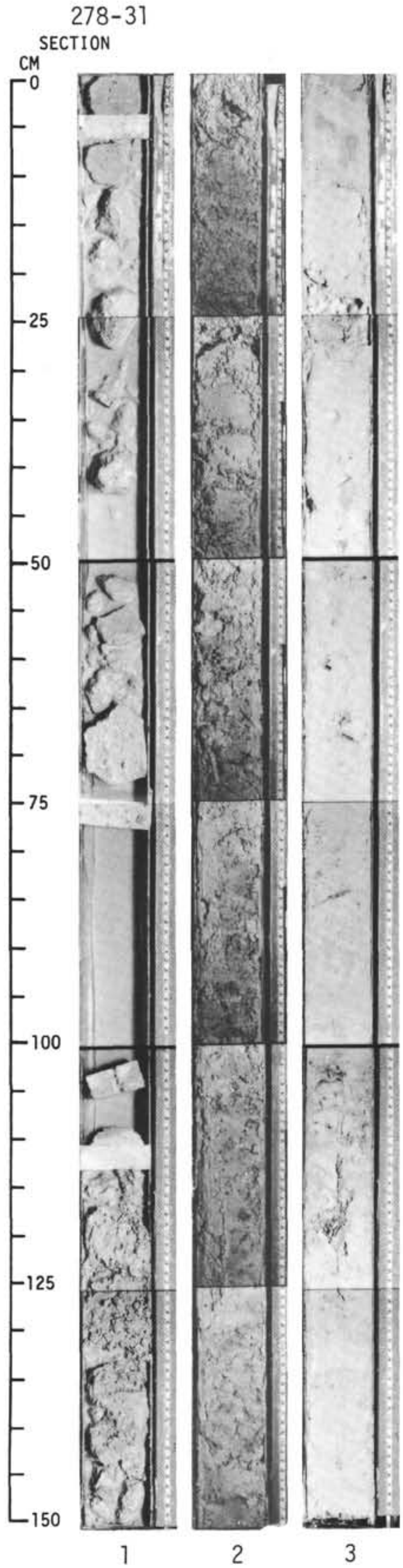
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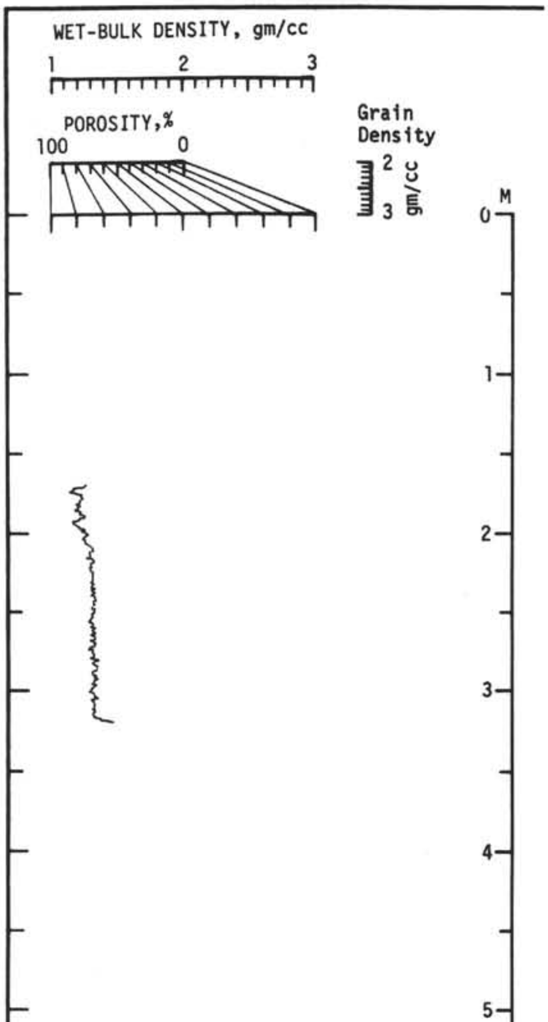
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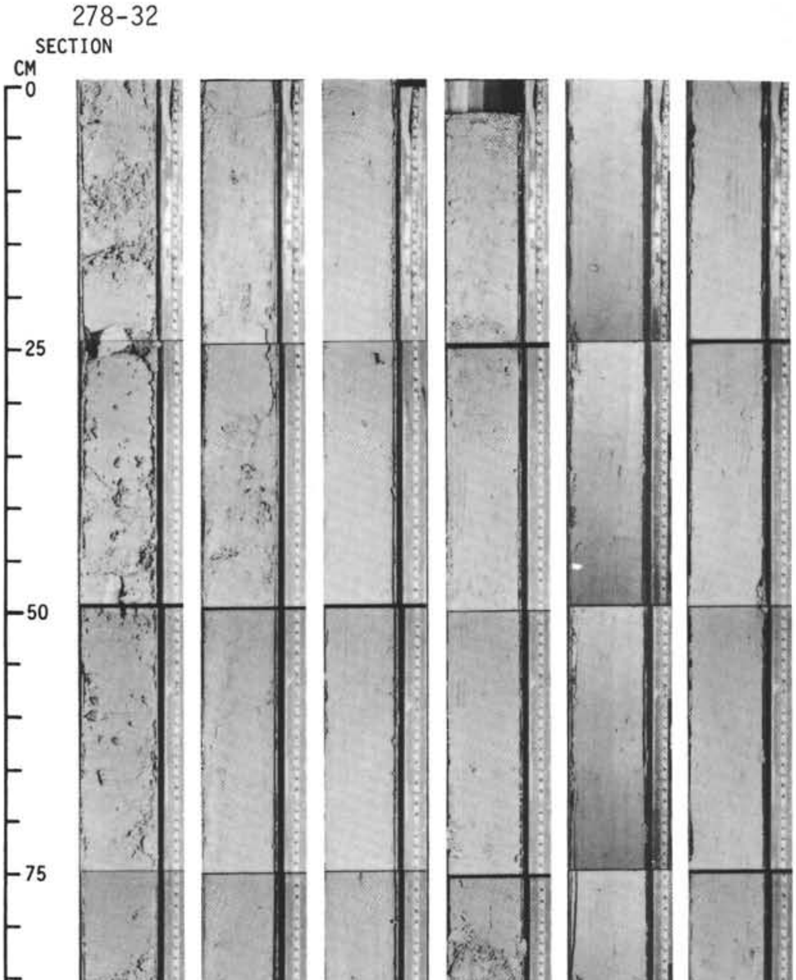
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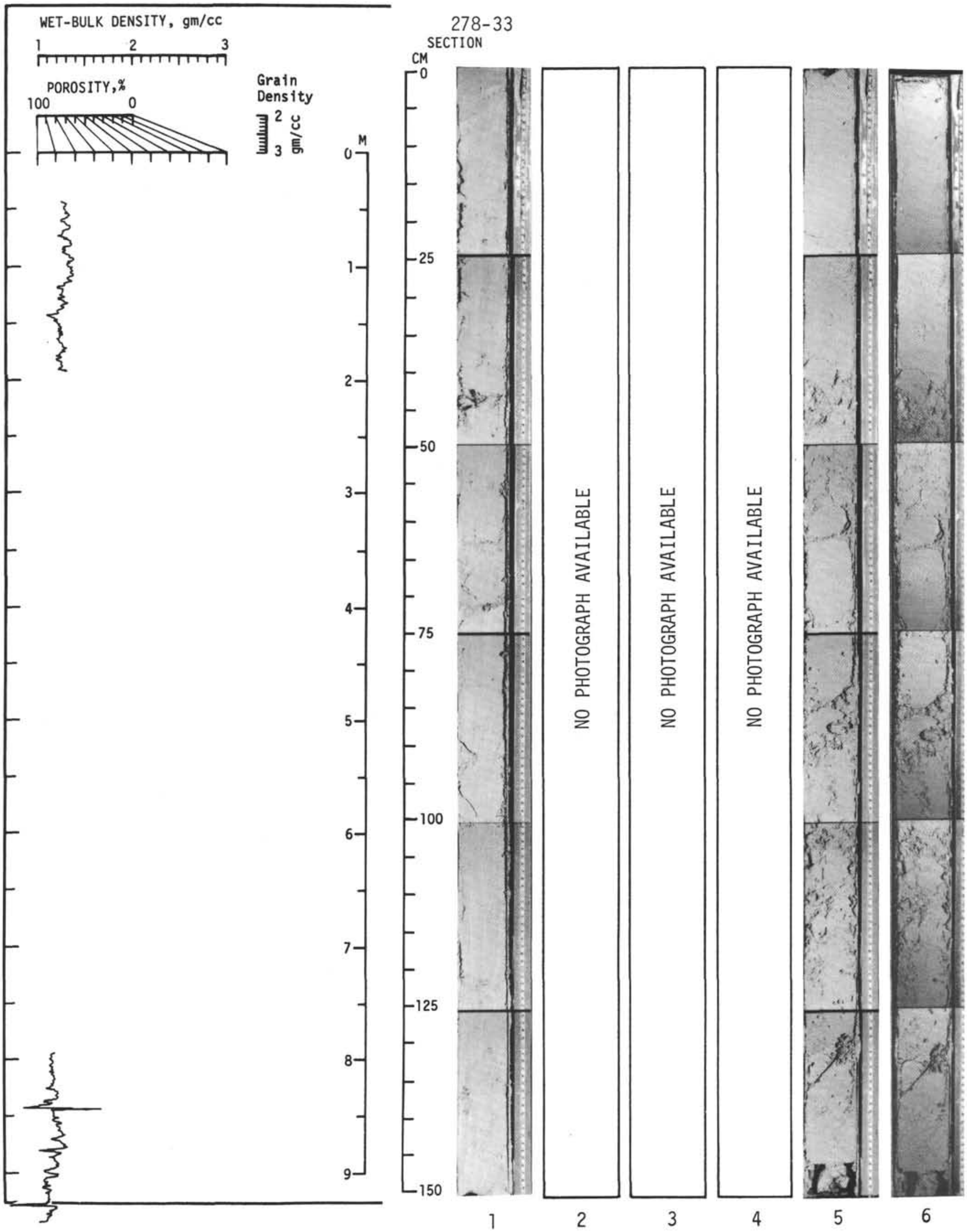
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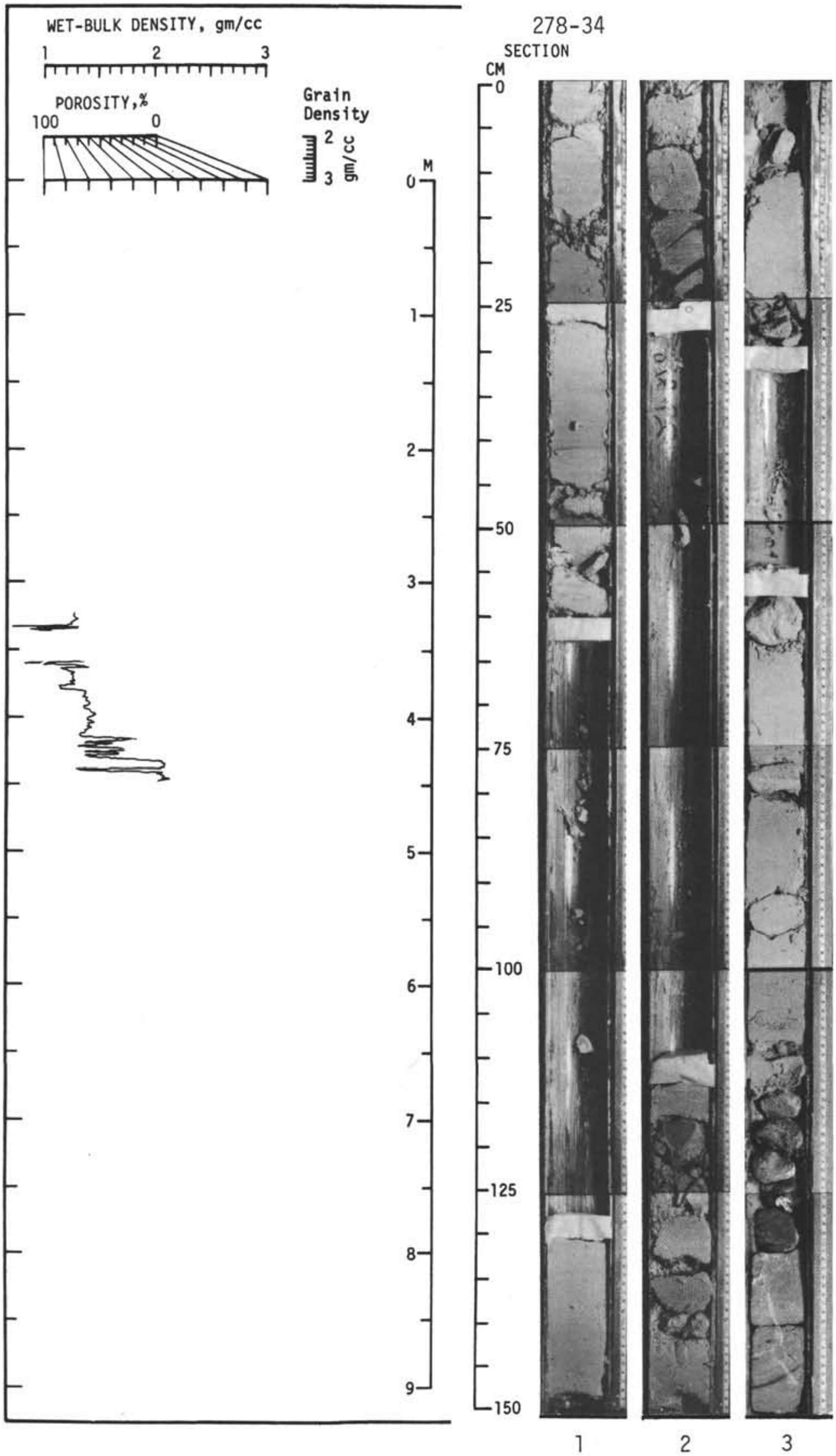
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278-34
SECTION
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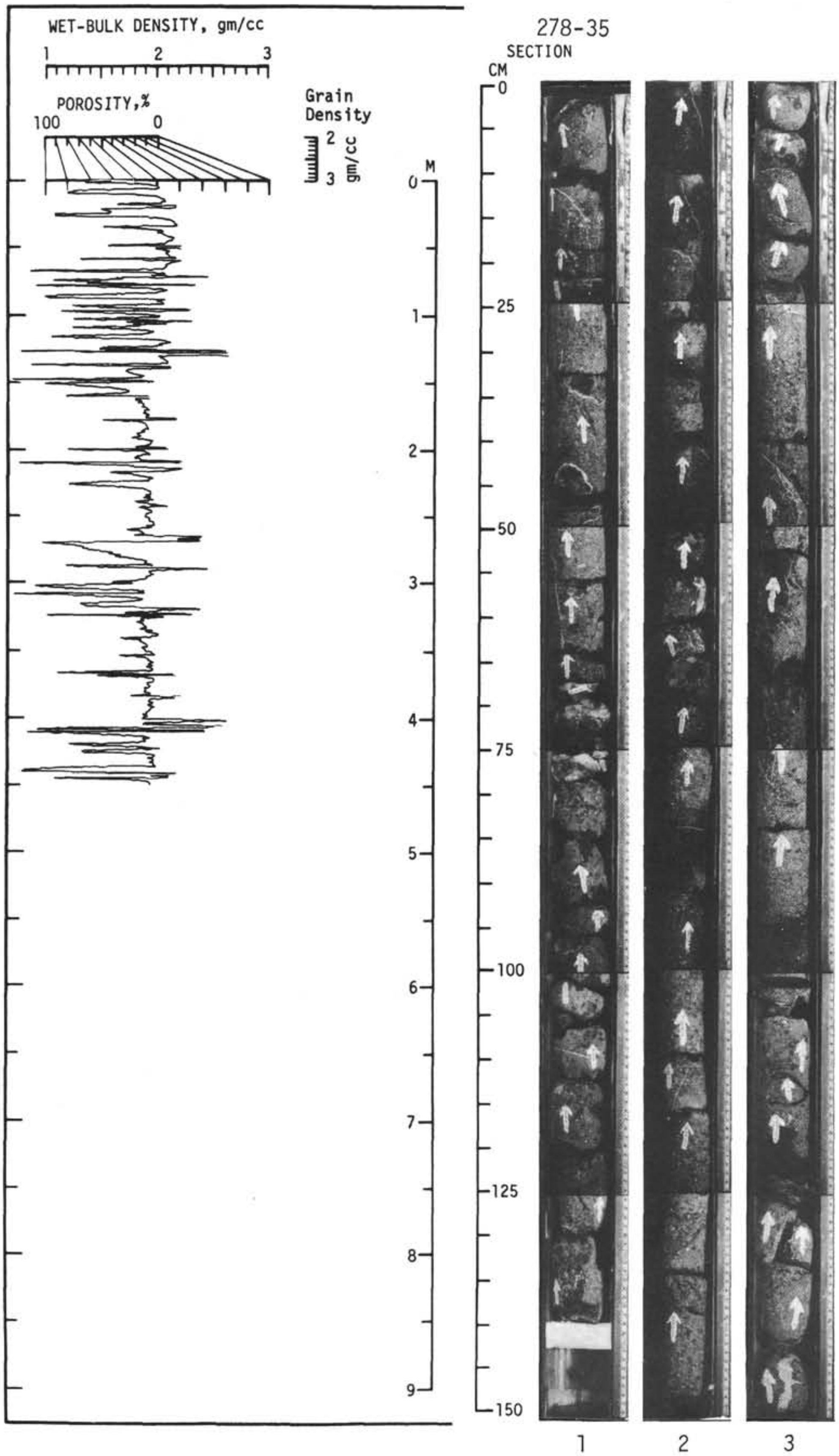
1 2 3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gm/cc
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278-35
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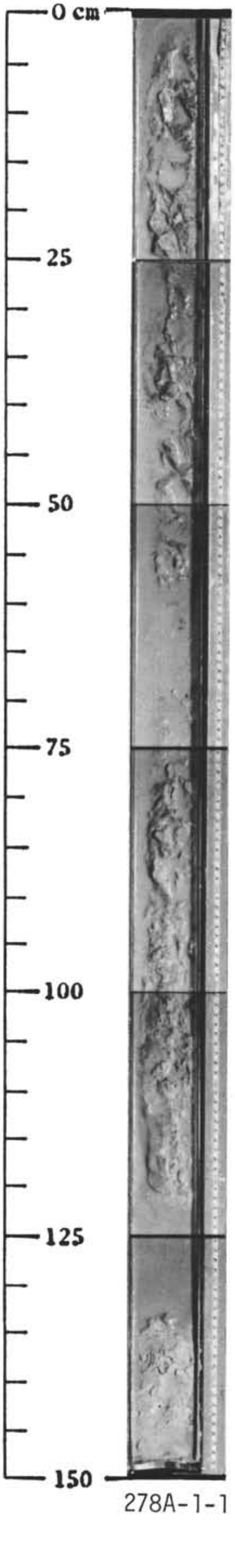
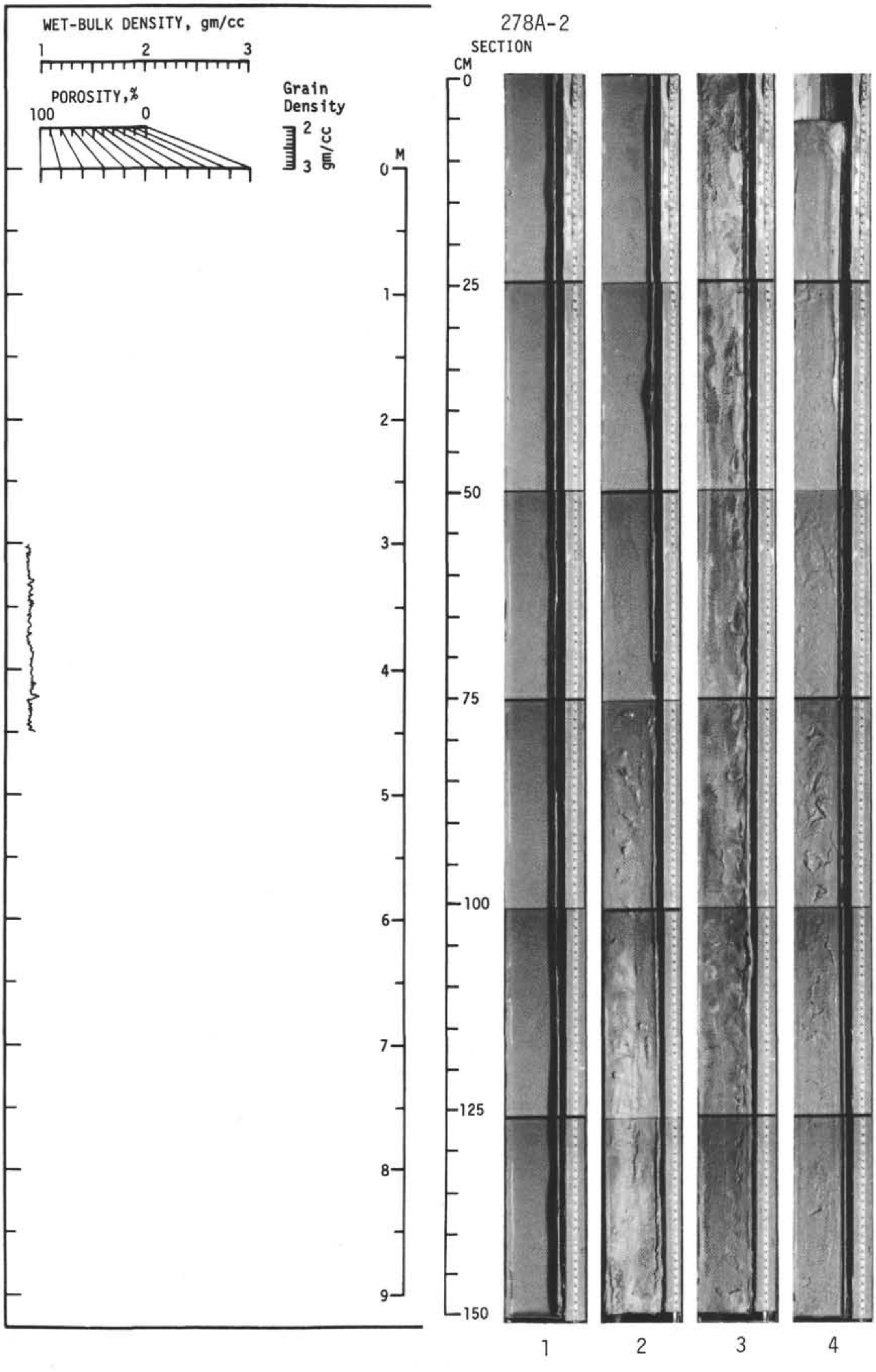


278A-1-1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278A-2
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