9. SITE 178

The Shipboard Scientific Party[1]

ABSTRACT

At Site 178, 777.5 meters of sediment and 17 meters of basalt were cored and drilled. The upper 270 meters is gray mud with ice-rafted erratics; glacial-marine sediments are as old as mid-Pliocene. From 270 meters to 742 meters there are interbedded muds, diatomaceous sediments, thin poorly sorted silts and sand turbidites. At 742 meters, a distinctive varicolored claystone and chalk separates the turbidites above from the underlying 29 meters of pelagic shale above basement. The section ranges in age from Pleistocene through earliest Miocene. The 20 m.y. discrepancy between the earliest Miocene age and the anomaly 20 basement age is not resolved; however, no microfossils were recovered in the 27 meters of shale above the basalt and the basement may occur below the basalt drilled. Rates of sedimentation based on diatom and radiolarian zonations in the section younger than 1 m.y. are are from 70 to 180 m/m.y. and between early Pleistocene and earliest Miocene they are about 30 m/m.y. (Sedimentation rates uncorrected for compaction).

SITE SUMMARY

Date Occupied: 1-5 July 1971.

Position (Satellite):
Latitude: 56°57.38′N;
Longitude: 147°07.86′W.

Number of Holes: One

Water Depth: 4218 meters.

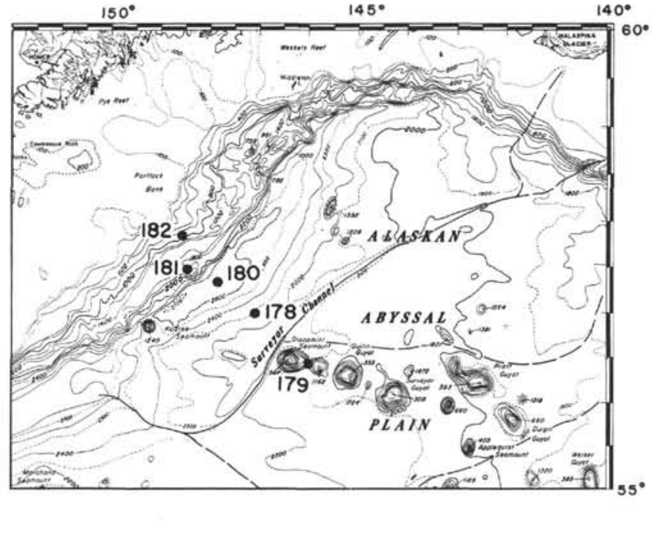
Penetration: 794.5 meters below sea floor.

Number of Cores: 59.

Total Core Recovered: 212.5 meters, 40.9%.

Age of Oldest Sediment: Early Miocene.

Acoustic Basement:
Depth: 777.5 meters.
Nature: Basalt.



BACKGROUND AND OBJECTIVES

Site Description

Site 178 is on the western Alaskan Abyssal Plain, 330 km from Kodiak Island at latitude 56°57.38′N and longitude 147°07.86°W, in 4218 meters of water. The Aleutian Trench and Kodiak Seamount are west of the site, Surveyor Channel and Giacomini Seamount are on the east (Figure 1). Seismic reflection records indicate that a 800- to 1100-meter-thick section of turbidites and hemipelagic sediments occur at the site. This section extends from under the Aleutian Trench into the Gulf of Alaska and it is thought to be representative of the Alaskan Abyssal Plain stratigraphy.

The seismic records show single reflections and groups of reflections that can be traced more than 100 km. Lateral variation in layering is seen where moderate to small buried turbidity current channels disturb the otherwise parallel reflections. Vertically the record shows moderate variability from weak narrow reflectors to strong wide ones.

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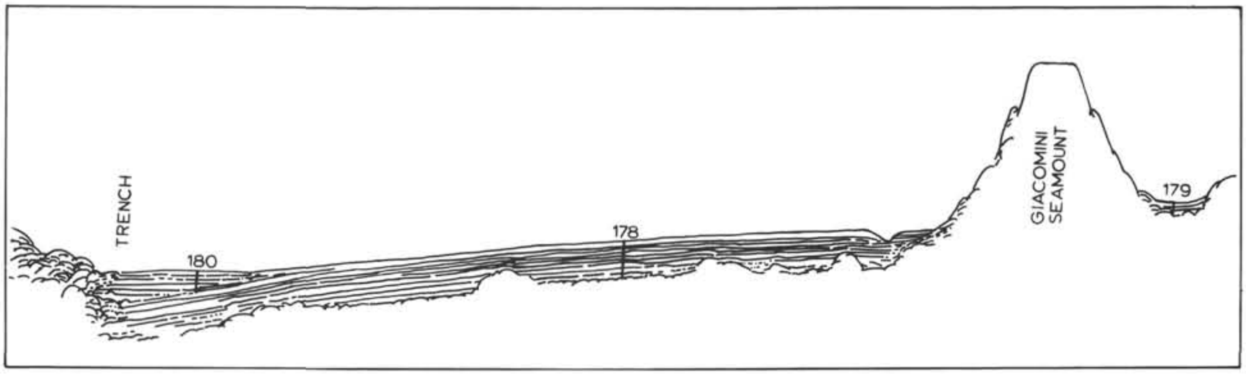

Figure 1. *Diagrammatic section (based on reflection records) across the Aleutian Trench and adjacent abyssal plain showing setting of Sites 178 through 180.*

Site Objectives

The broad objectives in sampling at this site are to study tectonism of the continental margin of Alaska and investigate the geologic history of the Gulf of Alaska. The biostratigraphy of this section is needed to help establish Tertiary faunal and floral successions for high-latitude regions. The time span of glacially derived material at this site may indicate when strong glaciation began in Alaska. It is also possible that the ocean crust now in the Gulf of Alaska was once farther south and that it migrated north as new sea floor was generated (Atwater, 1970). This idea may at least be partially tested by studying the lithology and biostratigraphy at Site 178. It is also possible to date sediments filling the Aleutian Trench. The objectives of this site are closely tied to the similar objectives of the set of sites 178, 180 and 181.

LITHOLOGIC SUMMARY

General Statement

A 777.5 meter section of deep-sea sediments overlies olivine basalt at this site. The uppermost 280 meters consists mainly of thick bedded silty clay with sand- to pebble-sized metamorphic and sedimentary erratics.[2] Towards the base of this unit, the erratics decrease in number and silt laminae and beds increase in abundance, reaching a maximum of 6 per meter section. From 280 to 742 meters, erratics are absent and silty clay, diatomaceous sediments (diatom-bearing silty clays to diatom ooze) and thin bedded very poorly sorted silt and very fine sand turbidites are interbedded in varying proportions. At 742 meters, a readily identifiable marker unit exists; it consists of 6.5 meters of interbedded chalk and varicolored claystone (shades of brown and olive gray) with abundant, well-preserved burrows emphasized by color contrasts. Between this marker unit and the basalt, there are 29 meters of clay shales barren of microfossils. The contact between the basalt and the overlying clay shale is not baked, and the basalt is glassy and vesicular, indicating that the fine-grained sediments were laid down on submarine basalt flows. The following units are defined on the basis of different proportions of various sediment types.

Lithologic Units

Unit 1 (0-96 m; Cores 1-11)

This uppermost unit consists of very sticky, medium dark gray (N 4) silty clay, commonly with erratics (1 to 6 pebbles per meter exposed in the cut surface of the core). Erratics are especially abundant in two zones, from 24 to 33 meters and from 60 to 96 meters. They range in size up to 9-cm pebbles; the granules and pebbles are angular to subrounded with a few having recognizable striations of their surfaces. The lithologies include graywacke, sandstone, shale, and amphibolite. Laminae of silt occur very rarely. Diatoms are noticeably absent, although rare intervals of diatom-bearing silty clay and two layers of olive gray (5 Y 4/1) silty clay-rich diatom ooze (36 and 16 cm thick at 7 and 9 meters, respectively) are present. Several layers of light ash are visible (noted on summary core log); they are 1 to 14 cm thick, silt to fine sand sized, and occasionally graded.

Unit 2 (96-141 m; Cores 12-16)

This unit also consists of medium dark gray silty clay but the number of erratics decreases noticeably below 96 meters (less than 1 pebble per meter). Several diatom-bearing to diatom-rich silty clay intervals are present; they tend to be dark greenish gray (5 GY 4/1). Silty clay diatom oozes occur at 100 meters (8 cm thick), 106 meters (10 cm), 135 meters (5 cm) and 137 meters (215 cm). Silt laminae are rare.

Unit 3 (141-280 m; Cores 17-29)

In this unit, the number of visible erratics is greater than in the second unit but low (1 pebble per meter). However, the abundance of silt layers increases in the silty clays which are olive gray (5 Y 4/1) and medium dark gray, and the diatoms decrease. The silt layers are generally 2 mm to 2 cm thick, although layers up to 12 cm thick occur rarely.

[2] The relative abundances of erratics noted are based on visual inspection of cut core surfaces only. The abundances of erratics, based on X-radiography is explained in von Huene, Chapter 21. A more thorough discussion of silts is given in Chapter 23, this volume.

On the average, 1 to 6 layers are present per meter of core, with the abundance increasing with depth in the subunit. The silt layers frequently have sharp bases and grade upward into silty clays through a zone of interlaminated silt and silty clay. Concentrations of hornblende at the bases of silt beds are present in the interval between 175 and 180 meters. A few layers of light ash, 1 to 5 cm thick, occur, and two layers of very fine sand sized brown glass are visible at 152 meters (50 cm thick) and 224 meters (3 cm thick).

Unit 4 (280-357 m; Cores 30-37)

This unit consists of predominantly diatomaceous sediments (diatom-bearing silty clay to diatom ooze) with interbeds of silty clay and thin, poorly sorted silt to very fine sand turbidites. The silty clayey sediments are olive gray, dark greenish gray, and greenish gray (5 GY 5/1), with those sediments having higher concentrations of diatoms frequently tending towards greenish gray. Contacts between fine sediments of varying diatom concentration are not well defined. The sand or silt intervals of the turbidites generally are 2 to 15 cm thick but can be as thick as 55 cm. They comprise about 5 to 10 per cent of the upper part of the unit and generally increase down section to a maximum of 30 per cent. The poorly sorted nature of these turbidites is due more to admixed medium and fine silt than to clay. Sharp bases and grading are evident in many of the turbidites, and, occasionally, the diatom abundances increase upwards in the silty clays overlying sandy bases.

Unit 5 (357-410±10 m; Cores 37-39)

This unit consists predominantly of olive gray to greenish gray silty clay and diatom-bearing silty clay to diatom ooze; sandy or silty turbidites are generally absent. Occasional horizontal burrows, *Zoophycus*, are revealed by color contrasts in the silty clays. From 392 to 399 meters, there is an unusual occurrence of thin interbeds of olive gray fine silt and medium dark gray silty clay. The silt layers have a modal size of 6 to 8 microns, are composed dominantly of quartz with some carbonate, are well sorted and occur in laminae 2 mm to 2 cm thick, and are separated by 2- to 15-cm-thick silty clay intervals with no biogenous components.

Unit 6 (410±10 - 456 m; Cores 40-43)

This unit is characterized by thin, poorly sorted silt and very fine sand turbidites interbedded with olive gray and dark greenish gray silty clays. The sand-silt basal portions of the turbidites are up to 25 cm thick and may comprise around 35 per cent of the section. Well-preserved, pebble-sized mud clasts are present above a basal sand in one turbidite at 447 meters. Some of the sand-silt beds may be cemented by calcium carbonate as indicated by one such bed recovered in the core catcher at 437 meters.

Unit 7 (456-505±10 m; Cores 44-46)

This unit is characterized by olive gray to dark greenish gray silty clay with intervals of greenish gray clayey diatom ooze, clay-bearing diatom ooze, or diatom ooze, and rare beds of very fine sand.

Unit 8 (505±10 - 560 m; Cores 47-48)

This unit consists predominantly of poorly sorted silt and very fine sand turbidites with the sand-silt intervals comprising a total of 30 to 50 per cent of the section and ranging in thickness from 1 to 40 cm. The silty clay intervals (pelagic and turbidite tails) are dark greenish gray to olive gray. Carbonate-cemented siltstone and sandstone were encountered at 553 meters.

Unit 9 (560-630 m; Core 49)

Turbidites are absent and olive gray and dark greenish gray silty clay and diatomaceous sediments characterize the interval between 615 and 645 meters. A 150-cm-thick greenish gray diatom ooze bed extends from 631 to 632.5 meters.

Unit 10 (630-688 m; Cores 50-52)

This section consists of thin-bedded, poorly sorted silt and very fine sand turbidites and olive gray to dark greenish gray silty clays with rare diatomaceous sediments. Calcareous-cemented, poorly sorted fine sandstone (25 cm thick) is present at 658 meters.

Unit 11 (688-742 m; Cores 52-53)

Hard, olive gray and dark greenish gray silty clays with no or only trace biogenous components characterize this lowermost unit.

Unit 12 (742-748.5 m; Core 54)

A readily identifiable unit occurs between 742 and 748.5 meters; it consists of interbedded chalk and vari-colored claystone. Four chalk intervals (25 to 60 cm thick) are present, and they vary from light olive gray (5 Y 6/2) to light greenish gray (5 GY 7/1) to grayish orange pink (5 YR 7/2). They are separated by claystone intervals (25 to 300 cm thick) that range from dark yellowish brown (10 YR 4/2) to moderate brown (5 YR 4/4) to to light olive gray (5 Y 6/2) and pale yellowish brown (10 Y 6/2). Some zones of the claystones contain as much as 20 per cent diatoms and radiolarians, while others are barren. The entire unit is mottled by burrowing, with most of the burrowing being horizontal (including *Zoophycus*).

Unit 13 (748.5-777.5 m; Cores 55-57)

A 31-meter-thick olive gray, dusky yellowish brown (10 YR 2/2) and dark yellowish brown (10 YR 4/2) clay shale unit occurs just above the basalt basement. It is barren of biogenous materials.

Unit 14 (777.5-794.5 m; Cores 58-59)

Olivine basalt in contact with the overlying olive gray shale was recovered at 777.5 meters. The basalt continues downwards to at least 794.5 meters, at which point the drilling was terminated.

PETROGRAPHY OF THE BASALT

Hole 178 penetrated 17 meters of basalt of which 40 cm were recovered. In hand specimen the basalt core is dark gray and generally unaltered. In thin section, the rock ranges from glass with scattered phenocrysts of olivine to rather coarse-grained holocrystalline basalt. Between the two textural extremes, the rock shows progressive increase in crystallinity and, particularly interesting, shows a feathery texture of the olivine.

The glass phase of the rock is a translucent brown to nearly opaque. Olivine phenocrysts range from few to numerous in the thin sections, but have a very irregular distribution. Most are euhedral but occasional phenocrysts show the start of additional terminal growth.

The intermediate stage of crystallization consists of small plagioclase laths and a very fine grained ground mass containing feathery olivine. Occasional phenocrysts and crystals of olivine can be seen to form nuclei from which the feathery lattice structure has grown. A different aspect of the growth consists of a network of acicular crystals up to 2 mm in length that dominate the slide. By extrapolation through a series of slides, the olivine nature of all the acicular and feathery forms can be demonstrated.

Coarse-grained variations of the basalt have a diabasic sort of texture with laths of plagioclase, interstitial pyroxene and much chloritized groundmass. In a few coarse-grained sections, relict phenocrysts of olivine have altered to a mixture of serpentine, carbonate, and iddingsite. Several of the coarsest-grained rocks have no indication of olivine.

The core section is incomplete and rather broken up; samples from both of the cores lack a consistent pattern of crystallinity. In fact, the glassiest samples are from the lower part of the section. It is, therefore, probable that the cored section was through a series of pillows on the sea floor or multiple thin surface flows.

PALEONTOLOGIC SUMMARY

Introduction

Calcareous microfossils are rare or absent in post-Lower Miocene sediments encountered from 0 to 720 meters (Cores 0 to 53) at Site 178 due to deposition below the calcium carbonate compensation level (CCL). In contrast, siliceous microfossils are present throughout the entire Pleistocene through Lower Miocene section with diatom-rich muds and diatomites predominant within the 287- to 742-meter interval (Cores 30 to 53). A striking coccolith-rich chalk[3] containing Lower Miocene foraminifera occurs in Core 54 (742 to 749 meters) and appears to represent the terminal phase of a regionally significant lithologic event produced by a lowered CCL and/or prolific production of calcareous nannoplankton.

The base of the lower Pleistocene *Eucyrtidium matuyamai* radiolarian zone could not be precisely located at Site 178 although it occurs at the base of or below Core 22 (195 m). Apparent Pliocene radiolarian faunas occur below Core 22. The Pliocene-Pleistocene boundary is arbitrarily located at the base of Core 22 (195 meters) on the basis of this tentative radiolarian zonation; diatom and planktonic foraminiferal zonation tend to support this placement of the boundary.[4] North Pacific Diatom (NPD) Zone V, thought to correlate in part with the base of the Olduvai geomagnetic event, spans Cores 18 through 28 (152 to 243 meters). In addition, *Globigerina pachyderma* exhibits a change from sinistral to dextral coiling between Cores 14 to 18 (123 to 159 meters) representing a major increase in surface temperature thought to correlate with the lower portion of Blow's (1969) basal Pleistocene zone N22.

Pliocene radiolarian species are present as low as Core 37 (360 meters). Radiolarians do not provide good stratigraphic control below Core 22. Pliocene planktonic foraminifera are present through Core 29 (255 meters).

Pliocene diatom floras encompassing NPD Zones V through X are recognized from Core 28 through Core 52 (690.5 meters) with an Upper Miocene flora (NPD Zone XIV) recognized in Core 53.

Well preserved planktonic foraminfera of Lower Miocene age are present in the multicolored chalk encountered in Core 54 (742 to 749 meters) and are correlated with Blow's (1969) zone N5 and the lower portion of zone N6. Beggren (1972) currently correlates the base of zone N5 with an estimated radiometric age of 21 m.y. and the top of this zone with an age of 19.5 m.y. A limited coccolith flora in Core 54 supports the Lower Miocene age of this unit.

Calcareous Nannofossils

Most of the sediment examined from Site 178 was deposited below the calcium carbonate compensation level; therefore, few calcareous nannofossils were found in Cores 1 through 50 (0 to 638.5 meters). A few nondiagnostic species such as *Coccolithus pelagicus* were noted in isolated samples and these are assumed to have been deposited in association with turbidites. The Core 51 core catcher (667 meters) contains reworked Oligocene-Miocene coccoliths and discoasters deposited within a gray turbidite silt. Core 54 (742 to 749 meters) recovered a multicolored chalk composed almost exclusively of broken or isolated rims derived from *Coccolithus miopelagicus, Coccolithus* sp. cf. *pliopelagicus*, and *Cyclicargolithus bukryi* Wise n. sp. *Discoaster deflandrei*, including forms heavily overgrown by secondary calcite, is also common in some samples of this chalk. The calcite overgrowths on the discoasters are similar to those described at Site 172 which indicates that the nannofossil ooze deposited at the Site 178 underwent some amount of early diagenesis and cementation prior to deep burial under 742 meters of clastic sediment. This would explain the surprising absence of compaction features in the chalk. *Zoophycus* burrows show little or no flattening and delicate features such as partially etched but intact coccosphaeres show no distortion at all. Apparently, the nannofossil ooze was sufficiently well lithified during early cementation to prevent significant compaction during the subsequent loading of hundreds of meters of clastic sediment.

The nannofossil assemblage from the chalk is highly restricted to a few cold-water species including forms not

[3]See Wise, Chapter 15, this volume, for a detailed discussion of chalk ultrastructure and origin.

[4]See Chapter 21 for 1.8 m.y. paleomagnetic boundary.

found in warmer waters. *Coccolithus pliopelagicus* closely resembles a cold-water member of the *Coccolithus* sp. cf. *pelagicus* lineage. *Cyclicargolithus floridanus.* The cosmopolitan *Discoaster deflandrei* is the only astrolith present. As a rule, *Discoaster* is a warm-water genus with well over a hundred species reported from low and middle latitudes. The relatively small numbers of *Discoaster deflandrei* present in Core 54 and those reworked into higher strata are the only Neogene discoasters reported to date from the Gulf of Alaska.

Planktonic foraminifera indicate that the chalk is Early Miocene in age. The calcareous nannofossils are considered to be Early Miocene as well, certainly not younger than Middle Middle Miocene. Diatoms extend down to Section 3 in Core 54 and these are classified Late Miocene in age; perhaps these have been reworked downward by burrowing organisms. Above the chalk, siliceous organisms are the dominant constituent of the planktonic fauna and flora. As evidenced by the records at Sites 177 and 178, the cold-water-restricted calcareous nannoplankton floras made only minor contributions to the post-Lower Miocene fossil record in northeast Pacific during the remainder of the Neogene. This has resulted in the breakdown of the "standard" Neogene calcareous nannofossil zonation based on their occurrence (summarized by Martini and Worsley, 1970).

The occurrence of nannofossil chalk at this high latitude (56°N) and at such great depth (4960 meters below sea level) is somewhat remarkable. Although tectonics could be invoked to explain this phenomenon, it is noteworthy that the chalk is underlain by pelagic clays rather than turbidites. Thus, it is most probable that the chalk represents a sharp downward excursion of the carbonate compensation level produced by an exceptionally high production of calcareous phytoplankton. These supplied large amounts of skeletal carbonate to the sea floor and increased the sedimentation rate sufficiently to depress the carbonate compensation level several hundreds of meters. It has previously been noted (Tracy et al., 1971) that in the equatorial Pacific, the Early Miocene was a time of widespread carbonate deposition. Perhaps favorable current conditions allowed the incursion of carbonates into the Gulf of Alaska during this time.

Diatoms

Varying abundances of diatoms in good to poor states of preservation were found throughout the sequence penetrated at Site 178. The interval from 0 to 740 meters (Cores 1 to 53) represents a continuous record of high diatom productivity from the Holocene through the Upper Miocene interrupted only by intermittent influxes of terrigenous sand, silt, and mud turbidites. The amount of older reworked microfossils is negligible.

The base of Pleistocene NPD Zone I is placed at 46 meters (178-6-3, 130-132cm), the base of NPD Zone II at 125 meters (178-15-2, 36-38cm), and the base of combined NPD zones II and IV at 152 meters (178-18-2, 45-47cm). The base of Pliocene NPD Zone V is placed at 243 meters (178-28-4, 5-7cm), the base of NPD Zone VII is tentatively placed at 360 meters (178-37-4, 133-135cm), and the base of NPD VIII is tentatively placed at 465 meters (178-46-6, 121-123cm). The base of Pliocene NPD Zone IX and X is tentatively placed at 690.5 meters (178-52, CC).

Upper Miocene NPD Zone XIV was recognized in Core 53 at Site 178 but the base of this zone could not be defined. The oldest diatom-bearing sediment recovered at Site 178 is placed within NPD Zone XIV and occurs at 746 meters (178-54-3, 126-127cm).

The preservation of diatom frustules is generally poor due to dissolution from 289 to 746 meters (178-30-2, 62-64cm to 178-54-3, 126-127cm) with only the more robust tests been preserved. Thus, *Coscinodiscus marginatus, C. marginatus* forma *fossilis,* and *C. symbolophorus* occur in abundance within this interval whereas weakly silicified diatoms including various species of *Denticula, Thalassiosira,* and *Nitzschia* have been dissolved.

Planktonic Foraminifera

Foraminifera are absent or rare in most of the sediments recovered at Site 178. Paucity of foraminifera and other calcareous microfossils apparently reflects continuous deposition below the calcium carbonate compensation level during most of the interval represented. Rare and occasionally common specimens of poorly preserved foraminifera were found in Cores 1 to 14 (0 to 123 meters) and in Cores 18 to 29 (150 to 270 meters) within a sequence characterized by muds, silts, and glacial erratics. Relatively rapid burial by terrigenous clastics apparently provided minimal protection from aggressive bottom water during this interval. Predominantly diatomaceous sediments recovered from 270 to 742 meters (cores 30 to 53) are barren of foraminifera with the exception of rare benthic specimens in Cores 31, 33, and 34 reflecting the slower rate of sedimentation and consequent exposure of tests during this interval. Common and well-preserved foraminifera are present in Core 54 (742 to 749 meters) within a multicolored coccolith chalk. A clay shale encountered from 749 to 778 meters (cores 54 to 58) proved to be barren of all microfossils.

Planktonic foraminiferal faunas encountered from 0 to 123 meters (Cores 1 to 14) are dominated by sinistral coiling populations of *Globigerina pachyderma* representing mean surface temperatures lower than 5°C and are correlated with Pleistocene zones N23 and N22. Dextral coiling populations of this same species dominate faunas from 150 to 225 meters (cores 18 to 29) and probably represent surface temperatures higher than 15°C within the Alaskan Current gyre. Correlations with Sites 173 and 174 suggest this latter warm event encompasses the later Pliocene and early Pleistocene equivalent to zones N21 and N22. *Globigerina bulloides* and *G. quinqueloba* constitute common accessory species within the Plio-Pleistocene interval with one unusual assemblage at 242 meters (178-28-3, 65-67cm) characterized by an abundance of *Globorotalia scitula*.

Planktonic foraminifera recovered from the chalk in Core 54 (742 to 749 meters) include *Catapsydrax dissimilis, C. stainforthi, C. unacava* s.l., *Globorotalia obesa, G. opima nana, G. praescitula,* and *Globoquadrina* cf. *praedehiscens* indicating this important lithologic horizon is Lower Miocene in age equivalent to Blow's (1969) zone N5 through perhaps the lower portion of Zone N6.

Benthonic Foraminifera

Sparse calcareous and arenaceous benthonic foraminifera occur at scattered horizons within the Plio-Pleistocene clastic sediments from 0 to 270 meters (Cores 1 to 29). These faunas are composed of species common to modern high-latitude lower bathyal-abyssal faunas and include *Cibicides wuellerstorfi, Gyroidina soldani, Melonis pompilioides, Pulleria bulloides,* and *Uvigerina auberiana.* Admixtures of species displaced from shallower water include common specimens of *Eilohedra levicula, Epistominella exigua,* and *Globobulimina affinis* with graded intervals containing rare abraded specimens of neritic species such as *Elphidium clavatum*.

Benthonic foraminifera are common and well preserved within the lower Miocene chalk of Core 54 (749 to 778 meters). These faunas are relatively diverse but retain a lower bathyal character with common specimens of *Cibicides kullenbergi, Nuttallides umbonifera, Pleurostomella elliptica, Pullenia bulloides,* and several species of *Stilostomella.*

Radiolaria

Cores 1 through 22 (0 to 195 meters) contain reasonably rich radiolarian faunas. Cores 23 to 53 (195 to 720 meters) contain only sporadic radiolarian occurrences with few age-diagnostic species.

Cores 1 through 8 (0 to 69 meters) contain assemblages representing the upper Pleistocene-Holocene *Artostrobium miralestense* Zone of Hays (1970). The upper limit of *Druppatractus acquilonius* occurs at 51 to 60 meters (178-6, CC to 178-7, CC) within this zone and is correlative with an estimated radiometric age of 0.3 m.y. Cores 9 through 15 (69 to 125 meters) represent *Axoprunum angelinum* zone; the top of this zone (178-8, CC to 178-9-1, 136-138 cm) has an estimated radiometric age of 0.4 m.y. whereas the base of the zone has an age of 0.9 m.y. Cores 15 through 22 (125 to 196 meters) represent the lower Pleistocene *Eucyrtidium mutuyamai* zone, but its base cannot be recognized with certainty. Below Core 22 (195 meters) sporadic specimens of *Lamprocyrtis heteroporos* indicate Pliocene ages through at least Core 37 (363 meters). Cores 52 (686.5 to 690.5 meters) and 54 (742 to 749 meters) contain Miocene species that are not diagnostic of any specific zones.

Spores and Pollen

Samples examined from Site 178 generally contain few or no palynomorphs. Pollen occurring in amounts worthy of note (Cores 24 and 42) is so badly preserved and oxidized that specific identification is impossible. Moreover, identifiable grains (*Tsuga, Alnus, Salix, Pinus*, psilate and trilete spores) were present in such small quantities that no paleoclimatological determinations could be made.

Coaly fragments occur commonly throughout the cores. When samples were high in diatomaceous material, no palynomorphs or coal fragments were observed. This is certainly the result of dilution by terrigenous sediment and by rapid deposition of organic silica.

PHYSICAL PROPERTIES

Physical properties were measured at Site 178 in the standard manner as on previous sites. Time was available to measure physical properties on more sections than previously because of long core retrieval time and a faster GRAPE carriage speed.

GRAPE porosity shows some good correlations with lithology. For instance, hard fissile muds show a marked increase in porosity as do ash beds and diatom-rich sediments. Clean sands also correlate with a well-defined porosity increase, but when dirty, the sands produce a good low-porosity peak in the GRAPE records. Larger ice-rafted erratics are easily spotted. However, to be meaningful, the GRAPE records must be interpreted with care because almost all of the above effects can be confused in the records with effects from drilling disturbance. Another effect that invalidates the absolute GRAPE porosity value is the small core diameter resulting when harder rock is cored. Porosity and density values for the shales, sandstones, and limey mudstones (all harder rocks) from this site are invalid in an absolute sense but are considered very good in a relative sense.

In the upper 100 meters of core, porosity values generally range between 45 and 60 percent. Fairly pure mud shows a GRAPE variation of only 5 percent and with ash and silt admixtures, porosities range as much as 20 percent. The range in porosity increases somewhat between 100 and 300 meters correlating with the increasing frequency and amount of the silts, ashes and diatomaceous sediments recognized visually. Below 300 meters, large ranges of GRAPE values indicate large variation in sediment type or a change from a more monolithologic sequence to significantly greater variation of beds with a large range in porosity (as great as 50 percent in one section). One of the greatest ranges in values results when a diatomaceous bed is found in the same section with a sand.

Sonic velocity measurements were made on the least disturbed and most consolidated material in one or more sections of all but two cores. The material was taken out of the core liner for measurement. Three measurements were made on each sample and, on some shales, measurements were made parallel and perpendicular to bedding planes.

CORRELATION BETWEEN REFLECTION RECORDS AND THE STRATIGRAPHIC COLUMN

Site 178 was selected from seismic records made in 1970 by the USGS (von Huene, 1972). Because of their good quality, these records were relied on most for a comparison with lithologies in the drill hole and to extrapolate lateral variations in specific lithologic intervals (Figure 2). However, all depths are calculated using travel times picked from the on-station record because the site may be located as much as 2 km from the ship's track along which the USGS seismic record was made.

Velocities used in calculating depths from travel times are a composite of those reported in the previous section and sonobuoy velocities (von Heune, 1972). Because of poor velocity control in the lower part of the hole due to interval coring, poor recovery, and wide ranges in velocity values, the seismic and lithologic sections are not correlated with as great a certainty as in the upper part of the hole. In some instances, such as Unit 4, changes in reflective character that approximate lithologic units were relied on most.

Table 1 summarizes the correlation of seismic information and lithology. Five records (two USGS, two *Challenger,* and one University of Washington) were available

Figure 2. *Seismic record (U.S.G.S.) near Site 178 showing lithologic and acoustic character is best in the multiple for Units 1-4 and better in the primary for Units 5-13.*

TABLE 1
DSDP Site 178 – Acoustic and Lithologic Summary

Unit	Cores	Interval (sec)	Velocity (km/sec)	Depths (m)	Lithologic Description	Acoustic Character	Thickness	Interpretation of Lithologic and Acoustic Information
1	1-11	0-0.13	(1.5)	0-96	Mud, dark gray, sticky, few to abundant erratics.	Sharp, fine, unevenly spaced, reflections with variable amplitude; stronger reflection at 0.07 sec (53 m)	96 m	Massive continuous beds of gray mud, with variable amounts of erratics broken by thin diatom-rich muds and ash probably with a very continuous 5 to 10-m-thick diatom-rich mud bed or sand in the middle of the unit. The unit was probably deposited during the most intense period of glaciation (0.7 to 0.9 m.y. long).
2	12-16	0.13-0.19	(1.5)	96-141	As Unit 1 with more diatom-rich intervals and fewer erratics.	A "translucent" unit with weak, fuzzy, non-persistent, low-frequency reflections.	45 m	Same as above with more frequent diatom-rich mud intervals that may have gradational contacts and less distinct bedding. (May indicate slightly less intense glacial environment.)
3	17-29	0.19-0.37	(1.5)	141-280	As Unit 1 with more silt and fewer diatom-rich intervals.	Generally weaker low-frequency but moderately continuous reflections that are stronger; unit at same depth as a channel.	139 m	Same as 96 m with more frequent continuous silt beds. Silt below 182 m probably derived from last overbank activity of a tributary of Surveyor Channel system about 1.5 to 2.0 m.y. ago. The bottom of this unit probably received the first erratics from occasional times of heavy sea ice and a large contribution of finely ground mountain-valley glacial debris to give muds their gray color.
4	30-37	0.37-0.45	(2.0)	280-357	Mud interbedded with diatom-rich mud, diatom ooze, and fine sand to silt turbidites.	Strong continuous high-frequency reflections and low-frequency reflections grading into Unit 5.	77 m	Irregular lensing and pinching beds of mud interbeds with diatom-rich intervals and silt and sand deposits from either a single large channel to the west or a series of smaller shifting channels.
5	37-39	0.45-0.51	(1.7)	357-410±10	As in 4 without silt and fine sand turbidites.	As in 4, with weaker reflectivity on *Slave* and and *Challenger* record, but stronger on primary.	53 m	Massive beds of mud. Probably a period of lower Pliocene abyssal conditions without effects of deep-sea turbidity current channels.
6 & 7	39-46	0.51-0.63	(1.7)	410±10-505±10	Mud with interbedded silt and fine sand turbidites grading to diatom-rich intervals in lower part.	Strong low-frequency reflections in upper part separated from weaker reflections in lower part by a single strong reflection on *Challenger* record, consistently strong low-frequency on U.S.G.S. record.	95 m	Mudstone beds broken by silts and some fine sand beds. Lower part broken by beds of diatom oozes. Abyssal condition with some turbidity current action. First ashes indicate beginning of present volcanic period on the Alaska Peninsula.
8	47-48	0.63-0.70	(1.6)	505±10-560	Mainly silt and sand turbidites with some mud.	Weak low-frequency reflections, now persistent, that pinch out toward trench.	55 m	A thick unit of sand and silt turbidites with breaks of mud. This unit is derived from a channel to the east pinching to one-half its thickness in 100 km.

9	49	0.70-0.76	(2.0)	560-630	Silt and very fine sand turbidites with mud intervals.	Very strong continuous low-frequency reflections becoming wider toward trench.	70 m	Thick sand and silt interbedded with mud
10 & 11	50-53	0.76-0.84	(2.7)	630-742	Variable sequence of sediments from mud to silt and sand.	Weak to moderate discontinuous low-frequency reflections showing very indistinct signs of stratification.	110 m	Generally hard mud and silt with a possible silt to sand bed near the middle of the unit. Bedding appears very irregular at drill site but on the other side of a basement hump to the west the beds at the same depth are very well stratified. Site 178 may be in an unusual basement area, and the configuration of the basalt flow may cause unique lithology.
12 & 13	54-57			742	Chalk underlain by claystone.	Very strong low-frequency reflections with a somewhat irregular upper surface.		Continuous beds with a rough upper surface indicating pelagic deposition.

for interpretation and each record provided some information not available in the others. Figure 2 is a USGS record that shows most of the main acoustically determined features.

SUMMARY AND CONCLUSIONS

Site 178 is on the Alaskan Abyssal Plain about midway between Surveyor Channel and the Aleutian Trench. The abyssal sediment section is often more than 800 meters thick. The age of basement at this site, based on magnetic anomaly 20 (Pitman and Hays, 1967), is about 50 m.y. In seismic records, the layered section can be followed under the Aleutian Trench and in some instances seen under the continental slope (von Huene, 1972). The configuration of reflections suggests that the section consists of turbidite layers interbedded with some hemipelagic and pelagic layers.

This site was one of three chosen to study tectonic mechanisms operating along the continental margin of Alaska and to investigate the geologic history of the Gulf of Alaska. The site was also drilled in an attempt to establish the biostratigraphy of siliceous microfossils at this latitude.

Core recovery was poor because of a malfunction in the bottom-hole assembly. Accordingly, the stratigraphic section is not well known, especially below 360 meters where continuous coring was terminated and interval coring was started. The hole was drilled to a total depth of 794.5 meters which includes about 17 meters of coring in basalt.

Sediments at Site 178 may be grouped into three main lithologic sequences with each sequence suggesting a pronounced change in environment. The upper 270 meters consist of dark and medium gray muds with ice-rafted erratics. The erratics are most abundant in the first 100 meters, and decrease in the lower part of the unit where the number of silt beds increase. From 270 to 742 meters, muds, diatomaceous sediments, and thin, very poorly sorted silt and very fine sand turbidites are interbedded in varying proportions. At 742 meters, a distinctive varicolored mottled claystone and chalk was recovered. Between this horizon and the basalt basement, there are 27 meters of shale composed of pelagic clay.

The lower sequence indicates a typical abyssal environment and a sudden short interception of the bottom by the calcium carbonate compensation level. This lower Miocene depression of the compensation level may have been synchronous with major uplift of the Chugach-St. Elias Mountains. This may also have been a time when the Kula Ridge was being subducted (Atwater 1970). The intermediate sequence marks a change from the previous pelagic and hemipelagic sedimentation to turbidite sedimentation. It is a time of abyssal turbidity current channels broken by short periods of quiescence as marked by zones rich in diatoms. Continued uplift of the mountains fringing the Gulf of Alaska and short periods of mountain-valley glaciation may have provided changing types of sediment. An increasing proximity to land by westward plate movement may also be reflected in the lithology. The first volcanic ash, possibly from the Alaska Peninsula, is in the upper Miocene section. The upper sequence reflects strong glaciation and the uppermost 100 meters indicate exceedingly rapid denudation on land.

The sedimentary section ranges in age from Pleistocene through early Miocene. Calcareous microfossils are absent through much of it because water depths are below the calcium carbonate compensation zone. However, siliceous microfossils are present in most of the cores with diatom floras being locally abundant. Microfossil assemblages date the upper gray muds containing erratics as Pleistocene and the glacial erratics and gray mud continue about halfway through the Pliocene section. The distinctive varicolored chalk and mudstone interval in Core 54 contains lowermost Miocene nannofossils, planktonic foraminifers, radiolarians, and diatoms. Unfortunately, the 29-meter interval between the varicolored horizon and basement proved barren of microfossils.

On the basis of the diatom ages, rates of sedimentation in the Pleistocene section vary between 170 and 180 m/m.y. assuming the beginning of Pleistocene time at the 1.8 to 2.0 m.y. boundary in Core 23. From Core 28 to Core 54, the rate is 35 m/m.y. assuming a 20 m.y. age at the base of Core 54.[5]

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APPENDIX A. OPERATIONS

Pre-drilling Site Survey

Site 178 was approached from the east on a course of 277° T navigated by Loran A. About 6 hours prior to arrival, it was established that *Challenger* was 5 miles north of the proposed track line. Rather than correcting for the northerly set, *Challenger* remained on course to a point due north of the site and then came to 180° T and 6 knots to make a seismic record crossing the site selection record at right angles. The *Challenger* record showed that no turbidity current channels or faults hindered the objectives for Site 178 and upon reaching the plotted position the geophysical gear was brought aboard, the ship stopped, and the beacon dropped.

Drilling Program

Site 178 is located in 4218 meters of water on the flat Alaskan Abyssal Plain. The water depth was calculated from Matthews Tables (Area 44 was used because Areas 45 and 24 were not available) and the "Hawaii factor" (i.e., 4198 + 14 = 4212 meters to the transducer). The vessel was positioned directly over the beacon.

Site 178 was continuously cored to a depth of 258.5 meters below the sea floor and cored at selected intervals between this depth to the total depth of 794.5 meters. Thin hard sandstone layers encountered at various levels below 427.5 meters did not affect the drilling and several good sandstone cores were recovered. Recovery was poor below the 7-meter-thick varicolored mudstone in Core 54 (749 meters) because of the extreme fissility of the shale encountered. Basalt occurred at 777.5 meters; a total of 3 meters was obtained in Cores 58 and 59.

Hole conditions at Site 178 were excellent largely due to the high percentage of mud in the sedimentary column. The weather was excellent, with calm seas and no currents.

The recovery at Site 178 was 40.9 percent. The unusually low recovery was probably caused by a malfunction in the bottom-hole assembly causing the core barrel to turn.

Drilling Specifications

This hole was cored and drilled from 4229 meters to 5023.5 meters for a total sub-mudline penetration of 794.5 meters. Of the 794.5 meters penetrated, 275 meters were drilled without coring and 519.5 meters were cored with 212.5 meters of core recovered (see Table 2 for the coring summary). The recovery was 40.9 percent. The drilling assembly was the same as used on Holes 177 and 177A; a Smith 4 cone button bit was run.

Hole conditions were very good, positioning was good, and the weather was excellent, but recovery of cores was a problem. The 40.9 percent recovery was marginal for the scientific objectives and disappointing to the operational people. After the drilling assembly was pulled out of the hole, it was discovered that the support housing was sanded up which apparently caused the inner barrel to rotate.

Hole 178 was abandoned and filled with 240 barrels of 10.2 p.p.g. mud.

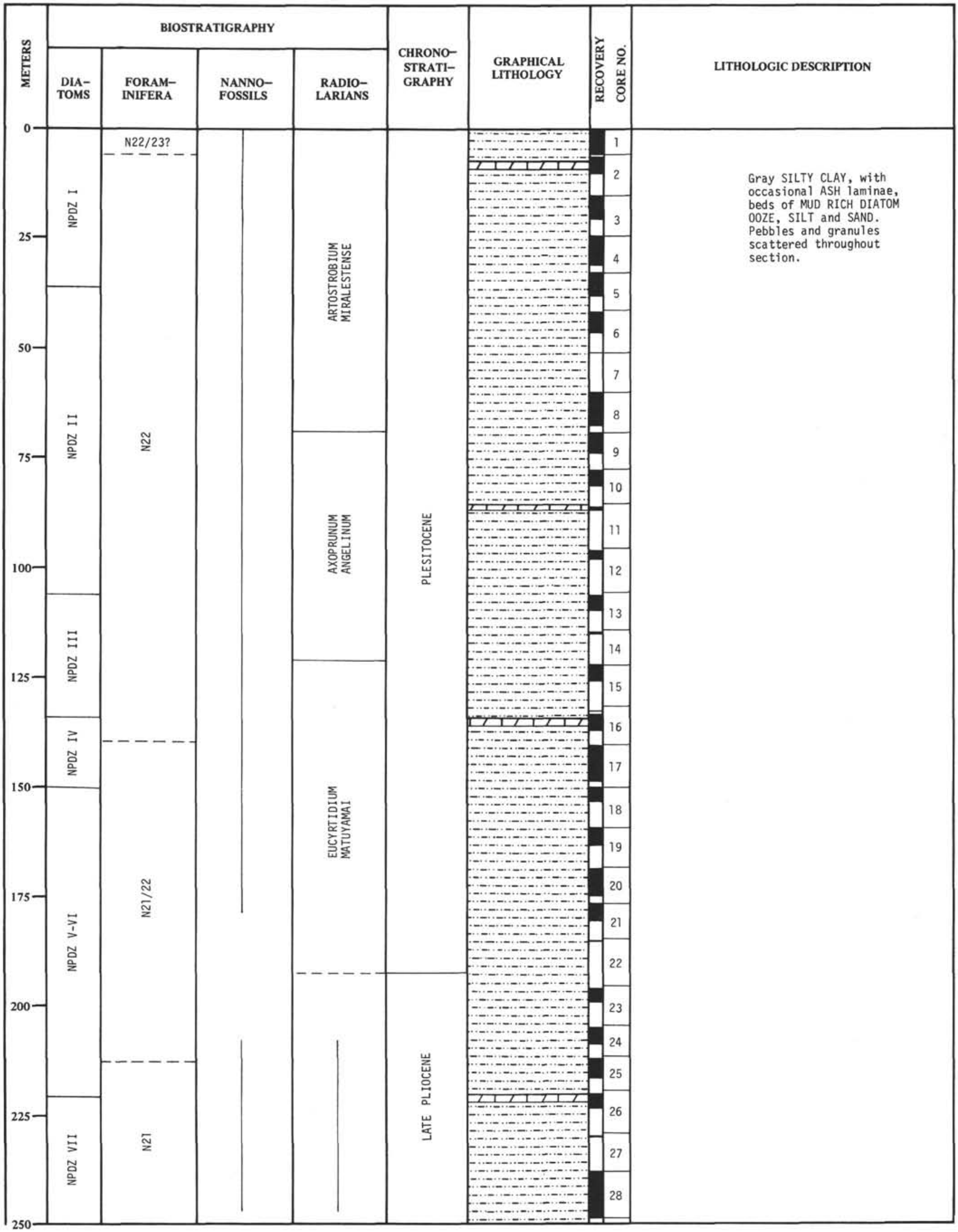
Post-drilling Site Survey

No post-drilling survey was run.

[5] All rates are uncorrected for compaction.

TABLE 2
DSDP Site 178 Coring Summary

Core	Cored Interval Below		Cored	Recovered	
	Derrick Floor (m)	Sea Floor (m)	(m)	(m)	(%)
1	4229.0-4235.0	0-6	6	6.0	100.0
2	4235.0-4244.0	6-15	9	4.0	44.4
3	4244.0-4253.0	15-24	9	5.0	55.6
4	4253.0-4262.0	24-33	9	6.0	66.7
5	4262.0-4271.0	33-42	9	5.5	61.1
6	4271.0-4280.0	42-51	9	4.5	50.0
7	4280.0-4289.0	51-60	9	CC	–
8	4289.0-4298.0	60-69	9	5.5	61.1
9	4298.0-4307.0	69-78	9	5.0	55.6
10	4307.0-4316.0	78-87	9	4.0	44.4
11	4316.0-4325.0	87-96	9	2.5	27.8
12	4325.0-4334.0	96-105	9	3.5	38.9
13	4334.0-4343.0	105-114	9	3.5	38.9
14	4343.0-4352.0	114-123	9	0.5	5.6
15	4352.0-4361.0	123-132	9	3.0	33.3
16	4316.0-4325.0	132-141	9	4.5	50.0
17	4370.0-4379.0	141-150	9	7.0	77.8
18	4379.0-4388.0	150-159	9	3.5	38.9
19	4388.0-4397.0	159-168	9	4.0	44.4
20	4397.0-4406.0	168-177	9	8.0	88.9
21	4406.0-4415.0	177-186	9	5.0	55.6
22	4415.0-4424.0	186-195	9	1.5	16.7
23	4424.0-4433.0	195-204	9	3.5	38.9
24	4433.0-4440.0	204-211	7	4.0	57.1
25	4440.0-4449.5	211.0-220.5	9.5	7.5	78.9
26	4449.5-4459.0	220.5-230.0	9.5	3.5	36.8
27	4459.0-4468.5	230.0-239.5	9.5	1.5	15.8
28	4468.5-4478.0	239.5-249.0	9.5	9.0	94.7
29	4478.0-4487.5	249.0-258.5	9.5	6.0	63.1
30	4516.0-4525.5	287.0-296.5	9.5	1.5	15.8
31	4525.5-4535.0	296.5-306.0	9.5	2.0	21.1
32	4535.0-4544.5	306.0-315.5	9.5	4.5	47.4
33	4544.5-4554.0	315.5-325.0	9.5	7.5	78.9
34	4554.0-4563.5	325.0-334.5	9.5	9.0	94.7
35	4563.5-4573.0	334.5-344.0	9.5	2.0	21.1
36	4573.0-4582.5	344.0-353.5	9.5	2.5	26.3
37	4582.5-4592.0	353.5-363.0	9.5	6.0	63.2
38	4611.0-4620.5	382.0-391.5	9.5	1.5	15.8
39	4620.5-4630.0	391.5-401.0	9.5	7.5	78.9
40	4655.5-4656.5	426.5-427.5	1.0	CC	–
41	4656.5-4666.0	427.5-437.0	9.5	CC	–
42	4666.0-4675.5	437.0-446.5	9.5	CC	–
43	4675.5-4685.0	446.5-456.0	9.5	1.5	15.8
44	4685.0-4694.5	456.0-465.5	9.5	8.5	89.5
45	4694.5-4704.0	465.5-475.0	9.5	1.5	15.8
46	4725.0-4734.5	496.0-505.5	9.5	2.0	21.1
47	4734.5-4744.0	505.5-515.0	9.5	2.5	26.3
48	4763.0-4772.5	534.0-543.5	9.5	1.5	15.8
49	4791.5-4820.0	591.0-600.5	9.5	1.5	15.8
50	4848.5-4858.0	629.0-638.5	9.5	4.5	47.4
51	4886.5-4896.0	657.5-667.0	9.5	2.5	26.3
52	4915.0-4919.0	686.0-690.0	4.0	2.5	62.5
53	4945.0-4949.0	716.0-720.0	4.0	2.5	62.5
54	4971.0-4978.0	742.0-749.0	7.0	7.0	100.0
55	4978.0-4987.5	749.0-758.5	9.5	–	–
56	4987.5-4997.0	758.5-768.0	9.5	CC	–
57	4997.0-5006.5	768.0-777.5	9.5	0.5	5.3
58	5006.5-5016.0	777.5-787.0	9.5	1.5	15.8
59	5016.0-5023.5	787.0-794.5	7.5	1.5	20.0
		Total	519.5	212.5	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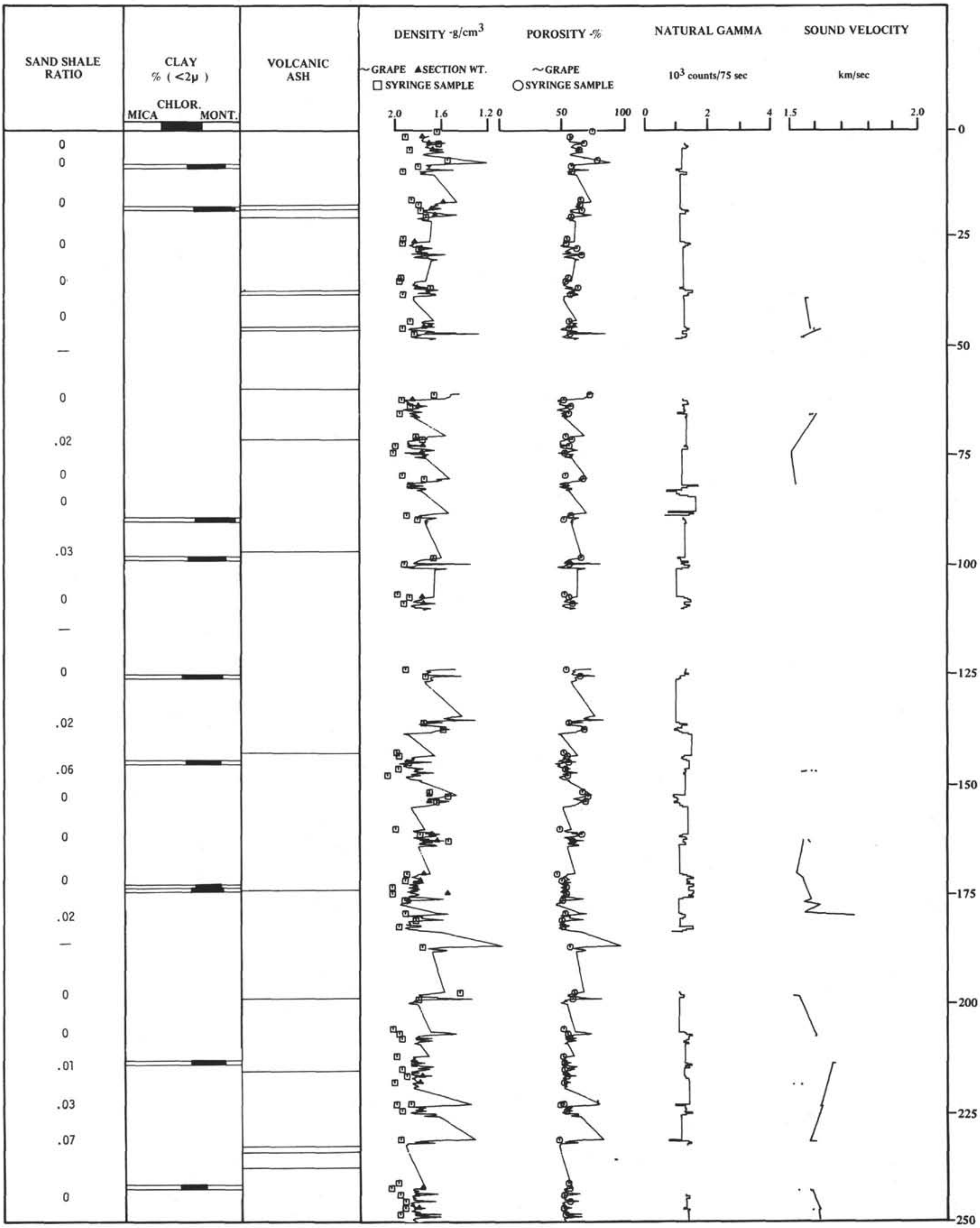
BIOSTRATIGRAPHY
DIA- TOMS
FORAM- INIFERA
NANNO- FOSSILS
RADIO- LARIANS
CHRONO- STRATI- GRAPHY
GRAPHICAL LITHOLOGY
RECOVERY
CORE NO.
LITHOLOGIC DESCRIPTION
0
25
50
75
100
125
150
175
200
225
250
NPDZ I
NPDZ II
NPDZ III
NPDZ IV
NPDZ V-VI
NPDZ VII
N22/23?
N22
N21/22
N21
ARTOSTROBIUM MIRALESTENSE
AXOPRUNUM ANGELINUM
EUCYRTIDIUM MATUYAMAI
PLESITOCENE
LATE PLIOCENE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
Gray SILTY CLAY, with occasional ASH laminae, beds of MUD RICH DIATOM OOZE, SILT and SAND. Pebbles and granules scattered throughout section.



SAND SHALE RATIO
CLAY % (<2μ)
CHLOR.
MICA
MONT.
VOLCANIC ASH
DENSITY -g/cm^3
~GRAPE ▲SECTION WT.
□ SYRINGE SAMPLE
2.0 1.6 1.2
POROSITY -%
~GRAPE
○SYRINGE SAMPLE
0 50 100
NATURAL GAMMA
10^3 counts/75 sec
0 2 4
SOUND VELOCITY
km/sec
1.5 2.0
0
0
0
0
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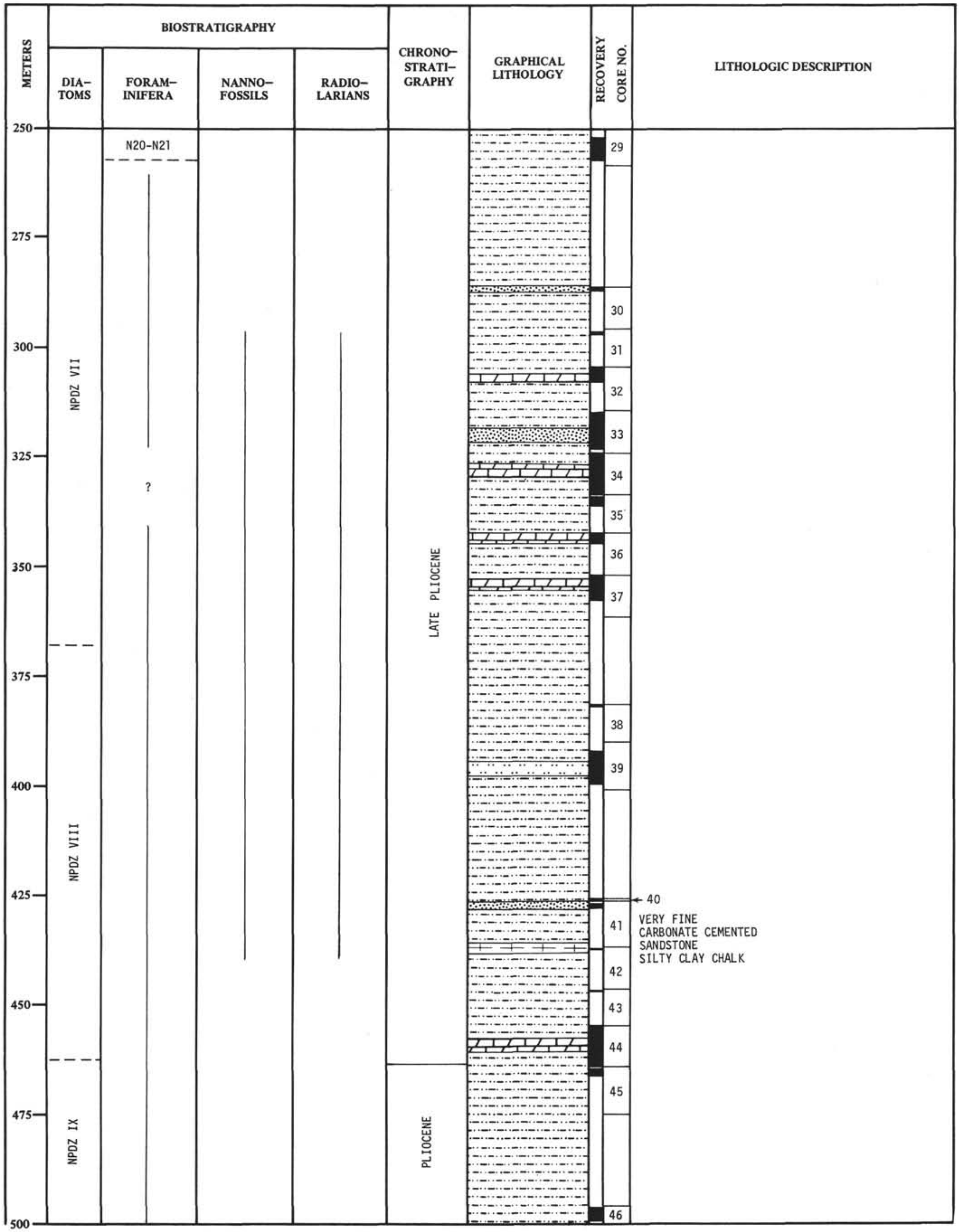
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BIOSTRATIGRAPHY
DIA-TOMS
FORAM-INIFERA
NANNO-FOSSILS
RADIO-LARIANS
CHRONO-STRATI-GRAPHY
GRAPHICAL LITHOLOGY
RECOVERY
CORE NO.
LITHOLOGIC DESCRIPTION
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275
300
325
350
375
400
425
450
475
500
N20-N21
?
NPDZ VII
NPDZ VIII
NPDZ IX
LATE PLIOCENE
PLIOCENE
29
30
31
32
33
34
35
36
37
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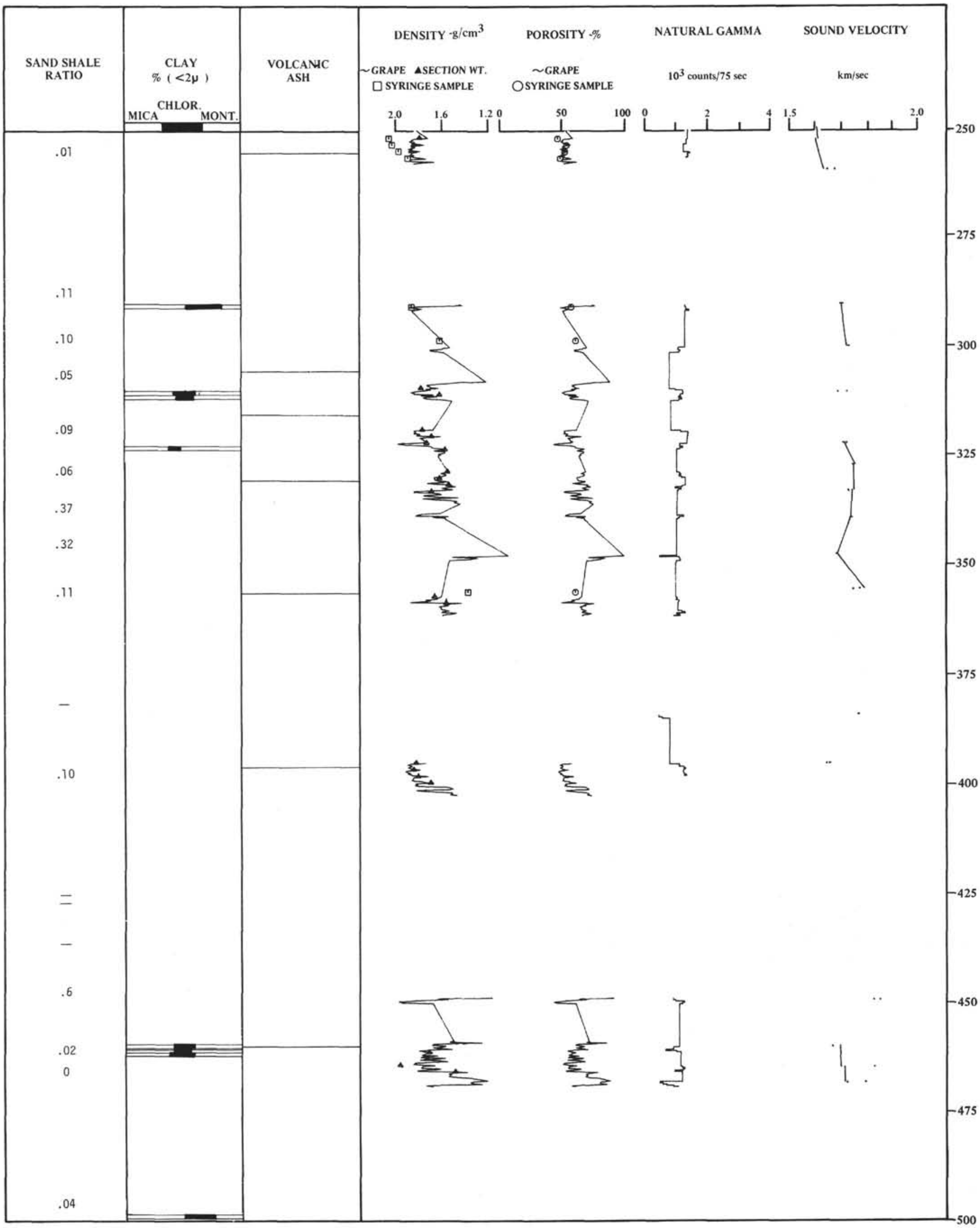
44
45
46
VERY FINE
CARBONATE CEMENTED
SANDSTONE
SILTY CLAY CHALK


SAND SHALE RATIO
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MICA
CHLOR.
MONT.
VOLCANIC ASH
DENSITY -g/cm3
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□ SYRINGE SAMPLE
2.0
1.6
1.2
POROSITY -%
~GRAPE
○SYRINGE SAMPLE
0
50
100
NATURAL GAMMA
10³ counts/75 sec
0
2
4
SOUND VELOCITY
km/sec
1.5
2.0
.01
.11
.10
.05
.09
.06
.37
.32
.11
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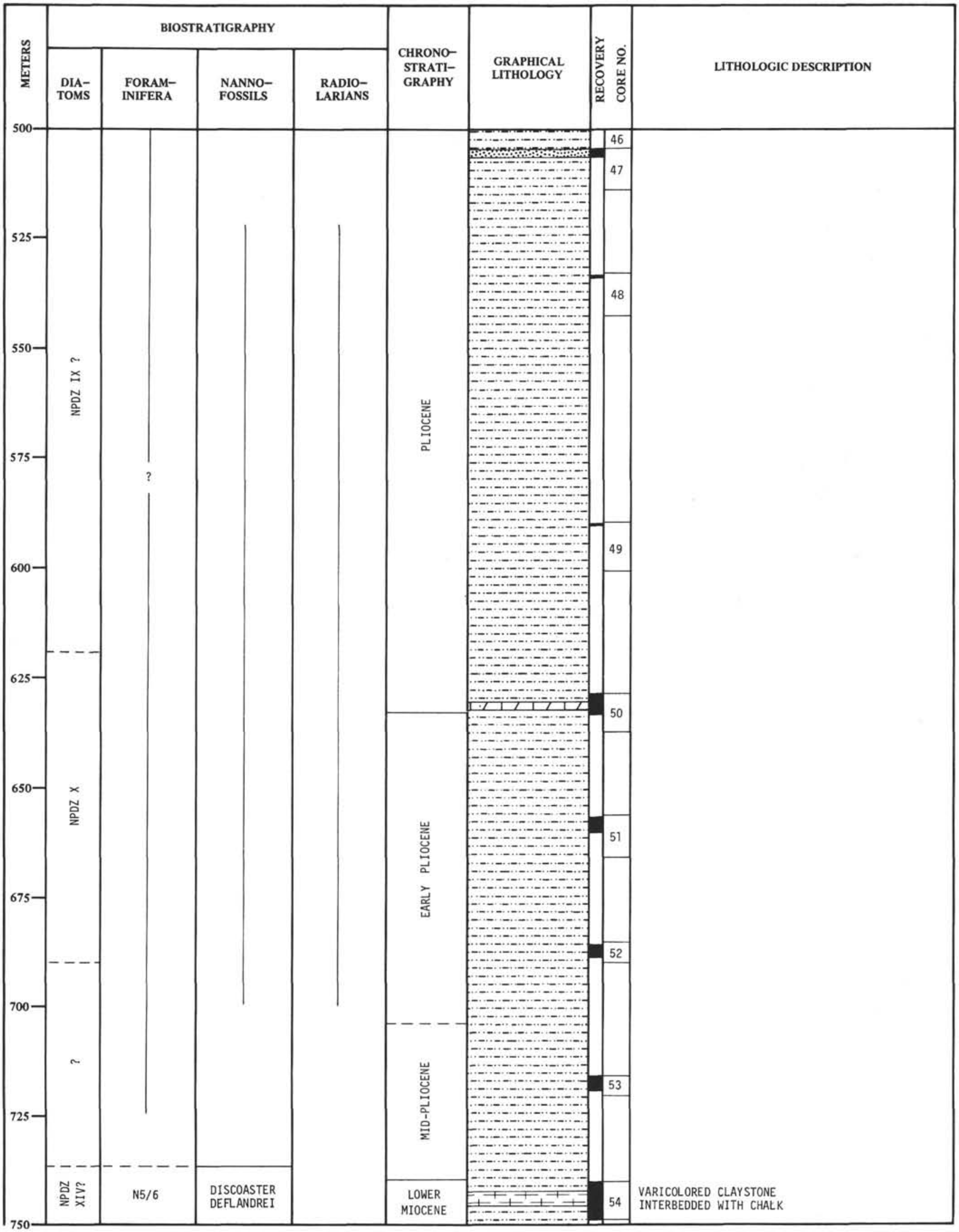
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FORAM-INIFERA
NANNO-FOSSILS
RADIO-LARIANS
CHRONO-STRATI-GRAPHY
GRAPHICAL LITHOLOGY
RECOVERY
CORE NO.
LITHOLOGIC DESCRIPTION
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550
575
600
625
650
675
700
725
750
NPDZ IX ?
NPDZ X
?
NPDZ XIV?
?
N5/6
DISCOASTER DEFLANDREI
PLIOCENE
EARLY PLIOCENE
MID-PLIOCENE
LOWER MIOCENE
46
47
48
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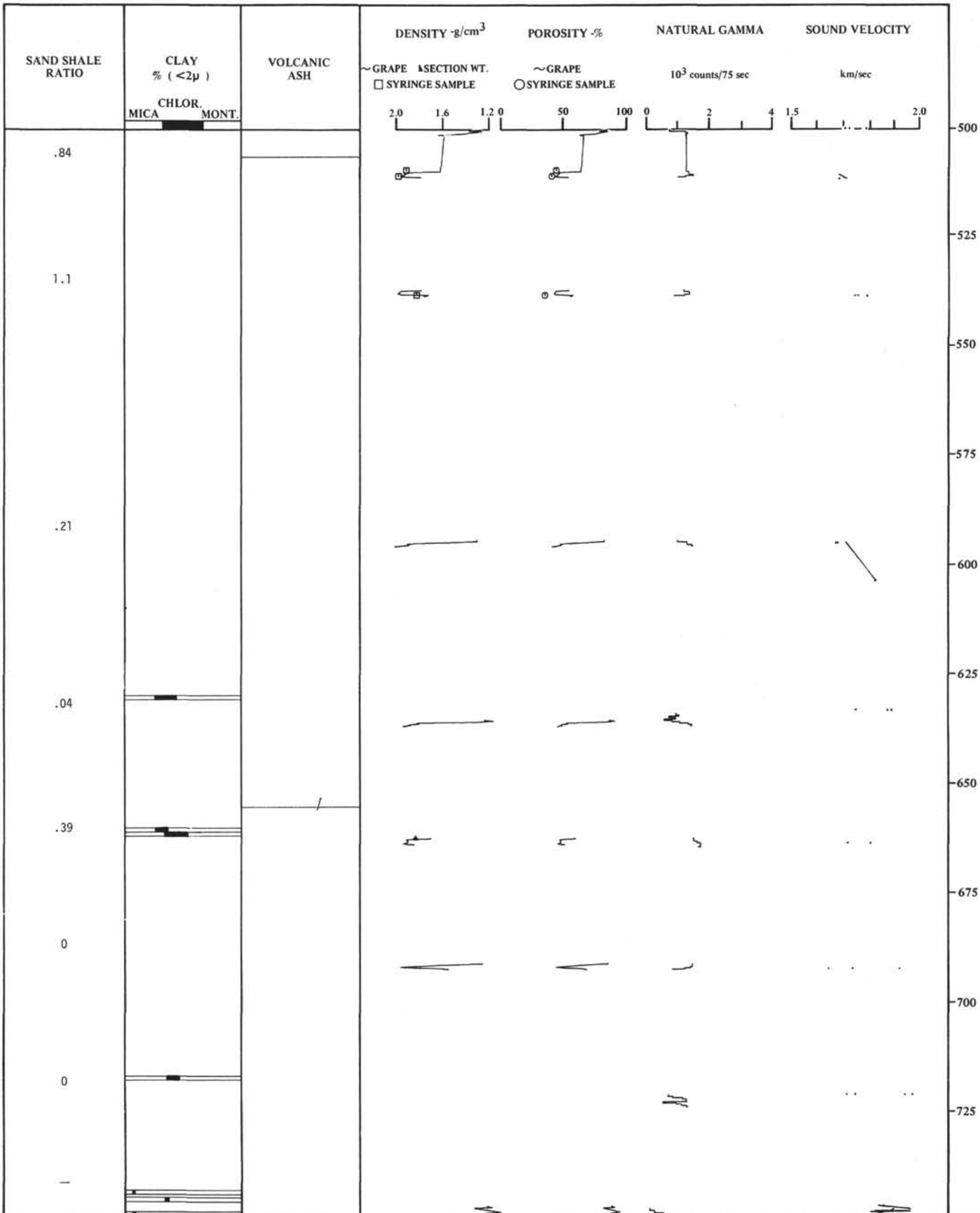
50
51
52
53
54
VARICOLORED CLAYSTONE INTERBEDDED WITH CHALK


SAND SHALE RATIO
CLAY % (<2μ)
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VOLCANIC ASH
DENSITY -g/cm³
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□ SYRINGE SAMPLE
2.0 1.6 1.2
POROSITY -%
~GRAPE
○SYRINGE SAMPLE
0 50 100
NATURAL GAMMA
10³ counts/75 sec
0 2 4
SOUND VELOCITY
km/sec
1.5 2.0
.84
1.1
.21
.04
.39
0
0
—
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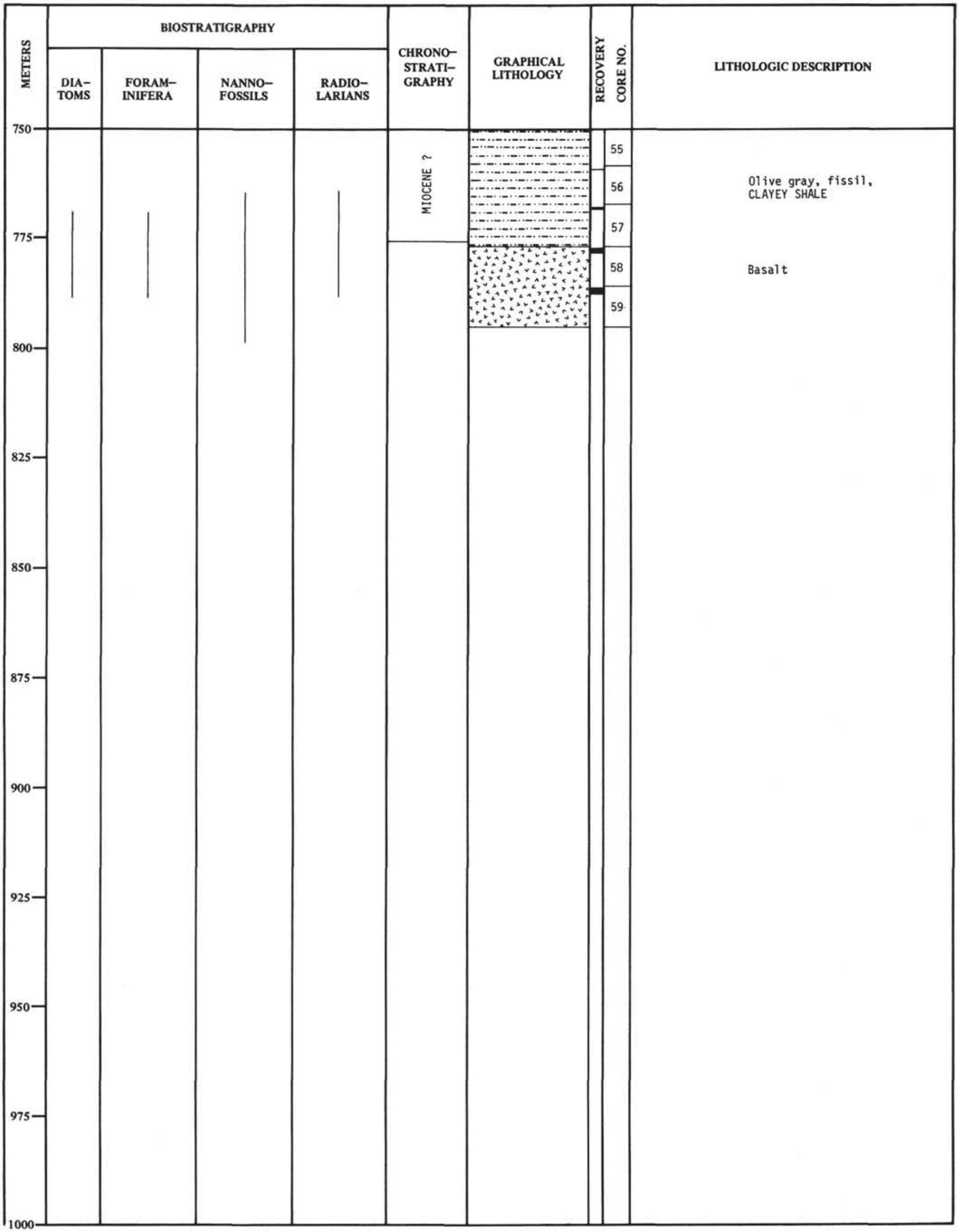
550
575
600
625
650
675
700
725
750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TOMS
FORAM-
INIFERA
NANNO-
FOSSILS
RADIO-
LARIANS
CHRONO-
STRATI-
GRAPHY
GRAPHICAL
LITHOLOGY
RECOVERY
CORE NO.
LITHOLOGIC DESCRIPTION
750
775
800
825
850
875
900
925
950
975
1000
MIOCENE ?
55
56
57
58
59
Olive gray, fissil,
CLAYEY SHALE
Basalt

SAND SHALE RATIO	CLAY % (<2μ) MICA CHLOR. MONT.	VOLCANIC ASH	DENSITY -g/cm^3 ~GRAPE ▲SECTION WT. ☐ SYRINGE SAMPLE 2.0 1.6 1.2	POROSITY -% ~GRAPE ○SYRINGE SAMPLE 0 50 100	NATURAL GAMMA 10^3 counts/75 sec 0 2 4	SOUND VELOCITY km/sec 1.5 2.0
—						
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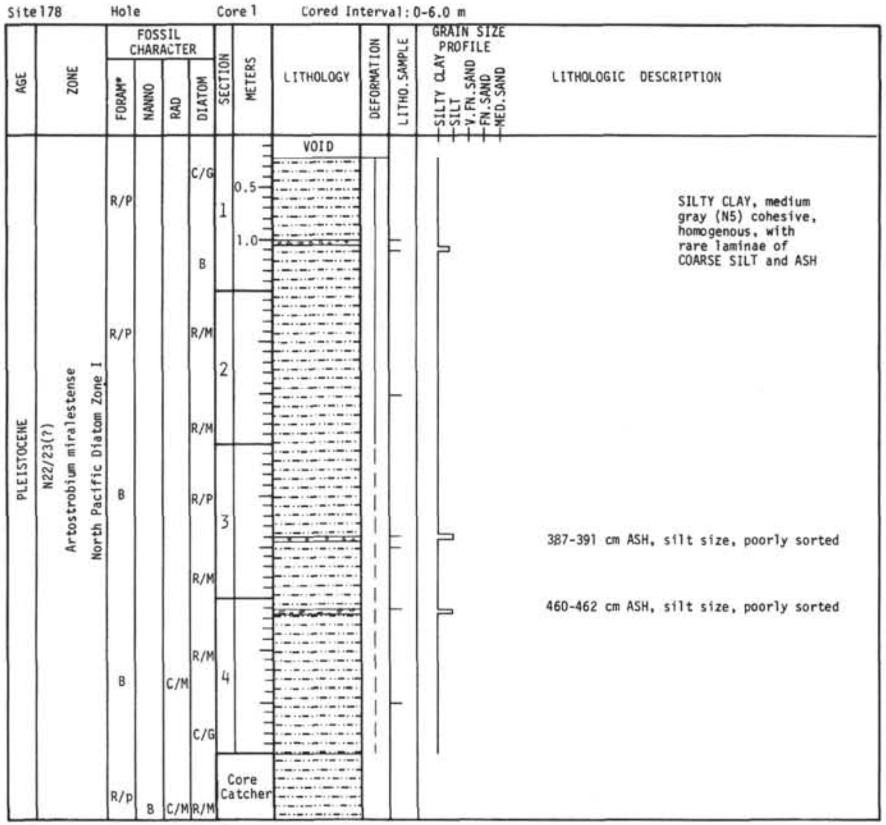
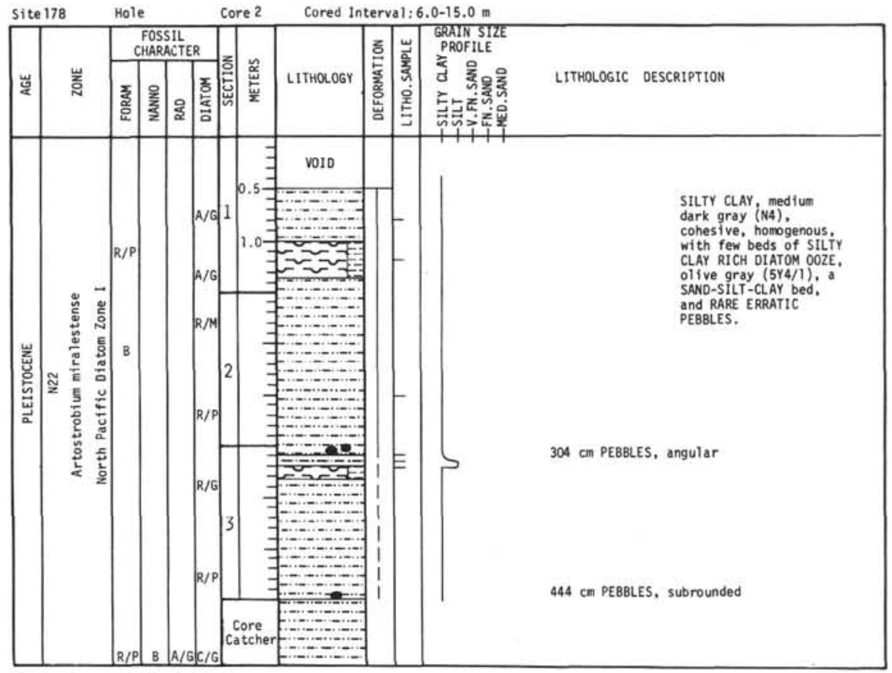
750
775
800
825
850
875
900
925
950
975
1000



Explanatory notes in chapter 1
*PLANKTONIC FORAMINIFERA



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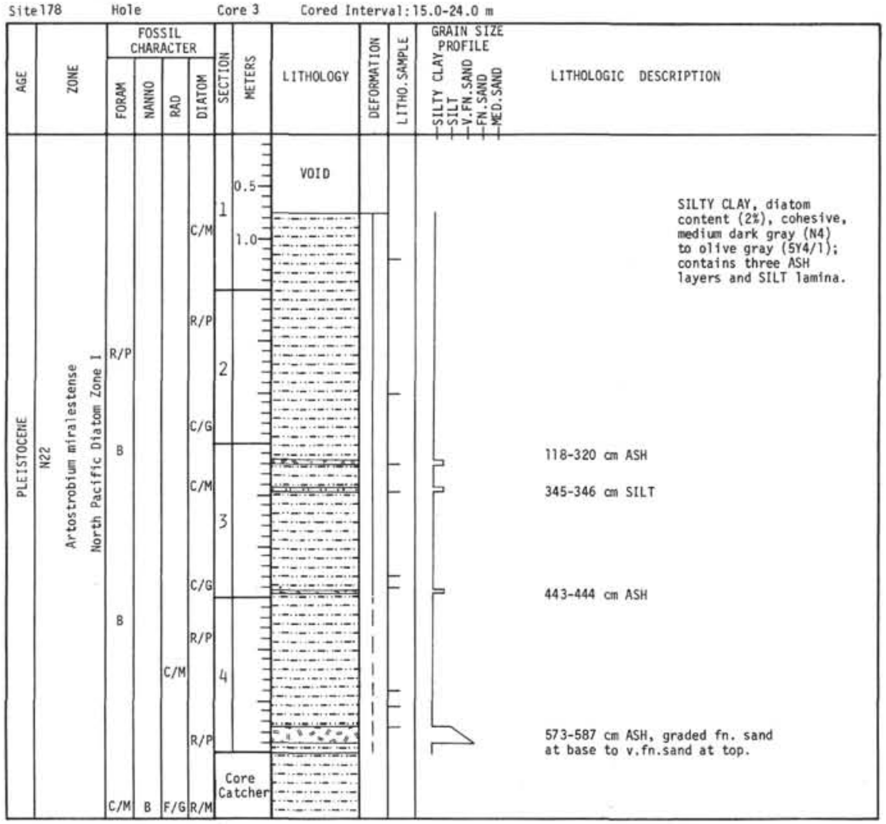
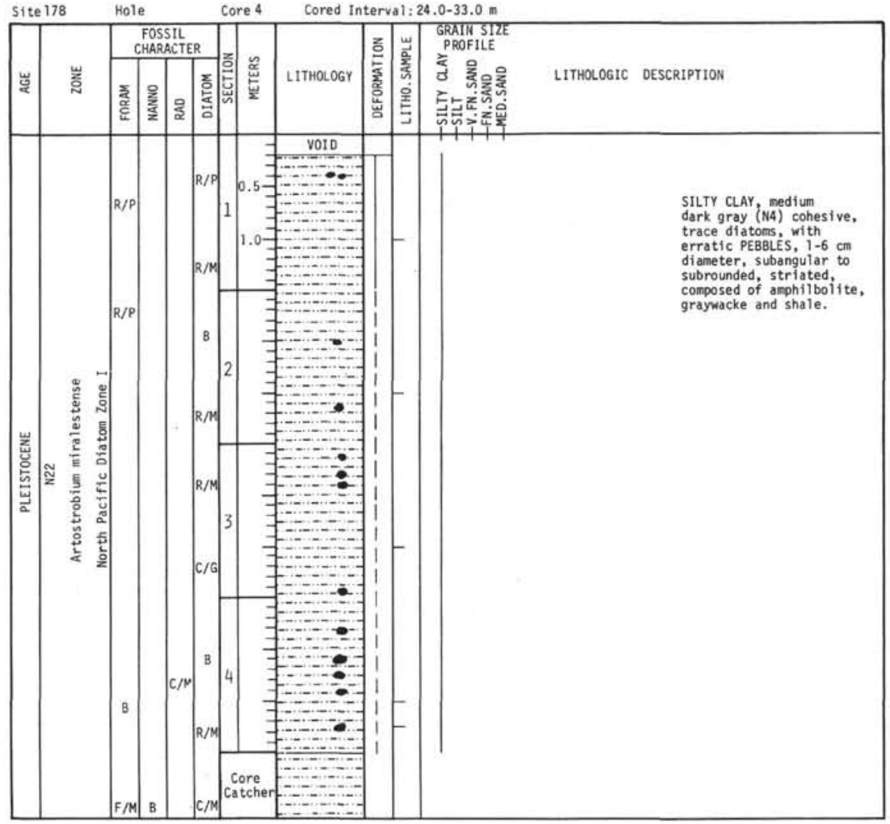
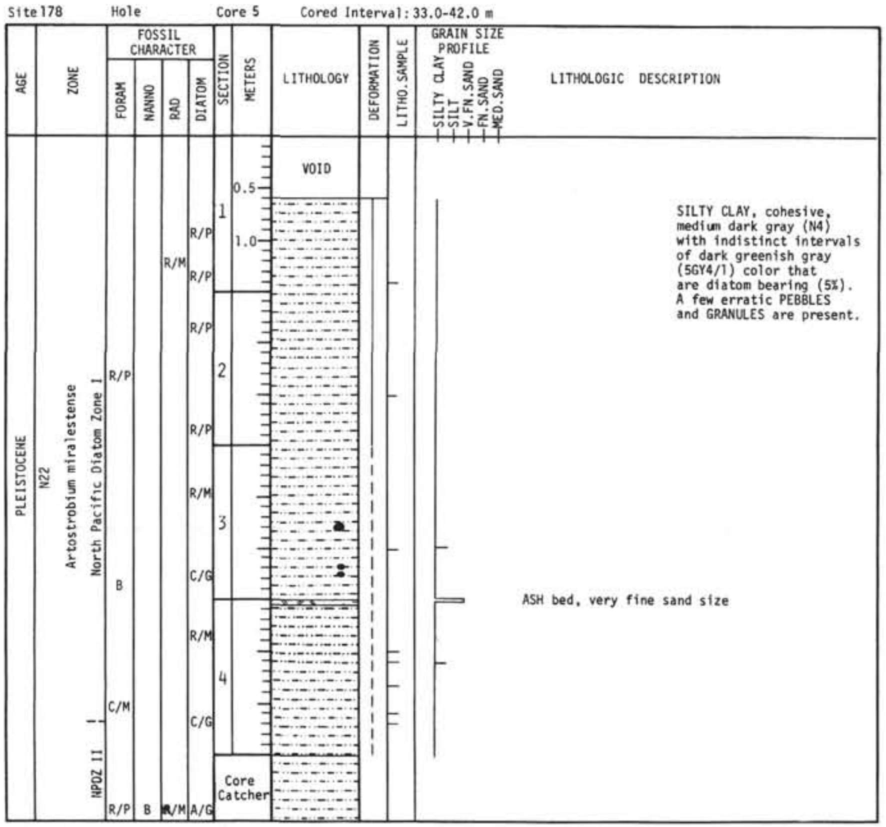


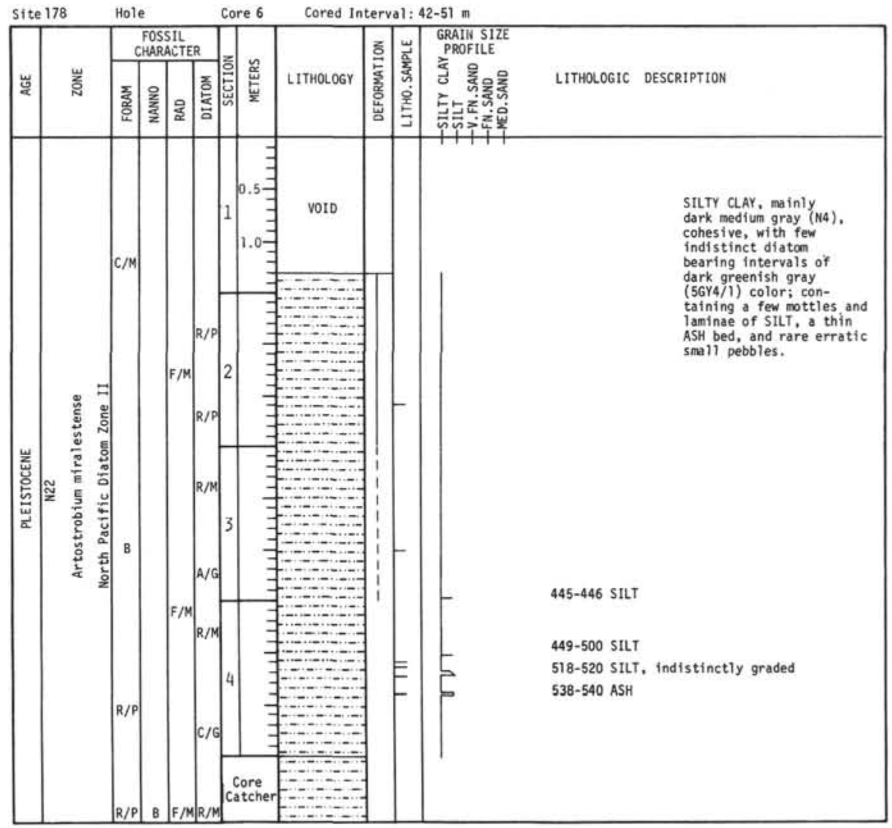
Explanatory notes in chapter 1



Explanatory notes in chapter 1



Explanatory notes in chapter 1



Explanatory notes in chapter 1

Site 178 Hole Core 7 Cored Interval: 51.0-60.0 m

AGE	ZONE	FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	GRAIN SIZE PROFILE	LITHOLOGIC DESCRIPTION
PLEIST.	N22 * NPDZ II	C/M	B	F/M	R/G	Core Catcher						NO CORE RECOVERED CC: SILTY CLAY, with PYRITE nodule.

Site 178 Hole Core 8 Cored Interval: 60.0-69.0 m

AGE: PLEISTOCENE

ZONE: N22; Artostrobium miralestense; North Pacific Diatom Zone II

FOSSIL CHARACTER: FORAM A/M, C/P, A/G, B, B; NANNO B; RAD C/M, R/M, R/M, R/M; DIATOM R/G, C/M, C/M, B, B, R/M, R/G, R/M, C/G, R/M

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

METERS: 0.5, 1.0

LITHOLOGY: VOID

GRAIN SIZE PROFILE: SILTY CLAY, SILT, V.FN.SAND, FN.SAND, MED.SAND

LITHOLOGIC DESCRIPTION:

SILTY CLAY, medium dark gray (N4) with intervals of dark greenish gray (5GY4/1) DIATOM BEARING SILTY CLAY. From 300 to 600 cm granule to pebble size erratics are present.

Explanatory notes in chapter 1

Site 178 Hole Core 9 Cored Interval: 69.0-78.0 m

AGE: PLEISTOCENE

ZONE: N22; Axoprunum angelinum; North Pacific Diatom Zone II

FOSSIL CHARACTER: FORAM R/P, B, C/M, F/M; NANNO B; RAD R/M, R/M, R/M, C/G, F/M; DIATOM R/M, R/M, R/M, R/P, A/G, A/G, R/M, R/M, R/M

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

METERS: 0.5, 1.0

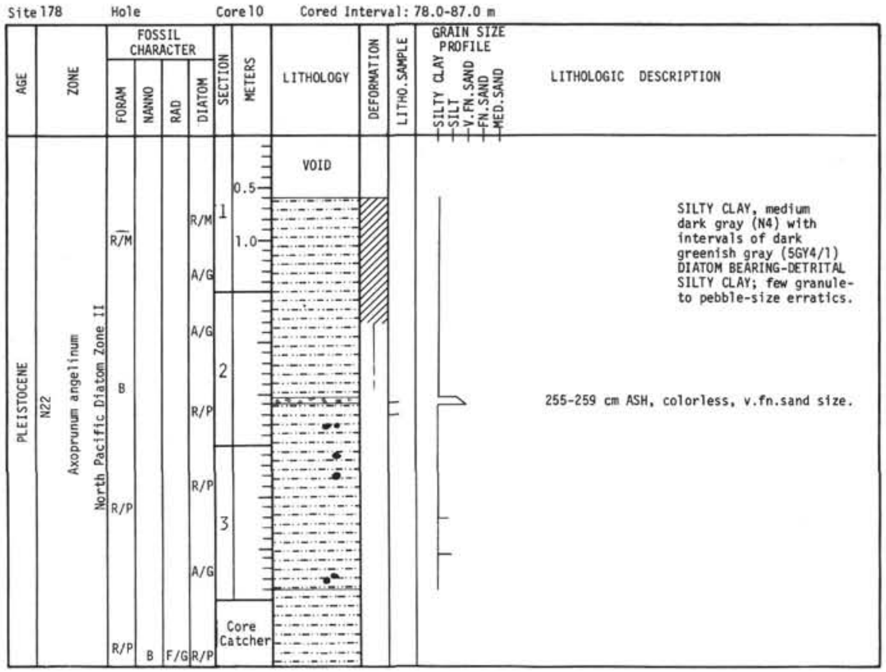
LITHOLOGY: VOID

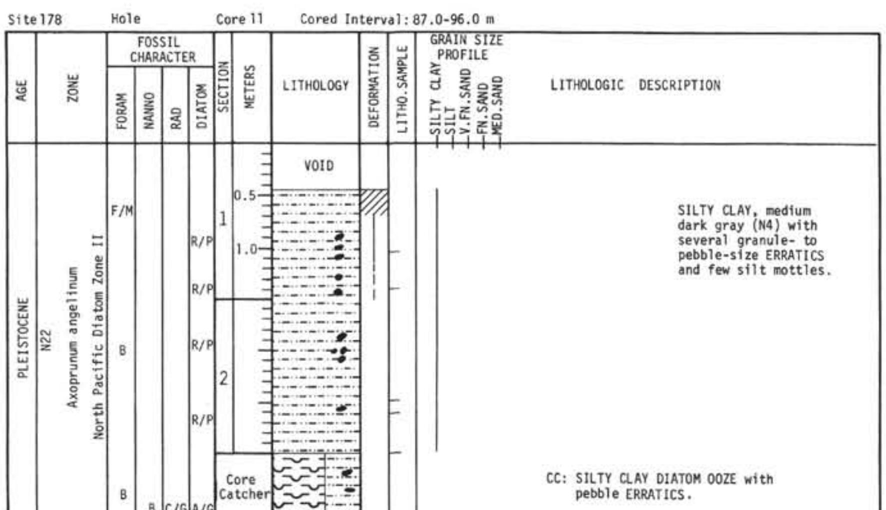
GRAIN SIZE PROFILE: SILTY CLAY, SILT, V.FN.SAND, FN.SAND, MED.SAND

LITHOLOGIC DESCRIPTION:

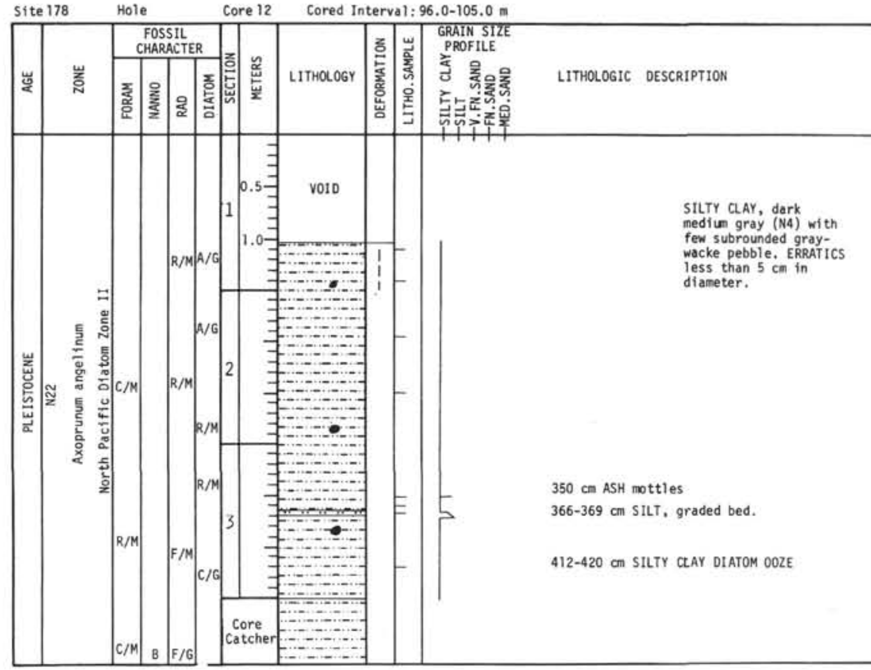
SILTY CLAY with intervals of DIATOM BEARING-DETRITAL SILTY CLAY to DIATOM RICH-DETRITAL SILTY CLAY, medium dark gray (N5) to dark greenish gray (5GY4/1), containing granule-to pebble-size ERRATICS, and few SILT laminae.

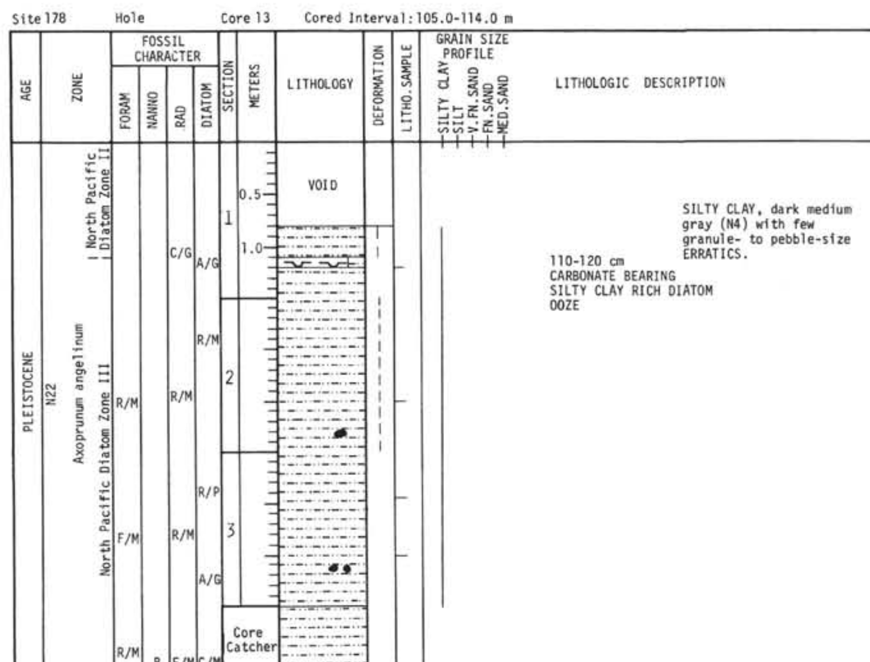
Explanatory notes in chapter 1





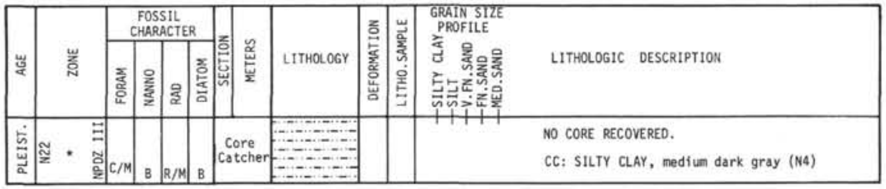
Explanatory notes in chapter 1



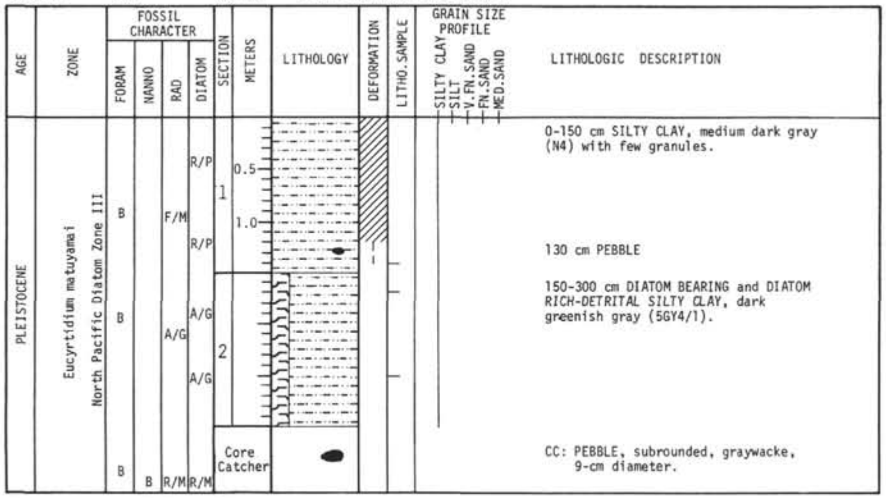


Explanatory notes in chapter 1

Site 178 Hole Core 14 Cored Interval: 114.0-123.0 m

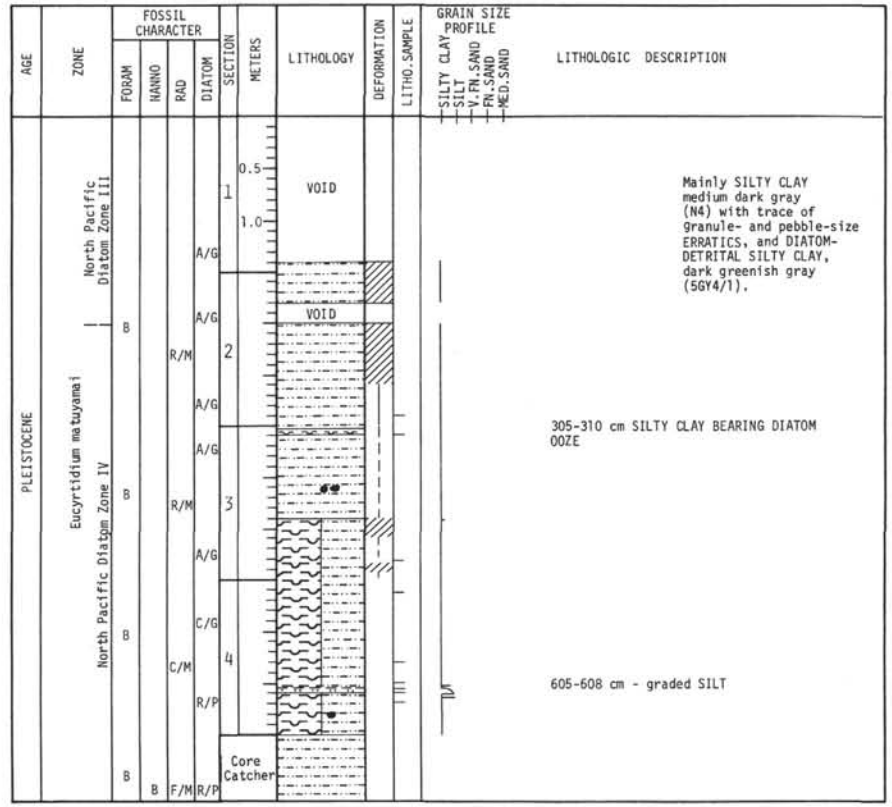


Site 178 Hole Core 15 Cored Interval: 123.0-132.0 m



Explanatory notes in chapter 1

Site 178 Hole Core 16 Cored Interval: 132.0-141.0 m



Explanatory notes in chapter 1

Site 178 Hole Core 17 Cored Interval: 141.0-150.0 m

AGE	ZONE	FOSSIL CHARACTER: FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	GRAIN SIZE PROFILE (SILTY CLAY, SILT, V.FN.SAND, FN.SAND, MED.SAND)	LITHOLOGIC DESCRIPTION
PLEISTOCENE	*Eucyrtidium matuyamai*; North Pacific Diatom Zone IV	B, B, B, B, B	B	R/M, R/M, R/M, R/M, R/M, F/M	C/M, R/P, R/P, B, B, B, B, B, R/P, R/M	1, 2, 3, 4, 5, Core Catcher	0.5, 1.0	VOID				SILTY CLAY, dark greenish gray (5GY4/1), olive gray (5Y4/1), medium dark gray (N4) with pebble-size ERRATICS and graded and non-graded SILT LAMINAE as noted. 168-171 cm SILT 178-182 cm SILT 192-192.5 cm SILT 265-265.5 cm SILT 272-274 cm SILT 287-290 cm SILTSTONE cross laminated, graded, calcareous cement. 547-554 cm ASH BEARING SILTY CLAY 574-576 cm SILT, graded 640-641 cm SILT, graded

Explanatory notes in chapter 1

Site 178 Hole Core 18 Cored Interval: 150.0-159.0 m

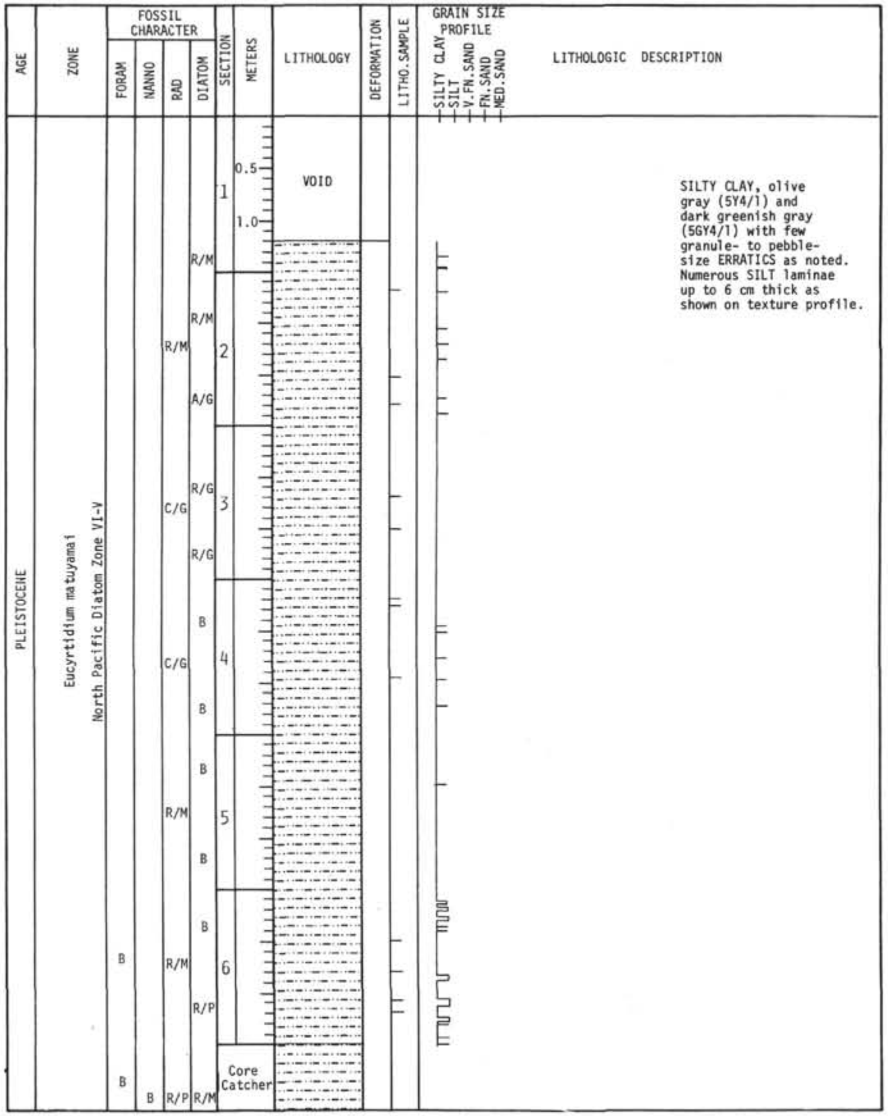
AGE	ZONE	FOSSIL CHARACTER: FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	GRAIN SIZE PROFILE (SILTY CLAY, SILT, V.FN.SAND, FN.SAND, MED.SAND)	LITHOLOGIC DESCRIPTION
PLEISTOCENE	N21/22; *Eucyrtidium matuyamai*; North Pacific Diatom Zone IV; North Pacific Diatom Zone VI-V	B, B, F/M	B	A/G, R/M, C/G, F/M	C/G, A/G, B, R/M, R/G	1, 2, 3, Core Catcher	0.5, 1.0	VOID				Mainly DIATOM BEARING DETRITAL SILTY CLAY, greenish gray (5G6/1). 220-270 cm VOLCANIC GLASS, brown, refractive index greater than 1.55, very fine sand size. 423-450 cm SILTY CLAY, medium dark gray, (N4) with few granule ERRATICS.

Site 178 Hole Core 19 Cored Interval: 159.0-168.0 m

AGE	ZONE	FOSSIL CHARACTER: FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	GRAIN SIZE PROFILE (SILTY CLAY, SILT, V.FN.SAND, FN.SAND, MED.SAND)	LITHOLOGIC DESCRIPTION
PLEISTOCENE	*Eucyrtidium matuyamai*; North Pacific Diatom Zone VI-V	B, B, B	B	F/M, R/M, C/G, R/M	R/G, R/G, C/G, C/G, R/M, R/G, B	1, 2, 3, Core Catcher	0.5, 1.0	VOID				SILTY CLAY, medium dark gray (N4) with trace of granule- to pebble size ERRATICS, SILT laminae as noted on texture profile.

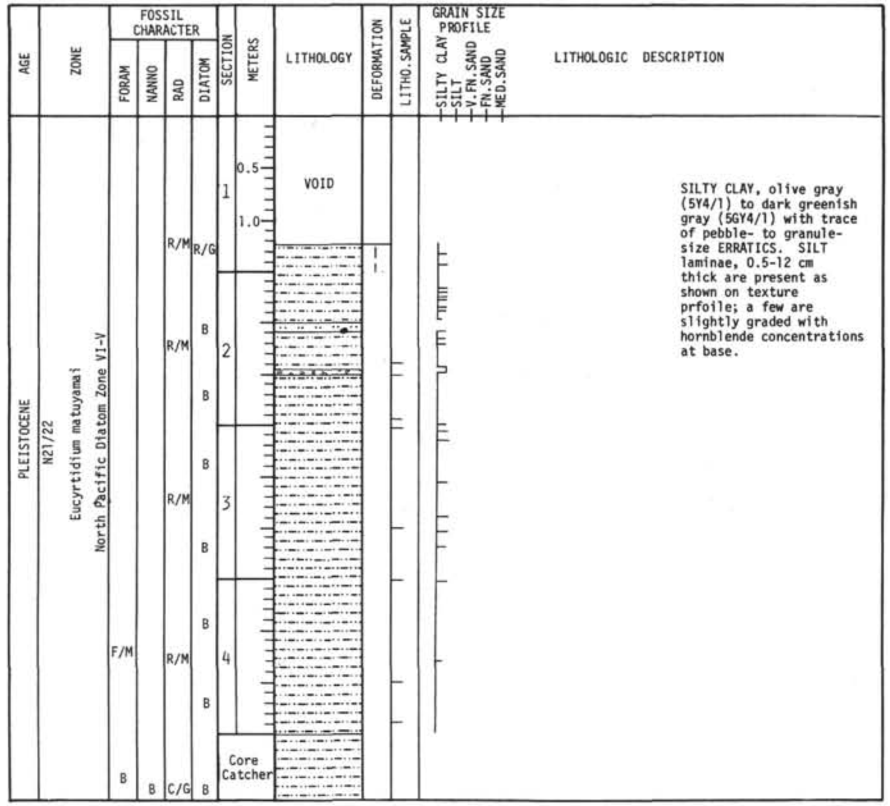
Explanatory notes in chapter 1

Site 178 Hole Core 20 Cored Interval: 168.0-177.0 m

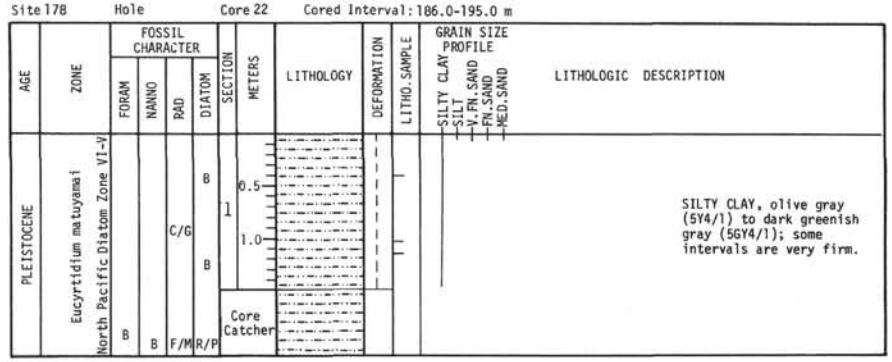


Explanatory notes in chapter 1

Site 178 Hole Core 21 Cored Interval: 177.0-186.0 m



Site 178 Hole Core 22 Cored Interval: 186.0-195.0 m



Explanatory notes in chapter 1

Site 178 Hole Core 23 Cored Interval: 195.0-204.0 m

AGE: LATE PLIOCENE

ZONE: N21/22; North Pacific Diatom Zone VI-V

FOSSIL CHARACTER (FORAM, NANNO, RAD, DIATOM): B; F/M; B | F/M; F/P; R/M; R/P; R/M; A/G; B | B B B B

SECTION: 1, 2, 3, Core Catcher

METERS: 0.5, 1.0

LITHOLOGY: VOID

DEFORMATION | LITHO. SAMPLE | GRAIN SIZE PROFILE (SILTY CLAY, SILT, V.FN.SAND, FN.SAND, MED.SAND)

LITHOLOGIC DESCRIPTION

SILTY CLAY, olive gray (5Y4/1) and dark greenish gray (5GY4/1) with trace of granule- to pebble-size ERRATICS. Few SILT laminae present as noted on texture profile, slightly graded.

353-354 cm DIATOM BEARING DETRITAL SILTY CLAY
355 cm CHALK PEBBLE

Site 178 Hole Core 24 Cored Interval: 204.0-211.0 m

AGE: LATE PLIOCENE

ZONE: North Pacific Diatom Zone VI-V

FOSSIL CHARACTER (FORAM, NANNO, RAD, DIATOM): B; B; B; B; B; B; B | R/M B B B

SECTION: 1, 2, 3, Core Catcher

METERS: 0.5, 1.0

LITHOLOGY: VOID

DEFORMATION | LITHO. SAMPLE | GRAIN SIZE PROFILE (SILTY CLAY, SILT, V.FN.SAND, FN.SAND, MED.SAND)

LITHOLOGIC DESCRIPTION

SILTY CLAY, olive gray (5Y4/1), with several SILT Laminae, 0.25-3.0 cm thick, graded and non-graded as shown on texture profile. Few pebble-size ERRATICS below 390 cm.

133-134 cm SILTY CLAYEY ASH

Explanatory notes in chapter 1

Site 178 Hole Core 25 Cored Interval: 211.0-220.5 m

AGE: LATE PLIOCENE

ZONE: N21; North Pacific Diatom Zone VI-V; N21

FOSSIL CHARACTER (FORAM, NANNO, RAD, DIATOM): R/M; B; C/M; B; B B B; diatom: B, B, B, B, B, B, B, B, B, B, B, B

SECTION: 1, 2, 3, 4, 5, Core Catcher

METERS: 0.5, 1.0

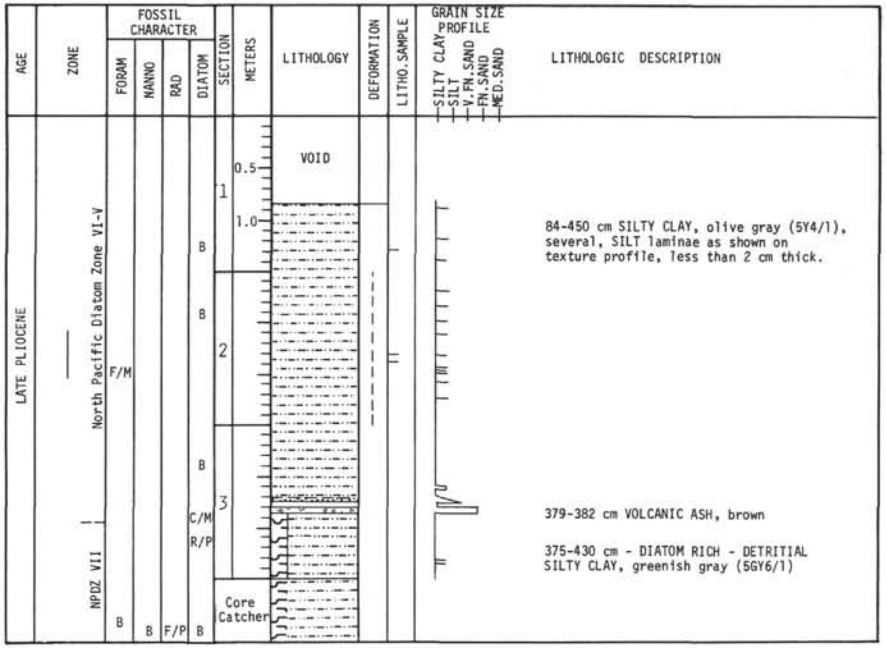
LITHOLOGY | DEFORMATION | LITHO. SAMPLE | GRAIN SIZE PROFILE (SILTY CLAY, SILT, V.FN.SAND, FN.SAND, MED.SAND)

LITHOLOGIC DESCRIPTION

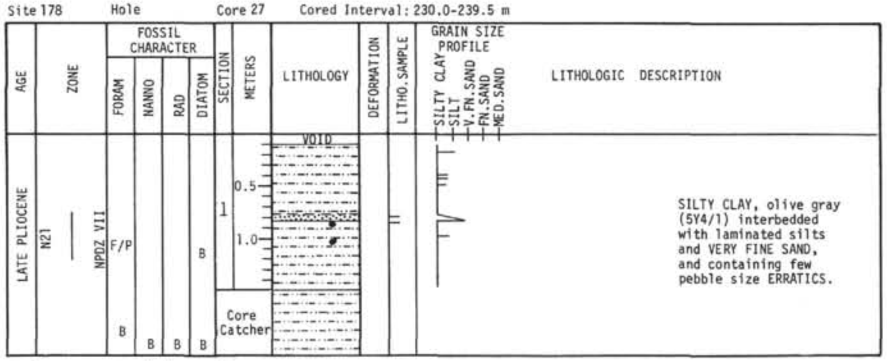
SILTY CLAY, medium dark gray (N4) to olive gray (5Y4/1) with trace of granule- to pebble-size ERRATICS. Abundant SILT laminae as shown on texture profile, 0.25-3.0 cm thick, some slightly graded.

Explanatory notes in chapter 1

Site 178 Hole Core 26 Cored Interval: 220.5-230.0 m

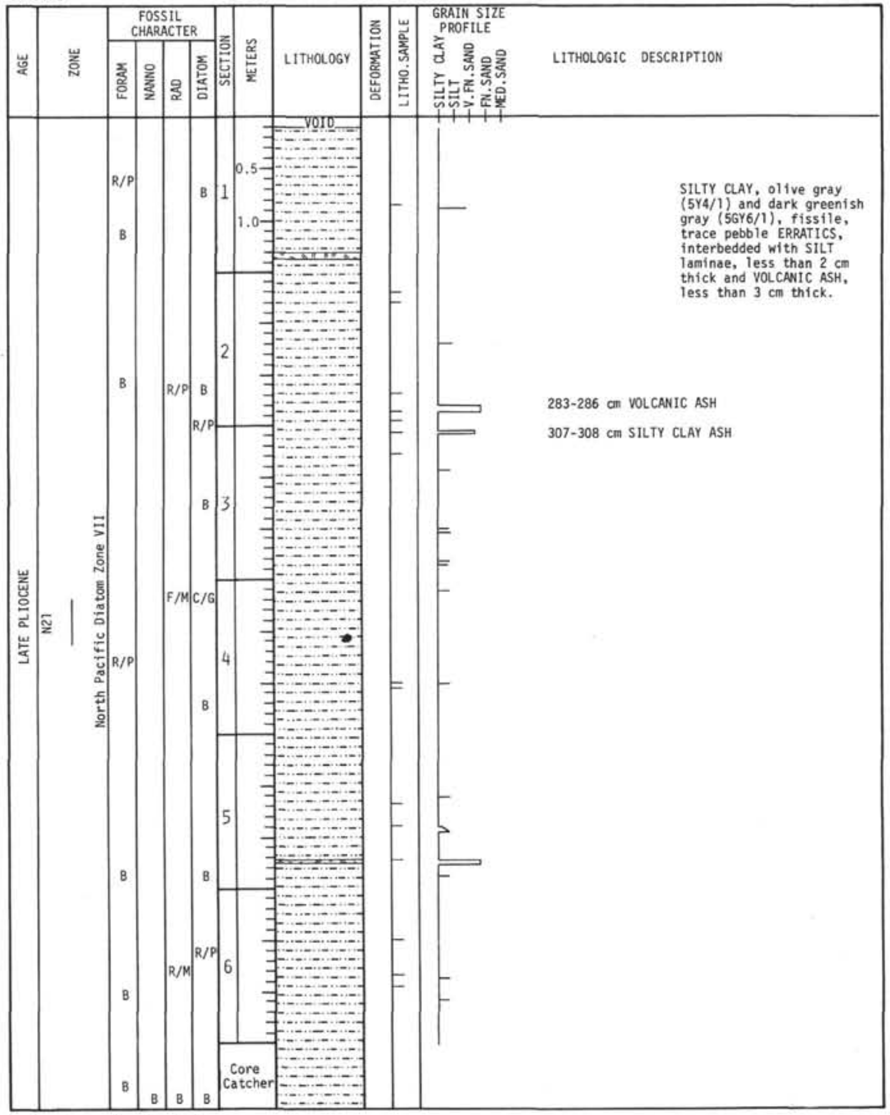


Site 178 Hole Core 27 Cored Interval: 230.0-239.5 m

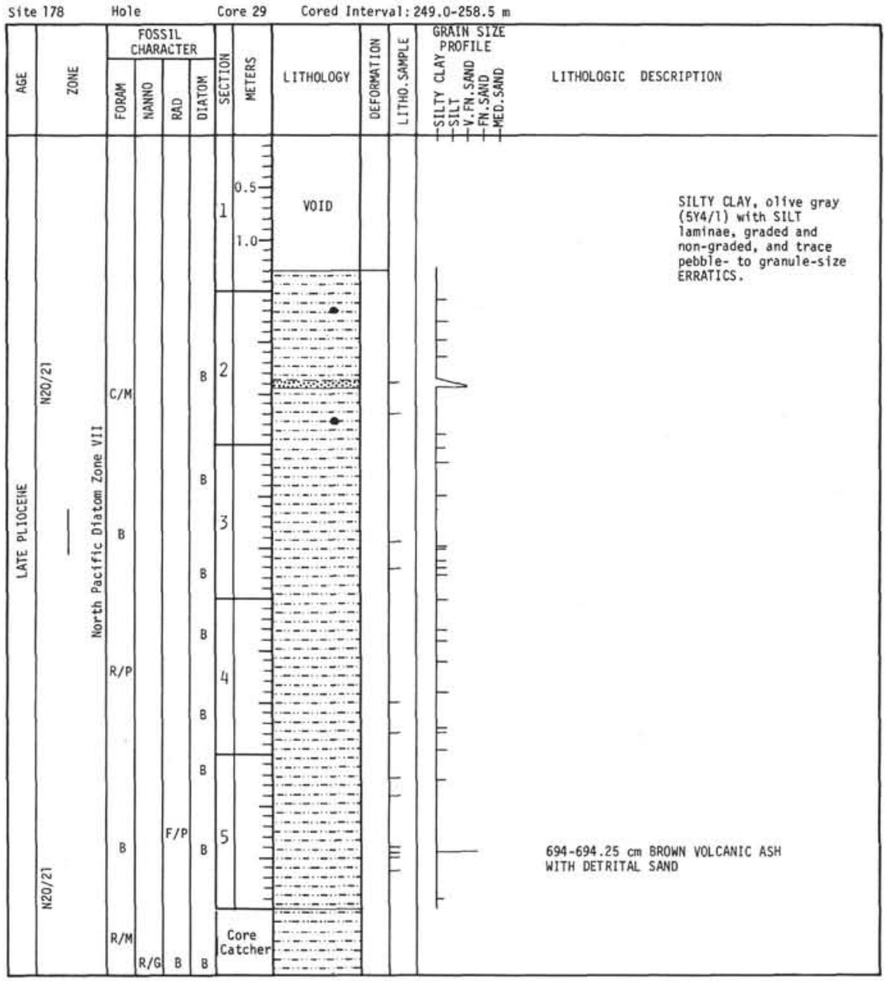


Explanatory notes in chapter 1

Site 178 Hole Core 28 Cored Interval: 239.5-249.0 m



Explanatory notes in chapter 1



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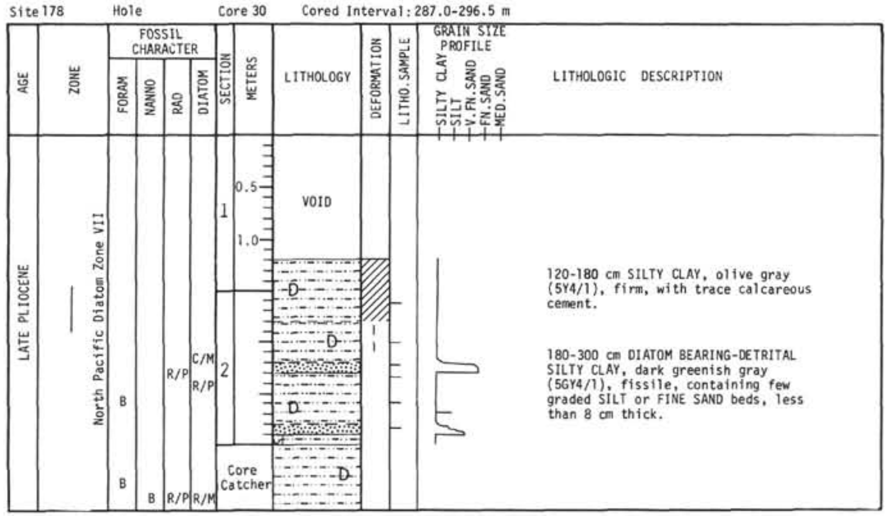
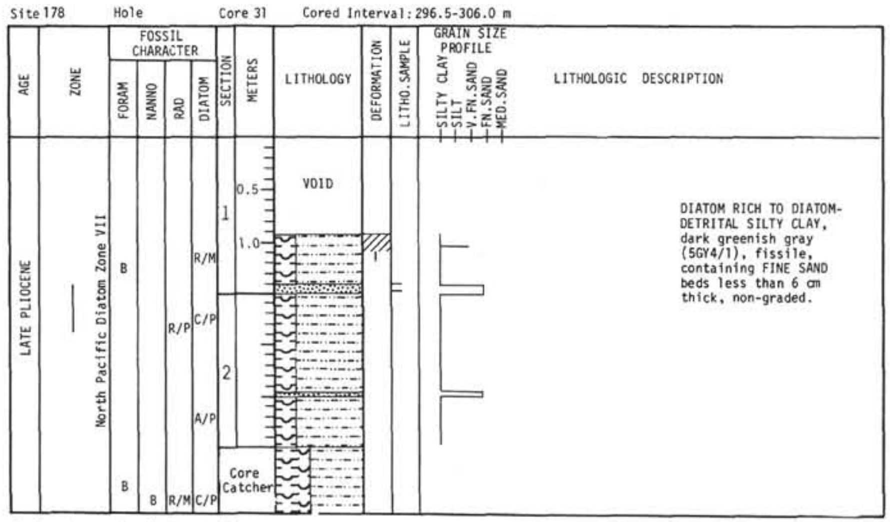
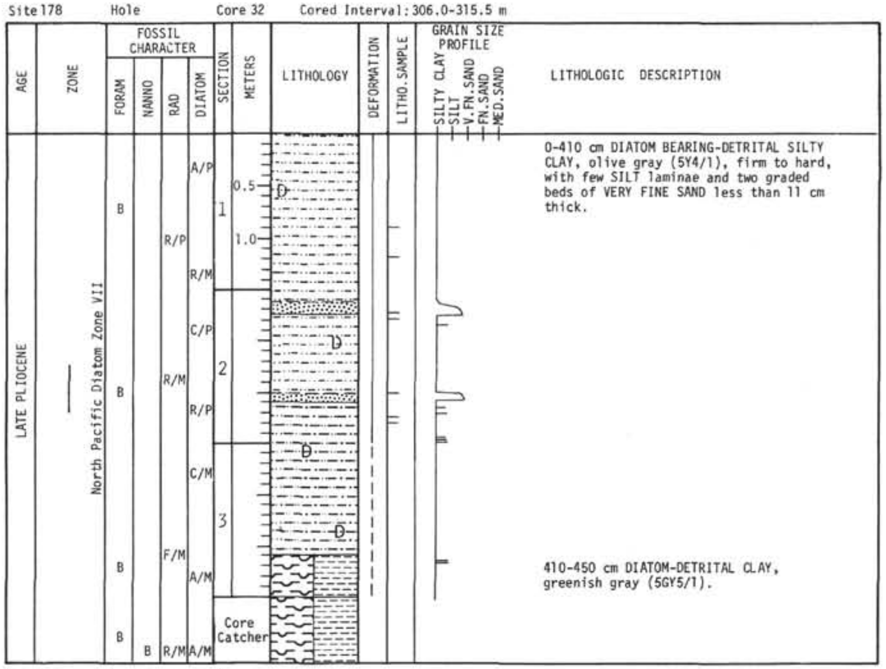




Explanatory notes in chapter 1



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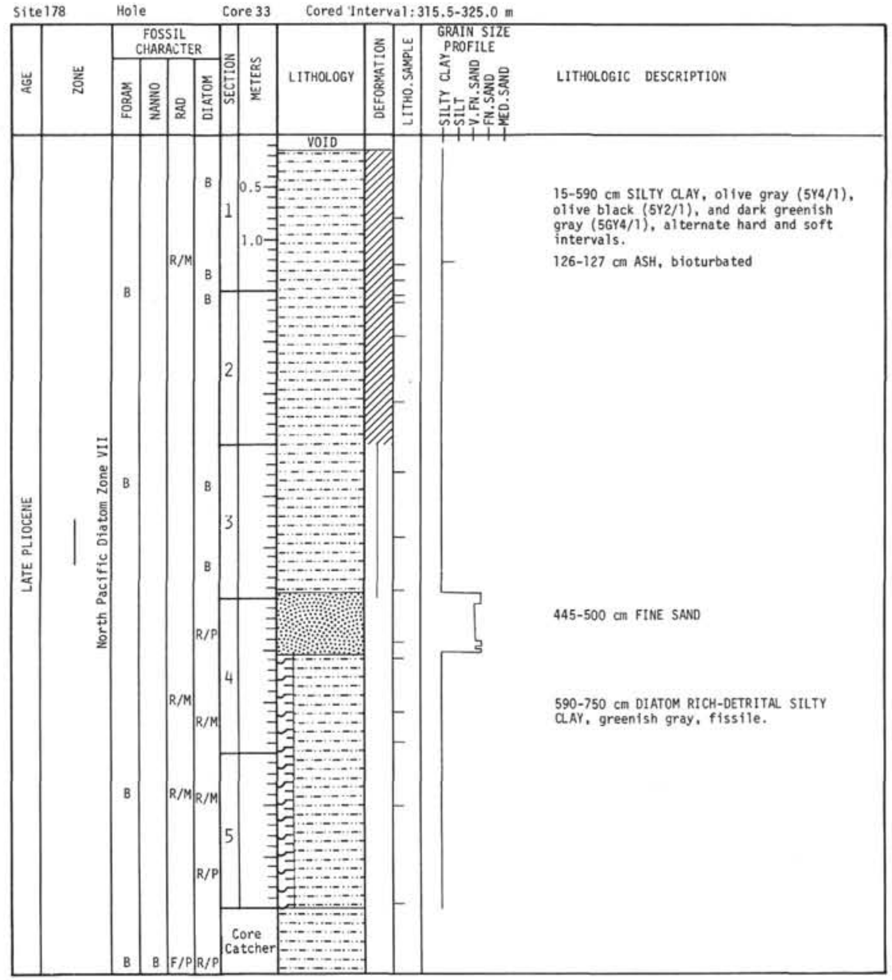

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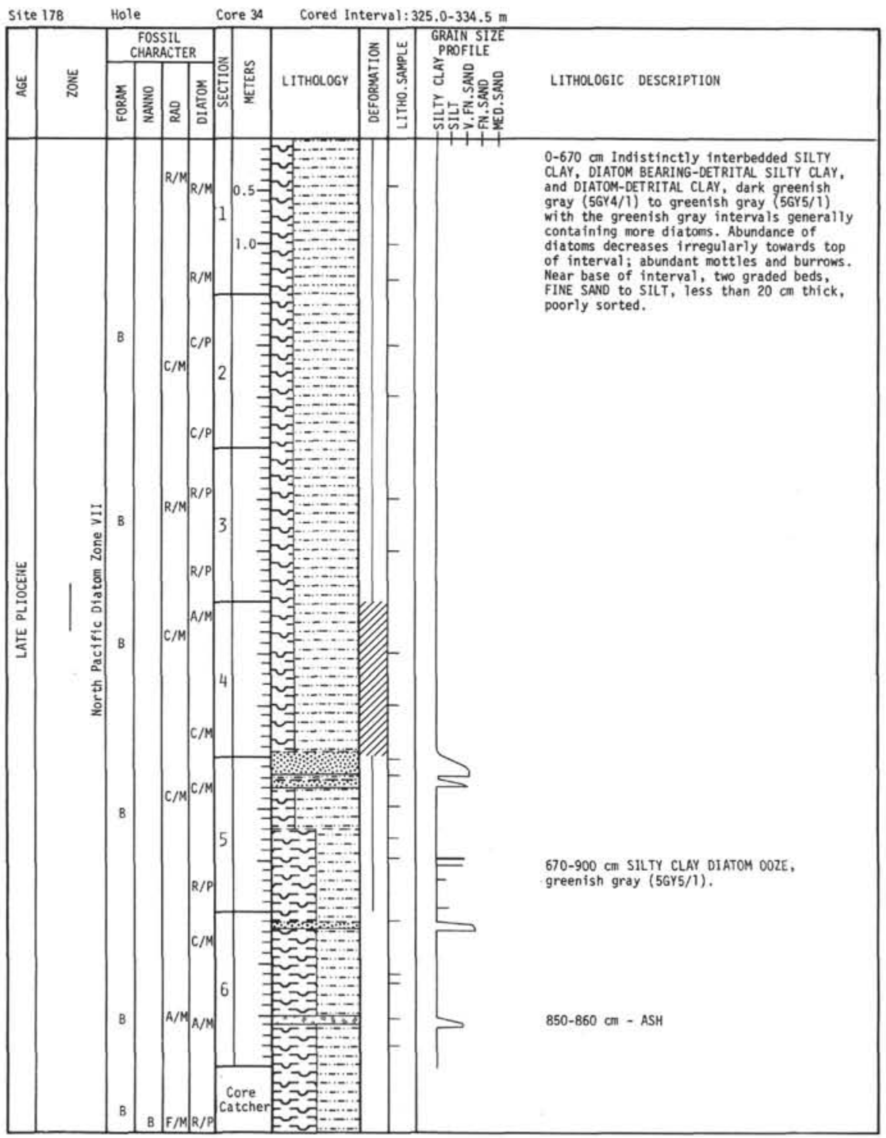
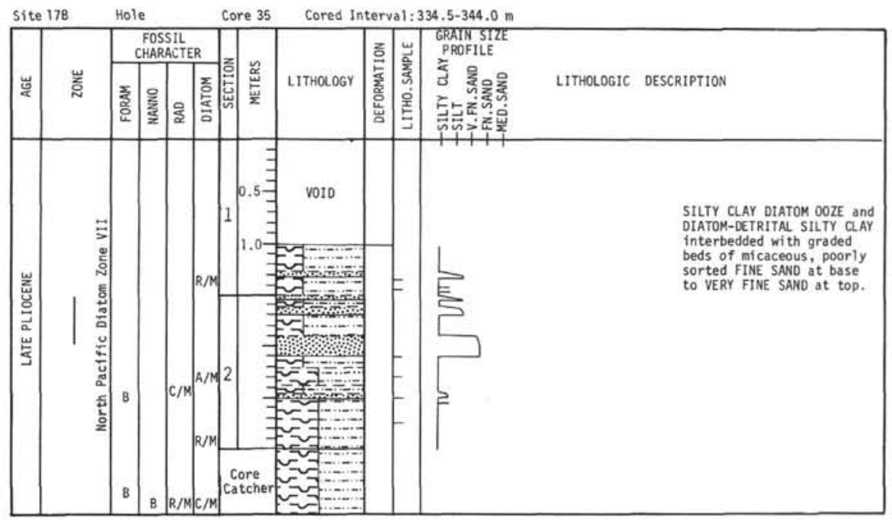
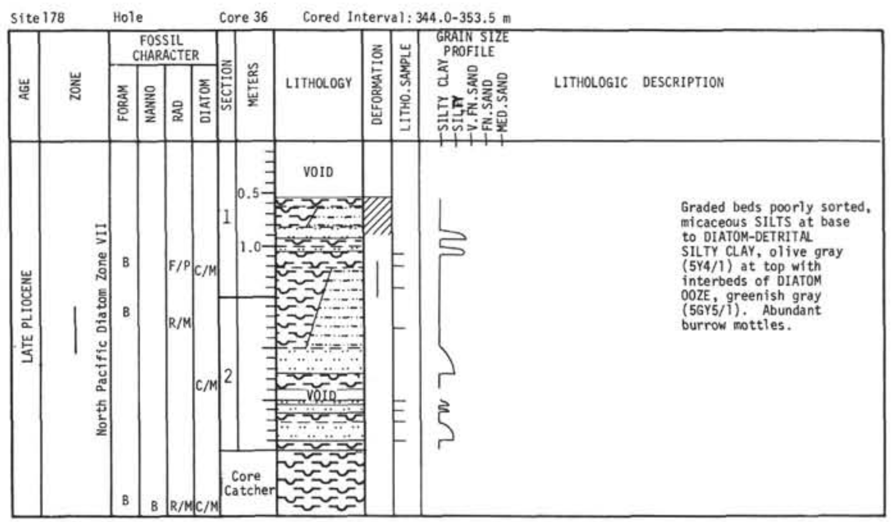


Explanatory notes in chapter 1





Explanatory notes in chapter 1

Site 178 Hole Core 37 Cored Interval: 353.5-363.0 m

AGE	ZONE	FOSSIL CHARACTER (FORAM, NANNO, RAD, DIATOM)	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	GRAIN SIZE PROFILE (SILTY CLAY, SILT, V.FN.SAND, FN.SAND, MED.SAND)	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	North Pacific Diatom Zone VII	RAD A/M; DIATOM A/M, A/M; FORAM B, B; RAD R/P; DIATOM A/M, A/M, C/M; FORAM B; DIATOM C/M; RAD F/M; RAD A/M; FORAM B; DIATOM A/M, A/M; FORAM B; NANNO B; RAD F/M; DIATOM A/M	1, 2, 3, 4, Core Catcher	0.5, 1.0					Indistinctly bedded SILTY CLAYEY DIATOM OOZE and DIATOM-DETRITAL SILTY CLAY, olive gray (5Y4/1) to greenish gray (5GY5/1) interbedded with graded beds of poorly sorted VERY FINE SAND or SILT at base to SILT at top.

Site 178 Hole Core 38 Cored Interval: 382.0-391.5 m

AGE	ZONE	FOSSIL CHARACTER (FORAM, NANNO, RAD, DIATOM)	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	GRAIN SIZE PROFILE (SILTY CLAY, SILT, V.FN.SAND, FN.SAND, MED.SAND)	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	North Pacific Diatom Zone VIII	FORAM B; RAD A/M; DIATOM C/P; FORAM B; NANNO B; RAD R/M; DIATOM R/M	1, Core Catcher	0.5, 1.0					Indistinctly interbedded SILTY CLAYEY DIATOM OOZE, greenish gray (5GY5/1) and DIATOM-DETRITAL SILTY CLAY, olive gray (5Y3/2), all with abundant horizontal worm burrows.

Explanatory notes in chapter 1

Site 178 Hole Core 39 Cored Interval: 391.5-401.0 m

AGE	ZONE	FOSSIL CHARACTER (FORAM, NANNO, RAD, DIATOM)	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	GRAIN SIZE PROFILE (SILTY CLAY, SILT, V.FN.SAND, FN.SAND, MED.SAND)	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	North Pacific Diatom Zone VIII	DIATOM B; FORAM B; DIATOM B; FORAM B; DIATOM B, B; FORAM B; DIATOM B, B, B, B; RAD R/M; DIATOM A/P; FORAM B; DIATOM C/P; FORAM B; RAD R/M; DIATOM A/P; FORAM B; NANNO B; RAD R/M; DIATOM C/P	1, 2, 3, 4, 5, 6, Core Catcher	0.5, 1.0	VOID				140-700 cm interbedded FINE SILT, 2 mm - 2 cm thick, well sorted, and SILTY CLAY, medium dark gray (N4), 2-4 cm thick. 700-720 cm VOLCANIC ASH 720-900 cm CLAYEY DIATOM OOZE, greenish gray (5G5/1) grading upwards to DIATOM BEARING-DETRITAL SILTY CLAY, light olive gray (5Y5/1).

Explanatory notes in chapter 1

Site 178 Hole Core 40 Cored Interval: 426.5-427.5 m

AGE	ZONE	FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	GRAIN SIZE PROFILE (SILTY CLAY, SILT, V.FN.SAND, FN.SAND, MED.SAND)	LITHOLOGIC DESCRIPTION
		B	B	R/M	A/P	Core Catcher						NO CORE RECOVERED Compact greenish gray SILTY CLAY

Site 178 Hole Core 41 Cored Interval: 427.5-437.0 m

AGE	ZONE	FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	NPDZ VIII?	B	B	B	B	Core Catcher					NO CORE RECOVERED CC: VERY FINE SANDSTONE with carbonate cement.

Site 178 Hole Core 42 Cored Interval: 437.0-446.5 m

AGE	ZONE	FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	NPDZ VIII	B	B	R/M	B	Core Catcher					NO CORE RECOVERED CC: SILTY CLAY CHALK

Site 178 Hole Core 43 Cored Interval: 446.5-456.0 m

AGE	ZONE	FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	GRAIN SIZE PROFILE (SILTY CLAY, SILT, V.FN.SAND, FN.SAND, MED.SAND)	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	NPDZ VIII	B			B	1	0.5, 1.0	VOID				Graded beds of poorly sorted, micaceous SILT and SILTY VERY FINE SAND at base to SILTY CLAY, olive gray (5Y3/2) and greenish gray (5GY5/1) at top.
					R/P							
		B	B	B	R/P	Core Catcher						

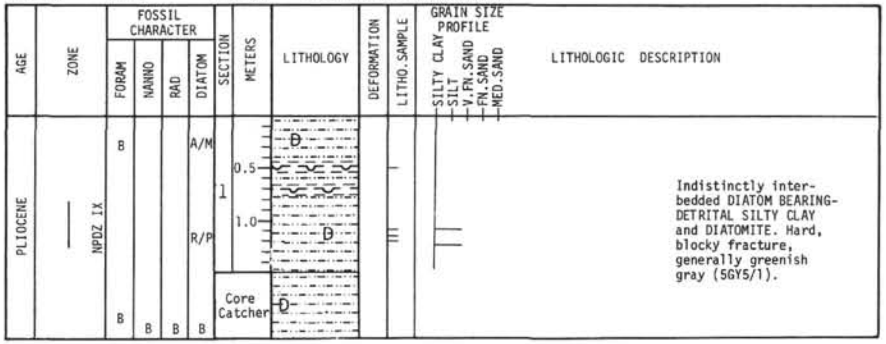
Explanatory notes in chapter 1

Site 178 Hole Core 44 Cored Interval: 456.0-465.5 m

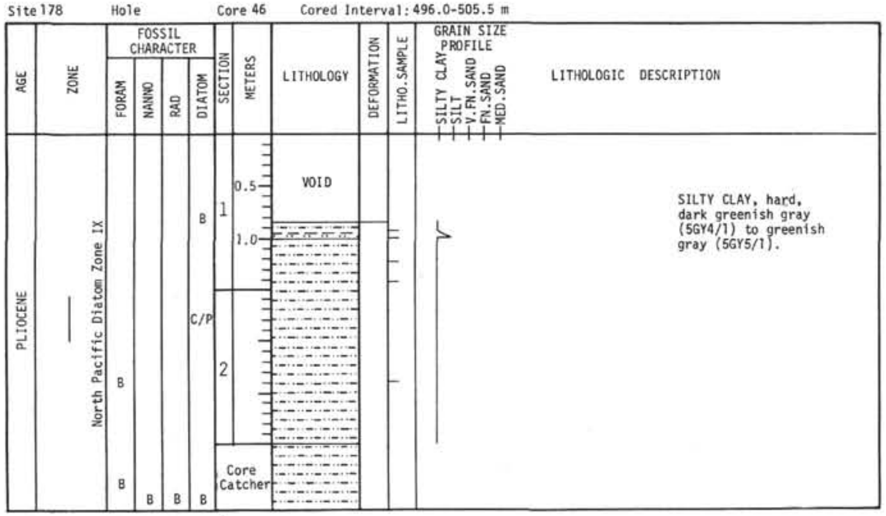
AGE	ZONE	FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	GRAIN SIZE PROFILE (SILTY CLAY, SILT, V.FN.SAND, FN.SAND, MED.SAND)	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	North Pacific Diatom Zone VIII							VOID				
				R/P	C/P	1	0.5, 1.0					Hard, fissile, indistinctly interbedded SILTY CLAY olive gray (5Y4/1) and (5Y3/2), DIATOM BEARING-DETRITAL SILTY CLAY, CLAYEY DIATOM OOZE, and DIATOMITE, pale green (10G6/2); rare, thin graded, FINE SAND to SILT beds.
					R/P							
		B		R/M	A/P	2						
					A/P	3						
		B			B	4						520-530 cm ASH, graded
					R/P							
		B		R/M	A/M	5						
		B		R/P	A/M	6						
					A/M							
		B	B	R/M	A/M	Core Catcher						

Explanatory notes in chapter 1

Site 178 Hole Core 45 Cored Interval: 465.5-475.0 m

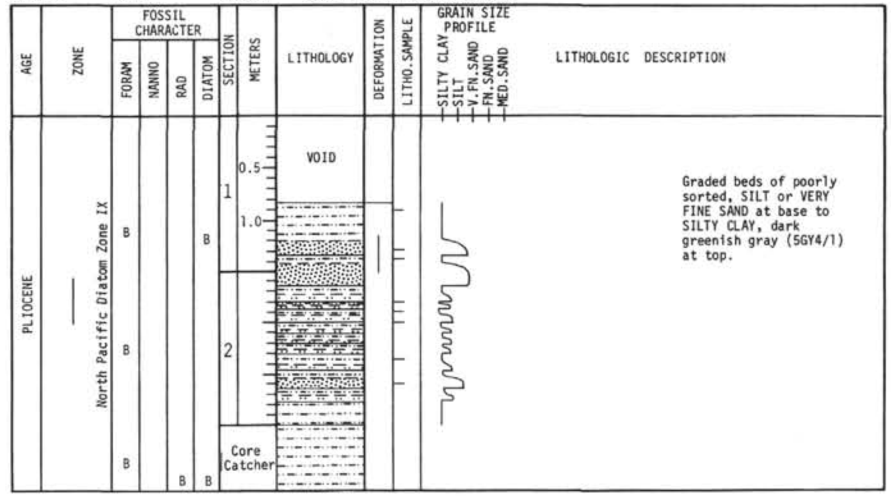


Site 178 Hole Core 46 Cored Interval: 496.0-505.5 m

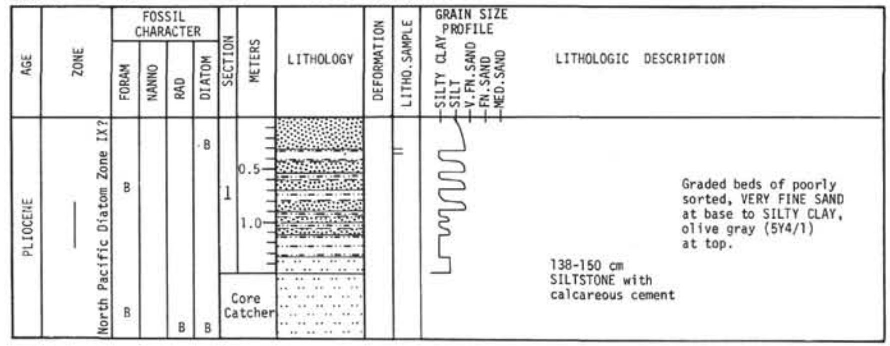


Explanatory notes in chapter 1

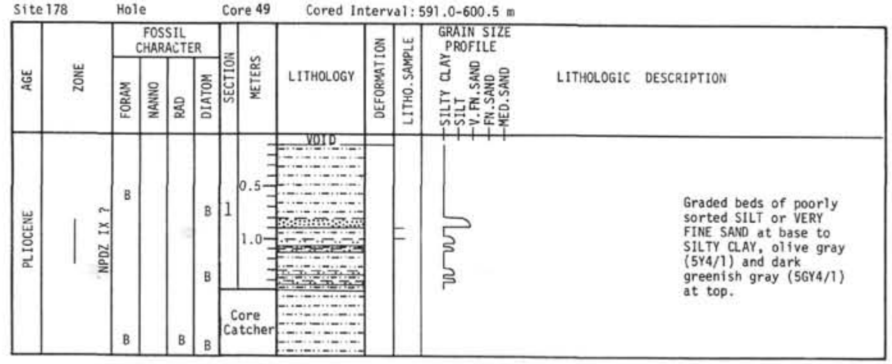
Site 178 Hole Core 47 Cored Interval: 505.5-515.0 m



Site 178 Hole Core 48 Cored Interval: 534.0-543.5 m

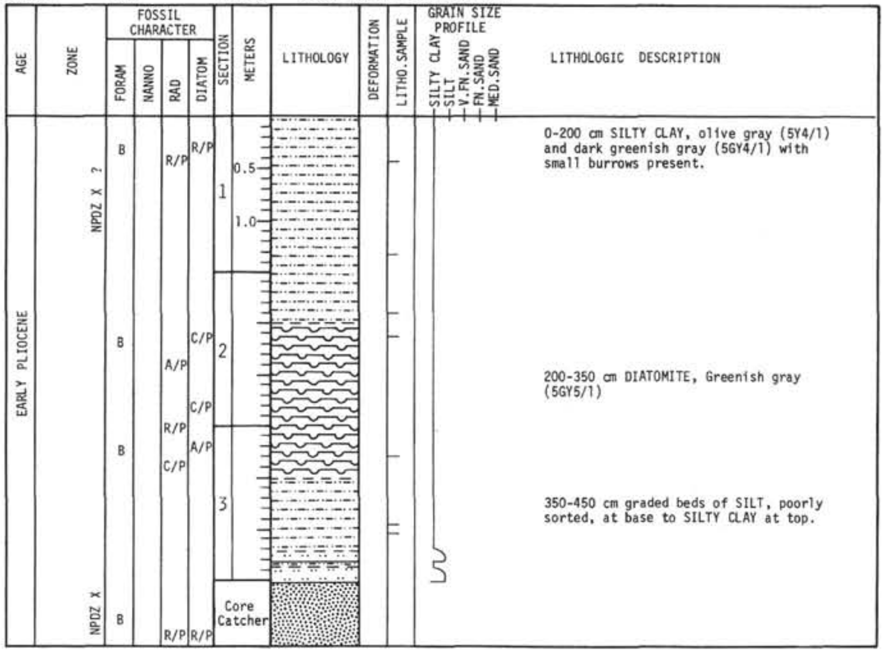


Site 178 Hole Core 49 Cored Interval: 591.0-600.5 m

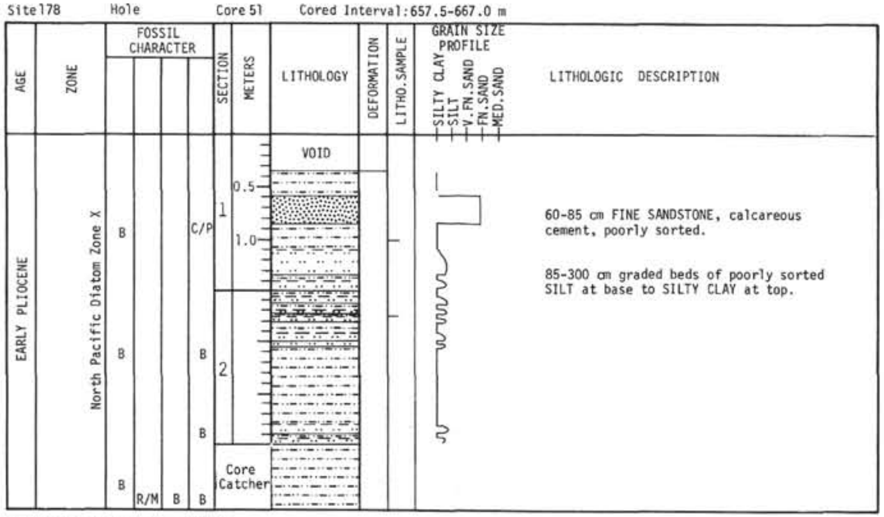


Explanatory notes in chapter 1

Site 178 Hole Core 50 Cored Interval: 629.0-638.5 m

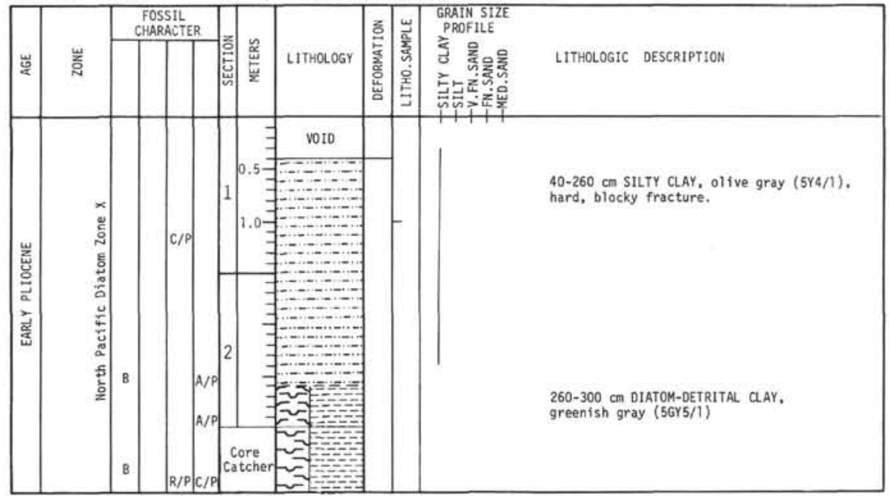


Site 178 Hole Core 51 Cored Interval: 657.5-667.0 m

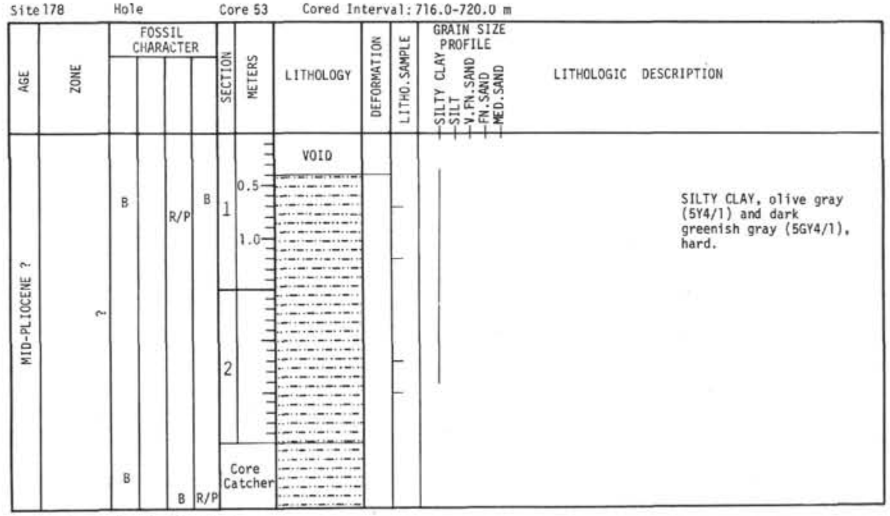


Explanatory notes in chapter 1

Site 178 Hole Core 52 Cored Interval: 686.5-690.5 m



Site 178 Hole Core 53 Cored Interval: 716.0-720.0 m



Explanatory notes in chapter 1

Site 178 Hole Core 54 Cored Interval: 742.0-749.0 m

AGE	ZONE	FOSSIL CHARACTER	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	GRAIN SIZE PROFILE (SILTY CLAY, SILT, V.FN.SAND, FN.SAND, MED.SAND)	LITHOLOGIC DESCRIPTION
EARLY MIOCENE	N7?; N5/6; Discoaster deflandrei Zone; North Pacific Diatom Zone XIV ?; N5/6	B, C/P, R/P; F/M, F/P, R/P, A/P; F/M, C/P, A/P; B, C/M, R/P; B, C/P, C/M, R/M; B, F/P, R/P, R/P; F/M, F/P, B, B; B, C/P; B, B; F/M, B, B, B; C/M	1	0.5, 1.0	VOID				32-690 cm varicolored CLAYSTONE, dark yellowish brown (10YR4/2), moderate brown (5YR4/4), light olive gray (5Y6/2), pale yellowish brown (10YR6/2), containing up to 20 percent diatoms and radiolarians in a few indistinct intervals, interbedded with CHALK, light olive gray (5Y6/2), light greenish gray (5GY7/1) and grayish orange pink (5YR7/2). Well preserved burrows over entire interval.
			2						
			3						
			4						
			5						
		B, B, B, B	Core Catcher						690-750 CLAY SHALE, olive gray (5Y4/1), fissile, possible 6 degree dips on bedding planes.

Explanatory notes in chapter 1

Site 178 Hole Core 55 Cored Interval: 749.0-758.5 m

AGE	ZONE	FOSSIL CHARACTER	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIOCENE ?			Core Catcher					NO CORE RECOVERED

Site 178 Hole Core 56 Cored Interval: 758.5-768.0 m

AGE	ZONE	FOSSIL CHARACTER	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	GRAIN SIZE PROFILE (SILTY CLAY, SILT, V.FN.SAND, FN.SAND, MED.SAND)	LITHOLOGIC DESCRIPTION
MIOCENE ?		B, B, B	Core Catcher						NO CORE RECOVERED. CC: CLAY SHALE, fissile, olive gray (5Y4/1)

Site 178 Hole Core 57 Cored Interval: 768.0-777.5 m

AGE	ZONE	FOSSIL CHARACTER	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	GRAIN SIZE PROFILE (SILTY CLAY, SILTY, V.FN.SAND, FN.SAND, MED.SAND)	LITHOLOGIC DESCRIPTION
MIOCENE ?		B, B, B	1	0.5, 1.0	VOID				100-150 cm CLAY SHALE, fissile, possible 12° dips, dusky yellowish brown (10YR2/2), dark yellowish brown (10YR4/2).
		B, B, B, B	Core Catcher						

Explanatory notes in chapter 1

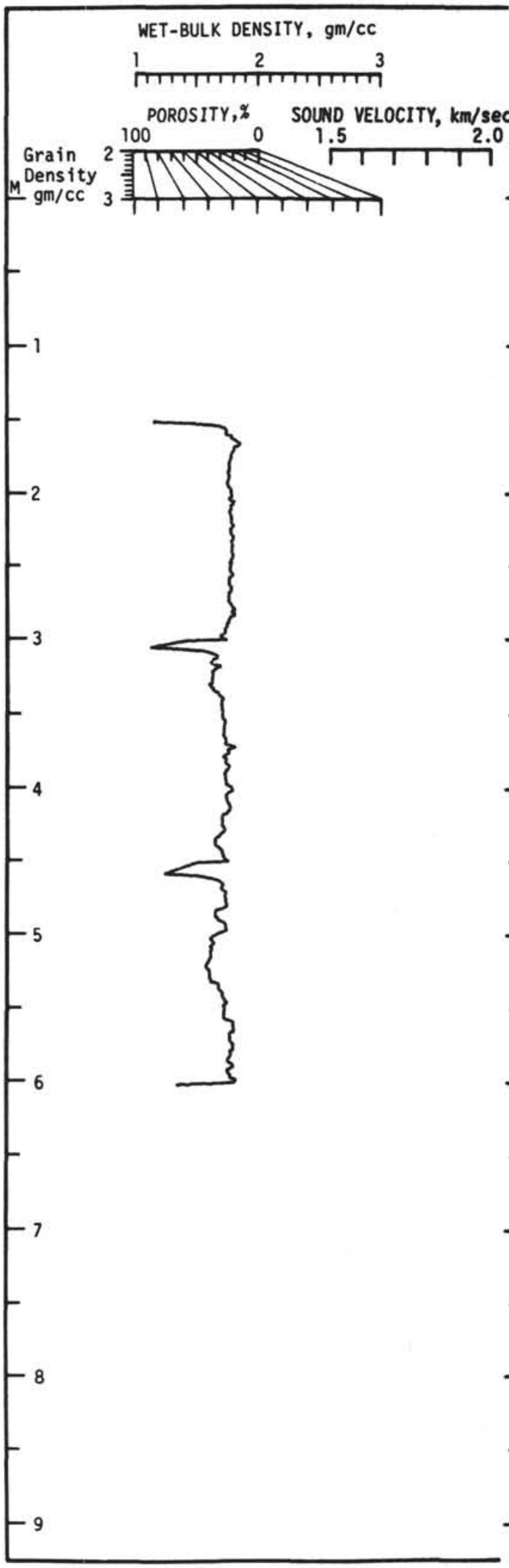
Site 178 Hole Core 58 Cored Interval: 777.5-787.0 m

AGE	ZONE	FOSSIL CHARACTER				SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	GRAIN SIZE PROFILE (SILTY CLAY, SILT, V.FN.SAND, FN.SAND, MED.SAND)	LITHOLOGIC DESCRIPTION
		B	B	B	B	1	0.5, 1.0	VOID				20-30 cm CLAY SHALE, olive gray (5Y4/1), no baking evident, possibly recovered contact with underlying basalt. 30-150 cm BASALT.
						Core Catcher						

Site 178 Hole Core 59 Cored Interval: 787.0-794.5 m

AGE	ZONE	FOSSIL CHARACTER				SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	GRAIN SIZE PROFILE (SILTY CLAY, SILT, V.FN.SAND, FN.SAND, MED.SAND)	LITHOLOGIC DESCRIPTION
						1	0.5, 1.0					0-150 cm BASALT
						Core Catcher						

Explanatory notes in chapter 1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1
2
3
POROSITY,%
100
0
SOUND VELOCITY, km/sec
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2.0
Grain Density gm/cc
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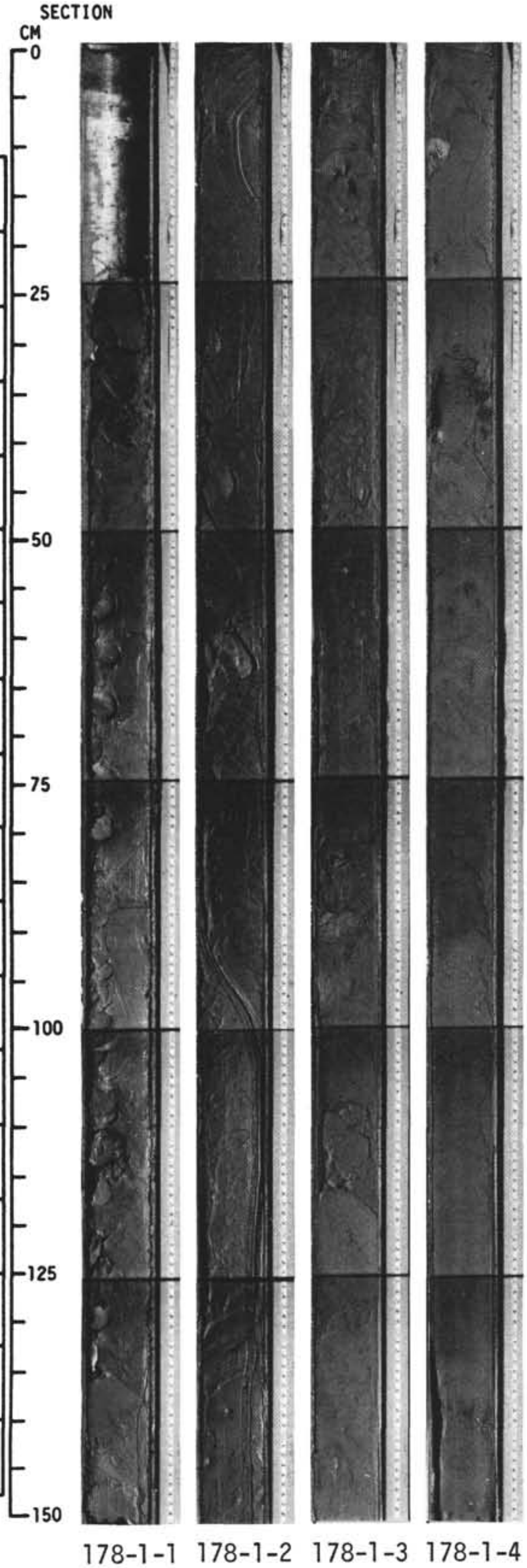
5
6
7
8
9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CM
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75
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125
150
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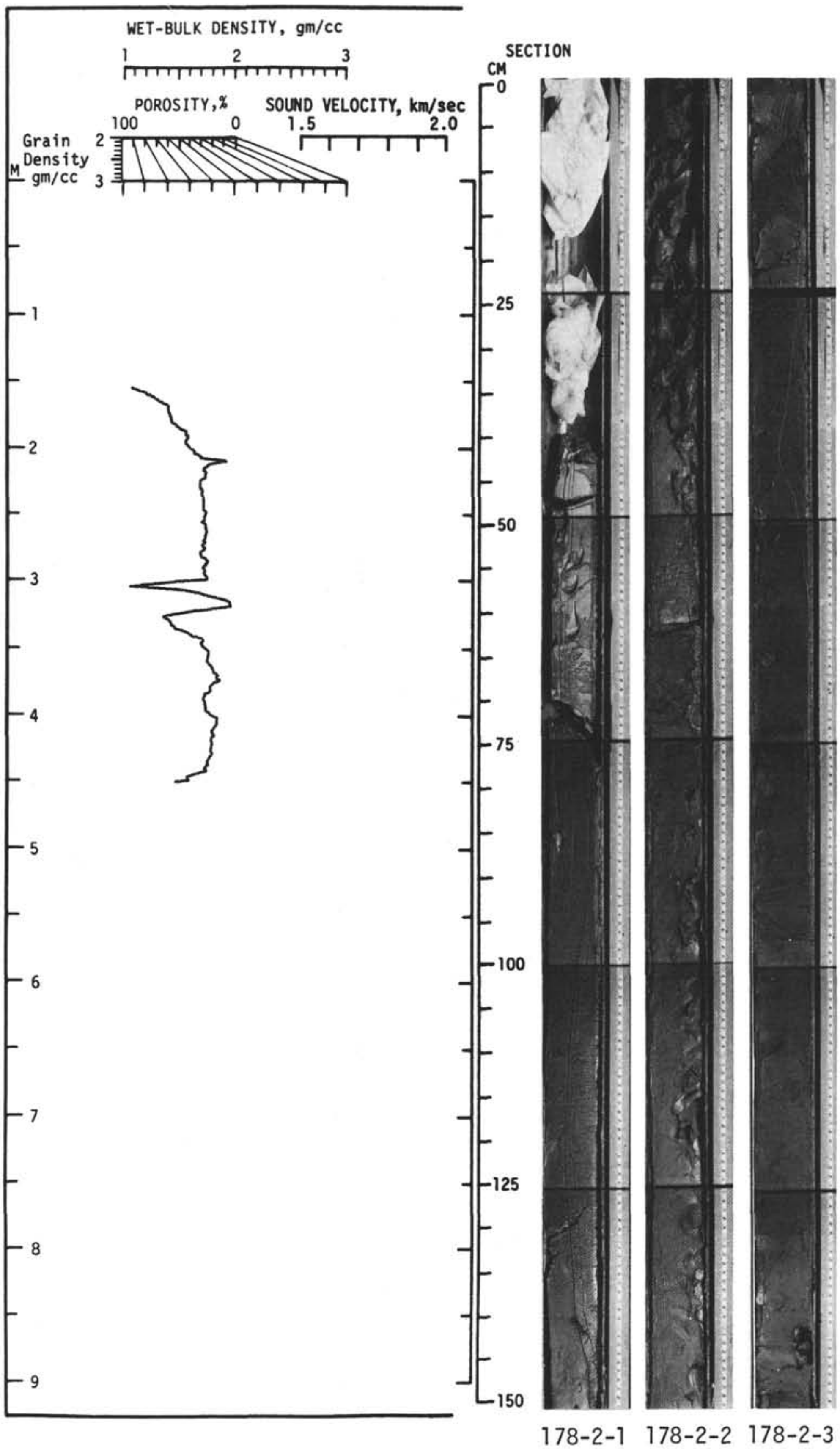
178-1-2
178-1-3
178-1-4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POROSITY,%
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SOUND VELOCITY, km/sec
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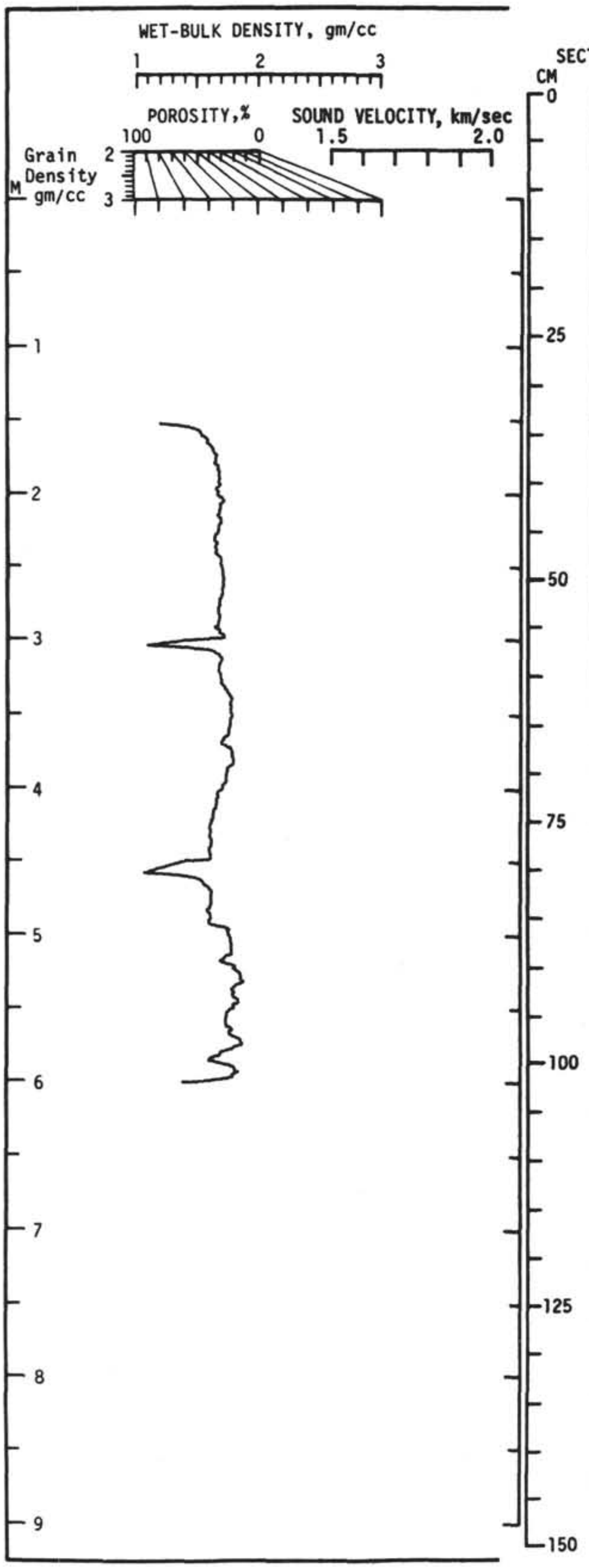
2.0
Grain Density gm/cc
M
SECTION
CM
0
25
50
75
100
125
150
1
2
3
4
5
6
7
8
9
178-2-1
178-2-2
178-2-3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SOUND VELOCITY, km/sec
1.5
2.0
Grain Density gm/cc
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M
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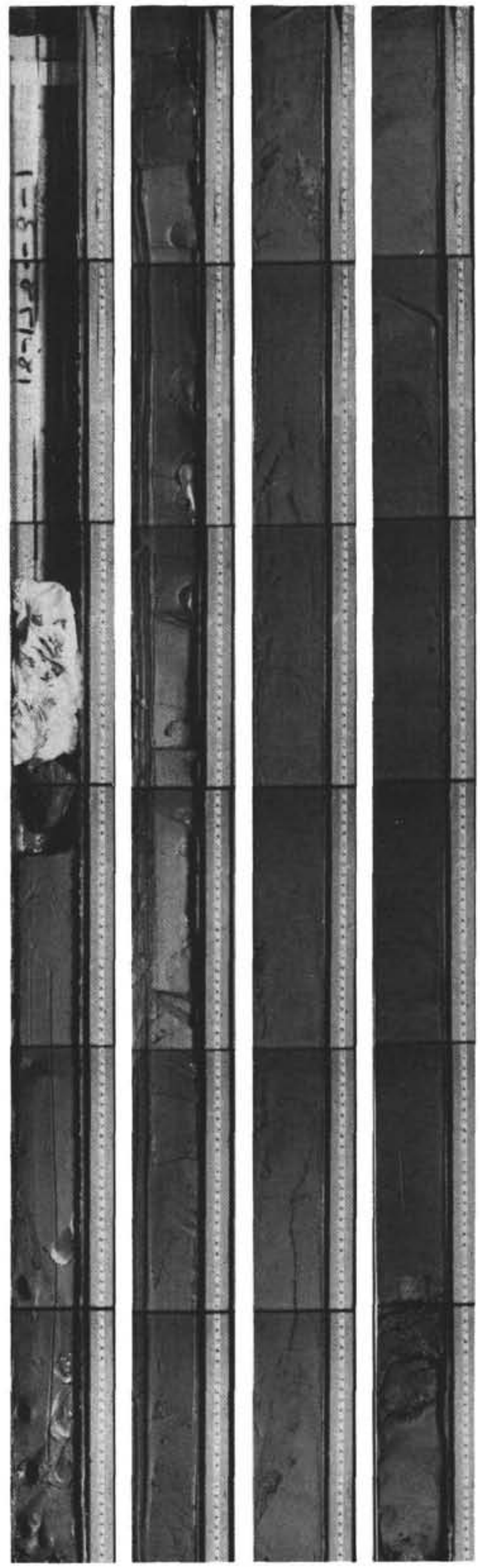
2
3
4
5
6
7
8
9
SECTION CM
0
25
50
75
100
125
150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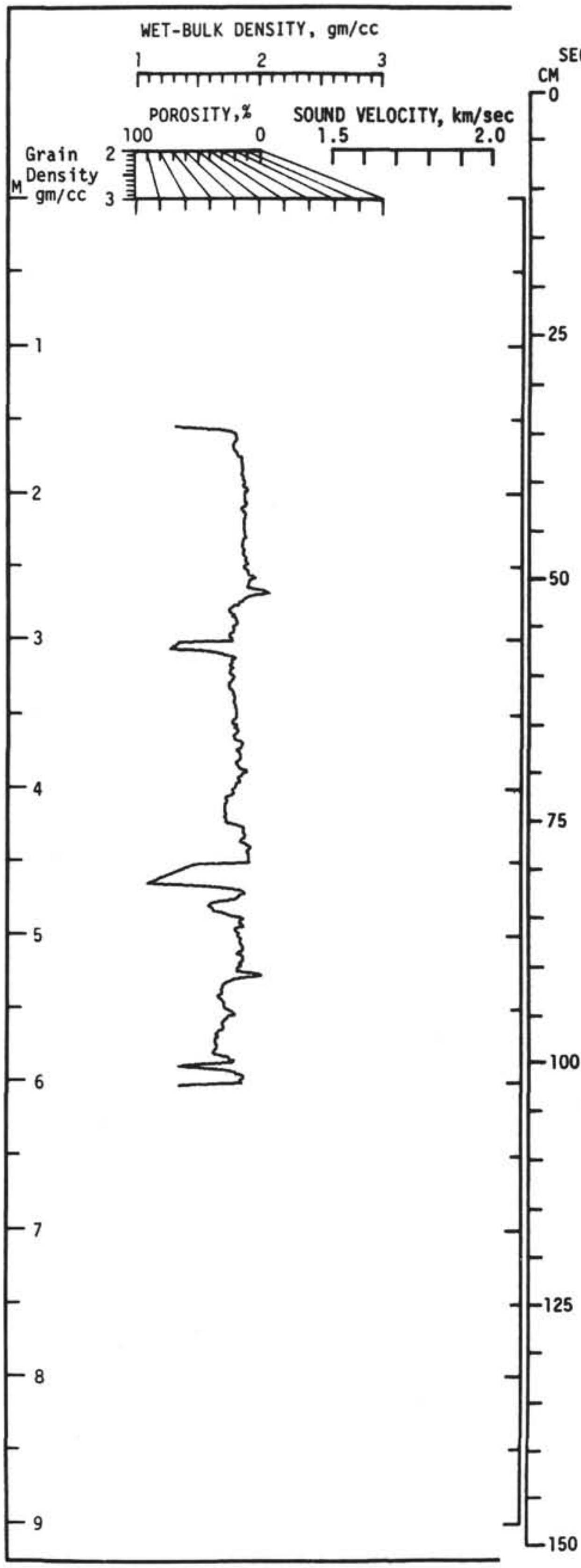
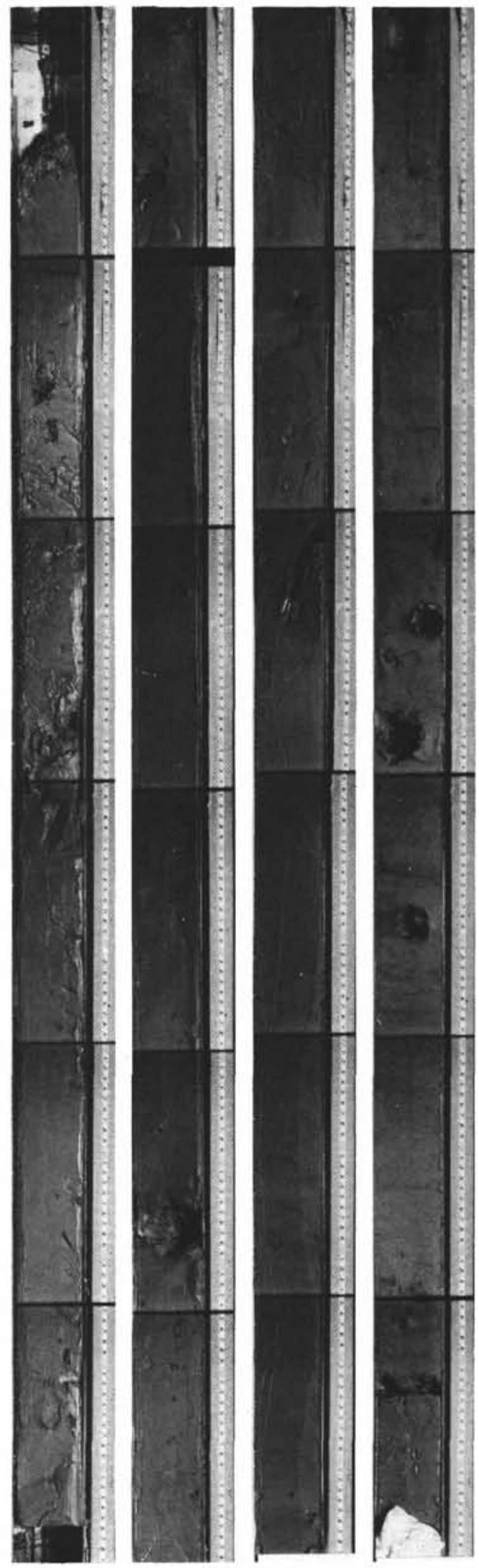
178-3-4





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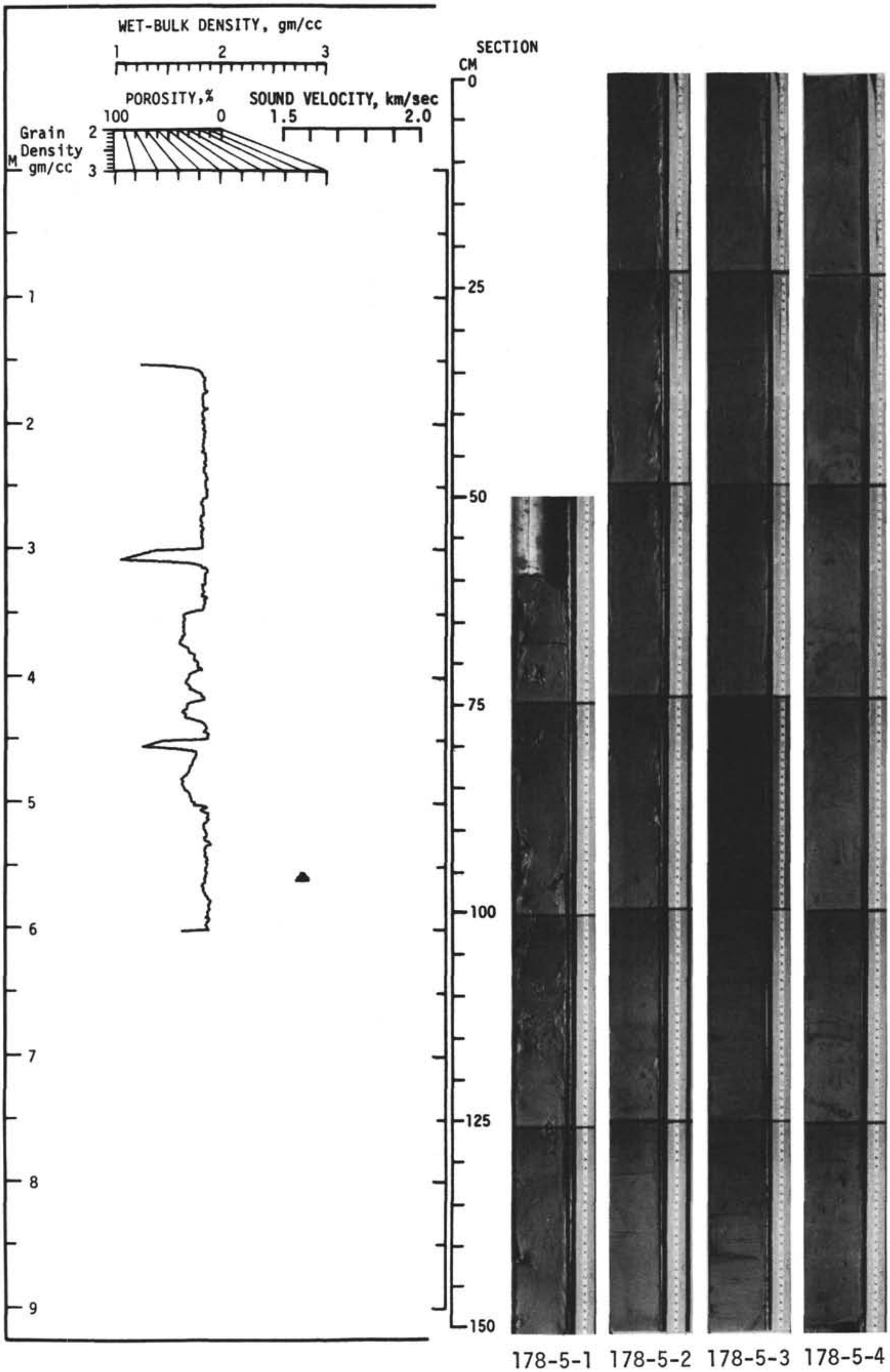
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SOUND VELOCITY, km/sec
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2.0
Grain Density gm/cc
2
3
M
1
2
3
4
5
6
7
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SECTION
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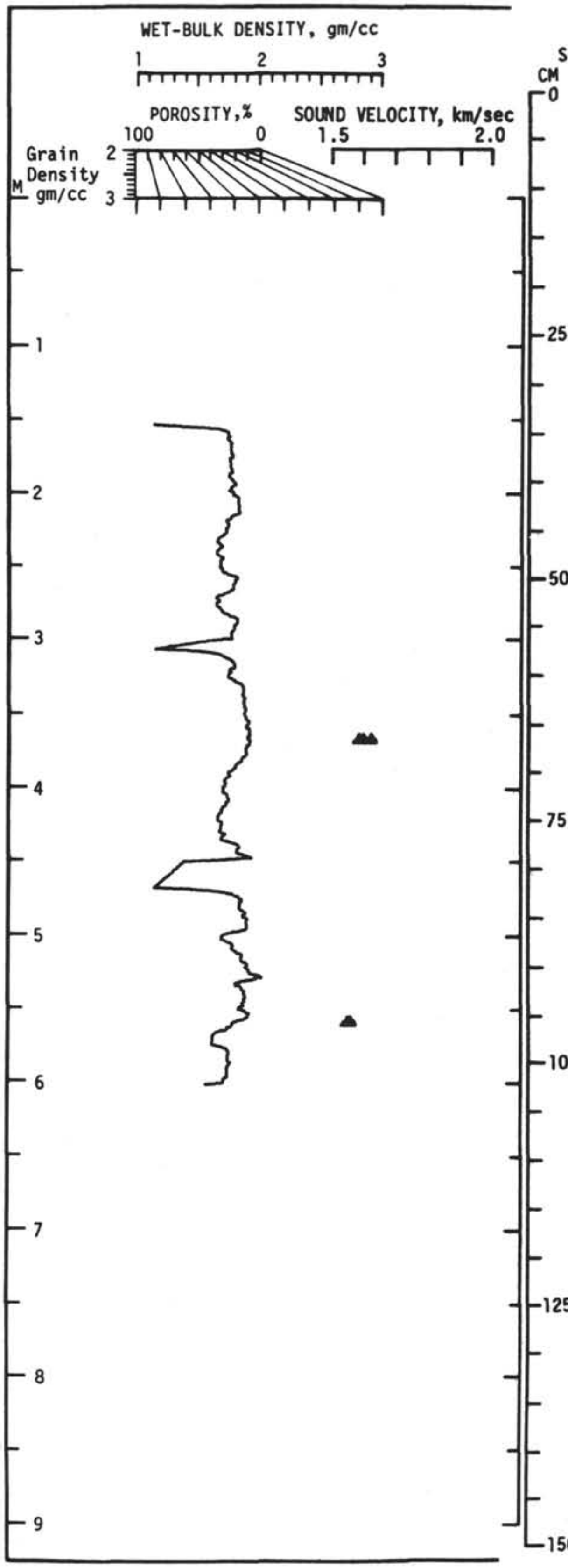
50
75
100
125
150
178-5-1
178-5-2
178-5-3
178-5-4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POROSITY,%
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SOUND VELOCITY, km/sec
1.5
2.0
Grain Density gm/cc
2
3
M
1
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3
4
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7
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9
SECTION
CM
0
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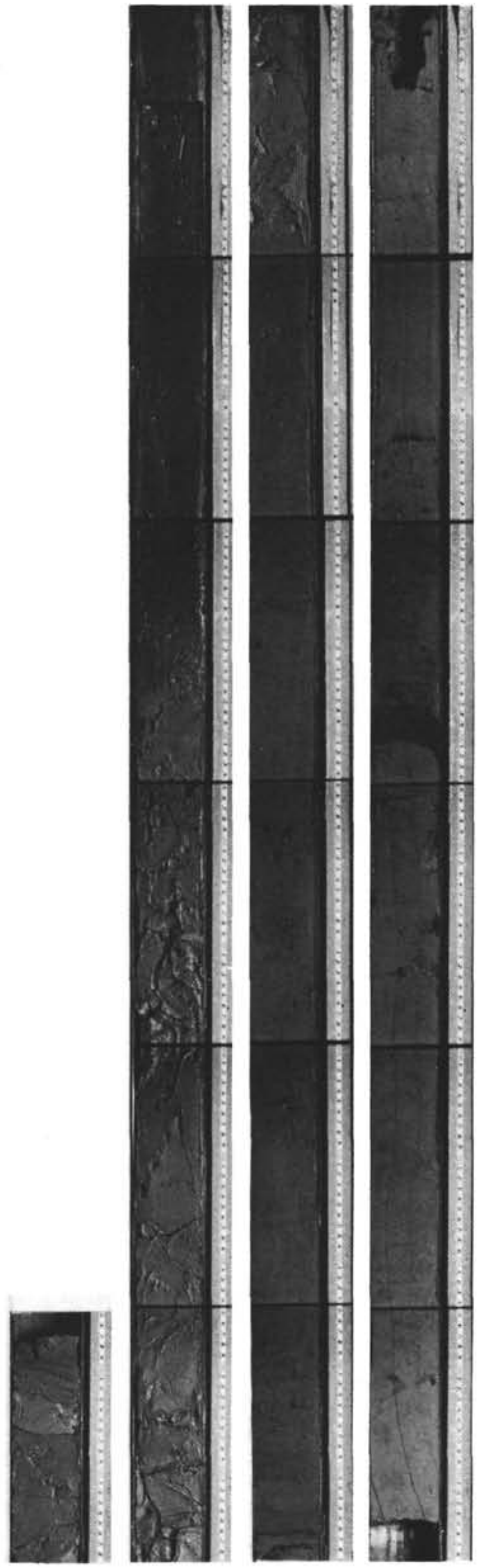
50
75
100
125
150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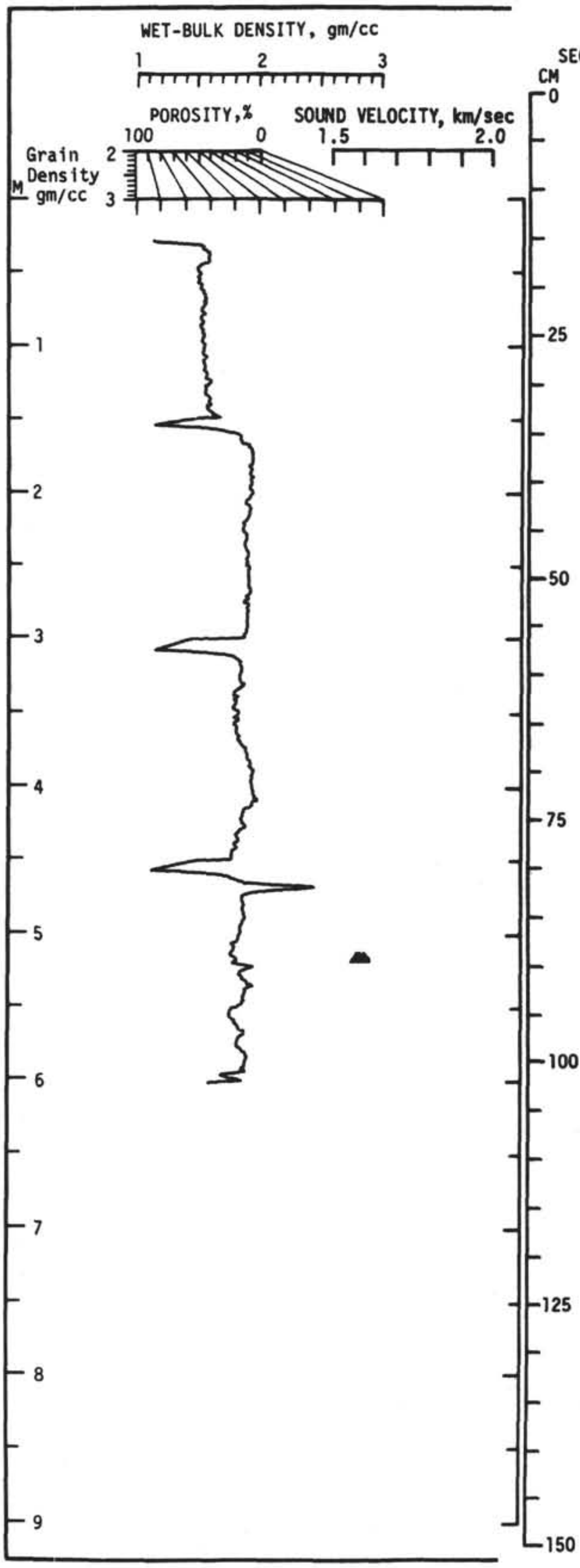
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Grain Density gm/cc
2
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CM
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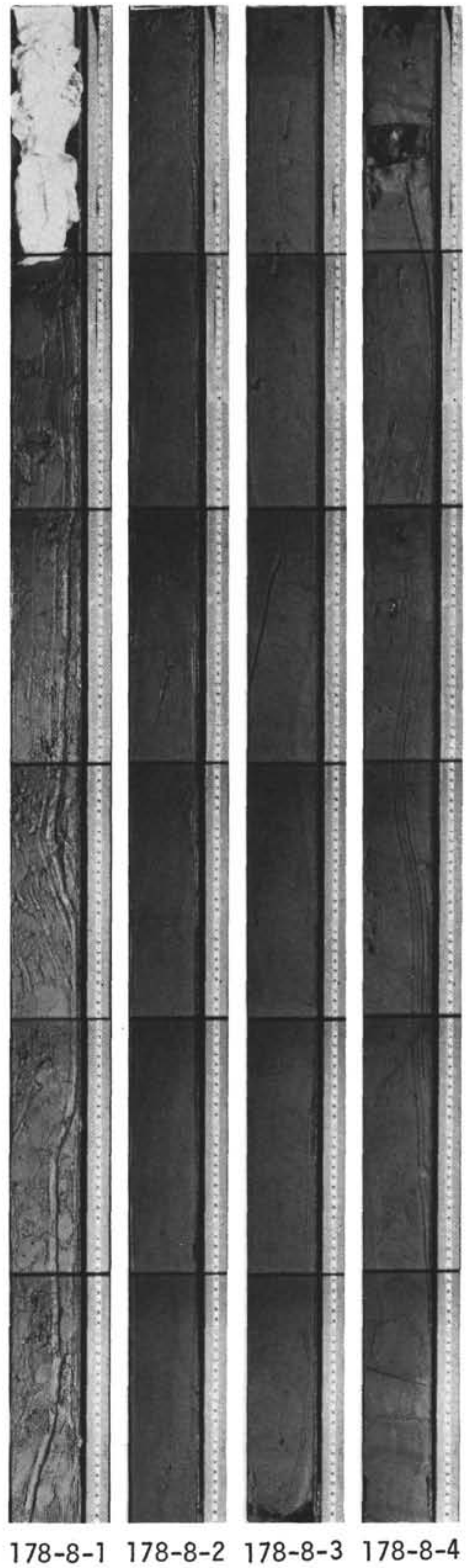
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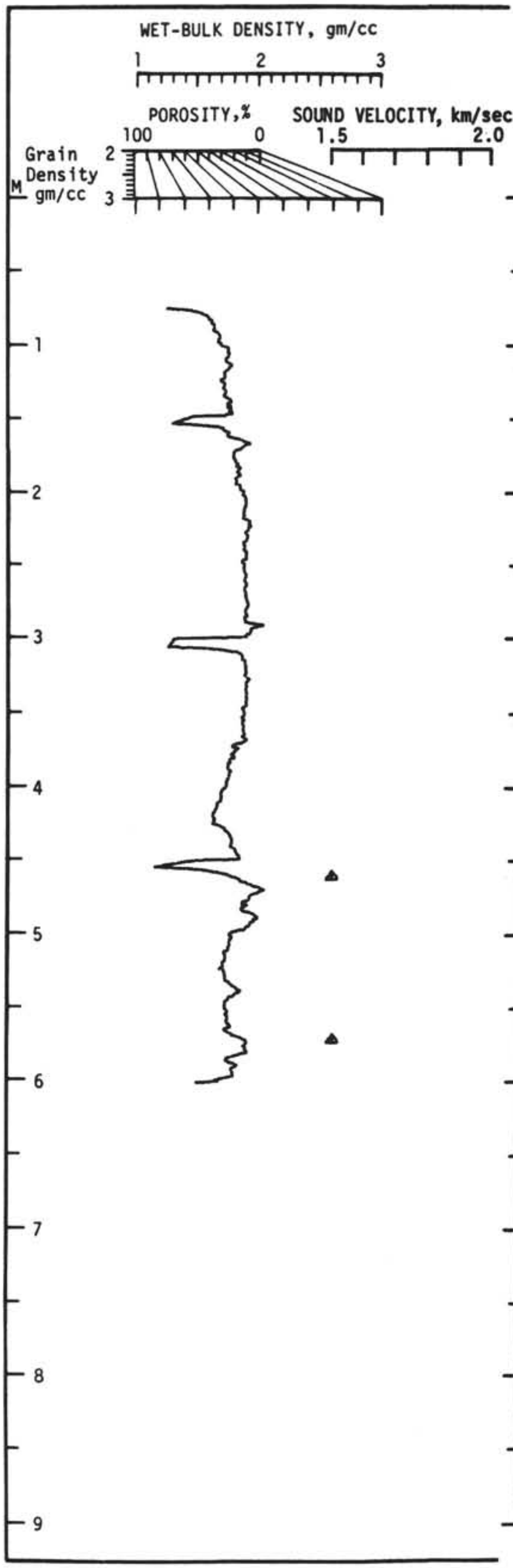

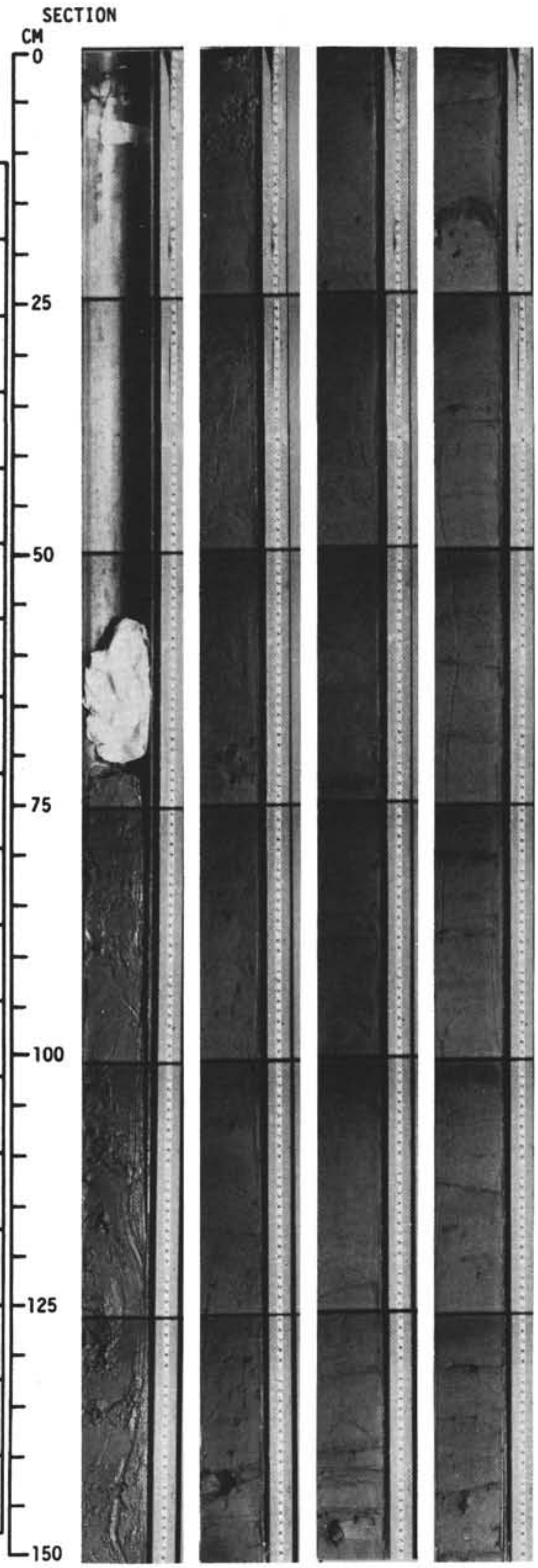

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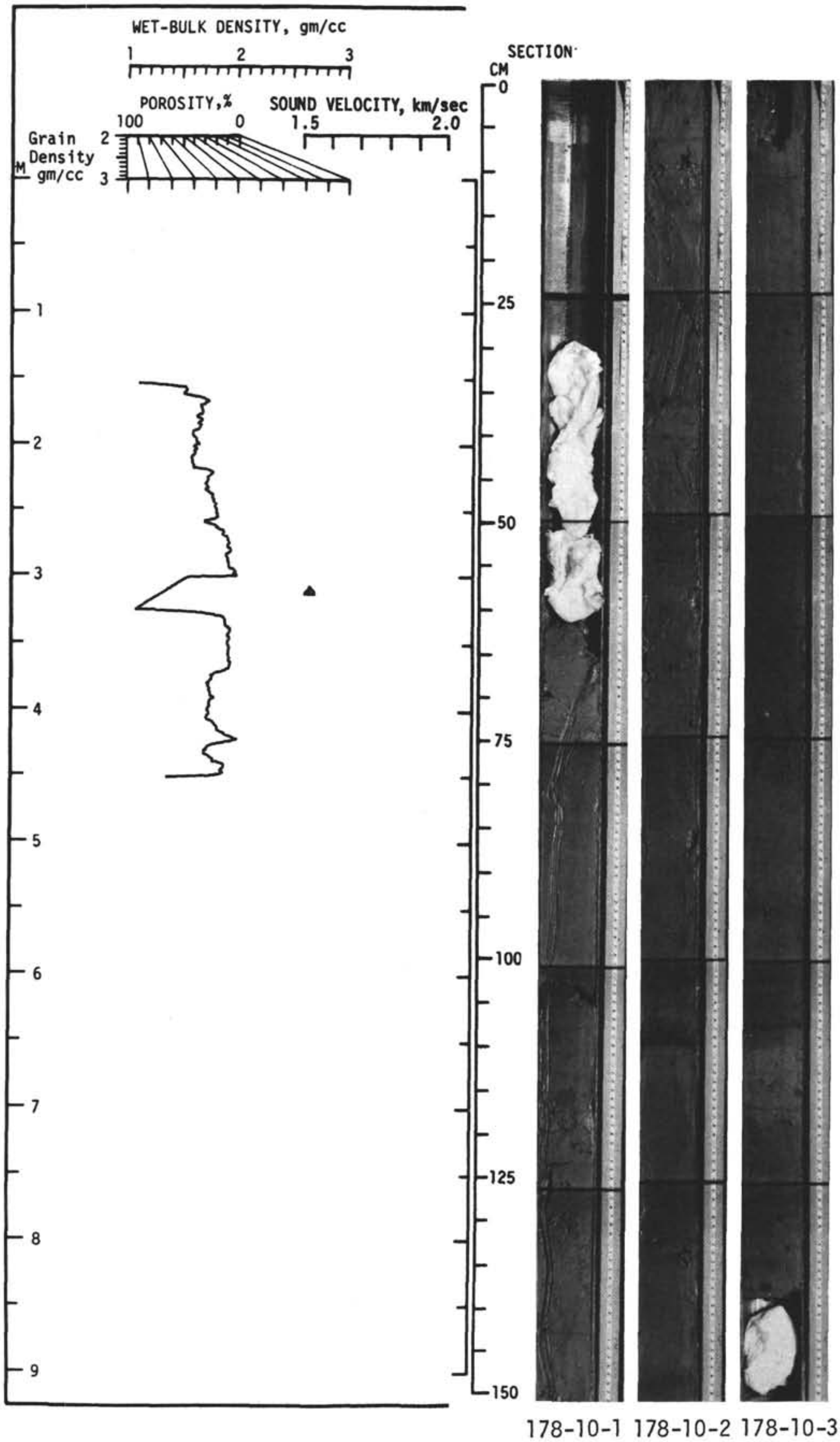
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Grain Density gm/cc
2
3
M
1
2
3
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SECTION
CM
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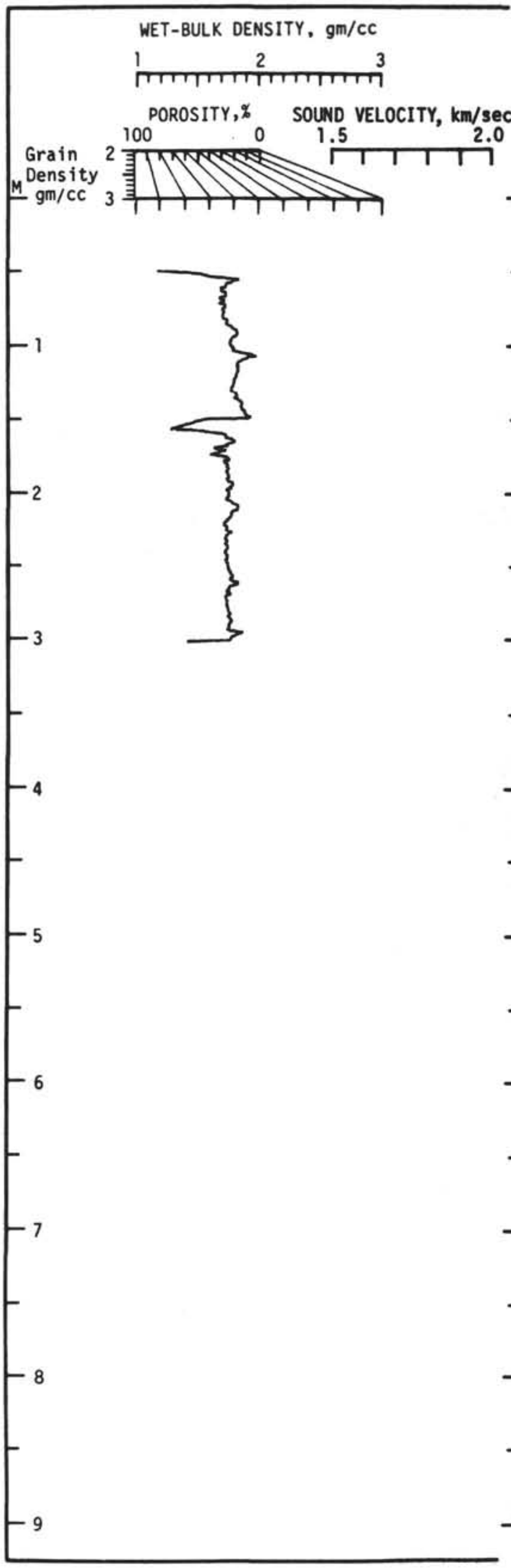
50
75
100
125
150
178-10-1 178-10-2 178-10-3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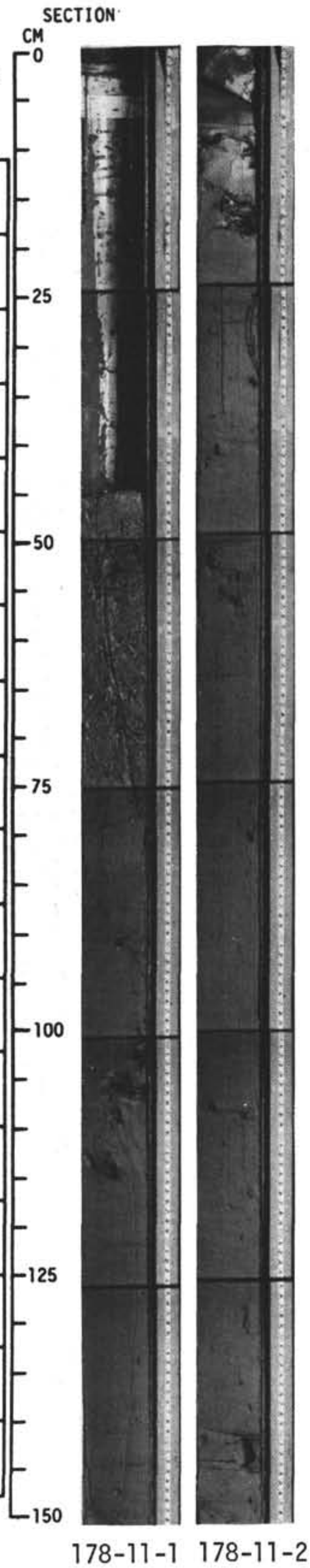
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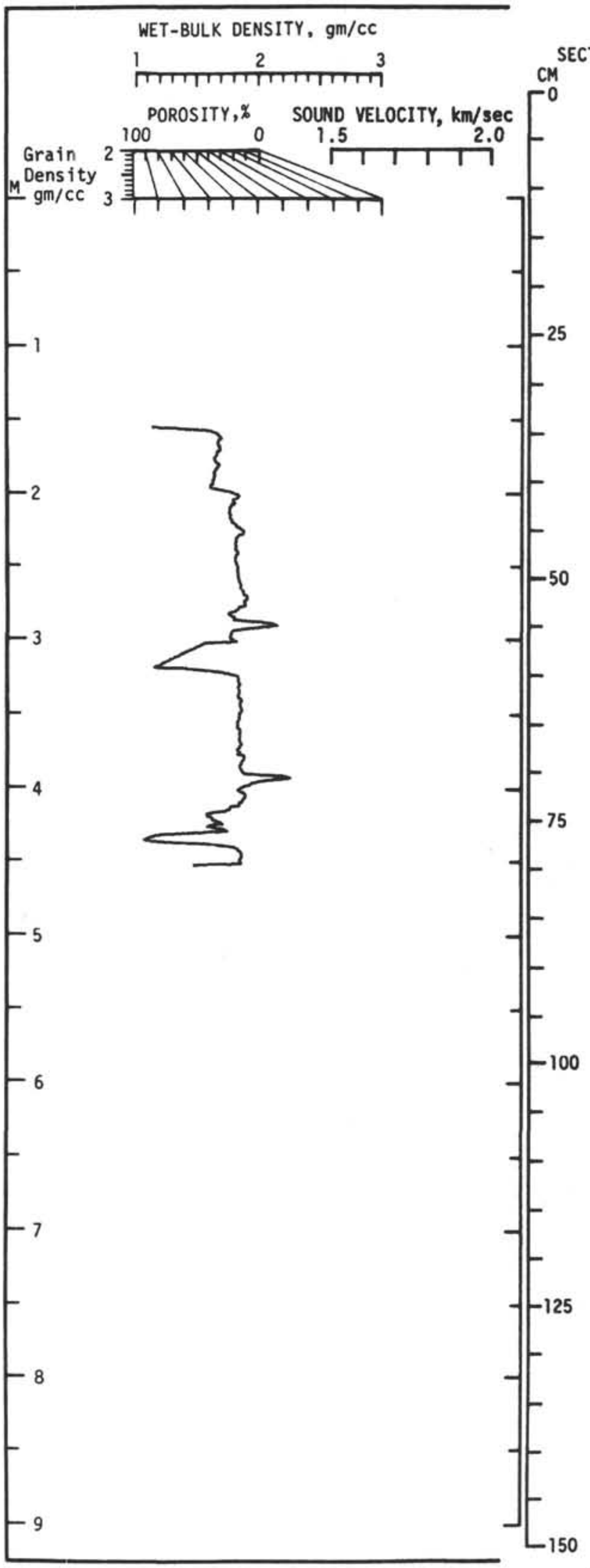

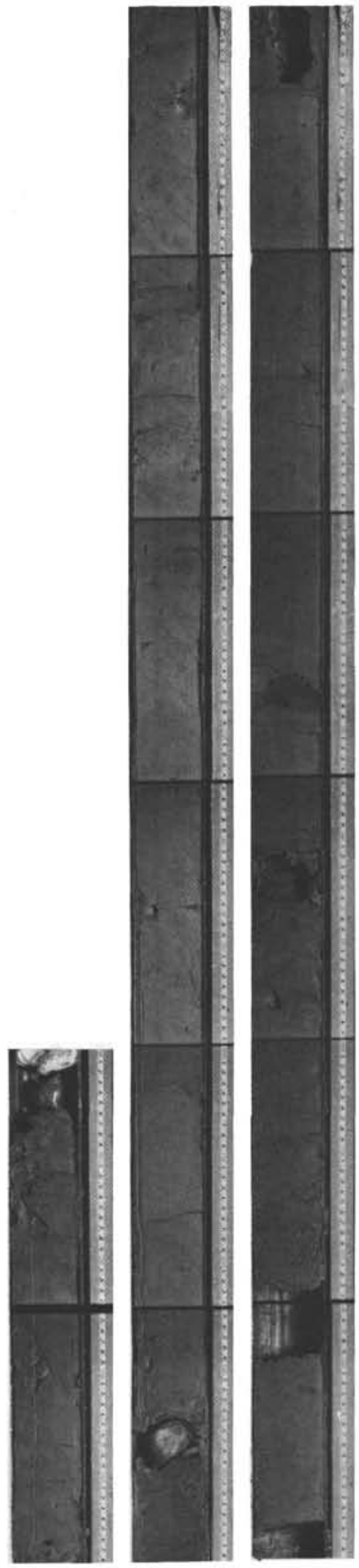

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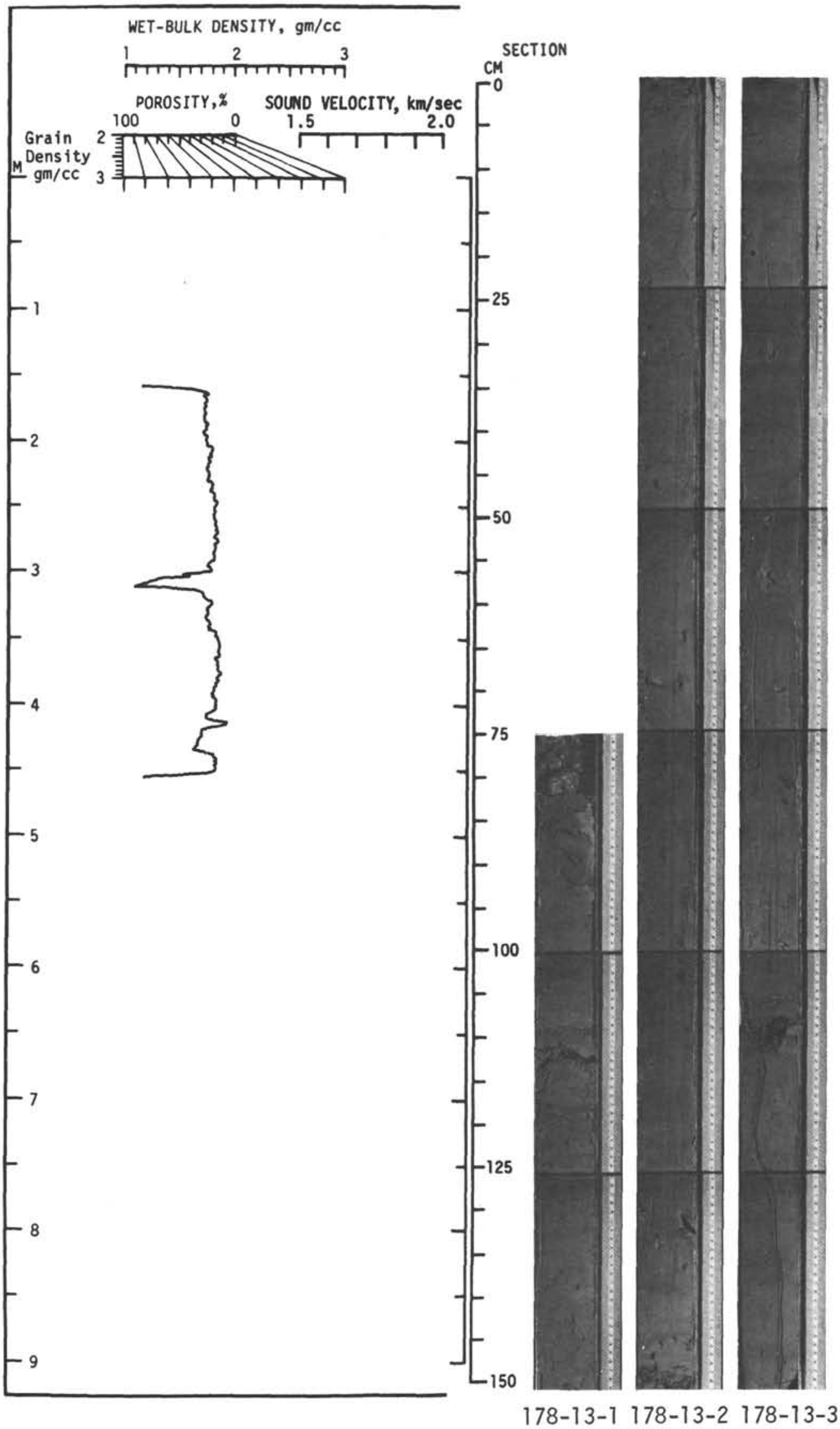
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Grain Density gm/cc
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M
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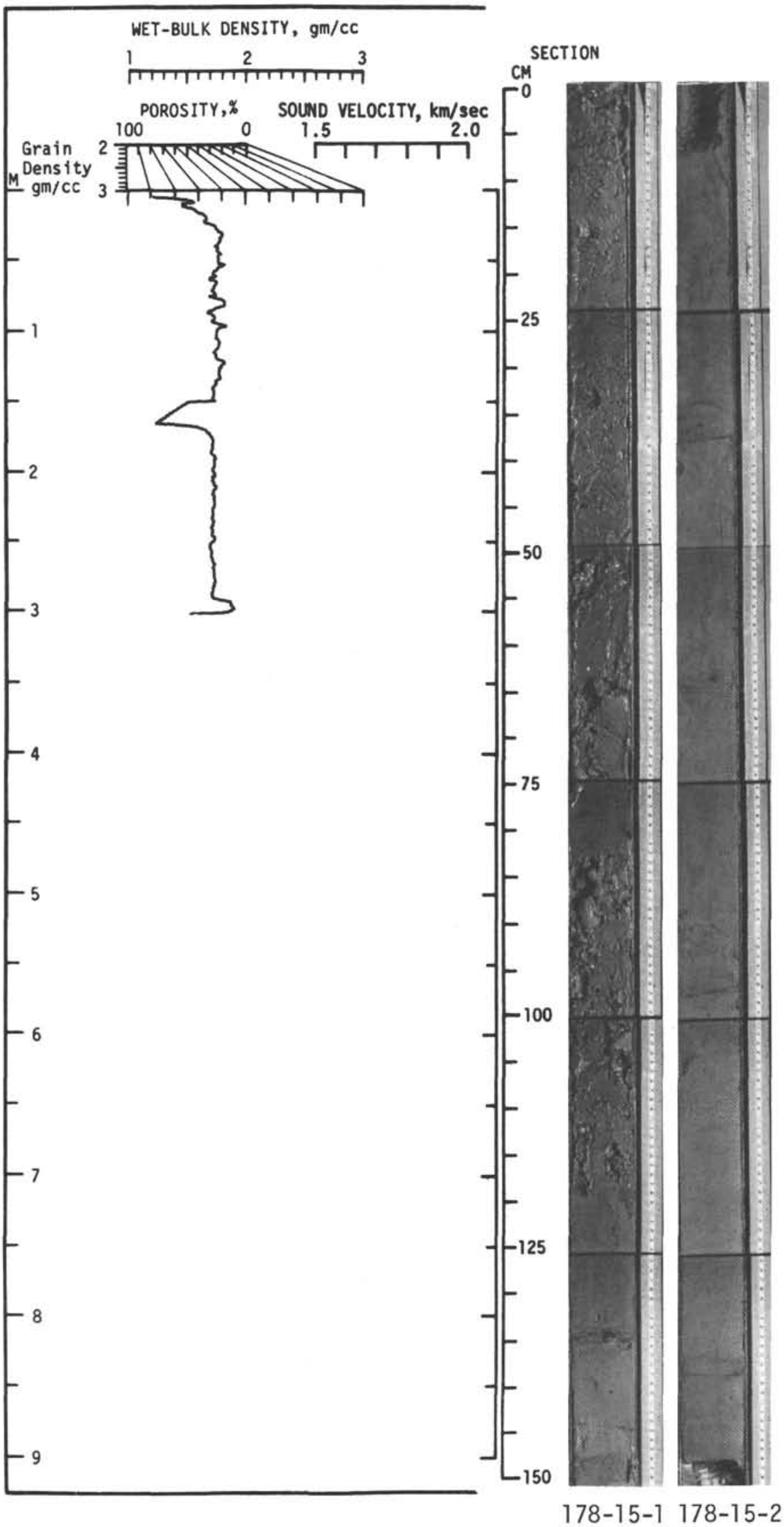
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Grain Density gm/cc
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M
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SECTION
CM
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125
150
178-15-1
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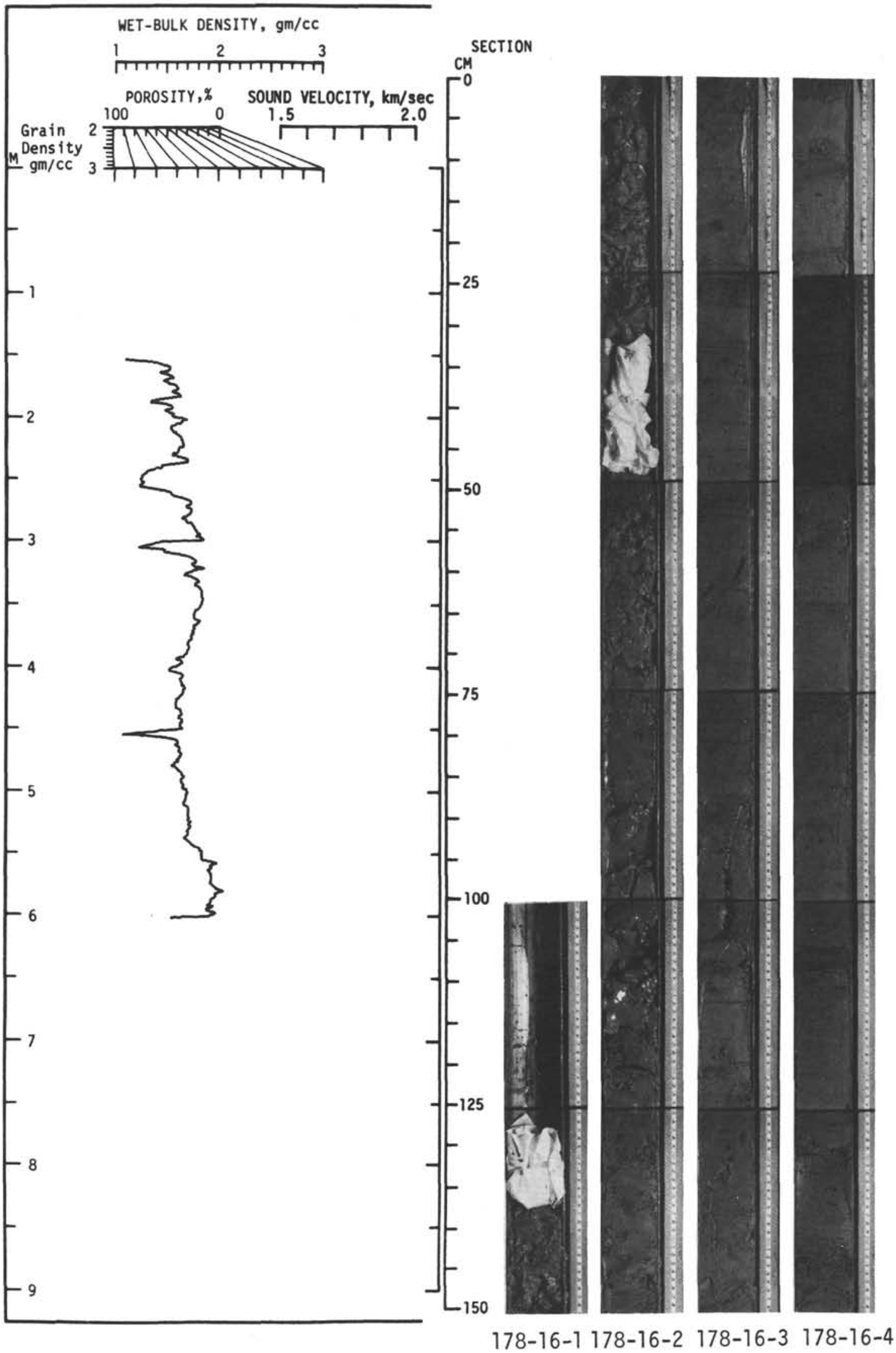
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Grain Density gm/cc
M
SECTION
CM
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75
100
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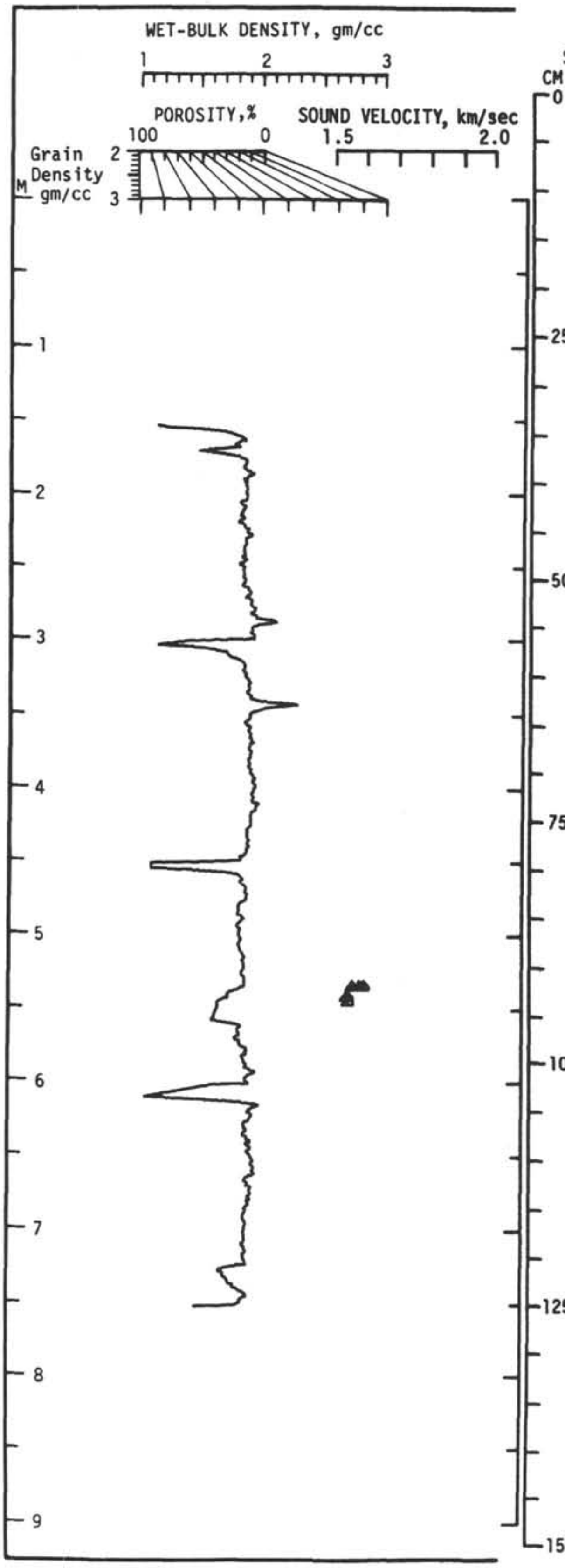
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Grain Density gm/cc
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CM
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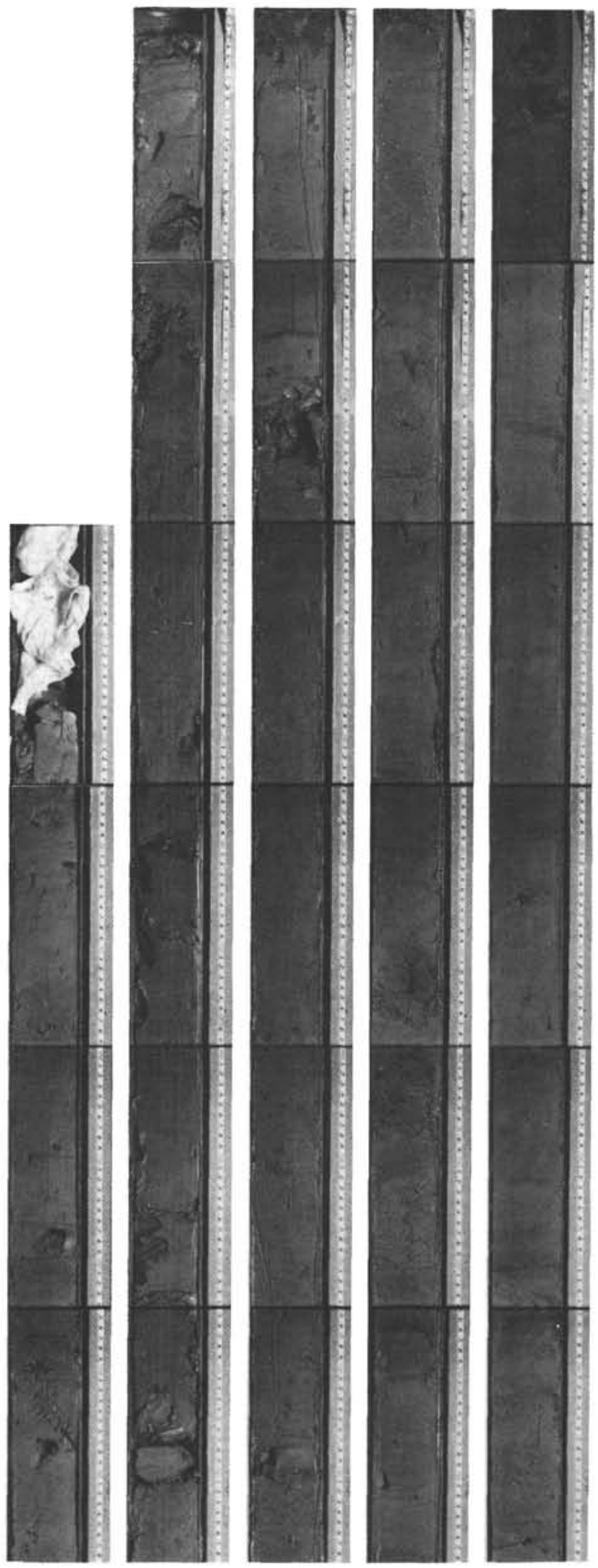
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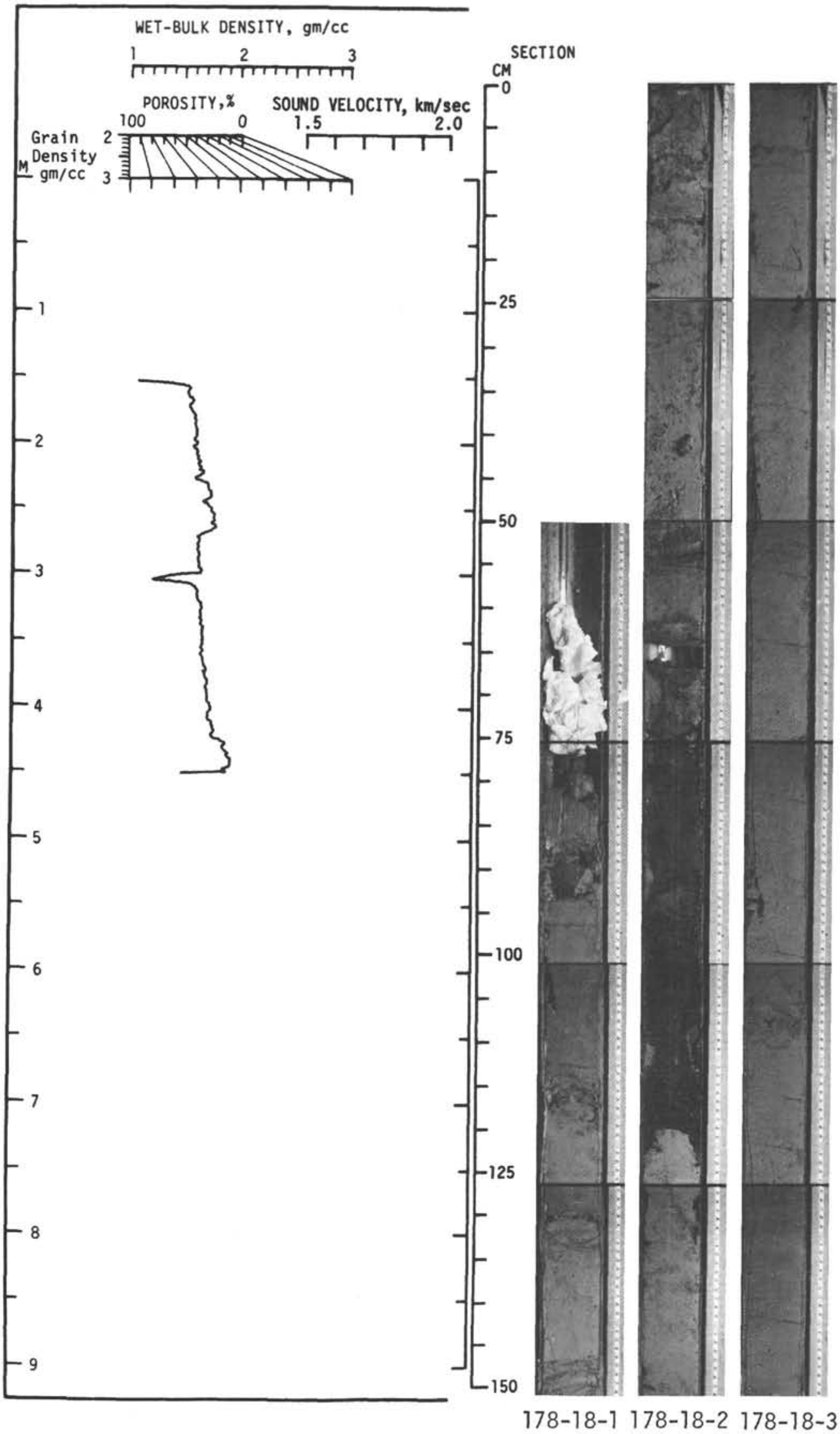
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0
SOUND VELOCITY, km/sec
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2.0
Grain Density gm/cc
2
3
M
1
2
3
4
5
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SECTION
CM
0
25
50
75
100
125
150
178-18-1
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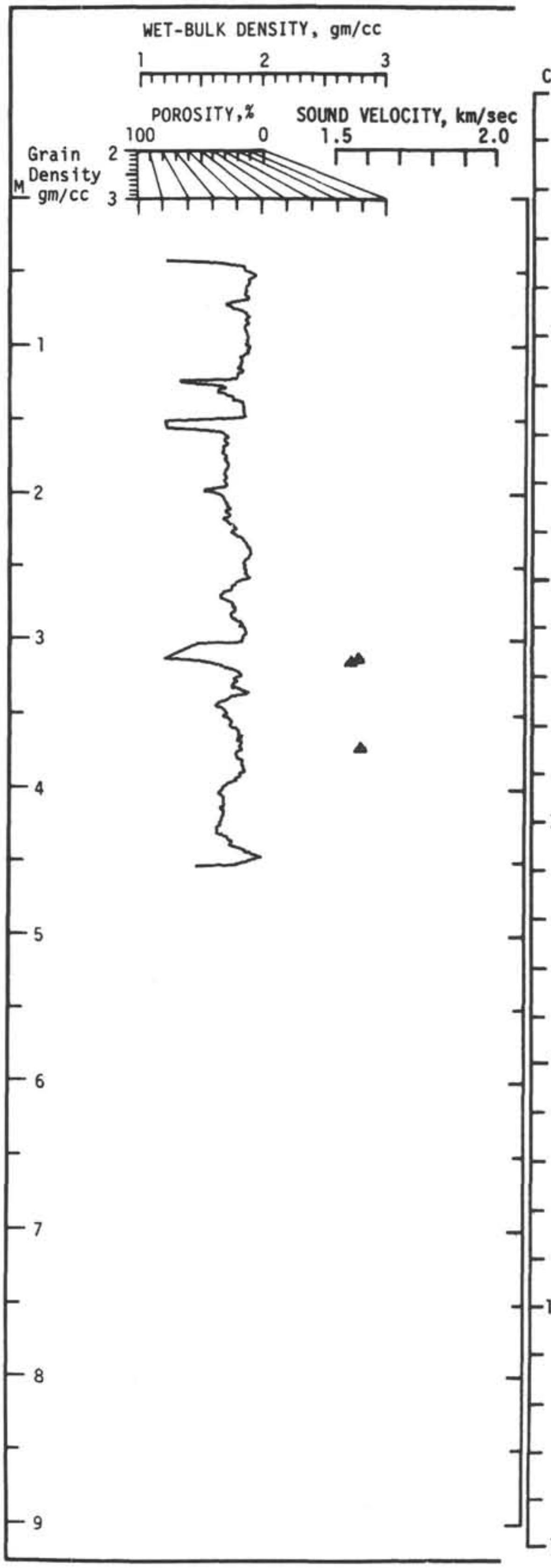
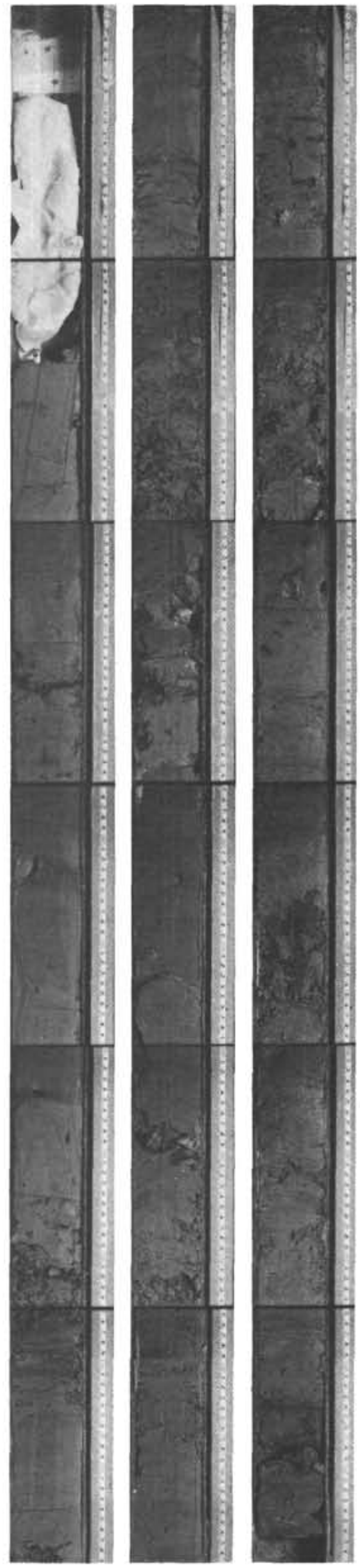
178-18-3





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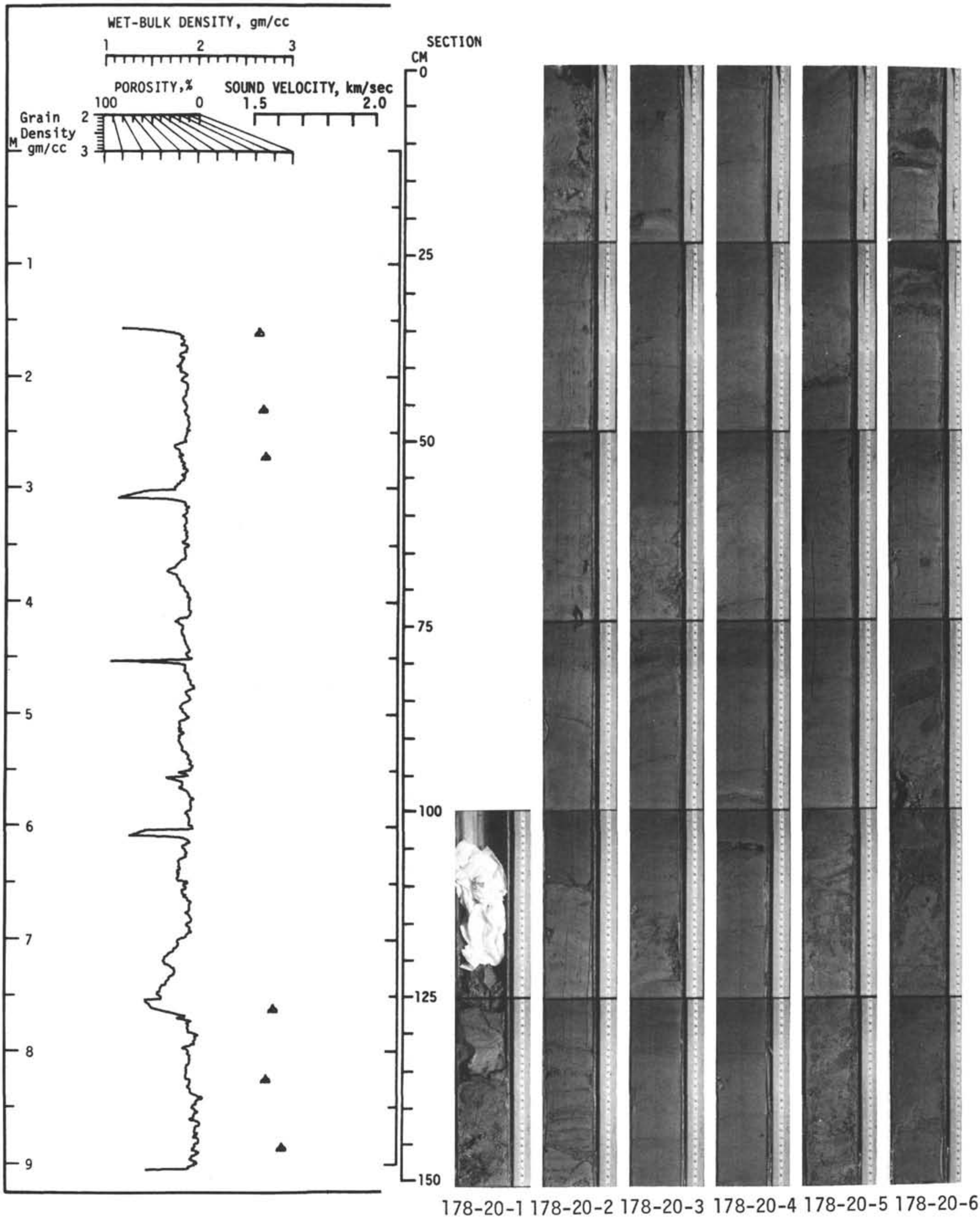
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SOUND VELOCITY, km/sec
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2.0
Grain Density gm/cc
2
3
M
1
2
3
4
5
6
7
8
9
SECTION
CM
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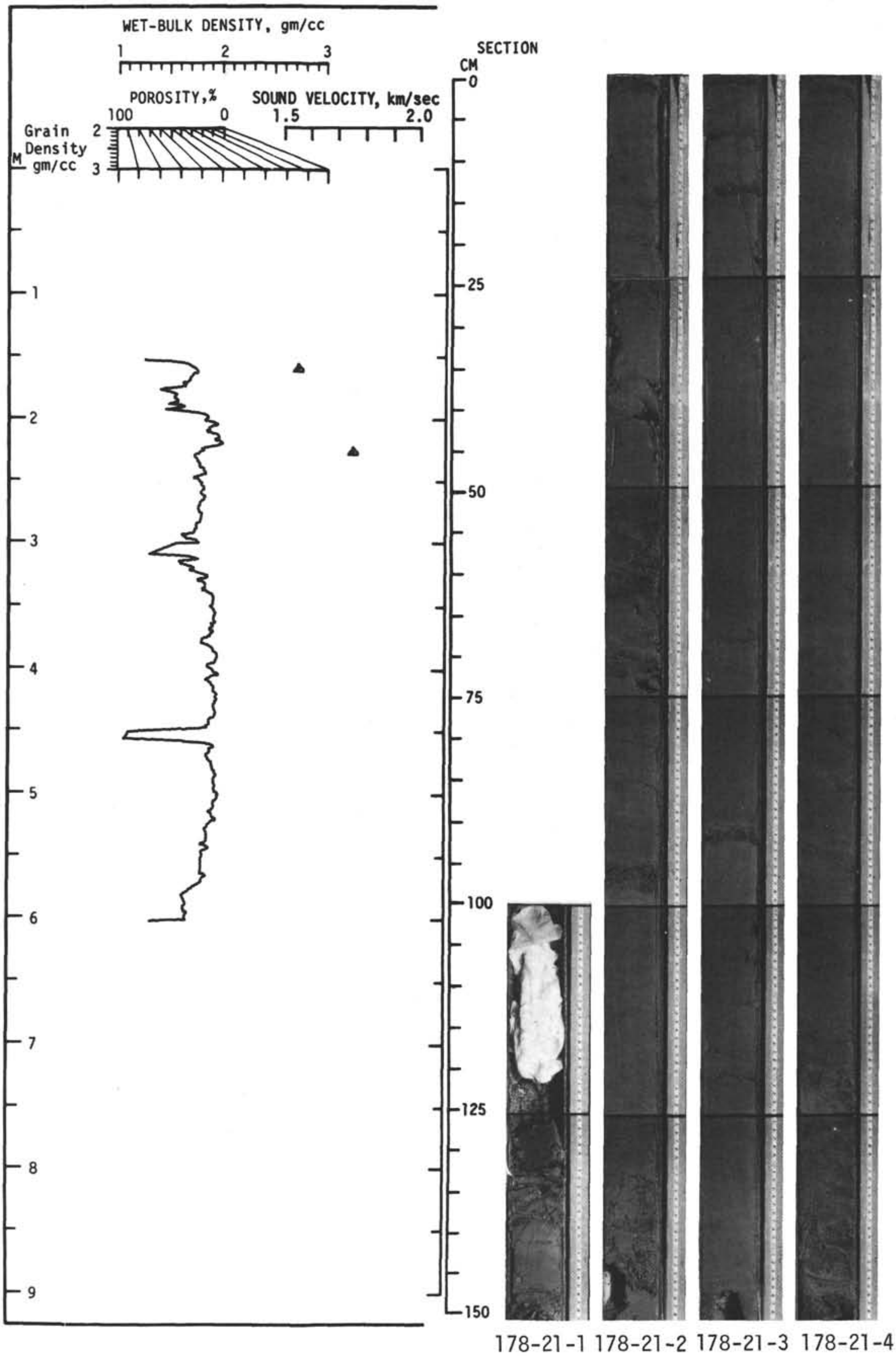
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Grain Density gm/cc
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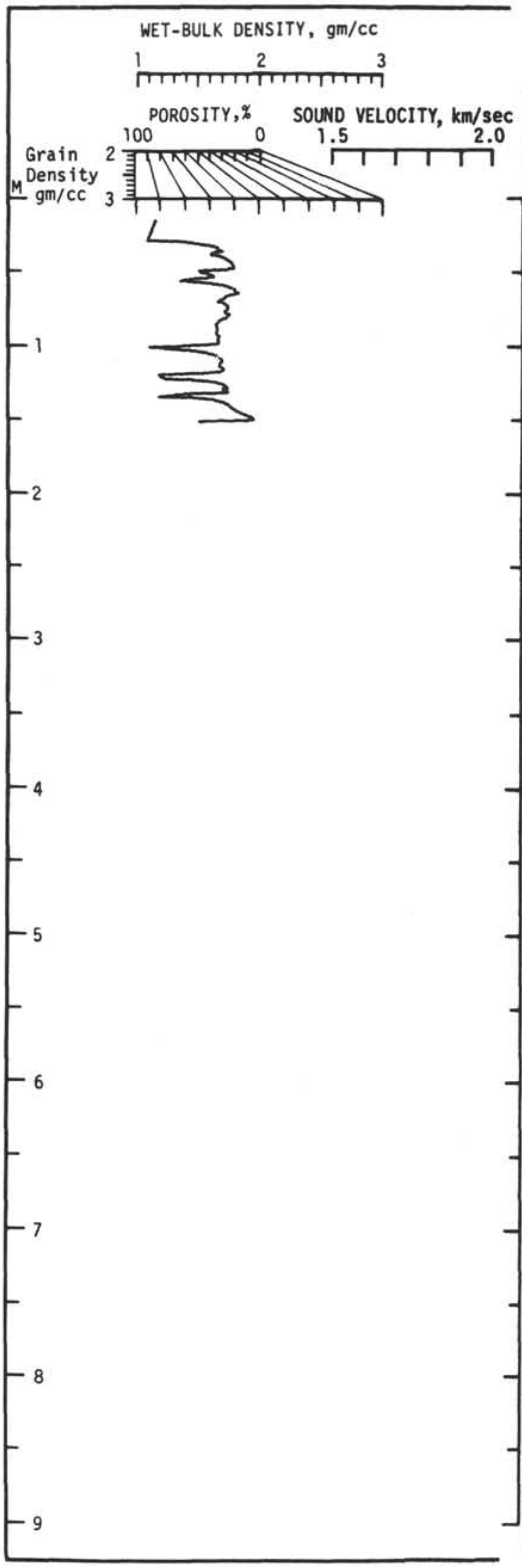
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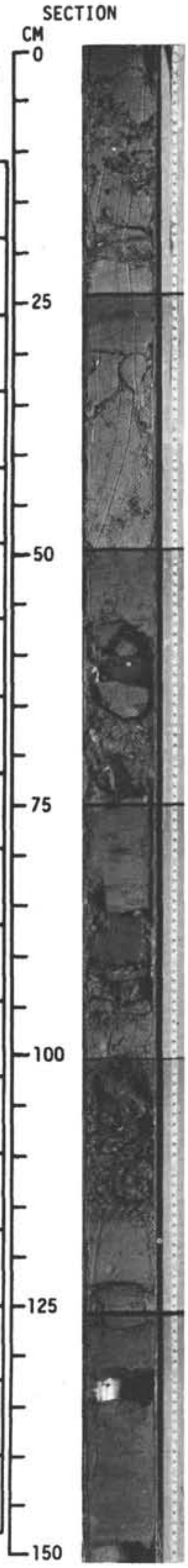
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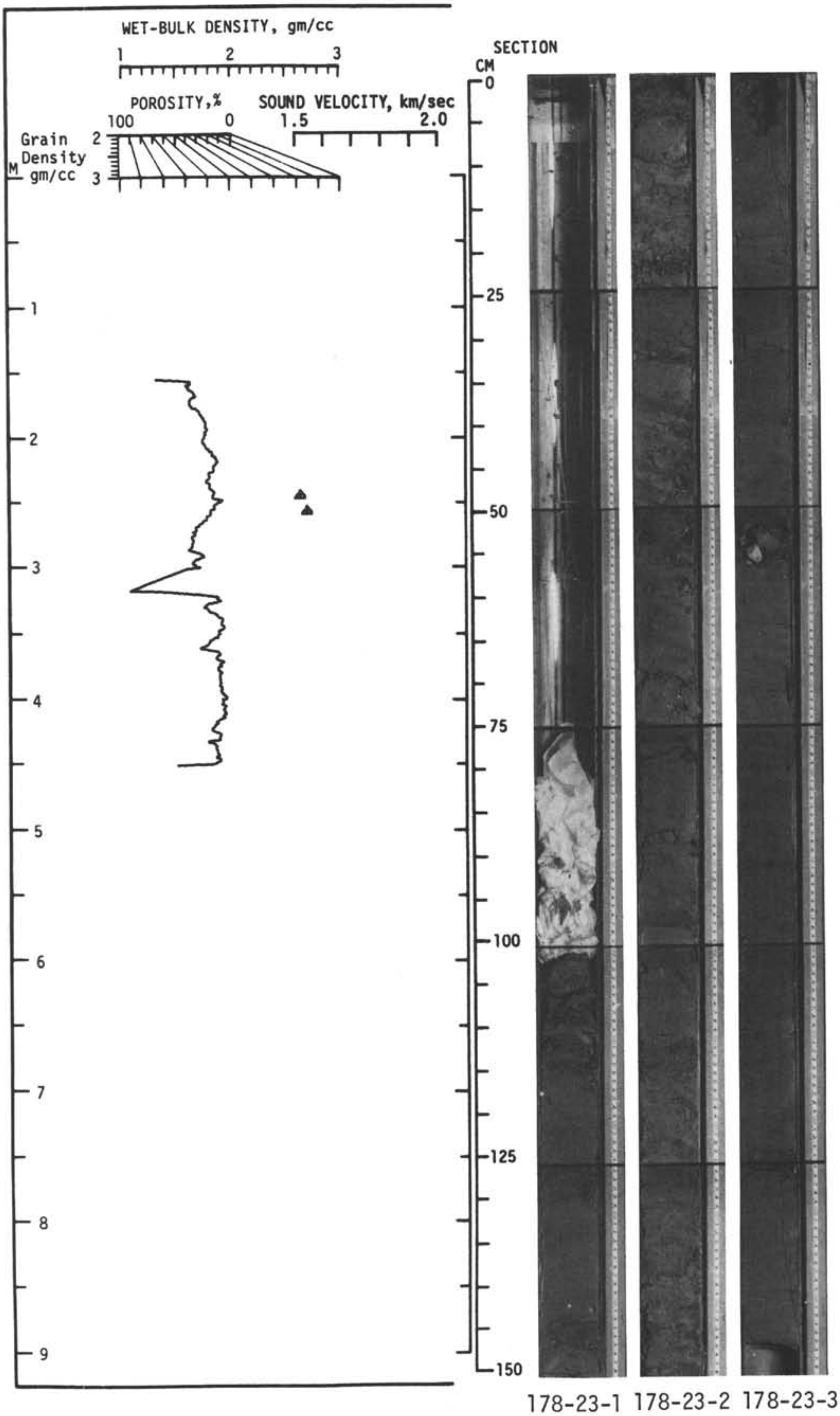
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Grain Density gm/cc
2
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M
1
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4
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SECTION
CM
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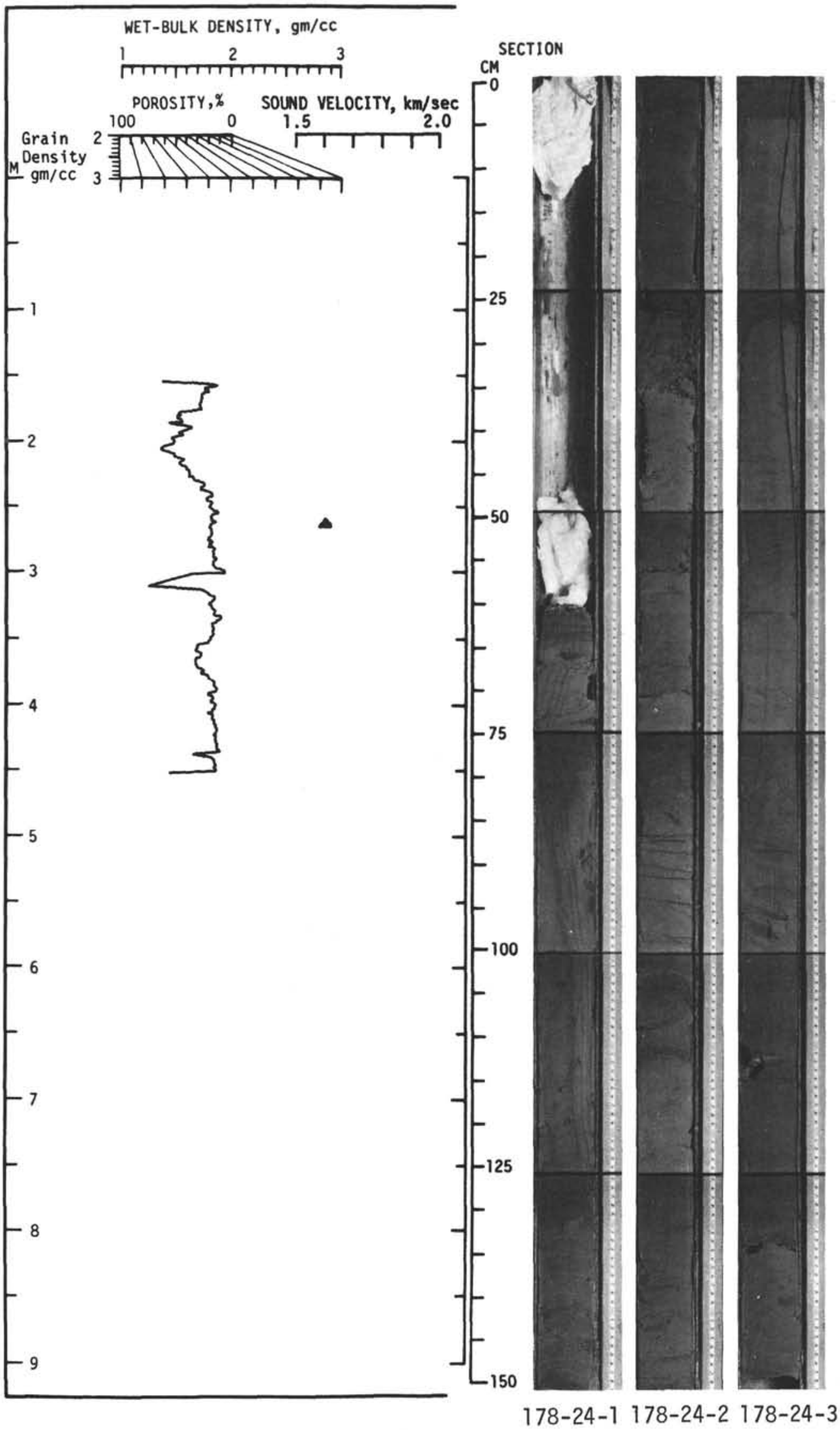
100
125
150
178-23-1
178-23-2
178-23-3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0
SOUND VELOCITY, km/sec
1.5
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Grain Density gm/cc
2
3
M
1
2
3
4
5
6
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8
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SECTION
CM
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50
75
100
125
150
178-24-1
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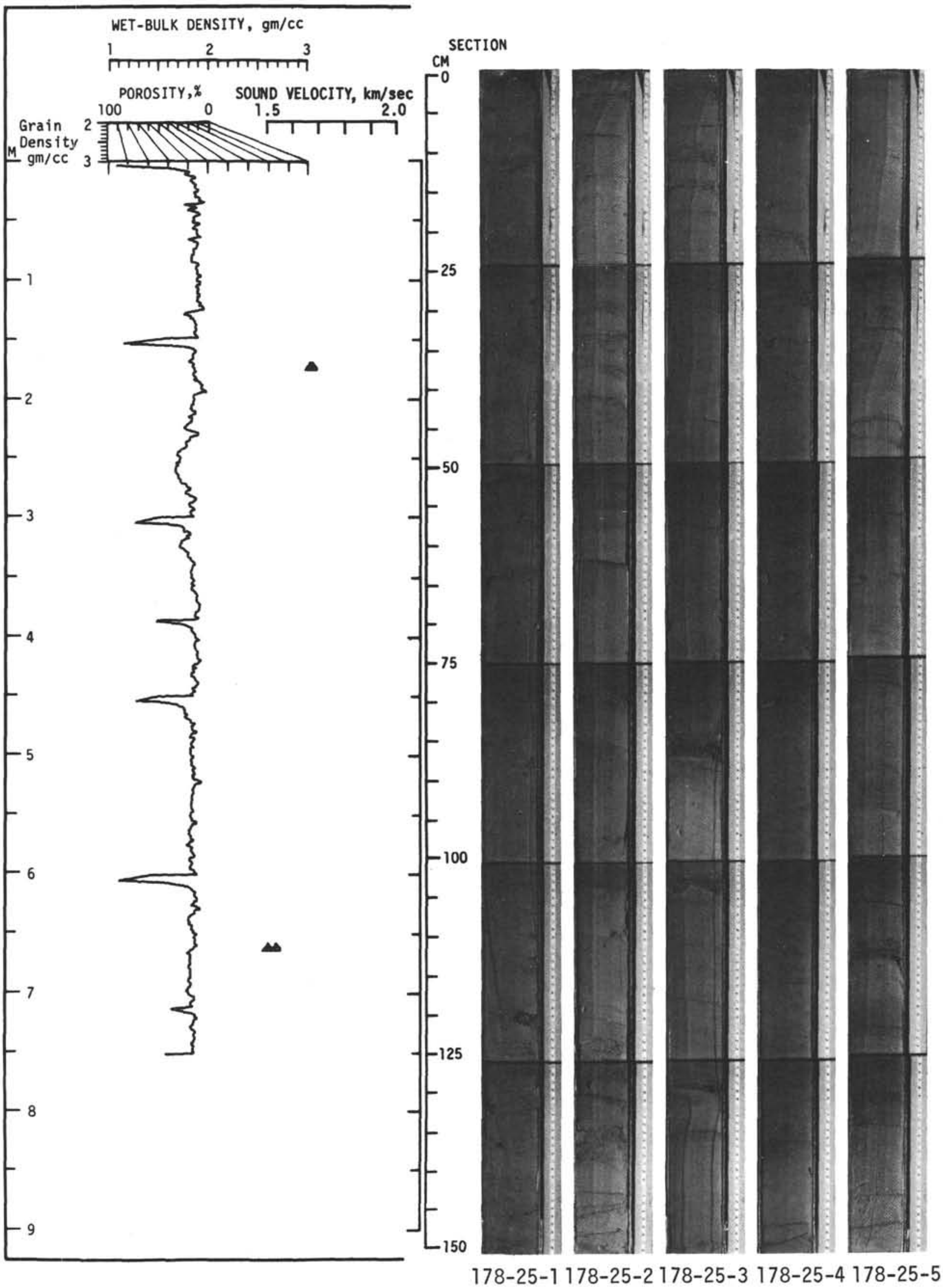
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SOUND VELOCITY, km/sec
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2.0
Grain Density gm/cc
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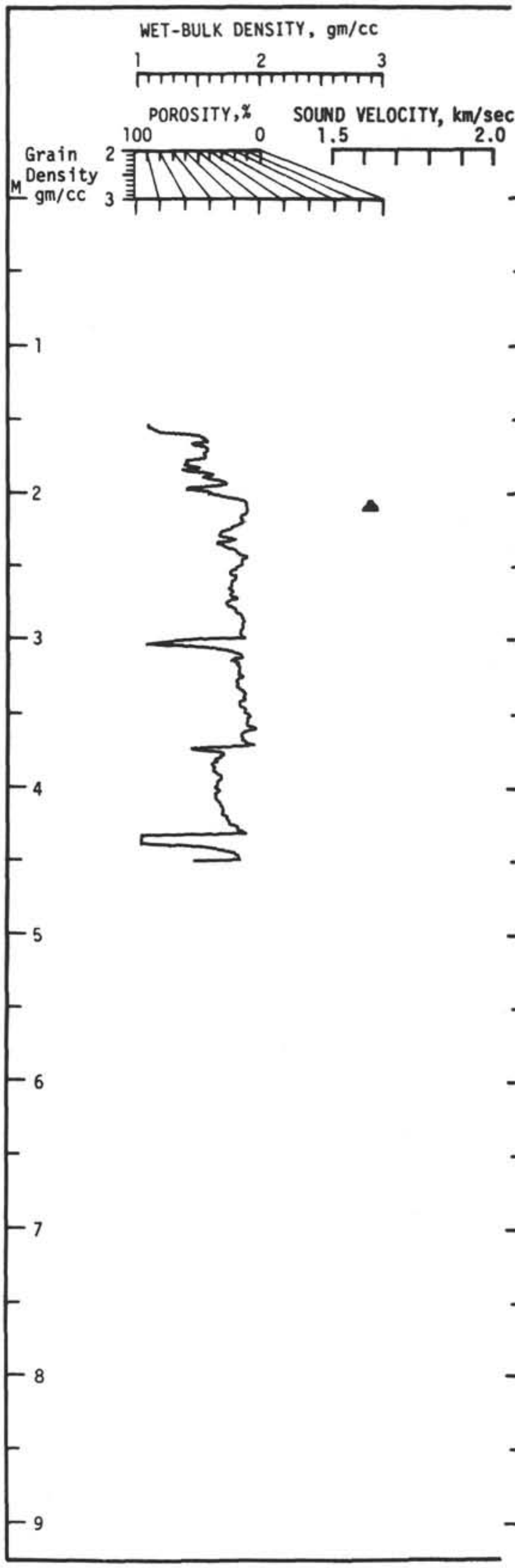
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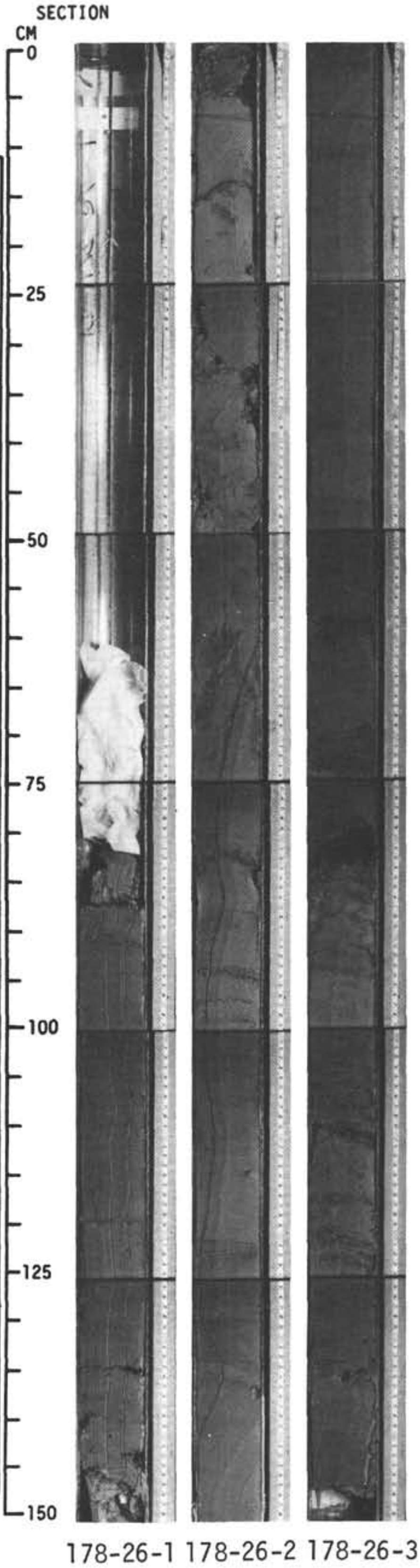
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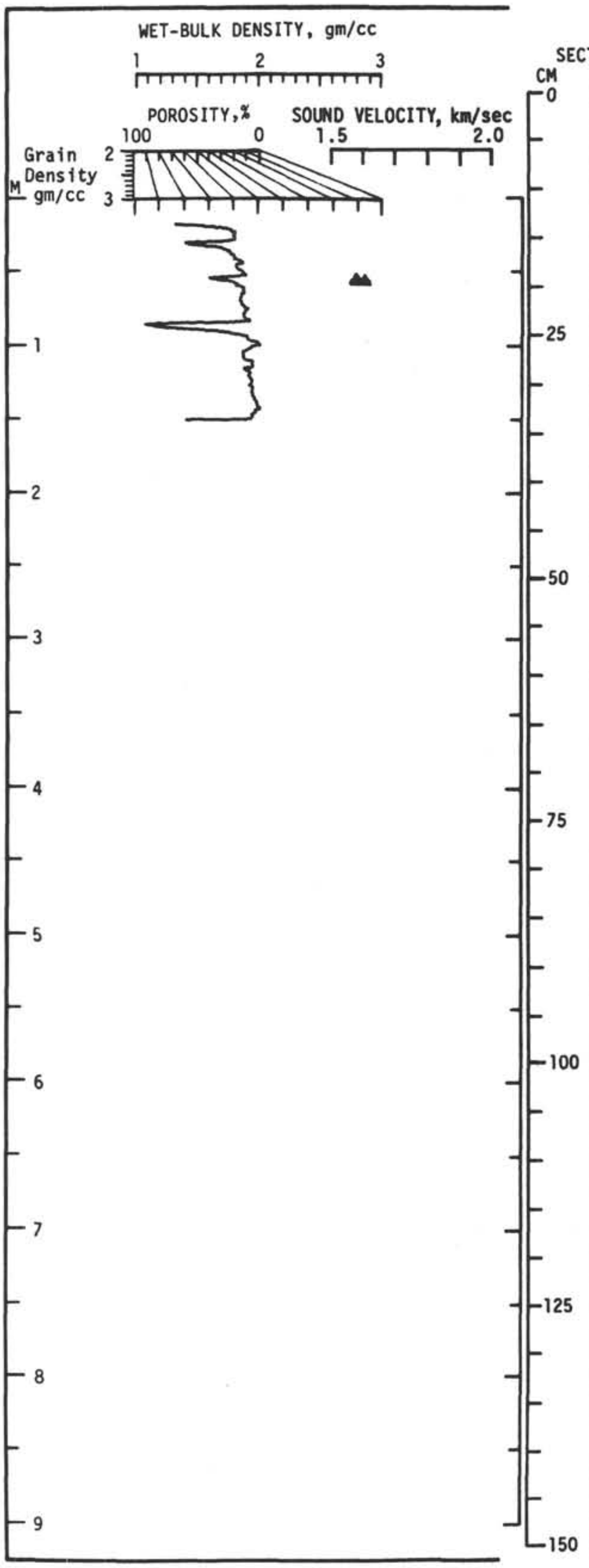
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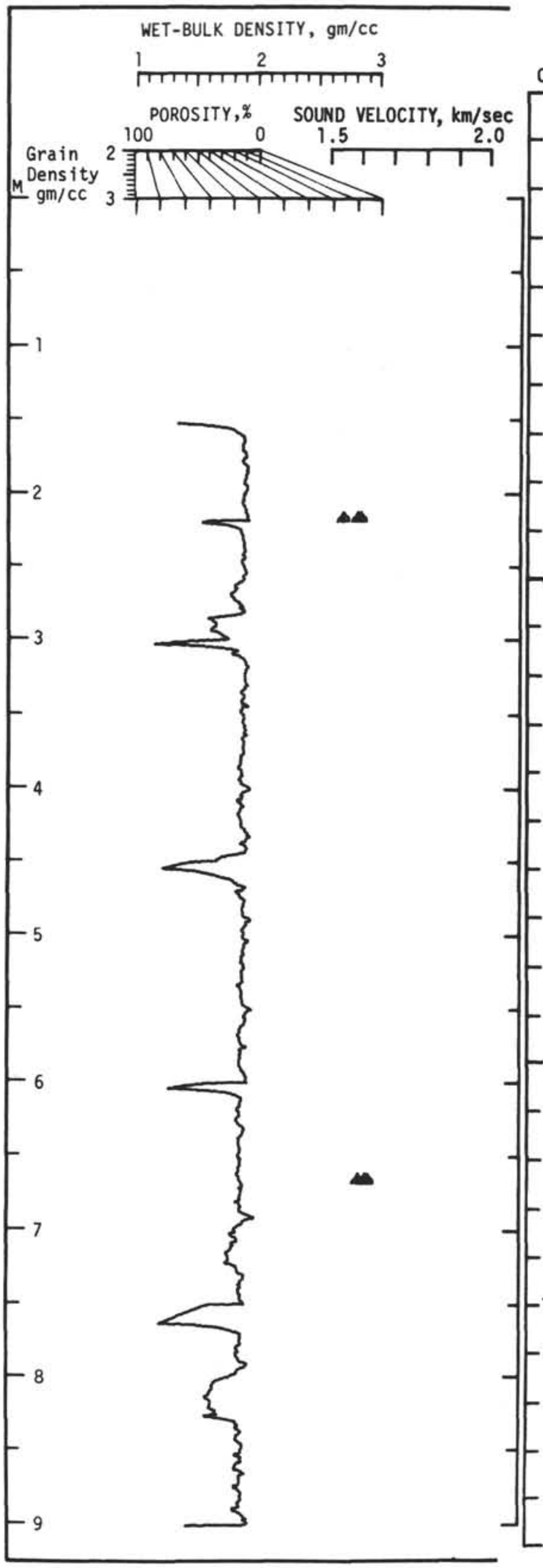
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Grain Density gm/cc
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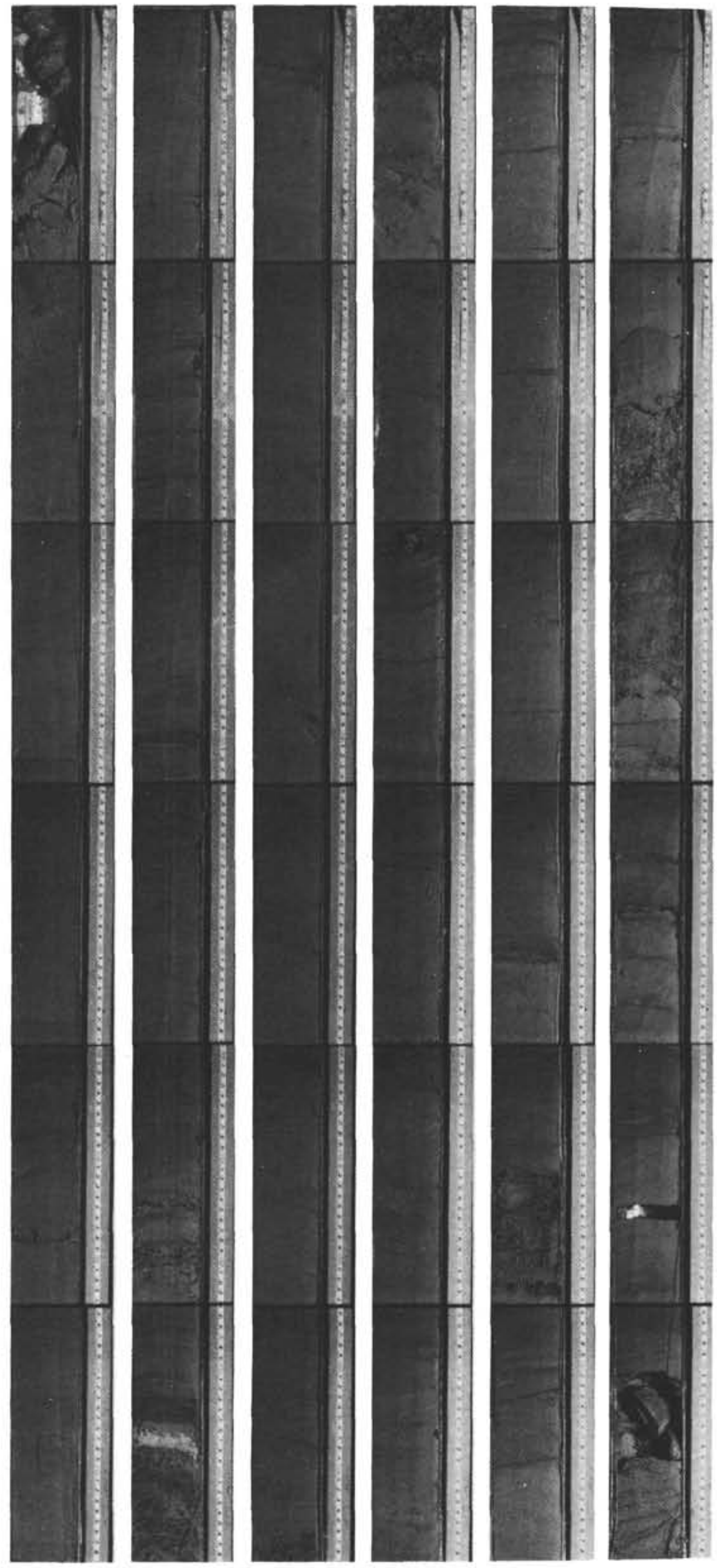
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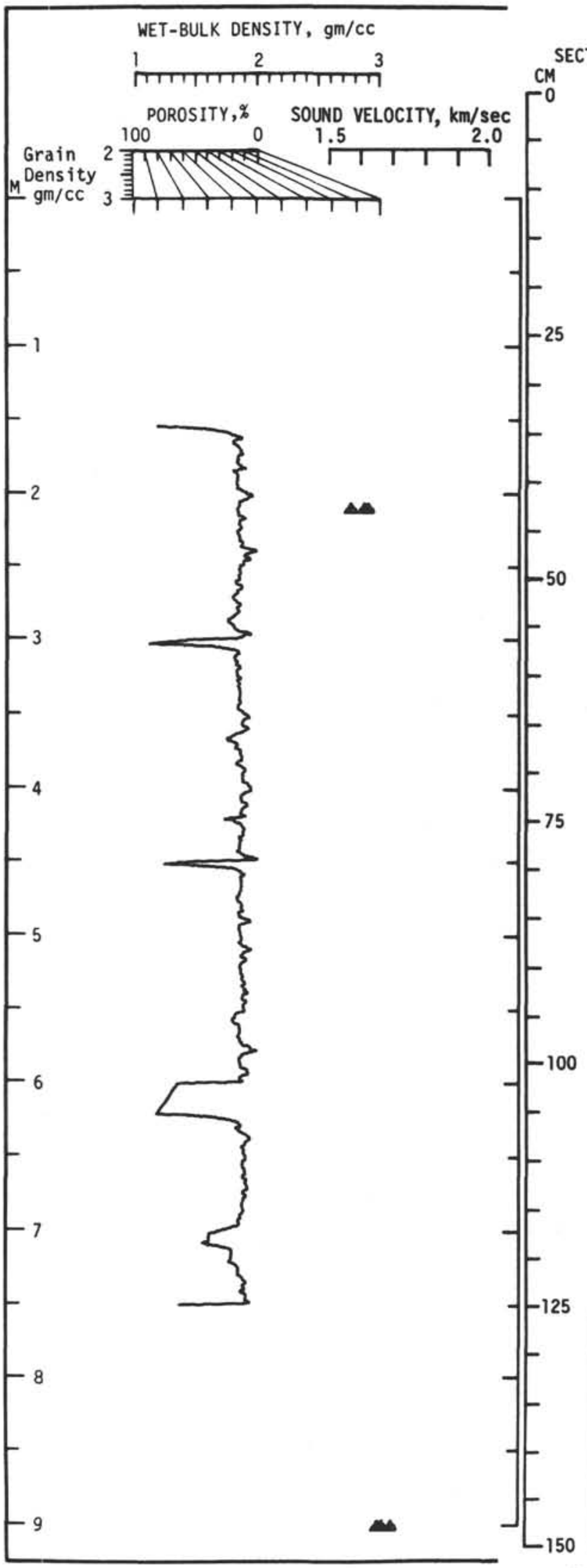
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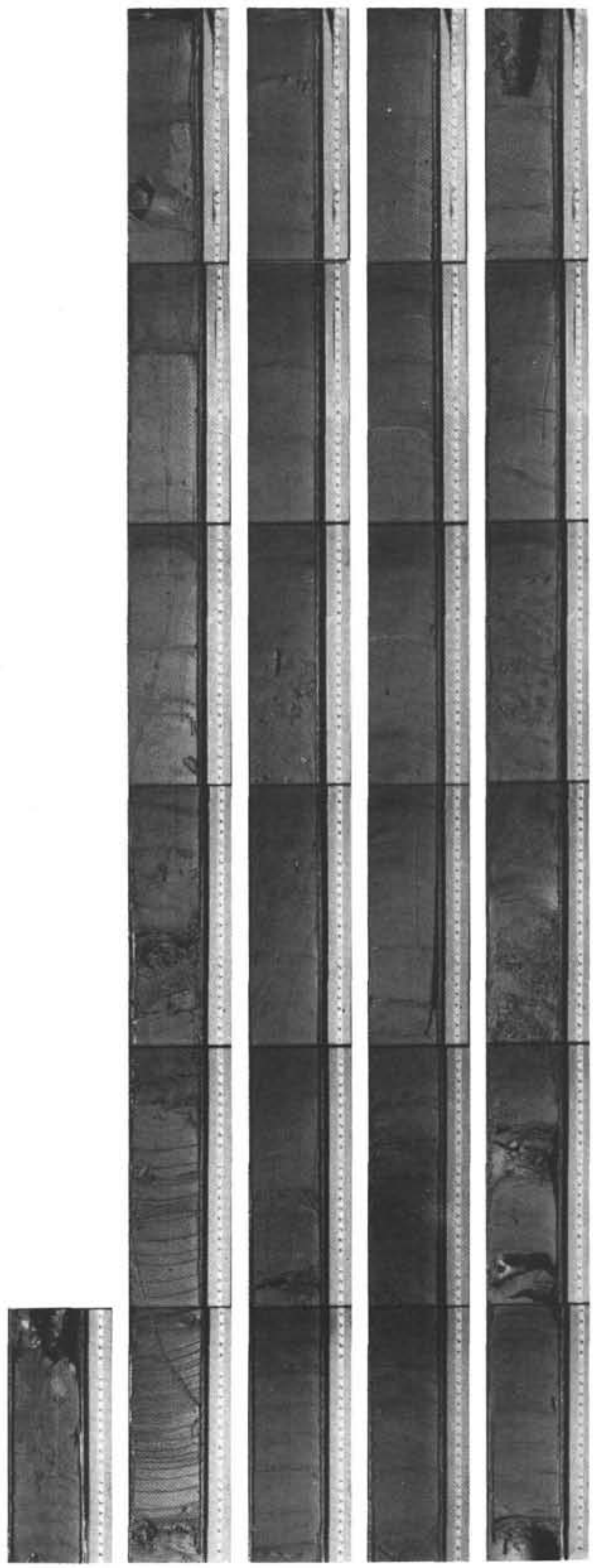
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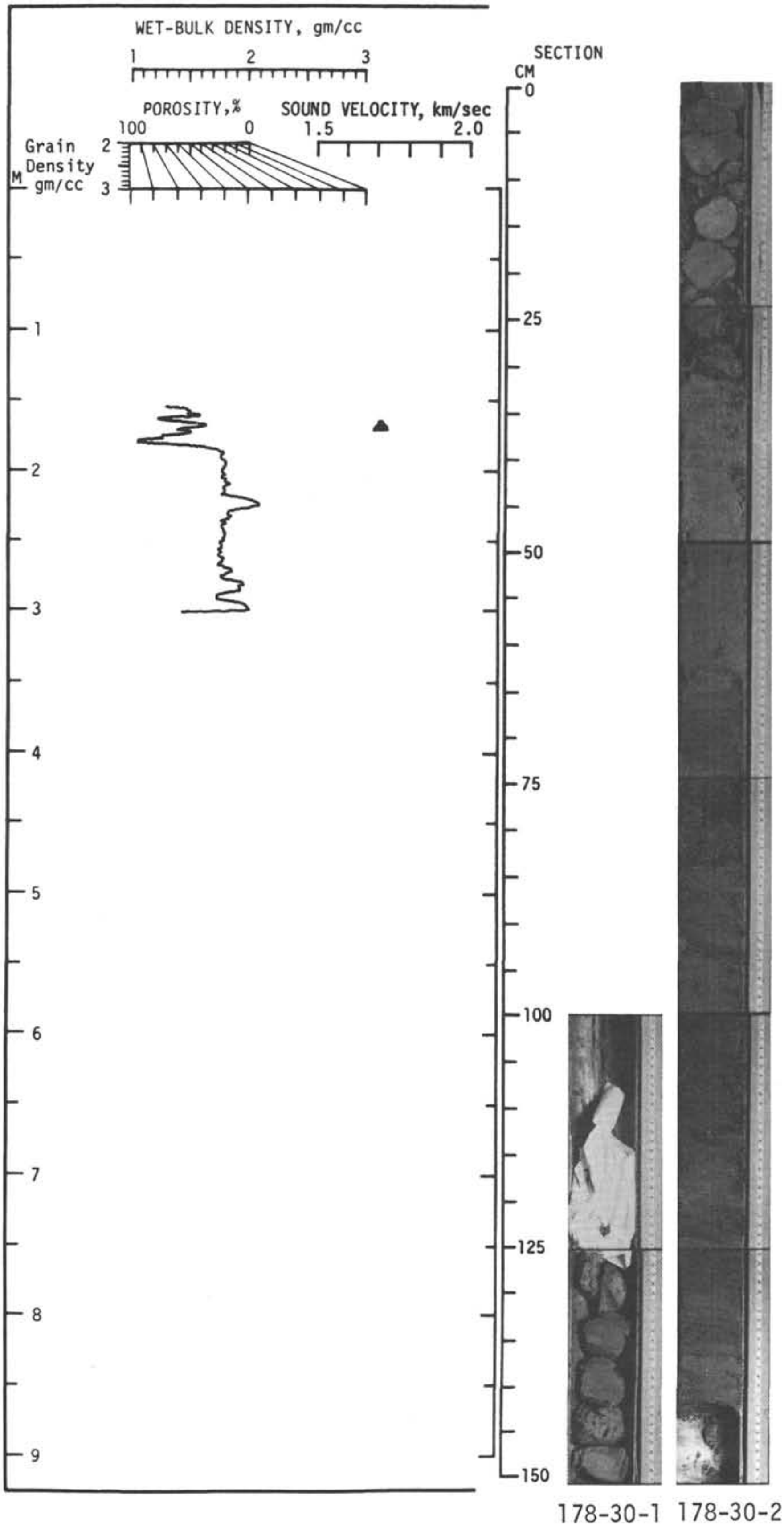
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100 0
SOUND VELOCITY, km/sec
1.5 2.0
Grain Density gm/cc
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M
1
2
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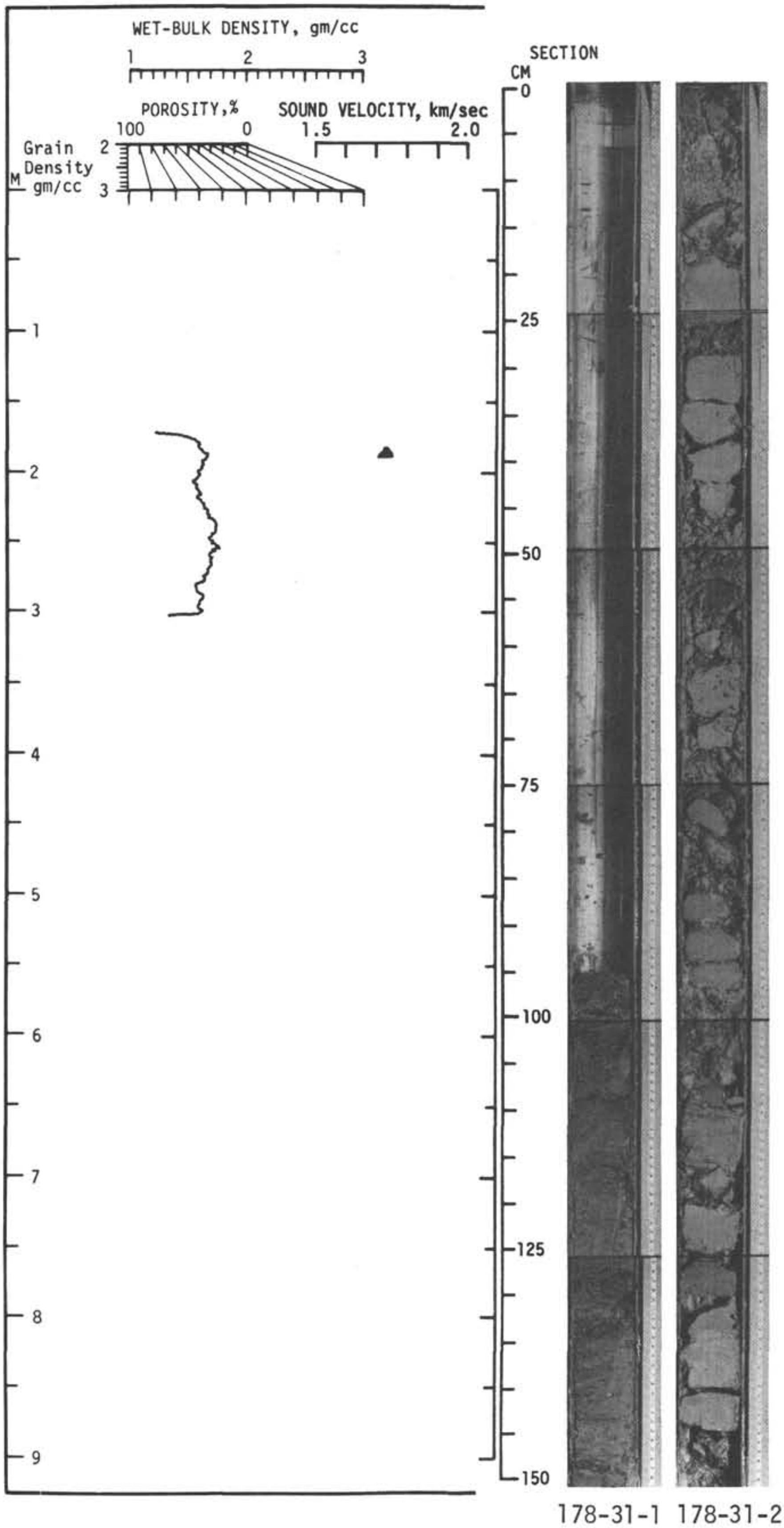
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Grain Density gm/cc
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SECTION
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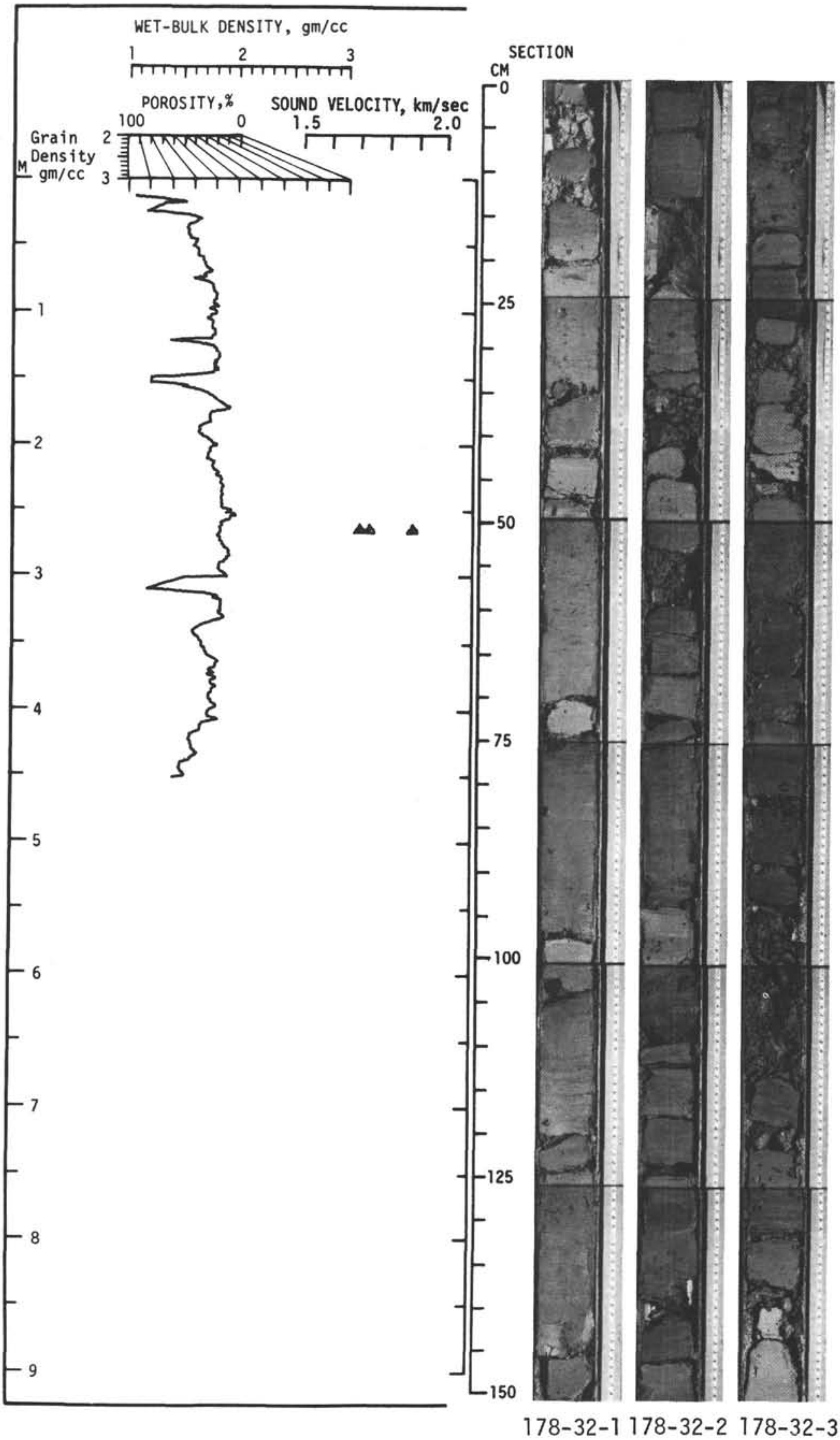
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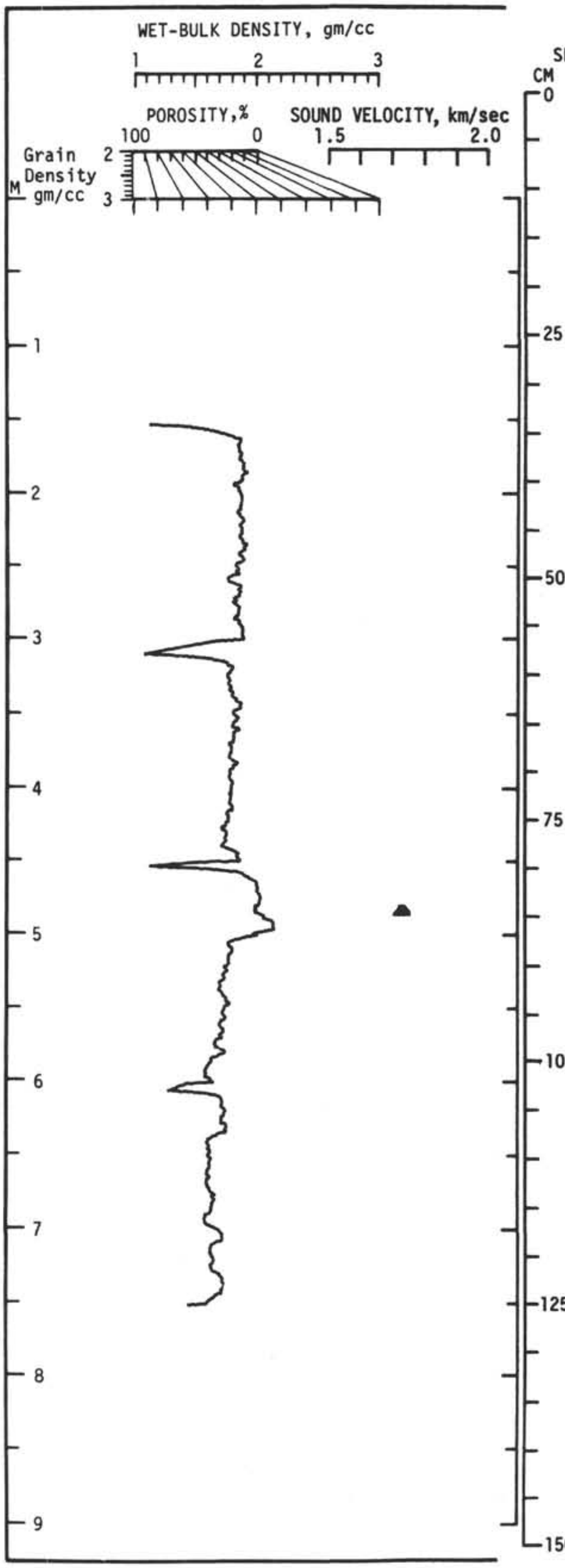
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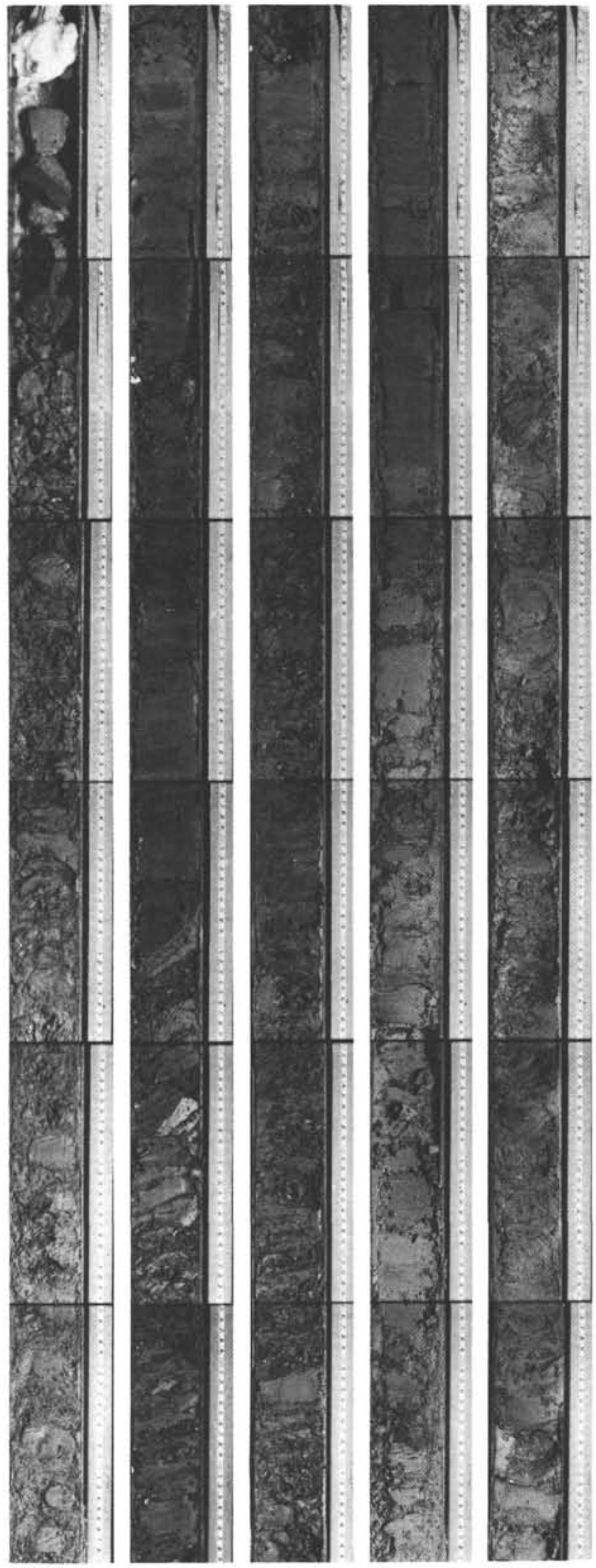
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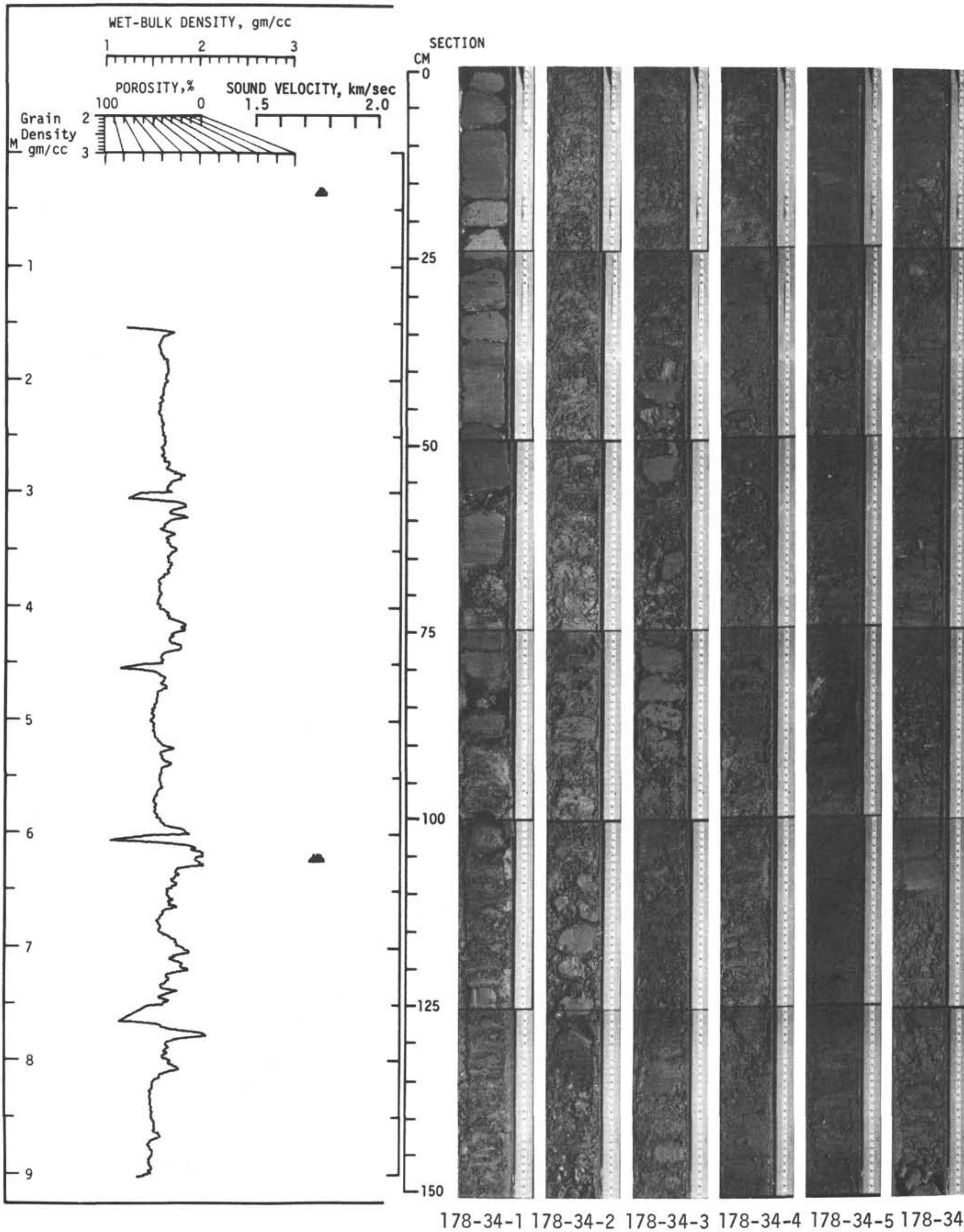

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Grain Density gm/cc
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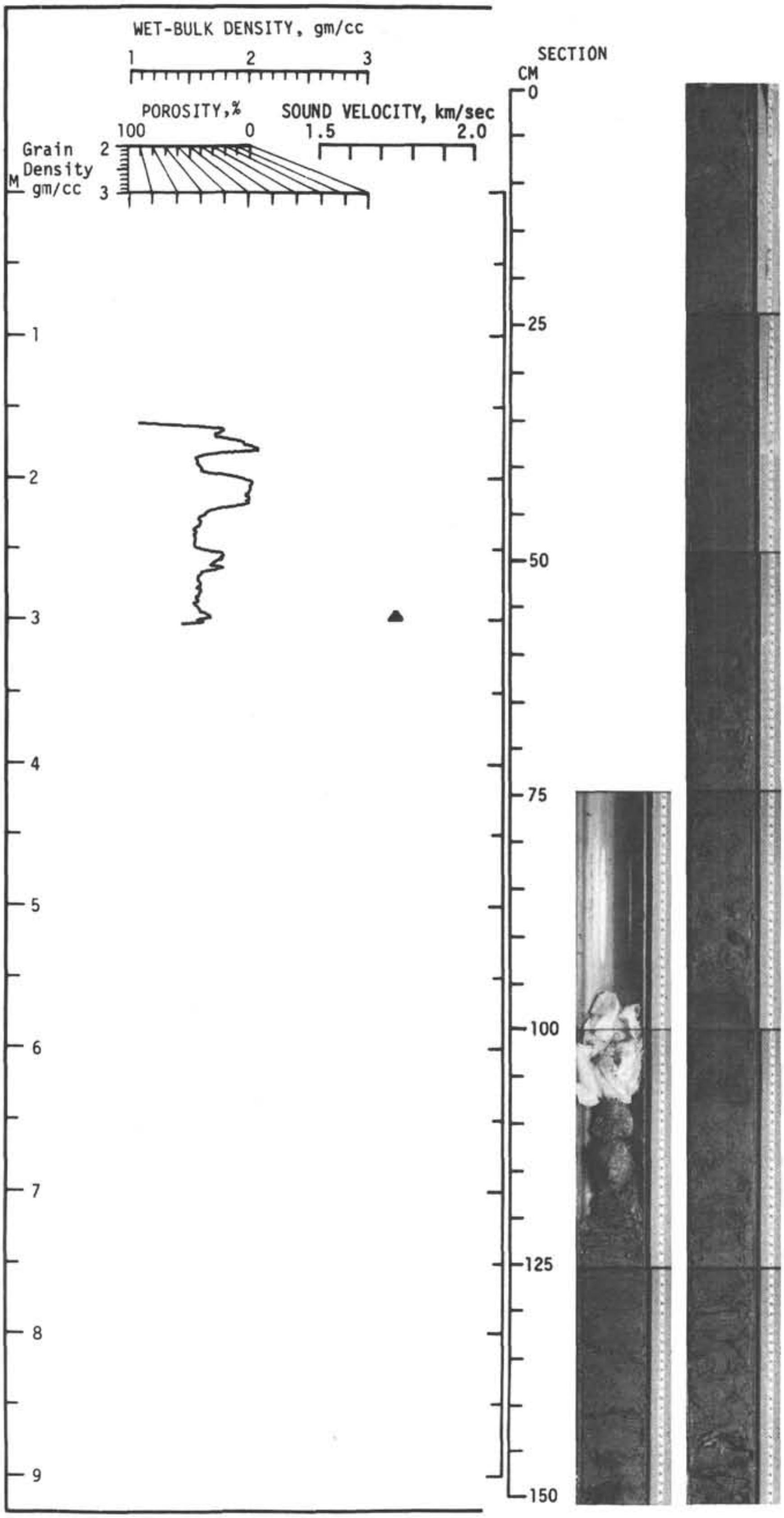

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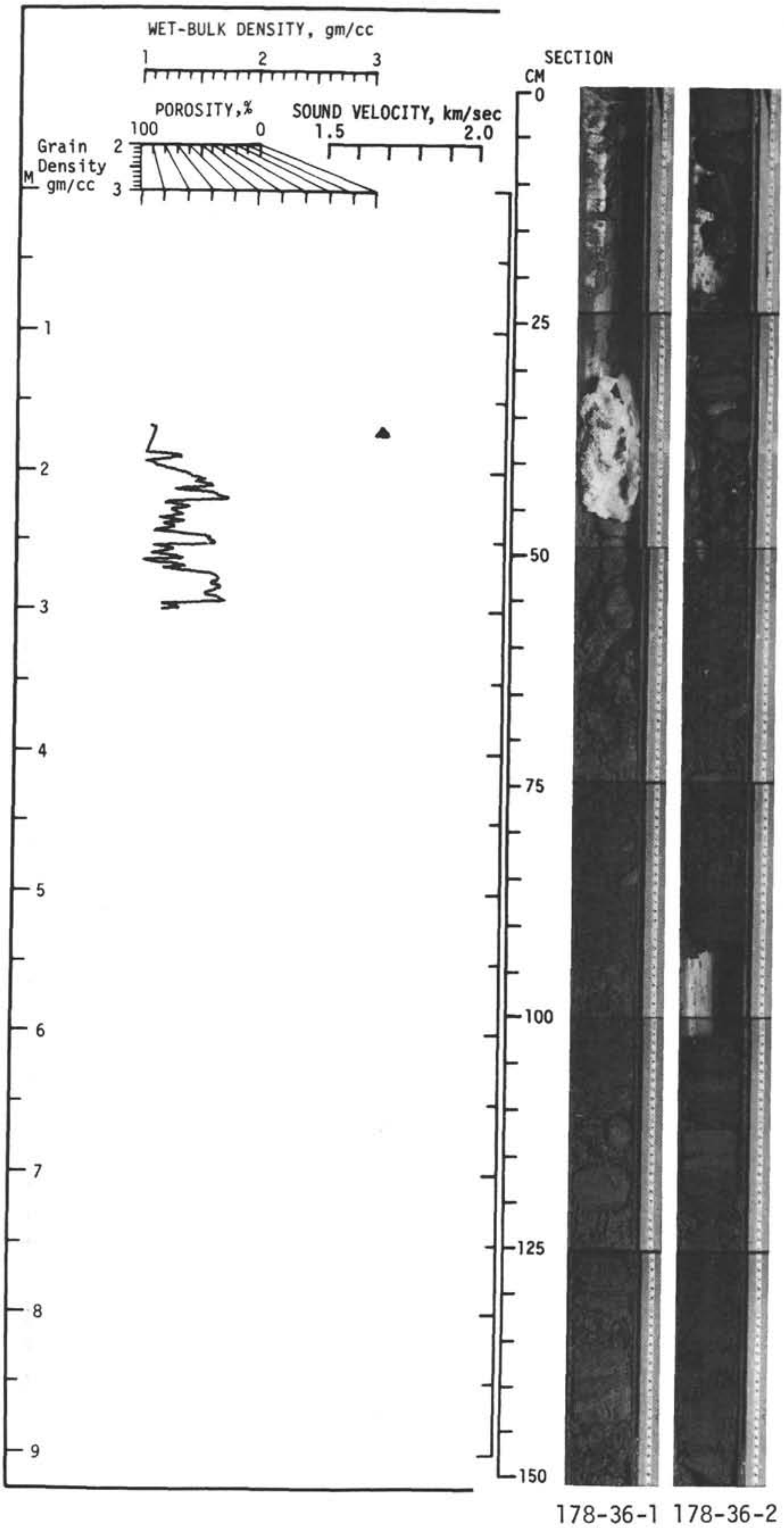
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Grain Density gm/cc
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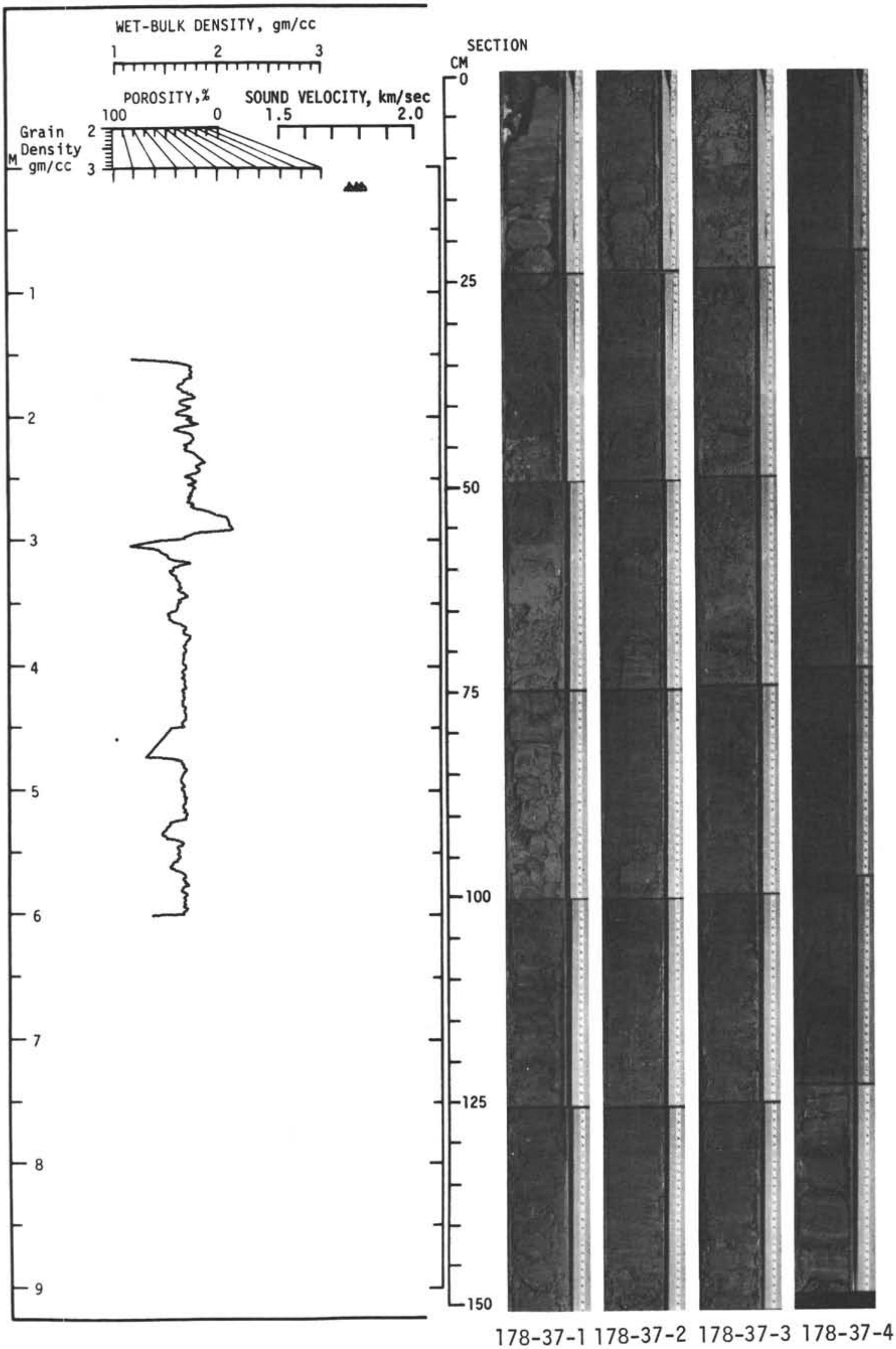
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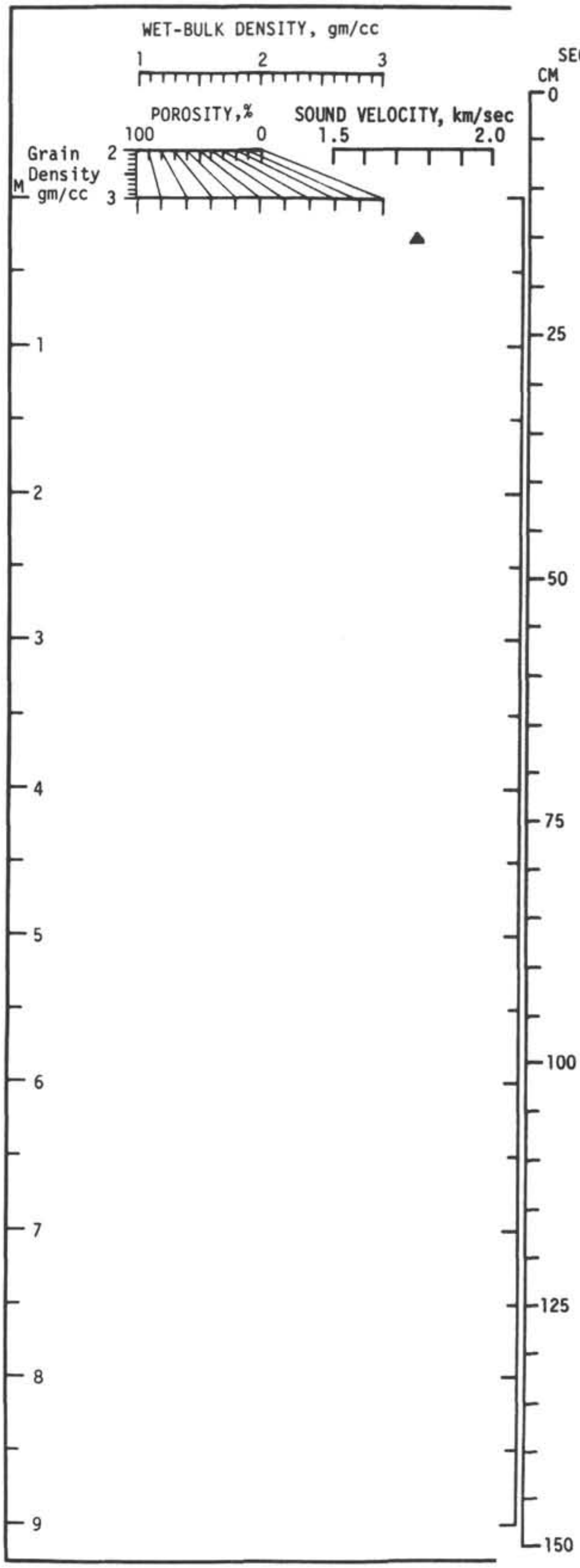
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Grain Density gm/cc
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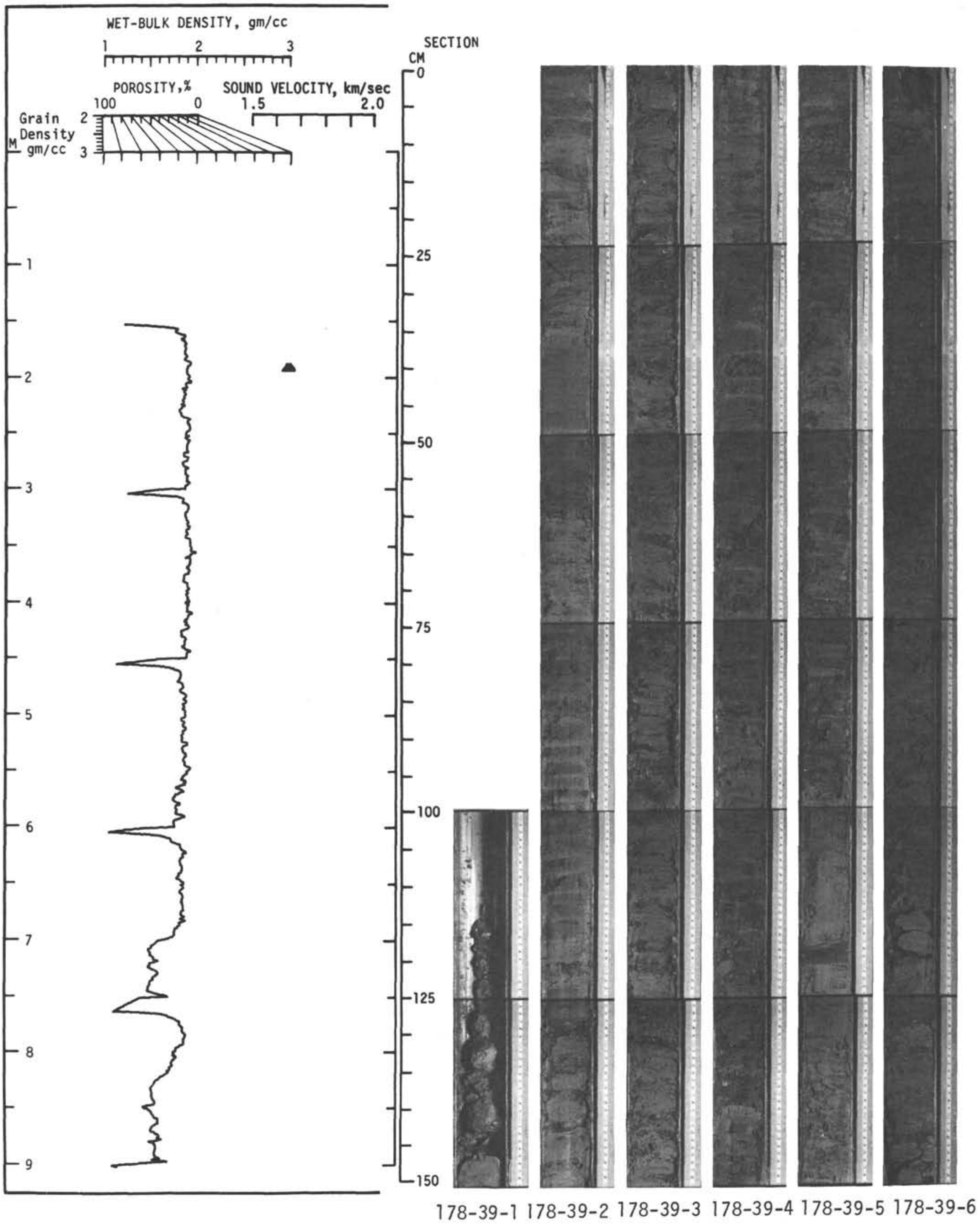
178-38-1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Grain Density gm/cc
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M
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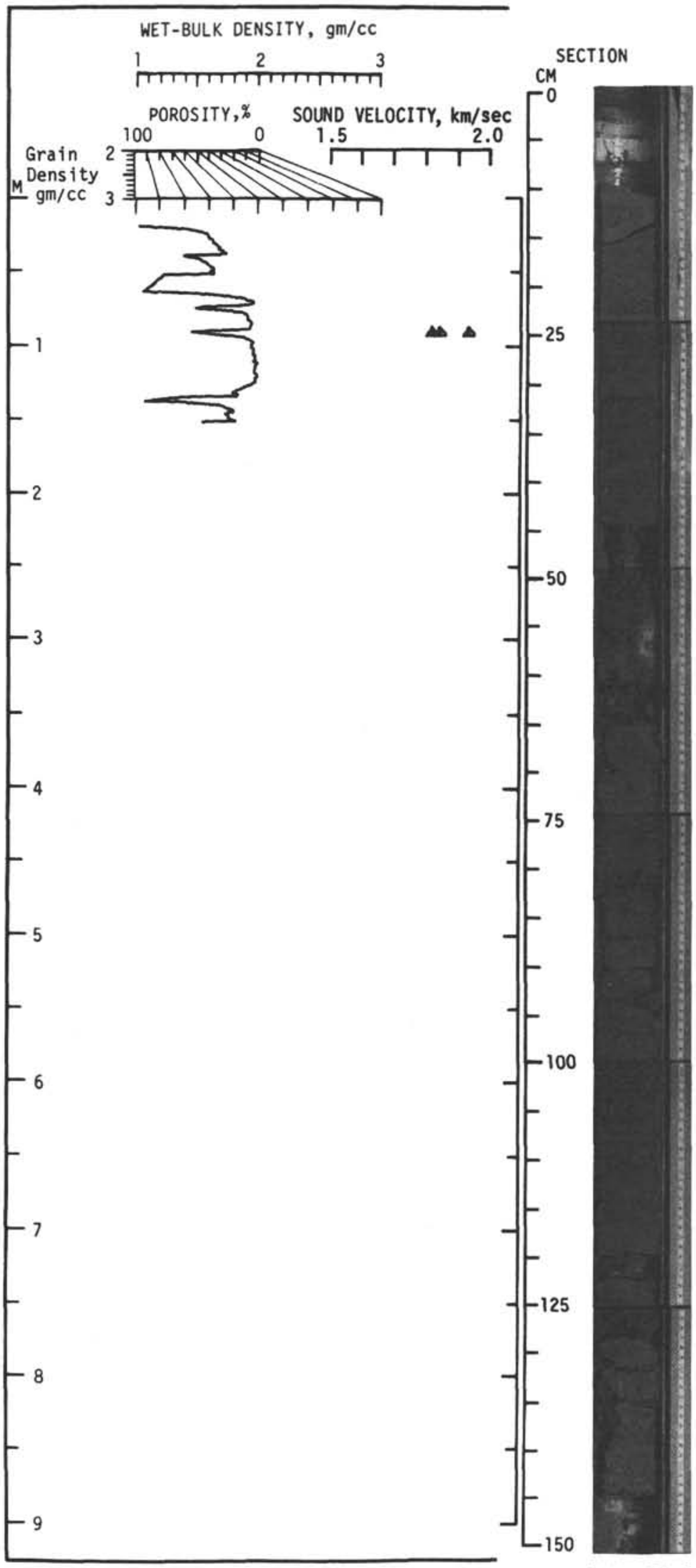
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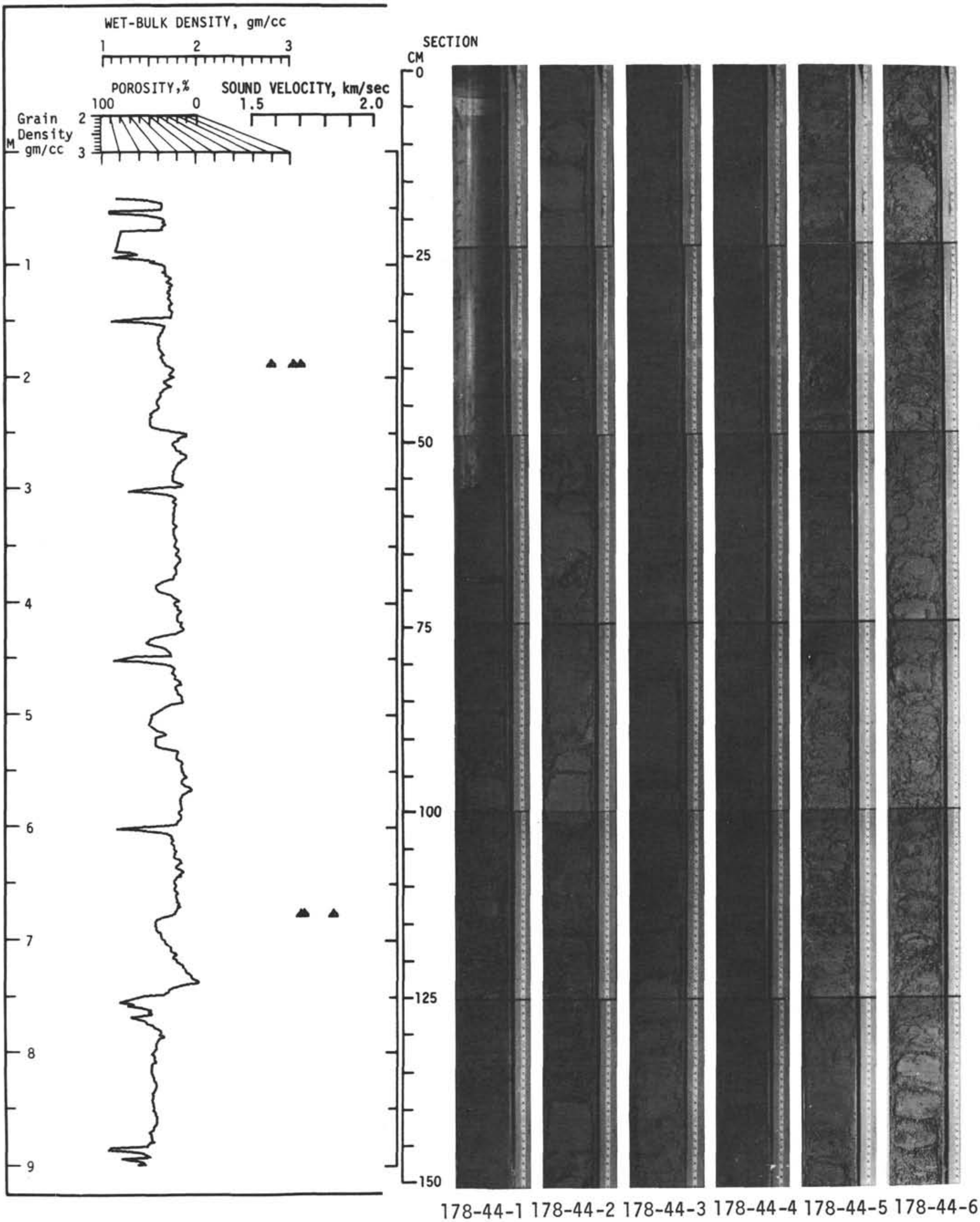
178-43-1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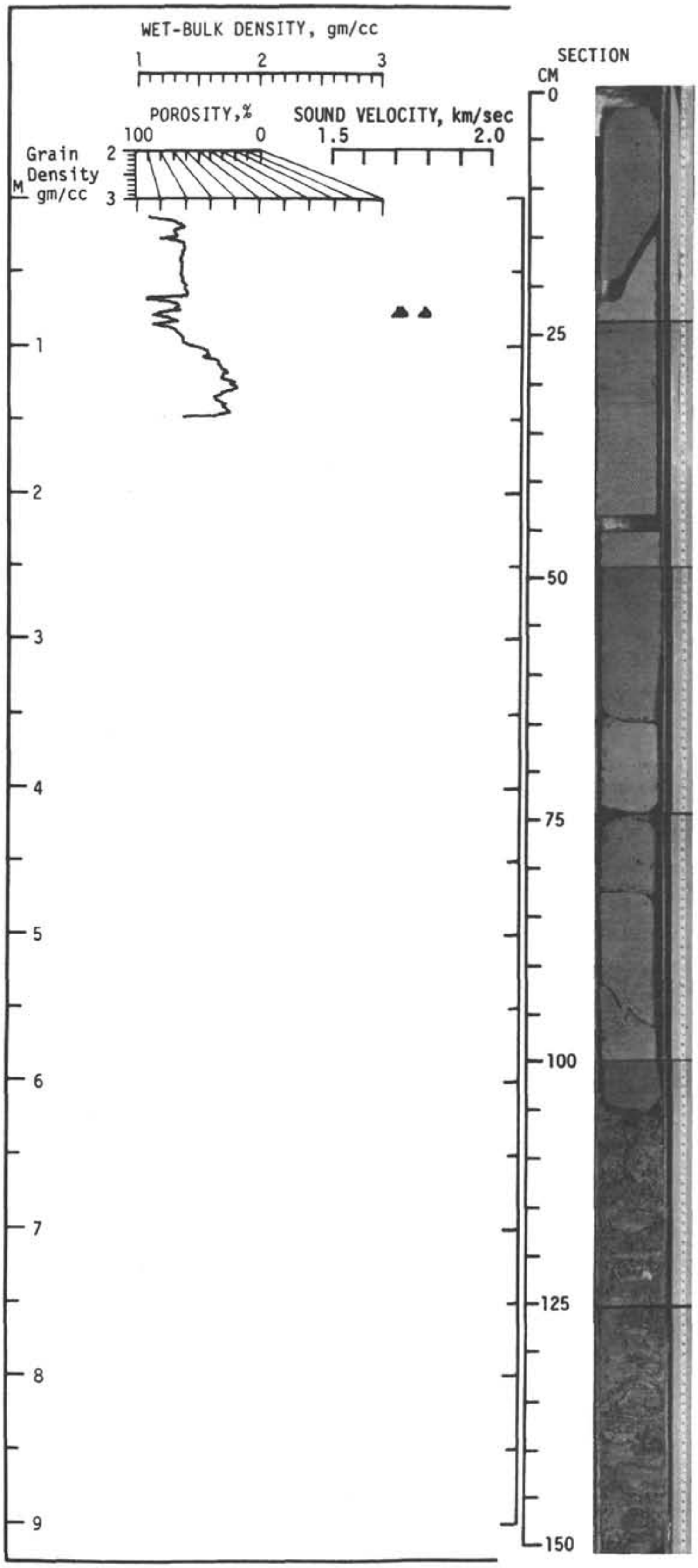
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Grain Density gm/cc
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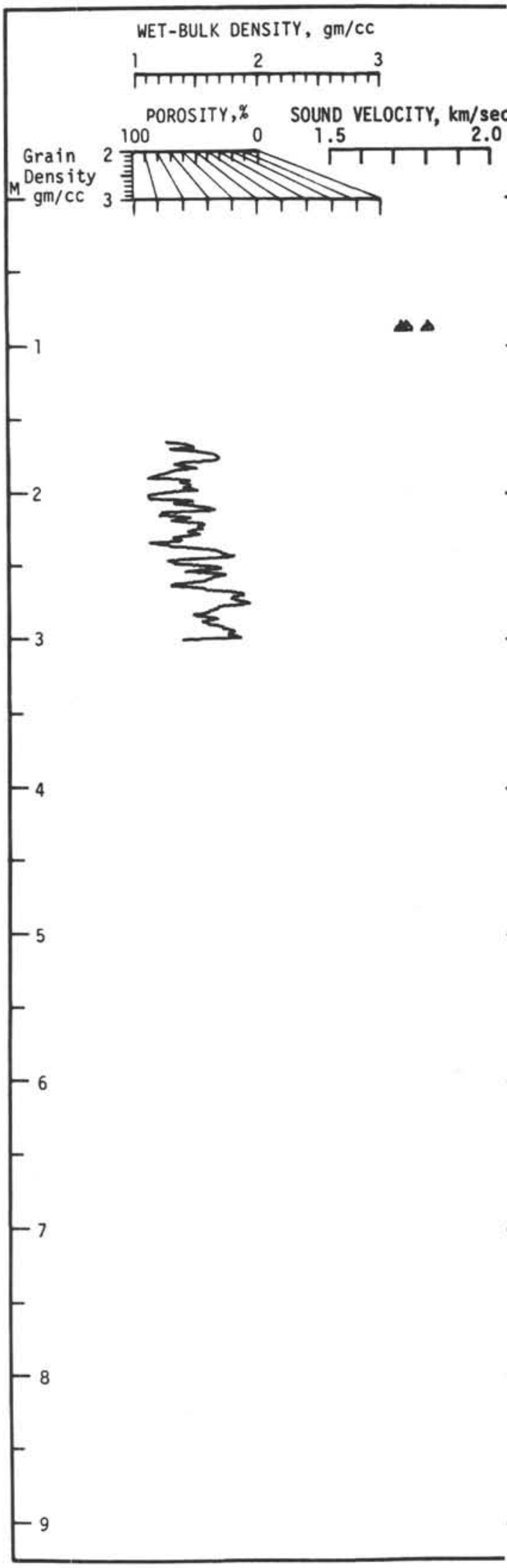
178-45-1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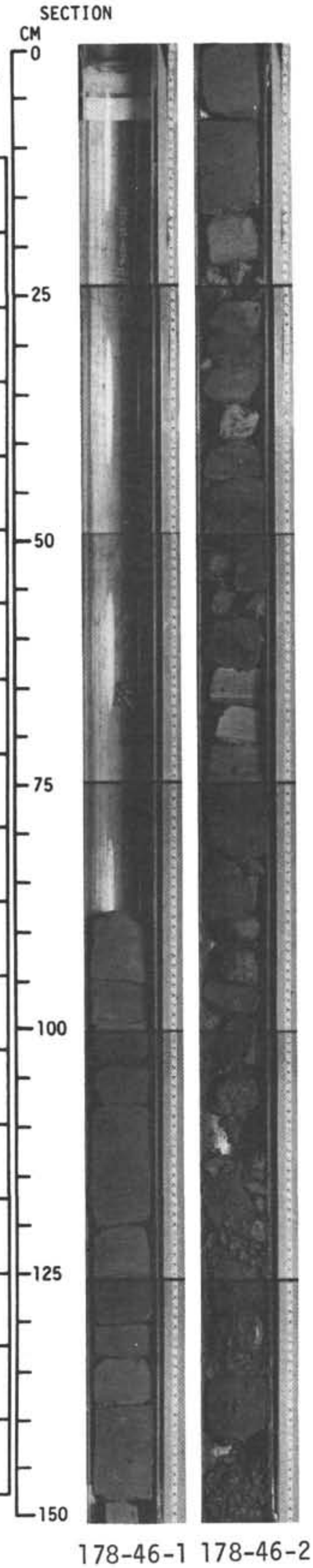
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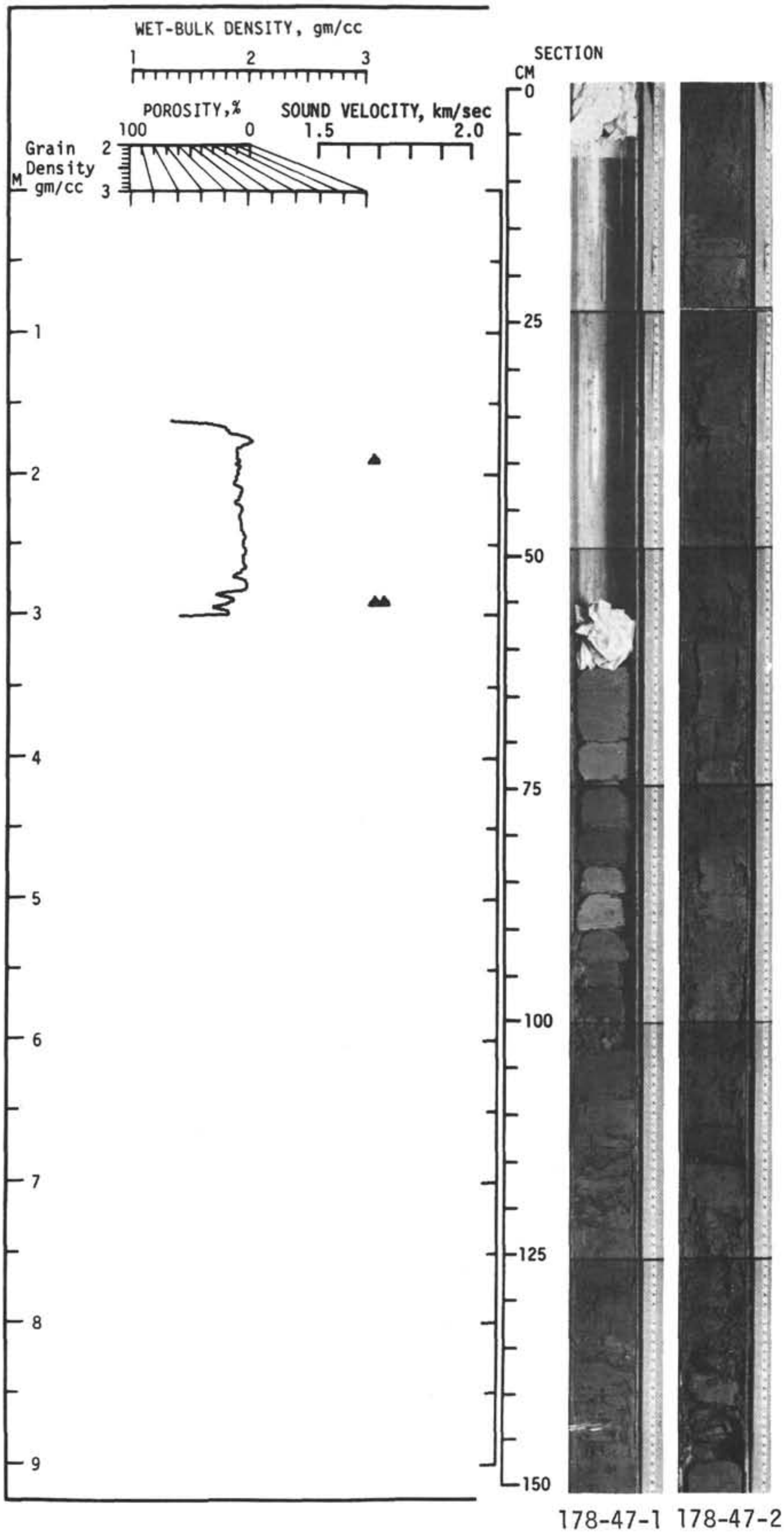
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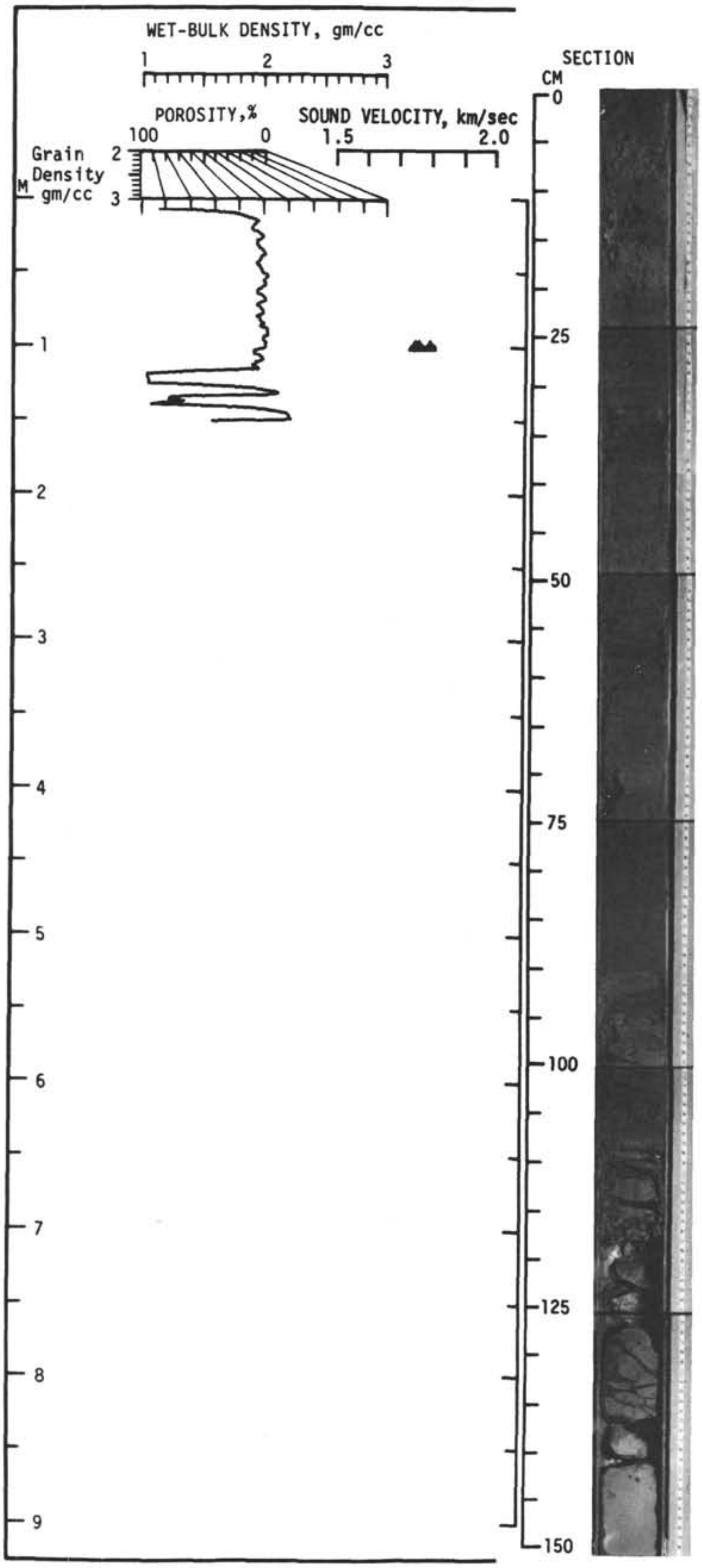
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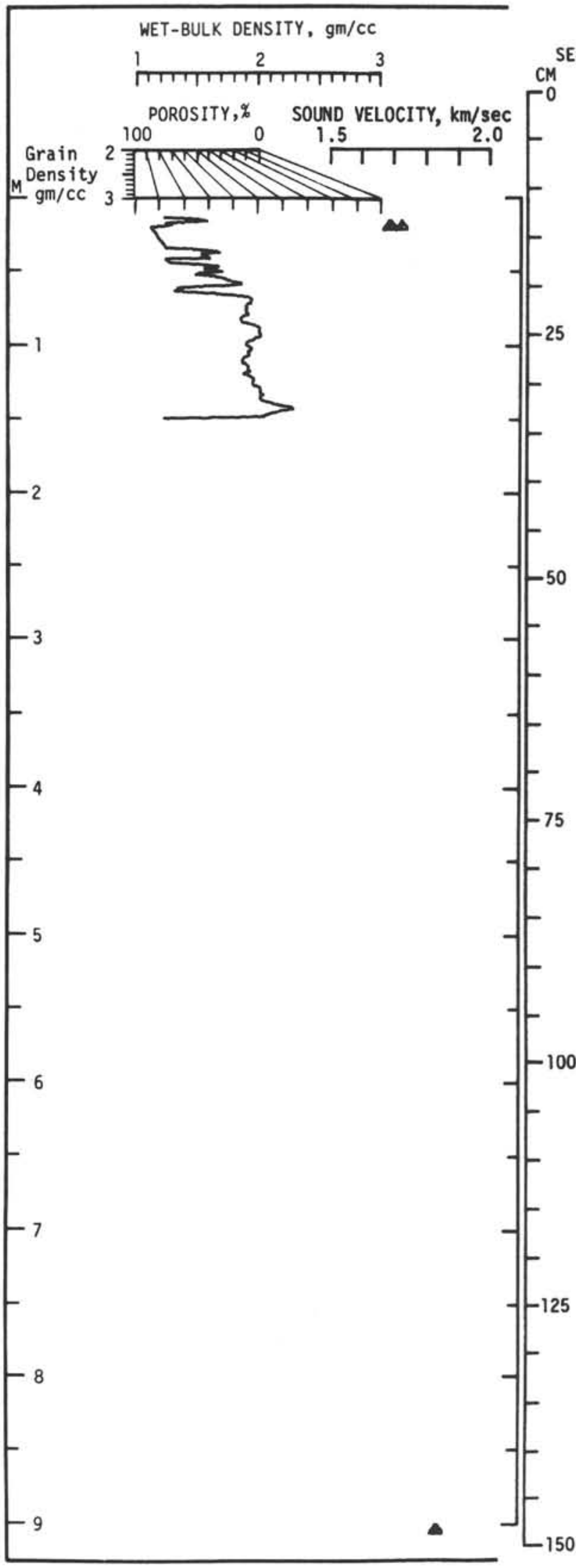
178-48-1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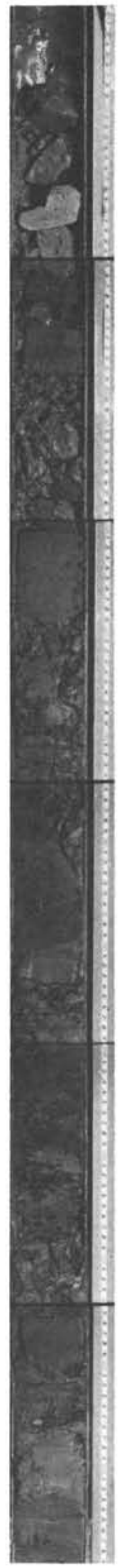

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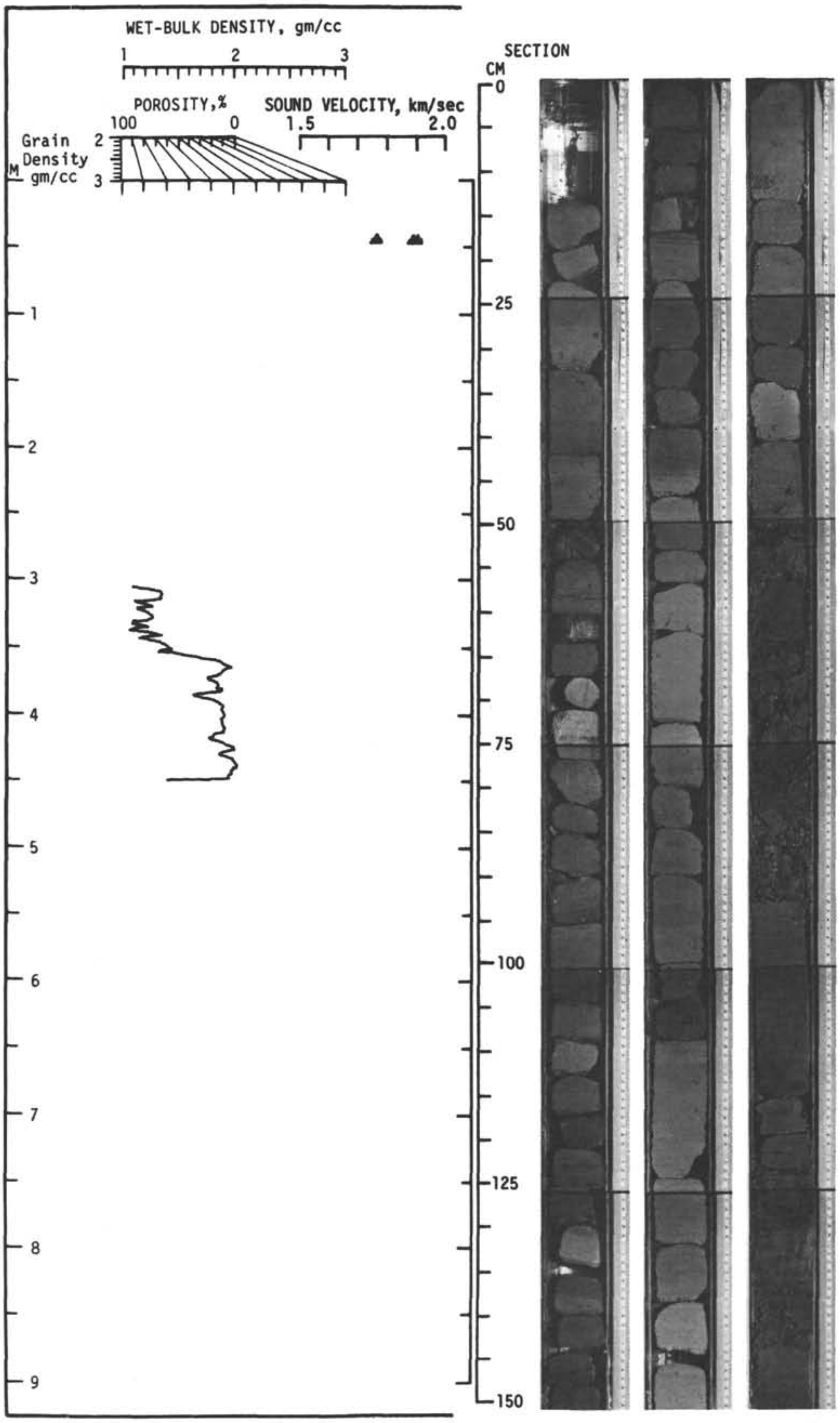

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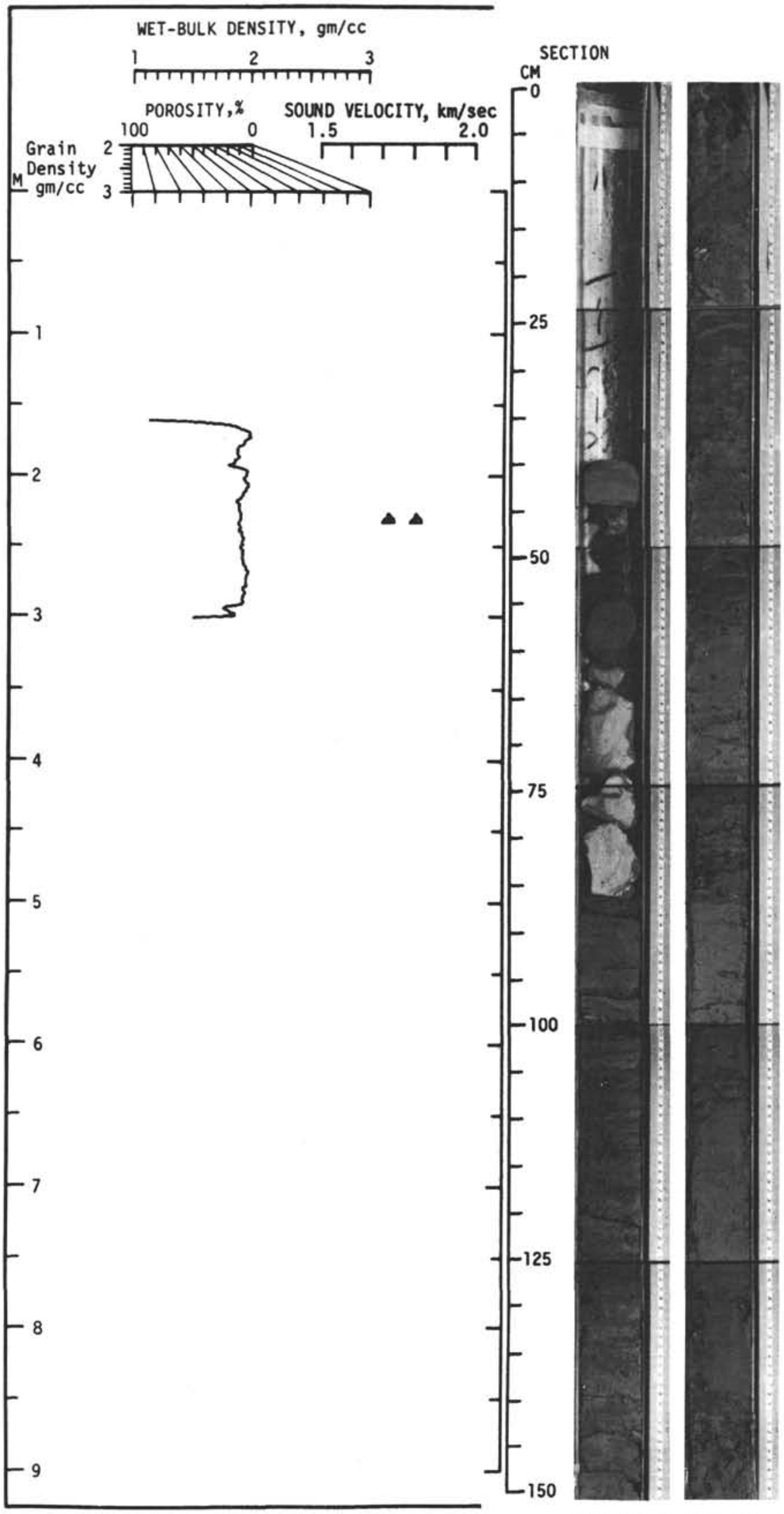
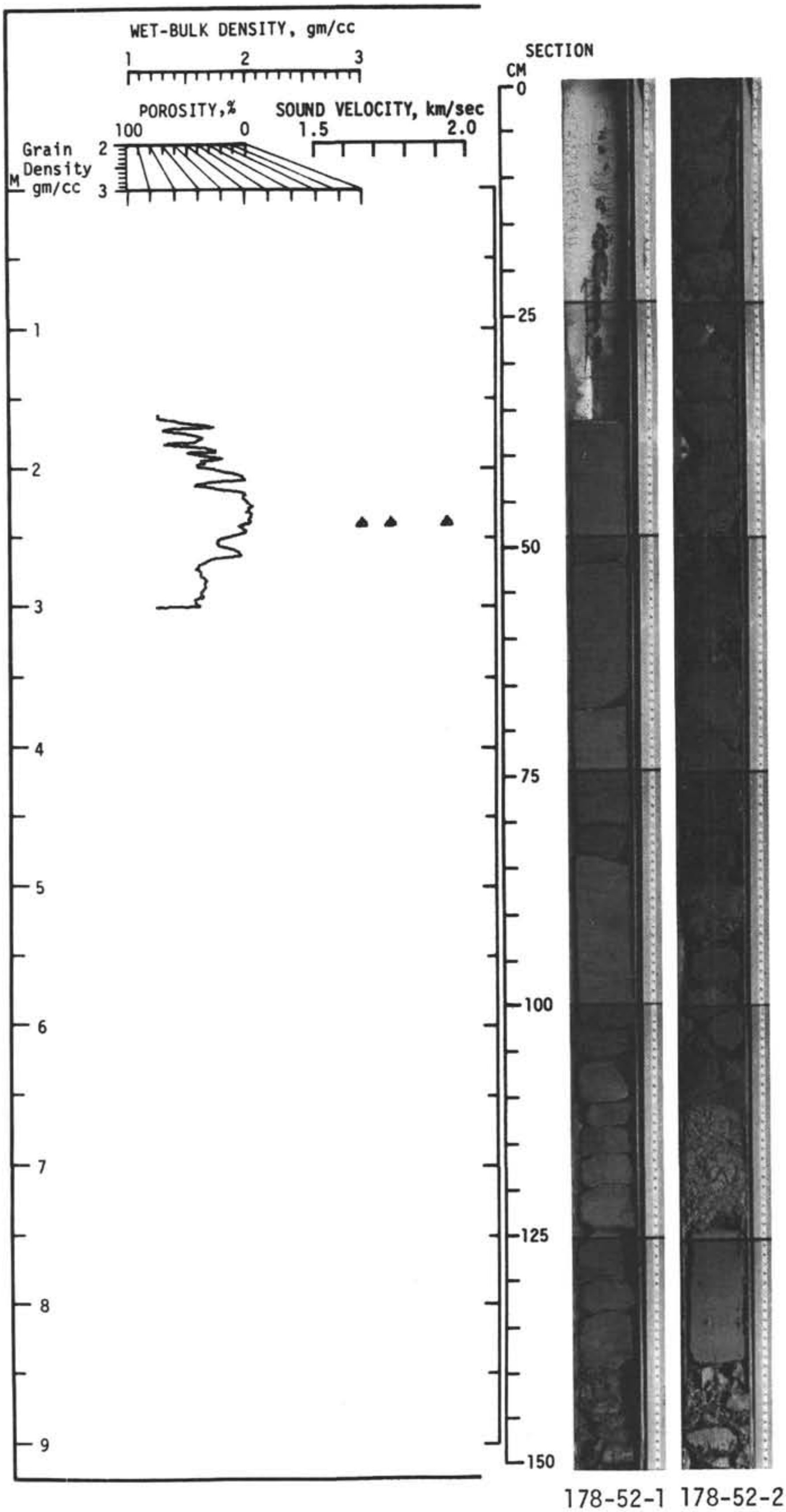


178-51-1 178-51-2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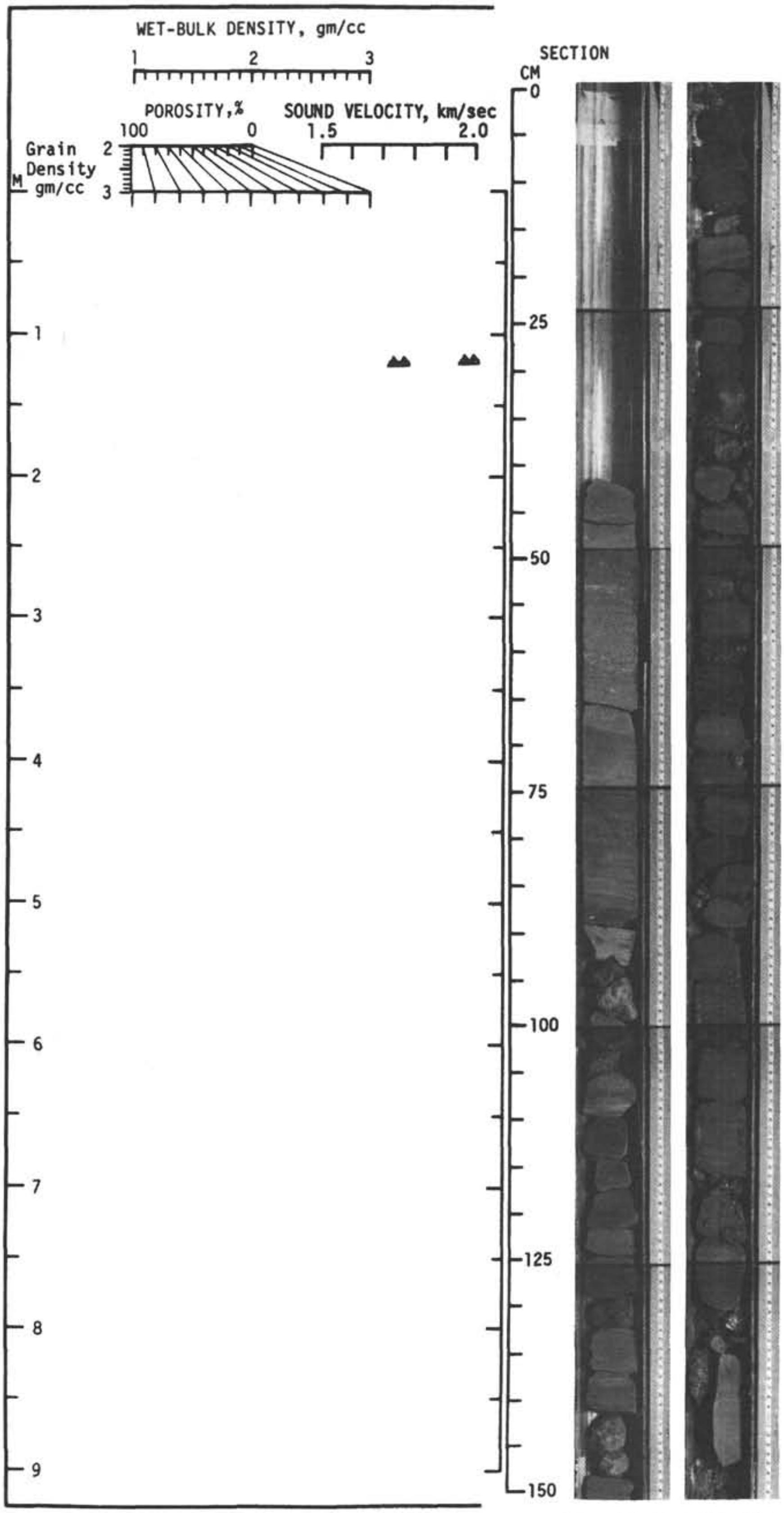

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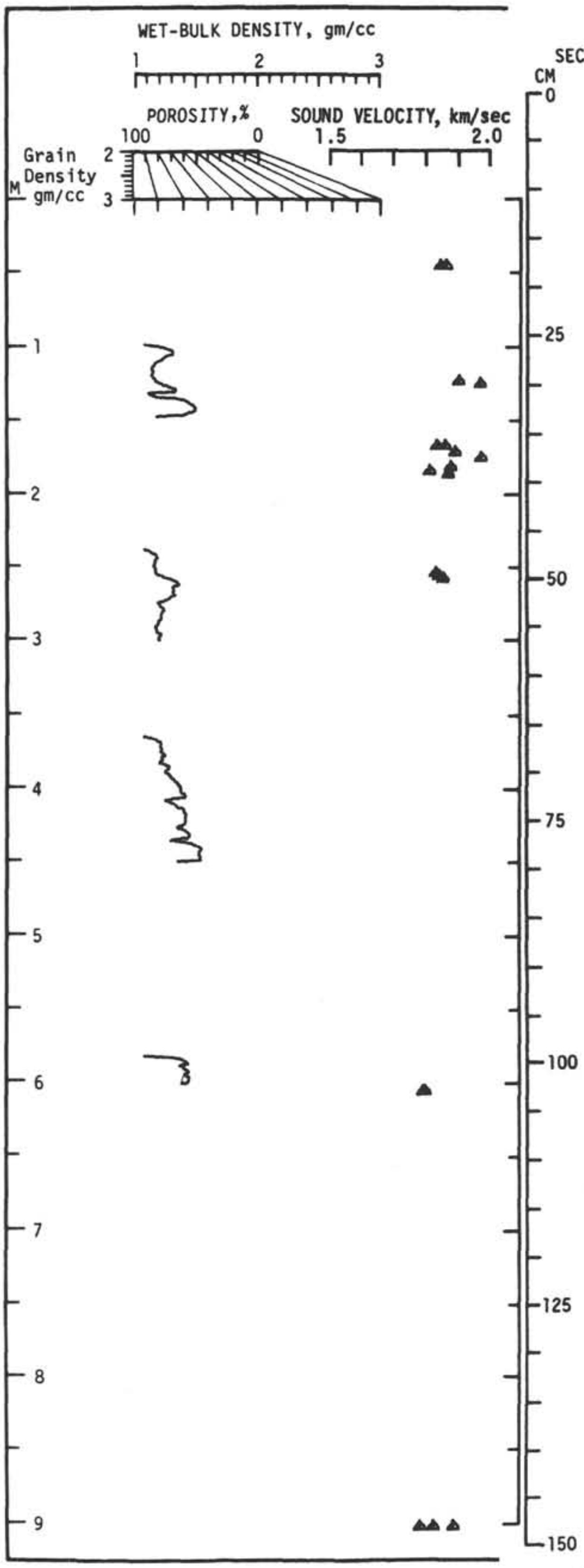

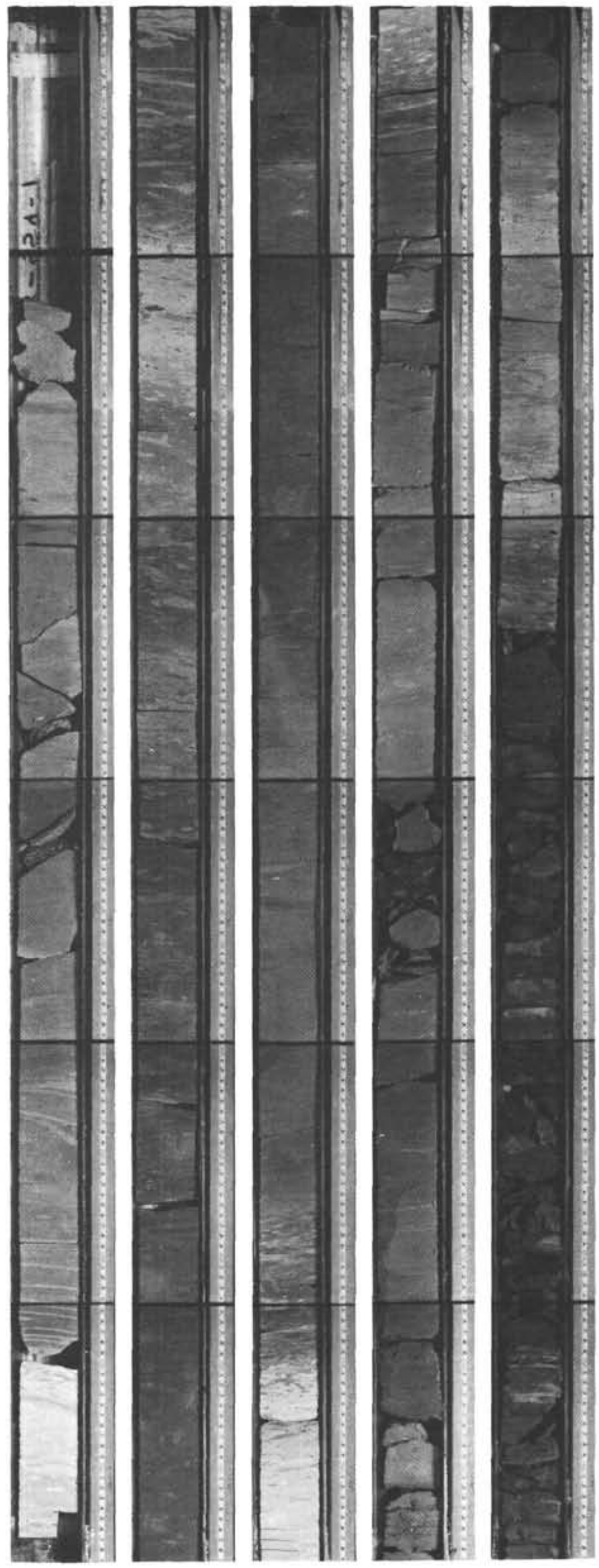

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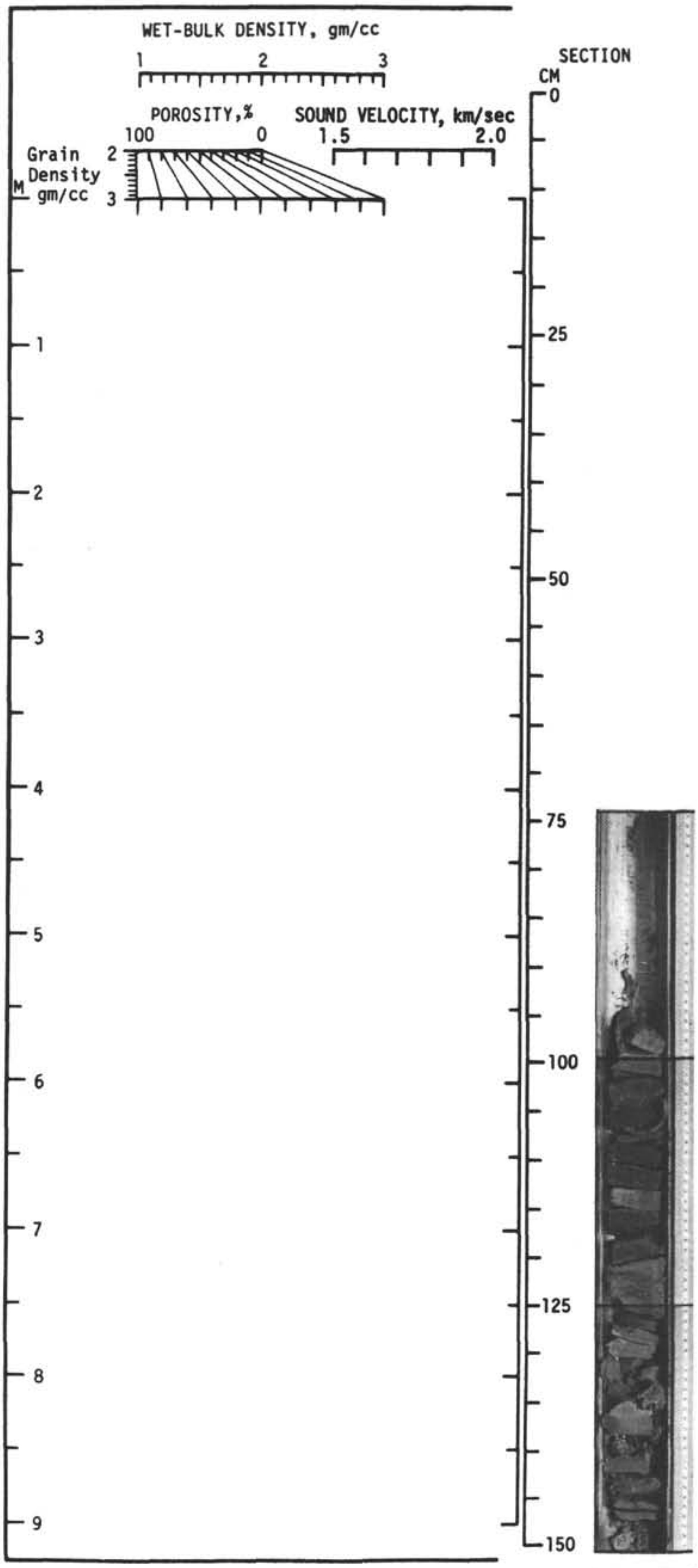
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Grain Density gm/cc
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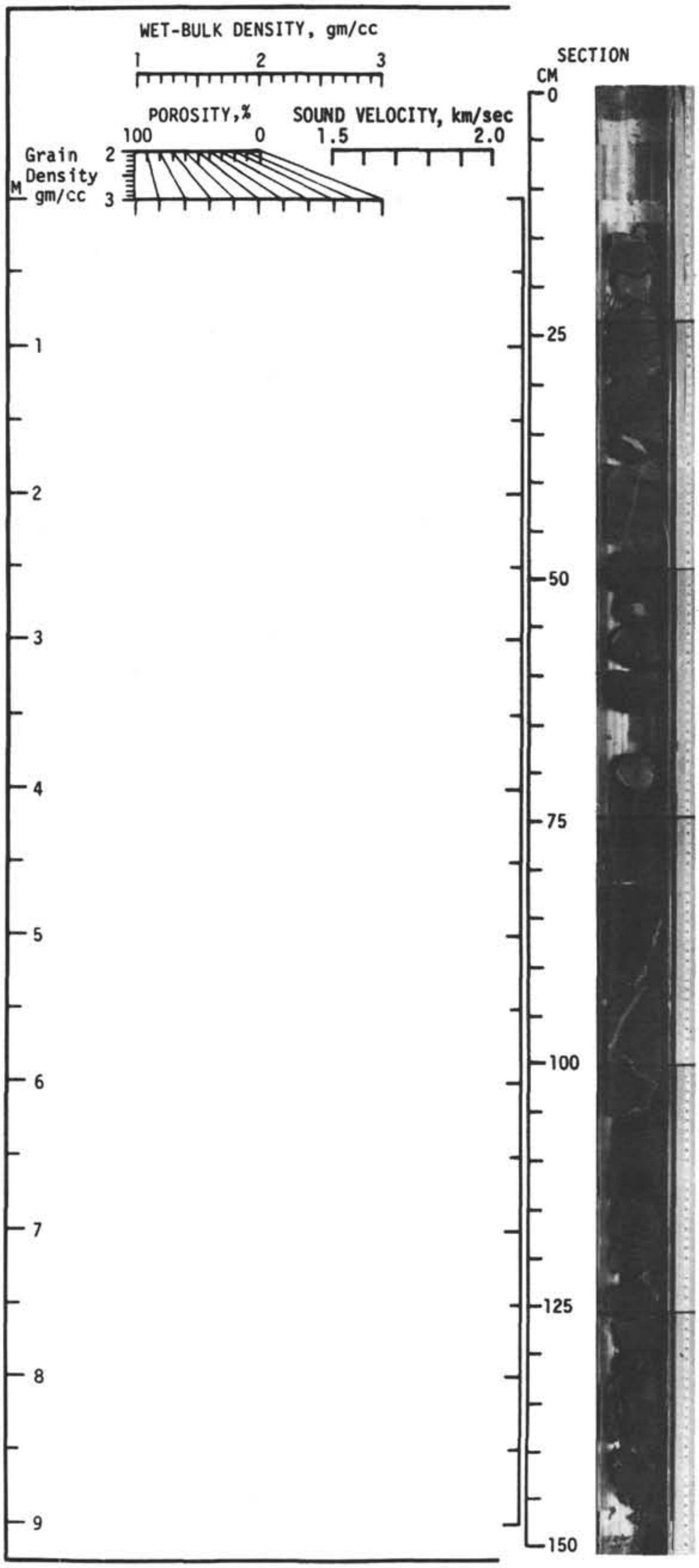
178-57-1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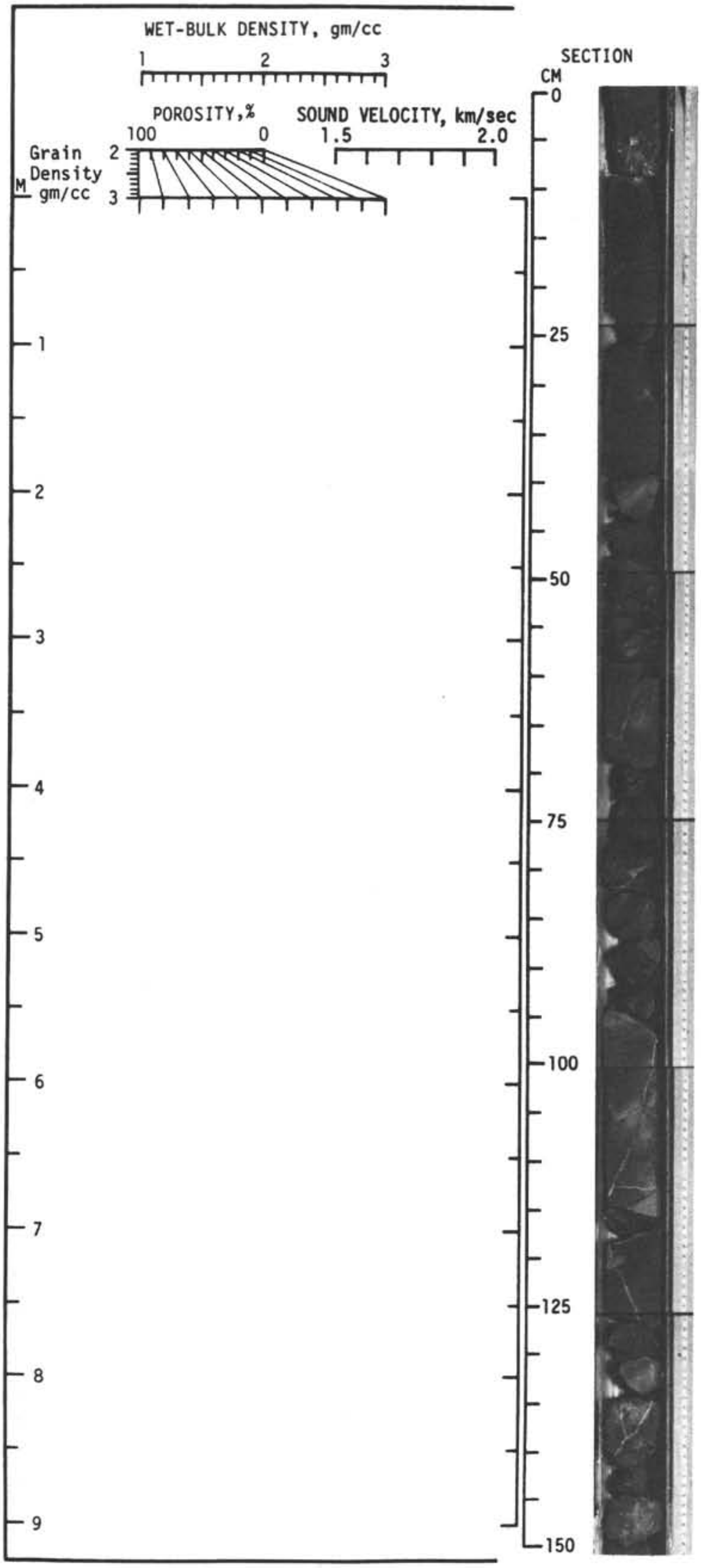
178-58-1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178-59-1