4. SITE 173

The Shipboard Scientific Party[1]

ABSTRACT

Site 173 was drilled to explore Delgada Fan and to penetrate and sample the basement; however, the drill encountered lower continental slope deposits consisting of Pleistocene to upper Miocene grayish green mud with very fine sand horizons (0-138 m), upper to lowermost Miocene pale olive to grayish olive green diatomites (138-285 m), gray nanno ooze (285-320 m), and andesite basement (320-333.5 m).

The basement is broken by steep faults whereas little deformation is seen in the sediments. Basement deformation may correlate with a late Oligocene or early Miocene episode of major tectonism along the California coast. The occurrence of andesite below a sequence of continental slope deposits is unexplained.

SITE SUMMARY

Date Occupied: 10-12 June 1971.

Position (Satellite):
Latitude: 39°57.71′N;
Longitude: 125°27.12′W.

Number of Holes: One

Water Depth: 2927 meters.

Penetration: 333.5 meters below sea floor.

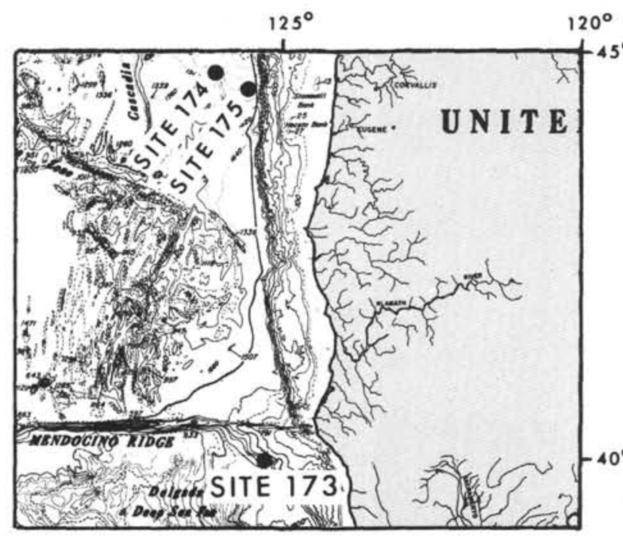
Number of Cores: 38

Total Core Recovered: 196 meters, 58.7% recovery.

Age of Oldest Sediment: Lowermost Miocene.

Acoustic Basement:
Depth: 320 meters.
Nature: Andesite.
Inferred Velocity: 1.57 km/sec.

Basement: Andesite.



BACKGROUND AND OBJECTIVES

Site Description

Site 173 is on a large conical feature of the continental slope southwest of Cape Mendocino. It was thought that the whole feature was part of Delgada Fan but this was discounted after drilling.

Seismic records (Figure 1) obtained by Silver, Curray, and Cooper (1971) show a thick series of stratified rocks near shore that thin over the lower continental slope and then increase in thickness at the foot of the slope to form Delgada Fan. The distal part of the fan was drilled on Leg 5 and DSDP Holes 32 and 34 encountered fine sediments ranging from upper Oligocene and lower Miocene nannofossil ooze to Pleistocene clastic deposits including sand.

It was thought that since the previous holes were drilled near the edge of Delgada Fan, they did not penetrate an expected typical sequence of turbidites and fan deposits. Possibly these materials could be found closer to the source of sediment on the upper fan. Coarse and fine clastic fan deposits were presumed to make up the sediments at Site 173 on the basis of the discontinuous and somewhat irregular reflectors in seismic records. Individual reflectors are short, they occasionally pinch and become disconformable, and they have variable reflectivities (Silver, Curray and

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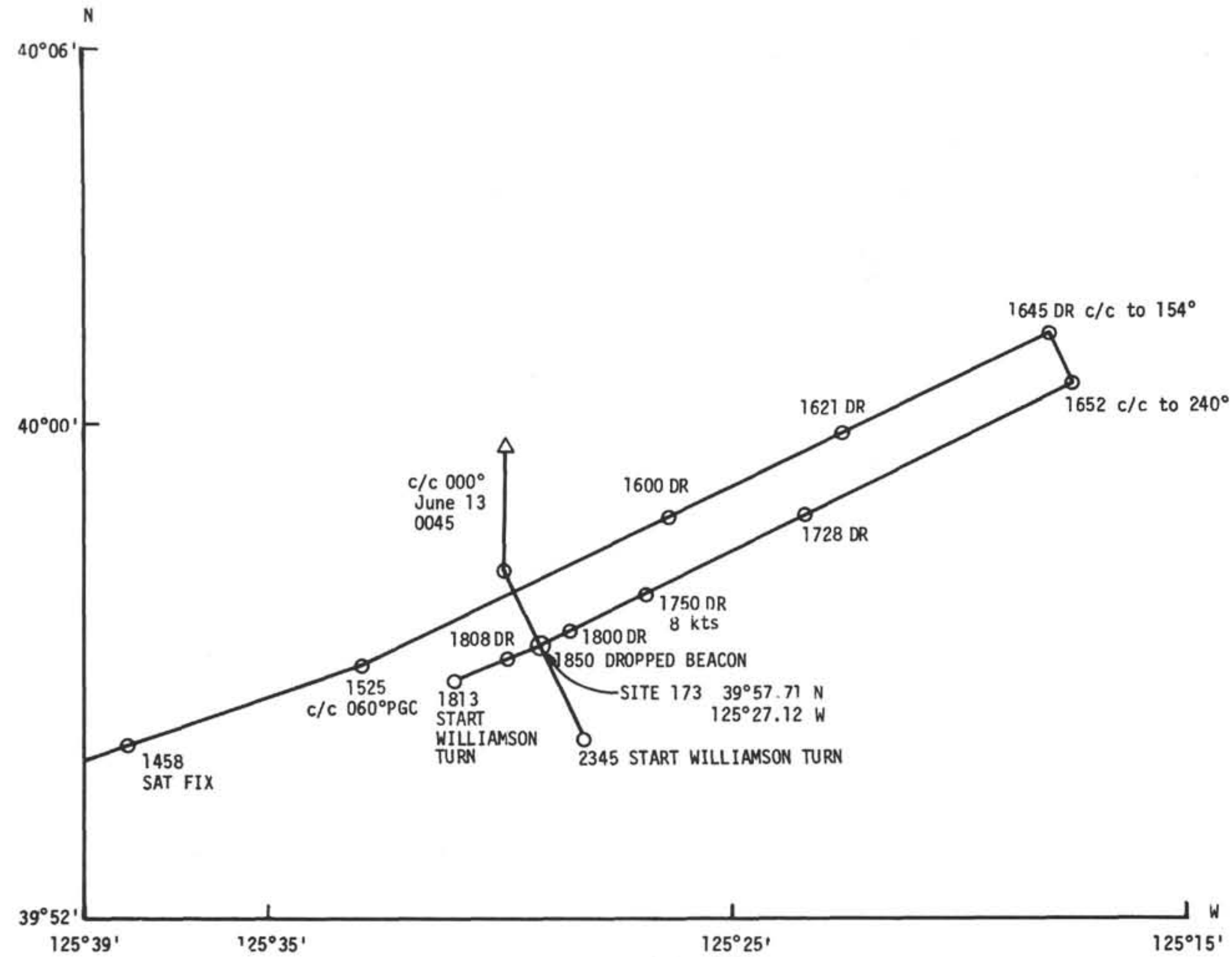


Figure 1. *Track chart of* Glomar Challenger *for site survey of Site 173.*

Cooper, 1971). Sediments were expected to have accumulated continuously since at least middle Miocene time. They were thought to be equivalent in age to the onshore late Tertiary Humbolt Basin section.

Below the stratified unit is an irregular acoustic basement with major relief. A short distance south, Silver and Curray dredged an outcrop in Noyo Sea Valley from which rocks resembling the Franciscan assemblage were recovered. The authors proposed that basement at Site 173 is probably a Franciscan type of rock.

Site Objectives

The objectives at this site were threefold. First, it seemed possible to study displacement along the San Andreas Fault by determining the changing provenance of Delgada Fan deposits since Miocene time which would indicate if the fan first formed off San Francisco and if it was moved north past successive sources for 500 km to its present position. It was also hoped that presumed Franciscan basement might indicate whether an early Tertiary compressional and metamorphic history was followed by quiescence. Secondly, sediments of the fan might help in understanding the mechanisms of fan deposition such as the conditions that produce sandy or silty phases and various distinctive sedimentary structures. The third objective was to establish a continuous integrated biostratigraphy for the northeast Pacific upper Tertiary with emphasis on diatoms and radiolarians. Such a stratigraphic section is not available for cooler waters such as those found in the California current.

LITHOLOGIC SUMMARY

General Statement

The upper 138 meters of the section is dominated by terrigenous muds. Very thin fine sands are found at a few horizons. From 138 to 285 meters, the section is dominated by diatomite, in places with a high nannofossil content. At 285 meters, a thin sandy mudstone or chert is underlain by up to 35 meters of nannofossil ooze. Andesite (a thick flow or basement) is found at 320 meters. Light ashes (RI = 1.55) are found throughout the section.

Lithologic Units

Unit 1 (0-66.5 m; Cores 1-8)

Unit 1 is grayish green fine mud, with 1 to 5 percent biogenous components, mainly diatoms and sponge spicules, except from 5 to 40 meters where foraminifers constitute up to 2 to 4 percent of the core. Two thin bioturbated ash layers occur at around 4 meters, and a 5-cm bed of sand occurs at 58 meters.

Unit 2 (66.5-100.5 m; Cores 8-11)

Unit 2 consists of grayish olive green muds, as before, but with never more than 1 percent foraminifers. About thirteen interbedded thin arkosic fine and very fine sand laminae are concentrated in the upper and lower parts of the unit.

Unit 3 (100.5-138 m; Cores 12-15)

Grayish green muds occur which usually have more than 4 percent biogenous components, mainly diatoms. Diatoms make up as much as 15 percent of some samples. Very occasional thin arkosic very fine sands and rare glass shards occur in the muds.

Unit 4 (138-165 m; Cores 16-18)

Light olive diatomite, rich in nannofossils (around 10-15 percent) make up this unit.

Unit 5 (165-198 m; Cores 19-22)

Light olive diatomite, rich in nannofossils (around 10-15 percent) makes up the bulk of this unit, with about five interbedded thin ash beds, and occasional glass shards in other parts of the diatomite. A thin fine sand occurs at 169 meters. A few darker beds with very few nannofossils are found.

Unit 6 (198-224 m; Cores 22-24)

This unit is a pale olive nannofossil diatomite, with at least two interbedded thin ash beds. The nannofossil content is around 30 to 40 percent.

Unit 7 (224-254.5 m; Cores 25-28)

This unit contains interbedded pale olive nannofossil diatomite and light olive nannofossil-rich diatomite with several thin ash beds. The nannofossil diatomite has around 40 percent nannofossils; the nannofossil-rich diatomite 20 to 30 percent. The sediment is frequently mottled, indicating bioturbation to various degrees. The ash is often pyritized.

Unit 8 (254.5-263 m; Core 28)

A grayish olive muddy diatomite occurs here with 1 to 5 percent calcareous nannofossils.

Unit 9 (263-285 m; Cores 29-31)

This unit consists of a grayish olive diatomite, with some muddy diatomite in places near the top and some nanno diatomite near the base. A 3-cm partly chertified bed, and a 2.5-cm ash were recovered. Core recovery in this unit is low.

Unit 10 (285-(?) 186 m; Core 32)

This short interval contains calcareous glauconite-bearing sandy (?) mudstone or chert and possibly a basalt flow. A single rounded pebble of very altered basalt was found (see "Petrography of the Volcanics," Chapter 31, this volume).

Unit 11 ((?)286-320 m; Cores 32-35)

Dark greenish gray nannofossil ooze was recovered. Core recovery from this unit (especially the upper part) is low. Chert chips occur in the core catcher but not in the cores. At 320 meters, ash-bearing clayey dolomite was found in the core catcher with the first andesite.

Unit 12 (Below 320 m; Core 36)

Unit 12 is andesite, amygdaloidal and altered at the surface, with some brecciation, becoming coarser and fresher with depth. Petrologically, it contains feldspar phenocrysts and altered pyroxene phenocrysts, in a fine-grained groundmass.

Notes on Specific Lithologies

1. **Lithification.** One well-lithified ash was found, a 2.5-cm bed in Core 30. Its lithification compared with the other ashes may be due to (a) depth of burial and (b) its thickness preventing bioturbation and thus allowing more flux of interstitial water.

The cherts recovered in Section 29-2 are rather muddy and contain about 20 percent very fine sand, mainly angular to subrounded quartz and plagioclase feldspar. The calcareous glauconite-bearing sandy (?) mudstone or chert is not broken down by acid, suggesting at least part of the cement is chert or silicate. In thin section, the groundmass is difficult to resolve, but resembles that of the chert.

2. **Dolomite.** A hard, partly lithified, glass-bearing dolomite mud was found in the core catcher of Core 31, probably closely overlying the andesite. (In nearby Site 32, abundant dolomite rhombs were found in red clay closely overlying basalt basement). The carbonate source may have been nannofossils—they are absent from the mud, although nanno ooze is found in overlying cores. Dolomite commonly develops in carbonate rocks near major boundaries with Mg-rich rocks, and its occurrence need not indicate an intrusive andesite. No metamorphosed sediments were recovered but recovery was poor.

3. **Calcareous glauconite-bearing sandy (?) mudstone or chert.** The only example of this lithology is found in the core catcher of Cores 31 and 32. In thin section, about 60 to 80 percent of the rock is fine-grained groundmass. It was not determined whether this is chert, mud, or altered ash, but it is most probably chert. Glauconite, mainly of very fine grade, comprises about 10 percent of the rock. Some grains are pseudomorphs of foraminifer tests. A few radiolarians, mostly pseudomorphed by pyrite, and rare diatoms are also present. Sand grains (making up around 20 percent of the rock) are mainly angular to sub-rounded quartz and plagioclase feldspar, with rare dark brown biotite, all of very fine grade. There is a 1-cm bed of fine sand with abundant glauconite in the diatomite section in Section 19-2. Glauconite is occasionally found elsewhere in the diatomite, and there is at least one sandy ash.

4. **Pyritized ash.** Pyrite is abundant in most ash beds, and in a few sand beds, but is otherwise only rarely noted in the sediments. Some glass shards are partly replaced by pyrite along cracks, and others are completely pseudomorphed.

5. **Colors in diatomites.** The section from 224 to 254.5 meters in the diatomite has much interbedding of different-colored sediment. Beds more than 20 cm thick are indicated schematically in the barrel summaries. In places, there are alternations of beds on the scale of 3 to 10 cm.

In any one barrel, there is the following correspondence between color and lithology:

a) Pale olive is richest in nannofossils (often around 40 percent);

b) Light olive has fewer nannofossils (often 20-30 percent); and

c) Grayish olive usually has few nannofossils (less than 10 percent) and some clay (10-35 percent).

However, this correspondence is not infallible. A pale olive diatomite in Sample 28-2-100 has 5 percent nannofossils and 10 percent clay. In Core 21, pale olive has only about 10 percent nannofossils and light grayish olive has none.

Small (2 mm) black mottles are found in places, and are probably pyritic.

6. **Bioturbation in the diatomites.** Where there is variation in color of the diatomites, mottling is common. This is not due to core disturbance, since some color boundaries are sharp and sometimes even show no downbowing. Mottles on the scale of 1 to 2 mm are the most common, but those 5 to 10 mm thick are more prominent. Visible mottling on this scale is observed up to 30 cm from a contact between different-colored beds. There is an 8-cm-long vertical pyrite-margined burrow 12 mm in diameter in Core 18-3.

Most of the sharp color boundaries are between grayish olive (usually mud rich) and diatomites of other colors.

7. **Bioturbation of sand and ash beds.** With the possible exception of the thicker ash beds in Cores 7 and 34, all ash and sand beds are partially bioturbated. All the beds are penetrated by burrows, except for the 16-cm sand bed in Core 11. This bed has completely undisturbed alternating 2-mm laminae of "clean" and "dirty" sand over 1 cm in the middle of the bed, but both the top and the base are disturbed.

With the observed amounts of bioturbation, the ash found in small amounts in many smear slides could have all been derived from bioturbation of ash beds.

8. **Emplacement of sand beds in the terrigenous section.** The following observations were made:

a) Sand beds and grains are generally absent from the section.

b) The only well-preserved sand has alternating clean and dirty laminae.

c) There is no visible grading in this sand.

d) The sand-sized component of the mud is almost exclusively biogenic.

The general absence of sand from the section suggests that the occasional sand beds are turbidites rather than a residue from the winnowing of the muds. The high proportion of biogenous material in the sand fraction of the muds also rules out a bottom current-winnowing origin.

9. **Origin of the non-biogenic sandy material in the diatomites and nannofossil ooze section.** The nonbiogenic sandy materials are almost all of very fine grade and consist of (a) glauconite, often pseudomorphing foraminifers, (b) glass, and (c) angular to subrounded quartz and plagioclase feldspar grains and rare brown biotite. These materials could be of volcanic origin.

The only bed of clean very fine sand (in Section 19-2) is 5 to 10 percent glauconite, and otherwise mainly quartz, with some feldspar. This high glauconite content suggests that it is unlikely to be a crystal tuff.

PALEONTOLOGIC SUMMARY

Introduction

Site 173 proved to be exceptionally productive in terms of abundance and preservation of planktonic foraminifera, radiolarians, diatoms, and silicoflagellates. Indeed, diatomites and diatom-rich muds comprise well over 50 percent of the 333 meters of sediment penetrated at this site. Calcareous nannofossils are sparse to common in most cores, becoming abundant only at the base of the hole (Cores 34 and 35; 304.5-320 m). Spores and pollen are common to abundant only in the upper portion of the column (Cores 1 to 18; 0-170 m). Zonation of calcareous and siliceous microfossils indicates that the sequence penetrated at Site 173 represents an essentially continuous record of deposition during an interval spanning the latest Oligocene or lowest Miocene to the late Pleistocene. Thus, Site 173 constitutes an excellent biostratigraphic reference section for the eastern North Pacific Ocean and provides a record of planktonic events over a 23 m.y. interval within a dominantly cool temperate to subarctic zoogeographic province.

Low species diversity characterizes calcareous and siliceous microfossil assemblages at Site 173 and is a direct function of the relatively high latitude of this site, together with its location beneath the path of a major eastern boundary current (California Current). In turn, the low species diversity and absence of well-known planktonic index species of lower latitudes creates problems in biostratigraphic zonation of some groups. For example, only portions of the well-established calcareous nannoplankton and planktonic foraminiferal zones of tropical latitudes can be recognized and utilized at Site 173, requiring supplementary regional zonations based on high-latitude species to provide control within many intervals. Conversely, major oscillations of surface temperature during the late Oligocene-Pleistocene interval are clearly expressed in brief appearances of tropical elements as well as incursions of exclusively boreal biofacies; these events provide a means for correlation often unavailable at low latitudes.

The multiple biostratigraphic zonations delineated at Site 173 provide an exceptional opportunity to refine high latitude correlations between the various calcareous and siliceous planktonic groups. In addition, the multiple zonations provide a means of subdividing the column into relatively short intervals of time, a feat which is often difficult in cool water provinces where long ranging and morphologically simple forms tend to dominate the biota. Significantly, correlations can also be made with regional biostratigraphic zonations established in the middle to late Tertiary marine sections exposed on land in California, Oregon, and Washington. However, the first-order nature of some zonations defined and utilized at Site 173 must be tested further, and, as might be expected, there are discrepancies in placement of epoch boundaries between various groups; further study of this sequence is imperative.

The Pliocene/Pleistocene boundary at Site 173 is placed at 74 meters (Core 9) at the base of the *Eucyrtidium matuyami* Zone (radiolarian). This zone is currently correlated with the base of the Olduvai geomagnetic event

(Hays, 1970), which is in turn equated with a radiometric age of 1.85 m.y. (Opdyke, 1972). The base of North Pacific Diatom Zone V[2] occurs at 77 meters (Core 9) and is thought to fall within or near the base of the Olduvai event. Thus, the alignment of both radiolarian and diatom zonal boundaries with the base of the Olduvai paleomagnetic event exhibits some degree of consistency. Recognition of a definitive Pliocene/Pleistocene boundary utilizing calcareous nannoplankton and planktonic foraminifera is hampered by the absence of *Discoaster* and *Globorotalia truncatulinoides* within this interval at Site 173 equivalent to the approximate base of Blow (1969) Zone N. 18 whereas the arbitrary boundary picked herein falls within Zone N. 18.

The Miocene/Pliocene boundary is placed at 129 meters (top of Core 15) based upon the first occurrence of Pliocene (Zone 19) foraminiferal index species at 122 meters (Core 14), the base of the Pliocene *Lampcyrtis heteroporus* Zone (radiolarian) at 131 meters (Core 15), the base of the Pliocene *Ceratolithus rugosus* Zone (calcareous nannofossil) at 130-133 meters (Core 15), and the tentative placement of the base of the Pliocene *Distephanus speculum* Zone (silicoflagellate) at 130 meters (Core 15). This horizon is in turn correlated with an estimated radiometric age of 5.0 m.y. (Berggren, 1972). Correlations based upon diatom biostratigraphy currently place the Miocene/Pliocene boundary at the base of North Pacific Diatom Zone XI which occurs at 150 meters (Core 17) at Site 173.

The Middle Miocene/Upper Miocene boundary is arbitrarily placed at 186 meters (Core 20) at the base of the *Dictyocha asper-Reticulofenestra pseudoumbilicata* silicoflagellate-calcareous nannofossil combination zone. The approximate base of the Pliocene *Dictyocha pseudofibula* silicoflagellate zone occurs within the 170-179-meter interval (Cores 19 and 20) and the approximate base of the basal Pliocene *Ommatartus antepenultimus* radiolarian zone occurs within the 186-196-meter interval (Cores 20 and 21) compatible with the epoch boundary cited above. The earliest occurrence of a dominantly sinistral population of *Globigerina pachyderma* s.l.[3] currently correlated with planktonic foraminiferal zone N. 15 (Bandy and Ingle, 1970; and Bandy, 1971, 1972) takes place at 180 meters (Core 20) and marks a horizon approximately equivalent to the Middle Miocene/Upper Miocene boundary as defined by Blow (1969), Berggren (1969, 1972) and others. Berggren (1972) correlates this latter horizon with an estimated radiometric age of 10.5 m.y. It should be noted, however, that Bandy and Ingle (1970), Bandy, Casey and Wright (1971); and Bandy (1972) place the Middle Miocene/Upper Miocene boundary between Zones N. 12 and N. 13 as marked by the initial appearance of *Globigerina pachyderma* s.l. in temperate and boreal latitudes. This latter horizon occurs at 195.5 meters (base of Core 21) at Site 173. Interestingly, the base of North Pacific Diatom Zone XIX is correlated with the Middle Miocene/Upper Miocene boundary and this zonal boundary occurs within the 207-224-meter interval (Cores 23 to 24) at Site 173.

The Middle Miocene/Lower Miocene boundary is placed at 252.5 meters (bottom of Core 27) based upon the first occurrence of *Orbulina suturalis,* a planktonic foraminifera commonly used to mark this boundary (Zones N. 9/N. 8) at low and mid latitudes. Berggren (1972) correlates this horizon with an estimated radiometric age of 16 m.y. The base of the *Sphenolithus heteromorphus* calcareous nannoplankton zone of tropical latitudes is correlated with the first appearance of *Discoaster exilis* in Core 28 (264 m) at Site 173[4] in turn marking the base of the newly defined *Cyclicargolithus floridanus* range zone of Wise (Chapter 15, this volume). The base of the *S. heteromorphus* zone is currently correlated with an interval falling midway between the final appearance of the planktonic foraminifer *Catapsydrax stainforthi* and the initial appearance of *Orbulina suturalis* essentially compatible with the sequence observed at Site 173. However, it should be noted that portions of Cores 28, 29, and 30 are barren or contain only sparse planktonic foraminiferal assemblages. Consequently, it is conceivable that the *Orbulina* datum (base of planktonic foraminiferal Zone N. 9) may occur below Core 27 but no lower than the base of Core 30 (281 m) where abundant assemblages barren of this species reappear. Moreover, the base of North Pacific Diatom Zone XXIV equates with the Lower Miocene/Middle Miocene boundary occurs at 281 meters (base of Core 30) and the estimated base of the *Dorcadospyris alata* radiolarian zone also equated with this epoch boundary occurs within the 252-281-meter interval (Cores 28 to 31). Thus an alternate conservative case can be made for placing the Lower Miocene/Middle Miocene boundary as low as 218 meters (base of Core 30) at Site 173.

No sediment was recovered from the 285.5 to 304.5 meter interval (Cores 32 and 33) with the exception of a glauconitic sand at 295.5 meters which is barren of microfossils.

The Lower Miocene/Upper Oligocene boundary is arbitrarily placed at 312 meters (bottom of Core 34) based upon the top of the *Reticulofenestra bisecta-Triquetrorhabulus carinatus* Range-zone (combination calcareous nannofossil-silicoflagellate) at this horizon. Moderately to poorly preserved planktonic foraminifera in Cores 34 and 35 (304.5 to 320 m) include *Globigerina angulisuturalis, G. euaperta, Globorotalia nana*, and *Catapsydrax dissimilis* suggesting assignment to the lowermost Miocene or uppermost Oligocene (Zone N.3 or N.4). This epoch boundary is currently correlated with an estimated radiometric age of 22.5 m.y. (Berggren, 1972). Diatoms are absent from 281 meters to the base of the hole whereas radiolarians are absent or poorly preserved from 285 meters to the base of the hole.

Finally, it is important to note that three major sedimentologic/paleocologic events are represented at Site

[2]North Pacific Diatom Zones of Schrader as defined in this volume (Chapter 17).

[3]"*Globigerina*" *pachyderma* s.l. includes morphotypes referred to *G. incompta* Cifelli and *G. atlantica* Berggren.

[4]This zone is incompassed within the longer *Cyclicargolithus floridanus* Zone (combination range) of Wise (Chapter 15, this volume).

173. Deposition of calcareous nannofossil ooze ceased and a lengthy period of prolific diatom productivity and deposition commenced during the Lower Miocene (Core 31; 282 m). The 138 meters of diatomites penetrated at Site 173 span almost the entire Lower Miocene-Upper Miocene interval. Tentative placement of epoch boundaries at Site 173 and their alignment with the radiometric and paleomagnetic time scales of Berggren (1972) and Opdyke (1972) indicate rates of deposition within the diatomaceous interval varied as follows: Lower Miocene–4.8 m/m.y.; Middle Miocene–17.4 m/m.y.; and Upper Miocene–9.5 m/m.y. Significantly, Lower Miocene through Upper Miocene laminated diatomites and siliceous shales assigned to the Monterey Shale and coeval units of similar lithology are exposed in coastal California, Oregon, Washington and Baja California, Mexico, emphasizing the regional nature of this event. A third major event occurred at the beginning of the Pliocene (Core 15; 129 m) when a massive influx of terrigenous clays, silts, and sands appear in the record diluting biogenous deposits. The estimated rate of deposition during the Pliocene interval based on the correlations noted above is 25.8 m/m.y., whereas the estimated rate for the Pleistocene interval is 62.5 m/m.y. emphasizing the acceleration of sedimentation during a period of severe climatic deterioration.

Calcareous Nannofossils and Silicoflagellates

Small to moderate numbers of calcareous nannofossils were recovered from diatomaceous green muds. These Neogene assemblages are highly diluted by siliceous microfossils and terrigenous clays, especially those assemblages within the Pliocene/Pleistocene interval. Calcareous nannofossils only become abundant at the base of the hole where the lithology changes to gray mud. Silicoflagellate assemblages are common at various horizons and are most abundant within Miocene diatomites.

Species diversity of both calcareous nannofossils and silicoflagellates is low at Site 173 compared with coeval assemblages at tropical latitudes. This is directly attributable to the relatively high latitudinal position of this site (39°57.7′N). Indeed, it has been well documented that species diversity among Quaternary coccoliths in the Atlantic and Pacific oceans decreases dramatically from low to high latitude (McIntyre and Bé, 1967; McIntyre et al., 1970). Thus, at Site 173 it is not surprising to find that many tropical, subtropical, and transitional species are conspicuously absent. Conversely, some species encountered are clearly indicative of cool temperatures; *Coccolithus pelagicus*, which is common within the Pleistocene interval at Site 173, can only tolerate seasonal surface water temperatures of between 6° and 14°C (McIntyre et al., 1970).

Low species diversity characterizing the cool water assemblages of Site 173 presents an acute problem for the biostratigrapher because many key marker species of lower latitudes are absent, especially among the discoasters, sphenoliths, and helicopontosphaerids. In fact, few of the twenty-six calcareous nannofossil zones and subzones defined for the Neogene of the equatorial Pacific (Bukry, 1971) can be recognized at Site 173. Therefore, it has been necessary to employ a broader zonal concept in order to subdivide this section[5] utilizing techniques such as combining two or more zones recognized in equatorial regions into one zone and using secondary marker species. Furthermore, ranges of selected species of silicoflagellates are used in conjunction with zonation by calcareous nannofossils in order to provide control in Upper and Middle Miocene intervals lacking significant calcareous nannofossil floras at Site 173. One Middle Miocene silicoflagellate datum level (the *Corbisena triacantha* datum) proposed by Martini (1971) for the equatorial Pacific can be recognized at Site 173 and is used here in combination with datum levels provided by calcareous nannofossils to define new subzones ultimately resulting in "combination range zones" (see Wise, this volume).

The three "standard" calcareous nannofossil zones commonly used to subdivide the Pleistocene (Martini and Worsley, 1968) can be recognized in Cores 1 through 4 (0-34 m) at Site 173 and the first appearance of *Geophyrocapsa* can be used to approximate the Pliocene/Pleistocene boundary at the base of Core 4 (34 m) in the absence of *Discoaster*. However, this tentative boundary is in conflict with the Pliocene/Pleistocene boundary defined on the basis of radiolarian and diatom zonations. Unfortunately, only sparse floras are present in Cores 3 through 13 (34 to 119.5 m) and the virtual absence of discoasters and ceratoliths makes it difficult to subdivide this portion of the column. Indeed Bukry (Chapter 19, this volume) assigns a portion of this interval (44 to 97 m) to an undifferentiated Pliocene/Pleistocene zone. It is important to note that Pliocene discoaster assemblages are better represented at more westerly DSDP Sites 34 and 36 (McManus et al., 1970).

Cores 15 to 23 (129-214.5 m) contain Miocene cool water assemblages dominated by *Reticulofenestra pseudoumbilica*, *Discoaster variabilis*, and *Discoaster exilis*. A new discoaster species, *Discoaster mendomobensis* Wise, is used to define two new Miocene nannofossil zones in this interval. This geographically restricted species flourished at Site 173 during an unusually warm interval during the late Miocene as evidenced by paleoecologic interpretations based on planktonic foraminifera, diatoms, and silicoflagellates. Assemblages encountered between the bottom of Core 22 (205 m) and the top of Core 30 (271.5 m) are little changed from those immediately above this interval except for the addition of *Cyclicargolithus floridanus* with the Middle Miocene/Lower Miocene boundary placed within the lower portion of the *Cyclicargolithus floridanus-Discoaster exilis* Zone. Samples below 273 meters (Core 30), however, contain abundant *Sphenolithus moriformis*, *Discoaster deflandrei*, and an assortment of discoaster forms which show signs of secondary calcite overgrowths. The presence of *Helicopontosphaera kamptneri* indicates somewhat warmer water conditions during the Middle Miocene than prevailed at this site during later intervals.

A glauconitic (?) interval barren of all microfossils is represented in Cores 32 to 33 (285.5-304.5 m). Cores 34 and 35 do contain calcareous nannofossils and those found

[5]See Chapter 15 by Wise and Chapter 19 by Bukry for detailed discussion of calcareous nannoplankton and silicoflagellate zonation.

in Core 35 (310.5-320 m) are placed in the *Reticulofenestra bisecta-Triquetrorhabdulus carinatus* Zone of the uppermost Oligocene.

In summary, the calcareous nannoflora at Site 173 went through three major transitions, two of which were accompanied by a marked change in the depositional pattern at the site. The first occurs in the Lower Miocene (Cores 31 and 30) where a reasonably diverse assemblage containing some discoasters showing secondary calcite overgrowths is replaced by a somewhat more restricted assemblage which lived in surface waters that, for the first time, were dominated not by calcareous nannoplankton, but by diatoms. The second change occurs in the Upper Miocene (Core 16; *Discoaster mendomobensis* Zone) where an atypical assemblage of heavily constructed discoasters dominates a calcareous nannoflora which thrived in surface waters usually warm for this locality. The third major change occurs in the Lower Pliocene (Cores 14 and 13) at a point above which, the calcareous nannofossils are severely restricted in numbers and their preservation is generally poor.

Planktonic Foraminifera

Well-preserved planktonic foraminifera are abundant to common within the Pleistocene and Pliocene terrigenous muds encountered from 0 to about 130 meters (Core 15). Moderately to well-preserved faunas are generally common within Miocene diatomites and diatom-rich muds encountered from 130 to 285 meters (Cores 15 to 31). However, the number of planktonic specimens per unit volume of sediment is generally low due to dilution by prolific numbers of diatom frustules. Cores 32 and 33 (285.5 to 304.5 m) are completely barren. Common to rare numbers of foraminifera occur in the lower Miocene/Upper Oligocene nannofossil ooze encountered in Cores 34 and 35 (304.5 to 320 m). An anomalous Pliocene assemblage is present within disturbed sediment at the base of Core 35 (313 to 320 m) apparently representing downhole slumping or displacement by drilling operations.

The planktonic foraminiferal sequence at Site 173 represents a nearly continuous record of planktonic productivity within a cooler portion of the California Current system during the late Oligocene to Pleistocene interval. The boreal aspect of these faunas precludes the common occurrence of the critical index species of planktonic foraminifera recognized in tropical regions. However, a series of cool, temperate, and subtropical planktonic biofacies have been recognized in the mid-Tertiary to Recent interval of this region (Lipps, 1964, 1967; Ingle, 1967, 1972; Bandy and Ingle, 1970; Bandy et al., 1971; Bandy, 1971, 1972) which, together with occasional occurrences of tropical species, allow epoch boundaries to be recognized and the faunas to be placed within the context of Blow's (1969) planktonic zones. Biostratigraphic resolution is in fact enhanced by the periodic latitudinal migrations of planktonic faunas in this region representing distinct paleo-oceanographic events. This sort of phenomenon is characterized by the well-established changes in coiling direction of *Globigerina pachyderma* s.l. within Neogene surface sections exposed along the Pacific Coast of North America representing variations in surface temperature within this region. These trends were utilized in recognizing various stratigraphic horizons at Site 173 and other sites drilled during DSDP Leg 18.

Late Pleistocene assemblages representing zone N.23 at Site 173 are dominated by sinistral coiling populations of *Globigerina pachyderma* (Cores 1 to 4; 0-34 m) whereas early Pleistocene and Pliocene populations exhibit alternating dextral and sinistral coiling (Cores 5 to 9; 34-74 m). *Globigerina bulloides* increases in abundance within warmer intervals marked by dextral populations of *G. pachyderma.* Indeed, the predominance of the transitional water mass species *Globorotalia inflata* at some horizons indicates that the northward adjustment of the 20°C isotherm relative to its present position off Baja California occurred several times during this interval. Significantly, *Globorotalia truncatulinoides* was not found within the Pleistocene interval at this site although rare specimens of *G. tosaensis* were encountered at 54 meters (Core 7). However, this bioseries is present at Site 36 northwest of Site 173 and correlations with this sequence reinforce placement of the Pliocene/Pleistocene boundary at the base of Core 9 (74 m).

Pliocene assemblages encountered in Cores 9 through 14 (74 to 122 m) contain significant populations of *Globorotalia puncticulata* and *Globoquadrina humerosa* along with *Globorotalia crassaformis* s.s., *G. crassaformis oceanica, G. crassaformis ronda,* and *Globigerina decoraperta* representing zones N.22 through N.19.

Upper Miocene assemblages dominated by *Globigerina bulloides* and *G. pachyderma* s.l. representing zones N.18 to N.16 occur from 131 to 164 meters (Cores 15 to 19). Rare specimens of *Globigerina apertura, G. decoraperta, Globorotalia acostaensis, G.* cf. *margaritae, G. minutissima, G. miozea, G. tumida,* and *Globoquadrina dehiscens* occur within this interval. The base of the oldest dominantly sinistral population of *Globigerina pachyderma* s.l. occurs at 164 meters (Core 18) and reflects a major period of Miocene polar refrigeration sensed as far south as 28°N (Mohole cores) and known to be correlative with a portion of the Mohnian Stage of California (Ingle, 1967; Bandy and Ingle, 1970) and zone N.16 (Bandy, 1971).

Middle Miocene populations representing zones N.15 through N.9 and correlative with the lower Mohnian, Luisian, and Relizian stages of California occur from 176.5 to 252.5 meters (Cores 20 to 27). *Globigerina angustiumbilicata* and *Globigerinita glutinata* var. dominate faunas in the early portion of this interval (Cores 27 to 23; 252.5 to 218 m) with the initial appearance of *Orbulina suturalis* at 252.5 meters (Core 27). Late Middle Miocene faunas are dominated by *Globigerina bulloides, G. praebulloides,* and *G. concinna.* Assemblages dominated by *Globorotaloides trema* occur from 215 to 218 meters (Core 24) and represent a significant planktonic event correlative with zone N.11 and the Luisian Stage of California. Rare specimens of *Globigerina obesa, Globorotalia continuosa, G. peripheroronda, G. praescitula,* and *Globoquadrina venezuelana* also occur within the Middle Miocene interval.

Core 28 (252.5 to 262 m) contains only sparse foraminifera and Cores 29 and 30 are barren of planktonic foraminifera. Distinctly Lower Miocene faunas representing zones N.7 through N.5 first occur in Core 31 (285.5 m) marked by well-developed specimens of *Catapsydrax dissimilis.* This fauna is correlative with a portion of the Saucesian Stage of California (Lipps, 1967; Bandy, et al., 1969). Another barren interval occurs in Cores 32 and 33 (285.5 to 304.5 m) with sparse faunas containing *Globigerina angulisuturalis, G. officinalis, G. euaperta, Globorotalia nana, Catapsydrax dissimilis,* and *C. unicava* appearing in the nannofossil ooze of Cores 34 and 35 (304.5 to 313.5 m). These latter faunas are equivalent to zones N.4 and N.3 spanning the Lower Miocene/Upper Oligocene boundary as confirmed by zonation of associated calcareous nannoplankton.

Benthonic Foraminifera

Pleistocene through Upper Oligocene benthonic foraminiferal assemblages encountered at Site 173 exhibit a remarkable similarity considering the length of time represented by this interval. Important bathymetric index species are present in almost every sample and include *Melonis pompilioides, M. barleeanus, Gyroidina soldani, Uvigerina senticosa, Pullenia bulloides, Hoeglundina elegans, Bulimina rostrata, Eggerella bradyi,* and several species of *Stilostomella.* All of these species are common in Recent faunas found at depths between 2500 to 3500 meters in the eastern North Pacific Ocean. However, persistent admixtures of species representative of slightly shallower depths occur in many samples and include *Bulimina striata mexicana, Uvigerina peregrina dirupta, U. hispido-costata, U. hispida,* and *Globobulimina affinis* indicating continuous downslope displacement of sediments onto this site. Percentages of displaced species are highest in the Lower Miocene/Upper Oligocene interval.

The benthonic assemblages encountered at Site 173 are typical of a continental slope environment some distance from the shelf and main avenues of downslope transport of shallow water sediments. They are not representative of a typical proximal deep-sea fan environment.

Most of the benthonic species recovered are not stratigraphically significant. Nevertheless, one specimen of *Valvulineria californica,* an index species of the Luisian Stage of California (Kleinpell, 1938), was found in Core 23 (110 m) and one specimen of *Gyroidina reliziesis* indicative of the Relizian Stage was recovered in Core 27 (250 m). Moreover, rare specimens of *Uvigerina galloway* and *Rectouvigerina* ("*Siphogenerina*") *kleinpelli,* present in the Saucesian Stage of California, were found in Core 28 (262 m) and *R. smithi,* common in the Zemorrian Stage of California, was found in Core 35 (312 m). Further study of the benthonic foraminifera at Site 173 will likely reveal additional but rare specimens of other stratigraphically diagnostic species.

Radiolaria

Cores 1 through 31 (0-285.5 m) are rich in radiolarians of Neogene age. Cores 32, 34, and 35 (285.5-320 m) contain poorly preserved recrystallized specimens including some probable Cretaceous species with minor quantities of well-preserved Tertiary species. Core 36 was not examined and Core 37 (322.5-328 m) contains no radiolarians.

Core 1 and the upper portion of Core 2 (0-8.3 m) contain as assemblage lacking *Druppatractus aequitonius* and *Stylatractus universus* indicating this interval is within the upper Pleistocene *Astostrobium miralestense* Zone of Hays (1970). The base of this zone, as identified in Samples 173-2-2 (118-120 cm) to 173-2-3 (40-42 cm), corresponds to a radiometric-paleomagnetic age of 0.4 m.y. in the North Pacific according to Hays (1970). The lower part of Core 2 through Core 8 (8.3-73 m) represents the next older *Stylatractus universus* Zone whose base (Samples 173-8-5, 57-59 cm, to 173-8-6, 57-59 cm) is thought to represent 0.9 m.y. (Hays, 1970). Interestingly, *Lamprocyclas heteroporos* ranges up into *Stylatractus universus* Zone at Site 173 unlike the subarctic Pacific where it reaches an upper limit at the base of this zone according to the interpretation presented here. Cores 9 through 14 (73-129 m) contain *Lampcyrtis heteroporus* below the lower limit of *L. heteroporus* near the Miocene-Pliocene boundary of California.

Cores 15 through 31 (129-285.5 m) contain radiolarians diagnostic of the Miocene epoch. Riedel and San Filippo's (1970) *Ommatartus antepennultinnus* Zone, *Cannartus petterssoni* Zone, *Dorcadospyris alata* Zone, and *Calocycletta costata* Zone can be recognized in this interval, however, precise zonal boundaries cannot be established. The oldest zone recognized indicates an upper lower Miocene age for Core 31 (281-285.5 m).

Diatoms

Diatoms are common to abundant and moderately well preserved in the terrigenous muds from 0 to 130 meters (Cores 1 to 15) at Site 173. They are abundant and well preserved within diatomaceous sediments of the 130 to 280 meter (Cores 15 to 30) interval. Lower horizons from 282 to 333.5 meters (Cores 31 to 38) are barren of diatoms. Reworked older species are common in the Pleistocene interval (0-66 m as defined on the basis of diatom biostratigraphy), as well as in the lower portions of the hole where displacement occurred due to slumping during coring. The abundance of ecologically displaced diatoms (littoral marine, fresh-water benthonic, and planktonic forms) increases abruptly within the Pleistocene terrigenous muds.

The abundant and diverse Pleistocene through Early Miocene diatom floras encountered at Site 173 provided the basis for definition of the North Pacific Diatom Zones (NPD Zones) utilized in this report (Schrader, Chapter 17, this volume) the following NPD zonal boundaries were recognized: base of NPD Zone I at 17 meters (173-2-2, 104-105 cm), base of NPD Zone II at 28 meters (173-4-2, 55-56 cm), base of NPD Zone III at 53 meters (173-6-3, 55-56 cm), base of NPD Zone IV at 67 meters (173-8-2, 55-56 cm), base of NPD Zone V at 77 meters (173-9-4, 55-56 cm), base of NPD Zone VI at 90 meters (173-10-5, 55-56 cm), base of NPD Zone VII at 104 meters (173-12-2, 55-56 cm), base of NPD Zone VIII at 123 meters (173-14-1, 55-56 cm), base of NPD Zone IX at 130 meters (173-14, CC), base of NPD Zone X at 139 meters (173-15, CC), base of NPD Zone XI at 152 meters (173-17-2, 55-56 cm), base of NPD Zone XII at 160 meters (173-17, CC), base of NPD Zone XIII at 168 meters (173-18-4, 56-57 cm), base of NPD Zone XIV at 173 meters (173-19-2, 55-56 cm), base of NPD Zone XV at 177 meters (173-20-2, 55-56 cm), base of NPD Zone XVI at 182 meters (173-21-1, 99-100 cm), base of NPD Zone XVII at 197 meters (173-22-2, 55-56 cm), base of NPD Zone XVIII at 205 meters (173-23-1, 110-222 cm), base of NPD Zone XIX at 225 meters (173-24, CC), base of NPD Zone XX at 234 meters (173-25, CC), base of NPD Zone XXI at 244 meters (173-26, CC), base of NPD Zone XXII at 254 meters (173-27, CC), base of NPD Zone XXIII at 264 meters (173-29-1, 55-56 cm), and the base of NPD Zone XXIV at 281 meters (173-30, CC). The base of NPD Zone XXV has not been defined.

The base of NPD Zone IV at 67 meters is correlated with the Pleistocene-Pliocene boundary of Donahue (1970) and is thought to represent the top of the Olduvai paleomagnetic event. The Miocene-Pliocene boundary is placed at the base of NPD Zone XI at 152 meters in turn correlated with an interval thought to represent the top of magnetic epoch 5 equivalent to an estimated radiometric age of 5.5 m.y. (Berggren, 1962, 1972).

Pollen and Spores

Palynomorphs are common to abundant in Cores 1 through 18 (0-167 m) and in Core 25 (224-233.5 m) of Site 173, but are essentially absent from all other horizons sampled. The absence of pollen in the majority of cores sampled is probably due to dilution of terrigenous sediment by the high frequency of marine microfossils, particularly diatoms (Korneva, 1964) and by the lack of preservation of the grains at the base of the hole. This latter phenomenon is reflected by the increasing amount of apparently poorly preserved pollen downhole, where it forms 90 percent of the sample in Core 25. Corrosion and yellow staining of pollen may be a product of overburden pressure and high temperature (Staplin, 1969).

Composition of assemblages encountered indicates fluctuating cooler and warmer horizons, but most dramatic is the sharp break at the base of Core 8 (72 m) indicating a warm period which continues to the base of the section studied. Pine frequency decreases from a maximum of 85% at 55 meters to a minimum of 10% at 100 meters. Correspondingly, there is an increase in species diversity. This break corresponds to the Pliocene-Pleistocene boundary as determined by marine microfossils.

Lack of detail in climatic trends at Site 173 is likely the product of relatively widely spaced sampling which precludes the detection of small-scale climatic events.

The appearance of *Ephedra* in Core 12 (110 m) marks the only occurrence of a genus extinct in this area since Pliocene time.

PHYSICAL PROPERTIES

Physical properties were measured on only two sections of most cores because the cores were coming aboard at a rate of one core per hour. Porosity and bulk density were measured with the GRAPE and by shipboard laboratory methods on Sections 2 and 5 of most cores. Sonic velocity was measured on the same sections with the Hamilton frame instrument. After Core 10, the consistency of the sediments allowed velocity measurements to be made out of the core liner. The three velocity measurements made on the most consolidated part of each section had insignificant variation between the values.

The relatively low disturbance of cores below 50 meters probably makes the measurements at Site 173 more reliable than usual. This impression is obtained from the correlation between GRAPE and sonic velocity measurements with the described lithology. For instance, the change from mud to diatom-rich sediment between 100 meters and 138 meters correlates with a distinct event in the three physical properties curves plotted. There is also a distinct change in the level of natural gamma radiation. A similar situation is seen near the bottom of the drill hole at Core 29 where a change from diatomite to nannofossil ooze occurs. The physical properties suggest that the changes from diatomaceous to nondiatomaceous sediment was more gradual than color changes indicate.

CORRELATION BETWEEN REFLECTION RECORDS AND STRATIGRAPHIC COLUMN

Two seismic reflection records along a track perpendicular to the continental slope were made during the predrilling site survey (see Appendix I). One was made at 8 knots and the other at 4 knots (Figure 2).

Based largely on the reflectivity shown in the 4-knot record and a stationary record, the sedimentary section is divided into two acoustic units. The upper unit is composed of weak reflections that generally parallel the ocean floor. Its lower contact conforms with a lower unit which has stronger reflections of variable intensity. The lower unit conforms to the acoustic basement where basement slopes are near horizontal and abuts unconformably against steeper basement slopes. The unit has filled lows and its thicker basal portions on either side of Site 173 may be older than the section drilled.

The acoustic basement is marked by a highly reverberent reflector and possibly crude layering. The basement has large steps and steep slopes that suggest tectonism rather than original topography. If the steps are faults, little of this tectonism is expressed in the overlying sedimentary section.

The reflection records suggest the following sequence of events: (a) formation of basement followed by probable faulting and tilting, (6) after most of the tectonism occurred, deposition of a thick layered sequence on the irregular surface, and (c) deposition of the upper unit.

The upper acoustic unit correlates well with the Pleistocene and Pliocene section of grayish green muds from 0 to 138 meters (see "Lithologic Summary"). If 138 meters is the lower boundary, an interval velocity of 1.57 km/sec is calculated, which compares favorably with velocities measured on the cores (see "Physical Properties"). A discrepancy of about 15 meters occurs in the

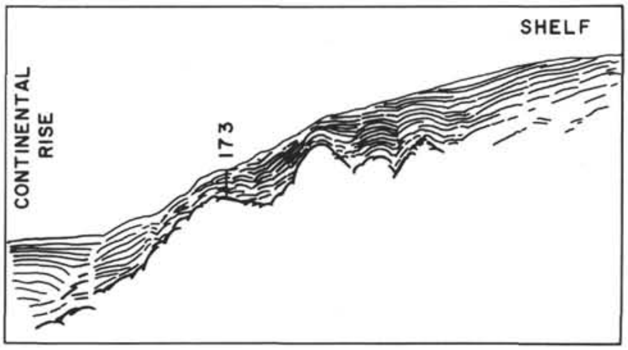


Figure 2. *Diagrammatic section across Delgada Fan along a line SW from Cape Mendocino (based on seismic records in Silver, 1971).*

lower unit-basement contact if laboratory velocities are used. This discrepancy is probably within the limits of error for the seismic- and velocity-measuring techniques.

SUMMARY AND CONCLUSIONS

Site 173 is located on the lower continental slope off Cape Mendocino, northern California at a water depth of 2927 meters. It was continuously cored to a total depth of 333.5 meters below the sea floor (Table 1). Andesite was encountered at 320 meters. Fossils suggest continuous deposition from at least upper to middle Pleistocene through the lowermost Miocene. This hole provides an important biostratigraphic section for the northeast Pacific.

The upper 138 meters of the sedimentary section is dominated by Pleistocene to late Miocene grayish green muds with a few horizons of very thinly bedded fine sands. Sedimentation rates of 22 m/m.y. are calculated on the basis of planktonic foraminiferal zonations determined according to the Berggren (1969) time scale.[6] The bulk of the section (138-285 meters) consists of upper to lowermost Miocene pale olive to grayish olive diatomites. It is underlain by up to 35 meters of gray nannofossil ooze which rests upon the andesite. Thin ash beds are found through the entire sedimentary section. The middle Miocene-lower Miocene diatomaceous unit has an extrapolated sedimentation rate of 13 m/m.y.

Thin section and hand specimen analysis of the volcanic rock fragments shows that they have a diverse composition but most of them appear to be andesitic in character. Rocks of this composition are atypical of a deeper ocean environment which raises the possibility that the lower slope has subsided. The small fragments recovered are dark colored with greenish and purplish hues. Some hand specimens have vesicles that are several millimeters in diameter. Good glass in some samples suggests emplacement in a submarine environment.

Site 173 is characterized paleontologically by the abundance, preservation, and diversity of foraminifers, radiolarians, and diatoms throughout the entire section cored. Spores and pollen are sparce, but more common to the Pleistocene. Calcareous nannofossils become more abundant in the middle to lower Miocene section. Variable species composition indicates a significant series of climatic oscillations throughout the late Tertiary in this area. Prolific diatomites represent a response to vigorous upwelling, similar to that of today, and a much lower influx of terrigenous sediments during the Miocene. The rain of diatom frustules became diluted as the rate of terrigenous sedimentation increased significantly at the end of the Miocene and beginning of the Pliocene. This may have been a delayed response to the large-scale tectonic activity along the Pacific coast of North America during the Oligocene-Miocene interval. The seaward advance of terrigenous sedimentation may be reflected in the grayish green muds that began to accumulate rapidly at the site near the end of the Miocene and beginning of the Pliocene. The benthonic foraminiferal assemblages are typical of a continental slope environment. The fine-grained nature of the deposits also suggests that most of the deposition was some distance beyond the continental shelf either by hemipelagic sedimentation and/or slow downslope movement of bottom-seeking turbid layers. The presence of shallower-water benthonic forams in the slope deposits indicates displacement, most likely from the upper slope. An alternative but less attractive explanation is that downslope displacement is minimal and that subsidence has occurred throughout the late Tertiary at Site 173.

Cretaceous radiolarians occur in the lower Miocene sediments. Apparently, they were contributed from a nearby source because they show little or no evidence of surface abrasion. Their state of preservation suggests an origin from rocks of the Franciscan Formation. A Franciscan type of rock was dredged a short distance south of Site 173 in Noyo Sea Valley (Silver, Curray, and Cooper, 1971).

[6] All sedimentation rates uncorrected for compaction in this chapter.

TABLE 1
DSDP Site 173 Coring Summary

Core	Cored Interval Below: Derrick Floor (m)	Cored Interval Below: Sea Floor (m)	Cored (m)	Recovered (m)	Recovered (%)
1	2984.5-2990.0	0-5.5	5.5	5.5	100.0
2	2990.0-2999.5	5.5-15.0	9.5	9.5	100.0
3	2999.5-3009.0	15.0-24.5	9.5	8.0	84.2
4	3009.0-3018.5	24.5-34.0	9.5	8.0	84.2
5	3018.5-3028.0	34.0-43.5	9.5	7.5	78.9
6	3028.0-3037.5	43.5-53.0	9.5	4.5	47.4
7	3037.5-3047.0	53.0-62.5	9.5	6.0	63.2
8	3047.0-3056.5	62.5-72.0	9.5	8.5	89.5
9	3056.5-3066.0	72.0-81.5	9.5	9.5	100.0
10	3066.0-3075.5	81.5-91.0	9.5	9.0	94.7
11	3075.5-3085.0	91.0-100.5	9.5	5.5	57.9
12	3085.0-3094.5	100.5-110.0	9.5	9.5	100.0
13	3094.5-3104.0	110.0-119.5	9.5	9.5	100.0
14	3104.0-3113.5	119.5-129.0	9.5	5.0	52.6
15	3113.5-3123.0	129.0-138.5	9.5	5.0	52.6
16	3123.0-3132.5	138.5-148.0	9.5	4.5	47.4
17	3132.5-3142.0	148.0-157.5	9.5	4.0	42.1
18	3142.0-3151.5	157.5-167.0	9.5	8.5	89.5
19	3151.5-3161.0	167.0-176.5	9.5	5.5	57.9
20	3161.0-3170.5	176.5-186.0	9.5	3.5	36.8
21	3170.5-3180.0	186.0-195.5	9.5	5.5	57.9
22	3180.0-3189.5	195.5-205.0	9.5	7.0	73.7
23	3189.5-3199.0	205.0-214.5	9.5	3.5	36.8
24	3199.0-3208.5	214.5-224.0	9.5	7.0	73.7
25	3208.5-3218.0	224.0-233.5	9.5	7.5	78.9
26	3218.0-3227.5	233.5-243.0	9.5	5.5	57.9
27	3227.5-3237.0	243.0-252.5	9.5	6.0	63.2
28	3237.0-3246.5	252.5-262.0	9.5	4.5	47.4
29	3246.5-3256.0	262.0-271.5	9.5	3.0	31.6
30	3256.0-3265.5	271.5-281.0	9.5	1.0	10.5
31	3265.5-3270.0	281.0-285.5	4.5	1.0	22.2
32	3270.0-3279.5	285.5-295.0	9.5	CC	–
33	3279.5-3289.0	295.0-304.5	9.5	–	–
34	3289.0-3295.0	304.5-310.5	6.0	4.0	66.7
35	3295.0-3304.5	310.5-320.0	9.5	3.5	36.8
36	3304.5-3307.0	320.0-322.5	2.5	0.5	20.0
37	3307.0-3312.5	322.5-328.0	5.5	CC	–
38	3312.5-3318.0	328.0-333.5	5.5	CC	–
		Totals	333.5	196.0	58.77

Information relating to tectonics near Site 173 fits most easily into a rather static unifying scheme. In sequence, the principal deductions are the following:

1) The Franciscan Formation may form a basement in this area.

2) Above the possible Franciscan is an andesite. Since the occurrence of andesite is rare in deep water, this unit may have been extruded and altered in shallow water. However, no other evidence reinforces this interpretation and it seems equally likely that the andesite has a deep-water origin.

3) The basement complex was broken by large steep faults no later than late Oligocene or early Miocene time. This deformation may correlate with an episode of major tectonism that began along the adjacent California coast in late Oligocene or early Miocene time. Subsequent layered units are not deformed and no local tectonism is apparent in the area after this event but later regional deformation is possible.

4) Unabraded Cretaceous radiolarians incorporated in early Miocene sediments are most easily explained by an exposure of Franciscan rock in submarine outcrop nearby.

5) Terrigenous sedimentation was low at Site 173 from late Oligocene (?) through most of the Miocene. During this time nannofossil ooze and then diatomaceous sediments accumulated at a relatively slow rate. The environments deduced from lithologic and paleontologic data indicate continental slope conditions prevailed at this site throughout the Miocene.

6) At the end of Miocene time, an influx of terrigenous sediment dominated the depositional history at Site 173 with rates of accumulation about twice previous rates. This influx may have been a function of a progressive seaward prograding of terrigenous sediments in addition to any climatic fluctuations.

REFERENCES

Bandy, O. L., 1971. Recognition of Upper Miocene Neogene Zone 18, Experimental Mohole, Guadalupe Site. Nature. **233** (5320), 476.

———, 1971. Neogene planktonic foraminiferal zones, California, and some geologic implications. *In* Lipps, J. H. (Ed.), Eastern Pacific plankton biostratigraphy and paleoecology. Paleogeog., Paleoclim., and Paleoecol. **12** (1/2), 131.

Bandy, O. L. and Ingle, J. C., Jr., 1970. Neogene planktonic events and radiometric scale, California. *In* Bandy, O. L. (Ed.), Radiometric Dating and Paleontologic Zonation. Geol. Soc. Am. Spec. Paper 124., 131.

Bandy, O. L., Morin, R. W. and Wright, R., 1969. Definition of the *Catapsydrax stainforthi* Zone in the Saucesian Stage of California. Nature. **222**, 468.

Bandy, O. L., Casey, R. E. and Wright, R. C., 1971. Late Neogene planktonic zonation, magnetic reversals, and radiometric dates, Antarctic to the tropics. *In* Reid, J. L. (Ed.), Biology of the Antarctic Seas IV. Am. Geophys. Union, Antarctic Res. Ser. **15**, 1.

Berggren, W. A., 1969. Cenozoic chronostratigraphy, planktonic foraminiferal zonation and the radiometric time-scale. Nature. **224** (5224), 1072.

———, 1972. A Cenozoic time scale–some implications for regional geology and paleobiogeography. Lethia. **5** (2), 195.

Blow, W. H., 1969. Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. Proc. First Intern. Conf. Planktonic Microfossils. **1**, 199.

Bukry, D., 1971. Cenozoic calcareous nannofossils from the Pacific Ocean. Trans. San Diego Soc. Nat. Hist. **16**, 303.

Donahue, J. G., 1970. Diatoms as Quaternary biostratigraphic and paleoclimatic indicators in high latitudes of the Pacific Ocean. Ph.D. thesis, Columbia Univ., New York. 230.

Hays, J. D., 1970. Stratigraphy and evolutionary trends of Radiolaria in North Pacific deep sea sediments. *In* Hays, J. D. (Ed.), Geological Investigations of the North Pacific. Geol. Soc. Am. Mem. 126. 185.

Ingle, J. C., Jr., 1967. Foraminiferal biofacies and the Miocene-Pliocene boundary in southern California. Bull. Am. Paleontol. **52**, 217.

———, 1972. Biostratigraphy and paleoecology of Early Miocene through Early Pleistocene benthonic and planktonic foraminifera, San Joaquin Hills-Newport Bay, Orange County, California. *In* Stinemeyer, E. H. (Ed.), The Pacific Coast Miocene Biostratigraphic Symposium, March 9-10, 1972. Bakersfield, California. Pacific Sed., Soc. Economic Paleontol. Mineral. 225.

Kleinbell, R. M., 1938. Miocene stratigraphy of California. Am. Assoc. Petrol. Geol. Tulsa, Oklahoma. 450 pp.

Koreneva, E. V., 1964. Distribution of spores and pollen of terrestrial plants in bottom sediments of the Pacific Ocean. *In* Ancient Pacific Floras. Univ. Hawaii Press. 31.

Lipps, J. H., 1964. Miocene planktonic foraminifera from Newport Bay, California. Tulane Studies Geol. **2**, 109.

———, 1967. Planktonic foraminifera, intercontinental correlation and age of the California mid-Cenozoic microfaunal stages. J. Paleontol. **41**, 994.

McIntyre, A. and Bé, A. W. H., 1967. Modern Coccolithophoridae of the Atlantic Ocean–I. Placoliths and Cyrtoliths. Deep-Sea Res. **14**, 561.

McIntyre, A., Bé, A. W. H. and Roche, M. B., 1970. Modern Pacific Coccolithophorida: a paleontologic thermometer. Trans. New York Acad. Sci. Ser. II. **32**, 720.

Martini, E., 1971. Neogene silicoflagellates from the equatorial Pacific. *In* Winterer, E. L., Riedel, W. R. et al., 1971. Initial Reports of the Deep Sea Drilling Project, Volume VII. Washington (U.S. Government Printing Office). 1695.

Martini, E. and Worsley, T., 1970. Standard Neogene calcareous nannoplankton zonation. Nature. **225**, 289.

McManus, D. A., Burns, R. E. et al., 1970. Initial Reports of the Deep Sea Drilling Project, Volume V. Washington (U.S. Government Printing Office). 827 p.

Opdyke, N. D., 1972. Paleomagnetism of deep-sea cores. Rev. Geophys. Space Sci. **10**(1), 213.

Riedel, W. R. and Sanfilippo, A., 1970. Radiolaria, Leg 4, Deep Sea Drilling Project. *In* Bader, R. G., Gerard, R. D. et al., 1970. Initial Reports of the Deep Sea Drilling Project, Volume 4. Washington (U.S. Government Printing Office). 503.

Silver, E. A., Cunay, J. R. and Cooper, A. K., 1971. Tectonic Development of the Continental Margin off Central California. Geol. Soc. Sacramento, Ann. Field Trip Guide Book.

Staplin, F., 1969. Sedimentary organic matter, organic metamorphism and oil and gas occurrence. Canadian Petrol. Geol. **17**(1), 47.

APPENDIX A. OPERATIONS

Pre-drilling Survey

The predrilling site survey was made along a track connecting Site 34 of Leg 5 with Site 173. The attempt to make a seismic record in which stratigraphy could be correlated between the two holes failed when the seismic instruments did not function properly.

It was difficult to find the site picked on Silver's record along the first *Challenger* track and a 1525 navigational satellite position indicated the track was 2 km north of the course plotted by Silver (Figure 3). The line was continued until 1645 to outline structure after which *Challenger* turned to a reciprocal of 240° T on the proposed Silver course. At 1730, basement depth and structure looked favorable and at 1800 a "basement" bench was selected as the site. The ship continued on course until 1813 to detail structure. After coming to a reciprocal course and slowing to 4 knots for good seismic control, a presoaked beacon was dropped underway along with a spar buoy. The course was continued until the whole bench was again recorded by the seismic system whereupon geophysical gear was retrieved and the ship came back to the beacon. In the hour between the beacon and spar buoy drop and the return to the beacon, the buoy drifted relative to the beacon 0.8 miles, 080°T. It was thought that winds prevailing at the time could not have driven the buoy this far and since the ship did not experience difficulty in holding position the only explanation was that deep water currents may have carried the beacon off position. From a stationary seismic record it appeared that the beacon may have drifted shoreward during its 26-minute descent about 50 meters because the basement is deeper and the sea floor is shallower. The position of Site 173 from nine satellite fixes is 39°57.71′N; 125°27.12′W.

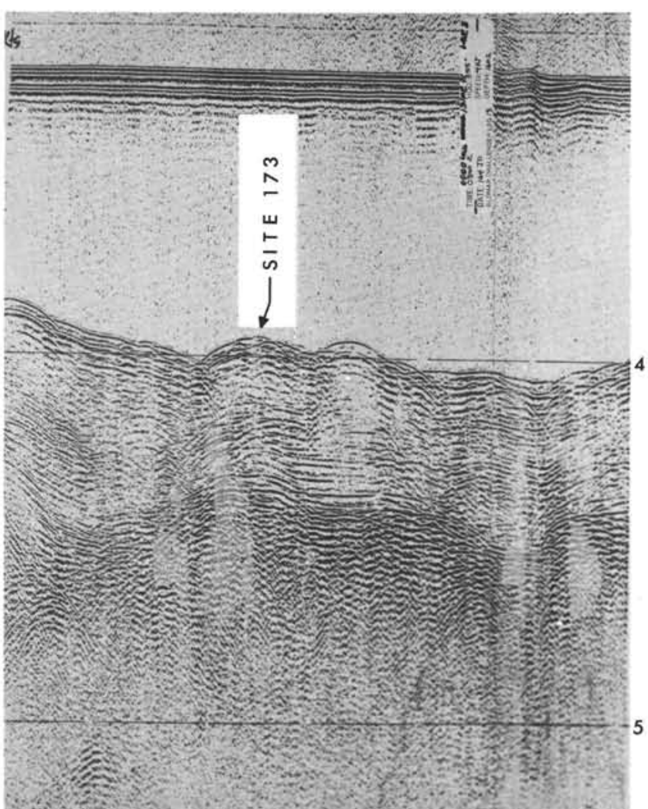


Figure 3. *Seismic profile across Site 173 taken aboard* Glomar Challenger.

Post-drilling Survey

A course crossing the predrilling survey track at right angles was run to obtain better control on structure. *Challenger* got underway at 2330, on a course of 155° T on June 12 and streamed geophysical gear. About 2 miles southwest of the site, at 2345, the seismic system was tuned up and the ship came about to 335° T at 4 knots passing over the beacon at 0015 T, June 13. A good record was made for 2 more miles and speed was increased at 0049 to 10 knots and course was changed to 000° ending the site survey (Figure 3).

Drilling Program

Site 173 was continuously cored (10-12 June) until an andesite flow was encountered at 320 meters below the sea floor. Repeated drilling to 333.5 meters produced only fragments of andesite that were lodged in the core catcher and extended barrel. The new bit assembly, described in the drilling specifications section, was used successfully on this site. However, one of the cone bearings was worn out.

The drill pipe was lowered at 1930 hours June 9. Bottom depth was originally picked at 1572 fathoms (uncorrected) (2921 meters corrected by Mathews tables) at the transducer or a depth of 2937 meters to the derrick floor. Three empty core barrels were pulled before it was realized that the bottom slope of 2 to 3 degrees had a 30-meter effect on the total depth. Even with the 30 meter correction, the pipe was still about 16 meters from the sea floor. North Pacific velocity values from Latham (personal communication) reduce the discrepancy to 2 meters. The bottom was encountered at 2984.5 meters.

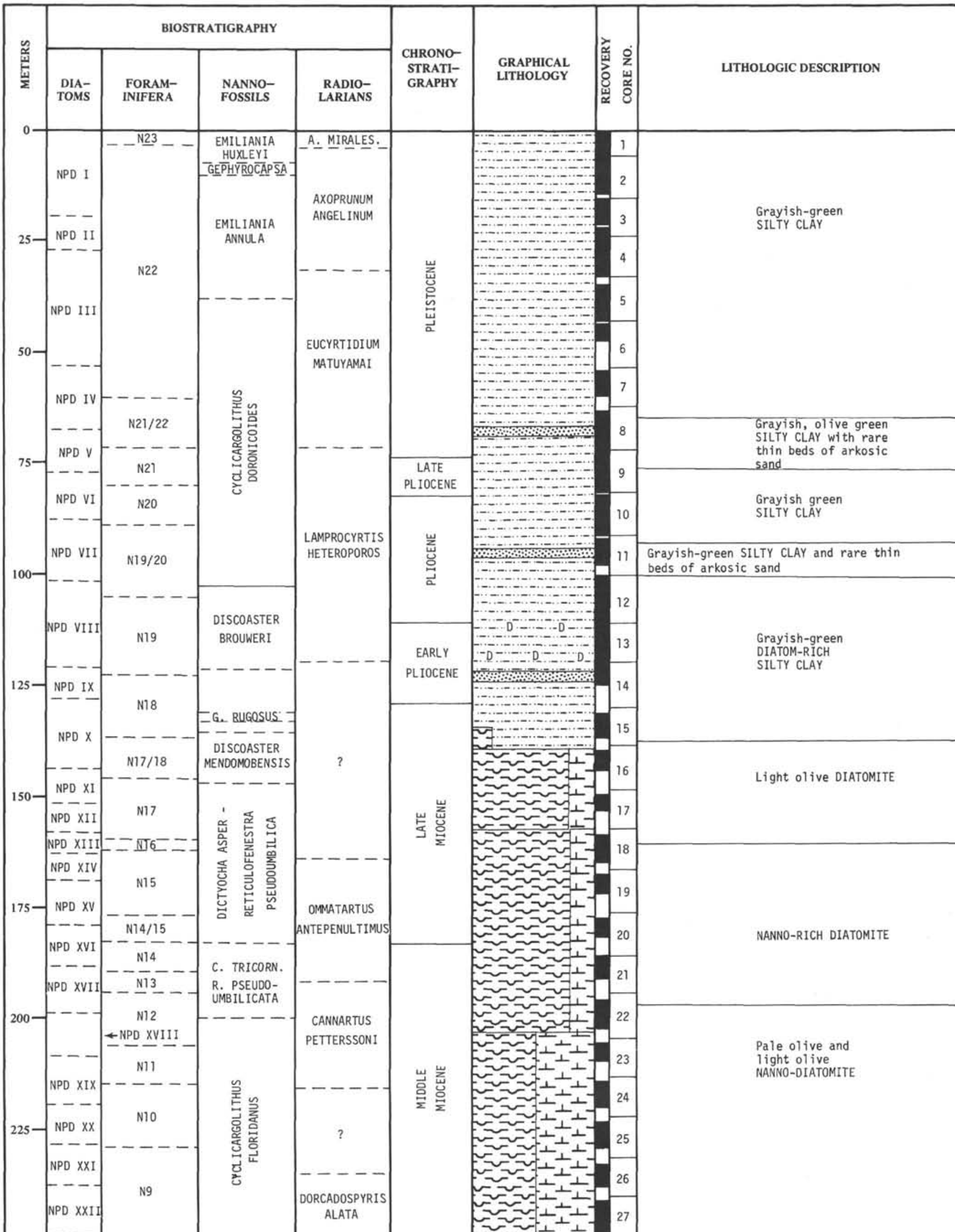
Punch cores were taken on barrels 1 through 5. On barrel 6, the drill string was rotated at 35 RPM (both the inner and outer barrels rotate with this type of system). Most cores taken with rotation showed only moderate distortion and disturbance. For example, a laminated sand was perfectly preserved. Some diatomites showed only a little downbowing of laminae near the edges of the core. Minimum circulation was used in cutting Core 7 with no adverse effects on recovery and on subsequent cores, circulation was used as necessary. Flows up to 200 gal/min were used in cutting Core 28. It is difficult to say whether or not large amounts of water washed the core away from the extended barrel, but it seemed they were not badly washed. On several occasions, good recovery was obtained when a high flow of water circulated around the bit.

Core 33 came up empty with the exception of one small ball of sand on the side of the core catcher. Marks on the extended barrel indicated abrasive action and it was surmised that the nonreversing circulation valve about 0.5 meters from the bit had jammed and prevented the core barrel from bottoming. The next core (34) recovered 4.0 meters of consolidated and soupy material; 6 meters were drilled. Barrel 35 was similar with 3.5 meters recovered in the 9.5 meters drilled. Drilling conditions during coring of the three barrels was similar. Circulation was required to keep the bit clean and drilling time increased over previous intervals. Drilling for Core 36 was even longer since the bit balled up easily. The drill string was raised and lowered to clean the bit—the hole appeared to stand up well with no caving or excess drilling torque. Mud was used on Core 36. After approximately 11 hours of drilling the andesite, the drill string was pulled.

A total of 196 meters of core was recovered from the 333.5-meter section. The recovery was 58.77 percent. This value was lowered by the repeated attempts to penetrate the volcanic floor first encountered in Core 34. Also, the diatomites were quite sticky and difficult to core; this lithology roughly corresponds with the lower recovery.

Drilling Specifications

The bottom hole assembly consisted of an 11¼-inch Smith 4 cone seal bearing button bit and bit sub, core barrel, three 8¼-inch drill collars, one 7¼-inch drill collar, and one joint of heavy wall drill pipe. Site 173 was the first time this particular assembly was run. The unique part of this system is the extended inner core barrel that projects 4 inches below the 11¼-inch Smith core bit. Holding the inner barrel in the extended position is a spring mandrel at the upper end of the inner barrel. While coring in ooze to medium hard formations the inner barrel is penetrating the formations before the core bit disturbs the area.


METERS
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
NPD I
NPD II
NPD III
NPD IV
NPD V
NPD VI
NPD VII
NPD VIII
NPD IX
NPD X
NPD XI
NPD XII
NPD XIII
NPD XIV
NPD XV
NPD XVI
NPD XVII
NPD XIX
NPD XX
NPD XXI
NPD XXII
N23
N22
N21/22
N21
N20
N19/20
N19
N18
N17/18
N17
N16
N15
N14/15
N14
N13
N12
NPD XVIII
N11
N10
N9
EMILIANIA HUXLEYI
GEPHYROCAPSA
EMILIANIA ANNULA
CYCLICARGOLITHUS DORONICOIDES
DISCOASTER BROUWERI
G. RUGOSUS
DISCOASTER MENDOMOBENSIS
DICTYOCHA ASPER - RETICULOFENESTRA PSEUDOUMBILICA
C. TRICORN.
R. PSEUDO-UMBILICATA
CYCLICARGOLITHUS FLORIDANUS
A. MIRALES.
AXOPRUNUM ANGELINUM
EUCYRTIDIUM MATUYAMAI
LAMPROCYRTIS HETEROPOROS
?
OMMATARTUS ANTEPENULTIMUS
CANNARTUS PETTERSSONI
?
DORCADOSPYRIS ALATA
PLEISTOCENE
LATE PLIOCENE
PLIOCENE
EARLY PLIOCENE
LATE MIOCENE
MIDDLE MIOCENE
D
1
2
3
4
5
6
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13
14
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16
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22
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24
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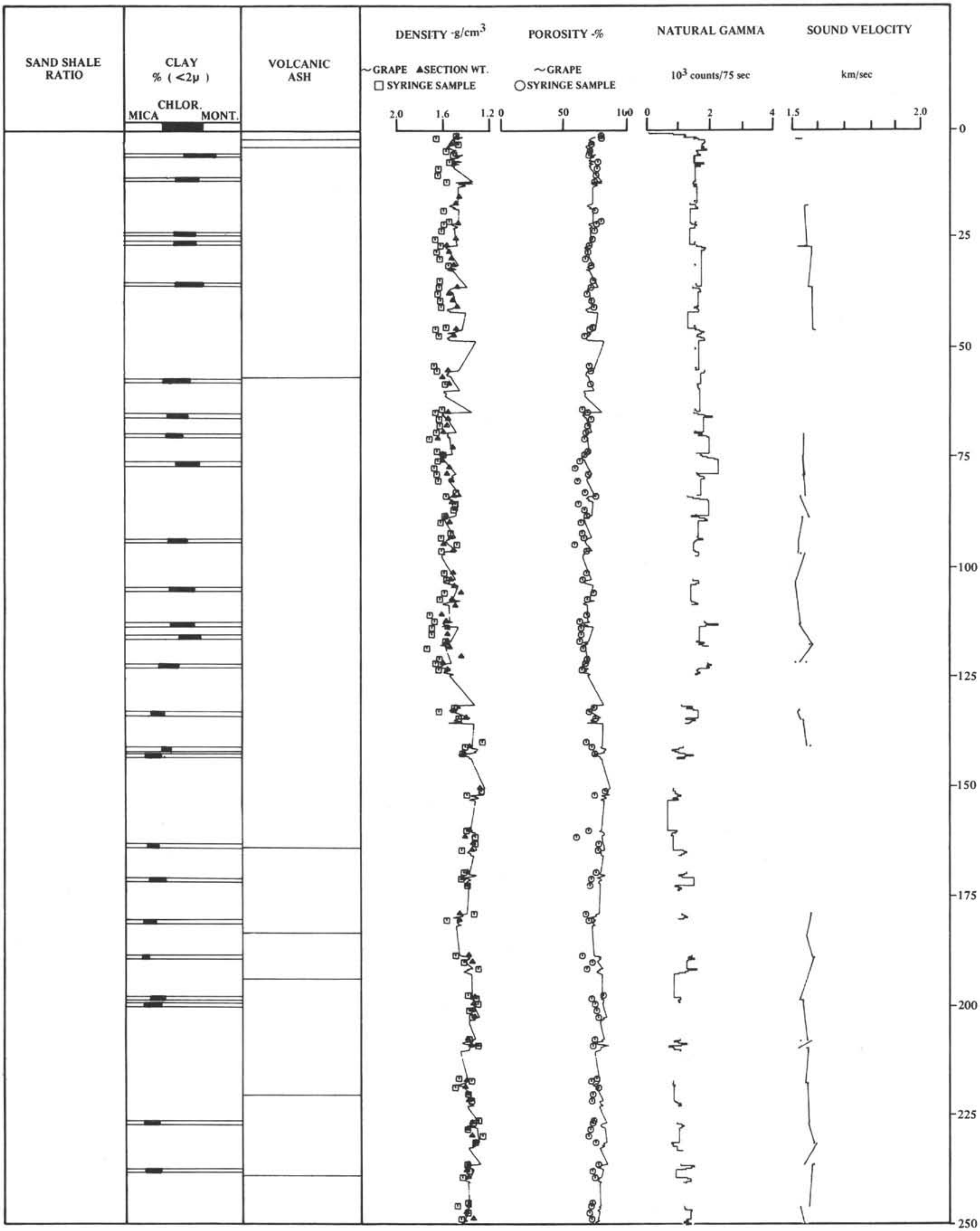
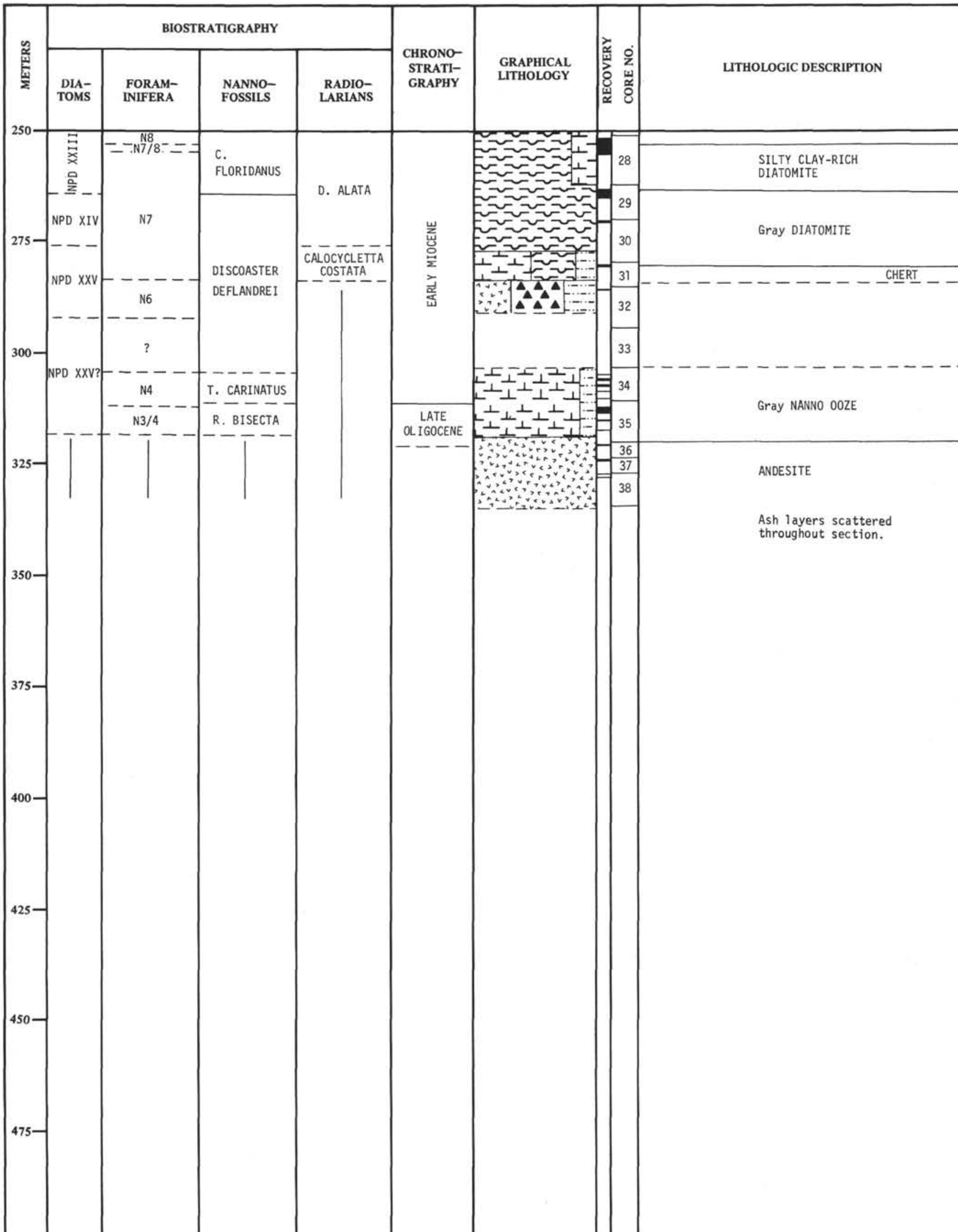
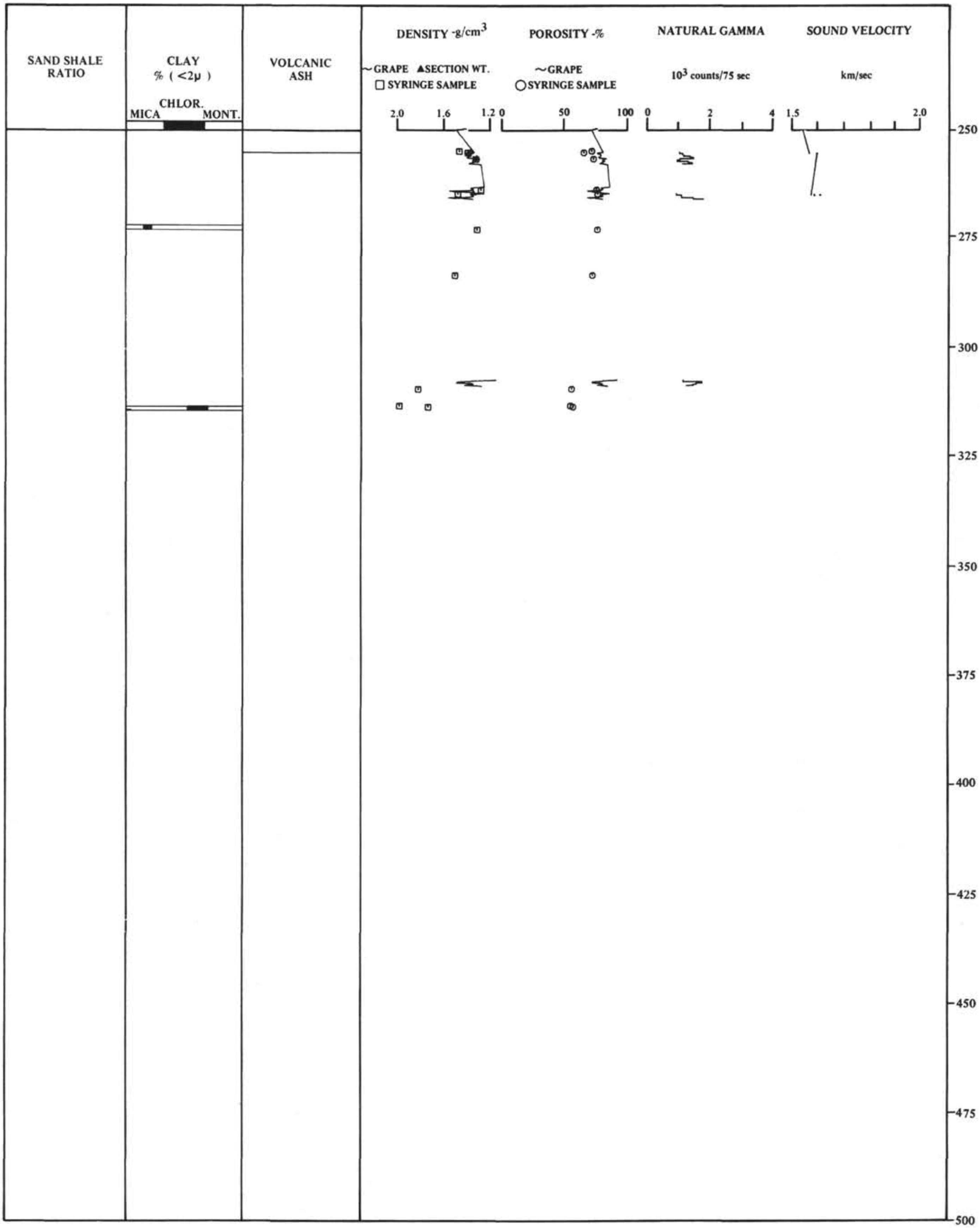
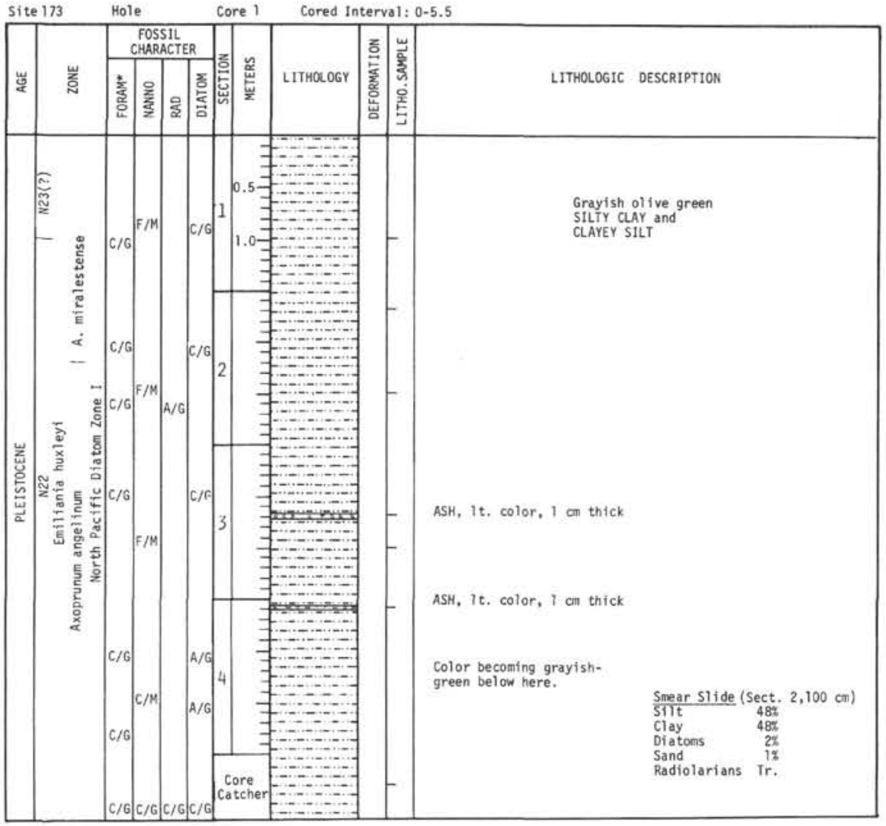
26
27
Grayish-green SILTY CLAY
Grayish, olive green SILTY CLAY with rare thin beds of arkosic sand
Grayish green SILTY CLAY
Grayish-green SILTY CLAY and rare thin beds of arkosic sand
Grayish-green DIATOM-RICH SILTY CLAY
Light olive DIATOMITE
NANNO-RICH DIATOMITE
Pale olive and light olive NANNO-DIATOMITE

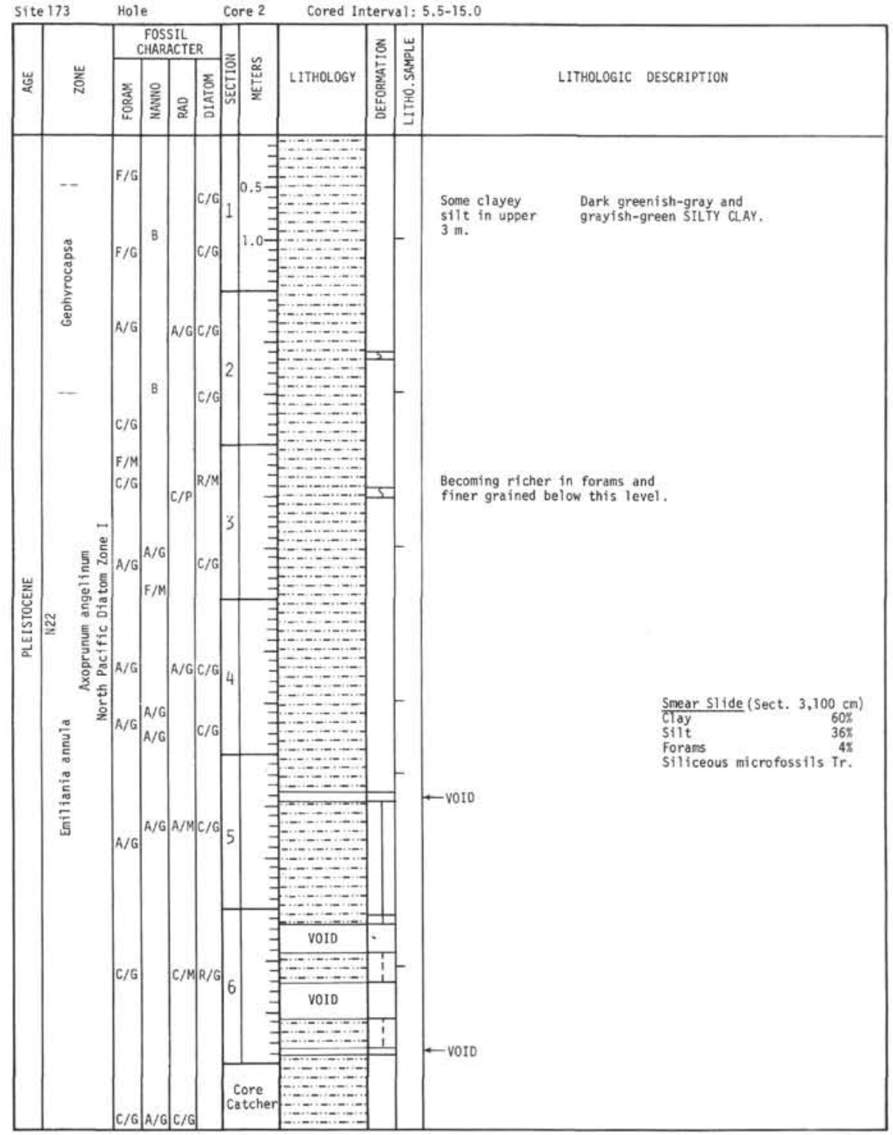

SAND SHALE RATIO
CLAY % (<2μ)
MICA CHLOR. MONT.
VOLCANIC ASH
DENSITY -g/cm3
~GRAPE ▲SECTION WT.
☐ SYRINGE SAMPLE
2.0 1.6 1.2
POROSITY -%
~GRAPE
○SYRINGE SAMPLE
0 50 100
NATURAL GAMMA
10³ counts/75 sec
0 2 4
SOUND VELOCITY
km/sec
1.5 2.0
0
25
50
75
100
125
150
175
200
225
250


METERS
BIOSTRATIGRAPHY
DIA-TOMS
FORAM-INIFERA
NANNO-FOSSILS
RADIO-LARIANS
CHRONO-STRATI-GRAPHY
GRAPHICAL LITHOLOGY
RECOVERY
CORE NO.
LITHOLOGIC DESCRIPTION
250
275
300
325
350
375
400
425
450
475
500
NPD XXIII
NPD XIV
NPD XXV
NPD XXV?
N8
N7/8
N7
N6
?
N4
N3/4
C. FLORIDANUS
DISCOASTER DEFLANDREI
T. CARINATUS
R. BISECTA
D. ALATA
CALOCYCLETTA COSTATA
EARLY MIOCENE
LATE OLIGOCENE
28
29
30
31
32
33
34
35
36
37
38
SILTY CLAY-RICH DIATOMITE
Gray DIATOMITE
CHERT
Gray NANNO OOZE
ANDESITE
Ash layers scattered throughout section.


SAND SHALE RATIO
CLAY % (<2μ)
MICA CHLOR. MONT.
VOLCANIC ASH
DENSITY -g/cm3
~GRAPE ▲SECTION WT.
□ 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
250
275
300
325
350
375
400
425
450
475
500



Explanatory notes in chapter 1
*PLANKTONIC FORAMINIFERA



Explanatory notes in chapter 1

Site 173 Hole Core 3 Cored Interval: 15.0-24.5

AGE	ZONE	FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
PLEISTOCENE	NPDZ I; N22 Emiliania annula Axoprunum angelinum North Pacific Diatom Zone II	F/M, C/M, A/G, A/G, A/G, C/G, C/G, C/G	C/M, F/M, C/G, C/G, C/M, C/M	C/G, C/G, F/G	C/G, C/G, C/G, C/G, C/G, R/G, C/G	1, 2, 3, 4, 5, 6, Core Catcher	0.5, 1.0	VOID, VOID, VOID			Greenish-gray SILTY CLAY and CLAYEY SILT

Smear Slide (Sect. 3,100 cm)

Clay	48%
Silt	48%
Forams	2%
Diatoms	1%
Sponge spicules	1%

Explanatory notes in chapter 1

Site 173 Hole Core 4 Cored Interval: 24.5-34.0

AGE	ZONE	FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
PLEISTOCENE	NPDZ II; N22 Emiliania annula Axoprunum angelinum North Pacific Diatom Zone III	C/G, C/G, C/G, A/G, A/G, A/G	F/M, C/G, B, C/M, C/G, C/M	A/G, A/G, A/G, A/G, A/G, C/G	C/G, A/G, A/G, A/G, C/G	1, 2, 3, 4, 5, Core Catcher	0.5, 1.0				Dark greenish gray SILTY CLAY

Smear Slide (Sect. 3,100 cm)

Clay	57%
Silt	40%
Sponge spicules	2%
Diatoms	1%
Forams	Tr.
Radiolaria	Tr.

Explanatory notes in chapter 1

Site 173 Hole Core 5 Cored Interval: 34.0-43.5

AGE: PLEISTOCENE

ZONE: Emiliania annula; N22 – Eucyrtidium matuyamai – North Pacific Diatom Zone III; C. doronicoides

SECTION	FORAM	NANNO	RAD	DIATOM
1	C/M	C/M	A/G	A/G
2	C/M	F/M	C/G	R/G
3	C/G	F/M	C/G	R/G
4	C/G	B	A/G	C/G
5	B	F/M	A/G	C/G
Core Catcher	A/M	C/M	C/G	

LITHOLOGY: VOID (top of Section 1); VOID (base of Section 5)

LITHOLOGIC DESCRIPTION

Dark greenish-gray
SILTY CLAY

Smear Slide (Sect. 3,100 cm)	
Clay	50%
Silt	38%
Forams	2%
Sponge spicules	1%
Diatoms	Tr.
Radiolaria	Tr.

Explanatory notes in chapter 1

Site 173 Hole Core 6 Cored Interval: 43.5-53.0

AGE: PLEISTOCENE

ZONE: N22 – Cyclicargolithus doronicoides – Eucyrtidium matuyamai – NPDZ III

SECTION	FORAM	NANNO	RAD	DIATOM
1	C/M	F/P	C/M	A/G
2	A/G	C/M	A/M	C/G
3	C/G	F/M	A/M	C/G
Core Catcher	C/M	C/M	C/G	

LITHOLOGY: VOID (top of Section 1)

LITHOLOGIC DESCRIPTION

Dark greenish-gray
SILTY CLAY

Possible sand layer

Smear Slide	
Clay	50%
Silt	45%
Siliceous	3%
Forams	2%
Microfossils	Tr.

Silty clay with trace glass shards and glauconite.

Explanatory notes in chapter 1

Site 173 Hole Core 7 Cored Interval: 53.0-62.5

AGE	ZONE	FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
PLEISTOCENE	N22 Cyclicargolithus doronicoides Eucyrtidium matuyamai North Pacific Diatom Zone IV	C/G	F/M F/M	A/M	C/G	1	0.5 1.0	VOID			Dark greenish-gray SILTY CLAY
		C/G	F/P	A/M	C/G	2					
		R/P	B	A/M	C/G	3					
		B	F/P	A/G	C/G	4					ASH, lt. color, 5 cm thick, v. fn. sand size
		F/M	B			Core Catcher					

Smear Slide

Clay	79%
Silt	20%
Diatoms	1%
Radiolaria	Tr.
Sponge spicules	Tr.

Explanatory notes in chapter 1

Site 173 Hole Core 8 Cored Interval: 62.5-72.0

AGE	ZONE	FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
PLEISTOCENE	NPDZ IV	C/M	B	A/G	C/G	1	0.5 1.0	VOID			Grayish olive-green SILTY CLAY A few bioturbated thin beds of FINE SAND Some clayey silt.
	N21/22? Cyclicargolithus doronicoides Eucyrtidium matuyamai North Pacific Diatom Zone V	C/M	F/M	A/M	R/M	2					Upper silty clay is dk. gnish. gy.
		R/P	F/M	A/M	C/G	3					
		C/G	C/M	A/M	C/G	4					
		R/P	B	A/M	C/G	5					
		F/P	B	A/M	C/G	6					Sand, pyrite bearing
		R/P	B		C/G	Core Catcher					

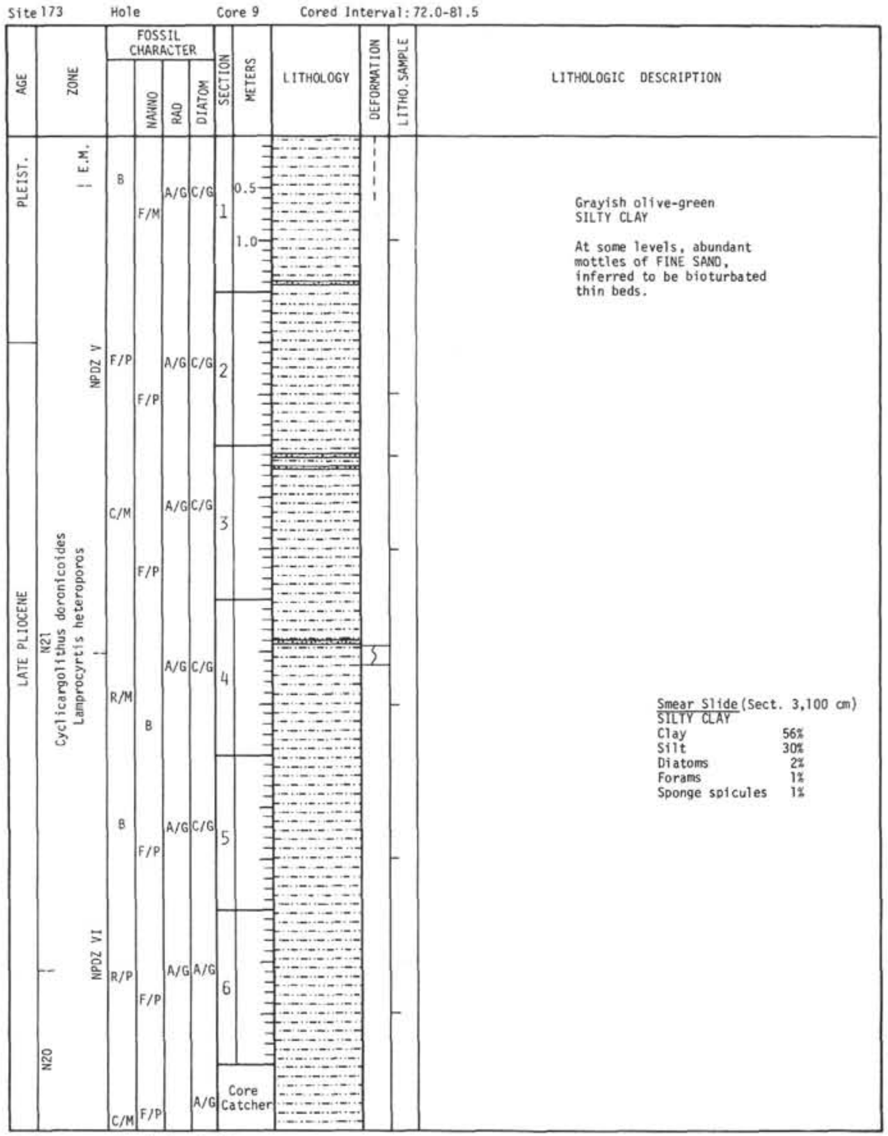
Smear Slide (Sect. 1,100 cm)
SILTY CLAY

Clay	70%
Silt	30%

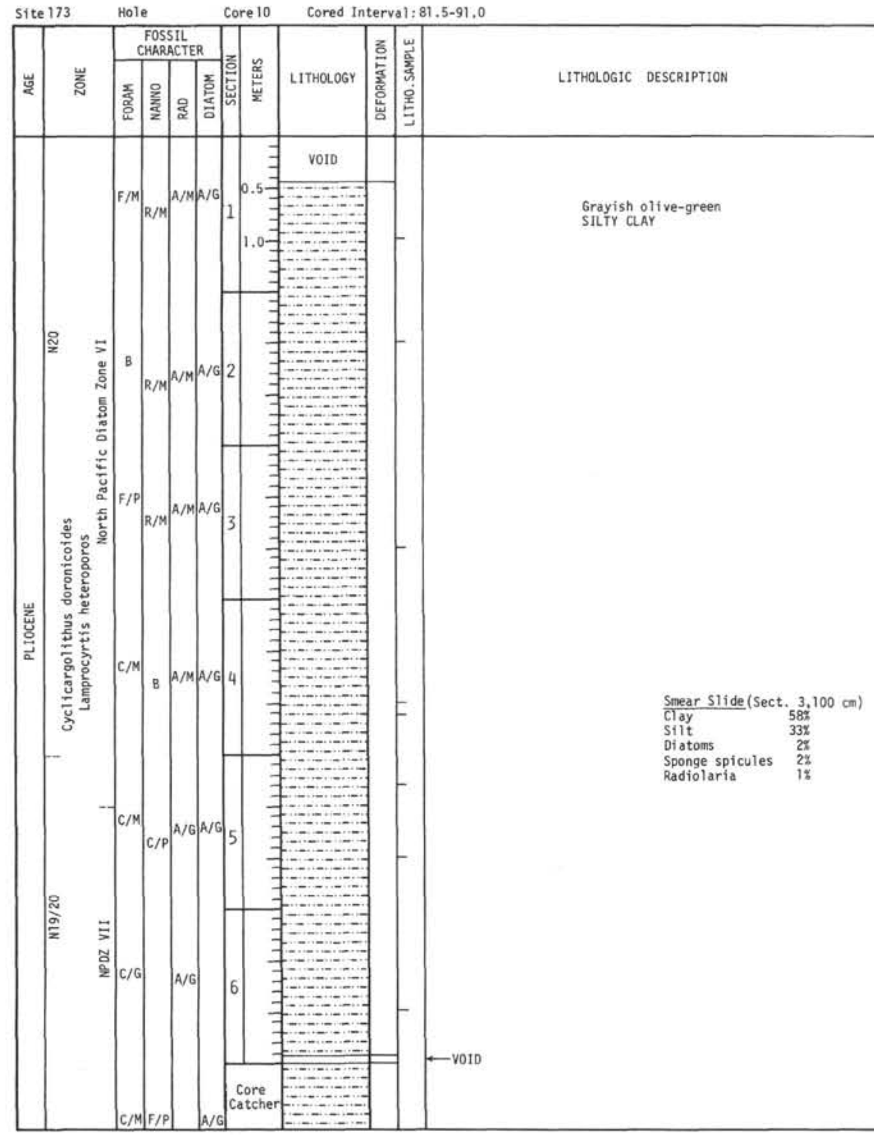
Smear Slide (Sect. 3,139 cm)
SAND

Feldspar	65%
Quartz	35%

Explanatory notes in chapter 1

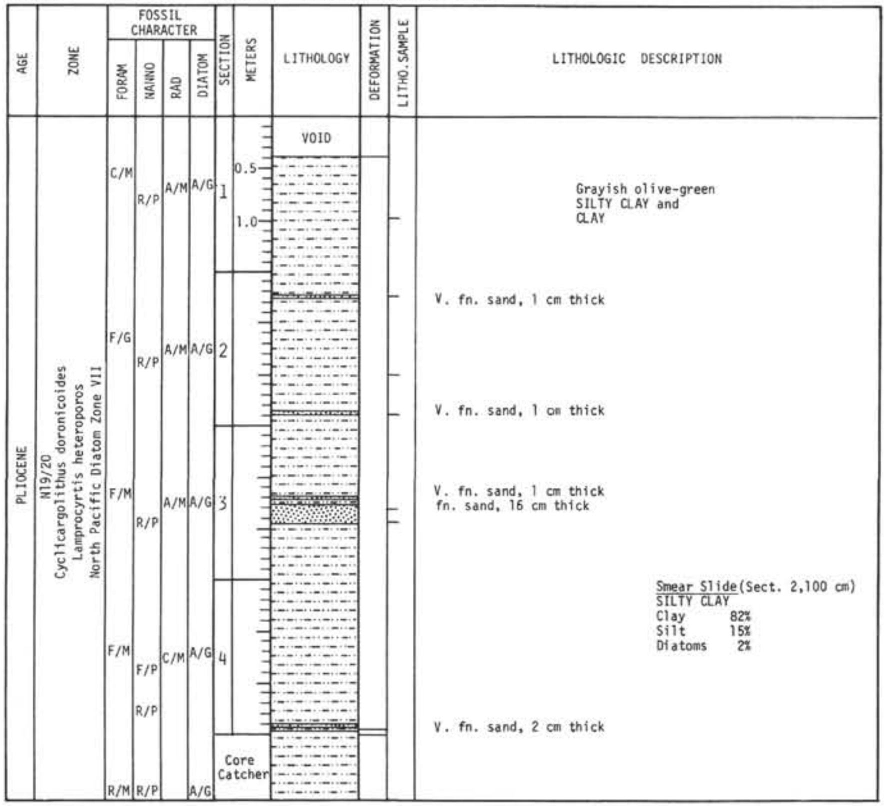


Explanatory notes in chapter 1



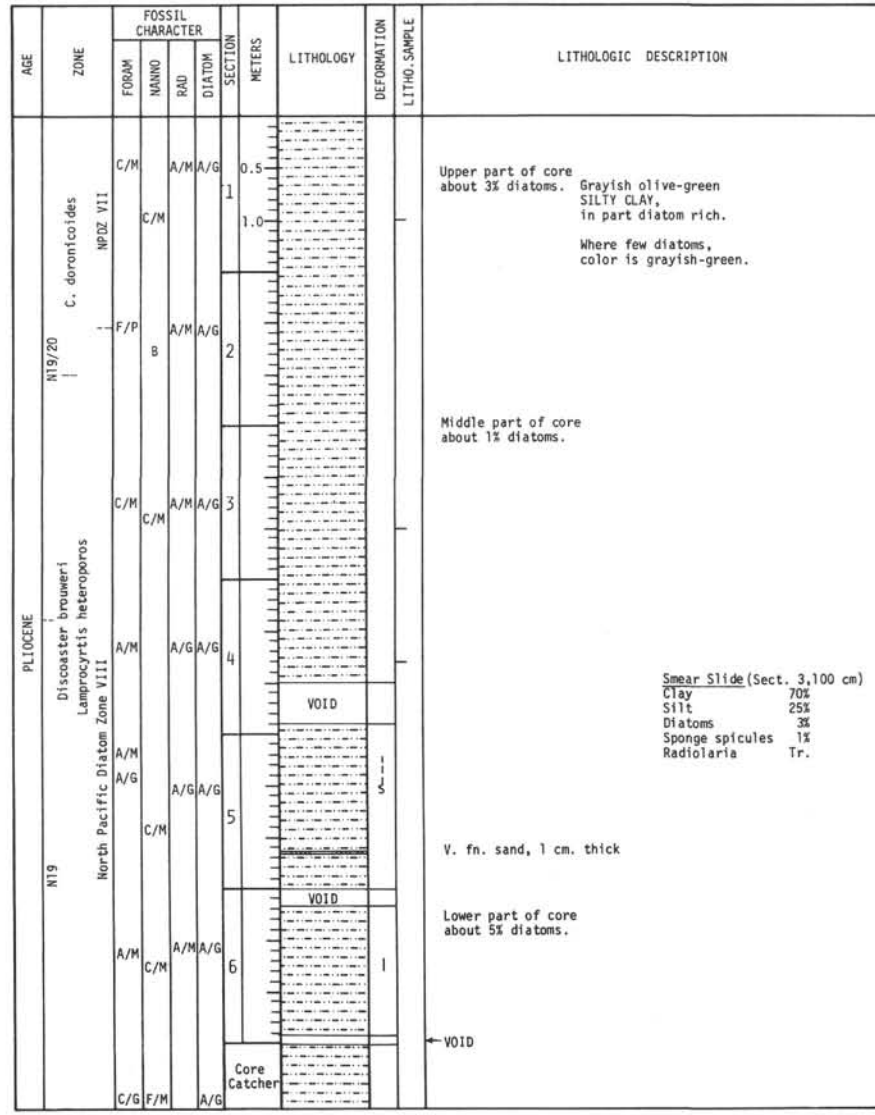
Explanatory notes in chapter 1

Site 173 Hole Core 11 Cored Interval: 91.0-100.5



Explanatory notes in chapter 1

Site 173 Hole Core 12 Cored Interval: 100.5-110.0



Explanatory notes in chapter 1

Site 173 Hole Core 13 Cored Interval: 110.0-119.5

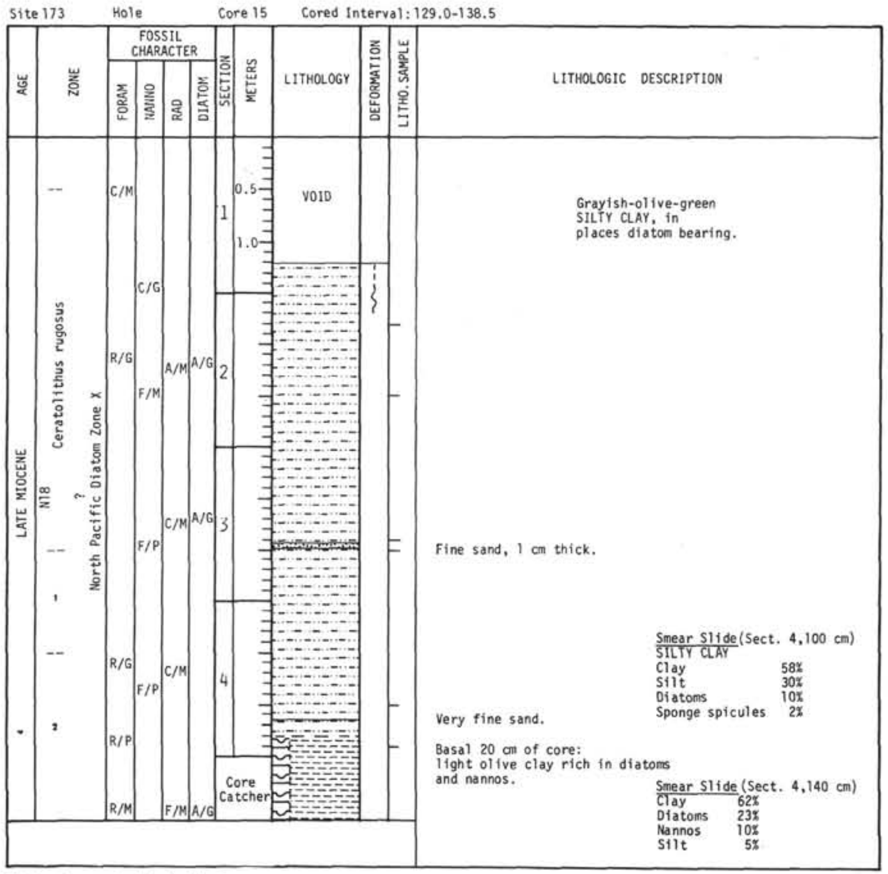
AGE	ZONE	FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY PLIOCENE	N19 Discoaster brouweri Lamprocyrtis heteroporos North Pacific Diatom Zone VIII	A/M	F/M		A/G	1	0.5, 1.0				Upper half of core: color is dusky yellow-green. DIATOM RICH SILTY CLAY
											←VOID
		C/M	F/M		A/G	2					←VOID ←VOID
		C/M	F/P	A/G	A/G	3					Smear Slide (Sect. 2,100 cm) DIATOM RICH-SILTY CLAY: Silt and clay 85%, Diatoms 15%. ←VOID
		C/M	F/P		A/G	4					Lower half of core: color is grayish-olive-green. Irregular 3 cm thick layers of pale grayish-green clay about every 50 cm.
		C/M	F/P		A/G	5		VOID			Smear Slide (Sect. 5,100 cm) SILTY CLAY: Clay 54%, Silt 39%, Diatoms 4%, Sponge spicules 2%, Sand 1%. Smear Slide (Sect. 5,128 cm) CLAY: Clay 90%, Silt 10%, Diatoms 1%, Sponge spicules 1%
		F/P			A/G	6					
		F/G	F/P		A/G	Core Catcher					

Explanatory notes in chapter 1

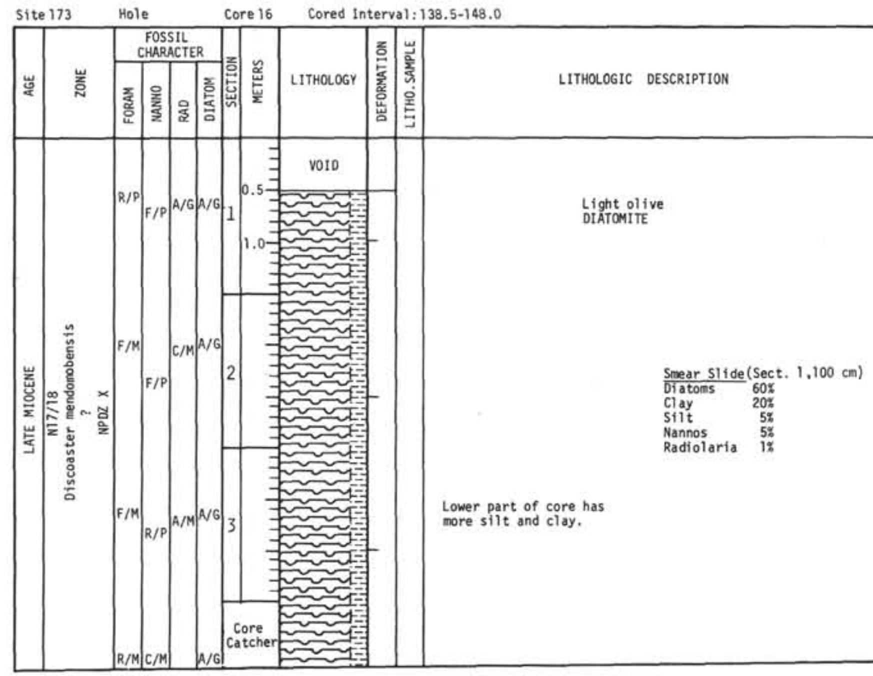
Site 173 Hole Core 14 Cored Interval: 119.5-129.0

AGE	ZONE	FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY PLIOCENE	N19 D. brouweri NPDZ VIII *	C/F	R/P	A/G	A/G	1	0.5, 1.0				Grayish-green SILTY CLAY
	? N18 R. pseudoumbilicata NPDZ IX	C/G	R/P	A/M	A/G	2					Very fine sand, 1 cm thick. Smear Slide (Sect. 2,100 cm): Clay 64%, Silt 35%, Diatoms 2%, Sponge spicules 1%
		B	R/G	A/M	A/G	3					Very fine sand, 0.5 cm thick.
		C/M	C/G	C/G		Core Catcher					

Explanatory notes in chapter 1
* Lamprocyrtis heteroporos



Explanatory notes in chapter 1
1 Ceratolithus tricarniculatus
2 Discoaster mendomobensis



Explanatory notes in chapter 1

Site 173 Hole Core 17 Cored Interval: 148.0-157.5

AGE	ZONE	FOSSIL CHARACTER: FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	N17 Dictyocha asper - Reticulofenestra pseudoumbilica ? NPDZ XI		F/M			1	0.5 1.0	VOID			Light olive DIATOMITE
		R/M	F/M	C/M	A/G	2					
	NPDZ XII	F/M	F/M	C/M	A/G, A/G	3					Bed of very pale green nanno-rich diatomite: Smear Slide (Sect. 3,100 cm) Diatoms 70%, Nannos 20%, Clay 7%, Silt 2%, Radiolaria 1%
		F/M	F/G		A/G	Core Catcher					Typical Smear Slide of diatomite: Smear Slide (Sect. 3,60 cm) Diatoms 71%, Nannos 15%, Clay 10%, Silt 2%, Radiolaria 1%

Explanatory notes in chapter 1

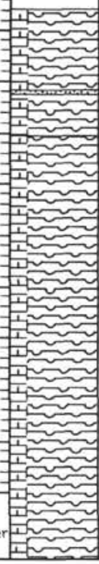
Site 173 Hole Core 18 Cored Interval: 157.5-167.0

AGE	ZONE	FOSSIL CHARACTER: FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	N17		F/G			1	0.5 1.0	VOID			Light olive NANNO-RICH DIATOMITE
	N16 Dictyocha asper - Reticulofenestra pseudoumbilicata ? NPDZ XIII	F/M	F/G	C/M	A/G	2					Smear Slide (Sect. 2,100 cm) Diatoms 75%, Nannos 15%, Clay 5%, Silt 3%, Radiolaria 2%, Glauconite 1%
		F/M	C/G	C/M	A/G	3					Foram rich lamina; Lt. colored bed, 5 cm thick
		R/M	F/G	C/M	A/G	4					Lt. colored bed, 30 cm thick
	NPDZ XIV	C/M		C/M	A/G	5					Basal 110 cm of core is pale olive color
	N15	C/G	F/G		A/G	Core Catcher					Ash bearing diatomite

Explanatory notes in chapter 1

Site 173 Hole Core 19 Cored Interval: 167.0-176.5

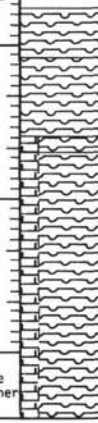
AGE	ZONE	FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	N15 Dictyocha asper - Reticulofenestra pseudoumbilicata Ommatartus antepenultimus; NPDZ XIV / NPDZ XV	R/M	F/G			1	0.5, 1.0	VOID			Light olive NANNO-RICH DIATOMITE
			F/M	C/M	A/G	2					Fine sand, 1 cm thick, much bioturbated. Above this level, color is light olive; below is pale olive
		C/G	F/P	C/M		3					Trace lt. ash in lower part of core 20 cm bed with paler color. No detectable lithology change.
		F/M		C/M	A/G	4					Smear Slide (Sect. 3,100 cm) Diatoms 70% Nannos 15% Clay 10% Silt 4% Radiolaria 1%
		C/M	F/G		A/G	Core Catcher					



Explanatory notes in chapter 1

Site 173 Hole Core 20 Cored Interval: 176.5-186.0

AGE	ZONE	FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	N15 / N14/15 Dictyocha asper - Reticulofenestra pseudoumbilicata Ommatartus antepenultimus; NPDZ XV / NPDZ XVI		F/M		A/G	1	0.5, 1.0	VOID			Light to pale olive DIATOMITE
		R/P	F/M	C/M		2					Thin bed of sandy ash Above this level, color is lt. olive; below, pale olive, and nanno-rich. Thin ash bed
		C/M	F/M	C/M	A/G	3					Smear Slide (Sect. 3,100 cm) Diatoms 80% Nannos 10% Clay 7% Silt 3%
		C/M	F/M	C/M	A/G	Core Catcher					



Explanatory notes in chapter 1

Site 173 Hole Core 21 Cored Interval: 186.0-195.5

AGE	ZONE	FOSSIL CHARACTER: FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE MIOCENE	N14; Corbisema tricantha - Reticulofenestra pseudoumbilica; Ommatartus antepenultimus; NPDZ XVI	B		A/M	A/G	1	0.5	VOID			Pale olive DIATOMITE
			B		A/G		1.0				Very pale olive nanno-rich diatomite. Smear Slide (Sect. 1,100 cm) Diatoms 80%, Nannos 10%, Clay 7%, Silt 3%
		R/P	C/P								
						2					Middle part of core grayish olive color, with only a trace of nannos.
		B		C/M	A/G	3					Smear Slide (Sect. 2,100 cm) Diatoms 80%, Clay 15%, Silt 5%
			F/P								Lt. ash, 0.5 cm thick bed, v. fn. sand size.
		B									Ash bed 1 cm thick
	NPDZ XVII	F/M		C/G	A/G	4					Pale olive nanno-rich diatomite
			F/P								
	N13	F/M	C/P	C/M	A/G	Core Catcher					

Explanatory notes in chapter 1

Site 173 Hole Core 22 Cored Interval: 195.5-205.0

AGE	ZONE	FOSSIL CHARACTER: FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE MIOCENE	C. triacantha - R. pseudoumbilicata; NPDZ XVII					1	0.5	VOID			Light olive NANNO-RICH DIATOMITE
			R/P		A/G		1.0				Pebble of pyrite-rich fine sand at top of core
		F/M									
		R/P		C/G	A/G	2					Nannos increase in abundance down the core
			F/M								
	N12; Cannartus petterssoni	B		A/G	A/G	3					
		B									
			F/M								
		R/M									
	Cyclicargolithus floridanus; NPDZ XVIII	B		C/M	A/G	4					Smear Slide (Sect. 4,100 cm) Diatoms 76%, Calc. nannos 10%, Clay 10%, Silt 2%, Forams 1%, Radiolaria 1%
			F/M								
		R/M									
		B		C/M	A/G	5					
		F/M	R/P		A/G	Core Catcher					

Explanatory notes in chapter 1

Site 173 Hole Core 23 Cored Interval: 205.0-214.5

AGE	ZONE	FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE MIOCENE	N12; Cyclicargolithus floridanus; Cannartus petterssoni; NPDZ XVIII				A/G	1	0.5, 1.0	VOID			Pale olive NANNO-DIATOMITE
		R/M, B	F/P	C/M	A/G	2					Lt. ash, 1.5 cm thick bed, bioturbated; Lt. olive color; Lt. olive color
	NPDZ XIX; N11	R/M, C/M	F/P	C/M	A/G	3					Gy. olive color, fewer nannos
		F/M	F/M	C/M	A/G	Core Catcher					

Smear Slide

Diatoms	65%
Calc. nannos	20%
Silt	10%
Radiolaria	5%

Explanatory notes in chapter 1

Site 173 Hole Core 24 Cored Interval: 214.5-224.0

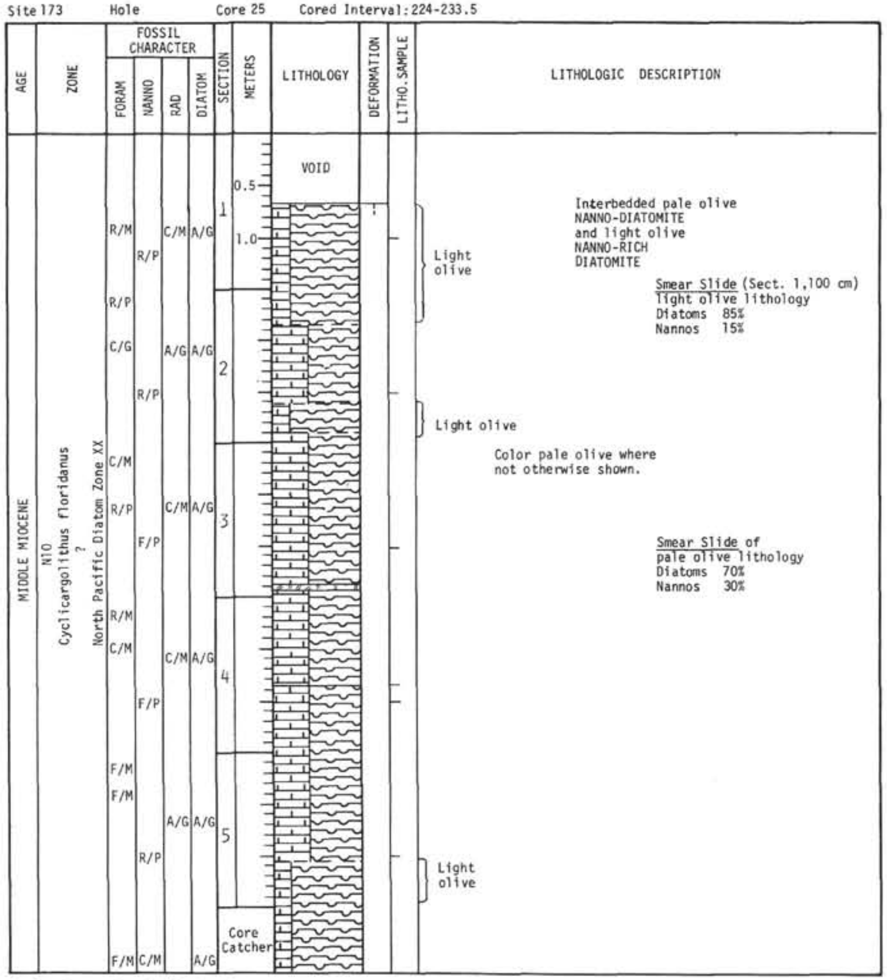
AGE	ZONE	FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE MIOCENE	N11; C. petterssoni	C/M	R/P	C/M	A/G	1	0.5, 1.0	VOID			Pale olive NANNO DIATOMITE
	N10; Cyclicargolithus floridanus; North Pacific Diatom Zone XIX	F/M, F/M	R/P	A/G	A/G	2					
		C/M, F/M	R/P	A/M	A/G	3					
		F/M, F/M		C/M	A/G	4					Thin ash bed
	?	C/M, C/M		C/M	A/G	5					Passes gradually into light olive color
		R/P	R/P		A/G	Core Catcher					

Smear Slide (Sect. 1,130 cm)

Diatoms	55%
Nannos	40%
Clay	3%
Silt	1%
Radiolaria	1%

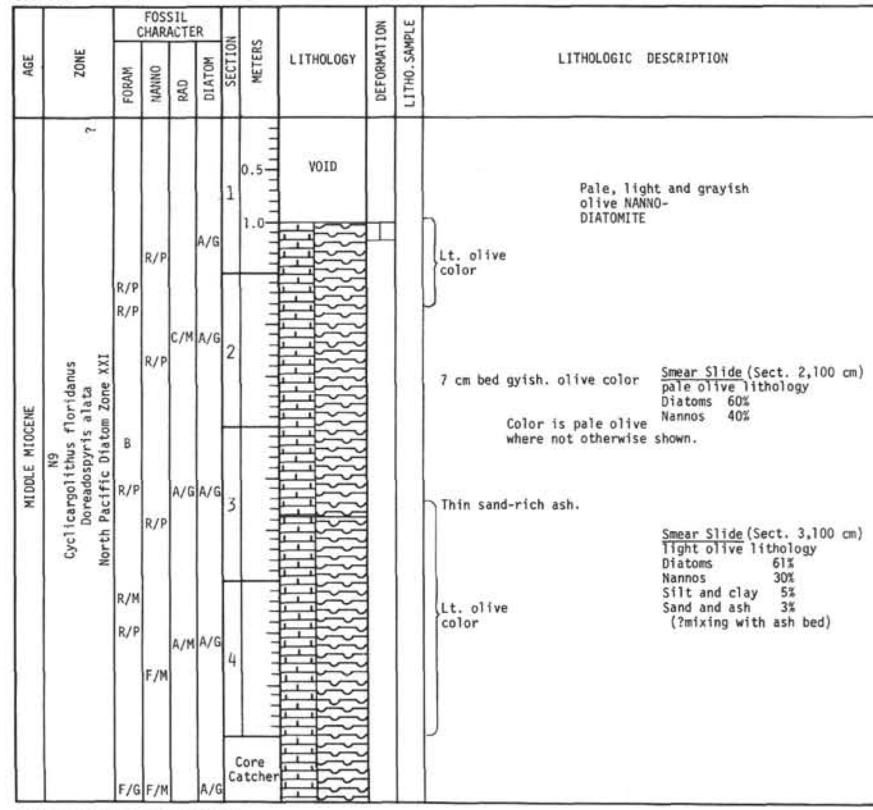
Explanatory notes in chapter 1

Site 173 Hole Core 25 Cored Interval: 224-233.5



Explanatory notes in chapter 1

Site 173 Hole Core 26 Cored Interval: 233.5-243.0



Explanatory notes in chapter 1

Site 173 Hole Core 27 Cored Interval: 243.0-252.5

AGE	ZONE	FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE MIOCENE	N9 Cyclicargolithus floridanus Doreadospyris alata North Pacific Diatom Zone XXII	R/P	F/P	A/G	A/G	1	0.5, 1.0	VOID			Pale and light olive NANNO-DIATOMITE; Lt. olive color
		R/M, F/M	F/P	A/G	A/G	2					Interbedding lt. and pale olive colors
		R/M, B	F/M	C/M	A/G	3					Color is pale olive where not otherwise shown.
		R/P, R/P	F/P	A/G	A/G	4					Lt. olive color; 10 cm gyish. olive bed
		F/M	C/M	A/G	A/G	Core Catcher					

Smear Slide (Sect. 3,100 cm)
lt. olive lithology
Diatoms 79%
Clay 10%
Silt 4%
Lt. glass 4%
Nannos 3%

Smear Slide (Sect. 2,100 cm)
pale olive lithology
Diatoms 65%
Nannos 31%
Lt. glass 4%

Explanatory notes in chapter 1

Site 173 Hole Core 28 Cored Interval: 252.5-262.0

AGE	ZONE	FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY MIOCENE	N8	B	F/M	C/G	A/G	1	0.5, 1.0	VOID		P, g, P	Pale and light olive NANNO-RICH DIATOMITE and grayish olive CLAY DIATOMITE; 1 cm thick ash bed, bioturbated
	N7/8 Cyclicargolithus floridanus Doreadospyris alata NPDZ XXIII	R/G, B	B	A/M	A/G	2				g, P, l, P, g, P	
		C/M	F/P, F/P	C/G	A/G	3				l, P, g, l	
	N7	F/M	F/M		A/G	Core Catcher					

Smear Slide (Sect. 2,100 cm)
pale olive lithology
Diatoms 72%
Clay 10%
Nannos 5%
Silt 4%
Lt. glass 3%
Radiolaria 1%

Smear Slide (Sect. 3,100 cm)
grayish olive lithology
Diatoms 50%
Clay 35%
Silt 10%
Lt. glass 3%
Nannos 2%
Glauconite 1%
Forams 1%

COLORS: P=pale olive
l=light olive
g=grayish olive

Site 173 Hole Core 29 Cored Interval: 262.0-271.5

AGE	ZONE	FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY MIOCENE	C. floridanus *					1	0.5, 1.0	VOID			Parts of the top meter of core are light olive and moderate olive brown. Grayish olive DIATOMITE and CLAY DIATOMITE
	N7 Doreadospyris alata NPDZ XXIV D. deflandrei					2					Chert, 1 cm thick; Chert, 3 cm thick
						Core Catcher					

Smear Slide (Sect. 1,74 cm)
diatomite
Diatoms 95%
Calc. nannos 3%
Silt and clay 2%

N.B. "Chert" is a highly lithified diatomite, with little recrystallization.

Explanatory notes in chapter 1
* NPDZ XXIII

Site 173 Hole Core 30 Cored Interval: 271.5-281.0

AGE	ZONE	FOSSIL CHARACTER FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY MIO.	N7 [1] [2] NPDZ XXIV	B	B C/M C/M R/P	C/G	A/G	Core Catcher					Grayish olive CLAY-RICH DIATOMITE

[1]Discoaster deflandrei
[2]Doreadospyris alata

Smear Slide	
Diatoms	82%
Clay	15%
Silt	3%

Site 173 Hole Core 31 Cored Interval: 281.0-285.5

AGE	ZONE	FOSSIL CHARACTER FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY MIOCENE	N7 D. deflandrei Calocycletta costata NPDZ XXV	B	F/M	A/M	C/M	1	0.5 1.0	VOID			Greenish gray NANNO-DIATOMITE
		C/M	C/M	F/M		Core Catcher					Lump of "chert" or highly lithified diatomite. Contains trace glauconite.

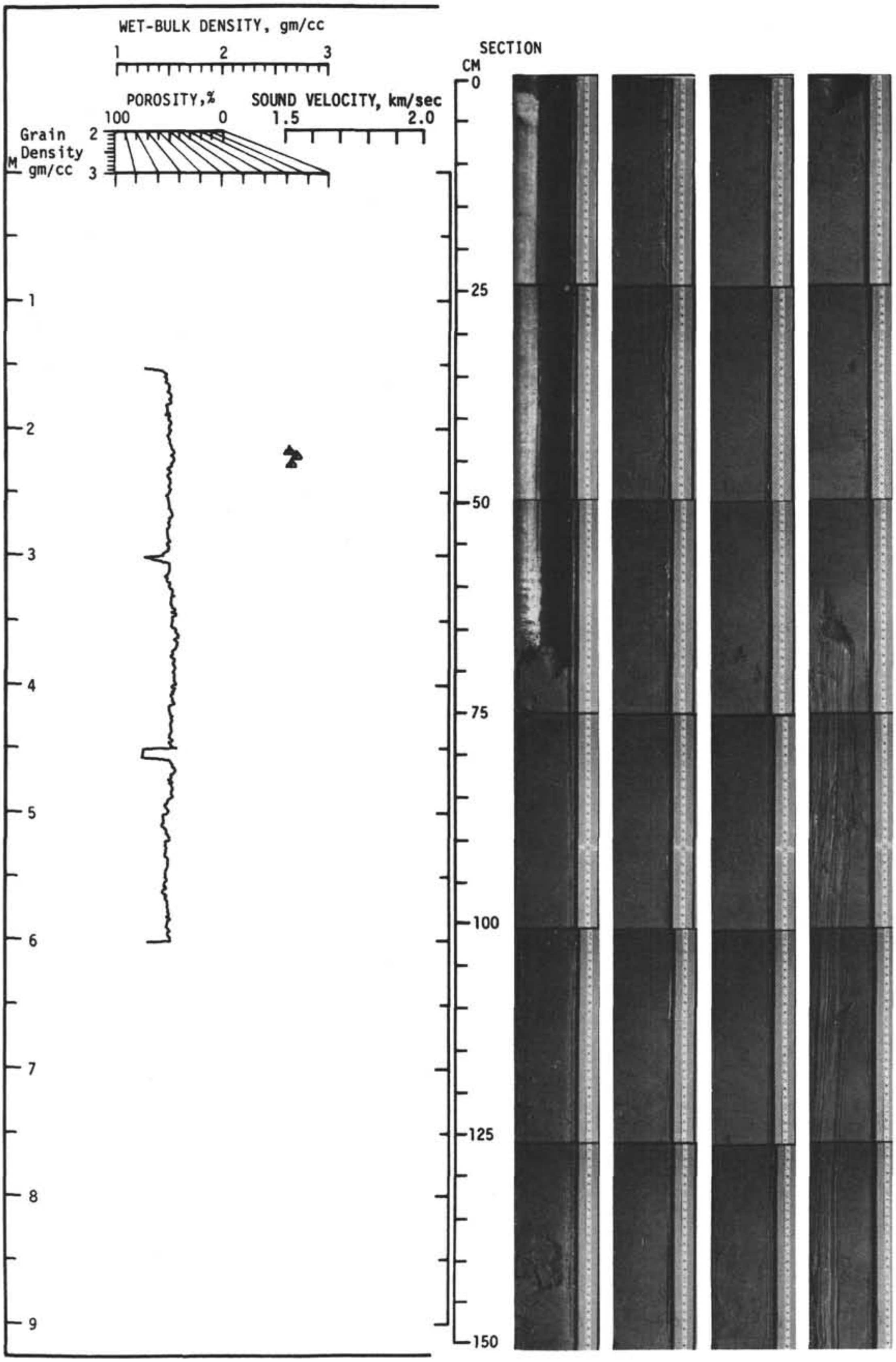
Smear Slide	
Diatoms	50%
Nannos	30%
Silt and clay	15%
Lt. glass	5%

Site 173 Hole Core 32 Cored Interval: 285.5-295.0

AGE	ZONE	FOSSIL CHARACTER FORAM	NANNO	RAD	DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY MIO.	N6 * ? NPDZ XXV	B	B	B	B	Core Catcher					Pieces of 1. altered basic volcanic 2. chert 3. lithified calcareous clay-sand-diatomite

Explanatory notes in chapter 1
*Discoaster deflandrei

NOTE: Core 33, no recovery. Cored interval: 295.0-304.5 m.



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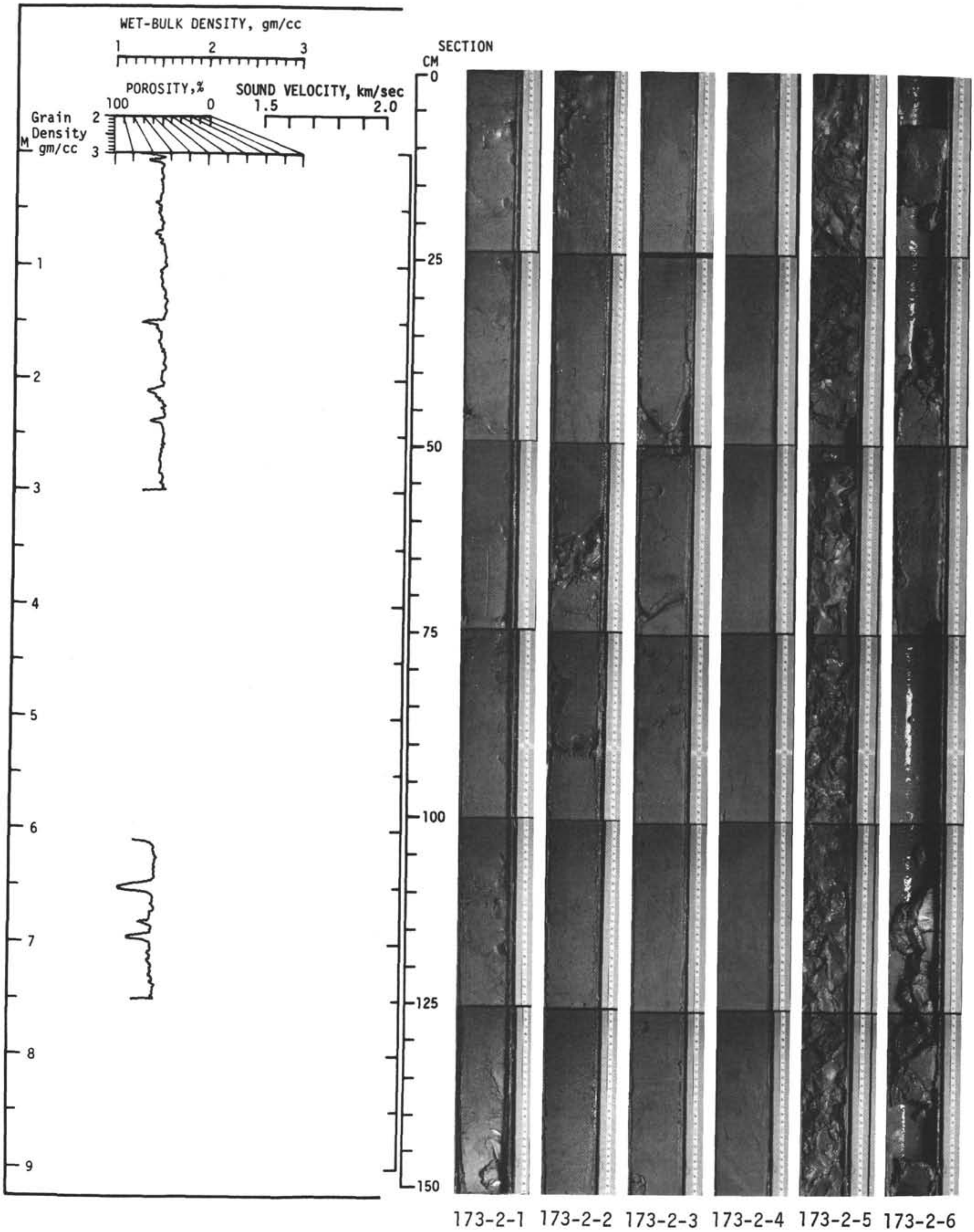
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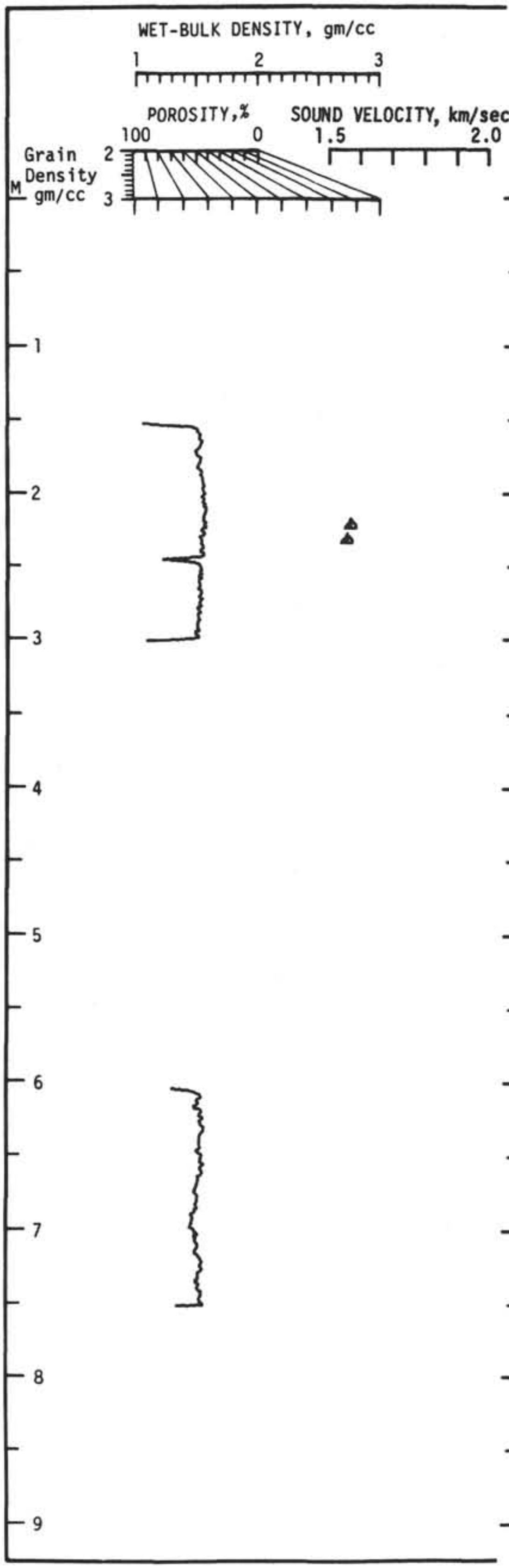
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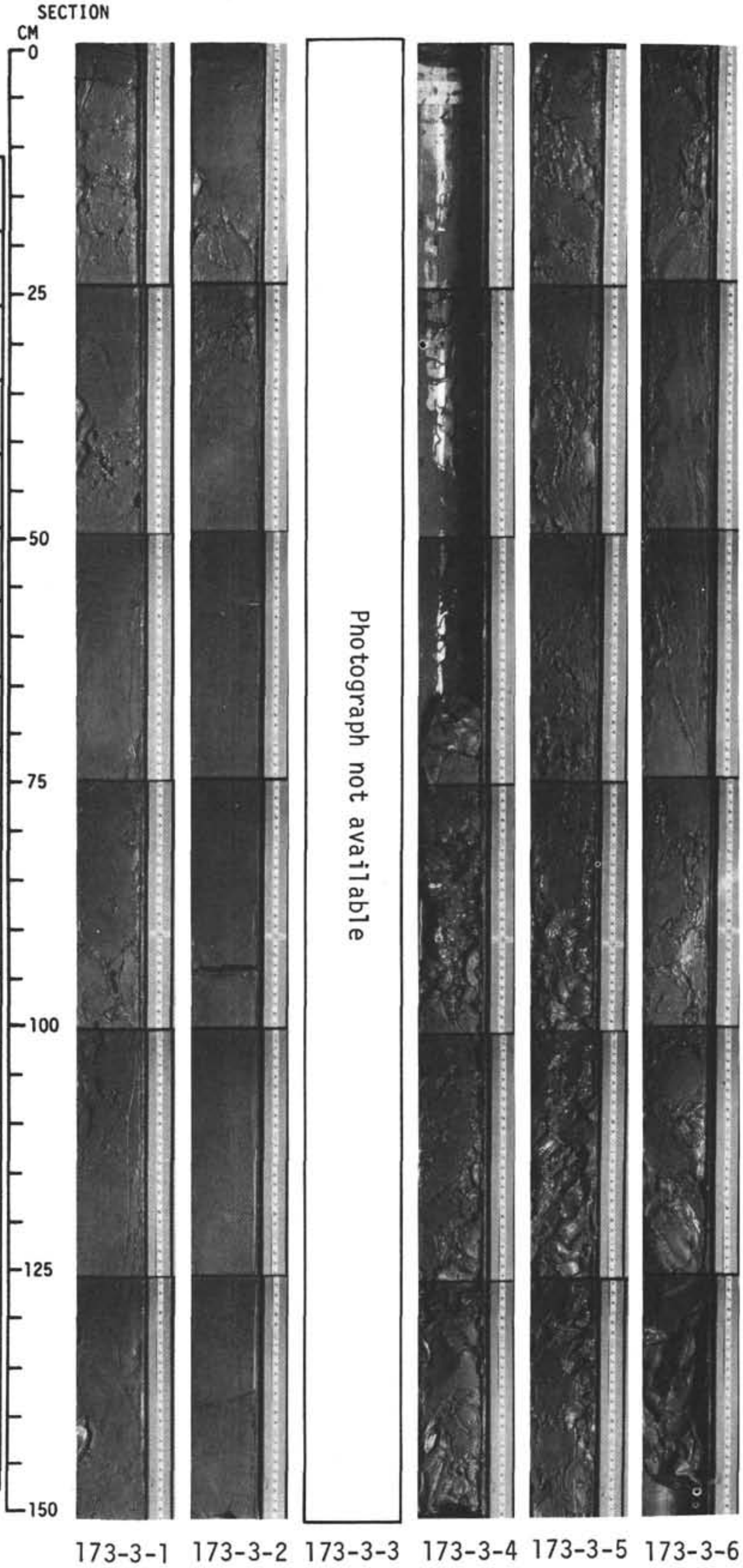
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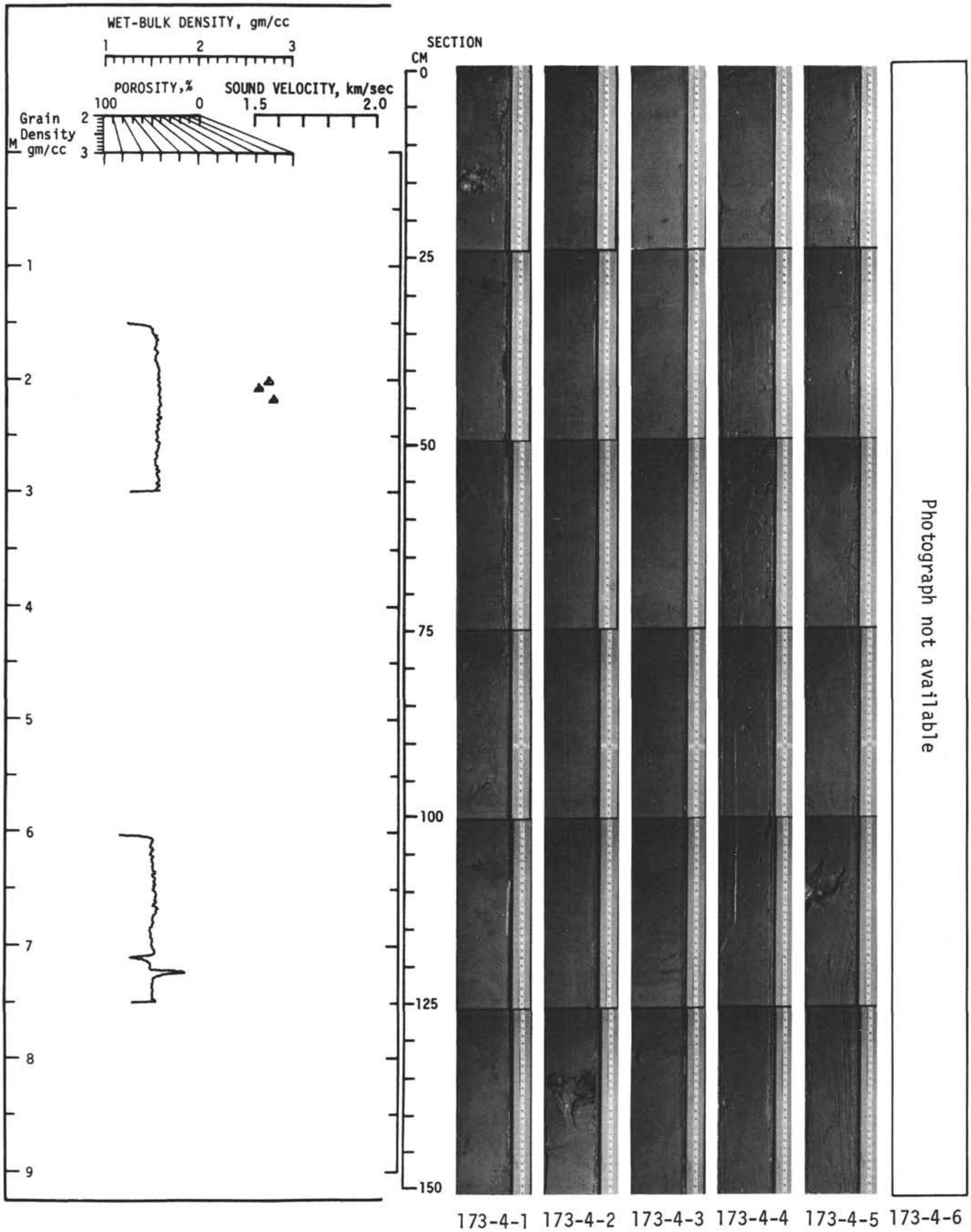
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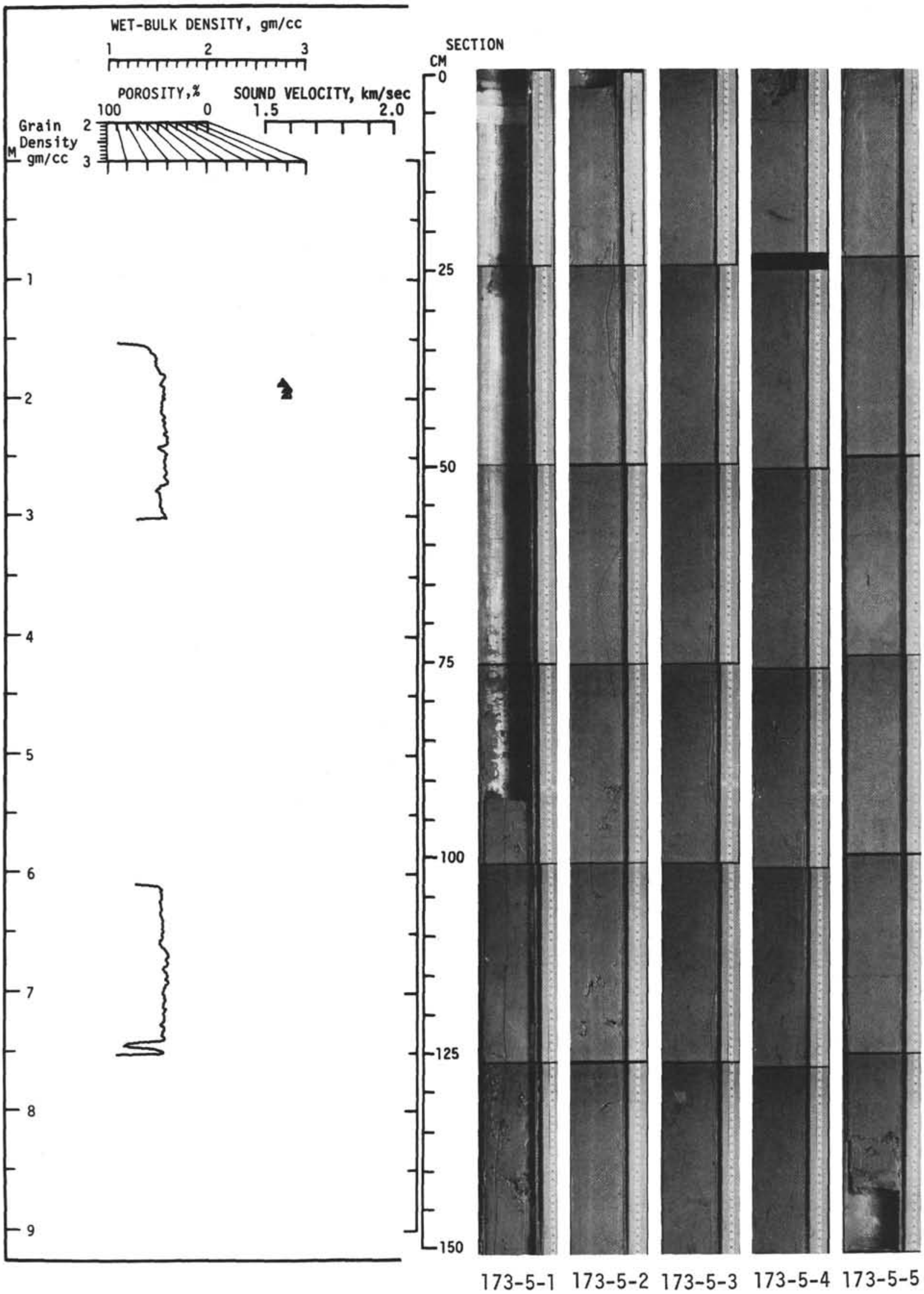
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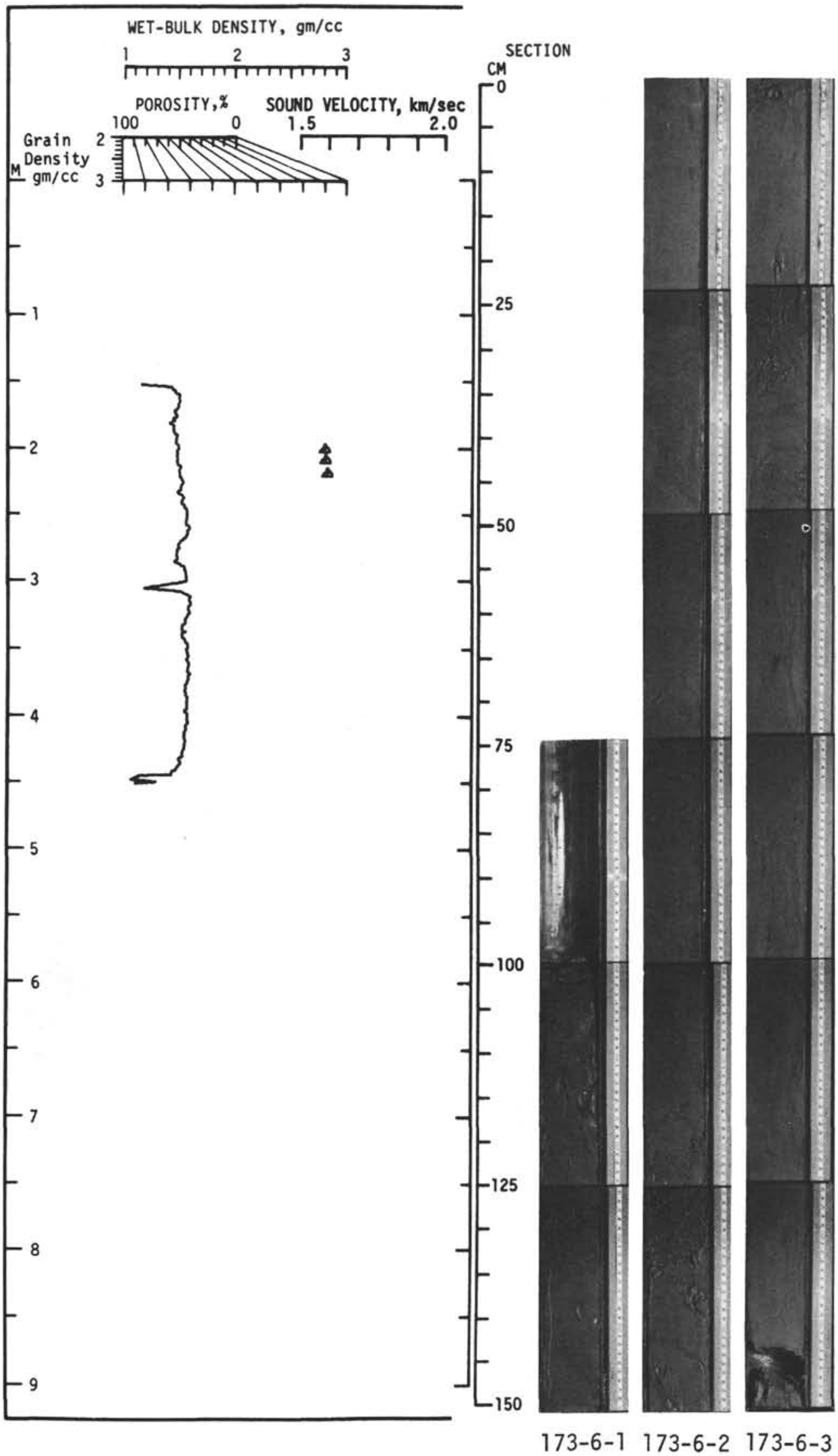
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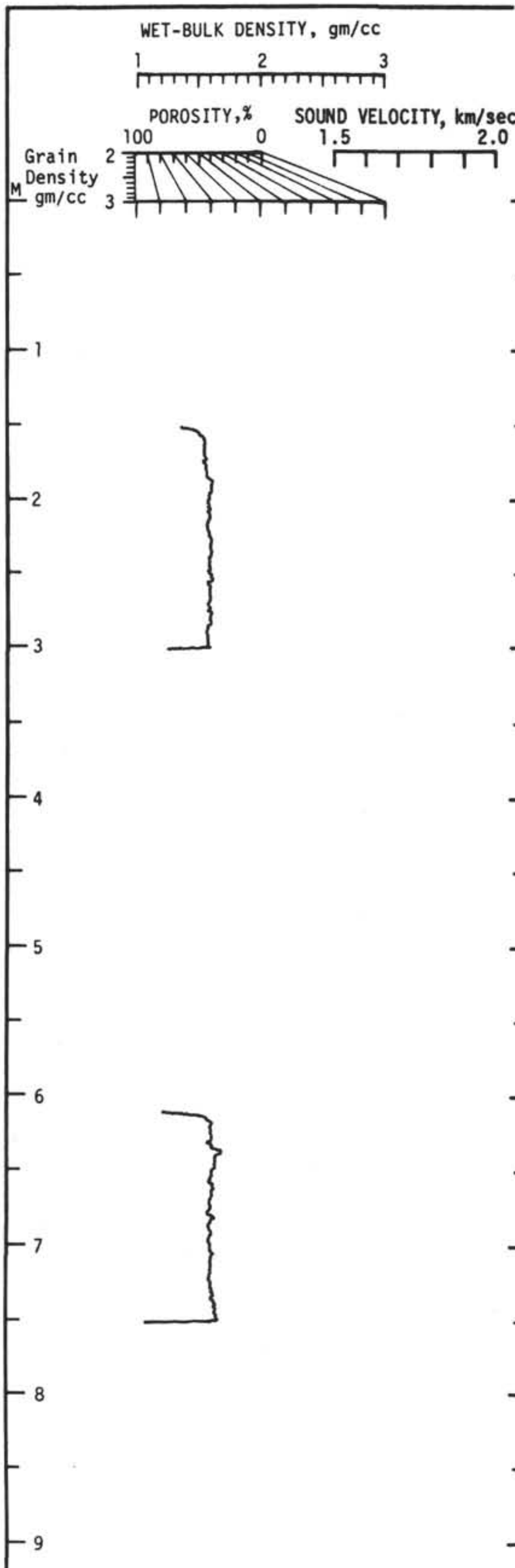

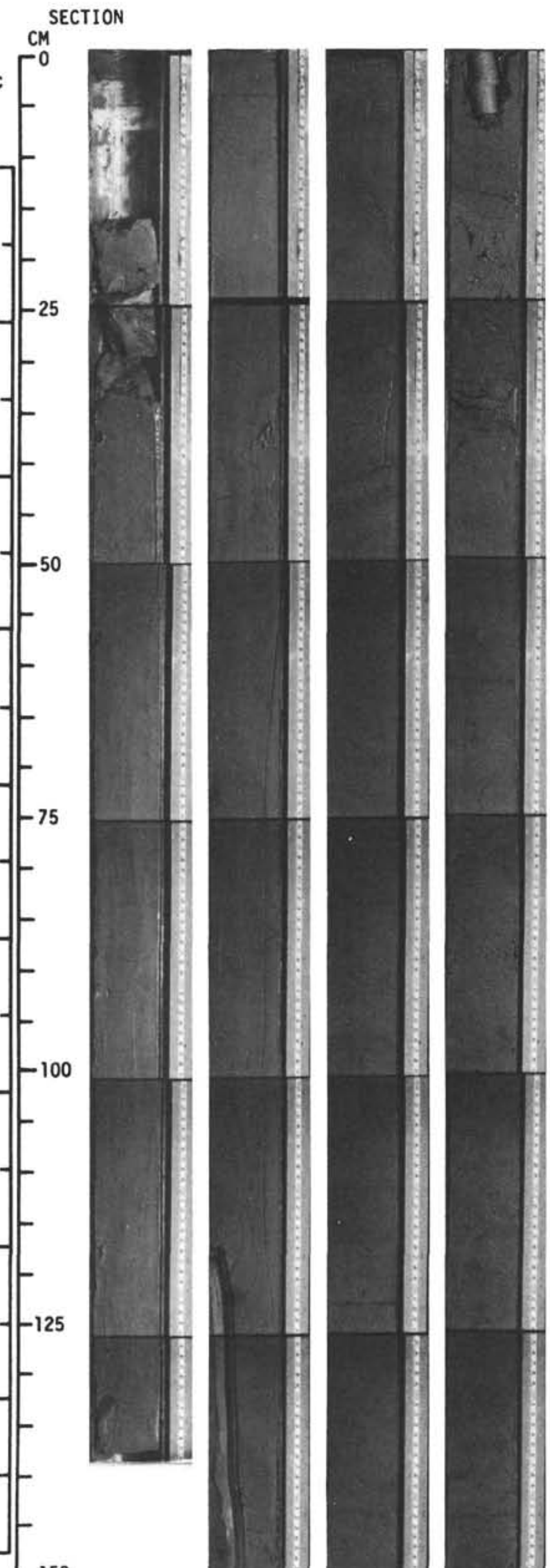

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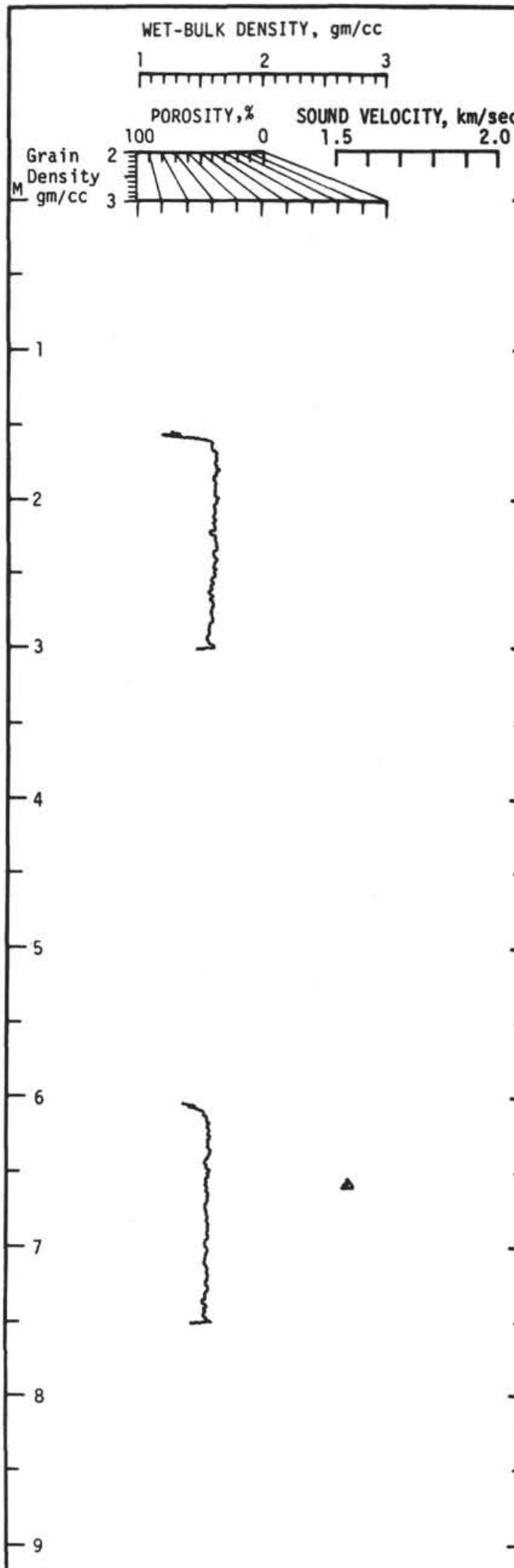

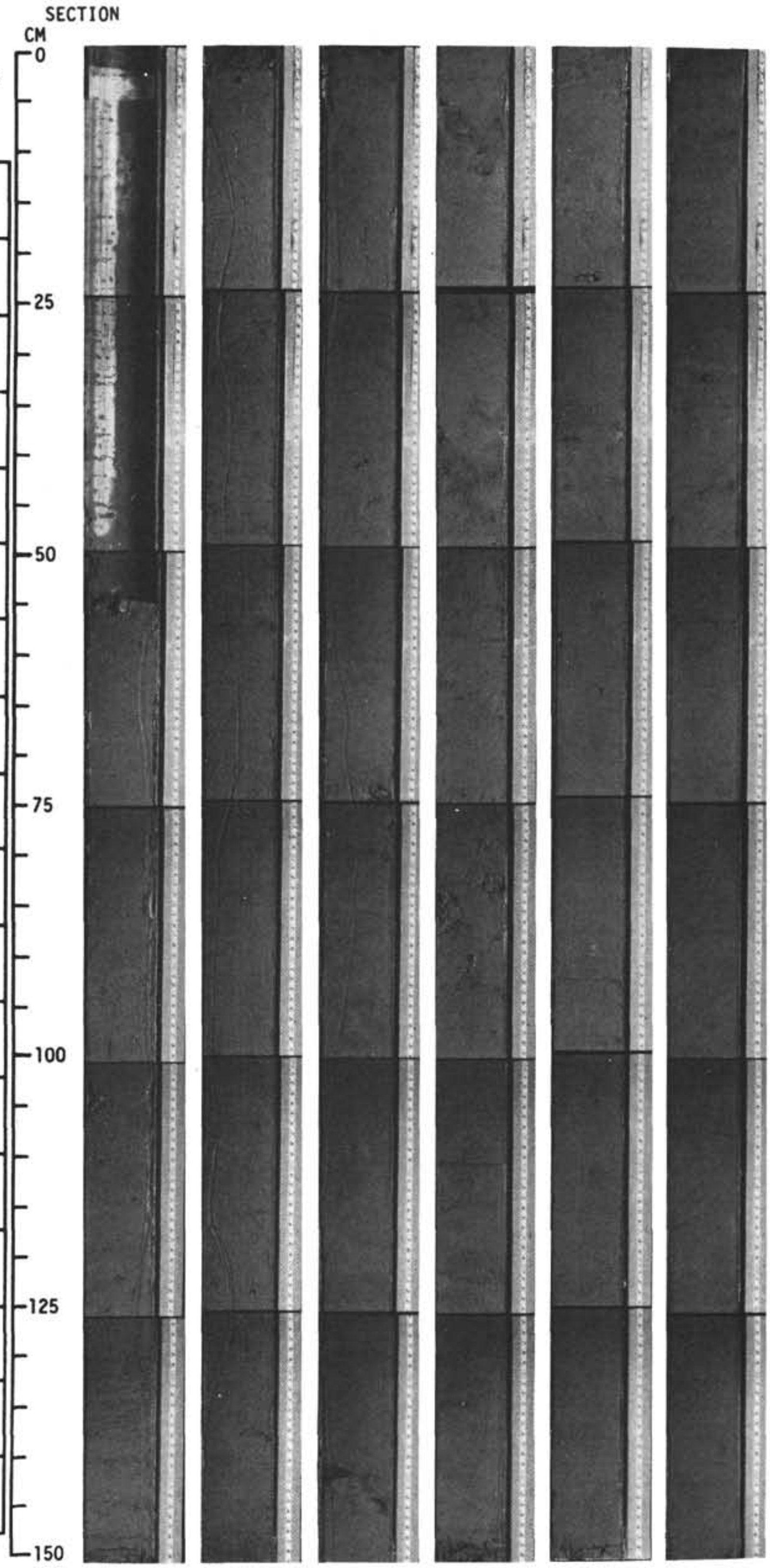

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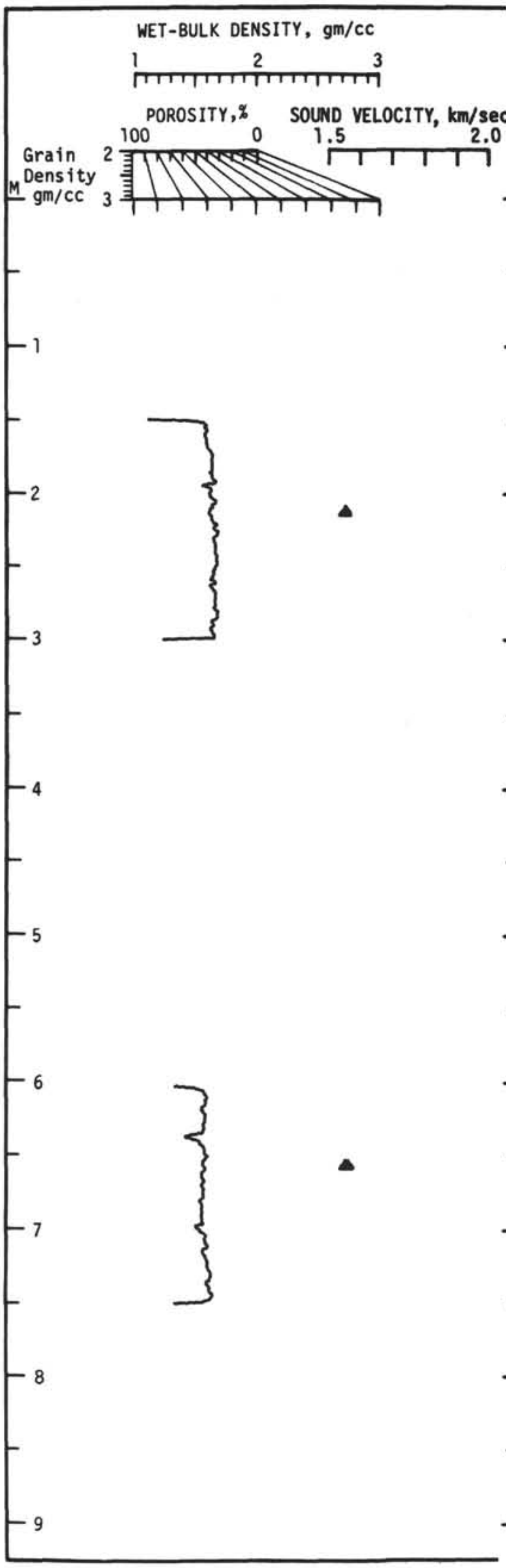
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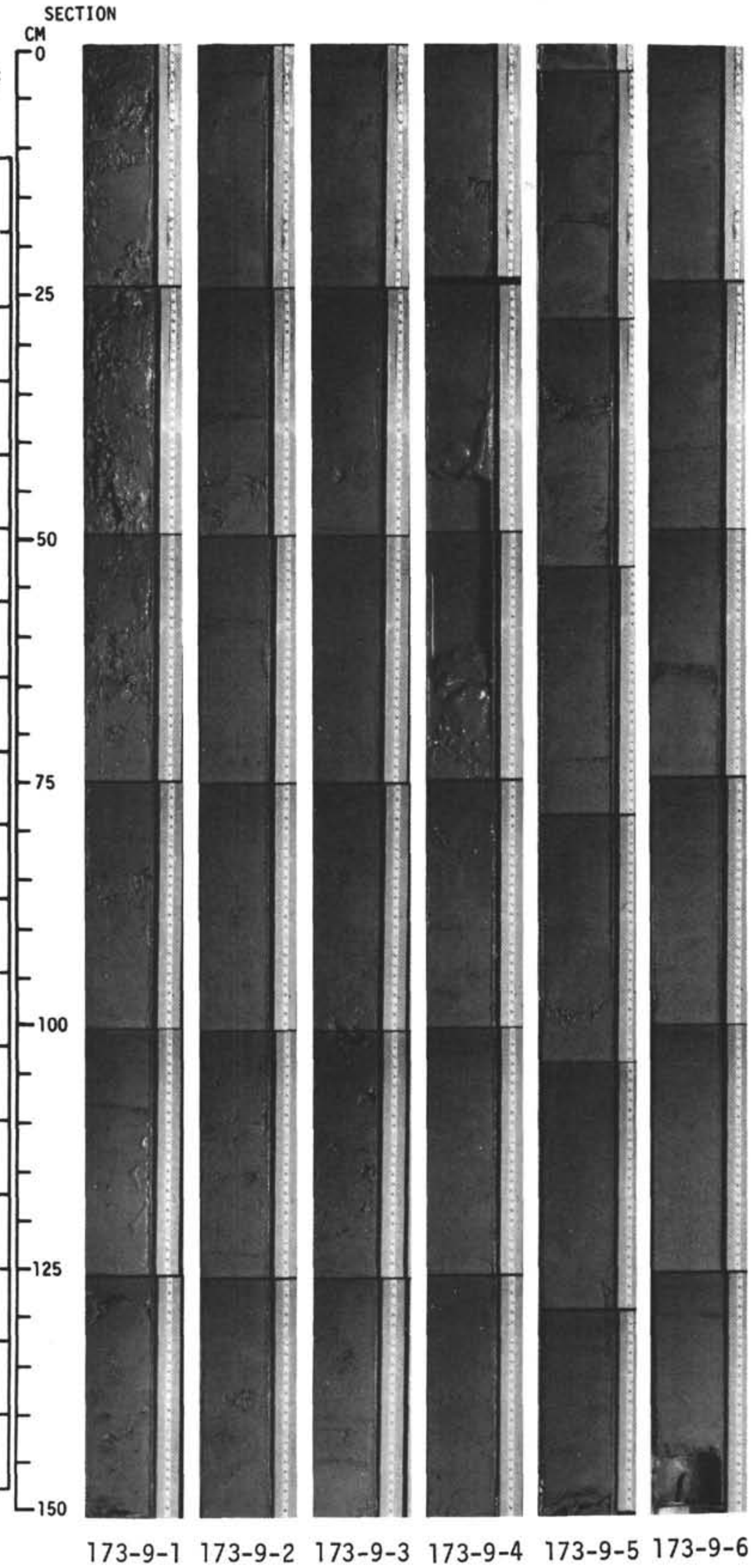
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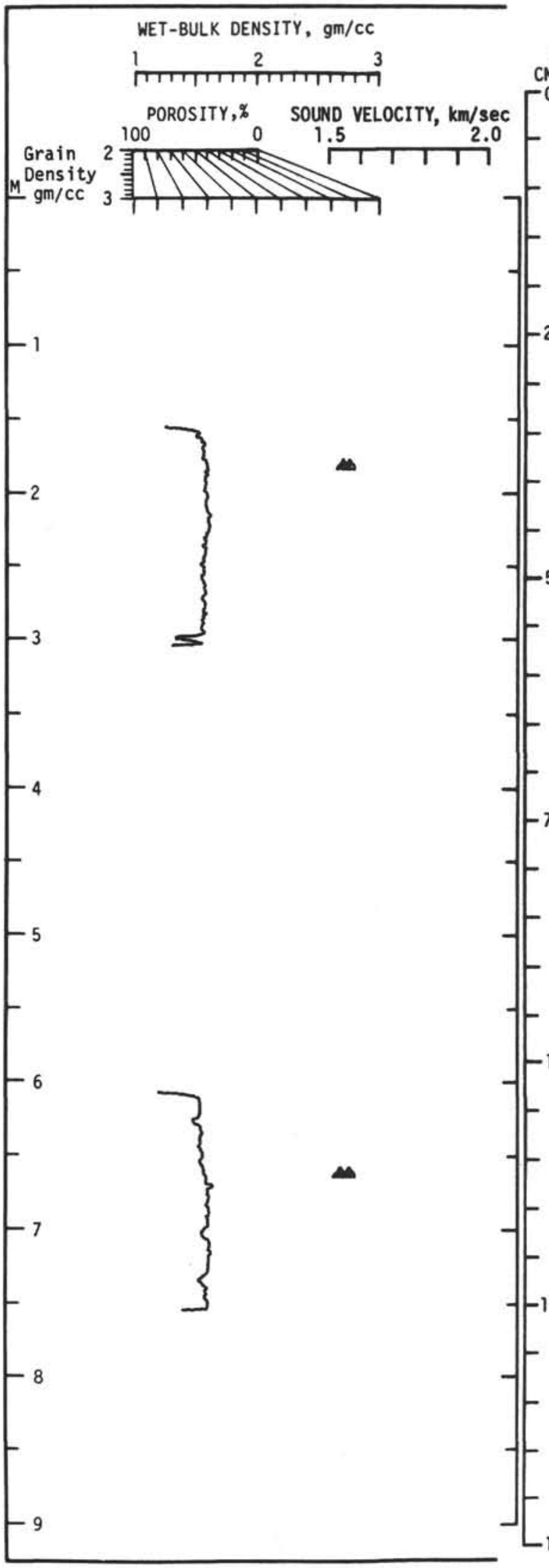
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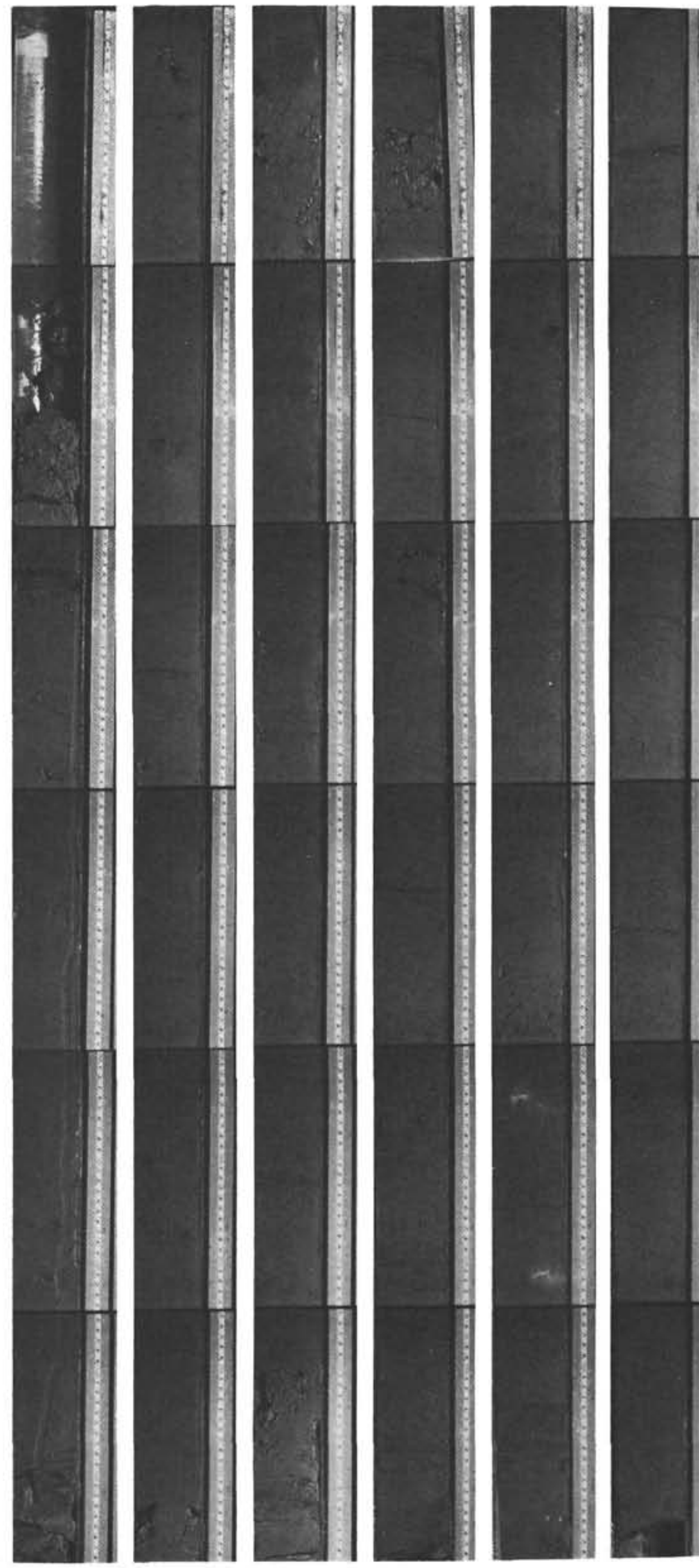
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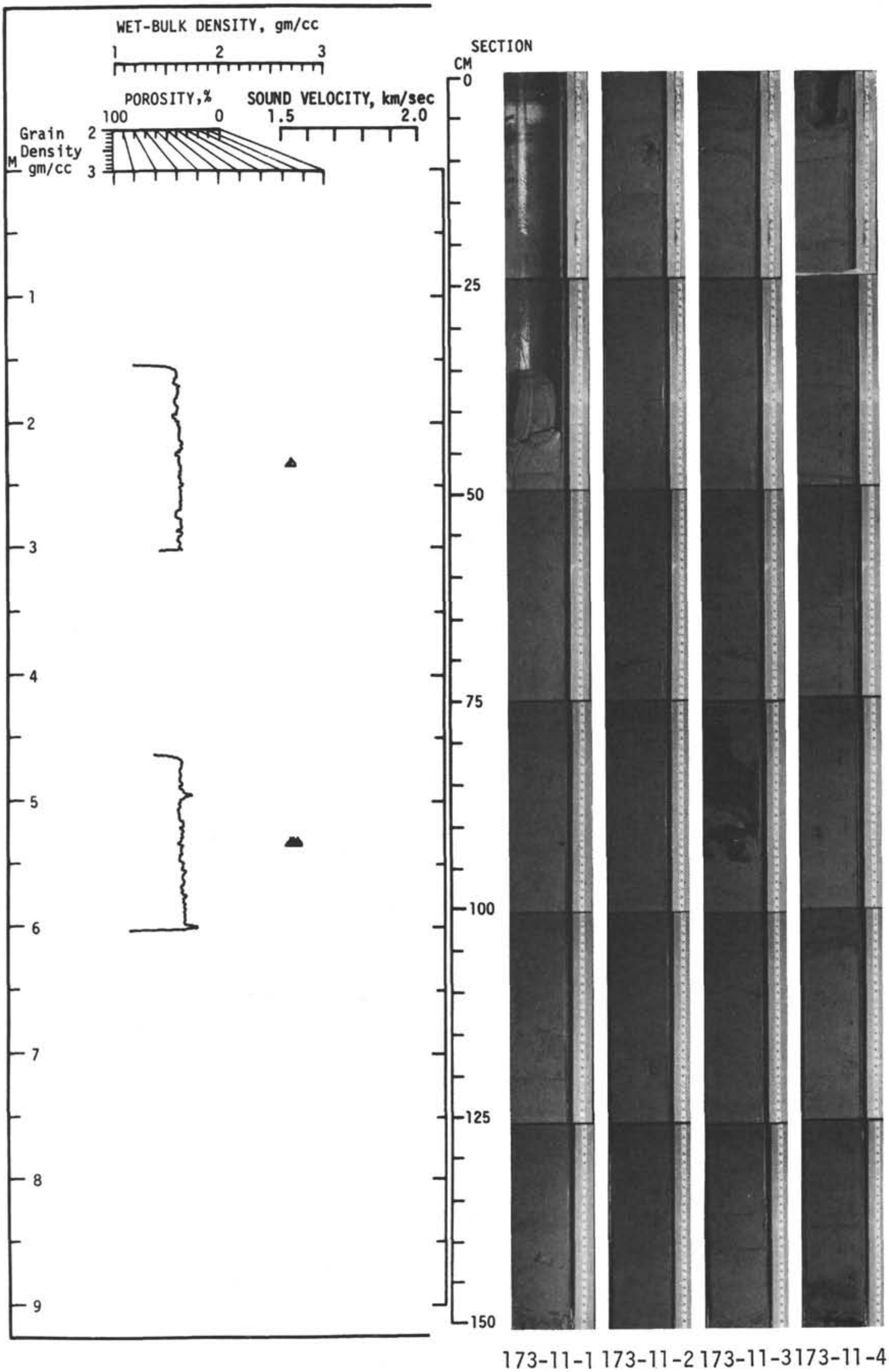

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SOUND VELOCITY, km/sec
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Grain Density gm/cc
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2
3
4
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6
7
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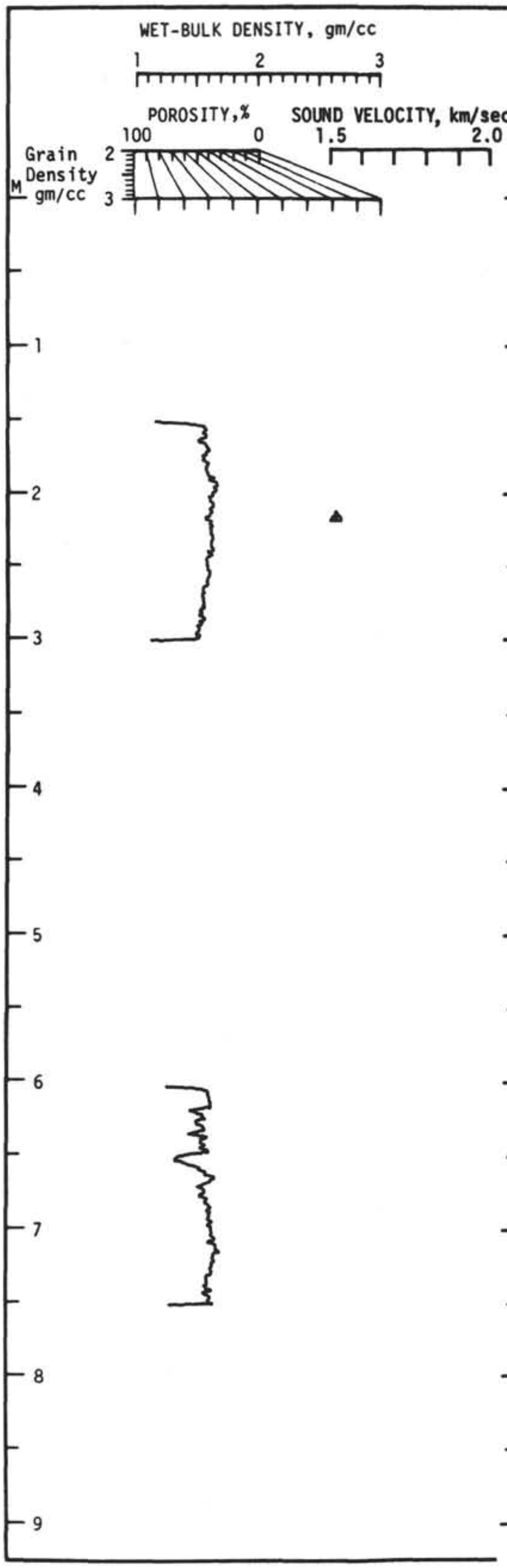
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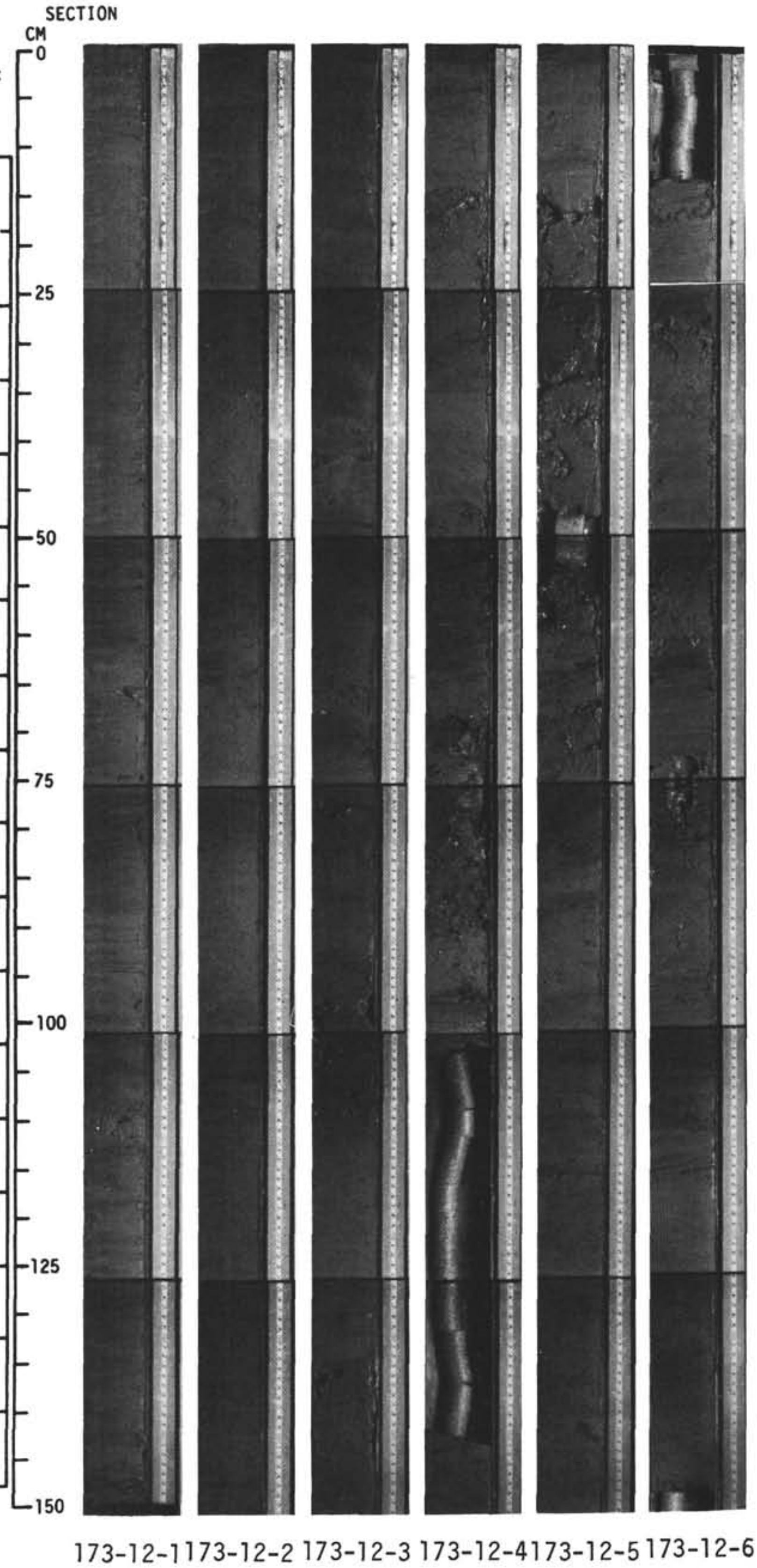
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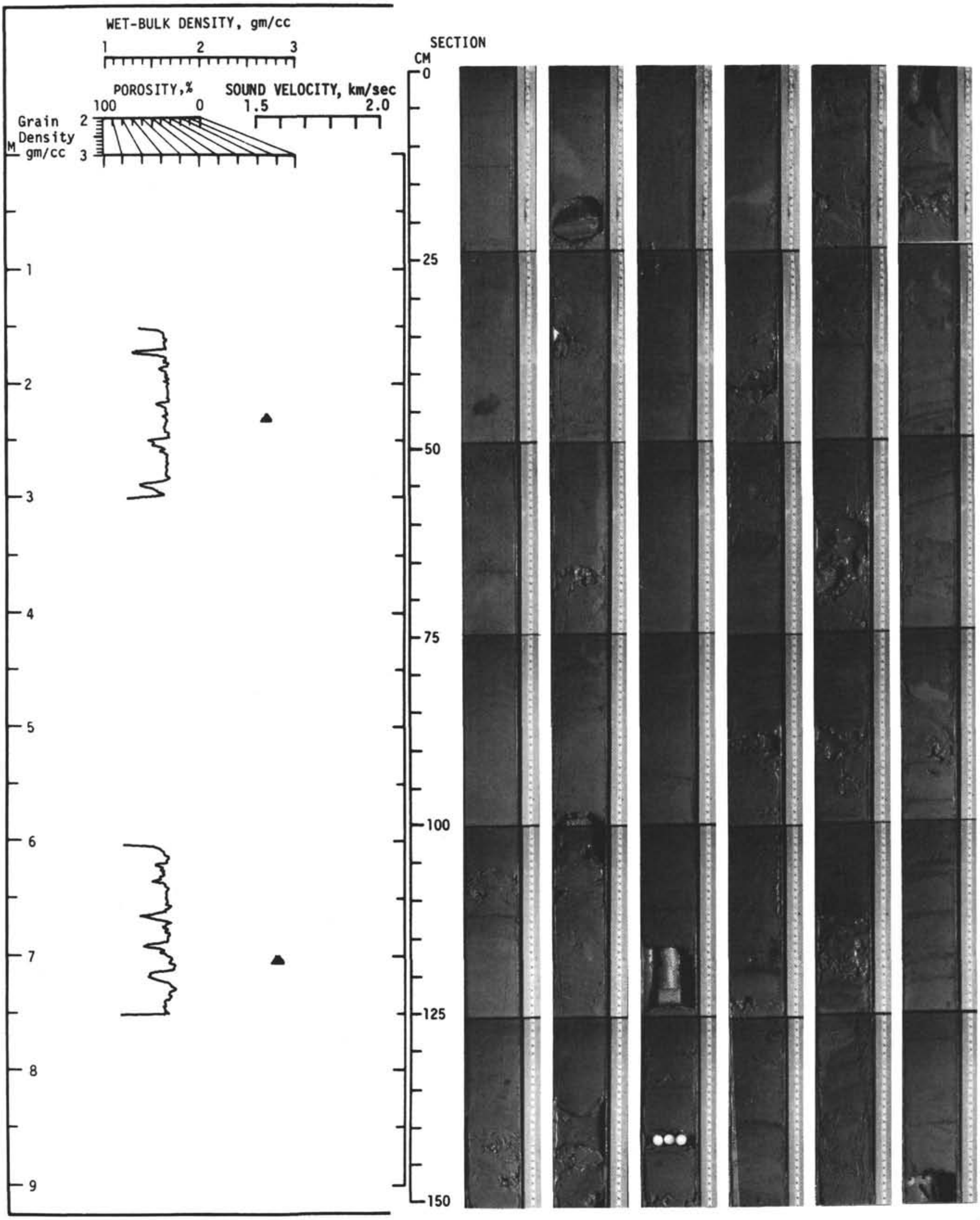

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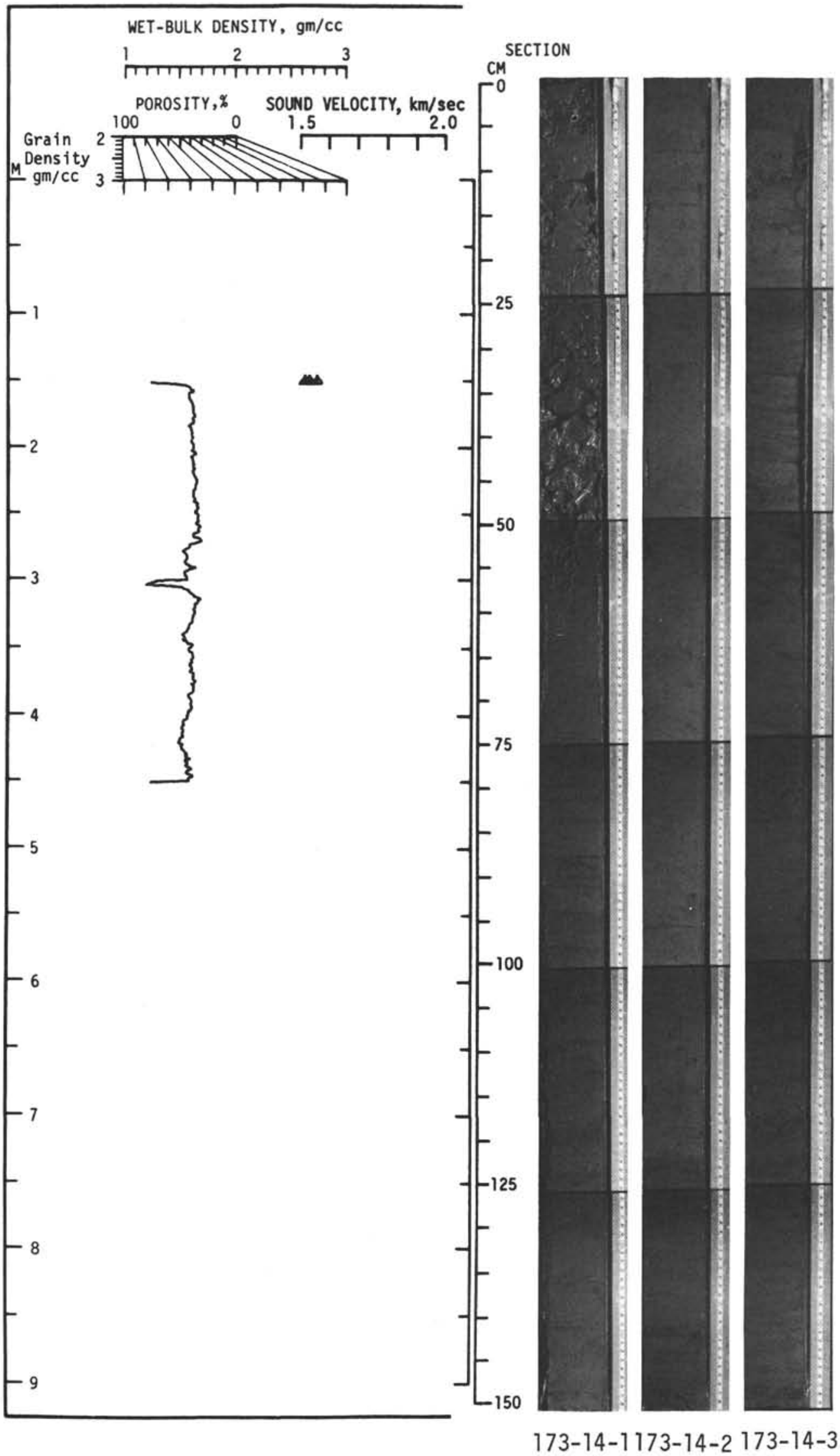
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Grain Density gm/cc
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M
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SECTION
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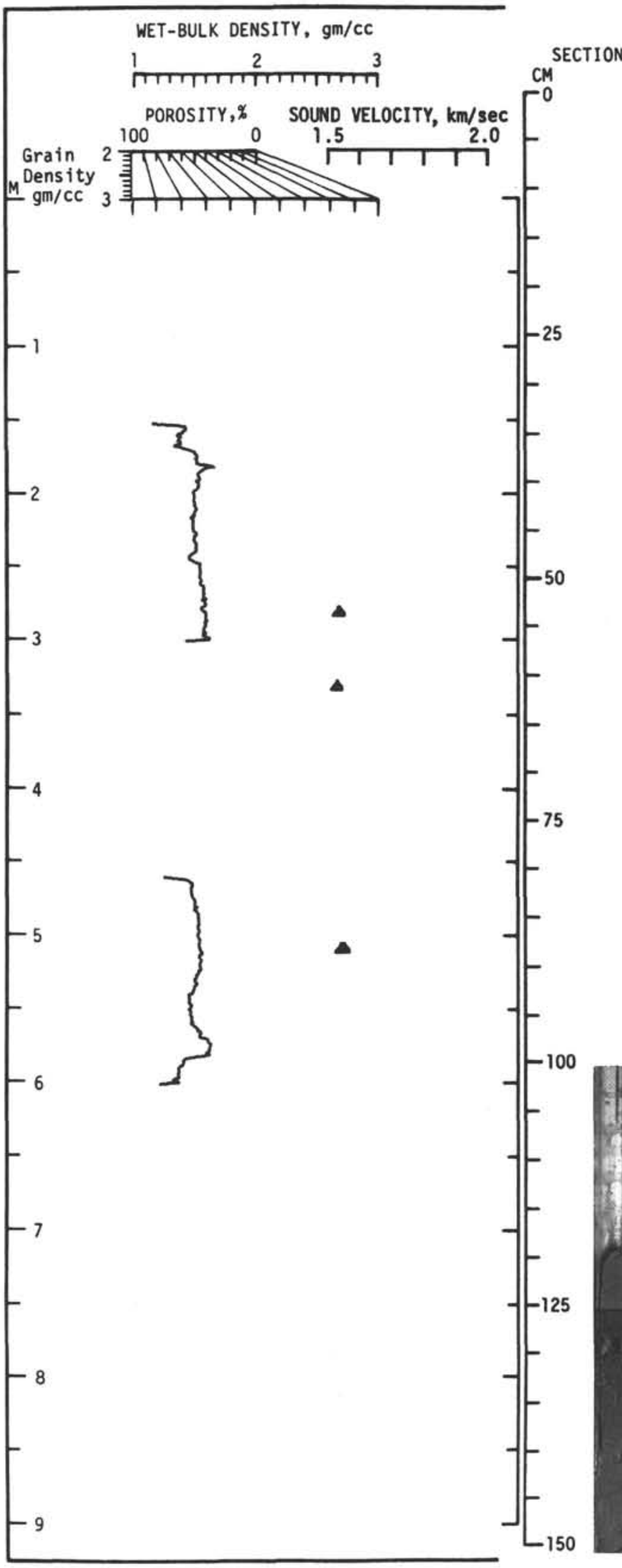
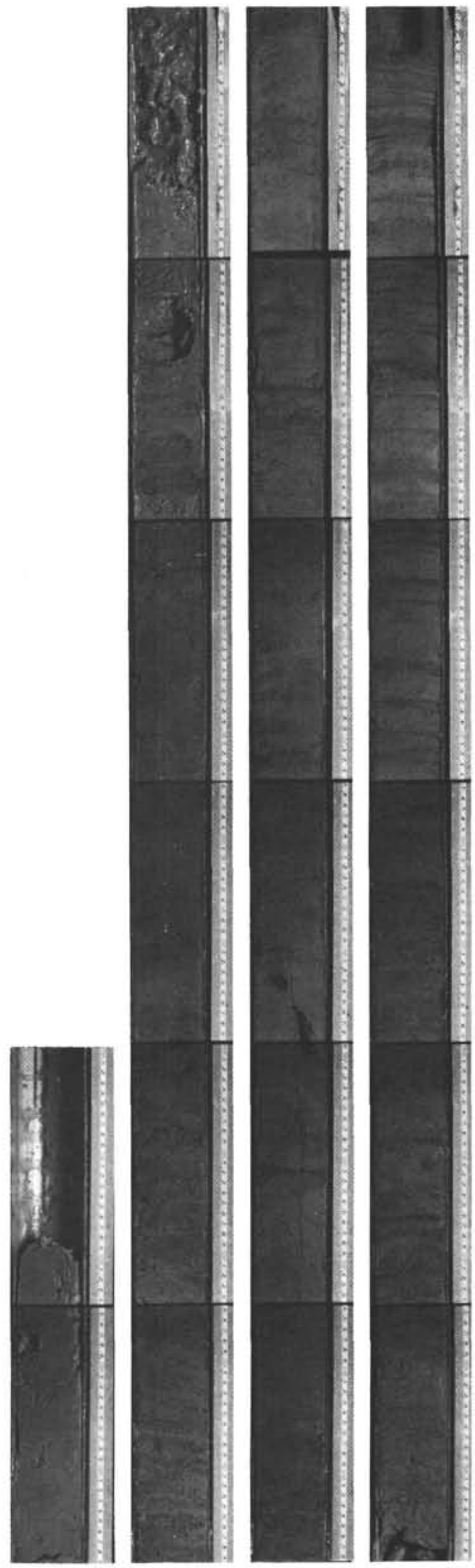
173-14-3





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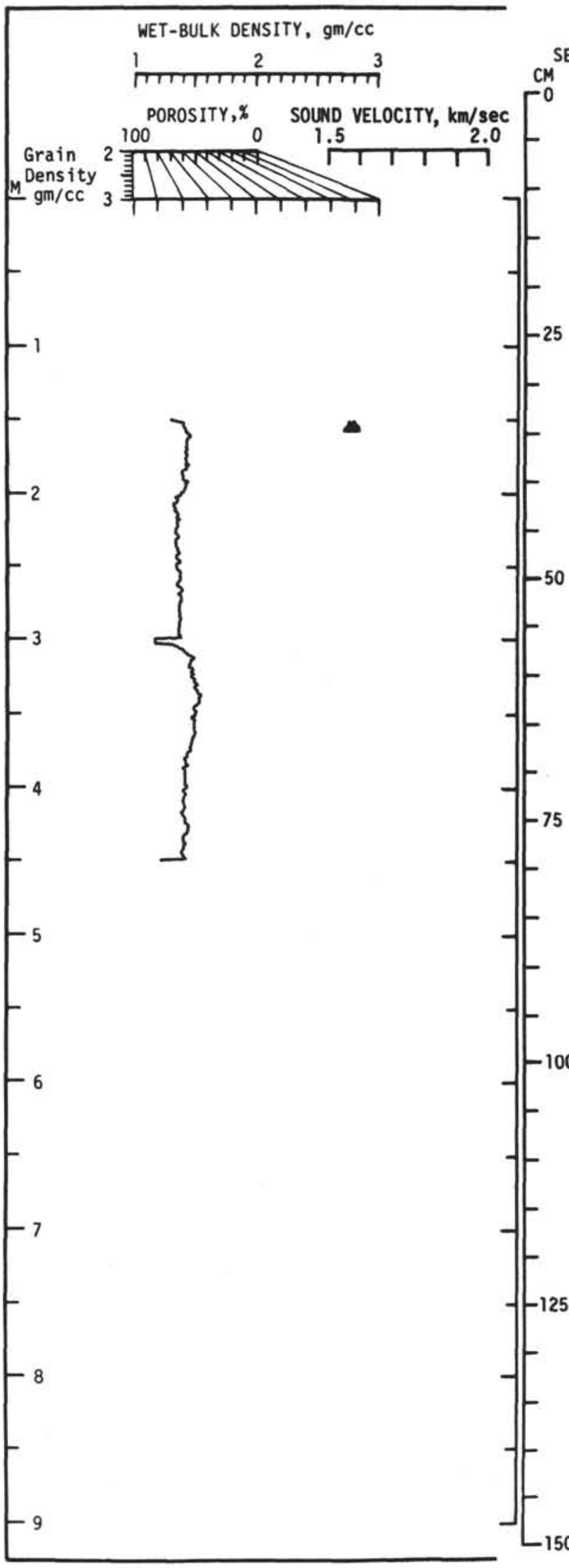

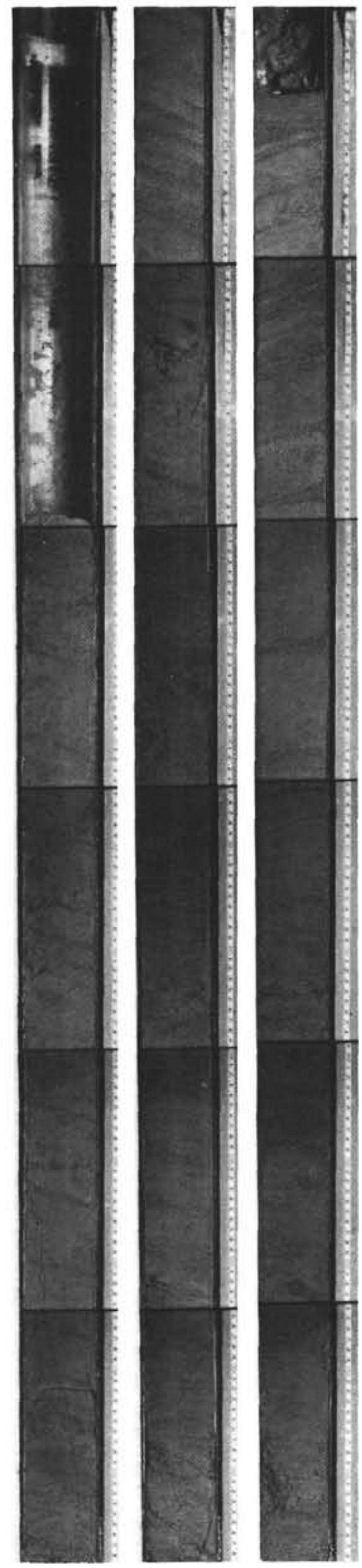

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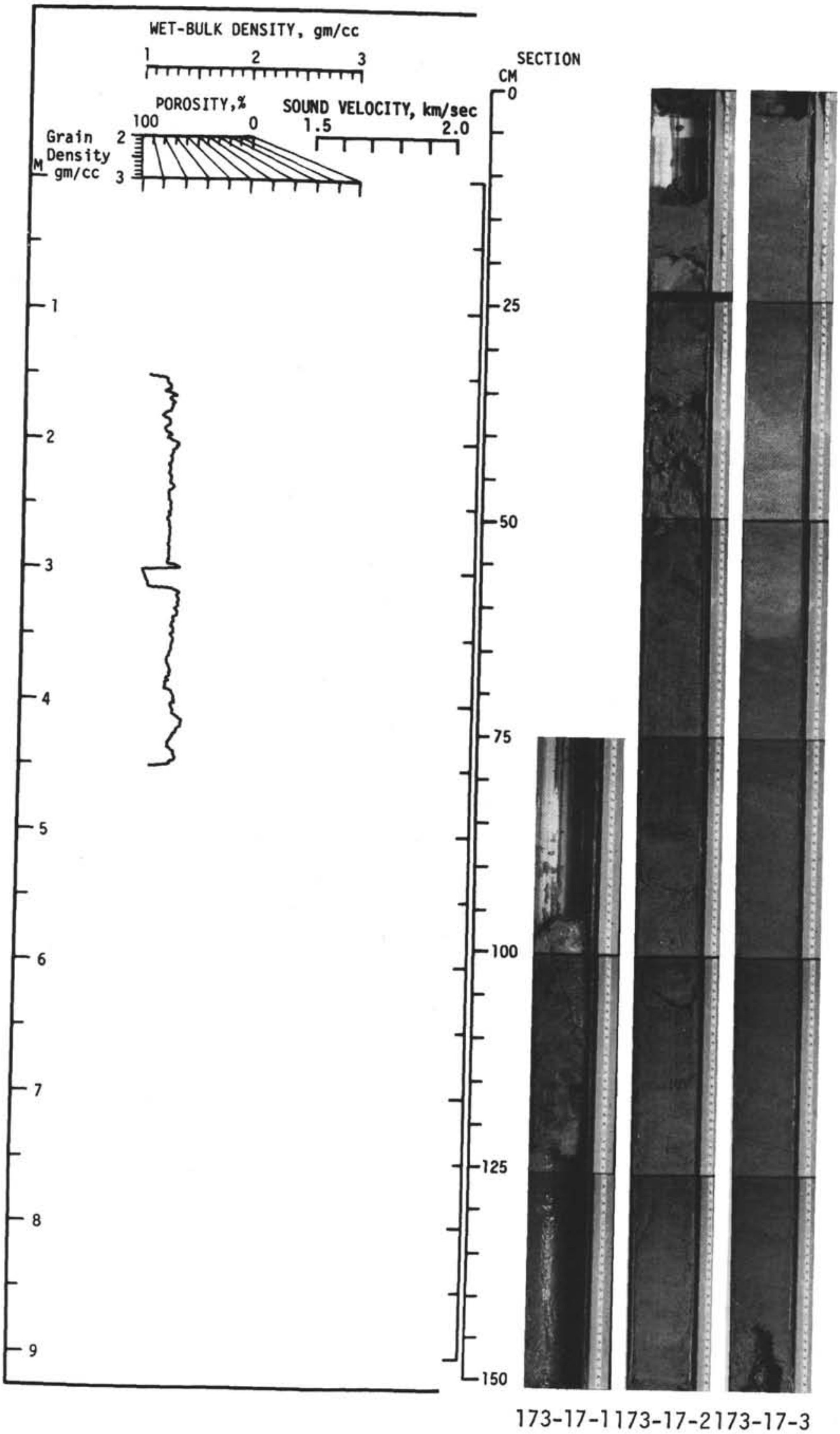
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Grain Density gm/cc
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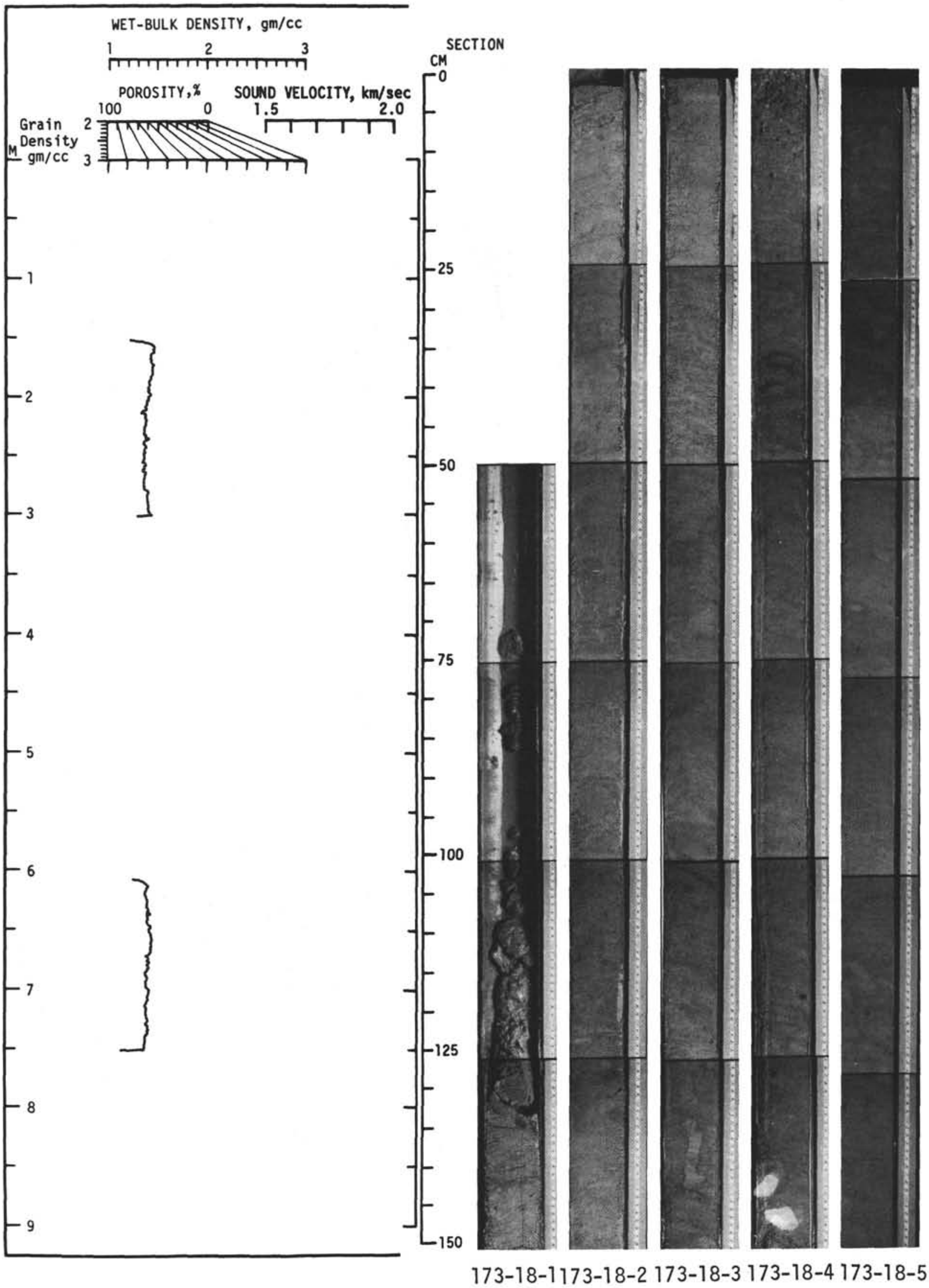
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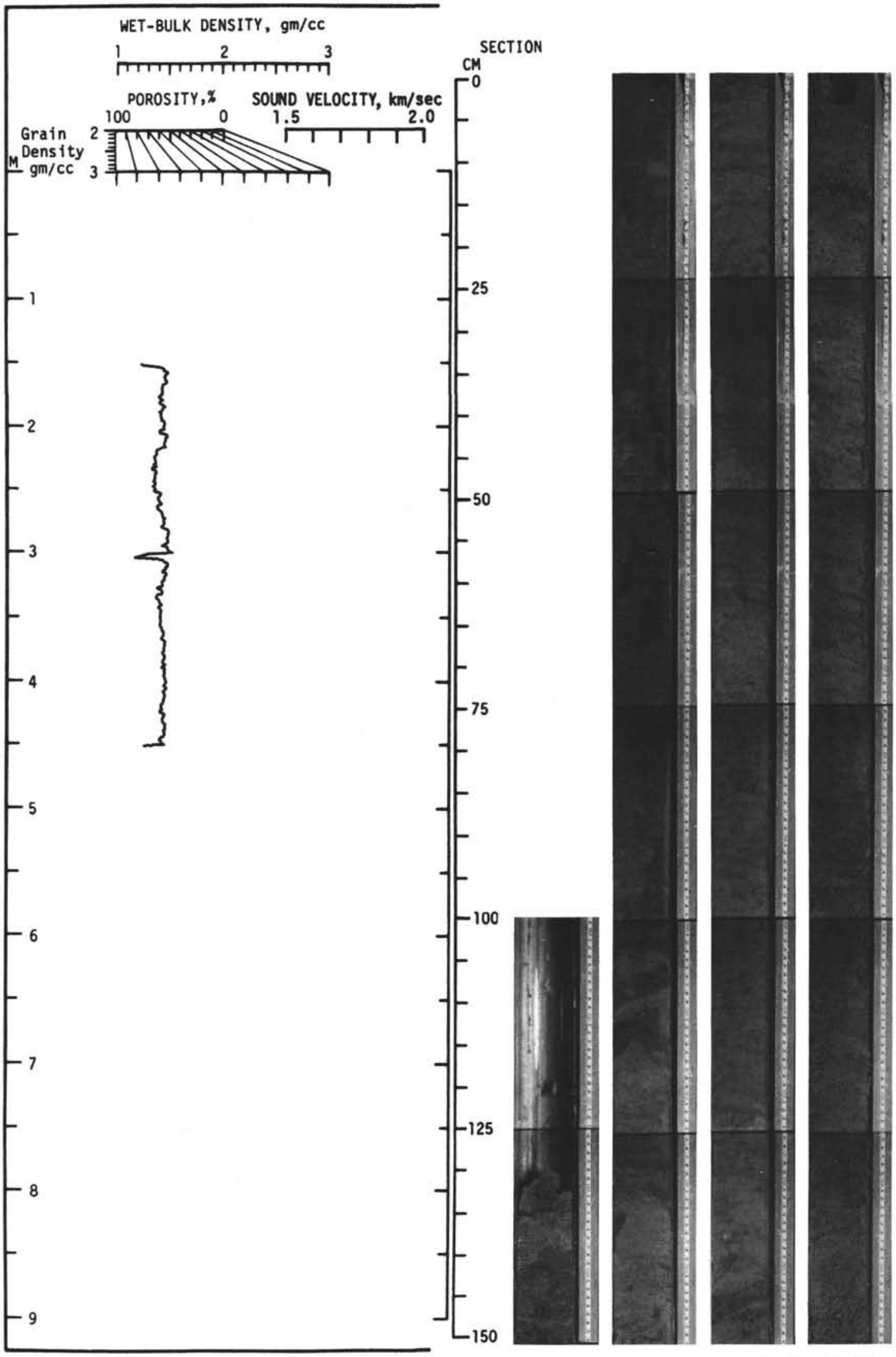
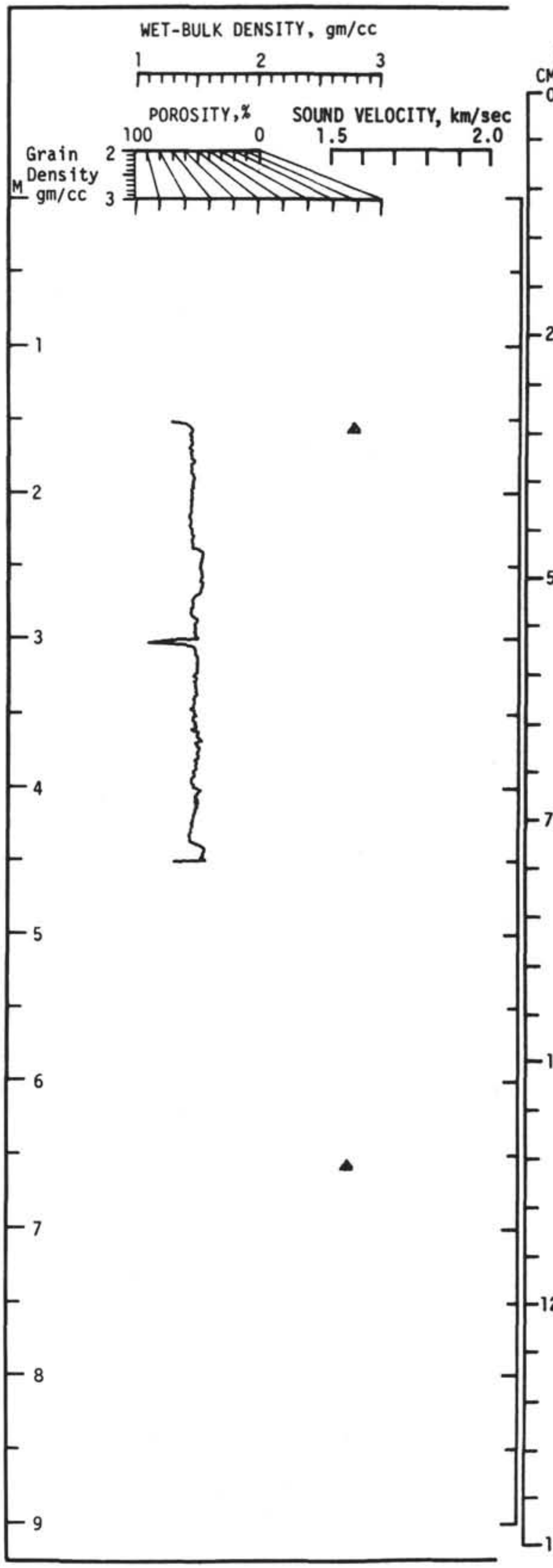
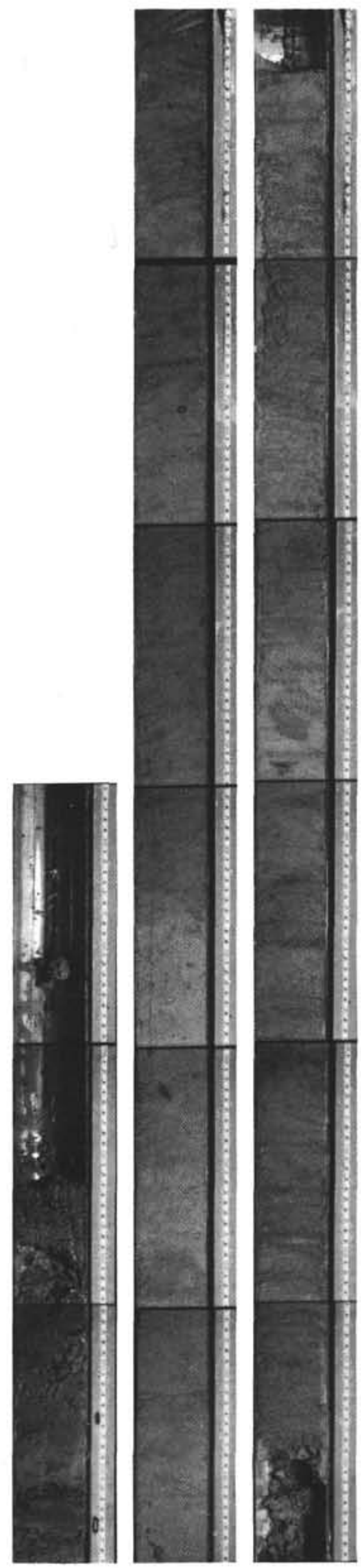
173-18-5

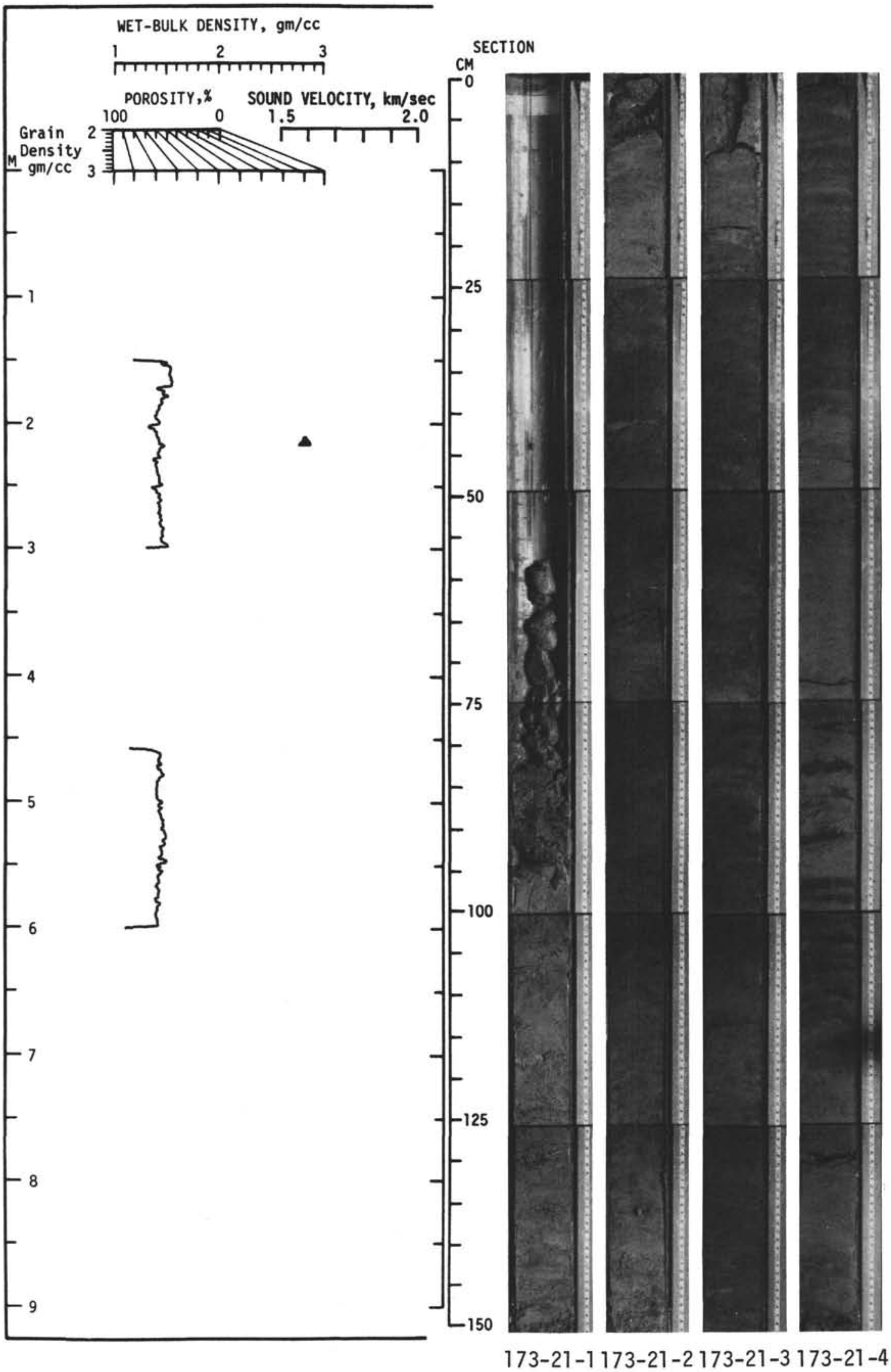


173-19-1 173-19-2 173-19-3 173-19-4





173-20-1 173-20-2 173-20-3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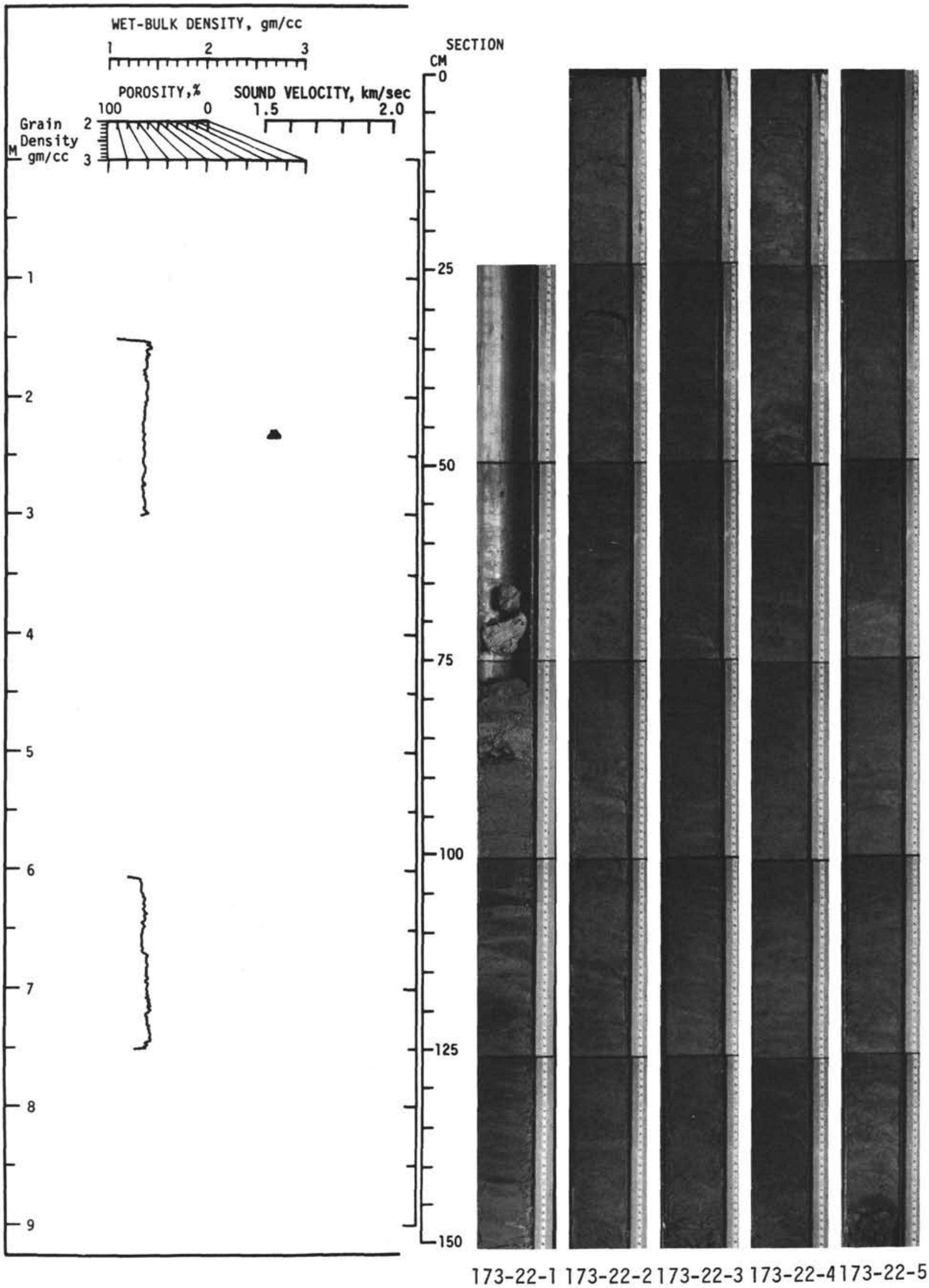
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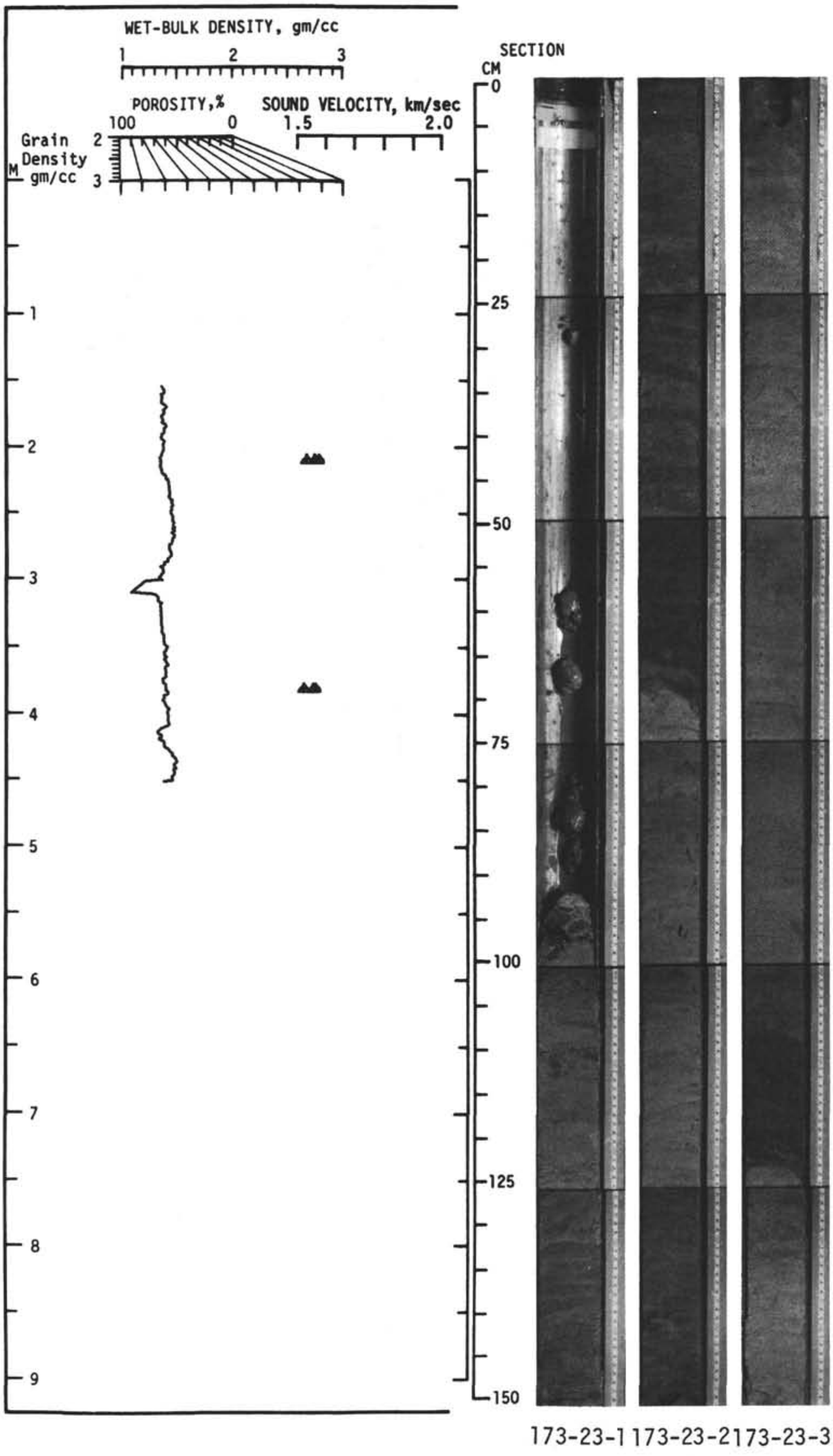
173-22-4
173-22-5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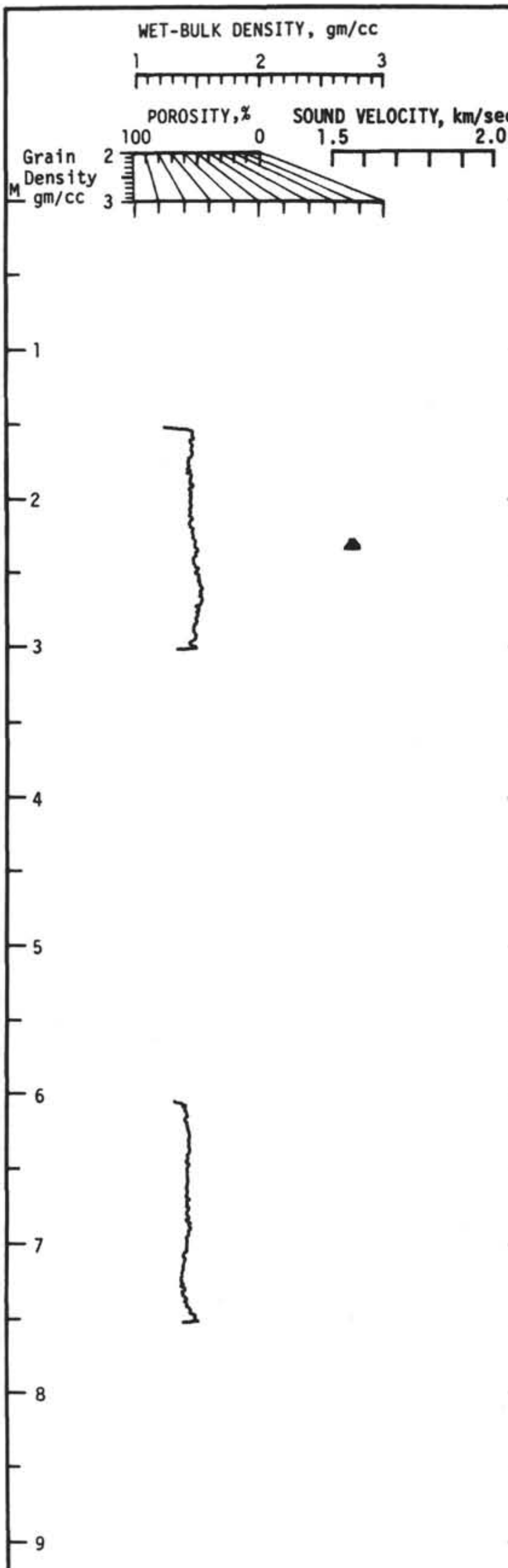

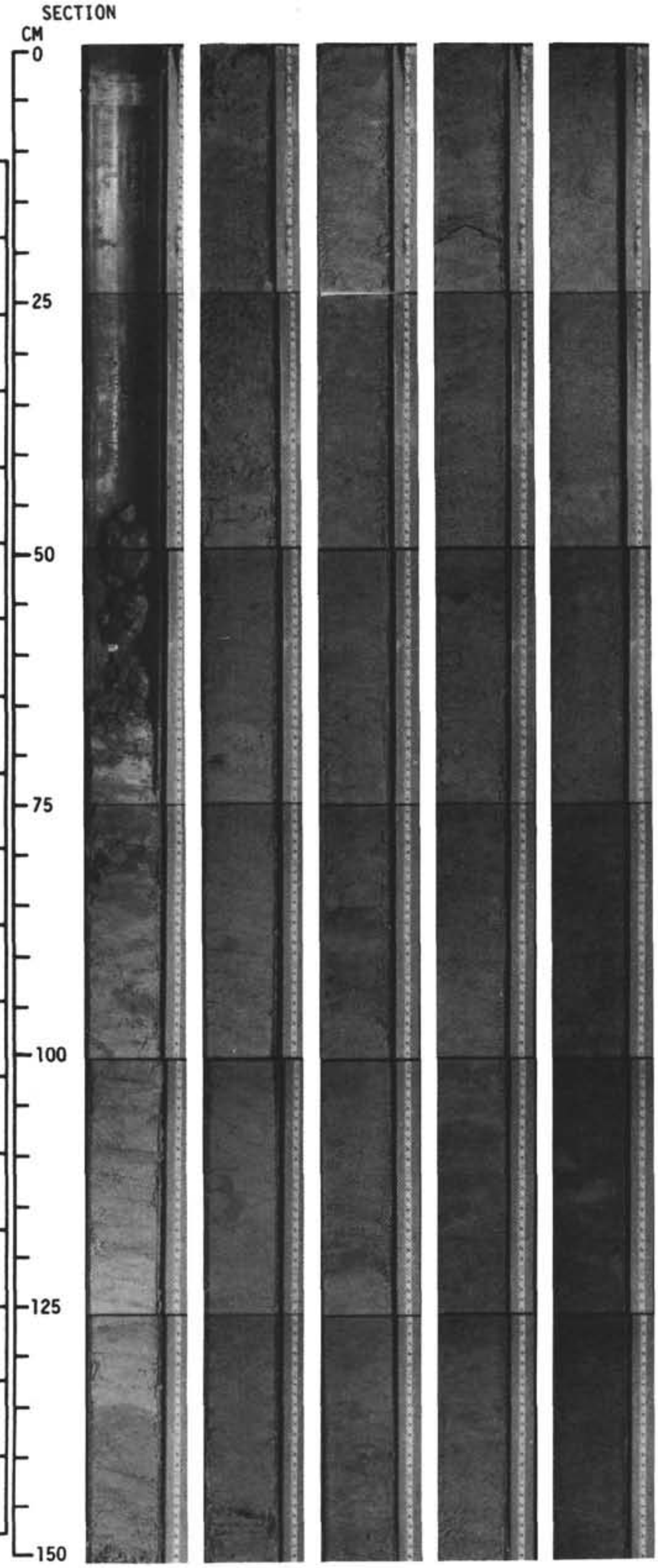

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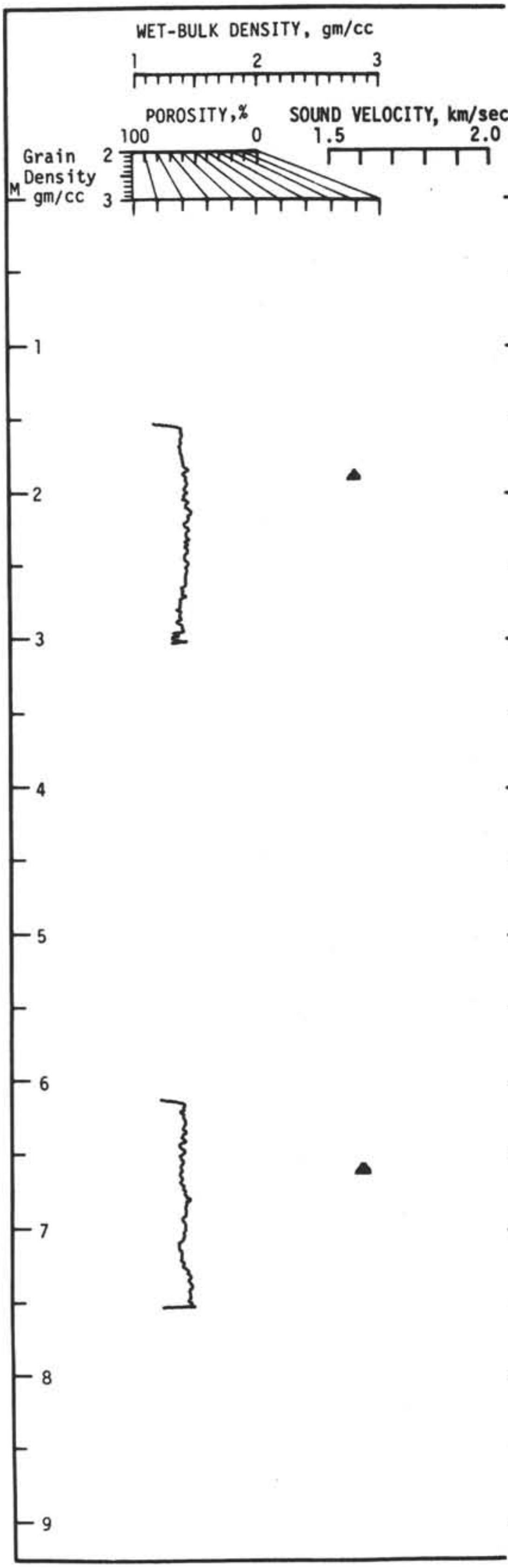

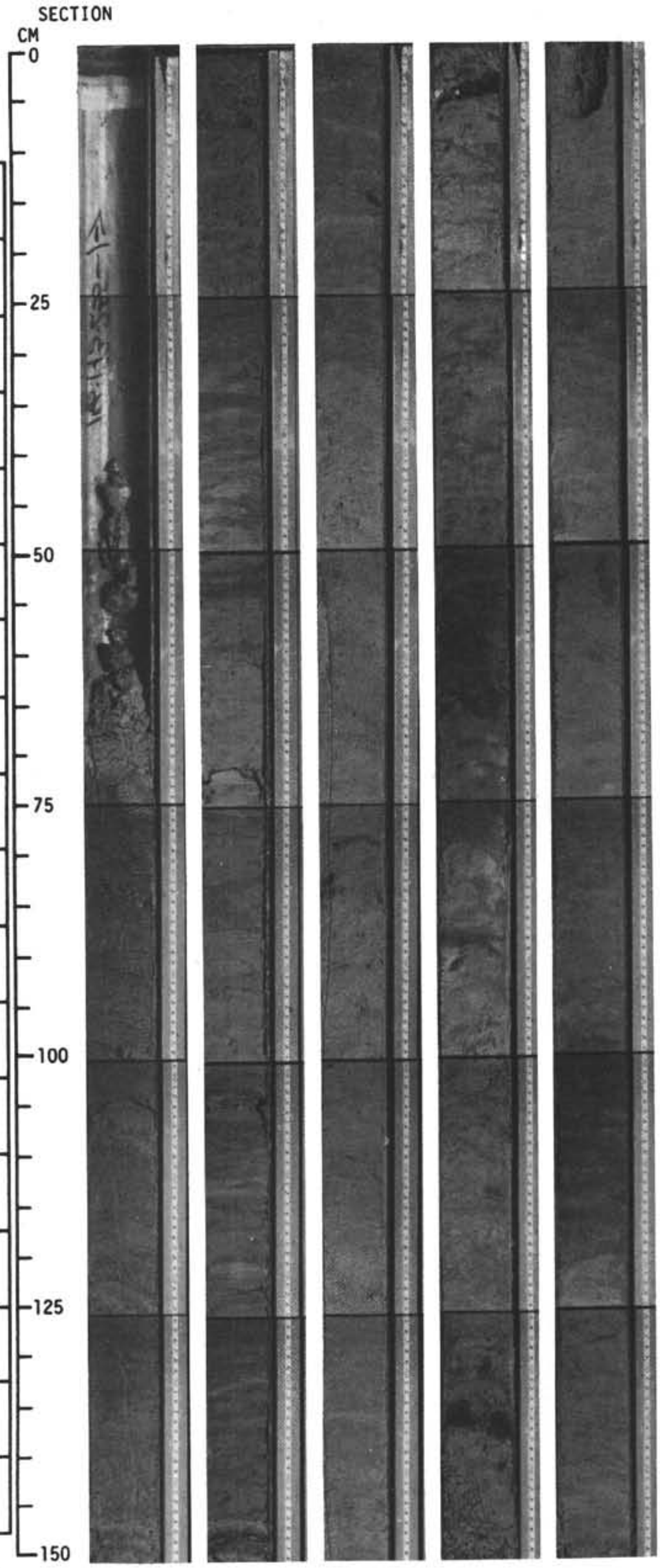

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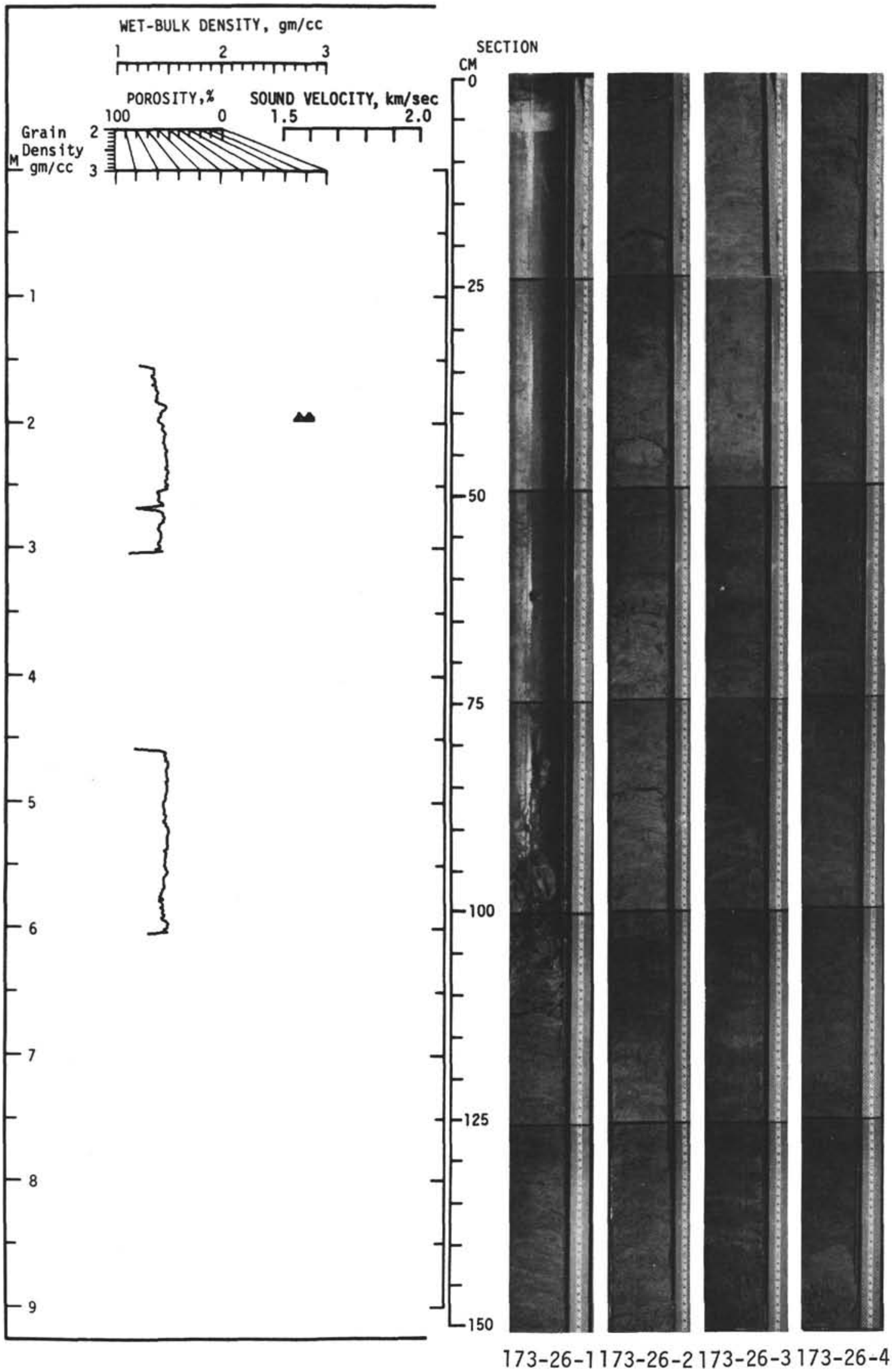
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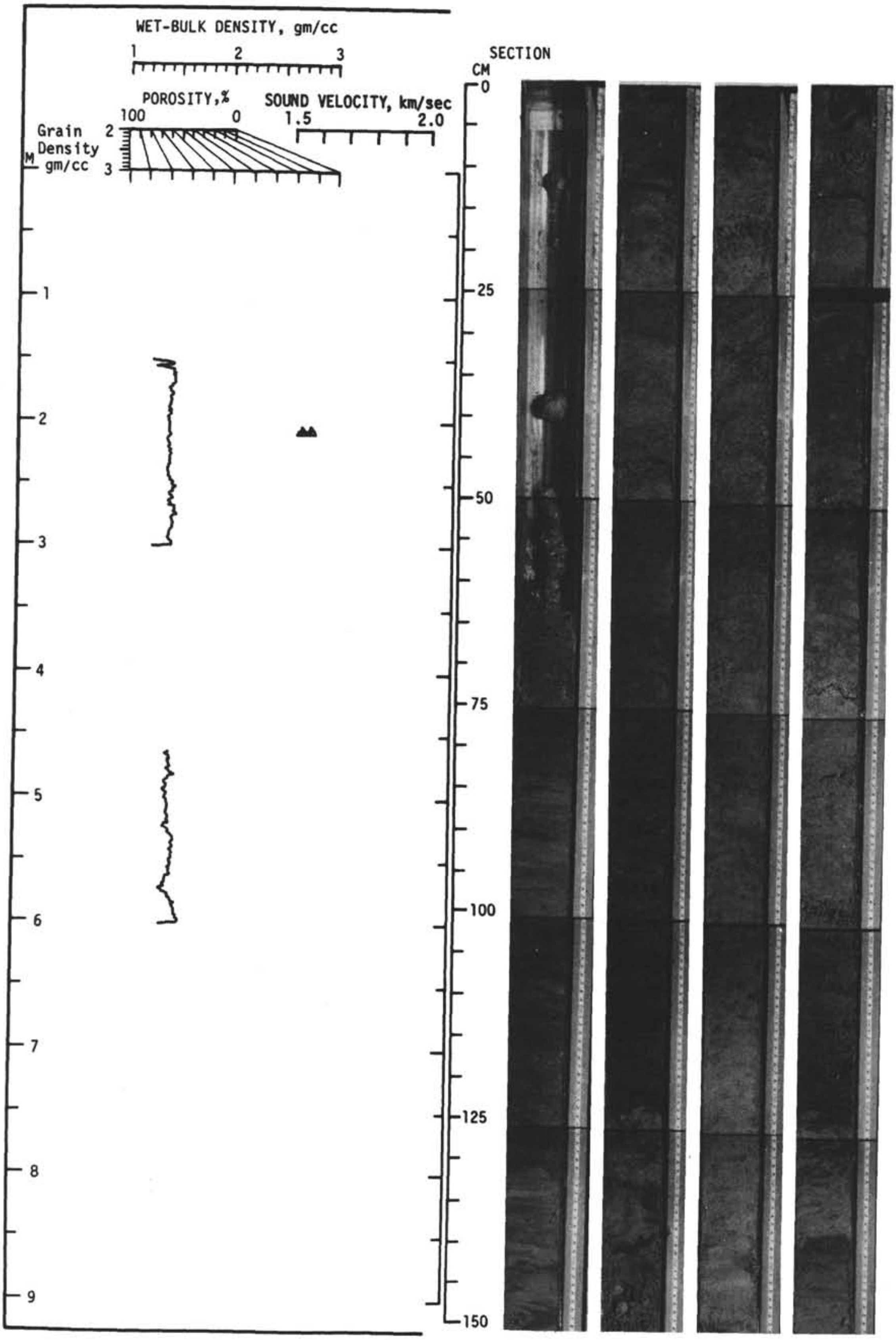
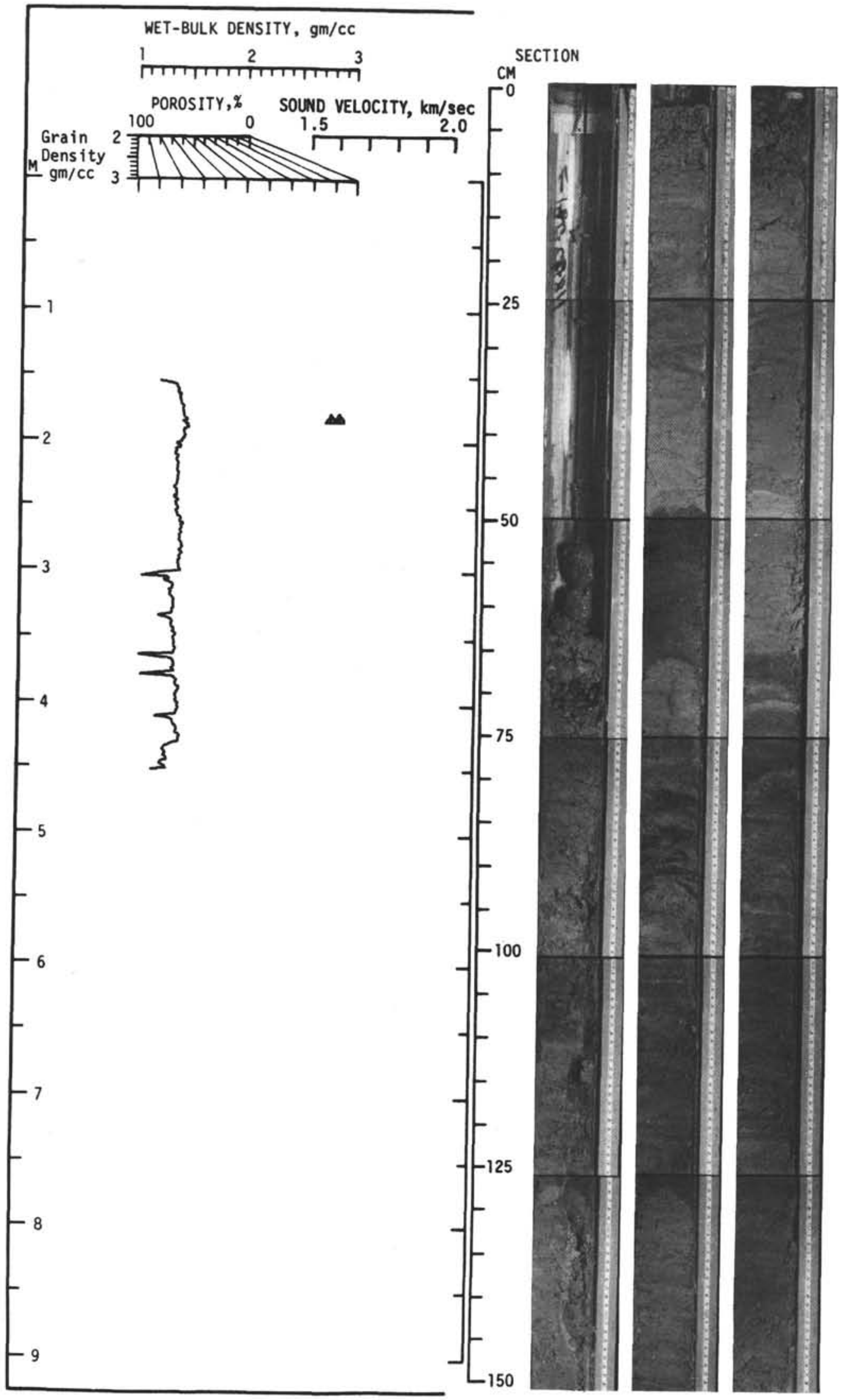
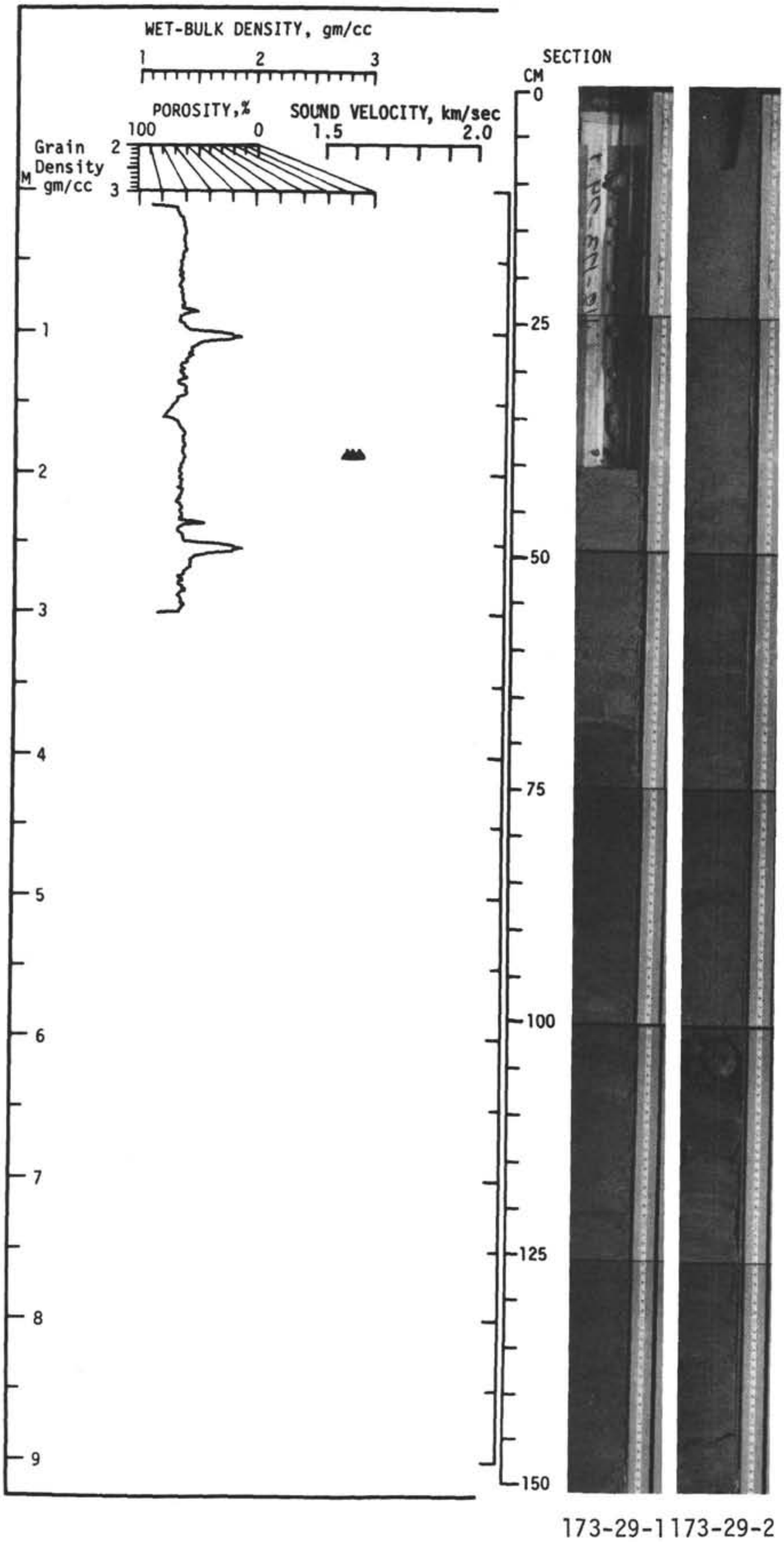


173-27-1 173-27-2 173-27-3 173-27-4



173-28-1 173-28-2 173-28-3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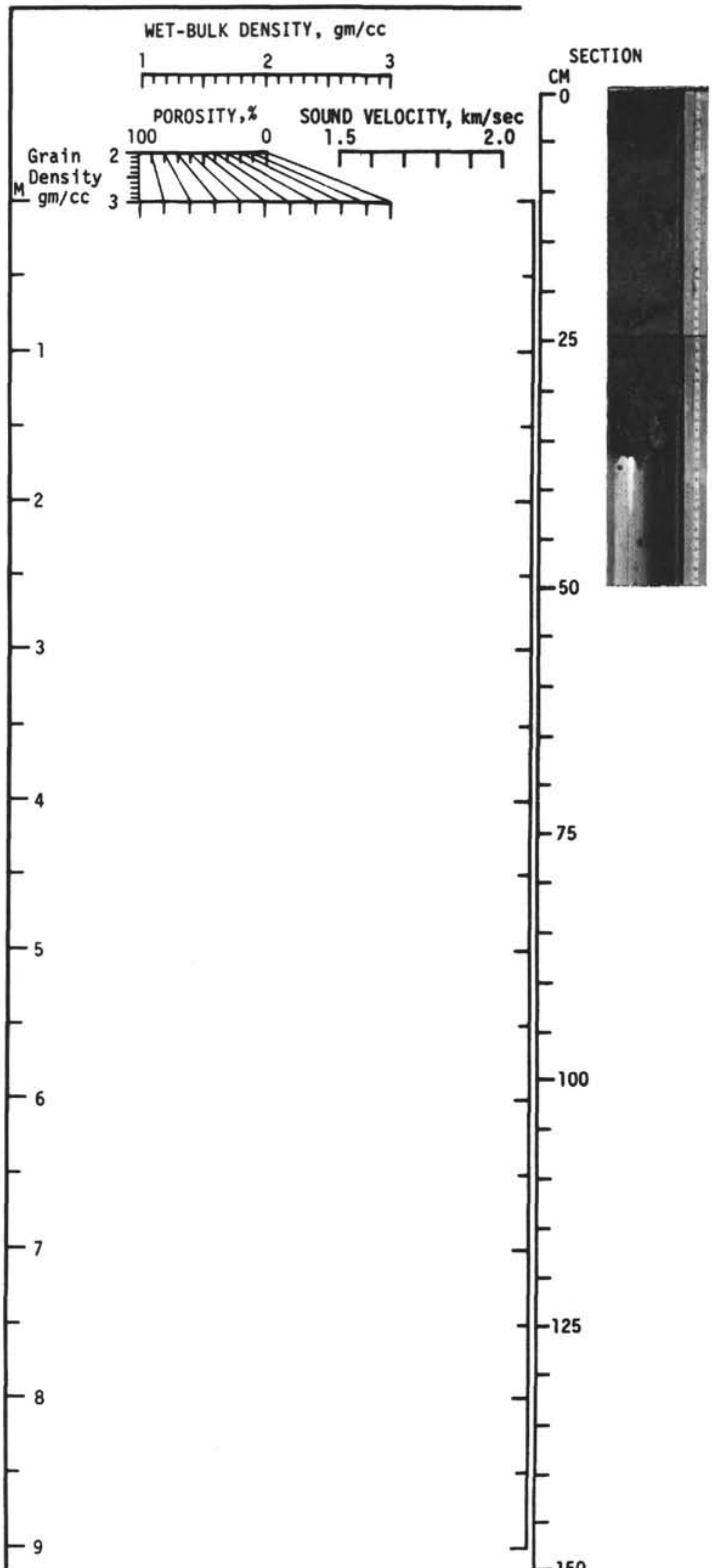
173-29-2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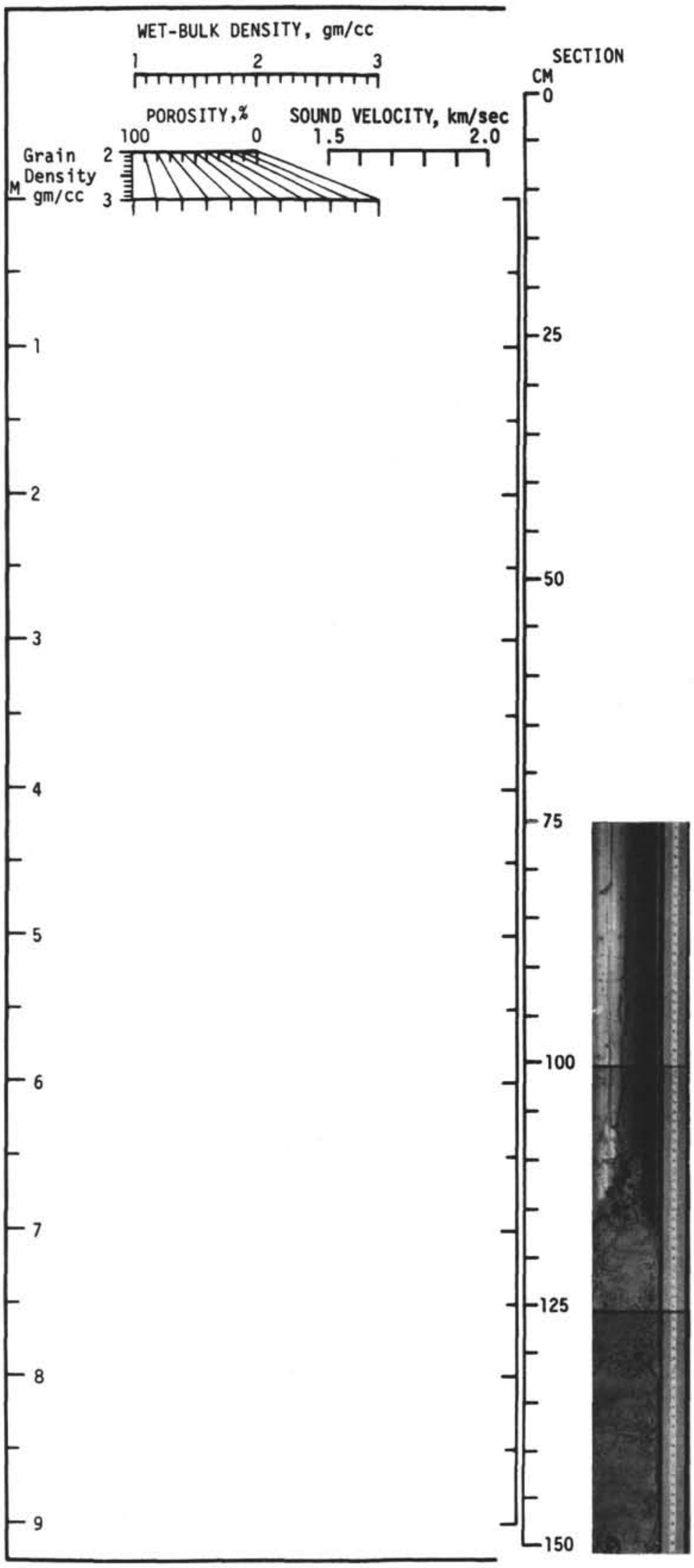
173-30-1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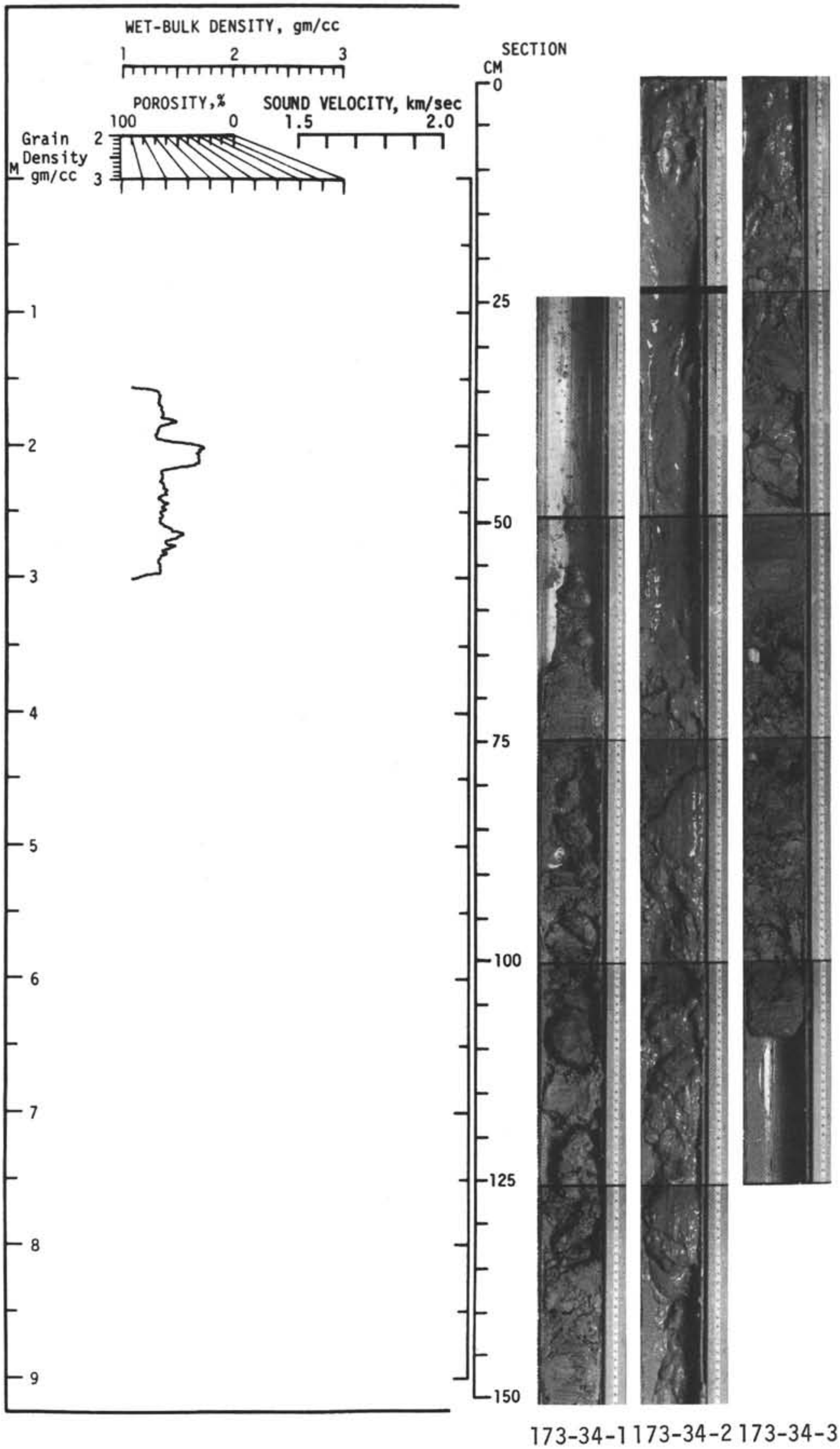
173-31-1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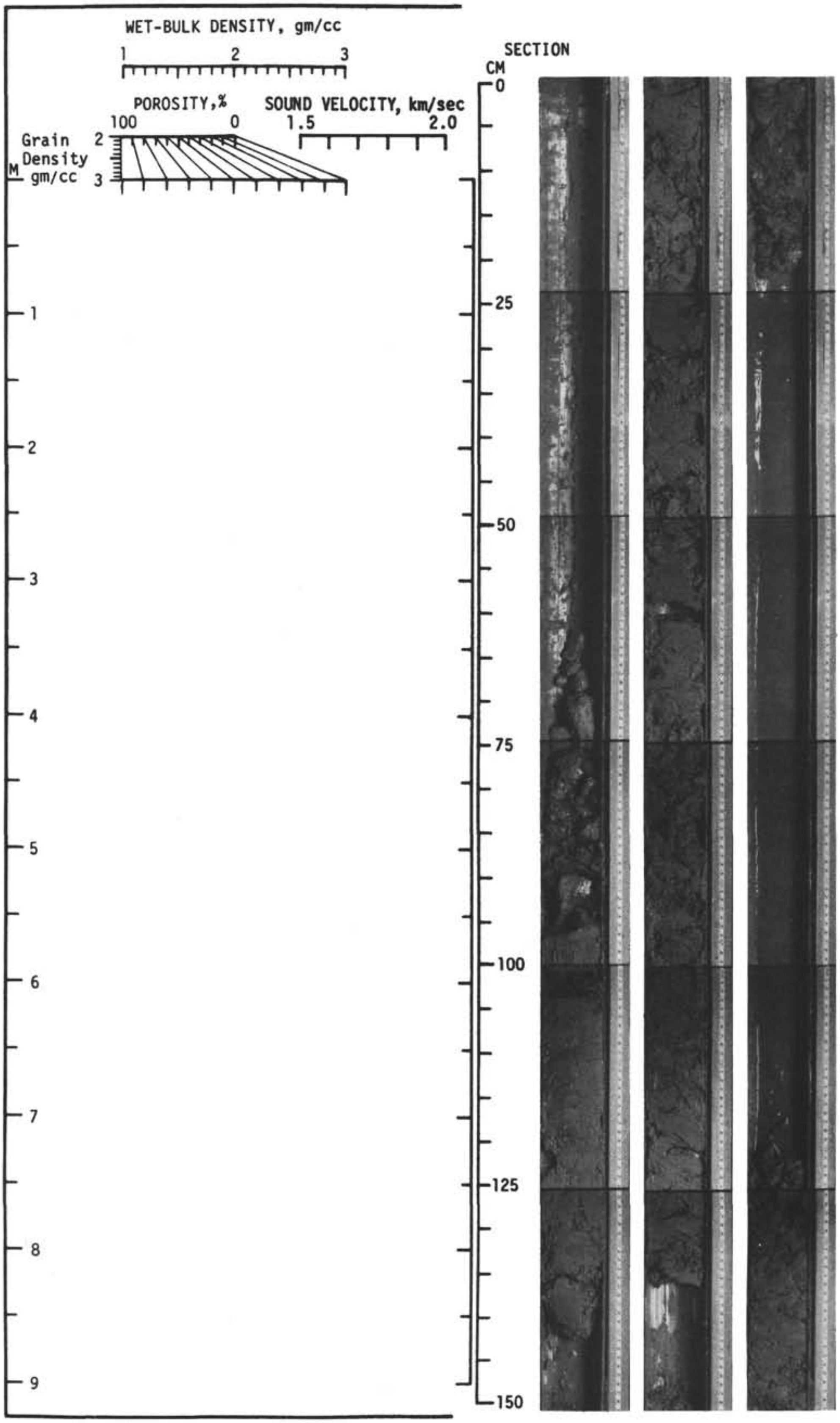

173-35-1 173-35-2 173-35-3