8. SITE 281

The Shipboard Scientific Party[1]
With Additional Contribution From
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SITE DATA

Location: South Tasman Rise

Position: 47°59.84′S; 147°45.85′E

Water Depth:
PDR, from sea level: 1591 meters
From drill pipe measurement from derrick floor: 1601 meters (adopted)

Dates Occupied: 31 March to 2 April 1973

Depth of Maximum Penetration:
Hole 281: 169 meters
Hole 281A: 45.5 meters

Number of Holes: 2

Number of Cores:
Hole 281: 19
Hole 281A: 3

Total Length of Cored Section:
Hole 281: 169 meters
Hole 281A: 28.5 meters

Total Recovery:
Length:
Hole 281: 105.6 meters
Hole 281A: 7.1 meters
Hole 281: 62.5
Hole 281A: 24.9
Percentage:
Hole 281: 62.5
Hole 281A: 24.9

Age of Oldest Sediment Cored: Late Eocene

Summary: 112 meters of early Miocene to Recent nannofossil-foraminiferal ooze and foraminiferal-nannofossil ooze, underlain in continuous sequence by 9.3 meters of late Oligocene glauconitic sand. Major disconformities span most of the Oligocene and much of the late Eocene, although 0.2 meters of early Oligocene greensand occur between the disconformities. Underlain by 28.5 meters of early late Eocene biogenic-rich glauconitic silty sands, in turn underlain by 19 meters of late Eocene glauconitic sandstone and probable mica schist breccia. Large fragments of schist obtained near basement prove continental nature of South Tasman Rise; hence Antarctic bottom water was not free to circulate before the rise separated from Victoria Land, even though Australia had already detached from Antarctica. Shallow-water foraminifera and neritic nannofossils in the late Eocene indicate subsidence of the rise during the Paleogene related with early spreading of Australia from Antarctica. Oligocene-late Eocene unconformity is equivalent and genetically related to regional unconformity in north Tasman Sea and Coral Sea (Leg 21). Sedimentary deposition at Site 281 almost opposite to that of Site 280 which is in deep water to the south, and records shallow-water connection between Indian and Pacific water masses during late Eocene and Oligocene with high sustained currents, followed in Neogene by uninterrupted sedimentation when deep-seated circumpolar circulation was established to south (Site 280). Site 281 has close affinities with northern Tasman Sea sites, while Site 280 has closer affinities with sites south of New Zealand, both sites recording major middle Cenozoic paleocirculation changes in southwest Pacific related to development of circumpolar current. Excellent Pleistocene to Miocene calcareous biogenic northern subantarctic biostratigraphic sequence. Significant warming in early Miocene. Obvious cooling in late Miocene and earliest Pliocene.

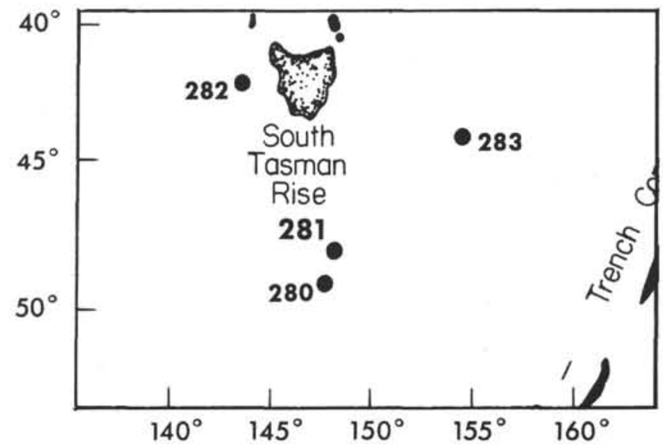

Figure 1. *Location of Site 281, DSDP Leg 29.*

BACKGROUND AND OBJECTIVES

Site 281 was located on the South Tasman Rise in a thin sedimentary sequence that laps onto a basement high (Figures 1 and 2). The water depth was 1530

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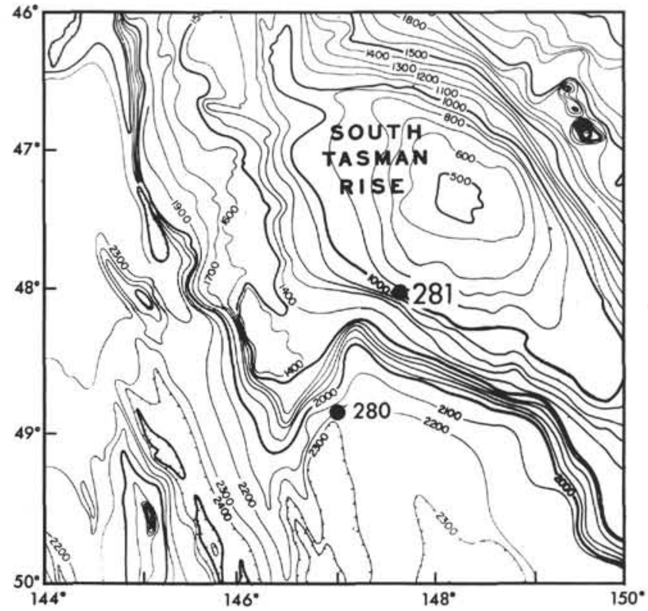

Figure 2. *Bathymetry at Site 281.*

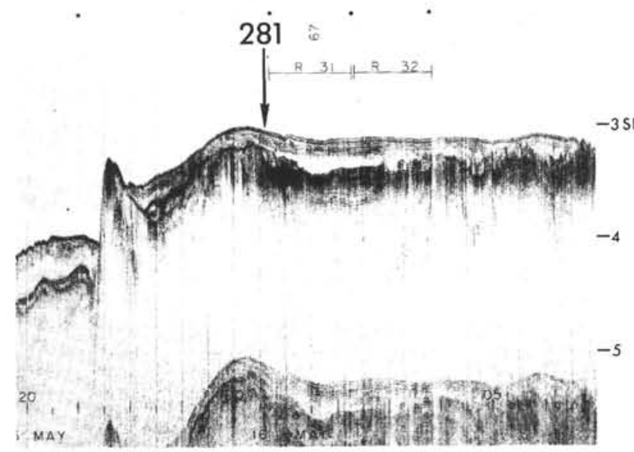

Figure 3. *Profiler section at Site 281.*

meters. A strong reflector, midway in the section, was judged to represent a major lithologic change and possibly an unconformity (Figure 3). The site was located within the northern subantarctic water mass 200-300 km south of the subtropical convergence (Garner, 1954).

The site was selected for drilling to obtain information on the early rifting history of the Tasmanian area and Antarctica, and to determine the structure of the South Tasman Rise. The depth of the South Tasman Rise, its topographic relationship with Tasmania, and its general structure raised the possibility of continental crust being found here. Unlike the Campbell Plateau, however, there are no nearby islands present that might provide information on the nature of basement.

Reconstruction of the Tasmanian area with Antarctica shows the South Tasman Rise to be closely adjacent to the Iselin Bank, north of the Ross Sea.

The primary objectives of Site 281 were: (1) To determine the nature and, if possible, the age of basement. If the material is continental, it is reasonably assured that the circumpolar breakthrough occurred well after initial rifting and that the Iselin Bank overlap cannot be due to postrift volcanism. (2) To determine the history of sedimentation of the older sequence. This should assist in understanding the development history of the circumpolar current south of Australia and Tasmania. (3) To obtain a biostratigraphic section in northern subantarctic waters in shallow waters where the calcareous biogenic components are well preserved. The position of Site 281 near the subtropical convergence makes the late Cenozoic sequence potentially important for paleoclimatic paleo-oceanographic studies.

OPERATIONS

Site 281 on the South Tasman Rise was approached from the west along an *Eltanin*-53 track (Figure 4). The site was selected on the first pass and the beacon was dropped while underway at over 9 km/hr (5 knots).

The bottom hole assembly and drill pipe were run in. An apparent sea floor was tagged at 1580 meters. However, this indication proved to be false. A positive sea floor was tagged at 1601 meters, and the hole was spudded with a mudline punch core. Continuous coring was carried out with erratic recoveries to a depth of 1760.5 meters or 159.5 meters penetration. Core 17 recovered a sample of schist. Two additional cores were cut to a total depth of 1770 meters (169 meters penetration) without any usable recoveries.

Hole 281A was spudded to recore those intervals missed in Hole 281. Three cores were attempted from mudline (1601 m) to 1646.5 meters with very poor recovery. The coring summary at Holes 281 and 281A are included in Table 1.

LITHOLOGY

Drilling at Hole 281 penetrated approximately 162.5 meters of sediment, and bottomed in continental metamorphic basement rocks. Hole 281A was drilled to obtain samples from late Cenozoic intervals missed in Hole 281, and to obtain a better section above the middle Tertiary disconformities found in Hole 281.

The lithologic section at Hole 281 consists of six units, which are summarized in Table 2 and on Figure 5. The section at Hole 281A extended to a depth of 45.5 meters, and is summarized in Figure 6. The cored intervals correspond to Units 1A and 1B at Hole 281.

A coarse-grained granite pebble (6 × 5 cm) was retrieved in a core catcher sample at Hole 281A, at a depth of about 36 meters. This pebble had a coating of white nannofossil ooze, dated as late Pleistocene, and light red clay containing Pleistocene, middle Miocene, and early Pliocene faunal elements. This pebble probably is an ice-rafted erratic from Antarctica as have previously been reported at similar latitudes in the New Zealand region.

Unit 1

Unit 1, 112 meters thick, is a nearly pure calcareous biogenic ooze divided into two subunits based on bedding characteristics and composition. Subunit 1A is

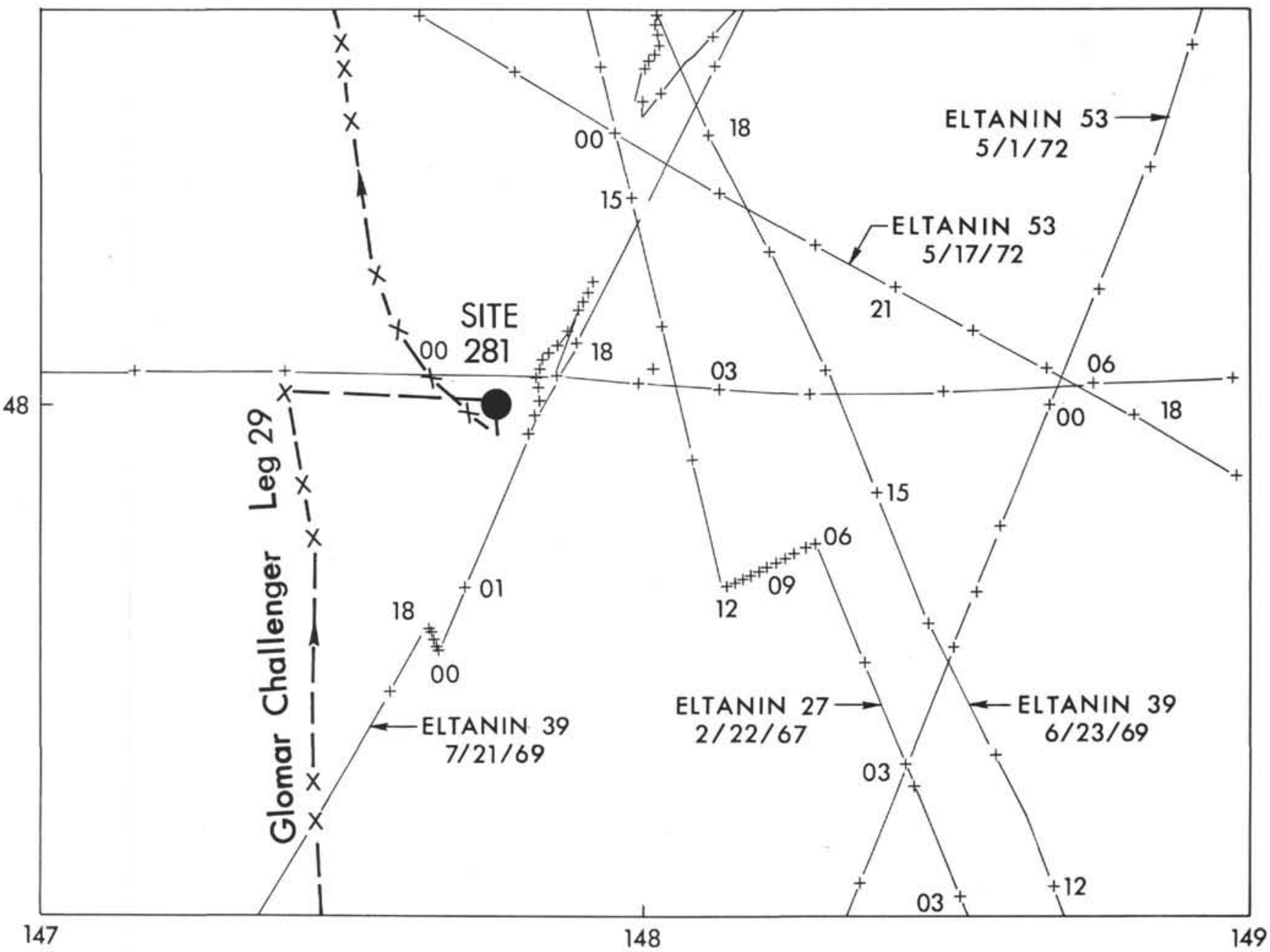

Figure 4. *Track chart.*

composed of white and slightly gray interbeds. The composition ranges from a nannofossil-rich foraminiferal ooze to foraminiferal-nannofossil ooze. The abundance of nannofossils increases downsection, but most sediments except the lowermost few meters contain more foraminifera than nannofossils. Minor amounts of diatoms, radiolarians, spicules, and detrital minerals also occur.

The source of the color differences is unknown. Bedding thicknesses in Subunit 1A range from about 10 cm to 9 meters. The thicker beds are typically white, but contain streaks, patches, and laminations of the grayer white.

Subunit 1B is a massive, white foraminiferal-nannofossil ooze with essentially a uniform composition, although a few smear slides showed more foraminifera than nannofossils. Some light-gray and light-brown patches and streaks occur. Minor constituents include silicoflagellates, diatoms, radiolarians, sponge spicules, and ostracod(?) fragments.

Unit 2

Unit 2, 9.5 meters thick, exhibits a gradational lithologic change from top to bottom. At the top, the sediment is distinguished from the overlying white foraminiferal-nannofossil ooze of Subunit 1B only by the appearance of sand-sized glauconite detrital constituents, and sponge spicules. Downward, the percentage of detrital minerals, and glauconite increases, while the percentage of fossils, especially foraminifera, decreases. Near the base of the unit up to 30% glauconite and 60% detritals are present.

The glauconite and detritals are approximately the same grain size, about 0.4 mm maximum, and many glauconite grains have pitted surfaces. Quartz grains typically are angular. Dolomite rhombohedrons occur in basal portions in this unit.

A biostratigraphically significant lithologic change occurs in a core catcher sample at the base of Unit 2. Dusky-yellowish-green glauconitic sand is present overlying a dusky-green glauconitic sand. A major disconformity spanning the late Oligocene to early Oligocene occurs at this point. Smear slides and washed coarse fractions show the composition of both greensands to be similar: angular quartz and feldspar sand, dark-green to black silt to sand-sized glauconite, foraminifera, and dolomite rhombohedrons. The lower greensand, however, contains coarser and greater abundance of dark glauconite.

TABLE 1
Coring Summary, Site 281

Core	Cored Interval Below Bottom (m)	Cored (m)	Recovery (m)	Recovery (%)
Hole 281				
1	0.0-7.5	7.5	CC	0
2	7.5-17.0	9.5	9.0	95
3	17.0-26.5	9.5	8.7	92
4	26.5-36.0	9.5	0.0	0
5	36.0-45.5	9.5	3.5	37
6	45.5-55.0	9.5	8.1	85
7	55.0-64.5	9.5	9.5	100
8	64.5-74.0	9.5	CC	0
9	74.0-83.5	9.5	9.5	100
10	83.5-93.0	9.5	8.4	88
11	93.0-102.5	9.5	9.3	98
12	102.5-112.0	9.5	9.3	98
13	112.0-121.5	9.5	6.5	68
14	121.5-131.0	9.5	9.5	100
15	131.0-140.5	9.5	3.2	34
16	140.5-150.0	9.5	9.3	98
17	150.0-159.5	9.5	1.8	19
18	159.5-162.5	3.0	CC	0
19	162.5-169.0	6.5	0.0	0
Total		169.0	105.6	62.5
Hole 281A				
1	0.0-9.5	9.5	5.0	53
2	26.5-36.0	9.5	CC	0
3	36.0-45.5	9.5	2.1	22
Total		28.5	7.1	24.9

TABLE 2
Lithologic Summary, Site 281

Unit	Lithology	Subbottom Depth (m)	Unit Thickness (m)
1A	Predominantly interbedded white nannofossil-bearing foraminiferal ooze and foraminiferal-nannofossil ooze	0.0-~59.0	~59.0
1B	Massive, white foraminiferal-nannofossil ooze	~59.0-112.0	~53.0
2	Grading downward from white foraminiferal-nannofossil ooze, to dusky-yellowish-green dolomite and foraminifera-bearing nannofossil and glauconite-rich detrital sand	112.0-121.5	9.5
3	Mostly grayish-olive sandy silts and silty clays	121.5-150.0	28.5
4	Lithified grayish-olive glauconite-bearing detrital sand and foraminifera-rich nannofossil chalk	150.0-153.0+	3.0+
5	Medium greenish-gray quartz-mica schist breccia	~157.5-159.5	2.0±
6	Quartz-mica schist	159.4+	?

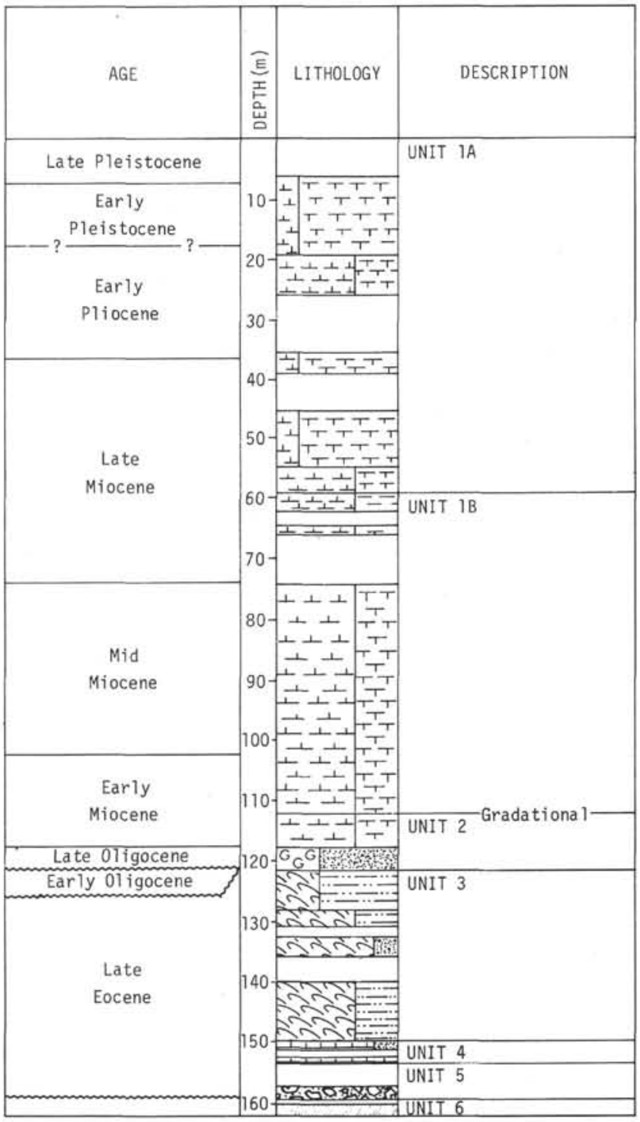

Figure 5. *Stratigraphic sequence, Site 281 (Hole 281).*

Unit 3

Unit 3 is about 28.5 meters thick and consists mostly of grayish-olive glauconitic silty sand to silty clay with a wide variety of abundant microfossils (foraminifera, radiolarians, diatoms, and sponge spicules). The grain size and abundance of detrital constituents decreases down the unit; the proportion of microfossils increases. The uppermost sediment in Unit 3 is a glauconite, foraminiferal, radiolarian, and spicule-bearing detrital silty sand; a typical intermediate-depth sediment is a radiolarian/foraminifera-bearing sponge spicule-rich diatom detrital sandy silty clay; and a typical deeper sediment is a nannofossil-bearing spicule/foraminifera-rich detrital silty clay diatom ooze. The lowermost sediments are diatom oozes with sand-sized detritals instead of silt and clay.

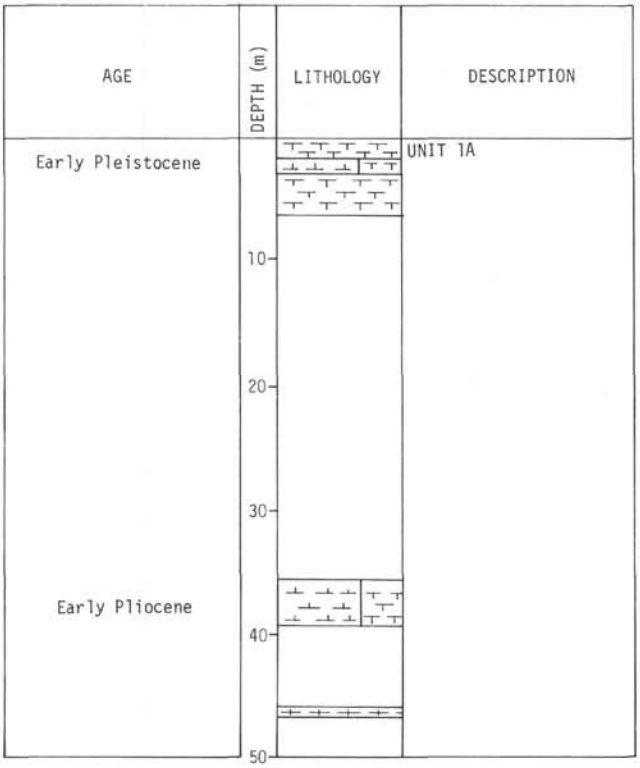

Figure 6. *Stratigraphic sequence, Site 281 (Hole 281A).*

Inspection of the detrital heavy minerals of Units 2 and 3 indicate a metamorphic source. Minerals included are (in order of decreasing abundance): epidote, hornblende, tourmaline, zircon, garnet, andalusite, sillimanite, kyanite, staurolite, and periclase.

Unit 4

Unit 4 is a lithified, peppered light-grayish-olive glauconite-bearing detrital sand, and foraminifera-rich nannofossil chalk. The recovered material (70 cm) consists of lithified blocks alternating with drilling breccia and silty sand (also drilling material?). The lowest lithified block is intensely mottled with patches of grayish olive and lighter grayish olive. The darker areas contain more glauconite than the lighter areas. The reason for the abrupt appearance of lithification at this depth is unknown. The overlying sediments, do not show any marked trend toward increasing lithification with depth and the material underlying Unit 4 is unlithified.

Unit 5

Unit 5 consists of stratified, unlithified breccia containing sand to pebble-size clasts of mica schist, with smaller amounts of quartz, quartzite, glauconite, glauconitic sandstone, and granite. This unit was cored through a depth of 1.3 meters, but may be up to 6 meters thick. The silt and clay-sized matrix material, medium greenish gray, consists of detritals such as quartz and mica.

A very coarse sand to granule breccia occurs in the upper 18 cm of Unit 5. Below this is a 30-cm thick sandy silty clay, which is essentially matrix material of the breccias. Underlying the fine layer is a 75-cm bed of breccia grading from very coarse sand at the top to pebble-sized fragments at its base. The lowest layer, about 10 cm thick, is fine matrix material with some granules. Rare late Eocene benthonic foraminifera were found in Unit 5, implying a marine depositional environment.

Most of the coarse fragments are angular, but some quartz grains are highly rounded and polished. This, and the wide variety of clast types rules out the possibility of the brecciation being totally a result of drilling. However, the breccia may be partially due to drilling. This interval may represent a thin layer of basal pebbly conglomerate that originally rested on schist basement and during drilling the conglomerate grains were mixed downward with drilling chips of schist. This argument is supported by the observation that the largest fragments are mostly angular schist chips, although some large pieces of angular glauconitic sandstone and quartzite are present. The roundness of the sand-size particles generally increases with decreasing size, especially in the nonschistose fraction. Much of the schist has a fresh (just-broken) appearance, but a few fragments including some quartz grains, are iron-stained. This is evidence that at least some schist is detrital, having suffered some weathering.

Another possibility is that the breccia is entirely depositional, and that the round mineral grains (e.g., quartz) are second cycle and/or derived from a further source than the glauconitic sand; the schist would have been derived from very nearby rocks.

Unit 6

This unit is composed of lithified, greenish-black quartz-mica schist. This rock, as recovered, consisted of several laths, about 1 × 6 cm, in a core catcher. Muscovite makes up about 10% of the rock, with the remainder being quartz and perhaps albite.

The total thickness of Unit 6 is unknown. However, acoustic basement is at the approximate depth of Unit 6, and drilling rates decreased significantly at this depth, both strongly suggesting that the schist fragment was from true basement. Drilling continued another 3 meters below the recovery depth of the schist. A 2 × 5 cm moderately rounded pebble, consisting half of dark-gray glauconitic sandstone, and half of light-gray silty limestone, apparently unmetamorphosed, was the only recovery from this deepest core. The significance of this pebble is uncertain, but may represent downhole contamination.

Conclusions

The lithology of the sequence at Site 281, in conjunction with the position of this site on the South Tasman Rise, can be interpreted in terms of the development of the Antarctic circumpolar current and the final rifting of continental Australia from continental Antarctica.

The quartz-mica schist recovered at the bottom of the sequence represents continental basement, part of the southernmost extremity of Australia that formed the last connection with Antarctica. The overlying, poorly sorted schist breccia probably is locally derived. It was deposited in a high-energy, marginal marine environment during the initial transgression of the subsiding South Tasman Rise in the late Eocene. A restricted and battered benthonic foraminiferal assemblage supports this conclusion. The material for this breccia may have been derived from nearby, nonsubsiding high areas.

Shallow-water conditions (neritic-upper bathyal) prevailed during deposition of Units 3 and 4. Lower energy conditions prevailed compared with the underlying schist breccia. This is shown by the smaller average grain size and preservation of delicate benthonic foraminifera.

The upward gradation of sandy sediments of Unit 4 to silty clay oozes at the base of Unit 3 suggests a temporary decrease in current intensity, with an increase again during the deposition of most of Unit 3. This is suggested by the increased grain size and abundance of detritals which may represent the initial development of oceanic circulation between the southeastern Indian Ocean and the Tasman Sea as rifting progressed and caused subsidence of the South Tasman Rise and a shallow-water connection between the two water bodies.

At the top of Unit 3, within the late Eocene, current intensity increased to transportational or erosional regimes producing the late Eocene-early Oligocene disconformity between Unit 3 and the base of Unit 2. Currents temporarily waned to deposit early Oligocene glauconitic sand at the base of Unit 2, but strengthened again to produce a disconformity spanning most of the Oligocene. The late Oligocene glauconitic sand in Unit 2 was deposited by a current with a gradually decreasing load of coarse detrital sand and glauconite. The relative deposition of microfossils increased so that the detrital sediments of Unit 2 grade into an apparently continuous sequence of early Miocene to Recent biogenic oozes in Unit 1.

The glauconite of Unit 2 probably is of detrital origin. The pitted surfaces of the grains suggest transport abrasion (and solution?). The approximate size equivalence of the glauconite to the other detrital grains suggests contemporaneous transport of both components.

The coarse grain size of the detritals and the angular nature of the quartz grains suggests a brief transportational history. Assuming a generally eastward-moving current, transport probably was from nearby shallow areas of the Tasman Rise or Australian shelf-slope. The general upward decrease in abundance of detrital minerals in Unit 2, including glauconite, suggests a general waning of current activity. The current waned in terms of capacity rather than competence because the grain size of detritals does not decrease along with the abundance. The decreased supply of detritals may have occurred as the shallow "proto circumpolar current" moved to the present oceanic position of the circumpolar current south of the South Tasman Rise. This was in response to opening the last deep-water barriers between the southeastern Indian Ocean and the south Tasman Sea-South Pacific Ocean.

The fine-grained, but moderately well-preserved nannofossils of Unit 2 are anomalous in terms of moderate energy currents, but perhaps were originally emplaced as a component of fecal pellets. The decrease of foraminifera toward the lower part of Unit 2 may have been caused by removal of these light tests by currents.

After migration of the "proto circumpolar current" to the south, Site 281 became an area of pelagic biogenic sedimentation that continues to the present day, forming the foraminiferal-nannofossil oozes of Unit 1.

GEOCHEMICAL MEASUREMENTS

Table 3 and Figure 7 show the variations of the geochemical data within the lithologic units. *p*H values in the sediments are all lower in the sediments than in surface seawater reference. Alkalinity and salinity values are all higher in sediments than in seawater.

BIOSTRATIGRAPHY

Site 281, yielded a good sequence of marine microfossils from the late Eocene to Pleistocene. The widespread late Eocene to late Oligocene unconformity recorded by Kennett et al. (1972) and Edwards (1973) in the Coral and Tasman seas is also present.

Calcareous nannofossils are common to abundant throughout the sequence with planktonic foraminifera common in the Neogene and rare in the late Eocene. The stratigraphic distribution of siliceous fossils is complicated, with diatoms present in only some of the

TABLE 3
Shipboard Geochemical Data, Site 281

		Sample Interval		*p*H				
Core	Section	Top (m)	Avg (m)	Punch-in	Flow-thru	Alkalinity (meq/kg)	Salinity (°/oo)	Lithologic Unit
Surface Seawater Reference				7.97	7.79	2.35	34.6	
Hole 281								
3	6	17.0	25.03	7.35	7.46	3.03	35.2	1A
Hole 281A								
3	2	36.0	44.03	7.39	7.51	2.83	35.2	1B
7	4	55.0	60.03	7.42	7.42	3.13	35.2	1B
11	6	93.0	101.03	7.42	7.40	3.03	35.2	1B
14	6	121.5	129.53	7.37	7.45	3.42	35.8	3
Average				7.39	7.43	3.16	35.4	

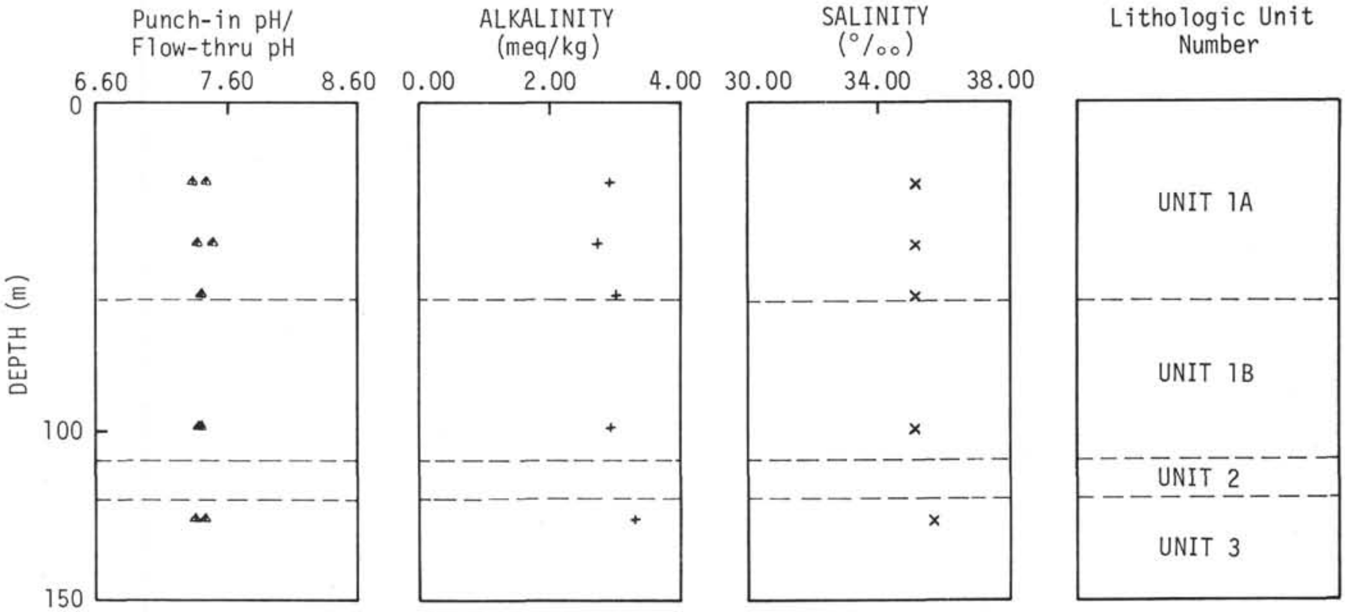

Figure 7. *Shipboard geochemical data versus depth, Site 281.*

Neogene cores but abundant in the late Eocene. Radiolaria are well preserved and abundant in the late Miocene to Pleistocene, rare in the middle-early Miocene, and abundant in the late Eocene. Silicoflagellates are rare to common in the late Eocene, late Miocene and Pleistocene, and palynofloras are common in the upper Eocene.

The late Oligocene to Pleistocene appears to be a complete sequence from the evidence of calcareous nannofossils and planktonic foraminifera, with supporting evidence from the late Miocene to late Pleistocene Radiolaria. Ten planktonic foraminiferal zones and five calcareous nannofossil zones were identified. The late Neogene radiolarian sequence is similar to the Antarctic zonation.

Between the late Eocene in Core 14 and the late Oligocene in Core 13 there are biostratigraphic hiatuses which are listed in Table 4.

TABLE 4
Position of Middle Cenozoic Disconformities at Site 281

Unit	Core[a]		Disconformities
Early Miocene	13		
Late Oligocene	13-3, 130 cm 13		
	13, CC	Upper Greensand	Disconformity
Early Oligocene	13, CC	Lower Greensand	Disconformity
Late Eocene	14		

[a]Recovery for Core 13, 6.5 meters: for Core 14, 9.5 meters.

Foraminifera

Ten Neogene and one late Eocene planktonic foraminiferal zones were identified, (Table 5). The faunas show few signs of solution.

The site is just south of the subtropical convergence and there is some evidence in the early Miocene to Pleistocene faunal sequence that the convergence oscillated north and south over the area. A few specimens of the warm-water *Globigerinella aequilateralis* are present in the Pliocene-Pleistocene *G. (G.) truncatulinoides, G. (T.) inflata,* and *G. (T.) puncticulata* Zones, but it was not accompanied by other warm-water taxa. The only representative of *Globigerinoides,* a relatively warm-water indicator, is *G. trilobus trilobus* occurring in the early Miocene.

The preservation of the Neogene foraminifera is moderate to good, the diversity low to moderate. In contrast, the late Eocene planktonic foraminifera are of low diversity with only a few specimens and the preservation is poor to moderate. Possibly due to the relatively shallow nature of the site during the late Eocene, the benthonic foraminifera are well developed and show no signs of being either reworked or transported. It could be interpreted that the benthonic fauna indicate outer neritic-upper bathyal water depths (200-400 meters), as opposed to the present 1591 meters of water at the site.

Apart from the major unconformity below the early Miocene in the lower part of Core 13, CC, no other stratigraphic breaks were detected.

Globorotalia (G.) truncatulinoides Zone

The fauna is indicative of temperate water but with a few specimens of thw warmer-water *Globigerinella aequilateralis. Globorotalia (G.) truncatulinoides* appears cryptogenically, without its ancestor *G. (T.) tosaensis.*

TABLE 5
Planktonic Foraminiferal Zones, Site 281

Age	Planktonic Foraminiferal Zones	Taxa Used to Delimit the Zones
Pleistocene	*Globorotalia (G.) truncatulinoides*	I.A. *G. (G.) truncatulinoides*
– –?– ?–	*Globorotalia (T.) inflata*	I.A. *G. (T.) inflata*
Pliocene	*Globorotalia (T.) puncticulata*	Ext. *G. (G.) conomiozea*
Upper Miocene	*Globorotalia (G.) conomiozea*	I.A. *G. (G.) conomiozea*
Upper Miocene	*Globorotalia (G.) miotumida miotumida*	Ext. *Globorotalia (T.) mayeri mayeri*
Middle Miocene	*Globorotalia (T.) mayeri mayeri*	I.A. *G. (T.) mayeri mayeri*
Middle Miocene	*Orbulina suturalis*	I.A. *O. suturalis*
Middle Miocene	*Praeorbulina glomerosa curva*	I.A. *P. glomerosa curva*
Lower Miocene	*Globigerinoides trilobus trilobus*	I.A. *G. trilobus trilobus*
Lower Miocene	*Globigerina (G.) woodi connecta*	
	Unconformity	
Upper Eocene	*Globigerina (S.) linaperta*	

Note: I.A. = initial appearance; Ext. = extinction.

Preservation is good and diversity moderate. The boundary between the *G. (G.) truncatulinoides* and the *G. (T.) inflata* zones has been placed between Samples 2-4, 90 cm, and 2-5, 90 cm.

Globorotalia (T.) inflata Zone

At this site the *G. inflata* Zone appears to represent only a short period of time. The lack of warm-water keeled *Globorotalia* is notable, but specimens of *Globigerinella aequilateralis* were recovered. Preservation is good and diversity moderate. The boundary between the *G. (T.) inflata* and the *G. (T.) puncticulata* zones has been placed between Samples 3-2, 20 cm, and 3-2, 100 cm.

Globorotalia (T.) puncticulata Zone

There are no keeled *Globorotalia* in the zone with the numerically dominant species being the zone fossil and *Globorotalia (T.) crassaformis.* Preservation is good and diversity moderate. The boundary between the *G. (T.) puncticulata* and the *G. (G.) conomiozea* zones has been placed between Samples 281A-3-2, 20 cm, and 281A-3-2, 135 cm.

Globorotalia (G.) conomiozea Zone

As distinct from the succeeding two zones, the *G. (G.) conomiozea* Zone contains the keeled *Globorotalia (G.) miozea conoidea, G. (G.) miozea sphericomiozea,* and the zone fossil. Other warmer-water taxa such as *Globigerinoides* are not present. Preservation is good and diversity moderate. The boundary between the *G. (G.) conomiozea* and the *G. (G.) miotumida miotumida* zones has been placed between Samples 5, CC, and 6-2, 45 cm.

Globorotalia (G.) miotumida miotumida Zone

The possibly warm-water keeled *Globorotalia (G.) miozea conoidea* and *G. (G.) miotumida miotumida* contrast with the supposed cooler-water left-coiled *G. (T.) pachyderma* which makes its initial appearance in the zone. This event has also been recorded in New Zealand marine sections at about the same stratigraphic level. It is distinctly possible that the left coiling of *G. (T.) pachyderma* is merely an inherited preference (Jenkins, 1967) rather than reflecting cool climatic conditions. Preservation is moderate to good and diversity moderate. The boundary between the *G. (G.) miotumida miotumida* and the *G. (T.) mayeri mayeri* zones has been placed between Samples 9-3, 100 cm, and 9-4, 20 cm.

Globorotalia (T.) mayeri mayeri Zone

There are only very rare keeled *G. (G.) miotumida* in the zone with a predominance of unkeeled *Globorotalia. Globorotalia (T.) peripheroronda,* ancestor of the zone fossil, was not recorded in the lower part of the zone in contrast to its presence in southeastern Australia and New Zealand (Jenkins, 1960, 1971). It is assumed that *G. (T.) mayeri mayeri* is cryptogenic in this region. Preservation is moderate and diversity fairly low. The boundary between the *G. (T.) mayeri mayeri* and the *O. suturalis* zones has been placed between Samples 9, CC, and 10-3, 50 cm.

Orbulina suturalis Zone

Globorotalia (T.) conica is a common species in the zone with both thick- and thin-walled forms: the thick-walled forms can easily be misidentified as *G. (G.) miozea.* The zone fossil is very rare and occurs without its ancestor *Praeorbulina.* Preservation is moderate and diversity low. The boundary between the *O. suturalis* and the *P. glomerosa curva* zones has been placed between Samples 10, CC, and 11-1, 20 cm.

Praeorbulina glomerosa curva Zone

There are so few specimens of the *Orbulina* lineage in the zone that it is not possible to observe the transition from *Globigerinoides trilobus bisphericus* to *P. glomerosa curva.* The paucity of members of the *Orbulina* lineage is best explained by the high latitude position of the site. Preservation is moderate and diversity low. The boundary between the *P. glomerosa curva* and the *G. trilobus trilobus* zones has been placed between Samples 11-1, 20 cm, and 11-1, 102 cm.

Globigerinoides trilobus trilobus Zone

The zone fossil, presumed to have been temperature controlled, is very rare in the zone. As at Site 279, *Globigerinita dissimilis* ranges into the lower part of the *G. trilobus trilobus* Zone, an extinction level which is much higher stratigraphically than that recorded in New Zealand. Preservation is moderate and diversity low to moderate. The boundary between the *G. trilobus trilobus* and the *G. woodi connecta* zones has been placed between Samples 12-3, 100 cm, and 12-4, 20 cm.

Globigerina (G.) woodi connecta Zone

The presence of *Globigerina (G.) eamesi* in the zone, not recorded at sites further south, suggests that its southern distribution is probably temperature controlled. The more northern warmer-water species, such as *Globorotalia (T.) kugleri* and *Globigerinoides altiapertures,* are not present in the zone. Preservation is moderate and diversity moderate to low. A major unconformity exists between the lower Miocene *G. (G.) woodi connecta* Zone of Core 13, and the upper Eocene *G. (S.) linaperta* Zone of Core 14. In the lower part of Core 13, CC, the presence of *G. (G.)* cf. *ampliapertura* and *G. (S.) angiporoides angiporoides* suggests an early Oligocene age.

Globigerina (S.) linaperta Zone

A poor planktonic foraminiferal fauna in this zone is best developed in Core 16, but in Cores 14 to 15 there is a decrease in number of specimens.

Benthonic foraminifera occur in all samples examined including one from Core 17. The following are recorded: *Alabamina, Anomalinoides, Bulimina, Cassidulina, Cibicides, Elphidium, Frondicularia, Gyroidinoides, Nodosaria, Nonion, Trifarina,* with some polymorphinids and rare agglutinated forms. Similar assemblages are found in Recent sediments on the outer continental shelf to upper continental slope. The benthonic specimens show no indication of being transported from shallower water, thus probably represent evidence of deposition on the outer continental shelf and upper continental slope.

Calcareous Nannofossils

This site provided common to abundant and fairly well preserved but rather low diversity nannofloras throughout all but the basal part. There they are sparse, poorly preserved, and very low in diversity. The assemblages obtained indicate a sequence consisting of a relatively thin but apparently complete latest Pleistocene to late Oligocene succession unconformably underlain by very thin mid early Oligocene. This in turn is underlain, probably unconformably, by relatively thick early late Eocene (Table 6). Thus this site appears to have been subjected to the same events as those which formed the late Oligocene unconformity at Site 282 and the regional Eocene-Oligocene unconformity of DSDP Leg 21 in the southwest Pacific (Kennett et al., 1972; Edwards, 1973). A thin but distinctive greensand of early Oligocene age separates these events at this locality.

In general the nannofloras obtained from this site imply moderately quiet water deposition at bathyal depths from cool oceanic surface waters. However, several significant trends and variations were observed which are considered to reflect local and regional paleocirculation changes resulting from active sea-floor spreading between Antarctica and Australia. The mid-late Neogene climatic deterioration trend evident at this site closely parallels that at Site 279 on the opposite side of the Tasman Sea. Similar trends have been recorded to the north in southeast Australia, New Zealand (Hornibrook, 1971), and the Tasman Sea Leg 21 sites. It is clearly a regional feature.

The late Pleistocene *Coccolithus pelagicus* Zone of this site appears to be represented by two distinctly different foraminiferal ooze successions. In Hole 281, this zone contains questionable specimens of the latest Pleistocene taxon *Emiliania huxleyi* at the top (Sample 281-1, CC). In Hole 281A, this zone does not appear to contain *E. huxleyi.* This difference could be a real feature. However, the observed situation probably results from either downhole contamination (in 281), or reworking (in 281A). The nannofloras of this zone are abundant and excellently preserved, however, the diversity is rather low, as expected in the subantarctic. The presence of a relatively high ratio of large to small coccoliths in most assemblages indicates that the original floral balance has often been substantially modified by winnowing. Sample 281-1, CC, the youngest sample obtained, contains low numbers of *Syracosphaera hystrica, Gephyrocapsa oceanica, Rhabdosphaera claviger, Pontosphaera japonica,* and other taxa characteristic of the warm-water sphere. Other samples almost completely lack these species.

TABLE 6
Calcareous Nannofossil Biostratigraphy of Site 281

Age	Zone	Hole 281	Hole 281A
Pleistocene	*C. pelagicus*	1, CC 2-1, 30 cm to 2-2, 130 cm	1-1, 145 cm
Pleistocene / Pliocene	*P. lacunosa*	2-3, 30 cm to 3-5, 130 cm	1-2, 145 cm to 1, CC
Pliocene / Late Miocene / Mid Miocene	*Reticulofenestra pseudoumbilica*	3-6, 30 cm to 5, CC 6-2, 30 cm to 9, CC	3, CC
Mid Miocene	*Cyclicargolithus neogammation*	10-3, 63 cm to 12-4, 30 cm	Not drilled
Early Miocene	*Discoaster deflandrei*	12-4, 130 cm to 13-3, 57 cm	
Late Oligocene	*Reticulofenestra bisecta*	13-3, 130 cm to 13, CC (middle)	
Mid Oligocene		Major unconformity	
Early Oligocene	*Reticulofenestra placomorpha*		
	Blackites rectus	13, CC (base)	
Late Eocene	*R. oamaruensis*	Unconformity or very condensed sequence	
	D. saipanensis		
	I. recurvus		
	C. oamaruensis	14-1, 0 cm to 17-6, 36 cm	
	R. bisecta	Major hiatus	

The mid Pleistocene to late Pliocene *Pseudoemiliania lacunosa* Zone is 10 meters thick in Hole 281, and at least 4 meters thick in Hole 281A. However, the true thickness may be as great as 23 meters. The nannofloras of this interval are common to abundant and moderately well preserved but are usually of low diversity and subjected to varying degrees of winnowing. All of the nannofloras contain abundant *Gephyrocapsa s.l.* plus rare *P. lacunosa,* but no discoasters were observed. An undifferentiated mid Pleistocene to late Pliocene age is adopted for this interval. Sample 281-3-5, 130 cm, contains a surprisingly large number of warm-water species including, in decreasing order of abundance, *Scyphosphaera* spp., *Syracosphaera pulchra, S. hystrica,* and *Rhabdosphaera claviger.* Apart from *S. hystrica,* which has an upward decreasing frequency, these taxa were not observed in the overlying samples examined from this interval. This situation would appear to indicate the occurrence of a short lived, but significant climatic amelioration pulse at the base of the late Pliocene. It appears to have been preceded and succeeded by very slightly warmer than normal conditions.

The early Pliocene to late mid Miocene *Reticulofenestra pseudoumbilica* Zone of this sequence is 60 meters thick. The nannofloras of this interval are common to abundant and moderately well preserved but are usually of low diversity and some have been subjected to significant winnowing. Fortunately, at this site this large time interval can be informally subdivided into two parts based on the last appearance of very rare *Triquetrorhabdulus rugosus s.l.,* a late Miocene to late-mid Miocene taxon.

The upper part of this zone is 15-20 meters thick and, in addition to abundant *R. pseudoumbilica,* contains at its base (e.g., Sample 281-5, CC) a few of the early Pliocene to latest Miocene index species *Ceratolithus tricorniculatus s.s.* Comparison with unpublished New Zealand investigations implies a "mid" Opoitian to basal Kapitean (early Pliocene to ?late late Miocene) age for this interval. During shipboard investigations a single specimen of the early early Pliocene index species *Ceratolithus amplificus* was observed in Sample 281A-3, CC (just above Sample 281-5, CC), but this species was not observed again. Discoasters are present throughout this interval, but collectively only 21 specimens (*Discoaster variabilis, D.* sp. indeterminate, and *D. surculus*) were observed. Obviously they must be considered as "visitors" to this subantarctic area. The occurrence of very rare *R. claviger* and *S. pulchra* at the top of this interval, and of very rare *C. tricorniculatus* at the base of this interval, are attributed to the occurrence of very slightly warmer than normal conditions.

Sample 281A-2, CC consists of a granite pebble presumed to have been ice-rafted to this site. Recesses in the pebble contain two different lithologies; a white foraminifera-rich nannofossil ooze and a reddish gritty fine silt. Nannofossils are abundant and moderately well preserved in the ooze, but very rare and poorly preserved in the silt; both assemblages have very low diversities. A late early Pliocene age seems likely since both nannofloras contain common *Gephyrocapsa s.l.* plus very sparse *R. pseudoumbilica.* However, the possibility that this pebble fell down the hole during drilling operations cannot be excluded.

The lower part of the *R. pseudoumbilica* Zone contains extremely low numbers of corroded *T. rugosus s.l.*, but lacks ceratoliths. This situation, suggests a late Miocene to late mid Miocene age for this interval. As in the overlying interval discoasters are extremely rare throughout, being represented by occasional specimens of *D. variabilis, D. brouweri,* and *D.* sp. indeterminate. The only other nannolith present is *Sphenolithus moriformis s.l.* which occurs in low but variable numbers in the lower two thirds of this interval. The presence of this "warm water" taxon may indicate the occurrence of slightly warmer conditions than those characteristic of the overlying intervals.

The early mid Miocene *Cyclicargolithus neogammation* Zone consists of about 25 meters of foraminiferal-nannofossil ooze. The nannofloras of this interval are abundant and moderately well preserved but have rather low diversities. Apart from the common presence of *C. neogammation,* the assemblages present in the upper part of this zone are very similar to those in the lower part of the overlying zone. In contrast the nannofloras from the lower part of this zone additionally contain rare to very rare *Discoaster adamanteus* and *D. variabilis s.l.* This situation is attributed to a gradually deteriorating climate.

The early Miocene *Discoaster deflandrei* Zone consists of about 7 meters of foraminiferal-nannofossil ooze which near the base becomes glauconitic. The nannofloras are abundant and more or less moderately well preserved but have low diversities. Nannoliths are present in large numbers throughout, especially in the upper part. Taxa identified include, in decreasing order of abundance, *D. deflandrei* group, *D. adamanteus, S. moriformis* group, and in Sample 281-12, CC, a specimen of *S.* cf. *heteromorphus.* The nannoliths have been subjected to strong overgrowth. Using only calcareous nannofossils it is not possible to determine whether or not this very thin interval provides a complete depositional record. The presence of large numbers of nannoliths in this interval is attributed to the presence of a climate which was significantly warmer than today (cf. Site 279).

The late Oligocene is represented by 4 meters of disturbed sediment. The nannofloras grade from abundant, moderately well preserved, and essentially unwinnowed at the top to few, poorly preserved, and strongly battered at the base. Despite this, the diversity does not vary greatly through the interval and only one out of place specimen (*Reticulofenestra oamaruensis* in Sample 281-13, CC [upper]) was observed. Consequently, despite a substantial unconformity (disconformity?) at the base of this interval, all of the assemblages can be unambiguously placed in the mid to late Oligocene *Reticulofenestra bisecta* Zone of Leg 29. Because of the relatively low frequency of the index species and the absence of *Chiasmolithus oamaruensis,* late Oligocene is suggested for this interval. The validity of this age refinement cannot be assessed using only nannofossils because of the absence of undoubted mid Oligocene sediments. The common occurrence of *Chiasmolithus altus* and the complete absence of *Zygrhablithus bijugatus* clearly indicates a high latitude origin for the assemblages of this interval. No neritic nannofossils were observed and discoasters are only rarely present.

The early Oligocene contains a common, rather variably preserved, and fairly diverse assemblage which includes both abundant nannofossil detritus and moderately well preserved specimens of *Reticulofenestra oamaruensis,* complete with its large fragile central grill. Although this situation clearly implies at least partial bottom current transport prior to deposition, no obvious reworking from older sediments was observed. The nannoflora conforms to the early early Oligocene (earliest Whaingaroan) *Blackites rectus* Zone of Edwards (1971). Furthermore, the presence of sparse *Discoaster deflandrei* suggests a position high in this zone. This assemblage also conforms to the late early Oligocene *Helicopontosphaera reticulata* (NP22) Zone of Martini (1971). However, at this locality the validity of the age assignments normally given to these zones are open to question since neither *Discoaster saipanensis* nor *"Cyclococcolithus" formosus* occur in this sequence. Despite this, mid early Oligocene still seems likely because of the absence of *Cyclicargolithus reticulatus,* a species which became extinct at the end of the Eocene (Gartner, 1971). No neritic nannofossils were observed. An unconformity or a highly condensed sequence (maximum thickness of 2 m) separates this interval from that below.

The early late Eocene is represented by a 30-meter interval. Nannofloras are common to abundant, moderately well preserved, and diverse in the upper unit, but sparse, very poorly preserved, and low in diversity in the lower unit. Part of the assemblage in the basal breccia is moderately well preserved and may result from downhole contamination. All of the assemblages in this interval conform to the early late Eocene (mid Kaiatan) *Chiasmolithus oamaruensis* Zones of Edwards (1971) and Martini (1971). *Discolithina pulchra* and *D. pulcheroides* occur rarely in the upper lithologic unit. Their presence is interpreted as indicating the occurrence of a neritic environment somewhere in the general vicinity of this site. The in situ nannofloras obtained from the lower unit consist almost entirely of three small species the same as the upper unit, the result of either selective deposition or restricted environmental conditions. The latter is consistent with the close proximity of Site 281 to Antarctica at this time (Weissel and Hayes, 1972, fig. 13).

Diatoms

Samples from Cores 1-16, and Sample 281-17-6, 133 cm, were studied. Only poorly preserved rare diatoms were found in Sample 3-3, 120 cm, and from 6-2 120 cm to 9, CC. Very well-preserved diatoms with high diversity were found in Cores 14-16. All the other samples were barren of diatoms.

The abundance of diatoms correlates with the abundance of Radiolaria, silicoflagellates, and sponge spicules. The thanathocoenosis consists of large marine species, with no records of fresh water or brackish water species.

Sample 281-1, CC contains some poorly preserved specimens including *Coscinodiscus* sp., *Nitzschia* sp., *Thalassionema* sp., and *Thalassiotrix longissima.* These indicate a late Pleistocene age.

Sample 281-3-3, 120-122 cm contains *Actinocyclus ellipticus, A. ingens, A. octonarius, Schimperiella antarctica,* and *Thalassionema nitzschioides.* A middle Pliocene age is suggested.

Samples 281-6-2, 120 cm, to 9, CC: The number and diversity of diatoms present is higher than in the overlying intervals, but they are poorly preserved and many are fragmented. The taxa present consist of long-ranging species but these assemblages can be easily separated from the Pleistocene, because the presence of *Actinocyclus ellipticus, A. ingens, A. octonarius, Coscinodiscus marginatus, C. tabularis, Denticula lauta, D. punctata, Fragilariopsis* sp., *Hemidiscus antarcticus, H. karstenii, Rhisosolenia curvirostris, Rouxia californica, Thalassionema nitzschioides, T.* sp., and *Triceratium* sp. A late middle Miocene age is suggested.

Samples 14, CC to 16, CC: These thanathocoenoses are markedly different from those in the overlying middle Miocene because of the lack of certain typically Neogene diatoms and the presence of several forms which are probably new taxa. The samples include new species of *Pyrgopyxis, Pyxilla, Rhisosolenia, Stictodiscus, Triceratium,* and *Trinacria.* The assemblages are very rich in well-preserved diatoms, and the diversity is very high.

The following species are described and known from the late Eocene diatomite deposits in Oamaru, New Zealand: *Acanthodiscus vulcaniformis, Arachnoidiscus russicus, Auliscus oamaruensis, Biddulphia rigida, Coscinodiscus stellaris* var. *symbolophora* f. *oamaruensis, Muelleriopsis limbata, Pseudorutilaria monile, Pyxilla danica, Stephanopyxis barbadensis, S. marginata, S. megapora, S. superba, Stictodiscus grovei, Triceratium crenulatum, T. dobreanum* n. var. *zelandica, T. fractum, T. morlandii, T. pulvinar, Trinacria excavata,* and *Xanthiopyxis panduraeformis.* The age of this sediment is late Eocene. Plates 1 and 2 illustrate the late Eocene assemblage recovered from Hole 281.

Radiolaria

Scattered, well preserved radiolarians occur in the late Miocene to late Pleistocene at Site 281. That part of the sequence that is represented appears to be similar to the Antarctic zonation of Hays (1965) and Hays and Opdyke (1968) although subtropical forms are more important at some horizons because of the influence of the southern subtropical water mass close to the north.

From Samples 281-1, CC to 281-3-1, 10 cm, Radiolaria are absent or very rare. In Samples 281-3-1, 90 cm to 281-3, CC, the presence of *Eucyrtidium calvertense* and *Clathrocyclas bicornis* indicates early Matuyama (late Pliocene). In Sample 281A-3-5, 10 cm to Section 281-6-2 the presence of *C. bicornis, E. calvertense, Lychnocanium grande rugosum, Triceraspyris* sp., and *Stichocorys peregrina* indicates an early Gilbert age which in terms of the dated New Zealand section is of latest Miocene age (Kennett and Watkins, 1972). Below about Section 281-6-5 no known subantarctic radiolarian zonation can be applied. Radiolaria are rare to common and moderately well preserved from Section 281-7-2 to Sample 281-16, CC.

Silicoflagellates

Silicoflagellates were found to be rare to common in the Pleistocene (Core 1), the late Miocene (Cores 6-8), and the late Eocene (Cores 14-16). *Distephanus speculum* dominates in the Pleistocene, *Mesocena diodon* in the late Miocene, and different species of *Naviculopsis* in the late Eocene. *Dictyocha* is rare in the Pleistocene, missing in the late Miocene, and common in the late Eocene. Diversity is high (4-12 species) in the late Eocene and low (1-4 species) in the late Miocene and Pleistocene. Based on the *Dictyocha/Distephanus* ratio (Mandra, 1969) climatic conditions were possibly subantarctic in the Pleistocene, Antarctic in the late Miocene and subtropical to tropical in the late Eocene.

Palynology

Five cores (10 samples) were examined for palynomorphs, all from the lowest part of the succession (Units 2-6). (See also Chapter 16, this volume). Unit 2 (Core 13), dated as Oligocene-early Miocene was barren of palynofloras. Unit 3 (Cores 14-16, 7 samples) yielded good palynofloras indicating a probable late Eocene age in comparison both with other DSDP sites and Antarctic and South American localities (McIntyre and Wilson, 1966; Wilson, 1967; Archangelsky, 1969). Dinoflagellate species include *Spinidinium aperturum* Wilson, *S. rotundum* Wilson, *Deflandrea phosphoritica* Eis., *D. asymmetrica* Wilson, *D. macmurdoensis* Wilson, *Palaeoperidinium* sp., *Cleistosphaeridium* spp., *Operculodinium* sp., *Spiniferites cingulatus* (O. Wetz.), *Turbiosphaera filosa* (Wilson), *Palmnickia* aff. *lobifera* Eis., *Horologinella* sp., and *?Fromea* sp. Palynofloras are dominated by *Spinidinium* spp. Miospores are relatively rare and include *Nothofagus* (*fusca* group), *Nothofagus* (*brassi* group), Myrtaceae, *Proteacidites parvus* Cookson, *Microcachryidites antarcticus* Cookson, and rare disaccate species. Unit 4 was not examined. Sample 281-17-6, 86 cm from Unit 5 yielded a moderately good dinoflagellate assemblage dominated by *Deflandrea macmurdoensis* Wilson. Other species include *D. asymmetrica* Wilson, *D. distincta* Wilson, *D. phosphoritica* Eis., *Spinidinium aperturum* Wilson, *S. rotundum* Wilson, and *Cleistosphaeridium* sp. Miospores are very rare. No significant age difference between this assemblage and those of Unit 3 could be distinguished; probably late Eocene. Unit 6 was not examined.

SEISMIC DATA

Profiler data in the region of Sites 280 and 281 show a thick (≅2km) sequence of acoustically transparent sediment filling a rough basement surface. As nearly as can be judged, these sediments are Eocene on the basement surface at both sites; it seems reasonable that the entire transparent sequence will not be any older in the lows areas. This is borne out by the existence of very numerous schist fragments in the basal sediment at Site 281, which is on a structural high, and by the history of opening between Australia and Antarctica. Hence the Late Cretaceous on the southern Campbell Plateau is analogous to the thick late Eocene on the Tasman Rise: both were formed near the time of initial spreading.

The very rough basement of the South Tasman Rise (see also, the structure section, Figure 10 of Chapter 42, this volume) may be an indicator of its continental origin. The basement has been truncated by an erosional surface that correlates with a very strong reflector in the profiles. This reflector at a depth of 0.14 sec of reflection time corresponds exactly with the Oligocene-late Eocene unconformity at a depth of 120 meters. The mean velocity of 1.7 km/sec in this layer is predicted by the sonobuoy results.

SEDIMENTATION RATES

Sedimentation rates are based on several accurately determined biostratigraphic horizons. The sedimentation rate curve (Figure 8) clearly shows the following major events in the sedimentary history: (a) moderately rapid sedimentation in the early late Eocene; (b) a major unconformity spanning almost the entire Oligocene and much of the late Eocene; and (c) slow and continuous deposition during the early Miocene-Recent.

Estimated ages of nannofossil zones within the late Eocene indicate that moderately rapid sedimentation rates (2-3 cm/1000 yr) occurred during deposition of biogenic-detrital sediments.

The major unconformity is associated with a thin (8 cm) greensand layer, the lower part of which is early Oligocene, and the upper part early Miocene. The greensand appears to represent a period of extremely slow deposition (nondeposition) resulting from intensified bottom current activity. The unconformity is equivalent to and almost certainly genetically related to the southwest Pacific regional unconformity discovered during DSDP Leg 21.

Sedimentation began again in the earliest Miocene or latest Oligocene with deposition of foraminiferal-nannofossil, and nannofossil-foraminiferal oozes. Sedimentation rates in the Neogene are very slow (0.7 cm/1000 yr), although there are no apparent breaks in sedimentation.

SUMMARY AND CONCLUSIONS

Site 281 was drilled in a water depth of 1530 meters on the South Tasman Rise in a sedimentary sequence that onlaps a basement high (Figures 1 and 2). Approximately 159 meters of sediment was drilled, bottoming out in continental metamorphic rocks. Six units are distinguished: 112 meters of early Miocene-Recent nannofossil-foraminiferal and foraminiferal-nannofossil oozes (Unit 1) underlain gradationally by 9.3 meters of greenish-gray glauconitic sands of late Oligocene and early Oligocene age (Unit 2). Two major unconformities span most of the Oligocene and late late Eocene. A very thin layer (0.2 m) of early Oligocene greensand occurs between the unconformities, forming the base of Unit 2. The late Eocene unconformity is underlain by 28.5 meters of biogenic-rich glauconitic silty sands of early late Eocene age (Unit 3), in turn underlain by more than 3 meters of glauconite-bearing detrital sand and foraminifera-rich nannofossil ooze of early late Eocene age (Unit 4). Beneath this are more than 2 meters of heterogeneous pebbly breccia of late Eocene age containing abundant fragments of quartz-mica schist (Unit 5). Underlying the breccia is quartz-mica schist basement rock (Unit 6), proving the continental nature of the South Tasman Rise. Paleozoic schist is known from Tasmania. The schist cored at Site 281 is probably of similar age.

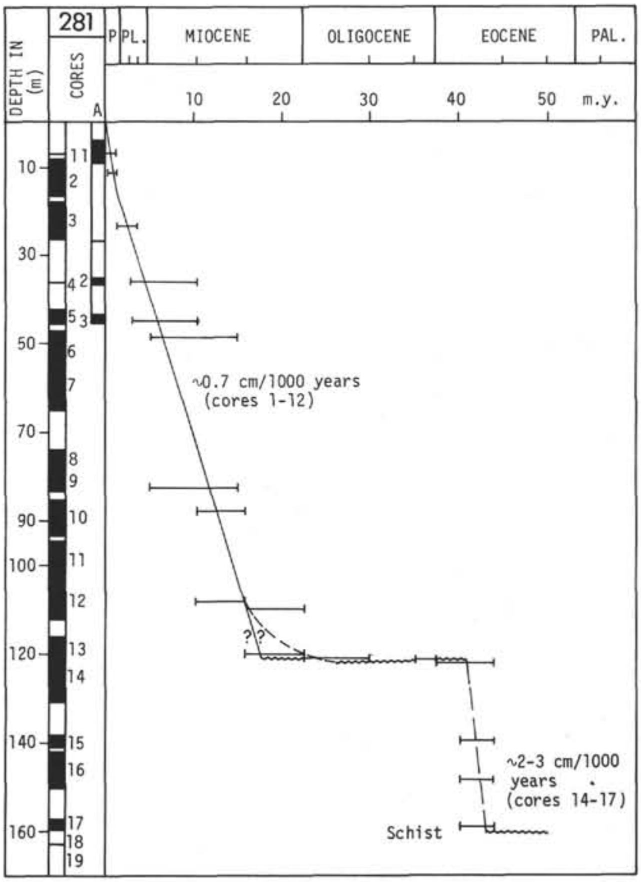

Figure 8. *Sedimentation rate curve for Site 281; ages based on nannofossils.*

The sequence, located in present-day subantarctic waters, yielded marine microfossils from the late Eocene and the early Miocene to Pleistocene. It is particularly notable for the excellent Pleistocene to Miocene calcareous biogenic northern subantarctic biostratigraphic sequence. Presence of common discoasters in the early Miocene of these latitudes indicate surprising warmth, also known in northern New Zealand at the time. The nannofossils also indicate substantial cooling in the late Miocene and earliest Pliocene.

Hole 281A was drilled to obtain samples from late Cenozoic intervals missed in Hole 281 and a better section over the middle Cenozoic disconformities. Three cores were obtained, consisting of foraminiferal-nannofossil and nannofossil-foraminiferal oozes, belonging to Unit 1. A large granite pebble from an early Pliocene interval, coated with late Pleistocene nannofossil ooze, is an ice-rafted erratic similar to erratics previously reported at similar latitudes in the New Zealand region.

Conclusions

Confirming that the South Tasman Rise is continental and not formed by postrift volcanism, it is now well established that the main circumpolar current breakthrough occurred well after initial rifting of Australia and Antarctica. However, the problem of overlap of the South Tasman Rise with the Iselin Bank may still exist and must be accounted for in any model of Australian-Antarctic reconstruction.

The basal sediments at Sites 280 and 281 are at least 10 m.y. younger than the oldest anomalies dated by Weissel and Hayes (1972). It seems unlikely that older sediments have eroded off the basement high at the drill site because the transition from the mica-schist basement to a basal angular conglomerate of schist fragments seems to be uninterrupted. Presumably, the South Tasman Rise subsided well after initial separation. This may be related to its fault contact with Victoria Land during the initial phases of separation, i.e., it was not free to subside in isostatic equilibrium while it was largely in contact with the mainland.

During the early late Eocene, sedimentation began with the deposition of poorly-sorted schist breccia. This was locally derived and deposited in a high energy, probably shallow-water, marine environment during the initial transgression of the subsiding South Tasman Rise. A low diversity and battered benthonic foraminiferal assemblage supports this conclusion. Further subsidence occurred during the early late Eocene during moderately rapid deposition (2-3 cm/1000 yr) of thin sequences of glauconite bearing detrital sand, foraminifera-rich nannofossil chalk, and biogenic rich glauconitic silty sands. Shallow-water benthonic foraminifera and neritic nannofossils indicate deposition at neritic-upper bathyal depths throughout this interval. The presence of rare *Elphidium* in the latest part of the late Eocene may indicate shallower conditions at this time. Much lower energy conditions prevailed compared with the underlying breccia as shown by the fine sediments. The presence of detrital grains indicate that bottom currents were active although not strong enough to fragment delicate nannofossils and benthonic foraminifera. The gradation of sandy sediments to silty clay oozes within the late Eocene suggests that current intensity temporarily decreased again. This trend was again reversed even later in the late Eocene, indicated by increased sediment grain size and abundance of detritals. Relatively high biogenic productivity in the late Eocene, despite shallow-water conditions may have been caused by upwelling of deeper waters over the rise.

The near absence of planktonic foraminifera in the late Eocene is puzzling. Calcium carbonate dissolution does not seem to have occurred because of the presence of rather delicately preserved calcareous benthonic foraminiferal assemblages and a well preserved calcareous nannofossil assemblage. Their absence cannot be explained by restricted oceanic conditions because forms that are even more sensitive to near shore or less oceanic conditions, including diatoms, radiolaria, and calcareous nannofossils, are present in large numbers.

Toward the end of the Eocene, bottom currents increased to transportational or erosional intensity, producing the late late Eocene to earliest Oligocene disconformity. Currents waned temporarily during a brief interval in the early Oligocene causing the deposition of glauconitic sand at the base of Unit 2. This current again increased in intensity and continued to be active to the late Oligocene, producing the other major disconformity spanning most of the Oligocene and the earliest Miocene. Together these two unconformities or highly condensed sequences involving most of the Oligocene and the late late Eocene can be correlated with the regional Coral and Tasman Sea unconformity found during DSDP Leg 21. Association of the disconformities with greensand suggests a period of nondeposition or slow deposition rather than erosion, resulting from moderately intense bottom currents.

Sedimentation resumed in the late Oligocene with deposition of a thin sequence of glauconitic sand by a current with gradually decreasing load of coarse detritals and glauconite. Pitted surfaces of the glauconite and size equivalence to detrital grains suggest a transported (detrital) origin rather than an authigenic origin. Upward decrease in detritals suggests decrease in bottom current activity. At the same time, the biogenic fraction increases upwards so that the late Oligocene detrital sediments grade rapidly into calcareous biogenic oozes of the Neogene. Sedimentation rates in the Neogene are very slow (0.7 cm/1000 yr) but with no apparent breaks in sedimentation.

The sequence at Site 281, in conjunction with its position on the South Tasman Rise, is interpreted in terms of an initial development in the late Eocene of a shallow marine connection between Tasmania and Antarctica, associated with the rifting and early spreading of Australia and Antarctica. This was followed by a changing sedimentary environment due to the development near the Oligocene-Miocene boundary, of deep-sea circumpolar circulation south of the South Tasman Rise.

Evidence from Sites 280 and 282 suggest that deep circumpolar circulation south of the South Tasman Rise was not established until about the middle Oligocene. Shallow marine conditions were, however, established earlier than this in the late Eocene over the South Tasman Rise. Current intensities were low in the early late Eocene. Intensification of bottom current activity in the latest Eocene and in the Oligocene may have been due to increased glaciation of Antarctica at that time. The effects of intensified circulation are recorded at Site 281 by the prolonged period of nondeposition or very slow glauconite sedimentation. Reinitiation of sedimentation and decreasing detrital influence in the late Oligocene and earliest Miocene reflects the diminishing effects of the circumpolar current over the South Tasman Rise as it moved farther northward from Antarctica; the circumpolar flow established the position south of the South Tasman Rise much as it is in the present day.

Much of the South Tasman Rise then became a quiet area of pelagic biogenic sedimentation that has persisted to the present forming the early Miocene-Recent foraminiferal-nannofossil oozes.

The sedimentary record at Site 281, which is distinctly different from that of Site 280 in deep water to the south, records the development of a shallow marine connection between Indian Ocean and Pacific Ocean waters in the late Eocene and continuing throughout the Oligocene. During this time sustained currents flowed over the rise. At the beginning of the Neogene uninterrupted sedimentation commenced when deep-seated circumpolar flow became established to the south (Site 280); and as the northward movement of the South Tasman Rise, widened the path of potential west-east flow. Site 281 has close affinities with north Tasman Sea-Coral Sea sites, while Site 280 has closer affinities with sites south of New Zealand. Both sites record major middle Cenozoic paleocirculation changes in the southwest Pacific related to the development of the circumpolar current.

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PLATE 1

Late Eocene Diatom Assemblage from Hole 281

Figure 1	*Stephanopyxis grunowii* Gr. and St.; Sample 14, CC.
Figure 2	*Dicladia* sp.; Sample 14, CC.
Figure 3	*Stephanopyxis* sp.; Sample 15, CC.
Figures 4, 5, 7, 9	*Pyxilla* sp. 4. Sample 14, CC. 5, 9. Sample 16, CC.
Figure 6	*Pyxilla dubia* Grun.; Sample 14, CC.
Figures 8, 10	*Xanthiopyxis* sp.; Sample 16, CC.
Figures 11, 13, 14	*Triceratium* sp.; Sample 14, CC.
Figure 12	*Triceratium crenulatum* Gr. and St.; Sample 16, CC.

Figure 11, obj. 16: 0 50 100μ

All other figures, obj. 25: 0 50 100μ

PLATE 1

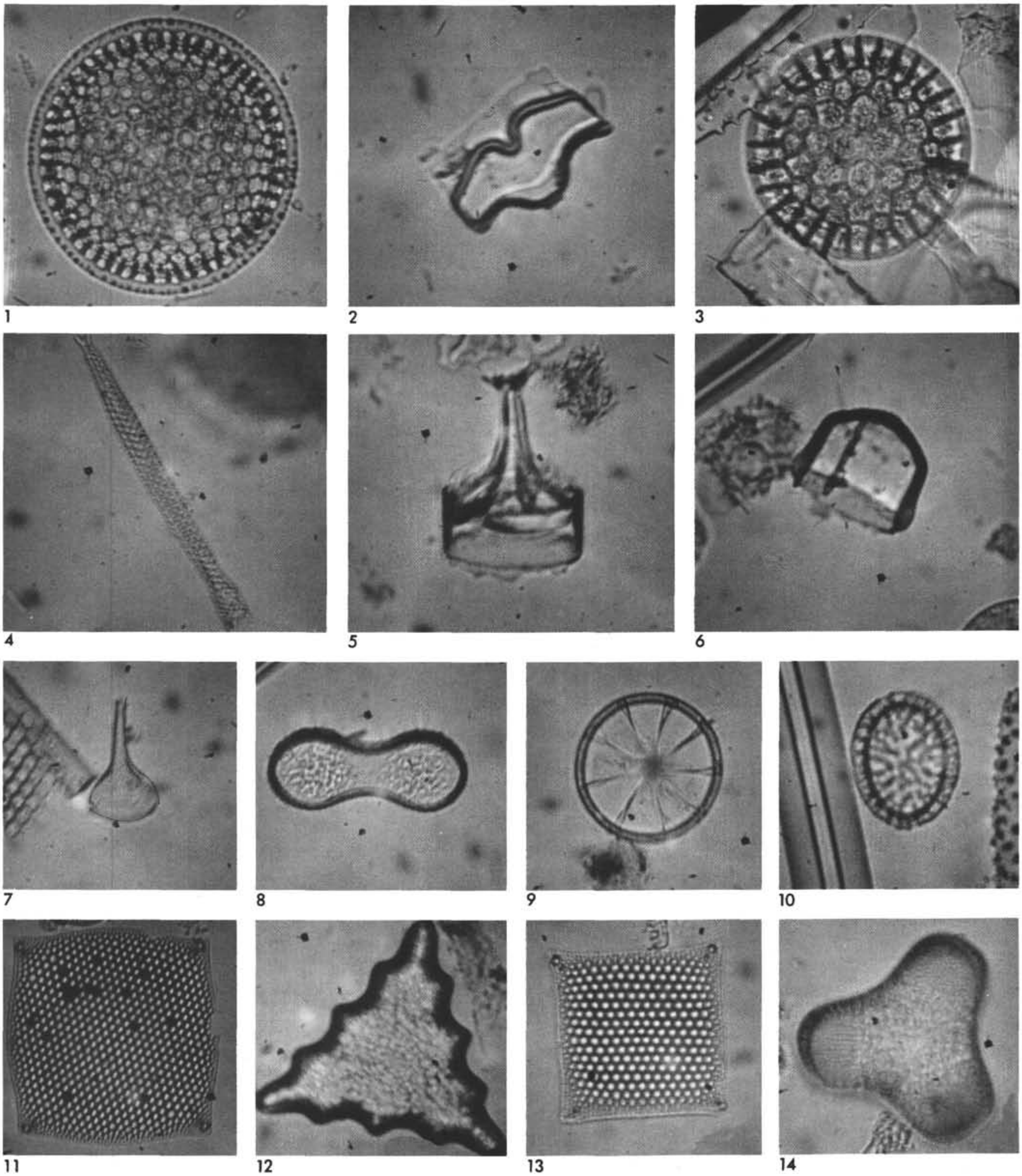

PLATE 2

Late Eocene Diatom Assemblage from Sample 281-14, CC

Figure 1	*Triceratium* sp., girdle view
Figure 2	*Stictodiscus boryanus* Pant.
Figure 3	*Hercotheca* sp., and *Naviculopsis biapiculata* (Lemm.)
Figure 4	*Chactoceros* sp., and *Coscinodiscus oculus iridis* Ehr.
Figure 5	*Stephanopyxis barbadensis* (Grev.) Grun., and forma indet.
Figure 6	*Triceratium* sp.
Figure 7	*Arachnoidiscus oamaruensis* N. E. Brown
Figure 8	*Stephanopyxis antiqua* Pant., and *Plagiogramma* sp.
Figure 9	*Hercotheca* sp., and *Pyxilla* sp.

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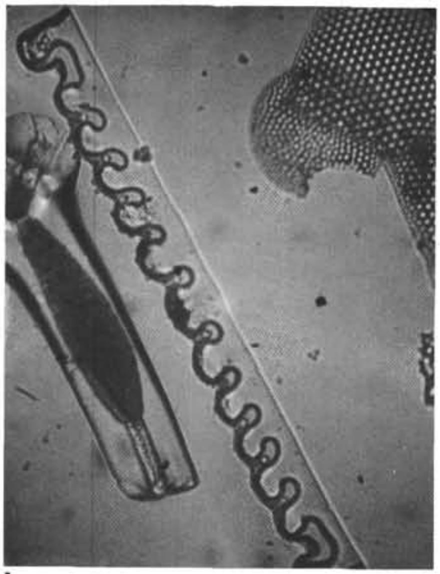
All other figures, obj. 25: 0 50 100μ

PLATE 2



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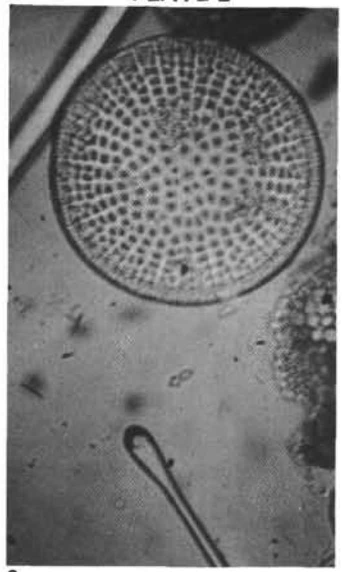

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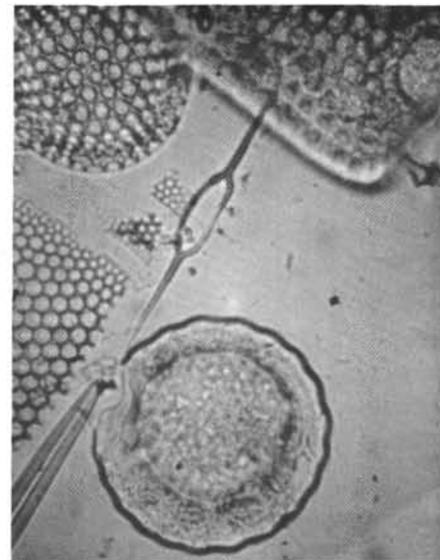

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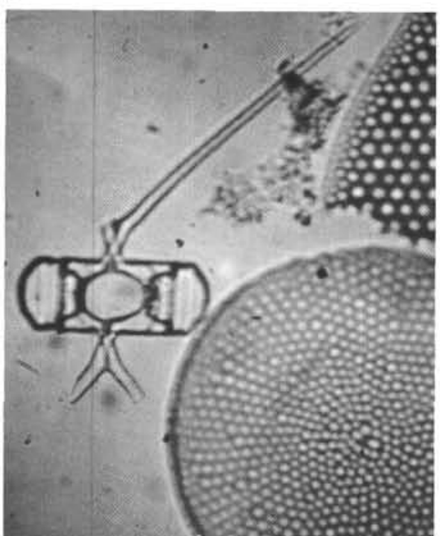

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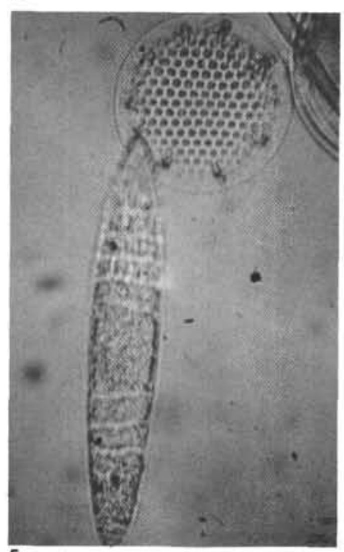

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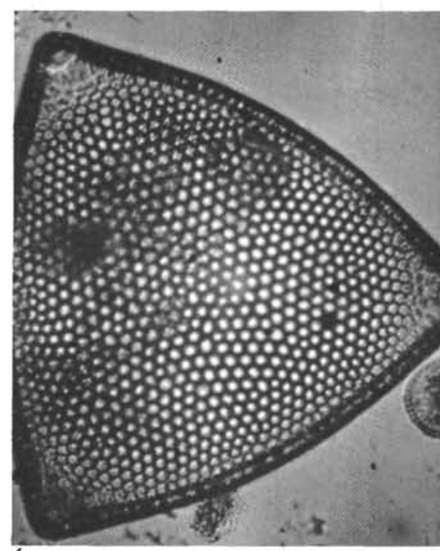

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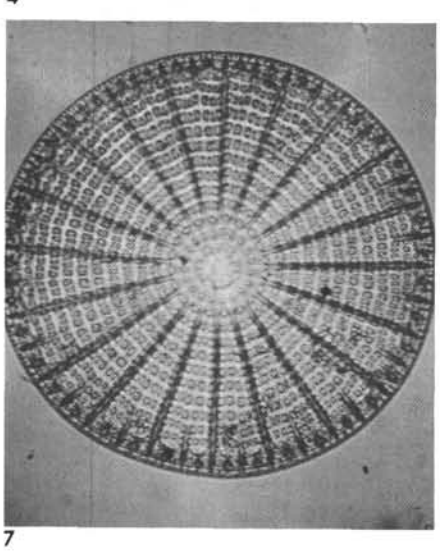

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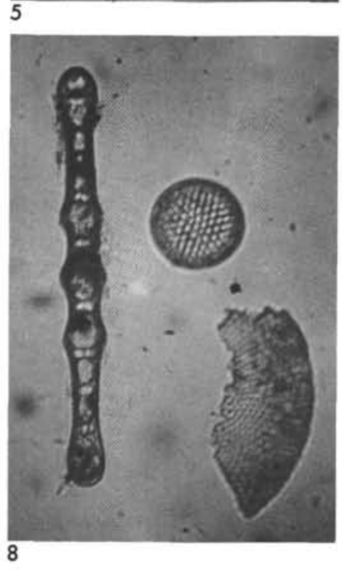

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APPENDIX A
Summary of X-Ray[a], Grain Size, and Carbon-Carbonate Results, Site 281

Section	Sample Depth Below Sea Floor (m)	Lithology	Age	X-Ray[b] Bulk Sample Major Constituent 1	2	3	$2\text{-}20\mu$ Fraction[d] Major Constituent 1	2	3	$<2\mu$ Fraction[d] Major Constituent 1	2	3	Grain Size Sand (%)	Silt (%)	Clay (%)	Classification	Carbon Carbonate Total (%)	Organic (%)	$CaCO_3$ (%)	Comments
281-1-4	4.7	**Unit 1A**															11.5	0.0	95	
281A-1-4	5.7	Nannofossil-											76.0	15.1	9.0	Sand				
281-2-1	8.8	bearing foram- iniferal ooze and		Calc.	–	–	–	–	–*	Quar.	Mica	Mont.					11.5	0.0	95	Bari. in $<2\mu$ *No data available
281-3-2	19.3	foraminifera.															11.3	0.0	93	
281-3-2	19.9	nannofossil															11.6	0.0	96	
281-3-6	25.2-25.3	ooze		Calc.	–	–	–	–	–*	Mont.	Kaol.	Mica	45.0	31.5	23.5	Sand silt clay	11.4	0.1	95	*No data available
281-5-2	38.1		Early to										28.5	39.0	32.5	Sand-silt clay	11.7	0.1	97	Gyps., Bari., Hali., $<2\mu$
281A-3-2	38.7-38.9		Recent	Calc.	Quar.	–	–	–	–*	Mont.	Kaol.	Quar.	35.5	39.2	35.3	Sand-silt-clay				*No data available
281-6-5	52.3-52.4		Miocene	Calc.	–	–	Quar.	Mica	Bari.	Mont.	Quar.	Kaol.	16.6	37.9	45.5	Silty clay	11.4	0.0	95	Bari. in $<2\mu$
281-9-1	75.1-75.2	**Unit 1B**		Calc.	–	–	Bari.	Quar.	Plag.	Mont.	Quar.	Bari.	6.0	57.4	36.6	Clayey silt	11.3	0.0	94	
281-10-5	90.5-90.6	Foraminiferal-		Calc.	–	–	–	–	–*	Mont.	Quar.	Mica	16.4	46.4	37.2	Clayey silt	11.5	0.0	96	*No data available
281-11-5	99.6-99.8	nannofossil ooze		Calc.	–	–	Quar.	Mica	K-Fe	Mica	Mont.	Quar.	16.1	48.2	35.7	Clayey silt	11.1	0.0	92	
281-12-5	109.6			Calc.	–	–	–	–	–*	Mont.	Mica	Bari.	13.0	56.5	30.4	Clayey silt	11.4	0.0	95	*No data available
281-13-5	119.3-119	**Unit 2** Calcareous ooze and glauconite sand	Early to late Oligocene	Quar.	Mix L.	K-Fe	Mica	Quar.	Mix L.	Mix L.	Apat.	Chlo.	61.9	13.3	24.8	Clayey sand	4.3	0.0	35	Apat. in bulk, $2\text{-}20\mu$ and $<2\mu$
281-14-1	122.1-122.2	**Unit 3**	Early	Quar.	Calc.	Mica	Quar.	Mica	Plag.	Mica	Mont.	Pyri.	61.5	22.0	16.5	Silty sand	1.6	0.3	11	Gyps. in bulk and $<2\mu$
281-15-2	132.7	Glauconitic	late														3.7	0.5	27	
281-15-2	133.8	silty sand to	Eocene	Calc.	Quar.	Mica	Quar.	Mica	Plag.	Mont.	Pyri.	Mica	16.0	41.4	42.6	Silty clay	4.1	0.6	29	Gyps. in $<2\mu$
281-16-3	144.7-144.8	silty clay		Clac.	Mica	Quar.	Quar.	Mica	Plag.	Mont.	Mica	Pyri.	2.3	50.0	47.8	Clayey silt	4.7	0.5	35	Gyps. in $<2\mu$

Note: * = see comments column.

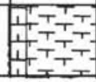
[a]Complete results for X-Ray, Site 281 will be found in Appendix I.

[b]Legend in Appendix A, Chapter 2.

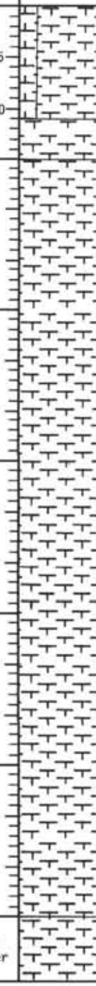
[c]Peaks at 5.76Å, 3.63Å, and 8.12Å among others. 0%-5% for Section 281-11-5.

[d]Broad peaks at 10.1Å, 3.31Å, 2.58Å, 1.995Å, 1.513Å, and 1.656Å among others.
Mineral is a mixed layer mica-montmorillonite (12.8%) in Section 281-13-5 for $2\text{-}20\mu$ and (91.2%) for $<2\mu$.

Site 281 Hole Core 1 Cored Interval: 0.0-7.5 m

AGE	ZONE		FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLEISTOCENE	G. (G.) truncatulinoides	C. pelagicus	F R D S	A C A R –	G G P –	Core Catcher					Core catcher only: a white (2.5Y 8/2), soupy NANNO-RICH FORAM OOZE. SS CC F -75% N -23% D - 1% S - 1%

Site 281 Hole Core 2 Cored Interval: 7.5-17.0 m

AGE	ZONE		FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
LATE PLEISTOCENE	G. (G.) truncatulinoides	C. pelagicus	F N N	A A A	M G P	1	0.5 1.0		|	
			N F N	A A A	M M G	2				
EARLY PLEISTOCENE			N F N	A A A	M M M	3				
			F N	A A	M M	4				
LATE PLIOCENE	G. (T.) inflata	P. lacunosa	F N	A A	M M	5				
			F N	A A	M M	6				
			F R N D S	A R A – –	M G M – –	Core Catcher				CC

LITHOLOGIC DESCRIPTION

Sec. 1 white (2.5Y 8/2), soft NANNO-RICH FORAM OOZE to 110 cm. Sharp contact at 110 cm, slightly deformed to a white (N9), soft NANNO-BEARING FORAM OOZE. Secs. 2 to core catcher consist of: white (2.5Y 8/2), soupy and soft NANNO-RICH FORAM OOZE intermixed with lesser amounts (~40%) of diffused patches and layers of white (N9), soupy and soft NANNO-BEARING FORAM OOZE (SS CC).

SS CC
F -90%
N -10%

X-ray 1-128 (Bulk)
Calc - M

Carbon Carbonate 1-126 (11.5, 0.0, 95)

Explanatory notes in Chapter 1

Site 281 Hole Core 3 Cored Interval: 17.0-26.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS
LATE PLIOCENE	G. (T.) inflata	F	A	M	1	0.5
		N	A	P		1.0
		F	A	M	2	
		N	A	M		
		F	A	M		
	P. lacunosa	N	A	M	3	
		F	A	M		
		N	A	M		
		N	A	M	4	
	G. (T.) puncticulata	N	A	M	5	
		N	C	M		
		N	C	M	6	
	R. pseudoumbilica	N	C	M		
		F R N D S	A C A – –	M M M – –	Core Catcher	

LITHO. SAMPLE: 10, 30 (Sec. 2); CC

LITHOLOGIC DESCRIPTION

Sec. 1 to 50 cm Sec. 2 white (2.5Y 8/2), soupy and (mostly) soft NANNO-BEARING FORAM OOZE. Color grades to white (N9) at 50 cm and to very light gray (N8) at 85 cm; at 105 cm Sec. 2 color grades to light gray (N7) FORAM-RICH NANNO OOZE. At 25 cm, Sec. 3 is a sharp contact, with slight deformation to a white (N9) FORAM NANNO OOZE. At 115 cm, Sec. 3 color grades to light gray (N8) and is intermixed with small amounts of white (N9), and very light gray (N8). A medium dark gray (N4) layer, with moderate deformation, occurs in Sec. 6 (114-117 cm). Core catcher is a white (2.5Y 8/1), soft MICARB-BEARING NANNO-FORAM OOZE.

SS 3-10		SS 3-30		SS CC	
DE	- 2%	F	-45%	M	- 5%
F	-20%	N	-50%	F	-60%
N	-73%	S	- 2%	N	-35%
D	- 5%				

X-ray 6-73 (Bulk)
Calc - M

Grain Size 6-76 (45.0, 31.5 23.5)

Carbon Carbonate 2-81 (11.3, 0.0, 93)

Carbon Carbonate 2-141 (11.6, 0.0, 96)

Carbon Carbonate 6-78 (11.4, 0.1, 95)

Site 281 Hole Core 4 Cored Interval: 26.5-36.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	LITHO. SAMPLE
EARLY PLIOCENE	G. (G.) miozea conomiozea / R. pseudoumbilica	F N D S	C C – –	M M – –	Core Catcher	CC

LITHOLOGIC DESCRIPTION

Small core catcher sample only: core catcher empty. Smear slide made from material stuck to catcher, DETRITAL-BEARING NANNO FORAM OOZE.

SS-CC	
DE	- 5%
F	-60%
N	-35%

Site 281 Hole Core 5 Cored Interval: 36.0-45.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS
LATE MIOCENE	G. (G.) miozea conomiozea / R. pseudoumbilica	F	A	G	1	0.5
		N	A	M		1.0
		N	A	M	2	
		F R N D S	A C C – –	G G M – –	Core Catcher	

LITHO. SAMPLE: CC

LITHOLOGIC DESCRIPTION

Intermixed streaks of white (N9), very light gray (N8), and white (5Y 8/2), soft NANNO FORAM OOZE, intensely deformed.

SS CC	
F	-65%
N	-35%

Grain Size 2-60 (28.5, 39.0, 32.5)

Carbon Carbonate 2-63 (11.7, 0.1, 97)

Explanatory notes in Chapter 1

Site 281 Hole Core 6 Cored Interval: 45.5-55.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	G. (G.) miotumida miotumida / R. pseudoumbilica				1	0.5 / 1.0				Core is typically a white (N9), soupy to soft NANNO FORAM OOZE. At 80-150 cm, Sec. 4 are ~10% streaks and patches of medium gray (N5), also in Sec. 5 (0-13 cm). Below 100 cm, Sec. 5 is a subtle color change to white (N8). The core catcher consists of a very light gray (N8), soft SILICEOUS-BEARING NANNO FORAM OOZE.
		F / N	A / A	M / M	2					
		N	A	M	3					
		N	A	M	4					
		N	A	M	5					
		N	A	M	6					
		F R N D S	A C A F R	M G M P P	Core Catcher				CC	

SS CC
DE - 2%
F -55%
N -35%
D - 1%
R - 1%
S - 1%
SI - 5%

X-ray 5-83 (Bulk)
Calc - M

Grain Size 5-87 (16.6, 37.9, 45.5)

Carbon Carbonate 5-90 (11.4, 0.0, 95)

Site 281 Hole Core 7 Cored Interval: 55.0-64.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	G. (G.) miotumida miotumida / R. pseudoumbilica				1	0.5 / 1.0				Sec. 1 (0-150 cm): white (N9), soupy and soft FORAM NANNO OOZE. Sec. 2 (0-150 cm) white (N9) to greenish white (5GY 9/1) FORAM NANNO OOZE (soft and soupy). Sec. 3 is a greenish white (5GY 9/1), soft-stiff FORAM NANNO OOZE and Sec. 4 is a white (N9) to greenish white (5GY 9/1), soft FORAM NANNO OOZE grading to a white (N9), soft, FORAM NANNO OOZE in Sec. 5 and in Sec. 6 and core catcher.
		N	A	M	2					
		N	A	M	3					
		N	A	M	4					
					5		VOID			
					6					
		F R N D S	A C A R –	M G M P –	Core Catcher				CC	

SS CC
F -40%
N -59%
D - 1%

Explanatory notes in Chapter 1

Site 281 Hole Core 8 Cored Interval: 64.5-74.0 m

AGE	ZONE		FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	G. (G.) miotumida miotumida	R. pseudoumbilica	F R N D S	C C A R -	M G M P -	Core Catcher				CC	Core catcher only: white (N9), soft SPICULE-BEARING FORAM-RICH NANNO OOZE. SS CC F -25% N -70% S - 5%

Site 281 Hole Core 9 Cored Interval: 74.0-83.5 m

AGE	ZONE		FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	G. (G.) miotumida miotumida	R. pseudoumbilica	N	A	M	1	0.5 1.0				Core is typically a white (N9), soft to soft-stiff FORAM NANNO OOZE with sparse faint gray-black spots in Sec. 6. SS CC F -40% N -55% OST - 1% X-ray 1-114 (Bulk) Calc - M Grain Size 1-117 (6.0, 57.4, 36.6) Carbon Carbonate 1-120 (11.3, 0.0, 94)
			F N	A A	M M	2					
			F N	A A	M M	3					
MIDDLE MIOCENE	G. (T.) mayeri mayeri		F	A	M	4					
			N	A	M						
			N	A	M	5					
			N	A	M	6					
			F R N D S	A R A R	M P M P	Core Catcher					

Explanatory notes in Chapter 1

Site 281 Hole Core 10 Cored Interval: 83.5-93.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
MIDDLE MIOCENE	O. suturalis; C. neogammation				1	0.5; 1.0	VOID; VOID		
					2				
		F; N; N	A; A; A	M; M; M	3				
		N; F	A; A	M; M	4				
		N	A	M	5				
		N	A	M	6				
		F R N D S	A R A	M P M	Core Catcher				CC

LITHOLOGIC DESCRIPTION

Typically - white (N9), soupy, soft, and soft-stiff NANNO FORAM OOZE.

SS CC
DE - 1%
F -60%
N -35%
S - 2%
OST - 1%

X-ray 5-104 (Bulk)
Calc - M

Grain Size 5-108 (16.4, 46.4, 37.2)

Carbon Carbonate 5-110 (11.5, 0.0, 96)

Site 281 Hole Core 11 Cored Interval: 93.0-102.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
MID MIOCENE	P. glomerusa curva	F	A	M	1	0.5; 1.0			
EARLY MIOCENE	G. trilobus trilobus; C. neogammation	N; F	A; A	M; M					
		N	A	M	2				
		N	A	M	3				
		F; N	A; A	M; M	4				
		N	A	M	5				
		N	A	M	6				
		F S N D R	A - A - C	M - M - G	Core Catcher				CC

LITHOLOGIC DESCRIPTION

Core is white (N9), soft to soft-stiff FORAM NANNO OOZE with faint, slightly grayer lamination showing moderate deformation in Sec. 1 and sparse, faint gray-black patches in Sec. 2.

SS CC
F -35%
N -64%
SI - 1%

X-ray 5-84 (Bulk)
Calc - M

Grain Size 5-87 (16.1, 48.2, 35.7)

Carbon Carbonate 5-90 (11.1, 0.0, 92)

Explanatory notes in Chapter 1

Site 281 Hole Core 12 Cored Interval: 102.5-112.0 m

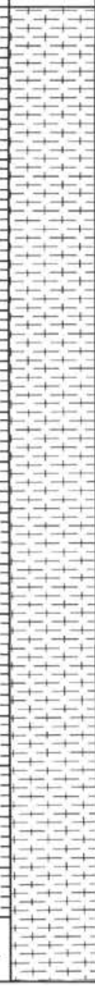
AGE: EARLY MIOCENE

ZONE: G. trilobus trilobus; C. neogammation; G. (G.) woodi connecta; D. deflandrei

FOSSIL CHARACTER (FOSSIL / ABUND. / PRES.): N A M; F A M; N A M; F A M; F A M; N A M; N A M; N A P; N A M; F A M; D – –; N A M; S – –; R R M

SECTION: 1, 2, 3, 4, 5, 6, Core Catcher

METERS: 0.5, 1.0



LITHO. SAMPLE: CC

LITHOLOGIC DESCRIPTION

White (N9), soupy, soft, and soft-stiff FORAM NANNO OOZE with faint, slightly browner patches at 59-77 cm, Sec. 5 and faint, slightly broxner patches and streaks, and faint gray streak in Sec. 6 (40-75 cm).

SS CC
F -35%
N -64%
SI - 1%

X-ray 5-105 (Bulk)
Calc - M

Grain Size 5-107 (13.0, 56.5, 30.4)

Carbon Carbonate 5-110 (11.4, 0.0, 95)

Site 281 Hole Core 13 Cored Interval: 112.0-121.5 m

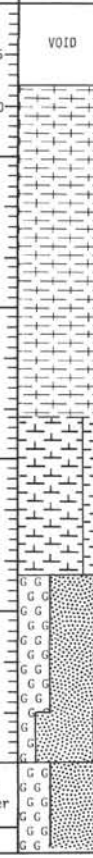
AGE: EARLY MIOCENE; EARLY OLIGOCENE

ZONE: D. deflandrei; G. (G.) woodi connecta; R. bisecta; Blackites rectus

FOSSIL CHARACTER (FOSSIL / ABUND. / PRES.): N A M; N A M; F R M; N A M; P; N A M; N A M; N A P; N A M; F R M; P –; N A M; F R M; F R M; N E M; D; R; F VR M; N C M

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

METERS: 0.5, 1.0



LITHO. SAMPLE: 120, 140, 125, 133, CC

LITHOLOGIC DESCRIPTION

White (N9), soft to soupy FORAM NANNO OOZE, with <1%, fine to medium-grained GLAUCONITE. Glauconite grains gradationally increase in abundance down-core and gives peppered appearance to sediment: Sec. 2 (150 cm) has ~5%, fine to medium-grained glauconite, as a GLAUCONITE-BEARING NANNO FORAM OOZE: at 100 cm in Sec. 3 the matrix becomes light greenish gray (5GY 8/1), and the lithology is a DETRITAL SAND AND GLAUCONITE-BEARING FORAM-RICH NANNO OOZE (visual estimate of glauconite from core is ~15%; greater than estimate from SS 140): Sec. 4 (115 cm) begins a light greenish gray (5GY 8/1), soupy NANNO AND FORAM-BEARING GLAUCONITE DETRITAL SAND and in Sec. 5 at 20-49 cm and 100-150 cm there is an intermixed, dusky yellowish green (10GY 3/2) (mostly) and dark yellowish green (10GY 4/4), soft DOLOMITE AND FORAM-BEARING GLAUCONITE AND NANNO-RICH DETRITAL SAND. The core catcher has colors between dark yellowish green (10GY 4/4) and dusky yellowish green (10GY 3/2), stiff; as a FELDSPAR-RICH GLAUCONITE QUARTZ SAND underlain by darker dusky green (5G 2/2) material of similar composition.

SS 2-120		SS 3-140		SS 4-125		SS 5-133		SS CC	
DE	- 1%	DE	- 7%	DE	-50%	DE	-60%	DE	-70%
G	- 2%	G	- 7%	G	-30%	G	-15%	G	-26%
F	-65%	F	-20%	F	-10%	Dolo	- 4%	F	- 1%
N	-30%	N	-66%	N	- 8%	F	- 5%	N	- 1%
				S	- 2%	N	-15%	Dolo	- 2%

X-ray 5-135 (Bulk)
Calc - TR Chlo - TR
Quar - A Mixl - P
K-Fe - P Apat - TR
Plag - P

Grain Size 5-147 (61.9, 13.3, 24.8)

Carbon Carbonate 5-141 (4.3, 0.0, 35)

Explanatory notes in Chapter 1

Site 281 Hole Core 14 Cored Interval: 121.5-131.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
LATE EOCENE	G. (S.) linaperta / C. oamaruensis	N	C	M	1	0.5, 1.0			8
		N	C	P					
		P	A	G					
		F	R	P	2				75
		N	C	P					
		N	C	P					
		N	F	P	3				
		F	R	P					
		P	A	G					
		N	C	P					
		N	A	P	4				
		F	R	P					
		N	A	P					
		N	A	P	5				75
		P	A	G					
		N	A	P					
		N	A	M	6				
		N	A	M					
		F D N S R	R C C R R	VP G M M P	Core Catcher				CC

LITHOLOGIC DESCRIPTION

Sec. 1: a grayish olive (10Y 4/3), soft-stiff GLAUCONITE, FORAM, RAD, AND SPICULE-BEARING DIATOM-DETRITAL SILTY SAND with greenish-black, angular GLAUCONITIC SANDSTONE pebble (1 cm diameter) at 17-18 cm. Sec. 2: a grayish olive (10Y 4/3), soft-stiff RAD, SPICULE, AND Glauconite Bearing/Diatom-Rich DETRITAL SANDY SILTY CLAY with ~10% faint, grayish olive (10Y 4/2) streaks; intensely deformed. Sec. 3: a grayish olive (10Y 4/2), soft-stiff, with intensely deformed layers and streaks - mostly slightly lighter; ~1 cm diameter GLAUCONITIC SANDSTONE pebble is at 57-58 cm. Secs. 4, 5, and 6 have variable lithologic patterns: (0-64 cm) grayish olive (10Y 4/2), soft-stiff, with olive-gray (5Y 4/2) moderately to intensely deformed layers and patches (~10%); 64-113 cm, intermixed, intensely mottled, light olive (10Y 5/2), pale olive (10Y 6/2), and moderate olive gray (5Y 4/2) and at 113-150 cm same as 0-64 cm. Glauconitic sandstone pebble at 123 cm. Sec. 5, 0-49 cm pale olive (10Y 6/2), soft-stiff, moderately mottled with grayish olive (10Y 4/2); 49-80 cm, grayish olive (10Y 4/2), soft-stiff, RAD AND FORAM-BEARING SPICULE-RICH DIATOM DETRITAL SAND SILT CLAY and 80-150 cm is light grayish olive (10Y 5/2), soft-stiff, with faint, moderate mottling, slightly darker and lighter streaks. Sec. 6 is light grayish olive (10Y 5/2), soft-stiff, with moderate swirled mottling, mostly light olive brown (5Y 5/4). The core catcher is a light grayish olive (10Y 5/2), soft-stiff, GLAUCONITE, RAD, AND SPICULE-BEARING DETRITAL SILT-RICH FORAM DIATOM OOZE.

SS 1-8		SS 2-75		SS 5-75		SS CC	
DE	-50%	DE	-60%	DE	-45%	DE	-20%
G	- 5%	G	-10%	G	- 5%	G	- 5%
F	- 5%	D	-20%	F	- 1%	F	-30%
D	-25%	R	- 5%	D	-30%	D	-30%
R	- 5%	S	- 5%	R	- 5%	R	- 5%
S	-10%			S	-14%	S	-10%

X-ray 1-64 (Bulk)

Calc	- P	Mica	- P
Quar	- A	Chlo	- TR
K-Fe	- P	Gyps	- TR
Plag	- P		

Grain Size 1-68 (61.5, 22.0, 16.5)

Carbon Carbonate 1-70 (1.6, 0.3, 11)

Site 281 Hole Core 15 Cored Interval: 131.0-140.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
LATE EOCENE	G. (S.) linaperta / C. oamaruensis				1	0.5, 1.0	VOID		
		N	A	P	2				73
		P	A	G					94
		N	A	P					
		N	A	M	3				
		N	A	M					
		F D N S R	R C C R R	P G M P M	Core Catcher				CC

LITHOLOGIC DESCRIPTION

Light grayish olive (10Y 5/2), soft, with slight mottling - light olive (10Y 5/4) grading into a light grayish green (10Y 5/2), soft-stiff FORAM, NANNO, SPONGE SPICULE, and DETRITAL SAND-RICH DIATOM OOZE with slight mottling - light olive brown (5Y 5/6). Sec. 3 is a FORAM, NANNO, SPICULE-BEARING DETRITAL CLAYEY SILT DIATOM OOZE (mottles have more fine-grained detritals). The core catcher consists of a light grayish olive (10Y 5/2), soft GLAUCONITE-BEARING FORAM, NANNO, SPONGE SPICULE, AND DETRITAL SILTY SAND-RICH DIATOM OOZE.

SS 2-73		SS 2-94		SS CC	
DE	-45%	DE	-10%	DE	-15%
G	- 2%	G	- 1%	G	- 3%
F	- 5%	F	-10%	F	-10%
N	- 5%	N	-15%	N	-20%
D	-30%	D	-54%	D	-35%
S	-11%	S	-10%	R	- 1%
				S	-15%

X-ray 2-125 (Bulk)

Calc	- A	Mica	- P
Quar	- P	Chlo	- TR
K-Fe	- TR	Pyri	- TR
Plag	- TR		

Grain Size 2-128 (16.0, 41.4, 42.6)

Carbon Carbonate 2-20 (3.7, 0.5, 27)

Carbon Carbonate 2-130 (4.1, 0.6, 29)

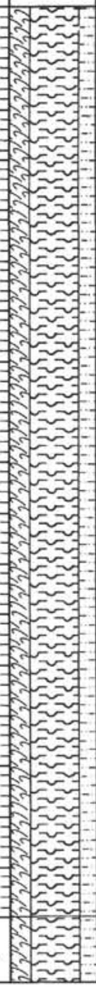
Explanatory notes in Chapter 1

Site 281 Hole Core 16 Cored Interval. 140.5-150.0 m

AGE: LATE EOCENE

ZONE: G. (S.) linaperta; C. oamaruensis

Section	Meters	Fossil	Abund.	Pres.	Litho. Sample
1	0.5	N	A	M	
		P	F	G	
	1.0	N	A	M	
2		N	A	M	
		N	A	M	
3		N	A	M	
		P	R	G	
		N	A	M	
4		N	C	M	
		N	A	M	
5		N	A	M	
		P	A	G	
		N	A	M	
6		N	A	M	
		F	M	R	
		N	A	M	107
					145
Core Catcher		F	F	M	CC
		D	C	G	
		N	A	M	
		S	R	M	
		R	R	M	



LITHOLOGIC DESCRIPTION

Core is typically light grayish olive (10Y 5/2) NANNO-BEARING SPICULE AND FORAM-RICH DETRITAL CLAYEY SILT DIATOM OOZE with faint, lighter mottles and swirls. At Sec. 4 (127-129 cm) is a grayish-green (10GY 5/2) patch (~2 cm diameter). Sec. 6 (104-112 cm) is a grayish olive (10Y 4/2) layer DETRITAL SAND-RICH NANNO DIATOM OOZE. The core catcher consists of a light grayish olive (10Y 5/2), soft RAD AND NANNO-BEARING FORAM, DETRITAL SAND, AND SPICULE-RICH DIATOM OOZE.

SS 6-107		SS 6-145		SS CC	
DE	-15%	DE	-45%	DE	-15%
G	- 1%	F	-15%	F	-15%
F	- 2%	D	-25%	N	-10%
N	-35%	S	-10%	D	-30%
D	-40%	N	- 5%	R	-10%
S	- 5%			S	-20%

X-ray 3-123 (Bulk)

Calc	- M	Mica	- P
Quar	- P	Chlo	- TR
Plag	- TR	Pyri	- TR

Grain Size 3-126 (2.3, 50.0, 47.8)

Carbon Carbonate 3-129 (4.7, 0.5, 35)

Site 281 Hole Core 17 Cored Interval: 150.0-159.5 m

AGE: LATE EOCENE?

ZONE: C. oamaruensis

Section	Meters	Fossil	Abund.	Pres.	Litho. Sample
1	0.5	N	F	P	10
	1.0				
2		N	R	P	
3					
4					
5					
6		N	R	P	
		N	R	P	
		P	A	G	
Core Catcher					

LITHOLOGIC DESCRIPTION

Light grayish olive (10Y 5/2), lithified GLAUCONITE-BEARING DETRITAL SAND AND FORAM-RICH NANNO CHALK. Sec. 1: 0-8 cm - lithified block; 8-19 cm - drilling breccia; 19-24 cm - silty-fine sand; 24-29 cm - drilling breccia; 29-41 cm - two lithified blocks; 41-50 cm - silty-fine sand; 50-55 cm - drilling breccia. Sec. 1 contains lithified blocks as well as drilling breccia. Sec. 3 (0-6 cm) is a grayish olive (10Y 4/2) drilling breccia and 6-14 cm, a light grayish olive (10Y 5/2) and grayish olive (10Y 4/2), intensely mottled, lithified block, with fine to coarse-grained glauconite. (Mottling due to clustering of glauconite grains). At the top of Sec. 6 occurs a medium greenish gray (5GY 5/1) MICA SCHIST BRECCIA; coarse fraction containing: ~65% mica schist; 15% glauconite; 15% vein quartz or quartzite, and quartz; 5% glauconite sandstone; and 0% granite. Fine matrix contains mostly clay-size comminuted minerals. The core catcher contains greenish-black QUARTZ-MICA SCHIST fragments (1 cm x 6 cm laths).

SS 1-10	
DE	-20%
G	- 5%
MN(?)	- 2%
Dolo	- 1%
F	-15%
N	-52%

Explanatory notes in Chapter 1

Site 281 Hole Core 18 Cored Interval: 159.5-162.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					Core Catcher					Core catcher contains a 2 x 5 cm lithified pebble. One half is dark gray (N4) GLAUCONITIC SANDSTONE, fine-medium-grained; and one half is light gray (5Y 7/1) SILTY LIMESTONE.

Site 281 Hole A Core 1 Cored Interval: 0.0-9.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLEISTOCENE	C. pelagicus	N	A	G	1	0.5, 1.0			12	Core is typically white (2.5Y 8/2), soft-stiff NANNO-BEARING FORAM OOZE grading into Sec. 1, 137-150 cm white (N9), soft-stiff FORAM-NANNO OOZE at 137 cm, Sec. 1. In Sec. 2 at 0-22 cm, 30-40 cm, and 120-130 cm - is white (N9), soft-stiff FORAM-NANNO OOZE. SS 2-12: OST - 5%, F -45%, N -50% SS 2-75: F -95%, N - 5% Grain Size 4-118 (76.0, 15.1, 9.0)
					2				75	
EARLY PLEISTOCENE	G. (G.) truncatulinoides / P. lacunosa	N	C	M	3					
		N	C	M	4					
		F D N S	A C	G M	Core Catcher					

Site 281 Hole A Core 2 Cored Interval: 26.5-36.0 m

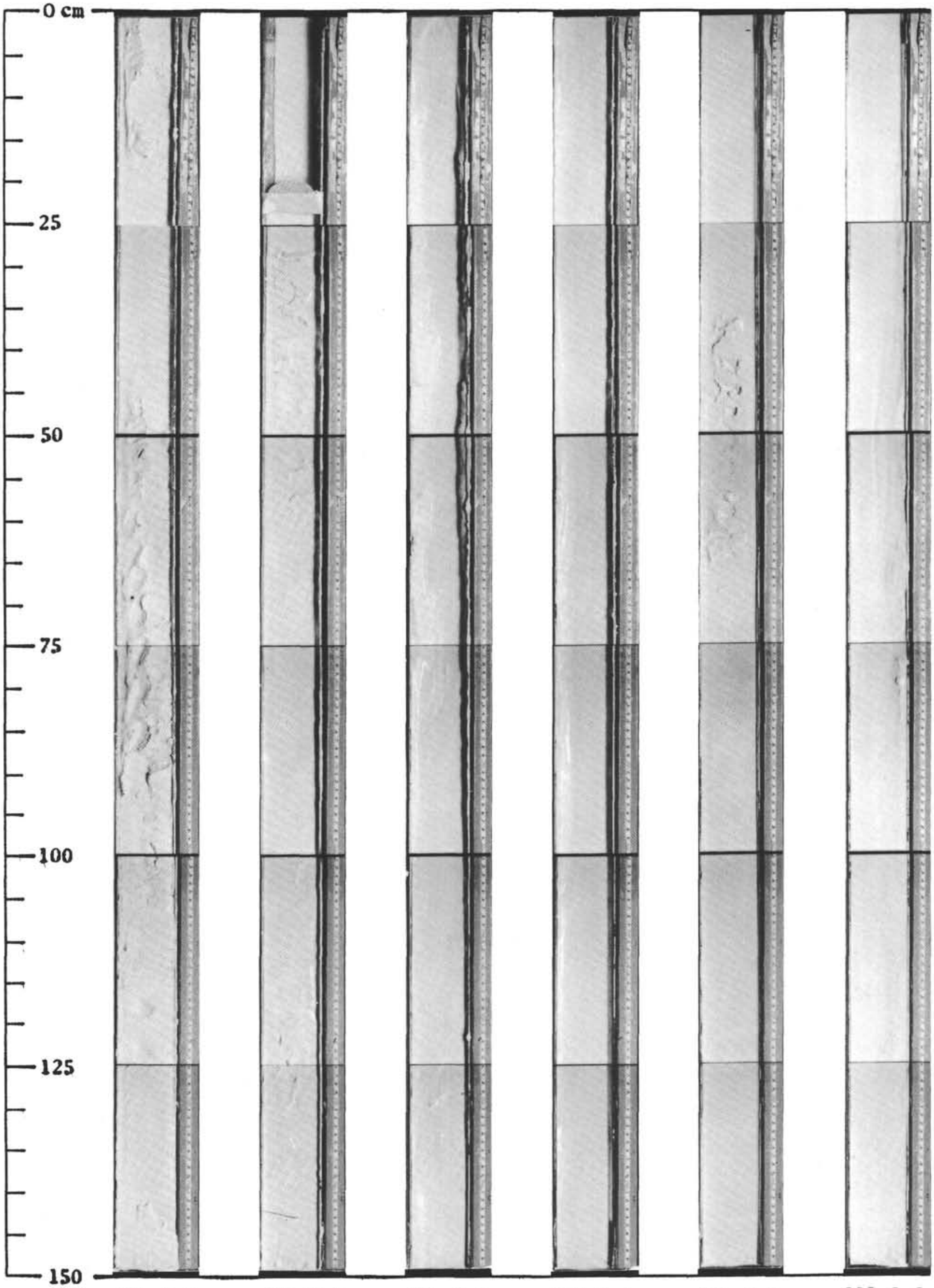
AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		N N	A R	M[1] M[2]	Core Catcher					Core catcher contained a coarse-grained GRANITE pebble (6 x 5 cm) with coating of light red (5R 6/6) clay(?) and white (N9) nanno ooze(?).

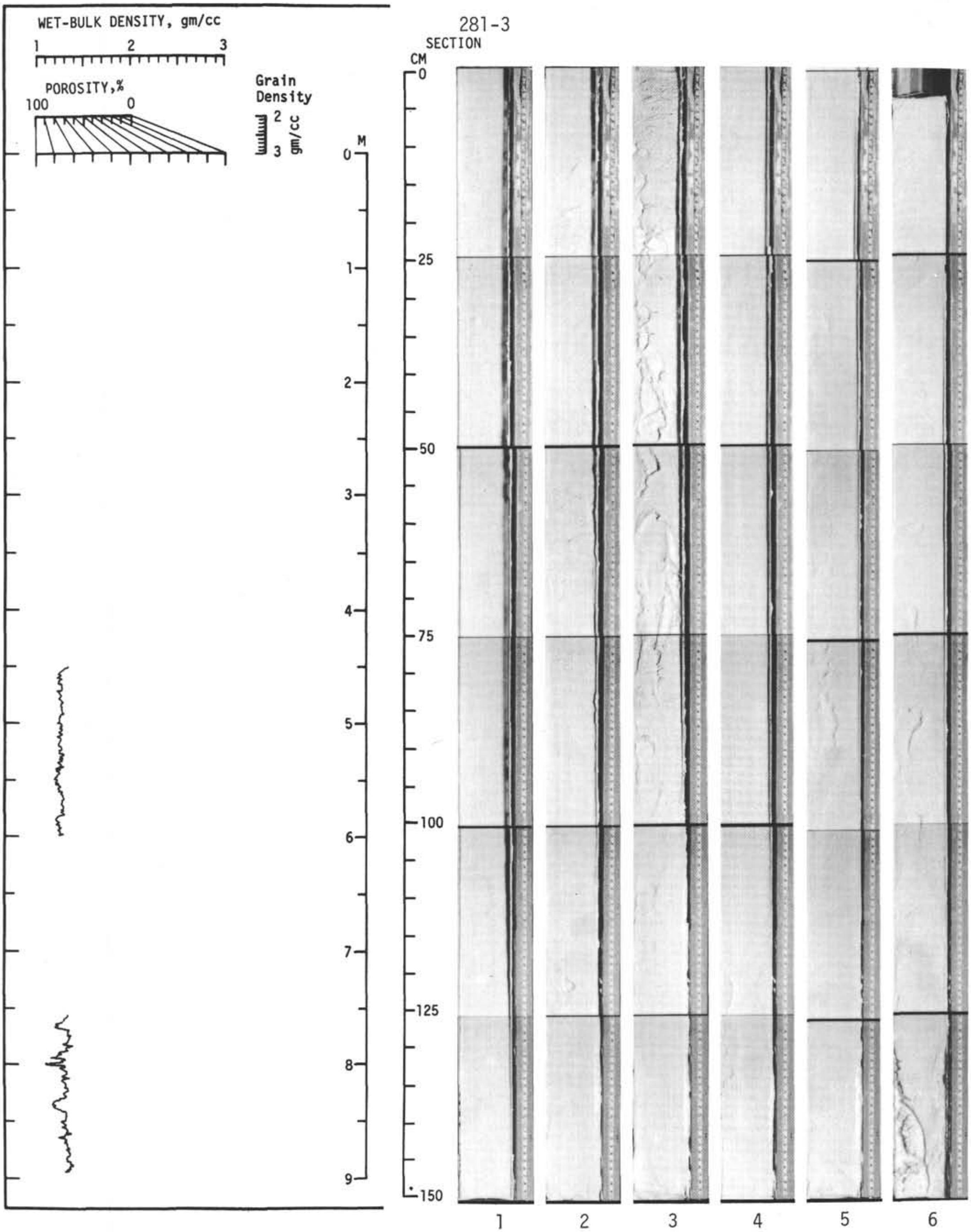
[1] From white nanno ooze
[2] From light red fine silt

Site 281 Hole A Core 3 Cored Interval: 36.0-45.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY PLIOCENE	G. (T.) puncticulata	F	A	G	1	0.5, 1.0				Core is a white (N9), soft FORAM NANNO OOZE to a white (N9), soft NANNO FORAM OOZE in the core catcher. SS CC: F -60%, N -40% X-ray 2-120 (Bulk): Calc - M, Quar - TR Grain Size 2-138 (25.5, 39.2, 35.3)
		F	A	G	2					
		F	A	G						
LATE MIOCENE	G. (G.) miozea conomiozea / R. pseudoumbilica	F	A	G						
		F D N S	A R A -	G P M -	Core Catcher					

Explanatory notes in Chapter1


0 cm
25
50
75
100
125
150
281-2-1
281-2-2
281-2-3
281-2-4
281-2-5
281-2-6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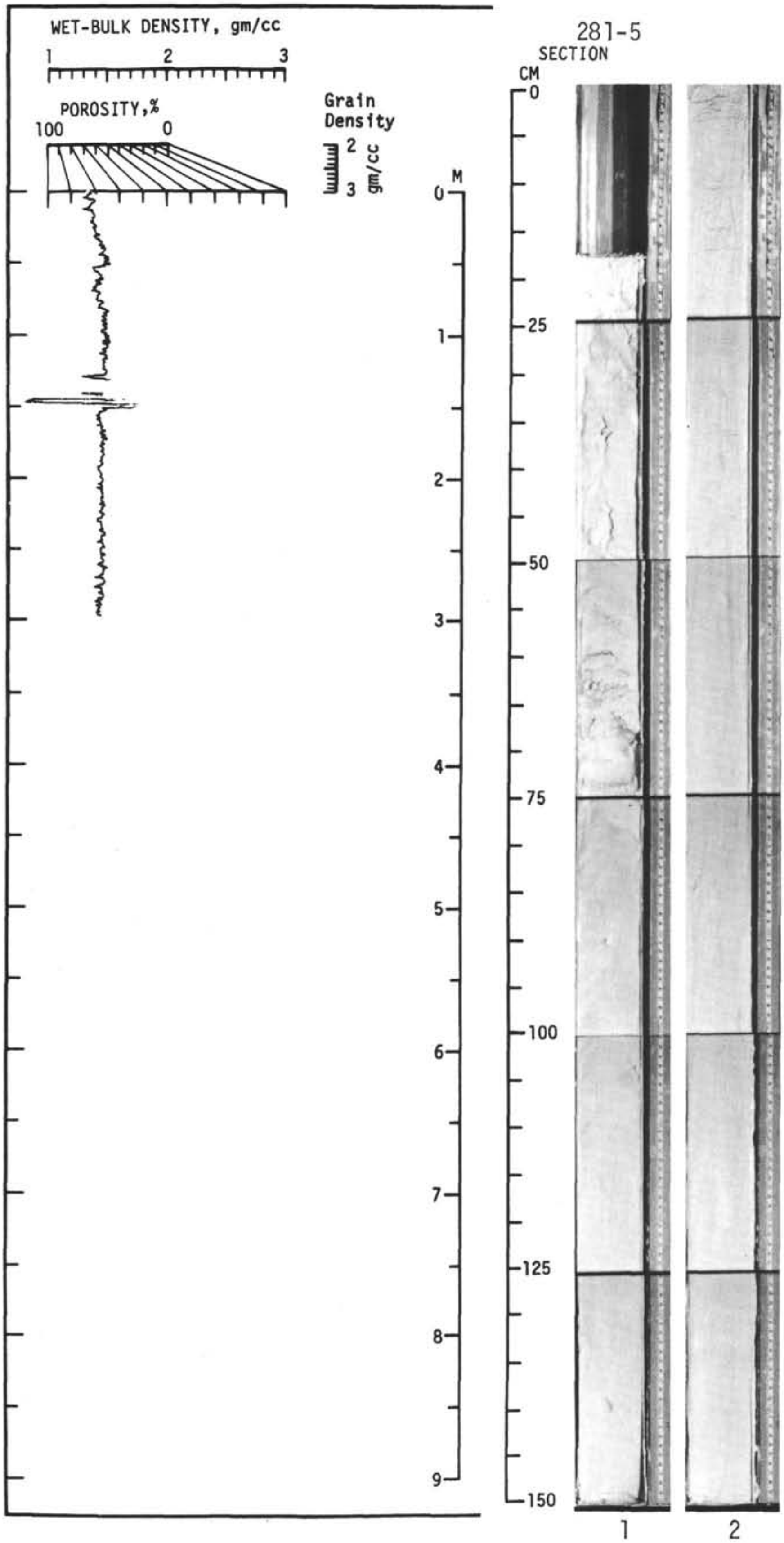
1
2
3
POROSITY,%
100
0
Grain Density
2
3
gm/cc
M
0
1
2
3
4
5
6
7
8
9
281-3
SECTION
CM
0
25
50
75
100
125
150
1
2
3
4
5
6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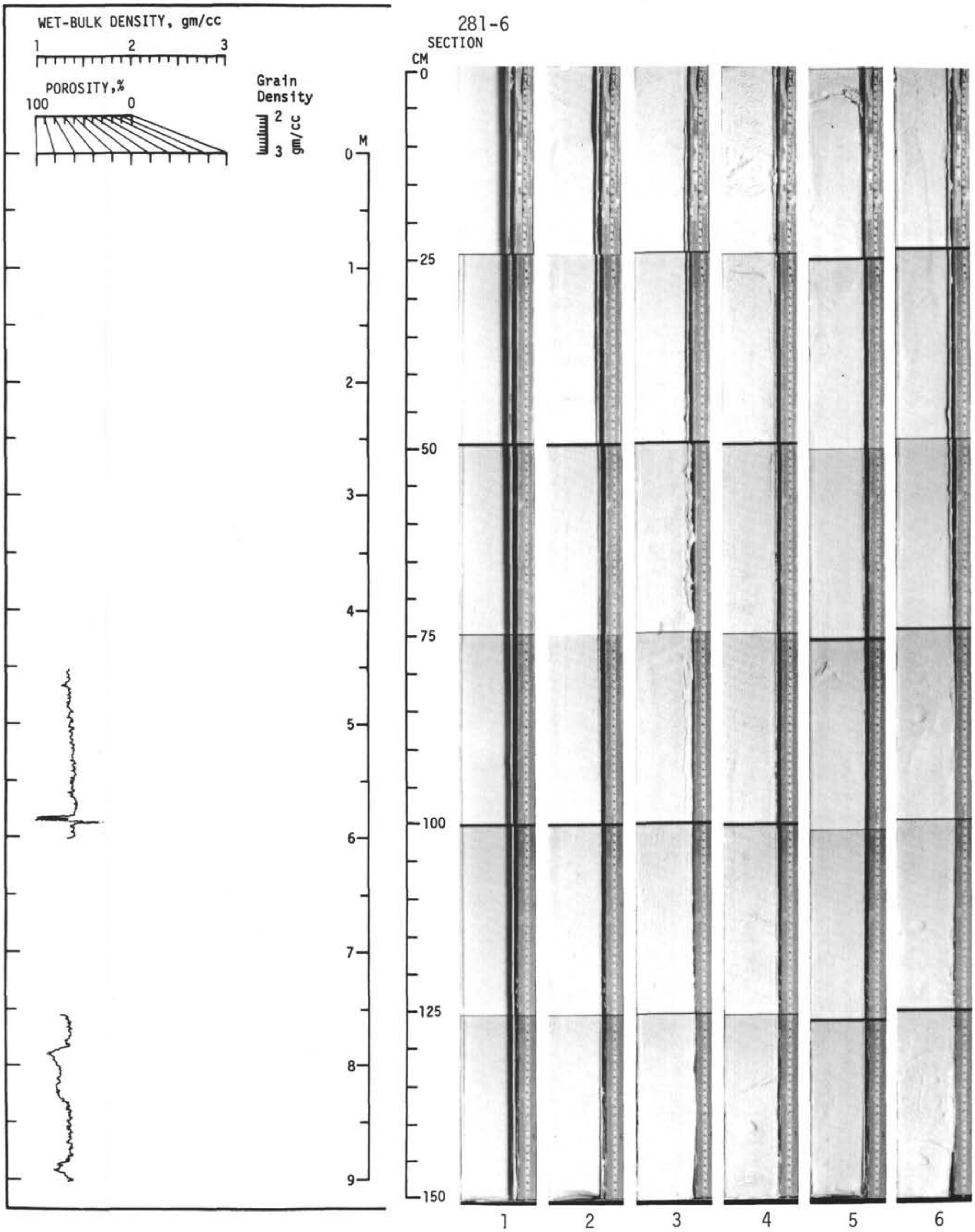
1
2
3
POROSITY,%
100
0
Grain Density
2
3
gm/cc
M
0
1
2
3
4
5
6
7
8
9
281-5
SECTION
CM
0
25
50
75
100
125
150
1
2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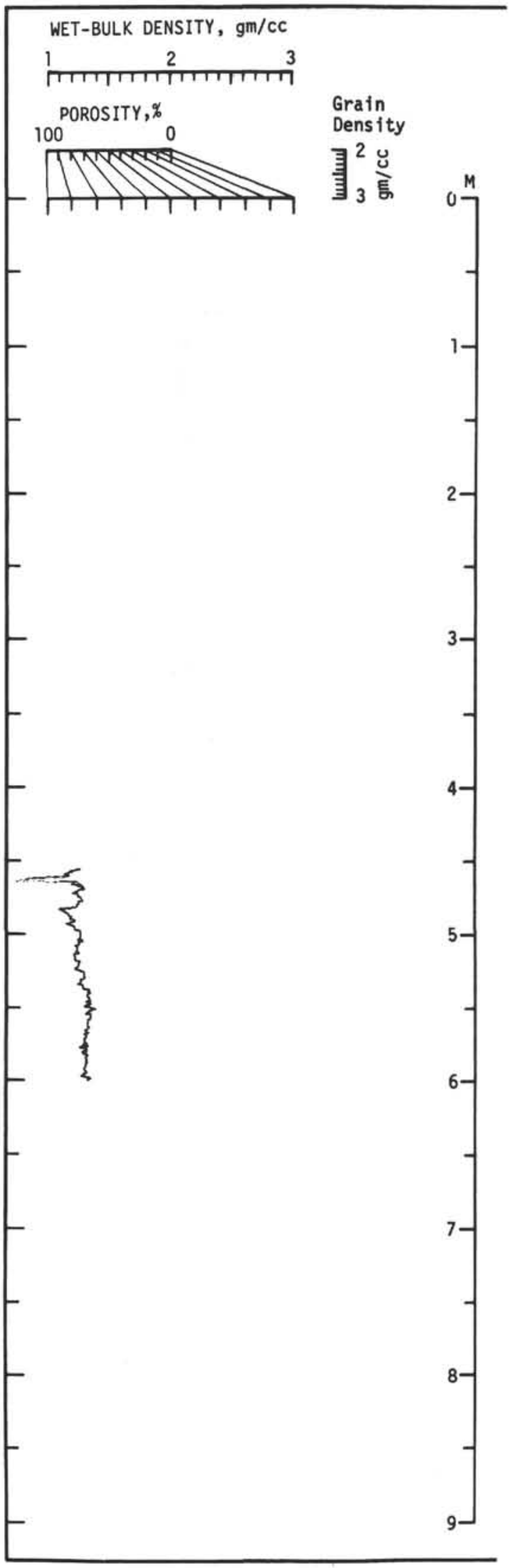
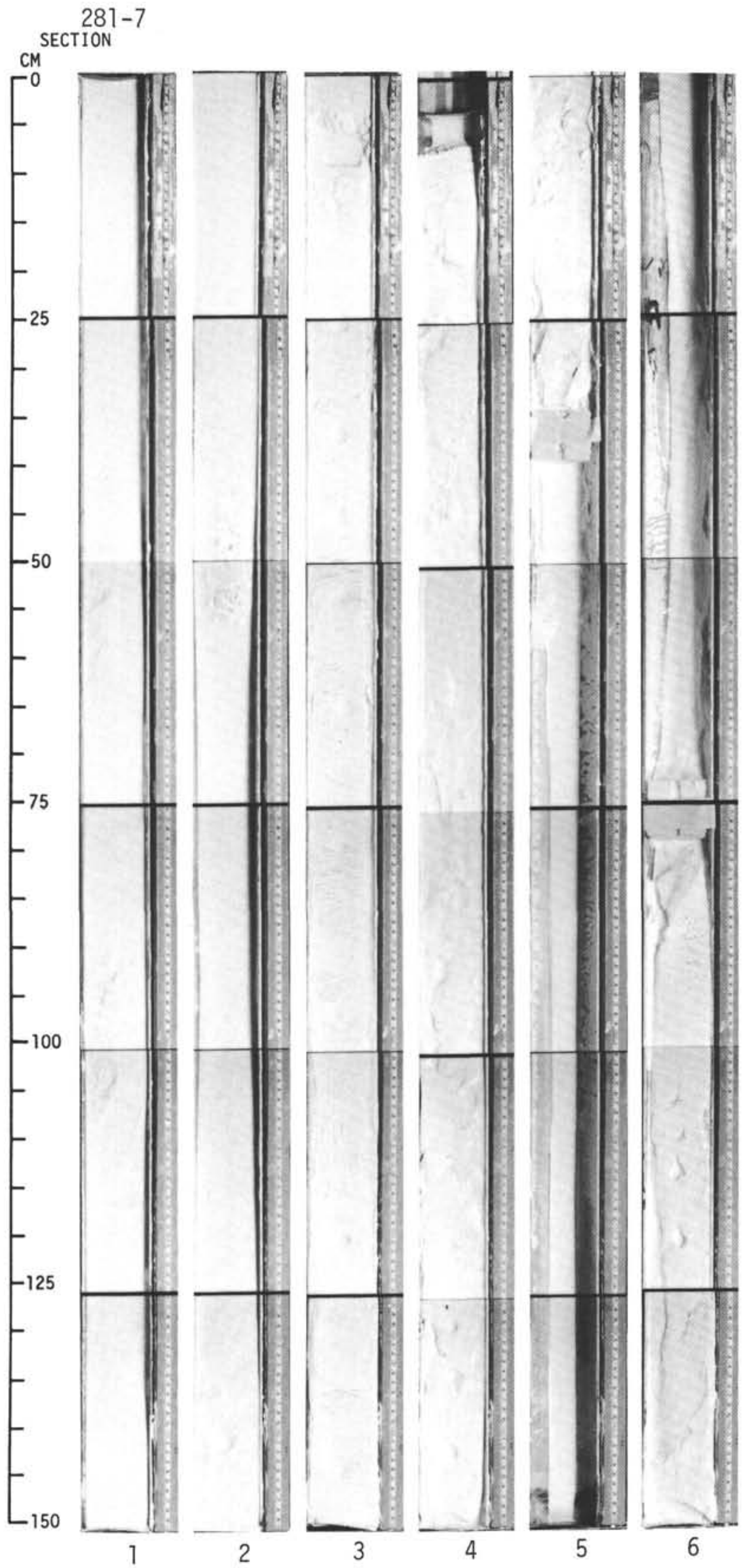
2
3
POROSITY,%
100
0
Grain Density
2
3
gm/cc
M
0
1
2
3
4
5
6
7
8
9
281-6
SECTION
CM
0
25
50
75
100
125
150
1
2
3
4
5
6


WET-BULK DENSITY, gm/cc
1
2
3
POROSITY,%
100
0
Grain Density
2
3
gm/cc
M
0
1
2
3
4
5
6
7
8
9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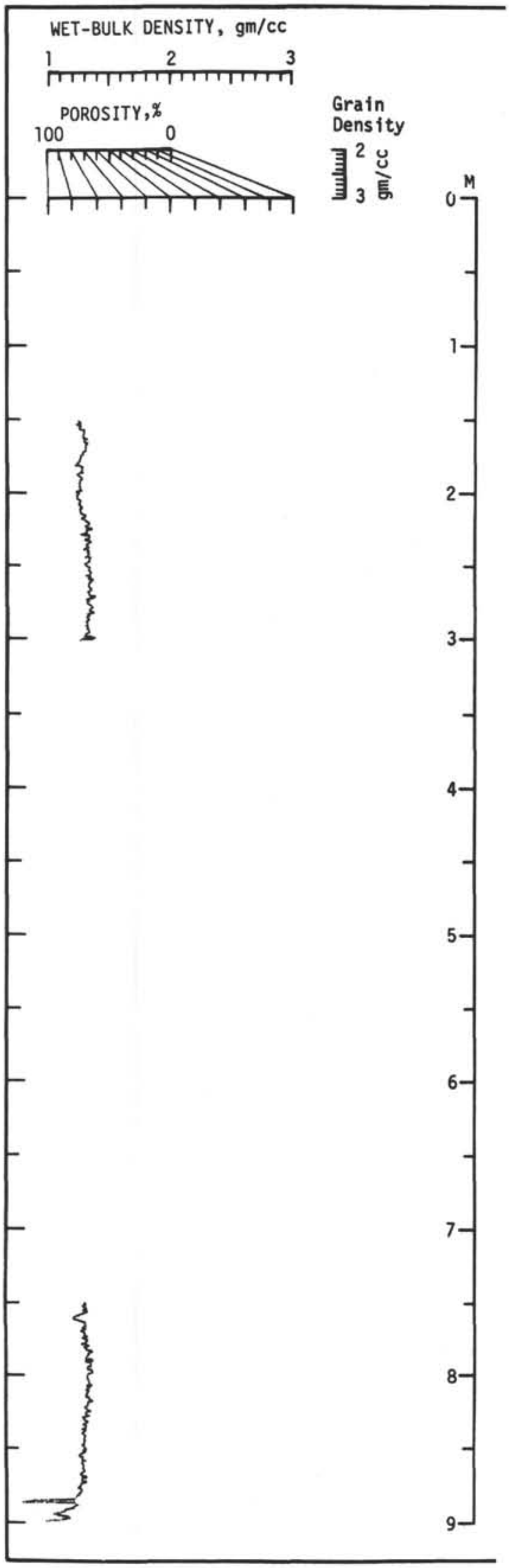
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gm/cc
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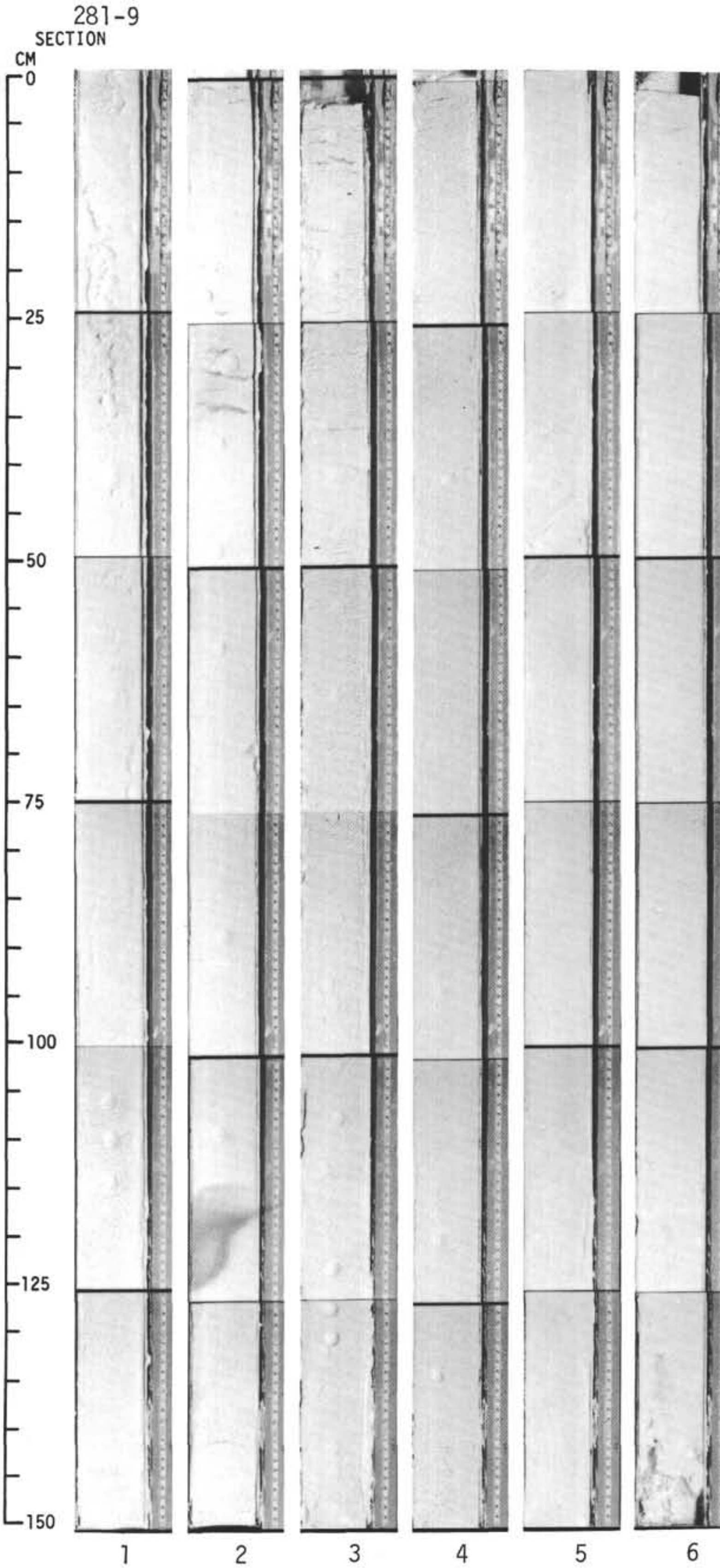
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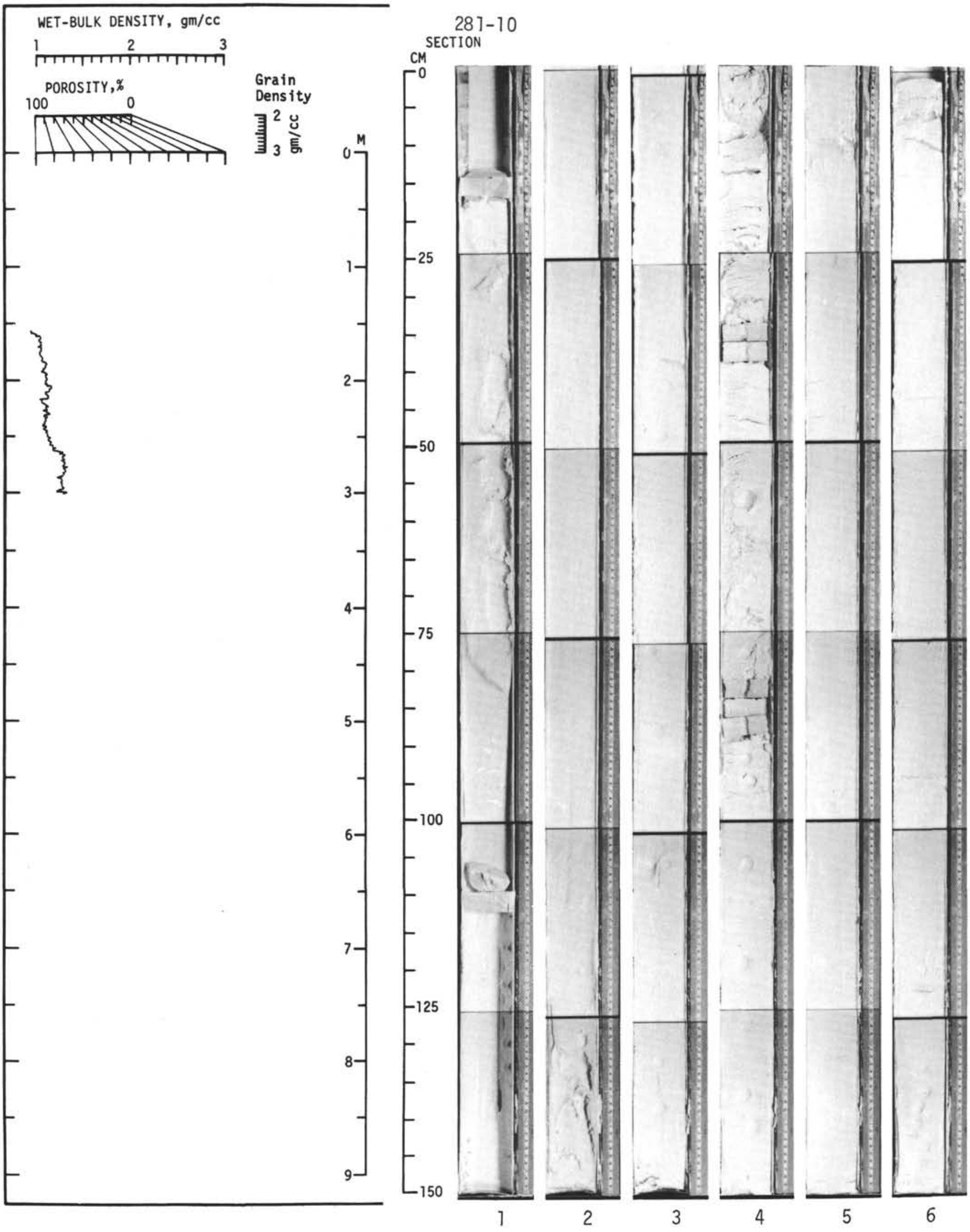
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gm/cc
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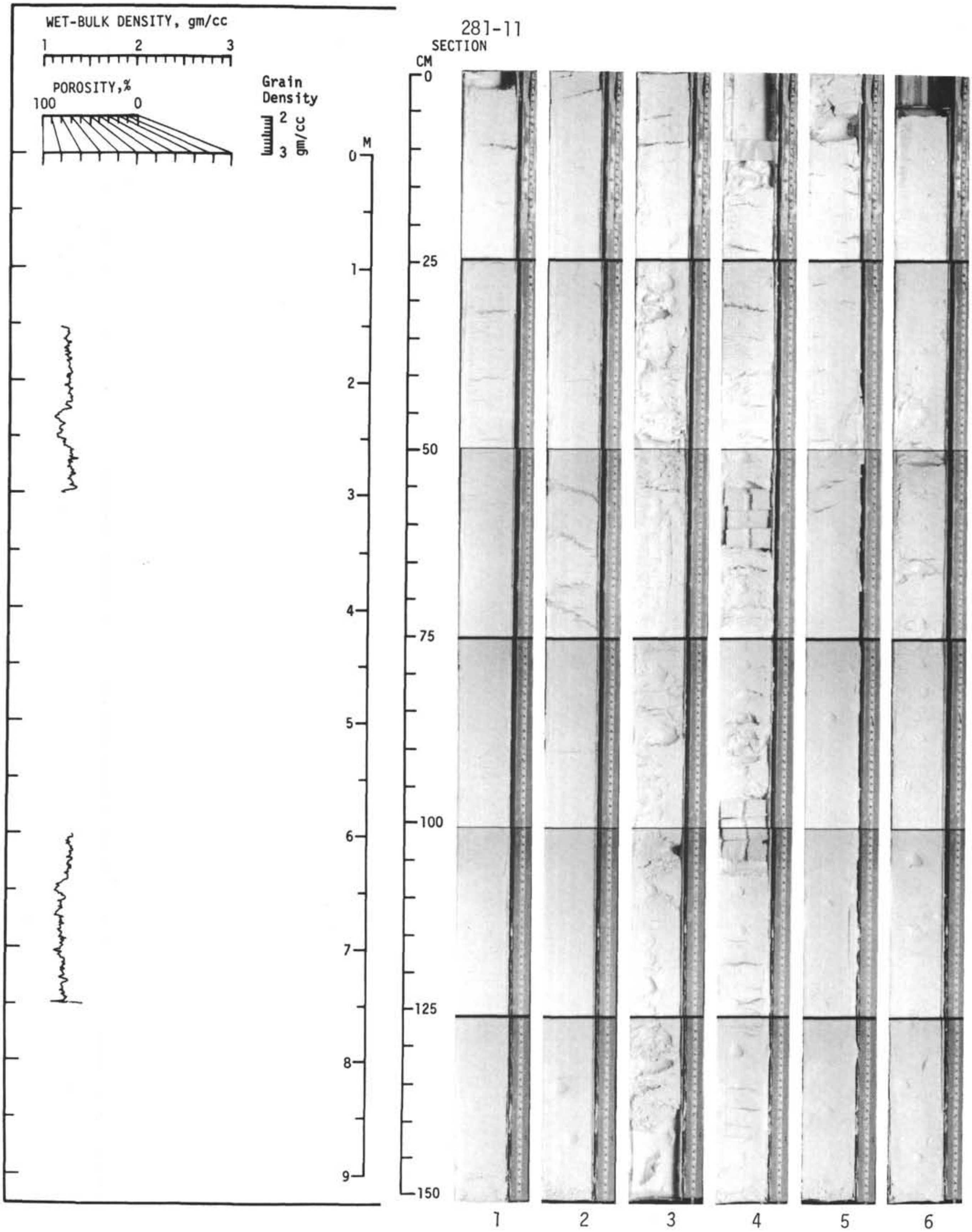
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Density
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gm/cc
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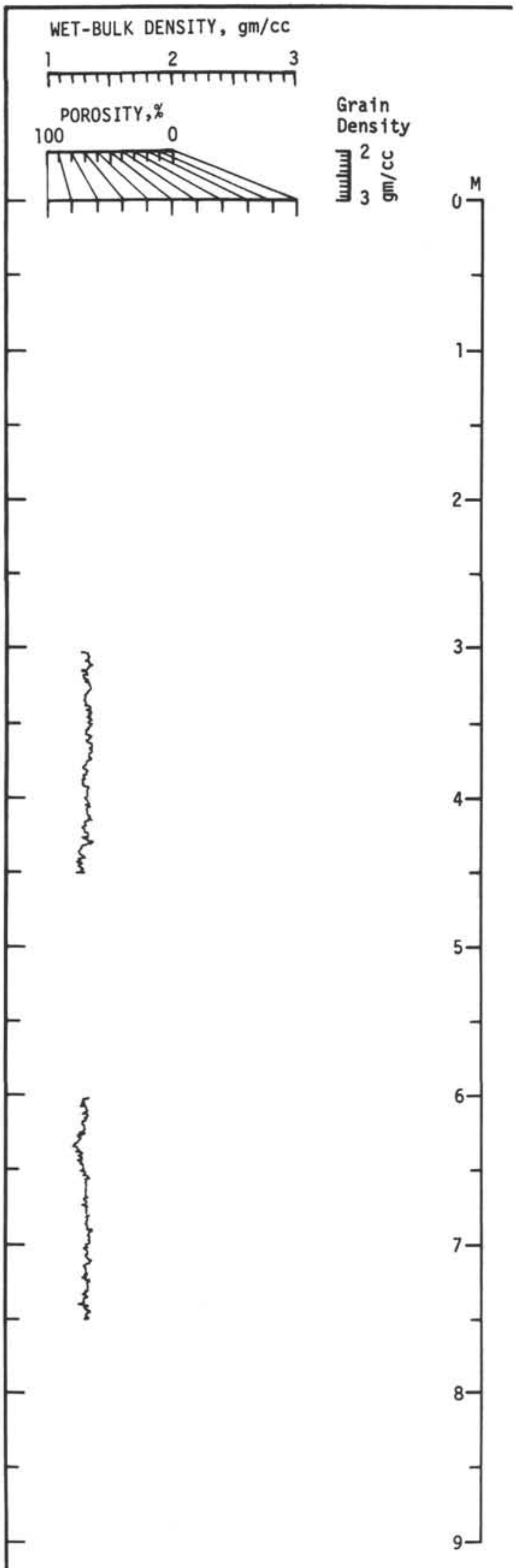
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gm/cc
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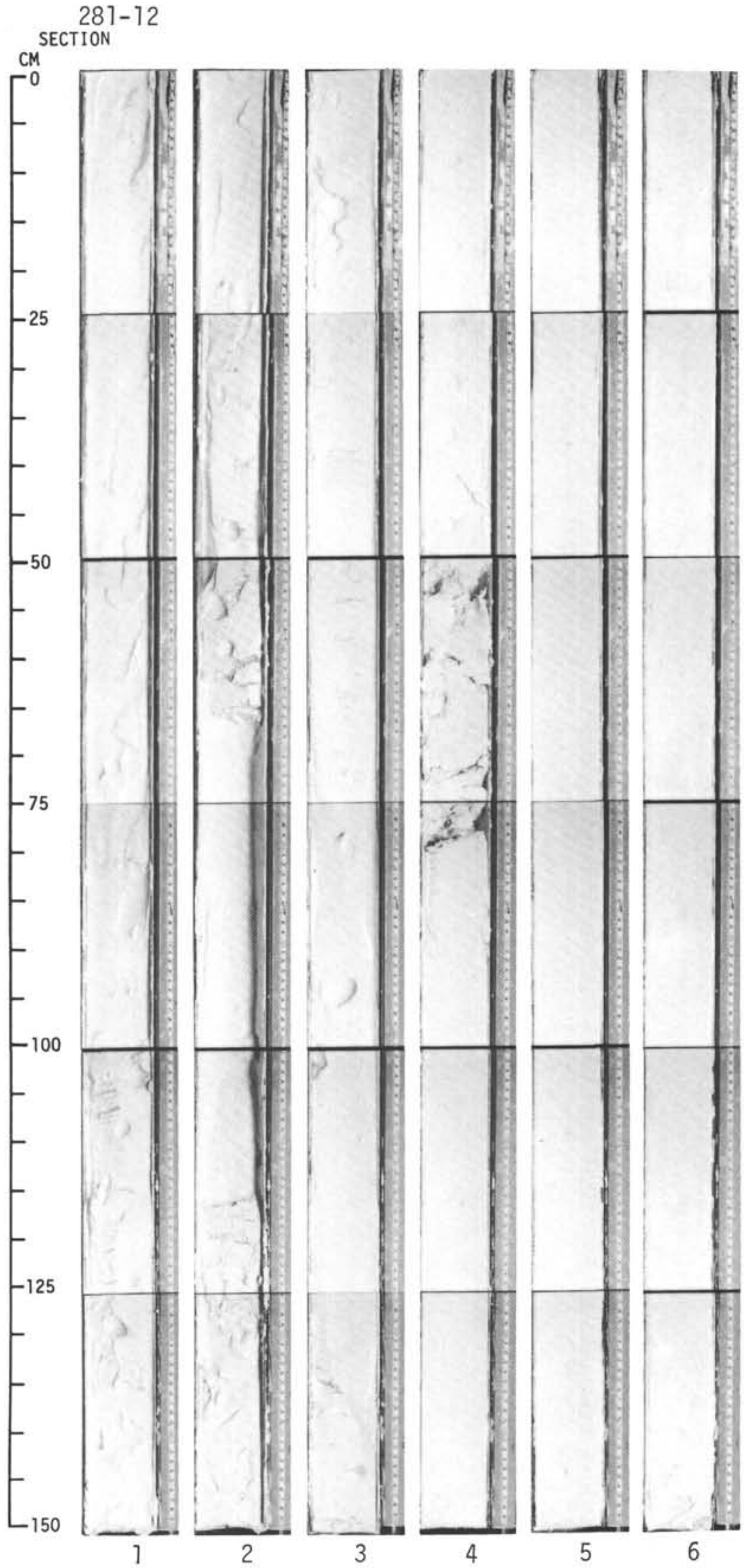
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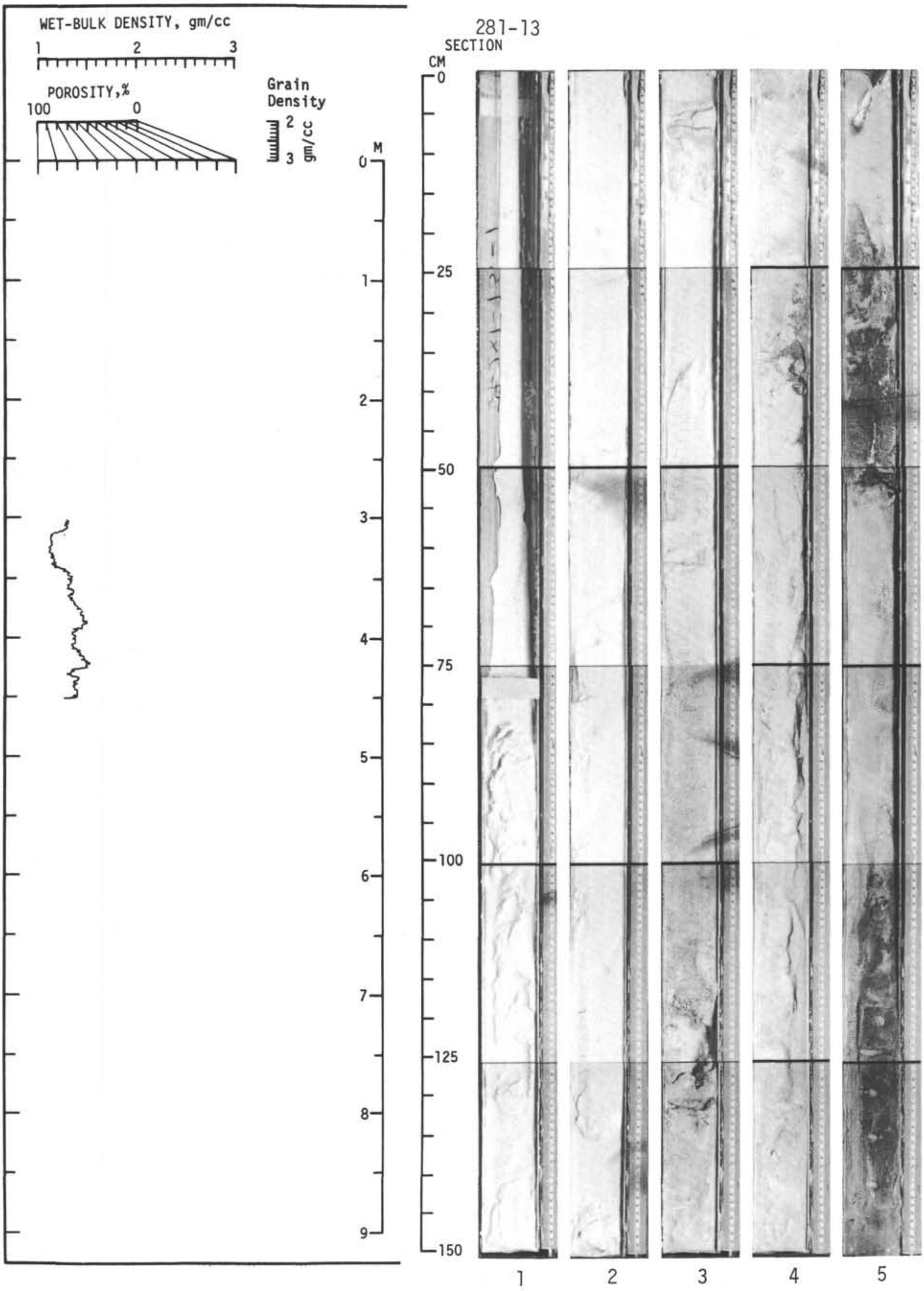
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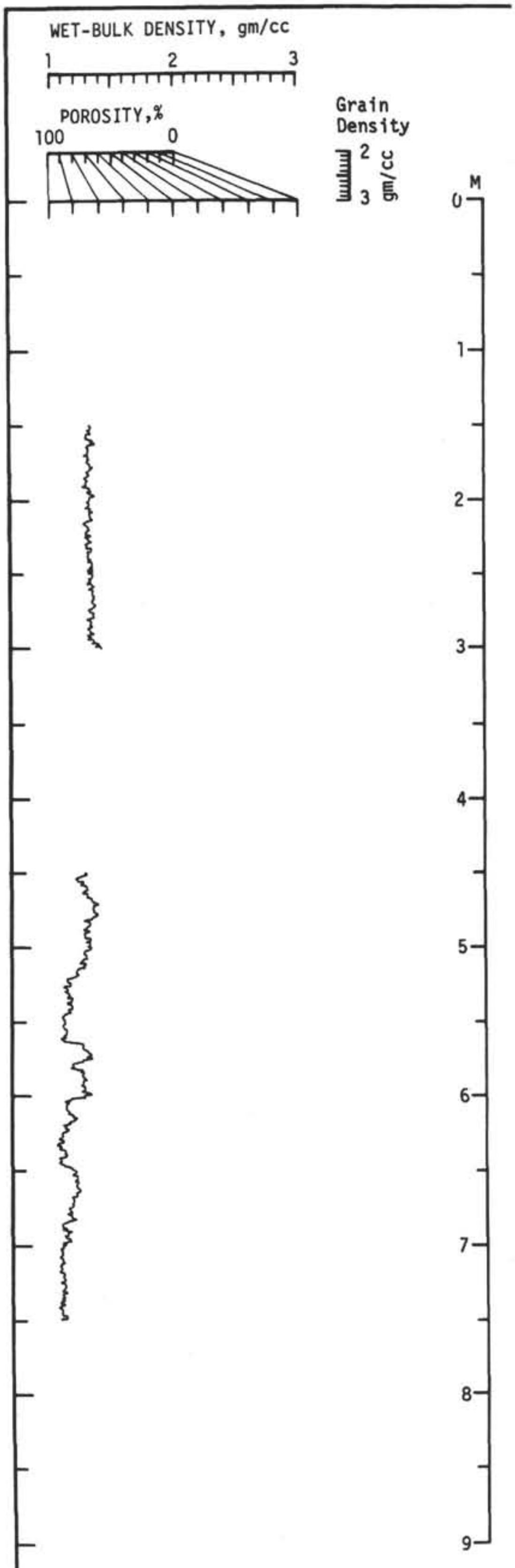
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gm/cc
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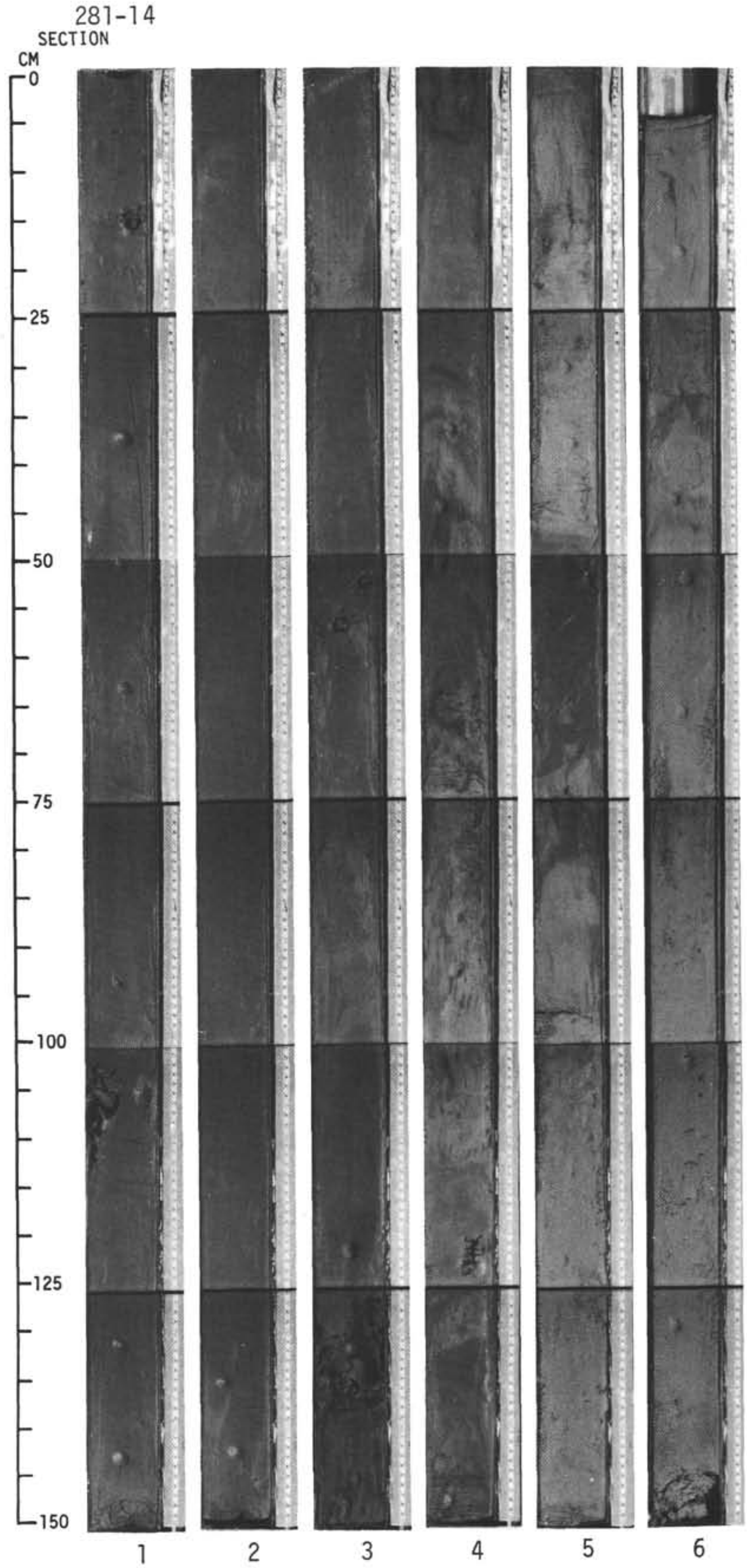
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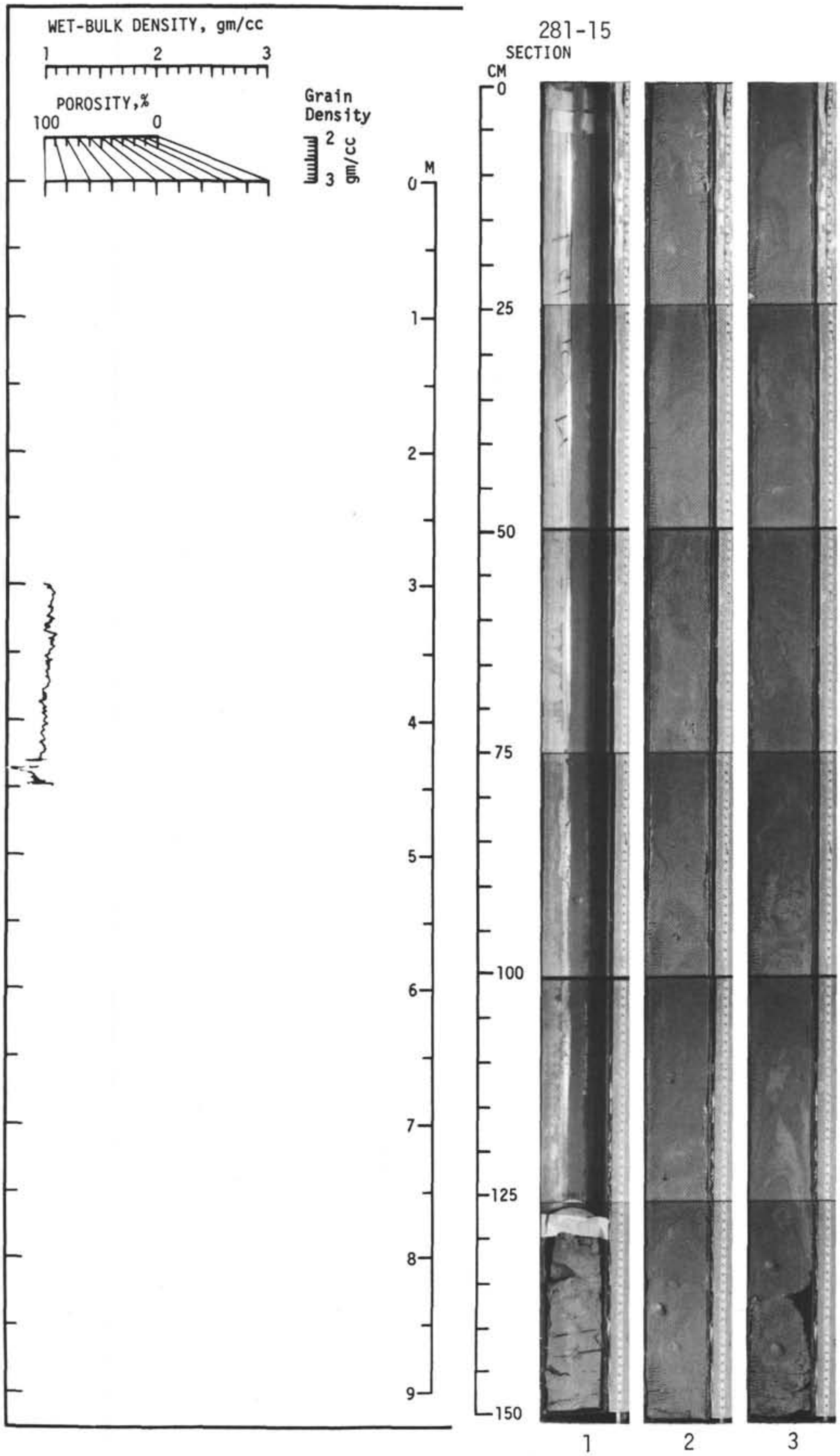
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281-15
SECTION
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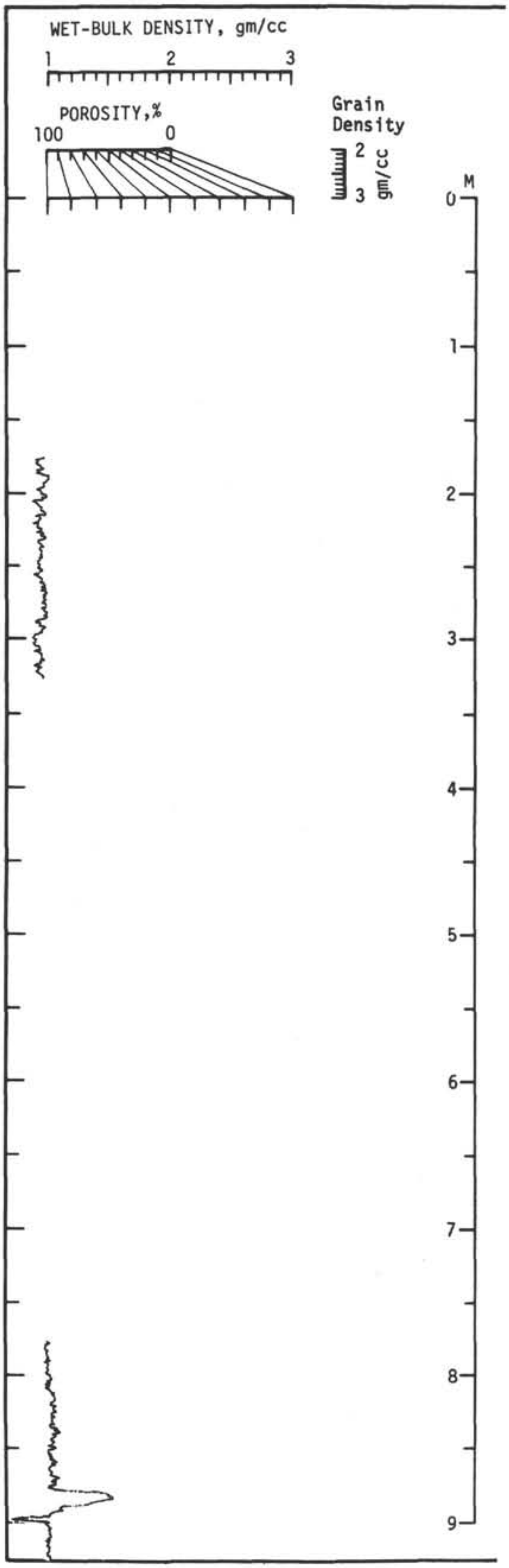
1 2 3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gm/cc
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2
3
4
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6
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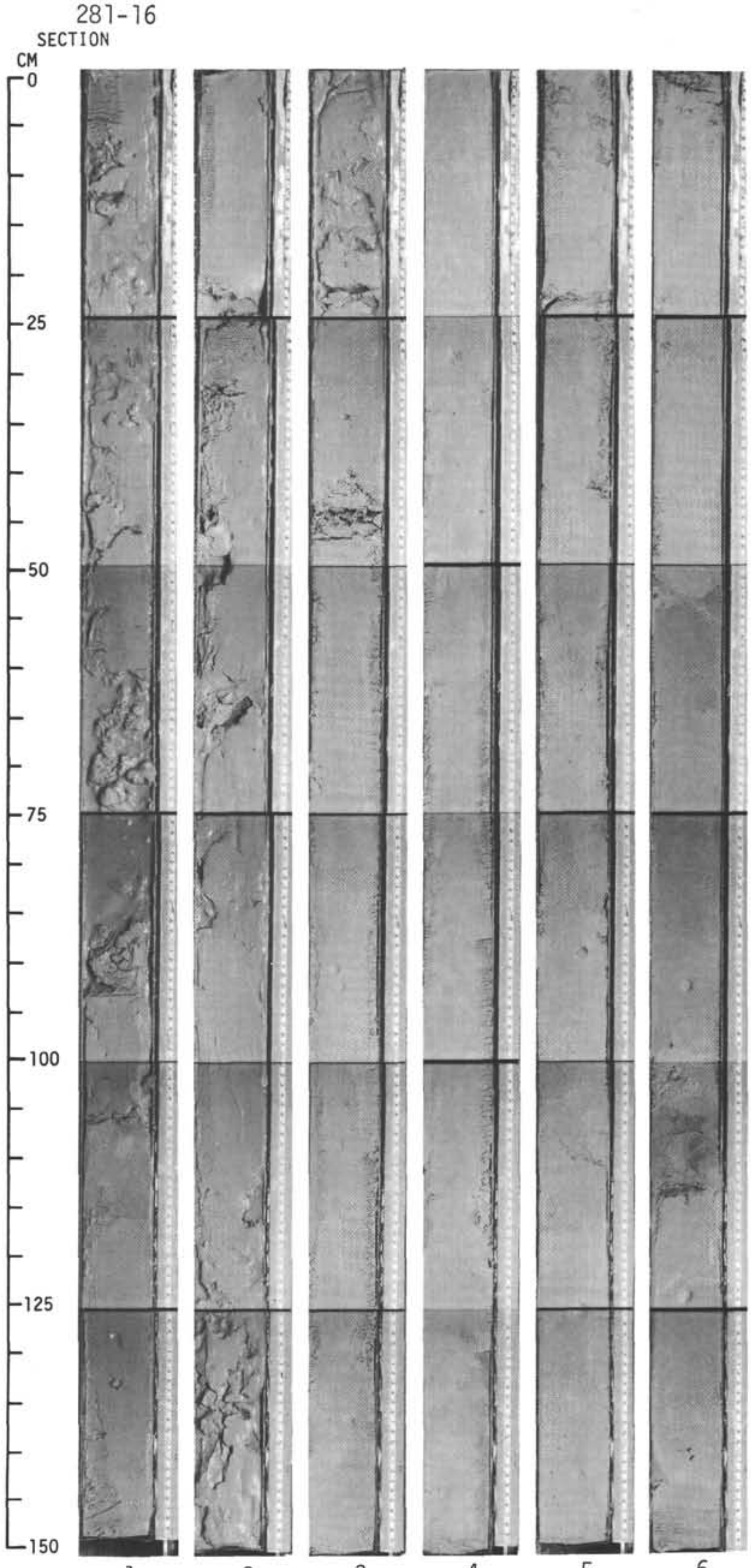
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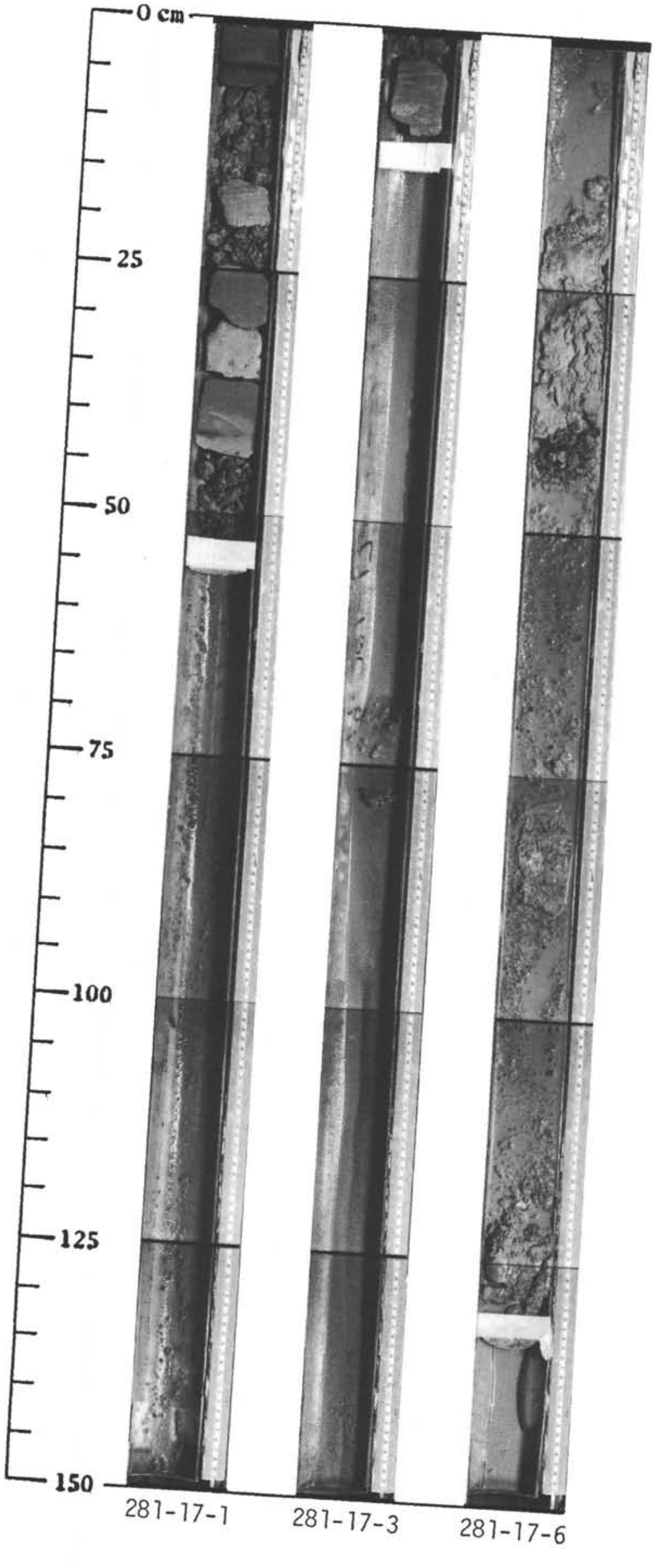
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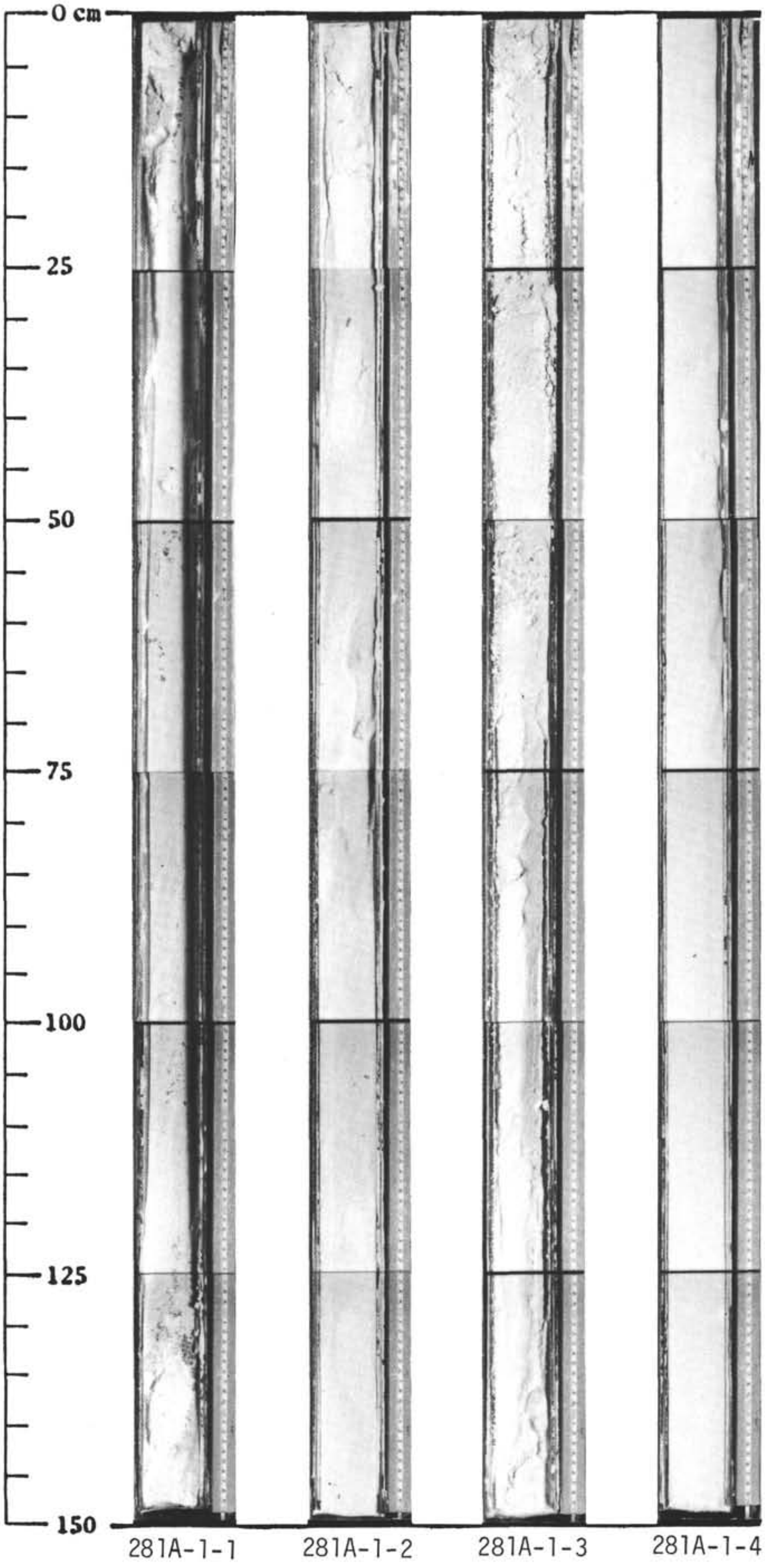
281-17-6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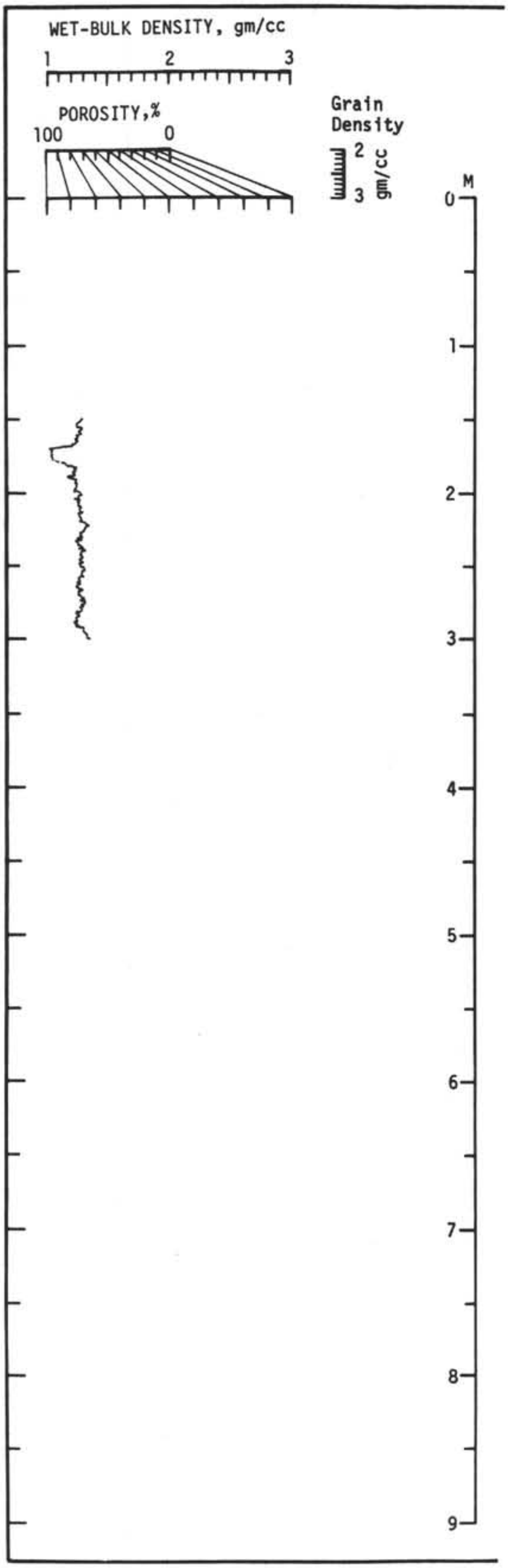
281A-1-2
281A-1-3
281A-1-4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Grain Density
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gm/cc
M
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2
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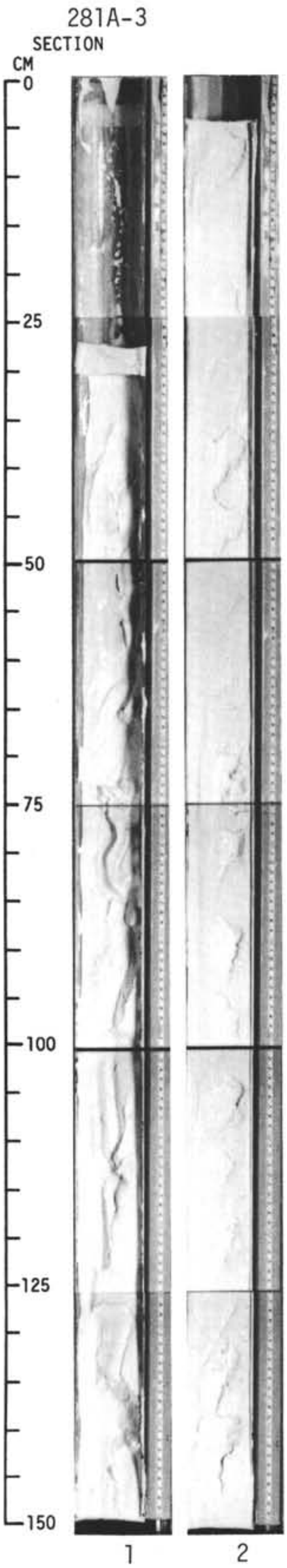
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