7. SITE 81

The Shipboard Scientific Party[1]

MAIN RESULTS

The one hole drilled at Site 81 penetrated a 407-meter (apparently continuous) section ranging in age from Lower Miocene to Pleistocene which was discontinuously cored. The average sedimentation rate at this site is 21 m/m.y. The bit was stopped by basalt and a section of this basalt was recovered. The contact between the basalt and the overlying sediment is baked and brecciated. The age of the basal sediments is estimated to be about 14 million years old. All the major groups of microfossils are present throughout the sections cored.

INTRODUCTION

Background and Objectives

This site was selected by the JOIDES Pacific Panel, and their stated objectives were to "establish the biostratigraphy of the central equatorial belt near the flank of the East Pacific Rise to determine the age and composition of basement rock and to determine rates of sea floor spreading." The knowledge acquired from the results of Sites 77, 78, 79 and 80 increased the significance of Site 81 (Figure 1). At all these sites the basal sediments show signs of baking. The extent of this phenomena can be further tested by drilling Site 81. The rates of sea floor spreading between Site 77 and Sites 79 and 80 (79 km/10^6 yrs) are faster than the recent rates for the region. However, since the age of basement at Site 79 was confirmed by drilling Site 80, these rates can be considered reliable, and any sill encountered at Site 81 would cause the estimated age of basement to be younger than the real age and the inferred spreading rates slower than the actual spreading rates. There was no survey at this site prior to the arrival of the *Challenger.*

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Operations

Site Survey

Since there was no prior survey of this site, the *Challenger* made a short survey over the selected site, which consisted of a box 2 miles on a side (Figure 2). The sediments approaching the site are highly stratified—the stratification gently undulating in conformity with the basement relief. The sediments have a uniform thickness of about 0.5 second reflection time. The stratification through the section is not uniform, but is most highly stratified in the upper 0.03 second and again between 0.12 and 0.21 second and again between about 0.3 and the bottom of the sediment column. These highly stratified units are separated by less stratified units. At the very base of the section a thin layer of nearly transparent sediment occurs. The topographic relief in the vicinity of the site is gentle amounting to about 100 fathoms.

During the site survey a section of relatively smooth ocean floor was crossed. It was decided to make this our drilling site and we pulled in the seismic gear. In attempting to return to the specified location, the P.D.R. record indicated greater depths than we had encountered when the ship previously crossed the site. The seismic gear was again streamed and the ship returned to the proper location. This difficulty in returning to the selected drilling site was a prelude to the major problem of drilling at this site—strong currents. When the selected site was reached a Burnett beacon was dropped and the ship attempted to station itself above the beacon. Seven hours were spent trying to maneuver the ship over the beacon. By this time in our voyage we had lost the use of one bow thruster, and in the strong currents we were encountering (3 to 4 knots) the bow of the ship could not be held into the current. Consequently, the stern of the *Challenger* was put into the current and in this position she could just be held with available power. Under these circumstances it was necessary to adjust our goals for this site in order to accomplish those with highest priority. Our highest priority was to sample basement and the contact with the overlying sediment.

Coring

Since our time on this site might be limited due to the strong currents and possibility of squalls it was decided to take a core at the sea floor and then drill down to

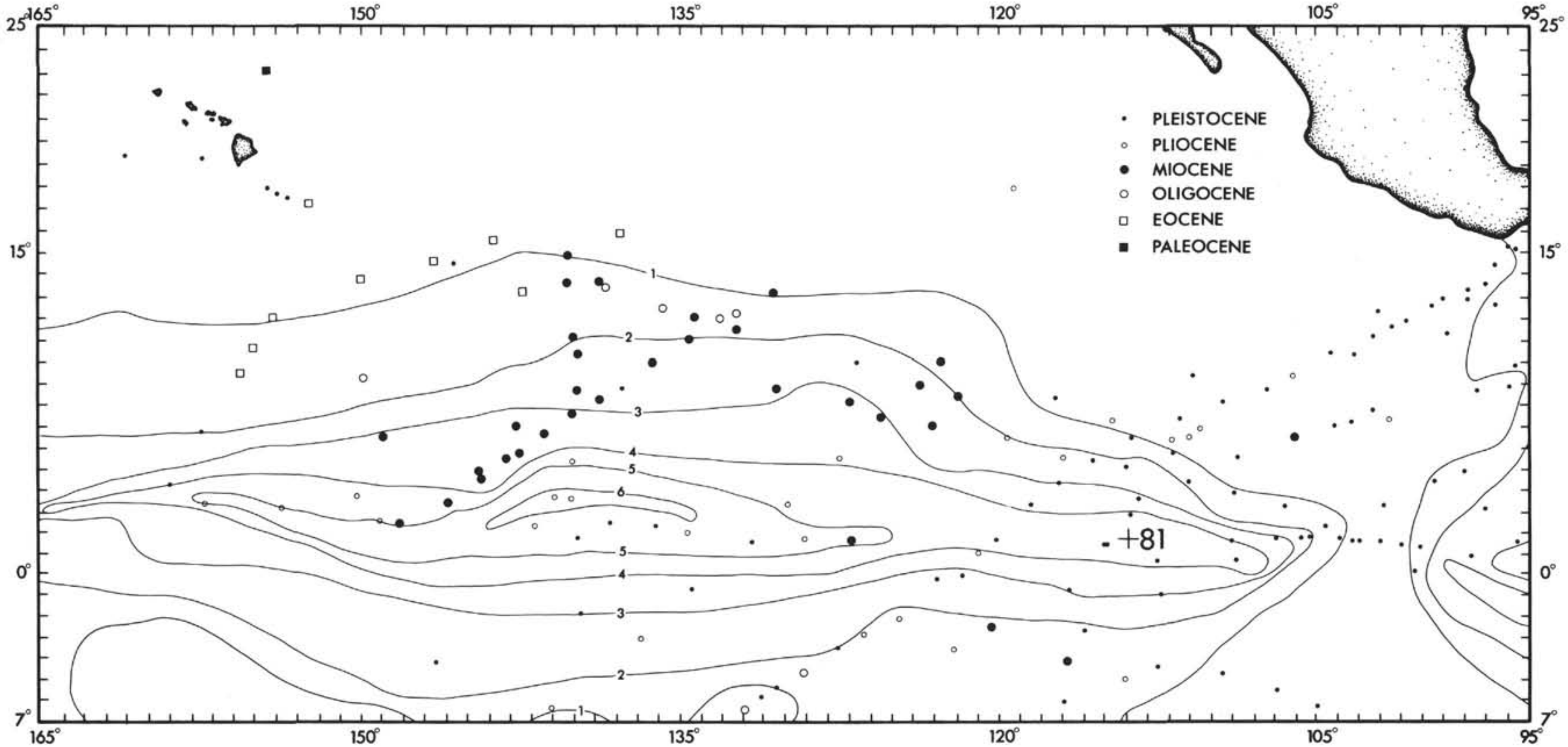


Figure 1. *Location of Site 81; sediment isopachs in hundreds of meters after Ewing* et al. *(1968); distribution of piston core ages after Hays* et al. *(1969).*

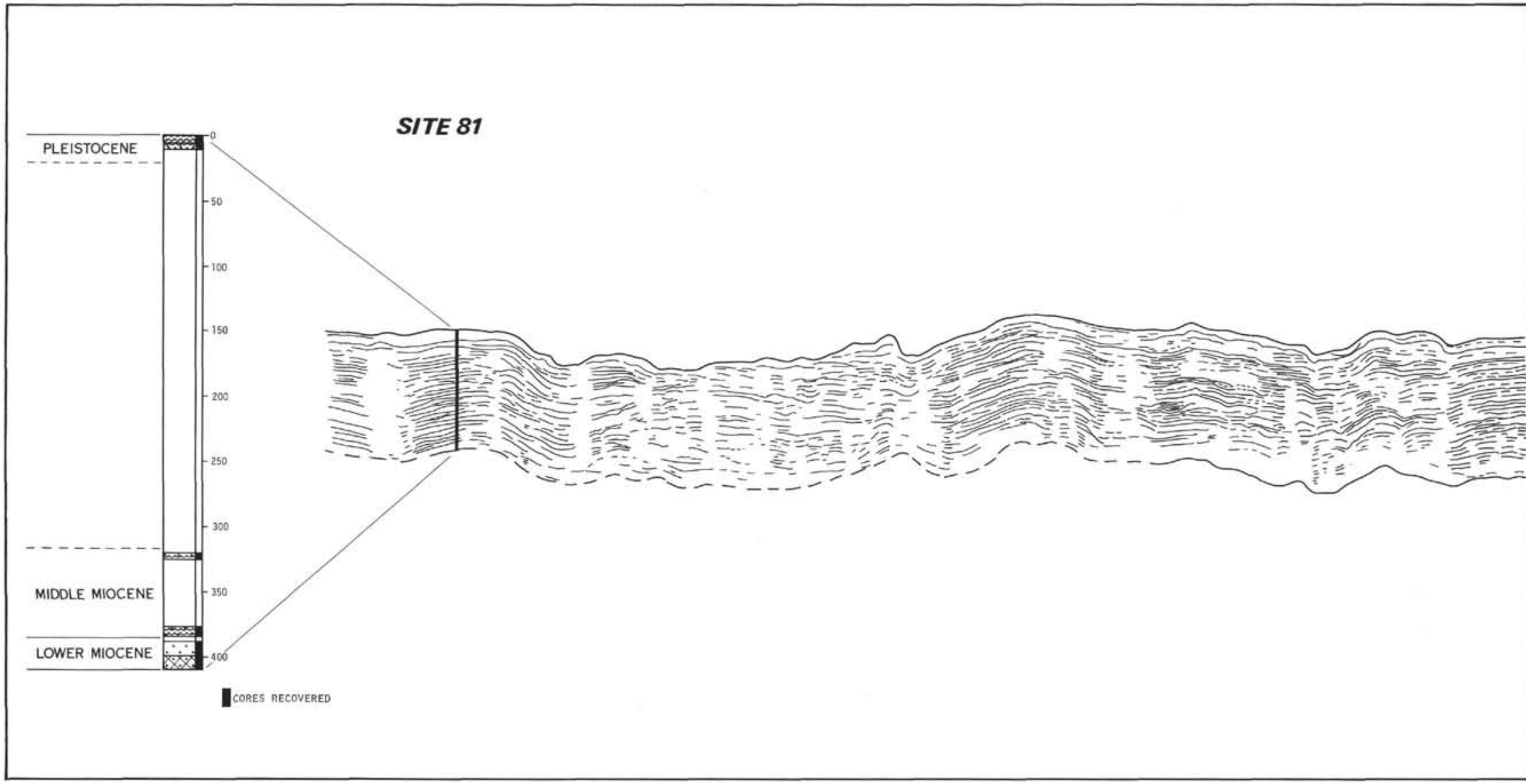


Figure 2. *Sketch of seismic reflection record in vicinity of Site 81 showing interval cored in each hole.*

the vicinity of basement and core continuously until basement was reached. The coring operations for this site are summarized in Tables 1 and 2.

Seven cores were taken at this site; one was taken at the ocean floor, the others near the base of the sediment section.

LITHOLOGY

Three sedimentary formations are present at Site 81: The Clipperton Oceanic Formation (0 to 60 meters) consisting of the cyclic unit (0 to 2.3 meters) of alternating siliceous and calcareous oozes and the varicolored unit (2.3 to 60 meters); the San Blas Oceanic Formation (60 to 385 meters) of green and bluish-gray montmorillonite calcareous chalk; and the Line Islands Oceanic Formation (385 to 409.1 meters) of yellow and dusky brown, amorphous iron-rich, calcareous chalks. Basement at this site is a black, fine-grained basalt.

Clipperton Oceanic Formation

Cyclic Unit (0 to 2.3 meters)

At this site the cyclic unit is similar to the cyclic unit at previous sites. Here, it consists of thin, interbedded cycles of siliceous and calcareous ooze. However, there are differences; the "red clay" content in the siliceous oozes is very low and the dark brown colors are not a major characteristic. Beds range from 0.5 to 25 meters in thickness with sharp upper and lower contacts. No visible laminations were seen within the beds, although laminated oozes are easily destroyed during coring.

The two dominant lithologies are:

1. Very pale orange (10YR8/2) to grayish-orange (10YR7/4) foraminiferal (20 to 30 per cent)–calcareous nannofossil (30 to 40 per cent)–radiolarian (30 to 50 per cent) ooze with about 1 to 2 per cent "red clay".

2. Yellowish-gray (5Y8/1) to light greenish-gray (5GY8/1) foraminiferal (10 to 20 per cent)–radiolarian (10 to 20 per cent)–calcareous nannofossil (60 to 80 per cent) ooze.

The contact with the underlying varicolored unit was cored and is placed at the first appearance of purple oozes.

Varicolored Unit (2.3 to 60 meters)

Only the upper 6.8 meters of the varicolored unit were cored at this site, thus its total thickness can only be estimated. Its lower boundary is placed within an uncored interval at 60 meters on the basis of its thickness at Site 80 and its eastward thinning.

It exhibits well-defined 2 to 25-centimeter thick beds with sharp upper and lower contacts. In undisturbed zones the bedding planes appear to be horizontal. The sediment types include:

1. Pale purple (5P6/2) to very dusky purple (5P2/2) foraminiferal (10 to 20 per cent)–radiolarian (30 to 40 per cent)–calcareous nannofossil (40 to 50 per cent) ooze.

2. Very pale orange (10YR8/2), white (N9), and light gray (N7) foraminiferal (15 to 25 per cent)–radiolarian (20 to 30 per cent)–calcareous nannofossil (40 to 60 per cent) ooze.

San Blas Oceanic Formation

The San Blas Oceanic Formation is here named for the San Blas Islands off the west coast of Panama. This formation can be lithologically correlated to Sites 82, 83 and 84. Although this formation was first cored at Site 81, it was continuously cored at Site 84 and Site 84 is designated as its type locality. Sites 81-83 are reference sections.

The San Blas is easily distinguished from the other formations by its dominant green colors which usually persist over long intervals with no obvious laminations which result in massive-appearing beds. Other characteristic features are occasional dusky purple manganese (?)-rich streaks, and grayish orange burrows.

The coloration in the San Blas is due to green montmorillonite (Cook and Zemmels, 1971) which is forming from the devitrification of pyroclastic glass shards and pumice fragments. This formation becomes a progressively darker green color as Central America is approached. This darker green apparently reflects a higher percentage of pyroclastic material in the sediments which is altering to montmorillonite (Cook and Zemmels, 1971).

At Site 81 the dominant sediment types include:

1. Light bluish-gray (5B7/1) and medium bluish-gray (5B5/1) radiolarian (30 to 40 per cent)–calcareous nannofossil (50 to 70 per cent) chalk with a small percentage of manganese (?) coating the radiolarians.

2. Greenish-gray (5G6/1) to dark greenish gray (5G4/1) montmorillonite (2 to 5 per cent)–foraminiferal (10 to 20 per cent)–radiolarian (10 to 20 per cent)–calcareous nannofossil (60 to 80 per cent) chalk.

3. Light greenish-gray (5GY8/1) to light bluish-gray (5B7/1) radiolarian (10 to 20 per cent)–foraminiferal (10 to 20 per cent)–calcareous nannofossil (60 to 80 per cent) chalk.

4. Grayish-orange (10YR7/4) to pale yellowish-brown (10YR6/2) calcareous nannofossil (30 to 40 per cent)–radiolarian (60 to 70 per cent) chalk.

TABLE 1
Site Operational Summary

Site 81

Latitude 01° 26.49′N; Longitude: 113° 48.54′W.

Time of arrival: 2048 hours, 1/8/70; Time of departure: 2045 hours, 1/10/70.

Total time on site: 1 day, 23 hours, 57 minutes.

Water depth: 3854 meters.

Sediment thickness determined by drilling: 409 meters.

Acoustical thickness: 0.5 second.

Average sound velocity of sediments: ≅1.6 km/sec.

Hole	Penetration (m)	Cores Attempted	Cores Recovered	Per Cent Cored	Recovery (m)	Per Cent Recovered
81	409.5	7	7	9.6	39.3	100

TABLE 2
Hole Drilling Summary, Site 81
(Latitude 01° 26.49′N, Longitude 113° 48.54′W; 3854 meters depth)

Hole 81

Interval Below Sea Floor (m)	(ft)	Cores Drilled	Core	Core Cut (m)	(ft)	Core Recovered (m)	(ft)	Drill Stem Rotated	Pump Circ	Drilling Rate (ft/min)
0.0-9.1	0-30		1	9.1	30	9.1	30			
9.1-319.8	30-1049									
319.8-323.2	1049-1060		2	3.4	11	6.4	21			
323.2-376.5	1060-1235									
376.5-383.2	1235-1257		3	6.7	22	8.5	28		Cont	
383.2-389.3	1257-1277									
389.3-395.7	1277-1298		4	6.4	21	7.3	24		Cont	
395.7-404.9	1298-1328		5	9.1	30	3.4	11		Cont	
404.9-408.5	1328-1340		6	3.7	12	3.7	12		Cont	
408.5-409.5	1340-1343		7	0.9	3	0.9	3		Cont	
Total 409.5	1343		7	39.3	129	39.3	129			

The contact between the San Blas and underlying Line Islands Oceanic Formation was not cored.

Line Islands Oceanic Formation

At this site the Line Islands Oceanic Formation consists of interbedded pale orange and pale yellowish-brown chalks that occur in 1 to 5-centimeter thick beds. The pale orange predominate in the upper part of the formation, whereas, the lower part contains equal amounts of orange and brown chalk. Other characteristics include very pale orange burrows and abundant black manganese (?) dendrites.

The basal meter is partially brecciated and exhibits baking and deutric mineralization–all of which become more intense toward the basalt contact (Figures 33 and 34).

This formation contains the following sediment types:

1. Pale orange (10YR7/2) foraminiferal (5 to 10 per cent)–radiolarian (5 to 10 per cent)–calcareous nannofossil (80 to 90 per cent) chalk with abundant manganese (?) dendrites parallel to bedding planes.

2. Pale yellowish-brown (10YR6/2) foraminiferal (15 to 20 per cent)–calcareous nannofossil (80 to 85 per cent) chalk with deuteric iron oxide, clay and tridymite.

3. Dusky brown (5YR2/2) and moderate reddish-brown (10R4/6) calcareous nannofossil (40 to 50 per cent)–iron oxide, plus clay (50 to 60 per cent) chalk mudstone.

Basalt

This basalt is black (N-1), fine-grained, and has an isotropic chilled glass rind. The refractive index of this apparently non-devitrified glass is 1.580 which suggests a silica (SiO_2) content of about 50 to 52 per cent.

PHYSICAL PROPERTIES

Natural Gamma

Natural gamma readings at Site 81 usually range from 785 to 1000 counts/75 sec with increases up to 1115 counts in the upper half of Core 1 and in Core 3.

The cyclic unit of the Clipperton Oceanic Formation recorded readings from 950 to 1100 counts in Core 1. Potassic feldspar probably is responsible for these readings.

The varicolored unit of the Clipperton Oceanic Formation shows readings from 875 to 950 and up to 1000 counts in Core 3. Pumice or clay probably is responsible for these readings. The varicolored unit can be distinguished at this site from the cyclic unit because of the lower natural gamma emission readings in the varicolored unit (Figure 4).

The San Blas Oceanic Formation yielded readings from 875 to 950 counts. These low counts serve to distinguish it from the overlying Clipperton Formation.

The Line Islands Oceanic Formation was not tested for natural gamma emission at this site because of technical malfunctioning of the recorder.

Porosity

Porosity at Site 81 ranges from 74 per cent in bluish-gray radiolarian-calcareous nannofossil chalks to 64 per cent in light greenish-gray radiolarian-foraminiferal calcareous nannofossil chalks. GRAPE data is available only in Cores 1 through 3. The porosities are 74 per cent, 70 per cent, and 64 per cent, respectively. The three porosities decrease with depth which may result from compaction and/or incipient cementation. No correlation can be made between porosity and lithology at this site because of insufficient data.

Sound Velocity

The sound velocity ranges from 1484 to 1653 m/sec, and averages 1540 m/sec. Sound velocities generally increase downhole and probably reflect sediment compaction.

Bulk Density

The bulk densities range from 1.317 g/cc to 1.661 g/cc. The highest density reading is at 384.6 meters, and the lowest reading was recorded at 383 meters. Whether this definitely is an artificially created situation due to drilling disturbance is not known. There is no correlation between density and depth or change in lithology.

Penetrometer

At Site 81 a high range of readings was obtained in the top ten meters. This reflects the different lithologies in the cyclic unit of the Clipperton Oceanic Formation. The downhole decrease in readings appears to be real and to reflect some type of induration process. Very high readings at 385 meters indicate soupy sediments which were disturbed and injected with sea water during coring.

BIOSTRATIGRAPHY

Foraminifera

The biostratigraphic data from this site are very limited, mainly because of the spacing of the cored intervals. Only seven cores bearing sediment were recovered at the site over an interval of ~409 meters, and most of these cores consist of less than a full barrel of sediment.

The uppermost core yielded a Pleistocene *Pulleniatina obliquiloculata* fauna. Between this uppermost core and a series of closely spaced short cores at the base of the hole, a single short core was taken at ~300 meters which yielded a middle Miocene *Globorotalia fohsi fohsi-Globorotalia peripheroacuta* zonal assemblage. Despite the spacing of the cores, the recorded faunas were well preserved and diverse with the exception of the last two cores in the hole. The lower Miocene subzonal marker species *Globigerinoides bisphericus* was not recovered from either of the final two cores (Cores 6 and 7), and the subzonal assignment was based on the presence of *Hastigerinella bermudezi* in baked chalks overlying basalt in Core 7.

Radiolaria

The recovery at Site 81 is so minimal that little can be said about the radiolarian biostratigraphy. Radiolaria are common to abundant and well preserved in Cores 1 through 5. Radiolaria are either absent or rare and poorly preserved in Cores 6 and 7. Representatives of the Orosphaeridae are common in Cores 3, 4 and 5, and scarce in the younger section. Diatoms become progressively more abundant down section.

The zonal assignment of the lower portion of Core 5 is problematic. Species such as *Brachiospyris alata* and *Stichocorys diploconus* have anomalous distributions in Cores 4 and 5. *Brachiospyris alata* has a sporadic occurrence in only three samples. The criterion of restricting the *D. alata* Zone only to the continuous portion of the range of *B. alata* is followed here as it was at Site 77; consequently, this zone is not indicated for these cores. The *Cannartus laticonus* Zone reaches its maximum thickness here. At Site 81, this zone is at least 68 meters thick. The only other site on Leg 9 which has a complete *C. laticonus* Zone is Site 77, where the zone is approximately 35 meters thick.

DISCUSSION AND INTERPRETATION

The bit penetrated 409 meters of sediment before being stopped by basalt. The sediment just above basement at this site are of lower Miocene age, and according to Berggren (1969) have an age of about 15 million years. The average rate of accumulation is about 21 m/m.y., which is in accord with the rates of sedimentation beneath the zone of highest productivity at other sites on this leg.

Sediment Basement Contact

The sediment basalt contact at this site shows signs of alteration in a 2.5-meter thick zone. There is also brecciation near the contact between sediment and basalt indicating that the sediment was broken and twisted as the sill was intruded. Although the precise rate of sediment accumulation at the base of the section is not known, if you use the average rate for the whole section as a first approximation (21 $m/10^6$ yrs) then the thermally altered section above the contact would have taken about 100,000 years to be deposited.

There is no way of estimating the amount of sediment at this site when the basalt sill which stopped our drill was intruded, but the baked zone provides a minimum thickness. The very infrequent coring at this site makes estimate of series sedimentation rates impossible.

Sea Floor Spreading

Assuming that in the lower Miocene the sea floor was spreading in a nearly westerly direction parallel to the trends of the major fracture zones to the north (such as, the Clipperton and Clarion, etc.), then to measure the rate of motion, the motion should be measured along lines of latitude. The distance between the longitude lines of Site 79, where the basal sediments have an age of about 21 million years, and the longitude line of Site 81, where the basal sediments have an age of about 14.5 million years, is 806 kilometers. If we assume that the basalt was intruded at or near the sediment basalt interface, so that the age of the basal sediment is similar to that of the basement, then the rate of spreading between these two sites is 124 km/m.y.

This rate is considerably higher than the rate of 79.5 $km/10^6$ yrs calculated for the sea floor between Sites 77 and 79, but we consider this a minimum value for the following reasons: Since all basalt contacts at Sites 79, 80 and 81 are baked, the basalts are sills and may or may not have some thickness of sediment beneath them that separates them from the basement formed at the ridge crest. Since the age of the basal sediments at Sites 77 and 80 are so nearly the same age the probability is high that there is little sediment beneath these sills and that they rest directly on basement. We have no second site to check Site 81, so there may be a considerable thickness of sediment beneath the basalt at Site 81. If there is, then the rate of spreading we infer is too low and the spreading was actually faster, since this would mean the age of the basement is older than we infer from the age of the oldest sediments.

The time required to deposit the sediments included in the baked zone as indicated above is about 100,000 years, thus indicating a minimum time from the formation of basement at the ridge crest to the intrusion of the sill which stopped the bit. Using a spreading rate of 124 $km/10^6$ yrs, then the sill was intruded a minimum distance from the ridge crest of 12.4 kilometers.

REFERENCES

Berggren, W. A., 1969. Rates of evolution in some Cenozoic planktonic foraminifera. *Micropaleontol.* **15** (3), 351 p.

Cook, H. E. and Zemmels, I., 1971. X-ray mineralogy studies–Leg 9. **In** J. D. Hays, *et al.*, 1971, *Initial Reports of the Deep Sea Drilling Project, Volume IX.* Washington (U. S. Government Printing Office), in press.

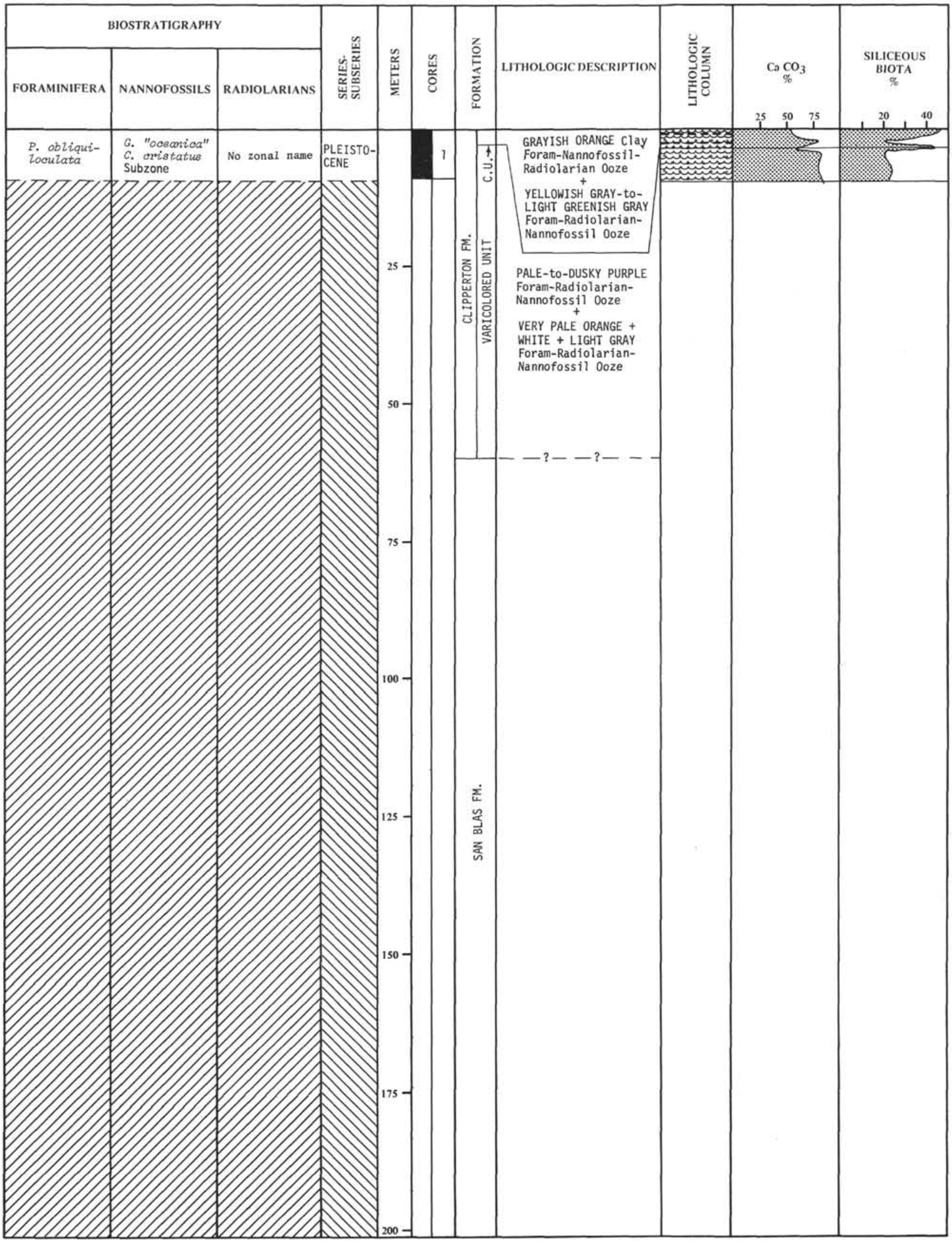


Figure 3. *Site 81 summary.*

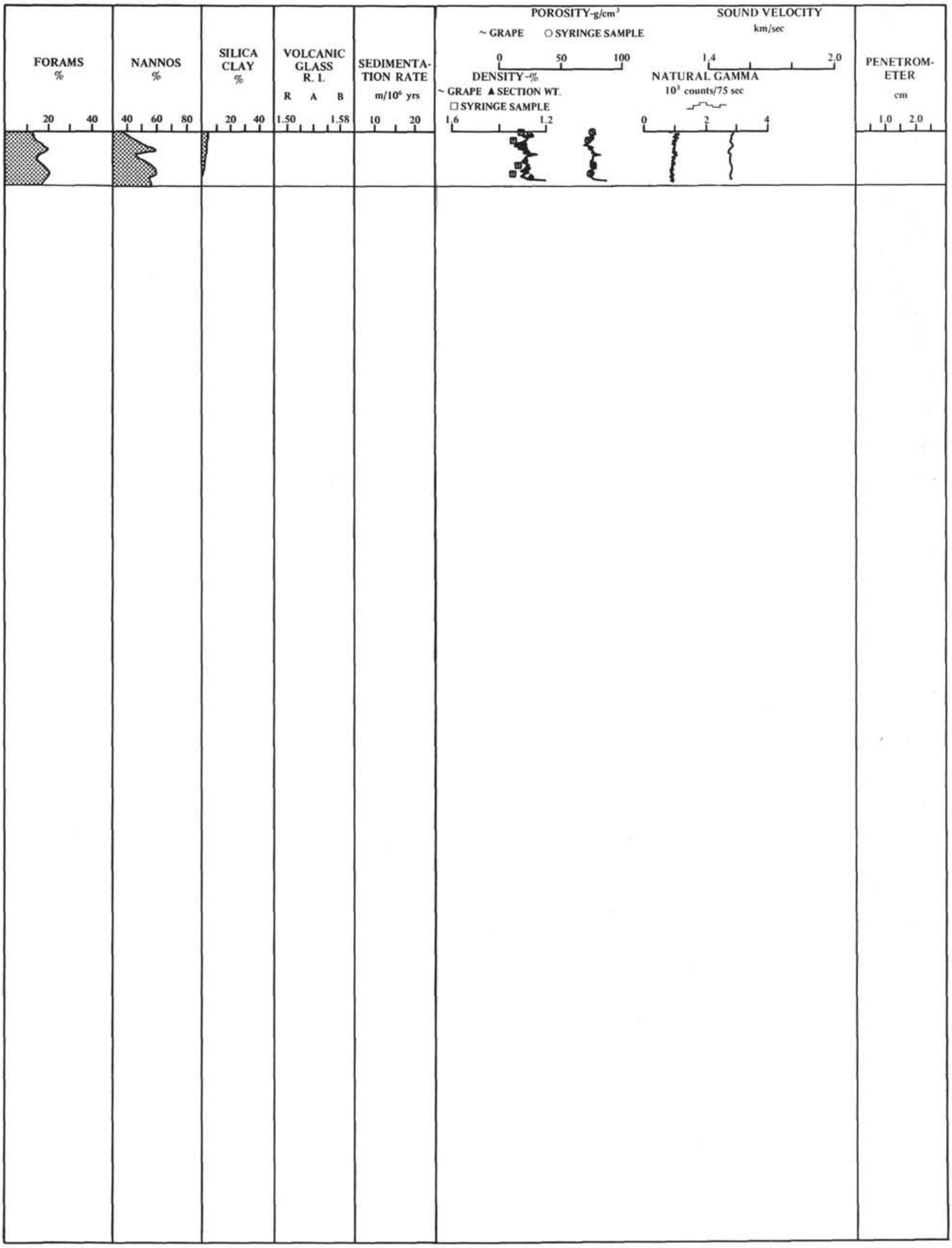


Figure 4. *Site 81 summary (continued).*

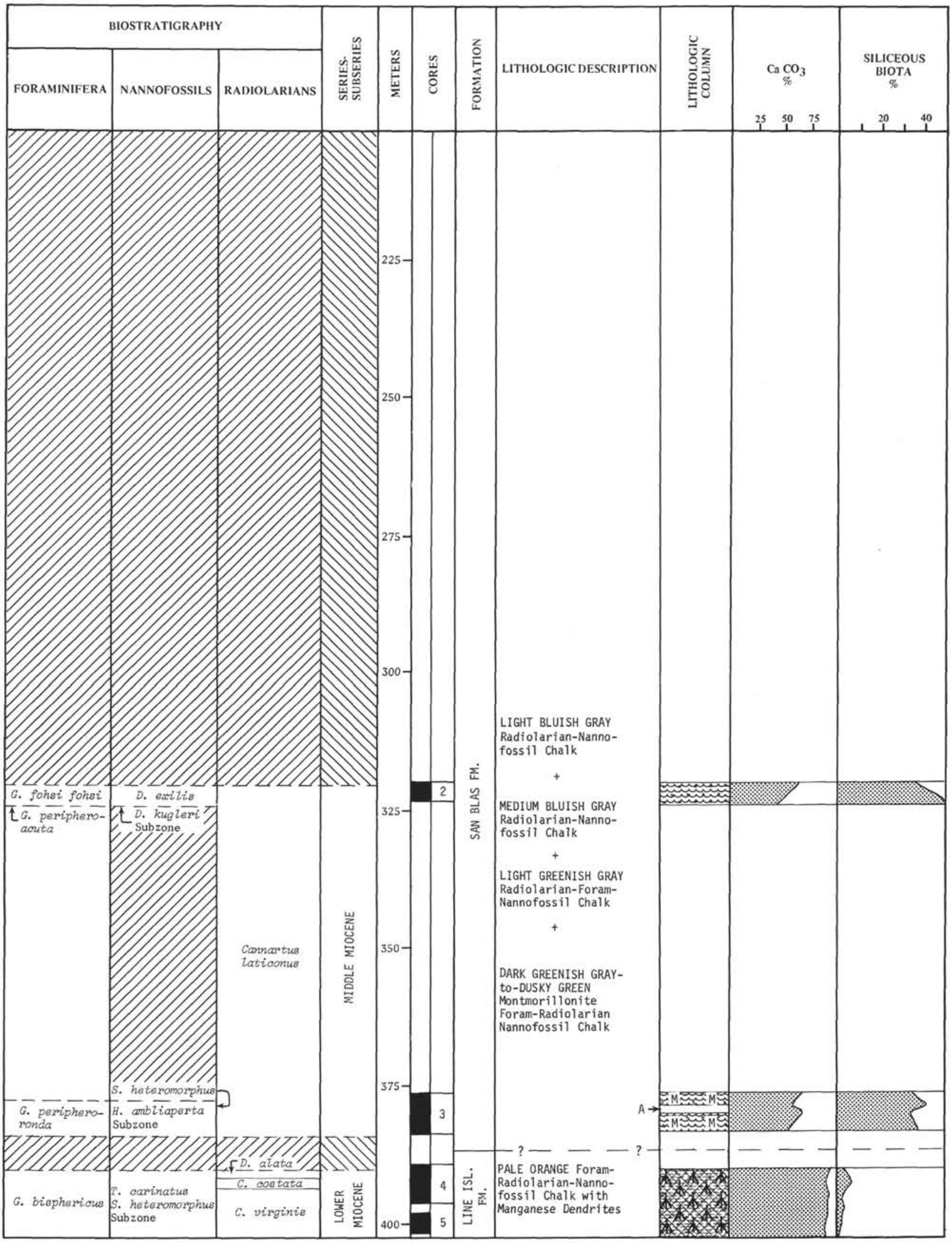


Figure 5. *Site 81 summary (continued).*

Figure 6. *Site 81 summary (continued).*

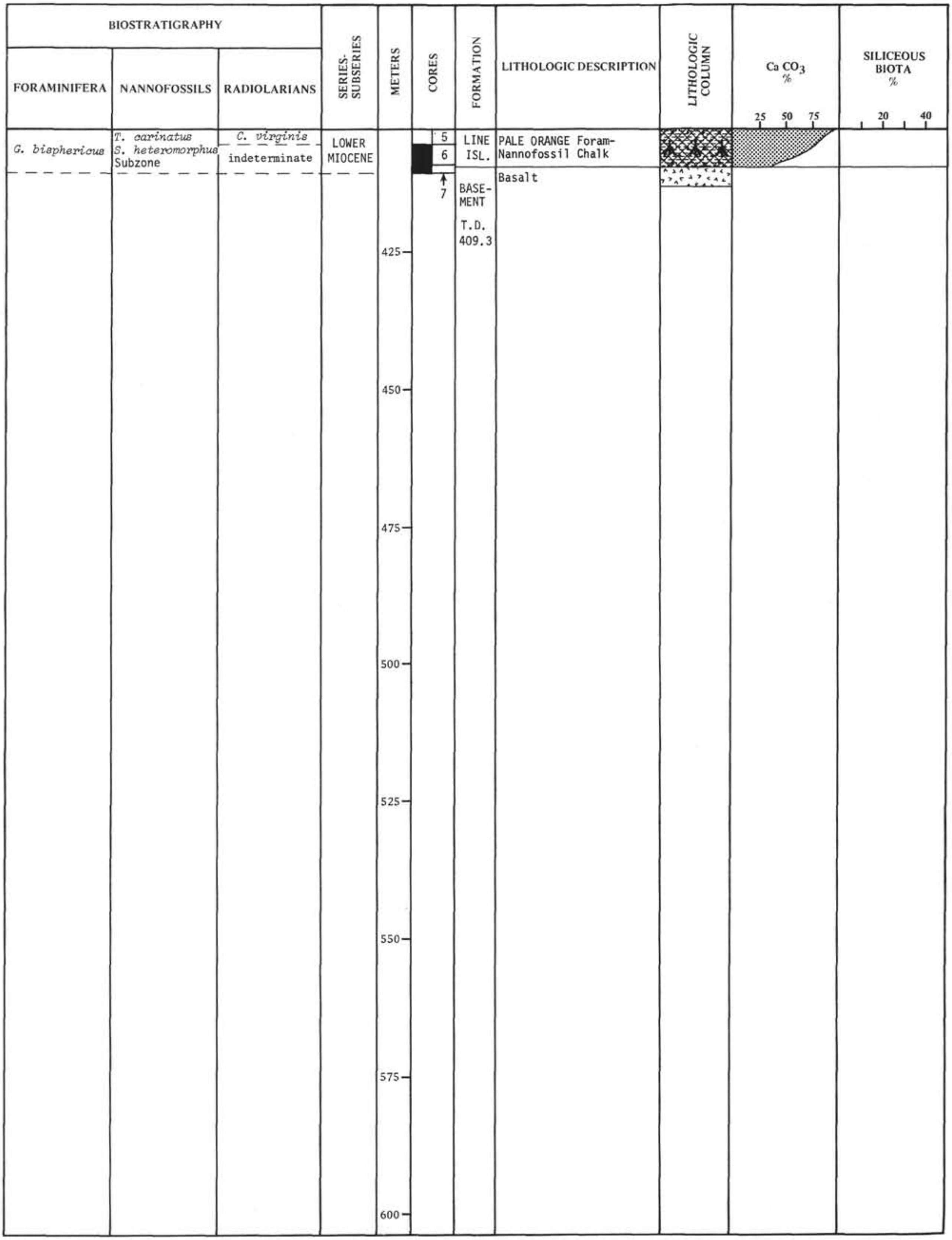


Figure 7. *Site 81 summary (continued).*

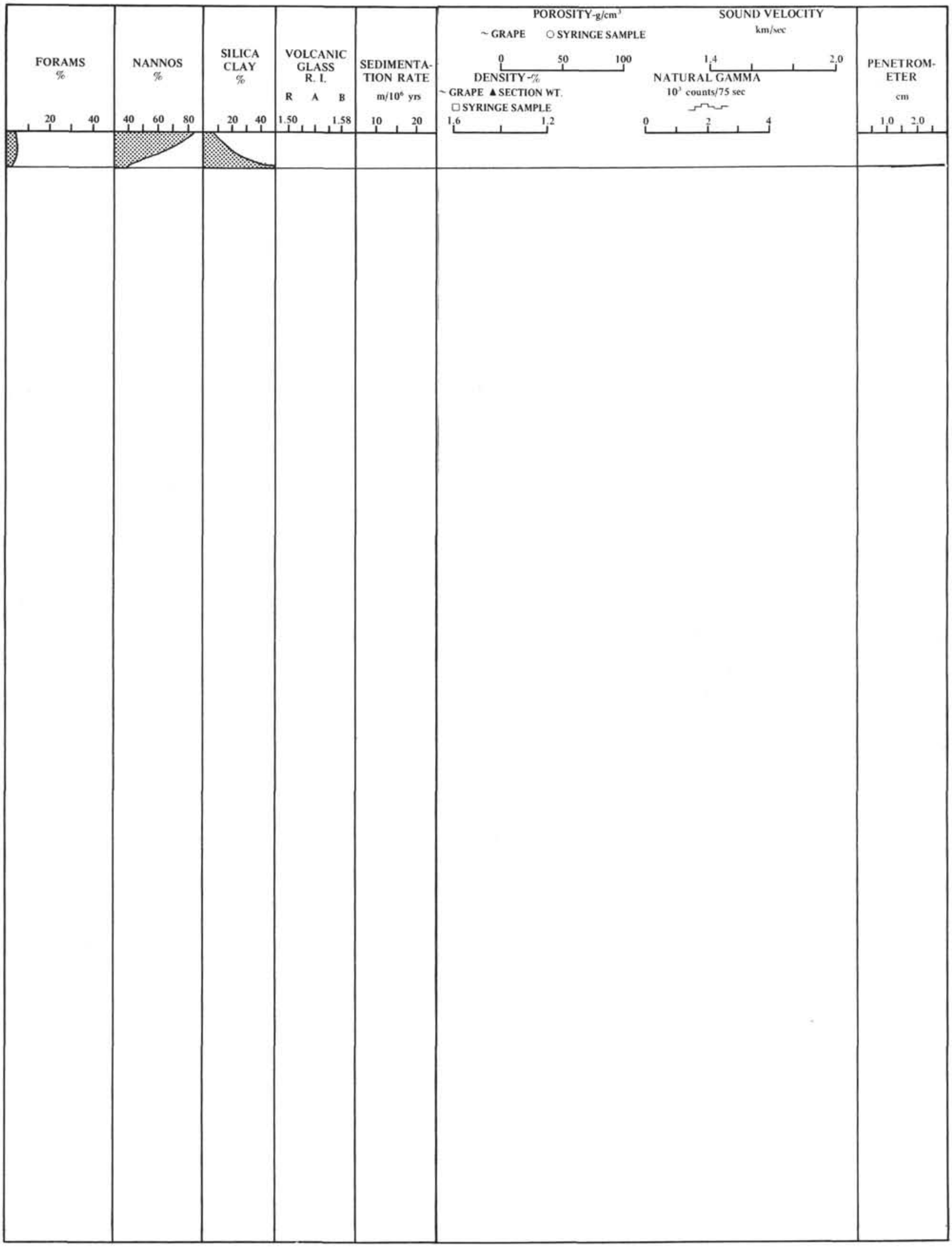


Figure 8. *Site 81 summary (continued).*

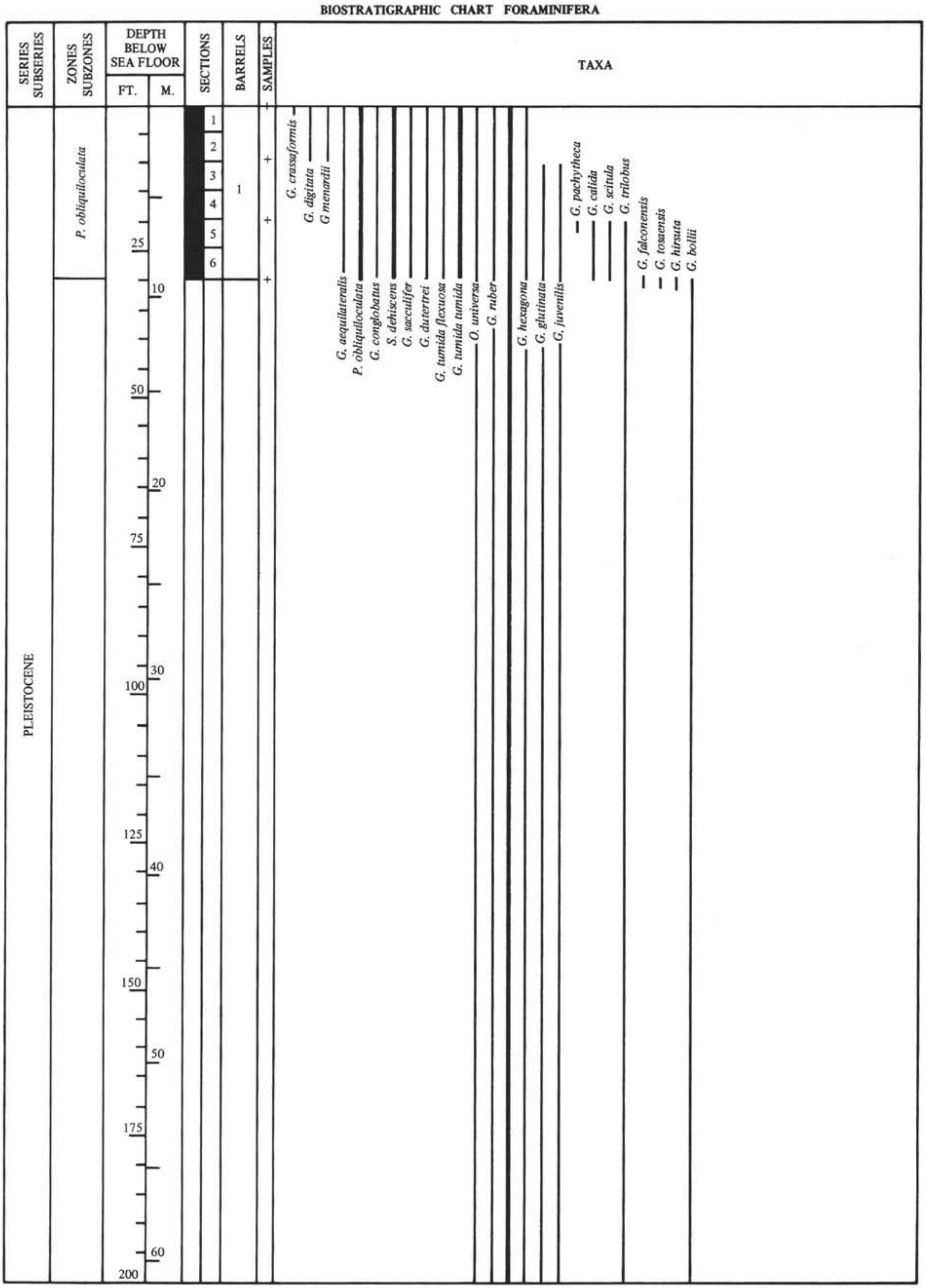


Figure 9. *Biostratigraphic chart Foraminifera (0 to 200 feet).*

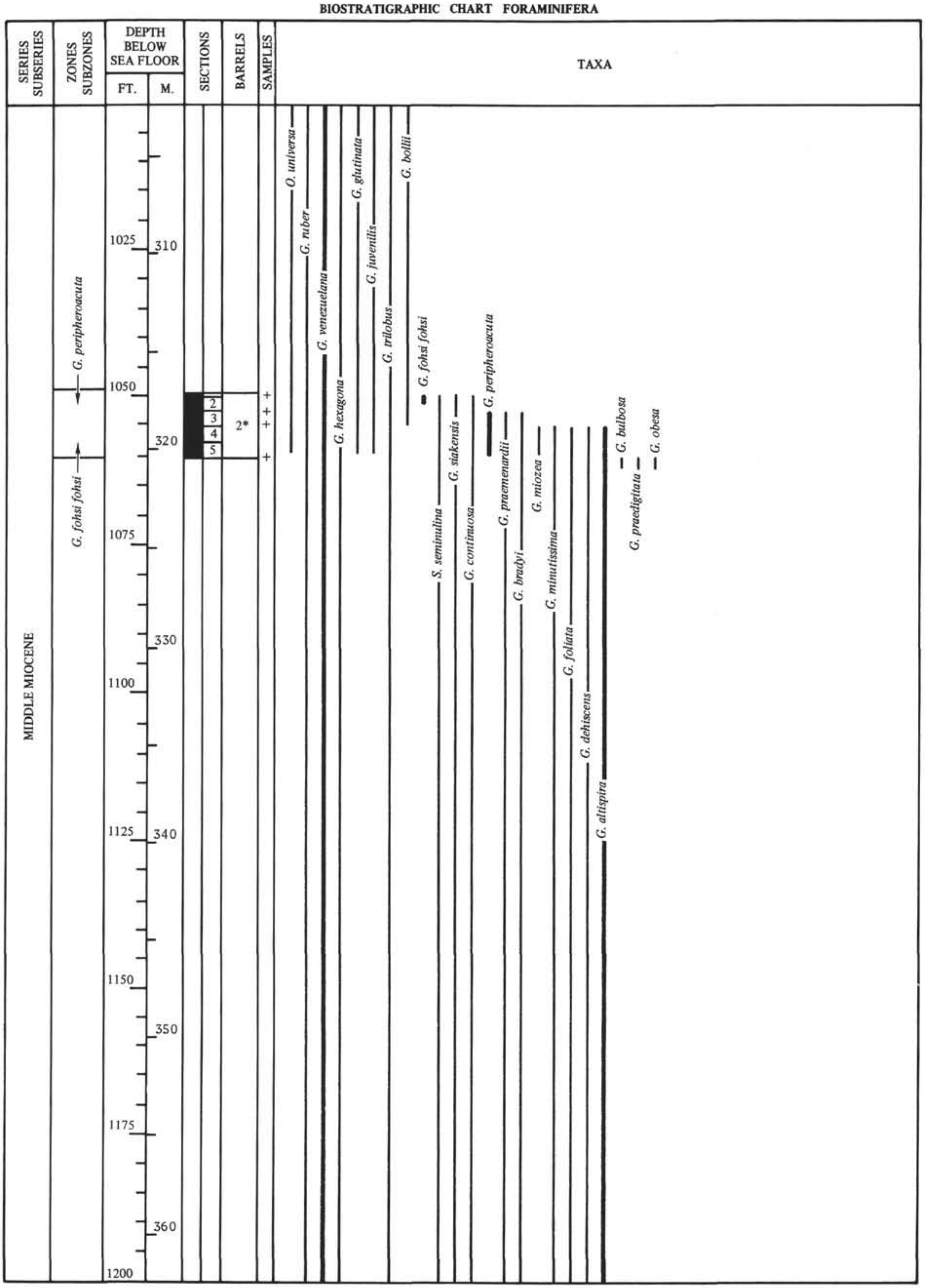


Figure 10. *Biostratigraphic chart Foraminifera (1000 to 1200 feet).*

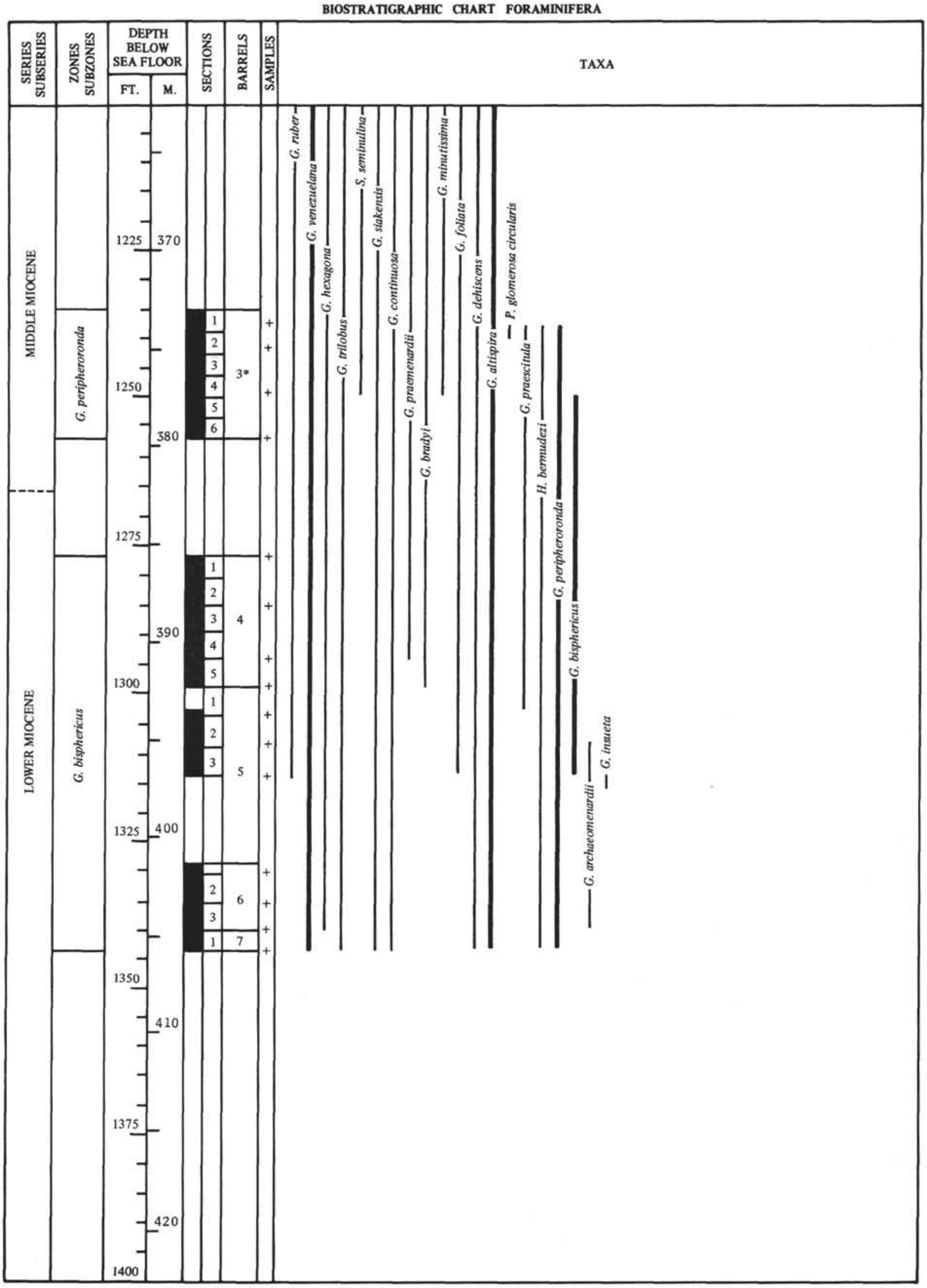


Figure 11. *Biostratigraphic chart Foraminifera (1200 to 1400 feet).*

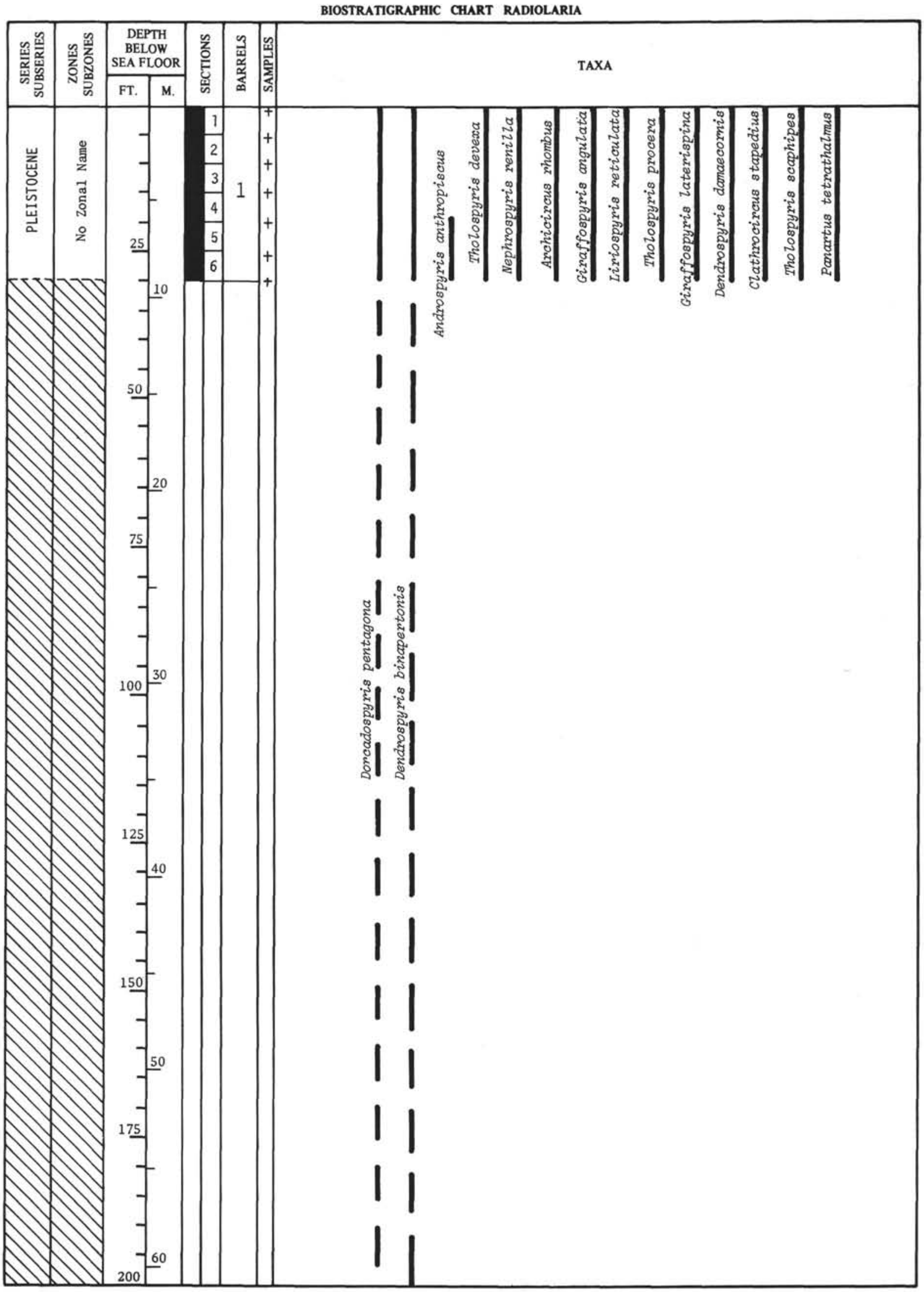


Figure 12. *Biostratigraphic chart Radiolaria (0 to 200 feet).*

BIOSTRATIGRAPHIC CHART RADIOLARIA

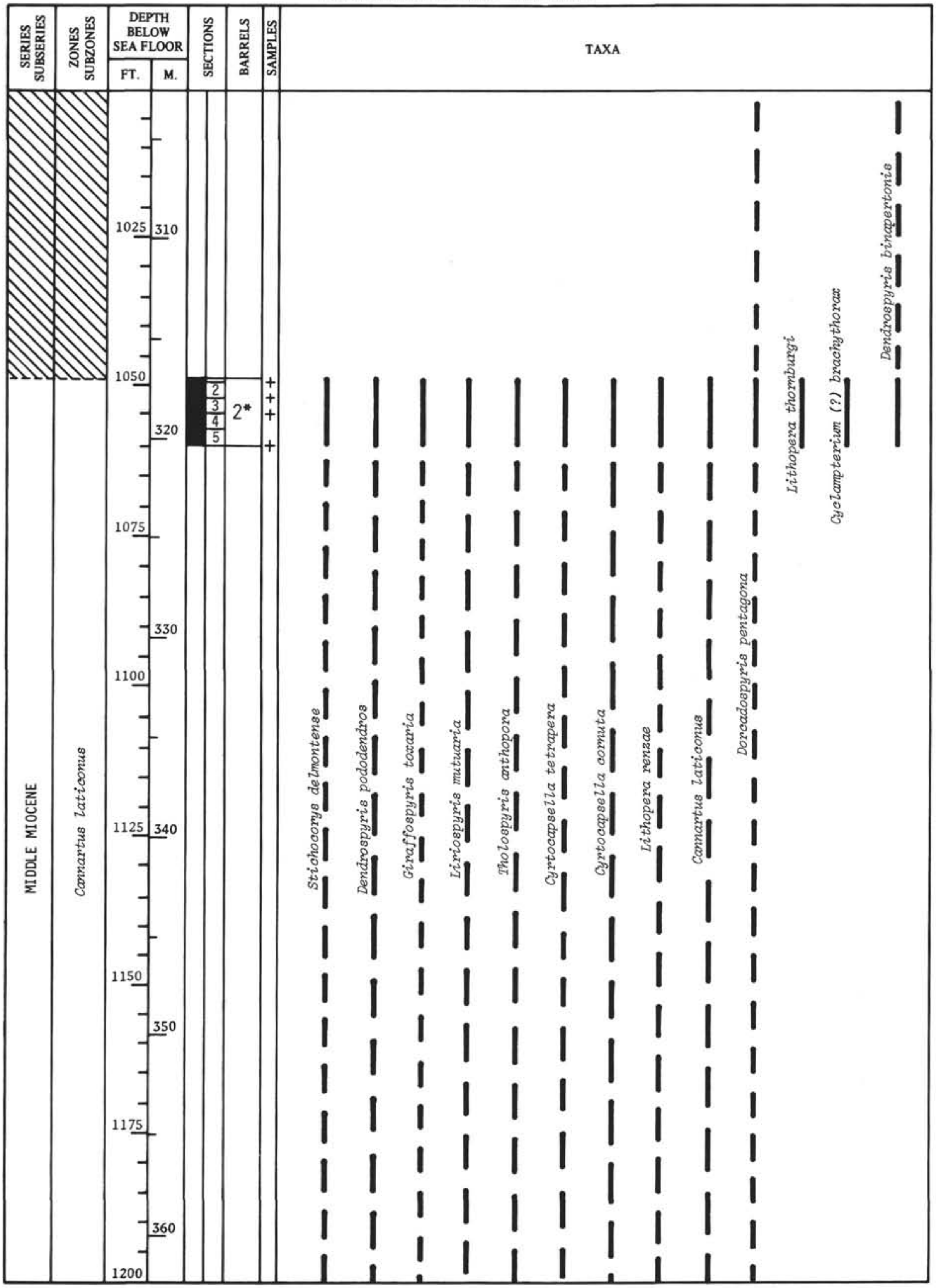


Figure 13. *Biostratigraphic chart Radiolaria (1000 to 1200 feet).*

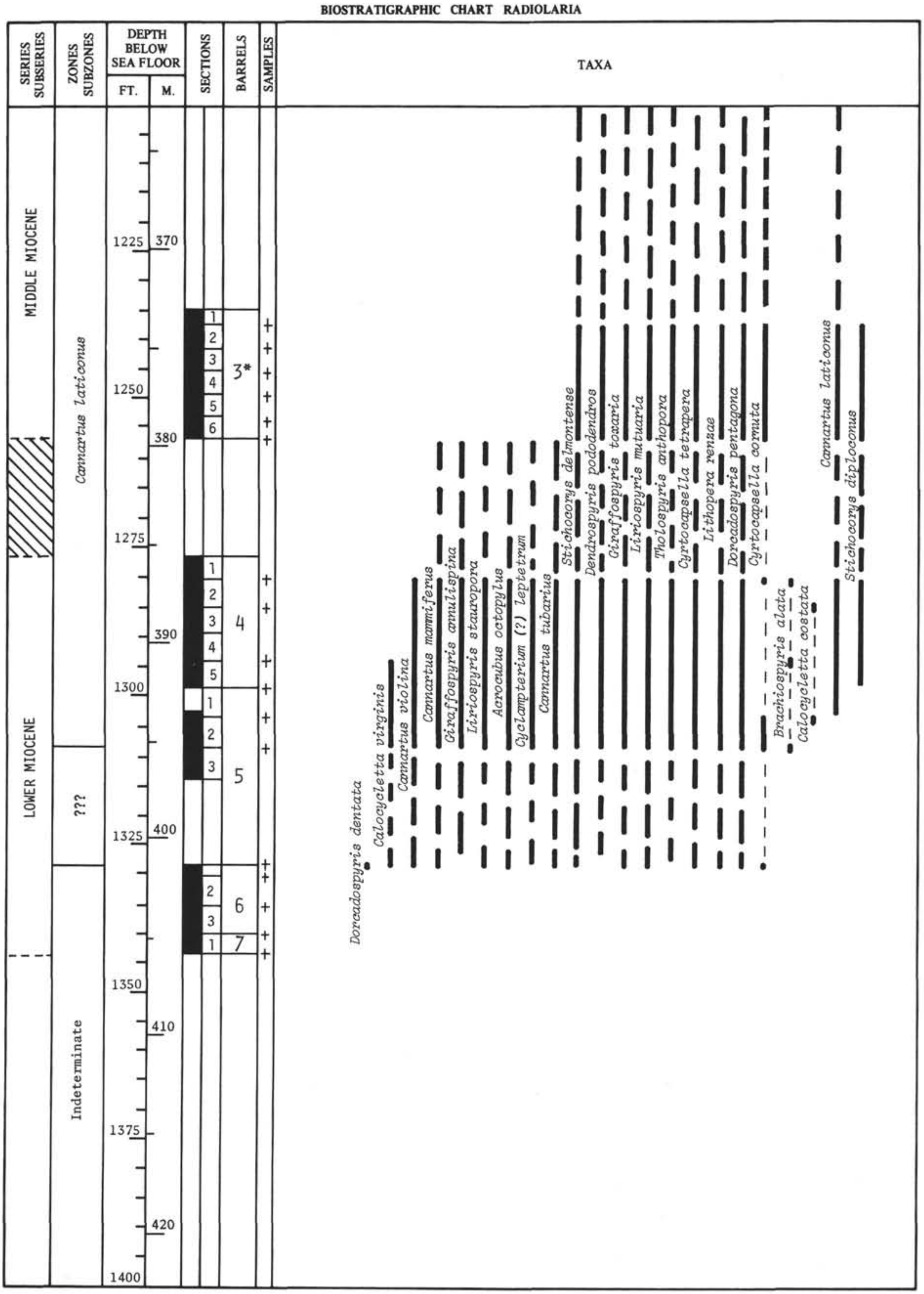


Figure 14. *Biostratigraphic chart Radiolaria (1200 to 1400 feet).*

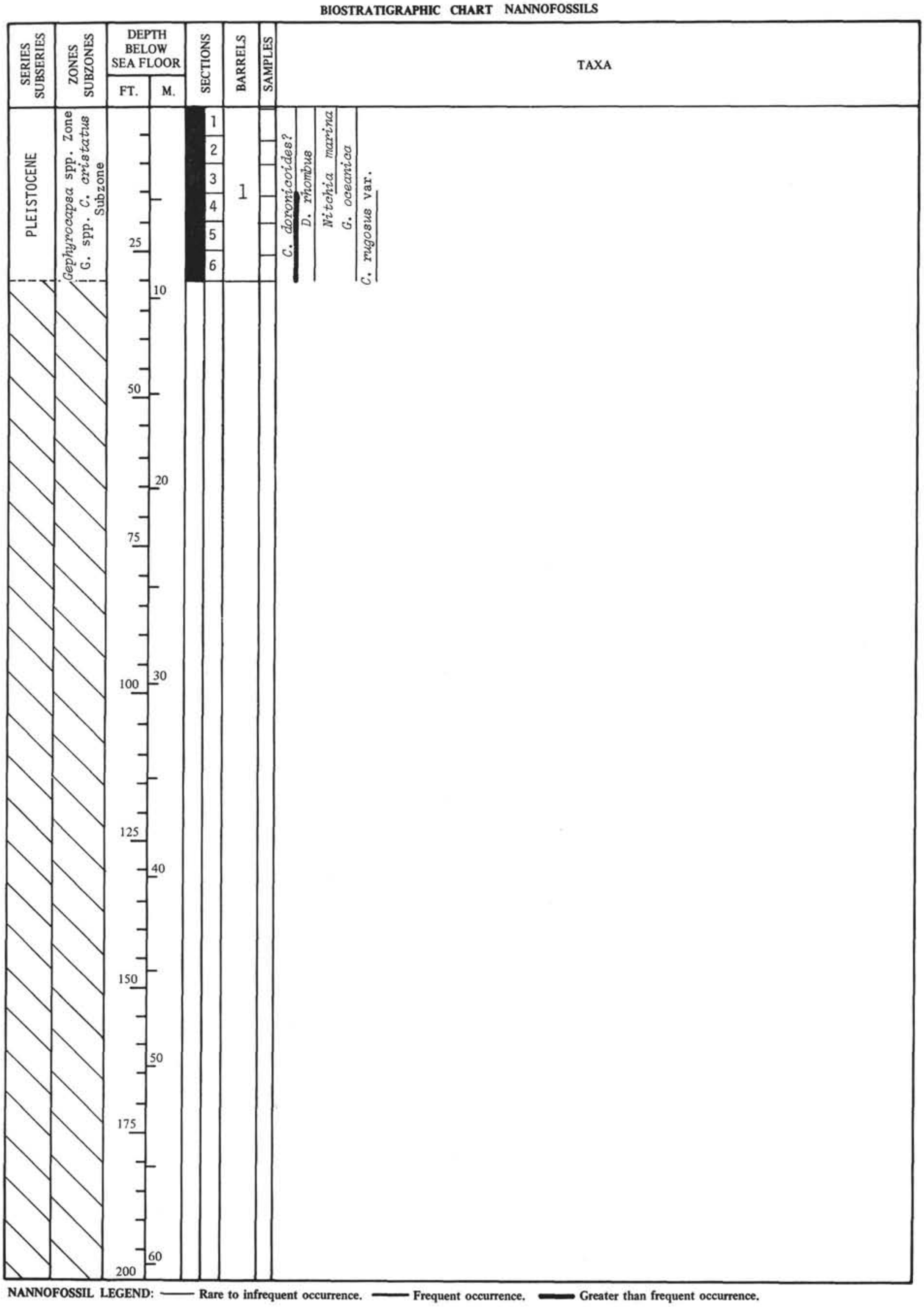
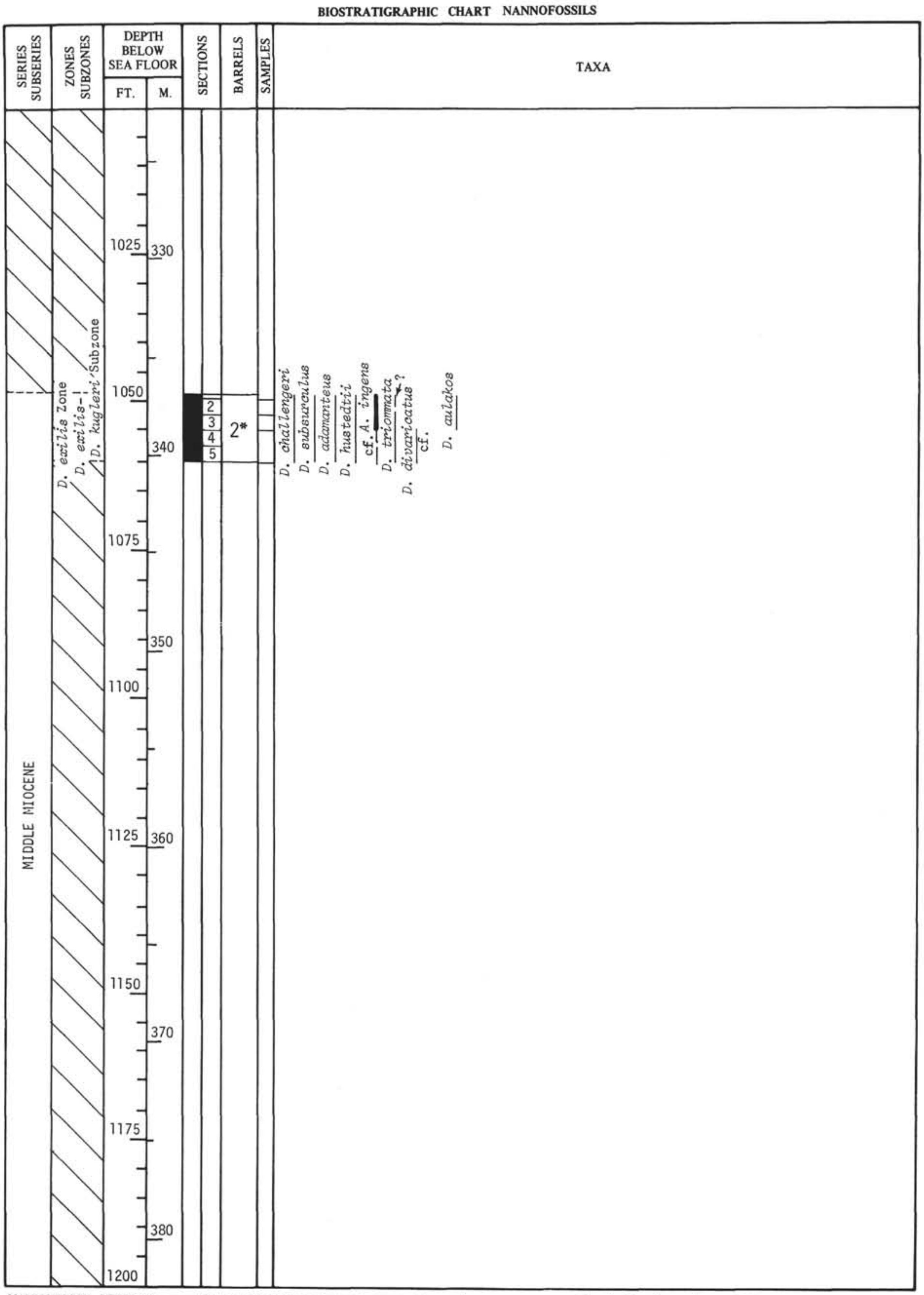


Figure 15. *Biostratigraphic chart Nannofossils (0 to 200 feet).*



NANNOFOSSIL LEGEND: —— Rare to infrequent occurrence. —— Frequent occurrence. ▬▬ Greater than frequent occurrence.

Figure 16. *Biostratigraphic chart Nannofossils (1000 to 1200 feet).*

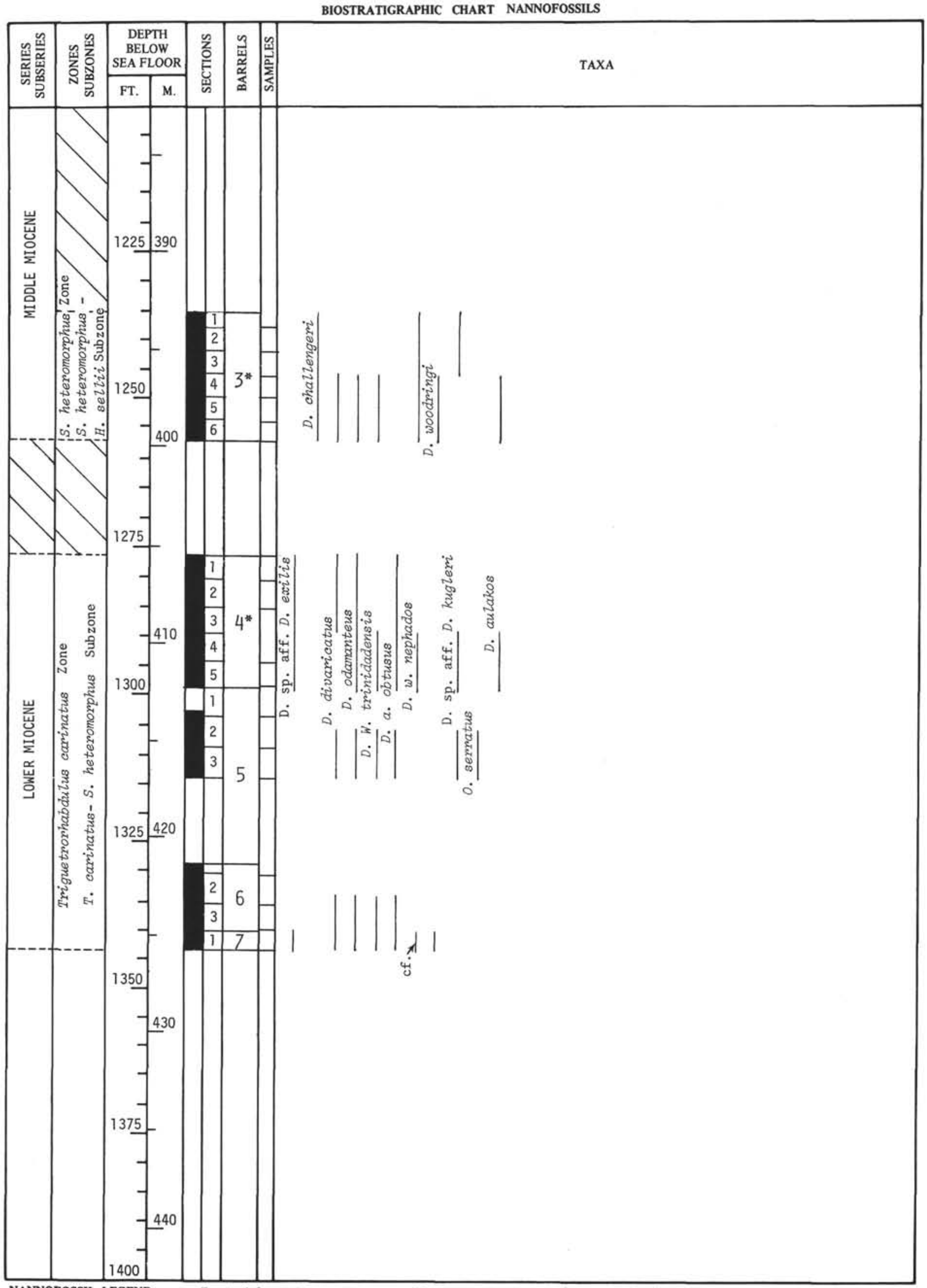


Figure 17. *Biostratigraphic chart Nannofossils (1200 to 1400 feet).*

BIOSTRATIGRAPHIC COMPARISON CHART

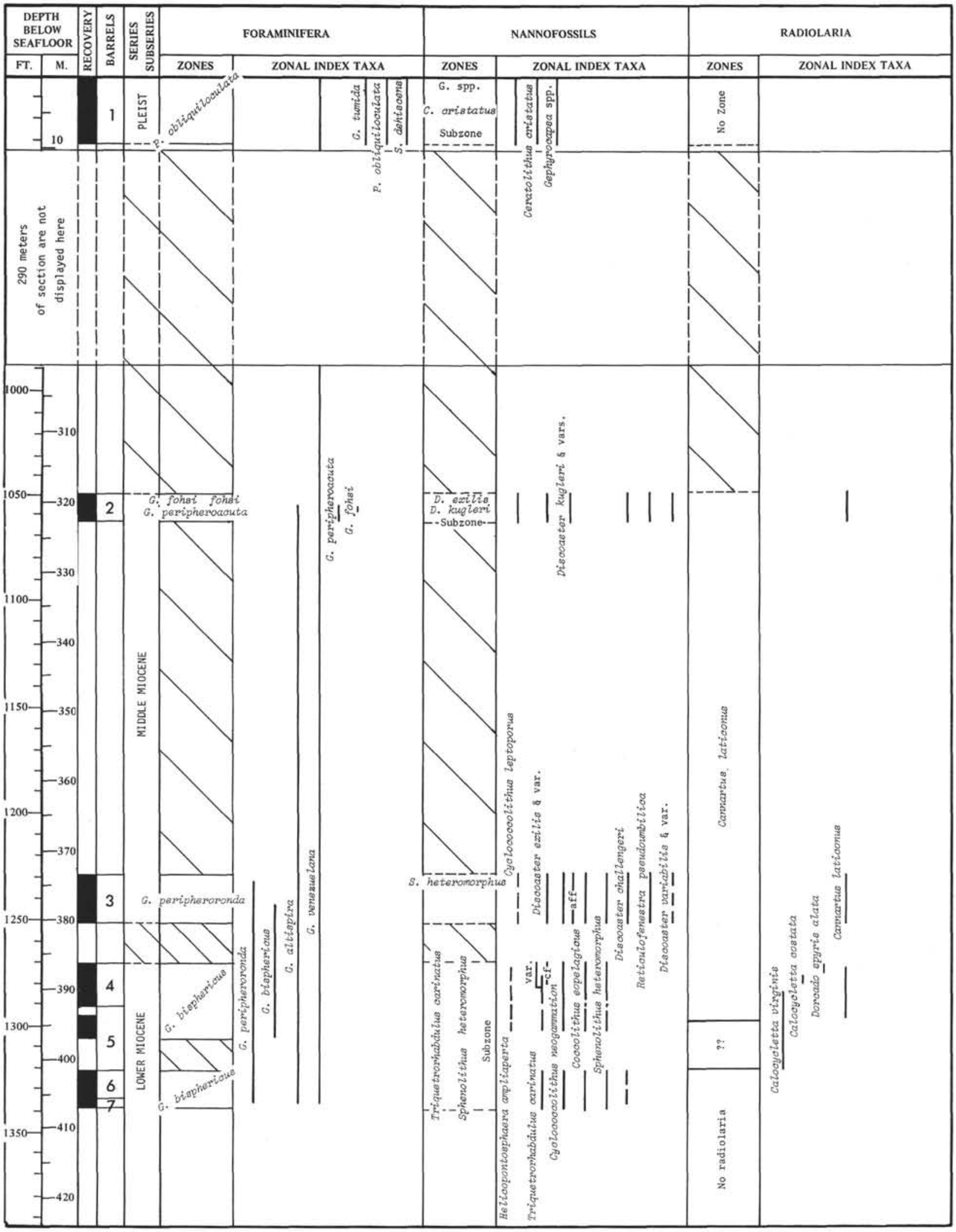


Figure 18. *Biostratigraphic comparison chart.*

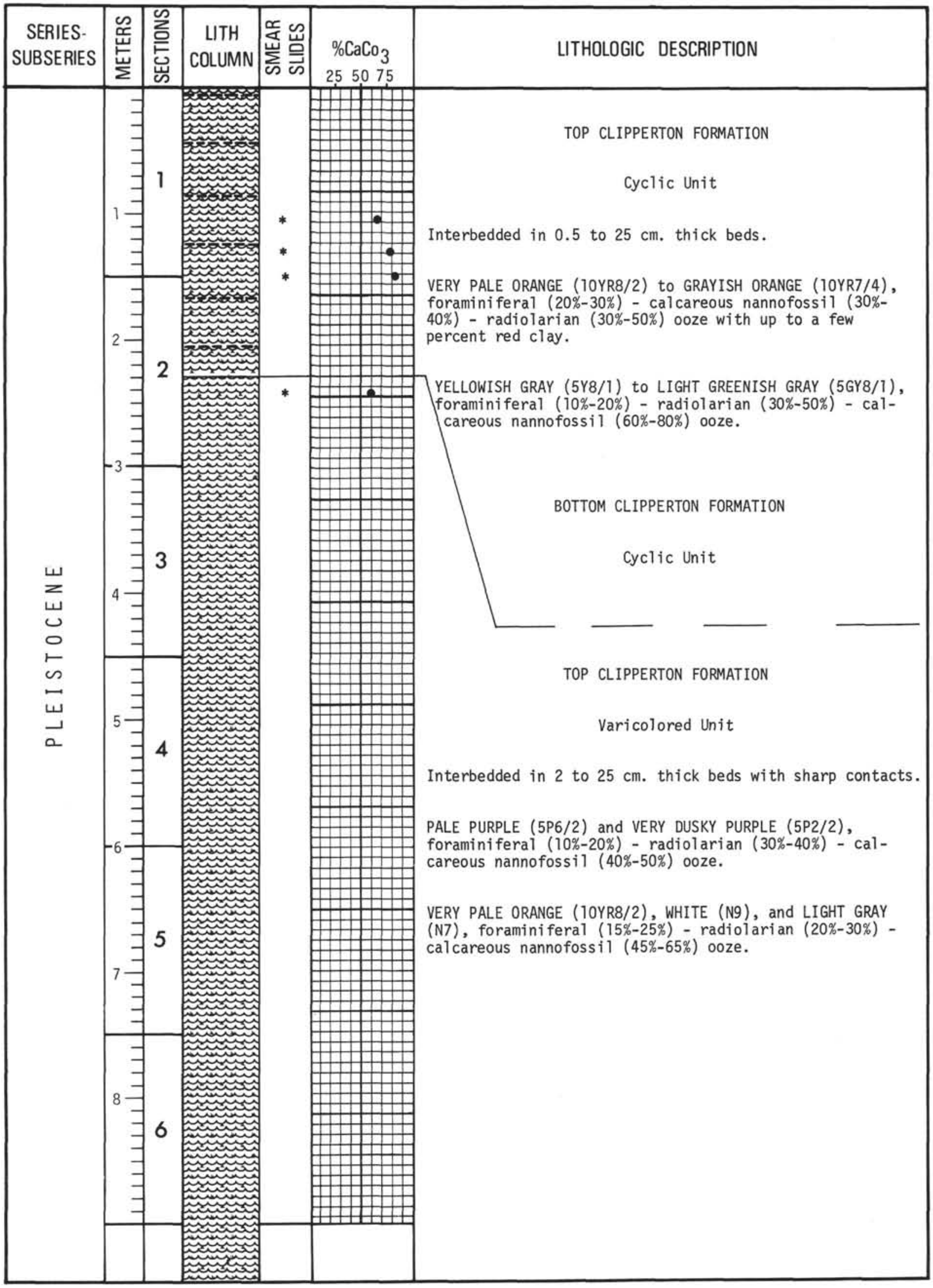


Figure 19. *Hole 81, Core 1 (0 to 9.1 m).*

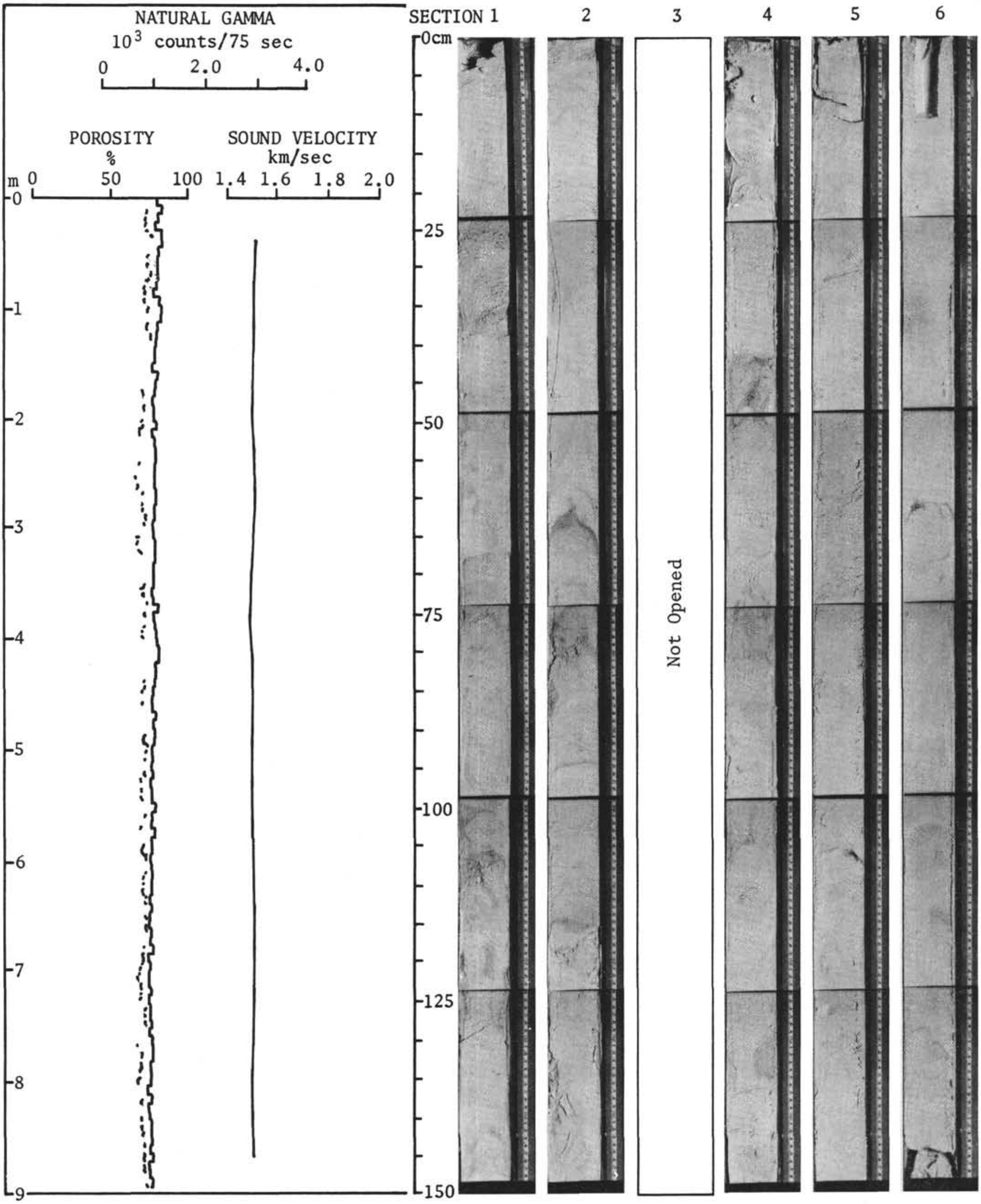


Figure 20. *Hole 81, Core 1, Sections 1-6, physical properties.*

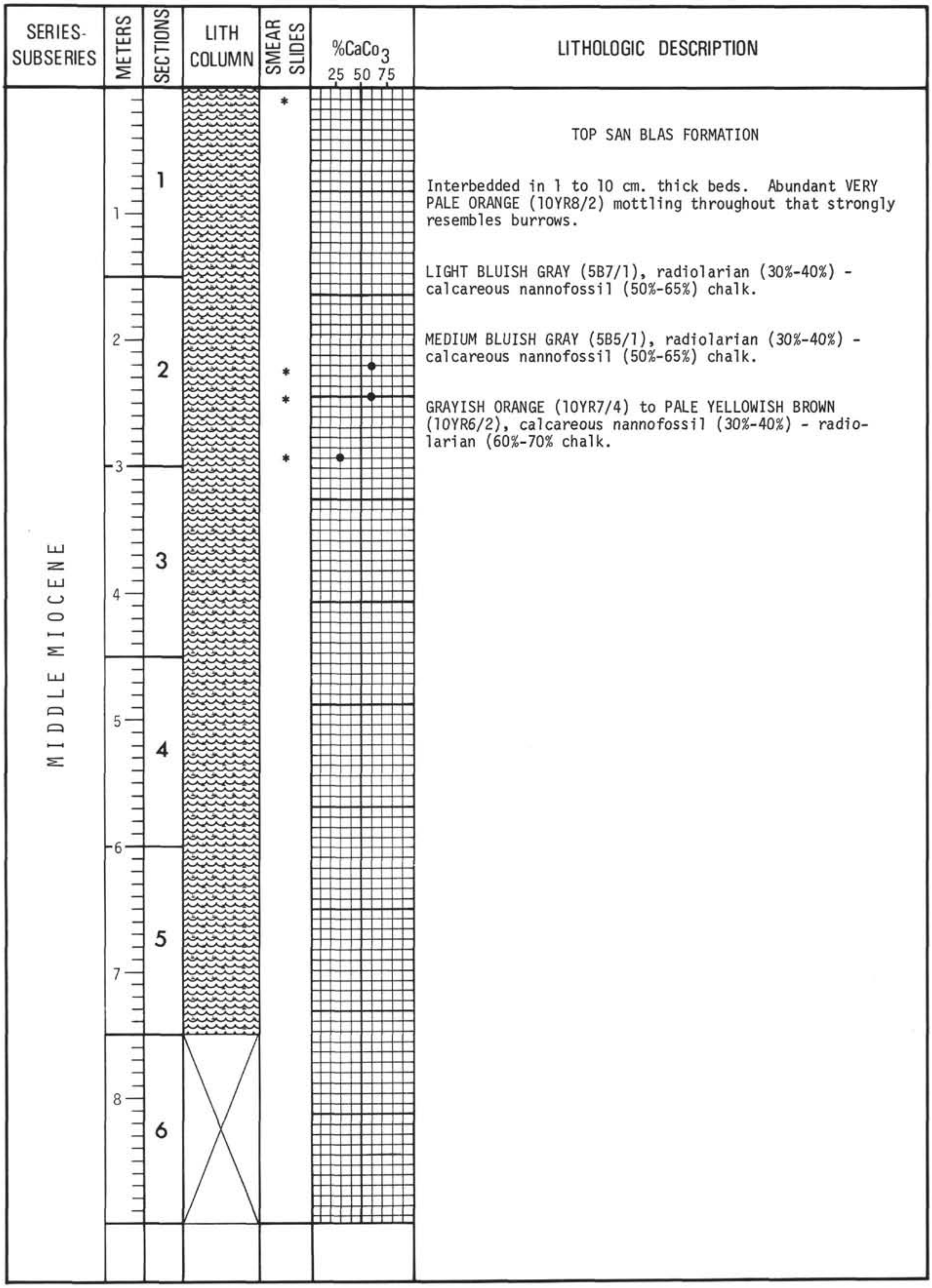


Figure 21. *Hole 81, Core 2 (319.7 to 323.3 m).*

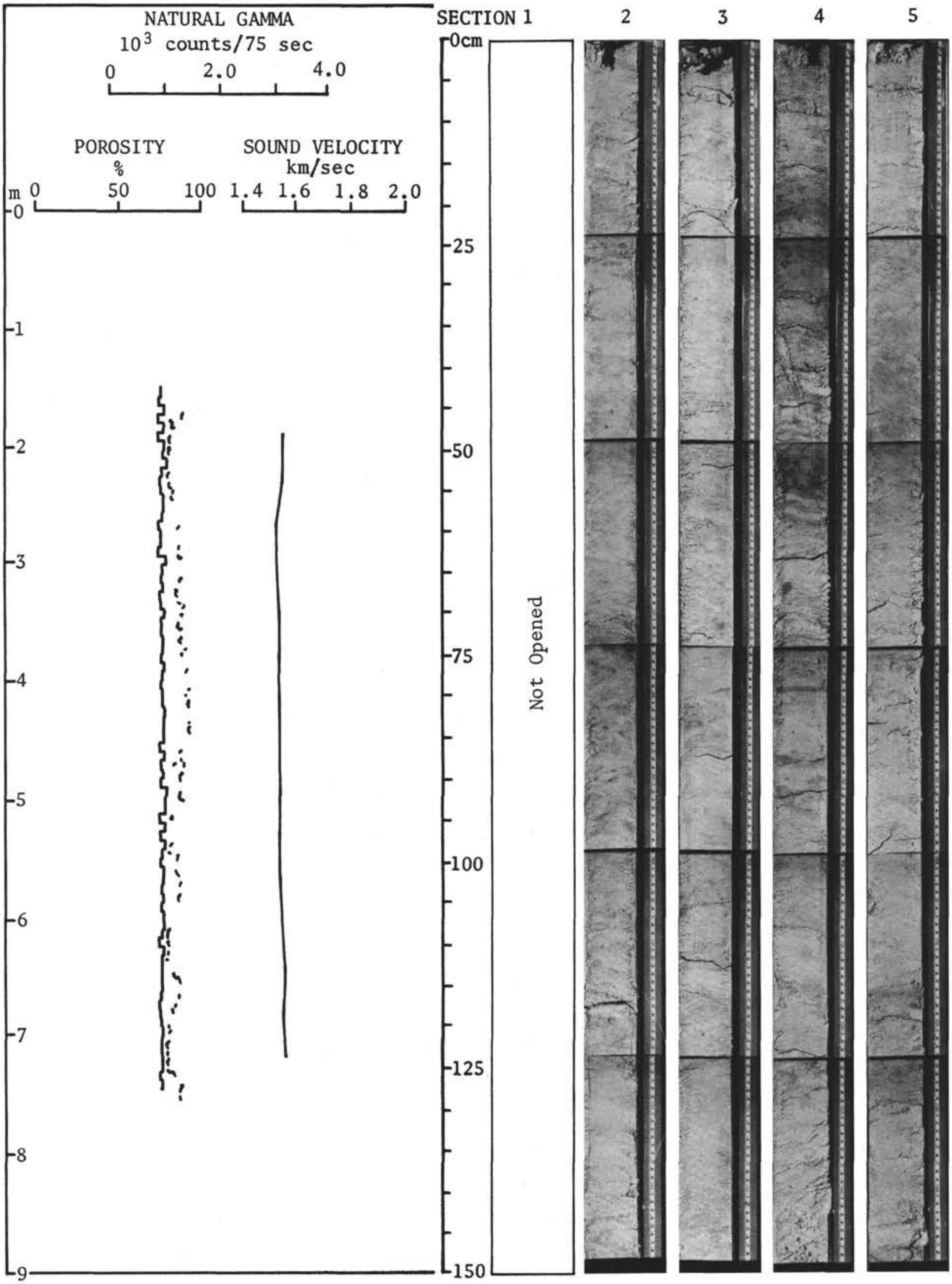


Figure 22. *Hole 81, Core 2, Sections 1-5, physical properties.*

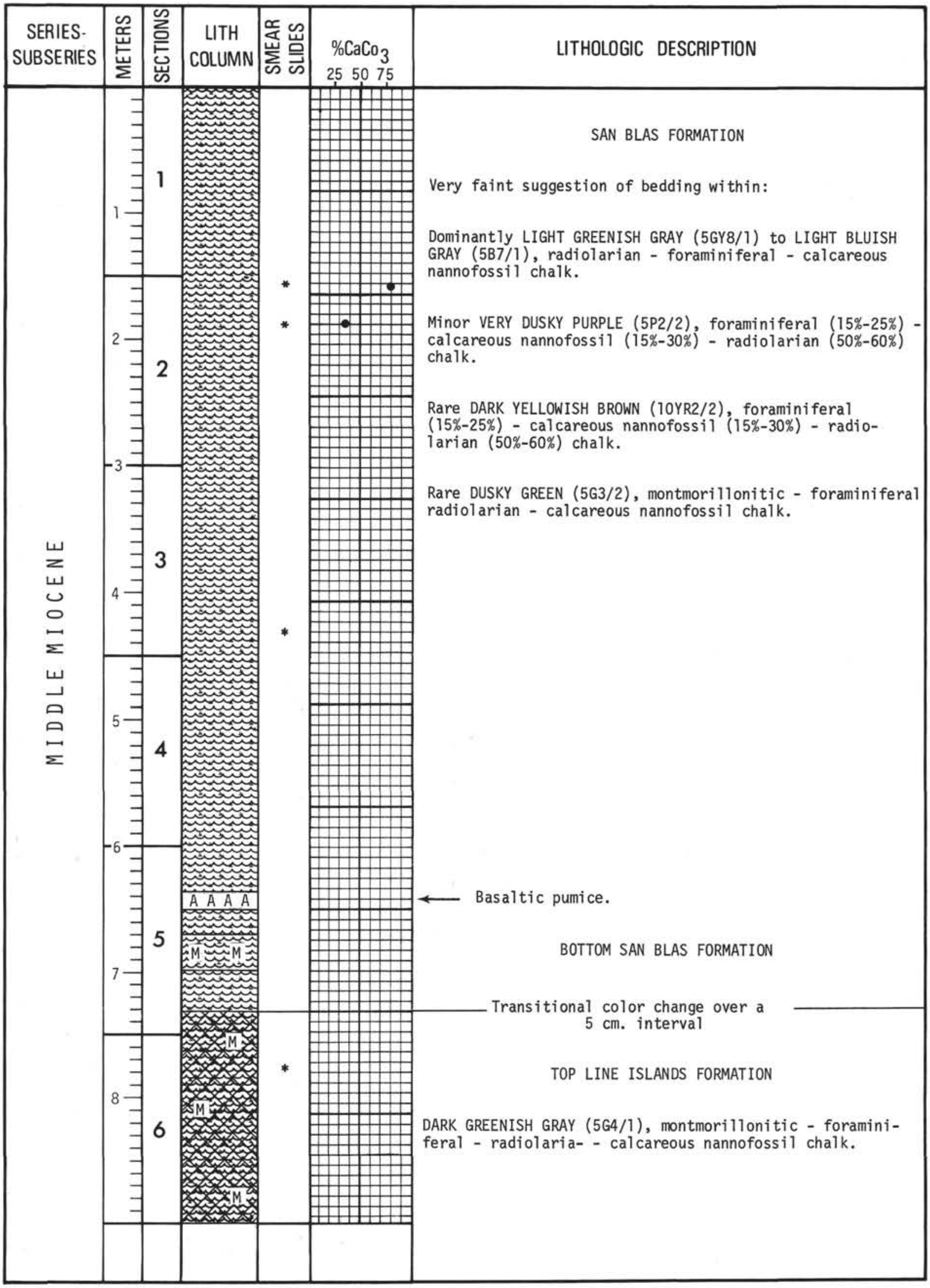


Figure 23. *Hole 81, Core 3 (376.3 to 383.1 m).*

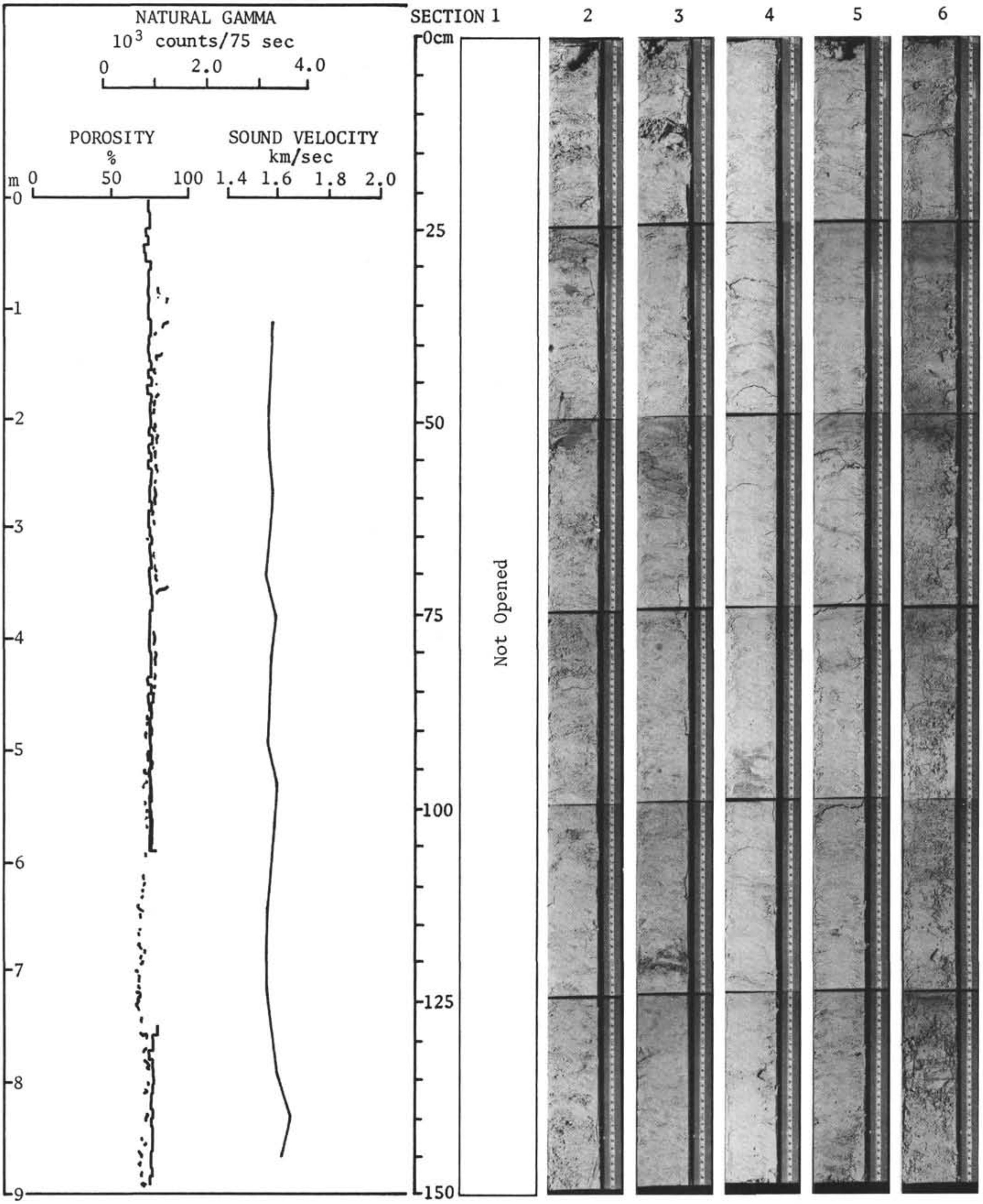
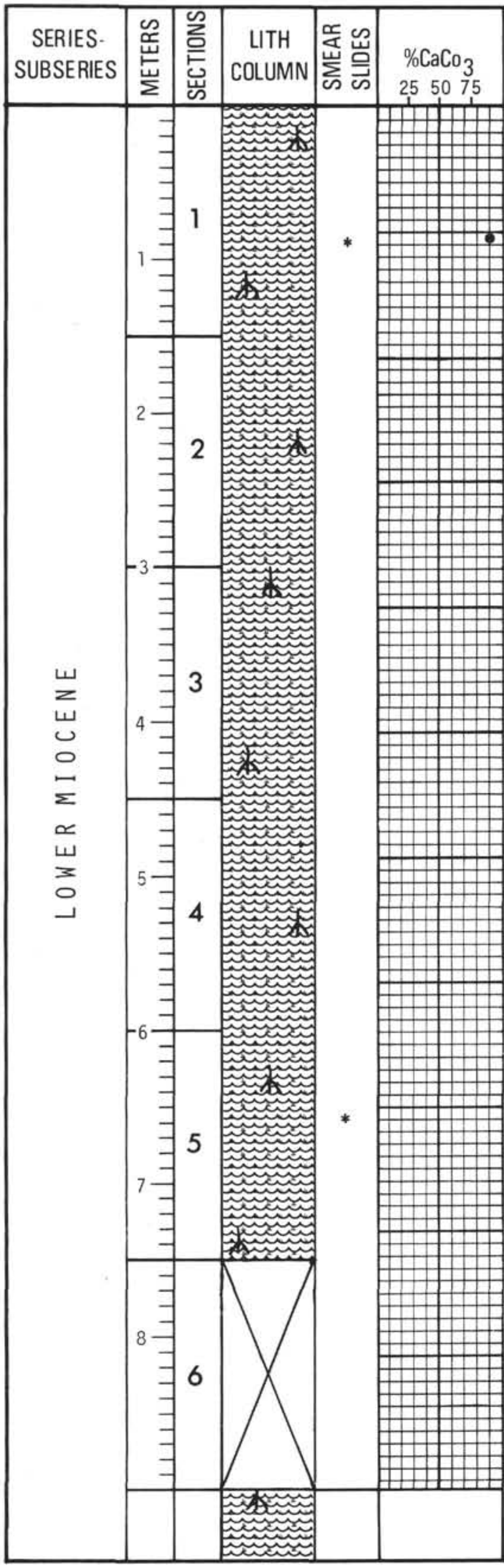


Figure 24. *Hole 81, Core 3, Sections 1-6, physical properties.*



LITHOLOGIC DESCRIPTION

LINE ISLANDS FORMATION

Very well bedded in 1 to 10 cm. thick beds with abundant mottling that appears to be due to burrowing. Also these chalks have abundant manganese (?) dendrites on bedding planes.

PALE ORANGE (10YR7/2), foraminiferal (10%) - radiolarian (10%) - calcareous nannofossil (80%-90%) very well indurated chalk; this chalk is sometimes partly silicified.

Figure 25. *Hole 81, Core 4 (389.1 to 395.6 m).*

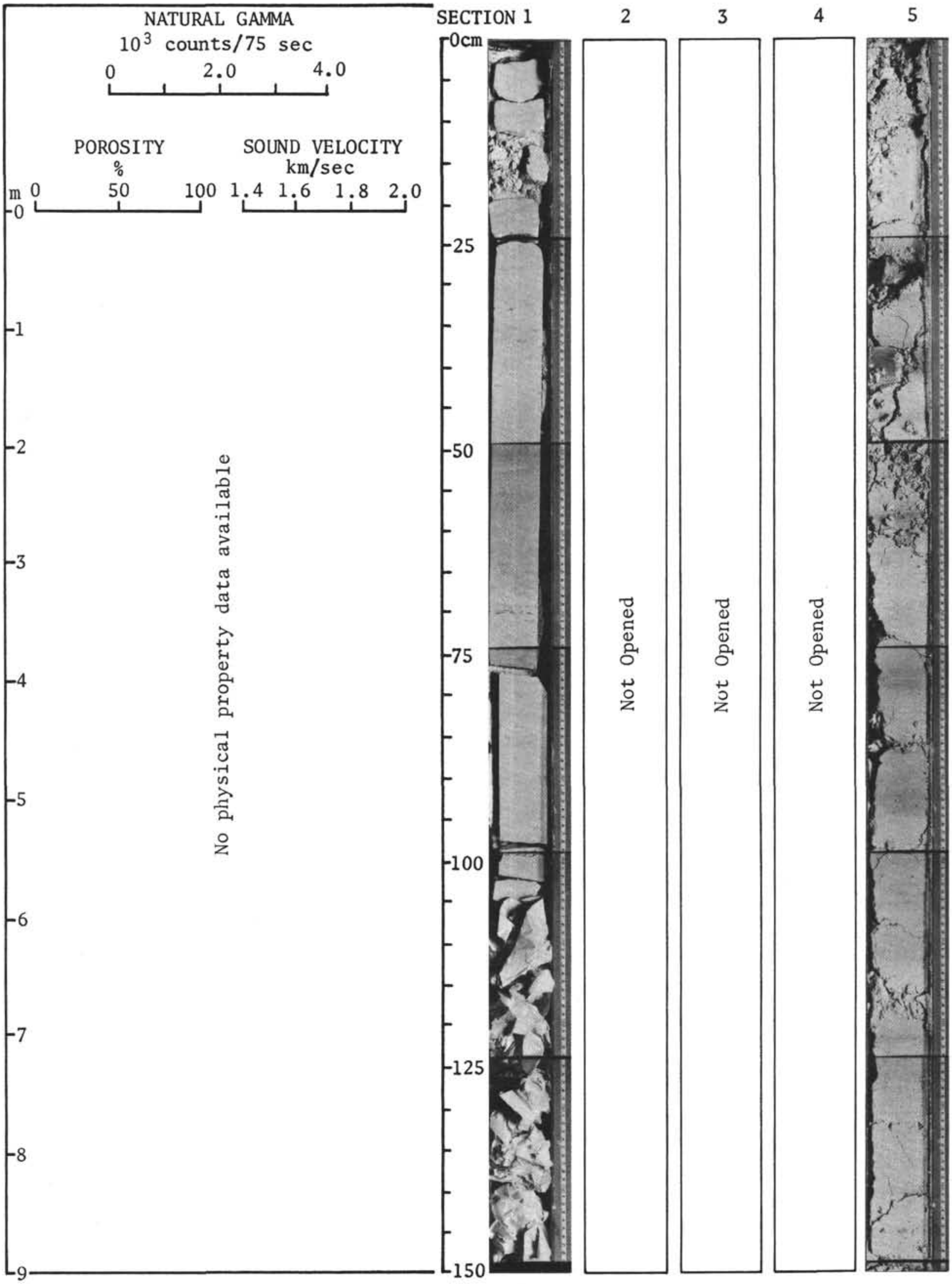


Figure 26. *Hole 81, Core 4, Sections 1-5, physical properties.*

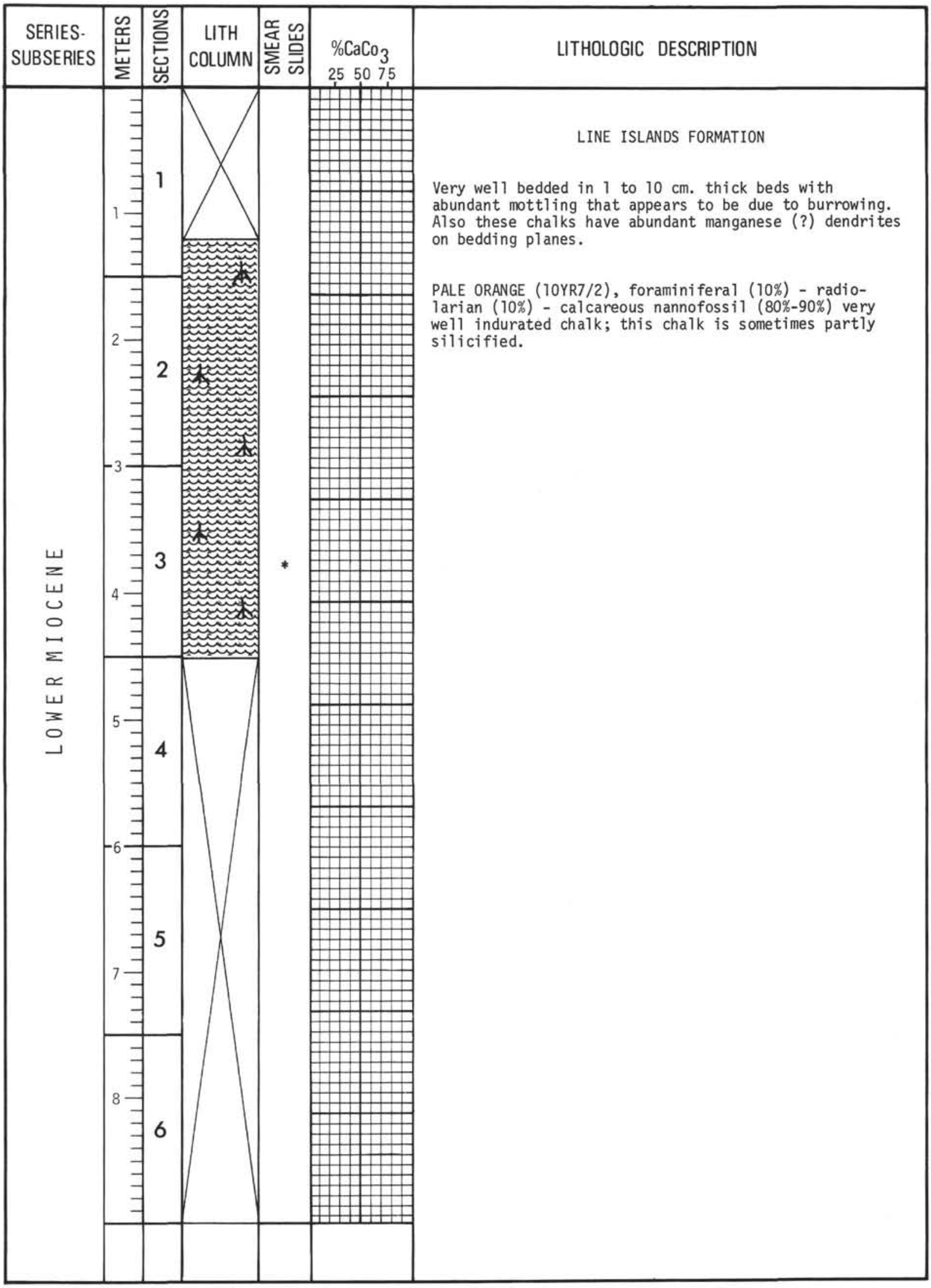


Figure 27. *Hole 81, Core 5 (395.6 to 404.7 m).*

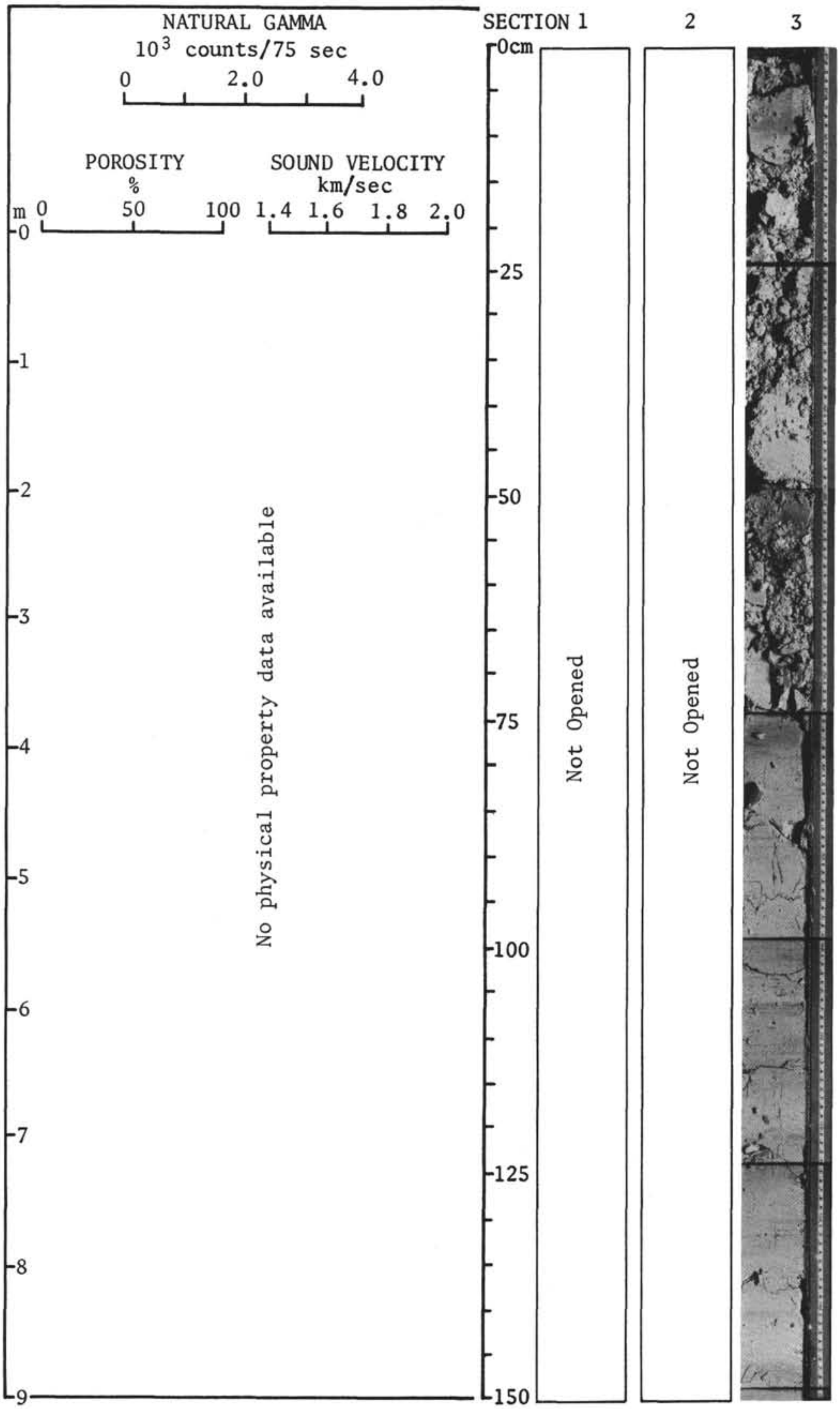
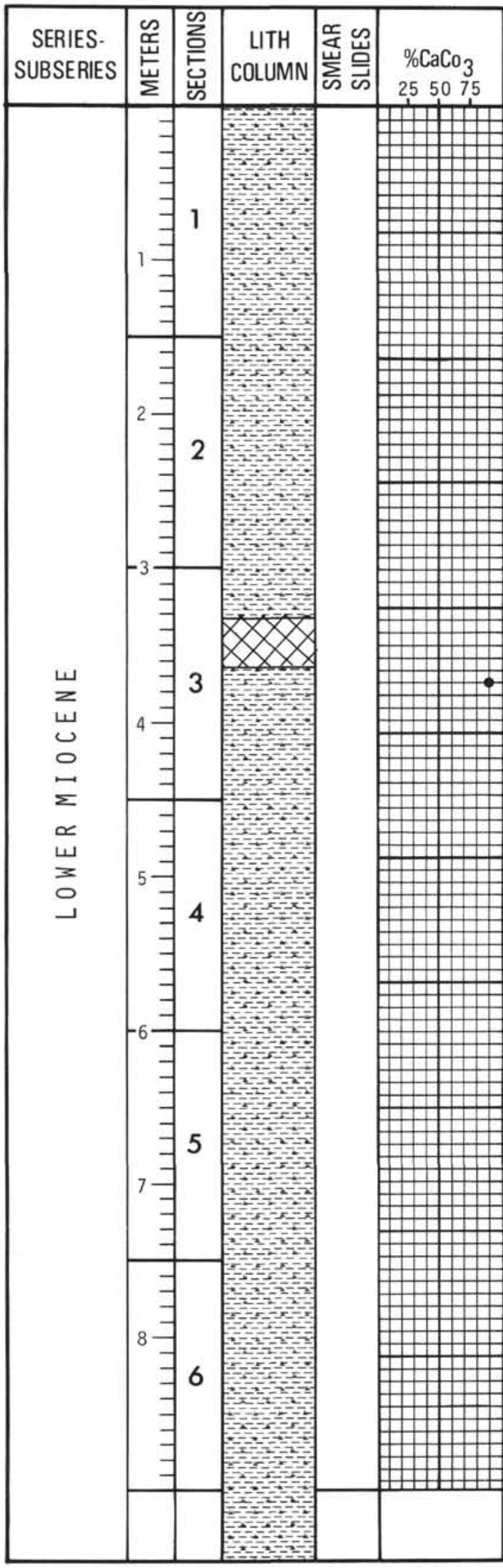


Figure 28. *Hole 81, Core 5, Sections 1, 2, 3, physical properties.*



LITHOLOGIC DESCRIPTION

LINE ISLANDS FORMATION

Well bedded in 1 to 5 cm. thick beds that are mottled and brecciated.

VERY PALE ORANGE (10YR8/2) and PALE YELLOWISH BROWN (10YR6/2), foraminiferal (15%-20%) - calcareous nannofossil (80%) chalk with iron oxides and red and green clay.

Figure 29. *Hole 81, Core 6 (404.7 to 408.3 m).*

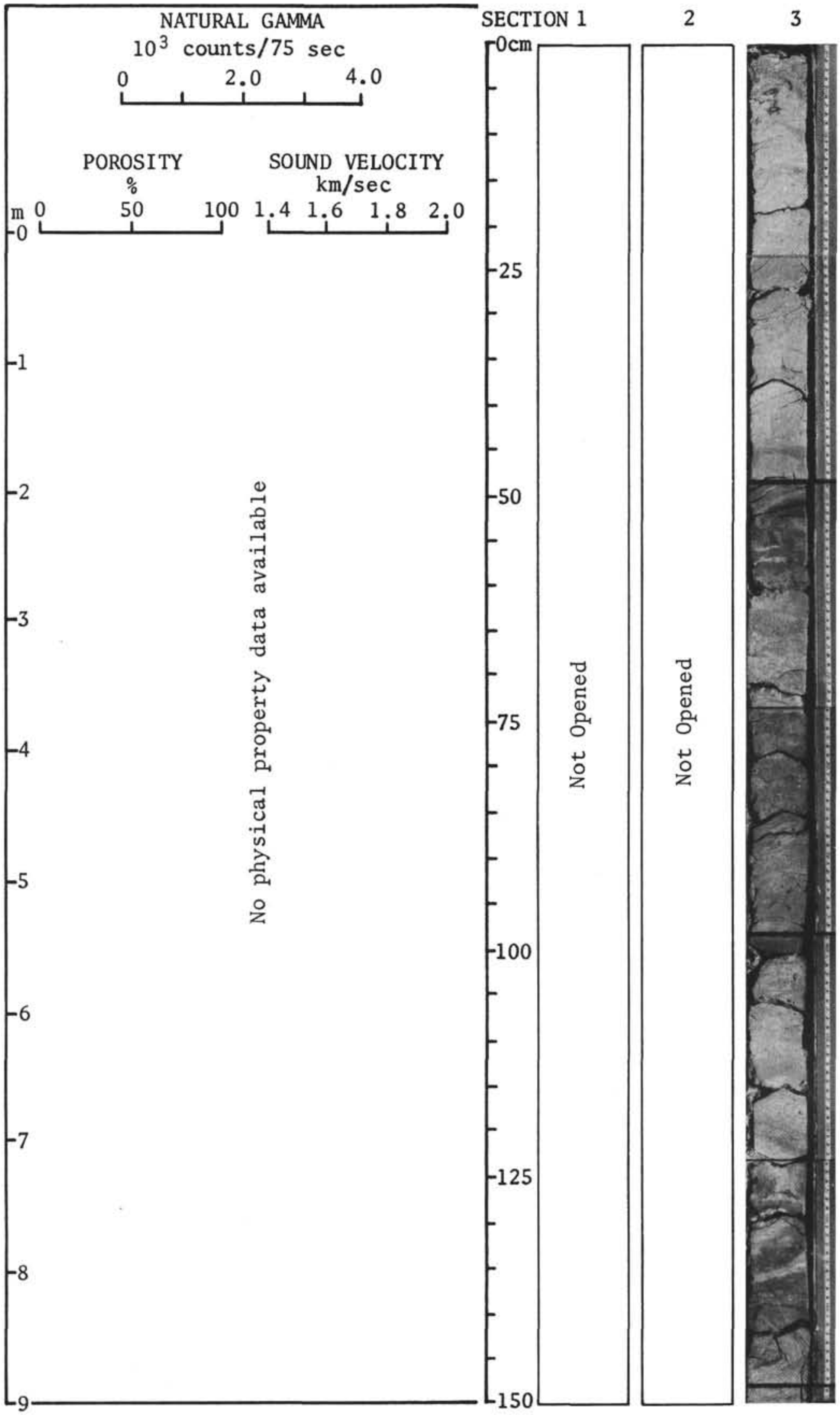


Figure 30. *Hole 81, Core 6, Sections 1, 2, 3, physical properties.*

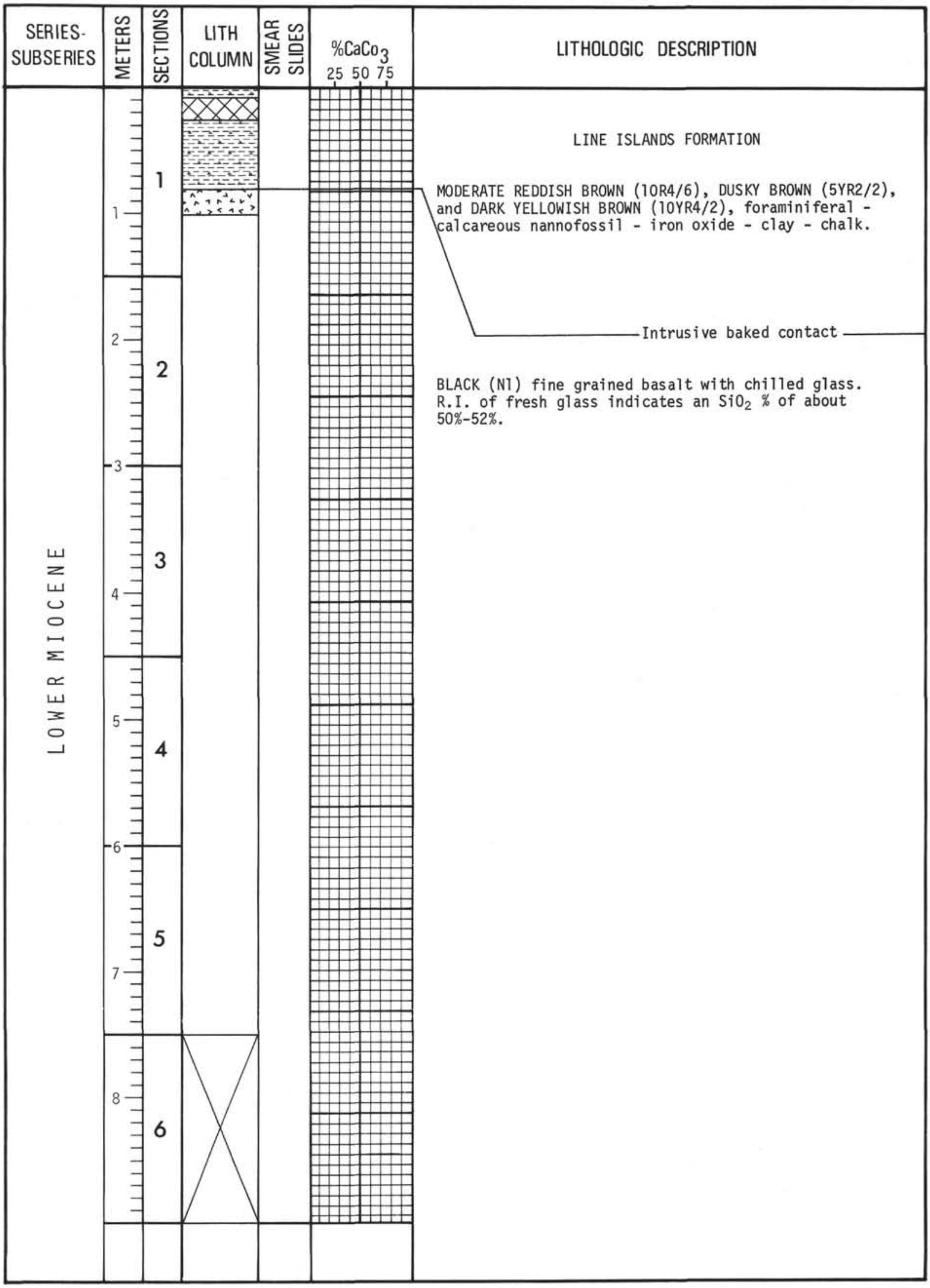


Figure 31. *Hole 81, Core 7 (408.3 to 409.3 m).*

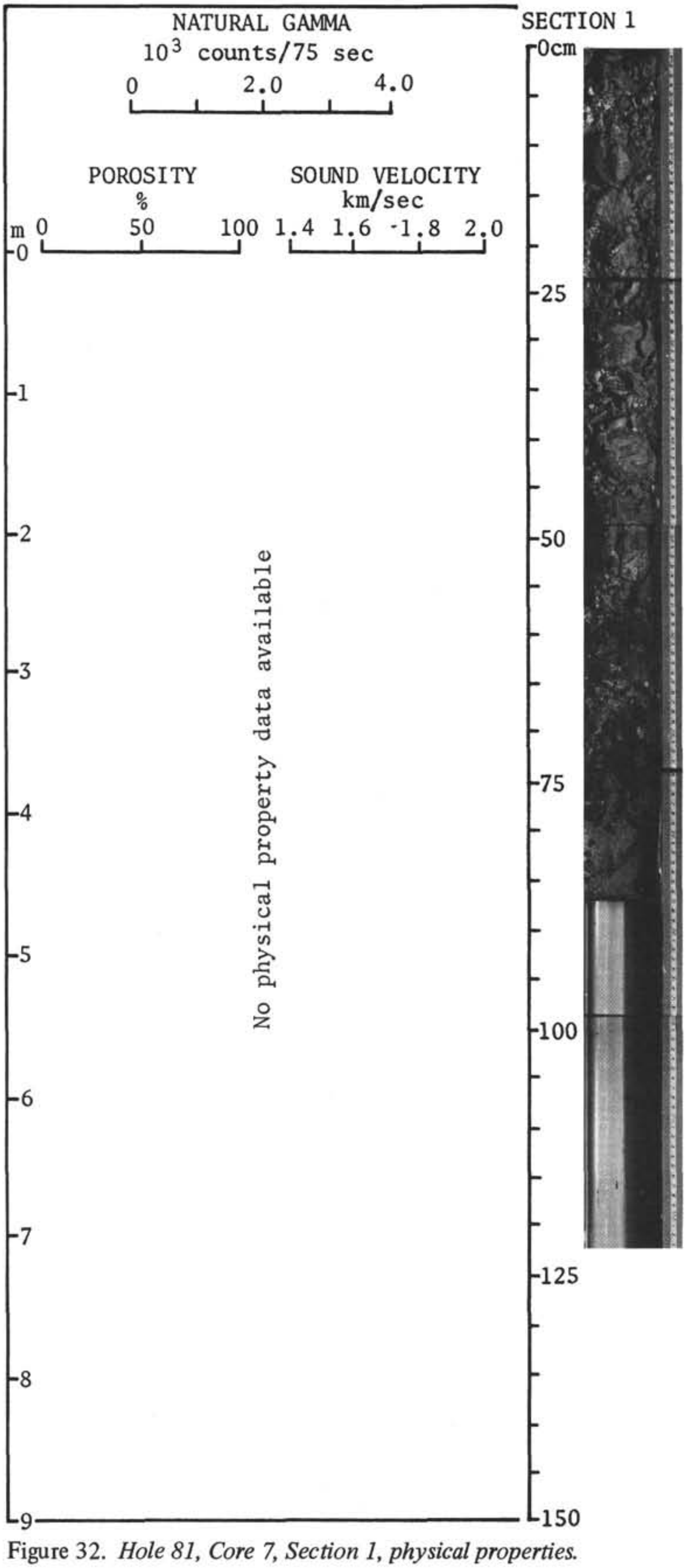


Figure 32. *Hole 81, Core 7, Section 1, physical properties.*

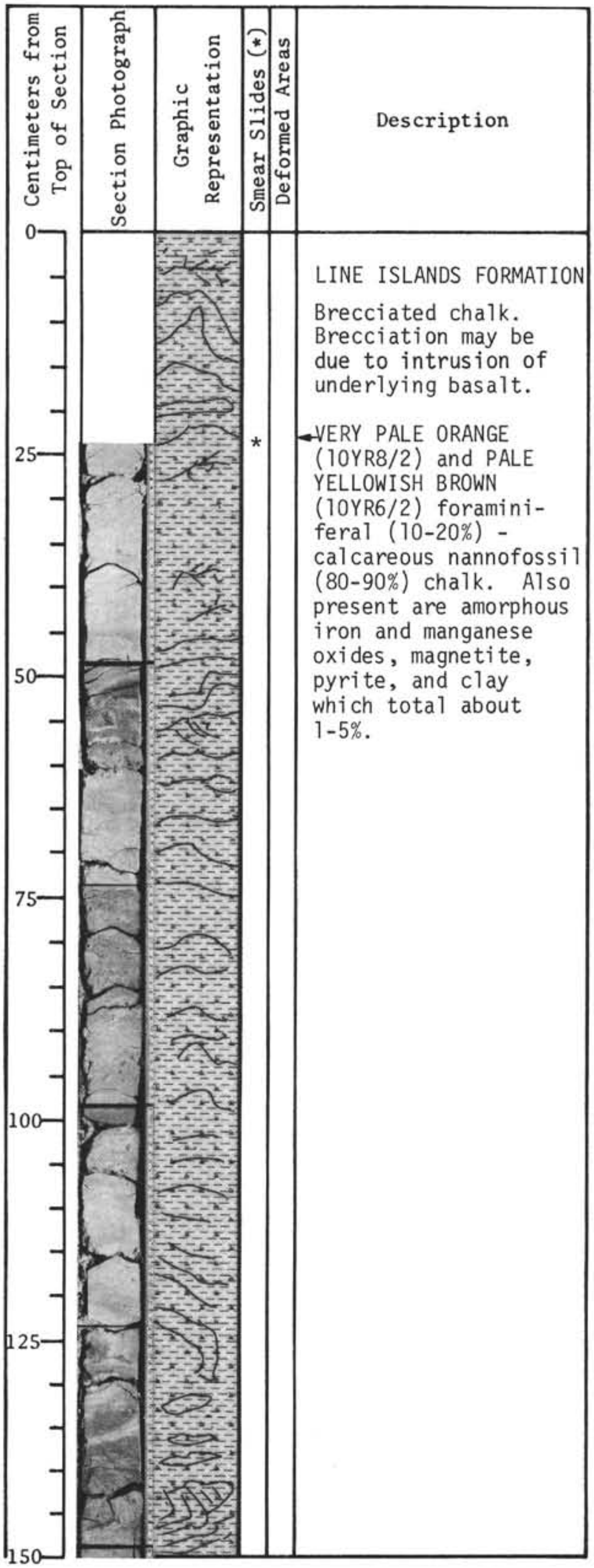


Figure 33. *Hole 81, Core 6, Section 3.*

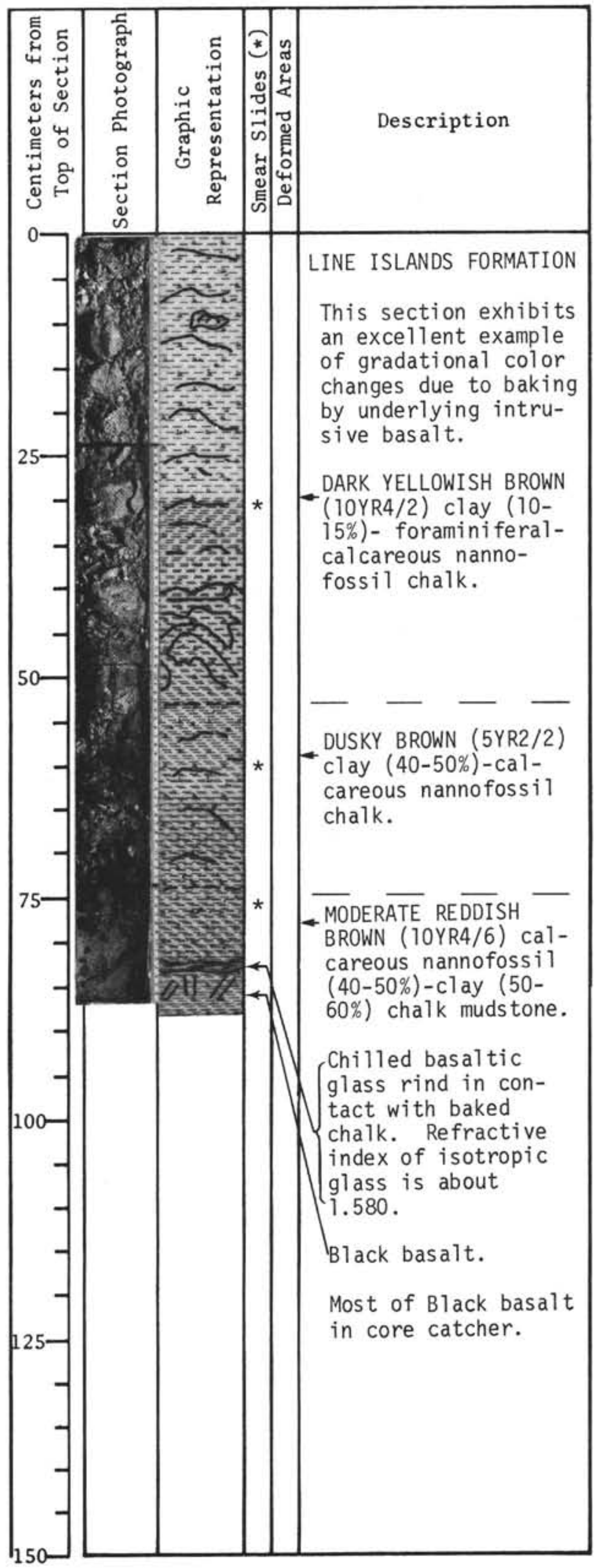


Figure 34. *Hole 81, Core 7, Section 1.*