# 18. SITE 60

Shipboard Scientific Party[1]

## SITE DATA

**Occupied:** August 3-5, 1969.

**Position:** Sediment apron on west wall of Mariana Trench: Latitude: 13° 40.0'N. Longitude: 145° 41.9'E.

**Water Depth:** 3717 meters.

**Cores:** Nine.

**Total Depth:** 348 meters in Lower Miocene volcanic ash.

## MAIN RESULTS

A thick apron of Miocene pyroclastics extends eastward from Guam. This apron forms a counterpart to the Miocene volcanic apron on the west flank of the Iwo Jima Ridge.

The sediments are mainly pumice ash, with a variable admixture of planktonic skeletons, interbedded with well-sorted, in some cases graded, beds of volcanic sand.

Consolidation increases downward, but no evidence of metamorphism was noted.

## BACKGROUND

When Hole 59.2 was abandoned on August 2, there was no operative seismic profiler, one beacon, and three days to go before scheduled arrival in Guam.

With the bits on board, it seemed pointless to undertake another frontal attack on the cherts in Site 59, or elsewhere along that profile. Thus, the alternatives were drilling a "blind" hole at random in the Pacific, or drilling an area surveyed by *Argo* prospect 18 A, on the west wall of the Mariana Trench east of Guam (Figure 17-1, 2). For this prospect there was a sketch made from the *Argo's* profiler records by D. Karig, and transmitted to us by facsimile. This showed a thick sequence of sediments near Guam, thinning rapidly toward the trench by down-dip overlap above a marked unconformity.

The upper sequence of sediments seemed best interpreted as a pyroclastic apron, possibly mixed with resedimented shallow-water carbonates derived from Guam; it appeared possible, however, that the rocks beneath the unconformity might be shallow-water sediments, sunk in the subsidence of the trench, and they might in any case, furnish information on the tectonic history of the Mariana Trench.

## OPERATIONS

The hole was drilled to a total depth of 349 meters. Drilling rates decreased drastically with greater compaction of volcanic ash in the lower part of the hole. The site was abandoned at 0130 hours, August 5 in order to meet arrival schedule at Apra Harbor, Guam, on that same morning.

## NATURE OF THE SEDIMENTS

Nine cores taken from the single hole at this site recovered sediment between 52.1 and 348.1 meters subbottom depth. Two general lithologies are present:

(1) *Nannoplankton chalk ooze* that is pale brown to gray, heavily burrowed, very compact, and has thin (2 to 5 centimeters) interlayers of sandy volcanic ash. This sediment was recovered in Core 1 and in the top 80 centimeters (Section 1) of Core 2. Compositionally this ooze is dominated by nannofossils, among which discoasters are most frequent. Sponge spicules and well-preserved radiolarian tests are present in amounts that vary from rare to common. Minor components also include clay minerals, volcanic glass that is colorless to reddish brown, and yellowish palagonite that varies from unaltered to somewhat altered and slightly birefringent.

(2) *Volcanic ash* that is gray to dark gray, sandy to silty, and is usually calcareous. This material was recovered in Section 2 of Core 2 and in Cores 3 through 9. Volcanic glass is the most abundant component and is largely colorless to pale brown. Typically the glass occurs as very angular, elongate, vesicular shards. Also present are small amounts of reddish brown glass and yellowish palagonite or altered palagonite. Other lesser components include pyroxenes, brown and green amphiboles, plagioclase, quartz, sponge spicules, unaltered

[1] B. C. Heezen, Lamont-Doherty Geological Observatory; A. G. Fischer, Princeton University; R. E. Boyce, Scripps Institution of Oceanography; D. Bukry, U.S.G.S. La Jolla; R. G. Douglas, Case Western Reserve University; R. E. Garrison, University of California, Santa Cruz; S. A. Kling, Cities Service Oil Company; V. Krasheninnikov, Academy of Sciences of the U.S.S.R.; A. P. Lisitzin, Academy of Sciences of the U.S.S.R.; A. C. Pimm, Scripps Institution of Oceanography.

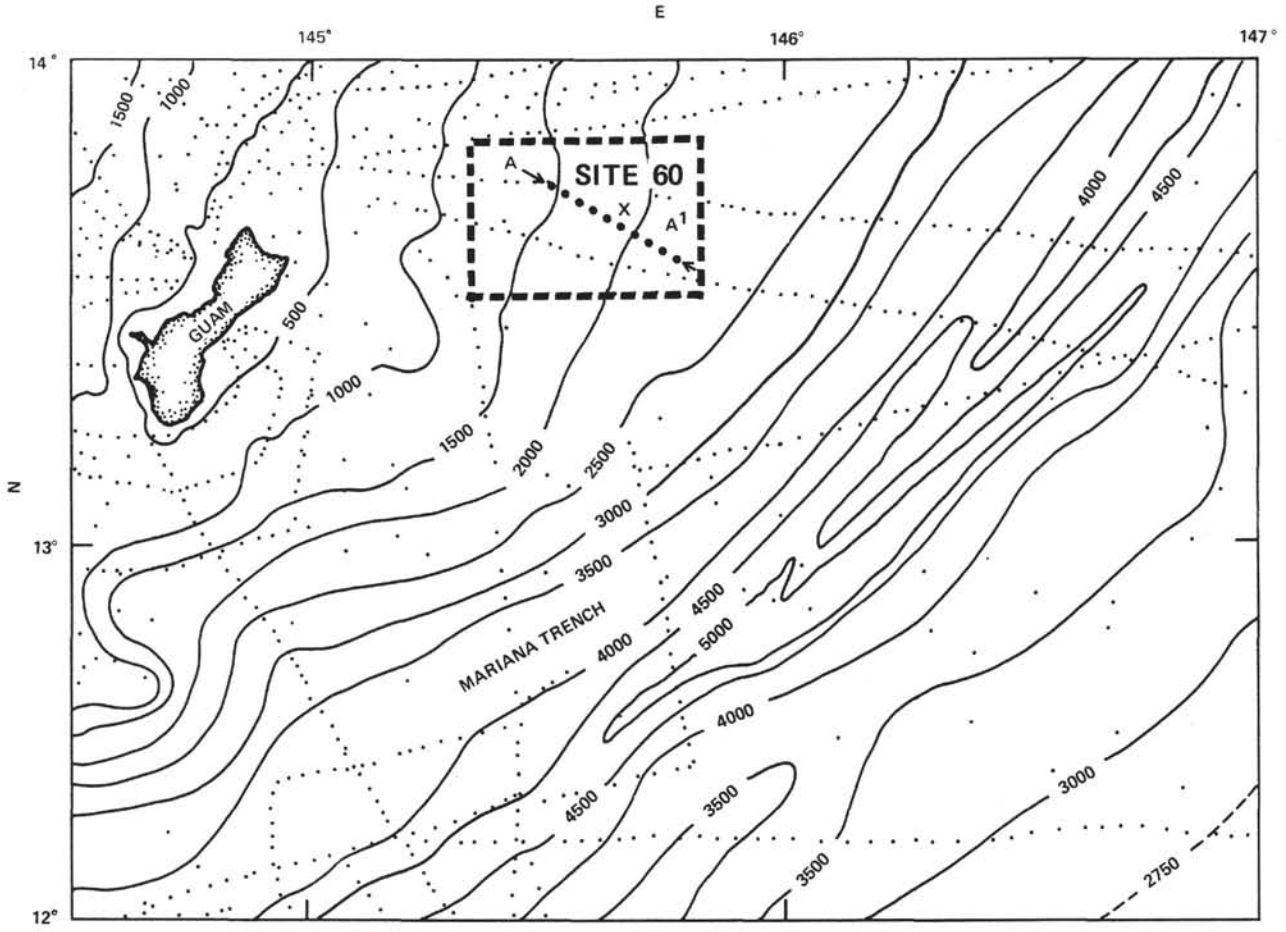


Figure 1. *Bathymetric contour map at Site 60.*

and secondarily silicified radiolarian tests, traces of glauconite, opaque volcanic rock fragments, chloritized volcanic fragments, calcareous nannofossils, and very rare planktonic foraminifers. The detrital components tend to be very angular. X-ray studies by Rex indicate the presence of the zeolite mineral erionite in Section 3 of Core 9.

Thin layers of light gray nannoplankton chalk ooze are scattered through this ash, particularly in Cores 6 and 7. Although usually badly distorted, these two cores record cyclic units showing graded bedding. A typical cycle averages about 40 to 60 centimeters thick and starts with 5 to 10 centimeters of light gray nannoplankton chalk ooze; this grades downward into a relatively thick (30 to 50 centimeters) interval of gray silty volcanic ash that is often laminated toward the base; this in turn is underlain by a thin basal interval of black, well sorted sandy volcanic ash that commonly is cross laminated and lies above a chalk ooze layer, representing the top of the next cycle, along a sharp contact. These cycles appear to be products of turbidity currents or other types of mass flow.

The volcanic ash varies from well compacted to indurated, and the degree and frequency of indurated layers increases downward in the section. Many of the finer-grained, silty volcanic ash layers have a slight fissility.

## PHYSICAL PROPERTIES

As these cores were disturbed during drilling operations, the physical properties do not necessarily represent *in situ* conditions.

### Natural Gamma Radiation

Natural gamma radiation averaged 600 counts with a range of 100 to 2450 counts/7.6-cm core segment/1.25 minutes in the three cores measured (others were cored without liners). The 52.1 to 56.7 meter interval, containing Miocene pale brown to light gray nannoplankton chalk ooze with some graded ash beds, had a lower average count of 400, with the highest count of 900 from a volcanic sand layer. Cores 2 and 3 (61 to 70 meters and 129 to 134 meters) interbedded ash and chalk ooze had high average counts of 900. The highest

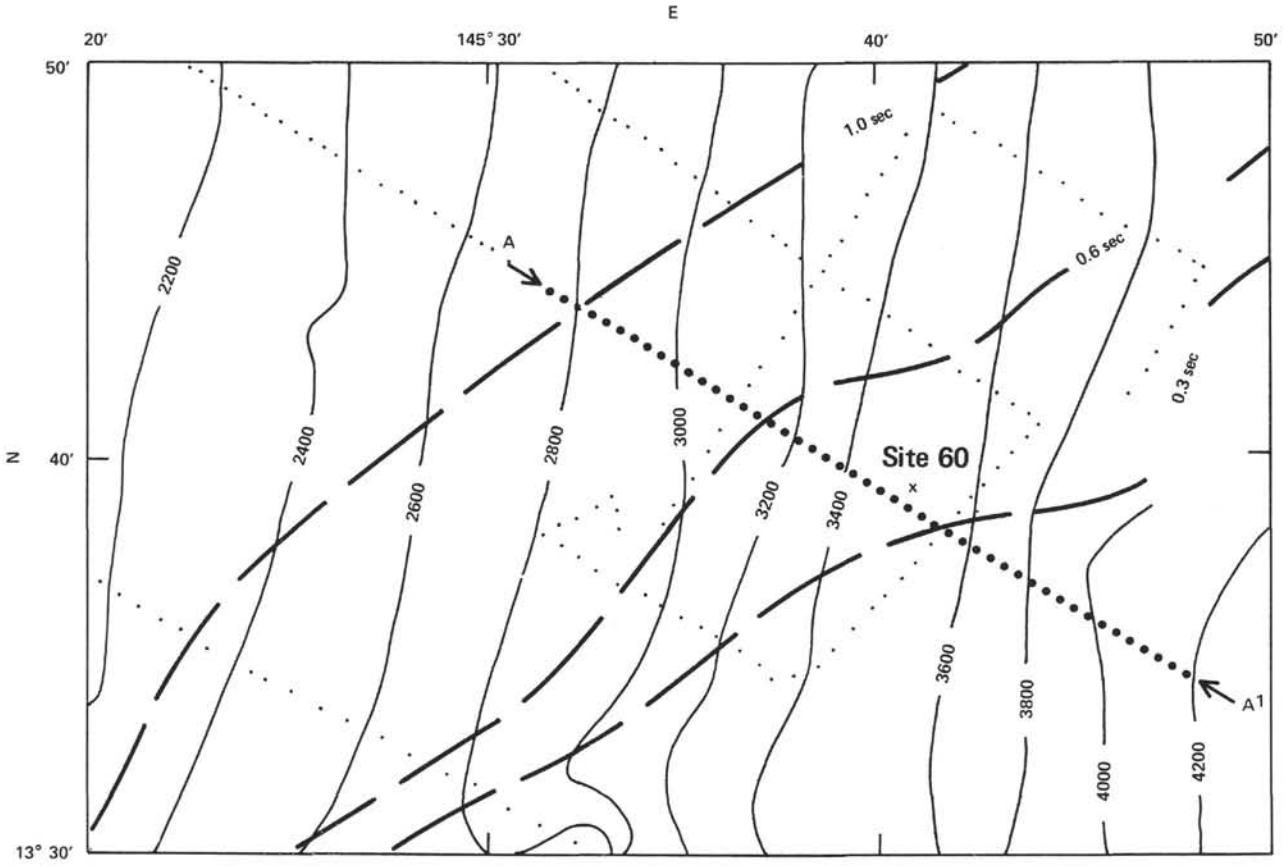


Figure 2. *Bathymetric contour map at Site 60.*

count was 2450 from concentrated volcanic ash. Gamma radiation versus depth appeared to be related directly to wet-bulk density in some areas.

### Porosity and Wet-Bulk Density

Miocene nannoplankton chalk ooze and volcanic ash were cored within the depth interval of 52 to 141 meters at Site 60. Porosities and wet-bulk densities ranged from 36 per cent to 70 per cent and 1.46 g/cc to 1.96 g/cc. Typical porosities were about 60 per cent in the Miocene nannoplankton ooze with ash (52.1 to 61.0 meters), and cyclic graded ash with nannoplankton marl ooze (61.0 to 70.1 meters). The average wet-bulk densities were about 1.67 g/cc. In general, the volcanic sand layers had porosities as low as 43 per cent. At the 129 to 131 meter interval, the typical density increased to 1.75 g/cc, and the typical porosity decreased to about 50 per cent in the volcanic ash, clayey ash and nannoplankton ooze of Core 3.

In general, wet-bulk density had an apparent increase from upper mid-Miocene to lower mid-Miocene. It also had a direct variation to sound velocity.

### Sound Velocity

Site 60 sound velocities through Miocene nannoplankton chalk ooze (51 to 54 meters beneath sediment surface), graded ash beds and nannoplankton-marl chalk ooze (61 to 63 meters below sediment surface), and ash and clayey ash (129 to 131 meters below the sediment surface) averaged 1.64, 1.66 and 1.91 km/sec, respectively. These averages can be misleading as the size of the sample in Cores 2 and 3 was very small. The velocity range was 1.54 to 1.95 km/sec. It appeared that the amount of volcanic ash was directly related to higher velocities and higher wet-bulk density.

### Thermal Conductivity

Thermal conductivities at Site 60 ranged from 2.50 to $4.13 \times 10^{-3}$ cal-°$C^{-1}$ $cm^{-1}$ $sec^{-1}$ with an average of 2.64. The Miocene nannoplankton marl ooze at 51 to 54 meters had a conductivity of about $2.55 \times 10^{-3}$ cal-° $C^{-1}$ $cm^{-1}$ $sec^{-1}$ with one extreme value of $4.13 \times 10^{-3}$. In general, these values were lower than the Miocene ashey sediments at 213 to 231 meters where conductivity values ranged from 2.6 to $2.9 \times 10^{-3}$ cal-°$C^{-1}$ $cm^{-1}$ $sec^{-1}$. This may be the result of a decrease in porosity. A single conductivity of $2.3 \times 10^{-3}$ was measured in Miocene ash at 291 meters.

### Penetrometer

Penetrometer measurements at Site 60 in nannoplankton chalk oozes and volcanic ashes ranged from 2 to 90

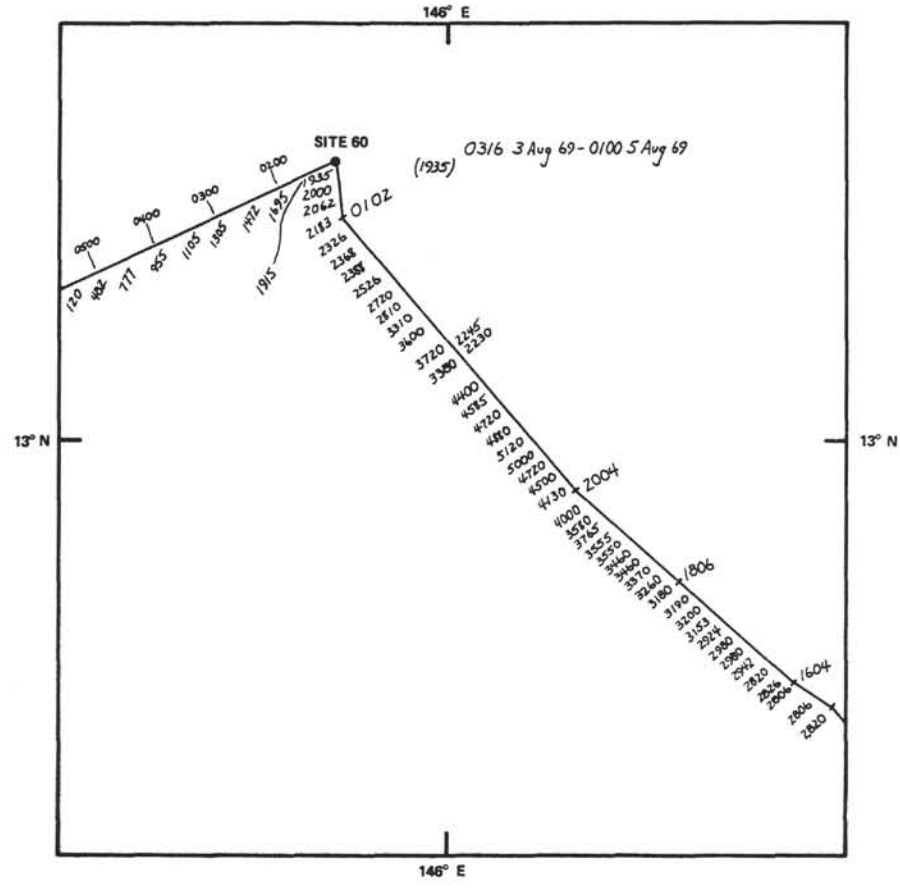


Figure 3. *Bottom soundings in area of Site 60.*

**TABLE 1**
**Summary of Coring at Site 60**

| Core No. | Interval Cored (below mudline) (ft) | (m) | Recovery (ft) | (m) |
|---|---|---|---|---|
| 60.0-1 | 171-200 | 52.1-61.0 | 15 | 4.6 |
| 60.0-2 | 200-230 | 61.0-70.1 | 7 | 2.1 |
| 60.0-3 | 424-440 | 129.2-134.1 | 7 | 2.1 |
| 60.0-4 | 440-457 | 134.1-139.3 | 7 | 2.1 |
| 60.0-5 | 698-728 | 212.8-221.9 | 15 | 4.6 |
| 60.0-6 | 728-758 | 221.9-231.0 | 30 | 9.1 |
| 60.0-7 | 947-977 | 228.6-297.8 | 6 | 1.8 |
| 60.0-8 | 1125-1138 | 342.9-346.9 | 13 | 4.0 |
| 60.0-9 | 1138-1142 | 346.9-348.1 | 14 | 4.3 |

Water Depth: 3717.3 meters (12,196 feet)

$\times 10^{-1}$ millimeters. The amount of penetration varies irregularly with increasing depth and did not appear to be systematically related to lithology or age.

## CONCLUSIONS

Guam has, on its east, a thick apron of Miocene pyroclastics. This forms a compliment to the Miocene pyroclastic apron shed westward from the Iwo Jima Ridge, which was drilled at Sites 53 and 54.

For reasons not clear, but possibly related to depth of burial, the pyroclastics in the lower part of Hole 60.0 are more consolidated than are those drilled at Sites 53 and 54.

The unconformity suggested by the *Argo's* profiler record and the *Challenger* profiles was probably penetrated, without a marked change in rock type or age.

The sediments cored show no suggestion of a shallow-water episode, nor of resedimentation of carbonates from shallow water. Thus, comparatively deep water existed here at least since the end of Early Miocene time.

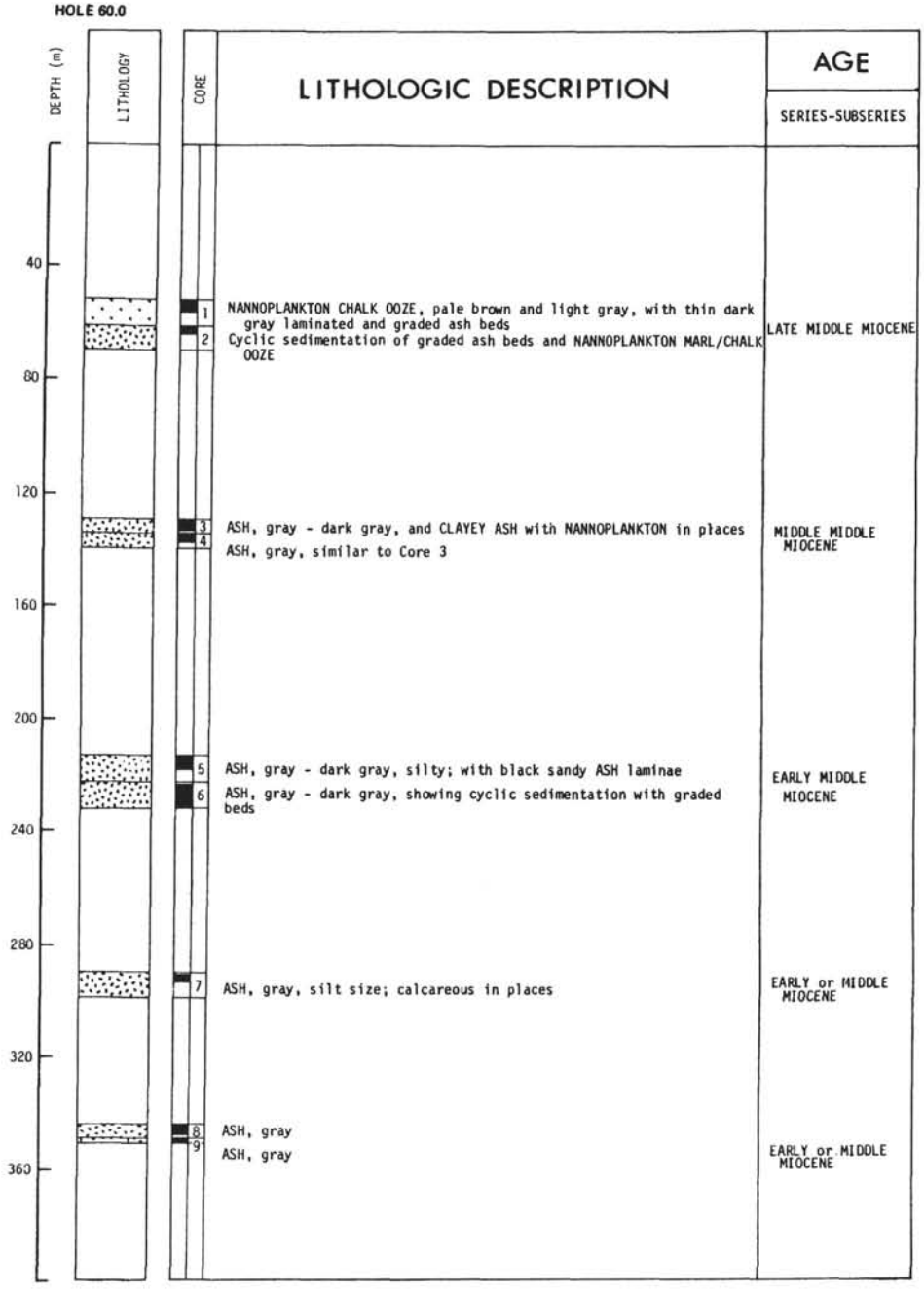


Figure 4. *Summary of lithology in Hole 60.0.*

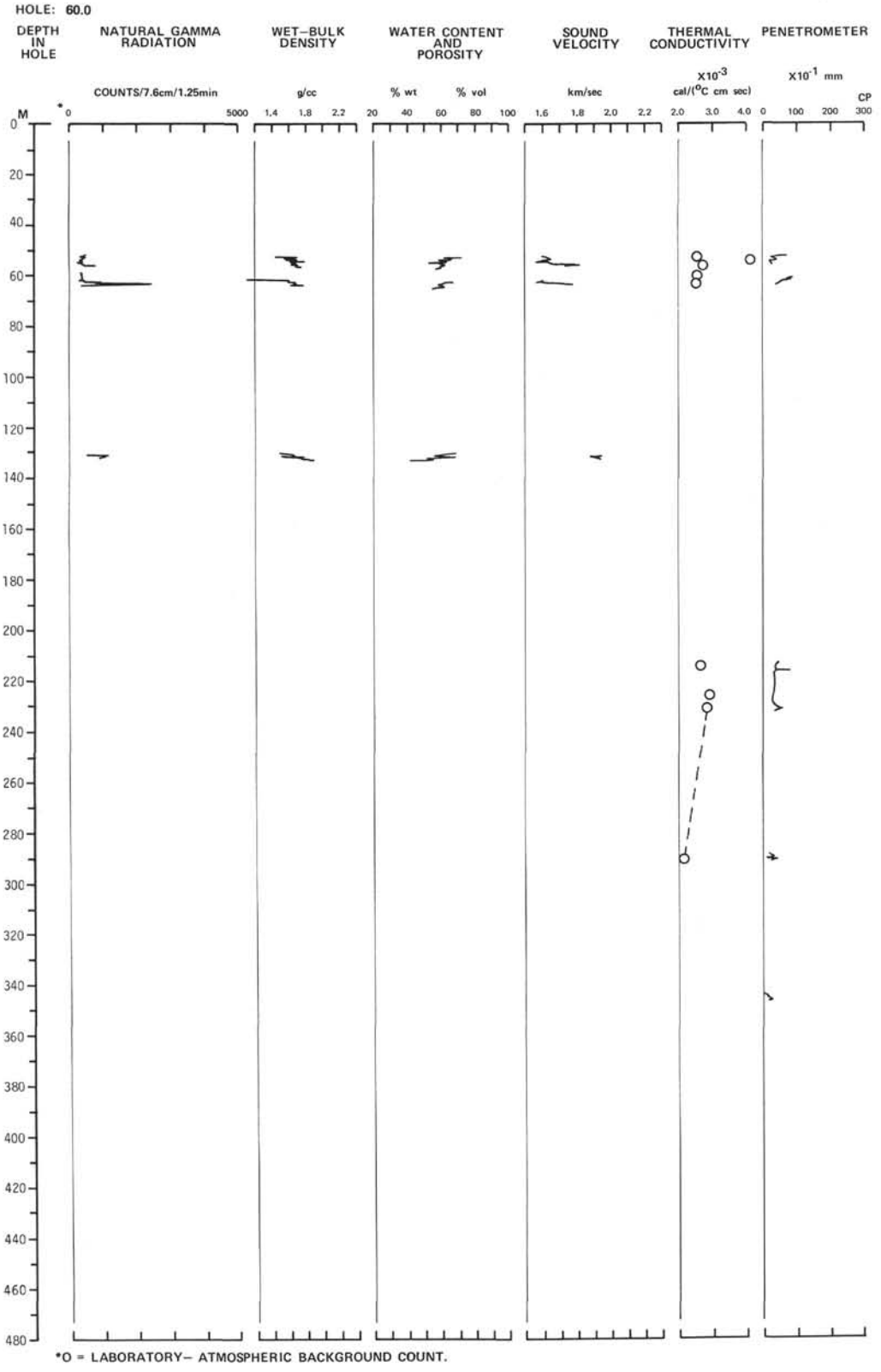


Figure 5. *Summary of physical properties in Hole 60.0.*

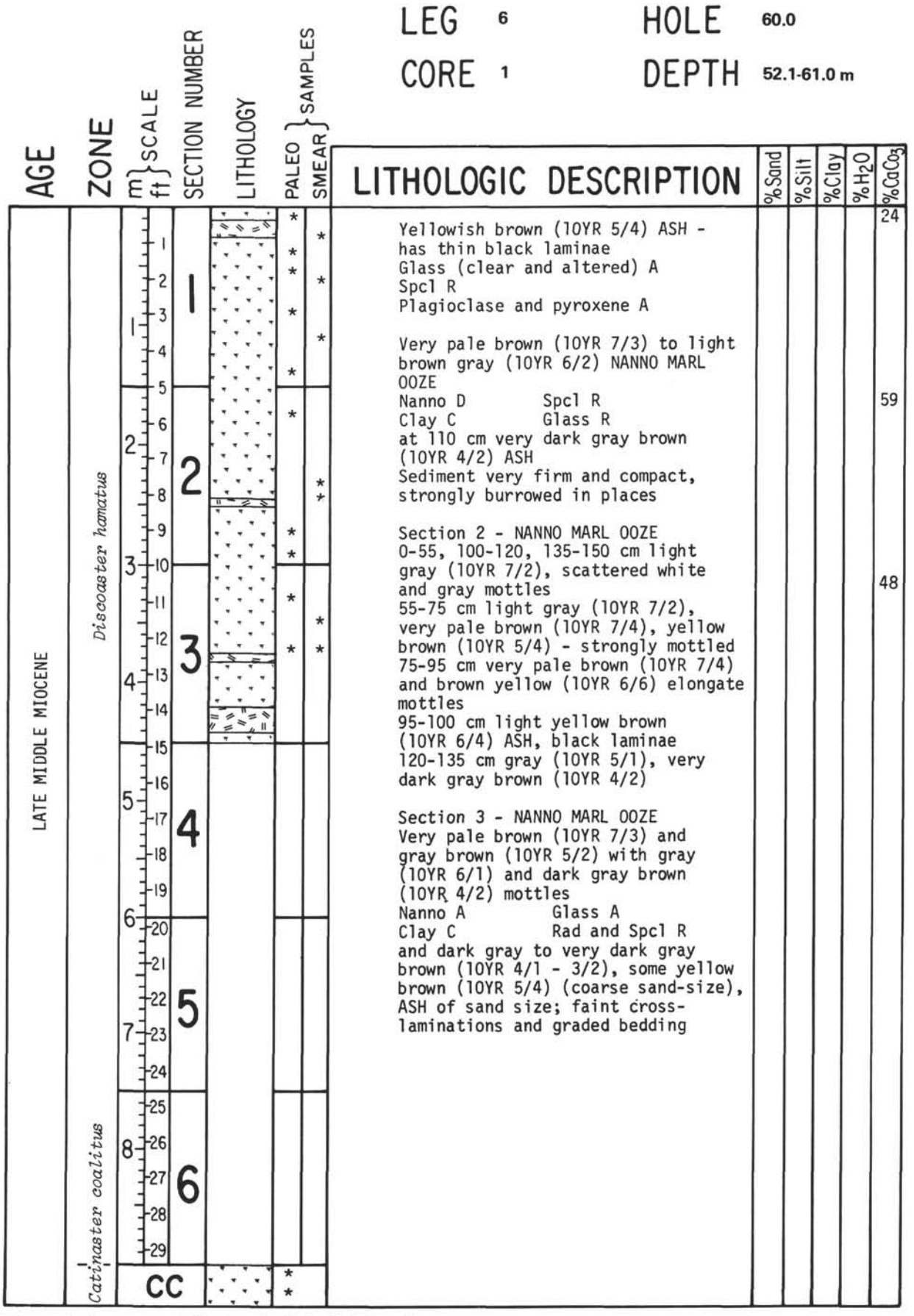


Figure 6. *Summary of lithology in Hole 60.0 Core 1.*

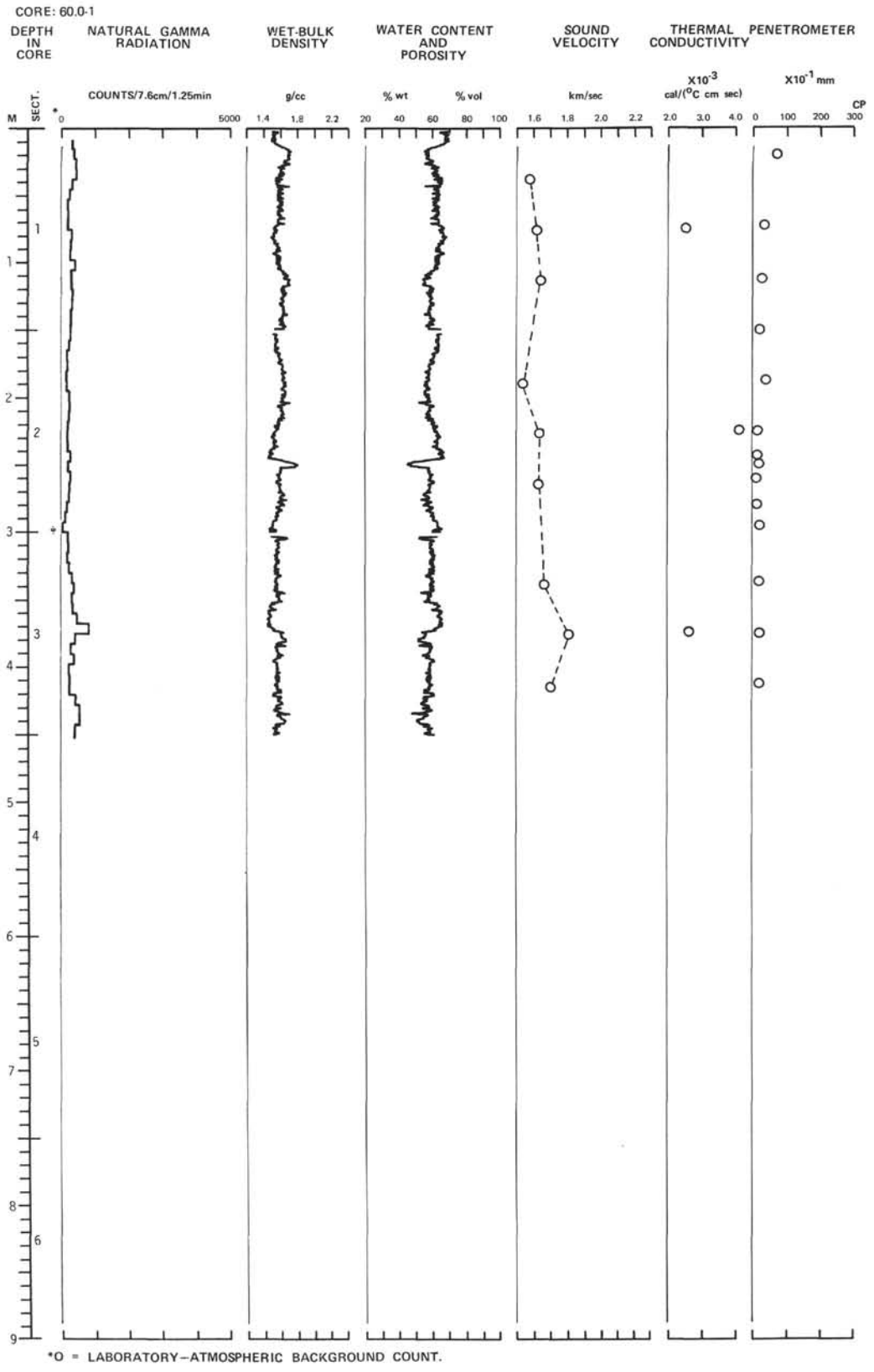


Figure 7. *Summary of physical properties in Hole 60.0 Core 1.*

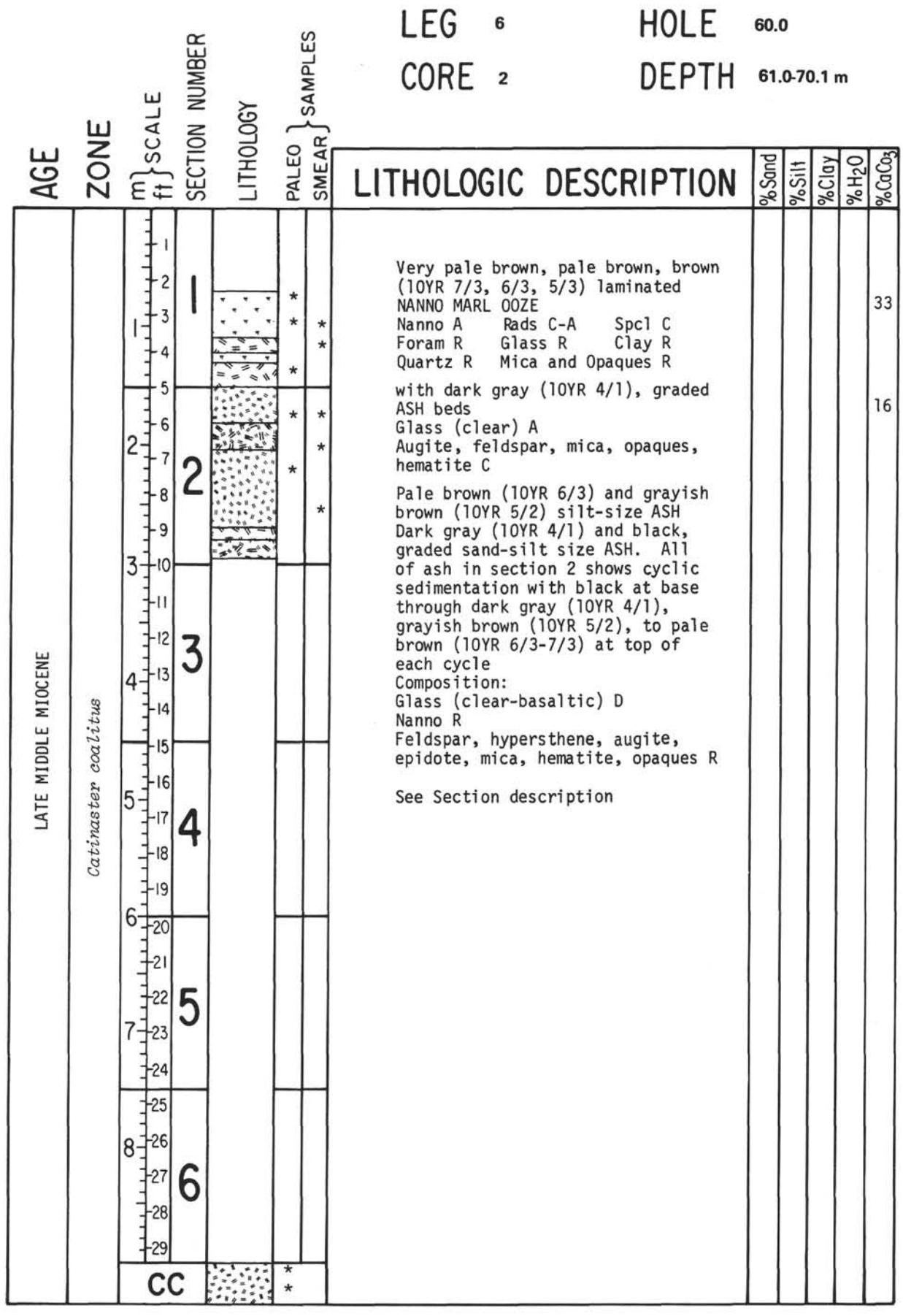


Figure 8. *Summary of lithology in Hole 60.0 Core 2.*

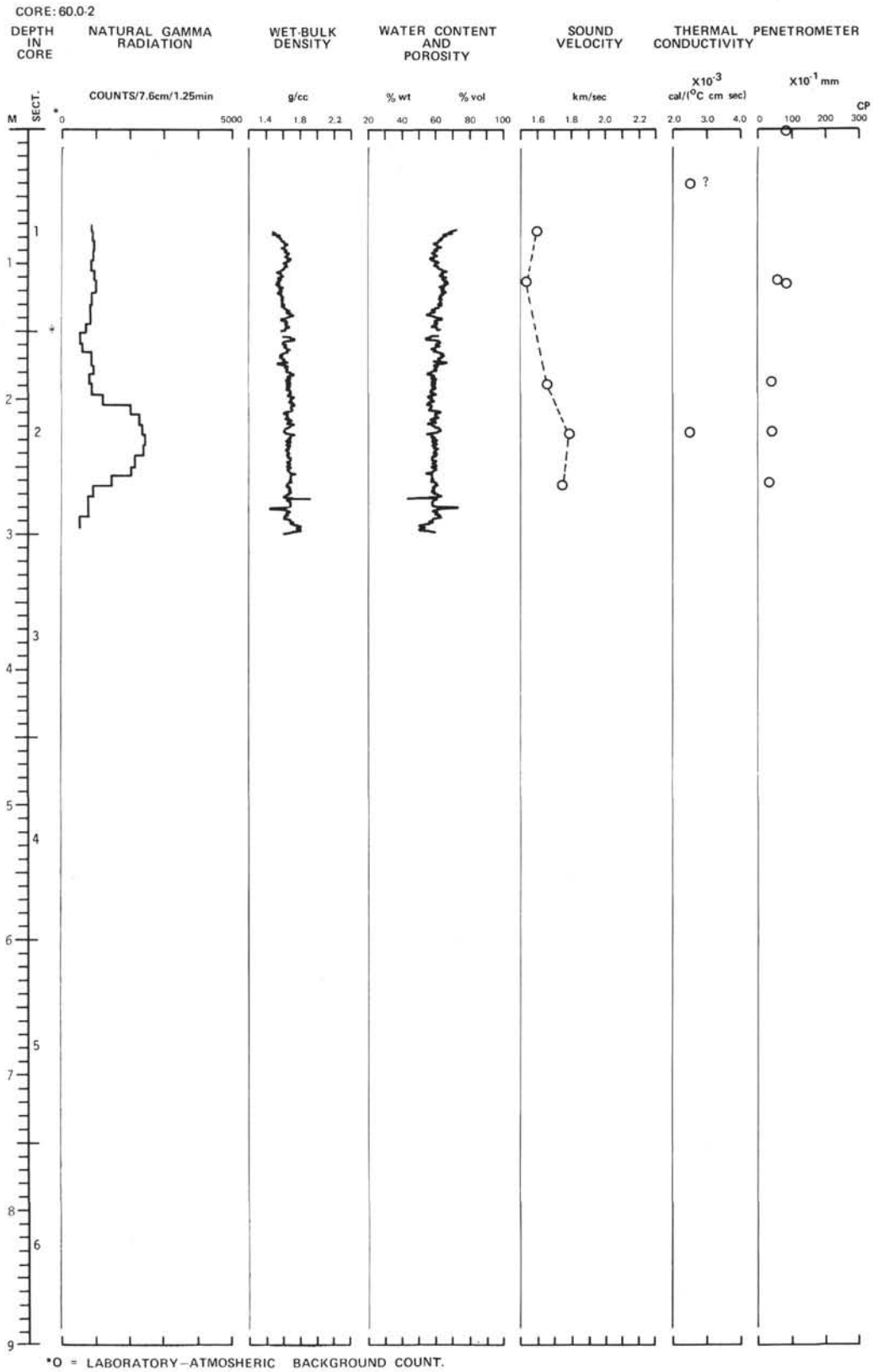


Figure 9. *Summary of physical properties in Hole 60.0 Core 2.*

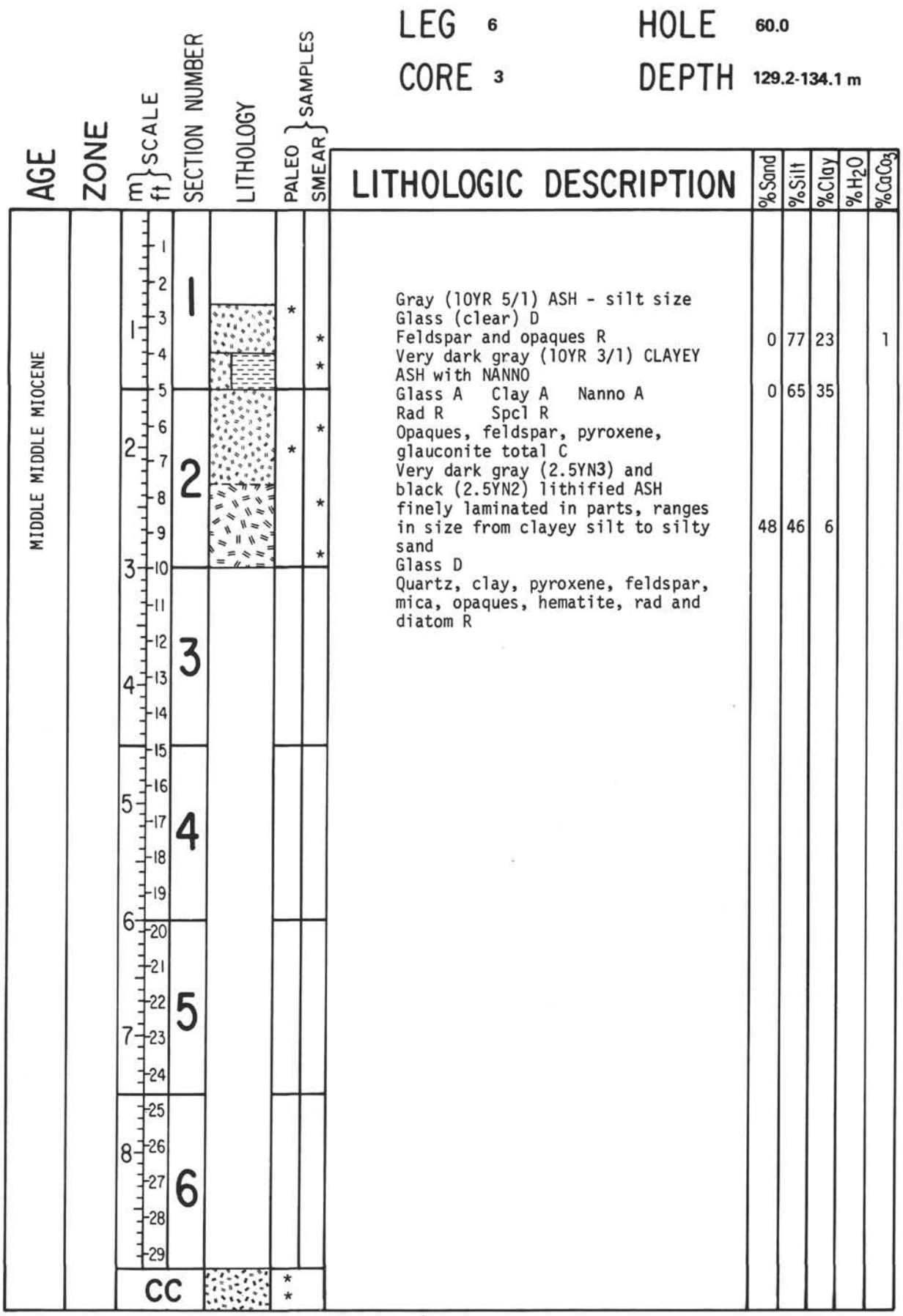


Figure 10. *Summary of lithology in Hole 60.0 Core 3.*

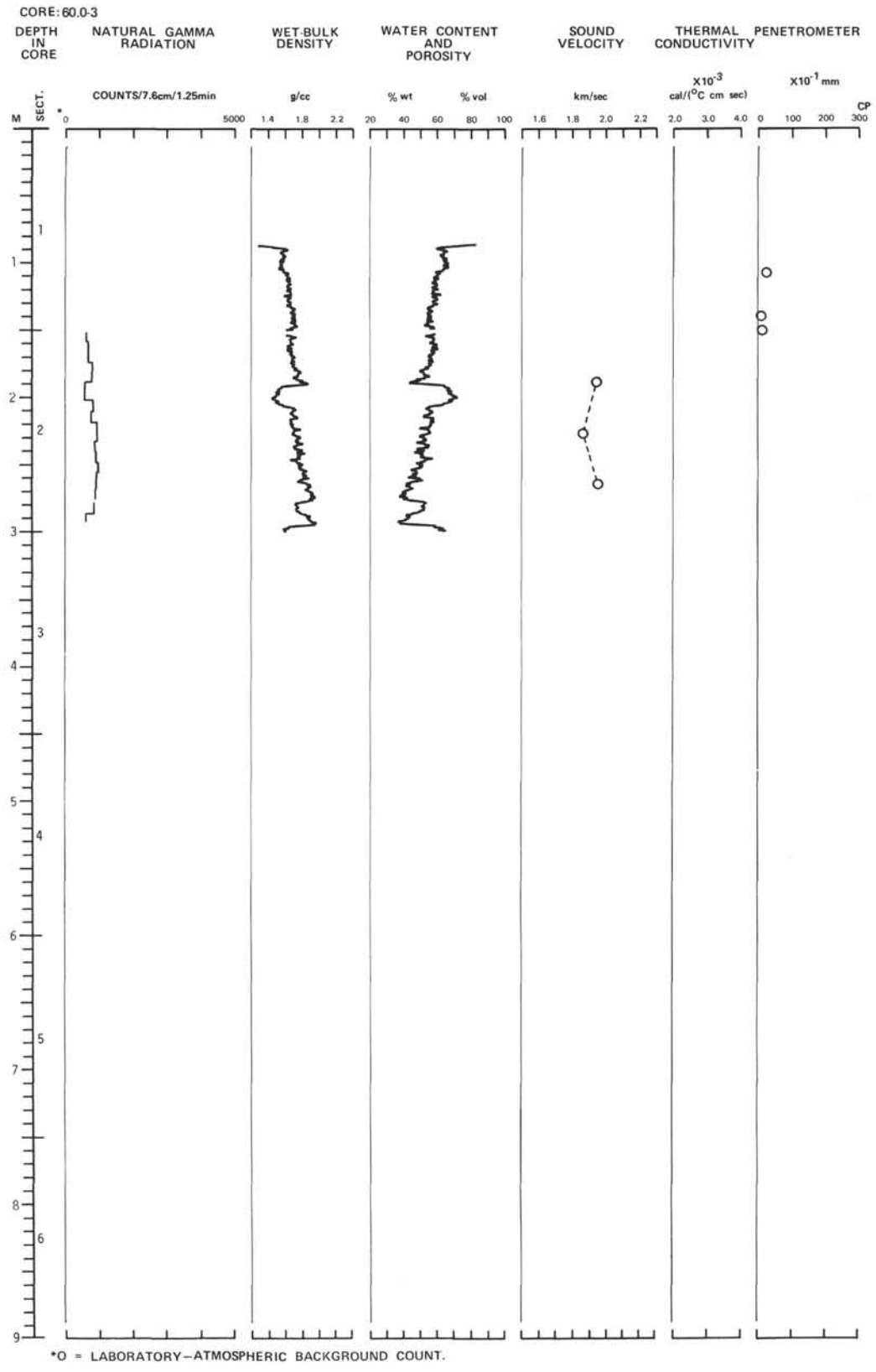


Figure 11. *Summary of physical properties in Hole 60.0 Core 3.*

NO PHOTOGRAPHS FOR HOLE 60.0 CORE 4

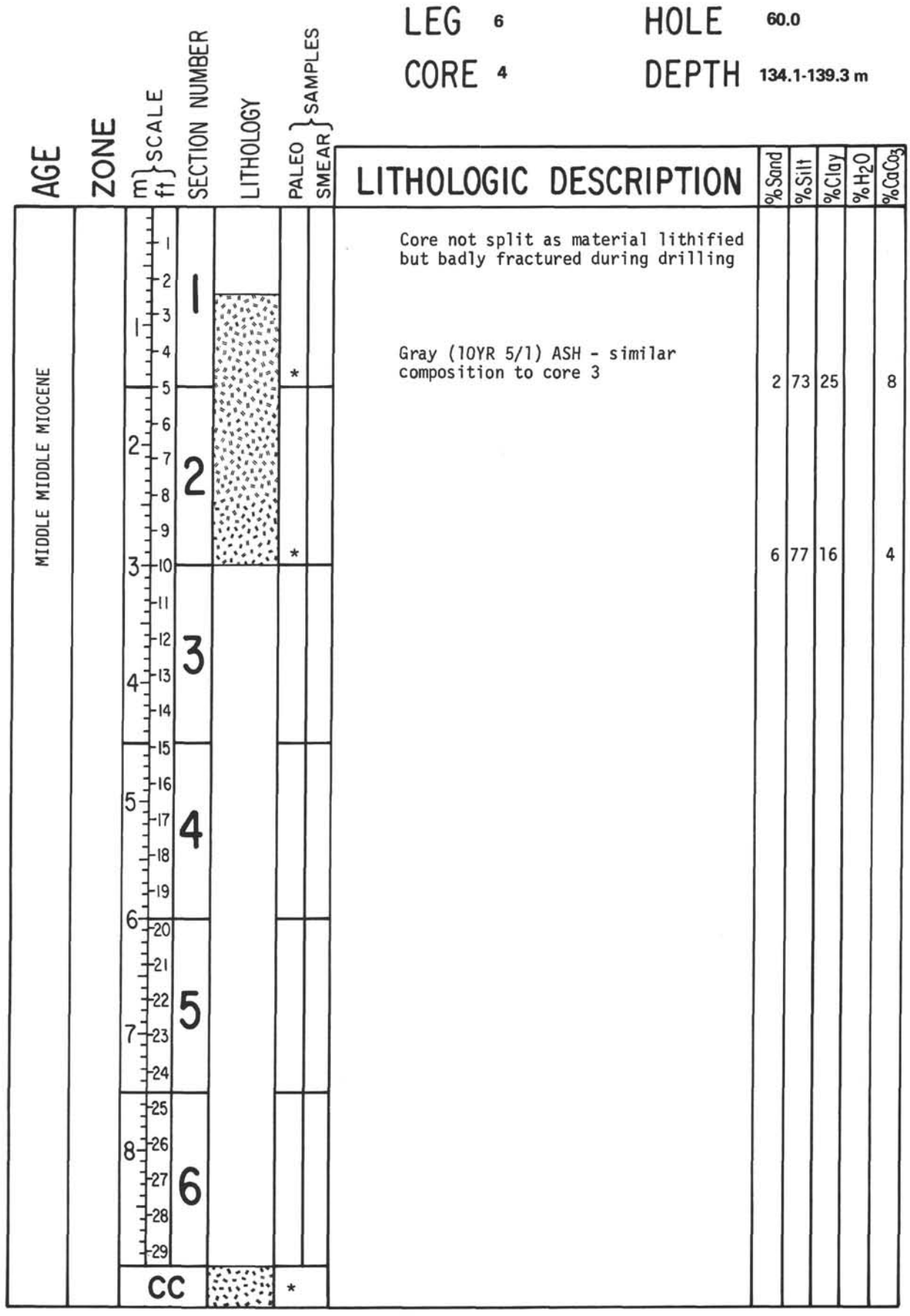


Figure 12. *Summary of lithology in Hole 60.0 Core 4.*

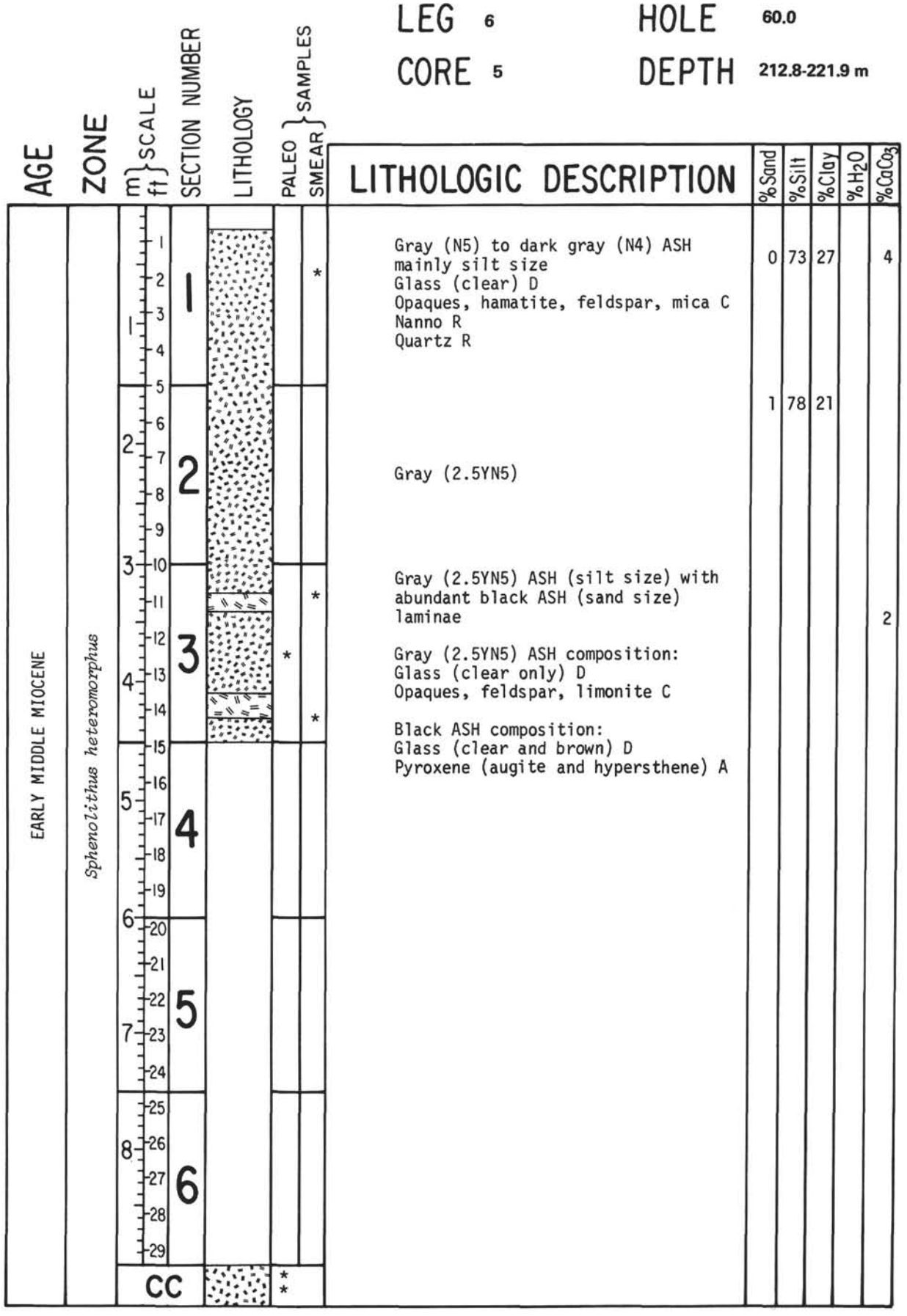


Figure 13. *Summary of lithology in Hole 60.0 Core 5.*

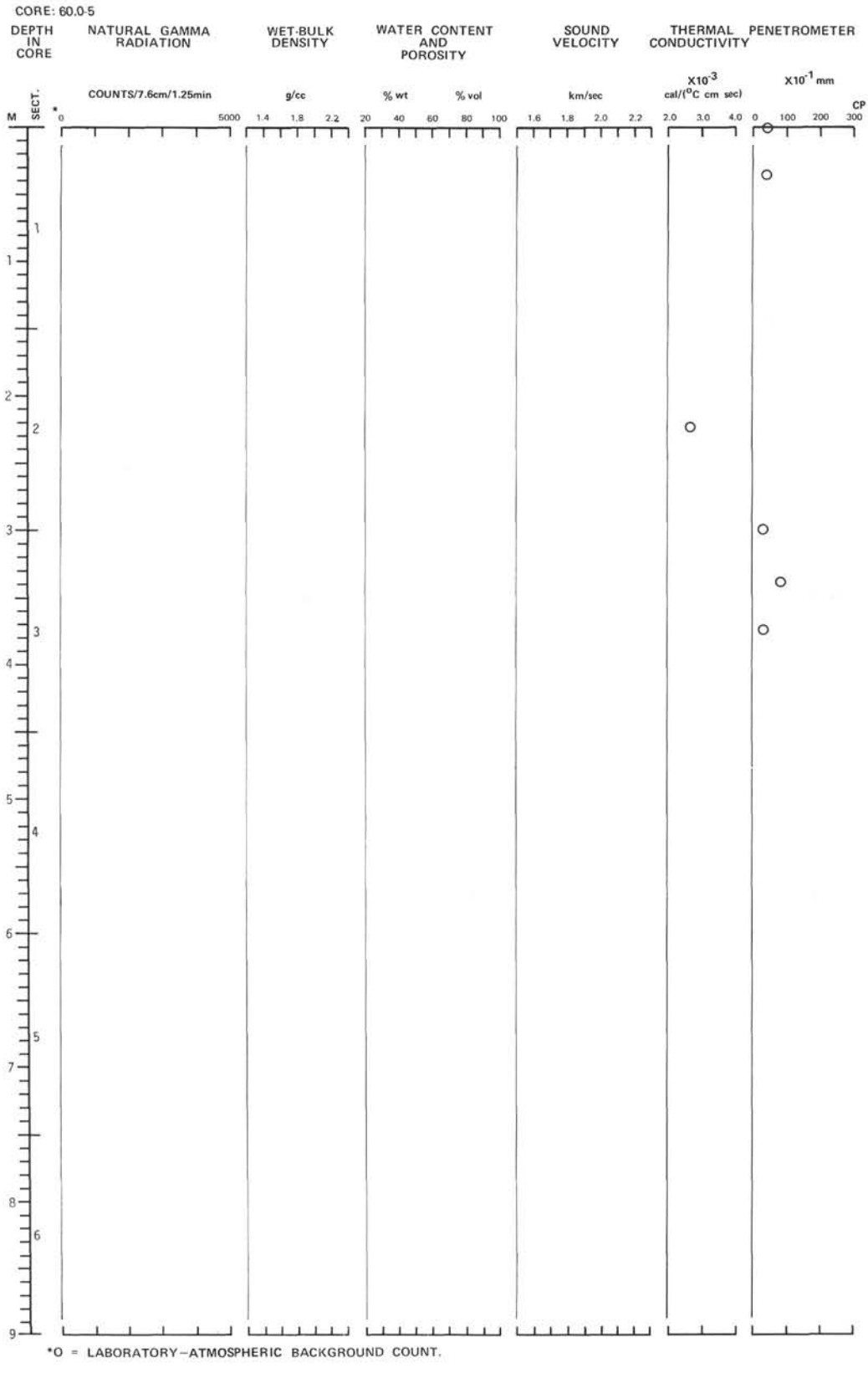


Figure 14. *Summary of physical properties in Hole 60.0 Core 5.*

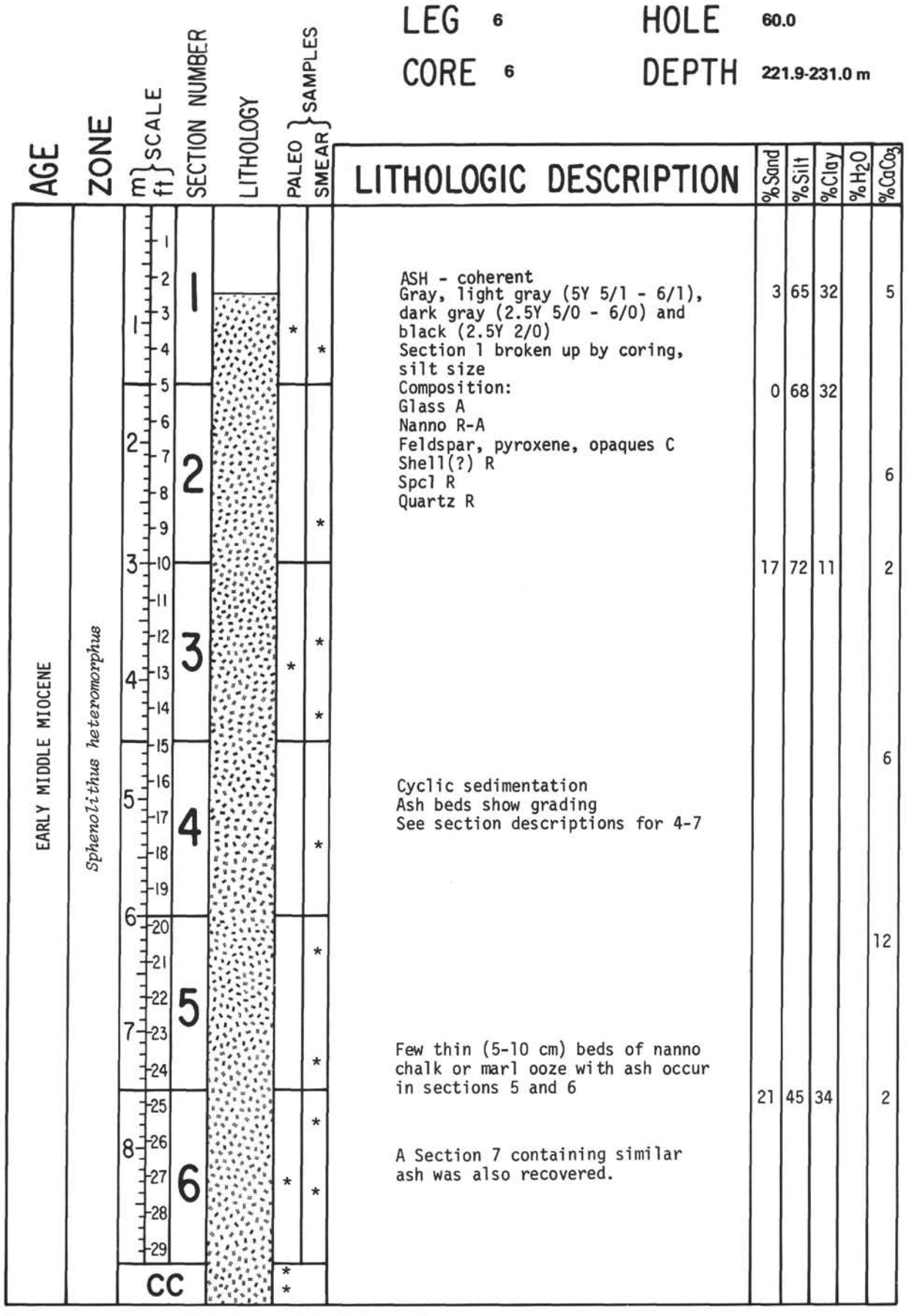


Figure 15. *Summary of lithology in Hole 60.0 Core 6.*

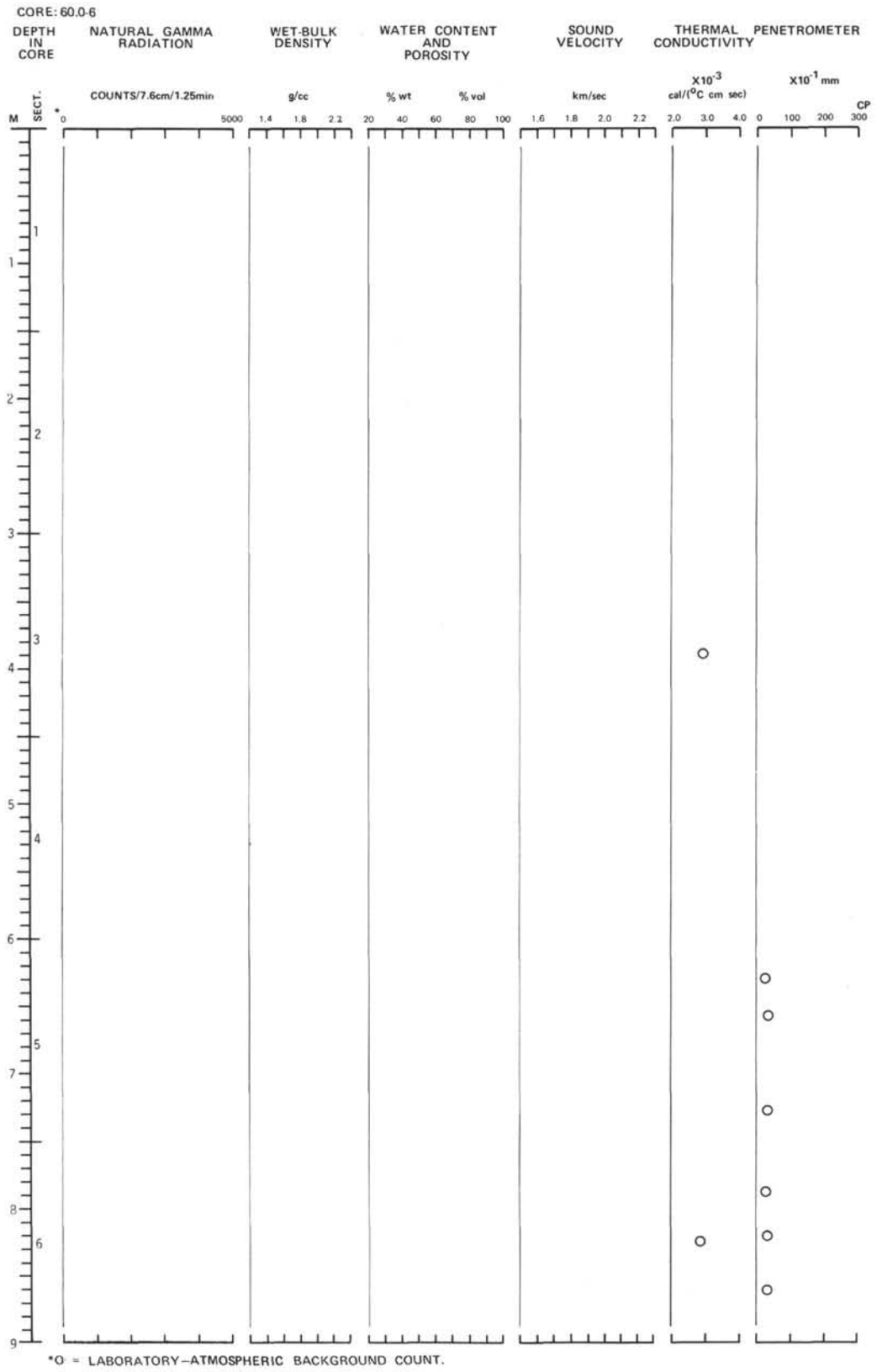


Figure 16. *Summary of physical properties in Hole 60.0 Core 6.*

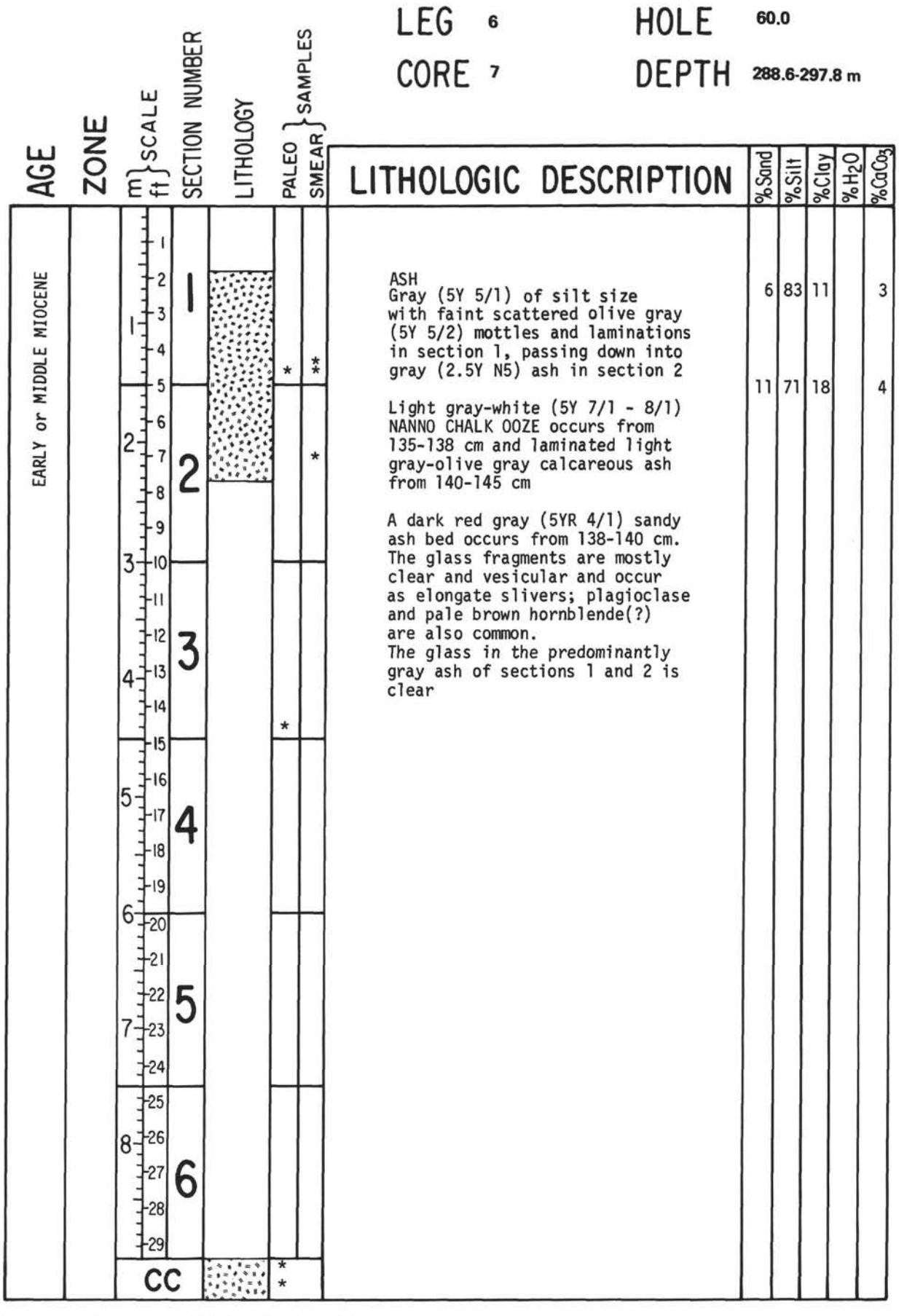


Figure 17. *Summary of lithology in Hole 60.0 Core 7.*

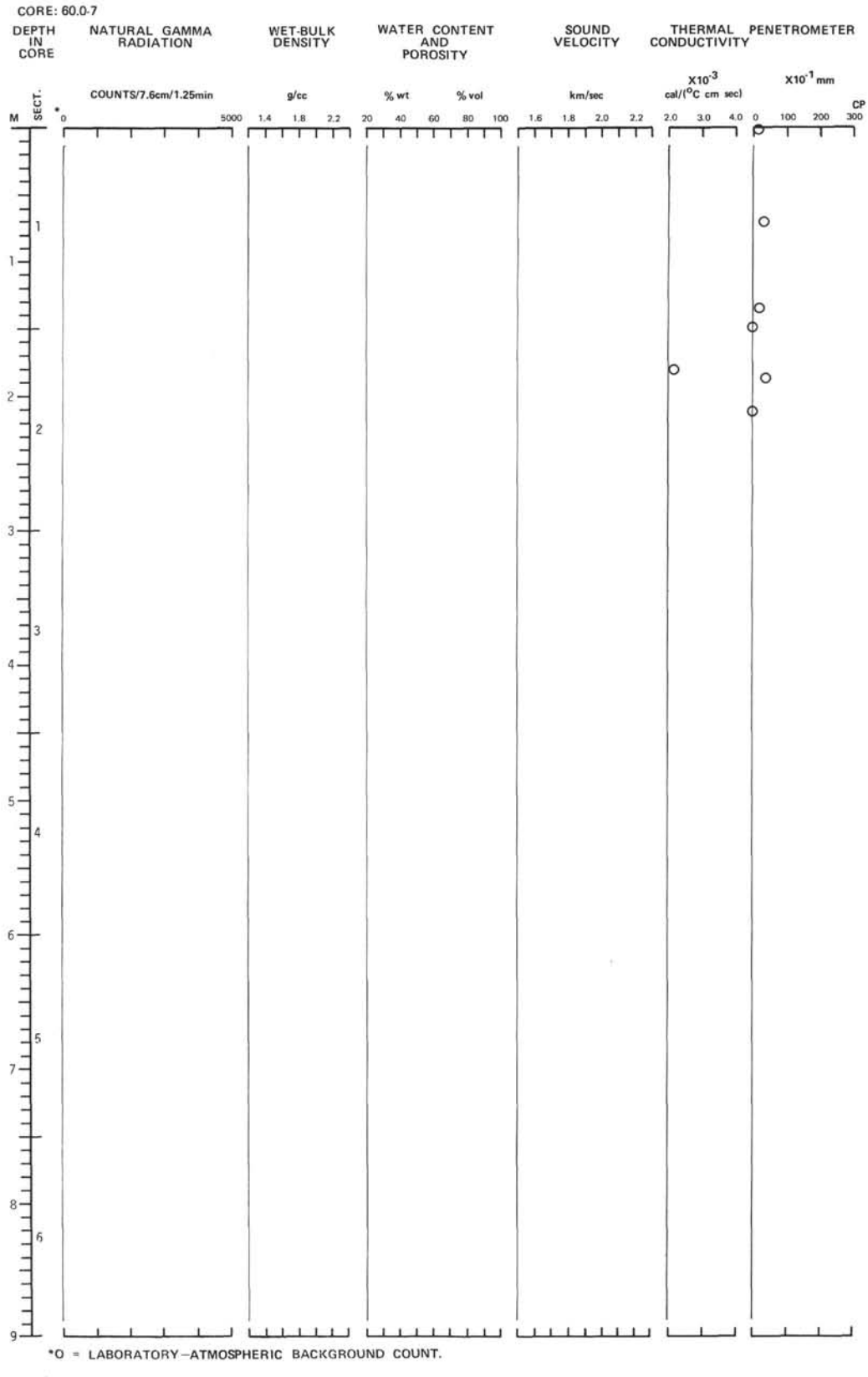


Figure 18. *Summary of physical properties in Hole 60.0 Core 7.*

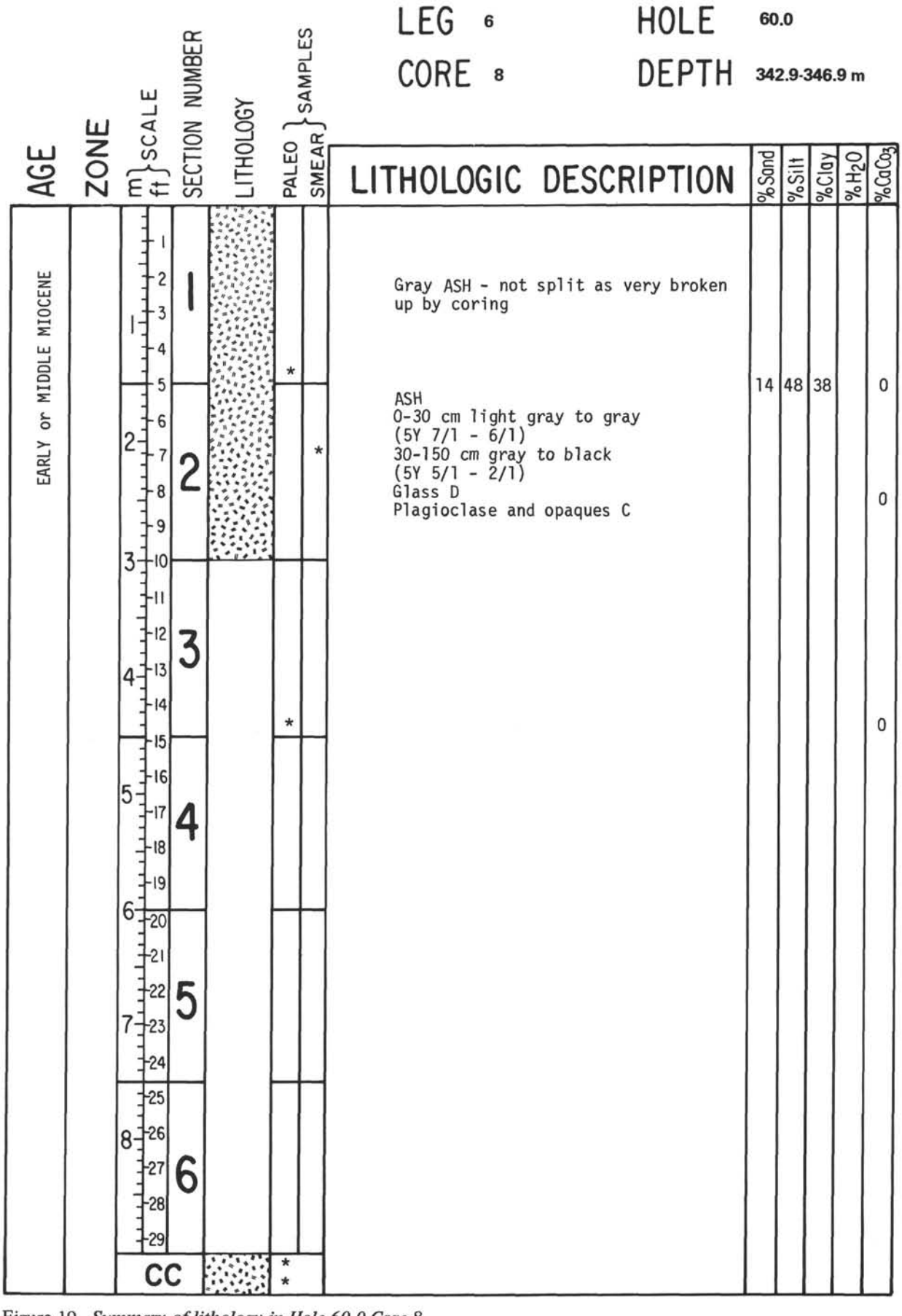


Figure 19. *Summary of lithology in Hole 60.0 Core 8.*

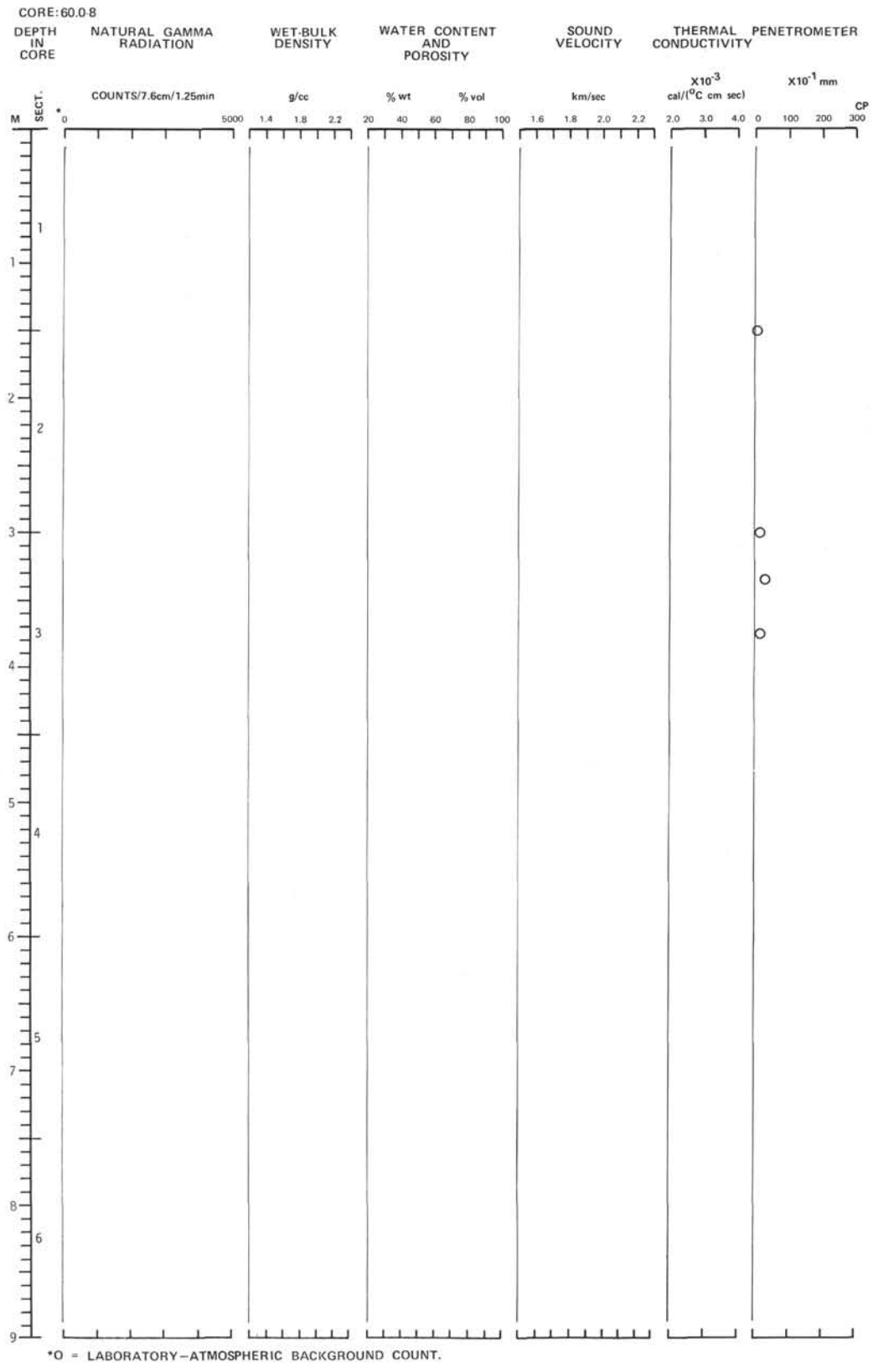


Figure 20. *Summary of physical properties in Hole 60.0 Core 8.*

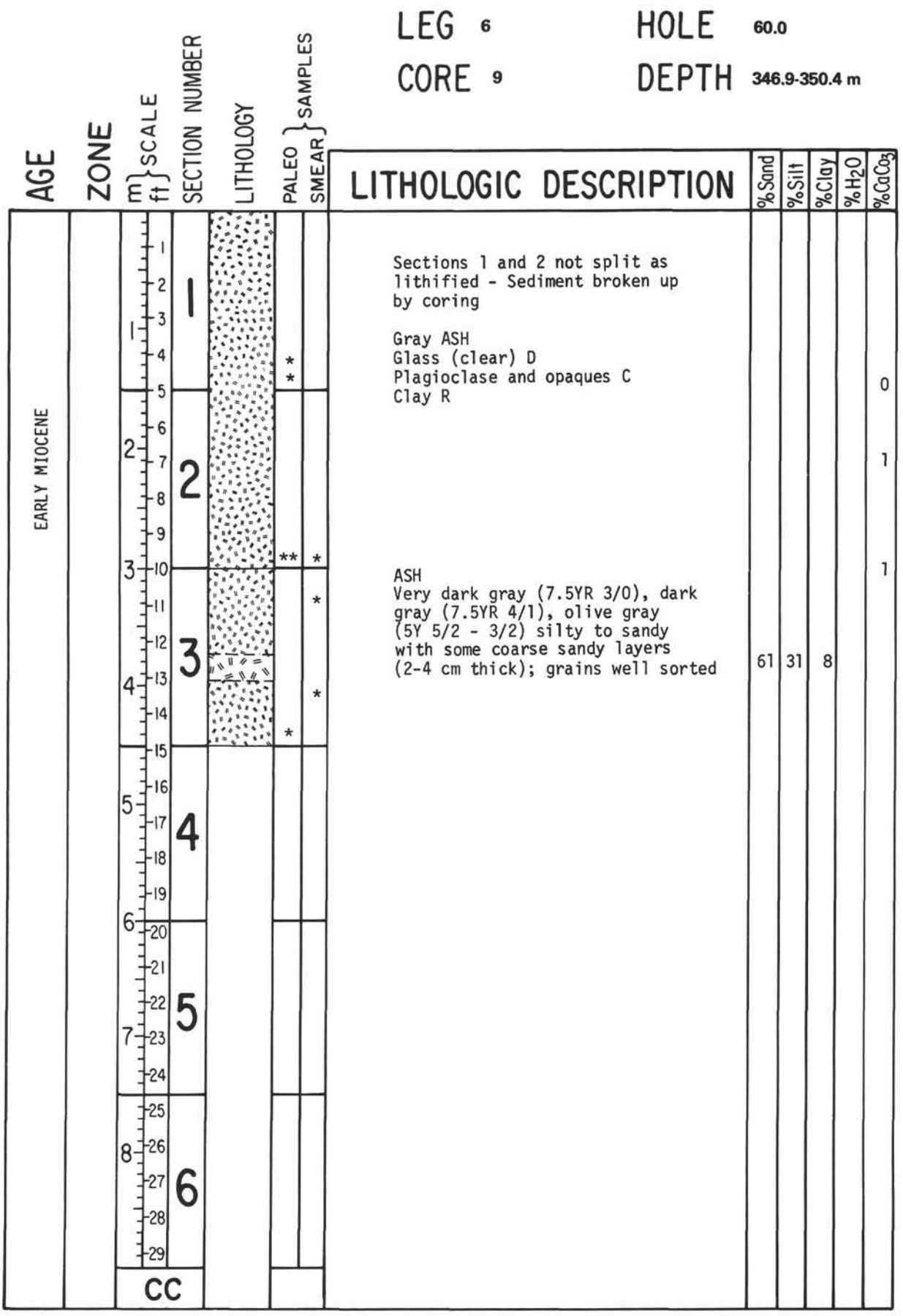


Figure 21. *Summary of lithology in Hole 60.0 Core 9.*

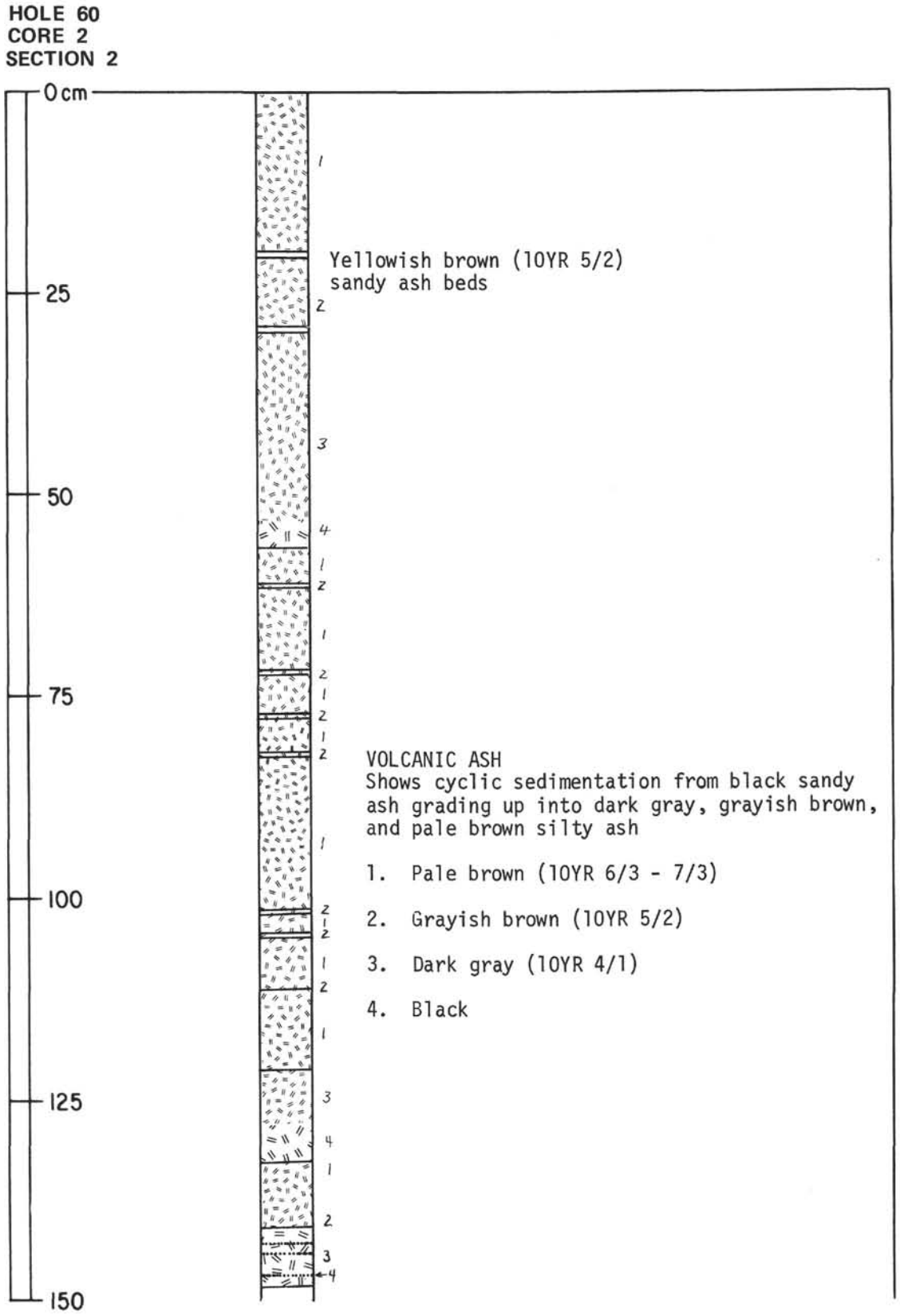


Figure 22. *Summary of lithology in Hole 60.0 Core 2 Section 2.*

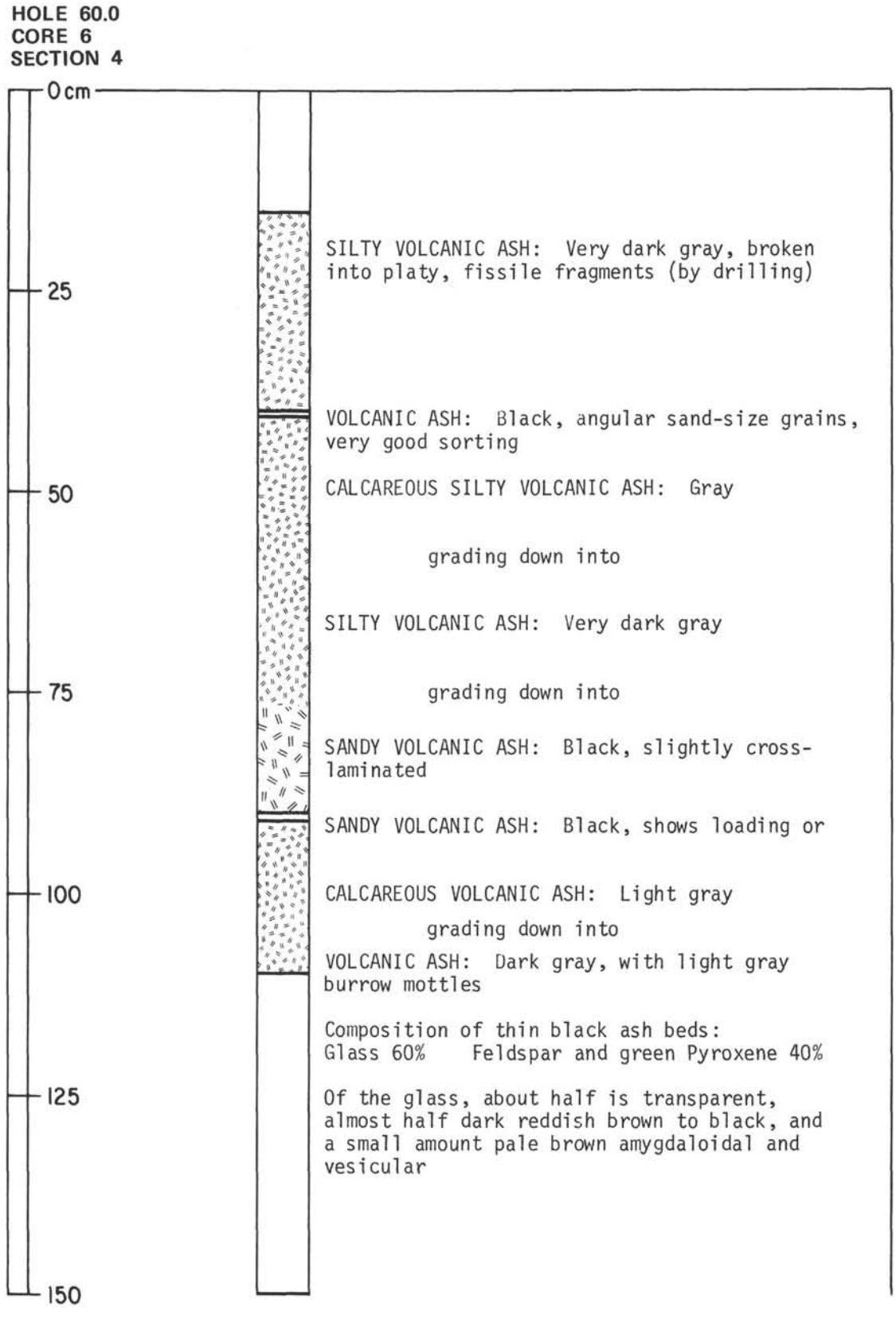


Figure 23. *Summary of lithology in Hole 60.0 Core 6 Section 4.*

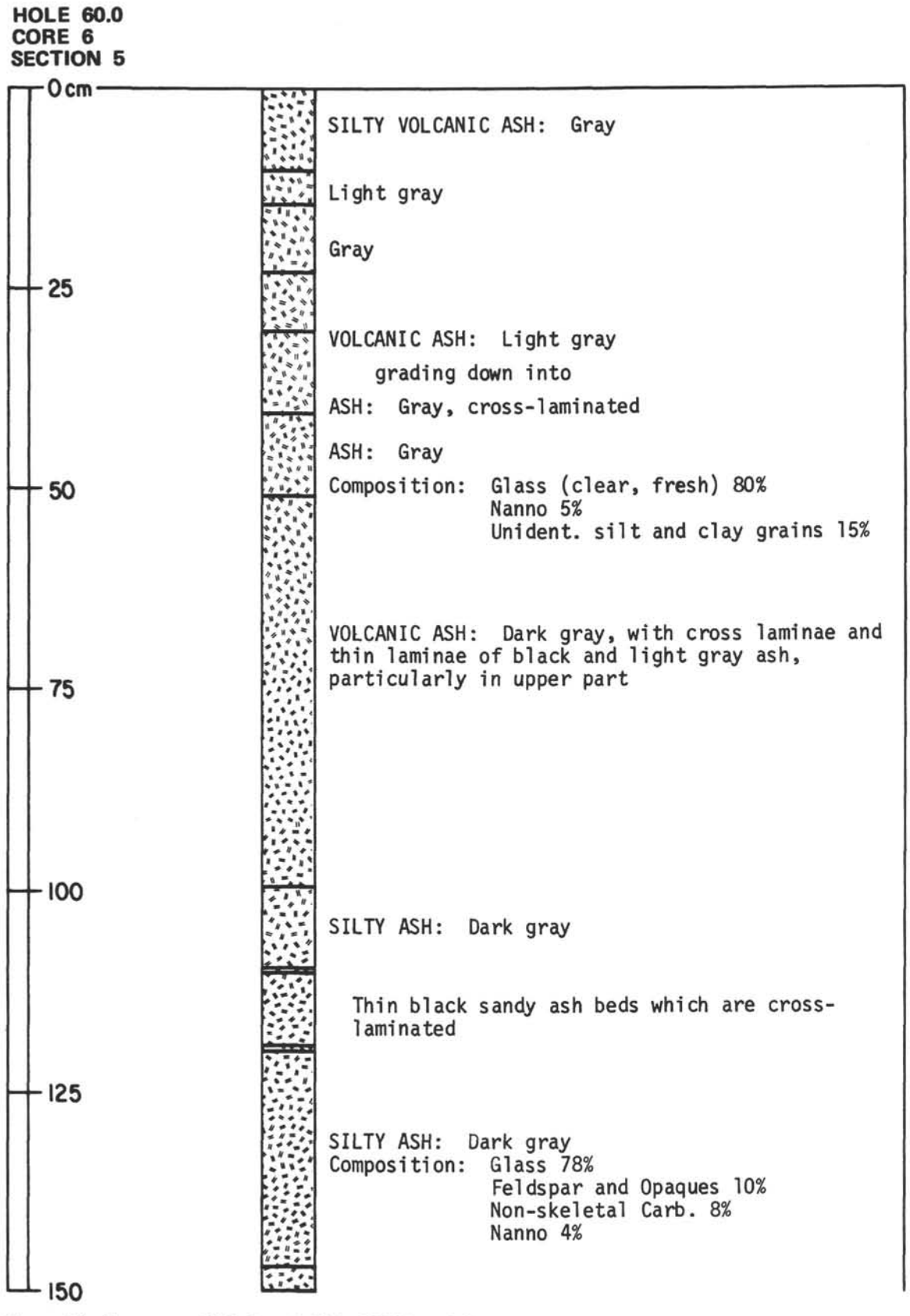


Figure 24. *Summary of lithology in Hole 60.0 Core 6 Section 5.*

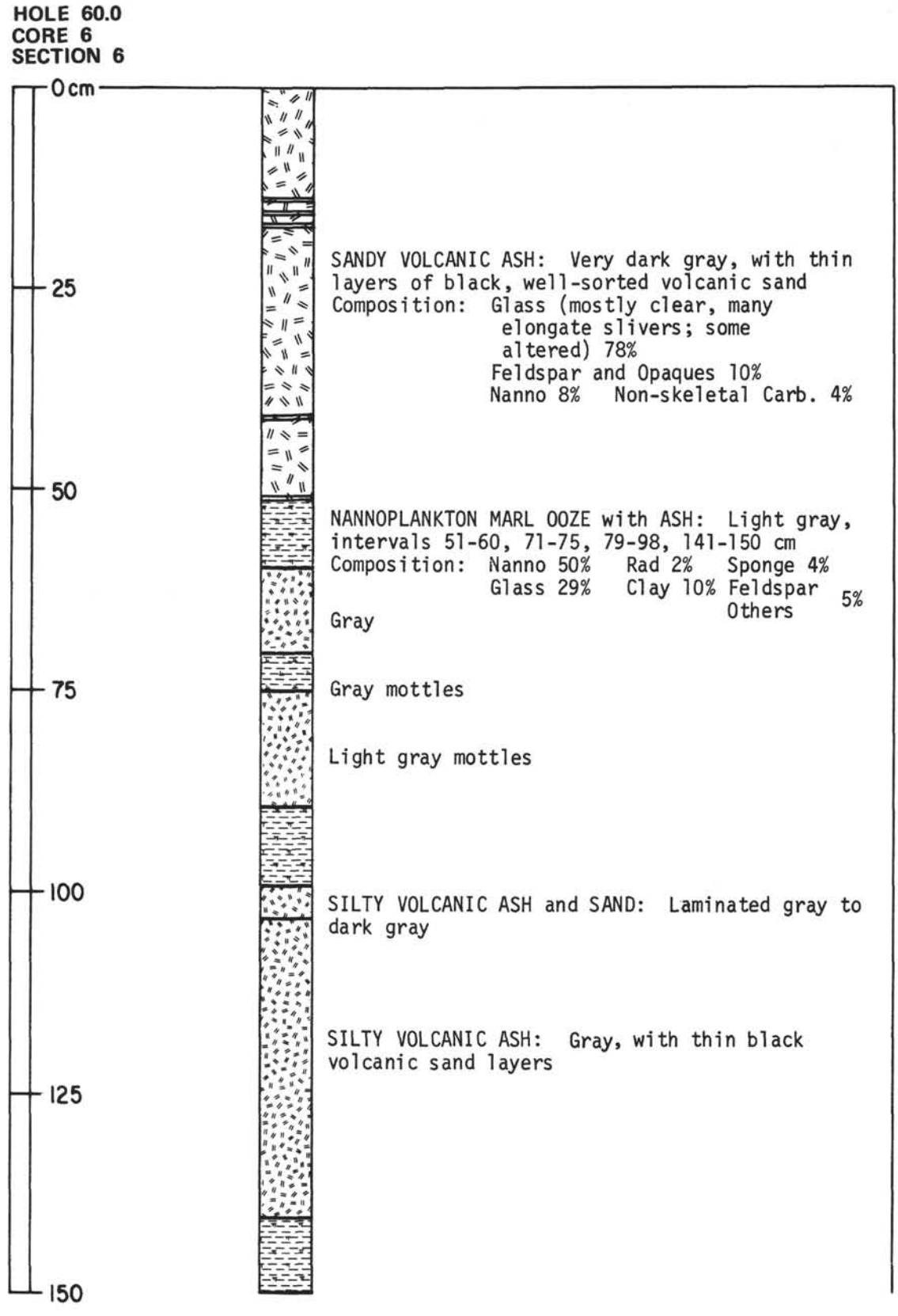


Figure 25. *Summary of lithology in Hole 60.0 Core 6 Section 6.*

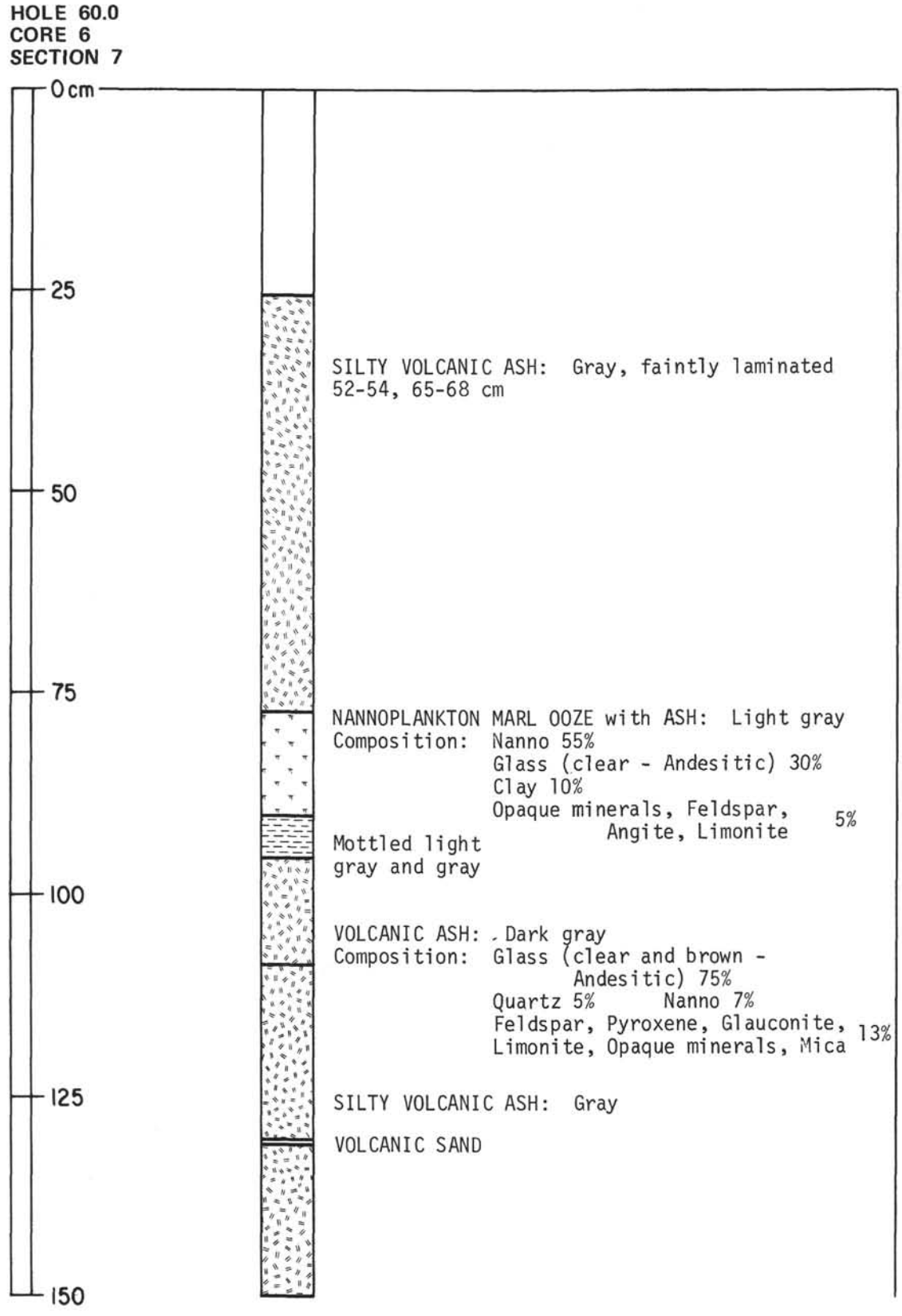


Figure 26. *Summary of lithology in Hole 60.0 Core 6 Section 7.*

LEG 6 HOLE 60.0

CORE 1 DEPTH 52.1-61.0 m

| FORAMINIFERA | NANNOPLANKTON | RADIOLARIA |
|---|---|---|
| Very rare planktonic Foraminifera of the Middle Miocene were found in this core - *Sphaeroidinellopsis rutschi, Globigerinoides bollii, G. trilobus.* | Specimens of discoasters are particularly abundant. The entire assemblage is that of the *Discoaster hamatus* Zone and in the core-catcher sample the *Catinaster coalitus* Zone is present. These zones are generally considered to represent upper middle Miocene and to represent a higher level than type Langhian. Common species in the core include: *Catinaster coalitus, Discoaster brouweri* s.l., *D. challengeri, D. hamatus,* and *Triquetrorhabdulus rugosus.* Also present are *Catinaster calyculus, Discoaster calcaris,* and *Reticulofenestra pseudoumbilica.* | Radiolaria are rare through most of this core. The identifiable species are from the middle Miocene. This is supported by the presence of both bifurcating and curved, flattened orosphaerid spines. TOP: *Dorcadospyris simplex, D. dentata,* and *Calocycletta costata.* BOTTOM: *Cannartus laticonus, Lithopera bacca,* and *L. neotera.* |

Figure 27. *Summary of biostratigraphy in Hole 60.0 Core 1.*

LEG 6 HOLE 60.0

CORE 2 DEPTH 61.0-70.1 m

| FORAMINIFERA | NANNOPLANKTON | RADIOLARIA |
|---|---|---|
| Very rare species of the Middle Miocene are present in this core - *Sphaeroidinellopsis rutschi, Globigerinoides trilobus, Globorotalia mayeri.* | The assemblages of core 2 represent the upper middle Miocene *Catinaster coalitus* Zone, throughout. Species present include *Catinaster coalitus, C.* sp. cf. *C. coalitus, Discoaster brouweri s.l., D. challengeri, D. exilis, D. variabilis, Reticulofenestra pseudoumbilica,* and *Triquetrorhabdulus rugosus.* | Radiolaria are rare in this core. The few identifiable species suggest a middle Miocene age. This is supported by the presence throughout the core of bifurcating and curved, flattened orosphaerid spines. TOP: no species identified. BOTTOM: *Cannartus laticonus.* |

Figure 28. *Summary of biostratigraphy in Hole 60.0 Core 2.*

LEG 6 HOLE 60.0

CORE 3 DEPTH 129.2-134.1 m

| FORAMINIFERA | NANNOPLANKTON | RADIOLARIA |
|---|---|---|
| Very rare specimens of the Middle Miocene *Sphaeroidinellopsis grimsdalei*, *Globigerinoides bollii*, *G. Trilobus* are present in this core. | Middle middle Miocene assemblages are present in core 3. Species occurring include *Discoaster browweri* s.l., *D. challengeri*, *D. exilis*, and *Reticulofenestra pseudoumbilica*. | None. |

Figure 29. *Summary of biostratigraphy in Hole 60.0 Core 3.*

LEG 6 HOLE 60.0

CORE 4 DEPTH 134.1-139.3 m

| FORAMINIFERA | NANNOPLANKTON | RADIOLARIA |
|---|---|---|
| None. | This core contains a middle middle Miocene assemblage which represents the level just above the lower middle Miocene *Sphenolithus heteromorphus* Zone. The assemblage includes *Cyclococcolithina neogammation*, *Discoaster* sp. cf. *D. challengeri* [small], *D. exilis*, *D. variabilis*, *Discolithina* sp. [large], *Helicopontosphaera kamptneri*, *H.* sp. aff. *H. obliqua*, and *Reticulofenestra pseudoumbilica*. | None. |

Figure 30. *Summary of biostratigraphy in Hole 60.0 Core 4.*

LEG 6 HOLE 60.0

CORE 5 DEPTH 212.8-221.9 m

| FORAMINIFERA | NANNOPLANKTON | RADIOLARIA |
|---|---|---|
| None. | Sparse coccoliths of the lower middle Miocene *Sphenolithus heteromorphus* Zone occur in this core. The assemblage is composed of *Cyclococcolithina neogammation*, *Discoaster* sp. cf. *D. challengeri* [small], *D. deflandrei*, *D. exilis*, *Discolithina* sp. [large], *Helicopontosphaera kamptneri*, and *Sphenolithus heteromorphus*. | None. |

Figure 31. *Summary of biostratigraphy in Hole 60.0 Core 5.*

LEG 6 HOLE 60.0

CORE 6 DEPTH 221.9-231.0 m

| FORAMINIFERA | NANNOPLANKTON | RADIOLARIA |
|---|---|---|
| Very rare specimens of the Middle Miocene *Sphaeroidinellopsis grimsdalei, Globigerinoides irregularis, Globigerina concinna* were met in this core. | Lower middle Miocene assemblages of the *Sphenolithus heteromorphus* Zone are present. Species present include *Cyclococcolithina neogammation, Discoaster challengeri, D. deflandrei, D. exilis, D. variabilis, Helicopontosphaera kamptneri,* and *Sphenolithus heteromorphus.* | None. |

Figure 32. *Summary of biostratigraphy in Hole 60.0 Core 6.*

LEG 6 HOLE 60.0

CORE 7 DEPTH 288.6-297.8 m

| FORAMINIFERA | NANNOPLANKTON | RADIOLARIA |
|---|---|---|
| None. | Lower middle Miocene assemblages of the *Sphenolithus heteromorphus* Zone are present. Species present include *Cyclococcolithina neogammation*, *Discoaster* sp. cf. *D. challengeri* [small], *D. deflandrei*, and *Sphenolithus heteromorphus*. | Radiolaria are rare in this core. One tentatively identified species indicates an early Miocene age. TOP: not examined. BOTTOM: *Stichocorys wolffii (?)*. |

Figure 33. *Summary of biostratigraphy in Hole 60.0 Core 7.*

LEG 6 HOLE 60.0

CORE 8 DEPTH 342.9-346.9 m

| FORAMINIFERA | NANNOPLANKTON | RADIOLARIA |
|---|---|---|
| None. | Nannoplankton are rare or absent in samples from this core. Species recorded include *Cyclococcolithina neogammation*, *Discoaster deflandrei*, *D. variabilis*, and *Discolithina* sp. This assemblage suggests a lower or middle Miocene correlation. | Radiolaria are rare and poorly preserved in this core. The few identifiable species indicate an early Miocene age. TOP: *Stichocorys wolffii* and *Calocycletta costata* BOTTOM: *Stichocorys wolffii*. |

Figure 34. *Summary of biostratigraphy in Hole 60.0 Core 8.*

LEG 6 HOLE 60.0

CORE 9 DEPTH 346.9-348.1 m

| FORAMINIFERA | NANNOPLANKTON | RADIOLARIA |
|---|---|---|
| None. | No nannoplankton are present in samples from this core. | Radiolaria are rare and poorly preserved in this core. The few identifiable species indicate an early Miocene age.<br>TOP: *Stichocorys wolffii* and *Calocycletta costata*<br>BOTTOM: same. |

Figure 35. *Summary of biostratigraphy in Hole 60.0 Core 9.*

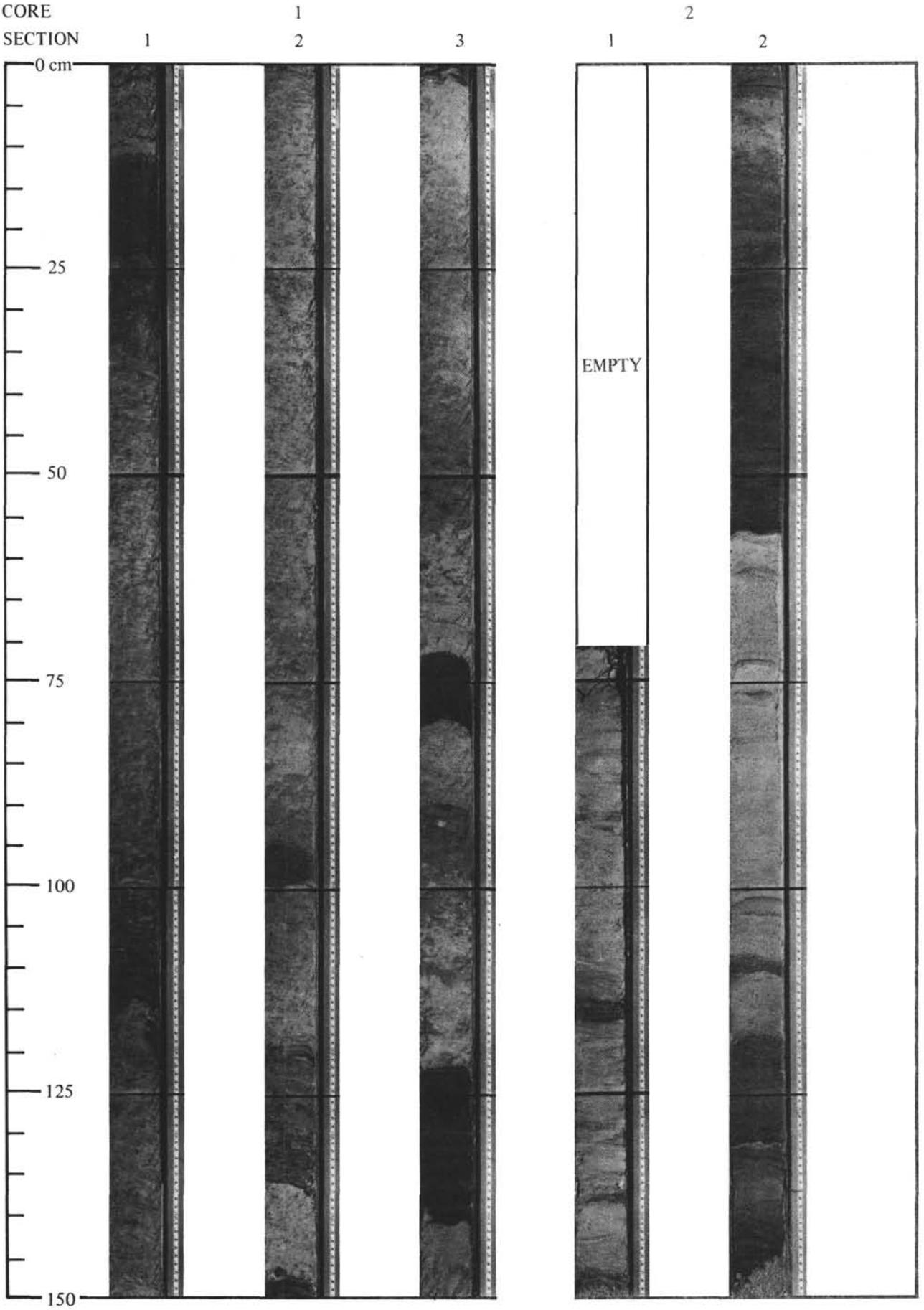


Plate 1. *Photographs of Hole 60.0 Cores 1 and 2.*

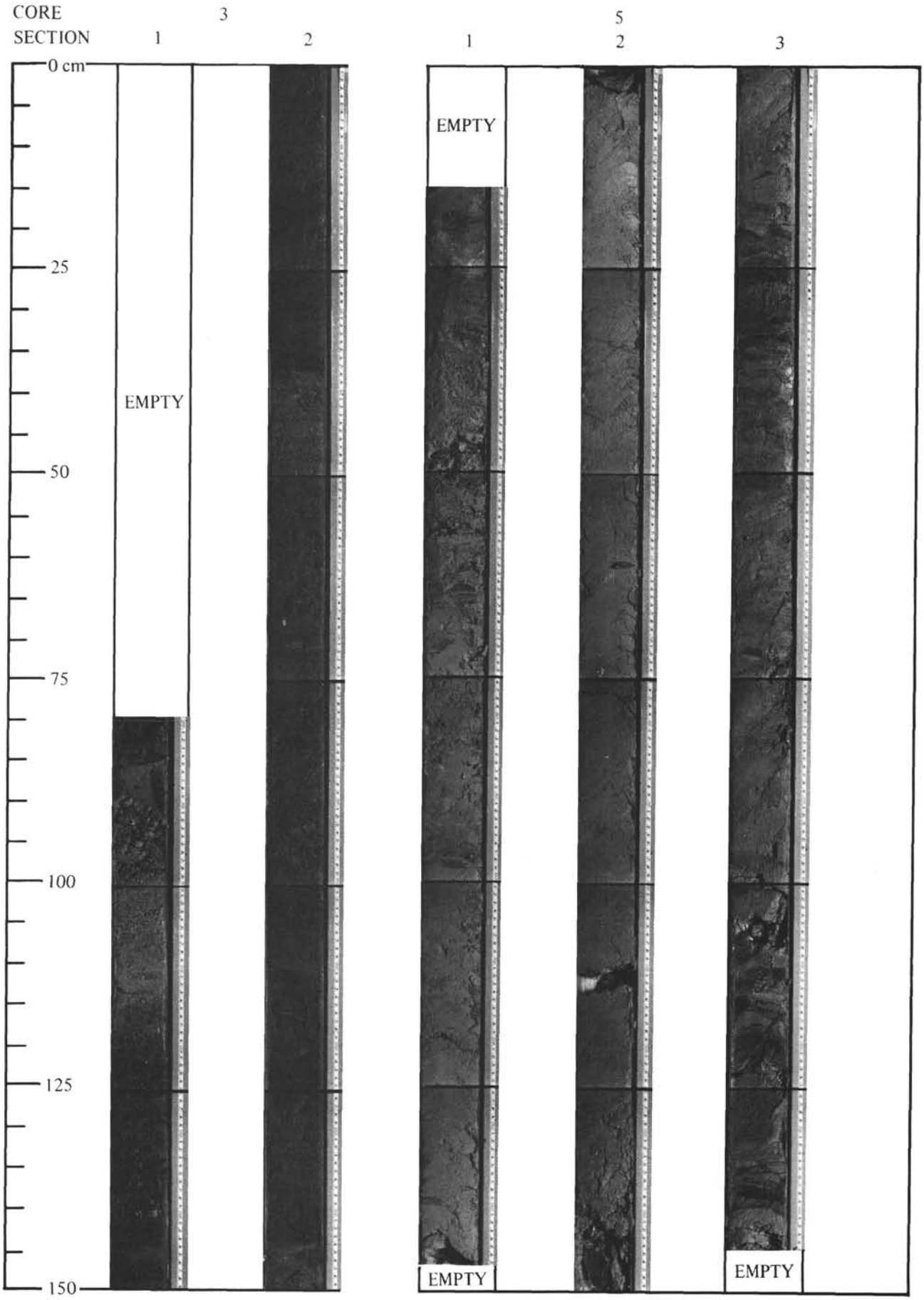


Plate 2. *Photographs of Hole 60.0 Cores 3 and 5.*

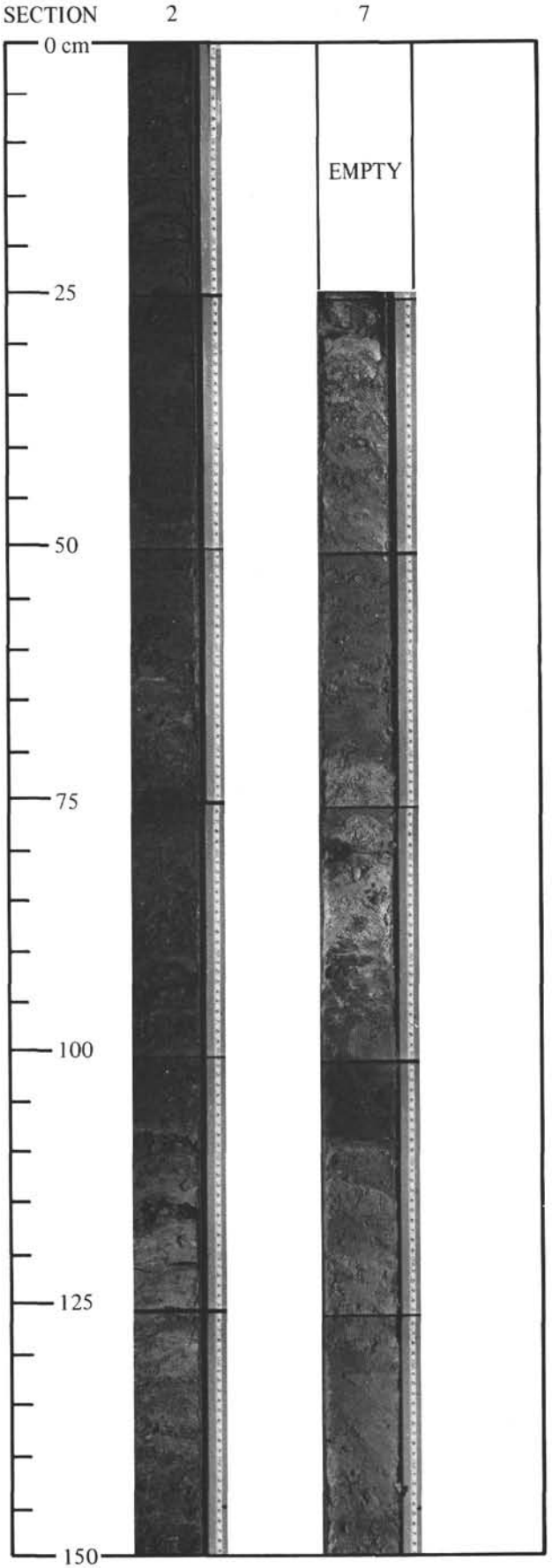


Plate 3. *Photographs of Hole 60.0 Core 6.*