3. SITE 147

The Shipboard Scientific Party[1]

Position:

147: 10° 42.48′N; 65° 10.48′W
147A, B, C: 10° 42.68′N; 65° 10.45′W.

Water Depth: 892 meters.

Penetration:

147: 162 meters
147A: 13 meters
147B: 116 meters
147C: 189 meters

Recovery:

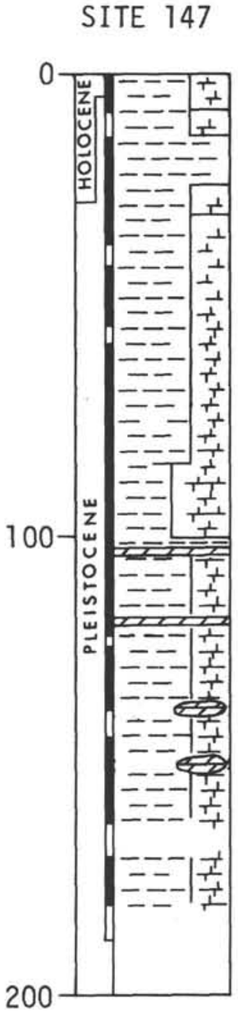
147: 119.2 meters (74%)
147A: 6.5 meters
147B: 81.0 meters
147C: 32.1 meters.

ABSTRACT

The site is located on a ridge separating two small deeps in the Cariaco Basin (Trench), a fault depression in the Venezuelan continental shelf that is characterized by the presence of anaerobic water below 360 meters. The sediment is a uniform organic-rich olive gray clay interrupted at three levels by gray and brown clays low in organic content. The average organic content is about 1.5 percent or about twice that of the average marine sediment. The upper few meters of the site (Holocene) contain about 4 percent organic carbon. From piston core data the gray and brown clays were related to the low stand of sea level associated with glaciation (Wisconsin). A relationship of similar clays deeper in the hole with earlier glacial events is not evident.

BACKGROUND

The Cariaco Basin (Trench) is an east-west trending structural depression on the continental shelf of Venezuela that is surrounded by shallow water less than 200 meters deep (Figure 1). It is divided by a ridge across its width into two flat-floored (abyssal plains) deeps, the eastern one being 2550 meters and the western one 1380 meters deep.



Two unreversed seismic refraction profiles shot over the basin by Officer et al. (1957) describe about 1.5 km of sediment (2.3 km/sec) overlying a layer characterized by velocities of 4.5 to 5.3 km/sec. These velocities are representative of a number of lithologies, either sedimentary, igneous, or metamorphic, but the presence of Mesozoic metamorphic rocks on nearby islands such as Margarita and Tortuga, as well as the coast ranges of Venezuela, lead one to conclude that the layer underlying the sediments in the Cariaco Basin is composed of metamorphic rocks.

A comprehensive report on a marine geophysical survey of the Cariaco Basin was presented by Ball et al. (1971). Their seismic reflection data indicate that the Cariaco Basin is a downfaulted block, or a graben. Numerous small faults were noted displacing or deforming the most recent sedimentary cover. The sediments in the two deeps of the trench are thick and highly stratified (acoustically) suggesting rapid clastic sedimentation.

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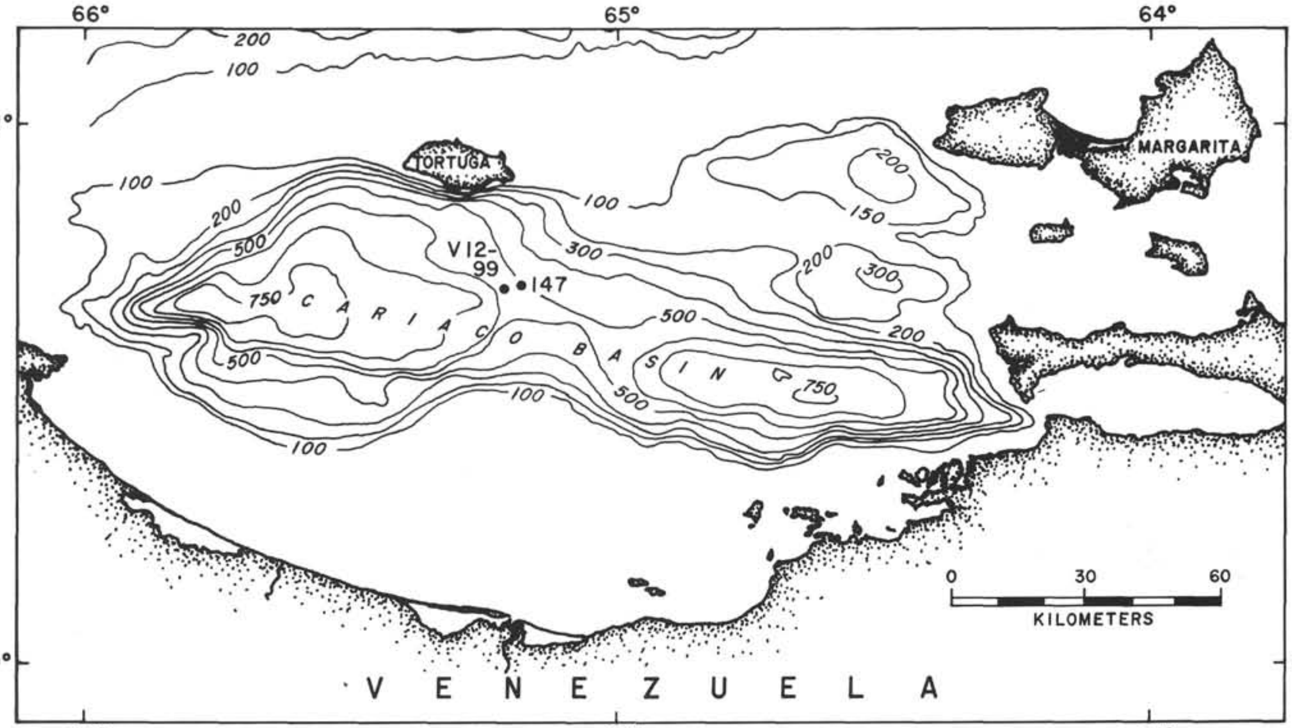


Figure 1. *Chart of the Cariaco Basin showing bathymetry, location of* Vema *core V12-99, and Site 147.*

Of particular interest is the fact that the waters in the basin are presently anerobic below 360 meters; a condition that is exceptionally favorable for the preservation of fossils. L. V. Worthington first noted the toxic waters in December, 1954, during a cruise on Woods Hold's R/V *Atlantis*. The results were reported by Richards and Vaccaro (1956) and studies were made on the sediments by Athearn (1959; 1965) and Heezen et al. (1958; 1959). A detailed investigation of the sediments recovered by piston cores is in preparation (Ph.D. thesis) by D. H. Needham (Lamont-Doherty Geological Observatory).

Piston Core V12-99 was taken by R/V *Vema* in the middle of the ridge not far from the location of Site 147 (Figure 2). The top sediments are dark green, organic-rich clays typical of deposition in the anaerobic conditions (Heezen et al., 1959). At the base of this layer is a sharp contact with a bed of "steel-gray lutite 10 to 50 cm thick and below this is a brown oxidized lutite". They noted that estimates of surface water temperatures based on foraminifera indicated that an abrupt warming corresponded to the beginning of anaerobic conditions and that these conditions began at 11,200 years B.P. (radiocarbon), the date generally accepted as marking the end of Wisconsin time.

The drill site was selected on the north side of the ridge separating the two basins rather than in the abyssal plain, because the rate of sedimentation in the abyssal plains is many times that noted on the ridge (D. H. Needham, personal communication), requiring much deeper penetration to reach old sediments. In addition, drilling in sands and silts associated with abyssal plains commonly causes the drill pipe to become stuck in the hole.

After a short survey (Figures 3 and 4) the site was located in what appeared to be acoustically well stratified sediments. The site survey records show a Recent fault that trends approximately east-west through the ridge. In addition, there is a relatively stronger reflector at about 0.1 sec reflection time.

OBJECTIVES

There were four basic items of interest in the Cariaco site.

1. The high sedimentation rate and good preservation of fossil material (piston cores described above) offered an exceptionally fine opportunity to study Quaternary biostratigraphy.
2. If the aerobic/anaerobic conditions represented glacial/interglacial stages as proposed by Heezen et al. (1958; 1959), then it may be possible to recover several similar events in the older sediments.
3. The pore water geochemists were interested in the nature of the pore waters associated with ancient sediments deposited in aerobic and anaerobic conditions (see Part III, this volume).
4. The organic geochemists were interested in obtaining a relatively complete section of the organic-rich sediments to investigate the appearance and disappearance of a number of organic compounds in the 30 to 300 meter depth range (see Part III, this volume).

OPERATIONS

The Cariaco Basin was approached from the west and after a short survey a site was selected on the north side of the saddle separating the eastern and western deeps (Figures

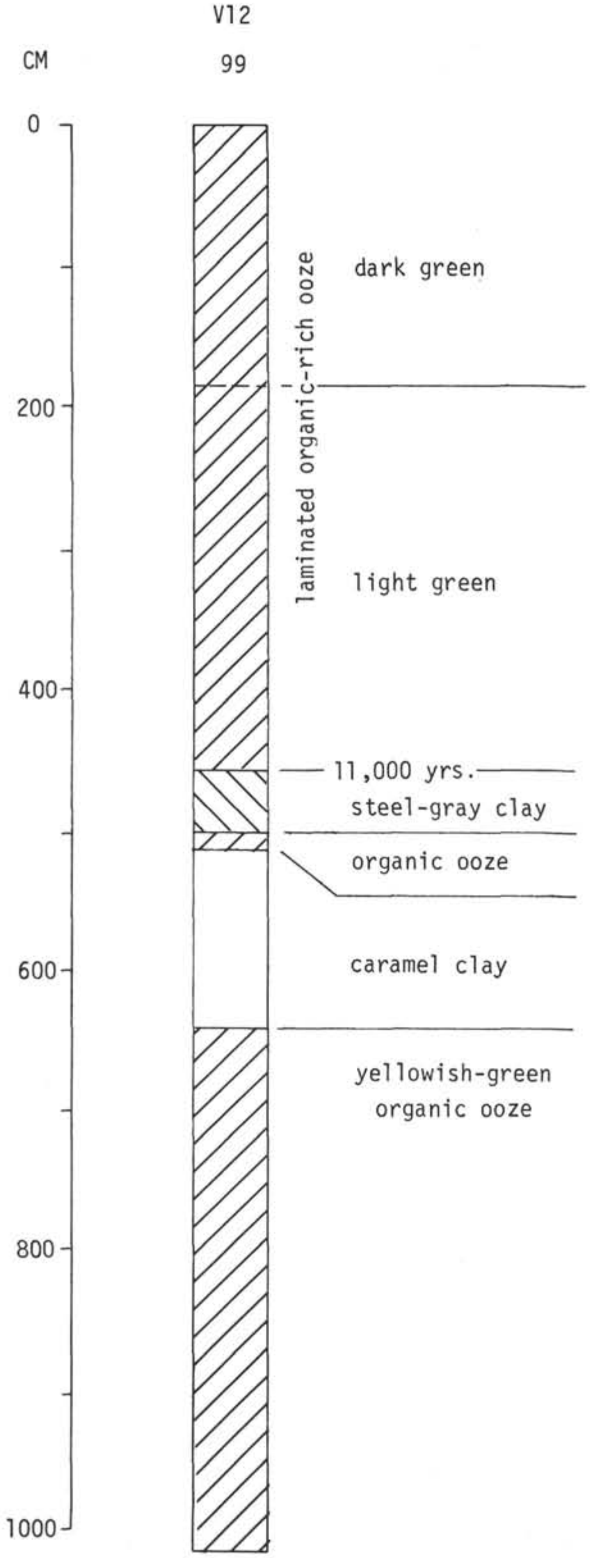


Figure 2. *Piston Core V12-99 was taken by R/V* Vema *in the middle of the ridge not far from the location of Site 147 (from Heezen et al., 1959).* Vema *piston core recovered upper sediments that are green organic-rich clays typical of deposition in anaerobic conditions (Heezen et al., 1959). At the base of this layer is a "steel gray" clay and an oxidized caramel clay. They noted that estimates of surface water temperatures based on foraminifera indicated that an abrupt warming corresponded to the beginning of anaerobic conditions and that these conditions began at 11,200 years B.P., the date generally accepted as marking the end of the Wisconsin time.*

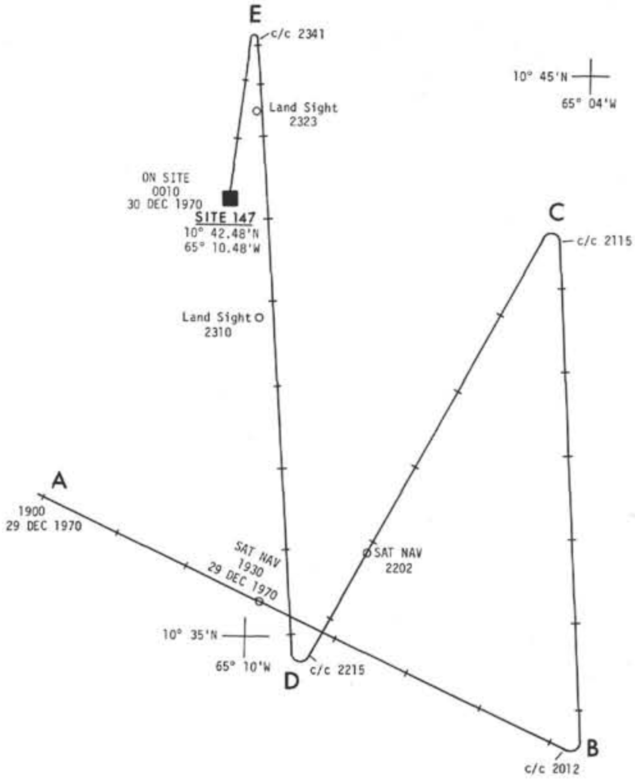


Figure 3. *Track of the D/V* Glomar Challenger *during Site 147 survey.*

2 and 3). Four holes were drilled at this site, 147, 147A, 147B, and 147C. See Figure 5 for a diagram of coring at each hole.

At the first hole the conventional core barrel recovered sediments that were so highly disturbed by the coring operation that consequently a core barrel was used that extended beyond the bit, cutting core in soft sediment ahead of the bit. The extended barrel was very successful, but was used sparingly because it required a smaller diameter plastic liner of which there were only a few on board. Continuous coring (Core 1 – no recovery) continued to 162 meters where the hole was terminated primarily due to the presence of large volumes of methane gas.

A second hole, 147A, was started at the request of the pore water geochemists to recover the surface sediments. Two cores were taken to a depth of 13 meters before terminating the hole. No core descriptions were prepared for these two cores.

The third hole, 147B, was planned to be a deep penetration for the pore water and organic geochemistry programs. The new hole was started to recover the uppermost sediments for the geochemists interested in the

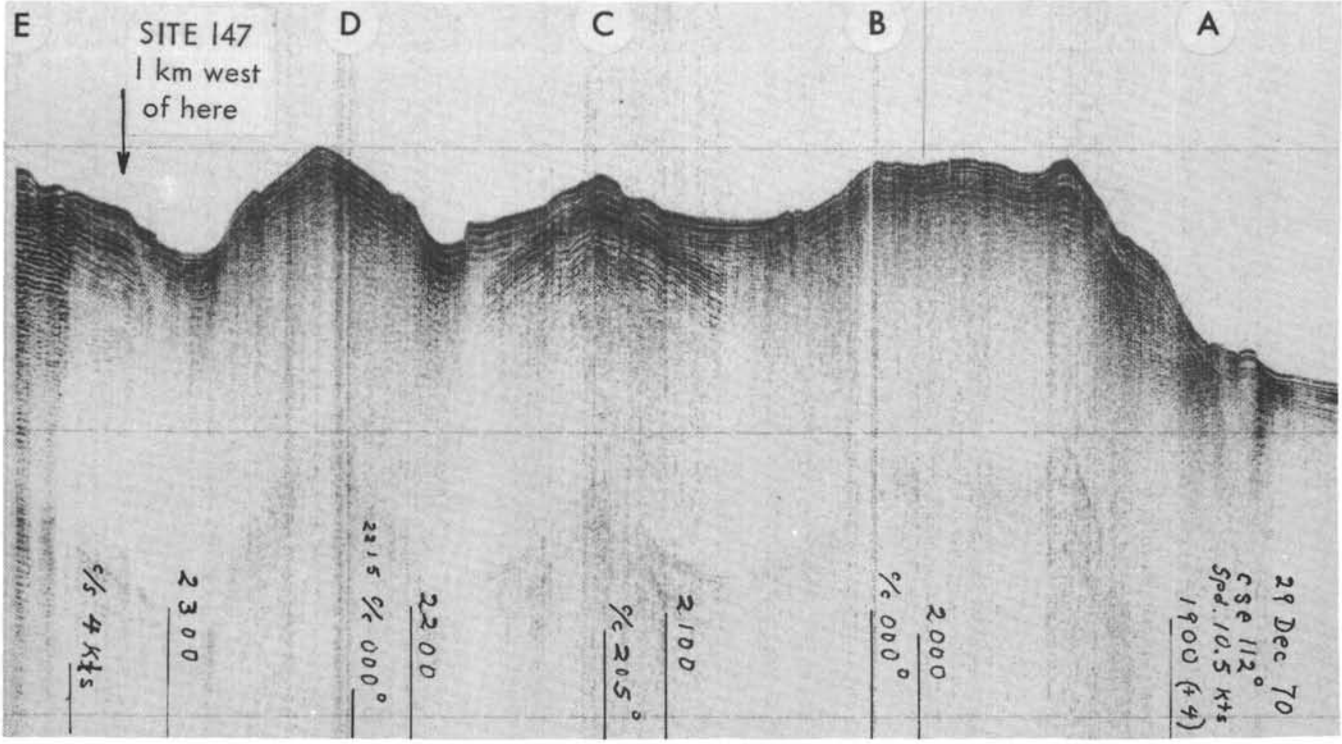


Figure 4. *D/V* Glomar Challenger *reflection profile of Site 147 survey. Site 147 was located in what appears to be well-stratified sediment. Note recent fault.*

organic content of the sediments. The hole was continuously cored to 116 meters. All cores were frozen (for organic geochemistry studies to be conducted later on shore) with the exception of 1/2 meter every other core for pore water studies (no core descriptions were prepared). At 116 meters the latch on the core barrel broke, rendering retrieval of the core barrel impossible without disassembling the entire drill string.

In order to pursue further the organic geochemist's interests a fourth hole was drilled, 147C, to 116 meters where continuous coring was resumed. Eight cores were attempted–two cores (6C and 8C) were empty; Cores 1C through 5C were totally frozen for geochemists (no description); but Core 7C, because of good recovery, was frozen only in part with the remainder being described and preserved for sedimentology.

Methane gas presented problems throughout the hole, in particular because pressure would cause extrusion of sediment from the core liner onto the deck after the core catcher had been removed. The hole was terminated at 189 meters for several reasons: 1) the core barrel jammed in the drill pipe 300 feet above the bit and could not be recovered without pulling out of the hole; 2) the time scheduled for Site 147 was running out, and 3) the problems associated with gassy sediments were causing increasing concern.

All holes were plugged with cement.

LITHOLOGY

The geologic section recovered at Site 147 consists of a grayish olive calcareous clay with the exception of a few thin, conspicuous layers of gray and brown clays.

All of the cores contain pyrite, but it is only abundant in the upper 50 meters, and all have a hydrogen sulfide smell when cut. A fine, silty component is dominantly quartz, but detrital feldspar and some metamorphic minerals (including glaucophane) are also found. The upper 12 meters, above the topmost brown and gray clays are rich in organic carbonaceous matter and are laminated, in some cases by thin diatomite layers alternating with the very dark carbonaceous clay (Figure 6). Dolomite grains are found below 26 meters and becomes increasingly abundant with depth, forming essentially monomineralic beds (Figures 7 and 8) a few centimeters thick at 103 and 119 meters and possibly at 139.4 and 148.9 meters where dolomite rock fragments were found.

Distinctive gray and brown clays, first found in piston cores (Figure 2), were recovered in Core 2 between 8.4 and 9.0 meters (Frontispiece A). Similar clays were also recovered at 101.79 to 102.99 meters and 115.00 to 116.60 meters. A firm dark bluish gray clay was recovered at 119.25 meters. The clays at 103 and 119 meters were underlain by dolomite layers.

Throughout most of the hole the organic carbon content exceeded that of normal marine sediments which is about 0.8 percent. In the upper 8 meters (Holocene) the organic content averaged about 4 percent which classifies the sediment as sapropelitic (greater than 2%; Olausson, 1960). In the large interval from 10 to 130 meters the organic carbon averages about 1.5 percent. The lowest part of the hole is characterized by a substantial increase to about 2.5 to 3 percent. The brown and gray clays all contain less than 1 percent, but these values are not unique; fifteen samples from other parts of the hole yielded similar values.

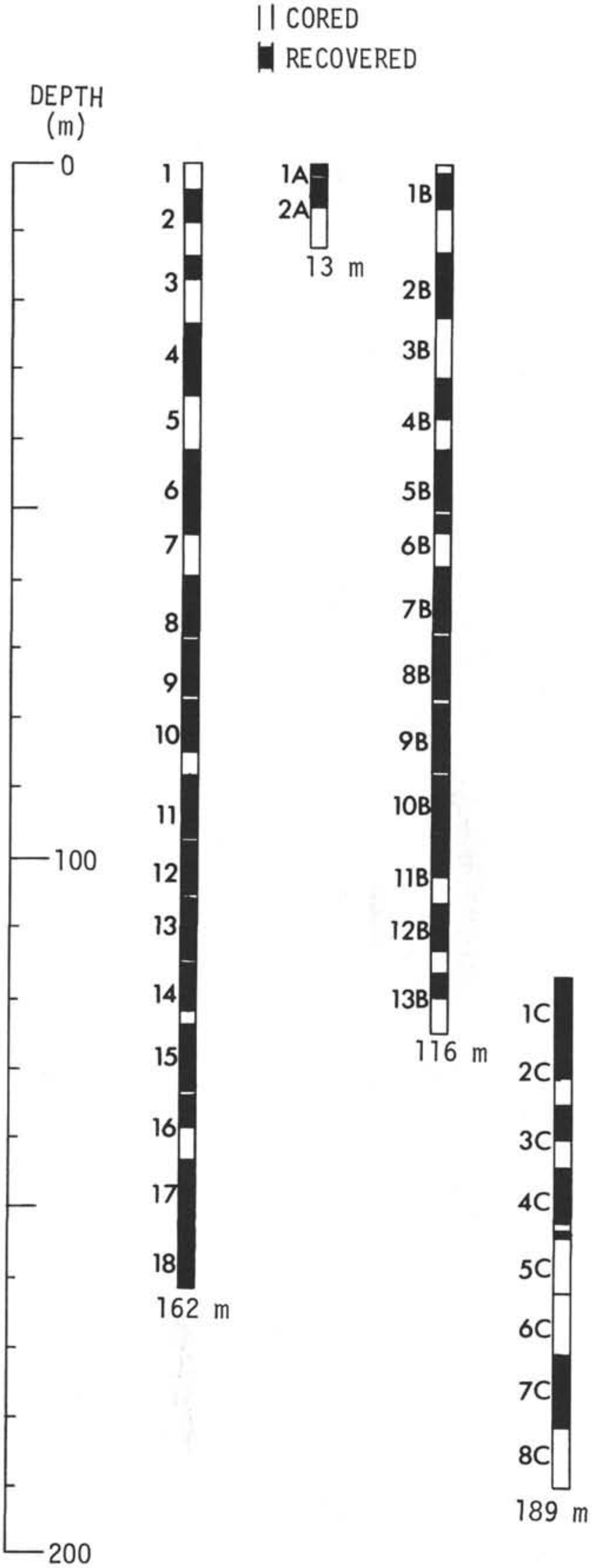


Figure 5. *Four holes were drilled at Site 147 and their core recovery versus depth is schematically displayed for Holes 147, 147A, 147B, and 147C.*

Figure 6. *Laminated (diatomite/dark, organic clay) clays overlying gray clay. Contact marks beginning of anaerobic sedimentation that continued to present. 147-2-3(111-147).*

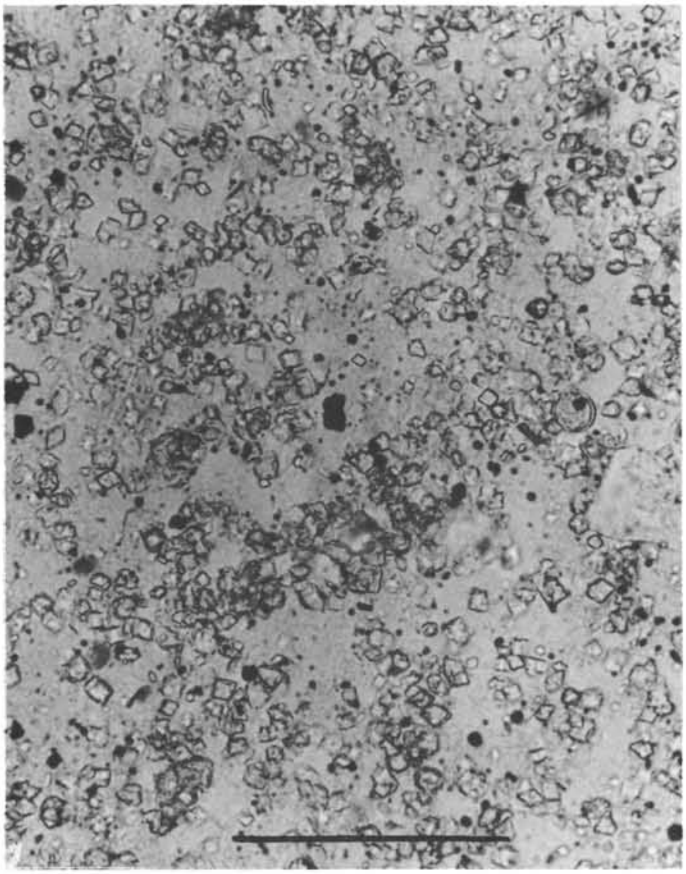


Figure 7. *Smear slide showing dolomite rhombs and minor pyrite. Bar is 100 microns long. Pleistocene. 147-9(CC).*

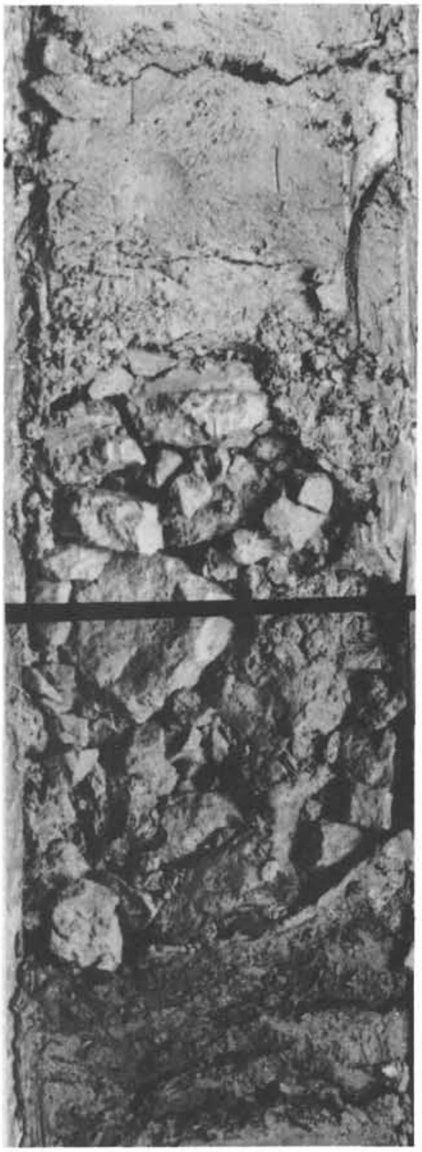


Figure 8. *Bed of almost pure dolomite (22-30 cm) lying below gray clay and above very dark, organic clay. 147-12-5(15-34).*

PHYSICAL PROPERTIES

Wet-bulk Density, Water Content, and Porosity

Wet-bulk density and porosity were measured by two methods: GRAPE, the results of which are the line plots; and individual sample data, results of which are plotted as enclosed dots in the hole and core plots. Water contents were measured by specific samples. Methods error, equipment, and disturbed sediment are discussed in the Appendix. In general, data precision is about ±5 percent.

When observing the plotted GRAPE and sample data together, the sample data are considerably denser (lower porosity) than the GRAPE data. This is because the cores are disturbed and the GRAPE scans the entire diameter of the core which includes the highly disturbed portions of the sediment. Individual samples are only of the relatively undisturbed portion of the sediment (see Appendix I for discussions of data comparison).

Only the individual sample data at this site represent the "undisturbed" sediment density and porosity. However, the GRAPE data are still presented as an internal control for correcting the varying porosity which affects the natural gamma radiation measurements.

At Site 147, sampled densities in Pleistocene green clays from 0 to 175 meters below the sea floor ranged from 1.47 g/cc (67% porosity), to 1.85 g/cc (40%), with typical values varying about 1.68 g/cc (56%). Corresponding water contents are 46, 23, and 36 percent, resepctively. These densities increase slightly and irregularly with increasing depth.

A dolomite silt layer has the highest density recorded by the GRAPE, which was 2.1 g/cc (39% porosity with an assumed 2.8 g/cc grain matrix density) in the upper part of Section 5 in Core 12. The high densities above and below this layer appear to be related in part to compaction and lithification and in part to the varying content of calcite or dolomite. The GRAPE porosity here is subject to gross errors depending on the varying grain matrix density.

Sound Velocity

No sound velocity measurements were possible through sediments recovered at Site 147. Each core was spot checked but none was found which could transmit sufficient signal to make a reading. This appears to be caused by the high gas content of these sediments.

Natural Gamma Radiation

Natural gamma radiation is counted for a period of 1.25 minutes at 7.62 cm (3 in) intervals along the length of the core, with a precision of ±100 counts. Methods, equipment, and disturbance problems are discussed in the Appendix.

At Site 147, Pleistocene green clays, recovered from 0 to 160 meters below the sea floor, emitted natural gamma radiation between 200 and 2600 counts per 1.25 minutes for each 7.62 cm (3 in) core interval. Typical gamma variation is between 1000 and 2000 counts, and the gray and brown clays in Core 12 do not show any characterizing differences from the other sediments.

Gamma radiation, in general, is directly related to the varying densities of the disturbed cores. The density and porosity of these cores are continuously measured, which allows the reader to estimate the amount of solid material scanned and to determine which gamma values he believes to be most pertinent, or representative of in situ conditions. See Appendix I for a discussion of porosity corrections.

Penetrometer

Penetration tests were measured with a 1 mm diameter needle. See Appendix I for discussion of methods and equipment. At Site 147 sediments are disturbed and thus the data may not represent in situ conditions.

Needle penetration ranged from 25 mm to 3 mm, irregularly decreasing with depth in Pleistocene green clay between 0 and 86 meters below the sea floor. The greatest change occurred within the first 10 meters depth from 25 mm to 10 mm of penetration, which may be related to surface disturbance. Below 10 meters depth the penetration irregularly decreases to 3 mm at a depth of 86 meters. Below 86 meters penetration was either zero or insignificant.

BIOSTRATIGRAPHY

This site, because of its high sedimentation rate, has proved very important for establishing detailed biostratigraphic subdivisions using both planktonic foraminifera (Rogl and Bolli, this volume) and calcareous nannofossils (Hay and Beaudry, this volume). In addition to establishing a new sequence of subzones for the later Pleistocene and Holocene, Rogl and Bolli have used the ratio of warm/cool planktonic foraminiferal indicator species to correlate changing climate at this site with the paleotemperature curves of Emiliani (1966) and Ericson and Wollin (1968). Radiolarians are not present in these sediments.

None of the boundaries of the suggested sedimentary "rhythms" at this site corresponds exactly to biostratigraphic events. The closest correspondence is between the uppermost biostratigraphic event, the lowest occurrence of *Globorotalia fimbriata*, in the middle of Section 2 of Core 2, and the base of the first rhythm, marked by yellowish brown clay, in Section 4 of Core 2. The appearance of *Globorotalia fimbriata* has been dated by Wollin et al. (1971) as 11,000 yrs B.P. and is considered by them to mark the base of the Holocene. It marks the base of Rogl and Bolli's *Globorotalia fimbriata* Subzone of the *Globorotalia truncatulinoides truncatulinoides* Zone. The yellowish brown clay in Section 4 of Core 2 may be related to the rise in sea level as the continental glaciers retreated, although similar clays recovered deeper in the hole show no apparent relationship to glacial events.

Three nannoplankton events which may be of stratigraphic importance occur in Core 4: the highest occurrence of *Syracosphaera clava* is in Section 1, the highest occurrence of *Syracosphaera decussata* lies between samples from Sections 2 and 3, and the highest occurrence of *Gephyrocapsa kumphieri* lies in Section 6.

Another useful planktonic foraminiferal event, the highest occurrence of *Globorotalia tumida flexuosa* which defines the base of the *Globigerina bermudezi* Subzone of the *Globorotalia truncatulinoides truncatulinoides* Zone lies between Cores 5 and 6. This is known to correspond to the top of stage 5 of Emiliana (1969), and belong within Zone X of Ericson et al., (1961).

Two important nannofossil events occur slightly below this level. The distinctive small species *Gephyrocapsa sinuosa* has its highest occurrence between samples from Section 1 and 2 of Core 7. The important and ubiquitous species *Emiliania huxleyi* has its lowest occurrence in the unsampled interval between material recovered in Core 7 and the top of Core 8, but is also very rare in Core 7.

The base of *Globorotalia calida calida*, which defines the base of the *Globorotalia calida calida* Subzone of the *Globorotalia truncatulinoides* Zone, lies between Cores 8 and 9.

One additional biostratigraphic event is noted—the highest occurrence of circular forms of *Pseudoemiliania lacunosa* between Cores 14 and 15.

Dr. T. van der Hammen (Amsterdam) has not yet completed a study of the palynomorphs of selected samples from Site 147, but he reported the following based on work accomplished to date:

"Those samples corresponding to warm water phases in Rogl and Bolli's curves contain associations of dicotyledoneous pollen grains from tropical vegetation, mostly trees. Those samples corresponding to cold water phases (e.g., 147-10-2; 147-15-1; 147-18-6) yielded relatively rich associations of pollen including *Rhizophora*, Amaranthaceae, and Cyperaceae. This seems to indicate that the coastal mangrove vegetation and coastal open swamps were much nearer to the site and hence indicate a lower sea level as could be expected. On the other hand, the "cold water" samples were the only ones that yielded grains from upland genera (*Podocarpus, Myrica, Hedyosmum*). This seems to indicate that the montane zones in the mountains were at a lower elevation (and had a larger extension). This is in agreement with a colder climate. The presence of much more pollen of grasses in some of these cold samples may eventually be explained by extension of savanna-vegetation in the tropical lowland, or equally from a greater influx of high montane open grassland pollen."

CONCLUSIONS

Site 147 represents extremely rapid sedimentation in an environment which has alternated between anaerobic and partially aerobic. The anaerobic sediment at the top (0-8 m) is correlated with the post-glacial Holocene (Heezen et al.,

1959) and is distinctly laminated. About 1 meter of more oxygenated and normal marine sediment (brown and gray clays) underlies the anaerobic sediment, but it has only scarce benthonic foraminifera. The underlying sediment is predominantly anaerobic, but with thin layers of similar brown and gray clays. The entire section at Site 147 lies within the *Emiliania huxleyi* and *Gephyrocapsa oceanica* zones.

The sediment consists of planktonic calcareous remains mixed with terrigenous clay and contains 1 to 3 percent organic carbonaceous matter. A nearly constant admixture of terrigenous, silty minerals (dominantly quartz, but also containing plagioclase, orthoclase, epidote, and glaucophane) indicates a sedimentary-metamorphic provenance, probably from nearby sedimentary and metamorphic rocks along the Araya Peninsula and possibly from Margarita Island, where blue-schist metamorphics are known to outcrop. The occurrence of layered dolomite is of interest.

Dolomite is ubiquitous in minor amounts at depths greater than 15 meters, but the occurrence of highly concentrated dolomite at 103, 119, 137, and 149 meters is of particular interest. The fragments found at 137 and 149 meters may have fallen down the hole from the layers at 103 and 119 meters. The two upper layers are found at the boundary between underlying carbonaceous-rich clays and the overlying, more normal marine (brown and gray) clays. The repetition of these lithologies (Figure 8) suggests that conditions for the formation of dolomite are optimal at the point of transition from anaerobic to aerobic sediments. Similar occurrences of dolomite associated with organic-rich sediments recovered on Leg 14 have been discussed in detail by Berger and von Rad (1972). They favored redeposition by turbidity flow to explain cycles of dolomite lutite and sapropelite, but characteristic features of turbidites were not observed anywhere in the geologic section at Site 147. The ridge on which Site 147 was drilled is not a recipient of turbidity deposits. The evidence, therefore, points to post-depositional dolomite enrichment at the contact between carbonaceous-rich clays and normal marine clays. The absence of dolomite at the uppermost contact between anaerobic and aerobic sediments (8.4 m) may be attributed to the youth of the sediment. The shallowest occurrence of dolomite was noted at 15 meters depth.

The organic carbon-rich olive green clays and the brown and gray clays occur in a sequence that suggests rhythmic sedimentation. Figure 9 demonstrates the sequences of (a) grayish olive green calcareous clay, (b) gray and brown calcareous clay, (c) varicolored calcareous clay and dolomite. Only the 2nd and 3rd rhythms contain all three components (a, b, and c); the 1st "rhythm" does not have component (c) and, in the 4th rhythm, only the top (a) component was recovered.

An attempt was made to correlate the three reoccurring clay layers or "rhythms" to other mineralogical or chemical properties, but, except for trivial observations such as the lack of pyrite in the brownish clays, there were no evident correlations. Calcium carbonate and organic carbon (Figure 10) showed fluctuations, but these did not necessarily correlate with the "rhythm" boundaries or even to each other. There was a high percentage of smear slides (Figure 11) with recognizable quartz. Detrital feldspar was more variable, but again failed to correlate with the unit boundaries. Although dolomite beds were found at two unit boundaries, several fragments were also found below these at 139 and 149 meters, but these may have fallen from the overlying layers. Instead, depth was a limiting factor in its occurrence, and it was slightly antipathetically related to content of organic matter. Pyrite and dolomite were slightly antipathetic, and pyrite is poorly correlated with organic content. Based on preliminary observations there is no satisfactory correlation between these variables. Gypsum in minor quantities was found by X-ray diffraction (Fan et al., this volume) along with dolomite near the lower boundaries of the first and second units.

It was hoped that the gray and brown clays, which seemed to correlate with the end of Wisconsin glaciations, would mark similar events in Pleistocene history. Consequently, the "rhythmic" appearance of the lithologies was encouraging, but more detailed analysis (see Cruise Synthesis) failed to support any relationship between changes in lithology and glacial events.

REFERENCES

Athearn, R., 1959. Sediments of the Cariaco Trench, Venezuela. Intern. Oceanogr. Congr. 594.

———, 1965. Sediment cores from the Cariaco Trench, Venezuela. Woods Hole Oceanogr. Inst. Tech. Rept. 65-37. 20.

Ball, M. M., Harrison, C. G. A., Supko, P. R., Bock, W. and Maloney, N. J., 1971. *In* Donnelly, T. W., Caribbean Geophysical, Tectonic and Petrologic Studies. Boulder, Colorado (Geol. Soc. Am.), 1.

Berger, W. H. and von Rad, U., 1972. Cretaceous and Cenozoic sediments from the Atlantic Ocean. *In* Hayes, D. E., Pimm, A. C. et al., 1972. Initial Reports of the Deep Sea Drilling Project, Volume XIV. Washington (U. S. Government Printing Office). 787.

Emiliani, C., 1966. Paleotemperature analysis of the Caribbean Cores P6304-8 and P6304-9, and a generalized temperature curve for the past 425,000 years. J. Geol. **74**, 109.

———, 1969. A new paleontology. Micropaleontology. **15**, 265.

Ericson, D. B. and Wollin, G., 1968. Pleistocene climates and chronology in deep-sea sediments. Science. **162** (3859), 1227.

Ericson, D. B., Ewing, H., Wollin, G. and Heezen, B. C., 1961. Atlantic deep-sea sediment cores. Bull. Geol. Soc. Am. **72**, 193.

Heezen, B. C., 1960. Some problems of Caribbean submarine geology. *In* Weaver, J. D., Transactions of the Second Caribbean Geological Conference. Mayaguez, Puerto Rico (University of Puerto Rico), 12.

Heezen, B. C., Menzies, R. J., Broecker, W. S. and Ewing, W. M., 1958. Date of stagnation of the Cariaco trench, southeastern Caribbean. Bull. Geol. Soc. Am. **69**, 1579.

Heezen, B. C., Menzies, R. J., Broecker, W. S. and Ewing, W. M., 1959. *In* Sears, M., International Oceanographic Congress. Washington (Am. Assoc. Adv. Sci.), 99.

Officer, C. B., Ewing, J. I., Edwards, R. S. and Johnson, H. R., 1957. Geophysical investigations in the eastern Caribbean: Venezuelan Basin, Antilles Island arc, and Puerto Rico trench. Bull. Geol. Soc. Am. **68**, 359.

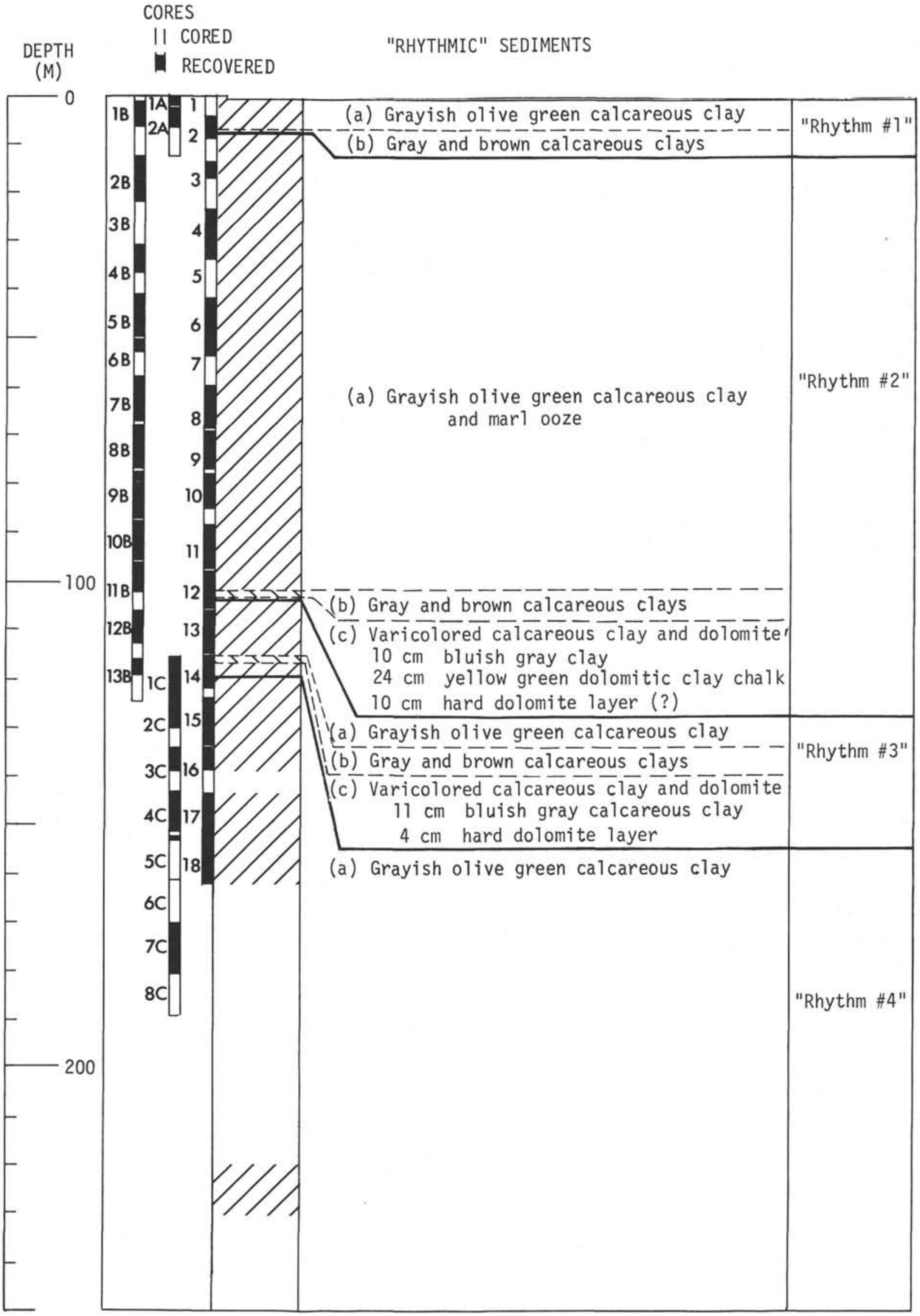


Figure 9. *Organic carbon-rich olive green clays, the brown and gray clays, and dolomite occur in sequences that suggest rhythmic sedimentation.*

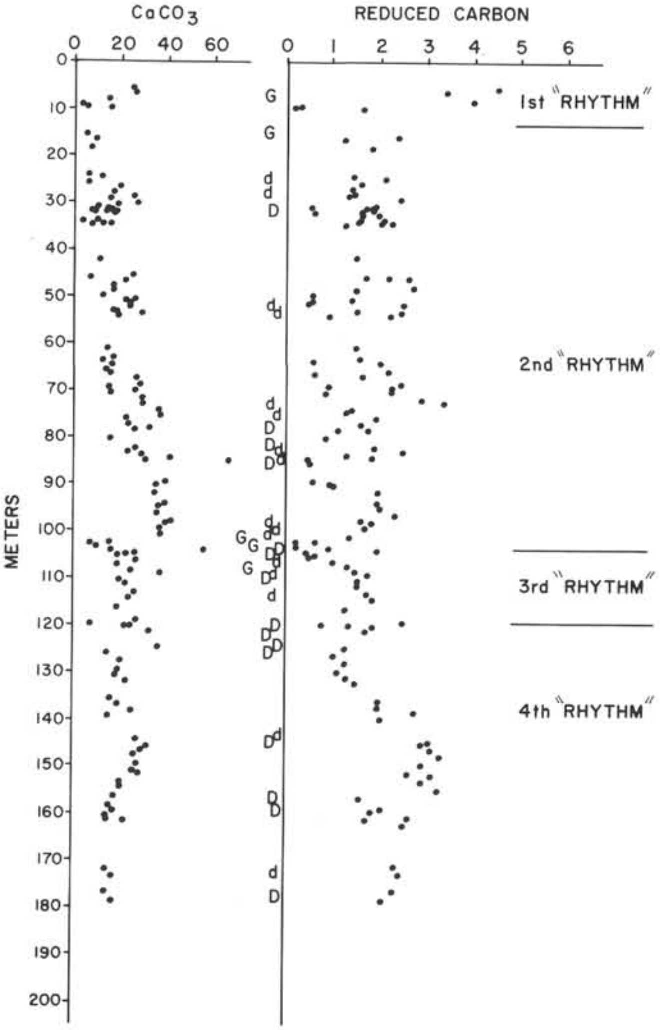


Figure 10. *Plot of depth vs. $CaCO_3$ and reduced carbon, Site 147. "d" indicates occurrences of dolomite in smear slide; "D" indicates abundant dolomite; "G" indicates gypsum detected by X-ray diffraction. Boundaries of "rhythms" shown. Calcium carbonate and organic carbon showed fluctuations, but these did not necessarily correlate with unit boundaries.*

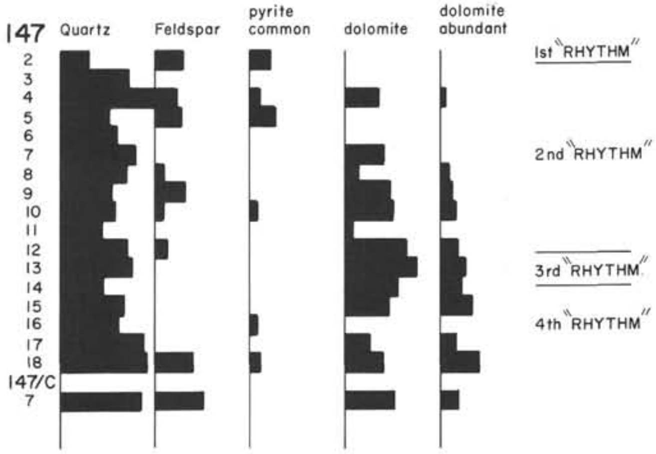


Figure 11. *Histograms showing percentages of smear slides in cores containing detrital quartz and feldspar, common pyrite, dolomite, and abundant dolomite. Boundaries of "rhythms" are shown.*

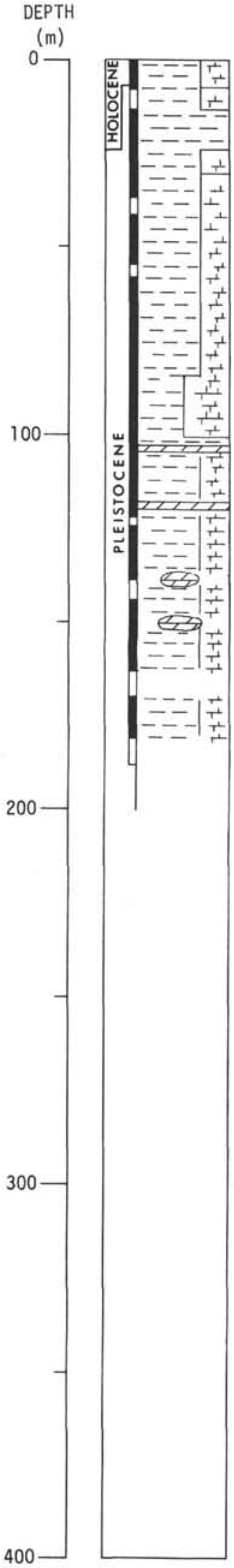
Olausson, E., 1960. Description of sediment cores from the central and western Pacific with the adjacent Indonesian region. Rept. Swedish Deep-Sea Exped., 1947-1948. **6,** 163.

Richards, F. A. and Vaccaro, R. F., 1956. The Cariaco Trench, an anaerobic basin in the Caribbean sea. Deep-Sea Res. **3,** 214.

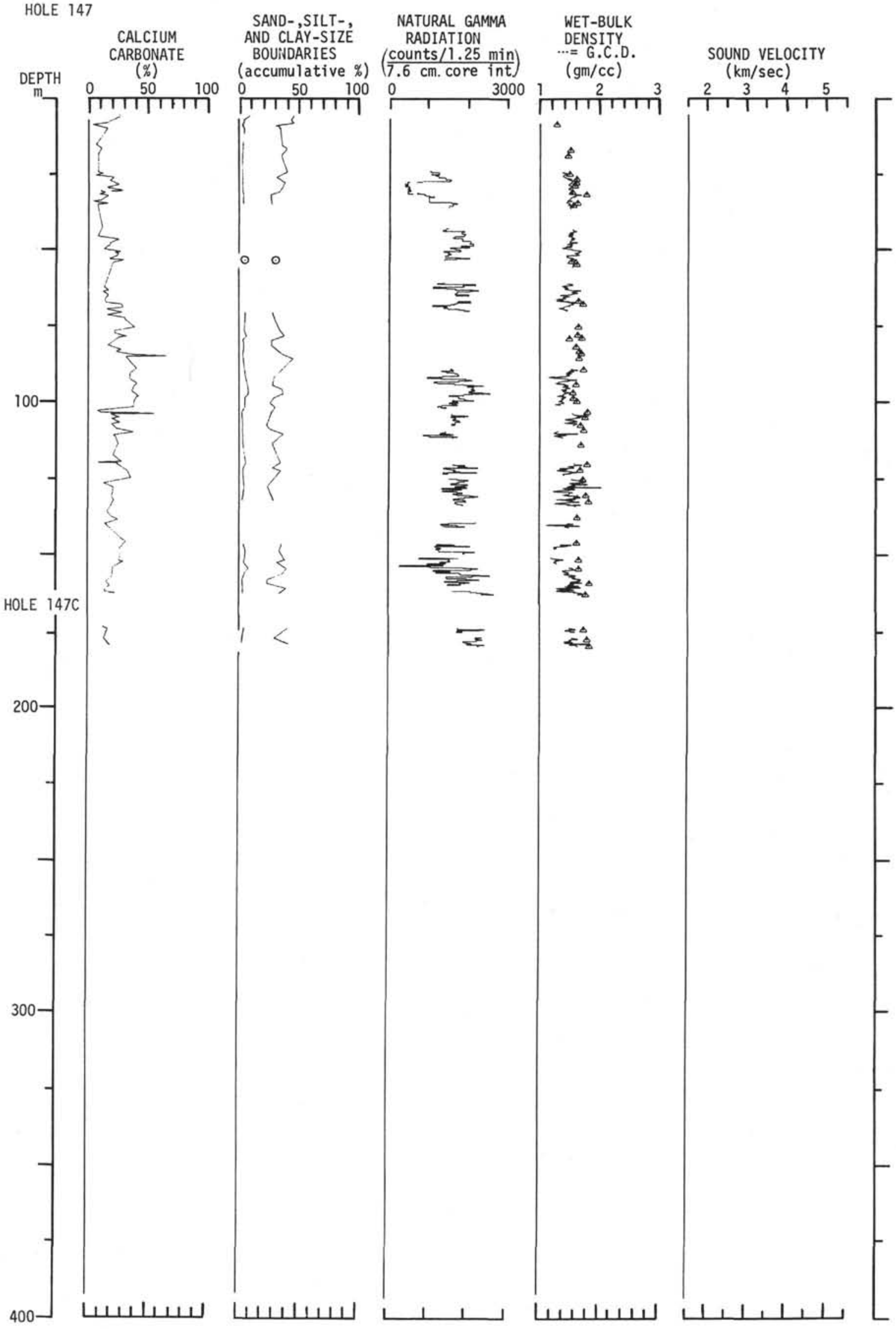
Wollin, G., Ericson, D. B., and Ewing, M., 1971. Late Pleistocene climates recorded in Atlantic and Pacific deep-sea sediments. *In* Turkian, K. K. (ed), The Late Cenozoic Ages. Yale University. 199.

SITE 147

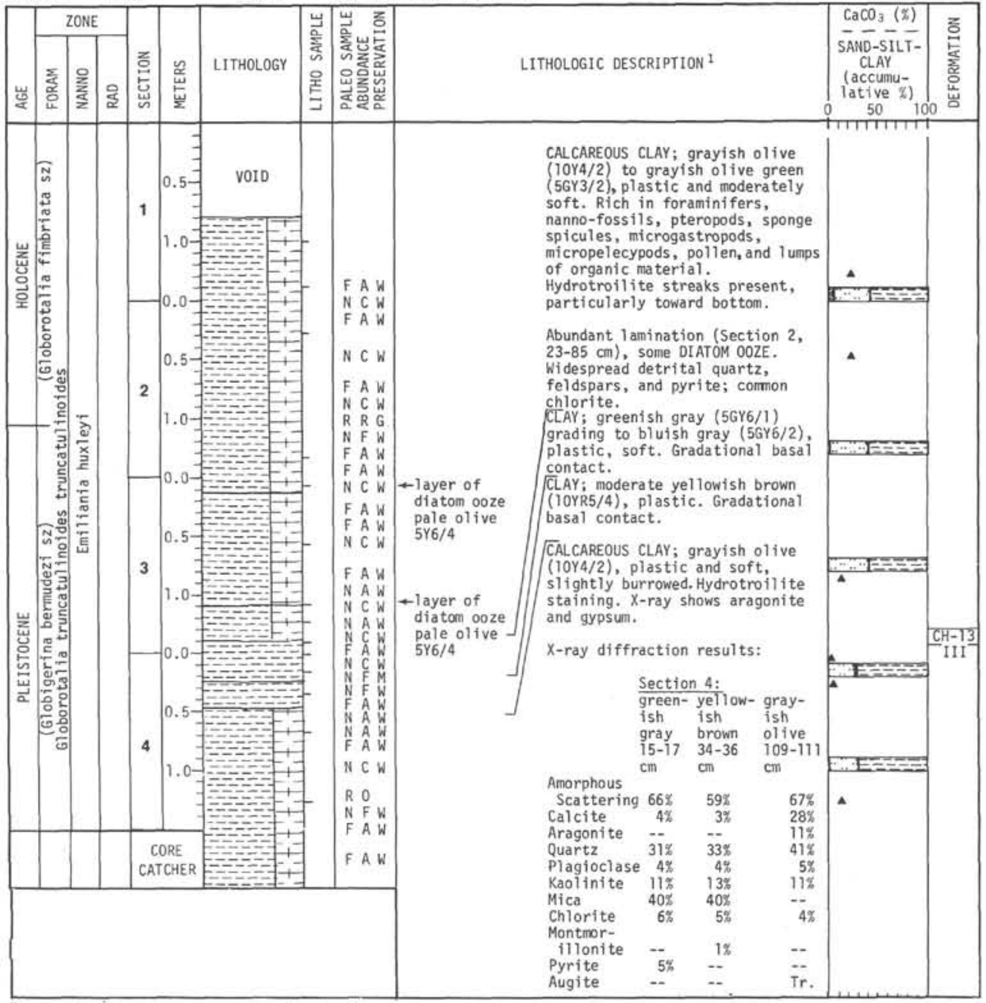
LITHOLOGY



UNITS	SUBUNITS OR DESCRIPTION
FORAM-NANNO RICH CLAY	FORAM-NANNO RICH CLAY and MARL OOZE, grayish olive green with some pteropods, diatoms, fish debris, wood, and pollen (0 to 189 m).
	CLAY, in part FORAM-NANNO RICH, greenish gray and yellowish brown, and bluish at 8.40 to 8.98 m, 101.79 to 102.99 m, and 115 to 116.60 m.
	CLAY, dark bluish gray at 119.14 to 119.26 m overlying a thin dolomite layer.
	CLAY RICH FORAM-NANNO CHALK gray yellow green at 102.99 to 103.23 m overlying dolomite.
	DOLOMITE, grayish yellow green (103.23 to 103.32 m) and light olive gray (119.26 to 119.30 m). Dolomite rock fragments were also found at 139.40 and 148.90 m.


HOLE 147
DEPTH m
CALCIUM CARBONATE (%)
0
50
100
SAND-,SILT-, AND CLAY-SIZE BOUNDARIES (accumulative %)
0
50
100
NATURAL GAMMA RADIATION (counts/1.25 min / 7.6 cm. core int.)
0
3000
WET-BULK DENSITY ···= G.C.D. (gm/cc)
1
2
3
SOUND VELOCITY (km/sec)
2
3
4
5
100
HOLE 147C
200
300
400

SITE 147 HOLE CORE 2 CORED INTERVAL (m) 4-14



CALCAREOUS CLAY; grayish olive (10Y4/2) to grayish olive green (5GY3/2), plastic and moderately soft. Rich in foraminifers, nanno-fossils, pteropods, sponge spicules, microgastropods, micropelecypods, pollen, and lumps of organic material. Hydrotroilite streaks present, particularly toward bottom.

Abundant lamination (Section 2, 23-85 cm), some DIATOM OOZE. Widespread detrital quartz, feldspars, and pyrite; common chlorite.

CLAY; greenish gray (5GY6/1) grading to bluish gray (5GY6/2), plastic, soft. Gradational basal contact.

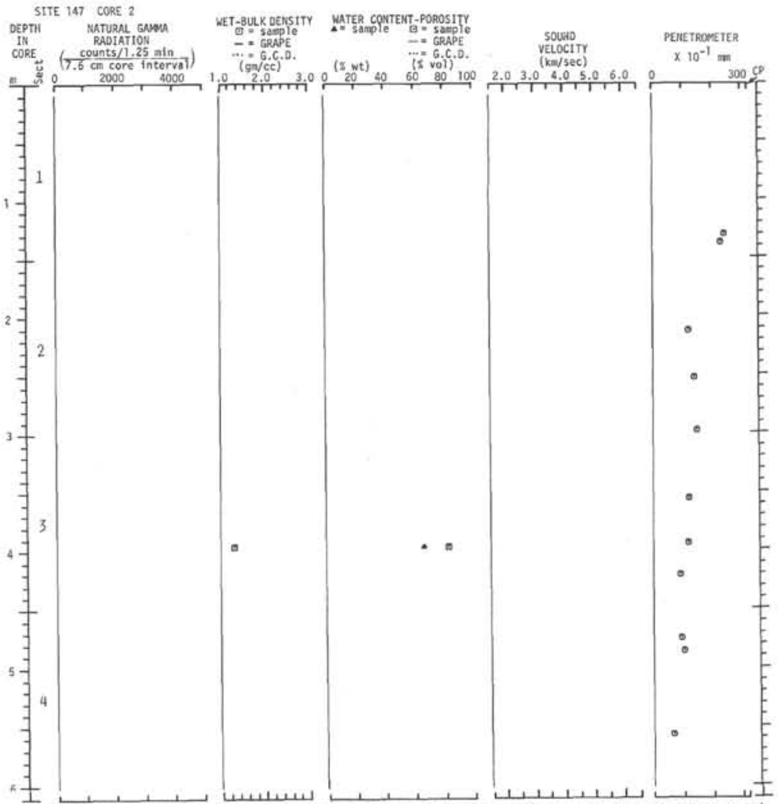
CLAY; moderate yellowish brown (10YR5/4), plastic. Gradational basal contact.

CALCAREOUS CLAY; grayish olive (10Y4/2), plastic and soft, slightly burrowed. Hydrotroilite staining. X-ray shows aragonite and gypsum.

X-ray diffraction results:

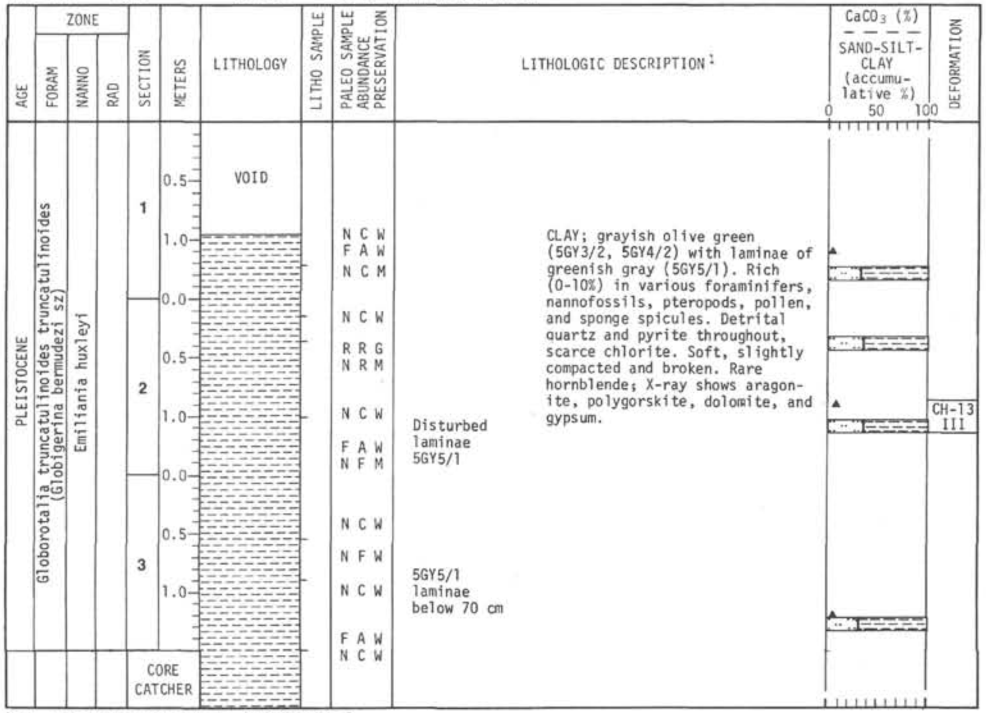
	Section 4: greenish gray 15-17 cm	yellowish brown 34-36 cm	grayish olive 109-111 cm
Amorphous Scattering	66%	59%	67%
Calcite	4%	3%	28%
Aragonite	--	--	11%
Quartz	31%	33%	41%
Plagioclase	4%	4%	5%
Kaolinite	11%	13%	11%
Mica	40%	40%	--
Chlorite	6%	5%	4%
Montmorillonite	--	1%	--
Pyrite	5%	--	--
Augite	--	--	Tr.

[1] For explanation of symbols, see Chapter 1



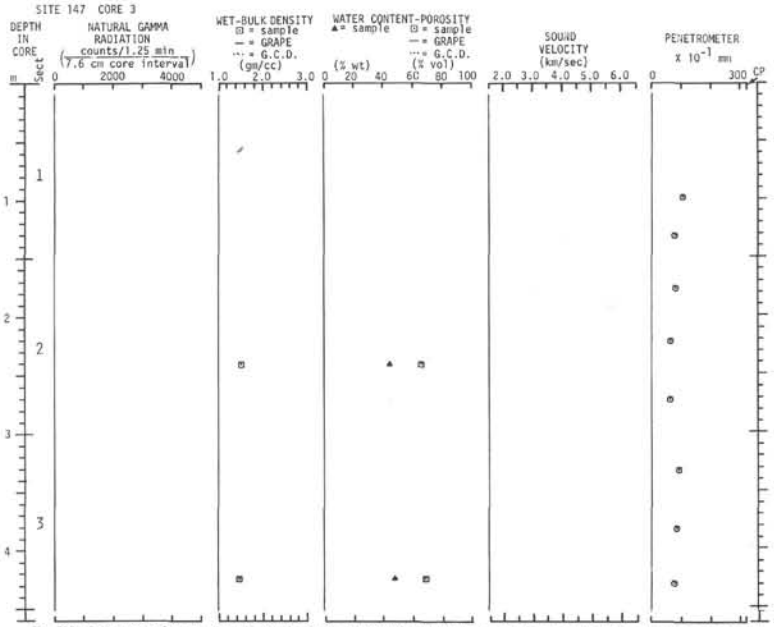
The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1300. This background was subtracted from the data.

SITE 147 HOLE CORE 3 CORED INTERVAL (m) 14-23



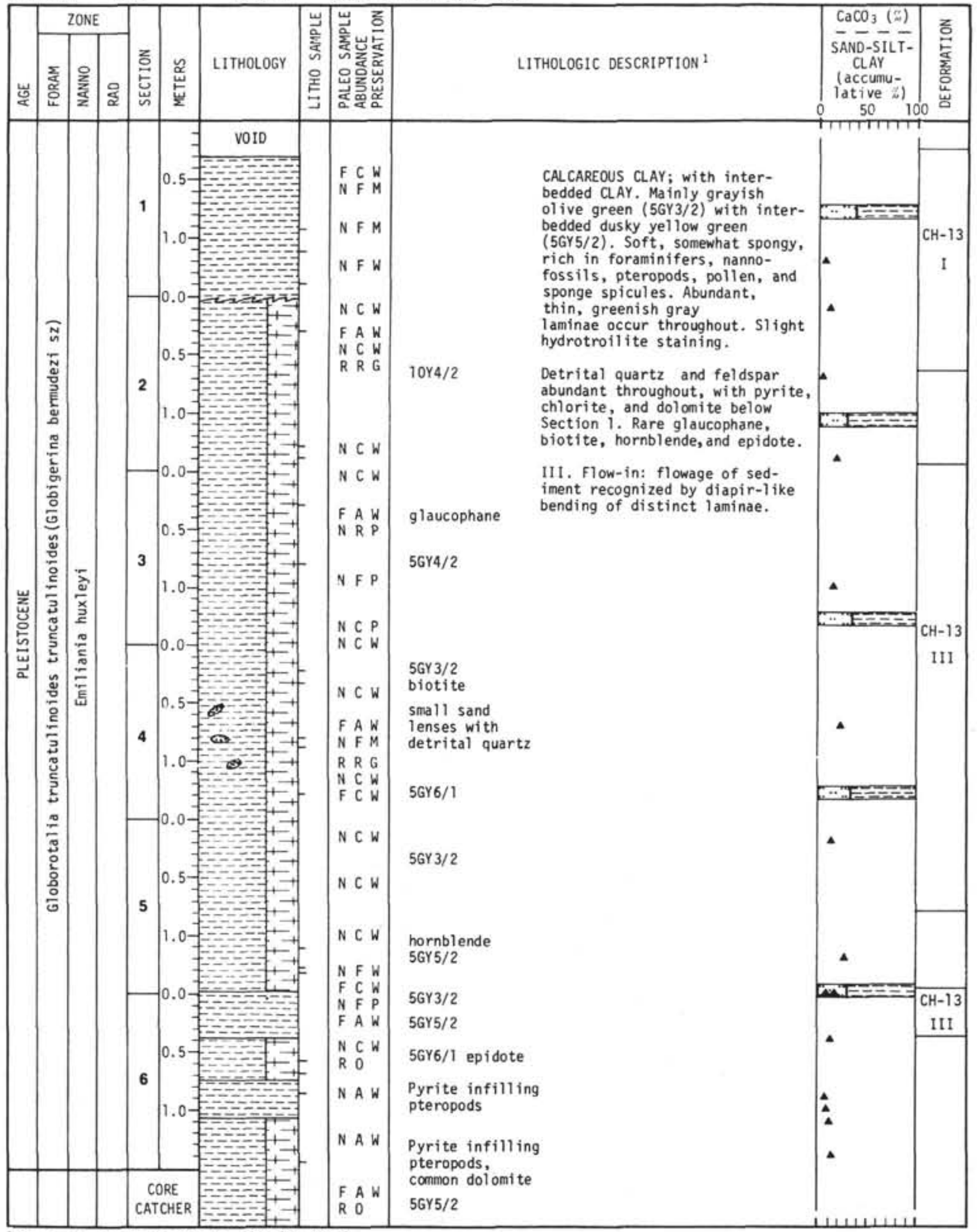
CLAY; grayish olive green (5GY3/2, 5GY4/2) with laminae of greenish gray (5GY5/1). Rich (0-10%) in various foraminifers, nannofossils, pteropods, pollen, and sponge spicules. Detrital quartz and pyrite throughout, scarce chlorite. Soft, slightly compacted and broken. Rare hornblende; X-ray shows aragonite, polygorskite, dolomite, and gypsum.

¹For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1300. This background was subtracted from the data.

SITE 147 HOLE CORE 4 CORED INTERVAL (m) 23-32



CALCAREOUS CLAY; with interbedded CLAY. Mainly grayish olive green (5GY3/2) with interbedded dusky yellow green (5GY5/2). Soft, somewhat spongy, rich in foraminifers, nannofossils, pteropods, pollen, and sponge spicules. Abundant, thin, greenish gray laminae occur throughout. Slight hydrotroilite staining.

Detrital quartz and feldspar abundant throughout, with pyrite, chlorite, and dolomite below Section 1. Rare glaucophane, biotite, hornblende, and epidote.

III. Flow-in: flowage of sediment recognized by diapir-like bending of distinct laminae.

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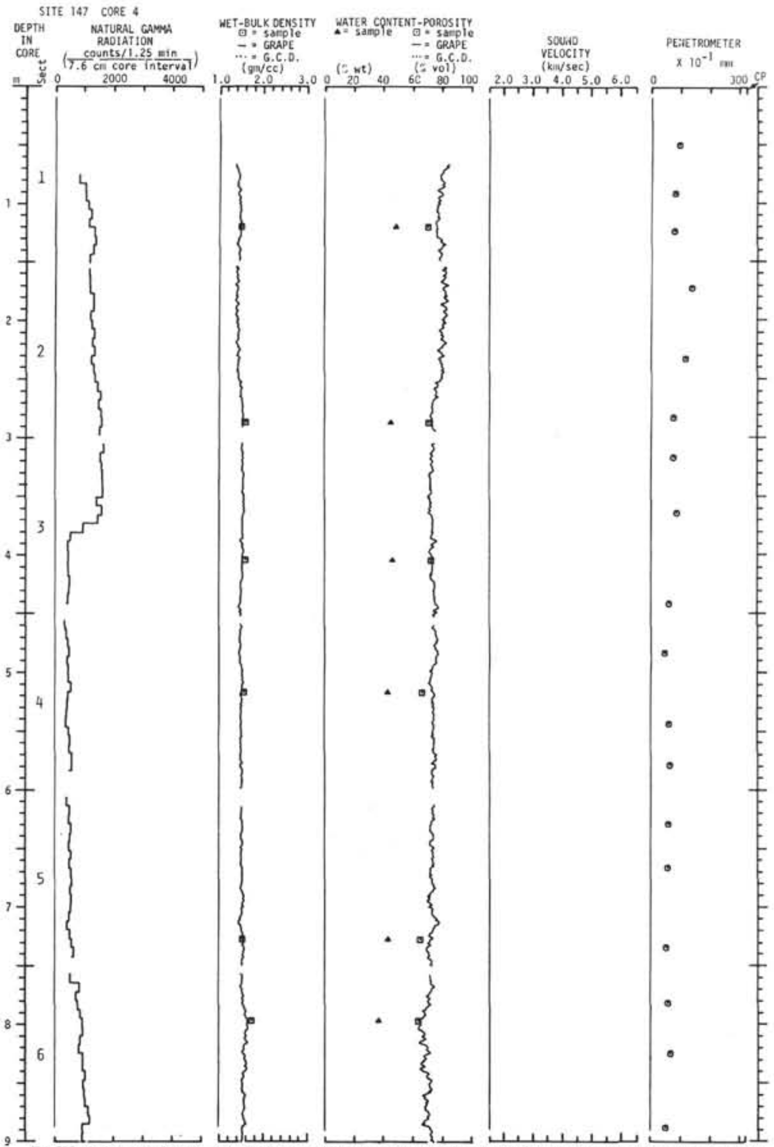
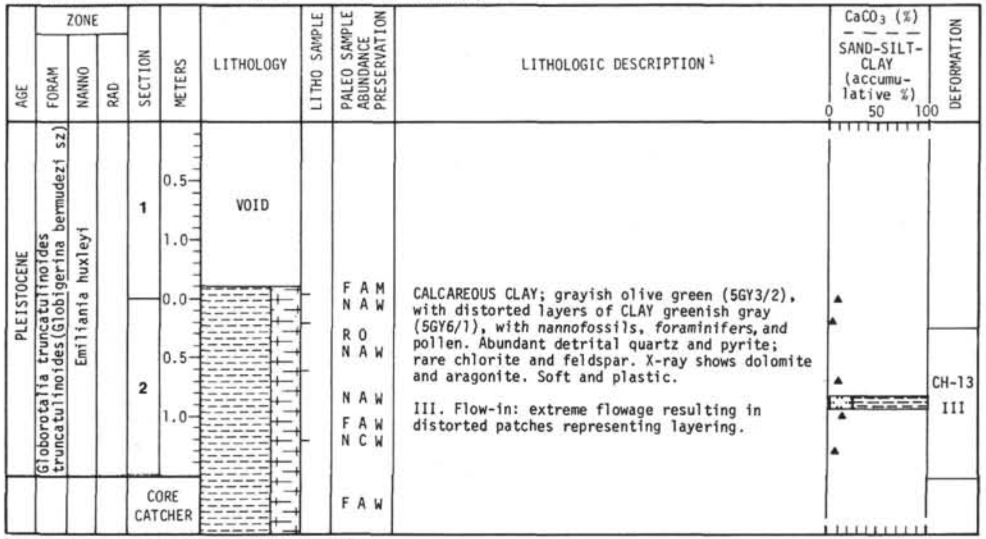
¹For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1377. This background was subtracted from the data.

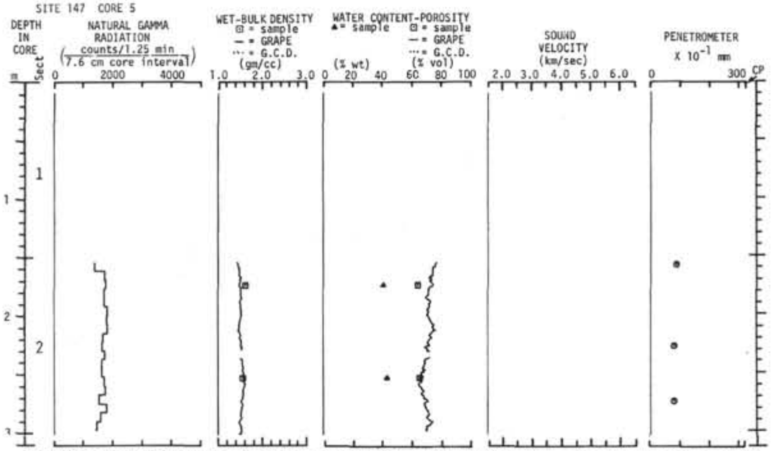
SITE 147 HOLE CORE 5 CORED INTERVAL (m) 32-42



CALCAREOUS CLAY; grayish olive green (5GY3/2), with distorted layers of CLAY greenish gray (5GY6/1), with *nannofossils*, *foraminifers*, and pollen. Abundant detrital quartz and pyrite; rare chlorite and feldspar. X-ray shows dolomite and aragonite. Soft and plastic.

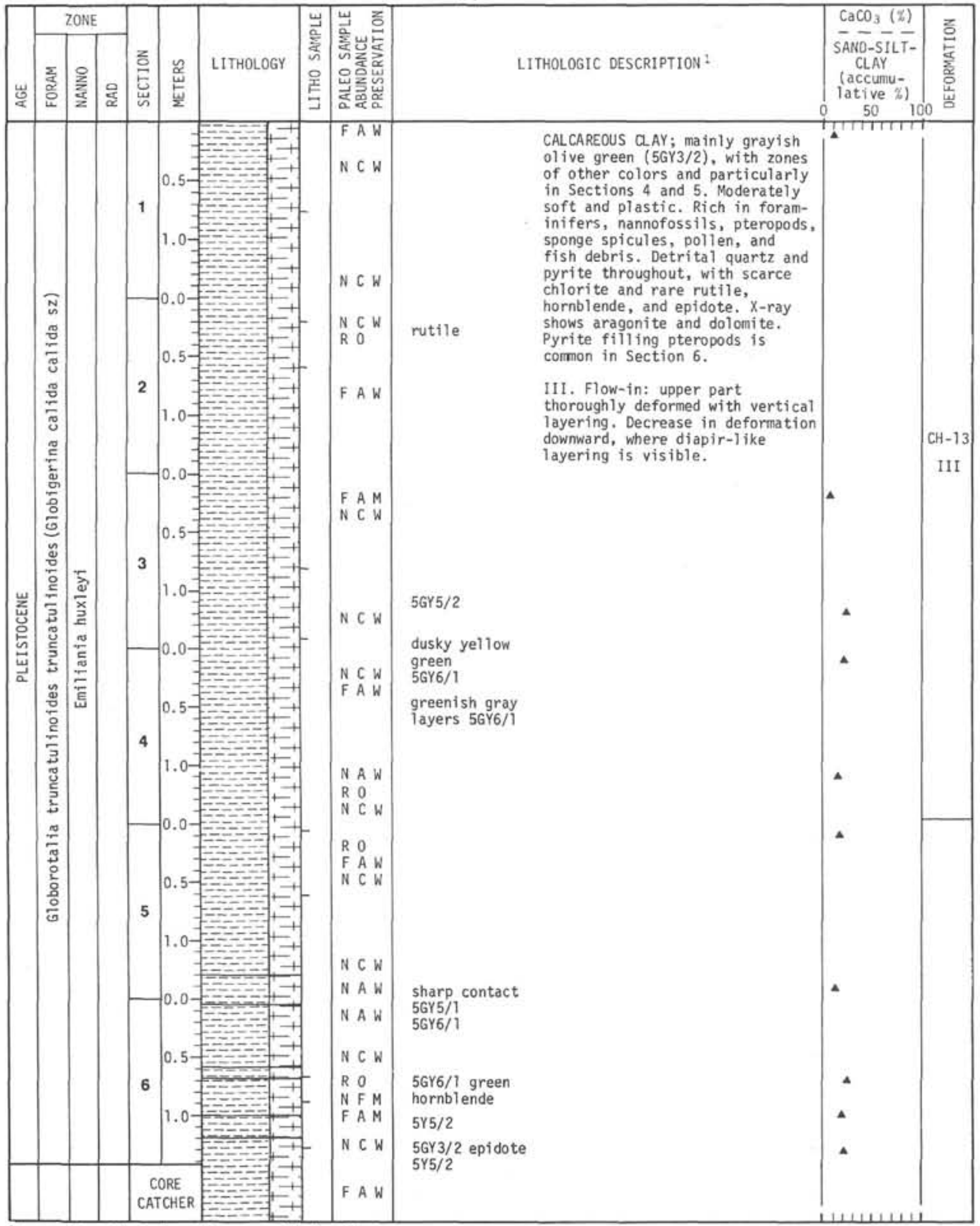
III. Flow-in: extreme flowage resulting in distorted patches representing layering.

[1] For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1205. This background was subtracted from the data.

SITE 147 HOLE CORE 6 CORED INTERVAL (m) 42-51



CALCAREOUS CLAY; mainly grayish olive green (5GY3/2), with zones of other colors and particularly in Sections 4 and 5. Moderately soft and plastic. Rich in foraminifers, nannofossils, pteropods, sponge spicules, pollen, and fish debris. Detrital quartz and pyrite throughout, with scarce chlorite and rare rutile, hornblende, and epidote. X-ray shows aragonite and dolomite. Pyrite filling pteropods is common in Section 6.

III. Flow-in: upper part thoroughly deformed with vertical layering. Decrease in deformation downward, where diapir-like layering is visible.

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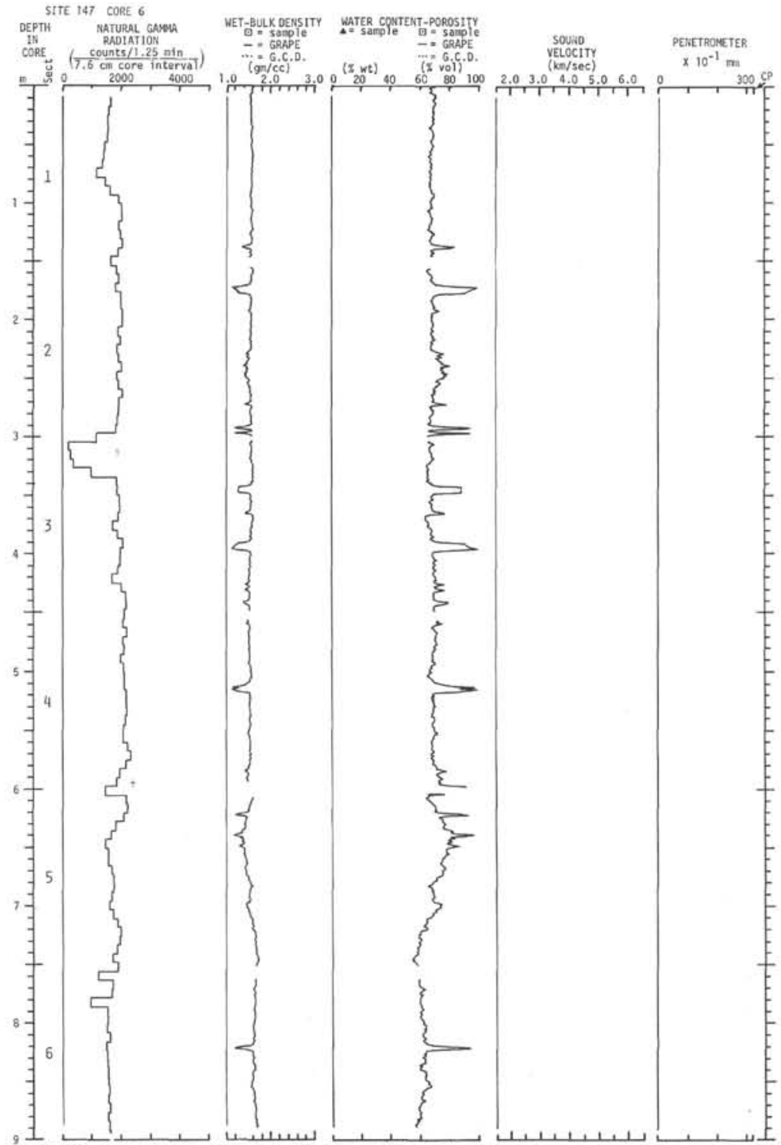
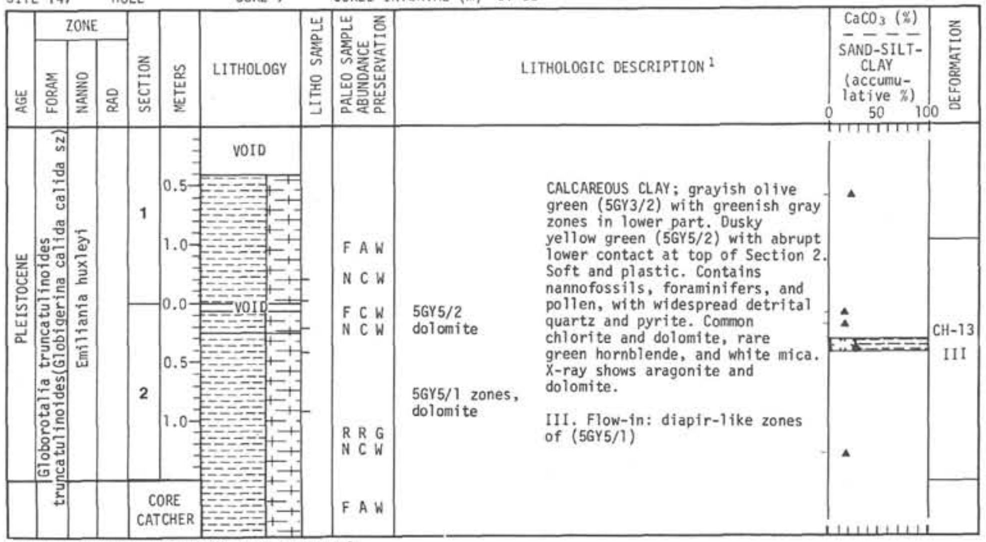
¹For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1205. This background was subtracted from the data.

SITE 147 HOLE CORE 7 CORED INTERVAL (m) 51-60



CALCAREOUS CLAY; grayish olive green (5GY3/2) with greenish gray zones in lower part. Dusky yellow green (5GY5/2) with abrupt lower contact at top of Section 2. Soft and plastic. Contains nannofossils, foraminifers, and pollen, with widespread detrital quartz and pyrite. Common chlorite and dolomite, rare green hornblende, and white mica. X-ray shows aragonite and dolomite.

III. Flow-in: diapir-like zones of (5GY5/1)

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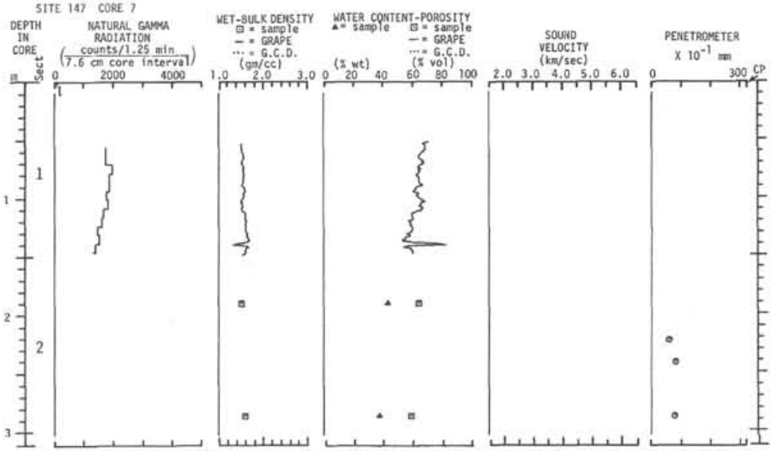
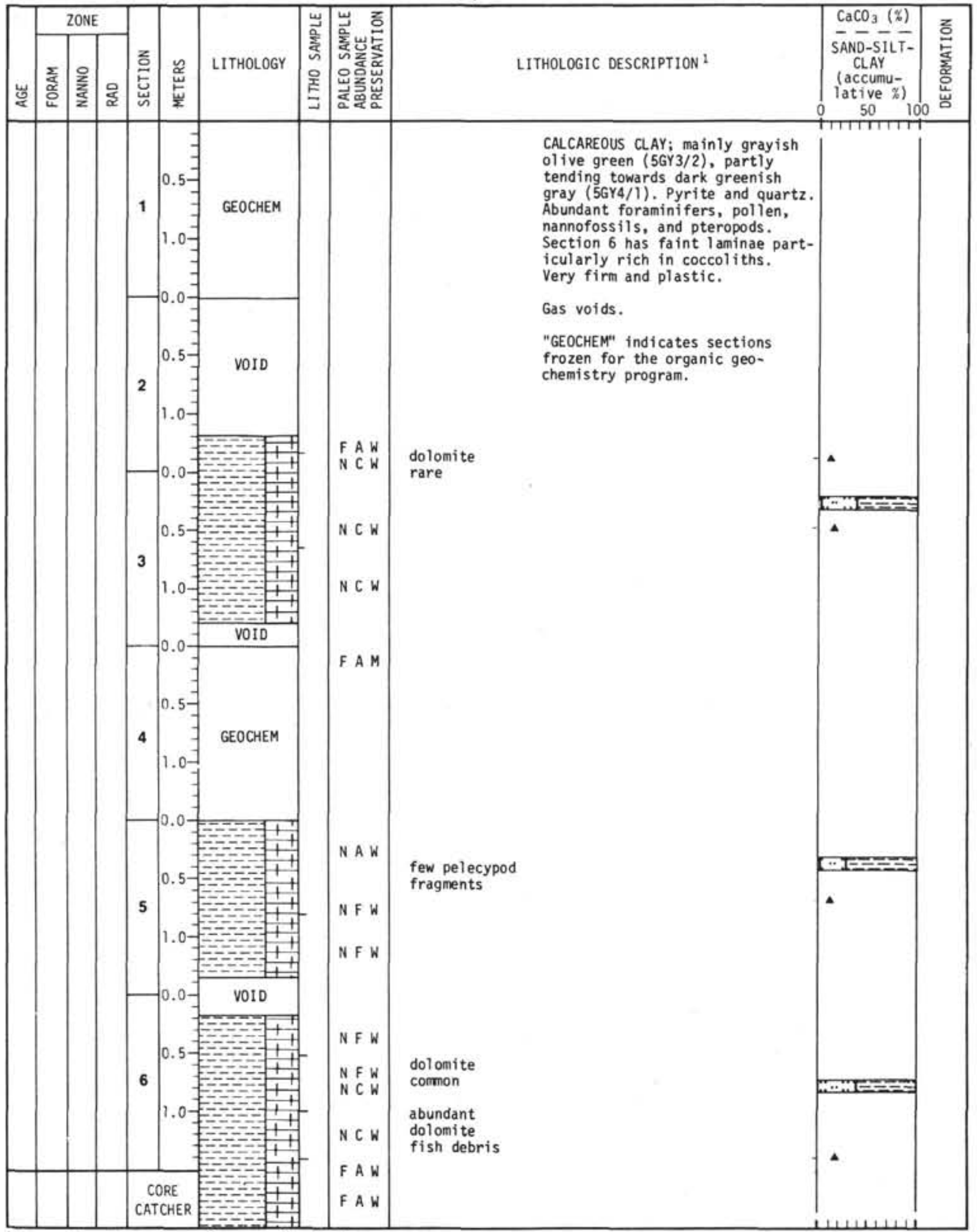
[1] For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1341. This background was subtracted from the data.

SITE 147 HOLE C CORE 7 CORED INTERVAL (m) 170-180



CALCAREOUS CLAY; mainly grayish olive green (5GY3/2), partly tending towards dark greenish gray (5GY4/1). Pyrite and quartz. Abundant foraminifers, pollen, nannofossils, and pteropods. Section 6 has faint laminae particularly rich in coccoliths. Very firm and plastic.

Gas voids.

"GEOCHEM" indicates sections frozen for the organic geochemistry program.

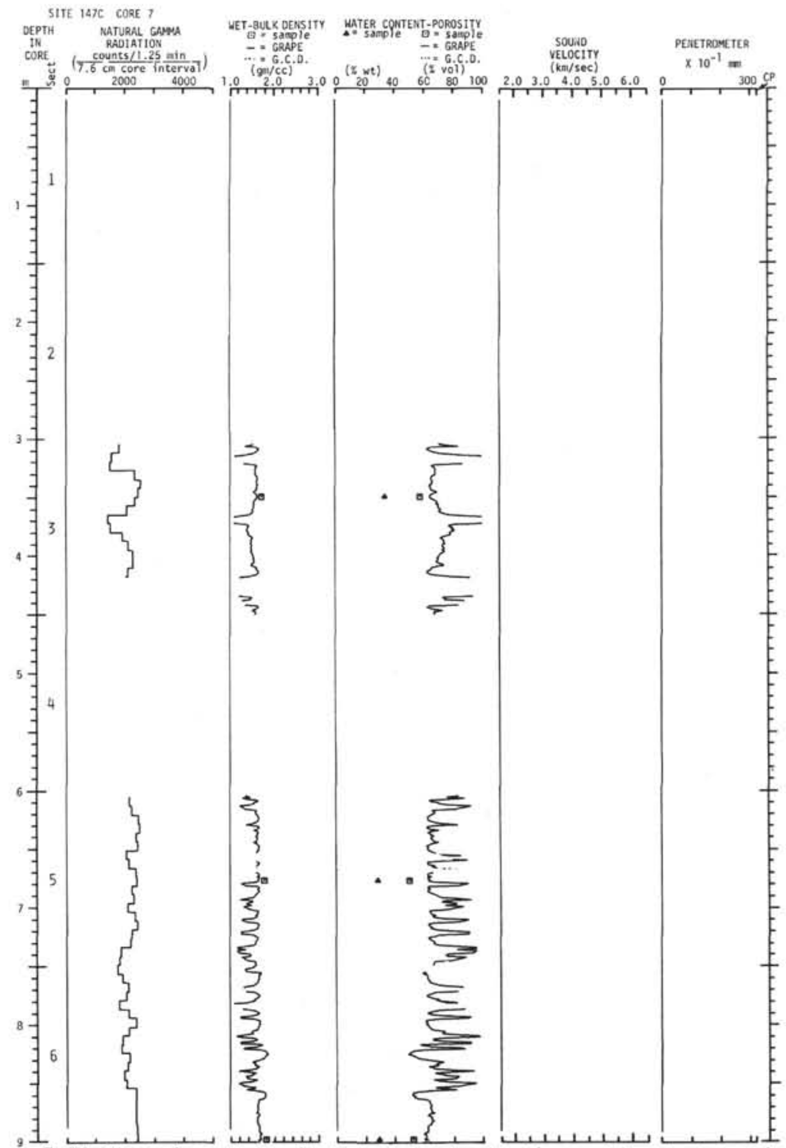
dolomite rare

few pelecypod fragments

dolomite common

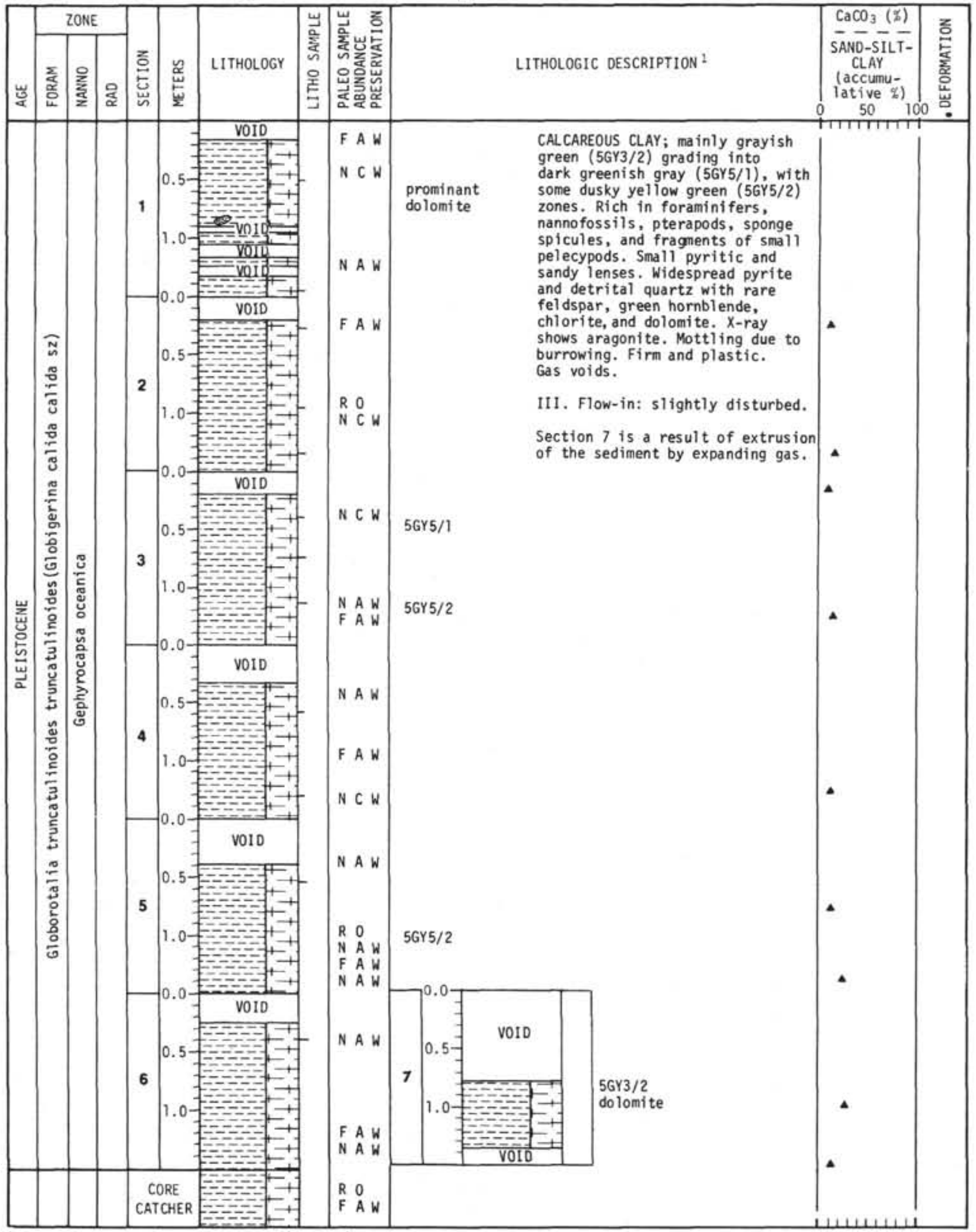
abundant dolomite fish debris

¹For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1348. This background was subtracted from the data.

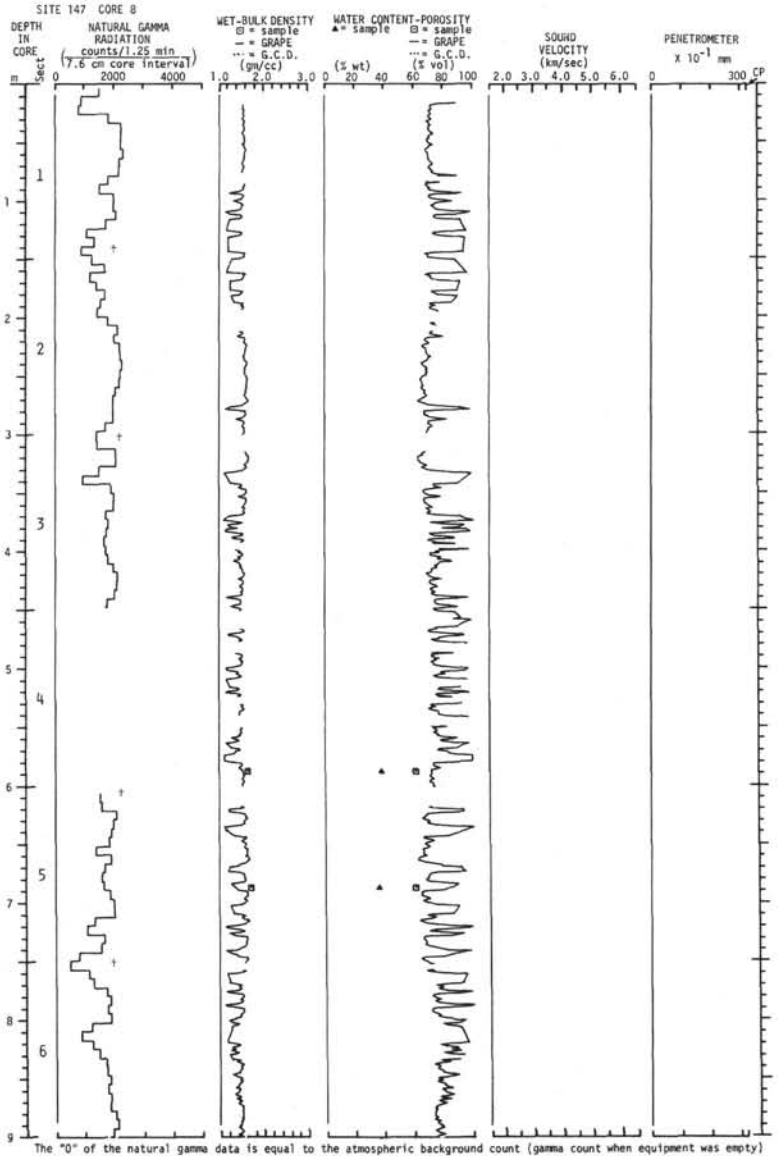
SITE 147 HOLE CORE 8 CORED INTERVAL (m) 60-69



CALCAREOUS CLAY; mainly grayish green (5GY3/2) grading into dark greenish gray (5GY5/1), with some dusky yellow green (5GY5/2) zones. Rich in foraminifers, nannofossils, pteropods, sponge spicules, and fragments of small pelecypods. Small pyritic and sandy lenses. Widespread pyrite and detrital quartz with rare feldspar, green hornblende, chlorite, and dolomite. X-ray shows aragonite. Mottling due to burrowing. Firm and plastic. Gas voids.

III. Flow-in: slightly disturbed.

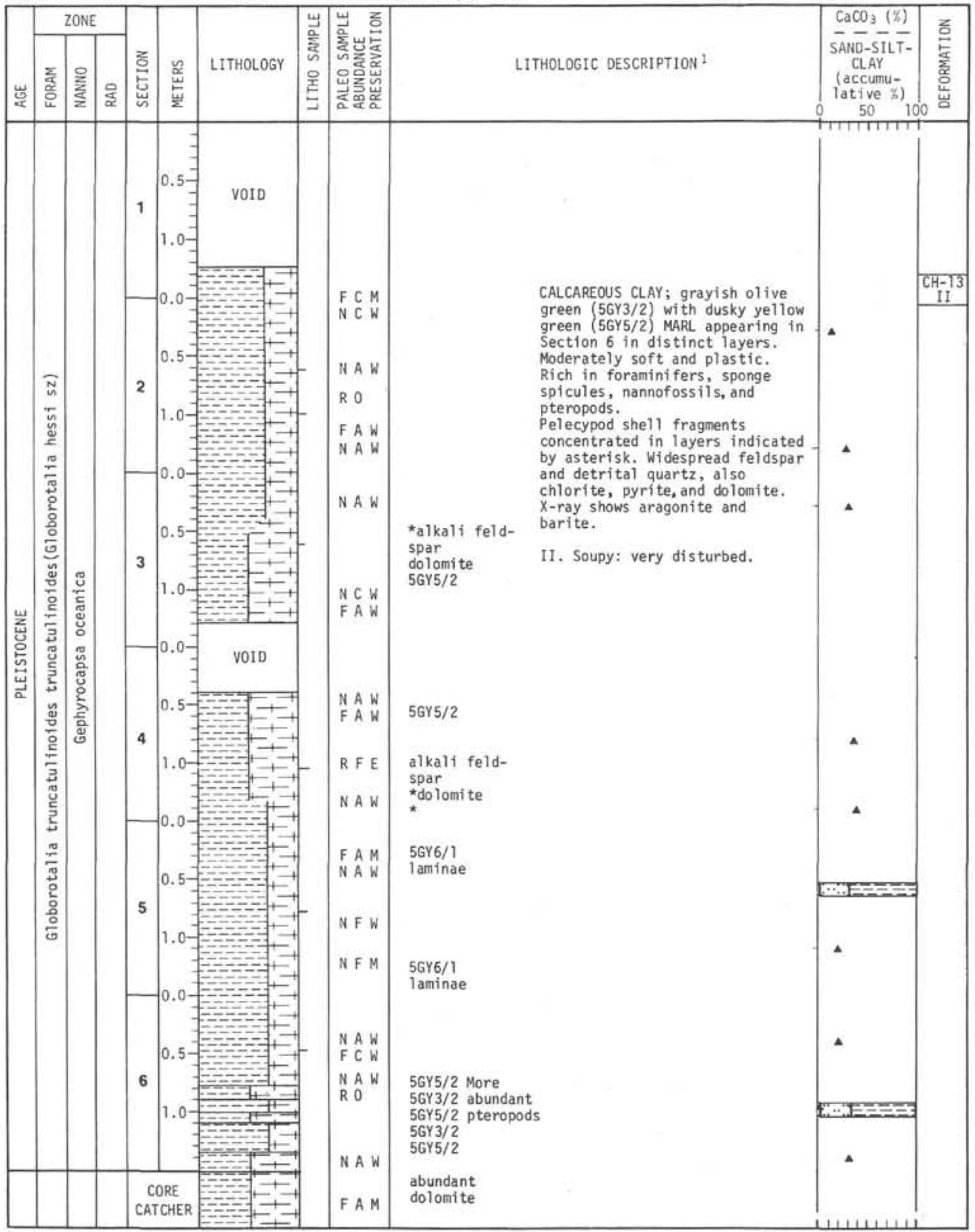
Section 7 is a result of extrusion of the sediment by expanding gas.



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1330. This background was subtracted from the data.

¹For explanation of symbols, see Chapter 1

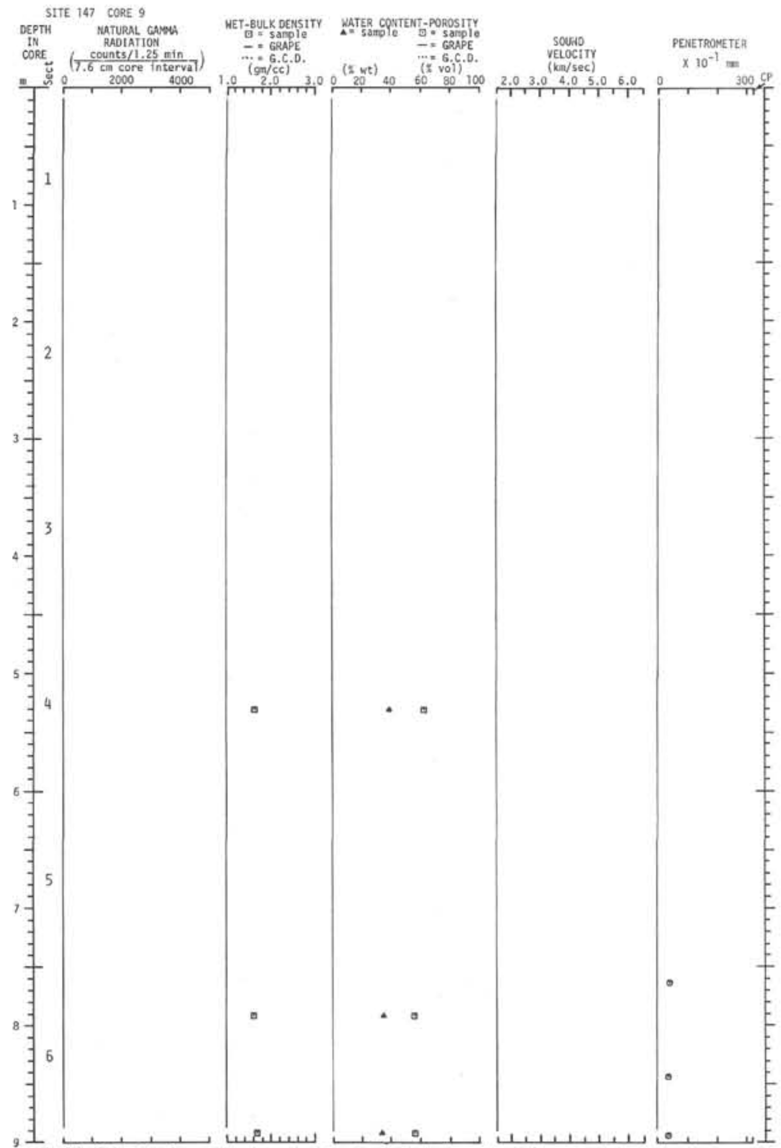
SITE 147 HOLE CORE 9 CORED INTERVAL (m) 69-78



CALCAREOUS CLAY; grayish olive green (5GY3/2) with dusky yellow green (5GY5/2) MARL appearing in Section 6 in distinct layers. Moderately soft and plastic. Rich in foraminifers, sponge spicules, nannofossils, and pteropods. Pelecypod shell fragments concentrated in layers indicated by asterisk. Widespread feldspar and detrital quartz, also chlorite, pyrite, and dolomite. X-ray shows aragonite and barite.

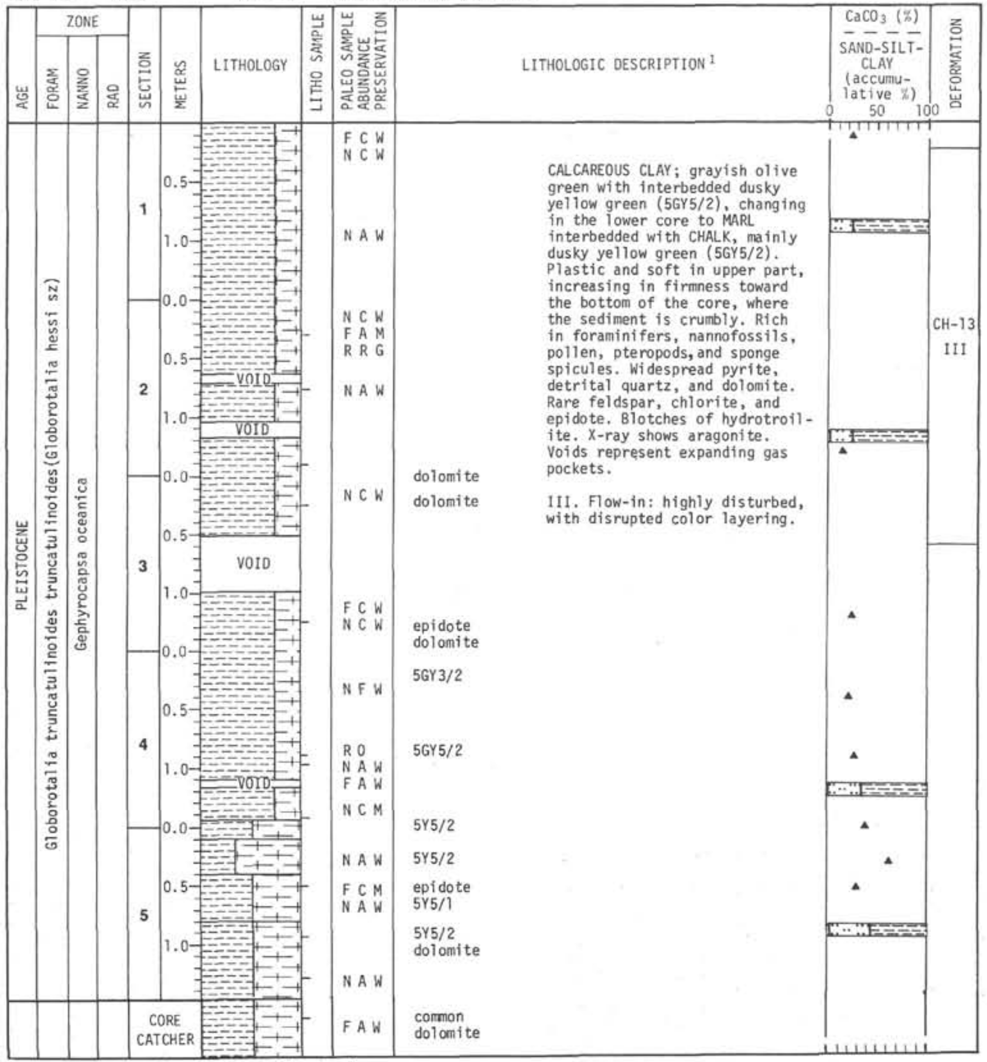
II. Soupy: very disturbed.

¹For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1302. This background was subtracted from the data.

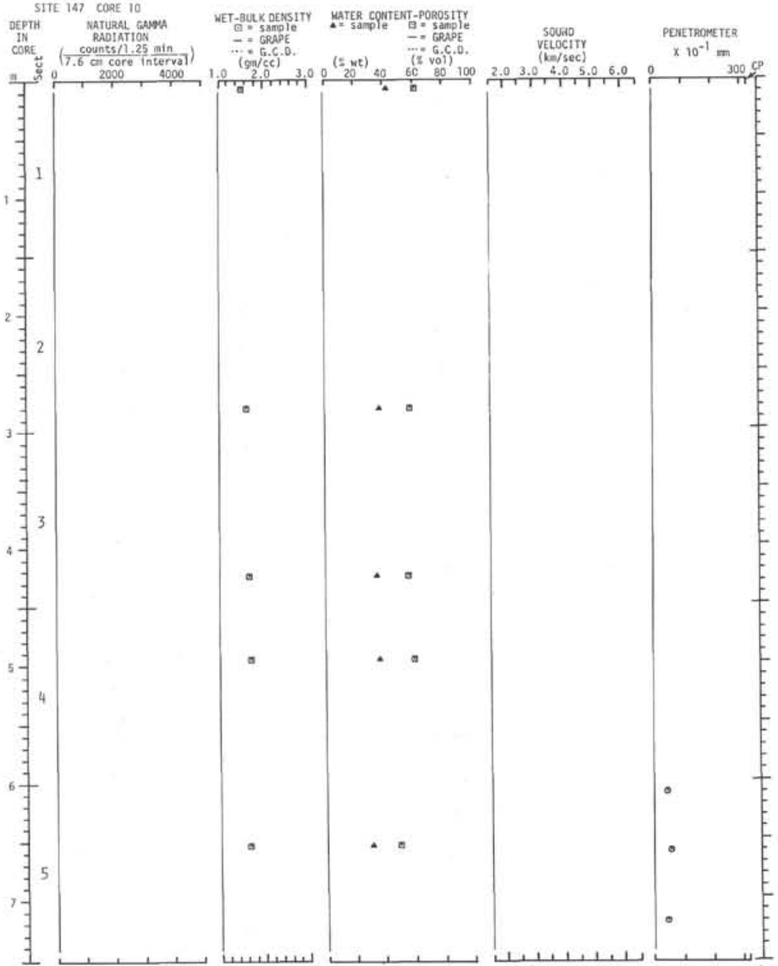
SITE 147 HOLE CORE 10 CORED INTERVAL (m) 78-88



CALCAREOUS CLAY; grayish olive green with interbedded dusky yellow green (5GY5/2), changing in the lower core to MARL interbedded with CHALK, mainly dusky yellow green (5GY5/2). Plastic and soft in upper part, increasing in firmness toward the bottom of the core, where the sediment is crumbly. Rich in foraminifers, nannofossils, pollen, pteropods, and sponge spicules. Widespread pyrite, detrital quartz, and dolomite. Rare feldspar, chlorite, and epidote. Blotches of hydrotroilite. X-ray shows aragonite. Voids represent expanding gas pockets.

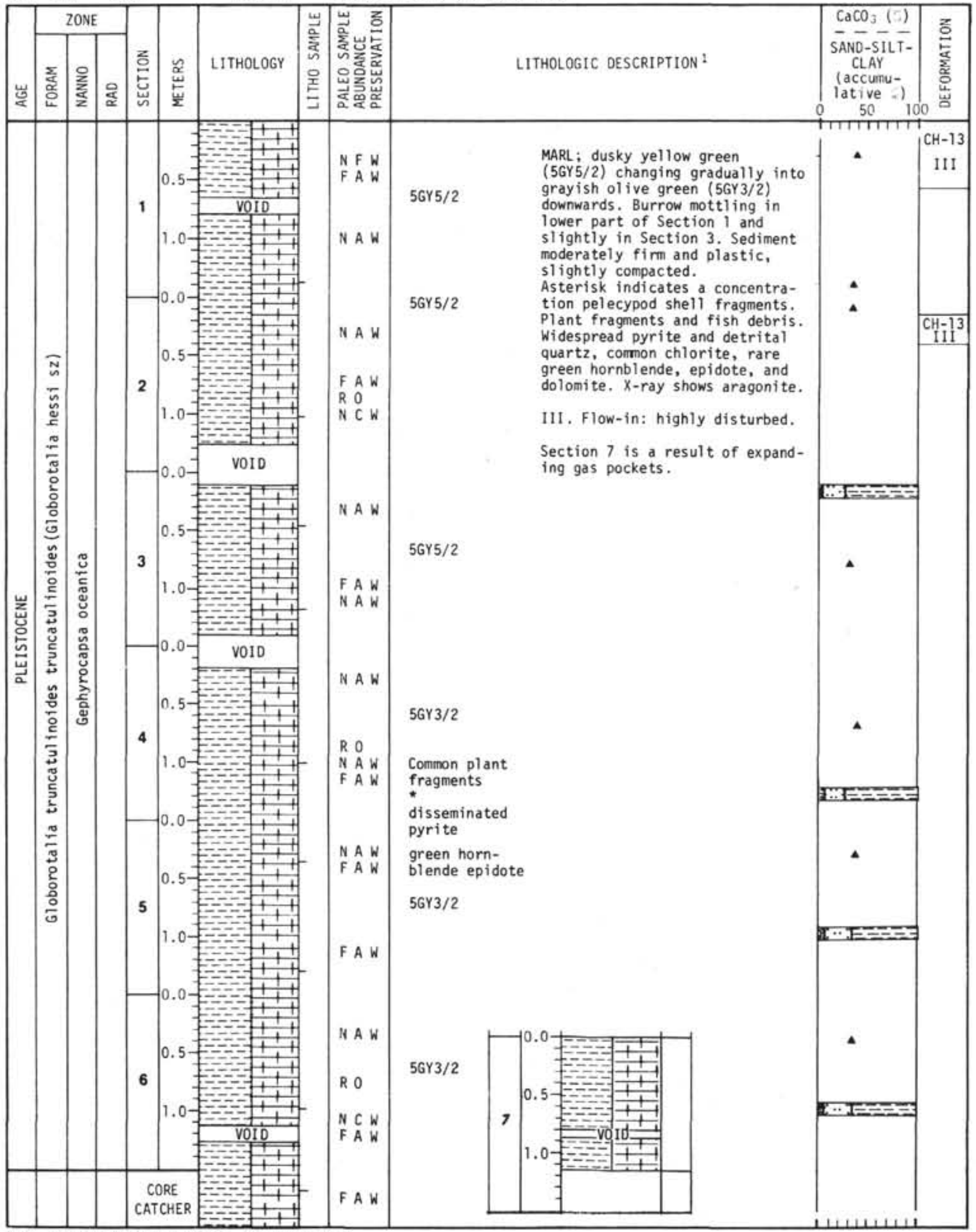
III. Flow-in: highly disturbed, with disrupted color layering.

[1] For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1302. This background was subtracted from the data.

SITE 147 HOLE CORE 11 CORED INTERVAL (m) 88.0-97.0



MARL; dusky yellow green (5GY5/2) changing gradually into grayish olive green (5GY3/2) downwards. Burrow mottling in lower part of Section 1 and slightly in Section 3. Sediment moderately firm and plastic, slightly compacted.
Asterisk indicates a concentration pelecypod shell fragments. Plant fragments and fish debris. Widespread pyrite and detrital quartz, common chlorite, rare green hornblende, epidote, and dolomite. X-ray shows aragonite.

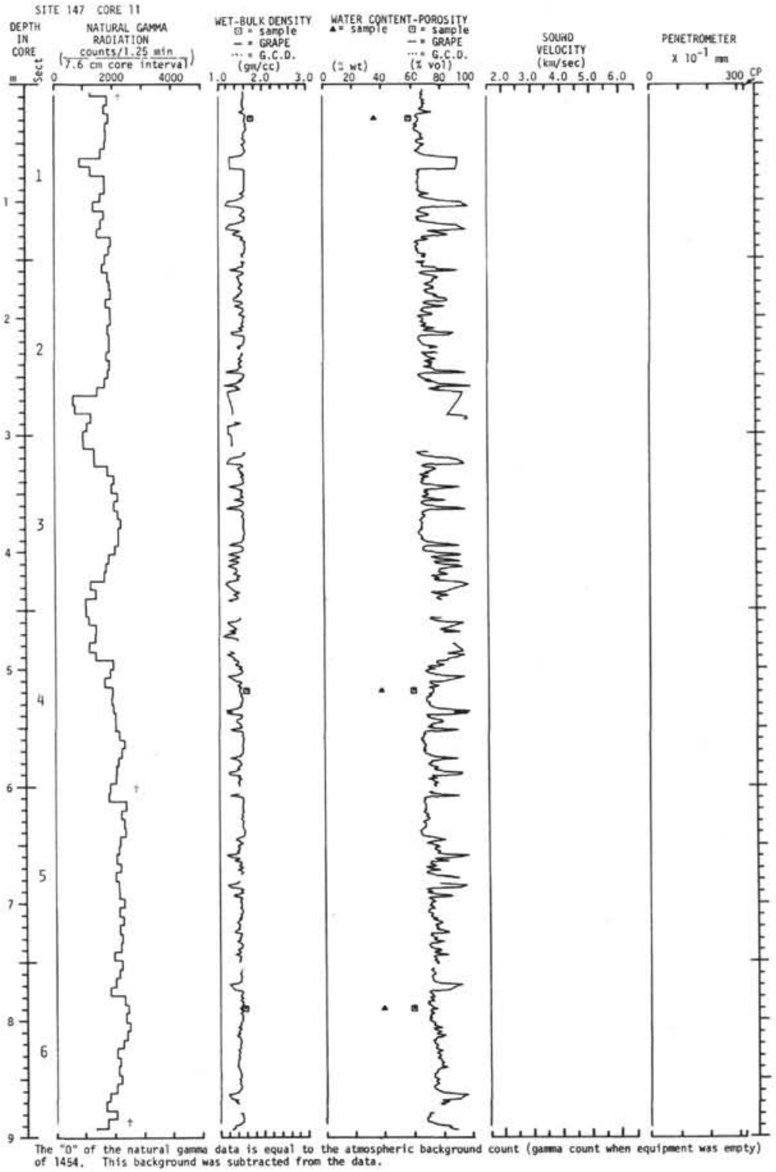
III. Flow-in: highly disturbed.

Section 7 is a result of expanding gas pockets.

Common plant fragments
*
disseminated pyrite

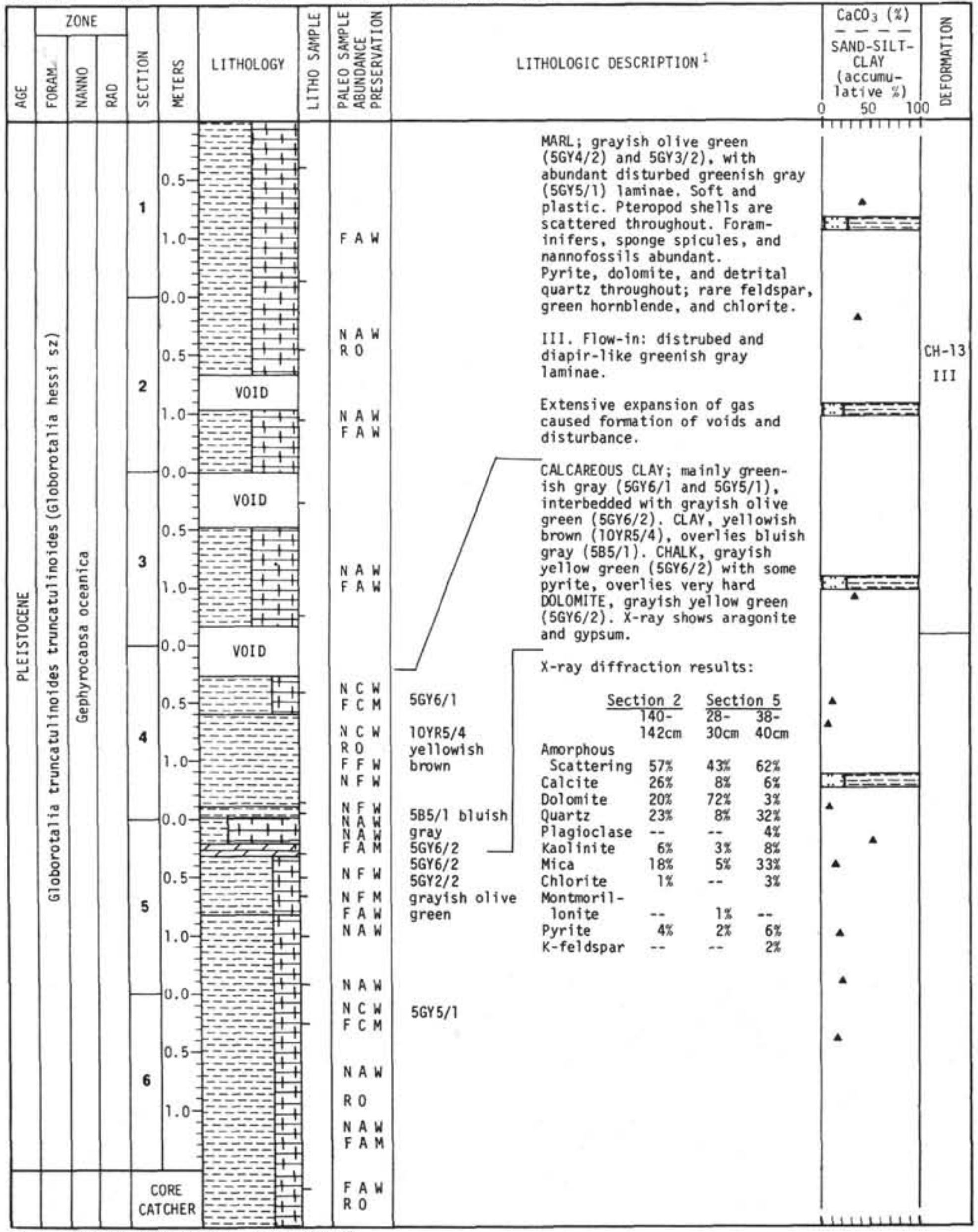
green hornblende epidote

¹For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1454. This background was subtracted from the data.

SITE 147 HOLE CORE 12 CORED INTERVAL (m) 97-106



MARL; grayish olive green (5GY4/2) and 5GY3/2), with abundant disturbed greenish gray (5GY5/1) laminae. Soft and plastic. Pteropod shells are scattered throughout. Foraminifers, sponge spicules, and nannofossils abundant. Pyrite, dolomite, and detrital quartz throughout; rare feldspar, green hornblende, and chlorite.

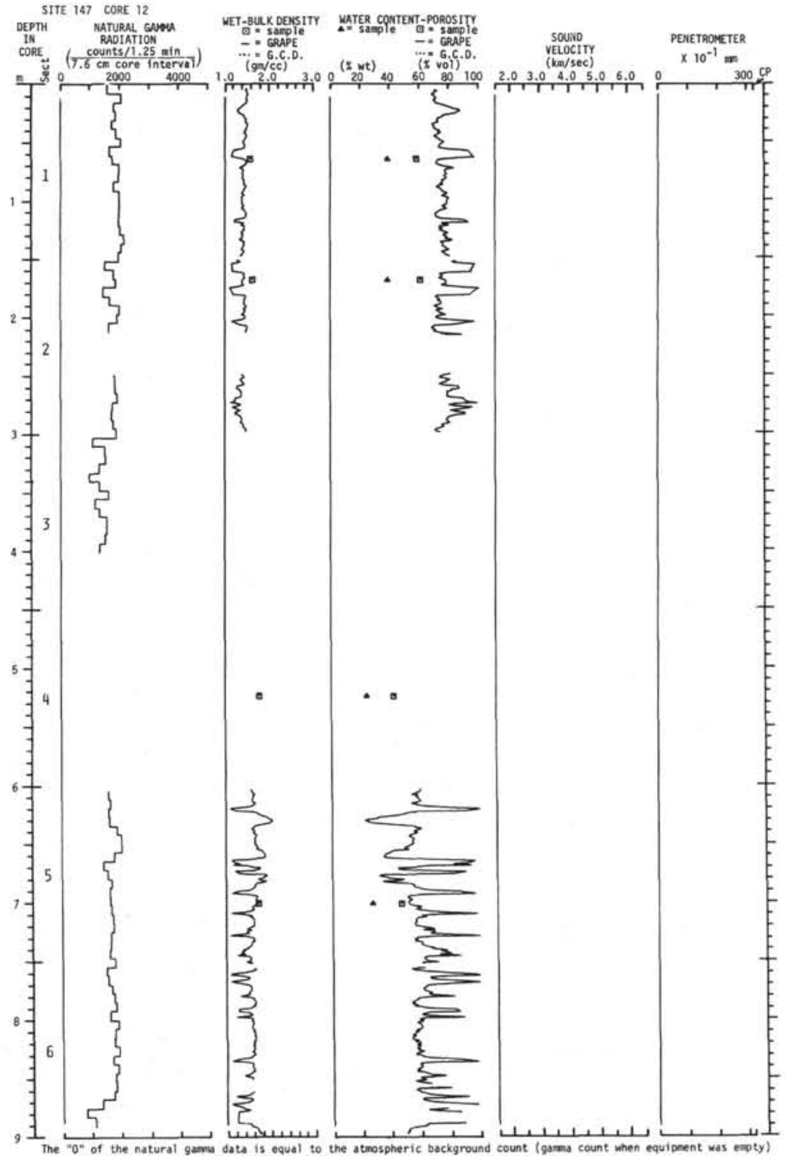
III. Flow-in: distrubed and diapir-like greenish gray laminae.

Extensive expansion of gas caused formation of voids and disturbance.

CALCAREOUS CLAY; mainly greenish gray (5GY6/1 and 5GY5/1), interbedded with grayish olive green (5GY6/2). CLAY, yellowish brown (10YR5/4), overlies bluish gray (5B5/1). CHALK, grayish yellow green (5GY6/2) with some pyrite, overlies very hard DOLOMITE, grayish yellow green (5GY6/2). X-ray shows aragonite and gypsum.

X-ray diffraction results:

	Section 2	Section 5	
	140-142cm	28-30cm	38-40cm
Amorphous Scattering	57%	43%	62%
Calcite	26%	8%	6%
Dolomite	20%	72%	3%
Quartz	23%	8%	32%
Plagioclase	--	--	4%
Kaolinite	6%	3%	8%
Mica	18%	5%	33%
Chlorite	1%	--	3%
Montmorillonite	--	1%	--
Pyrite	4%	2%	6%
K-feldspar	--	--	2%



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1349. This background was subtracted from the data.

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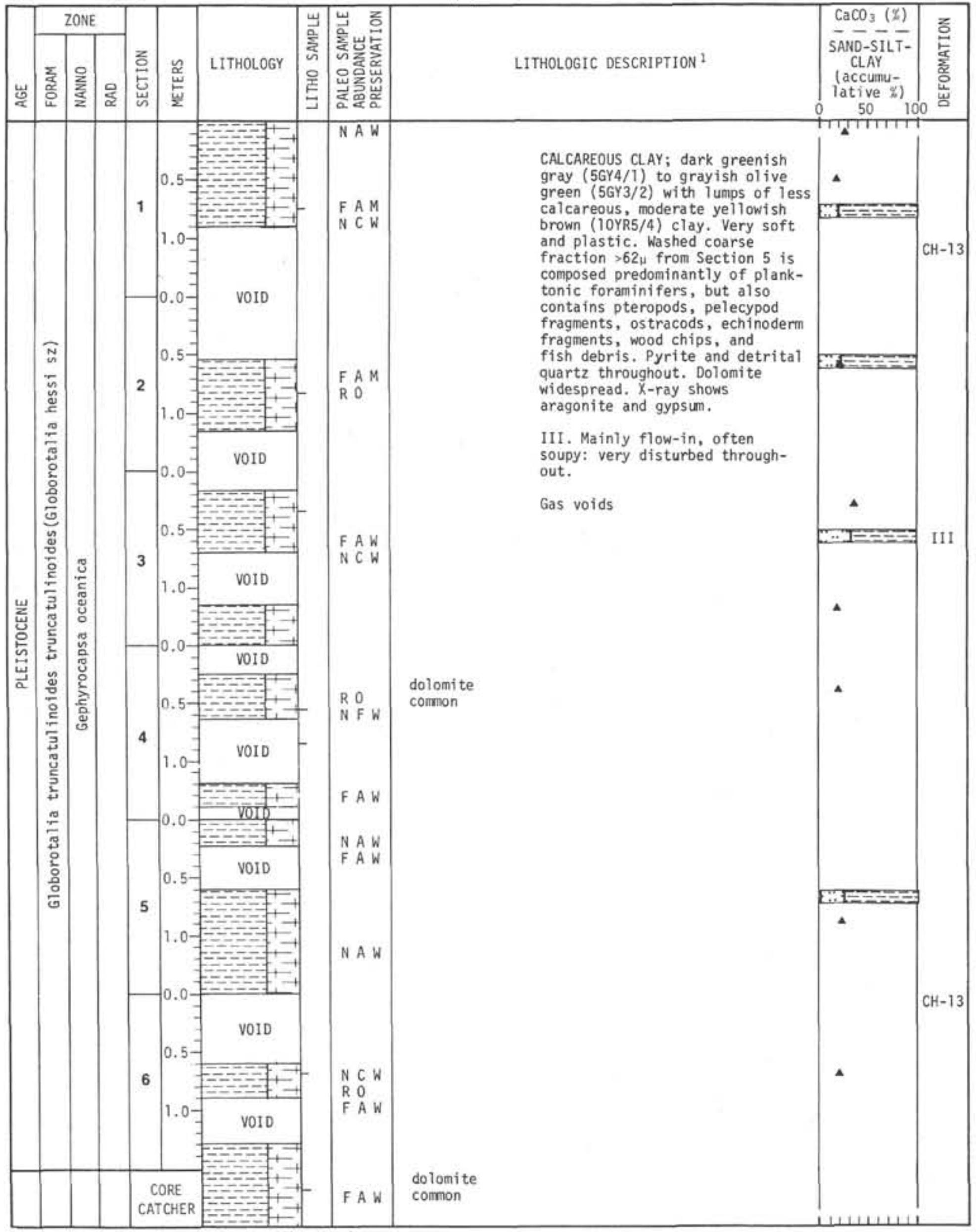
¹For explanation of symbols, see Chapter 1

SITE 147 HOLE CORE 13 CORED INTERVAL (m) 106.0-115.0

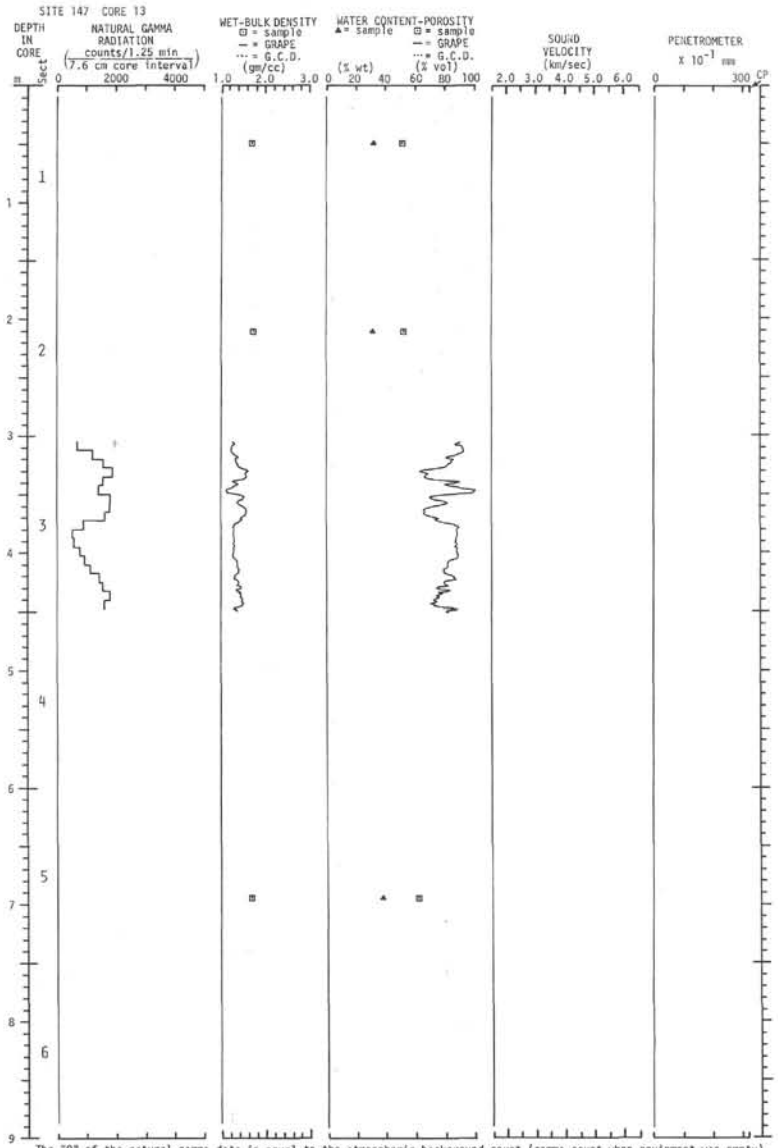


CALCAREOUS CLAY; dark greenish gray (5GY4/1) to grayish olive green (5GY3/2) with lumps of less calcareous, moderate yellowish brown (10YR5/4) clay. Very soft and plastic. Washed coarse fraction >62μ from Section 5 is composed predominantly of planktonic foraminifers, but also contains pteropods, pelecypod fragments, ostracods, echinoderm fragments, wood chips, and fish debris. Pyrite and detrital quartz throughout. Dolomite widespread. X-ray shows aragonite and gypsum.

III. Mainly flow-in, often soupy: very disturbed throughout.

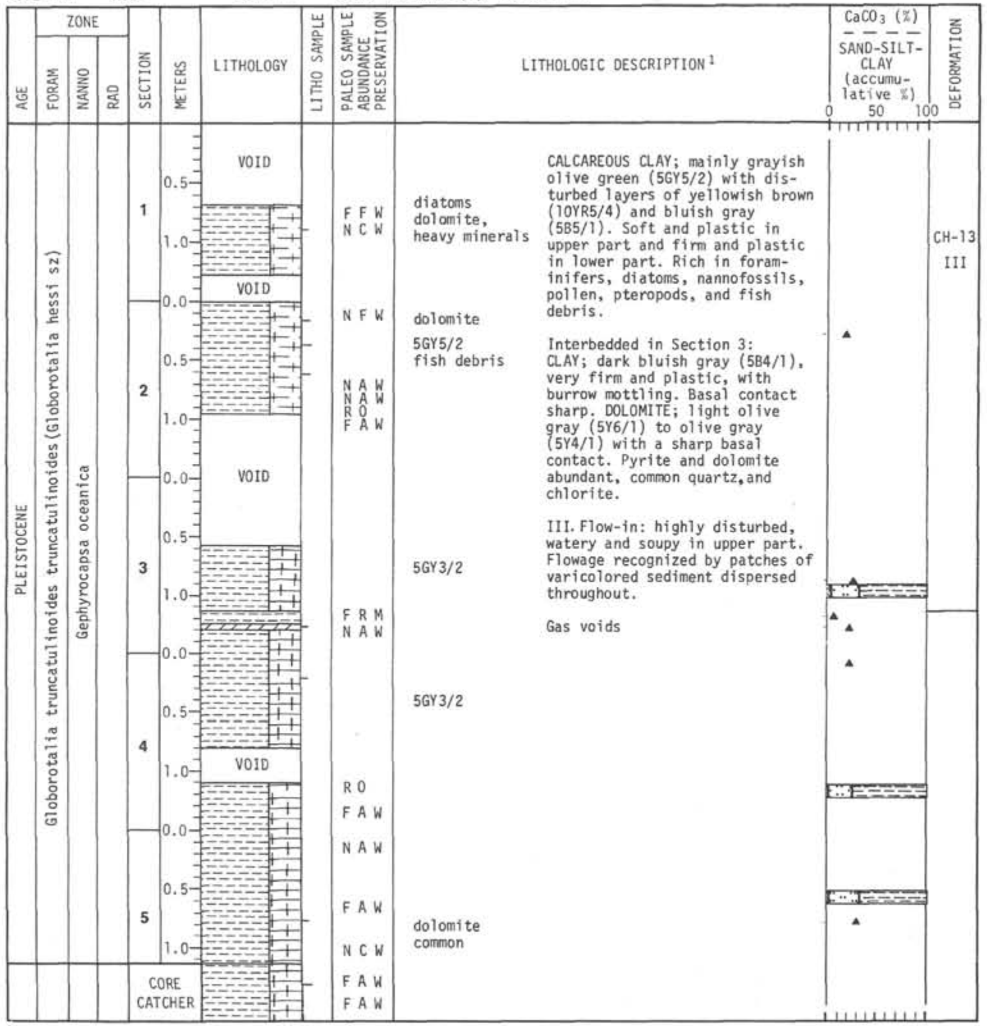
Gas voids

¹For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1349. This background was subtracted from the data.

SITE 147 HOLE CORE 14 CORED INTERVAL (m) 115.0-124.0



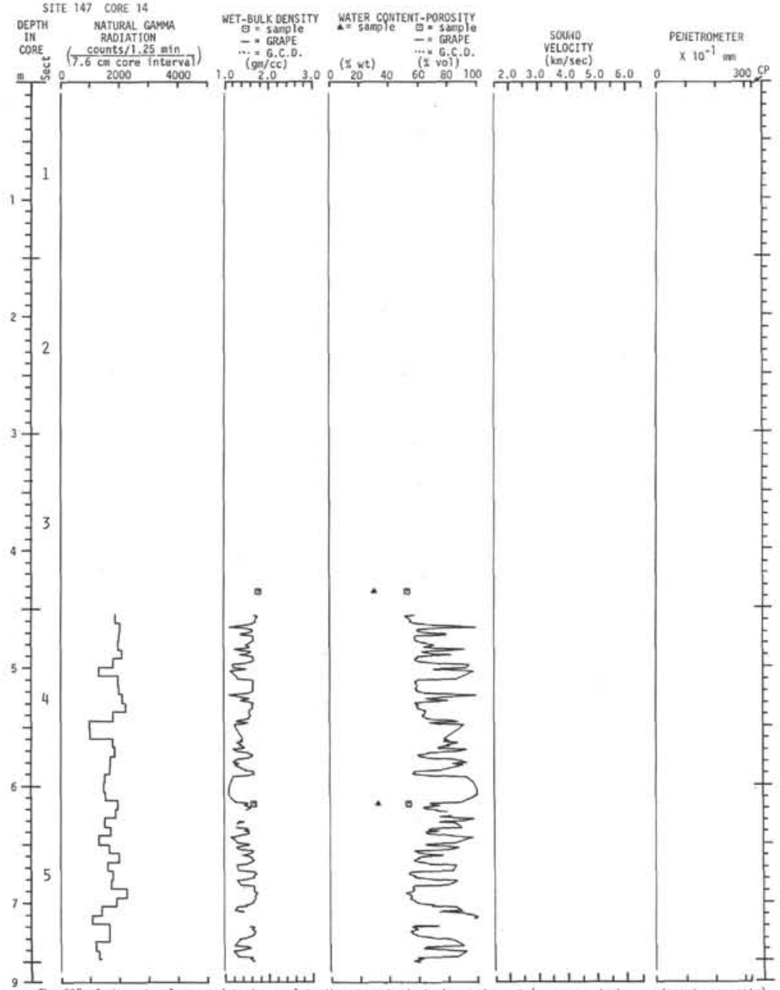
CALCAREOUS CLAY; mainly grayish olive green (5GY5/2) with disturbed layers of yellowish brown (10YR5/4) and bluish gray (5B5/1). Soft and plastic in upper part and firm and plastic in lower part. Rich in foraminifers, diatoms, nannofossils, pollen, pteropods, and fish debris.

Interbedded in Section 3: CLAY; dark bluish gray (5B4/1), very firm and plastic, with burrow mottling. Basal contact sharp. DOLOMITE; light olive gray (5Y6/1) to olive gray (5Y4/1) with a sharp basal contact. Pyrite and dolomite abundant, common quartz, and chlorite.

III. Flow-in: highly disturbed, watery and soupy in upper part. Flowage recognized by patches of varicolored sediment dispersed throughout.

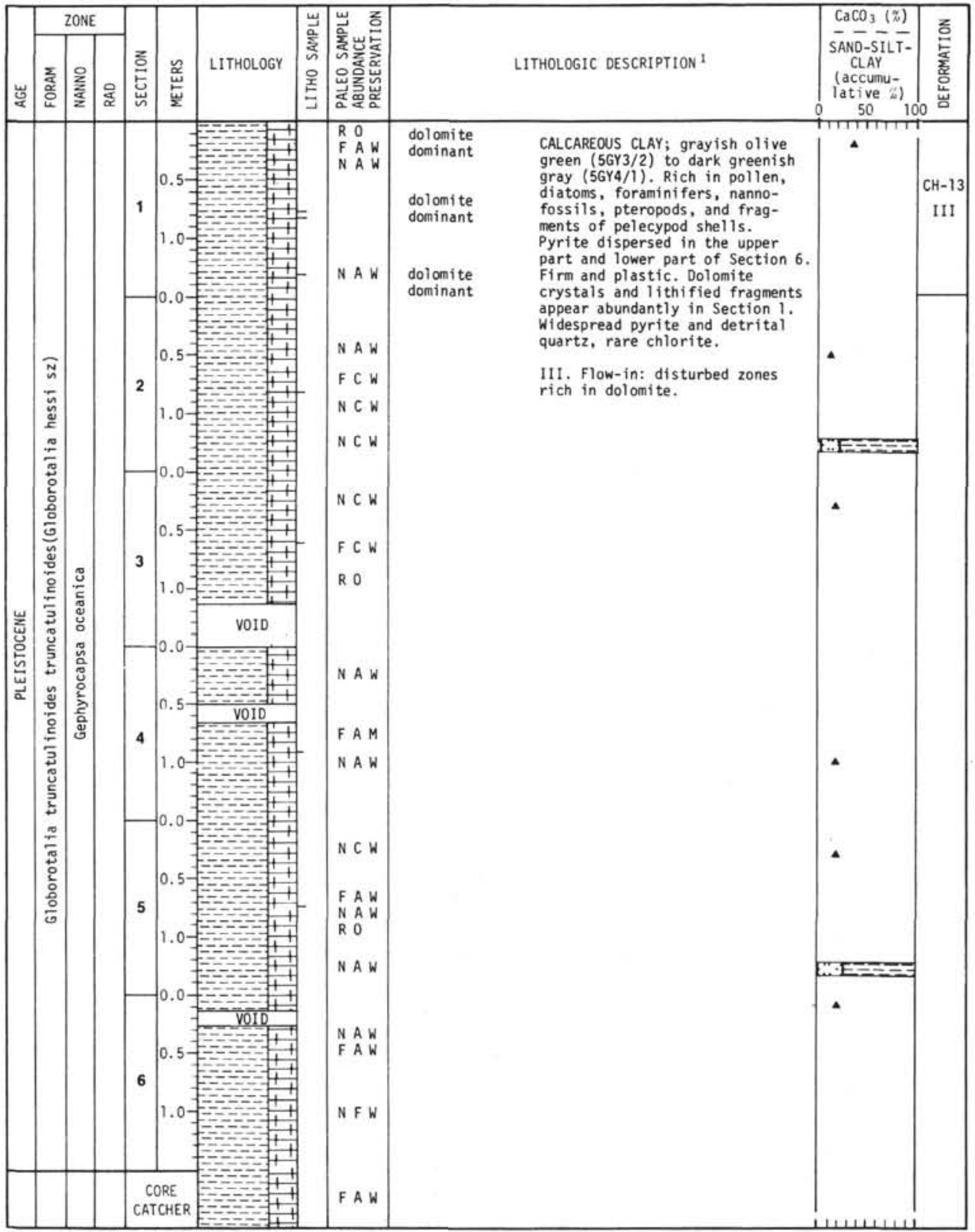
Gas voids

¹For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1349. This background was subtracted from the data.

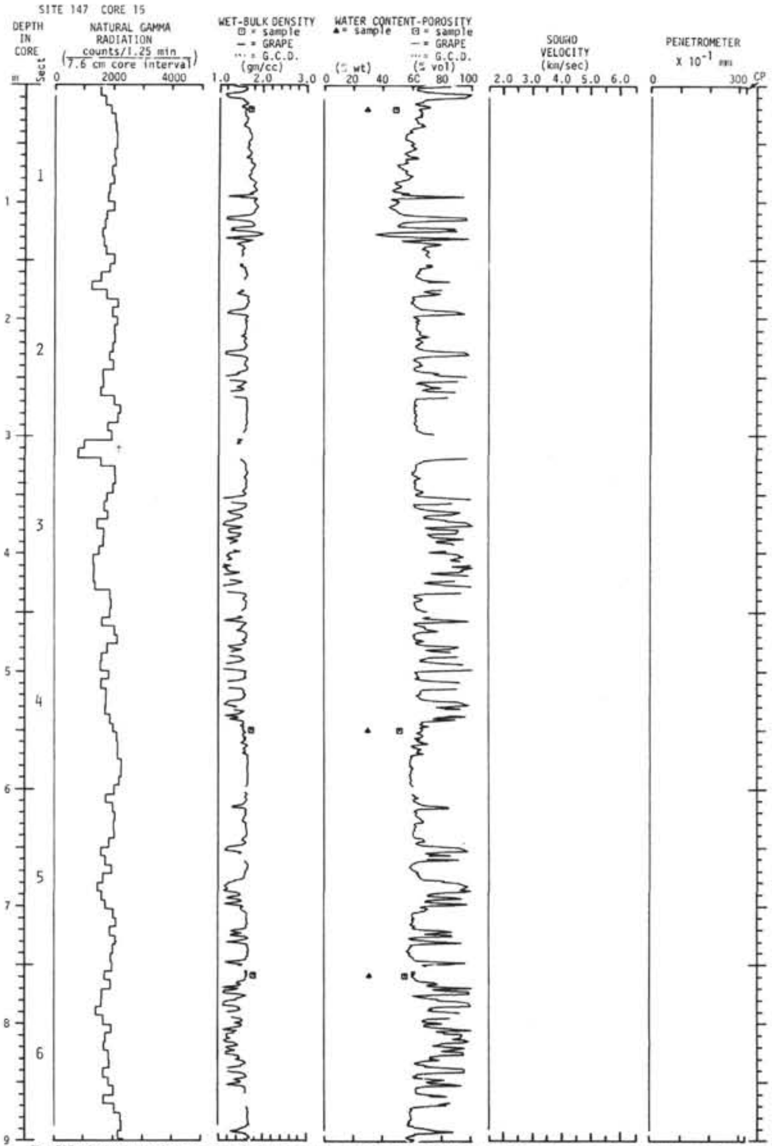
SITE 147 HOLE CORE 15 CORED INTERVAL (m) 124-134



CALCAREOUS CLAY; grayish olive green (5GY3/2) to dark greenish gray (5GY4/1). Rich in pollen, diatoms, foraminifers, nannofossils, pteropods, and fragments of pelecypod shells. Pyrite dispersed in the upper part and lower part of Section 6. Firm and plastic. Dolomite crystals and lithified fragments appear abundantly in Section 1. Widespread pyrite and detrital quartz, rare chlorite.

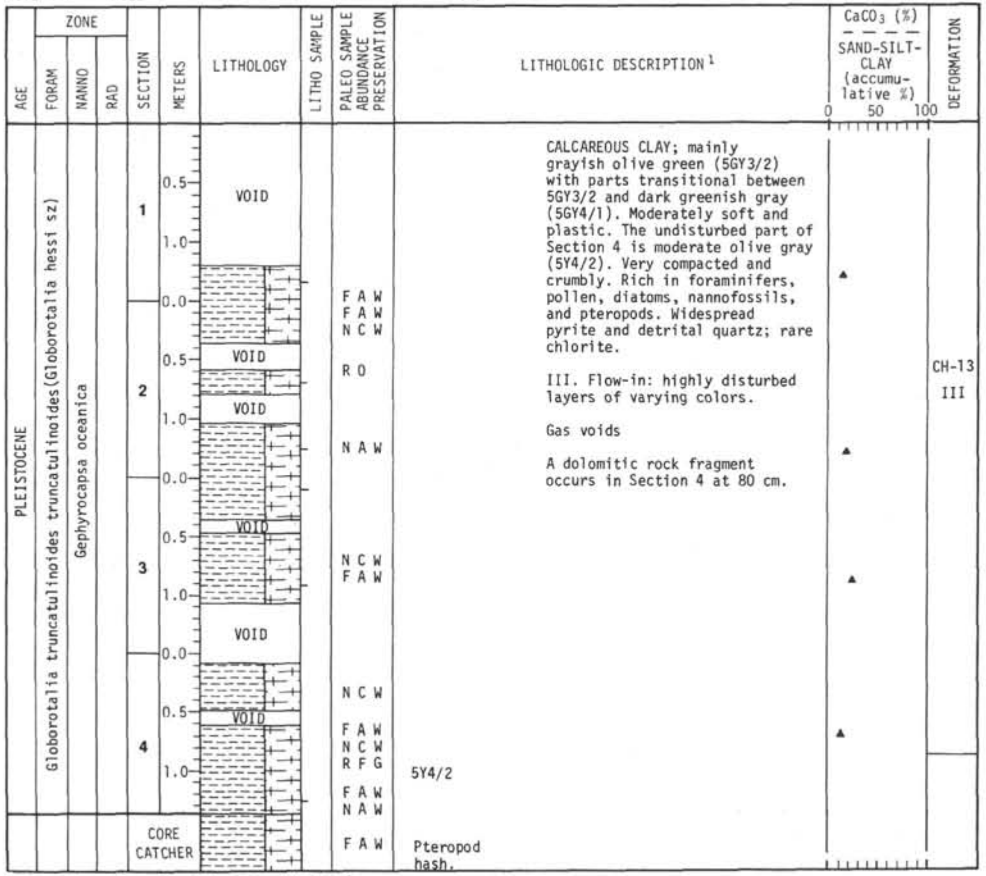
III. Flow-in: disturbed zones rich in dolomite.

¹For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1334. This background was subtracted from the data.

SITE 147 HOLE CORE 16 CORED INTERVAL (m) 134-144



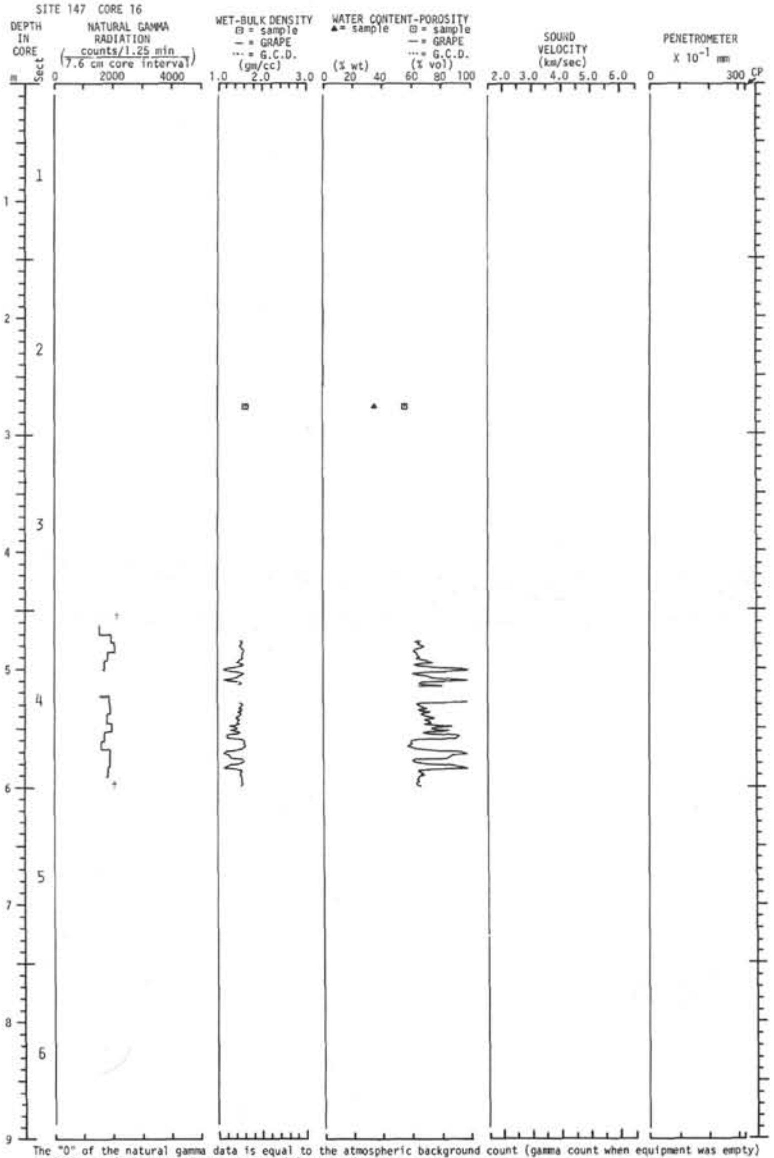
CALCAREOUS CLAY; mainly grayish olive green (5GY3/2) with parts transitional between 5GY3/2 and dark greenish gray (5GY4/1). Moderately soft and plastic. The undisturbed part of Section 4 is moderate olive gray (5Y4/2). Very compacted and crumbly. Rich in foraminifers, pollen, diatoms, nannofossils, and pteropods. Widespread pyrite and detrital quartz; rare chlorite.

III. Flow-in: highly disturbed layers of varying colors.

Gas voids

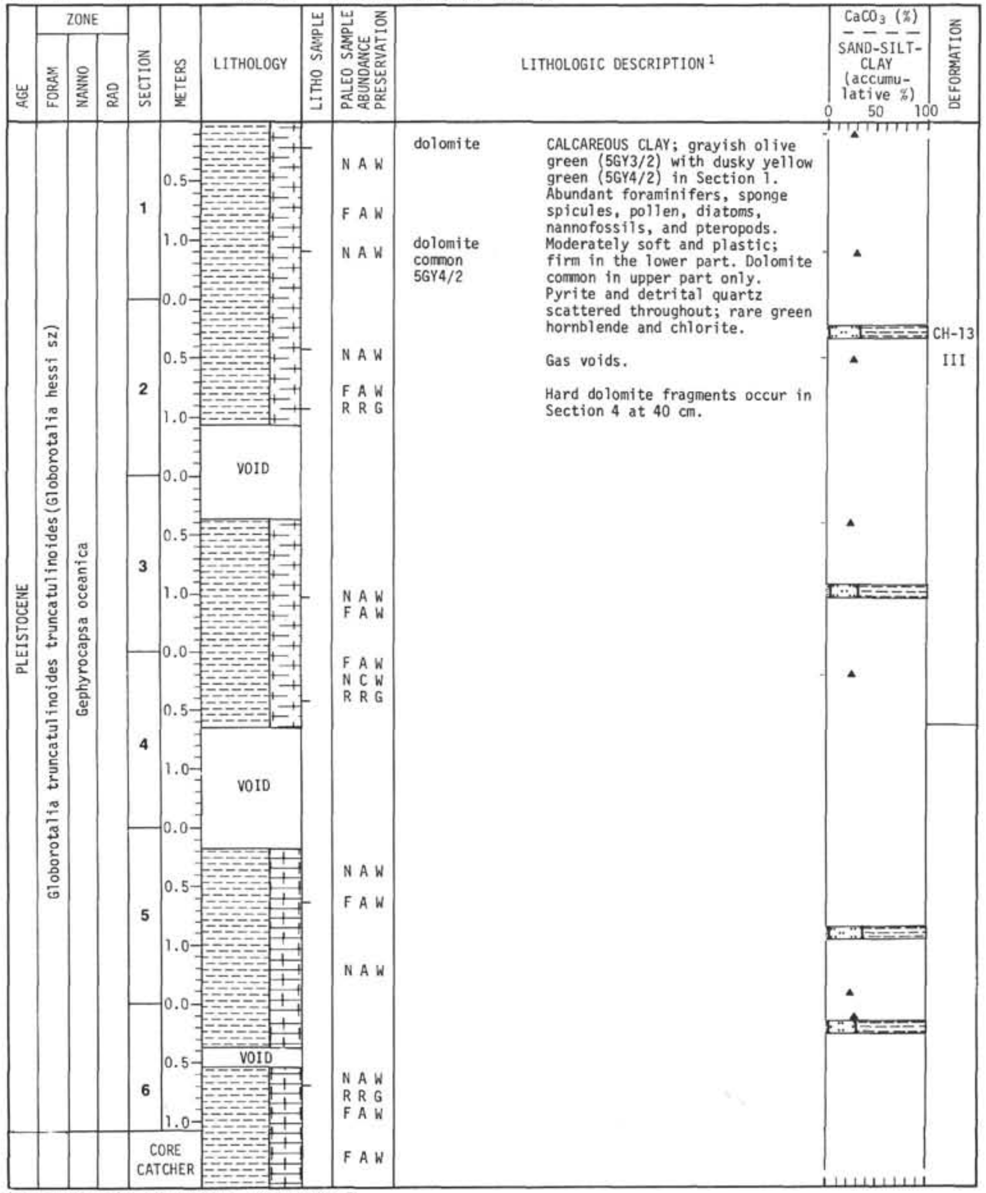
A dolomitic rock fragment occurs in Section 4 at 80 cm.

[1] For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1327. This background was subtracted from the data.

SITE 147 HOLE CORE 17 CORED INTERVAL (m) 144-153



dolomite

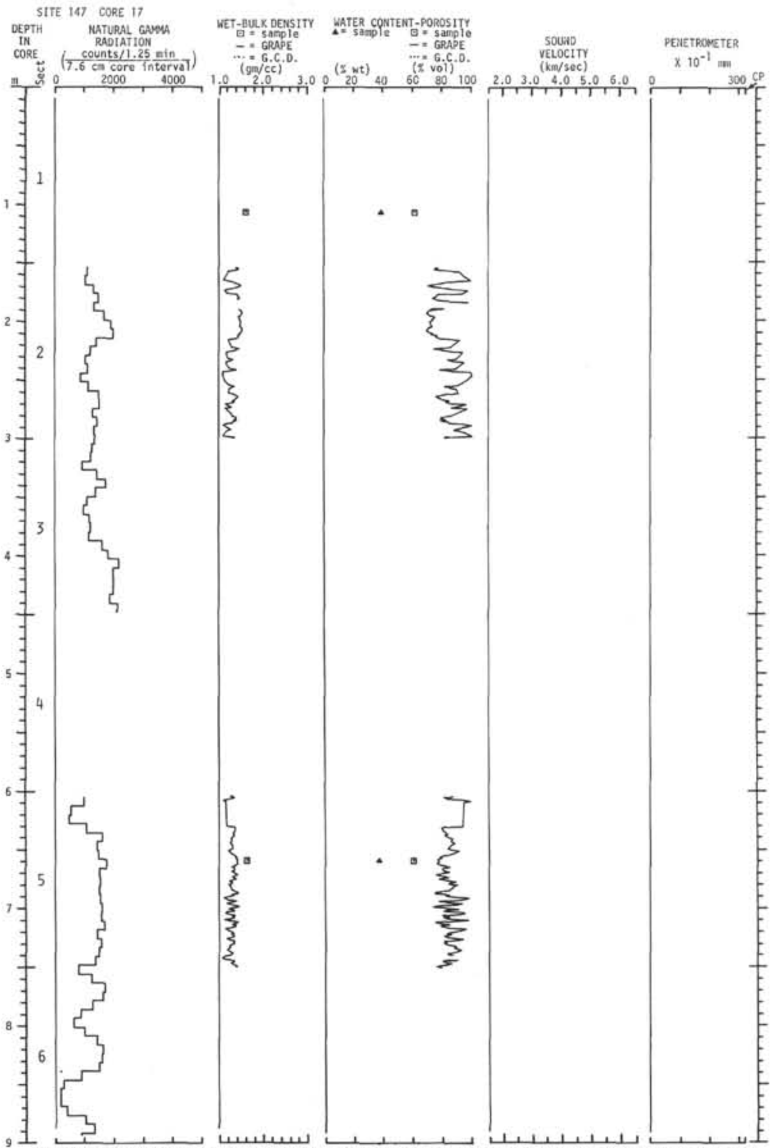
dolomite common 5GY4/2

CALCAREOUS CLAY; grayish olive green (5GY3/2) with dusky yellow green (5GY4/2) in Section 1. Abundant foraminifers, sponge spicules, pollen, diatoms, nannofossils, and pteropods. Moderately soft and plastic; firm in the lower part. Dolomite common in upper part only. Pyrite and detrital quartz scattered throughout; rare green hornblende and chlorite.

Gas voids.

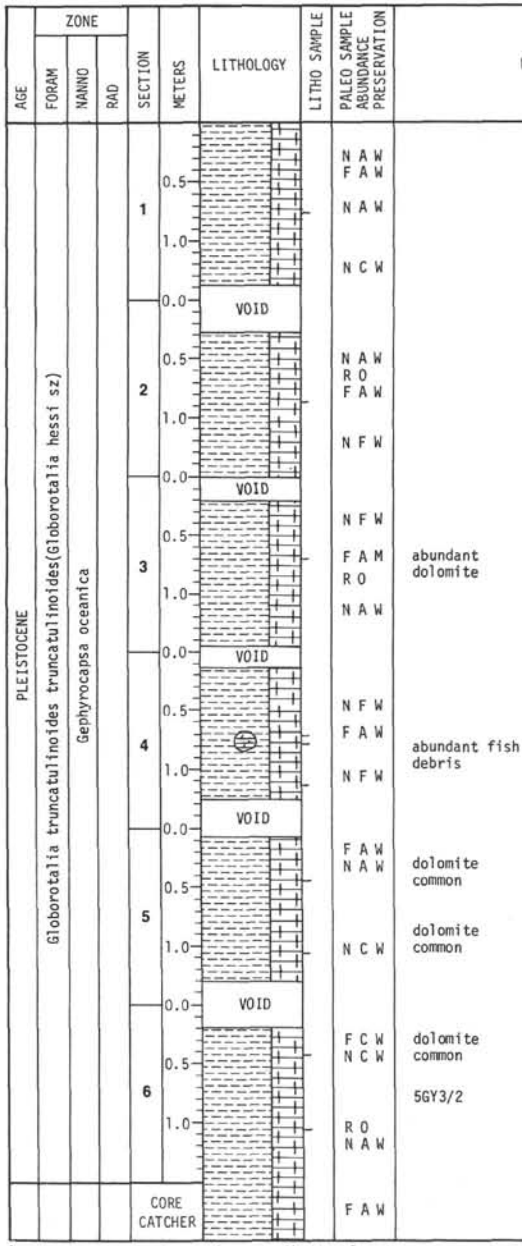
Hard dolomite fragments occur in Section 4 at 40 cm.

¹For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1327. This background was subtracted from the data.

SITE 147 HOLE CORE 18 CORED INTERVAL (m) 152-162 m



LITHOLOGIC DESCRIPTION[1]

CALCAREOUS CLAY; grayish olive green (5GY3/2) and dark greenish gray (5GY5/1). Abundant foraminifers, sponge spicules, nannofossils, pollen, and pteropods. Very firm and plastic, becoming slightly crumbly downward. Hydrotroilite blotches occur throughout. Dolomite, pyrite, and detrital quartz abundant throughout; rare feldspars and chlorite.

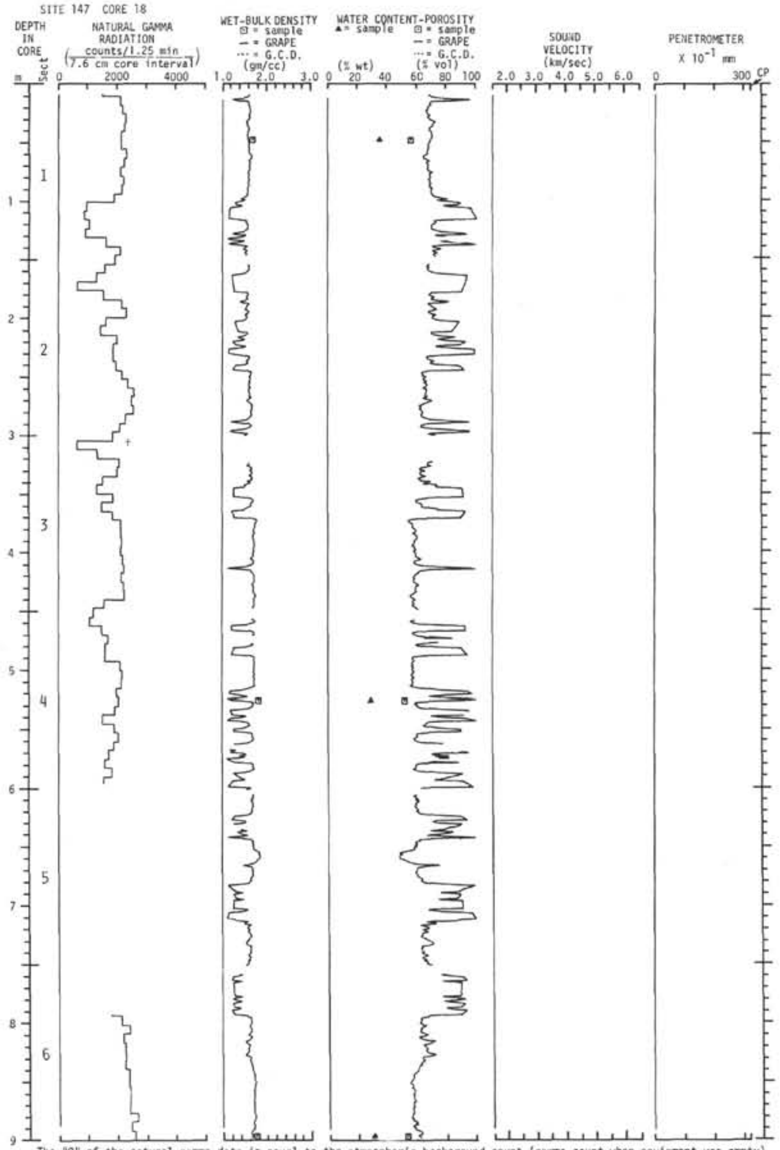
Hard, pyrite-rich dolomitic rock fragments occur in Section 4 at 70 cm.

Broken pelecypod shells occur in Section 5 at 80 cm as does a pyritized wood frament.

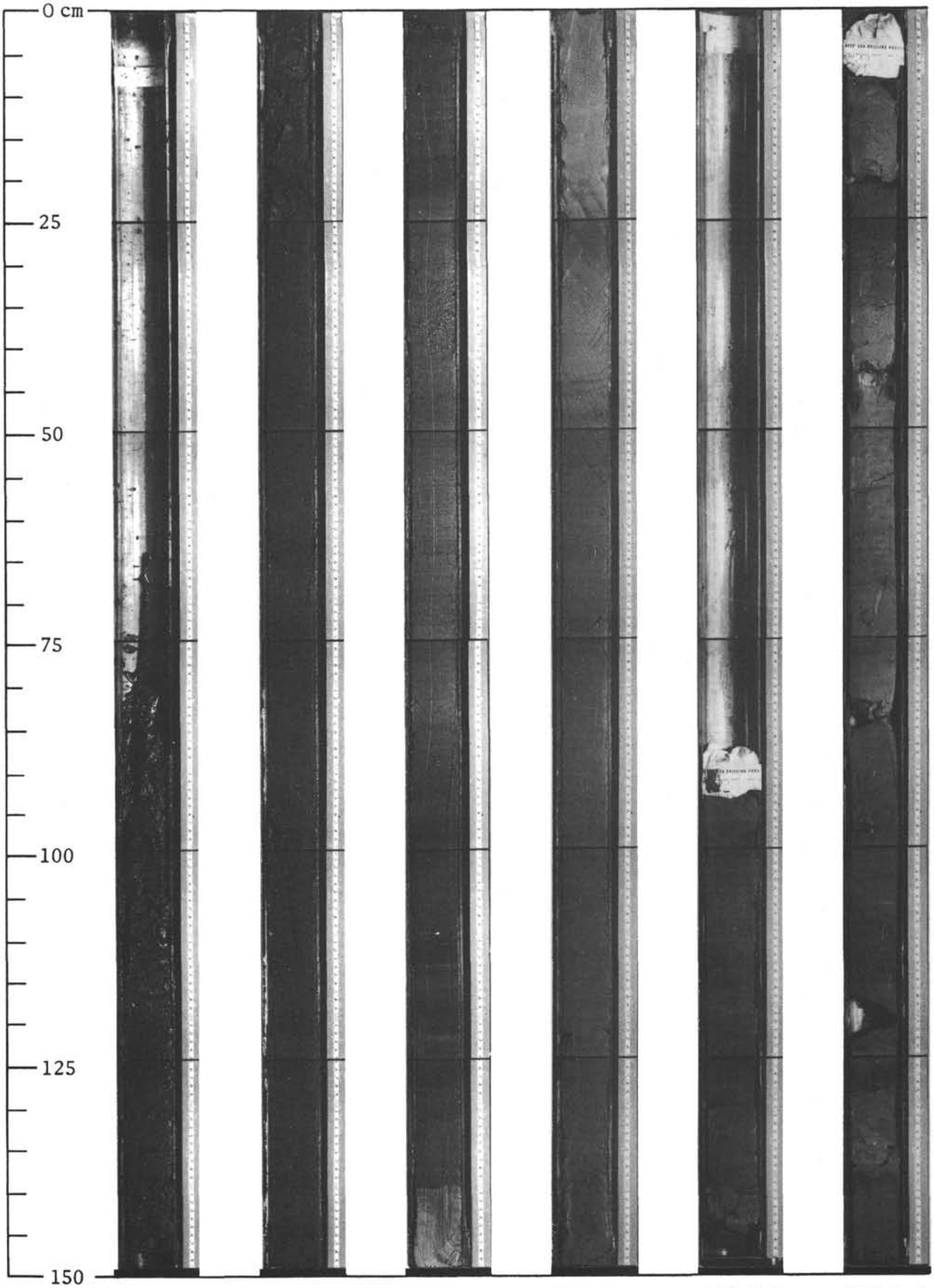
X-ray diffraction results, Section 1, 117-119 cm:

Amorphous Scattering	64%
Calcite	28%
Dolomite	1%
Quartz	23%
Plagioclase	2%
Kaolinite	8%
Mica	30%
Chlorite	2%
Pyrite	6%

[1]For explanation of symbols, see Chapter 1



The "0" of the natural gamma data is equal to the atmospheric background count (gamma count when equipment was empty) of 1348. This background was subtracted from the data.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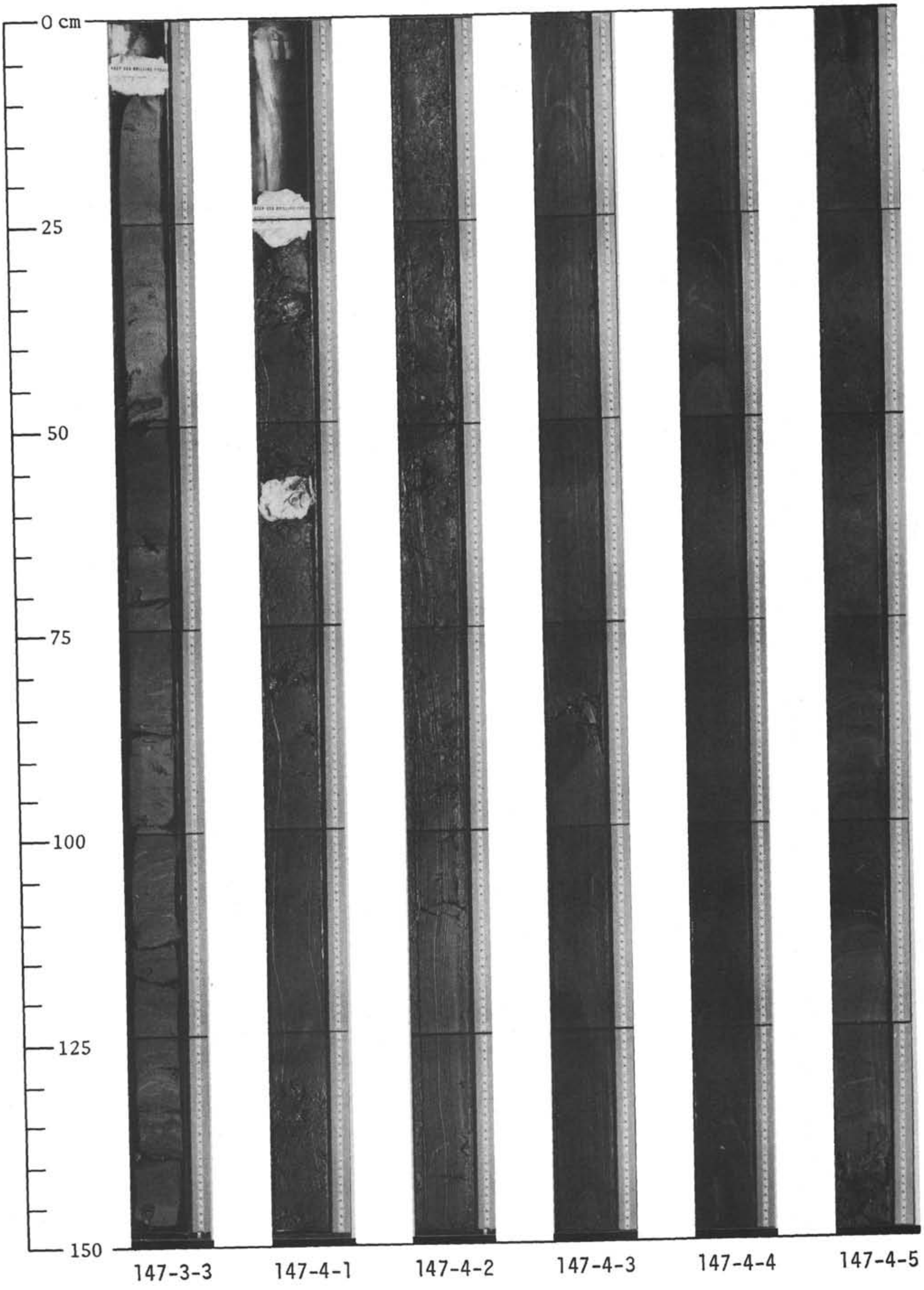
147-2-2
147-2-3
147-2-4
147-3-1
147-3-2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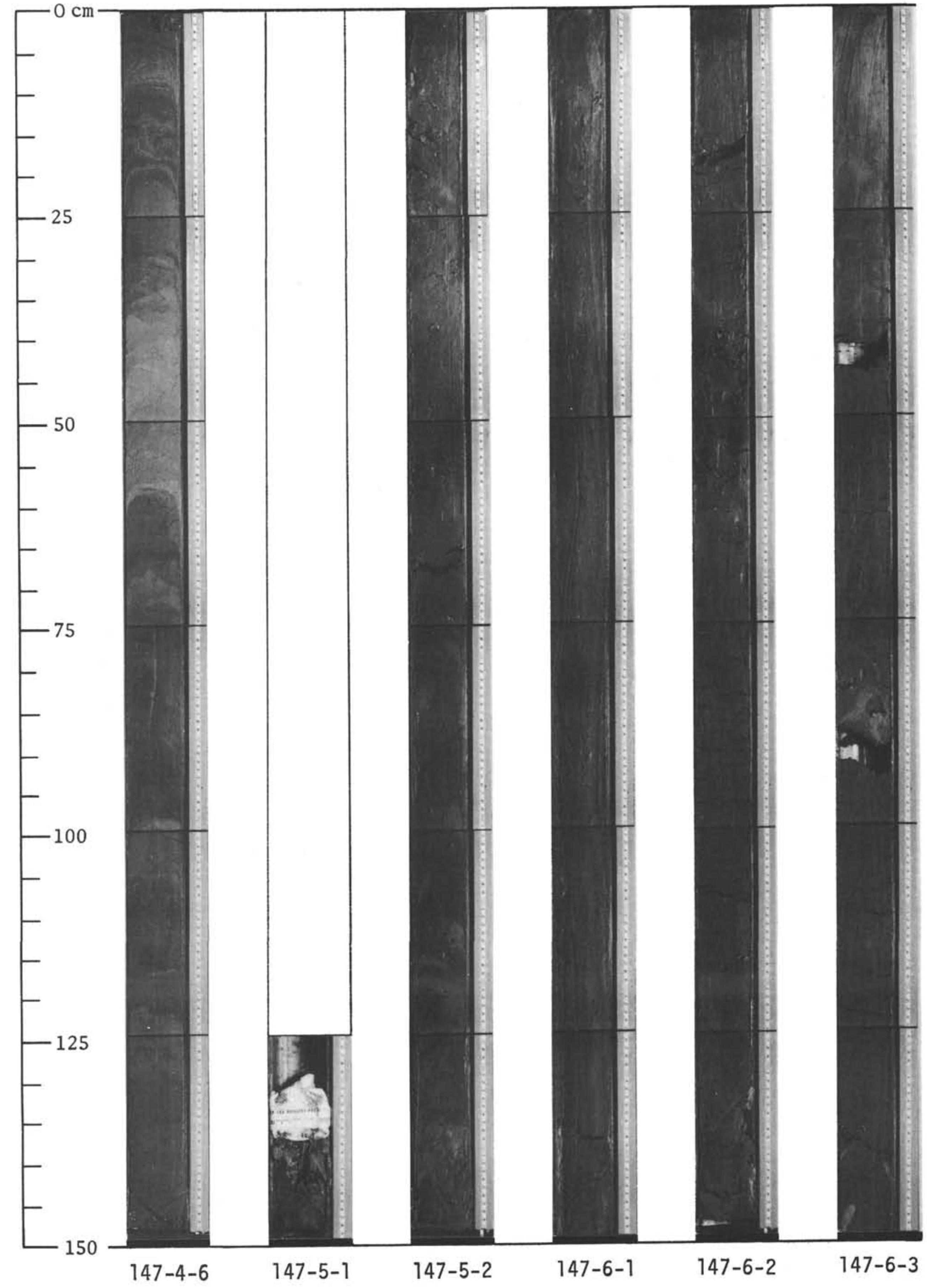
147-4-3
147-4-4
147-4-5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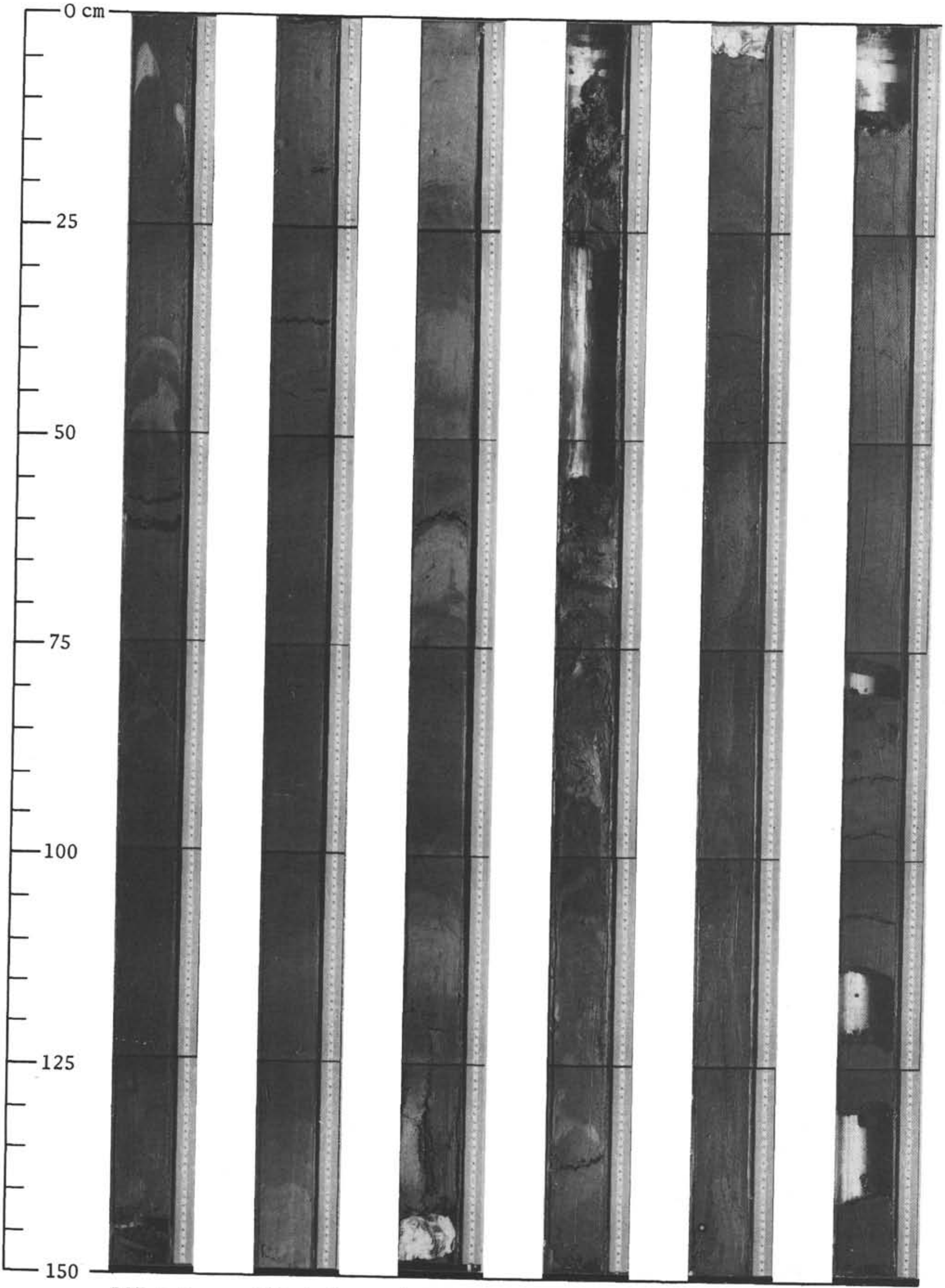
147-5-1
147-5-2
147-6-1
147-6-2
147-6-3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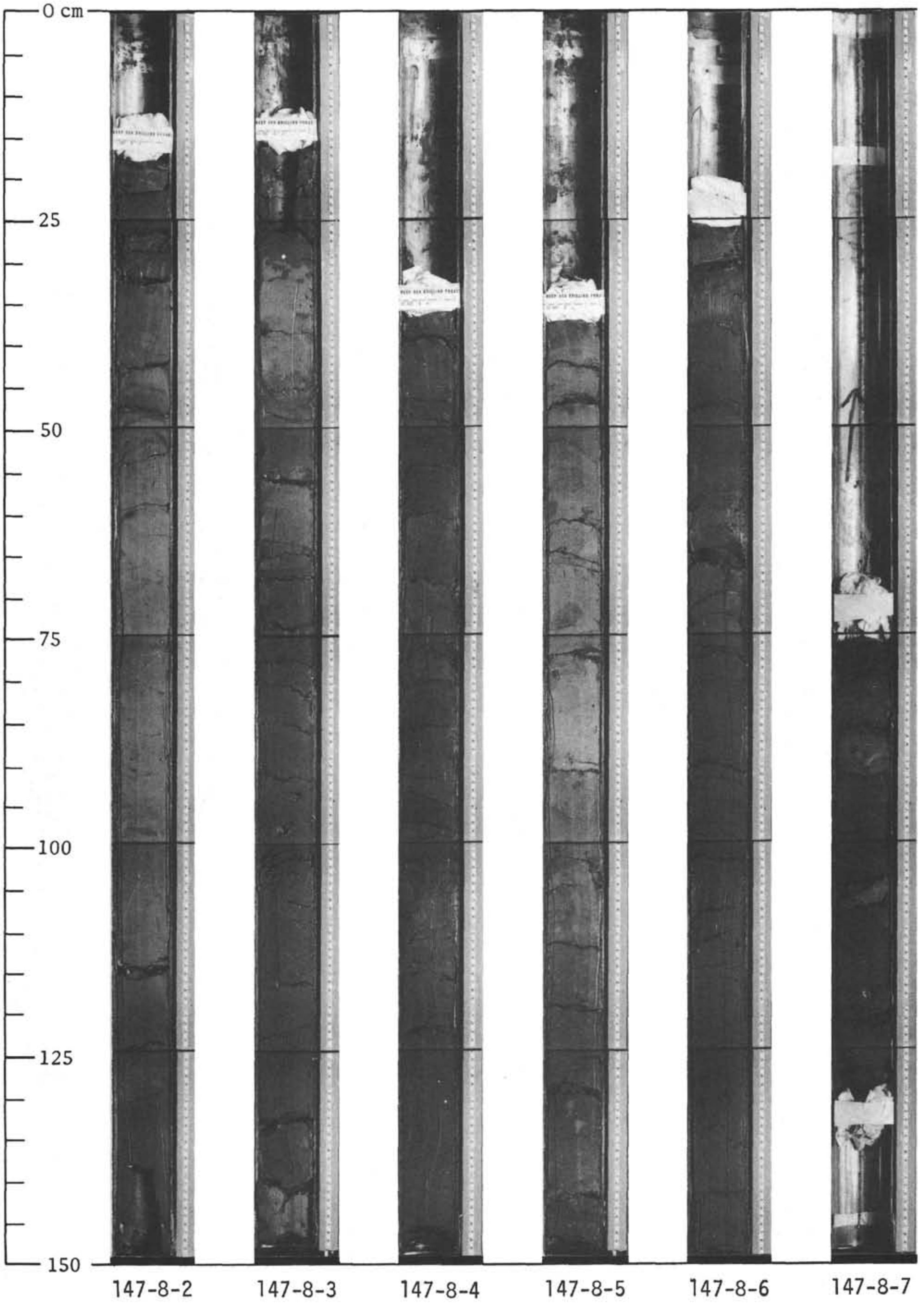
147-8-1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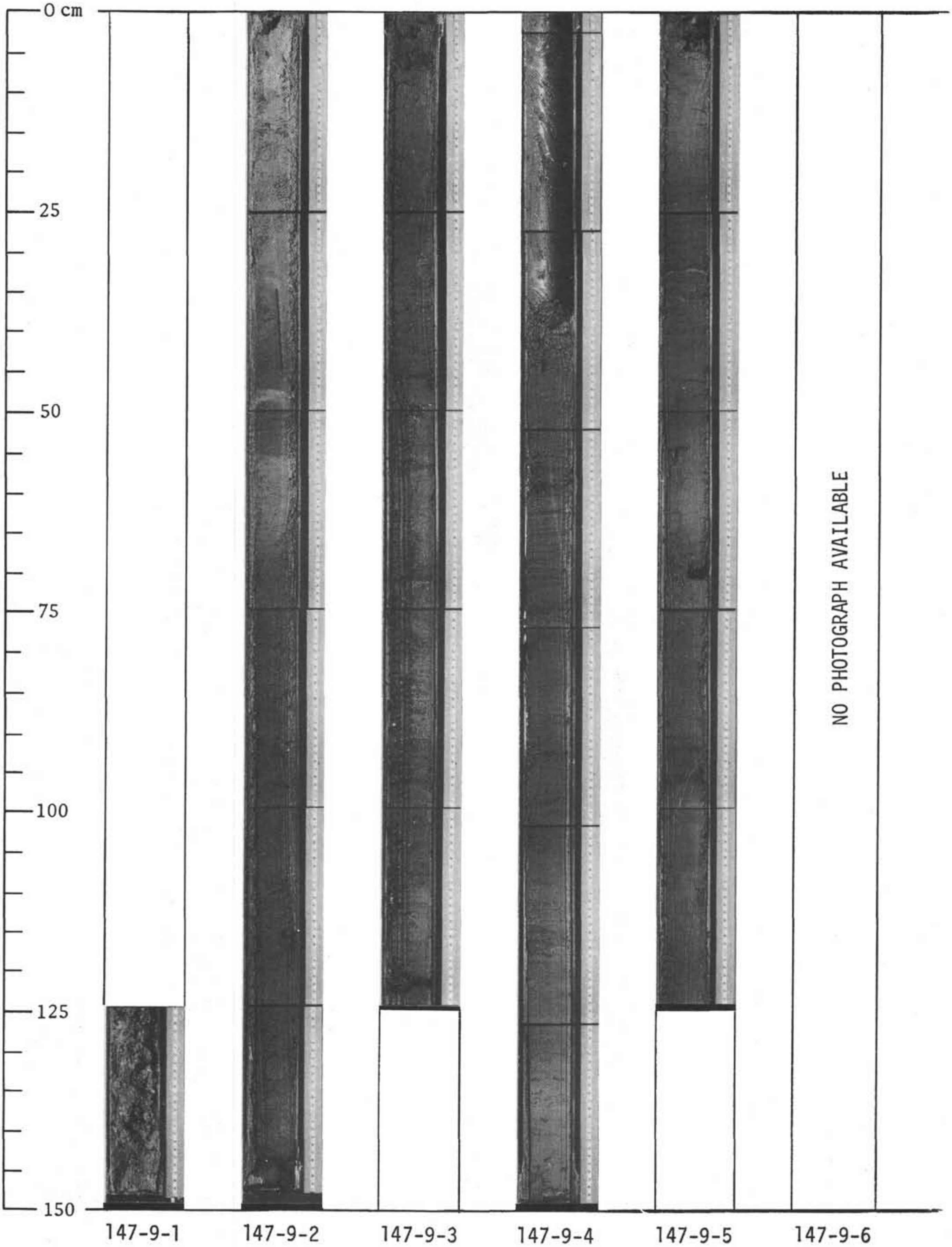
147-8-7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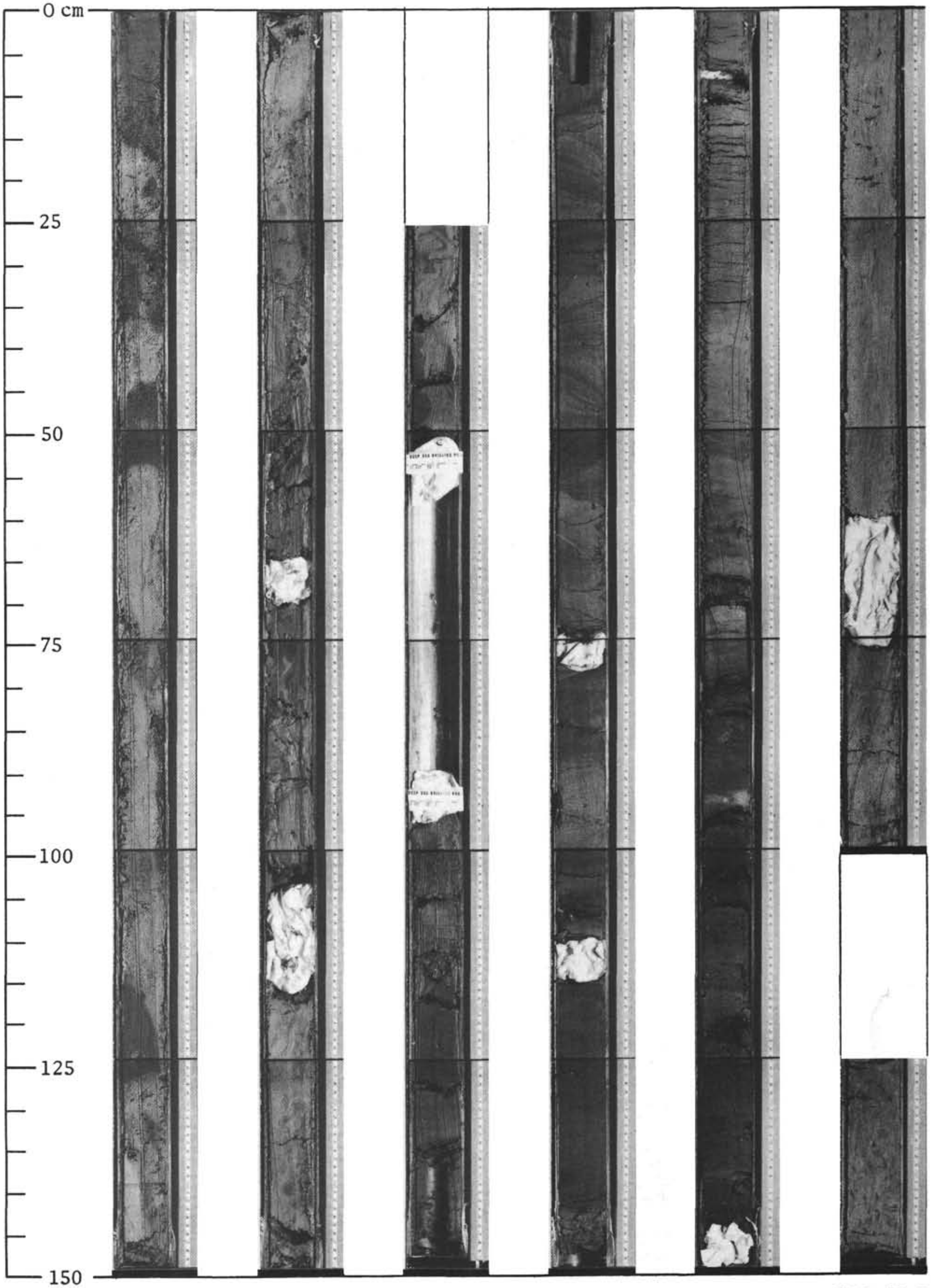
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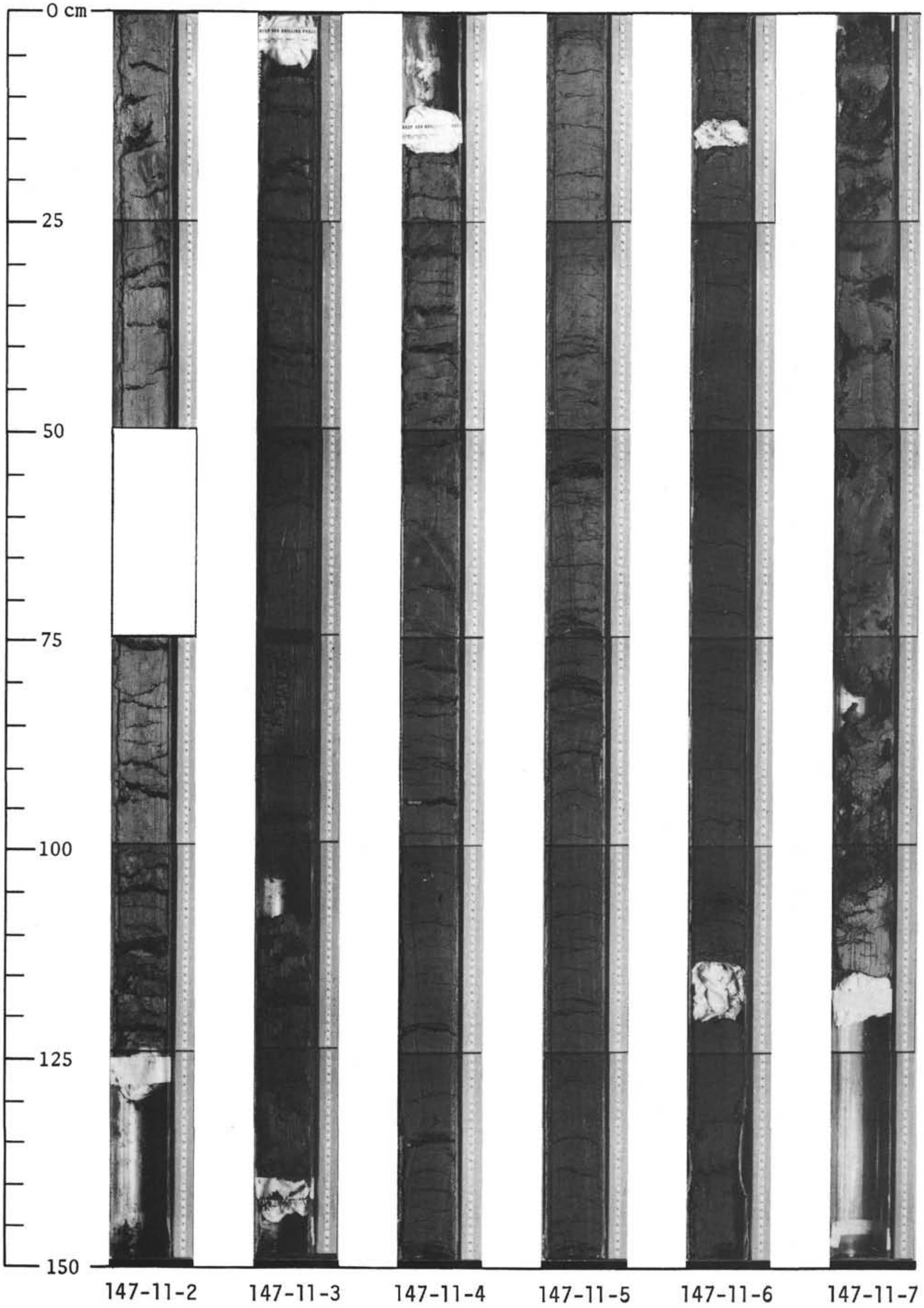
147-11-1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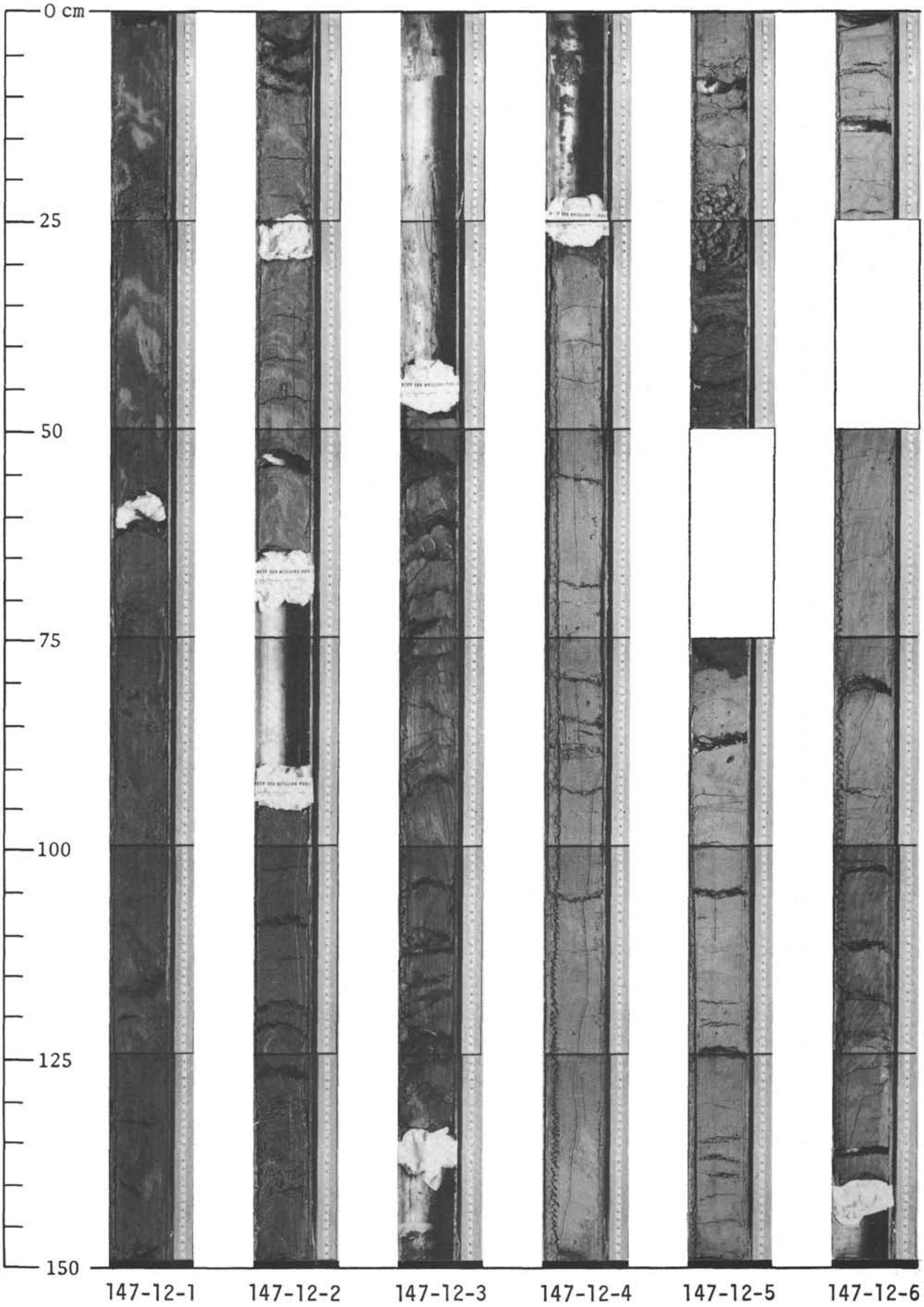
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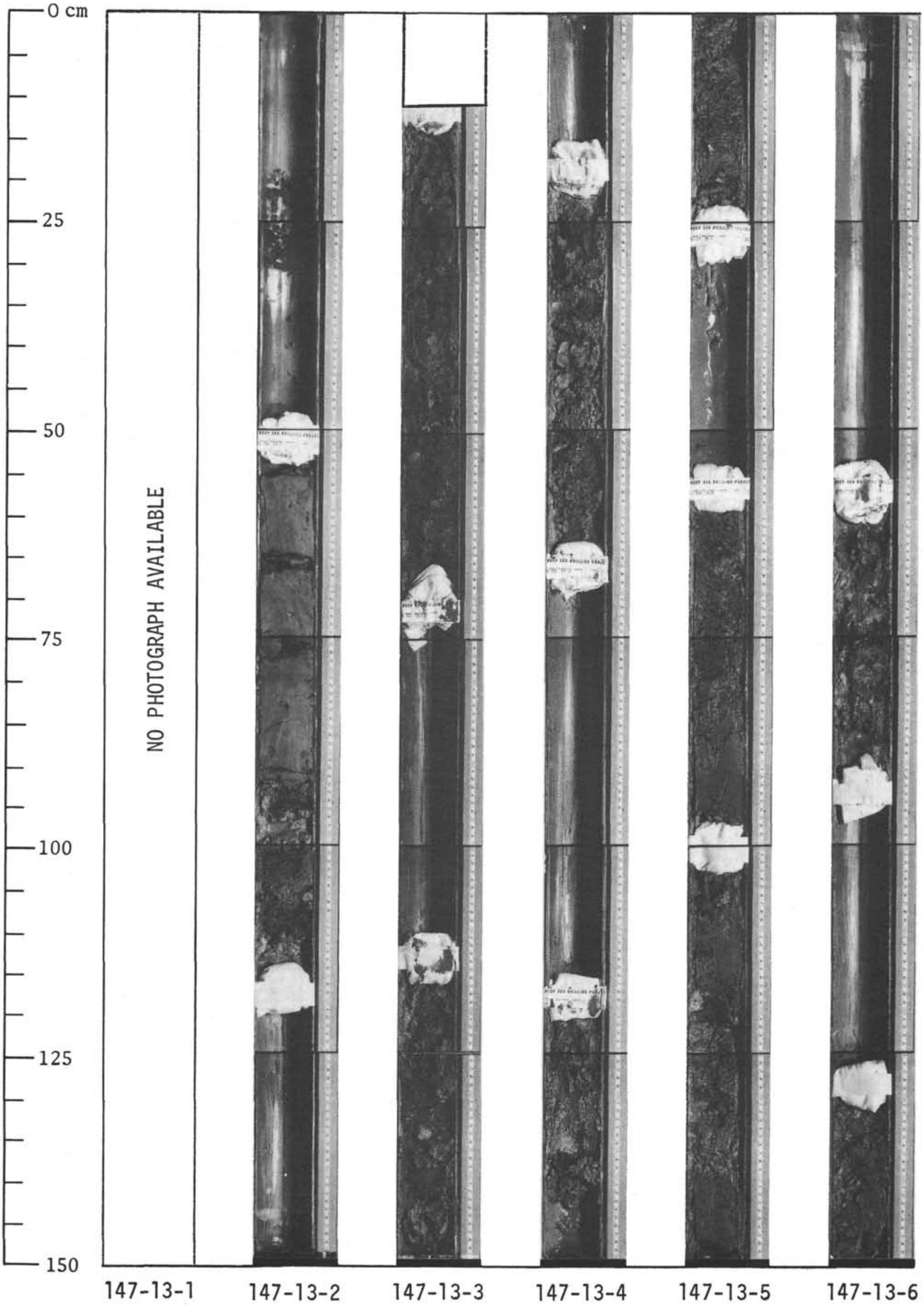
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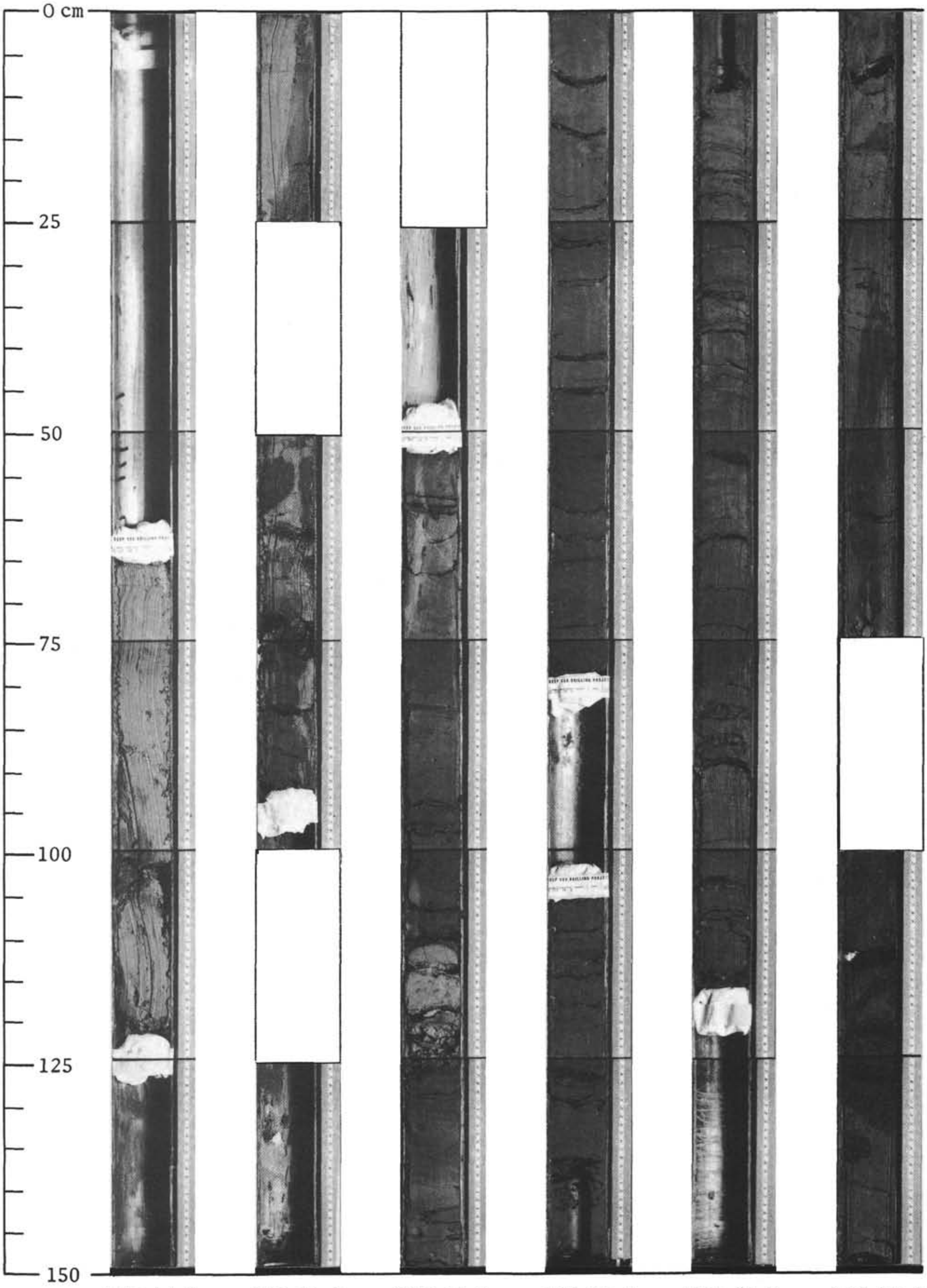
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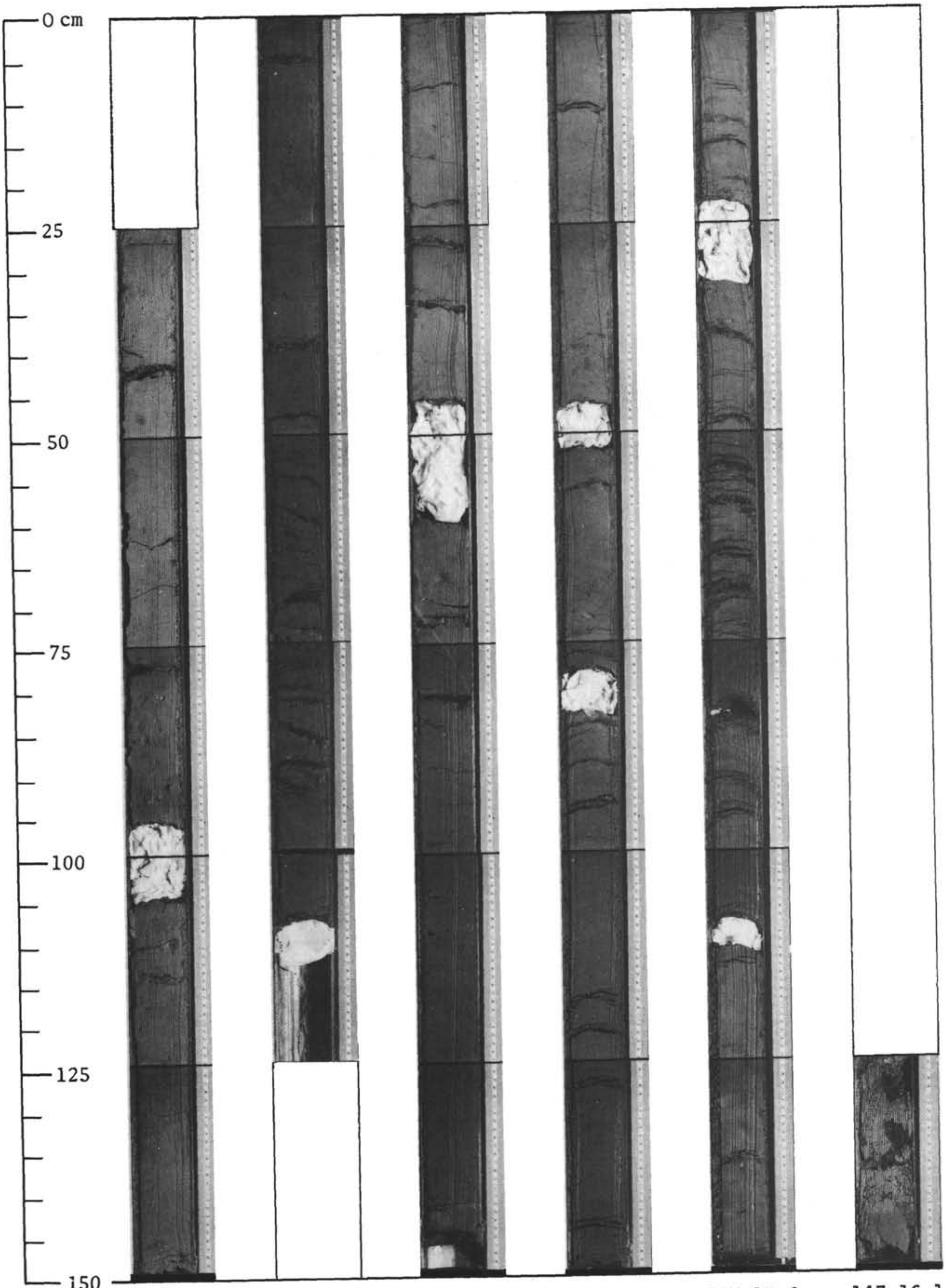
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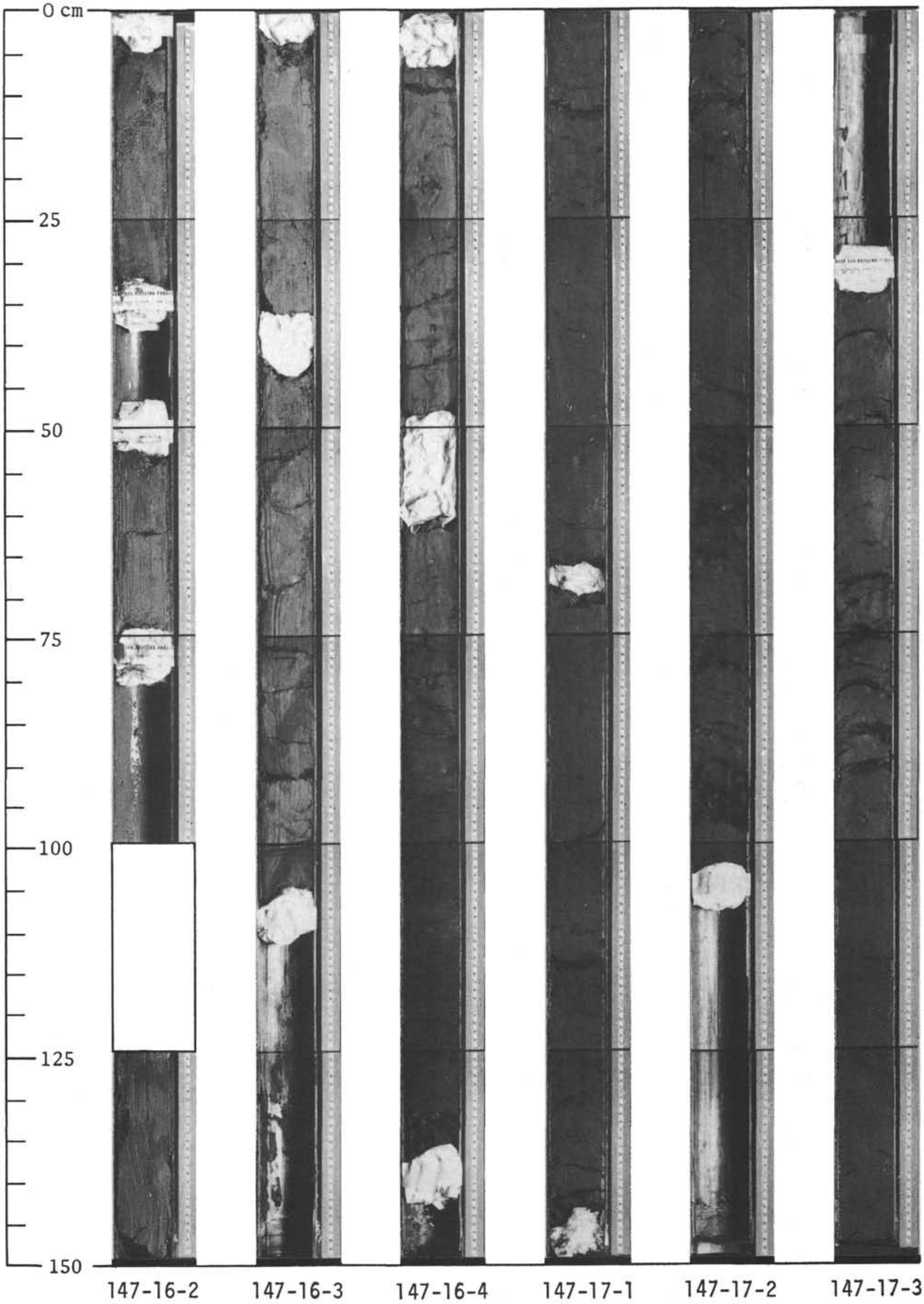
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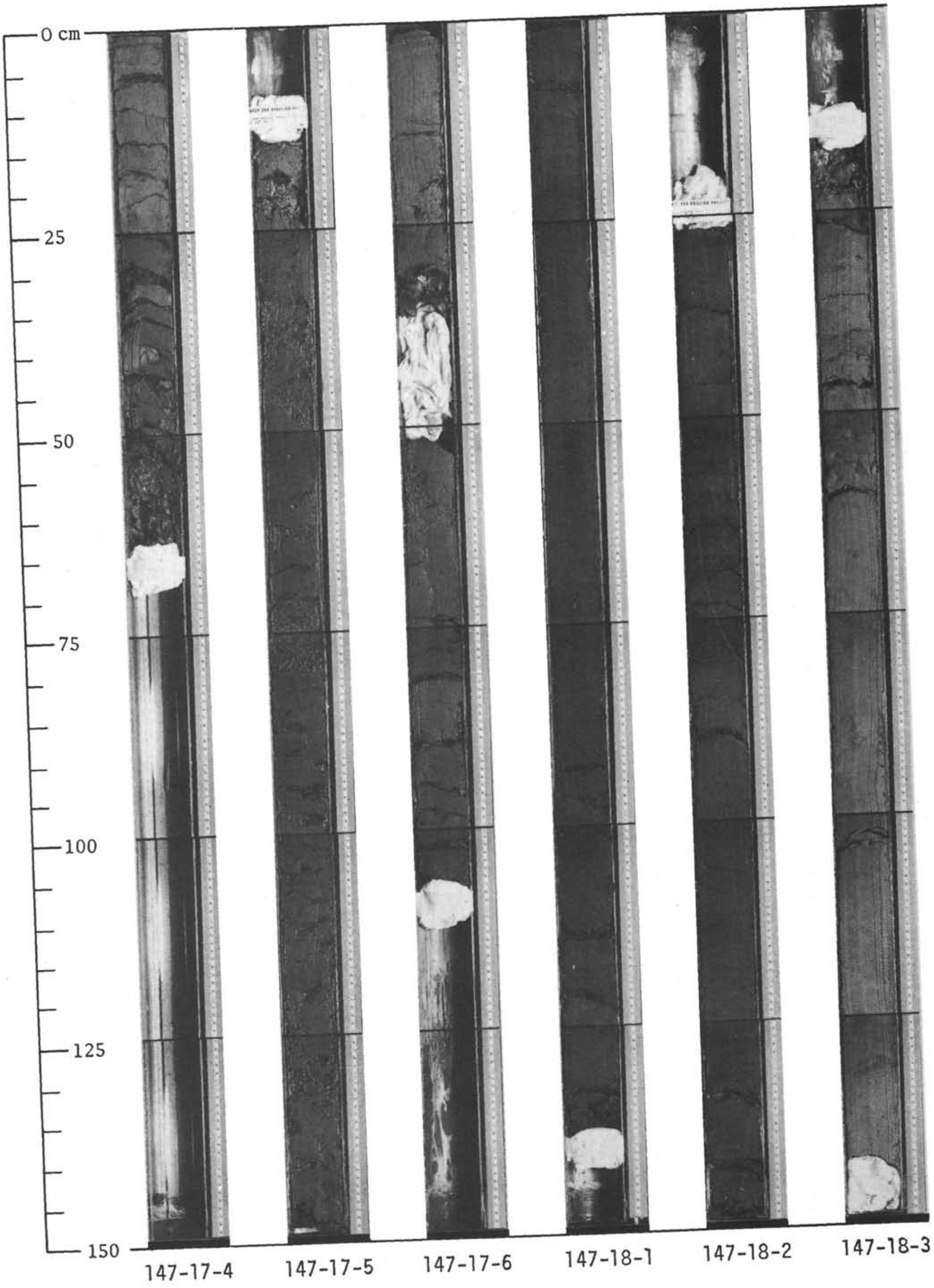
147-17-1
147-17-2
147-17-3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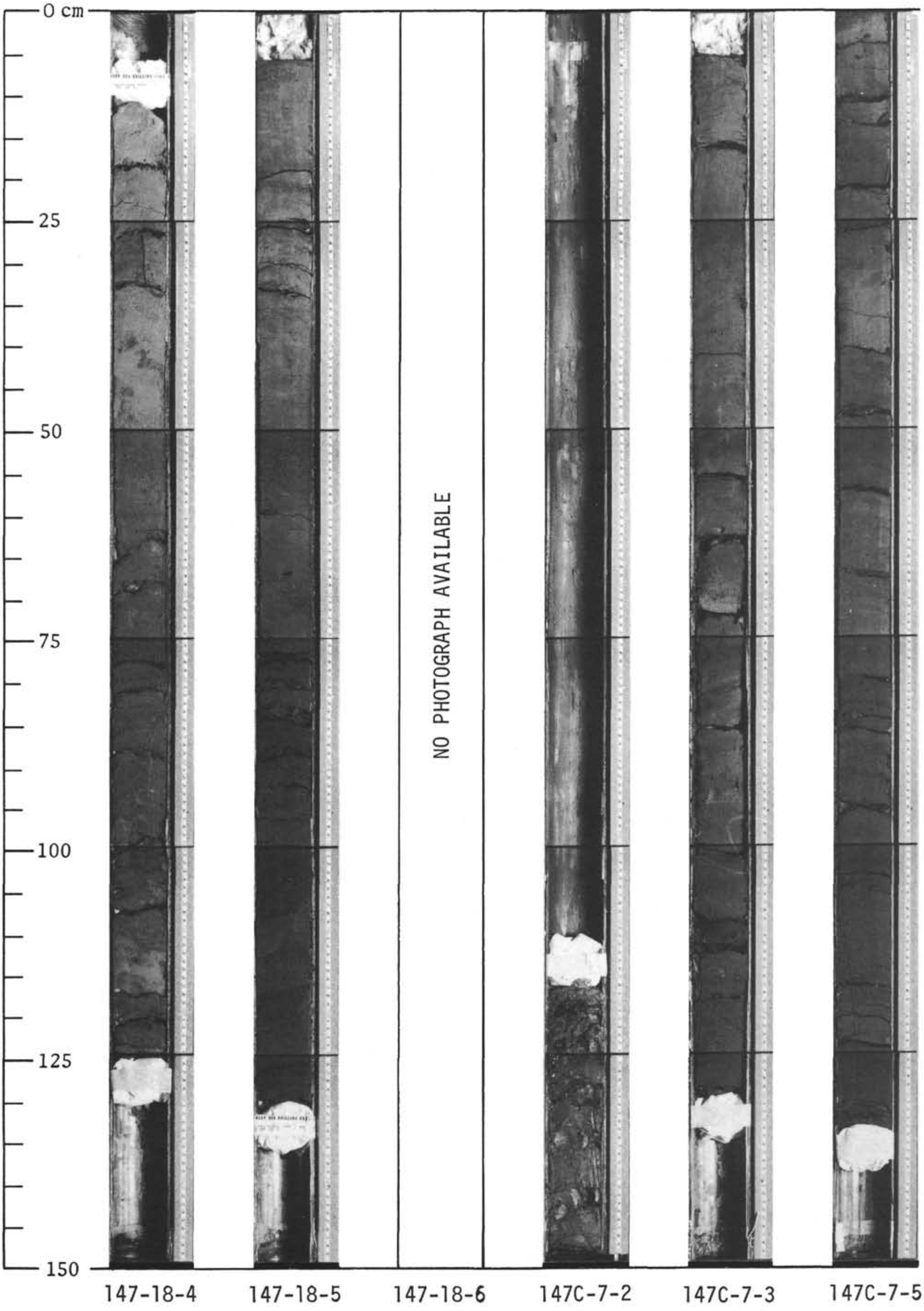
147-18-3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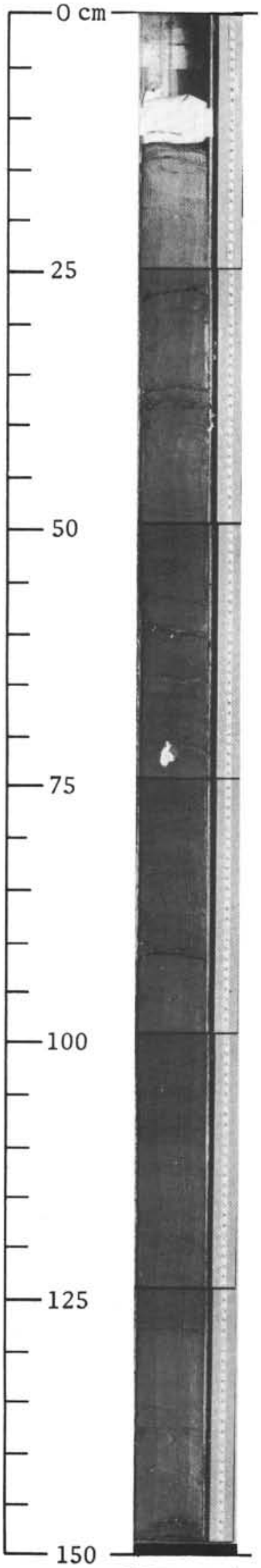

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