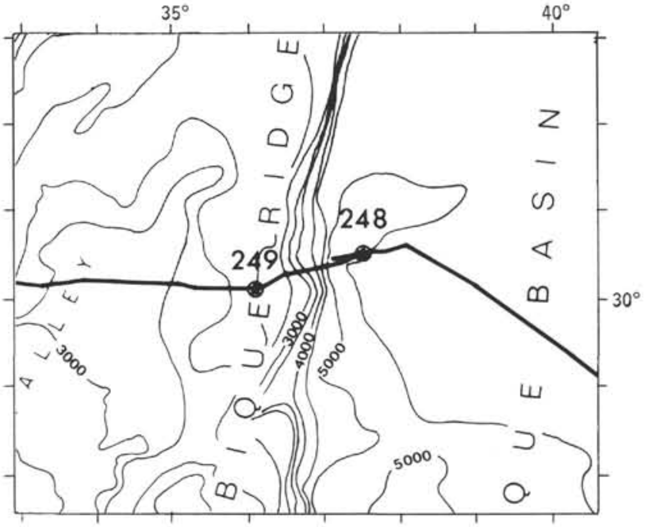
10. SITE 249

The Shipboard Scientific Party[1]

SITE DATA



Location: Mozambique Ridge

Position: 29°56.99′S, 36°04.62′E

Water Depth: 2088 meters

Total Penetration: 412 meters

Cores: 33 cores (285 m cut, 221.4 m recovered)

Deepest Unit Recovered: Basalt

BACKGROUND AND OBJECTIVES

One of the characteristics of the Indian Ocean which serves to distinguish it from the Atlantic and Pacific oceans is the abundance of aseismic, relatively shallow, flat-topped, often sediment-covered and steep-sided ridge- or plateau-like morphological features which have been termed "microcontinents" by Heezen and Tharp (1965) and "oceanic ridges" by Udintsev (1965),

The limited geological and geophysical data available suggest that these features may represent more than one type of crustal structure and composition, and Laughton, Matthews, and Fisher (1970) have proposed the following provisional classification of the Indian Ocean aseismic ridges and plateaus. (Those marked with an asterisk are located in the western part of the Indian Ocean between Africa and the seismically active mid-ocean ridge.)

Continental in origin: *Seamount chain southeast of Socotra, *north part of Mascarene Plateau, *Mozambique Ridge, *Madagascar Ridge, *Agulhas Plateau, Crozet Plateau (?), Kerguelen Plateau (?), Broken Plateau (?), Naturaliste Plateau (?), Wallaby Plateau (?).

Linear volcanic features: Chagos-Laccadive Ridge, *south part of Mascarene Plateau.

Uplifted oceanic crust: Ninetyeast Ridge.

Several attempts have been made to drill three of these features (Leg 22: Sites 214, 216, 217; Leg 26: Sites 253, 254 on the Ninetyeast Ridge; Leg 23: Site 219 on the Laccadive-Maldive Ridge; and Leg 24: Site 237 on the Mascarene Plateau).

Flexotir reflection data obtained by Schlich et al. (1971) on the Kerguelen-Heard Plateau suggest a possible continental structure for this feature.

Some of the microcontinents (e.g., the Seychelles Bank at the northern end of the Mascarene Plateau) are evidently at least partly granitic, and gravity measurements show them to be in isostatic equilibrium, hence crustal thickness varies inversely with depth below sea level. It has been suggested (Francis and Raitt, 1967) that such microcontinents represent the result of crustal stretching and thinning before fracture during the initial stages of continental separation. More evidence relating to microcontinental basement composition and age and history of their vertical movements is clearly necessary to throw some light on the problem. The Mozambique and Madagascar ridges are obvious sites for deep-sea drilling with this major objective.

Figure 1 shows that both the Madagascar and Mozambique ridges are 1000 to 2000 meters deep and trend southward continuously from Madagascar and the "Mozambique bulge" of southeastern Africa, respectively. Both are shallowest (<1000 and 20 m, respectively) near the southern end, and both terminate abruptly with bold squared-off bluffs at about 35°S. They are separated by the 5000-meter-deep, 300-mile-wide Mozambique Basin, towards which they are bounded by steep scarps. By contrast, the eastern flank of the Madagascar Ridge slopes gently down to the southern Madagascar Basin, while the western flank of the Mozambique Ridge follows a gradual descent into the Natal Valley, which separates the southern part of the ridge from the steep continental margin of southeastern Africa. The gross morphological features described above are strongly suggestive of very large-scale vertical block-faulting and tilting. The deep Mozambique

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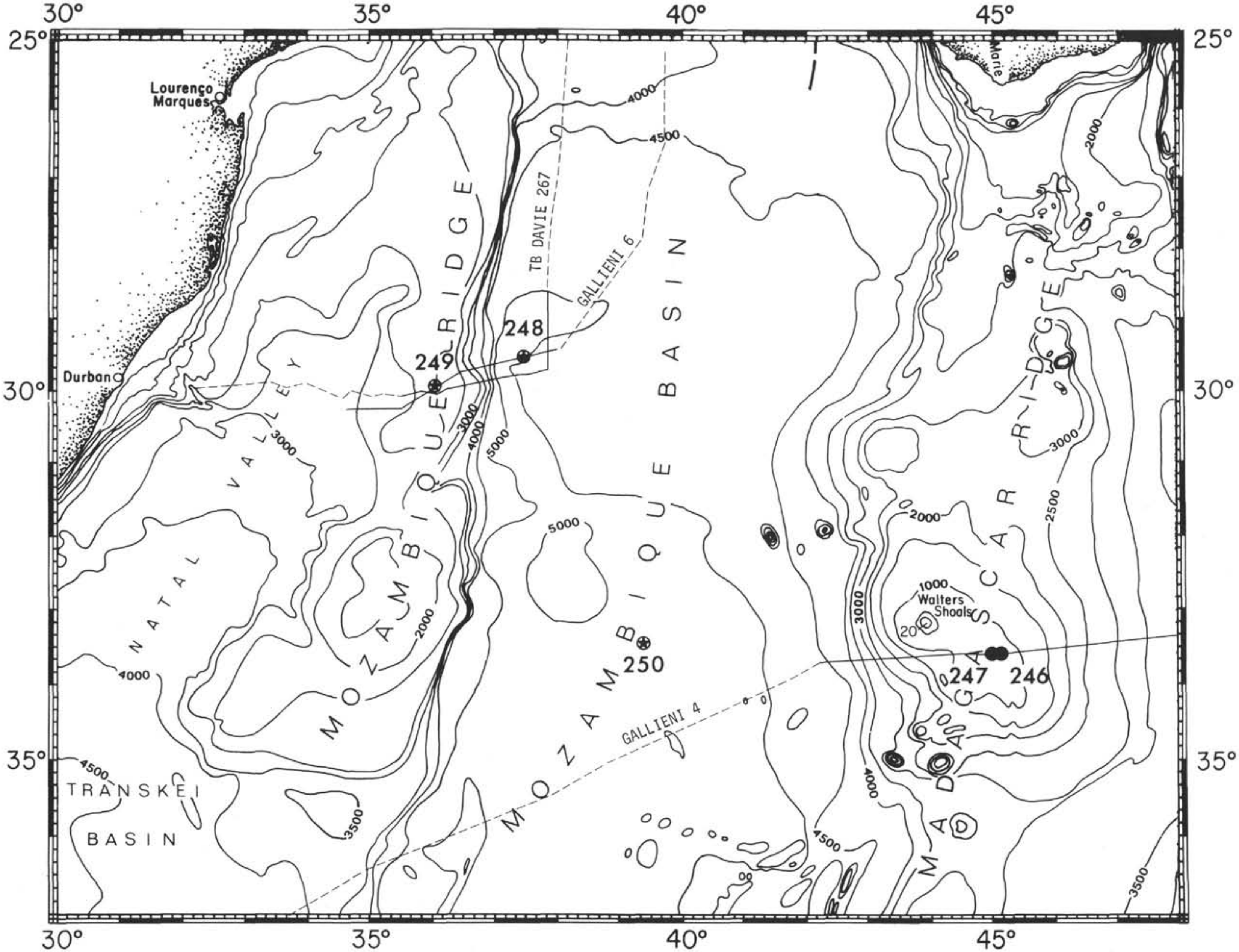


Figure 1. *Bathymetric chart showing major morphological features and deep-sea drilling site locations between Madagascar Ridge and southeast Africa. Isobaths are drawn at 500-meter intervals. Tracks of ships providing survey data for Sites 248 and 249 are indicated (solid lines).*

Basin shallows progressively north of about 27°S, merging with the 3000-meter-deep Mozambique Channel which separates the Madagascar and African continental blocks.

Airgun reflection profiles were obtained in the near-site area by *T. B. Davie* in 1971 (Cruise 267) as shown in Figure 2 and provided useful information for selection of Site 249.

Flexotir reflection data were also obtained, just prior to the *Glomar Challenger* Leg 25 cruise, by *Gallieni* in May 1972 (Cruise 6) along a profile almost east-northeast-west-southwest starting at a depth of about 5000 meters in the Mozambique Basin and crossing the Mozambique Ridge at a latitude of about 30°S (Figure 1). Site 249 on the Mozambique Ridge was finally selected according to the results of this survey.

The flexotir reflection profile obtained on the Mozambique Ridge shows a very rough basement topography with overlying sedimentary accumulations of variable thickness (0-1.0 sec DT [double way time]). The uppermost sediments are acoustically transparent and reach a thickness of about 0.4 sec DT at some locations. Below this transparent material are well-stratified layers which rest upon a well-defined acoustic basement reflector (Figure 3).

The site on the Mozambique Ridge, provisionally located in position 30°00'S, 36°00'E and with a water depth of about 2000 meters, is situated in a small but deep basin limited to the west by an almost vertical basement rise and eastward by a more or less gradual thinning of the sediment cover.

The main objectives of drilling this hole on the Mozambique Ridge were to sample, identify, and date the basement material and to recover as complete as possible a sedimentary sequence in order to establish a high midlatitude biostratigraphic succession above the carbonate compensation depth (CCD).

SURVEY DATA AND OPERATIONS

Glomar Challenger departed from Site 248 at about 0400 hours LT (local time) (0200 GMT) on 17 August 1972. After about 8 hours of steaming in a west-southwest direction across the northwestern part of the Mozambique Basin and over the very steep scarp slope of the Mozambique Ridge, it reached the area surveyed by *T. B. Davie* in 1971 (Cruise 267) and by *Gallieni* in May 1972 (Cruise 6). The selected site (30°00'S, 36°00'E), with a water depth of about 2100 meters, was approached at a speed of about 6 knots along a course of 230° and identified according to the flexotir reflection data at about 1300 LT (1100 GMT) on 17 August 1972. The airgun reflection profile was continued in the same direction at the same speed for about 4 miles. At 1352 LT (1152 GMT), *Glomar Challenger* reversed course to 043°. Based on several satellite fixes, the course was slightly altered successively to 045° and 052°. At 1442 LT, the site was identified and the 13.5-kHz beacon was dropped under way. Immediately after the airguns, hydrophones, and magnetometer were retrieved, the ship reversed course to take up station over the beacon. The geographical coordinates of Site 249 are: 29°56.99'S, 36°04.62'E (Figure 4).

The *Glomar Challenger* airgun reflection profile obtained in the near-site area almost coincides with the *Gallieni* flexotir reflection profile from which the site was selected. Both records show a very rough basement topography overlain by sediment accumulations of variable thickness (0-1 sec DT). At Site 249, the acoustic basement is at a depth of 0.46 sec DT (Figure 5).

The site objectives were to sample ridge basement material and to recover a complete sedimentary sequence above the CCD. Consequently, a program of nearly continuous coring was planned. Basement was reached at a depth of 408 meters and penetrated down to 412 meters.

Drilling and coring at this site started at 0145 (LT) on 18 August 1972 and ended at 2300 (LT) on 19 August 1972. Thirty-three cores were taken; the total cored section being 285 meters and the total core recovered, 221.4 meters (Table 1). The good core recovery was undoubtedly due to the excellent sea conditions and the type of formation encountered. After Core 14 at 140 meters depth, heat flow measurements were successfully conducted, and downhole inclinometer tests made at the same time indicated that the hole was about 4° off the vertical. The total time spent on the site was 2 days and 14 hours. The average drilling rate was 27.6 m/hr and the average coring rate was 22.1 m/hr. After completing the drilling and

TABLE 1
Coring Summary, Site 249

Core	Depth Below Sea Floor (m)	Cored (m)	Recovered (m)	Recovery (%)
1	0-8	8	8.0	100
2	8-17	9	5.5	61
3	17-26	9	8.3	92
4	27-36	9	9.5	100
5	36-45	9	8.6	96
6	46-55	9	9.3	100
7	55-64	9	9.3	100
8	65-74	9	8.3	92
9	74-83	9	7.3	81
10	84-93	9	9.5	100
11	93-102	9	9.0	100
12	103-112	9	9.0	100
13	112-121	9	9.4	100
14	131-140	9	9.4	100
15	150-159	9	9.4	100
16	169-178	9	2.0	22
17	178-187	9	8.7	97
18	198-207	9	9.5	100
19	218-227	9	5.1	57
20	237-246	9	9.6	100
21	256-265	9	9.5	100
22	275-284	9	9.5	100
23	284-293	9	6.7	74
24	294-303	9	1.2	13
25	303-312	9	3.6	40
26	313-322	9	2.6	29
27	322-331	9	3.6	40
28	332-341	9	4.4	49
29	351-360	9	1.2	13
30	370-379	9	5.0	56
31	389-398	9	5.3	59
32	405-408	3	0.6	20
33	408-412	4	3.1	86
Total		285	221	78

Note: Echo sounding depth (to drill floor) = 2098 meters; drill pipe length to bottom = 2103 meters.

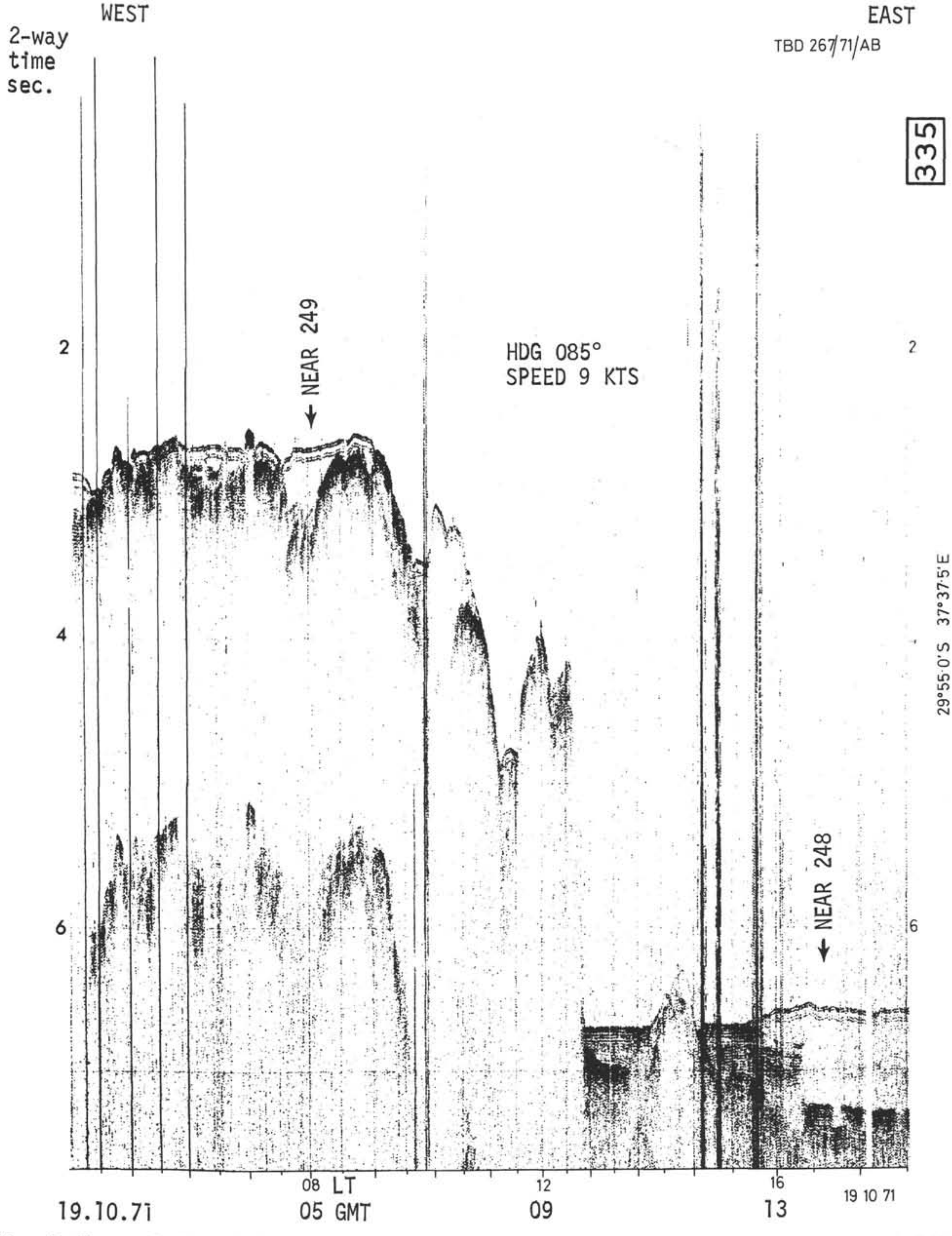


Figure 2. Thomas B. Davie *267 airgun seismic reflection profile across the Mozambique Ridge near Site 249 (location shown in Figure 2). Unpublished data provided by E.S.W. Simpson.*

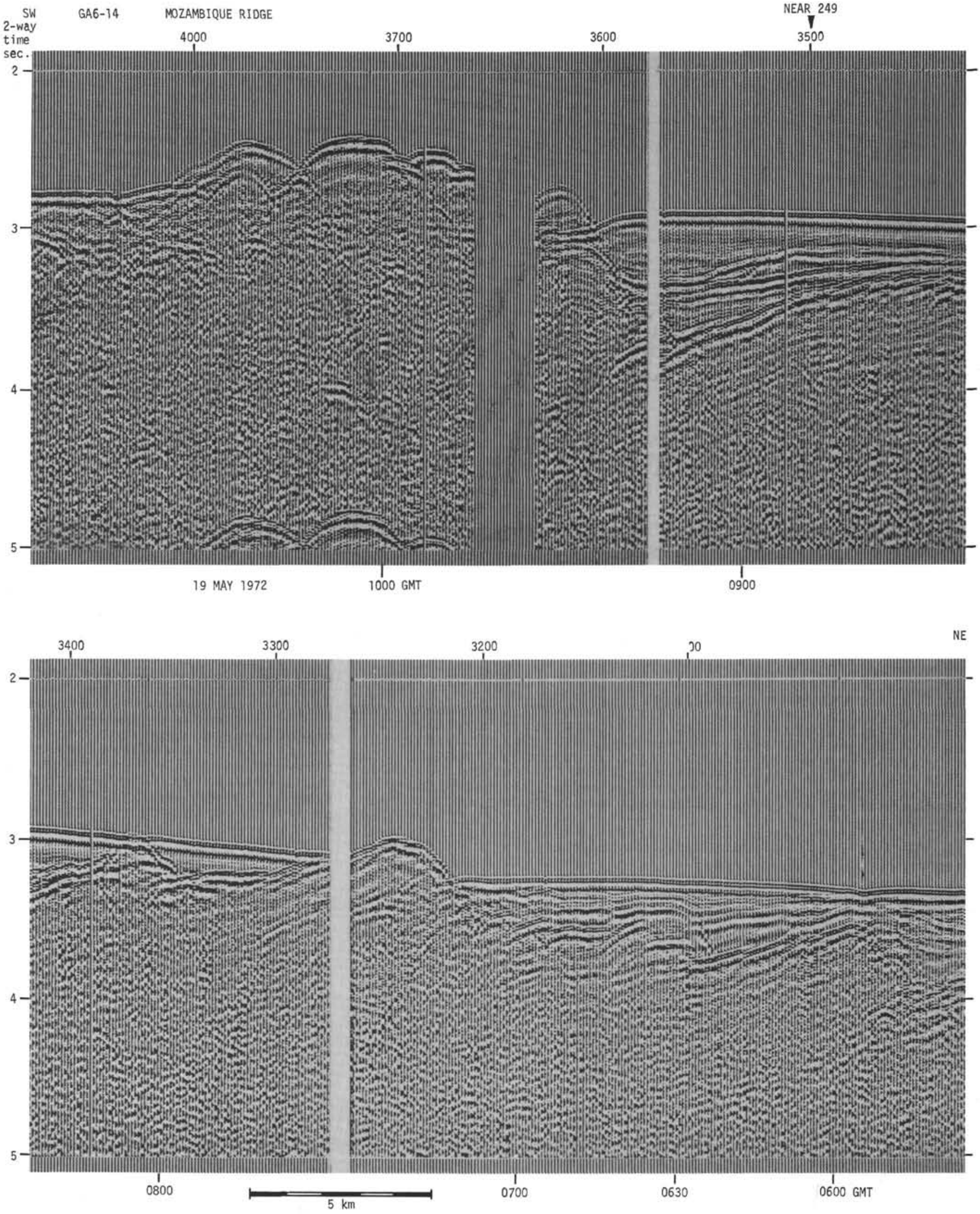


Figure 3. Gallieni 6 *flexotir seismic reflection profile across the Mozambique Ridge near Site 249 (location shown in Figure 1).* Gallieni 6 *records are from unpublished Institut de Physique du Globe de Paris and Comité d'Études Pétrolières Marines (Schlich, personal communication).*

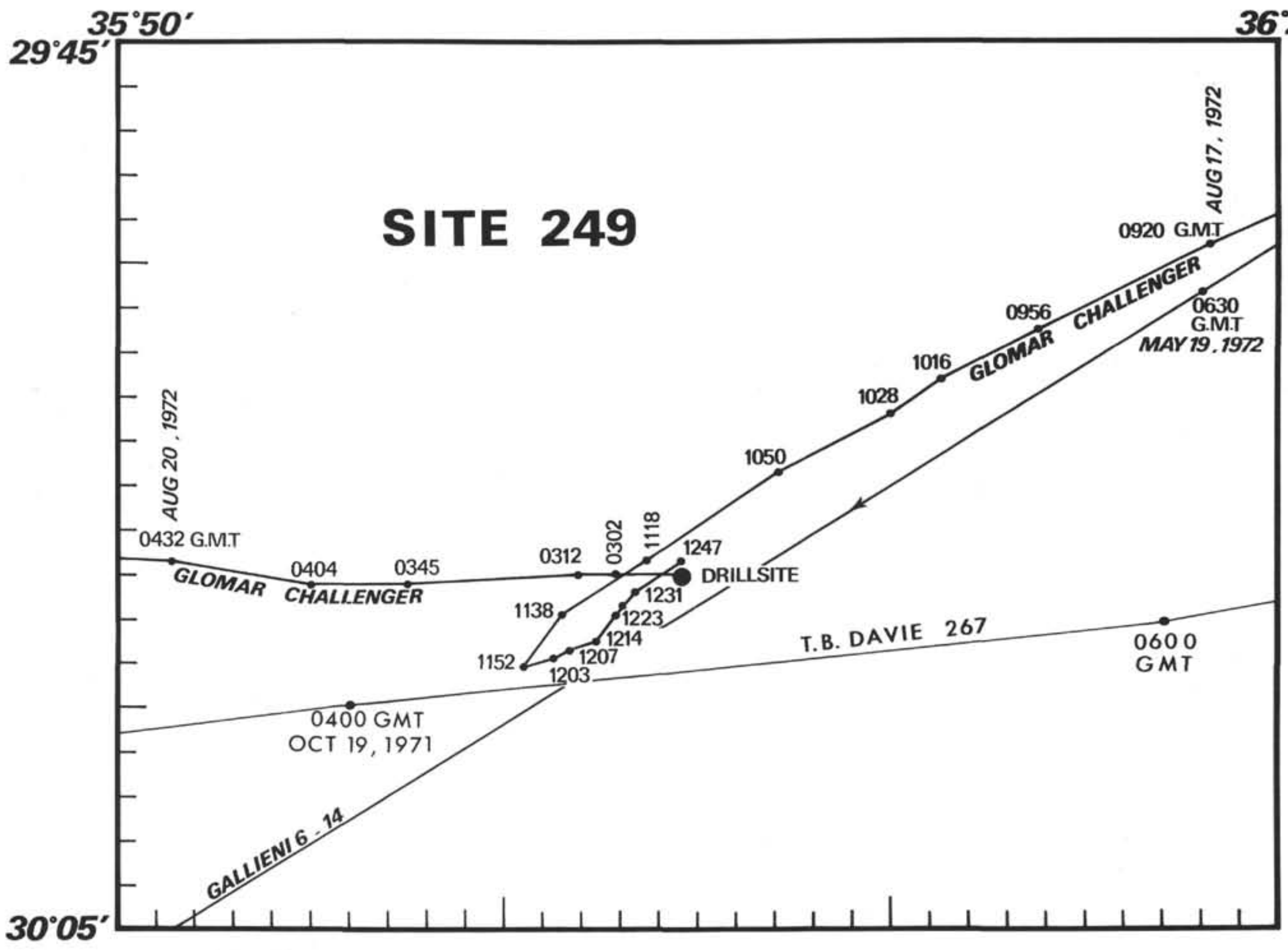


Figure 4. *Details of the* Glomar Challenger *site approach.*

coring, the four-cone bit appeared to be in very good condition.

Glomar Challenger departed from Site 249 at 0430 LT (0230 GMT) on 20 August 1972 in an easterly direction while the airguns, hydrophones, and magnetometer were streamed. At 0435 LT (0235 GMT), *Glomar Challenger* reversed course so as to pass over the beacon. The beacon was passed at 0451 LT (0251 GMT), and the ship steamed westward in the direction of Durban.

LITHOLOGY

Introduction

Site 249 was drilled on the Mozambique Ridge in 2088 meters of water and penetrated 408 meters of sediment and sedimentary rock of Tertiary and Late Cretaceous ages prior to bottoming in basaltic basement. Four meters of basement were cored from which 3.1 meters of vesicular, partly amygdaloidal, glassy basalt were recovered. The total penetration of Site 249 was 412 meters. A nearly continuous coring program and an excellent core recovery (79%) allowed optimum lithologic and paleontologic analyses of this site.

Three major lithologic units and two subunits are recognized in the sedimentary section above basement (Table 2). These divisions are established on the basis of changes in color, mineral composition, textures, degree of lithification, and biogenous components. A stratigraphic summary is given in Figure 6.

TABLE 2
Lithologic Units and Subunits, Site 249

Depth (m)	Lithologic Units	Lithologic Subunits	Thickness (m)
	(I) Gray foram-rich nanno ooze		172
172	(II) Brown and gray foram-bearing clay-rich nanno chalk		115
287	(III) Gray, olive, and olive-black silty claystone and volcanic siltstone	A) Gray and olive silty claystone and volcanic siltstone	121
352		B) Gray and olive-black silty claystone	
408	(IV) Basalt, vesicular and glassy		4
412			

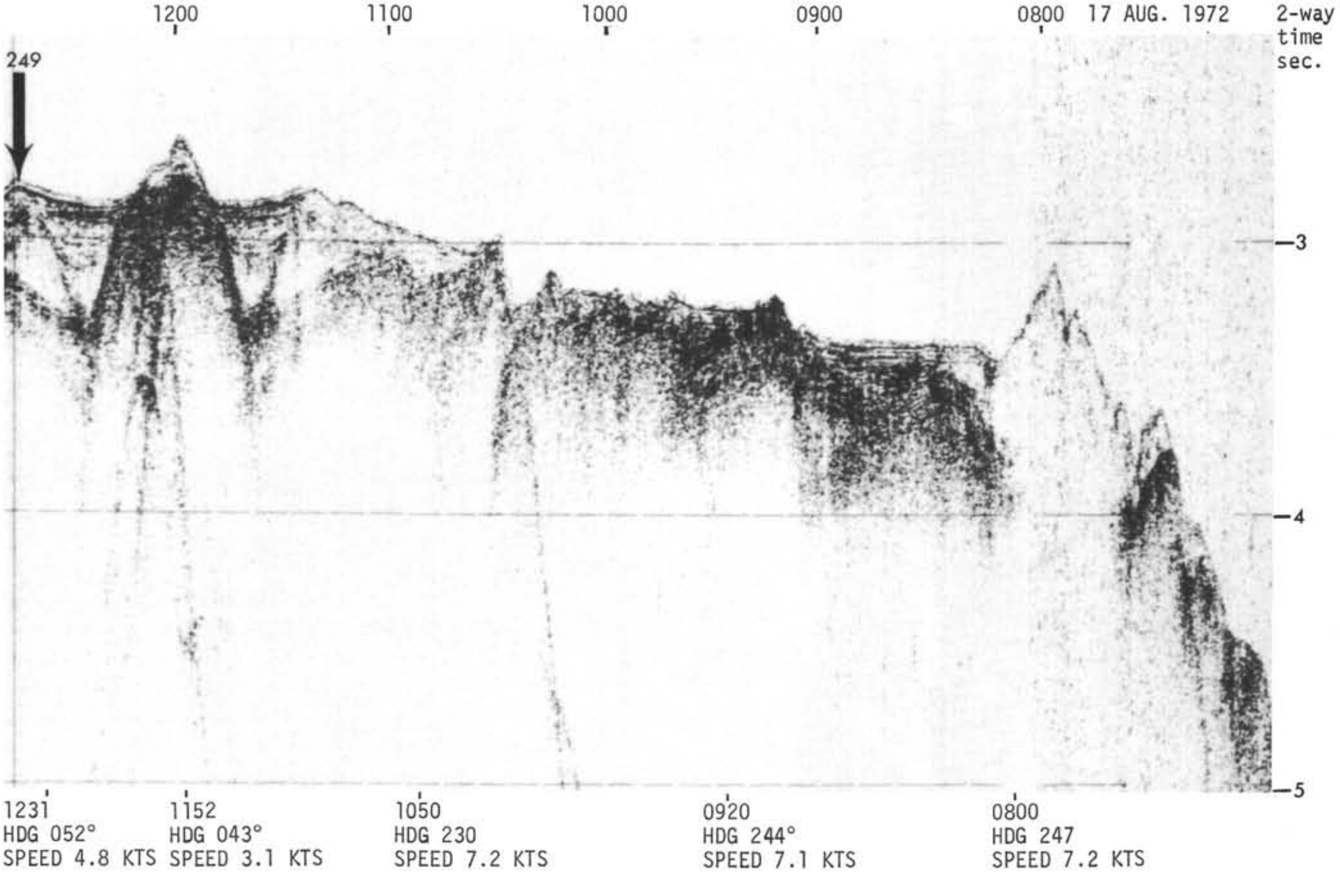


Figure 5. Glomar Challenger *seismic reflection profile on approach to Site 249.*

Description of Lithologic Units

UNIT I: Gray Foram-Rich Nanno Ooze (Cores 1-16)

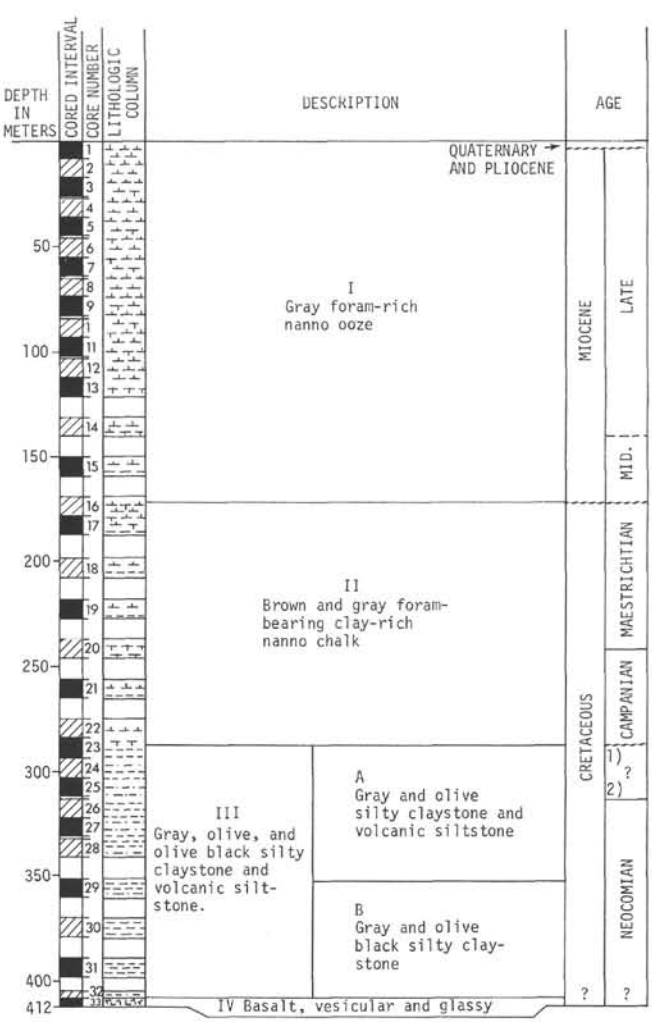
The topmost 172 meters of sediment penetrated is predominantly a foram-rich nanno ooze which ranges from Pleistocene to middle Miocene in age. This unit is a white to light gray pelagic ooze (locally chalk) containing variable amounts of foraminifera and pelagic clays. While the dominant sediment is foram-rich nanno ooze, the percentage of foraminifera varies locally from about 5 to 55 percent, thereby warranting a sediment classification range from foram-bearing nanno ooze to foram nanno ooze. There is a general decrease in the percentage of foraminifera with depth. Clay is apparently absent or occurs only in trace amounts above 32 meters but comprises from 4 to 10 percent below that depth; thus, there locally occurs clay-bearing nanno ooze. There are also minor silt-bearing intervals. The silt-sized particles are generally compound clay mineral grains with lesser amounts of angular quartz grains.

Most of Unit I is very soft and highly disturbed by drilling, but beginning at approximately 115 meters, there appear thin (5-10 cm) semilithified layers which indicate incipient lithification and which are designated "chalks." Such chalky layers generally increase in number and thickness downward so that below Core 15 (159 m), Unit I is entirely chalk. Tiny black pyrite spots and streaks appear throughout the unit.

UNIT II: Brown and Gray Foram-Bearing Clay-Rich Nanno Chalk (Cores 16-23)

At 172 meters, near the bottom of Core 16, a sharp lithologic break separates light gray foram-rich nanno chalks and oozes of Unit I from moderate brown silt-bearing nanno chalk which marks the top of Unit II. This abrupt change coincides with an unconformity between the middle Miocene and the Late Cretaceous (Maestrichtian) based on paleontologic evidence and also apparently correlates closely with anticipated acoustical changes indicated by airgun and flexotir profiles.

Unit II is designated as that portion of Site 249 below the unconformity at 172 meters to a depth of 287 meters giving the unit a thickness of 115 meters. Brown and greenish-gray hues predominate, although compositionally the sediments are similar to those of Unit I. The major lithology is foram-bearing clay-rich nanno chalk, which indicates a general increase in clay and a decrease in foraminifera as compared to Unit I. Locally, Unit II is silt-rich (as much as 15% silt) or foram-rich with forams comprising as much as 29 percent. X-ray analyses indicate that the noncarbonate components include quartz, K-feldspar, mica, and palygorskite. At the extreme top of the unit, a silt-rich nanno chalk contains trace amounts of heavy minerals which include zircon, rutile, and hematite. Iron-stained clays apparently produce the brown colors. Silt content decreases with depth while clay becomes generally



1) Early Cenomanian or Late Albian
2) Early Aptian or Barremian

Figure 6. *Stratigraphic column, Site 249. Dashed lines indicate uncertain boundaries. Wavy lines indicate hiatuses.*

more abundant. Most of the cored interval exhibits extreme bioturbation; burrows generally attributed to marine worms are especially prominent. One particular burrow in Section 2 of Core 22 is outstanding in that it is large (over 10 cm long), is of a form resembling a pine tree, and suggests development as a grazing pattern by an organism (Zoophycos?) which excavated a spiral tube. Burrowed zones are generally colored by lighter hues and are chiefly composed of the same material as the host sediment; however, locally they are filled with nearly homogeneous clay. There are aragonite laminae locally in Cores 19 and 20 which are possibly displaced pelecypod (Inoceramus?) shell fragments.

Unit II is entirely chalk, although several soft zones occur locally which may have been caused by drilling. The entire unit is Late Cretaceous in age (Maestrichtian-Campanian).

UNIT III: Gray and Olive Black Silty Claystone and Volcanic Siltstone (Cores 23-32)

The boundary separating Units II and III is selected at a depth of 287 meters in Section 2 of Core 23 where a significant increase in clay content begins (as much as 77%) with an accompanying decrease in biogenous components. The boundary is not sharp and could have been selected from within the 3-meter interval between 287 and 290 meters since no obvious color change occurs. The dominant character of Unit III actually first appears at 290 meters just below a gypsum-rich clay where black color becomes prevalent. This color change marks the appearance of sedimentary rock rich in volcanic derivatives, iron sulfides, and carbonaceous materials. It is apparently the presence of the latter which imparts the striking black color to Unit III, as organic carbon is present in amounts as large as 1.6 percent.

Unit III is divided into two subunits based chiefly upon textural difference: an upper unit (IIIA) is predominantly silty claystone, while in the lower unit (IIIB), silt-sized particles are notably less abundant.

Subunit IIIA (Cores 23 to 29): This subunit contains the youngest (early Cenomanian or late Aptian) volcanic materials encountered. The first indication of volcanic material is an 8-cm-thick ash-bearing bed at 290 meters in Core 23, Section 3, and the remainder of subunit IIIA is generally also ash bearing. The dominant rock types are silty claystone, volcanic ash-rich siltstone, and calcic volcanic ash siltstone in olive black and medium gray hues. Several layers contain fresh, or only slightly altered, volcanic glass shards, but much of the volcanic material identified is now a clay derivative of devitrified glass. X-ray analyses reveal the presence of quartz, cristobalite, tridymite, K-feldspar, mica, palygorskite, montmorillonite, and the zeolite clinoptilolite. Those layers containing ash or its derivatives possess as much as 88 percent of these substances (e.g., Core 23), and unaltered shards are best displayed in Cores 25 and 26, where they locally comprise 95 percent. In Cores 27 and 28, three limestones, each only a few centimeters thick, occur. These are composed almost entirely of irregularly shaped silt- and clay-sized carbonate fragments (micarb) of unknown origin. Some silt zones are themselves rich in carbonate particles which give rise to calcic siltstones.

Subunit IIIA is generally well indurated, presumably in part due to calcite cement and to the abundance of clay. Laminations are the rule, and locally very low angle cross-stratification is apparent. A few graded beds occur, some with rather sharp basal contacts, suggesting possible turbidity current deposition. There is considerable alternation of rock types, although no particular pattern of episodic cycles can be demonstrated. Particle sizes in the coarser layers reach 0.5 mm, but these are exceptions to the generally fine-grained nature of the unit. Minor constituents of subunit IIIA include glauconite and trace amounts of foraminifera and calcareous nannofossils.

Subunit IIIB (Cores 29 to 32): This subunit is similar to subunit IIIA in composition but possesses less silt-sized components. Silty claystone is still the dominant rock type. Compositionally, material of volcanic origin comprises from 55 to 88 percent of the claystones although much of such material is now a clay due to devitrification of primary volcanic ash. A sufficient amount of dark opaque matter, including both reduced iron and organic carbon, gives subunit IIIB a distinctive black color as in subunit IIIA.

Mineral components of ash-rich layers are identical to those given for subunit IIIA. Minor constituents, which occur locally in appreciable amounts, include carbonate particles and glauconite. Only trace amounts of foraminifera and calcareous nannofossils are present. Bedding characteristics are similar to those in Subunit IIIA.

UNIT IV. Basalt

Basalt was reached at a depth of 408 meters in core catcher 32; 3.1 meters of basalt were retrieved after coring to 412 meters at which point drilling was terminated.

The uppermost portion of the core is highly vesicular, glassy, and weathered. Vesicles filled with calcite and dark green chlorite are numerous, and calcite vein filling occurs at several places. The size and abundance of vesicles decrease downward. Dark green chlorite is replaced by light blue-green spherules of a smectite (probably nontronite) as an infilling in the sample from core catcher 32. This sample also shows an abrupt change in texture and vesicularity, with the lower portion more massive and crystalline and containing clots of pyroxene 0.8 mm across. The texture in thin section is hyalopilitic to intersertal depending on the degree of crystallinity. Slender laths of plagioclase 0.1-0.2 mm long are loosely intergrown with granular clinopyroxene. The crystalline fabric is set in a base of dark brown altered glass containing a mixture of smectite (montmorillonite) and zeolite. A few anhedral microphenocrysts of plagioclase with their centers choked with tiny inclusions also occur.

The fine-grained hemicrystalline nature of the rocks precludes the determination of detailed modes, but average values for the vesicular type is plagioclase, 50 percent; augite, 23 percent; glass (including alteration products and opaque grains), 22 percent; vesicle infilling (mainly chlorite and calcite), 5 percent. For the coarser grained type containing few microvesicles, plagioclase, 45 percent; augite, 44 percent; glass (including alteration products and opaque grains), 10 percent, vesicle infilling (nontronite and calcite), 1 percent.

The major and trace element analyses indicate that the basalt has compositional similarities with the low K tholeiites recovered from the mid-ocean ridges. However this basalt is somewhat enriched in Ba when compared with mid-ocean ridge low K tholeiites and the basalts from Sites 239, 240, and 245.

Lithologic Interpretations

The following conclusions and interpretations seem to raise more questions than are answered. Further research is necessary to determine the geologic history of this site and of its relationship to the geology of the southwestern Indian Ocean.

1) Unit I is a 172-meter-thick section composed of biogenic oozes and chalks with minor amounts of clay and silt and which has accumulated under tectonically quiescent conditions since middle Miocene time. The high sedimentation rate, approximately 14 meters per million years, reflects the site's location beneath waters of high plankton production and its position above the CCD.

2) The general lithologic character of Unit II is so similar to that of Unit I as to suggest that they were deposited under closely similar conditions although at widely separated times.

3) A profound unconformity of 40 m.y. (middle Miocene-Late Cretaceous) separates Units I and II. Neither unit contains sufficient lithologic evidence to demonstrate with certainty the cause of the unconformity. However, the presence of silt (15%) which includes the heavy minerals zircon, rutile, and hematite in the top of Unit II may indicate the onset of tectonic instability which was followed by upwarp and erosion in this area.

4) A second unconformity of about 14 m.y. duration separates Unit II (Campanian) from Unit III (Cenomanian). This break is recognized on both paleontologic and lithologic evidence. Unit II is predominantly biogenic chalks, whereas Unit III consists of black clay-rich volcanic siltstones and claystones. The contrasting natures of Units II and III indicate a radical change in the depositional environment for this site, and the tectonic process responsible for the unconformity led to the development of depositional conditions for Unit II.

5) Unit III contains many distinctive features: claystone and siltstone lithologies; dark colors, presumably due to reduced iron and carbonaceous organic carbon; a high content of volcanic derivatives; detrital carbonate fragments, locally abundant enough to form thin limestones; detrital quartz and feldspar; glauconite; laminar, graded, and cross-stratification; and sparse fossils. These characteristics, when considered as a whole, are indicative of tectonic instability accompanied by volcanism. The depositional basin was of a restricted nature (euxinic) on the basis of high percentage of reduced iron, carbon content, and sparsity of fossils. It should be noted that much of the volcanic material and carbonate fragments probably were redeposited at this site after initial deposition elsewhere.

6) Unit IV, the vesicular glassy basalt, is the acoustic basement for this site. Megascopic evidence is not apparent to demonstrate conclusively that this basalt is oceanic although the high glass content indicates rapid cooling, which in turn suggests subaqueous extrusion. The presence of volcanic materials in Unit III immediately above the basalt may indicate that the basalt was a forerunner to or associated with volcanism which produced sediments comprising Unit III.

PHYSICAL PROPERTIES

The large number of cores and the generally good percentage of recovery provided for fairly detailed physical property measurements.

Sonic velocity values are essentially constant at about 1.56 km/sec from the sea floor to somewhere in the interval of 56-81 meters. At 81 meters, the value is 1.62 km/sec. The trend below this depth to about 292 meters is one of slightly increasing velocities with possible positive anomalies at 109-156 meters and at 204 meters. At about 292 meters, large variations in the values from velocities of volcanic ash, silt-rich nanno clay, and volcanic siltstone produce striking changes. Both minimum and maximum values just below 292 meters increase sharply. The sonic velocity is variable from 292 meters to basement where there is a sharp increase to about 4.02 km/sec.

The acoustic impedance increases sharply between 7-9 meters as a reflection of the change in bulk density. This increase may not be valid since the lower GRAPE bulk density values are from disturbed sediments also. The remaining acoustic impedance values follow the same general pattern as the sonic velocities.

Section weight bulk density values were lower than corresponding GRAPE values. Syringe bulk density values were generally close to GRAPE values except in the interval 0 to 4 meters. Here the syringe values of 1.65 and 1.68 g/cc are considered better because they were selectively chosen from less deformed sediments. Density values increase slightly with depth to about 304 meters. Below this depth, the scatter increases greatly due to variations in the sediment, but no trend is apparent.

Except for a low value at 49 meters, the thermal conductivity values lie close to the average value of 2.72 mcal/cm sec °C for approximately the first 112-117 meters of sediment. Below this, the data are more variable but suggest a possible positive anomaly in the approximate interval 138-184 meters and a possible negative anomaly associated with the low value at 289 meters. The latter value lies near the top of lithology Unit II, which is a clay and foram-bearing nanno chalk.

Water content and porosity curves have the same general features. The data are somewhat variable for the first 25 meters. The values appear reasonably constant from about 38 meters to about 140 meters. Between approximately 140-153 meters there is a significant reduction in the values. Below this, the water content and porosity values tend to decrease with depth with no apparent anomalies.

BIOSTRATIGRAPHY

Calcareous Nannoplankton

In the interval of Samples 1-1 to 1-2, 40 cm, a Quaternary nannoplankton assemblage was observed. It was not possible to determine the Pliocene (Figure 7). The Neogene sequence at Site 249 is very thick and very rich in nannoplankton, which show good preservation. Directly below the Quaternary (1-2, 40 cm) is the late Miocene *Ceratolithus tricorniculatus* Zone, NN 12. This zone is characterized by the abundance of species of the genus *Scyphosphaera.* Other very abundant species are *Ceratolithus tricorniculatus, Coccolithus pelagicus, Discoaster surculus, Discoaster variabilis, Discoaster pentaradiatus, Discoaster brouweri,* and *Rhabdosphaera* sp. In the uppermost part of this zone is a variation of *Ceratolithus tricorniculatus* with a long horn.

The *Discoaster quinqueramus* Zone (NN 11), which becomes very thick at Site 249, includes the interval from level 4-5 to 12 CC. The samples are abundant in calcareous nannoplankton, which show good preservation. The most frequent species are *Discoaster quinqueramus, Discoaster calcaris, Discoaster brouweri, Discoaster pentaradiatus, Discoaster variabilis, Discoaster neohamatus* (in the lower part of this zone), and *Discoaster surculus.* In some samples, species of the genus *Scyphosphaera* are very abundant. Within Cores 10 and 11 can be observed an alternation of Zone NN 11 and Zone NN 10. These cores may be disturbed by drilling.

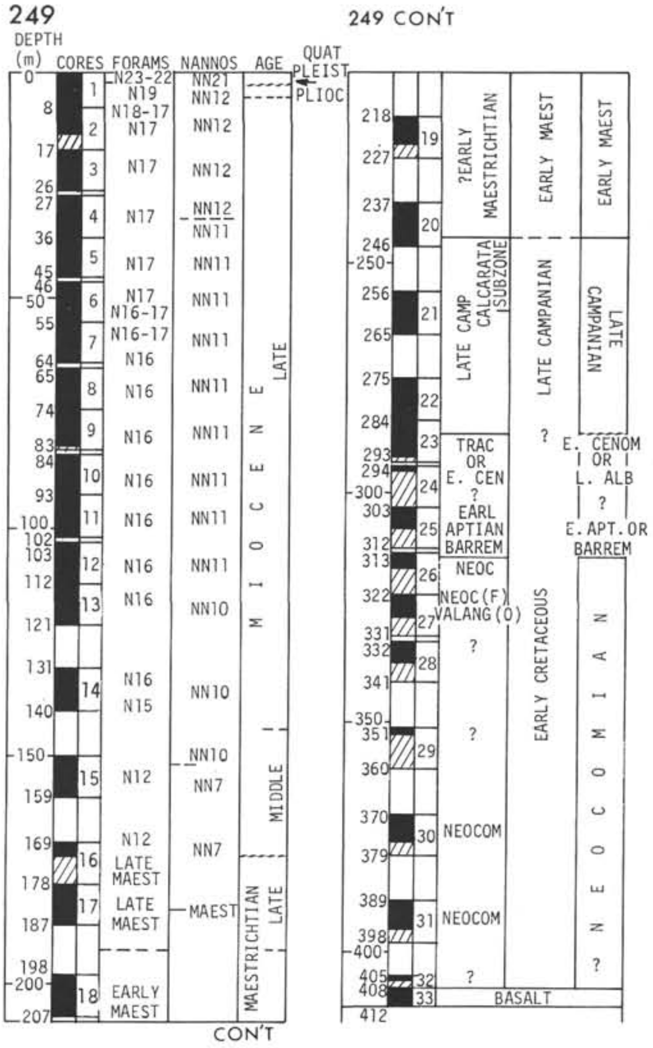


Figure 7. *Biostratigraphic Column, Site 249.*

Cores 13 and 14 belong to the *Discoaster calcaris* Zone (NN 10). The typical species are: *Discoaster calcaris, Discoaster neohamatus, Discoaster bollii* (in the lower part of this zone), *Triquetrorhabdulus rugosus, Reticulofenestra pseudoumbilica,* and *Sphenolithus abies.* The *Discoaster hamatus* Zone (NN 9) and the *Catinaster coalitus* Zone (NN 8) are not determinable with certainty, although a very few specimens of *Catinaster coalitus, Catinaster calyculus,* and *Discoaster bollii,* which becomes abundant in places, were observed within the upper part of Core 14. However, in the lower part of this core, the *Discoaster calcaris* Zone (NN 10) was again determined. Therefore, a mixing by drilling is suspected.

The *Discoaster kugleri* Zone (NN 7) was found in the interval between Samples 15-3 and 16-2, 140 cm, with *Discoaster kugleri, Triquetrorhabdulus rugosus,* and *Sphenolithus abies.*

The boundary between the Neogene and the Cretaceous lies between Samples 16-2, 140 cm and 16-2, 148 cm. This boundary is very distinct as indicated by a change in lithology and color. The Upper Cretaceous at Site 249 is very rich in calcareous nannoplankton, which is well preserved. Determinations of the boundaries within the Cretaceous is not always certain because guide fossils are either very rare or are missing. Further on, the range of some species is not well known. *Nephrolithus frequens* and *Lithraphidites quadratus*, typical for the Maestrichtian, were observed in the interval between Samples 16-2, 148 cm and 17-4, 140 cm. The boundary between the *Nephrolithus frequens* Zone and the *Lithraphidites quadratus* Zone lies within Core 16.

The boundary between the Maestrichtian and the Campanian is not distinct. The assemblage of the interval between Sample 17-4 and Core 20 are without *Nephrolithus frequens* and *Lithraphidites quadratus* but with *Arkhangelskiella cymbiformis*, which becomes very abundant within some of the samples. This part seems to belong to the early Maestrichtian.

Cores 21 and 22 are rich in nannoplankton. The most frequent species are: *Broinsonia parca, Eiffelithus turiseiffeli, Parhabdolithus embergeri, Watznaueria barnesae, Micula staurophora, Cribrosphaera ehrenbergi, Cretarhabdus conicus, Reinhardites? anthoporus, Kamptnerius magnificus, Tetralithus aculeus, Deflandrius cretaceus, Tetralithus gothicus, Cricolithus pemmatoides, Cretarhabdus splendens* and *Zygolithus diplogrammus.* They belong to the Campanian. Below Sample 23-2, 100 cm, very few nannoplankton occurs; therefore, it is not possible to give an exact age determination, but the sequence seems to belong to the Early Cretaceous.

Foraminifera

Quaternary and Neogene

This is the only site on Leg 25 with continuous coring in the upper part of the hole. Since the sea floor at the site is situated well above the CCD and on an isolated ridge, there was a good chance to get an excellently preserved complete Quaternary and Neogene section. In addition, no turbidite layers were expected. These expectations were verified regarding the preservation and composition of the foraminiferal contents of the sediments. Throughout the Quaternary and Neogene section, highly diversified planktonic foraminiferal associations were found; they are well preserved and contain only a small portion of deep-water benthonic foraminifera and other skeletal remains. Unfortunately, the stratigraphic sequence was not equally well developed. The Quaternary sediments (1.7 m) are underlain by about 1 meter of Pliocene with *Globigerinoides obliquus obliquus, Globorotalia margaritae, G.* cf. *multicamerata, Globoquadrina altispira altispira, Sphaeroidinella dehiscens dehiscens, Sphaeroidinellopsis seminulina* ssp., *Pulleniatina obliquiloculata obliquiloculata,* and *P. obliquiloculata praecursor,* to name only the more important species for age determination. The Pliocene faunas down to level 1-2, 102 cm contain specimens which are of Quaternary age, for example *Globigerina bulloides calida, Globorotalia truncatulinoides truncatulinoides,* and *Pulleniatina obliquiloculata finalis.* Possibly, an originally more complete Quaternary and Pliocene section has been reworked either during late Quaternary time on the sea floor or during the insertion of the core tube. This would give an explanation for the discrepancy in thickness between the Miocene and the younger sediments as well as for the presence of late Quaternary foraminifera in all samples from the top of the core to the lower part of Section 2.

From Sample 1-2, 120 cm, an excellent, unmixed foraminiferal association is present which fits Blow's Zone N. 19. The boundary between Pliocene and Miocene is to be drawn at the top of Section 3. From here, a continuous late and middle Miocene pelagic sedimentation with highly diversified planktonic faunas proceeds to Core 16, Section 2 where, with an abrupt change of color and lithology, late Maestrichtian is in contact with the overlying middle Miocene.

Biostratigraphic age determinations in this hole have been made comparing the presence of as many species as possible with the range tables of Blow (1969). There seem to be some species in the samples which have not been regarded as important for biostratigraphy in the Neogene sediments of the other oceans. A more thorough investigation will be carried out at a later date. In any case, all stratigraphically important species of Miocene planktonic foraminifera are present.

Since the sedimentation rate in this hole during Miocene time is relatively high (~17.5 m/m.y.) and the sedimentation is without a hiatus, the transition from one zone to the next is very gradual. In consequence, the position of the boundaries between foraminiferal zones is not given to the exact centimeter because of the sampling density. Late Miocene comprises the sediments between about 3 meters and 132 meters (Cores 1-14)., giving a sedimentation rate of 24 m/m.y. A disturbance of the sediment succession is suspected in the interval below Core 10 down to, perhaps, Core 13. There seems to be a repeat of Zone N.17 within the Zone N.16 interval. Nothing can be stated at this time about the exact nature of this disturbance because it concerns two zones (N.16 and N.17) which have very similar foraminifera associations. The middle Miocene, as far as present, reaches from 132 to 171 meters in the hole (Cores 14-16), giving a lower sedimentation rate of about 10 m/m.y. This might be at least partly due to a gradually increasing dissolution of calcium carbonate.

Cretaceous and Paleogene[2]

Three faunal groups can be separated in the Mesozoic sediments. The Late Cretaceous (more precisely, the late Senonian) is typical between level 16-2, 148-146 cm, situated directly under the Miocene, and level 23-2, 130-132 cm (probably even 23-2, 144-146 cm). A "middle" Cretaceous, which is relatively well characterized from place to place in the midst of radiolarian deposits, stretches between levels 23-3, 3-6 cm and 24-1, 107 cm. Then, after a barren zone corresponding to and influx of volcanic sediments (Core 25), the Early Cretaceous is reached and can be dated with accuracy in only a few cases because of the general microfossil poverty or the absence of characteristic species. Core 32 has no microfossils.

These three groups will be examined in their stratigraphic order beginning with the oldest sediments.

Early Cretaceous

The levels that can possibly be disaggregated by washing are not very numerous, especially in the lower cores.

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[2] Work (Ostracods) was accomplished with the assistance of N. Grekoff, 140 Cours de la Reine, 92100 Boulogne, France.

The microfauna is mainly made up of Lagenidae. However, mention should also be made of the presence of two microfossil groups which prove to be important, i.e., Ostracods, which are always sparse and scattered, and Globigerinids, which are also quite sparse and tiny in size.

Very few species can be identified from the existing literature. However, several, undeniably, belong to "specific groups" which are either limited to the Neocomian or which also extend to the Aptian-Albian.

The following species, by order of appearance, are worth noting:

Species	Sample
Astacolus gr. *gibber* Espitalié and Sigal, 1963	31-3, 135-137 cm
Saracenaria pravoslavlevi var. *minor,* Romanova, 1960	30-4, 57-59 cm
Citharina gr. *thoerenensis* Bartenst. and Brand, 1955	30-4, 57-59 cm
Citharina gr. *Planularia pseudocrepidula,* Adams, 1957	30-4, 57-59 cm
Lingulina cf. *bohemica* Reuss, 1846	30-4, 57-59 cm
? *Frondicularia* cf. *F. bettenstaedti* Zedler, 1961	30-4, 57-59 cm
? *Eoguttulina* gr. *Glandulopleurostomella (Palaeopolymorphina) ozawai* Tappan, 1940	30-4, 57-59 cm
Marginulina cf. *parallelaeformis* (Romanova, 1960)	27-3, 125-127 cm
Marginulina zaspelovae Romanova, 1960	27-3, 125-127 cm
Marginulina gr. *bettenstaedti* Bart. and Brd., 1951	27-3, 125-127 cm
Astacolus cf. *Marginulina lata* (Cornuel, 1848)	27-3, 125-127 cm
Citharinella cf. *Flabellinella didyma* (Berthelin, 1880) (= *F. parkeri* Reuss, 1863)	27-3, 125-127 cm
Lenticulina cf. *lideri* Romanova, 1960	26-1, 120-122 cm
Saracenaria cf. *frankei* ten Dam, 1946	26-1, 120-122 cm
Conorboides cf. *glabra* Fuchs, 1971	26-1, 40-42 cm
Globigerinidae	26-1, 40-42 cm

The above list is a partial reflection of the actual composition of the assemblage gathered where there are a great many *Lenticulina, Marginulina, Saracenaria,* and *Dentalina* which either could not be specifically identified or whose value is not certain.

The lower levels, at least (Cores 31 to the lower part of 26), belong to the Neocomian (Valanginian or Hauterivian). In addition to foraminifers, there are ostracods which were identified by N. Grekoff. The lower cores (32, 31, 30) produced only *Cytherella* or occasional Cytherideinae, from which no information could be obtained. Levels 27-3, 26-28 cm and 27-3, 56-58 cm are highly valuable in that they contain *Majungaella nematis* Grekoff, 1963. This species was originally described (and is still unknown higher up) in the Valanginian in the Majunga Basin of Madagascar, and it was mentioned by Dingle under the name of *Neocythere uitenhagensis* in South Africa. In Core 27 (level 27-3, 56-58 cm), a *Cytheropteron* was also found and is probably new.

In the upper part of Core 26, the globigerinids suggest a Barremian or Bedoulian (early Aptian) age. However, they are extremely small forms which are difficult to precisely identify and are apparently highly polymorphous. The following can be recognized: *G.* cf. *tardita* or cf. *quadricamerata* Antonova, 1964 (= G. 19963 of the Barremian stratotype) and *G.* cf. *tuschepensis* Antonova, 1964 (= G. 19968 of the Barremian stratotype). Ostracods are also present in the core. According to N. Grekoff, they consist of a few *Cytherella,* without much apparent value, and an intermediate form between *Amphicytherura (Sondagella) theloides* Dingle, 1969 from the Neocomian in South Africa and *Vicinia sutilis* Kuznetsova, 1957 from the Barremian in Transcaucasia.

We must emphasize the presence of species which enable a comparison and relationship at the bottom of the Cretaceous to be made with Madagascar (Zones E-F in the Majunga Basin) or with Tierra del Fuego, southern Chile, as well as with the marine series in the coastal basins in South Africa.

Therefore, the hole penetrated Barremian and Neocomian (in which the Valanginian alone appears to be characterized) series, but the small thickness represented by Cores 27 and 26 is striking when compared with the total thickness. The special nature of the conditions in which the sediments must have accumulated perhaps explains this disparity. It also would be possible to consider that the Berriasian and Jurassic had been reached; however, the deepest fossils favor a Cretaceous age only. Dating the basalt can provide a minimum age that will be interesting to consider. At the same time, it appears indispensable to begin a palynological investigation of these levels.

Samples examined include:

32, CC
32-1, 104-106 cm
32-1, 145 cm
31-3, 135-136 cm
30, CC
30-4, 57-59 cm
30-3, 123-124 cm
30-1, 127-128 cm
29, CC
27-3, 125-127 cm
27-3, 26-28 cm
27-2, 80-82 cm
27-1, 125-127 cm
26-2, 40-42 cm
26-1, 120-122 cm
26-1, 40-42 cm
25-3, 48-50 cm
25-2, 100-102 cm

"Middle" Cretaceous

This interval is actually characterized by its richness in radiolarians, which are now being analyzed. However, twc levels rich in foraminifers were also found: (1) 23-4, 136-139 cm; 23-4, 130-131 cm; and 23-4, 124-127 cm, with numerous *Gavelinella* and Globigerinidae; and (2) level 23-3, 3-6 cm.

Indeed, the latter produced a Vraconian (or perhaps early Cenomanian) association:

Hedbergella delrioensis (Carsey, 1926)
Hedbergella cf. *Praeglobotruncana modesta* Bolli, 1959
Hedbergella cf. *gauttierensis* (Brönnimann, 1952)
Hedbergella cf. *simplicissima* Magné and Sigal, 1954
Planomalina sp. aff. *eaglefordensis* (Moreman, 1927)
Rotalipora balernaensis Gandolfi, 1957
Ticinella sp. (? *T. roberti* or gr. *Rotalipora praebalernaensis* ?)

Core 23 also revealed a few ostracods (levels 23-3, 3-5 cm; 23-4, 30-32 cm; and 23-4, 130-132 cm) including the generic groups *Cythereis*, ? *Pterygocythere* and ? *Parexophthalmocythere.* Although the nanism of these species merits being emphasized, no stratigraphic evidence could be deduced from them.

Actually, the presence of microfossils is highly irregular, and their abundance varies considerably throughout the sequence going from the levels attributed to the Early Cretaceous to those in the Late Cretaceous. For example, Cores 25 and 24 correspond to a volcanic sedimentary episode which produces a black azoic residue. Core 23, on the other hand, contains fossils, but there are numerous alternations. Section 5 has a volcanic-sedimentary dominance, with rare radiolarians, except in one level (38-41), which, in addition to a few foraminifers, contains spicules and a bit of glauconite. The bottom of Section 4 is comparable to the preceding section. However, between 124 and 139 cm, radiolarians, spicules, and foraminifers are abundant. Above this, only radiolarians are found, but they are rare, except at the extreme uppermost part which is related to the overlying levels. The bottom of Section 3 (140-120) is rich in radiolarians, then once again becomes impoverished (120-18). Foraminifers are almost nonexistent. Lastly, the top of Section 3, as we have seen, is particularly rich in radiolarians and foraminifers, and it is especially characteristic on account of the planktonic species.

Samples examined from this interval are:

24-1, 136-139 cm
24-1, 124-127 cm
24-1, 107-109 cm
24-1, 102-104 cm
24-1, 80 cm
23, CC
23-5, 120-121 cm
23-5, 89-91 cm
23-5, 38-41 cm
23-5, 20-21 cm
23-5, 7-10 cm
23-4, 150 cm
23-4, 136-139 cm
23-4, 130-131 cm
23-4, 124-127 cm
23-4, 86-88 cm
23-4, 61-62 cm
23-4, 8-10 cm
23-4, top
23-3, 140 cm
23-3, 120-121 cm
23-3, 102-105 cm
23-3, 66-68 cm
23-3, 63 cm
23-3, 42-44 cm
23-3, 18-20 cm
23-3, 3-6 cm

Late Cretaceous

Beginning with level 23-2, 130-132 cm, the microfauna, which is still poor, reaches a Late Cretaceous age.

The underlying level 23-2, 144-146 cm, can only doubtfully be assigned to this age. It contains sparse specimens of *Globotruncana,* but this fact is not convincing, as some of the same genus are also found lower down as the result of mechanical pollution. In addition, after washing, the residual sediment is comparable to that in the levels of Section 3 of the core, although with less glauconite and very few radiolarians. It might thus show signs of reworking like that found in the Senonian at level 23-2, 130-132 cm.

The Late Cretaceous microfauna is extremely rich and diversified. For the present investigation, only a preliminary inventory was made to determine the stratigraphy of the deposit.

The very first levels (Section 2 of Core 23) contain few planktonic elements, i.e., Globigerinidae or Globotruncanidae. On the other hand, the benthonic assemblage is quite rich, and its Campanian age is certain. We find, in particular:

Reussella szajnochae (Grzyb. 1896) (variants of Campanian age)
Bolivinitella eleyi (Cushman, 1927)
Arenobulimina cf. *ovoidea* Marie, 1941
Gyroidina cf. *tendami* Schijfsma, 1946
Gyroidina moskvini Keller, 1946
Pseudovalvulineria cf. *gyroidina* (?) *stellaria* Vasil. and Mjatl., 1947
Stensioeina altissima Hofker, 1956
Stensioeina causasica var. *transuralica* Balakhm.. 1960
Osangularia cordieriana (D'Orb., 1840)
Neoflabellina interpunctata var. *gibbera* (Wedekind, 1940)

The remainder of the section, on the other hand, is rich in planktonic species and individual specimens. This is especially the case for the genus *Globotruncana.* Some species of this genus, such as have already been described, are recognizable. However, quite a few appear to be new ones or, at the most, can be assigned to specific groups (e.g., to groups such as *arca, caliciformis, rosetta,* and *falsostuarti*).

Two important occurrences seem important at the present time. These are:

1) The presence of *Globotruncana calcarata* Cushman, 1925. This species was not found in the few samples examined on shipboard. It is present, always rarely, in part of Core 21 (it appears between levels 3, 132-134 cm and 3, 120-122 cm) and at the bottom of Core 20 (it disappears between levels 5, 85-87 cm and 5, 40-42 cm), i.e., over a space of about 15 meters, which is the order of magnitude of standard observation in "normal" pelagic sedimentation.

2) The presence of only a few sparse specimens of *Racemiguembelina fruticosa* (Egger, 1900), *Globotruncana contusa* var. *galeoides* Herm, 1962, and *G. mayaroensis* Bolli, 1951 in the core catcher of Core 16, as well as *Trinitella scotti* Brönnimann, 1952 in both Core 17 and the core catcher of Core 16.

Therefore: (1) the Campanian-Maestrichtian boundary can be conventionally located at the top of the "subzone with *calcarata*"; and (2) Cores 17 and 16 are in the late Maestrichtian (even in its highest part for Core 16). It is probable that Cores 21 (below the subzone with *G. calcarata*) to 23 belong to the upper part of the Campanian because of the presence of:

Reussella szajochae (Grzyb. 1896) (some variants)
Aragonia gr. *seranensis* (v. d. Sluis, 1950)
Stensioeina interm. *pommerana* Brotzen, 1936-*labyrinthica* Cushman and Dorsey, 1940
Globotruncana fundiconulosa Subbotina, 1953
G. gr. *wiedenmayeri* Gandolfi, 1955

and specimens close to *G. contusa* (Cushman, 1926) and to *G. caliciformis* (J. de Lappar., 1918).

The inventory of this Late Cretaceous microfauna is a rather hasty one because of the short time available, but it nonetheless reveals one particular characteristic of these assemblages, i.e., the absence of some species and, at the same time, considerable difference from the microfauna in the same levels and especially in comparable pelagic facies in the Majunga Basin, which is not far way. In addition to the species already mentioned, the following can be added, for example:

Globotruncana elevata (Brotzen, 1934)
G. stuartiformis Dalbiez, 1955
G. arca (Cushman, 1926)
G. ventricosa White, 1928
the *Rugoglobigerina* group
Guembelina semicostata Cushman, 1938
Guembelina robusta Stenestad, 1968
Planoglobulina glabrata Cushman, 1938
Bolivinoides gr. *senonicus* var. *desnensis* Vasilenko, 1950
Stensioeina excolata (Cushman, 1926).

Moreover, there are various striking instances such as the scarcity of *Globotruncana stuarti* (J. de Lappar., 1918), of *G. falsostuarti* Sigal, 1952 (represented by relatively untypical forms), of *G. contusa* and of *G. caliciformis;* the absence of typical *G. gansseri* and of a goodly number of *Guembelina, Gueblerina* and *Planoglobulina* normally found at such levels; and the almost complete absence of the genus *Bolivinoides*, especially its classic species at such levels, as well as of *Bolivina* from the group of *incrassata* Reuss, 1851, and of *Neoflabellina* (one specimen of *N.* cf. *lacostei* [Marie, 1945] in 17-2, 40-42 cm).

Samples examined:

23-2, 140-146 cm
23-2, 130-132 cm
23-2, 100-102 cm
23-2, 40-42 cm
23-1, 127-129 cm
23-1, 99-101 cm
22, CC
22-6, 120-122 cm
22-6, 40-42 cm
22-5, 120-122 cm
22-5, 40-42 cm
22-4, 120-122 cm
22-4, 40-42 cm
22-3, 120-122 cm
22-3, 40-42 cm
22-2, 120-122 cm
22-2, 40-42 cm
22-1, 120-122 cm
22-1, 100-102 cm
21, CC
21-6, 120-122 cm
21-6, 40-42 cm
21-5, 120-122 cm
21-5, 40-42 cm
21-4, 120-122 cm
21-4, 40-42 cm
21-4, 8-10 cm
21-3, 132-134 cm
21-3, 130 cm
21-3, 120-122 cm
21-3, 40-42 cm
21-2, 120-122 cm
21-2, 40-42 cm
21-1, 120-122 cm
21-1, 40-42 cm
20-3, 120-122 cm
20-3, 40-42 cm
20-2, 120-122 cm
20-2, 40-42 cm
20-1, 120-122 cm
20-1, 30-32 cm
19, CC
19-4, 120-122 cm
19-4, 40-42 cm
19-3, 110-112 cm
19-3, 40-42 cm
19-2, 120-122 cm
19-2, 40-42 cm
19-1, 120-122 cm
18, CC
18-6, 120-122 cm
18-5, 40-42 cm
18-4, 120-122 cm
18-4, 40-42 cm
18-3, 120-122 cm
18-3, 40-42 cm
18-2, 120-122 cm
18-2, 45-47 cm
18-1, 120-122 cm
18-1, 40-42 cm
17, CC
17-6, 40-42 cm
17-5, 120-122 cm
17-5, 40-42 cm
17-4, 120-122 cm
17-4, 40-42 cm
17-4, 30 cm
17-3, 120-122 cm
17-3, 40-42 cm
17-2, 120-122 cm
20, CC
20-6, 40-42 cm
20-5, 120-122 cm
20-5, 85-87 cm
20-5, 40-42 cm
20-4, 120-122 cm
20-4, 40-42 cm
17-2, 40-42 cm
17-1, 130-132 cm
17-1, 78-80 cm
17-1, 10-12 cm
16, CC
16-2, 148-150 cm

There is a very large gap separating the Maestrichtian from the Miocene within the same core (Core 16) between levels 16-2, 148-150 cm and 137-139 cm.

Biostratigraphic Summary

Site 249 was cored nearly continuously in the upper part in order to obtain a complete sequence of the Quaternary and Neogene. Coring in the lower part was also fairly dense. The position of the site on a ridge, well above the CCD, guaranteed a good state of preservation for the calcareous fossils. In consequence, the younger sediments contain abundant and well-preserved foraminifera and nannoplankton assemblages.

The Quaternary has a thickness of about 1.7 meters. The lower part of the Pleistocene seems to be missing. One meter of very incomplete Pliocene, heavily mixed with Quaternary material, was identified by means of foraminifera. However, no Pliocene nannoplankton was found. From these determinations, a hiatus of at least 3 to 4 m.y. may be present.

The late Miocene shows an extremely high rate of sedimentation, up to 60 m/m.y. We suspect that there is a duplication of part of the upper Miocene sediments because of technical mixing. The sedimentation rate for the middle Miocene—so far as it exists—is about 8 m/m.y. This seems reasonable for the site. The overall sedimentation rate for the Miocene of Site 249 is about 19 m/m.y.

A very large hiatus, about 50-55 m.y., occurs between middle Miocene and Maestrichtian (even a part of the late Maestrichtian is missing). This gap, probably, is at least partly erosional as Paleocene (foraminifera) as well as Cretaceous (nannofossils) reworked material occur in the lowermost Miocene layers.

The Cretaceous stratigraphic sequence is far from complete; a wide hiatus of about 25 m.y. occurs between late Campanian and earliest Cenomanian or latest Albian. Moreover, there remains the possibility of a third gap just below, inside the interval between the Cenomanian/Albian and early Aptian/Barremian. Although neither foraminifera nor nannofossils have been observed in this interval, Radiolaria are present and may afford valuable data during later studies.

Finally, a thick Neocomian sequence (with the exception of Core 32, which is barren) overlies basalt. Foraminifera and ostracods indicate Hauterivian and Valanginian stages, comparable to the ones described from Madagascar and from along the coast of South Africa.

Sedimentation rates can be estimated for the Neocomian and the late Campanian-Maestrichtian, respectively, of about 5 and 20 m/m.y.

CORRELATION OF REFLECTION PROFILES AND LITHOLOGIES

The characteristics of the airgun reflection profile run by *Glomar Challenger* in the near-site area are essentially similar to the data obtained by *Gallieni* in 1972 (Cruise 6). Both records show a very rough basement topography intermittently overlain by sediment of variable thickness (0 to 1 sec DT). At Site 249, the acoustic basement is at a depth of 0.46 sec DT. The upper transparent layer is 0.35 sec DT thick and includes two minor reflectors, the first at 0.13 sec DT, and the second at 0.24 sec DT. The lower stratified series which rests upon the basement is 0.11 sec DT thick (Figures 5 and 8).

The lithologic description shows that the whole cored section above basement can be subdivided into three main lithostratigraphic units: Unit I, gray foram-rich nanno ooze (Cores 1 to 16, subbottom depth: 0 to 172 m); Unit II, brown and gray foram-bearing clay-rich nanno chalk (Cores 16 to 23, subbottom depth: 172 to 287 m), and Unit III, which is divided into two subunits: IIIA, gray and olive volcanic ash siltstones (Cores 23 to 29, subbottom depth: 287-352 m); and IIIB, gray and olive black silty claystones (Cores 29 to 32, subbottom depth: 352 to 408 m).

In the upper transparent layer, the first minor reflector at 0.13 sec DT cannot be correlated with any of the above mentioned lithologic subdivisions but may correspond to the sudden appearance in Core 13 (112-121 m), at approximately 115 meters depth, of thin semilithified layers. The measured sonic velocity and derived acoustic impedance show a clear increase at this same depth: the mean measured velocity for Cores 11 and 12 is 1.60 km/sec against 1.70 km/sec for Core 13. The second minor reflector at 0.24 sec DT could be correlated with the interface between Units I and II at 172 meters depth, but in this case the computed interval velocity would be 1.43 km/sec. This value is too low to support such a correlation. The very clear reflector at 0.35 sec DT, which separates the upper transparent layer and the stratified sequence, can confidently be correlated with the interface of Units II and III at 287 meters depth. If this correlation is valid, then the interval velocity for the transparent layer (0.35 sec DT thick) is about 1.64 km/sec, which is consistent with the average measured velocity of 1.65 km/sec for Cores 1 to 22. The boundary between subunits IIIA and IIIB at 352 meters does not correspond to any particular reflector. The last reflector at 0.46 sec DT corresponds to the basement, which was encountered at 408 meters depth. The overall interval velocity for the sedimentary sequence is 1.77 km/sec.

Figure 8 shows the correlation which can be established between the reflection profiler records and the lithology.

SUMMARY AND CONCLUSIONS

Site 249 is located close to the crest of the Mozambique Ridge near Latitude 30° S (with a water depth of 2088 m) and about 80 miles west of Site 248, which lies in the adjacent deep Mozambique Basin. The single hole penetrated 408 meters of almost exclusively Miocene and Cretaceous sediments and 4 meters into the underlying basaltic acoustic basement. The scientific results are summarized in Figure 9.

Seismic reflection profiles by *Conrad* Cruise 14 (1971), *Thomas B. Davie* Cruise 267 (1971), and *Gallieni* Cruise 6 (1972) show that the Mozambique Ridge is expressed morphologically by rough basement topography with overlying sedimentary accumulations of variable thickness (0–1.0 sec DT). The *Glomar Challenger* airgun profile shows, at the Site, an upper acoustically transparent layer 0.35 sec DT thick overlying a lower stratified layer 0.11 sec DT thick which rests upon acoustic basement at a depth of 0.46 sec DT. The main objectives of drilling this site were (a) to identify and date the presumed microcontinental basement material, and (b) to establish a midlatitude biostratigraphic succession above the CCD.

A nearly continuous coring program and excellent core recovery (79%) provided optimum conditions for attainment of the objectives.

The upper, acoustically transparent layer comprises two lithologic units and is 287 meters thick, with an inferred interval velocity of 1.64 km/sec. Unit I consists of 172 meters of soft gray foram-rich nanno ooze with clay content increasing downwards to about 10 percent and with local minor silt-bearing intervals. Thin semilithified chalk layers increase in frequency and thickness becoming the dominant lithology of Unit I below 159 meters. Rich and well-preserved foraminifera and nannoplankton assemblages indicate only 1.7 meters of Pleistocene sediment unconformably overlying material of incomplete early Pliocene, late Miocene and late middle Miocene ages. Unit II is composed of brown and gray foram-bearing clay-rich nanno chalk, 115 meters thick, of similar composition to the light gray foram-rich nanno chalks at the base of Unit I but showing a downward increase in clay, decrease in foraminifera, and the appearance of local silt-rich beds (some with trace amounts of zircon, rutile, and hematite). Extreme bioturbation is characteristic. The contact between Units I and II approximates very closely (at 172-176 m depth) the unconformity between late middle Miocene (Unit I) and the Late Cretaceous (late Maestrichtian to Campanian) Unit II. The early Miocene and entire Paleogene are absent.

At a subbottom depth of 287 meters, the Campanian chalk of Unit II rests unconformably upon Cenomanian/Neocomian siltstones and claystones of Unit III which comprise the acoustically stratified layer, 0.11 sec DT thick, overlying acoustic basement. The prominent seismic reflector marking the top of Unit III correlates very well with the change in lithology and with abrupt increases in sonic velocity, acoustic impedance, and bulk density. Unit III is 121 meters thick and is characteristically dark gray and olive, almost black, in color possibly due to the presence of free carbon (up to 1.6%) and iron sulfides. Foraminifera and nannofossils are rare and without precise age-significance (the former consisting of benthonic forams), but Radiolaria are well represented. Siltstones predominate near the top, claystones towards the bottom, both carrying a very large proportion of either fresh or devitrified and altered volcanic ash. The beds are laminated with low-angle cross-stratification and are occasionally graded. A few thin limestone beds were observed, together with minor amounts of glauconite.

The acoustic basement was penetrated at a depth of 408 meters and identified as glassy basalt, weathered on top and vesicular in the upper two meters with amygdules of calcite and chlorite and calcite-filled veins. Phenocrysts of plagioclase are set in a groundmass of brown palagonite.

A single heat flow measurement gave a preliminary value of 1.00 micro-cal/cm^2 sec which, surprisingly, is identical

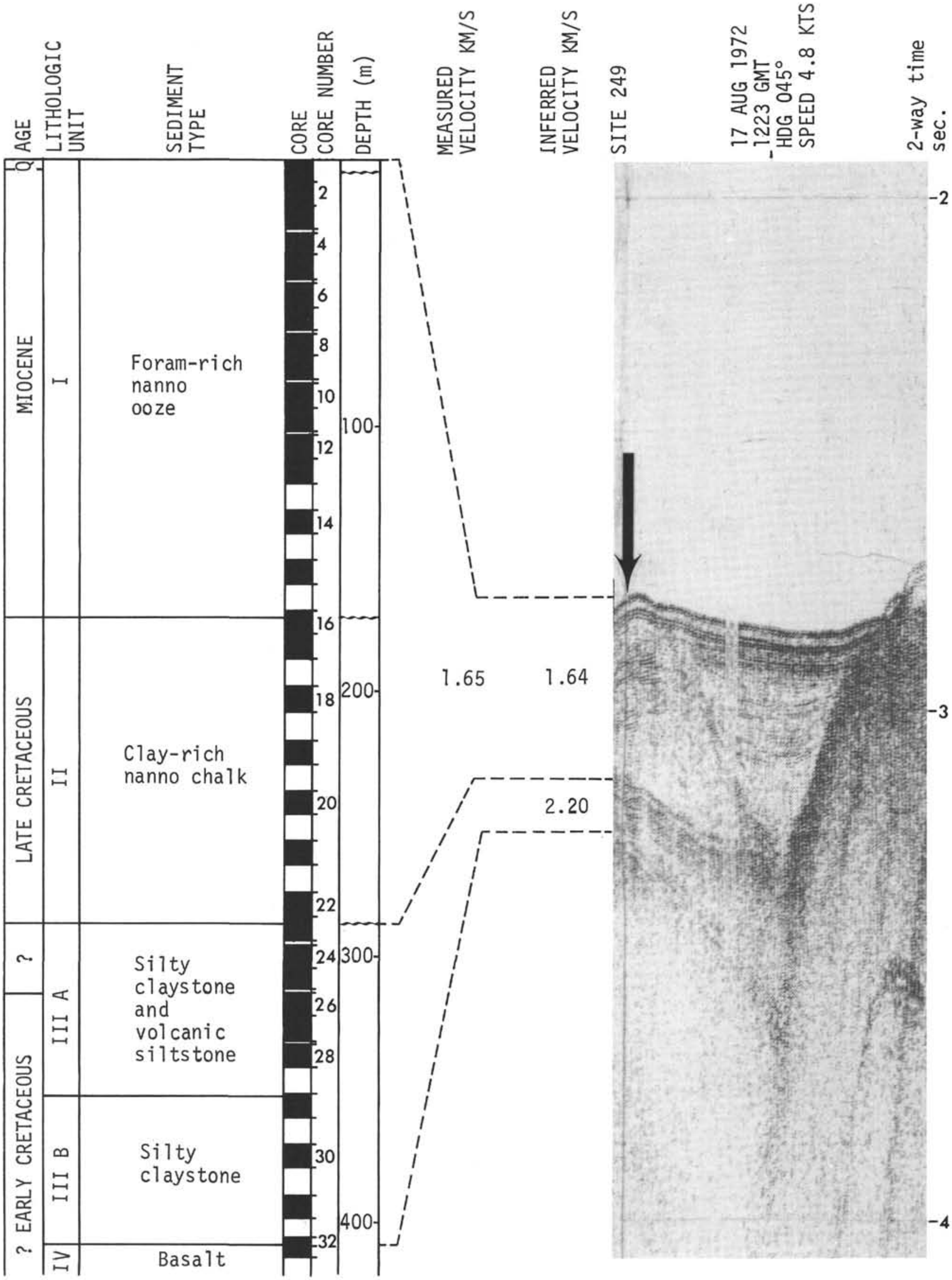

Figure 8. *Correlation of seismic reflection profile with lithology. Wavy lines in the depth column indicate hiatuses.*

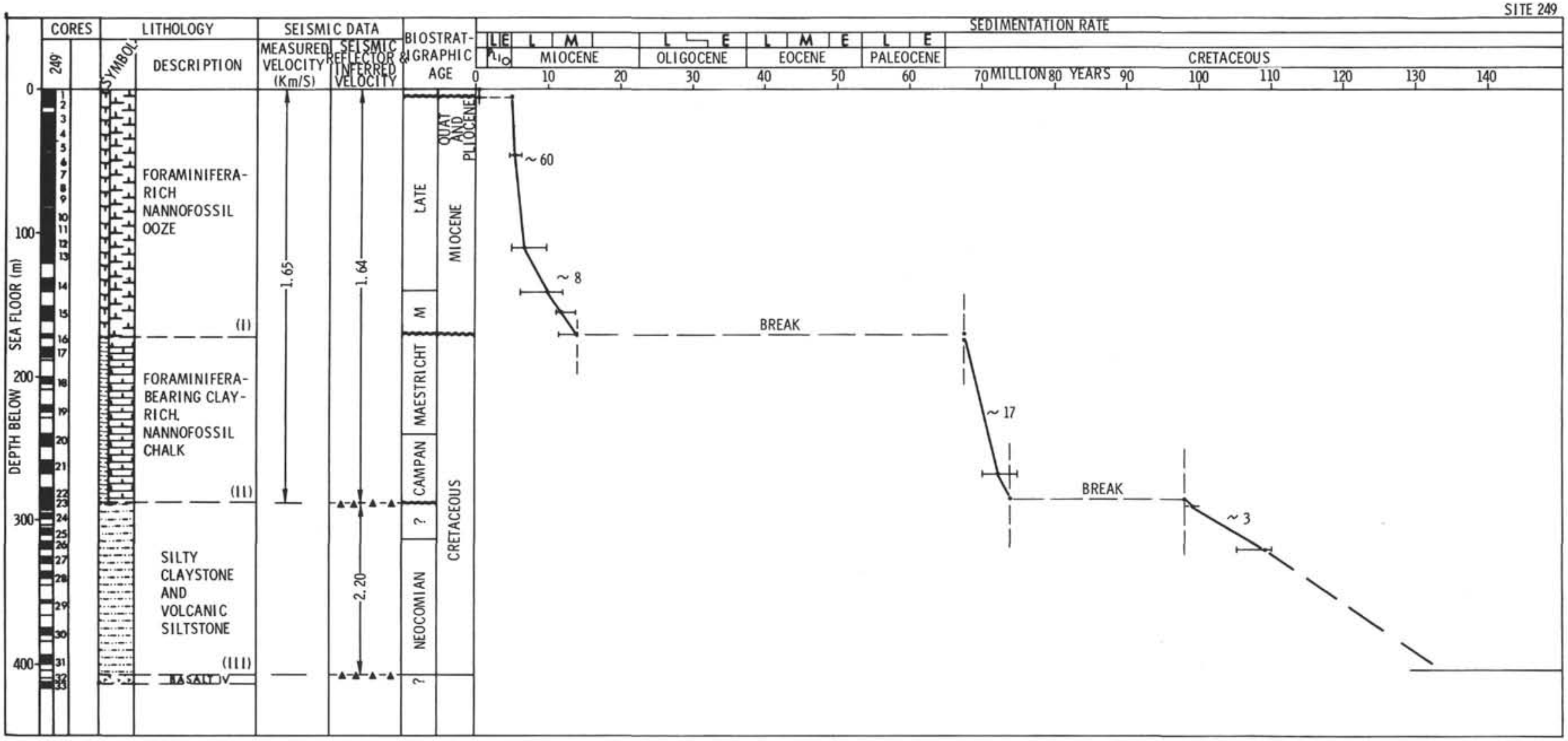

Figure 9. *Summary diagram, Site 249.*

with the value obtained at Site 248 in the adjacent Mozambique Basin.

Preliminary consideration of the bio- and lithostratigraphic succession at Site 249 leads to the interesting possibility of a close comparison with the Cretaceous and Tertiary of certain parts of western Madagascar. Correspondence with parts of the Cretaceous succession described from coastal Mozambique is also close.

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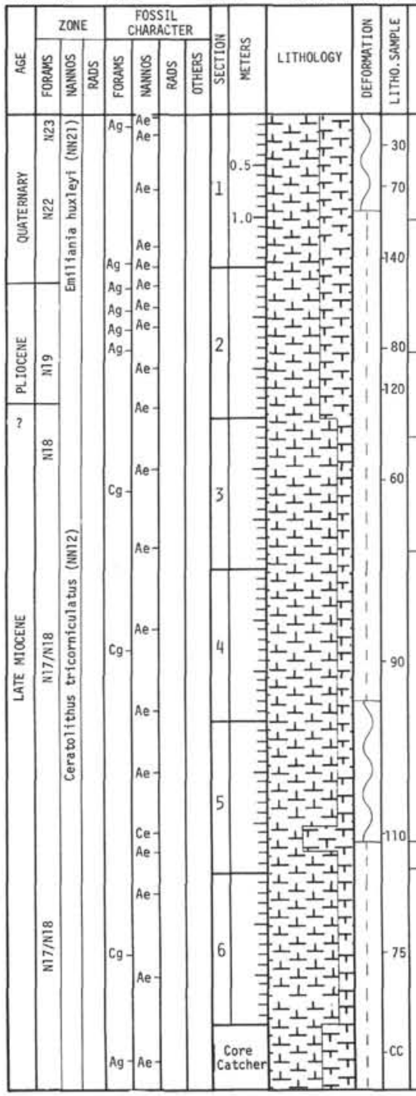
Site 249 Hole Core 1 Cored Interval: 0-8 m



LITHOLOGIC DESCRIPTION

Core is very soft to soupy. Colors are mostly pale yellow brown (10YR6/2) and very pale orange (10YR8/2) in upper portions, becoming white (N9), pink gray (5YR8/1) and very light gray (N8) with depth.

10YR6/2

FORAM-RICH/FORAM NANNO OOZE
Smears 1-30, 1-70, 1-140, 2-80, 2-120, 3-60, 4-90, 6-75, CC

10YR8/2

Composition

forams	20-40%
calc. nannos	45-85%
qtz. & feld.	0- 1%

NANNO/FORAM OOZE
Smear 5-110

N9

Composition

forams	55%
calc. nannos	44%
qtz. & feld.	1%

5YR8/1

Carbon-Carbonate
1-80 (10.8-0.1-89.0)
3-70 (10.3-0.1-85.0)
6-71 (10.4-0.1-86.0)

Wt. % forams (>100μ)

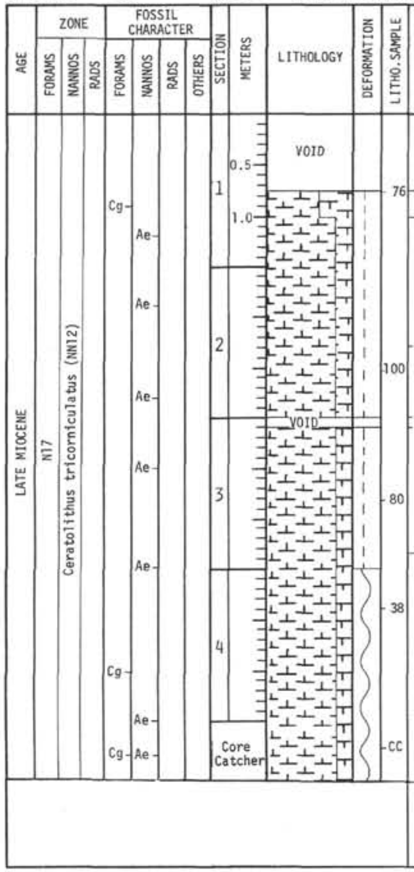
1-1	56%
1-140	20%
2-50	20%
CC	10%

N8

10YR6/2-
5YR8/1

Foraminifera in the core catcher sample are of mixed ages.

Site 249 Hole Core 2 Cored Interval: 8-17 m



LITHOLOGIC DESCRIPTION

Core is slightly deformed. Colors lighten to base with very pale orange (10YR8/2), very light gray (N8) grading to black white (5B9/1); few black pyrite streaks.

10YR8/2 very pale orange

N8 very light gray

FORAM-RICH/FORAM NANNO OOZE
Smears 1-76, 2-100, 3-80, 4-28, CC

Composition

calc. nannos	54-74%
forams	20-40%
clay	5%
qtz.	1%

5B9/1 bluish white

Carbon-Carbonate
2-135 (10.8-0.1-89.0)
3-90 (10.7-0.1-88.0)

N8 very light gray

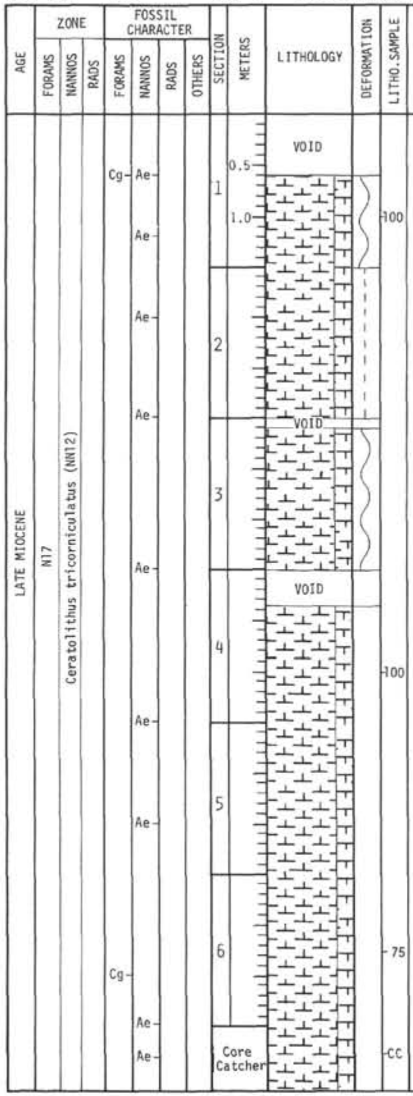
$CaCO_3$ Content

2-91	89%
3-69	89%
CC	87%

5B9/1 bluish white

Explanatory notes in chapter 1

Site 249 Hole Core 3 Cored Interval: 17-26 m



LITHOLOGIC DESCRIPTION

Core is very soft to soupy throughout; mainly light gray (N7-N8) with few black pyritic streaks.

N8 very light gray
to
N7 light gray

FORAM-RICH NANNO OOZE
Smears 1-100, 4-100, 6-75, CC
Composition

calc. nannos	85%	qtz.	Tr.
forams	15%		

N8 very light gray
to
N7 light gray

Carbon-Carbonate
6-80 (10.6-0.1-87.0)

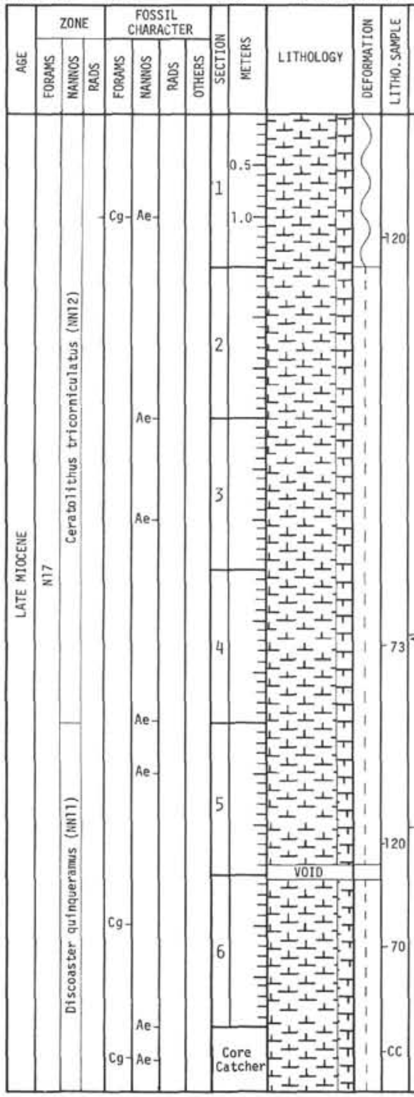
CaCO₃ Content

4-60	87%
CC	90%

Wt. % forams (>100μ)

CC	8%

Site 249 Hole Core 4 Cored Interval: 27-36 m



LITHOLOGIC DESCRIPTION

Core is soupy in top 1.5 m, trending to slightly deformed. Colors are mainly very light-light gray (N7-N8) with green and black pyritic streaks. Local burrow mottling.

FORAM-RICH NANNO OOZE
Smears 1-120, 5-120, 6-70, CC
Composition

↑	calc. nannos	85%
N8-N7	forams	10%
↓	clay	5%

burrows (2-40)

CLAY/FORAM-RICH NANNO OOZE
Smear 4-73
Composition

calc. nannos	75%
forams	15%
clay	10%

Carbon-Carbonate
5-80 (10.6-0.1-87.0)

CaCO₃ Content

6-80	90%
CC	87%

Wt. % forams (>100μ)

CC	7%

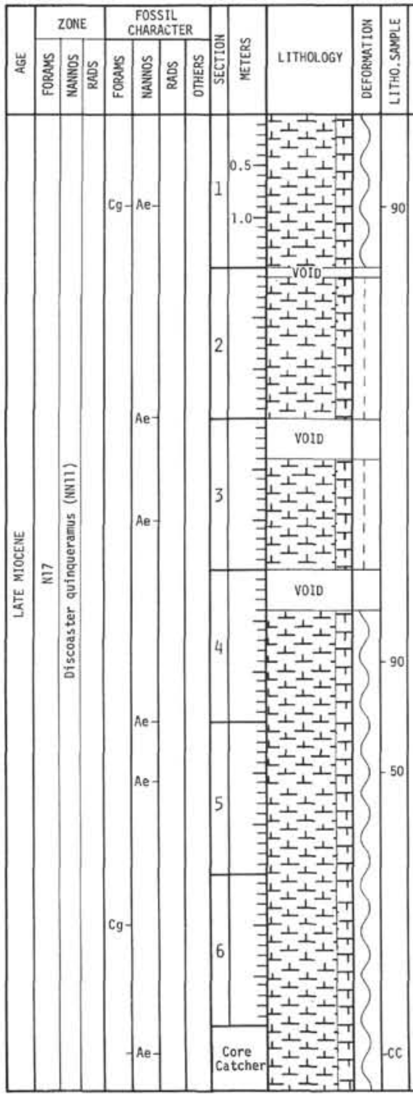
pale green (5G7/2) streak

N7 light gray

N8 very light gray

Explanatory notes in chapter 1

Site 249 Hole Core 5 Cored Interval: 36-45 m



LITHOLOGIC DESCRIPTION

Core is soupy in Sections 1, 4, 5 & 6, being slightly deformed in Sections 2 & 3. Very light gray-light gray (N8-N7) throughout with black streaks.

N8 very light gray
to
N7 light gray

FORAM-RICH NANNO OOZE
Smears 1-90, 4-90, 5-50, CC
<u>Composition</u>

calc. nannos	85%
forams	10%
clay	4%
qtz.	1%

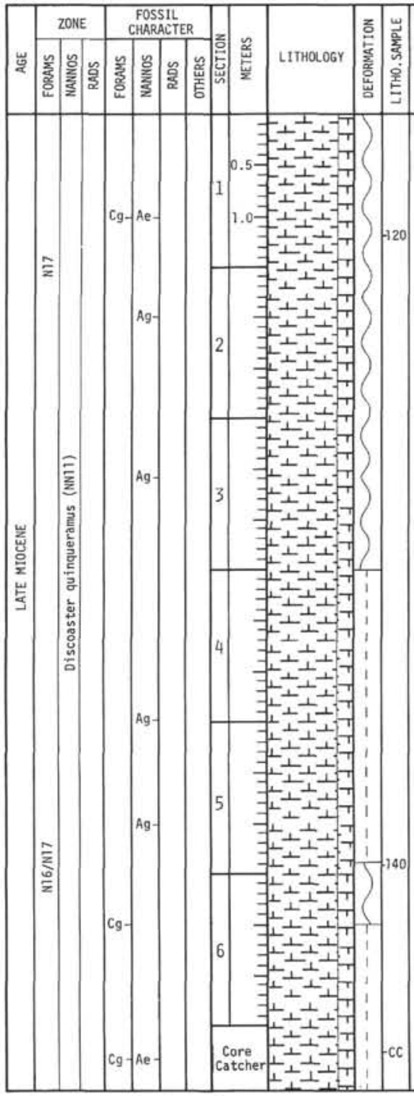
black streaks

<u>Carbon-Carbonate</u>
3-80 (10.6-0.1-87.0)

<u>Wt. % forams (>100μ)</u>
3-81 0.5%

N8 very light gray

Site 249 Hole Core 6 Cored Interval: 46-55 m



LITHOLOGIC DESCRIPTION

Core is soupy in upper half; slightly deformed in lower half. Color is light gray (N7) to very light gray (N8) throughout with some green (5G7/2) and black streaks (pyrite).

N7
to
N8

black pyritic streaks

FORAM-RICH NANNO OOZE
Smears 1-120, 5-140
<u>Composition</u>

calc. nannos	80%
forams	15%
clay	5%

<u>Carbon-Carbonate</u>
3-80 (10.2-0.1-84.0)

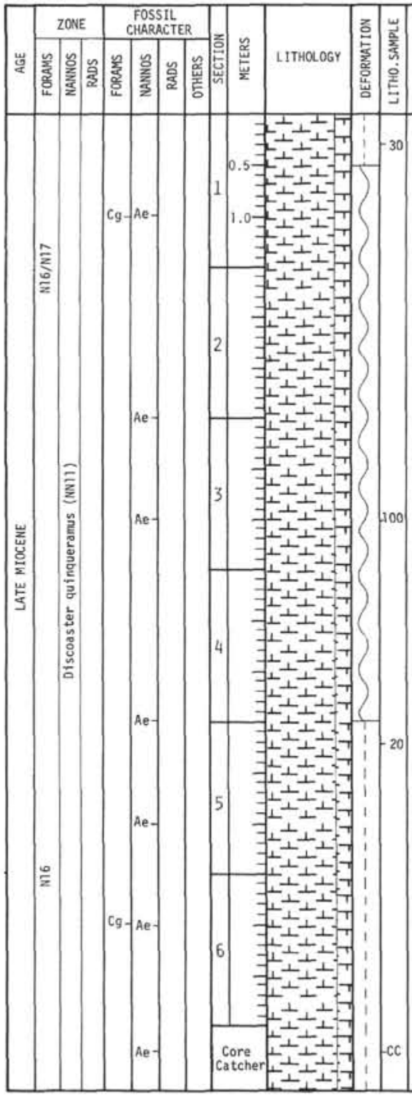
<u>$CaCO_3$ Content</u>
1-80 85%
CC 86%

vertical streaks 3-75 to 3-140
black-pale green (5G7/2)

<u>Wt. % forams (>100μ)</u>
1-81 0.6%
CC 0.9%

Explanatory notes in chapter 1

Site 249 Hole Core 7 Cored Interval: 55-64 m



LITHOLOGIC DESCRIPTION

N8
to
N7

Core is one-half soupy, one-half slightly deformed with colors light gray (N7) to very light gray (N8); occasional black pyrite streaks.

FORAM-RICH NANNO OOZE
Smears 1-30, 3-100, 5-20, CC
Composition

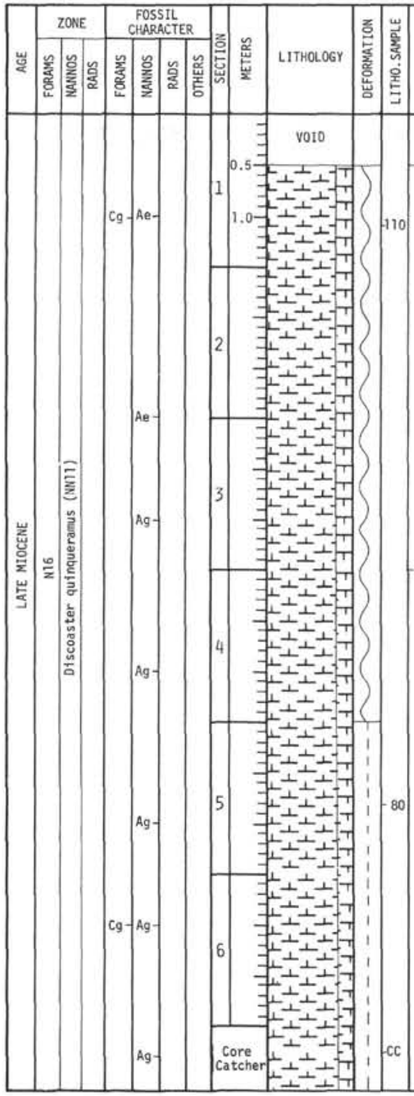
calc. nannos	85%
forams	10%
clay	5%

Carbon-Carbonate
1-32 (10.4-0.1-86.0)

$CaCO_3$ Content
2-80 86%
CC 86%

Pyritic streaks

Site 249 Hole Core 8 Cored Interval: 65-74 m



LITHOLOGIC DESCRIPTION

N8
&
N7

Core is very deformed in upper two-thirds becoming slightly deformed in lower one-third. Color basically light gray (N7) to very light gray (N8) with black pyritic streaks.

FORAM-RICH NANNO OOZE
Smears 1-110, 5-80, CC
Composition

calc. nannos	85%
forams	10%
clay	5%

Grain Size
1-134 (2-31-67) silty clay

Carbon-Carbonate
1-129 (10.5-0.1-87)

$CaCO_3$ Content
1-130 86%

N8 very light gray

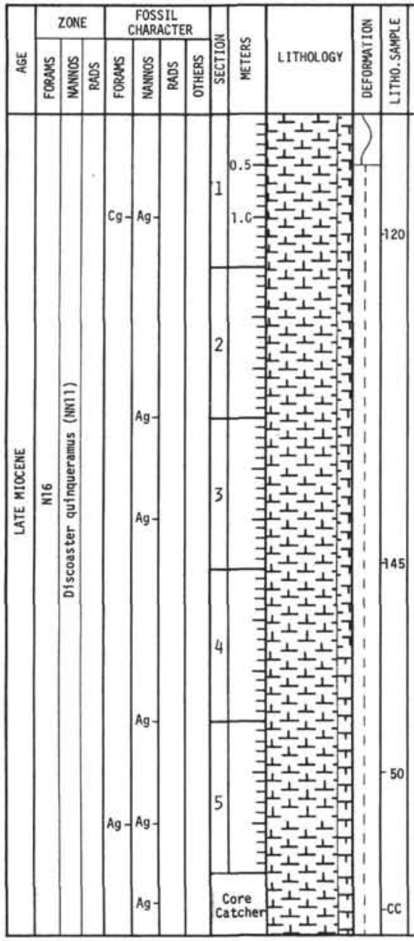
black pyritic streaks

N8

N8

Explanatory notes in chapter 1

Site 249 Hole Core 9 Cored Interval: 74-83 m



LITHOLOGIC DESCRIPTION

N7
&
N8

Core is slightly deformed throughout with color light gray (N7) to very light gray (N8) and occasional black pyrite streaks.

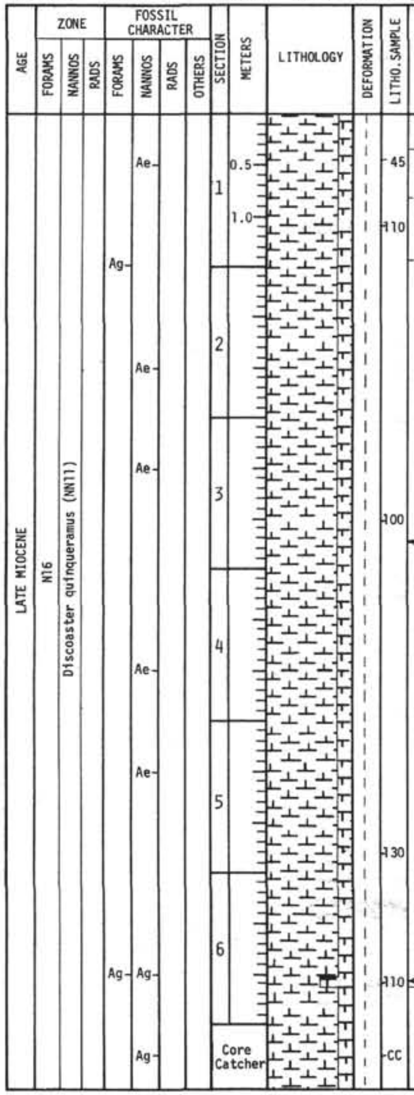
FORAM-RICH NANNO OOZE
Smears 1-120, 3-145, 5-50, CC
<u>Composition</u>

calc. nannos	75%
forams	20%
clay	5%

<u>Grain Size</u>
3-79 (4-31-65)

<u>Carbon-Carbonate</u>
1-102 (10.5-0.1-87)

Site 249 Hole Core 10 Cored Interval: 84-93 m



LITHOLOGIC DESCRIPTION

5GY8/1
light green gray

5B7/1 light blue gray

Core mostly soft but with few alternating stiff layers with higher foram content. Colors light gray (N7), with areas of light green gray (5G8/1). Few black pyritic streaks throughout.

5G8/1
light
green gray

N7 light gray

FORAM-RICH NANNO OOZE
Smears 1-45, 1-110, 3-100, 5-130, CC
<u>Composition</u>

calc. nannos	70-75%
forams	20-25%
clay	5-10%

FORAM NANNO OOZE
Smear 6-110
<u>Composition</u>

calc. nannos	50-60%
forams	40-50%

<u>Carbon-Carbonate</u>
1-98 (9.1-0.1-75)

Pyrite in burrows

few stiff layers in otherwise soft sediment

<u>$CaCO_3$ Content</u>

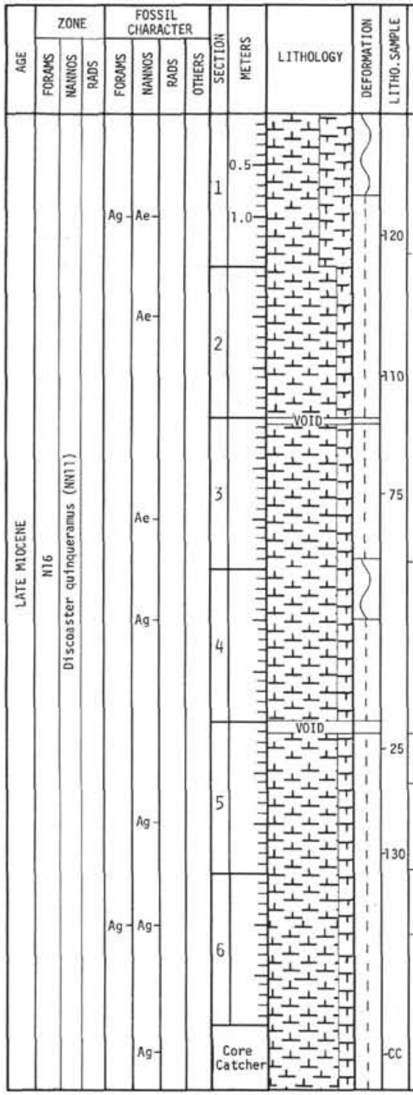
1-101	83%
CC	80%

N8 very light gray

becomes very stiff
N7 light gray
N8 very light gray

Explanatory notes in chapter 1

Site 249 Hole Core 11 Cored Interval: 93-102 m



LITHOLOGIC DESCRIPTION

Core is slightly deformed with alternating soft and stiff layers which do not reflect compositional differences. Colors are mainly light gray (N7) and very light gray (N8).

N7
to
N8

FORAM NANNO OOZE
Smears 1-120, 3-75, 5-25, 5-13
Composition

calc. nannos	54%	clay	5%
forams	40%	qtz.	1%

N8 very light gray

FORAM-RICH NANNO OOZE
Smear 2-110
Composition

calc. nannos	80%
forams	15%
clay	5%
qtz.	Tr.

Section 4: alternating soft and stiff layers.

Carbon-Carbonate
1-60 (10.5-0.1-87.0)

CaCO$_3$ Content
2-61 85%
CC 86%

Section 6: soft with alternating stiff layers.

N7 light gray

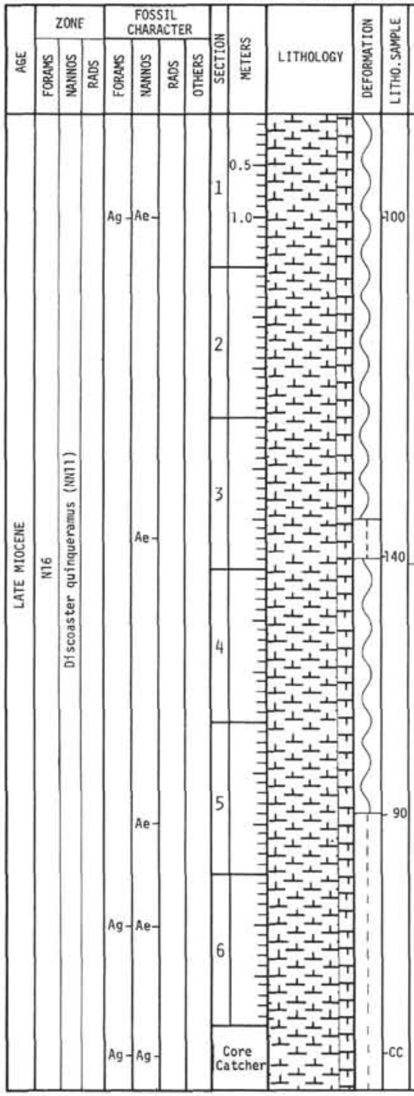
N7-N6
light gray-medium light gray

N7 light gray

N8 very light gray

N7 light gray

Site 249 Hole Core 12 Cored Interval: 103-112 m



LITHOLOGIC DESCRIPTION

Core is soft to soupy but locally becomes stiff. Color is predominately light gray (N7) and very light gray (N8).

N8

FORAM-RICH NANNO OOZE
Smears 1-100, 3-140, 5-90, CC
Composition

calc. nannos	75%
forams	24%
qtz.	1%

Carbon-Carbonate
1-80 (10.4-0.2-86.0)

CaCO$_3$ Content
1-81 86%
5-110 82%

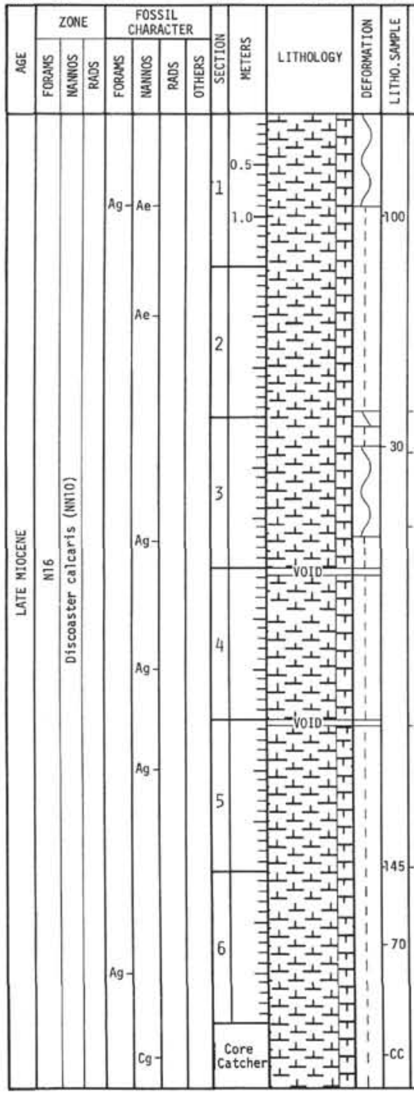
3-103 becomes stiff

N7 light gray

Generally soft with stiff zone 140-150 cm.

Explanatory notes in chapter 1

Site 249 Hole Core 13 Cored Interval: 112-121 m



LITHOLOGIC DESCRIPTION

Core soupy in some areas but slightly stiff to semilithified in others. Color primarily light gray (N7) and very light gray (N8), with light olive gray (5Y6/1) and green gray (5GY6/1) zones.

N7

FORAM-RICH NANNO OOZE
Smears 1-100, 3-30, 5-145, 6-70, CC

Composition	
calc. nannos	74%
forams	25%
qtz.	1%

Contains chalky layers at:
2: 75-110 cm
3: 12-35 cm, 115-150 cm
4: alternating thin layers
5: alternating thin layers
6: alternating thin layers

N6 medium light gray

N8 very light gray

N7 light gray

Generally a FORAM-RICH NANNO OOZE containing local thin zones which contain some clay. Mostly an ooze but locally is semilithified to chalk. Chalks too thin to show as distinct beds at this scale.

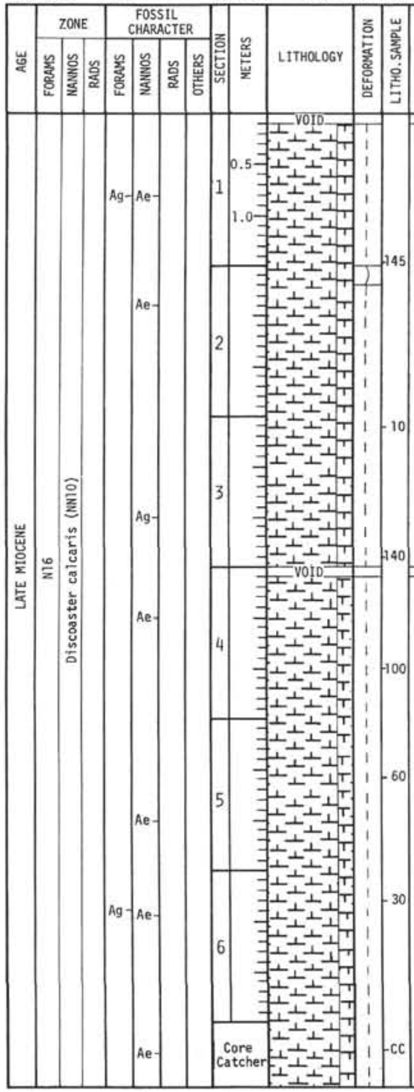
Carbon-Carbonate
1-99 (10.1-0.1-83.0)

$CaCO_3$ Content	
1-97	83%
5-100	84%
CC	85%

5Y6/1
light olive gray

green gray
5GY6/1

Site 249 Hole Core 14 Cored Interval: 131-140 m



LITHOLOGIC DESCRIPTION

Core is slightly deformed. Local clay-rich or chalky layers yield alternating soft and stiff layers. Colors are light gray (N7) with very pale orange (10YR8,2) and black pyrite streaks.

N7

very pale orange (10YR8/2) at:
2: 50-55, 90-100, 135-145
3: 0-18 cm.

FORAM-RICH NANNO OOZE
Smears 1-145, 3-10, 3-140, 4-100, 5-60, 6-30, CC

Composition	
calc. nannos	68%
forams	25%
clay	5%
qtz.	2%

N7

Carbon-Carbonate
1-42 (10.0-0.1-83.0)

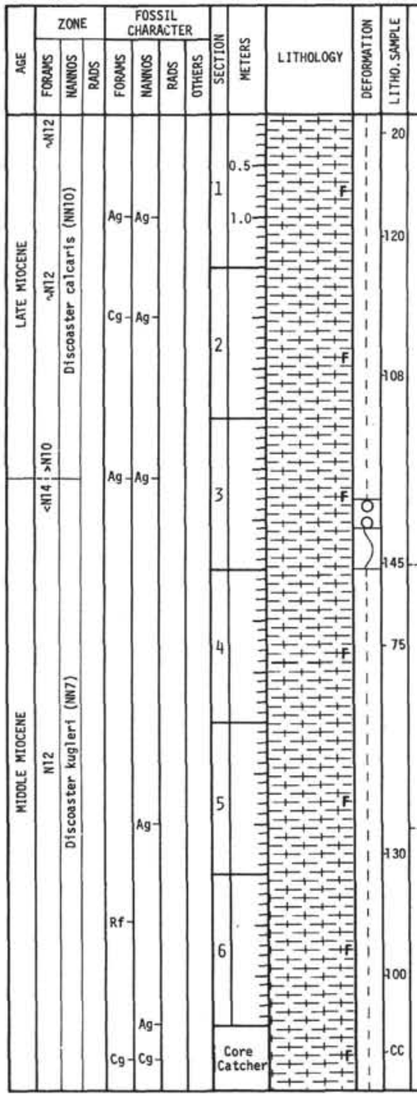
Section 4, 30-40 cm black pyritic streaks

N7

N7

Explanatory notes in chapter 1

Site 249 Hole Core 15 Cored Interval: 150-159 m



LITHOLOGIC DESCRIPTION

5Y8/1 yellow gray
with 5GY6/1 green gray

thin zone irregular laminae

Core is generally an ooze, being slightly deformed but with local stiff and soft laminae. Local burrow mottling. Colors are dominately yellow gray (5Y8/1) with local light gray (N7) and green gray (5GY6/1) streaks.

burrows at 2: 40-70 cm

FORAM/CLAY-BEARING NANNO OOZE AND CHALK
Smears 1-20, 1-120, 2-108, 3-145, 4-75, 5-130, 6-100, CC

Composition

calc. nannos	83-86%
clays	7-10%
forams	7%

Dissolution of foram tests apparent in Section 6.

5Y8/1 yellow gray

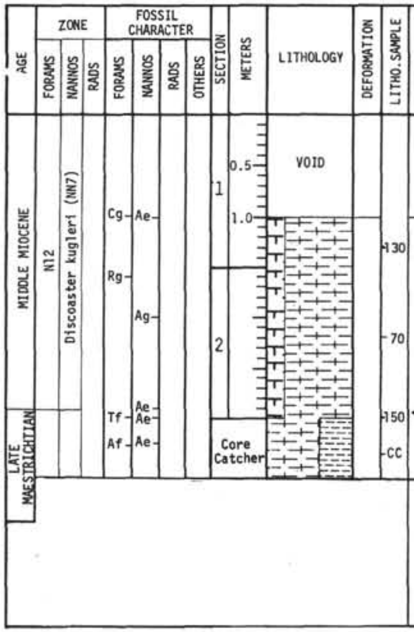
CaCO$_3$ Content
1-64 78%

5Y8/1 yellow gray
with N7 light gray

Section 5 has many alternating stiff and soft layers.

N7 light gray with 5Y8/1 yellow gray

Site 249 Hole Core 16 Cored Interval: 169-178 m



LITHOLOGIC DESCRIPTION

Core is stiff and chalky throughout. Colors are light gray (N7) with local very light gray (N9) and pale orange (10YR8/2). Sharp color change and lithologic break at base of Section 2.

Deformed bedding and black pyrite streaks 100-125 cm.
N7 light gray

N8 very light gray with 10YR8/2 pale orange

FORAM-RICH NANNO CHALK
Smears 1-130, 2-70, 2-150

Composition

calc. nannos	76%	qtz.	2%
forams	20%	micarb.	2%

UNCONFORMABLE CONTACT

moderate brown 5YR4/4

SILT-RICH CLAY NANNO CHALK
Smear CC

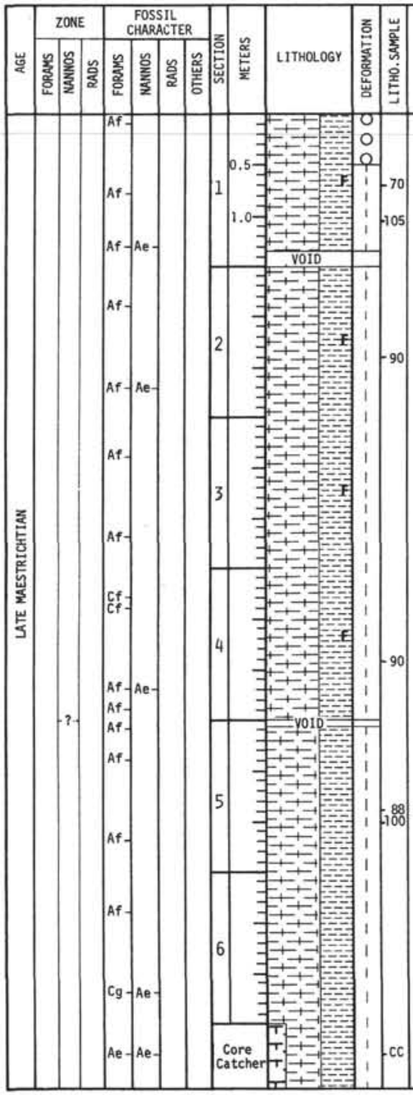
Composition

calc. nannos	45%	carb. rhombs	Tr.
qtz. & feld.	10%	heavies	Tr.
clay	45%		

CaCO$_3$ Content
2-34 84%
CC 38%

Explanatory notes in chapter 1

Site 249 Hole Core 17 Cored Interval: 178-187 m



LITHOLOGIC DESCRIPTION

Core is slightly to moderately deformed and is brecciated near top of Section 1. Color is light brown (5YR5/6) with several zones of very light gray (N8).

FORAM BEARING CLAYEY NANNO CHALK
Smears 2-90, 4-90

Composition

nannos	60%
clays	30%
forams	7%
det. silt	3%

Aragonite vein

Carbon-Carbonate
1-49 (5.7-0.1-47.0)

$CaCO_3$ Content
CC 47%

CLAY-BEARING LIMESTONE
Smear 5-88

Composition

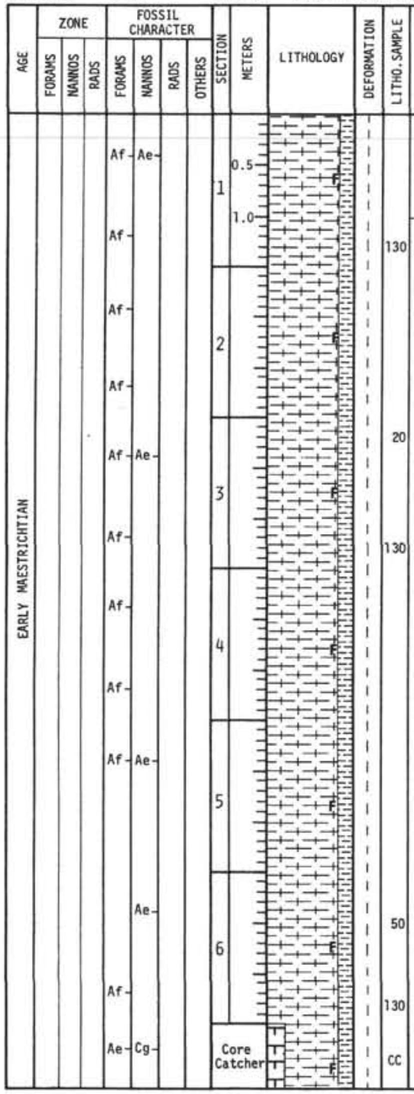
micarb.	90%
calc. nannos	5%
clays	5%

Nannoplankton indicate Maestrichtian above Section 4 and late(?) Campanian below. Forams indicate Maastrichtian.

Aragonite

←1 cm limestone

Site 249 Hole Core 18 Cored Interval: 198-207 m



LITHOLOGIC DESCRIPTION

Core is moderately deformed throughout. Entire core is intermixture of FORAM-BEARING and CLAY-RICH NANNO CHALK becoming clay-rich and foram-rich locally. Color changes are gradual but frequent between light brown (5YR5/6 and light olive gray (5Y6/1). Most of core is chalk but local zones are soft.

light olive gray (5Y6/1) predominates

FORAM/CLAY-RICH NANNO CHALK
Smear 6-50

Composition

calc. nannos	60%
forams	10%
clays	29%
qtz.	1%

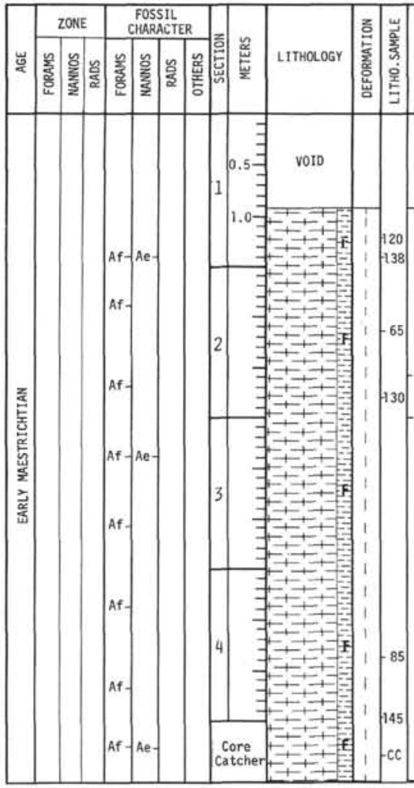
Carbon-Carbonate
1-100 (6.8-0.1-55.0)

Aragonite shell fragment 3-90

Core is late Campanian according to nannoplankton.

Explanatory notes in chapter 1

Site 249 Hole Core 19 Cored Interval: 218-227 m



LITHOLOGIC DESCRIPTION

Core is moderately deformed throughout. Color alternates between light brown (5YR5/6) and light olive gray (5Y6/1) with local green gray (5G6/1); core contains many burrows.

5YR5/6 light brown
with light olive gray (5Y6/1)

FORAM/CLAY-RICH NANNO CHALK
Smear 2-130
<u>Composition</u>
calc. nannos 70%
forams 10%
clays 19%
qtz. 1%

10YR6/2 pale yellow brown

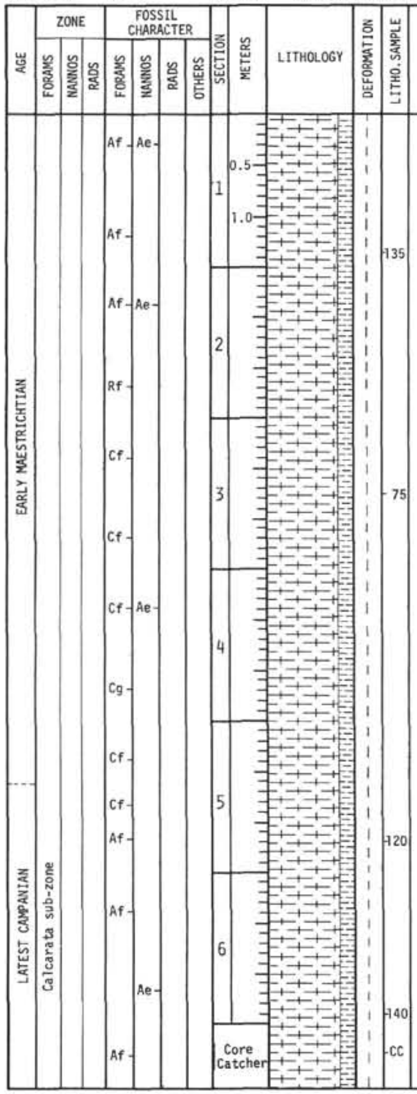
<u>Carbon-Carbonate</u>
1-102 (6.7-0.1-55.0)

light brown (5YR5/6)
and
light olive gray (5Y6/1)

Aragonite shell fragments

Late Campanian(?) according to nannoplankton.

Site 249 Hole Core 20 Cored Interval: 237-246 m



LITHOLOGIC DESCRIPTION

Core is slightly deformed. Color varies from olive gray (5Y4/1) to light gray (N7) and exhibits burrow mottling.

CLAY-RICH NANNO CHALK
Smear 3-75
<u>Composition</u>
calc. nannos 80%
clays 18%
forams 2%

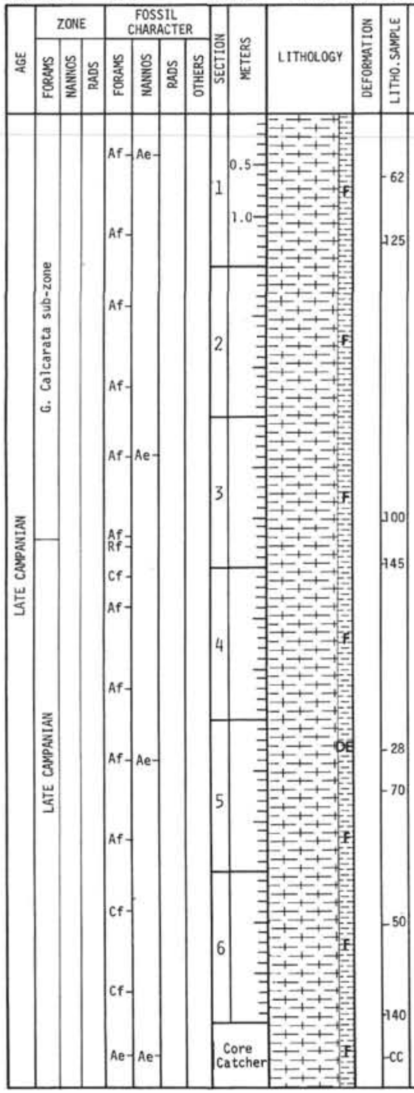
<u>Carbon-Carbonate</u>
1-125 (7.4-0.2-60.0)

Core is late Campanian according to nannoplankton.

Aragonite shell fragments

Explanatory notes in chapter 1

Site 249 Hole Core 21 Cored Interval: 256-265 m



LITHOLOGIC DESCRIPTION

Core is slightly to moderately deformed. Color is predominantly brown (5YR5/6) with layers and irregular patches of light olive gray (5Y6/1). Burrows occur throughout.

CLAY-RICH and FORAM-BEARING NANNO CHALK
Smears 3-100, 5-70

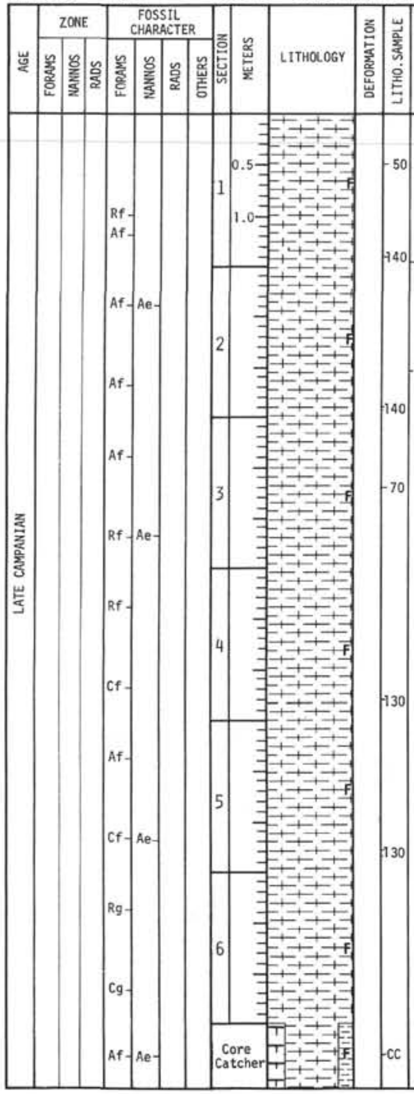
<u>Composition</u>

calc. nannos	80%
clays	13%
forams	6%
qtz.	1%

<u>Carbon-Carbonate</u>
1-93 (6.8-0.1-55.0)

<u>X-ray 2-10</u>		<u>X-ray 2-102</u>	
calc.	A	calc.	A
qtz.	T	qtz.	P
k-feld.	T	mica	P
mica	T	paly.	P
paly.	T	k-feld.	T
		plag.	T

Site 249 Hole Core 22 Cored Interval: 275-284 m



LITHOLOGIC DESCRIPTION

Core is lithified and undeformed throughout. Color varies between brown and gray with abundant bioturbation mottling. Core is locally clay-rich or foram-rich.

5G6/1
green gray
with N7
light gray

unusual burrow
pattern at 2-50

5Y6/1 olive gray

5YR4/4 moderate brown
mottled by light gray (N7)

CLAY-and FORAM-BEARING NANNO CHALK
Smear 3-70

<u>Composition</u>

calc. nannos	84%
forams	7%
clay	7%
qtz.	2%

CLAY-FORAM RICH NANNO CHALK
Smears 1-50, 1-140, 2-140, CC

<u>Composition</u>

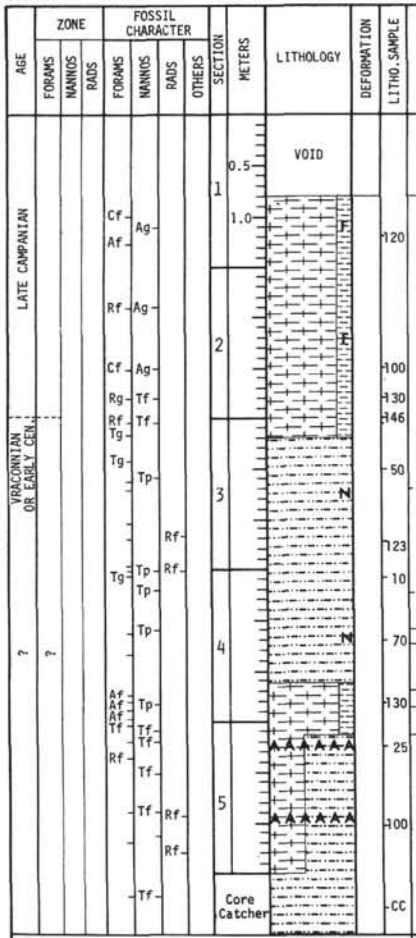
calc. nannos	68%
forams	10%
clay	20%
qtz.	1%

Forams are mainly benthonic.

<u>Carbon-Carbonate</u>
1-61 (5.6-0.1-46.0)

Explanatory notes in chapter 1

Site 249 Hole Core 23 Cored Interval: 284-293 m



LITHOLOGIC DESCRIPTION

Core is undeformed. Color varies greatly between moderate brown (5YR4/4) and light gray (N7). Mottled where burrowed. Lithology varies greatly throughout core. Local silt-size clay mineral zones, some iron rich; local devitrified ash beds.

5YR4/4 moderate brown

FORAM-BEARING CLAY-RICH NANNO CHALK
Smears 1-20, 2-100, 4-130, 5-25

Composition

calc. nannos	70%
clays	25%
forams	4%
qtz.	1%

black iron rich burrow fill 71-73 cm

128-150 cm: CLAY MIN. ZONES

BLACK IRON RICH 0-22 cm.

5YR4/4 olive gray

NANNO-BEARING SILT-RICH CLAYSTONE
Smears 3-50, 3-123, 4-10, 4-70, 4-130, 5-100, CC

Composition

clays	75%	chlor.	1%
qtz. & feld.	15%	calc. nannos	6%
opaques	3%		

green gray 5GY6/1

5GY5/2 dusky yellow green

5GY6/1 gray green

Carbon-Carbonate

2-60	(5.3-0.1-43.0)
4-218	(5.5-0.1-45.0)
5-27	(2.1-0.4-14.0)
5-125	(1.3-1.0-2.0)

5GY5/2

5GY6/1 gray green 122-136 cm
5GY5/2

black (N1)
ASH BED 28-36 cm

Grain Size

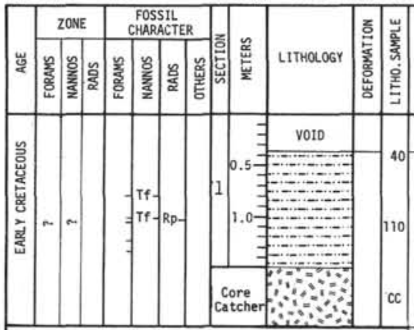
2-58	(1.5-26.2-72.2)
4-129	(6.8-40.0-53.1)
5-70	(0.1-32.7-67.2)

pyrite crystals
ASH BED 95-104 cm

X-ray 2-56		X-ray 4-85	
calc.	A	calc.	P
qtz.	P	qtz.	P
plag.	P	plag.	P
mica	P	mica	P
paly.	P	mont.	P
k-feld.	T	paly.	P
mont.	T	clino.	P
clino.	T	k-feld.	T

Age is early Late Cretaceous according to Radiolaria.

Site 249 Hole Core 24 Cored Interval: 294-303 m



LITHOLOGIC DESCRIPTION

Core is undeformed and stiff. Color is predominantly black.

N5 medium gray

black (N1)

CARBON-BEARING SILTY CLAY
Smear 1-110

Texture	Composition	
(0-30-70)	clay min.	60%
	cris. & trid. qtz. & feld.	33%
	carb. mat.	7%
	pyrite	Tr.

TUFF

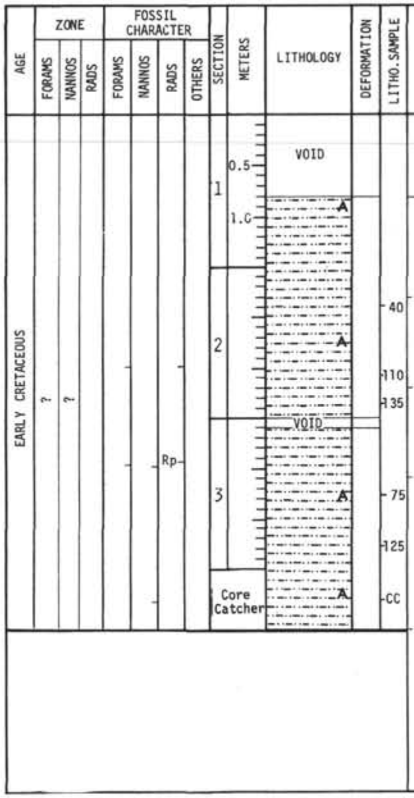
Carbon-Carbonate

1-75	(5.5-1.1-37.0)
1-144	(1.3-1.2-1.0)
CC	(0.3-0.3-0.0)

Grain Size
1-75 (0-29-71) silty clay

X-ray CC			
cris.	A	k-feld.	T
qtz.	P	mica	T
plag.	P	paly.	T
trid.	P	pyrite	T

Site 249 Hole Core 25 Cored Interval: 303-312 m



LITHOLOGIC DESCRIPTION

Core is undeformed and lithified. Colors are mostly dark grays to blacks. Color boundaries are gradational. Black color at top of core is due to high organic matter content. Local silt size clay min. zones.

black (N1)

olive gray (5Y4/1) and green gray (5G6/1)

medium light gray (N6)

green gray (5G4/1)

medium dark gray (N4)

brecciated

VOLCANIC SILTY CLAYSTONE
Smears 2-40, 2-110, 2-135, 3-75, 3-125

Texture	Composition	
(5-35-60)	clay (volcanic)	60%
	vol. gls.	10%
	organic mat.	10%
	qtz., feld., cris.	15%
	blk. opaques	5%

Carbon-Carbonate
1-82 (3.6-1.6-16.0)
2-82 (0.2-0.1-1.0)
3-17 (0.2-0.0-2.0)
CC (6.4-0.5-49.0)

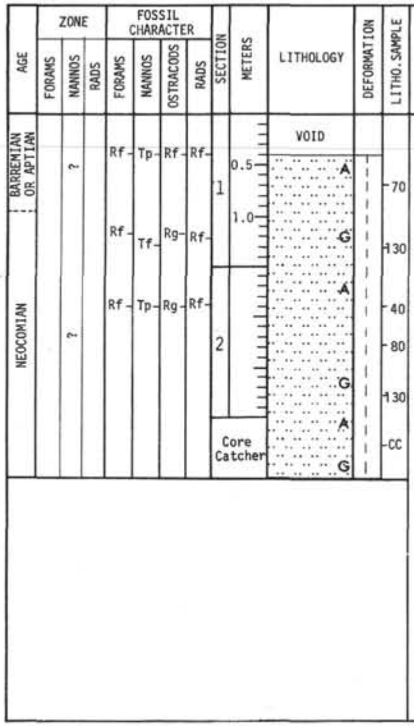
Grain Size
1-82 (6-41-53)
2-82 (4-35-61)
3-17 (13-21-66)

X-ray 1-82		X-ray 2-82		X-ray CC	
calc.	P	mont.	A	calc.	A
qtz.	P	calc.	P	qtz.	P
cris.	P	qtz.	P	plag.	P
k-feld.	P	plag.	P	clino.	P
plag.	P	pyrite	T	pyrite	P
paly.	P			mica	T
trid.	P				
clino.	P				
mica	T				
mont.	T				
pyrite	T				

Age according to Radiolaria.

Explanatory notes in chapter 1

Site 249 Hole Core 26 Cored Interval: 313-322 m



LITHOLOGIC DESCRIPTION

medium gray (N5) and olive black (5Y2/1) alternate throughout

Core is slightly deformed with alternate hard-soft layers. Colors predominately olive black (5Y2/1) with light gray (N6), medium gray (N5) and local medium brown (5YR4/4) concentrations.

VOLCANIC SILTSTONE
Smears 1-70, 1-130, 2-40, 2-80

Texture	Composition	
(5-85-10)	vol. gls.	60-76%
	micarb.	10-20%
	qtz. & feld.	10-15%
	glauc.	Tr.- 5%
	black opaques	2- 3%
	mica & heavies	1- 2%
	forams	Tr.

IRON-RICH VOLCANIC SILTSTONE
Smear 2-130

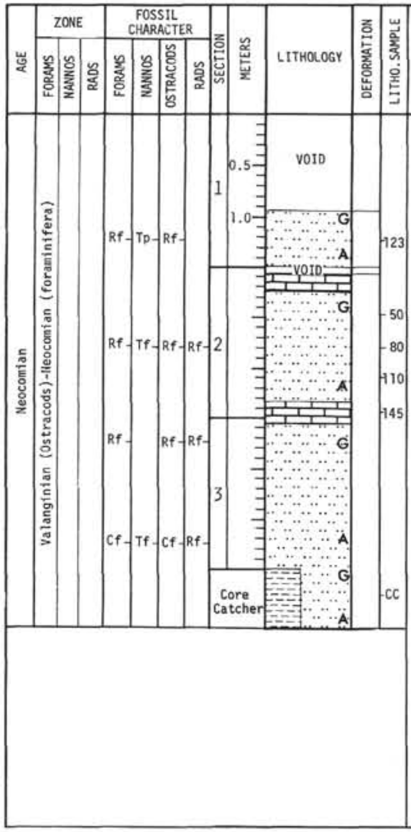
Composition	
volc. gls.	75%
blk. opaques	20%
qtz. & feld.	5%

Carbon-Carbonate
1-56 (1.8-0.4-11.0)
CC (3.0-0.4-22.0)

X-ray 2-87		X-ray CC	
calc.	P	cris.	A
cris.	P	calc.	P
plag.	P	qtz.	P
mont.	P	trid.	P
clino.	P	plag.	T
pyrite	P	clino.	T
qtz.	T	pyrite	T
trid.	T		

Age according to foraminifera.

Site 249 Hole Core 27 Cored Interval: 322-331 m



LITHOLOGIC DESCRIPTION

Core is essentially undeformed. Colors are grays, green grays, and blacks.

95 cm medium gray (N5) to olive black (5Y2/1)

green gray (5GY6/1)

medium gray (N5) and olive black (5Y2/1)

very calcareous

green gray (5GY6/1)

medium gray (N5) to olive black (5Y2/1)

VOLCANIC SILTSTONE
Smear 1-123

<u>Composition</u>	
volc. gls.	70%
clay	20%
qtz. & feld.	5%
opaques	5%

VOLCANIC MUDSTONE
Smears 2-50, 2-110

<u>Composition</u>	
volc. gls.	35%
qtz., feld., cris.	20%
clay	20%
organic mat.	10%
opaques	10%
glauc.	5%

LIMESTONE
Smear 2-140

<u>Composition</u>	
micarb.	95%
others	5%

<u>Grain Size</u>
2-90 (4-46-50)

CARBONACEOUS CALCAREOUS CLAYEY SILTSTONE

<u>Carbon-Carbonate</u>
2-90 (2.7-1.6-9.0)
3-2 (11.1-0.3-90.0)
3-23 (2.5-1.5-9.0)
CC (1.7-1.0-6.0)

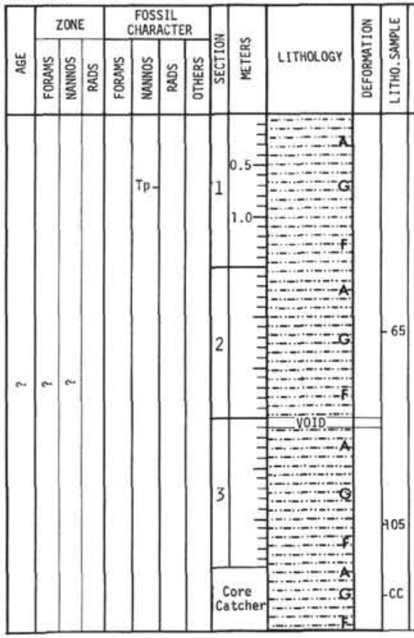
<u>X-ray CC</u>

cris.	A	trid.	P
calc.	P	pyrite	P
qtz.	P	clino.	T
plag.	P		

Age is Valanginian(?) according to ostracods.

Explanatory notes in chapter 1

Site 249 Hole Core 28 Cored Interval: 332-341 m



LITHOLOGIC DESCRIPTION

Core is undeformed and lithified. Color ranges from medium gray (N5) to olive black (5Y2/1). Dark color is due to carbonaceous material. Local volcanic ash zone at 3-105; local carbonate rich zones.

SILTY VOLCANIC CLAYSTONE
Smears 2-65, 3-105, CC

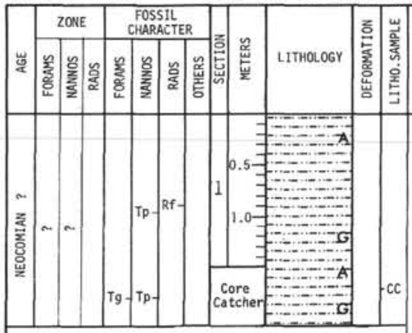
<u>Texture</u>	<u>Composition</u>	
(0-25-75)	clay (devitrified ash)	45%
	micarb.	15%
	opaques	20%
	qtz., feld., cris.	10%
	forams	10%
	glauc.	2%
	calc. nannos	Tr.

<u>Carbon-Carbonate</u>
1-77 (3.1-1.5-13.0)
2-86 (3.4-1.6-15.0)
CC (4.0-1.4-22.0)

<u>X-ray CC</u>

calc.	A	plag.	T
cris.	A	mont.	T
trid.	P	clino.	T
qtz.	T	pyrite	T
k-feld.	T		

Site 249 Hole Core 29 Cored Interval: 351-360 m



LITHOLOGIC DESCRIPTION

Core is undeformed. Softer beds dark (medium dark gray [N4] and olive black [5Y2/1]) harder beds - medium gray (N5) vague bedding.

CALCIC CLAYEY VOLCANIC SILTSTONE

Texture	Composition	
(3-57-40)	devitrified ash-clay	35%
	micarb. & shells	30%
	qtz., feld., cris.	10%
	opaques	20%
	glauc.	5%

BLACK SILTY CLAYSTONE
Smear CC

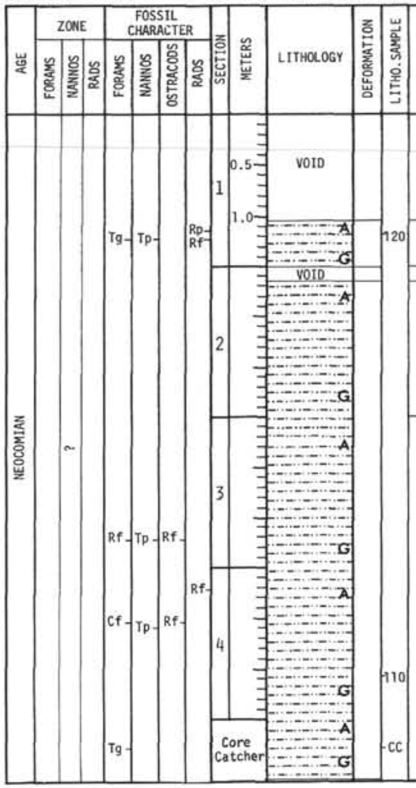
Texture	Composition	
(0-40-60)	black clays	76%
	qtz., feld., cris.	10%
	opaques	5%
	micarb. & shells	5%
	mica	3%
	glauc.	1%

Carbon-Carbonate
1-90 (3.5-1.7-15.0)
1-122 (10.2-0.5-80.0)
CC (3.1-1.7-12.0)

X-ray CC

cris.	A	qtz.	T
calc.	P	k-feld.	T
plag.	P	mont.	T
trid.	P	clino.	T
pyrite	P		

Site 249 Hole Core 30 Cored Interval: 370-379 m



LITHOLOGIC DESCRIPTION

Core consists of hard and semi-hard units with faint laminae bedding throughout. Colors - gray black (N2), medium gray (N5) and olive black (5Y2/1).

CALCIC SILTY VOLCANIC CLAYSTONE
Smear 1-120, 4-110, CC

Texture	Composition	
(5-40-55)	clay min. (ash)	40-80%
	opaques	2-30%
	micarb. & shells	1-20%
	glauc.	1- 5%
	forams, nannos	1- 5%
	vol. gls.	Tr.
	qtz., feld., cris.	5-10%

gray black (N2), medium gray (N5), and olive black (5Y2/1)

Grain Size
CC (4.2-38.1-57.7) silty clay

Carbon-Carbonate
1-105 (2.0-1.2-7.0)
4-64 (1.7-0.7-8.0)
CC (2.1-1.0-9.0)

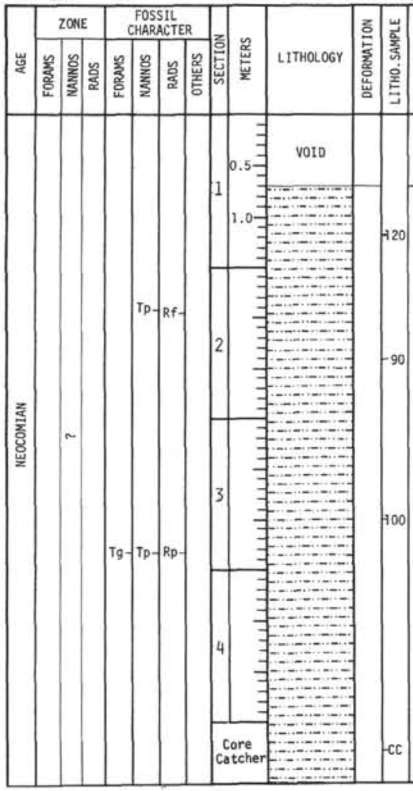
olive black (5Y2/1) and medium gray (N5)

X-ray CC

cris.	A	qtz.	T
calc.	P	k-feld.	T
plag.	P	mont.	T
trid.	P	pyrite	T
clino.	P		

Explanatory notes in chapter 1

Site 249 Hole Core 31 Cored Interval: 389-398 m



LITHOLOGIC DESCRIPTION

Core is lithified and undeformed. Colors vary from medium gray (N5) to olive black (5Y2/1). Core consists primarily of claystone which contains small-scale variations in color, silt content and carbonate fragment content.

SILTY CLAYSTONE
Smears at 1-120, 2-90, 3-100

medium gray (N5)
to olive black (5Y2/1)

Texture
(5-40-55)

Composition	
micarb.	10-15%
clays	55-58%
qtz. & feld.	10%
opaques	5- 7%
glauc.-mica	3- 5%
calc. nannos	3%

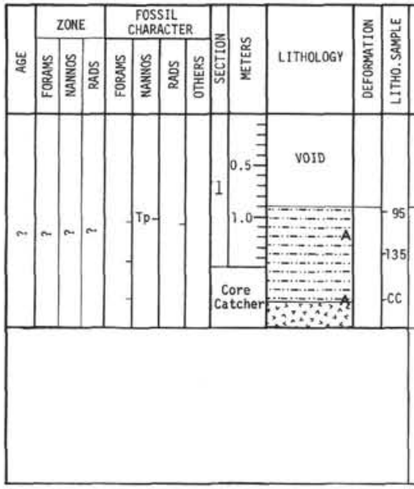
Grain Size
3-36 (5.5-43.1-51.5) silty clay

Carbon-Carbonate
1-74 (1.0-0.5-4.0)
3-37 (1.7-1.0-6.0)
CC (1.3-0.6-6.0)

X-ray 3-36	
clino.	A
calc.	P
qtz.	P
plag.	P
mont.	P
pyrite	P

X-ray CC	
cris.	A
calc.	P
plag.	P
trid.	P
clino.	P
qtz.	T
mont.	T
pyrite	T

Site 249 Hole Core 32 Cored Interval: 405-408 m



LITHOLOGIC DESCRIPTION

Core indurated with fine laminae bedding. Colors predominately medium dark gray (N4) and olive gray (5Y4/1).

SILT-RICH CLAYSTONE
Smears 1-95, 1-135

90 cm
medium
dark gray
(N4)

olive gray (5Y4/1)

Texture
(0-20-80)

Composition	
clays	85%
opaques	5%
qtz. & feld.	5%
mica	2%
glauc.	2%
micarb.	1%

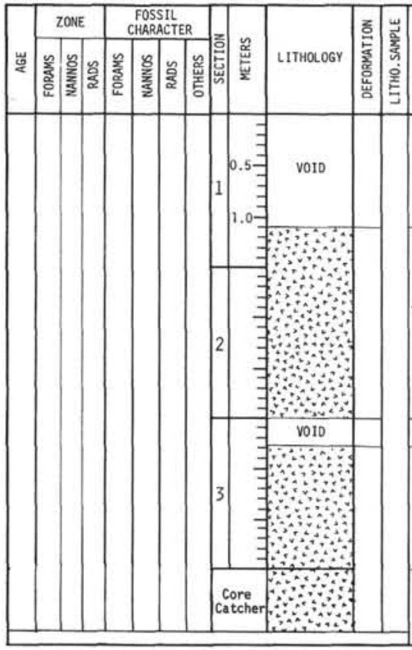
SILT-BEARING CLAYSTONE with altered GLASSY BASALT in bottom of core catcher.

Carbon-Carbonate
1-101 (1.2-1.1-1.0)
CC (0.3-0.2-0.0)

Grain Size
CC (0-14-86)

X-ray CC	
mont.	A
qtz.	P
kaol.	P

Site 249 Hole Core 33 Cored Interval: 408-412 m



LITHOLOGIC DESCRIPTION

Core is broken and weathered, especially near top; calcite-filled fractures are present in Sections 1 and 2. Color is brown gray (5YR4/1) to dark green gray (5GY4/1).

5YR4/1 brown gray
and 5GY4/1 dark green gray
calcite veins: 10-15 cm

← possible flow boundary

vesicular glassy BASALT

Composition	
palagonite & clay	60%
plag.	35%
altered pyroxene	3%
opaques, calcite, chlor.	2%

Calcite and chlorite fill some vesicles.

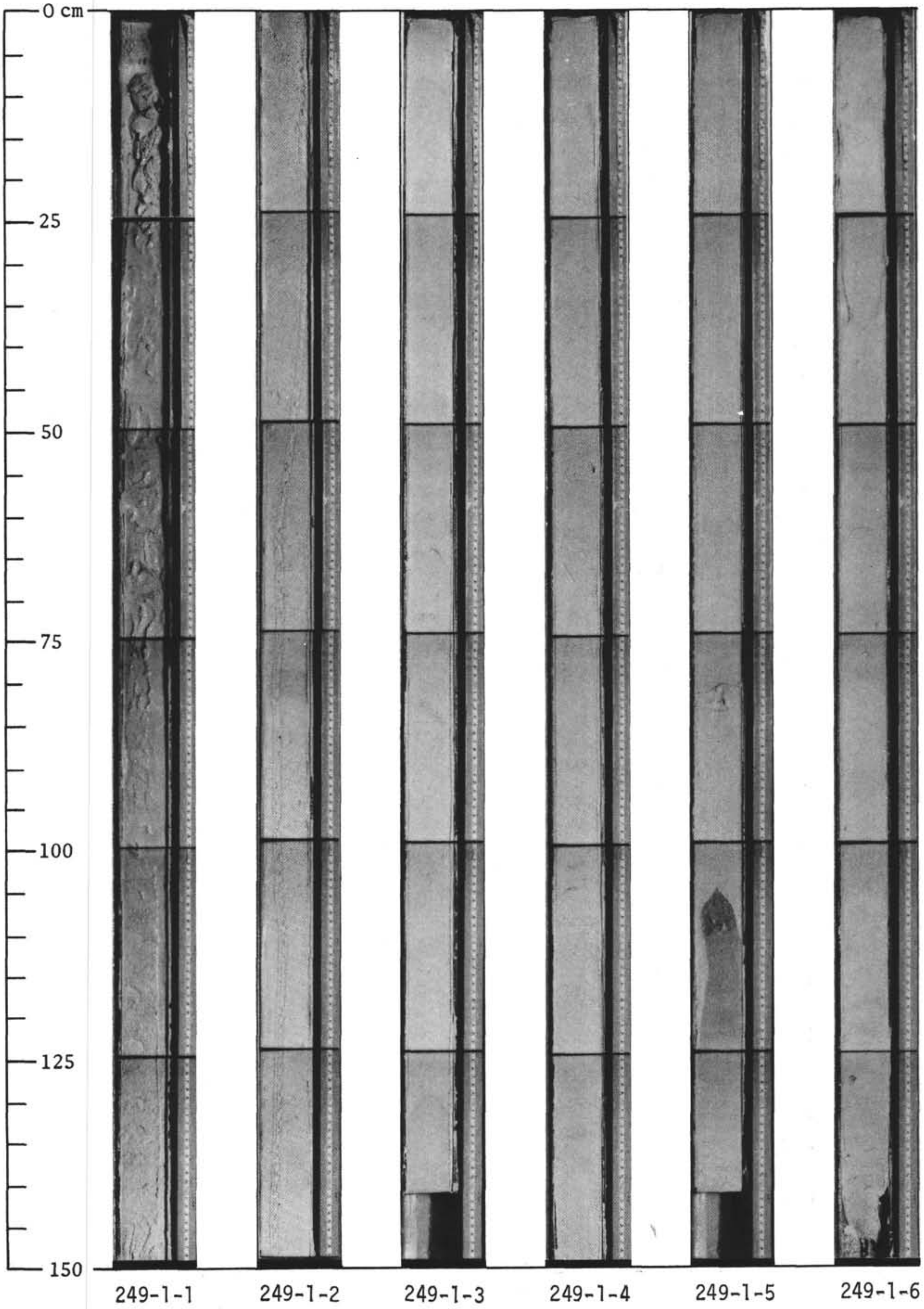
calcite veins 95-105 cm

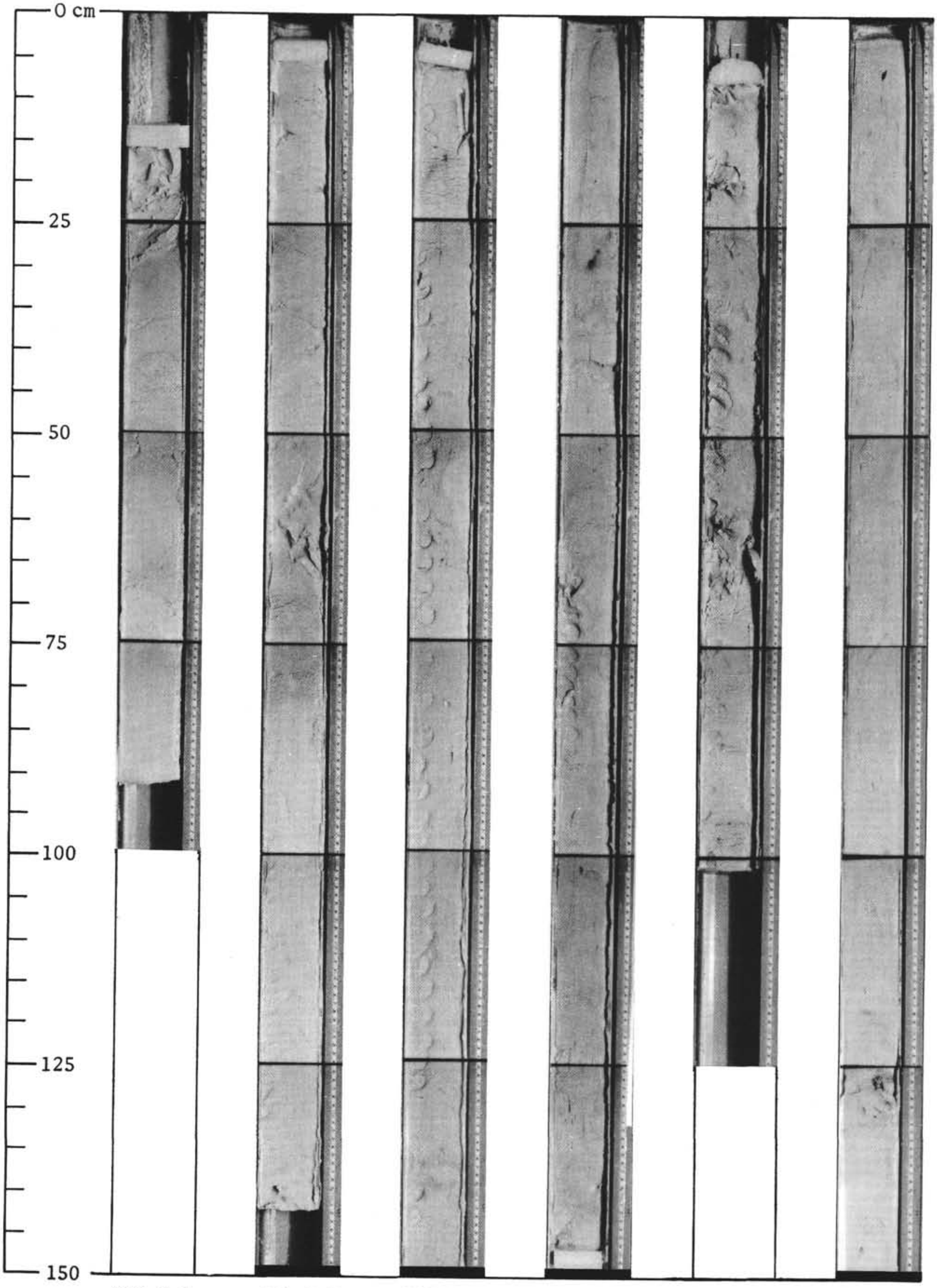
X-ray 2-20	
calc.	A
mont.	P
qtz.	T
plag.	T
clino.	T

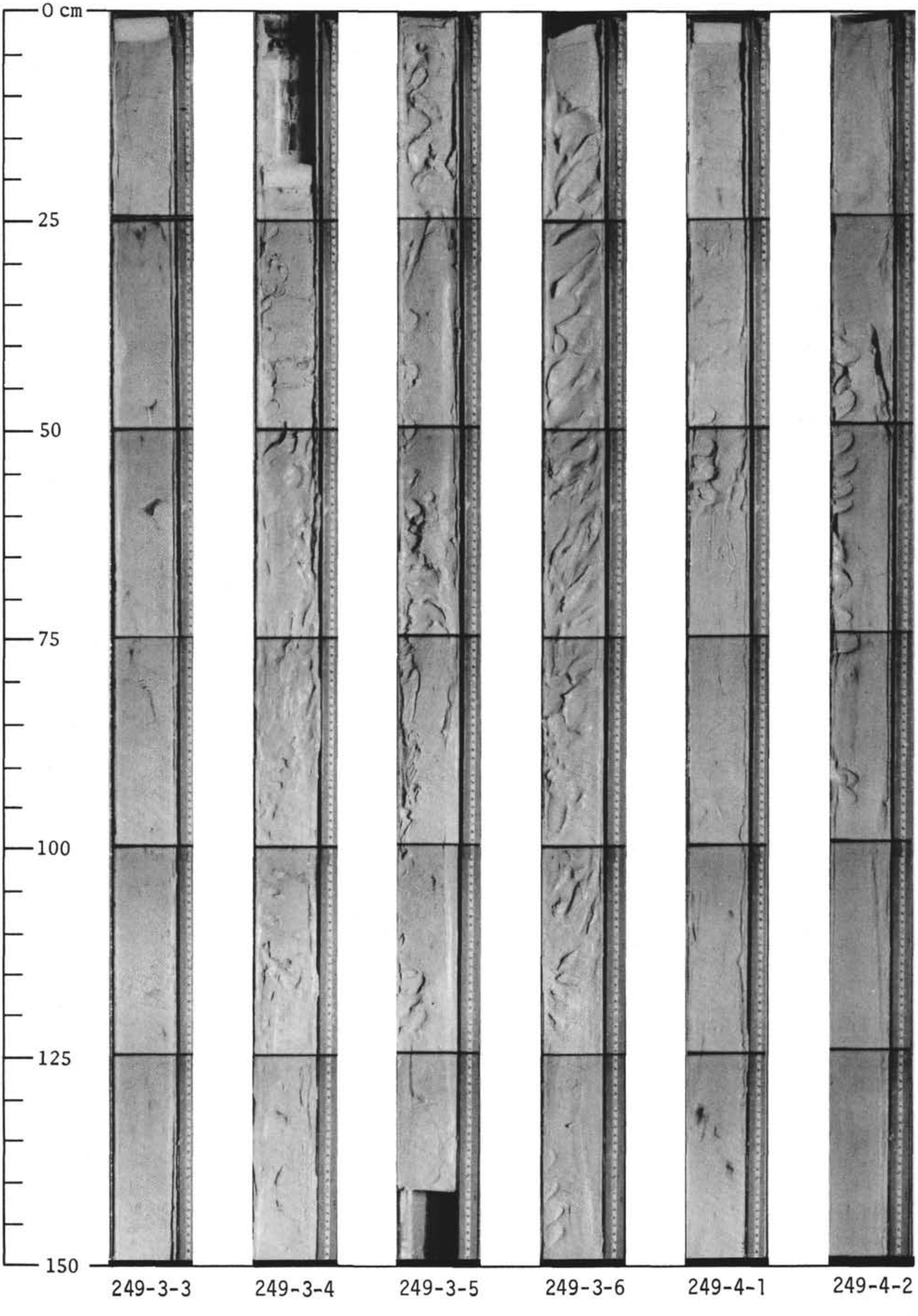
X-ray 2-82	
mont.	A
clino.	A
mica	P
calc.	T
anal.	T

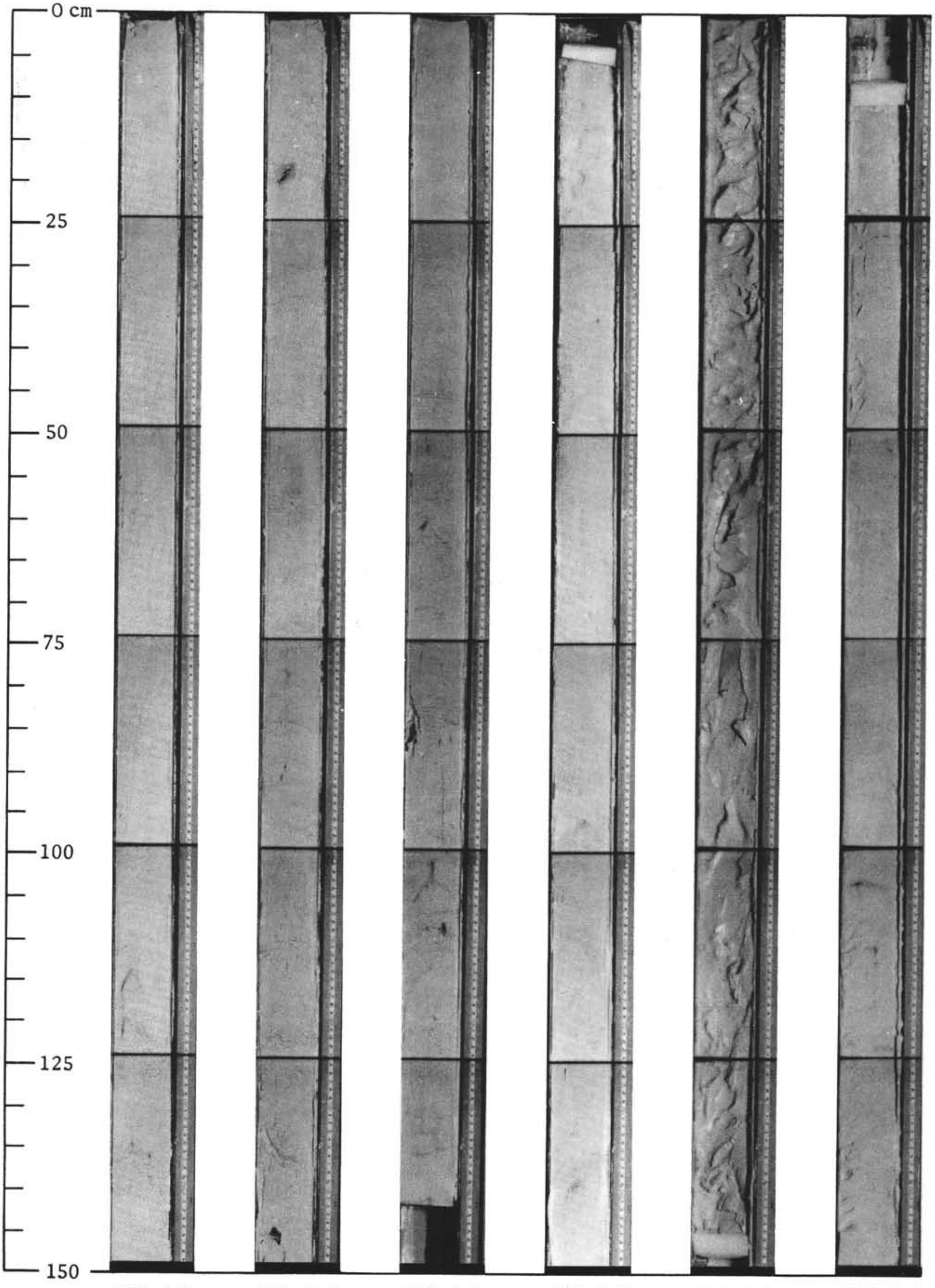
X-ray 2-89	
plag.	A
mont.	A
qtz.	T
mica	T
clino.	T
mag.	T

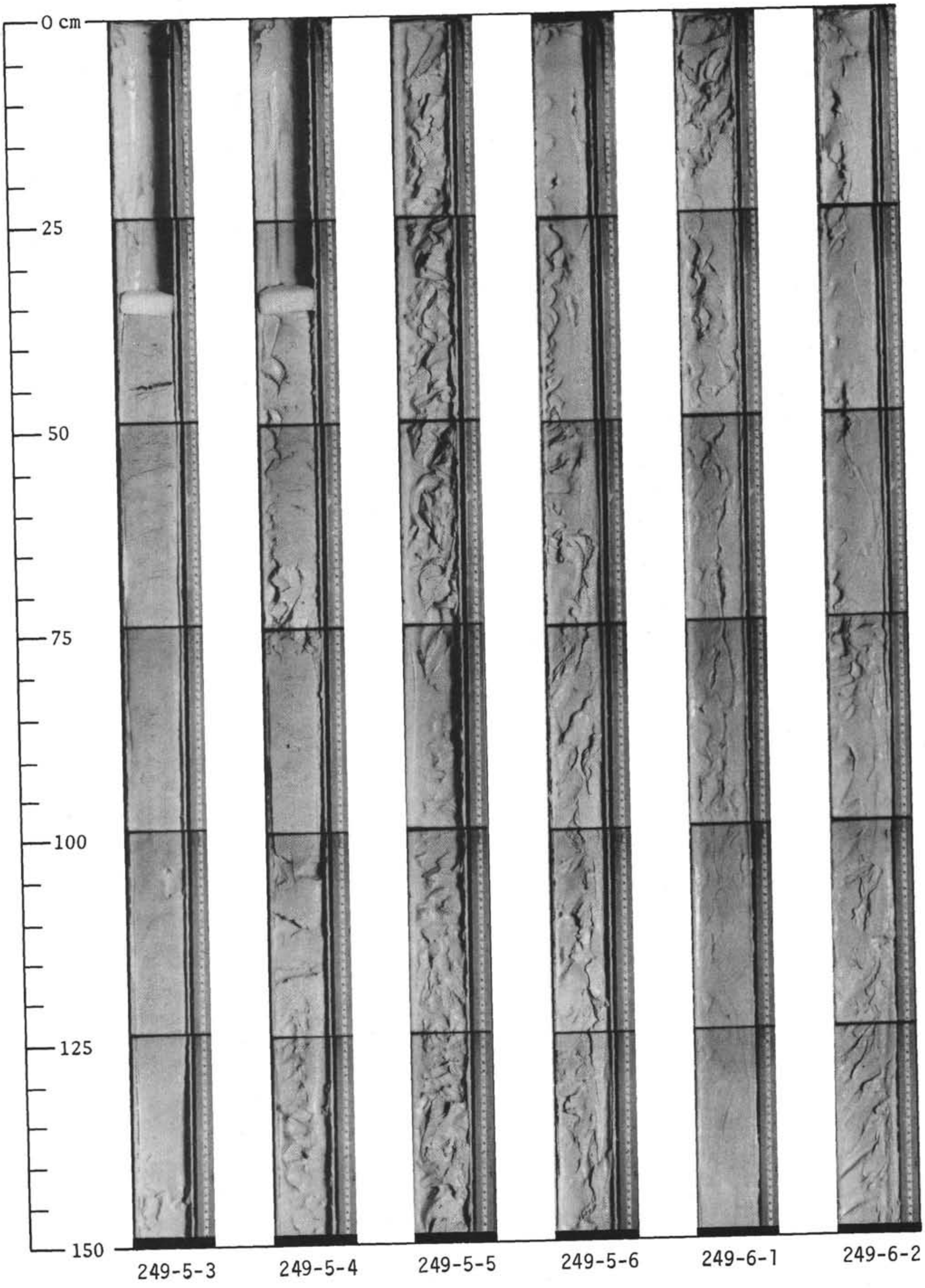
Explanatory notes in chapter 1


0 cm
25
50
75
100
125
150
249-1-1
249-1-2
249-1-3
249-1-4
249-1-5
249-1-6


0 cm
25
50
75
100
125
150
249-2-1
249-2-2
249-2-3
249-2-4
249-3-1
249-3-2


0 cm
25
50
75
100
125
150
249-3-3
249-3-4
249-3-5
249-3-6
249-4-1
249-4-2


0 cm
25
50
75
100
125
150
249-4-3
249-4-4
249-4-5
249-4-6
249-5-1
249-5-2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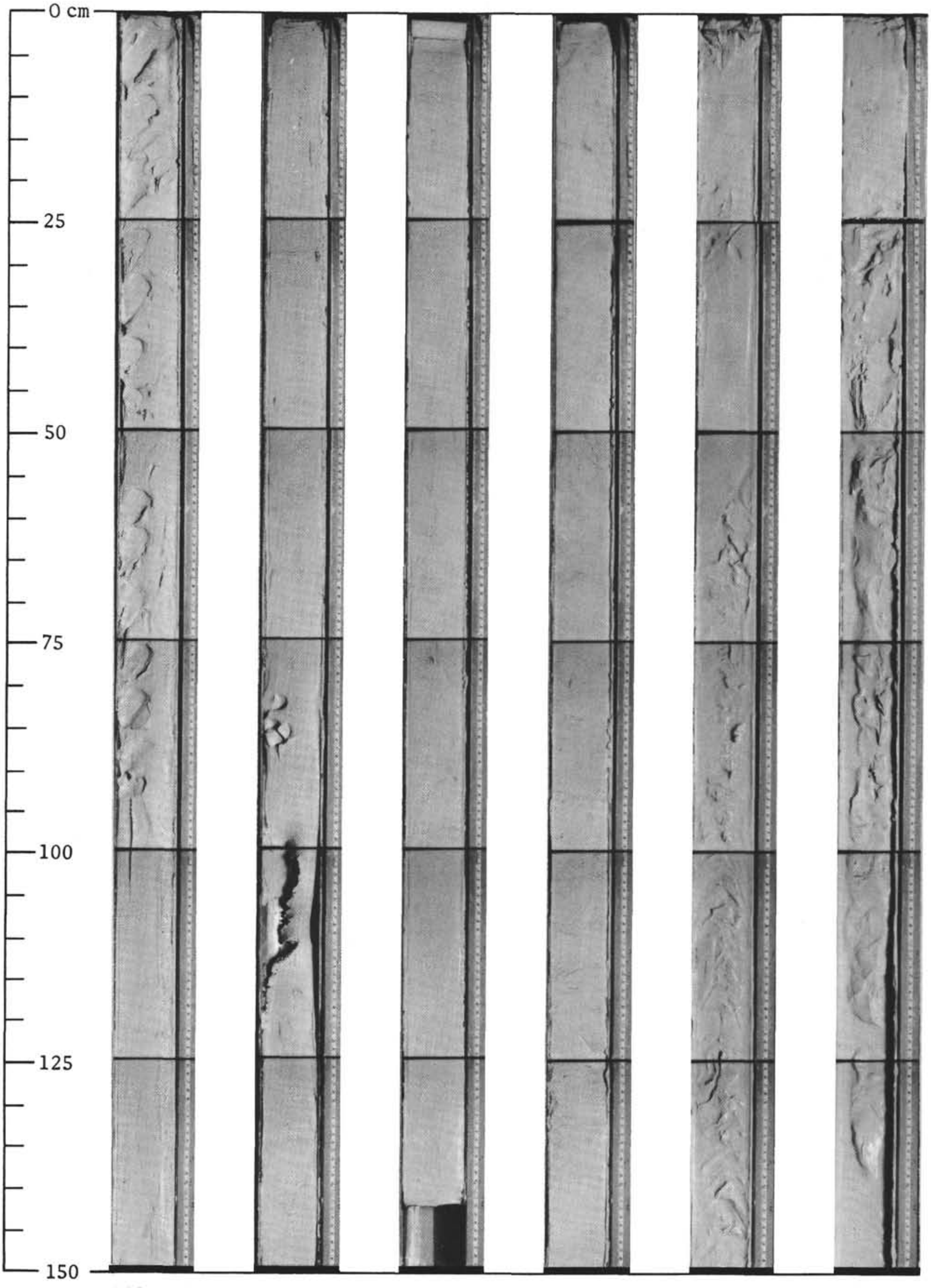
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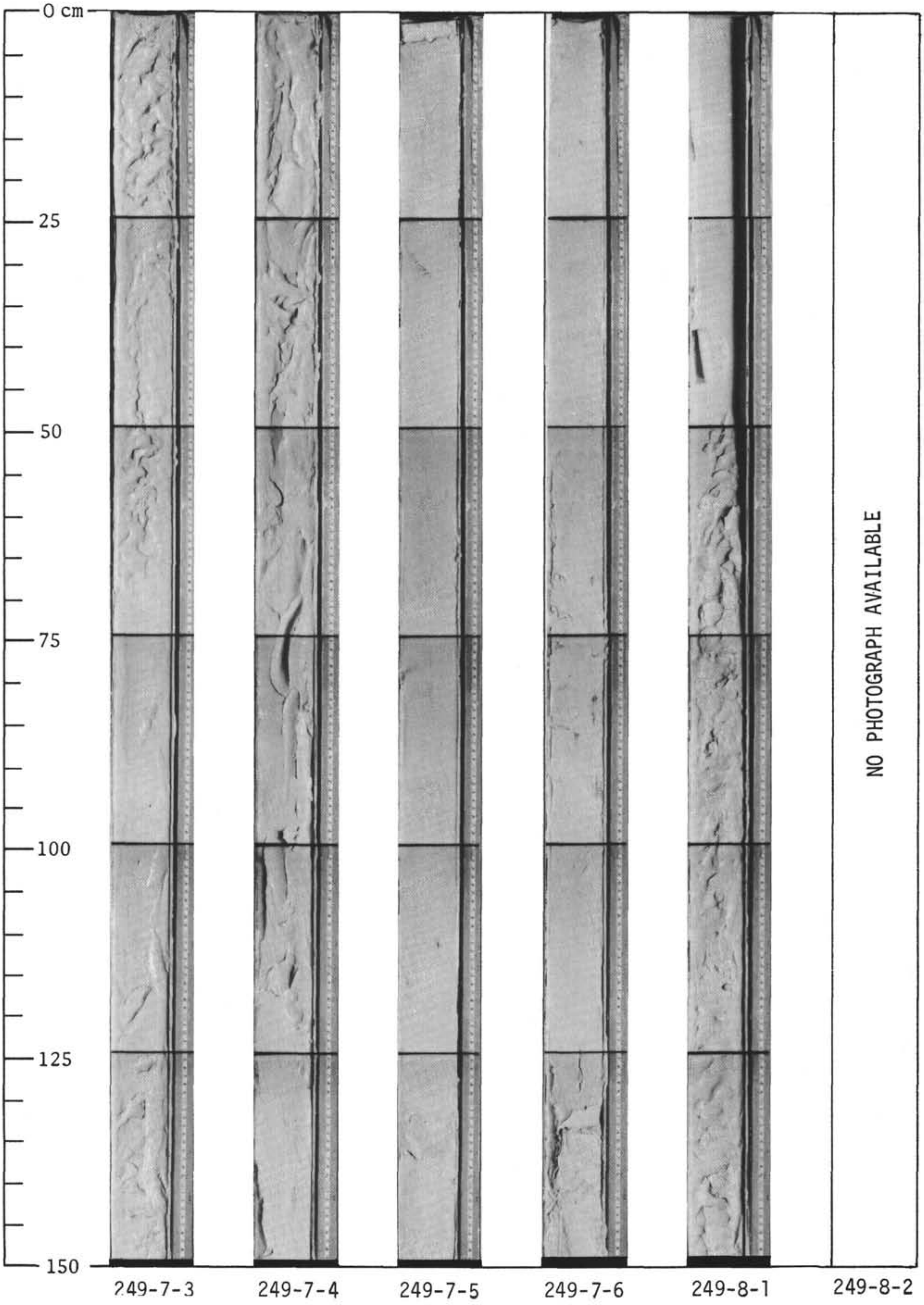
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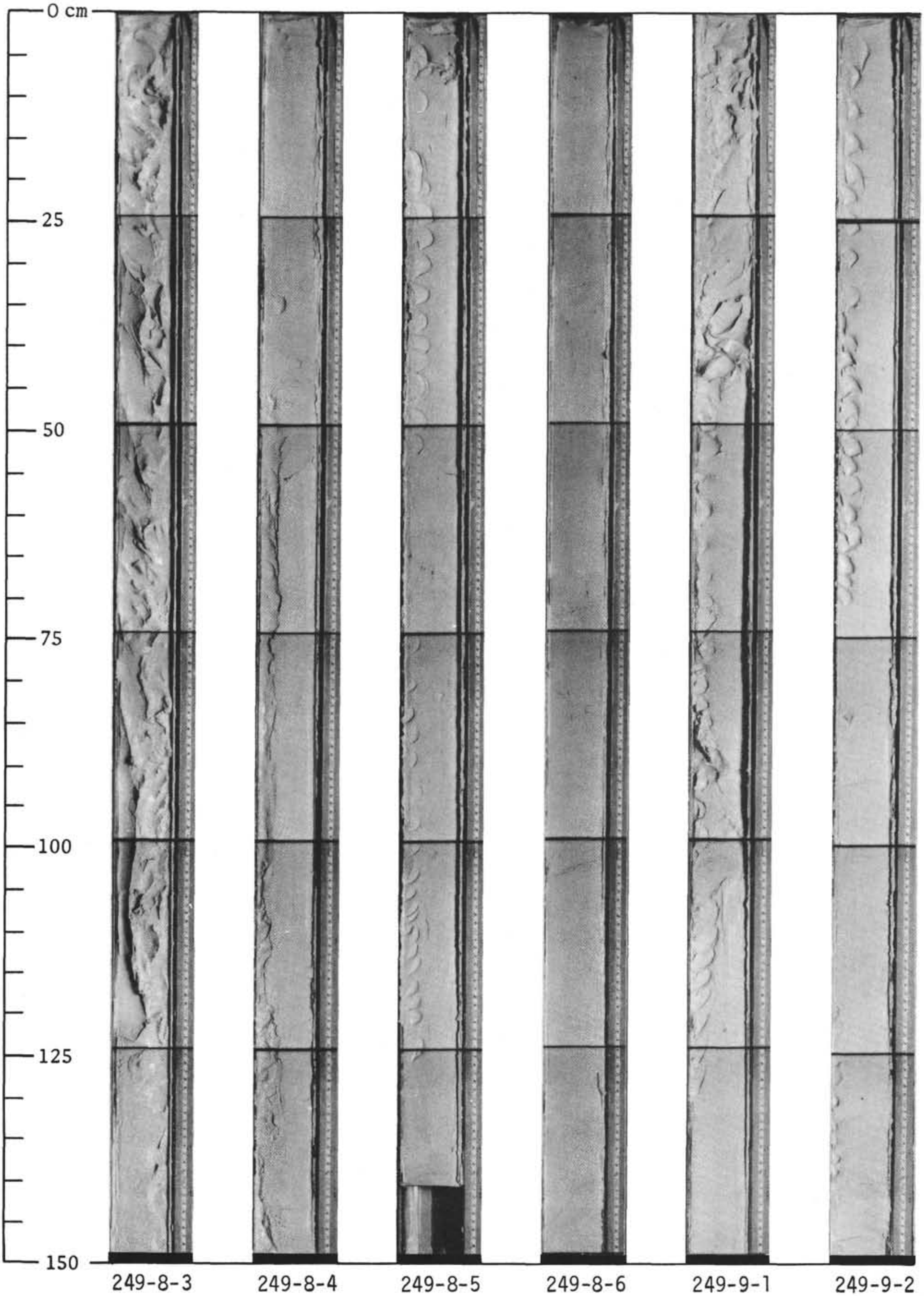
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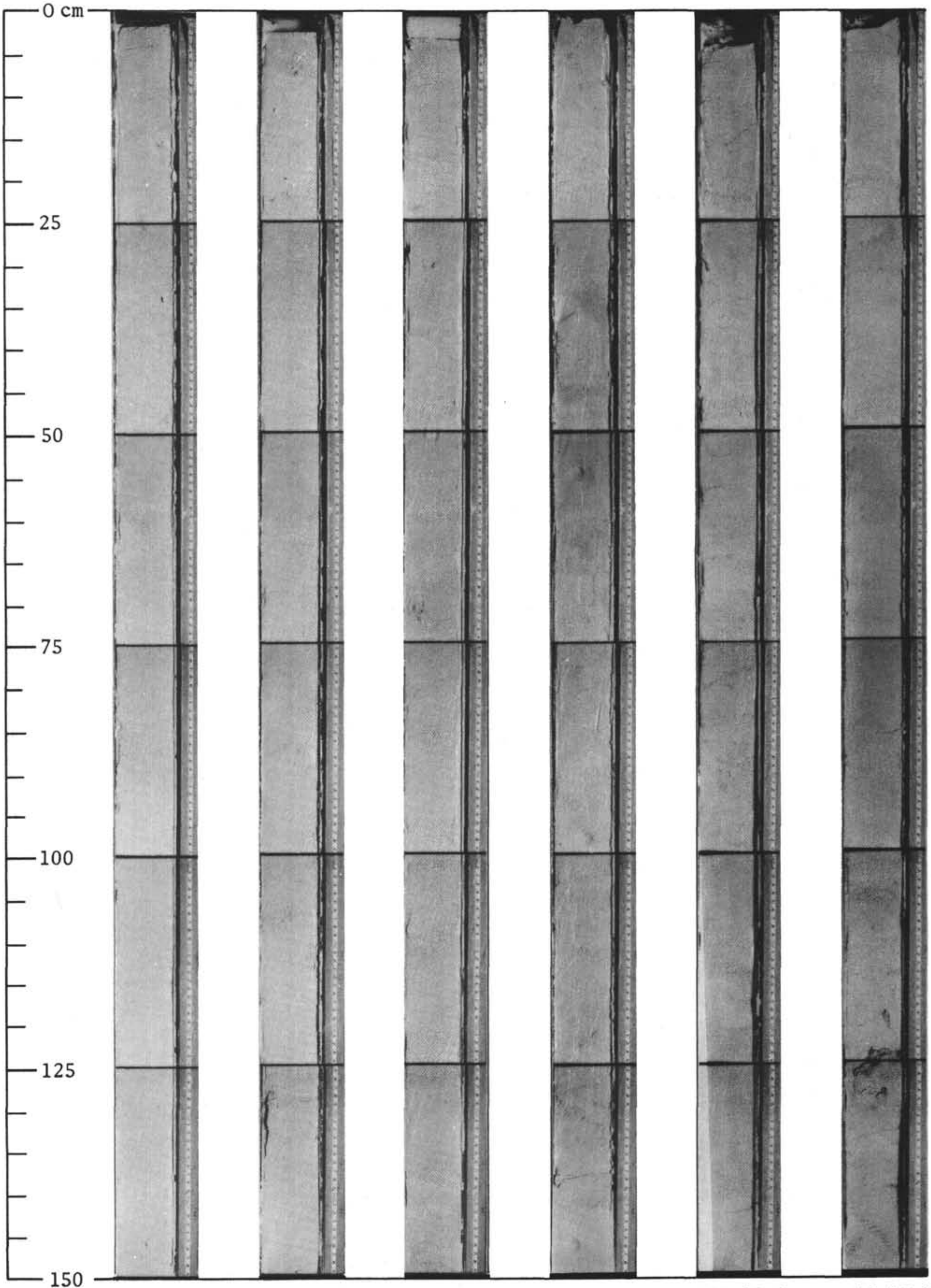
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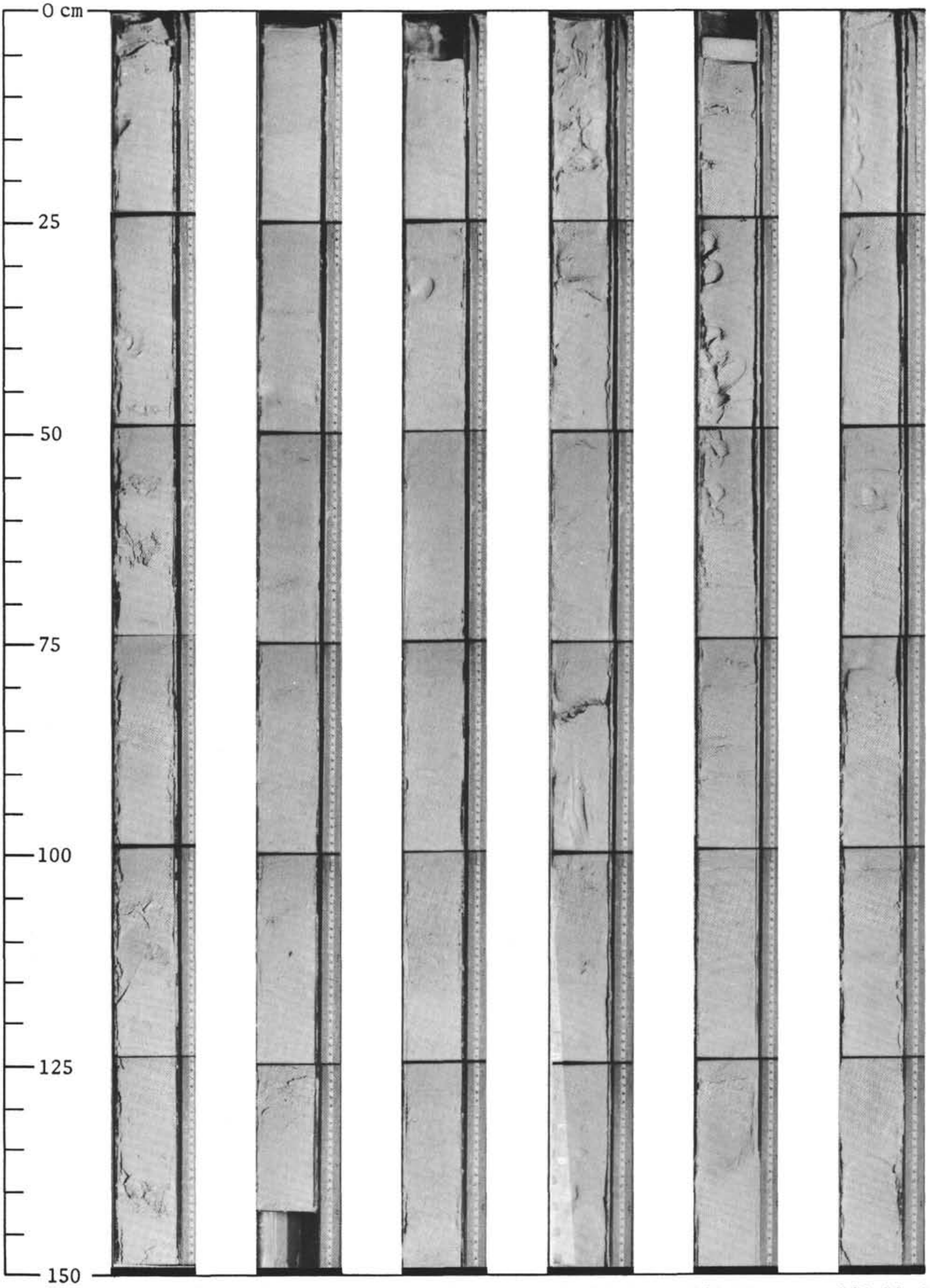
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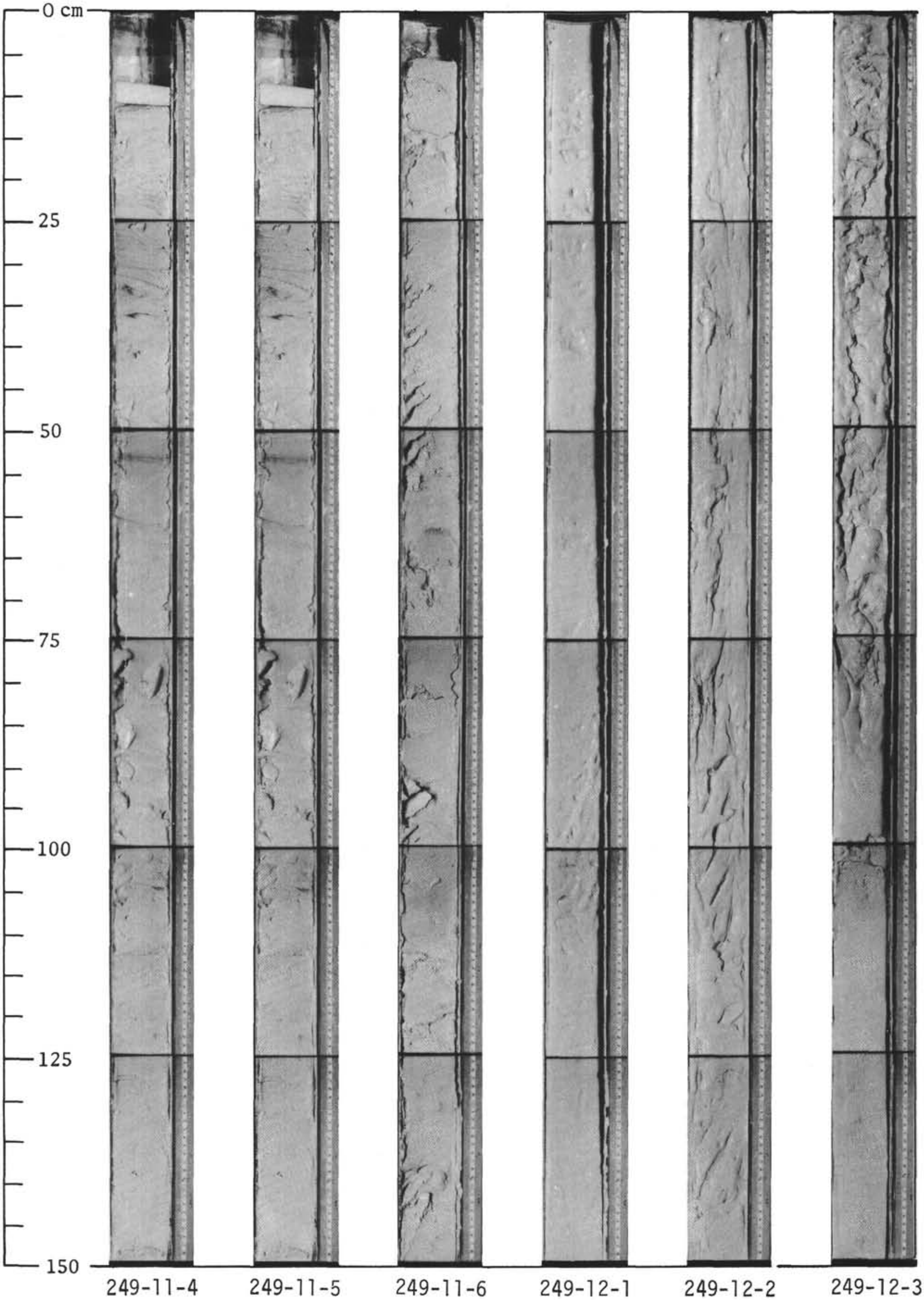
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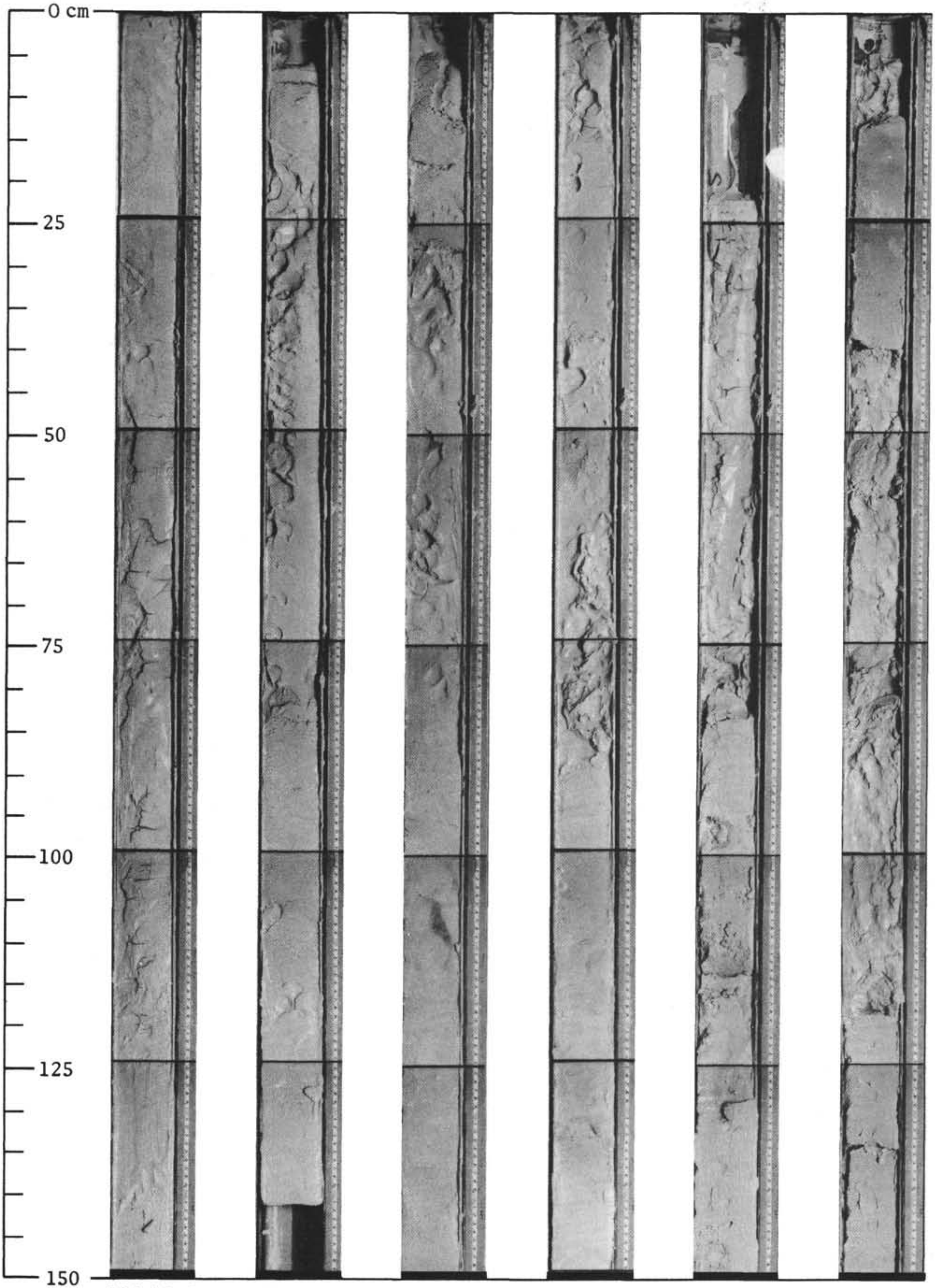
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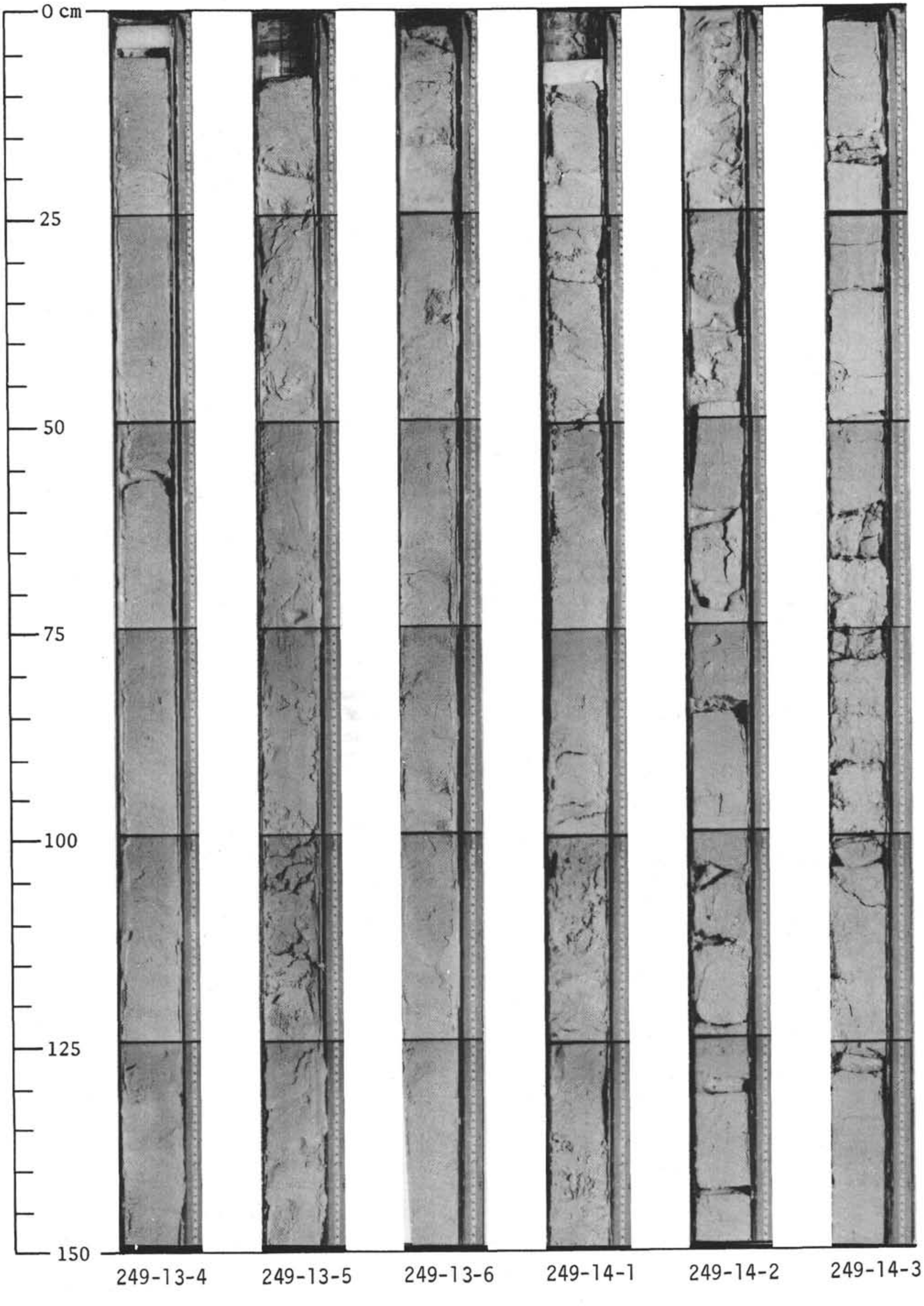
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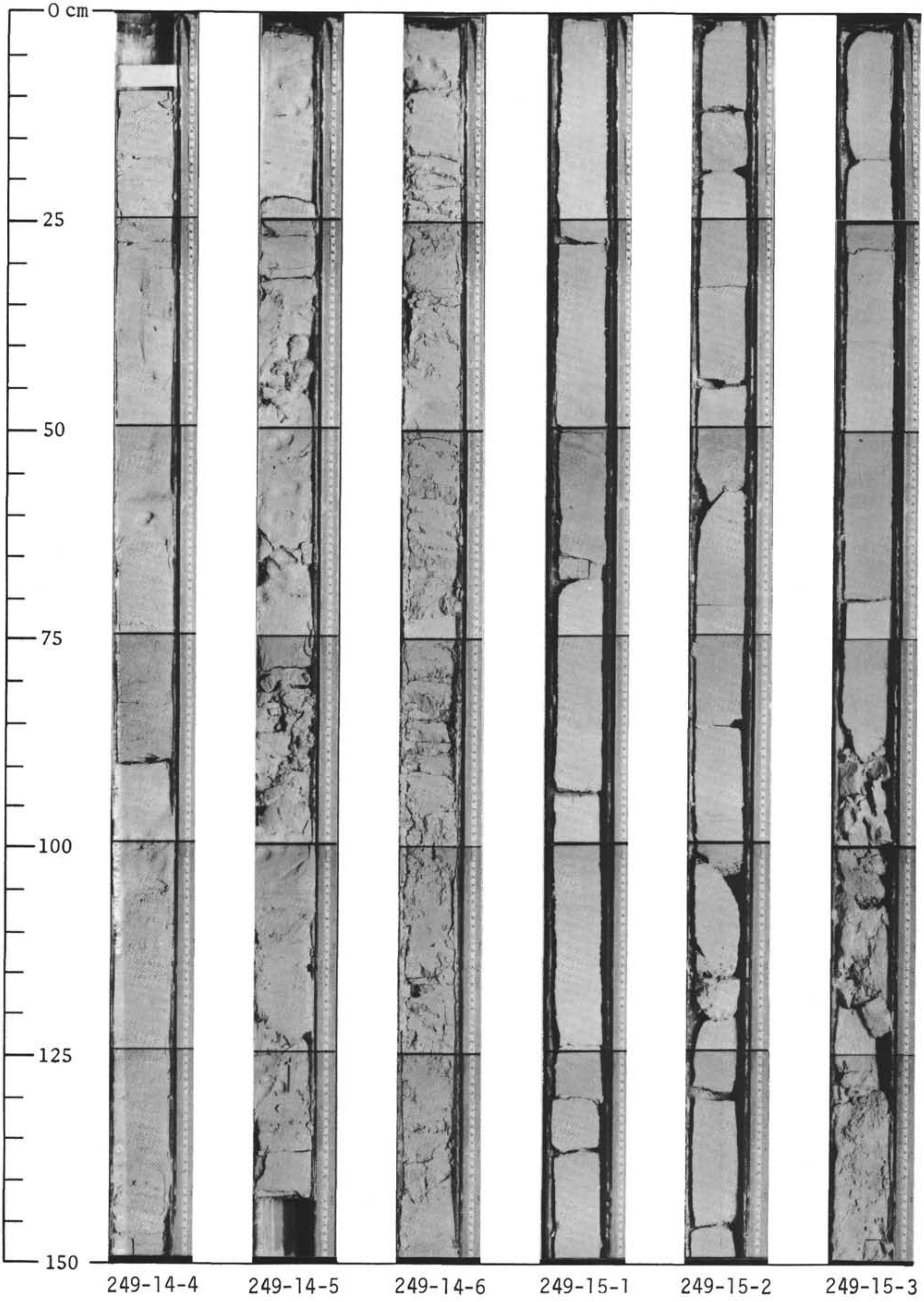
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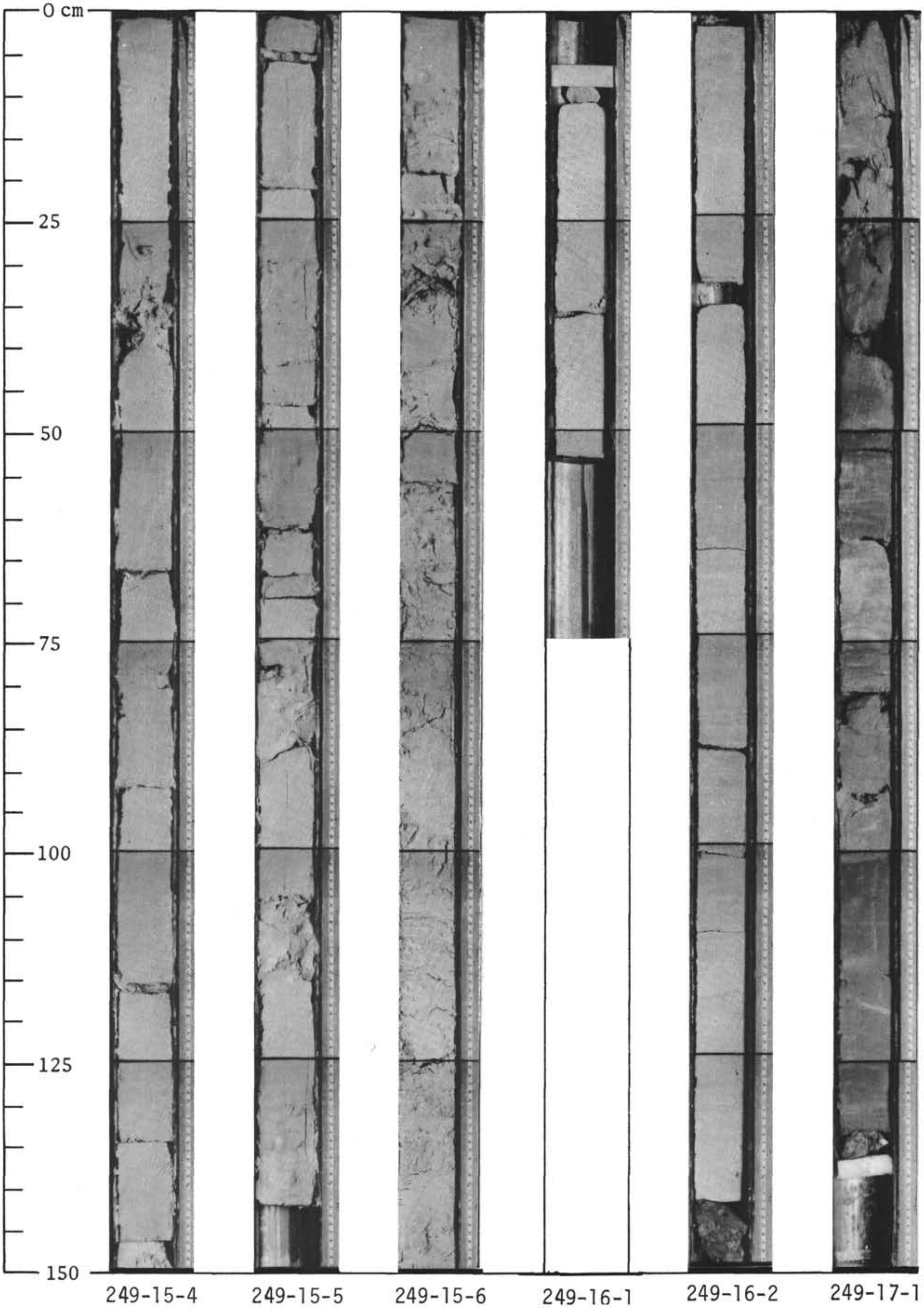
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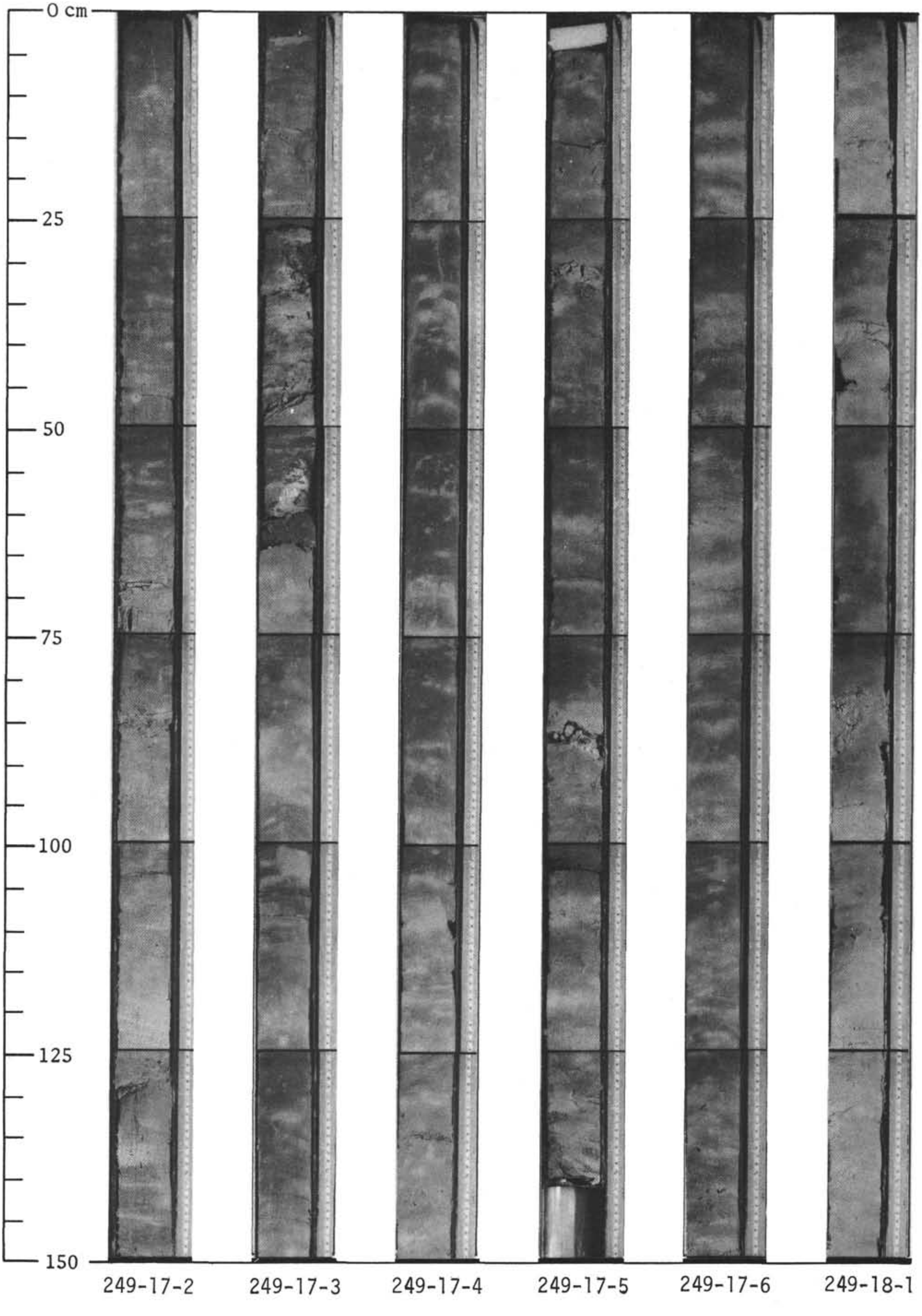
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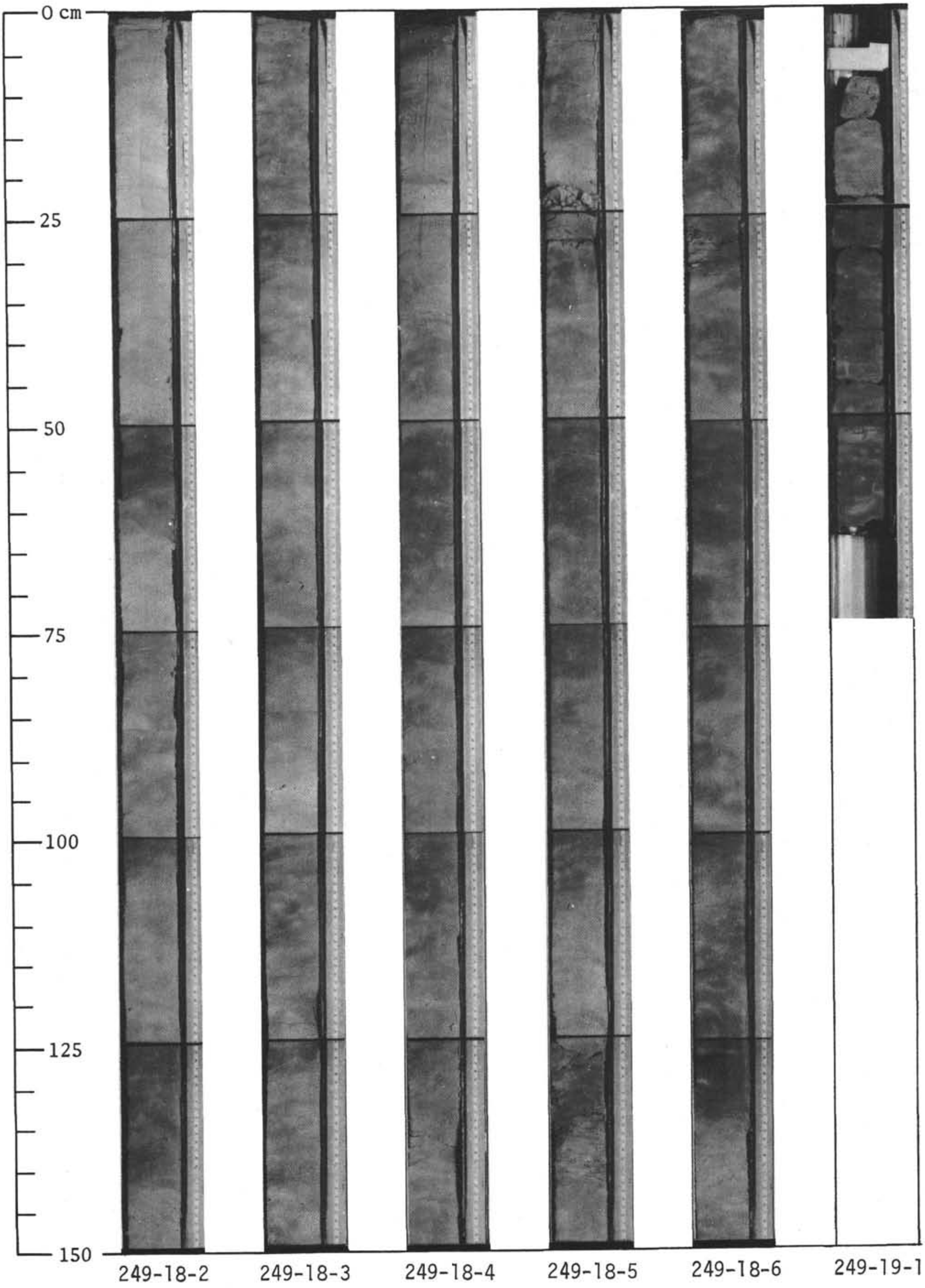
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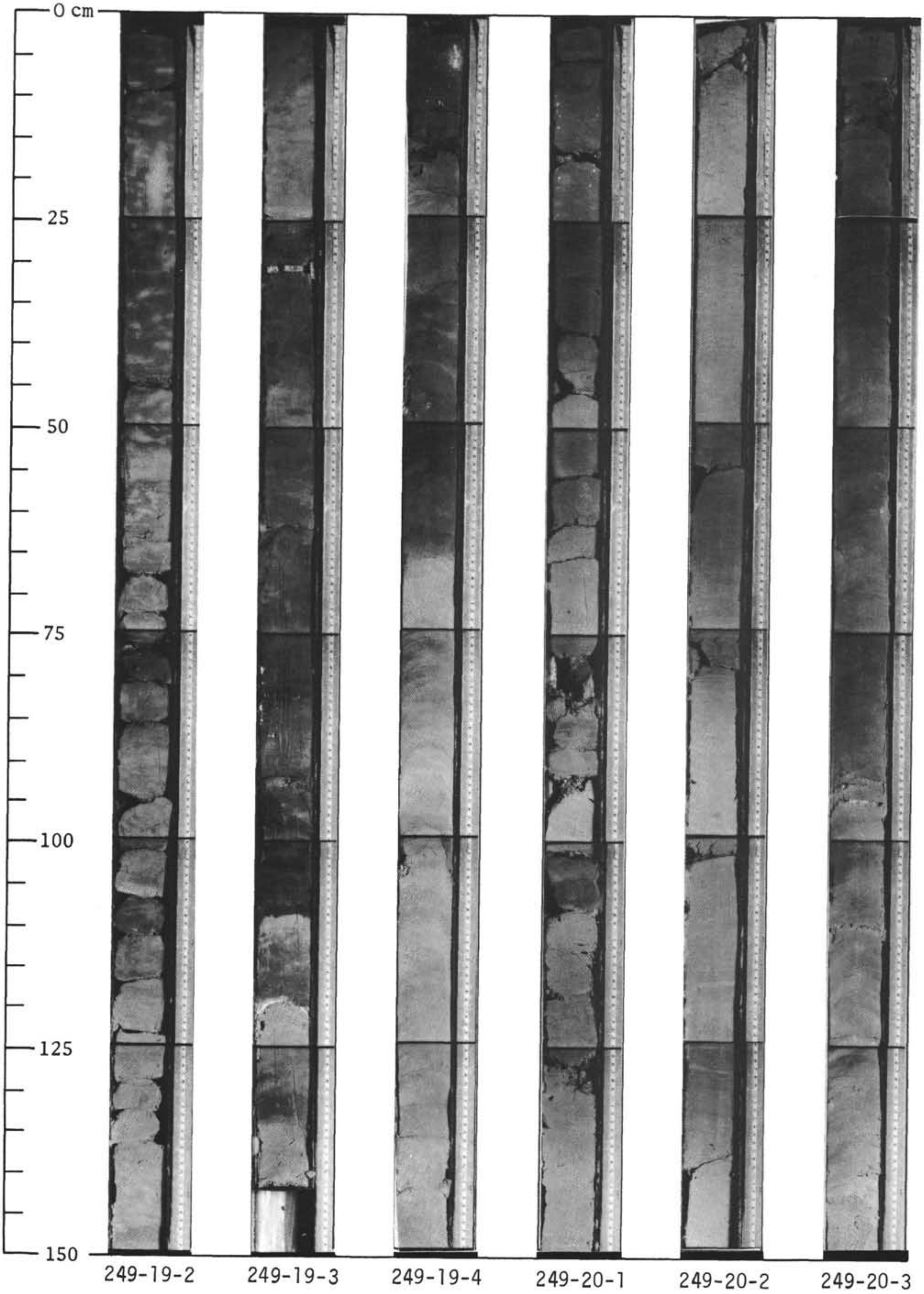
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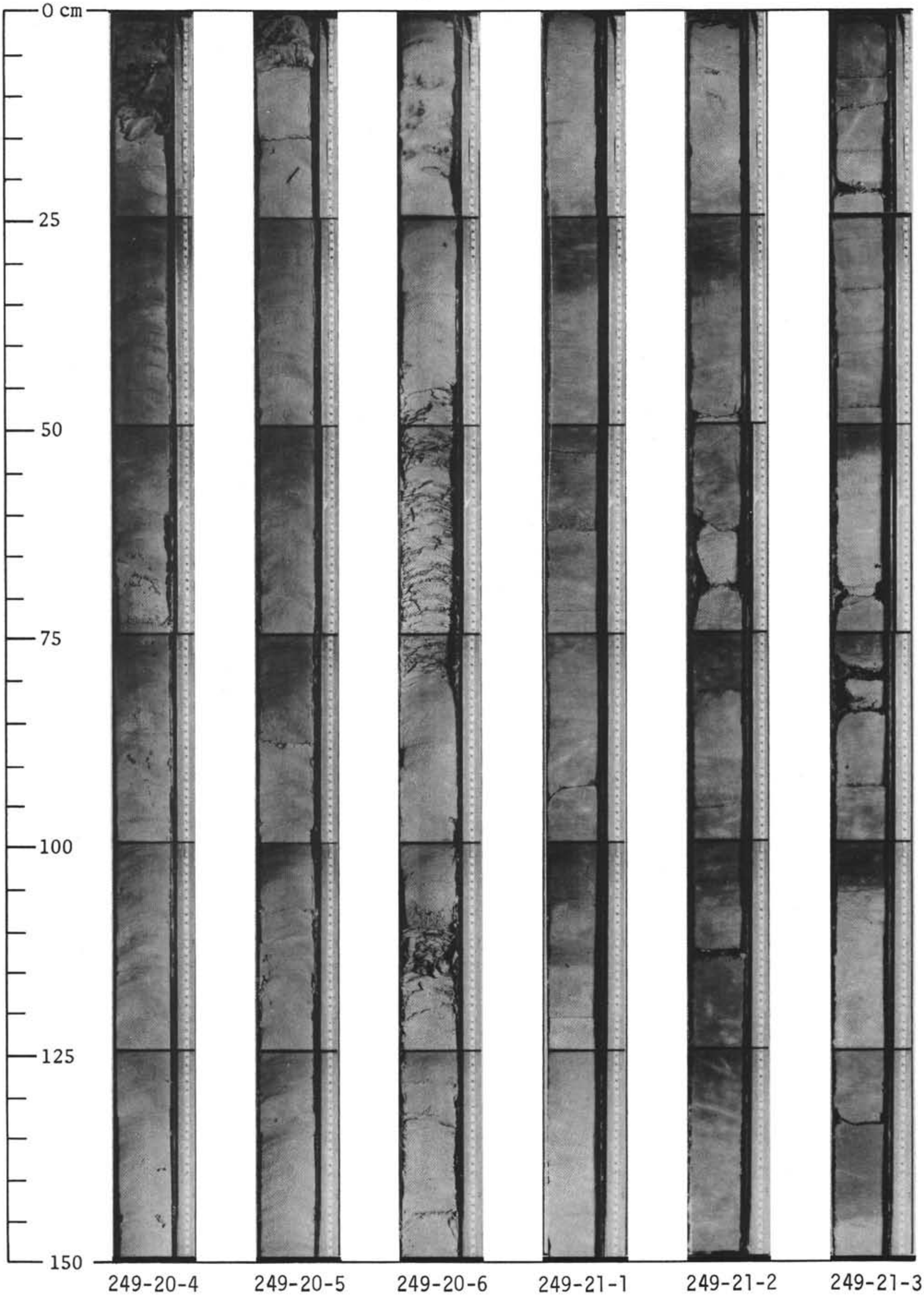
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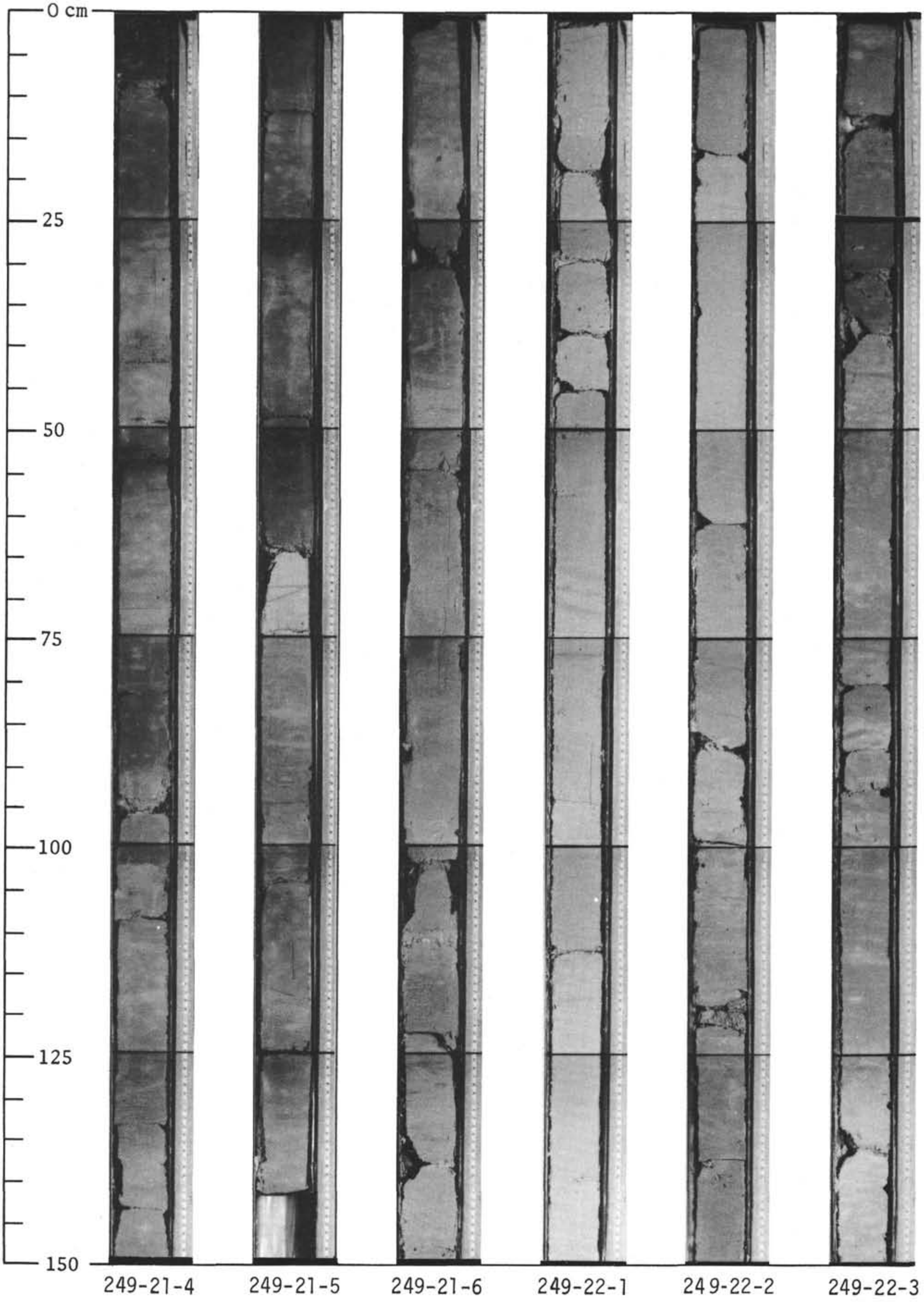
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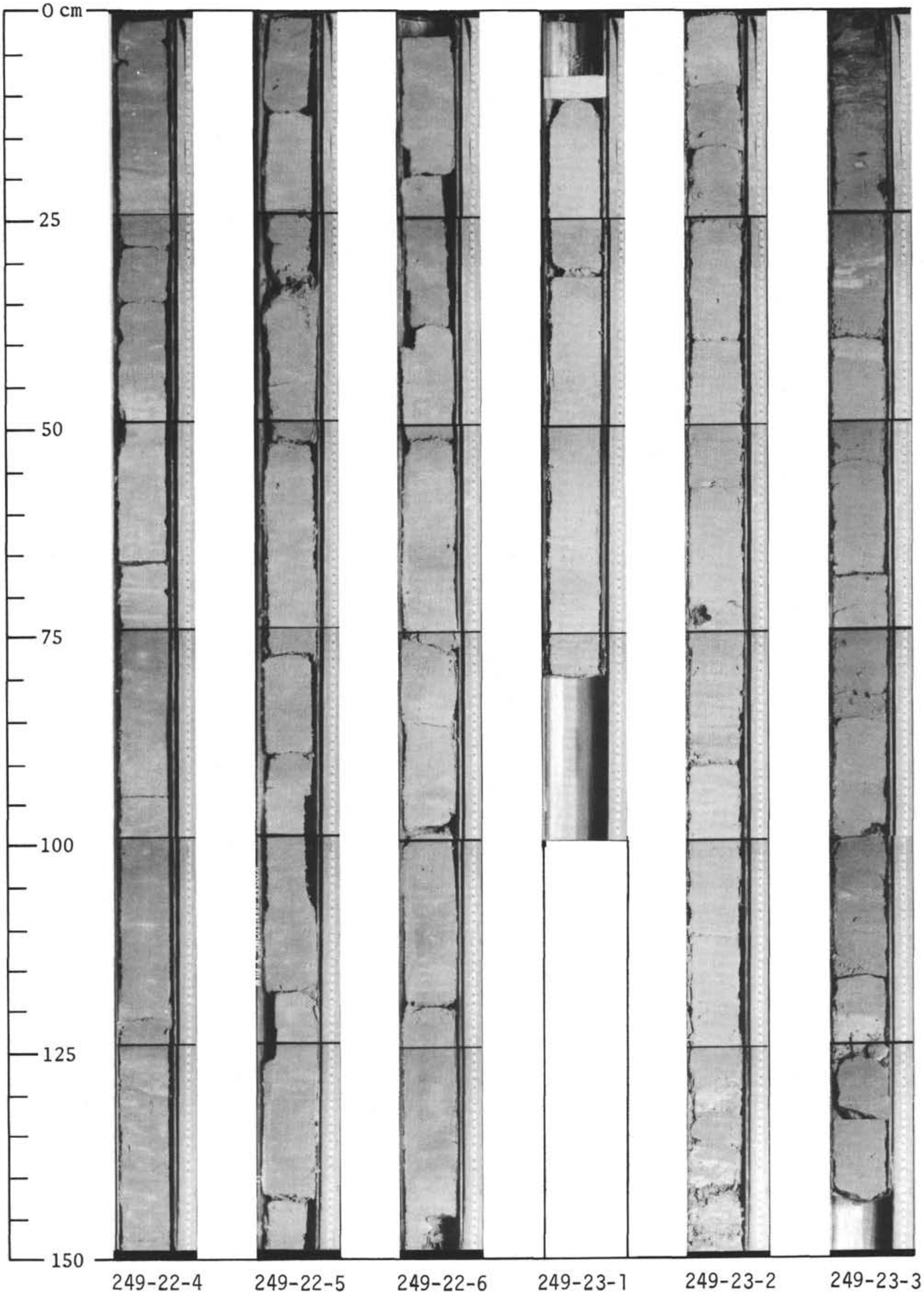
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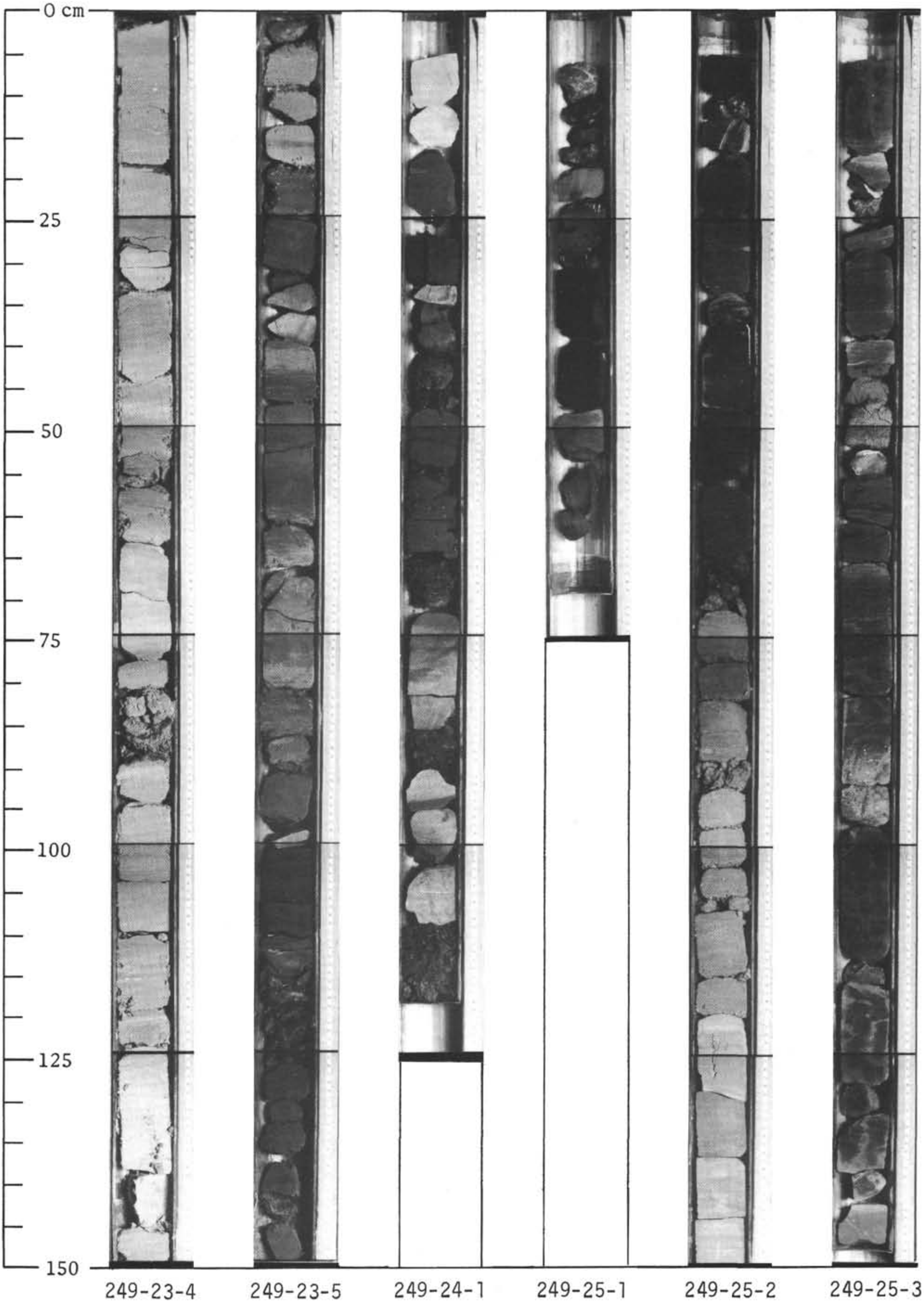

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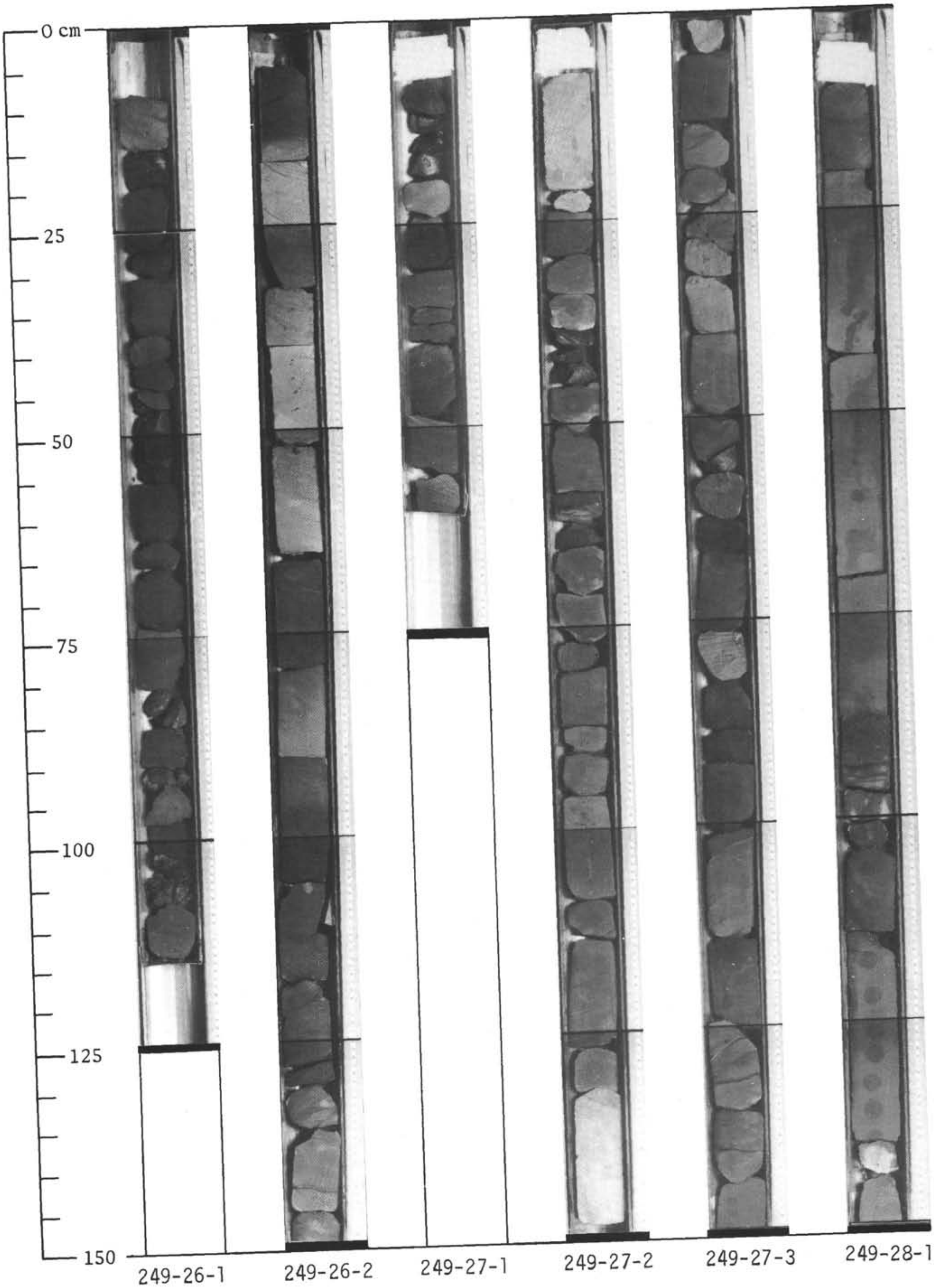
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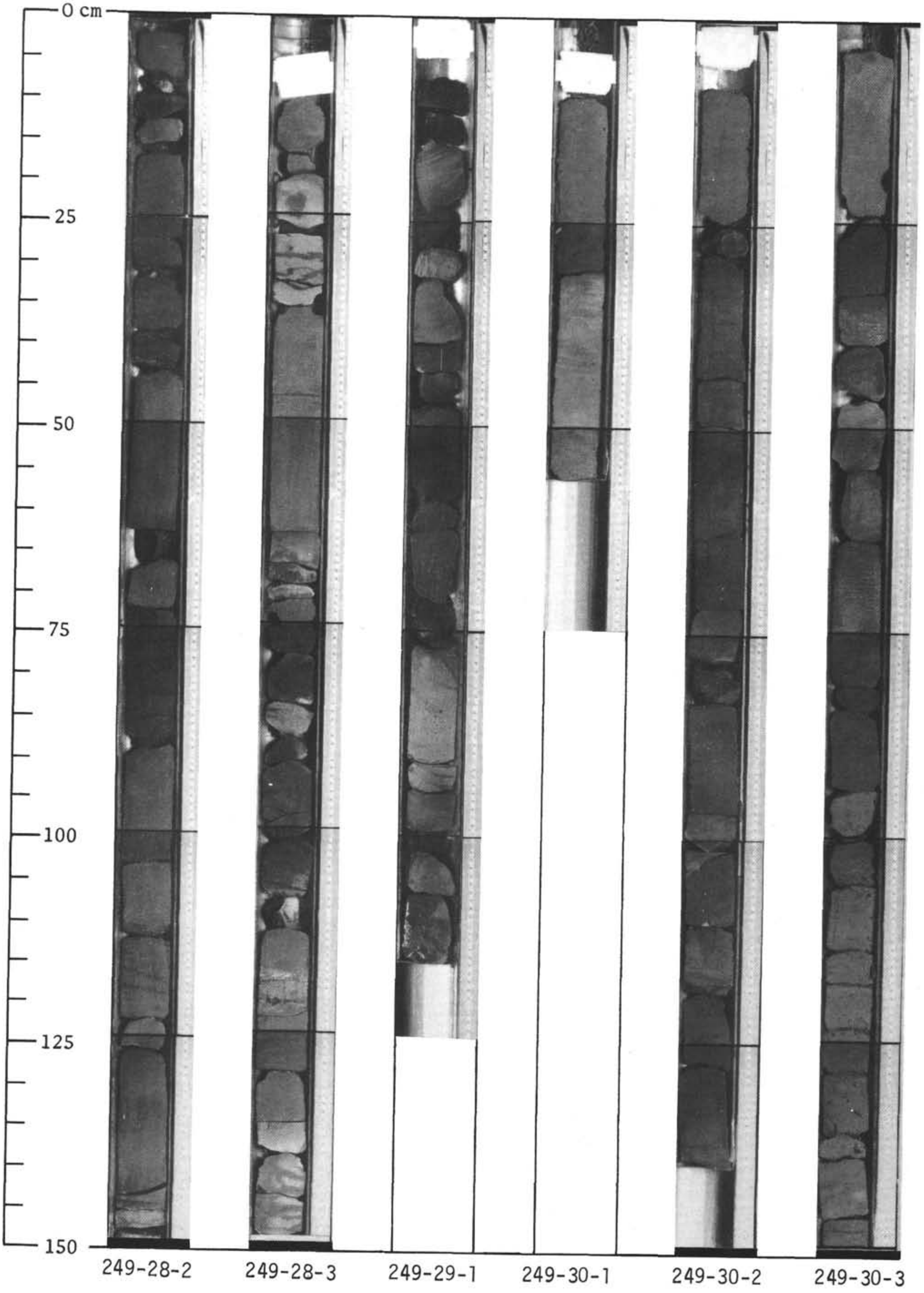
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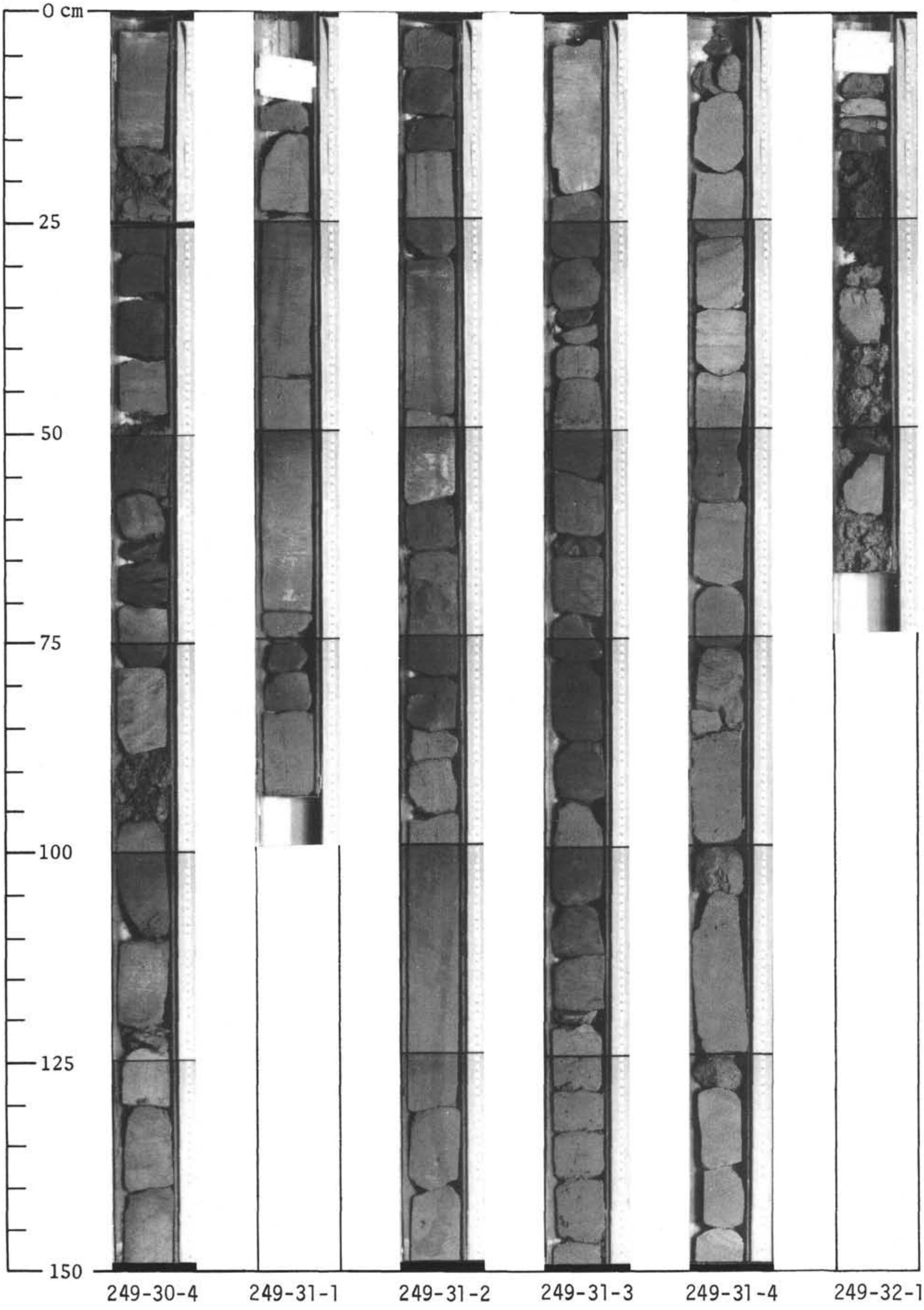
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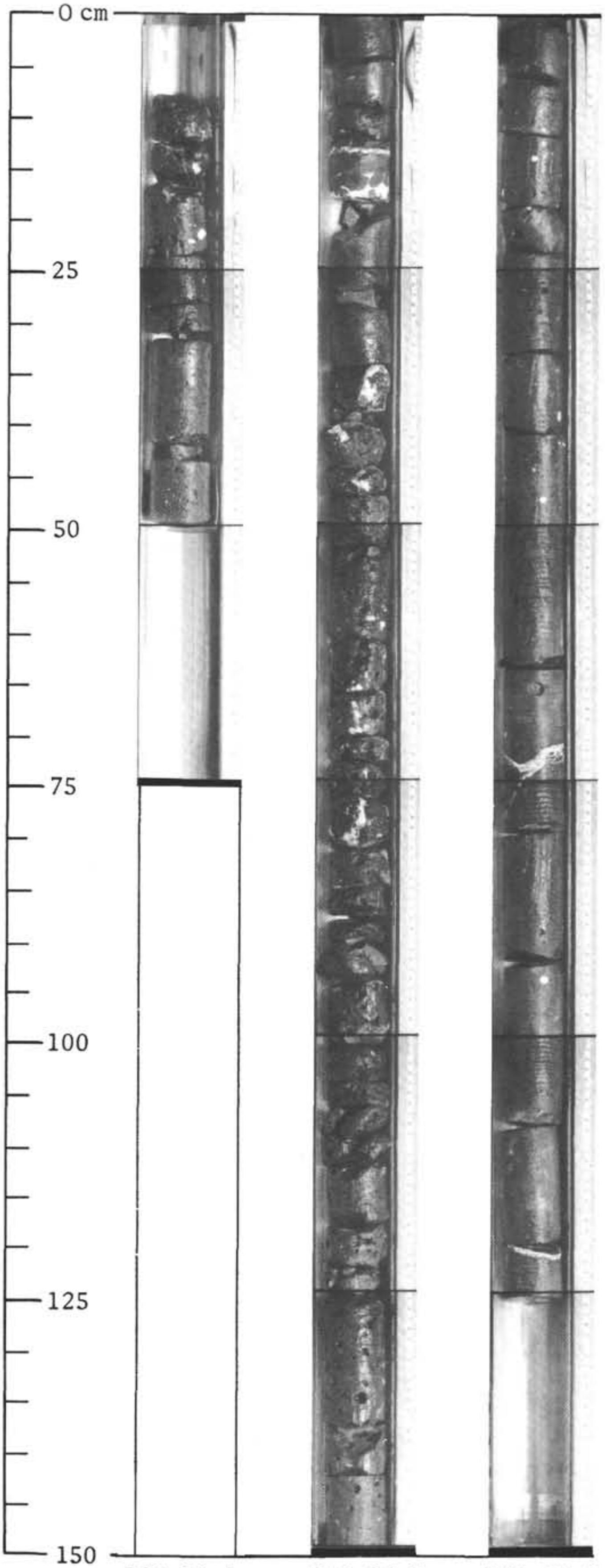
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