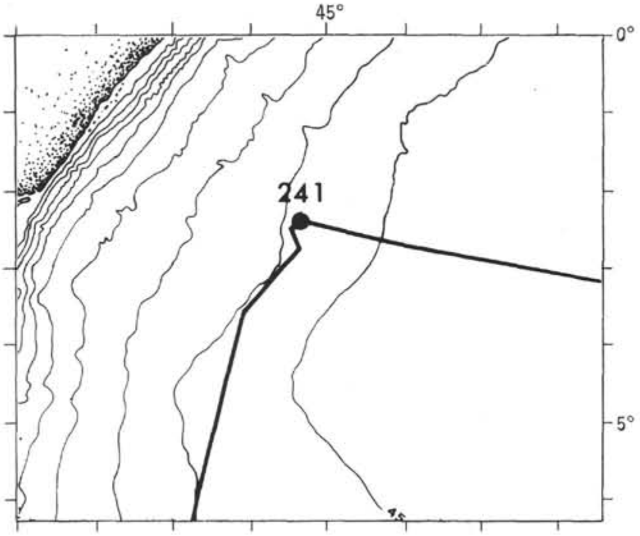
4. SITE 241

The Shipboard Scientific Party[1]

SITE DATA



Location: East African continental rise

Position: 02°22.24′S, 44°40.77′E

Water Depth: 4054 meters

Total Penetration: 1174 meters

Cores: 29 cores (252 m cut, 136.7 m recovered)

Deepest Unit Recovered: Claystone and sandstone of earliest Turonian age

BACKGROUND AND OBJECTIVES

The Somali Basin, in the northwestern part of the Indian Ocean, is limited on the west and northwest by the African continental margin, on the east and northeast by the Carlsberg Ridge, and on the south by an irregular boundary which passes through the Comores Islands and the northern end of Madagascar, thence north to the Seychelles Islands, and along the northeastern border of the Mascarene Plateau to the Central Ridge. The Somali Basin itself is divided into eastern and western parts by a nearly north-south line extending from Chain Ridge down to Madagascar. Site 241 is located on the East African continental rise in the western part of the Somali Basin, 680 miles to the west of Seychelles Islands and about 170 miles from the coast of Africa (Figure 1).

Continuous bathymetric, magnetic, and gravity measurements made in the Somali Basin between Seychelles Islands and East Africa, first by *Owen* between 1961 and 1963 during the International Indian Ocean Expedition, later by *Vema* and *Chain*, and in 1970 by *Gallieni*, showed for at least 300 miles out from the coast of Kenya the absence of bathymetric, magnetic, and gravimetric relief. This led to the conclusion that the area between Kenya and 48°E is underlain by a thick sedimentary cover (Loncarevic and Matthews, 1962). According to Dixey (1960) it seems clear that from geological considerations, the East African coast has subsided intermittently since about the end of the Karroo and that the coastline had once been much further to the east of its present position. Baker and Miller (1963) went further to suggest that the Seychelles-Mauritius Ridge (Mascarene Plateau) was once the eastern boundary of the continent. The existence of an oceanic crust west of the Seychelles Bank has been proven by Francis et al. (1966) from the results of a series of seismic refraction profiles shot in a south southwest-north northeast direction by *Discovery* and *Owen* (September-October 1963) between Lamu on the Kenya coast and the Seychelles Islands (Figure 1). The same data also showed the presence of thick sedimentary layers overlying deep basement for 300-400 km from the African coast.

The proposed Site 241 is located very close to refraction station 3 of Francis et al. (1966). The data obtained were particularly consistent at this location, and their interpretation indicated an uppermost layer of soft sediments, probably formed during the Tertiary (thickness: 1.0 km, velocity: 1.93 km/sec), a second layer of consolidated sediments of inferred Cretaceous and Jurassic age (thickness: 2.7 km, velocity: 2.53 km/sec), and a third layer of about 4.6 km with a velocity of 6.56 km/sec, which is typical for basic crustal rocks beneath both oceans and continents and which rests upon the 8.1 km/sec mantle. A general interpretation by Francis et al. (1966) of their seismic refraction results is shown in Figure 2 (figure 19 of Francis et al., 1966) where the geological column at Lamu is inferred from nearby geological and geophysical work by B. P. Petroleum Development, Limited. Among the more striking results of this work are the thickness of the sediments observed 300-400 km from the African coast and the existence of material of about 4.8 km/sec velocity, which could correspond to the Karroo beds on the coast at Lamu.

The location of Site 241 was proposed on the basis of seismic reflection data (flexotir) obtained by *Galliéni* 4 in

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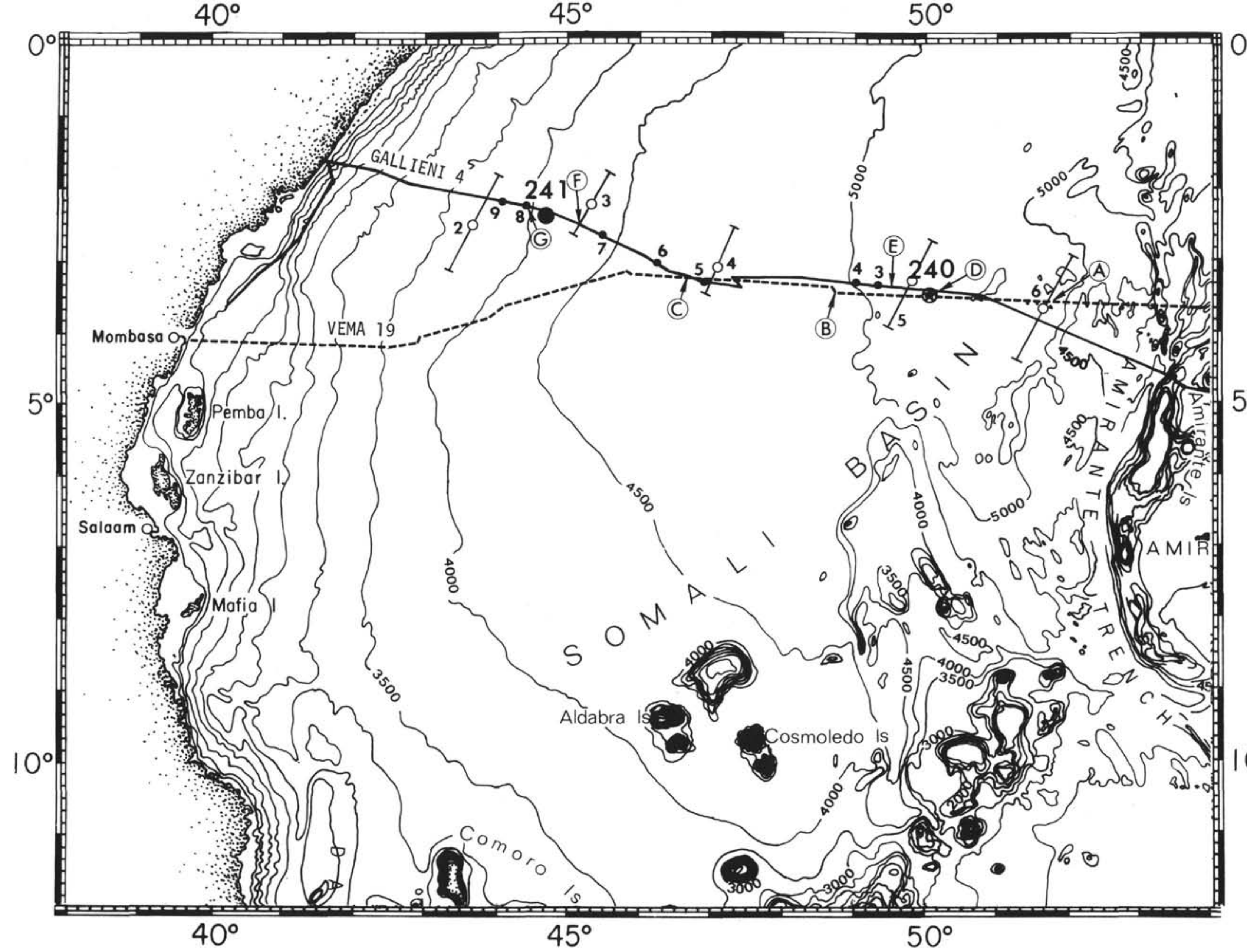

Figure 1. *Location map for Site 241. Isobaths are in meters. The letters shown refer to the seismic reflection profile given in Figure 4. The open circles indicate the refraction profiles of Francis et al. (1966); the dots are used to denote the sonobuoy stations of Schlich et al. (1972).*

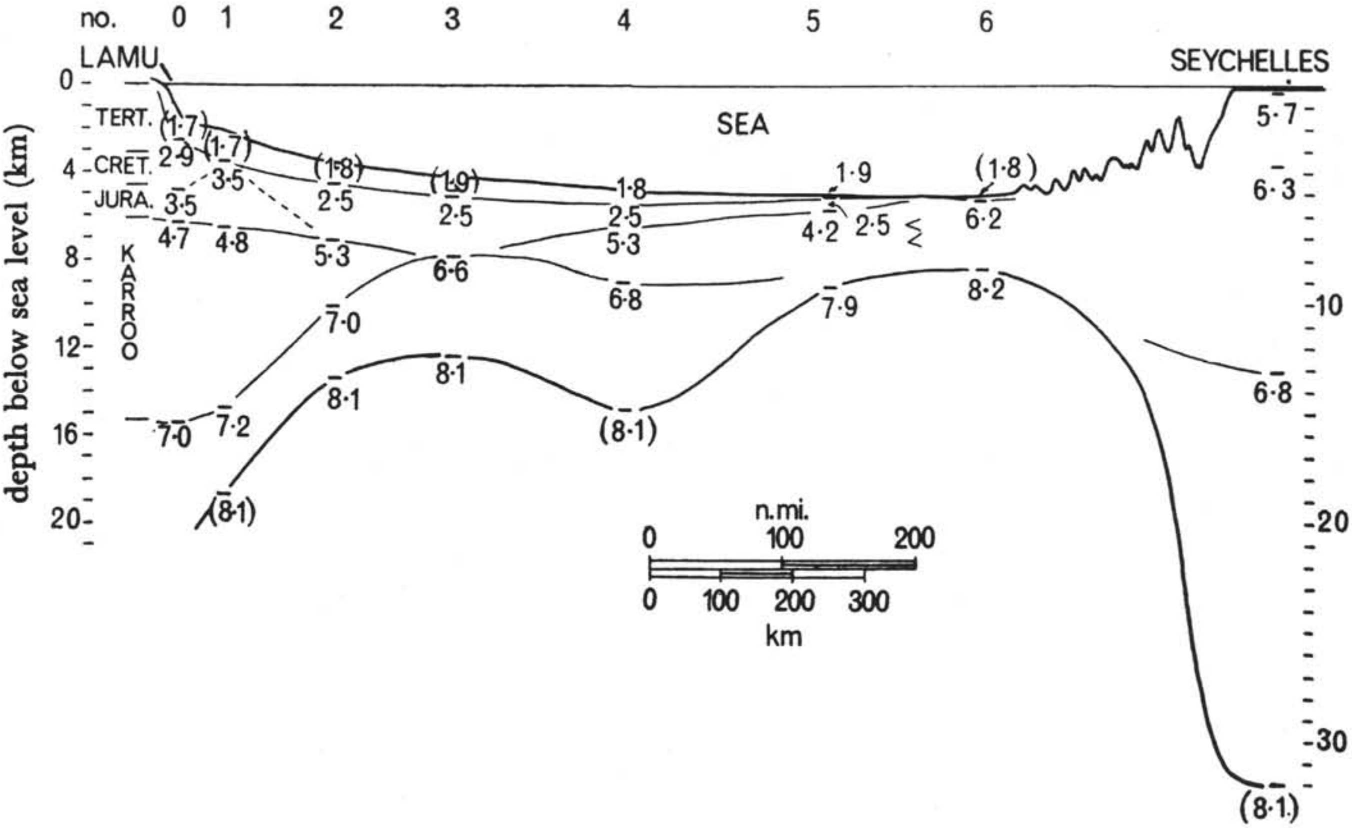

Figure 2. *Seismic section between the coast of Kenya and the Seychelles Islands combined with the B. P. postulated geological column at Lamu after Francis et al. (1966) Figure 19. The seismic velocities are given in km/sec; the larger numbers given at the top correspond to the refraction profiles.*

1970 along a profile almost due west from Seychelles Bank to Mombasa on the African coast (Schlich et al., 1972). The authors recognize five different zones from east to west, characterized essentially by differences in the structure and thickness of the sediments overlying the basement which deepens westward beneath the East African continental margin.

Site 241, provisionally located in position 02°22′S, 44°40′E, is situated on the lower East African rise at the western limit of Schlich et al. (1972) structure zone 4. The interpretation of the flexotir profile in the vicinity of Site 241 is diagrammatically represented in Figure 3. Here, the sediment cover is about 3 sec DT (doubleway time) thick, the lowest reflector not necessarily being the basement. The lowest layer, limited at the top by horizon B and interpreted by Schlich et al. (1972) as the boundary between Cretaceous and Tertiary, is 1.8 sec DT thick and acoustically unstratified. The overlying series are clearly stratified and can be divided mainly into three members—the lowest about 0.2 sec DT thick; the second 0.5 sec DT thick; and the uppermost layer, limited at the bottom by horizon A, 0.5 sec DT thick (Figures 3 and 4). Wide-angle reflection and refraction sonobuoy data obtained by *Gallieni* very close to the proposed site suggest for the bottom layer a velocity of 3.5 km/sec, which corresponds to a thickness of about 3.1 km; for the two overlying stratified series a velocity ranging between 2.3 and 2.8 km/sec, which gives a thickness for these two layers of about 0.8 km; and a velocity of about 1.8 km/sec for the uppermost member, which corresponds to a thickness of about 0.45 km. These results are consistent to some extent with the interpretation of Francis et al. (1966).

The objectives of drilling this hole were to recover as deep and as complete as possible a sedimentary record in order to (a) determine the stratigraphic succession with particular reference to seismic layer identification, composition, and age; (b) to sample and date, if possible, horizon B at 1.2 sec DT for possible correlation with the Lamu geological column on shore; and (c) to establish what evidence, if any, is available to deduce a possible paleoposition of Madagascar.

SURVEY DATA AND OPERATIONS

Glomar Challenger departed from Site 240 at 0530 LT (local time) (0130 GMT) on 12 July 1972, and Site 241 was approached along a course of 290° after 1 day and 13 hours of steaming across the abyssal plain of the Somali Basin. At 1740 LT (1340 GMT) on 13 July 1972, about 8 miles before reaching the proposed site, *Glomar Challenger* speed was reduced to 6 knots to enhance the clarity of the airgun seismic reflection records. At 1840 LT (1440 GMT), the site was identified from the airgun records, and the 13.5 kHz beacon was dropped immediately. The airguns, hydrophones, and magnetometer were retrieved, and

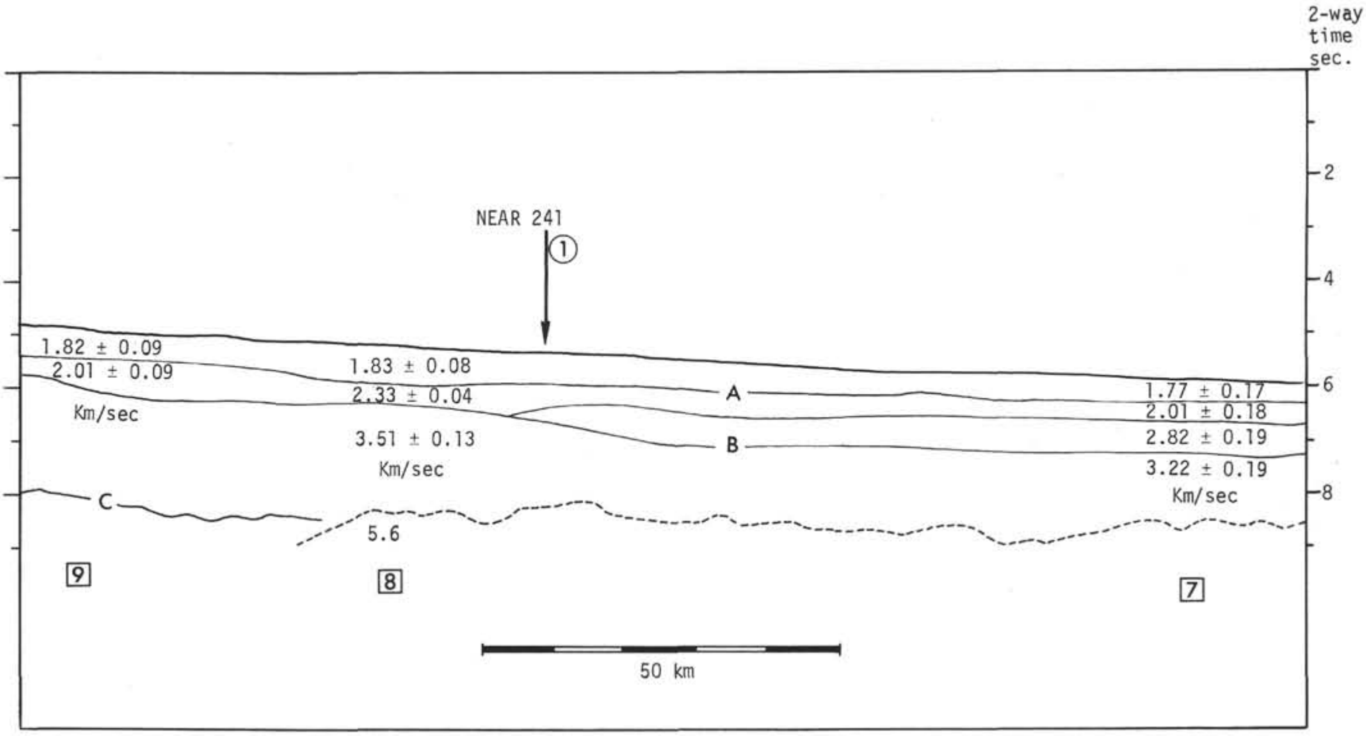

Figure 3. *Diagrammatic interpretation of seismic reflection profile (flexotir) between Seychelles and Mombasa in the vicinity of Site 241 (Schlich et al., 1972). The seismic velocities are given in km/sec; the numbers in squares correspond to the location of the sonobuoy stations.*

Glomar Challenger reversed course to take up station over the beacon. The geographical coordinates of Site 241 are 02°22.24'S, 44°40.77'E (Figure 5).

The *Glomar Challenger* track was slightly to the north of, and nearly parallel to, the *Gallieni* reflection profile from which the original site was proposed. The two ships' tracks intersected close to the proposed site. The *Glomar Challenger* airgun records show a series of well-stratified layers which could be correlated with the characteristic reflectors observed on the flexotir record with the exception of horizon B at 1.2 sec DT and the horizon at 3.0 sec DT (Figure 6). The last visible horizon at 1.0 sec DT is the only one which has a marked slope down to the west, while the sea floor bottom rises to the west; consequently, it was possible to check the positioning of the flexotir data by using the observations made on the airgun record. It appears from a comparison with the *Gallieni* data that the beacon location corresponds to the fire point 15263, which is very close to the first arrow from the right on Figure 4.

The main site objective was to reach the layer at about 1.2 sec DT seen on the flexotir record. A program of intermittent coring was planned: one or two cores every 50 meters with special attention being given to sample the different interfaces. This program was altered somewhat after 700 meters penetration due to increasing sediment hardness and problems relating to hole stability. For the last 500 meters, a core was taken only every 80-90 meters. The last core was cut between 1167 and 1174 meters below the sea floor, and from the measured sonic velocity made at different depths, it can be computed with reasonable confidence that the reflector at 1.2 sec DT (1.24 sec DT at the site) was reached.

Drilling and coring at this site started at 0400 (LT) on 14 July 1972 and ended at 0415 (LT) on 18 July 1972. Twenty-nine cores were taken, the total cored section being 252 meters and the total core recovered, 136.7 meters. The total time spent on the site was about 4 days and 20 hours (Table 1). The average drilling rate was 27.0 m/hr, and the average coring rate was 14.4 m/hr. The rate of drilling and coring decreased very abruptly at a depth of about 850 meters and was only 15 m/hr for drilling and 4 m/hr for coring at about 1150 meters. Figure 7 gives a graphic representation of these drilling and coring rates. After completion of operations, the teeth of the four-cone bit were found to be in good condition except for two inserts which were missing. Three of the bearing's seals were damaged, and one bearing was apparently broken.

Glomar Challenger departed from Site 241 at 1430 LT (1030 GMT) in a northerly direction at a speed of about 6 knots while the airguns, hydrophones, and magnetometer were streamed. At a distance of about 1.5 miles from the beacon *Glomar Challenger* reversed course to 215° so as to again pass over the beacon and check its position. The beacon was passed at 1508 LT (1108 GMT), and at 1510 LT (1110 GMT), a sonobuoy for wide-angle reflection and refraction was successfully launched over the site. The signal became weak after 1 hour of operation, penetration was rather minimal, and it seems difficult to derive from these data any good sonic velocity determination. At 1624 LT (1224 GMT), the speed was increased to maximum, and

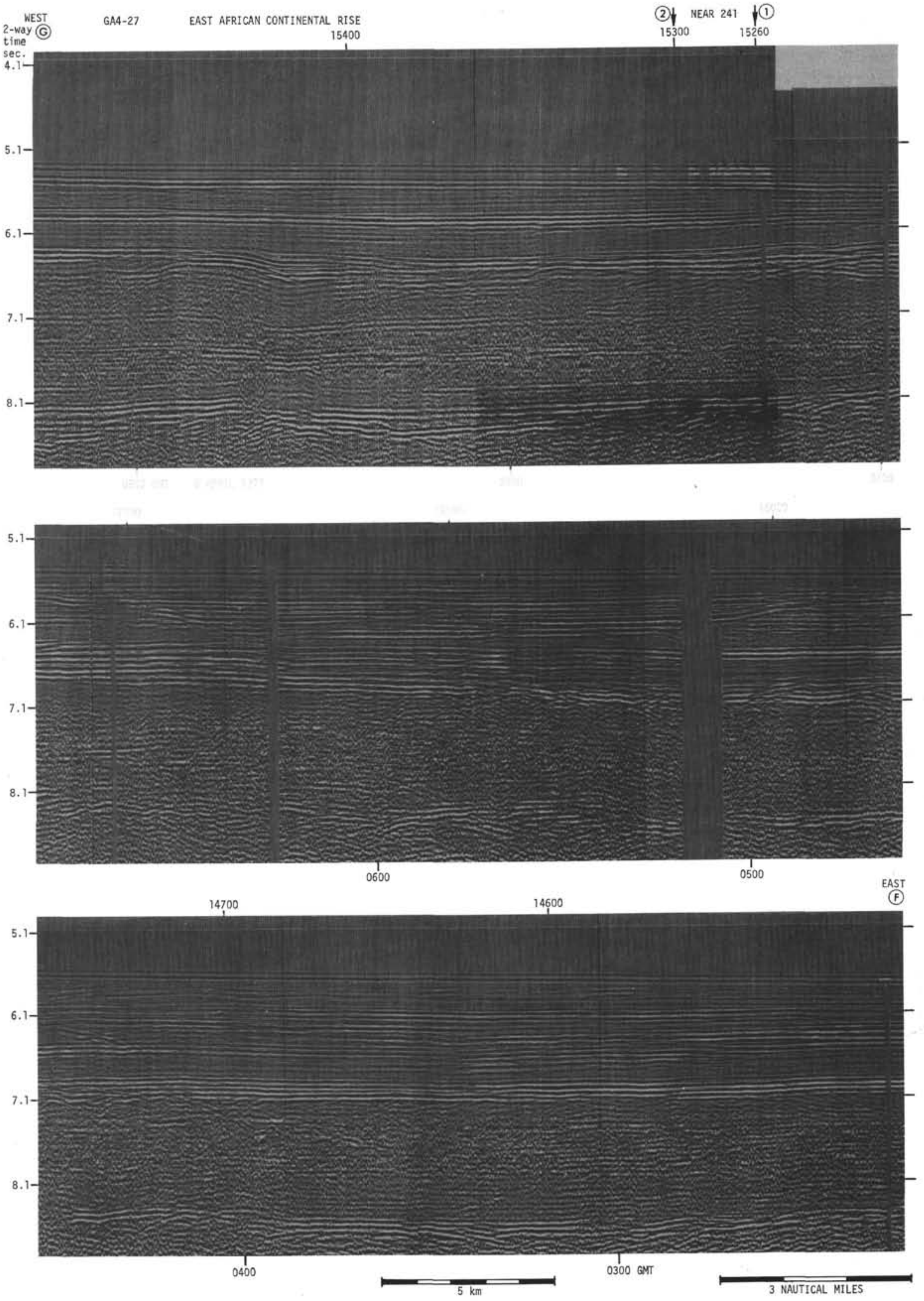

Figure 4. Gallieni *4 seismic reflection profile (flexotir sound source and variable area recording) in the vicinity of Site 241. The location of this section is given in Figure 1.* Gallieni *4 records are from Schlich et al., 1972 (courtesy of Institut de Physique du Globe de Paris and Comité d'Études Pétrolières Marines).*

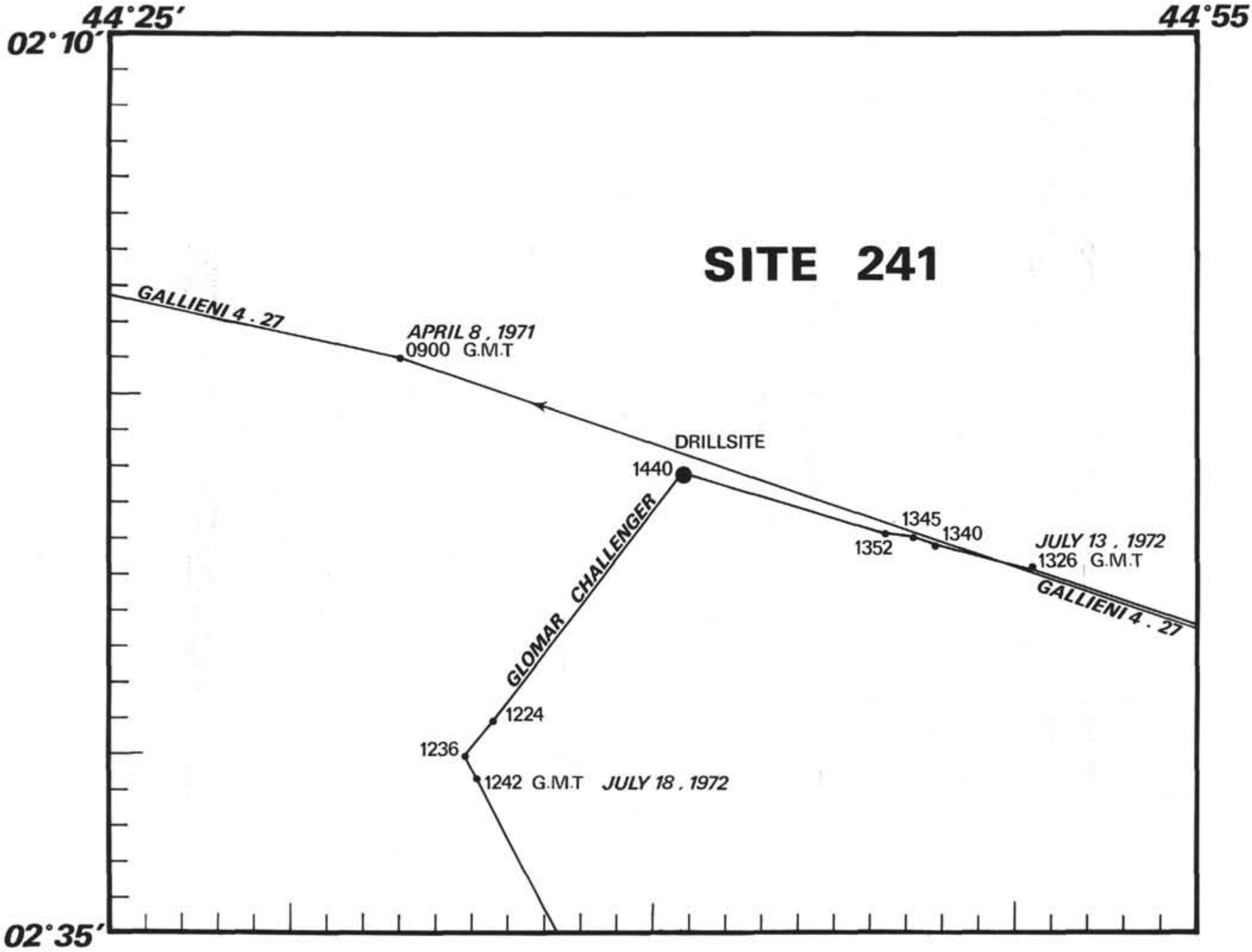

Figure 5. *Details of the* Glomar Challenger *site approach.*

the ship steamed to Site 242 via a point at 10°00'S, 42°40'E, along a route parallel to a 1970 *Gallieni* track.

LITHOLOGY

Introduction

Twenty-nine cores were recovered during the drilling at Site 241 to a depth of 1174 meters below the sea floor. The recovered lithology can be subdivided into two major stratigraphic units easily distinguished by clay and calcium carbonate content (Table 2, Figures 8 and 9). Cores 25 to 29 in Unit II comprise an informal lithologic division characterized by well-lithified sandstone beds and copious sedimentary structures.

To date, Site 241 records the deepest penetration into a continental rise. The cored lithology provides a good example of the kinds of deposits which may accumulate in this sedimentary environment.

Description of Lithologic Units

Unit I: Clay and Clay-Rich Nanno Ooze (Cores 1 to 16),

Clay and clay-rich nanno ooze comprise most of Unit I. Foraminifera average 10 percent of a portion of Core 1 and approximately 40 percent of foram nanno chalk in Core 16. Radiolarians and diatoms comprise 10 percent of Cores 1 and 2. Feldspar and quartz range from trace abundances to several percent throughout Unit I.

Volcanic glass occurs in trace amounts in Cores 1 to 11, 12, and 14. An apparently devitrified volcanic ash bed occurs in Core 15. Trace abundances of pyrite are present in Cores 1 to 11 and 14. Authigenic carbonate rhombs occur in trace amounts in Core 4.

Graded beds and distinct segregations of silt and/or very fine sand comprise a minor lithology best developed in Cores 10 and 11 but also distributed through Cores 2 to 5, 8, 13, 15, and 16. The basal contact of the graded beds is typically sharp with tops being indistinct. Thin section observations indicate that the basal portions of the graded beds average greater than 50 percent biogenic detritus including foraminifera, sponge spicules, Radiolaria, and diatoms. Benthonic foraminifera from graded beds in Core 11 (3, 74-76 cm and 4, 35-37 cm) were derived from inner shelf (nonreefal), outer shelf, upper slope, and abyssal environments. Miocene graded beds (Cores 13 and 15) include reworked foraminifera of Eocene age. Glauconite occurs in a few basal silts and fine sands.

The nanno chalk of Core 16 marks the first macroscopic sign of lithification.

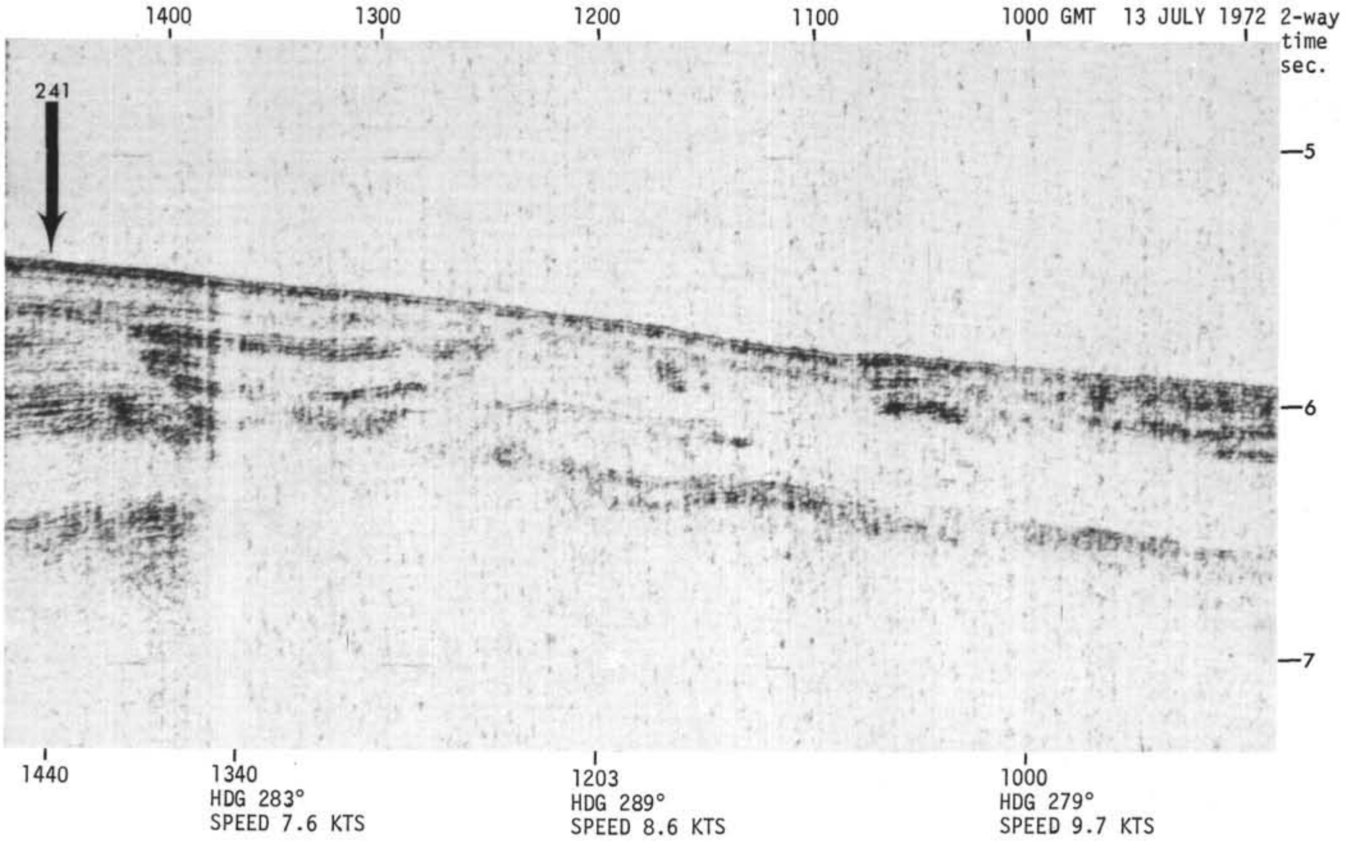

Figure 6. Glomar Challenger *seismic reflection profile on approach to Site 241.*

Unit II: Clay/Claystone and Silty Clay/Claystone (Cores 17 to 29)

The dominant lithologies of Unit II are clay-claystone and silty clay-claystone. Minor lithologies include nanno ooze-chalk, clayey silt-siltstone, and calcareous quartz sandstone. The upper limit of Unit II is defined by Core 17, composed entirely of silty clay.

Unit II is differentiated from the preceding units by an almost complete lack of calcium carbonate detritus (Figure 8). However, in Cores 21 to 24, nannofossils account for Tr-15 percent of the sediment. Trace amounts of authigenic carbonate rhombs were observed in Cores 24, 26, 28, and 29. Carbonate particles of unknown origin comprise up to 30 percent of a minor lithology in Core 27. Conspicuous concentrations of calcium carbonate are restricted to the basal portions of graded beds except in Cores 21 to 24. Calcium carbonate micro- and nannofossils average 2 ± 1 percent of Unit II.

Moderate brown clay-claystone is conspicuously present in Cores 17 through 21. Smear slides indicate that these units are primarily clay with little quartz and feldspar silt (some clay particles are of silt size). A few percent iron oxide apparently accounts for the red brown color of these clays. Calcareous micro- and nannofossils are generally absent or present only in trace amounts.

A devitrified volcanic ash occurs in Core 20. Partially devitrified volcanic glass is present in trace amounts to 2 percent of Cores 25, 26, and 28.

Graded beds or distinct layers of silt and/or sand-sized detrital particles are present in all cores, except Cores 18 and 29. A thin sand layer, preserved at the top of Core 17, may represent the remains of extensive unconsolidated sand washed during the coring process. The uncontrollable washing of sand must be considered in any comparison of cores from unconsolidated and lithified units.

Cores 25 to 29 (835-1174 m below sea floor) recovered an exceptional section of calcareous sandstone, obviously graded beds, and finely laminated rock in addition to the common claystone and silty claystone. The calcareous quartz sandstone is comprised of approximately equal amounts of quartz sand and detrital carbonate (see petrographic descriptions for details). These layers, in general, are indurated and range in thickness from 3-38 cm. They make up 7 percent (by volume) of Cores 25 to 29. Macroscopic observations suggest that very fine sand is the dominant grain size. The sandstone shows massive bedding, parallel lamination, cross bedding, convolute lamination, minor graded bedding, slump folds, and rip-up clasts. One calcareous sandstone (27-2, 125-135 cm) exhibits, from top to bottom, a massive unit overlain by a laminated unit, followed by a convoluted bed topped by a laminated clayey silt which grades to clay. This composite bed contains the entire Bouma sequence (A-E) characteristic of turbidity current deposits (Bouma, 1962).

Obviously, graded beds occur in thicknesses ranging from a few mm to 10 cm. These beds are defined by sharp

TABLE 1
Coring Summary, Site 241

Core	Depth Below Sea Floor (m)	Cored (m)	Recovered (m)	Recovery (%)
1	0-9	9	9.0	100
2	9-18	9	8.8	97
3	47-56	9	9.2	100
4	56-65	9	6.7	74
5	65-74	9	7.2	80
6	104-113	9	9.0	100
7	142-151	9	7.0	78
8	180-189	9	4.2	47
9	209-218	9	1.8	20
10	218-227	9	4.7	52
11	256-265	9	5.0	55
12	294-303	9	1.9	21
13	322-331	9	6.0	66
14	379-388	9	2.2	24
15	398-407	9	5.6	62
16	455-464	9	1.7	19
17	483-492	9	0.4	4
18	492-501	9	0.6	6
19	530-539	9	2.7	30
20	539-548	9	0.7	8
21	578-587	9	6.7	74
22	626-635	9	5.8	64
23	683-692	9	5.8	64
24	749-758	9	2.2	24
25	835-844	9	5.3	59
26	873-879	6	4.5	75
27	977-986	9	5.9	66
28	1067-1072	5	4.4	88
29	1167-1174	7	1.7	24
Total		252	136.7	54

Note: Echo sounding depth (to drill floor) = 4064 meters; drill pipe length to bottom = 4084 meters.

basal contacts and indistinct upper contacts. Six of the best defined graded beds have sand:shale ratios averaging 3:5. Some of these units show flame structures; many include rip-up clasts.

A third class of sedimentary deposits observed in Cores 25 to 29 are finely laminated (2 mm) clayey siltstone, silty claystone, and siltstone. These beds have no obvious grading. Locally, they may show subtle cut and fill structure along basal contacts. They may also occur in moderately well defined units 1-3 cm thick.

Sandstone-Limestone: Petrographic Description

Four lithified units (25-2, 50 cm; 26, 2-15 cm; 27, 2-125 cm; and 29-2, 12 cm) were examined to determine their petrographic characteristics. The mineral grains range from very angular grains (generally in the silt sizes) to sub-well-rounded grains in the coarser sizes. The roundness characteristics generally apply to all detrital components. The detrial quartz, feldspar, and rock fragments have dolomitic overgrowths and/or replacement. This is more prevalent with the coarse grains and tends to enhance the roundness characteristics. A cement/matrix fraction is present and consists of an interstitial mosaic of predominantly silt-sized detrital grains (70%-80%) with chemically precipitated calcite and dolomite and minor clay (20%).

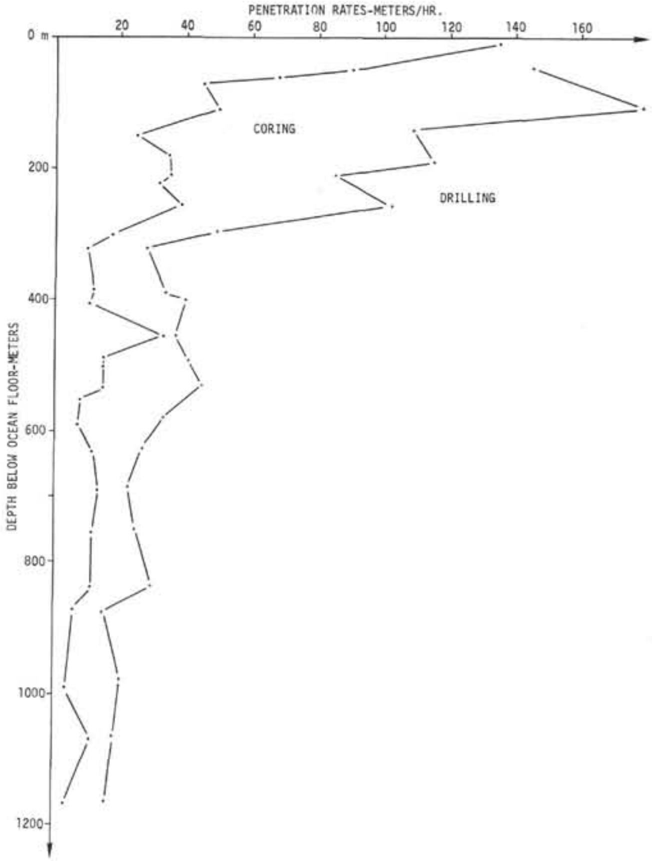

Figure 7. *Record of drilling and coring rates at Site 241.*

The grain fraction consists of detrital quartz (25%-65%), detrital feldspar (2%-4%), detrital dolomite (5%-15%), foraminiferal tests (1%-2%), dolomite rhombs (1%), grains replaced by calcite (5%-10%), rock fragments (1%-2%), and accessory minerals (<1%). The quartz grains generally exhibit undulatory extinction and a high percent of inclusions, including zircon. Nearly all quartz grains have

TABLE 2
Lithologic Units, Site 241

Depth (m)[a]	Lithologic Units	Thickness (m)
464 to 483	I Greenish-gray clay-rich and clayey nanno ooze; minor dark greenish-gray nanno-rich clay and nanno clay	464 to 483
1174	II Dark greenish-gray and moderate brown clay-claystone; minor nanno-rich claystone, silty clay, and calcareous sandstone	691 to 710

[a] Depth to Unit II is between 464 and 483 m. Contact occurs in an uncored interval.

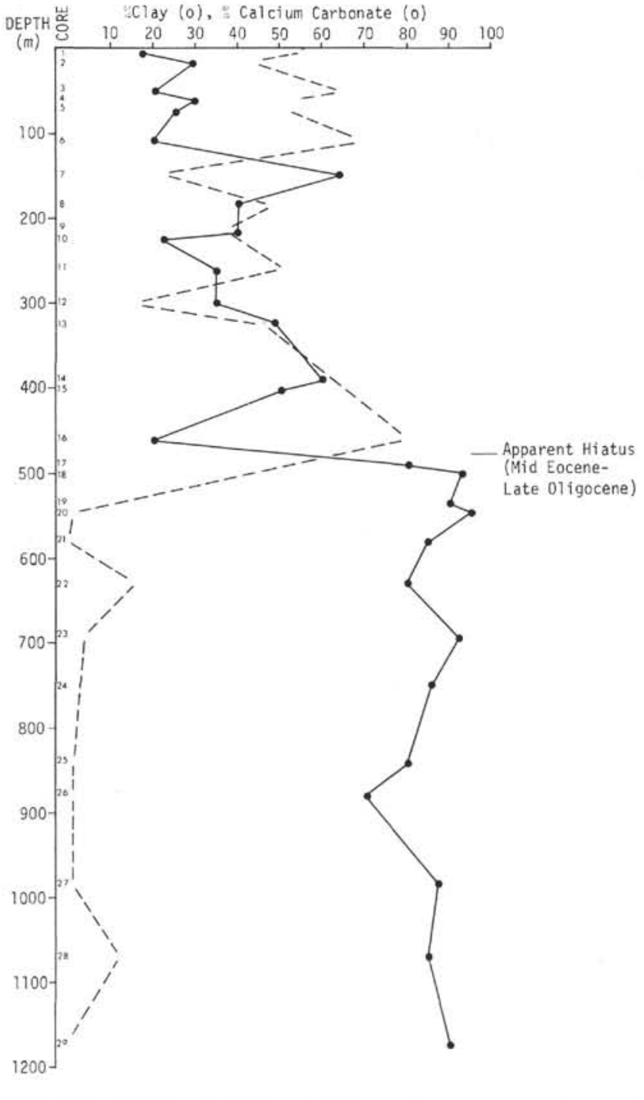

Figure 8. *Graph showing relative changes in clay and calcium carbonate percentages, Site 241.*

dolomitic overgrowths. Feldspar varieties include both microcline and plagioclase and have dolomitic overgrowths. Accessory minerals (<1%) include augite, hornblende, micas, zircon, glauconite, and opaques. Fossil fragments and whole tests occur in the samples with a variety of sizes (silt-sand). Dolomite is prevalent as detrital single and composite fragments, rhombs, and overgrowths.

These four lithified rocks straddle the classification boundary between calcarenite/calcsiltite and calcareous quartz sandstone/siltstone. They are referred to as calcareous sandstones in the text and on the core forms.

Preliminary Interpretations and Speculations

1) The entire stratigraphic sequence cored at Site 241 is of deep-sea origin and consists of biogenic oozes, hemipelagic sediments, and turbidity current deposits. Thus, if and when continental separation or drastic subsidence occurred at this continental margin, it preceded the age (Turonian) of the oldest deposits penetrated at Site 241.

2) The sedimentary section cored at Site 241 shows a sharp decrease in calcareous biogenic detritus between Cores 16 and 17, apparently coincident with the middle Eocene to late Oligocene hiatus. Excluding the calcareous sandstones (turbidites), Unit II contains 2 percent or less calcium carbonate detritus; hence, it may be considered as having been deposited below the calcium carbonate compensation depth (CCD), in contrast to Unit I.

An explanation of this fundamental lithologic change may include any of the following possibilities or combinations thereof:

a) Severe dilution of the calcareous biogenic component by terrigenous influx. This is not a complete explanation since only a sparse solution-resistant nannoflora remains in Unit II, suggesting selective dissolution.

b) Dissolution of calcareous biogenic material. This is possible but would require movement of the sea floor relative to compensation depth. This change could be accomplished by: uplift or upbuilding of the sea floor; lateral movement of the sea floor to a zone where the compensation depth is deeper (e.g., the equatorial zone); and a major change in oceanic circulation which could alter the temperature and chemistry of deep-water masses and hence the compensation depth. The erosion or nondeposition which produced the middle Eocene to late Oligocene hiatus could also be related to a change in oceanic circulation.

3) Cores 25 to 29, Unit II, may be considered a flysch sequence as defined by Dzulinski and Walton (1965). This section includes a range from relatively proximal (massive sandstone) to distal (fine-grained graded beds) turbidites. It is likely that these turbidites accumulated as channel levee and overbank deposits of a migrating submarine distributary system at the base of the Cretaceous continental slope.

4) Any portion of the sequence of Site 241 is clearly more distal than the coarse massive sand cored at Site 240. If the sand of Site 240, on the abyssal plain, was derived from Africa it bypassed the continental rise (Site 241), possibly through relatively localized distributary channels.

PHYSICAL PROPERTIES

Bulk density values obtained from the three methods—GRAPE, syringe, and section weight—were generally in good agreement. Several syringe values fit better with peak (maximum) GRAPE values than with averaged ones. This is most apparent where the sediments are semilithified clays and the diameter of the cores vary irregularly, producing a highly fluctuating GRAPE record. The general increase in bulk density with depth is associated with a decrease in water content and attendant increased compaction. In Core 27, at about 980 meters, a sudden increase in bulk density to 2.50 g/cm^3 approaches that of a well-lithified rock and reflects the presence of an indurated calcareous sandstone.

Sonic velocity measurements indicate a general increase of velocity with depth. Single, high values at depths of about 874, 978, and 1169 meters are apparently associated with thin beds of limestone. Most of the sonic velocity tests are made with the split core in the liner; this usually

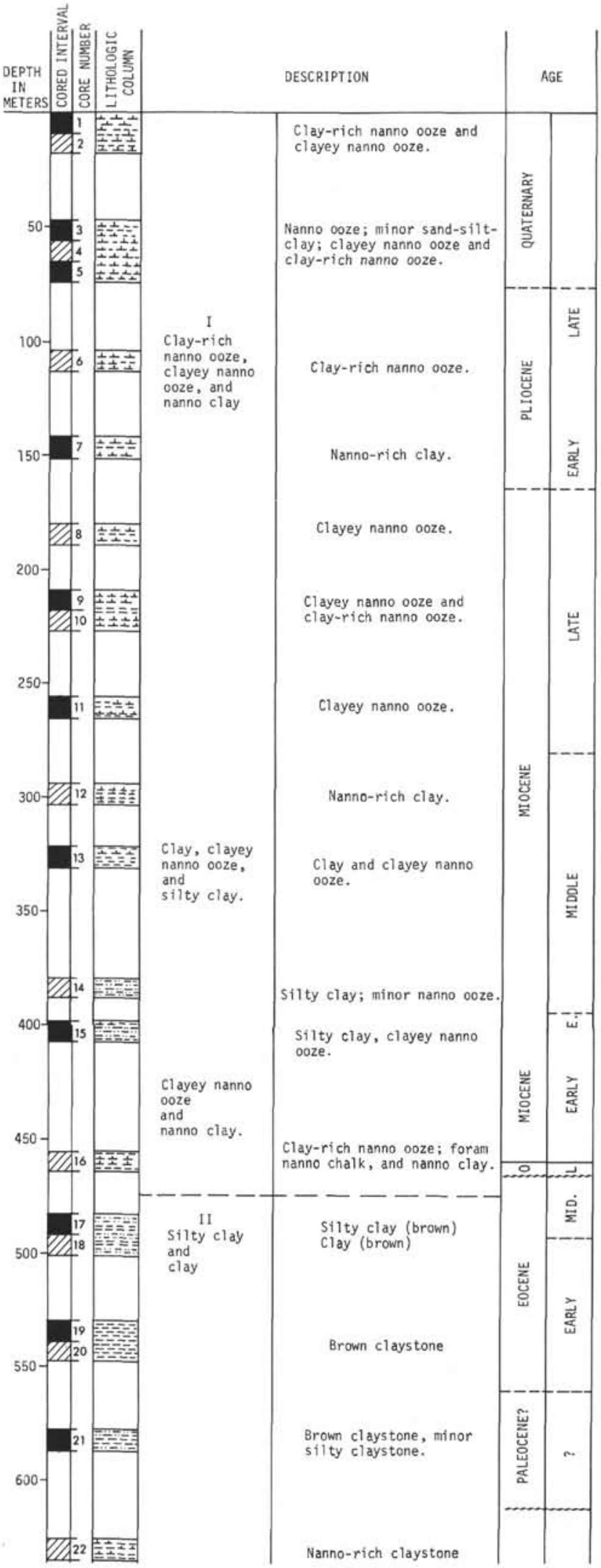

Figure 9. *Stratigraphic column, Site 241. Dashed lines indicate uncertain boundaries; wavy lines indicate hiatuses.*

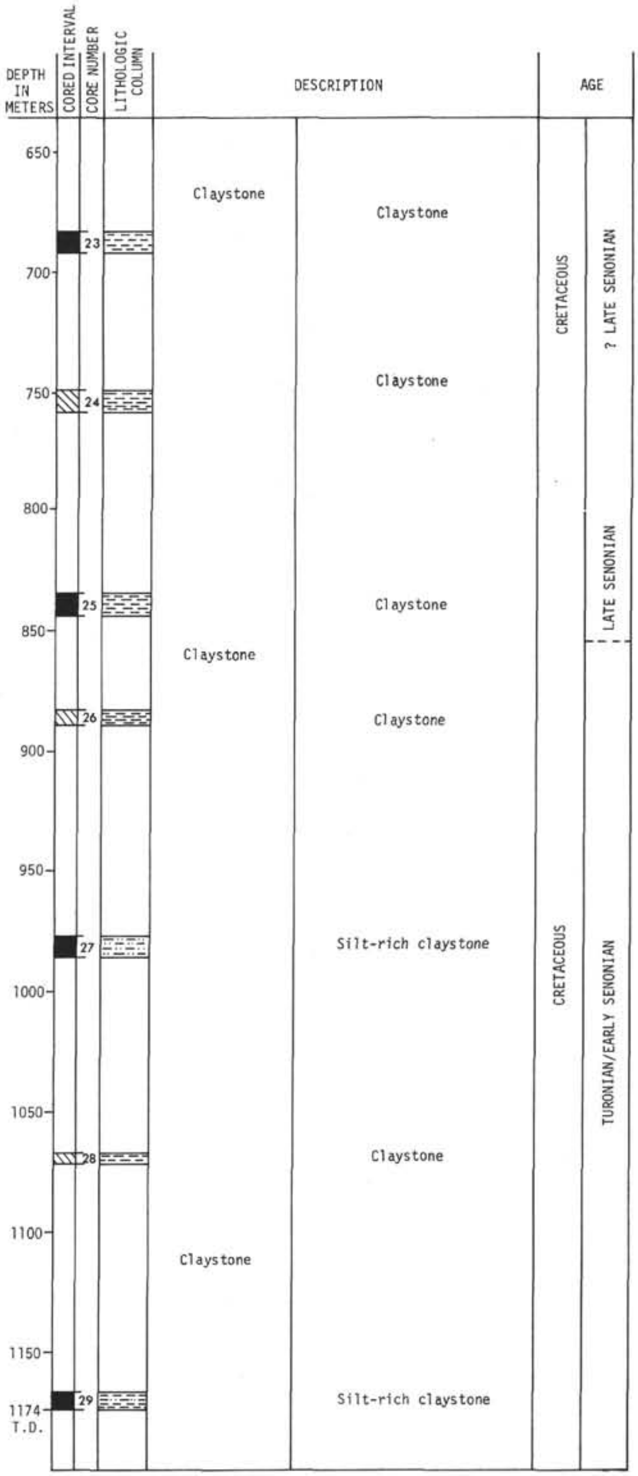

Figure 9. *(Continued).*

yields values parallel to the bedding. Using only these velocities, we find:

1) A possible linear relationship to 400 meters for the increase of velocity with depth. Two positive anomalies of about 5 percent each are from sand layers at approximately 221 and 246 meters.

2) From 400 to 600 meters, the data are more scattered but suggest the possibility of the following two step increases. A velocity of about 1.73 km/sec from 400 meters to approximately 550 meters with a 10 percent positive anomaly at approximately 463 meters related to a foram nanno chalk. Below 550 meters, the sonic velocity is approximately 1.85 km/sec. The second step occurs somewhere between 750-850 meters, and the velocities below range between 1.95 and 2.3 km/sec for the claystones and from 3.12 to 5.5 km/sec for the anomalous sandstones. The values of 3.12 km/sec for the sandstone at 873 meters is the average of two values; this value is essentially the same as that of the limestone.

Some of the core was taken out of the liner for velocity tests. When this was done, measurements were taken in directions parallel and perpendicular to the assumed bedding plane. Roughly 80 percent of the samples tested have slightly higher (average of 4.7%) velocities in the horizontal plane. This difference could be related to the very strong horizontal interbedding which was observed on several cores and/or to the reduction in pressure from in situ conditions.

The changes in acoustic impedance values follow closely the variations in sonic velocity. There is one strong anomaly in Core 15 and one between Cores 24 and 26. Less pronounced ones occur between Cores 2 and 3, possibly at Core 7, between Cores 20 and 23, and between Cores 26 and 28. These are assigned the numbers 1 to 6 and are listed with approximate depths and lithology correlations in Table 3.

Thermal conductivity and water content appear to be inversely related over most of the cores. Below about 260 meters, the percent water data vary roughly between 19 and 28 percent, while the thermal conductivity is confined between the limits of 2.24-3.07 mcal/cm sec °C. A significant change in both properties occurs in Core 7 at approximately 150 meters. Here the lower conductivity may be associated with one of the silty clays and clayey silts found in lithology Unit I. At about 260 meters (Core 11), one high thermal conductivity value (3.07 mcal/cm sec °C) was measured in a fine sand of a graded bed. Near a depth of 325 meters the conductivity varies from 2.34 to 2.64 mcal/cm sec °C with the lower values probably related to the more clayey beds and the higher value to a graded bed of reworked foraminifera. Near the base of lithology Unit II (Core 15), a high of about 2.76 mcal/cm sec °C was measured at approximately 398 meters in a nanno ooze with silty clay. Below 400 meters, thermal conductivities vary approximately between 2.40-2.62 mcal/cm sec °C, with most values either at the high or low boundary. The lower values are located roughly at 580 meters and 745-835 meters, while the two highs are near 630 and 980 meters. The data, however, are sparse, and the depths where changes in thermal conductivity were measured do not necessarily identify lithologic boundaries.

TABLE 3
Comparison of Acoustic Impedance and Lithology

Acoustic Impedance Anomalous Value No.	Depth (m)	Lithology
1	53	Thin bed of fine sand
2	108	Nanno ooze with pyrite streaks
3	223	Thin sandy layer
4	261	Sand-bearing foram nanno ooze
5	402	Interbedded clayey silt and clay
6	979	Lithified calcareous sand

BIOSTRATIGRAPHY

Calcareous Nannoplankton

Quaternary

The *Emiliania huxleyi* Zone (NN21) and the *Gephyrocapsa oceanica* Zone (NN20) of the late Quaternary were observed in Cores 1 and 2 (Figure 10). Determination of the boundary between both zones, which is distinguished by the first occurrence of *Emiliania huxleyi*, is difficult in the light microscope because *Emiliania huxleyi* is a very small species.

The boundary between the *Gephyrocapsa oceanica* Zone (NN20) and the *Pseudoemiliania lacunosa* Zone (NN19) is not very distinct because some specimens of *Pseudoemiliania lacunosa* also appear in the upper part of the profile. The boundary probably lies near Sample 3-5, 100 cm. The *Pseudoemiliania lacunosa* Zone (NN19) includes Cores 3 and 4 with the following species: *Gephyrocapsa oceanica, Pseudoemiliania lacunosa, Helicopontosphaera kamptneri, Cyclococcolithus leptoporus, Syracosphaera pulchra, Ceratolithus cristatus, Thoracosphaera albatrosiana,* and *Umbilicosphaera mirabilis.* The core catcher of Core 5 belongs to the lower part of the *Pseudoemiliania lacunosa* Zone without *Gephyrocapsa oceanica.*

Cores of the Quaternary are very rich in well-preserved calcareous nannoplankton. In them are found some reworked species of the Pliocene and Miocene. The sediments also are rich in diatoms and Radiolaria.

Neogene

The *Discoaster brouweri* Zone (NN18) and the *Discoaster pentaradiatus* Zone (NN17) were observed in Core 6. The boundary lies between Samples 6-6, 50 cm and 6-6, 146 cm. The upper part of Core 7 includes the *Discoaster surculus* Zone (NN16). The following species were found: *Discoaster surculus, Discoaster pentaradiatus, Discoaster brouweri, Ceratolithus rugosus,* and a few specimens of *Pseudoemiliania lacunosa.* In the lower part of this core, the *Reticulofenestra pseudoumbilica* Zone (NN15) was determined with the same species as before but with *Reticulofenestra pseudoumbilica.*

The *Ceratolithus tricorniculatus* Zone (NN12) of the late Miocene was observed in Core 8.

The Core 9 to Core 11 interval includes the *Discoaster quinqueramus* Zone (NN11). *Discoaster quinqueramus* was observed in two variations. One form has long arms and the other is very compact with a thick central area and short arms. Both variations are found in the same samples. The sediments of these cores are very rich in well-preserved calcareous nannoplankton. The uppermost samples of Core 12 may belong to the *Discoaster calcaris* Zone (NN10). The lower part corresponds to the *Discoaster hamatus* Zone (NN9) with the typical assemblage of *Catinaster coalitus, Catinaster calyculus, Discoaster bollii, Discoaster hamatus,* and *Discoaster calcaris.*

Cores 13 and 14 belong to the *Sphenolithus heteromorphus* Zone (NN5) with *Sphenolithus heteromorphus,*

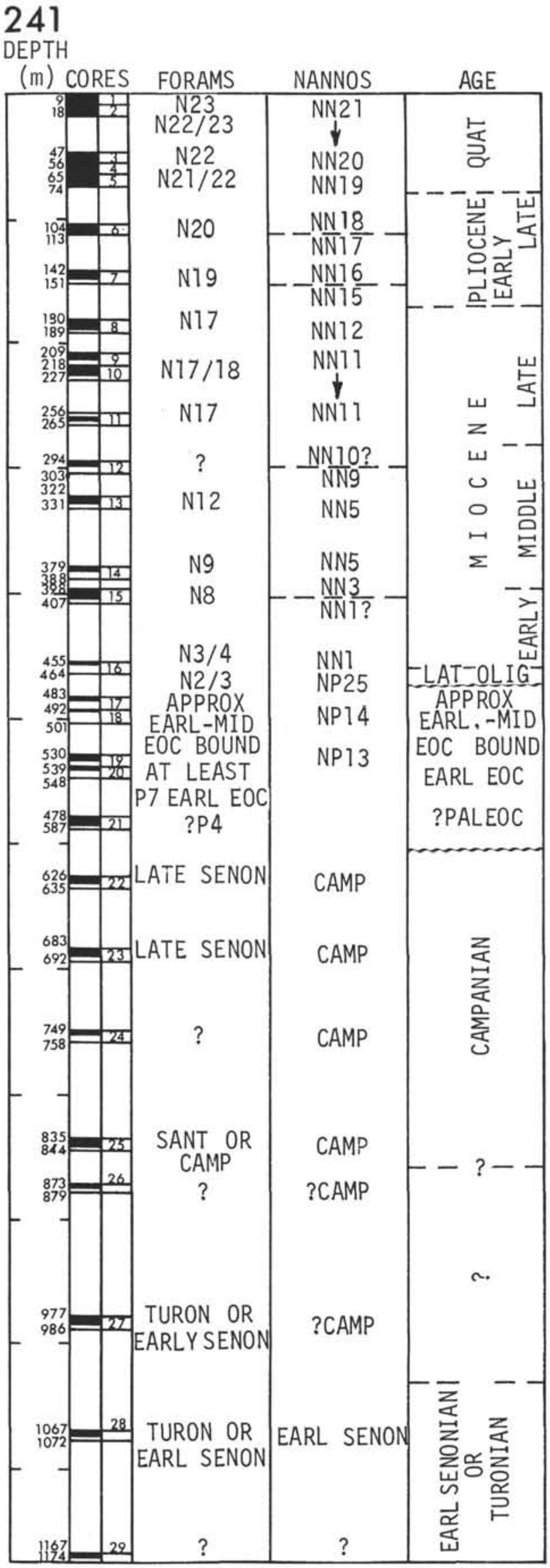

Figure 10. *Biostratigraphic column for Site 241.*

Discoaster brouweri, and *Discoaster variabilis.* The nannoplankton content is sparse, and specimens show weak dissolution.

The *Sphenolithus belemnos* Zone (NN3) was observed in Core 15, Section 1 and continued to Sample 15-3, 50 cm. The assemblage consists of *Discoaster druggi, Sphenolithus belemnos,* and *Triquetrorhabdulus carinatus.* Core catcher 15 and the upper part of Core 16 (16-2, 10 cm) still belong to the early Miocene, probably the *Triquetrorhabdulus carinatus* Zone (NN1), with *Triquetrorhabdulus carinatus, Coccolithus abisectus,* and *Sphenolithus* cf. *belemnos.*

Paleogene

The boundary between the Neogene and Paleogene lies in Core 16, Section 2. The lower part of this core belongs to the *Sphenolithus ciperoensis* Zone (NP25) of the late Oligocene with *Sphenolithus ciperoensis, Helicopontosphaera recta, Helicopontosphaera euphratis, Coccolithus abisectus, Triquetrorhabdulus carinatus,* and *Dictyococcites dictyodus.*

In Sample 16-2, 130 cm, some specimens of *Sphenolithus ciperoensis* were found with long and large arms. This form was only observed at Site 241.

Cores 17 and 18 contain only few nannoplankton and only the discoasters are preserved. In both cores, an assemblage with *Discoaster lodoensis, Discoaster sublodoensis,* and *Discoaster barbadiensis* was observed, indicating the *Discoaster sublodoensis* Zone (NP14).

In Core 19, nannoplankton was only found in Sample 19-1,' 15 cm. The assemblage consists of *Discoaster lodoensis, Discoaster barbadiensis, Cyclococcolithus formosus,* and *Sphenolithus radians,* typical for the *Discoaster lodoensis* Zone (NP13). Cores 20 and 21 are without nannoplankton.

Cretaceous

Cores 22 to 29 belong to the Cretaceous. The content of nannoplankton within them is different. There are some layers which are more or less abundant in calcareous nannoplankton.

Cores 22 to 27 include the Campanian with: *Broinsonia parca, Tetralithus aculeus, Tetralithus gothicus, Ahmuellerella octoradiata, Cribrosphaera ehrenbergi, Watznaueria barnesae, Eiffellithus turriseiffeli, Cricolithus pemmatoides,* and *Parhabdolithus embergeri.* In the upper part of this sequence, *Tetralithus gothicus* becomes very abundant. In Samples 25-4, 130 cm, *Tetralithus gothicus* was found only in a few specimens, while *Tetralithus aculeus,* which is typical for the Campanian, seems to have its last occurrence. In the lower part of Core 26, atypical species only were found. Cores 27 and 28 probably belong to the early Senonian with *Corrolithion exigum, Corrolithion signum,* and *Lithastrinus grilli* but without *Tetralithus gothicus* and *Tetralithus aculeus.* Core 29 was without nannoplankton.

Foraminifera

Quaternary, Neogene, and Oligocene

In Hole 241, a very thick late Quaternary section occurs, with Zone N.23 as defined by Blow (1969) comprising the whole of Core 1. Nine meters of upper Quaternary sediments in a region where piston cores give thicknesses of about 1 meter or less for Holocene sedimentation (Zobel, unpublished data) suggests that the core tube repeatedly penetrated the uppermost sediment layer. This assumption is supported by the fact that a continuously increasing dissolution of calcium carbonate is to be observed from the top of the core down to at least the base of Section 2 while in Section 3 there are once again excellently preserved foraminiferal faunas which decrease in quality with depth. The facies is purely pelagic, less than 5 percent of the fauna (>160μ grain size fraction) being benthonic foraminifera.

Core 2 (Sections 1-4) again is of late Quaternary age with all samples containing *Sphaeroidinella dehiscens excavata* and/or *Pulleniatina obliquiloculata finalis*, which, according to Blow (1969), are characteristic of Zone N.23. The lower part of the core does not contain these subspecies but instead contains *Globorotalia tosaensis* and *Pulleniatina obliquiloculata praecursor*. Similar in faunal composition and facies are the samples from Cores 3 through 5. Only the lowermost part of Core 5 shows a Pliocene age (*Globigerinoides obliquus, G. bollii, Globorotalia tosaensis,* and no *Globorotalia truncatulinoides*). That means at Site 241 there is an abnormally thick Quaternary section of about 70 meters.

From Core 3, Section 3 downwards, the grain-size fraction 160μ-63μ of all samples investigated contain angular quartz grains in varying amounts. Benthonic foraminifera of shallower depths than the species of deep basins normally found are rare (*Ammonia beccarii* is found in Samples 3-3, 90 cm and 5-1, 100 cm).

Core 6 is wholly of late Pliocene age. In the upper part of the core, pyritized fossil material which originated on the inner shelf is observed (e.g., *Elphidium lessonii,* and *Hanzawaia concentrica*).

All cores of Site 241 mentioned to this point contain Radiolaria in varying amounts. From the sea floor down to the upper part of Core 4, diatoms also can be found.

The uppermost part of Core 7 is still late Pliocene in age because of the presence of *Pulleniatina obliquiloculata obilquiloculata* together with a lot of species which fit Zone N.20 as defined by Blow (1969). The benthonic foraminifera point to a mixed sediment with some specimens from the inner shelf (*Amphistegina lessonii,* and *Hanzawaia concentrica*) together with deep-water indicators. This sample is heavily affected by calcium carbonate dissolution. The well-preserved samples of Sections 2 and 3 are mixed assemblages from deep-water and shelf environments. They can be assigned to Blow's Zone N.19. Below Section 3, the calcium carbonate dissolution increases with depth. The remaining species of planktonic foraminifera all correspond to an early Pliocene age (N.19).

Calcium carbonate dissolution affects Cores 8 to 11 as well. Age determinations by means of foraminifera, therefore, are difficult or impossible in some samples. In all well-preserved samples the planktonic foraminiferal community indicates a late Miocene age, about Blow Zone N.17 (with *Globorotalia tumida plesiotumida* without typical *G. tumida tumida, Globorotalia multicamerata, Globorotalia merotumida* [in the deeper part of Core 11], *Sphaeroidinellopsis subdehiscens paenedehiscens* and *Pulleniatina primalis*—these latter two preferredly in Core 8).

In Cores 10 and 11, the determinable material is most likely found in the turbidites. The planktonic foraminifera also give an age of about Zone N.17 although they could possibly contain material of an older age. Benthonic foraminifera are from deep water to a nearshore or very shallow environment (for instance *Ammonia, Elphidium, Amphistegina,* and *Heterostegina*). The mode of preservation of the turbidite material (interpenetration of foraminifera of quite different species because of calcium carbonate dissolution and recrystallization, an event that seems comparable to the development of "Drucksuturen," and replacement of opal by pyrite in siliceous microfossils and sponge spicules) should be of interest to sedimentologists who investigate diagenesis.

Cores 12 to 15, except the core catcher of Core 15, probably belong to the middle Miocene. Preservation and composition of the material are about the same as in the upper cores. No ages could be given to Core 12 and the upper part of Core 13 because of the absence of foraminifera caused by extreme calcium carbonate dissolution. Samples from the lower part of Core 13 contain several subspecies of the *Globorotalia fohsi* group together with several wider ranging species of the Neogene, thus pointing to a middle Miocene age (N.12-N.10 Blow zones). Samples from Cores 14 and 15, as far as remaining planktonic foraminifera can be identified, contain *Globorotalia peripheroronda, Globorotalia mayeri, Globigerinita dissimilis,* several species of *Globoquadrina,* and sometimes *Globigerinoides.* Because of this fossil community, the material can hardly be older than early middle Miocene (about N.9 Blow zone). In addition to the planktonic foraminifera already named in the core catcher of Core 15, *Globigerinatella insueta, Praeorbulina glomerosa, Globigerinoides bisphaericus,* and many *Globigerinoides* spp., can be observed, which point to a latest early Miocene age. This is not in good agreement with the nannoplankton age determinations, which give a middle early Miocene age.

The upper part of Core 16 contains the Oligocene-Miocene boundary. The identification of planktonic foraminifera is rendered more difficult because of diagenetic alteration of the sediment material. There is a change in facies within Core 16, Section 2, the lower part of the core having relatively fewer planktonic foraminifera and, in addition, large foraminifera. These have been kindly identified by Dr. Butterlin from the École Normale Supérieure de Saint-Cloud. He has found, among others, *Lepidocyclina (Eulepidina) ephippioides* (Jones and Chapman), which give an Aquitanian (early Miocene) age.

In Core 16, Section 2, along with more or less long-ranging species like *Globigerina angustiumbilicata, G. rohri, G. venezuelana, Globigerinita dissimilis,* and *G. dissimilis ciperoensis,* there are species whose contemporaneous occurrence is indicative of Blow's N.3 or N.4 zones (*Globigerina angulisuturalis, G. ciperoensis, Globorotalia* cf. *kugleri,* and *Globigerina binaiensis*). As previously mentioned, the lack of *Globigerinoides* in such a rich and diversified planktonic assemblage points to a late Oligocene (N.3) age. That age can be confirmed by the additional presence of *Globigerina sellii* in the core catcher sample.

Cretaceous, Paleocene, and Eocene

This hole penetrated a thick sequence of sediments of Late Cretaceous age and a very thin Eocene sequence, probably limited to the early Eocene but perhaps including the bottom of the middle Eocene. Directly above is the late Oligocene. It is to be noted that faunas are described from older to younger in this section.

Cretaceous

The Cretaceous was drilled and cored through a thickness of at least 450 meters. It was sampled by Cores 22 to 29. Washed residue was mainly silty, sometimes rich in mica and quartz (the residue from level 23-3, 45-47 cm is even a sand), occasionally with pyrite (29-1; and 27-3, 107-109 cm) and contained poorly preserved and sparse fossil assemblages. One-third (20 out of 58) of the samples examined contain no foraminifers, and among the 38 containing foraminifers, 25 were not really usable because they contained only agglutinated forms (*Ammodiscus, Glomospira, Haplophragmoides, Trochammina,* etc.) without any chronostratigraphic value. Hence, there is only a small number (13) of sample levels able to provide ages, and even these are mostly concentrated (8 samples) in the two upper cores (22 and 23). This means that chronostratigraphic conclusions are somewhat tentative at this time.

Core 29 cannot be dated, nor can most of Core 28. Only levels 29, CC and 29-2, 91-93 cm revealed a few *Ammodiscus* (a fragment of Radiolaria was found at 28-3, 125-127 m).

The upper sample from Core 28 (28-1, 100-102 m) and the core catcher from Core 27, as well as levels 27-3, 107-109 cm and 26-2, 22-25 cm, revealed a very poor assemblage, of probable Turonian or early Senonian age, which includes:

Glomospirella cf. *gordialis* var. *diffundens* (Cushman and Renz, 1946)
Bolivina cf. *kalinini* Vasilenko and Mjatljuk, 1947
Gyroidina cf. *umbilicata* (d'Orb., 1840)
Valvulineria aff. *marianosi* Trujillo, 1960
"Eponides" sp. (cf. *Eponides brönnimanni* Cushman and Renz, 1946)
Gümbelina gr. *pseudotessera* Cushman, 1938-*pulchra* Brotzen, 1936
Gümbelina cf. *globulosa* var. *striatula* Marie, 1941.

Level 25-2, 40-42 cm is the next higher one to yield foraminifers (most likely of Santonian to Campanian age) including:

"Discorbis" (cf. *Conorbina tabernacularis* var. *levis* (Liebus and Schubert, 1903)
Aragonia paynei (Martin, 1964)
Eponides sp.p.
Gyroidina sp.

Cores 23 (4, 26-28 cm; 3, 45-47 cm) and 22 (CC; 4, 73-75 cm; 3, 139-141 cm; 3, 78-80 cm; 2, 145-157 cm; and 1, 120-122 cm) produced an assemblage that is relatively diversified but difficult to determine and poor in specimens. These are:

Glomospirella sp.
Spiroplectammina sp.
Lenticulina sp.
Ellipsoidella pleurostomelloides Heron-Allen and Earland, 1910
Bulimina gr. *reussi* Morrow, 1934
Baliminella sp.
Aragonia cf. *ouezzanensis* Rey, 1955
Stensiöina cf. *causasica* var. *transuralica* Balakhmatoya, 1960
Globorotalites sp.
Gyroidina depressa (Alth, 1850)
Epistominella ripleyensis (Sandidge, 1932)

A late Senonian age can be deduced. The *Aragonia* localized in Core 22 suggests the uppermost levels of the Campanian or the Maestrichtian.

The absence of planktonic species is striking (a few dwarfed *Globigerina* specimen do occur in levels 28-1, 100-102 m and 27-3, 107-109 m). It is quite likely that this is a bathyal depositional environment in which the pelagic elements were dissolved and the few benthonic species with calcareous tests may have been brought in from the outside by turbidity currents.

Samples examined:

29, CC	(no value)
29-2, 130-132 cm	(no foram)
29-2, 91-93 cm	(no value)
29-2, 80-82 cm	(no foram)
29-2, 22-24 cm	(no foram)
28, CC	(no foram)
28-3, 125-127 cm	(no foram)
28-3, 70-72 cm	(no foram)
28-2, 125-127 cm	(no foram)
28-1, 100-102 cm	
27, CC	
27-4, 144-146 cm	(no value)
27-4, 64-66 cm	(no foram)
27-3, 107-109 cm	
27-3, 35-37 cm	(no value)
27-2, 123-125 cm	(no foram)
27-2, 17-19 cm	(no value)
27-1, 140-142 cm	(no value)
27-1, 77-79 cm	(no foram)
26, CC	(no foram)
26-3, 110-112 cm	(no value)
26-3, 85-87 cm	(no foram)
26-2, 56-58 cm	(no foram)
26-2, 33-35 cm	
26-1, 134-136 cm	(no foram)
26-1, 76-78 cm	(no foram)
25, CC	(no value)
25-5, 131-133 cm	(no foram)
25-5, 60-62 cm	(no value)
25-4, 138-140 cm	(no value)
25-4, 40-42 cm	(no value)
25-3, 130-132 cm	(no value)
25-2, 107-109 cm	(no value)
25-2, 40-42 cm	
25-1, 130-132 cm	(no foram)
24, CC	(no value)
24-2, 130-132 cm	(no value)
24-2, 36-38 cm	(no foram)
24-1, 98-100 cm	(no value)
23, CC	(no value)
23-4, 104-106 cm	(no foram)
23-4, 26-28 cm	
23-3, 116-118 cm	(no value)
23-3, 45-47 cm	

23-2, 135-137 cm	(no value)
23-2, 30-32 cm	(no value)
23-1, 96-98 cm	(no value)
23-1, 70-72 cm	(no value)
22, CC	
22-4, 148-150 cm	(no value)
22-4, 73-75 cm	
22-3, 139-141 cm	
22-3, 78-80 cm	
22-2, 145-147 cm	
22-2, 79-80 cm	(no value)
22-1, 120-122 cm	
22-1, 57-59 cm	(no foram)

Eocene

The Eocene was sampled in Cores 21 through 17. Only about 150 meters was penetrated. The fossil assemblages are extremely poor in the midst of highly sandy and micaceous residues where fish teeth are the only other organic remains. The planktonic assemblages are poor but become relatively richer farther upward. However, they provide few characteristic species so that chronostratigraphic assignments remain rather inaccurate. In addition, reworked forms are encountered in most samples (insofar as we can be certain of a relatively well-established age for the level considered). This reworking, however, continues farther upward, especially in the Oligocene where some species are found, such as, *Globorotalia (Morozovella) aragonensis* and *Globorotalia lehneri* which either were not, or were only rarely, found in the cores that should have contained them. On the other hand, mixing by Oligocene or Neogene species is common.

Core 21 produced only a very small number of foraminifers belonging to the genera *Ammodiscus, Glomospira,* and *Haplophragmoides.* Only the core catcher revealed two poorly preserved planktonic specimens which can be compared with *Globigerina (Subbotina) triloculinoides* Plummer, 1926 and *Globorotalia (Planorotalites) pseudomenardii*, Bolli, 1957. Hence, it is possible that these samples are from the corresponding zone of the Paleocene (*G. pseudomenardii* Zone). However, other holes showed, in the early Eocene, forms quite similar to the latter mentioned species. Therefore, the age assignment is tentative. It is possible that the sediments were deposited in bathyal conditions below the carbonate compensation depth.

Samples studied:
21, CC
21-5, 30-32 cm
21-4, 60-62 cm
21-3, 47-49 cm
21-2, 64-68 cm
21-1, 107-109 cm

Cores 20 and 19 yield very few foraminifers. However, planktonic species are slightly more numerous than before. In addition to the same benthonic species, there are some *Trochammina* and *Nonionella* (gr. *africana* Le Roy, 1953).

Only the core catcher of Core 20 reveals planktonic species (although few specimens). These include, among others:

Pseudohastigerina cf. *iota* (Finlay, 1940), but not entirely symmetrically coiled.
Transition form between *Globorotalia (Turborotalia) chapmanni* Parr, 1938 and *Pseudohastigerina* gr. *wilcoxensis* (Cushman and Ponton, 1932), still with a dissymmetrical opening and coil.
Globorotalia (Planorotalites) cf. *elongata* Glaessner, 1937
Globorotalia (Planorotalites) cf. *pseudomenardii* Bolli, 1957
Globorotalia (Acarinina) convexa Subbotina, 1953
Globorotalia sp. (? gr. *capdevilensis* Cushman and Bermúdez, 1949).

Some of the species probably are reworked. Many of the species, as well as their proximity to Core 19, suggest that the age is early Eocene.

Levels 19-2, 20-22 cm and 19-1, 29-31 cm are of interest because they produced *Globorotalia (Morozovella) aragonensis* Nuttall, 1930 and *Globorotalia* aff. *spinulosa* Cushman, 1937 (not so lobed at the periphery, with a less pronounced keel).

The age suggested by the nannoplankton as the end of the early Eocene is thus plausible. In Core 19, as a whole, there are few species, some probably reworked, other than those already mentioned:

Globorotalia (Acarinina) cf. *convexa* (Subbotina, 1953)
Globorotalia (Acarinina) esnaensis (Le Roy, 1953)
Globorotalia (Acarinina) cf. *traubi* Gohrbandt, 1963
Globorotalia sp. (? gr. *capdevilensis* Cushman and Bermúdez, 1949)
Gümbelitria sp.

Samples examined:
20, CC
20-1, 46-48 cm
20-1, 15-17 cm
19-2, 109-111 cm
19-2, 60-62 cm
19-2, 20-22 cm
19-1, 115-117 cm
19-1, 65-67 cm
19-1, 29-31 cm

Cores 18 and 17 have an assemblage that is richer than in previous ones, and it is also more meaningful. In particular, Core 18 and the core catcher from Core 17 revealed the following species, among others:

Globorotalia (Morozovella) aragonensis Nuttall, 1930
Globorotalia (Morozovella) crater Finlay, 1939
Globorotalia (Acarinina) sp. (gr. *broedermanni* Cushman and Bermúdez, 1949)
Globorotalia (Acarinina) cf. *convexa* Subbotina, 1953
Globorotalia (Acarinina) cf. *aspensis* Colom, 1954
Globorotalia (Acarinina) cf. *mattseensis* Gohrbandt, 1967
Globorotalia sp. (? gr. *capdevilensis* Cushman and Bermúdez, 1949)
"Globigerina" cf. *senni* (Beckmann, 1953)
Pseudogloboquadrina primitiva (Finlay, 1947).

An age coinciding with the end of the early Eocene or the beginning of the middle Eocene is thus probable and corresponds to the one suggested by the nannoplankton. Other species the color of whose test is different, are reworked:

Globorotalia (Morozovella) cf. *angulata* (White, 1928).
Globorotalia (Morozovella) subbotinae Morozova, 1939

Globorotalia (Acarinina) cf. *traubi* Gohrbandt, 1963
Globorotalia (Acarinina) soldadoensis (Brönnimann, 1952)

The benthonic assemblage is slightly richer and most likely corresponds to the middle or relatively deep part of the slope. It includes:

Bulimina forticosta Finlay, 1940
Aragonia cf. *capdevilensis* (Cushman and Bermúdez, 1937)
Pararotalia cf. *bicarinata* Colom, 1954
Nuttallides trumpyi (Nuttall, 1930)
Parrella sp.
Cibicides sp.
Siphonodosaria sp.

Samples examined:
18, CC
18-1, 132-134 cm
18-1, 114-116 cm
17, CC
17-1, 130-132 cm
17-1, 125-127 cm

BIOSTRATIGRAPHIC SUMMARY SITE 241

In Hole 241, a nearly complete section of Quaternary and Neogene sediments is recognized (Core 1–Core 16, Section 2). The Quaternary has a thickness of about 70 meters (Cores 1-5), which indicates a high sedimentation rate of about 40 m/m.y. The high sedimentation rate at this site would be in good agreement with its location near the continental margin where a large sediment supply would be expected (high amount of detrital material and high biogenous production). However, it must be kept in mind that the upper cores in the hole were greatly disturbed by drilling and, at least for the Quaternary section, doubling of the section might be expected. The sediments of Quaternary age are very rich in calcareous as well as siliceous microfossils. The detrital parts of sediments in the Pliocene and Miocene sequence become more coarse grained, connected with an increase of benthonic foraminifera from a shelf or slope environment. The amount of siliceous microfossils decreases rapidly within the Pliocene. Beginning with Core 7, increased calcium carbonate dissolution makes age determination by means of foraminifera increasingly difficult. Many of the age determinations depend on well-preserved allochthonous samples (proved by the presence of shallower-water benthonic foraminifera). In the upper Miocene, there is a discrepancy in the ages determined by means of foraminifera and nannofossils. The Oligocene-Miocene boundary lies within Core 16, Section 2 between 10 and 50 cm. The Oligocene section is very rich in nannoplankton. Within the upper Oligocene sequence, a form of *Sphenolithus ciperoensis* with very large spines was observed. Foraminifera show first signs of diagenetic alteration. From late Oligocene to Quaternary, the sedimentation rate increases in a somewhat discontinuous manner. Between the early Miocene and Quaternary, the sedimentation rate (m/m.y.) changes from 18 to 8, 11, 76, 34, and 50. It cannot be decided yet if the irregularities in the sedimentation rate curve are due to real changes in the sediment accumulation or if they are partly caused by drilling problems.

A large hiatus of about 25 m.y. separates the Oligocene and Eocene series; the late Oligocene overlies levels which belong to approximately the early-middle Eocene boundary. Early Eocene can be recognized with both foraminifera and nannoplankton; Paleocene is only suspected from the presence of foraminifera. Assemblages of foraminifera become rich upwards; the benthonics probably belong to the middle or deep part of the continental slope. The nannoplankton assemblages of the Eocene sequence are not very rich and most of the coccoliths are dissolved, even though the discoasters are still well preserved.

A hiatus of 13 to 19 m.y. duration precedes Cretaceous "flysch-type" series, the upper part of which belongs to the Campanian according to both the foraminifera and nannoplankton. The Campanian overlies an undated sequence, probably of early Senonian age, which precedes Turonian or early Senonian beds. The last cores, at the base of the hole, are devoid of fossils. Fossils were either very rare or completely dissolved; nannofossils appear only in some thin layers. Benthonic foraminifera probably have been transported into a bathyal depositional environment, and planktonics have likely disappeared through dissolution processes.

Sedimentation rates for Cretaceous and Paleogene can only be estimated. They are at least 30 m/m.y. for the Senonian and about 11 m/m.y. for the Eocene and Paleocene(?).

CORRELATION OF REFLECTION PROFILES AND LITHOLOGIES

Characteristics of the airgun reflection profiles run by *Glomar Challenger* in the near-site area and on site are quite comparable to the data obtained by *Gallieni 4* cruise in 1970 (see Figures 4 and 6). The sequence observed on both records consists mainly of a succession of well-stratified layers separated by weakly stratified interbeds. The deepest reflector which can be seen on the airgun record is at 1.0 sec DT (Figure 6). On the flexotir record, deeper reflectors can be seen, including horizon B at about 1.2 sec DT and the lowest (which is not necessarily basement) at 3.0 sec DT (Figures 3 and 4). The main objective of drilling this hole was to reach, identify and, if possible, date the layer immediately below horizon B.

Details of the seismic reflection profiles (*Glomar Challenger* airgun record and *Gallieni* flexotir record) at Site 241 show mainly two well-defined reflectors above horizon B: the first (horizon A) is at a depth of about 0.5 sec DT (0.50 sec DT on the airgun record and 0.52 sec DT on the flexotir record) and the second is at 1.0 sec DT (airgun and flexotir records). Several minor reflectors occur above horizon A and can be correlated on both records. From the airgun record, these minor reflectors are at 0.15 sec DT, 0.28 sec DT, and 0.41 sec DT.

The lithologic description shows that the whole section can be broadly subdivided into two major stratigraphic units: (1) greenish-gray clay-rich and clayey nanno ooze with minor dark greenish-gray nanno-rich clay and nanno clay; and (2) dark greenish-gray and moderate brown clay-claystone with minor nanno-rich claystone, silty clay, and calcareous sandstone. The different reflectors from the top down to about 0.5 sec DT (0.15 sec, 0.28 sec, and 0.41 sec DT) observed on the airgun record cannot be correlated with any lithologic changes but are related to sediment inhomogeneities and slight changes in texture and progressively increasing compaction. The reflector at about 0.50 sec DT (0.52 on the flexotir record), which corresponds to horizon A, can be correlated with the upper limit of silt and fine sand layers which were observed very clearly for the first time in Core 15 (398-407 m). This limit can also be inferred from the physical properties since a notable change of acoustic impedance has been reported for Core 15 (the slowly increasing sonic velocity changes from 1.64 km/sec to 1.73 km/sec at about 400 m depth). The very clear reflector which appears on both records at 1.0 sec DT can be correlated in lithologic Unit II with the appearance in Core 25 (835-844 meters) of calcareous sandstones and calcarenites. This limit corresponds also to a very strong change of acoustic impedance which was recorded for Cores 25 and 26, between 800 and 900 meters. Horizon B at about 1.2 sec DT is the last and most persistent of a series of very strong reflectors which are visible on the flexotir record below 1.0 sec DT, excluding the deep horizon at about 3.0 sec DT. It is suggested that these strong reflectors are related to the sharp changes in composition and in degree of lithification which have been observed in all the cores taken below 835 meters (Core 25 to Core 29): calcareous sandstones are interbedded with claystones and silty claystones.

If the above correlations are true, then the interval velocity between the sea floor and the reflector at 0.51 ± 0.01 sec DT (0 to 402 m) is 1.58 ± 0.03 km/sec. The average measured velocity for this section is 1.58 km/sec (Core 1 to Core 14). The interval velocity between the reflector at 0.51 ± 0.01 sec DT and the reflector at 1.00 sec DT (402 to 840 meters) is 1.79 ± 0.04 km/sec. The average measured velocity for this section is 1.79 km/sec (Core 15 to Core 25). The interval velocity between the reflectors at 1.0 sec DT and horizon B cannot be accurately computed since it is not possible to relate the successive strong reflections in this interval to the different calcareous sandstone layers. The weighted average measured velocity for this layer (represented by Core 26 to Core 28) is about 2.3 km/sec (2.12 km/sec for the claystones and 3.95 km/sec for the sandstones, the percentage of sandstones being about 10%). Considering the above computed interval velocities and assuming the correctness of the measured velocity for the stratified layer between the reflectors at 1.0 sec DT and horizon B at about 1.2 sec DT, this last reflector should be at a depth of about 1100 meters. Consequently, Core 29 (1167-1174 m) must have been cut below horizon B. The velocity measurements made on Core 29 indicate values ranging between 1.9 and 2.3 km/sec for the claystones and 5.2 to 5.8 km/sec for the sandstones. These values are indeed high compared with the values obtained for Cores 26 and 28. The overall interval velocity down to the reflector at 1.00 sec DT is 1.68 km/sec.

Figure 11 shows the correlation which can be established between the reflection profiles and the lithologies.

Considering Francis et al. (1966) results and Schlich et al. (1972) flexotir reflection and refraction data, the existence of an uppermost layer of soft sediments of about 1000 meters thickness is consistent with the drilling and coring data. The sonic velocity for this uppermost layer is 1.68 km/sec, whereas Francis et al. (1966) and Schlich et al. (1972) derived from their refraction data a value of 1.9 km/sec. The measured velocity of about 2.3 km/sec obtained for the more consolidated sediments (1.0 sec DT to about 1.2 sec DT) is also consistent with Francis et al. (1966) 2.53 km/sec and Schlich et al. (1972) 2.5 km/sec velocities.

SUMMARY AND CONCLUSIONS

Synthesis of Site 241 Data

The site is located on the East African continental rise in the western part of the southern Somali Basin, about 170 miles from the African coast. The seismic reflection and refraction data of Francis et al. (1966) and Schlich et al. (1972) indicate a sediment thickness in excess of 4 km overlying basement for 300-400 km seaward of the coast. Correlation by Francis et al. (1966) with the results of geological and geophysical work on the Kenya coast at Lamu suggests that the stratigraphic succession includes the Tertiary, Cretaceous, and Jurassic, and possibly even a Karroo section. This seems to support the conclusion of Dixey (1960) that the East African coast has subsided intermittently in post-Karroo time.

Site 241 was located from the seismic reflection and refraction data obtained by *Gallieni* 4 in 1970 (see Figure 4). The principal objectives were (a) to reach, identify, and date the deepest layer (velocity 3.5 km/sec) recognized by Schlich et al. (1972) at an indicated depth of about 1.2 sec DT (horizon B), and (b) to establish the bio- and lithostratigraphic successions with particular reference to post-Karroo epeirogenic movements of East Africa and the evolution of the continental margin.

The hole was drilled and intermittently cored to a depth of 1174 meters and probably records the deepest penetration to date into a continental rise. Below 700 meters, the intervals between cores were increased owing to time restriction, increasing sediment hardness, and problems relating to hole stability. The major scientific results are summarized in Figure 12.

The section penetrated can be broadly subdivided into two major stratigraphic units from Holocene to Late Cretaceous (early Senonian or Turonian) age. The progressive decrease downward in foraminifera and nannofossil content is accompanied by a darkening of the green and gray clay and ooze to brown lithified sediments below. The lack of sand recovery in the upper unconsolidated units is possibly due to their removal by washing during the cutting of cores.

Unit I consists of about 470 meters (Cores 1-16) of Holocene to late Oligocene greenish-gray nanno ooze, with minor greenish-gray foraminiferal, diatom, and radiolarian ooze, and dark greenish-gray silty clay and clayey silt. Pyrite and volcanic glass are present throughout in trace amounts, with a devitrified volcanic ash layer in Core 15 (400 m–lower middle Miocene). Graded beds of fine sand and silt are best developed towards the base of the unit, and include benthonic foraminifera of inner and outer shelf, upper slope, and deep sea origins.

Unit II is about 700 meters thick (Cores 17-29) and consists of lithified middle Eocene to Upper Cretaceous (early Senonian or Turonian) clay, claystone and shale,

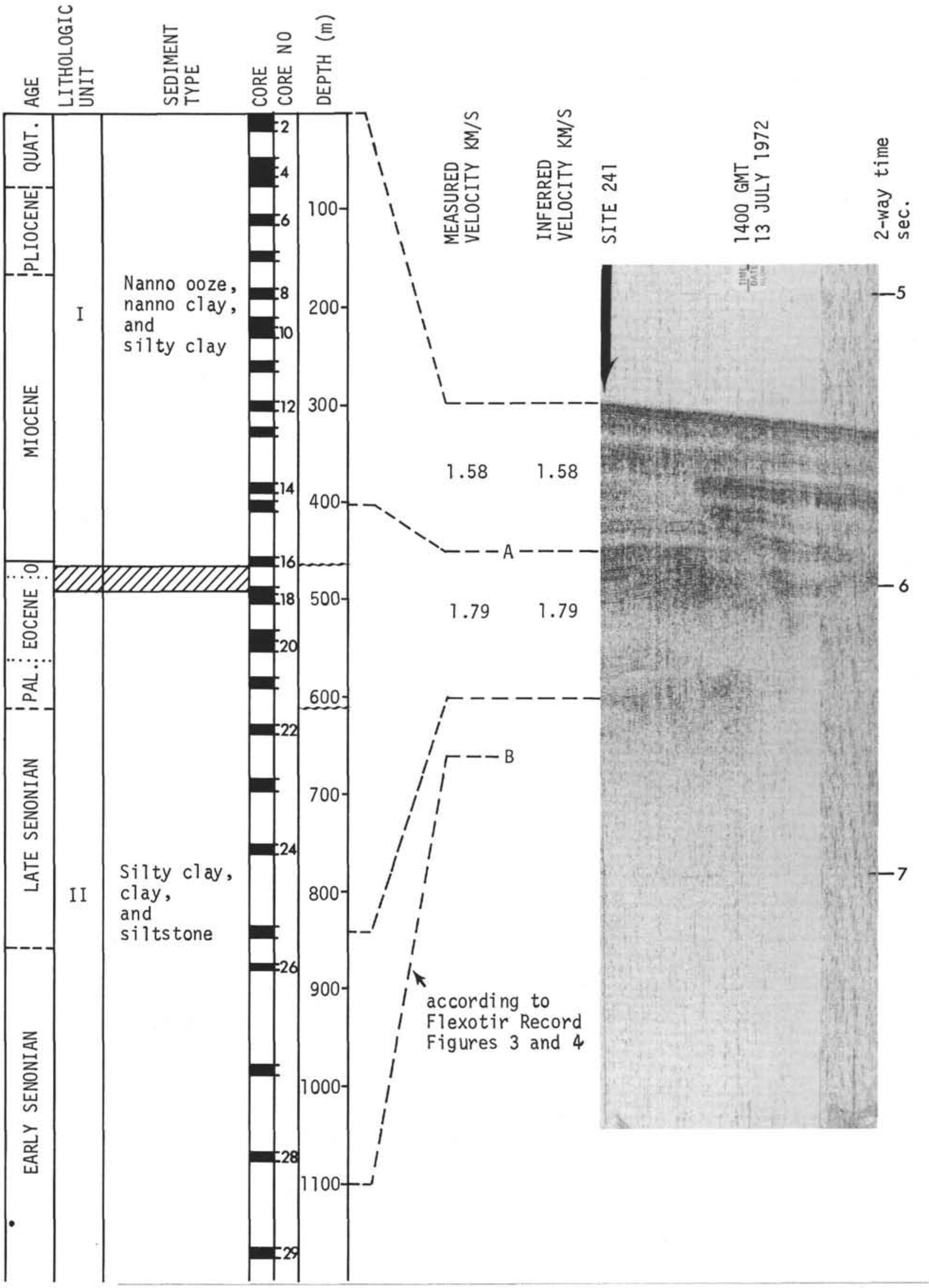

Figure 11. *Correlation of seismic reflection profile with lithology; wavy lines in the depth column indicate hiatuses.*

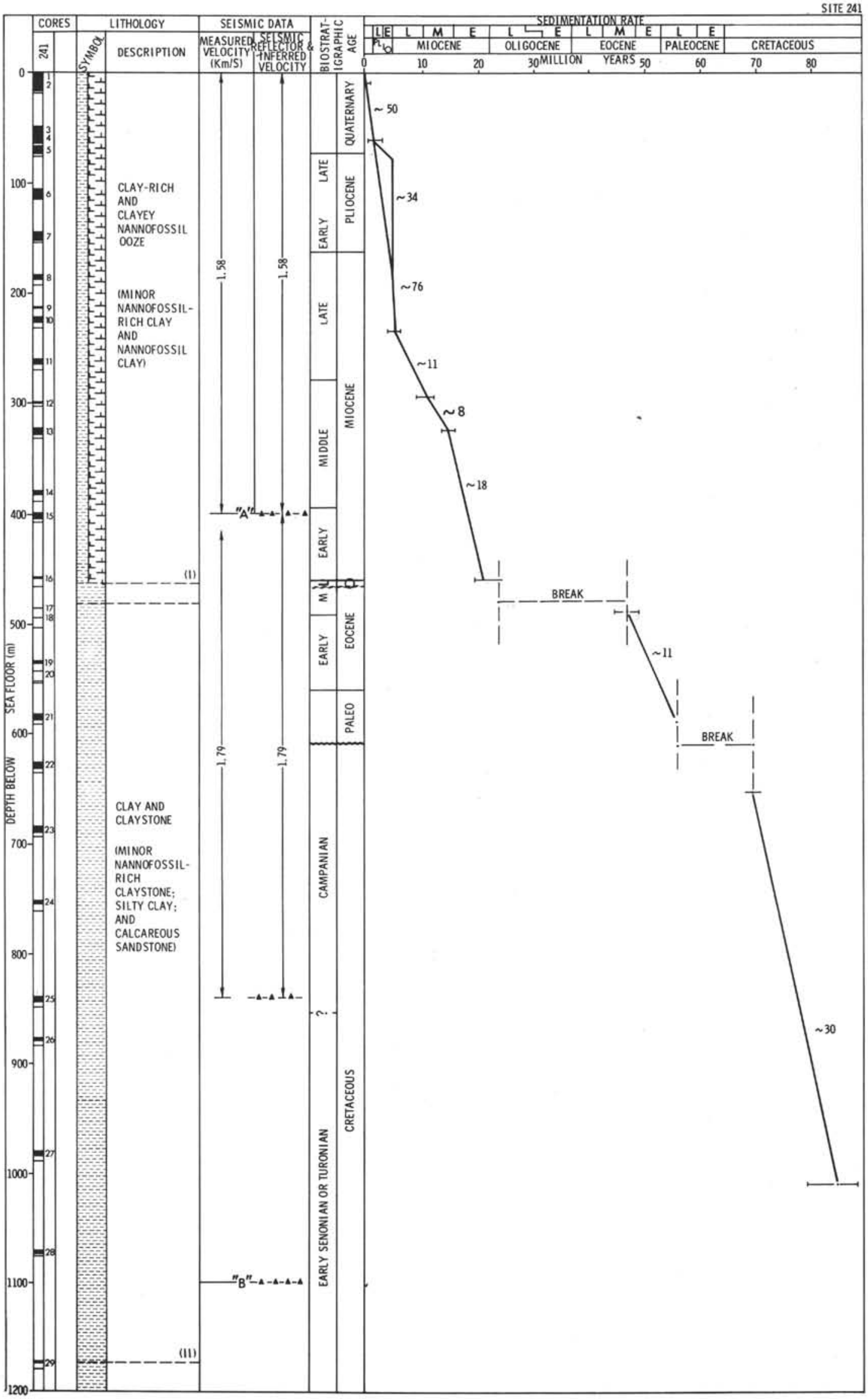

Figure 12. *Summary diagram, Site 241.*

some silty, and subordinate amounts of nanno ooze and chalk, clayey silt, siltstone, calcareous quartz sandstone, and calcarenite. Calcium carbonate is almost completely absent. The argillites in Cores 17 to 21 are characteristically brown in color. Devitrified volcanic ash occurs in Core 20 (early Eocene) and in trace amounts below this horizon. Most cores show graded beds or distinct layers of silt and/or sand. Lithified calcareous sandstone and calcarenite in Cores 25 to 29 (835-1174 m subbottom) show massive, graded, and cross bedding, parallel and convolute lamination, slump folds, and rip-up clasts, which are characteristic of turdibites. Accessory minerals include pyroxene, hornblende, micas, zircon, glauconite, and opaque minerals.

A nearly complete Quaternary and Neogene section is represented by Unit I (0-470 meters below bottom), which contains a very rich and excellently preserved tropical foraminiferal fauna. By contast, the Paleogene and Upper Cretaceous section (sampled by Cores 17-29 from 470 to 1174 m) is almost devoid of fossils, some cores contain none. In the Cretaceous sequence, nannoplankton occur only in thin layers, with evidence of dissolution of the smaller and thinner species, but Cores 22 to 25 seem to be Campanian and Cores 26 to 28 contain possible Campanian to early Senonian nannoplankton. The sparse foraminiferal assemblage in the lower part of Unit II, unfortunately, comprises only long range species which indicate that the maximum age of the oldest sediment cored is early Senonian, possibly Turonian.

The entire lithologic sequence cored in Hole 241 consists of biogenic oozes of both shelf and deep-sea origin, terrigenous hemipelagic sediments, and turbidites which have accumulated since Turonian time. Therefore, the continental margin here is at least 90 m.y. old. Unit II (Eocene and older) was evidently deposited below the CCD. Unit I (Holocene to late Oligocene) contains abundant carbonate fossils and detritus.

An approximate rate of sedimentation for the Turonian-Campanian section is about 30 m/m.y. During the Miocene, the average sedimentation rate was 16 m/m.y., increasing sharply to about 30 m/m.y. during the Pliocene and to about 50 m/m.y. during the Quaternary. Two breaks in sedimentation are recorded; the first is of about 17 m.y. duration, which includes the Maestrichtian and early Paleocene; and the second is of about 25 m.y. duration, from early Eocene to late Oligocene. The Oligocene is hardly represented, as is the case on land in East Africa (Dixey, 1960).

The *Glomar Challenger* seismic reflection profile for the approach to Site 241 shows reflectors at 0.15 sec, 0.28 sec, and 0.41 sec DT, which cannot be correlated with any specific lithologic changes. The reflector at 0.5 sec DT can be correlated with silt and sand layers first encountered in Core 15 (398-407 meters), where a notable change in acoustic impedance and abrupt rise in sonic velocity from 1.64 to 1.73 km/sec occurs. The very clear reflector at 1.0 sec DT corresponds to the first appearance in Unit II of calcareous sandstone and calcarenite (Core 25, 835-844 m), accompanied by a marked change in acoustic impedance. The alternation of these layers (sonic velocity about 4.0 km/sec) with lithified claystone (about 2.1 km/sec) is responsible for the series of strong reflectors which appear on the flexotir record between 1.0 and about 1.3 sec DT. None of the seismic reflectors corresponds to the boundaries between the two lithologic units recognized in the section penetrated; they are more closely related to sharp changes in sediment layer composition and degree of lithification.

Both Francis et al. (1966) and Schlich et al. (1972) calculated independently a thickness of about 1000 meters and a velocity of 1.9 km/sec for the (presumed Tertiary) uppermost layer of soft sediment. In fact, the boundary between Tertiary and Cretaceous sediments was located by drilling at a depth of about 600 meters. Horizon B (Figure 3), at about 1.2 sec DT, and even the reflector at 1.0 sec DT, are of Cretaceous age. The sediments cored below the reflector at 1.0 sec DT are of early Senonian age; their mean sonic velocity is 2.3 km/sec for Cores 26-28 (873-1072 m). This value is somewhat lower than that derived by Francis et al. (1966) (2.53 km/sec) and Schlich et al. (1972) (2.5 km/sec) and indicates a depth of about 1100 meters for horizon B. The higher velocities (probably near an average of 3 km/sec) measured in Core 29 (1167-1174 m) support this conclusion and indicate that the layer below was reached but without positive evidence for a significant increase in age across the boundary reflector.

Regional Interpretation and Speculation

Site 241 is located 30 km west of seismic refraction section 3 of Francis et al. (1966), who correlate their East African continental margin seismic section (which extends 400 km from the coast through stations 1-3) with the onshore geological and geophysical data shown below (also see Figure 2):

Thickness Range (West-East) (km)	Velocity (km/sec)	Stratigraphic Section
3-1	1.7-1.9	Tertiary
1.5-2.7	2.5-2.9	Cretaceous
1.4-0(?)	3.5	Jurassic
9.2-0	3.7-5.3	Karroo

Deep drilling at Site 241 penetrated 0.6 km of Tertiary sediment and a further 0.6 km of Upper Cretaceous, terminating in lower Senonian sediments of about 90 m.y. age. The entire section represents the accumulation in a hemipelagic and deep-water environment of terrigenous and pelagic material characteristic of progressive seaward extension of the continental margin by sedimentation on the slope and rise. The deeper horizons of the Cretaceous show no evidence of transition to the shallow-water/continental depositional facies typical of the East African onshore Jurassic (Furon, 1963). On the evidence available, it seems more logical to conclude that the marine/continental sedimentation facies transition of the Mesozoic is lateral rather than vertical; if this is true of the Karroo (late Paleozoic to Mesozoic) as well, there is no evidence in support of post-Karroo tectonic movements other than intermittent uplift on land coupled with subsidence of the continental margin beneath the load of accumulated sediment.

Relatively high sedimentation rates (15-50 m/m.y.) and breaks in the sedimentation record indicate intermittent epeirogenic uplift of the East African hinterland during the following periods:

90-75 m.y. (at least Turonian to Campanian)–30 m/m.y. sedimentation rate.

60-50 m.y. (mid-Paleocene to mid-Eocene)–10 m/m.y. sedimentation rate.

25-0 m.y. (Miocene to Recent)–16 increasing to 50 m/m.y. sedimentation rate.

The first period corresponds to the post-Gondwana erosion surface of King (1962); the second to the African surface; and the third to the Victoria Falls surface. Disconformities within the drilled section suggest little or no epeirogenic uplift of the continent during Late Cretaceous/Paleocene (75-60 m.y.) and mid-Eocene to end-Oligocene (45-22 m.y.). Major volcanic events, probably near the coast, are recorded during the Paleocene and Pliocene.

Active sedimentation and construction of the East African continental margin, extending to at least 400 km from the present coastline, has been in progress for at least 90 m.y. On this evidence it is unlikely that Madagascar occupied a position adjacent to the East African coast as proposed by du Toit (1937), Smith and Hallam (1970), and Heirtzler and Burroughs (1971) in view of the constraint placed by paleomagnetic data upon the movement of India (McElhinny, 1968) relative to Africa and Madagascar not earlier than the early Tertiary (65-42 m.y.).

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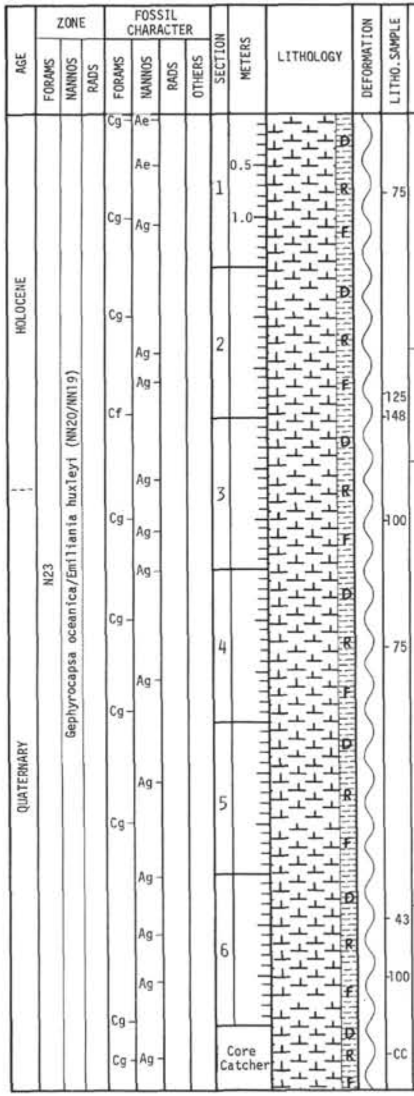
Site 241 Hole Core 1 Cored Interval: 0-9 m



LITHOLOGIC DESCRIPTION

Core is greatly deformed throughout. Colors are green gray (5GY6/1) light to medium gray (N7-N5) and dark green gray (5GY4/1).

5GY6/1

Core is predominantly NANNO OOZE with admixtures (generally 15-20%) of detrital clay, rads, diatoms, forams, and micarb. Silty clay beds occur in Sections 1 and 2.

FORAM/RAD/DIATOM-BEARING CLAY-RICH NANNO OOZE
Smears 2-125, 2-148, 3-100
<u>Composition</u>

calc. nannos	60%	rads	5%
det. clay	15%	micarb.	5%
forams	10%	qtz. & feld.	Tr.
diatoms	5%		

In green-gray colors, clay becomes larger in percentage.

5GY6/1 with N7 & N5 streaks

CLAY/FORAM/RAD/DIATOM-BEARING NANNO OOZE
Smear 4-75, CC
<u>Composition</u>

calc. nannos	55%	diatoms	5%
det. clay	20%	rads	5%
forams	10%	sp. spic.	5%

CLAY-RICH NANNO OOZE
Smear 6-100
<u>Composition</u>

calc. nannos	80%	micarb.	5%
det. clay	15%	forams	Tr.

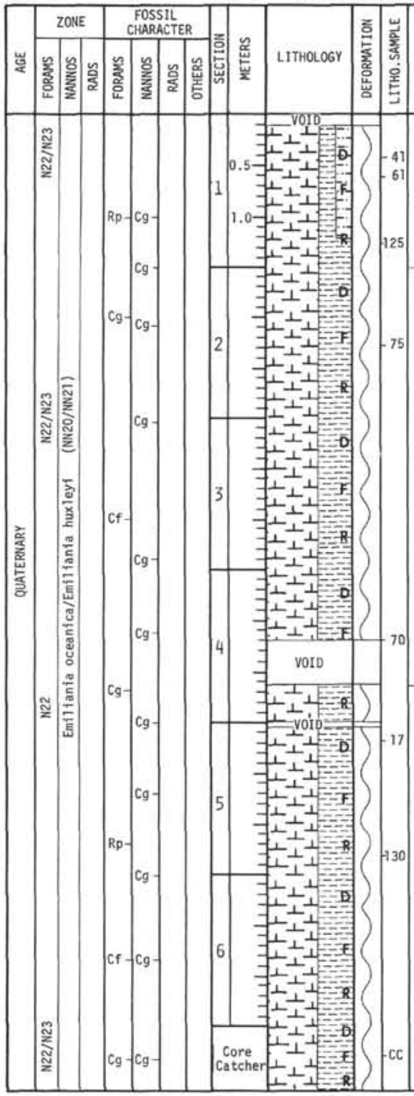
<u>Carbon-Carbonate</u>
1-75 (7.4-0.5-57)
3-59 (7.1-0.6-54)

5GY6/1

<u>X-ray 2-109</u>		<u>X-ray 5-34</u>	
calc.	M	calc.	M
qtz.	T	qtz.	P
k-feld.	T	k-feld.	T
kaol.	T	plag.	T
		kaol.	T
		mica	T
		mont.	T

5GY6/1 with patches & streaks of N7 & 5GY4/1

Site 241 Hole Core 2 Cored Interval: 9-18 m



LITHOLOGIC DESCRIPTION

Core is greatly deformed and soupy in some sections. Colors are green gray (5GY6/1) and dark green gray (5GY4/1) with some small beds of light/medium gray (N5-N7).

5GY4/1 & 5GY6/1

RAD/DIATOM/FORAM-BEARING CLAYEY NANNO OOZE
Smears 1-61, 5-130
<u>Composition</u>

calc. nannos	50%
det. clay	30%
rads	5%
forams	5%
diatoms	5%
micarb.	4%
sp. spic.	1%
qtz. & feld.	Tr.
pyrite	Tr.

White streaks have very little clay. Some smears contain more rads and diatoms. Smear 1-41 is a sand-rich detrital nanno ooze with heavy minerals, augite, hornblende, chlorite, and tourmaline.

5GY6/1 with some N7

<u>Grain Size</u>
1-49 (3-18-79) clay

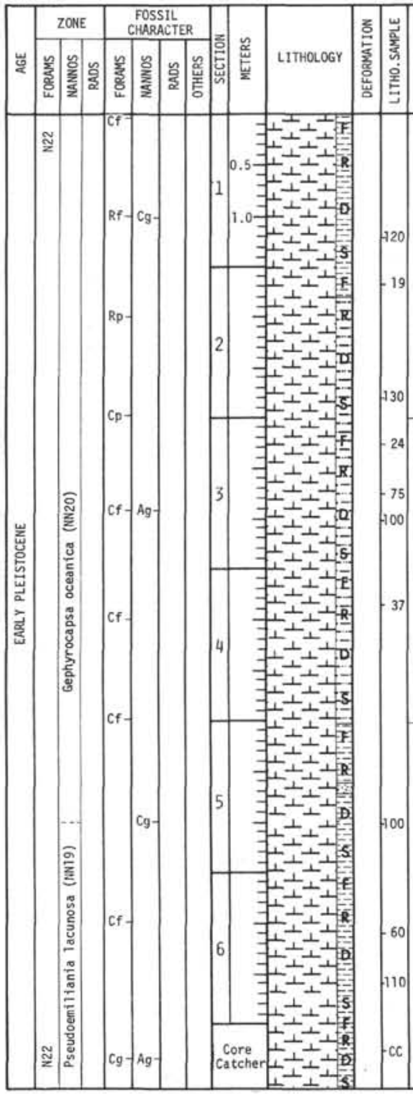
<u>Carbon-Carbonate</u>
1-105 (7.4-0.4-58)
4-49 (4.1-0.6-30)

<u>X-ray 1-102</u>		<u>X-ray 6-110</u>	
calc.	M	calc.	M
qtz.	P	qtz.	T
mica	P	k-feld.	T
plag.	T	mica	T
kaol.	T	paly.	T
mont.	T		
paly.	T		

5GY6/1 with minor N5 & 5GY4/1

Explanatory notes in chapter 1

Site 241 Hole Core 3 Cored Interval: 47-56 m



LITHOLOGIC DESCRIPTION

5GY4/1

Core is deformed, characterized by vertical bedding, irregular blebs, and bent stiff layers near base of core. Colors are green gray (5GY7/1, 5GY6/1, and 5GY5/1) and dark green gray (5GY4/1).

FORAM/CLAY-BEARING NANNO OOZE
Smears 2-130, 3-75, 5-100, 6-60, 6-110
Composition

calc. nannos	70%	sp. spic.	1%
det. clay	20%	pyrite	Tr.
forams	5%	vol. gls.	Tr.
rads	2%	carb. rhombs	Tr.
diatoms	2%	qtz. & fldspr.	Tr.

Dark gray streaks and blebs are pyrite-rich nanno ooze. Silts and sands are major components of thin dark green gray beds in Sections 3 and 4. Carbonate rhombs are ubiquitous. Diatoms and rads are more abundant in Section 1. Pyrite fills tests of forams and rads.

pyritized worm tube

Grain Size (samples from deformed turbidites)
2-19 (11-58-31) clayey silt
3-97 (53-28-19) silty sand

turbidite sand bed, 97-100 cm

Carbon-Carbonate
1-49 (7.1-0.5-56) 6-121 (7.3-0.3-58)
3-61 (9.1-0.2-74)

5GY7/1 with minor 5GY4/1

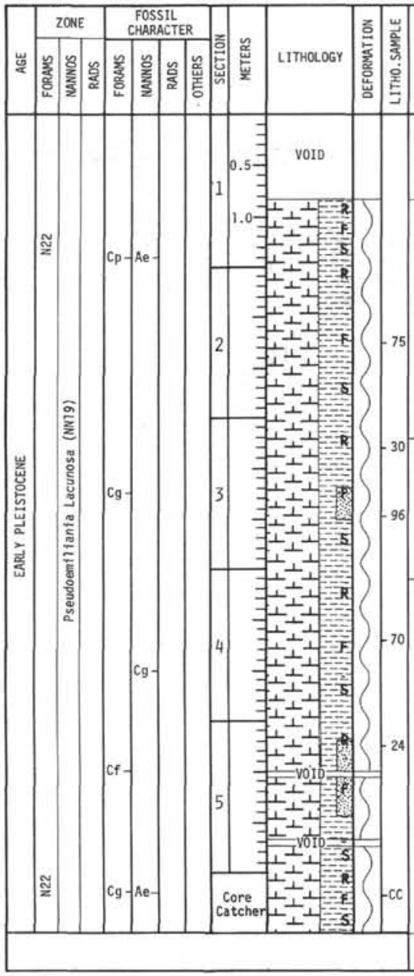
Thin beds of silt, 100-150 cm. Heavy minerals include: hornblende, pyrite, glauconite, and sphene.

soupy zone of fine sand, 65-70 cm

X-ray 1-119		X-ray 3-74	
calc.	M	calc.	M
qtz.	P	qtz.	T
mica	P	k-feld.	T
mont.	P	kaol.	T
paly.	P	mica	T
dolo.	T		
k-feld.	T		
plag.	T		
kaol.	T		
pyrite	T		

5GY5/1

Site 241 Hole Core 4 Cored Interval: 56-65 m



LITHOLOGIC DESCRIPTION

Core is deformed; most is soft and soupy. Sand beds are brecciated and streaked. Colors are mainly green gray (5GY6/1 and 5GY7/1).

FORAM-BEARING CLAYEY NANNO OOZE
Smears 2-75, 3-30, 4-70
Composition

calc. nannos	55%	diatoms	3%
det. clay	31%	sp. spic.	3%
forams	5%	vol. gls.	Tr.
rads	3%	qtz. & feld.	Tr.

5GY6/1

Patches, streaks, and blebs (formerly thin beds) of silt and fine sand occur in Section 3 (70-100 cm) and in Section 5 (20-95 cm). Section 3 sand is composed of detrital foram sand with quartz, feldspar, hornblende, tourmaline, and chlorite.

Grain Size
3-93 (27-37-36) sand-silt-clay
5-109 (26-25-49) sand-silt-clay

5GY6/1 with streaks of 5GY7/1

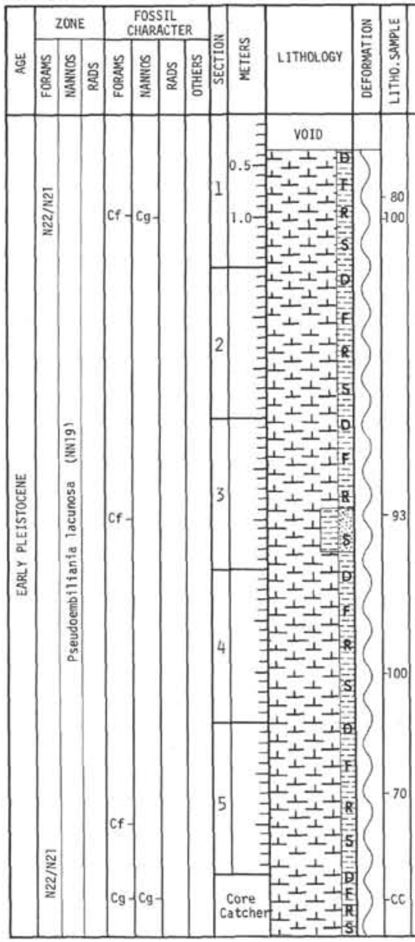
Carbon-Carbonate
2-79 (6.7-0.4-52)
4-109 (7.0-0.4-55)

X-ray 2-129	
calc.	M
qtz.	P
dolo.	T
k-feld.	T
plag.	T
kaol.	T
mica	T
paly.	T

5GY6/1 & 5GY7/1

Explanatory notes in chapter 1

Site 241 Hole Core 5 Cored Interval: 65-74 m



LITHOLOGIC DESCRIPTION

Core is greatly deformed by drilling. Color is dominantly green gray (5GY5/1) with zones, patches, and streaks of lighter green gray colors (5GY6/1 and 5GY7/1) and dark green gray (5GY4/1).

FORAM-BEARING CARBONATE/CLAY-RICH NANNO OOZE

Composition

calc. nannos	45%	rads	3%
clay	25%	diatoms	3%
micarb.	15%	sp. spic.	3%
forams	5%	qtz. & feld.	Tr.
		pyrite	Tr.

Detrital foram-rich, qtz. sand-rich nanno ooze in Section 3 (93 cm) indicates significant bottom transport.

patches & streaks of very fine sand and silt (90-130 cm) (see grain size analysis below)

Pyrite-rich streaks and blebs common in Sections 4 and 5.

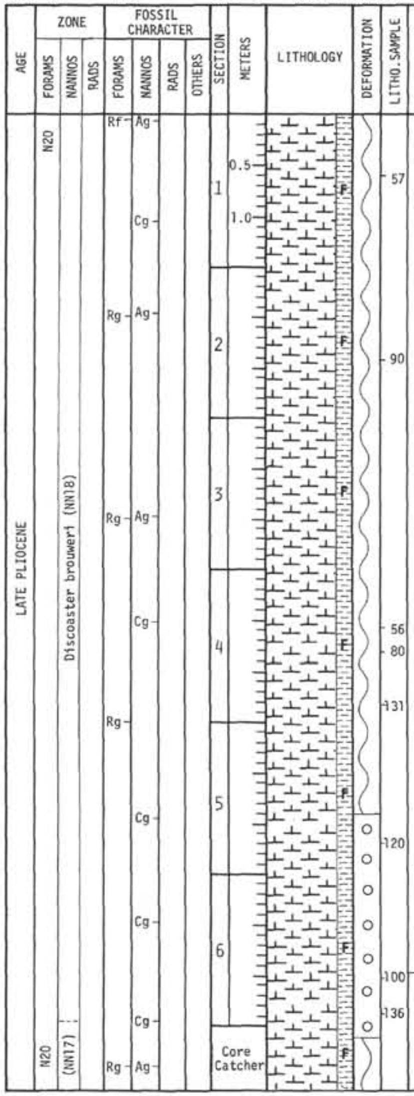
Grain Size
3-90 (37-40-23) sand-silt-clay

Carbon-Carbonate
1-59 (7.0-0.4-55)
5-29 (6.3-0.5-48)

X-ray 5-99

calc.	M	kaol.	T
qtz.	T	mica	T
k-feld.	T	mont.	T
plag.	T	paly.	T

Site 241 Hole Core 6 Cored Interval: 104-113 m



LITHOLOGIC DESCRIPTION

Core is deformed throughout. Drilling breccia is dominant in Sections 5 and 6. Color is dominantly green gray (5GY6/1) with green gray (5GY5/1 and 5GY4/1) streaks and clasts.

FORAM-BEARING CLAY-RICH NANNO OOZE
Smears 2-90, 4-56, 5-120, 6-100

Composition

calc. nannos	70%	sp. spic.	1%
det. clay	20%	micarb.	1%
forams	5%	carb. rhombs	Tr.
rads	1%	pyrite	Tr.
diatoms	1%	vol. gls.	Tr.
		qtz. & feld.	Tr.

Smear slides have differing amounts of clay, but most have contents greater than 10%. Forams are ubiquitous.

Pyrite streaks and blebs are common in Sections 1-4.

Carbon-Carbonate
2-29 (8.9-0.2-72)
5-109 (8.2-0.3-66)

X-ray 2-99

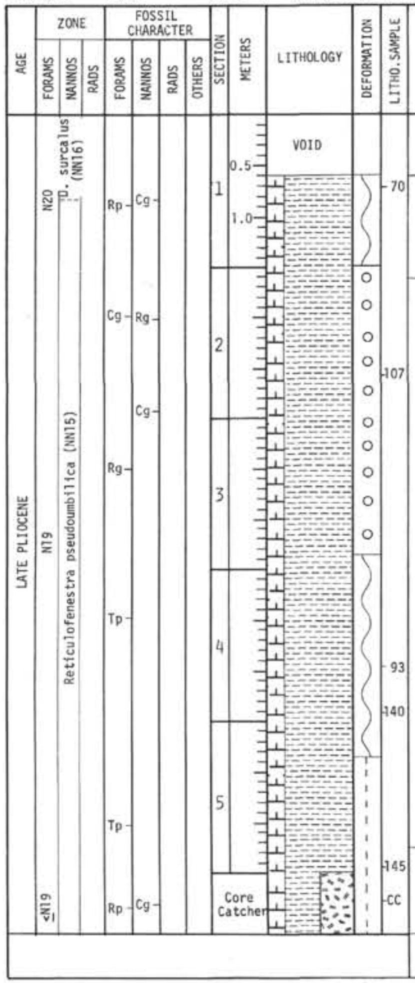
calc.	M	plag.	T
qtz.	T	mica	T
k-feld.	T	pyrite	T

5GY6/1

5GY4/1

Explanatory notes in chapter 1

Site 241 Hole Core 7 Cored Interval: 142-151 m



LITHOLOGIC DESCRIPTION

Core is deformed, soft near the top and becoming a drilling breccia in Sections 2 and 3. Core is stiffer and less deformed in Section 5. Colors are green gray (5GY4/1 and 5GY5/1) and dark green gray (5G4/1).

5GY4/1

NANNO-RICH CLAY
Smears 2-107, 4-140, 5-145
<u>Composition</u>

det. clay	65%	qtz. & feld.	2%
calc. nannos	25%	vol. gls.	Tr.
micarb.	5%	carb. rhombs	Tr.
forams	3%	pyrite	Tr.

Dark green gray clasts have larger clay and silt contents. Clasts represent beds, now deformed by drilling.

5GY4/1 with clasts of 5G4/1

Volcanic ash bed with nanno ooze in the core catcher. Ash is fresh and unaltered.

<u>Carbon-Carbonate</u>
3-109 (3.0-0.3-23)

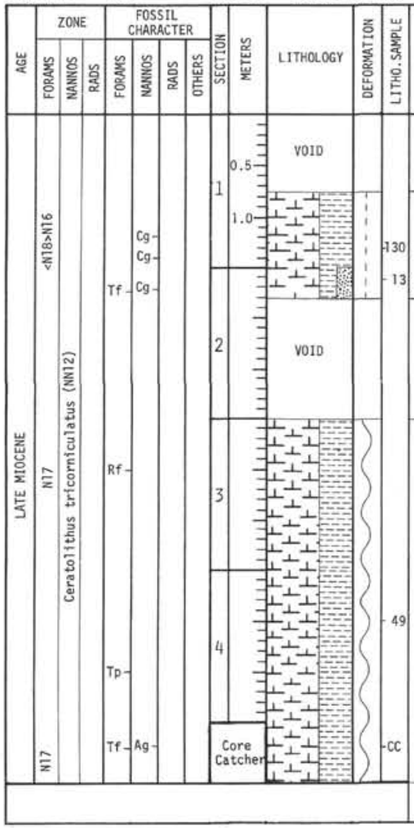
<u>X-ray 2-106</u>

calc.	A	mont.	P
qtz.	P	k-feld.	T
plag.	P	kaol.	T
mica	P	paly.	T

Some mixing of forams in upper sample.

5GY5/1

Site 241 Hole Core 8 Cored Interval: 180-189 m



LITHOLOGIC DESCRIPTION

Core is stiff and only moderately deformed in Section 1, greatly deformed in Sections 3 and 4. Colors are dark green gray (5GY4/1) with minor green gray (5G5/1).

5GY4/1 & 5G5/1

CLAYEY NANNO OOZE
Smears 1-130, 4-49
<u>Composition</u>

calc. nannos.	50%	opaques	2%
det. clay	40%	vol. gls.	Tr.
qtz. & feld.	5%	micarb.	Tr.
forams	3%		

Blebs of fine sand and silt occur in Section 2 (5-30 cm). Voids may represent sandy intervals that were washed out during drilling.

FORAM-BEARING SAND-RICH NANNO OOZE
Smear 2-13
<u>Composition</u>

calc. nannos	80%	pyrite	Tr.
qtz. & feld.	15%	vol. gls.	Tr.
forams	5%	heavies	Tr.
glauconite	Tr.	sp. spic.	Tr.

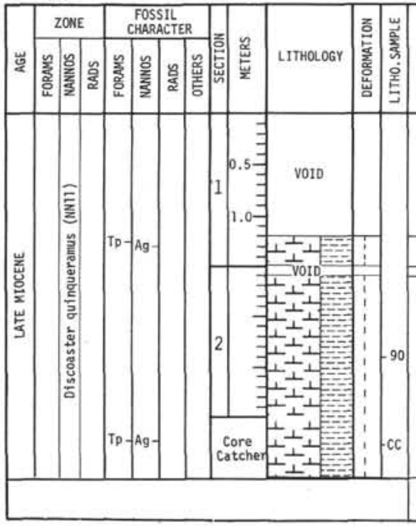
Heavy minerals include hornblende, epidote, zircon, pyrite, and garnet.

5GY4/1 with minor 5G5/1

<u>Carbon-Carbonate</u>
3-59 (6.2-0.4-48)

Explanatory notes in chapter 1

Site 241 Hole Core 9 Cored Interval: 209-218 m



LITHOLOGIC DESCRIPTION

Core is stiff, only slightly deformed. Colors are green gray (5GY5/1) and dark green gray (5GY4/1).

CLAYEY NANNO OOZE
Smear 2-90, CC

Composition

calc. nannos	50%	forams	3%
det. clay	40%	pyrite	1%
qtz. & feld.	6%	vol. gls.	Tr.

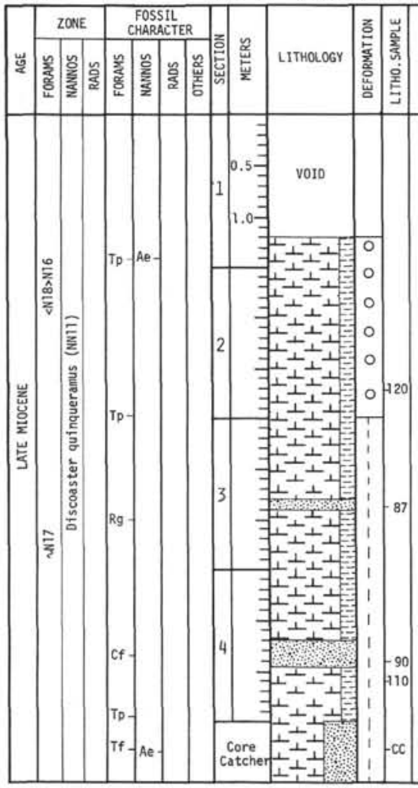
Carbon-Carbonate
1-125 (4.9-0.5-37)

5GY5/1 & 5GY4/1

X-ray 2-119

calc.	A	mont.	P
qtz.	P	paly.	P
k-feld.	P	kaol.	T
plag.	P	pyrite	T
mica	P		

Site 241 Hole Core 10 Cored Interval: 218-227 m



LITHOLOGIC DESCRIPTION

Core is deformed with drilling breccia in Sections 1 and 2; stiff and slightly deformed in Sections 3 and 4. Dark green gray (5GY4/1). Color is dominant with minor green gray (5GY6/1) occurring in sand and silt beds 10-20 cm thick.

CLAY-RICH NANNO OOZE
Smears 2-120, 4-110

Composition

calc. nannos	70%	qtz. & feld.	2%
det. clay	22%	pyrite	1%
forams	3%	carb. rhombs	Tr.
micarb.	2%		

Deep water forams from sample 3-100.

DETRITAL FORAM ARKOSIC SAND
Smears 3-87, CC

Composition

qtz. & feld.	50%	calc. nannos	10%
forams	30%	heavies	Tr.
micarb.	10%	pyrite	Tr.
		glauconite	Tr.

Heavies include: hornblende, garnet, zircon, sphene, and pyrite.

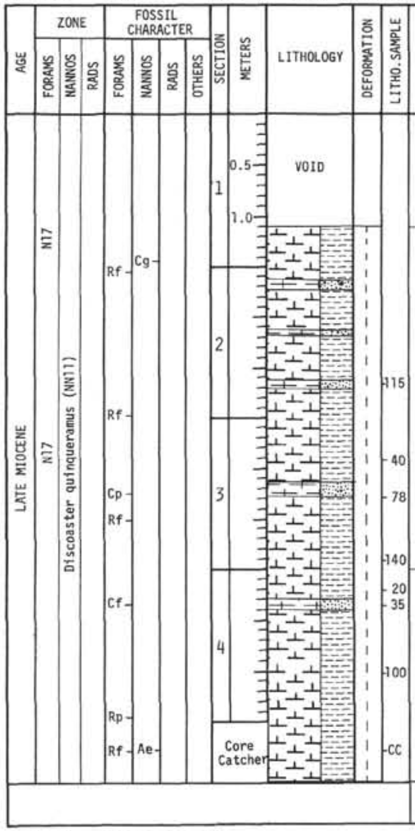
graded sand-silt bed, 85-88 cm.

*Grain Size
3-87 (26-36-38) sand-silt-clay
4-75 (67-20-13) silty sand
4-78 (66-21-13) silty sand
4-82 (69-20-11) silty sand
4-85 (69-20-11) silty sand
4-88 (36-36-28) sand-silt-clay

graded sand-silt bed, 70-95 cm.

*All grain size analyses are from graded beds.

Site 241 Hole Core 11 Cored Interval: 256-265 m



LITHOLOGIC DESCRIPTION

Core is stiff and only slightly deformed. Dark green gray (5GY4/1) is dominant color with minor green gray (5GY6/1).

CLAYEY NANNO OOZE
Smears 3-40, 4-20, 4-100

Composition

calc. nannos	60%	qtz. & feld.	1%
det. clay	35%	pyrite	Tr.
forams	2%	sp. spic.	Tr.
micarb.	2%		

DETRITAL QUARTZ-RICH FORAM NANNO OOZE
Smears 3-78, 4-35

Composition

calc. nannos	45%	pyrite	Tr.
forams	30%	heavies	Tr.
qtz. & feld.	15%	mica	Tr.
micarb.	10%		

5GY4/1

These occur in graded beds. Forams are allochthonous benthonics from the shelf and slope; represent turbidites.

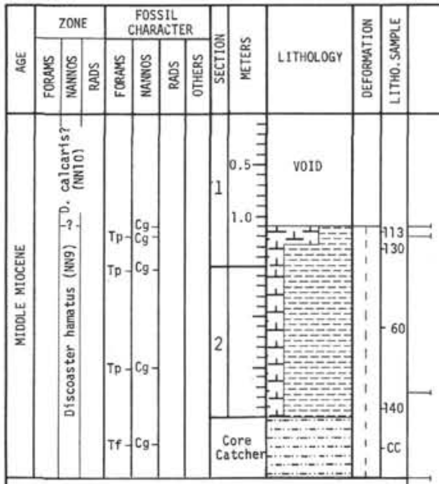
Grain Size
2-18 (15-33-52) silty clay
3-77 (36-44-20) sand-silt-clay
4-30 (65-19-16) silty sand
4-39 (41-37-22) sand-silt-clay

Carbon-Carbonate
2-99 (5.5-0.2-44)
4-99 (7.2-0.2-58)

5GY6/1

Explanatory notes in chapter 1

Site 241 Hole Core 12 Cored Interval: 294-303 m



LITHOLOGIC DESCRIPTION

Core is stiff and slightly deformed; top of Section 1 is greatly deformed. Colors are dominantly dark green gray (5GY4/1) with minor green black (5G2/1) and green gray (5GY6/1).

5GY6/1

5GY4/1

NANNO-RICH CLAY
Smears 2-60, 2-140
Composition

det. clay	80%	carb. rhombs	Tr.
calc. nannos	13%	pyrite	Tr.
micarb.	5%	qtz. & feld.	2%

CLAYEY NANNO OOZE
Smears 1-113, 1-130
Composition

calc. nannos	60%	qtz.	Tr.
det. clay	35%	pyrite	Tr.
micarb.	4%	vol. gls.	Tr.
forams	1%	sp. spic.	Tr.

5G2/1

Carbon-Carbonate
2-80 (2.1-0.2-16)

X-ray 2-70

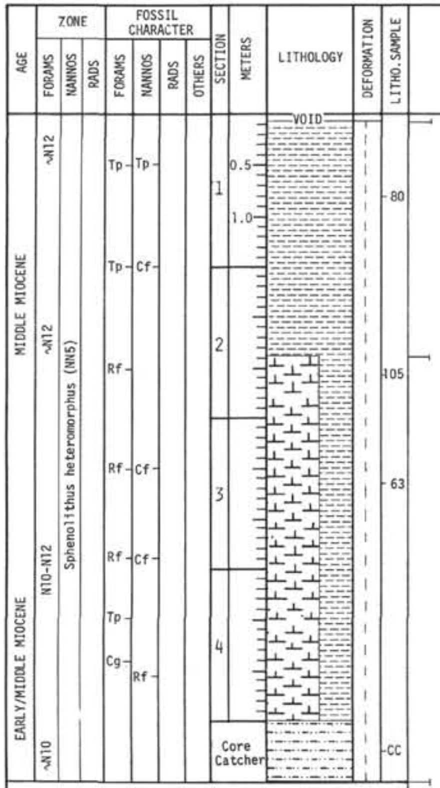
calc.	A
qtz.	P
k-feld.	P
plag.	P
mica	P
mont.	P
paly.	P
pyri.	T
kaol.	T

X-ray 2-139

qtz.	P
k-feld.	P
plag.	P
mica	P
mont.	P
paly.	P
kaol.	T

Explanatory notes in chapter 1

Site 241 Hole Core 13 Cored Interval: 322-331 m



LITHOLOGIC DESCRIPTION

Core is stiff and only moderately deformed. Colors are dark green gray (5G4/1) in Section 1 and upper part of Section 2, then interlayered gray olive (10Y4/1), green gray (5GY6/1), and dark green gray (5GY4/1).

5G4/1

CLAY
Smear 1-80
Composition

det. clay	98%
qtz. & feld.	2%
calc. nannos	Tr.

CLAYEY NANNO OOZE
Smear 2-105
Composition

calc. nannos	51%	forams.	Tr.
det. clay	49%	pyrite	Tr.
qtz. & feld.	Tr.	micarb.	Tr.

10Y4/1,
5GY6/1, &
5GY4/1

graded bed
61-63 cm

Alternating clay, nanno clay, and clay-rich nanno ooze occur below 2-83. Turbidite foram sand in graded bed at 3-61 to 63. Other dark green gray layers may represent turbidites. Silty clay is in core catcher. Burrowing is widespread. Graded bed in Section 4 contains reworked Eocene forams.

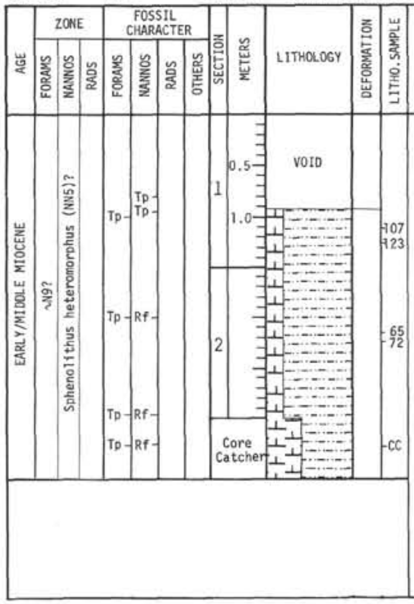
Carbon-Carbonate
2-120 (5.7-0.2-46)

graded bed
86-91 cm

X-ray 1-79

qtz.	P
k-feld.	P
plag.	P
kaol.	P
mica	P
mont.	P
paly.	P

Site 241 Hole Core 14 Cored Interval: 379-388 m



LITHOLOGIC DESCRIPTION

Core is stiff and moderately deformed. Bedding can be recognized. Colors are dark green gray (5GY4/1) with minor light gray (N7) and dusky yellow (10YR2/2). Core is interlayered silty clay and nanno ooze. Nanno clay in core catcher.

SILTY CLAY interbedded with minor (10-15%) NANNO OOZE.
Smears 1-107, 2-65 (Silty Clay)

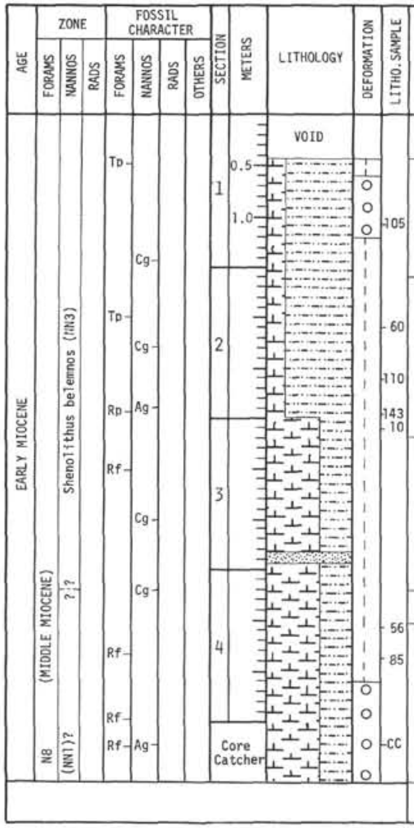
Composition	
det. clay (some in silt-sized clumps)	90%
qtz. & feld.	5%
calc. nannos	5%

Some fish remains in Section 2, 50 and 150 cm.

Carbon-Carbonate
1-141 (7.8-0.1-64)

X-ray 1-74	
calc.	A
qtz.	P
k-feld.	P
mica	P
mont.	P
paly.	P
dolo.	T
plag.	T
kaol.	T

Site 241 Hole Core 15 Cored Interval: 398-407 m



LITHOLOGIC DESCRIPTION

Core is stiff and slightly deformed. Drilling breccia in top of Section 1 and near base of Section 2. Colors are dark green gray (5GY4/1), yellow brown (10YR5/2), dark yellow brown (10YR4/2), and green gray (5GY6/1).

5GY4/1

SILTY CLAY with interbedded CLAYEY NANNO OOZE in Sections 1 and 2
Smear 1-105 (Silty Clay)

5GY4/1 with interbedded 10YR4/2

Texture	Composition	
(0-35-65)	det. clay	60%
	silt-sized clay part.	20%
	qtz. & feld.	14%
	calc. nannos	5%
	pyrite	1%

CLAYEY NANNO OOZE (dominant in Sections 3 and 4)
Smear 3-10

10YR5/2 with interbedded 5GY6/1

Composition	
calc. nannos	50%
det. clay	35%
micarb.	10%
qtz. & feld.	5%
vol. gls.	Tr.

graded bed, 136-146 cm with Eocene forams and glauconite

10YR4/2

Graded beds (fine silt to clay) occur throughout the core. Most are <10 cm thick. Clay at 2-60 is a devitrified vol. ash; see X-ray results.

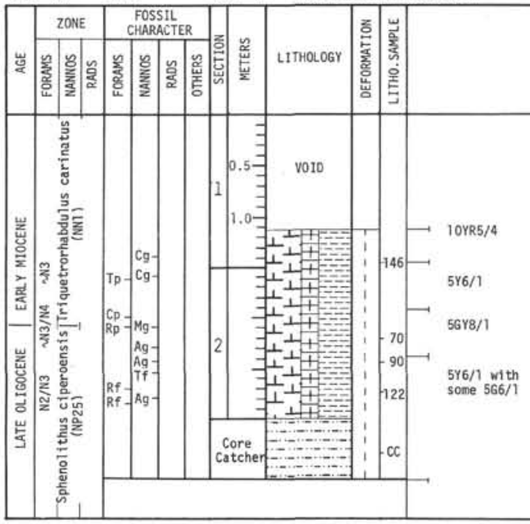
5GY4/1

Grain Size
1-144 (27-32-41) sand-silt-clay

X-ray 2-59 (devitrified ash)	
mont.	M
qtz.	T

Explanatory notes in chapter 1

Site 241 Hole Core 16 Cored Interval: 455-464 m



LITHOLOGIC DESCRIPTION

Core is stiff and slightly deformed. Colors are moderate brown (10YR5/4), light olive gray (5Y6/1), light green gray (5GY8/1), and green gray (5G6/1).

CLAY-RICH NANNO OOZE and FORAM NANNO CHALK beds (70%) with NANNO CLAYS (30%). All are interlayered. Some clays may be devitrified ashes. Burrowing is moderate.

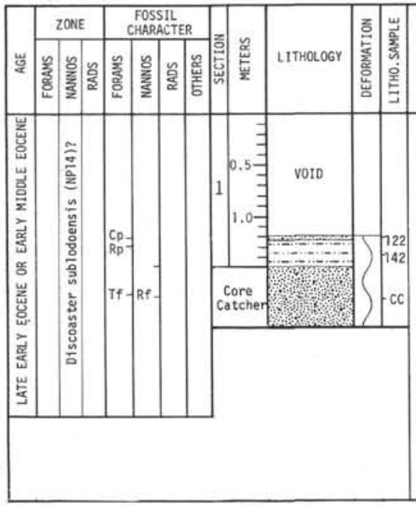
In Section 2, 68 through 85 cm, graded foram nanno chalk bed, probably all detrital. Also, possible graded bed, Section 2, 32 through 68 cm.

SILTY CLAY in core catcher.

Grain Size
2-63 (29-42-29) sand-silt-clay

Carbon-Carbonate
2-57 (9.7-0.1-80)

Site 241 Hole Core 17 Cored Interval: 483-492 m



LITHOLOGIC DESCRIPTION

Badly disturbed core. Mixture of dominantly moderate brown (5YR4/4), pale green (10G6/2), and light olive green (5Y5/2).

SILTY CLAY
Smear 1-122

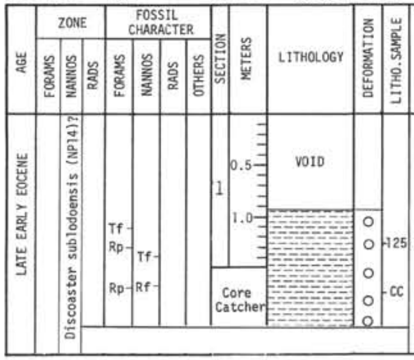
Texture	Composition	
(3-30-67)	det. clay	80%
	qtz. & feld.	17%
	others	3%

Sand and silty sand occur at top of Section 1 and in core catcher. This may have been a sandy interval washed during drilling.

X-ray 1-137

k-feld.	A
plag.	A
qtz.	P
mica	P
mont.	P
kaol.	T
paly.	T

Site 241 Hole Core 18 Cored Interval: 492-501 m



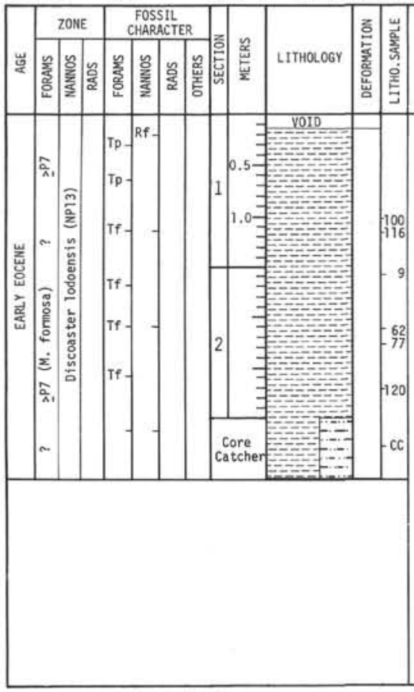
LITHOLOGIC DESCRIPTION

Drilling breccia. Varicolored with moderate brown (5Y4/4), pale gray green, and light olive.

CLAY
Smears 1-125, CC

Texture	Composition	
(0-7-93)	det. clay	93%
	qtz. & feld.	6%
	opaques	1%
	calc. nannos	Tr.

Site 241 Hole Core 19 Cored Interval: 530-539 m



LITHOLOGIC DESCRIPTION

Core is stiff and only moderately deformed. Most bedding is recognizable. Mostly moderate brown (5YR4/4) with thin (<5 cm) layers of green gray (5G4/1).

Core is predominantly brown CLAYSTONE with green SILTSTONE layers, probably turbidites, minor.

CLAYSTONE
Smears 1-110, 2-120

Texture	Composition	
(0-7-93)	clay	90%
	qtz. & feld.	5%
	opaques	5%

CLAYEY SILTSTONE
Smear 1-116

Texture	Composition	
(3-75-22)	qtz. & feld.	65%
	clay	25%
	opaques	5%
	others	5%

Heavies in sandy siltstone bed at 2-62 include: zircon, epidote, garnet, opaques, rutile, sphene, and chlorite.

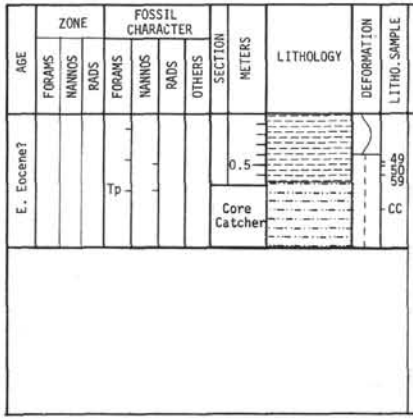
Grain Size
1-124 (0-7-93) clay
2-87 (1-81-18) silt

X-ray 1-49

paly.	P	qtz.	P
mont.	P	k-feld.	P
mica	P	plag.	T
kaol.	P	goethite	T

Explanatory notes in chapter 1

Site 241 Hole Core 20 Cored Interval: 539-548 m



LITHOLOGIC DESCRIPTION

Core is deformed near top and becomes stiff and less deformed with depth. Color is dominantly moderate brown (5YR3/4).

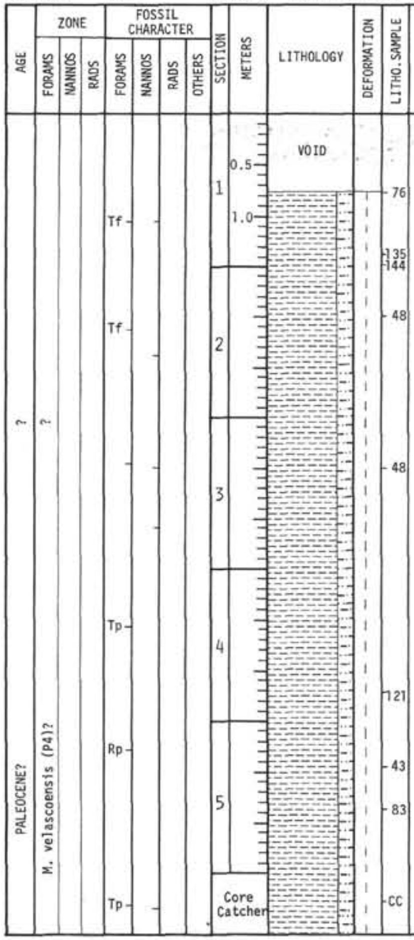
CLAYSTONE
Smears 1-50, 1-59

Texture	Composition	
(0-5-95)	clay	95%
	qtz.	3%
	opaques	2%

Devitrified ash bed at 1-44 is now entirely clay. Nanno-bearing silty claystone in core catcher.

Carbon-Carbonate
1-68 (0.2-0.1-1.0)

Site 241 Hole Core 21 Cored Interval: 578-587 m



LITHOLOGIC DESCRIPTION

Core is stiff and only slightly deformed. Color is dominantly moderate brown (5YR4/4) interbedded with minor (10%) dark green gray (5GY4/1). Most of the moderate brown beds are claystone.
Dark green gray beds are silty claystone and sand-bearing silty claystone. Most represent turbidite deposits; grading is apparent.

CLAYSTONE
Smears 1-135, 3-48, 4-83

Texture	Composition	
(0-10-90)	det. clay	90%
	qtz. & feld.	7%
	Fe oxides	3%
	heavy min.	Tr.
	calc. nannos	Tr.

SILTY CLAYSTONE
Smear 5-83

Texture	Composition	
(1-24-75)	det. clay	75%
	qtz. & feld.	15%
	Fe oxides	5%
	dol. rhombs	5%
	heavy min.	Tr.

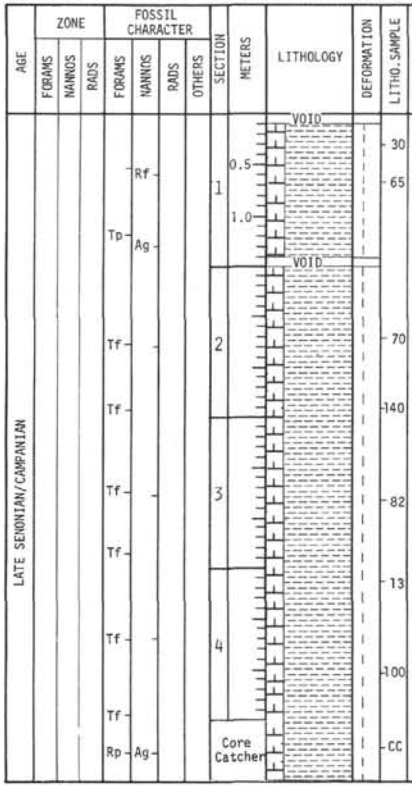
Some burrowing in the sequence. Best bedding in Sections 2 and 3 - outlined by color and texture. Core probably represents distal turbidite deposits.

Carbon-carbonate
2-19 (0.1-0.1-0)

X-ray 2-114		X-ray 5-93	
mica	A	qtz.	P
paly.	P	mica	P
qtz.	P	paly.	P
k-feld.	P	k-feld.	P
mont.	P	mont.	P
kaol.	P	kaol.	P
plag.	P	plag.	T
chlo.	T	chlo.	T
goethite	T	goethite	T

Explanatory notes in chapter 1

Site 241 Hole Core 22 Cored Interval: 626-635 m



LITHOLOGIC DESCRIPTION

Core is semi-lithified and slightly deformed. Color is dominantly dark yellow brown (10YR4/2) with bands of dark green gray (5GY4/1) and olive gray (5Y4/1).

NANNO-RICH CLAYSTONE
Smears 1-30, 4-100

Texture	Composition	
(0-10-90)	det. clay	75%
	calc. nannos	15%
	qtz. & feld.	8%
	Fe oxides	2%

CLAYSTONE
Smear 2-70

Texture	Composition	
(0-5-95)	det. clay	90%
	calc. nannos	5%
	micarb.	3%
	qtz. & feld.	2%

graded bed

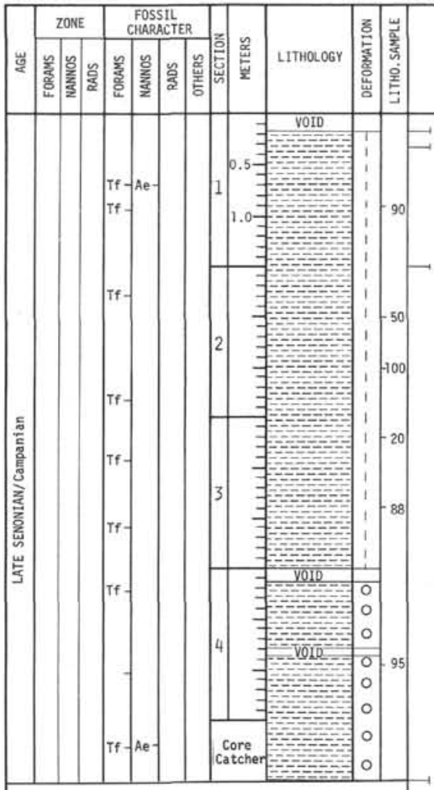
Core is dominantly (80%) yellow brown nanno-rich claystone with interbedded (20%) dark green gray and olive gray claystone. Some green layers which show grading from clayey siltstone to claystone probably are turbidites.

Carbon-Carbonate
1-46 (2.0-0.2-16)

X-ray 1-93

calc.	A
qtz.	P
k-feld.	P
mica	P
mont.	P
paly.	P
plag.	T
kaol.	T
chlo.	T

Site 241 Hole Core 23 Cored Interval: 683-692 m



LITHOLOGIC DESCRIPTION

5YR4/4

5YR2/2

Core is semi-lithifed and slightly deformed through Section 3. Drilling breccia occurs in Section 4. Colors are dominantly dark gray (N3), dusky brown (5YR2/2), moderate brown (5YR4/4), and rarely reddish brown (10YR3/4).

CLAYSTONE
Smears 1-90, 2-100, 3-88, 4-95

Texture	Composition	
(0-5-95)	det. clay	95%
	calc. nannos	3%
	opaques	1%
	micarb.	1%
	carb. rhombs	Tr.
	qtz. & feld.	Tr.

graded bed
98-100 cm

NANNO-BEARING CLAYSTONE
Smears 2-50, 3-20

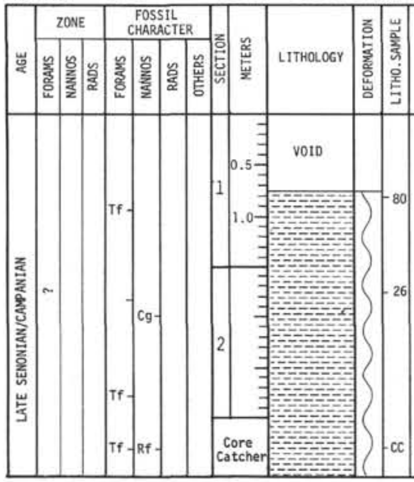
Texture	Composition	
(0-5-95)	det. clay	92%
	calc. nannos	5%
	micarb.	2%
	opaques	1%
	carb. rhombs	Tr.
	qtz. & feld.	Tr.

N3 with
streaks of
10YR3/4

Grain Size
3-47 (22-46-32)

Carbon-Carbonate
1-107 (0.7-0.2-4)

Site 241 Hole Core 24 Cored Interval: 749-758 m



LITHOLOGIC DESCRIPTION

Core is moderately deformed by drilling. Color is dominantly olive black (5Y2/1) with minor moderate brown (5YR3/4).

graded bed

CLAYSTONE
Smears 1-80, 2-26

Texture	Composition	
(0-5-95)	det. clay	86%
	calc. nannos	8%
	qtz. & feld.	5%
	opaques	1%
	carb. rhombs	Tr.
	micarb.	Tr.

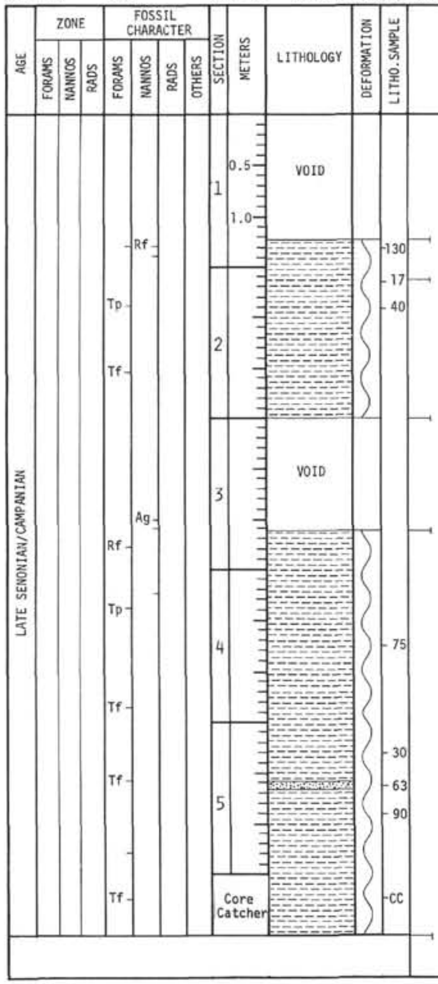
Carbon-Carbonate
1-118 (1.2-0.1-8)

X-ray 1-119

calc.	P	paly.	P
qtz.	P	plag.	T
k-feld.	P	kaol.	T
mica	P	chlor.	T
mont.	P		

Explanatory notes in chapter 1

Site 241 Hole Core 25 Cored Interval: 835-844 m



LITHOLOGIC DESCRIPTION

Core is moderately deformed and sediment is semi-lithified. Colors are dominantly olive black (5Y2/1) with interbedded gray brown (5YR3/2).

5YR3/2

CLAYSTONE (SILT-RICH)
Smears 4-75, 5-30

Texture	Composition	
(0-15-85)	det. clay	80%
	qtz. & feld.	15%
	iron oxides	2%
	calc. nannos	2%
	carb. rhombs	1%

5Y2/1

Core is dominantly olive black claystone with minor interbedded gray brown claystone. Silt-sized particles comprise 5-20%. Volcanic clays (derived from ash) at 3-125 and in core catcher. Cross-bedded calc. qtz. sandstone at 59-64 cm in Section 5 is lithified.

Grain Size
3-123 (0-12-88) clay

Carbon-Carbonate
5-65 (5.7-0.6-42) calcareous sandstone
5-79 (0.4-0.3-1.0)

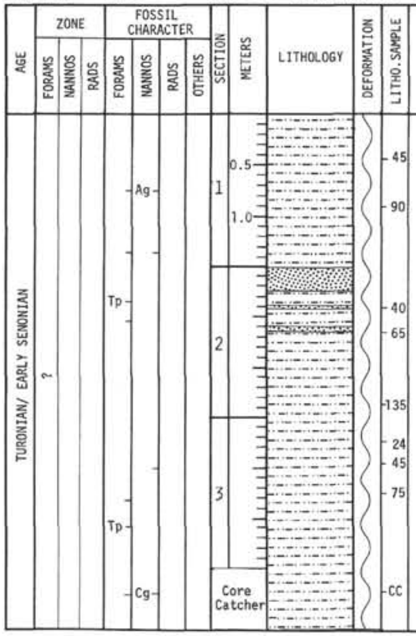
probable devitrified ash layer

5Y2/1 with minor 5YR3/2

X-ray 2-48	
calc.	P
qtz.	P
k-feld.	P
mica	P
mont.	P
paly.	P
dolo.	T
plag.	T
kaol.	T
chlor.	T

59-64 cm, cross bedded calcareous qtz. sandstone

Site 241 Hole Core 26 Cored Interval: 873-879 m



LITHOLOGIC DESCRIPTION

Core is deformed, mostly from mechanical splitting of the core. Colors dominantly green black (5GY2/1) and dark green gray (5GY6/1) with minor moderate brown (5YR3/4).

SILTY CLAYSTONE
Smears 1-90, 3-24

Texture	Composition	
(2-28-70)	det. clay	70%
	qtz. & feld.	20%
	micarb.	3%
	carb. rhombs	3%
	calc. nannos	3%
	heavy mins.	1%
	vol. gls.	Tr.

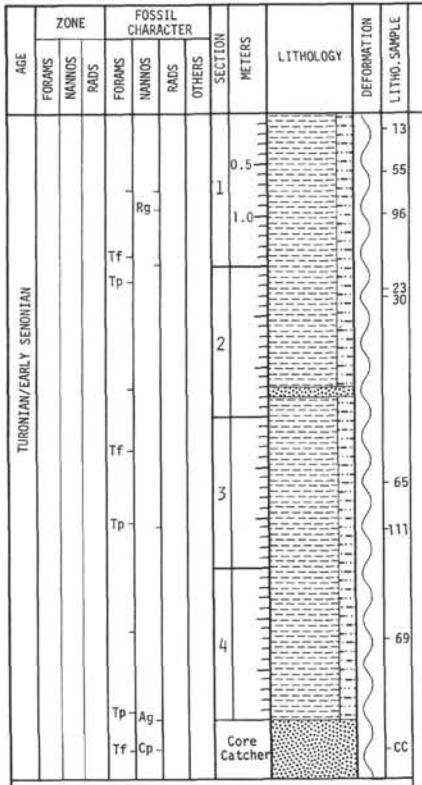
Slump fold in graded bed of fine grained calc. qtz. sandstone, Section 2, 0-25 cm.

Calc. qtz. sandstone beds (probable turbidites) in Section 2, 39-42 cm and 59-64 cm.

Carbon-Carbonate
1-66 (0.3-0.2-1.0)
2-23 (5.6-0.1-46) calc. sandstone
2-40 (4.6-0-38) calc. sandstone
2-65 (4.3-0-36) calc. sandstone

Explanatory notes in chapter 1

Site 241 Hole Core 27 Cored Interval: 977-986 m



LITHOLOGIC DESCRIPTION

Core is semi-lithified and somewhat broken up through core splitting and drilling processes. Colors are dominantly olive black (5Y2/1) and dark green gray (5GY4/1) with minor amounts of interbedded olive gray (5Y4/1).

CLAYSTONE (SILT-RICH)
Smear 3-65

Texture	Composition			
(0-12-88)	det. clay	88%	opaques	1%
	qtz. & feld.	10%	carb. rhombs	1%

Graded beds at 1-30 to 34 cm, 2-23 to 30 cm, and at 4-62 to 69 cm. Sandstone bed at 2-122 is a calcarenite and displays convolute bedding. Cores are mostly silt-rich claystone (olive black and dark green gray) interbedded with clayey siltstone, siltstone, and fine sandstone (olive gray). The coarser-grained, olive gray beds show graded bedding, sharp basal contacts, rip-up clasts, and convolute bedding.

Grain Size
1-124 (0-17-83) clay
2-32 (2-54-44) clayey silt
3-110 (0-52-48) clayey silt
3-126 (0-23-77) clay
4-62 (0-21-79) silty clay
4-68 (0-24-76) silty clay

Carbon-Carbonate
1-104 (0.2-0.2-1.0)
2-122 (6.2-0.1-51) calc. sandstone
3-127 (0.3-0.2-1.0)
CC (4.9-0.0-40) calc. sandstone

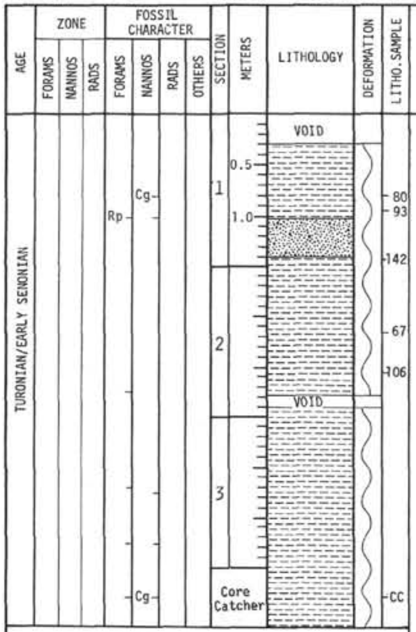
X-ray 1-66		X-ray 2-27		X-ray 2-117	
calc.	A	calc.	P	calc.	A
qtz.	P	qtz.	P	qtz.	P
k-feld.	P	k-feld.	P	kaol.	P
mica	P	kaol.	P	mica	P
mont.	P	mica	P	mont.	P
dolo.	T	mont.	P	paly.	P
plag.	T	paly.	P	dolo.	T
kaol.	T	dolo.	T	k-feld.	T
chlor.	T	plag.	T	plag.	T
paly.-	T	chlor.	T		

X-Ray 3-105.5		X-ray 4-66		X-ray 4-102	
calc.	A	calc.	A	calc.	A
mont.	P	qtz.	P	qtz.	P
qtz.	P	mica	P	mica	P
paly.	P	mont.	P	mont.	P
mica	P	paly.	P	paly.	P
kaol.	T	dolo.	T	dolo.	T
chlor.	T	k-feld.	T	k-feld.	T
k-feld.	T	plag.	T	kaol.	T
dolo.	T	kaol.	T	chlor.	T
		chlor.	T		

X-ray 4-131	
mica	A
calc.	P
qtz.	P
k-feld.	P
mont.	P
dolo.	T
plag.	T
kaol.	T
chlor.	T

Explanatory notes in chapter 1

Site 241 Hole Core 28 Cored Interval: 1067-1072 m



LITHOLOGIC DESCRIPTION

Core is semi-lithified and badly fractured during cutting of the core. Core is dominantly finely interlayered green black (5G2/1) claystone, green gray (5GY6/1) clayey siltstone and very fine sandstone. Many beds show grading (1-5 mm scale); other interbeds display no grading.

CLAYSTONE
Smear 1-80

Texture	Composition			
(0-5-95)	det. clay	85%	pyrite	Tr.
	micarb.	15%	carb. rhombs	Tr.
	qtz. & feld.	Tr.	calc. nannos	Tr.

Numerous graded beds (<3 cm thick) in Section 1 (31-104 cm), Section 3 (11-19, 45-60, and 87-97 cm). Fine grained sandstone in Section 1 (104-142 cm) with abundant rip-up clasts.

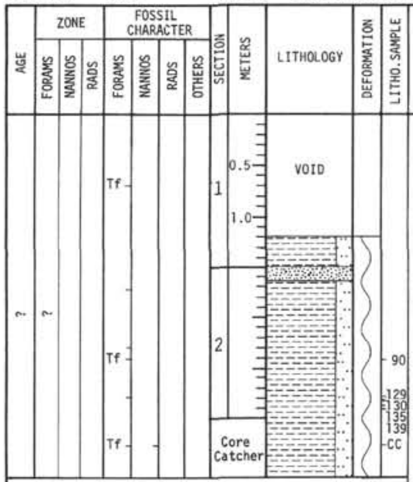
Grain Size
1-101 (36-50-14) sandy silt Top
1-141 (40-43-17) sandy silt Base
"Massive Sand" bed
2-71 (19-52-29) clayey silt
3-18 (0-63-37) clayey silt
3-95 (2-60-40) clayey silt

Carbon-Carbonate
1-86 (014-012-2.0)
1-140 (3.5-0.4-26)
2-24 (2.5-0.3-19) "Massive Sand"
2-66 (4.0-2.0-17) "Massive Sand"

X-ray 1-84		X-ray 3-11		X-ray 3-68		X-ray 3-87	
calc.	A	qtz.	P	mont.	P	qtz.	A
dolo.	P	k-feld.	P	qtz.	P	k-feld.	P
qtz.	P	plag.	P	mica	P	plag.	P
k-feld.	P	mica	P	k-feld.	P	mica	P
mica	P	mont.	P	paly.	P	mont.	P
mont.	P	paly.	P	plag.	P	dolo.	T
plag.	T	dolo.	T	chlor.	T		
paly.	T	chlor.	T				

Explanatory notes in chapter 1

Site 241 Hole Core 29 Cored Interval: 1167-1174 m



LITHOLOGIC DESCRIPTION

Sediments are semi-lithified. Core is fractured from cutting process. Dominantly dark green gray (5GY4/1) claystone interbedded w:th moderate brown (5YR3/4) silt-rich claystone.

CLAYSTONE (SILT-RICH)
Smear 2-129

Texture	Composition	
(0-10-90)	det. clay	90%
	qtz. & feld.	7%
	opaques	3%

0-16 cm
medium dark
gray (N4)
calcareous qtz.
sandstone

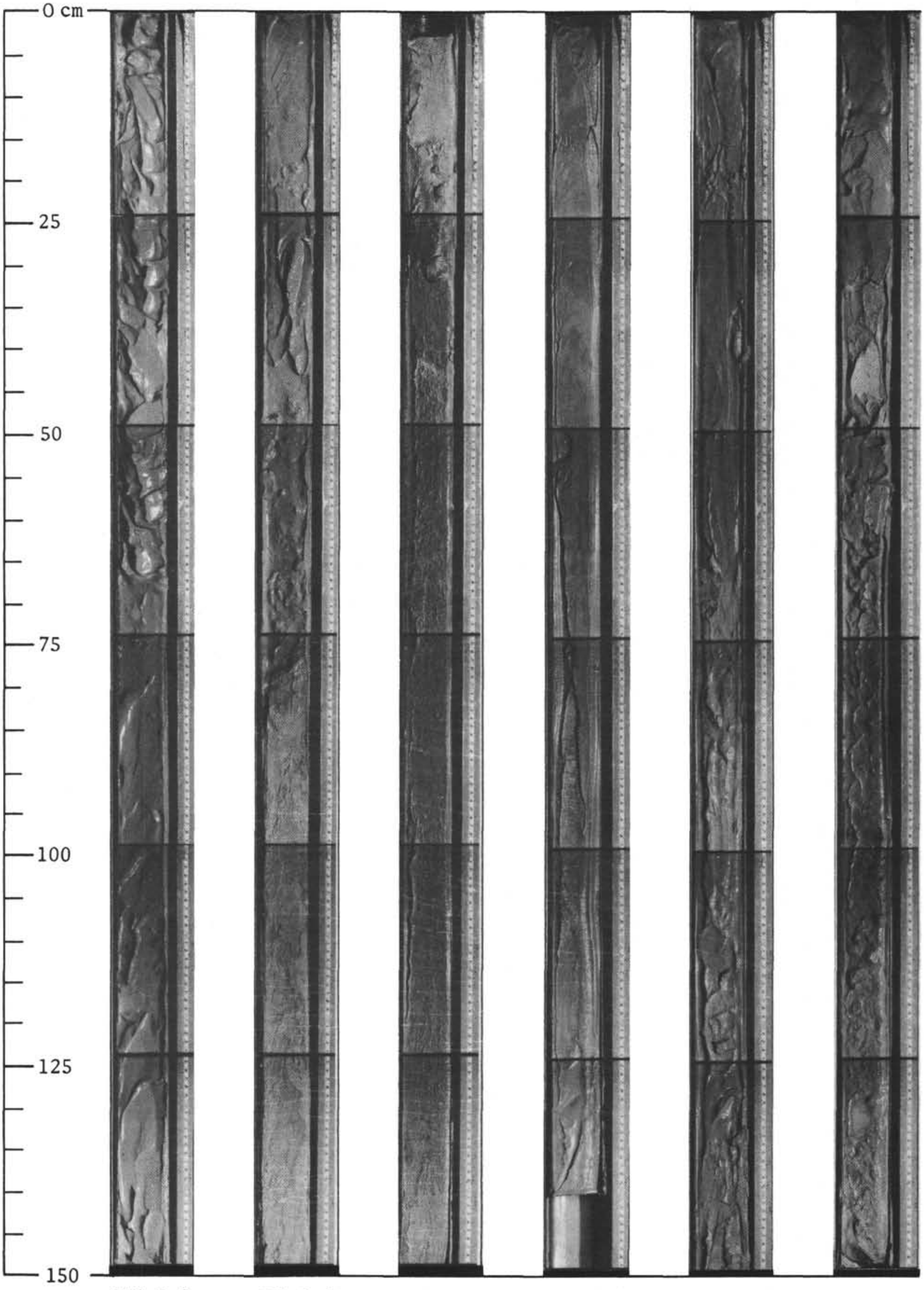
Abundant marcasite crystals in Section 1, 140-142 cm.

Grain Size
1-140 (0-9-91) clay
2-39 (0-14-86) clay

Carbon-Carbonate
2-10 (5.6-0.1-46) calc. sandstone
2-124 (0.3-0.3-0)

X-ray 2-89		X-ray 2-108		X-ray 2-113	
qtz.	A	mont.	A	mont.	A
mont.	A	qtz.	P	qtz.	P
paly.	A	mica	P	paly.	P
plag.	P	paly.	P	mica	P
mica	P	hem.	P	hem.	P
k-feld.	T	kaol.	T	k-feld.	P
chlor.	T	plag.	T	plag.	T
				kaol.	T

Explanatory notes in chapter 1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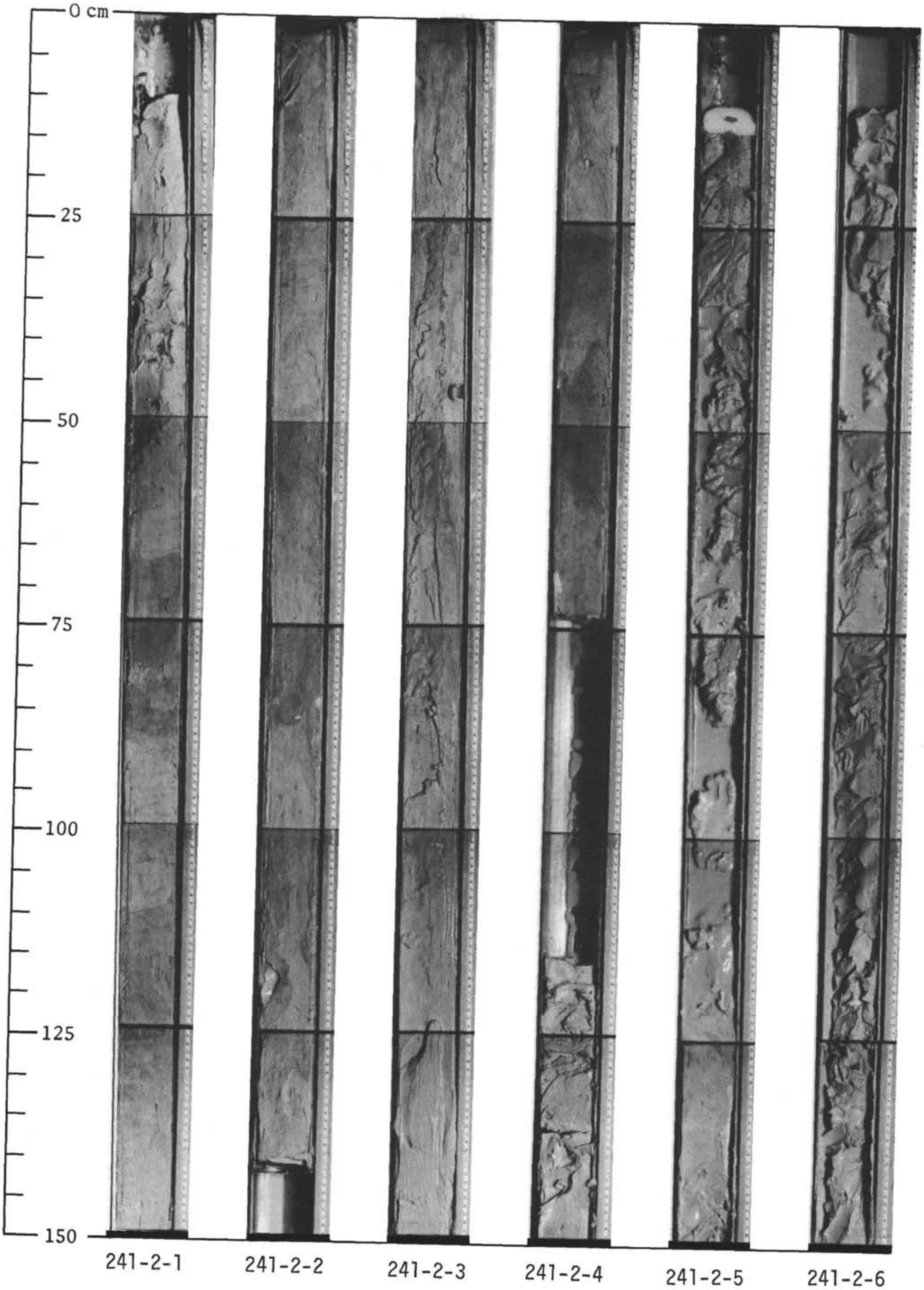
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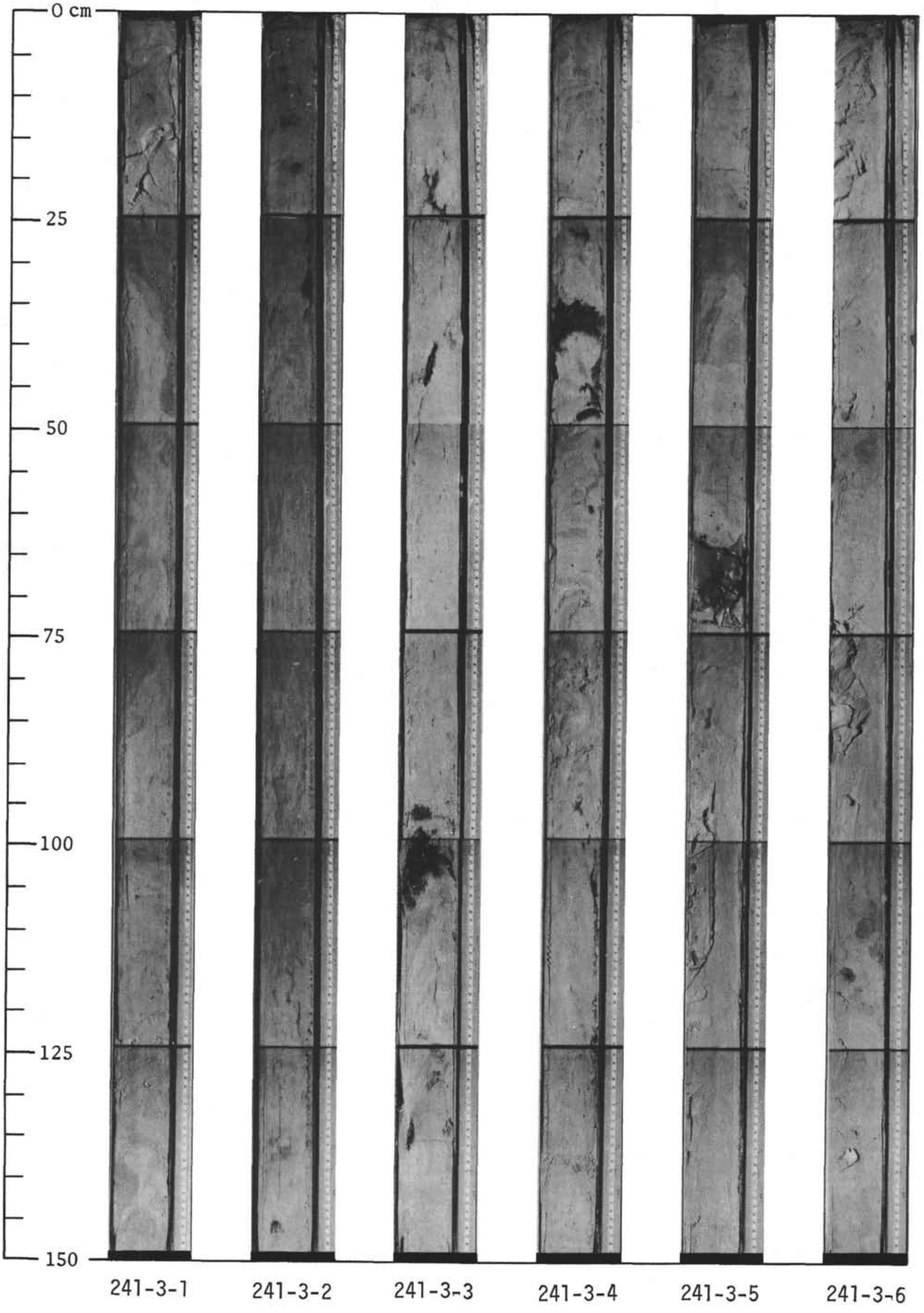
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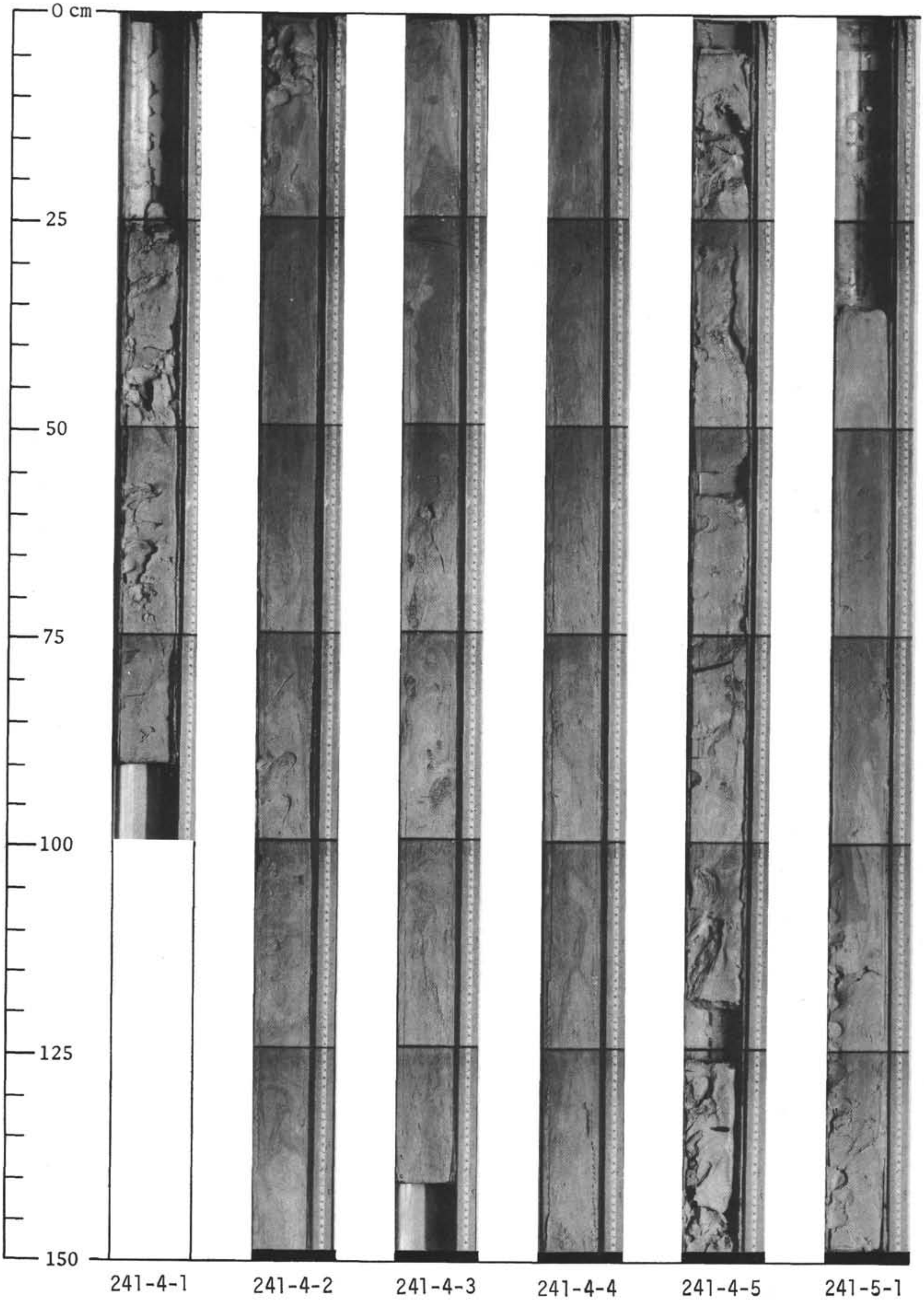
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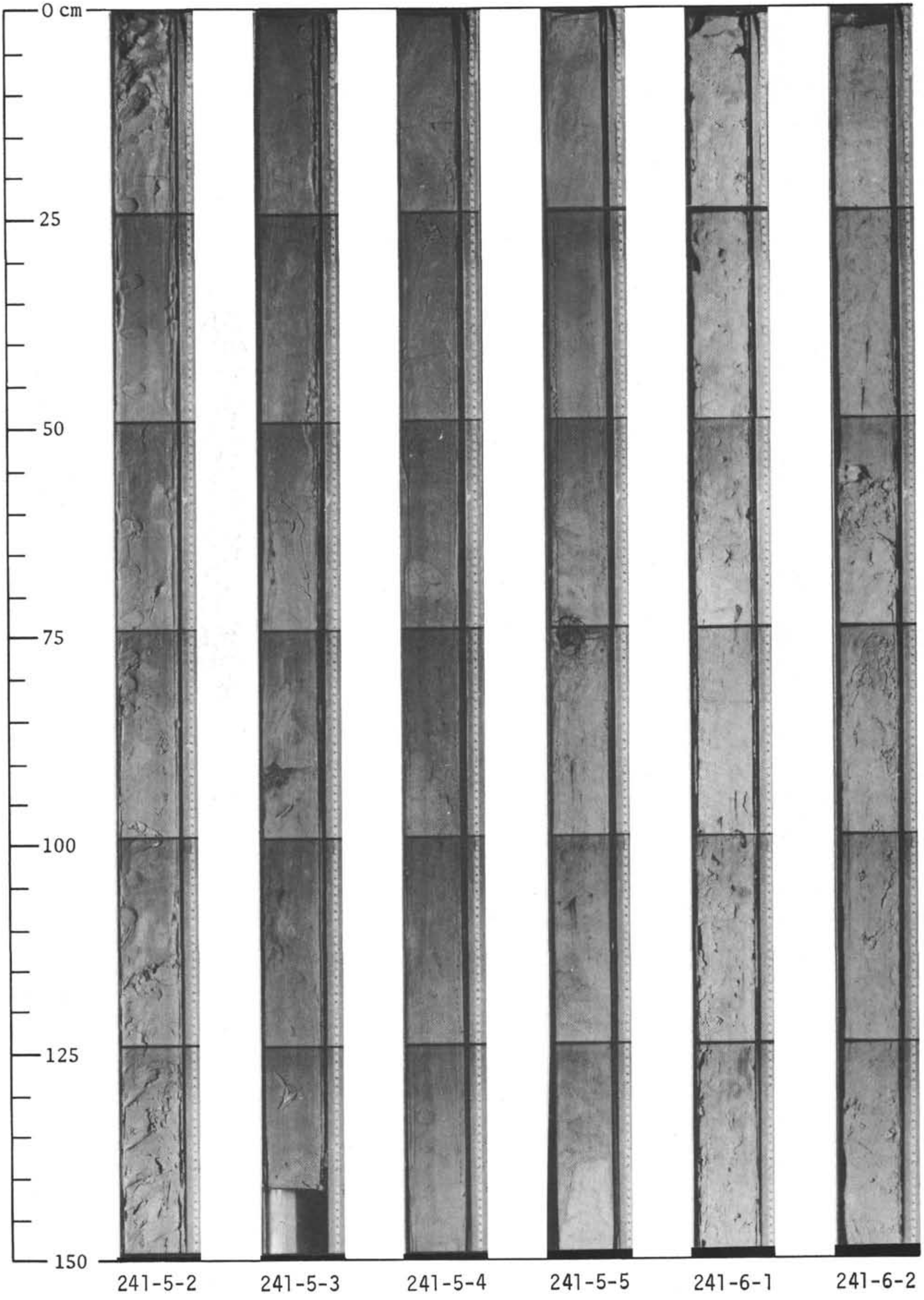
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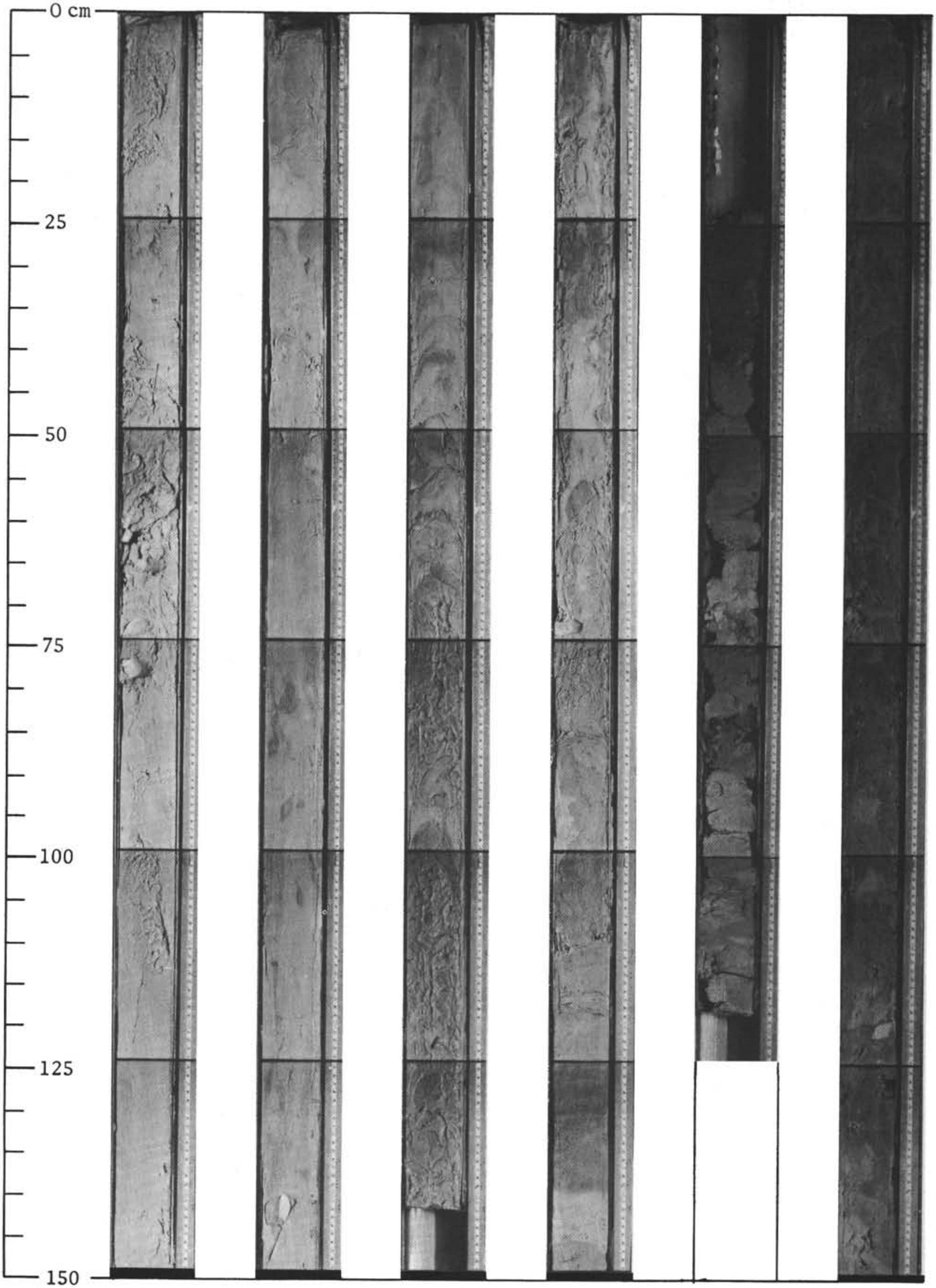
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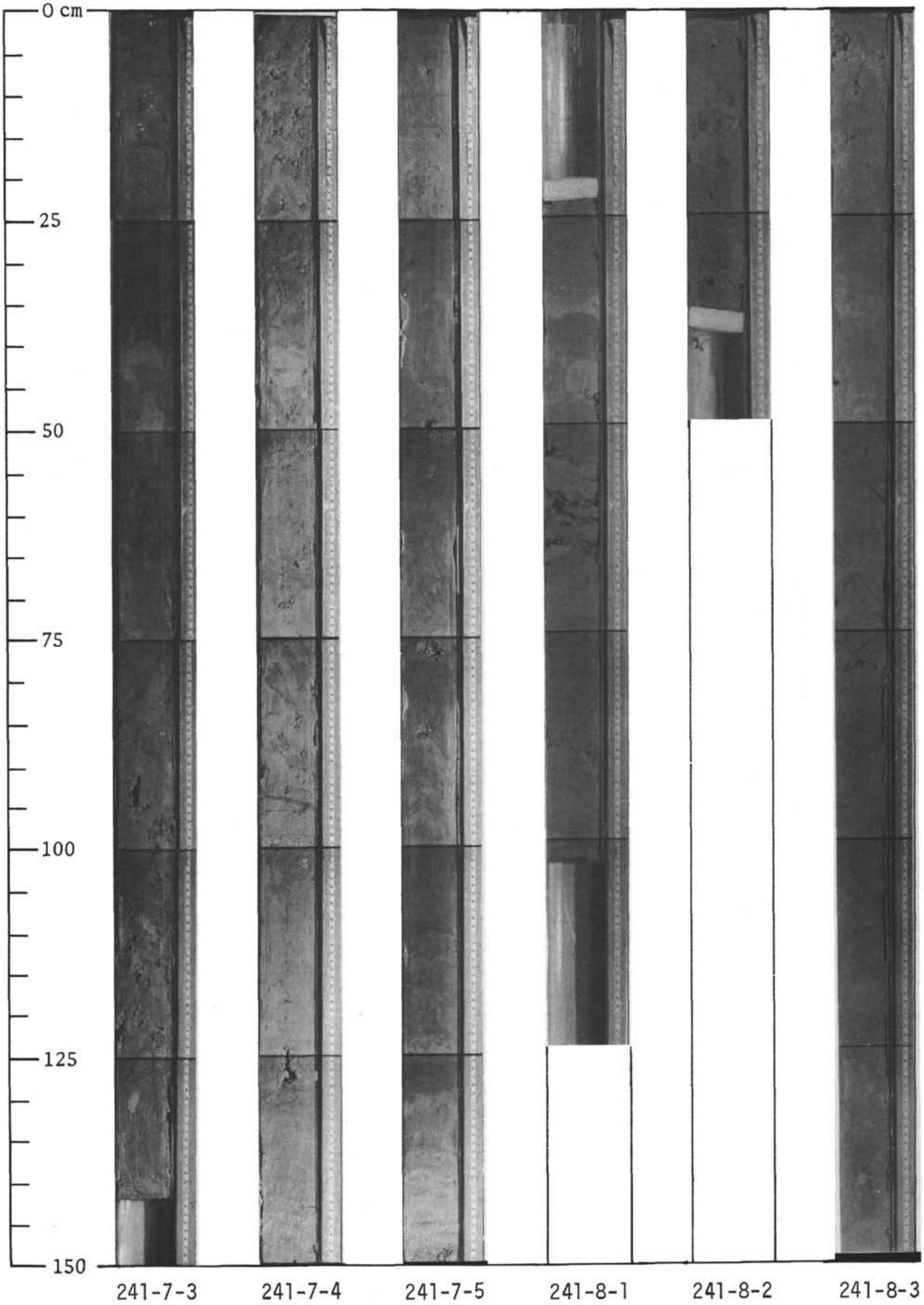
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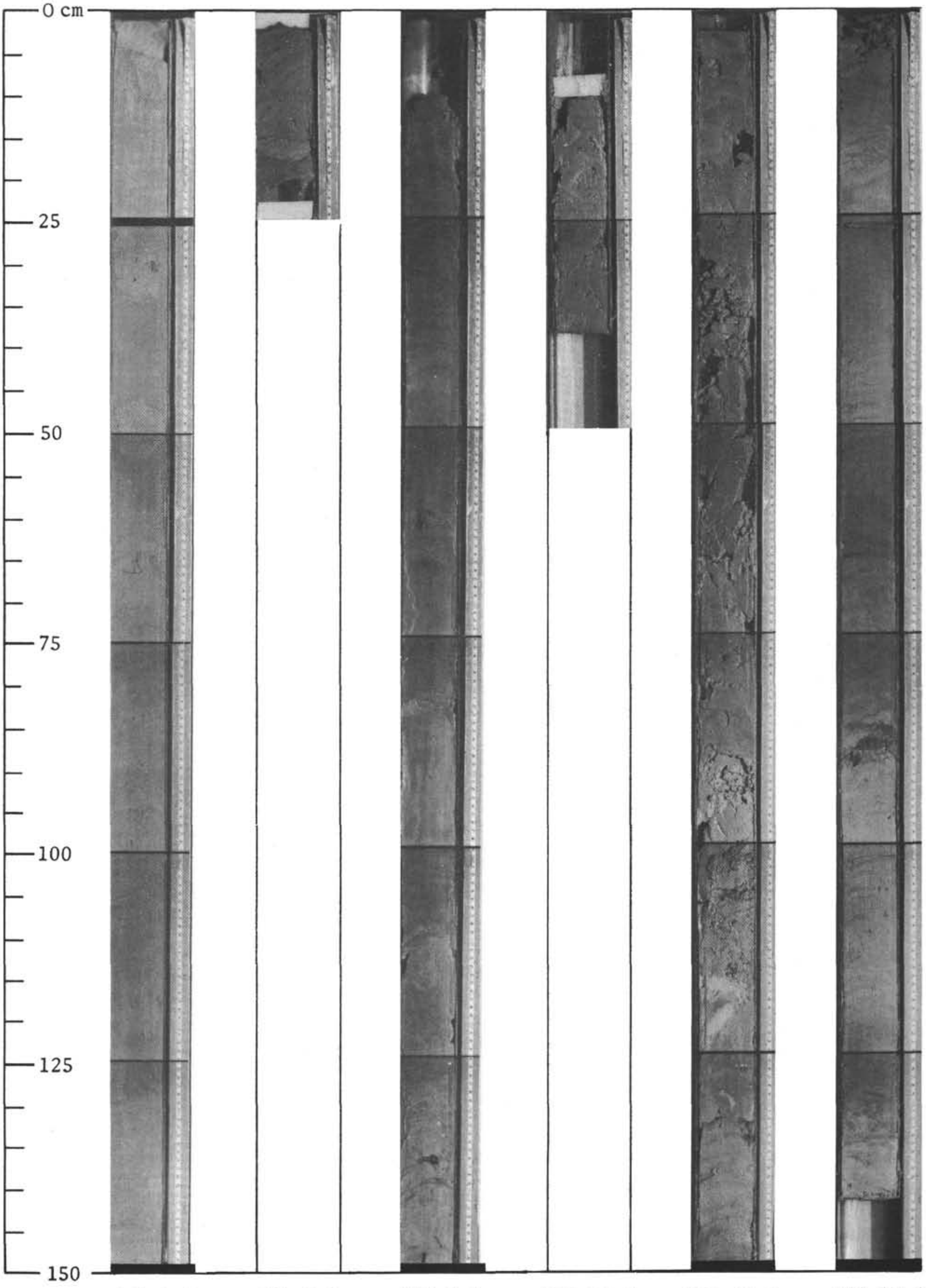
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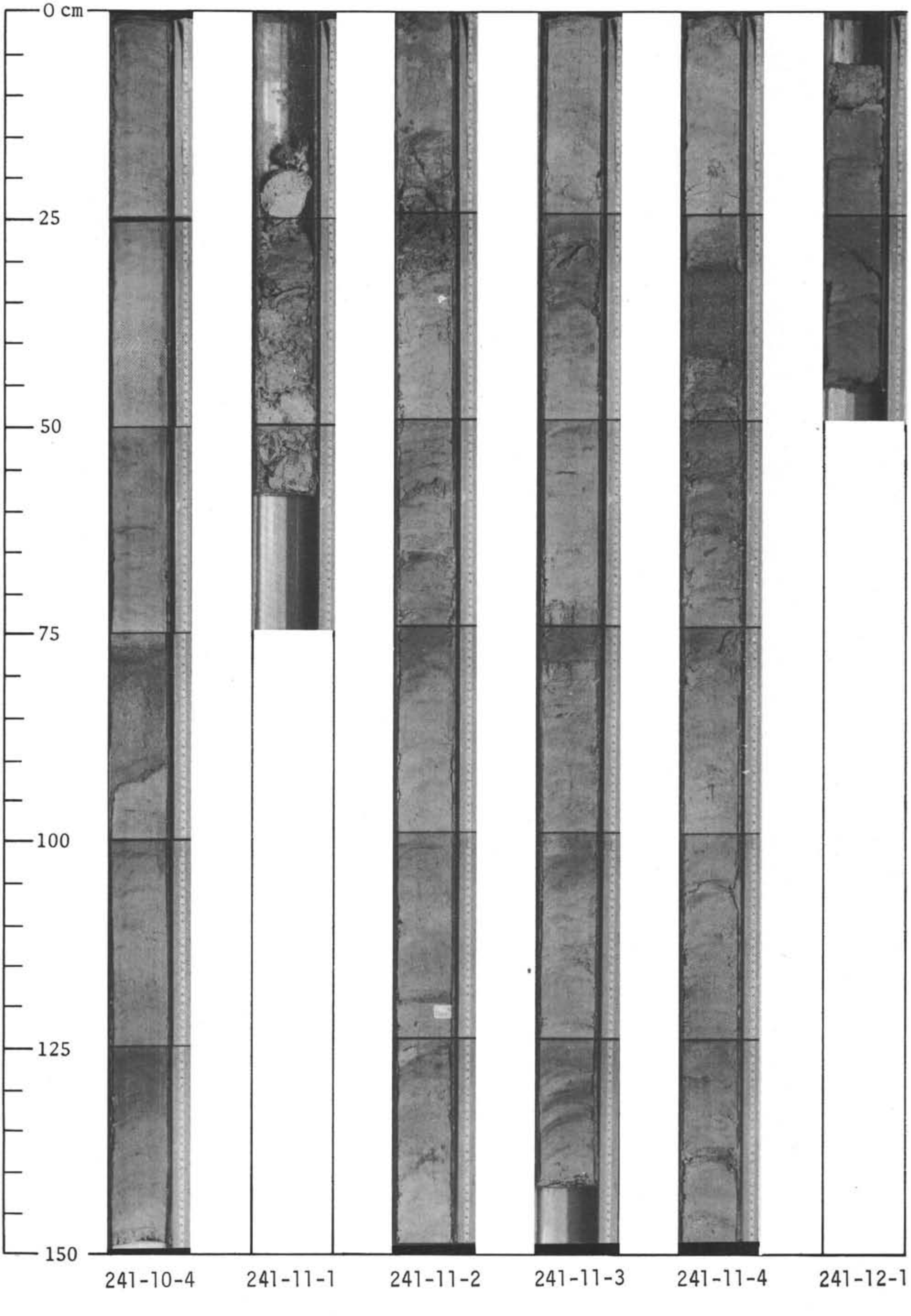
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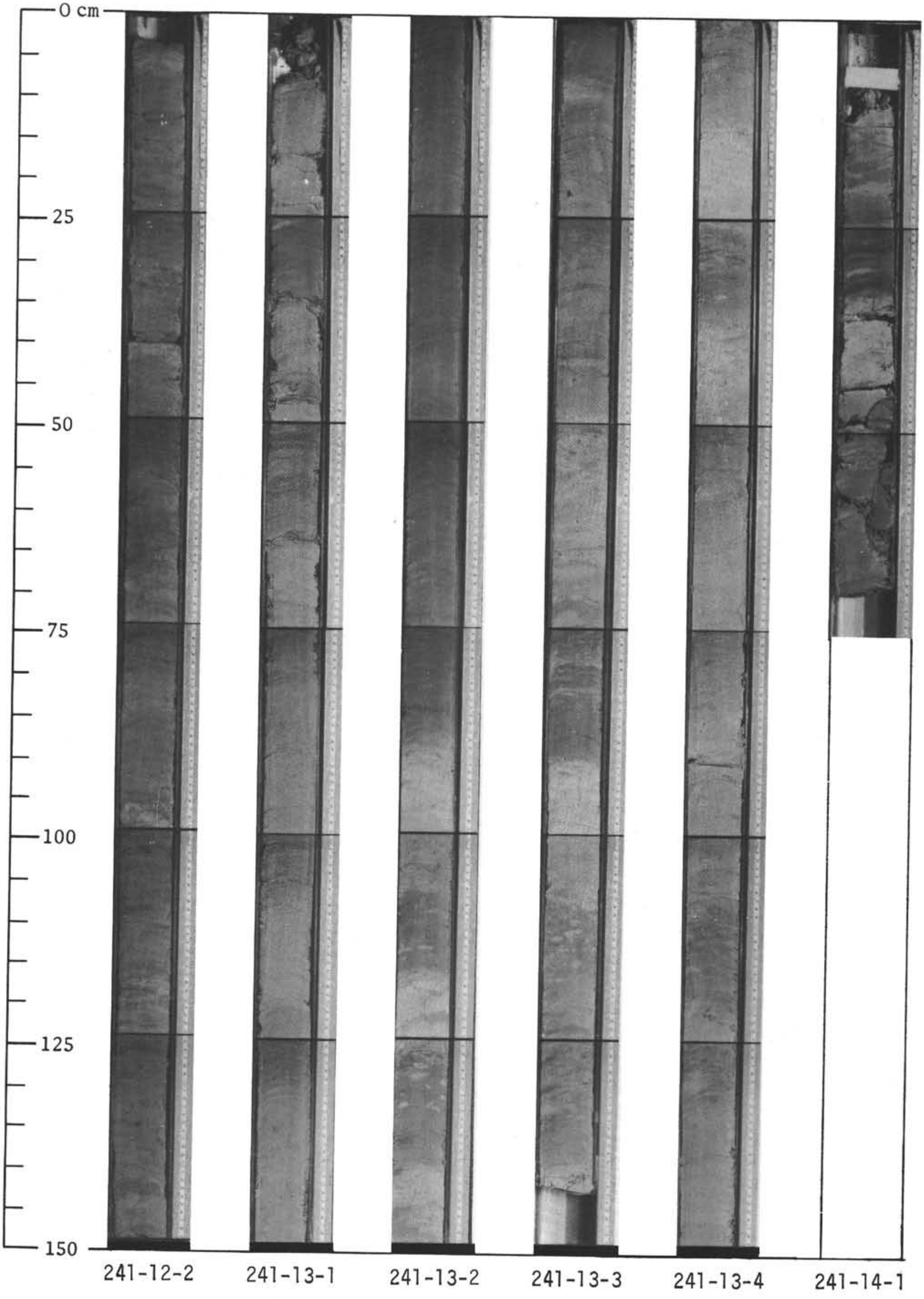
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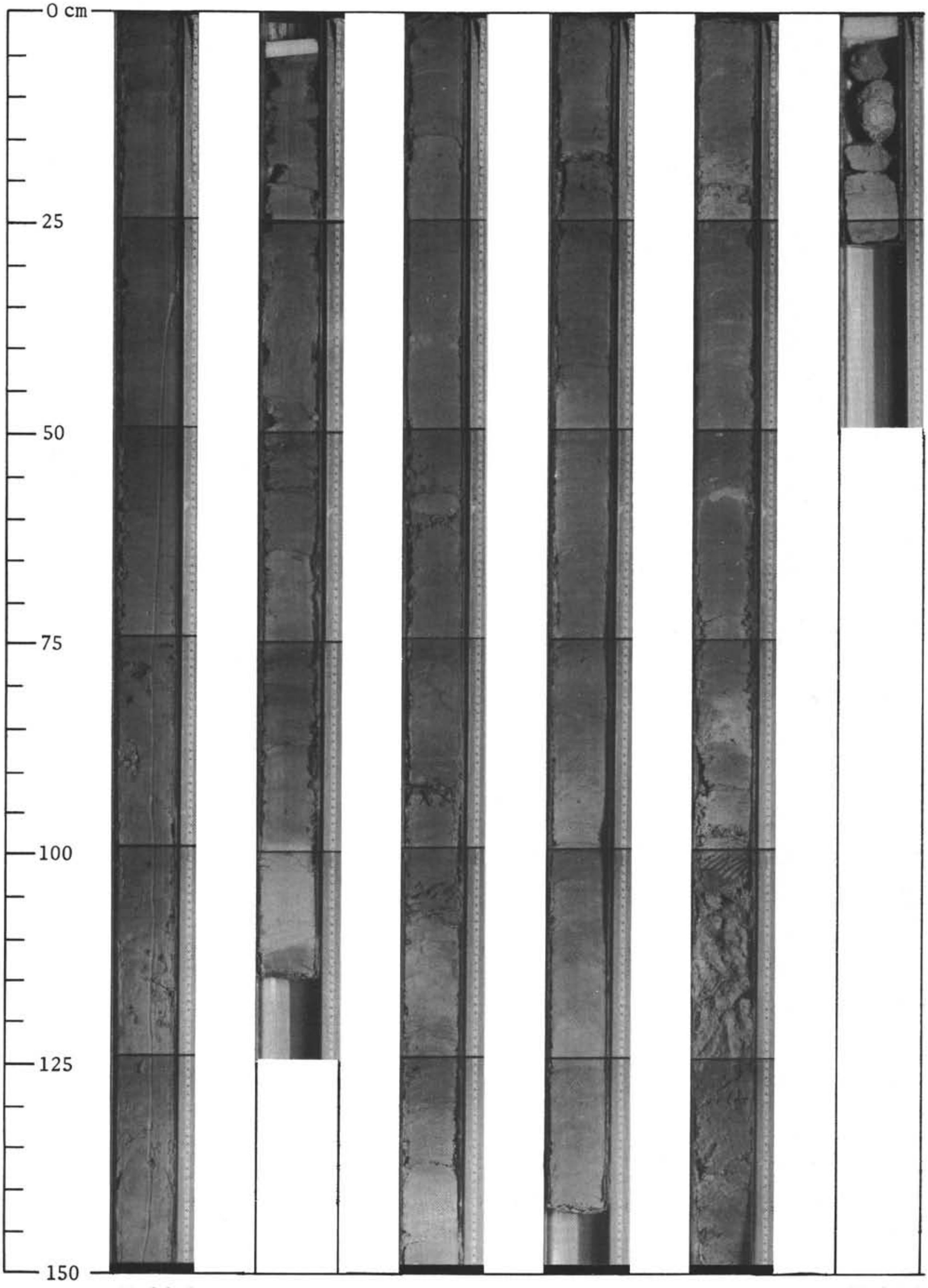

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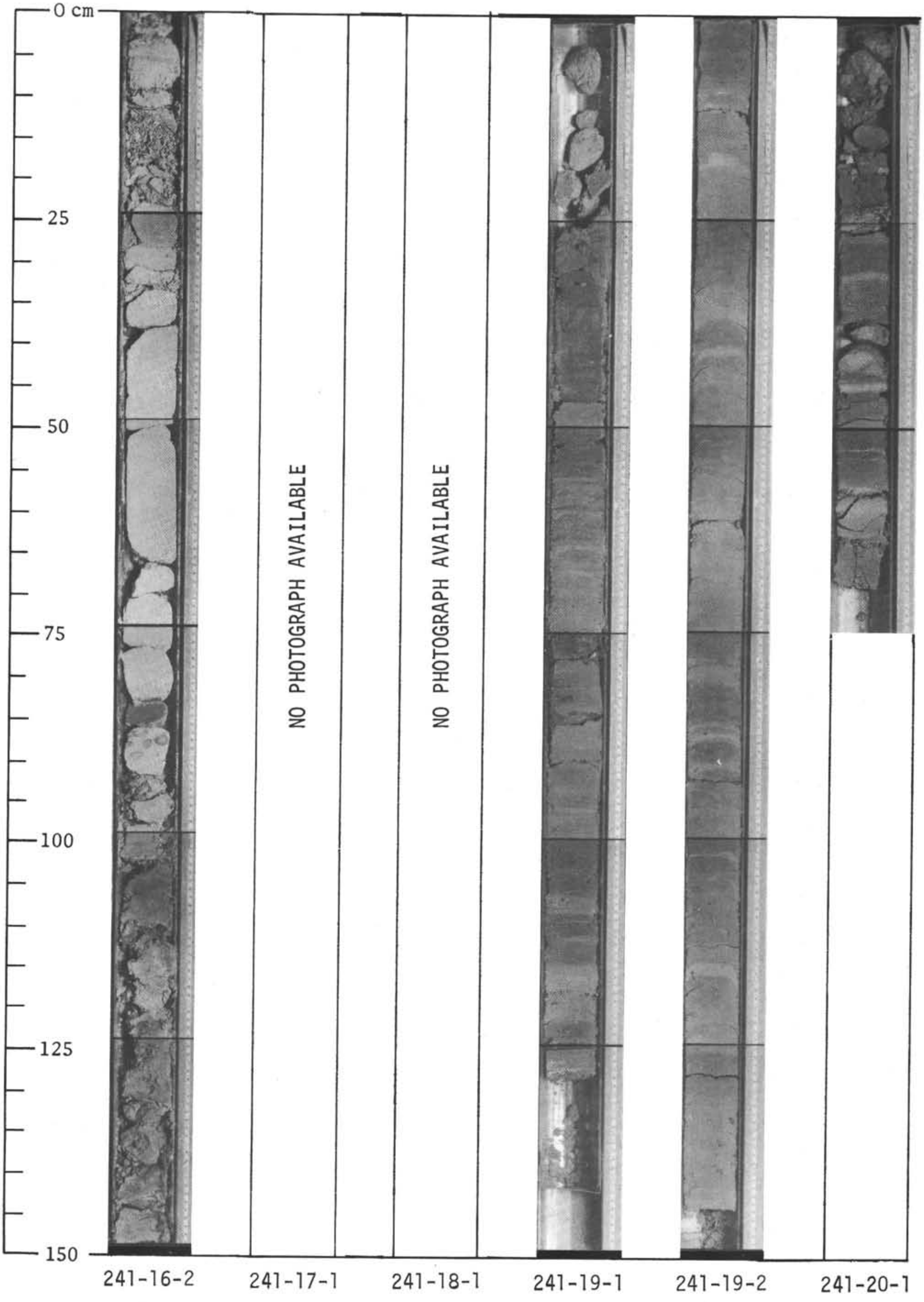
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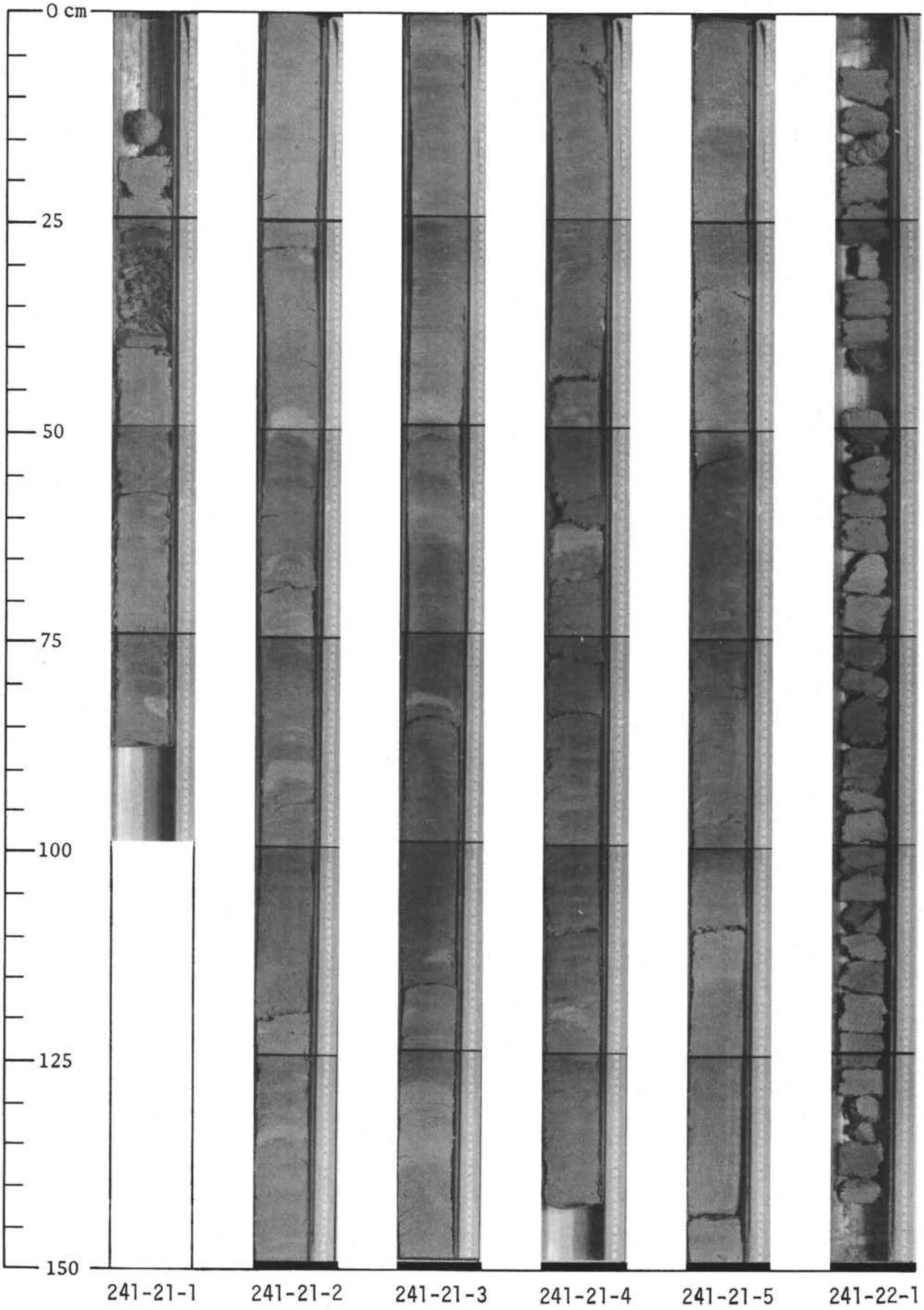
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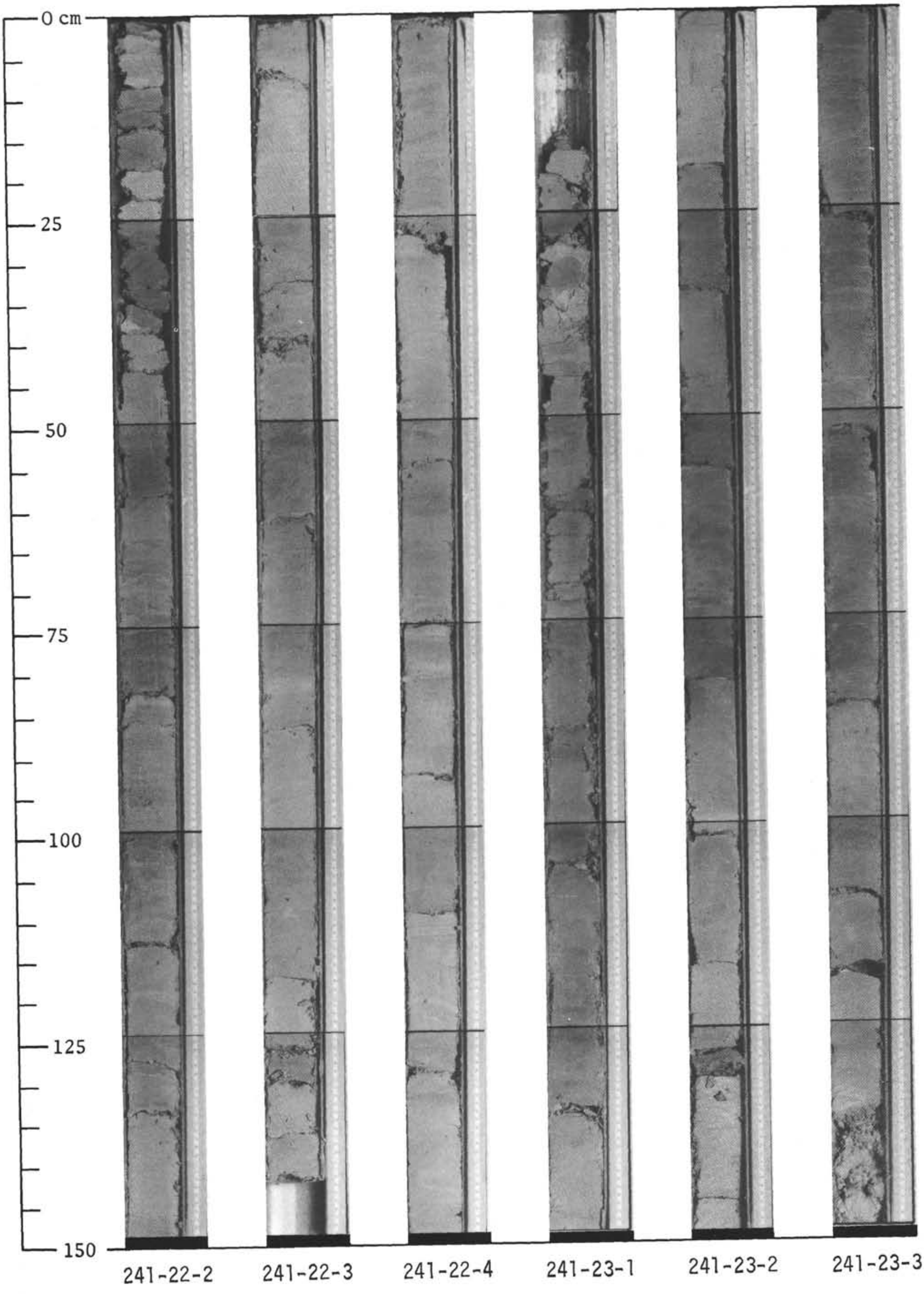
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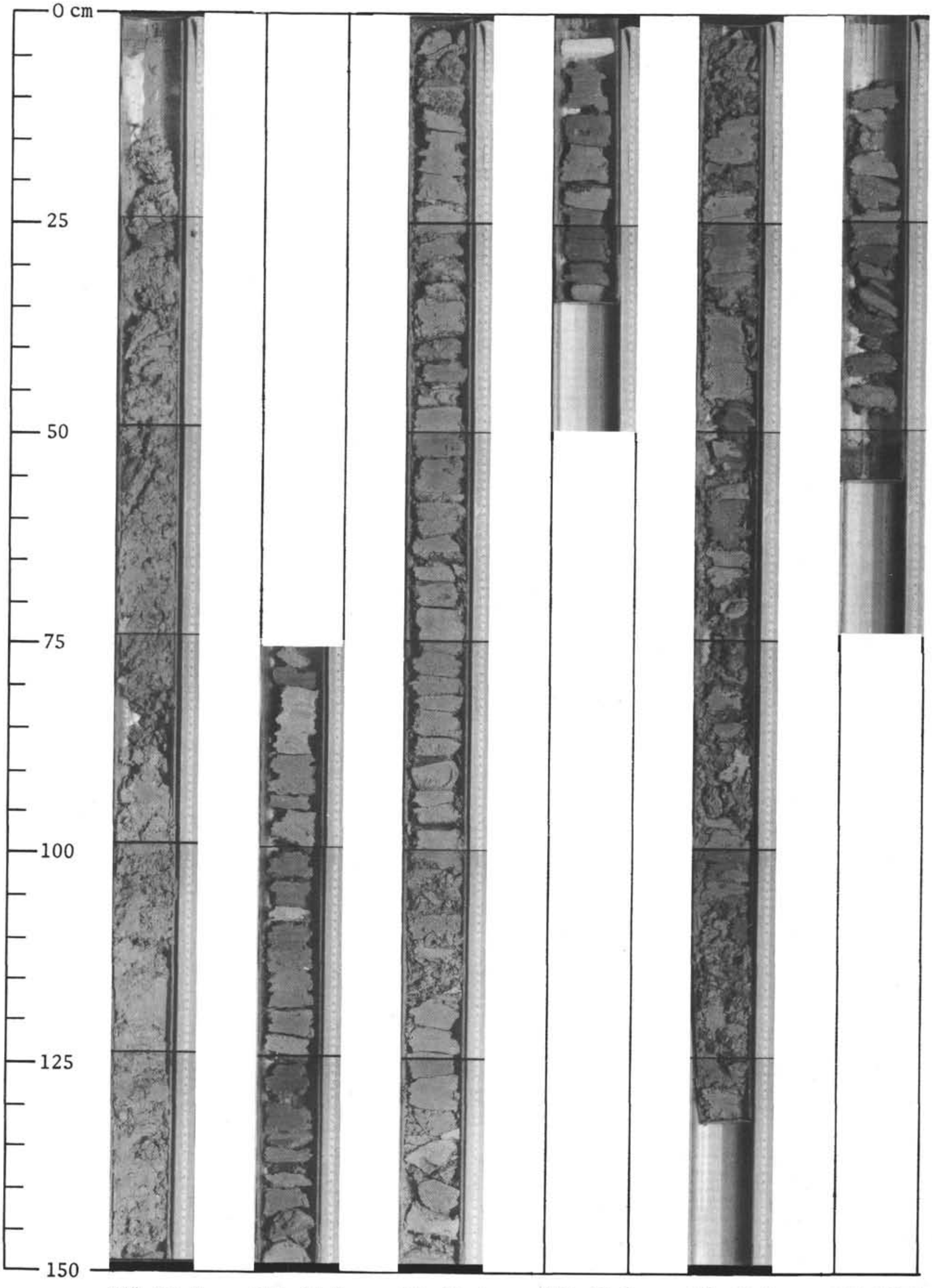
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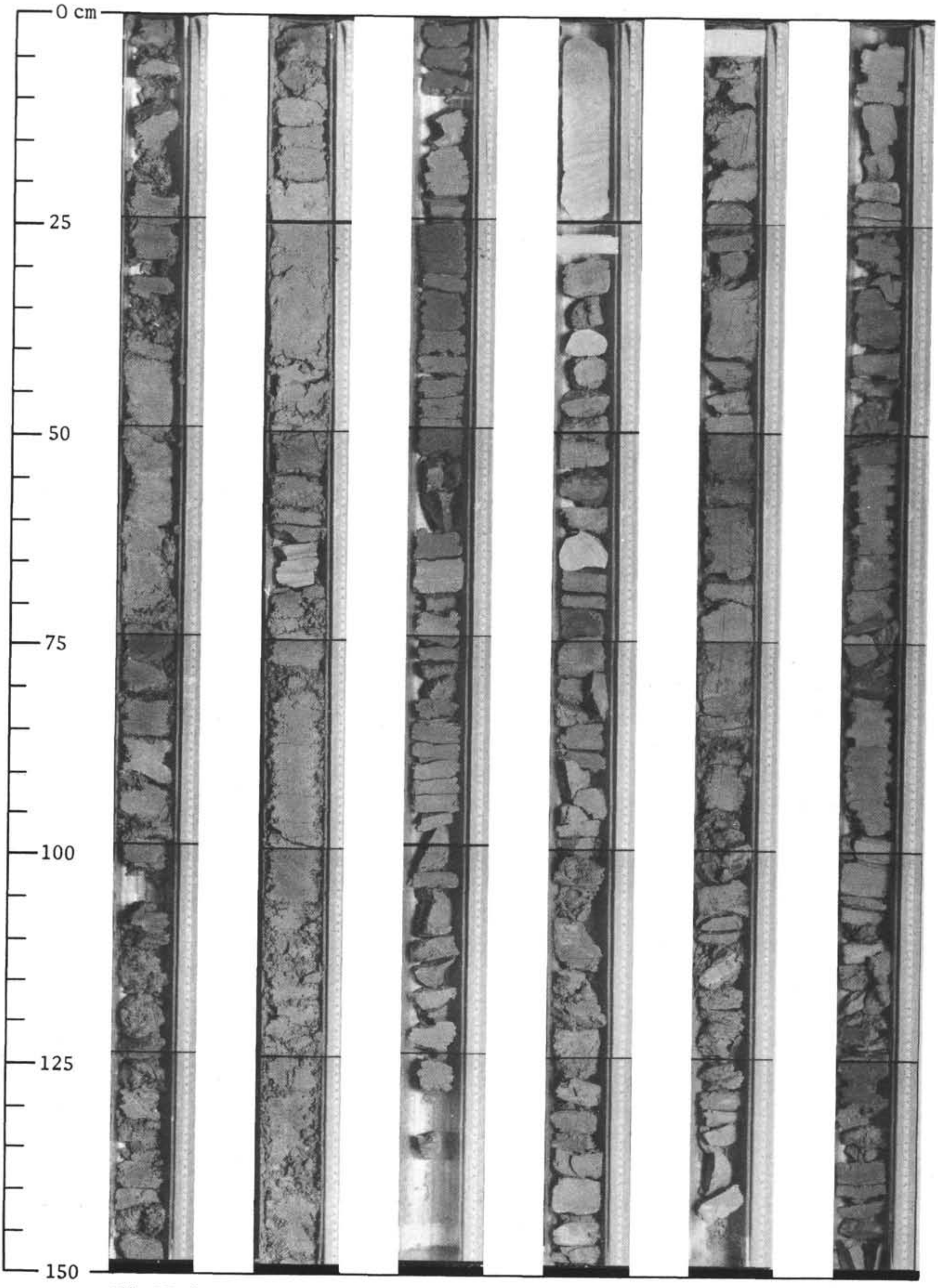
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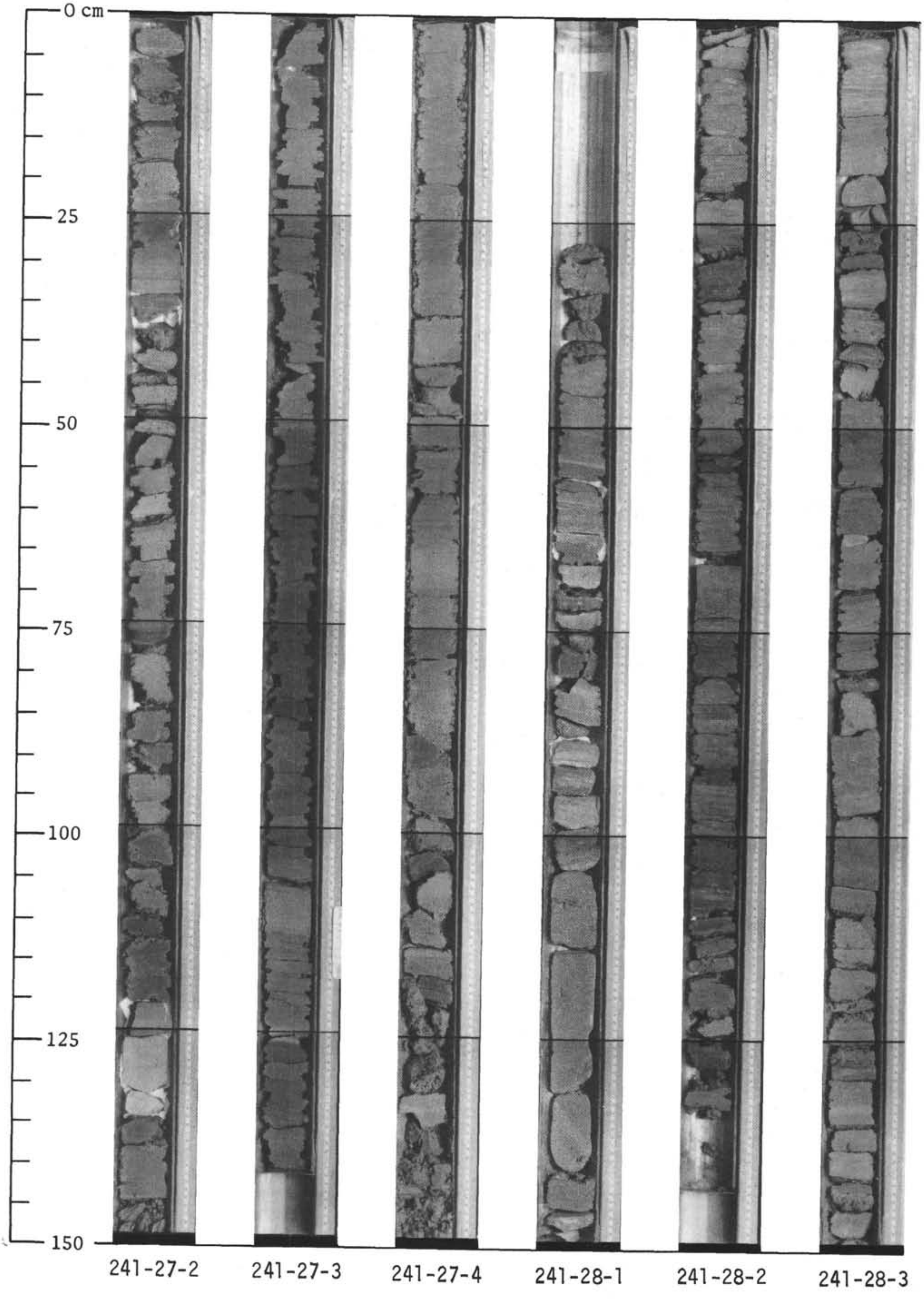
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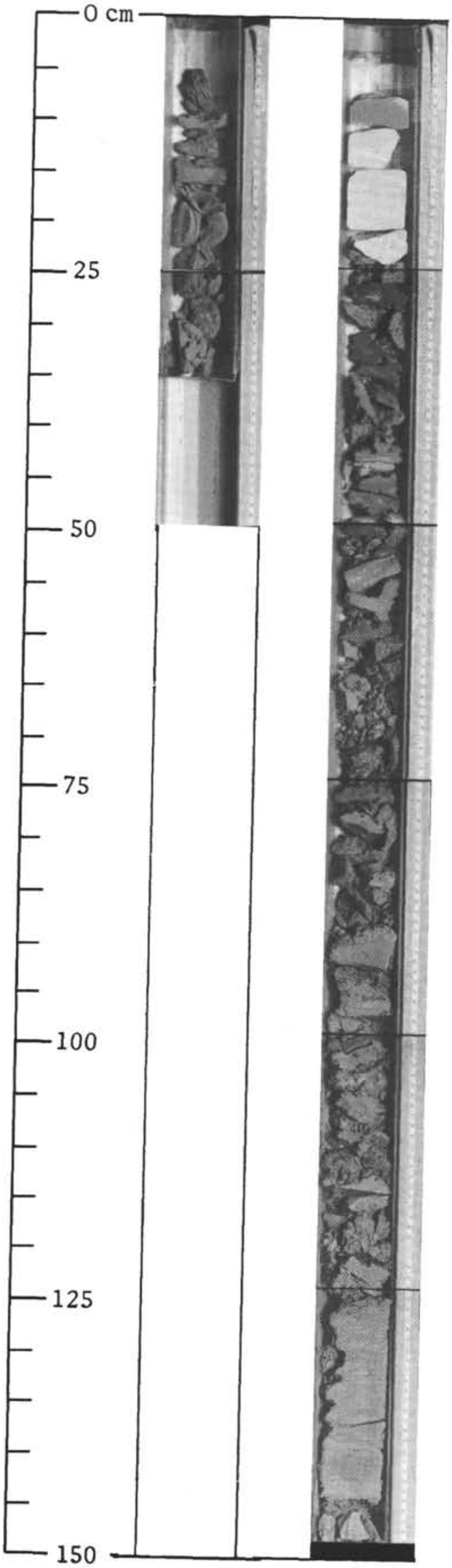
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