9. SITE 209

The Shipboard Scientific Party[1]
With Additional Contributions From
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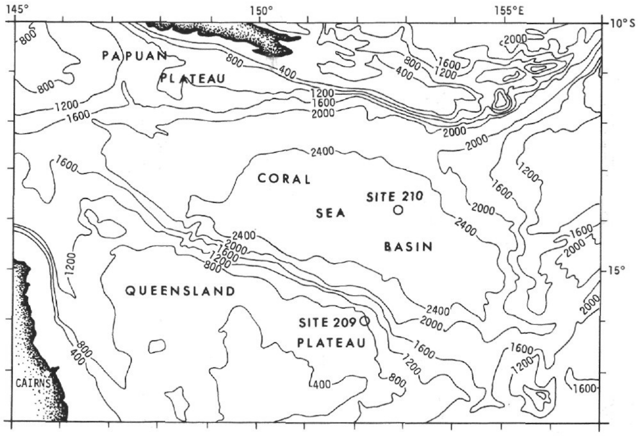
Location: Queensland Plateau
Position: 15°56.19'S, 152°11.27'E
Water Depth: 1428 meters
Total Penetration: 344 meters



Contour interval 400 fathoms. (After Mammerickx, Chase, Smith, and Taylor, 1971. Bathymetry of the South Pacific, Charts 11 and 12: Scripps Institution of Oceanography, California.)

Summary: Foraminiferal ooze and nannofossil ooze overlie the regional unconformity (late Oligocene/late Eocene) below which is sand-bearing foraminiferal ooze and chert. The prominent regional acoustic reflector has been identified as a late Eocene chert horizon. Terrigenous detrital sands and silts are a prominent component of the middle Eocene glauconite-bearing calcareous silty sandstone to sandy siltstone in which the hole was terminated.

BACKGROUND AND OBJECTIVES

General

Site 209 was proposed to examine the age and structural history of the Queensland Plateau, the relationship of the plateau to the adjoining Coral Sea Basin, and to provide a biostratigraphic sequence from this subequatorial portion of the region traversed by Leg 21.

Prior to site survey, several seismic profiles had been run over the plateau, and the regional continuity of the prominent acoustic reflector had been established. Site survey was conducted by R/V *Kana Keoki*, and data from the survey were the principal sources of information for selecting the specific drilling site.

Review of the proposed site by the JOIDES Panel on Pollution Prevention and Safety indicated that the site and the drilling program were satisfactory with continuous coring, moderate drilling precautions, and standard abandonment procedures.

Site Survey

The site survey for Site 209 was conducted by the R/V *Kana Keoki* in September 1971 and covered a section of the outer plateau and the slope break (Figure 1). Prior to the site survey, several seismic, reflection profiles across the Queensland Plateau (e.g., Ewing et al., 1970) had established the regional continuity of a prominent reflector at an average of 0.25 sec subbottom. Profiles obtained during the site survey (Figure 2) show this reflector and several others giving rise to a regularly layered appearance of the plateau. Many of these reflectors crop out at the plateau margin (see Figures 1 and 3), and the depth of the prominent regional reflector outcrop is an approximately 2000 meters of water. The pattern of exposure suggests slumping of blocks

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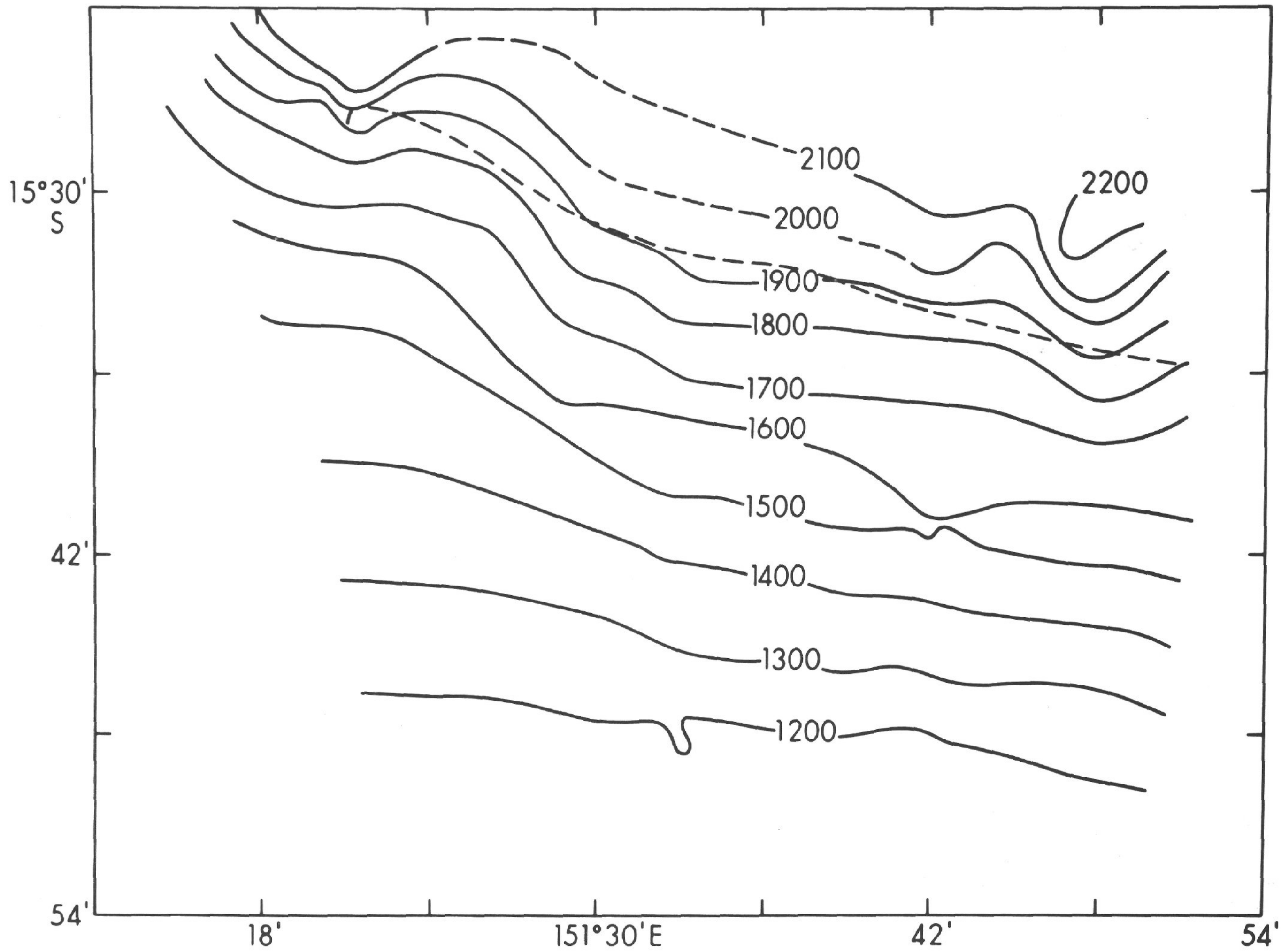

Figure 1. *Bathymetry of proposed area of Site 209. Outer margin of the Queensland Plateau. Dashed line marks outcrop of 0.25 sec reflector. Actual site was occupied to the southeast of this area.* Kana Keoki *site survey September 1971.*

with glide planes on several of the horizons. In the northeast corner of the site survey area is a small reentrant. This appears to be a slump scar on the 0.25-sec reflector which may have acted as a submarine canyon which channeled shallower debris off the plateau. An indistinct basement reflector occurs at depths of 0.75 to 1.00 sec subbottom throughout the surveyed area, rising irregularly to within 0.35 sec of the sea floor.

OPERATIONS

Site Approach

The drilling site was selected on the *Kana Keoki* track to the original site survey at a point at which the acoustic basement rose to within 0.38 sec subbottom, and the 0.25-sec reflector was clearly defined. Site approach (Figure 4) was along the *Kana Keoki* track on a course of 320°T. The beacon was dropped underway after an initial crossing to verify the site structure. The basement reflector becomes much deeper south of the site.

Sonobuoy

The Site 209 sonobuoy record (Figure 5) is considerably more reflective than the underway profiles. Reflectors are generally strong, and all major ones are picked up at the low frequency settings (10 to 40 Hz). The acoustic basement (Reflector 5) and the 0.25-sec reflector (Reflector 4) give the strongest signals. These are broad bands 0.1 to 0.2 sec thick. On the 20 to 160 Hz setting the basement reflector shows closely spaced signals (whether real or reverberation cannot be determined) to a depth of over 1.0 sec subbottom. The character of these signals suggests the horizons represent marked changes in acoustic impedance and that they may well be layer structures–presumably

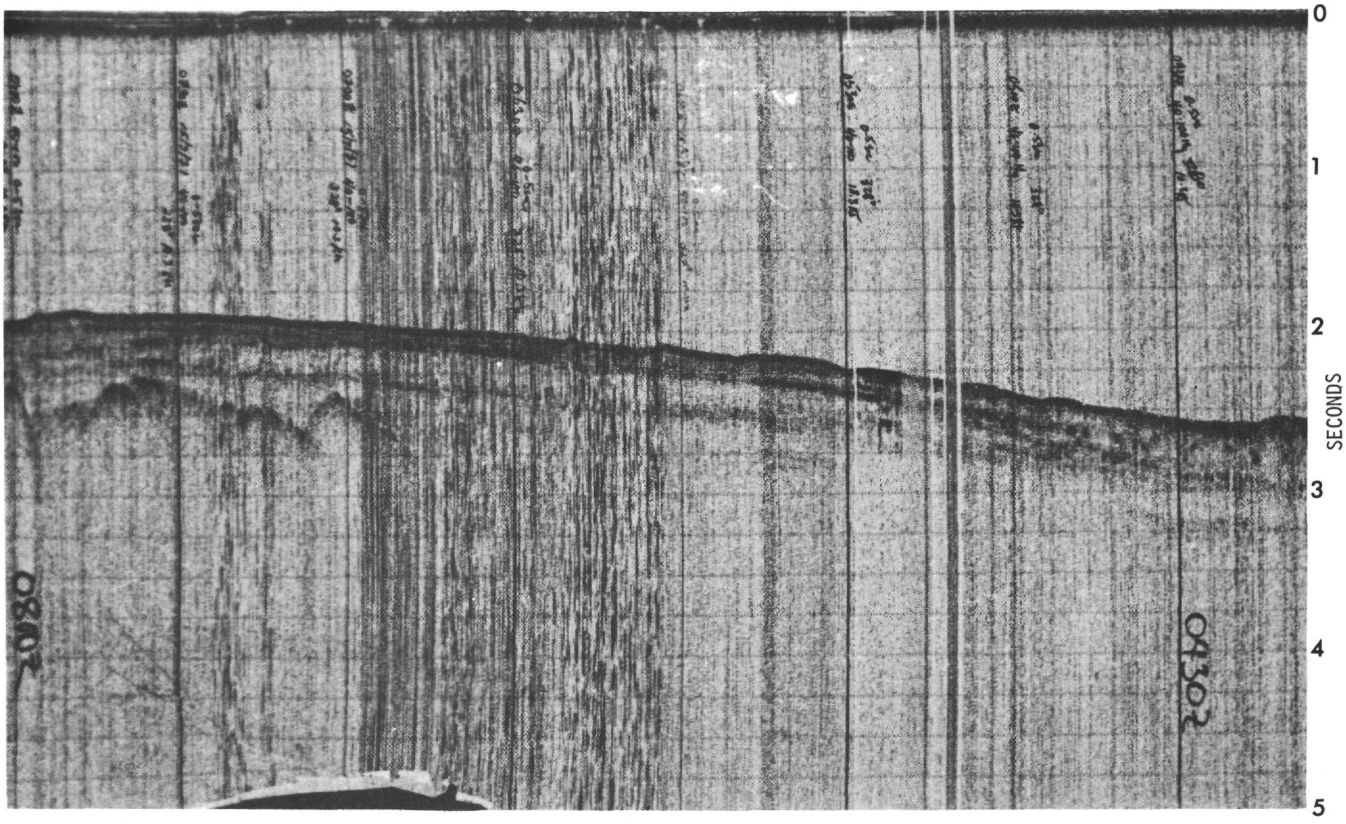

Figure 2. *Seismic profile from* Kana Keoki *site survey showing Plateau structure.*

lithified sediments. Table 1[2] summarizes the sonobuoy data and initial interpretations.

Drilling Program

The first core (Table 2) was aboard at 1010 on 28 December, and a continuous coring routine was established following the recommendations of the Safety and Pollution Prevention Panel. Recovery was good down to 54 meters following which practically no recovery was made for the interval 54 to 119 meters. The sediment in this interval was a well-sorted foraminiferal ooze which appears to flow as a fluid when wet. Because of the negligible recovery, an alternation of wash and core was run through the interval 119 to 196 meters with very slight improvement in recovery. At 196 meters the continuous coring routine was reestablished and was continued to the bottom of the hole at 344 meters.

The string was then retracted to the mud line, and Hole 209A was spudded at 1515 on 29 December. This was to test the new prototype piston corer. The test was unsuccessful and the corer jammed at the bit. The string was secured and the core (Table 3) returned when the bit was recovered.

Two downhole temperature measurements were made in Hole 209; the planned attempt at 209A was scratched when the piston corer jammed.

The site was abandoned at 2200 on 29 December 1971.

LITHOLOGY

General

Site 209 was continuously cored to a depth of 344 meters below the sea floor. Thirty-four cores were attempted, but 11 of these had no core recovery. The reason for the low core recovery is uncertain but was probably due to a very uneven hardness of the sediments and pumping during the coring process. In addition, the evenly sized foraminiferal ooze that was present in much of the section was probably disaggregated during coring and ran out of the core barrel. In Cores 15, 16, and 20 graded bedding and sorting of cuttings indicate their suspension and settling in the drilling fluid.

The lithology in this hole can be conveniently subdivided into three units. From top to bottom they are:

1) Unit 1 (0 to 140 m)–foraminiferal ooze and nannofossil ooze (late Oligocene to Pleistocene)

2) Unit 2 (140 to 275 m)–sand-bearing foraminiferal ooze and chert (middle Eocene to late Eocene)

3) Unit 3 (275 to 344 m)–sand-rich foraminiferal limestone with secondary chert filling of voids (middle Eocene)

Unit 1 (Foraminiferal Ooze and Nannofossil Ooze)

This unit, penetrated in Cores 1 through 14, forms the upper part of the sequence. The sediment is composed of carbonate with less than 10% insoluble minerals, mostly silt-sized quartz but also including traces of detrital feldspar and volcanic glass.

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[2] Final correlations of sonobuoy profiles using laboratory-measured velocities, other physical properties, and lithologic boundaries are presented in Part II of this Initial Report.

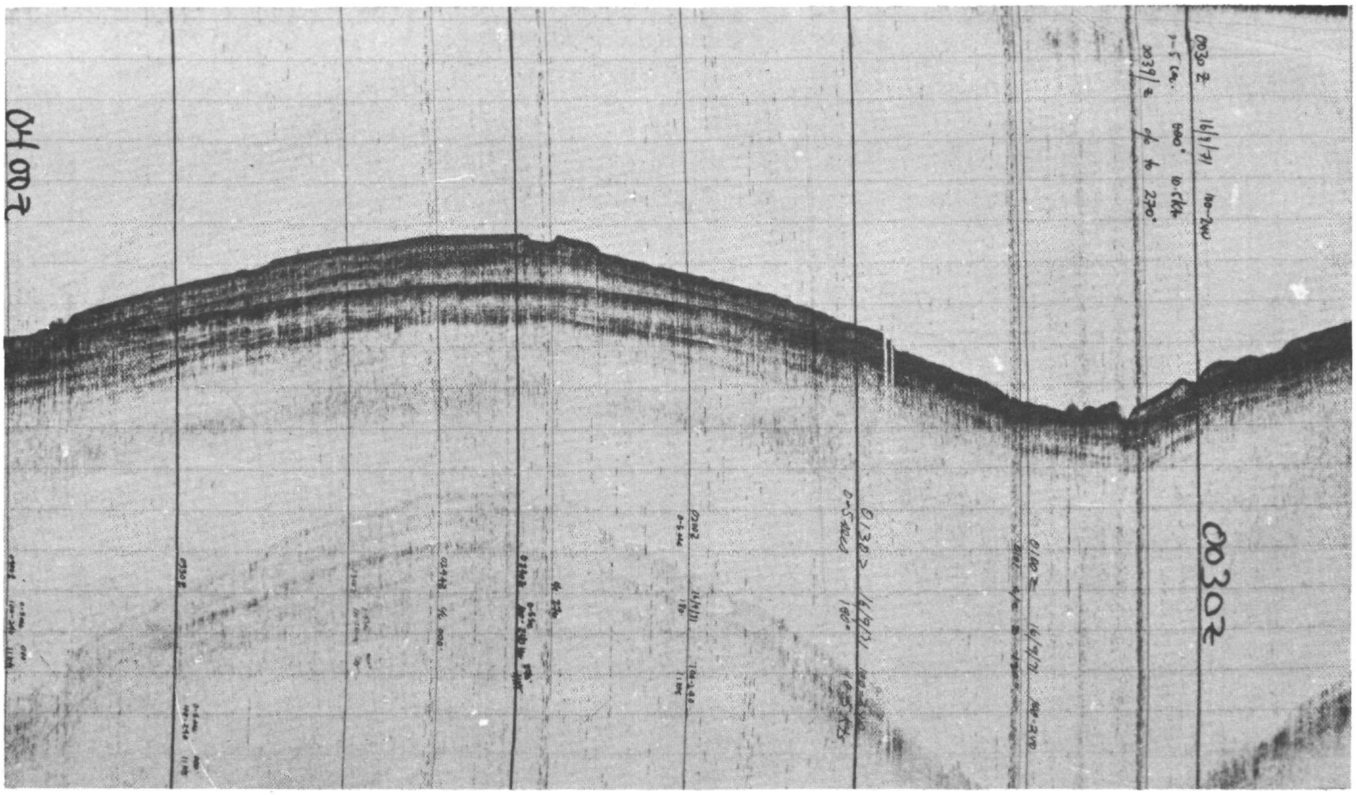

Figure 3. *Seismic profile from site survey showing outcropping of 0.25-sec reflector. R/V* Kana Keoki.

Most of the carbonate grains are sand- and silt-sized fossils. Foraminifera and nannofossils are by far the most abundant, but rare echinoderm, bryozoan, and mollusc fragments are also present. There is a substantial amount of angular sand- and silt-sized carbonate grains that partly represent broken fossils. However, some of the carbonate grains are euhedral (scalenahedra) and probably represent authigenic sparry calcite as overgrowths on clastic grains and fossils and interstitial cement.

Cores 1 and 2 at the top of the hole are very pale orange-grayish orange, while Cores 3 through 5 are white. This color change approximates the Pliocene-Pleistocene boundary.

The part of Unit 1 that lies below Core 6 (the interval 55-145 meters below the sea floor) is composed almost entirely of foraminifera. Nannoplankton form only about 5% of the ooze. The resulting sand-sized sediment is well sorted and may reflect current action that has winnowed out most of the smaller silt-sized nannoplankton. The presence of a few apparently reworked benthonic foraminifera in the predominantly planktonic foraminifera ooze may also reflect transport to the site by bottom currents. Delicate spines preserved on many of the planktonic foraminifera, however, indicate no major bottom transport within the site area. The contact with Unit 2, although not recovered in the cores, appears to be an abrupt lithologic change and seems to correlate with a break in the biostratigraphic record spanning the early and middle Oligocene.

Unit 2 (Sand-bearing Foraminiferal Ooze and Chert)

The samples recovered from this unit (Cores 15 through 27) are believed to represent thin layers of silicified limestone and chert within a generally unlithified section of foraminiferal ooze. In contrast to the overlying essentially pure carbonate sequence, Unit 2 has about 10% to 30% detrital silt and very fine sand grains. Most of these are quartz and feldspar, but both light and dark volcanic glass and amphibole are present. In addition, there are a few grains of bright green glauconite. Routine X-ray analyses indicate substantial quantities of cristobalite, tridymite, and clinoptilolite in the lower part of this unit. Some of the cristobalite may be a product of biogenous opal reacting to form secondary chert. Because of pumping during drilling, it is hard to know which sections are most representative of the softer parts of the unit. Cores 23 through 25 and 27 have homogeneous foraminiferal ooze intervals that seem to be least disturbed and mixed by drilling.

The hard layers are silicified limestone (porcellanite) replaced irregularly by darker (olive gray) chert. Textural details in thin section suggest every step in the process of chert replacement of foraminiferal ooze may be present. The original bioclastic texture is preserved to some degree in all of the chert. A biogenic origin for the chert is likely as

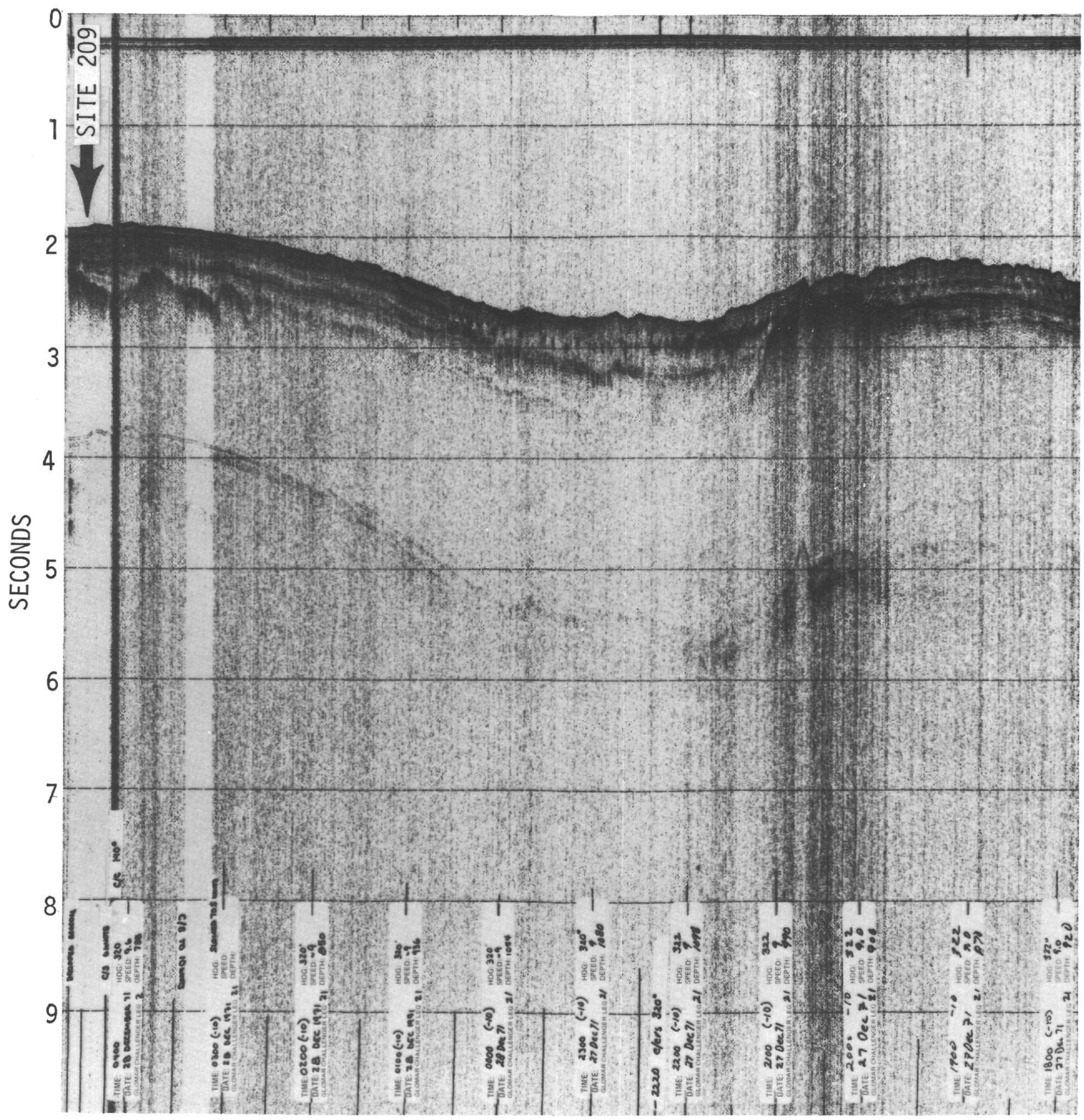

Figure 4. *Seismic profile along approach to Site 209.* Glomar Challenger *December 1971.*

there are abundant siliceous sponge spicules in Cores 23 and 24 of the unit.

Unit 3 (Sand Foraminiferal Limestone with Secondary Chert Filling of Voids)

The contact between Units 2 and 3 seems to be gradational with a downward increase in detrital silt and sand from Core 27. Unit 3 is composed of more than 50% noncarbonate material, mainly secondary chert (including colloform opal, microcrystalline quartz, cristobalite, and tridymite) but including up to 15% very fine grained sand and silt. Like the overlying unit, the carbonate fraction is composed of foraminifera, nannofossils, broken shelly fossils, and microcrystalline and sparry calcite cement. Most of the detrital sand grains are quartz and feldspar. Most of these grains are subangular, and some of the grains have impurities suggesting a terrigenous, rather than subaerial explosive volcanic origin.

Grains of glauconite, hornblende, dark and light volcanic glass, devitrified glass, together with argillaceous material, give the rock a graying olive to dusky yellow green color that is darker than that of the overlying more calcareous unit.

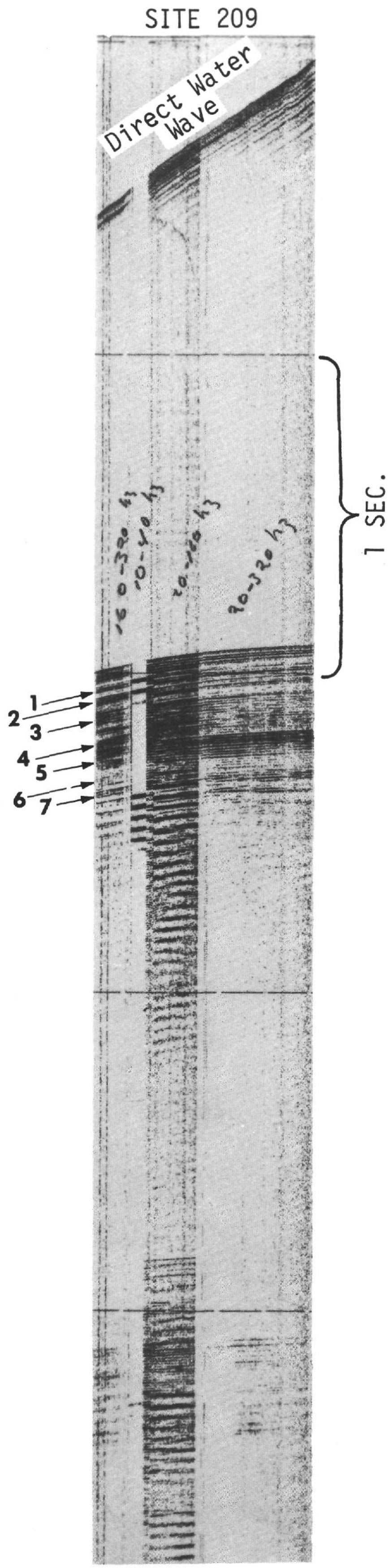

Figure 5. *On-site sonobuoy profile at Site 209.*

TABLE 1
Site 209 Sonobuoy Data

Reflector	Depth (sec)	Nature	Estimated Velocity Structure (m/sec)	Estimated Depth (m)
1	0.08	Strong, good low frequency	1500	60
2	0.12	Strong, good low frequency	1500	90
3	0.21	Strong, good low frequency	1500	157
4	0.25	Very strong, good low frequency, regional reflector	2500	207
5	0.31	Moderate, no low frequency	2500	282
6	0.38	Very strong, good low frequency, acoustic basement	4000	422

Sequence of Geologic events Interpreted from Lithology

Late Middle Eocene

Deposition in relatively shallow water (probably on the continental margin) of bioclastic (sediment) rich in foraminifera and containing subordinate terrigenous silt and sand. The presence of glauconite grains with authigenic mammillary-shaped surfaces indicates a marine origin in water depths less than 100 fathoms (Williams, Turner, and Gilbert, 1954). The fresh glass suggests volcanic ash showers from volcanoes of intermediate composition. On the other hand, some of the more altered volcanic detritus and rounded quartz may have come from land.

Latest Middle Eocene through Late Eocene

Gradual deepening of the site of deposition and reduction of terrigenous detritus reaching the site. Development of pelagic oozes mainly composed of sand-sized planktonic foraminifera. Some fragments of larger echinoderms, molluscs, and bryozoa were transported to the site. Silt-sized nannoplankton possibly winnowed out by same currents. Secondary silicification and replacement of ooze by chert in late Eocene or later.

Late Eocene to Late Oligocene

Nondeposition or very slight submarine erosion.

Late Oligocene to Late Middle Miocene

Further deepening of water and deposition of almost pure foraminiferal ooze. Some marine currents transporting shallower water benthonic foraminifera to site and winnowing out all but a small amount of nannoplankton.

TABLE 2
Coring Summary – Hole 209

Core	Date	Time	Depth from Drill Floor (m)	Depth Below Sea Floor (m)	Cored (m)	Recovered (m)	Recovery (%)
1	12/28	1010	1438-1447	0-9	9	9.2	100
2	12/28	1050	1447-1456	9-18	9	8.4	93
3	12/28	1130	1456-1465	18-27	9	9.0	100
4	12/28	1220	1465-1474	27-36	9	8.2	91
5	12/28	1255	1474-1483	36-45	9	6.8	76
6	12/28	1325	1483-1492	45-54	9	9.3	100
7	12/28	1415	1492-1501	54-63	9	0.0	0
8	12/28	1500	1501-1510	63-72	9	0.0	0
9	12/28	1545	1512-1521	74-83	9	0.5	6
10	12/28	1646	1521-1530	83-92	9	0.0	0
11	12/28	1730	1530-1539	92-101	9	0.0	0
12	12/28	1820	1539-1548	101-110	9	0.0	0
13	12/28	1900	1548-1557	110-119	9	0.0	0
14	12/28	1950	1569-1578	131-140	9	2.1	23
15	12/28	2035	1588-1597	150-159	9	1.0	11
16	12/28	2125	1606-1615	168-177	9	2.4	27
17	12/28	2245	1625-1634	187-196	9	1.1	12
18	12/28	2345	1634-1643	196-205	9	1.0	11
19	12/29	0050	1643-1652	205-214	9	0.0	0
20	12/29	0150	1652-1661	214-223	9	1.5	17
21	12/29	0255	1661-1670	223-232	9	0.7	8
22	12/29	0355	1670-1679	232-241	9	0.0	0
23	12/29	0450	1679-1688	241-250	9	3.0	33
24	12/29	0550	1688-1697	250-259	9	1.3	14
25	12/29	0625	1697-1706	259-268	9	1.5	17
26	12/29	0700	1706-1710	268-272	9	0.0	0
27	12/29	0745	1710-1719	272-281	9	1.9	21
28	12/29	0840	1719-1728	281-290	9	3.9	43
29	12/29	0925	1728-1737	290-299	9	0.6	7
30	12/29	1010	1737-1746	299-308	9	0.0	0
31	12/29	1120	1746-1755	308-317	9	0.8	9
32	12/29	1215	1755-1764	317-326	9	0.2	2
33	12/29	1310	1764-1773	326-335	9	0.0	0
34	12/29	1410	1773-1782	335-344	9	2.3	26
Total					301	76.7	25

Note: Echo sounding depth (to drill floor) = 1438 meters;
drill pipe length to bottom = 1438 meters.

TABLE 3
Coring Summary – Hole 209A

Core	Date	Time	Depth from Drill Floor (m)	Depth Below Sea Floor (m)	Cored (m)	Recovered (m)	Recovery (%)
1	12/29	2130	1438-1447	0-9	9	2.2	24

Note: Only core attempted. Echo sounding depth (to drill floor) = 1438 meters;
drill pipe length to bottom = 1438 meters.

Late Middle Miocene to Middle Pliocene

Nondeposition or very slight submarine erosion.

Middle Pliocene to Recent

Continued deepening of water to present 1438 meter depth. Decrease in oceanic currents permitting higher proportion of nannoplankton/planktonic foraminifera than in the Miocene or earlier.

BIOSTRATIGRAPHY

General

Site 209, which reached a subbottom depth of 344 meters, represents an incomplete late middle Eocene to late Pleistocene sequence. Interpretation of the sequence is somewhat complicated by poor core recovery, the presence of cherts, downhole contamination, and poorly preserved microfossils at certain intervals.

Three factors of general interest are as follows: (1) The presence of an unconformity representing the middle and early Oligocene that is of regional significance, having also been found in Sites 206, 207, 208, and 210. (2) A record of substantial and possibly progressive deepening from the middle Eocene to the late Pleistocene, due to tectonic subsidence of this part of the Queensland Plateau. (3) The presence of an excellent sequence of well-preserved, abundant calcareous microfossils of middle Pliocene to late Pleistocene age.

The three following biostratigraphic units are recognizable, each separated by sedimentary breaks:

1) Late Pleistocene to middle Pliocene (209-1 to 209-5, CC) containing abundant, well-preserved planktonic foraminifera and common, moderately preserved calcareous nannofossils but lacking Radiolaria.

2) Late middle Miocene to late Oligocene (209-6-1 to 209-14, CC) containing abundant, moderate to well-preserved planktonic foraminifera and low frequencies of moderately to poorly preserved calcareous nannofossils. Radiolaria are also absent in this interval.

3) Late Eocene to late middle Eocene (209-15-1, 75 cm to 209-34, CC) containing rather poor faunas of planktonic foraminifera and rare, poorly to moderately preserved nannofloras. Radiolaria are present in two samples of late Eocene age.

Paleodepth Interpretation

Distinct upward deepening is evident within this middle Eocene to Pleistocene sequence.

Middle to late Eocene sediments, in general, contain a benthonic foraminiferal assemblage—Discorbids, Polymorphids, *Rectuvigerina,* and *Cibicides* (compressed)—indicative of upper bathyal to outer sublittoral depths. No deeper-water forms are present. Planktonic foraminifera are much less abundant than in younger sediments, further supporting the implied relatively shallow depths of deposition. Echinoid spines are common, and bryozoan fragments occur in some samples. The presence of the characteristically neritic calcareous nannofossils *Discolithina* and *Braarudosphaera*, especially in the middle Eocene, represents further strong evidence of moderately shallow depths. A gradual change to more open oceanic conditions in the late Eocene is suggested by the gradual reduction of these near-shore calcareous nannofossils. An absence of Radiolaria, which are alsmot exclusively of open-ocean habitat, in the middle Eocene can be attributed to the shallow-water character of these sediments. Drilling at the previous sites has demonstrated that Radiolaria are particularly abundant in sediments of this age, and thus their absence at this site is related to local conditions.

Reworked benthonic foraminifera occur in the late Oligocene sediments, and depth analysis is difficult without additional studies. The much greater abundance of planktonic foraminifera compared with underlying sediments suggests deeper, more open-ocean conditions. Very low frequencies of calcareous nannofossils are probably due to winnowing by bottom currents.

Further deepening to the late middle Miocene is suggested by benthonic foraminiferal assemblages clearly indicative of upper bathyal depths (*Planulina, Ehrenbergina, Textularia, Saracenaria, Pullenia bulloides,* and hispid *Uvigerina*; lack of shallow-water forms; lack of deeper-water forms). Additional support for bathyal depths is the presence of an abundant planktonic foraminiferal fauna.

Pliocene-Pleistocene benthonic foraminifera (hispidocostate and hispid Uvigerinids; *Gyroidina* (large), *Pleurostomella, Cibicides* (rounded), *Oridorsalis,* and *Eggerella*; lack of shallower forms) reflect even further deepening to that of the present day (approximately 1400 meters). Thus considerable, and possibly progressive deepening, has taken place from the upper bathyal or outer sublittoral conditions prevailing during the Eocene to the middle bathyal depths of the present day.

Foraminifera

Site 209 represents an intermittent record of planktonic foraminifera ranging in age from the Pleistocene to the middle Eocene. The sequence from late Oligocene to Pleistocene age is of tropical character, while assemblages of Eocene age, although containing tropical elements, have close affinities with Eocene temperate faunas.

Three distinct episodes of sedimentation are separated by disconformities as shown by the following:

> Pleistocene to middle Pliocene containing abundant, very well preserved planktonic foraminifera (209-1, CC to 209-5, CC)
>
> (Disconformity)
>
> Late middle Miocene to late Oligocene containing abundant, moderate to well preserved planktonic foraminifera (209-6-1, 66 cm to 209-14, CC). A large sampling break exists between 209-6, CC and 209-10, CC
>
> (Disconformity)
>
> Late Eocene to middle Eocene (209-15, CC to 209-34, CC) of rather poor biostratigraphic character due to intermittent coring, poor recovery, presence of chert horizons, poor preservation at several intervals, and downcore contamination

The Pleistocene (Core 209-1 and Sample 209-3-5, 146 cm) is fairly condensed as at Site 208 and probably reflects the less prolific productivity of calcareous microfossils in the lower latitudes of the southwest Pacific. As expected, warm and cool cycles, although obviously present, are less distinct than at higher latitudes. The *Globorotalia truncatulinoides-Globorotalia tosaensis* transition is complicated within Core 2 by oscillations in ratio of these two forms.

The late to middle Pliocene (209-3, CC to 209-5, CC) is represented by approximately 20 meters of sediment and, like Site 208, contains extremely well preserved planktonic foraminifera. Of particular biostratigraphic interest is the *Globigerinoides sacculifera fistulosus* bioseries, clearly preserved throughout this Pliocene sequence. Elsewhere, this bioseries is often poorly represented because of poor preservation. The Pliocene-Pleistocene sequence is clearly of tropical character.

No samples were recovered from an interval of assumed foraminiferal sands between 54 and 83 meters, although this interval almost certainly contains a rather condensed sequence of early middle to late early Miocene age.

The middle early Miocene to late Oligocene is represented by a classical sequence of tropical forms including such forms as *Globigerinoides primordius, Globigerinoides altiaperturus*, and *Globigerina angulisuturalis*.

The Oligocene-Miocene boundary is marked by the last appearance of *G. angulisuturalis* and the first appearance of *Globigerinoides primordius* and *Globorotalia kugleri*.

The late to middle Eocene planktonic foraminiferal faunas are characterized by relatively low diversity and closer affinities to the New Zealand sequence compared with the overlying Neogene. This possibly reflects a more southerly location of this site of deposition during the Eocene compared with the Neogene, related to northward drift of Australia away from Antarctica since the middle Eocene.

Calcareous Nannofossils

Nannofloras obtained at this site indicate the presence of an incomplete late middle Eocene to late Pleistocene sequence which can be divided into the following biostratigraphic units separated either by sedimentary breaks or, less likely, by highly condensed intervals: late Pleistocene to earliest late Pliocene (209-1-1 to 209-5, CC); mid Micoene to late Oligocene (209-6-1 to 209-14, CC); late Eocene to late mid Eocene (209-15-1 to 209-34, CC).

However, interpretation of this sequence of events was not straightforward, being complicated by semicontinuous coring, by lack of core recovery (Cores 7 and 8), by massive downhole contamination (Cores 9 and 14), and by the presence of cherts (core catchers of Cores 16, 19, 21, 22, and 27).

Pleistocene (209-1-1, 35 cm to 209-3-2, 35 cm; Nannofossil Ooze)

The Pleistocene sediments contain lower than usual numbers of moderately preserved calcareous nannofossils. Species present are: *Emiliania huxleyi, Gephyrocapsa oceanica,* other *Gephyrocapsa* spp., *Pseudoemiliania lacunosa, Oolithotus antillarum, Cyclococcolithus leptoporus, Helicopontosphaera kamptneri, Rhabdosphaera clavigera,Thoracosphaera heimi, Umbilicosphaera mirabilis, "Discoaster" perplexus, Ceratolithus cristatus, Syracosphaera pulchra, Scyphosphaera apstenii, Cyclolithella annula, Anaplosolenia brasiliensis, Scapholithus ganerotus,* and *Pontosphaera* spp.

Calcareous nannofossil content of the Pleistocene sediments of Hole 209 is lower than in the corresponding sediments of other holes. However, the Pleistocene sediments contain high proportions of foraminifera. The combination of these two factors suggests winnowing of the sediments has been occurring throughout the Pleistocene. A generally tropical environment of deposition is indicated for Pleistocene sediments.

The Pleistocene sediments can be fitted to the zonal scheme of Martini (1971) as follows: 209-1-1, 35 cm to 209-1-2, 110 cm, NN21; 209-1-3, 35 cm to 209-1-3, 110 cm, NN20; and 209-1-4, 35 cm to 209-3-2, 35 cm.

Late Pliocene (209-3-2, 110 cm to 209-5, CC; Nannofossil-Foraminiferal Ooze)

The late Pliocene sediments contain common moderately preserved calcareous nannofossils. Species commonly present are: *Cyclococcolithina macintyrei, Discoaster brouweri, Discoaster pentaradiatus, Discoaster survulus, Oolithotus antillarum,* and *"Discoaster" perplexus.* Other species present in smaller numbers or as isolated specimens are: *Scyphosphaera* sp., *Thoracosphaera heimi, Scyphosphaera apstenii, Pontosphaera* cf. *scutellum, Pseudoemiliania lacunosa, Gephyrocapsa* sp., *Helicopontosphaera kamptneri, Rhabdosphaera clavigera,Syracosphaera pulchra, Umbilicosphaera mirabilis,* other *Pontosphaera* spp., *Scyphosphaera campanula, Ceratolithus rugosus,* and *Coccolithus pelagicus.* Reworked species include *Discoaster challengeri, Discoaster variabilis, Sphenolithus* cf. *abies,* and, in the 209-5-4, 35 cm to 20905, CC interval, very sparse *Reticulofenestra pseudoumbilica.*

The late Pliocene/Pleistocene boundary is marked by a general increase in the number of calcareous nannofossils present in the sediment, as well as the first downward appearance of *Discoaster brouweri.* The increased calcareous nannofossil content persists throughout the late Pliocene. The environment of deposition was tropical for the majority of the late Pliocene, with some slight fluctuations to cooler marginal tropical conditions (209-3-2 to 209-4-1) for short periods.

The Late Pliocene sediments can be fitted into the zonal scheme of Martini (1971) as follows: 209-3-2, 110 cm, NN18; 209-3-3, 35 cm to 209-3-3, 110 cm, NN17; and 2090304, 35 cm to 20905, CC, NN16.

Mid Miocene (209-6-1, 35 cm to 209-6, CC; Nannofossil-Foraminiferal Ooze)

Taxa present in this interval, which contains moderately well preserved, abundant nannofloras throughout, include: *Catinaster coalitus* (base at 209-6-1, 110 cm), *Coccolithus* cf. *pelagicus, Cyclococcolithina macintyrei, "Discoaster" perplexus, Discoaster variabilis* group, *Helicopontosphaera kamptneri, Reticulofenestra pseudoumbilica* group, *Scyposphaera* spp., *Spenolithus moriformis* group, and *Thoracosphaera.* Also undoubtedly present are a number of discoasters other than *D. variabilis* s.l., but unfortunately they could not be specifically identified due to all the nannoliths being strongly overgrown. Under these circumstances dating these assemblages, which definitely lack both *Cyclicargolithus floridanus* and *Discoaster pentaradiatus,* more exactly than mid Miocene s.l. is difficult. However, judging from the observed range of *C. coalitus* the 209-6-1 assemblages are probably correlative with the mid Miocene 4/4 *Catinaster coalitus* (NN8) Zone of Martini (1971), whereas the underlying 209-6-2 to 209-6, CC assemblages may be correlative with his mid Miocene 3/4 *Discoaster kugleri* (NN7) Zone.

Downhole Plio-Pleistocene (Core 9; Essentially Foraminiferal Calcic Ooze)

Taxa present in one of several small "white fine lumps" surrounded by "brown coarse matrix"—the dominant lithology—in the core catcher include: *Ceratolithus rugosus, Cyclococcolithina macintyrei, Discoaster brouweri, D. pentaradiatus, D. surculus, D. variabilis, Gephyrocapsa, Helicopontosphaera kamptneri, Pseudoemiliania lacunosa* (dominant), *Reticulofenestra pseudoumbilica* group, and *Spenolithus moriformis* group. Clearly this assemblage, which is abundant and moderately well preserved, represents downhole caving from the overlying unconsolidated Plio-Pleistocene.

Early Miocene (209-10, CC to 209-12, CC; Foraminiferal Calcic Ooze)

This interval, characterized by core catcher only recovery, contains two distinctly different types of assemblages. The upper type, obtained by crushing planktonic foraminifera from the core catchers of Cores 10 and 11, essentially consists of very rare, poorly preserved *Coccolithus eopelagicus, Cyclicargolithus floridanus, Discoaster deflandrei,* and *Spenolithus moriformis* group. Also observed were single specimens of *Coccolithus ovalis* s.l., *Discolithina* sp., *Helicopontosphaera* sp. cf. *parallela* (209-11, CC), and *Spenolithus* cf. *belemnos* (209-11, CC). Judging from their sequential position (see below) and the presence of *D. deflandrei,* these assemblages are of undifferentiated early Miocene age. As in the underlying sample, this interval includes rare objects resembling aragonite needles.

The lower assemblage type, represented by a small ("few") moderately well preserved nannoflora, occurs in the core catcher of Core 12. Taxa present include: *Braarudosphaera floridanus, B.* cf. *discula, Coccolithus ovalis* s.l., *Cyclicargolithus floridanus, Discoaster deflandrei, Helicopontosphaera parallela, H. recta* (highest occurrence), *Spenolithus* cf. *belemnos* (lowest occurrence), and *S. moriformis.* Despite a careful search *Reticulofenestra bisecta, Spenolithus ciperoensis,* and *Zygrhablithus bijugatus* were not found. By lacking these taxa and containing *H. recta* and *S.* cf. *belemnos,* this assemblage clearly is that characteristic of the uppermost part of the *Spenolithus ciperoensis* Zone (NP25) of Martini (1971). According to Martini (1971) this zone is of late Oligocene age and occurs in the upper part of the stratotype Bormidian of Italy. However, this particular sample (209-12, CC) and that underlying (209-13, CC) also contain *Globigerinoides primordius*, a foraminifera which, according to Blow (1969, p. 223), has its first appearance very close (immediately below?) to the base of the stratotype Aquitanian—the lowest Miocene stage. Attempts to extract nannofossils from the stratotype Aquitanian have so far failed (Bramlette and Wilcoxon, 1967, p. 100; Edwards, 1971, p. 415), so for the purposes of Leg 21 reports the nannofossil assemblage listed above is considered to be of early Miocene 1/5 age. Datum levels closely approximating the base of *Globigerinoides* in Site 209 are top *Helicopontosphaera recta,* top *Reticulofenestra bisecta,* top *Zygrhablithus bijugatus,* and base *Spenolithus* cf. *belemnos.* Of these the writer considers top *R. bisecta* (209-13, CC) to be the most reliable for, although prone to reworking, it is abundant, distinctive, highly solution resistant, and ubiquitous whereas the others have known environmental preferences. Thin elongated objects similar to aragonite needles occur in this sample.

Late Oligocene (209-13, CC; Calcic Foraminiferal Ooze)

This interval, represented only by the core catcher of Core 13, contains a small ("few") moderately well preserved nannnoflora. Taxa present include: *Braarudosphaera bigelowi*?, *Coccolithus eopelagicus, C. ovalis* s.l., *Cyclicargolithus floridanus, Discoaster deflandrei* (lowest definite occurrence), *Helicopontosphaera obliqua* (highest occurrence), *H. parallela* (lowest occurrence), *Micrantholithus flos*?, *Reticulofenestra bisecta* (highest occurrence), *Spenolithus moriformis* group, and *Zygrhablithus bijugatus* (highest) occurrence). Also observed were "aragonite" needles, *Cyclococcolithina macintyrei* (minor downhole contamination), and a single specimen of *Helicopontosphaera recta* (shipboard identification only). In containing *R. bisecta,* lacking *S. ciperoensis*, and underlying the 209-12, CC flora this assemblage is clearly correlatable with the upper part of the late Oligocene 2/2 part of the *Spenolithus ciperoensis* (NP25) Zone of Martini (1971). This zone is recognizable in the upper part of the stratotype Bormidian Stage according to Martini (1971). This assemblage is probably also a correlative of the late Duntroonian to early Waitakian *Discoaster deflandrei* Zone of Edwards (1971).

An unconformity spanning most of the late Eocene and Oligocene occurs between 209-13, CC and 209-15-1, 75 cm judging by the undoubted biostratigraphic progress made between these samples. This feature, which is part of the regional Eocene-Oligocene unconformity also found at Sites 206 to 208 and 210, probably underlies 209-14, CC, but this cannot be confirmed by the nannofossils due to the mixed nature of the Core 14 assemblages (q.v.).

?Late Oligocene (209-14-1, 90 cm to 209-14, CC; Calcic Silty Sand)

This interval, examined at 209-14-1, 90 cm and 209-14, CC, contains small, variably preserved nannofloras in which at least two distinctly different components can be recognized. The more abundant ("few") and better preserved ("moderate") fraction, which clearly represents downhole contamination, includes: *Ceratolithus cristatus, Cyclococcolithina macintyrei, Discoaster brouweri, Gephyrocapsa, Pontosphaera discorpora*?, *Pseudoemiliania lacunosa* (relatively common), *Reticulofenestra pseudoumbilica,* and *Syracosphaera histrica.* This Plio-Pleistocene component is more conspicuous in the upper of the two samples examined.

The second fraction, which is very rare and poorly preserved, consists of *Coccolithus ovalis* sl., *Cyclicargolithus floridanus, Discoaster deflandrei*?, and *Helicopontosphaera obliqua* in 209-14-1, 90 cm and of *Coccolithus ovalis* s.l., *Cyclicargolithus floridanus, Helicopontosphaera obliqua, Reticulofenestra bisecta, Spenolithus moriformis,* and *Zygrhablithus bijugatus* in 209-14, CC. This component is considered here largely on the rather tenuous grounds of floral similarity and the presence of the Oligocene species *H. obliqua*, to be of similar, late Oligocene, age to the 209-13, CC assembalge (q.v.). This conclusion is supported by a definite, but shipboard only, recognition of the late Oligocene to early Miocene species *Triquetrorhabdulus carinatus* in 209-14, CC. The probable occurrence of a third component is implied by the presence, in 209-14, CC only, of common ascidian sclerites and of occasional poorly preserved *Cyclococcolithina formosa, Discolithina* sp., and *Micrantholithus basquensis*?. These taxa are characteristic of the underlying sediment (q.v.), and the presence of *C. formosa* indicates an age not younger than early Oligocene. The presence of this component is interpreted on the grounds that the presence of common ascidian sclerites probably indicates sediment redeposition from a shallower environment, as reworking from older strata. This interpretation is consistent with the recovery of late Eocene 1/5 sediments in Core 15, some 9 to 18 meters below 209-14, CC and with the implied presence of the regional Eocene-Oligocene unconformity in that unsampled interval (see Core 13 above).

The assemblage components described above suggest that Core 14 represents an intimate mixture of downhole caved and in situ sediments. This conclusion is compatible with the lithological description of this core.

Late Eocene (209-15-1, 75 cm to 209-27-2, 35 cm; Sandy Foraminiferal Ooze and Limestone with Chert)

This interval is characterized by low core recovery due to alternating hard and soft lithologies with the latter having little cohesion. Wherever possible, the harder, often cherty horizons and the immediately adjacent sediment were not sampled for calcareous nannofossils. Despite this, most assemblages extracted were poorly preserved and small ("very rare" to "few"); the only horizons from which moderately common floras were obtained being those below Core 22 where the chert content is less obvious. Taxa present include: *Braarudosphaera* cf. *discula*; *Coccolithus eopelagicus; C. ovalis; Cyclicargolithus floridanus* (base at 209-27-2, 35 cm; *C. reticulatus* (209-15, CC to 209-27-2, 35 cm range); *Cyclococcolithina formosa* (209-15-1, 75 cm); *C. protoannula* (209-17-1, 80 cm); *Discoaster saipanensis* (209-15-1, 75 cm; *D.* sp. of *tani* group; *Discolithina multipora* (top at 209-17, CC); *D. obliquipons* (top at 209-17, CC); *D. pulcheroides* (top at 209-18, CC); *D.* sp., *Helicopontosphaera lophota* (top probably at 209-17-1, 80 cm; very sporadic); *Micrantholithus basquensis; Reticulofenestra bisecta* (base at 209-27-2, 35 cm); *R. hampdenensis*? (209-17-1, 80 cm); *R. placomorpha* (top at 209-15-1, 75 cm); *Spenolithus furcatolithoides* (top at 209-33, CC); and similar nonbifurcating forms such as *S. moriformis; Zygolithus dubius* (top at 209-25, CC; very rare); *Zygrhablithus bijugatus*; and several different forms of rhabdolith stems. Also observed were rare ascidian sclerites (in 209-15-1, 75 cm; 209-17, CC; and 209-23, CC) and, only in 209-15-1, 75 cm minor mid Miocene or younger downhole contamination (*Cyclococcolithina macintyrei* and *Reticulofenestra pseudoumbilica* group).

Although these assemblages are small, they are also diverse. This fact coupled with the variety and consistent presence of warm neritic preferring taxa such as *Braarudosphaera, Discolithina,* and *Micrantholithus* indicate proximity to a neritic water mass. However, these taxa are present in relatively low numbers. For this reason an open-water depositional site marginal to a broad shallow (epicontinental) platform seems more likely than deposition under truly sublittoral conditions. That a relatively warm climatic regime prevailed during the deposition of this interval seems probable judging from the presence of *braarudosphaerids*, discoliths, and a large spenolith plus the sparsity of zygoliths. Also conspicuously absent, although not necessarily for climatic reasons alone, is the genus *Chiasmolithus.*

Although making a good paleoenvironmental story possible, these assemblage characteristics unfortunately make the exact age of this interval distinctly more difficult to determine. That it is of late Eocene age seems beyond doubt since *Discoaster saipanensis* and *Reticulofenestra bisecta* overlap throughout. Furthermore, the presence of *Reticulofenestra hampdenensis*?, rare *Helicopontosphaera lophota,* and *Zygolithus dubius* and the absence of *Helicopontosphaera reticulata, Spenolithus predistentus*, and *S. pseudoradians* suggest a position within the late Eocene 1/5 to 3/5. Refinement beyond this of the age or zonal assignment becomes very subjective. For example, opinions would vary as to whether the absence of *Chiasmolithus oamaruensis* and *Isthmolithus recurvus* (a zygolith) reflects age or environmental factors. Consequently, for the purposes of this report, a late Eocene 1/5 to 3/5 (Kaiatan) age is adopted for this interval which, in biostratigraphic terms, clearly conforms to both the *Reticulofenestra bisecta* and *Discoaster saipanensis* (NP17) zones of Edwards (1971) and Martini (1971), respectively. A late Eocene 1/5 (early Kaiatan) age would normally be applied to these zones.

A small unconformity appears to separate this interval from the immediately underlying sediments judging from the apparent absence in this sequence of assemblages correlative with the mid Eocene 7/7 (late Bortonian to early Kaiatan) *Discoaster tani nodifer* Zone of Edwards (1971). This conclusion is supported by coincident changes in the hardness, clastic content, and sonic velocity of the sediments. However, from the nannofossil point of view, an element of doubt exists due to the apparent presence of minor downhole contamination from this interval in the uppermost part of the underlying interval (q.v.).

Mid Eocene (209-28-2, 35 cm to 209-34, CC; Sandy Limestone Becoming Calcic Silty Sandstone)

This interval, also characterized by low core recovery, contains diverse, poorly to moderately preserved, small (mostly "few") nannofloras. Taxa present include: *Braarudosphaera bigelowi; B.* cf. *discula; Chiasmotolithus grandis* (top at 209-31, CC); *C. solitus* (top at 209-28, CC); *Coccolithus eopelagicus; C. ovalis* s.l.; *Cyclococcolithina foramsa; C. protoannula; Discoaster barbadiensis* (top at 209-29, CC); *D. saipanensis* (base at 209-30, CC); *D.* sp. of *distinctus* group; *D. wemmelensis* (209-33, CC range); *Discolithina multipora; D. pulchra* (top at 209-28, CC); *D. pulcheroides; D.* sp. *Helicopontosphaera lophota; H. seminula; Microantholithus basquensis; Reticulofenestra hampdenensis* (throughout interval); *R. placomorpha* (throughout interval); *Rhabdosphaera gladius* (top at 209-29, CC); *R.* spp. (including parallel-sided stems); *Spenolithus furcatolithoides* s.l. (throughout interval; no bifurcation of the apical spine evident); *S. moriformis; Zygolithus dubius*; and *Zygrhablithus bijugatus.* Also present, apparently as downhole contamination from the overlying late Eocene, are rare *Cyclicargolithus floridanus* (209-28-2, 35 cm); *C. reticulatus* (209-28-2, 35 cm and 209-28, CC); and *Reticulofenestra bisecta* (209-29-1, 85 cm). The presence of these latter taxa is incompatible with the cooccurrence of relatively common *Chiasmolithus solitus.*

Definite evidence for direct deposition of this interval from a warm neritic water mass is provided by the variety, relatively high abundance, and consistent presence of braarudosphaerids and discoliths. The overall calcareous nannofossil characteristics of this interval, particularly those of high diversity and constant occurrence, indicate an essentially open-water origin and thus imply a middle or outer sublittoral, rather than inner sublittoral, depositional site unless on-shore drift conditions prevailed. These conclusions are consistent with the other paleontological and lithologic evidence available, for example, the high benthonic versus planktonic foraminiferal ratio; the absence of both ascidian sclerites and radiolarians; and the highly clastic, glauconite-bearing, essentially noncarbonaceous nature of the sediments.

In containing *C. solitus, R. hampdenensis, R. placomorpha,* and *R. gladius* throughout and lacking both *C. reticulatus* and *R. bisecta,* the 209-29, CC to 209-34, CC part of this interval is clearly correlative with the mid Eocene 6/7 (early and mid Bortonian) combined *Discoaster distinctus* and *Reticulofenestra hampdenensis* zones of Edwards (1971) and with the *Chiphragmalithus alatus* (NP15) Zone of Martini (1971). The age of the uppermost, 209-28-2 to 209-29-1, part of this interval is more difficult to determine due to the presence of anomalous taxa (see above). For the purposes of this report their occurrence is considered to be totally due to contamination from the overlying strata. However, there is a very real possibility that the occurrence of *R. reticulatus* is not due to contamination. If this is so, then Core 28 must be considered correlative with the mid Eocene 7/7 (late Bortonian to early Kaiatan) *Discoaster tani nodifer* zones of Edwards (1971) and Martini (1970; NP16).

Siliceous Microfossils

Although cherts are frequent in almost all late Eocene cores at this site, siliceous microfossils occur only in Cores 23 and 24. Studies on thin sections of the chert show that foraminifera are the most important organic component present. Sponge spicules are rare and partly dissolved and are probably the origin of the silica of the cherts at this site.

Radiolarians are rare in Cores 23 and 24. Their preservation is moderate, many specimens being broken due to the impact with the abundant sponge spicules with which they cooccur. In fact, the latter are so abundant that the sediment looks like a spongolite. Such an abundance of sponge spicules is almost certainly related to rather shallow water conditions in the Eocene at this site. Radiolarians present include: *Calocyclas hispida, C. turris, Lychnocanoma* sp., *Thyrsocyrtis triacantha, Podocyrtis* cf. *argus*, and *Theocampe mongolfieri.* Such an assemblage is indicative of late Eocene age.

PHYSICAL PROPERTIES

Density and Sonic Velocity

Core reocvery at Site 209 was relatively poor, so it is difficult to present a coherent picture of the physical properties of the rocks sampled. Reasonably continuous data were recorded for Cores 1 through 6 and again near the bottom of the hole (see summary). The physical properties results largely support the tripartite division of the sequence cored, adopted on the basis of lithology (see lithology report).

Unit 1, consisting of late Oligocene to Pleistocene foraminiferal and nannofossil oozes, has densities in the range 1.56 to 1.88 gm/cc and sonic velocities of about 1.59 km/sec. As will be seen from the other site reports, these are typical densities and velocities for these lithologies at these shallow subbottom depths.

Unit 2, consisting of sandy foraminiferal ooze, silicified limestone, and chert of late Eocene age, probably has densities in the range 1.9 to 2.3 gm/cc and velocities ranging from 3.0 to 5.8 km/sec. Core recovery was very poor and data are sparse. It is clear that only the hard parts of the unit were sampled and that both density and velocity are highly variable.

Unit 3, middle Eocene calcareous sandstones and sandy siltstones, is marked by a drop in velocity and density between Cores 27 and 28. Density falls into the range 1.8 to 2.0 gm/cc, and velocities drop to 1.91 to 2.39 km/sec. The drop in density presumably reflects the increase in the clay and detrital mineral content of these very impure limestones and the concurrent rise in porosity, as opposed to the very dense, low porosity, highly silicified sediments of Unit 2.

Thermal Conductivity and Heat Flow

Measurements of thermal conductivity by the needle probe method on cores to depths of 50 meters below bottom (Cores 1 through 6, inclusive) gave relatively uniform values, about 2.8 ± 0.2 m cal/°C cm sec uncorrected for ambient pressure and temperature at the sea floor. Values are slightly higher below 30 meters depth than above, which is most obviously explained by compaction. The relatively high values are typical of carbonate oozes which are relatively low in water content.

Useful data for heat-flow measurements were obtained on two attempts to measure downhole temperatures at this site. At 27 meters depth, a relatively steady temperature of 4.84 ± 0.05°C was measured over several minutes after the start of coring. Before that, the temperature remained quite steady at 3.70 ± 0.02°C, suggesting that the instrumentation may have prematurely entered the core barrel, showing an increased temperature only after the warmer sediments had been cored. At 54 meters depth, the measurement was somewhat ambiguous. The temperature during bottom penetration was relatively steady at 7.1 ± 0.2°C, whereas that during coring was equally steady at 7.5 ± 0.2°C. It is possible that the coring disturbance in this instance introduced additional heat to the sediment.

Assuming a bottom water temperature of 3.70°C, as recorded during the steady portion of the measurement before penetration at 27 meters depth, the temperature gradient to 27 meters is 0.042°C/m. On the other hand, the measurement at 54 meters gave an overall gradient of 0.063°C/m. The heat flow values in the two instances are 1.2 and 1.8 HFU (μ cal cm^{-2} sec^{-1}), respectively. These are within the range of normal values. The difference would be reconciled if the bottom water temperature were 2.4°C, and in this case the gradient and heat flow would be somewhat higher than normal.

SUMMARY AND CONCLUSIONS

Drilling at Site 209 on the edge of the Queensland Plateau penetrated 344 meters, sampling three lithologic units. Unit 3, from 308 to 344 meters, is glauconite-bearing calcareous silty sandstone to sandy siltstone of late middle Eocene age. Terrigenous detrital sands and silts comprise over 50% of the sediment. Microfossils in this unit indicate deposition in upper bathyal to neritic depths. Unit 2, from 150 to 308 meters, consists of detrital-rich foraminiferal ooze and chert of late Eocene age. Core recovery was poor in this section due to the interbedding of the hard chert and silicified limestone with unlithified foraminiferal ooze. Approximately 10% to 30% of the sediment is composed of quartz, feldspar, minor glass, and authigenic (?) glauconite. Unit 1, from 0 to 150 meters, is made up of foraminiferal ooze and nannofossil ooze of late Oligocene to Pleistocene age with a break in the sequence from late Middle Miocene to middle Pliocene. Winnowing is evident throughout the section, but is most conspicuous prior to late middle Miocene.

The regional unconformity occurs at Site 209 between Units 1 and 2 and extends from late Eocene to late Oligocene. The unconformity is not closely approximated by reflector in the seismic profiles. The most prominent reflector above basement (Reflector 4) crops out along the seaward margin of the Plateau near 2000 meters depth and had previously been interpreted as an unconformity surface. This is now identified as a late Eocene chert horizon. The boundary between Units 2 and 3 is gradational.

A rough acoustic basement rises to 0.38 sec subbottom at this site. This is calculated as 387 meters below the sea floor based on the velocities in Units 2 and 3. The site survey by the *Kana Keoki* shows this basement reflector as a faint rather smooth horizon at depths up to 1.0 sec beneath portions of the Plateau adjacent to the site. This reflector becomes deeper and cannot be traced on the seismic profiles near the margin of the Plateau.

The sedimentary record indicates that the Queensland Plateau has undergone net subsidence from upper bathyal to neritic depths in the middle Eocene to mid-bathyal depths (near 1500 m) at the present time. During late Eocene, as deepending progressed and oceanic circulation established itself over the shelf, oceanic pelagic sediments began to predominate.

Terrigenous detrital input decreased, and to a major extent ceased, by late Eocene. Unit 1 has less than 5% terrigenous component compared with 10% to 30% in Unit 2 and over 50% in Unit 3. Development of reefs and cays on the central Plateau during middle Eocene may have blocked bottom transport and impeded current distribution of the land-derived sediments at that time. Alternatively, development of the Queensland and Townsville Troughs, narrow deeps isolating the plateau from the Australian mainland, may have resulted in terrigenous debris failing to reach the Plateau.

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NOTE CONCERNING THE APPENDICES

The appendices consist of tables of shore laboratory determinations of grain size, carbon content, and mineralogical composition, summary visual descriptions of the cores recovered from the site, photographs of the cores and, finally, an overall summary of the results of drilling at the site. The symbols used to represent lithology in the core summary forms are explained in Chapter 2 of this volume. The lithologic description of each core contains typical results of shipboard examination of smear slides of each lithology. In order to make the lithologic descriptions more complete we have also included many of the shore laboratory results. These are identified by being placed in square brackets.

APPENDIX A
Grain Size Determinations, Site 209

Core, Section, Top of Interval (cm)	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Classification
1-4,116.0	5.7	39.9	19.1	41.0	Sandy clay
2-4,110.0	14.6	38.7	17.1	44.3	Sandy clay
3-4,110.0	23.6	29.7	20.9	49.5	Sand-silt-clay
4-4,110.0	32.6	26.5	22.7	50.8	Sand-silt-clay
5-4,110.0	41.6	29.4	25.7	44.9	Sand-silt-clay
6-5,110.0	52.1	42.1	38.2	19.7	Silty sand
9-1,136.0	75.4	68.7	21.8	9.5	Silty sand
14-2,110.0	133.6	96.9	1.2	1.9	Sand
15-1,104.0	151.0	91.3	4.8	3.9	Sand
23-2,116.0	243.7	43.3	43.3	13.4	Sandy silt
28-2,78.0	283.3	21.7	49.6	28.7	Sand-silt-clay
29-1,133.0	291.3	31.1	46.0	22.8	Sand-silt-clay
31-1,122.0	309.2	73.2	15.4	11.3	Silty sand
34-2,96.0	337.5	1.1	63.0	35.9	Clayey silt

APPENDIX B
Carbon-Carbonate Determinations, Site 209

Core, Section, Top of Interval (cm)	Depth in Hole (m)	Carbon Total (%)	Organic Carbon (%)	$CaCO_3$ (%)
1-4,86.0	5.4	10.9	0.0	90
2-4,86.0	14.4	11.2	0.0	93
3-4,86.0	23.4	11.5	0.0	96
4-4,86.0	32.4	11.3	0.0	94
4-6,0	34.5	11.3	0.0	94
5-4,86.0	41.4	11.4	0.0	95
6-5,86.0	51.9	11.1	0.0	92
9-1,116.0	75.2	11.5	0.0	95
14-2,86.0	133.4	10.1	0.1	83
15-1,86.0	150.9	9.9	0.0	83
23-2,86.0	243.4	7.0	0.1	58
27-2,60.0	274.1	9.5	0.1	78
28-2,78.0	283.3	7.1	0.2	58
29-1,133.0	291.3	5.6	0.2	45
31-1,122.0	309.2	3.1	0.3	23
32-1,125.0	318.3	3.9	0.4	29
34-2,113.0	337.6	3.5	0.4	26

APPENDIX D
Thermal Conductivity Measurements, Site 209

Core, Section, Interval Below Top (cm)	Thermal Conductivity (mcal/°C cm sec)	Standard Deviation	Ambient Core Tempera-ture (°C)	Remarks
1-3,75	0.002771	0.005465	22.25	
2-3,75	0.002719	0.004725	23.61	
3-3,70	0.002783	0.004810	22.15	
4-3,70	0.002907	0.009094	21.76	
5-3,70	0.003016	0.008416	21.01	
6-3,70	0.002575	0.008451	23.61	

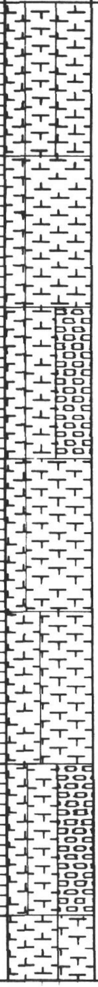
APPENDIX C
X-ray Mineralogy Determinations, Site 209

Core	Cored Interval Below Sea Floor (m)	Sample Depth Below Sea Floor (m)	Diff.	Amor.	Calc.	Quar.	Cris.	K-Fe.	Plag.	Mica	Mont.	Trid.	Clin.	Pyri.	Amph.	U-3[a]	Kaol.	Chlo.	Apat.	U-1[b]
Bulk Sample																				
1	0-9	5.6	53.7	27.7	99.1	0.9	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	9-18	14.7	51.5	24.3	99.7	0.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3	18-27	23.7	50.4	22.5	100.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4	27-36	32.7	50.7	22.9	99.6	0.4	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5	36-45	41.7	51.3	23.9	99.5	0.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6	45-54	52.2	52.9	26.5	99.6	0.4	–	–	–	–	–	–	–	–	–	–	–	–	–	–
9	74-83	75.3	53.6	27.4	100.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14	131-140	133.7	47.6	18.1	100.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15	150-159	151.0	52.8	26.3	92.7	4.3	3.1	–	–	–	–	–	–	–	–	–	–	–	–	–
23	241-250	243.6	68.3	50.5	98.6	1.4	–	–	–	–	–	–	–	–	–	Pres.	–	–	–	–
27	272-281	274.1	62.6	41.6	82.6	3.8	9.1	–	–	–	–	4.5	–	–	–	–	–	–	–	–
28	281-290	283.3	67.8	49.7	68.9	8.6	10.9	–	4.6	–	–	5.1	1.9	–	–	–	–	–	–	–
29	290-299	291.3	66.1	47.0	62.6	15.2	2.8	4.2	10.1	2.1	0.9	0.6	1.5	–	–	–	–	–	–	–
31	308-317	309.2	77.6	64.9	35.5	16.1	24.4	–	10.1	3.8	2.1	5.7	1.5	–	0.7	–	–	–	–	–
32	317-326	318.3	77.2	64.4	40.4	12.4	26.1	–	8.6	4.3	2.4	4.7	–	1.1	–	–	–	–	–	–
34	335-344	337.5	73.3	58.2	91.1	2.3	2.8	–	1.8	0.7	–	0.8	0.5	–	–	–	–	–	–	–
2-20μ Fraction																				
23	241-250	243.6	97.7	96.5	–	57.8	–	17.1	14.9	10.2	–	–	–	–	–	–	–	–	–	–
27	272-281	274.1	87.8	80.9	–	12.4	58.8	–	4.6	–	–	17.8	6.3	–	–	–	–	–	–	–
28	281-290	283.3	84.1	75.1	–	13.3	50.1	–	6.7	3.0	–	13.5	12.1	1.2	–	–	–	–	–	–
29	290-299	291.3	73.2	58.1	–	38.2	–	5.8	25.4	8.1	–	–	18.9	2.5	1.2	–	–	–	–	–
31	308-317	309.2	81.4	70.9	–	23.6	39.8	3.3	17.0	4.3	–	6.6	3.8	1.7	–	–	–	–	–	–
32	317-326	318.3	82.2	72.2	–	22.9	41.4	–	17.6	6.4	–	6.5	3.7	1.6	–	–	–	–	–	–
34	335-344	337.5	79.3	67.7	–	22.8	33.2	4.3	17.4	6.9	–	6.7	6.5	2.2	–	–	–	–	–	–
<2μ Fraction																				
1	0-9	5.6	85.0	76.6	–	11.7	–	–	8.8	13.5	50.0	–	–	–	–	–	12.7	3.2	–	–
2	9-18	14.7	90.9	85.7	–	12.8	–	–	20.0	14.2	38.4	–	–	–	–	–	14.6	–	–	–
3	18-27	23.7	97.2	95.6	–	14.9	–	–	12.0	19.3	37.4	–	–	–	–	–	16.5	–	–	–
4	27-36	32.7	87.9	81.0	–	11.0	–	–	2.8	19.9	38.8	–	–	–	–	–	27.6	–	–	–
5	36-45	41.7	90.6	85.3	–	12.4	–	–	3.1	18.5	41.9	–	–	–	–	–	24.0	–	–	–
6	45-54	52.2	98.6	97.9	–	15.5	–	–	–	–	58.7	–	–	–	–	–	25.7	–	–	–
14	131-140	133.7	98.9	98.2	–	10.9	–	–	11.7	–	35.1	–	–	–	–	–	–	–	42.3	–
15	150-159	151.0	92.7	88.6	–	8.3	28.4	–	1.9	4.9	33.7	6.1	1.7	–	–	–	–	–	15.0	–
23	241-250	243.6	91.7	87.1	–	7.1	–	–	3.2	8.4	62.3	–	–	1.6	–	–	9.6	–	7.8	–
27	272-281	274.1	90.1	84.5	–	2.0	68.5	–	–	2.5	11.1	15.0	0.9	–	–	–	–	–	–	–
28	281-290	283.3	91.2	86.3	–	1.5	63.3	–	1.8	2.3	9.6	14.9	1.2	–	–	–	–	–	5.5	–
29	290-299	291.3	86.7	79.2	–	5.1	21.6	2.4	7.5	8.3	23.5	17.4	5.9	2.4	–	–	–	–	5.9	Trace
31	308-317	309.2	88.5	82.0	–	1.7	64.2	–	0.9	3.3	11.6	16.9	–	1.4	–	–	–	–	–	–
32	317-326	318.3	89.2	83.1	–	1.5	64.3	–	0.7	2.0	15.5	13.4	1.1	1.6	–	–	–	–	–	–
34	335-344	337.5	87.6	80.6	–	1.6	64.8	–	0.9	2.3	10.5	16.2	2.2	1.6	–	–	–	–	–	–

[a] U-3 peak at 3.23 Å.

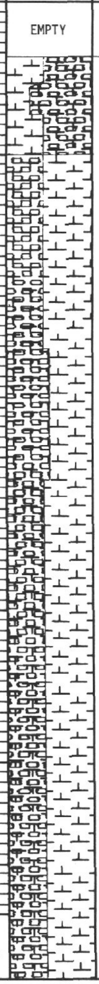
[b] U-1 peak at 12.1 Å.

Site 209 Hole Core 1 Cored Interval: 0-9 m



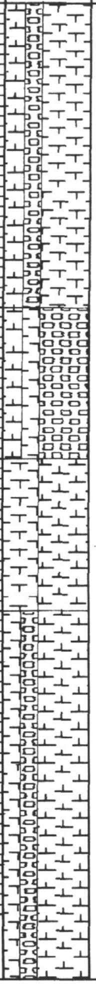
AGE	ZONE		FOSSIL CHARACTER			SECTION	METERS	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
			FOSSIL	ABUND.	PRES.					
PLEISTOCENE	N22	NN21	N N	R R	M M	1	0.5 1.0	3		<u>NANNO BEARING FORAM CALCIC OOZE</u> <u>AND FORAM RICH CALCIC NANNO OOZE</u> Very pale orange (10YR8/2) - grayish orange (10YR7/4) creamy, homogenous. Insoluble residue ~5% quartz and feldspar.
			N N	R R	M M	2				20% forams 80% nannos
		NN20	N N	R R	M M	3				35% angular carbonate grains (mainly foram) fragments 25% forams 40% nannos Shipboard lab about 95% CaCO$_3$
		NN19	N N	R R	M M	4			CC GZ XM	trace of zeolite crystals parallel extinction R.I. <1.56 [90% CaCO$_3$] trace of carbonate spicules [40% sand, 19% silt, 41% clay] [X-ray - 28% amorphous, 72% crystalline: 99% calcite, 1% quartz]
			N N	R F	M M	5				
			N N	C C	M M	6				40% clay and larger sized angular calcite 20% forams 20% nannos
			N F R	C A -	M G -	Core Catcher				53% nannos 45% forams <u>FORAM NANNO OOZE</u> [96% CaCO$_3$]

Site 209 Hole Core 2 Cored Interval: 9-18 m



AGE	ZONE		FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
			FOSSIL	ABUND.	PRES.						
						1	0.5 1.0	EMPTY			
PLEISTOCENE	N22	NN19	N	R	M						<u>CALCIC RICH FORAM NANNO OOZE AND</u> <u>NANNO FORAM OOZE</u> Homogeneous, creamy, very pale orange (10YR8/2 - grayish orange (10YR7/4). 60-40% forams plus angular carbonate (probably broken forams and authigenic calcite) 40-60% nannos trace of carbonate spicules
	N22 N21		N N	F R	M M	2					
	N21		N N	F R	M M	3			3		Large amounts of very fine detrital mineral material at Section 3, 35 cm.
			N N	R R	M M	4				CC GZ XM	[93% CaCO$_3$] Shipboard lab 96% CaCO$_3$ [39% sand, 17% silt, 44% clay] [X-ray - 24% amorphous, 76% crystalline: 99% calcite, 1% quartz] Moderate yellowish brown (10YR5/4) streak of FELDSPAR BEARING FORAM RICH NANNO ASH Glass is devitrified. Feldspar ~Ab$_5$ An$_5$
			N N	R R	M M	5					
			N N	R R	M M	6					
			N F R	C A -	M G -	Core Catcher					

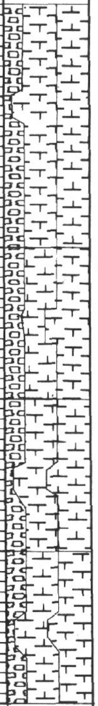
Site 209 Hole Core 3 Cored Interval: 18-27 m

AGE	ZONE		FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	N21	NN19	N N	R R	M M	1	0.5 1.0				40% forams 60% nannos CALCIC RICH NANNO, FORAM OOZE AND FORAM NANNO OOZE Homogeneous, creamy very light gray N8 to white N9.
		NN19 NN18	N N	R R	M M	2					50% forams 30% nannos 19% carbonate, unknown origin Shipboard lab 99% $CaCO_3$
		NN17	N N	F F	M M	3			3 or 4		50% carbonate, unknown origin 25% forams 25% nannos
		NN16	N N	F C	M M	4				CC GZ XM	60% nannos 38% forams [96% $CaCO_3$] [30% sand, 21% silt, 49% clay] [X-ray - 23% amorphous, 77% crystalline: 100% calcite]
			N N	F R	M M	5					60% nannos 20% forams 20% carbonate, unknown
			N N	C C	M M	6					
			N F R	C A -	M G -	Core Catcher					69% nannos 20% forams 20% carbonate

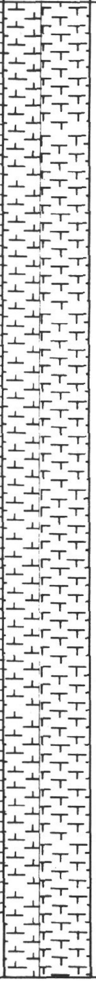
Site 209 Hole Core 4 Cored Interval: 27-36 m

AGE	ZONE		FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
						1	0.5	EMPTY			
EARLY LATE PLIOCENE	N20	NN16	N N	C F	M M		1.0				40% nannos 39% forams 20% carbonate unknown origin CALCIC RICH FORAM NANNO OOZE AND NANNO FORAM OOZE Homogeneous, creamy, white N9
			N N	C C	M M	2					50% forams 29% nannos 10% carbonate
			N N	F F	M M	3					45% carbonate 30% forams 25% nannos Shipboard lab determination 99% $CaCO_3$
			N N	F F	M M	4				CC GZ XM	60% nannos 20% forams 20% carbonate [94% $CaCO_3$] [26% sand, 23% silt, 51% clay] [X-ray - 23% amorphous, 77% crystalline: 99% calcite, 1% quartz]
			N N	F C	M M	5				CC	[94% $CaCO_3$]
			N N	F C	M M	6					
			N F R	C A -	M G -	Core Catcher					45% forams 44% nannos 10% carbonate

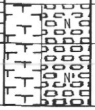
Site 209 Hole Core 5 Cored Interval: 36-45 m

AGE	ZONE	FOSSIL CHARACTER FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE PLIOCENE	NN16	N N	F F	M M	1	0.5 1.0	EMPTY 	3 or 4		63% nannos 25% forams 10% carbonate unknown origin Shipboard lab 99% $CaCO_3$
		N	A	M	2					CALCIC RICH FORAM NANNO OOZE AND NANNO FORAM OOZE Homogeneous, creamy white, N9.
					3					50% forams 39% nannos 10% carbonate Shipboard lab 99% $CaCO_3$
	NN15	N	A	M	4				CC GZ XM	70% nannos 30% forams 9% carbonate [95% $CaCO_3$] [29% sand, 26% silt, 45% clay] [X-ray - 24% amorphous, 76% crystalline: 99% calcite, 1% quartz]
					5					40% forams 40% nannos 20% carbonate
		N F R	A A -	M G -	Core Catcher					67% nannos 30% forams

Site 209 Hole Core 6 Cored Interval: 45-54 m

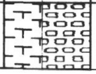
AGE	ZONE	FOSSIL CHARACTER FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIDDLE MIOCENE	N14 ≈NN8	N N	A A	M M	1	0.5 1.0		4		60% forams 37% nannos 2% other carbonate
	≈NN7	N N	A A	M M	2					50% forams 43% nannos 5% other carbonate
					3					Shipboard lab 98% $CaCO_3$ 60% forams 40% nannos
		N	A	M	4					NANNO FORAM OOZE Homogeneous, creamy yellowish gray (5Y8/1)
		N	A	M	5				CC GZ XM	50% forams 45% nannos 5% other carbonate [92% $CaCO_3$] [42% sand, 38% silt, 20% clay] [X-ray - 27% amorphous scattering, 73% crystalline: 99.6% calcite, 0.4% quartz]
					6					55% forams 40% nannos 5% other carbonate
		N F R	A A -	M G -	Core Catcher					65% forams 35% nannos

Site 209 Hole Core 9 Cored Interval: 74-83 m

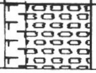
AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
DOWNHOLE ENTIRELY ("PLIO-PLEISTOCENE")					1	0.5 1.0	EMPTY 	4	CC XM GZ	CORES 7 & 8: NO RECOVERY 50% carbonate NANNO BEARING FORAM CALCIC OOZE 45% forams 5% nannos Very pale orange (10YR8/2). [95% $CaCO_3$] [69% sand, 22% silt, 9% clay] [X-ray - 27% amorphous, 73% crystalline: 100% calcite]
		N F R	A A -	M* G -	Core Catcher					65% sand and silt size carbonate 30% forams 5% nannos NANNO BEARING FORAM CALCIC OOZE

*From white fine grained lumps.

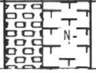
Site 209 Hole Core 10 Cored Interval: 83-92 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
MIDDLE EARLY MIOCENE	Not determinable.	N F R	R A -	P M -	Core Catcher					58% carbonate grains 39% forams 2% nannos FORAM CALCIC OOZE

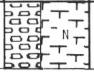
Site 209 Hole · Core 11 Cored Interval: 92-101 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
MIDDLE EARLY MIOCENE	N5-N6 Not determinable.	N F R	R A -	P G -	Core Catcher					84% sand and silt size carbonate 15% forams FORAM RICH CALCIC OOZE

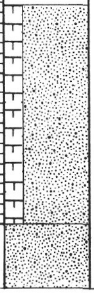
Site 209 Hole Core 12 Cored Interval: 101-110 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
EARLIEST MIOCENE (WAITAKIAN)	N4 NP25 (upper)	N F R	F A -	M G -	Core Catcher					50% forams 40% carbonate unknown origin 5% nannos NANNO BEARING CALCIC FORAM OOZE

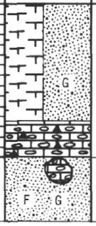
Site 209 Hole Core 13 Cored Interval: 110-119 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
LATE OLIGOCENE	NP25 (lower)	N F R	F A -	M G -	Core Catcher					80% forams 15% carbonate unknown origin 5% nannos NANNO BEARING CALCIC FORAM OOZE

Site 209 Hole Core 14 Cored Interval: 131-140 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
LATE OLIGOCENE		N	R	M	1 2	0.5 1.0	EMPTY 	4	CC GZ XM	92-76% carbonate crystals; some authigenic calcite has scalenohedron crystals as overgrowths of finer grain calcite and forams. 5-20% forams 2% nannos 2% glauconite FORAM RICH SILTY CALCIC SAND Friable, light greenish gray (56Y8/1) Largely cavings. [83% $CaCO_3$] [97% sand, 1% silt, 2% clay]
	Not determinable	N F R	F A -	P G -	Core Catcher					CALCIC SILTY SAND

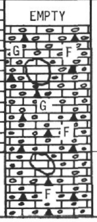
Site 209 Hole Core 15 Cored Interval: 150-159 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
LATE EOCENE (KAIATAN)	R. bisecta (NP17)	N	R	P	1	0.5 1.0			4 CC GZ XM	50% forams 45% carbonate, unknown orig. including calcite overgrowths on forams and fine grain calcite grains 2% nannos 2% glauconite 2% feldspar FORAM, SILTY CARBONATE SAND Homogeneous, yellowish gray (5Y8/1) [83% $CaCO_3$] [91% sand, 5% silt, 4% clay] CHERT AND CHERTY LIMESTONE Light olive gray (5Y6/1) [X-ray - 26% amorphous, 74% crystalline: 93% calcite, 4% quartz, 3% cristobalite] SILICIFIED ECHINODERM, FORAM BEARING SILTY SANDY LIMESTONE
	N F R	F C -	P M -		Core Catcher					

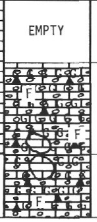
Site 209 Hole Core 16 Cored Interval: 168-177 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
					1	0.5 1.0	 EMPTY		4	77% carbonate crystals & grains 20% forams 2% glauconite GLAUCONITE BEARING FORAM RICH SILTY LIMSTONE, SILICIFIED LIMESTONE AND CHERT Light olive gray (5Y6/1); chert is olive gray (5Y4/1). Shipboard lab 47% $CaCO_3$ This is a foram-rich calcarenite (Foram and lime mud grains cemented by calcite) that by drilling was broken into sand and silt size grains that show overgrowths of clear calcite cement over original clastic grains and fossils. Shipboard lab 33% $CaCO_3$ QUARTZ, VERY FINE SAND AND SILT BEARING AND FORAM RICH LIMESTONE; SILICIFIED AND REPLACED BY CHERT.
					2					
LATE EOCENE (KAIATAN)	R. bisecta (NP17)	F R	- -	- -	Core Catcher					

Site 209 Hole Core 17 Cored Interval: 187-196 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
LATE EOCENE (KAIATAN)	R. bisecta (NP17)	N	R	P	1	0.5 1.0	 EMPTY		4	60% forams 34% carbonate (lime mud & cement) 2% glauconite 1% feldspar + quartz GLAUCONITE BEARING FORAM LIMESTONE AND SILICIFIED LIMESTONE CHERT yellowish gray (5Y8/1) - light olive gray (5Y6/1) chert - olive gray (5Y4/1) FORAM LIMESTONE REPLACED BY IRREGULAR SECONDARY CHERT
		N F R	R C -	P M -	Core Catcher					

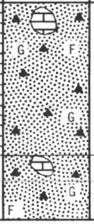
Site 209 Hole Core 18 Cored Interval: 196-205 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
					1	0.5 1.0	 EMPTY			QUARTZ SAND AND GLAUCONITE BEARING FORAM LIMESTOME; CHERT Yellowish gray (5Y8/1) chert - olive gray 45% forams Shipboard lab 93% $CaCO_3$ FORAM LIMESTONE AND SECONDARY CHERT
LATE EOCENE (KAIATAN)	R. bisecta (NP17)	N F R	F F -	P M -	Core Catcher					

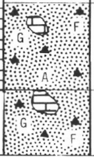
Site 209 Hole Core 19 Cored Interval: 205-214 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
LATE EOCENE (KAIATAN)	R. bisecta (NP17)	F R	C -	M -	Core Catcher					QUARTZ SAND AND GLAUCONITE BEARING FORAM LIMESTONE; CHERT light olive gray (5Y6/2) chert - olive black (5Y2/1)

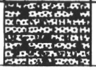
Site 209 Hole Core 20 Cored Interval: 214-223 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
LATE EOCENE (KAIATAN)	R. bisecta (NP17)	N F R	R R -	P P -	1	0.5 1.0		4		QUARTZ SAND AND CLAUCONITE-BEARING FORAM LIMESTONE CHERT limestone - light gray (N7) chert - olive gray (5Y4/1) Artificial graded bedding produced by drilling. Only hard layers preserved in chips. Soft intervening layers probably similar but unlithified foram oozes.
					Core Catcher					

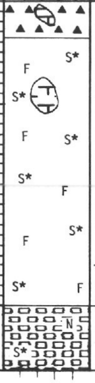
Site 209 Hole Core 21 Cored Interval. 223-232 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
LATE EOCENE (KAIATAN)	R. bisecta (NP17)				1	0.5 1.0	EMPTY 	2		QUARTZ SAND AND GLAUCONITE BEARING FORAM LIMESTONE; CHERT limestone - very light gray (N8) - yellow gray (5Y8/1) chert - olive gray (5Y4/1) Forams, and minor echinoderms and mollusca are cemented by sparry calcite with scalenohedron shaped crystals; volcanic glass - light R.I. <1.56
		F R	- -	- -	Core Catcher					

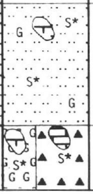
Site 209 Hole Core 22 Cored Interval: 232-241 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
LATE EOCENE (KAIATAN)	R. bisecta (NP17)	F R	- -	- -	Core Catcher					QUARTZ SAND AND GLAUCONITE BEARING LIMESTONE; CHERT light olive gray (5Y6/1) chert - olive gray (5Y4/1)

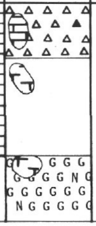
Site 209 Hole Core 23 Cored Interval: 241-250 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
LATE EOCENE (KAIATAN)	R. bisecta (NP17)	N	F	P	1	0.5 1.0		2 2 ?		LIMESTONE (BIOSPARITE) IRREGULARLY REPLACED BY CHERT limestone - light olive gray (5Y6/1) chert - olive gray (5Y4/1) NANNO BEARING FORAM AND SPONGE SPICULE* RICH LIMESTONE creamy, homogeneous, yellow gray (5Y8/1) - light olive gray (5Y6/1)
					2			GZ XM CC		No artificial grading or sorting by drilling. May represent soft interbeds between hard cherty layers. [58% $CaCO_3$] [43% sand, 43% silt, 14% clay] [X-ray - 51% amorphous scattering, 49% crystalline: 98.6% calcite, 1.4% quartz]
		N F R	C C F	P M G	Core Catcher					FORAM AND NANNO BEARING SPONGE SPICULE RICH CALCIC OOZE

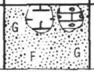
Site 209 Hole Core 24 Cored Interval: 250-259 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
LATE EOCENE (KAIATAN)	R. bisecta (NP17)				1	0.5 1.0	EMPTY 			GLAUCONITE BEARING QUARTZ SILT, NANNO AND FORAM-RICH SPONGE SPICULE* CALCIC OOZE 46% carbonate crystals 25% forams 25% sponge spicules 2% nannos 1% glauconite 1% radiolaria
		N F R	C C R	P M G	Core Catcher					GLAUCONITE-NANNO BEARING FORAM AND SPONGE SPICULE OOZE; CHERT IRREGULARLY REPLACING SPONGE SPICULE LIMESTONE

Site 209 Hole Core 25 Cored Interval: 259-268 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
		FOSSIL	ABUND.	PRES.						
LATE EOCENE (KAIATAN)	R. bisecta (NP17)				1	0.5 1.0				LIMESTONE; CHERT chert - olive gray (5Y4/1) FORAM CALCIC OOZE Shipboard lab determination 88% $CaCO_3$ 50% carbonate crystals (sparry calcite, broken shell fragments) 45% forams 1% nannos 2% quartz and feldspar 1% glauconite
		N F R	R A -	P M -	Core Catcher					GLAUCONITE-NANNO BEARING FORAM RICH CALCIC OOZE semilithified greenish gray (5GY6/1)

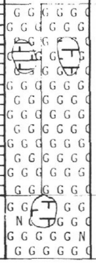
Site 209 Hole Core 26 Cored Interval: 268-272 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
		FOSSIL	ABUND.	PRES.					
LATE EOCENE (KAIATAN)	R. bisecta (NP17)	N F R	F A -	P M -	Core Catcher				

LITHOLOGIC DESCRIPTION

VERY FINE GRAINED QUARTZ SAND, GLAUCONITE, FORAM AND NANNO BEARING CALCIC CHALK light greenish gray (5GY8/1) and SILICIFIED LIMESTONE equivalent light gray (N7)

Site 209 Hole Core 27 Cored Interval: 272-281 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
		FOSSIL	ABUND.	PRES.					
					1	0.5 1.0	EMPTY		
LATE EOCENE (KAIATAN)	R. bisecta (NP17)	N	C	M	2				CC XM
		F R	A -	M -	Core Catcher				

LITHOLOGIC DESCRIPTION

NANNO AND GLAUCONITE BEARING SANDY CALCIC FORAM OOZE AND LITHIFIED LIMESTONE EQUIVALENT
greenish gray (5GY6/1)

[78% CaCO$_3$]

57% forams
32% carbonate
5% nannos
2% glass
2% quartz & feldspar + cristobalite & tridymite
1% glauconite

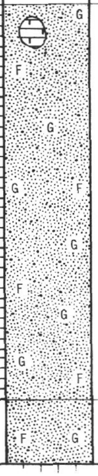
Shipboard lab determination 82% CaCO$_3$

[X-ray - 42% amorphous scattering, 58% crystalline: 83% calcite, 4% quartz, 9% cristobalite, 4% tridymite]

Microcrystalline calcite cements fossils and detrital grains.
Chert fills foram chambers and voids.

GLAUCONITE-NANNO SILICEOUS SPICULE BEARING CALCIC FORAM OOZE <2% detrital quartz sand microxln. calcite cement; chert fills voids and replaces fossils. Sponge? spicules have secondary overgrowths of chalcedony.

Site 209 Hole Core 28 Cored Interval: 281-290 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
		FOSSIL	ABUND.	PRES.					
						0.5	EMPTY		
MIDDLE EOCENE (BORTONIAN)	D. distinctus + R. hampdenensis (≈NP15)	N	F	M	1 2 3	1.0			GZ CC XM
		N F R	R - -	P - -	Core Catcher				

LITHOLOGIC DESCRIPTION

GLAUCONITE BEARING, SAND-RICH FORAM LIMESTONE
Laminated, slighty mottled greenish gray (5GY6/1) to grayish olive (10Y4/2).

[22% sand, 50% silt, 28% clay]

[58% CaCO$_3$]

[X-ray - 50% amorphous scattering, 50% crystalline: 69% calcite, 9% quartz, 11% cristobalite, 5% plagioclase, 5% tridymite, 1.9% clin.]

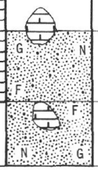
Insoluble residue subangular grains

Tourmaline? inclusion in quartz, devitrified glass, altered feldspar

50% quartz
15% glauconite
10% feldspar
10% light glass
3% dark glass - yellowish brown R.I. >1.56
2% amphibole
5% clay

Shipboard lab 68% CaCO$_3$

Site 209 Hole Core 29 Cored Interval: 290-299 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
		FOSSIL	ABUND.	PRES.					
MIDDLE EOCENE (BORTONIAN)	D. distinctus + R. hampdenensis (≈NP15)				1	0.5	EMPTY		
		N	F	P		1.0			GZ CC XM
		N F R	C C -	M M -	Core Catcher				

LITHOLOGIC DESCRIPTION

GLAUCONITE-NANNO SPONGE SPICULE BEARING SANDY FORAM RICH LIMESTONE
greenish gray (5GY6/1) to grayish olive (10Y4/2), slightly burrowed

[45% CaCO$_3$]

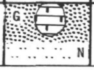
35% carbonate (sparry calcite, microcrystalline cement)
25% forams
10% amphibole
5% nannos
5% glauconite
5% light glass R.I. <1.56
5% dark glass R.I. >1.56
5% quartz
5% feldspar

[31% sand, 46% silt, 23% clay]

[X-ray - 47% amorphous, 53% crystalline: 63% calcite, 15% qtz., 3% cris., 4% K-feldspar, 10% plag., 2% mica, 1% mont., 1% tridymite, 1% clin.]

Abundant secondary chert.

Site 209 Hole Core 30 Cored Interval: 299-308 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
		FOSSIL	ABUND.	PRES.					
MIDDLE EOCENE (BORTONIAN)	D. distinctus + R. hampdenensis (≈NP15)	N F R	C F -	M P -	Core Catcher				

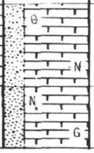
LITHOLOGIC DESCRIPTION

Abundant secondary chert filling foram chambers and voids. Has well-developed microxln. calcite cement.

GLAUCONITE-NANNO BEARING SILICEOUS SPICULE RICH SANDY LIMESTONE
pale olive (10Y6/2)

Insol.
25% quartz
5% feldspar
3% glass
4% glauconite
3% hornblende

Site 209 Hole Core 31 Cored Interval: 308-317 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
		FOSSIL	ABUND.	PRES.					
					1	0.5 1.0	EMPTY 		GZ CC XM
MIDDLE EOCENE (BORTONIAN)	D. distinctus + R. hampdenensis (≈NP15)	N F R	F R -	P P -	Core Catcher				

LITHOLOGIC DESCRIPTION

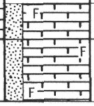
GLAUCONITE NANNO BEARING QUARTZ SAND RICH FORAM LIMESTONE
grayish olive (10Y4/2)

[73% sand, 15% silt, 11% clay]

[23% $CaCO_3$]

[X-ray - 65% amorphous scattering, 35% crystalline:
36% calcite, 16% qtz., 24% cris.,
10% plag., 4% mica, 2% mont.,
6% tridymite, 1.5% clin., 0.7% amphibole]

Site 209 Hole Core 32 Cored Interval: 317-326 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
		FOSSIL	ABUND.	PRES.					
					1	0.5 1.0	EMPTY 		CC XM
MIDDLE EOCENE (BORTONIAN)	D. distinctus + R. hampdenensis (≈NP15)	N F R	C R -	P P -	Core Catcher				

LITHOLOGIC DESCRIPTION

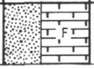
FELDSPAR AND QUARTZ SAND BEARING FORAM LIMESTONE
dusky yellowish green (5GY5/2) to grayish olive green (5GY3/2), slightly burrowed

[29% $CaCO_3$]

[X-ray - 64% amorphous, 36% crystalline:
40% calcite, 12% qtz., 26% cris.,
9% plag., 4% mica, 2% mont.,
5% tridymite, 1% pyrite]

light olive gray (5Y5/2) to gray olive (10Y4/2)

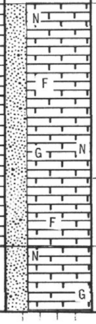
Site 209 Hole Core 33 Cored Interval: 326-335 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
		FOSSIL	ABUND.	PRES.					
MIDDLE EOCENE (BORTONIAN)	D. distinctus + R. hampdenensis (≈NP15)	N F R	F C -	P M -	Core Catcher				

LITHOLOGIC DESCRIPTION

GLAUCONITE SILICEOUS SPICULE BEARING QUARTZ SAND RICH FORAM LIMESTONE

Site 209 Hole Core 34 Cored Interval: 335-344 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
		FOSSIL	ABUND.	PRES.					
					1	0.5 1.0	EMPTY 		
MIDDLE EOCENE (BORTONIAN)	D. distinctus + R. hampdenensis (≈NP15)	N	F	M	2				GZ XM CC
		N F R	R C -	P P -	Core Catcher				

LITHOLOGIC DESCRIPTION

GLAUCONITE SILICEOUS SPICULE NANNO BEARING QUARTZ SAND RICH FORAM LIMESTONE
dusky yellow green (5GY5/2) to gray olive green (5GY3/2), slightly to moderately mottled

Shipboard lab 35% $CaCO_3$

[1% sand, 63% silt, 36% clay]

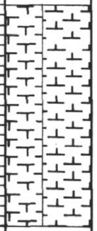
[X-ray - 58% amorphous scattering, 42% crystalline:
51% calcite, 13% qtz., 15% cris.,
10% plag., 4% mica, 4% tridymite,
3% clin.]

[26% $CaCO_3$]

Shipboard lab determination 43% $CaCO_3$

In thin section microcrysta-line calcite cements forams, detrital quartz, plagioclase and siliceous sponge spicules. Secondary chert (microxln. quartz, christobalite and tridymite) fill foram chambers and voids.

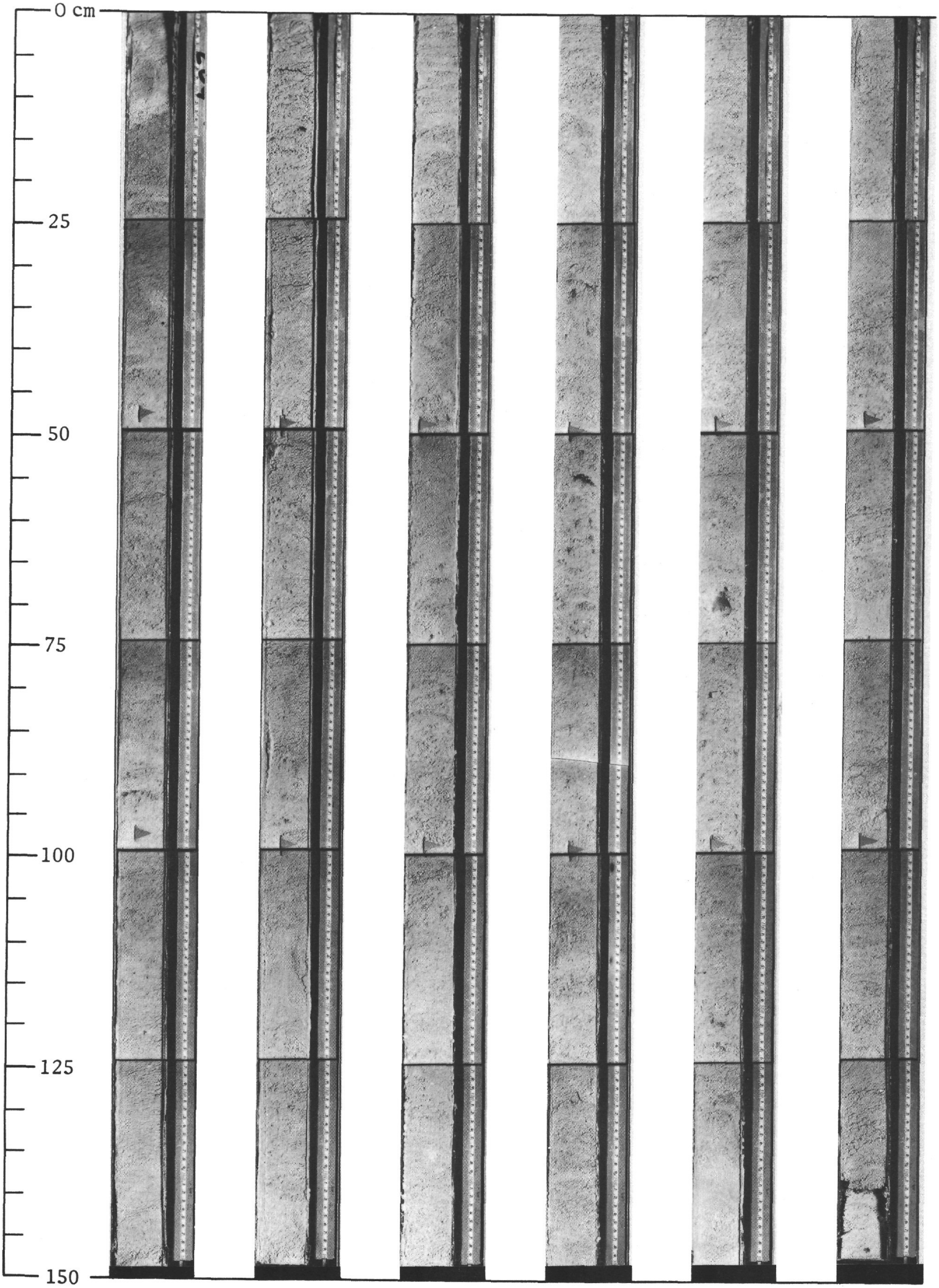
Site 209A Hole Core 1 Cored Interval: 0-9 m

AGE	ZONE	FOSSIL CHARACTER			SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
		FOSSIL	ABUND.	PRES.					
		N			1	0.5 1.0			
		N N N			2				
					Core Catcher		?		

LITHOLOGIC DESCRIPTION

50% nannos
49% forams
1% zeolites

FORAM NANNO OOZE
Creamy, homogeneous, very pale orange (10YR8/2).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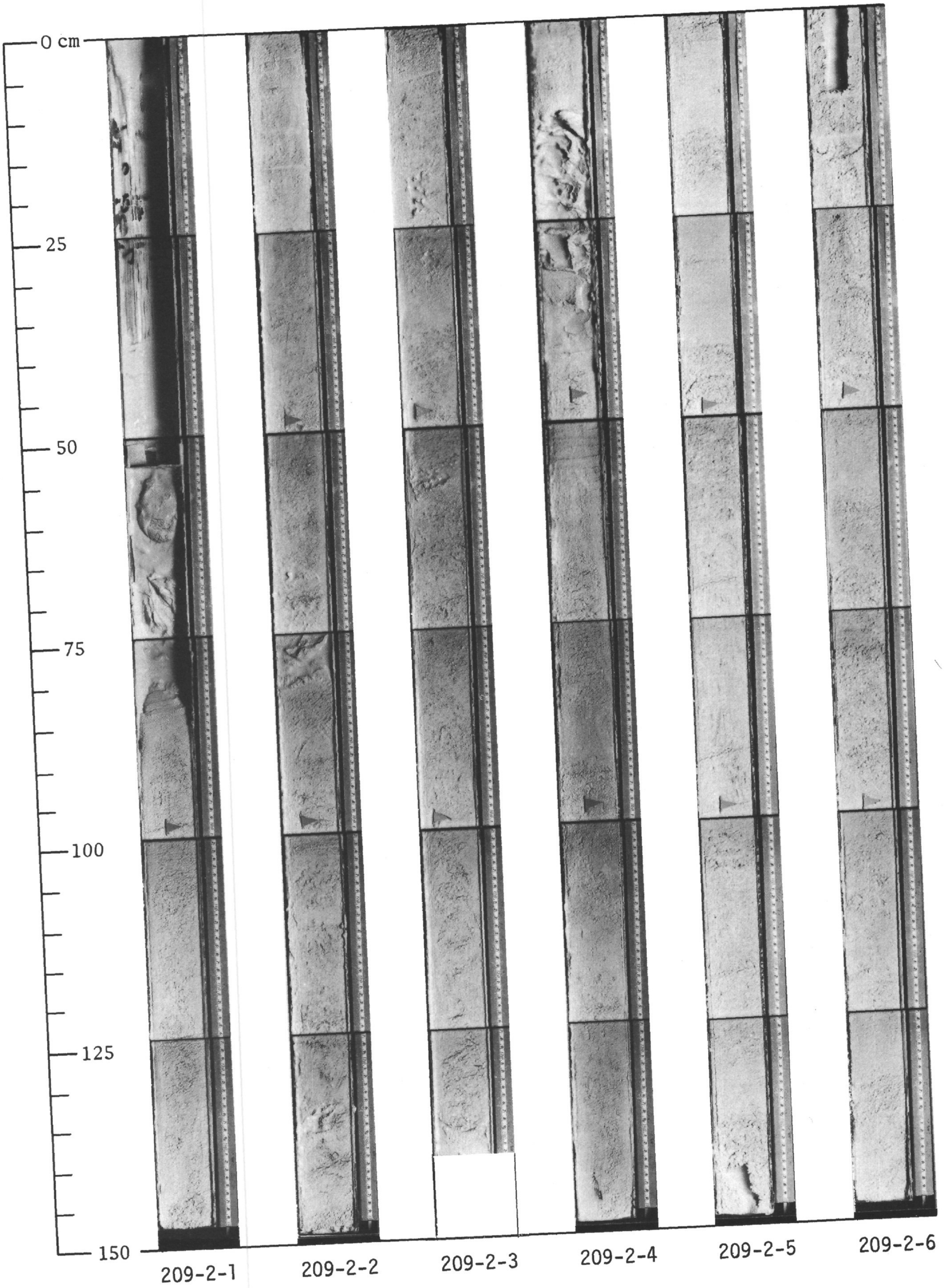
209-1-2
209-1-3
209-1-4
209-1-5
209-1-6


0 cm
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209-2-2
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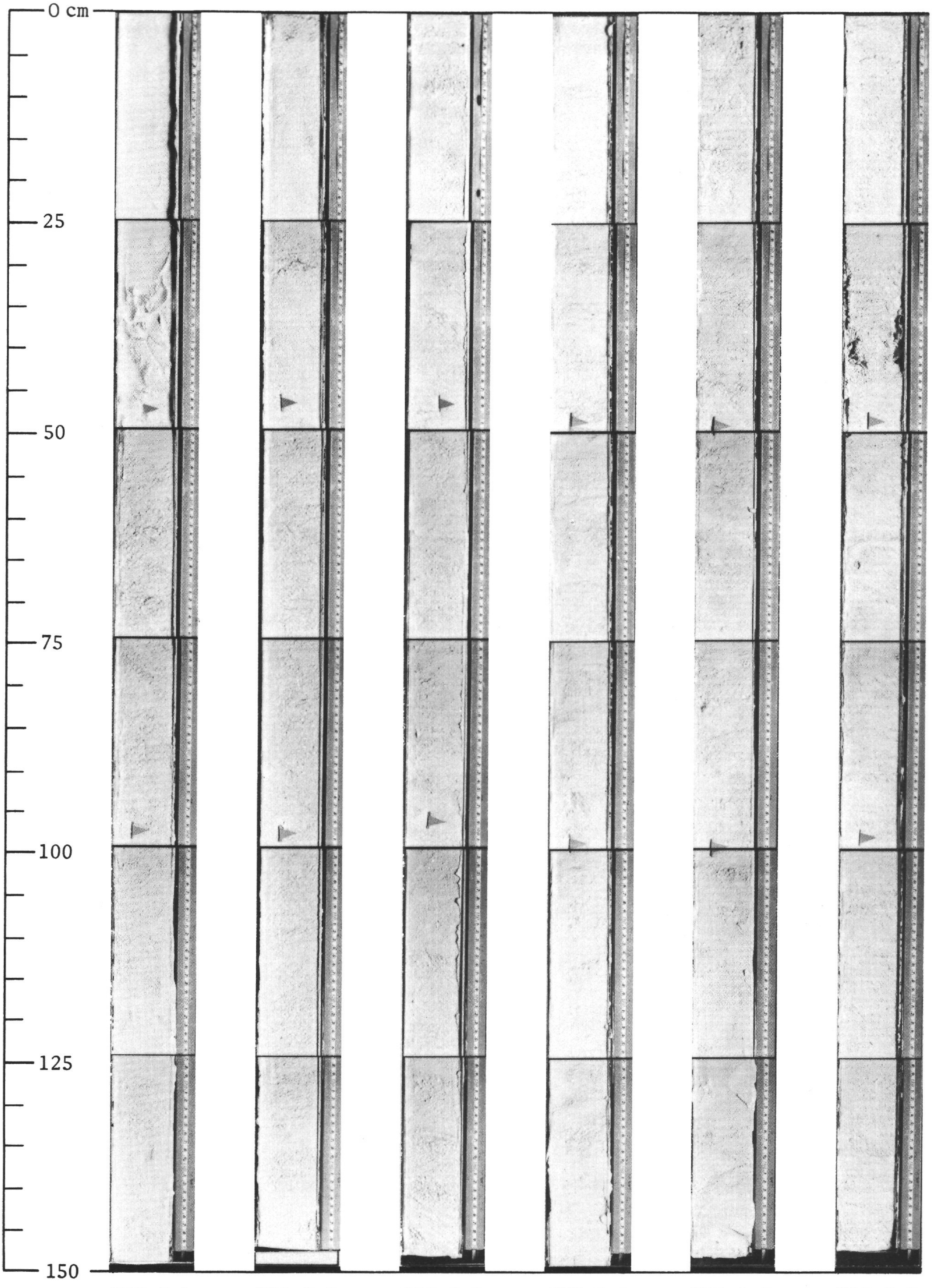
209-2-4
209-2-5
209-2-6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209-3-2
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209-3-4
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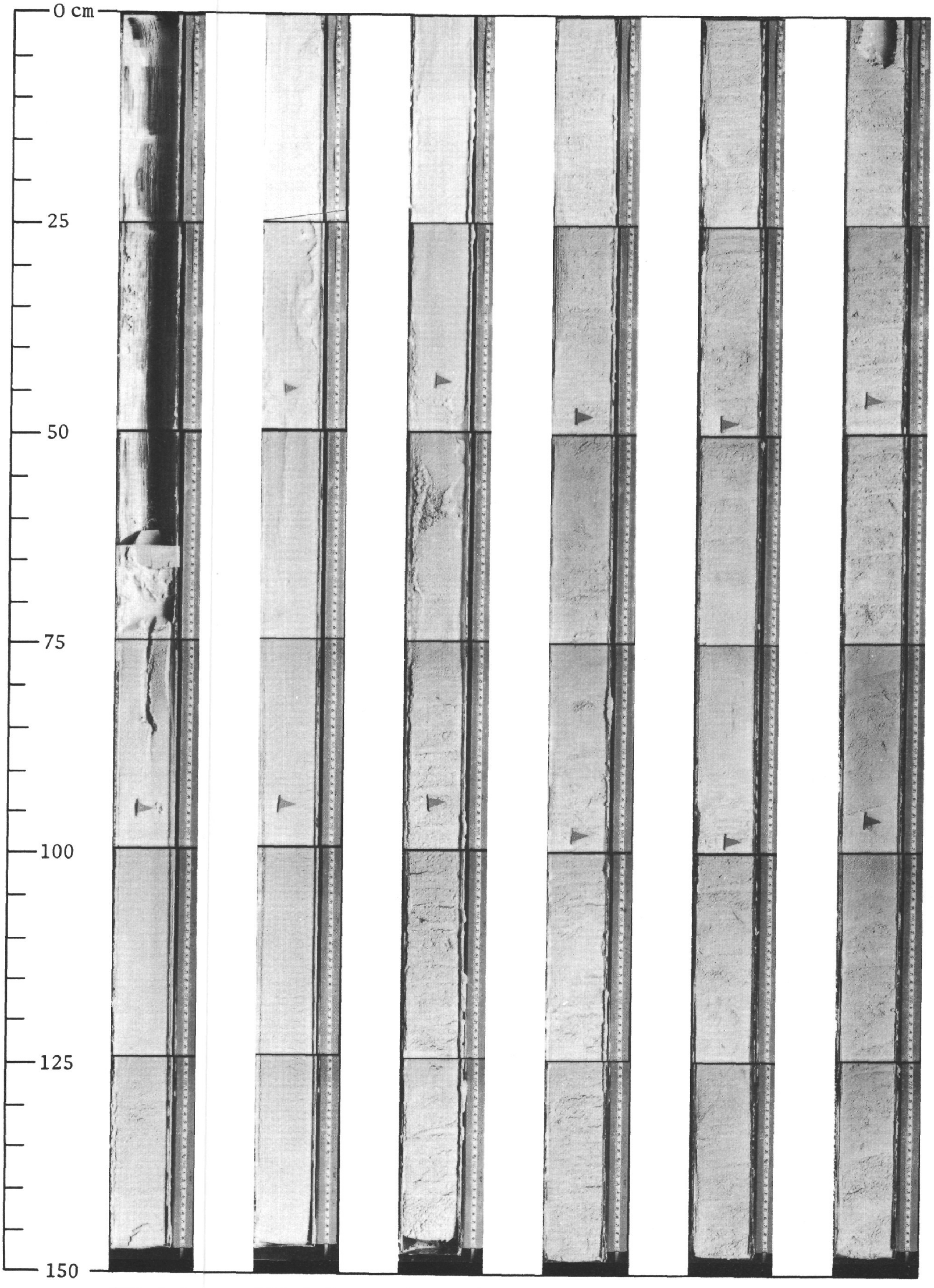
209-3-6


0 cm
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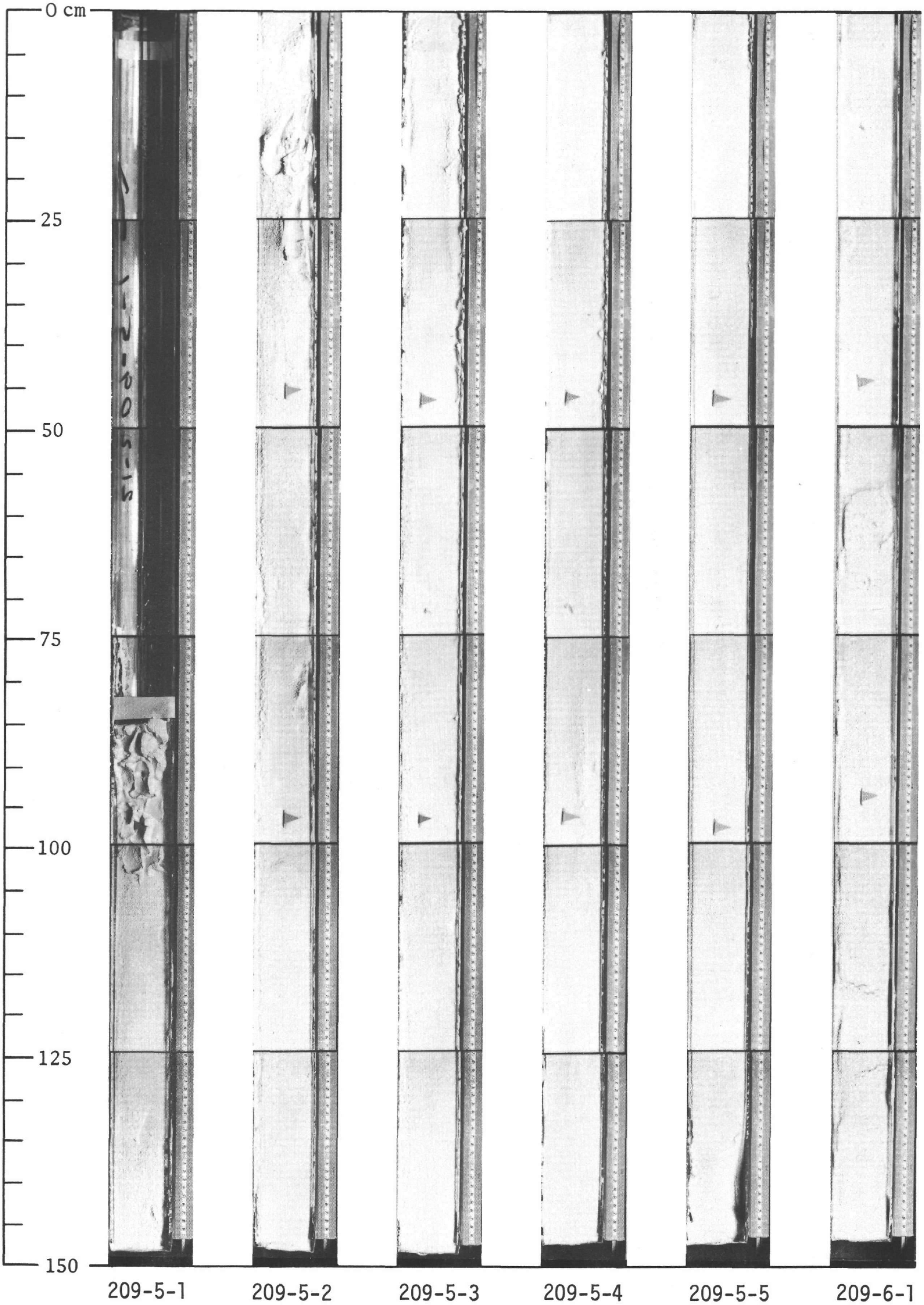
209-4-2
209-4-3
209-4-4
209-4-5
209-4-6


0 cm
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100
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150
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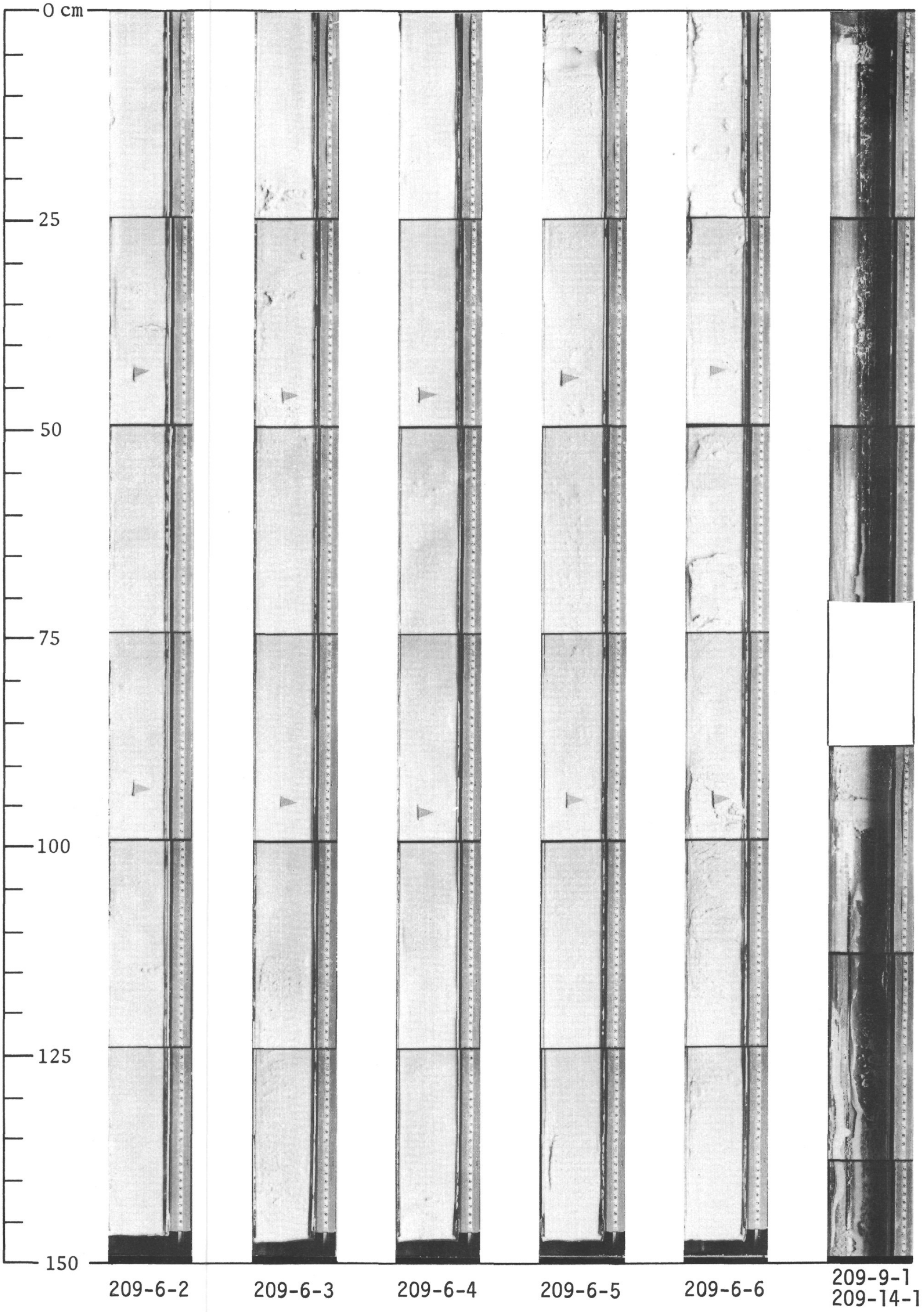
209-5-2
209-5-3
209-5-4
209-5-5
209-6-1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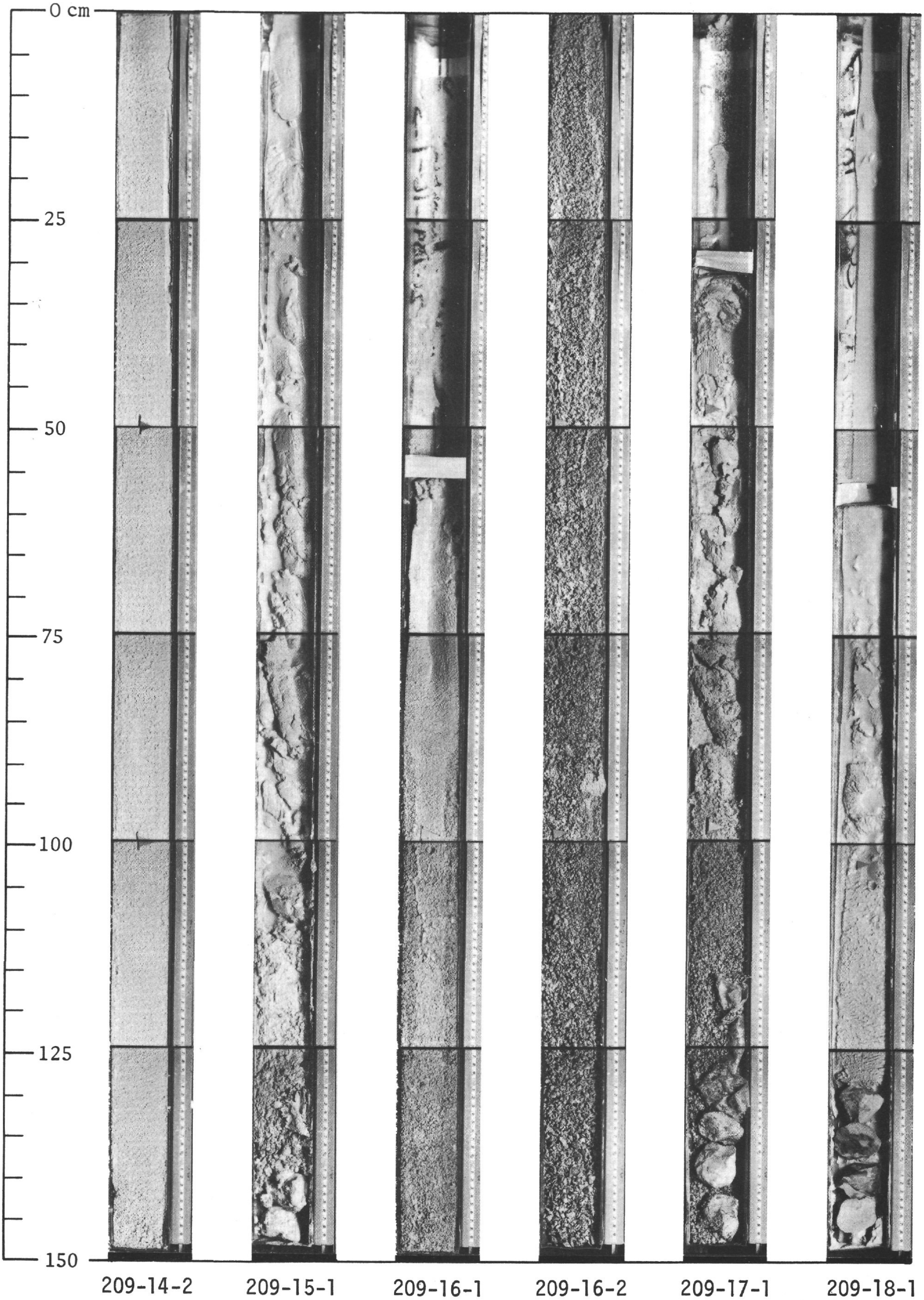
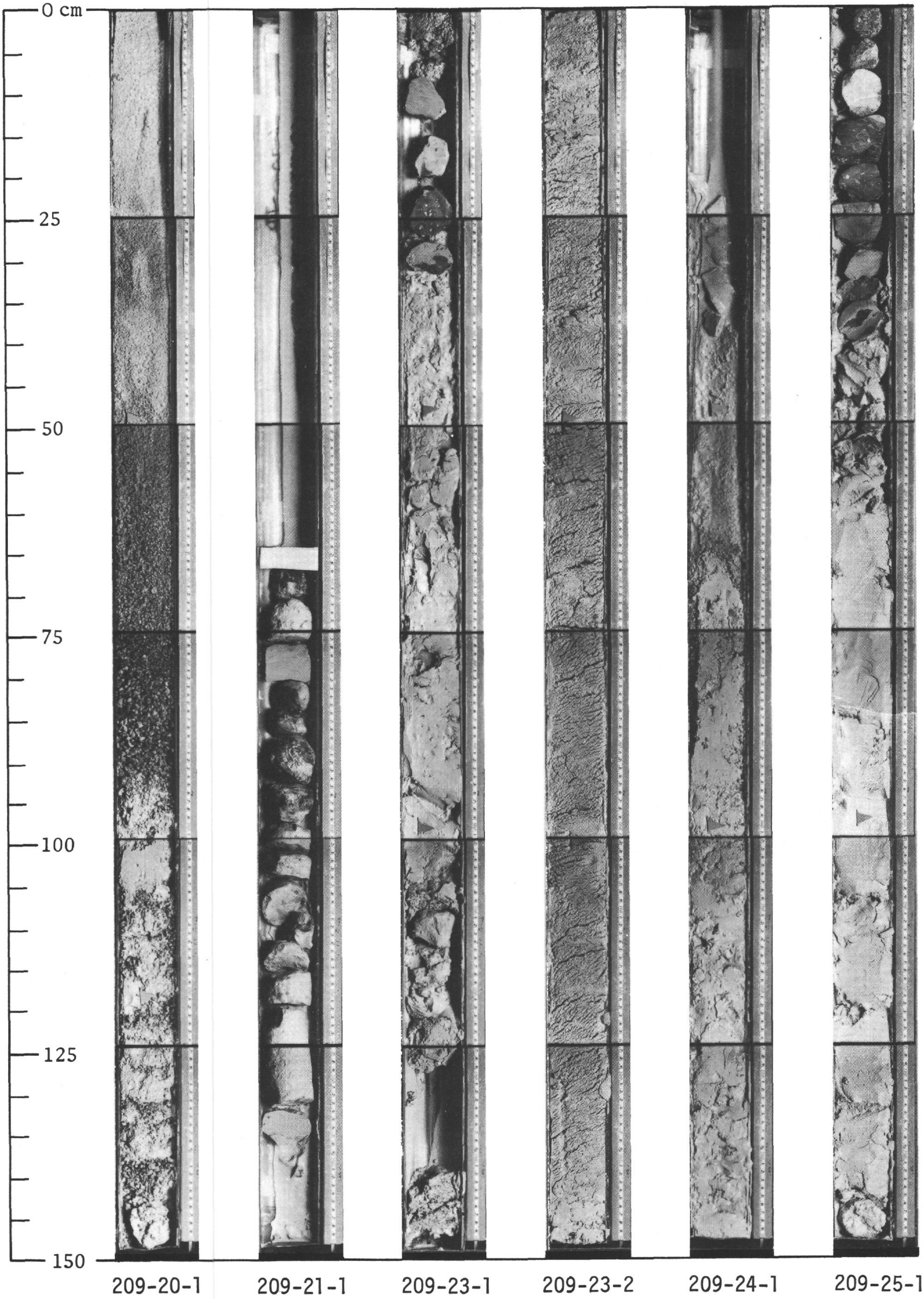
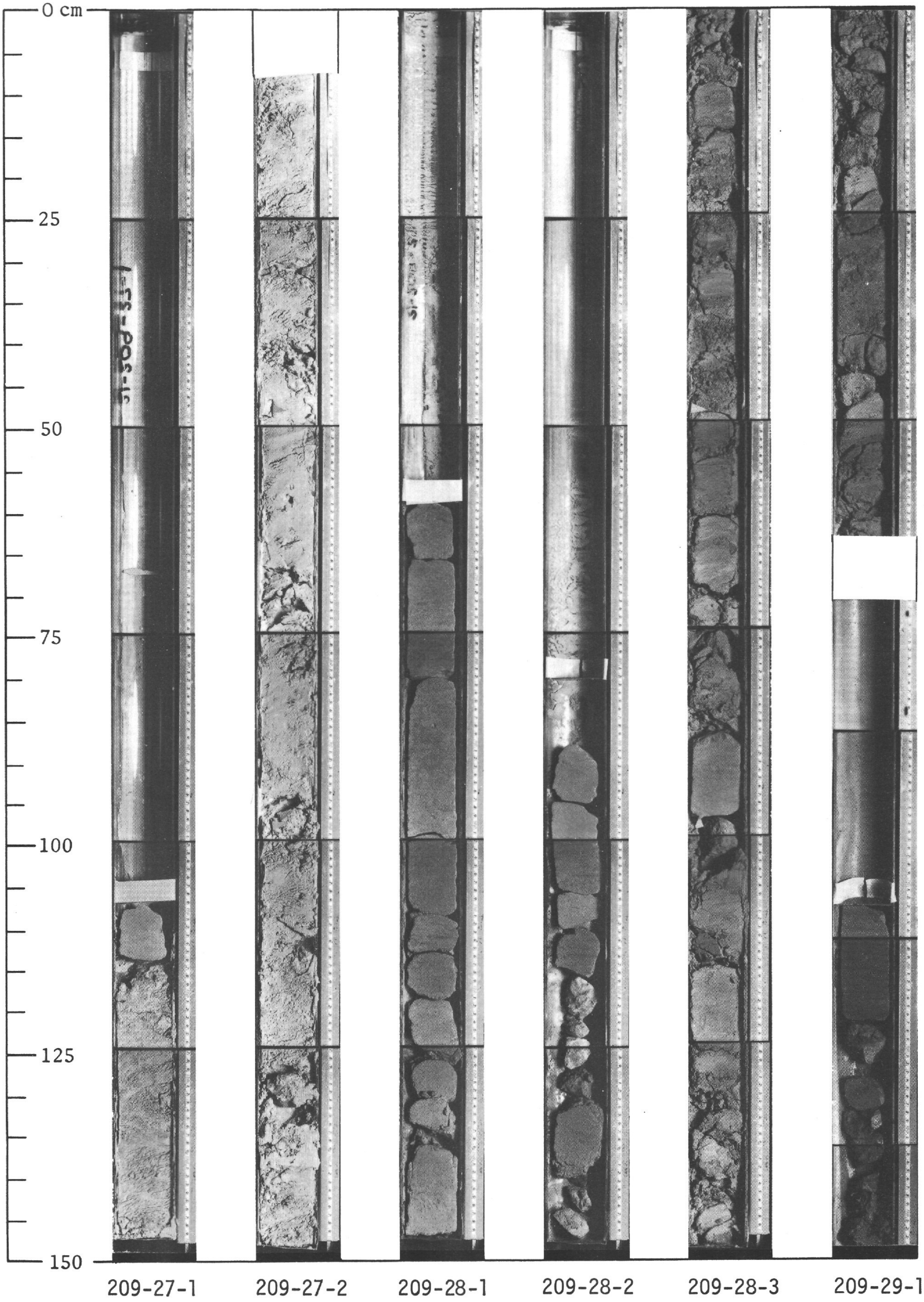
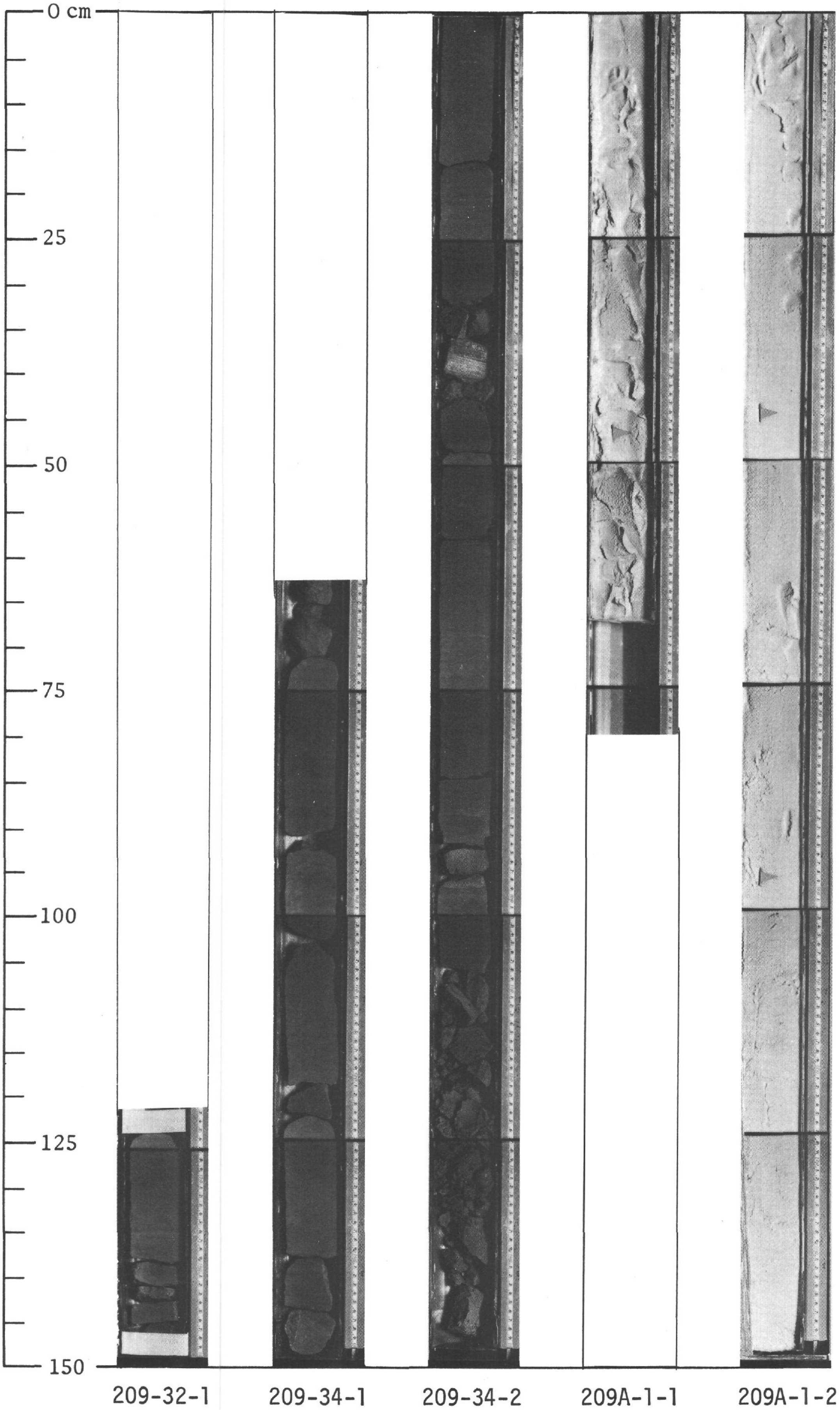
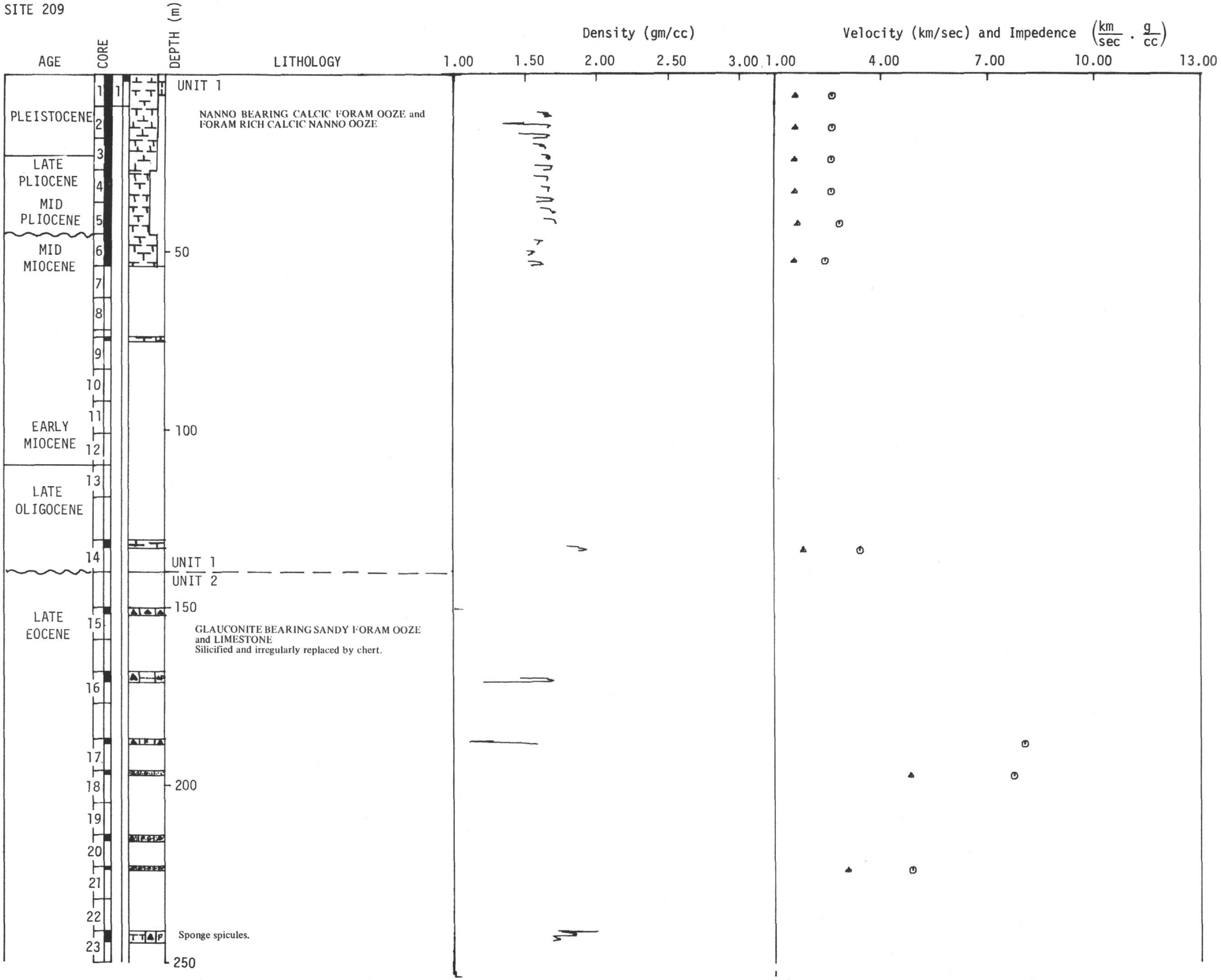
209-6-3
209-6-4
209-6-5
209-6-6
209-9-1
209-14-1

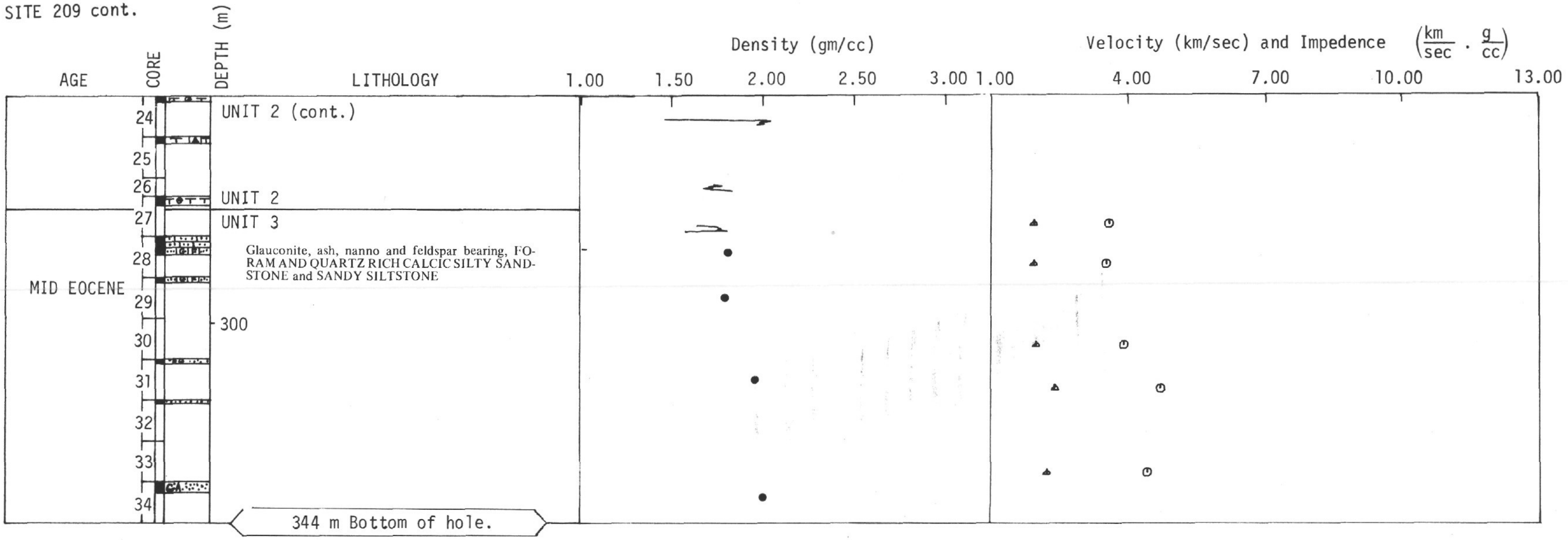

0 cm
25
50
75
100
125
150
209-14-2
209-15-1
209-16-1
209-16-2
209-17-1
209-18-1


0 cm
25
50
75
100
125
150
209-20-1
209-21-1
209-23-1
209-23-2
209-24-1
209-25-1


0 cm
25
50
75
100
125
150
209-27-1
209-27-2
209-28-1
209-28-2
209-28-3
209-29-1


0 cm
25
50
75
100
125
150
209-32-1
209-34-1
209-34-2
209A-1-1
209A-1-2


SITE 209
AGE
CORE
DEPTH (m)
LITHOLOGY
Density (gm/cc)
1.00
1.50
2.00
2.50
3.00
Velocity (km/sec) and Impedence $\left(\frac{km}{sec} \cdot \frac{g}{cc}\right)$
1.00
4.00
7.00
10.00
13.00
PLEISTOCENE
LATE PLIOCENE
MID PLIOCENE
MID MIOCENE
EARLY MIOCENE
LATE OLIGOCENE
LATE EOCENE
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
50
100
150
200
250
UNIT 1
NANNO BEARING CALCIC FORAM OOZE and FORAM RICH CALCIC NANNO OOZE
UNIT 1
UNIT 2
GLAUCONITE BEARING SANDY FORAM OOZE and LIMESTONE
Silicified and irregularly replaced by chert.
Sponge spicules.


SITE 209 cont.
AGE
CORE
DEPTH (m)
LITHOLOGY
Density (gm/cc)
Velocity (km/sec) and Impedence $\left(\frac{km}{sec} \cdot \frac{g}{cc}\right)$
1.00
1.50
2.00
2.50
3.00
1.00
4.00
7.00
10.00
13.00
24
25
26
27
28
29
30
31
32
33
34
300
UNIT 2 (cont.)
UNIT 2
UNIT 3
Glauconite, ash, nanno and feldspar bearing, FORAM AND QUARTZ RICH CALCIC SILTY SANDSTONE and SANDY SILTSTONE
MID EOCENE
344 m Bottom of hole.