9. SITE 142

The Shipboard Scientific Party[1]

ABSTRACT

Site 142 lies in the Ceara Abyssal Plain about 10 km south of the steep southern flank of the Ceara Rise and about 650 km northeast of the Amazon River.

The seismic reflection profile at Site 142 shows three main units in the abyssal plain sediments abutting against the flank of the Ceara Rise. An upper reflective zone represents a unit about 305 meters thick and consists of Pleistocene subarkosic silty sand and calcareous mud to nannoplankton marl ooze. A transparent zone represents a unit about 120 meters thick and consists of Pliocene foraminifera nannoplankton chalk ooze passing down into calcareous clay, foram sand, and sandy silt. A lower reflective zone represents a unit about 100 meters thick and consists of interbedded marl muds, nannoplankton marl/chalk ooze, foram sands, and clay. The age of this unit ranges from topmost Miocene to the Early Miocene. The top of this zone is defined by a very prominent seismic reflector which extends over thousands of square kilometers. The reflecting horizon boundary coincides with transition from Unit 2 to Unit 3, described above, and may serve as an important Pliocene/Miocene marker horizon. The flank of the Ceara Rise was penetrated near 537 meters sub-bottom. Only one core, indurated nannoplankton marl mud of Early Miocene age, was recovered beneath this level. At about 606 meters sub-bottom, a center bit sample of nannplankton marl yielded an Early Miocene flora.

Subsidence of the drilling site since Early Miocene is indicated on lithologic grounds.

SITE DATA

Time: 1220 13 November 1970
0000 16 November 1970

Position: 03° 22.15′N
42° 23.49′W

Water Depth: 13,914 feet
2,319 nominal fathoms
4,372 meters

Total Penetration: 626 meters

Cores taken: Nine cores and one center bit sample

BACKGROUND, SURVEY, AND OPERATIONS

Site 142 lies in the Ceara Abyssal Plain about 10 km south of the steep southern flank of the Ceara Rise (Figures 1 and 2). The overall structure of the Ceara Rise is unknown, however, most of its 1000 meters of relief above the abyssal plain is associated with materials of relatively low seismic velocities (Vp < 2.50 km/sec, see Chapter 12).

Seismic profiles from *Conrad* 13 and *Challenger* are shown in Figure 2. A preliminary site survey was conducted during *Conrad* 13 and additional seismic records are given in Chapter 12, this volume. The major flat-lying reflector that extends over the entire Ceara Abyssal Plain (Hayes and Ewing, 1970) is well illustrated in the region of C-D′ and C′ on the *Conrad* 13 profiles. This reflector can also be seen on the *Challenger* profile as it onlaps onto the flank of the Ceara Rise. However, only a very small portion of this reflector is shown on the *Challenger* record. An enlargement of the *Challenger* profile at Site 142 is given in the composite diagram as Figure 3. Selected *Conrad* traverses show deep reflectors extending 0.6 to 0.7 second below the top of the Ceara Rise which can be traced down the flank of the Rise beneath the sediments of the Ceara Abyssal Plain. A major portion of the Ceara Rise appears to be composed of sediments. Portions of the oceanic basement rise to near the top of the Ceara Rise especially near the central part of the feature (see also Chapter 12, this volume and Embly *et al.*, 1972). There is a slight upwarping of the main sub-bottom reflector shown between C′ and B′ on the *Conrad* profile. This upwarping is minor and is not typical

[1] D. E. Hayes, Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York; A. C. Pimm, Scripps Institution of Oceanography, La Jolla, California; W. E. Benson, National Science Foundation, Washington, D. C.; W. H. Berger, Geologisch Palaeontologisches Institut-Kiel, Kiel, Germany; U. von Rad, Bundesanstalt für Bodenforschung-Hannover, Hannover, Germany; P. R. Supko, Scripps Institution of Oceanography, La Jolla, California; J. P. Beckmann, Geologisches Institut-Zurich, Zurich, Switzerland; P. H. Roth, Geologisches Institut-Zurich, Zurich, Switzerland.

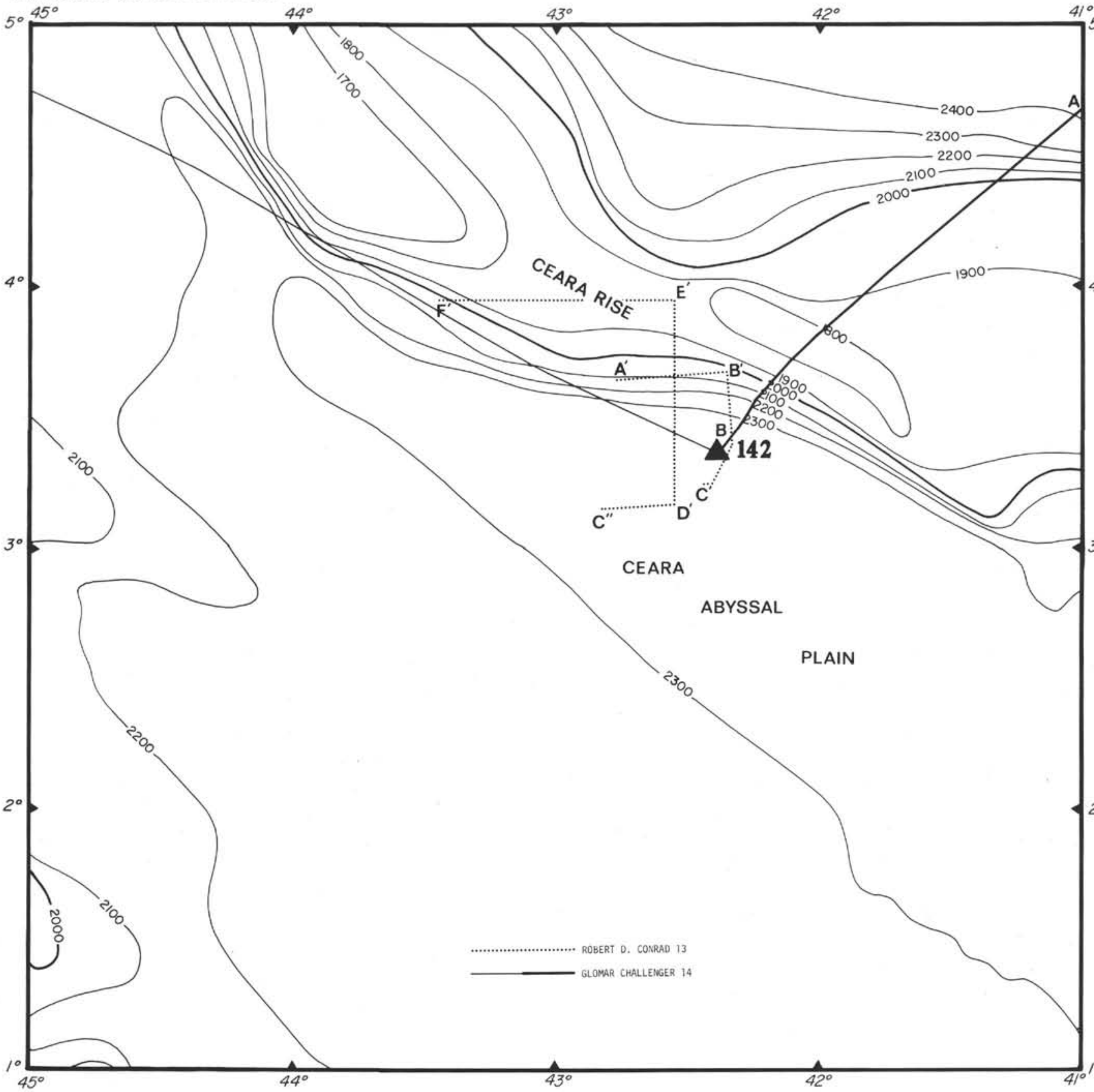


Figure 1. *Location map for Site 142. Contours are in nominal fathoms and taken from U.S. Naval Oceanographic Office Charts, BC Charts 0501N and 0502N. Letters key seismic profiles in Figure 2.*

of most of the traverses which cross the Ceara Abyssal Plain-Ceara Rise boundary.

The scientific objectives at this site were twofold. One was to sample the sediments near the prominent and extensive abyssal plain reflector (Figure 2) to determine its age and sedimentary nature. The second objective was to drill into the flank of the Ceara Rise, which lies unconformably below the prominent reflector, to establish the composition of the rise. It was anticipated that the rise was composed mainly of unconsolidated and semi-consolidated sediments; however, apparent basement highs approach the ocean floor at several places near the center of the rise. It was presumed that the thick sequence (~500 m) of well layered sediments overlying the prominent abyssal plain reflector (Figures 2, 3) is largely terrigenous and relatively young.

Vema 25 piston cores taken on the upper flank of the Ceara Rise east of Site 142 encountered Middle Miocene sediments at the sea floor (see Chapter 12).

Seismic Reflection Data:	*Conrad* 13	*Challenger*
Reflectors 1	0.3 sec	0.37 sec
2	0.5 sec	0.50 sec
Rise Flank	0.7 sec	0.60 sec
Deepest Reflector	1.2 sec	?

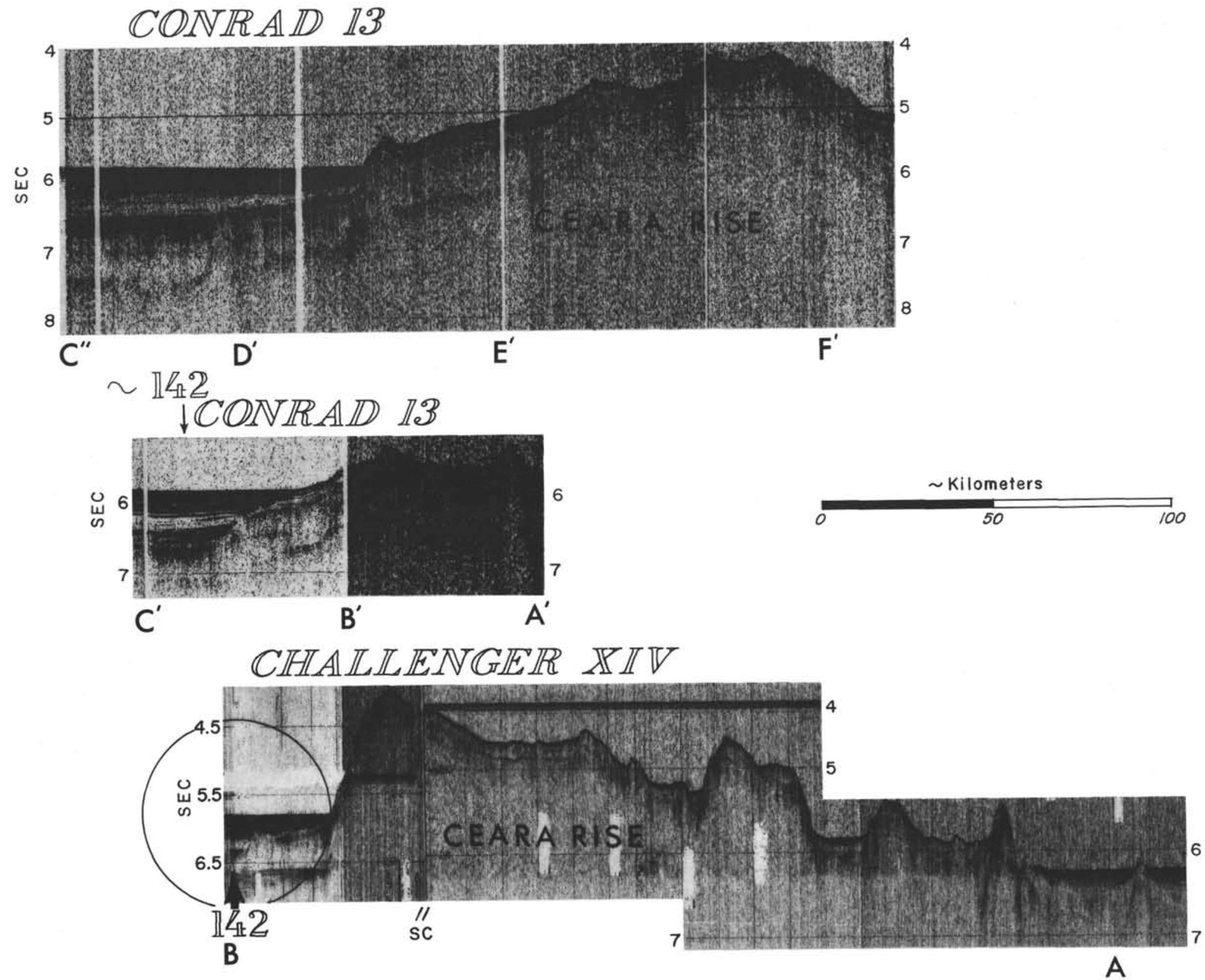


Figure 2. *Seismic profiles in the vicinity of Site 142. Note scale change (11 SC) on* Challenger *profile.* Conrad *13 profiles are from unpublished LDGO data. (J. Ewing, pers. comm.) and Chapter 12 this volume.*

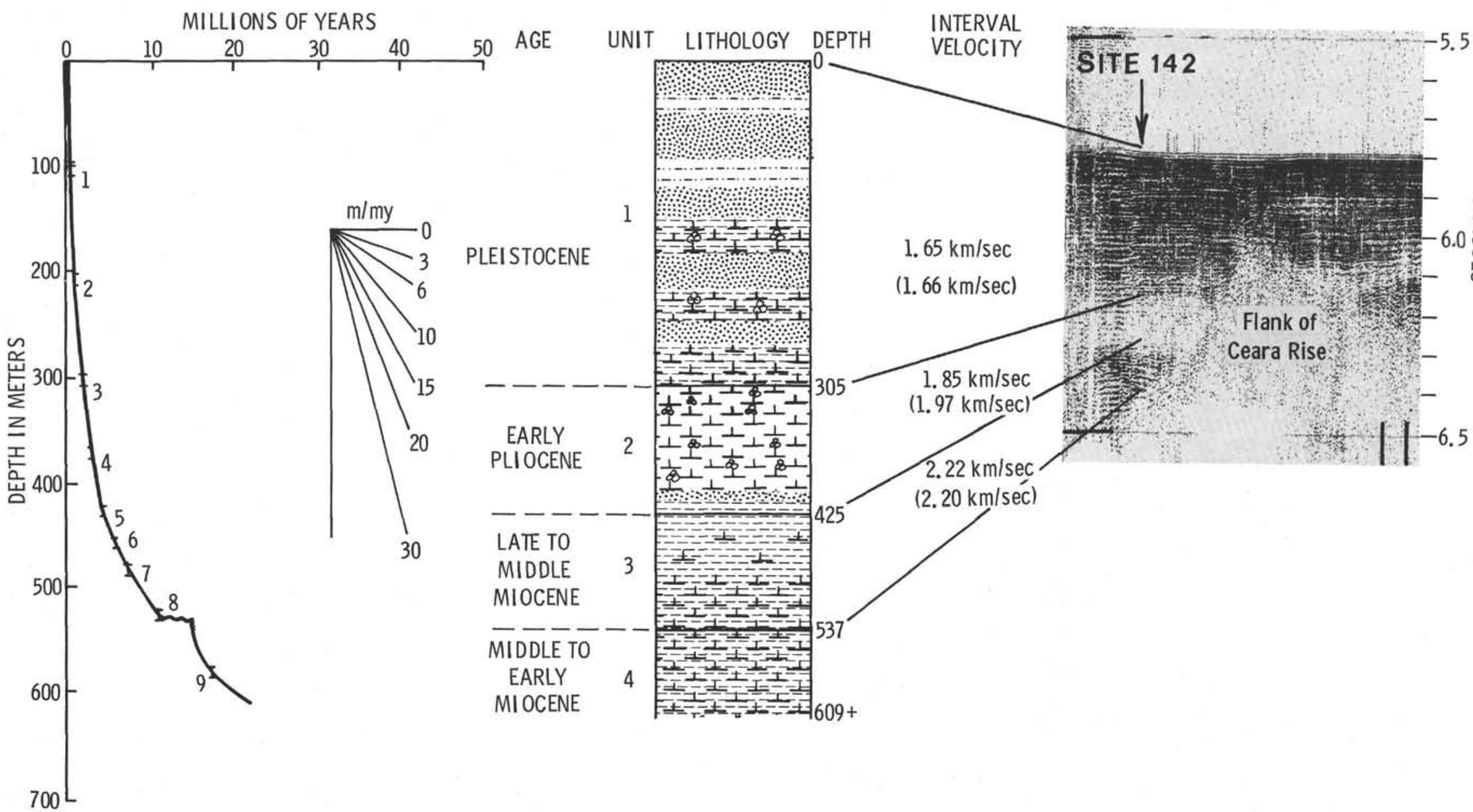


Figure 3. *Geological synthesis of Site 142. Internal velocities from our correlation are shown on top. Velocities determined from sonobuoy measurements, about 50 km southwest of Site 142, are shown below in parentheses.*

The drilling and coring records are given in Table 1 and Figure 4.

TABLE 1
Drilling and Coring Record for Site 142

Description	Interval Below Sea Floor (m)	Core Recovery (m)	Drilling Rate (m/min)
Drill	0-12		4.0
	12-31		4.5
	31-50		2.7
	50-60		3.3
	60-79		2.1
	79-89		2.5
	89-98		2.1
Core 1	98-106	8.0	
Drill	106-126		2.5
	126-135		1.9
	135-154		1.6
	154-163		4.5
	163-179		1.1
	179-191		2.0
	191-200		1.3
Core 2	200-209	9.0	
Drill	209-219		1.4
	219-228		0.8
	228-238		1.3
	238-256		1.5
	256-266		2.0
	266-284		1.8
Core 3 (?)	293-302	0.9	
Drill	302-321		1.9
	321-339		1.8
	339-358		1.4
	358-367		3.0
Core 4 (?)	387-398	7.1	
Drill	398-417		1.0
	417-426		0.8
	426-445		0.8
Core 5	423-429	1.5	
Drill	423-429		1.4
Core 6	451-457	2.7	
Drill	457-479		0.6
Core 7	479-487	8.4	
Drill	487-507		0.6
	507-517		0.7
	517-529		0.3
Core 8	529-538	2.8	
Drill	538-546		0.7
	546-565		0.3
	565-575		0.3
Core 9	575-581	4.4	
Drill	581-584		0.6
	584-604		0.8

Several technical difficulties were encountered at this site. About 2130 hours, 13 November, the ship's main generator failed, and power was temporarily restored via the emergency generator. However, as a consequence of the power failure, the ship's positioning computer was rendered inoperative and could not be reinitiated until the ship's main power was restored. Operations were held in standby status for about 4 hours until automatic positioning was resumed.

The first acoustic beacon (13.5 kHz) dropped developed an abnormally long transmission pulse which was unacceptable to the shipboard dynamic positioning computer. A second beacon (16 kHz) was then deployed and drilling operations were maintained on standby status until the new beacon reached bottom and the positioning system could be referenced to it.

After drilling about 25 meters below Core 9, intermittent problems developed in the acoustic signal of the 16 kHz beacon. The situation was carefully monitored, and operations were held in standby status. The intermittent acoustic failures became more frequent, and the decision was made to trip pipe out of the hole. The ship was held over the site by operating in semi-automatic mode using at times, both the 13.5 kHz and the 16 kHz beacons and by utilizing the strain gauge positioning device. After clearing the mudline, the decision was made to trip to the surface and abandon the site.

A situation such as this points to an added (perhaps the most important) potential value of a beacon retrieval system. Defective beacons could be recalled, allowing an additional beacon of the same frequency to be dropped, thus avoiding the necessity of losing a hole if two successive beacon failures should occur.

BIOSTRATIGRAPHY

General

The location of this site near the Ceara Rise and the Amazon Cone is reflected in the complexity of its fossil assemblages. The following are present in Cores 1, 2, 3, 5, 6, and 8: autochthonous faunas (with moderately to strongly dissolved planktonic foraminifera recognizable by their good preservation), rich benthonic foraminiferal assemblages, shallow water fossils (calcareous algae, Bryozoa), and plant material. Intervals of relatively homogeneous composition were also found (Cores 4 and 7). Another piston core (V-25-62), collected on a steep scarp near the Southeastern end of the Ceara Rise, is of early Middle Miocene age (*Globorotalia fohsi peripheroacuta* Zone) at the top and of latest Early Miocene age (*Praeorbulina glomerosa* Zone) near the bottom. Since the fauna of Core 9 of Site 142 is of similar composition, and even slightly older (*Globigerinatella insueta* Zone), this provides additional evidence that Hole 142 reached the sediments which also constitute the Ceara Rise.

The age of the rocks penetrated at this site extends from the Pleistocene to the Early Miocene. The greater than 300 meter thickness of the Pleistocene sediments demonstrates high sedimentation rates. The Pliocene (Cores 4 and 5) and the Miocene (Cores 6 to 9, and center bit sample below Core (9) sedimentation rates are much less than the Pleistocene rate (see Figure 3), however, it is probable that the greater part of the Pliocene and Upper Miocene constituents is allochthonous.

The age diagnostic fossils from each core are given in Table 2.

TABLE 2

CORE	DIAGNOSTIC FOSSILS HOLE 142		
	FORAMINIFERA	**NANNOPLANKTON**	**AGE**
1	Fairly rich, predominantly planktonic faunas with *Globorotalia truncatulinoides* (mostly random coiling), *Gr. cultrata, Globigerina dutertrei, Globigerinoides ruber, Pulleniatina obliquiloculata, P. finalis, Sphaeroidinella dehiscens* (rare). The abundant plant fragments, rare bryozoans, and the presence of two types of preservation in the planktonic foraminifera (glossy and slightly etched) are evidence that the fossil assemblages are mixed and partially re-deposited. Age: Quaternary, *Globorotalia truncatulinoides* Zone.	Rich nannoflora with abundant *Gephyrocapsa oceanica,* rare *Pseudoemiliania lacunosa* (circular and elloptical) *Umbilicosphaera sibogae.* Preservation: G. Zone: *Gephyrocapsa oceanica* Age: Pleistocene	Pleistocene
2	Rich, predominantly planktonic faunas with *Globorotalia truncatulinoides* (predominantly sinistral), *Gr. pseudopima, Gr. cultrata* (rare), *Gr. conomiozea, Globigerina dutertrei, Globigerinoides ruber* (rare), *Gr. conomiozea, Globigerina dutertrei, Globigerinoides ruber* (rare),*G. trilobus* s.l., *Sphaeroidinella dehiscens, Pulleniatina obliquiloculata.* Mollusk shells and Bryozoan fragments suggest mixing with derived shallow water material. Age: Quaternary, *Globorotalia truncatulinoides* Zone.	*Pseudoemiliania lacunosa* is more abundant than in the core above and *Gephyrocapsa oceanica* is no longer present. Preservation: G Zone: *Pseudoemiliania lacunosa.* Age: Early Pleistocene	Pleistocene
3	Fairly rich, predominantly planktonic faunas with *Globorotalia truncatulinoides* (sinistral), *Gr. humerosa, Gr. crassaformis* A (Bolli, Leg IV Initial Report), *Globigerinoides ruber* and spp., *Sphaeroidinella dehiscens, Pulleniatina obliquiloculata,* and fairly common benthonic foraminifera *(Dorothia, Miliolidae, Gyroidina tenera* etc.). Mostly with distinct solution effect. Flood of well preserved specimens at Sec. 1, cm 137 may be allochthonous. Age: Quaternary, *Globorotalia truncatulinoides* Zone (presence of *Globorotalia crassaformis* A indicates Early Pleistocene).	Similar assemblages as in Core 2. Zone: *Pseudoemiliania lacunosa.* Age: Early Pleistocene.	Pleistocene
4	Rich, predominantly planktonic faunas with *Globorotalia multicamerata, Gr. tumida* (dextral), *Gr. humerosa, Gr. exilis, Gr. crassaformis* s.l., *Gr.* cf. *plesiotumida, Gr. margaritae* (rare, small), *Globigerina venezuelana, Globoquadrina altispira, Globigerinoides obliquus extremus, G. ruber* (rare), *Sphaeroidinella dehiscens* (mostly forma "immatura"), *Sphaeroidinellopsis seminulina, S. paenedehiscens, Pulleniatina primalis* (dextral). Common small (pelagic?) Bolivinidae in fine fraction. Age: Early Pliocene, *Globorotalia margaritae* Zone.	Abundant nannoplankton includes *Reticulofenestra pseudoumbilica, Discoaster brouweri, D. asymmetricus, Ceratolithus rugosus, Sphenolithus abies.* Zone: *Reticulofenestra pseudoumbilica.* Age: Early Pliocene	Early Pliocene

TABLE 2 – *Continued*

CORE	DIAGNOSTIC FOSSILS HOLE 142 FORAMINIFERA	NANNOPLANKTON	AGE
5	Mixed assemblages consisting of: a) autochthonous faunas (mainly planktonic foraminifera showing rather strong solution effects), b) transported and redeposited material with calcareous algae *(Halimeda, Galaxaura)*, foraminifera (well-preserved, thin-walled Globigerinidae; *Amphistegina* sp.), Bryozoa *(Nellia, Thalamoporella)*, and plant fragments. Distinctive planktonic foraminifera are *Globorotalia margaritae* (small), *Gr. multicamerata, Gr. cultrata, Gr.* cf. *tumida/plesiotumida, Gr. pertenuis, Globoquadrina altispira, Globigerina venezuelana, Globigerinoides obliquus, Sphaeroidinella dehiscens* (forma "immatura"), *Sphaeroidinellopsis seminulina, S. paenedehiscens, Pulleniatina primalis* (sinistral). Age: Early Pliocene, *Globorotalia margaritae* Zone.	Similar assemblages as in core 4. Preservation: E_1 - 01. Zone: *Reticulofenestra pseudoumbilica*. Age: Early Pliocene	Early Pliocene
6	Samples from clay layers contain fish teeth and few strongly etched planktonic foraminifera. Interbedded are pelagic foraminiferal sands with varying proportions of calcareous algal fragments (mainly *Halimeda)*, Bryozoa, and benthonic foraminifera (Buliminidae, Nonionidae, *Amphistegina* sp.), sometimes containing abundant and well preserved minute Globigerinidae and (pelagic?) Bolivinidae. Typical planktonic foraminifera are *Globorotalia cultrata* (random coiling), *Gr. acostaensis, Gr.* cf. *plesiotumida, Gr. humerosa, Gr. margaritae?* (rare in Sec. 1), *Globigerinoides obliquus extremus, G. conglobatus, Globigerina nepenthes, Sphaeroidinellopsis seminulina, S. paenedehiscens.* Age: Transition Miocene/Pliocene, *Globorotalia margaritae* Zone and or *"Globorotalia dutertrei"* Zone.	Strongly etched nannoplankton with *Coccolithus pelagicus, Discoaster variabilis, D. brouweri* and rare *Ceratolithus tricorniculatus.* Preservation: E_2 to E_3. Zone: *Ceratolithus tricorniculatus.* Age: Early Pliocene or Late Miocene	Early Pliocene or Late Miocene
7	Rich, predominantly planktonic faunas with *Globorotalia cultrata, Gr. acostaensis, Gr. pseudomiocenica, Gr.* cf. *lenguaensis, Globigerina nepenthes, Globoquadrina dehiscens, Globigerinoides obliquus obliquus, Sphaeroidinellopsis seminulina, S. paenedehiscens?* Age: Late Miocene, *Globorotalia acostaensis* Zone (or possible *"Globigerina dutertrei"* Zone).	Well preserved rich assemblages with *Discoaster quinqueramus, Ceratolithus tricorniculatus* and rare *C. primus.* Preservation: E_1 - 01. Zone: *Discoaster quinqueramus.* Age: Late Miocene	Late Miocene
8	Mixed faunas containing Middle Miocene (and Late Miocene?) material, ranging from the *Globorotalia fohsi peripheroronda* Zone to the *Globorotalia mayeri* (or *G. acostaensis?)* Zone. The presumably autochthonous faunas consist of strongly etched planktonic foraminifera, fish debris, and *Bathysiphon* sp. Thin-shelled globigerinids (Sec. 2) may be allochthonous. Typical planktonic species are *Globorotalia cultrata, Gr. mayeri, Gr. acostaensis?* (Sec. 1), *Gr. lenguaensis, Gr. fohsi peripheroronda* (Sec. 1), *Gr. fohsi fohsi, Globigerina nepenthes, Globigerinoides obliquus, G. subquadratus* (Sec. 2), and *Sphaeroidinellopsis seminulina.*	Sections 1 and 2: Poorly preserved nannoplankton including *Discoaster neohamatus, D. calcaris, D. variabilis.* Preservation: E2 - 01. Zone: *Discoaster neohamatus.* Age: Late Miocene Core Catcher: *Discoaster exilis, Discoaster deflandrei.* Preservation: E_3 Zone: *Discoaster exilis.* Age: Middle Miocene	Late Miocene - Middle Miocene

TABLE 2 – *Continued*

CORE	DIAGNOSTIC FOSSILS HOLE 142		
	FORAMINIFERA	NANNOPLANKTON	AGE
9	Rich, predominantly planktonic faunas with *Globorotalia fohsi peripheroronda*, *Gr. mayeri*, *Gr. birnagae*, *Globoquadrina dehiscens*, *Globigerinoides subquadratus*, *G. sicanus*, and *Globigerinatella insueta*. Fairly strong solution effects; many specimens are compressed. Age: Late Early Miocene, *Globigerinatella insueta* Zone (upper part with *Globigerinoides sicanus*).	Strongly etched assemblages with *Sphenolithus heteromorphus*, *Discoaster exilis*, *Coccolithus eopelagicus*, *Cyclococcolithina floridana*, *C. leptopora*. Preservation E_2 to E_3 - 01. Zone: *Sphenolithus heteromorphus?* Age: Early Miocene	Early Miocene

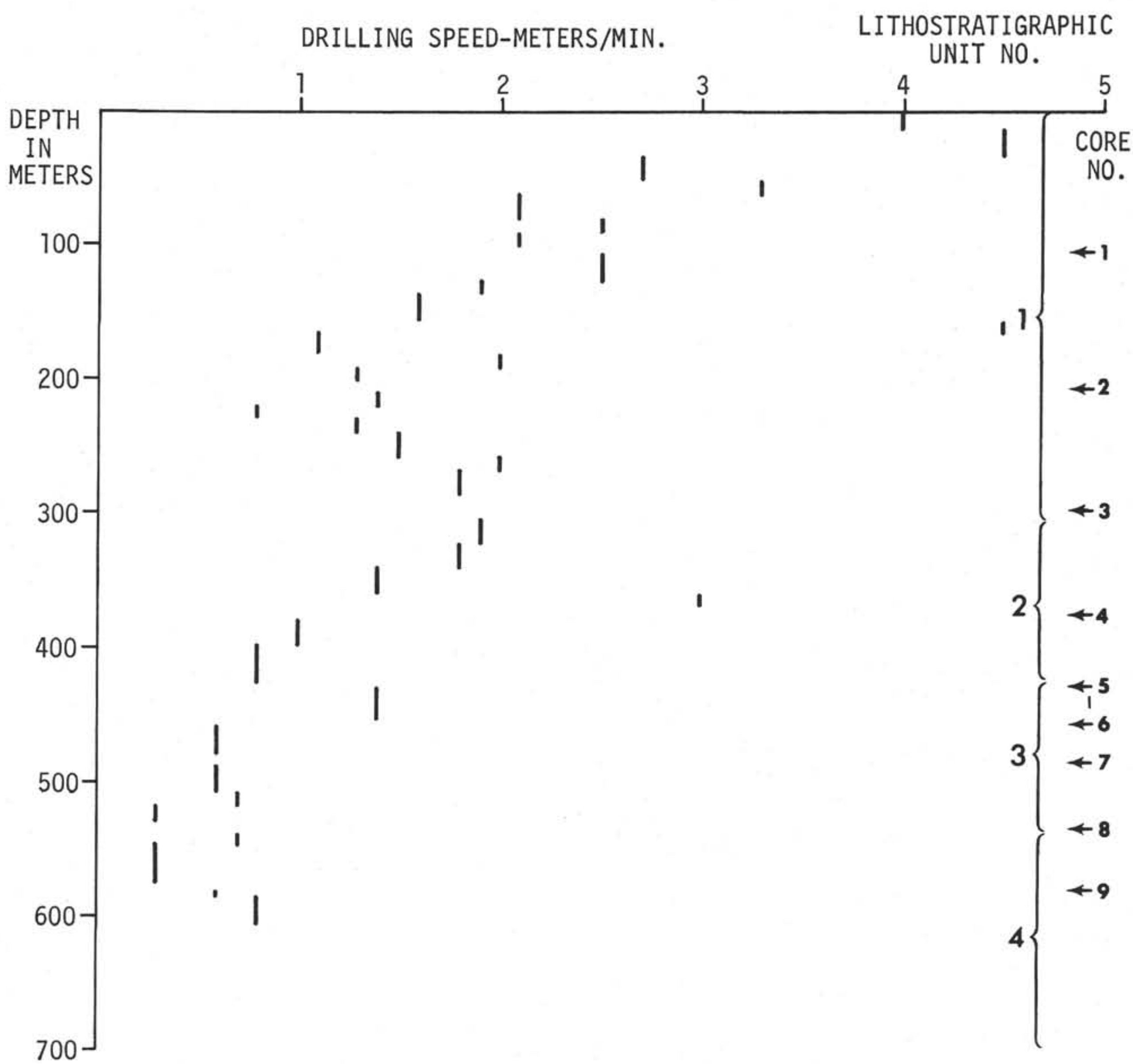


Figure 4. *Drilling and coring summary at Site 142.*

Foraminifera

The foraminifera form a significant part of the highly complex microfaunas and floras of this Site. In the Pleistocene cores 1 to 3, the presumed autochthonous planktonic foraminifera are slightly etched and indicate depth of deposition similar to that of the present. On the other hand, the abundant light-weight, small-sized and well-preserved planktonic shells were almost certainly transported down slope and redeposited at relatively rapid rates. The relatively rare shallow water fossils (Bryozoa, mollusk shells) and the abundant, land-derived plant fragments were deposited following downslope transport. The Pliocene and Upper Miocene is represented by homogeneous faunas (Cores 4, 7) and mixed ones (Cores 5 and 6). Layers of clean foraminiferal sand, sometimes also containing common fragments of calcareous algae, are characteristic of Cores 5 and 6. The clayey layers of these cores mostly contain strongly dissolved planktonic foraminifera. The fauna of Core 8 contains Middle and probably Upper Miocene elements of different ages and is difficult to interpret.

Nannoplankton

The finer grained layers of Cores 1 to 3 contain abundant Pleistocene nannoplankton. A high percentage of broken discoasters in the Upper Pliocene through Upper Miocene (Cores 4-8) probably reflect damage sustained during transportation. The upper part of the Middle Miocene is missing (see Figure 3). The Core Catcher of Cores 8 and 9 belong to the Middle to Lower Miocene and represent sediments of the Ceara Rise. A sample from the center bit, recovered after drilling 25 meters below Core 9, yielded poorly preserved Lower Miocene nannoplankton.

Organic Microfossils

By D. O. J. Diederix, R. de Haan and W. O. Tichler[2]

Core 1 Section 5: 5-7 cm:

Poor sporomorph flora containing rare Croton type pollen, *Chenopodiacea sp., Mauritia sp.*, Alnoide pollen, *Euphorbiaceae sp., Poaceae (Graminae) sp., Alchornea sp., Malpighiaceae sp., Proteaceae sp., Grimsdalea magnaclavata.*
Age: Tertiary, Middle-Miocene or younger.

Only indeterminate microplankton fragments.

Core 5 Section 1: 96-98 cm:

Only a few sporomorphs of *Poaceae (Graminae) sp., Cycadopites sp., cf. Jussieua sp.*, and *cf. Spheripollenites sp.*.
Age: Eocene or younger.

Only a few indeterminate microplankton fragments.

LITHOSTRATIGRAPHIC SUMMARY

Site 142, drilled in the Ceara Abyssal Plain, consists of a single hole with a maximum sub-bottom penetration of 609 meters. Nine cores were taken at 100 meters (upper 300m) and 30 to 50 meter intervals (lowermost 300 m). The whole sedimentary sequence consists of Neogene terrigenous clastic sediments and biogenous oozes in variable proportions. Based on lithologic differences, degree of consolidation, stratigraphy, and breaks in drilling rate, four major units can be distinguished:

Unit	Cores	Lithology	Depth Below Sea Floor (m)	Age
1	(*Vema* Core V24-258) 1,2,3	Unconsolidated to semiconsolidated calcareous mud and foram-nanno-marl ooze interbedded with thick, graded layers of olive-gray subarkosic terrigenous sand. Upward increase of terrigenous and decrease of biogenous components	0-305	Quaternary to Pleistocene
2	4,5	Well consolidated, banded and varicolored foram nanno chalk ooze, calcareous clay, foram sand, and terrigenous subarkosic sand.	305-425	Early Pliocene
		PROMINENT REFLECTOR		
3	6,7,8	Consolidated to indurated nanno marl mud foram marl nanno chalk ooze, clay with redeposited silty foram sands.	425-537	Late Miocene to Middle Miocene
4	8,9 Center bit sample below Core 9	Indurated greenish gray to medium bluish gray foram-rich nanno marl ooze, highly burrowed (=Ceara Rise sediments)	537-609+	Middle to Early Miocene

UNIT 1 – Calcareous Mud, Foram-Nanno Ooze, and Subarkosic Sands. (Cores 1-3)

This unit is about 305 meters thick and is of Pleistocene to Recent age. It consists of dark gray and olive gray terrigenous sediments ranging from slightly silty clay to medium sand and accumulating at a rate of 150 m/my interbedded with carbonate-rich clay and oozes. Drilling rates range from 1.0 to 4.5 meters per minute; somewhat faster rates may correlate with sand layers.

The nearby piston cores V25-49 and V24-258 (unpublished *Vema* Reports, LDGO) contain Pleistocene sediments similar to those of Cores 1 to 3. The cored intervals (Cores 1-3) show alternations of unconsolidated gray, slightly silty, calcareous mud (clayey calcilutite) and foraminiferal nannoplankton marl ooze with very fine to medium-grained silty subarkosic sands. The upper part of *Vema* core V24-258 has a low sand: lutite layer ratio (<0.1). It increases downward from a core depth of 300 cm (increase of frequency and thickness of sand layers). In Core 1, the ratio is 1:1 (individual sand layers up to 300 cm thick). It decreases to 0.4 in Core 2. This suggests that the middle (and upper?) part of Unit 1 consists of about 20 to 50 percent sand layers, a typical value for flysch-type sediments.

1. Sand Layers: (a) Composition – The sands are subarkoses according to Folk's (1968) quartz (Q)–

[2]Koninklijke/Shell Exploratie en Produktie Laboratorium

feldspar (F)–rock fragments (R) compositional triangle. The average end member composition is about $Q_{86}F_{12}R_2$, but these percentages neglect the characteristically high content of chlorite and biotite (up to 20%), reworked glauconite, plant fragments (5-10%), heavy minerals (2-5%), and displaced biogenous carbonate (5-10%). Also, the sands are rich in clay matrix (>10%) so they might also be considered feldspar-rich quartz-greywackes poor in lithic fragments (some chert, shist). Quartz is mostly subangular. Both K-feldspar and plagioclase (much of it sericitized and kaolinized) occur. Much of the biogenous carbonate consists of displaced pelagic components such as coccoliths and planktonic foraminifera. The preservation of planktonic foraminifera varies greatly within samples, between sections, and between cores of this unit. Also, shallow water fossils are common as are certain benthonic foraminifera, *Turritella*-type gastropods, and *Limacina*-type pteropods). The heavy mineral suite is very diverse, with minerals of intermediate to low transport stability and of plutonic (to volcanic) origin, such as amphiboles (>pyroxenes), dominating stable minerals like zircon, rutile, sphene, etc. A similar composition, but with higher feldspar contents (up to 35%), was reported by Damuth and Fairbridge (1970) from late Pleistocene (latest Wisconsin) sediments of the Ceara Abyssal Plain and from DSDP Leg 4 Sites 23, 24, and 26.

1. (b) Sedimentary Structures and Texture – All sand layers are uniform and massive (no bedding observed). Most of these layers appear to have sharp lower and gradational upper contacts, but the boundaries are frequently disturbed by the coring progress. Most sand layers are indistinctly graded with a slight upward decrease of grain size (medium 100-70μ, maximum size of quartz 200-100μ), and a slight decrease of sorting from the base (poorly sorted) to the top (very poorly sorted). The size distribution is highly fine-skewed with 30 percent (base) to 50 percent (top) of matrix material (<62μ). The increase of mud content towards the top of the 300 cm thick sand layer in Core 1 is well reflected by the upward increase of natural gamma measurements (minimum near the coarse-grained base of the sand layer). Clayey, slightly sandy, terrigenous silts (10 percent sand, 65 percent silt, 25 percent clay) occur in Core 1.

2. Lutites: Slightly silty, carbonate-rich (40%) clays (calcareous muds, "marl muds," or "clayey calcilutities") occur in Cores 1, 2, and 3 as well as coccoliths and fragmented foraminifera). The carbonate consists of very finely-ground (<2μ) irregular calcite grains ("flour")–possibly the detritus of highly triturated nannoplankton and foraminifera. These calcareous muds, which are probably redeposited, grade into foram-nanno marl oozes containing about 40 to 50 per cent terrigenous silt- and clay-size material: 5 to 10 per cent quartz, 5 per cent mica and heavy minerals, and 35 per cent clay minerals. Large resistant pelagic foraminifera (mainly *Pulleniatina*) are scattered in the ooze near the base of Core 2, indicating conditions of strong carbonate dissolution.

UNITS 2 and 3 – Calcareous Mud, Oozes, Calcarenite, Calcisiltite, and Subarkosic Sand (Cores 4-8)

Unit 2 (Cores 4, 5) is about 120 meters thick and is of Early Pliocene age. Unit 3 (Cores 6, 7, 8) is about 100 meters thick and is of Late to Middle Miocene age. These two units are described together, however, on the basis of their very different acoustic character, the prominent seismic reflector separating them, and their age differences, they should be considered as two separate lithostratigraphic units despite similarities in lithology of some of their constituents. Units 2 and 3 are characterized by a well-consolidated varicolored, often color-banded sequence of foraminiferal nannoplankton marl to chalk oozes with thin, sometimes graded, layers of foraminiferal calcisiltite to calcarenite. Terrigenous sands are very rare; only one graded, thick, silty subarkosic sand layer was found in Core 5 (Unit 2). Near the base of unit 3 is a carbonate-free clay. Sedimentation rates varied from 15 m/my in the lower half of the unit to 60 m/my years in the upper half. Drilling rates normally range from 1 to 2 meters per minute in the upper part and less than 1 meter per minute in the lower part. The four most important sediment types will be discussed separately:

1. Varicolored banded foraminiferal nannoplankton oozes: These sediments occur in Cores 4, 6, 7 and 8. The color banding is best developed in Core 4 where a few millimeters to centimeters thick light brownish gray and light gray color zones alternate with transitional boundaries. Dark hydrotroilite or Mn-oxide streaks appear near these boundaries. The color bands are either parallel or inclinded with apparent dip angles between 10 and 40°. While in most cases this "cross bedding" is due to coring disturbance (rotation of 5 to 10 cm long core segments along horizontal and vertical rotational axes), the possibility of an *in situ* dip of the color beds of 5 to 15° cannot be excluded. In Cores 6, 7 and 8 (2), the color zones (brownish and light gray hues) are much thicker (in the order of dm) and might be graded and of different origin (see below).

The nannoplankton chalk oozes contain about 35 to 40 per cent foraminifera and 35 per cent nannoplankton in the light gray laminae, whereas the darker colored (light-brownish) ooze is considerably richer in nannoplankton (Core 4). Even darker varieties (brown to olive gray) are rich in clay (>40%) and can be termed nannofossil marl mud or clayey nannofossil calcilutite (Core 6). In Core 7, the relative percentages of foraminifera (10-50%) and nannoplankton (20-70%) vary inversely over small distances. Foraminiferal preservation varies greatly within this unit without definite trends.

2. Light-colored Foraminiferal Calcarenite to Calcisiltite Layers: These layers, sometimes grading into the darker and finer-grained overlying nannoplankton calcilutite, occur especially in Cores 5 and 6. The calcarenites, a few cm to a maximum of 25 cm thick, have a sharp lower boundary and consist of up to 70 per cent foraminifera and foraminiferal fragments, 15 to 20 per cent nannoplankton, and small amounts of tunicate spicules, mollusk, and echinoid fragments. They also contain finely ground calcite "flour" and traces of quartz, mica, chlorite, pyrite, and clay minerals. Shallow-water benthonic and redeposited, perfectly preserved, thin-walled, planktonic foraminifera–as opposed to highly corroded authochtonous faunas–are frequent in the calcarenites and calcisiltites of Cores 5

and 6. A typical cycle seems to consist of (top of base of Core 6, Section 2):

a) Top (Mn-oxide streaks)

Light brownish-gray clayey nanno calcilutite (nanno marl ooze burrowed color gradation to grayish-brown calcilutite (to siltite) gradational (to sharp) boundary

White foram sand	poorly sorted calcisiltite	Md	50μ
	moderately well sorted silty calcarenite	Md	100μ

b) Base (Sharp lower boundary)

Nanno marl ooze

Mottled zone

Some cycles appear to start with a calcisiltite or nanno-rich calcilutite at the base.

3. Terrigenous Subarkosic Sand: Only one graded subarkosic sand layer was cored in Unit 2 (Core 5) indicating the reduced terrigenous influence during the Plio-Miocene. The 35 cm thick layer is distinctly graded from silty sand to sandy silt to clayey silt and is overlain by slightly silty clay, containing foraminifera. The natural gamma correlates well with the gradual upward decrease of grain size. Compositionally, the sand layer is very similar to the Pleistocene subarkosic sands.

4. Medium-bluish Unfossiliferous Carbonate-free Clay: This clay is present in Core 8 near the base of Unit 3. It is very slightly burrowed.

5. Slumped Sediments: Core 8 also contains a 40 cm thick section where two lithologies, a brown and a white clayey foraminiferal nannoplankton calcilutite, are thoroughly mixed, apparently by early post-depositional slumping. Rounded pebbles of white and laminated brown lutite (maximum size about 3 × 1 cm) are embedded in a light brownish matrix. Disrupted zig-zag and recumbent folds with horizontal fold axes and convolutions are present.

UNIT 4 – Nannoplankton Marl Ooze (Core 9; Core Catcher of Core 8)

This unit is of Early to Middle Miocene age and is at least 70 meters thick. Core 9 consists of an indurated greenish gray to medium bluish gray nannoplankton marl ooze (calcilutite) rich in nannoplankton (40-55%) and pelagic foraminifera (up to 15%) and highly burrowed. Minor percentages of radiolarians and siliceous spicules are also present. The colors alternate with sharp boundaries. This unit is characterized by a high content of pelagic foraminifera, lack of shallow-water benthonic faunas, relatively rich radiolarian fauna, lack of terrigenous sand layers, comparatively high degree of bioturbation and low rate of deposition (<8m/my). Drilling rates were usually less than 0.5 meter per minute.

PHYSICAL AND CHEMICAL PROPERTIES

Penetrometer readings (mm × 10^{-1}) clearly distinguish the sands from the clays, and indicate a general increase in degree of compaction with depth. In Core 1, values in the clays run 30 to 45 and values in the sands run from 58 to 125. Below Core 1, penetrometer readings decrease gradually downward to a depth of ~450 meters, below which uniform values of 2 to 3 were recorded.

Bulk density values for all sediments are relatively high, clustering around 1.7 gm/cc. There is, however, considerable scatter and only a very general trend of increase with depth. The scatter of values has no apparent correlation with detailed lithology. In general, both the water content and the porosity (calculated) are low, ranging from 17 to 37 per cent and from 30 to 59 per cent respectively, and decrease slightly with depth. Values from the GRAPE do not agree with those calculated from water content measurements (Table 3). The GRAPE values are probably more reliable.

The natural gamma radiation of the samples correlates reasonably well with lithology. In Core 1, counts average about 1400 in the subarkosic terrigenous sands and about 2000 in the clays. In Core 2, a 150 cm sand layer (1200 counts) overlies a nanno marl ooze. Average counts for the ooze are atypically high (over 1500) and may be due to the clay fraction. Cores 4 and 7 are foraminiferal nannofossil chalk oozes and have fairly high readings in the 400-1000 ranges. At the top of Core 5, low count values (~500) are associated with a foram rich layer. A 70 cm graded silty sand bed lying below gives readings up to 1900 in the middle of the bed and drops off to 1400 in the coarse basal part. The barren clay at the base of Core 5 yields counts of 1900. In Core 6, nanno marl muds have average values of about 1600 similar to the nanno marl values for Core 2. Two foram rich beds in Core 6 have charactristically low count values. In Core 8, counts on the nanno marl muds range from 1400 to 1800 while a 50 cm section rich in carbonate gives values of less than 1000. Counts on the older nanno marl muds of Core 9 range from 900 to 1300.

Sonic velocity measurements were made on selected core sections. In the upper part of the section, compressional wave velocities range from 1.50 to 1.65 km/sec, increasing with depth. Core 9, which is believed to represent sediment of the flank of the Ceara Rise, gives velocity values of 1.90 to 1.95 km/sec.

The range of pH values in the cores is 6.81 to 7.84. Salinity values are slightly lower than normal seawater, ranging between 31.4 and 34.7 per cent. There is a general but irregular increase in salinity with depth. A list of the chemical property measurements is given in Table 4.

DISCUSSION AND CONCLUSIONS

Site 142 lies in the Ceara Abyssal Plain at a water depth of 4372 meters, about 10 km south of the steep (maximum 3.50 degrees slope) flank of the 3000 to 3500 meter deep Ceara Rise. The continental shelf edge and the Amazon River lie respectively about 550 km and 800 km to the southwest. One of the main objectives at Site 142 was to penetrate the flank of the Ceara Rise which lies buried beneath the adjacent abyssal plain sediments at a depth of 0.60 to 0.66 second on the *Challenger* seismic profile. The sub-bottom reflection time to the flank of the Ceara Rise is uncertain. The final location of the site was over the abyssal plain, hence the depth could not be used to locate the site precisely with respect to the initial seismic traverse. In spite of a malfunctioning acoustic beacon which caused a premature end to this hole, a center bit sample recovered from a depth of 609 meters was dated as earliest Miocene. It is believed that the Ceara Rise was penetrated–probably at a depth of 537 meters. Evidence for this is listed as follows: The nannoplankton indicate an approximately 3 million year hiatus between the core catcher sample of Core 8 (Middle Miocene) and Section 2 of the same core (Late

TABLE 3
Summary of Density, Porosity and Water Content Data for Site 142

			GRAPE			Sediment Sample			
Hole	Core	Section	Depth Below Sea Floor (m)	Density (gm/cc)	Porosity (%)	Depth Below Sea Floor (m)	Water Content (%)	Density (gm/cc)	Porosity (%)
142	1	1	108.75	1.60	57	108.63	33	1.61	53
142	1	2	110.25	1.74	48	109.73	38	1.58	60
142	1	3	111.75	1.71	49	111.14	21	1.91	41
142	1	4	113.25	1.75	47	112.64	18	1.89	33
142	1	5	114.75	1.68	51	114.90	33	1.59	53
142	1	6	116.25	1.69	51	115.65	33	1.63	54
142	2	1	210.75	1.63	55	–	–	–	–
142	2	2	212.25	1.69	55	–	–	–	–
142	2	3	213.75	1.73	53	213.14	29	1.84	54
142	2	4	215.25	1.69	56	214.55	28	1.70	48
142	3	1	303.75	1.77	50	304.19	21	1.91	40
142	4	1	377.75	1.67	52	377.34	28	1.69	47
142	4	2	379.25	1.61	57	378.64	26	1.79	46
142	4	3	380.75	1.67	52	380.14	27	1.73	46
142	4	4	382.25	1.59	58	381.64	27	1.69	46
142	4	5	383.75	1.67	52	383.14	24	1.81	44
142	5	1	433.75	1.70	50	–	–	–	–
142	6	1	451.75	1.86[a]	35	–	–	–	–
142	6	2	453.25	1.96[a]	27	453.64	22	1.78	40
142	7	2	–	–	–	490.64	21	1.71	35
142	7	3	–	–	–	492.14	21	1.73	36
142	7	4	–	–	–	493.64	22	1.67	36
142	7	5	–	–	–	495.14	20	1.77	36
142	7	6	–	–	–	496.64	18	1.67	31
142	8	1	539.75	1.67	45	539.14	25	1.68	42
142	8	2	541.25	1.81	34	540.64	17	1.87	31
142	9	1	585.75	1.69	42	585.64	21	1.54	33
142	9	2	587.25	1.60	50	–	–	–	–
142	9	3	588.75	1.68	42	588.14	27	1.79	48

[a]Anomalously high value is unexplained.

TABLE 4
Chemical Property Measurements on Samples from Site 142

Hole	Core	Section	Sample Interval (cm) Top	Bottom	pH	Eh	Salinity (°/oo)
142	1	6	0.0	10.0	7.84	+126	31.4
	2	4	0.0	8.0	7.66	+124	31.4
	3	CC			7.57	+132	31.9
	4	3	0.0	5.0	6.81	+142	33.0
	5	CC			7.48	+132	33.0
	6	CC			7.42	+143	33.6
	7	6	0.0	5.0	7.20	+148	34.1
	8	CC			7.63	+146	33.6
	9	1	145.0	150.0	7.09	+10	34.7

Miocene). Furthermore, the flora in Core 9, some 38 meters lower down, shows no sign of redeposition as they do higher in the section. The calcareous benthonic foraminifera in Core 9 show no typical shallow water forms, but all cores above do. Core 9 contained Radiolaria, but higher up the cores contained none. The sediments in Core 9 and in the core catcher of Core 8 are indurated calcilutites. Those in Core 8 and above are also calcilutites, but in addition they contain a large terrigenous component and resedimented carbonates (presumably derived from the uplifted Ceara Rise).

The abyssal plain sediments form three well defined units on the seismic profile records. These acoustic units can be correlated with the age and lithology as follows:

1. A lower reflective zone extends upwards from the flank of the Rise at 537 meters to a sub-bottom depth of ~135 meters. This zone is therefore about 100 meters thick, consists of interbedded calcareous mud, marl/chalk ooze, and foram sand and is Late Miocene age.

The top of this reflective zone forms a very strong acoustic reflector, visible over many thousands of square kilometers. Its age coincides fairly closely with the Miocene/Pliocene boundary.

2. A transparent zone, 120 meters thick, extends from 435 to 305 meters (0.37-0.50 sec) with an average velocity of 1.85 km/sec. The zone is Pliocene in age (NN 15) in two cores recovered and is made up of nannoplankton chalk/marl ooze with moderate amounts of clay in the lower portion and a terrigenous subarkosic sand at the base of the unit (Core 5).) to the sea floor.

3. A strongly reflective upper zone extends from a depth of 305 meters (0.37 sec) to the sea floor. The unit is Pleistocene to Recent in age and comprises marl ooze,

calcareous mud and numerous thick subarkosic sand beds. This unit has an average velocity of 1.65 km/sec, and was accumulated at an average sedimentation rate of 240 m/my.

At Site 142, the Pliocene-Miocene reflecting horizon is essentially flat lying as it overlaps the southern flank of the Ceara Rise. At some other nearby localities, the reflector is slightly upturned indicating that minor uplift may have occurred following the Early Pliocene, although if major uplift occurred, it preceded the Late Miocene.

Although the major relief of the Rise above the abyssal plain is associated with low seismic velocities (<2.5 km/sec, see Chapter 12), seismic reflection data show some areas near the crest of the Rise, where peaks in the acoustic basement rise to near the sea floor. Two explanations for the structure of the Rise appear to be equally plausible: 1) The sediments comprising the rise were originally deposited in a deep basinal environment and were subsequently uplifted to their present position. Intrusion of crystalline rocks may have caused the uplift or may have been associated with it. 2) The basement highs near the center of the Ceara Rise (see Chapter 12) may represent the original morphology of the sea floor which served to localize the deposition of sediments, thus building up the rise to its present configurations. Recent studies by Embley *et al.*, (1972) generally support this interpretation.

About 600 meters of Miocene to Pleistocene pelagic and terrigenous sediments have been deposited at Site 142. The deposition is characterized by biogenic calcareous turbidites and slump deposits (Miocene-Pliocene) and by terrigenous subarkosic sands during the Pleistocene. The history of deposition appears to have been as follows:

1) Early Miocene (Unit 4). Hemi-pelagic siliceous marl oozes mottled by burrowing organism were deposited at a low rate of deposition (5-10m/my).

Core catcher 8 is Middle Miocene age, as opposed to the rest of Core 8, (Upper Miocene). The sediments of Unit 4 are very similar to the Middle to late Early Miocene sediments obtained in piston core V25-62 (water depth 4321 m) from the flank of the Ceara Rise. Therefore, it is concluded that Unit 4 represents Ceara Rise sediments and may be allochthonous material redeposited higher on the rise.

Foraminifera show strong evidence of dissolution. However, deposition below the carbonate compensation depth should have led to total disolution because of the low sedimentation rate. Therefore, deposition just above the carbonate compensation depth is suggested. As the depth of Core 9 should have been shallower than the Early Miocene, downward movement at the carbonate compensation depth of the drilling site is implied.

2. Middle Miocene-Pliocene (Units 2 and 3). In the Middle Miocene bluish gray non-calcareous clay, laid down below the calcite compensation depth, was deposited on the lower flanks of the Ceara Rise. Planktonic foraminifera in Core 8 include both well preserved and highly corroded assemblages. Slumping (from the nearby Ceara Rise?) mixed laminated brown and white calcilutites with different ages (Middle to Late Miocene) with Late Miocene nannoplankton foram oozes. The average rate of deposition for the Middle and Upper Miocene (Cores 8-7) was still moderately low (approximately 15 m/My).

Most of the calcisiltites and calcarenites (especially in Cores 5 and 6) may be redeposited material from the nearby Ceara Rise (low terrigenous admixtures) rather than the Brazilian Shield. The following observations suggest that these sediments are biogenic turbidites:

(a) Size grading in some layers

(b) Sharp lower, sometimes gradational upper contacts

(c) Presence of shallow-water benthonic faunas

(d) Co-occurrence of well-preserved planktonic foraminifera with highly broken discoasters

(e) Faintly mottled zones overlying these layers

Both large-scale slumping and tectonic deformation must be considered as possible causes for the inclination (up to 15°) of the color-banded beds in Core 4.

The one thick, graded, subarkosic sand found in Core 5, indicates that from time to time terrigenous turbidites from the continent could reach this area.

3. Pleistocene (Unit 1). During Late Pliocene to Early Pleistocene times, thick terrigenous turbidites were deposited frequently resulting in rates of deposition of about 150 m/my. Whereas the frequency of emplacement of allochthonous carbonate sands in Unit 3 (Core 6) was on the order of 50,000 to 100,000 years; a thick terrigenous turbidite was deposited about every 1000 to 5000 years in the Pleistocene.

Arkosic sands were derived from the Brazilian and Guiana Shields. The sands were not chemically weathered to lateritic clay (gibbsite and kaolinite) as happens today, suggesting an arid climate on land (Damuth and Fairbridge 1970) and river transport to the coast by bedload. During the time of lowest sea level, the shelf off the Amazon River mouth was only 20 to 50 km wide as compared to 170 to 340 km today, so that the coarse-grained sediment could easily cross the shelf and reach the Ceara Abyssal Plain via the numerous canyons on the Amazon Cone. Similar terrigenous turbidites, also derived from the Amazon River, were cored at Site 26 (Leg 4, DSDP) in the *Vema* Fracture Zone.

The sediment between the arkosic sand layers consists of foraminiferal nannoplankton oozes and clayey calcilutites (calcareous muds). Co-occurrence of well and poorly preserved foraminifera suggests redeposition processes. Enrichment with certain small, easily transported forms also indicates sorting and resedimentation. Deposition near the calcite compensation depth is indicated by the minimum preservation of planktonic foraminifera. No coarse-grained terrigenous material from the shelf or from the Amazon River reaches the position of Site 142 today; similar conditions might have prevailed in Pleistocene interglacial times, as seen in *Vema* Cores V25-49 and V24-258.

REFERENCES

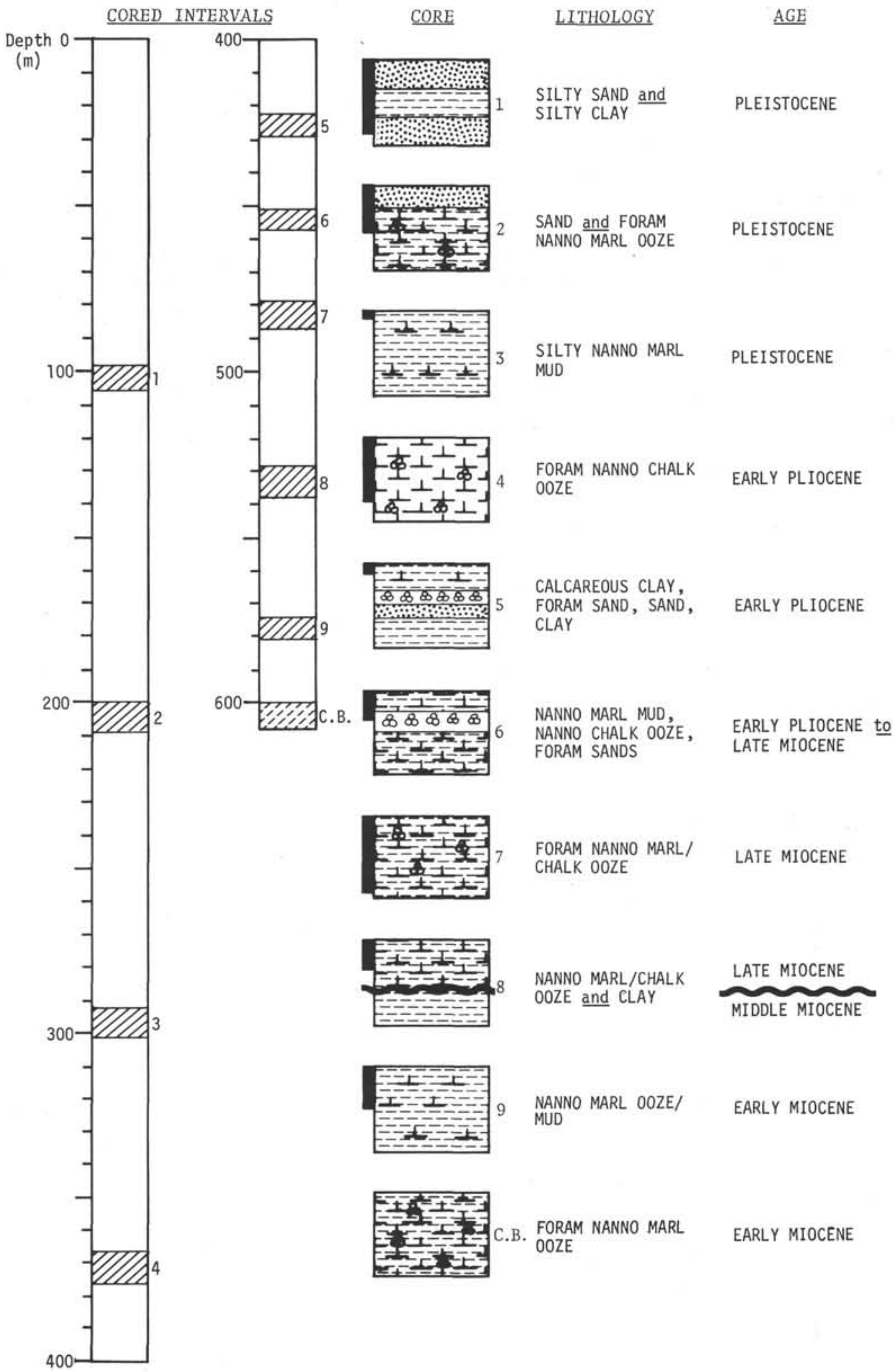
Damuth, J. E. and Fairbridge, R. W., 1970. Equatorial Atlantic deep-sea Arkosic sands and ice-age aridity in tropical America. *Bull. Geol. Soc. Am.* **81**, 189-206.

Embley, R., Hayes, D. E. and Damuth, J. E., 1972. The Ceara Rise: Western Equatorial Atlantic. *Trans. Am. Geophys. Union* **53** (4), 408.

Folk, R. L., 1968. Petrology of sedimentary rocks. The University of Texas, Austin. 159p.

Hayes, D. E. and Ewing, M., 1970. North Brazilian Ridge and adjacent continental margin. *Amer. Assoc. Petrol. Geol. Bull.*, **54** (11), 2120-2150.

SITE 142–SUMMARY



SITE 142 CORE 1 DEPTH (m) 98-106

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE	LITHOLOGIC DESCRIPTION
PLEISTOCENE	*Globorotalia truncatulinoides*	*Emiliania lacunosa/Gephyrocapsa oceanica*		1, 2, 3, 4, 5, 6, CC	1–8	VOID	50, 55, 75, 110, 110, 35, 130	see below

Alternating SILTY SAND and SILTY CLAY as indicated below

CLAY
Olive gray (5Y 4/1) $CaCO_3$ 1

GZ 2-24-74

SILTY SAND
Dark gray (5Y 4/1) to black (5Y 2/1)

GZ 49-36-15 $CaCO_3$ 4

Smear (50 cm):

Quartz	50%
Clay	10%
Feldspar,'alterite'	5%
Forams fragments, nannos	5%
Opaques	5%
Chlorite	5%
Pyroxene	3%
Amphibole.	2%
Biotite	2%
Heavies	3%

CLAY
Gray (5Y 2/1-3/1)

SILTY SAND
Very dark gray (5Y 3/1)

$CaCO_3$ 2

GZ 53-35-12

Smear (75 cm):

Quartz	45%
Feldspar (Kspar & plagioclase, some altered to kaolinite)	10%
Biotite & muscovite	5%
Chlorite	5%
Plant debris	5%
Forams & gastropods	4%
Nannos	1%
Heavies (hornblende 5%, zircon, sphene, beryl, corundum, apatite, rutile, olivine (?), pyroxene, lithic fragments)	10%

$CaCO_3$ 1

GZ 74-17-9

SILTY CLAY
Very dark gray to black (5Y 3/1 to 5Y 2/1); Clay ~65%, rest quartz, some feldspar, chlorite, biotite, heavies

SILT and SAND, mixed by coring
sec.4, 110 cm GZ 5-37-59
GZ 8-73-19
SILTY SAND
GZ 43-40-17 $CaCO_3$ 33
GZ 0-15-85

Smear Slide (110 cm, Sec 5):

Clay	50%
Triturated carbonate	15%
Nannos	15%
Authigenic calcite	10%

CLAY, calcareous

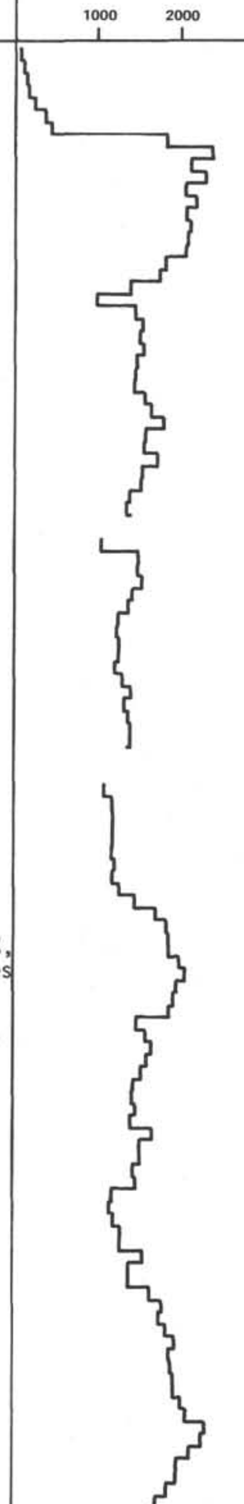
$CaCO_3$ 1

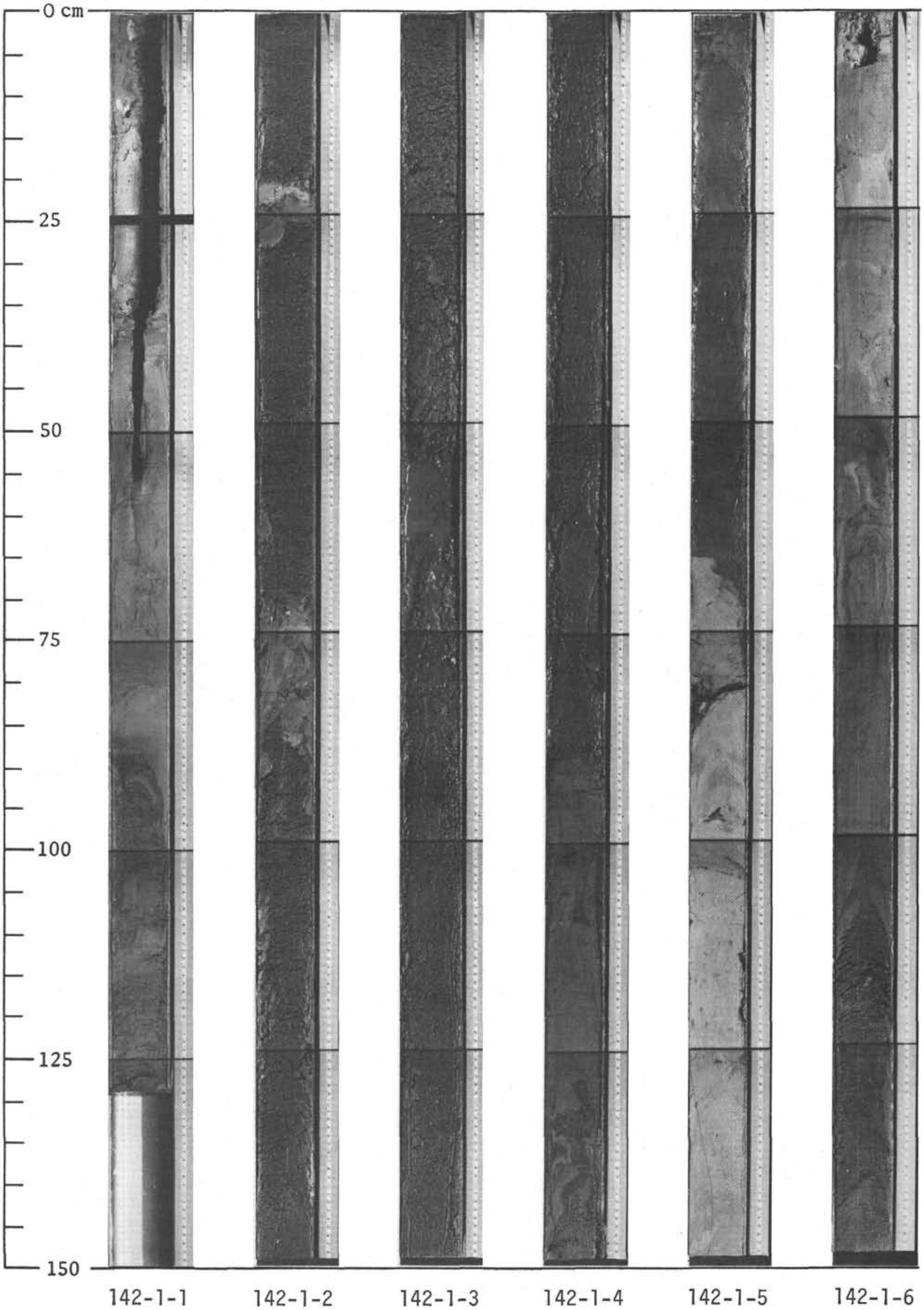
GZ 1-23-76

SILTY CLAY
Dark gray (5Y 4/1)

SILT

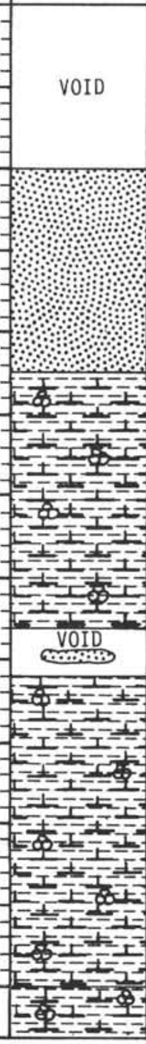
NATURAL GAMMA RADIATION
COUNTS/7.6 cm/1.5 min




0 cm
25
50
75
100
125
150
142-1-1
142-1-2
142-1-3
142-1-4
142-1-5
142-1-6

SITE 142 **CORE** 2 **DEPTH (m)** 200-209

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE	LITHOLOGIC DESCRIPTION	NATURAL GAMMA RADIATION (COUNTS/7.6 cm/1.5 min; 1000, 2000)
PLEISTOCENE	*Globorotalia truncatulinoides*	*Pseudoemiliania lacunosa*		1, 2, 3, 4, CC	1, 2, 3, 4, 5	see figure	130, 50, 25, 82	see below	see figure



sec.2, 14 cm $CaCO_3$ 2

SAND
Dark olive gray
(5Y 3/2)

sec.1, 140 cm GZ 74-17-9
GZ 71-16-13
GZ 73-15-12

Smear Slide (130 cm, Sec 1):

Quartz	50%
Chlorite	10%
Alterite	10%
Feldspar	7%
Forams and fragments	5%
Nannos	5%
Clay	4%
Amphibole, pyroxene	2%
Heavies (zircon, tourmaline, apatite)	3%
Plant debris	2%
Biotite, muscovite	Tr.

FORAM NANNO MARL OOZE
Dark gray (5Y 4/1-6/1) $CaCO_3$ 28

Smear Slide (25 cm):

Clay	35%
Carbonate flour	25%
Forams and fragments	15%
Nannos	10%
Mica	5%
Heavies (clay size)	3%
Opaques	2%

$CaCO_3$ 32
GZ 3-19-79

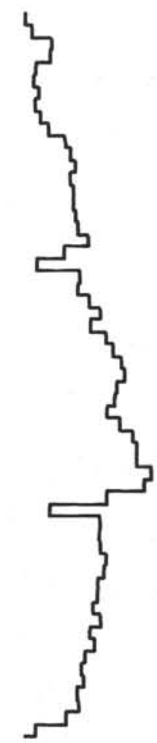
Smear Slide (82 cm):

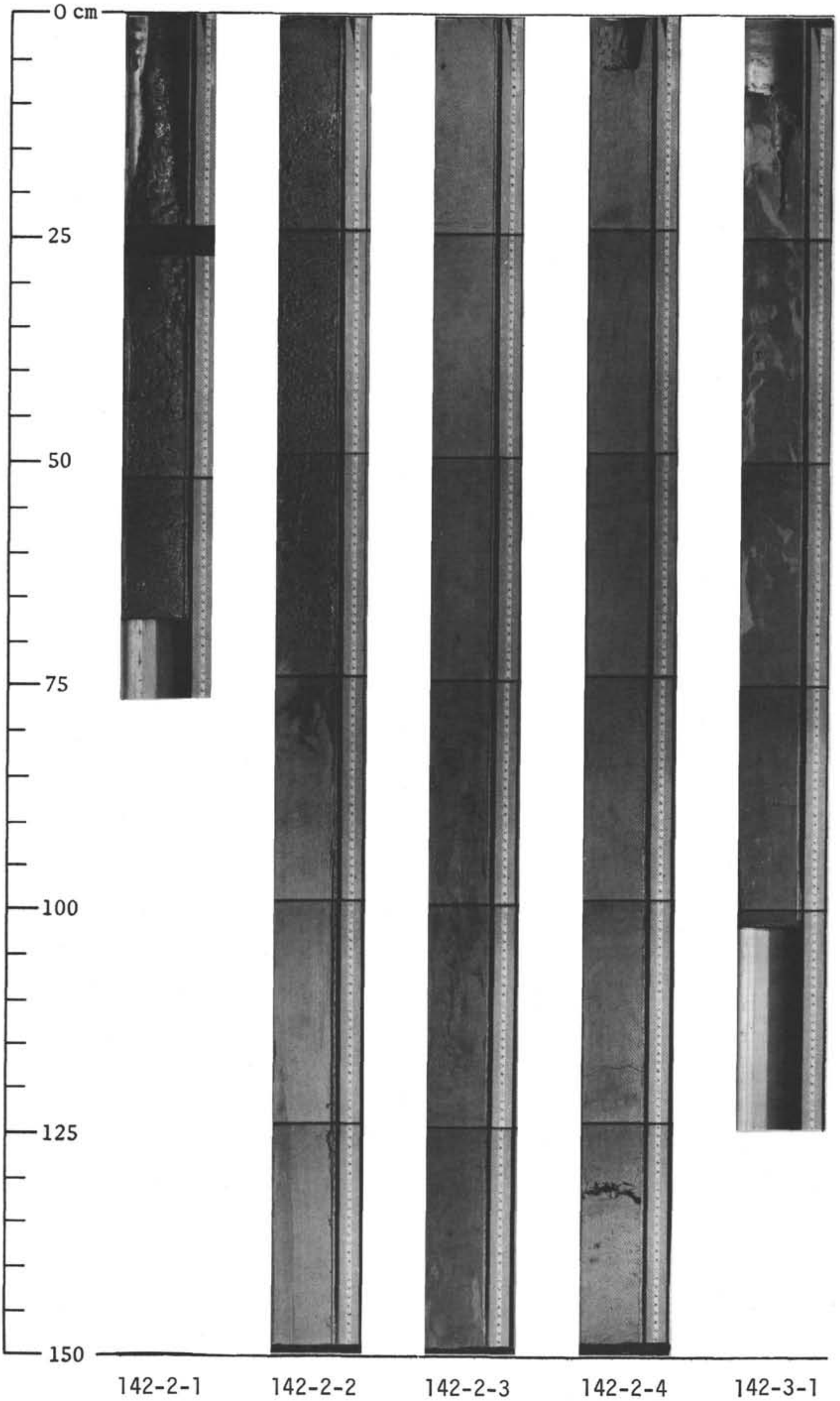
Forams and fragments	20%
Nannos	20%
Carbonate flour	20%
Clay	35%
Quartz	5-10%
Mica	3%
Heavies	2%
Opaques	2%
Limonite	2%

Many large forams

X-Ray (cc):

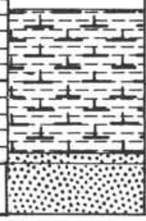
Quartz	A
Feldspar, mica, chlorite	C




0 cm
25
50
75
100
125
150
142-2-1
142-2-2
142-2-3
142-2-4
142-3-1

SITE 142 CORE 3 DEPTH (m) 293-301

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE
PLEISTOCENE	*Gr. truncatulinoides*	*P. lacunosa*		1	1	VOID	100, 149
				CC			



LITHOLOGIC DESCRIPTION

SILTY NANNO MARL MUD
Gray (5Y 6/1) to dark gray (5Y 4/1)

Smear Slide (100 cm)

Clay	40%
Nannos (triturated)	30%
Quartz	12%
Feldspar	4%
Forams plus fragments	3%
Opaques (includes hematite, chlorite, biotite, amphibole	3%
Heavies (corundum, sphene, topaz, zircon)	2%

$CaCO_3$ 5

Smear Slide (149 cm):

Carbonate fragments*	35%
Foram fragments	30%
Quartz	20%
Carbonate rhombs	5%
Nannos	3%
Feldspar	3%
Opaques, heavies	2%

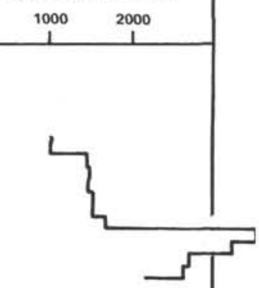
* Mostly of silt size, not known if biogenic or not, or if redeposited.

110 cm GZ 0-32-68

Coarse Fraction:
Terrigenous minerals, plant debris

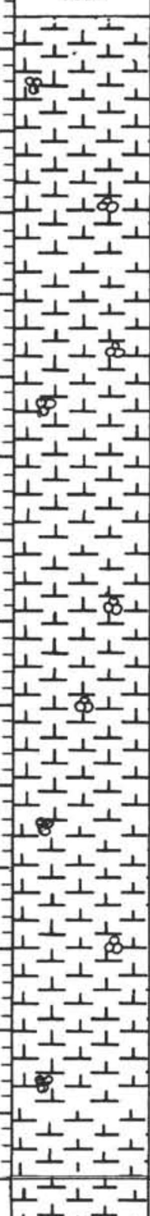
NATURAL GAMMA RADIATION

COUNTS/7.6 cm/1.5 min



SITE 142 CORE 4 DEPTH (m) 367-376

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE	LITHOLOGIC DESCRIPTION	NATURAL GAMMA RADIATION (COUNTS/7.6 cm/1.5 min; 1000, 2000)
PLIOCENE	*Globorotalia margaritae*	*Reticulofenestra pseudoumbilica*		1, 2, 3, 4, 5, CC	1–7	VOID	53, 96, 47, 128, 75, 75	see below	see log



FORAM NANNO CHALK OOZE

Two basic colors — $CaCO_3$ 64

Light brownish gray (10YR 6/2)

Light gray (10YR 7/1)

Smear Slide Average (light brownish gray)

Nannos	50%
Forams and fragments	25%
Clay	15-20%
Opaques	2%
Quartz, zeolite	2%
Heavies, biotite, carbonate rhombs	Tr.

$CaCO_3$ 56

Smear Slide Average (light grey)

Nannos	30-40%
Forams and fragments	35-40%
Clay	20%
Quartz, biotite, carbonate rhombs, heavies	Tr.-2%
Diatoms	Tr.
Zeolite	1-2%
Opaques	1%

$CaCO_3$ 68 $CaCO_3$ 104

Colors alternate in bands 10-50 cm long. Boundaries between bands may be transitional over 2-4 cm. Bedding is at angles of up to 25° to the horizontal. Relative notion between adjacent bands makes for lesser apparent angles and reversals.

Most angularity of bedding, and the reversals, probably due to coring, but an original dip up to 10° is not precluded.

$CaCO_3$ 69

Coarse Fraction:

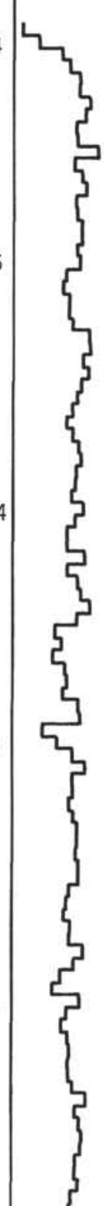
Planktonic forams, moderately well to poorly preserved, quartz

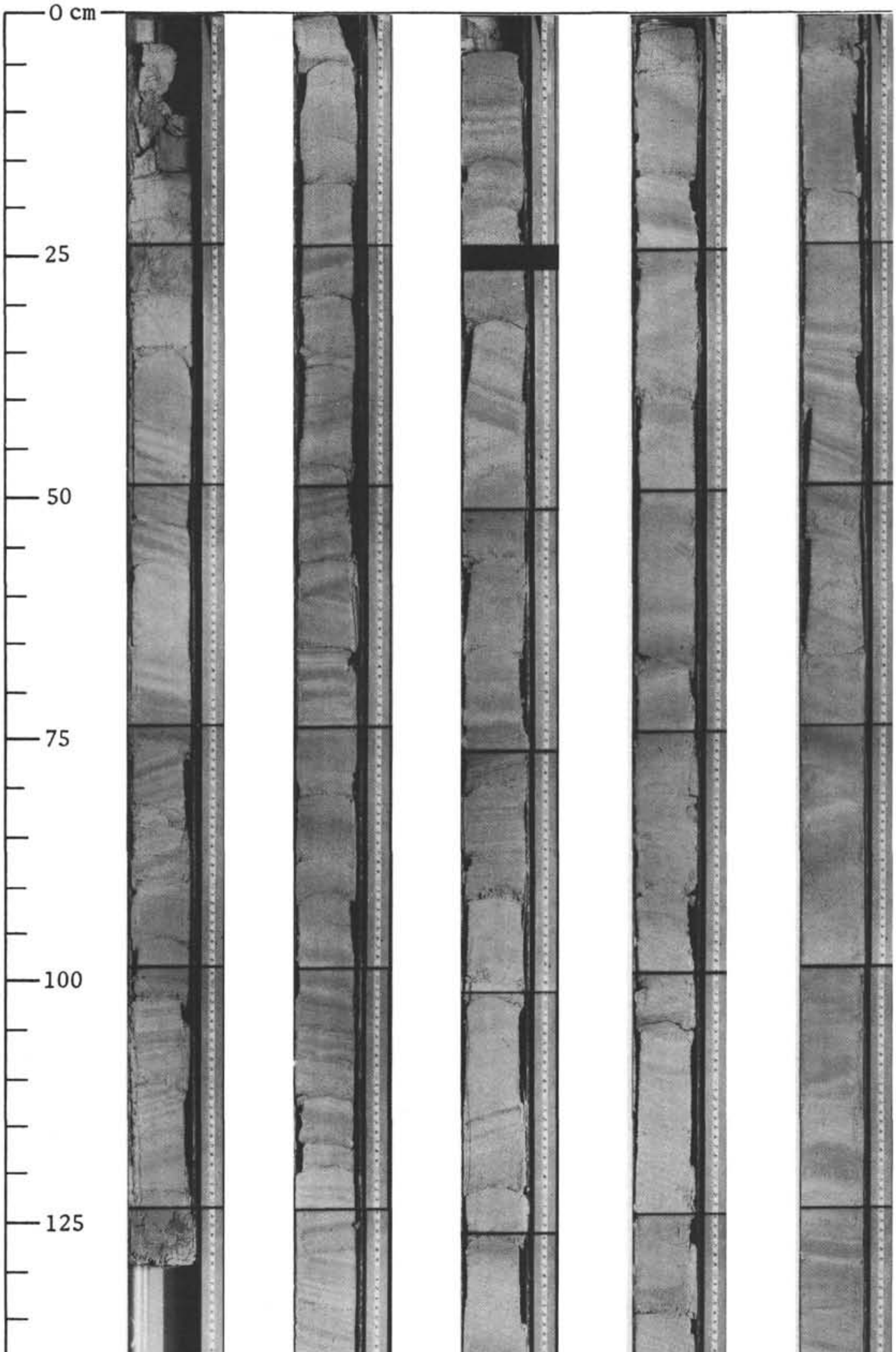
sec.1, 40 cm GZ 9-22-69

sec.2, 25 cm GZ 17-22-61

sec.3, 25 cm GZ 14-22-64

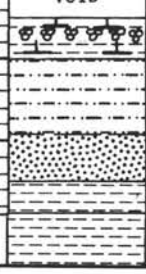
GZ 15-19-66 $CaCO_3$ 54




0 cm
25
50
75
100
125
150
142-4-1
142-4-2
142-4-3
142-4-4
142-4-5

SITE 142 CORE 5 DEPTH (m) 423-429

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE
EARLY PLIOCENE	*Globorotalia margaritae*	*R. pseudoumbilica*		1	1	VOID	35, 80, 110, 130
				CC			



LITHOLOGIC DESCRIPTION

0-50 cm:

CALCAREOUS CLAY
Light gray (10YR 5/1-6/1) with
FORAM SAND LAYER between 25-45 cm
Light gray (5Y 4/2) $CaCO_3$ 17

Smear Slide (35 cm):

Forams	35%
Nannos	20%
Carbonate fragments	15%
Mollusc debris	5%
Micas	10%
Fe oxide and opaques	4%
Quartz	3%
Heavies	1%

50-125 cm:

10 cm GZ 66-16-18
15 cm GZ 81-5-14
25 cm GZ 74-10-16

SILTY CLAY
Grayish brown (10YR 5/2) becoming less rich in carbonate and grading into grayish brown (10YR 5/2)
SAND 85 cm GZ 83-74-18

Smear Slide (80 cm):

Clay	55%
Nannos	20%
Carbonate fragments	10%
Pyrite, quartz, micas	5%

Smear Slide (110 cm):

Quartz	30%
Clay	20%
Forams	10%
Calcite fragments	10%
Nannos	5%
Chlorite	8%
Biotite	2%
Feldspar	8%
Fe oxide and opaques	5%
Heavies (pyroxene, hornblende, apatite, clinozoisite)	2%

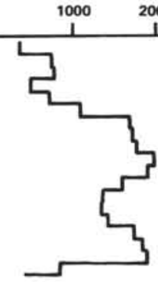
125-145 cm:

CLAY
Grayish brown (10YR 5/2) becoming silty at bottom

Coarse Fraction:
Sand layers: planktonic forams, bryozoans, spicules, terrigenous minerals, pyrite, plant debris
Other: planktonic forams, very poorly preserved, spicules
100 cm GZ 40-46-14
110 cm GZ 46-42-12

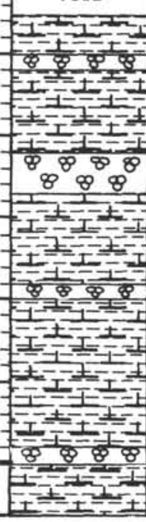
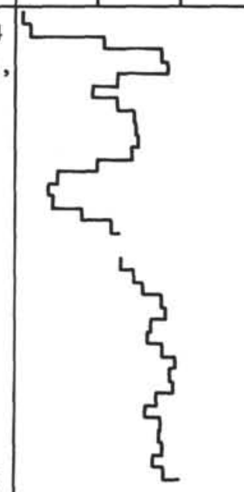
NATURAL GAMMA RADIATION

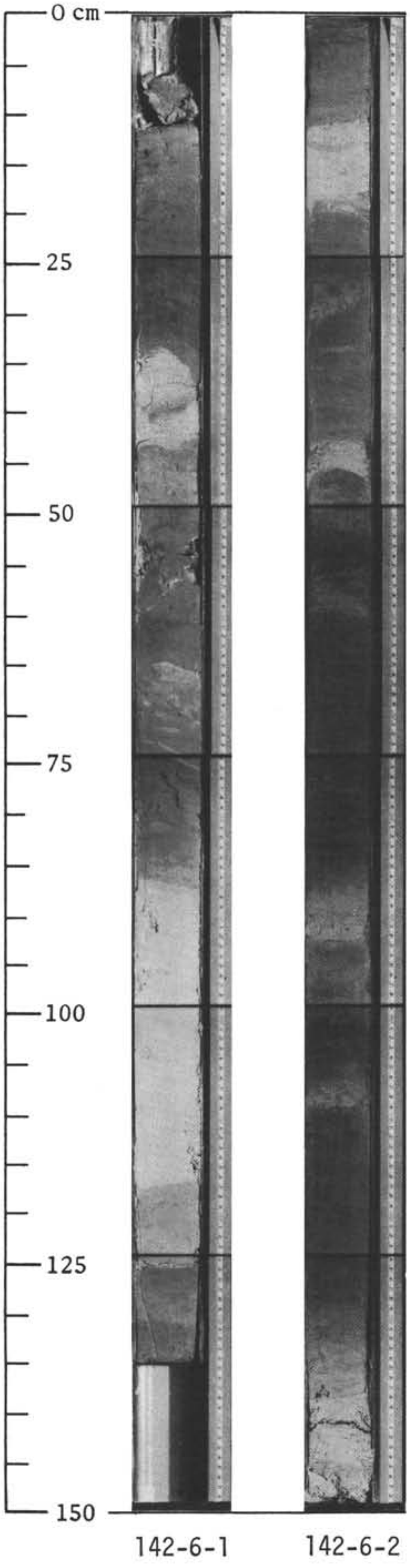
COUNTS/7.6 cm/1.5 min



142-5-1

SITE 142 **CORE** 6 **DEPTH (m)** 451-457

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE	LITHOLOGIC DESCRIPTION	NATURAL GAMMA RADIATION COUNTS/7.6 cm/1.5 min (1000, 2000)
LATE MIOCENE	*G. margaritae* or "*G. dutertrei*"	*Ceratolithus tricorniculatus*		1*	1	VOID 		NANNO MARL MUD 40 cm $CaCO_3$ 14 Olive gray (5Y 5/2) and brownish grays (10YR 6/2-5/3), grading locally to NANNO CHALK OOZE, light gray (10YR 8/1) with layers of FORAM SANDS Well indurated and little disturbed. Foram sands exhibit grading. * See Section Summary Coarse Fraction: Sand Layer: planktonic forams, bryozoans Other: foram fragments sec.1, 20 cm GZ 0-16-84 sec.1, 100 cm GZ 34-42-24 sec.1, 120 cm GZ 50-36-14 $CaCO_3$ 55	
				2	2				
				CC					


0 cm
25
50
75
100
125
150
142-6-1
142-6-2

SITE 142 CORE 7 DEPTH (m) 479-487

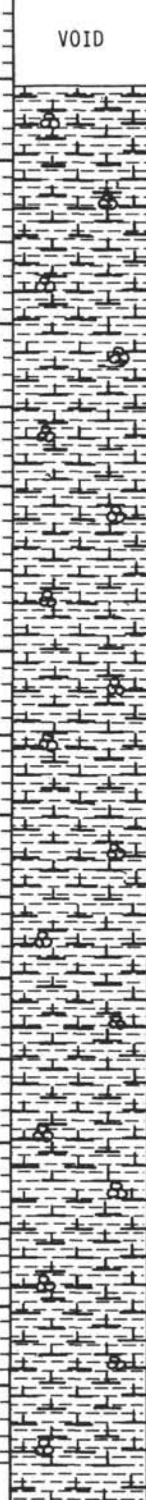
AGE: LATE MIOCENE

ZONE: FORAM: *G. acostaensis* or ?"*G. dutertrei*"; NANNO: *Discoaster quinqueramus*; RAD: —

SECTION: 1, 2, 3, 4, 5, 6, CC

METERS: 1, 2, 3, 4, 5, 6, 7, 8

LITHOLOGIC SYMBOLS



SMEAR SLIDE: 75 (Sec 1), 75 (Sec 2), 75 (Sec 3), 138 (Sec 4), 75 (Sec 5), 100 (Sec 6)

LITHOLOGIC DESCRIPTION

FORAM NANNO CHALK OOZE grading locally to NANNO MARL OOZE

Pale yellow (5Y 7/3-7/4), very pale brown (10YR 7/3), and light gray (2.5YR 7/2) — $CaCO_3$ 75

Smear Slide (75 cm, Sec 1)

Forams and fragments	25%
Nannos and triturated carbonate	55%
Clay	20%
Quartz	Tr.

Smear Slide (75 cm, Sec 2) — $CaCO_3$ 74

Forams and fragments	10%
Nannos	40%
Clay	40%
Quartz	Tr.

Laminated and streaked, finely and densely mottled. "Bedding" has angle up to 40° to the horizontal.

Smear Slide (75 cm, Sec 3):

Forams and fragments*	50%
Nannos	20%
Clay	30%
Quartz, opaques, heavies	Tr.

* 5-10% Benthonics

$CaCO_3$ 71

Smear Slide (138 cm, Sec 4):

Forams and fragments	20%
Nannos	70%
Clay	10%
Quartz, chlorite, mica, Fe oxides	Tr.

Smear Slide (75 cm, Sec 5)

Forams and fragments	10%
Nannos	70%
Clay	30%

$CaCO_3$ 73 — $CaCO_3$ 103

Smear Slide (100 cm, Sec 6):

Forams and fragments	25-30%
Nannos and triturated carbonate	65%
Clay	5%

Coarse Fraction:
Planktonic forams, poorly to very poorly preserved. — $CaCO_3$ 76

GZ 12-23-65

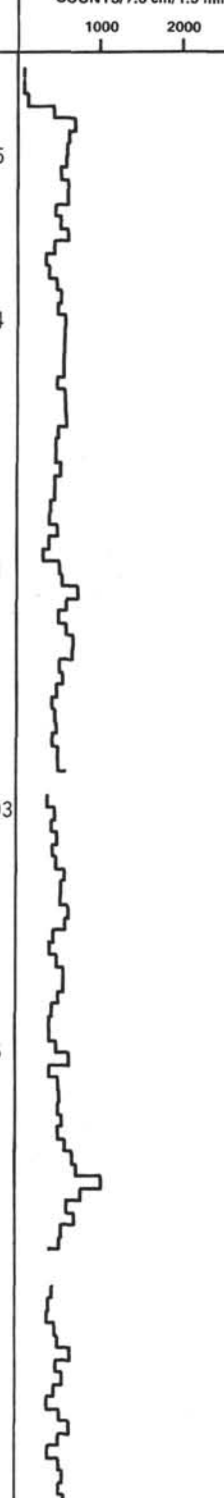
sec.1, 85 cm GZ 12-22-66
sec.2, 25 cm GZ 11-24-65
sec.3, 25 cm GZ 10-23-67
sec.4, 20 cm GZ 12-30-58

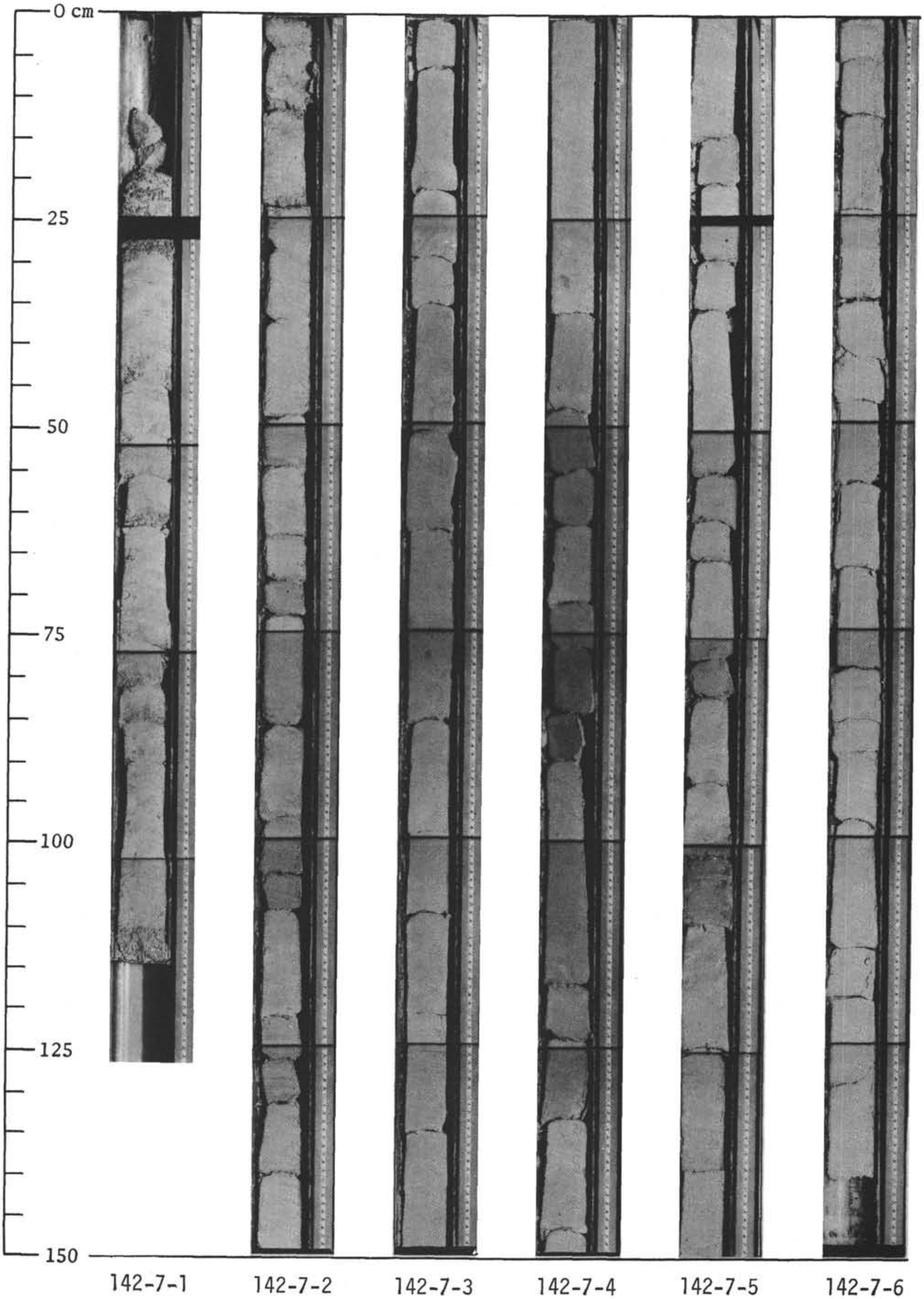
$CaCO_3$ 72

GZ 13-24-63

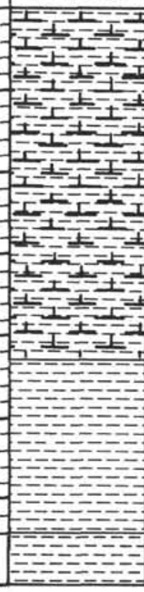
NATURAL GAMMA RADIATION

COUNTS/7.6 cm/1.5 min




0 cm
25
50
75
100
125
150
142-7-1
142-7-2
142-7-3
142-7-4
142-7-5
142-7-6

SITE 142 **CORE** 8 **DEPTH (m)** 529-538

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE	LITHOLOGIC DESCRIPTION	NATURAL GAMMA RADIATION (COUNTS/7.6 cm/1.5 min; 1000, 2000)
MIXED MIDDLE-LATE MIOCENE		*Discoaster neohamatus*		1, 2	1, 2, 3		70, 119, 100	see below	
LATE EARLY MIOCENE				CC					

NANNO CHALK OOZE grading locally to NANNO MARL OOZE — $CaCO_3$ 11
Greenish gray (5GY 6/1) and olive gray (5YR 5/2-4/2)

20 cm GZ 0-6-94

Large burrows, 1-3 cm by 2-5 mm, filled with white material and flattened by compaction. Also rounded and slumped clasts. Evidence of bioturbation

30 cm GZ 0-8-92

CLAY
Medium bluish gray (5B 5/1)
Very little burrowing or mottling

Smear Slide (70 cm):

Nannos	80%
Foram fragments	10%
Clay	10%
Quartz, chlorite, mica, Fe oxide	Tr.

$CaCO_3$ 51

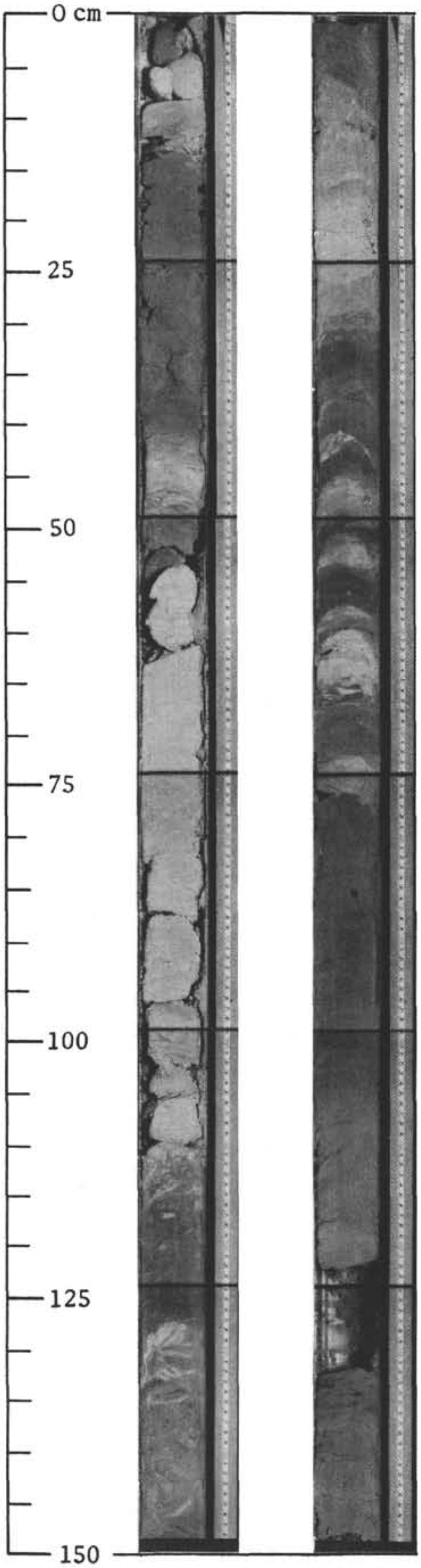
Smear Slide (119 cm):

Nannos	50%
Foram fragments	12%
Clay	30%
Pyrite and Fe oxides	5%
Quartz	3%
Chlorite, mica	Tr.

Smear Slide (100 cm):

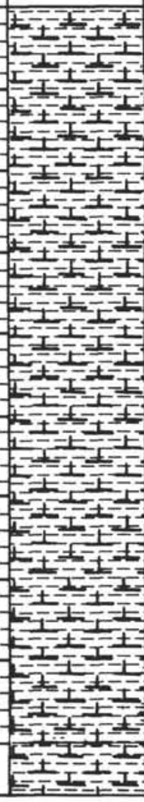
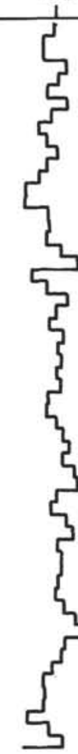
Clay	>95%
Quartz, nannos, zeolite	Tr.

Coarse Fraction:
Planktonic forams, fish debris, benthonic forams, (calcareous and arenaceous), quartz



142-8-1 142-8-2

SITE 142 **CORE** 9 **DEPTH (m)** 575-581

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE	LITHOLOGIC DESCRIPTION	NATURAL GAMMA RADIATION (COUNTS/7.6 cm/1.5 min; 1000, 2000)
MIDDLE TO EARLY MIOCENE	*Globigerinatella insueta*	*Sphenolithus heteromorphus?*		1, 2, 3, CC	1, 2, 3, 4		43, 57	see below	

NANNO MARL OOZE to
NANNO MARL MUD
Greyish gray (5G 6/1) and medium bluish gray (5G 6/1)
Sharp boundaries between the colors — $CaCO_3$ 53

Bioturbation indicated by burrows of two types:

1) Small chondrite-type burrows, horizontal, 1-2 mm wide, to 20 mm long
2) Large burrows, 5-12 mm wide, 10-50 mm long, extend both horizontal and diagonal. Flattened by compaction. — $CaCO_3$ 23

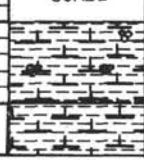
Smear Slide Average:

Nannos	40-55%
Clay	30-50%
Rads and sponge spicules	~2%
Quartz, mica, Fe oxide	Tr.

Coarse Fraction:
Planktonic forams, poorly preserved, rads, spicules, benthonic forams — $CaCO_3$ 42

sec.1, 110 cm GZ 6-35-59
sec.2, 30 cm GZ 7-33-60
sec.3, 40 cm GZ 0-31-69

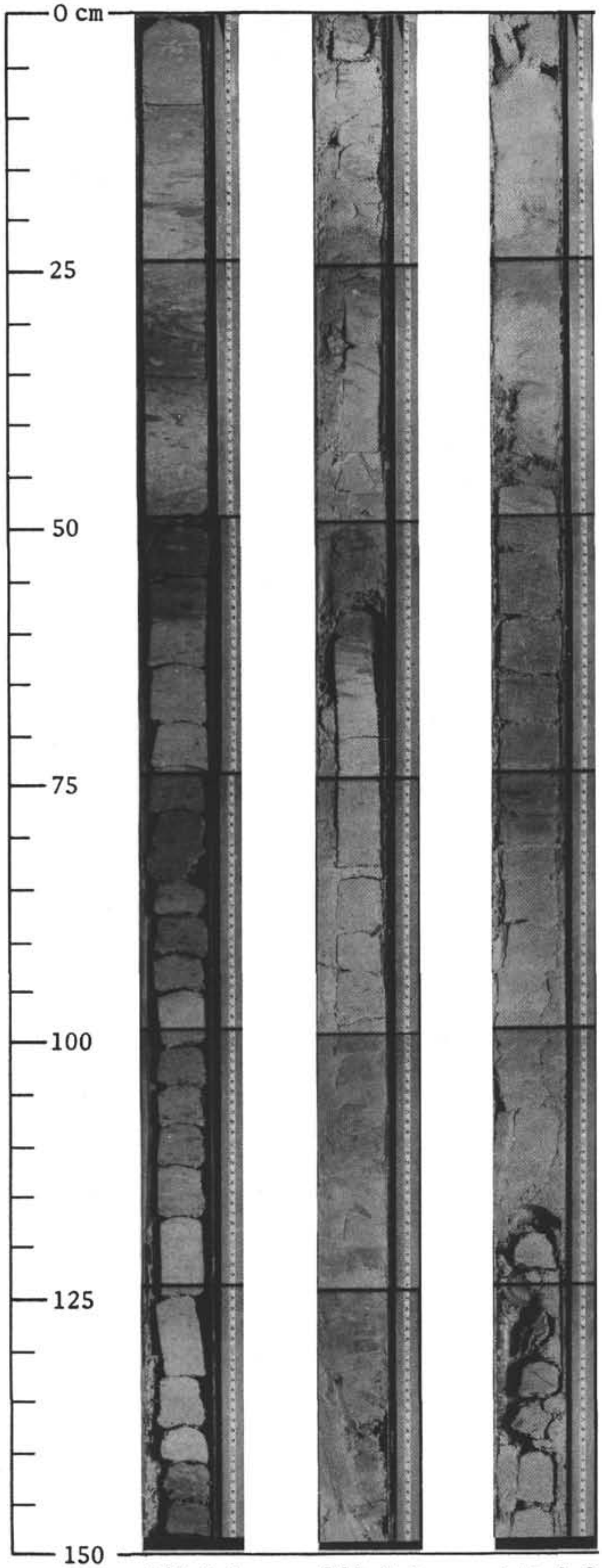
SITE 142 CENTER BIT SAMPLE **DEPTH (m)** ~ 600-609

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE	LITHOLOGIC DESCRIPTION	NATURAL GAMMA RADIATION (COUNTS/7.6 cm/1.5 min; 1000, 2000)
EARLY MIOCENE		*T. carinatus*		1, CC		NOT TO SCALE 		see below	

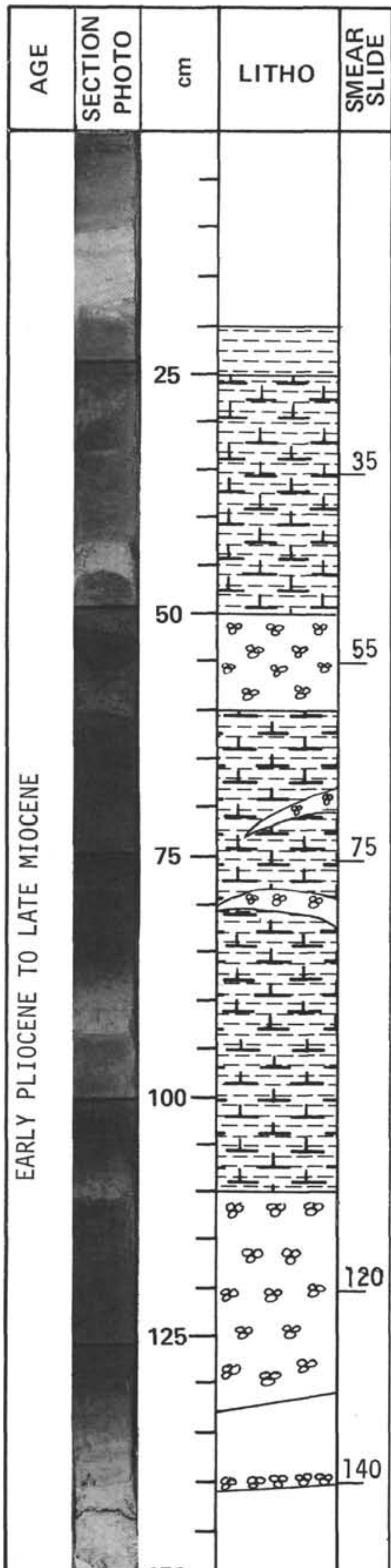
FORAM NANNO MARL OOZE
Slightly siliceous

Smear Slide:

Nannos	40%
Clay	~45%
Forams	10%
Sponge spicules, rads	5%


0 cm
25
50
75
100
125
150
142-9-1
142-9-2
142-9-3

SITE 142 CORE 6 SECTION 1



DESCRIPTION

NANNO MARL MUD
Olive gray (5Y 5/2)

Smear Slide (35 cm):

Nannos	50%
Clay	30%
Opaques	4%
Carbonate fragments	3%
Chlorite,(?)zeolite	2%
Carbonate rhombs	1%
Heavies (pyroxene, hornblende, topaz, zircon)	3%

FORAM SAND
Light gray (5Y 5/1) with Mn streaks

Smear Slide (55 cm):

Forams and fragments	65%
Carbonate fragments	10%
Nannos	15%
Clay	5%
Quartz	5%
Pyrite, chlorite	Tr.