6. SITE 590: LORD HOWE RISE, 31°S1

Shipboard Scientific Party²

HOLE 590

Date occupied: 15 December 1982 Date departed: 15 December 1982

Time on hole: 13 hr.

Position: 31°10.02'S; 163°21.51'E

Water depth (sea level; corrected m, echo-sounding): 1299

Water depth (rig floor; corrected m, echo-sounding): 1309

Bottom felt (m, drill pipe): 1308

Penetration (m): 26.2

Number of cores: 3

Total length of cored section (m): 26.2

Total core recovered (m): 26.36

Core recovery (%): 100

Oldest sediment cored: Depth sub-bottom (m): 26.2 Nature: Foraminifer-nannofossil ooze Age: early Quaternary

Basement: Not reached

HOLE 590A

Date occupied: 15 December 1982

Date departed: 17 December 1982

Time on hole: 51 hr.

Position: 31°10.02'S; 163°21.51'E

Water depth (sea level; corrected m, echo-sounding): 1299

Water depth (rig floor; corrected m, echo-sounding): 1309 Bottom felt (m, drill pipe): 1308 Penetration (m): 280.8 Number of cores: 27 Total length of cored section (m): 254.6 Total core recovered (m): 224.17

Core recovery (%): 88.1

Oldest sediment cored: Depth sub-bottom (m): 280.8 Nature: Nannofossil ooze Age: Middle late Miocene

Basement: Not reached

HOLE 590B

Date occupied: 17 December 1982

Date departed: 19 December 1982

Time on hole: 49 hr.

Position: 31°10.02'S; 163°21.51'E

Water depth (sea level; corrected m, echo-sounding): 1299

Water depth (rig floor; corrected m, echo-sounding): 1309

Bottom felt (m, drill pipe): 1308

Penetration (m): 499.1

Number of cores: 53

Total length of cored section (m): 499.1

Total core recovered (m): 465.26

Core recovery (%): 93.2

Oldest sediment cored: Depth sub-bottom (m): 499.1 Nature: Recrystallized nannofossil chalk Age: Earliest Miocene

Basement: Not reached

Principal results: Site 590 consists of three holes: Hole 590, which was cored continuously with the hydraulic piston corer (HPC) to 26.2 m sub-bottom; Hole 590A, which was cored continuously with the HPC from 26.2–280.8 m sub-bottom; and Hole 590B, which was cored continuously with the HPC from 0–250.7 m sub-bottom and rotary drilled with the extended core barrel (XCB) from 250.7–499.1 m sub-bottom. Cores recovered using the HPC are relatively undisturbed. Cores recovered using the XCB are slightly to moderately disturbed and in many cases consist of biscuits of sediment, in stratigraphic sequence but surrounded by soft ooze injected during the coring process. This represents the first successful use of the XCB and it proves to be a most useful new coring tool.

The section is made up of one lithostratigraphic unit, represented mostly by foraminifer-bearing nannofossil ooze or foraminifer-rich nannofossil ooze. The sequence is divided into three subunits based on changes in color and degree of diagenesis. The upper part of the sequence contains more foraminifer-rich intervals because of increased winnowing that began about 3 m.y. The sequence contains only traces of nonbiogenic components, but volcanic ash is quite persistent. Multiple light green laminae from ear-

Kennett, J. P., von der Borch, C. C., et al., *Init. Repts. DSDP*, 90: Washington (U.S. Govt. Printing Office).
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ly late Miocene to early Miocene are possibly altered volcanic ash layers. Biostratigraphic zonal sequences of transitional type are an important temperate component of the assemblages. The zonal sequence is complete for basal middle Miocene (16.5 m.y.) to Quaternary. Hiatuses cut the early Miocene. A paleomagnetic polarity stratigraphy has been identified down to the middle part of the Gilbert Chron (about 4.2 m.y.).

The Site 590 section provides a superb sequence of pristine foraminifers during the last 15 m.y. and of calcareous nannofossils during the last 10 m.y. The Pliocene/Quaternary and Miocene/Pliocene boundaries are well represented and exhibit clear, gradual, evolutionary sequences within some lineages. The Miocene/Pliocene boundary sequence is missing from the nearby Site 206 sequence.

Remarkably high calcareous biogenic sedimentation rates occur during most of the Pliocene and the middle and late Miocene. Rates (uncorrected for sediment porosity) are as follows for Hole 590B: early Miocene (base NN2-top NN3) 14.4 m/m.y.; middle Miocene (to top NN7) 29.4 m/m.y.; middle late Miocene-early Pliocene (to top NN13) 29.1 m/m.y.; early late Pliocene (to top N18) 52.4 m/m.y.; Quaternary, 17.2 m/m.y.

The seismic profile in the area shows no clear ponding of sediments in much of the sequence (except the Quaternary) or other evidence of sediment transport such as winnowing. Also the microfossil assemblages exhibit virtually no evidence of reworking. Therefore it seems that the high sedimentation rates, which are spectacularly high in the Pliocene, are due to biogenic productivity associated with the Tasman Front.

BACKGROUND AND OBJECTIVES

Site 590 lies to the east of the crest of Lord Howe Rise (Fig. 1). This site was selected as one of several that make up a north-south traverse of hydraulically piston cored Neogene sites (Site 586 in the north to 593 in the south). It is also the shallowest of three sites which form a depth traverse for the study of changes in the vertical water mass structure of the southwest Pacific during the Neogene. The other sites in this vertical traverse are 591 (2100 m) and 206 (3196 m). The seismic reflection profile (Fig. 2) indicates the presence of a relatively thick sequence of pelagic sediments near the site.

Site 590 is located 120 n. mi. to the northwest of Site 206 in the same surface water mass. Site 206 is situated at 32°00'S; 165.27'E. Although Site 206 is a valuable Neogene rotary-cored section, it suffers from a large num-

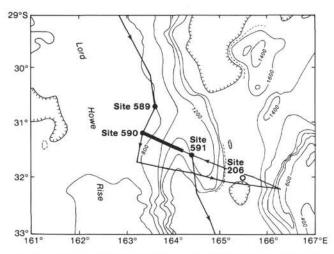


Figure 1. Regional bathymetry (fathoms) around Site 590, after Mammerickx et al., 1974. *Glomar Challenger* Leg 90 track shown; heavy portion locates water gun seismic profile illustrated in Fig. 2.

ber of coring gaps, especially in the early Miocene, and contains an unconformity over the Miocene/Pliocene boundary which eliminates important biostratigraphic information. Furthermore, because of the depth of this site (3196 m, below the foraminiferal lysocline), the planktonic foraminiferal assemblage has been altered by dissolution.

There are three main reasons why Site 590 was chosen:

1. It is strategically located in waters transitional between the warm subtropical and temperate water masses and is of potential importance in correlating stratigraphic sequences of those areas.

2. It lies at relatively shallow depths near the crest of Lord Howe Rise; and

3. Seismic profile data (Fig. 2) indicate that the area is a quiet pelagic environment and should provide a complete or nearly complete Neogene sequence of carbonate oozes.

Because Site 590 is located in such shallow water, and almost certainly has been located above the foraminiferal lysocline during the entire Neogene, it was expected that foraminiferal and calcareous nannofossil assemblages of this age would be well preserved and would provide an excellent paleoceanographic and paleoclimatic record. An important water mass boundary-the Tropical Convergence-separates the transitional from the warm subtropical water masses. The boundary represents the zone between the eastward flowing East Australian Current and the Trade Wind drift. Its position corresponds fairly closely with the southern limit of the southeast Trade Wind belt, where wind directions change from southwest to southeast, thereby creating convergent flow. The system is quite weak and disappears in summer when the Trade Wind drift turns south. That the tropical convergence is an important surface water mass barrier is suggested by the biogeographic and paleobiogeographic patterns of the planktonic foraminifers (Srinivasan and Kennett, 1981). Faunas at Site 206 have a much more important temperate element than those at Site 208. Paleoreconstructions of this region (Sclater et al., in press) show that Site 590 was about 5-10° of latitude further south in the early Neogene than it is now. This would have placed it well within the zone of westerlies during the early Neogene, with truly temperate planktonic assemblages.

The drilling plan at Site 590 was to core two sites using the hydraulic piston corer to refusal and then to rotary core continuously down to the upper Oligocene.

OPERATIONS

Sites 589 to 590

Following the shipboard computer failure at Site 589, southward transit to an alternate site (1) provided extra time to discover and repair the problem with the positioning computer, (2) if that proved impossible within 8 hr., would have placed the ship closer to New Zealand, where repairs could be made with expert assistance, and (3) would provide time to take seismic profiles in areas of potential new sites (alternates to SW-4 and SW-6) for

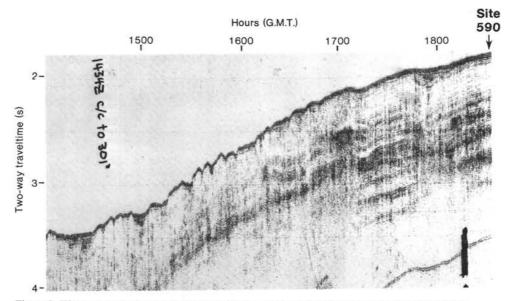


Figure 2. Water gun seismic profile (Glomar Challenger) near Site 590; bandpass filter 40-160 Hz.

the same scientific objectives. Further time was also necessary to obtain approval to drill the new sites from the JOIDES Safety Panel.

After possible alternate sites had been surveyed, the problem with the computer had still not been identified, and the ship changed course for Auckland, New Zealand, at 2003 hr., 13 December.

After we had steamed toward Auckland for more than 17 hr., the computer problem was located and repaired, and the vessel immediately returned to the newly chosen Site SW-4, following a track close to the one profiled upon departure from that site. The beacon (13.5 kHz) was dropped at 0533 hr., 15 December 1982. The total distance traveled since departure from Site 589 was 413 mi., at an average speed of 10.09 knots.

Site 590 (new SW-4): Central Lord Howe Rise

Site 590 was located on the Lord Howe Rise, roughly south of and at a water depth equivalent to that of the original SW-4 site specified in the scientific prospectus. Seismic profiling (Fig. 2) showed a sub-bottom character similar to the original SW-4.

Authorization to piston core the new site was received via radio before reaching SW-4, so there was no delay in operations. Once again a dual-purpose bottom-hole assembly (BHA) was lowered to enable piston coring followed by XCB rotary coring. The bit was lowered to 1305 m and a mudline variable-length (VL) HPC core containing 7 m of sediment was taken at 1210 hr., 15 December, after an initial mudline core had been discarded when the core liner shattered.

Three 9.5-m VLHPC cores were taken routinely (Table 1). The fourth attempt was unsuccessful when the coring tool was accidently allowed to fall several feet, so that it hit the lifting clamp violently. This ultimately caused a dislocation of the lower section of the piston core, which was lost through the bit. Unfortunately, the Von Herzen heat-flow package was attached to the lost tool. Because only one Von Herzen heat-flow electronic unit had been available to Leg 90, its scientific value was high; therefore an unsuccessful effort was made to fish for the lost barrel, which was believed to be stuck in the mud only about 3 ft. below the bit. About $2\frac{1}{2}$ hr. were spent making up a special fishing spear and deploying it through the bit. Hole 590 was terminated because of the obstruction.

Hole 590A

The bit was pulled to the mudline and washed back to the point where Core 590-4 was to have been taken. Hole 590A was spudded at 1810 hr., 15 December, and routine piston coring operations were resumed.

At Core 590A-13, the sand line parted at the rope socket on top of the sinker bar assembly. The sinker bars and VLHPC were successfully fished on the first attempt, so little time was lost.

As at the previous sites, full stroke of the piston corer was achieved continuously, generally with only two shear pins. At a depth of 275.8 m BSF, overpulls of 45,000 lb. made it necessary to wash the bit over the protruding corer in order to retrieve the tool. A 5-m VLHPC was then deployed, but it, too, had to be washed over for release. Therefore, piston coring was deemed to be too dangerous to be continued, despite the fact that highquality full-stroke cores were still being taken.

Hole 590B

Authorization to rotary core this new site had not yet been received, so the repeat piston core sequence was begun by pulling to the mudline and re-establishing water depth with a mudline core after the vessel had been offset 100 ft. The first core was shot with the bit at 1301 m, in order to overlap the piston cores with those from Hole 590A. Hole 590B was officially spudded at 2110 hr., 16 December.

Twenty-seven 9.5-m VLHPC cores were taken without any difficulties in calcareous sediment grading from soupy ooze to firm chalk. Piston coring was terminated at 250.7 m BSF when the familiar pattern of increasing overpull symptoms repeated itself.

Table 1. Coring summary, Site 590.

Core	Date (Dec.	T	dri	th from Il floor (m)	Depth below seafloor (m)	Length	Length	Percentag
no. Hole 590	1982)	Time	Тор	Bottom	Top Bottom	(m)	(m)	recovered
		1226	1207	<	00.70		< 00	100
1 2	15 15	1235 1305		.6-1314.6	0.0-7.0 7.0-16.6	7.0	6.99 9.70	100 100 +
3	15	1408	1324	.2-1333.8	16.6-26.2	9.6	9.67	100+
		Core b	arrel b	roken		26.20	26.36	100
Hole 590A								
1 2	15 15	1430 2012		.8-1343.4 .4-1353.0	26.2-35.8 35.8-45.4	9.6 9.6	9.41 9.39	98 98
3	15	2115	1353.	.0-1362.6	45.4-55.0	9.6	8.53	89
4	15	2200 2255		.6-1372.2	55.0-64.6 64.6-74.2	9.6 9.6	8.76 9.22	91 96
6	15	2343	1381.	8-1391.4	74.2-83.8	9.6	9.42	98
7 8	16 16	0015 0100		4-1401.0	83.8-93.4 93.4-103.0	9.6 9.6	9.02 9.50	94 99
9	16	0150	1410.	6-1420.2	103.0-112.6	9.6	0.0	0
10 11	16 16	0245 0330		2-1429.8 8-1439.4	112.6-122.2 122.2-131.8	9.6 9.6	8.86 9.71	92 100
12	16	0445		4-1449.0	131.8-141.4	9.6	9.60	100
132	16 16	0630 0800		0-1458.6	141.4-151.0	9.6 9.6	8.26	86 97
15	16	0850		2-1477.8	151.0-160.6 160.6-170.2	9.6	9.29 9.50	99
16	16	0950		8-1487.4	170.2-179.8	9.6	7.45	78
17 18	16 16	1015		4-1497.0	179.8-189.4 189.4-199.0	9.6 9.6	7.85	82 95
19	16	1200	1506.	6-1516.2	199.0-208.6	9.6	8.26	86
20 21	16 16	1255 1345		2-1525.8	208.6-218.2 218.2-227.8	9.6 9.6	8.75 9.74	91 100 +
22	16	1420		4-1545.0	227.8-237.4	9.6	2.42	25
23 24	16	1510 1600		0-1554.6	237.4-247.0	9.6	9.20	96
25	16 16	1710		6-1564.2 2-1573.8	247.0-256.6 256.6-266.2	9.6 9.6	9.71 9.11	100 + 100 +
26	16	1820	1573.	8-1583.4	266.2-275.8	9.6	8.91	93
27	16	1915	1583.	4-1588.4	275.8-280.8	5.0	5.20	100 +
						254.60	224.17	88.1
Hole 590B								
1 2	16 16	2135 2220		4-1310.6	0.0-2.2 2.2-11.8	2.2	2.10	95 96
3	16	2300		6-1320.2 2-1329.8	11.8-21.4	9.6 9.6	9.22 9.65	100 +
4	16	2355	1329.	8-1339.4	21.4-31.0	9.6	9.58	99.7
5	17 17	0035		4-1349.0 0-1358.6	31.0-40.6 40.6-50.2	9.6 9.6	9.40 9.60	97.9 100
7	17	0140	1358.	6-1368.2	50.2-59.8	9.6	9.59	99.9
8	17 17	0300 0400		2-1377.8 8-1387.4	59.8-69.4 69.4-79.0	9.6 9.6	9.24 8.05	96.2 83.8
10	17	0400		4-1397.0	79.0-88.6	9.6	8.87	92.4
11	17	0535		0-1406.6	88.6-98.2	9.6	9.00	93.7
12 13	17 17	0620 0700		6-1416.2 2-1425.8	98.2-107.8 107.8-117.4	9.6 9.6	8.52 9.29	88.7 96.7
14	17	0740	1425.	8-1435.4	117.4-127.0	9.6	9.74	100 +
15	17	0830		4-1445.0 0-1454.6	127.0-136.6 136.6-146.2	9.6 9.6	9.06 8.76	94.4 91.2
17	17	1005		6-1464.2	146.2-155.8	9.6	9.49	98.8
18	17	1045		2-1473.8	155.8-165.4	9.6	8.03	83.6
19 20	17 17	1120 1210		8-1483.4 4-1493.0	165.4-175.0 175.0-184.6	9.6 9.6	8.33 9.38	86.7 98
21	17	1315	1493.	0-1502.6	184.6-194.2	9.6	8.44	88
22 23	17	1410 1510		6-1512.2 2-1521.8	194.2-203.8 203.8-213.4	9.6 9.6	6.07 9.47	63.2 99
24	17	1550	1521.	8-1531.4	213.4-223.0	9.6	8.66	90
25 26	17 17	1645 1750		4-1541.0 0-1550.6	223.0-232.6 232.6-242.2	9.6 9.6	8.51 9.73	89 100 +
20	17	1855		6-1559.1	242.2-250.7	8.5	8.49	99
28	17	1950		1-1567.5	250.7-259.1	8.4	9.28	100 +
29 30	17	2055 2200		5-1577.1	259.1-268.7 268.7-278.3	9.6 9.6	8.88 8.28	92 86
31	17	2310	1586.	7-1596.3	278.3-287.9	9.6	7.84	81.6
32 33	17 18	2345 0043		3-1605.9 9-1615.5	287.9-297.5 297.5-307.1	9.6 9.6	9.25	96.3 100+
34	18	0200		5-1625.1	307.1-316.7	9.6	9.63 8.43	87.8
35	18	0250		1-1634.7	316.7-326.3	9.6	7.60	79.1
36 37	18 18	0340 0432		7-1644.3 3-1653.9	326.3-335.9 335.9-345.5	9.6 9.6	9.50 9.64	98.9 100 +
38	18	0520	1653.	9-1663.5	345.5-355.1	9.6	9.65	100 +
39 40	18 18	0610 0700		5-1673.1 1-1682.7	355.1-364.7 364.7-374.3	9.6 9.6	9.73 9.71	100 + 100 +
41	18	0745	1682.	7-1692.3	374.3-383.9	9.6	9.76	100 +
42	18	0830	1692.	3-1701.9	383.9-393.5	9.6	9.61	100 +
43	18 18	0915		9-1711.5 5-1721.1	393.5-403.1 403.1-412.7	9.6 9.6	7.48 9.65	77.9 100+
45	18	1100	1721.	1-1730.7	412.7-422.3	9.6	7.72	80.4
46 47	18	1200		7-1740.3	422.3-431.9	9.6	9.78	100+
48	18 18	1255 1355		3-1749.6 6-1759.2	431.9-441.5 441.5-451.1	9.6 9.6	9.68 9.68	100 + 100 +
49	18	1450	1759.	2-1769.1	451.1-460.7	9.6	7.19	75
50 51	18 18	1550 1650		1-1778.7 7-1788.3	460.7-470.3 470.3-479.9	9.6 9.6	4.31 9.42	45 98
52	18	1755	1788.	3-1797.9	479.9-489.5	9.6	9.61	100+
62	18	1850	1797	9-1807.5	489.5-499.1	9.6	9.68	100 +
53				9-1007.5	407.0 477.1	7.0		100 1

The XCB with its latest modifications was deployed. Excellent cores with high recovery rates were taken. Seven of the first nine cores were retrieved with the liner partially collapsed, but the collapse was always limited to the top 3 ft. or less. This problem was soon eliminated. Twenty-six cores were taken with the XCB to a depth of 499.1 m BSF, where the hole was terminated when the quality of the recovered microfossils deteriorated to the point that useful paleoceanographic work became impossible.

The pipe was tripped and the rig floor was secured for sea. The vessel departed for Site 591 at 2248 hr., 18 December 1982.

LITHOSTRATIGRAPHY

The sequence recovered at Site 590 is dominantly composed of calcareous biogenic sediments which constitute a single lithostratigraphic unit with three subunits (Table 2; Fig. 3). The principal biogenic components are calcareous nannofossils and foraminifers (Fig. 4). The sediments range from an occasional nannofossil-foraminifer ooze through common foraminifer-bearing nannofossil ooze (or chalk) to fairly pure nannofossil ooze (or chalk). Biosiliceous components are generally absent, but occasionally are present in trace to rare amounts, having greatest abundance (1 to 5%) in Cores 590B-32 to 590B-35. The siliceous components consist primarily of whole and fragmented radiolarians, diatom frustules, and occasionally sponge spicules.

Nonbiogenic components comprise an extremely small proportion of the sediment. Occasional quartz and feldspar grains are present. Trace quantities of clear volcanic glass occur throughout the sequence, and distinct concentrations of volcanic ash were observed in Cores 590A-6, 590B-38, and 590B-51. Zeolites(?) and palagonite occur in Cores 590B-48 to 590B-53. Numerous pale green laminae occur and are most prevalent in Cores 590B-33 to 590B-53. These are possibly related to the presence of increased quantities of volcanic ash. Authigenic iron sulfide occurs within burrows and foraminifer tests, and as finely dispersed medium gray streaks and halos throughout the sequence. Gravish yellow concretions measuring up to 5 cm in diameter were found in Cores 590B-18, 590B-20, and 590B-23. These are composed predominantly of celestite with pyrite crystals occurring on the surface or as a central core.

The sediment becomes more indurated with depth. Sediments above 280 m sub-bottom are ooze that becomes progressively stiffer with depth. Sediments below

Table 2. Lithostratigraphy at Site 590.

Lithostratigraphic unit	Core	Sub-bottom depth (m)	General lithology	Age
IA	590-1 590B-1	0-40 cm 0-30 cm	Yellowish orange foramini- fer-nannofossil ooze	late Quaternary
IB	590-1 to 590-3 590A-1 to 590A-27	0.4-26.2 26.2-280.8	Very light gray foraminifer- bearing nannofossil ooze to light olive gray foraminifer-nannofossil	late Miocene
	590B-1 to 590B-30	0.4-278.3	ooze.	
IC	590B-31 to 590B-53	278.1-499.1	Light gray foraminifer- bearing nannofossil chalk to recrystallized nannofossil chalk	late Miocene to early Mio- cene

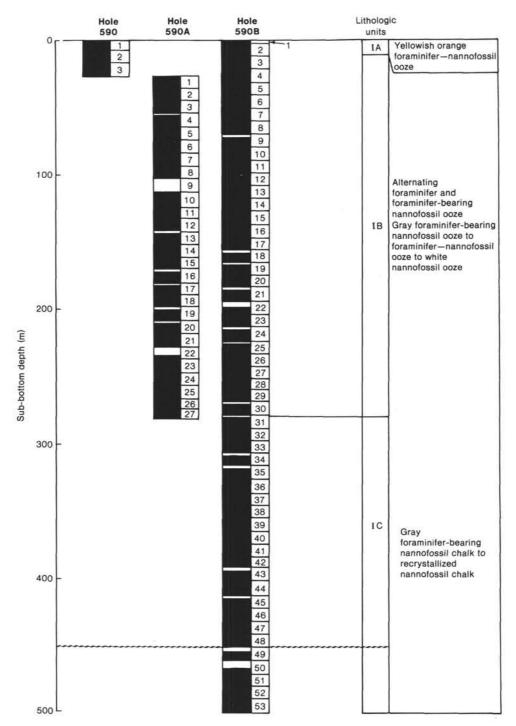
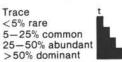


Figure 3. Lithology of Site 590. Recovery in black.

approximately 280 m sub-bottom are chalk with clear recrystallization in Cores 590B-51 to 590B-53.

Sedimentary structures have been created by chemical, physical, and biological effects. Bioturbation is slight in the upper part of the sequence (Cores 590-1 to 590-3, 590A-1 to 590A-16, and 590B-1 to 590B-19), increases to moderate downhole (Cores 590A-17 to 590A-28, and 590B-20 to 590B-31), and becomes intense in Cores 590B-32 to 590B-47. The lowest part of the sequence, Cores 590B-48 to 590B-53, exhibits moderate bioturbation. Various color bands are apparent against the very light gray (N8) to white background of the ooze or chalk. The zones richer in foraminifers tend to be darker gray to light olive gray. Many burrows are yellowish gray (5Y 8/1). Numerous examples of Zoophycos as well as occasional Planolites-like and Chondrites-like burrows are apparent. Several suites of fractures were observed cutting the sediment sequence, but it is not clear whether or not they represent drilling artifacts. One microfault in Core 590B-35 is definitely unrelated to drilling activity, however, because it has clearly been annealed and occurs within a biscuit of hard sediment.



Dominant lithology, Hole 590

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Figure 4. Smear slide summaries, Site 590.

The sequence at Site 590 is divided into three subunits, based on changes in color and degree of diagenesis.

Subunit IA extends from the seafloor to 40 cm subbottom and is of late Quaternary age. The sediment is a yellowish orange foraminifer-nannofossil ooze. This subunit corresponds to the zone of oxidation and possible current winnowing activity and indicates that the uppermost sediments recovered are from near the sediment/ water interface.

Subunit IB extends from 40 cm to approximately 280 m sub-bottom. The upper part of this subunit (to 80 m) is late Pliocene to Pleistocene in age and consists of alternating layers of very light gray foraminifer-bearing (5 to 10%) nannofossil ooze and layers of light olive gray foraminifer (20 to 50%) nannofossil ooze. The change in

Trace <5% rare 5-25% common 25-50% abundant >50% dominant

Dominant lithology, Hole 590A

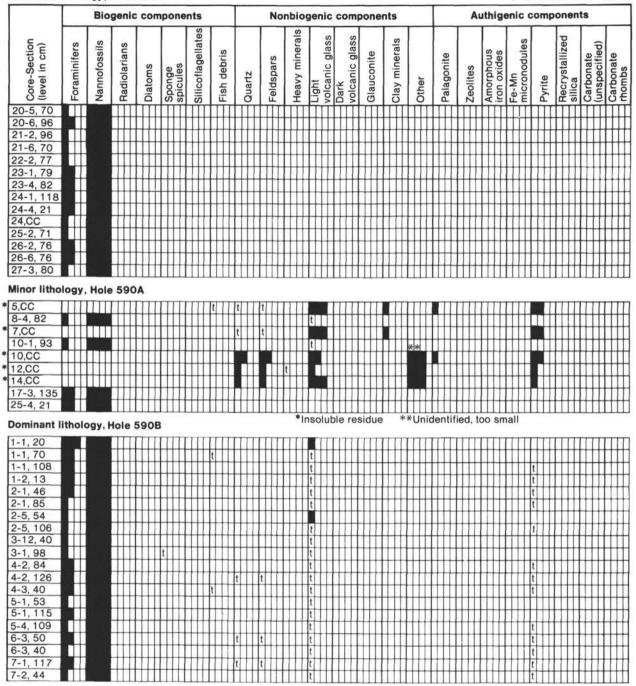
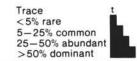


Figure 4. (Continued).

percentages of foraminifers may indicate that these sediments were deposited during a period of fluctuating bottom current activity. The more foraminifer-rich units probably represent episodes of increased winnowing activity by bottom waters, as in Subunit IA.

The lower part of Subunit IB extends from approximately 80 to 280 m sub-bottom and is mid-late Miocene to late Pliocene in age. This part of the subunit consists of fairly uniform nannofossil ooze with occasional zones of foraminifer-bearing (5 to 10%) nannofossil ooze and is very light gray to white in color. The uniform nature of this part of the subunit indicates a period of less variable oceanographic conditions compared with the upper part of Subunit IB.

Subunit IC extends from approximately 280 to 499 m sub-bottom. The upper part of this subunit (to 400 m) is



Dominant lithology, Hole 590B

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Figure 4. (Continued).

middle Miocene to early late Miocene in age. The only significant quantities of biosiliceous sediments occur near the top of this part of the subunit. This subunit resembles the upper part of Subunit IB in consisting of alternating very light gray foraminifer-bearing and light olive gray foraminifer-rich layers that have been lithified to foraminifer-bearing nannofossil chalk and foraminifernannofossil chalk, respectively. The upper part of Subunit IC is also delineated by the highest rates of bioturbation encountered in the sequence, suggesting increased transport of organic material to the seafloor during this period.

The lower part of Subunit IC (450 to 499 m sub-bottom) is of early Miocene age. It is composed of recrystallized nannofossil chalk. This part of the subunit lacks the foraminifer-rich layers of the portion above and is

Trace t <5% rare 5-25% common 25-50% abundant

>50% dominant

Dominant lithology, Hole 590B

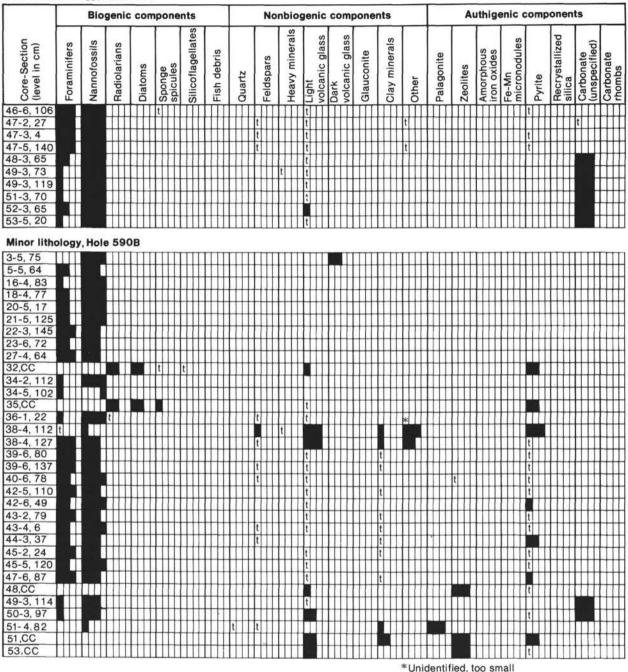


Figure 4. (Continued).

less heavily bioturbated. It contains the highest occurrence of volcanic ash and its alteration products.

PHYSICAL PROPERTIES

Wet-bulk density, porosity, and grain density were determined throughout the sediment column by using standard gravimetric methods (Boyce, 1976). The HPC cores were also continuously scanned with the GRAPE apparatus to measure wet-bulk density. Sonic velocity and shear strength were determined on each core section as well (see Introduction for specific techniques). A full discussion of the physical properties data for Site 590 is presented by Morin (this volume).

The GRAPE wet-bulk densities (points) for Hole 590B are plotted versus depth in Figure 5A. The results are averaged across each meter and these arithmetic mean values are plotted as the solid line (also relevant for Fig. 5B and 5C). The GRAPE porosities are directly calculated

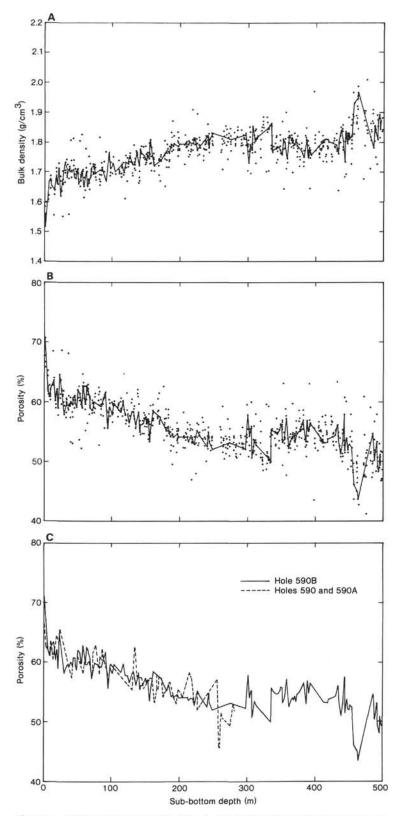


Figure 5. Physical properties, Site 590. A. GRAPE wet-bulk density versus sub-bottom depth for Hole 590B. B. GRAPE porosity versus sub-bottom depth for Hole 590B. C. GRAPE porosity versus sub-bottom depth for Holes 590, 590A, and 590B. D. Compressional velocity versus sub-bottom depth for Hole 590B.
E. Porosity versus compressional velocity for Site 590. F. Shear strength versus sub-bottom depth for Hole 590B. G. Porosity versus shear strength for Hole 590B. H. Impedance versus depth for Hole 590B.

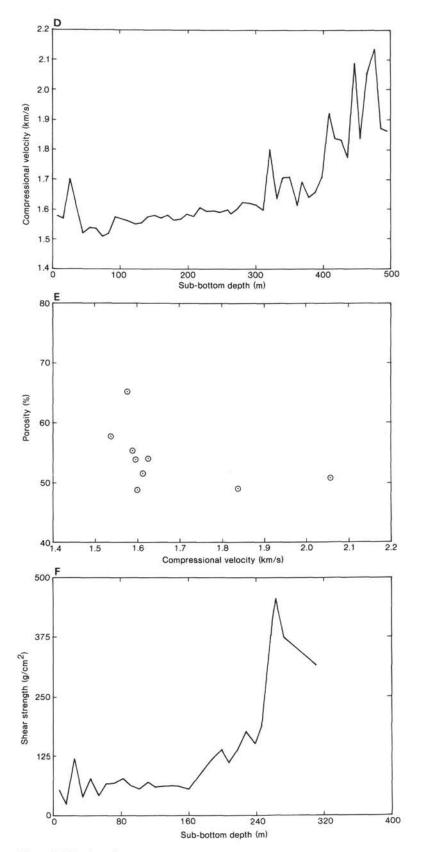


Figure 5. (Continued).

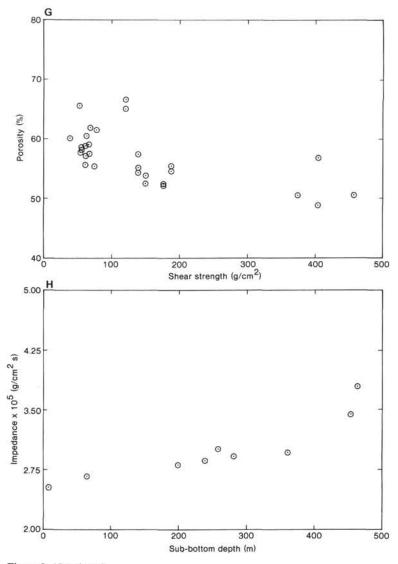


Figure 5. (Continued).

from the density results by assuming a grain density of 2.691 g/cm³. Since the carbonate content of these sediments is very high (CaCO₃ grain density = 2.71 g/cm³), this assumption provides a reasonable estimate of porosity versus depth (Fig. 5B). The porosity profile for Holes 590 and 590A is compared with that of Hole 590B in Figure 5C.

The results of the compressional velocity measurements performed on the split cores are illustrated in Figure 5D. A sharp increase in this property occurs at approximately 300 m, where the ooze-to-chalk transition is observed. When these data are correlated with the porosity profile, a plot of P-wave velocity versus porosity results (Fig. 5E). This graph illustrates how the acoustic velocity through the sediment at Site 590 increases dramatically as the porosity approaches 50%.

A similar presentation can be made with the shear strength data (Fig. 5F). The shear strength increases rapidly at 250 m. Below a depth of 300 m, the sediment becomes so lithified that its strength measurement is beyond the range of the Wykeham Farrance miniature vane shear device. Again, the sharp rise in the magnitude of this property occurs at the onset of chalk, where the sediment porosity approaches 50% (Fig. 5G).

An estimate of acoustic impedance as a function of depth can be derived by combining the P-wave velocity results with the GRAPE wet-bulk density profile (Fig. 5H). A rapid increase in impedance at a depth of approximately 450 m corresponds to the observed diagenetic recrystallization of the foraminifer-bearing nannofossil chalk.

SEISMIC STRATIGRAPHY

Figure 6 illustrates a portion of the shipboard water gun seismic profile collected during approach to Site 590. Five acoustic units have been identified (A to E), broadly equivalent to the regional acoustic units selected by Willcox et al., 1980. These are correlated in part with the lithology of the site (lithostratigraphic Subunits IA, IB, and IC).

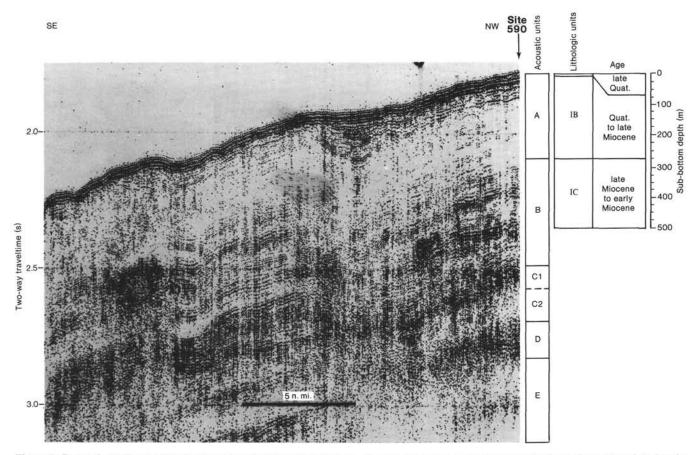


Figure 6. Comparison of acoustic Units A and B with lithologic Unit I Cored at Site 590; shipboard water gun seismic profile, collected during site approach; depths in meters estimated by assuming a sediment sound velocity of 1800 m/s.

Acoustic Unit A is a relatively transparent layer at recorded frequencies. Some relatively coherent reflectors are visible in its uppermost portion, below the reflected wave form. A small basin occurs 7 n. mi. southeast of Site 590, filled with significantly more reflective material. Further down the slope of Lord Howe Rise to the east-southeast (not shown in Fig. 6), additional filled channels or minor basins occur in a similar position with respect to the sediment surface.

Acoustic Unit B is not readily differentiated from A in the water gun record near Site 590. The upper boundary of B has been selected at the top of a slightly more reflective zone which contains layers of coherent reflectors.

Acoustic Unit C can be correlated regionally between drill sites on Lord Howe Rise with a high degree of confidence. It has a well-defined upper limit, and comprises a series of high-amplitude, relatively coherent reflectors (C1) underlain by a transparent zone (C2).³ This unit has been subdivided in this summary into Subunits C1 and C2, in order to include the transparent zone (C2) which occurs below Site 590 and which occurs typically in grabens between acoustic units C and D. Generally, the highs between grabens are overlain by close juxtaposition of Units C and D, and the transparent Subunit C2 is missing.

Acoustic Unit D comprises a high-amplitude, relatively coherent set of reflectors with an appearance similar to that of Subunit C1.

Acoustic Unit E is a low-amplitude zone which, like C2, is largely confined to basinal areas (e.g., grabens). Its possible occurrence below Site 590 relates to what appears to be a relatively thick sedimentary sequence in this region of the Lord Howe Rise.

Site 590 was drilled to a total depth of 499.1 m, through acoustic Unit A and into B. The sequence has been assigned to three lithostratigraphic subunits. Subunit IA comprises late Quaternary foraminifer-nannofossil ooze, only 40 cm thick, and thus is not represented on Figure 6. Subunit IB comprises mixed foraminifer-bearing nannofossil ooze, foraminifer-nannofossil ooze, and nannofossil ooze, whereas Subunit IC is composed of foraminifer-bearing nannofossil chalk to recrystallized nannofossil chalk. Within the sequence, the downward gradation from ooze to chalk begins at a sub-bottom depth of about 275 m.

Comparison of these seismic and lithologic data suggests that the ooze/chalk boundary correlates with the

³ Acoustic Unit C was not subdivided into C1 and C2 in the summary of Willcox et al., 1980, who may not have recognized Subunit C2 because of the lower frequencies employed during their seismic profiling. However, an effort has been made in this report to adhere to the original units chosen by Willcox et al.; accordingly, the transparent zone has been designated as a subunit.

boundary between acoustic Units A and B. This estimate is based on an interval velocity of 1.8 km/s, averaged from shipboard velocimeter measurements on cores. As described in the preceding section on Physical Properties, a rapid increase in acoustic impedance at a depth of approximately 450 m corresponds to diagenetic recrystallization of the foraminifer-bearing nannofossil chalk. The drilling terminated midway through acoustic Unit B.

BIOSTRATIGRAPHY

The three holes drilled at Site 590 provide a complete calcareous sequence from the early Miocene through Recent, except for an unconformity at 470.3 m sub-bottom depth. At this level, the planktonic foraminifers show that the lower part of the *Globorotalia fohsi* s.l. Zone (earliest middle Miocene) to the upper part of the *G. miozea* Zone (latest early Miocene) is missing. This gap is not noted in the calcareous nannoplankton zonation, but may be within the *Sphenolithus heteromorphus* Zone (NN5, earliest middle Miocene). The unconformity at the Miocene/Pliocene boundary reported from nearby Site 206 was not observed at this site.

Preservation of calcareous nannoplankton is good in the upper part of the sequence and moderate to poor in the lower part. In particular, the Miocene discoasters become progressively more heavily overgrown with depth. The preservation of planktonic foraminifers is good above the lower Miocene unconformity and very poor below. The benthic foraminifers are well preserved throughout much of the sequence; however, below the upper Miocene, some specimen breakage occurs and some samples exhibit very low abundances of benthic foraminifers, perhaps as a result of diagenesis. Rare radiolarians were noted in the section below Sample 590B-25,CC (middle late Miocene).

For correlations between different fossil groups see Figure 7.

Planktonic Foraminifers

Zones

The planktonic foraminiferal zones recognized at Site 590 are shown in Figure 7. The zonal boundary marker species are noted in parentheses in the faunal descriptions that follow.

An unconformity exists between Samples 590B-48,CC and 590B-49,CC and the *Orbulina suturalis* Zone and *Praeorbulina glomerosa curva* Zone appear to be missing.

Faunas

Globorotalia truncatulinoides Zone (L.A. Globorotalia tosaensis)

The zone fossil is in abundance and exists with Globorotalia menardii, G. tumida, G. inflata, and Pulleniatina obliquiloculata.

Globorotalia truncatulinoides-G. tosaensis Zone (I.A. G. truncatulinoides)

The two zone fossils coexisted together with most species which survived into the *G. truncatulinoides* Zone.

Globorotalia tosaensis Zone (I.A. G. tosaensis)

The zone fossil is abundant, with evidence of its evolution from G. crassaformis in the lower part of the zone; other important taxa include Globigerinoides fistulosus, Globorotalia inflata, G. multicamerata, Dentoglobigerina altispira, and P. obliquiloculata.

Globorotalia inflata Zone (I.A. G. inflata)

The zone fossil is abundant at this site and occurs with G. menardii, G. tumida, and P. obliquiloculata.

Globorotalia crassaformis Zone (I.A. G. crassaformis)

The zone fossil is abundant in the middle and upper part of the zone but is rarer in the lower part; important markers include *G. margaritae*, *G. puncticulata*, and *P. primalis*.

Globorotalia puncticulata Zone (I.A. G. puncticulata)

The lower boundary was marked by the evolutionary appearance of the zone fossil with a transition form G. *sphericomiozea;* other important species within the zone include G. *miotumida* and P. *primalis*.

Globorotalia conomiozea Zone (I.A. G. conomiozea)

The zone fossil is common within the zone with its typical morphology; thus it differs from Site 588; *G. conomiozea* and *G. margaritae* overlap in the uppermost part of the zone in 590A-18, CC.

Globigerina nepenthes Zone (L.A. Neogloboquadrina continuosa)

The upper boundary is well established at this site with the probable evolutionary appearance of *Globorotalia conomiozea*; the lower boundary, based on the extinction of *N. continuosa*, is less securely established because of the scarcity of this species.

Neogloboquadrina continuosa Zone (L.A. G. mayeri)

The zonal boundaries are marked by the extinction of the zone fossil at the top and *G. mayeri* at the base; within the zone there is little faunal change.

Globorotalia mayeri Zone (L.A. Fohsella group)

The zone fossil was common within the zone; the lower boundary, marked by the extinction of the *Fohsella* lineage, may be stratigraphically low at this site because the keeled members of the *G. fohsi* lineage are absent.

Globorotalia fohsi s.l. Zone (I.A. G. peripheroncuta)

The zone fossils, G. peripheroacuta and G. fohsi s.l., are rare within the zone, and the lower part of the zone may be missing.

Globorotalia miozea Zone (L.A. Catapsydrax dissimilis)

Assemblages are poorly preserved within this zone, and identifications were difficult; nevertheless, the absence of *Orbulina* and *Praeorbulina* and the presence of the early Miocene *G. zealandica* confirmed the *G. miozea* Zone.

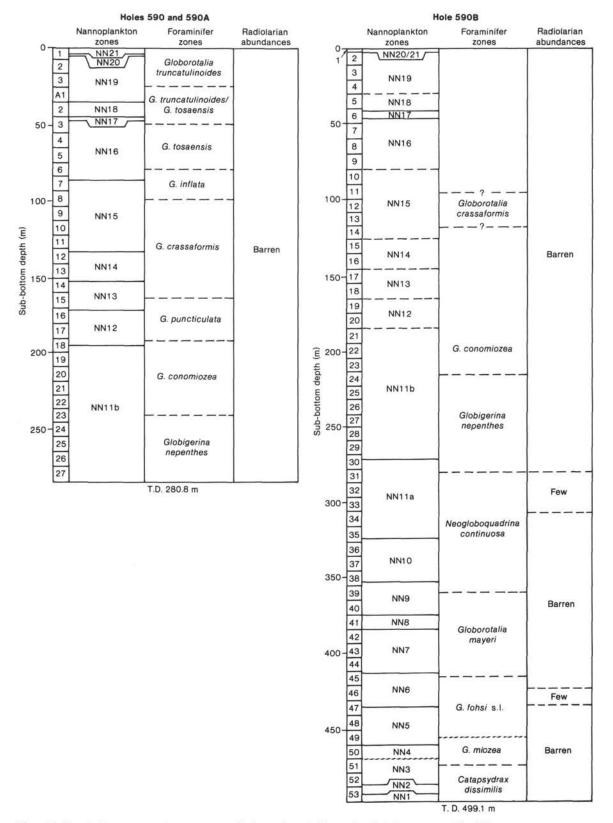


Figure 7. Correlation among calcareous nannoplankton, foraminifer, and radiolarian zones at Site 590.

Catapsydrax dissimilis Zone

There was very poor preservation of the fauna; the presence of the zonal fossil and the absence of *G. kugle-ri* confirmed the zonal designation.

Paleobiogeography

It is difficult to interpret the early Miocene fauna because of the low diversity caused by bad preservation, but it appears to be a relatively cool water fauna which lacks such tropical species as *Globigerinatella insueta* and *Hastigerinella bermudezi*.

The middle Miocene appears also to be represented by a relatively cool water fauna. The dominant keeled *Globorotalia* is *G. miotumida* (= *G. conoidea*), a temperate form, and the absence of keeled *G. fohsi* taxa, which are distinctive tropical forms, supports this general observation about the assemblages.

The late Miocene up to and including the early Pliocene G. puncticulata Zone fauna is represented by relatively cool water faunas. The younger faunas from the early Pliocene to Pleistocene, indicate sporadically warmer conditions, with the influx of G. tumida and Pulleniatina obliquiloculata.

Major Boundaries

Pliocene/Pleistocene: well marked by the evolutionary first appearance of *Globorotalia truncatulinoides*.

Miocene/Pliocene: is established at this site at the last appearance of *Globorotalia conomiozea* in Core 590A-18; the first appearance of *G. puncticulata* occurs in Sample 590A-17,CC.

Benthic Foraminifers

Benthic foraminifers were examined in the fraction >63 μ m in core-catcher samples from Cores 590-1 to 590-3, 590A-1 to 590A-27, and 590B-30 to 590B-53. The larger part of the Miocene section (590A-24 to 590A-27, 590B-30 to 590B-53) was not well preserved, the foraminiferal faunas are impoverished, and in the middle to lower Miocene (590B-35 to 590B-53) there may be as few as six species remaining in the samples. Pliocene faunas are well preserved, particularly in the upper Pliocene. Fluctuations in faunal abundance through the lower Pliocene are probably a function of variations in the otherwise high sedimentation rates.

The most diagenetically altered faunas occur in the Globorotalia miozea-G. fohsi s.l. Zones (590B-53 to 590B-44,CC). Species apparently resistant to diagenetic dissolution include Oridorsalis umbonatus, Bolivina subaenariensis, Cibicides rugosus, Melonis barleeanum, Heterolepa kullenbergi, and Globocassidulina subglobosa. These species occur most consistently through the remainder of the Miocene section. Although the majority of appearances and disappearances and the fluctuations in specific abundances are considered an artifact of diagenesis, the disappearance of Cibicidoides tuxpamensis at the top of the Globorotalia fohsi s.l. Zone (590B-45,CC) is considered real, as it occurs at approximately the same level at Site 588.

The one species which may be indicative of upslope benthic migration, *Melonis pompilioides*, was found in only one interval (590B-34,CC) in the mid-*Neogloboquadrina continuosa* Zone of early late Miocene age.

Radiolarians occur throughout the section from the *Globigerina nepenthes* Zone (590A-25 to 590A-27,CC (mid-late Miocene), to 590B-27 to 590B-47,CC (middle Miocene). They are joined by increased amounts of spicules and a large influx of pyritized worm burrows at 590A-27,CC and 590B-28,CC. These samples contain a unique benthic fauna, more than 50% of which consists of *Rectuvigerina multistriata*, accompanied by *Hopkinsina mioindex* in large numbers, a rare *Buliminella* which occurs only at this level (as at Site 588), and a fauna otherwise similar to those above and below.

At the top of the *Globorotalia conomiozea* Zone, preservation improves, benthic diversity increases, the first miliolids appear (or are preserved), and the first hispido-costate uvigerinids, *Uvigerina hispido-costata* and *U. peregrina*, occur in the faunas. Uvigerinids occur in increased abundance in many areas of the world near the top of the Miocene, for example, in the Canary Current (Lutze, 1979). The fact that a new group colonizes the Site 590 area, a group which will dominate the uvigerinid populations from the late Pliocene through the Quaternary, suggests that conditions resembling those during the glacials developed temporarily during the latest Miocene.

Pliocene benthic faunas contain about 20 to 25 species and closely resemble faunas from the Miocene. Only six new species appear throughout the epoch. Benthics are very abundant in the residues and faunal composition appears to be very similar throughout the section. In the top few samples of Hole 590A, preservation favors even delicate species such as *Anomalina semipunctata*, and the very flattened, spinose morphotype of that taxon found at this site.

A pronounced faunal and sedimentation change occurs at the top of the lower Miocene (590A-7 to 590A-8,CC). U. hispido-costata rejoins the faunas, and in the sample directly above, U. peregrina reappears, joined by M. pompilioides. These benthic changes suggest cooling and upward migration of benthics, which then remain in this area through the course of the Pliocene and into the Quaternary.

The three Quaternary samples (590-1 to 590-3,CC) contain benthic samples similar to those of the Pliocene. Glacial-interglacial cycles may be determinable by the alternating abundances of uvigerinids versus cibicidids and cassidulinids.

Calcareous Nannoplankton

Core-catcher samples, along with additional samples sufficient to accurately determine zonal boundaries, were examined for calcareous nannoplankton. All of the zonal indicators are present, with the exception of *Helicosphaera ampliaperta*. The upper boundary of the *Helicosphaera ampliaperta* Zone (NN4) is determined instead by the first occurrence of *Discoaster exilis*. Calcareous nannoplankton are abundant throughout the section at Site 590. Preservation is good in the Quaternary and Pliocene. In the Miocene, preservation deteriorates from moderate to poor, and in particular most of the discoasters are heavily overgrown.

Hole 590

Quaternary

Three cores were obtained before the hole terminated at a depth of 26.2 m BSF. Samples 590-1-1, 5-6 cm to 590-3, 5-6 cm contain *Emiliania huxleyi* and belong in the late Pleistocene *Emiliania huxleyi* Zone (NN21). The late Pleistocene *Gephyrocapsa oceanica* Zone (NN20) includes Samples 590-1-4, 5-6 cm and 590-1-5, 5-6 cm. Samples 590-1,CC to 590-3-2, 5-6 cm contain common *Emiliania ovata* and are placed in the upper subzone of the early Pleistocene *Emiliania ovata* Zone (NN19b). The presence of *Calcidiscus macintyrei* in Samples 590-3-3, 5-6 cm to 590-3,CC places these samples in the lower subzone of the early Pleistocene *E. ovata* Zone (NN19a).

Hole 590A

Quaternary

Sample 590A-1-7, 5-6 cm is placed in the lower subzone of the early Pleistocene E. ovata Zone (NN19a) based upon the common occurrences of E. ovata and C. macintyrei.

Pliocene

The presence of *D. brouweri* from Sample 590A-2-1, 5-6 cm to the last occurrence of *D. pentaradiatus* in 590A-3-1, 5-6 cm places Core 590A-1 to Samples 590A-2-1, 5-6 cm to 590A-2, CC in the late Pliocene *Discoaster brouweri* Zone (NN18). Sample 590A-3-2, 5-6 cm, above the last occurrence of *D. surculus* in Sample 590A-3-2, 5-6 cm, is placed in the late Pliocene *D. pentaradiatus* Zone (NN17). The interval from Samples 590A-3-2, 5-6 cm to 590A-7-3, 0-1 cm, above the last occurrence of *Reticulofenestra pseudoumbilica* in Sample 590A-7-4, 0-1 cm, is placed in the late Pliocene *D. surculus* Zone (NN16).

The early Pliocene Reticulofenestra pseudoumbilica Zone (NN15) is represented in Samples 590A-7-4, 0-1 cm to 590A-11-7, 0-1 cm, above the last occurrence of Amaurolithus tricorniculatus in Sample 590A-11, CC. Samples 590A-11, CC to 590A-14-1, 0-1 cm are placed in the early Pliocene D. asymmetricus Zone (NN14), based upon the co-occurrence of D. asymmetricus and A. tricorniculatus. Sample 590A-14-2, 0-1 cm, below the first occurrence of D. asymmetricus to the first occurrence of Ceratolithus rugosus in Sample 590A-16-2, 5-6 cm, is placed in the early Pliocene Ceratolithus rugosus Zone (NN13). Samples 590A-16-3, 5-6 cm to 590A-18-5, 5-6 cm, are placed in the early Pliocene Amaurolithus tricorniculatus Zone (NN12).

Miocene

The co-occurrence of A. primus and D. quinqueramus in Samples 590A-18-6, 5-6 cm to 590A-27, CC places these samples in the upper subzone of the late Miocene *D. quinqueramus* Zone (NN11b). Hole 590A ended with Core 590A-27 at a depth of 280.8 m BSF.

Hole 590B

Hole 590B begins at the top of the section in Zone NN20; therefore, only core-catcher samples were examined until Zone NN11b was reached.

Miocene

The first occurrence of A. primus is in Sample 590B-30-3, 5-6 cm. Therefore the boundary between the upper and lower subzone of the late Miocene D. quinqueramus Zone (NN11a/b) is between this sample and Sample 590B-30-4, 5-6 cm. The interval from Sample 590B-30-4, 5-6 cm to the first occurrence of D. quinqueramus in Sample 590B-35-5, 5-6 cm is placed in the lower subzone of the late Miocene D. quinqueramus Zone (NN11a). The interval between the first occurrence of D. quinqueramus in Sample 590B-35-5, 5-6 cm and the last occurrence of D. hamatus in Sample 590B-38, CC is placed in the middle Miocene D. calcaris Zone (NN10). The range of D. hamatus from Samples 590B-38,CC to 590B-40,CC places these samples in the middle Miocene D. hamatus Zone (NN9). Samples 590B-41-5, 5-6 cm and 590B-41,CC, above the first occurrence of Catinaster coalitus, are placed in the middle Miocene Catinaster coalitus Zone (NN8). The interval from Samples 590B-42-1, 5-6 cm and 590B-45-1, 5-6 cm, above the first occurrence of D. kugleri, is placed in middle Miocene D. kugleri Zone (NN7). Samples 590B-45-3, 5-6 cm to 590B-47-3, 5-6 cm, above the last occurrence of Sphenolithus heteromorphus in Sample 590B-47-5, 5-6 cm, are placed in the middle Miocene D. exilis Zone (NN6). The first occurrence of D. exilis in Sample 590B-49, CC places Samples 590B-47-5, 5-6 cm to 590B-49,CC in the middle Miocene Sphenolithus heteromorphus Zone (NN5). Samples 590B-50-1, 5-6 cm to 590B-50,CC, above the last occurrence of S. belemnos in Sample 590B-51-1, 5-6 cm, are placed in the early Miocene Helicosphaera ampliaperta Zone (NN4). The interval from the last occurrence of S. belemnos in Sample 590B-51-1, 5-6 cm to the last occurrence of Triauetrorhabdulus carinatus in Sample 590B-52, CC, is placed in the early Miocene S. belemnos Zone (NN3). The co-occurrence of T. carinatus and D. druggii in Samples 590B-52, CC and 590B-53-1, 5-6 cm places these samples in the early Miocene D. druggii Zone (NN2). The absence of D. druggii and the presence of T. carinatus in Samples 590B-53-3, 5-6 cm to 590B-53,CC places these samples in the early Miocene Triquetrorhabdulus carinatus Zone (NN1). Drilling was terminated at a depth of 499.1 m BSF.

PALEOMAGNETISM

The paleomagnetic properties of sediments from this site were generally similar to those of previous Leg 90 sites, except that there is more evidence of viscous overprinting and long-term remagnetization.

Holes 590 and 590A were subsampled at three specimens per section, and 590B was subsampled at two per section of HPC cores and one per section of XCB cores (590A-28 onward). The Kuster orientation tool was deployed in Holes 590A and 590B with success rates of 60 and 48%, respectively. To date, laboratory NRM measurements have been completed on one specimen per section from Holes 590 and 590A (Table 3). The pattern of intensity variation is: (1) high values (1 to 5 μ G) in the oxidized surface Subunit IA, Core 590-1, (2) medium intensities (about 0.1 μ G) in Subunit IB, Cores 590-2 to 590-5, and (3) very low intensities (0.005 to 0.1 μ G) in the remainder of Hole 590A. The last region is characterized by very high accumulation rates during the late Pliocene; they dilute the detrital ferromagnetic component. Depths at which high-intensity spikes were noted are reported in Table 4.

A polarity stratigraphy can be traced back to 4 m.y. (Fig. 8); it is consistent with the microfossil zonations. The Olduvai Event is poorly resolved. Prior to 4 m.y. ago, inclinations are consistently shallower than the expected axial dipole value, and show a definite negative (normal) bias. This must be a consequence of viscous overprinting and/or authigenic growth of magnetic minerals on a time scale which is long compared with the average polarity interval of about 3×10^5 yr. Authigenic iron sulfides are common throughout the section and probably reflect authigenic growth.

SEDIMENTATION RATES

Sedimentation rates are determined by calcareous nannoplankton boundaries and their ages, as discussed in the Introduction.

At Site 590, three holes were drilled in present-day water depths of about 1300 m. The first two holes cover the recent to late Miocene (NN11b) interval down to 280.8 m (Fig. 9). Hole 590B duplicated this interval and was terminated at 499.1 m, after penetrating lower upper Miocene to lower Miocene calcareous sediments. In Hole 590B only core catchers were investigated from 0 to about 280 m sub-bottom, and calculated sedimen-

Table 3. Laboratory NRM measurements, Holes 590 and 590A.

	Hole 590	Hole 590A
Geometric mean intensity (µG)	0.335	0.045
Scalar mean inclination $(\pm 1 \text{ s.d.})$	$-26.5 \pm 39.0^{\circ}$	$-12.9 \pm 37.6^{\circ}$
Axial dipole inclination	- 5	0.9
Mean angle between repeats		6.1°

Table	4.	High	intensity	magnetization
spi	kes	in He	oles 590 a	nd 590A.

Sample (level in cm)	Sub-bottom depth (m)	Intensity (µG)
Hole 590		
2-7, 25	16.25	3.375
Hole 590A		
6-5, 75	80.95	0.353
14-6, 75	159.25	0.534
21-6, 75	226.45	0.244
23-6, 75	245.65	0.378
25-5, 75	263.35	0.391

Chron	Age (m.y.)	Boundary (Core-Section, level in cm)	Sub-bottom depth (m)	Sediment (m/r	
Brunhes				14.0 to 16.1	Î
	0.73	2-3, 25	10.25		
	0.91	2-4, 25	11.75		
	Jaramillo 0.98	2-1,25	16.25		
	10000000	3-2, 25	18.35 21.35		
, J.		3-5, 25	22.85		
Matuyama		A1-5, 75	32.95	20.6 to 22.3	
Matu	1.66 Olduvai	A1-6, 85	34.55	i	
	1.88	A2-1, 80	36.60		
	2.47	A3-2, 75 A3-3, 75	47.65 49.15		24.1 to 24.8
ISS	2.92	A4-5, 75	61.75	34.2 to	
Gauss	2.92	A4-6, 85	63.35	37.4	
1	3.18	A5-4, 75	69.85		
		A5-5, 75	71.35 80.95		
	3.40 ⁶	A6-5, 75 A6-6, 75	80.95		
Gilbert	Cochiti	A7-6, 75 A8-1, 75 A8-2, 75		23.1 to 31.0	
		A8-4, 70	98.60		

Figure 8. Magnetic polarity stratigraphy and sedimentation rates for Hole 590 and the upper part of Hole 590A. The Olduvai Subchron is poorly resolved.

tation rates are less reliable in this particular interval (dashed line in Fig. 10).

In the early Miocene (Hole 590B, NN1 to top of NN3) the sedimentation rate is 14.4 m/m.y. in indurated calcareous sediments. Between Samples 590B-50,CC and 590B-51-1, the sedimentation rate changes, reaching 29.4 m/m.y. in the middle Miocene (Hole 590B, NN5 to NN7 top) (Fig. 10). The sedimentation rate in the late middle Miocene to early Pliocene interval (Hole 590B, NN7 top to NN13 top) is based on seven datum levels and is 29.1 m/m.y., also in calcareous sediments (Fig. 10). Then a rather remarkable increase to 56.7 m/m.y. was noted in the early to late Pliocene calcareous sequence in Hole 590A (NN13 top to NN18 top), based on five datum levels (Fig. 9). In the Quaternary (Holes 590 and 590A, above NN18 top) the sedimentation rate drops to 19.9 m/m.y. (Fig. 9), probably because of winnowing, as sediments are somewhat coarser than below.

Sedimentation rates in the upper part of Hole 590B, in which only core-catcher samples were investigated, are similar to those of Holes 590 and 590A for the early to late Pliocene (52.4 m/m.y.) and for the Quaternary (17.2 m/m.y.).

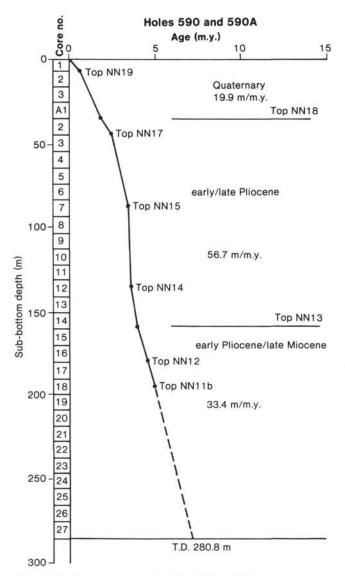


Figure 9. Sedimentation rates in Holes 590 and 590A.

SUMMARY AND CONCLUSIONS

Site 590 lies to the east of the crest of Lord Howe Rise. This site was selected as one of several that make up a north-south traverse of hydraulically piston cored Neogene sites (Site 586 in the north to 593 in the south). It is also the shallowest of three sites forming a depth traverse to study changes in the vertical water mass structure of the southwest Pacific during the Neogene. The other sites in this vertical traverse are 591 (2100 m) and 206 (3196 m).

Site 590 is located 120 n. mi. to the northwest of Site 206 in the same surface water mass. It occupies a shallow-water, transitional position between warm subtropical waters to the north (Site 588) and temperate sites to be drilled further south and provides an important section for correlation between these sites.

Site 590 consists of three holes (Fig. 11): Hole 590, which was continuously cored with the HPC from 0–26.2 m sub-bottom; Hole 590A, which was continuously cored with the HPC from 26.2–280.8 m sub-bottom; and

Hole 590B, which was continuously cored with the HPC from 0-250.7 m sub-bottom and rotary drilled with the XCB from 250.7-499.1 m sub-bottom. Cores recovered using the HPC are relatively undisturbed. The primary and persistent disturbance exists as a zone of soupy sediments usually 20-30 cm in thickness, at the top of each core. In a few cores inflow has caused highly disturbed intervals in the upper one or two sections, but a very high percentage of the core lengths are mechanically undisturbed sediments. Cores recovered using the XCB are slightly to moderately disturbed and in many cases consist of biscuits of sediment, in stratigraphic sequence but surrounded by soft ooze injected during the coring process. The value of the cores obtained using the extended core barrel is that at most levels the sediment biscuits do not seem to have been moved far from their original stratigraphic positions, in contrast with conventional rotary coring which, in the less consolidated layers, creates clear vertical disturbance within each core.

The three holes drilled at Site 590 provide a complete calcareous sequence from early Miocene through Recent (Fig. 11), with the exception of an unconformity at 470.3 m sub-bottom depth. At this level, the planktonic foraminifers show that the lower part of the *Globorota-lia fohsi* s.l. Zone (earliest middle Miocene) to the upper part of the *G. miozea* Zone (latest early Miocene) is missing. The unconformity at the Miocene/Pliocene boundary reported from nearby Site 206 does not occur at this site. A paleomagnetic polarity stratigraphy has been identified down to the middle part of Gilbert Chron (about 4.2 m.y. ago).

The section (Fig. 11) is represented mostly by foraminifer-bearing nannofossil ooze (or chalk) or foraminiferrich nannofossil ooze (or chalk). Biosiliceous components are generally absent, but occasionally are present in trace to rare amounts, with greatest abundance (1 to 5%) in the early late Miocene (Cores 590B-32 to 590B-35). The siliceous components consist primarily of whole and fragmented radiolarians, diatom frustules, and occasional sponge spicules.

The sequence contains only traces of nonbiogenic components, but clear volcanic ash is quite persistent. Numerous light green laminae from early late Miocene to early Miocene may be altered volcanic ash layers. Much of the sequence is very light gray to white ooze and chalk. Zones richer in foraminifers are darker gray to light olive gray. Bioturbation is moderate in the early Miocene, intense in the middle to early late Miocene, moderate in the late late Miocene and only slight in the Pliocene and Quaternary.

The sediment becomes more indurated with depth. Sediments above 275 m sub-bottom (middle late Miocene) consist of ooze which becomes progressively stiffer with depth. Sediments below ~ 275 m sub-bottom are chalk, with clear recrystallization seen in the early Miocene (Cores 590B-51 to 590B-53).

The sequence at Site 590 is divided into three subunits (Fig. 11) based on changes in color and degree of diagenesis.

Subunit IA extends from the seafloor to 40 cm subbottom and is of late Quaternary age. The sediment is a yellowish orange foraminifer-nannofossil ooze, and repre-

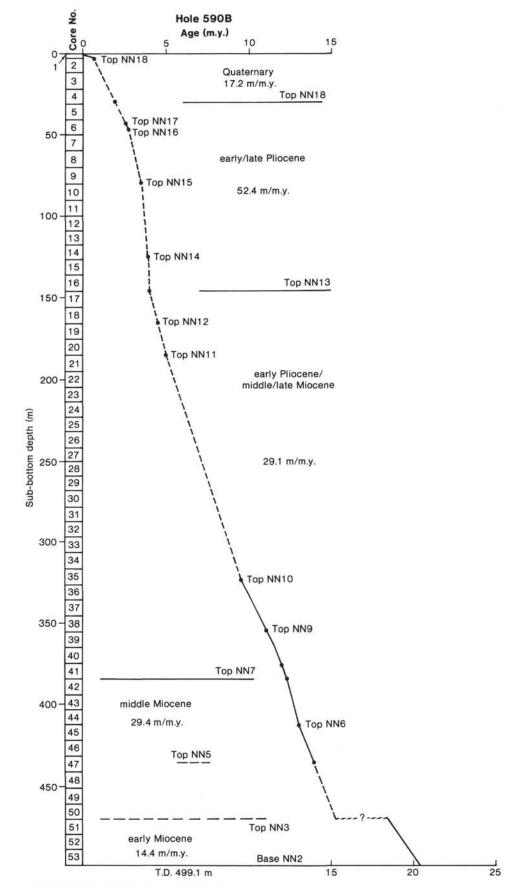


Figure 10. Sedimentation rates in Hole 590B.

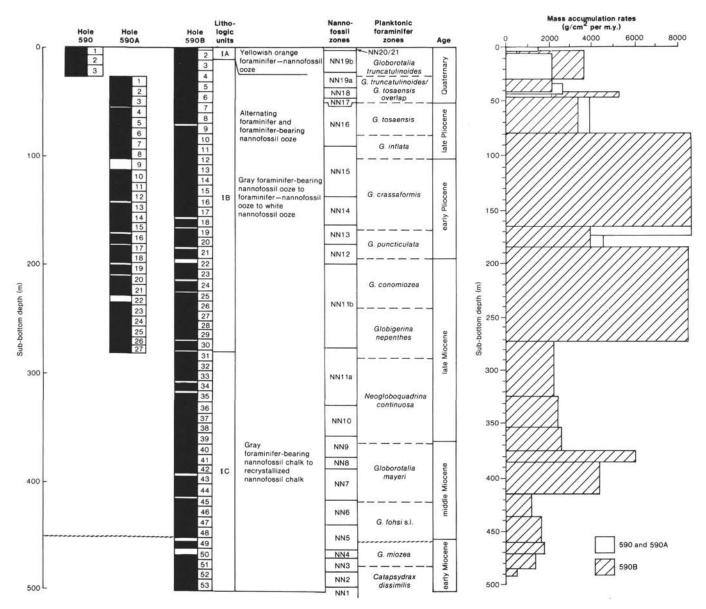


Figure 11. Summary lithology, biostratigraphy, and mass accumulation rates of Site 590. Recovery in black.

sents the zone of oxidation and possible current winnowing activity near the sediment/water interface.

Subunit IB extends from 40 cm to approximately 280 m sub-bottom. The upper part of this subunit (to 80 m) is late Pliocene to Pleistocene in age and consists of alternating layers of very light gray foraminifer-bearing nannofossil ooze and layers of light olive gray foraminifernannofossil ooze. The change in percentages of foraminifers may indicate that these sediments were deposited during a period of fluctuating bottom-current activity. The more foraminifer-rich units probably represent episodes of increased winnowing activity by bottom waters, as in Subunit IA.

The lower part of Subunit IB extends from approximately 80 to 280 m sub-bottom and is mid-late Miocene to late Pliocene in age. This part of the subunit consists of fairly uniform nannofossil ooze with occasional foraminifer-bearing nannofossil ooze and is very light gray to white in color. The uniform nature of this part of the subunit indicates a period of less variable oceanographic conditions.

Subunit IC extends from approximately 280 to 499 m sub-bottom. The upper part of this subunit (to 400 m) is middle Miocene to early late Miocene in age. The only significant quantities of biosiliceous sediments occur near the top of this subunit, which resembles the upper part of Subunit IB in consisting of alternating, very light gray foraminifer-bearing and light olive gray foraminifer-rich layers that have been lithified to chalk. The upper part of Subunit IC is also delineated by the highest rates of bioturbation encountered in the sequence, suggesting increased transport of organic material to the seafloor during this period.

The lower part of Subunit IC (450-499 m sub-bottom) is of early Miocene age. It is composed of recrystallized nannofossil chalk, lacks the foraminifer-rich layers of the portion above, and is less heavily bioturbated. It contains the highest occurrence of volcanic ash and its alteration products.

Site 590 provides a superb stratigraphic sequence of calcareous microfossils for the middle Miocene and younger. Biostratigraphic zonal sequences of transitional type occur in combination with an important temperate component. The zonal sequence is complete for basal middle Miocene (16.5 m.y.) to Quaternary. Hiatuses cut the early Miocene.

It is difficult to interpret the early Miocene fauna because of the low diversity arising from bad preservation, but it appears to be a temperate fauna lacking tropical species.

The middle Miocene appears also to be represented by a temperate fauna. The dominate keeled globorotaliid is *Globorotalia miotumida* (= *G. conoidea*), a temperate form, and the absence of keeled *G. fohsi* taxa, which are clear tropical forms, support this general observation of the assemblages.

The fauna of the late Miocene, up to and including the early Pliocene *Globorotalia puncticulata* Zone, is also represented mostly by temperate faunas. The younger faunas from the early Pliocene to Pleistocene were sporadically warmer, with the influx of *G. tumida* and *Pulleniatina obliquiloculata*.

Preservation of calcareous nannoplankton is good in the upper part of the sequence (Quaternary–Pliocene) and moderate (late Miocene) to poor (early middle Miocene) in the lower part. In particular, the Miocene discoasters become progressively more heavily overgrown with depth. The preservation of planktonic foraminifers is good above the early Miocene unconformity and very poor below. The benthic foraminifers are well-preserved throughout much of the sequence; however, below the late Miocene, some specimen breakage occurs and some samples exhibit very low abundances of benthic foraminifers. Rare radiolarians were noted in the section below Sample 590B-25,CC (middle late Miocene).

At Site 590 the Pliocene/Quaternary and Miocene/ Pliocene boundaries are well represented and the late Neogene exhibits clear, gradual, evolutionary sequences within some lineages. This is particularly noticeable for the *Globorotalia (Globoconella)* lineage, with clear transitions from G. (G.) conoidea (= G. miotumida) to G. (G.) conomiozea to G. puncticulata sphericomiozea to G. puncticulata to G. inflata. At nearby Site 206, much of the lineage was missing in the hiatus associated with the Miocene/Pliocene boundary.

Benthic foraminifers occur throughout the sequence but with varying quality of preservation. In the early and middle Miocene, as few as six species remain following diagenetic dissolution. Diversity increases in the early part of the late Miocene and preservation is only moderately good. Preservation improves in the middle late Miocene and assemblages are very well preserved in the Pliocene and Quaternary.

Paleoenvironmental History of Site 590

Neogene sediments at Site 590, near the crest of Lord Howe Rise, were laid down in a pelagic, open-ocean environment at middle bathyal depths that have changed little during the last 23 m.y. Calcareous oozes were deposited in a relatively uncomplicated environment at these shallow depths, and with virtually no terrigenous sedimentary influences other than traces of fine eolian sediments and more common and fluctuating input of volcanic ash. During this time, very little siliceous biogenic material was preserved in the sediment, although almost certainly there was moderate siliceous productivity by plankton in the overlying surface waters. In this region, the Neogene planktonic foraminiferal assemblages are dominated by temperate rather than tropical elements, although the latter exhibit brief incursions of greater abundance.

During the early Miocene, from about 23 to 16 m.y., there were low rates of sedimentation (14 m/m.y.) in this area, and hiatus-forming erosion occurred fairly briefly at about 17.5 and 16.5 m.y. A scarcity of foraminifers in this interval probably resulted from diagenetic dissolution rather than from changes in productivity or dissolution. The earliest Miocene at this site represents an acme of explosive volcanicity in the source regions, judging from a large number of altered volcanic ash layers. Explosive volcanicity of sufficient intensity to form visible ash layers continued through to the early late Miocene, but at lower intensities than during the early late Miocene.

During the middle to early late Miocene (15 to 8 m.y.), sedimentation rates of calcareous biogenic materials increased significantly to about 30 m/m.y. and no hiatusforming erosion occurred. This situation resulted from decreased bottom-water erosion in the ocean, although deposition of more foraminifer-rich horizons in otherwise foraminifer-bearing nannofossil ooze indicates intervals where bottom-water activity was sufficiently intense to cause winnowing of fine sediments. During this interval, bioturbation was the highest of the entire Neogene, suggesting that organic material was delivered at a higher rate to the ocean floor.

During the late late Miocene (8 m.y.) to the middle Pliocene (3 m.y.) rates of calcareous sediment deposition increased even further to a surprisingly high 57 m/m.y. At this time, rather uniform nannofossil oozes were laid down. Few of the more foraminifer-rich levels were deposited. The lithofacies suggests deposition in a rather uniform environment on the ocean floor, mostly lacking the episodes of increased bottom-water activity that occurred during other times of the Neogene. Bioturbation decreased to moderate levels. The rather uniform depositional conditions were not matched by surface water, which, in contrast, exhibited great paleoceanographic change. For example, during the latest Miocene, from 6 to 5 m.y., the planktonic foraminiferal assemblages became distinctly cooler as temperate waters migrated northward across the area. There were also decreases in faunal diversity and in average specimen size. The latest Miocene cooling is well documented elsewhere, including areas to the south of Site 590 (Kennett and Vella, 1975). At the same time, the first hispido-costate uvigerinids appeared within the benthic foraminifer assemblages. Uvigerinids appeared in increased abundances in many

areas of the world's oceans in the latest Miocene in association with the δC^{13} shift (Keigwin, 1979), which reflected important paleoceanographic changes. Since these uvigerinids become more typical on a permanent basis in late Pliocene to Quaternary benthic foraminiferal assemblages, their presence suggests that conditions resembling the glacials developed temporarily during the latest Miocene.

The middle Pliocene (3 m.y.) to Quaternary represents the latest phase of paleoenvironmental evolution at Site 590. About 3 m.y. ago, a pronounced sediment change occurred which is marked by greater winnowing of the fine-grained sediment fraction at certain intervals in alternation with calcareous-nannofossil-rich, foraminiferpoor layers. The succession again indicates episodes of enhanced bottom-water activity alternating with quieter episodes. Sedimentation rates responded by decreasing to 17–20 m/m.y., which is quite low for this area.

The hispido-costate uvigerinids returned on a permanent basis by upward migration from greater depths during a cooling episode. Large-scale oscillations occurred in surface water masses, with brief incursions of relatively warm subtropical assemblages into sequences otherwise dominated by temperate elements.

The youngest part of this interval, which is at and close to the sediment/water interface (upper 40 cm), is winnowed, oxidized, and more foraminifer-rich. This represents the latest of a succession of such layers, which reflect an increase in bottom-water activity. Older such intervals in the section have since undergone chemical reduction and inferred color change from brown to light olive gray.

The changes in sedimentation and in benthic foraminiferal faunas ~ 3 m.y. ago certainly were related to widespread paleoceanographic changes in the ocean associated with global climatic cooling. At that time bottom waters intensified in activity even at the shallow-water depths of Site 590, and cooler, deeper waters migrated upwards to shallow intermediate depths.

One of the surprises resulting from drilling at Site 590 was the high sedimentation rate (uncorrected for sed-

iment porosity) in largely calcareous biogenic intervals, especially during the Pliocene (50-57 m/m.y.).

The seismic profile in the area shows no clear ponding of sediments for much of the sequence (except the Quaternary) or other evidence of sediment transport such as winnowing. Also the microfossil assemblages exhibit virtually no evidence of reworking. Therefore it seems that the high sedimentation rates, spectacularly high in the Pliocene, are due to high levels of calcareous biogenic productivity.

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₽ FOSSIL	CORE 1 CORED INTERVAL 26.2-		SITE 590 HOLE A	CORE 2 CORED INTERVA	20.0-40.0 m
TIME - ROCK UNIT BIOSTRATIGRAPH FORAMINIFERS NANNOFOSSILS RADIOLARIANS BUATOMIS		LITHOLOGIC DESCRIPTION	TIME - ROCK UNIT BIOSTRATIGRAPHI BIOSTRATIGRAPHI PIONAMINIFERS NAWNOFOSSILS PONTAMIANS PLATOMS DIATOMS	SUBJUE SU	LITHOLOGIC DESCRIPTION
Gurrenzervier Gurrenzen Gurrenzen Gurrenzervier Gurrenzen G	1 1 <td>FORAMINIFER BEARING NANNOFOSSIL ODZE, very light gay (NB), koft, accasional biebs and streaks of pyrite, accasional biebs and streaks of pyrite and burrows. SMEAR SLIDE SUMMARY 2,80 3,114 5,11 0 0 0 10 0 0 10 0 0 10 0 0 11 0 0 12 0 0 13 0 0 14 0 0 15 0 0 16 0 0 16 0 0 16 0 0 17 18 0 0 18 0 0 0 19 0 0 0 10 0 0 0 10 0 0 0 10 0 0 0 10 0 0 0 10 0 0 0 11 0 0 0 12 0 0</td> <td>G. trunchruicholee/G. tosennis MNIB NVIB</td> <td></td> <td>N8 FORAMINIFEE BEARING NANNOFOSSIL OOZE, very light gray (N8) to light gray (N7), soft, occasional burrows and strakes and blebs of pyrite. N7 NANNOFOSSIL FORAMINIFER OOZE, light olive gray (SY 6/1), soft, occasional burrows and strakes and blebs of pyrite. Art, gap SMEAR SLIDE SUMMARY: 2, 51 3, 90 N8 2, 51 3, 90 EV 6/1 Santa Sist A D Composition: Foraminferi A C Cale, nanoofossili A D N8 SY 6/1 N8 SY 6/1 N8 N8 Sy 6/1 N8 N8 N8 Sy 6/1 N8 N8 N8 Sy 6/1 N8 N8 N8</td>	FORAMINIFER BEARING NANNOFOSSIL ODZE, very light gay (NB), koft, accasional biebs and streaks of pyrite, accasional biebs and streaks of pyrite and burrows. SMEAR SLIDE SUMMARY 2,80 3,114 5,11 0 0 0 10 0 0 10 0 0 10 0 0 11 0 0 12 0 0 13 0 0 14 0 0 15 0 0 16 0 0 16 0 0 16 0 0 17 18 0 0 18 0 0 0 19 0 0 0 10 0 0 0 10 0 0 0 10 0 0 0 10 0 0 0 10 0 0 0 11 0 0 0 12 0 0	G. trunchruicholee/G. tosennis MNIB NVIB		N8 FORAMINIFEE BEARING NANNOFOSSIL OOZE, very light gray (N8) to light gray (N7), soft, occasional burrows and strakes and blebs of pyrite. N7 NANNOFOSSIL FORAMINIFER OOZE, light olive gray (SY 6/1), soft, occasional burrows and strakes and blebs of pyrite. Art, gap SMEAR SLIDE SUMMARY: 2, 51 3, 90 N8 2, 51 3, 90 EV 6/1 Santa Sist A D Composition: Foraminferi A C Cale, nanoofossili A D N8 SY 6/1 N8 SY 6/1 N8 N8 Sy 6/1 N8 N8 N8 Sy 6/1 N8 N8 N8 Sy 6/1 N8 N8 N8

SITE 590 HOLE A	CORE 3 CORED INTERVAL 45.4-55.	0 m	SITE 590 HOLE A CORE 4 CORED INTERVAL 55.0-64.6 m	
	SE CTION METERS ADOTOHLIT ADOTOHLITING SEDWERTNES SEDWERTNES SEDWERTNES SEDWERTNES	LITHOLOGIC DESCRIPTION	DIA DESTRUCTION STATES	
late Pilocere G. comenta MN16 M112 > N116 M112 > N116 M112 > N116 N112	1 1 1 5 5 6/1 1 1 1 5 6/1 5 1 1 1 1 5 6/1 1 1 1 1 5 6/1 1 1 1 1 5 6/1 1 1 1 1 1 5 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	FORAMINIFER-BEARING NANNOFOSSIL QOZE, very ibit gray (NB), soft, occasional bithe and streaks of pyrite, burrows common. FORAMINIFER NANNOFOSSIL OOZE, light olive gray (KP)(1), soft, occasional burrows and blebs and streaks of pyrite. NEAR SLIDE SUMMARY: 2, 70 4, 96 0 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0	No Second Reserved Second Reserved Second Reserved Second Reserved Second Reserved Second Reserved	

SITE 590 HOLE A CORE 5 CORED INT	RVAL 64.6-74.2 m	SITE 590 HOLE A CORE 6 CORED INTERVAL	74.283.8 m
TORE CHARACTER C	LITHOLOGIC DESCRIPTION		LITHOLOGIC DESCRIPTION
a a <td>N8 FORAMINIFER-BEARING NANNOFOSSIL COZE, soft, very light gray (N8) to light grannish gray (SGY 8/1), dark (N5) spots and traks throughout the entire core, cl-prion SGY 8/1 SGY 8/1 suffide minerals), undefined burrows, near 30–40 cm (Section 6) Planother. SGY 8/1 SMEAR SLIDE SUMMARY: 3,80 4,85 CC¹ SGY 8/1 D Void Composition: Quartz Void Composition: Quartz Void Composition: Quartz Void Composition: Quartz Void Composition: Quartz Voidanic glass T Voidanic glass T Pyrite P alagonite: Privite Pyrite C Core Contractions C Pyrite Pilace: nanofositis N8 T Pyrite T Pyrite T SGY 8/1 C C C Pyrite T Pyrite T N8 T N8 SGY 8/1 N8<!--</td--><td></td><td>N8 NANNOFOSSIL GOZE, soft, very light gray (N8) to gray its yellow graen (EGY 7/2, dark (M4-N5) spots and streaks throughout the antice ore (L→ iron sulfide) undefined SGY 7/2 SMEAR SLIDE SUMMARY: 1,72,2,92 N8 0 SGY 8/1 0 N8 SGY 7/2 N8 SGY 8/1 N8 SGY 8/2 N6 N8<</td></td>	N8 FORAMINIFER-BEARING NANNOFOSSIL COZE, soft, very light gray (N8) to light grannish gray (SGY 8/1), dark (N5) spots and traks throughout the entire core, cl-prion SGY 8/1 SGY 8/1 suffide minerals), undefined burrows, near 30–40 cm (Section 6) Planother. SGY 8/1 SMEAR SLIDE SUMMARY: 3,80 4,85 CC ¹ SGY 8/1 D Void Composition: Quartz Void Composition: Quartz Void Composition: Quartz Void Composition: Quartz Void Composition: Quartz Voidanic glass T Voidanic glass T Pyrite P alagonite: Privite Pyrite C Core Contractions C Pyrite Pilace: nanofositis N8 T Pyrite T Pyrite T SGY 8/1 C C C Pyrite T Pyrite T N8 T N8 SGY 8/1 N8 </td <td></td> <td>N8 NANNOFOSSIL GOZE, soft, very light gray (N8) to gray its yellow graen (EGY 7/2, dark (M4-N5) spots and streaks throughout the antice ore (L→ iron sulfide) undefined SGY 7/2 SMEAR SLIDE SUMMARY: 1,72,2,92 N8 0 SGY 8/1 0 N8 SGY 7/2 N8 SGY 8/1 N8 SGY 8/2 N6 N8<</td>		N8 NANNOFOSSIL GOZE, soft, very light gray (N8) to gray its yellow graen (EGY 7/2, dark (M4-N5) spots and streaks throughout the antice ore (L→ iron sulfide) undefined SGY 7/2 SMEAR SLIDE SUMMARY: 1,72,2,92 N8 0 SGY 8/1 0 N8 SGY 7/2 N8 SGY 8/1 N8 SGY 8/2 N6 N8<

	DHIC		F	OSS		ER					T						
TIME - ROCK UNIT							METERS	GRAPHIC LITHOLOGY	DISTURBANCE DISTURBANCE SEDIMENTARY	STRUCTURES	SAMPLES		LITHOLOGIC DI	ESCRI	PTION		
late Pliocene	8		A				2	0.5				*	NB 5GY 8/1 NB 5GY 8/1 NB 5GY 8/1	NANNOFOSSIL CO greenish gray (5G' core. Nate: H ₂ S adar with SMEAR SLIDE SL Composition: Quartz Feldpar Clay Volcanic glass. Pyrite Sponge spicules ¹ Insol. residua	Y 8/1 hen spi JMMA 1, 1 D - T T R) dark (N	
	BINN SINN		A			1.0	3	and and and and and					NB/N9 5GY 8/1 5GY 8/1 5GY 8/1 NB				
early Pliocene	Seta 15		A				5	and the second second second second					→ 5GY 8/1 N8 5GY 8/1 N9				
	G. inflata NN15	A	A				cc				-		5GY 8/1				

TIME - ROCK UNIT OSTRATIGRAPI	2.		CU14	RAG	TER							
RIOST	ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE SEDIMENTARY	STRUCTURES		LITHOLOGIC DESCRIPTION
late Plocene G, inflate		A 40	W	2	10	1	0.5				N8 5GY 7/2 N8 → N5 + N5 + SGY 7/2 + N5 - SG 8/1 - IW + N5 - N8 - SGY 7/2 - SGY 7/2 - SGY 7/2	NANNOFOSSIL DOZE, soft, very light gray (N8) to light greenish grav (5GY 8/1) and gavish velow green (5GY 7/2) iron sufficies spot (N5) throughout the entire core; grade- tional color changes; bioturbation rare. SMEAR SLIDE SUMMARY: 2, 105 4, 62 D M Composition: Volcanic glass T T Palagonite T T Partini T T Foraminifers R R Cate, annofostilis D D Core 9, 103.0–112.6 m: no recovery.
afornis	5. Crasserformus NN15					5					N8 ← N6 N8	

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SITE 590

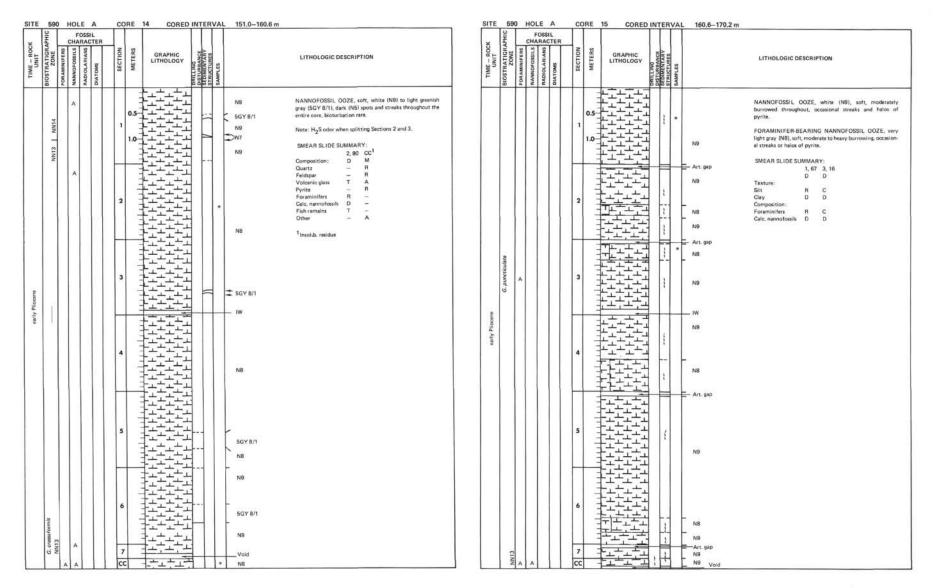
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FOSSIL CHARACTE		DIH		FOSSIL		11		
TIME - ROCK UNIT UNIT BIOSTRATIGRAP ZONE FORAMINIFERS RADIOLARIANS RADIOLARIANS BLATOME	LITHOLOGIC DESCRIPTION	TIME - ROCK UNIT	10	RADIOLARIANS DIATOMS	SECTION	DISTURBANCE SEDIMENTARY STRUCTURES	0.11	LITHOLOGIC DESCRIPTION
early Pilostere G. crastformis NN15 >	M D M Downtz C Peldippr C Peldippr C Volcanic glass T T C Palagonite T - C Porter R T - C Foraminiters R T Calc. nonofossils D D Other - A ¹ Imsol. residue IGY 8/1 I8 IGY 8/1 I8	aarly Pilosena G. creatiformit		A.	1 2 3 4 5 6 7		N8 N5 N8 EGY 7/2 - EGY 7/2 - Void N8 N8 N8 N8 N8 N8 N8 N8 N8 N8	NANNOFOSSIL OOZE, soft, very light gray (N8), h geneou, dark (N6) spots and straks throughout the e core f-siron sulfide), some unidentified burrows.

	HIC		F	OSS	L	T			П	T		
TIME - ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE SEDIMENTARY	STRUCTURES	SAMPLES	LITHOLOGIC DESCRIPTION
						1	0.5					NANNOFOSSIL GOZE, soft, very light gray (N8), homo- geneous, dark (N5) spots and straaks throughout the entire core, some unidentified burrows. SMEAR SLIDE SUMMARY: 3, 80 CC ¹ D M Composition: Quartz – R Feldspar – R Heavy minerals – T Voicanic datas T R
						2						Volcanic glass T R Pvrite T R Foraminifers R – Cate namofosis D – 5GY 8/1 Other – A
aue	NN14 NN15		A			3						N81W
early Pliocene			A			4	in the the true			1		N5
						5	an far dan					Void N8
	mà					6	and the second second			E		N7 N8
	G. crassaformia NN14	A	A			7 CC				1		

	59		F	OSS	IL		T	RE	13 CORED	Π	T	. 141.4-151.0 m	
TIME - ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS		SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING	STRUCTURES SAMPLES		LITHOLOGIC DESCRIPTION
							1	0.5				N8 5GY 8/1 N8	NANNOFOSSIL OOZE, soft, very light gray (N8), homo- geneous, dark (N5) spots rare, core slightly to very de formed. SMEAR SLIDE SUMMARY: 3, 71 D Composition;
							2	Juninu				N8-N9	Quartz T Feldspar T Pelagonite. T Pyrite T Foreminifers R Cale, nannofossila D
early Pliocene							3	hundunu				-	
							4	Level and the contract of the			-	5GY 8/1 	
							5				-	5GY 8/1	
	G. crasseformis NN14	A	A			Ļ	6					N8-9	

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	PHIC			OSS	IL										
TIME - ROCK	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	IAMS	DIATOMS		METERS	GRAPHIC LITHOLOGY	DISTURBANCE	SEDIMENTARY	SAMPLES		LITHOLOGIC DI	ESCRIF	PTION
							0.5			1		N9	(N8/N9), soft, occa are yellowish gray (isional (5Y 8/1	
							1.0			= =		≓ 5Y 8/1	SMEAR SLIDE SI Texture: Sand	1, 97 M	2, 83 D
			A			T						N9/N8	Sand Silt Clay Composition: Mica	R D R	C D
	V12 NN13						2			***	•		Foraminifers Calc. nannofossils	D	R D
locene	Pliocene NN12		A				3			1		Art. gap N9/N8			
early PI															
							4					N9			
			A							***		N9/NB			
	G. puncticulata NN12						5			1					
	G. pun NN12	A	A			ł	c	1	-		-	Void N9			

	PHIC	1		OSS	TER										
TIME - ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES		LITHOLOGIC D	SCRI	PTION
						,	0.5			1		N9		yellow	white (N9) to very light gray (N8) vish gray (5Y 8/1) burrows and throughout.
						Г	1.0			ŧ		N9/N8	SMEAR SLIDE SU		
							1.0			1		- N9	Texture:	3, 1: M	35 1, 91 D
						+		┶┶┶┶┶				-	Sand Silt	R	R
							100					N9/N8	Clay Composition: Foraminifers	D	D
						2	10.000			-			Calc, nannofossils	D	D
						$\left \right $						N9/N8			
locane						3	d taken and								
early Pliocene						+	-				*				
						4				-		N9/N8			
												Ξ— Алт. дар			
						5				1		N9/N8			
	G. puncticulara NN12						To a set			1		N9			
	N12		A	A		6				1		н _{N9}			

ORED INTERVAL 208.6-218.2 m			_	HOLE A	CORE	21 CORED I	NTERVA	L 218,2-227,8 m
DRILLING DRILLING SIDUCTURE SAMPLES SAMPLES	LITHOLOGIC DESCRIPTION	TIME - ROCK UNIT		FOSSIL CHARACTER STISSOJONNAM STISSOJONNAM STORAGE	SECTION		DISTURBANCE SEDIMINTARY STRUCTURES SAMPLES	LITHOLOGIC DESCRIPTION
Image: Second second	NANNOFOSSIL OOZE, white (NB), soft, pyrite streaks and burrows, yellowish gay (5Y 8/1). FORAMINIFERBEARING NANNOFOSSIL OOZE, light gay zones (N7), soft, burrows and pyrite streaks through- out. SMEAR SLIDE SUMMARY: 5,70 6,96 D D Texture: Sand — R Sit R C Caronosition: Foraminifers R C Cate, namofossila D D 	late Moorre	G. conomizes N118		0. 1 2 3 4 5 6 7 CC		us the state date was a set at	NB ANNOFOSSIL OOZE, very light gray (NB), soft, mod- erately burrows yellowidh gray (ISY 8/1), pyrite streaks throughout, one pyrite concretion. SMEAR SLIDE SUMMARY: 1, 96 6, 70 D D Texture: NB SI NB Cate, nannofosilta D D NB NB NB NB NB NB

SITE 590 HOLE A	CORE 18 CORED INTERVA	L 189.4–199.0 m	SITE	590	н	DLE A	A	COR	RE 19	CORED I	NTERVAL	- 199.0–208.6 m	
TIME - ROCK UNIT AUTORA BIOSTRATIRAPHIC ZONE FORAMINFERS AMANOFOSILIS ANANOFOSILIS	SERVICION BUILDEN BUILTING BUILTING BUILTING BUILTING BUILTING STAVALS STAVALS	LITHOLOGIC DESCRIPTION	TIME - ROCK	BIOSTRATIGRAPHIC ZONE	Ch	FOSSI TARAC SITESOTORIA	L TER SMOTAID	SECTION	METERS	GRAPHIC THOLOGY	DISTURANCE SEDIMENTARY STRUCTURES SAMPLES		LITHOLOGIC DESCRIPTION
Iare Micene G. conomizere MN11B NN11B NN12 Conomizere MN12 Conomizere		Art. gap NANNOFOSSIL OOZE, while (N9), soft, with periodic burrows yellowish gay (5Y 8/1), pyrite streaks and bur- rows throughout. N9 FORAMINIFER-BEARING NANNOFOSSIL OOZE, light gay (07), soft, occasional burrows and pyrite streaks. SMEAR SLIDE SUMMARY: 3, 87 6, 91 0 0 Texture: Sand — R Sitt C C Calay D D Composition; Foraminifers R C Calc, nannofossils D D Art. gap N9 N9 N9 N9 N9 N9 N9 N9 N9 N9 N9 N9 N9	Late Mocenn			A.		1				N7 N8 N9 N9 N9 N9 N9 N9 N9 N9 N9 N9 N9 N9 N9	FORAMINIFER BEARING NANNOFOSSIL OOZE, light grav (N7), soft, burnowi, and pyrife streaks common. NANNOFOSSIL OOZE, white (N9) to very light grav (N8), soft, moderate to heavy burnowing, pyrife streaks common. SMEAR SLIDE SUMMARY: 1, 12, 196 0 D Texture: Send R – City D D Composition: Foraminifers C R Cate, nannofossitis D D

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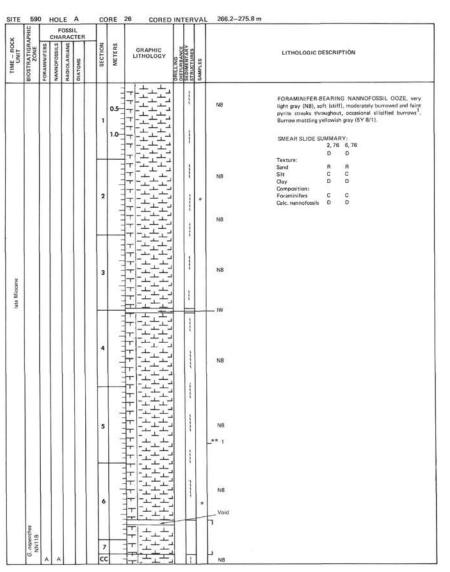
×	APHIC	1		OSSI	L							
UNIT UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE SEDIMENTARV STRUCTURES SAMPLES		LITHOLOGIC DI	ESCRIPTION
							0.5		0 0	NB		DOZE, very light gray (N8), moderately s yellowish gray (SY 8/1), faint streak ut,
						1	1.0		00000	NB	SMEAR SLIDE SU	2, 77 D
late Miocene							-			NB	Silt Clay Composition: Foraminifers	R D R
-	iozea					2	T. Li I. I.			NB	Calc. nannofossils	D
	G. conomiozee NN11B	A	A			CC	-			Art.gap NB		

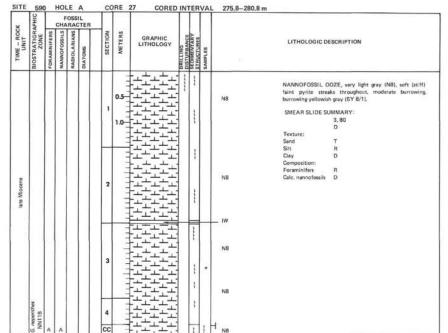
BIOSTHATIGRAPHIC ZONE	FORAMINIFERS		RADIOLARIANS	SWOLVIG	SECTION	METERS	GRAPHIC	VCE			
					-			DRILLING DISTURBANCE SEDIMENTARY	SAMPLES		LITHOLOGIC DESCRIPTION
					1	0.5		1		N8	FORAMINIFER-BEARING NANNOFOSSIL ODZE, light gray (NB), soft, burrows and faint prvite stin throughout, Burrows vellowish gray (SY 8/1). SMEAR SLIDE SUMMARY: 1, 79 4, 82 D D
					2	2		-		NB	Texture: Sand R T Silt C C Clay D D Composition: Foraminifers C C Calc. nannofosals D D
e:					_	correction () or				NB	
on capacity and	A				3	tradient.		1		IW	
					4			11		NB	
					5	Turther		11		NB	
					-	Free core				N8	
0. nepentnes NN118						and a second second				n	
		A	NN118 ×	W1116	A A A A A A A A A A A A A A A A A A A	A 3	A 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4		A	A A A A A A A A A A A A A A	A A A A A A A A A A A A A A

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l≌ [FOSSIL	24 CORED INTERVA	AL 247.0-256.6 m				HOLE A		RE 25	CORED INT	ERVA	AL 256.6-266.2 m
8 . 12	MANNOFOSSILS FRADIOLARIANS DiATOMS SECTION METERS	GRAPHIC LITHOLOGY SEMULTING SECONDERVISION STANYS		LITHOLOGIC DESCRIPTION	TIME - ROCK UNIT		RAMNDFOSSILS		METERS	GRAPHIC ITHOLOGY DISTURDED	SEDIMENTARY STRUCTURES SAMPLES	LITHOLOGIC DESCRIPTION
	0.5		NB II NB II S T S S	ORAMINIFER-BEARING NANNOFOSSIL OOZE, very ght grav (N8), soft to stiff, moderate to light burrowing throughout, burrows, vellowish grav (5Y 8/1), faint pyrife treak throughout. SMEAR SLIDE SUMMARY: 1, 118 4, 21 D D exture: D D exture: and T T it C C C Jay D D				1	F.H.F.F.F.F.F.F.F.			NANNOFOSSIL OOZE, very light gray (NB), soft (sti N8 moderately burrowed, faint streaks of pyrite, burro yellowish gray (5Y 8/1). SMEAR SLIDE SUMMARY: 2,71 4,21 D M Texture: Art.gap Sand T R Sitt R C Clay D D
	2		C F	oraminifen: C C oraminifen: C C alc. nannofossils D D				2				Contraction: 0 Contraction: 0 Composition: 0 Contraction: 0 Contr
	3		NB IW		late Miocene			3	ENER. E.E.E.E.		-	7 NB IW
	4		NB					4				NB
	5		NB					5				NB
G. Indpanthat NN11B >	6		748 NB			G. nepenthes NN11B >	~	6 CC			11	NB NS







×	APHIC			OSSI	TER											
TIME - ROCK UNIT	BIOSTRATIGRA	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DISTURBANCE SEDIMENTARY STRUCTURES	SAMPLES		LITHOLOGIC DI	SCRIPT	TION		
Quaternary	truncatulinokies 120					1	0.5			•	10YR 7/4 10YR 8/6 5Y 6/4 10Y 6/2 N8 5GY 7/2 N8 10Y 6/2	FORAMINIFER gray (10YR 7/4) coarser than sectio FORAMINIFER-B pale olive (10Y f the light (N8) par Core Catcher—sec	to pale below. EARING 3/2) to ts some	yellov 3 NAN very li dark	vish ora INOFOS ght gray (N5) spo	nge (10YR 8/6); SIL OOZE, soft, 7 (N8) colort, in
	xcat					2	1.12	TL		*		SMEAR SLIDE SU				
	G. trun NN20	51			1	-	1.7	TL	4 🖂		-SGY 7/2				1, 108	
	υź	Α	A			CC	-	マーニーニー	4		5GY 8/1 and 5GY 7/2	Composition:	D	D	D	D
- 1												Volcanic glass	R	т	т	T
- 11				6.8		- J				- 1		Pyrite	-	-	T	т
										- 1		Foraminifers	A	C	T C D	C D
										- 4		Calc. nannofossils	D	D	D	D

	PHIC			OS	SIL					Τ						
TIME - ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE SEDIMENTARY	STRUCTURES	SAMPLES	LITHOLOGIC DE	SCRIPT	NION		
						1	0.5				- 5GY 6/1 - 5G 8/1 - 5GY 7/2 5GY 8/1 N7 N8 N7	NANNOFOSSIL O (N8), some darker FORAMINIFER-B	(N5) spi EARING	S NAN	iron sul	fide). SIL OOZE, s
							1.0				* N8 5 GY 8/1 N8	greenish gray (5G) to light greenish (than the lighter par Sharp contacts rea	ts of the	G 8/1) a cora.	dark (1	v5) spots, cos
						T				-	N8 5GY 8/1	SMEAR SLIDE SU	MMAR	Y:		
						2	415			-	5GY 7/2 - N8	Composition:	D	1,85 D	D	5, 106 D
						1					- 5Y 7/2 N8	Volcanic glats Pyrite Foraminifers Calc. nannofossils	TC	T R D	R	T R D
						-	-			1	N9	Carc. nannorosini	U	^o		
						3	0.00		-	-	- NB					
						3	- I -	유승승		-	5G 8/1					
Quaternary						-	-		HE		5G 8/1					
U						4	- the			-	N9 - N8					
							1.1.1				5G 8/1					
						+					5G 8/1					
						5			F	-	* 5G 8/1					
							1				* 5GY 7/2 5G 8/1					
						-				-	5GY 7/2					
						6				-	-					
							4				5G 8/1					
	61NN		A			7		Void	11	-	- N9					
	Z		1			cc		Void	1		5G 8/1					

SITE 590 HOLE B	CORE 3 CORED INTERVAL 11.8-21.4 m		SITE E	90 H	OLE B	C	ORE 4	CORED	INTERVA	AL 21,4-31.0 m
TIME - ROCK UNIT BIOSTRATIGRAPHIC BIOSTRATIGRAPHIC FORAMINIFER FORAMINIFER MANNOFOSSILLE FORAMINIFER	RECTION RELEAS ADDITUTING BITURING BITU	LITHOLOGIC DESCRIPTION	TIME - ROCK UNIT BIOSTRATIGRAPHIC		FOSSIL HARACTE BADIOLARIANS BADIOLARIANS		METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE SEDIMENTARY STRUCTURES SAMPLES	LITHOLOGIC DESCRIPTION
Outerrary NN19 Y	→ → → → × N8 0.5 → → → × × N8 1 → → → × × SG % 6/1 1.0 → → → × SG % 1 → → → × × → → → × × → → × × × → → × × × → → × × × → → × × × → × × × × → × × × × → × × × × × × ×	NANNOFOSSIL OOZE, soft, very light gray (NS) to greenish gay (IGY 011, dark (NS-N4) spots and streaks throughout the entire core (L-icon-suffice). SMEAR SLIDE SUMMARY: 1,40 1,98 5,75 D M Composition: Volanic glass T T - A Foraminites R R - Gale, nannofossii B D D D Sponge spicules - T -	Outerney	51MN	~	3 3 4 4				N8 FORAMINIFER BEARING NANNOFOSSIL ODZE, soft, white (N9) to light greenish grav (5G 8/1), sharp contacts near 100 cm [Section 1] and 110 cm (Section 2), dark (N5) spots and streaks throughout the entire core. N8-N9 SMEAR SLIDE SUMMARY: 2, 284 2, 126 3, 40 0 0 0 0 0 SGY 8/1 Composition: 1 and treaks throughout the entire core. N8-N9 Volcanic gas T T N8-N9 Volcanic gas T T T F N8-N9 Volcanic gas T T T F SG 8/1 Composition: Cale, nanofositis D D D C SG 8/1 SG 8/1 SG 8/1 N8 N8 N8 N8 N8 N8 N8 N8 N8 SG 8/1 N8 SG 8/1 N8 SG 8/1 SG 8/1 N8 SG 8/1 N8 N8 SG 8/1 SG 8/1 SG 8/1 SG 8/1 N8 SG 8/1 SG 8/1 SG 8/1 SG 8/1 SG 8/1 SG 8/1 SG 8/1 SG 8/1 N8 SG 8/1 </td

SITE 590 HOLE B	CORE 5 CORED INTERVAL 31.0	040.6 m	SITE		HO	EB	co	RE 6	CORE	DINTER	RVAL 40.6-50.2 m	
TIME - ROCK INIO PORAMINITERS P	NOTICE REAL SANTA SA	LITHOLOGIC DESCRIPTION	TIME - ROCK UNIT	BIOSTRATIGRAPHIC	CHA	BIADIOLARIANS BIADIOLARIANS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURRANCE SEDIMENTARY STRUCTURES	SUDJOINT STANS	
International In	3	NANNOFOSSIL DOZE, toft, while (NB) to very light gray (NB), dark (NS-NA) spots and streaks (linon sulfide). PORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, greenish yellow green (SGV 7/2) to light greenish gray (IGO Sulfide), coarser than the while the parts. 7/2 Some bioturbation (Planot/ted). 7/2 Sharp contacts near 20 and 123 cm in Section 1. 9/1 SMEAR SLIDE SUMMARY: 1, 53 1, 115 5, 64 4, 109 Composition: Volcanic glass T T C T Pyrite T Foraminfers R C C R Cate, nannofostil D D A D Sponge spicules T - 9/1 Composition: Volcanic glass T T Foraminfers R C C R Cate, nannofostil D D A D Sponge spicules T - 9/1 Y12 9/1 Y12	late Pilocine	NNIG I NNI7 I NNI8	~ ~ ~		3				N9 5G 8/1 N8 5G 8/1 N8-N9 5GY 7/2 N8 N7 N8 N7 N9 5GY 7/2 N9	ioft, (5G arts.

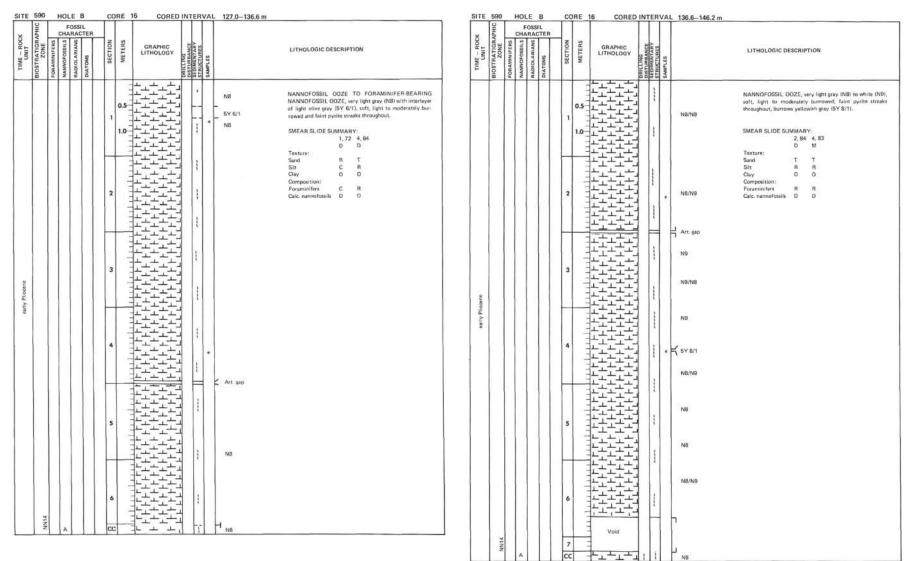
FOSSIL		ERVAL 50.259.8 m	SITE 590 HOLE B	CORE 8 CORED INTERV	
BIOSTRATIGRAPH FORAMINIFERS NANNOFOSSILS RADIOLARIANS PLATOMS	TS 2 GRABHIC	LITHOLOGIC DESCRIPTION	TIME - ROCK INT - ROCK BIOSTRATIGRAPHIC SONG - ROCK - ROCK FORMANNELS - ROCK ARMOLANIAS - ROCK - ROC	RRAPHIC STREET	LITHOLOGIC DESCRIPTION
MIG		N8 NANNOFOSSIL DOZE, soft, very light gray (N8), dark spots and streaks. SGY 7/2 FORAMINIFER BEARING NANNOFOSSIL DOZE, soft, grayih vellow green (SGY 7/2) to light granish gray (SGY 7/2 SGY 7/2 If the core. Intensive bioturbation throughout the strife core. N8 SMEAR SLIDE SUMMARY 1117 2, 44 D D D Composition: Outratz Quartz T Poraminifier C N8 SMEAR SLIDE SUMMARY SG 8/1 Peldapar N8 SG 8/1 SG 8/1 N8 SG 8/1 N8 SG 8/1 N8 SG 8/1 N8 SG 8/1 SG 8/1	Iate Plocane NV16		NB NANNOPOSSIL TO FORAMINIFE® BEARING NANNO 56.8/1 FOSSIL ODZE, soft, wrv light gav, (N8) to gravit vytica grav, (SG 7/2) and light gravenide grav, (SG 8/1) dari 56.8/1 NB 56.8/1 SMEAR SLIDE SUMMARY: 56.8/1 NB 56.8/1 SMEAR SLIDE SUMMARY: 56.8/1 Composition: 56.8/1 Composition: 56.8/1 Composition: 56.8/1 Composition: 56.8/1 Composition: 56.8/1 Composition: N8 Heavy minerals 7 NS 56.8/1 Cate.nannofositis N8 SG 8/1 N8 Gate.nannofositis 7 N8 7 SG 8/1 N8 SG 8/1 <t< td=""></t<>

SITE 590 HOLE B	CORE 9 CORED INTERVA	L 69.479.0 m	SITE 590 HOLE B	CORE 10 CORED INTERVA	L 79.0–88.6 m
TIME - PIOCK UNIT BIOSTRATICRAPHIC FORAMINITERS FORAMINITERS MANINOPOSISION MANININA MANININA MANINA MANINOPOSI	SECTION BUILTING BUIL	LITHOLOGIC DESCRIPTION	TIME - ROCK UNIT UNIT BIOSTATTICRAPHIC FOBAMMICE FOBAMMICE RABIOLAMIANCOSSILS	Stanta Stanta	LITHOLOGIC DESCRIPTION
late Pilcome NN16 >	Void 0.5	FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, white (NB) to very light gray (NB). Greenish parts fewer foraminifers L-NANNOFOSSIL OOZE. NB-N9 Dark (NS) spots and streaks throughout the entire core. SMEAR SLIDE SUMMARY. 2.81 3, 36 SG 8/1 D N8-N9 Composition: N8-N9 T Yotanic glass T N8-N9 Composition: N8-N9 T SG 8/1 D SG 8/1 Calc. nannofossili N9 SG 8/1 SG 8/1 SG 8/1 SG 8/1 SG 8/1 N9 SG 8/1 SG 8/1 SG 8/1 SG 8/1 SG 8/1 SG 8/1 SG 8/1	MILS RefY Ploatere	1 1	NO NANNOFOSSIL DOZE, soft, white (ND) to very light gray INB, dark (ND) spots (Liron suffide), Bioturbation in Section 1 and 4. NB SMEAR SLIDE SUMMARY: 3,38 6,107 D D Composition: NO Underlic glass T T Pyrite T - Foraminifers R R Catc. nannofossile D D NB N9 SG 8/1 N9 SG 8/1 N9 SG 8/1 N9 SG 8/1 N9 SG 8/1

SITE 590 HOLE B	CORE 11 CORED INTERVAL	88.6–98.2 m	SITE 590 HOLE B	CORE 12 CORED INTERV	AL 98.2–107.8 m
TIME - ROCK UNIT BIOSTRATIGRAPHIC FORAMINITERS AMMVOFOSSILS RADIOLARIANS BADIOLARIANS DIATOMS		LITHOLOGIC DESCRIPTION	TIME - ROCK INN - ROCK BIOSTRATIGRAPHIC FORMAINER RADIOLAMARKE RADIOLA	GRAPHIC COLON CHORE COLON COLO	LITHOLOGIC DESCRIPTION
G. creationnis NN15 >		N8 NANNOFOSSIL OOZE, soft, white (N8) to very light gray 86 (N8), dark spots and straks. 5GY 7/2 FORAMINIFER-BEARING NANNOFOSSIL OOZE, soft, grayish vellow green (SGY 7/2) to light gray (SG 8/1) dark spots and straks, coarser than the white parts of the core. 86 SMEAR SLIDE SUMMARY: 90 SMEAR SLIDE SUMMARY: 91 O 92 SG 8/1 93 SMEAR SLIDE SUMMARY: 94 D 95 SMEAR SLIDE SUMMARY: 95 D 96 SMEAR SLIDE SUMMARY: 96 D 97 Composition: 98 Policies grass 99 SG 8/1 90 SG 6/1 90 SG 6/1 90 SG 6/1 90 SG 6/1 91 SG 6/1 92 SG 6/1 93 SG 6/1 94 SG 8/1	early Pilocine 6. crassformic Mi15 P V		N8 NANNOFOSSIL OOZE, toft, while (N9) to grayish yellow 5GY 7/2 green (SGY 7/2). Some dark spots and straks (Lawiron N9 N7 5G 8/1 SMEAR SLIDE SUMMARY: N8 2, 96 Composition: Volcanic glass Volcanic glass T N8 Pyrite N7 Gelc. nannofostib N8 N7 N8 N8 N8 N7 N8 N8 N8 N8 N9 N8 N9 N8 N8 N8 N9 N9 N9 N9 N9 N9 N9 N9

	PHIC			OSS	TER							
UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	ILANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE SEDIMENTARY	SAMPLES		LITHOLOGIC DESCRIPTION
						1	0.5				5Y 6/1 - N8	NANNOFOSSIL OOZE, soft, very light gray (N8) to white (N8), with layers of light olive gray (5Y 6/1), moderately burrowed, burrows yellowish gray (5Y 8/1), occasional pyrite biebs and concretions, faint pyrite strasks through- out.
							1.0		TT.		5Y 8/1	SMEAR SLIDE SUMMARY: 2, 73 5, 73
						F	1 1 1 1		11		N8	D D Texture: Send T T Silt R R Clay D D
						2	11111			•	5Y 8/1 - N8/N9	Composition: Foraminifers R R Calc. nannofossils D D
						F			1		No/N9	
ne						3	- I		1		N8/N9	
early Pliocene						-			-		N8	
						4			1		N8/N9	
						5	and a set		1	*		
											N8/N9	
						6					5Y 8/1	
	formis								1	1	N8	
	G. crasseformus NN15	A	A			7					<u>ر</u>	

SITE			FC	E	-	T	T	E 14 COREC			. 117.4–127.0 m	
TIME - ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS		INANS	DIATOMS	SECTION		GRAPHIC LITHOLOGY	DISTURBANCE	STRUCTURES SAMPLES		LITHOLOGIC DESCRIPTION
						3	0.	主法			NB/N9	NANNOFOSSIL OOZE, soft, very light gray (N8) to white (N9), light to moderately burrowed, faint pyrite streak throughout, occasional pyrite blebs. SMEAR SLIDE SUMMARY: 3,69 D Texture: Sand T
				1		3					NB	Sit R Clay D Composition: R Foraminifers R Calc. nannofossils D
ane						3					NS	
early Pliocene						4					NB	
				9		5						
						6					NS	
	NN15					1710				1	N8	



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Ś	APH		CHA	RAC	TER							
UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE SEDIMENTARY	SAMPLES		LITHOLOGIC DESCRIPTION
						1	0.5		-0		NB	NANNOFOSSIL OOZE, very light grav (N8), soft, light to heavy burrowing with faint pyrite streaks throughout. SMEAR SLIDE SUMMARY: 6, 97 D Texture:
						2	of the second		1		NB	Sand T Silt R Clay D Composition: Foraminifers R Cale, nannofossils D
							den and and a				NB	
early Pliocene						3	the state of the state				NB	
early						4	- Constraints					
						5	diameter of the second				NB	
											NB	
	ELNN					6			3		NB	

Hd	CH	FOS	SIL						
UNIT UNIT BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE SEDIMENYARY STRUCTURES SAMPLES		LITHOLOGIC DESCRIPTION
early Plocens				3	0.5		3 2 3 3 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	N8 N8 N8 Concretion N8	NANNOFOSSIL OOZE, very light gray (NB), soft, light to moderately borrowed with faint pyrite streaks throughout burrows yellowish gray (5Y 8/1). Rare mineral concretion present. SMEAR SLIDE SUMMARY: 4, 77 M Texture: Sand T Sitt C Clay D Composition: Foraminifers C Cate, nannofossits D

SITE 590 HOLE		AL 165.4-175.0 m	SITE 590 HOLE B	CORE 20 CORED INTERV	AL 175.0–184.6 m
TIME – ROCK UNIT UNIT BIOSTRATIGRAPHI SONAMINIFENS PORAMINIFENS MANWOFOSSILS APPAU	METERS MARCHON MARCHON METERS MARCHON MARCHON METERS MARCHON METERS MARCHONA	LITHOLOGIC DESCRIPTION		R SB GRAPHIC SG GRAPHIC SB GRAPHIC SG GRAPHI	LITHOLOGIC DESCRIPTION
		NANNOFOSSIL DOZE, very light gray (NB), soft, moder- ately burrowed with faint gyrite streaks and helos through- out. Burrows yellowish gray (5Y 8/1). SMEAR SLIDE SUMMARY: 2, 92 D Texture: Sand T			NANNOFOSSIL OOZE, very light gray (N8), soft, light to heavily mottled vellowish gray (SY 8/1) by burrowing, faint pyrite streaks throughout. Mineralized burrow ¹ at 5, 110 cm. SMEAR SLIDE SUMMARY:
		Silt B Cay D Composition: Foraminifers R N8 Calc. nanotossis D			Sand T T Sitt R C Clay D D Composition: NB Foraminifers R C Calc, nannofossils D D
early Plicome		N8	Ploone		NB
		N8	early?		NB
	5 	NB		5 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	Art.gap NB Concretion ¹
NN12		N8 N8			NB
			A NN12	7	_ N8 _ N8

12	T.		FO	ISSI	L.	- 1	- 1						
APH	L		AF	AC	TER								
BIOSTRATIGRAPHIC ZONE	EAB AMMUTER NO	PORAMINIFERS MANNAGAGE	WWW.ALLOSSITS	RADIOLARIANS	DIATOMS		SECTION	GRA LITHO	LOGY	DISTURBANCE SEDIMENTARY	STRUCTURES SAMPLES	LITHOLOG	IC DESCRIPTION
late Missene							1				a	ately burrowe	C

×	APHIC	L	CHA	OSS	IL CTER									
TIME - ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DISTURBANCE SEDIMENTARY STRUCTURES	SAMPLES		LITHOLOGIC DE	SCRIP	TION
late Milocene		-		-		1	0.5			*	N8 N8 N8		ng wi ray (5° MMAR	
	NN11B					4	a damitana				NB			

	CORED INTERVAL 203.8-213.4 m		SITE 590 HOLE	B CORE 24 CORED INTER	VAL 213.4-223.0 m	
TIME - ROCK CHARACTER DIATODOC 4 WANNOL 0000 2000 2000 2000 2000 2000 2000 200	PHIC LOGY SHALLWINGS SHALLWINGS SHALLWINGS SHALLWINGS	LITHOLOGIC DESCRIPTION	TIME - ROCK UNIT BIOSTRATICE PORAMINITERIE MANNOFOSSILE MANNOFOSSILE RADIOLARIANE	CTER NOILCUS Stool LUS Stool LUS Sto	SAMPL ES	LITHOLOGIC DESCRIPTION
Site Motor Site Site Site Site Site Site Site Site	Image: Second second	NANNOFOSSIL OOZE, very light grav (N8) with heavily burrowed portions ysilowith grav (5Y 8/1), soft, moderate to heavily burrowed, large concretion present. ¹ SMEAR SLIDE SUMMARY 2, 80 6, 72 Texture: Sint R C Clay C A Composition: Foramider: R C Claic. nanofossils D A Clay minerals T – Pyrite T –	late Mocene Motene V		Art. gap NS CArt. gap NS NS NS NS	NANNOFOSSIL OOZE, very light grav (N8), soft, moder- ately burrowd with light streaks of pyrite. Burrows yei lowidh grav (BY 8/1). SMEAR SLIDE SUMMARY: 4, 80 D Texture: Sand R Sint R City D Composition: Foraminifers R Cate, namofoslik D Feldqoar T Volcanic glas T Pyrite T

	PHIC			OSS	TER										
UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIAMS	DIATOMS	acoviou.	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE SEDIMENTARY	SAMPLES		LITHOLOGIC DE	SCRI	PTION	
							0.5			•	NB	moderate to heav	ily bi reaks JMMA	arrowed, burr and halos med	ay (N8), soft (stiff), ows yellowish gray Jium Hight gray (N6).
							2				NB	Texture; Sand Silt Clay Composition: Foraminifers Calc. nanofosile Quartz Volcanic glass Clay minerals Pyrire	T R D	T R D - T T T	
late Miocene							3				NB	- YALON	0		
											NB				
							5		1		≓ Art.gap N8				
	NN11B						5 .				N8				

	590 9	Г	HOI	oss	11	1	RE 2		TT		232.6-242.2 m		_	
×	APH		CHA	RAG	TER									
TIME - ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DISTURBANCE SEDIMENTARY STRUCTURES	SAMPLES	LITHOL	OGIC DE	SCRIPT	rion -
						1	0.5				moderate (5Y 8/1)	ly burrow	ed thro rite stre MMAR	ery light gray (N8), soft (stiff) sughout, burrows yellowish gray aks medium gray (N6) frequent Y: 5, 86
						2	and the first first		1		Texture: Sand Sitt Campoint Calary NB Foramini Calar, man Volcanic: Clay min Pyrite Feldspar	fers notossils glass	D R R D R	D T R D R D T T T T T
ocene						3	interestion.		1		NS			
late Miscene						4	and and and and		4 		NB			
						5	and and and		*		NB			
						6	and to a farm				NB			
	NN118		A			7					N8 N8			

VITE 590 HOLE B CORE 2 FOSSIL CHARACTER NY WHO COSSIL CHARACTER NY 7 CORED INTERVAL 242 GRAPHIC LITHOLOGY	LITHOLOGIC DESCRIPTION	PHIC	HOLE B FOSSIL CHARACTER STISSOJONNYN SWOLLYIG SUCCESSION	NOTTO	AL 250,7–259,1 m	LITHOLOGIC DESCRIPTION	
05-1 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.		Sitt R C Clay D A Composition: Foraminifies R A	late Micene	*	0.5 1 1 1 0.5 1 1 1 1 1 1 1	NB Planolites NB Zoophycos NB	NANNOFOSSIL DOZE, very light gray (NB), soft, mod- erately burrowed, burrows (Planolites, Zoophycos) gravith vellow green (SGY 7/2) to vellowish grav (SY B/1), grav (NB-N5) streaks rare. SMEAR SLIDE SUMMARY: 4, 54 0 composition: Volenic glass T Porteini T Colaric glass T Cate, reannofossits D

SITE 590 HOLE B	CORE 29 CORED INTERVAL	259.1–268.7 m	SITI	590		LEB	COF	RE 30	CORED	INTERVA	L 268.7–278.3 m	
TIME - ROCK UNIT BIOSTRATIGRAPHIC BIOSTRATIGRAPHIC ZONE FORAMINIFERS MANVOFOSSILS BIATIONS BIATIONS BIATIONS	Standard Control of Co	LITHOLOGIC DESCRIPTION	TIME - ROCK	ERAPHI	CHA	RADIOLARIANS DIATOMS		METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE SEDIMENTARY STRUCTURES SAMPLES		LITHOLOGIC DESCRIPTION
late Micorne NN118		NANNOFOSSIL QOZE, very light gray (NB), soft, slightly biotribated, burrows vellowish gray (BY B/1) (Planofilter, undefined). Gray (NB-N5) spots throughout the core (tare). Dilling disturbance: 20 307 B/1 NB Selection of the core (tare). Planofilter NB SGY B/1 NB	Late Micene	G resenther NN11A NN11B NN11A NN11B	A A A A		1			-	N8 5G 7/2 (pale green L wh layer?) N8 N8 N8 N8 N8 	NANNOFOSSIL CHALK, Iim, very light gray (N8): intenively biorurbated, Burrows (2000/you, Planofired) yellowih gray (SY 21) to grayih yellow graen (ISGY 7/2). Dark (N6) spots throughout the core (rare).
		N8										

SITE 590 HOLE B	CORE 31 CORED INTERVA	L 278.3-287.9 m		SITE		HOLE B		CORE 3	CORED I	NTERVA	L 287.9–297.5 m	
TIME - ROCK UNIT BIOSTRATIGRAPHIC FORAMINIFEIS FORAMINIFEIS MANNOFOSSILE RADIOLARIANS RADIOLARIANS DIATOMS	SECTION SECTION METERS ADDINULURA ADDINA ADDINULURA ADDININA ADDININA ADDININA ADDININA ADDININA ADDININA ADDININA ADDININA ADDININA ADDININA ADDININA ADDININA ADDIN		LITHOLOGIC DESCRIPTION	TIME - ROCK UNIT	BIOSTRATIGRAPHIC ZONE FORAMINIFERS	FOSSIL CHARACT STISSOLUANNOLOSSILS	ER	METERS	GRAPHIC LITHOLOGY	DISTURBANCE SEDIMENTARY STRUCTURES SAMPLES		LITHOLOGIC DESCRIPTION
At continuous At Minocone InterMinocone Inte	2 3 4 4 4 4 4 4 4 4 4 4 4 4 4	NB	NANNOFOSSIL CHALK, firm, very light gray (NB), moderately to intensively bioturbated, Burrow (Zogohycor, Phan/Iters y Very (NZ). Dark (NS-N2) spots throughout the entire core (rare). SMEAR SLIDE SUMMARY: 3, 102 Composition: D Volcanic glass T Pyrita T Foraminifers R Calc. nanofossilis D Radiolarians T	Lee Moorne	94	N 10 10		0.5			NB NB NB	NANNOFOSSIL CHALK, firm, very light grav (N8), intensively bioturbated burrows (Zoophycor, Planoline) yellow grav (5Y 8/1) and light grav (N7). Dark (N8–N7) SMEAR SLIDE SUMMARY: 2, 46 CC ¹ D M Composition: Votanic glass T R Pyrior T C Foraminifers R – Calk, annofossis D – Datarem – C Radiolairans(7) – C Ssonge spicules – T Silicoflagellates – T
					eso			-		۵	NB	

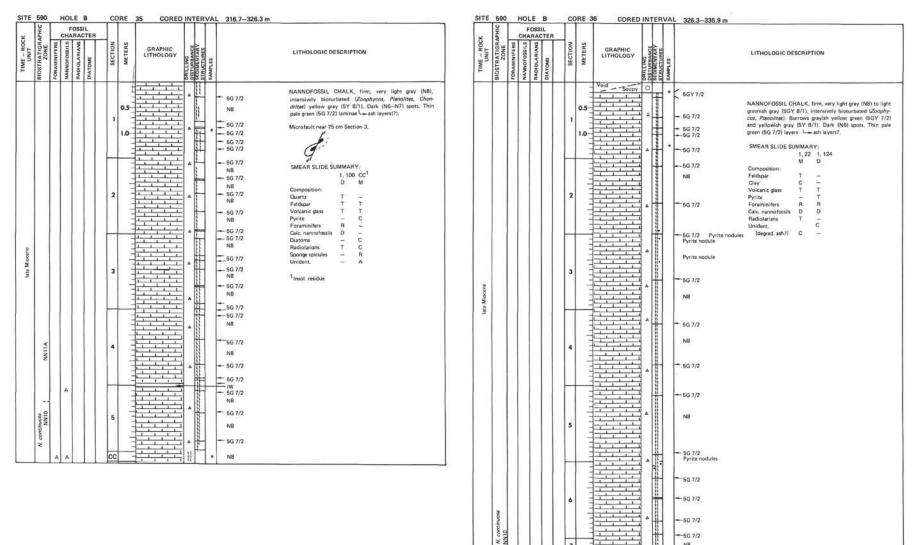
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SITE 590 HOLE B	CORE 33 CORED INTERVAL 297.5-307.1 n	· · · · · · · · · · · · · · · · · · ·	SITE E	90	HOLE B	(CORE	34 CORED	INTERVA	L 307.1–316.7 m	
TIME – ROCK INIT CHARACTE FORMINERIS MAMOFOSSILLS MAMOFOSSILLS FORMINERIS MAMOFOSSILLS FORMINERIS FORMICA MAMOFOSSILLS FORMICA		LITHOLOGIC DESCRIPTION	TIME - ROCK UNIT		FOSSIL CHARACTER BIATOMO	-	SECTION METERS	GRAPHIC LITHOLOGY	DATLLING DISTURBANCE SEDIMENTARY STRUCTURES SAMPLES		LITHOLOGIC DESCRIPTION
Late Mocene M. contributes NN11A > > >	0.5 1	NANNOFOSSIL CHALK, firm, very light gary (N8), moderately to intensively bioturbated, Burrows (ZogAy- or, Flanoliter, Chandriter) velicowin garv (BY B/1) to light gar (BC 7/2) layers — and layers(). SHEAR SLIDE SUMMARY: D Composition: Volcanic glass T F Foraminifers R Cicanofossil D Radiolarians T	Late Miccene	- VIIIN	A		2 2 2			N8-5GY 8/1 + 56 7/2 + 56 7/2 + 50 7/2 + 50 7/2 + 50 7/2 + 50 7/2 + 50 7/2 + 56	NANNOFOSSIL CHALK, firm, very light gray (N8) to light greefish gray (550 8/1); moderately to havily bioturbated. Burrows. (Zoophycoc, Panolifes) vellowish gray (5% 8/1); to grayin by vellow green (550 7/2). Dark spot throughout the core. Pale green (55 7/2) thin layers (1 → ash layer?). SMEAR SLIDE SUMMARY: 2,70 2,112 5,102 D M M Composition: 0 M M Volcanic glass T - - Pyrite T - - Poraminities: R R R Cale: nannofoxilis D D D



N8

- 5G 7/2

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SITE 590 HOLE B	CORE 37 CORED INTERVAL 335.9-345.5 m		SITE 59	0 1	IOLE B	co	RE 38 CORED INTE	RVAL 345.5-365.1 m	
TIME - ROCK UNIT BIOSTRATICRAPHIC PORAMINIFERS NAWOFOSSILS RADIOLATIANS DIATONS		THOLOGIC DESCRIPTION	TIME - ROCK UNIT BIOSTRATIGRAPHIC	in I	FOSSIL HARACTEF DIATOMS	SECTION	S GRAPHIC LITHOLOGY LITHOLOGY BUILTING	SAMPLES_	LITHOLOGIC DESCRIPTION
late Miccons M. contritious N. 10 N J V	2	RAMINIFER-BEARING NANNOFOSSIL CHALK, firm, ight gray (BS) to light greenish gray (BS G1); inten- iy bioturbated (Planoliter, Zoophycos, Choordiner); ross valiowish gray (BY) (31); dark soots (N6). Thin pale in (SG 7/2) laminae L-ash layers(7). AEAR SLIDE SUMMARY: 3,28 D mpoolition: ary minerula T tionic glass T ciannofossik A diotariam T rite T	Late Miscene	NNN N	A .	1 2 3 4 5 6 7 7 CC		- 5Y 8/1 N8 - 5G 7/2 N8 - 5G 7/2 N8	FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, very lipht grav (NB), intensity bolturbated with burrows yellowith grav (NG) pyrite streaks. Pale grave, (BG 7/2), sh(7) lipht grav, (NG) pyrite streaks. Pale grave, (BG 7/2), sh(7) light grav, (NG) pyrite streaks. Pale grave, (BG 7/2), sh(7) light grav, to bight grav, (NJ). Zoophycor burrows obvious. SMEAR SLIDE SUMMARY: 1,43 4,112 4,127 D M M Texture: Sand R R A Sit C D A City D R A Composition: Feldopar – R T City minerals – T – Volcani glass T A A Rediolarians T – –

SITE 590 HOLE B	CORE 39 CORED INTERVAL	355.1–364.7 m	SITE 590 HOLE B	CORE 40 CORED INTERV	AL 364.7-374.3 m
TIME - ROCK IUN - ROCK IUN - ROCK ROCK - ROCK - ROCK ROCK - ROCK - ROCK ROCK - ROCK	SECTION RECTION METCHAR MENTIONE PERMEMANCE PERMEMANCE SAMPLE	LITHOLOGIC DESCRIPTION	TIME - ROCK JUIT BIOSTRATIGRAPHIC FORAMINUTERS MANNOFOSSILE RABIOLATIANS PUBLICA	TER	LITHOLOGIC DESCRIPTION
G. Tudyler K.N.99 V	0.5 1<	N8 FOR AMINIFER-BEA RING NANNOFOSSIL CHALK, firm, very light grav (N8), intensely bioturbated, Burrows vel- iowish grav (SY 6/1). Zoophycos burrows common. Pale green (SG 7/2) taylers. common. Medium dark grav (N4) T5G 7/2 SMEAR SLIDE SUMMARY: 1.68 6, 80 6, 137 N8 Texture: Sand: C C C C Sint C C C C C Sint 5G 7/2 Clay marantic (non-mark) A A N8 Texture: Sand: C C C C C Sint T T C C C C Sint T T C C C C C C Sint 5G 7/2 Clay marantic (non-mark) T T C C C C C C C C Sint T T C C C C C C C C Sint 5G 7/2 Clay marantic Forazimiters C A A A N8 Privite Forazimiters C A A A SG 7/2 Valcanic glass T T Forazimiters A A N8 SG 7/2 N8 SG 7/2 N8 SG 7/2 N8 SG 7/2 N8 SG 7/2 N8 SG 7/2 N8 SG 7/2 N8 SG 7/2 N8 SG 7/2 N8 SG 7/2 N8 SG 7/2 N8 SG 7/2 N8 SG 7/2 N8 SG 7/2	Economic middle Mocarte middle Mocarte Conomic	0.5	Gap FOR AMINIFER BEARING NANNOFOSSIL CHALK, firm, pair (N7) to velocitis gay (N8), internetly biourbated. Burrows light gay (N7) to velocitis gay (SY 01). Zoophycor apparent, pair green (IS 7/2) layers. Medium dark gay (N4) streaks common. N8 SMEAR SLIDE SUMMARY: 1,82 0,78 N8 SMEAR SLIDE SUMMARY: 0 M Sord C Carponition: T Pridepar T N8 For anniafers Sof 7/2 N8 N8

Bit Integration Bit Integrate Bit Integration Bit Integrat	BS A BS FORAMINIFE®BEARING MANNOFOSSIL CHALK, Itra, wrv (dit) gary (N4) treaks throughout, layers common, Medium deir, gary (N4) treaks throughout, layers common, medium deir, gary (N4) treaks throughout, layers common, medium deir, gary (N4) treaks throughout, layers common, medium deir, gary (N4) treaks throughout, layers common, layers common, medium deir, gary (N4) trea	No No<		590 21			FOS	SIL		Π	RE		Π		L 374.3-383.9			59 0 1 1		HO
BER A BER FORAMINIFER-BEARING MANNOFOSSIL CHALK, tim, very light gray (NR), intensely biofurbated, burrow light gray (NR) to vellowith gray (SF 871). Pale green (SG 7/2) light gray (NR) to vellowith gray (SF 871). Pale green (SG 7/2) light gray (NR) to vellowith gray (SF 871). Pale green (SG 7/2) light gray (NR) to vellowith gray (SF 871). Pale green (SG 7/2) light gray (NR) to vellowith gray (SF 871). Pale green (SG 7/2) light gray (SG 7/2) light	BS A BS FORAMINIFE®BEARING MANNOFOSSIL CHALK, Itra, wrv (dit) gary (N4) treaks throughout, layers common, Medium deir, gary (N4) treaks throughout, layers common, medium deir, gary (N4) treaks throughout, layers common, medium deir, gary (N4) treaks throughout, layers common, medium deir, gary (N4) treaks throughout, layers common, layers common, medium deir, gary (N4) trea	No No No No No No No 1000 1 0.5 1 1 1 1 1 1 1 1 1 1 1	TIME - ROCK UNIT	BIOSTRATIGRAP			-	-	Τ	SECTION	METERS	GRAPHIC LITHOLOGY	SEDIMENTARY	SAMPLES		LITHOLOGIC DESCRIPTION	TIME - ROCK	BIOSTRATIGRAP	FORAMINIFERS	
Sund C C Sitt C C Clay D D Composition: Cuartz T Composition: Cuartz T Volcanic glass T T Portion: Cuartz T Sitt C C Outposition: Cuartz T Volcanic glass T T Provinities C C Sitt C C N8 Poraminities C Volcanic glass T - Poraminities C C Sitt Sitt N8 Sitt Sitt Sitt Sitt T - Sitt Sitt C Sitt C C Sitt C C Sitt C C Sitt Sitt C Sitt Sitt Sitt Sit	Pooly apper 3	Sand C C Site C C Composition: Oumrit T Quartz T T Voltanic gias N8 S Voltanic gias N8 S Voltanic gias N8 S Voltanic N8				-				1	11		R		— 5G 7/2	very light gray (NS), intensely bioturbated, burrows light gray (NS) to yellowide gray (5Y K). Pale green (5G 7/2) layers common. Medium dark gray (N4) streaks throughout. SMEAR SLIDE SUMMARY: 1, 119 4, 76 D D			Т	
amoo w appour a a b a b b c c c c c c c c c c	Page 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	Peopy apper								2	The second second second second second second second second second second second second second second second s				NB	Sand C C Sitt C C Clay D D Composition: Quartz T – Mica – T Volcanic glass T T Pyrite T – Foraminifers C C				
4 - 56 7/2	- 56 7/2 - 56 7/2 - 56 7/2 - 56 7/2	5 5 7/2 5 7/2 5 7/2								3	11111111111				NB	Cate: nannofossils D D	liocene			
	5 5 7/2	5 7/2 5	middle Miocene							4	trantana 1				N8 — 5G 7/2		middle M			
6 5 7/2 NB				G. mayeri NNB	A	A				cc	1		123		- 5G 7/2	10		62	A	A

	590 ₽		F	OSS	IL			2 CORED	TT	T	L 383.9–393.5 m				
ž	APH	-	CHA	RAC	TER										
TIME - ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE SEDIMENTARY	SAMPLES		LITHOLOGIC DE	SCRIP	TION	
	NN7		A			1	0.5				N9/N8	very light gray (N burrowed, burrow	8) to w light (5G 7/2)	hite (N pray (N	NOFOSSIL CHALK, firm 9). Moderate to intensel 7) to light olive gray (5' occur. Medium dark gra
							-				NB	SMEAR SLIDE SL	3, 93 D	5,110 M	6,49 M
						2	in line				= 5G 7/2	Texture: Sand Silt Clay	C C D	C C A	C C D
							11111		. *		NB	Composition: Clay minerals (Incl. mica) Volcanic glass Pyrite	T T T	T T T	T R
							tri tri t		- H		- 5G 7/2	Foraminifers Calc. nannofossils Radiolarians	C D T	A A -	с р -
middle Miocene						3	11111		▲ 	•	NB				
middle						4	111111		▲ []		ina				
							ti li ti				5G 7/2 N8 5G 7/2				
						5	riti i i		1		N8 5G 7/2				
						3	in the second se			'	N8 5G 7/2				
							- tarta				NB 5G 7/2				
						6	- I and the		1		NB				
	-								1		5G 7/2 NB				
	G. mayeri NN7					7	-		1		01265				
	5. SUN	A	A			cc	-		0		NB				

321

SITE 590 HOLE B	CORE 43 CORED INTERVAL	393.5-403.1 m	SITE 590	HOLE B	CORE 44 CORED INTERVA	L 403.1-412.7 m
TIME - ROCK UNIT UNIT BIOSTRATIGRAPHIC FORAMINIFERS MANINOPOSSILLE RABIOLARIANS BABIOLARIANS BABIOLARIANS PLATOMS	GRAPHIC Stat GRAPHIC Building Stat LithoLogy Stat LithoLogy Stat States	LITHOLOGIC DESCRIPTION	TIME - ROCK UNIT BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER CHARACTER SUPPORT	SERVICE SER	LITHOLOGIC DESCRIPTION
Gurayeori V >		NB FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm, werv light gray (NB), intensity bioturbated, burrows light gray (N7) to light gray (N4) streaks common. 56 7/2 gray (N7) to light gray (N4) streaks common. N8 SMEAR SLIDE SUMMARY: 50 7/2 50 7/2 A, 6 N8 Sand Sand C C R SG 7/2 Sit N8 Sand C C C G 7/2 C law N8 Sand C C C C (Ind. mica) T Clay minerais (Ind. mica) (Ind. mica) T SG 7/2 Cale. nannofosils N8 Sand SG 7/2 N8 SG 7	middle Mooene			FORAMINIFER-BEARING NANNOFOSSIL CHALK, firm very light gey (N8), intecsity burrows, burrows, ligh grav (N7) to light dive grav (87 6/1). Pale geen 15G 7/2 isyter. Medium dark grav (144) streads common. SMEAR SLIDE SUMMARY: 5G 7/2 D M Texture: N8 Sand R R Silt C A Clay D A Clay D A Clay D A Clay C A SG 7/2 Volcanic glas T – Pridopar T C Foraminifers C C C Coromotions D A N8 5G 7/2 N8 5G 7/2 N8 5G 7/2 N8 5G 7/2 N8 5G 7/2 N8

G. mayeri NN7 5G 7/2 N8 5G 7/2 N8 5G 7/2 N8

	PHIC		F	OSS	IL										
TIME - HOCK	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DISTURBANCE DISTURBANCE SEDIMENYARY	STRUCTURES SAMPLES		LITHOLOGIC DE	SCRIP	TION	
	2NN7		A			1	0.5		4	222*	N8		intensel gray (51) JMMAF	y buri (6/1). (Y:	SSIL CHALK, firm, very rowed, burrows light gray 19.5, 120 M R C
						2	and the state of the state		4	•	Void	Glay Composition: Mica Volcanic glass Pyrita Foraminifers Calc. nannofossila	A T T A	D TT CD	T T C D
middle Miocene	9NN		•			3			4		NB				
						4	ter level ter				— IW				
						5	in the second		1		NB				
	G. fohsi s. l. NNG	A	A			6 CC			4 4	*	N8 NB				

~	PHIC		F	OSS RAG	TER									
TIME - ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DETLEND	SEDIMENTARY STRUCTURES SAMPLES		LITHOLOGIC DE	SCRIP	TION
						1	0.5				N8 5G 7/2 N7	gray (N8), heavily	burrow Y 8/1)	FOSSIL CHALK, firm, very ligh wed, burrows light gray (N7) t I. Pale green (5G 7/2) alteratio streaks.
							1.0	++++++			NB	SMEAR SLIDE SU		
							-	++++++	7		NO		3, 86 D	6, 106 D
						F	1		11	222	5G 7/2	Texture: Sand Silt	c	c
							3				N8	Clay Composition:	A	A
- 1						2	=		1		N7	Quartz Volcanic glass	T	T
							-			ili	5Y 8/1	Pyrite	т	т
							1	111111			N7	Foraminifers Calc. nannofossils	A	A A
						\vdash			1 X I		NB	Sponge spicules	т	T
						3	- upu							
							9			-	5GY 7/2 N7			
						+			4		NB			
							4		4		5G 7/2			
middle Miocene						4				挄	5Y 8/1 N7			
middl							1							
							-				N8			
							E		4		5G 7/2 N8			
						5	1111			122	5G 7/2			
							- Inter				NB			
							1011			111	148			
						6					NB			
							100			\$t •				
	G. fohsi s. l. NN6					7	Ŧ		-	122	NB			
	NG	A				cc	1			222	NB			

SITE 590 HOLE B	CORE 47 CORED INTERVAL	431.9-441.5 m	SITE 590 HOLE B	CORE 48 CORED INTERVAL	441.5-451.1 m
	GRAPHIC GRAPHIC COLONIA COLONI	LITHOLOGIC DESCRIPTION		GRAPHIC GRAPHIC UTHOLOGY SUBJURING SUBJURIN SUBJURING SUBJURING SUBJURING SUBJURING SU	LITHOLOGIC DESCRIPTION
G. Aphol s. I. Mulde Micene G. Aphol s. I. Muld Milds	2 1 1 1 1 1 1 1 1 1 1 1 1 1	N7 NANNOFOSSIL FORAMINIFER CHALK, frm, very light gray (N8) to light gray (N7) to light olive gray (SY 8/1) with pale graen (SG 7/2) and medium dark gray (N4) straks. Interestly bioturbated. Burrows concentrated in light (N7-N9) zone. Contacts gradational. Light (N8) zones lower in foraminifes becoming a foraminifer namo- focal chalk. 5G 7/2 SMEAR SLIDESUMMARY: N7 2,27 3,4 5,140 6,87 N7 Sand C C C A N7 Sand C C C C N8 Mica T T T T N7 Volcanic glas T T T T N8 Carbonate unpace, T - - - - N8 SG 7/2 SG 7/2	middle Micene		N8 5G 5/2

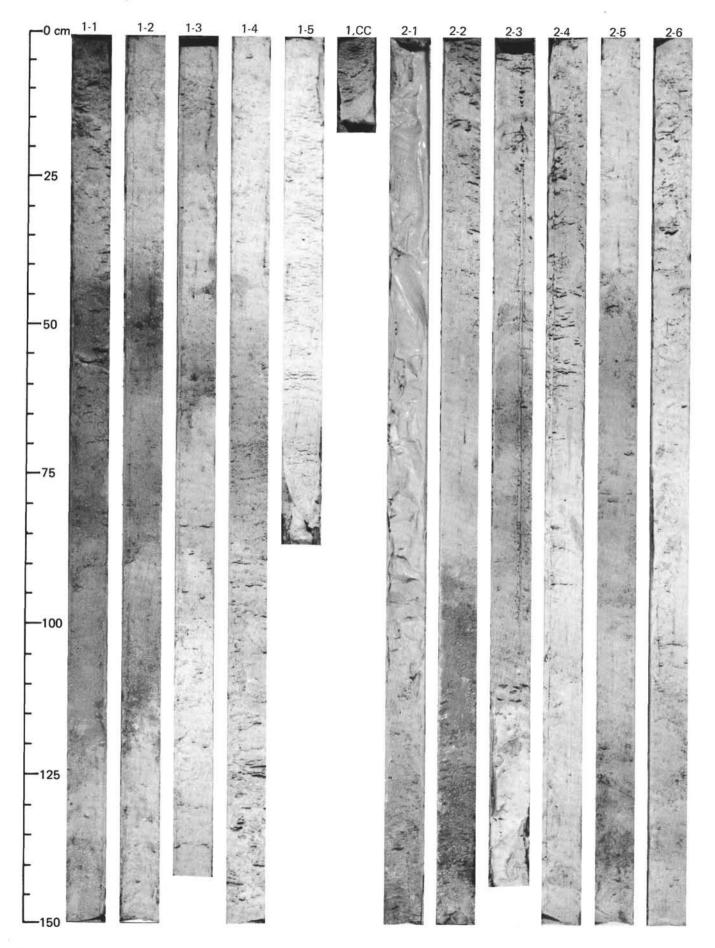
PHIC		Cł		SSI	L TER	Т			Π	Т	
UNIT UNIT BIOSTRATIGRAPI	ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DISTURBANCE	SEDIMENTARY STRUCTURES SAMPLES	LITHOLOGIC DESCRIPTION
early Miccene	G. muzzał NNS					3	0.5				NANNOFOSSIL CHALK, firm, very light gray (NB) to il greening gray (GS &/I), less bioturbated greening gray (GS &/I), less bioturbated greening end type bedding(). SMEAR SLIDEWINAMAY:

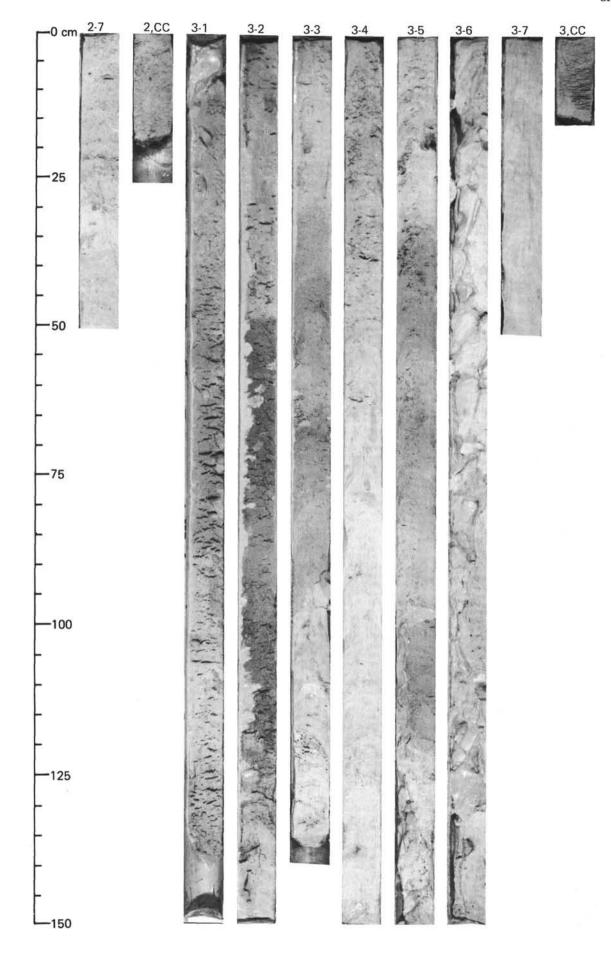
SITE	590	HOLE	В	CORE 50	CORED INTERVAL	460.7-470.3 m
	0		212.			

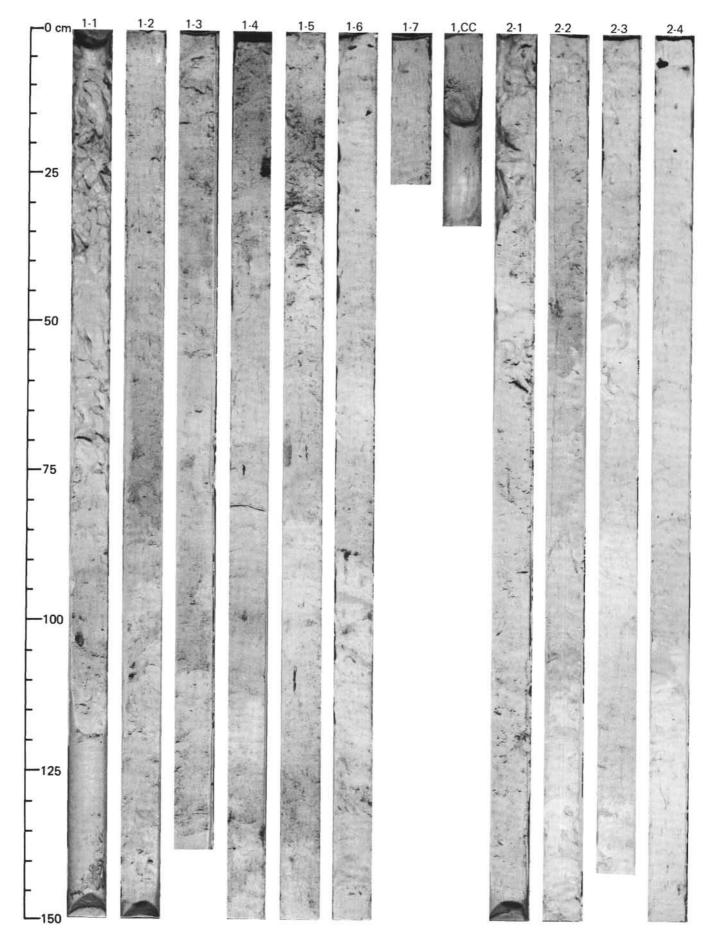
×	VPHIC	- 8		RAC	TER									
TIME - ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING	SEDIMENTARY	SAMPLES		LITHOLOGIC DI	SCRIPTION
	NN4		A			1	0.5		4			5GY 8/1 N8 5GY 6/1 N8	8/1) to greenish g phycos, Planolites	CHALK, firm, light greenish gray (SGY ray (SGY 6/1), bioturbation rare (Zoo- , undefined). Some greenish (SG 3/2) c ah? Some flaser bedding (), cm breccis (bx).
sariy Miocene						2			4	service and and and a service of the		- 5G 3/2 - 5G 9/1 - 5G 6/1 - 5G 6/1 - N8 N9 - 5G 7/1 - N8 Stylo/ites(?) - 5G 7/1	SMEAR SLIDE SU Composition: Volcanic glass Pyrite Carbonate unspec. Foraminifers Calc. nannofossils	3,97 M C T
	miozea 14		A			3	the local		4			5G 8/1 E N9 5G 8/1 -5G 3/2 5G 6/1		
	G. mi NN4	A	A			C	c .		4	1	•	5G 8/1		

SITE 590 HOLE B	 470,3–479.9 m	SITE 590 HOLE	INTERVAL 479.9-489.5 m	
TIME - ROCK UNIT BIOSTRATICE BIOSTRATICE FORAMINIERS MANNIOFOSSILS HADIOLATIANS	LITHOLOGIC DESCRIPTION	X 5 CHAR	DISTURANCE DISTURANCE STRUCTURES SAMPLES SAMPLES	LITHOLOGIC DESCRIPTION
c. detaciólite C. detaciólite NM3 NM3 NM3 NM3 NM3 NM3 NM3 NM3	56.8/1 N8 RECRYSTALLIZED NANNOFOSSIL CHALK, firm, very light gray (N8) and white (N9) to greenish gray (56/ 011, bioturbation moderate (Planofiles, Zosphycas, Chardrines). 10GY 5/2 Section moderate (Planofiles, Zosphycas, Chardrines). 56.8/1 Section of 6.6-8.2° minae (greenish gray (SG 4/1) to gray/sh black (N2) part, firm tennine. (Planofiles Green tilde — ALTERED VOLCANIC GLASS (palagonite). N8 Chondrikes Green tilde — ALTERED VOLCANIC GLASS (palagonite). SMEAR SLIDE SUMMARY! N8-N9 N8 Composition: D M M 56.8/1 Garbonite Green tilde — ALTERED VOLCANIC GLASS (palagonite). SMEAR SLIDE SUMMARY! N8-N9 N8 Palagonite). SG 8/1 Composition: D M M SG 8/1 Garbonate unspect N8 Palagonite N8 Pyrite N8 Portion: SG 8/1 Calc. nanofostili A R N8 Ne-N9 'No-N9 Status unspected and R 'NA-N9 Status unspected and R 'NA-N9	C. distinuida MAC2 IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	N8 SG 5/2 N8 SG 5/2 N8 N7 (#7) N8 N7 (#7) N8 SG 5/2 SG 5/2 <td< td=""><td>RECRYSTALLIZED FORAMINIFER-BEARING NANNO- FOSSIL CHALK, firm, very light grav (NB) to light green- lish grav (56 8/1), moderately biourbated (Planolike, Zoophycot). Thin, gravith green (56 5/2) Iuminae L- vol- canic akh survit). Haar bedding (2007). SMEAR SLIDE SUMMARY: 3, 85 D Composition: Volamic glass R. A Foraminifers C Catic nanofosils A</td></td<>	RECRYSTALLIZED FORAMINIFER-BEARING NANNO- FOSSIL CHALK, firm, very light grav (NB) to light green- lish grav (56 8/1), moderately biourbated (Planolike, Zoophycot). Thin, gravith green (56 5/2) Iuminae L- vol- canic akh survit). Haar bedding (2007). SMEAR SLIDE SUMMARY: 3, 85 D Composition: Volamic glass R. A Foraminifers C Catic nanofosils A

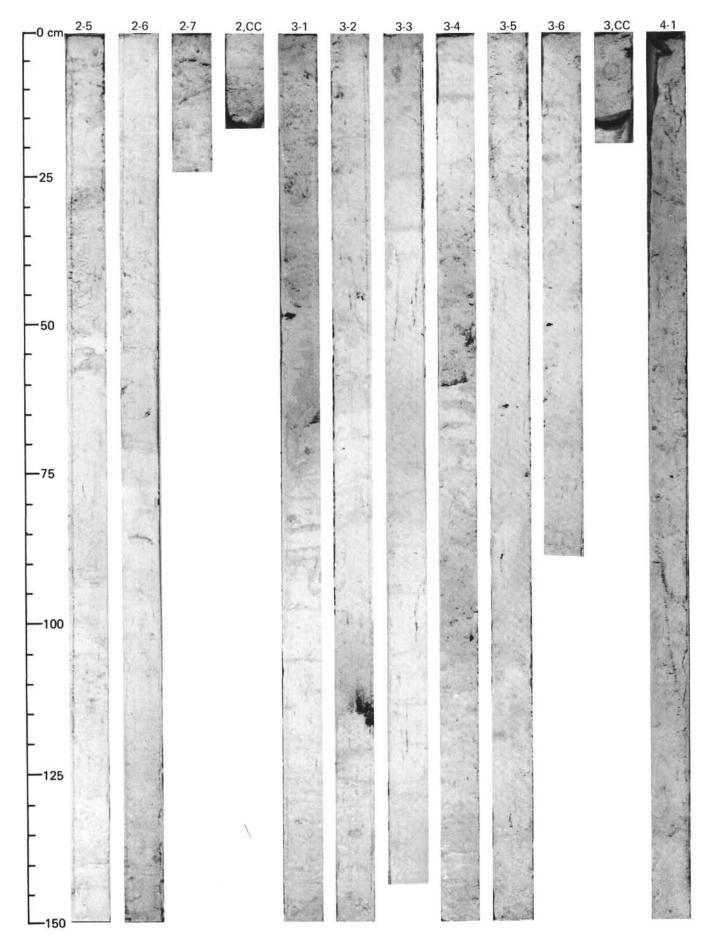
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000 A	×	APH	-	CHA	RAG	TER	_						
000000 All A 0 5 5 55	TIME - ROC	BIOSTRATIGR	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DISTURBANCE	SEDIMENTARY	SAMPLES	LITHOLOGIC DESCRIPTION
Sign 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	early Milocene						3	2					5,20 CC ¹ D M Volcanic glass T C Zeofites — A Pyrite — T Foraminifers R — Calc, nannofossilis A —

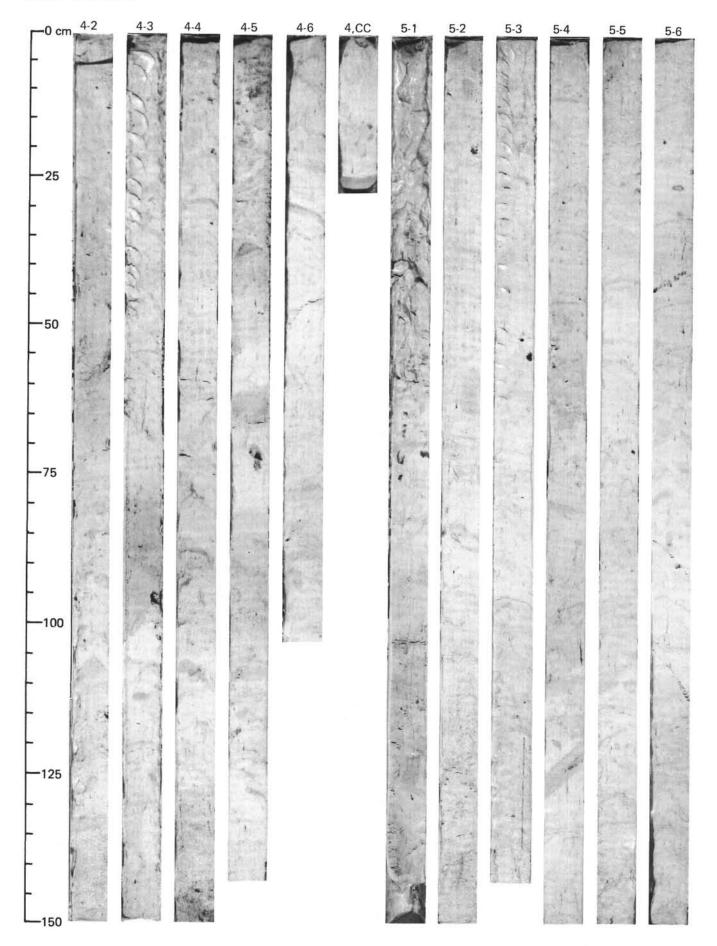






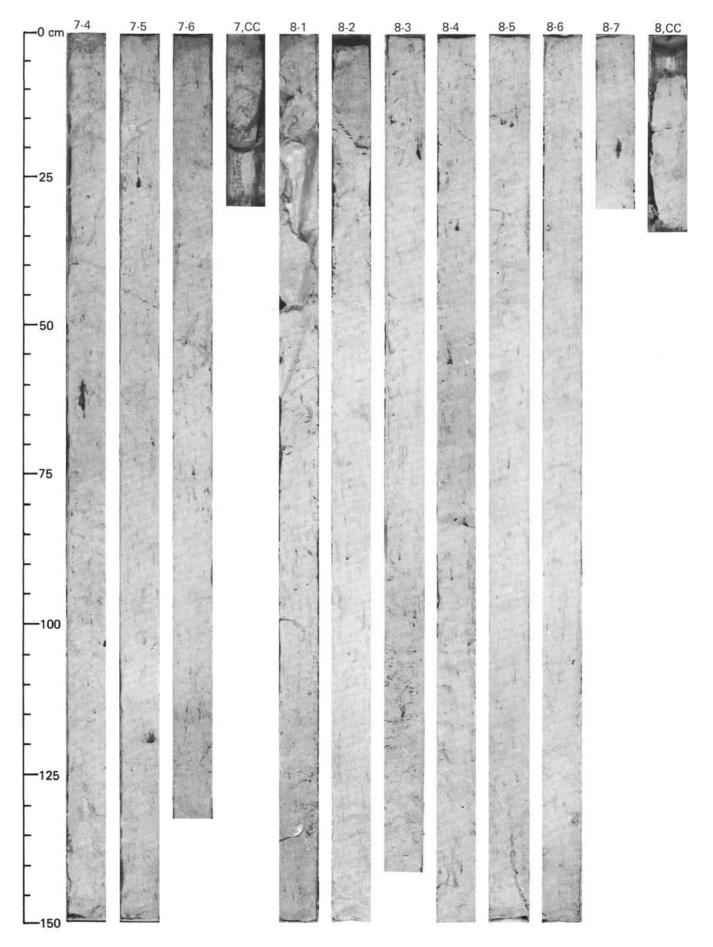
SITE 590 (HOLE 590A)



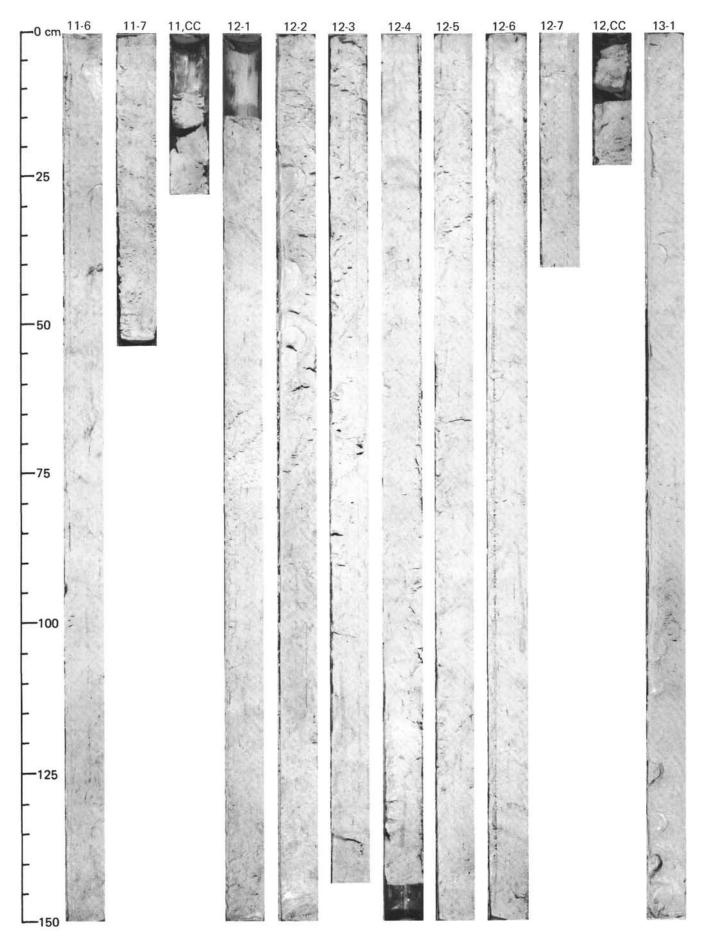


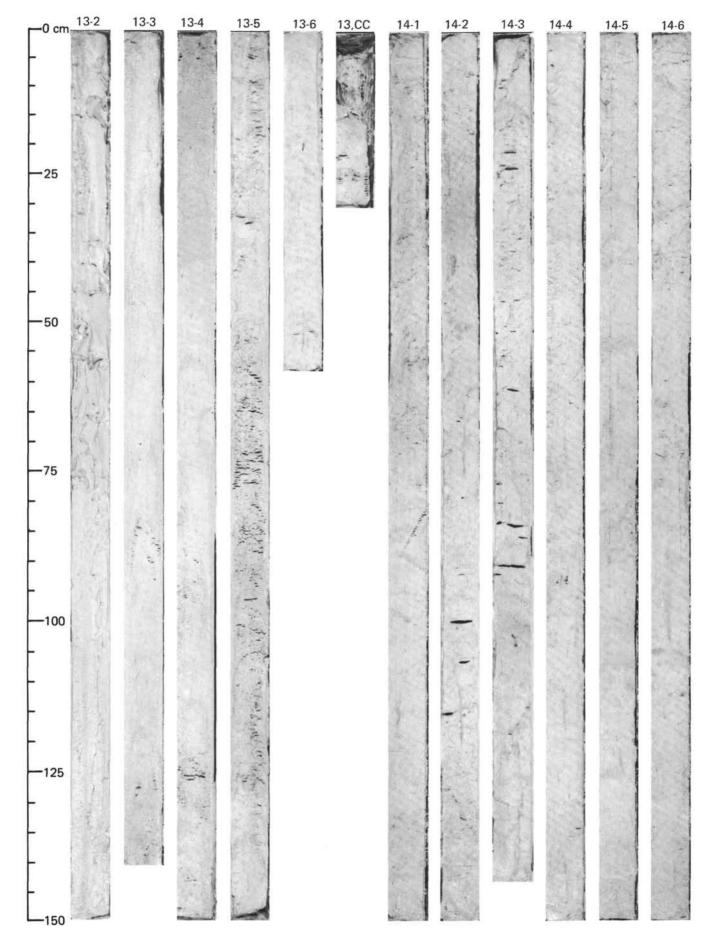
SITE 590 (HOLE 590A)

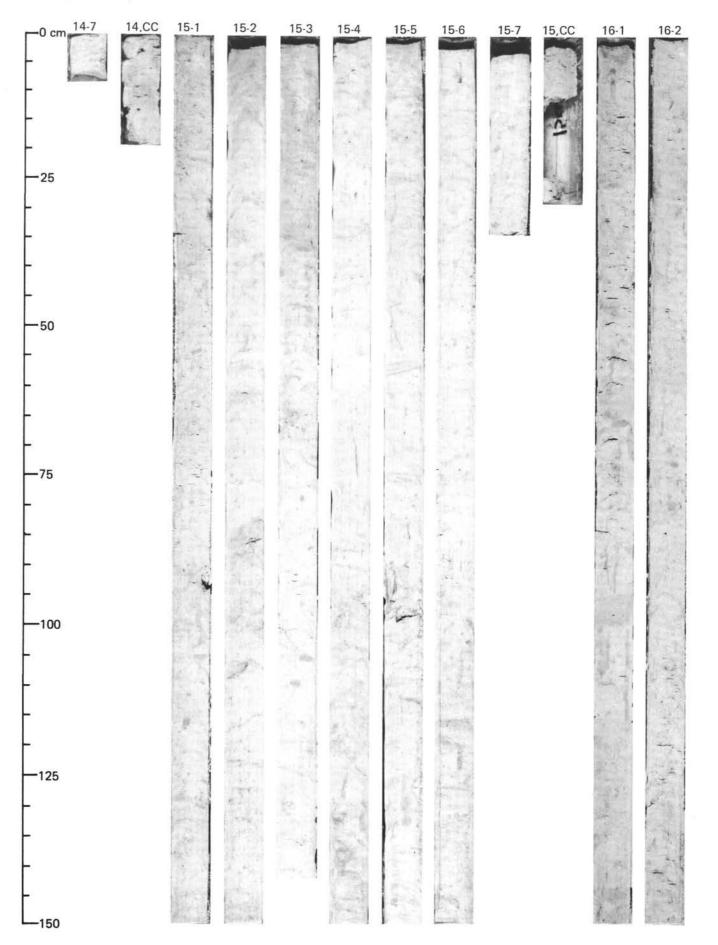
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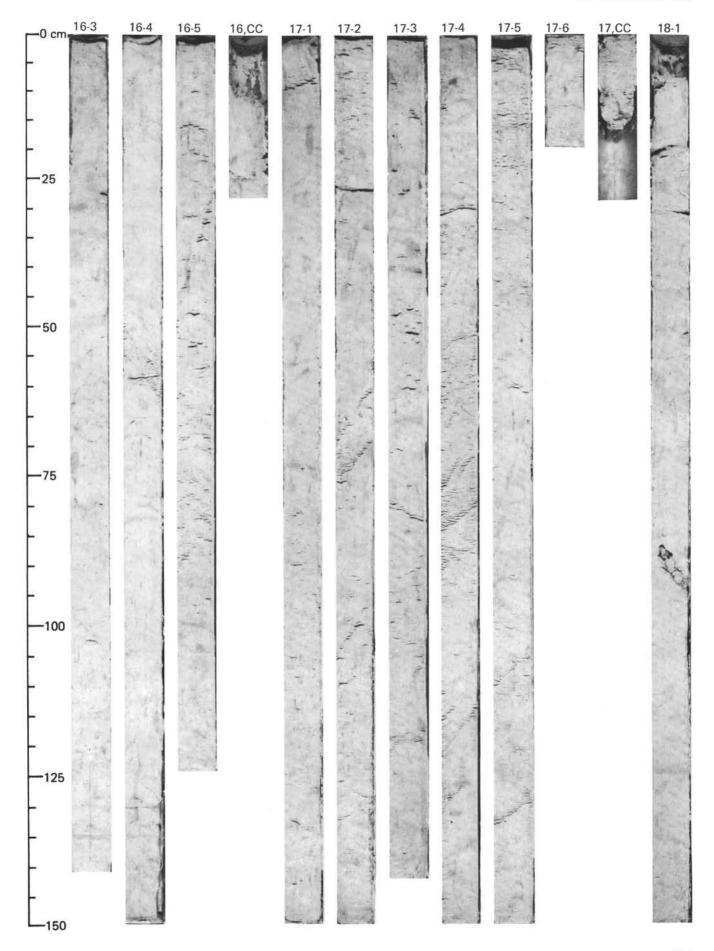


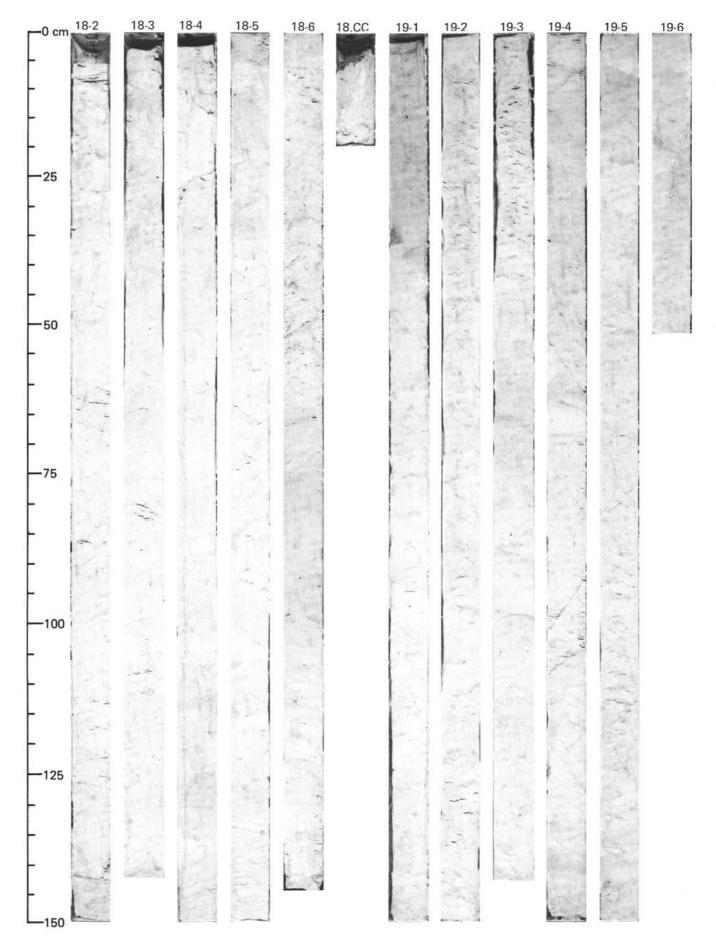
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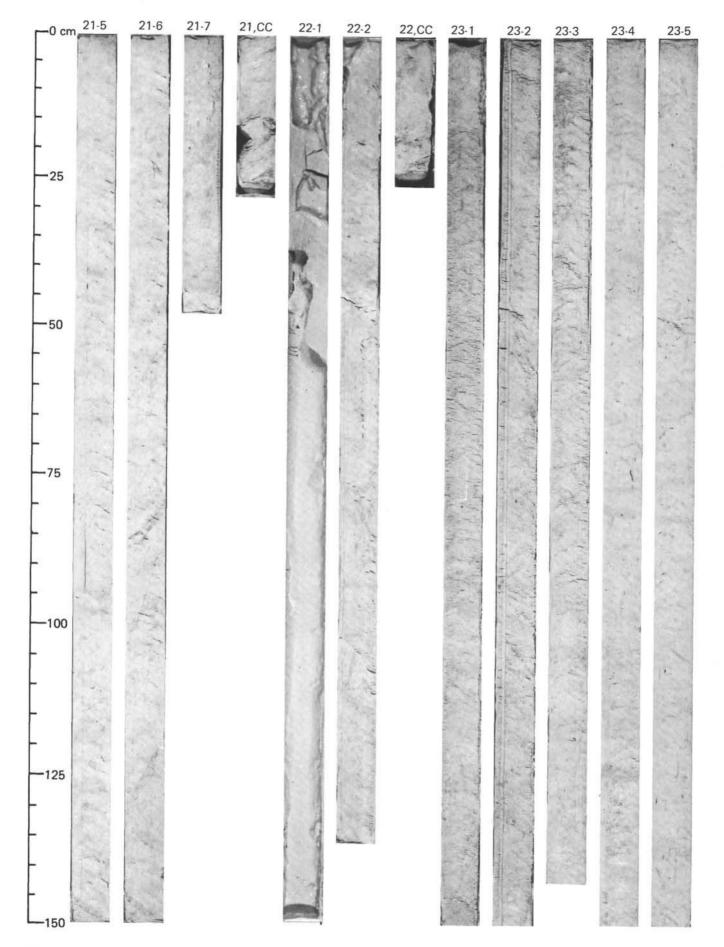




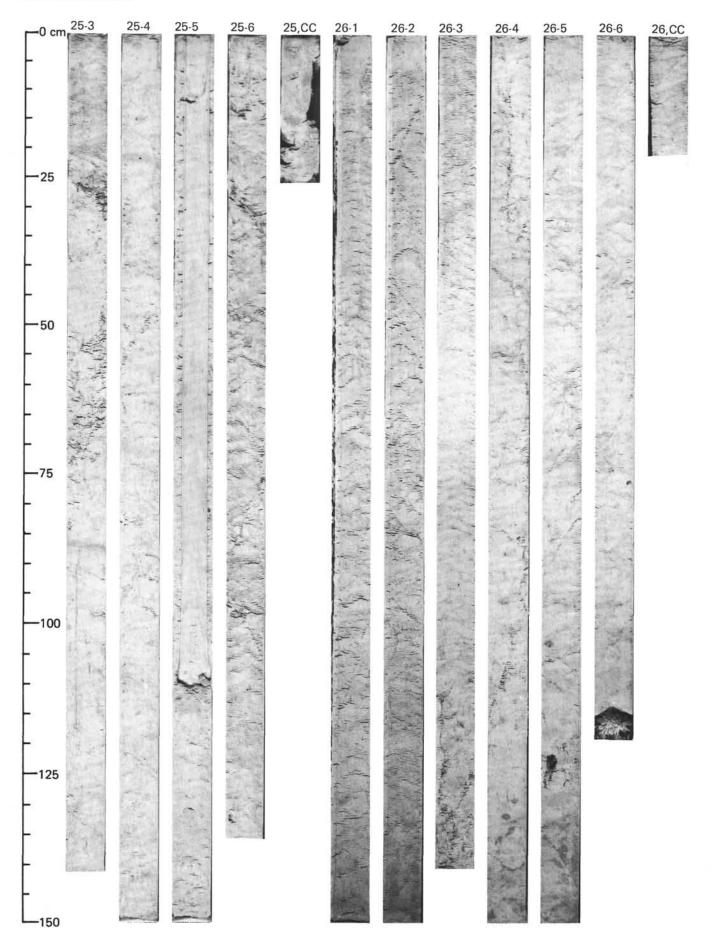




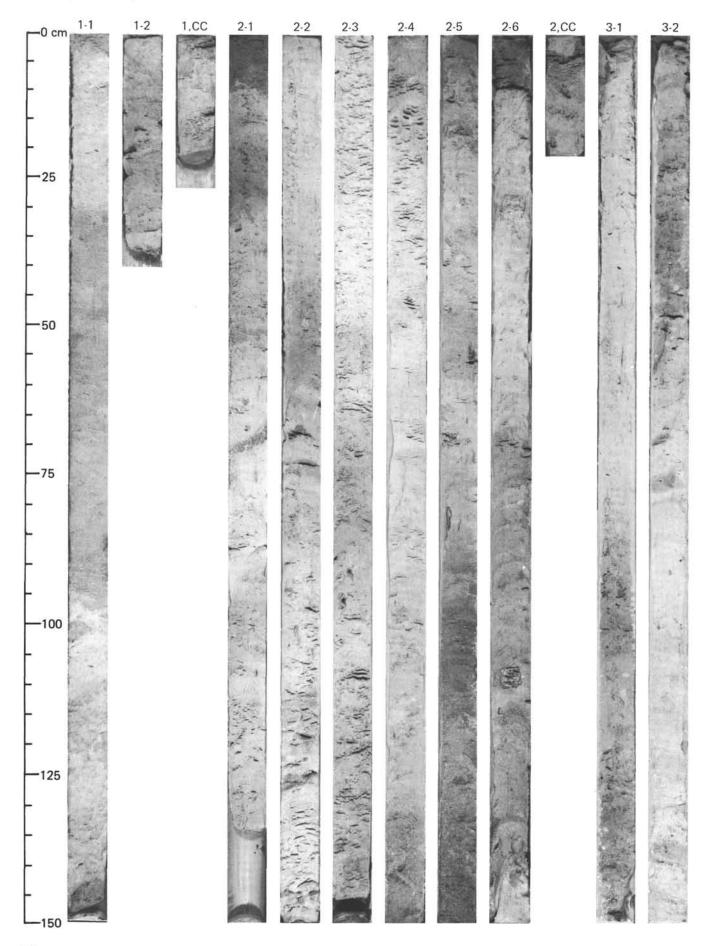
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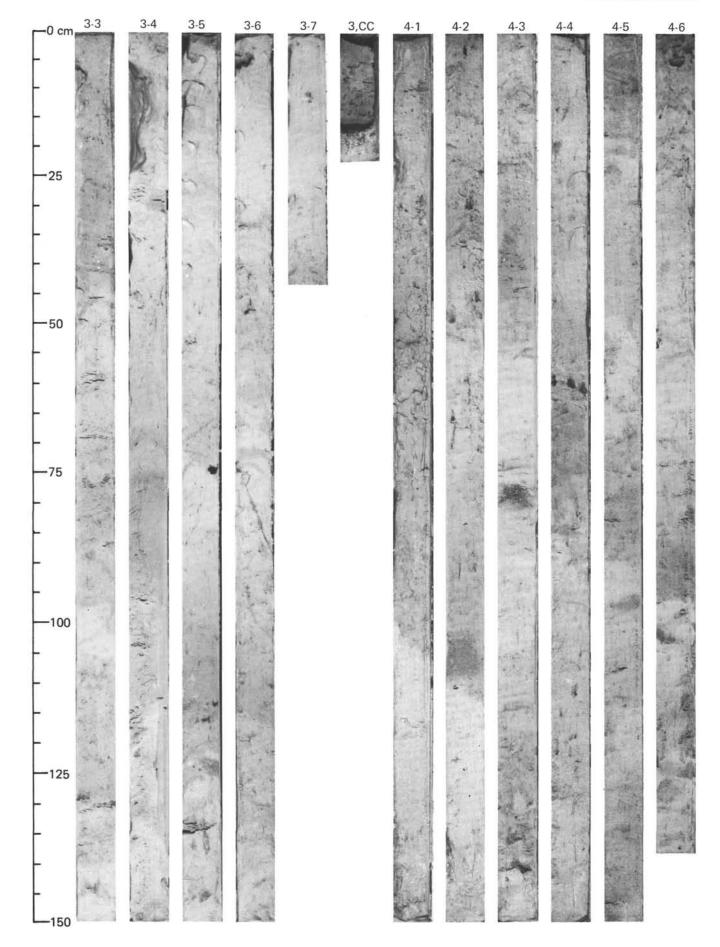


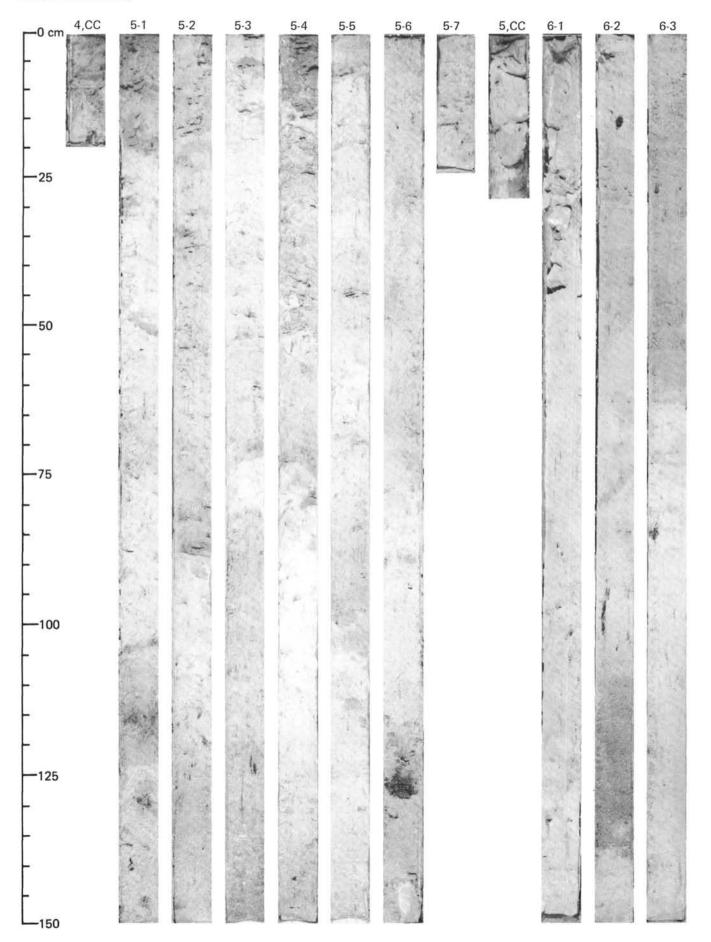
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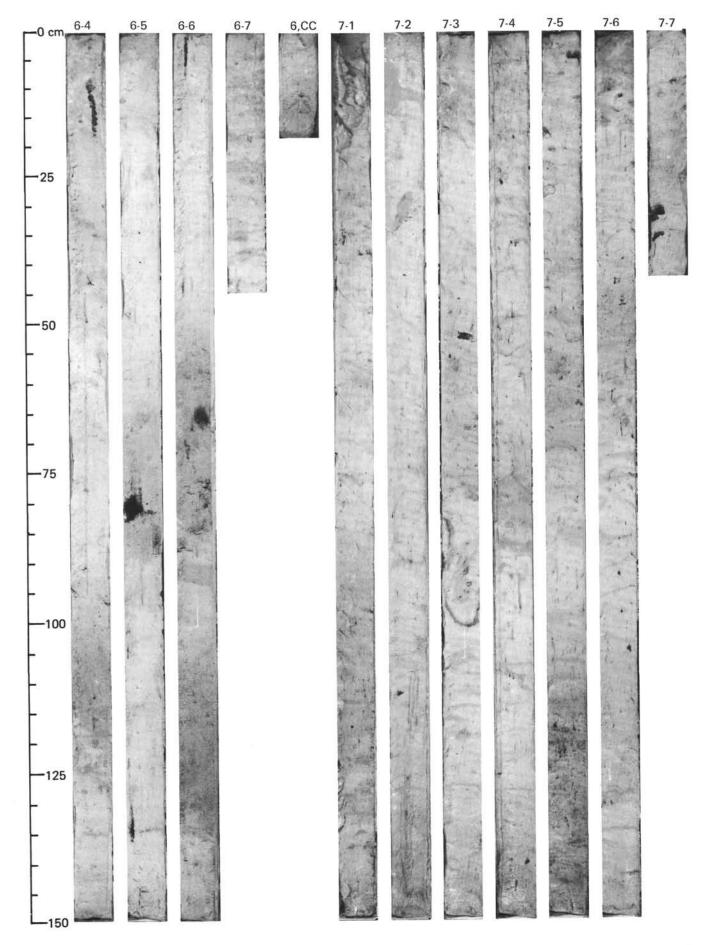


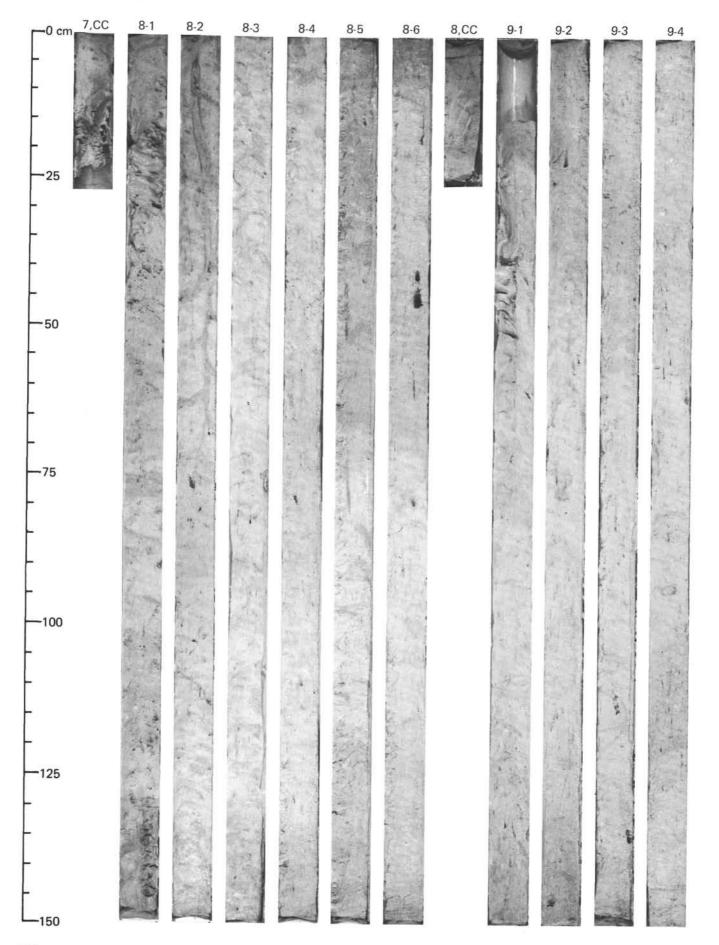
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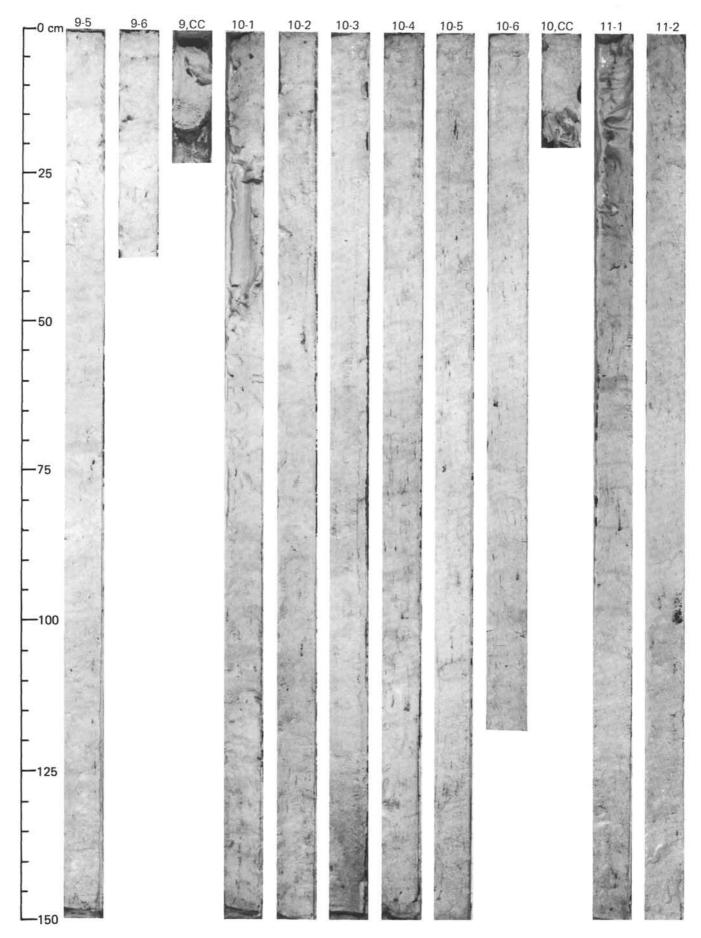


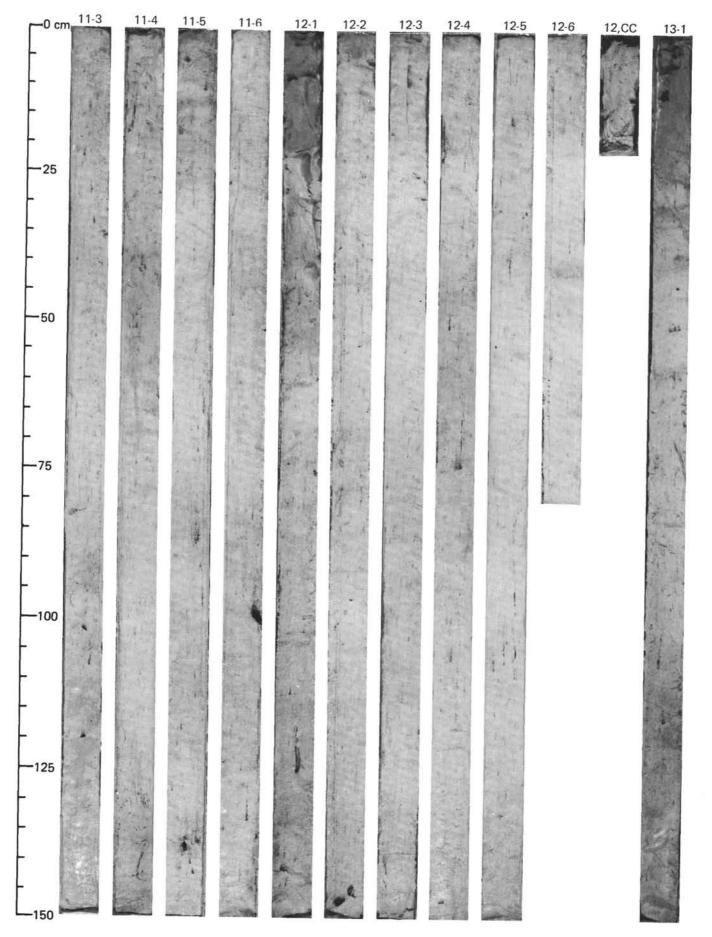


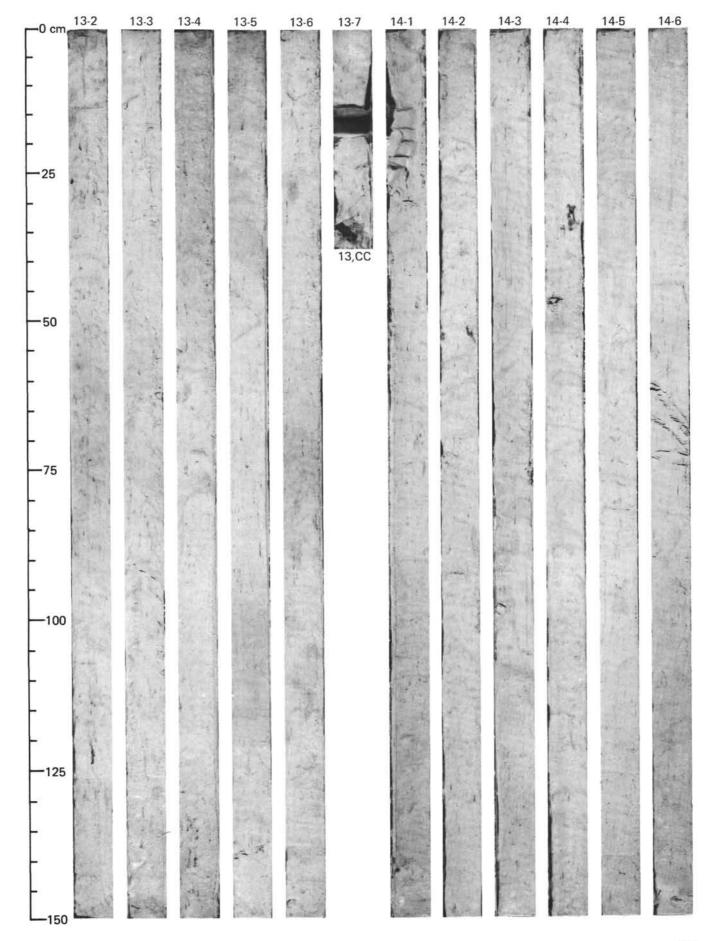


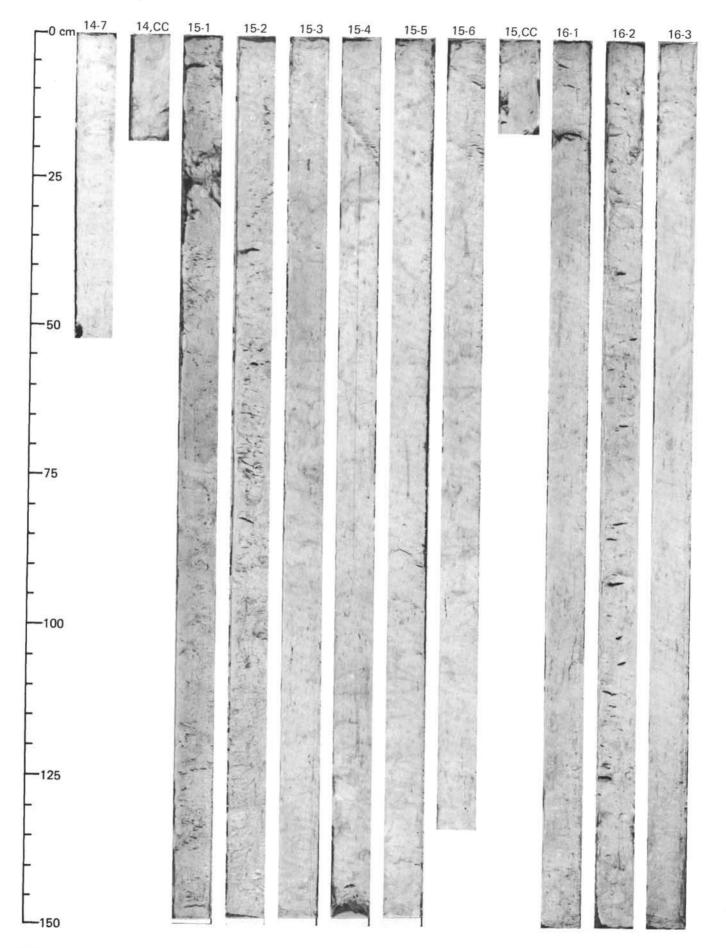


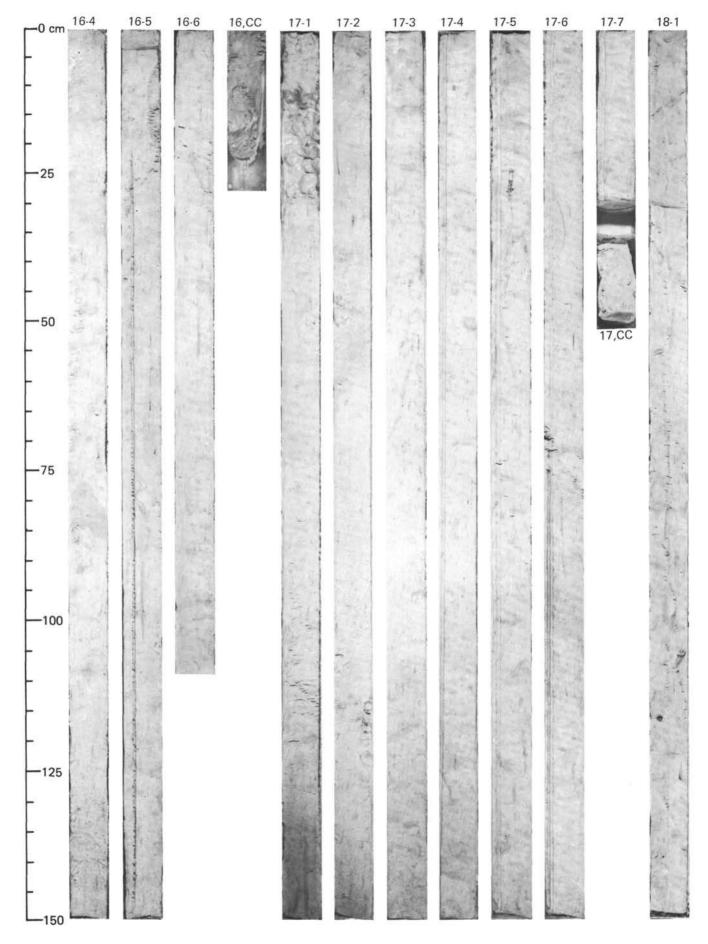


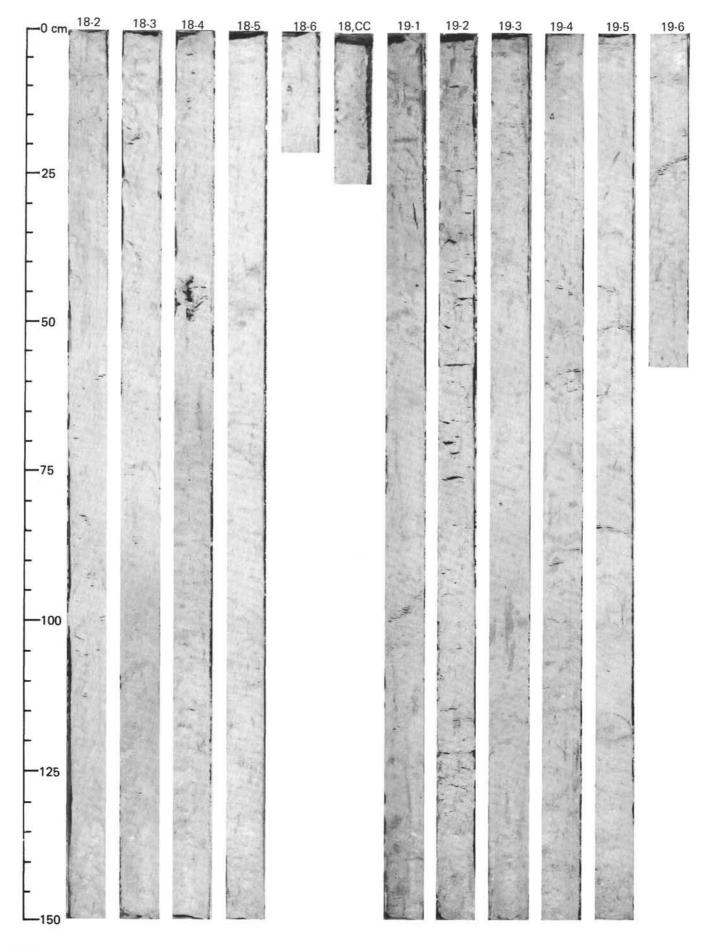


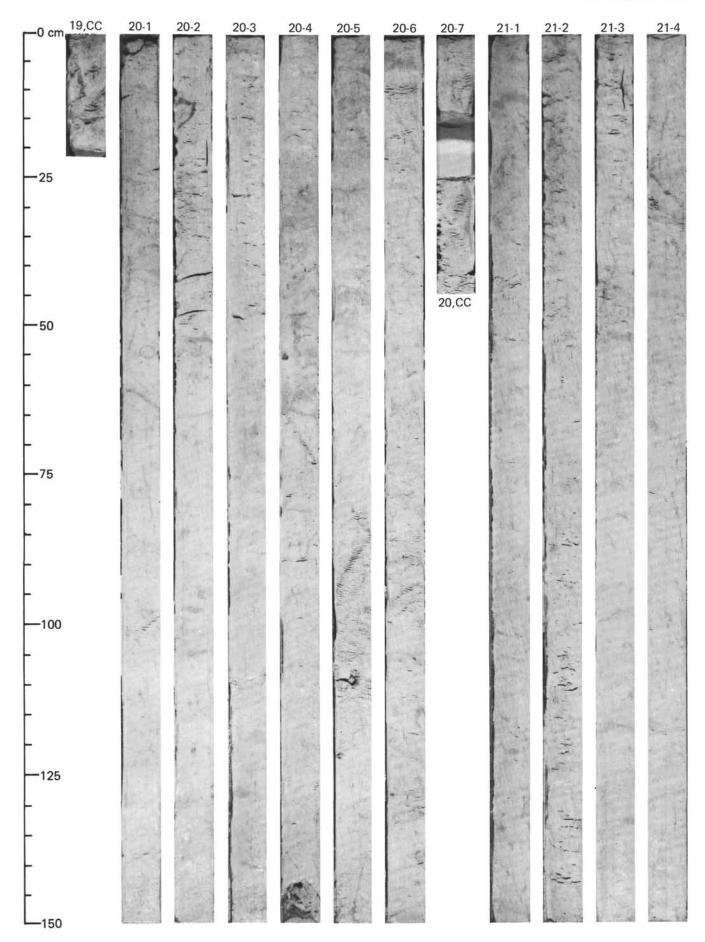


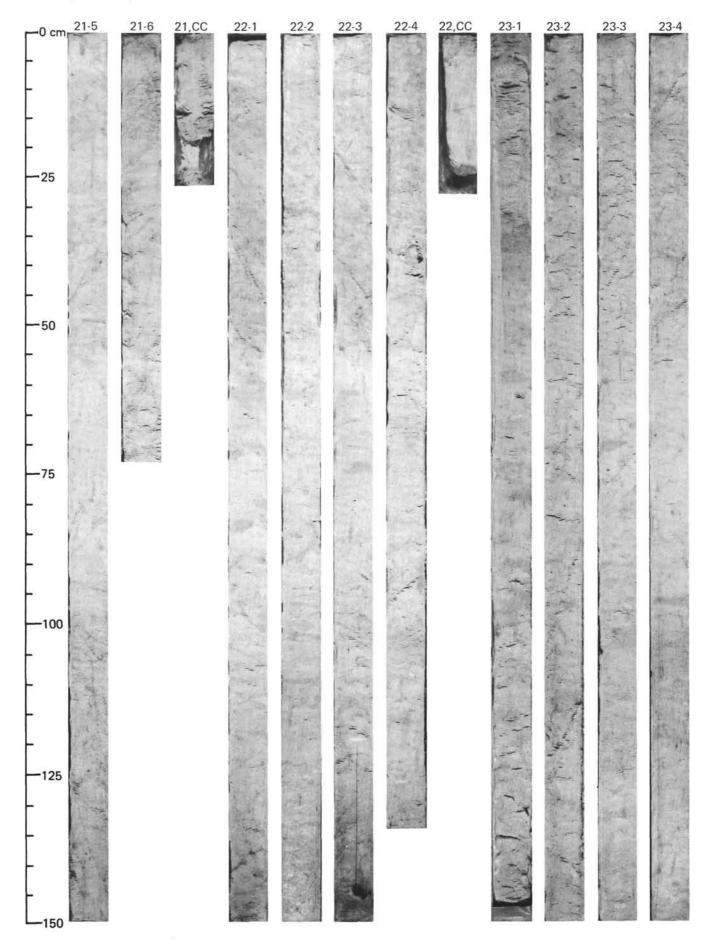




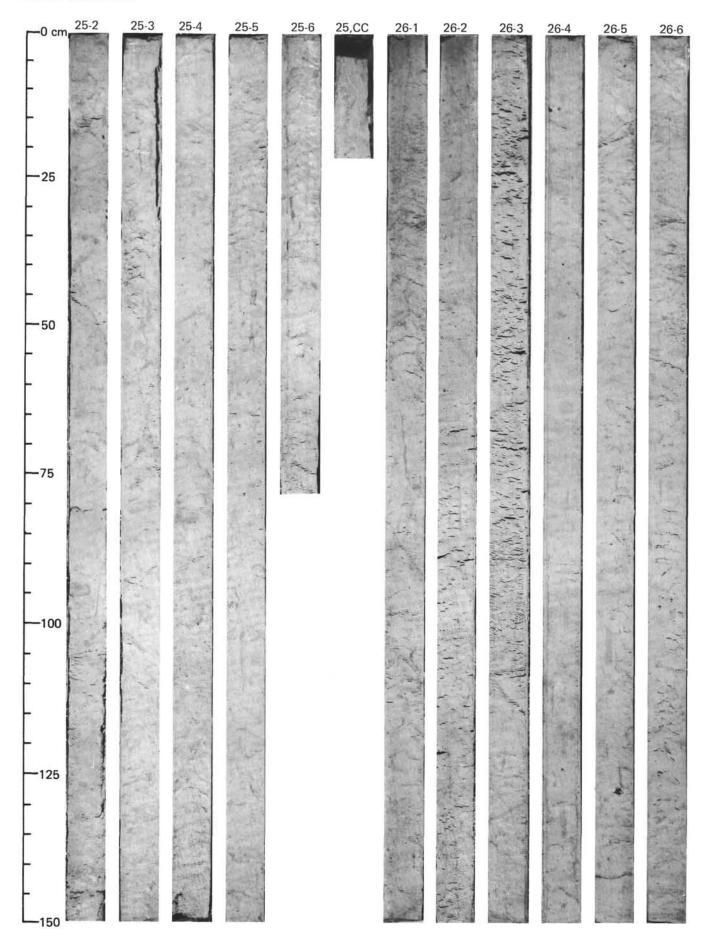






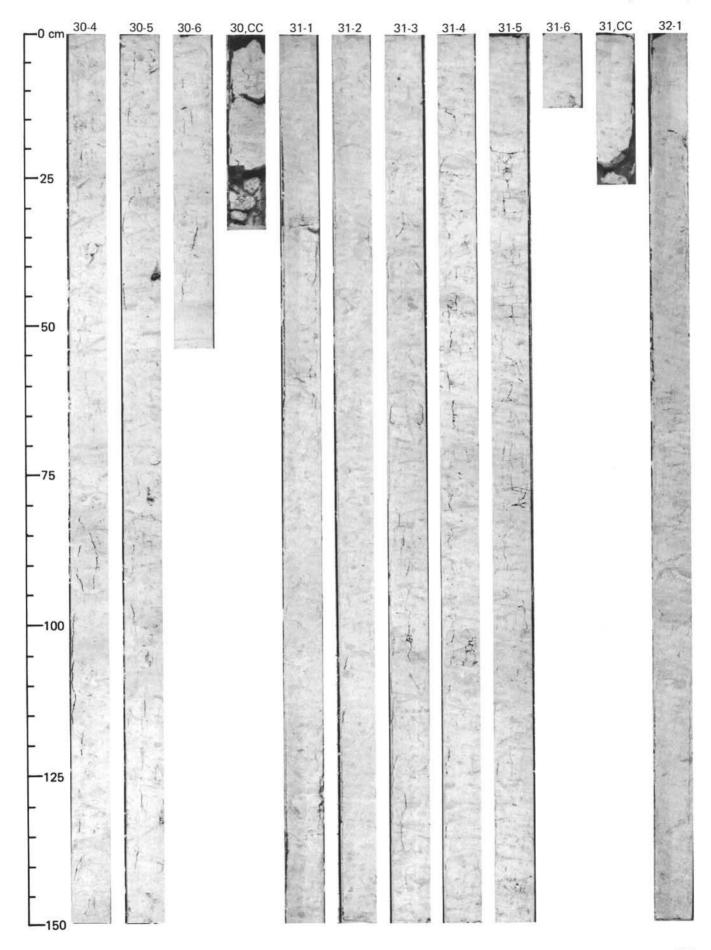


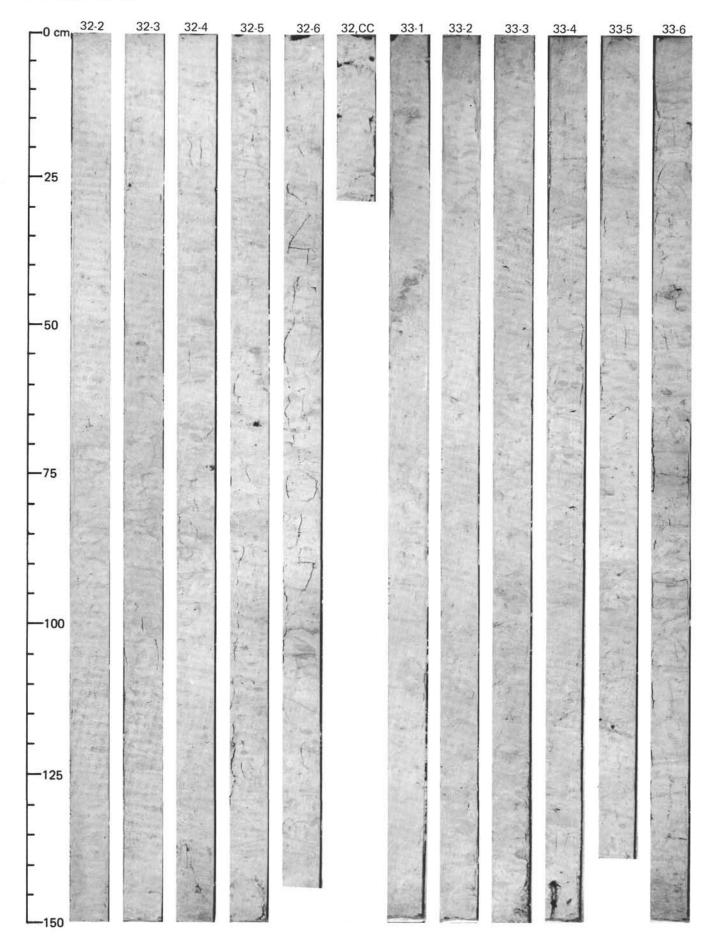
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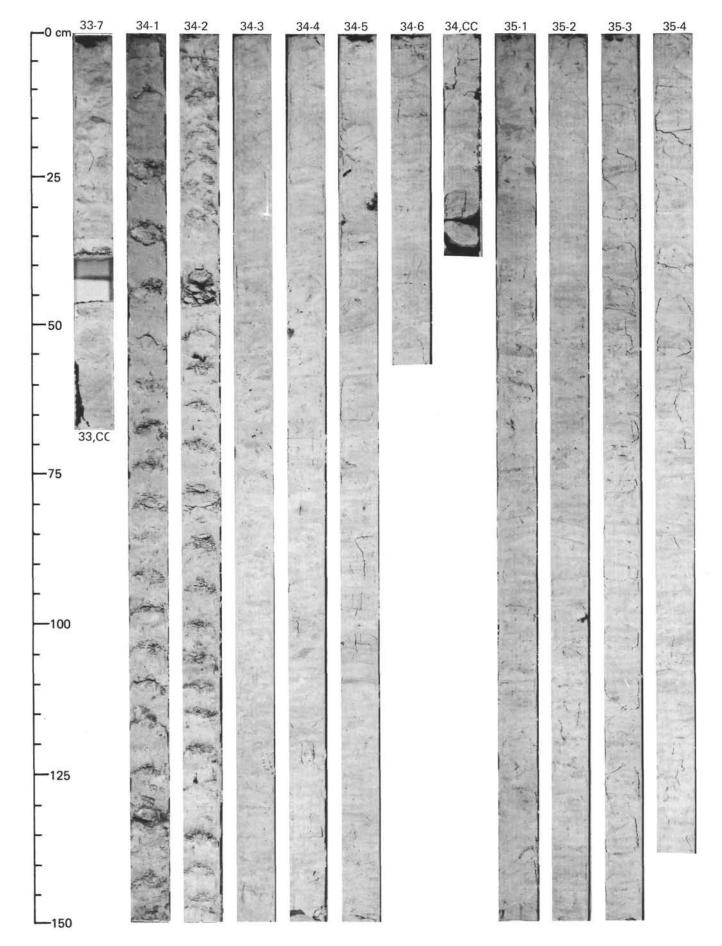


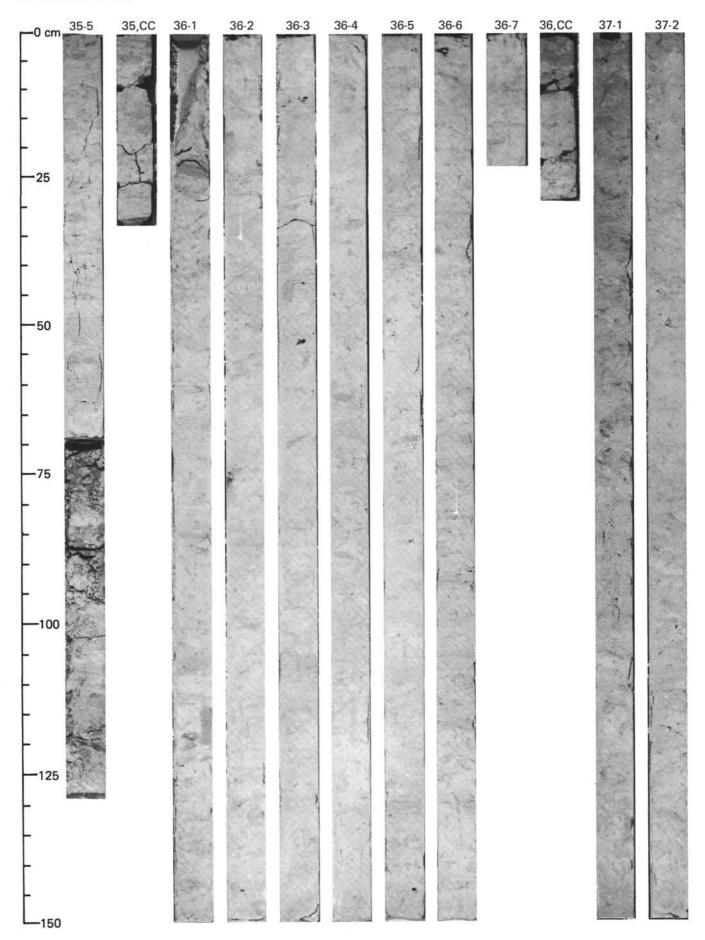
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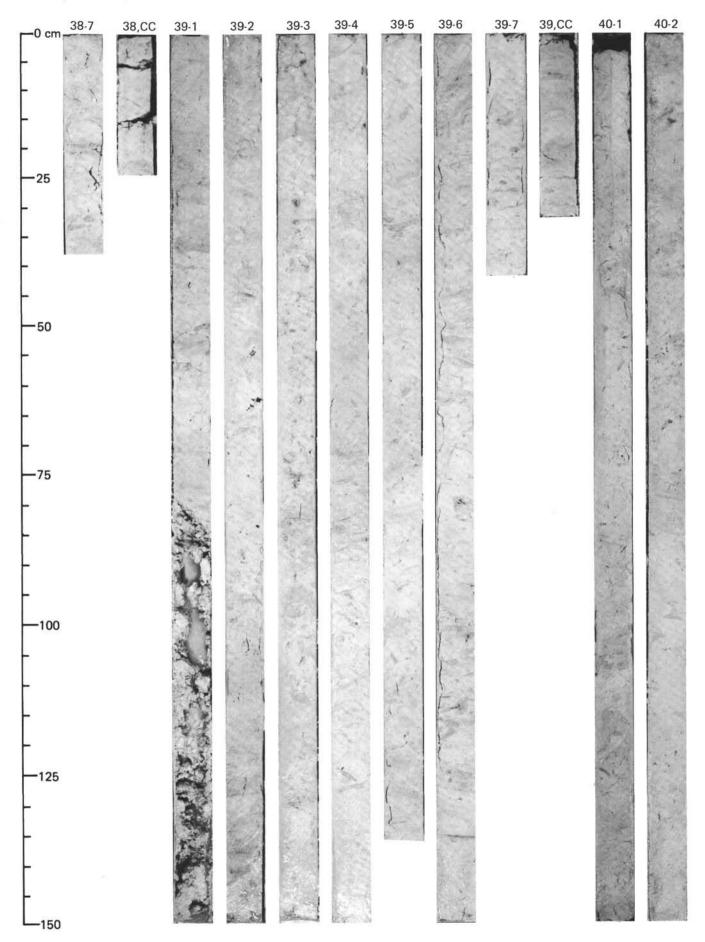








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