7. SITE 966¹

Shipboard Scientific Party²

HOLE 966A

Date occupied: 27 March 1995
Date departed: 27 March 1995
Time on hole: 15 hr, 45 min
Position: 33°47.799'N, 32°42.095'E
Bottom felt (drill-pipe measurement from rig floor, m): 937.7
Distance between rig floor and sea level (m): 11.1
Water depth (drill-pipe measurement from sea level, m): 926.6
Total depth (from rig floor, m): 1044.5
Penetration (m): 106.8
Number of cores (including cores having no recovery): 13
Total length of cored section (m): 106.8
Total core recovered (m): 73.2
Core recovery (%): 68.5
Oldest sediment cored:
Depth (mbsf): 106.80
Nature: carbonate conglomerate

HOLE 966B

Date occupied: 27 March 1995
Date departed: 28 March 1995
Time on hole: 15 hr, 30 min
Position: 33°47.765'N, 32°42.090'E
Bottom felt (drill-pipe measurement from rig floor, m): 937.8
Distance between rig floor and sea level (m): 11.1
Water depth (drill-pipe measurement from sea level, m): 926.6
Total depth (from rig floor, m): 1083.8
Penetration (m): 146.0
Number of cores (including cores having no recovery): 16
Total length of cored section (m): 146.0
Total core recovered (m): 96.5
Core recovery (%): 66.0
Oldest sediment cored:
Depth (mbsf): 146.00
Nature: conglomerate, matrix supported

HOLE 966C

Date occupied: 28 March 1995
Date departed: 29 March 1995
Time on hole: 14 hr
Position: 33°47.779'N, 32°42.089'E
Bottom felt (drill-pipe measurement from rig floor, m): 937.0
Distance between rig floor and sea level (m): 11.1
Water depth (drill-pipe measurement from sea level, m): 925.9
Total depth (from rig floor, m): 1064.0
Penetration (m): 127.0
Number of cores (including cores having no recovery): 17
Total length of cored section (m): 127.0
Total core recovered (m): 101.6
Core recovery (%): 80.0
Oldest sediment cored:
Depth (mbsf): 146.00
Nature: carbonate breccia

HOLE 966D

Date occupied: 29 March 1995
Date departed: 29 March 1995
Time on hole: 15 hr, 30 min
Position: 33°47.790'N, 32°42.048'E
Bottom felt (drill-pipe measurement from rig floor, m): 937.5
Distance between rig floor and sea level (m): 11.1
Water depth (drill-pipe measurement from sea level, m): 926.3
Total depth (from rig floor, m): 1074.0
Penetration (m): 136.5
Number of cores (including cores having no recovery): 20
Total length of cored section (m): 136.5
Total core recovered (m): 105.9
Core recovery (%): 77.0
Oldest sediment cored:
Depth (mbsf): 136.50
Nature: calcarenite

HOLE 966E

Date occupied: 29 March 1995
Date departed: 29 March 1995
Time on hole: 05 hr

¹Emeis, K.-C., Robertson, A.H.F., Richter, C., et al., 1996. *Proc. ODP, Init. Repts.*, 160: College Station, TX (Ocean Drilling Program).

²Shipboard Scientific Party is given in the list preceding the Table of Contents.

Position: 33°47.779'N, 32°42.083'E

Bottom felt (drill-pipe measurement from rig floor, m): 946.0

Distance between rig floor and sea level (m): 11.1

Water depth (drill-pipe measurement from sea level, m): 926.3

Total depth (from rig floor, m): 954.5

Penetration (m): 8.5

Number of cores (including cores having no recovery): 1

Total length of cored section (m): 8.5

Total core recovered (m): 8.5

Core recovery (%): 99.9

Oldest sediment cored:

Depth (mbsf): 8.50

Nature: nannofossil ooze

Earliest age: Pleistocene

HOLE 966F

Date occupied: 29 March 1995

Date departed: 1 April 1995

Time on hole: 1 day, 10 hr, 15 min

Position: 33°47.858'N, 32°42.093'E

Bottom felt (drill-pipe measurement from rig floor, m): 934.0

Distance between rig floor and sea level (m): 11.1

Water depth (drill-pipe measurement from sea level, m): 922.9

Total depth (from rig floor, m): 1290.0

Penetration (m): 356.0

Number of cores (including cores having no recovery): 31

Total length of cored section (m): 297.0

Total core recovered (m): 65.9

Core recovery (%): 22.1

Oldest sediment cored:

Depth (mbsf): 356.00

Nature: nannofossil ooze

Earliest age: Eocene

Principal results: Site 966, located toward the northern edge of the plateau area of the Eratosthenes Seamount, was the second site in the transect drilled across the Eratosthenes Seamount to the Cyprus margin. This site had two main objectives.

The first objective was paleoceanographic. It was to recover as complete as possible a record of Pliocene-Quaternary sapropels as an indicator of paleoenvironmental change in the easternmost Mediterranean Sea. Our efforts were rewarded by the recovery of more than 90 discrete sapropels, which increase markedly in abundance lower in the succession. Organic carbon values reach 11%. Many of the organic-rich layers are bioturbated and show geochemical evidence of partial oxidation of organic matter. Micropaleontological studies show that a complete Holocene-Pleistocene to early Pliocene record is preserved, with relatively uniform sedimentation rates of about 15 m/m.y. From the five APC holes drilled it was possible to establish a detailed correlation, based on high-resolution physical property measurements and lithologic data. The organic-rich layers recovered thus provide us with a critical record of changing paleoceanographic conditions during the Pliocene-Quaternary in this significant area of the Mediterranean Sea.

The second objective was tectonic. It was to infer the subsidence history of the plateau area of the Eratosthenes Seamount and the age and origin of the units beneath that could be recovered by drilling to 350 mbsf. The Pliocene-Quaternary succession was found to be dominated by nan-

Figure 1. Outline bathymetric map showing the location of Site 966 relative to the others on the north-south transect across the Eratosthenes Seamount. Bathymetric data are from the ETOPO5 data set.

nofossil ooze. Volcanic ash is disseminated throughout, and the succession shows limited evidence of tectonic instability and faulting especially near the base. This is followed by distinctive matrix-supported breccias, in which mainly limestone clasts are scattered through a clay-rich matrix. This unit is interpreted as the result of rapid deposition by mass-flow processes, and is of early Pliocene age. The next unit is shallow-water limestone of Miocene age, which accumulated in a shallow-water, near-reef setting and can be lithologically correlated with a similar limestone at Site 965. The final unit recovered is pelagic chalk of middle Eocene age, with scattered chert nodules, which is considered a counterpart of the Lefkara Formation of southern Cyprus. Site 966 therefore records Eocene deep-sea carbonate sedimentation, Miocene(?) shallow-water carbonate deposition, an episode of major, probably fault-induced, deposition in the early Pliocene (and possibly earlier), and finally more stable deep-water Pliocene-Quaternary deposition. Improved paleontological dating of the pre-Pliocene deposits and quantitative assessment of the subsidence history are key topics for post-cruise tectonic studies.

BACKGROUND AND OBJECTIVES

Site 966 is located near the northern margin of the plateau area of the Eratosthenes Seamount in a water depth of 940 m (Fig. 1; see "Geological Setting" section, this chapter). The site was selected to accommodate both paleoceanographic and tectonic objectives. From the paleoceanographic standpoint, interpretation of the available site-survey data had indicated that the Pliocene and Pleistocene succession, with an estimated thickness of approximately 100 m, is significantly expanded and more level bedded and uniform in character than farther south on the Eratosthenes plateau area. Although the entire plateau area has been subject to recent faulting, Site 966 was located away from seismically imaged fault scarps (Limonov et al., 1994; Robertson et al., 1994c, 1995). On the other hand, the Pliocene-Quaternary could be penetrated at Site 966 to reveal the character of the underlying units; they constituted the main tectonic targets at this site.

The Pliocene and Pleistocene sedimentary units were expected to provide a complete record of sapropel formation in the eastern subsidence basin, and this site constitutes the shallow-water member of a longitudinal and depth transect across the Mediterranean Sea. Situated underneath the present-day area of intermediate-water formation (Levantine Intermediate Water, a component of Mediterranean Intermediate Water), the depth interval at Site 966 corresponds to the lower depth of MIW (i.e., 1000 m; Wüst, 1961). The top of Eratosthenes

Seamount is close to the Nile River—a possible source of fresh water during sapropel formation—without being affected by fan deposition of the Nile Cone. A core previously recovered from the top of the seamount (Core KC20; “Cruise Report *R/V Marion Dufresne* Cruise MARFLUX II,” unpubl. data) documented sapropel occurrences back to the middle Pleistocene and sedimentation rates of approximately 15 m/m.y. The record at Site 966 was thus expected to extend back into the early Pliocene.

Our principal sapropel-related objective was to construct a detailed age model from the sedimentary record through continuous and highly resolved measurements of physical parameters (density, susceptibility, color) and sedimentological correlation, which can be linked to magnetostratigraphic and paleontological age models. The composite section at Site 966 will be tied to the stratigraphic record to be provided by Site 964; this will permit detailed comparison of environmental gradients (salinity, temperature, nutrients) and their chemical and paleontological expressions across the Eastern Mediterranean during times of sapropel deposition.

Objectives from the tectonic point of view were (1) to determine if the Pliocene-Quaternary sediments accumulated under more stable tectonic conditions than those recorded on the present-day northern slopes of the seamount (i.e., Sites 965, 967, and 968); (2) to work out the subsidence history, if any, relative to the other Eratosthenes Seamount transect sites; (3) to determine the lithology, physical properties, age, and origin of the prominent seismic reflector at the base of the Pliocene-Quaternary succession, and the same for a less distinct inclined reflector at greater depth; and (4) to shed light on late Miocene paleoenvironments in relation to desiccation and refilling of the Mediterranean Sea.

GEOLOGICAL SETTING

Site 966 is located near the northern margin of the plateau area of the Eratosthenes Seamount (Fig. 2). The site-survey data, including swath bathymetry conducted by *Academician Nikolai Strakhov*, indicate that the plateau area is relatively flat, but cut by a number of nearly east-west-trending lineaments, interpreted as active normal faults (Robertson et al., 1994a, 1994b; Limonov and Woodside, 1994). The Pliocene-Quaternary sediments of the plateau area are semitransparent and of relatively constant thickness, although they thicken somewhat in the north in the vicinity of Site 966 (Fig. 2). The upper part of the Pliocene-Quaternary succession at Site 966 was cored during the *Gelendzhik* site-survey cruise (Cores 109, 110, and 111 G), and recovered nannofossil oozes, with intercalated sapropels (S1 and S5) and the Y5 tephra (Lucchi et al., 1994).

The *Gelendzhik* air-gun seismic data reveal a number of faults that cut a prominent reflector at the base of the Pliocene-Quaternary succession (Fig. 3). In most cases, the Pliocene-Quaternary sediments appear to be draped over and not offset by these faults, implying that faulting predated sedimentation. On the other hand, some of the large, mainly east-west-trending normal faults give rise to distinct steps in the plateau topography, with vertical offsets of up to several hundred meters. These normal faults extend to the seafloor and expose lithified rocks on their walls, suggesting that they are still active today.

The top of the highly reflective interval beneath the Pliocene-Quaternary succession shows local irregularities (on a scale of hundreds of meters) that could be erosion features or fault effects (see “Site Geophysics” section, this chapter). In addition, a prominent inclined reflector at greater depth could record an additional lithologic change that could be tested by drilling at Site 966.

Wide-beam OKEAN sonar records across the southwestern edge of the plateau area reveal two sets of faults, the first north-south and the second northeast-southwest striking. Crosscutting relations sug-

Figure 2. Location of Site 966. Note the semitransparent upper Pliocene-Quaternary sediments and the highly reflective unit beneath that was shown by drilling to be shallow-water limestone. Part of TREDMAR Line 120, 1993.

gest that the north-south fault is older (Alibes et al., 1994), but the data are insufficient to generalize.

An important, but previously not well-understood, feature revealed in the high-resolution MAK-1 profiler records is the presence of trains of small (i.e., several tens of meters in wavelength) anticlines and synclines within the lower part of the inferred Pliocene-Quaternary succession (Beijdorff et al., 1994; Fig. 4). Such folds could be the result of compression affecting the seamount as a whole or the effects of more local rotation of fault blocks in the underlying pre-Pliocene-Quaternary. Although such folds affect mainly the lower part of the Pliocene-Quaternary succession, in places even the uppermost levels of the succession show subtle seismic evidence of disturbance.

The available site-survey data, thus, suggest that the Eratosthenes plateau area existed as a rugged, fault-controlled topography in the pre-Pliocene-Quaternary (?Messinian). Sediments draped over these faults during the Pliocene-Quaternary imply the existence of syn-depositional compression resulting in folding, disconformities, and small-scale angular discordances. A number of large east-west-trending normal faults remain active at the present time. The seismic evidence could be taken to indicate that a major phase of faulting (late Miocene?) was followed by a relatively tectonically quiescent phase (early Pliocene?), during which compression was active, followed by further important extensional faulting continuing to recent time. Drilling constituted a test of these inferences and provided critical evidence of the timing of tectonic movements.

OPERATIONS

Transit to Site 966

The 8-nmi sea voyage to Site 966 (proposed Site ESM-1A) required 0.7 hr at an average speed of 11.4 kt. A Datasonics 354M beacon (S/N 783, 15.0 kHz) was deployed at 0558 hr on 27 March 1995.

Hole 966A

The same APC/XCB BHA used at the previous sites was used on Site 966: a 10 1/8-in. RBI PDC bit, APC/XCB BHA with a nonmagnetic drill collar, and the subs required to run the motor-driven core barrel.

Figure 3. Position of Site 966 on the northern part of the Eratosthenes Seamount plateau area. Note the fault-controlled steps in the bathymetry. Most of these faults are inferred to be pre-Pliocene in age, but some are still active. Part of TREDMAR Line 120, 1993.

Hole 966A was spudded at 0940 hr on 27 March. A 5.84-m-core was recovered, indicating a seafloor depth of 926.6 m by drill-pipe measurement. APC Cores 160-966A-1H through 9H were taken from 0 to 68.3 mbsf, with 68.3 m cored and 68.83 m recovered (12.9% recovery, Table 1). Cores were oriented from Core 160-966A-4H. ADARA heat-flow measurements were taken on Cores 160-966A-5H, 7H, and 9H. Core 160-966A-9H was a partial stroke that bottomed in a hard limestone. The maximum gas detected was 4 ppm methane.

XCB Cores 160-966A-10X through 13X were taken from 68.3 to 106.8 mbsf, with 38.5 m cored and 4.38 m recovered (11.4% recovery, Table 1). XCB recovery was poor in limestones and carbonate debris using a standard shoe and 8- and 9-finger core catchers. All four cores jammed in the shoe. Overall recovery was 68.5%. The bit cleared the seafloor at 2146 hr on 27 March.

Hole 966B

The ship was offset 78 m to the south. Hole 966B was spudded at 2345 hr on 27 March. Core 160-966B-1H indicated a seafloor depth of 926.6 m. APC Cores 160-966B-1H through 10H were taken from 0 to 90.3 mbsf, with 90.3 m cored and 90.32 m recovered (100% recovery, Table 1). Cores were oriented from Core 160-966B-3H. Cores 160-966B-8H through 10H had partial strokes, but piston coring continued because the XCB had very poor recovery and suck-in disturbance in the APC cores could be detected. The maximum gas detected was 3 ppm methane. Core 160-966B-10H bottomed in hard limestone reef debris.

XCB Cores 160-966B-11X through 16X were taken from 90.3 to 146.0 mbsf, with 55.7 m cored and 6.14 m recovered (11% recovery). XCB recovery was poor in limestones and carbonate breccia using a hard-formation tungsten carbide shoe and 8- and 9-finger core catchers. All four XCB cores jammed in the shoe. Overall recovery was 66%. The bit cleared the seafloor at 1312 hr on 28 March.

Hole 966C

The ship was offset 20 m to the north. Hole 966C was spudded at 1400 hr on 28 March. Core 160-966C-1H indicated a seafloor depth of 925.9 m. APC Cores 160-966C-1H through 11H were taken from 0 to 95.1 mbsf, with 95.1 m cored and 99.13 m recovered (104.2% recovery, Table 1). Cores were oriented from Core 160-966C-3H. The formation was a nannofossil ooze with numerous sapropels. Cores 160-966C-9H and 10H had partial strokes, but piston coring continued because the XCB had very poor recovery and suck-in disturbance in the APC cores could be detected. Core 160-966C-11H failed to penetrate and there was no pull-out.

XCB Cores 160-966C-12X through 17X were taken from 95.1 to 127.0 mbsf, with 31.9 m cored and 2.47 m recovered (7.7% recovery). XCB recovery was poor in the nannofossil ooze using a hard-formation tungsten carbide shoe and 8- and 9-finger core catchers. One-half of the XCB cores jammed in the shoe. Overall recovery was 80%. The bit cleared the seafloor at 0320 hr on 29 March.

Hole 966D

The ship was offset 10 m to the north. Hole 966D was spudded at 0350 hr on 29 March. Core 160-966D-1H indicated a seafloor depth of 926.3 m. APC Cores 160-966D-1H through 10H were taken from 0 to 84.5 mbsf, with 84.5 m cored and 91.80 m recovered (108.6% recovery, Table 1). Cores were oriented from Core 160-966D-3H. The liner shattered on Core 160-966D-9H. Core 160-966D-10H hit a large cobblestone and bottomed in a well-compacted carbonate debris flow with sporadic cobblestones.

XCB "half" Cores 160-966D-11X through 20X were taken from 88.5 to 136.5 mbsf, with 52.0 m cored and 14.14 m recovered (27.2% recovery). XCB recovery was poor in the nannofossil ooze with sporadic cobblestones, which jammed the liner and shoe, acting as center bits. A short-extension hard-formation tungsten carbide shoe was

Figure 4. Part of the MAK-1 high-resolution profiler seismic record (view from above overlies the profile) showing trains of small anticlinal structures within the lower part of the Pliocene-Quaternary succession. Such structures imply compressional deformation during sedimentation. The location is on MAK Line 22 on the uppermost northern slopes of Eratosthenes Seamount. Similar deformation structures are present in the vicinity of Site 966 (32°48'N, 33°50'E).

used with 8- and 9-finger core catchers. All but one of the XCB cores jammed in the shoe. Overall recovery was 80%. The bit cleared the seafloor at 1838 hr on 29 March.

Hole 966E

The ship was offset 10 m to the north. Hole 966E was spudded at 1900 hr on 29 March. The single mud-line core taken indicated a seafloor depth of 926.3 m below rig floor (mbrf). APC Core 160-966D-1H was taken from 0 to 8.5 mbsf with 8.5 m cored and 8.48 m recovered (99.7% recovery). The APC/XCB BHA was pulled out of the hole, and the bit cleared the rotary at 2345 hr on 29 March.

Hole 966F

An RCB BHA was assembled, and Hole 966F was spudded at 0550 hr on 30 March. The hole was drilled to 59.0 mbsf. RCB Cores 160-966F-1R through 31R were taken from 0 to 356.0 mbsf, with 297.0 m cored and 65.85 m recovered (22.1% recovery). The rotary stalled and the pipe stuck with 65-klb overpull at 1074.0 mbrf. The McCullough jars were hit down one time to free the string. A 15-bbl high-viscosity gel sweep was pumped every other core from Core 106-966F-9R.

Logging Operations at Hole 966F

A short trip was made to condition the hole for logs. No drag and 2.5 m of light fill at the bottom indicated good hole conditions for

logging. The hole was displaced with 9.0-ppg sepiolite/seawater mud, the bit was released with the mechanical bit release, and the sleeve was shifted shut. The pipe was pulled back to 87.9 mbsf for logging. The Quad combination, FMS, and GHMT logs were run to 355 mbsf with no fill. Logging finished at 0700 hr on 1 April, and the bit was pulled, clearing the rotary table at 0955 hr on 1 April. The beacon was recovered, and the transit to Site 967 began at 1150 hr.

SITE GEOPHYSICS

Two seismic profiles were made across this site: east to west and south to north (Fig. 5). Although the south to north line connects directly with Site 965, there are two fault zones between the two, making the correlation of reflectors at the sites problematic. The character of the reflecting horizons remains, in general, the same at both sites, but there are several interesting differences. At each fault zone there is a vertical shift of about 300 ms two-way traveltime (TWT), or about 225 m; thus, Site 966 is about 570 m shallower than Site 965. It is situated on a relatively elevated fault-bounded block at the north edge of the upper plateau region of the seamount. This block is more extensive in all directions than the block on which Site 965 was drilled.

The upper seismic facies at Site 966 has very low-amplitude chaotic reflectors that are barely visible on the ship's seismic data (Fig. 6). This has been described as a relatively reflection-free unit of presumed post-Miocene age according to previous interpretations (Limonov et al., 1994). It is probably the same unit as at Site 965, but it differs in the slightly greater distortion of reflectors near the base and in the strong reflector defining the base. At Site 966 the strong reflector has a very broken appearance, is not as strong and continuous, and lies slightly deeper (about 140 ms TWT). This site was chosen because the intention here was to obtain a good sequence of sapropels from a thick accumulation of pelagic sediments above the consolidated sediments that make up the more reflective sequences below.

Below the discontinuous strong reflector at the base of the upper unit are at least two medium to strong discontinuous reflectors. The deepest of these lies at about 475 ms TWT below the seafloor at both Sites 965 and 966. It can be seen to dip at up to 7° or 8° to the north. At Site 966 the intermediate reflectors are also seen more clearly on the cross line. A reflector at about 325 ms TWT at Site 966 deepens to the north to a depth of about 425 ms TWT below the seafloor at Site 965, thinning the unit below in the process. This reflector appears relatively horizontal in the east-west line but dips to the north at Site 966 at roughly the same angle as the deeper reflector. Both these reflectors dip at progressively lower angles across the two fault zones to the north, but may become more westward dipping by Site 965.

At Site 966, the deeper reflectors appear to be truncated by a relatively strong continuous reflector that dips westward at about 4°. This reflecting horizon is itself truncated by the strong relatively horizontal reflector below the upper sedimentary unit. Thus, there are two apparent angular unconformities observed. The strong westward-dipping reflector intersects the unconformity surface below the upper unit at a distance of about 1100 m to the east of Site 966, and the thickness of the wedge of sediments above it is about 80 ms TWT at Site 966 (between 140 ms and 220 ms TWT below the seafloor).

The character of the strong reflector beneath the upper sedimentary unit changes along the east-west line but not along the north-south line. In the vicinity of Site 966, it appears to be slightly weaker, slightly shallower, and slightly less continuous than to the west or to the east. Possible explanations for this apparent facies change are variations in the lithologies truncated along the angular unconformity, destruction of sedimentary structures by water circulation facilitated by the presence of the dipping unconformity below, or the presence of debris shed onto the unconformity from previously elevated topography nearby.

Table 1. Coring summary for Site 966.

Core	Date (March 1995)	Time (UTC)	Depth (mbsf)	Length cored (m)	Length recovered (m)	Recovery (%)
160-966A-						
1H	27	0750	0.0–5.8	5.8	5.84	100.0
2H	27	0815	5.8–15.3	9.5	8.47	89.1
3H	27	0845	15.3–24.8	9.5	9.12	96.0
4H	27	0935	24.8–34.3	9.5	9.87	104.0
5H	27	1030	34.3–43.8	9.5	10.00	105.2
6H	27	1100	43.8–53.3	9.5	9.93	104.0
7H	27	1150	53.3–62.8	9.5	10.01	105.3
8H	27	1225	62.8–66.3	3.5	3.59	102.0
9H	27	1320	66.3–68.3	2.0	2.00	100.0
10X	27	1435	68.3–78.0	9.7	3.64	37.5
11X	27	1540	78.0–87.6	9.6	0.19	2.0
12X	27	1645	87.6–97.2	9.6	0.30	3.1
13X	27	1840	97.2–106.8	9.6	0.25	2.6
Coring totals:				106.8	73.2	68.5
160-966B-						
1H	27	2150	0.0–7.7	7.7	7.73	100.0
2H	27	2210	7.7–17.2	9.5	10.02	105.5
3H	27	2240	17.2–26.7	9.5	9.94	104.0
4H	27	2305	26.7–32.2	5.5	9.89	180.0
5H	27	2330	36.2–45.7	9.5	9.89	104.0
6H	28	0000	45.7–55.2	9.5	9.82	103.0
7H	28	0025	55.2–64.7	9.5	10.03	105.6
8H	28	0055	64.7–74.2	9.5	9.99	105.0
9H	28	0130	74.2–83.7	9.5	6.39	67.2
10H	28	0245	83.7–90.3	6.6	6.66	101.0
11X	28	0410	90.3–97.9	7.6	3.59	47.2
12X	28	0505	97.9–107.5	9.6	1.37	14.3
13X	28	0545	107.5–117.1	9.6	0.25	2.6
14X	28	0710	117.1–126.7	9.6	0.19	2.0
15X	28	0810	126.7–136.3	9.6	0.63	6.6
16X	28	0930	136.3–146.0	9.7	0.11	1.1
Coring totals:				142.0	96.5	68.0
160-966C-						
1H	28	1205	0.0–9.5	9.5	9.60	101.0
2H	28	1235	9.5–19.0	9.5	9.91	104.0
3H	28	1310	19.0–28.5	9.5	9.97	105.0
4H	28	1340	28.5–38.0	9.5	9.82	103.0
5H	28	1405	38.0–47.5	9.5	10.00	105.2
6H	28	1430	47.5–57.0	9.5	9.95	105.0
7H	28	1455	57.0–66.5	9.5	9.94	104.0
8H	28	0055	64.7–74.2	9.5	9.99	105.0
9H	28	0130	74.2–83.7	9.5	6.39	67.2
10H	28	0245	83.7–90.3	6.6	6.66	101.0
11H	28	0410	90.3–97.9	7.6	3.59	47.2
12X	28	0505	97.9–107.5	9.6	1.37	14.3
13X	28	0545	107.5–117.1	9.6	0.25	2.6
14X	28	0710	117.1–126.7	9.6	0.19	2.0
15X	28	0810	126.7–136.3	9.6	0.63	6.6
16X	28	0930	136.3–146.0	9.7	0.11	1.1
17X	29	0005		0.0	0.00	0.0
Coring totals:				146.0	96.5	66.1
160-966D-						
1H	29	0200	0.0–3.5	3.5	3.50	100.0
2H	29	0220	3.5–13.0	9.5	10.01	105.3
Core	Date (March 1995)	Time (UTC)	Depth (mbsf)	Length cored (m)	Length recovered (m)	Recovery (%)
3H						
3H	29	0245	13.0–22.5	9.5	10.02	105.5
4H	29	0310	22.5–32.0	9.5	9.84	103.0
5H	29	0340	32.0–41.5	9.5	10.02	105.5
6H	29	0405	41.5–51.0	9.5	9.83	103.0
7H	29	0430	51.0–60.5	9.5	9.95	104.0
8H	29	0455	60.5–70.0	9.5	10.09	106.2
9H	29	0525	70.0–79.5	9.5	9.45	99.5
10H	29	0610	79.5–84.5	5.0	9.09	182.0
11X	29	0755	84.5–88.5	4.0	1.59	39.7
12X	29	0830	88.5–93.3	4.8	6.35	132.0
13X	29	0905	93.3–98.1	4.8	2.71	56.4
14X	29	0935	98.1–102.9	4.8	0.12	2.5
15X	29	1005	102.9–107.7	4.8	0.50	10.4
16X	29	1050	107.7–112.5	4.8	0.00	0.0
17X	29	1130	112.5–117.3	4.8	0.18	3.8
18X	29	1220	117.3–122.1	4.8	1.95	40.6
19X	29	1320	122.1–126.9	4.8	0.43	9.0
20X	29	1520	126.9–136.5	9.6	0.31	3.2
Coring totals:				136.5	105.9	77.6
160-966E-						
1H	29	1910	0.0–8.5	8.5	8.48	99.7
Coring totals:				8.5	8.5	99.7
160-966F-						
1R	30	0525	59.0–68.0	9.0	1.37	15.2
2R	30	0605	68.0–77.0	9.0	0.39	4.3
3R	30	0645	77.0–86.6	9.6	3.56	37.1
4R	30	0715	86.6–96.2	9.6	0.70	7.3
5R	30	0745	96.2–105.8	9.6	0.00	0.0
6R	30	0815	105.8–115.4	9.6	0.22	2.3
7R	30	0900	115.4–125.0	9.6	1.85	19.3
8R	30	0945	125.0–134.6	9.6	0.87	9.1
9R	30	1045	134.6–144.2	9.6	0.16	1.7
10R	30	1145	144.2–153.8	9.6	2.28	23.7
11R	30	1245	153.8–163.5	9.7	3.16	32.6
12R	30	1340	163.5–173.1	9.6	1.88	19.6
13R	30	1425	173.1–182.7	9.6	1.02	10.6
14R	30	1530	182.7–192.4	9.7	1.50	15.4
15R	30	1635	192.4–202.0	9.6	1.99	20.7
16R	30	1755	202.0–211.6	9.6	3.62	37.7
17R	30	1920	211.6–221.3	9.7	4.22	43.5
18R	30	2025	221.3–231.0	9.7	2.03	20.9
19R	30	2140	231.0–240.6	9.6	3.52	36.6
20R	30	2235	240.6–250.3	9.7	0.10	1.0
21R	30	2325	250.3–259.9	9.6	0.25	2.6
22R	31	0015	259.9–269.4	9.5	0.14	1.5
23R	31	0105	269.4–279.0	9.6	0.60	6.3
24R	31	0205	279.0–288.6	9.6	0.10	1.0
25R	31	0310	288.6–298.3	9.7	0.20	2.1
26R	31	0440	298.3–307.9	9.6	4.30	44.8
27R	31	0545	307.9–317.5	9.6	7.14	74.4
28R	31	0650	317.5–327.1	9.6	7.69	80.1
29R	31	0805	327.1–336.8	9.7	3.52	36.3
30R	31	0910	336.8–346.4	9.6	4.07	42.4
31R	31	1055	346.4–356.0	9.6	3.41	35.5
Coring totals:				297.0	65.9	22.2

In summary, Site 966 has a thick upper sedimentary unit in comparison with Site 965. The irregular reflectors in the lower part of the upper unit suggest facies differences with Site 965 that may be caused by more contorted or heterogeneous lithologies. This upper unit lies on an unconformity defined by a strong reflector that is not as strong and continuous a reflector as the one at Site 965. Below the strong unconformity is a second unconformity, which dips at about 4° to the west and is itself truncated at the shallower unconformity just to the east of Site 966. The deeper units appear to dip to the north at Site 966 at angles of up to 7° or 8°.

LITHOSTRATIGRAPHY

The lithostratigraphic section recovered from six holes at Site 966 comprises 356.0 m of Eocene to Quaternary sediment (Fig. 7). The Pliocene to Holocene section consists of decimeter- to meter-scale intervals of bioturbated nannofossil ooze, clayey nannofossil ooze, and nannofossil ooze with foraminifers. An interval of distinctive matrix-

supported carbonate breccias of early Pliocene age is followed by a thick (approximately 180 m) bioclastic limestone succession of at least partly early Miocene age. This lithology is dominated by biomicritic and biosparitic limestone clasts, displaying a diverse biota, within a matrix of micrite or calcarenite.

Four lithostratigraphic units were identified on the basis of visual core description, smear-slide and thin-section analyses, and mineralogy determined by X-ray diffraction (XRD). In addition, spectral reflectance data obtained from undisturbed intervals provided information used to corroborate the correlation among the holes at the site and to produce a composite section (Fig. 8) (see also "Composite Depths" section, this chapter).

Description of Lithostratigraphic Units

Lithostratigraphic Unit I

Description: Nannofossil ooze, clayey nannofossil ooze, and nannofossil ooze with foraminifers

Figure 5. Track chart showing survey lines run across Site 966 with the seismic reflection system.

Intervals: Cores 160-966A-1H through 7H, 160-966B-1H through 8H, 160-966C-1H through 8H, 160-966D-1H through 8H, 160-966E-1H, and 160-966F-1R

Depth: 0–55.3 mbsf, Hole 966A; 0–64.8 mbsf, Hole 966B; 0–66.7 mbsf, Hole 966C; 0–63.2 mbsf, Hole 966D; 0–8.5 mbsf, Hole 966E; 0–60 mbsf, Hole 966F

Age: early Pliocene to Holocene

The dominant lithology of the uppermost unit at Site 966 is nannofossil ooze with less abundant clayey nannofossil ooze and nannofossil ooze with foraminifers. The sediment is generally light gray (5Y 6/1) to light greenish-gray (5GY 7/1) in color and structureless. Bioturbation appears to be slight to moderate throughout, and is most obvious where organisms have burrowed downward from darker sediments into paler intervals or where burrow infills have been diagenetically altered and contain pyrite. Large burrows, mostly *Zoophycos*, but including *Planolites*, are commonly ringed with faint blue to purple diagenetic halos.

According to area-percentage determinations by smear-slide analysis, the major components throughout the dominant lithology of Unit I are nannofossils, clay, and foraminifers. A slight downhole increase in foraminifers was observed (Fig. 9). Between 20 and 40 mbsf there is a marked decrease in nannofossils and corresponding increase in foraminifers, clay, and glass. Inorganic calcite is present in trace amounts in the upper 60 m of Unit I, and increases sharply near the bottom of the unit. Fragments of cryptocrystalline silica and rock fragments also appear as major components toward the bottom of the unit. XRD analysis indicates that the carbonates of Unit I consist mostly of calcite with dolomite and rare aragonite.

Alternating with the light-colored nannofossil ooze, clayey nannofossil ooze, and nannofossil ooze with foraminifers are dark-colored decimeter-thick beds of clayey nannofossil ooze rich in organic matter and pyrite. These sapropels are common throughout Unit I and the upper few meters of Unit II, and are described in detail following the Unit II description.

Only seven discrete thin ash layers were identified in Unit I (Cores 160-966A-1H and 3H). These are burrowed and appear reworked. Volcanic glass is present as a minor component (up to 9%) of the dominant lithology, particularly in the upper 40 m of the unit.

Lithostratigraphic Unit II

Description: Calcareous paraconglomerate to limestone breccia

Intervals: Cores 160-966A-7H through 10X, 160-966B-8H through 12X, 160-966C-8H through 10H, 160-966D-8H through 13X, and 160-966F-2R through 4R

Depth: 55.3–78 mbsf, Hole 966A; 64.8–107.5 mbsf, Hole 966B; 66.7–95 mbsf, Hole 966C; 63.2–122.1 mbsf, Hole 966D; 60–96.2 mbsf, Hole 966F

Age: late Miocene(?) to early Pliocene

Unit II varies in thickness from 22.7 m (Hole 966A) to 58.9 m (Hole 966D). The upper few meters (thickness varies from hole to hole) are characterized by soft-sediment deformation (see Fig. 36, "Structural Geology" section, this chapter). Sediments appear deformed though not completely reworked, and some primary bedding is still discernable. Hole 966C has several sapropels that have been deformed along shear surfaces (see "Structural Geology" section, this chapter).

The lower part of Unit II is characterized by the occurrence of large carbonate clasts in a micritic matrix and may be classified as a calcareous paraconglomerate to limestone breccia. Clasts show a range of lithologies from chalk to hard limestone; thin-section analyses of some of the clasts indicate that they are similar to carbonates found in the underlying unit (Unit III). Smear-slide analysis indicates that the dominant matrix lithology is mixed calcite/silica silt with large percentages of opaline silica fragments, inorganic calcite grains, and rock fragments; very few microfossils are present.

Sapropels

More than 90 intervals of nannofossil ooze and clayey nannofossil ooze rich in organic matter and pyrite were identified within the Pliocene-Holocene sequence at Site 966 (Units I and II). Sixty-five of these intervals are characterized by easily distinguishable beds that are slightly to moderately bioturbated, dark-colored (5Y 3/1 to 5Y 2.5/1), and organic-rich (0.41% to 10.03% organic carbon) and can be correlated between holes (Table 2, Figs. 10, 11). The intense level of bioturbation and diagenetic redox effects appears, in some instances, to have reduced the original bed thickness and altered color (Figs. 12–15).

Two intervals of distinctive organic-rich beds occur in Unit I. The first lies between approximately 10 and 20 mbsf and is characterized by intense bioturbation by *Zoophycos* and/or oxidation, which in some cases almost completely obscures the bed boundaries (Fig. 16). The second group occurs the lower part of Unit I between approximately 45 and 55 mbsf. These beds are dark gray (5Y 4/1) and, although bioturbated, show distinct upper and lower contacts (Fig. 17). Shipboard geochemical analysis showed that the organic carbon content of these beds is between 0.36% and 1.27% (see "Organic Geochemistry" section, this chapter).

Lithostratigraphic Unit III

Description: Shallow-water carbonate limestones

Intervals: Cores 160-966A-11X through 13X, 160-966B-13X through 16X, 160-966C-11H through 16X, 160-966D-14X through 20X, and 160-966F-5R through 26R

Depth: 78.0–106.8 mbsf, Hole 966A; 107.5–146.0 mbsf, Hole 966B; 95–122.2 mbsf, Hole 966C; 122.1–136.5 mbsf, Hole 966D; 96.2–298.45 mbsf, Hole 966F

Age: Miocene(?)

Unit III is a biosparite with less abundant biomicrite and recrystallized limestone of Miocene age. Contained within this unit are several different facies of shallow-water platform carbonates, including a corallgal, oncolitic (Fig. 18), and oolitic facies; within all of these, benthic foraminifers, echinoids, and bryozoa are locally abundant.

Figure 6. **A.** West to east seismic profile across Site 966 showing unconformity surfaces drilled. **B.** North to south seismic line across Site 966.

Bivalves and gastropods are particularly abundant in the interval between 223 and 240 mbsf (Cores 160-966F-18R and 19R) (Fig. 19), where a moldic porosity formed after solution of the shells.

This unit contains only trace constituents other than calcium carbonate, with the exception of a thin interval of chert between approximately 182 and 194 mbsf. Chert sporadically replaces some biota. The bottom 50 to 60 m of this unit (Cores 160-966F-21R through 25R) shows minor fracturing, with veins in places filled with secondary calcite (see "Structural Geology" section, this chapter).

Lithostratigraphic Unit IV

Description: Biomicrite with foraminifers
Intervals: Cores 160-966F-26R through 31R
Depth: 298.45–356 mbsf
Age: middle Eocene(?)

Unit IV is middle Eocene in age and is dominated by a finely laminated and intensely bioturbated, very light gray (N8) biomicrite with foraminifers. The top few meters of the section are dark gray (5Y 4/1) owing to a high organic carbon content (5.25%, Sections 160-966F-26R-1 through 26R-3; see "Organic Geochemistry," this chapter).

XRD analysis of the minor lithologies indicates the presence of fluorapatite and glauconite. There is practically no terrigenous material present in this unit. Chert nodules, up to 4 cm in diameter, occur sporadically.

Paleoenvironmental Interpretation

The succession of Eocene to Holocene sediments recovered at Site 966 is undoubtedly closely tied to the tectonic history of the Eratosthenes Seamount; the sedimentary record suggests considerable fluctuation in water depth and depositional environment.

Unit I and the uppermost interval of Unit II contain sediments characterized by deposition in an oxygenated water column (light-colored lithologies), punctuated by periods of sapropel sedimentation when increased amounts of carbon were preserved on the seafloor. These intervals are usually darker than the surrounding sediment. The high level of bioturbation and relatively low concentrations of organic carbon may be related to the relatively shallow depositional depth on the crest of the seamount (800 m) in comparison to the high organic-carbon values recorded in the deep basin environments (see, for example, "Lithostratigraphy" and "Organic Geochemistry" sections, "Site 964" chapter, this volume). It is interesting to note that the organic-rich intervals recorded in the interval between 45 and 55 mbsf are similar in many respects to the sapropels recovered at Site 963 (see "Lithostratigraphy" section, "Site 963" chapter, this volume) and other similar sapropel deposits recovered from shallower depositional environments in the eastern basin (e.g., Cramp et al., 1988; Shaw and Evans, 1984).

Unit II is interpreted as a debris-flow deposit. The chaotic assemblage of matrix-supported clasts points to transport via mass move-

Figure 8. Composite section of Unit I. Columns indicate, from left to right: age; lithologic summary; location of reddish brown beds indicating intervals where the sediment ranges from light brown (10YR 6/3) to reddish brown (5YR 5/4); color reflectance a^* value (values greater than zero indicate a red chroma); location of sapropels; and color reflectance at 550 nm. The two upper intervals of reddish brown beds correlate with similar intervals at Site 964 (see Fig. 9, "Site 964" chapter, this volume).

erally poor, which may imply that the ratio of carbonate to chert in the recovered sediments may not be representative of the actual amounts present in the formation. Logging data, particularly from the FMS, aid in resolving this issue (see "Downhole Measurements" section, this chapter).

The finer grain size, lamination, and biota (see "Biostratigraphy and Sedimentation Rates" this chapter) present in Unit IV suggest a deeper depositional environment than that in Unit III. In addition, the

Figure 9. Major grain components of samples from Holes 966A, 966B, 966C, 966D, and 966F.

presence of the bituminous layer at the top of Unit IV may represent an oxygen-minimum zone such as exists below areas of high productivity on continental slopes. Several different lines of evidence, including logging, physical properties, and disparate age estimates (Miocene shallow carbonates, Eocene deep carbonates), as well as the distinct lithologic change, suggest the existence of a major unconformity at approximately 298.5 mbsf, which is the boundary between Units III and IV (Section 160-966F-26R-1, 17 cm; Fig. 20).

BIOSTRATIGRAPHY AND SEDIMENTATION RATES

Calcareous Nannofossils

Calcareous nannofossils were studied from core-catcher samples of Holes 966A, 966C, 966D, 966E, and 966F. To provide higher resolution biostratigraphy, additional samples were collected from each core section that contained sediment or lightly indurated rock from Hole 966A.

The calcareous nannofossil assemblages are generally diverse and well preserved in samples analyzed from above 60 mbsf of each hole. Conversely, samples collected below 60 mbsf are either poorly preserved or barren. The age of the samples analyzed ranges from latest Pleistocene to middle Eocene. Miocene, Oligocene, and upper Eocene rocks, if present, could not be determined using calcareous nannofossils owing to barren intervals associated with shallow-water carbonates.

Hole 966A

The calcareous nannofossil biostratigraphy in Hole 966A is typified by three general units. The first consists of an apparently continuous Neogene sequence that contains all of the nannofossil biozones from the upper Pleistocene (MNN21) through the lower Pliocene (MNN13/12). A second interval, composed of shallow-water limestones, is devoid of recognizable calcareous nannofossil specimens. The remaining interval drilled consists of a marly chalk that contains overgrown middle Eocene taxa. A summary of the biostratigraphy is described below and displayed on Figures 21 and 22.

The base of the first biozone (MNN21) occurs in Sample 160-966A-1H-3, 140 cm. This zone is defined by the presence of *Emiliania huxleyi* in quantities lower than those of the acme zone, which was not identified upsection. The accompanying assemblage includes small *Gephyrocapsa* (<3.5 μ m), *Gephyrocapsa oceanica* s.l., *Helicosphaera kamptneri*, *Coccolithus pelagicus*, *Rhabdosphaera clavigera*, and *Pontosphaera japonica*.

Table 2. Position and organic carbon content of sapropels recovered at Site 966.

Core, section, interval (cm)	Depth (mbsf)	Thickness (cm)	Number	C _{org} (%)	Core, section, interval (cm)	Depth (mbsf)	Thickness (cm)	Number	Core, section, interval (cm)	Depth (mbsf)	Thickness (cm)	Number	Core, section, interval (cm)	Depth (mbsf)	Thickness (cm)	Number
160-966A-					160-966B-				160-966C-				160-966D-			
1H-1, 22-28	0.28	6	1		1H-1, 29-31	0.31	2	1	1H-1, 21-30	0.28	7	1	1H-1, 15-26	0.26	11	1
1H-2, 63-66	2.16	3		1.02	1H-2, 75-85	2.35	10		1H-2, 89-92	2.42	3		1H-2, 76-77	2.27	1	
1H-3, 13-25	3.25	12	2	5.24	1H-3, 30-40	3.40	10	2	1H-3, 42-57	3.57	15	2	1H-CC, 4, to 2H-1, 27	3.50	56	2
1H-3, 119-137	4.37	18	3	2.44	1H-3, 131, to 1H-4, 7	4.57	26	3	1H-3, 144, to 1H-4, 14	4.64	20	3	2H-1, 128-146	4.96	18	3
1H-4, 14-28	4.78	14	4		1H-4, 28-52	5.02	24	4	1H-4, 39-50	5.00	11	4	2H-2, 18-34	5.34	16	4
1H-4, 66-74	5.24	8	5	1.45	1H-4, 90-99	5.49	9	5	1H-4, 89-101	5.51	12	5	2H-2, 84-93	5.93	9	5
3H-1, 5-15	15.45	10		1.30	3H-1, 37-53	54.26	6		2H-6, 115-122	18.22	7		3H-3, 85-103	17.03	18	
3H-2, 9-15	16.95	6	6		3H-2, 70-78	19.48	8	6	3H-1, 32-49	19.47	15	6	3H-4, 105-116	18.66	11	6
3H-2, 65-80	17.60	15			3H-2, 128-130	20.00	2		3H-1, 114-116	20.16	2		3H-5, 15-31	19.31	16	
3H-2, 137-140	18.20	3			3H-3, 69-77	20.97	8		3H-2, 30-35	20.85	5		3H-5, 108-114	20.14	6	
3H-3, 17-27	18.57	10			3H-3, 105-111	21.31	6		3H-2, 59-67	21.17	8		3H-5, 138-150	20.50	12	
3H-4, 28-43	20.23	15		1.07	3H-4, 131-148	23.18	17		3H-3, 78-92	22.92	14		3H-7, 39-41	22.41	2	
3H-4, 122-130	21.10	8	7	7.57	3H-5, 104-113	24.33	9	7	3H-4, 39-47	23.97	8	7				
					3H-6, 28-34	25.04	6						4H-1, 25-37	22.87	12	
					3H-6, 80-84	25.54	4	8	3H-5, 6-9	25.09	3	8	4H-1, 75-79	23.29	4	8
3H-5, 75-79	22.09	4	8	8.71	3H-6, 126-134	26.04	8		3H-5, 51-67	25.59	8		4H-1, 120-134	23.84	14	
3H-5, 125-126	22.56	1			3H-7, 10-13	26.33	3	9					4H-2, 62-72	24.72	10	9
3H-6, 42-46	23.26	4	9	4.47	4H-1, 100-112	27.82	12		3H-5, 149, to 3H-6, 3	26.53	4	9	4H-4, 0-13	27.13	13	10
4H-1, 37-52	25.22	5	10	1.39	4H-2, 37-60	28.8	23	10	4H-1, 0-13	28.63	13	10	4H-4, 27-31	27.31	4	11
4H-1, 63-70	25.50	7	11	1.29	4H-2, 75-83	29.03	8	11	4H-1, 24-27	28.77	3	11				
					4H-2, 85-89	29.09	4									
					4H-2, 130-136	29.56	6		4H-1, 83-98	29.48	15		4H-4, 100-102	28.02	2	
4H-3, 10-15	27.95	5			4H-4, 70-90	32.1	20		4H-3, 10-15	31.65	5		4H-5, 142-145	29.95	3	
4H-3, 100-107	28.87	7	12	4.02	4H-5, 5-10	32.8	5	12	4H-3, 86-92	32.42	6	12	4H-6, 90-102	31.02	12	
4H-3, 133-135	29.15	2	13		4H-5, 40-41	33.11	1	13	4H-3, 115-122	32.72	7	13	4H-6, 142-147	31.47	5	13
4H-4, 10-14	29.44	4		1.65	4H-5, 102-107	33.77	5		4H-3, 143-146	32.96	3		4H-CC, 20-25	32.31	5	
4H-4, 88-94	30.24	6	14		4H-6, 10-20	34.4	10	14	4H-4, 76-89	33.89	13	14	5H-1, 6-14	32.14	8	14
4H-6, 58-69	32.99	11	15	3.77	5H-1, 66-72	36.92	6	15	4H-6, 96-105	37.05	9	15	5H-1, 148, to 5H-2, 7	35.07	9	15
4H-6, 110-120	33.50	10	16	3.19	5H-1, 115-120	37.40	5	16	4H-7, 0-12	37.62	12	16	5H-3, 48-55	35.55	7	16
4H-7, 14-15	33.95	1			5H-2, 7-15	37.85	8		4H-7, 43-55	38.05	12		5H-3, 82-87	35.87	5	
4H-7, 25, to 4H-CC, 1	34.24	19	17	2.43	5H-2, 33-41	38.11	8	17	4H-CC, 19-23	38.27	4	17	5H-3, 101-102	36.02	1	17
5H-1, 16.5-29	34.60	12.5	18	0.82	5H-3, 58-62	39.82	4	18	5H-1, 115-117	39.17	2	18	5H-4, 114-115	37.65	1	18
5H-1, 66-78	35.08	12	19	4.03	5H-3, 108-119	40.39	11	19	5H-2, 11-22	39.72	11	19	5H-5, 11-24	38.24	13	19
5H-1, 120-125	35.55	5		1.44	5H-4, 15-25	40.97	10		5H-2, 65-75	40.25	10		5H-5, 60-67	38.67	7	
5H-1, 143.5, to 5H-2, 3	35.84	9.5	20	1.34	5H-4, 36-50	41.50	44	20	5H-2, 86-99	40.49	13	20	5H-5, 84-96	38.96	12	20
5H-2, 25-31	36.11	6	21	6.39	5H-4, 75-84	41.54	9	21	5H-2, 121-132	40.82	11	21	5H-5, 125-129	39.29	4	21
5H-2, 51-60	36.40	9	22	3.69	5H-4, 106-114	41.84	8	22	5H-3, 2-12	41.12	10	22	5H-6, 0-7	39.57	7	22
5H-2, 80.5-89.5	36.70	9	23	4.58	5H-4, 135-149	42.19	14	23	5H-3, 39-46	41.46	7	23	5H-6, 29-40	39.90	11	23
5H-2, 117-129	37.09	12	24	3.90	5H-5, 26-40	42.60	14	24	5H-3, 73-83	41.83	10	24	5H-6, 63-80	40.30	17	24
5H-3, 0-14	37.44	14	25	10.03	5H-5, 64-80	43.00	16	25	5H-3, 119-123.5	42.24	4.5	25	5H-6, 106-119	40.69	13	25
5H-3, 56-63	37.93	7	26	8.42	5H-5, 110-122	43.42	12	26	5H-3, 148, to 5H-4, 13	42.63	15	26	5H-6, 145, to 5H-7, 5	41.05	15	26
5H-3, 70-83.5	38.14	13.5	27	7.03	5H-5, 141, to 5H-6, 7	43.79	18	27	5H-4, 42-57	43.07	15	27	5H-7, 23-38	41.38	15	27
5H-3, 112-121	38.51	9	28	4.36	5H-6, 34-45	44.15	11	28	5H-4, 78-86	43.36	8	28	5H-CC, 16-24	41.89	8	28
5H-4, 4-10	38.90	6	29	2.83	5H-6, 77-89	44.59	12	29	5H-4, 120-133	43.83	13	29	6H-1, 9-22	41.72	13	29
5H-4, 32-49	39.29	17	30	9.61	5H-6, 110-128	44.98	18	30	5H-5, 9-19	44.19	10	30	6H-1, 39-53	42.03	14	30
5H-4, 67-78	39.58	11	31	8.71	5H-6, 149, to 5H-7, 8	45.28	9	31	5H-5, 42-53	44.53	11	31	6H-1, 74-79	42.29	6	31
5H-5, 11-19	40.49	8	32	2.61					5H-6, 10-24	45.74	14	32	6H-2, 19-24	43.24	5	32
									5H-6, 76-83	46.33	7		6H-2, 84-95	43.95	11	
5H-5, 78-87	41.17	9		0.36	6H-1, 35-45	46.15	10									
5H-5, 102-115.5	41.46	13.5			6H-1, 70-77	46.47	7									
5H-5, 133-146	41.76	13	33	1.27	6H-1, 96-110	46.80	14	33	5H-6, 138, to 5H-7, 6	47.06	18	33	6H-2, 140-150	44.50	10	33
5H-6, 15-30	42.10	15	34	1.11	6H-1, 133-145	47.15	12	34	5H-7, 24-33	47.33	9	34	6H-3, 19-30	45.00	11	34
5H-6, 53-79.5	42.60	26.5	35	0.83	6H-2, 17-39	47.59	22	35	5H-7, 57, to 5H-CC, 1	547.77	20	35	6H-3, 52-64	45.00	12	35
5H-7, 5-22	43.52	17	36	0.80	6H-2, 110-123	48.43	13	36	6H-1, 24.5-47	48.23	22.5	36	6H-3, 134-146	45.96	12	36
5H-7, 40-47	44.07	7	37	0.74	6H-2, 149, to 6H-2, 13	48.83	14	37	6H-1, 64-78	48.28	14	37	6H-4, 20-30	46.30	10	37
					6H-3, 32-48	49.18	16	38	6H-1, 100-111	48.61	11	38	6H-4, 50-59	46.59	9	38
					6H-3, 64-74	49.44	10	39	6H-1, 135-145	48.95	10	39	6H-4, 79-87	46.87	8	39
									6H-2, 44-46	49.46	2		6H-4, 129-138	47.38	9	
					6H-3, 140, to 6H-4, 7	50.27	17	40	6H-2, 62-78	49.78	16	40	6H-5, 5-16	47.66	11	40
					6H-4, 40-45	50.67	5		6H-2, 106-111	50.11	5		6H-5, 43-51	48.01	8	
					6H-4, 61-79	50.99	18	41	6H-2, 134.5-150	50.50	15.5	41	6H-5, 72-86	48.36	14	41
					6H-4, 136, to 6H-5, 1	51.71	15	42	6H-3, 61-72	51.22	11	42	6H-5, 139, to 6H-6, 3	48.53	14	42
					6H-5, 25-40	52.10	15		6H-3, 104-110	51.60	6		6H-6, 26-33	49.33	7	
					6H-5, 56-78	52.48	22	43	6H-3, 134, to 6H-4, 8	52.08	24	43	6H-6, 53-72	49.72	19	43
					6H-5, 140-145	53.15	5		6H-4, 74-78	52.78	4		6H-6, 129-139	50.39	10	

Table 2 (continued).

Core, section, interval (cm)	Depth (mbsf)	Thickness (cm)	Number	C _{org} (%)	Core, section, interval (cm)	Depth (mbsf)	Thickness (cm)	Number	Core, section, interval (cm)	Depth (mbsf)	Thickness (cm)	Number	Core, section, interval (cm)	Depth (mbsf)	Thickness (cm)	Number
6H-1, 8-15	43.95	7	45	1.00	6H-6, 25-39	53.59	14	44	6H-4, 112-123	53.23	11	44	6H-7, 17-28	50.78	11	44
6H-1, 60-70	44.50	10	46	0.41	6H-6, 64-76	53.92	8	45	6H-5, 5-17	53.67	12	45	6H-7, 52, to 6H-CC, 1	50.90	13	45
6H-1, 115-117	44.97	2			6H-6, 106-120	54.40	14	46	6H-5, 47-67	54.17	20	46				
									6H-6, 11-16	54.65	5		7H-1, 0-10	51.10	10	
									6H-6, 41-55	55.16	14					
									6H-6, 97-103	55.55	6	47	7H-1, 112-123	52.23	11	47
6H-2, 9-23	45.53	14	49		7H-1, 30-45	55.65	15	49	6H-6, 135, to 6H-7, 3	56.03	18	48	7H-2, 5-10	52.60	5	48
6H-2, 114-123	46.53	9	50	1.24	7H-1, 96-97	55.87	1	50	6H-7, 52-62	56.53	10	49	7H-2, 36-49	52.99	13	49
6H-2, 0-5	46.85	5			7H-1, 124-127	56.47	3		6H-CC, 20-25	57.12	5	50	7H-2, 49-109	53.59	60	50
6H-3, 90-96	47.76	6	51	5.92	7H-2, 3-17	56.87	14	51					7H-2, 131-136	53.86	5	
													7H-3, 13-26	54.26	13	51
6H-3, 135-140	48.20	5	52		7H-2, 45-52	57.22	7	52					7H-3, 50-56	54.56	6	52
6H-4, 19-23	48.53	4	53		7H-2, 80-94	57.64	14	53					7H-3, 83-97	54.97	14	53
6H-4, 130-139	49.69	9	54	3.49	7H-2, 138-140	58.10	2	54	7H-1, 18-36	57.36	18	54	7H-3, 141-142	55.42	1	54
6H-5, 43-53	50.33	10	55	1.12	7H-3, 10-19	58.39	9	55	7H-1, 84-96	57.96	12	55	7H-4, 13-21	55.71	8	55
6H-6, 59-66	51.96	7	56	1.35	7H-4, 16-24	59.94	8	56	7H-1, 120-134	58.34	14	56	7H-4, 140, to 7H-5, 10	57.10	20	56
6H-6, 134-142	52.72	8	57	1.47	7H-4, 62-80	60.50	18	57	7H-2, 108-125	59.75	17	57	7H-5, 31-38	57.38	7	57
6H-7, 12-26	53.06	14	58		7H-4, 109-126	60.96	17	58	7H-3, 2-17	60.17	15	58	7H-5, 66-79	57.79	13	58
6H-7, 42-52	53.32	10	59	11.03	7H-5, 5-17	61.37	12	59	7H-3, 47-64	60.64	17	59	7H-5, 96-104	58.04	8	59
6H-CC, 10-21	53.66	11	60	8.60	7H-5, 45-64	61.84	19	60	7H-3, 99-115	61.15	16	60	7H-5, 131, to 7H-6, 10	58.10	24	60
					7H-5, 87-99	62.19	12	61	7H-3, 147, to 7H-4, 12	61.62	15	61	7H-6, 22-40	58.90	18	61
					7H-5, 125-137	62.57	12	62	7H-4, 39-52	62.02	13	62	7H-6, 55-63	59.13	8	62
					7H-6, 21-42	63.12	21	63	7H-4, 79-119	62.69	40	63	7H-6, 106-134	59.84	28	63
7H-1, 23-70	54.00	47	64	3.15	7H-6, 79-94	63.64	15	64	7H-5, 15-53	63.53	38	64	7H-7, 25-47	60.47	22	64
7H-2, 127-45	55.25	68	65	7.31	7H-7, 24-31	64.05	7	65	7H-5, 98-150	64.50	52		7H-CC, 23-27	60.94	4	
					7H-7, 44-57	64.30	13	65	7H-6, 67-83	65.89	71	65	8H-1, 146, to 8H-2, 13	62.13	17	
					7H-CC, 7-16	65.60	9	65	8H-4, 55-70	71.70	15		8H-2, 99-130	63.30	31	
					8H-1, 7-12	64.82	5									
									9H-1, 73-77	76.73	4					
									9H-2, 60-90	78.10	30					
									9H-2, 147, to 9H-3, 10	78.97	13					
									9H-3, 30-40	79.30	10					
									9H-3, 70-80	79.70	10

Figure 10. Correlation of sapropels from Site 966. Correlation was done on the basis of the position and character of individual layers. Numbered beds are those that appear as distinct and well-defined intervals in at least two of the six holes.

Figure 11. A distinctive, 7-cm-thick, correlatable sapropel recovered in two holes. **A.** Section 160-966C-3H-4, 31–60 cm; **B.** Section 160-966A-3H-4, 114–141 cm.

Figure 12. An example of one of the Pleistocene sapropels (S1), which shows a distinctive subjacent dark gray proto-sapropel succeeded by a sapropel with intense *Chondrites* burrows. The upper margin of the sapropel is disrupted by larger burrows and is more diffuse (Section 160-966A-1H-3, 114–146 cm).

Figure 13. An example of sapropel that is almost entirely obliterated by intense burrows, in this case of *Planolites* and *Zoophycos* (Section 160-966A-4H-1, 34–86 cm).

Figure 14. An example of an original sapropel pervasively burrowed by *Chondrites* and larger burrows (Section 160-966A-4H-4, 80–112 cm).

Samples 160-966A-1H-4, 30 cm, through 2H-1, 70 cm, were placed into Zone MNN20. This zone is a gap zone defined by the absence of both *E. huxleyi* and *Pseudoemiliania lacunosa*. The accompanying assemblage is similar to that found uphole.

Samples 160-966A-2H-2, 70 cm, through 2H-6, 55 cm, contain nanofossils from Zone MNN19f. The upper boundary of the zone is defined by the last occurrence of *P. lacunosa*, whereas the lower boundary is defined by the first occurrence of *Gephyrocapsa* sp. 3. *Gephyrocapsa* sp. 3 is located only in Sections 160-966A-2H-5 and 2H-6. The accompanying assemblage is similar to that of the preceding zone.

Samples 160-966A-2H-CC through 3H-3, 80 cm, contain nanofossils from Zone MNN19e. This interval is interpreted as a gap zone identified by the absence of *Gephyrocapsa* sp. 3 and either *Helicosphaera sellii* or large *Gephyrocapsa* (>5.5 μ m). Small *Gephyrocapsa* and *P. lacunosa* dominate the accompanying assemblage.

Samples 160-966A-3H-4, 80 cm, through 3H-5, 80 cm, contain nanofossils from Zone MNN19d. This zone is identified by the presence of large *Gephyrocapsa* (>5.5 μ m). The accompanying assemblage is dominated by small *Gephyrocapsa*, *P. lacunosa*, and *G. oceanica* s.l.

Sample 160-966A-3H-6, 80 cm, contains nanofossils from Zone MNN19c. This zone is a gap zone defined by the absence of both *Calcidiscus macintyreii* and large *Gephyrocapsa* (>5.5 μ m). Small *Gephyrocapsa* and *G. oceanica* s.l. dominate the assemblage.

Sample 160-966A-3H-CC contains nanofossils from Zone MNN19b. This zone is identified by the presence both *G. oceanica* s.l. and *C. macintyreii*. The first occurrence of *G. oceanica* s.l. and the last occurrence of *C. macintyreii* in the same sample suggest the presence of a minor unconformity or short hiatus. Because all of the zones were recognized, any missing portion of the sequence can comprise only a portion of Zone MNN19b and at most only a portion of an adjoining zone. The accompanying assemblage is similar to that found in the previous sample.

Samples 160-966A-4H-1, 15 cm, through 4H-1, 80 cm, contain nanofossils from Zone MNN19a. This interval represents a gap zone identified by the absence of both *G. oceanica* s.l. and *Discoaster brouweri*. The accompanying assemblage is diverse and includes *H. kamptneri*, small *Gephyrocapsa*, *Syracosphaera pulchra*, and small reticulofenestrids. The top of this zone marks the approximate location of the Pleistocene/Pliocene boundary in Hole 966A.

Samples 160-966A-4H-1, 130 cm, and 4H-5, 130 cm, contain nanofossils from Zone MNN18. In this zone, *D. brouweri* and *Discoaster triradiatus* occur in the absence of both *Discoaster pentaradiatus* and *G. oceanica* s.l. From the uppermost part of this interval to Sample 160-966A-4H-2, 15 cm, *D. triradiatus* fluctuates in abundance from common to few. Diminished abundance of *D. triradiatus* is typical in the first five sections of Core 160-966A-8H.

Samples 160-966A-4H-6, 10 cm, through 4H-CC contain nanofossils from Zone MNN17–16b. This zone is recognized as the interval between the last occurrence of *D. pentaradiatus* and the last common occurrence of *Discoaster tamalis*. The accompanying assemblage includes small *Gephyrocapsa*, *D. brouweri*, *Discoaster surculus*, small reticulofenestrids, and rare occurrences of *D. tamalis*.

Samples 160-966A-5H-1, 21 cm, through 6H-3, 149 cm, contain nanofossils belonging to Zone MNN16a. This zone is identified by the common occurrence of *D. tamalis* above the last occurrence of *Reticulofenestra pseudoumbilicus*. The accompanying assemblage is similar to that found in the preceding zone.

Samples 160-966A-6H-4, 42 cm, through 6H-6, 68 cm, contain nanofossils belonging to Zone MNN14–15. This zone contains both *R. pseudoumbilicus* (>7 μ m) and common specimens of *Discoaster asymmetricus*. The accompanying assemblage is similar to that found in the preceding zone.

Samples 160-966A-6H-6, 146 cm, through 7H-4, 115 cm, contain nanofossils belonging to the Zone MNN13. This zone is identified by the presence of *H. sellii* below the common occurrence of *D.*

Figure 15. A comparison of differential burrowing of sapropels at Site 966. **A.** Sapropel displaying substantial burrowing of the upper margin (mainly by *Chondrites*), but with minimal internal disruption by isolated *Planolites* and *Zoophycos* burrows. Note the well-defined base and underlying 1-cm-thick dark gray proto-sapropel (Section 160-966D-6H-1, 30–66 cm). **B.** Sapropel showing upper contact intensely burrowed by *Planolites*, *Zoophycos*, and *Chondrites*. The base is relatively sharp, but the subjacent dark burrow fills attest to disruption of the sapropel interior (Section 160-966D-5H-7, 14–47 cm). **C.** Sapropel showing pervasive *Chondrites* burrowing throughout (Section 160-966D-5H-6, 55–90 cm).

Figure 16. A thin sapropel remnant showing evidence of pervasive disruption, with typical subjacent *Zoophycos* spreiten. Note the distinctive paler colored sediment below the sapropel (Section 160-966D-3H-4, 96–127 cm).

Figure 17. A distinctive gray proto-sapropel displaying some burrowing (Section 160-966D-6H-5, 30–61 cm).

Figure 18. Oncolites in brown micrite (Section 160-966F-17R-1, 45–60 cm).

asymmetricus. Additional changes from the preceding zone include the disappearance of *P. lacunosa* and small *Gephyrocapsa*. A few specimens of *Amaurolithus delicatus* are also present in some samples.

The interval between Samples 160-966A-7H-4, 115 cm, and 10X-CC is problematic because of severe overgrowths of calcite on many specimens and a general decline in abundance. No nannofossils were identified in this interval.

Sample 160-966A-10X-CC contains a diverse nannofossil assemblage that includes *A. delicatus*, *D. surculus*, *D. pentaradiatus*, *Discoaster variabilis*, *Sphenolithus abies*, *R. pseudoumbilicus*, *Amaurolithus tricorniculatus*, and *Amaurolithus primus*. *H. sellii* does not occur in the assemblage, which places this sample into Zone MNN12.

Hole 966C

Samples from each core catcher were studied from Hole 966C. These samples were placed into zonations and compared with interpretations of samples collected from each section in Hole 966A. Generally, the two interpretations agreed; however, discrepancies in the depth of zones and overlap of some zones occur (Fig. 23). These inconsistencies can be attributed to either incorrect depths that do not account for unrecovered material (see “Composite Depths” section, this chapter) or incorrect identification of gap zones in the Pleistocene portion of the sequence. In either case, shore-based studies should account for these discrepancies through additional biostratigraphic work and composite section correlations.

Hole 966D

Samples from each core catcher were studied from Hole 966D. These samples were placed into zonations and compared with the Hole 966A results. As with samples from Hole 966C, not all core-catcher samples from Hole 966D agree with the Hole 966A biostratigraphy. Figure 23 shows the discrepancies in core-catcher analyses.

In addition to the core-catcher samples, 18 samples were analyzed from Core 160-966D-18X. This interval contains numerous chalk clasts in a chalk matrix that was disturbed during drilling. The clasts

Figure 19. Large bivalves in biosparite (Section 160-966F-10R-2, 45–85 cm).

Figure 20. The contact between lithostratigraphic Units III and IV, showing the difference in lithologies. Although the exact nature of the contact is not known owing to the low core recovery, the change from an Eocene bituminous calcilutite (top of Unit IV) to a Miocene biosparite (base of Unit III) in the space of less than 10 m suggests the existence of an unconformity at this level (Section 160-966F-26R-1, 10–50 cm).

Figure 21. Composite of biostratigraphic events recognized in Pleistocene and Pliocene sediments recovered from Hole 966A including lithostratigraphic and magnetostratigraphic records.

all contain abundant calcite fragments. Most of the samples are devoid of calcareous nannofossils. The calcareous nannofossils observed are not age diagnostic and most are severely altered by calcite overgrowths.

Hole 966E

Hole 966E consists of only one core-catcher sample that contains abundant quantities of *E. huxleyi*. This sample was placed into Zone MNN21 (Fig. 23).

Hole 966F

Hole 966F recovered rocks and sediments from 31 cores. The hole was washed to approximately 48 mbsf (Fig. 23). From 48 to 357 mbsf rotary drilling recovered chalk containing numerous clasts, indurated shallow-water limestones, and chalk intercalated with local organic-rich layers.

Sample 160-966F-1R-CC contains an assemblage that includes *A. delicatus*, *D. surculus*, *D. pentaradiatus*, *D. variabilis*, *S. abies*, and *R. pseudoumbilicus*. *A. tricorculatus* and *A. primus* were not observed in this sample; therefore, the sample was placed in Zone MNN13. With few exceptions, the core-catcher samples below Core 160-966F-1R are either barren or contain overgrown taxa that are not age diagnostic.

Within Core 160-966F-3R, several samples were collected from chalk clasts and chalk matrix. One of the clasts contains a diverse, well-preserved assemblage that includes *A. delicatus*, *D. brouweri*, *D. variabilis*, *D. surculus*, *D. pentaradiatus*, *Reticulofenestra* sp. (>5

Figure 22. Composite of biostratigraphic events recognized in Eocene chalk recovered from Hole 966F including the lithostratigraphic record.

µm), and a round specimen with an open center that was classified as *Reticulofenestra rotaria*. *R. rotaria* was used as a marker in Mediterranean geologic sections by Theodoridis (1984). This species marks the top of the *R. rotaria* Zone of Theodoridis (1984) and occurs only in the lower part of the Messinian stage. Although this taxa was identified only from a clast, it restricts the age of the host breccia to younger than early Messinian.

The interval from Cores 160-966F-3R through 26R is composed of shallow-water limestones and is devoid of identifiable nannofossils.

Core 160-966F-26R recovered chalk containing an assemblage that includes *Discoaster barbadiensis*, *Discoaster saipanensis*, *Ericsonia formosa*, and overgrown chiasmoliths, some of which are identified as *Chiasmolithus grandis*. This assemblage places this core in

Figure 23. Composite of calcareous nannofossil zones recognized from core-catcher samples recovered from Holes 966A, 966C, 966D, 966E, and 966F. The thick line at 23 mbsf in Hole 966A represents Zone MNN19b, which was present in only one sample.

middle Eocene Zone NP16-17. Below Core 160-966F-26R, preservation diminishes and the cores were tentatively placed in Zone NP16-17.

Planktonic Foraminifers

Hole 966A was studied in detail in order to provide a complete stratigraphic record of the sedimentary sequence. All the core-catcher samples containing sediments suitable for planktonic foraminiferal studies were analyzed together with 45 additional samples from within the cores.

Core catchers of Hole 966C and a few of Holes 966D and 966F were also analyzed. Planktonic foraminifers range in abundance from absent in the lower part of the section to dominant and consist of di-

versified and poorly to well-preserved Pleistocene and Pliocene faunas. Faunal assemblages are generally well preserved and abundant and very similar to those observed for Sites 963 through 965.

According to the zonation scheme of Cita (1975) emended by Sprovieri (1993), the interval spanning the *Truncorotalia truncatulinoides excelsa*–*Globigerina cariacensis* Zones was identified for the Pleistocene and seven zonal boundaries, which encompass Zones MPL6 through MPL2, were identified for the Pliocene (Fig. 21).

Two samples per section were taken from Hole 966A in order to provide a better division of the Pleistocene. However, as observed at Sites 963 and 964, the zonal boundary between the *Truncorotalia truncatulinoides excelsa* and *Globigerina cariacensis* Zones was not recognized owing to the scarcity of *T. truncatulinoides excelsa*. This latter species is present only in the upper part of the sedimentary sequence in those intervals interpreted as cool-temperate events. The two zones span the entire Pleistocene, from Samples 160-966A-1H-1, 110–112 cm, through 4H-1, 29–31 cm.

Pliocene Zone MPL6 was recognized only in Sample 160-966A-4H-2, 29–31 cm, based on the presence of highest occurrence of the Pliocene species *Sphaeroidinella dehiscens* and *Globigerinoides extremus* together with *Globorotalia inflata*, the lowest occurrence of which would normally mark the base of this zone. As observed at the previous sites, the increase in abundance of *Neogloboquadrina pachyderma sinistral* was not identified in Hole 966A.

Zone MPL5b is identified from Samples 160-966A-4H-3, 63–65 cm, through 4H-4, 80–82 cm. It is marked by the first occurrence of *G. inflata* at the top and the last occurrence of *Globorotalia bononiensis* at the bottom. Samples 160-966A-4H-5, 80–82 cm, through 5H-3, 130–132 cm, contain *G. bononiensis* and were attributed to Zone MPL5a. The highest occurrence of *Sphaeroidinellopsis* spp. in Sample 160-966A-5H-5, 61–63 cm, marks the top of MPL4b. This zone was identified through Sample 160-966A-5H-CC. Zone MPL4a was identified from Samples 160-966A-6H-1, 93–95 cm, through 6H-4, 144–116 cm. Its top is marked by the highest occurrence of *Globorotalia puncticulata*. The highest occurrence of *Globorotalia margaritae* and the lowest occurrence of *G. puncticulata* allow identification of Zone MPL3 from Samples 160-966A-6H-6, 25–27 cm, through 7H-5, 81–83 cm. Samples 160-966A-7H-CC and 8H-CC were attributed to Zone MPL2 based on the absence of *G. puncticulata*.

From Samples 160-966A-9H-1, 47–48 cm, through 12X-CC no age-diagnostic faunas were identified. The residues are characterized by a high abundance of evaporite fragments together with less abundant lithified and hard carbonates.

Only Sample 160-966A-13X-CC contains extremely rare specimens of *G. margaritae* together with *Sphaeroidinellopsis* spp. Because the sediments are most likely affected by reworking (see “Lithostratigraphy” section, this chapter), those specimens may not be in place and we cannot attribute them to Zone MPL2. Further and more detailed studies are needed.

Pliocene planktonic foraminiferal assemblages resemble those of the previous sites.

The single sample (Sample 160-966F-26R-4, 84 cm) analyzed from Hole 966F for its planktonic foraminiferal content contains a poorly preserved and scarce middle Eocene fauna consisting of *Acarinina bulbrooki*, *Acarinina rugosoaculeata*, *Acarinina pentacamera*, *Acarinina* cf. *brodermanni*, *Truncorotaloides pseudotopilensis*, *Globigerinatheka subconglobata*, *Globigerinatheka* cf. *index*, *Globigerina linaperta*, *Turborotalia* cf. *griffinae*, *Planorotalites pseudoscutulus*, and *chiloguembelinids*.

Reworking has affected the planktonic foraminiferal assemblages at Site 966 in two intervals. A few samples in Cores 160-966A-1H and 2H contain specimens of Early Cretaceous age hedbergellids. From Samples 160-966A-4H-CC through 8H-CC reworking of the Burdigalian–Langhian species *Praeorbulina transitoria*, *Praeorbulina sicana*, *Praeorbulina glomerata*, and *Globigerinoides bisphericus* is common.

Further shore-based studies are needed to clarify if the early Pliocene assemblages contained in Core 160-966A-13X-CC are displaced within “older” sediments.

Bolboforma

Only very few specimens of *Bolboforma* sp. E (Spiegler and Rögl, 1992) were found in Hole 966A. Their highest occurrence was observed in Sample 160-966A-5H-3, 130–132 cm. A few specimens of the microfossil morphologically similar to *Bolboforma*, and described for Holes 964A and 965A, were also found in Hole 966A. Its highest occurrence is in Sample 160-966A-3H-6, 7–9 cm.

Other Taxa

The carbonate sequence approximately located between 85 and 298 mbsf was not studied in detail aboard ship. However, sedimentological descriptions of these cores indicate the presence of corals, bivalves, echinoderms, calcareous algae, and benthic foraminifers (see “Lithostratigraphy” section, this chapter).

Approximately 60 thin sections were examined for microfossils from Holes 966A, 966B, 966C, 966D, and 966F. Most of them are devoid of microfossils or contain benthic foraminifers that are not age diagnostic (e.g., shallow-water miliolids and a few specimens of *Ammonia* sp., *Spiroplectammina* sp., and *Amphistegina* sp.). Calcareous algae are more abundant than benthic foraminifers and are distributed throughout the carbonate sequence. Some of the algae were tentatively attributed to the genus *Lithothamnium*.

Only two thin sections are suitable for age determination. Samples 160-966F-23R-1, 28–31 cm, and 23R-1, 63–65 cm, contain several specimens of *Operculina* sp., *Lepidocyclina* sp., and *Miogypsina* sp. Range distribution of the *Orbitoidae* group in the Mediterranean area is restricted to the lower Miocene (Sartorio and Venturini, 1988).

Paleoenvironmental Interpretation

The strong reworking occurring throughout the Pliocene–Quaternary sequence prevents a reliable paleoclimatic interpretation. However, the paleoclimatic signal may be inferred from planktonic foraminiferal assemblages for some intervals.

Cool-temperate conditions and a high nutrient supply may have prevailed in the late Pleistocene, as suggested by the low abundance of warm-water indicators such as *Orbulina universa* and the *Globigerinoides* group and by the presence of cold-water indicators (e.g., *Neogloboquadrina* group) and *Limacina retroversa* (pteropod). A similar paleoclimatic trend was previously observed also for Hole 964A.

Warm conditions with minor fluctuations toward temperate or cooler conditions prevailed from the middle Pleistocene to the early Pliocene (upper part of Zone MPL4a). The paleoclimatic signal is, however, weaker than that in Hole 964A and it may also be biased by the reworking of the early-middle Miocene planktonic foraminiferal specimens.

An apparently more pronounced cooler or more temperate episode occurred from about the middle part of Zone MPL4a to Zone MPL3.

Sedimentation Rates

Sedimentation rates for Hole 966A were calculated using 18 calcareous nannofossil and planktonic foraminiferal events (Table 3). The data are plotted on the age vs. depth curve shown in Figure 24. An error line is shown on the figure to indicate the degree of uncertainty as to the location of the nannofossil and foraminiferal events within the hole.

Calculated sedimentation rates vary from 1 to 32 m/m.y. through the sequence. Eight significant shifts in sedimentation rates were ob-

Table 3. Stratigraphic list of calcareous nannofossil and planktonic foraminifer events for Site 966.

Event	Core, section, interval (cm)	Depth (mbsf)	Depth (mcd)	Age (Ma)
FO <i>E. huxleyi</i> *	160-966A-1H-3, 140	4.4	4.59	0.26
LO <i>P. lacunosa</i>	2H-2, 70	8	10.23	0.46
FO <i>Gephyrocapsa</i> sp. 3	2H-6, 80	13.85	16.08	0.99
LO <i>Gephyrocapsa</i> >5.5 μ m	3H-4, 80	20.6	23.86	1.25
FO <i>Gephyrocapsa</i> >5.5 μ m	3H-5, 80	22.1	25.36	1.5
LO <i>C. macintyre</i>	3H-CC	24.42	27.68	1.62
FO <i>G. oceanica</i> s.l.	3H-CC	24.42	27.68	1.75
LO <i>D. brouweri</i>	4H-1, 130	26.1	30.57	1.99
FO <i>G. inflata</i>	4H-2, 29-31	26.6	31.07	2.13
LO <i>G. bononiensis</i>	4H-5, 80-82	31.61	36.08	2.45
LO <i>D. pentaradiatus</i>	4H-6, 10	32.4	36.87	2.51
LCO <i>D. tamalis</i>	5H-1, 21	34.51	41.1	2.82
LO <i>Sphaeroidinellopsis</i> spp.	5H-5, 61-63	40.92	47.51	3.22
LO <i>G. punctulata</i>	6H-1, 93-95	44.74	53.81	3.57
LO <i>R. pseudumbilicus</i>	6H-4, 42	48.72	57.79	3.85
LCO <i>G. margaritae</i>	6H-6, 25-27	51.56	60.63	3.94
FCO <i>D. asymmetricus</i>	6H-6, 68	51.98	61.05	4.11
FO <i>G. punctulata</i>	7H-5, 81-83	60.12	72.77	4.52

Notes: FO = first occurrence; LO = last occurrence; FCO = first common occurrence; LCO = last common occurrence; * = to be confirmed by scanning electron microscopy.

served. From the seafloor to the first occurrence of *Gephyrocapsa* sp. 3 (0.99 Ma) the sedimentation rate was approximately 19 m/m.y. The sedimentation rate increased to 30 m/m.y. in the interval from the first occurrence of *Gephyrocapsa* sp. 3 to the last occurrence of *Gephyrocapsa* (>5.5 μ m) (1.25 Ma). Sedimentation generally declined to 13 m/m.y. in the interval from *Gephyrocapsa* (>5.5 μ m) (1.25 Ma) to the last occurrence of *D. brouweri* (1.99 Ma). In the interval between the latter bioevent and the first occurrence of *G. inflata* (2.13 Ma), the sedimentation rate reached its minimum value of 1 m/m.y. From the first occurrence of *G. inflata* to the last occurrence of *R. pseudumbilicus* (3.85 Ma) the average sedimentation rate was 15 m/m.y. The sedimentation rate increased to its maximum value of 32 m/m.y. from the last occurrence of *R. pseudumbilicus* (3.85 Ma) to the last occurrence of *G. margaritae* (3.94 Ma). Between the *G. margaritae* (3.94 Ma) bioevent and the first occurrence of *D. asymmetricus* (4.11 Ma), sedimentation rates decreased to 2 m/m.y. The final interval, which ranges from the first occurrence of *D. asymmetricus* (4.11 Ma) to the first occurrence of *G. punctulata* (4.52 Ma), showed a sedimentation rate of 29 m/m.y.

PALEOMAGNETISM

Paleomagnetic measurements were made on cores from Holes 966A through 966D following the methods discussed in the "Explanatory Notes" chapter (this volume). The NRM was routinely measured at 10-cm intervals on the archive half of each core section for each hole after AF demagnetization at the appropriate level. Hole 966A was subjected to demagnetization at 10 and 20 mT in order to assess the paleomagnetic stability of the sediments. Holes 966B through 966D were demagnetized at a single level (25 mT). NRM intensities were measurable throughout the recovered sequence and were well above the noise level of the magnetometer after demagnetization at each of the selected AF demagnetization levels (Fig. 25). Intensity peaks coincide with sapropels, as discussed by Roberts et al. (this volume). Reliable orientation data were not obtained from the Tensor orientation tool at Site 966; therefore, the declinations could not be reoriented to geographic coordinates.

No significant differences are evident in the paleomagnetic directions measured from Hole 966A after demagnetization at 10 and 20 mT. This suggests that the sediments are relatively stably magnetized and that the whole-core measurements may provide a useful magnetostratigraphy. Fifty discrete samples from Hole 966A, at least one

Figure 24. Age vs. depth diagram showing selected calcareous nannofossil and planktonic foraminifer datums with corresponding sedimentation rates. The line corresponds to the sample where the marker species was found for a corresponding first or last occurrence datum, and the dashed line corresponds to the nearest sample where the marker species was not found.

from each core section, were subjected to stepwise AF demagnetization to verify the reliability of the whole-core measurements. Most discrete samples are stably magnetized, and the paleomagnetic direction can be determined readily from straight lines that are directed to the origin of the vector component diagrams (Fig. 26A, D). The discrete sample data confirm that a significant drill-string overprint is removed at 10 mT and that stable directions are usually reached by 20 mT (Fig. 26A, D). Because the magnetizations are stable at low coercivities, there is generally good agreement between the inclinations determined from the discrete samples and those obtained from the whole-core record at 20 mT (Fig. 27).

The interval that we interpret to include the Matuyama/Brunhes boundary, as well as a significant portion of the Matuyama Chron (at about 10–25 mbsf), appears to have a significantly harder overprint than the other sediments from Hole 966A. The overprint persists to above 30 mT, as is evident in continually curving portions of the vector components in the demagnetization diagrams (e.g., Fig. 26B). Parts of this interval are also weakly magnetized and stable paleomagnetic directions could not be determined from several of the discrete samples. These observations suggest that the whole-core data may not be entirely reliable in the interval from 10 to 25 mbsf.

Similarly, it was difficult to extract reliable paleomagnetic directions in the interval from 37 to 39 mbsf. This zone consists of a gray sediment that is strongly diagenetically reduced. After removal of a strong drill-string overprint, the remanent magnetizations are extremely weak, with shallow inclinations. No stable end points were isolated for discrete samples above the noise level of the shipboard spinner magnetometer (e.g., Fig. 26C). It is therefore unclear whether this interval represents a zone of true reverse geomagnetic polarity or whether the shallow reverse polarity inclinations are an artifact of the weak remanence. Mineral magnetic results indicate that the remanence within the reduced zone at 36–38 mbsf is dominated by a magnetically hard mineral such as hematite, as evident in S-ratios of about 0.6 (Fig. 28) (see King and Channell [1991] and Verosub and Roberts [1995] for a definition of the S-ratio). This result is surprising because magnetically hard minerals such as goethite and hematite are

Figure 25. NRM intensity after AF demagnetization at 20 mT for Hole 966A and at 25 mT for Holes 966B, 966C, and 966D. Note the different intensity scale for each plot.

Figure 26. Vector component demagnetization diagrams that illustrate different types of behavior observed in discrete samples subjected to stepwise AF demagnetization. **A.** Sample 160-966A-1H-4, 5 cm (4.55 mbsf); **B.** Sample 160-966A-2H-5, 114 cm (12.94 mbsf); **C.** Sample 160-966A-5H-3, 20 cm (37.50 mbsf); **D.** Sample 160-966A-6H-4, 39 cm (48.69 mbsf). Open (solid) symbols represent projections onto the vertical (horizontal) plane. Demagnetization steps (in mT) are shown below each diagram. The majority of samples from Hole 966A behave similarly to those in Figures 25A and 25D for normal and reverse polarity, respectively.

Figure 27. Whole-core inclination for Hole 966A compared with inclinations from stepwise-demagnetized discrete samples. Inclinations for discrete samples were determined by linear regression fits to multiple demagnetization points in each case. These data reproduce many of the features seen in the whole-core results, particularly in the lower part of the record (see text). The preliminary polarity interpretation agrees well with the positions of biostratigraphic datums, as shown to the right of the inclination data. See "Biostratigraphy and Sedimentation Rates" section (this chapter) for discussion of the biostratigraphic datums. Ages for biostratigraphic datums are after Sprovieri (1993) and those for geomagnetic polarity boundaries are after Cande and Kent (1995).

Figure 28. Selected mineral magnetic properties determined from discrete samples from Hole 966A (see text for discussion). For definitions of the S-ratio and HIRM, see King and Channell (1991).

Table 4. Depth of boundaries of magnetic polarity zones in Hole 966A.

Chron boundary	Core, section, interval (cm)	Depth (mbsf)
Base of Brunhes (C1n/C1r.1)	Between 2H-4, 35, and 2H-4, 95	10.65–11.25
Base of Olduvai (C2n/C2r.1)	Between 4H-2, 37, and 4H-3, 90	26.67–28.7
Base of Matuyama (C2r/C2An)	Between 4H-7, 25, and 5H-1, 5	34.05–34.35
Base of Gauss (C2An/C2Ar)	Between 6H-1, 33, and 6H-2, 33	44.13–45.63
Top of Cochiti (C2Ar/C3n.1n)	Between 6H-6, 40, and 7H-7, 31	51.7–53.13

much more reactive than magnetite and are more susceptible to dissolution under sulfate-reducing conditions (Canfield et al., 1992). Nevertheless, although hematite is the likely remanence carrier in this interval, low values of the “hard” isothermal remanent magnetization (HIRM) (cf., King and Channell, 1991) indicate that hematite occurs in low concentrations (Fig. 28). This mineral magnetic evidence suggests that the intervals of gray sediment are strongly diagenetically reduced, with only small concentrations of magnetically hard minerals remaining. High S-ratios (between 0.90 and 1.00) from the remainder of the discrete samples are indicative of a mineralogy that is dominated by a ferrimagnetic mineral, such as magnetite. It should be noted that the results shown in Figure 28 give a biased view of the magnetic properties of Hole 966A because intervals of reduced (gray) sediment were specifically avoided where possible (except the interval from 36 to 38 mbsf where no other sediment was available). Nevertheless, high HIRM values suggest that a significant amount of hematite is also present throughout the sequence. Because hematite is relatively resistant to AF demagnetization, it will be necessary to undertake thermal demagnetization studies in order to assess the contribution of different magnetic minerals to the magnetization of the sediment and to check the reliability of the results from AF demagnetization studies. The polarity interpretation shown in Figure 27 and Table 4 must therefore be considered preliminary until a more thorough characterization of the magnetization can be made.

Despite the problems encountered in the zones discussed above and the need to conduct detailed shore-based thermal demagnetization studies, it appears that the discrete sample and whole-core data from Hole 966A yield a promising preliminary magnetostratigraphy that is consistent with biostratigraphic determinations (Figs. 27, 29) (see “Biostratigraphy and Sedimentation Rates” section, this chapter). In particular, there is excellent agreement with the interpreted positions of the upper Cochiti Subchron (within the Gilbert Chron) to the lower part of the Olduvai Subchron (within the Matuyama Chron) and the positions of the biostratigraphic datums recorded in Hole 966A (Fig. 27). It should be noted, however, that the interpretation shown does not include the zone of reversed polarity between the Nunivak and Cochiti Subchrons (4.48–4.29 Ma) and the Mammoth and Kaena Subchrons (3.33–3.22 and 3.11–3.04 Ma). These zones may be missing because of core gaps or inadequacies in the record. Clearly, further work is required on a composite sequence to resolve these ambiguities. The polarity pattern above the interpreted lower Olduvai Subchron is uncertain and also requires further post-cruise investigation. Depth assignments for polarity boundaries from the preliminary magnetostratigraphic interpretation for Hole 966A are given in Table 4.

Comparison of whole-core inclination data among the holes at Site 966 is less encouraging at first inspection than the results presented above from Hole 966A. In Figure 30, no clear correlation is evident between the inclination features in Holes 966A through 966D. Correlation of color reflectance data among the holes indicates that Hole 966A represents a significantly condensed sequence in comparison to the other holes (see “Lithostratigraphy” and “Composite Depths” sections, this chapter). Also, the paleomagnetic records from the less condensed sequences in Holes 966B and 966D are much noisier than those from Holes 966A and 966C. Preliminary comparison of the records on a composite depth section suggests that intervals of some of the records are adversely affected by secondary components of magnetization. Although it is likely that it will be pos-

Figure 29. Age vs. depth plot for preliminary magnetostratigraphic data compared with positions of biostratigraphic datums (see “Biostratigraphy and Sedimentation Rates” section, this chapter). Ages for datums are the same as those in Figure 27.

sible to obtain a reliable magnetostratigraphy from Site 966, this goal awaits detailed post-cruise studies.

STRUCTURAL GEOLOGY

The succession drilled in the six holes at Site 966 can be split into four lithostratigraphic units in terms of lithostratigraphy, organic geochemistry, FMS, and seismic data (see “Lithostratigraphy,” “Organic Geochemistry,” “Downhole Measurements,” and “Site Geophysics” sections, this chapter):

- Unit I: upper unit of nannofossil ooze and organic-rich layers;
- Unit II: sequence containing a mixture of tilted beds and debris flows;
- Unit III: shallow-water carbonate succession; and
- Unit IV: basal unit of pelagic chalks with chert nodules and rare finely laminated bituminous layers.

These units are characterized by a variety of both structural features (Table 5) and deformational intensity (Fig. 31). Lithostratigraphic Unit I consists of a predominantly horizontally bedded sequence that contains virtually no faults. The bedding in Unit II is commonly inclined and offset by dominantly high-angle normal faults (Table 5). Unit III contains a little evidence of brittle failure toward the bottom of the sequence, where narrow calcite-filled veins and high-angle faults can be seen, both in the core face and in thin sections. Unit IV is characterized by a much higher intensity of deformation than any of the higher units. Here, relatively high-angle faults and veins crosscut a well-defined low-angle fabric that is subparallel to primary bedding surfaces. Strain shadows around burrows and intensely sheared calcitic material indicate that subhorizontal shear has occurred subparallel to the fabric.

Data and Data Manipulation

Three-dimensional measurement of structures in the upper two units was permitted only in Holes 966A and 966D because of the necessity of preserving intact sapropel sequences for post-cruise sampling. The Tensor orientation tool was run in Holes 966A, 966B, 966C, and 966D. Unfortunately, the placement of a magnetic collar directly above the tool as part of the drilling strategy caused measurement of the total magnetic field to be anomalously high and to give a positive declination. Suspicion that the resulting Tensor data are incorrect was confirmed by the apparent misfit between the Tensor data

Figure 30. Paleomagnetic inclinations measured in archive-half cores using the shipboard pass-through magnetometer for Hole 966A (after AF demagnetization at 20 mT) and Holes 966B, 966C, and 966D (after AF demagnetization at 25 mT).

and paleomagnetic measurements made on individual samples from Holes 966A and 966D (see “Paleomagnetism” section, this chapter).

Lithostratigraphic Units III and IV were recovered by RCB drilling. Although measurements of structures with respect to the core liner were made throughout these intervals, there is no indication of how much rotation occurred between the core and liner during the drilling process. Shipboard reorientation of the structures back to geographic coordinates was therefore impossible.

Description of the Deformational Features of the Units

Units I and II

The transition from Unit I to Unit II occurs between 55 and 67 mbsf in Holes 966A through 966D. It is marked by a fairly abrupt change from largely undeformed, horizontally bedded nannofossil ooze and organic-rich layers to tilted (45° – 65° , e.g., Sections 160-966C-8H-1 through 9H-1) beds and debris flows. Although the majority of the fault deformation occurs at the top of Unit II in association with coherent debris-flow textures (e.g., Fig. 32; Sections 160-966A-7H-3 through 7H-5, 160-966B-8H-1 through 9H-1, 160-966C-8H-1 through 10H-1, and 160-966D-8H-1 and 8H-2), rare faults were observed at the base of Unit I (e.g., Section 160-966D-7H-1, 115–130 cm). The upper part of Unit II comprises well-bedded chaotic layers (e.g., Fig. 32). The lower part, in contrast, is characterized by cemented carbonate clasts in a fine-grained, relatively homogenous, commonly moist, mud matrix (e.g., Section 160-966A-7H-6). The matrix-supported texture is thought to represent primary depositional fabrics as matrix-supported debris flows, although some fluidization may have occurred during drilling. Within this part of Unit II, few brittle deformational structures were observed.

The majority of the faults in the upper two units are high-angle planar faults with normal offsets in the order of 0.5–5 cm (e.g., Fig. 32; also Sections 160-966D-7H-1, 115–130 cm, and 160-966D-6H-2, 135–145 cm) (Table 5, Fig. 33). The angles of dip of almost all faults for which it was possible to calculate a true dip with respect to the core liner cluster between 40° and 90° (Fig. 34). Rare reverse faults are also visible (e.g., Sections 160-966A-7H-4, 44–53.5 cm, and 160-966C-9H-4, 65–123 cm). These faults have similar dip angles to the normal faults, but the offset is generally less than 2 cm (Table 5). In many cases it was not possible to match offset intervals on either side of the faults. In these instances, the sense of movement could not be determined, but the displacement was inferred to have been greater than the length of the fault exposed in the core face. High-angle planar discontinuities marked either by the trace of a dark mineral (possibly sulfides) or by slightly different colored material along their length can be seen in the lower part of Unit I and the upper part of Unit II (e.g., Section 160-966A-7H-4, 95–115 cm).

Although most of the fault geometries observed in this sequence are single high-angle faults, high-angle structures with more diffuse zones of deformation were also found (e.g., Fig. 35, Section 160-966A-7H-5, 42–52 cm, and 77–114 cm). Within these zones anastomosing microdiscontinuities can be seen with millimeter offsets and traces of different colored material. Similar features can be seen in the tilted beds found at the top of Unit II in Core 160-966C-8H (Fig. 36). Here, dark organic-rich material forms a diffuse zone of millimeter-scale irregular laminations subparallel to the tilted beds observed in the remainder of the core. This fabric may be the product of bedding-parallel shear caused during the tilting process. Small-scale discrete shear along individual subhorizontal planes can also be seen (Fig. 37).

Unit III

Unit III is defined on the basis of a small amount (5%–10%) of core recovered from this interval (see “Lithostratigraphy” section, this chapter) and the FMS data (see “Downhole Measurements” section, this chapter). The shallow-water carbonate pieces from the top of Unit III contain little evidence of brittle deformation. Toward the bottom (e.g., Section 160-966F-21R-1), however, small calcite-filled veins with millimeter offsets were observed (Fig. 38). Larger scale fractures were observed in the FMS data over this interval (see “Downhole Measurements” section, this chapter), and their presence provides one possible reason for the poor recovery of Unit III.

Unit IV

The top of Unit IV occurs at about 300 mbsf in Hole 966F. It is defined by a lithologic change from shallow-water carbonates to heavily bioturbated Eocene pelagic carbonates with current-reworked organic-rich layers in Core 160-966F-26R (see “Lithostratigraphy” and “Organic Geochemistry” sections, this chapter) and by a marked change in the character of the Quad combo logs and FMS signatures (see “Downhole Measurements” section, this chapter). The structural features of the rocks recovered also change markedly over this abrupt boundary. Unit IV is characterized throughout by a strong shallow-dipping to subhorizontal fabric (Fig. 39C). This fabric is most prominent in the more organic-rich layers, but is still present in the paler intervals (Fig. 40). Burrows throughout Unit IV are flattened with respect to this fabric (Fig. 41) and rarely show evidence of minor strain shadows (e.g., Section 160-966F-29R-3, 55 cm, Fig. 40).

Crosscutting this fabric is a series of faults with a variety of dip angles, mainly between 30° and 60° (Fig. 39A). Many have slickenside lineations preserved along them. These include both normal and

Table 5. Structural data collected at Site 966.

Core, section, interval (cm)	Depth (mbsf)	Feature	Offset width (cm)	Orientation on core face (degrees)		Second apparent orientation (degrees)		Calculated orientation (degrees)		Comments
				Apparent dip	Direction	Apparent dip	Direction	Dip (degrees)	Direction (degrees)	
160-966A-										
7H-1, 82-85	54.12	F	0.5	80	90	0	349	80	79	Lined by dark mineral (Mn?); sense?
7H-2, 50-74	55.3	F	1	73	90	0	9	73	99	Normal
7H-2, 90-100	55.7	F	1	78	270	0	353	78	263	Normal
7H-3, 98-119	57.28	F	4	65	270	0	10	65	280	Normal
7H-3, 120-122	57.5	F	1	81	270	0	32	82	302	Reverse
7H-4, 44-53.5	58.24	F	1	70	270	0	341	82	251	Reverse and lined by dark mineral (Mn?)
7H-4, 94-112	58.74	F		68	270	0	18	68	288	Lined by dark mineral (Mn?); sense?
7H-5, 0-5	59.3	F		72	270					
7H-5, 19-22	59.49	F?		48	270	0	2	48	272	
7H-5, 42-52	59.72	F ₃		73	270	0	345	74	255	Shear in organic-rich layers
7H-5, 77-102	60.07	F ₄		55	270	0	340	57	250	Shear zone, very irregular, measurement approximate
7H-5, 100-114	60.3	F ₅		66	270	0	328	69	238	Base of shear zone
160-966C-										
8H-1, 10-11	66.6	SB		45	270					
8H-1, 21-22	66.7	SB		65	270					
9H-2, 11-17	77.61	F ₁	0.5	47	90					
9H-2, 11-15	77.61	SB		20	270					
9H-2, 77-85	78.27	F ₂		51	90					
9H-2, 80-89	78.3	F ₃		48	90					
9H-2, 85-97	78.35	F ₄		50	90					
9H-2, 95-104	78.45	F ₅		47	90					
9H-2, 114-126	78.64	F ₆		43	90					
9H-2, 124-127	78.74	SB ₂		25	270					
9H-2, 138-143	78.88	F ₇		31	90					
9H-3, 100-105	80	F ₁		52	270					
9H-3, 105-107	80.05	F ₂	1	42	270					Dextral
9H-3, 109	80.09	F ₃	1	10	90					Dextral
9H-3, 110	80.1	F ₄	1	28	90					Dextral
9H-3, 33	79.33	F ₅		14	270					
9H-3, 35	79.35	F ₆		11	270					Dextral
9H-3, 39-40	79.39	F ₇		26	270					
9H-3, 41-45	79.41	F ₈		44	270					
9H-3, 45-50	79.45	F ₉		37	270					
9H-4, 5-14	80.55	F ₁		58	90					
9H-4, 11-22	80.61	F ₂		60	90					
9H-4, 30-33.5	80.8	F ₃		20	90					
9H-4, 38-50	80.88	F ₄	1	65	90					Reverse
9H-4, 57-58	81.07	F ₅	1	11	90					Normal?
9H-4, 65-79	81.15	F ₆		67	90					
9H-4, 94-104	81.44	F ₇		42	90					Reverse?
9H-4, 103-115	81.53	F ₈	5	53	90					Reverse?
9H-4, 109-119	81.59	F ₉		51	90					Reverse?
9H-4, 114-119	81.64	SB		35	270					
9H-4, 119-123	81.69	F ₁₀		52	90					Reverse?
160-966D-										
6H-1, 114	42.64	SB		36	270	0	38	43	308	Bedding
6H-2, 33-85	43.33	F		84	270	0	6	84	276	Fault or discontinuity
6H-2, 71-76	43.71	F	1	45	90	0	47	56	317	Microfault
6H-2, 135-144	44.35	F	2	47	270	0	351	47	261	Normal fault with irregular plane
6H-3, 115	45.65	F		49	90	0	328	54	58	Microfault
6H-3, 113-133	45.63	F		70	90	0	322	74	52	Microfault
6H-5, 15-22	47.65	F	4	48	270	0	316	57	226	Normal fault
6H-5, 17-25	47.67	F	4	51	270	0				
6H-6, 133-142	50.33	F		50	90	0	336	53	66	Normal fault
6H-7, 18-30	50.68	F	2	46	90					Microfault
6H-7, 18-30	50.68	F	1	87	90					Microfault
7H-1, 113-142	52.13	F	3	68	270	0	360	68	90	Normal fault?
8H-2, 8-11	62.08	SB ₁		28	270	0	335	30	245	Bottom of a sapropel
8H-2, 83-94	62.83	F ₁ ?		60	270					Bottom of a sapropel
8H-2, 89-96	62.89	F ₂	0.5	68	90					Bottom of a sapropel
8H-2, 98-101	62.98	DIS ₂		26	90					Bottom of a sapropel

Table 5 (continued).

Core, section, interval (cm)	Depth (mbsf)	Feature	Orientation on core face (degrees)		Second apparent orientation (degrees)		Calculated orientation (degrees)		Comments
			Offset width (cm)	Apparent dip	Direction	Apparent dip	Direction	Dip	Direction
8H-2, 110-115	63.1	SB ₂		43	270	0	28	43	118
8H-2, 113-120	63.13	F ₁	1	45	90	0	319	72	49
8H-2, 125-130	63.25	DIS ₁	3	39	270	0	322	63	52
8H-3, 111-116	64.61	F ₁		67	90	0	35	60	305
8H-3, 113-123	64.63	F ₂		57	270	0			
9H-2, 82-93	72.32	F ₂		55	270	0			
9H-4, 7-16	74.08	F ₂	2	51	90	0			
9H-4, 26-33	74.27	V		38	270	0	318	46	48
9H-4, 42-52	74.43	F		50	90	0	44	59	134
9H-4, 51	74.52	V		Horizontal					
9H-4, 53	74.54	V		Horizontal					
9H-4, 57	74.58	V		Horizontal					
9H-4, 62-67	74.63	V		42	270				
9H-4, 69-70	74.7	V		10	270				
9H-4, 76-91	74.77	F		60	270	0	50	70	320
9H-4, 82-93	74.83	F		60	270				
9H-4, 85-87	74.86	F		19	90				
9H-6, 100-105	77.6	F	1	39	90	0	0	78	270
9H-7, 48-72	78.14	DIS		78	270				

Note: Feature symbols defined in Table 2 ("Explanatory Notes" chapter, this volume).

reverse faults (e.g., Sections 160-966F-29R-1, 146-148 cm, and 160-966F-30R-3, 59-63 cm), generally with an offset <5 cm. Distinct fractures and veins with a great variety of dip angles were also found (Figs. 31, 39B). There is a continuum of structures, with many of the small offset faults also containing material of different color and grain size than the surrounding rock. In thin section, these infills appear to be fine-grained granular calcite and dark organic material.

A prominent shear zone can be seen in Section 160-966F-30R-2, 6-14 cm (348 mbsf). Here, a 3-cm-thick layer of highly sheared gray material that XRD examination showed to be predominately calcite is bounded on both sides by dark anastomosing shear lamellae both subparallel to the major shear and at an angle to it. Smaller similar features were found in association with other low-angle veins and faults throughout Unit IV (e.g., Section 160-966F-28R-3, 37-43 cm).

Interpretation

The association of faults with the transition from a sequence of debris-flow deposits and tilted beds in Unit II to Unit I in which the bedding is largely horizontal and undisturbed suggests that processes related to the initiation of catastrophic units also resulted in faulting. Isolated limestone clasts in fine-grained nannofossil ooze may also be a product of faulting supplying coarse blocks of older limestone to deeper water environments. Bedding-plane-parallel shear within the tilted unit (Fig. 36) is thought to have been caused by slump activity and differential movement between semilithified layers. The tendency of the high-angle faults to occur within the interval at the very top of Unit II and at the base of Unit I suggests that these features may have formed as a result of compaction differences after debris flow and slump deposition. It is possible, however, that they represent a period of high-angle faulting that occurred soon after the beginning of deposition of Unit I.

Two possibilities were considered for the origin of the subhorizontal fabric and the flattening of the burrows in Unit IV. One possibility is that they were subjected to an unusual degree of compaction that the overlying unit did not experience because of early cementation in the shallow-water carbonates of Unit III. More likely, however, the compaction and flattening that affects the lower unit occurred soon after the deposition of Unit IV and prior to its lithification. This is supported by the presence of strain shadows in the lee of burrows. These most likely formed by plastic deformation associated with small amounts of shear along bedding-parallel planes induced initially by primary depositional fabric (e.g., current laminations, see "Lithostratigraphy" section, this chapter). The crosscutting structures found in Unit IV are thought to have occurred significantly later than the fabric development, but evidence from the cores recovered is not sufficient to indicate whether faults in the overlying limestone were caused by the same stress orientation.

In summary, compaction and small-scale shear occurred prior to complete lithification of the Eocene sediments in Unit IV. Subsequently, higher angle fractures and faults were formed, but it is not clear whether they also affect the limestone in Unit III. The deformational features found in Unit II and at the bottom of Unit I are compatible with a faulting event possibly generated by subsidence of the area after shallow-water carbonate deposition. Subsequent slump and debris-flow deposition probably reflect downslope movement in a predominantly fine-grained depositional environment with periodic input of coarser material.

COMPOSITE DEPTHS

High-resolution (2-10-cm scale) data collected on whole cores on the MST and percent color reflectance collected on split cores from Holes 966A through 966E were used to determine depth offsets in the composite section. On the composite depth scale, sedimentary fea-

Figure 31. Composite frequency plot of structural features (microfaults, fractures, and veins) with depth in Holes 966D and 966F shows the concentration of deformational fabrics at the boundary of Units I and II, base of Unit III, and within Unit IV.

Figure 32. High-angle normal microfault offsetting a debris-flow deposit at Section 160-966A-7H-3, 98–117 cm.

tures present in adjacent holes are aligned so that they occur at approximately the same depth. Working from the top of the sedimentary sequence, a constant was added to the depth in meters below seafloor for each core in each hole to arrive at a composite depth for that core. The depths offsets that comprise the composite depth section are given in Table 6. Continuity of the sedimentary sequence was documented for the entire section above 75 mcd. Below 75 mcd, the recovery was too low to permit accurate construction of a composite depth scale.

Percent color reflectance (collected at 2-cm intervals) and magnetic susceptibility data (collected at 3-cm intervals) were the prima-

Figure 33. Equal-area stereographic projection of poles to faults for Holes 966A and 966D.

Figure 34. Frequency plot of true dip angles of microfaults measured in Units I and II in Holes 966A and 966D shows the predominance of high-angle features.

ry parameters used for correlation purposes at this site. Natural gamma-ray data (collected at 10-cm intervals) provided supplementary verification of core overlap and depth offsets. GRAPE wet-bulk density variations were of low amplitude and thus not useful for composite depth construction at this site.

The percent color reflectance records (550-nm wavelength) and magnetic susceptibility data used to verify core overlap for Site 966 are shown on a composite depth scale in Figures 42 and 43. The cores from Holes 966A through 966D provide continuous overlap to almost 75 mcd. Cores below this depth level in each of Holes 966A through 966D could not be tied into the composite section because recovery was too low and/or the core material was too disturbed to be processed through the MST or with the color reflectance scanner.

Significant stratigraphic gaps (greater than 2 m) occur between most cores from Hole 966A. Most core gaps in Holes 966B through 966D are less than 1 m, with many less than 50 cm. The large gaps between cores from Hole 966A are largely an artifact of the composite construction procedure. Hole 966A is condensed relative to the other holes but retains almost all of the same stratigraphic features. This lower sedimentation rate can result in an artificially large gap between similar features in cores as shown in Figure 44. Similar examples were seen throughout Hole 966A, where a simple linear stretch of a core would result in a much higher correlation and smaller "coring gaps" (e.g., Core 160-966A-6H). Confirmation of the continuity of the section in the upper 70 mcd was possible only after Hole 966D was cored.

Stretching and compression of the sedimentary features in aligned cores indicates distortion of the cored sequence as well as variations in the sedimentation rate. Because much of the distortion occurs within individual cores on depth scales of less than 9 m it was not possible to align many features in the color reflection and magnetic susceptibility records accurately by simply adding a constant to the mbsf core depth. Within-core scale changes will require post-cruise processing to align these distorted sedimentary features.

Figure 35. A nearly vertical shear zone crosscutting an organic-rich layer with associated anastomosing microfabrics at Section 160-966A-7H-5, 78–113 cm.

Figure 36. Bedding-parallel shear affecting an organic-rich layer in the tilted bedding section of Section 160-966C-8H-4, 46–80 cm.

Figure 37. Discrete shear along horizontal zones offsetting purple diagenetic bands visible in the core face at Section 160-966C-9H-3, 102–113 cm.

Figure 38. Thin-section photograph of a calcite-filled fault that offsets a mollusk shell from the base of Unit III in Sample 160-966F-21R-1, 8 cm.

Figure 39. Frequency plots of dip angles for (A) faults and fractures, (B) veins, and (C) dominant fabrics in Unit IV in Hole 966F.

Following construction of the composite depth section for Site 966, a single spliced record was assembled from the aligned cores. The Site 966 spliced record can be used as a sampling guide to recover a single sedimentary sequence. The spliced record consists primarily of cores from Holes 966B, 966C, and 966D. Cores from Hole 966A were not used to construct the splice as the section is condensed relative to the other holes. Intervals with significant disturbance or distortion were avoided when possible. The tie points for the splice are given in Table 7. A small (20 cm) depth discrepancy may result when comparing composite depths generated from the offset depth table (Table 6) with a single downcore record (e.g., magnetic susceptibility) generated using the splice table (Table 7). This discrepancy results from slight misalignments of stratigraphic features (see discussion in previous paragraph) used to make the splice. A spliced record of reflectance (550 nm) is given on the accompanying CD-ROM (back pocket).

INORGANIC GEOCHEMISTRY

Interstitial-water samples were obtained at Site 966 from 1.45 to 95.78 mbsf, using the standard ODP titanium/stainless-steel squeezer (Manheim and Sayles, 1974). In total, 14 samples were squeezed, and the retrieved pore waters were subsequently analyzed for salinity, alkalinity, chloride, sulfate, bromide, lithium, potassium, rubidium, sodium, calcium, magnesium, strontium, ammonium, and silica (Table 8) using methods described in the "Explanatory Notes" chapter (this volume).

In this section, we have included two interstitial-water samples from Hole 965A from 6.75 and 16.25 mbsf that were analyzed by the same methods as described above.

Figure 40. Subhorizontal development of bedding-parallel fabric in bituminous pelagic carbonate in Unit IV at Section 160-966F-29R-3, 47–59 cm. Note the flattened burrows and the small strain shadows around a burrow at 55 cm.

Figure 41. Axial ratios of cross sections through burrows in Unit IV that are assumed randomly distributed with respect to the core face. The plot shows that there is a distinct flattening of burrows perpendicular to the fabric. The best fit is shown by the line.

Table 6. Site 966 composite depth section.

Core	Depth (mbsf)	Offset (m)	Depth (mcd)
160-966A-			
1H	0.00	0.19	0.19
2H	5.80	2.23	8.03
3H	15.30	3.26	18.56
4H	24.80	4.47	29.27
5H	34.30	6.59	40.89
6H	43.80	9.07	52.87
7H	53.30	12.65	65.95
160-966B-			
1H	0.00	0.00	0.00
2H	7.70	0.49	8.19
3H	17.20	0.46	17.66
4H	26.70	0.56	27.26
5H	36.20	1.07	37.27
6H	45.70	1.59	47.29
7H	55.20	1.91	57.11
160-966C-			
1H	0.00	0.00	0.00
2H	9.50	0.40	9.90
3H	19.00	0.55	19.55
4H	28.50	0.91	29.41
5H	38.00	1.89	39.89
6H	47.50	2.03	49.53
7H	57.00	2.11	59.11
160-966D-			
1H	0.00	0.02	0.02
2H	3.50	-0.22	3.28
3H	13.00	1.49	14.49
4H	22.50	2.43	24.93
5H	32.00	2.87	34.87
6H	41.50	4.07	45.57
7H	51.00	5.33	56.33
160-966E-			
1H	0.00	-0.03	-0.03

The pore-water profiles at both sites are characterized by subtle changes in chemical composition. A minor decrease occurs in the concentration of chloride, whereas the salinity and the concentrations of sodium, lithium, and potassium remain fairly constant. Decomposition of metabolizable organic matter seems to be of minor importance and affects the pore-water composition only slightly. However, some pronounced reactions involving carbonates appear to occur.

The lowermost sample at Site 966 was taken from the core catcher of Core 160-966D-13X, which had a low recovery (30%). Therefore, it cannot be ruled out that element concentrations in this sample are altered by the drilling process (e.g., heating, contamination with seawater), which may have caused enhanced mobilization and/or exchange reactions of fluids with mineral surfaces and the precipitation of carbonate. A number of pore-water constituents in this sample deviate in a manner that seems unrelated to possible in situ processes. This sample is, therefore, shown in parentheses and labeled with a question mark in all figures, and is not discussed further.

Salinity, Chloride, Sulfate, Sodium, Potassium, and Rubidium

Salinity remains nearly constant within the given precision of the refractometer reading, whereas a small but distinct decrease occurs in the concentration of chloride vs. depth relative to bottom water at Sites 966 and 965 (Fig. 45). The concentrations of sodium, sulfate, potassium, and lithium exhibit only slight variations with depth and do not seem to be involved in major uptake or release processes (Figs. 45, 46). It must be noted here that the precision of the chloride determination is better than that of the other pore-water constituents (see "Explanatory Notes" chapter, this volume). Therefore, minor changes may be visible in the chloride profile whereas they are not visible for the other elements.

Usually, a gradual decrease is observed in the potassium and rubidium concentrations vs. depth in marine sediments (see "Inorganic

Figure 42. Percent color reflection (550-nm wavelength) from Site 966 on the composite depth scale. Holes 966A through 966E are offset from each other by a constant (30 instrument units). Cores for each hole are shown (e.g., B3 = Core 160-966B-3H).

Geochemistry" section, "Site 963" chapter, this volume). At Sites 965 and 966, relatively high carbonate contents occur particularly in the lower part of the sedimentary column (see "Organic Geochemistry" section, this chapter). As a consequence, the clay content is relatively low, and exchange reactions of potassium and rubidium are of minor importance (Figs. 45, 46). Possibly, this effect is enhanced because of the relatively low sedimentation rates at Sites 966 and 965. These reactions seem to be more pronounced for rubidium than they are for potassium at Sites 965 and 966.

The minor decreases observed in the chlorinity vs. depth profiles for Sites 965 and 966 are consistent with findings by Van Santvoort and de Lange (in press), who reported a decrease in chloride concentration of approximately 10–15 mM over a depth interval of 12 m at a location close to Site 965. On the basis of the present data set, one can only speculate about the origin of such low-salinity waters. Possible explanations for the origin of lower salinity waters include meteoric water, formation and decomposition of gas hydrates, "subduction" fluids, and a paleo-ocean-water imprint. Whereas a small (about 2%) admixture of meteoric waters cannot be excluded, gas hydrates are unlikely to have formed at Site 965 because sulfate concentrations in the pore waters remain high and the zone of methanogenesis is never reached (see "Organic Geochemistry" section, this chapter).

The absence of an increase in the concentration of sodium, bromide, lithium, sulfate, potassium, and salinity and the presence of a small decrease in the concentration of chloride vs. depth all strongly

indicate that evaporites or evaporite brines do not occur in deeper levels at these sites (Figs. 45–47).

Although the concentration of lithium remains fairly constant with depth, a few remarks can be made: (1) a sharp increase occurs in the top few meters and (2) the general level is higher than expected according to the observed salinity concentrations. Such a lithium increase is comparable to that found in the upper parts of Sites 963 and 964 and is accordingly attributed to ammonium-related exchange reactions.

Ammonium, Bromide, Alkalinity, and Silica

Some ammonium and alkalinity seem to be produced by organic matter decomposition reactions in the top 5 m (Fig. 47). In general, the concentration of ammonium is low (cf., "Inorganic Geochemistry" section, "Site 963" chapter, this volume). The concentration of bromide is only slightly higher than in seawater (Fig. 47). The low degradation rates of sedimentary organic matter inferred from these low concentrations agree with the low average sedimentation rate at this site (see "Biostratigraphy and Sedimentation Rates" section, this chapter). The gradual, but minor, decrease of ammonium with depth is probably related to uptake and/or exchange reactions with mineral surfaces.

The silica pore-water profile distinctly increases in the upper 5 m and in the lower part of this site (Fig. 46). The early diagenetic mobilization of silica at about 5 mbsf is possibly related to minor amounts

Figure 43. Magnetic susceptibility (uncorrected instrument units) data from Site 966 on the composite depth scale. Holes 966A through 966F are offset from each other by a constant (50 instrument units). Note the different scale for 0–25 mcd. Cores for each hole are shown (e.g., B3 = Core 160-966B-3H).

of biogenic silica (such as radiolarian or diatom remains), whereas the major increase seen at the bottom of this site indicates the presence of more abundant amorphous silica phases (e.g., opal-A or opal-CT) at or below this depth level.

Carbonate Diagenesis

In the upper part of Site 966, small alkalinity increases reflect the low decomposition rate or abundance of organic matter. Values from deeper downhole are lower than seawater (Fig. 47), which indicates that some carbonate precipitation occurs below 30 mbsf. In the calcium vs. depth profile one does not observe an accompanying decrease, but a rather pronounced increase (Fig. 48) accompanied by a slight decrease in the concentration of magnesium. The molar $\text{Ca}^{2+}/\text{Mg}^{2+}$ ratio increases from a seawater value of 0.19 to values of about 0.27 (Fig. 48).

Relative to the uppermost pore-water sample, the equivalent concentration changes of CO_3^{2-} (alkalinity/2), Mg^{2+} , and Ca^{2+} at depth are approximately -1, -3, and +4 mM, respectively. Consequently, the pore-water decrease in magnesium is largely compensated by an increase in calcium. The most likely mechanism causing these changes is a dolomitization reaction (Baker and Burns, 1985) changing biogenic calcium carbonates into high-Mg calcites. This assumption is substantiated by preliminary data for the calcium and magnesium concentrations of carbonates from Site 965 (Table 9), which is located close to Site 966. Although the sample from Core 160-965A-4H has a molar Ca/Mg ratio of 65, samples from deeper intervals gener-

ally have much lower Ca/Mg ratios (1.3 to 16.2), that demonstrate the presence of high-Mg calcite.

During such recrystallization processes, strontium is partly liberated from the solid carbonate phase, leading to increases in the strontium pore-water concentration (Fig. 48). During this process only minor amounts of strontium are incorporated into the newly formed carbonate phases. Therefore, the pore-water strontium profile accurately records the active zone of carbonate recrystallization at Site 966. The depth interval with the highest strontium pore-water concentrations (40 to 70 mbsf) coincides with the level where the magnesium concentrations are lowest and where the major decrease occurs in alkalinity and calcium.

ORGANIC GEOCHEMISTRY

Volatile Hydrocarbons

As part of the shipboard safety and pollution-prevention monitoring program, hydrocarbon gases were analyzed in Cores 160-966A-1H through 8H, 10X, and 13X, and in Core 160-966B-9H by the headspace technique. Only trace concentrations of methane in the range of 2 to 4 ppm were recorded.

Carbonate and Organic Carbon

The abundances of total, inorganic, and organic carbon and of calcium carbonate in sediments from Hole 966A are summarized in Ta-

Figure 44. Comparison of magnetic susceptibility curves (uncorrected instrument units) from Cores 160-966A-2H and 160-966B-2H. The curves are offset from each other by a constant (50 instrument units). Note that although Core 160-966A-2H has the same major features as Core 160-966B-2H, significant (1 m) differences in alignment occur at 9 and 15 mcd if the two cores are aligned using the peak at 11.5 mcd. Hole 966A consists of a relatively condensed section as compared to the other hole, and misalignment of features between Hole 966A and the other holes usually results.

ble 10. Random sampling was performed for carbonate analysis. For organic matter assessment, samples were specifically taken from the sapropels.

Carbonate contents, with a few exceptions, are generally high throughout the sequence of soft sediments from Cores 160-966A-1H through 7H, including the sapropels (Fig. 49). The average carbonate content is 55% ($n = 93$). There is a tendency for carbonate concentrations to be slightly higher in the lower part of the profile.

Organic carbon was determined mainly for visually distinguished organic-matter-rich intervals. Values are higher than 2% and in several cases exceed 4%, with a maximum of 11% (Table 10, Fig. 49).

Organic Matter Type: C_{org}/N ratios, Rock-Eval Pyrolysis, and Pyrolysis-gas Chromatography

C_{org}/N ratios for all sapropels exceed a value of 14 and show a maximum of 22.7 (Table 10, Fig. 49). As already observed for sapropels at Site 964 (see "Organic Geochemistry" section, "Site 964" chapter, this volume), the surprisingly high values of the C_{org}/N ratio indicate an origin for organic matter that is not in accordance with the pyrolysis parameters. Thus, rather than following accepted lines of interpretation (e.g., Emerson and Hedges, 1988), the high C_{org}/N ratios of the sapropels are tentatively interpreted as representing an effective removal of nitrogen compounds from the marine organic matter during diagenesis; however, it cannot be ruled out that the primary marine organic matter was already poor in nitrogen-bearing constituents.

Results of Rock-Eval pyrolysis (Table 11) show hydrogen indices for many samples exceed 300; a maximum value of 582 was determined for Sample 160-966A-6H-CC, 19–20 cm. Consistent with the relationship between organic matter type and elemental composition, oxygen indices show an opposite trend to the hydrogen indices. Ox-

Table 7. Site 966 splice tie points.

Hole, core, section, interval (cm)	Depth (mbsf)	Depth (mcd)		Hole, core, section, interval (cm)	Depth (mbsf)	Depth (mcd)
966C-1H-6, 76.0	8.26	8.26	ties to	966B-2H-1, 26.0	7.96	8.26
966B-2H-5, 98.0	14.68	14.98	ties to	966D-3H-1, 52.0	13.52	14.98
966D-3H-4, 108.0	18.58	20.04	ties to	966C-3H-1, 36.0	19.36	20.04
966C-3H-7, 32.0	28.32	29.00	ties to	966B-4H-2, 6.0	28.26	29.00
966B-4H-6, 142.0	35.62	36.36	ties to	966D-5H-1, 126.0	33.26	36.36
966D-5H-7, 16.0	41.16	44.26	ties to	966C-5H-4, 28.0	42.78	44.26
966C-5H-6, 146.0	46.96	48.44	ties to	966B-6H-1, 104.0	46.74	48.44
966B-6H-7, 6.0	54.76	56.46	ties to	966D-7H-1, 38.0	51.38	56.46
966D-7H-3, 88.0	54.88	59.96	ties to	966C-7H-1, 28.0	57.28	59.96
966C-7H-5, 104.0	64.04	66.72	ties to	966A-7H-1, 32.0	53.62	66.72

ygen indices in samples down to about 33 mbsf are relatively high because of low-temperature (<390°C) decomposition of carbonates during pyrolysis and subsequent trapping of the CO_2 formed together with that derived from organic matter decomposition.

The maximum hydrogen index value of 582 for Sample 160-966A-6H-CC, 19–20 cm, is typical of marine organic matter that retained its hydrogen richness during deposition under reducing conditions. Lower hydrogen index values for the other sapropels indicate partial oxidation of the primary marine organic matter and/or an admixture of terrigenous organic matter. Extensive postdepositional alteration of the sapropels (e.g., by burrowing organisms) in the shallower section of Hole 966A (see "Lithostratigraphy" section, this chapter) has reduced the hydrogen content of the organic matter particularly in these sediments. There is a general tendency for higher hydrogen indices with increasing content of organic matter (Fig. 50).

Results of pyrolysis-gas chromatography of selected samples yield additional evidence of generally enhanced preservation of hydrogen-rich marine organic matter with increasing depth.

Sulfur

The sulfur contents reported in Table 10 in general exceed 2% in sapropels, with a maximum of 6% in Sample 160-966A-5H-4, 73–74 cm. However, sulfur contents did not reach the extremely high values determined in sapropels from Site 964 (see "Organic Geochemistry" section, "Site 964" chapter, this volume). Most of the sulfur is present as pyrite because pyrite concretions were visually detected in the sapropels and abundant disseminated pyrite was observed under the microscope. The downhole profile of sulfur roughly parallels that of organic carbon (Fig. 51).

Extractable Bitumen: Assessment of Paleotemperatures

Twenty-eight sapropel samples were analyzed for long-chain alkenones following the procedure described in the "Explanatory Notes" chapter (this volume). Long-chain alkenones were moderately to highly abundant in all sapropel extracts, so that ratios of di- and tri-unsaturated C_{37} alkenones (U_{37}^* index) could be determined for a first approximation of paleo-sea-surface temperatures based on the calibrations of Prahl and Wakeham (1987), Brassell (1993), and Sikes and Volkman (1993). All the samples yielded similar temperature values. Although the ratios calculated from the gas chromatograms may provide a reasonable approximation of the relative temperature changes with age, a mass spectrometric search for compounds possibly collating with the alkenones (particularly with the $C_{37:3}$ ketone at low concentrations) is necessary to validate the absolute temperatures (which for this reason are not tabulated here). Figure 52 shows that sea-surface temperatures were variable during the Pleistocene, down to a depth of about 23 mbsf, ranging from 18° to 24°C. In the Pliocene (below about 23 mbsf) temperatures were higher and less variable. The alkenone sea-surface temperature pattern is in general accordance with the results of previous geochemical studies on Mediterranean sapropels (ten Haven, 1986; ten Haven et al., 1987; K.C.

Table 8. Results of pore-water analysis for Sites 966 and 965.

Core, section, interval (cm)	Depth (mbsf)	pH	Alkalinity (meq/L)	Salinity (g/kg)	Cl ⁻ (mM)	Mg ²⁺ (mM)	Ca ²⁺ (mM)	SO ₄ ²⁻ (mM)	NH ₄ ⁺ (μM)	SiO ₂ (μM)	K ⁺ (mM)	Br ⁻ (mM)	Sr ²⁺ (μM)	Li ⁺ (μM)	Na ⁺ (mM)
160-966A-															
2H-5, 145-150	13.25	7.38	2.983	38.0	617	53.6	11.8	30.2	90	140	12.4	1.0	133	35	538
3H-5, 145-150	22.75	7.43	3.846	38.0	615	53.7	12.4	29.4	97	149	12.0	1.1	149	36	525
6H-5, 145-150	51.25	7.50	2.372	37.5	608	53.6	12.7	29.4	99	155	11.6	1.0	163	36	523
160-966D-															
4H-5, 145-150	29.95	7.42	3.036	37.5	609	52.7	13.0	29.4	105	153	11.3	1.1	170	36	527
5H-5, 145-150	39.45	7.37	2.618	37.5	607	51.4	13.5	28.9	94	146	11.9	1.0	169	35	527
7H-5, 145-150	58.45	7.60	2.013	38.0	606	51.7	13.8	29.6	87	149	11.3	1.1	176	36	530
8H-5, 145-150	67.95	7.58	1.822	38.0	606	51.7	13.8	30.0	80	208	11.8	1.0	176	34	540
9H-2, 145-150	72.95	7.70	1.392	38.0	609	53.3	13.8	29.5	84	201	12.0	1.0	166	36	534
10H-4, 145-150	85.45	7.64	1.518	37.5	606	52.2	13.8	30.3	51	303	11.9	1.0	153	33	538
12X-3, 140-150	92.90	7.71	1.607	38.0	606	54.2	14.5	30.1	47	395	11.5	1.0	135	36	532
13X-CC, 22-32	95.78	7.85	2.409	40.0	607	53.5	13.8	30.3	59	309	12.3	1.0	128	43	530
160-966E-															
1H-1, 145-150	1.45	7.46	3.168	38.5	620	56.3	11.4	30.9	37	149	12.2	0.9	106	30	532
1H-3, 145-150	4.45	7.55	3.240	38.0	620	56.2	11.5	30.5	74	238	12.2	0.9	114	35	543
1H-5, 145-150	7.45	7.58	3.216	38.0	615	55.5	11.5	30.3	90	149	12.3	1.0	120	35	522
160-965A-															
2H-4, 145-150	6.75	7.35	2.566	38.0	608	57.3	11.9	30.70	43	176	11.8	1.0	111	38	528
3H-4, 145-150	16.25	7.41	2.762	38.0	607	56.5	12.2	30.20	29	163	12.2	1.1	110	38	—

Note: — = no data.

Figure 45. Pore-water vs. depth profiles at Site 966 (solid symbols) and Hole 965A (open symbols) for salinity, chloride, sodium, and potassium. The dashed line indicates the bottom-water concentration. The analyses of questionable Sample 160-966D-13X-CC are marked in parentheses.

Figure 46. Pore-water vs. depth profiles at Site 966 (solid symbols) and Hole 965A (open symbols) for rubidium, sulfate, lithium, and silica. The dashed line indicates the bottom-water concentration. The analyses of questionable Sample 160-966D-13X-CC are marked in parentheses.

Emeis, pers. comm., 1995) and the current understanding of climate development during the past few million years.

Bituminous Limestone in Section 160-966F-26R-1

Sample 160-966F-26R-1, 17–22 cm, taken from the top of a bituminous limestone several decimeters thick, contains 5.25% organic carbon and 75.7% calcium carbonate. The nitrogen and sulfur contents are 0.32% and 0.41%, respectively. The low sulfur content indicates the absence or paucity of pyrite caused by iron limitation during deposition of this sedimentary rock. Rock-Eval data (HI =

429, OI = 63, $T_{max} = 413^{\circ}\text{C}$) and pyrolysis-gas chromatography indicate a dominance of marine organic matter, although at the top of the bituminous limestone section some oxidation may have occurred; no sample was available from the central, strongly laminated part of the bituminous limestone for shipboard analysis. Extraction of the rock sample followed by gas chromatographic analysis of the less polar extract fraction corroborates the pyrolysis results. Short-chain *n*-alkanes of marine origin with a maximum at C_{16} clearly dominate over the long-chain homologs derived from higher land plant waxes. Owing to the low maturity of the organic matter (cf., T_{max} value), however, nonhydrocarbons dominate the gas chromatogram.

Figure 47. Pore-water vs. depth profiles at Site 966 (solid symbols) and Hole 965A (open symbols) for ammonium, bromide, and alkalinity. The dashed line indicates the bottom-water concentration. The analyses of questionable Sample 160-966D-13X-CC are marked in parentheses.

PHYSICAL PROPERTIES

Standard physical properties (see “Explanatory Notes” section, this volume) were measured in all APC cores obtained at Site 966 and some lithified samples from RCB and XCB cores (see Tables 12–15). Because lithified rocks are not suitable for MST measurements, data gathered with the MST are available only for the upper 70 m of core obtained at Site 966. In this section, we describe the downhole distribution of measured physical properties at Hole 966A.

Index Properties

Measured bulk and dry density both increase sharply in the first 2 m (Table 12), which is consistent with porosity and water loss from the sediment/water interface downward (Fig. 53). Between 2 and 10 mbsf, a slight decrease in density and porosity occurs; this trend is not explained by downhole lithologic or structural changes (see “Biostratigraphy and Sedimentation Rates” and “Structural Geology” sections, this chapter). From 10 to ~70 mbsf, porosity decreases gradually from values of ~60% to about 55%; this decrease is not matched by a systematic increase in bulk- or grain-density values (cf., the two plots on Fig. 53).

Discrete-sample *P*-wave and Shear Strength Measurements

Curves showing horizontal and vertical *P*-wave velocities measured using the digital sonic velocimeter show three decreasing and two increasing trends with depth in Hole 966A (Table 13, Fig. 54). Decreases in DSV velocity were measured in the intervals 0–8, 28–38, and 46–56 mbsf and increases in DSV are in the intervals 10–28 and 38–46 mbsf. Below 56 mbsf, Figure 54 indicates increasing DSV velocity, although there is considerable scatter in the data.

Shear strength, measured in discrete samples using the motorized vane-shear device, shows an overall downhole increase (Table 13, Fig. 54). In detail, strength decreases between 28 and 34 mbsf; below 38 mbsf, there is considerable scatter in the data.

Some agreement exists between the DSV and strength data (Fig. 54). In particular, both increase in the interval from approximately 10 to 28 mbsf, and both decrease between 28 and 34 mbsf. However, from 34 to 38 mbsf, strength increases whereas velocity drops, and below 38 mbsf there is little coherence between the velocity and strength data.

GRAPE Density

The overall trend of the GRAPE data (Fig. 55A) is toward slightly increasing density with depth, and the rate of density increase is low

and constant. In detail, the GRAPE data show considerable variation, as is typical for this and other high-resolution measurements taken using the MST. A comparison of discrete index properties density measurements with GRAPE density (Fig. 55A) suggests that GRAPE measurements in this hole underestimate density, despite application of the Boyce correction (see “Explanatory Notes” chapter, this volume). This may be due to the fact that the calcite mineralogy in the hole differs from the quartz mineralogy assumed in the correction. In addition, GRAPE density is measured in undrained cores, and index properties sample preparation involves some water loss. In order to test the reliability of the GRAPE measurements, we resampled the GRAPE data to match the sample spacing of the index property measurements. A linear regression of the two density measures (Fig. 55B) confirms that the GRAPE underestimates density. Although there is not a strong correlation between the data sets, this suggests that the GRAPE variations do represent real density changes. Figure 55B suggests that a simple linear correction could be applied to readjust the GRAPE data.

P-wave Logger

High-resolution compressional wave velocities were measured using the PWL of the MST (Table 14, Fig. 56). The data exhibit considerable scatter, primarily because the measurements were made on cores that were not completely filled with sediment. Despite the scatter, there is some agreement between the long-wavelength trend of the PWL data and velocities measured in discrete samples (Fig. 56A). A linear regression between discrete-sample velocities and resampled PWL velocities (Fig. 56B) indicates a poor correlation. PWL data in their present form cannot be considered a reliable indicator of downhole velocity changes, nor are they likely to be useful as a correlation tool without filtering.

Magnetic Susceptibility

Figure 57 shows the results of magnetic susceptibility measurements for Hole 966A. The general trend of the data is gradually decreasing susceptibility with depth to 61 mbsf. From 61 mbsf to the base of the MST data, susceptibility drops sharply. On a finer scale, there is considerable variation. Susceptibility has empirically been shown to be a good correlation tool, and short-wavelength susceptibility changes probably reflect a complex interplay between sedimentological, chemical, and mineralogical effects. The first-order features of Figure 57 agree with inclination (see “Paleomagnetism” section, this chapter), and the decrease in susceptibility between 33 and 40 mbsf corresponds to an interval containing 23 sapropels (see “Lithostratigraphy” section, this chapter).

Natural Gamma-ray Radiation

NGR values in Hole 966A show several first-order trends. Between 0 and 30 mbsf, NGR values increase overall (Fig. 58); at 31 mbsf, NGR values decrease abruptly and then increase to 38 mbsf; another drop in values occurs at 39 mbsf, followed by an increase in the interval from 40 to 54 mbsf. From 54 mbsf to the downhole limit of the MST data, NGR values decrease. Superimposed on these first-order trends are many centimeter- to decimeter-scale variations; the cause of these cannot be confidently inferred from the lithologic descriptions. It is likely that the NGR fluctuations represent variations in radioactive mineral content associated with diagenetic changes.

Thermal Conductivity

Thermal conductivity at Hole 966A was sampled once per section in all APC cores and at irregular intervals in XCB and RCB cores (Table 15, Fig. 59). Thermal conductivity values increase overall downhole but show large variations on a scale of a few meters. This fluctuation is similar to that seen in the MST data and probably re-

Figure 48. Pore-water vs. depth profiles at Site 966 (solid symbols) and Hole 965A (open symbols) for calcium, magnesium, calcium/magnesium ratio, and strontium. The dashed line indicates the bottom-water concentration. The analyses of questionable Sample 160-966D-13X-CC are marked in parentheses.

Table 9. Preliminary atomic adsorption analysis of carbonates from Site 965.

Core, section, interval (cm)	Mg (%)	Ca (%)	Fe (ppm)	Mn (ppm)	Sr (ppm)	Ca/Mg (weight)	Ca/Mg (molar)
160-965A-							
4H-3, 98-100	0.4	40.1	1100	80	390	107.4	65.1
17X-1, 1-3	1.7	38.4	170	50	615	22.0	13.4
19X-1, 1-3	5.9	32.9	150	40	650	5.6	3.4
19X-1, 49-51	3.5	36.5	120	30	755	10.4	6.3
21X-1, 5-7	11.1	25.0	190	40	320	2.2	1.4
23X-1, 28-30	11.3	24.7	140	30	290	2.2	1.3
24X-1, 80-82	5.2	33.6	140	40	530	6.4	3.9
25X-1, 57-58	11.5	25.3	280	50	260	2.2	1.3
26X-1, 57-59	1.4	38.8	100	30	425	26.8	16.2
26X-1, 115-117	6.5	32.2	80	35	370	5.0	3.0
27X-1, 45-47	6.9	31.4	60	45	410	4.6	2.8

Notes: All data generated from HCl digestion (dilution 1:1000) of oven-dried (110°C) and homogenized samples. Only the first sample contained some visible clay, which explains the relatively high iron value.

flects an interplay of geochemical, sedimentological, and possibly structural effects. The overall increase in thermal conductivity values is most likely the result of compaction.

Summary of Physical Properties Measurements

Discrete physical properties measurements at Hole 966A served two main purposes: (1) to provide a test of the ability of high-resolution MST data to predict physical properties and (2) to allow evaluation of the validity of the MST data set as a correlation tool. In the first respect, it is clear that the PWL data are the least useful at this hole; the GRAPE data have good potential for explicit prediction of velocity values provided further corrections are made; and the predictive ability of the NGR and susceptibility data requires further evaluation. As a correlation tool, the MST data are of variable utility. NGR data are potentially useful, but the 10-cm sampling interval limits these data to first-order correlations. The GRAPE and susceptibility data are both useful for correlation, but PWL data from this hole in their present form should not be used in correlation studies. Paleontological results (see "Biostratigraphy and Sedimentation Rates" section, this chapter) indicate that there are no major hiatuses in the section that could correlate with the changes in physical properties discussed here.

DOWNHOLE MEASUREMENTS

At Site 966, we acquired a suite of log data by using the Quad combination, Formation MicroScanner, and geological high-sensitivity magnetic tool strings (see "Explanatory Notes" chapter, this

volume). The Lamont-Doherty temperature logging tool was attached to the bottom of the Quad combo string. After coring and drilling operations were completed in Hole 966F, the borehole was conditioned with 9-ppg sepiolite/seawater mud. The base of the BHA was set at 87.9 mbsf and pulled back to 64 mbsf to maximize the logging interval.

The borehole varied in diameter significantly from 28 cm (minimum opening of the density tool caliper) to a maximum of 46 cm. Major washout zones are located from the top of the logged interval to 104 mbsf and between 218 and 260 mbsf; along these zones the caliper of the density tool reached its maximum aperture. Intervals between 0.5 and 2 m long are washed out between 125 and 218. Locally, the bad hole conditions affected the quality of the density, sonic, and magnetic data and some of the FMS data.

Table 16 summarizes the intervals logged with each tool string. One run was made with the Quad combination and TLT string recording data while moving both downhole below the pipe and uphole through the pipe to the sea bottom. In spite of locally adverse hole conditions, the upgoing logs are of fair quality (Fig. 60). The sonic log, recorded with the SDT is noisy and requires reprocessing.

The FMS tool string provided two runs of high-resolution resistivity images of the borehole wall, measurements of the three vector components of the local magnetic field, and borehole inclination, deviation, and diameter in two orthogonal directions. Within the washed-out intervals, although only two or three of the FMS pads maintained contact with the borehole wall, the data quality is fairly good.

Two runs of the GHMT provided logs of the total magnetic field intensity and magnetic susceptibility (Table 16). The data acquired need recalibration and onshore processing and can be used only on a qualitative basis. Total magnetic induction shows a shift toward high values, caused by the highly magnetic BHA at the top and the released drill bit at the bottom of the hole.

Results and Preliminary Interpretation

Logging results are essential to reconstruct the sedimentary section and to place lithostratigraphic boundaries precisely at this site (Fig. 61) where core recovery was poor. The standard logs and especially the preliminary processed FMS images have been useful in determining the boundaries and lithology of some of the units drilled at this site. Here, we present an integrated interpretation of the full set of log data acquired at Hole 966F.

Four logging units can be distinguished on the basis of the log data. The units identified in Hole 966F correspond to major changes in the composition and texture of the sediments. Within each unit, sub-units were identified based on minor changes in the log response. They are interpreted as related to facies changes. The abrupt changes in log character at the boundaries between units suggest that they are

Table 10. Concentration of total, inorganic, and organic carbon, calcium carbonate, total nitrogen, and sulfur in sediments from Hole 966A.

Core, section, interval (cm)	Depth (mbsf)	Total carbon (%)	Inorganic carbon (%)	Organic carbon (%)	CaCO ₃ (%)	Nitrogen (%)	Sulfur (%)	C _{org} /N	C _{org} /S
160-966A-									
1H-1, 70-71	0.70		7.65		63.72				
1H-2, 63-64	2.13	5.70	4.68	1.02	38.98	0.08	0.15	12.5	6.9
1H-3, 15-16	3.15	9.20	3.96	5.24	32.99	0.34	3.48	15.6	1.5
1H-3, 70-71	3.70		6.58		54.81				
1H-3, 122-123	4.22	9.07	7.13	1.94	59.39	0.12	0.94	15.6	2.1
1H-3, 130-131	4.30	8.18	5.74	2.44	47.81	0.16	1.35	15.5	1.8
1H-4, 68-69	5.18	7.86	6.41	1.45	53.40	0.10	0.97	14.8	1.5
2H-1, 60-61	6.40		5.40		44.98				
2H-2, 60-61	7.90		5.21		43.40				
2H-3, 60-61	9.40	4.66	4.73	0.00	39.40	0.03	0.06	0.0	0.0
2H-4, 60-61	10.90		5.45		45.40				
2H-5, 60-61	12.40		5.90		49.15				
3H-1, 8-9	15.38		5.47		45.57				
3H-1, 70-71	16.00		6.96		57.98				
3H-2, 12-13	16.92	7.11	5.81	1.30	48.40	0.08	0.70	16.1	1.9
3H-2, 92-93	17.72		6.30		52.48				
3H-4, 30-31	20.10	6.15	5.08	1.07	42.32	0.08	0.72	14.0	1.5
3H-4, 83-84	20.63		6.45		53.73				
3H-4, 127-128	21.07	10.19	2.62	7.57	21.82	0.39	4.14	19.6	1.8
3H-5, 50-51	21.80		6.02		50.15				
3H-5, 77-78	22.07	12.64	3.93	8.71	32.74	0.45	5.86	19.4	1.5
3H-6, 44-45	23.24	6.42	1.95	4.47	16.24	0.24	2.12	18.6	2.1
3H-6, 70-71	23.50		5.87		48.90				
4H-1, 43-44	25.23	7.62	6.23	1.39	51.90	0.09	0.62	15.8	2.2
4H-1, 65-66	25.45	7.97	6.68	1.29	55.64	0.08	0.76	16.1	1.7
4H-2, 60-61	26.90		7.37		61.39				
4H-3, 105-106	28.85	9.74	5.72	4.02	47.65	0.19	1.29	20.7	3.1
4H-4, 11-12	29.41	8.68	7.03	1.65	58.56	0.10	0.14	17.0	11.5
4H-4, 40-41	29.70		6.97		58.06				
4H-5, 60-61	31.40		7.69		64.06				
4H-6, 60-61	32.90	9.28	7.71	1.57	64.22	0.09	0.48	18.3	3.3
4H-6, 66-67	32.96	11.49	7.72	3.77	64.31	0.19	0.80	19.7	4.7
4H-6, 117-118	33.47	9.07	5.88	3.19	48.98	0.16	2.30	19.6	1.4
4H-7, 27-28	34.07	9.11	6.68	2.43	55.64	0.13	1.10	18.8	2.2
5H-1, 18-19	34.48	7.80	6.98	0.82	58.14	0.05	0.16	16.0	5.2
5H-1, 41-42	34.71		7.40		61.64				
5H-1, 55-56	34.85		7.42		61.81				
5H-1, 69-70	34.99	9.56	7.08	2.48	58.98	0.15	0.18	16.9	13.9
5H-1, 76-77	35.06	10.83	6.80	4.03	56.64	0.21	2.16	19.4	1.9
5H-1, 123-124	35.53	8.79	7.35	1.44	61.23	0.09	3.09	15.5	0.5
5H-1, 145-146	35.75	9.08	7.74	1.34	64.47	0.08	1.16	17.5	1.2
5H-2, 20-21	36.00		7.10		59.14				
5H-2, 30-31	36.10	12.13	5.74	6.39	47.81	0.34	5.89	19.0	1.1
5H-2, 58-59	36.38	10.70	7.01	3.69	58.39	0.19	1.98	19.3	1.9
5H-2, 83-84	36.63	9.65	7.56	2.09	62.97	0.12	0.52	17.0	4.1
5H-2, 88-89	36.68	12.09	7.51	4.58	62.56	0.26	1.13	17.9	4.1
5H-2, 122-123	37.02	11.39	7.49	3.90	62.39	0.19	3.29	20.3	1.2
5H-2, 127-128	37.07	12.20	8.71	3.49	72.55	0.17	0.91	20.6	3.8
5H-3, 3-4	37.33	9.70	6.91	2.79	57.56	0.14	3.38	20.4	0.8
5H-3, 9-10	37.39	15.60	5.57	10.03	46.40	0.44	3.25	22.7	3.1
5H-3, 13-14	37.43	14.67	7.12	7.55	59.31	0.36	0.81	21.0	9.3
5H-3, 51-52	37.81	14.97	6.55	8.42	54.56	0.39	3.87	21.6	2.2
5H-3, 82-83	38.12	14.07	7.04	7.03	58.64	0.36	2.13	19.8	3.3
5H-3, 97-98	38.27		8.03		66.89				
5H-3, 113-114	38.43	9.93	7.36	2.57	61.31	0.15	0.99	17.2	2.6
5H-3, 119-120	38.49	11.41	7.05	4.36	58.73	0.26	0.81	17.0	5.4
5H-4, 8-9	38.88	9.76	6.93	2.83	57.73	0.16	1.35	17.6	2.1
5H-4, 43-44	39.23	15.43	5.82	9.61	48.48	0.45	5.23	21.2	1.8
5H-4, 48-49	39.28	12.95	7.11	5.84	59.23	0.31	1.60	19.1	3.7
5H-4, 73-74	39.53	11.20	2.49	8.71	20.74	0.46	6.02	18.9	1.4
5H-4, 114-115	39.94		8.00		66.64				
5H-5, 14-14	40.44	9.00	6.39	2.61	53.23	0.17	4.87	15.1	0.5
5H-5, 140-141	41.70	8.72	7.45	1.27	62.06	0.09	0.18	13.9	7.2
5H-6, 22-23	42.02	9.34	8.23	1.11	68.56	0.08	0.15	14.2	7.3
5H-6, 70-71	42.50	8.74	7.91	0.83	65.89	0.06	0.19	13.1	4.4
5H-6, 100-101	42.80		7.98		66.47				
5H-7, 19-20	43.49	7.79	6.99	0.80	58.23	0.07	0.16	12.2	5.1
5H-7, 44-45	43.74	9.51	8.77	0.74	73.05	0.06	0.19	12.9	4.0
6H-1, 11-12	43.91	8.47	7.47	1.00	62.66	0.07	0.15	13.5	6.6
6H-1, 65-66	44.45	8.88	8.47	0.41	70.56	0.05	0.09	8.9	4.3
6H-1, 100-101	44.80		8.39		69.89				
6H-4, 125-126	49.55		7.89		65.72				
6H-4, 136-137	49.66	10.26	6.77	3.49	56.39	0.22	1.23	16.2	2.8
6H-5, 51-52	50.31	8.74	7.62	1.12	63.47	0.08	0.18	14.1	6.1
6H-6, 62-63	51.92	8.28	6.93	1.35	57.73	0.11	0.28	12.9	4.8
6H-6, 140-141	52.70	8.53	7.06	1.47	58.81	0.11	0.27	13.1	5.4
6H-7, 48-49	53.28	12.05	1.02	11.03	8.50	0.61	2.00	17.9	5.5
6H-CC, 19-20	53.64	14.47	5.87	8.60	48.90	0.44	4.85	19.4	1.8
7H-1, 40-41	53.70	8.27	7.10	1.17	59.14	0.09	0.25	12.3	4.7
7H-1, 68-69	53.98	9.17	6.02	3.15	50.15	0.22	1.38	14.3	2.3
7H-1, 110-111	54.40		7.97		66.39				
7H-1, 131-132	54.61	9.54	7.74	1.80	64.47	0.14	2.48	12.5	0.7
7H-1, 145-146	54.75	9.50	7.51	1.99	62.56	0.15	0.93	13.2	2.1
7H-2, 10-11	54.90	8.56	6.93	1.63	57.73	0.12	0.14	13.1	11.3
7H-2, 42-43	55.22	12.51	5.20	7.31	43.32	0.48	2.45	15.3	3.0
7H-3, 30-31	56.60		7.89		65.72				
7H-4, 90-91	58.70		7.74		64.47				
7H-5, 96-97	60.26		8.60		71.64				
7H-5, 130-131	60.60		8.46		70.47				
7H-6, 104-105	61.84		9.59		79.88

Figure 49. Downhole distribution of calcium carbonate and organic carbon concentrations and the ratio of organic carbon to total nitrogen in sediments from Hole 966A.

major discontinuities, probably unconformities. They are located at 114, 239.3, and 299.8 mbsf.

Log Unit 1 (68.8–114 mbsf)

Log Unit 1 consists of muddy, low-resistivity sediments of low radioactivity in the upper part and higher radioactivity sediments (breccia) at the bottom. We differentiated three subunits, from top to bottom: Subunit 1A (68.8–89.2 mbsf), Subunit 1B (89.2–100.6 mbsf), and Subunit 1C (100.6–114 mbsf). Subunits 1A and 1B are of low radioactivity. The boundary between these two subunits is emphasized by an increase in natural radioactivity (increase in uranium content) and also by an increase in resistivity and density within Subunit 1B. Subunit 1A is more conductive and homogeneous, showing the presence of scattered pebbles or nodules within a muddy (conductive) matrix, whereas Subunit 1B shows the existence of higher resistivity intervals displaying cross-lamination-like features.

All the standard log data indicate a significant change at the boundary between Subunit 1B and Subunit 1C (i.e., increased natural radioactivity shown by higher U and Th contents) and a reduction in resistivity values. The magnetic data are affected by the proximity of the pipe, but Subunit 1C can be characterized by a moderate magnetic susceptibility ($<150 \times 10^6$ SI) that increases toward the bottom ($>160 \times 10^6$ SI). The changes in the values of the log measurements that are the most sensitive to lithology (gamma ray, PEF, etc.) observed within this subunit suggest a gradual change in composition from the bottom to the top of Subunit 1C. No major change was observed on the FMS images between Subunit 1B and Subunit 1C, except that Subunit 1C is clearly recognized as a breccia with a greater concentration of high-resistivity clasts than that observed above in Subunit 1B.

Log Unit 2 (114–239.3 mbsf)

The boundary between log Units 1 and 2 is clearly recognized on the FMS images by a change from the conductive “breccia facies” to the laminated and cross-laminated, more resistive materials of Unit 2, which corresponds to a sharp change in log values and in the character of the other logs. It is interpreted as an unconformity on the basis of the fact that the sediments below and above show a significant contrast in composition and log facies. The depth of the Pliocene/Miocene boundary inferred from the incomplete core record might logically be shifted to correspond to this important change in stratigraphy inferred from the logs (see “Biostratigraphy and Sedimentation Rates” section, this chapter).

Log Unit 2 is characterized by high natural radioactivity values (20–60 GAPI) and higher resistivity than Unit 1 and the uppermost portion of Unit 3. The values of PEF, density, and resistivity suggest

that the lithology of this unit is a generally porous limestone. The washout zones correlate with changes in logs that are not substantially sensitive to borehole diameter (deep induction, gamma ray, PEF). This fact suggests that the caliper is also reflecting changes in formation composition and texture. The washout zones correlate best with low-radioactivity and low-resistivity zones suggesting muddy intervals. Intervals with better hole conditions correlate with higher resistivity zones, which suggests a less porous and/or better cemented lithology. These intervals also coincide with higher radioactivity, which suggests a probable depositional change. FMS images indicate that the conductive intervals are coincident with lower radioactivity, low resistivity, and the washout zones. The deep-induction log also indicates low resistivity and confirms that it is a real feature and not a borehole effect. The trends observed in the logs suggest an increase and then a decrease in the relative abundance of fine-grained clay-rich sediment, with a change at about 197.8 mbsf, and several minor sequences. The zones of increase in magnetic susceptibility within this unit correspond roughly with the increase in uranium content.

FMS images show that Unit 2 sediments are mostly cross laminated and characterized by resistive sediments alternating with thin, more conductive layers. The fractures that were identified will be analyzed in detail post-cruise.

At the base of Unit 2, a highly radioactive and relatively resistive interval marks the boundary between Unit 2 and Unit 3. It corresponds to uranium-rich (organic), slightly resistive levels that could represent the onset of different conditions within the sedimentary environment. The FMS images show a sharp facies change at the boundary between Units 2 and 3.

Log Unit 3 (239.3–299.8 mbsf)

Log Unit 3 is extremely homogeneous and can be characterized by low and fairly constant values (usually below 15 GAPI) of the natural radioactivity characteristic of limestone and by fairly constant density and magnetic susceptibility values. A slight increase in resistivity toward the base, which is coincident with better borehole conditions, and a slight increase in density values suggest better cementation or lower porosity of the carbonates. Poor pad contact resulted in poor-quality FMS images. The caliper, resistivity logs, and FMS data indicate the existence of fractures within this unit.

Log Unit 4 (299.8–352.8 mbsf)

Log Unit 4 is relatively homogeneous. It is characterized by a moderate radioactivity (usually 15–30 GAPI). An exception is the top of the unit, where a highly radioactive, uranium-rich (organic) interval (299.8–304.3 mbsf) was identified. The uppermost level, just at the unit boundary, reflects an increase not only in uranium but also in thorium and potassium. Within Unit 4, the content of thorium and potassium is slightly higher than within Unit 3, which denotes differences in the environment or source area. A change in composition and presumably higher clay content (related to higher potassium) would account for the decrease observed in acoustic velocity. The sonic, density, PEF, neutron, and magnetic susceptibility logs all reflect slight changes that indicate the existence of beds that appear on the FMS images as high-resistivity levels at a centimeter to decimeter scale. Open fractures (high angle and low angle) are indicated on the FMS images and are probably evidenced also by the caliper and resistivity log features (Fig. 61).

Correlation with Lithostratigraphy

The section logged at Hole 966F coincides with the interval of low core recovery. The logging data correspond to lithostratigraphic Units II through V (see “Lithostratigraphy” section, this chapter). The log features allow locating the depths where the most significant changes occur in Hole 966F (Fig. 61). The combination with geolog-

Table 11. Results of Rock-Eval analysis for Hole 966A.

Core, section, interval (cm)	Depth (mbsf)	S ₁ (mg/g)	S ₂ (mg/g)	S ₃ (mg/g)	TOC (%)	PC	HI	OI	T _{max} (°C)	PI	S ₂ /S ₃
160-966A-											
1H-2, 63-64	2.13	0.20	0.61	9.48	1.02	0.07	60	929	412	0.25	0.06
1H-3, 15-16	3.15	1.54	11.71	18.32	5.24	1.10	223	350	420	0.12	0.64
1H-3, 122-123	4.22	0.46	2.41	9.99	1.94	0.24	124	515	415	0.16	0.24
1H-3, 130-131	4.30	0.63	4.11	12.08	2.44	0.39	168	495	423	0.13	0.34
1H-4, 68-69	5.18	0.33	1.52	9.12	1.45	0.15	105	629	409	0.18	0.17
3H-2, 12-13	16.92	0.17	0.90	8.56	1.30	0.09	69	658	425	0.16	0.11
3H-4, 30-31	20.10	0.14	0.65	7.41	1.07	0.07	61	693	418	0.18	0.09
3H-4, 127-128	21.07	1.94	23.07	18.31	7.57	2.08	305	242	426	0.08	1.26
3H-5, 77-78	22.07	3.07	30.65	19.16	8.71	2.80	352	220	425	0.09	1.60
3H-6, 44-45	23.24	1.02	10.26	13.92	4.47	0.94	230	311	428	0.09	0.74
4H-1, 43-44	25.23	0.42	2.65	7.41	1.39	0.25	191	533	421	0.14	0.36
4H-1, 65-66	25.45	0.22	1.27	6.90	1.29	0.12	98	535	426	0.15	0.18
4H-3, 105-106	28.85	1.26	12.28	12.31	4.02	1.12	305	306	423	0.09	1.00
4H-4, 11-12	29.41	0.37	3.87	8.29	1.65	0.35	235	502	427	0.09	0.47
4H-6, 60-61	31.40	0.38	2.44	8.28	1.57	0.23	155	527	417	0.13	0.29
4H-6, 66-67	32.96	1.03	10.08	11.57	3.77	0.92	267	307	419	0.09	0.87
4H-6, 117-118	33.47	0.68	8.08	4.63	3.19	0.73	253	145	423	0.08	1.75
4H-7, 27-28	34.07	0.47	6.16	4.06	2.43	0.55	253	167	429	0.07	1.52
5H-1, 69-70	34.99	0.76	6.08	4.60	2.48	0.57	245	185	416	0.11	1.32
5H-1, 76-77	35.06	0.82	10.43	5.14	4.03	0.93	259	128	421	0.07	2.03
5H-1, 123-124	35.53	0.20	1.54	3.24	1.44	0.14	107	225	419	0.11	0.48
5H-1, 145-146	35.75	0.23	2.00	3.08	1.34	0.19	149	230	426	0.10	0.65
5H-2, 30-31	36.10	1.87	19.08	6.77	6.39	1.74	299	106	416	0.09	2.82
5H-2, 122-123	37.02	0.97	12.07	5.30	3.90	1.08	309	136	420	0.07	2.28
5H-3, 3-4	37.33	0.61	7.36	4.44	2.79	0.66	264	159	421	0.08	1.66
5H-3, 9-10	37.39	5.73	43.79	8.74	10.03	4.11	437	87	419	0.12	5.01
5H-3, 13-14	37.43	4.28	30.00	7.94	7.55	2.85	397	105	419	0.12	3.78
5H-3, 51-52	37.81	5.81	32.78	8.16	8.42	3.20	389	97	417	0.15	4.02
5H-3, 82-83	38.12	4.79	26.30	7.61	7.03	2.58	374	108	409	0.15	3.46
5H-3, 119-120	38.49	0.84	12.46	5.75	4.36	1.10	286	132	424	0.06	2.17
5H-4, 43-44	39.23	4.95	38.96	9.35	9.61	3.64	405	97	420	0.11	4.17
5H-4, 48-49	39.28	2.61	20.20	7.13	5.84	1.89	346	122	414	0.11	2.83
5H-4, 73-74	39.53	2.08	32.38	9.41	8.71	2.86	372	108	425	0.06	3.44
6H-1, 11-12	43.91	0.19	1.25	2.29	1.00	0.12	125	229	420	0.13	0.55
6H-3, 94-95	47.75	1.79	21.56	4.73	5.92	1.94	364	80	415	0.08	4.56
6H-4, 136-137	49.66	0.83	9.50	3.30	3.49	0.86	272	95	415	0.08	2.88
6H-7, 48-49	53.28	2.65	43.35	5.72	11.03	3.82	393	52	420	0.06	7.58
6H-CC, 19-20	53.64	4.76	50.01	5.48	8.60	4.55	582	64	414	0.09	9.13
7H-1, 68-69	53.98	0.83	9.20	3.35	3.15	0.83	292	106	416	0.08	2.75
7H-2, 42-43	55.22	2.29	34.88	5.05	7.31	3.09	477	69	417	0.06	6.91

Notes: TOC = total organic carbon; PC = petroleum potential as pyrolyzable carbon; HI = hydrogen index; OI = oxygen index; PI = production index; see the "Explanatory Notes" chapter (this volume) for units for these parameters.

Figure 50. Relationship between organic carbon and hydrogen index for sediments from Hole 966A.

ical data made it possible to identify most of the log-interpreted boundaries: 114 mbsf—boundary between the Pliocene matrix-supported breccias and the shallow-water limestone of probable Miocene age; 239.3 mbsf—noticeable textural and compositional change in the carbonates suggesting a different episode of sedimentation for these shallow-water carbonates; and 299.8 mbsf—boundary between the Miocene and the middle Eocene pelagic limestone.

Figure 51. Downhole variation of organic carbon and total sulfur contents in sediments from Hole 966A.

Our preliminary interpretation allows us to differentiate three sub-units within the Pliocene matrix-supported breccias that suggest at least three different episodes of deposition of the "breccia unit." Within log Unit 2, analysis of the log data indicates the existence of trends related to progressive changes in composition that can be the expression of changing conditions within the sedimentary environ-

Figure 52. Variation of paleo-sea-surface temperature (SST) during times of sapropel deposition as a function of depth in Hole 966A. Temperatures were calculated from the alkenone unsaturation index (U_{37}^*) according to the calibrations of (a) Sikes and Volkman (1993), (b) Prahl and Wakeham (1987), and (c) Brassell (1993).

ment (Fig. 61). Log Unit 3 may be correlated with the shallow-water carbonates logged at Hole 965A.

Temperature Logging Tool

The TLT was deployed 3 hr after hole conditioning was completed and measured temperatures to a depth of 350 mbsf (Fig. 62) with downhole and uphole runs. The tool string remained at the bottom of the hole for 3 min in order to record the bottom-hole temperature. The fast-thermistor and slow-thermistor curves show a constant offset of about 0.3°C . The values from the fast thermistor will be considered because they are more representative of sudden temperature changes. Figure 62 shows the fast- and slow-thermistor temperatures for both runs. The bottom-hole temperature measured is about 15.2°C , but the temperature of the borehole was still equilibrating (0.7 to 1.0°C/hr ; Fig. 63). There are noticeable downhole changes in the temperature gradient (Fig. 62).

The anomalies in the profiles may result either from temperature disturbances following circulation during operations or from fluid flow coming from the formation into the borehole (Table 17). Fluid flow is suggested by a negative gradient below 250 mbsf calculated from the temperature values of the downhole run. An average thermal gradient is difficult to define, but the data indicate that it is below 10 K/km .

SUMMARY AND CONCLUSIONS

Site 966, the second site of the transect drilled across the Eratosthenes Seamount to the Cyprus margin, is located on a broad high on the fault-bounded northern margin of the seamount plateau area. Objectives here were (1) to recover a Pliocene-Quaternary succession with abundant sapropels; (2) to determine the nature of the Miocene-Pliocene paleoenvironments and tectonic setting; (3) to elucidate the earlier history of the Eratosthenes Seamount; and (4) to infer the subsidence history of the site in relation to the Eratosthenes collision hypothesis. Seismic data show that a distinct (but complex)

reflector at the base of the Pliocene-Quaternary succession is underlain by several deeper, westward-inclined reflectors, of which the uppermost was penetrated by drilling. Four lithostratigraphic units were recognized in the recovered sequence within Holes 966A–966F as follows:

Unit I is approximately 60 m thick in the six holes and is composed of greenish gray to olive-green nannofossil ooze, which is clay rich toward the top and increasingly foraminifer rich in the lower part of the section. Volcanic ash is disseminated through the entire interval, which is mainly intensely bioturbated. The succession includes sporadic evidence of both high-angle normal and reverse faults, together with isolated small ($<3\text{ cm}$) clasts of limestone.

Within Units I and II, more than 90 discrete sapropels were identified. These are dark olive green to black in color, a few centimeters to 60 cm thick, and are mostly strongly bioturbated; in a few intervals, only the tops of the sapropels are slightly bioturbated with *Chondrites*. The abundance of the sapropels increases significantly toward the base of the section, where as many as 26 were found within one core. The sapropels vary in organic carbon concentration from 2% to 11% and show moderately high to low hydrogen indices coupled to the extent of secondary alteration (bioturbation). The source of the organic matter is assumed to be mainly marine, based on shipboard organic geochemical data. Preliminary assessment of paleo-sea-surface temperatures, based on alkenone ratios in lipids from sapropel extracts, indicates a fairly stable and warm climate in the Pliocene.

From the five APC holes, a composite section was compiled by means of high-resolution physical property measurements and sedimentological correlation. Coring gaps were identified between individual cores at each hole, and slight differences in sediment thickness were recognized between individual holes. Micropaleontological studies have established 18 datum levels in the composite section; these represent the time from the early Pliocene (MPL2 for planktonic foraminifers, and MNN12 for calcareous nannofossils) to the Holocene (sapropel S1 was found near the sediment surface). They imply deposition at nearly uniform rates of about 15 m/m.y. Paleomagnetic measurements reveal extensive diagenetic modifications and neoformation of magnetic carriers in sapropel-bearing intervals; these effects have overprinted the magnetic signal in the sediments and preclude recognition of a coherent shipboard magnetic stratigraphy.

Unit II ranges in thickness from approximately 20 to 60 m in five holes and is dominated by matrix-supported breccias, interpreted as debris flow. The top of the unit is marked by some debris flows and evidence of faulting. The remainder of the unit is mainly matrix-supported breccia, composed mostly of angular, soft carbonate, or well-cemented limestone clasts (up to 5 cm in size) in a matrix of green and brownish micrite. The uppermost breccia contains rare well-rounded clasts, indicative of reworking under high-energy conditions. The breccias lower in the section are locally cemented by sparry calcite. Sporadic mud clasts yield calcareous nannofossils of early Pliocene age (MNN12 for nannofossils and MPL2 for planktonic foraminifers), whereas one of the clasts is provisionally dated as late Miocene. Numerous small high-angle faults with normal offsets were observed. A few limestone clasts show evidence of shearing and cataclastic deformation. The FMS data show alternations of clast-rich and clast-poor fine-grained sediment and confirm that the breccia was not the result of drilling disturbance. In addition, the five holes drilled into Unit II at this site allowed an irregular paleotopography to be inferred beneath the Pliocene-Quaternary succession.

Unit III is approximately 200 m thick in Hole 966D, contains well-cemented packstones and grainstones, and shows cyclical variations in grain size and sedimentary structures. Individual layers include variable abundances of red and green calcareous algae, coral, benthic foraminifers, bivalves, and bryozoa. Benthic foraminifers are locally abundant and suggest a Miocene age. Coarser and thicker

Table 12. Index properties measured in cores from Hole 966A.

Core, section, interval (cm)	Depth (mbsf)	Water content (wt%)	Porosity (vol%)	Bulk density (g/cm ³)		Grain density (g/cm ³)		Dry density (g/cm ³)	
				Method B	Method C	Method B	Method C	Method B	Method C
160-966A-									
1H-1, 30-32	0.30	49.32	97.31	1.58	1.50	3.33	2.77	0.80	0.76
1H-1, 77-79	0.77	34.08	51.70	1.83	1.75	3.07	2.75	1.20	1.15
1H-2, 85-87	2.35	31.09	45.11	1.85	1.79	2.89	2.71	1.27	1.24
1H-3, 68-70	3.68	33.08	49.43	1.85	1.78	3.07	2.82	1.24	1.19
1H-4, 46-48	4.96	31.51	46.02	1.85	1.79	2.94	2.74	1.27	1.23
2H-1, 66-68	6.46	34.56	52.80	1.83	1.76	3.11	2.84	1.19	1.15
2H-2, 70-72	8.00	35.13	54.15	1.79	1.74	3.00	2.80	1.16	1.13
2H-3, 70-72	9.50	37.39	59.71	1.74	1.69	2.97	2.77	1.09	1.06
2H-4, 70-72	11.00	35.02	53.90	1.80	1.73	3.05	2.76	1.17	1.13
2H-5, 70-72	12.50	35.13	54.16	1.82	1.74	3.16	2.79	1.18	1.13

Only part of this table is reproduced here. The entire table appears on the CD-ROM (back pocket).

Table 13. Compressional wave velocity measured in cores from Hole 966A.

Core, section, interval (cm)	Depth (mbsf)	Measurement type	Velocity (km/s)
160-966A-			
1H-1, 79.5	0.80	DSV 2	1.593
1H-1, 80.1	0.80	DSV 1	1.588
1H-2, 88	2.38	DSV 1	1.728
1H-2, 88.6	2.39	DSV 2	1.607
1H-3, 69.4	3.70	DSV 2	1.693
1H-3, 69.4	3.70	DSV 2	1.693
1H-3, 69.9	3.70	DSV 1	1.593
2H-1, 65.3	6.45	DSV 1	1.567
2H-1, 67	6.47	DSV 2	1.561
2H-2, 72.2	8.02	DSV 1	1.571

Note: Direct DSV measurements.

Only part of this table is reproduced here. The entire table appears on the CD-ROM (back pocket).

Table 14. Vane shear strength measured in cores from Hole 966A.

Core, section, interval (cm)	Depth (mbsf)	Strength (kPa)
160-966A-		
1H-1, 72	0.72	5.8
1H-2, 93.5	2.44	9.2
1H-3, 75.6	3.76	11.7
1H-4, 42.7	4.93	15.2
2H-1, 56.6	6.37	16.1
2H-2, 69.6	8.00	16.5
2H-3, 66.1	9.46	16.4
2H-4, 64.9	10.95	17.5
2H-5, 47.8	12.28	17.1
2H-6, 27	13.57	21.6

Only part of this table is reproduced here. The entire table appears on the CD-ROM (back pocket).

Table 15. Thermal conductivity measured in whole cores from Hole 966A.

Core, section, interval (cm)	Depth (mbsf)	Thermal conductivity (W/(m · K))
160-966A-		
1H-1, 0.50	0.50	0.96
1H-2, 0.50	2.00	0.96
1H-3, 0.50	3.50	1.15
1H-4, 0.50	5.00	0.93
2H-1, 0.50	6.30	1.20
2H-2, 0.50	7.80	1.14
2H-3, 0.50	9.30	0.99
2H-4, 0.50	10.80	1.25
2H-5, 0.50	12.30	0.96
2H-6, 0.50	13.80	1.20

Only part of this table is reproduced here. The entire table appears on the CD-ROM (back pocket).

Figure 53. Index properties measured in Hole 966A cores.

bedded intervals have a high moldic porosity (e.g., from dissolution of bivalves) that is locally infilled with brown opaline silica. Several limestone layers are strongly cemented by sparry calcite. Minor dolomitization was also noted. Various trends in the log data (e.g., uranium spikes and other features) correlate with primary sedimentary variations (e.g., grain size), or diagenesis (e.g., secondary porosity and cementation). A relatively small number of high-angle faults and fractures were noted in the cores and FMS data. The base of Unit III is marked by a sharp discontinuity in the log data at 304 mbsf.

Unit IV is approximately 360 m thick and comprises an interval of finely laminated, highly burrowed, well-cemented chalky limestones rich in planktonic foraminifers of middle Eocene age. The limestones contain scattered nodules of black vitreous chert, com-

posed mainly of finely crystalline chalcedonic quartz. There are also several intervals (each tens of centimeters thick) that are composed of finely laminated bituminous limestone, which is thermally immature. The organic matter is hydrogen rich, has a low sulfur content, and is mainly marine in origin. The lowermost four cores exhibit a well-developed tectonic fabric, defined by mainly low-angle veins and shear planes that are cut by later high-angle normal faults and fractures. Individual burrows within the limestone are "plastically deformed," which indicates shear displacement prior to complete lithification.

Figure 54. P -wave velocity and shear strength measured in split sections. DSV 1 (parallel to core axis) = solid circles; DSV 2 (perpendicular to core axis) = solid squares; shear strength = open squares.

Figure 57. Magnetic susceptibility measured with the MST in cores from Hole 966A.

Figure 55. **A.** Density measured as part of index property measurements (connected open symbols) and GRAPE density (line) measured using the MST. **B.** Linear regression of index property density with GRAPE density at common depths. The dashed line represents a hypothetical one-to-one correspondence between the two density data sets.

Figure 56. **A.** P -wave velocities measured using the PWL component of the MST (small points) compared with velocities measured in discrete samples using the DSV apparatus (connected open symbols). **B.** Correlation of PWL velocity with DSV velocity at common depths.

Figure 58. Natural gamma-ray radiation measured with the MST in cores from Hole 966A.

Figure 59. Thermal conductivity measured in cores from Hole 966A.

Table 16. Hole 966F logged depth intervals for the three tool strings.

String	Run	Open-hole depth		In-pipe depth		Tools
		(mbsf)	(mbrf)	(mbsf)	(mbrf)	
Quad combination	Up 1	355.9–77.1	1290.4–1011.6	77.1–0	1011.6–934.5	NGT/SDT/CNT/HLDT/DIT/TLT
	Up 2 (repeat section)	141.1–77.1	1075.6–1011.6	77.1–69.1	1011.6–1003.6	
FMS	Up 1	357.4–77.1	1291.9–1011.6	77.1–74.4	1011.6–1008.9	NGT/GPIT/FMS
	Up 2	357.1–77.1	1291.6–1011.6	77.1–49.4	1011.6–983.9	
GHMT	Up 1	355.9–77.1	1290.4–1011.6	77.1–68.1	1011.6–1002.6	NGT/GHMT
	Up 2	355.9–77.1	1290.4–1011.6	77.1–58.5	1011.6–993	

The preserved sedimentation history of Site 966 began in the middle Eocene with the accumulation of deep-water pelagic carbonates (Unit I), similar to the coeval Lefkara Formation of southern Cyprus. Both these units experienced silica diagenesis and chert formation. The black, laminated sediments, in which organic matter is of mainly marine origin, reflect an interval of enhanced organic matter deposition under low-oxygen conditions. Deep-water sedimentation was terminated by regression (driven dominantly by tectonic uplift), and was followed unconformably by the accumulation of Unit III as a shallow-water coralline facies in an inferred near-reef setting of Miocene age. Lithologically similar limestones were cored at Site 965. After a second unconformity, matrix-supported breccias were shed from a rugged (fault-controlled) topography into an open-marine setting in the lowermost Pliocene. The local existence of this mass-wasted unit may explain the irregular and rather diffuse nature of the seismic reflectors directly below the semitransparent Pliocene-Quaternary at this site. Marine nannofossil ooze and sapropel deposition followed, with local evidence of minor syndepositional faulting and the derivation of limestone clasts from inferred active faults. Bioturbation and partial oxidation of the sapropels is in keeping with the relatively condensed nature and shallow setting (<1000 m) of sedimentation on the Eratosthenes Seamount plateau area.

In summary, drilling at Site 966 was clearly successful: we retrieved an extensive record of Pliocene to Pleistocene sapropels, identified the nature of the upper Miocene/Pliocene transition at this locality, and shed light on the earlier, Tertiary history of the Eratosthenes Seamount. Tectonically induced collapse of the seamount, inferred from evidence at Site 965, was identified to have occurred in the early Pliocene, although this event may be begun earlier.

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NOTE: Core-description forms (“barrel sheets”) and core photographs can be found in Section 5, beginning on page 535. Forms containing smear-slide data can be found in Section 6, beginning on page 951. Color reflectance, physical properties, chemistry, and thin-section data are presented on the CD-ROM (back pocket).

Figure 60. Hole 966F Quad combination tool and FMS (4-arm) caliper results.

Figure 60 (continued).

Figure 60 (continued).

Figure 60 (continued).

Figure 60 (continued).

Figure 60 (continued).

Figure 61. Interpreted log Units 1 through 4 in Hole 966F. The ILD, SFLU, ILM, and RHO logs show significant changes in log character related to changes in the composition and texture of the sediments. The dotted lines within log Unit 1 correspond to the boundaries between intervals that display remarkable differences in log values indicating changes in composition and texture.

Figure 62. Data from the temperature logging tool in Hole 966F.

Figure 63. Detail of bottom-hole temperature measurements, Hole 966F.

Table 17. Zones of possible water flow.

Zone	Depth (mbsf)
1	43, 63, 70, and 86
2	135
3	252, 254, 259, 263, 267, and 272
4	286, 292, 296, 300, 304, 312, 318, 322, and 328

SHORE-BASED LOG PROCESSING

HOLE 966F

Bottom felt: 934 mbrf
Total penetration: 356.0 mbsf
Total core recovered: 65.9 m (22.20%)

Logging Runs

Logging string 1: DIT/SDT-LSS/HLDT/CNT/NGT
Logging string 2: FMS/GPIT/NGT (2 passes)
Logging string 3: GHMT/NGT (2 passes)

The wireline heave compensator was used to counter ship heave resulting from the mild sea conditions.

Bottom-hole Assembly

The following depths for the BHA are as they appear on the logs after differential depth shift (see **Depth shift** section) and depth shift to the seafloor. As such, there might be a discrepancy with the original depths given by the drillers on board. Possible reasons for depth discrepancies are ship heave, use of the wireline heave compensator, and drill string and/or wireline stretch.

DIT/SDT-LSS/HLDT/CNT/NGT: BHA at ~70 mbsf.

FMS/GPIT/NGT: BHA at ~70 mbsf.

GHMT/NGT: BHA at ~70 mbsf.

Processing

Depth shift: All original logs were interactively depth shifted with reference to the NGT from the DIT/SDT-LSS/HLDT/CNT/NGT run (main pass) and to the seafloor (934 mbrf).

Gamma-ray processing: The NGT data were processed to correct for borehole size and type of drilling fluid.

Acoustic data processing: The sonic logs were processed to eliminate some of the noise and cycle skipping experienced during recording.

Quality Control

Data recorded through the BHA, such as the NGT and CNT data above 70 mbsf, should be used only qualitatively because of the attenuation on the incoming signal. The joints of the BHA are visible on the CNT log as high readings evenly spaced every 10 m. Invalid NGT values were recorded at 54–59 and 64–69 mbsf.

The overall quality of the acoustic data, even after reprocessing from transit times, is poor, particularly in the interval from 120 to 245 mbsf. Sonic waveform processing is recommended to obtain reliable results.

Density measurements are particularly affected by the enlarged and irregular borehole in the interval from 115 to 225 mbsf.

The hole diameter was recorded by the hydraulic caliper on the HLDT tool (CALI) and the caliper on the FMS string (C1 and C2).

Details of the standard shore-based processing procedures are found in the "Explanatory Notes" section (this volume). For further information about the logs, please contact:

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Hole 966F: Natural Gamma Ray-Density-Porosity Logging Data

Hole 966F: Natural Gamma Ray-Density-Porosity Logging Data (cont.)

Hole 966F: Natural Gamma Ray-Density-Porosity Logging Data (cont.)

Core Recovery	Depth (mbsf)	Caliper			Potassium			Depth (mbsf)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
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Hole 966F: Natural Gamma Ray-Resistivity-Sonic Logging Data

Hole 966F: Natural Gamma Ray-Resistivity-Sonic Logging Data (cont.)

Hole 966F: Natural Gamma Ray-Resistivity-Sonic Logging Data (cont.)