2. SITE 511

Shipboard Scientific Party

Date occupied: 15 January 1980; 0611 hr. (beacon dropped)
Date departed: 21 January 1980; 0342 hr. (underway; beacon close aboard 0532)
Number of holes: 1
Time on hole: 141 hr.
Position: 51°00.28'S, 46°58.30'W
Water depth (sea level; corrected m, echo-sounding): 51°00.28'S, 46°58.30'W
Water depth (rig floor; corrected m, echo-sounding): 2599
Bottom felt (m, drill pipe): 2589
Penetration (m): 632
Number of cores: 70
Total length of cored section (m): 632
Total core recovered (m): 385.62
Core recovery (%): 61
Oldest sediment cored:
Depth sub-bottom (m): 632
Nature: Black mudstone and nannofossil mudstone (black shales), rich in organic matter
Age: Late Jurassic
Measured velocity (km/s): ~2.3

Principal results: Drilling at Site 511 gave definitive results on the nature and age of the seismically determined wedge of sediments on the Falkland Plateau. The section drilled and continuously cored in the basin province of the plateau, about 10 km south of Site 330 on Maurice Ewing Bank, consists largely of diatomaceous, nannofossil, calcareous, and zeolitic oozes of Paleocene–Eocene to early Oligocene age between seafloor and a major erosional unconformity at 195 meters depth. This unit is underlain by 14 meters of early Maestrichtian calcareous and zeolitic calcareous oozes followed by 203 meters of zeolitic clays and claystones of Turonian to Campanian age, below which are 86 meters of early Albian to Turonian claystones and nannofossil claystones and chalks. The chalks rest on mudstones and nannofossil mudstones of Jurassic to early Albian age, rich in organic matter and called the black shales, of which 134 meters were cored for a TD of 632 meters below seafloor. A depositional hiatus of some 20 m.y. separates the Jurassic from the Cretaceous sediments.

At Site 511, the first successful heat flow measurement was obtained on the plateau, through use of the Downhole Temperature Probe. The heat flow is 1.5 HFU.

BACKGROUND AND OBJECTIVES

The Falkland Plateau extending eastward off southernmost South America is bounded on the north by the Falkland Escarpment and on the south by the Falkland Trough and North Scotia Ridge (Fig. 1). The western part of the plateau is a segment of oceanic crust (or attenuated continental crust) over which have been deposited 4–6 km of sediment in a basin bounded by the Falkland Islands Platform on the west, a narrow ridge associated with the Falkland Escarpment on the north, Maurice Ewing Bank on the east, and the North Scotia Ridge on the south. Maurice Ewing Bank, a subsided continental block that received thick carbonate as well as siliceous biogenic sediment throughout most of its history, forms the eastern part of the plateau.

In the basin thick, widespread sheets of sediment dip southward from the Falkland Escarpment ridge and are terminated updip by erosional truncation (Ludwig, this volume). They lap out against the Falkland Islands Platform and Maurice Ewing Bank. The lower boundary of the depositional sequence has been disrupted through movement of the North Scotia Ridge toward the plateau, resulting in deformation and uplift of near-surface sediment layers onto the north side of the ridge and subduction of lower layers beneath the ridge.

The wedge of sediments on the plateau appears to represent basin-slope and basin-floor seismic facies units. In the parallel sheet-drape facies generally described by Sangree and Widmier (1977), “Parallel reflections... drape over contemporaneous topography with only gradual changes in thickness or reflection character and suggest uniform deposition independent of the bottom relief. This pattern is strongly indicative of deep-marine hemipelagic clays and ooze” (p. 176).

Site 511 is located in the basin province of the Falkland Plateau, on the back slope of a cuesta-type ridge and about 10 km south of DSDP Site 330 on Maurice Ewing Bank, where Leg 36 scientists drilled 567 meters of Mesozoic and Cenozoic sediment above continental basement (Shipboard Scientific Party et al., 1977). During Middle to Late Jurassic to late Early Cretaceous (Aptian) time, shallow marine sedimentation, sometimes under euxinic conditions, prevailed on the bank. Predominantly pelagic deposition was established over the bank during Albian time as the bank subsided, with subsequent accumulation of clays containing planktonic fossils.

Multichannel seismic reflection records collected during Conrad cruise 21-06 (Fig. 2) show reflections dipping steeply to the south from the vicinity of Site 330.
Figure 1. Locations of Site 511 and other Leg 71 drill sites.
Figure 2. Robert D. Conrad 21-06 multichannel seismic reflection profile near Sites 511, 330, and 327. See Figure 3 for location.
Under the ridge structure, reflections are weak owing to the effect of scattering of seismic energy. Nevertheless, several prominent reflections may be traced from Site 330 to Site 511. The unconformity that apparently marks a major erosional hiatus on the plateau is present at Site 511. Thus Site 511 has been situated to delineate and define the depositional environment and the erosion and subsidence history of the Falkland Plateau. Cores from the site are expected to help clarify the bionstratigraphic, biogeographic, and sedimentological history related to major changes in circulation patterns through the Mesozoic and Cenozoic. The paleoceanographic alterations occurred in response to the breakup of Gondwanaland and the initial opening and enlargement of the South Atlantic, the development of bottom water passageways through the North Scotia Ridge, the opening of the Drake Passage, and the climatic evolution of Antarctica and the Southern Ocean.

SURVEY AND OPERATIONS

*Glomar Challenger* left Punta Arenas, Chile, at 1535 hr. on 10 January 1980. The route to the first drill site took the ship through the Strait of Magellan, then eastward to skirt the Falkland Islands to the south and on to Site 511 on the Falkland Plateau. The magnetometer and seismic reflection gear were streamed about midway between the mainland and the Falkland Islands. Progress was slowed first by head winds, then by low visibility in fog, and the average speed was held to 8.3 kn. As a result the ship arrived on site about 18 hr. later than anticipated.

Multichannel Seismic Line 142 (Fig. 2) obtained during *Conrad* cruise 21-06 was used as the basis for site location. *Challenger* arrived at the longitudinal location of the seismic line at 0430, 15 January, at a preselected point south of Site 511. After the ship changed course to the north and the speed was reduced to 5 kn., the site area on the back slope of a well-mapped, cuesta-type ridge was soon located. We profiled a short distance past the site to confirm its morphostructural setting, turned back, and dropped the beacon at 0611 hr., 15 January. Subsequent satellite fixes indicated that at 1700 hr. we were about one mile to the east of the approved site on the *Conrad* 21-06 seismic line; however, because the *Challenger* seismic line matched the *Conrad* line, the beacon position was occupied for the site (Fig. 3).

The first core was recovered from Site 511 at 1838 hr., 15 January (Table 1). Drilling and coring proceeded routinely to 0812, 20 January, when the hole was terminated at 632 meters below seafloor (the depth corresponding approximately to a 4.1 s reflector limit of penetration imposed by the JOIDES Safety Panel). Heat flow measurements were obtained at 52.5 meters and 119 meters below seafloor. Upon completion of the hole, a gamma-ray and neutron log was run through the pipe.

Our plan called for offsetting *Challenger* about 600 meters to the south and drilling an A hole to obtain a better percentage of core recovery in the 110-220-meter interval (below seafloor) than was obtained at the main site. The Paleocene section there is either missing or was missed in the coring, and as a consequence we were unable accurately to date a major erosional unconformity at 195 meters depth. However, after the drill string was pulled above the mud line, it was found that the hydraulic release on the drill bit had been activated and the bit had been dropped. Because of increasingly heavy seas and a 7-day limitation on site occupation time south of 50°S, it became necessary to leave Site 511 and move on to the next site on Maurice Ewing Bank.

LITHOLOGICAL SUMMARY

A sequence of pelagic and hemipelagic oozes and claystones was continuously cored at Site 511 to a sub-bottom depth of 632 meters. Below a thin veneer of Pliocene to Recent sediments, strata ranged in age from Late Jurassic to early Oligocene. The dominant lithologies cored were nanofossil–diatomaceous oozes, zeolitic claystones, and muddy nanofossil chalks.

Lithologic units were distinguished principally on the basis of color and composition. The six major units, their ages, thicknesses, colors, and major characteristics are summarized in Figure 4 and Table 2. In general, sediments cored below Core 27 (223.5 m) were sufficiently indurated to be termed claystones and chalks, whereas those above this depth were clays and oozes.

**Unit 1**

Unit 1 consists of a 3-meter veneer of gray to olive gray, siliceous, gravelly sands and thin foraminiferal oozes of Pliocene–Recent age. Pebbles are subangular to angular and of highly varied lithology including quartzite, basalt, and granite. Several Mn nodules (up to 5 cm in diameter) and manganiferous zones several centimeters thick were encountered in this unit. These youngest Cenozoic glaciomarine sediments unconformably overlie Unit 2.

**Unit 2**

**Subunit 2A**

Subunit 2A consists of massive, gray to dark gray, muddy diatomaceous oozes and muddy nanofossil–diatomaceous oozes of Paleogene age recovered in Cores 3 to 20 (3–186 m sub-bottom). This subunit consists of slightly to moderately bioturbated diatomaceous oozes with variable carbonate content.

The recovered cores are characterized by severe drilling disturbance resulting in the occurrence of frequent zones of coarse sand and gravel caved in from the Pliocene–Recent strata above; it is thought that many of the large Mn nodules from the lower part of this unit may have been similarly derived. The small Mn nodules (less than 1 cm diameter) which occur commonly in the uppermost part of the unit are thought to be in situ.

Disseminated, very fine, sand-sized detrital glauconite is common, particularly in the lower part of the unit. Several more indurated zones (4–10 cm thick) were encountered in Core 12. No apparent difference in composition was noted between these harder layers and the surrounding oozes.
Figure 3. Glomar Challenger 71 and Conrad 21-06 tracks (bold lines) and other ship tracks in the vicinity of Site 511.
Figure 4. Columnar section of Hole 511 showing the lithology recovered and biostratigraphic correlations. Although the cored interval for Core 24 was 4.5 m, 9 m of sediment were recovered. (Refer to Ludwig et al., Introduction, this volume, for a key to the lithologic symbols.).
Table 1. Coring summary, Site 511.

<table>
<thead>
<tr>
<th>Core No.</th>
<th>Date (Jan 1980)</th>
<th>Time</th>
<th>Depth from Drill Floor (m)</th>
<th>Depth below Seafloor (m)</th>
<th>Length Core Recovered (m)</th>
<th>Length Recovered (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>1388</td>
<td>5002.0-5007.0</td>
<td>0.0-5.0</td>
<td>5.0</td>
<td>4.89</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>2105</td>
<td>5007.0-5016.5</td>
<td>5.0-14.5</td>
<td>9.5</td>
<td>6.50</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>2211</td>
<td>5016.5-5026.0</td>
<td>14.5-24.0</td>
<td>9.5</td>
<td>6.50</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>2320</td>
<td>5026.5-5036.5</td>
<td>24.0-33.5</td>
<td>9.5</td>
<td>7.30</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>0067</td>
<td>5036.5-5046.5</td>
<td>33.5-43.5</td>
<td>9.5</td>
<td>5.90</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
<td>0210</td>
<td>5046.5-5056.5</td>
<td>43.5-53.5</td>
<td>9.5</td>
<td>5.41</td>
</tr>
<tr>
<td>7</td>
<td>16</td>
<td>0501</td>
<td>5056.5-5066.0</td>
<td>53.5-62.0</td>
<td>9.5</td>
<td>3.54</td>
</tr>
<tr>
<td>8</td>
<td>16</td>
<td>0610</td>
<td>5066.0-5076.5</td>
<td>62.0-71.5</td>
<td>9.5</td>
<td>0.04</td>
</tr>
<tr>
<td>9</td>
<td>16</td>
<td>0720</td>
<td>5076.5-5086.0</td>
<td>71.5-81.0</td>
<td>9.5</td>
<td>6.67</td>
</tr>
<tr>
<td>10</td>
<td>16</td>
<td>0834</td>
<td>5086.5-5096.5</td>
<td>81.0-90.5</td>
<td>9.5</td>
<td>0.40</td>
</tr>
<tr>
<td>11</td>
<td>16</td>
<td>1000</td>
<td>5096.5-5107.0</td>
<td>90.5-100.0</td>
<td>9.5</td>
<td>4.94</td>
</tr>
<tr>
<td>12</td>
<td>16</td>
<td>1120</td>
<td>5107.0-5117.5</td>
<td>100.0-110.0</td>
<td>9.5</td>
<td>3.12</td>
</tr>
<tr>
<td>13</td>
<td>16</td>
<td>1243</td>
<td>5117.5-5127.0</td>
<td>110.0-120.0</td>
<td>9.5</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Unit 2B

Subunit 2B, consisting of 72 cm of greenish gray (5GY 6/1) clays obtained in Core 21, is characterized by minor amounts of glauconite, chert, and volcanic ash. In Core 22, no sample was recovered; in the absence of core, Subunit 2B is arbitrarily continued to the base of Core 22.

Unit 3

This unit consists of gray, calcareous, and zeolitic foraminiferal oozes in Cores 23 and 24 (195-209 m, sub-bottom). These sediments are early Maestrichtian to late Campanian in age and are characterized by minor to moderate bioturbation, the presence of occasional chert pebbles (up to 5 cm diameter), and disseminated minor glauconite.

Unit 4

Unit 4 (Cores 25-47, 209-412 m sub-bottom) consists of zeolitic clays and claystones commencing near the bottom of Core 24. These units are Maestrichtian-Campanian to Turonian in age. Though the contact with Unit 3 is transitional, marked by an alternation of zeolitic clays and calcareous oozes, it is placed at 209 meters (bottom of Core 24), below which the zeolitic clays and claystones predominate. In general the darker zones (5Y 4/1) are more zeolitic than the lighter sections (5Y 6/1), which tend to be somewhat more calcareous. Dark greenish black mottles, lenses, and thin laminae (1-2 mm) were common throughout the unit.

The generally gray zeolitic clays and claystones are characterized by moderate to very intense bioturbation which has, in many sections, completely obliterated any evidence of stratification. The tremendous concentration of burrows of different colors (gray, light gray, dark gray, greenish gray, and dark greenish gray) in some sections gives the core a "conglomeratic" appearance. Many types of burrows were identified, including solid ring, Zoophycos, Chondrites, Planolites, and Teichichnus.

Pyrite is frequently encountered, usually in burrows. In Core 42, however, pyrite occurs as a vein-filling along vertically and obliquely oriented fractures. Irregularly shaped, slightly brown concretions of barite, ranging in diameter from ~0.5-4 cm, occur frequently throughout the unit.

Below Core 41, Section 3, fragments of the pelecypod Inoceramus, up to 3 mm thick and 3-4 cm long, were locally abundant.

Unit 5

Cores 48-56 (413.5-492 m sub-bottom) are early Albian to Turonian sediments dominated by reddish brown zones that frequently have a "blotchy" appearance. The unit is marked by minor to intense bioturbation with burrows frequently filled with pyrite.

Layers of skeletal carbonate debris, principally pelecypods (Aquellina and Inoceramus), occur frequently (Fig. 5) as muddy microcoquinas. Single, thin, whole pelecypod valves occur as well throughout the unit and Inoceramus "needles" are frequently concentrated in thin olive-gray claystone bands. Scattered solitary corals also occur in this unit.

Small barite nodules (approximately 0.5 cm), similar to those in Unit 4, occur in Cores 54 and 55.

In Core 51, Section 1, several very dark gray, highly calcareous sapropelic claystone layers (0.5 cm thick) are interstratified with reddish brown calcareous claystones and muddy calcareous chalks (muddy microcoquinas).

Unit 6

The lowest lithologic unit cored (Cores 57-70, 498-632 m sub-bottom) is Late Jurassic to early Albanian in
Table 2. Characteristics of lithologic units.

<table>
<thead>
<tr>
<th>Depth below Seafloor (m)</th>
<th>Core</th>
<th>Unit</th>
<th>Major Lithology</th>
<th>Color</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1, Sect. 2</td>
<td>1</td>
<td>Siliceous gravelly sand and minor foramin oozes</td>
<td>5Y 6/4 (pale olive)</td>
<td>Subangular-angular pebbles (up to 4 cm), varied lithologies. Mn nodules (up to 5 cm), thin Mn-rich zones, interstratified foram oozes and gravelly sand.</td>
</tr>
<tr>
<td>186</td>
<td>20</td>
<td>2B Clay</td>
<td>5Y 6/1 (gray)</td>
<td>Minor glauconite, chert, ash</td>
<td></td>
</tr>
<tr>
<td>195</td>
<td>22</td>
<td>3 Calcareous ooze and zeolitic calcareous oozes</td>
<td>5Y 7/1 (lt. gray)</td>
<td>Minor-moderate bioturbation, chert pebbles (4-5 cm), minor glauconite</td>
<td></td>
</tr>
<tr>
<td>209</td>
<td>24</td>
<td>4 Zeolitic clays and claystones</td>
<td>5G 6/1 (greenish-gray)</td>
<td>Moderate-very intense bioturbation, pyrite common, minor glauconite in upper part. Inoceramus fragments common in lower part. Barite (?) nodules</td>
<td></td>
</tr>
<tr>
<td>412</td>
<td>47</td>
<td>5 Claystones, nanofossil claystones, and muddy nanofossil chalks</td>
<td>5Y 5/3 (lt. olive-gray)</td>
<td>Minor-intense bioturbation, pyrite common, thin pelecypod fragments locally very abundant. Solitary corals, small barite (?) nodules, thin, dark gray, sapropelic layers (Core 51-1)</td>
<td></td>
</tr>
<tr>
<td>498</td>
<td>56, Sect. 4</td>
<td>6 Mudstones and nanofossil mudstones</td>
<td>5Y 5/1 (gray)</td>
<td>Black shales; peliliferous; often finely laminared and fusile, minor bioturbation, pyrite very common, thin zeolite claystones, minor chert, cone-in-cone calcite. Hard calcareous zones with local very high concentrations of pelecypod debris, belemnites common</td>
<td></td>
</tr>
</tbody>
</table>

AGE and consists of black, massive, thinly laminated mudstones and nanofossil claystones which in places are very fissile. These mudstones (black shales) are highly petroliferous below Core 60 and display only minor bioturbation. The monotonous sequence of black mudstones is interrupted by (1) occasional layers of concentrated pelecypod debris (Aucellina and Inoceramus) forming muddy microcoquinas similar to those in the overlying unit; (2) soft gray (5Y 5/1) layers (0.5-3.0 cm thick) of zeolitic claystone; (3) hard, muddy calcarenite layers; and (4) occasional layers of coarsely crystalline cone-in-cone calcite.

Pyrite is a common constituent, occurring as masses up to several centimeters in diameter, in burrows, and finely disseminated along thin laminae in zones 1-2 cm thick. Belemnites (up to 1 cm diameter and several cm long) occur scattered throughout this unit (Fig. 6).

Minor slumping and microfaulting of laminae were noted in the unit (e.g., Core 56, Sections 4-5; Core 62, Section 4). Dips of strata are generally 0.5° throughout the unit except in Core 52, in which dips are consistently 10-15° despite dip test results of less than 1° from the vertical for the inclination of the hole.

PALEONTOLOGY

Biostratigraphy Summary

The 70 cores taken continuously at Site 511 ranged from Holocene to Late Jurassic in age. Nearly all cores contained microfossils and those in the lower portions of the hole contained fossil mollusks and solitary corals as well. A broad range of microfossil groups are represented in various intervals of the section. Those dealt with in these reports include benthic and planktonic foraminifers, calcareous nannofossils, diatoms, silicoflagellates, radiolarians, pollen, spores, dinoflagellates, sponge spicules, calcisphaerulids, onychites, and calcareous microorganisms of unknown affinity (Upper Cretaceous).

One of the most significant results of this site was the collection of a 154-meter diatomaceous-ooze sequence of early Oligocene age, with exceptionally well preserved and diverse diatoms, radiolarians, and silicoflagellates along with sufficient numbers of calcareous nannofossils and foraminifers to provide temporal control by correlation with lower-latitude zonations and the well-established New Zealand stages. Although siliceous se-
Figure 5. Layers of skeletal carbonate debris, principally pelecypods, occur frequently as microcoquinas in Lithologic Unit 5 (Sample 511-48-2, 77-102 cm).

Figure 6. Belemnites in Unit 6 (Sample 511-60-2, 15-35 cm).

sequences of this age have been sampled before by DSDP (for example, DSDP Site 274, Leg 28), the critical time control by calcareous planktonic faunas and floras has, until now, always been lacking. The section at Site 511, combined with the upper Oligocene to lower Miocene section recovered at Site 513, provides a complete Oligocene section rich in siliceous microfossils. This composite section is the most complete record available in the
southern high latitudes for Oligocene diatom stratigraphy. Gombos and Ciesielski (this volume) have defined 12 diatom biostratigraphic zones for the interval from lower Miocene to upper Eocene based on a study of the composite section.

A second notable result of coring at Site 511 was the sampling of a long (174 m) Campanian-Coniacian section in the Cretaceous. Most of this unexpectedly thick section was not encountered at the nearby DSDP Site 327, Leg 36.

In addition to these results, a continuously cored section was taken through the upper portion of the Lower Cretaceous-Jurassic black shale sequence of the Falkland Plateau. This long, continuous section was characterized by high core recovery, and therefore makes possible further subdivision of the black shales by the calcareous microfossils, palynomorphs, and mollusks.

**Cenozoic**

The top 3 meters of the Cenozoic section contains a glacial marine sequence characteristic of this area (see Ciesielski, 1978). Approximately 10 cm of Pleistocene to Holocene calcareous ooze (repeated by a double hit of the core barrel) overlies sandy or gravelly diamictic sediments, dated from the Brunhes to the Gauss chron. These are separated by an erosional unconformity from the long lower Oligocene sequence. Upper age limits for the Oligocene section are imposed by the presence of the coccoliths *Reticulofenestra umbilica* in Core 2 and *Ismolithus recurvus* in Core 4; their extinctions (according to Hardenbol and Berggren, 1978) fall well within the early Oligocene. This age is supported by co-occurring planktonic foraminifers which are dated within Zones P18-P20. The luxuriant and well-preserved assemblages of siliceous microfossils offer the opportunity for a finer siliceous zonation of this interval in addition to the description of many new taxa. Pollen and spores are also relatively diverse and numerous in the lower Oligocene sediments.

The Oligocene sequence spans two radiolarian zones, four silicoflagellate zones, and five diatom zones. Many of these siliceous microfossil zones or datums within these zones have been revised or defined as new in these reports (see Gombos and Ciesielski, this volume; Weaver, this volume; Shaw and Ciesielski, this volume). The lowermost Oligocene and the underlying upper Eocene section, however, fall within the same silicoflagellate zone; thus, the group cannot at present be used to distinguish the Oligocene/Eocene boundary. This boundary has been placed at the top of Core 17 because of the occurrence of a single specimen of the planktonic foraminifer, *Globigerina index* and the presence of rare specimens of the coccolith *Discocysta saipanensis*. Dino- flagellate assemblages also suggest placement of the boundary there. Interestingly, two distinct assemblages of glass sponge spicules were noted, one characteristic of the Oligocene sediments (Cores 2-16) and the other present in Cores 17-20.

Calcareous microfossils do provide good control for the upper Eocene diatomaceous ooze which were sampled in Cores 18 and 20. Unfortunately, a complete sampling of this section and of much of the lower Oligocene was precluded by drilling problems. Coccoliths, however, are exceptionally well preserved in Cores 18 and 20 and correlate well with the *Reticulofenestra oamaruensis* Zone of New Zealand. The planktonic foraminifers belong to Zones P15 and P16 and can also be tied in closely to the classic New Zealand sections. It is not certain if the uppermost Eocene zone for planktonic foraminifers was sampled in Hole 511, primarily because of drilling problems.

Dating of the Eocene section is supported by the radiolarians, which are assigned to the *Thysocytis bromia* zonal equivalent. When the Eocene and Oligocene radiolarian assemblages are considered together, an overall cooling trend is noted. The Eocene populations indicate relatively warm (temperate) conditions whereas a cooling is evident in those from the Oligocene Cores 16-13. Radiolarians from Cores 12-11 are characteristic of proximity to Polar Front upwelling conditions and those from Cores 9-2 suggest a cool subantarctic/antarctic water mass. This overall cooling trend may reflect the northward migration of major water mass boundaries across Site 511 during the Eocene-Oligocene. A transgression over the Falkland Plateau of the front separating temperature and subantarctic/antarctic water masses may account for the upwelling and temperature change noted in Cores 13-2.

A high productivity of siliceous planktonic organisms throughout the late Eocene-early Oligocene is indicated by the exceptionally high sediment accumulation rate of about 44 m/m.y. recorded for this interval (Fig. 7).

Core 21 sampled a yellowish pelagic clay (Lithologic Subunit 2B) with some poorly preserved radiolarians and a few specimens of the diatom *Trinacria simulacrum*. This core is thought to be late Paleocene to early Eocene in age. Unfortunately, Core 22 contained no sediment so little more can be said about this poorly dated interval. Low accumulation rates plotted in Figure 7 suggest a disconformity between these cores and the Cretaceous sediment of Core 23.

**Mesozoic**

Cores 23 and 24 recovered an early Maestrichtian-late Campanian calcareous ooze which contained well-preserved foraminifers and a high-latitude coccolith assemblage so far observed only from DSDP Hole 327A. DSDP cores of this age from comparable latitudes in the Pacific sector of the Southern Ocean contain no carbonate. Benthic foraminifers dominated by calcareous species which lived above the lysocline data Cores 25-27 as early Maestrichtian-Campanian. The next core down, however, is nearly barren of all microfossils, owing to dissolution; only a few benthic foraminifers and lower Campanian coccoliths are present. Below that begins the long (19-core) section of zeolitic clays and claystones which are dated primarily by planktonic foraminifers. Sedimentation rates in this interval were exceptionally high (Fig. 7). Core 29 to Sample 511-41,CC to Sample 511-43,CC
is Santonian (probably late Santonian because of the absence of the coccolith \textit{Lithastrinus floralis}), whereas Cores 44–46 are considered undifferentiated Coniacian–Santonian. Planktonic foraminifers date Core 47 down to the topmost sample of Core 48 as Turonian in age; the remainder of that core is Cenomanian.

In general, the occurrence of planktonic foraminifers in the Upper Cretaceous sediments is quite sporadic because of dissolution. Preservation varies from moderate to poor. Two rather distinct assemblages of benthic foraminiferal assemblages were noted in this interval. An upper assemblage (Cores 31–41) includes diverse calcareous forms (up to 150 species) which inhabit bathyal depths above the CCD, whereas the lower assemblage (Cores 41–49) is dominated by agglutinated species. Benthic foraminifers are generally rare and poorly preserved in the lower section, with pronounced alternations in the percentages of calcareous and arenaceous species. This suggests numerous fluctuations of the CCD above and below the site of deposition.

Calcisphaerulids are found throughout the Maestrichtian–upper Cenomanian interval, and calcareous

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Figure 7. Sedimentation rates at Site 511.
microorganisms of unknown affinity, first described by Sliter (1977), are present in Cores 44-47. Cores 50-56 contain abundant calcareous microfossils dated as middle to early Albian ( Prediscosphaera prediscosphaera) calcareous nannofossil Zone). The change in sedimentation rate from the Turonian to the middle Albian is striking (Fig. 7) and indicates a highly condensed section with hiatuses in and about the Coniacian–late Albian interval. This was interpreted by DSDP Leg 36 scientists as a time of rapid subsidence of the Falkland Plateau, from shelf-break depths down close to its present depth below sea level, as a result of seafloor spreading.

This interpretation seems to be substantiated by the invertebrate macrofossils which became common in the shallow-water deposits below the Campanian–Coniacian interval. Fragile bivalves are present in Core 49, Section 3, and become very abundant in the Albian section below, where the genus Aucllina is identified. Solitary corals appear in Sections 4, 5, and 6 of Core 49 and also in Core 50. Fragments of the bivalve Inoceramus are the only mollusk shells found with any regularity in the Santonian–Coniacian section. These first appear in Core 41 and are present down the hole to Core 70. Cores 50–70 sampled continuously an Albian–Upper Jurassic section nearly identical to that which was cored on an interval basis in DSDP Holes 327A and 330. Rich benthic foraminiferal faunas indicative of shelf-break depths (100–400 m) are present down to Core 57, which is dated by foraminifers as Albian (the Tinctella roberti Zone). Coccoliths occur sporadically in Core 57 and are assigned to the Parhabdolithus angustus Zone, which Thierstein (1973) dates as late Aptian to early Albian. Coccoliths become notably less common in the black shales, which are first encountered downhole in Core 56 (Lithologic Unit 6).

Planktonic foraminifers occur sporadically in Cores 58–62 but date this portion of the black shales as Barremian to Aptian. Mollusks date Cores 57 and 58 as Aptian and Cores 59–62 as Barremian. From Core 58 down to the fourth section of Core 62, abundant fragments of the shallow-water coccolith Micrantholithus obtusus (mid-Aptian or older) occur at selected intervals, but few other age-diagnostic calcareous nannofossils are present. No coccoliths positively indicate the presence of Hauterivian or older Cretaceous strata. Palynomorphs do indicate an Early Cretaceous age for Cores 58–61. Although spores are not numerous, species present are also found in Lower Cretaceous rocks of Argentina and South Africa which have been dated with various degrees of certainty as later Valanginian to Barremian in age. For this report, we adopt an age of Aptian to Neocomian for Cores 58–62.

Palynomorphs, coccoliths, and mollusks all indicate a Late Jurassic age for Cores 63–70. The pollen and spore assemblages, which abound with Classopolis pollen, are conditionally attributed to the Tithonian. The mollusks, which include the bivalves Malayomarica and Jeletzykella, the perisphinctid ammonite Virgatosphinctes, and the belemnite Hibolithes, indicate an early late Tithonian to a probable early Kimmeridgian age for Cores 63-1 to 67-3. Cores 67-4 to 70-5 did not yield any diagnostic macrofossils. Cores 63–70 contain the coccolith Watznaueria britanica with a well-developed small central area and bar. The co-occurrence of Stephano lithon bifiot (short lateral spines) and Vekshinella stradneri in Cores 65–67 indicates an Oxfordian to early Tithonian age for that interval. The absence of V. stradneri and the presence of S. bifiot and S. hexum in Core 70 may suggest an early Oxfordian to Callovian age for that core. Dinoflagellates suggest an early Oxfordian to late Callovian age for Core 70.

In addition to the above, onychites (arm hooks associated with the belemnite animal) were encountered in foraminiferal washings from Cores 66–70. These had also been encountered in the Jurassic strata of Core 49. 58–70. These had also been encountered in the Jurassic strata of Core 49. 65–67 indicates an Oxfordian to early Tithonian age for Core 70.

**Sedimentation Rates**

The accumulation rates indicated in Figure 7 testify to the highly episodic nature of sedimentation on the Falkland Plateau. At any given locality, episodes of exceptionally high sedimentation separated by hiatuses or condensed intervals seem to be the norm for this area (compare with DSDP Leg 36 results). The Neogene and Mesozoic time scales used here were taken from Vail and Hardenbol (1979). The Plio/Pleistocene boundary in the Neogene was set at 1.8 Ma. The Paleogene time scale is from Hardenbol and Berggren (1978).

**Foraminifers**

Both planktonic and benthic foraminifers occur through the entire Site 511 section in almost all stratigraphic subdivisions of the Mesozoic and Cenozoic deposits, but their species diversity and abundance show significant fluctuations (Fig. 8). Foraminifers are missing or extremely rare at the base of the section (Jurassic–Aptian), in the dissolution facies at the Tertiary/Cretaceous boundary, and in some beds within the upper Cenomanian–Campanian interval. Benthic foraminifers are rather scarce compared to planktonic forms. Nevertheless, their distribution through the section permits interpretation of the Mesozoic–Cenozoic palaeoenvironmental changes in the area under study.

**Cenozoic**

Quaternary foraminifers are found in Core 1 (Samples 511-1-top to 511-1-2, 85–87 cm). This assemblage consists of abundant Globorotalia inflata, Globigerina pachyderma, G. bulloides, common Globorotalia truncatulinaoides, and rare G. scitula. G. truncatulinaoides is represented by low-conical specimens which are considered a cool-water form (subspecies?) of this species (Herb, 1968). A low-diversity benthic foraminifer assemblage is present, consisting of the deep-water species Pyrgo murrhina, Hoeglundina elegans, Gyroidina soldanii, Laticarinina pauperata, and Cibicidoides wuellerstorfi; all are characteristic of the lower bathyal zone north of the Antarctic Convergence (Herb, 1971). Foraminifers are absent in the remaining siliceous oozes of Cores 1 and 2 (except Sample 511-2, CC). Lower Oligocene assemblages of planktonic foraminifers are found in the diatomaceous oozes and nannodiatomaceous oozes of Core 2 (Sample 511-2, CC) to
Core 15. They are sparse and preservation is poor except in several samples (Cores 9, 11, 15) from the lower part of the section. They are represented by Globigerina angiporoides, G. aff. linaperta, G. prasaepis, G. officinalis, G. praebulloides, G. ouachitensis, G. brevispira, Globorotaloides suteri, Globigerinita martini, Chiloguembelina cubensis, Globorotalia pernicra, G. munda, and G. gemma. According to Blow’s (1969) zonal scale, this assemblage limits the age of the sediments and is restricted to the Globigerina tapurienis Zone through the G. ampliapertura Zone. Impoverished assemblages of planktonic foraminifers reflect cold-water conditions at high latitudes in the Southern Hemisphere. They resemble the lower Oligocene foraminiferal fauna of the southern part of New Zealand (the G. angiporoides Zone and the upper part of the G. brevis Zone according to Jenkins’s [1971] zonal scale). Samples of Core 16 contain very poor assemblages of planktonic foraminifers: Globigerina aff. linaperta, G. labiocrassata, G. angiporoides, and Globorotaloides suteri. This interval is tentatively assigned to the lower Oligocene because of the absence of the typical upper Eocene species.

In the interval from Sample 511-17-1, 90–92 cm to Sample 511-18-2, 27–29 cm, sediments also include an impoverished assemblage of planktonic foraminifers: Globorotaloides suteri, Globigerina linaperta, G. angiporoides, G. aff. galavisii, G. praebulloides, Globigerinita martini, and Globorotalia munda. In Sample 511-17-1, 90–92 cm, however, one specimen of Globigerapopsis index was found. If it is in situ, sediments should be attributed to the uppermost part of the upper Eocene.

Sample 511-18,CC and Core 20 are characterized by the low-diversity planktonic foraminiferal assemblage composed of Globigerina angiporoides, G. linaperta, G. tripartita, Globigerinita pera, Globorotaloides suteri, Chiloguembelina cubensis, and Globigerapsis index. The presence of the latter testifies to the late Eocene age of the sediments. The upper Eocene/lower Oligocene boundary is placed just above Sample 511-17-1, 90–92 cm, the last sample containing G. index. These deposits are correlated with the tropical G. semiinvoluta, Globorotalia cocoensis, and G. cuniaensis zones and with the Globigerina linaperta and G. brevis zones (lower part) of New Zealand.

The upper Eocene/lower Oligocene portion of the section is characterized by a rather diverse assemblage of benthic foraminifers consisting of about 80 species. The quantity of specimens is low in these sediments owing to dissolution and dilution by radiolarians and diatoms; most species are very rare and irregular in occurrence. Preservation is poor.

The dominant benthic species occurring throughout the whole upper Eocene/lower Oligocene section are Fissurina sp., Gatulina adhaerens, Pullenia bulboides, P. quinqueloba, Cibicidoides sp., Orsidorsalis umbonatus, Nonion havanense, Anomalinoidea spissiformis, Silitostomella curvatura, S. bradyi, S. antillea, and Bulimina sp. Common are also Karreriella sp., Pyrulina cylinndroides, Gyroidina planulata, G. zealandica, Orthomorpha rohri, and O. glandigens.

The presence of these foraminifers is consistent with the accumulation of Paleogene diatomaceous and nanodiatomaceous oozes at lower bathyal water depths. Poor preservation of benthic and planktonic species shows that the foraminiferal lysoclone probably occupied the same position.

In Cores 21 and 22 and Sample 511-23-1, 3–4 cm, foraminifers are absent (dissolution facies).
Mesozoic

Comparatively rich planktonic foraminiferal assemblages characterize calcareous sediments in the interval from Sample 511-23-1, 27-29 cm to Sample 511-26, CC: Globigerinelloides multispinatus, G. impensus, Schackoina multispinata, Hedbergella holmdelensis, Ruguoglobigerina pilula, R. rotundata, R. pustulosa, Heterohelix reussi, H. pulchra, H. globulosa, and H. glabrans. All these species are well developed in the Campanian-Maestrichtian. The influence of Austral climates is evidenced by the absence of representatives of the Globotruncanana and by many species of heterohelicids. As a result, neither zonal subdivision of these sediments nor an exact age determination within the Campanian-Maestrichtian interval are possible. Taking into account the age of the underlying deposits, which are Campanian, it is probable that the calcareous oozes of Cores 23-26 belong only to the Maestrichtian. Calcisphaerulids are common in many samples.

The upper Campanian(?)-Maestrichtian calcareous sediments contain a very monotonous, highly diverse assemblage of benthic foraminifers mainly dominated by Gaudryina healyi, G. pyramidalis, Spiriopecten amplexanata, Ramulina aculeata, Marginulinospis texensis, Dentalina gracilis, D. legumen, Globulina subphaerica, Lenticulina muenerst, Pullenia coreyi, P. americana, Valvuliniera brotzeni, V. alamorphina, Gyroidinoides gudkoffii, G. nitidus, G. quadratus, Quadrimorphina camerata, Gavelinella beccariiformis, Globorotalites spineus, and Reussella sarsinoidea. The abundance of these moderately well preserved benthic foraminifers dominated by calcareous species leads us to conclude that they inhabited depths similar to their modern counterparts, that is, depths above the foraminiferal lysocline.

Sediments of Core 27 and most of Core 28 (to Sample 511-28-5, 90-92 cm) represent a dissolution facies and contain a very low diversity assemblage of Upper Cretaceous benthic foraminifers, consisting of rare Dentalina gracilis, Ramulina aculeata, Valvuliniera brotzeni, Osangularia corderiana, Globorotalites michelinianus, and Bandyella aff. greatvalleynensis.

Comparatively diverse and quite different assemblages of planktonic foraminifers were encountered in sediments of Campanian age (from Core 29 to Sample 511-41-3, 55-57 cm). They include Globotruncanana lineiana, G. cretacea, G. marginata, G. bulloides, G. globigerinoides, Globigerinelloides asperus, G. bollii, Archaeoglobigerina blowi, Heterohelix globulosa, H. reussi, H. pulchra, H. ramsaysiensis, Hedbergella crassa, H. spp. Specimens of Globotruncanana arca and G. plummerae are rare but very important for age determinations. In general, hedbergellids and heterohelicids, together with some representatives of the genus Globigerinelloides, strongly dominate and are accompanied by comparatively rare Globotruncanana.

Sediments within the interval from Sample 511-41, CC to Sample 511-43, CC belong to the Santonian. Among planktonic foraminifers are numerous low- and high-spired specimens of Archaeoglobigerina bosquensis, accompanied by Whiteinella baltica, Globotruncanana pseudolinneiana, G. marginata, G. cretacea, Globigerinelloides asperus, Hedbergella crassa, H. spp., Heterohelix reussi, H. globulosa, and H. glabrans.

To the undifferentiated Coniacian-Santonian are assigned sediments within the interval from Sample 511-44-1, 44-46 cm to Sample 511-46, CC. Whiteinella baltica and Archaeoglobigerina bosquensis occupy a subordinate position; the genus Globotruncanana is represented only by G. pseudolinneiana and G. marginata. Very common are specimens of Hedbergella spp., Heterohelix globulosa, H. reussi, and Globigerinelloides asperus. Schackoina cenomanica is present but very rare in almost every sample.

The planktonic foraminiferal assemblage from Sample 511-47-3, 44-46 cm to Sample 511-47-6, 44-46 cm includes rare specimens of small Globotruncanana pseudolinneiana (the G. lapparenti type) together with Schackoina cenomanica, Hedbergella aff. agalarovae, Globigerinelloides asperus, Heterohelix globulosa, and Globotruncanella inornata. If these sediments correspond to the level of the evolutionary appearance of Globotruncanana pseudolinneiana, they belong to the upper Turonian.

In sediments within the interval from Sample 511-47, CC to Sample 511-48-1, 35-37 cm, double-keeled Globotruncanana species are absent. The assemblage of planktonic foraminifers consists of rather numerous Praeglobotruncanana aff. oraviensis (with a spinose test), together with Hedbergella planispira, H. bornhollensis, H. aff. holtzi, Schackoina cenomanica, Globigerinelloides asperus, Heterohelix globulosa, H. reussi. The age of the sediments is Turonian, probably early Turonian.

Sediments within the interval from Sample 511-48-1, 70-72 cm to Sample 511-49-5, 102-104 cm are characterized by Hedbergella praehelvetica, H. planispira, H. delrioensis, H. portsdownensis, H. infracretacea, Heterohelix sp. (a very small form), Globigerinelloides eaglesfordiensis, and Schackoina cenomanica. In Sample 511-49-5, 102-104 cm, very rare specimens of Praeglobotruncanana turbinata were found. This last species indicates a late Cenomanian age for the sediments (although an early Turonian age is not excluded).

The distribution of planktonic foraminifers in the Upper Cretaceous sediments is very inconsistent. Many samples from Cores 30, 32-36, 40-44, and 47-49 contain few to common tests of moderate preservation; in other layers, poorly preserved tests or barren intervals (dissolution facies) were observed.

The Coniacian-Santonian assemblage of planktonic foraminifers at Site 511 closely resembles that of the high latitudes of the Northern Hemisphere (the lower Senonian microfauna of Bornholm Island, Denmark [Douglas and Rankin, 1969]).

Calcisphaerulids occur throughout the Maestrichtian–upper Cenomanian section, and calcareous microorganisms of unknown affinity (Sliter, 1977, plate 14) were found in Cores 41-47.

The upper (Cores 28-37) and lower (Cores 38-48) parts of the Campanian–upper Cenomanian section are characterized by two different ecological assemblages of
benthic foraminifers. Cores 28–37 contain more than 150 species which usually inhabit bathyal water depths above the CCD. Many of these species occur in sediments very rarely and irregularly; others, such as *Dentonina legumen*, *Lenticulina muensteri*, *Gyroidinoides nitidus*, *Globorotalites michelinianus*, *G. sp.*, *Gavelinella stevensoni*, *Valvulinella brotenzi*, and *Pleurostomella obtusa*, are present constantly. Common are also *Dentonina gracilis*, *D. catenula*, *D. basiplanata*, *Asterocidaris raynaudi*, *P. subnodosa*, *Bolivina watersi*, and *Dorothia trochoides*, *Lingulina pygmaea*, *Globulina lamona.*

The lower part of the section (Cores 38–48) is characterized by an assemblage which includes most species in the overlying sediments, but agglutinated species are dominant. *Glomospira corona*, *G. gordialis*, *G. irregularis*, *Ammodiscus sp.*, *Silicosigmoilinella sp.*, *Hyperammina elongata*, *H. gaultina*, *H. friabilis*, *Rzehakina epigona*, *Ammonobaculites echinatus*, and *Spiroplectammina sp.* are also present sporadically. The species composition and diversity are quite variable in this interval, especially in the lower part. Assemblages where calcareous species dominate, testifying to conditions above the CCD, alternate with assemblages consisting mostly of arenaceous species, indicative of sedimentation below the CCD. The quantity of benthic foraminifers and their state of preservation also vary throughout the section. These foraminifers are usually rare or very rare and poorly preserved; only in some samples of Cores 30–34, 36, 41, 42, and 47 are they common to few, with moderate preservation.

Rather rich assemblages of planktonic foraminifers are characteristic of Albian sediments recovered in the interval from Sample 511-49-5, 120–122 cm to Sample 511-55-6, 11–13 cm. They include moderately preserved tests of *Hedbergella delrioensis*, *H. trocoidea*, *H. planispira*, *H. infracretacea*, *H. brittonensis*, *H. amabilis*, and *H. globigerinelloides*. Sediments from Sample 511-55-6, 34–36 cm down to Sample 511-57-6, 11–13 cm contain the lower Albian species *Tinellina roberti*, *T. aff. primula*, *H. trocoidea*, *H. infracretacea*, *H. delrioensis*, *H. planispira*, and *Globigerinelloides gyroideaformis*; these belong to the *T. roberti* Zone. Foraminifers are abundant to common with some exceptions in Cores 49–54 and 56; preservation is generally moderate. In Sample 511-49-5, 120–122 cm, among the common Albian planktonic foraminifers, very rare specimens of *T. raynaudi* were identified; these indicate late Albian age for the sediments.

Calcisphaerulids are abundant to common in Cores 50–51 (down to Sample 511-51-2, 60–62 cm), rare in Samples 511-51-3, 60–62 cm to 511-51,CC, disappear completely in Cores 52–53, and again are present in some sample of Cores 54–55. They are not present in Cores 56–57.

Albian sediments (Cores 49–57) contain a moderately well preserved and diverse benthic foraminiferal fauna consisting mostly of shallow-water species ("shallow-water" is defined as 100–400 m, shelf-break fauna, after Sliter, 1977): *Dorothia trochoidea*, *Glomospira corona*, *G. gordialis*, *Clavulina gabonica*, *Lenticulina sp.*, *Uvigerinammina jankoi*, *Osangularia utaturiensis*, *Patellina australis*, *Spirillina elongata*, *Gyroidinoides primitiva*, *Anomalinae indica*, *Gavelinella intermedia*, and *Pleurostomella obtusa*. Less common are *D. gradata*, *Gaudryina dividen*, *L. turgidula*, *Hoeglundina cretacea*, *S. minima*, *Conorboides minutissima*, *Tribrachia australiana*, *Marginalina sp.*, and *Præbulimina*. This assemblage is typical for the Albian deposits of the Southern Hemisphere (Austral fauna) (Scheibenerová, 1974; Sliter, 1977).

Cores 58–62 are characterized by a low-diversity assemblage of planktonic foraminifers composed of *Hedbergella infracretacea*, *H. globigerinelloides*, *H. aff. delrioensis*, *H. similis*, *H. gorbachikae*, *H. sigali*, *H. sp.*, and *Globigerinelloides ferreolensis*; the assemblage suggests a Barremian–Aptian age for the sediments. The Aptian/Albian boundary is drawn below the first occurrence of *Tinellina roberti* and *T. aff. primula* in Sample 511-57-6, 11–13 cm. Benthic foraminifers are practically absent in Cores 58–62 sediments except in Samples 511-61,CC and 511-62,CC, where tiny, thin-walled Asterocidaris, *Gyroidinoides*, *Gavelinella*, *Frondicularia*, and *Marginalina* are recognized.

Cores 63–70 (Upper Jurassic section) are barren of foraminifers.

**Calcareous Nannofossils**

Coccoliths were present in sparse to moderate numbers throughout most of the Cenozoic–Mesozoic section of Hole 511, becoming abundant only in the Maestrichtian–Campanian and mid-Cretaceous intervals. Preservation was generally poor to moderate because of dissolution, although exceptionally well preserved assemblages were noted in the upper Eocene, Campanian, and Albian. Diversity was generally low because of the high latitude of the site, the problem of dissolution, and in the case of the Aptian–Jurassic, a highly restricted (euxinic) depositional environment.

A short (10-cm) interval (repeated by a double hit of the drill string) at the top of Section 511-1-1, belongs to the *Emiliania huxleyi* Zone; the rest of that core is barren of coccoliths. Cores 2 and 3 contain a limited flora and belong to the *Emiliania huxleyi* Zone whereas Sections 1–3 and 511-4 contain *Clausioioccus fenestratus* and are assigned to the zone of that name. These two zones are equivalent to the *Reticulofenestra umbilica* and belong to the *R. daviesi* Zone whereas Sections 1–3 of 511-4 contain *Clausioioccus fenestratus* and are assigned to the zone of that name. These two zones are equivalent to the *R. daviesi* Zone whereas Sections 1–3 of 511-4 contain *Clausioioccus fenestratus* and are assigned to the zone of that name. These two zones are equivalent to the *R. daviesi* Zone whereas Sections 1–3 of 511-4 contain *Clausioioccus fenestratus* and are assigned to the zone of that name.

Sample 511-4,CC to Core 16 contains an assemblage similar to that just noted plus *Isommolithus recurvus* and can be assigned to the early Oligocene *Blackites spinosus* Zone of Edwards (originally called the *B. rectus* Zone; see Edwards, 1971). A few rhabdoliths are seen in
this interval, as well as Pontosphaera multipora and P. pulcheroides.

Cores 17–20 contain common and exceptionally well preserved coccoliths of late Eocene age. These are assigned to the Reticulofenestra oamaruensis Zone of Edwards (1971) because of the presence of R. oamaruensis and Discoaster saipanensis. Other members of this assemblage include Isomolithus recurvus, R. bisecta, Chiasmolithus oamaruensis, D. tani (few), C. altus, and Coccolithus pelagicus. Core 21 is barren of coccoliths.

Core 23 contains an early Maestrichtian nannoflora dominated by the cool-water Biscutum coronum and can be assigned to Wind’s (1979) proposed zone of the same name. Other species include B. dissimilis, Arkhangelskiella speciellata, Gaertnerago costatum, Eiffellithus turrisiffeli, Prediscosphaera cretacea, Nephrolithus corystus (mostly rims), Kamptnerius magnificus, Ahuellerella octoradiata, and members of the Lucianorhabdus/Phanolithus plexus. Core 24 contains a somewhat different assemblage with common Monomarginatus pectinatus, Misceomarginatus pleniporus, Marthasterites inopinicus, and Biscutum coronum. This assemblage is also assigned to the B. coronum Zone of Wind (1979), but the core may be early Maestrichtian or latest Campanian in age (see Wind and Wise, this volume).

The interval from Core 25 through Section 511-27-2 was barren of coccoliths. Section 511-28-1 through Core 42 contained Marthasterites furcatus but no Lithistirinus floralis and, considering the foraminifers present, is mostly dated as early Campanian in age. L. floralis is present downhole starting in Core 43, indicating an age of mid-Santonian or older. Other common species within this interval are Watznaueria barnesae, Micula decussata, Biscutum constans, Eiffellithus eximius, E. turrisiffeli, Seribiscutum primitivum, Kamptnerius magnificus, Cretarhabdus conicus, and Prediscosphaera cretacea. E. trabeculatus makes a brief appearance in Cores 39 and 40 (warm interval!). Thiersteinia ecclesiastica n. gen., n. sp., is present from Section 511-46-1 to Section 511-48-1 and is used to define a new zone.

Micula decussata and Kamptnerius magnificus are present down to the uppermost sample of Core 48 (middle Turonian or younger); the other core sections are barren. These species are absent in Core 49 (lower Turonian or older).

Section 511-50-2 to Section 511-56-1 contains an assemblage similar to Core 49 except that Eiffellithus turrisiffeli is absent; thus this interval is assigned to the Prediscosphaera cretacea Zone of Thierstein (1973). Core 51 contains common Sollasites falklandensis and overlies the subzone of the same name.

Prediscosphaera cretacea is absent below Core 56, Section 1, but Lithistirinus floralis is present down through Section 511-58-2; therefore this assemblage belongs to the Parhabdolithus angustus Zone which Thierstein (1973) dates as middle Aptian to early Alban in age. Cores 58 to 62, Section 1, do not contain L. floralis but in selected intervals are flooded with fragments of Micrantholithus obtusus. The rest of Core 62 is essentially barren of coccoliths except for the core catcher.

Sample 511-62, CC to Core 70 contains Watznaueria britanica (small central area and bar generally present), Zygolithus erectus, and other forms described from the Jurassic of DSDP Hole 330, Leg 36 (Vekhinsella stradneri, Ethmorhabdus gallicus, and Stephanolithion minutum with short lateral spines). This assemblage is found in the Volgian of the Russian platform (Medd, in press). S. hexum and S. bigoti co-occur in Core 70, which would indicate a Callovian–early Oxfordian age for the base of the drilled sequence.

Radiolarians

Radiolarians are common and well preserved in Cores 1 through 20 at Site 511. Cores 21, 23, 56, and 57 also contain radiolarians but they are sparse and generally recrystallized. All other cores examined are barren of any siliceous microfossil remains. Only core-catcher samples were studied at Site 511.

In the absence of any well-established, high-latitude, Paleogene radiolarian zonation, the cored sequence between Cores 2 and 20 is equated to Riedel and Sanfilippo’s (1978) standard low-latitude zonal scheme.

Age Determinations

Age determinations can be summarized as follows:

Core 23: Late Cretaceous
Core 21: middle to early Eocene
Cores 17–20: late Eocene
Cores 5–16: early Oligocene
Cores 2–4: early Oligocene—possibly early late Oligocene
Core 1: mixed Pleistocene and Oligocene

Core 23 is dated as Late Cretaceous because several radiolarian genera known to be restricted to this time period occur in it. No identifications to the specific level are possible because the specimens are very poorly preserved. Most radiolarians are represented as internal casts composed of glauconite or are entirely replaced by this mineral.

Core 21 is tentatively dated as middle to early Eocene, because the Amphymenium splendiiarmatum and Amphiarcaspum prolixum group co-occur in the presence of many specimens of Buryella species. Nearly all specimens are recrystallized to some degree and most cannot be identified to the specific level.

Cores 20–17 are late Eocene in age, equivalent to the Thyrsocystis bromia zonal equivalent at low latitudes. This age determination is based upon the occurrence of Theocrytis sp., the ancestral form of Theocrytis tuberosa known only to occur in the upper half of the T. bromia Zone at low latitudes. In addition, the co-occurrence of Cryptopora ornata, Theocrytis diabloensis, and Lychnocanoma amphitrite within these cores indicates a late Eocene age.

Cores 17 through 5 are early Oligocene, equivalent to the Theocrytis tuberosa Zone at low latitudes. This determination is based upon the occurrence of Calcocycletta achanthocephala throughout the sequence of cores. This radiolarian is known only from sediments of the early Oligocene age (T. tuberosa Zone) in mid- to low-latitude regions (DSDP, Legs 22 and 31). Johnson
(1974) found *C. acanthocephala* restricted to *T. tuberosa* Zone sediments in the Indian Ocean (DSDP Site 216, Leg 22) and Ling (1975) also encountered this species in the lower half of the *T. tuberosa* Zone at DSDP Site 292, Leg 31, in the Northwest Pacific–Japan Sea area.

Cores 4 to 2 contain *Calocycletta* cf. *parva*. This species is believed to be the ancestral form of *C. parva*, which appears in the late Oligocene in mid- to low-latitude areas. Dinkelman (1973) reports which appears in the late Oligocene in mid- to low-latitude areas. Dinkelman (1973) reports that the species is restricted to the early Oligocene *Theocyrtils tuberosa Zone*, but Moore (1972) believes this species may range into the basal *Dorcadospyris ateuchus* Zone, or early late Oligocene. Therefore, Cores 4 through 2 are dated as probable early Oligocene, but possibly early late Oligocene in age.

Core 1 contains a homogenized mixture of Pleistocene and early Oligocene radiolarians, indicating that the integrity of this interval is disrupted.

**Paleoclimatic Interpretation**

The presence in Cores 20 through 16 of *Calocycletta* species of Orosphaerid and Colloporaerid radiolarians, and of *Cryptopora arneta, Theocyrtils* sp. (ancestral *T. tuberosa*), *Lychnocanoma amphitrite, Lithocycletta crusta*, and *Thysocyrtils bromia* (very rare) are indicative of relatively warm conditions, probably cool temperate waters, in the vicinity of Site 511 during the latest Eocene and early Oligocene interval.

However, by Core 12 the dominant species in the overall radiolarian assemblage have changed. Most warm-water elements such as the *Calocycletta* have disappeared, and the assemblage becomes dominated by cooler-water *Spongoplegma, Prunopyle*, and Eucyrtid species. This assemblage persists through Core 11 and is considered transitional, indicative of significant upwelling conditions during climatic deterioration within the earliest Oligocene. The convergence of cool temperate and subtropical waters and the eventual transgression of subtropical waters over Site 511 are proposed. However, the exact timing of this event cannot be ascertained from radiolarian data.

Between Cores 11 and 9 further climatic deterioration is evidenced by the radiolarian taxa encountered. The radiolarian assemblage in Cores 9 through 2 generally resembles the early Oligocene radiolarian assemblage recorded by Chen (1975), from Leg 28, Site 274, at 69°S on the Ross Sea continental margin. *Cyclamptium(?)* *longiventers*, *Spongoplegma fenestrata*, *Liithocycla challengerae*, *S. sphaerocephalis*, *S. sp.*, and *Eucyrtidium* sp. are significant constituents of the radiolarian assemblage. Chen (1975) encountered this assemblage in Cores 31 through 39 at Site 274, and owing to the proximity of Site 274 to the Antarctic continent, it must be considered antarctic in character. Radiolarians in Cores 9 through 2 at Site 511 appear to represent the northerly elements of a broad antarctic/subantarctic paleobiogeographic province encompassing 18° of latitude in the circum-Antarctic seas during the early Oligocene.

By Core 5 at Site 511, a slight moderation of climate is evidenced by the reappearance of *Calocycletta* and warm-water Eucyrtid species. A slight southerly shift of warmer subantarctic waters over Site 511 seems feasible to explain this faunal modification.

In summary, climate through the latest Eocene and early Oligocene at Site 511 fluctuates from cool temperate to broadly subantarctic/antarctic in character. The exact timing of this transition cannot be ascertained from radiolarian data; it is, however, an early Oligocene event.

**Diatoms**

Diatoms are well preserved and abundant in Core 1. A detailed examination of this core revealed the presence of three disconformities. The siliceous gravelly sand and foraminiferal ooze from 0–37 cm of Section 1 is assigned to the *Coscinodiscus lentiginosus* Zone of the Brunhes Magnetic Chronzone.

The lithology change at 37 cm marks a disconformable boundary separating the upper *Coscinodiscus lentiginosus* Zone from the *C. elliptiptora/Actinocyclus ingens* Zone encountered at 511-1-1, 52–53 cm. Sample 511-1-1, 91–92 cm is assigned to the *C. kolbei/Rhizosolenia barboi* Zone of the uppermost Pliocene.

No zonal designation is given to Sample 511-1-1, 120–121 cm because of considerable downhole slumping of younger microfossils and reworking of lower Pliocene and upper Miocene microfossils. This sample is probably close to an apparent disconformity separating lower Matuyama Chronzone sediments (511-1-1, 91–92 cm) from upper Gauss Chronzone sediments (511-1-1, 142–143 cm). Sample 511-1-1, 142–143 cm contains a flora characteristic of the *Nitzschia weaveri* Zone. Samples 511-1-2, 31–31, 65–66, and 89–90 cm are assigned to the *N. interfrigidaria/Coscinodiscus vulnificus* Zone of the mid-Gauss and are apparently conformable to the *N. weaveri* Zone of basal Section 1.

The third disconformity in Core 1 probably coincides with the sharp lithology change at Section 2, 144 cm. This sharp boundary between the silaceous gravelly sand above and the diatom ooze below separates the middle Pliocene of Sample 511-1-2, 89–90 cm from the lower Oligocene of Sample 511-3-1, 4–5 cm.

Abundant and diverse diatom assemblages of early Oligocene to late Eocene age occur in sediments recovered in Core 1, Section 3 through Core 20, Section 3. Six diatom zones have been identified in this interval (see Gombos and Ciesielski, this volume). The interval from Sample 511-1-3, 132–134 cm through Sample 511-4-3, 10–12 cm contains part of the *Coscinodiscus superbus* group Zone; that from Sample 511-5-1, 10–12 cm through Sample 511-11-2, 30–32 cm contains the *Rhizosolenia gravida* Zone; Sample 511-11-3, 30–32 cm through Sample 511-12-1, 11–13 cm contains the *Brightwellia spiralis* Zone; Sample 511-12-2, 11–13 cm through Sample 511-15-1, 13–15 cm contains the *Melosira architecturalis* Zone; Sample 511-16-1, 22–24 cm through Sample 511-16-2, 22–24 cm contains the *Asterolampra insignis* Zone; and Sample 511-17-1, 83–85 cm through Sample 511-20-3, 23–25 cm contains the *Rylandina inaequiradiata* Zone.
In Hole 511, the Eocene/Oligocene boundary occurs somewhere within or between Cores 16 and 17; that is, close to the top of the R. inaequidens Zone. This boundary cannot be closely defined on the basis of any definite diatom appearance or extinction datum. However, a significant change in the relative abundance of the genus Pityosira was observed in the vicinity of the boundary. In Core 20 (below the boundary) the abundance of this genus is about 1500-2000 specimens per 2 traverses at ×400 magnification. Above Core 20 the abundance decreases by an order of magnitude. It is not certain if this dramatic abundance change reflects actual oceanographic conditions or if it is a preservational phenomenon.

Sporadic specimens of reworked Eocene diatoms were noted throughout the hole.

Siliocflagellates
Siliocflagellates are common and well preserved in most sediments examined from Cores 1-20; below Sample 511-20,CC, they are absent. Species diversity is low in Pliocene to Recent sediments and high in lower Oligocene to upper Eocene sediments.

Samples 511-1, 15-16 cm, through 511-3, 65-66 cm, are assigned to the revised Naviculopsis constricta-Corisbema archangelskiana Interval Zone of the lower Oligocene (see Shaw and Ciesielski, this volume). The dominant siliocflagellate flora throughout this interval are Naviculopsis trispinosa, N. biapiculata, Distephanus crux, and Dictyocha deflandrei. Other species commonly present in this zone include Corbisema apiculata, C. fliexuosa, C. geometrica, Dictyocha aspera martini, Distephanus crux loeblichii, and others.

Core 3 below Sample 511-3, 65-66 cm, Cores 4 through 7, and Core 9 through Sample 511-9, 80-81 cm contain a newly defined Naviculopsis constricta/Dictyocha deflandrei concurrent Range Zone. The well-preserved and diverse assemblage in these lower Oligocene sediments includes N. constricta, N. biapiculata, N. trispinosa, Corbisema geometrica, C. apiculata, Dictyocha aspera martini, Distephanus crux loeblichii, and others. Sediment recovery in Core 8 was poor and the core was not sampled for study.

Sample 511-9, 80-81 cm through Sample 511-11, 5-6 cm is placed in the newly defined Naviculopsis trispinosa Zone of the lower Oligocene and is characterized by the abundant occurrence of N. trispinosa. The first consistent occurrence of Dictyocha deflandrei marks the top of this zone; only few to rare D. deflandrei occur sporadically within the zone. Other species common in this interval include Corbisema hastata globulata, C. triacantha, Mesocena apiculata, M. occidentalis, N. biapiculata, and N. constricta.

Sample 511-11,CC through Sample 511-18,CC is present (<10%) but is significantly less abundant than in younger strata of this site.

Sponge Spicules
At Site 511 sponge spicules were recognized in Paleogene sediments (Cores 2-20); in Mesozoic deposits they are totally absent. In Cores 2-20 the assemblage is represented mostly by spicules of glass sponges (class Hyalospongiae) with a compact skeleton. In much smaller numbers are isolated macroscelers and microscelers. Rare are spicules of tetraradiate sponges (order Tetraxonida), the number of which increases considerably in the upper Eocene deposits.

When morphological types are compared, two assemblages of sponge spicules are distinguished. The first characterizes the lower Oligocene deposits (from Sample 511-2, 98-100 cm to Sample 511-16,CC) The second association is present in upper Eocene sediments (Cores 17-20). Rather numerous are representatives of the order Tetraxonida: dichotriaenes, anatriaenes, oxycetes, strongytes, styles. Fossil microscelers such as sigmas occurred rarely, and only in the upper Eocene.

Pollen and Spores

Cenozoic
In Cores 1-3 (Quaternary to the uppermost layers of the lower Oligocene) spores and pollen are absent.

In Cores 4, 5, 6, 9, 11, 12 (lower Oligocene), pollen and spores are relatively diverse and numerous. Abundant are Gymnosperm pollens: Podocarpus sp., Dacrydium sp., D. cupressinum, Phyllocladus sp., P. mawsonii, Microacridites antarcticus, and Pinus sp. Angiosperms are represented by the pollens Nothofagus (brassii type and fusca type), Casuarina sp., Myrtaceae, Proteaceae, Combretaceae, Tricolpites sp., T. reticulata, Rhoipites minusculus, R. baculatus, Psilatricolporites sp. Among spores were identified Cyathea sp., Gleichenia sp., Anogramma sp., Matonisporites sp., Cyathacidites sp., Leiotriletes regularis, Cingutriletes australis, cicatriciosporites sp., Polypodiaspores.

In Cores 15-17 palynomorphs are few: Podocarpus sp., Dacrydium sp., D. cupressinum, Phyllocladus sp., Nothofagus sp., N. sp. (fusca type), N. sp. (brassii type), Tricolpites sp., Triatripollenites sp., Psilatricolporites sp., Polypodiaspores, Cyathea sp., Leiotriletes sp., Gleichenia sp., and Cicatriciosporites sp.

In Cores 18-20 only very rare grains of pollen and spores were found: Podocarpus sp., Dacrydium sp., Phyllocladus sp., Nothofagus sp., T. reticulata, Rhoipites minusculus, R. baculatus, Psilatricolporites sp. Among spores were identified Cyathea sp., Gleichenia sp., Anogramma sp., Matonisporites sp., Cyathacidites sp., Leiotriletes regularis, Cingutriletes australis, Cicatriciosporites sp., Polypodiaspores.

In Upper Cretaceous deposits (Cores 29-49), spores and pollen grains are sporadic. They are missing in the greater part of Albian sediments (Cores 49-55). In underlying deposits of the Lower Cretaceous and Upper Jurassic, considerable amounts of satisfactorily pre-
served spores and pollen make it possible to subdivide assemblages into three units with different palynological assemblages.

In Cores 56–58 Gymnosperm spores and pollen are present in relatively equal quantities. Sporadic grains of Angiosperm pollen of the genus Clavatipollenites were recognized. Among spores, Gleicheniidites spp. and Cycathidites minor are predominant. Very common are spores such as Cicatricosispores spp., Ceratosporites distalgranulatus, Coronatispora valdensis, Cymbelospories spp., Cyathidites tectifera, Murchingulisporis annulatus, Perotelliellae linearis, Taurocuspores sp., Polypodiaceoisporites elegans. Claspospores pollen predominates within the Gymnosperms. Pollen of Cyclusphaera psilata is also present.

This assemblage has some species common to a palynological association from the Baqueró continental formation (Santa Cruz Province, Argentina), the age of which is palynologically determined as Barremian–Aptian (Archangelsky and Camerero, 1967). It is also similar to an assemblage, tentatively assigned an Aptian–Albian age, from deposits off the South African coast penetrated by Hole 361, Leg 40 (McLachlan and Peters, 1978) and to an Albian assemblage from Hole 327, Leg 36, on the Falkland Plateau (Hedlund and Béjeu, 1977). It is noteworthy that according to planktonic foraminifers, the age of the sediments at Site 511 is dated as upper Aptian (Core 58)–lower Albian, the Tienella roberti Zone (Cores 57 and 56).

In Cores 59–62 the palynological assemblage is characterized by a predominance of Gymnosperm pollens; among them Claspospores is dominant. Pollens from Cyclusphaera psilata and Inaperturopollenites limbatus are constantly present. Angiosperm pollens are missing. Spores are not numerous, though represented by diverse genera and species such as Antulissipites aemulum, Coniospores cooksoni, Cicatricosispores spp., Dictyotospores complex, Distaltriangulisporites sp., Foveospores subtriangularis, Ischiospores volkheimeri, Interolubiles algaeonis, I. sinuosus, I. aff. triangularis, Matonispores crassianulatus, Nevesispores sp., Polypodiaceoisporites elegans, Staplinispores caminus, Taurocuspores segmentatus.

Though most spore species of this assemblage are peculiar to the Upper Jurassic and Lower Cretaceous deposits of Argentina, South Africa, and Australia, presence of such typically Lower Cretaceous forms as Cyclusphaera psilata, Cicatricosispores spp., Inaperturopollenites limbatus, Polypodiaceoisporites elegans, and Taurocuspores segmentatus enable us to date deposits as Early Cretaceous. The assemblage can be correlated with spores and pollen from the Agrio and Ortiz formations of Neuquén Territory in Argentina (Volkheimer and Sepulveda, 1976; Volkheimer et al., 1977), the age of which was determined by ammonites in the Agrio Formation as Hauterivian–Barremian. In addition, a similar assemblage was observed in deposits of the Sundays River Formation (Alboa Basin, South Africa). Its age was tentatively determined as late Valanginian–early Hauterivian on the basis of ostracodes, benthic foraminifers, and mollusks (Scott, 1976).

In Cores 63–70 the palynological assemblage abounds with Claspospores pollen. Spores are not numerous, being represented mainly by the same species and genera as in the previous assemblage. A peculiar feature is the absence of species typical of the Lower Cretaceous deposits only. From this standpoint the age of the assemblage is Late Jurassic. Most similar to this assemblage are those from the Vaca Muerta Formation (Argentina) of Tithonian age (Volkheimer and Quattrocchio, 1975) and the Kirkwood Formation (the Uitenhage Group, Algoa Basin, South Africa), supposedly of Late Jurassic–Early Cretaceous age (Scott, 1976). Similarity with the above formations is suggested by the absence of Cyclusphaera psilata and presence of some species of the genus Interolubiles. As there are no data on Oxfordian and Kimmeridgian palynoassemblages from Argentina and South Africa, and no spores of Interolubiles have been identified from the Oxfordian–Kimmeridgian of Australia (Filatoff, 1975), the assemblage at Site 511 in the interval from 556 to 632 meters is conditionally attributed to the Tithonian.

**Mesozoic Dinoflagellates**

The interval between Sample 511-29-1, 0–3 cm and Sample 511-40-5, 34–36 cm is dated as Late Cretaceous (early Campanian to Santonian). Restricted to this interval are Isabeladinium latum and Chatangiella granulifera, Odontochitina porifera, Amphidinulides denticulata, and A. nucula. Xenascus ceratoides occurs at and below Sample 511-34-4, 124–126 cm; the last appearance datum (LAD) of Conosphaeridium striatoconus is in Sample 511-40-5, 34–36 cm. The underlying interval between Sample 511-41-3, 51–53 cm and Sample 511-47-1, 42–44 cm is Late Cretaceous (Coniacian to Turonian). C. striatoconus occurs throughout the interval, and the LAD of Palaeohystrichophora infusorioides is in Sample 511-42-4, 110–112 cm. Actinotheca aphyrodite occurs only in Sample 511-42-4, 110–112 cm. No dinoflagellates were recovered from the interval between Sample 511-48-3, 42–44 cm and Sample 511-53-CC; the age is therefore indeterminate. The interval between Sample 511-54-3, 46–48 cm and Sample 511-58-2, 52–54 cm contains a low-diversity assemblage with Ovoidinium scabrosus, Angustidinium acrirobes, and Oligosphaeridium asterigerum. The interval is interpreted as Early Cretaceous (Cenomanian to Albian) because of this association. Samples from Cores 59 and 60 were not examined.

The interval between Sample 511-61-1, 69–71 cm and Sample 511-67-2, 80–82 cm contains Endoscrinium luridum (in Sample 511-61-1, 69–71 cm only), Leptodinium mirabile (LAD in Sample 511-64-5, 45–47 cm), and Gonyaulacysa jurassica (LAD in Sample 511-67-2, 80–82 cm). The interval is dated as Late Jurassic (early Kimmeridgian to late Oxfordian) by this assemblage. Samples from Cores 68 and 69 are nondiagnostic. The deepest sample examined is at 511-70-1, 50–52 cm; it contains Wanaea digitata, Rigaudella sp. cf. R. aemulum, Endoscrinium galeriitum; and Gonyaulacysa juras-

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sica, which indicate an early Late to late Middle Jurassic (early Oxfordian to late Callovian) age. Based on dinoflagellate data, the Jurassic/Cretaceous boundary is in the interval between Sample 511-58-2, 52-54 cm and Sample 511-61-1, 69-71 cm. No Cretaceous sediments older than Albian and no Jurassic sediments younger than early Kimmeridgian were identified.

**Macrofauna**

Cores 41-43 contain numerous but fragmentary remains of *Inoceramus* s.l., a few other indeterminate pelecypods, and locally, a number of generically indeterminate solitary corals (evidently redeposited, at least in part). The sediments were deposited in the bathyal to outermost neritic environment, judging by the general absence of such shelf-bound fossils as belemnites and thick-shelled pelecypods in the presence of depth-tolerant organisms such as *Inoceramus*.

In Cores 50-56 *Aucellina* species range from extremely numerous (coquinas) to rare—*A. sp. cf. radiatostriatia, A. sp. cf. andina*, and *A. sp. indet*. The coquinas were deposited under the influence of strong bottom currents. The presence of other, apparently shelf-bound pelecypods suggests an inner neritic origin, although an alternate interpretation can be made in favor of an outer neritic to bathyal environment.

Rare aconeceratid, cheloniceratic, and ancyloceratic ammonites of Aptian affinities are found in Sections 57-3 to 58-1. These are all depth-tolerant or nectoplanktonic ammonites which suggest a bathyal to outermost neritic environment similar to that of Cores 41-49.

Section 58-4 to Core 62 did not yield any immediately diagnostic macrofossils, although belemnites and bichi-rid pelecypods were present. No shells comparable to *Aucellina* were present; this fact could suggest a pre-Aptian age. A significant fluctuation in water depth is seen in this interval. Sections 58-4 to 60-4 were definitely deposited in an inner neritic to littoral environment in close proximity to the basin shoreline. This is indicated by abundant thick-shelled shallow-water pelecypods (often forming coquinas), including numerous oysters. Belemnites, which come from inner- to median-shelf environments at depths of less than 150 meters, are common, whereas ammonites, which favor outer-shelf to upper bathyal environments, are nearly totally absent. The alteration of belemnite-bearing and oyster-rich units indicates a frequent alternation between a normally saline environment and a distinctly brackish (presumably delta-influenced) environment.

The interval from Section 60-5 to Core 63, on the other hand, was deposited in the same bathyal to outermost neritic environment as Section 41-3 to Core 49 and Sections 57-2 to 58-3. This is suggested by the general paucity or complete absence of most fossils (pelecypods, belemnites, and large ornate gastropods). The depositional environment is one of very low energy and reducing conditions.

The hiatus between Core 62 and Core 63 probably includes the upper Tithonian as well as the Berriasian to Hauterivian (or possibly even Barremian) rocks. This is strongly suggested by the occurrence of the exclusively

Late (but not Latest) Jurassic *Malayomaorica* sp. and/or *Jeletzkyella* sp. in Core 63. A perisphinctid ammonite in Sample 511-63-3, 49-50 cm is identified as *Virgatosphinxes (Pseudovoluiticeras)* sp. of early Tithonian affinities. The appearance of fairly common belemnites and a general increase of fossil content in Sections 64-1 to 65-2 suggest a shallowing trend which apparently brought the bottom of the basin into a mid- to outer neritic environment. This trend culminates in the appearance of numerous interbeds of a presumably inner neritic to littoral pelecypod coquina in sandy siltstone containing common to abundant pelecypods and some *Hibolites*-like belemnites (Sample 511-65-2, 90 cm). This abrupt lithological and faunal change marks the second episode downhole of inner neritic to littoral deposition at Site 511.

This second interval of shallow depositional environment is seen from Sections 65-2 to 65-3 in a distinctly cyclical alternation of fossil-rich sandy to pure siltstones with very thin interbeds of pelecypod coquina. The faunal composition of these units is exactly the same as in the Cretaceous (Sections 58-4 to 60-4), including numerous oysters in some coquinoi interbeds. The environment was much the same as in the Cretaceous.

The lowermost cores from Site 511 (Sections 67-4 to 70-5) consist of siltstone (black and petroliferous), rich in belemnite of the genus *Hibolites* but lacking thick-shelled shallow-water pelecypods. This suggests a low-to very low energy, mid-neritic (50-7150-meter) depositional environment.

**PALEOMAGNETISM**

Paleomagnetic measurements were made on Leg 71 sediments using samples taken by pushing plastic cylinders (2.5 cm in diameter and approximately 2.5 cm in length) into the sediment. These samples are oriented by a notch pointing in the uphole direction. Additional samples were taken in the harder sediments of Site 511 using a diamond-tipped drill, after an orientation arrow was inscribed on the sediment. Measurement of natural remanent magnetization (NRM) and postdemagnetization remanence were carried out using the shipboard Digico fluxgate spinner magnetometer, integrating the readings to a total of 2500 spins. Demagnetization was performed on board the *Glomar Challenger* by means of a Schonstedt alternating field demagnetizer. Samples were demagnetized along three mutually perpendicular axes at the peak field; then one further demagnetization was carried out at half the peak field with the third axis reversed with respect to the demagnetizer coils. This additional demagnetization reduces the effect of any anhysteretic remanent magnetization (ARM) which may build up in the sample.

At Site 511, 135 samples were taken for paleomagnetic study at intervals of approximately 3 meters in the more complete sections of the hole. Pilot demagnetization shows that the NRM is stable and probably represents a primary magnetization. Samples with stronger NRM intensities were demagnetized at 150 oersteds (Oe). Demagnetization produced changes in inclination of us-
ually less than 10°. Gaps in sampling in the upper part of the hole prevent the identification of magnetic epochs within the Cenozoic. The NRM inclinations of Mesozoic sediments are shown in Figure 9. The majority of the samples are normally magnetized (i.e., have negative inclinations), representing the long Cretaceous Normal Interval. Three samples with low or reversed inclination occur in the lower part of the Cretaceous sediments. Only the zone between Samples 511-60-6, 44-46 cm and 511-60-6, 51-53 cm has been confirmed by resampling; however, it is possible that these sediments were deposited during the Serra Geral Mixed Interval (as defined by van Hinte, 1976). The NRM of these samples may comprise a reversed primary magnetization with a normal secondary overprint. Demagnetization of these samples was not carried out on board the Glomar Challenger because the NRM intensities were too low. Two reversed samples occur in Jurassic sediments (in Cores 63 and 68), but these have not been confirmed by resampling.

The upper boundary of the long Cretaceous Normal Interval is marked by the top of Core 27. The reversed sample in Core 35 has a very weak intensity and is not considered to represent a true geomagnetic reversal. The mean absolute inclination for the Mesozoic sediments is $53.5 \pm 21.9°$, which would indicate a paleolatitude of 34.0° for the Falkland Plateau.

Intensity variation in Hole 511 sediments reflects lithology (Fig. 10). The Cenozoic and Maestrichtian oozes (Subunits 2A and 2B, and Unit 3) were predominantly low in intensity, ranging from 0.2 to 0.9 $\mu$G. Intensity in the zeolitic clays is low (0.5–2.0 $\mu$G) to a depth of about 320 meters, below which values increase to between 20 and 140 $\mu$G. Sediments have a marked red color below 350 meters, reflecting a high iron oxide content; this red coloration is also marked in the nannofossil claystones and chalks of Unit 5, which have an intensity of 10–140 $\mu$G. Intensities within the black shales (Unit 6) are low (0.1–1.0 $\mu$G).

![Figure 9. Variation in natural remanent magnetization (NRM) inclinations within the Mesozoic at Site 511.](image-url)
Figure 10. Correlation between natural remanent magnetization (NRM) intensity and lithology at Site 511.
ORGANIC GEOCHEMISTRY

Sediments encountered in Site 511 were analyzed on-board ship for organic carbon, gases in gas pockets, and fluorescence and were subjected to a pyrolysis/fluorescence procedure (Heacock et al., 1970) to provide an estimate of hydrocarbon occurrence. Gas samples were taken wherever possible, although the gases were not severely pressured in any of the cores taken. Results of these shipboard procedures and analyses are discussed hereafter, followed by General Observations that take into account both the shipboard and shore laboratory studies (see Schaefer et al.; von der Dick et al.; Copelin and Larter; Deroo et al.; all this volume). In some instances, the more sophisticated shore laboratory analyses changed significantly the impressions of the maturation and migration patterns derived from the shipboard analyses (Ludwig et al., 1980).

Organic Carbon

Samples for organic carbon analyses were selected mainly in fine-grained and dark material. The values obtained should therefore reflect zones of enrichment in organic carbon. Samples were dried, crushed, treated with HCl, washed, weighed, and analyzed on a Hewlett Packard 185B CHN analyzer. Prior to this, the HP 185B was calibrated by different standards, and integrator counts were plotted against weight in milligrams of organic carbon. Samples for organic carbon analyses were selected to organic carbon contents (determined by the carbonate bomb technique) and especially to weighing on a rolling and pitching vessel. Both the organic carbon values and the carbonate contents (determined by the carbonate bomb technique) are listed in Table 3.

Pyrolysis/Fluorescence

Pyrolysis/fluorescence should give a background for both the presence of heavy free hydrocarbons in a sediment and the generative potential of the sediment for releasing bitumen at stages of higher maturity when related to organic carbon content. The procedure was improved by injecting N₂ into the pyrolysis tube, thus preventing hydrocarbons from burning. The values obtained by this method seem to be more reliable.

The fluorescence units of pyrolyzed sediments of different types and ages are plotted against carbon content in Figure 11.

Gas Analyses

We noticed no highly pressured gas or large gas pockets in any of the cores. Gas analyses were run on a Carle-GC equipped with a thermal conductivity cell and a much more sensitive Hewlett Packard 5710 AGC, equipped with a dual FID system.

Fluorescence

Random samples were taken to look for fluorescence, but even the black shales showed no indications.

Discussion of the Shipboard Results

Organic carbon values of Site 511 range from 0.1% to 4.1% and can be roughly divided into two units.

Table 3. Organic carbon, nitrogen, and carbonate content, Hole 511.

<table>
<thead>
<tr>
<th>Core/Section (interval in cm)</th>
<th>N (%)</th>
<th>Corg (%)</th>
<th>Corrected for CO₂ (%)</th>
<th>CO₃⁻ (%)</th>
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<tr>
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<td>0.08</td>
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<td>0.37</td>
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<td>0.15</td>
<td>0.14</td>
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<td>0.31</td>
<td>0.31</td>
<td>2</td>
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<td>0.25</td>
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<td>0.41</td>
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<td>70-4, 96-98</td>
<td>0.16</td>
<td>0.25</td>
<td>0.25</td>
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</table>

Samples from the Tertiary and Cretaceous down to the Aptian contain only small quantities of organic carbon. This is in agreement with the general features of sediments exhibiting brighter and reddish colors and indications of bioturbation. Probably this type of organic matter belongs to a kerogen Type III originating from continental runoff of higher terrestrial plant debris and perhaps reworked coaly and/or oxidized sedimentary particles. If this is so, the low content of organic carbon is apparently a result of a low but relatively constant ratio of the flux of organic and mineral matter through the water column (von der Dick, 1979). Extreme low values at the Tertiary/Cretaceous boundary can be assigned to more variable conditions. Pyrolysis/fluorescence data (Fig. 11) are very low and seem to reflect primarily the crudity of the method. The sedimentary sequence completely changed when the Lower Cretaceous black shales were encountered. Organic carbon values average 3.5%.

Pyrolysis/fluorescence data exhibit an extreme increase compared to the claystones and muddy nano-
fossil chalk in the upper part of the section (Fig. 11), thus reflecting the high potential of the black shales for generating oil. Although very crude, this quick method seems to be a useful indicator for any hydrocarbon-bearing sediments and accumulations, whether free or bound to the kerogen matrix.

When Core 60 was drilled at about 530 meters and retrieved, an intense odor of oil was present. This odor was most intense in Cores 60-63 and dropped to moderate intensity in the subsequent cores. Methane was detected first in Core 41, and ethane was initially encountered in Core 54, where it exhibited a C1/C2 ratio of 400. This ratio decreased to a minimum value of C1/C2 = 93 in Core 61 (Fig. 12) and fluctuated between 130 and 210 in the deeper parts of the section. The same trend could be traced in the C2/C5 and C2/C3 ratios (Fig. 12). In general, low C1/C2, C2/C3, and C2/C5 ratios together with strong odor and high fluorescence values indicate a high degree of maturity. However, an objective determination of the thermal evolution is necessary; this was done in shore laboratory studies described hereafter.

The upper part of the shales (Core 60-63) seems to be of special interest for hydrocarbon generation and migration. Indications for a high hydrocarbon potential and/or a migration of released low-molecular organics within this part include (1) the intense odor of oil; (2) the minimum values for C1/C2; C2/C5; C2/C3 (Fig. 12); inversion of iC4/nC4 (Table 4); and absolute maximum fluorescence values (Fig. 11).

Gaseous hydrocarbons encountered in the hole consist predominantly of methane up to 30%, followed by ethane up to 0.4% and higher hydrocarbons, each decreasing in concentration by about one order of magnitude per increasing carbon number. Ratios of C1/C2, C1/C2, and C2/C5 follow the same pattern below Core 63, but are different above Core 60.

These features of Cores 63-70, reflecting “in phase” behavior (Whelan, 1979), were also recognized in Site 397; the behavior is apparently a result of an in situ reaction. Migrating hydrocarbons, if leaving the source rock, are not in phase because of the now discernible separation process involved in migration and diffusion. The ratio of iC4/nC4 is always 1, except in Cores 60-63 (Table 4). Indeed, this inversion is a result either of a different organic facies or of migration toward barren sediments across a border. If a migration has taken place, light hydrocarbons generated below this border (in phase) are selectively separated when reaching the denser chalks. According to their molecular size and form, volatility, water solubility, and polarity (which are important for migration and diffusion processes to take place), these compounds are gradually allowed to pass the border.

General Observations from Shipboard and Shore Laboratory Studies

Amount and Type of Organic Matter

The black shales of Site 511 (Lithologic Unit 6) exhibit high organic-carbon contents, on average about 3.5% per dry weight. Both microscopy and geochemical analyses reveal that the high organic content is the result mainly of an accumulation of liptinitic (to a great part marine) organic matter. Because of the high content of organic carbon and high amounts of liptinitic (“bituminous”) organic matter, the black shales have an excellent potential to generate hydrocarbons from the source rock at stages of a higher maturity. Based on Rock-Eval pyrolysis and microscopy, the type of organic matter present in the shales can be defined as a kerogen Type II. The organic gross composition of the Aptian–Upper Jurassic shales is relatively homogeneous throughout the cored sections. Nevertheless, a detailed geochemical analysis shows a general decrease in the contribution of land-derived organic matter from the Jurassic toward the lower Albian. This trend is in agreement with the occurrence of marine chalks at the top of the shales.

The change from euxinic conditions toward a better-ventilated sedimentary system on the Maurice Ewing Bank is reflected by the rapid drop of organic carbon within a “transitional zone” (Deroo et al., this volume) to lower and very low values at the boundary of the Aptian/Albian. The drop of organic carbon accompanies a general shift from a bituminous organic facies to a non-marine and residual type of organic matter (von der Dick et al.; Deroo et al.; both this volume).
The remarkable change in the composition and quantity of organic matter at the Aptian/Albian boundary can be related to the improvement of the water circulation on the Falkland Plateau and in other southern parts of the early South Atlantic Ocean (Reyment, 1980). Apart from a few exceptions, a residual type of organic matter represents the organic fraction of the Albian–Recent sediments. The low organic content (about 0.2–0.3% for Units 1, 3, and 5 and Subunit 2B, and 0.4–0.5% for Subunit 2A and Unit 4) and the dominating inert type of organic carbon indicate environmental conditions opposite to those in the black shales. The slightly higher accumulation of organic carbon in Subunit 2A and Unit 4 may be related to the high sedimentation rates of these units, which hinder through rapid burial the almost complete oxidation of organic matter. Microscopic analyses made on shore and chemical analyses of the extracts suggest that no liquid compounds have migrated upward in the section.

The redistribution of light hydrocarbons has been minimal and is discernible only at major stratigraphic or lithologic boundaries (i.e., the Tertiary/Cretaceous unconformity, or the transition from the black shales to the Cretaceous chalks and claystones).
Thermal Evolution of the Black Shales

The vitrinite reflectance, as an indicator of the thermal history of organic matter, is 0.44% Rm downhole at a depth of 630 meters. Therefore, the shales are still in an immature stage of oil generation. The low amounts of extractable compounds (bitumen or extract) and of light hydrocarbons (Schaefler et al., this volume), as well as the patterns of the hydrocarbons all indicate low maturity. Thus, the distribution of hydrocarbons reflects mainly the type of organic matter rather than a diagenetic transformation.

The gradients of several parameters as indicators of an increasing thermal evolution with depth of burial are quite high, apparently in response to the relatively high thermal gradient of about 7°C/100 m (Langseth and Ludwig, this volume). On the Northwest African continental margin, which has a much lower thermal gradient of 4.2°C/100 m, a comparable vitrinite reflectance is reached at a depth of 1400 meters in sediments of an equivalent age (Cornford et al., 1979). Decreasing atomic N/C and O/C ratios of bitumen point to splitting off of functional groups and correspond to the slow increase of hydrocarbons (normalized to organic carbon) with depth of burial. We expect, therefore, that the zone of oil formation will be quickly reached in the black shales in regions of somewhat deeper burial and comparable thermal gradient (either updip on Maurice Ewing Bank or downdip in the “basinal” province of the Falkland Plateau).

An estimation of the vitrinite reflectance in the Tertiary claystones is 0.26% Rm. The only slightly higher degree of maturity at the top of the Cretaceous black shales does not allow for significant additional overburden at the Cretaceous/Tertiary disconformity of Site 511.

PHYSICAL PROPERTIES

Sound velocities, gravimetric densities, vane shear penetration, and thermal conductivity measurements were taken. In general, sound velocity and gravimetric density were measured on identical samples. Penetration and vane shear were taken as close to the sample as possible without disturbing it. From the basic measurements, acoustic impedance, water content, and porosity have been computed without corrections for salt content. For the wet-bulk density samples, determined by the cylinder technique, a raw, estimated shrinkage coefficient was determined. The procedures for determination of sound velocity and vane shear strength followed Boyce (1976). The results of the physical properties measurements are given in the core descriptions at the end of this chapter.

Wet-Bulk Density

The wet-bulk density data discussed here were determined by gravimetric methods, either by cylinder technique (in soft sediments) or chunk technique. For the uppermost few meters only the GRAPE densities must suffice, because no gravimetric determinations were possible in this section (Table 5).

Table 5. GRAPE densities, Cores 1 and 2.

<table>
<thead>
<tr>
<th>Core/Section</th>
<th>Dist. from Top of Section (m)</th>
<th>GRAPE Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>0</td>
<td>2.2</td>
</tr>
<tr>
<td>1-2</td>
<td>0.4</td>
<td>2.15</td>
</tr>
<tr>
<td>1-3</td>
<td>0.5</td>
<td>2.25</td>
</tr>
<tr>
<td>2-1</td>
<td>1.5</td>
<td>1.9</td>
</tr>
<tr>
<td>1-2</td>
<td>1.4</td>
<td>1.9</td>
</tr>
<tr>
<td>1-3</td>
<td>1.4</td>
<td>1.6</td>
</tr>
<tr>
<td>2-1</td>
<td>1.4</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Water Content and Porosity

The values for water content and porosity discussed here and plotted in the core descriptions are not corrected for salt water. Because of the homogeneous lithology (at least over large parts of the site), water content and porosity correlate quite well.

Porosity decreases from 80% at the top of the section to 75% at 100 meters and then increases again to 80% at the Tertiary/Cretaceous boundary. In this section the normal inverse relation with bulk density is obvious. In the uppermost Cretaceous, the porosity drops within 50 meters down to 55% and then increases rapidly again to 68%. There is some evidence that an increase in calcium carbonate may in part cause the drop in porosity. A partial decrease of the bulk-density curve from the consolidation trend can be recognized during the same interval.

From 250 meters to the bottom of the hole, the porosity of the fine-grained sediments follows a normal consolidation curve similar to bulk density. Some low porosities, especially in the black shales, are due to carbonates, carbonate sands, and sandy layers.

Sound Velocity

The sound velocities are very stable within the Tertiary sediments, with a mean value of 1.6 km/s for the
upper 200 meters. Between 200 and 250 meters a strong increase to 2.5 km/s occurs; it is parallel to the observed drop in porosity in the same interval. The sound velocity is again stable between 250 and 300 meters (1.6–1.8 km/s) and increases to about 2.2 km/s between 300 and 350 meters. From 350 meters down to the bottom of the hole, the fine-grained sediments show a continuous increase in sound velocity from 1.7 to 1.9 km/s. High velocities, mainly in the upper part of the black shales, are caused by calcareous layers and the associated drop in porosity. Large differences between horizontal and vertical velocities are due to shell layers. Down to the Tertiary/Cretaceous boundary the acoustic impedance (velocity × density) is stable, whereas in the Cretaceous it increases continuously owing to the increase of bulk density; all peaks of the sound velocity curve are apparent in the acoustic impedance data.

**Penetration and Shear Strength**

Penetration was measured down to 400 meters and shear strength down to 300 meters. The penetration values are very high in the upper 130 meters of the section; this may in part be caused by drilling disturbance. Some lower values are due to higher CaCO₃ percentages.

From 150 to 210 meters penetration values are stable near 5 mm, whereas below that point penetrations near 2 mm were measured. The change occurs within the interval with significantly lower porosities. The vane shear values are widely scattered and give no more than a general trend since only a few measurements are valid; most of them did not show a clear shear point.

**GEOPHYSICS**

**Correlation of Seismic Reflectors with Lithology**

Site 511 is located on the back slope of a cuesta-type sedimentary ridge in the basin province of the Falkland Plateau. The general configuration of reflectors in this province is that of thick sheets of sediments dipping to the south and terminated updip by erosional truncation (Fig. 2) (Ludwig, this volume).

Correlation of geologic units cored with reflectors of the Conrad 21-06 seismic line is shown in Figure 13.

Drilling at Site 511 provided definitive information on the nature and age of the wedge of sediments filling the Falkland Plateau Basin. From analyses of vertical reflection and sonobuoy reflection and refraction data, Ludwig and Rabinowitz (1980) conclude that after the inception of seafloor spreading off the north flank of the Falkland Plateau, the plateau was a broad depression well below sea level, bordered on the west by the Falkland Islands Platform, on the north by a continental rim, on the east by the emergent microcontinental Maurice Ewing Bank, and on the south by the North Scotia Ridge. The basin floor thus formed was underlain either by oceanic crust or attenuated continental crust. The configuration of apparently conformable uniform forsets shown by seismic profiles and the configurations shown by Ludwig et al. (1978) strongly indicate deposition as a single, continuous event. Therefore, Ludwig and Rabinowitz (1980) postulate that the wedge of sediments may represent some post-breakup, prograded slope-type deposition of sediments eroded from the continental rim followed by basin-slope and basin-floor seismic facies units of deep-marine, pelagic, and hemipelagic sediments. The reflection geometry and lithology at drill sites indicate shallow-marine coastal downlap of sediments on a paleoshelf edge, followed by slope front fill, and by draping of pelagic sequences.

**Heat Flow**

At Site 511, a successful heat flow measurement was obtained for the first time on the Falkland Plateau using the DSDP Downhole Temperature Probe (DHTP), consisting of an Uyeda electronic package and von Herzen thermistors. More than 50 previous attempts by Lamont-Doherty scientists to obtain heat flow measurements through use of thermistor probes attached to a conventional piston corer had failed, owing to a seafloor cover of manganese and glacial material which destroyed the probes.

At Site 511 the DHTP was lowered twice, to sub-bottom depths of 52.5 and 113 meters. Readings of thermistor resistance sampled every minute are stored in the probe and are played back and displayed upon retrieval. Resistance readings are then converted to temperature data using the thermistor calibration data. The heave compensator was used during the drilling; this usually results in good stability of the bottom hole assembly in the unconsolidated sediments penetrated by the probe.

The temperature versus time data of the two lowerings were then plotted. The temperatures in the sediments at their depths sub-bottom define a gradient of 0.074°C m⁻¹ (Langseth and Ludwig, this volume).

Thermal conductivities were measured on core samples at irregular intervals aboard ship and on shore. These measurements gave a mean value of 0.842 W m⁻¹ °C⁻¹. The heat flow indicated by these observations is 62.3 mW m⁻² (1.49 HFU), a value compatible with the geological evolution of the plateau.

**SUMMARY AND CONCLUSIONS**

Site 511 is located about 10 km south of Site 330 (DSDP Leg 36) in the basin province of the Falkland Plateau. The site was drilled and continuously cored to a sub-bottom depth of 632 meters. Heat flow measurements were made in unconsolidated sediments at sub-bottom depths of 52.5 and 113 meters.

**Lithostratigraphy**

From top to bottom, the sediments cored consist of the following lithologic units:

- **Unit 1**—3 meters of gray to olive gray siliceous oozes and thin foraminiferal oozes of Pliocene–Recent age, with manganese nodules and ice-rafted pebbles and grains.
- **Unit 2**—192 meters of section divisible into two subunits. Subunit 2A comprises 182.5 meters of olive to dark gray muddy diatomaceous oozes and muddy nanofossil–diatomaceous oozes spanning the late Eocene–early Oligocene interval. Subunit 2B encompasses 9.5 meters, of which only the uppermost 72 cm were recov...
Figure 13. Interpretative line drawing of Conrad 21-06 seismic reflection profile (Fig. 2) and correlation with lithology cored at Sites 327, 330, and 511.
er. It consists of greenish gray pelagic clay with minor glauconite, chert, and volcanic ash, of Paleocene or Eocene age.

Unit 3—14 meters of gray calcareous oozes and zeolitic foraminiferal oozes with occasional chert pebbles and disseminated minor glauconite, of late Campanian (?) to early Maestrichtian age.

Unit 4—203.5 meters of gray to greenish gray zeolitic clays and claystones with intercalations of nannofossil and foraminiferal claystones, ranging in age from Turonian to Campanian–early Maestrichtian.

Unit 5—80 meters of variegated, often reddish brown claystones, nannofossil claystones, and muddy nannofossil chalk, of early Albian to Turonian age.

Unit 6—140 meters of black, massive, thinly laminated mudstones and nannofossil mudstones of Late Jurassic to early Albian age, in places highly petrolierous and indicative of anoxic conditions. Pyrite is common. Belemnite rostra are common, benthic microfossils are essentially absent, and microcoquinas of Inoceramus and Aucellina occur frequently.

Principal Results

Hiatuses recognized within this succession occur at the Quaternary/Pliocene, Pliocene/early Oligocene, Paleocene or Eocene/Maestrichtian, Cenomanian/Albian, and Upper Jurassic/Lower Cretaceous boundaries. The unconformity that truncates the southward-dipping sheets of sediment on the plateau (Figs. 2 and 13) lies between Units 2 and 3 at Site 511 and probably corresponds to the Paleocene or Eocene/Maestrichtian hiatus, the maximum duration of which was not precisely determined. The unconformity is believed to represent a major erosional surface caused by bottom-current scouring.

Microfossils occur in nearly all of the cores. The most significant biostratigraphic results at Site 511 are the collection of the following assemblages:

1) 183 meters of lower Oligocene and upper Eocene diatomaceous ooze and muddy nannofossil–diatomaceous oozes with exceptionally well preserved and diverse diatoms, radiolarians, and silicoflagellates, together with sufficient numbers of calcareous nannofossils and foraminifers to provide temporal control by correlation with lower-latitude zonations and the well-established New Zealand stages;

2) 183 meters of lower Campanian–Turonian biogenic sediments, sometimes containing rich and diverse planktonic foraminifers and nannofossils not previously described from the high latitudes of the Southern Hemisphere;

3) Continuous cores through most of the Lower Cretaceous–Upper Jurassic black shale and claystone that enabled us to determine stratigraphic subdivisions and to refine paleogeographic reconstructions based on moluskan and microfossil data;

4) Benthic foraminifers and other floral and faunal groups that demonstrate subsidence of the Falkland Plateau with a distinct acceleration at or near the Lower/Upper Cretaceous boundary.

Accumulation rates of biogenic sediments testify to the highly episodic nature of sedimentation on the Falkland Plateau; periods of exceptionally rapid sedimentation separated by hiatuses or condensed intervals seem to be the norm for the area. High productivity of siliceous plankton during the late Eocene–early Oligocene is indicated by the very high sediment accumulation rate (about 44 m/m.y.) calculated for this interval. A rather high sedimentation rate marks the Campanian interval.

Sediments of Tertiary through Albian age contain only small quantities of organic carbon. In contrast, the underlying black shale of Late Jurassic–Aptian age contains 1.7–4.1% organic carbon (average 3.5%). Organic geochemical investigations and ratios of gaseous hydrocarbons suggest that (1) the black shale has not reached a high degree of maturity; (2) the hydrocarbons presently occurring in the black shale were formed in situ, that is, the shale is both the source and host rock; and (3) no significant amount of additional overburden is necessary to explain the degree of organic maturation of the black shales.

Drilling at Site 511 provided data that significantly build on drilling results from Leg 36 on Maurice Ewing Bank. They indicate that, with some exceptions, lithostratigraphic units were essentially continuous across the bank and the basin province of the plateau; interruption of units is due largely to erosion. Further, a major erosional event took place at or near the Paleocene or Eocene/Maestrichtian boundary, implying that a circum-Antarctic Australia current may have been in existence and admitted to the area prior to the opening of the Drake Passage in the Oligocene–middle Miocene. This, in turn, implies the existence of a passageway for currents between East and West Antarctica during the Late Cretaceous–early Tertiary, a fact which has already been determined from paleomagnetic data.

REFERENCES


Information on core description sheets, for ALL sites, represents field notes taken aboard ship under time pressure. Some of this information has been refined in accord with post-cruise findings, but production schedules prohibit definitive correlation of these sheets with subsequent findings. Thus the reader should be alerted to the occasional ambiguity or discrepancy.
**SITE 511 HOLE CORE 3 CORED INTERVAL 14.5-24.0 m**

**LITHOLOGIC DESCRIPTION**

Section 1, 0-33 cm: DIATOM Ooze; dark gray (2.5Y 6/2); carbonate content increases downward. Small (<1 cm) pale yellow (2.5Y 8/4) siliciclastic clasts at 29-31 cm.

Section 1, 33 cm-Section 3, 100 cm: NANNOFossil DIATOMACEOUS Ooze: light gray (2.5Y 7/1), very slightly bioturbated; occasional large dark stringers, some with radiolarians.

Section 3, 100-150 cm: DIATOMACEOUS NANNOFossil Ooze; gray (2.5Y 7/0) and very dark gray (2.5Y 3/0); irregularly interbedded with sandy mudstone; very slightly bioturbated.

Section 4 and Section 5, 0-33 cm: MUDDY DIATOMACEOUS Ooze; gray (2.5Y 5/0). Very slightly bioturbated throughout.

Core-Catcher: MUDDY DIATOMACEOUS Ooze; gray (2.5Y 5/0).

**SMEAR SLIDE SUMMARY**

1-50 2-50 5-10
- Radiolarians - Silicoflagellates - Sponge spicules

**CARBONATE BOMB:**

2, 5-9 (2)

**GRAIN SIZE:**

2-32 (1, 24, 75)

4-32 (1, 32, 67)

**MAGNETIC DATA:**

Inclination 31.7
Declination 30.7
Intensity (emu/cc) 0.260E-06

**SITE 511 HOLE CORE 5 CORED INTERVAL 33.5-43.0 m**

**LITHOLOGIC DESCRIPTION**

Section 1, 0-33 cm: MUDDY DIATOMACEOUS Ooze; as in Core 4, dark gray (2.5Y 4/0); carbonate content increases downward.

**SMEAR SLIDE SUMMARY**

1-60 2-50 5-10
- Radiolarians - Silicoflagellates - Sponge spicules

**CARBONATE BOMB:**

5, 7-9 (8)

**GRAIN SIZE:**

2-32 (1, 24, 75)

4-32 (1, 32, 67)

**SITE 511 HOLE CORE 6 CORED INTERVAL 24.0-33.6 m**

**LITHOLOGIC DESCRIPTION**

Section 1-Section 3, 65 cm: MUDDY DIATOMACEOUS Ooze; gray (2.5Y 5/0) and dark gray (7.5YR 4/0) with lenses and stringers of light gray (2.5Y 7/0-2.5Y 7/0) ooze containing high nannofossil percentages. Very slight bioturbation throughout.

Core-Catcher: MUDDY DIATOMACEOUS Ooze; gray (2.5Y 5/0).

**SMEAR SLIDE SUMMARY**

2-120 2-99
- Quartz - Clay minerals - Foraminifera

**CARBONATE BOMB:**

2, 61-62 (8.5)
LITHOLOGIC DESCRIPTION

NAOMFOSSIL DIATOMACEOUS Ooze, as in Core 6, with intercalations (1.0-2.0 cm) of clayey/breezy clay containing fewer nannofossils; diatomaceous ooze is present through Section 3. Clay content appreciable in Section 1 (0-12 cm), decreasing downward.

SMEAR SLIDE SUMMARY

- Quartz: 1-2%
- Clay minerals: 35%
- Foraminifers: 1%
- Nannofossils: 3%
- Diatoms: 60%
- Radiolarians: 1%
- Silicoflagellates: 1%
- Sponge spicules: 1%
- Volcanic glass: 1%
- CARBONATE BOMB:
  - 4,58-60 (5.5)
- MAGNETIC DATA:
  - Inclination: 2.8°
  - Declination: 76.1°
  - Intensity (emu/cc): 0.430E-06

SITE 511 HOLE CORE 6 CORED INTERVAL 43.0-53.5 m

LITHOLOGIC DESCRIPTION

NAOMFOSSIL DIATOMACEOUS Ooze, as in Core 6, with intercalations (1.0-2.0 cm) of clayey/breezy clay containing fewer nannofossils; diatomaceous ooze is present through Section 3. Clay content appreciable in Section 1 (0-12 cm), decreasing downward.

SMEAR SLIDE SUMMARY

- Quartz: 1-2%
- Clay minerals: 35%
- Foraminifers: 1%
- Nannofossils: 3%
- Diatoms: 60%
- Radiolarians: 1%
- Silicoflagellates: 1%
- Sponge spicules: 1%
- Volcanic glass: 1%
- CARBONATE BOMB:
  - 4,58-60 (5.5)
- MAGNETIC DATA:
  - Inclination: 2.8°
  - Declination: 76.1°
  - Intensity (emu/cc): 0.430E-06

SITE 511 HOLE CORE 7 CORED INTERVAL 62.0-71.5 m

LITHOLOGIC DESCRIPTION

NAOMFOSSIL DIATOMACEOUS Ooze, as in Core 6, with intercalations (1.0-2.0 cm) of clayey/breezy clay containing fewer nannofossils; diatomaceous ooze is present through Section 3. Clay content appreciable in Section 1 (0-12 cm), decreasing downward.

SMEAR SLIDE SUMMARY

- Quartz: 1-2%
- Clay minerals: 35%
- Foraminifers: 1%
- Nannofossils: 3%
- Diatoms: 60%
- Radiolarians: 1%
- Silicoflagellates: 1%
- Sponge spicules: 1%
- Volcanic glass: 1%
- CARBONATE BOMB:
  - 4,58-60 (5.5)
- MAGNETIC DATA:
  - Inclination: 2.8°
  - Declination: 76.1°
  - Intensity (emu/cc): 0.430E-06

SITE 511 HOLE CORE 8 CORED INTERVAL 62.0-71.5 m

LITHOLOGIC DESCRIPTION

NAOMFOSSIL DIATOMACEOUS Ooze, as in Core 6, with intercalations (1.0-2.0 cm) of clayey/breezy clay containing fewer nannofossils; diatomaceous ooze is present through Section 3. Clay content appreciable in Section 1 (0-12 cm), decreasing downward.

SMEAR SLIDE SUMMARY

- Quartz: 1-2%
- Clay minerals: 35%
- Foraminifers: 1%
- Nannofossils: 3%
- Diatoms: 60%
- Radiolarians: 1%
- Silicoflagellates: 1%
- Sponge spicules: 1%
- Volcanic glass: 1%
- CARBONATE BOMB:
  - 4,58-60 (5.5)
- MAGNETIC DATA:
  - Inclination: 2.8°
  - Declination: 76.1°
  - Intensity (emu/cc): 0.430E-06
**SITE 511 HOLE 9 CORE 1 CORED INTERVAL 71.5-80.0 m**

**LITHOLOGIC DESCRIPTION**

NANNOFOSSIL DIATOMACEOUS Ooze; dark gray (5Y 4/1), slightly mottled, homogeneous. Abundant Mn nodules up to 3 cm, and sub-angular to sub-rounded clasts, up to 4 cm, of varied lithologies, in upper 60 cm of Section 1. Also, in that interval, 1-2 cm lenses of light gray (2.5Y 7/2) slightly diatomaceous fine quartz sand.

**SMEAR SLIDE SUMMARY**

1-58 1-125 2-75 3-75 4-75 5-75 6-75 7-50

Radiolaria:πs

Silicoflagella

Sponge spicule

**CARBONATE BOMB:**

2, 111-112 (9)

**MAGNETIC DATA:**

Intensity (emu/cc)

Inclination

Declination

0.570E-06 0.167E-05 0.510E-06

0.140E-06 0.180E-05 0.340E-06

0.100E-05 0.200E-05

GRAIN SIZE:

1-71 (1.36, 63)

3-71 (1.38, 62)

**SITE 511 HOLE 10 CORE 1 CORED INTERVAL 80.0-89.5 m**

**LITHOLOGIC DESCRIPTION**

NANNOFOSSIL DIATOMACEOUS Ooze; as in previous core, dark gray, slightly mottled, homogeneous. High clay content, Pleistocene Diatomites, and gray micrite in lower 5 cm of Section 1.

**SMEAR SLIDE SUMMARY**

1-58 1-125 2-75 3-75 4-75 5-75 6-75 7-50

**CARBONATE BOMB:**

2, 111-112 (9)

**MAGNETIC DATA:**

Intensity (emu/cc)

Inclination

Declination

0.140E-06 0.200E-06 0.160E-06

0.100E-06 0.150E-05 0.200E-05

GRAIN SIZE:

1-71 (1.36, 63)

3-71 (1.38, 62)
### Site 511 - Hole Core 12 - Cored Interval 99.0–108.5 m

<table>
<thead>
<tr>
<th>Time–Depth Unit</th>
<th>Graphic Lithology</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>Muddy nanofossil diatomaceous ooze, as in previous zone. Dark gray (SY 2/1), slightly mottled, more indurated than overlying zone. Very fine sandy, glauconite-rich, very dark gray (SY 3/1) lens, 2 cm thick, in Section 6, 74 cm. Lower 50 cm of Section 2, higher gray (SY 0/1), as in Core C2.</td>
<td></td>
</tr>
</tbody>
</table>

**Smear Slide Summary**

- **NaCl:** 1.95
- **NaCl:** 1.95
- **NaCl:** 1.95

### Site 511 - Hole Core 13 - Cored Interval 109.5–113.0 m

<table>
<thead>
<tr>
<th>Time–Depth Unit</th>
<th>Graphic Lithology</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>Muddy nanofossil diatomaceous ooze, as in previous zone. Gray (5Y 5/1 to 5Y 6/1), homogeneous; slightly mottled; less indurated. Large, fine-grained calcite crystal in top 7 cm.</td>
<td></td>
</tr>
</tbody>
</table>

**Smear Slide Summary**

- **NaCl:** 1.95
- **NaCl:** 1.95
- **NaCl:** 1.95

### Site 511 - Hole Core 14 - Cored Interval 119.0–128.5 m

<table>
<thead>
<tr>
<th>Time–Depth Unit</th>
<th>Graphic Lithology</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>Gravel in Core-Catcher, assorted pebbles (2–7 cm), angular to subrounded. Granite, fine sandstone, Mn nodules.</td>
<td></td>
</tr>
</tbody>
</table>

**Smear Slide Summary**

- **NaCl:** 1.95
- **NaCl:** 1.95
- **NaCl:** 1.95

### Site 511 - Hole Core 15 - Cored Interval 128.5–138.0 m

<table>
<thead>
<tr>
<th>Time–Depth Unit</th>
<th>Graphic Lithology</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
<td>Gravel in Core-Catcher, assorted pebbles (2–7 cm), angular to subrounded. Granite, fine sandstone, Mn nodules.</td>
<td></td>
</tr>
</tbody>
</table>

**Smear Slide Summary**

- **NaCl:** 1.95
- **NaCl:** 1.95
- **NaCl:** 1.95
SITE 511 HOLE 16 CORED INTERVAL 138.0-147.5 m

**LITHOLOGIC DESCRIPTION**

*NANNOFOSSIL DIATOMACEOUS Ooze*: olive gray (BY 4/20); slightly mottled. Small concentrations of glauconite in core 14 through 16 meters; glauconite concentrations are seen in section 2, 21-42 cm. In section 2, 42-64 cm, marked increase in glauconite content and in fine horizontal gray (5Y 5/1) laminae; top contact of this interval is sharp, inclined. Section 2, 42-64 cm is gray (5Y 5/1), very slightly mottled. Top 17 cm of core are very dark gray (5Y 3/1), highly disturbed, gravelly, sandy, muddy sediment containing lithic clasts and Mn nodules.

**SMEAR SLIDE SUMMARY**

- **Quartz**: 2-25
- **Feldspar**: 2-25
- **Clay minerals**: 2-25
- **Foraminifers**: 2-25
- **Nannofossils**: 2-25
- **Diatoms**: 2-25
- **Radiolarians**: 2-25
- **Silicoflagellates**: 2-25
- **Sponge spicules**: 2-25
- **Volcanic glass**: 2-25
- **Micronodules**: 2-25

**CARBONATE BOMB**: 2, 79-82 (1)

**MAGNETIC DATA**: 1-76

- **Intensity (emu/cc)**: 0.170E-06

CORE 18 CORED INTERVAL 157.0-166.5 m

**JIOSTRATIGRAPHIC ZONE**

**AND FOSSIL CHARACTER**

**LITHOLOGIC DESCRIPTION**

*NANNOFOSSIL DIATOMACEOUS Ooze*: as in previous cores; gray (5Y 6/1); slightly mottled; very faint color banding. In section 1, 115-135 cm, very dark gray (5Y 3/1), highly disturbed, gravelly, sandy, muddy sediment containing lithic clasts and Mn nodules.

**SMEAR SLIDE SUMMARY**

- **Quartz**: 2-25
- **Feldspar**: 2-25
- **Clay minerals**: 2-25
- **Foraminifers**: 2-25
- **Nannofossils**: 2-25
- **Diatoms**: 2-25
- **Radiolarians**: 2-25
- **Silicoflagellates**: 2-25
- **Sponge spicules**: 2-25
- **Volcanic glass**: 2-25
- **Micronodules**: 2-25

**CARBONATE BOMB**: 2, 79-82 (1)

**MAGNETIC DATA**: 1-76

- **Intensity (emu/cc)**: 0.170E-06

Core 15, 166.5-176.0 m: No recovery.

SITE 511 HOLE 20 CORED INTERVAL 176.0-185.5 m

**LITHOLOGIC DESCRIPTION**

*NANNOFOSSIL DIATOMACEOUS Ooze*: as in previous cores; gray (5Y 6/1); slightly mottled; very faint color banding. Top 17 cm of core are very dark gray (5Y 3/1), highly disturbed, gravelly, sandy, muddy sediment containing lithic clasts and Mn nodules.

**SMEAR SLIDE SUMMARY**

- **Quartz**: 2-25
- **Feldspar**: 2-25
- **Clay minerals**: 2-25
- **Foraminifers**: 2-25
- **Nannofossils**: 2-25
- **Diatoms**: 2-25
- **Radiolarians**: 2-25
- **Silicoflagellates**: 2-25
- **Sponge spicules**: 2-25
- **Volcanic glass**: 2-25
- **Micronodules**: 2-25

**CARBONATE BOMB**: 2, 79-82 (1)

**MAGNETIC DATA**: 1-76

- **Intensity (emu/cc)**: 0.170E-06

**GRAIN SIZE**: 1-100 (1, 44)

1.0-

- **Quartz**: 1-100 (1, 44)
- **Feldspar**: 1-100 (1, 44)
- **Clay minerals**: 1-100 (1, 44)
- **Foraminifers**: 1-100 (1, 44)
- **Nannofossils**: 1-100 (1, 44)
- **Diatoms**: 1-100 (1, 44)
- **Radiolarians**: 1-100 (1, 44)
- **Silicoflagellates**: 1-100 (1, 44)
- **Sponge spicules**: 1-100 (1, 44)
- **Volcanic glass**: 1-100 (1, 44)
- **Micronodules**: 1-100 (1, 44)
### Lithologic Description

#### Site 511, Hole 21, Core 21, Cored Interval 195.5-198.0 m

**Graphic Lithology**

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<tr>
<th>Depth (m)</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>195.5</td>
<td>Pelagic Clay, greenish gray (5Y 6/1), moderate glauconitic, in upper 6 cm, slightly mottled throughout; dark brown stringer at 18-20 cm. Lower 6 cm (2Y 4/1) heavily mottled with ash stringer between 71 and 72 cm and 0.5 cm ash-rich clast between 70 and 71 cm.</td>
</tr>
</tbody>
</table>

**Smear Slide Summary**

<table>
<thead>
<tr>
<th>Component</th>
<th>1-21</th>
<th>2-21</th>
<th>3-21</th>
<th>4-21</th>
<th>5-21</th>
<th>6-21</th>
<th>7-21</th>
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<tr>
<td>Feldspar</td>
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<td>Clay minerals</td>
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<tr>
<td>Glauconite</td>
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<td>1</td>
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<tr>
<td>Zeolites</td>
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<tr>
<td>Volcanic glass</td>
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<td>1</td>
<td>1</td>
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**Carbonate Bomb:**

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<tr>
<th>Depth (m)</th>
<th>Value</th>
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<tr>
<td>0-21</td>
<td>1-21</td>
</tr>
</tbody>
</table>

#### Site 511, Hole 24, Core 24, Cored Interval 204.5-209.0 m

**Graphic Lithology**

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>204.5</td>
<td>Zeolitic Calcareous Foraminiferal Ooze, light gray (5Y 6/2), intercalated 5-8% glauconitic, in upper 6 cm, slightly mottled with ash stringer at 18-20 cm.</td>
</tr>
</tbody>
</table>

**Smear Slide Summary**

<table>
<thead>
<tr>
<th>Component</th>
<th>1-63</th>
<th>2-63</th>
<th>3-63</th>
<th>4-60</th>
<th>5-70</th>
<th>6-75</th>
<th>7-63</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
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<tr>
<td>Feldspar</td>
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<tr>
<td>Clay minerals</td>
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<tr>
<td>Glauconite</td>
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<td>Zeolites</td>
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<tr>
<td>Volcanic glass</td>
<td>0.5</td>
<td>0.5</td>
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**Magnetic Data:**

<table>
<thead>
<tr>
<th>Inclination</th>
<th>Declination</th>
<th>Intensity (emu/cc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-95</td>
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<tr>
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</tbody>
</table>

**Grain Size:**

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<th>1-11</th>
<th>2-11</th>
<th>3-11</th>
<th>4-11</th>
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<tbody>
<tr>
<td>1-11</td>
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</tr>
<tr>
<td>STRATIGRAPHIC ZONE</td>
<td>FOSSIL CHARACTER</td>
<td>TIME - ROCK UNIT</td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td>------------------</td>
<td>----------------</td>
<td></td>
</tr>
<tr>
<td>SITE 511 HOLE</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CORE 25 CORED INTERVAL 209.0-214.0 m**

**LITHOLOGIC DESCRIPTION**

- **ZEOLITIC CLAY**: brown (7.5YR 5/2); intensely mottled gray and cream colored clay; very intensely mottled between 148-150 cm: small (<1 cm) black basalt clasts.
- At 90-150 cm: reddish brown (5YR 4/3), less mottled.
- Core-Catcher: contains brown (10YR 5/3) intensely clay enclosing carbonate bomb.

**CARBONATE BOMB:**

**MAGNETIC DATA:**

- Declination: 285.2
- Intensity (emu/cc): 0.110E-04

**GRAIN SIZE:**

- 1-8: 10,20,80

---

**SITE 511 HOLE**

**CORE 26 CORED INTERVAL 214.0-219.0 m**

**LITHOLOGIC DESCRIPTION**

- Core-Catcher: ZEOLITIC CLAY; gray (2.5Y 6/0) and grayish brown (10YR 5/2).

---

**SITE 511 HOLE**

**CORE 28 CORED INTERVAL 219.0-219.0 m**

**LITHOLOGIC DESCRIPTION**

- Core-Catcher: ZEOLITIC CLAY; gray (2.5Y 6/0) and grayish brown (10YR 5/2).
**SITE 511 HOLE**  
**CORE 27 CORED INTERVAL**  
**TIME -- ROCK UNIT**

<table>
<thead>
<tr>
<th>Section</th>
<th>0-108 cm</th>
<th>117-150 cm</th>
<th>223.5-233.0 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithologic Description</td>
<td>Section 1, 0-108 cm:</td>
<td>olive (5Y 5/3); more indurated, more fissured than above, and moderately mottled.</td>
<td>Section 1, 0-36 cm: dark gray (5Y 4/1); prominent 0.5 cm green laminations.</td>
</tr>
</tbody>
</table>

**MAGNETIC DATA:**

- **inclination:** 61.7°  
- **declination:** 165.6°  
- **intensity (emu/cc):** 0.190E-06

**GRAIN SIZE:**

- 1-100: (0, 10, 90)  
- 2-50: (22, 11, 67)

**LITHOLOGIC DESCRIPTION**

- **Section 1, 0-108 cm:** olive (5Y 5/3); more indurated, more fissured than above, and moderately mottled.
- **Section 2, 0-41 cm:** very soupy mixture of coarse sand to granules, moderately well sorted lithic sand of varied lithologies -- quartz, Mn nodules, granitoids, chert, volcanics, metamorphics.

**MAGNETIC DATA:**

- **inclination:** 61.7°  
- **declination:** 165.6°  
- **intensity (emu/cc):** 0.190E-06

**GRAIN SIZE:**

- 1-100: (0, 10, 90)  
- 2-50: (22, 11, 67)

**LITHOLOGIC DESCRIPTION**

- **Section 1, 0-36 cm:** dark gray (5Y 4/1).
- **Section 1, 0-36 cm:** dark gray (5Y 4/1); finely laminated (2-5 mm), laminae inclined 6°.
- **Section 2, 0-36 cm:** olive gray; prominent 0.5 cm green laminations.
- **Section 2, 36-143 cm:** dark gray (5Y 4/1); laminated.
- **Section 2, 143 cm-Section 3, 2 cm:** olive gray.
- **Section 3, 0-117 cm:** dark gray (5Y 4/1).
- **Section 3, 117-131 cm:** olive gray (6Y 5/1).
- **Section 3, 131 cm-Section 5, 30 cm:** gray (5Y 5/1), I.

**MAGNETIC DATA:**

- **inclination:** -65.4° -81.6° -82.6° -46.0° -58.9° -120.3° -182.3° -334.5°  
- **declination:** 326.0° 21.9°  
- **intensity (emu/cc):** 0.144E-05 0.720E-06 0.441E-05 0.273E-05

**GRAIN SIZE:**

- 1-140: (0, 9, 91)  
- 2-5: (0, 11, 89)
SITE 511 HOLE 25 CORED INTERVAL 233.0-242.5 m

LITLOGICAL DESCRIPTION

ZEOLITIC CLAYSTONE; dark gray (5Y 4/1); intensely bioturbated.
Core-Catcher, 0-8 cm: light olive gray (5Y 6/2), chaotic mixture with <0.5 cm zones of gray, green and cream clay.
Core-Catcher, 8-20 cm: very dark gray (2.5Y 3/0) to dark gray (2.5Y 4/0); homogeneity, only slights indicated.

SUEM SLIDE SUMMARY
1-12 OD
0 0
Quartz 1 1
Mica T T
Clay minerals 50 47
Zeolites 30 36
Carbonate unspc. 5 5
Porosities 1 1
Noncarbonates 10 17
Varano clay 1
Zeolite 2 TR

CARBONATE BOMB:
CO (10)

GRAFIC LITHOLOGY

MAGNETIC DATA:
Declination
Intensity (emu/cc)
2-8 23.0 0.680E-06
4-8 28.3 0.730E-06
6-8 312.8 0.890E-06
3-31 23.0 0.270E-05
301.3 0.630E-06

MAGNETIC DATA:
Declination
Intensity (emu/cc)
3.0 0.800E-04
6.3 0.920E-06

GRAIN SIZE:
2-8 1.31 3.21 3.21
4-8 1.31 3.21 3.21
6-8 1.31 3.21 3.21
3-31 1.31 3.21 3.21
301.3 392.4
0.890E-06

MAGNETIC DATA:
Declination
Intensity (emu/cc)
3.0 0.800E-04
6.3 0.920E-06

GRAIN SIZE:
2-8 1.31 3.21 3.21
4-8 1.31 3.21 3.21
6-8 1.31 3.21 3.21
3-31 1.31 3.21 3.21
301.3 392.4
0.890E-06

MAGNETIC DATA:
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Intensity (emu/cc)
3.0 0.800E-04
6.3 0.920E-06

GRAIN SIZE:
2-8 1.31 3.21 3.21
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6-8 1.31 3.21 3.21
3-31 1.31 3.21 3.21
301.3 392.4
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6.3 0.920E-06

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6-8 1.31 3.21 3.21
3-31 1.31 3.21 3.21
301.3 392.4
0.890E-06

MAGNETIC DATA:
Declination
Intensity (emu/cc)
3.0 0.800E-04
6.3 0.920E-06

GRAIN SIZE:
2-8 1.31 3.21 3.21
4-8 1.31 3.21 3.21
6-8 1.31 3.21 3.21
3-31 1.31 3.21 3.21
301.3 392.4
0.890E-06
LITHOLOGIC DESCRIPTION

SITE 511 HOLE CORE 31 CORED INTERVAL 262.0-261.5 m

ZEOLITIC CLAYSTONE; dark gray (2.5Y 4/0) with color changes in matrix; fine burrows throughout core; drilling hours oblique.

Intercalated with the predominate dark gray claystone are zones, 2-5 cm thick, which may be one of three colors - 1) greenish black (5GY 2/1); 2) light gray (2.5Y 7/0) and 3) pale yellow (2.5Y 7/4).

The greenish black zones may contain very small chlorite grains. Sedimentary clasts, pink yellow and brown (10YR 8/2 and 10YR 5/3) noted in Section 6, 16-17 cm (see smear slide 6-17).

SMALL SLIDE SUMMARY

<table>
<thead>
<tr>
<th>1/8</th>
<th>2/8</th>
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<th>5/2-5</th>
<th>6/7</th>
<th>0/9</th>
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<td>D</td>
<td>D</td>
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</tbody>
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Quartz

Zeolites

Fossils

Matrix

Volume change: 1

CARBONATE (1H)

ZEOLITIC CLAYSTONE; as in Core 31.

Burrows in Section 1 may be Planolites and Chondrites types.

Unusual shaped burrow in Section 6, 45-50 cm; ?Zoophycos.

PALE yellow zones may contain less quartz than dark gray zones.

SMALL SLIDE SUMMARY

<table>
<thead>
<tr>
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<th>1/40</th>
<th>1/40</th>
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Heavy minerals

Zircons

Fossils

Matrix

Volume change: 1

CARBONATE (2H)

1. 136-138 (4)
2. 140-144 (4)

MAGNETIC DATA:

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<th>Intensity (emu/cm²)</th>
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<tr>
<td>90.6</td>
<td>-84.1</td>
<td>0.519-05</td>
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GRAIN SIZE:

- 1-2 (1.2) 12.8
- 2-3 (2.9) 30.0
- 3-4 (4.1) 51.9
- 4-5 (5.2) 82.4
- 5-6 (6.2) 113.9

Graham
SITE 511 HOLE CORE 33 CORED INTERVAL 271.0-280.5 m

LITHOLOGIC DESCRIPTION
ZEOLITIC CLAYSTONE; as in previous cores. Baritel? nodules in Section 4, 3-11 cm. Thiichichnus? burrow in Section 5, 20—30 cm.

CARBONATE UNSPEC.

MAGNETIC DATA: 1-33

GRAIN SIZE:
3-32 (0,19,81)
5-32 I0, 6, 94)

4-103 5-94 6-96 73 76 77 20 8 22

SITE 511 HOLE CORE 34 CORED INTERVAL 280.5-290.0 m

LITHOLOGIC DESCRIPTION
ZEOLITIC CLAYSTONE; as in previous cores. Intense burrowing possibly Chondrites and Planolites types. Baritel? nodules. Section 3, 88-89 cm and Section 6, 118-122 cm.

CARBONATE BOMB: 1, 1-3(3)

MAGNETIC DATA: 5-17
Declination 127.2
Intensity (emu/cc) 0.600E-06

GRAIN SIZE:
1-26(0, 13,87)
3-26(0, 12,88)
5-26 (0,9,91)
7-26 (0, 12,88)
SITE 511  HOLE 35  CORED INTERVAL 290.0-299.5 m

LITHOLOGIC DESCRIPTION

ZEOLITIC CLAYSTONE, as in previous zone, Section 2, 40-41 cm. pyrite nodule.

SHEAR SLIDE SUMMARY

Q: 5
Clay minerals: 72
Zincite: 25
Nannofossils: 1
Volcanic glass: 1

MAGNETIC DATA: 1-80
Inclination: 56.3
Declination: 246.1
Intensity (emu/cc): 0.800E-07

GRAIN SIZE:
1-26 (0, 14,87)

SITE 511  HOLE 36  CORED INTERVAL 299.5-309.0 m

LITHOLOGIC DESCRIPTION

ZEOLITIC CLAYSTONE, as in previous zone, Section 4, 0-18 and 145-146 cm. pyrite nodule.

MAGNETIC DATA: 4-67
Declination: 124.9
Intensity (emu/cc): 0.320E-06

GRAIN SIZE:
1-18 (0, 19,81)
3-18 (0, 18,82)
5-18 (0, 15,85)
7-18 (0, 18,82)
**SITE 511 HOLE**

**CORE 37**

**CORED INTERVAL** 309.0–318.5 m

<table>
<thead>
<tr>
<th>GRAPHIC ZONE</th>
<th>STRATIGRAPHIC ZONAL CHARACTER</th>
<th>MEASUREMENT</th>
<th>APPEARANCE</th>
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<tr>
<td>1</td>
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<tr>
<td>4</td>
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**LITHOLOGIC DESCRIPTION**

Zeolitic Claystone, as in previous cores: horizontal stratification evident, despite intense burrowing.

**SMR SLIDE SUMMARY**

<table>
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<tr>
<th>Component</th>
<th>Count</th>
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<tr>
<td>Quartz</td>
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<tr>
<td>Biotite</td>
<td>2</td>
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<tr>
<td>Clay matrix</td>
<td>1</td>
</tr>
<tr>
<td>Zeolite</td>
<td>1</td>
</tr>
<tr>
<td>Foraminifera</td>
<td>1</td>
</tr>
<tr>
<td>Phosphate</td>
<td>1</td>
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<tr>
<td>Microfossils</td>
<td>3</td>
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**CARBONATE BOMBS**

1,50–51 (5)

**MAGNETIC DATA**

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<th>Intensity (emu/cc)</th>
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<td>-77.7</td>
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**GRAIN SIZE**

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<tr>
<td>2-3</td>
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<tr>
<td>3-2</td>
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**SITE 511 HOLE**

**CORE 38**

**CORED INTERVAL** 318.5–328.0 m

<table>
<thead>
<tr>
<th>GRAPHIC ZONE</th>
<th>STRATIGRAPHIC ZONAL CHARACTER</th>
<th>MEASUREMENT</th>
<th>APPEARANCE</th>
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<td>4</td>
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**LITHOLOGIC DESCRIPTION**

Zeolitic Claystone, as in previous cores; mostly dark gray (2.5Y 4/1) with gradations into zones of light gray (2.5Y 7/2) light olive gray (5Y 6/2) greenish black (5GY 2/1). Abundant burrows; especially Izooophycos; mostly "solid burrows".

Section 1, 106–112 cm: non-zeolitic very hard, light gray siltstone.

**SMR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>Component</th>
<th>Count</th>
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<tbody>
<tr>
<td>Quartz</td>
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</tr>
<tr>
<td>Biotite</td>
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<tr>
<td>Clay matrix</td>
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<tr>
<td>Zeolite</td>
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</tr>
<tr>
<td>Foraminifera</td>
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<td>Phosphate</td>
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<tr>
<td>Microfossils</td>
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**CARBONATE BOMBS**

3, 64–65 (2)

**MAGNETIC DATA**

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**GRAIN SIZE**

<table>
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<tr>
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<tbody>
<tr>
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<td>93</td>
</tr>
<tr>
<td>4-6</td>
<td>86</td>
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<td>6-8</td>
<td>87</td>
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**GRAIN SIZE**

<table>
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<tr>
<th>Size</th>
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<tbody>
<tr>
<td>2-4</td>
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</tr>
<tr>
<td>4-6</td>
<td>86</td>
</tr>
<tr>
<td>6-8</td>
<td>87</td>
</tr>
</tbody>
</table>

---

**GRAIN SIZE**

3, 67 (2.5, 7.2)

4-6 (4.5, 8.6)

6-8 (10, 12.8)
**SITE 511 HOLE**

**CORE INTERVAL**

**LITHOLOGIC DESCRIPTION**

- **SITE 511 HOLE**
- **CORE 39**
- **CORED INTERVAL** 328.0-337.51 m
- **STRATIGRAPHIC ZONE**
- **FOSSIL CHARACTER**

**LITHOLOGIC DESCRIPTION**

- Zeolitic Claystone; as in previous cores.
- Rows up to 2 cm in diameter, often filled with finely disseminated pyrite which also occurs disseminated and as small crystals elsewhere.

**Section A:**

- Feldspar
- Clay minerals
- Zeolites

**MAGNETIC DATA:**

- Inclination -59.5
- Declination 225.4

**GRAIN SIZE:**

- 2-31 (0, 11, 89)

**CARBONATE BOMB:**

- 3,31-32 (28)

**MAGNETIC DATA:**

- Intensity (emu/cm^3)

**GRAIN SIZE:**

- 2-12 (0, 14, 87)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Z (mm)</th>
<th>Y (mm)</th>
<th>X (mm)</th>
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<td>5-80</td>
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</table>

**GRAIN SIZE:**

- 2-12 (0, 14, 87)
- 4-12 (0, 23, 77)
- β-12 (0, 8, 92)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Z (mm)</th>
<th>Y (mm)</th>
<th>X (mm)</th>
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<tbody>
<tr>
<td>1-118</td>
<td>-66.2</td>
<td>240.4</td>
<td></td>
</tr>
<tr>
<td>3-127</td>
<td>-62.0</td>
<td>166.3</td>
<td></td>
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<tr>
<td>5-73</td>
<td>-78.5</td>
<td>266.2</td>
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**MAGNETIC DATA:**

- Intensity (emu/cm^3)

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<th>X (mm)</th>
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<tr>
<td>1-118</td>
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<tr>
<td>5-73</td>
<td>-78.5</td>
<td>266.2</td>
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</tbody>
</table>

**GRAIN SIZE:**

- 2-31 (0, 11, 89)
- 4-31 (0, 13, 87)
- 79 90 76

<table>
<thead>
<tr>
<th>Sample</th>
<th>Z (mm)</th>
<th>Y (mm)</th>
<th>X (mm)</th>
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<tbody>
<tr>
<td>1-118</td>
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<tr>
<td>5-73</td>
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<td>266.2</td>
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**MAGNETIC DATA:**

- Intensity (emu/cm^3)

<table>
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<th>Y (mm)</th>
<th>X (mm)</th>
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<tr>
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<td>266.2</td>
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**GRAIN SIZE:**

- 2-31 (0, 11, 89)
- 4-31 (0, 13, 87)
- 79 90 76

<table>
<thead>
<tr>
<th>Sample</th>
<th>Z (mm)</th>
<th>Y (mm)</th>
<th>X (mm)</th>
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<td>5-73</td>
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**MAGNETIC DATA:**

- Intensity (emu/cm^3)

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<th>X (mm)</th>
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<td>5-73</td>
<td>-78.5</td>
<td>266.2</td>
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**GRAIN SIZE:**

- 2-31 (0, 11, 89)
- 4-31 (0, 13, 87)
- 79 90 76
ZEOLITIC CLAYSTONE AND CLAYSTONES

Section 3, 106-145 cm: Section 2, 16-103 cm: CLAYSTONE, reddish brown (2.5YR 4/4), moderately burrowed with local 3-5 cm and fine grained. Zeolitic claystone at 76 cm. Some contact with Section 2, 106-146 cm: light gray (7.5Y 1/1) to white (5Y 8/1), slightly mottled. Contact with Section 2, 146 cm. Section 2, 146 cm: reddish brown (2.5Y 4/4) to white (5Y 8/1), slightly mottled. Contact with Section 3, 146 cm. Soft claystone at Section 1, 80-88 cm.

Section 3, 70-106 cm: transition from reddish brown claystones to gray (5Y 7/1) to white (5Y 8/1), slightly mottled. Claystone, in sharp contact with Section 3, 146 cm. Section 3, 106-145 cm: abundant pyrite in burrow and astring fractures. Large barite crystal in Section 1, 80-88 cm.

Section 2, 50-55 cm: abundant pyrite in burrow and astring fractures. Dark gray reolitic claystone (Section 3, 106-145 cm). Abundant and Inoceramus (Section 3, 70-106 cm): transition from reddish brown claystones to gray (5Y 7/1) to white (5Y 8/1), slightly mottled. Claystone, in sharp contact with Section 2, 146 cm. Section 3, 106-145 cm: abundant pyrite in burrow and astring fractures. Large barite crystal in Section 1, 80-88 cm.

Core moderately burrowed, locally with pyrite and barite. Abundant pyrite and barite in Cer-3Ch 3.

SANDSTONE SUMMARY

<table>
<thead>
<tr>
<th>Depth (cm)</th>
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<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
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<tbody>
<tr>
<td>Quartz</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Feldspar</td>
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<td>8</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Mica</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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CARBONATE BOMB:
1. 133-145 cm:
2. 195-205 cm:
3. 36-40 cm:

MAGNETIC DATA:
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<th>Intensity (emu/cc)</th>
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MAGNITE:
1. 133-145 cm:
2. 195-205 cm:
3. 36-40 cm:

MAGNETIC DATA:
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<th>Sample</th>
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<td>98.3</td>
<td>-59.3</td>
</tr>
</tbody>
</table>

GRAIN SIZE:
| Sample | 0.44 (2, 10, 6) |

SITE 511 HOLE CORE 41 COGRED INTERVAL 542.0-368.5 m
<table>
<thead>
<tr>
<th>Section</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Zeolitic claystone; as in Cores 43 and 44, dark gray (5Y 6/1) and dark greenish gray (5G 4/1) with pale yellow laminae and white laminae in Section 1, 366-377 cm, Well preserved Chondrites and Zoophycos in Section 2. Burrowing moderate to light except Section 2, 131-141 cm which is heavily burrowed. Section 2, 364-375 cm, dark reddish brown (2.5YR 3/4) slightly burrowed, with dark gray lenses and greenish black stringers, parallel to the Core-Catcher. Dark grayish black, negligible burrowing.</td>
</tr>
</tbody>
</table>

**SKEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>Material</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Quartz</td>
<td>1</td>
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<tr>
<td>Zeolite</td>
<td>10</td>
</tr>
<tr>
<td>Foraminifers</td>
<td>0.5</td>
</tr>
<tr>
<td>Nannofossils</td>
<td>2</td>
</tr>
<tr>
<td>Volcanic glass</td>
<td>1</td>
</tr>
</tbody>
</table>

**CARBONATE BOMB**

<table>
<thead>
<tr>
<th>Size (mm)</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-30</td>
<td>291-293</td>
</tr>
<tr>
<td>3-30</td>
<td>293-296</td>
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</table>

**GRAIN SIZE**

<table>
<thead>
<tr>
<th>Size (mm)</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-30</td>
<td>364-366</td>
</tr>
<tr>
<td>3-30</td>
<td>366-369</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Section</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Claystone and zeolitic claystone; gray (2.5Y 5/0) to dark gray (2.5Y 4/0) with intervals 10-30 cm of greenish gray (5GY 5/1) and greenish black. Chert nodules 0.5-3 cm common. Nannofossils present in Sections 1 and 3. Burrowing moderate to slight; minor foraminifers present.</td>
</tr>
</tbody>
</table>

**CARBONATE BOMB**

<table>
<thead>
<tr>
<th>Size (mm)</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-30</td>
<td>361-363</td>
</tr>
</tbody>
</table>

**GRAIN SIZE**

<table>
<thead>
<tr>
<th>Size (mm)</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-30</td>
<td>364-366</td>
</tr>
<tr>
<td>3-30</td>
<td>366-369</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Section</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Claystone and zeolitic claystone; gray (2.5Y 5/0) to dark gray (2.5Y 4/0) with intervals 10-30 cm of greenish gray (5GY 5/1) and greenish black. Chert nodules 0.5-3 cm common. Nannofossils present in Sections 1 and 3. Burrowing moderate to slight; minor foraminifers present.</td>
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</tbody>
</table>

**CARBONATE BOMB**

<table>
<thead>
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<th>Depth (m)</th>
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<td>341-343</td>
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**GRAIN SIZE**

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<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-30</td>
<td>344-346</td>
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<table>
<thead>
<tr>
<th>Section</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Claystone and zeolitic claystone; gray (2.5Y 5/0) to dark gray (2.5Y 4/0) with intervals 10-30 cm of greenish gray (5GY 5/1) and greenish black. Chert nodules 0.5-3 cm common. Nannofossils present in Sections 1 and 3. Burrowing moderate to slight; minor foraminifers present.</td>
</tr>
</tbody>
</table>

**CARBONATE BOMB**

<table>
<thead>
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<th>Depth (m)</th>
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</thead>
<tbody>
<tr>
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<td>304.5-306.5</td>
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**GRAIN SIZE**

<table>
<thead>
<tr>
<th>Size (mm)</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-30</td>
<td>306-308</td>
</tr>
<tr>
<td>3-30</td>
<td>308-310</td>
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</table>

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<table>
<thead>
<tr>
<th>Section</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Claystone and zeolitic claystone; gray (2.5Y 5/0) to dark gray (2.5Y 4/0) with intervals 10-30 cm of greenish gray (5GY 5/1) and greenish black. Chert nodules 0.5-3 cm common. Nannofossils present in Sections 1 and 3. Burrowing moderate to slight; minor foraminifers present.</td>
</tr>
</tbody>
</table>

**CARBONATE BOMB**

<table>
<thead>
<tr>
<th>Size (mm)</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-30</td>
<td>361-363</td>
</tr>
</tbody>
</table>

**GRAIN SIZE**

<table>
<thead>
<tr>
<th>Size (mm)</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-30</td>
<td>364-366</td>
</tr>
<tr>
<td>3-30</td>
<td>366-369</td>
</tr>
</tbody>
</table>
SITE 511 HOLE CORE 47 CORED INTERVAL 404.0–413.5 m

**Zeolitic Claystone and Claystone** as in preceding Core 46.

Section 1, 0–20 cm: dark reddish brown (2.5YR 3/3).

Zeolitic claystones through Section 1–5 predominantly gray and dark gray with areas of greenish-gray (2.5G 4/1) and zones 1–5 cm where greenish-black (2.5Y 3/2) and yellowish laminae appear.

Remains vary from light to heavy in show; nodule outlines present.

Chevron structure rare to absent; rare chert clasts in Section 2, 4–13 and 50–83 cm.

Assessment present in Sections 4, 5, and 6.

Section 6: greenish-gray (2.5G 4/4) claystone mixed with grayish brown (2.5Y 5/2) at 67–68 cm. Lightly burrowed. Grits and sandstones at 68–69 cm. From 112–115 cm and Core-Catcher, dark reddish-brown (2.5YR 3/3) with light blue (5B 7/6) mottling.

**SMEAR SLIDE SUMMARY**

1-14 1-49 3-90 6-61 CC

**CARBONATE BOMBS:**

2, 69–90 (4) 4, 69–90 (4)

**MAGNETIC DATA:**

1.23 4.02

1.37 4.02

1.43 4.02

**GRAIN SIZE:**

1.23 (0.25, 0.75)

2.29 (0.25, 0.75)

3.27 (0.25, 0.75)

Section 1, 0–20 cm: dark reddish brown (2.5YR 3/3).

Zeolitic claystones through Section 1–5 predominantly gray and dark gray with areas of greenish-gray (2.5G 4/1) and zones 1–5 cm where greenish-black (2.5Y 3/2) and yellowish laminae appear.

Remains vary from light to heavy in show; nodule outlines present.

Chevron structure rare to absent; rare chert clasts in Section 2, 4–13 and 50–83 cm.

Assessment present in Sections 4, 5, and 6.

Section 6: greenish-gray (2.5G 4/4) claystone mixed with grayish brown (2.5Y 5/2) at 67–68 cm. Lightly burrowed. Grits and sandstones at 68–69 cm. From 112–115 cm and Core-Catcher, dark reddish-brown (2.5YR 3/3) with light blue (5B 7/6) mottling.

**SMEAR SLIDE SUMMARY**

1-14 1-49 3-90 6-61 CC

**CARBONATE BOMBS:**

2, 69–90 (4) 4, 69–90 (4)

**MAGNETIC DATA:**

1.23 4.02

1.37 4.02

1.43 4.02

**GRAIN SIZE:**

1.23 (0.25, 0.75)

2.29 (0.25, 0.75)

3.27 (0.25, 0.75)

SITE 511 HOLE CORE 48 CORED INTERVAL 413.5–423.0 m

**Zeolitic Claystone**

Dark section brown (2.5YR 3/3) with sparse light blue (5B 7/6) and pale blue green (2G 3/2) mottling. Rare chert clasts and lenses, Section 2, 112–118 cm, and yellow (5YR 7/8) mottling in Section 6, 68–71 cm. Pyrite present in this section in Section 1, 104–106 cm, and as pyrite (11W) in Section 4 where it appears to be related to yellow mottling. Burrowing is light to moderate as shown.

In Section 2, the intervals 83–95 and 93–100 cm are rich in yellow mottling at 76–80 cm. From 122–128 cm and Core-Catcher, claystone is dark reddish brown (2.5YR 3/3) with light blue (5B 7/6) mottling.

**SMEAR SLIDE SUMMARY**

1-63 2-96 3-72 4-109

**CARBONATE BOMBS:**

2, 69–90 (4) 4, 69–90 (4)

**MAGNETIC DATA:**

1.23 4.02

1.37 4.02

1.43 4.02

**GRAIN SIZE:**

1.23 (0.25, 0.75)

2.29 (0.25, 0.75)

3.27 (0.25, 0.75)
CLAYSTONE AND CALCARCEOUS CLAYSTONE: predominantly dark reddish brown (5YR 3/3) with shingles of reddish brown (5YR 4/4), 4-8 cm dark red mud sheets (2.5YR 3/4). Black, dark gray and yellowish brown (5YR 5/4) laminae, approximately 2 cm thick. The CLAYSTONE AND CALCARCEOUS CLAYSTONE in Section 2, 110-150 cm is highly variegated; in color, in thickness from 0.5-10 cm thick. Colors range through tones of brown, gray, yellow, green, and black with streaks. Burrowing is slight. Anhydrite fragments occur in Section 3 and Section 4, 73-89 cm. Intermittent streaks and unidentified shell material are present in Section 6, and silt and thin sand in well preserved in Section 6, 94-122 cm and throughout Section 5.

SMEAR SLIDE SUMMARY

CARBONATE BOMB:

MAGNETIC DATA:

GRAIN SIZE:

0.3991±0.06 0.171±0.04 0.1496±0.04

CLAYSTONE AND MUDDY CALCAREOUS CLAYSTONE: predominant reddish brown (5YR 3/3) with shingles of reddish brown (5YR 4/4), 4-8 cm dark red mud sheets (2.5YR 3/4). Black, dark gray and yellowish brown (5YR 5/4) laminae, approximately 2 cm thick. Colors range through tones of brown, gray, yellow, green, and black with streaks. Burrowing is slight. Anhydrite fragments occur in Section 3 and Section 4, 73-89 cm. Intermittent streaks and unidentified shell material are present in Section 6, and silt and thin sand in well preserved in Section 6, 94-122 cm and throughout Section 5.

SMEAR SLIDE SUMMARY

CARBONATE BOMB:

MAGNETIC DATA:

GRAIN SIZE:

0.3991±0.06 0.171±0.04 0.1496±0.04

0.094 0.122 0.13 0.114 0.089 0.07 0.051 0.032 0.017 0.01

Clay minerals TKB TR TR TR

Calcic clay TR TR TR TR

Carbonate unsorted TR 40 40 40 40 25

Ferromagnesia TR TR TR TR TR

Nanoflakes TR TR TR TR

Intermediate fragments TR TR TR TR

CARBONATE BOMB:

1. 3-4 (16)

MAGNETIC DATA:

Intensity 0.881E-05 0.242E-04

GRAIN SIZE:

0.171±0.04 0.1496±0.04

1. 3-4 (16)

MAGNETIC DATA:

Intensity 0.881E-05 0.242E-04

GRAIN SIZE:

0.171±0.04 0.1496±0.04

1. 3-4 (16)

MAGNETIC DATA:

Intensity 0.881E-05 0.242E-04

GRAIN SIZE:

0.171±0.04 0.1496±0.04

1. 3-4 (16)

MAGNETIC DATA:

Intensity 0.881E-05 0.242E-04

GRAIN SIZE:

0.171±0.04 0.1496±0.04

1. 3-4 (16)

MAGNETIC DATA:

Intensity 0.881E-05 0.242E-04

GRAIN SIZE:

0.171±0.04 0.1496±0.04

1. 3-4 (16)

MAGNETIC DATA:

Intensity 0.881E-05 0.242E-04

GRAIN SIZE:

0.171±0.04 0.1496±0.04

1. 3-4 (16)

MAGNETIC DATA:

Intensity 0.881E-05 0.242E-04

GRAIN SIZE:

0.171±0.04 0.1496±0.04

1. 3-4 (16)

MAGNETIC DATA:

Intensity 0.881E-05 0.242E-04

GRAIN SIZE:

0.171±0.04 0.1496±0.04

1. 3-4 (16)

MAGNETIC DATA:

Intensity 0.881E-05 0.242E-04

GRAIN SIZE:

0.171±0.04 0.1496±0.04

1. 3-4 (16)

MAGNETIC DATA:

Intensity 0.881E-05 0.242E-04

GRAIN SIZE:

0.171±0.04 0.1496±0.04

1. 3-4 (16)

MAGNETIC DATA:

Intensity 0.881E-05 0.242E-04

GRAIN SIZE:

0.171±0.04 0.1496±0.04

1. 3-4 (16)

MAGNETIC DATA:

Intensity 0.881E-05 0.242E-04

GRAIN SIZE:

0.171±0.04 0.1496±0.04

1. 3-4 (16)
MUDDY CALCAREOUS CHALK AND CALCAREOUS CLAYSTONE

Section 1, 0-27 cm: muddy chalk (coquina); light greenish gray (2.5GY 5/1) tints and white chalk (2.5GY 6/2) about 2 cm above. Abundant pelecypods (~1 cm) and shell debris. Sharp erosional lower contact.

Section 2, 1-18 cm: interbedded red to red brown (5YR 5/3) chalk and red to red brown (5YR 4/4) claystone. Abundant pelecypods (~1 cm).

Section 3, 18-90 cm: interbedded red to red brown (5YR 5/3) chalk and red to red brown (5YR 4/4) claystone. Abundant pelecypods (~1 cm). Section 3, 54-27 cm: red to red brown (5YR 4/4) chalk (coquina) and red to red brown (5YR 5/3) chalk (coquina).

Section 4, 27-130 cm: red to red brown (5YR 4/4) chalk (coquina) and red to red brown (5YR 5/3) chalk (coquina). Abundant pelecypods (~1 cm). Section 4, 54-27 cm: red to red brown (5YR 4/4) chalk (coquina) and red to red brown (5YR 5/3) chalk (coquina).

Section 5, 27-130 cm: red to red brown (5YR 4/4) chalk (coquina) and red to red brown (5YR 5/3) chalk (coquina). Abundant pelecypods (~1 cm). Section 5, 54-27 cm: red to red brown (5YR 4/4) chalk (coquina) and red to red brown (5YR 5/3) chalk (coquina).

Section 6, 27-130 cm: red to red brown (5YR 4/4) chalk (coquina) and red to red brown (5YR 5/3) chalk (coquina). Abundant pelecypods (~1 cm). Section 6, 54-27 cm: red to red brown (5YR 4/4) chalk (coquina) and red to red brown (5YR 5/3) chalk (coquina).

Section 7, 27-130 cm: red to red brown (5YR 4/4) chalk (coquina) and red to red brown (5YR 5/3) chalk (coquina). Abundant pelecypods (~1 cm). Section 7, 54-27 cm: red to red brown (5YR 4/4) chalk (coquina) and red to red brown (5YR 5/3) chalk (coquina).

Section 8, 27-130 cm: red to red brown (5YR 4/4) chalk (coquina) and red to red brown (5YR 5/3) chalk (coquina). Abundant pelecypods (~1 cm). Section 8, 54-27 cm: red to red brown (5YR 4/4) chalk (coquina) and red to red brown (5YR 5/3) chalk (coquina).

Note: Section 8 is 67 cm long.

SUMMARY

1-75 2-75 3-55 4-76 5-24 6-14 7-12

CARBONATE BOMB:

2, 22-23 (28)
3-38
-54.3
124.4
553
-40.2
245.9
9E-05 0.407E-0

MAGNETIC DATA:

1-79 2-39 3-53
3-40 4-60
5-25 6-10
7-10
8-5
9-5

GRAIN SIZE:

1-42 (12, 30.58)
3-42 (3, 21, 76)
5-42 (3, 19, 79)
MUDDY NANNOFOSSIL CHALK

Intercalated and "blotchy" light gray to greenish gray (5YR 5/4) with gray zones becoming more abundant down section.

Section 1, 4-8, 30-37, and 145-150 cm. Are sparsely fossiliferous, predominantly reddish brown (5YR 5/4) with gray zones becoming more abundant down section. Abundant gastropod and oyster fragments throughout the core.

SMEAR SLIDE SUMMARY

1-35 1-130 2-105 3-68 4-120 5-72 6-78

CARBONATE BOMB:

5, 64-65 (25.5)

MAGNETIC DATA:

Intensity (emu/cc)

1.92 4.03 6.19

GRAIN SIZE:

2-20 (1, 19, 80)

4-20 (2, 17, 80)

6-20 (0, 11, 89)

0.367E-05 0.128E-05 0.288E-04

CARBONATE BOMB:

5, 62-63 (15)

MAGNETIC DATA:

Intensity (emu/cc)

1.92 4.03 6.19

GRAIN SIZE:

2-20 (1, 19, 80)

4-20 (2, 17, 80)

6-20 (0, 11, 89)

0.367E-05 0.128E-05 0.288E-04

DRAW SIZE:

2-20 (1, 19, 80)

4-20 (2, 17, 80)

6-20 (0, 11, 80)
**SITE 511 HOLE**

**CORE 55 CORED INTERVAL** 480.6-490.5 m

**LITHOLOGIC DESCRIPTION**

MUDDY NANNOSCOLES CHALK, as in previous Core 54 and 55 - except that below Section 1, 74 cm, the top is a progressively grayer gray (2.5G 6/1) with lesser reddish brown (7.5YR 5/3) grays; light brown (5Y 6/1) grays in 481.0 cm to a grayish purple (2.5P 6/2) claystone layer. Petrophysical fragments are sparse throughout. Burrowing moderate to heavy, as shown; Zoophycos and Cylindrinids present. Sparsely leporal fragments in sections 3, 4.

**SMEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>1-85</th>
<th>2-52</th>
<th>3-110</th>
<th>4-60</th>
<th>4-102</th>
<th>5-45</th>
<th>5-74</th>
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<td>TR</td>
<td>TR</td>
<td>TR</td>
<td>TR</td>
<td>TR</td>
</tr>
</tbody>
</table>

**CARBONATE BOMB:**

1.45-21 (10, 11, 89)

**GRAIN SIZE:**

4.21 (10, 99)

**MAGNETIC DATA:**

- Intensity (0.604E-04, 0.210E-06)

**DIP:**

1.58 T 2.98 S 3.04

**GRAIN SIZE:**

1-28 (10, 11, 89)

**MAGNETIC DATA:**

- Intensity (0.604E-04, 0.210E-06)

**DIP:**

1.58 T 2.98 S 3.04

---

**SITE 511 HOLE**

**CORE 56 CORED INTERVAL** 490.5-499.5 m

**LITHOLOGIC DESCRIPTION**

MUDDY NANNOSCOLES CHALK AND “BLACK SHALE”:

- Sections 1-3: muddy chalk as in previous Cores 54 and 55; grayer gray (2.5G 6/1) with zones of grayish black (2.5G 6/2) except top 25 cm. Section 5 and 6 are grayer gray (2.5G 6/2) with some red zones (7.5YR 5/2). Burrowing moderate to heavy as shown; Zoophycos and Cylindrinids present. Sparsely leporal fragments in sections 3, 4.
- Sections 4 and 5, 1-143 cm alternating layers of muddy chalk, grayer black zeolitic claystone, and black shale. Chalks moderately burrowed; thin Zoophycos and Cylindrinids present. Zeolitic claystones moderately burrowed, filled with indurated carbonates. Black shales, very finely laminated, with moderate burrowing.
- Sections 4, 1-143 cm: “black shale” (2.5S 2/3); finely laminated, greenish gray laminae in intervals 66-70, 102-104, and 141-142 cm. Slight to moderate burrowing in Sections 4 and 5.

**SMEAR SLIDE SUMMARY**

1.25 1.13 511 4.36 4.11 5.10

**CARBONATE BOMB:**

1.45-21 (10, 11, 89)

**GRAIN SIZE:**

4.21 (10, 99)

**MAGNETIC DATA:**

- Intensity (0.604E-04, 0.210E-06)

**DIP:**

1.58 T 2.98 S 3.04

---

**SITE 511 HOLE**

**CORE 56 CORED INTERVAL** 490.5-499.5 m

**LITHOLOGIC DESCRIPTION**

MUDDY NANNOSCOLES CHALK AND “BLACK SHALE”:

- Sections 1-3: muddy chalk as in previous Cores 54 and 55; grayer gray (2.5G 6/1) with zones of grayish black (2.5G 6/2) except top 25 cm. Section 5 and 6 are grayer gray (2.5G 6/2) with some red zones (7.5YR 5/2). Burrowing moderate to heavy as shown; Zoophycos and Cylindrinids present. Sparsely leporal fragments in sections 3, 4.
- Sections 4 and 5, 1-143 cm alternating layers of muddy chalk, grayer black zeolitic claystone, and black shale. Chalks moderately burrowed; thin Zoophycos and Cylindrinids present. Zeolitic claystones moderately burrowed, filled with indurated carbonates. Black shales, very finely laminated, with moderate burrowing.
- Sections 4, 1-143 cm: “black shale” (2.5S 2/3); finely laminated, greenish gray laminae in intervals 66-70, 102-104, and 141-142 cm. Slight to moderate burrowing in Sections 4 and 5.
SITE 511 HOLE CORE 57 CORED INTERVAL 498.6-508.5 m

LITHOLOGIC DESCRIPTION

"BLACK SHALE" SY 2.5/1. Most probably a black mudstone; very fine grained, frequently with an ochreous base. In Section 1, 1-23 cm, 51-52 cm, 95-96 cm, and 130-134 cm; in Section 2, 1-3, 9-10, 11-12, 13-14, 20-21, 35-37, 39-41, 54-56, and 142-143 cm; in Section 3, 12-16, 35-37, 54-56, and 123-134 cm; in Section 4, 1-8, 10-12, 21-22, 38-40, and 100-101 cm.

Burrowing sparse to moderate as shown, including Zoophycos and Microfaulting in Section 2, 1-2, 6-7, 9-10, 11-12, and 20-21 cm; in Section 3, 12-14, 15-16, 21-22, and 26-27 cm; in Section 4, 1-3, 6-7, 10-11, and 14-15 cm.

In Section 5, 1-2, 6-7 cm: white (2.5Y 8/2 and 2.5Y 8/0) layers rich in carbonate. Aucellina sp. sparse through Sections 1, 2, and 4. Pale yellow (2.5Y 8/4) lens, Section 3, 60-62 cm, contains 40% carbonates.

Microfaulting in Section 1, 45-47 cm, and Section 3, 101-104 cm.

Coquina in Core-Catcher, 11-18 cm.

“BLACK SHALE”, as in Core 57. Sparsely laminated shingled, laminated, and scattered black or dark shingled. In Section 2, 120-144 cm; in Section 3, 120-142 cm, and in Section 4, 130-144 cm. In Section 1, 52-53 cm, 120-121 cm, and 146-147 cm; in Section 2, 120-142 cm, and 146-147 cm; in Section 3, 130-142 cm, and 132-133 cm; in Section 4, 130-142 cm, and 132-133 cm. In Section 5, 120-144 cm; in Section 6, 120-144 cm. In Section 1, 92-101 cm, and 130-132 cm; in Section 2, 92-101 cm, 130-142 cm, and 132-133 cm; in Section 3, 92-101 cm, 130-142 cm, and 132-133 cm; in Section 4, 92-101 cm, 130-142 cm, and 132-133 cm. In Section 1, 92-101 cm, 130-142 cm, and 132-133 cm. In Section 2, 92-101 cm, 130-142 cm, and 132-133 cm. In Section 3, 92-101 cm, 130-142 cm, and 132-133 cm. In Section 4, 92-101 cm, 130-142 cm, and 132-133 cm. In Section 5, 120-144 cm; in Section 6, 120-144 cm. In Section 1, 52-53 cm, 120-121 cm, and 146-147 cm; in Section 2, 120-142 cm, and 146-147 cm; in Section 3, 130-142 cm, and 132-133 cm; in Section 4, 130-142 cm, and 132-133 cm. In Section 5, 120-144 cm; in Section 6, 120-144 cm. In Section 1, 92-101 cm, and 130-132 cm; in Section 2, 92-101 cm, 130-142 cm, and 132-133 cm; in Section 3, 92-101 cm, 130-142 cm, and 132-133 cm; in Section 4, 92-101 cm, 130-142 cm, and 132-133 cm. In Section 5, 120-144 cm; in Section 6, 120-144 cm. In Section 1, 92-101 cm, and 130-132 cm; in Section 2, 92-101 cm, 130-142 cm, and 132-133 cm; in Section 3, 92-101 cm, 130-142 cm, and 132-133 cm; in Section 4, 92-101 cm, 130-142 cm, and 132-133 cm. In Section 5, 120-144 cm; in Section 6, 120-144 cm. In Section 1, 92-101 cm, and 130-132 cm; in Section 2, 92-101 cm, 130-142 cm, and 132-133 cm; in Section 3, 92-101 cm, 130-142 cm, and 132-133 cm; in Section 4, 92-101 cm, 130-142 cm, and 132-133 cm.
**SITE 511 HOLE CORE 59 CORED INTERVAL 518.0–527.5 m**

**LITHOLOGIC DESCRIPTION**

- "BLACK SHALE", as in previous cores. Soft greyish brown, with minor greenish grey lenses, 0.5 to 1.0 cm thick. Lenses are common, 5 cm thick, and occur in a grey interval. These lenses are common in the interval 565-575 cm. The lenses contain bioturbation and are highly indurated. Laminations are common in the interval 565-575 cm.

**SMEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>GRAIN SIZE</th>
<th>B</th>
<th>M</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.0625 &amp; 0.0625-0.125</td>
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<td>2</td>
<td>3</td>
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**MAGNETIC DATA:**

<table>
<thead>
<tr>
<th>Inclination</th>
<th>Declination</th>
<th>Intensity (emu/cc)</th>
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</thead>
<tbody>
<tr>
<td>38.7</td>
<td>-122.2</td>
<td>0.410E-06</td>
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<tr>
<td>41.0</td>
<td>-102.6</td>
<td>0.260E-06</td>
</tr>
</tbody>
</table>

**CARBONATE BOMB:**

| 1, 2, 3 | 121-126 (44) |

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**SITE 511 HOLE CORE 60 CORED INTERVAL 527.5–537.0 m**

**LITHOLOGIC DESCRIPTION**

- MUDDY CHALK AND CHALK
  - Predominately dark grey (5Y 4/1) and grey (5Y 6/1) chalk, with less than 2% of nannofossils and carbonate unspecified, and less than 5% of plastic. The rock is highly indurated. Laminations are common. Pale grey laminae in dark grey chalk are enriched in carbonate.

**SMEAR SLIDE SUMMARY**

<table>
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<tr>
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<td>3</td>
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<td>0.410E-06</td>
</tr>
<tr>
<td>41.0</td>
<td>-102.6</td>
<td>0.260E-06</td>
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**CARBONATE BOMB:**

| 1, 2, 3 | 121-126 (44) |

---

**MAGNETIC DATA:**

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</tr>
<tr>
<td>41.0</td>
<td>-102.6</td>
<td>0.260E-06</td>
</tr>
</tbody>
</table>
LITHOLOGIC DESCRIPTION

**SITE 511 HOLE 61 CORE 61 CORED INTERVAL 546.5-556.0 m**

**LITHOLOGIC DESCRIPTION**

**SITE 511 HOLE 62 CORE 62 CORED INTERVAL 548.5-564.0 m**

**LITHOLOGIC DESCRIPTION**

**BLACK SHALE (CLAYSTONE)**

Black (RV 2/2), thinly laminated, highly indurated, serpentine. Generalized layers: 1-2 cm, light gray (RV 6/2) alternating with very con- 
miscitated unpepped debris. Fine gray laminae (RV 5/1-1.5 cm). Are present, combining appreciable calcite in Section 1.

Through Sections 3, 4, and 5, color becomes lighter, to very dark gray (RV 2/3) and light olive gray (RV 5/2.5) in alternating layers.

**Section 6, 90 cm-Screen 5, 30 cm: dark olive gray (RV 3/3) NANNOFOSIL CLAYSTONE. Interval Section 5, 30-120 cm is less car-
bonate-rich and very dark gray (RV 3/1), as in Section 2 and 3.

Pyrite lamina, Section 4, 25 cm.

Coarse-grained calcite and pyrite gray (RV 5/1) to light gray (RV 7/1) in Section 4, 14-17 cm.

**SMEAR SLIDE SUMMARY**

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<tr>
<th>1-74</th>
<th>1-115</th>
<th>2-75</th>
<th>3-80</th>
<th>4-75</th>
<th>5-75</th>
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<td>1</td>
<td>1</td>
<td>1</td>
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**CARBONATE BOMB:**

1, 22-24 (6)

**MAGNETIC DATA:**

<table>
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<tr>
<th>1-24</th>
<th>1-68</th>
<th>1-126</th>
<th>1-26</th>
<th>1-59</th>
<th>1-70</th>
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<tbody>
<tr>
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<td>4</td>
<td>1</td>
<td>2</td>
<td>2</td>
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**CARBONATE BOMB:**

1, 22-24 (6)

**MAGNETIC DATA:**

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<tr>
<th>1-24</th>
<th>1-68</th>
<th>1-126</th>
<th>1-26</th>
<th>1-59</th>
<th>1-70</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

**INCLINATION:**

-49.1

**DECLINATION:**

25.3

**INTENSITY (emu/cc):**

0.108E-05

**GRAIN SIZE:**

1.02 (0.73, 0.8)
**SITE 511 HOLE**

**CORE 63**

**CORED INTERVAL**

**556.0-565.5 m**

**LITHOLOGIC DESCRIPTION**

- **CLAYSTONE (BLACK SHALE)**
  - Black (5Y 2.5/1), petroliferous, hard; vague horizontal laminations; thin, weakly calcitic; microsparite concentration Section 1, 84 and 160-163 cm.
  - Thin (0.5 cm) lenses (2.5Y 6/1) and (locally) Section 3, 109-110 cm.
  - Referenced Section 2, 102 cm, in Core 63 core, Section 2, 72-73 cm, high in calcite.

**SMERE SLIDE SUMMARY**

- **Quartz:** 1 1 1
- **Feldspar:** 10 8 10
- **Dolomite:** 75 68 82 85
- **Zeolite:** 2 2 3 1
- **Carbonate:** 1 1 1 1
- **Nannofossil:** 10 5 15
- **Organic:** 10 10 15

**CARBONATE BOMB:**

- **Clay mineral:**
- **Zeolite:**
- **Organic:**

**MAGNETIC DATA:**

- **Inclination:**
- **Declination:**

**GRAIN SIZE:**

<table>
<thead>
<tr>
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<th>4</th>
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<tbody>
<tr>
<td>32</td>
<td>34</td>
<td>32</td>
<td>32</td>
</tr>
</tbody>
</table>

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**SITE 511 HOLE**

**CORE 64**

**CORED INTERVAL**

**565.0-575.0 m**

**LITHOLOGIC DESCRIPTION**

- **CLAYSTONE (BLACK SHALE)**
  - As in previous Core 63.
  - White laminae of fine, thin-shelled pelecypod debris at Section 1, 129, 133, and 141 cm; Section 3, 41 and 100 cm; Section 5, 33, 37, 40, and 196 cm; Section 6, 41, 102, and 125 cm; and Section 8, 31, 121, 130, and 146 cm.
  - Nannofossils present in all sections and Core-Catch Core: when the fossil is fragment is surrounded by 0.5 cm halo of fine pyrite.

**SMERE SLIDE SUMMARY**

- **Quartz:** 1 1 1 1
- **Feldspar:** 5 5 5 5
- **Clay mineral:** 2 1 5 2 1
- **Nannofossil:** 2 1 2 1
- **Organic:** 10 10 15

**CARBONATE BOMB:**

- **Clay mineral:**
- **Zeolite:**
- **Organic:**

**MAGNETIC DATA:**

- **Inclination:**
- **Declination:**

**GRAIN SIZE:**

<table>
<thead>
<tr>
<th>1</th>
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<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>33</td>
<td>32</td>
<td>32</td>
</tr>
</tbody>
</table>
CLAYSTONE (BLACK SHALE); as in previous sections; petroliferous; enriched in many laminae of pelecypod debris, i.e. Section 2, 110-124 cm; Section 2, 144 cm, and Section 3, 7-14 cm.

Very fine- to fine-grained, hard, muddy, gray (2.5Y 6/0) calcarenite intervals occur in Sections 1, 3-10, 22-28 cm; Section 2, 124-144 cm; Section 3, 7-14 cm; and Section 4, 29-32 cm.

Nannofossil assemblages present in every section, common in Section 4.

CARBONATE BOMB: 2, 125-127 (75.5; 38.0-100.0)

CARBONATE BOMB: 3, 92-94 (3)

MAGNETIC DATA:

<table>
<thead>
<tr>
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<th>Intensity (emu/cc)</th>
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</thead>
<tbody>
<tr>
<td>-46.1</td>
<td>136.0</td>
<td>0.470E-06</td>
</tr>
<tr>
<td>-74.1</td>
<td>322.6</td>
<td>0.300E-07</td>
</tr>
</tbody>
</table>

GRAIN SIZE:

| Section 1 | 1-90 (0.18, 82) |
| Section 3 | 1-90 (1.22, 77) |

SNAKE OIL BULLET: 2, 125-127 (75.5; 38.0-100.0)

MAGNETIC DATA:

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<tr>
<td>-74.1</td>
<td>322.6</td>
<td>0.300E-07</td>
</tr>
</tbody>
</table>

GRAIN SIZE:

| Section 1 | 1-90 (0.18, 82) |
| Section 3 | 1-90 (1.22, 77) |
SITE 511 HOLE
CORE 67 CORED INTERVAL 594.0-603.5 m

LITHOLOGIC DESCRIPTION
NANNOFOSSIL CLAYSTONE (BLACK SHALE); as in Core I black, thinly laminated, Inoceramus sparsely distributed in thin laminae. Gray (2.5Y 5/0) zeolitic layers in Section 3, 107-109 cm; Section 4, 96-98 cm; and Section 5, 10-11, 29-30, 83-85 and 102 cm. Pyrite laminae Section 5, 77-80 cm.

Core-Catcher, 0-7 cm: dark gray calcarenite with Inoceramus sparsely distributed. Quartz, Clay matrix. Zeolites: 71 74 72 73 72 27 23 27 26 27 1 2

CARBONATE BOMB: 3, 43-45 (8)

GRAIN SIZE:
161 (1,22,78)

SITE 511 HOLE
CORE 68 CORED INTERVAL 603.5-613.0 m

LITHOLOGIC DESCRIPTION
CLAYSTONE (BLACK SHALE); as in previous intervals with strong fissile tendency. Dark gray (2.5Y 4/0) calcarenite layers in Section 1, 124 cm. Gray (2.5Y 6/0) calcareous chalk layer. Section 1, Inoceramus and other shell debris sparsely distributed. Aucellina sparse. Gray zeolitic layers in Section 2, as shown.

Zeolites: 1,115-117 (80) 2, 70-72 (0)

MAGNETIC DATA: 1-112
Declination 123.6
Intensity (emu/cc) 0.540E-06

GRAIN SIZE:
1-29(0, 16,84)

Site 511
SITE 511 HOLE
CORE 69 CORED INTERVAL 613.0-622.5 m

LITHOLOGIC DESCRIPTION

MUDSTONE (BLACK SHALE)
Black (5Y 2.5/1) and finely laminated as in previous core.
Gray (2.5Y 5/0) zeolitic layers as shown.
Section 5, 0-5 cm, greenish (5G 6/1) with abundant black (5GY 2/1) grains; ?glauconite?
Section 5, 6-7 cm, 0.5 cm pyrite nodule.

CARBONATE BOMB:
3, 73-76 (0)
5, 2-4 (3)

GRAIN SIZE:
1-70 (0, 23, 77)

SITE 511 HOLE
CORE 70 CORED INTERVAL 622.5-632.0 m

OSTRATIGRAPHIC ZONE

LITHOLOGIC DESCRIPTION

MUDSTONE (BLACK SHALE); as in Core 69; black, laminated, with sparse shell debris laminae except in Sections 4 and 5, where they are moderately abundant and 0.5-1 cm thick. Belemnites continue to be present but not abundant. A lamina of carbonate sand "needles" occurs in Section 5, 36 cm.
Aucellina (?) also present in Section 5, 18-21 and 27-35 cm.
In Section 2, 136-138 cm: an inclusion is embedded; plant (?) large, elongate black (shiny)

SMEAR SLIDE SUMMARY

Clay minerals
Zeolites
Carbonate unspec.
Undetermined minerals

CARBONATE BOMB:
4, 92-95 (0.2)

GRAIN SIZE:
2-65 (0.1, 90)
5-25 (0.7)