SITE DATA

Data Occupied: 3 November 1972
Data Departed: 7 November 1972
Time on Site: 108 hours
Position:
  lat 29°37.05'S
  long 112°41.78'E
Water Depth (from sea level): 4696 corrected meters (echo sounding)
Water Depth (from drill floor): 4706 corrected meters (echo sounding)
Bottom Felt At: 4712 meters (drill pipe)
Penetration: 346 meters
Number of Holes: 1
Number of Cores: 41
Total Length of Cored Section: 346 meters
Total Core Recovered: 248.75 meters
Percentage Core Recovery: 71.9
Oldest Sediment Cored:
  Depth below sea floor: 304.3 meters
  Nature: Green-gray clay
  Age: Aptian
  Measured velocity: 1.6 km/sec
Basement:
  Depth below sea floor: 0.35 sec DT (seismic profiler)
  304.3 meters (drilled)
  Inferred velocity of basement: 1.75 km/sec
  Nature: Altered basalt

Principal Results: The principal result was to determine the basement age is Aptian. Another important result is the discovery of the hiatus in the Upper Cretaceous and lower part of Paleocene.

BACKGROUND AND OBJECTIVES

Two different models for the origin of the south-eastern Indian Ocean have recently been proposed:

1) by the spreading of the sea floor between Australia and India (Crawford, 1969; Heirtzler, 1971; Veevers et al., 1971) or between Australia and southeast Asia (Ridd, 1971; Audley-Charles et al., 1972). The essence of these reconstructions is that Gondwanaland was continuous westward from southwest Australia.

2) as an original oceanic embayment in Gondwanaland—the sinus australis of Dietz and Holden (1971), which is implicit in the classical reconstruction of Du Toit (1937), and which is supported by Smith and Hallam (1970) and McElhinny and Luck (1970). McKenzie and Sclater (1971) reassembled the Gondwanaland fragments back to the Upper Cretaceous (75 m.y. ago) from sea-floor magnetic anomalies, and found that:

"It is also difficult to understand how the fit proposed by Du Toit (1937) and refined by Smith and Hallam (1970) could evolve to the Upper Cretaceous arrangement proposed in this paper. Recent paleomagnetic observations (McElhinny and Luck, 1970) have strongly supported Du Toit's fit, and it is therefore unlikely that major errors are present in Du Toit's reconstruction. Perhaps the solution of these difficulties will come from the results of the Deep Sea Drilling programme."

The Du Toit reconstruction conflicts with the geological evidence from Western Australia (Veevers et al., 1971) of a Permian to Jurassic facies change from non-marine in the south to marine in the north. Falvey (1972) attempted to reconcile this conflict by adopting an extended eastern margin of India (now beneath the Tibetan Plateau), which lay against the southwest Australian margin.

A common element of these models, as modified above, is that there was land west of Australia and that this land has been dispersed by sea-floor spreading. The next stage is to outline the salient details of the assembly of the continents and the timing of their dispersal.

The geology of Western Australia sets constraints on the timing: rupture occurred in the basal Cretaceous approximately 130 m.y. ago (Veevers et al., 1971), and the first phase of dispersal was completed by the Upper Cretaceous. The geology of Western Australia is not so pertinent in detailing the reassembly and subsequent spreading except for one point, the lineament of the southwest margin and the parallel Perth and Carnarvon...
basins and the Darling Fault. Veevers et al., (1971) and Veevers and Gass (1974) relate the development of the Permain-Jurassic Perth and Carnarvon basins to rifting along a lineament that became a spreading ridge in the Cretaceous, so that the lineament is normal to subsequent spreading. On the other hand, Falvey (1972) interprets the lineament as the trace of a transform fault, and thus parallel to spreading. From these interpretations, Veevers et al., (1971) imply west-east spreading, whereas Falvey (1972) implies northwest-southeast spreading. It was to test such ideas that Site 259 was drilled.

SITE SURVEY

Details of the site area (Figures 1, 2) are provided by reflection profiles of Lamont-Doherty Geological Observatory (Conrad-11), the Australian Bureau of Mineral Resources (BMR 18), and by a survey from Glomar Challenger, all navigated by satellite fixes. The site area is bounded by the 4900-meter-depth contour to form a southwest-sloping elevated area with a sharp ridge (4200 m) in the northeast part of the map area, and smaller scarps in the south and west. The sediment on the elevated area is no thicker than 0.4 sec, and is acoustically transparent. Outside the immediate area the transparent layer is thicker (≥1.0 sec) and is overlain by stratified sediments. It was the discovery (by Conrad-11) of Paleocene sediment (L. H. Burckle, personal communication) on the elevated area that made this an attractive site for drilling. The basement reflector has the character and the shape of oceanic basalt. Site 259 is located in an elongate steep-walled depression in the acoustic basement which is filled with 0.35 sec of sediment.

OPERATIONS

The approach to Site 259 was essentially along Conrad-11’s track out of Fremantle. As the proposed site was approached the track of Glomar Challenger was found to be about one mile to the east of Conrad’s track but parallel to it. Although there was a general similarity to Conrad’s seismic record, significant differences were noted. Glomar Challenger turned on a southerly, then northeasterly course to cross both Conrad’s track and to cross our own track and to observe the east-west extent of the sedimentary cover. It was soon realized that the bottom and subbottom topography were somewhat more complex than originally supposed. The ship turned and made two more runs parallel to Conrad’s track before finally selecting a place that appeared to have 350 meters of sediment of the same type as that found on Conrad’s track.

The beacon was dropped at 0430, 3 November 1972 while underway at 7.5 km/hr (4 knots). Survey gear was retrieved and the ship positioned over the beacon. The bottom hole assembly and drill pipe were run in and bottom tagged at 4712 meters. The hole was spudded at 1700, 3 November and continuously cored to a total depth of 5058 meters or 346 meters below sea floor. Details of the coring are included in the coring summary, Table 1.

Weather conditions were generally good and positioning was excellent, allowing rig-floor operations to proceed unhindered. Basement was reached at 307.5 meters below sea floor in Core 33 and 38.5 meters of basalt were cored. A deviation survey was run on Core 39 and indicated a deviation of 2° at 5042 meters. Coring was completed at 0600, 7 November. The drill string was pulled and we were underway to Site 260 at 1630, 7 November.

LITHOLOGY

Site 259 was drilled to a depth of 346 meters. The hole penetrated a sedimentary sequence 304.3 meters thick ranging in age from Quaternary to Lower Cretaceous. The sediments rest on a basement of highly altered basalt breccia that grades downward into relatively fresh, moderately brecciated basalt.

The sedimentary sequence can be divided into four distinct units based on color and composition (Table 2).

Unit 1 (0.0-60.0 m)

Unit 1 consists of approximately 60 meters of light-orange to light-brown, interbedded, nanno ooze, nanno clay, and zeolite clay. The sediments are stiff, well bedded, and usually highly contorted. Individual beds range from 1 to 5 cm in thickness.

Nanno ooze and zeolite clay are the dominant lithologies. The ooze typically is about 80% nannos, 15% zeolite, 5% clay and mica with minor amounts of dolomite rhombs. Coarse fractions (greater than 62µ in diameter) contain dolomite rhombs. The ooze typically consists of quartz, feldspar, and nannos. Coarse fractions consist chiefly of quartz, forams, and micarb fragments with traces of sponge spicules, fish remains, silicoflagellates, and black micronodules.

Numerous small nodules ranging from 0.5 to 2 cm in diameter are present from 30- and 33-meters depth. Some nodules are dark gray to black, possibly manganese or iron oxide in composition. Others are light gray and consist of dolomite- or zeolite-cemented clay.

Fossils are abundant throughout Unit 1, consisting chiefly of coccoliths, discoasters, forams, and sponge spicules with lesser quantities of Radiolaria, diatoms, and silicoflagellates. Several thin sandy layers in the upper part of the unit consist largely of shallow-water forams and carbonate fragments in a clay matrix. These layers, which range from 2 to 5 cm in thickness, are poorly sorted but show no obvious grading. The presence of shallow-water forams suggests transport of material from the shelf into deeper water.

The upper part of Unit 1 is Quaternary in age whereas the lower part ranges from lower Eocene to upper Paleocene. A major disconformity probably exists in the unit somewhere between 9 and 27 meters in depth. The base of the unit at 60 meters is marked by a fairly distinct color change to dark or dusky yellowish brown and by a marked decrease in the abundance of nannofossils.

Unit 2 (60.0-103.0 m)

Unit 2 consists of about 43 meters of dark or dusky yellow-brown zeolite clay and zeolite-rich clay. The clay is strongly contorted with vertical striping and no
Figure 1. Location of Site 259 and generalized stratigraphic columns of Site 259 and adjacent sites.
bedding is preserved. Typical specimens are about 50%-65% clay, 20%-25% zeolite, 10%-20% cristobalite and microcrystalline quartz, and a few percent of heavy minerals, quartz, feldspar, and nannos. Fossils are scarce in the clays but forams are present in most coarse fractions. Olive-black nodules are locally present between 80 and 90 meters in depth. These consist of zeolite and opaque material, possibly iron oxide.

Unit 2 is Cretaceous. The base of the unit is marked by a slight color change to yellow brown and light brown and the reappearance of abundant nannofossils.

Unit 3 (103.0-154.0 m)

Approximately 50 meters of zeolite-rich nanno clay with lesser zeolite-rich clayey nanno ooze comprise Unit 3. The sediments are moderate yellowish brown and light brown in color with some greenish-gray zones. Most of the clay has been strongly disturbed and brec-
Clay and microcrystalline cristobalite and quartz make up 95% of average specimens; detrital quartz, feldspar, and heavy minerals make up the remainder. Most specimens also contain trace amounts of feldspar and chlorite. The mineralogy suggest a volcanic origin for much of the clay, either by weathering of exposed volcanics or by alteration in situ of pyroclastic material.

Nodules are common throughout Unit 4 and range from 2 mm to 10 cm in diameter. Most are light gray in color and consist of dolomite- or zeolite-cemented clay. A few pyrite nodules, up to 4 cm across, are present and small crystals of pyrite are common in the coarse fraction. Euhedral gypsum crystals, 1-2 mm long, are also present in the clays. Fossils are rare in this unit although forams are usually present in the coarse fraction. Tiny opaque globules generally less than 1 mm in diameter are also present in the clays.

Unit 3 is Lower Cretaceous (Albian) in age. The base of the unit is indicated by a sharp color break and a virtually complete disappearance of nannofossils.

**Unit 4 (154.0-304.3 m)**

Unit 4 is a very uniform sequence of dark greenish-gray claystone about 150 meters thick. The claystone is stiff to indurated and usually highly deformed. Rare preserved beds are regular repetitions of 1 cm-thick layers of dark greenish-gray and olive-black clay.

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Unit 4 is Lower Cretaceous (Aptian) in age with the upper boundary corresponding to an unconformity between Albian and Aptian.
Basalt Basement

Basalt basement was encountered at 304.3 meters and drilled to a depth of 346 meters. Approximately 20 meters of basalt were recovered from this interval. The sediments immediately overlying the basalt are somewhat indurated but show no signs of an intrusive contact.

The upper part of the basalt consists of light-gray to greenish-gray breccia. This grades downward into dark-gray fine-grained basalt at about 25 meters below the sediment-basement contact. The breccia consists of angular to subangular fragments of altered basalt up to 50 cm across. The fragments grade from light gray in the center to light green near the margins and are typically separated by zones of black to dark-green altered glass(?) 1-2 cm thick. Veinlets and small masses of calcite and chlorite are common throughout the breccia and a few geodes of quartz are locally present. The solid basalt is dark gray to light gray in color and is generally fresher than the breccia.

The basalt is fine- to medium-grained and sparsely porphyritic with a variolitic, intergranular to interstitial groundmass. The average grain size ranges from 0.3 to 0.5 mm with a few phenocrysts up to 5 mm long. A few small vesicles up to 0.5 mm in diameter are usually present.

Typical specimens consist of small, ragged laths of labradorite set in a matrix of poorly crystallized clinopyroxene, iron oxide, and clay minerals. The clinopyroxene forms radiating, sheaf-like masses indicating incipient crystallization from glass. Rare microphenocrysts of clinopyroxene are augite (2V, \( \approx 50^\circ \)) and the groundmass crystals are probably the same. The iron oxide is chiefly magnetite which occurs in small clusters and fern-like masses of octahedra. Olivine is present in some specimens but never makes up more than 2%-3% by volume. It occurs in small corroded crystals, 0.3-0.5 mm in diameter, which have been replaced by clay minerals and iron oxides.

All of the basalt are altered but the degree of alteration decreases markedly with depth. In the most altered specimens, green montmorillonite makes up 30%-40% by volume and replaces olivine, glass, clinopyroxene, and, occasionally, plagioclase. In the fresher specimens, clay rarely exceeds 10% and occurs chiefly as vesicle fillings and as pseudomorphs after olivine.

The mineralogy of the basalt indicates a tholeiitic composition typical of oceanic basement. The grain size and texture indicate rapid cooling, probably in contact with water, suggesting extrusion onto the sea floor.

Preliminary Interpretation

Site 259 is at a water depth of 4712 meters. Based on the presence of abundant calcareous nannofossils and forams in the uppermost sediments, this depth is above the present carbonate compensation level which averages about 5000 meters in the world's oceans. Carbonate fossils are abundant throughout Unit 1 suggesting that similar conditions existed in the early Tertiary. However, a hiatus occurs in the sequence between the Quaternary and the lower Eocene so most of the Tertiary record is missing.

Terrigenous sand and silt are absent in the sediments at this site; however, a few thin layers of sand-size shallow-water forams occur in Unit 1. These suggest transport of material from a shallow-water-shelf environment into deeper water. The transporting mechanism was presumably turbidity currents and the thinness of the layers and their bimodal grain distribution (sand and clay) suggest deposition at the distal ends of the flows.

Unit 2, which is Cretaceous in age, consists chiefly of zeolite clay and contains only 1%-2% calcareous fossils. The existing fossils show strong dissolution effects suggesting that the scarcity of nannofossils in this unit is due to solution of carbonate below the carbonate compensation level rather than to changes in planktonic production. In contrast, the reappearance of relatively abundant nannofossils in Unit 3 probably reflects a return to shallow water conditions.

Unit 4, consisting of dark greenish-gray and black cristobalite claystone makes up nearly half of the sedimentary sequence. Zeolites generally make up 1%-2% of this unit and trace amounts of quartz, feldspar, heavy minerals, and chlorite are ubiquitous. Calcareous fossils are very rare and there is no evidence of bioturbation in the sediments. Finely divided pyrite is abundant.

### Table 2

<table>
<thead>
<tr>
<th>Interval (m)</th>
<th>Unit</th>
<th>Description</th>
<th>Age</th>
<th>Thickness (including gaps)(m)</th>
<th>Cores</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0-60.0</td>
<td>1</td>
<td>Soft, grayish-orange clay-rich nanno oozze and zeolite clay</td>
<td>Quaternary to upper Paleocene</td>
<td>60.0</td>
<td>1-7</td>
</tr>
<tr>
<td>60.0-103.0</td>
<td>2</td>
<td>Dark-yellow-brown zeolite clay</td>
<td>Cretaceous</td>
<td>43.0</td>
<td>7-11</td>
</tr>
<tr>
<td>103.0-154.0</td>
<td>3</td>
<td>Light-brown zeolite-nanno oozze and clayey nanno oozze</td>
<td>Lower Cretaceous</td>
<td>51.0</td>
<td>12-17</td>
</tr>
<tr>
<td>154.0-304.3</td>
<td>4</td>
<td>Greenish-gray zeolite-bearing claystone</td>
<td>Lower Cretaceous</td>
<td>150.3</td>
<td>17-33</td>
</tr>
<tr>
<td>304.3-346.0</td>
<td>Basalt</td>
<td></td>
<td></td>
<td>41.7</td>
<td>33-41</td>
</tr>
</tbody>
</table>
and presumably is responsible for the dark colors. Small, euhedral gypsum crystals are also present throughout the unit.

The paucity of carbonate fossils and absence of terrigenous sand or silt suggest deposition in quiet, deep water. The mineralogy of the clay suggests a volcanic origin for much of the unit, either by weathering of exposed volcanic rocks or by alteration in situ of pyroclastic material. The quartz grains are typically rounded and frosted and probably are windblown in origin.

The contact between the basal sediments and the basaltic basement appears to be normal, with no evidence of baking, hydrothermal alteration, or metasomatism in the sediments. The basement consists of fine-grained tholeitic basalt typical of oceanic spreading centers.

**BIOSTRATIGRAPHY AND PALEONTOLOGY**

**General**

The Cenozoic is represented by only fragmentary material. The top core (0.0-8.0 m) consists of Pleistocene foraminiferal nanno ooze. Cores 2 and 3 (8.0-27.0 m) have no diagnostic fossils. The zeolite nanno ooze of Core 4 (27.0-36.5 m) is lower Eocene, and the interval between Cores 4 and 8 (36.5-65.0 m) is upper Paleocene. The remaining sediments (Cores 8-33; 65-304.3 m), composed largely of claystone and some zeolite nanno ooze, are Cretaceous, mainly Albian and Aptian.

Cores 11-17 (93.5-154.0 m) are the most interesting paleontologically. These sediments are very rich in calcareous faunas such as benthonic and planktonic foraminifera, nannoplankton, and Calcisphaerulidae. Also present are ostracods and, in one level, bivalvia. Radiolaria are abundant. Of considerable interest is the sudden appearance of this rich fauna within Core 17, apparently not connected with a major lithological change. No calcareous forms are present below this interval; only sparse arenaceous foraminifera and Radiolaria are present. Above this interval the sediment contains chiefly palynomorphs which abound in dinoflagellates, spores, and pollen. See Figure 3.

**Biostratigraphy**

**Quaternary:** Core 1 (0.0-8.0 m). *Globorotalia truncatulinoides* Zone; *Emiliania huxleyi* to *Pseudoemiliania lacunosa* Zone. Foram nanno ooze, partially affected by CaCO₃ dissolution. *Globorotalia inflata*, a temperate-water form is predominant, *G. truncatulinoides* is common. Faunal assemblages indicate that the sediments in the lower part of the core were deposited in waters slightly warmer than those of the upper part.

**Age unknown:** Cores 2, 3 (8.0-27.0 m). Core 2 had no recovery. Core 3 consists of zeolite clay with very rare, inconclusive, arenaceous foraminifera.

**Lower Eocene:** Core 4 (27.0-36.5 m). *Globorotalia subbotiniae*/*Globorotalia formosa* Zone; *Discocaster lodoensis* to *Tribrachiatus contortus* Zone. The complete sequence of lower Eocene nanoplankton zones is represented in the zeolite clay and nanno ooze of this interval, which is apparently strongly condensed due to CaCO₃ dissolution. Benthonic and planktonic foraminifera such as *Globorotalia aequa*, *G. formosa*, and some *Acarinina* species, are present. Radiolaria are very rare and poorly preserved.

**Upper Paleocene:** Core 5-Core 7, Section 3 (36.5-60.0 m). *Globorotalia velascoensis* Zone; *Discocaster multiradiatus* Zone. Only the upper part of the upper Paleocene, consisting of zeolite nanno ooze is present. However, it is considerably thicker than the lower Eocene above. Rare, probably transported, planktonic foraminifera are represented mainly by some *Acarinina* species. Calcareous nanoplankton are common, Radiolaria are rare and poorly preserved.

**Cretaceous s.l.:** Core 7, Section 4-Core 11, Section 4 (60.0-99.5 m). A lithologic break occurs in Core 7 between Sections 3 and 4. Radiolaria become frequent in Core 7, Section 4, suggesting a Cretaceous age. Paleocene foraminifera continue to the base of Core 7 but are probably due to contamination as a result of drilling disturbance. Below the much reduced and incomplete Tertiary section is an interval that contains almost exclusively Radiolaria, indicating a Cretaceous s.l. age. The Cretaceous-Tertiary boundary is placed within Core 8 based on the Radiolaria.

**Lower Cretaceous, Albian:** Core 11, Section 5-Core 17, Section 3 (99.5-155.0 m). This interval of zeolite-rich clay contains abundant microfaunas with benthonic and planktonic foraminifera, including different species of *Hedbergella*, nannoplankton, Radiolaria, and Calcisphaerulidae. Present in lesser numbers are ostracods, and, in one level, bivalves. The nanoplankton indicate Middle Albian (*Prediscosphaera cretacea* Zone), the planktonic foraminifera indicate Albian, and the benthonic foraminifera indicate upper Albian. The composition of the very rich *Hedbergella* fauna, poor in species, indicates comparatively deep open-sea deposition, still above the lysocline, and a temperate climate.

**Lower Cretaceous, Aptian:** Core 17, Section 4 to Core 33 Section 1; (155.0-304.3 m). A distinct change occurs between Sections 3 and 4 Core 17. Nannoplankton drops from an estimated 55% by volume in the upper interval to zero in the lower unit. The richcalcereous and arenaceous foraminifera are replaced by a monotonous and very poor arenaceous fauna. Arenaceous foraminifera are frequent only in the basal part of the lower unit. Calcisphaerulidae and ostracods are completely absent in the lower unit, but palynomorphs, with dinoflagellates are abundant, indicating a lower Aptian age for Cores 25-33 and an upper Aptian age for Cores 18-24. The absence of calcareous fossils suggests deposition below the lysocline, or possibly somewhat shallower if deposition was in a cold-water environment. The poor arenaceous foraminiferal fauna is of deep-water character, but may also have lived at somewhat shallower depth in colder, higher latitudes. The absence of planktonic organisms and the presence of bottom-living arenaceous foraminifera exclude euxinic conditions.

**Paleontology**

For more information on the individual fossil groups briefly discussed below, refer to the special reports in this volume.
<table>
<thead>
<tr>
<th>FORAMINIFERA</th>
<th>NANNOPLANKTON</th>
<th>RADIOLARIANS</th>
<th>AGE</th>
<th>CORES</th>
<th>DEPTH</th>
<th>LITHOLOGIC DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Globorotalia trunatulinoides</td>
<td>Radiolaria common to rare-moderate well preserved. Quaternary assemblage of moderate diversity including Quinqueloculina elegans, Carponiscus sp., Emiliania huxleyi, and several species of the Pseudopterogypsida family.</td>
<td></td>
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<tr>
<td>G. subbotinae-G. formosa</td>
<td>Dairyaster lodoensis, Marthasterites trilobatus, Discocyclina binodosus, Marthasterites contortus.</td>
<td>Radiolaria range from common to rare; preservation very poor in all cases due to recrystallization and corrosion.</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Globorotalia velasauensis</td>
<td>Discoaster multiradiatus</td>
<td>Barren of calcareous nannoplankton.</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Rich association of benthonic foraminifera, Hedbergella infracreata, H. ploinispira, Hedbergella sp.</td>
<td>Prediacoena arietina</td>
<td>Radiolaria generally abundant but very poorly preserved; species diversity low.</td>
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<tr>
<td>Barren of calcareous nanoplankton.</td>
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</tr>
<tr>
<td>Prediacoena arietina</td>
<td>Few to rare Radiolaria; very poorly preserved.</td>
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<tr>
<td>Association of primitive anenaceous foraminifera.</td>
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</tbody>
</table>

Figure 3. Biostratigraphic zones, Site 259.
Foraminifera

All samples of Core 1 (0.0-8.0 m) contain very rich assemblages of predominantly planktonic foraminifera. *Globorotalia inflata* is strongly predominant in most samples. Present in decreasing order of frequency are:

- **Abundant**: *Globorotalia inflata*, *G. dutertrei*, *Globigerinella bulloidea*.
- **Common**: *Globorotalia truncatulinoides truncatulinoides, G. menardi, G. crassaformis, Globigerinoides trilobus s.l., G. congobatus*.
- **Rare**: *Pulvinitina obliquiloculata, Globorotalia cultrata, Hristigerina siphonifera, Globigerinita glutinata, Globigerinoides ruber*.

Present in only some of the examined samples are: *Orbulina universa, Globorotalia tumida tumida, Candeina nitida, Sphaeroidinella dehiscens*.

Benthonic forms are not numerous, but are rich in species.

Core 3 (17.5-27.0 m) only contains very rare specimens of *Glomospira* and *Haplophragmoides* which are insufficient for an age determination.

Core 4 (27.0-36.5 m) contains a very poor planktonic foraminiferal fauna. In Section 3, casts of the *Globorotalia aequa*, *G. subbotinae* and the *Globorotalia subbotinae*-G. *formosa* groups are present along with complete specimens of *Acarinina primitiva*, *A. soldadoensis*, and *Chiloguembelinella aff. wilcoxensis*. The planktonic foraminifera are accompanied by numerous benthonic forms.

Core 4, CC, Core 5-Core 7, Section 3 and the top of Core 8 (36.5-60.0 m) contain an assemblage of planktonic and benthonic foraminifera including *Acarinina acarinata, A. mckannai, A. aff. primitiva, Globorotalia imitata*, *Chiloguembelinella aff. wilcoxensis*. Typical benthonic forms are *Tappanina, and Aragonia*.

A rich assemblage of planktonic and benthonic foraminifera is present in Sample 14, CC, including several species of *Hedbergella*. Similar but less abundant foraminifera are also present in Cores 11 (lower part)-13, 15, 16, and upper part of Core 17 (103.0-155.0 m). The fauna indicates a temperate water, open-sea environment of deposition, with a water depth equal to shelf slope or deeper, but above the lysocline.

Core 17 Section 4 to Core 30 (155.0-283.5 m) contain poor arenaceous foraminifera of mainly dwarfed *Glomospira* sp., *Ammodiscus* sp., *Bathydiscus* sp., *Trocchanmina* sp., *Reophax* sp., and *Textularia* sp. The arenaceous foraminifera of Cores 31-33 (283.5-304.5 m) are somewhat richer and more diversified.

Nannoplankton

Rich well-preserved temperate- to warm-water Pleistocene assemblages are present in Core 1. A complete sequence of lower Eocene to upper Paleocene nannoplankton zones (*Discocoaster lodoensis, Tribrachiatus orthostylus, Discocoaster binodosus, Tribrachiatus contortus, Discocoaster multiradiatus*) is present from Core 4-Core 7, Section 3 (27.0-60.0 m). The assemblages are composed of solution-resistant taxa, *Discocoaster, Fasciculithus*, and some *Coccolithus*. Based on a typical Albian *Prediscosphaera cretacea* Zone assemblage, present in Cores 13-14, the interval Core 11, Section 5-Core 17, Section 3 (99.5-155.0 m) is referred to the middle Albian. The lower part of the sedimentary section, Core 17, Section 4-Core 33 (155.0 m to the basalt contact at 304.3 m), is barren of calcareous nannofossils.

Radiolaria

Quaternary Radiolaria range from common to absent in Core 1 (0.0-8.0 m). Preservation is moderately good but decreases rapidly with depth in the core.

Cores 3-30 (17.5-283.5 m) contain Radiolaria in fluctuating abundances. Preservation is so poor that few specimens can be identified and none can be used for age determination. Some specimens from Core 8 and lower, however, can be classified on the family or even the generic level indicating the material is Cretaceous, i.e., *Dicoelocapsa* spp., *Dictyomitra* spp., and several Spongodiscidae.

Palyonomorphs

Only the Cretaceous sediments, Cores 10-33, were investigated for palyynomorphs. In the upper part, Cores 10-17 (84.0-160.0 m) are barren. Cores 18-33 (160-304.3 m) contain rich dinoflagellate assemblages typical of the Aptian. *Hystrichosphaera ramosa var. reticulata* in Cores 19-23 is suggestive of upper Aptian: *Oligosphaeridium asterigerum* in Cores 25-27, and *Dingodinium albertii* in Core 29 to Core 33, Section 1 are indicative of lower Aptian.

Spores and pollen occur in Core 18 to Core 33, Section 1. The presence of *Crybels spirites stylosus* in Core 31 suggests a *C. stylosus* Zone age (Neocomian) for the lower part of the interval. Higher in the section, at least up to Core 20, the flora is correlated with the Microcachrydites-Assemblage of Neocomian to Aptian age.

Calcisphaerulidae

Seven *Pithonella* species which occur exclusively at Site 259 are distinguished in the Albian Cores 12-17 (103.0-160.0 m). These species were not recorded at Site 260, Cores 9-15 (234.0-300.5 m). Based on other fossil evidence, however, this interval at Site 260, which contains a *Pithonella* association of nine different species, is approximately equivalent in age to Cores 12-17, Site 259.

This difference in *Pithonella* species—a similar difference is apparent for the ostracods—indicates a difference in the environment, or a slight age difference within the Albian of the two intervals.

Pithonella is common to abundant in most samples examined in Site 259, Cores 12-17; more frequent than in any other Leg 27 site, except for Cores 31-33 of Site 261, where they occur in floods.

Ostracods

Six species in open nomenclature occur in Cores 12-17 (103.0-160.0 m). *Arculicythere* sp. A, by far the most numerous, occurs in most of the examined samples. All six species are present in Sample 14, CC, which contains the richest ostracod fauna of the interval. The dominance of smooth forms, mainly Bairdiids and
Cythereella, and the virtual absence of the Cythereis group (only one specimen present), which is indicative of Lower Cretaceous near-shore and shelf deposits, indicates a depth of deposition deeper than the shelf.

**Bivalves**

Numerous exfoliated fragments of *Aucellina* sp. A (Family Buchiidae) were recovered from Sample 14, CC (131.5 m). A definite species identification is prevented by the small size of the fragments. However, the fragments closely resemble the juvenile phase of *Aucellina* cf. *gryphaeoides* from the Great Artesian Basin of Australia. The fragments are most closely comparable to Aptian-Albian species, particularly with Albian forms. This age is in agreement with the age obtained from foraminifera and nannoplankton.

**Fish debris**

Fish remains are fairly frequent in the Paleogene, Cores 4-8 (27.0-74.5 m); in Cores 9-33 (74.5-304.3 m) they are rare, and often absent altogether. They are particularly rare in the basal part of the Cretaceous interval.

**GEOCHEMICAL MEASUREMENTS**

Alkalinity, pH, and salinity data are summarized in Table 3 and in Figure 4. Analytical methods used for determining these values are discussed later in this section.

**Alkalinity**

Alkalinity values at Site 259 are in general low, showing a mean of 2.64 which is close to the mean of 2.49 for seawater at this site. A low alkalinity value is commonly ascribed to a slow rate of deposition (see earlier DSDP reports) and this would also seem to be compatible with the probable slow rate of sedimentation at Site 259. However, the consistent decrease of alkalinity with depth suggests that postdepositional modification of interstitial solutions by such factors as precipitation of minerals from solution and the increase due to alternating inorganic clay and nanno ooze layers. This decrease may result from the removal of ions from solution, particularly Ca$^{++}$ and SO$_4^{--}$, as gypsum is present in Units 3 and 4. The apparent co-existence of gypsum with a comparatively dilute solution (maximum salinity 35.5°/oo) is somewhat problematic, particularly as the gypsum may have crystallized out in localized pockets isolated from the bulk of the interstitial fluids.

**pH**

Only three “punch-in” values were obtained; consequently, this discussion will be limited to the “flow-through” results. Throughout most of the column, pH values are below that of seawater, ranging from 7.24 to 8.09. At most DSDP sites pH values are below those of seawater, consequently Site 259 fits into the normal pattern. There is also a consistent increase in pH with depth (Figure 4) which is probably the result of diagenetic changes although the nature of the processes involved is unknown.

**Salinity**

There is a consistent decrease in salinity with depth at Site 259, (Figure 4) with values ranging from 35.5°/oo at the top of the hole, to 34.1°/oo at a depth of 282 meters. This decrease may result from the removal of ions from solution, particularly Ca$^{++}$ and SO$_4^{--}$, as gypsum is present in Units 3 and 4. The apparent co-existence of gypsum with a comparatively dilute solution (maximum salinity 35.5°/oo) is somewhat problematical, particularly as the gypsum may have crystallized out in localized pockets isolated from the bulk of the interstitial fluids.

**PHYSICAL PROPERTIES**

Bulk-density, sound-velocity, porosity, vane shear-strength, and residual pore-pressure measurements were made on materials recovered at Site 259. Density, porosity, and sonic velocity are plotted alongside the site summary sheets. Continuous GRAPE density (and porosity) are plotted alongside the core photographs. A description of the testing procedures and discussion of wet bulk-density determinations and vane shear results are included in later chapters in Part IV.

Site 259 produced the largest quantity of sediment suitable for physical properties testing of the five sites drilled. Coring was continuous through the unconsolidated sediment column and in most cases each core had some portion which displayed only mild layer distortion. These areas of relatively low disturbance are toward the bottom of the core, usually in the lowest section. Due to layer color variation, photographs from Cores 1, 8, 14, and 16 show well the wide range of drilling disturbance. Many of these color changes are due to alternating inorganic clay and nanno oooze layers. Since both materials have undergone the same history after deposition, the variation of their properties with depth may be compared.

**Density**

Wet bulk density was determined on fresh unsplit core sections by continuous GRAPE measurements and by

**TABLE 3**

Summary of Shipboard Geochemical Data, Site 259

<table>
<thead>
<tr>
<th>Sample (Interval in cm)</th>
<th>Depth Below Sea Floor (m)</th>
<th>pH</th>
<th>Alkalinity (meq/kg)</th>
<th>Salinity (°/oo)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Punch-in Flow through</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-6, 0-6</td>
<td>6.5-6.56</td>
<td>8.00</td>
<td>2.44</td>
<td>36.0</td>
<td>Reference seawater</td>
</tr>
<tr>
<td>5-5, 0-6</td>
<td>44.5-44.56</td>
<td>7.46</td>
<td>3.13</td>
<td>35.5</td>
<td></td>
</tr>
<tr>
<td>10-5, 0-6</td>
<td>90.5-90.56</td>
<td>7.30</td>
<td>2.93</td>
<td>35.2</td>
<td></td>
</tr>
<tr>
<td>15-6, 0-6</td>
<td>139.5-139.56</td>
<td>7.13</td>
<td>2.83</td>
<td>34.9</td>
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</tr>
<tr>
<td>20-5, 0-6</td>
<td>185.5-185.56</td>
<td></td>
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</tr>
<tr>
<td>25-3, 0-6</td>
<td>230.0-230.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-6, 0-6</td>
<td>282.0-282.06</td>
<td>8.34</td>
<td>1.86</td>
<td>34.1</td>
<td>Reference seawater</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.34</td>
<td>2.54</td>
<td>35.8</td>
<td></td>
</tr>
</tbody>
</table>
weighing each section. A third value was determined from syringe samples taken routinely for water contents or immediately adjacent to each vane shear test, at which point two syringe samples were taken. In eight other locations samples were taken for shore-laboratory determination of density. The profile drawn on the site summary corresponds to GRAPE data from relatively undisturbed sediments, considered the most accurate indicator of in situ density at Site 259. The section-weight determinations are considerably lower than these GRAPE data because although both methods are density averages of a specific sediment volume, the section-weight method includes more low-density disturbed sediment. (In most cases, core sections containing relatively undisturbed sediments also contain large areas of lower density disturbed material and often a slurry of even lower density. The section weight averages all materials within the section. However, even in unusual core sections, which may contain 150 cm of relatively undisturbed sediment, the section weight method should measure a lower density, because of the inevitable higher disturbance of the sediment immediately adjacent to the core liner. While section weight is a total core cross-sectional average, the GRAPE is not and averages a lower percentage of the outer material within its pencil-thin gamma ray beam.)

The syringe values, while more accurate than the section weight data, are slightly lower and less accurate than GRAPE determinations.

Major density variations occur at Site 259 within the top 55 meters of the sedimentary column. However, these variations appear more dependent on sediment type than on depth. Adjacent layers of nanno ooze and zeolitic clay do not have the same density. Within the surface core ooze density is 1.50-1.70 g/cc while clay density is only 1.25-1.35 g/cc, even though the clay is in a deeper layer. Nanno clay, found between these sediments, shows an intermediate density of about 1.45 g/cc. Clay density rises to about 1.60 g/cc at 55 meters with most of the increase occurring in a zone of low recovery between 20 and 35 meters. Fewer measurements were made on nanno ooze. Ooze density is approximately 1.70 g/cc at 45 meters and 1.80 g/cc at the 55-meter level. Behavior is difficult to trace because, although layers of each sediment type were found within most cores, much of the material was too highly disturbed for testing.

Below 55 meters the sediment is predominantly inorganic clay. Density variation is less dramatic, even where nanno ooze is abundant in layers between 105 and 154 meters. Density rises steadily to 1.80 g/cc between 55 and 154 meters, then drops to 1.65 g/cc. (Nanno ooze

Figure 4. Geochemical analysis of interstitial water at Site 259.
is not found in the clay below 154 meters.) Density then
remains relatively constant until 255 meters and again
rises gradually to 1.80 g/cc above the basalt.

The density fluctuations correspond closely to the
four units identified on the basis of color and
composition. These units include the intervals of 0.0-
60.0 meters, 60.0-103.0 meters, 103.0-154.0 meters, and
154.0-304.3 meters.

Porosity

Porosity plotted on the site summary sheets was
determined from continuous GRAPE readings and
from syringe samples. Only those syringe samples which
were taken in relatively undisturbed material are shown.
Porosity is directly related to wet bulk density and
mineral grain density. Variation in porosity follows
variation of bulk density very closely. The effect of grain
density is as follows. In two sediments with the same
bulk density, the sediment with a higher grain density
also has the higher porosity. Grain density of most-
sediments, however, does not vary enough to overcome
the close dependence of porosity on bulk density. A
continuous readout is available for GRAPE
measurements by working with the GRAPE density
trace shown beside the core photographs. A variable
porosity scale has been included above the wet bulk-
density scale for this purpose. The correct scale to use
depends on grain density of the sediment. Although a
porosity plot may be computer-produced in a manner
similar to GRAPE density plots, it is necessary to
specify the grain density for each sediment layer. In
some cores mineralogical variations occur often enough
to make this procedure approach hand reduction.

Sonic Velocity

Sonic-velocity measurements shown on the site
summary sheets were made on relatively undisturbed
sediment and on basalt specimens prepared by trimming
to produce parallel flat surfaces. Sonic velocity increases
gradually from 1.50 km/sec at the sediment surface to
1.60 km/sec at 295 meters. Velocity in basalt ranges
from 3.4 to 5.0 km/sec in the deepest basalt recovered.
On some specimens, measurements were made in the
vertical direction, perpendicular to bedding. (Sonic
velocity on Glomar Challenger is normally measured in
the horizontal direction—parallel to bedding planes.) In
another study, velocity was measured on the same basalt
specimens at 5°C and at 21°C. Comparison of the
measurements in both studies is inconclusive due to data
scatter. Poor Hamilton frame transducer contacts and
fissures in the basalt are suspected to have caused the
scatter.

CORRELATION OF SEISMIC REFLECTION
PROFILE WITH DRILLING RESULTS

At this site, drilling records show that 304.3 meters of
sediment and 42 meters of basalt were penetrated below
the sea floor. The seismic profiles show a single strong
reflector at a depth of 0.35 sec. It was assumed that this
reflector is basaltic basement. (Figure 5.)

The 0.35-sec DT through 304.3 meters of sediment
gives an average velocity of 1.73 km/sec. The velocity
measured in the ship laboratory is approximately 1.5-1.6
km/sec.

A sonobuoy was run while the ship was on-station
drilling. Side reflections prevented this record from
showing other possible reflectors in the sediment column. The steep slope of the basement is evident from
the isopachs shown in the site survey map (Figure 2).
Additional evidence for the slope of the basement was
provided when the ship left this site. As the seismic gear
was placed in the water, the basement depth was found
at 0.3 sec, i.e., 0.05 sec less than indicated on the record
when the ship came on this station. The incoming profile
is regarded as the more reliable so the accepted value is
0.35 sec.

Compressional wave velocities measured for basalt
from this site range from 3.4 km/sec at the top of the
recovered basalt to about 5.0 km/sec for the lower
pieces recovered about 38.5 meters below the sediment-
basalt interface. These values are somewhat lower than
average basalt and probably result from the fact that the
basalt is altered.

SUMMARY AND CONCLUSIONS

Summary

Site 259 is located in 4706 meters of water near the
southeastern edge of the Wharton Basin. Near the site,
Conclusions

that the accumulation rate was 1.6 m/m.y. in the lower that each biostratigraphic division identified was com-
petition. Figure 6 was compiled on the arbitrary assumption only approximate due to the uncertain location of extrusion onto the sea floor. A thickness of 150 meters the Aptian with extrusion of basalt and the same order of magnitude, and the lower Eocene rate is an order of magnitude smaller.

Figure 9.

Precise biostratigraphic boundaries in the drilled sec-
coring or to original reworking. The upper, calcareous part of the Cretaceous sequence is Albian, as indicated by nannoplankton and foraminifera. The lower part is Aptian with arenaceous foraminifera.

Accumulation rates calculated from these data are only approximate due to the uncertain location of precise biostratigraphic boundaries in the drilled section. Figure 6 was compiled on the arbitrary assumption that each biostratigraphic division identified was complete. This is demonstrable at the site for the lower Eocene only. The compiled curve therefore should show minimum rates only. The time-scale adopted here is shown in Figure 9.

In the terms of these approximations, the curve shows that the accumulation rate was 1.6 m/m.y. in the lower Eocene, 12 m/m.y. in the upper Paleocene, 14 m/m.y. in the Aptian. The only comment warranted here is that the upper Paleocene and Lower Cretaceous rates are of the same order of magnitude, and the lower Eocene rate is an order of magnitude smaller.

Conclusions

Deposition at Site 259 began in an unknown part of the Aptian with extrusion of basalt and the accumulation of green-gray clay. The basalt was altered before deposition of the overlying sediment, probably by rapid cooling in contact with seawater during extrusion onto the sea floor. A thickness of 150 meters of green-gray clay accumulated during the Aptian at a rate of approximately 25 m/m.y. Stagnation of the bottom water is suggested by the uniformly dark tone of the sediments; uniform, though crude, laminations; fairly abundant pyrite; the impoverished biota of primitive arenaceous foraminifera and rare Radiolaria; and the reduction of the other microfossils. The arenaceous foraminifera indicate cold or deep water, or both. The impoverished biota is probably due to selective solution. The stagnation at the very bottom must have been mild to have allowed the existence of the bottom-dwelling foraminifera but stronger anaerobic conditions must have prevailed a short interval beneath the sediment surface. The composition of the clay suggests a volcanic origin either by alteration in situ of volcanic ash or by inflow of the weathering products of exposed volcanic rocks.

A preliminary interpretation of the Aptian sequence is that it was largely derived from a volcanic source associated with the early stages of continental rupture and drift, represented ashore by the basal Cretaceous Bunbury Basalt (Veevers, 1971); and that it was deposited during the initial opening of an oceanic rift in which oceanic circulation was somewhat inhibited.

Sedimentation in the Albian, led to the accumulation, presumably above the lysocline, of 51 meters of light-colored zeolite-rich nanno clay and nanno ooze similar to part of the approximately equivalent sequence at Site 257 (Leg 26) 500 km to the west-southwest. The sediment of this age at Site 257 rests above 15 meters of barren clay, on basalt, so that the entire unit of green-gray claystone at Site 259 wedges out between these sites, presumably as a result of sea-floor spreading to the west.

The rest of the Albian is yellow-brown zeolitic clay with poorly preserved nannofossils and Radiolaria. The lack of foraminifera probably indicates deposition below the lysocline.

A long hiatus representing most of the Upper Cretaceous and lower part of the Paleocene has no obvious lithological expression, probably due to original reworking or to disturbance during coring. Reworked Upper Cretaceous Radiolaria from near the base of the upper Paleocene clay probably indicate a source on the Australian continental margin. The succession of upper Paleocene yellow-brown clay overlain by pale orange nanno ooze is interpreted as indicating a relatively downward movement of the lysocline. Partial dis-
solution of the nannoplankton in the thin lower Eocene interval may explain its low accumulation rate. After the deposition of clay of unknown age, Quaternary nanno and foraminiferal ooze and zeolitic clay were deposited, and the carbonates were partially affected by dis-
solution. Ten km southward, at Station 150 of Conrad-11 (Figure 2), Paleocene ooze is exposed at the sea floor, showing that the 36.5 meters of Eocene and younger sediments of Site 259 are not preserved everywhere on the elevated area around Site 259.

The elevated position of Site 259 may have caused other gaps in the record. The Upper Cretaceous clay found at Site 257 is lacking at Site 259, and seismic profiles show that a fuller Cenozoic section is possibly present in the deeper part of the Perth Abyssal Plain.

PROGRAM TO STUDY AIR TRANSPORTED DUST AND SEDIMENTS SUSPENDED IN SURFACE WATERS

A limited program to study air-transported dust and suspended surface sediments was undertaken on this
cruise. The Western Australian coast is one of several areas of the world where a major desert is near the sea coast and off-shore winds are likely to carry considerable dust out to sea. In addition, these winds could blow surface waters off shore, causing an upwelling of nutrient-rich water and stimulating a biogenic component to sediments deposited on the sea floor. A third factor which may influence the nature of the sediments is the discharge of rivers from the Australian drainage basins into the eastern Indian Ocean.

Informal estimates indicate that river discharge of sediments is small on the average, but flash floods may carry a large sediment load near the estuaries. Firm figures should be established for these rates.

It is the opinion of oceanographers that upwelling is not strong off Western Australia but may occur in a more significant manner off northwest Australia or in the Timor Sea area. It may also occur in local areas that may not be significant to the marine biologist or oceanographer but may be significant geologically.

To provide data to study these effects, the following efforts were carried out:

1) The number of dust particles/cc of air was measured 3-4 times each day by the weatherman.
2) Surface observations were made 3-4 times each day by the weatherman. These observations included wind, clouds, pressure, air and sea-surface temperatures, dew point, sea, and swell.
3) Sea and cloud observations were made each 2 hours by the ship's officers.
4) Satellite cloud maps were obtained directly from the satellite by the weatherman approximately once each day.
5) Weather maps for the western Australian region were received by radio approximately twice each day.
6) A sample of surface water was filtered through a preweighed millipore filter each 6 hours. Surface temperature and salinity were also measured at that time. Occasionally, silver filters were used so samples could be analyzed by X-ray spectroscopy.

REFERENCES


### Site 259

#### Hole Core 1

**Cored Interval:** 0-8 m

<table>
<thead>
<tr>
<th>Meter</th>
<th>Core Catcher</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
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</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

**Lithologic Description**

- **Core is undisturbed to weakly deformed near base.** Color chiefly very pale orange (10YR8/2) with alternations and layers of pinkish gray (5YR8/1), light brown (5YR5/6) and moderate orange (5YR8/4).

**Foram Bearing Nanno Ooze**

- Smear slides 1-110, 2-61, 3-110, 4-26, 5-93

**Composition**

- Forams 80%
- Nannos 9%
- Sponge spicules 5%
- Rads 2%
- Carb. frags. 2%
- Diatoms 1%
- Silicoflag. 1%

**Sponge Spicule Bearing Nanno Ooze**

- Smear slide 5-64

**Texture Composition**

- Clay 65%
- Nannos 85%
- Silt 32%
- Sponge spicules 10%
- Sand 3%
- Micarb 5%

**Zeolitic Clay**

- Smear slide 6-75

**Composition**

- Clay 72%
- Zeolite-clinoptilolite 25%
- Quartz 25%
- Feldspar 11%
- Nannos Tr.
- Opaques Tr.

**Bulk X-ray (3.30 m)**

- Calcite 96%
- Quartz 3%
- Mica 1%

Explanatory notes in chapter 1
### Site 259

<table>
<thead>
<tr>
<th>Core</th>
<th>Hole</th>
<th>Cored Interval</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core 8</td>
<td>Hole</td>
<td>65-74.5 m</td>
<td>Strongly disturbed stiff clay. Chiefly dark yellowish brown with distorted layers and streaks of grayish orange (10YR7/4) and dusky yellowish brown (10YR2/1).</td>
</tr>
</tbody>
</table>

#### Fossil Character

- **Zone**: Core 8
- **Core Catcher**: 1.0 m

#### Lithologic Description

- Clay: 62%
- Silt: 24%
- Sand: 4%

#### Explanatory notes in chapter 1

---

### Site 259

<table>
<thead>
<tr>
<th>Core</th>
<th>Hole</th>
<th>Cored Interval</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core 9</td>
<td>Hole</td>
<td>74-84.0 m</td>
<td>Highly disturbed stiff clay. Color chiefly dusky yellowish brown with smeared layers and patches of dark yellowish brown and grayish orange.</td>
</tr>
</tbody>
</table>

#### Fossil Character

- **Zone**: Core 9
- **Core Catcher**: 1.0 m

#### Lithologic Description

- Clay: 33%
- Silt: 28%
- Sand: 18%
- Plagioclase: 8%

#### Explanatory notes in chapter 1
### Litho-Samples

<table>
<thead>
<tr>
<th>Site</th>
<th>Hole</th>
<th>Cored Interval</th>
<th>Litho. Sample</th>
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</thead>
<tbody>
<tr>
<td>259</td>
<td>Corel</td>
<td>93.5-103 m</td>
<td></td>
</tr>
</tbody>
</table>

**Lithology and Description**

- **Cretaceous (based on Radiolarians)**
  - **Zone**
  - **Forams**
  - **Nannos**
  - **Radiolarians**
  - **Others**

**Texture Composition**

- Clay 76%
- Clay and Cristobal 68%
- Sand 1%
- Zeolite 30%
- Opal 10%
- Zeolite Clay 60%
- void Highly contorted stiff clay with some patches of dark yellowish brown.

**Lithologic Orientation**

- **Deformation**
  - Highly deformed stiff clay. Chiefly smears slides 1-130, 2-75, 3-75, 4-75, 5-75.
  - Smear slides 5-145, CC 100.
  - Smear slides 1-95, 2-100, 3-75, 4-74, 5-71.

**Character**

- Zeolite 25%
- Opalescent nodules.
- Void Highly contorted stiff clay with some patches of dark yellowish brown.

**Composition**

- Plagioclase:
- Tridymite 2%
- Palygorskite 16%
- Smear slides 5-145, CC 100.
- Smear slides 1-95, 2-100, 3-75, 4-74, 5-71.
- Montmorillonite 15%
- Cristobalite 19%
- Zeolite 30%
- Clay 70%
- void Highly contorted stiff clay with some patches of dark yellowish brown.
### Site 259 Hole Corel2 Cored Interval: 103.0-112.5 m

#### Lithology

<table>
<thead>
<tr>
<th>Interval</th>
<th>LITHOLOGY</th>
<th>LITHOLOGIC DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>103.0-104.5 m</td>
<td>Plagioclase 1J</td>
<td>Montmorillonite 12%</td>
</tr>
<tr>
<td>104.5-106.0 m</td>
<td>K-feldspar 2%</td>
<td>Calcite 35%</td>
</tr>
<tr>
<td>106.0-107.5 m</td>
<td>Clinoptilolite 22%</td>
<td>Clay and Cristobalite 30%</td>
</tr>
</tbody>
</table>

#### Texture Composition

- Zeolite 20%
- Clay 76%
- Nannos 50%

#### LITNO, Sample

- Smear slides 1-80, 1-89, CC

---

### Site 259 Hole Corel3 Cored Interval: 112.5-122 m

#### Lithology

<table>
<thead>
<tr>
<th>Interval</th>
<th>LITHOLOGY</th>
<th>LITHOLOGIC DESCRIPTION</th>
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<td>112.5-114.0 m</td>
<td>Plagioclase 1%</td>
<td>K-feldspar 2%</td>
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<tr>
<td>114.0-115.5 m</td>
<td>Clinoptilolite 16%</td>
<td>Cristobalite 21%</td>
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<tr>
<td>115.5-117.0 m</td>
<td>Calcite 35%</td>
<td>Clay and Cristobalite 30%</td>
</tr>
</tbody>
</table>

#### Texture Composition

- Zeolite 20%
- Clay 76%
- Nannos 50%

#### LITNO, Sample

- Smear slides 1-80, 1-89, CC

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### Notes

- Explanatory notes in chapter 1

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**SITE 259**
### Site 259 Hole Cored Interval: 122-131.5 m

#### Lithologic Description

<table>
<thead>
<tr>
<th>Age</th>
<th>Zone</th>
<th>Limestone Character</th>
<th>Lithology</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Greatly disturbed stiff clay. Chiefly moderate yellowish brown to 1.5 meters thick yellowish brown with some admixed moderate yellowish brown.</td>
</tr>
</tbody>
</table>

**Texture Composition**

- Clay 73%
- Nannos 72%
- Silt 26%
- Zeolite 15%
- Clay and cristobalite 10%
- Zeolite 20%
- Dolomite rhombs 1%
- Heavy minerals 1%

**Bulk X-ray (125.5 m)**

- Calcite 51%
- Cristobalite 16%
- Montmorillonite 6%
- Mica 5%
- Quartz 7%
- Kaolinite 25%
- Plagioclase 25%

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### Site 259 Hole Cored Interval: 131.5-141 m

#### Lithologic Description

<table>
<thead>
<tr>
<th>Age</th>
<th>Zone</th>
<th>Limestone Character</th>
<th>Lithology</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Highly deformed and brecciated stiff nanno ooze. Chiefly light brown in upper half and greenish gray in lower half.</td>
</tr>
</tbody>
</table>

**Texture Composition**

- Calcite 51%
- Cristobalite 16%
- Montmorillonite 6%
- Mica 5%
- Quartz 7%
- Kaolinite 25%
- Plagioclase 25%
- Tridymite 15%

**Bulk X-ray (136.8 m)**

- Calcite 51%
- Cristobalite 16%
- Montmorillonite 6%
- Mica 5%
- Quartz 7%
- Plagioclase 25%
- Kaolinite 25%
- Tridymite 15%

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Explanatory notes in chapter 1
### Site 259

#### Core 9a

<table>
<thead>
<tr>
<th>Zone</th>
<th>Lithology Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>Weakly deformed stiff clay. Color yellow-green at top. Sharp break to grayish green at 1-110 cm and to N2 black 2-10 cm.</td>
</tr>
</tbody>
</table>

**Fossil Character**
- Zeolite
- Heavy minerals
- Glauconite

**Composition**
- Clay: 73%
- Zeolite: 25%
- Heavy minerals: 2%

**Texture**
- CTaY

**Smear Slides**
- 2-75, 3-75, CC

**Bulk X-Ray**
- Montmorillonite
- Cristobalite
- Quartz
- Feldspar
- Chlorite
- Pyrite

### Site 259

#### Core 9b

<table>
<thead>
<tr>
<th>Zone</th>
<th>Lithology Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Weakly deformed stiff to very stiff clay. Chieflly grayish black in color with some olive black.</td>
</tr>
</tbody>
</table>

**Fossil Character**
- Zeolite

**Lithology**
- Clay
- Silt
- Heavy minerals

**Composition**
- Clay: 96%
- Quartz: 8%
- Feldspar, chlorite, glauconite, nannos Tr.

**Texture**
- CTaY

**Smear Slides**
- 1-87, 2-72, 3-74, 4-76, 5-71, CC

**Bulk X-Ray**
- Montmorillonite
- Cristobalite
- Quartz
- Feldspar
- Chlorite
- Pyrite

Explanatory notes in Chapter 1
Site 259 Hole Core 20 Cored Interval: 179-188.5 m

<table>
<thead>
<tr>
<th>AGE</th>
<th>ZONE</th>
<th>CHARACTER</th>
<th>FORMS</th>
<th>LITHOLOGY</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>RP</td>
<td>1</td>
<td>0.5</td>
<td>CRYSTOBALITE CLAY</td>
<td>Weekly to moderately deformed stiff clay. Alternating layers of dark greenish gray and olive black.</td>
</tr>
<tr>
<td>3.0</td>
<td>RP</td>
<td>4</td>
<td>3.0</td>
<td>CRYSTOBALITE CLAY</td>
<td>Weakly to strongly disturbed clay - soupy in part. Chiefly interlayered greenish gray and olive black clay.</td>
</tr>
</tbody>
</table>

**Texture & Composition**
- Smear slides 1-75, 2-75, 3-75
- Clay 88% Clay and Cristobalite 97%
- Silt 12% Zeolite 1%
- Heavy minerals 1%
- Zeolite 1%
- Quartz, feldspar, Tr.

**X-RAY**
- Montmorillonite 38%
- Cristobalite 23%
- Quartz 12%
- Feldspar 15%
- K-feldspar 5%
- Plagioclase 28%
- Pyrite 19%
- Chlorite 18%

Explanatory notes in chapter 1
Cored Interval: 198-207.5 m

Core 23

LITHOLOGIC DESCRIPTION

Weakly to strongly deformed mixture of greenish gray and olive black stiff clay. A few dolomite-rich nodules are dusky yellow in color.

5GY4/1 & 5Y2/1

Cristobalite Clay

Texture

Clay 69%
Silt 31%

Composition

Clay and Cristobalite 98%
Zeolite 1%
Heavy minerals, chlorite Tr.

BULK X-RAY (210.8 m)

Montmorillonite 42%
Cristobalite 25%
Quartz 14%
K-feldspar 9%
Plagioclase 8%
Chlorite 5%
Pyrinite 5%
### Cored Interval: 217-226.5 m

**FOSSIL CHARACTER**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Color</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>5Y7/2</td>
<td>Moderately to strongly disturbed stiff clay, chiefly dark greenish gray and olive black with yellowish gray nodules and specks. Nodules are dolomite cemented clay.</td>
<td></td>
</tr>
</tbody>
</table>

**LITHOLOGIC DESCRIPTION**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Color</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>5Y7/2</td>
<td>Moderate to strongly deformed stiff clay, locally soupy in lower parts. Chiefly dark greenish gray and olive black with specks and nodules of yellowish gray.</td>
<td></td>
</tr>
</tbody>
</table>

### Cored Interval: 226.5-236 m

**FOSSIL CHARACTER**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Color</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>5Y6/4</td>
<td>Weakly to strongly deformed stiff clay, locally soupy in lower parts. Chiefly dark greenish gray and olive black with specks and nodules of yellowish gray.</td>
<td></td>
</tr>
</tbody>
</table>

**LITHOLOGIC DESCRIPTION**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Color</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>5Y6/4</td>
<td>Weakly to strongly deformed stiff clay, locally soupy in lower parts. Chiefly dark greenish gray and olive black with specks and nodules of yellowish gray.</td>
<td></td>
</tr>
</tbody>
</table>

Explanatory notes in chapter 1
<table>
<thead>
<tr>
<th>AGE</th>
<th>ZONE</th>
<th>FOSSIL CHARACTER</th>
<th>LITHOLOGIC DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Weakly to moderately deformed stiff clay. Chiefly dark greenish gray and olive black in color with streaks and nodules of very light gray and yellowish gray.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>CRYSTALLITE CLAY</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Smear slides 1-55, 2-70, 3-75, 4-75, 6-70</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Texture Composition</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Clay 275, F and Cristobalite 985</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Heavy minerals 15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Feldspar, chlorite, zeolites Tr.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nodule 5GY4/1, 5Y7/2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nodule 5GY4/1, 5Y7/2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nodule 26-28</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nodule 10YR5/4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Texture Composition</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Clay 275, F and Cristobalite 975</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Quartz 15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Feldspar 15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cristobalite 15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Chert, dolomite 13</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Feldspar, chlorite, zeolites Tr.</td>
</tr>
</tbody>
</table>

Explanatory notes in chapter 1
### Core 35 Cored Interval: 315-321.5 m

<table>
<thead>
<tr>
<th>Fossil Character</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Basalt breccia. Fragments have gray (N7) cores and rims of greenish gray (5GN9/7). Freshout glass is black (N1). Some zones of dark reddish brown (10R2/4). Veinlets of calcite.</td>
</tr>
</tbody>
</table>

### Core 36 Cored Interval: 321.5-326.5 m

<table>
<thead>
<tr>
<th>Fossil Character</th>
<th>Lithologic Description</th>
</tr>
</thead>
</table>

### Core 37 Cored Interval: 326.5-331 m

<table>
<thead>
<tr>
<th>Fossil Character</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gray basalt (N3) with some patches of grayish red (10N4/2). Numerous veinlets of calcite.</td>
</tr>
</tbody>
</table>

### Core 38 Cored Interval: 331-335.5 m

<table>
<thead>
<tr>
<th>Fossil Character</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gray basalt (N3) with some patches of grayish red (10N4/2). Numerous veinlets of calcite.</td>
</tr>
</tbody>
</table>

Explanatory notes in chapter 1
Site 259 Hole Core 39 Cored Interval: 335.5-337 m

**LITHOLOGIC DESCRIPTION**

Basalt - dark greenish gray (5GY4/1) with veinlets of calcite. Fine-grained, non-porphyritic. Rare pyrite crystals in cavities. A few reddish zones (5R4/2).

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Site 259 Hole Core 40 Cored Interval: 340-346 m

**LITHOLOGIC DESCRIPTION**


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Explanatory notes in chapter 1.
NO PHOTOGRAPH AVAILABLE