9. SITE 593: CHALLENGER PLATEAU

Shipboard Scientific Party

**HOLE 593**

- **Date occupied:** 28 December 1982
- **Date departed:** 30 December 1982
- **Time on hole:** 2 days, 16 hr.
- **Position:** 40°30.47'S; 167°40.47'E
- **Water depth (sea level; corrected m, echo-sounding):** 1068 m
- **Water depth (rig floor; corrected m, echo-sounding):** 1078 m
- **Bottom felt (m, drill pipe):** 1079 m
- **Penetration (m):** 571.5 m
- **Number of cores:** 60
- **Total length of cored section (m):** 571.5 m
- **Total core recovered (m):** 468.21 m
- **Core recovery (%):** 81.9%
- **Oldest sediment cored:**
  - **Depth sub-bottom (m):** 571.5 m
  - **Nature:** Nannofossil chalk
  - **Age:** Late Eocene
  - **Measured velocity (km/s):** 2.340 km/s at 554 m
- **Basement:** Not reached

**HOLE 593A**

- **Date occupied:** 30 December 1982
- **Date departed:** 1 January 1983
- **Time on hole:** 25 hr.
- **Position:** 40°30.47'S; 167°40.47'E
- **Water depth (sea level; corrected m, echo-sounding):** 1068 m
- **Water depth (rig floor; corrected m, echo-sounding):** 1078 m
- **Bottom felt (m, drill pipe):** 1080.3 m
- **Penetration (m):** 496.8 m
- **Number of cores:** 27
- **Total length of cored section (m):** 257.3 m
- **Total core recovered (m):** 227.71 m
- **Core recovery (%):** 88.5%
- **Oldest sediment cored:**
  - **Depth sub-bottom (m):** 496.8 m
  - **Nature:** Nannofossil chalk
  - **Age:** Latest Oligocene
- **Basement:** Not reached

**Principal results:** Site 593 is located on the Challenger Plateau, a western extension of the New Zealand Plateau. The western part of the Challenger Plateau provides a shallow-water pedestal of ca. 270 km distant from the nearest land mass of northern South Island, New Zealand. This setting has allowed accumulation of an uncomplicated Paleogene–Neogene pelagic ooze sequence with virtually no terrigenous sedimentary influences. Site 593 is a reoccupation of Site 284, cored during Leg 29 of DSDP.

Site 593 consists of two holes continuously cored to a maximum sub-bottom depth of 571.5 m. Hole 593 was cored with the hydraulic piston corer (HPC) from 0 to 245.1 m sub-bottom and continued to a total depth of 571.5 m with the extended core barrel (XCB). Hole 593A was continuously cored with the HPC from 0 to 209.3 m sub-bottom, then washed down to 448.8 m and cored with the XCB to 496.8 m to recover the Oligocene/Miocene transition. This interval was poorly cored in the first hole.

**HOLE 593A**

Site 593 is an apparently continuous stratigraphic sequence from the late Eocene (42 m.y.) to the Quaternary. A paleomagnetic polarity stratigraphy has been identified to the middle of the Gauss Chron (3.2 m.y.).

The general facies is a foraminiferal-bearing nannofossil ooze that grades into nannofossil ooze and nannofossil chalk with depth. Only traces of biosiliceous sediments occur in a few intervals. The section has been divided into two units of earliest Oligocene to Recent age.

**Unit I** is subdivided into four units:
- **Subunit IA:** Late Quaternary age, represents a veneer (0–6 m) of yellow gray foraminiferal-bearing nannofossil ooze within the oxidized zone near the seafloor.
- **Subunit IB:** A thick (6–393 m) sequence of Quaternary to middle Miocene age, is a rather monotonous light-colored foraminiferal-bearing nannofossil ooze to nannofossil ooze.
- **Subunit IC:** A thin (393 to 418 m) early middle Miocene sequence, is an oxidized sediment zone of pale orange color.
- **Subunit ID:** A thick (418 to 545.5 m) sequence of nannofossil ooze of early middle Miocene to earliest Oligocene age.

**Unit II** is a thin (545.5 to 571.5 m) sequence of lithified volcanogenic turbidites and pyroclastics emplaced at the Eocene/Oligocene boundary and probably derived from nearby “Lalitha Pinnacle.” The volcanogenic rocks are overlain by nannofossil chalk at the base of the hole. This chalk contains many thin laminae of altered volcanic glass, indicating an episode of active explosive volcanism.

Site 593 is a fine, complete stratigraphic succession in southern temperate waters with abundant, well-preserved planktonic foraminifers except in the volcanogenic material. Calcareous nannofossils are abundant throughout, but not well preserved below the Pliocene. An excellent success of the benthic foraminifers is preserved.

Planktonic foraminiferal zonations are typically temperate in character. A number of calcareous nannofossil zones are missing
because the warm-water marker forms are rare or absent. All epoch boundaries are well represented between the Eocene/Oligocene and the Pliocene/Pleistocene boundaries. The Oligocene/Miocene boundary coincides with a more lithified ooze layer. The Eocene/Oligocene boundary coincides with the volcanoennial sequence (Unit II) with no apparent break in sedimentation. Evidence from the seismic profiles suggest that the volcanic rocks resulted from a single episode of submarine extrusion. These volcanic are approximately coeval with extensive volcanism in New Zealand, including the Deborah volcanics of South Canterbury. A number of volcanic pinnacles with seismic character similar to that of “Lalitha Pinnacle” occur over the Challenger Plateau, indicating widespread volcanism at that time.

The middle Miocene oxidized ooze (Subunit IC) was deposited between 15.5 and 15 m.y., immediately preceding the time of major ice-sheet growth on east Antarctica. It is, therefore, possible that it reflects important paleoceanographic changes at an oceanographic front in the Southern Ocean tied to this glacial evolution. The oxidized sediment contains a temporary benthic foraminiferal fauna that is typical of oxygen-rich waters.

The late early Pliocene (4-3 m.y.) is marked, as in other Leg 90 sites, by an episode when enhanced carbonate productivity caused extremely high sedimentation rates.

BACKGROUND AND OBJECTIVES

Site 593 is located on the Challenger Plateau, a western extension of the New Zealand Plateau (Figs. 1 and 2). The Challenger Plateau is effectively a topographic extension of the Lord Howe Rise and its western part provides a shallow-water pedestal 270 km distant from the nearest land mass of northern South Island, New Zealand. This setting has allowed the accumulation of an uncomplicated sequence of Neogene pelagic ooze with virtually no terrigenous sedimentary influences.

Site 593 is a reoccupation of Site 284, which was cored during Leg 29 of the Deep Sea Drilling Project in April, 1973 (Kennett, Houtz, et al., 1975). Site 284 was added very near the end of Leg 29 when it became apparent that two spare days could be made available for an additional site. Because no formal safety panel reviews had been made, coring was restricted to the upper 208 m lest hydrocarbons occur below this depth. Site 284 is a valuable middle late Miocene to Quaternary sequence of calcareous oozes, located in cool-temperate waters. The site has provided material for a wide variety of paleoceanographic and biostratigraphic studies (e.g. Shackleton and Kennett, 1975; Kennett and Vella, 1975; Kennett et al., 1979; Hornibrook, 1982).

Because Site 284 had been shown to contain an excellent late Neogene section, it was decided to recore this location using the HPC and the XCB. It was hoped that a pair of hydraulic piston cores would provide a better quality sequence for higher-resolution biostratigraphic and paleoceanographic studies. Also the section needed to be extended to include as much of the Neogene as possible. The seismic profile record (Fig. 2) shows that the first distinct reflector lies at about 500 m. This may be the regional Eocene/Oligocene hiatus (or Oligocene/Miocene, as at Site 592). Therefore a major objective at Site 593 was to core the entire Neogene sequence. Because sedimentation rates were known to be high (about 40 m/m.y.) at this location, this sequence was expected to provide material for high-resolution stratigraphic studies.

The scientific objectives of Site 593 were much the same as the other sites in the southwest Pacific latitudinal traverse: to understand, using a variety of analytical approaches, the Neogene paleoceanographic evolution of the South Pacific and its relations with global paleoenvironmental change; to develop a tephrachronology and to study the diagenetic history of the sediment column.

OPERATIONS

Site 592 to Site 593

The pipe was pulled out of the hole, the rig floor made secure for sea, and the vessel was under way for Site 593 at 1242 hr., 27 December. The trip south was made in pleasant weather. As had become customary, a direct approach was made and the 13.5 kHz beacon was dropped on the first pass at 1632 hr., 28 December. The transit took 27.9 hr. and covered 264.8 n. mi. at an average speed of 13 knots.

Site 593 (SW-2): Challenger Plateau

The routine short hook-up BHA for both XCB and variable length (VL)HPC work was made up and run to the shoot-off point for the first piston core attempt. A good mudline core was recovered, establishing the water
depth at 1079 m, thus spudding Hole 593 at 2155 hr., 28 December (Table 1).

Using the 9.5-m VLHPC with two shear pins, coring progressed easily through unusually soft carbonate oozes. Full stroke of the piston corer was achieved on all cores. At Core 593-22 (206.7 m BSF) a crumpled liner indicated that the adhesive properties of the sediment were becoming significant. Two cores later the barrel could not be withdrawn with 30,000 lb. overpull and was partially washed over to free it; piston coring was then terminated.

The XCB coring tools were then rigged up and deployed. After some initial fine-tuning on the troublesome XCB latch good results were achieved for the next 24 cores.

At Core 593-49 shattered liners reappeared. In each off-numbered core of the next three, recovery was marginal because the liner was shattered, which suggested that one of the two XCB tools being alternated was faulty. However, no obvious problem was discovered. To deal with the problem, the remaining cores in the hole were taken by running the XCB tools in on the wire line. By this means good cores with liners intact were achieved for the rest of the hole. Core 593-51 became stuck in the pipe before reaching the bit and could not be worked loose with the wire line until after the interval had been drilled, so no core was recovered.

Starting with Core 593-58 at about 550 m BSF, a 10-m interval of very hard volcanogenic turbidites was encountered and was cored successfully using the XCB soft-formation cutting shoes.

The hole was terminated at 571.5 m BSF when the sediments of the Eocene objective were reached.

The bit was pulled to the mudline and the vessel offset 100 ft. north by 100 ft. west in preparation for the repeat piston core sequence.

**Hole 593A**

Hole 593A was spudded with a mudline piston core at 2337 hr., 30 December (Table 1). Piston coring continued as in the previous hole with no difficulties at all up to Core 593A-22 at 209.3 m BSF. At this point no further cores in the piston corer “zone” were desired. Next the XCB was deployed and washed to 448.8 m BSF in order to recover the section which lost during the interlude of shattered liners and associated poor recovery in the first hole. Each of the five XCB cores was taken by running in on the wire line. Recovery was good through the boundary except for Core 593A-24 which, apparently, suffered a slight blockage and recovered only 3.15 m. The hole was terminated after the fifth XCB core at a total depth of 496.8 m BSF. The pipe was then pulled out of the hole and the bit arrived on deck just 15 min. after the start of the New Year, 1983.

**LITHOSTRATIGRAPHY**

The sequence recovered at Site 593 represents two lithostratigraphic units. Unit I has been subdivided into four subunits based on color and composition (Table 2).

**Unit I**

The general facies of Site 593 is a foraminifer-bearing nannofossil ooze that grades into a nannofossil ooze and a nannofossil chalk with depth. The transition to reduced abundances of foraminifers, from about 15 to about 5% (smear-slide estimates only), occurs around 110 m sub-bottom depth. The facies is predominantly calcareous nannofossils with very subordinate foraminifers. Other components, such as quartz and feldspar grains, volcanic glass, and pyrite(?), only occur in trace abundances (< 1%) (Fig. 3). Micritic carbonate occurs in persistent abundances of 5 to 10% from 323 m sub-bottom to total depth, but the sediment does not become chalk until 562 m. The only biogenic silica found were traces (less than 1%) of sponge spicules in a zone from about 249 to 296 m sub-bottom.

**Subunit IA (Hole 593: 0-1.5 m; Hole 593A: 0-6 m; late Quaternary)**

This subunit recognized by its yellowish gray (5Y 7/2) color, is foraminifer-bearing nannofossil ooze. The contact with underlying Subunit IB is gradational over about...


Table 2. Lithostratigraphy at Site 593.

<table>
<thead>
<tr>
<th>Lithostratigraphic Unit</th>
<th>Core Section</th>
<th>Sub-bottom depth (m)</th>
<th>Description</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>IA</td>
<td>1</td>
<td>0.0-1.5</td>
<td>Yellowish gray (oxidized) foraminifere-bearing nannofossil ooze to nanofossil ooze</td>
<td>late Quaternary to middle Miocene</td>
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<tr>
<td>IB</td>
<td>2 to 42-3</td>
<td>1.5-391.5</td>
<td>Light gray to white foraminifer-bearing nannofossil ooze to nanofossil ooze</td>
<td>late Quaternary to middle Miocene</td>
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<tr>
<td>IC</td>
<td>42-4 to 44</td>
<td>393.8-418.0</td>
<td>Pale orange to yellow zone (oxidized) nanofossil ooze</td>
<td>middle Miocene</td>
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<tr>
<td>ID</td>
<td>45 to 58-2</td>
<td>418.0-545.5</td>
<td>White nanofossil ooze</td>
<td>early middle Miocene to earliest Oligocene</td>
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<tr>
<td>II</td>
<td>58-3 to 60</td>
<td>545.5-637.1</td>
<td>Interbedded lithified volcanogenic turbidites and light greenish gray to white nanofossil chalk</td>
<td>late Eocene</td>
</tr>
</tbody>
</table>

*Boreholes from Hole 593A. All others from Hole 593.*

5 cm. Subunit IA represents the upper oxidized layer and correlates with a similar subunit at Sites 586, 588, 589, 590, 591, and 592. The relatively high content of foraminifers is probably the result of winnowing.

**Subunit IB (593: 1.5-393.5 m; 593A: 6.0 to more than 496.8 m; late Quaternary to middle Miocene)**

Subunit IB is a light gray (N6) to white (N9) foraminifer-bearing nannofossil ooze that grades into a nannofossil ooze with depth. It is distinguished by its color from overlying Subunit IA and underlying Subunit IC. Subunit IB is mottled and burrowed and has ubiquitous streaks, blebs, and diffusion bands of iron sulfides(?). Four distinct, very light gray (N5-N7) ash beds are found at 21.5, 27.7, 29.5, and 29.60 m sub-bottom. Unusual pockets of foraminifers and pyrite(?) occur between 15 and 178 m sub-bottom. Small zones of cemented nodules occur between 100 and 110 m sub-bottom. The cement may be either gypsum, found at this same sub-bottom depth at Site 284 (Kennett, Houtz, et al., 1975), or possibly celestite. Numerous very thin (less than 1 mm) laminae of pale green hues (5G) occur throughout this subunit. These thin laminae may represent altered volcanic glass.

**Subunit IC (593: 393.8-418.0 m sub-bottom; middle Miocene)**

Subunit IC is distinguished from two overlying and underlying subunits by its distinctive pale orange (10YR 8/2) color but is lithologically identical to the surrounding subunits. The upper contact is quite sharp but the lower contact is gradational and varies in color from very pale orange (10YR 8/2) through yellowish gray (5Y 8/1) to light greenish gray (5GY 8/1) with depth.

**Subunit ID (593: 418.0-545.5 m sub-bottom; early middle Miocene to earliest Oligocene)**

Subunit ID is a white (N9) nannofossil ooze that is identical in lithology to the lower part of Subunit IB. Subunit ID is defined by its stratigraphic position below the easily recognized pale orange Subunit IC.

Between about 475 and 485 m sub-bottom in Hole 593 and about 455 and 468 m sub-bottom in Hole 593A
Figure 3. Smear slide summary, Site 593.
### Dominant Lithology, Hole 593

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<tr>
<th>Core Section Level in cm</th>
<th>Biogenic Components</th>
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### Minor Lithology, Hole 593

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### Dominant Lithology, Hole 593A

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Figure 3. (Continued).
there occurs a zone that proved difficult to recover. The material recovered is composed of very homogeneous, firm, nannofossil ooze, indistinguishable from the sediment above and below. This zone occurs across the Miocene/Oligocene boundary, but the significance of the lack of recovery is unknown.

**Unit II (593: 545.5-571.5 m; early late Eocene)**

Unit II is composed of interbedded, lithified volcanogenic turbidites and light greenish gray (5GY 7/2) or white (N9) foraminifer-bearing nannofossil chalk to nannofossil chalk. The turbidites are grayish olive green (5GY 3/2) to dark gray (N4) and occur as a sequence of very fine- to coarse-grained packets. Some individual turbidites display good examples of Bouma A and B divisions (coarse massive, graded, to finely laminated) (Fig. 4) which generally dominate Bouma D and E divisions (very fine-grained).

The interbedded nannofossil chalk is identical in lithology to the overlying pelagic subunits but additionally has many thin (less than 2 mm thick), very pale green (10G 8/1) laminae that appear to be altered volcanic ash. The upper contact with Subunit ID is very sharp.

**Discussion**

The lithofacies at Site 593 is a thick sequence from the early late Eocene to Holocene that represents remarkably consistent pelagic conditions. Curiously there was no evidence of preserved siliceous biogenic material, even though the area had relatively high biogenic productivity—a situation similar to that at Sites 587 through 592. Insoluble residues of bulk sediment yield very small quantities of quartz grains, light-colored volcanic glass, clays, and pyrite(?). No evidence was found of ice-rafted debris at this mid-latitude site, which supports the conclusions of Kennett, Houtz, et al. (1975) that the site has been north of the iceberg limit since the late Miocene and extends this observation back to the late Eocene.

The color change that distinguishes Subunit IC from the surrounding subunits represents a change from post-depositional reduced conditions (Subunit ID) to oxidized conditions (Subunit IC) and back to a post-depositional reduced state (Subunit IB). The event that caused the oxidized state of Subunit IC must have altered the balance between available dissolved oxygen supplied to the seafloor and available organic carbon supplied to the in-

![Figure 4. Examples of Bouma structures within lithostratigraphic Unit II, volcanogenic turbidites. A. Sharp basal contact at 48.5 cm with normally graded sequence beginning cross-bedded and laminated fine-grained, then at 28.5 cm the start of another packet. B. A coarse-grained, massive to bedded sequence, beginning at 93 cm, grading at 83 cm into fine-grained interbed, then at 75.5 cm another packet. C. A laminated, coarse-grained sequence at 115 cm, becoming massive and graded at 114 through 108.5 cm, then a rippled, fine-grained sequence through 103.7 cm. Notice the erosional contact at 103.7 cm; coarse-grained slits have eroded into the finer-grained underlying material.](https://example.com/figure4.jpg)
fauna and bacteria within the sediment. Compared to over- and underlying subunits, Subunit IC accumulated at a reduced sedimentation rate that allowed aerobic combustion of organic matter to greater burial depths. One possible explanation of this event would be the brief development or intensification of an oceanographic convergence not far to the south of Site 593 during this period. The effects of this convergence would have been relatively short-lived, because the sediment returns to a reduced state in Subunit IB. The surface oxidized zone (Subunit IA) may represent a similar phenomenon that reflects the flow of oxygen-charged Antarctic Intermediate Water from the Antarctic Convergence (Fig. 5).

The lithified volcanogenic turbidites and thin laminae of altered volcanic ash represents an episode of local volcanism in the late Eocene. The thin laminae of ash probably represents air-fall deposits and were regional precursors to the event or events that generated the turbidites. The internal structures of the individual flows, especially the dominant occurrence of Bouma A and B divisions compared to Bouma D and E divisions, suggest proximal rather than distal deposits (Walker, 1967). These observations imply that the source of the volcanioclastic material may have been nearby on the Challenger Plateau or, more likely, from “Lalitha Pinnacle,” a buried volcanic “high” observed on the seismic profile to be near Site 593. The upper 115 m of the sequence is a foraminifer-bearing nannofossil ooze that probably represents an interval when bottom currents in this area were strong enough to winnow some nannofossils from the sediment, thereby increasing the relative abundance of foraminifers. The upper winnowed sequence at Site 593 is similar to the uppermost recovered sections at Sites 587 through 592 and probably coincides with a period of more intensive global oceanic circulation.

**PHYSICAL PROPERTIES**

The HPC cores recovered from Hole 593 were sampled for gravimetric evaluation using the standard cylinder technique on all of the cores except the final two, for which chunk samples were taken (Boyce, 1976). The GRAPE was employed on selected cores (see Introduction for details of experimental methods). Additional analyses of the physical properties results for Site 593 are reported by Morin (this volume).

The GRAPE saturated-bulk density results (points) are plotted versus depth in Figure 6A. These data are directly converted to sediment porosity by assuming a grain density of 2.691 g/cm$^3$. The corresponding GRAPE porosity results are presented versus depth in Figure 6B. Mean values of density and porosity across each meter interval are calculated and these averages are plotted as the solid lines. After initially declining through the upper 50 m, porosity remains relatively constant over the next 300 m. This unusual behavior is reflected in the bulk density data. The sediment column shows little or no evidence of systematic, lithostatic compaction within the depth interval of 50 to 350 m. At 550 m, the porosity...
finally decreases to less than 50% with the appearance of a layer of indurated volcanic material. Below this 15-m-thick zone, chalk appears with a slightly lower porosity.

A few chunk samples of the volcanic material was removed from Core 59 for preliminary evaluation. This material has a grain density of approximately 2.80 g/cm³. Sonic velocity data for these samples were determined and the results show values which are slightly higher (faster) than those found for calcareous sediments of equivalent porosity. For the Core 59 samples, few measurements were performed both parallel and perpendicular to bedding, with the latter producing slightly lower velocities:

<table>
<thead>
<tr>
<th>Section (level in cm)</th>
<th>Sonic velocity (km/s)</th>
<th>Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 70</td>
<td>2.546</td>
<td>Parallel to bedding</td>
</tr>
<tr>
<td>2, 70</td>
<td>2.340</td>
<td>Parallel</td>
</tr>
<tr>
<td>5, 70</td>
<td>2.155</td>
<td>Perpendicular</td>
</tr>
</tbody>
</table>

**SEISMIC STRATIGRAPHY**

Figure 7A is a portion of the shipboard water gun seismic profile collected during the approach to Site 593. Figure 7B is a line drawing of the profile, illustrating a possible unconformity at a sub-bottom depth of 0.54 s. Six acoustic units (A–F) have tentatively been identified, and these are compared in part with lithostratigraphic Units IA, IB, IC, ID, and II.

Acoustic Unit A comprises relatively low amplitude parallel reflectors, some of which are separated by acoustically transparent intervals. Acoustic Unit B is a zone of closely spaced parallel reflectors of moderate amplitude. Acoustic Unit C includes an interval of closely spaced parallel reflectors which lie directly below an apparent angular unconformity separating B and C. Alternatively, Units C and B may simply converge in the vicinity of Site 593, at the expense of a somewhat more transparent unit between B and C, which can be seen to lens out or be removed by erosion about 5 n. mi. north of Site 593 (Fig. 7B).
Figure 7. A. Comparison of acoustic Units A–F with lithological Units I and II. Shipboard water gun seismic profile, collected during site approach; depths in meters estimated by assuming a sediment sound velocity of 1800 m/s. B. Line drawing of seismic profile shown in A; note possible angular unconformity and lenticular transparent zone.
Acoustic Unit D is a relatively transparent zone of uniform thickness. This overlies Unit E, an interval of strong, parallel reflectors which are subparallel to those of Unit C.

Acoustic Unit F is a transparent unit which includes an irregular zone of diffuse reflectors. Unit F overlies acoustic basement at a sub-bottom depth of 0.97 s.

Site 593 was drilled to a total depth of 571.5 m. Two lithostratigraphic units (Units I and II) are identified, with Unit I being subdivided into four subunits. Basic lithology of Unit I is a foraminifer-bearing nannofossil ooze. Unit II comprises a sequence of interbedded, lithified, volcanogenic turbidites and minor chalks which co-incide with the Eocene/Oligocene boundary.

The lithologic units column shown in Figure 7A arbitrarily correlates the upper Eocene lithologic Unit II with acoustic Unit D. However, it is equally likely that Unit II may be correlated with the relatively strong reflector of acoustic Unit E, or the closely spaced reflectors of acoustic Unit C. Either of these may represent the seismic signature of the volcanogenic turbidites of lithologic Unit II.

**BIOSTRATIGRAPHY**

At Site 593 a complete sequence of Quaternary to late Eocene age was recovered. Hole 593A duplicated the Quaternary to late Miocene and the early Miocene to late Oligocene interval.

Calcareous nannoplankton and foraminifers are common throughout the drilled succession with the exception of the volcanic sequence in Cores 593-58 and 593-59, where both fossil groups were found only sporadically as contamination from above. Radiolarians, diatoms, and silicoflagellates have not been found at this site. Nannoplankton and foraminiferal zones are correlated in Figures 8 and 9.

The zonations of the calcareous nannoplankton and the planktonic foraminifers are hampered by the lack of certain index species. Discoasters and some ceratoliths are rare or absent from the early Pliocene; this is also true for Catinaster and some Discoaster species in the middle Miocene and for sphenoliths in the middle and late Oligocene.

A remarkable change in color from yellow brown below to white above was noted in Core 593-42, approximately at the top of nannoplankton Zones NN4/NN5, that is, just prior to the extinction of *Sphenolithus heteromorphus*. Calculation of the sedimentation rates indicates a sudden increase from 9.7 to 48.4 m/m.y. at this level.

The Oligocene/Miocene boundary was placed in Core 593-50, as indicated by the boundary between nannoplankton Zones NP25 and NN1 and the base of the foraminiferal *Globoripta dehiscens* Zone. The Eocene/Oligocene boundary probably falls in the interval containing volcanic material in Cores 593-58 and 593-59. The first calcareous layers above contain nannoplankton of the early Oligocene Zone NP21 and a foraminiferal fauna of the *Globigerina brevis* Zone. Samples from within the volcanic sequence contain only some species

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![Figure 8](image-url)  
*Figure 8. Correlation between calcareous nannoplankton and foraminiferal zones in Hole 593. Hole barren of radiolarians.*
Planktonic Foraminifers

The following zones were identified at Site 593; the zonal boundary markers are shown below:

- **Globorotalia truncatulinoides Zone**
  - *G. truncatulinoides*

- **Globorotalia inflata Zone**
  - *G. inflata*

- **Globorotalia punciculata Zone**
  - *L. A. G. conomiozea*

- **Globorotalia conomiozea Zone**
  - *I. A. G. conomiozea*

- **Globorotalia miotumida Zone**
  - *L. A. G. dehiscens*

- **Neogloboquadrina continuosa Zone**
  - *L. A. G. mayeri*

- **Globorotalia mayeri Zone**
  - *I. A. G. peripheroacuta*

- **Globorotalia peripheroacuta Zone**
  - *I. A. G. peripheroacuta*

- **Orbulina suturalis Zone**
  - *I. A. S. suturalis*

- **Praeorbublina glomerosa curva Zone**
  - *I. A. P. glomerosa curva*

- **Globorotalia miozea Zone**
  - *I. A. G. miozea*

- **Globigerinoides trilobus Zone**
  - *I. A. G. trilobus*

- **Globigerina connecta Zone**
  - *I. A. G. connecta*

- **Globigerina woodi Zone**
  - *I. A. G. woodi*

- **Globoquadridina dehiscens Zone**
  - *I. A. G. dehiscens*

- **Globoquadridina euapertura Zone**
  - *I. A. G. angiporoides*

- **Globoquadridina angiporoides Zone**
  - *L. A. G. brevis*

- **Globoquadridina brevis Zone**
  - *I. A. G. brevis*

- **Subbotina linaperta Zone**
  - *L. A. G. aculeata*

- **Globorotalia aculeata Zone**

The **Globorotalia tosaensis Zone** and **G. truncatulinoides/G. tosaensis Zones** were not recognized at this site because of the low numbers of **G. tosaensis**. Because of the low numbers of **N. continuosa** and its gradation into **N. pachyderma** in the early late Miocene, it was decided to redefine the upper boundary of the **N. continuosa Zone** at the extinction of **Globoquadridina dehiscens**. This event is regarded as a good marker in the temperate water mass of the southwest Pacific; further north in the Pacific, **G. dehiscens** survived into the base of the N18 Zone at Site 289 (Srinivasan and Kennett, 1981). The **G. dehiscens** are commonly sturdy and exhibit considerable calcite overgrowths. In the late Eocene below the volcanic intercalation, preservation of the calcareous nanoplankton is moderate, but excellent foraminiferal preservation occurs in Sample 593-60, CC.
peripherocuta Zone of middle Miocene age is recognized on the total range of the zone fossil.

**Paleobiogeography**

The planktonic foraminifers are abundant and well preserved from the Pleistocene through the Oligocene; faunas were less well preserved in the late Eocene but the lower core-catcher sample at the site produced an excellent fauna.

The late Eocene faunas show a progressive reduction in diversity toward the Eocene/Oligocene boundary; a lower diversity in the early Oligocene indicates cooler waters. Diversity increases toward the end of the Oligocene, which suggests a progressive warming, probably continuing through the early Miocene to the early part of the late Miocene in the lower Globorotalia miotumida Zone, where there is a marked change with the extinction of Globigerinoides trilobus. There probably was a warming in the late Miocene toward the top of the Globorotalia miotumida Zone to the base of the G. conomiozea Zone; this observation is based on the presence of Globigerinella aequilateralis. During the remaining late Miocene–early Pliocene, G. aequilateralis was not present in the area. For the remaining Pliocene to the Pleistocene, the surface water supported G. aequilateralis and the occasional Globigerinoides ruber.

Of importance at Site 593 is the presence of the short-ranging Guembelitria samwelli in the late Oligocene Globigerina euapertura Zone; its first appearance may have been a biogeographic response to the initiation of the Circum-Antarctic Current (Jenkins, 1974). Associated with Guembelitria samwelli is Streptochilus pristinum, and its presence here may also be associated with the initiation of the current.

**Major Boundaries**

Pliocene/Pleistocene: first appearance of Globoquadritina dehiscens.

Oligocene/Miocene: the extinction of Globigerinatheka index.

**Benthic Foraminifers**

Benthic foraminifers were examined from all core catchers at Site 593 in the fractions >63 µm. Benthics were very abundant in nearly all samples and their preservation remained good almost to the bottom of the hole; cementation was a slight problem in Cores 593-52 through 593-60. At many levels the benthics were fragmented. Dolomite occurs in Cores 593-23 and 593-52 to 593-55; free rhombs and crystals growing out of the foraminifers occur in Core 593-53.

Although the exact species composition of samples varied through the section, in general faunas contained large numbers of cibicidids and planulinids, with *Ori-
fauna remains surprisingly constant. A few forms appear, including Melonis barleanum, Bolivina anastomosa, and Uvigerina auberiana. However, the small, hispid uvigerinids occur in large numbers in Sample 593-42,CC and may be a reflection of the suggested oxidation of these levels. Such uvigerinids are typical of the shallowest and deepest parts of the oceanic water column, which are generally oxygen-rich.

The large change during the lower Miocene occurs in the P. glomerosa curva to Orbulina suturalis Zones. Both the diversity and abundance of benthics increase. The rectuvigerinids disappear temporarily and seven new entrants appear, at least four of which are cibicidids. Nuttalides umbonifera, a form correlated with deep water masses later in the Neogene, first occurs at this site.

The new, typically Pliocene-Quaternary benthic species first evolve in the mid-Miocene Globorotalia Zone (Cores 593-38 to 593-34). Such species as Cassidulina carinata, Cibicidoides mundulus, C. ciceroccus, and Rectuvigerina spinosa appear at this time, but disappear by the Neogloboquadrina contiusa and conglobata Zones. Both P. glomerosa curva and P. quinqueloba, as well as other species, including Bulimina aculeata, occur for the first time and continue to occur throughout the Pliocene-Quaternary. The early Pliocene (Cores 593-3 to 593-2) at this site.

The first pulse of miliolids, accompanied by the deep-water index, Pullenia quinqueloba, appears in the G. mitutumida Zone (Cores 28 to 27). The only consistent occurrences of the more northerly species Osangularia bengalensis and less common O. cultor occur throughout most of this zone.

Uvigerinids again appear at the top of the G. conomiozae Zone, at other sites on this leg; however, at this site the species which mark the top of the Miocene are Uvigerina auberiana and U. pygmaea, both tiny species more typical of deeper waters and sites.

A larger change in benthic faunas and in the uvigerinids occurs, however, in the basal Pliocene (Cores 593-11 and 593-12). Benthic diversity drops, there is an influx of miliolids, and particularly large, abraded spiriloculids which may be redeposited from shallower water. U. hispido-costata occurs for the first time and continues to occur at this site throughout the course of the Pliocene and Quaternary.

The faunal changes associated with the development of Northern Hemisphere glaciation between Cores 593-11 and 593-9 (Globorotalia punctulicata/G. inflata Zones) are less prominent than the changes that occur in the early Pliocene. Diversity drops, several species disappear, Globocassidulina increases in abundance, and N. umbonifera again appears in the faunas, albeit in small numbers.

Within the Globorotalia inflata Zone (Cores 593-7 to 593-4) miliolids become more important, Bulimina aculeata first occurs and becomes a prominent part of the faunas, and the deeper-water index, P. quinqueloba, occurs through most of the zone. Beginning in this zone there is a trend to lower diversity and higher dominance of the fewer species. This trend is accentuated in the Quaternary, when only a few species, including Cassidulina carinata and B. aculeata, are very abundant. Epistominella exigua appears in the Pleistocene (Sample 593-2,CC) at this site.

Calcareous Nannoplankton

Core-catcher samples and enough additional samples accurately to determine zonal boundaries were examined for calcareous nannoplankton. Some of the zonal indicators are absent at Site 593. Middle and late Oligocene zone-defining sphenoliths were not observed, and Zones NP24/NP25 could not be differentiated. The first occurrence of Discoaster exilis is used to define the top of the Helicosphaera ampliaperta Zone (NN4) instead of the last occurrence of Helicosphaera ampliaperta. The top of the D. asyrtius Zone (NN14) is defined on the last occurrence of Amaurolithus primus instead of A. tricorniculatus in Hole 593. (A. tricorniculatus was observed at this level in Hole 593A.) The last occurrence of D. neohamatus is used instead of the first occurrence of D. quinquergamus to approximate the top of the D. calcaris Zone (NN10). Catinaster coolidus and D. kugleri were not observed at this site.

Calcareous nannoplankton are abundant throughout the section at Site 593. Most species are well preserved but most discoasters become progressively more overgrown with depth. Many early and middle Miocene sphenoliths are also overgrown.

Hole 593

Quaternary

Samples 593-1,CC and 593-2-3, 3-4 cm are above the last occurrence of Pseudoemiliania lacunosa and belong in the late Quaternary Gephyrocapsa oceanica Zone or Emiliania huxleyi Zone (NN20/NN21).

The upper part of the early Pleistocene Pseudoemiliania lacunosa Zone (NN19b) includes Samples 593-2-5, 3-4 cm to 593-3-1, 3-4 cm. The last occurrence of Calcidiscus macintyrei in Sample 593-3-3, 3-4 cm places this Sample 593-5, CC in the lower part of the P. lacunosa Zone (NN19a).

Pliocene

The last occurrence of Discoaster brouweri in Sample 593-6-1, 3-4 cm places this sample in the late Pliocene Discoaster brouweri Zone (NN18). The addition of D. pentaradiatus in Sample 593-6-2, 3-4 cm places this sample in the D. pentaradiatus Zone (NN17). The late Pliocene D. surculus Zone (NN16) includes Samples 593-6-3, 3-4 cm to 593-9-1, 3-4 cm, above the last occurrence of Reticulofenestra pseudoumbilica Zone (NN15) includes Samples 593-9-3, 3-4 cm. The early Pliocene Reticulofenestra pseudoumbilica in Sample 593-9-3, 3-4 cm to 593-13-1, 3-4 cm. Amaurolithus tricorniculatus was not observed in Hole 593. Instead, the last occurrence of A. primus in Sample 593-13-3, 3-4 cm is used to mark the top of the early Pliocene Discoaster asymmetrical Zone (NN14), which includes this sample to 593-15-5, 3-4 cm. Samples 593-15,CC and 593-16,CC are placed in the combined A. tricorniculatus/Ceratolithus rugosus Zone (NN12/13). The boundary between these zones is defined by the first occurrence of Ceratolithus rugosus, which was not observed at this site.
Miocene

The last occurrence of *D. quinqueramus* in Sample 593-17-5, 3-4 cm and first occurrence of *A. primus* in Sample 593-22, CC places this interval in the upper subzone of the late Miocene *D. quinqueramus* Zone (NN11b). In the absence of *D. quinqueramus* below this level, the base of the lower subzone (NN11a) is placed between Samples 593-25-1, 3-4 cm and 593-25-3, 3-4 cm, the last occurrence of *D. neohamatus*, which approximates the first occurrence of *D. quinqueramus*. Samples 593-25-3, 3-4 cm to 593-26-5, 3-4 cm, above the last occurrence of *D. hamatus* in Sample 593-26-CC, are placed in the middle Miocene *D. calcaris* Zone (NN10). The range of *D. hamatus* from Samples 593-27, CC to 593-27, CC places these samples in the middle Miocene *D. hamatus* Zone (NN9).

Catenaster coilitus and *D. kugleri* were not observed at this site; therefore, boundaries between the middle Miocene Zones NN8, NN7, and NN6 cannot be determined. This unzoned interval includes Samples 593-28-1, 3-4 cm to 593-42-4, 99-100 cm. The last occurrence of *Sphenolithus heteromorphus* in Sample 593-42-5, 3-4 cm marks the top of the middle Miocene *Sphenolithus heteromorphus* Zone (NN5). In the absence of *Helicosphaera amphiapertaris* at this site, the first occurrence of *D. exilis* in Sample 593-43, CC is used for the base of Zone NN5. Samples 593-44-1, 3-4 cm and 593-44-5, 3-4 cm, above the last occurrence of *S. bellemnos* in Sample 593-44, CC, are placed in the early Miocene *Helicosphaera amphiapertaris* Zone (NN4). The last occurrence of *Triquetrorhabdulus carinatus* is in Sample 593-46, CC. Therefore Samples 593-44, CC to 593-46-5, 3-4 cm are placed in the early Miocene *Sphenolithus bellemnos* Zone (NN3). One sample, 593-46, CC, contains both *T. carinatus* and *D. druggi*, which places it in the early Miocene *D. druggi* Zone (NN2). Samples 593-47-1, 3-4 cm to 593-50-5, 3-4 cm, below the first occurrence of *D. druggi*, are placed in the early Miocene *Triquetrorhabdulus carinatus* Zone (NN1).

Oligocene

The last occurrence of *Zygryphalithus bijugatus* in Sample 593-5, 3-4 cm marks the top of the Oligocene. The last occurrence of *R. umbilica* in Samples 593-56-3, 3-4 cm to 593-57-5, 3-4 cm, above the last occurrence of *Cyclococcolithus formosus* in Sample 593-57-3, 3-4 cm, places these samples in the early Oligocene *H. reticulata* Zone (NP22). The early Oligocene *Erioconia? subdisticha* Zone (NP21) extends down at least to Sample 593-58-2, 110-111 cm. The base of Zone NP21, the Oligocene/Eocene boundary, is within an interval from Samples 593-58-3, 13 cm to 593-59-4, 71-72 cm.

Eocene

The occurrence of *D. saipanensis* and *Cribrocentrum reticulatum* below or in Sample 593-59, CC and the occurrence of *Isthmolithus recurvus* down to Sample 593-60, CC places this interval in the late Eocene Zone NP19/NP20. From Sample 593-60-1, 6-7 cm downward reworked nannoplankton species from the late middle and early late Eocene, like *Neococcolithus dubius* and *Chiasmolithus solitus*, were noted.

Hole 593A

Core-catcher samples were examined through Core 22 with no significant differences between Holes 593 and 593A. The hole was washed down to 448.8 m sub-bottom. Samples 593A-23, CC to 593A-24-1, 3-4 cm are placed in the early Miocene *T. carinatus* Zone (NN1) by the presence of *T. carinatus* and the absence of *D. druggi*.

The occurrence of *Z. bijugatus* and *H. recta* in Sample 593A-24, CC places this sample in the late Oligocene *S. ciperoensis* Zone (NP25). The Oligocene/Miocene boundary is within Samples 593A-24-1, 3-4 cm and 593A-24, CC. Three additional cores were drilled below Core 24 and are of late Oligocene age.

Radiolarians, Diatoms, and Silicoflagellates

Radiolarians, diatoms, and silicoflagellates were not observed in the late Eocene to Recent sequence at this site.

PALEOMAGNETISM

The magnetic properties of sediments from Site 593 were generally similar to those from Site 592 except for an extended zone of high intensity from 360 to 455 m sub-bottom depth encompassing Subunit IC. Intensities were slightly higher than at Site 592. A polarity stratigraphy was obtained back to 3.3 m.y. ago.

Hole 593 was generally subsampled at three specimens per section and the first 11 cores from Hole 593A were subsampled at two or sometimes three specimens per section. The Kuster orientation tool has a success rate of 64% in Hole 593, with good agreement between drift (i.e., tilt) azimuths. Four cores from Hole 593A were oriented. Laboratory measurements for NRM have been completed on most specimens from Hole 593, and low-field susceptibility measurements have been made on Cores 593-1 to 593-24. Shipboard NRM measurements were made on the volcanogenic turbidite zone in Hole 593. The few shipboard measurements made on Hole 593A were consistent with results from Hole 593. NRM statistics for Hole 593, excluding the volcanogenic turbidite zone, are as follows:

<table>
<thead>
<tr>
<th>Zone</th>
<th>(Core-Section, level in cm)</th>
<th>Susceptibility</th>
<th>Geometric mean intensity (µG)</th>
<th>Scalar mean inclination (± 1 s.d.)</th>
<th>Axial dipole inclination</th>
<th>Mean angle between repeats</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1, 10 to 1-1, 125</td>
<td>Weak positive</td>
<td>Diamagnetic</td>
<td>0.110</td>
<td>+3.9 ± 41.7°</td>
<td>- 59.7°</td>
<td>20.3° (55 repeats)</td>
</tr>
<tr>
<td>1-2, 10 to 6-3, 25</td>
<td>Weak positive (-1-3 µG/Oe)</td>
<td>Diamagnetic</td>
<td>0.010</td>
<td>+3.9 ± 41.7°</td>
<td>- 59.7°</td>
<td>20.3° (55 repeats)</td>
</tr>
<tr>
<td>6-4, 25 to 14-4, 125</td>
<td>Very weak positive (&lt;1 µG/Oe)</td>
<td>Diamagnetic</td>
<td>0.010</td>
<td>+3.9 ± 41.7°</td>
<td>- 59.7°</td>
<td>20.3° (55 repeats)</td>
</tr>
<tr>
<td>14-5, 25 to 17-2, 25</td>
<td>Very weak positive (&lt;1 µG/Oe)</td>
<td>Diamagnetic</td>
<td>0.010</td>
<td>+3.9 ± 41.7°</td>
<td>- 59.7°</td>
<td>20.3° (55 repeats)</td>
</tr>
<tr>
<td>14-7, 75 to 26-1, 75</td>
<td>Very weak positive (&lt;1 µG/Oe)</td>
<td>Diamagnetic</td>
<td>0.010</td>
<td>+3.9 ± 41.7°</td>
<td>- 59.7°</td>
<td>20.3° (55 repeats)</td>
</tr>
</tbody>
</table>
The comment made in the Site 592 paleomagnetic report concerning the significance of diamagnetic (negative) susceptibilities is equally applicable here.

The magnetization of these carbonate oozes is extremely weak. Intensities fall from about 15 to about 0.4 \( \mu \text{G} \) in the uppermost half meter of pale brown oxidized sediment, thence to characteristically low values below the bottom of Core 593-1. The surficial high-intensity layer was absent from the top of Hole 593A. A region of uniformly high intensity (1.5 to 4 \( \mu \text{G} \)) spans Cores 593-41 through 593-46, preceded by a gradual increase starting at the bottom of Core 593-50 and terminating with a steady decline in Cores 593-40 and 593-39. The range of this zone is somewhat wider than that of the pale orange to yellow gray Subunit IC. It appears to correlate with similar zones at Sites 588 and 592 and marks a change in the sedimentological regime over a wide area during the early and middle Miocene. Stein and Sarnthein (this volume) propose that during this period Australia would have been at higher latitudes and exposed to strong westerly winds, resulting in an increase in collian terrigenous material in sediments on the Lord Howe Rise. This would account for the high-intensity zone, but is not a convincing explanation of the fairly abrupt termination of the zone.

A magnetic polarity stratigraphy can be traced downward as far as the middle of the Gauss Chron at about 3.3 m.y. (Fig. 10). Deformation caused by coring was fairly common in the first eight cores from Hole 593. Despite this the Brunhes/Matuyama boundary and the Jaramillo Subchron appear to be well resolved. It was not possible to identify the Olduvai Subchron, and the lower part of the stratigraphy given in the figure is somewhat speculative. At greater depths, with the exception of the volcanogenic Unit II, directions are too scattered for a polarity interpretation to be made based on the NRM data.

It was surprising to find predominantly reversed (positive) inclinations for Cores 593-34 through 593-46. Much of this interval comprises the early and early middle Miocene high-intensity region in which directional data are highly reproducible. Furthermore, declinations in the high-intensity region were found to fall nearly always in the same quadrant for successive cores with positive inclinations, despite the fact that the azimuthal orientation of successive cores is expected to be random. It must be concluded therefore that the sediments in this region have acquired a large secondary remanence, either during or after coring. Partial AF demagnetization tests on this hole have yet to be performed.

Shipboard NRM measurements on the volcanogenic turbidite Unit II indicated reversed polarity throughout and magnetizations much less than would be expected for fresh volcanic material (Table 3). Lower intensities tended to be associated with the more fine-grained samples, which points to a greater degree of alteration in the fine-grained material.

**SEDIMENTATION RATES**

Sedimentation rates are calculated as outlined for the previous sites, but intervals used are subdivided if necessary or slightly changed according to datum levels available, especially in the early and middle Jurassic in the lower part of the stratigraphy given in the figure. A few nannoplankton zones had to be combined, because some index species are missing at this southern high latitude.

In the late Eocene and Oligocene interval (nannoplankton Zones NP19/NP20 top to NP25 top) the sedimentation rate is only 4.6 m/m.y. (including the volcanic material in Cores 58 and 59). In the early to middle Miocene (Zones NP25 top to NN5 top) the sedimentation rate is 9.7 m/m.y., based on five datum levels. At the top of nannoplankton Zone NN5 the sedimentation rate increases very suddenly to 48.4 m/m.y. in the middle Miocene (Zones NN5 top to NN8 top), at a level which is marked by change of color from yellow brown to white in the calcareous sediments (Core 593-42). In the late Miocene and early Pliocene (nannoplankton Zones NP8/NP9 top to NP14 top) the sedimentation rate is about 10.6 m/m.y., based on eight datum levels.

Table 3. NRM data for the volcanogenic turbidite Unit II.

<table>
<thead>
<tr>
<th>Core-Section (level in cm)</th>
<th>Intensity (( \mu \text{G} ))</th>
<th>Polarity*</th>
<th>Inclination</th>
<th>Comments</th>
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<tbody>
<tr>
<td>58-3, 30-32</td>
<td>6.94</td>
<td>R</td>
<td>15</td>
<td>Bedded, fine-grained, black</td>
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<td>58-3, 72-74</td>
<td>14.91</td>
<td>R</td>
<td>50</td>
<td>Uniform, med.-grained, green/gray</td>
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<td>59-1, 94-96</td>
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<td>R</td>
<td>53</td>
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<td>59-2, 132-134</td>
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<td>70</td>
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<tr>
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<td>Fine, black/green</td>
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<td>59-5, 65-71</td>
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<td>59-5, 160-102</td>
<td>1.61</td>
<td>R</td>
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<td>Fine, half gray, half black laminated</td>
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<td>59-CC 10-12</td>
<td>0.35</td>
<td>R</td>
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<td>Med., gray (with CO2)</td>
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<td>R</td>
<td>45</td>
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</table>

* R = reversed, N = normal.

Note: Queries denote specimens too weak to be measured reliably.
Zones NN8 top to NN13 top) the sedimentation rate drops to 15.0 m/m.y., based on five datum levels.

As was true for previous sites, the sedimentation rate increases in the late early Pliocene (nannoplankton Zones NN14 and NN15), and is 103.3 m/m.y. In the late Pliocene (Zones NN16 to NN18) it drops again to 19.0 m/m.y., based on three datum levels. In the Quaternary (above nannoplankton Zone NN18 top), it increases slightly to 22.9 m/m.y., which is more than twice the amount of that at Site 592.

SUMMARY AND CONCLUSIONS

Site 593 is located on the Challenger Plateau, a western extension of the New Zealand Plateau, in a relatively shallow water depth of 1068 m at a position 40°30.47'S, 167°40.47'E. The Challenger Plateau is effectively a topographic extension of Lord Howe Rise and its western part provides a shallow-water pedestal 270 km distant from the nearest land mass of northern South Island, New Zealand. This setting has allowed accumulation of an uncomplicated Paleogene to Neogene pelagic ooze sequence with virtually no terrigenous sedimentary influences. Site 593 is a reoccupation of Site 284, which was cored during Leg 29 of the Deep Sea Drilling Project.

Site 593 consists of two holes continuously cored to a maximum sub-bottom depth of 571.5 m. Hole 593 was cored with the HPC from 0 to 254.1 m sub-bottom and
continued to a total depth of 571.5 m with the XCB. Hole 593A was continuously cored with the HPC from 0 to 209.3 m sub-bottom, then washed down to 448.8 m and cored with the XCB to 496.8 m to recover the Oligocene/Miocene transition. This interval was poorly cored in the first hole.

Site 593 is an apparently continuous stratigraphic sequence from the late Eocene (42 m.y. ago) to the Quaternary (Fig. 12). The facies is a rather monotonous foraminifer-bearing nannofossil ooze that grades into a nannofossil ooze and a nannofossil chalk with depth. The transition to reduced abundances of foraminifers, from about 15 to about 5%, occurs at about 110 m. The sediment is predominantly calcareous nannofossils with subordinate foraminifers. Other components, such as quartz and feldspar grains, volcanic glass, and pyrite(?), occur only in trace (<1%) abundances (Fig. 3). Micritic carbonate occurs in persistent abundances of 5 to 10% from 323 m to total depth, but the sediment does not become chalk until 562 m. The only biogenic silica found comprised traces (<1%) of sponge spicules in a zone from about 249 to 296 m.

The sequence at Site 593 has been divided into two units. Unit I has been subdivided into four subunits (Fig. 12):

Subunit IA, of late Quaternary age, is a yellow gray foraminifer-bearing nannofossil ooze and represents an upper oxidized layer, correlating with a similar subunit at most other sites. The relatively high content of foraminifers appears to be the result of winnowing.

Subunit IB, of late Quaternary to middle Miocene age, is a light gray foraminifer-bearing nannofossil ooze that grades into a nannofossil ooze with depth. It is distinguished by its much lighter color compared with underlying Subunit IA and underlying Subunit IC.

Subunit IC, of middle Miocene age, is distinguished from two overlying and underlying subunits by its distinctive pale orange color, but is otherwise homogeneous and identical in lithology to the surrounding subunits.

Subunit ID, of early middle Miocene to earliest Oligocene age, is a white nannofossil ooze that is identical in lithology to the lower part of Subunit IB. Subunit ID is defined by its stratigraphic position below the easily recognized pale orange Subunit IC.

Between about 475 and 485 m in Hole 593 and about 455 and 468 m in Hole 593A, there occurs a zone that was difficult to recover. It comprises very homogeneous, firm, nannofossil ooze, indistinguishable from the sediment above and below. This zone occurs across the Miocene/Oligocene boundary. The reason for lack of recovery is unknown.

Unit II, of late earliest Oligocene to early late Eocene age, is composed of interbedded, lithified volcanogenic turbidites and pyroclastic flows and light greenish gray or white foraminifer-bearing nannofossil chalk to nannofossil chalk. The turbidites are grayish olive gray to dark gray and occur as a sequence of very fine- to coarse-grained packets.

The interbedded nannofossil chalk is identical in lithology to the overlying pelagic subunits but addition-
Figure 12. Summary lithology, biostratigraphy, and mass accumulation rates of Site 593 (recovery in black).
and the determination of a radiometric age for the volcanic material should assist with the dating of the Eocene/Oligocene boundary.

Paleoenvironmental History of Site 593

In general, the monotonous sedimentary sequence at Site 593 indicates a very consistent environment of deposition during the last 42 m.y., punctuated only by two major events at 38 m.y. ago and 15.5 to 15 m.y. ago and a minor event at 23.5 m.y. ago. The calcareous oozes were deposited in an oceanic environment at middle bathyal depths on the Challenger Plateau, with little evidence that the depth of the ocean floor changed. There was virtually no terrigenous input except for minor volcanic ash layers.

Nannofossil ooze (now chalk) was deposited during the late Eocene. The presence of many altered volcanic ash layers indicate that this was an active period of explosive volcanicity (42 to 38 m.y. ago).

This largely biogenic sedimentation was suddenly interrupted at the end of the Eocene (about 38 m.y. ago) by the deposition at the Eocene/Oligocene boundary of a 15-m layer of volcanogenic proximal turbidites, debris flows, and pyroclastic flows. These were deposited, probably rapidly, as a result of submarine volcanism at middle(? bathyal depths, probably from “Lalitha Pinnacle,” a small, now-buried volcanic pinnacle only 2 or 3 km from Site 593. Judging by seismic evidence, this volcanogenic deposit seems to have flowed several kilometers to the north of Site 593 and also seems to have been the only such event in this region during the Paleogene. The laminae of altered volcanic ash in the late Eocene probably represent air-fall deposits that were precursors to the submarine volcanic event that produced the pyroclastic deposits. Concomitant volcanism occurred in the southern New Zealand region. The Deborah volcanics, South Canterbury, for instance, were also extruded at the time of the Eocene/Oligocene boundary. Similar volcanic pinacles like “Lalitha” occur at other locations on the Challenger Plateau, and their structural relations with the sediments suggest that they were deposited at the same time, indicating that it was a period of widespread volcanism in the region.

Sedimentation continued over the Eocene/Oligocene boundary without break. The usual extinctions of planktonic foraminifers and calcareous nannoplankton index forms occurred. Benthic forms also show significant changes over this interval. White nannofossil oozes were deposited from the early Oligocene to the early middle Miocene. Sedimentation rates were noticeably low (4.6 m/m.y.) during the Eocene–Oligocene interval.

Other than some minor event leading to the deposition of a layer of hard ooze at the Oligocene/Miocene boundary, depositional conditions remained remarkably unchanged until the beginning of the middle Miocene. However, benthic faunas did evolve, indicating changes in bottom-water character.

Between 15.5 and 15 m.y. ago, there commenced deposition of a remarkable 25-m deposit of orange ooze which differs from the surrounding sediments only by its bright color. The top of this layer coincides with the upper boundary of NN5 and the subunit falls within the Praeorbulina glomerosa curva Zone; hence it is about 15.5 to 15 m.y. in age. The subunit thus seems to have immediately preceeded the time of major ice build-up on Antarctica. The event that caused oxidation of this subunit must have altered the balance between available dissolved oxygen supplied to the seafloor and available organic carbon supplied to the infauna and bacteria within the sediment. It is possible that there was a brief development of a water mass front not far to the south of Site 593 that produced intermediate waters sufficiently highly oxygenated to prevent post-depositional reduction within the sediments. In the present day, oxygen-charged Antarctic Intermediate Waters are produced at the Antarctic Convergence and flow toward the north at about 1000 m water depth (Figs. 5 and 13). The middle Miocene episode was relatively short-lived because the sediment had returned to a reduced state by about 15 m.y. ago. The oxidized sediment layer may, therefore, represent a paleoenvironmental change associated with the evolution of Antarctic glaciation. In this interval the character of the benthic fauna remains surprisingly constant. A few new forms occur, including Melonis barlee-anum, Bolivina anastomosa, and Uvigerina auberiana. The small, hispid uvigerinids, however, occur in large numbers in Sample 593-42,CC and may be a reflection of the increased oxidation at that time.

Coincidentally, when deposition of the oxidized subunit ceased, sedimentation rates suddenly increased from 9.7 to 48.4 m/m.y. This increase may have resulted from increased biogenic productivity associated with stimulated circulation related to Miocene glaciation.

The large change occurs slightly later in the early Miocene (P. glomerosa curva to Orbulina suturalis zones). At this time, both the diversity and abundance of benthics increase. The rectuvigerinids disappear temporarily and seven new forms appear, at least four of which are cibicidids. Nuttalides umbonifera, a form correlated with deep water masses later in the Neogene, first occurs at this site.

High rates (48.4 m/m.y.) of sedimentation continued through the middle Miocene, with the deposition of relatively unchanging foraminifer-bearing nannofossil ooze to nannofossil oozes. These high rates diminished to 15 m/m.y. in the late Miocene to earliest Pliocene.

As in most of the sites drilled during Leg 90, there was a remarkable increase in sedimentation rates between 4 and 3 m.y. ago, in the late early Pliocene. Rates were 103 m/m.y. at Site 593. The paleoenvironmental event that caused this increase remains unknown but was almost certainly related to increased biogenic productivity. Beginning near the end of this interval, the percentage of foraminifers in the sediments increased.

The foraminifer-bearing nannofossil ooze that occurred at 3 m.y. in the sequence probably represents an interval when bottom currents in this area were strong enough to winnow some nannofossils from the sediment. The occurrence of an upper winnowed sequence at Site 593 is similar to the uppermost recovered sections at Sites 587 through 592, and probably coincides with a period of more intensive global oceanic circulation, perhaps re-
Figure 13. Dissolved-oxygen concentration (ml/l) along approximately 160°W from Antarctica to Alaska (reprinted with permission from Reid, 1965).
lated to the development of Northern Hemisphere glacia-
ations. This led to a marked decrease in sedimentation
rates (about 23 m/m.y.) through the late Pliocene to Qua-
ternary.

The section terminates with the familiar late Quater-
nary veneer (0 to 6 m) of oxidized sediments.

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### Lithologic Description

#### Section 1
- **Cored Interval**: 0.0 - 5.1 m
- **Description**: Foraminifer-bearing nanofossil ooze, soft, yellowish gray (5Y 7/2) and light gray (N7) in the first 0.50 m of Section 1. Then, sediment shows alternating zones of grayish yellow green (5GY 7/2), light gray (N7), and very light gray (N8) oozes. Grayish yellow green (5GY 7/2) burrows are present.

#### SMEAR SLIDE SUMMARY:
- **Composition**:
  - Quartz: D D D
  - Heavy minerals: T
  - Volcanic glass: D D
  - Pyrite: T T
  - Foraminifers: C C C
  - Calc. nannofossils: D D D
  - Sponge spicules: T T T

#### Section 2
- **Cored Interval**: 5.1 - 14.7 m
- **Description**: Foraminifer-bearing nanofossil ooze, very light gray (N8), light gray (N7), light greenish gray (5GY 7/2), and very light greenish gray (5GY 8/1) interbeds, all with gradational contacts, with Mottles apparent in Sections 5 and 6. Otherwise homogenous. Coring disturbance throughout.

#### SMEAR SLIDE SUMMARY:
- **Composition**:
  - Quartz: D D D
  - Heavy minerals: T T T
  - Volcanic glass: D D D
  - Pyrite: T T T
  - Foraminifers: C C C
  - Calc. nannofossils: D D D
  - Sponge spicules: T T T
FORAMINIFER-BEARING NANNOFORSSIL OOZE, alternating colors of light gray (N7), very light gray (N8), medium gray (N5), with soft, generally homogeneous grains yellow green (5GY 7/2) mottles. Pockets of ash-rich zones occur in Sections 2 and 3. Distinct ash occurs in Section 3, 30-50 cm and indistinct ash (?) occurs in Section 4. Occasional streaks of iron-stained, grayish yellow green (5GY 7/2) and light gray (N7) colored interbeds appear coarser grained than very light gray (N8) beds.
### SITE 993  HOLE 5  CORE 5  CORED INTERVAL 33.9–43.5 m

#### Lithologic Description

**Foraminifer-bearing Nanofossil Ooze**, very light gray (N8) with mottled zones of grayish yellow green (5GY 7/2). Soft and homogeneous. Pockets of forams occur throughout the core. Rare beds of iron sulfides occur, especially in Section 3. Section 6 badly disturbed.

#### Shear Slide Summary

<table>
<thead>
<tr>
<th>Pocket of forams</th>
<th>N8</th>
<th>Quartz</th>
<th>Feldspar</th>
<th>Volcanic glass</th>
<th>Foraminifers</th>
<th>Calc. nannofossils</th>
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### SITE 993  HOLE 6  CORE 6  CORED INTERVAL 43.5–53.1 m

#### Lithologic Description

**Foraminifer-bearing Nanofossil Ooze**, very light gray (N8) with zones of grayish yellow green (5GY 7/2) mottling. Soft and homogeneous. Pockets of forams occur throughout the core. Rare beds of iron sulfides and diffusion bands, especially in Section 3. Section 6 badly disturbed.

#### Shear Slide Summary

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<th>Quartz</th>
<th>Feldspar</th>
<th>Volcanic glass</th>
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**SITE 593 HOLE 7 CORED INTERVAL 53.1-62.7 m**

**LITHOLOGIC DESCRIPTION**

FORAMINIFER-BEARING NANNOFOSIL OOZE, severe core disturbance throughout. Light to very light gray (N8), soft, homogeneous. Streaks of iron sulfide (T). Faint hues of grayish yellow green (5GY 7/2) in Section 4.

**SMEAR SLIDE SUMMARY:**

Composition:

- Quartz (5,82)
- Feldspar (D)
- Volcanic glass (5,82)
- Foraminifers (T)
- Calc nannofossils (D)

**SITE 593 HOLE 8 CORED INTERVAL 62.7-72.3 m**

**LITHOLOGIC DESCRIPTION**

FORAMINIFER-BEARING NANNOFOSIL OOZE, severe core disturbance throughout core. Very light gray (N8), soft, with streaks of medium dark gray (N4) throughout.

**SMEAR SLIDE SUMMARY:**

Composition:

- Pyrite (T)
- Foraminifers (C)
- Calc nannofossils (D)
SITE 593 HOLE 11 CORED INTERVAL 91.5-101.1 m

**LITHOLOGIC DESCRIPTION**

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, extremely homogeneous with only rare streaks and blebs of medium dark gray (N4) iron sulfide.

**SMEAR SLIDE SUMMARY:**

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<th>4,73</th>
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</table>

- **Quartz**
- **Volcanic glass**

Core 10, 81.9-91.5 m

**LITHOLOGIC DESCRIPTION**

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous with streaks and blebs of iron sulfide dark gray (N3) scattered throughout. Diffusion bands of iron sulfide faintly show in Section 4.

**SMEAR SLIDE SUMMARY:**

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</thead>
</table>

- **D**
- **Volcanic glass**
- **Pyrite**
- **Calc. nannofossils**
**SITE 593 HOLE**

**CORE 12** CORED INTERVAL 101.1-110.7 m

**LITHOLOGIC DESCRIPTION**

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, very homogeneous with only a few faint iron sulfidel?) diffusion bands, and streaks. Several pockets of cemented (celestite or gypsum?) forams occur in Section 3, 30 cm; Section 3, 125 cm; and Section 6, 38 cm.

**SMEAR SLIDE SUMMARY:**

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8), soft, homogeneous, with rare streaks of iron sulfidel?). Pocket of cemented forams at Section 3, 48-50 cm.

**SMEAR SLIDE SUMMARY:**

Pocket of cemented band of forams. Pyrite T Calc. nanπofossils D
SITE 593 HOLE CORE 14 CORED INTERVAL 120.3–129.9 m

LITHOLOGIC DESCRIPTION

NANNOFOSSIL Ooze, very light gray (N8) with rare faint hues of medium light gray (N6) from iron sulfides. Soft and very homogeneous throughout.

Strong H2S odor when split.

SMEAR SLIDE SUMMARY:

Pyrite

Sponge spicules

SITE 593 HOLE CORE 15 CORED INTERVAL 129.9–139.5 m

LITHOLOGIC DESCRIPTION

NANNOFOSSIL Ooze, very light gray (N8), homogeneous, with rare light gray (N7) laminae of iron sulfides.

SMEAR SLIDE SUMMARY:

370 140 645

D M M

Sand R C C

Silt D C C

Clay D D C

Pyrite

Foraminifera

Calc. nannofossils

Sponge spicules
**SITE 593 HOLE CORE 16 CORED INTERVAL 130.5–140.1 m**

**LITHOLOGIC DESCRIPTION**

NANOFOSIL Ooze, very light gray (N8), soft, homogeneous. Rare light gray (N7) laminae and dark gray (N3) fine accumulations of iron sulfide. Rare grayish yellow (5GY 7/2) burrows.

**SMARK SLIDE SUMMARY**

Texture: T
Sand: R
Clay: D
Composition: Forams: R
Calc. nannofossils: D
Sponge spicules: 3.75

**SITE 593 HOLE CORE 17 CORED INTERVAL 140.1–150.7 m**

**LITHOLOGIC DESCRIPTION**

NANOFOSIL Ooze, very light gray (N8), soft, homogeneous. Light gray (N7) laminae and rare dark gray (N3) fine accumulations of iron sulfide are present. Pockets of foraminifera in Sections 2 and 3.

**SMARK SLIDE SUMMARY**

Texture: T
Sand: R
Clay: D
Composition: Forams: R
Heavy minerals: T
Pyrite: T
Calc. nannofossils: D
Sponge spicules: T
NANOFOSIL Ooze, very light gray (N9), soft, homogeneous. Light gray (N9) laminae and dark gray (N8) fine accumulations of iron sulfide(?). Beaded yellowish green (5GY 7/2) laminae, foraminifers pockets, and discrete yellowish gray (5Y 8/1) laminae are present.

SMEAR SLIDE SUMMARY:
3.75
Composition:
- Feldspar T
- Pyrite T
- Calc. nannofossils D
- Foraminifers R

NANOFOSIL Ooze, very light gray (N9), soft, homogeneous. Light gray (N9) laminae and dark gray (N8) fine accumulations of iron sulfide(?). Beaded yellowish green (5GY 7/2) laminae, foraminifers pockets, and discrete yellowish gray (5Y 8/1) laminae are present.

SMEAR SLIDE SUMMARY:
3.75
Composition:
- Feldspar T
- Pyrite T
- Foraminifers R
- Calc. nannofossils D
### Site 593 Hole 20 Cored Interval 172.9-189.5 m

#### Lithologic Description

- **Nanofossil Ooze:** very light gray (N8), soft, homogeneous. Light gray (N7) laminae of fine siltstone are present.

#### Smear Slide Summary:

- **Texture:**
  - Sandy (A)
  - Silt (A)

- **Composition:**
  - Quartz (T)
  - Heavy minerals (T)
  - Volcanic glass (T)
  - Foraminifers (R)
  - Calcareous nannofossils (D)

### Site 593 Hole 21 Cored Interval 187.5-197.1 m

#### Lithologic Description

- **Nanofossil Ooze:** very light gray (N8), soft, homogeneous. Light gray (N7) laminae and dark gray (N3) fine accumulations of iron sulfide (?) are present, as well as rare yellowish gray (5Y 7/2) burrows and spores.

#### Smear Slide Summary:

- **Texture:**
  - Sandy (A)
  - Silt (A)

- **Composition:**
  - Quartz (T)
  - Heavy minerals (T)
  - Volcanic glass (T)
  - Foraminifers (R)
  - Calcereous nannofossils (D)
**SITE 593**

**HOLE** 5

**CORE** 22

**CORED INTERVAL** 197.1–206.7 m

<table>
<thead>
<tr>
<th>STRATIGRAPHIC LEVEL</th>
<th>FOSSIL CHARACTER</th>
<th>GRAPHIC LITHOLOGY</th>
<th>FOSSIL REMAINS</th>
<th>LITHOLOGIC DESCRIPTION</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>0.5</td>
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<td>N7 halo</td>
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<td>1</td>
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<td>1.0</td>
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<td>N7 halo</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>N7 halo</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>Void</td>
</tr>
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</table>

**LITHOLOGIC DESCRIPTION**

**N7 halo**

NANOFORSSIL Ooze, very light gray (N8), soft, homogenous. Light gray (N7) laminae and dark gray (N3) fine accumulations of iron sulfide (SRM) present. Void in Section 4 between 0.40 and 0.70 m is due to drilling.

**SMEAR SLIDE SUMMARY:**

<table>
<thead>
<tr>
<th>Component</th>
<th>R</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feldspar</td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>Pyrite</td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>Foraminifers</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>Calc. nannofossils</td>
<td>D</td>
<td></td>
</tr>
</tbody>
</table>

**SITE 593**

**HOLE** 5

**CORE** 23

**CORED INTERVAL** 206.2–216.3 m

<table>
<thead>
<tr>
<th>STRATIGRAPHIC LEVEL</th>
<th>FOSSIL CHARACTER</th>
<th>GRAPHIC LITHOLOGY</th>
<th>FOSSIL REMAINS</th>
<th>LITHOLOGIC DESCRIPTION</th>
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<tbody>
<tr>
<td>7</td>
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<td>N7 halo</td>
</tr>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>N7 halo</td>
</tr>
</tbody>
</table>

**LITHOLOGIC DESCRIPTION**

**N7 halo**

NANOFORSSIL Ooze, very light gray (N8), soft, homoegenous, light gray (N7) laminae and rare fine accumulations of iron sulfide (SRM) present. Void in Section 4 between 0.40 and 0.70 m is due to drilling.

**SMEAR SLIDE SUMMARY:**

<table>
<thead>
<tr>
<th>Component</th>
<th>R</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feldspar</td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>Pyrite</td>
<td>T</td>
<td></td>
</tr>
<tr>
<td>Foraminifers</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>Calc. nannofossils</td>
<td>D</td>
<td></td>
</tr>
</tbody>
</table>
LITHOLOGIC DESCRIPTION

NANOFORSSIL OOZE, very light gray (N7), firm, homogeneous. Light gray (N7) laminae of iron sulfide(?). Rare pseudomorphs of non-sulfuric(?). Rare light greenish yellow (N8) laminae of iron sulfide(?). Rare pseudomorphs of non-sulfuric(?).

SMEAR SLIDE SUMMARY:
- Sand: 0.75, 4.42, 0.05
- Silt: 0.06, 0.05
- Clay: 0.06, 0.05
- Carbonate: 0.06, 0.05
- Foraminifera: 0.06, 0.05
- Calc. nannofossils: 0.06, 0.05
**SITE 593**

<table>
<thead>
<tr>
<th>HOLE</th>
<th>CORE</th>
<th>CORED INTERVAL</th>
<th>235.6-246.1 m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**LITHOLOGIC DESCRIPTION**

- **NANNOFOSSIL Ooze**, very light gray (N5), firm, homogeneous. Light gray (N7) laminae and dark gray (N3) fine accumulations of iron sulfides. Pyrite nodules are present in Sections 3 and 5. Light grayish grey (N5) B13 iron sulphides are present in Sections 5 and 6.

**SMEAR SLIDE SUMMARY:**

<table>
<thead>
<tr>
<th>Texture</th>
<th>Silica</th>
<th>Clay</th>
<th>Organic</th>
<th>Foraminifers</th>
<th>Calcite</th>
<th>Heavy minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firm</td>
<td>R</td>
<td>C</td>
<td></td>
<td>R</td>
<td>C</td>
<td>D</td>
</tr>
</tbody>
</table>

**Composition:**

- **Clay**
- **Silt**
- **Sand**
- **Heavy minerals**
- **Foraminifers**
- **Calcite**
- **Diatoms**
- **Pyrite**

**LITHOLOGY**

- **Composition:**
  - **Clay**
  - **Silt**
  - **Sand**
  - **Heavy minerals**
  - **Foraminifers**
  - **Calcite**
  - **Diatoms**
  - **Pyrite**

**Fossil Character:**

- **A**

**Hole:**

- **A**

**Core:**

- **A**

**Depth:**

- **CC**
### Lithostratigraphic Description

**Nannofossil ooze**, very light gray (N8), firm, homogeneous. Light gray (N7) laminae and dark gray (N3) fine accumulations of iron sulfide (?). Pyrite (?) nodules in Sections 3 and 4.

**Smear Slide Summary:**

- Text: R
- Clay: D
- Composition: T
- Volcanic glass: T
- Foraminifera: R
- Grains, nannofossils: D
- Sponge spicules: T

**Graphic Lithology**

### Core Log

<table>
<thead>
<tr>
<th>Depth Interval</th>
<th>Lithology</th>
<th>Nannofossil ooze</th>
<th>Pyrite (?)</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>254.7-264.3 m</td>
<td>Nannofossil ooze</td>
<td>Very light gray (N8)</td>
<td>Firm</td>
<td>Homogeneous</td>
</tr>
<tr>
<td></td>
<td>Light gray (N7) laminae</td>
<td>Dark gray (N3) fine accumulations of iron sulfide (?)</td>
<td>Pyrite (?) nodules</td>
<td>in Sections 3 and 4</td>
</tr>
</tbody>
</table>

### Diagram

- **Site 593 Hole Core 29 Cored Interval 264.3-273.9 m**

- **Site 593 Hole Core 28 Cored Interval 254.3-264.3 m**
### Site 593 Hole Core 30 Cored Interval 273.9-283.5 m

**Lithologic Description**

- **Nannofossil Ooze**: very light gray (N8), firm, homogeneous. Light gray (N7) laminae and accumulations of iron sulfides. Discrete light greenish gray (5G 8/1) laminae in Sections 3 and 4.

**Smear Slide Summary**:

<table>
<thead>
<tr>
<th>Clay Composition</th>
<th>Quartz</th>
<th>Feldspar</th>
<th>Volcanic</th>
<th>Foraminifera</th>
<th>Calc. nannofossils</th>
<th>Radiolarians</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

### Site 593 Hole Core 31 Cored Interval 283.5-293.1 m

**Lithologic Description**

- **Nannofossil Ooze**: very light gray (N8), firm, homogeneous. Light gray (N7) laminae and dark gray (N3) fine accumulations of iron sulfides. Discrete light greenish gray (5G 8/1) laminae are present.

**Smear Slide Summary**:

<table>
<thead>
<tr>
<th>Clay Composition</th>
<th>Quartz</th>
<th>Feldspar</th>
<th>Volcanic</th>
<th>Foraminifera</th>
<th>Calc. nannofossils</th>
<th>Radiolarians</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

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### Site 593 Hole Core 32 Cored Interval 282.5-292.1 m

**Lithologic Description**

- **Nannofossil Ooze**: very light gray (N8), firm, homogeneous. Light gray (N7) laminae and dark gray (N3) fine accumulations of iron sulfides. Discrete light greenish gray (5G 8/1) laminae are present.

**Smear Slide Summary**:

<table>
<thead>
<tr>
<th>Clay Composition</th>
<th>Quartz</th>
<th>Feldspar</th>
<th>Volcanic</th>
<th>Foraminifera</th>
<th>Calc. nannofossils</th>
<th>Radiolarians</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

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### Site 593 Hole Core 31 Cored Interval 283.5-293.1 m

**Lithologic Description**

- **Nannofossil Ooze**: very light gray (N8), firm, homogeneous. Light gray (N7) laminae and dark gray (N3) fine accumulations of iron sulfides. Discrete light greenish gray (5G 8/1) laminae are present.

**Smear Slide Summary**:

<table>
<thead>
<tr>
<th>Clay Composition</th>
<th>Quartz</th>
<th>Feldspar</th>
<th>Volcanic</th>
<th>Foraminifera</th>
<th>Calc. nannofossils</th>
<th>Radiolarians</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

### Site 593 Hole Core 32 Cored Interval 282.5-292.1 m

**Lithologic Description**

- **Nannofossil Ooze**: very light gray (N8), firm, homogeneous. Light gray (N7) laminae and dark gray (N3) fine accumulations of iron sulfides. Discrete light greenish gray (5G 8/1) laminae are present.

**Smear Slide Summary**:

<table>
<thead>
<tr>
<th>Clay Composition</th>
<th>Quartz</th>
<th>Feldspar</th>
<th>Volcanic</th>
<th>Foraminifera</th>
<th>Calc. nannofossils</th>
<th>Radiolarians</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---
SITE 593  HOLE 37  CORED INTERVAL 293.1–302.7 m

LITHOLOGIC DESCRIPTION
FORAMINIFER-BEARING NANNOFossil OOZE, very light gray (N8), firm, homogeneous. Light gray (7.5Y 7/1) and dark gray (N7) bands of iron sulfide(?). Rare grayish yellow green (5GY 7/2) mottles are present in Section 3. Distinct light greenish gray (5G 8/1) laminae are present.

SMEAR SLIDE SUMMARY:
Texture: Sand 1 T
Silt 1 2
Clay 1 3
Composition:
Heavy minerals 1 4
Talc 1 5
Pyrite 1 6
Permineralization 1 7
Calc. nannofossils 1 8
Sponges 1 9

SITE 593  HOLE 33  CORED INTERVAL 302.7–312.3 m

LITHOLOGIC DESCRIPTION
NANNOFossil Ooze, very light gray (N8), soft, very homogeneous with rare very faint bands of very light greenish gray (7.5Y 7/1) and streaks of iron sulfide (?).

SMEAR SLIDE SUMMARY:
Composition:
Phl 1 T
Foraminifers 1 R
Calc. nannofossils 1 D
**Lithologic Description**

- **NANNOFOSSIL OOZE**, very light gray (N8), soft, homogeneous. A few mottles (?) and streaks of medium gray iron sulfide (?)! Some zones have faint hues of very light greenish gray (5GY 9/1) but the nature of the split surface precludes any assessment of sedimentary structures.

**Smear Slide Summary:**

- Composition:
  - Volcanic glass
  - Carbonate unspec.
  - Foraminifers
  - Calc. nannofossils

- Faint hues of 5GY 9/1.
SITE 593 HOLE CORE 35 CORED INTERVAL 331.5–341.1 m

LITHOLOGIC DESCRIPTION

NANOFOSIL ODZEL: very light gray (N8), soft, homogeneous. Spots and streaks of various shades of gray (N6, N4) iron sulicide? Impossible to describe sediment structure because surface was destroyed when split.

SMER SLIDE SUMMARY:

Composition:
- N8 Heavy minerals T
- N8 Pyrite T
- N8 Carbonate veins C
- N8 Foraminifers R
- Calc. nannofossils D

SITE 593 HOLE CORE 37 CORED INTERVAL 341.1–350.7 m

LITHOLOGIC DESCRIPTION

NANOFOSIL ODZEL: very light gray (N8), soft and homogeneous. Faint blobs and streaks of various grays (N7, N6). Zone of faint hues of very light gray green (5GY 9/1) in Section 2. Surface badly distorted by splitting.

SMER SLIDE SUMMARY:

Composition:
- N8 Heavy minerals T
- N8 Pyrite T
- N8 Carbonate veins C
- N8 Foraminifers R
- Calc. nannofossils A
**SITE 593 HOLE CORE 38 CORED INTERVAL 350.7-360.3 m**

**LITHOLOGIC DESCRIPTION**

NANNOFOSSIL OOZE, very light gray (N8), soft to stiff, homogeneous. A few zones of faint hues of 5GY 9/1 and several zones of grays (N6, N5, N4) of iron sulfide(?). Surface disrupted by splitting.

**SMEAR SLIDE SUMMARY:**

Co Fe P T Ca Fv

"position:

dspar

donite

donite

donite

donite

donite

donite

donite

**SITE 593 HOLE CORE 39 CORED INTERVAL 360.3-369.9 m**

**LITHOLOGIC DESCRIPTION**

NANNOFOSSIL OOZE, very light gray (N8), soft to firm, homogeneous. Streaks of medium gray (N4) iron sul-
fide(?). Nodules of pyrite(? in Section 3, 75 cm and Section 1, 125 cm. Surface disrupted by splitting.

**SMEAR SLIDE SUMMARY:**

4, 50

"Hues of 5GY 9/1

Carbonate unspec. C

Foraminifers R

Calc. nannofossils D
SITE 593  HOLE CORE 40 CORED INTERVAL 369.9-379.5 m

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, very light gray (N8), stiff, very homogeneous. Only very occasional iron sulfide (?) streaks. Surface disrupted by splitting.

SMEAR SLIDE SUMMARY:

- Composition:
  - N8 Volcanic glass
  - Pyrite
  - Carbonate unspec.
  - Foraminifers
  - Calc. nannofossils

SITE 593  HOLE CORE 41 CORED INTERVAL 379.5-389.7 m

LITHOLOGIC DESCRIPTION

NANNOFOSSIL ooze, very light gray (N8), stiff, very homogeneous. A few streaks of iron sulfide (?) in Smeared Carbonate unspec. C.
SITE 593  HOLE  42  CORED INTERVAL  398.1-398.7 m

<table>
<thead>
<tr>
<th>TIME UNIT</th>
<th>Fossil Character</th>
<th>Graphic Lithology</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>NaNofossil ooze, very light gray (N8) overlying various hues of very pale orange (10YR 8/2), stiff, very homogeneous. Color boundary represents no change in lithology.</td>
</tr>
</tbody>
</table>

SMEAR SLIDE SUMMARY:
- Volcanic glass: T
- Carbonate, unspec.: A A
- Foraminifera: R R
- Calc. nannofossils: A A

SITE 593  HOLE  43  CORED INTERVAL  398.7-408.3 m

<table>
<thead>
<tr>
<th>TIME UNIT</th>
<th>Fossil Character</th>
<th>Graphic Lithology</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>NaNofossil ooze, very pale orange (10YR 8/2 and 10YR 9/2), stiff to firm, totally homogeneous and featureless.</td>
</tr>
</tbody>
</table>

SMEAR SLIDE SUMMARY:
- Volcanic glass: T
- Carbonate, unspec.: C
- Foraminifera: R R
- Calc. nannofossils: D
**LITHOLOGIC DESCRIPTION**

**SITE 593 HOLE**

**CORE 45 CORED INTERVAL**

**417.9-427.5 m**

**NANNOFOSSIL OOZE**, yellowish gray (5Y 8/1 to 5Y 9/1), stiff to firm, very homogeneous, essentially featureless except for pale yellowish orange (10YR 7/6) zones in Section 3. Fades becomes FORAMINIFER-BEARING NANOFOSSIL OOZE by Section 5.

**SMEAR SLIDE SUMMARY:**

<table>
<thead>
<tr>
<th>Meters</th>
<th>Section</th>
<th>M</th>
<th>L</th>
<th>S</th>
<th>Description</th>
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<tbody>
<tr>
<td></td>
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<td>Carbonate unspec.</td>
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<td>Calc. Nanofoossils</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Foraminifers</td>
</tr>
</tbody>
</table>

**SITE 593 HOLE**

**CORE 44 CORED INTERVAL**

**408.3-417.9 m**

**NANNOFOSSIL OOZE**, light greenish gray (5QY 8/1) 1 very light greenish gray (5GY 9/1), stiff, homogeneous.
NANNOFOSSIL Ooze, white (N9) to very light gray (N8). Ten, homogeneous. Light gray (N8-N7) streaks in Section 2.

SMEAR SLIDE SUMMARY:
3,80 5,36 5,39

Texture:
Silt - C
Clay - A

Composition:
Pyrite - T
Carbonate unspec. C
Foraminifers - R
Calc. nannofossils - A

NANNOFOSSIL Ooze, white (N9) to very light gray (N8). Ten, homogeneous. Light gray (N7-N8) streaks in Sections 5, 6, and CC. Discrete light greenish gray (5G) zones in Sections 4 and CC due to drilling and core handling.
### Lithologic Description

**Nanofossil ooze, white (N9) to very light gray (N8), firm, homogeneous. Light gray (N7) to very light gray (N8), and dark gray (N3) levels of core sulfur (N5) are present.**

**Smear Slie Summary:**
- Texture: D
- Composition: Carbonate unpal. C
- Foraminifers: T/R
- Calc. nannofossils D

**Texture:**
- Silt D
- Clay D
- Heavy minerals T
- Foraminifers: T/R
- Pyrite T
- Carbonate unpal. C
- Calc. nannofossils D

**Composition:**
- Carbonate unpal. C
- Foraminifers: T/R
- Calc. nannofossils D
**SITE 593 HOLE CORE 53 CORED INTERVAL 494.7-504.3 m**

**LITHOLOGIC DESCRIPTION**

- Void
- Void
- Void
- Void

NANNOFOSSIL Ooze, white (N9), firm, homogeneous. Very light gray (N8) level in Section 3. Rare light gray (N7) laminae. Voids are due to drilling and core handling.

**SMEAR SLIDE SUMMARY:**

<table>
<thead>
<tr>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
</tr>
<tr>
<td>Carbonate</td>
</tr>
<tr>
<td>Volcanic glass</td>
</tr>
<tr>
<td>Foraminifers</td>
</tr>
<tr>
<td>Calc. nannofossils</td>
</tr>
<tr>
<td>Desmoites</td>
</tr>
</tbody>
</table>

**SITE 593 HOLE CORE 54 CORED INTERVAL 504.3-513.9 m**

**LITHOLOGIC DESCRIPTION**

NANNOFOSSIL Ooze, white (N9) to very light gray (N8), firm, homogeneous. Rare light gray (N7) and dark gray (N3) laminae.

**SMEAR SLIDE SUMMARY:**

<table>
<thead>
<tr>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silt R</td>
</tr>
<tr>
<td>Clay D</td>
</tr>
<tr>
<td>Foraminifers</td>
</tr>
<tr>
<td>Calc. nannofossils</td>
</tr>
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</table>

**TIME - SCALE**

<table>
<thead>
<tr>
<th>SAMPLE</th>
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<td>4</td>
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<tr>
<td>5</td>
<td>3.87</td>
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</tbody>
</table>
### Site 593 Hole S6 Core 55 Cored Interval 513.9-523.5 m

**Lithological Description**

| Section | Textures | Color | Camber | Sediments | Fossil Character | Nannofossil Ooze, white (NB) to very light gray (NB), firm, homogeneous, Light gray (NB) laminae of non-sulfidic). Light gray (NB) laminae below Section 2.
|----------|----------|-------|--------|------------|-----------------|----------------|
| 1.0      |          |       |        |            |                 | Nannofossil Ooze, white (NB) to light gray (NB), firm, homogeneous, Light gray (NB) laminae of non-sulfidic). Light gray (NB) laminae below Section 2.
| 2.0      |          |       |        |            |                 | Nannofossil Ooze, very light gray (N8) to light greenish gray (5GY 8/11), homogeneous, with alternations of firm and stiff sediments. Light gray (N7) burrows and light gray (N7), light greenish gray (5G 8/1) to grayish green (10GY 5/2) laminae common. |

**Smear Slide Summary:**

- Clay:
- Quartz:
- Heavy minerals:
- Carbonate:
- Foraminifera:
- Other:
- Diatoms:

### Site 593 Hole S6 Core 56 Cored Interval 523.5-533.1 m

**Lithological Description**

<table>
<thead>
<tr>
<th>Section</th>
<th>Textures</th>
<th>Color</th>
<th>Camber</th>
<th>Sediments</th>
<th>Fossil Character</th>
<th>Nannofossil Ooze, very light gray (N8) to light greenish gray (5GY 8/11), homogeneous, with alternations of firm and stiff sediments. Light gray (N7) burrows and light gray (N7), light greenish gray (5G 8/1) to grayish green (10GY 5/2) laminae common.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
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<td></td>
<td>Nannofossil Ooze, very light gray (N8) to light greenish gray (5GY 8/11), homogeneous, with alternations of firm and stiff sediments. Light gray (N7) burrows and light gray (N7), light greenish gray (5G 8/1) to grayish green (10GY 5/2) laminae common.</td>
</tr>
<tr>
<td>2.0</td>
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<td></td>
<td>Nannofossil Ooze, very light gray (N8) to light greenish gray (5GY 8/11), homogeneous, with alternations of firm and stiff sediments. Light gray (N7) burrows and light gray (N7), light greenish gray (5G 8/1) to grayish green (10GY 5/2) laminae common.</td>
</tr>
</tbody>
</table>

**Smear Slide Summary:**

- Clay:
- Quartz:
- Heavy minerals:
- Carbonate:
- Foraminifera:
- Other:
- Diatoms:
**LITHOLOGIC DESCRIPTION**

**section 1, 0 cm through Section 2, 130 cm:** NANNOSILOUS, white (N9) to very light gray (N8), homogeneous, with alternations of firm and stiff sediments. Rare light gray (N7) burrows and laminae.

**SMEAR SLIDE SUMMARY:**
- Texture: D
- Clay: R
- Heavy minerals: T
- Volcanic glass: T
- Foraminifers: R
- Calc. nannofossils: C
- Dolomite: D

**section 2, 130 cm through Core section 3:** VOLCANOGENIC TURBIDITES, grayish olive green (5GY 3/2) to dusky yellowish green (10GY 3/2) until 25 cm Section 3 then grayish olive green (5GY 3/2) to dark gray (N4). White (N9) veins of calcite are present. White (N9) laminae of nannofossil chalk in Section 3. Sediment generally normally graded. Cross-beddings are present in Core Catcher.

**SMEAR SLIDE SUMMARY:**
- Ceramic - D
- Fossil - T
- Foraminifers - R
- Other - D

**LITHOLOGIC DESCRIPTION**

**section 3, 260 cm through Core section 4:** NANNOSILOUS, white (N9) to very light gray (N8), homogeneous, with alternations of firm and stiff sediments. Rare light gray (N7) burrows and laminae.

**SMEAR SLIDE SUMMARY:**
- Texture: D
- Clay: R
- Heavy minerals: T
- Volcanic glass: T
- Foraminifers: R
- Calc. nannofossils: C
- Dolomite: D

**section 4, 260 cm through Core section 5:** VOLCANOGENIC TURBIDITES, grayish olive green (5GY 3/2) to dusky yellowish green (10GY 3/2) until 25 cm Section 3 then grayish olive green (5GY 3/2) to dark gray (N4). White (N9) veins of calcite are present. White (N9) laminae of nannofossil chalk in Section 3. Sediment generally normally graded. Cross-beddings are present in Core Catcher.

**SMEAR SLIDE SUMMARY:**
- Ceramic - D
- Fossil - T
- Foraminifers - R
- Other - D

**LITHOLOGIC DESCRIPTION**

**section 5, 260 cm through Core section 6:** NANNOSILOUS, white (N9) to very light gray (N8), homogeneous, with alternations of firm and stiff sediments. Rare light gray (N7) burrows and laminae.

**SMEAR SLIDE SUMMARY:**
- Texture: D
- Clay: R
- Heavy minerals: T
- Volcanic glass: T
- Foraminifers: R
- Calc. nannofossils: C
- Dolomite: D

**section 6, 260 cm through Core section 7:** VOLCANOGENIC TURBIDITES, grayish olive green (5GY 3/2) to dusky yellowish green (10GY 3/2) until 25 cm Section 3 then grayish olive green (5GY 3/2) to dark gray (N4). White (N9) veins of calcite are present. White (N9) laminae of nannofossil chalk in Section 3. Sediment generally normally graded. Cross-beddings are present in Core Catcher.

**SMEAR SLIDE SUMMARY:**
- Ceramic - D
- Fossil - T
- Foraminifers - R
- Other - D
LITHIFIED VOLCANOGENIC TURBIDITES, predominantly grayish-black (N2) with some grayish-green (6GY) hues. Spring colorations due to weathering. Lithology patterns of alternating units leading from one set of varved lithologies to the other, characterized by stylolitization and stylolites. Fuselike and stylolite-bearing sequences with some bioturbation. Surface is covered in a scraggly, crenulated and detrital matrix of glassy obsidian. Overall sedimentary structure is significant. A, B, and C divisions are prominent. Glassy rhyolite composition. Occasional vesicular texture. Core retains stratigraphic units, but at sections include brecciated material due to corenging and some bioturbation structures.

FORAMINIFER BEARING NANNOFORSE CHALK, grading with depth to NANNOFORSE, CHALK. Light greenish gray (6GY 6/1) to white (N9), varies from soft to hard (6GY 6/1) to chalk. Numerous light gray pale green (6GY 5/1) calcite spar layers (indications for an alteration products of smectite). Volcanic beds common and dappled between matrix. Vesicular texture common. Volcanic texture, indicated in Section 2, 07 to 10 cm. Chalk below this turbidite almost featureless. Microfractures in Section 3. Volcanogenic turbidite in Section 3.

SMEAR SLIDE SUMMARY:
Composition:
- Feldspar
- Carbonates
- Mica
- Pyrite
- Opal-carnschaarl
- Vesicles
- Chert
- Nannofossils
- Foraminifera

Macroscopic:
- Vesicular
- Nodules
- Chert
- Calcite
- Mica
- Pyrite
SITE 593 HOLE A CORE 1 CORED INTERVAL 0.0-7.7 m

FORAMINIFER-BEARING NANNOFOSSIL OOZE, light yellowish gray (5Y 8/2) to yellowish gray (5Y 8/1) to light gray (N7), soft, swirls and faint mottles.

SITE 593 HOLE A CORE 2 CORED INTERVAL 7.7-17.3 m

FORAMINIFER BEARING NANNOFOSSIL OOZE, very light gray (N8 to N9), soft, homogeneous. Zones of yellowish gray (5Y 7/2) and yellowish green (5GY 7/2). Mottled in places.
**SITE 593 HOLE A CORE 3 CORED INTERVAL 17.3-26.9 m**

**LITHOLOGIC DESCRIPTION**

FORAMINIFER-BEARING NANOFOSIL Ooze, soft, homogeneous with mottles of yellowish gray (5Y 8/1). Major lithology is very light gray (N8).

Ash in Sections 2, 3, and 4?

---

**SITE 593 HOLE A CORE 4 CORED INTERVAL 26.9-36.5 m**

**LITHOLOGIC DESCRIPTION**

FORAMINIFER-BEARING NANOFOSIL Ooze, very light gray (NB) to light gray (N7), soft, homogeneous. Interbeds of green ash (5GY 7/2) and pockets of forams and pyrites scattered throughout. Possible ash in Section 3.
<table>
<thead>
<tr>
<th>TIME SCALE</th>
<th>FOSSIL CHARACTER</th>
<th>GRAPHIC LITHOLOGY</th>
<th>LITHOLOGIC DESCRIPTION</th>
</tr>
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<tbody>
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<td>0.5</td>
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<td>5</td>
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</tbody>
</table>

**SITE 593 HOLE A CORE 5**

**CORED INTERVAL 36.5-46.1 m**

- **LITHOLOGIC DESCRIPTION**
  - Pockets of forams + pyrite?
  - FORAMINIFER-BEARING NANNOFossil ooze, very light gray (N8), soft, homogeneous, rare specks and diffuse bands of iron sulfides.

**SITE 593 HOLE A CORE 6**

**CORED INTERVAL 46.1-55.7 m**

- **LITHOLOGIC DESCRIPTION**
  - FORAMINIFER-BEARING NANNOFossil ooze, very light gray (N8), soft, homogeneous.
### SITE 593 HOLE A CORE 7
**CORED INTERVAL 55.7-65.3 m**

**LITHOLOGIC DESCRIPTION**

- FORAMINIFER-BEARING NANOFOSIL Ooze, very light gray (N8), soft, severe coring disturbance in at least first 3 sections, homogeneous. Pocket of foraminifera in Sections 2 and 4.

### SITE 593 HOLE A CORE 8
**CORED INTERVAL 65.5-74.9 m**

**LITHOLOGIC DESCRIPTION**

- FORAMINIFER-BEARING NANOFOSIL Ooze, very light gray (N8), soft, some dark (N6) blebs and streaks. Mottles faint but present, especially in Section 5.
FORAMINIFER-BEARING NANOFOSIL Ooze, very light gray (N8), soft, homogeneous, severe coring disturbance through almost entire core.
SITE 593 HOLE A CORE 11 CORED INTERVAL 94.1-103.7 m

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, very light gray (N8). soft, very homogeneous with only very rare iron sulfide (?) diffusion bands and pockets of grayish yellow green (5GY 7/2).

SITE 593 HOLE A CORE 23 CORED INTERVAL 448.8-458.4 m

LITHOLOGIC DESCRIPTION

NANNOFOSSIL OOZE, white (N9) to very light gray (N8), firm, homogeneous.

SMEAR SLIDE SUMMARY:

Clay
Compc
Quartz
Mica
Volcanic glass
Silt<
Calc. nannofossils

SITE 593 HOLE A CORE 24 CORED INTERVAL 458.4-468.0 m

LITHOLOGIC DESCRIPTION

FORAMINIFER-BEARING NANNOFOSSIL OOZE, (N9I to very light gray (N8I, firm, homogeneous.

SMEAR SLIDE SUMMARY:

Clay
Compc
Heavy mineral
Pyrite
Carbonate
Foraminifers
Calc. nannofossils.
<table>
<thead>
<tr>
<th>TIME BLOCK</th>
<th>SITE</th>
<th>HOLE</th>
<th>CORE</th>
<th>CORED INTERVAL</th>
<th>LITHOLOGIC DESCRIPTION</th>
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</thead>
<tbody>
<tr>
<td>0.5</td>
<td>SITE 593</td>
<td>HOLE A</td>
<td>CORE 25</td>
<td>468.6–477.6 m</td>
<td>FORAMINIFER-BEARING NANOFOSIL Ooze, white to light gray (N9) to light greenish gray (5GY 6/1). Fines are non-clastic. Light gray (N7) and dark gray (N3) and light greenish gray (5G 8/1) laminae are present.</td>
</tr>
<tr>
<td>1</td>
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</tbody>
</table>

SITE 593
HOLE A
CORE 26
CORED INTERVAL 477.6–487.2 m

LITHOLOGIC DESCRIPTION
FORAMINIFER-BEARING NANOFOSIL Ooze, light gray (N7), homogeneous, fine to silt, partly lithified. Rare light gray (N7), dark gray (N3) or light greenish gray (5G 8/1) laminae.
<table>
<thead>
<tr>
<th>Nannofossils</th>
<th>Foraminifers</th>
</tr>
</thead>
<tbody>
<tr>
<td>ooze, light greenish gray (5GY 8/1)</td>
<td>Carbonate, unspecified T/R</td>
</tr>
<tr>
<td>Section 1 (0.95), then white (N9), homogeneous, fir to stiff. Light gray (N7) and dark gray (N3) laminae occur</td>
<td>Foraminifers R/C T/R</td>
</tr>
<tr>
<td>Clay</td>
<td>Carbonate</td>
</tr>
<tr>
<td>Calc. nanofossils D D</td>
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</tr>
</tbody>
</table>
SITE 593 (HOLE 593)
SITE 593 (HOLE 593A)