5. SITE 584

Shipboard Scientific Party

HOLE 584

Date occupied: 5 August 1982
Date departed: 12 August 1982
Time on hole: 85 hr., 30 min.
Position (latitude; longitude): 40°28.0’N; 143°57.1’E
Water depth (sea level; corrected m, echo-sounding): 4078
Water depth (rig floor; corrected m, echo-sounding): 4088
Bottom felt (rig floor; m, drill pipe): 4124
Penetration (m): 941.0

Number of cores: 98
Total length of cored section (m): 478.7
Core recovery (%): 51

Oldest sediment cored:
Depth sub-bottom (m): 941.0
Nature: Mudstone
Age: early middle Miocene
Measured velocity (km/s): \( V_p = 2.00 \) (at 932 m sub-bottom)

Principal results: See Summary and Conclusions section.

HOLE 584A

Date occupied: 5 August 1982
Date departed: 12 August 1982
Time on hole: 10 hr., 24 min.
Position (latitude; longitude): 40°28.0’N; 143°57.6’E
Water depth (sea level; corrected m, echo-sounding): 4086
Water depth (rig floor; corrected m, echo-sounding): 4104
Bottom felt (rig floor; m, drill pipe): 4125
Penetration (m): 901.5

Number of cores: 3
Total length of cored section (m): 10.66
Core recovery (%): 37

Oldest sediment cored:
Depth sub-bottom (m): Core H4 (804.8 to 901.5 m sub-bottom)
Nature: Mudstone
Age: early middle Miocene
Measured velocity (km/s): \( V_p = 1.86 \) (at 796 m sub-bottom)

Principal results: See Summary and Conclusions section.

HOLE 584B

Date occupied: 15 August 1982
Date departed: 16 August 1982
Time on hole: 13 hr., 42 min.
Position (latitude; longitude): 40°28.0’N; 143°56.7’E
Water depth (sea level; corrected m, echo-sounding): 4086
Water depth (rig floor; corrected m, echo-sounding): 4096
Bottom felt (rig floor; m, drill pipe): 4152
Penetration (m): 954

Number of cores: 3
Total length of cored section (m): 22
Core recovery (%): 54

Oldest sediment cored:
Depth sub-bottom (m): 954
Nature: Paisley mudstone
Age: early middle Miocene

Principal results: See Summary and Conclusions section.

BACKGROUND AND OBJECTIVES

Drilling at Site 584 was devoted to the study of the structure and the evolution of the Japan Trench off Sanriku, Honshu, an area of concentrated study ever since modern geoscience began. Recently, the Japanese earthquake prediction project and the IPOD project have both focused research efforts on this area and have accumulated a wealth of information in the fields of seismicity, magnetics, heat flow, gravity, and petrology. The results of DSDP Legs 56 and 57 (Scientific Party, 1980) together with other studies are summarized as follows:

Late Cretaceous

The area around the Site 584 was the Cretaceous Sanriku-oki forearc basin (Ishiwada and Ogawa, 1976). Cretaceous rocks dip toward the island arc at an angle of 20°, reaching a total apparent stratigraphic thickness of 45 km. This great thickness cannot be accommodated by subsidence of normal crust and simple basin filling.
The landward-dipping section is probably tectonically repeated by thrust faulting and is perhaps an accretionary prism (von Huene et al., 1982). This basin may continue northward to the Yezo geosyncline developed in the Ishikari-Tomakomai lowland during the middle to Late Cretaceous, and southward toward the Kinkazan and Joban basins. Extensive arc volcanism took place during the Late Cretaceous, a time characterized by subduction, accretion, and arc volcanism (von Huene et al., 1982).

**Paleogene**

During the early Paleogene, subduction slowed considerably or stopped, as did arc volcanism, owing to a change from convergent to largely strike-slip plate motion (Kuwahara, 1982). A strike-slip motion of the Tanakura Fracture Zone reflects the movement on land (Kuwahara, 1982). The region near the site rose considerably, but whether it was eroded subaerially is not clear. The reason for this episode of relative uplift and erosion is not fully understood. On seismic profiles, the Paleogene formations are easily traced offshore of the Kinkazan-oki and Joban-oki basins.

**Early Miocene (22 to 15 Ma)**

Dacite boulders found at Site 439 were isotopically dated as 22 to 24 Ma old and were probably deposited soon after their initial extrusion (Shipboard Scientific Party, 1980a). Short-lived magmatic activity reported for the Ishikari-Tomakomai lowland during the deposition of Takinoue Formation (Fig. 1) might relate to the dacite boulders found at Site 439.

During this period, the forearc region began to subside. Arc volcanism was particularly active along the present “green tuff” region, and the Japan Sea basin was probably spreading.

**Middle Miocene (15 to 10 Ma)**

The forearc region continued to subside and its depocenter shifted seaward with time. The fundamental cause of this subsidence is not well understood. Tectonic erosion and sediment subduction are a possibility because no Miocene accretionary prism was found at the toe area (von Huene et al., 1982). A thermal origin of the subsidence in the upper plate is also a possibility (Burch and Langseth, 1981).

During this time (12 to 13 Ma) of warm to temperate climate, the first wave of the cold Oyashio flow arrived at this region (Koizumi et al., 1980). Porcellanitic and siliceous facies represent this event. This change is not as distinct in this area as in the Japan Sea, which was still actively rifting and spreading.

**Late Miocene (10 to 5 Ma)**

The orientation of dikes and faults indicates that the stress vector perpendicular to the trench axis was first tensional and then compressional. The tensional field developed as early as 21 to 16 Ma and lasted until about 7 to 6 Ma (Nakamura and Uyeda, 1980). On the present backbone range of the northeast Honshu, extensive dacitic eruptions and consequent formation of calderas were associated with the compressional stress interval (Nakamura and Uyeda, 1980).

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**Figure 1.** Restored geologic section in the southern Ishikari-Tomakomai lowland and dacitic volcanic activity during the time of deposition of the Takinoue Formation (Masatani, 1982).
Pliocene to Recent

Relative uplift of the forearc region began and caused steepening of anticlinal ridges and deepening of basins. The lower trench slope reached a maximum accumulation rate during the Pliocene, owing partly to biogenic siliceous productivity and partly to local slumping (von Huene et al., 1982).

The present stress fields are estimated from analyses of focal mechanisms (Nakamura and Uyeda, 1980). Normal faults offset the ocean crust near the trench axis, low-angle thrust faults develop frequently at the Eurasian and Pacific plate boundary, and dip-slip motions of either normal or thrust faults prevail under the trench slope. Explosive volcanism recurred between about 5 and 2 Ma.

Summary of Objectives

Our specific scientific objectives for drilling at the middle trench slope seaward of the known edge of the Oyashio landmass, an area that has alternately undergone rapid subsidence and uplift, are: (1) to recover a detailed stratigraphic record that will allow us to assess the role of tectonic erosion or sediment subduction using seismic reflection profiles; well-log records; heat flow measurements; and rates of sediment accumulation, convergence, and accretion (all values perhaps related to the horst and graben topography developed on the ocean crust and to the extensional first-motion solutions for the ocean crust underlying the trench); (2) to estimate the paleotopography, slope gradient (or depth of slope), and the migration of the Neogene depocenter through time; (3) to assess the deformational features of the middle trench slope deposits in time and space and to determine the stress field, which was presumably a continuation of both lithostatic and tectonic stress; (4) to establish a high-resolution stratigraphy using biostratigraphy, palaeomagnetics, tephrostratigraphy, and stable isotopes, in order to correlate that result with the record from Sites 438 and 439 and from the island arc of Japan, a task complicated by the slight difference in reported tectonic phases of uplift between the arc and the slope area; and (5) to determine whether, on the basis of authigenic analcime, some 2000 m of Cretaceous basement has been eroded or whether, on the basis of hornfelsic Cretaceous shale, the temperature decreased some 50° C since the early Miocene.

OPERATIONS

Driven from Site 583 by the approach of Typhoon Bess, the Glomar Challenger steamed northward for approximately five days en route to Site 584, only to be intercepted by the eye of the storm. Typhoon Bess, designated Typhoon 10 by the Japanese Meteorological Agency, had winds gusting to 70 knots and a minimum atmospheric pressure of 968 mbar.

Hole 584

Approaching Site 584, we commenced a survey on a course of 268° at 1412 (0512Z) on 4 August 1982 (Fig. 2). Underway geophysical gear was pulled in as we passed over the site. From 1600 (0700Z), the vessel held steady on a course of 093° with a speed of 4 knots and dropped a 16 kHz beacon at 1651Z (Fig. 3). The site is located at shot point 270 on ORI 78-3 line (see Fig. 3A); its position is 40°28.0'N, 143°57.1'E.

A mudline core established the depth as 4114 m, measured by meters of drill pipe from sea level, which agrees with the precision-depth-recorder (PDR) depth of 4116 m to within 2 m. This PDR depth, however, corresponds to the second reflector, the shallowest being from 4088 m.

After continuously coring to 77 m sub-bottom with fairly good recovery (Table 1), we lowered the first heat-flow-pore-water-pressure-measuring instrument (HF-PW-PMI) down the pipe and collected in situ pore water, but the instrument failed to record temperature and pressure because of electrical problems. The experiment was repeated at 153.7 m sub-bottom with worse results. The needle of the probe bent when caught in the float valve, causing a circuit malfunction.

The bottom-hole assembly was stable with a drift angle of 2° at 29.4 m and again at 15.37 m sub-bottom. Low recovery between 50 to 60 m sub-bottom may have been due to a carbonate nodule, and between 130 to 170 m to soft and watery sediments, probably related to coarse-grained ash layers. Drill mud was first pumped at 221.3 m sub-bottom in an effort to clear the hole.

A third HF-PW-PMI probe was lowered to a depth of 230.8 m sub-bottom. The electrical circuit was reactivated when the pressure valve opened, therefore no reliable data were obtained. Pore water intake was blocked by clay at the filter. A fourth probe at 287.8 m sub-bottom finally “scored the hat trick.”

Inclination of the beds gradually steepened downhole below 300 m sub-bottom. Hole drift angles were measured as 2° at 402.6 m and as 2.5° at 508.1 m. Drilling character indicated softer intervals between Cores 46 and 47 and very fine sand layers were encountered in Core 48 (460 m sub-bottom). Below 584 m sub-bottom, the hole angle was still stable 2°, but the formation became progressively harder with intercalated silty layers, and core recovery decreased gradually downhole. Occasionally, the hole filled with cuttings, and it required periodic mud flushes.

Coring recovery improved again when the hole penetrated into middle Miocene sediment (757.5 m sub-bottom) (Table 1). The drift angle of the hole varied from 2° at 719.1 m to 1.5° at 815.5 m. By 2325Z on 10 August, the pipe had penetrated to 883.1 m, recovering lower middle Miocene mudstone with almost 70° inclination of bedding. At 941.0 m sub-bottom, the pipe nearly became stuck in about 8 m of hole fill, despite mud flushing between every core. Apparently, the trouble came from a interval at ~900 m sub-bottom, where the hole finally bridged after several hours of maneuvering to clean it. From the appearance of the core, an intensely fractured shear zone may occur in this interval. The hole was terminated and the pipe was retrieved above mudline by 1800Z on 11 August.

Hole 584A

The vessel began offsetting westward to Hole 584A at 1810Z and arrived at the new position of 40°28.0'N, 143°57.6'E. This location is 524.2 m west of the Site.
Figure 2. Site 584 approach track; location of Site 584. Times are local times. Inset figure is Leg 87 site location map. C/C = course change, C/S = change speed, SNF = satellite navigation fix, DR = dead reckoning.

Figure 3. Glomar Challenger 3.5-kHz seismic profile, showing the relative positions of Holes 584, 584A, and 584B.
### Table 1. Coring summary, Site 584.

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<th>Time (L.)</th>
<th>Depth from drill floor (m)</th>
<th>Depth below seafloor (m)</th>
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**Table 1. (Continued).**

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**SITE 584**

The vessel started offsetting from the Site 584 beacon at 1331Z on 14 August, and arrived at the new hole 584 beacon and the same distance away from Hole 584, which is located at the beacon. The location was selected to delineate the structural continuity of Hole 584, to determine the local structure, and in particular, to penetrate deeper than Hole 584. Because all bedding observed at Hole 584 is inclined east or northwest, westward offsetting was chosen in the hope of intercepting like horizons at shallower sub-bottom levels.

The drill string spudded in at a depth of 4115 m at 2011Z on 11 August. The PDR depth indicated 4094 m but the next deep reflector was 4117 m corresponding well with the drill pipe length. The hole was washed down to 602 m.

Core 1 was recovered from the depth of 611.8 m; its equivalent uppermost Miocene stratigraphic horizon in Hole 584 is some 50 m deeper. Another 100 m was washed down before taking Core 2 at 708.4 m sub-bottom. This core again indicated a 50-m stratigraphic offset. Core 3 was recovered from 804.8 m and is middle Miocene in age. Another 100 m was washed down, then Core H4 was retrieved from 901.5 m, the same lower-middle Miocene stratigraphic horizon as at Hole 584. Attempts to drill Core 4 were unsuccessful, because of a highly fractured zone, encountered near 870 m sub-bottom. Ultimately, the drill pipe stuck at 890 m at 0700Z, Friday, 13 August. After the pipe was freed, a shifting tool was pumped down, and the mechanical bit released at 0944Z in preparation for logging. After filling the hole with heavy mud, the pipe was pulled up to 120 m sub-bottom. Sonic and induction logs were run, but the tools malfunctioned. The second run (density, neutron, gamma ray, caliper) recorded data down to 495 m sub-bottom, at which point the hole was bridged. During a repeat run, the hole bridged at near 435 m sub-bottom. The sonde was on deck at 0415Z on 14 August, and the drill pipe was on deck at 1328Z the same day.

**Table 4**

Hole 584B

The vessel stopped offsetting from the Site 584 beacon at 1331Z on 14 August, and arrived at the new hole...
SITE 584

701.2 m to the east of the Site 584 beacon at 1325Z. Hole 584B is located at 40°28.0'N, 143°56.7'E. This position was selected to delineate the structural continuity of bedding inclination and of the paleontologic horizons from Hole 584, and, above all, to penetrate deeper.

After two water cores, the drill string spudded in at a depth of 4142.0 m. Evidently, PDR depth of 4113 m is not true bottom, but a second reflector from 4139 m does correspond to the drill pipe length to within 4 m. The hole was washed down to 509.7, then to 644.1 m sub-bottom. A spot core was taken at 644.1 to 653.8 m sub-bottom interval for stratigraphic control. Other wash cores were retrieved from 846.8 and 943.1 m sub-bottom. During the attempt to retrieve the last core barrel, the drill string began torquing and the pump pressure climbed. With time for Leg 87 fast running out, the final core was cut at 954 m. The hole was then filled with weighted mud. The pipe cleared mudline at 1657Z on 16 August and the bit was on deck at 1900Z.

The vessel, sounding its fog signal, left Site 584B at 2315Z on 16 August.

SEDIMENTOLOGY

Introduction

Hole 584, drilled about 42.5 km upslope from a mid-slope terrace, penetrated 941 m of Pleistocene to middle Miocene diatomaceous argillites. Variations in diatom content, number of ash beds, abundance of thin silt and very fine sand beds, abundance of pumice granules, and intensity of bioturbation enable us to distinguish three distinct lower Pliocene and Miocene units, divided into seven subunits (Fig. 4; Table 2). The thin Pleistocene mud at Site 584 (less than 4 m in Core 1) composes a fourth unit. Though we were unable to distinguish it visually from the soft lower Pliocene mud that it overlies in Hole 584, we assign the Pleistocene to a separate unit because the first wash core of our spot-coring program nearby in Hole 584A yielded a noticeably sandy Pleistocene mud. Most of the Hole 584 section is lower Pliocene and upper Miocene. The entire upper Pliocene and the upper part of the lower Pliocene are missing; this sequence may once have amounted to as much as several hundred meters of sediment or may never have been deposited.

We emphasize that unit or subunit boundaries are nowhere completely sharp. Many of the features that we use to subdivide our essentially rather monotonous muddy diatomaceous ooze section at Site 584 are minor components of the section. We expect some variation in any lithologic correlation with other drill sites in the Honshu forearc.

We will first describe the lithostratigraphy of Hole 584, then analyze the lithostratigraphic correlation of spot cores taken in Holes 584A and 584B. Next we will comment on ash content and on the evidence for late Miocene redeposition in the Site 584 area, and briefly describe the diagnostic abyssal Chondrites-Zoophycos, Planolites-Cylindrichnus ichnofauna that was beautifully preserved throughout the 584 section.

Strata below about 250 m sub-bottom (lower Pliocene) contain claystone-filled veins that cut bedding sub-perpendicular or at high angles (for details see following discussion of structural geology). The majority of these healed fractures indicate extension where offsets are evident, a conclusion supported by a spectacular fracture-fill system at 673 m sub-bottom (Core 584-71-2, Fig. 20). Anastomosing claystone-filled veins of probable dewatering origin, most commonly perpendicular to bedding, occur below 400 m (Core 584-42). The entire Miocene section is tilted from low to high angles (up to 70°), with an overall tendency for dip angle to increase downslope.

Throughout the descriptions below, core numbers refer to Hole 584 unless otherwise indicated.

Unit 1 (0 to 4 m sub-bottom, Sections 584-1-1 to 584-1-3)

Quaternary, dark olive gray diatomaceous mud occurs in the first three sections of Core 1, and the remainder of the core is lower Pliocene. Soft, locally soupy, sediments do not preserve an obvious lithologic or structural break between the two series. A thick glauconite layer at Core 584A-H1 marks a sharp break between Quaternary and lower Pliocene sediments.

Unit 2 (4 to 240.3 m sub-bottom, Section 584-1-3 to bottom of Core 25)

Predominantly olive gray diatomaceous mud and mudstone, Unit 2 is distinguished from Unit 3 by the paucity of sand and silt layers, and by the absence of dipping strata.

Subunit 2a (4 to 173.1 m sub-bottom, Section 584-1-3 to bottom of Core 18)

This subunit consists of lower Pliocene bioturbated dark olive gray to olive gray diatomaceous mud and local muddy diatomaceous ooze, consolidating below 88 m (Core 10) to diatomaceous mudstone and local muddy diatomite. Diatom contents locally in excess of 60% require that in places we call this sediment muddy diatomite (see Explanatory Notes chapter, this volume), but most of the section is diatomaceous mudstone. Smear-slide observations and X-ray diffraction analyses (see Inorganic Geochemistry section) define a continuous decreasing trend in the relative abundance of diatoms and opal-A throughout the Hole 584 units. Olive gray is the dominant color, but mottling to various hues of olive and gray occurs throughout the unit. Color mottling in places takes the form of obvious sharp burrow outlines and is clearly a manifestation of bioturbation; commonly mottling is more abstruse and less clearly associated with burrowing. Some light olive gray mottles are slightly calcareous, containing nanofossil concentrations of up to about 5% (e.g., Sections 584-13-2 and 584-13-4). Local vague lamination, defined by slight color changes in the mud, survives bioturbation.

Burrow forms include Chondrites, and minor Zoophycus and Cylindrichnus. The most common form is a large (up to 1 x 2 cm) Planolites trace. In such burrows, a common olive or pale olive color reflects slightly elevated diatom contents and/or a calcareous content (nanofossils or irresolvable micrite). Burrow margins are
Subunit 2b (173.1 to 202.1 m sub-bottom, Cores 19 to 21)

This subunit contains lower Pliocene light olive gray to olive gray firm laminated diatomaceous mudstone, only locally bioturbated. Thin (1 to 3 mm) laminations of lighter-colored diatom-rich sediment alternating with more muddy laminae predominate in Cores 19 to 21. A strong H₂S odor, local dark organic-carbon-rich streaks, and pyritic laminae combine with local burrowing to indicate a period of relative oxygen-impoverishment in the bottom waters. The parallel-laminated sections are interlayered with burrowed levels, and the burrows in Section 584-20-2 attain the large dimensions of the best-developed examples of Planolites in the previous unit. The most complete laminated interval occupies Sections 584-20-1 to 584-20-5.

Other features of Subunit 2a persist: several thin ash layers, and a very fine sand layer in Section 584-20-2. Sponge remains occur in Core 20. Slight fissility is developed in Sections 584-20-5 and 584-20-6.

The laminated nature of this unit may indicate that diatom productivity fluctuated in the Pliocene waters off Honshu, explaining the alternation on a millimeter-scale of thin laminae rich in diatoms and more muddy sediment. If so, evidence of such a means of sedimentation would have been obliterated by burrowing or drilling deformation in the majority of the section at Site 584.

Subunit 2c (202.1 to 240.3 m sub-bottom, Cores 22 to 25)

Like Subunit 2a (lower Pliocene), Subunit 2c marks a return to well-aerated bottom conditions, with bioturbation generally prominent in the mud. Most of the features listed for Subunit 2a occur also in 2c. Fine sandy layers up to 1 cm are a minor feature of Cores 22, 24, and 25. In Core 24, a diffuse concentration of fine-sand grains includes quartz, feldspar, brown and green hornblende, and plant debris. In Section 584-24-2 a large pumice clast (8 × 5 mm) occurs, and in Section 584-24-3 more than 14 ovoid to flattened pumice granules are concentrated in a 15-cm interval, perhaps representing transported ejecta from one major arc eruption.

The top of Core 25, the last belonging to Subunit 2c, contains granules and pebbles (28 mm maximum) of red chert, limestone, sandstone, siltstone, shale, and dacite. Although this segment is probably best interpreted as hole cavings, it is surprising that we recovered no exotic pebbles or granules in our in situ Pleistocene recovery (Core 1).

Unit 3 (240.3 to 536.6 m sub-bottom, Cores 26 to 56)

Predominantly dark olive gray to olive gray diatomaceous mudstone, Unit 3 is distinguished from Unit 2 by relatively common thin fine sand and silt beds, and scattered concentrations of grains in mudstone, especially in Subunit 3b. Strata are inclined and contain healed fractures. Unit 3 is distinguished from Unit 4 by higher diatom content, more abundant ash layers, and relative abundance of large carbonate-rich burrow mottles.

Subunit 3a (240.3 to 354.6 m sub-bottom, Cores 26 to 37)

This subunit contains lower Pliocene diatomaceous mudstone, noticeably more indurated than Subunit 2c, with inclined beds and healed fractures. There is little difference in lithology between Subunits 3a and 2c. Most significant, however, is the appearance of inclined bedding in Core 26. Slightly inclined lamination is visible locally in Core 24, but in Core 26 and below, to the base of the hole, all bedding traces (sandy layers, lamination, and, most commonly, burrow alignments) are inclined. The sediments first merit description as completely lithified rock in Core 27. Although the lithologic contrast is not marked, we choose to distinguish Units 2 and 3 because the inclined bedding would be an easily mappable...
Figure 4. A. Summary lithology for Sites 438, 439, 435, 440, and 584, visual smear-slide estimates, and number of ash layers per Ma for Site 584. T.D. = total depth. B. The frequency of volcanic activity through time, as recorded in ash layers at Site 584. Inset figure is the plot of number of ash layers per year versus sub-bottom depth and stratigraphic assignment (based on diatoms).
Additionally, we suspect that Core 25, as a zone of poor recovery with abundant hole cavings in a portion of the section otherwise characterized by excellent recovery, may represent a tectonic break of some kind.

Burrows are abundant throughout. Many are large *Planolites* traces, more olive than the surrounding mudstone, imparting a characteristic greenish gray and olive blotchy appearance to the sediment. *Zoophycos* trails pick out the bedding clearly, in all but a very few cases being exactly parallel to fine-sand layers and laminations.

Thin ash beds are common in Subunit 3a, though pumice granules are less common than in Unit 2, occurring only in Cores 27, 30, and 37.
Table 2. Lithologic units, thickness, age and description for Hole 584.

<table>
<thead>
<tr>
<th>Lithologic unit (Thickness in m)</th>
<th>Core or Section</th>
<th>Sub-bottom depth (m)</th>
<th>Age</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1 (4)</td>
<td>1-1 to 1-3</td>
<td>0 to 4</td>
<td>Quaternary</td>
<td>Dark olive gray diatomaceous mud—erratic pebbles?</td>
</tr>
<tr>
<td>Unit 2 (236)</td>
<td>1-3 to 25</td>
<td>4 to 240.3</td>
<td>early Pliocene</td>
<td>Predominantly olive gray diatomaceous mud and mudstone; distinguished from Unit 3 by paucity of sand and silt layers, and by absence of dipping strata.</td>
</tr>
<tr>
<td>Subunit 2a (169.1)</td>
<td>1-3 to 18</td>
<td>4 to 173.1</td>
<td>early Pliocene</td>
<td>Dark olive gray to olive gray diatomaceous mud and local muddy diatomaceous ooze, consolidating below 88 m (Core 10) to diatomaceous mudstone and local muddy diatomite; bioturbated throughout.</td>
</tr>
<tr>
<td>Subunit 2b (29)</td>
<td>19 to 21</td>
<td>173.1 to 202.1</td>
<td>early Pliocene</td>
<td>Light olive gray to olive clay firm laminated diatomite and diatomaceous mudstone; only local bioturbation.</td>
</tr>
<tr>
<td>Subunit 2c (28.7)</td>
<td>22 to 25</td>
<td>202.1 to 240.3</td>
<td>early Pliocene</td>
<td>Like Subunit 2a—some pure sandy layers.</td>
</tr>
<tr>
<td>Unit 3 (305.8)</td>
<td>26 to 56</td>
<td>240.3 to 536.6</td>
<td>early Pliocene to late Miocene</td>
<td>Predominantly dark olive gray to olive gray diatomaceous mudstone; distinguished from Unit 2 by relatively common thin fine sand and silt beds, and scattered concentrations of grains in mudstone especially in Subunit 3b; strata inclined, with healed fractures; distinguished from Unit 4 by higher diatom content, more abundant ash layers, and relative abundance of large carbonate-rich burrow mottles.</td>
</tr>
<tr>
<td>Unit 4 (404.4)</td>
<td>57 to 98</td>
<td>536.6 to 941.0</td>
<td>late to middle Miocene</td>
<td>Predominantly diatomaceous mudstone and mudstone (various green, gray, olive, and bluish hues); lower diatom content (and very minor olive burrow mottles) and fewer ash layers than Unit 3.</td>
</tr>
<tr>
<td>Subunit 4a (153.6)</td>
<td>57 to 71</td>
<td>536.6 to 680.6</td>
<td>late Miocene</td>
<td>Intensely bioturbated predominantly dark olive gray diatomaceous mudstone; sandy layers continued from Subunit 3a, but much more abundant, commonly graded, and in some cases overlain by gray, relatively structureless mudstone (probably muddy turbidites).</td>
</tr>
<tr>
<td>Subunit 4b (250.8)</td>
<td>72 to 98</td>
<td>680.6 to 941.0</td>
<td>late and middle Miocene</td>
<td>Intensely bioturbated diatomaceous mudstone, varicolored including dark greenish gray, grayish olive green, local dusky green, and olive gray streaks, with abstruse bluish hues, especially in lower cores; reduced number of sandy and silty layers, minor mud turbidites.</td>
</tr>
</tbody>
</table>

Glaucophitic spots (Core 37), pyritic streaks and laminae (Cores 29, 35, and 36), flecks of organic carbon (Core 34), sponge spicules, and wood flakes (Core 37) are minor features of the section. Another barite nodule, similar to the one seen recovered in Subunit 2a, occurs at 283 m sub-bottom (Section 584-30-4). Subunit 3b (354.6 to 536.6 m sub-bottom, Cores 38 to 56)

This subunit consists of upper Miocene highly bioturbated olive gray diatomaceous mudstone. There is a progressive increase in fine sand and silt with increasing sub-bottom depth.

The Pliocene/Miocene boundary occurs between 584-38,CC and 584-39,CC: the absence of an obvious lithologic contrast in Core 39 suggests that the transition is not marked by a hiatus in sedimentation. In Section 584-38-2, very fine sand is scattered in the mudstone. In Section 584-38-3, a thin, very sandy layer occurs in association with a very diffuse slight increase in sand comprising grains of volcanic glass, quartz, and feldspar. Below this level, sand and silt become progressively more important, but do not approach the status of the other major constituents.

Large olive-colored burrows are abundant and some of the best examples of their serrated form occur in Core 52 (Fig. 5). These occur in discrete intervals throughout the subunit and are generally richer in carbonate than the surrounding groundmass. At 522 m (Section 584-55-4), a 30-cm olive interval comprises calcareous matrix as well as burrow fills. Smear slides show that carbonate is a finely disseminated micrite.

Minor components of Subunit 3b are glauconite (nucleated on dark organic matter in Core 43), and a shell fragment, possibly from a gastropod, at 442 m sub-bottom (584-47-1, 120 cm). Sponge spicules are less common in this subunit than anywhere else, occurring only in Cores 38, 43, 47, and 53. Most of the sand is very fine grained, occurring as thin abstruse layers or being finely

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3 The position of the Pliocene/Miocene boundary was revised several times after the initial shipboard analyses. That contact is now placed between Cores 45 and 46. For details, see Akiba (this volume).
Figure 5. Serrated burrows in Core 584-52.

disseminated in the mud, probably as a result of bioturbation. The coarsest occurrence is at 402.5 m, a 5-cm soft coarse muddy sand in the core catcher of Core 42. In Section 584-36-4, two distinctive coarse pumiceous sand beds occupy 13 cm of section. Both have sharp bases and are mud rich. Their coarse to medium grains are distribution-graded. They may represent low-density muddy turbidity currents, capable of grading sand of up to coarse grain size because of the low density of pumice.

Unit 4 (536.6 to 941 m sub-bottom, Cores 584-57 to 584-98)

This unit contains upper to middle Miocene predominantly diatomaceous mudstone and mudstone (various green, gray, olive, and bluish hues). It has a lower diatom content (and very minor olive burrow mottles) and fewer ash layers than Unit 3.

Subunit 4a (536.6 to 680.6 m sub-bottom, Cores 57 to 71)

Upper Miocene intensely bioturbated diatomaceous mudstone, predominantly dark olive gray, composes this subunit. Sandy layers continue from Subunit 3a, but are much more abundant, commonly graded, and in some cases are overlain by gray relatively structureless mudstone (probable muddy turbidites).

The large olive mottles so prominent in Core 56 are missing in Core 57 and do not reappear. Two further examples of the olive carbonate-rich horizons seen in Subunit 3b (Core 55) occur. The first occupies 12 cm of section in Section 584-58-1, the second 30 cm in Section 584-63-3. A 2-cm limestone concretion occurs at 594 m (Core 63-1).

The first clear example of a muddy turbidite occurs in Core 57 (Fig. 6). These deposits are discussed in a later part of this section.

Subunit 4b (680.6 to 941 m sub-bottom, Cores 72 to 98)

This upper and middle Miocene diatomaceous mudstone, varicolored including dark greenish gray, grayish olive green, local dusky green, and olive gray streaks, with abstruse bluish hues (especially in lower cores), is intensely bioturbated. The numbers of sandy and silty layers and minor mud turbidites are reduced.

Subunit 4b commences in Core 83, where the diversity of colors, bioturbation, and intense dewatering veinlets led us to christen the facies “paisley” mudstone. Diatom and opal-A concentrations are higher than in Subunit 4a (Fig. 4). Pumice granules are more common than in 4a, but ash layers are still few (Cores 83, 88, and 89). Mud turbidites are limited to Core 95. An interesting 4-cm olive calcareous bed (and underlying burrow fill) at 626.7 m (Section 584-87-2) and a 4-cm-thick dolomitic sandy mudstone bed at 903 m sub-bottom (Section 584-95-1, Fig. 7) may be carbonate turbidites; the bases are sharp, and tops gradational. Smear slides show no nannofossils and structureless clay-grade carbonate. Glaucosotel concentrations are more common than in any of the previous subunits, locally tinting the sedi-
Figure 6. Mud turbidites in Core 584-57. Sub-bottom depth = 536.6-546.1 m.
1. 1-mm dark mudstone lamination with micro-offsets on dewatering veinlets (total <1 mm across the 27 mm exposed).
2. 7-mm layer of silt-to-medium sand grains; relatively sharp base, gradational top, but entirely mud-supported.
3. 22-mm sandstone, distribution-graded and size-graded, dusky yellow and dark gray medium-to-coarse grains, dusky yellow grains coarser, and concentrated at base.
4. Boundary between paisley and homogeneous facies gradational, drawn at base of Chondrites occurrences.
5. Irregular silty layer, 1—6 mm.
6. Stepped, irregular offset of 1—2 mm darker mudstone lamination.
7. Scattered silt to very coarse sand grains—vitric and sponge fragments.
8. Facies boundary gradational, drawn at base of abundant Chondrites (these become progressively less common downwards into homogeneous mudstone).
9. In homogeneous mudstone, minor trace fossils occur, as illustrated.
10. Faint parallel lamination.
11. Minute Zoophycos (vague) and Planolites (rind-type).
12. Mechanical break in archive half, part of depositional contact visible in working half.
13. Silty laminae.
14. Silt to very fine sand grain concentration, as 2 above.

**Idealized sequence:**

<table>
<thead>
<tr>
<th>Predominantly homogeneous mudstone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mottled and bioturbated mudstone ('paisley' units... dominant lithology in cores)</td>
</tr>
<tr>
<td>Dewatering veinlets</td>
</tr>
<tr>
<td>Dark seams (healed fracture fill)</td>
</tr>
<tr>
<td>Lamination</td>
</tr>
<tr>
<td>Mechanical break in section</td>
</tr>
<tr>
<td>Sand</td>
</tr>
<tr>
<td>Silt</td>
</tr>
<tr>
<td>Chondrites</td>
</tr>
<tr>
<td>Zoophycos</td>
</tr>
<tr>
<td>Planolites</td>
</tr>
</tbody>
</table>

Figure 7. Detailed description of lithology, structure, and ichnofacies of Section 584-95-1. Numbers refer to features discussed in text.

Green mottling (vague or no burrows) Chondrites Structureless mud

Hole cavings, including limestone pebbles, occur at the top of Cores 84 and 92.

**Spot Cores and Wash Cores at Holes 584A and 584B:**
**Description and Correlation with Hole 584**

We sampled the Miocene section briefly in holes 524 m upslope (Hole 584A) and 700 m downslope (Hole 584B).
of Hole 584. Despite steep dips in all cores recovered, the lithologies correlate remarkably well with those retrieved at similar depths in Hole 584 (Fig. 4).

Core 584A-1 (602.2 to 611.8 m sub-bottom), taken at the equivalent level of middle Subunit 4a, recovered classic "mud turbidite" facies of Subunit-4a type. Several thin sand layers are overlain by graded silty mudstones, with Chondrites-burrowed tops. This facies is superbly preserved in the next core, Core H2 (611.8 to 698.8 m sub-bottom), which most likely represents the section immediately below Core 1 (about 615 m; A. C. Wheeler, Jr., drilling superintendent, pers. comm.). Some of these mud turbidites are illustrated in Figures 6 and 8 and discussed in the Upper Miocene Mud Turbidites section.

Core 584A-2, 698.8 to 708.4 m sub-bottom (a level equivalent to the top of Subunit 4b), recovered grayish olive burrow-mottled mudstone with common Zoophycos traces and dewatering veinlets. The absence of sand in this core, and the fact that it does not possess the typical "paisley" mudstone attributes of the lower portion of Subunit 4a are consistent with a position in the upper part of the subunit. Wash Core H3 (708.4 to 795.1 m sub-bottom) contains a similar facies to Core 2; it includes a well-developed healed fracture network and a thin ash layer.

Core 584A-3, 795.1 to 804.8 m sub-bottom (a level equivalent to the middle portion of Subunit 4b), contains many though not all the attributes of the "paisley" mudstone facies. It is a dark olive gray bioturbated mudstone with common Zoophycos traces, healed fractures, and microveins. Blue green hues in the mudstone from Core 584A-H4 (804.8 to 901.5 m sub-bottom) are even more reminiscent of the "paisley" mudstones.

Hole 584A caved in at about 890 m sub-bottom, several tens of meters higher than had been the case in Hole 584.

The first core in Hole 584B (0 to 1.4 m sub-bottom) recovered soupy surface diatomaceous mud. Wash Core 584B-H1 (1.4 to 509.7 m) retrieved coarse vitric sand with a variety of granules and pebbles, and included a light yellow calcareous layer, which conceivably derives with a variety of granules and pebbles, and included a light yellow calcareous layer, which conceivably derives from the same level as the prominent carbonate layer in Subunit 2a in Hole 584 (Section 584-9-1, 77 m sub-bottom).

Diatomaceous mudstone in Core 584B-H2 (509.7 to 644.1 m sub-bottom) makes up a well-preserved and nearly complete section containing large yellow serrated burrow fills typical of Subunit 3b (see Fig. 5). The lithologic correspondence of these features suggest that the core derives from the top of the washed interval, at a depth equivalent to the lower part of Subunit 3b.

Core 584B-2, 644.1 to 653.8 m (a level equivalent to the lower middle portion of Subunit 4a in Hole 584), recovered sediment devoid of the large olive serrated burrows. Next, a wash core H4 (655.8 to 846.8 m sub-bottom) contains splendidly preserved mud turbidites facies, suggesting that it derives from the top of the washed interval, at a level equivalent to the lower part of Subunit 4a. Numerous thin, fine sand layers grade into dark silty mudstone and mudstone layers, commonly with Chondrites-burrowed tops, in Core H3. Well-preserved cross}

lamination, minute mudstone rip-ups, and a small-scale slump fold (overturned up-dip!) strongly argue for a turbiditic origin for these cyclic beds.

Wash Core 584B-H4 (846.8 to 943.1 m sub-bottom) recovered classic "paisley" mudstone facies at the same depth as it occurs in Hole 584. The greenish gray, bluish gray, and locally olive gray hues, intense anastomosing veinlets, and abundant burrows with common Zoophycos make this a highly distinctive rock type that would be worthy of ornamental stone if exposed on land.

Core 584B-3 recovered more "paisley" mudstone between 943.1 and 945.0 m sub-bottom. Hole 584B caved, 13 m deeper than in Hole 584. Three hole cavings at the same depth along a 1-km line perpendicular to the trench is surely significant (see Structural Geology section, this chapter). In the words of the eminent British philosopher James Bond, "Once is happenstance, twice is circumstance, three times is enemy action."

Volcanogenic Sediments

The Japan Trench provides an excellent opportunity to examine the Tertiary and Quaternary record of explosive volcanic activity of the Tohoku (northeastern Japan) Arc preserved at Site 584, located downwind, approximately 300 km to the east, from the volcanic source area. The history of explosive volcanism is related to tectonic processes occurring on the active margin.

Volcanogenic sediment recovered at Site 584 includes pumice fragments, distinct ash layers, bioturbated ash "pods" or "pockets," and dispersed glass shards. Pumice fragments were probably transported primarily by surface currents or by wind, eventually becoming waterlogged and sinking through the water column. These fragments are present more or less throughout Site 584 sediments and are abundant in some cores (e.g., Cores 1, 10, 11, and 37). Their shape is variable, generally rounded, sometimes angular, ranging from 1 mm to 5 cm in diameter. They are white or whitish gray in color and show typical degassing structure.

Volcanic ash layers are numerous (more than 100). Most of the ash is probably deposited by settling through the water column after being transported to the area through the atmosphere by the prevailing westerlies. Graded beds are frequent, however, and ash is sometimes intimately mixed with terrigenous or biogenic components, suggesting redistribution and resedimentation by either turbidity currents or other bottom currents. Thickness of these ash horizons is also very variable, but generally they are thin (2 to 3 cm) because of their distance from the volcanic arc. Some layers are as much as 10 cm thick (Sections 584-16-2; 584-38-2; and 584-53-2), with a maximum thickness of 20 cm (Section 584-17-3). Color ranges from dark gray to bluish gray (2.5Y 4/2), light gray, and white; coarser horizons (sandy or silty) appear to be darker in color than the finer-sized deposits. Bioturbation and mottling of the ash-containing sediments occurs frequently (Sections 584-15-3 and 584-15-4; and 584-24-4), and ash layers are redistributed as pods or pockets. Burrow fillings composed almost wholly of ash are also common and are usually found in the sediments immediately beneath the ash layers.
Optical petrography of the glass shards shows two different shapes: bubble wall and pumice types, as angular and elongated grains. These shards are translucent and isotropic, and they have low refractive indexes. Compositions are estimated visually to be primarily dacitic, rhyodacitic, and rhyolitic. Minor occurrences of dark to pale brown shards dispersed throughout the cores are more basic in composition (basaltic to andesitic). Grains are mostly of silt-sized clear glass shards, suggesting transport over a considerable distance from the volcanic source region. Phenocrysts range in abundance from 2 to 3% to a maximum of 20%, and consist mainly of quartz, plagioclase, brown and green hornblende, biotite, clino- pyroxene, and opaque minerals. Rarely, they include large amounts of tiny round pyrite micronodules. Sand-sized volcanic ash layers often include variable amounts (from 10 to 25%) of lithic fragments, diatoms, and sponge spicules.

In addition to the occurrence of volcanic ash as distinct layers, small amounts of glass shards (0 to 3%) are dispersed within the sediment. Variation of the dispersed component with sub-bottom depth follows the number...
of volcanic ash layers. Where distinct ash layers are abundant, slightly higher concentrations (from 10 to 30%) of dispersed shards occur in adjacent sediments, as determined by smear-slide observations.

Alteration of the volcanic glass shards is negligible throughout. Petrographic examination of glass shards as old as middle Miocene (the oldest sediment penetrated at this location) shows them to be optically isotropic and virtually unaltered.

The occurrence and distribution of volcanic ash layers in these sediments record episodes of explosive volcanism along the Japanese island arc. More than 200 distinct volcanic ash units were recovered in the various sites drilled during DSDP Legs 56 and 57; the data were used in establishing curves correlating frequency with age of the volcanic activity. Analysis of the distribution of the volcanic ash layers in Hole 584 sediments (Fig. 4A) shows that they are mainly concentrated between Cores 3 and 6 and between 33 and 43, and they are scarce below Core 63 (Fig. 4A). The number of volcanic ash layers reaches a distinct maximum in the Pliocene sediments of Cores 33 to 43 (Fig. 4B and Fujioka, this volume). This concentration of ash units strongly suggests an increase in volcanic activity since the early Pliocene. This pattern is quite similar to the results obtained at Sites 438 and 440, Leg 57 (Shipboard Scientific Party, 1980a, c) where volcanic ash abundance begins to increase at the end of Miocene and remains high during the first two-thirds of the Pliocene. After a period of decreased abundance, ash layers are again numerous in the upper Pleistocene.

The history of late Pliocene and Quaternary explosive volcanism in this area is poorly known because of the scarcity of data; at Site 584 the thickness of Quaternary sediments is only about 4 m, and no volcanic ash layers were found within this interval. Leg 56-57 sites having thick Quaternary sections show a slightly higher concentration of volcanic ash layers. Also, in the nearshore Japan Trench region, several diagnostically volcanic ash layers were obtained by piston coring (Ocean Research Institute Cruise reports, Cruses KH80-1, KH81-3, in prep.; Cruise KH77-1, Nasu et al., 1980). By their chemical composition, these tephras were correlated with the eruption of the Towada volcanoes (about 26,000 yr. and younger). In the northeastern Japan Arc, many active volcanoes are known, and Towada, Iwaki, Nasu, and Chokai are just a few examples. Therefore, high concentrations of acidic volcanic ash layers are expected in the Quaternary sediments. Evidently, explosive volcanism was much more intense during the Pliocene than in the Quaternary (Cadet and Fujioka, 1980), a conclusion tentatively confirmed by our drilling in the Japan Trench during Leg 87.

Upper Miocene Mud Turbidites

In Subunit 4a, and to a lesser extent in 4b, thin sandy beds are in places overlain by several decimeters of structureless or less than normally bioturbated mudstone, darker than the normal mudstone. A crude cyclicity is evident in such cases. A thin silt, very fine sand or sand layer (several mm to about 1 cm) sits with a sharp contact on normal mottled diatomaceous mudstone. In many cases, lamination is preserved in the sand, most commonly parallel lamination, but in places cross lamination, ripple drift lamination, or rarely climbing ripple lamination. The sandy layer passes gradationally into mudstone, in some cases with diffuse laminae of very fine sand in the lower part. The mudstone is commonly dark gray, contrasting with the greenish and grayish hues of the normal mottled mudstone. Such darker mudstone layers reach a maximum thickness of 45 cm (Section 584A-H2-1, Fig. 8), are commonly structureless for much of their thickness, and in many cases grade diffusely from silt to gray mudstone in the lower part. The mudstone is very common feature of such layers is a concentration of Chondrites burrows up to 10 cm down into the dark gray mudstone layer.

Smear slides show the mottled mudstone comprises 75% clay and 20% silt; the dark mudstone contains up to 70% silt and 20% clay, being richer in quartz, feldspar, lithic fragments, and heavy minerals. Preliminary X-ray mineralogy results show the mottled mudstone richer in smectite than the dark mudstone.

These cycles in a thick diatomaceous mudstone section (moderately to intensely burrowed more or less throughout) pose two interesting questions. First, how are the thin sandy or silty layers at the base of the cycles preserved from destruction by burrowing, as has clearly been the case in Subunit 3a? Second, how can much of the dark gray mudstone overlying the sandy or silt layers be devoid of burrowing?

We suggest that the thin sand-silts and dark mudstones are deposited by muddy, low-density turbidity currents. The thin sands and silts would represent the coarse fallout, and the dark structureless mudstone would represent deposition from the main body of the muddy current. Rapid deposition of the lower, commonly more silty, portion of the dark mudstone favors preservation of the thin basal sand or silt. Deposition of the remainder of the mud before recolonization by benthic organisms means that only the deeper burrowers reach the lower levels of the dark mudstone. In this way, the thicker dark mudstone units remain structureless or preserve vague parallel lamination probably formed during deposition from suspension as the muddy current waned. The cycle is completed by ambient hemipelagic sedimentation, forming the normal intensely burrowed and mottled diatomaceous mudstone.

First observed at ~ 540 m sub-bottom (top of Subunit 4a, Core 584-S7), the muddy turbidite cycles are best preserved in Cores 584-S5 (~ 905 m sub-bottom, Subunit 4b; Fig. 7), and 584A-H2 (about 615 m sub-bottom, Subunit 4a; Fig. 8). Measured sections from these cores illustrate the cycles, and highlight some complexities that qualify our interpretation. Numbers on Figures 7 and 8 refer to items in the following text. Numbering is sequential down the sections.

Sandy layer bases are invariably sharp, and usually flat (Fig. 8). Rare erosional bases are particularly well displayed in Core 584B-H3 (Subunit 4a, 654 m sub-bot-
tom). Between the 115 and 120 cm levels in Section 584B-H3-1, a highly irregular bed base has a relief of several millimeters across the width of the core, and the underlying mud intrudes into the sand layer as a tilted mud-stringer (~10 × 1 mm), lying at a low angle to bedding in the manner of a rip-up clast. Elsewhere in the core, several isolated lenticles of mudstone in sand layers probably represent detached rip-up clasts.

Cross-laminated sandy layers (Fig. 8, #2, and #5) are less common than parallel-laminated layers. Measurements suggest that the downdip direction is east throughout the core. In Core 584A-H2, several cross laminations demonstrate (in dip-section) downdip paleocurrents (i.e., eastwards). As expected, that flow-direction followed the present downslope direction. However, in Cores 584B-2 and 584B-H3, several micro-cross-laminated sandy layers show the opposite direction of paleocurrent flow. From this sequence we can infer either a local slope reversal in the Hole 584B area sometime in the late Miocene or a highly irregular current flow (not inconceivable in low-density, muddy turbidity currents).

The depth to which the Chondrites organism penetrated the newly deposited mud varies between 2 cm (Fig. 8, #3) and 8 cm (Fig. 8, #1). Nowhere did we observe more than 10 to 15 cm of penetration (allowing for dip correction). The Zoophycos organism may have been able to penetrate slightly deeper. One 18-cm dark, otherwise structureless mudstone contains Zoophycos throughout (Fig. 8, #4). These maximum depths of penetration agree with Ekdale's (1974) estimates based on an exhaustive study of abyssal bioturbation in DSDP cores. They require that completely structureless dark mudstone is only likely in turbidite sand-mud couplets more than 20 cm thick. This relationship is clear in Figure 8, and we found it generally reliable elsewhere in Subunit 4a.

As in any kind of mass-flow facies, however, breaks in cyclicity are common. Sand-mud couplets occur in places (Fig. 8, #5 and 12; Fig. 7, #2). Probable mud turbidites, without the basal thin sand or silt layer, also occur (see possible example at #7, Fig. 8). If amalgamated sequences of essentially ungraded mud turbidites formed, they would be particularly difficult to recognize. Sand layers without the characteristic dark gray, overlying, graded silty mud (Fig. 8, #8) might represent coarse fraction deposition under a muddy turbidity current that carried its fine-fraction load to another part of the slope.

A further complicating factor may arise in the nature of the turbidity-current generating process. The mud turbidites clearly derive from a source area devoid of coarse terrigenous detritus. Many are relatively thick (40 to 50 cm). A relatively local source on the slope therefore appears most likely. In slope settings, failure of oversteepened or textonically mobilized muddy sediment piles often occurs in a series of steps, cutting back from an initial, major failure scar. This sequential caving can generate pulses of mass-flow (regressive flow sliding). One failure event on a slope may therefore generate a series of mass-flow deposits, generally decreasing in magnitude, essentially inseparable in terms of geologic time. Sequential muddy turbidity currents may therefore have been involved in deposition of the thicker mud turbidites at Site 584. The thin basal sandy layer and graded portion of the overlying dark mudstone may represent the initial major failure and consequent mass flow. If there were one or more additional compensating failures on the same source scarp, consequent low-density, muddy turbidity currents could be represented in the bulk of the dark mudstone.

**Bioturbation**

The Chondrites-Zoophycos-Planolites-Cylindrichnus assemblage, characteristic of the abyssal environment, occurs throughout Site 584. The form taken by these trace fossils is as described by Ekdale (1974). Here we comment only on their distribution. There is no obvious pattern downsection. We suspect a slight overall increase in bioturbation downwards, although this is unquantified. Certainly the lower cores of Subunit 4b ("paisley" facies) are excessively bioturbated, compared with many cores above, though this may in part derive from diagenetic enhancement. Large (up to 2 cm) olive, commonly slightly serrate Planolites burrows are almost absent below ~530 m sub-bottom (base of Subunit 3b), and we detect a more obvious downhole increase in Zoophycos traces, reaching the status of abundant in the "paisley" facies.

Indistinct motting is more or less a characteristic of the whole section, suggesting that the more clear-cut burrows are the latest in a long history of reworking. The disseminated nature of many sandy concentrations (especially Subunit 3b), suggestive of reworking of original thin sand beds into overlying and underlying mud, supports this view. Burrow alignments are usually obvious, and in almost all cases are parallel to laminations, ash beds, and sandy layers.

Evidence of relative timing of burrows is abundant. In most cases large, ovoid Planolites burrows are cut by Chondrites and Zoophycos. Zoophycos is evidently the latest burrower in many sections. We observed "pellett-ed," "fat," and "simple" forms (sensu Ekdale, 1974) throughout the section. Width of traces varied greatly from <2 to 36 mm (Section 584-96-3). Average width is 1.5 to 2 cm.

Planolites traces are commonly lighter colored than the normal mudstones, in many cases olive or light olive gray. This coloration variously reflects higher diatom content and/or calcareous content. We detected no obvious pattern downsection in the type of Planolites burrows. In Pliocene cores, nannofossils are detectable in the calcareous burrow fills; in Miocene cores, they are generally not.

In Miocene cores, large (up to several cm) spheroidal, ovoid granular-looking, olive balls are a minor component. Following Okada (1980), we interpret these as armored mud pellets, probably of fecal origin. Discolored diffusion fronts often form halos to these balls.

Sequential sections are required to assess the dimensions and interrelationships of some of these trace fossils (Fig. 9; numbers in the following text refer to numbers in Fig. 9). For example, sections of Section 584-96-2 show that a large granulose ovoid body (#1) is spheroidal and is probably not a burrow but an armored mud pellet; it is surrounded by a diffusion front (#2). Bed-
Figure 9. Serial sections of trace fossils, Section 584-96-2 (Miocene, Subunit 4b). Numbers refer to features discussed in text. A–C are longitudinal core sections.

ding, defined by vague color laminations in the predominantly dark greenish gray diatomaceous mudstone, is steeply inclined, as it is everywhere in the lower part of the Site 584 section. Zoophycos trails are nearly everywhere parallel to all sedimentary bedding indicators, the traces curved either dextrally or sinistrally. A Chondrites concentration (Fig. 9, #6), crudely aligned with bedding in Plane A, passes to a rather uncommon stubby, branching form in Plane B. The diffusion front seems to have truncated this Chondrites concentration. Perhaps the diagenetic processes associated with this front homogenize chemistry between the burrow-fill and the matrix mudstone, rendering them invisible.

Most interesting is the medial Zoophycos, which deflects near the ball, cutting it, but clearly deviating from the normal bedding parallel path, and swinging towards the viewer in order to do so.

**STRUCTURAL GEOLOGY**

**Introduction**

Site 584 cores recovered an abundance of structural features in Miocene (and to a lesser extent in lower Pliocene) cores. These we categorize principally as “healed” fractures and dewatering veinlets. Tensional crack-fills and slumping are minor features of the section. We describe the structural features in turn, using drawings of representative cores and presenting evidence for relative timing of the features. We then briefly discuss the regional implications of our microstructural data, commenting on the possible significance of the moderately to highly inclined strata found in all 584 sites, and compare our data with structural features recorded at the Leg 56–57 sites.

Unless otherwise indicated, all core numbers in this section refer to cores from Hole 584.

**Healed Fractures**

First observed at 240 m sub-bottom in Core 26, steeply inclined, dark gray, claystone-filled seams are a common feature of the section and are, in general, more abundant downhole. These seams are commonly straight, generally <1 mm but locally several millimeters in width (they are most commonly at a high angle to bedding, which they cut with minor displacement). Where the sense of offset is visible, it is generally normal, commonly from several millimeters to several centimeters (see Fig. 10). The largest measurable true throw (i.e., downdip on the claystone seam) is 2.6 cm (Fig. 10). Some seams, however, throw distances in excess of the
part of the fracture plane recovered in the core. The preponderance of minor offsets leads us to suspect that such large offsets are not common.

Following Leg 57 procedure, we refer to these claystone seams as healed fractures because the initial offsets were most likely made on open fractures, with later deposition of claystone in the fractures causing reannealing. This claystone is structureless and may have been deposited in the open fractures during or after the displacement by upward-escaping water, rich in clay particles. In detail, some fractures comprise fine anastomosing stringers of dark claystone (584-15-3, 80-85 cm); small-scale stepped offsets are common (see Fig. 11). An interesting curved growth fault with 2-cm normal offset occurs in Section 584-47-2.

In all instances where cores were sectioned to give three-dimensional views, the healed fractures are either perpendicular-subperpendicular to bedding (Fig. 11) or highly inclined (50 to 70°) to bedding. Because of limited time during core descriptions, our three-dimensional observations were brief. We gained an impression that the high-angle and perpendicular healed fractures predominantly strike subparallel to bedding (Fig. 10).

Rare, low-angle healed fractures, locally bedding-parallel, are minor features of the section. We sectioned several of these to give a three-dimensional view, demonstrating that they are not high-angle features caught in strike-section. We have few observations concerning relative timing of high-angle and low-angle fractures.

Only locally did we observe more than one generation of healed fractures in the same core (Figs. 12 and 13). A 1-cm thick dark claystone seam with smeared parallel streaks (x-x', y-y') is subperpendicular to bedding, and cut by two sets of thin healed fractures at a low angle with respect to bedding (Fig. 13). Further complex histories are well preserved in Core 584-78.

In regard to the healed fracturing phenomenon, the main inferences are that extension on a microscale affected strata in the Site 584 area before, and possibly to a lesser extent after, the tilting event, and that the healed fractures, which occur from Core 26 downwards (below 240 m sub-bottom) affect strata ranging in age from middle Miocene to earliest Pliocene.

Dewatering Veinlets

Closely spaced, subparallel, locally anastomosing claystone-filled veinlets are ubiquitous in Miocene cores, especially in the lower portion of the section. These are almost all perpendicular to bedding (Figs. 14, 15). They tend to concentrate at particular levels and commonly form bands from several millimeters to several centi-
Figure 12. Two sets of thin healed fractures cut dewatering veinlets (A). The first (B) shows normal offset, the second (C) reverse offset. Bedding attitude unfortunately not clear here (~515 m sub-bottom depth; upper Miocene).

meters thick. In cores from lower levels they often permeate the core more abstrusely over the entire length of sections. They first occur in Core 41, at about 385 m sub-bottom.

Our three-dimensional investigations reveal that these veinlets strike parallel to bedding, forming a dark network of irregular, subparallel, locally anastomosing traces on bedding surfaces (Fig. 15).

They commonly show minute (<1 mm), stepped, normal displacements of fine laminae (Figs. 16 and 17) or burrows, but individual offsets only rarely exceed 1 mm (Fig. 18).

The veinlets everywhere postdate bioturbation but predate healed fracturing (Fig. 19). Following interpretations reached by the Leg 57 shipboard scientists, we infer that these features represent original water-escape microcracks (similar to the "beardlike" structure in Miocene turbidites of the Miura and Boso peninsulas, and Shimanto Belt), in which clays held suspended in residual water have promoted resealing (Ogawa, 1980).

The veinlet bands may comprise predominantly isolated strands (Fig. 16) or intense braiding networks (Fig. 18), the latter especially so in cores lower in the section. Individual veinlets commonly show slight asymptotic curving, with the seams thicker in the middle portions (Figs. 16 and 17).

Lithologic control on veinlet formation is locally evident on a small scale. Veinlet networks terminate in places at fine sand layers (Fig. 14), presumably because water was able to escape by intergranular flow in the more permeable sand without recourse to mechanical conduits.

Figure 13. Complex healed fracturing in middle Miocene, 584-86-2, 52-60 cm. Diatomaceous mudstone (1) preserves bedding (2) as vague color laminations. Line of section in archive half (lower) clearly oblique from three-dimensional investigation of working half (upper). A early, thick seam (the healed fracture?mudstone dike) x-x', y-y' is cut by two thin fractures. A 4-mm-thick bed of distinctive color (3) is cut by an en echelon third set of healed fractures.

Open Fractures

Open fractures are relatively common in the Hole 584 section, in consolidated material below Core 10. They may derive from in situ fracturing, or from drilling or core-handling processes, and they may take several forms. Irregular vertical fractures, commonly central in the core, certainly arise from drilling or core handling. A close irregular hackly fracture occurs in places (Section 584-43-2), probably arising from core shrinkage. Highly inclined, often conjugate, straight fractures are interpreted with more difficulty (Arthur et al., 1980). Some have no visible offset, others have minor normal displacement, commonly with vertical or highly inclined slickensides on the fracture planes. In places, healed fractures pass into open fractures, sometimes lined with the same dark claystone that anneals the healed fractures. We do not know if such transitions are original (in situ) features, or whether healed fractures opened during recovery. Certainly we observed no upsection transition from healed to open fractures, as recorded in Leg 57 lower-trench-slope Sites 441 and 434 (see Arthur et al., 1980).
Figure 14. Dewatering veinlets (1) terminating at a fine sand bed (2); silty laminae in fine sand bed (3, abstractly drawn) truncated by a healed fracture (4), which cuts plane of view in strike section.

Figure 15. Dewatering veinlets (2), commencing above a silty mud layer (1), form a clear lineation on bedding.

Slumping and Synsedimentary Faulting

We observed features best explained as slump structures in three places. In Section 584-12-3 (about 110 m sub-bottom, lower Pliocene) a small-scale unconformity, marked by a sharp color change in the mudstone at a high angle to bedding, is too large to be explained by bioturbation and may represent a slump scar. In Section 584-59-1 (557 m sub-bottom, upper Miocene) a color change boundary (between grayish olive and dark gray) is highly irregular and truncates laminations in what seems to be an angular mudstone block of ~10 cm maximum visible dimension. This may best be explained as a thin slumped horizon. In Section 584-96-4 (915 m sub-bottom, middle Miocene), chaotic curved laminations occur over 24 cm of core (76–100 cm). In the working half, this feature includes sub-centimeter-scale isoclinal fold hinges, with detached lower limbs, and appears to be a complex slump unit caught in very oblique section, further complicated by abundant healed fractures.

In only one place did we observe clear evidence of synsedimentary faulting. Silt layers in Section 584-21-2 (195 m sub-bottom, lower Pliocene) show millimeter-scale normal displacement on a healed fracture, which several centimeters upsection does not displace bedding.

Crack-Fills

In Core 584-71 (about 671 m sub-bottom, upper Miocene) a unique sand-filled vein system is preserved (Fig. 20). Up to 5 cm across, the main vein is perpendicular to bedding, with slightly irregular margins stepped somewhat on one side, tapering down over a 10-cm exposed length to zero. The section is broken by two thin zones of drilling breccia. In the lower part of the vein, angular chips of mudstone, identical to the host rock, are scattered in the fill forming a matrix-supported breccia. In the upper part, offshoots of the vein penetrate laterally both parallel to, and at a high angle to, bedding. The upper part of the vein, and the offshoots, are sand filled. Unfortunately the transition between breccia-filled and sand-filled portions is obscured by the drilling breccia zone.
This feature is best explained as a large tensional crack system that was filled by unconsolidated sand and spalled chips of host mudstone. The angularity of the mudstone chips indicates formation in at least semiconsolidated sediments. Such a crack system could easily form behind a slump scar.

Clastic Dykes

Many veins subperpendicular or at a high angle to bedding are claystone seams, which we infer, because of
Figure 18. Core 584-95, middle Miocene, ~905 m sub-bottom. Intense, braided dewatering veinlet array (3). All structures shown are in homogeneous dark greenish gray mudstone (1). (2) is a darker lamination, with both normal and reverse micro-offsets. Dark seams (4) cut microveins, at apparently low angles. Both are moderately inclined in three-dimensional view.

Figure 19. Structures and sequence of events recorded in Core 584A-2, archive half. A-A', B-B' = thick, late, healed fractures; (1) sinistral Zoophycos; (2, 3) amalgamated dextral Zoophycos, 2 formed before 3; (4) olive burrow mottles; (5) pelleted Zoophycos; (6) color laminations; (7) fat Zoophycos.

Sequence of events: (I) Burrowing. (II) Formation of anastomosing veinlets to bedding, with no or only up to several millimeters offset. (III) Formation of main fractures (conjugate, acute intersection vertical, strike subparallel to bedding strike); up to 26 mm normal offset. (IV) Healing of main fractures (see text discussion) (minor offsets on conjugate main fractures reflect slightly different chronologies in Stage III).

Their resemblance to comparable seams offsetting bedding, to be healed fractures. In Section 584-81-1 (770 m sub-bottom, middle Miocene) two veins, each about 1 cm wide, cut bedding at about 70° (in dip section) and have a homogeneous silt fill. Because healed fractures are elsewhere filled with sediment finer than the host mudstone, these silt-filled veins may best be explained as clastic...
dykes. Thin silt layers are relatively common in the section hereabouts and could have provided the necessary source.

Mud dykes and sills might also be expected at Site 584, because features described hitherto provide strong evidence for extensional tectonics affecting the Miocene and lower Pliocene Japan Trench inner slope (Arthur et al., 1980). We would have no means of discriminating claystone seams that represent healed fractures with offsets greater than the cored length from claystone seams that represent mud dykes or sills.

Shear Zones

In Section 584-80-1 (760 m sub-bottom, middle Miocene) a 2.5-cm thick, bedding-parallel disrupted layer comprises an upper brecciated mudstone zone and a lower sheared claystone layer. The latter contains flow-sheared mudstone chips, which indicate normal movement (Fig. 21). The degree of displacement on such a feature could conceivably be substantial.
Synthesis

Dewatering veinlets and healed fractures are the two main structural features in the Hole 584 section. Dewatering veinlets are the first formed, being everywhere cut by healed fractures. The veinlets commonly occur in concentrated networks and are almost all perpendicular to bedding, suggesting lithostatic stress was responsible for their inception. Local zones of steeply inclined veinlets may indicate superimposed tectonic stress during dewatering. The dewatering veinlets would have formed initially as open microcracks, becoming annealed in the later stages of water escape as clay minerals were deposited from water going through. We found no open dewatering veinlets in the 584 section, but such features were observed in Quaternary mudstones from the Nankai Trough inner slope (site chapter, Site 583, this volume). Dewatering veinlets occur throughout the Miocene section (below about 385 m sub-bottom) and most likely formed incrementally during deposition. Their relatively constant attitude with respect to bedding indicates that they were formed before tilting of the strata. Their sharp margins and generally straight profiles indicate formation during the later stages of consolidation. There is no clear evidence concerning timing of the crack-fill system and the possible clastic dykes relative to dewatering veinlets. The slump structures described are likely to have been surface or near-surface features, and probably pre-date dewatering.

Healed fractures cut all these features. They are commonly subperpendicular or at a high angle to bedding, in some cases conjugate, and have determinable offsets ranging from several millimeters to several centimeters. They would have formed initially as open fractures, being reannealed in the same fashion as the dewatering veinlets. Many of the fractures require a $\sigma_1$ (axis of maximum compression) at an acute angle to vertical in their present orientation. After bedding tilt correction, $\sigma_1$ is essentially vertical. Because the fractures occur in a slope section, their orientation suggests that they formed for the most part before tilting of the bedding. Like the dewatering veinlets, the fractures most likely formed incrementally after consolidation. The predominance of normal displacements indicates a prolonged extensional regime in the Miocene and early Pliocene slope section.

The most striking structural features at Site 584 are the consistently high inclination of bedding, a feature not observed in previous sites of the DSDP Japan Trench transect. Below 350 m sub-bottom, strata dip at angles between very shallow (a few degrees) and very steep (up to 70°) towards the Japan Trench (see Palaeomagnetics section, this chapter). Dips from 350 to 530 m sub-bottom range from 10 to 30°, but below 530 m the beds dip generally between 50 to 60°. We detect an overall pattern of progressive downslope steepening.

This inclined section in Hole 584 would appear to require tilting on rather steep, landward-dipping normal fault. Such features are not evident on the seismic profile across the Site 584 area (Profile ORI 78-3, Fig. 31A), though they are clearly present upslope in the region of Sites 438 and 439 (Nasu et al., 1980). Steep trenchward dips also occur about 500 m upslope of Site 584 in Hole 584A and about 700 m downslope in Hole 584B. The impressive subhorizontal correlations between lithostratigraphic and biostratigraphic markers in Holes 584A and 584B (see Sedimentology and Biostratigraphy (Diatoms) sections, this chapter) come as a further surprise, given the structural relief apparently required by the ubiquitous steep dips in the lower half of Hole 584. The geometry required by our observations at Holes 584A and 584B is best explained by a nest of normal faults giving stepped throws so that marker horizons can remain at much the same level in all three holes despite the steep dip of strata.

The very complexity of the required configuration, plus probable steepness of the normal faults, could explain its failure to show up on Profile ORI 78-3 (Fig. 31A). The required large-scale geometry is, however, consistent with microstructural evidence outlined hitherto. Evidence for extensional tectonics is found in small-scale structures throughout the Hole 584 section.

The shear zones described above would be likely manifestations of the normal faults required in the Hole 584 section. However, although the example described shows evidence of normal displacement, it is bedding-parallel, and the stepped displacements required would have to occur on faults at a high angle to bedding. In addition, we can perhaps conjecture that the zones of anomalous low recovery (for example, Core 584-33), in a hole where recovery was generally good, might represent passage of faults through the Hole 584 section.

Comparison with Previous Japan Trench Sites

Structural features of Japan Trench sites drilled on DSDP Leg 56–57 are summarized by Arthur and others (1980). Veins, fractures, and faults are present in both upper-trench-slope Sites 438 and 439 and lower-trench-slope Sites 400, 441, and 434, but not in the shallow-penetration Site 435. These features are also absent in ocean-plate-reference Site 436. Their veins are identical to our dewatering veinlets, occurring in sets up to a maximum length of 10 cm, anastomosing but generally perpendicular to bedding, and terminating at sandy layers. Arthur and others (1980) interpret these features as dewatering conduits associated with faults. “Fractures” are mostly healed, dip at between 45 and 90° to bedding, commonly occur in conjugate sets and show offsets of up to several centimeters in both the normal and reverse sense. Open fractures are common only on the lower part of the inner trench slope, between about 150 and 500 m sub-bottom (Sites 441 and 434); they do not offset bedding. No sediments younger than late Pliocene are deformed.

The depth to “consolidated” sediment (defined by Leg 56–57 scientists as sediment that required saw cutting) and the depths to the first occurrences of veins and healed fractures all shallow progressively toward the trench. Additionally, the upper 400 m of section in lower-slope sites is overconsolidated relative to upper slope sites. Arthur and others (1980) tentatively interpret these observations as a response to tectonic stress, in addition to lithostatic stress, during consolidation on lower-trench-
slopes. Their model for consolidation and deformation of lower-slope sediments further involves a coronalike zone of open fractures at about 200 to 300 m sub-bottom over a healed fracture network at depth. The fractures are held open by excess fluid pressure caused by dewatering, and fostered by a fine-grained low-permeability sediment cap. They argue that such an open-fractured zone could provide an overpressured horizon capable of sufficiently reducing shear strength in the lower-slope sedimentary cover to allow downslope mass movement even on low angles on the trench inner slope.

The model depends on interpretation of open fractures in cores from lower-slope Sites 440, 441, and 434 as in situ features. In favor of this opinion are the correlation between zones of open fractures and reverses in the density gradient, poorer recovery in the fracture intervals, and the relative paucity of open fractures in Sites 438, 439, and 436 (located away from the lower slope).

The central problem concerns the possible role of missing upper Pliocene and Pleistocene strata in consolidation of the lower-slope section. Holes 441 and 434 are in the axis of a submarine canyon (see JNOC Crossline C, fig. 7 of Arthur et al., 1980). Based on the depth of this canyon, Arthur and others (1980), suggest as much as 450 m of upper Pliocene and Pleistocene strata are missing. In contrast, lower-slope Site 440 (on the middle terrace) has no missing section, but consolidation and first appearance of deformational-dewatering features are shallower than at upper-slope Sites 438 and 439.

How well do data from Site 584, drilled on the upper part of the lower slope, support the concept of excess tectonic stress affecting the lower-slope sediment cover and in situ features? In order to observe in situ features in previously drilled sites. In a sequence upslope from the trench, the first (shallowest and youngest) mudstones were recovered at: 101 m (Site 441 on the lowermost slope, upper Pliocene); 130 m (Site 434 on the lowermost slope, upper Pliocene); 175 m (Site 440 on the mid-slope terrace, lower Pliocene); 250 m (Site 584 on or above the mid-slope terrace, lower Pliocene); and 430 m (Site 438 on the upper slope, upper Miocene).

The first appearance of veins and fractures in Hole 584 is similarly much higher than in upper-slope sites, and slightly higher than other lower-slope sites. Healed fractures first appear in Holes 438 and 439 (upper slope) at 603 m in middle Miocene strata. At Site 440 (mid-slope terrace) they appear at 252 m in lower Pleistocene sediments. At Site 434 (lower slope) they first appear at 255 m in (?)lower Pliocene sediments. Healed fractures first appear in Site 584 at about 240 m in lower Pliocene sediments; dewatering veiners first appear at about 383 m sub-bottom in upper Miocene sediments.

The data from Site 584 augment previous observations of a strong contrast between dewatering and deformation histories in the upper-slope and lower-slope sediment sections. Tectonic stress appears to affect the lower-slope section, and in addition to overburden stress, promotes earlier dewatering, consolidation, and deformation.

At Hole 584, we detected no precursory zone of open fractures before penetrating the healed fracture networks below 240 m sub-bottom. If the open-fractured corona postulated by Arthur and others (1980) for deeper on the slope at Sites 441 and 434 once existed at Site 584, it has now been annealed.

The most notable difference between Site 584 and previous sites is the high inclination of strata. In Holes 438 and 439 (upper slope) dips of 0 to 30° occur below 850 m (middle and lower Miocene strata). In Hole 440 (mid-slope terrace), dips of up to 10° occur between 254 to 350 m (lower Pliocene–upper Pliocene strata) and between 15 and 40° below 385 m (Pliocene and upper Miocene strata). In Site 441 (lower slope) dips vary “…irregularly and somewhat systematically downhole, ranging from horizontal in the upper part of the hole to 35° and locally 70° at depth” (Arthur et al., 1980, p. 579).

### BIOSTRATIGRAPHY

Siliceous microfossils are the dominant microfossil groups recovered from Pleistocene to middle Miocene muds and mudstones of Site 584 (Fig. 22). Diatoms in particular are extremely abundant in the upper 57 cores and are the most consistently reliable age indicators examined. Radiolarians are less common but, when present, support the diatom age determinations. Calcareous microfossils, foraminifers, and nannofossils are in general extremely rare or absent. In samples containing calcareous fossils, the preservation is typically moderate to poor.

Drilling at Hole 584A attempted to penetrate the same zone of steeply dipping, highly fractured beds that forced the cessation of drilling at Hole 584. Spot cores were taken every 100 m from 600 m to the end of drilling. Diatoms are used to date the retrieved cores as well as the sediments retrieved in the intervening wash cores. Radiolarians, foraminifers, and nannofossils are absent or rare and undiagnostic in these cores.

### Foraminifers

Foraminifers, both planktonic and benthic, are rare at Hole 584. Partial explanations for this situation include dilution by other sediments, dissolution of certain intervals below the calcite compensation depth (CCD) and difficulty of processing certain lithologies on board. Although the foraminifers do not provide refined biostratigraphic information, they do indicate some key paleoenvironmental aspects about the section penetrated.

### Planktonic Foraminifers, Hole 584

Planktonic foraminifers are absent to rare in all Hole 584 core catcher samples examined. The interval between Core 584-1 and 584-6, CC is barren of all foraminifers, but that from Cores 7 to 42 contains a few samples with rare, moderately to poorly preserved planktonic foraminifers. The most common species encountered are: *Globigerina bulloides* s.l., *Neogloboquadrina pachyderma*, *Orbulina universa*, *Globorotalia* cf. *puncticulata*, and

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Globigerina cf. decoraperta. This assemblage is not characteristic of any particular zone, but the absence of Globorotalia inflata s.l. and presence of Globorotalia cf. puncticulata suggests an early Pliocene age. The core catcher of Core 21 does contain a diagnostic assemblage that includes, in addition to the species previously listed, Pulleniata primitis, Globorotalia cf. cibaoensis, Globorotalia tumida, Globigerinoides ruber, Globigerinoides trilobus, and Sphaeroidinellopsis sp. This assemblage is characteristic of lower Pliocene Zone N19/20 (Blow, 1969), which is in agreement with age assignments by other microfossil groups.

Planktonic foraminifers are absent below Core 42 at Hole 584.

Benthic Foraminifers, Hole 584

The distribution of benthic foraminifers at Hole 584 parallels that described for the planktonic foraminifers. They are absent from Cores 1 to 6, rare to few from Cores 7 to 42, and absent below Sample 584-11-5. The assemblage in Cores 7 to 42 includes Melonis pompilioides, Sphaeroidina bulloides, Plectofrondicularia foliacea, Globobulimina auriculata, Stilostomella sp., Dentalina spp., Eponides cf. tumidulus, Hoeglundina elegans, Pullenia bulloides, Cibicides wuellerstorfi, smooth to hispid uigerines, Gyroidina sp., Martinottiella communis, and unilocular lagenids. This assemblage indicates lower bathyal to abyssal depths, below 2000 m. Below Core 42, benthic foraminifers are very sparse and consist of a nearly monospecific assemblage of M. communis. Very rare occurrences of Gyroidina sp. and Dentalina spp. are also recorded. This assemblage may represent either a bathymetric change from the assemblage above or a change in bottom-water character, possibly a shallower CCD.

Planktonic and Benthic Foraminifers

Hole 584A

All core catcher samples from the three cores taken in Hole 584A were barren of foraminifers.

Hole 584B

Foraminifers are rare to absent in core catcher samples from Hole 584B. Sample 584B-1, CC is barren, but Samples 584B-H1, CC to 584B-H3, CC contain rare Martinottiella communis and no calcareous foraminifers. These samples are similar to the interval below Core 584-42 and suggest deposition below the CCD.

Calcareous Nannofossils

Hole 584

Sediments recovered from rotary drilling at Hole 584 are generally lacking in calcareous nannofossils, particularly below Sample 584-38-4, 12-13 cm (358 m subbottom). Above that interval, nannofossils are few in number, moderately preserved, and do not provide continuous reliable age assignments. Sediment below Section 584-1-6 is Pliocene, but sediment immediately above is barren of nannofossils; perhaps the hiatus inferred at Hole 438A (Shaffer, 1980) involves this interval.

Several intervals of pale, rust-colored sediment are also relatively calcite rich. These zones were selectively sampled from Core 35 to the termination of coring and several show a dramatic rise in nannofossil abundance compared to the otherwise barren intervals. Unfortunately, most of these contain irregular grains and calcite rhombs of an indeterminate origin and are lacking in nannofossils.

Very few age assignments were made for sediments in Hole 584. Of the 138 samples examined on board, 67% are barren. Datable sediments in Cores 1 through 10 are assigned to the Discoscacer brouweri Zone (Bukry, 1973). The appearance of Reticulofenestra pseudoumbilica in Sample 584-11-5, 136-137 cm indicates a lower Pliocene assignment for sediments below this level. The first definitively Miocene nannofossils occur in Sample 584-47-1, 20-21 cm with the appearance of Discoscacer quinquerasmus. Boundaries between these zones are masked by undiagnostic intervals occurring immediately above and below samples containing age-diagnostic species.

Nannofossils decrease in abundance below Section 584-38-4. Of the 85 samples examined from this interval on board, all but 16 are barren. Detailed age assignments and zonal boundaries for this interval were not determined with any reliability during Leg 87.

Hole 584B

Calcareous nannofossils are also rare at Hole 584B. None of the samples examined contain age-diagnostic flora. Two samples, 584B-H1-1, 70-71 cm and 584B-H1-1, 117-118 cm contain abundant calcite debris. Only the latter have nannofossils, but even these are heavily overgrown specimens of long-ranging forms such as Calcidiscus leptoporus. Sample 584B-H3-1, 128-130 cm contains moderately preserved nannofossil including Reticulofenestra pseudoumbilica, Sphenolithus abies, and C. leptoporus, but lacks age-diagnostic discoasters.

Radiolarians

Hole 584

Radiolarians are few to rare in most sediment recovered at Hole 584. Preservation is moderate through Core 58 and generally poor in the remaining cores. Zonal age assignments are not possible for much of the sediment, because of the paucity of diagnostic species, but Sample 584-1-1, 43-44 cm is older than Quaternary, suggesting a hiatus of lower Pleistocene sediments.

The Lamprocystis heteroporos Zone occurs in Cores 3 and 4. Cores 12, 16, 24, 36, and 38 to approximately Core 53 are assigned to the Sphaeropyle langii Zone. The most consistently present radiolarians are in the interval from Cores 38 to 53. The Theocorys redondoensis Zone (Reynolds, 1980) is recognized in Core 54. The Diodymacystis penultima Zone and Didymocystis antipeculima Zone occur in Cores 57 and in Cores 73 to 79, respectively. The last zonal sequence recognized in this core was the Diartus hughesi Zone (Reynolds, 1980), apparent in sediments from Cores 80 through 87.

The radiolarians are far less abundant than the diatoms from Cores 1 through 58. In consecutive clay-rich sediments, both siliceous microfossil groups decrease in...
Hole 584
Core
Recovery
Lithology
Polarity
Epoch

Core
Recovery
Lithology

Core
Recovery

Sub-bottom depth (m)

early Pliocene

Age
Lith. unit
Core
Recovery
Lithology
Polarity
Epoch

Hole 584A
Wash

Hole 584B

Foraminifera
Calcarenites
nannofossils

Zonations
Radiolarians
diatoms

Probable early Pliocene
Probable early Pliocene
Probable Pliocene
Barren
Barren
Barren

Undiagnostic
Reticulofenestra pseudoumbilicalia
Discoaster brouweri
Lamprocyrtis heteroporus

Sphaeropyle langii

Denticulopsis seminae
Actinocyclus ocularis

Denticulopsis kamtschatica

Lamprocyrtis heteroporus

SITE 384
Figure 22. Summary biostratigraphy of Site 584. T.D. = total depth.

- Undiagnostic
- Discoaster quinqueramus
- Theocorys redoπdoensis
- Rouxia californica
- Didymocyrtis pen ultima
- Thalassionema schraderi
- Denticulopsis katayamae
- Denticulopsis dimorpha
- Didymocyrtis antepenultima
- Undiagnostic
- Thalassiosira yabei
- Diartus hughesi
- Denticulopsis praemorpha
- Undiagnostic
- Thalassionema schraderi
- Didymocyrtis amorpha
- Undiagnostic
- Rouxia californica
abundance and preservation. When the radiolarians are present in enough abundance for faunal analysis, the species found are characteristic of cool-water fauna with discoidal forms contributing the largest percentage of individuals.

**Hole 584B**

Radiolarians found in Hole 584B are generally moderately preserved and few to common in Cores 1, H1, and H2, and are rare in Cores 2, H3, and H4. Core 584B-1 is placed in the *Batryocyclus acquironaris* Zone, and this is the only sample to which a zonal age could be assigned. Core 584B-H1 contains Quaternary to upper Miocene species including *Eucyrtidium matuyamae*, a lower Pleistocene form not found in sediment cored in Hole 584.

**Diatoms**

Assemblages encountered at Site 584 are predominantly composed of high-latitude diatoms with a minor component of low-latitude diatoms introduced by the northern extension of the Kuroshio. Consequently, the high-latitude, Recent through middle Miocene diatom biostratigraphy of the North Pacific (Koizumi, 1973) is easily applied at this site. With some modifications, that scheme has been followed by successive workers (Barron, 1980; Akiba et al., 1982; Akiba, 1982a). In this report, a zonation modified basically by Akiba, which has been widely traced in many land sections of northeastern Honshu and Hokkaido (Akiba, et al., 1982; Akiba, this volume), is used.

**Hole 584**

A nearly complete lower middle Miocene through lower Pliocene section, unconformably overlain by a thin Quaternary sequence, was recovered at this hole. Diatoms occur consistently throughout the sequences with varying abundance and preservation, allowing continuous diatom zonal assignments. In general, Quaternary sediments yield common and moderately well preserved diatoms, and lower Pliocene through upper Miocene sediments yield abundant to common diatoms with good to moderate preservation. Both the abundance and preservation of diatoms decrease rapidly in the midst of the upper Miocene, until in the lower half of the upper Miocene through middle Miocene, common to few diatoms occur.

Diatom assemblages encountered in this hole are virtually identical to those in Hole 583A (Barron, 1980; Akiba, et al., 1982), drilled about 70 km northeast of the present hole. Correlation between these two holes is, therefore, straightforward.

Quaternary diatoms were recovered from Samples 584-1-1, 0-3 cm through 584-1-3, 3-5 cm. Samples 584-1-1, 0-3 and 584-1-1, 83-85 cm are assigned to the *Denticulopsis seminae* Zone and the *Rhizosolenia curvistris* Zone respectively. Samples 584-1-2, 83-85 cm and 584-1-3, 3-5 cm belong to the *Actinoceylcus oculatus* Zone.

Two upper Pliocene diatom zones, namely the *Denticulopsis seminae* var. *fossilis* Zone and the underlying *D. seminae* var. *fossilis*-*D. kamtschatica* Zone are missing in this hole between Samples 584-1-3, 3-5 and 584-1-3, 83-85 cm.

The lower Pliocene through uppermost Miocene *Denticulopsis kamtschatica* Zone occurs in Samples 584-1-3, 83-85 cm through 584-51-3, 15-16 cm. The Pliocene/Miocene boundary lies in the basal part of the *D. kamtschatica*, and is placed between Cores 45 and 46. The *D. kamtschatica* Zone has the best preserved diatoms of any samples in this hole.

The upper Miocene Rouxia californica Zone and *Thalassionema schraderi* Zone occur in the intervals from Samples 584-51-4, 31-33 cm through 584-61-2, 32-34 cm and from Samples 584-61-CC through 584-63-1, 123-124 cm, respectively. The intervals assigned to these zones yield abundant resting spores of neritic diatoms, which implies that the interval was deposited in a shallower environment than other intervals or was subjected to increased downslope transport. The interval from Samples 584-63-1, CC through 584-91-CC is generally characterized by abundant and limited occurrences of *Denticulopsis hustedii*. This portion of the stratigraphic record is subdivided into the following four zones based on occurrences of other marker diatoms: the *D. katayamae* Zone from Samples 584-63-1, CC through 584-64-CC; the *D. dimorpha* Zone from Samples 584-65-1, 138-139 cm through 584-74-CC; the *Thalassiosira yabei* Zone from Samples 584-75-CC through 584-82-CC; and the *D. prae- dimorpha* Zone from Samples 584-83, 119-140 cm through 584-91-CC. The upper Miocene/Middle Miocene boundary falls within the *T. yabei* Zone. The *D. hyalina* Zone comprises Samples 584-92, CC and 584-93, CC, and an interval from 584-94, CC through 584-98, CC is assigned to the *D. lauta* Zone. A hiatus of approximately 1 Ma occurs between Samples 584-91, CC and 584-92, CC. The middle Miocene lower Miocene boundary lies at the base of the *D. lauta* Zone.

**Hole 584A**

Four wash cores and three spot cores were recovered in this hole, all of which contained few to common diatoms. Quaternary diatoms are found in Samples 584A-H1-1, 121-123 cm through 584A-H1-6, 121-123 cm. The *Denticulopsis kamtschatica* Zone, lower Pliocene, is found in Sample 584A-H1-6, 130-131 cm. The *D. dimorpha* Zone is recognized from Cores 1 to H2. The upper Miocene/Middle Miocene boundary is placed between Cores 45 and 46. The *D. prae-dimorpha* Zone is found in Samples 584A-H1-6, 130-131 cm. The *D. hyalina* Zone comprises Samples 584A-92, CC and 584A-93, CC, and an interval from 584A-94, CC through 584A-98, CC is assigned to the *D. lauta* Zone. A hiatus of approximately 1 Ma occurs between Samples 584A-91, CC and 584A-92, CC. The middle Miocene lower Miocene boundary lies at the base of the *D. lauta* Zone.

**Hole 584B**

All seven cores recovered from Hole 584B contain diatoms with varying abundance and preservation. Core 1 is assigned to the *Denticulopsis seminae* Zone of the upper Quaternary. Samples 584B-H1-1, 39-40 cm through 584B-H1-CC fall within the *D. kamtschatica* Zone of the lower Pliocene, whereas the two underlying samples (584B-H2, CC and 584B-2, CC) are within the upper Miocene *Rouxia californica* Zone and *Thalassionema schraderi* Zone, respectively.
The D. katayamae Zone occurs in Core H3, and Core H4 falls within the Thalassiosira yabei Zone. Core 3 is assigned to the Subzone A of the D. lauta Zone (lower middle Miocene).

SEDIMENT ACCUMULATION RATES

Based on microbiostratigraphic and magnetostratigraphic data, sediment accumulation rates for Hole 584 were estimated from the lower Pliocene through middle Miocene (Fig. 23). The curve is shown using sub-bottom depth, not true thickness of sediments. In general, this sedimentation rate curve is similar to that for Hole 438A (Barron, 1980). An accumulation rate of ~200 m/Ma for the lower Pliocene through uppermost Miocene (3 to 6 Ma) may reflect very high, primary productivity of diatoms. The accumulation rate is lower, 50 m/Ma, near the top of the interval. In the upper Miocene, the rate of sediment accumulation is approximately 15 m/Ma, and the upper part of this interval is almost coincident with a horizon yielding very abundant resting spores of naticid foraminifers. A hiatus might occur within this interval, at a sub-bottom depth of approximately 600 m. From the lower part of the upper Miocene through the upper part of the middle Miocene, the accumulation rate is approximately 100 m/Ma. A possible hiatus of almost 1 Ma duration (13 to 14 Ma) follows this interval. The accumulation rate is approximately 50 m/Ma in the lower part of the middle Miocene (14.0 to 15.5 Ma).

INORGANIC GEOCHEMISTRY

Bulk X-Ray Mineralogy of Site 584 Sediments

X-ray powder diffraction analyses were made on 172 samples from mud and mudstone, 6 samples from sand and sandstone, 26 samples from ash layers, and 110 samples from concretions and nodules recovered at Site 584, using a shipboard Rigaku Miniflex X-ray diffractometer. Major and minor minerals detected were quartz, feldspars, high-cristobalite; 7Å, 10Å clay minerals; calcite, dolomite; siderite; pyrite; barite; and opal-A. Plagioclase and K-feldspar could not be discriminated because of the close proximity of their major peaks around 3.15Å, so they are referred to only as feldspars. The abundance of biogenic opal increases markedly at around 540 m sub-bottom, more than twice its abundance in the upper part. The content of feldspars relative to quartz (feldspar/[feldspar + quartz]) is somewhat lower, mostly less than 0.2 in this part compared to 0.2 to 0.3 in the upper part. This difference probably reflects the lower contribution of volcaniclastic sediments and ash layers in this middle part because tuff and tuffaceous mudstone usually have ratios of about 0.9. The lower part is again low in quartz and feldspars, but the content of clay minerals does not seem to decline. The abundance of biogenic opal increases slightly.

The higher opal-A content and the lower terrigenous clastic content in the lower and upper parts may be explained by (1) a rapid sedimentation rate of biogenic silica during the early Pliocene followed by a constant terrigenous-sedimentation rate, or (2) a lower terrigenous-sedimentation rate and constant biogenic-silica sedimentation, or (3) a combination of both. According to the biostratigraphic and paleomagnetic studies (see Sediment Accumulation Rates section, this chapter), the sediment accumulation rate drastically increases in the lower Pliocene. This increase suggests that higher opal-A content in the lower Pliocene sediments was not caused by a deficiency of terrigenous clastics but by blooms and rapid accumulation of siliceous organisms such as diatoms, radiolarians, and sponges.

Authigenic Minerals

Authigenic calcite, dolomite, and siderite occur as carbonate concretions, veins that fill contraction cracks in concretions, and as disseminated grains in mudstones, sandstones, and ash layers.

Carbonate concretions were recovered from nine horizons: Sections 584-2-5, 584-3-1, 584-9-1, and 584-95-1 (dolomitic); Sections 584-2, CC, 584-63-1, and 584-78-1 (calcitic); and Sections 584-92-1 and 584-93-2 (sideritic). They are brownish gray to light olive gray, hard, and often brecciated and isolated from the surrounding mudstones because of drilling. Generally, the boundary between the concretions and the host sediments is distinct and marked by abrupt color changes; but in some cases compositional gradations between the concretions and the host sediments do occur. Laminations, burrowing, and bioturbation in the host sediments continue into the concretions, and laminations are sometimes bent around them because of differential compaction.

Thin-section analysis of a calcitic concretion found in Section 584-2, CC shows that it contains abundant siliceous organisms (45% diatoms, 15% sponge spicules, which have been entirely replaced and partly filled with micrite or pseudosparite matrix (4% foraminifers, 4% quartz, 2% feldspars, and 30% micrite). Micrite pseudosparite, and/or framoidal pyrite filling in foramin-
fers rarely exhibit geopetal structures. Vitric sand layers and a mud clast in Section 584-95-1 have been replaced and cemented by dolomite. The carbonate content in these vitric layers is estimated to be about 10 to 30%, as determined by carbonate bomb analysis.

We recovered olive gray, irregularly shaped barite nodules from Sections 584-9-1 and 584-30-4. Both contain wood fragments as nuclei. According to the thin-section analysis of Sample 584-9-1, 1-3 cm, this barite nodule contains 70% diatom frustules and 7% sponge spicules,
both replaced and filled by barite. Wood fragments are filled with spherulitic barite crystals as large as 0.4 mm in diameter showing radial extinction. Framboidal pyrite occurs sporadically in the wood fragments.

Opal-A changes to opal-CT and fresh volcanic glass to clinoptilolite on burial with increasing temperature, serving as a general thermometer, accurate to within a few tenths of a degree centigrade. We expected the occurrence of these minerals, especially opal-CT, at Site 584, because at Sites 438 and 439, about 100 km to the west-northwest, opal-CT first appears at 700 m sub-bottom in the middle Miocene, and clinoptilolite at 930 m sub-bottom in the lower Miocene (Shipboard Scientific Party, 1980a). Surprisingly, we could not find these minerals in any of the Site 584 cores, even though these cores reached a depth of 950 m sub-bottom. Differences in the geothermal gradient or probable erosion of the Pliocene section at Site 584 area may have caused these discrepancies.

**PHYSICAL PROPERTIES**

Physical properties measured at Site 584 include wet-bulk density, water content, porosity, shear strength, and sonic velocity. Grain densities of representative samples were measured postcruise. Logging of Hole 584A from 91 to 500 m sub-bottom allows some correlation between laboratory and in situ data (see Logging section, this chapter). Similarly, seismic reflection Profile ORI 78-3 (Fig. 31A) allows comparison with laboratory physical property data (Appendix at the end of this volume). The split Cores 1 through 8 of Hole 584 were sampled with Boyce cylinders, which were also the sampling tools for the softer sections of Cores 9 through 22. A razor blade was used to cut and trim chunks from the stiffer intervals of Cores 9 through 22. Samples from Cores 23 through 98 of Hole 584 were either slabs cut with the rock saw or minicores. All physical properties specimens from Holes 584A and 584B were cut on the rock saw or minicorer. When the sample condition allowed, 2-minute GRAPE, water-content, and sonic-velocity measurements were performed.

**Shear Strength**

Shear-strength measurements (as measured by the Wykeham Farrance Vane Shear, Soil Test Torvane, and Soil Test Pocket Penetrometer) were obtained postcruise from Hole 584A. All cores recovered from Holes 584A and 584B are from >500 m sub-bottom and are too stiff to be measured by the shipboard shear-strength equipment. Shear-strength values at the sediment surface are relatively high (12 to 76 kPa), but vary widely with depth.

Reliable vane shear data were quite difficult to obtain throughout the upper 51 m because of horizontal, vertical, and radial surface cracking during testing. Shear-strength measurements obtained from the eight tests, which correctly resulted in failure on a cylindrical surface without surface cracking, range from 15.9 kPa at 12 m sub-bottom to 101.9 kPa at 51 m sub-bottom. Sensitivity (ratio of undisturbed to remolded shear strength) ranges from 4.38 to 6.77 and averages 5.53. No valid Torvane measurements were produced below 51 m sub-bottom, at which depth a value of 50.0 kPa was recorded. The rate of increase in maximum shear strength is 1.7 kPa/m for both sets of vane type measurements (Fig. 25).

Pocket penetrometer measurements were continued to 91 m sub-bottom, at which point the 216.3-kPa limit of the instrument was exceeded. This set of maximum shear-strength measurements indicates a slightly more rapid rate of increase of strength (3.0 kPa/m) than that obtained from the vane equipment.

**Wet-Bulk Density, Porosity, and Water Content**

Wet-bulk densities were determined on board with the continuous analog GRAPE and special 2-minute GRAPE counts. Because gas and voids in the core sections severely reduce the continuous GRAPE measurements, only the highest values are considered reliable and are here referred to as maximum sustained wet-bulk densities. Wet-bulk densities determined from special 2-minute GRAPE counts on Boyce cylinder and chunk samples were performed on selected and prepared representative samples. The wet-bulk density profile is of the special 2-minute counts (Fig. 25), because these values are more representative of in situ conditions than are the continuous GRAPE values.

Porosities were calculated from three data sets, including continuous GRAPE, special 2-minute GRAPE counts, and water contents. Because we did not have the necessary equipment on board for grain density measurements of un lithified sediments, a grain density of 2.40 Mg/m$^3$ was assumed for the upper diatomaceous part of the section for our preliminary shipboard calculations. Calculated porosities are highly dependent on the grain density, therefore 41 grain densities were measured on shore to allow refinement of the porosity profiles (Appendix at the end of this volume). Grain densities throughout this hole are very low and highly variable because of the low density of the diatom tests. Porosities calculated from the water-content data and the grain densities measured on shore, are the most reliable and consistently reproducible of the three data sets (Fig. 25).

The wet-bulk density, porosity, and sonic profiles presented in this section are produced from measurements on one set of samples. These profiles are divided into seven depth intervals delineated by abrupt changes of physical property trends.

**Interval 1 (0 to 75 m sub-bottom)**

Maximum sustained wet-bulk densities, as measured by the continuous GRAPE, are anomalously high in the upper sediments of Hole 584, ranging from 1.62 to 1.50 Mg/m$^3$. In the upper part of Lithologic Subunit 2a, 20 to 75 m sub-bottom, the maximum sustained wet-bulk density remains nearly constant and averages 1.45 Mg/m$^3$. Wet-bulk densities from 2-minute GRAPE counts from the sediment/water interface to 75 m sub-bottom remain nearly constant at 1.35 Mg/m$^3$. Concurrently, porosity remains nearly constant at 75%. This constant value is not expected in water-rich sediments near the surface, where rapid porosity decreases have been docu-
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**Sub-bottom depth (m)**: early Pliocene
Figure 24. Summary of X-ray mineralogy for Site 584. X-ray intensity is expressed in arbitrary units. Large open circles indicate X-ray intensities measured on ash layers in Quartz and Feldspar columns and on concretions in Dolomite, Siderite, and Barite columns.
Figure 25. Wet-bulk density, porosity, and maximum shear strength versus sub-bottom depth for Site 584.

Interval 2 (75 to 173.1 m sub-bottom)

Throughout the remainder of Subunit 2a, the maximum sustained wet-bulk densities, 2-minute wet-bulk densities, and porosities all remain nearly constant at 1.45 Mg/m$^3$, 1.35 Mg/m$^3$ and 75%, respectively. The minor fluctuations in these profiles, particularly in the wet-bulk density data, correlate with increases and decreases
in the diatom content of the sediments. Between 75 and 100 m sub-bottom, the diatom content decreases slightly, causing a slight increase in the wet-bulk density. A gradual increase in diatom content below 100 m, to a local maximum at ~175 m, corresponds to a slight decrease in the wet-bulk density values. These variations are minimized in the porosity profiles, because an increase in diatom content reduces the grain density as well as the bulk density of the sediments.

**Interval 3 (173.1 to 460.1 m sub-bottom)**

All three physical properties profiles change linearly in Interval 3, which corresponds to Lithologic Subunits 2b, 2c, 3a, and the upper portion of 3b. Maximum sustained wet-bulk densities and 2-minute wet-bulk densities increase from 1.45 to 1.60 Mg/m$^3$ and 1.35 to 1.60 Mg/m$^3$, respectively. Concurrently, porosity calculations decrease from 75 to 58% with increasing sub-bottom depth. These gradients are the expected and normal results of consolidation. Diatomaceous sediments, however, have relatively low compressibilities (Silva, 1974; Hamilton, 1976), and changes in mineralogy may also affect the profiles. Estimates of percentages of mineral content from smear slides indicate that the diatom content decreases and the clay mineral content increases within this zone. Increasing clay content may contribute to the apparent porosity decrease and density increase by increasing both the sediment compressibility and grain density.

With greater sub-bottom depths, the diameter of the recovered core decreases noticeably from its original maximum of 6.61 cm, as a result of a worn drilling bit. Below 460.1 m, wet-bulk densities obtained with the continuous GRAPE are therefore not directly comparable with those from the upper part of the hole.

**Interval 4 (460.1 to 500.0 m sub-bottom)**

Interval 4, which is included within Lithologic Subunit 3b, is distinguished by a reverse gradient in both the wet-bulk density and porosity profiles. An anomalously low wet-bulk density of 1.45 Mg/m$^3$ and high porosity of 65% were measured at 500 m sub-bottom. This anomaly, identified in two independent data sets, is believed to be real lithologic variation and not an artifact of sampling and measuring techniques.

**Interval 5 (500.0 to 642.0 m sub-bottom)**

In the base of Lithologic Subunit 3b and the upper part of Subunit 4a, both the density and porosity profiles reveal normal, but very steep gradients. These steep gradients are most likely the result of an increasing abundance of fine sand and silt downhole in both units. A relative maximum in wet-bulk density (2.00 Mg/m$^3$) and a relative minimum in porosity (37%) occur near 640 m sub-bottom.

**Interval 6 (642.0 to 775.0 m sub-bottom)**

Reverse gradients within Interval 6 reduce the wet-bulk density to 1.60 Mg/m$^3$ and increase the porosity to 55% by 775.0 m sub-bottom (Fig. 25). This reverse gradient is apparently due to downsection decreases in sand and silt abundance, as well as increases in diatom content. This change in composition is also reflected in the gradually decreasing mean grain densities.

**Interval 7 (775.0 to 941.0 sub-bottom)**

Wet-bulk density increases from 1.60 to 1.70 Mg/m$^3$ and porosity decreases gradually from 55 to 50% in the final intervals of the Hole 584 profiles (Fig. 25). Preliminary estimates indicate no significant mineralogic change within this zone, and the reduction in porosity is attributed to normal consolidation of a relatively uniform diatom-rich sediment. Note that these values are nearly those predicted by extending the linear trends of Interval 3 to this depth, suggesting that this is a continuation of a normal dewatering profile for these diatomaceous mudstones.

Data from spot coring from 602.2 to 795.0 m sub-bottom in Hole 584A are sparse (Fig. 25). Biostratigraphic correlation based on diatom zonation indicates that stratigraphic units in Hole 584A are 10 to 25 m shallower than in Hole 584. To allow correlation of equivalent units, the data from Hole 584A are plotted 25 m below their actual measured sub-bottom depth (Fig. 25).

Wash and spot cores from Hole 584B, located 700 m downslope from Hole 584 and at almost 30 m greater water depth, yield data from 509.7 to 954.0 m sub-bottom. Again, diatom biostratigraphy indicates that horizons dip eastward. The strata of Hole 584B are approximately 35 to 60 m deeper below the sediment/water interface than the equivalent strata of Hole 584; accordingly, the data from Hole 584B are shifted 50 m upsection to correlate stratigraphically with Hole 584 (Fig. 25). Note that the depth from which wash cores were actually obtained is not well defined, but experience has shown that the recovered interval is from the upper 25 m of the total washed interval.

Individual interpretation of the density and porosity data from Holes 584A and 584B is difficult because of the limited amount of data. The wash and spot coring programs at each of these two holes were selected, however, to attempt to reconfirm the results of Hole 584 and to document the lateral extent of the physical properties trends in the strata of Intervals 4 through 7. The density and porosity reversals measured in Hole 584 are also present both 500 m up and 700 m down the trench slope from Hole 584.

**Sonic Velocity**

The compressional-wave velocity profile very closely parallels the wet-bulk density profile (Figs. 25 and 26). In Hole 584 throughout Intervals 1, 2, and 3 (Lithologic Units 1 and 2, Subunit 3a, and the upper 100 m of Subunit 3b), compressional-wave velocities increase nearly linearly with depth. A minimum value of 1.52 km/s occurs at 43 m sub-bottom, and a local maximum of 1.79 km/s at 460.1 m sub-bottom. Between 460.1 and 510.0 m sub-bottom the velocity gradient reverses with a relative minimum of 1.50 km/s occurring at 510.0 m sub-bottom. This reversal correlates with the reversals of both wet-bulk density and porosity trends within Interval 4. Throughout Interval 5, compressional velocity in-
Compressional-wave velocity (km/s) increases rapidly to a maximum of 2.03 km/s at 613.0 m sub-bottom. From 613.0 to 775.0 m sub-bottom (roughly Interval 6), velocity reverses a second time, decreasing gradually to 1.85 km/s. As with the wet-bulk density profile, at 775.0 m sub-bottom the compressional velocity profile returns to a normal gradient. Within Interval 7, compressional velocity increases from 1.85 to 2.10 km/s at the base of the hole.

Shear-wave velocities are not available for the upper 640 m of Hole 584 because of very high energy attenuation. Scatter in the shear velocities is large, but the general trend is toward increasing velocity with depth. Velocities of 0.6 km/s at 640.0 sub-bottom increase to 0.9 km/s at 910.0 sub-bottom. Below this depth, velocity increases rapidly to a maximum of 1.28 km/s at 931 m sub-bottom.

Data from Holes 584A and 584B are scarce because of the wash and spot core programs, but neither compressional or shear velocities show significant deviation from the sonic profiles of Hole 584.
Discussion

Preliminary lithologic analysis yields satisfactory explanations for all fluctuations in the physical properties profiles, with the exception of the anomalously high-porosity and low-density zone at 500 m sub-bottom. This zone of low-density sediment was identified from the laboratory wet-bulk density and water-content data as well as from the relatively low laboratory compressional-wave velocities (Fig. 26). In situwell log data also indicate this local density minimum near 500 m (see Logging section, this chapter; Fig. 28). Although the laboratory data from Hole 584B are sparse, they suggest that this anomalous zone extends laterally in a seaward direction a minimum of 500 m. Unfortunately, there is no in situ or laboratory data from this zone in Hole 584A to document a similar landward extension of the anomalous zone. In the absence of a lithologic interpretation for this broad anomaly, an obvious hypothesis might be that the zone is overpressured. At this time, however, we have no additional evidence to support this supposition.

Seismic reflection Profile ORI 78-3 (Fig. 31A) shows a band of strong reflectors between 450 and 800 m sub-bottom that roughly coincides with the zones of fluctuation in porosity and compressional velocity from Site 584. It is difficult to explain, however, why the reflectors are horizontal or dipping slightly westward, whereas biostratigraphic correlation of Holes 584, 584A, and 584B indicates that the lithologies are dipping eastward.

Comparison of physical properties profiles from the sites of Leg 56–57 with those from Site 584 is difficult because of the different sedimentation histories and structural positions of the various sites. The section from Hole 440 is the best for comparison with Site 584 because both sites are located in similar structural positions on midslope terraces. Physical properties are compared for the sequences from 4 to 430 m sub-bottom in Hole 584 and from 420 to 750 m sub-bottom in Hole 440, which are correlated biostratigraphically and belong to the lower Pliocene to lower Miocene Denticulopsis kamtschatica Zone (Biostratigraphy section, this chapter; fig. 5, Shipboard Scientific Party, 1980c).

Within the D. kamtschatica zone, the wet-bulk density values are higher and porosities are lower in Hole 440 than in Hole 584 because this section is buried below 420 m of Quaternary and lower Pliocene sediments in Hole 440. The shapes of these profiles, however, are identical. The upper ~200 m of these zones show abnormally low densities and high porosities, which remain nearly constant with depth. The diatom content of these sediments is the highest of any drilled in either of these two holes. These diatom-rich sediments of the D. kamtschatica Zone also form high-porosity zones in Holes 435, 438, and 441 (see Shipboard Scientific Party, 1980a, b, d), indicating an abundant regional bloom. The lowermost portions of the D. kamtschatica Zone in Holes 440 and 584 also show similar physical properties trends. The porosity profiles through this zone in both holes indicate nearly linear decreases in porosity, which correspond to decreasing diatom content as well as to increasing overburden pressure.

Carson and Bruns (1980) have hypothesized that the zone of low density at the top of the D. kamtschatica Zone, between about 420 and 580 m sub-bottom in Hole 440, is a zone of underconsolidated sediments that are characterized by abnormally high pore-water pressures. They suggest that the relatively unfractured, near-surface diatomaceous mud constitutes the "impervious" lithology required to maintain pore-water pressures above the hydrostatic pressure gradient. Given the high diatom content and the resulting low grain density of these sediments, it seems unnecessary to suggest that abnormally high pore-water pressures are responsible for maintaining this low-density zone.

PALEOMAGNETICS

Samples for paleomagnetic studies were taken from each core section. For the orientation of structural features, measurements were made on bedding and on fault planes within the same block of sediment from which the magnetic sample was taken. For all samples shipboard measurements were made routinely for natural remanent magnetization (NRM), and after 100-Oe alternating field (AF) demagnetization the intensity of the signal from each was strong compared with the noise level of shipboard magnetometer. All samples were re-measured routinely for NRM after 15-mT AF demagnetization with a shore-based magnetometer (noise level 1 × 10⁻⁴ A/m).

The variation in intensities of remanent magnetization is large, ranging from less than 1 × 10⁻⁴ to 1 × 10⁻¹ A/m, and is directly related to the proportion of magnetic minerals in the samples analyzed. Three of the intervals at Site 584 are recognized as paleomagnetically distinct: (1) an uppermost 3 m of high intensity, (2) an interval from 35 to 190 m sub-bottom of extremely low intensity, and (3) a span from 605 to 650 m sub-bottom of high intensities. The remainder of the samples have normal remanent intensities. The uppermost division corresponds to Pleistocene pebbly mud, the second to diatomaceous mud, and the third to Miocene turbidites.Selected samples were examined by the stepwise AF demagnetization.

A sample from the first interval (0.74 m sub-bottom) has stable direction during stepwise AF demagnetization; however, intensity decreases to less than half of NRM after 100-Oe AF demagnetization, meaning that this sample contains coarse grains of magnetic minerals (larger than 10 μm). Samples from the second stratigraphic interval were examined only with shore-based magnetometer because of their weak intensities. Both of the samples from the third interval have negative inclination, stable direction, and stable intensity during stepwise AF demagnetization, meaning in this case that the samples contain large amounts of fine magnetic minerals. Because the changes in intensity are similar in the first and third groups, the character of magnetic minerals in the samples from those intervals are probably also similar.
and the small intensity variations are caused only by changes in the relative abundance of the magnetic mineral.

Inclinations and intensities after 15-mT AF demagnetization are shown in Niitsuma (this volume). Magnetostatigraphic correlation above 600 m sub-bottom depth was made from the Gauss Normal Polarity Epoch to Epoch 7 with reference to diatom biostratigraphy. Several intervals in the lower part have normal dipole inclination before beddng correction. After tilting, these sediments were probably remagnetized under a geomagnetic field of normal polarity.

The strata drilled in Hole 584 have dips as steep as 75°. Dip directions were oriented by using the measured declination of remanent magnetization after 10-mT AF demagnetization and are uniformly toward the east throughout the drill hole. The sediments recovered are continuously tilted below 300 m sub-bottom depth. The intervals between 195 and 200 m and between 250 and 255 m sub-bottom contain dipping bedding planes; however, both above and below these intervals bedding is semihorizontal.

A horizon at 613 m sub-bottom depth in Hole 584A is correlated to 630 m sub-bottom depth in Hole 584 by using magnetic polarity and intensity.

HEAT FLOW

Of a total of four attempts to measure bottom-hole temperature, one reliable reading was obtained at 278.5 m sub-bottom. Thermal conductivities of recovered cores were measured at 57 points between 0 and 280 m sub-bottom, giving average conductivity of 3.35 ± 0.04 × 10^{-3} cal/(cm·deg·s). Heat flow is herein computed by multiplying the overall temperature gradient and thermal conductivity over 280 m sub-bottom as 1.17 × 10^{-6} cal/(cm²·s). This value is somewhat higher than the average value obtained previously in this area through conventional spear-type probe methods (Fig. 27).

LOGGING

Logging at Site 584 was deferred from Hole 584 to 584A because we wished to preserve as much time as possible for drilling to the deep reflectors that defined our major objective. Because Hole 584A was only spot cored, the logs in that hole must be correlated primarily with coring results in Hole 584, which contained very steeply dipping beds. However, correlation based on biostratigraphy and physical properties indicates that stratigraphic horizons in Hole 584B are 0 to 50 m higher than at Hole 584 over the logged interval.

After the extensive caving below 850 m that caused termination of drilling at Hole 584A, the pipe was “worked down” to 879 m, where the mechanical bit release was successfully shifted, and the hole was filled with heavy mud. The first logging run was to include sonic, induction, gamma ray, and caliper tools, but this run was aborted following the inability to receive recognizable signals from the sonic tool. A combination of formation density (FDC), neutron porosity (CNL), gamma ray (GR), and caliper tools was rigged.

This combination of tools was “worked down” to 4620 m (495 m sub-bottom), where it encountered a bridged section. We suspected that the tools had passed this bridge, and an extra 200 m of cable was played out. An initial run was then made up to 400 m sub-bottom in order to duplicate-sample the critical depth interval where several large density and velocity anomalies were defined from laboratory measurements and within which a major reflecting horizon lay. Attempts to return to what was thought to be the original logging depth were blocked at (what was in retrospect) the same bridge near 500 m. A second logging run was then completed to the open pipe at 91 m sub-bottom. Our limitation to 500 m is unfortunate because the interval between 500 and 700 m contains most of the large fluctuations in physical properties.

A second attempt to lower the sonic-induction combination was no more successful than the first and, with the remaining time waning for a “last ditch effort” to clarify the complex structure at this site in a third hole, logging was terminated. From the end of hole conditioning to the rigging down of logging equipment, 17½ hr. were consumed in the logging operation.

The abbreviated set of logs (Fig. 28) is of high quality because of the calm sea conditions, because most of the hole was near gauge, and because the lithology is relatively simple. Two distinctive units are defined on the basis of the log response, but difficulties arise in correlating the log responses with lithologic units delineated in the cores from Hole 584.

Logging Unit 1 extended from the open pipe at 91 m sub-bottom to about 350 m. Over this interval the FDC log shows a downward, fairly linear increase in bulk density from 1.40 to 1.55 g/cm³ at 325 m. Superimposed on this increase are small-scale variations that do not correlate well with other logs. Over this interval the CNL values are relatively high with respect to the FDC values. A very distinctive characteristic of this unit is the low natural GR values, which average less than 20 API units near the top but rise gradually to about 25 units at 350 m. This unit correlates well with the diatom-rich muds, sediments with very low density and relatively low clay content. The downward increase in density and gamma radiation reflect the decrease in diatom content and resultant increase in clay content. Laboratory bulk densities from 2-minute GRAPE measurements are about 0.05 g/cm³ less than the log values, as expected from pressure release rebound (Shepard et al., 1982).

The second logging unit extends from about 350 m sub-bottom to the base of the logged interval. Within this zone, gamma log anomalies have higher amplitudes and higher mean values (25 to 35 API units) than in Unit 1. The caliper log indicates that this section of hole is much more rugose than above. Bulk densities over this section rise rapidly to 1.60 g/cm³ by 375 m and vary about this value with wave-length excursions of 0 to 2 m and amplitudes of 0.25 g/cm³. Maximum average densities of 1.65 g/cm³ occur near 450 m. The CNL log closely follows the FDC log and differs from that of Unit 1 in having lower values relative to the FDC log.
over the same interval. From 425 to 500 m sub-bottom, the CNL trace is consistently below the FDC trace in the stacked format. The highly variable and correlative GR, caliper and FDC logs over Unit 2 indicate interbedded sand-rich beds or silt-rich and clay-rich beds. Silt to fine-sand stringers recovered in the cores of this interval probably represent these sand-rich units, but the logs suggest that many more such intervals are present than were recovered. Several thin (0.5 m) high-density spikes, with bulk densities reaching 1.90 g/cm$^3$, may indicate thicker ash units, which are relatively abundant over the upper half of this interval.

In situ densities over Unit 2 compare well with the laboratory values. Both show relatively constant values with a relative density maximum near 400 to 450 m sub-bottom. In broader context of the laboratory-derived bulk-density profile, this response could better be explained as showing a general increase in density with depth, but with a superimposed local density minimum near 500 m in Hole 584 (Fig. 28).

**Comparison with Sites 440 and 439**

The strata logged in Hole 584B are chronologically equivalent to those logged between about 450 m and the end of logging, at 730 m in Hole 440. Bulk densities at the Pliocene/Miocene boundary in Hole 584 are significantly lower (1.50 to 1.55 g/cm$^3$) than at the same biostratigraphic level in Hole 440 (1.60 g/cm$^3$). In part, this difference reflects the much greater depth (670 m) to this level in Hole 440 than in 584. Tectonic factors are not thought to be the major cause of the difference, because strata at this sub-bottom depth in Hole 584 show significant dewatering veins and healed fractures. From the differences in values, we may infer that a thick section of upper Pliocene and Quaternary was never deposited at Site 584, and that nondeposition was dominant during that time span. The densities in these two sites converge downward into upper Miocene sediments, reflecting the gradual downward increase in values in Site 584 contrasted with the relatively constant profile at Site 440.

No inversion in *in situ* bulk densities comparable with that at Site 440 and at other drill sites on the inner slope was observed at Site 584. Such an inversion might have occurred in the upper Pliocene strata, missing at Site 584, but this is unlikely because the inversion at Site 440 and elsewhere occurs over a density range of 1.5 to 1.65 g/cm$^3$, where sediments are becoming indurated. In Hole 584B, this range is reached only in the lowermost Pliocene strata near a 300-m depth.

The deepest part of the FDC log and laboratory measurements indicate a marked density minimum between about 475 and 525 m, but for several reasons this anomaly is not correlated with that density minima at sites drilled on previous legs. First of all, this anomaly occurs where dewatering veins, healed fractures, and layer shears are already well-developed. In addition, this section of the hole was typified by very good recovery and cores with a minimum of open fractures. Moreover, both
the in situ and laboratory profiles show this anomaly, indicating that the anomalous density is an intensive characteristic and not due to larger-scale fracturing.

SEISMIC STRATIGRAPHY

Seismic Lines JNOC 1, ORI 78-3, ORI 78-4, and JNOC 2 flank DSDP Legs 56, 57, and 87 sites (Fig. 29), and of these Profile JNOC 1 was processed specifically by the Japan National Oil Corporation for Leg 87 (Fig. 30). Additionally, a new, migrated display was prepared for Profiles ORI 78-3 and ORI 78-4 (Fig. 31), and several kinds of multichannel displays were prepared for the profile-crossing proposed Site 584, particularly for Line ORI 78-3 between Shot Points (SP) 0 and 400 (see Fig. 31A). Several authors have discussed the meaning of the various seismic reflectors shown on these profiles (Nasu et al., 1980; Saki et al., 1980; Kagami et al., 1981). This report will discuss, therefore, only the problems related to Site 584, with particular emphasis on the origin of the midslope terrace in the trench slope.

The midslope terrace or bench on the trench slope is one of the most persistent topographic features of the slope and roughly parallels the trench axis (Nasu et al., 1980). The proposed site was selected on the midslope terrace because this is the seaward limit of the trace of the seismic reflectors from the landward reference Sites 438 and 439 (Shipboard Scientific Party, 1980a). Even so, reflectors traced on Profiles JNOC 1, JNOC A, ORI 81-2, and ORI 78-3 to Site 584 are not always continuous (Tsuboi et al., this volume). Drilling has shown that dips ranging between 20 and 70° occur in the cores below 350 m sub-bottom. These beds are disharmonic to the low-angle dips of seismic reflectors. Drilling results at Hole 584A clearly indicate that the vertical offset of the stratigraphic horizons does not exceed 50 to 100 m between the two holes, despite the much higher dips of the individual beds. The reflectors are, therefore, averaging structural features at a scale comparable to the distance between the Site 584 holes and are not resolving the details apparent in the lithologic section.

Kagami and others (1981) conducted a synthetic profile by revising the original based on logging at Site 439 (Saki et al., 1980). In the result, Reflector X is traced seaward to SP 1790 on Profile JNOC 1, where it becomes obscured (Fig. 30 and Table 3A). Reflector C is traced to SP 1780, where it also fades. A faded pattern might arise from tectonic phenomena such as fracturing. Reflector E, on the contrary, gets stronger near SP 1760 and maintains its reflectivity toward SP 1860. Reflector F cannot be traced on the profile. Reflector J is easily traced because of its strong acoustic impedance contrast.

Reflectors can be traced from the Sites 438 and 439 on the migrated depth section of the landward segment of Profile JNOC 1, through Profile JNOC A and Profiles ORI 80-2 to ORI 78-3, to Site 584 (Fig. 29). Tracing reflectors over a distance as great as 100 km limits the accuracy of the following discussion.

According to the Leg 57 site chapter for Site 440 (Shipboard Scientific Party, 1980c), Reflector C on Profile JNOC 2 is a tectonically induced reflector (Table 3B). Physical properties at that site show decreases in density and velocity at this interval. The stacking velocity for Profile ORI 78-3 indicates that between SP 0 and SP 150 a low-velocity zone exists roughly between Reflectors C and E, similar to Reflector C of Profile JNOC 2. The velocity inversion from 1.83 above to 1.51 km/s below Reflector C may correspond either to a Coscinodiscus spp. bloom as shown by marked increase in opal-A, or to development of tectonically induced fractures, faults, and veins at this level. Because both phenomena develop
Figure 29. Location map for multichannel seismic profiles near Site 584. Location numbers in the 400s are Leg 56, 57 drill sites. Contour intervals are 500 m.
at about the same level, it is difficult to evaluate which of the two is more important for the change of physical properties at Site 440. Also, seismic Line JNOC 2 was not migrated, so it is difficult to compare the reflectors at this stage.

Compared with Site 439, the lower section between Reflectors F and J on Profile ORI 78-3 (Fig. 31A and Table 3C) is three to four times thicker between SP 0 and SP 100, suggesting the presence of a Paleogene section. Reflector J dips seaward parallel to the surface of the trench slope and to a reflector probably from the Paleogene section. These supposed Paleogene rocks onlap the J reflector between SP 0 and SP 100.

The reflectors fade, the low-velocity zone disappears, and acoustic basement (Reflector J) reverses the structural gradient from seaward dipping to landward dipping from SP 150 seaward. At SP 270 on the migrated depth section, another velocity inversion of 1.82 to 1.57 km/s is estimated from the stacking velocity for the depth interval between 420 and 520 m sub-bottom. That inversion is about the same depth as the base of the abundant opal-A zone (see Inorganic Geochemistry section, this chapter) and is probably a result of tectonically induced fractures and faults or rapidly deposited mud turbidites (see Sedimentology section, this chapter).

A tentative correlation of seismic events with the drilling results is shown in Table 4 and in the segment from Profile ORI 78-3 (see Fig. 31A). Three seismic units are recognized, based on sharp velocity changes. Seismic Unit 1 ranges from 0 to 580 m sub-bottom. The interval velocity is 1.83 km/s. Seismic Unit 2 ranges from 580 to 1200 m sub-bottom where it is underlain by Reflector J, and its interval velocity is 2.10 km/s. Except for the basement reflector, no drilled lithologic horizon can be traced within seismic Unit 1. The strongest reflectors occur at 460, 499, and 584 m sub-bottom, one of which may represent Reflector E. Although they appear to be horizontal, they are subparallel to the basement high and also to the surface topography. The acoustic basement shows strong reflection because of its high velocity ranging from 3.1 to 4.2 km/s, which is within the range expected for the consolidation state of Cretaceous to Paleogene rocks. Seismic Unit 2 apparently corresponds to steeper bedding inclinations (see Structural Geology and Paleomagnetics sections, this chapter).

Drilling of Site 440 showed that the depth of the Miocene/Pliocene boundary was far below its projection from Site 435. Nasu and others (1980) deduced, therefore, that the downbowing of the seaward edge of the continent was responsible for formation of the filled trough or midslope terrace during the subsidence of the Oyashio landmass.

Profile ORI 78-4 more clearly shows relative basement uplift beginning at a hinge point under a trough and continuing to the trench slope break (Fig. 31B). The acoustic basement landward from the hinge point slopes seaward in almost a straight line, and seaward of that point basement also slopes uniformly, but with a reverse
gradient. Coastal terraces with a reverse gradient of topography have been discussed by many authors (Seno and Ishibashi, 1978). Uplifted subaerial coastal terraces are associated with great interplate earthquakes (Yonekura, 1975; Fitch and Scholz, 1971). During the interseismic period they subside. Of importance for topography, therefore, is the residual uplift for one seismic cycle. Seno and Ishibashi (1978) defined the residual uplift ratio as the ratio of the residual uplift ($V_c$) to total uplift ($V_c + V_d$) during seismic crustal movement. Total subsidence during the interseismic period is defined as $V_d$.

The reverse gradient observed for the acoustic basement shown on Profile ORI 78-4 might suggest that seismic crustal movement has been occurring at this convergent plate boundary. Can seismic crustal movements explain the occurrence of these filled troughs? A schematic figure represents the formation of a typical reverse gradient along the continental and ocean crust boundary (Fig. 32). Point A indicates the end of the present acoustic basement, Point C represents the estimated Pliocene position of Point A based on a straight line extrapolation. Point B corresponds to the depth of the hinge point. In this case, the residual uplift ratio indicates an integrated uplift for the time span between the Pleistocene and the Recent. The duration of the Pleistocene was taken from the previous work at Site 301.
Table 3A. Reflectors picked at SP 1840 on seismic Profile JNOC 1.

<table>
<thead>
<tr>
<th>Reflector</th>
<th>Sub-bottom depth (m)</th>
<th>Stratigraphic unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>290</td>
<td>Pleistocene</td>
</tr>
<tr>
<td>C</td>
<td>500</td>
<td>Pleistocene</td>
</tr>
<tr>
<td>E</td>
<td>700</td>
<td>Strong reflector</td>
</tr>
<tr>
<td>F</td>
<td>900</td>
<td>middle Miocene</td>
</tr>
<tr>
<td>J</td>
<td>1390</td>
<td>Cretaceous</td>
</tr>
</tbody>
</table>

Table 3B. Reflectors picked from Profile JNOC 2 at Site 440.

<table>
<thead>
<tr>
<th>Reflector</th>
<th>Depth (s)</th>
<th>Sub-bottom depth (m)</th>
<th>Stratigraphic unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>6.26</td>
<td>290</td>
<td>Pleistocene</td>
</tr>
<tr>
<td>C</td>
<td>6.41</td>
<td>450</td>
<td>Pliocene</td>
</tr>
<tr>
<td>E</td>
<td>6.64</td>
<td>690</td>
<td>upper Miocene</td>
</tr>
</tbody>
</table>

Table 3C. Reflectors picked from SP 00 (western end) of the revised migrated section of Profile ORI 78-3 (Fig. 31A).

<table>
<thead>
<tr>
<th>Reflector</th>
<th>Depth from sea level (km)</th>
<th>Sub-bottom depth (m)</th>
<th>Stratigraphic unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>3.6</td>
<td>320</td>
<td>Pliocene</td>
</tr>
<tr>
<td>(D)</td>
<td>4.1</td>
<td>970</td>
<td>upper Miocene</td>
</tr>
<tr>
<td>E</td>
<td>4.8</td>
<td>1220</td>
<td>middle Miocene</td>
</tr>
<tr>
<td>F</td>
<td>5.1</td>
<td>1820</td>
<td>Cretaceous</td>
</tr>
</tbody>
</table>

Table 4. Correlation of seismic events drilled at Site 584 (SP 270).

<table>
<thead>
<tr>
<th>Reflectors (m)</th>
<th>Drilled sub-bottom depth (m)</th>
<th>Remarks</th>
<th>Seismic unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>48</td>
<td>Moderate, carbonate concretion</td>
<td>1</td>
</tr>
<tr>
<td>55</td>
<td>58</td>
<td>Strong, carbonate concretion</td>
<td>1</td>
</tr>
<tr>
<td>100</td>
<td>105</td>
<td>Open fracture begins</td>
<td>1</td>
</tr>
<tr>
<td>150</td>
<td>153</td>
<td>Lithologic change</td>
<td>1</td>
</tr>
<tr>
<td>215</td>
<td>212</td>
<td>Lithologic change</td>
<td>1</td>
</tr>
<tr>
<td>350</td>
<td>345</td>
<td>Lithologic change</td>
<td>1</td>
</tr>
<tr>
<td>390</td>
<td>393</td>
<td>Fault?</td>
<td>1</td>
</tr>
<tr>
<td>460</td>
<td>460</td>
<td>Moderate, unconformity</td>
<td>2</td>
</tr>
<tr>
<td>500</td>
<td>499</td>
<td>Strong, unconformity</td>
<td>2</td>
</tr>
<tr>
<td>580</td>
<td>584</td>
<td>Strong, velocity increase</td>
<td>2</td>
</tr>
<tr>
<td>625</td>
<td>622</td>
<td>Strong, velocity maximum</td>
<td>2</td>
</tr>
<tr>
<td>695</td>
<td>690</td>
<td>Silty to clayey</td>
<td>2</td>
</tr>
<tr>
<td>715</td>
<td>719</td>
<td>Silt bearing</td>
<td>2</td>
</tr>
<tr>
<td>820</td>
<td>825</td>
<td>Hard claystone</td>
<td>2</td>
</tr>
<tr>
<td>860</td>
<td>873</td>
<td>Moderate, unconformity</td>
<td>2</td>
</tr>
<tr>
<td>900</td>
<td>892</td>
<td>Moderate, shear zone</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 5. Residual uplift ratios calculated from seismic reflection profiles.

<table>
<thead>
<tr>
<th>Seismic line</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>$V_c$</th>
<th>$V_d$</th>
<th>Residual uplift ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>JNOC 1</td>
<td>4500</td>
<td>5350</td>
<td>6550</td>
<td>850</td>
<td>1200</td>
<td>0.40</td>
</tr>
<tr>
<td>ORI 78-3</td>
<td>4750</td>
<td>5650</td>
<td>7050</td>
<td>900</td>
<td>1400</td>
<td>0.40</td>
</tr>
<tr>
<td>ORI 78-4</td>
<td>4890</td>
<td>5710</td>
<td>6900</td>
<td>820</td>
<td>380</td>
<td>0.68</td>
</tr>
<tr>
<td>JNOC 2</td>
<td>4455</td>
<td>5425</td>
<td>6125</td>
<td>970</td>
<td>700</td>
<td>0.60</td>
</tr>
</tbody>
</table>

Note: Values of A, B, and C represent depth in meters. For explanation of A, B, C, $V_c$, and $V_d$, see text.
Figure 33. Residual uplift of the midslope terrace based on: A. multichannel seismic reflection Profile JNOC 1, with interpretive horizons, and B. multichannel seismic reflection Profile JNOC 2, with interpretive horizons.
apparently persisted during the Miocene, only to diminish and perhaps to revert to episodes of relative uplift and possibly accretion since the late Pliocene–Quaternary. The combination of drilling results, logging, seismic profiles, and other geologic data should clarify the nature of deformation that controls the large-scale structural geometry in the trench-slope area.

Three holes were drilled across the midslope terrace of the Japan Trench, penetrating 954 m of the sedimentary section. The oldest sediment cored was early Middle Miocene. Four lithostratigraphic units are recognized (see Sedimentology section, this chapter).

The uppermost 4 m at Hole 584 are Pleistocene sediments, underlain without a visible lithologic contact by soft, lower Pliocene diatomaceous mud and mudstone, consolidating near 88 m sub-bottom. A third lithologic unit (240 to 537 m sub-bottom) is also a diatomaceous mudstone, but is distinguished by fine sand and silt beds, seaward-dipping strata, and markedly higher induration. The Pliocene/Miocene boundary occurs within this unit, near 425 m sub-bottom, but no lithologic contrast marks this event. A varicolored, bioturbated mudstone with a much-reduced diatom content constitutes Unit 4 and the remaining 941 m drilled at Hole 584. The lower portion is noteworthy for its paisley appearance and pervasive network of dewatering veinlets. Healed fractures begin in Core 27 and become more numerous downsection; in most cases the offsets are normal, but abundant examples of reverse motion also occur.

The frequency of ash layers and of dispersed glass and ash pods suggests that onshore volcanic activity increased near the end of the late Miocene and continued through the early Pliocene. Authigenic carbonate nodules, including siderite, are commonly disseminated in the lower Pliocene sediments and are frequently intercalated with ash layers or dispersed volcanic sediments.

The diatom biostratigraphy of Site 584 is virtually identical to that of Site 438, located about 70 km to the west. Rates of sediment accumulation are based on selected datum levels and are highest (200 to 70 m/Ma) for the lower Pliocene and upper upper Miocene (7 Ma). Lower upper Miocene through upper middle Miocene rates are less (15 m/Ma). Logging and laboratory physical properties measurements outline large fluctuations in bulk density and in sonic velocity in a zone of prominent reflectors beginning near 500 m sub-bottom.

A seismic-interval-velocity reversal at 470 m sub-bottom coincides with a density decrease between 470 and 550 m. These reversals are interpreted as follows: the stratigraphic level is the beginning of large sediment influx and is represented by a rapidly deposited muddy turbidite containing excess pore water and sealed by overlying sediments. The density reversal reflects sound in a zone of prominent reflectors. The acoustic basement shown on the migrated seismic section dips gradually seaward, but the dip reverses near the continental and ocean crust boundary. A hinge point located beneath the midslope terrace is clearly defined on the profile, and from that point the faults develop and the seismic horizons are obscured, owing mainly to steep bedding. Faulting may, therefore, control the landward dip of this segment of acoustic basement.

Using geometric simplifications of the available seismic reference lines, residual uplift ratios were computed, as was originally done to quantify deformation of Japanese coastal terraces (see Seismic Stratigraphy section, this chapter).

Many lines of evidence mark the commencement of the crustal movement along the Japan Trench. Foraminiferal assemblages at Site 438 indicate shallower environments since the Pleistocene (Shipboard Scientific Party, 1980a). The rate of sedimentation increased rapidly in the Pleistocene at Site 440 suggesting commencement of filling of the midslope terrace (Shipboard Scientific Party, 1980c). If we take 2 Ma as a starting time, the rate of the present phase of vertical crustal movement is 0.6 to 1.2 mm/yr., a range comparable to that measured for crustal movements on land.

Evidently, extensional tectonics from the middle Miocene continued until the early Pliocene, and Site 584 was already at bathyal depths by the late Miocene. A hiatus between lower Pliocene and Quaternary sediments found at Hole 584 might indicate commencement of reversed gradient of the acoustic basement, which can be explained by vertical crustal movement associated with great interplate earthquakes caused by a new cycle of subduction at the trench.

REFERENCES


**SITE 584 HOLE CORE 1 CORED INTERVAL 6.6–10.3 m**

<table>
<thead>
<tr>
<th>Time Domain</th>
<th>Rock Facies</th>
<th>Facies Description</th>
<th>Lithology &amp; Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil</td>
<td>Biofacies</td>
<td>Dark olive gray to gray biosiliceous mud</td>
<td>SY 4/2</td>
</tr>
</tbody>
</table>

**LITHOLOGIC DESCRIPTION**

- **Dark olive gray to gray biosiliceous mud**
  - SMEAR SLIDE SUMMARY (%):
    - 1,95 2,65 CC, 10
    - Sand: 25 15 7
    - Clay: 36 10
    - Heavy minerals: 10
    - Pyrite: 10
    - Volcanic glass: 45
    - Calc. nannofossils: 30
    - Diatoms: 20
    - Sponge spicules: 10
    - Plant debris: 10
  - ORGANIC CARBON & CARBONATE (%):
    - Carbonate: 1.1
    - Organic carbon: 1.1
  - Depressed ash (1/1)
  - Layer black silty silt
  - Void

**SITE 584 HOLE CORE 2 CORED INTERVAL 10.3–20.0 m**

<table>
<thead>
<tr>
<th>Time Domain</th>
<th>Rock Facies</th>
<th>Facies Description</th>
<th>Lithology &amp; Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil</td>
<td>Biofacies</td>
<td>Micritic limestone</td>
<td>SY 4/2</td>
</tr>
</tbody>
</table>

**LITHOLOGIC DESCRIPTION**

- **Micritic limestone**
  - SMEAR SLIDE SUMMARY (%):
    - 1,50 2,65 CC, 10
    - Sand: 25 15 7
    - Clay: 36 10
    - Heavy minerals: 10
    - Pyrite: 10
    - Volcanic glass: 45
    - Calc. nannofossils: 30
    - Diatoms: 20
    - Sponge spicules: 10
    - Plant debris: 10
  - ORGANIC CARBON & CARBONATE (%):
    - Carbonate: 1.1
    - Organic carbon: 1.1
  - Depressed ash (1/1)
  - Layer black silty silt
  - Void
### SITE 584 HOLE 3 CORE 2 Cored Interval 20.6–29.4 m

**Lithologic Description**

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Graphotype</th>
<th>Color (Munsell)</th>
<th>Texture</th>
<th>Sand</th>
<th>Clay</th>
<th>Mud</th>
<th>Ash</th>
<th>Foraminifers</th>
<th>Radiolarians</th>
<th>Sponges</th>
<th>Silicoflagellates</th>
<th>Fish remains</th>
<th>Lithic fragments</th>
<th>Organic Carbon and Carbonate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.0–19.4</td>
<td>5Y 4/2 with light stringy 5Y 6/3 zones rich in fusulinid tests</td>
<td>Diffuse areas, blunter than surrounding = pyrite concentrations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Smear Slide Summary (%)**

- Feldspar: 10
- Heavy minerals: 10
- Carbonate: 5
- Silicoflagellates: 1
- Radiolarians: 1
- Sponge spicules: 1
- Organic Carbon and Carbonate: 12.0

### SITE 584 HOLE 4 CORE 4 Cored Interval 29.4–38.8 m

**Lithologic Description**

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Graphotype</th>
<th>Color (Munsell)</th>
<th>Texture</th>
<th>Sand</th>
<th>Clay</th>
<th>Mud</th>
<th>Ash</th>
<th>Foraminifers</th>
<th>Radiolarians</th>
<th>Sponges</th>
<th>Silicoflagellates</th>
<th>Fish remains</th>
<th>Lithic fragments</th>
<th>Organic Carbon and Carbonate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.0–29.4</td>
<td>5Y 4/2 with light stringy 5Y 6/3 zones rich in fusulinid tests</td>
<td>Diffuse areas, blunter than surrounding = pyrite concentrations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Smear Slide Summary (%)**

- Clay: 10
- Pyrite: 10
- Opaque: 5
- Foraminifers: 1
- Diatoms: 1
- Radiolarians: 1
- Sponge spicules: 1
- Silicoflagellates: 1
- Organic Carbon and Carbonate: 12.0

### SITE 584 HOLE 4 CORE 4 Cored Interval 29.4–38.8 m

**Smear Slide Summary (%)**

- Ashy patch – V1: 2.5/6/7
  - Sand: 20
  - Clay: 20
  - Foraminifers: 1
  - Diatoms: 1
  - Radiolarians: 1
  - Sponge spicules: 1
  - Silicoflagellates: 1
  - Fish remains: 1
  - Lithic fragments: 1
  - Organic Carbon and Carbonate: 12.0
  - Silt: 14.0
SITE 584 HOLE CORE 5 CORED INTERVAL 38.8-48.2 m

LITHOLOGIC DESCRIPTION

MUDDY BIOSILICEOUS OOZE

Olive gray (5Y 4/3)

V1) dark gray ash, smeared by drilling

V2) olive gray, mottled.

D M M
5 45 56
10 55 56
20 35 35

6Y 5/3 mottled.

SMEAR SLIDE SUMMARY (%):

Quartz 8 7 15
Feldspar 3 3 7
Heavy minerals 2 3 8
Vx 10 23
Siliceous 6 4 2
Clay 83 21 16

V2) 180 cm, dark gray sandy patches

SMEAR SLIDE SUMMARY (%):

1, 50 1, 50 2, 50
D M M

Silt 6 45 56
Silt 15 55 56
Silt 30 35 35

6Y 5/3 mottled.

Organic Carbon and Carbonate (%)

Calcite 2, 50
Carbonate 0.0
LITHOLOGIC DESCRIPTION

V1, gray fine volcanic ash

Sponge spicules

FIRM BIOSILICEOUS MUD
Dark olive gray (5Y 4/2)

LITHOLOGIC DESCRIPTION

V1, N6, silty ash layer, 101 cm to 105 cm

SMEAR SLIDE SUMMARY

Texture: Sand 2 Silt 48 Clay 49 Composition: Clay 19 28 9 28 Quartz 1 1 1 1 Feldspar 6 6 6 6 Heavy minerals 3 3 3 3 Total carbonate 2 5 14 14 V1, N3, sandy volcanic ash

LITHOLOGIC DESCRIPTION

Siderite-dolomite clasts (XRD) 2.5Y 7/2

V1, gray (N5) silty volcanic ash

ORGANIC CARBON AND CARBONATE (%)

Organic carbon 0.0 Carbonate 0.0

LITHOLOGIC DESCRIPTION

SMEAR SLIDE SUMMARY (%)

Texture: Sand 15 10 30 Silt 50 40 10 Clay 26 40 30 Composition: Quartz 4 4 12 Feldspar 6 6 6 Heavy minerals Ti 1 1 1 Clay 26 26 26 Total carbonate 1 51 21 V1, gray (5) silty volcanic ash

LITHOLOGIC DESCRIPTION

SMEAR SLIDE SUMMARY (%)

Texture: Sand 15 10 30 Silt 60 40 Clay 26 40 30 Composition: Quartz 4 4 12 Feldspar 6 6 6 Heavy minerals Ti 1 1 1 Clay 26 26 26 Total carbonate 1 51 21 V1, gray (5) silty volcanic ash
### SITE 584 HOLE 10 CORED INTERVAL 86.5-96.0 m

#### Lithologic Description

**Firm Diatomaceous Mud**
- Olive gray to olive (5Y 4/2 to 4/4)
- Vertical cracks opening with drying, desiccation

**Section 2:** 60 cm to 90 cm, color changes to a yellower shade in laminations and burrows.

**Section 3:** Beginning of thin drilling laminations, irregular, wispy darker sediment concentrations in 10 cm and again in 30 cm to 30 cm

#### Siltstone Summary (2 cm)

<table>
<thead>
<tr>
<th>Texture</th>
<th>1.60</th>
<th>2.11</th>
<th>2.62</th>
<th>3.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Silt</td>
<td>X</td>
<td>X</td>
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<td></td>
</tr>
<tr>
<td>Clay</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### OrganoCarbon and Carbonate (%)

- Carbonate 0.0
- Organic Carbon 1.50
- Total Organic Carbon 1.50

---

### SITE 584 HOLE 11 CORED INTERVAL 96.0-105.5 m

#### Lithologic Description

**Firm Diatomaceous Mud**
- Olive gray to olive (5Y 4/2 to 4/4)
- Vertical cracks opening with drying, desiccation

**Section 1:** 0 cm to 30 cm, pyrite

**Section 2:** 0 cm to 20 cm, steeply spaced irregular fracturing

#### Siltstone Summary (2 cm)

<table>
<thead>
<tr>
<th>Texture</th>
<th>1.60</th>
<th>2.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Silt</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Clay</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

---

#### OrganoCarbon and Carbonate (%)

- Carbonate 0.0
- Organic Carbon 1.50
- Total Organic Carbon 1.50
**Lithologic Description**

**FIRM DIATOMACEOUS MUD**

- V1, ash layer 2 mm thick
- 39 cm to 42 cm, highly irregular, bioturbated interval

**SY 4/2**

- Diffuse color change back to SY 4/4
- 100 cm, diffuse concentration of free sand grains
- Other, perhaps drilling induced?

**Light color change to SY 4/3**

**Smear Slide Summary (%)**:

<table>
<thead>
<tr>
<th>Texture</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
<th>Quartz</th>
<th>Feldspar</th>
<th>Clay</th>
<th>Volcanic glass</th>
<th>Palagonite</th>
<th>Glauconite</th>
<th>Pyrite</th>
<th>Carbonate unspec.</th>
<th>Foraminifers</th>
<th>Calc. nannofossils</th>
<th>Diatoms</th>
<th>Radiolarians</th>
<th>Sponge spicules</th>
<th>Silicoflagellates</th>
<th>Lithic fragments</th>
<th>Org-Carbon and OR-Carbonate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>25</td>
<td>25</td>
<td>50</td>
<td>10</td>
<td>10</td>
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<tr>
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<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

**Organic Carbon and Carbonate (%)**:

- Carbonate: 0.0
- Org-Carbon: 1.50
### SITE 584 HOLE 17 CORE INTERVAL 153.7 - 162.4 m

<table>
<thead>
<tr>
<th>SECTION</th>
<th>LITHOLOGIC DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1.0</td>
<td>SY 4/3 Firm bioturbated mud</td>
</tr>
</tbody>
</table>

#### SMEAR SLIDE SUMMARY (%):

- **Feldspar**: 1 M 32 T1
- **Diatoms**: 45 5 9
- **Organic Carbon and Carbonate**: 1.1
- **Organic Carbon and Carbonate**: 2.5 N 10

### SITE 584 HOLE 19 CORE INTERVAL 172.1 - 182.8 m

<table>
<thead>
<tr>
<th>SECTION</th>
<th>LITHOLOGIC DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-6</td>
<td>SB1 T2 Firm bioturbated mud</td>
</tr>
</tbody>
</table>

#### SMEAR SLIDE SUMMARY (%):

- **Feldspar**: 1 M 21 1 M 10
- **Organic Carbon and Carbonate**: 1.1
- **Organic Carbon and Carbonate**: 3.5

### SITE 584 HOLE 18 CORE INTERVAL 162.4 - 172.1 m

<table>
<thead>
<tr>
<th>SECTION</th>
<th>LITHOLOGIC DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1.0</td>
<td>SY 5/3 Ashy firm bioturbated mud</td>
</tr>
</tbody>
</table>

#### SMEAR SLIDE SUMMARY (%):

- **Feldspar**: 1 M 10 1 M 42
- **Organic Carbon and Carbonate**: 1.1
- **Organic Carbon and Carbonate**: 3.5

---

**Lithologic Description**

- **SY 4/3**: Firm bioturbated mud
- **SB1 T2**: Firm bioturbated mud
- **SY 5/3**: Ashy firm bioturbated mud

**Smeared Slide Summary (%):**

- **Feldspar**: 1 M 32 T1
- **Diatoms**: 45 5 9
- **Organic Carbon and Carbonate**: 1.1

**Organic Carbon and Carbonate**: 2.5 N 10

---

**Fossil Character**

- **TIME**: 1
- **TIME**: 1
- **TIME**: 1

**Paleocharact**:

- **TIME**: 1
- **TIME**: 1
- **TIME**: 1

**Paleocharact**:

- **TIME**: 1
- **TIME**: 1
- **TIME**: 1

**Paleocharact**:

- **TIME**: 1
- **TIME**: 1
- **TIME**: 1

**Paleocharact**:

- **TIME**: 1
- **TIME**: 1
- **TIME**: 1

**Paleocharact**:

- **TIME**: 1
- **TIME**: 1
- **TIME**: 1
### SITE 584 HOLE 1 ROC

**INTRODUCTION**

<table>
<thead>
<tr>
<th>SECTION</th>
<th>METERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>0.5</td>
</tr>
<tr>
<td>3</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**ORETICAL FORMATION**

**SEDIMENTARY STRUCTURES**

**SAMPLES**

**LITHOLOGIC DESCRIPTION**

- Light-colored laminations throughout Section 1: laminations 16 cm—17.5 cm, light ash layer 34 cm—V1 100 cm, black 5Y 4/3
- Massive olive gray with a few slightly lighter colored ash layers

**SMEAR SLIDE SUMMARY (%):**

- Olive green gray (5Y 4/2)
- Carbonate 1.7
- Diatoms 40 6 42 2
- Glauconite - 1 - -
- Clay 20 8 15 7
- Quartz 10 11 10 8
- Clay 20 10 51 10
- Foraminifers Tr - 2 -

**ZONE DESCRIPTION**

<table>
<thead>
<tr>
<th>SECTION</th>
<th>GRAPHIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5-1.0</td>
<td></td>
</tr>
</tbody>
</table>

**ORGANIC CARBON AND CARBONATE (%)**

**DIAGRAM**

- Graph C
- Cored interval 182.8-192.5 m
### Site 584

#### Hole Z3

**Core Interval:** 202.1–211.7 m

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Character</th>
<th>Graphic Lithology</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5–1.5</td>
<td>Firm diatomaceous mud</td>
<td>S101 T2</td>
<td>Olive gray (S1Y1/3)</td>
</tr>
<tr>
<td>1.5–2.5</td>
<td>Diatomaceous mud</td>
<td>S101 T2</td>
<td>Light gray (S1Y1/3)</td>
</tr>
</tbody>
</table>

#### Core Interval: 211.7–221.3 m

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Character</th>
<th>Graphic Lithology</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5–1.5</td>
<td>Firm diatomaceous mud</td>
<td>S101 T2</td>
<td>Olive gray (S1Y1/3)</td>
</tr>
<tr>
<td>1.5–2.5</td>
<td>Diatomaceous mud</td>
<td>S101 T2</td>
<td>Light gray (S1Y1/3)</td>
</tr>
</tbody>
</table>

**Organic Carbon and Carbonate (%):**
- Carbonate: 0.0
- Organic Carbon: 1.50

**Smear Slide Summary (%):**
- Sand: 20
- Silt: 30
- Clay: 50

**Composition:**
- Quartz: 6
- Feldspar: 3
- Mica: 1
- Clay: 25
- Volcanic glass: 83
- Pyrite and opaque: 8
- Calc. nannofossils: 4
- Diatoms: 4
- Sponge spicules: 6
- Silicoflagellates: 4
- Plant debris: 1

---

**Site 584 HOLE CORE 22 CORED INTERVAL 202.1–211.7 m**

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Character</th>
<th>Graphic Lithology</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5–1.5</td>
<td>Firm diatomaceous mud</td>
<td>S101 T2</td>
<td>Olive gray (S1Y1/3)</td>
</tr>
<tr>
<td>1.5–2.5</td>
<td>Diatomaceous mud</td>
<td>S101 T2</td>
<td>Light gray (S1Y1/3)</td>
</tr>
</tbody>
</table>

**Organic Carbon and Carbonate (%):**
- Carbonate: 0.0
- Organic Carbon: 1.50

**Smear Slide Summary (%):**
- Sand: 20
- Silt: 30
- Clay: 50

**Composition:**
- Quartz: 6
- Feldspar: 3
- Mica: 1
- Clay: 25
- Volcanic glass: 83
- Pyrite and opaque: 8
- Calc. nannofossils: 4
- Diatoms: 4
- Sponge spicules: 6
- Silicoflagellates: 4
- Plant debris: 1

---

**Site 584 HOLE CORE 23 CORED INTERVAL 211.7–221.3 m**

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Character</th>
<th>Graphic Lithology</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5–1.5</td>
<td>Firm diatomaceous mud</td>
<td>S101 T2</td>
<td>Olive gray (S1Y1/3)</td>
</tr>
<tr>
<td>1.5–2.5</td>
<td>Diatomaceous mud</td>
<td>S101 T2</td>
<td>Light gray (S1Y1/3)</td>
</tr>
</tbody>
</table>

**Organic Carbon and Carbonate (%):**
- Carbonate: 0.0
- Organic Carbon: 1.50

**Smear Slide Summary (%):**
- Sand: 20
- Silt: 30
- Clay: 50

**Composition:**
- Quartz: 6
- Feldspar: 3
- Mica: 1
- Clay: 25
- Volcanic glass: 83
- Pyrite and opaque: 8
- Calc. nannofossils: 4
- Diatoms: 4
- Sponge spicules: 6
- Silicoflagellates: 4
- Plant debris: 1
## Lithological Description

### Site 584

**Core Interval:** 221.3–230.8 m

<table>
<thead>
<tr>
<th>Layer</th>
<th>Lithology</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Volcanic glass, 1 cm thick, probably closely related to the 100 cm thick tuff at Site 582</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Sedimentary breccia, minor interbeds of red, green, and dark green chert, siltstone, sandstone, and dacite clasts; pebbles and cobble-sized dacite clasts</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Thin, red chert, siltstone, sandstone, dacite clasts, cavings: pebbles and cobble-sized dacite clasts</td>
<td></td>
</tr>
</tbody>
</table>

### Smear Slide Summary (%):

<table>
<thead>
<tr>
<th>Component</th>
<th>Site 584</th>
<th>Site 683</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>42</td>
<td>42</td>
</tr>
<tr>
<td>Clay</td>
<td>32</td>
<td>28</td>
</tr>
<tr>
<td>Silt</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Sandy sand</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Lithic fragments</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Organic carbon and carbonate (%)</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

### Organics and Pyrobitumen

- **Sponge spicules:** 100 cm, V1
- **Calc. nannofossils:** Tr
- **Foraminifers:** 100 cm, V1
- **Feldspar:** 150 cm, V1
- **Quartz:** 150 cm, V1
- **Heavy minerals:** 150 cm, V1
- **Pyrite:** 150 cm, V1
- **Palagonite:** 150 cm, V1
- **Glauconite:** 150 cm, V1
- **Volcanic glass:** 150 cm, V1
- **Carbonate:** 150 cm, V1
- **Ash layer:** 100 cm, V1
- **Sponge spicules:** 100 cm, V1
- **Organic carbon and carbonate (%)**
  - **Sponge spicules:** 100 cm, V1
  - **Organic carbon and carbonate (%)**

---

**Note:** The descriptions and analyses are based on core samples from Site 584, detailing the lithological characteristics, organic content, and mineral composition. The data is presented in a tabular and graphical format to illustrate the variations in sediment types and compositions across the core interval.
### Lithologic Description

**Section 4:** Beginning of mudstone

Glauconite

**Silt Mudstone Summary (%):**

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>M</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1</td>
<td>1</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Clay</td>
<td>5</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Silt</td>
<td>10</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Quartz</td>
<td>3</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>Volcanic glass</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Palagonite</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pyrite</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Calc. nannofossils</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Radiolarians</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sponge spicules</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Silicoflagellates</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Plant debris</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Limestone fragments</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Organic Carbon and Carbonate (%):</strong></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**Texture:** Silt, 28 8 5

**Interpretation:** Glauconite

**Organic Carbon and Carbonate (%):**

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>M</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1</td>
<td>2</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Clay</td>
<td>5</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Silt</td>
<td>10</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Quartz</td>
<td>3</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>Volcanic glass</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Palagonite</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pyrite</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Calc. nannofossils</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Radiolarians</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sponge spicules</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Silicoflagellates</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Plant debris</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Limestone fragments</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Organic Carbon and Carbonate (%):</strong></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**Texture:** Silt, 28 8 5

**Interpretation:** Glauconite
### Site 584 Hole: Core 31 Cored Interval: 287.3 - 297.3 m

#### Lithologic Description

<table>
<thead>
<tr>
<th>Section</th>
<th>Unit</th>
<th>Graphic Lithology</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Fossil Character

- **Zone:** JBIOS
- **Tratigraphic Zone:** 1
- **Character:** FOSSIL
- **Lithology:** GRAPHIC
- **Description:** LITHOLOGIC DESCRIPTION

#### Smear Slide Summary (%):

- Sand: 30
- Silt: 25
- Clay: 45

#### Composition:

- Quartz: 10
- Feldspar: 5
- Heavy minerals: 1
- Clay: 24
- Glaucite: 3
- Pyrite: 5
- Carbonate unspec.: 1
- Foraminifers: 1
- Calc. nannofossils: 15
- Diatoms: 30
- Radiolarians: 5
- Sponge spicules: 15
- V1, faint ash layer: Silicoflagellates: 1

#### Organic Carbon and Carbonate (%):

- Carbonate: 0.0

---

### Site 584 Hole: Core 30 Cored Interval: 278.2 - 287.8 m

#### Lithologic Description

<table>
<thead>
<tr>
<th>Section</th>
<th>Unit</th>
<th>Graphic Lithology</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td></td>
</tr>
<tr>
<td>2</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Fossil Character

- **Zone:** JBIOS
- **Tratigraphic Zone:** 1
- **Character:** FOSSIL
- **Lithology:** GRAPHIC
- **Description:** LITHOLOGIC DESCRIPTION

#### Smear Slide Summary (%):

- Sand: 15
- Silt: 20
- Clay: 65

#### Composition:

- Quartz: 10
- Feldspar: 5
- Heavy minerals: 1
- Clay: 24
- Glaucite: 3
- Pyrite: 5
- 20 cm, dark green spot: Carbonate unspec.: 1
- 20 cm, dark green spot: Calc. nannofossils: 1
- Diatoms: 30
- Radiolarians: 5
- Sponge spicules: 15

#### Organic Carbon and Carbonate (%):

- Carbonate: 0.0

---

*Note: The image contains graphs and tables related to the described sections.*
SITE 584 | HOLE 37 | CORED INTERVAL 345.1–364.6 m

**LITHOLOGIC DESCRIPTION**

Section 1: mosaic of healed fractures, wealth of detail
Healed fractures

BIOSILICEOUS MUDSTONE

- Black spot in black green matrix
- SY 4/2, locally SY 4/4 in burrows
- Healed fracture, 52° dip

**SMearslide Summary (%)**

<table>
<thead>
<tr>
<th></th>
<th>V1</th>
<th>V2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture</td>
<td>1%</td>
<td>0%</td>
</tr>
<tr>
<td>Sand</td>
<td>22%</td>
<td>3%</td>
</tr>
<tr>
<td>Clay</td>
<td>32%</td>
<td>59%</td>
</tr>
<tr>
<td>Composition:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartz</td>
<td>15%</td>
<td>12%</td>
</tr>
<tr>
<td>Feldspar</td>
<td>9%</td>
<td>13%</td>
</tr>
<tr>
<td>Heavy minerals</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Vesicular</td>
<td>24%</td>
<td>10%</td>
</tr>
<tr>
<td>Glauconite</td>
<td>3%</td>
<td>46%</td>
</tr>
<tr>
<td>Foraminifer</td>
<td>2%</td>
<td>4%</td>
</tr>
<tr>
<td>Calcite</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Dolomite</td>
<td>30%</td>
<td>5%</td>
</tr>
<tr>
<td>Reticulolite</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Sponge spicules</td>
<td>9%</td>
<td>2%</td>
</tr>
<tr>
<td>Chert</td>
<td>Tr</td>
<td>Tr</td>
</tr>
<tr>
<td>Plant debris</td>
<td>1%</td>
<td>1%</td>
</tr>
</tbody>
</table>

**ORGANIC CARBON AND CARBONATE (%)**

- V1: 0%
- V2: 0%

---

**SITE 584 | HOLE 38 | CORED INTERVAL 364.6–361.1 m**

**LITHOLOGIC DESCRIPTION**

Section 1: mosaic of healed fractures, wealth of detail
Healed fractures

DIATOMACEOUS MUDSTONE

- SY 4/2, locally SY 4/4 in burrows
- Healed fracture, 52° dip

**SMearslide Summary (%)**

<table>
<thead>
<tr>
<th></th>
<th>V1</th>
<th>V2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture</td>
<td>1%</td>
<td>0%</td>
</tr>
<tr>
<td>Sand</td>
<td>22%</td>
<td>3%</td>
</tr>
<tr>
<td>Clay</td>
<td>32%</td>
<td>59%</td>
</tr>
<tr>
<td>Composition:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartz</td>
<td>15%</td>
<td>12%</td>
</tr>
<tr>
<td>Feldspar</td>
<td>9%</td>
<td>13%</td>
</tr>
<tr>
<td>Heavy minerals</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Vesicular</td>
<td>24%</td>
<td>10%</td>
</tr>
<tr>
<td>Glauconite</td>
<td>3%</td>
<td>46%</td>
</tr>
<tr>
<td>Foraminifer</td>
<td>2%</td>
<td>4%</td>
</tr>
<tr>
<td>Calcite</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Dolomite</td>
<td>30%</td>
<td>5%</td>
</tr>
<tr>
<td>Reticulolite</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Sponge spicules</td>
<td>9%</td>
<td>2%</td>
</tr>
<tr>
<td>Chert</td>
<td>Tr</td>
<td>Tr</td>
</tr>
<tr>
<td>Plant debris</td>
<td>1%</td>
<td>1%</td>
</tr>
</tbody>
</table>

**ORGANIC CARBON AND CARBONATE (%)**

- V1: 0%
- V2: 0%
**SITE 584 HOLE 38**

**CORED INTERVAL**: 364.1-373.7 m

---

**LITHOLOGIC DESCRIPTION**

- **10 cm to 23 cm**: Inclined burrow? Olive gray (5Y 4/2); pale olive (5Y 6/3) fill.
- **100 cm to 110 cm**: Slightly darker silty layer. Healed fractures and normal offsets.
- **120 cm**: Slightly closer fractures throughout.
- **Section 3**: Closely spaced fractures throughout.

---

**SMEAR SLIDE SUMMARY (%)**:

- **Texture**
  - Sand: 1, 69
  - Silt: 2, 5
  - Clay: 2, 1
- **Composition**
  - Quartz: 1, 60
  - Feldspar: 60
  - Heavy minerals: 5
  - Clay: 16
  - Volcanic glass: 1
  - Palagonite: 2
  - Pyrite: 2
  - Carbonate minerals: 1
  - Diatoms: 1
  - Lithic fragments: 1
  - Sponge spicules: 30
  - Silicoflagellates: 30
- **Organic Carbon and Carbonate (%)**
  - Carbonate: 5.2

---

**SITE 584 HOLE 40**

**CORED INTERVAL**: 373.7-383.3 m

---

**LITHOLOGIC DESCRIPTION**

- **125 cm**: Inclined burrow? Olive gray (5Y 4/2); pale olive (5Y 6/3) fill.
- **130 cm to 150 cm**: Dark bands of organic matter.
- **170 cm**: Particularly pale olive burrow fill - not carbonate-rich. Large concentration of pyrite fill, quartz, etc. 2 mm offset on fractures. 70 cm to 80 cm, burrow slightly inclined (foliation trending?).

---

**SMEAR SLIDE SUMMARY (%)**:

- **Texture**
  - Sand: 1, 69
  - Silt: 2, 5
  - Clay: 2, 1
- **Composition**
  - Quartz: 1, 60
  - Feldspar: 60
  - Heavy minerals: 5
  - Clay: 15
  - Volcanic glass: 1
  - Palagonite: 2
  - Pyrite: 2
  - Carbonate minerals: 1
  - Diatoms: 1
  - Lithic fragments: 2
- **Organic Carbon and Carbonate (%)**
  - Carbonate: 5.2
**SITE 584 HOLE 41 CORED INTERVAL 393.3-392.9 m**

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>32</td>
<td>38</td>
<td>40</td>
</tr>
</tbody>
</table>

**SMEAR SLIDE SUMMARY (%):**

<table>
<thead>
<tr>
<th>Texture</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>32</td>
<td>38</td>
<td>40</td>
</tr>
</tbody>
</table>

**Composition:**

- **Quartz:** 8
- **Feldspar:** 5
- **Heavy minerals:** 2
- **Clay:** 32
- **Volcanic glass:** 3
- **Pyroclasts:** 2
- **Pyrite and opaque:** 6
- **Carbonate:** 37
- **Diatoms:** 27
- **Plant debris:** 2
- **Lithic fragments:** 7

**Organic Carbon and Carbonates (%):**

- **Organic Carbon:** 2.50
- **Carbonates:** 0.9

**SITE 584 HOLE 42 CORED INTERVAL 392.9-402.6 m**

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>25</td>
<td>45</td>
<td>30</td>
</tr>
</tbody>
</table>

**SMEAR SLIDE SUMMARY (%):**

<table>
<thead>
<tr>
<th>Texture</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25</td>
<td>45</td>
<td>30</td>
</tr>
</tbody>
</table>

**Composition:**

- **Quartz:** 3
- **Feldspar:** 1
- **Heavy minerals:** 3
- **Clay:** 1
- **Volcanic glass:** 2
- **Pyroclasts:** 1
- **Pyrite and opaque:** 6
- **Carbonate:** 37
- **Diatoms:** 27
- **Sponge spicules:** 5
- **Silicoflagellates:** 4
- **Lithic fragments:** 8

**Organic Carbon and Carbonates (%):**

- **Organic Carbon:** 0.4
- **Carbonates:** 2.50

**DIATOMACEOUS MUDSTONE**

- 60 cm, hollow glauconite concentration
- 60 cm, veined with lenticular glauconite

**LITHOLOGIC DESCRIPTION**

- Core 42: DIATOMACEOUS MUDSTONE
- Core 41: DIATOMACEOUS MUDSTONE

**GRAPHIC LITHOLOGY**

- 0 cm, light grey color
- 10 cm, dark grey color

**FOLIATION**

- 0 cm, light grey color
- 10 cm, dark grey color

**X-RAY DIFFRACTION**

- 0 cm, light grey color
- 10 cm, dark grey color

**MINERALOGY**

- 0 cm, light grey color
- 10 cm, dark grey color

**TEXTURE**

- 0 cm, light grey color
- 10 cm, dark grey color

**CLAY MINERALS**

- 0 cm, light grey color
- 10 cm, dark grey color

**SOME FRAGMENTS**

- 0 cm, light grey color
- 10 cm, dark grey color

**DIATOMS**

- 0 cm, light grey color
- 10 cm, dark grey color

**SKELETONS**

- 0 cm, light grey color
- 10 cm, dark grey color

**INCLUSIONS**

- 0 cm, light grey color
- 10 cm, dark grey color

**LAMINATIONS**

- 0 cm, light grey color
- 10 cm, dark grey color

**VOIDS**

- 0 cm, light grey color
- 10 cm, dark grey color

**VOLCANIC GLASS**

- 0 cm, light grey color
- 10 cm, dark grey color

**PYRITE**

- 0 cm, light grey color
- 10 cm, dark grey color

**SPHINX**

- 0 cm, light grey color
- 10 cm, dark grey color

**PLANT MATERIAL**

- 0 cm, light grey color
- 10 cm, dark grey color

**LITHIC FRAGMENTS**

- 0 cm, light grey color
- 10 cm, dark grey color
SITE 584 HOLE 63 CORED INTERVAL 402.6–412.3 m

LITHOLOGIC DESCRIPTION

T4 – scattered sand grains

VI
DIATOMACEOUS MUDSTONE AND DIATOMS

50 cm to 80 cm, large burrows, yellow-green clay

SY 4/2

Small, healed fractures

ORGANIC CARBON AND CARBONATE (%):

1.50

Carbonate 0.0
### Lithologic Description

**SITE 584 HOLE CORE 45 CORED INTERVAL 422.0-431.5 m**

#### Lithologic Description

- **SY 4/2**: DRILL BRECCIA
  - Includes: shell fragments, clasts, red clast, black shale.

### Lithologic Description

**SITE 584 HOLE CORE 56 CORED INTERVAL 431.5-441.0 m**

#### Lithologic Description

- **SY 4/2**: DIATOMACEOUS MUDSTONE
  - Black pyrite lamination
  - 110 cm to 130 cm, inclined burrows
  - Fill 5Y 4/2

#### SMEAR SLIDE SUMMARY (%):

<table>
<thead>
<tr>
<th>Texture</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
<td>30</td>
<td>55</td>
</tr>
</tbody>
</table>

### Lithologic Description

**SITE 584 HOLE CORE 46 CORED INTERVAL 441.0-460.5 m**

#### Lithologic Description

- **SY 4/2**: DIATOMACEOUS MUDSTONE
  - Black pyrite lamination

#### SMEAR SLIDE SUMMARY (%):

<table>
<thead>
<tr>
<th>Texture</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
<td>30</td>
<td>55</td>
</tr>
</tbody>
</table>

### Lithologic Description

**SITE 584 HOLE CORE 47 CORED INTERVAL 461.0-480.5 m**

#### Lithologic Description

- **SY 4/2**: DIATOMACEOUS MUDSTONE
  - Black pyrite lamination

#### SMEAR SLIDE SUMMARY (%):

<table>
<thead>
<tr>
<th>Texture</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
<td>30</td>
<td>55</td>
</tr>
</tbody>
</table>

### Lithologic Description

**SITE 584 HOLE CORE 48 CORED INTERVAL 481.0-500.5 m**

#### Lithologic Description

- **SY 4/2**: DIATOMACEOUS MUDSTONE
  - Black pyrite lamination

#### SMEAR SLIDE SUMMARY (%):

<table>
<thead>
<tr>
<th>Texture</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
<td>30</td>
<td>55</td>
</tr>
</tbody>
</table>
SITE 584  HOLE 50  CORED INTERVAL 469.7-479.3 m

LITHOLOGIC DESCRIPTION

Layer 7

- 25 cm, inclined burrows
- Large, partially deformed burrows, overturned
- >90 cm, black smears

DIATOMACEOUS MUDSTONE

SMEAR SLIDE SUMMARY (%):

Texture:
- Sand: 15 42 18
- Silt: 26 62 36
- Clay: 20 26 47

Compaction:
- Quartz: 4 12 38
- Felspar: 2 10 11
- Mica: 1 2 1
- Heavy minerals: 2 4 1

Porosity:
- 94 70 50

Diatoms: 3 3 4

Carbonates: 1

Calc. nannofossils: 3 1 1

Organic matter: 1

Stones: 18

ORGANIC CARBON AND CARBONATE (%):
- Carbonate: 0.4

SITE 584  HOLE 51  CORED INTERVAL 478.3-488.9 m

LITHOLOGIC DESCRIPTION

Layer 7

- 60 cm to 60 cm, complicated set of features

DIATOMACEOUS MUDSTONE

SMEAR SLIDE SUMMARY (%):

Texture:
- Sand: 15 42 18
- Silt: 26 62 36
- Clay: 20 26 47

Compaction:
- Quartz: 4 12 38
- Felspar: 2 10 11
- Mica: 1 2 1
- Heavy minerals: 2 4 1

Porosity:
- 94 70 50

Diatoms: 3 3 4

Carbonates: 1

Calc. nannofossils: 3 1 1

Organic matter: 1

Stones: 18

ORGANIC CARBON AND CARBONATE (%):
- Carbonate: 0.4

### SITE 584 HOLE CORE 52 CORED INTERVAL 488.9-508.5 m

#### LITHOLOGIC DESCRIPTION

**DIATOMACEOUS MUDSTONE**
- Disrupted burrow traces
- 15 cm to 30 cm, thin, yellow brown, contorted burrows

**SPEAR SLIDE SUMMARY (%)**

<table>
<thead>
<tr>
<th>Texture</th>
<th>V1</th>
<th>1.39</th>
<th>1.17</th>
<th>2.20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>60</td>
<td>15</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Silt</td>
<td>30</td>
<td>25</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Clay</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

**Composition**
- Quartz: 3
- Feldspar: 2
- Mica: 2
- Heavy minerals: 0

**Organic Carbon and Carbohydrate (%)**
- Carbonate: 1.4

---

### SITE 584 HOLE CORE 53 CORED INTERVAL 498.5-508.1 m

#### LITHOLOGIC DESCRIPTION

**BIOSILICEOUS MUDSTONE**
- Healed fractures and melt veins offset ~3 mm to 5 mm
- 140 cm to 150 cm, small burrows, 1–2 cm diameter filled with white, sandy clay

**SPEAR SLIDE SUMMARY (%)**

<table>
<thead>
<tr>
<th>Texture</th>
<th>V1</th>
<th>1.39</th>
<th>1.17</th>
<th>2.20</th>
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</thead>
<tbody>
<tr>
<td>Sand</td>
<td>60</td>
<td>15</td>
<td>25</td>
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</tr>
<tr>
<td>Silt</td>
<td>30</td>
<td>25</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Clay</td>
<td>10</td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

**Composition**
- Quartz: 3
- Feldspar: 2
- Mica: 2
- Heavy minerals: 0

**Organic Carbon and Carbohydrate (%)**
- Carbonate: 1.4
SITE 584  HOLE  CS  CORED INTERVAL  508.1-517.6 m

LITHOLOGIC DESCRIPTION

Section 1: grayish olive (10Y 4/2)
DIATOMACEOUS MUDSTONE
70 cm to 80 cm, see blowup, below

Glauconiticspot
Large eelworms 6-10 cm, seen in blowup, below

Section 2: large olive burrows, serrated edges
38 cm, greyish olive in place

Diatoms

SMEAR SLIDE SUMMARY (%):

<table>
<thead>
<tr>
<th></th>
<th>1,81</th>
<th>4,49</th>
<th>0,12</th>
</tr>
</thead>
<tbody>
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<td>Clay</td>
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<tr>
<td>1</td>
<td>25</td>
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<td>3</td>
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<tr>
<td>8</td>
<td>25</td>
<td>25</td>
<td>50</td>
</tr>
</tbody>
</table>

Section 4: major offsets

Bioturbation

Veinlet network

Branching healed fractures

Clay
Composition:
Quartz
Feldspar
Heavy minerals
Clay
Volcanic glass
Palagonite
Pyrite
Carbonate unspe.
Foraminifers
Calc. nannofossils
Diatoms
Sponge spicules
Lithic fragments
ORIGIN CARBON AND CARBONATE (%):

2, 16
Carbonate 0.0

Organic Carbon 100

Section 5:

30° healed fracture trace in direction of 07° set

Section 6:

DIATOMACEOUS MUDSTONE

5Y5/1

Color change
5Y 4/2 to 5/2

Veinlet network

Section 5: major offsets

Bioturbation

Clay
Composition:
Quartz
Feldspar
Heavy minerals
Clay
Volcanic glass
Palagonite
Pyrite
Carbonate unspe.
Foraminifers
Calc. nannofossils
Diatoms
Sponge spicules
Lithic fragments
ORIGIN CARBON AND CARBONATE (%):

2, 16
Carbonate 0.0

Organic Carbon 100
**SITE 584 HOLE**

**TIME = ROCK UNIT**

**BORESTRATIGRAPHIC ZONE**

- FORAMINIFERAS
- NANNOPROSIAS
- RADIOCARBON
- DIATOMIC

**SECTION**

**METERS**

**LITHOLOGIC DESCRIPTION**

**ORGANIC CARBON AND CARBONATE (%):**

**TEXTURE:**

- Sand
- Silt
- Clay

**COMPOSITION:**

- Quartz
- Feldspar
- Clay
- Volcanic glass
- Palagonite
- Glauconite
- Pyrite
- Carbonate unspec.

**Diatoms**

**Sponge spicules**

**Plant debris**

**LITHIC FRAGMENTS**

**SITE 584 HOLE**
SITE 584 HOLE CORE 59 CORED INTERVAL 546.1–555.6 m

**LITHOLOGIC DESCRIPTION**

**DIATOMACEOUS MUDSTONE**

- Olive (SY 6/3)

**SHELL SLIDE SUMMARY (%)**

- 0

- Texture: Silt
- Sand: 15
- Silt: 60
- Clay: 25

**Composition:**
- Oolitic: 20
- Sandy: 10
- Muddy: 2
- Clay: 20
- Volcanic glass: 5
- Palynoclast: 1
- Diatomite: 2
- Pyrite: 5
- Carbonate fragments: 10
- Oolitic: 5
- Foraminifera: 2
- miscellaneous: 5
- Lithic fragments: 25

**ORGANIC CARBON AND CARBONATE (%)**

- Carbonate: 30

---

SITE 584 HOLE CORE 59 CORED INTERVAL 555.6–565.1 m

**LITHOLOGIC DESCRIPTION**

**DIATOMACEOUS MUDSTONE**

- Olive (SY 6/3)

**SHELL SLIDE SUMMARY (%)**

- 0

- Texture: Silt
- Sand: 15
- Silt: 60
- Clay: 25

**Composition:**
- Oolitic: 20
- Sandy: 10
- Muddy: 2
- Clay: 20
- Volcanic glass: 5
- Palynoclast: 1
- Diatomite: 2
- Pyrite: 5
- Carbonate fragments: 10
- Oolitic: 5
- Foraminifera: 2
- miscellaneous: 5
- Lithic fragments: 25

**ORGANIC CARBON AND CARBONATE (%)**

- Carbonate: 30

---

**DIATOMACEOUS MUDSTONE**

- Olive (SY 6/3)

**SHELL SLIDE SUMMARY (%)**

- 0

- Texture: Silt
- Sand: 15
- Silt: 60
- Clay: 25

**Composition:**
- Oolitic: 20
- Sandy: 10
- Muddy: 2
- Clay: 20
- Volcanic glass: 5
- Palynoclast: 1
- Diatomite: 2
- Pyrite: 5
- Carbonate fragments: 10
- Oolitic: 5
- Foraminifera: 2
- miscellaneous: 5
- Lithic fragments: 25

**ORGANIC CARBON AND CARBONATE (%)**

- Carbonate: 30
SITE 584 HOLE CORE 60 CORED INTERVAL 565.1-574.6 m

LITHOLOGIC DESCRIPTION

5Y3/1
Soft sediment deformation — sand swept up into clay layers
DIATOMACEOUS MUDSTONE
Dewatering residue
15 cm to 160 cm, Site 4/2, light-colored interval

SMEAR SLIDE SUMMARY (%):

ORGANIC CARBON AND CARBONATE (%):
1, 30
Carbonate 0.0

SITE 584 HOLE CORE 61 CORED INTERVAL 574.6-584.1 m

LITHOLOGIC DESCRIPTION

5Y 4/1-3/2
DIATOMACEOUS MUDSTONE
55 cm to 155 cm, multiple fractures, healed and not so disrupted sense of offset difficult to decipher

SMEAR SLIDE SUMMARY (%):

Texture:
Sand 10 12 25 35
Silt 15 20 35 40
Clay 70 60 30 20

Composition:
Quartz 20 35 15 18
Feldspar 5 8 5 10
Heavy minerals 5 7 11 7
Clay 40 23 43 21
Volcanic glass 6 5 1- 1
Pyrite and opaques 6 6 4 7
Carbonate unspec. 15 10 25 20
Diatoms 10 8 25 20
Sponge spicules 4 2 5 3
Fish remains Tr — — —
Lithics 4 8 - 5

ORGANIC CARBON AND CARBONATE (%):
1, 112 1, 116 2, 46 2, 50
Carbonate 0.0
LITHOLOGIC DESCRIPTION

DIATOMACEOUS MUDSTONE

VI, Nβ, burrow fill 5Y 5/2
50 cm to 150 cm, black grains throughout

Pyrite and opal
Radiolarians
Sponge spicules
Silicoflagellates
Lithics

ORGANIC CARBON AND CARBONATE (%):

Carbonate 0.0
### Lithologic Description

#### Section 1:
- *Apparent bedding 47°, real 54°*
- **Diatomaceous Mudstone**
- Small, en echelon fractures
- Marker beds, 5Y 4/3 mudstone
- Small, en echelon fractures

#### Shear Slide Summary (%):

<table>
<thead>
<tr>
<th>Texture</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
</tr>
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<tbody>
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<td>16</td>
<td>33</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
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<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
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<td>3</td>
<td>1</td>
<td>1</td>
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<tr>
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<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

#### Organic Carbon and Carbonate (%):
- *Carbonate 0.0*

---

#### Section 2:
- **Diatomaceous Mudstone**
- En echelon offsets, exaggerated here
- Dark sandy layers.
- 2 phases of slumping
- *5Y 3/1, bedding dips 30° - 40° throughout Section 2*

#### Shear Slide Summary (%):

<table>
<thead>
<tr>
<th>Texture</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
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<td>18</td>
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<td>57</td>
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<td>18</td>
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<td>46</td>
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<td></td>
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<td>15</td>
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<td></td>
<td>4</td>
<td>29</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>29</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>29</td>
<td>15</td>
</tr>
</tbody>
</table>

#### Organic Carbon and Carbonate (%):
- *Carbonate 0.0*
**SITE 584 HOLE CORE 66: CORED INTERVAL 622.4-632.1 m**

**LITHOLOGIC DESCRIPTION**

- Void: Г-Г

- Blue-green streak parallel to bedding

**SMEAR SLIDE SUMMARY (%):**

- Texture: Sand 60, Silt 25, Clay 15
- Composition: Quartz 37, Feldspar 22, Heavy minerals 7, Clay 5, Pyrite 3, Limestone 1, Hornblende 1

---

**SITE 584 HOLE CORE 67: CORED INTERVAL 632.1-641.8 m**

**LITHOLOGIC DESCRIPTION**

- DIATOMACEOUS MUDSTONE
  - Thin silty layers.
  - Thin silty layers, mud between

**SMEAR SLIDE SUMMARY (%):**

- Texture: Sand 20, Silt 40, Clay 40
- Composition: Quartz 26, Feldspar 36, Heavy minerals 10, Clay 8, Pyrite 5, Carbonate 3, Diatoms 5
- Organics 1,4, Carbonate 0.0

---

**SITE 584 HOLE CORE 68: CORED INTERVAL 641.8-651.5 m**

**LITHOLOGIC DESCRIPTION**

- Void
- Thin silty layers, mud between

**SMEAR SLIDE SUMMARY (%):**

- Texture: Sand 20, Silt 40, Clay 40
- Composition: Quartz 26, Feldspar 36, Heavy minerals 10, Clay 8, Pyrite 5, Carbonate 3, Diatoms 5
- Organics 1,4, Carbonate 0.0

---

**SITE 584 HOLE CORE 69: CORED INTERVAL 651.5-661.2 m**

**LITHOLOGIC DESCRIPTION**

- DRILL BRECCIA
- Contains some reworked pebbles

---

**SITE 584 HOLE CORE 68: CORED INTERVAL 661.5-671.1 m**

**LITHOLOGIC DESCRIPTION**

- Void
- Thin silty layers, mud between

**SMEAR SLIDE SUMMARY (%):**

- Texture: Sand 20, Silt 40, Clay 40
- Composition: Quartz 26, Feldspar 36, Heavy minerals 10, Clay 8, Pyrite 5, Carbonate 3, Diatoms 5
- Organics 1,4, Carbonate 0.0
SITE 584 HOLE 76 CORED INTERVAL 718.1-728.8 m

LITHOLOGIC DESCRIPTION

50Y 3.5-5Y 2.5

Section 3: deformed burrow traces and mud clasts.

MUDSTONE

Bouma's 45° to 47°

Color change

5Y 6/2 to 6/4 siltstone

Section 2: deformed burrow traces, mottles

Silica color change

SMAER SLIDE SUMMARY (%)

Texture

Sand: 10 12
Silt: 20 24
Clay: 56 64

Composition

Grain: 46 25
Foliation: 4 5
Mica: 2 7

Heavy minerals

Chert: 20 54
Volcanic glass: 5 1
Pyrite: 1 2

Calc. nannofossils: 2 7
Diatoms: 2 3
Lithics: 4 4

ORGANIC CARBON AND CARBONATE (%):

Carbonate: 0.0 4.2

SITE 584 HOLE 78 CORED INTERVAL 728.8-738.5 m

LITHOLOGIC DESCRIPTION

BIOSILICEOUS MUDSTONE

5Y 4/2 to 5Y 1

SMAER SLIDE SUMMARY (%)

Texture

Sand: 25 30
Silt: 40 40
Clay: 35 35

Composition

Grain: 25 30
Foliation: 25 30

Mica: 5 30
Heavy minerals: 10 25

Volcanic glass: 3 5
Pyrite: 3 5
Calc. nannofossils: 3 5
Diatoms: 3 5
Lithics: 3 5

ORGANIC CARBON AND CARBONATE (%):

Carbonate: 0.0 19.0

SITE 584 HOLE 79 CORED INTERVAL 738.5-748.0 m

LITHOLOGIC DESCRIPTION

DIATOMACEOUS MUDSTONE

5Y 1/2 to 5Y 4/3

SMAER SLIDE SUMMARY (%)

Texture

Sand: 0 0
Silt: 0 0
Clay: 20 55

Composition

Grain: 0 0
Foliation: 0 0

Mica: 5 5
Heavy minerals: 5 5

Volcanic glass: 15 15
Pyrite: 15 15
Calc. nannofossils: 5 5
Diatoms: 5 5
Lithics: 5 5

ORGANIC CARBON AND CARBONATE (%):

Carbonate: 0.0 0.0
**LITHOLOGIC DESCRIPTION**

**DIATOMACEOUS MUDSTONE**

- 5Y 4/2 burrowed silt
- Sharp contact, silt
- Burrows and fractures (0.2 mm offset, d~30°)
- Small anastamosing fractures, apparent d~34°

**SMEAR SLIDE SUMMARY (%):**

- Organic Carbon and Carbonate (g/l): 1.57
- Carbonate: 50%
### SITE 584 HOLE CORE 84 CORED INTERVAL 796.1-805.8 m

<table>
<thead>
<tr>
<th>Time Rock</th>
<th>Fossil Character</th>
<th>Graphic Lithology</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Veinlets less common than in Core 83</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5GY4/1 DIATOMACEOUS MUDSTONE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Large burrow network</td>
</tr>
<tr>
<td>2/27</td>
<td></td>
<td></td>
<td>By 2/7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bedding trace, 84° apparent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Debris seen at 59.5-6 m in 8 mm bed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Glauconite-rich</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dip 38° apparent</td>
</tr>
</tbody>
</table>

**SMEAR SLIDE SUMMARY (%)**:

<table>
<thead>
<tr>
<th>Texture</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
<th>Quartz</th>
<th>Feldspar</th>
<th>Heavy minerals</th>
<th>Glass</th>
<th>Pyrite</th>
<th>Carbonate unspec.</th>
<th>Diatoms</th>
<th>Sponge spicules</th>
<th>Lithic fragments</th>
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<tbody>
<tr>
<td>%</td>
<td>6</td>
<td>34</td>
<td>60</td>
<td>9</td>
<td>3</td>
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<td>8</td>
<td>8</td>
<td>—</td>
<td>15</td>
<td>4</td>
<td>2</td>
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</tbody>
</table>

### SITE 584 HOLE CORE 85 CORED INTERVAL 805.8-815.5 m

<table>
<thead>
<tr>
<th>Time Rock</th>
<th>Fossil Character</th>
<th>Graphic Lithology</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Veinlets less common than in Core 83</td>
</tr>
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<td></td>
<td></td>
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<tr>
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<td></td>
<td>By 2/7</td>
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<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>Glauconite-rich</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dip 38° apparent</td>
</tr>
</tbody>
</table>

**SMEAR SLIDE SUMMARY (%)**:

<table>
<thead>
<tr>
<th>Texture</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
<th>Quartz</th>
<th>Feldspar</th>
<th>Heavy minerals</th>
<th>Glass</th>
<th>Pyrite</th>
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<th>Diatoms</th>
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<th>Lithic fragments</th>
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<tbody>
<tr>
<td>%</td>
<td>6</td>
<td>34</td>
<td>60</td>
<td>9</td>
<td>3</td>
<td>9</td>
<td>8</td>
<td>8</td>
<td>—</td>
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### SITE 584 HOLE CORE 86 CORED INTERVAL 815.5-825.2 m

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<th>Fossil Character</th>
<th>Graphic Lithology</th>
<th>Lithologic Description</th>
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<td>Large burrow network</td>
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<td></td>
<td>By 2/7</td>
</tr>
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<td>Bedding trace, 84° apparent</td>
</tr>
<tr>
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<td></td>
<td>Debris seen at 59.5-6 m in 8 mm bed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Glauconite-rich</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dip 38° apparent</td>
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</tbody>
</table>

**SMEAR SLIDE SUMMARY (%)**:

<table>
<thead>
<tr>
<th>Texture</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
<th>Quartz</th>
<th>Feldspar</th>
<th>Heavy minerals</th>
<th>Glass</th>
<th>Pyrite</th>
<th>Carbonate unspec.</th>
<th>Diatoms</th>
<th>Sponge spicules</th>
<th>Lithic fragments</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>6</td>
<td>34</td>
<td>60</td>
<td>9</td>
<td>3</td>
<td>9</td>
<td>8</td>
<td>8</td>
<td>—</td>
<td>15</td>
<td>4</td>
<td>2</td>
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</tbody>
</table>

### SITE 584 HOLE CORE 87 CORED INTERVAL 825.2-835.9 m

<table>
<thead>
<tr>
<th>Time Rock</th>
<th>Fossil Character</th>
<th>Graphic Lithology</th>
<th>Lithologic Description</th>
</tr>
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<tbody>
<tr>
<td></td>
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<td></td>
<td>Veinlets less common than in Core 83</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5GY4/1 DIATOMACEOUS MUDSTONE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Large burrow network</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>By 2/7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bedding trace, 84° apparent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Debris seen at 59.5-6 m in 8 mm bed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Glauconite-rich</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dip 38° apparent</td>
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</table>

**SMEAR SLIDE SUMMARY (%)**:

<table>
<thead>
<tr>
<th>Texture</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
<th>Quartz</th>
<th>Feldspar</th>
<th>Heavy minerals</th>
<th>Glass</th>
<th>Pyrite</th>
<th>Carbonate unspec.</th>
<th>Diatoms</th>
<th>Sponge spicules</th>
<th>Lithic fragments</th>
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<tbody>
<tr>
<td>%</td>
<td>6</td>
<td>34</td>
<td>60</td>
<td>9</td>
<td>3</td>
<td>9</td>
<td>8</td>
<td>8</td>
<td>—</td>
<td>15</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>
**LITHOLOGIC DESCRIPTION**

**T6**
- Texture: Sand 35, Silt 10, Clay 15
- Composition: Quartz 15, Feldspar 4, Heavy minerals 1, Clay 38
- Volcanic glass: 61
- Palagonite: 3
- Glauconite: 3
- Pyrite: 4
- Calcite: 4
- Grains: 4
- Sponge spicules: 8
- Plant debris: 2
- Lithic fragments: 7
- Organic carbon and carbonate (%): 3.21
- Carbonate: 3.21

**T8**
- Texture: Sand 35, Silt 10, Clay 15
- Composition: Quartz 15, Feldspar 4, Heavy minerals 1, Clay 38
- Volcanic glass: 61
- Palagonite: 3
- Glauconite: 3
- Pyrite: 4
- Calcite: 4
- Grains: 4
- Sponge spicules: 8
- Plant debris: 2
- Lithic fragments: 7
- Organic carbon and carbonate (%): 3.21
- Carbonate: 3.21

**SY 6/1**
- Texture: Sand 35, Silt 10, Clay 15
- Composition: Quartz 15, Feldspar 4, Heavy minerals 1, Clay 38
- Volcanic glass: 61
- Palagonite: 3
- Glauconite: 3
- Pyrite: 4
- Calcite: 4
- Grains: 4
- Sponge spicules: 8
- Plant debris: 2
- Lithic fragments: 7
- Organic carbon and carbonate (%): 3.21
- Carbonate: 3.21
**SITE 584**

**HOLE**

**CORE 90**

**CORED INTERVAL** 844.4-854.0 m

---

**LITHOLOGIC DESCRIPTION**

**EV 4/2**

Section 1: complex, diatomaceous mudstone

- Blue green (5BG 3/2) - may be glauconitic

**EV 3/1**

- Siltier patches in burrowed sediments
- Normal fault, offset 3 cm
- Large cylindrical:

---

**SMEAR SLIDE SUMMARY (%)**

- 1, 102
- 1, 102
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<table>
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<tr>
<th>Site 584</th>
<th>Hole Core 91</th>
<th>Cored Interval</th>
<th>863.7-873.4 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 584</td>
<td>Hole Core 93</td>
<td>Cored Interval</td>
<td>883.1-892.8 m</td>
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<tr>
<td>Site 584</td>
<td>Hole Core 92</td>
<td>Cored Interval</td>
<td>873.4-883.1 m</td>
</tr>
</tbody>
</table>

**Time-Rock Unit**

- **Biostratigraphic Zone:**
  - Denticulopsis tauta Zone (b subzone)

**Mudstone**

- 5Y 3/1 to 5GY 3/2
- Black bed, true dip 55°
- 5Y 2.5/1, overlain by mixed black and light brown layer.
- 5Y 3/2, noncarbonate nodule
- 5Y 4/1
- Black reducing tuff with yellow spots
- 5Y 4/2 to 3/2, mottled blue-green, black

**Lithologic Description**

- **Organic Carbon and Carbonate (%):**
  - Carbonate 0.4

**Smear Slide Summary (%):**

- Sand 3
- Silt 45
- Clay 52

**Composition:**

- Quartz 3
- Feldspar 1
- Heavy minerals 1
- Glauconite 2
- Pyrite 3
- Carbonate unspec. 85
- Diatoms 2
- Sponge spicules 3

**Lithologic Description**

- Faulted, mottled, heavy bioturbation

**By 4/2 Faulted, mottled, heavy bioturbation**

**Lithology**

- **5Y 3/1 to 5GY 3/2**
- **Mudstone**
- CB9 (triangle)
- Black bed. true dip 55°
- 5Y 2.5/1, overlain by mixed black and light brown layer.
- 5Y 3/2, noncarbonate nodule
- 5Y 4/1
- Black reducing tuff with yellow spots
- 5Y 4/2 to 3/2, mottled blue-green, black

**Carbonate unspec. - 40**

**Radiolarians**

**Sponge spicules**
LITHOLOGIC DESCRIPTION

DRILL SEDIMENT

Brown spots, not carbonates (is solution)

Smear slide summary (%):

<table>
<thead>
<tr>
<th>Texture</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
<th>Completeness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25</td>
<td>50</td>
<td>25</td>
<td>100</td>
</tr>
</tbody>
</table>

LITHOLOGIC DESCRIPTION

SITE 584 HOLE 94 CORED INTERVAL 902.5-912.2 m

CB3:
Yellow brown (10YR 7/8) grain
Matrix is generally blue-green (5BG 3/2)
110 cm to 111 cm thinned turbidite?
Section 1: abundant zoophycos and cylindrical echinoderms?
Color: 5BG 3/2 to 5G 3/2

Section 2: abundant Zoophycos and cylindrical echinoderms, with blue-green gray (5G 4/2) intervals.

Section 3: 5G 5/1 predominant color with blue-green gray (5G 4/2) intervals.

BIOSILICEOUS MUDSTONE

SMEAR SLIDE SUMMARY (%):

<table>
<thead>
<tr>
<th>Texture</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
<th>Quartz</th>
<th>Feldspar</th>
<th>Mica</th>
<th>Heavy minerals</th>
<th>Clay</th>
<th>Volcanic glass</th>
<th>Glauconite</th>
<th>Pyrite</th>
<th>Carbonate unspec.</th>
<th>Diatoms</th>
<th>Radiolaria</th>
<th>Sponge spicules</th>
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<tbody>
<tr>
<td>Sand</td>
<td>25</td>
<td>50</td>
<td>25</td>
<td>35</td>
<td>10</td>
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<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>18</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Silt</td>
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<td>45</td>
<td>15</td>
<td>5</td>
<td>1</td>
<td>-</td>
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<td>-</td>
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<td>-</td>
<td>6</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Clay</td>
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<td>-</td>
<td>3</td>
<td>1</td>
<td>-</td>
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</tbody>
</table>

SMEAR SLIDE SUMMARY (%):

<table>
<thead>
<tr>
<th>Texture</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
<th>Quartz</th>
<th>Feldspar</th>
<th>Mica</th>
<th>Heavy minerals</th>
<th>Clay</th>
<th>Volcanic glass</th>
<th>Glauconite</th>
<th>Pyrite</th>
<th>Carbonate unspec.</th>
<th>Diatoms</th>
<th>Radiolaria</th>
<th>Sponge spicules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>25</td>
<td>50</td>
<td>25</td>
<td>35</td>
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<td>1</td>
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<td>18</td>
<td>1</td>
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</tr>
<tr>
<td>Silt</td>
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<tr>
<td>Clay</td>
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<td>-</td>
<td>3</td>
<td>1</td>
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</tbody>
</table>
SITE 584 HOLE A CORE M1 CORED INTERVAL 0.0–602.2 m

LITHOLOGIC DESCRIPTION

SITE 584 HOLE A CORE H2 CORED INTERVAL 611.8–698.8 m

LITHOLOGIC DESCRIPTION

MUDTURBIDITES

5Y3/1
Yellowish gray (5Y 8/1)
V1? = ashy or silty sand
5Y 3/1, with 5GYB/1 basalt
Some color banding

MUD TURBIDITES IN MUDSTONE

Olive gray (5Y 4/1) with dark green-gray layers
Swirled silt and mud

SMEAR SLIDE SUMMARY

Texture:
Sand
Silt
Clay
Composition:
Quartz
Feldspar
Heavy minerals
Clay
Volcanic glass
Paiagonite
Glauconite
Pyrite
Diatoms
Sponge spicules
Plant debris

SITE 584 HOLE A CORE 1 CORED INTERVAL 602.2–611.8 m

LITHOLOGIC DESCRIPTION

MUD TURBIDITES IN MUDSTONE

Olive gray (5Y 4/1) with dark green-gray layers
Swirled silt and mud

SMEAR SLIDE SUMMARY

Texture:
Sand
Silt
Clay
Composition:
Quartz
Feldspar
Heavy minerals
Clay
Volcanic glass
Paiagonite
Glauconite
Pyrite
Diatoms
Sponge spicules
Plant debris

SITE 584 HOLE A CORE M2 CORED INTERVAL 611.8–698.8 m

LITHOLOGIC DESCRIPTION

MUD TURBIDITES

SY 4/1
SY 3/1
Yellowish gray (SY 8/1)
Black silt
SY 4/1
SY 3/1
SY 8/1, with SY 8/1 basal beds
Some color banding
Microfossils
<table>
<thead>
<tr>
<th>SITE 584</th>
<th>HOLE A</th>
<th>CORE 3</th>
<th>CORED INTERVAL</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>688.8 - 708.4 m</td>
<td>MUDSTONE</td>
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<tr>
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<td></td>
<td>DIATOMACEOUS MUDSTONE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>795.1 - 804.8 m</td>
<td></td>
</tr>
</tbody>
</table>

**SITE 584** HOLE A CORE 3 CORED INTERVAL 688.8-708.4 m

**GRAPHIC LITHOLOGY**

**LITHOLOGIC DESCRIPTION**

- **MUDSTONE**
  - Graded (5Y 0/2)
  - Numerous greenish and olive
  - Max. 3 cm pellet fragments

- **DIATOMACEOUS MUDSTONE**
  - Fracture network (bouded)
  - Gray, dark green

**SMEAR SLIDE SUMMARY (%):**

- Texture:
  - Sand: 19
  - Silt: 41
  - Clay: 40

- Composition:
  - Quartz: 10
  - Felspar: 3
  - Heavy minerals: 2
  - Clay: 40
  - Volcanic glass: 2
  - Pyrite: 8
  - Carbonate: 2
  - Diatoms: 22
  - Radiolarians: 6
  - Sponge spicules: 4
  - Lithic fragments: 6

---

**SITE 584** HOLE A CORE 3 CORED INTERVAL 788.4 - 795.1 m

**GRAPHIC LITHOLOGY**

**LITHOLOGIC DESCRIPTION**

- **MUDSTONE**
  - Graded (5Y 0/2)
  - Numerous greenish and olive
  - Max. 3 cm pellet fragments

- **DIATOMACEOUS MUDSTONE**
  - Fracture network (bouded)
  - Gray, dark green

**SMEAR SLIDE SUMMARY (%):**

- Texture:
  - Sand: 19
  - Silt: 41
  - Clay: 40

- Composition:
  - Quartz: 10
  - Felspar: 3
  - Heavy minerals: 2
  - Clay: 40
  - Volcanic glass: 2
  - Pyrite: 8
  - Carbonate: 2
  - Diatoms: 22
  - Radiolarians: 6
  - Sponge spicules: 4
  - Lithic fragments: 6

---

**SITE 584** HOLE A CORE 3 CORED INTERVAL 795.1 - 804.8 m

**GRAPHIC LITHOLOGY**

**LITHOLOGIC DESCRIPTION**

- **MUDSTONE**
  - Graded (5Y 0/2)
  - Numerous greenish and olive
  - Max. 3 cm pellet fragments

- **DIATOMACEOUS MUDSTONE**
  - Fracture network (bouded)
  - Gray, dark green

**SMEAR SLIDE SUMMARY (%):**

- Texture:
  - Sand: 19
  - Silt: 41
  - Clay: 40

- Composition:
  - Quartz: 10
  - Felspar: 3
  - Heavy minerals: 2
  - Clay: 40
  - Volcanic glass: 2
  - Pyrite: 8
  - Carbonate: 2
  - Diatoms: 22
  - Radiolarians: 6
  - Sponge spicules: 4
  - Lithic fragments: 6
SITE 584 HOLE A CORE X1 CORED INTERVAL 804.8-901.5 m

LITHOLOGIC DESCRIPTION

Section 1: desiccating wind
SF 3:1 to 6:1
Lignite
MUStONE
SGY 4:1
Blue green stray
V1
SGY 4:1
0-6 cm to 78 cm yellow patches, advanced

SITE 584 HOLE A CORE X1 CORED INTERVAL 882.0-890.9 m

LITHOLOGIC DESCRIPTION

DRILL BRECCIA
From permeating active bottom, base ment, gel matrix
Horizon
Horizon

SITE 584 HOLE B CORE 1 CORED INTERVAL 0.0-1.4 m

LITHOLOGIC DESCRIPTION

SMEAR SLIDE SUMMARY (%):

- Siltstone, glauconitic
- Sponge spicule
- Lithic fragments

SITE 584 HOLE B CORE H1 CORED INTERVAL 1.4-209.7 m

DIATOMACEOUS MUDSTONE

DIATOMITE

- Gray yellow (5Y 4/2) mottled, undisturbed
- Burrow fill

SMEAR SLIDE SUMMARY (%):

- Texture:
  - Sand: 2
  - Silt: 13
  - Clay: 86
  - Grains: 1
  - Pyrite: 3
  - Silica: 5
  - Diatoms: 3
  - Sponge spicules: 1
  - Fish remains: 7
  - Marine fauna: 1

- Composition:
  - Quartz: 90
  - Feldspar: 80
  - Heavy minerals: 2
  - Clay: 8
  - Volcanic glass: 5
  - Pyrite: 5
  - Pumice: 5
  - sponge spicules: 5
  - Fish remains: 5

SITE 584 HOLE B CORE K2 CORED INTERVAL 504.7-644.1 m

LITHOLOGIC DESCRIPTION

DIATOMACEOUS MUDSTONE

DIATOMITE

- Burrow fill
- Pyrite and quartz

SMEAR SLIDE SUMMARY (%):

- Texture:
  - Sand: 2
  - Silt: 13
  - Clay: 86
  - Grains: 1
  - Pyrite: 3
  - Silica: 5
  - Diatoms: 3
  - Sponge spicules: 1
  - Fish remains: 7
  - Marine fauna: 1

- Composition:
  - Quartz: 90
  - Feldspar: 80
  - Heavy minerals: 2
  - Clay: 8
  - Volcanic glass: 5
  - Pyrite: 5
  - Pumice: 5
  - sponge spicules: 5
  - Fish remains: 5
SITE 584  HOLE B  CORE 2  CORED INTERVAL 644.1-653.8 m

LITHOLOGIC DESCRIPTION

BIOSILICEOUS MUDSTONE

SG 3/1 with SY 4/1

Apparent dip 9°/1

This is all that's left of the second zone of the previous core. The interval is the second, black marl.

Blue-black marl

SY 4/1

Directional apparent tip of marl.

Smear Slide Summary (%):

<table>
<thead>
<tr>
<th>Composition</th>
<th>Texture</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>21</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feldspar</td>
<td>9</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy minerals</td>
<td>16</td>
<td>46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcite/ gypsum</td>
<td>26</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pyrite</td>
<td>11</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carboxylates</td>
<td>15</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glauconite</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calc. nano-fossils</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Diatoms</td>
<td>3</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiolarians</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sponge spicules</td>
<td>4</td>
<td>3</td>
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</tr>
<tr>
<td>Plants debris</td>
<td>15</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LITHIC fragments</td>
<td>15</td>
<td>50</td>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

SITE 584  HOLE B  CORE H3  CORED INTERVAL 692.8-702.8 m

LITHOLOGIC DESCRIPTION

DIATOMACEOUS MUDSTONE

Dark gray (SY 2.5/1) coarse silt

Small-scale features indicate thin, up-dip flow, w.r.t. present dip.

Clastic dike

Silt beds are slumped

Debris form burrows

Halos?

Section 3: color changes within each cycle, light above, grading downward to darker colors.

Bioturbation between 2 healed fractures

Mottled blue-green and olive
**SITE 584**

**HOLE B**

**CORE 54**

**CORED INTERVAL**: 846.8 - 943.1 m T.D.

### LITHOLOGIC DESCRIPTION

**Greenish gray (5G 5/1, 5BG 5/1), locally bluish.**

**PAISLEY MUDSTONE**

- Feldspar
- Heavy minerals
- Clay
- Volcanic glass
- Palagonite
- Pyrite
- Carbonate
- Diatoms
- Radiolarians
- Sponge spicules
- Lithic fragments

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**SITE 584**

**HOLE B**

**CORE 55**

**CORED INTERVAL**: 943.1 - 954.6 m T.D. (3.06)

### LITHOLOGIC DESCRIPTION

**Veinlet, Crack grading.**

**PAISLEY MUDSTONE**

- Olive (5Y 5/3), heavily bioturbated, grain structure in thin section.

**Dark black stain, offset at intersection with veinlet network**

**Healed fracture**

**Black pyrite spot, 30 cm and 55 cm**

### SMEAR SLIDE SUMMARY (%):

<table>
<thead>
<tr>
<th>Component</th>
<th>Thin Section</th>
<th>Thin Section</th>
<th>Thin Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smear</td>
<td>1, 31</td>
<td>1, 49</td>
<td>2, 38</td>
</tr>
<tr>
<td>Texture</td>
<td>1, 40</td>
<td>1, 40</td>
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<tr>
<td>Sand</td>
<td>1, 40</td>
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</tr>
<tr>
<td>Silt</td>
<td>1, 31</td>
<td>1, 49</td>
<td>2, 38</td>
</tr>
<tr>
<td>Clay</td>
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<tr>
<td>Composition</td>
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<tr>
<td>Quartz</td>
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<tr>
<td>Volcanic glass</td>
<td>1, 40</td>
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<td>1, 40</td>
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<tr>
<td>Palagonite</td>
<td>1, 40</td>
<td>1, 40</td>
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</tr>
<tr>
<td>Pyrite</td>
<td>1, 40</td>
<td>1, 40</td>
<td>1, 40</td>
</tr>
<tr>
<td>Sponge spicules</td>
<td>1, 40</td>
<td>1, 40</td>
<td>1, 40</td>
</tr>
<tr>
<td>Lithic fragments</td>
<td>1, 40</td>
<td>1, 40</td>
<td>1, 40</td>
</tr>
</tbody>
</table>

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**SITE 584**

**HOLE B**

**CORE 56**

**CORED INTERVAL**: 943.1 - 954.6 m T.D. (3.06)