4. SITE 469: BASE OF PATTON ESCARPMENT

Shipboard Scientific Party

HOLE 469

Date occupied: 28 October 1978
Date departed: 31 October 1978
Position: 32°37.00'N, 120°32.90'W
Water depth (sea level; corrected m, echo-sounding): 3790
Bottom felt (m, drill pipe): 3802.5
Penetration (m): 453.5
Number of cores: 51
Total length of cored section (m): 453.5
Total core recovered (m): 178.5
Core recovery (%): 39

Oldest sediment cored:
Depth sub-bottom (m): 390.8
Nature: Metalliferous nannofossil chalk
Chronostratigraphy: Upper lower Miocene (16.5–17.5 m.y. old)

Basement:
Depth sub-bottom (m): 390.8
Nature: Basalt

Principal results:
At Site 469 on the foot of Patton Escarpment, a single hole was continuously cored to a total depth of 453.5 meters sub-bottom, the lower 57.5 meters in the basement. Because of a stubborn, unlubricated drill bit, the hole could not be logged. Four lithologic units were recovered: Unit 1 is a 42 meter Quaternary clay with minor foraminifer and nannofossil ooze. Unit 2 is divided into an upper sub-unit deposited in the Pliocene—foraminifer-nannofossil ooze with local silty clay layers—and a lower sub-unit—foraminifer ooze grading into glauconitic sand and siliceous nannofossil ooze deposited from the late middle to late Miocene. The two sub-units are separated by a hiatus from about 4.2 to 3.3 m.y. and together span the interval from 42 to 325 meters depth. Two more hiatuses (between 5.7 and 10 m.y. and between 10.8 and 13 m.y., respectively) occur within the lower sub-unit. Unit 3 is silty claystone and tuff in the upper part (225 to 368.5 m deep), an altered diabase sill (Sub-unit 3a—368.5–387 m deep) in the middle, and a nannofossil chalk with metalliferous sediments in the lower part (387 to 390.7 m deep). The sediments above the sill were deposited in the early middle Miocene and those below in the early Miocene. Unit 4 is a very thin (0.1 m) layer of dolomite iron-rich clay deposited in the early Miocene. The basement is microcrystalline pillow basalt with altered glass fragments forming hyaloclastites and rare thin layers of metalliferous sediment within basalt fractures and between pillows.

The sediment accumulation rates are 25 m/m.y. in the upper 80 meters, decreasing to 10 m/m.y. throughout the early Pliocene and late Miocene; in the middle Miocene, rates increased to 30 m/m.y. and in the early Miocene to 60 m/m.y. These high sedimentation rates are similar to those encountered at the previous borderland Sites 467 and 468 (and to those in Monterey Shale in onshore basins) and are related to the influx of terrigenous material at that time. The change from relatively higher to lower sedimentation rates in the late middle Miocene coincides with a major unconformity in the borderland area. At the top of Unit 3, the terrigenous contribution to Site 469 is reduced, which was most probably caused by the isolation of the continental source of sediments, resulting from the formation of intervening borderland basins and ridges in the late middle Miocene. This interpretation also explains the almost nonterrigenous nature of Unit 2 at this site. The middle Miocene volcanogenic sediments in Unit 3 were probably derived from sources such as the nearby San Juan seamount and Patton Ridge. And the presence of andesite and dacite at the edge of the continental shelf suggests that the volcanics are related to the intersection of the East Pacific Rise with the continental margin rather than to island-arc activity. The metalliferous sediments overlying typical ocean-floor pillow basalt with quench texture characterize this as an oceanic-crust site typical of the west flank of the East Pacific Rise. The micropaleontologic age of the basement is estimated to be 17 ± 0.5 m.y.

BACKGROUND AND OBJECTIVES

The asymmetric magnetic-anomaly pattern in the northeast Pacific has been interpreted by McKenzie and Morgan (1969) and Atwater (1970) to indicate the former presence of a trench off western North America that consumed the Farallon plate during the early to mid(? Tertiary. According to their models, the Farallon–Pacific Ridge first intersected the trench off western North America roughly 30 m.y. ago. Subsequent to this event, a pair of triple junctions migrated in opposite directions away from the intersection. Atwater (1970) concluded that at the time of intersection, subduction ceased between the two triple junctions and strike-slip (transform) faulting began along this segment of the continental margin. These tectonic processes probably played a major role in the structural development of the margin, but field investigators have had only moderate success in correlating geologic events on the margin with predictions based on the plate tectonic models. Discrepancies in the timing between model predictions and actual tectonic events may be due to the rather tenuous identifications of sea-floor magnetic anomalies adjacent to the margin. Here the magnetic signature is obscured because of the greater-than-normal thickness of sediments overlying oceanic basement as well as numerous topographic features, such as the San Juan seamount (Fig. 1).
The primary objective of Site 469 was to determine the precise time that the Farallon-Pacific Ridge intersected the trench off southern California. In order to accomplish this objective, the proposed site is located on the seaward flank of a sediment-filled trough that lies at the base of the continental slope off the California Continental Borderland (Fig. 2). The seismic profile shown in Figure 3 and the implications of plate tectonic models outlined above suggest that this trough may represent a trench that was active prior to subduction of the Farallon plate. We anticipated that cores recovered from this site would provide data on the age and nature of the sediment within the trough and the age of oceanic basement. DATING of the oceanic crust to determine the time of intersection of the Farallon-Pacific Ridge with the trench would allow us to evaluate the effect of this event on the structural development of the continental margin. Knowing the precise time of intersection would resolve some of the chronologic discrepancies of plate tectonic models with continental-margin and onshore studies. We also expected the estimated 700 meters of Miocene-Pleistocene sediment filling the trough to provide a detailed biogenic siliceous record. In addition, we anticipated a record of calcareous plankton in earlier periods (Miocene-Pliocene), when the site was probably above the carbonate compensation depth (CCD). With both calcareous and siliceous records, the site would provide further insights into the mid-latitude paleoceanographic history of the California Current.

**OPERATIONS**

The survey for Site 469 involved the use of the 120-cubic-inch air gun to provide enough energy to penetrate the 0.5 s of sedimentary section and reach basement, indicated by a 1976 single-channel line and a 1978 multichannel line (Fig. 3), both run by the USGS vessel *Lee*. The *Glomar Challenger* crossed the Patton Escarpment over the abyssal plain to the west at a cruising speed of 8.5 knots (Fig. 4). When speed was reduced to 5.5 knots, an excellent air-gun record was obtained, which showed an indistinct basement reflector dipping gently eastward toward the escarpment (Fig. 5). Deeper reflectors seen on this record (and on the multichannel presite survey) turned out to be artifacts of the record, as shown by the coring done at the site. The survey continued beyond the site to a point where the abyssal plain terminated westward against sediment-covered abyssal hills. The *Challenger* returned eastward to the site on its own track, dropped the beacon on the run at 0231 hours (local time) 27 October, and positioned over the site after a Williamson turn (Fig. 4).

The hole was spudded at 1640 hours. Continuous coring was routine, except that the core barrel was retrieved using the drawworks sand line instead of the regular sand line, thereby shortening the time necessary...
Figure 3. Multichannel seismic-reflection profile AA' showing proposed position of Site 469 (S. P. Lee). (The location of this profile is shown on Fig. 1.)
to retrieve each core barrel. Core recovery was high to a depth of 226 meters (Table 1), where harder sediment required an increase in pump strokes from 5 to 30 spm (strokes per min) and a reduction in core recovery. This drilling break corresponds to the boundary between Lithologic Units 2 and 3 and a sharp change in sediment density and velocity. Low recoveries higher in the section (Cores 16, 17, 19, and 21) cannot be explained by changes in pump pressure or in lithology. Coring times and recoveries were relatively uniform in Unit 3, but a sharp decrease in coring rate occurred with Core 40, which penetrated a diabase sill. Recoveries were high in the sill and in an underlying bed of claystone (Core 43), which was cored at the same rate as was Unit 3. Fractured, altered basalt was reached in Core 44. Coring rates varied from 80 min for Core 46 to 248 min for Core 49. Indications of progressive bit deterioration in basalt included reduced core diameter and ragged torque. The bit began to lock up while coring Core 51, and we terminated coring operations. (We later determined that a cone had been lost on Core 51.)

The hole was flushed with 50 barrels of gel mud followed by 20 barrels of MY-T gel in preparation for logging. The bit-release go-devil was pumped down and pressured up, but the bit did not release. A second go-devil also failed to release the bit, so it was impossible to run open-hole logs. The pipe was pulled, and at 0602 hours on 1 November we were underway for Site 470.

A postsite survey on an east–northeast heading was done at 5½ knots using the 120-cubic-inch air gun in hopes of better defining the geology at the contact between the abyssal plain and the Patton Escarpment, but the basement reflector could be traced only part way to the escarpment (Fig. 6).

Figure 4. Bathymetric map (in meters) showing the area around Sites 468 and 469 and the seismic lines of the Glomar Challenger’s approach to and departure from Site 469.

LITHOLOGY

Sediments and Sedimentary Rocks

The sedimentary section at Site 469 has been divided into four lithologic units (Table 2; Fig. 7) on the basis of microfossil abundance, mineralogical components, texture, and degree of lithification. These include gray hemipelagic clay (Unit 1), olive green nannofossil and siliceous nannofossil ooze (Unit 2), greenish gray silty claystone (Unit 3), and reddish brown metalliferous sediments (Unit 4). A diabase sill occurs within Unit 3 and is described in the section on igneous rocks.

Unit 1: Hemipelagic Clay (0–42 m)

Unit 1 consists of gray silty clay and minor amounts of calcareous ooze with varying proportions of nannofossils and foraminifers. The clay contains about 12% subangular quartz and feldspar. The nannofossil-foraminiferal ooze in this unit is olive brown to olive gray and varies from 15% to 80% nannofossils and from 10% to 60% foraminifers. The unit contains several patches and layers of glauconitic foraminiferal ooze (12% glauconite, 50% foraminifers). Patches and streaks of pyrite occur throughout. Some microfossils are pyritized. The boundary between Units 1 and 2 is gradational and was chosen on the basis of the relative proportion of calcareous ooze and clay in the cores.

Unit 2: Nannofossil Ooze (42–225 m)

Unit 2 is dominantly biogenic ooze. This unit is pale olive to pale green nannofossil ooze with varying amounts of foraminifers and siliceous microfossils. Minor lithologies include foraminiferal ooze, siliceous clay, and glauconitic foraminiferal ooze containing up
to 20% glauconite. The unit can be divided into two parts. Sub-unit 2a consists of nannofossil clay and foraminiferal-nannofossil ooze (Section 5-4 through Section 11-1; 42–94 m). Sub-unit 2b consists of nannofossil ooze and siliceous-nannofossil ooze (Section 11-1 through Core 24; 94–225 m).

Sub-unit 2a grades downward from clay-rich sediments (50%–80% clay) containing little silt to carbonate-rich sediments that are dominated by foraminiferal-nannofossil ooze. Core 10 consists of greenish gray silty clay and foraminiferal silt, with up to 30% silt in the nonbiogenic sediment fraction. The silt contains minor amounts of amphibole and glauconite and trace amounts of glaucophane and dolomite. The boundary between Sub-units 2a and 2b was determined on the basis of the marked decrease in silty clay and foraminifer abundance below Core 10.

Sub-unit 2b consists of variegated foraminiferal-nannofossil ooze, siliceous-nannofossil ooze, and nannofossil ooze. The cohesive sediment from Sub-unit 2b
has very fine purple and grayish purple laminations and cross-laminations that cut through burrows and surround some of the dark patches that are rich in pyrite; these are probably diagenetic aureoles and pseudolaminae caused by the migration of iron and/or manganese under reducing conditions in the sediment.

The upper portion of Sub-unit 2b contains sequences of greenish gray foraminiferal ooze that grade upward into greenish gray and olive gray siliceous-nannofossil ooze and greenish gray and greenish white nannofossil ooze. The foraminiferal ooze contains up to 20% glauconite and 5% pyrite and some plant debris and phosphate. The siliceous-nannofossil ooze ranges from 10% to 45% siliceous microfossils, principally diatoms and sponge spicules with lesser amounts of radiolarians and silicoflagellates. The siliceous-nannofossil ooze is also rich in pyrite. In the lower portion of Sub-unit 2b, the foraminiferal ooze is sometimes missing and the sequences consist of only siliceous-nannofossil ooze or diatomite grading upward to nannofossil ooze. The thickness of the sequences varies from about 0.5 to 3 meters and averages about 1 meter. There is no visible evidence of graded bedding or sedimentary structures within the sequences. The boundary between Units 2 and 3 is marked by a sharp change in induration from firm, cohesive nannofossil ooze (above) to sediments that are moderately to well indurated and sedimentary rocks with more terrigenous detritus (below).

Unit 3: Silty Claystone (225-390.7 m)

The dominant lithology of Unit 3 is greenish gray silty claystone, but the unit is very diverse, also comprising a number of characteristic minor lithologies includ-
Table 2. Summary of lithologic units, Site 469.

<table>
<thead>
<tr>
<th>Unit or Sub-unit</th>
<th>Core</th>
<th>Depth below Sea Floor (m)</th>
<th>Chronostratigraphy</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>Core 1-3, Section 4</td>
<td>0.0-42.0</td>
<td>Lower Miocene</td>
</tr>
<tr>
<td></td>
<td>2a</td>
<td>Core 4, Section 5</td>
<td>42.0-94.0</td>
<td>Pliocene</td>
</tr>
<tr>
<td></td>
<td>2b</td>
<td>Core 11, Section 1-24</td>
<td>94.0-225.9</td>
<td>Variegated igneous, glauconitic nonfossil ooze, siltstone, and basaltic hornblendes. Some beds contain fine silt-to clay-size particles. The thickness of the tuff layer is 3 meters thick.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Core 25-3, Section 9</td>
<td>225.0-390.7</td>
<td>Lower Miocene</td>
</tr>
<tr>
<td></td>
<td>3a</td>
<td>Core 40-42</td>
<td>368.5-387.0</td>
<td>Lower Miocene</td>
</tr>
<tr>
<td></td>
<td>3b</td>
<td>Core 43, Section 3</td>
<td>390.7-390.8</td>
<td>Lower Miocene</td>
</tr>
</tbody>
</table>

ing porcellanite, sand, and sandstone, altered vitric and pumiceous tuff, and a matrix-supported volcanioclastic breccia. In addition, there are minor amounts of nonfossil claystone, clayey and siliceous chalk, siliceous dolomite, zeolite-cemented silt, sandstone, and ash. A diabase sill occurs between 368.5 and 387 meters depth. This sill is defined as Sub-unit 3a and is described together with the basalts in the section on igneous rocks.

The sediments and rocks of Unit 3 are generally burrow-mottled and occasionally have lenticular bedding. The diagenetic pseudolaminae found in Unit 2 are commonly present in the silty claystones, chalks, and porcellanites of Unit 3. The claystone has about 15% silt-size quartz, feldspar, and lithic fragments. Glaucophane is a trace constituent.

The calcareous rocks of this unit are nonfossil claystone and sandstone with some clayey chalk or siliceous chalk. The chalk is greenish gray to light gray and has many features in common with the nonfossil ooze of Unit 2, such as bioturbation, reduction spots, and pseudolaminae. A siliceous dolomite occurs immediately above the diabase sill in the lower part of this unit. Sedimentary structures in the dolomite are similar to those of the siliceous-nannofossil chalk.

Opal-CT (crystalbaite) porcellanite is most common in the upper part of Unit 3; only one porcellanite was recovered from below 310 meters. The porcellanite ranges from greenish gray to light gray and has sedimentary structures similar to the siliceous-nannofossil ooze of Sub-unit 2b.

The sand and sandstone of Unit 3 contain subangular quartz (up to 25%), glauconite (up to 15%), feldspar (up to 10%), and lithic fragments, several of which are zeolite-cemented. Some sandstone is graded and contains abundant bentonic foraminifers. The sandstone occurs in Cores 27 to 32 (250-300 m), an interval in which many reworked nonfossil foramis were found. A coarse sand of feldspar, altered volcanic rock fragments, glauconite, and basaltic hornblende occurs in Core 43 above basalt basement.

Cores 36 to 39 (330-368.5 m) above the diabase sill contain layers of partially altered vitric and pumiceous tuff, many of which have graded bedding, sharp basal contacts (some with load structures), and gradational upper boundaries. The tuff is bluish gray to dark gray and contains fine silt-to clay-size particles. The thickness of the tuff layer is 3 meters thick. In general, the tuff is partially altered to green smectite. Some beds contain abundant vitric ash. Dispersed ash is also common in the sediment up to 50 meters above the depth at which the first tuff occurs.

Core 33 contains a volcanioclastic breccia. Two breccia sequences are present. The lower sequence is a breccia of pebble-size fragments of angular basalt, andesite, pumice, and volcanic glass. The clasts also include a few rounded sandstone and limestone pebbles and some rounded, green pebbles that are foliated. Other fragments include mollusk and bryozoan debris. The size of the clasts decreases upward. The matrix of the lower breccia is a siliceous (opal-CT) silty claystone with bentonic foraminifers, silt-size angular quartz and feldspar, and a few planktonic foraminifers. The upper breccia sequence is coarse-grained and graded. Most clasts are coarse sand-size, and there are layers of lapilli-size pumice. Clasts include partially altered pumice, volcanic rock fragments, lithic fragments, bentonic foraminifers, glauconite, and shell debris. The upper sequence is poorly cemented with opal-CT.

**Unit 4: Iron-rich Clay (390.7-390.8 m)**

Unit 4 consists of metalliferous sediment. The sediment is a red brown, dolomitic iron-rich clay with a few nannofossils. It contains X-ray amorphous iron-rich material and traces of hematite. Although only a small amount of this sediment was recovered from above the basalt, pieces of red brown lithified metalliferous sediment (Section 469-45-1 [Pieces a, b, c and d]) were recovered within the basalt, and the upper 30 meters of basalt contain chert and limestone intercalations as well as numerous veins filled with red brown jasper.

**Igneous Rocks**

The igneous sequence at Site 469 includes an 18.5-meter-thick diabase sill separated from underlying basaltic rocks by about 5 meters of clayey nannofossil chalk and iron-rich clay (Fig. 8). The diabase is dark green, fine- to medium-grained, and, except near its contacts, is texturally and compositionally uniform throughout. The mineralogic constituents of this diabase include plagioclase, clinopyroxene, brownish green clay, opaque minerals, calcite, zeolites, talc, quartz, and amphibole, in decreasing order of abundance. Interstitial to intergranular textures predominate. Plagioclases are strongly zoned, with labradorite cores and andesine rims. Clinopyroxenes are mostly pale green in plane light; several that have faint pink tints may be titaniferous. In addition, rare, brownish green, pleochroic clinopyroxenes also occur (Sample 469-42-1, 10-14 cm); these have large X A C extinction angles and are probably an iron-rich variety. Brownish green smectite is the most common alteration mineral in the diabase, occurring macroscopically as thin patches or layers and microscopically filling interstices between plagioclase laths and equant pyroxenes. Additional but minor alteration minerals include calcite, talc, mica, amphibole, and an unidentified zeolite.
Figure 7. Lithologic and biostratigraphic summary, Site 469.
Interstitial quartz occurs near the top of the sill, suggesting slight differentiation. Grain-size decreases toward the chilled basal contact of the diabase. The diabase changes to aphyric basalt at this chilled contact and consists of skeletal plagioclase microlites, opaque minerals, and trace amounts of clinopyroxene with abundant greenish brown smectite. The texture is subvariolitic.

The basaltic rocks recovered from the basal 62.7 meters at Site 469 include pillow basalts, basaltic breccias, and hyaloclastites. The pillow basalts are gray to dark gray, slightly vesicular, and moderately altered, particularly along common calcite- and green smectite-filled fractures. Most are aphyric with occasional glassy margins (Core 46); some are porphyritic with skeletal microphenocrysts of plagioclase or of plagioclase and clinopyroxene with well developed quench morphology. The plagioclase microphenocrysts are either normally zoned or have homogeneous labradoritic cores enclosed by thin, more sodic rims. Talc-smectite-magnetite pseudomorphs of olivine microphenocrysts occur rarely in these basalts (e.g., Section 43-3, 73 cm). Microscopic textures of these rocks vary from holohyaline to hyalopilitic intersertal and are locally subvariolitic or variolitic.

Angular basalt fragments that are texturally and compositionally similar to the pillow basalts are the major constituents of the basaltic breccias at this site. Clast size ranges from 0.5 to 3.0 cm, and they are most frequently cemented together by calcite or set in a matrix of green smectite. Hyaloclastites occur with these basaltic breccias. Although fresh, brown basaltic glass is still present in some of these hyaloclastites, most consist wholly of green smectite with subordinate calcite cement. These rocks are extremely soft and easily scratched with the fingernail. Shardlike textures and the occasional preservation of brown basaltic glass suggest that these hyaloclastites are alteration products of basaltic glass. The hyaloclastites and basaltic breccias are more common in the lower half of this basaltic sequence.

**BIOSTRATIGRAPHY**

Upper Quaternary through upper lower Miocene sediment was recovered at Site 469. Coccoliths deposited in the late early Miocene occur in Core 43 in the lower *Helicosphaera ampliaperta* Zone immediately above the basement; radiolarians of probably the same age (*Calocycletta costata* Zone) are present in Sample 469-38,CC. The possibility cannot be excluded, however, that the lower Miocene radiolarians of Core 38 are reworked. Coccoliths, diatoms, and radiolarians generally provide good biostratigraphic zonation of the interval from Cores 1 through 25 (Quaternary through lower middle Miocene). Planktonic foraminifera are abundant in the first nine cores but sparse or absent in the remaining cores. Siliceous microfossils are scarce just below Sample 469-25,CC, yielding only sporadic biostratigraphic data, whereas coccoliths continue downsection (Fig. 9). The oldest sediment of Site 469, intercalated in basalt of Core 45, yielded upper lower Miocene coccoliths.

The Quaternary/Pliocene boundary occurs in Core 5, and the Pliocene/Miocene boundary is placed between Cores 11 and 12. The upper Miocene/middle Miocene boundary occurs between Cores 17 and 19. Placement of the middle Miocene/lower Miocene boundary is uncertain. It could possibly fall within the interval between Cores 38 and 43. Figure 7 summarizes zone assignments for Site 469.

**Coccoliths**

At Site 469, lower Miocene to upper Quaternary coccolith assemblages are typically abundant, diverse (6 to 12 species recorded for shipboard biostratigraphy), and moderately well preserved. Lower upper Miocene warm-water discoasters—*Discoaetser bellus* Bukry and Percival, *D. loeblichii* Bukry, *D. neohamatus* Bukry and Bramlette, and *D. pentaradiatus* Tan—in Cores 13 to 17 distinguish the Site 469 assemblages from cooler-water, less diverse upper Miocene assemblages at Site 467. Although the upper Miocene record is less complete at nearby Site 468, the correlative assemblages are similar to those at Site 469 for the upper Miocene, suggesting a similar oceanographic environment.

Reworked Eocene or Oligocene coccoliths provide evidence of the amount and duration of erosion in the vicinity of Site 469. Displaced Eocene and Oligocene species are sparse in middle and lower Miocene Cores 27, 32 to 39, and 43, common in middle Miocene Cores 28 to 31, and absent in Quaternary to middle Miocene Cores 1 to 26. This distribution is in contrast to Site 467,
where reworked Eocene and Oligocene specimens are recorded only from the Pliocene and Quaternary.

The oldest coccoliths from Site 469 are sparse, moderately preserved specimens from a baked, reddish, metalliferous sediment intercalated with basalt in Core 45. A smear slide from Sample 469-45-1, 90-93 cm, contains *Helicosphaera carteri*, which indicates deposition in the early Miocene or later. The oldest sediment above basalt—in Core 43—is assigned to the lower part of the *Helicosphaera ampliaperta* Zone, considered to be upper lower Miocene (Bukry, 1975). An overlap between *Sphenolithus heteromorphus* and *Triquetrorhabdulus milowii* is used to identify the lower part of the *H. ampliaperta* Zone (Bukry, 1971) in Core 43.

A diabase sill in Cores 40 to 42 (368.5 to 387 m) is within the *H. ampliaperta* Zone (approximately 15.5-17.5 m.y.). *S. heteromorphus* Zone (approximately 14-15.5 m.y.) assemblages range from Core 24 to Core 35, providing evidence for a high rate of sedimentation for the middle Miocene. However, four cores from the interval contain sandy sediments with reworked Eocene or Oligocene coccoliths, such as *Chiasmolithus grandis* (Bramlette and Riedel), *Dictyococcites bisectus* (Hay, Mohler, and Wade), *Discoaster barbadensis* Tan, and *Reticulofenestra umbilica* (Levin).

The middle Miocene *Discoaster exilis* Zone of Core 19 is separated from the upper Miocene *Discoaster neohamatus* Zone (7 to 11 m.y.) in Core 17 by a probable unconformity. After encountering a “sand” during the cutting of Core 18, there was difficulty in retrieving the core barrel. It is apparent from the mixed colors and upper Miocene chronostratigraphy of the pea-sized drill cuttings constituting Core 18 that some contamination occurred. *Discoaster sp. aff. D. kugleri* Martini and Bramlette occurs in Core 19 in the upper part of the *D. exilis* Zone. This is the third consecutive site of Leg 63 where short-ranged *D. kugleri* has provided correlation: the other occurrences are in Core 90 at Site 467 and Core 3 at Hole 468B.

*Discoaster neohamatus* Bukry and Bramlette s. str. is present in Core 15 and represents the northernmost record of this tropical and subtropical species in the eastern Pacific. The *D. neohamatus* Zone—also identified by the use of *D. bellus*, *D. brouweri* Tan, *D. loeblichii*, *D. preptentaradiatus* Bukry and Percival, and *Mny litha convallis* Bukry—ranges from Core 14 to Core 17 (121.5 to 159.5 m). Silicoflagellates are especially common and diverse in this interval, suggesting fertile and variable oceanographic conditions.

A paucity of *Ceratolithus*, *Discoaster quinqueramus* Gartner, and *Triquetrorhabdulus rugosus* Bramlette and Wilcoxon precludes precise placement of the Miocene/Pliocene boundary. *Amaurolithus primus* (Bukry and Percival) ranges through the interval in Cores 10 and 13 and indicates the *Amaurolithus primus* Subzone or *Amaurolithus tricorniculatus* Zone.

The upper nine cores contain a seemingly incomplete upper Pliocene and Quaternary coccolith succession, although the recovered sediment commonly is disturbed by drilling operations. *Discoaster* and *Gephyrocapsa* are
sufficiently diverse to permit recognition of low-latitude subzones. However, cool-water *Coccolithus pelagicus* is present throughout the Quaternary and Pliocene and warm-water *Ceratolithus* occurs only at the top of the interval, in the upper *Emiliania huxleyi* Subzone of Core 3 and in Pliocene Cores 6 and 9. This contrasts with the occurrences of these taxa at the southern end of the California Current in the coring area of DSDP Leg 54 (Bukry, 1980).

**Silicoflagellates**

Silicoflagellates are well preserved at Site 469 but are common in only a few cores, such as middle Miocene Core 25 and upper Miocene Cores 13 to 17. Middle Miocene Cores 26 to 43 are barren, and silicoflagellates in Pliocene and Quaternary Cores 1 to 9 are sparse.

Taxa indicative of high-, mid-, and low-latitude silicoflagellate zones occur in the richly diversified upper Miocene assemblages of Cores 13 to 17 (112–159.5 m). For example, a count of 200 specimens for Sample 469-11,CC shows *Dictyocha brevispina* (Lemmermann) and *D. pulchella* Bukry predominant over *Dictyochoa sp.* (fibuloid) by 8% to 1%; this suggests the low-latitude *Dictyocha brevispina* Zone (Martini, 1971; Bukry and Foster, 1973). *Distephanus pseudocrux* (Schulz) and *D. pseudofibula* (Schulz) total 8% of the population and indicate affinities to the mid-latitude *Distephanus pseudofibula* Zone (Bukry, 1973). Finally, the occurrence in the same sample of 53% *Distephanus spectulum* *spectulum* (Ehrenberg), 4% *D. spectulum minutus* Bachmann, 4% *D. spectulum* s. ampl. (large), 6% *Mesocena circulus* (Ehrenberg), 6% *M. diodon borderlandensis* n. subsp., and 1% *M. diodon nodosa* Bukry indicates the high-latitude *Mesocena circulus* Subzone of the *Distephanus spectulum* *spectulum* Zone (Bukry, 1975).

**Radiolarians**

Abundant to rare middle Miocene through Quaternary radiolarians of poor to good preservation were recovered from Cores 1 through 25 of Site 469. Very rare and poorly preserved lower middle Miocene radiolarians occur sporadically in Cores 30, 35, 36, and 38 above the basement. The dissolved remains of siliceous microfossils in some cores of the lower middle Miocene section at Site 469 suggest that the absence of radiolarians in that region is due to diagenesis rather than to the primary lack of siliceous skeletons.

The Quaternary sediments of Hole 469 yielded radiolarian assemblages containing northeastern Pacific cold-water species as well as less numerous equatorial warm-water species, and Kling's (1973) zonation is applicable. Cores 1 through 3, Section 1 can be assigned to the upper Pleistocene *Axoprunum angelinum* Zone, as indicated by the rare to abundant presence of *Lamprocystis hayai* and *L. neoheteroporus* and the absence of *Eucyrtidium matuyamai* and *Lamprocystis heteroporus*. The upper Pleistocene interval contains sporadic older radiolarians, such as different species of *Cyrtocapsella*, *E. matuyamai*, *L. heteroporus*, and *Stichocorys peregrina*, which must be reworked. Characterized by the rare to common occurrence of *E. matuyamai*, and *L. neoheteroporus* in the upper part, and *L. heteroporus* in the lowermost part, Section 3-2 through Section 5-5 can be placed in the lower Pleistocene *E. matuyamai* Zone.

The presence of few to abundant specimens of *L. heteroporus* and the absence of *E. matuyamai* and *Stichocorys peregrina* indicate the upper Pliocene (*L. heteroporus* Zone) for Sample 469-5,CC through Section 8-1. The assemblage of common to abundant individuals of *L. heteroporus* and rare to common occurrences of *S. peregrina* suggest that Section 8-3 through Sample 469-11,CC (S. *peregrina* Zone, upper part) were deposited in the early Pliocene. The boundary between Miocene and Pliocene is marked by the sudden and abundant appearance of *L. heteroporus*.

The upper Miocene comprises Sections 12-1 through Sample 469-17,CC. The fact that all of this interval contains few to abundant *S. peregrina* but lacks *Ommatocapsa* *antepenultimus* and (except for Sample 469-17,CC) *O. penultimus* suggests that the lower part of the upper Miocene succession (*O. antepenultimus* and *O. penultimus* Zones) is partly or totally missing at Hole 469. *Cannartus petterssoni* was not found below Core 17. This indicates that the upper middle Miocene *C. petterssoni* Zone is either not represented by sediments or is condensed. Cores 19 through 30 are distinguished by the presence of *Cannartus laticornis*, *C. mammiferus*, and various species of *Cyrtocapsella*, *Stichocorys delmontensis*, *S. wolffi* a.o., which suggest the lower middle Miocene (*Doracospyris alata* Zone). The poor assemblages gained from Cores 31 through 36 were probably deposited in the early middle Miocene. As to the ages of Cores 38 and 39, a definite conclusion cannot be drawn. Sample 469-38,CC yields *Cyrtocapsella tetrapera* and *Cannartus violina*. Available evidence suggests that *C. violina* is restricted to the lower Miocene. Consequently, it follows that Samples 469-38,CC and 469-39,CC are either lower middle Miocene, with *C. violina* being reworked, or upper lower Miocene, with *C. violina* as an autochthonous fossil.

According to the radiolarian zonation, the Quaternary and Pliocene seem to be entirely represented at Site 469, perhaps with the exception of the upper Quaternary *Artiostrobus mirilesense* Zone. Upper and middle Miocene, however, seem to be only incompletely represented by sediments, because the assemblages with *O. penultimus*, *O. antepenultimus*, and *C. petterssoni* are partly or totally missing. The Pliocene and Quaternary radiolarian zones introduced by Kling (1973) are restricted to the cold-water regions of the North Pacific; they are associated with few specimens of equatorial species in Cores 1 through 8 at Site 469, such as the Pliocene–Quaternary species *Amphirhopalum pypsilon*, *Ommatartus tetrathalamus*, *Spongaster tetras*, and *Theocorythium vetulum*. The lower Pliocene and Miocene assemblages are mostly warm-water species, the number of which decreases from Miocene toward the lower Pliocene. The total lack of the equatorial lower middle Miocene *Doracospyris alata* may be considered an indicator of cold-water influence.
Diatoms

Abundant to few diatoms occur in the middle Miocene through lower Quaternary sediments at Site 469. Preservation is good to moderate, and the assemblages can readily be zoned.

Samples 469-3, CC through 469-5, 70-72 cm are placed in the lower Quaternary Actinocyclus oculatus Zone. The presence of Rhizosolenia matsuymami in Sample 469-3, CC indicates an age of about 0.93 to 1.0 m.y. (Burckle et al., in press). Deposition in the early Quaternary is supported by the occurrence of Nitzschia reinholdii and Thalassiosira plicata and the silicoflagellate Mesocena quadrangula in the same sample.

Samples 469-5, CC through 469-7, CC are correlated with the upper Pliocene Denticula seminai var. fossiliis Zone on the basis of the presence of Thalassiosira antiqua and Denticula seminai var. fossiliis without Denticula kamtschatica.

Core 8 through 10 contain rare diatoms that are mostly reworked from the middle Miocene. This interval apparently corresponds with the middle and lower parts of the Pliocene at nearby Site 467, in which diatoms are also rare.

The lower Pliocene Thalassiosira oestrupii Zone is represented in Samples 469-11-1, 40-42 cm and 469-11-3, 40-42 cm. The underlying interval from Sample 469-11, CC through Sample 469-13-1, 40-42 cm is assigned to the Nitzschia reinholdii Zone, which is mostly upper Miocene. The Miocene/Pliocene boundary is tentatively placed between Cores 11 and 12.

The interval from Sample 469-13-2, 40-42 cm through Sample 469-15-1, 40-42 cm correlates with the upper Miocene Thalassiosira antiqua Zone. A possible hiatus separates this zone from the overlying N. reinholdii Zone in the upper part of Core 13.

The presence of Nitzschia porteri and Thalassionema hirosakienis without younger diatoms in Sample 469-13-2, 40-42 cm indicates an age no younger than about 7.0 m.y. Immediately above, in Sample 469-13-1, 40-42 cm, Thalassiosira miocenica indicates an age no older than about 6.0 m.y.

Sample 469-15-2, 40-42 cm contains Thalassiosira bukhaniana without T. antiqua and correlates with the upper part of Subzone a of the Denticula hustedii Zone. Sample 469-15, CC contains Denticula dimorpha, D. lauta, and Lithodesmium reynoldsii and is placed in the Denticula hustedii-D. lauta Zone. The lower part of the D. hustedii Zone appears to have been removed from the interval between these two samples. Glauconitic sand in Section 15-2 is supportive of a hiatus.

The interval from Sample 469-15, CC through Sample 469-24-3, 90-92 cm is assigned to the Denticula hustedii-D. lauta Zone. This interval can be further subdivided into the following subzones: Subzone d (Samples 469-15, CC through 469-17, CC); Subzone e (Sample 469-19-1, 40-42 cm, with Sample 469-19, CC tentatively assigned to this Subzone); Subzone b (Samples 469-20-1, 120-122 cm through 469-20, CC); and Subzone a (Samples 469-22-1, 142-144 cm through 469-24-5, 90-92 cm). Core 18 contains drilling breccia, which represents downhole contamination, and Core 21 contains no sediment. The middle Miocene/upper Miocene boundary is placed in the interval of Core 18 (159.5 to 169 m).

Samples 469-24-6, 82-84 cm through 469-25, CC are correlated with the lower middle Miocene Denticula lauta Zone (Subzone b). Diagenetic alteration below this interval removes all but the robust, dissolution-resistant diatoms, so that biostratigraphic subdivision is not possible.

The Quaternary through upper Miocene section at Site 469 (Cores 1-17) contains consistent reworked middle Miocene diatoms. The middle Miocene (Cores 19-25) is almost completely free of reworked diatoms.

Foraminifers

Planktonic foraminifers are abundant in the first nine cores but sparse or absent in the remaining sediment cores recovered at Site 469. Planktonic foraminifer assemblages in all samples show some signs of dissolution.

Globigerina bulloides, Orbulina universa, Globorotalia inflata, and Neogloboquadrina pachyderma (s.s.) are common members of the assemblages in Cores 1 through 4, which are assigned to the Quaternary on the basis of nannofossil and diatom data. Abundant representatives of Neogloboquadrina humerosa and N. atlantica with Globorotalia inflata in Cores 5 through 7 suggest that this interval was deposited during the late Pliocene (Zone N21), whereas the occurrence of Globorotalia puncitculata in Cores 9 through 11 places these cores in Zone N19. Sparse, poorly preserved planktonic foraminifers encountered below Core 11 are not age diagnostic.

Benthic foraminifers are common in the first 14 cores of Hole 469. Bathyal water depths are indicated by the consistent occurrence of Pullenia bulloides and Uvigerina sentica, however, displaced specimens from shallower depths are usually present. Benthic foraminifers are generally sparse and poorly preserved in samples examined from below Core 14.

SEDIMENT ACCUMULATION RATES

The sediment accumulation rate curve (Fig. 10) for Site 469 was constructed from selected diatom (D), radiolarian (R), and coccolith (C) events. The curve shows rates of about 25 m/m.y. for the Quaternary and late Pliocene, 10 m/m.y. for the early Pliocene into the middle Miocene, 30 m/m.y. for the early middle Miocene, and 60 m/m.y. for the early Miocene of Site 469. We detected no significant time gaps in this section.

GEOCHEMICAL MEASUREMENTS

Interstitial Water

Interstitial water was extracted from seven Site 469 samples from 9 to 395 meters sub-bottom depth. The pH, salinity, chlorinity, alkalinity, and calcium and magnesium concentrations of the pore water were determined on board using the technique described by Gieskes (1974), with minor modifications. The results are
shown in Figure 11. Except for the sample at 395 meters depth, calcium and magnesium are well correlated. The concentration versus depth profiles suggest that the gradients in calcium and magnesium are essentially diffusional (McDuff and Gieskes, 1976) and probably result from reactions occurring in the underlying basalt.

**Calcium Carbonate Content**

The calcium carbonate concentration in samples from Site 469 was determined on board by the carbonate bomb technique. The results of these determinations are included in the core descriptions in this chapter and plotted in Figure 12. The calcium carbonate contents reflect, in a general way, the lithology of the sedimentary units. The calcium carbonate content of the hemipelagic clays of Unit 1 is less than 30%; that of the Unit 2 oozes ranges from 14% to 82%, depending on the proportion of foraminifers and nannofossils in the biogenic ooze. Below 225 meters sub-bottom depth, sediments are moderately to well indurated and are rich in terrigenous detritus. The carbonate content measured in these sediments is very low (2%-11%), but this measurement is probably biased, because the low-carbonate-content silty clay, silt, and sand were less well indurated and therefore easier to sample for carbonate than were the indurated porcellanite, chalk, and limestone. Thin sections of limestone and porcellaneous chalk from this interval contain about 50% microcrystalline calcite. Sediments in the lower part of Unit 3 have structures similar to those in some of the porcellanites and chalky limestones at shallower depths in the unit and contain 23% to 75% CaCO₃.
Figure 12. Summary of physical properties, Site 469.
PHYSICAL PROPERTIES

Figure 12 summarizes the physical-properties data at Site 469. The density and sonic velocity of the upper 227 meters of soft clay and nannofossil ooze at Site 469 are nearly constant, averaging 1.60 g/cm³ and 1.50 km/s, respectively. Near the base of this interval (Core 23, ~210 m), the sediments become slightly more indurated, as indicated by a subtle increase in both density and velocity. A marked increase in both of these parameters at 228 meters corresponds to the shallower, well indurated (cememented?) calcareous porcellanite (opal-CT). Similar layers of porcellanite alternate with less dense silty claystone in the subjacent interval (228–302 m). This alternation readily explains the variability in the density and velocity profiles at these depths. The density and velocity values of the silica-cemented, graded breccia at the base of this interval (~302 meters, Core 33) resemble the average values for the overlying porcellanite. In contrast, the underlying zone of interbedded claystone and tuff (302–365 m) has density and velocity values indistinguishable from the overlying silty claystone.

A sharp contrast in density and velocity occurs at about 369 meters (base of Core 39), corresponding to a lithologic change from tuff and claystone to a hard, dense siliceous dolomite (Sample 469-39, CC); densities increase from about 1.72 g/cm³ to 2.57 g/cm³, respectively, and velocities from 2.11 km/s to 4.09 km/s, respectively. We recovered only a small piece of this dolomite. It is immediately underlain by a diabase sill(?) 18.5 meters thick. The velocity and density of this igneous unit are identical to those of the dolomite, perhaps reflecting thermal alteration of the carbonate.

A low density and velocity interval consisting of nannofossil chalk underlies the diabase. This reversal in density and velocity is followed by another distinct increase in these two parameters corresponding to underlying basalts and altered hyaloclastites. The basalts have an average density of 2.75 g/cm³ and a sonic velocity of 4.81 km/s. The altered hyaloclastites have a lower density, about 2.3 g/cm³ (from continuous GRAPE); we made no velocity measurements of these altered rocks. Porosity and water content vary inversely with density throughout the section at Site 469.

Table 3 presents average density and velocity values; on the basis of these values, the impedance contrasts for boundaries between successive lithologies are:

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Impedance Contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay and nannofossil ooze overlying porcellanite</td>
<td>0.49</td>
</tr>
<tr>
<td>Porcellanite versus interbedded claystone</td>
<td>0.33</td>
</tr>
<tr>
<td>Claystone and tuff overlying diabase</td>
<td>0.49</td>
</tr>
<tr>
<td>Nannofossil chalk overlying basalt</td>
<td>0.59</td>
</tr>
</tbody>
</table>

These impedance contrasts suggest that at least three strong reflectors may be detected on seismic profiles: the tops of the porcellanite, diabase, and basalt. In addition, reflectors within the unit of interbedded porcellanite and claystone might also be expected.

We made only one measurement of shear strength in the sediments recovered at this site. The value is 229 mbar for Core 15 (at a sub-bottom depth of 133 m), a nannofossil ooze. This value is well below Bouma and Moore's (1975) curve relating unconfined shear strength to depth of burial for carbonate ooze; it bears a closer resemblance to their strength values for silty and clayey sand.

The physical-properties data at Site 469 clearly reflect the increase in lithification of sediments at about 210 meters. In addition, abrupt increases in density and porosity occur at about 228 meters, corresponding to the shallowest calcareous porcellanite. Although this layer occurs within the zone of increasing mechanical compaction, it signals the onset of silica diagenesis (i.e., the dissolution of diatom and radiolarian tests and precipitation of the silica as opal-CT). Both groups of siliceous microfossils are absent below about 225 meters. This process cements the sediment and increases its density and velocity. The fluctuations of the density and velocity profiles between 228 and 295 meters apparently reflect variations in the degree of silicification. A diabase sill capped by a siliceous dolomite corresponds to the next sharp increase in density and velocity. Below this is a low density and velocity interval of nannofossil chalk occurs, followed by underlying basalt having high density and velocity. Impedance contrasts of 0.5 to 0.6 indicate that the tops of the porcellanite, diabase, and basalt should be excellent seismic reflectors.

CORRELATION OF REFLECTION PROFILE WITH DRILLING RESULTS

The acoustic stratigraphy in the vicinity of Site 469 is shown on the seismic-reflection profile obtained by the Glomar Challenger (Fig. 6). Four distinguishable sequences of reflectors are seen on this record:

1) A sequence of strong, widely spaced, and persistent reflectors about 0.14 s thick at the top of the cored interval.
2) A sequence of closely spaced, very persistent reflectors about 0.06 s thick.
3) Strong, widely spaced reflectors about 0.095 s thick that are similar to the upper sequence of reflectors.
4) A zone of indistinct, discontinuous reflectors about 0.145 s thick.
5) A strong reflector at 0.44 s at the base of the zone of indistinct reflectors.

This sequence of acoustistratigraphic units at Site 469 inferred from the seismic profile is shown in Figure 13. The upper sequence of widely spaced reflectors correlates with Lithologic Units 1, Sub-unit 2a and uppermost Sub-unit 2b, which chiefly consist of Quaternary to upper Miocene clays. The very persistent and closely spaced reflectors correlate with the nannofossil ooze of the rest of Lithologic Sub-unit 2b. The change from closely spaced reflectors in this unit to widely spaced reflectors in the underlying unit at about 0.2 s is correlated with a hiatus in the upper Miocene section. Below this, the indistinct set of reflectors correlates with the change from predominantly pelagic and hemipelagic sediments to the clastic and volcanioclastic sediments (silty claystone, volcanic breccia and sandstone, and tuff) of Lithologic Unit 3. The prominent reflector at 0.44 s is correlated with the diabase sill.

CONCLUSIONS

1. The paleontological age of basement at Site 469 is probably 17 to 18 m.y. and is clearly no older than 18.3 m.y. This is in agreement with the magnetic anomaly age at the site as predicted by Atwater (1970). The age of sediments intercalated between the diabase sill and the underlying pillow basalt cannot be distinguished from that of the sediments immediately overlying the diabase.

2. An altered, homogeneous diabase sill occurs at 368.5 to 387 meters depth. Evidence of its intrusive nature is the decrease in crystal size toward the base of the sill; the top of the unit was not recovered in cores. From 387 to 390.7 meters, the sill is underlain by nannofossil chalk, which is itself underlain by metalliferous sediment and lithified sediment. This is underlain by microcrystalline pillow basalt with altered glass fragments forming hyaloclastite. Fractures in the basalt contain jasper.

3. The lower part of the sedimentary section includes volcanioclastic rocks with graded bedding, parallel lam-
nations, and scour marks; also present are reworked Eocene coccoliths, fragments of shallow-water mollusks, and glauconite. This many reflect uplift and subaerial erosion of the adjacent continental margin as it was met by the ancestral East Pacific Rise crest. The overlying sequence consists mainly of hemipelagic chalk and ooze, probably suggesting subsidence of the margin as the rise crest migrated south. This change is dated as occurring 13 to 15 m.y. ago, on the basis of changes in lithology (and about 13 m.y. on the basis of the decrease in the sedimentation rate upsection).

4. The volcaniclastic breccia is dominated by fragments of basalt and andesite. The volcaniclastic unit thickens eastward toward the continental slope and Site 468, as indicated by the seismic-reflection profiles. Similar volcaniclastic breccias at Site 468 on the upper continental slope suggest that Sites 468 and 469 were close to one another at the time of emplacement of the breccias.

5. The presence of opal-CT below Core 24 suggests that siliceous microfossils were present in the lower part of the hemipelagic sequence prior to diagenesis. Diagenetic trends at this site match similar depth- and temperature-controlled transformations at Sites 467, 468, 471, and 473.

REFERENCES


SITE 469 HOLE 1 CORE 1 CORDED INTERVAL 0.0-7.5m

LITHOLOGIC DESCRIPTION

CLAY, medium gray (N5I-3), with streaks of medium bluish gray (5B 5/1) ASH-RICH CLAY. Light gray (N7) patches and intervals of FORAMINIFER-NANNOFOSSIL OOZE patches of grayish black (N2) vitric ash. Intense drilling.

% Organic Carbon
% CaCO

SMEAR SLIDE SUMMARY

TEXTURE:
Sand 80 50 - 60
Silt 18 10 12 20 10
Clay 2 40 88 80 30

COMPOSITION:
Quartz - 3 6 8 6
Feldspar - TR 2 4 2
Mica TR TR TR 11
Heavy minerals 2 TR TR TR -
Clay - 4 88 67 4
Volcanic glass 97 TR TR 15 -
Glauconite TR 3 TR - 12
Pyrite TR - TR 4 2
Carbonate unspec. - - 2 15
Calc. Nannofossils 30 15
Diatoms 1 TR TR TR 1
Radiolarians TR TR 1 - TR
Silicoflagellates TR TR 1 TR 1
Iron oxides - - - 1

SITE 469 HOLE 1 CORE 2 CORED INTERVAL 7.5-17.0m

LITHOLOGIC DESCRIPTION

CLAY, medium gray (N5I-3), with streaks of medium bluish gray (5B 5/1) ASH-RICH CLAY. Light gray (N7) patches and intervals of FORAMINIFER-NANNOFOSSIL OOZE patches of grayish black (N2) vitric ash. Intense drilling.

% Organic Carbon
% CaCO

SMEAR SLIDE SUMMARY

TEXTURE:
Sand 80 50 - 60
Silt 18 10 12 20 10
Clay 2 40 88 80 30

COMPOSITION:
Quartz - 3 6 8 6
Feldspar - TR 2 4 2
Mica TR TR TR 11
Heavy minerals 2 TR TR TR -
Clay - 4 88 67 4
Volcanic glass 97 TR TR 15 -
Glauconite TR 3 TR - 12
Pyrite TR - TR 4 2
Carbonate unspec. - - 2 15
Calc. Nannofossils 30 15
Diatoms 1 TR TR TR 1
Radiolarians TR TR 1 - TR
Silicoflagellates TR TR 1 TR 1
Iron oxides - - - 1
CLAY, medium gray (N5), mixed by drilling with sandy yellow (5Y 6/4) and often brown (5Y 6/4) diatomaceous ooze, disturbed by drilling. Clay and ooze mixed in Sections 1-2. Nannofossil ooze becomes more abundant with increasing distance from the base, becoming more common in Sections 5-7. Clay and ooze mixed in Sections 1-2. Contact between clay and ooze is disturbed by drilling.

Organic Carbon and Carbonate

Texture:
- Sand
- Silt
- Clay

Composition:
- Quartz
- Feldspar
- Mica
- Heavy minerals
- Clay
- Volcanic glass
- Glauconite

% Organic Carbon - 3-36
% CaCO3 - 27

Smear Slide Summary:
- Silt
- Clay
- Mica
- Foraminifera
- Calc. Micrite
- Micrite
- Pyrite
- Calc. Micrite

Site 469 Hole 4 Core 4 Cored Interval 17.8-19.0 m

Lithologic Description

CLAY, medium gray (N5), mixed by drilling with sandy yellow (5Y 6/4) and often brown (5Y 6/4) diatomaceous ooze throughout. Clay contains several patches of diatomaceous ooze. Nannofossil ooze becomes more abundant with increasing distance from the base, becoming more common in Sections 5-7. Clay and ooze mixed in Sections 1-2. Contact between clay and ooze is disturbed by drilling.
FORAMINIFERA-NANNOFOSSIL CLAY, medium greenish gray (5GY 5/1) with lighter gray zones (5Y 4/2). Mottled clay corresponding to more nanofossil-rich sediments. Section 5 is mainly light greenish gray (2Y 6/2) FORAMINIFERA-NANNOFOSSIL CLAY. Glauconitic intervals in Sections 4 and 5. Scattered small patches of pyrite-rich sediment throughout. Interbedded organic rich.

ORGANIC CARBON AND CARBONATE

% Organic Carbon: 1-106
% CaCO₃: 24

SMEAR SLIDE SUMMARY

1-70
4-50
5-47

TEXTURE:
Sand:
Silt:
Clay:

COMPOSITION:
Quartz:
Feldspar:
Mica:
Feldspar:
Oxides:
Plants:
Organic matter:
Pyrite:
Fossils:
Calcareous nannofossils:
Diatoms:
Foraminifera:
Sponge spicules:
Silicoflagellates:

Calc. Nannofossils:
Sponge spicules:
Silicoflagellates:
SITE 469 HOLE 7
CORED INTERVAL 55.0-64.5 m

LITHOLOGIC DESCRIPTION
- Greenish gray (5GY 6/1) with greenish gray (5GY 2/1) and light greenish gray (5GY 8/1) streaks and zones that are more nannofossil-rich.
- Scattered pyrite-rich patches.
- Large back-filled burrows.
- Section 5.

LITHOLOGIC DESCRIPTION
- Mixed pyritic ash and nannofossil ooze, greenish gray (5GY 6/1) and light greenish gray (5GY 2/1).
- Medium gray (N4) pyritic vitric ash partly mixed with overlying ooze.
- Scattered pyrite-rich patches throughout core.

ORGANIC CARBON AND CARBONATE
- % Organic Carbon
- % CaCO3

SMEAR SLIDES
- TEXTURE:
  - Sand
  - Silt
  - Clay
- COMPOSITION:
  - Quartz
  - Feldspar
  - Mica
  - Heavy minerals
  - Clay
  - Glauconite
  - Pyrite
  - Foraminifers
  - Calc. Nannofossils
  - Diatoms
  - Radiolarians
  - Sponge spicules
  - Silicoflagellates
  - Plant debris

TEXTURE:
- Sand
- Silt
- Clay

COMPOSITION:
- Quartz
- Feldspar
- Mica
- Heavy minerals
- Clay
- Glauconite
- Pyrite
- Foraminifers
- Calc. Nannofossils
- Diatoms
- Radiolarians
- Sponge spicules
- Silicoflagellates
- Plant debris
SITE 469 HOLE
CORE 12 CORED INTERVAL 102.6–112.0 m

LITHOLOGIC DESCRIPTION

CLAYEY NANNOFOSIL Ooze, mottled light greenish gray (5G 8/1), light greenish white (5G 9/1), and greenish gray (5G 4/1) with nannofossils. Increase in Section 2. Diatom and nannofossils increase in Section 3. Greenish back (5G 2/1) glauconite and pyrite-rich patches 125 cm. Section 4. Pinkish purple pyritic streaks throughout. Core is intensely deformed by drilling.

ORGANIC CARBON AND CARBONATE

% Organic Carbon 0.42
% CaCO3 21

SMEAR SLIDE SUMMARY

TEXTURE:
Sand
Silt
Clay

COMPOSITION:
Clay
Glauconite
Pyrite
Carbonate unsp.
Foraminifers
Radiolarians
Sponge spicules
Silicoflagellates

SITE 469 HOLE
CORE 13 CORED INTERVAL 112.0–121.5 m

LITHOLOGIC DESCRIPTION

CLAYEY NANNOFOSIL Ooze, light greenish gray (5G 8/1), light greenish white (5G 9/1), and greenish gray (5G 4/1) with nannofossils. Increase in Section 2. Diatom and nannofossils increase in Section 3. Greenish back (5G 2/1) glauconite and pyrite-rich patches throughout. Core is intensely deformed by drilling.

ORGANIC CARBON AND CARBONATE

% Organic Carbon 0.88
% CaCO3 46

SMEAR SLIDE SUMMARY

TEXTURE:
Sand
Silt
Clay

COMPOSITION:
Quartz
Heavy minerals
Clay
Pyrite
Carbonate unsp.
Foraminifers
Radiolarians
Sponge spicules
Silicoflagellates

OTHER
LITHOLOGIC DESCRIPTION
DIATOM-NANOFOSIL Ooze, light olive (5Y 5/4) and pale olive (10Y 6/2) to dark greyish black (5Y 3/2). Distinct color change from light to dark greyish black occurs near 150 cm. Pinkish purple pyrite and olive black pyrite rich streaks and patches throughout.

SMEAR SLIDE SUMMARY
TEXTURE:
Sand 10
Silt 50
Clay 40
COMPOSITION:
Quartz 60
Heavy minerals 1
Glauconite 10
Pyrite 2
Calc. Nannofossils 2
Foraminifers 3
Plant debris 3
Silicoflagellate 2
Sponge spicules 2
Diatoms 2

LITHOLOGIC DESCRIPTION
NANOFOSIL Ooze, light greenish white (5G 9/1) to light greyish white (5G 7/1). Distinct color changes occur in light greyish white (5G 9/1) to light greyish white (5G 7/1), darker color sediment near top section of core. Light greyish white (5G 9/1) to light greyish white (5G 7/1). Distinct color changes occur in light greyish white (5G 9/1) to light greyish white (5G 7/1), darker color sediment near top section of core. Distinct color changes occur in light greyish white (5G 9/1) to light greyish white (5G 7/1), darker color sediment near top section of core.

SMEAR SLIDE SUMMARY
TEXTURE:
Sand 10
Silt 50
Clay 40
COMPOSITION:
Quartz 60
Heavy minerals 1
Glauconite 10
Pyrite 2
Calc. Nannofossils 2
Foraminifers 3
Plant debris 3
Silicoflagellate 2
Sponge spicules 2
Diatoms 2

LITHOLOGIC DESCRIPTION
Clayey Nanofossil Ooze, greenish grey (5G 6/1) to dark greyish grey (5G 3/1), broken by drilling. Thin olive black (5Y 2/1) layer of Vitric Ash at 18-20 cm. Distinct color changes occur in light greyish white (5G 9/1) to light greyish white (5G 7/1), darker color sediment near top section of core. Distinct color changes occur in light greyish white (5G 9/1) to light greyish white (5G 7/1), darker color sediment near top section of core.

SMEAR SLIDE SUMMARY
TEXTURE:
Sand 10
Silt 50
Clay 40
COMPOSITION:
Quartz 60
Heavy minerals 1
Glauconite 10
Pyrite 2
Calc. Nannofossils 2
Foraminifers 3
Plant debris 3
Silicoflagellate 2
Sponge spicules 2
Diatoms 2
SEDIMENTARY BRECCIA, dark greenish gray (5GY 4/1) with angular clasts of light gray (5G/1) pumice and very light gray (5G/1) volcanic ash. Clasts are cemented with a dark greenish gray (5GY 4/1) matrix. Porphyritic volcanic rock fragments are common. Fragments of volcaniclastic breccia are present in the core. Maximum clast size in core is ~3 cm. Matrix is dark greenish gray (5GY 4/1). Small, dark greenish gray (5GY 4/1) CLAYEY PORCELLANITE is present. Core is broken and fragmented by drilling.

SMEAR SLIDE SUMMARY

TEXTURE:
Sand 10
Silt 50
Clay 40

COMPOSITION:
Quartz 10
Feldspar 10
Mica 10
Carbonate 80
Pyrite 10
Diatoms 5
Volcanic glass 10
Foraminifers 5
Calc. Nannofossils 5

Organic Carbon and Carbonate

% Organic Carbon 1
% CaCO3 1

SMEAR SLIDE SUMMARY 1/13

TEXTURE:
Sand 5
Silt 25
Clay 70

COMPOSITION:
Quartz 15
Feldspar 5
Mica 2
Heavy minerals 4
Clay 2
Volcanic glass 2
Pyrite 2
Carbonate 1
Calc. Nannofossils 1
Interbedded medium dark gray (N4) to medium bluish gray (5G4/1) VITRIC TUFF and olive gray (5Y3/2) to dark greenish gray (5G4/1) CALCAREOUS SILTY CLAYSTONE. Tuff unit in upper part Section 1 contains two graded sequences with plane laminations. Tuff and claystone are interbedded top Section 2/base Section 1. Claystone is bioturbated; large burrows filled with lighter colored sediment.

ORGANIC CARBON AND CARBONATE

<table>
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<th>% Organic Carbon</th>
<th>% CaCO_3</th>
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</thead>
<tbody>
<tr>
<td>1-81</td>
<td>0.29</td>
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</tbody>
</table>

SMEAR SLIDE SUMMARY

TEXTURE:
- Sand
- Silt
- Clay

COMPOSITION:
- Feldspar
- Mica
- Clay
- Volcanic glass
- Pyrite
- Carbonate unspecified
- Calc. Nannofossils
- Diatoms
- Radiolarian
- Sponge spicules
- Plant debris
- Lithic fragments
- Glaucophane
**LITHOLOGIC DESCRIPTION**

Drilling breccia composed of fragments of CLAYSTONE and VITRIC TUFF. Basal 5 cm of core contains intact piece of burrow mottled, medium light gray (N6) SILICEOUS DOLOMITE. Limestone has slight pisolitic texture.

Core Catcher only.

**SMEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>Component</th>
<th>Composition</th>
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</thead>
<tbody>
<tr>
<td>Clay</td>
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<tr>
<td>Carbonate</td>
<td>51</td>
</tr>
<tr>
<td>Quartz</td>
<td>10</td>
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</table>

**CC-28**
MAJOR ROCK TYPE - DIABASE

Macroscopic Description
Diabase - medium gray, fine- to medium-grained. Homogeneous with scattered alteration patches of green clay up to 2 mm across. Some vesicles and calcite-filled voids (1 mm across) occur between 127-137 cm in Section 1.

Thin Section Descriptions
Diabase - Section 1, Piece 1A, 37-41 cm
Texture: intersertal
Phenocrysts: none
Groundmass: plagioclase, 45%, 0.05-1 mm, euhedral-subhedral; clinopyroxene, 30%, 0.05-0.2 mm, subhedral-anhedral; opaques, 5%, 0.05-0.5 mm, anhedral; quartz, 5%, 0.1-1 mm, subhedral
Alteration: greenish brown clays (25%) and calcite (TR) between plagioclase and pyroxene crystals

Diabase - Section 1, Piece 11, 121-124 cm
Texture: intersertal
Phenocrysts: none
Groundmass: plagioclase, 40%, 0.1-2 mm, subhedral-anhedral; clinopyroxene, 30%, 0.05-0.6 mm, subhedral-anhedral; opaques, 5%, 0.05-0.2 mm, anhedral; quartz, 5%, 0.1-1 mm, subhedral
Alteration: greenish brown clays (20%) and calcite (TR) between plagioclase and pyroxene crystals

Shipboard Data
Sample D V (11) V (2) P
Section 1, Piece 1G, 138 cm 2.52 3.98 4.03 19

DIABASE - Section 1, Page 11, 121-124 cm
Texture: intersertal
Phenocrysts: none
Groundmass: plagioclase, 40%, 0.3-2 mm, subhedral-anhedral; clinopyroxene, 25%, 0.5-1 mm, anhedral; opaques, 5%, 0.05-0.2 mm, anhedral
Alteration: brownish green clay (25%), calcite (TR), and zeolite (TR) between plagioclase and pyroxene crystals

Diabase - Section 2, Piece 1A, 2-4 cm
Texture: intersertal
Phenocrysts: none
Groundmass: plagioclase, 40%, 0.1-0.5 cm, subhedral-anhedral; clinopyroxene, 30%, 0.05-0.3 mm, subhedral-anhedral; opaques, 6%, 0.05-0.2 mm, anhedral; quartz, 2%, 0.1-0.3 mm, anhedral
Alteration: alteration: brownish green clay (23%), calcite (TR), and zeolite (TR) between plagioclase and pyroxene crystals

Diabase - Section 3, Piece 1D, 103-106 cm
Texture: intersertal
Phenocrysts: none
Groundmass: plagioclase, 40%, 0.1-1 mm, subhedral-anhedral; clinopyroxene, 30%, 0.05-0.3 mm, subhedral-anhedral; opaques, 6%, 0.05-0.2 mm, anhedral
Alteration: brownish green clay (16%), calcite (TR), and zeolite (TR) between plagioclase and pyroxene crystals

Shipboard Data
Sample D V (2) V (1) P
Section 1, Piece 1B, 24 cm 2.52 4.18 - 19
Section 2, Piece 1D, 148 cm 2.56 - 4.18 16
Thin Section Descriptions

Diabase - Section 1, Piece 1A, 10-14 cm
Texture: intergranular
Phenocrysts: -
Groundmass: Plagioclase (zoned labradorite-andesine), 55%, 0.1-1 mm, euhedral-subhedral; clinopyroxene (augite - a few grains have green tint at rim), 27%, 0.05-0.5 mm, subhedral-anhedral; opaques (Fe-Ti oxide?), 7%, 0.03-0.2 mm, anhedral. Clinopyroxene has slight purple tint.
Alteration: brownish green clay (29%), talc (TR), and calcite (TR) occur between plagioclase and pyroxene crystals.

Diabase - Section 2, Piece 1B, 27-29 cm
Texture: porphyritic (subporphyritic groundmass)
Phenocrysts: -
Groundmass: plagioclase (zoned from labradorite to andesine), 50%, 0.1-1 mm, subhedral-anhedral; clinopyroxene (augite - a few grains have green tint at rim), 30%, 0.05-0.5 mm, subhedral-anehedral; opaques (Fe-Ti oxide?), 8%, 0.03-0.2 mm, anhedral. Clinopyroxene has slight purple tint.
Alteration: brownish green clay (29%), talc (TR), and calcite (TR) occur between plagioclase and pyroxene crystals.

Diabase - Section 3, Piece 1A, 12-15 cm
Texture: intergranular
Phenocrysts: -
Groundmass: plagioclase (zoned from labradorite to andesine), 50%, 0.1-1 mm, subhedral-anhedral; clinopyroxene (augite - a few grains have green tint at rim), 20%, 0.05-0.3 mm, subhedral-anhedral; opaques, 27%, 0.05-0.5 mm, subhedral-anehedral. Clinopyroxene has slight purple tint.
Alteration: brownish green clay (29%), talc (TR), and calcite (TR) occur between plagioclase and pyroxene crystals.

Diabase - Section 4, Piece 1E, 32-35 cm
Texture: intergranular
Phenocrysts: -
Groundmass: plagioclase (zoned from labradorite to andesine), 55%, 0.1-0.5 mm, subhedral-anhedral; clinopyroxene (augite - a few grains have green tint at rim), 20%, 0.05-0.3 mm, subhedral-anehedral; opaques (Fe-Ti oxide?), 7%, 0.03-0.2 mm, anhedral. Clinopyroxene has slight purple tint.
Alteration: brownish green clay (29%), talc (TR), and calcite (TR) occur between plagioclase and pyroxene crystals.

Diabase - Section 5, Piece 1B, 58-61 cm
Texture: intergranular
Phenocrysts: -
Groundmass: plagioclase (zoned from labradorite to andesine), 55%, 0.1-0.5 mm, subhedral-anhedral; clinopyroxene (augite - a few grains have green tint at rim), 20%, 0.05-0.3 mm, subhedral-anehedral; opaques (Fe-Ti oxide?), 7%, 0.03-0.2 mm, anhedral. Clinopyroxene has slight purple tint.
Alteration: brownish green clay (29%), talc (TR), and calcite (TR) occur between plagioclase and pyroxene crystals.

Diabase - Section 6, Piece 1B, 58-61 cm
Texture: intergranular
Phenocrysts: -
Groundmass: plagioclase (zoned from labradorite to andesine), 55%, 0.1-1 mm, euhedral-subhedral; clinopyroxene (augite - a few grains have green tint at rim), 30%, 0.05-0.5 mm, subhedral-anehedral; opaques, 8%, 0.03-0.2 mm, anhedral. Clinopyroxene has slight purple tint.
Alteration: brownish green clay (29%), talc (TR), and calcite (TR) occur between plagioclase and pyroxene crystals.

Macroscopic Description

MAJOR ROCK TYPE - DIABASE
SITE 469 HOLE 43 CORED INTERVAL 387.0-396.0 m

Diabase - fine- to medium-grained with scattered small (~2 mm across) patches of contact. BASALT at base of core (65-86 cm, Section 3) is fractured and has some clayey matrix. Some fractures filled with reddish brown (10YR 4/6) jasper. Small piece of reddish brown CLAY occurs between basalt fragments in Section 3.

SMEAR SLIDE SUMMARY

% CaCO, 75 28
% Organic Carbon - 1.95
ORGANIC CARBON AND CARBONATE
Dolomite
Calc. Nannofossils
Glauconite
Heavy minerals
COMPOSITION:
Clay
Feldspar
Pyrite
Foraminifers
Carbonate unspec.

THIN SECTION DESCRIPTION - Basalt (Section 3.73 cm):
Between basalt fragments in Section 3.

CLAYEY NANNOFOSSIL CHALK AND NANNOFOSSIL FORAMINIFER (Dolomitic?) IRON-RICH CLAY occurs with reddish brown (10YR 4/6) jasper. Small piece of reddish brown CLAY occurs between basalt fragments in Section 3.
SITE 469, CORE 44, SECTION 1–3, 396.0–399.4 m

MAJOR ROCK TYPE — BASALT
MINOR ROCK TYPES — ALTERED HYALOCLASTITE, CHERT

Macroscopic Descriptions
Basalt — aphyric, moderately altered and highly fractured. Several areas have glassy margins (Pieces 6A–C, Section 1). Fractures are often filled with serpentine and/or green clay. Yellowish and greenish gray alteration rinds surround fractures.

Altered Hyaloclastite — pieces of basalt (originally glassy?), completely altered to green clays. Occur as small fragments between basalt at 70–100 cm, Section 1.

Chert — grayish red SIR 4/2, clayey and quartzose (Pieces 3A–5, Section 1).

Thin Section Descriptions
Basalt (glassy margin) — Section 1, Piece 9C, 58–60 cm
Texture: porphyritic with cryptocrystalline groundmass
Phenocrysts: plagioclase, <1%, 1.5 mm, euhedral
Groundmass: glass, 99%, devitrified
Alteration: glass altered to yellowish green clay minerals

Basalt — Section 2, Piece 5, 58–60 cm
Texture: intersertal
Phenocrysts: —
Groundmass: plagioclase, 30%, <0.02 mm, laths; clinopyroxene, 30%, <0.01 mm, anhedral and equant; mesostasis, 15%; opaques, 10%
Vesicles: 10%, 0.1–0.3 mm, circular
Alteration: green clays fill some vesicles and occur as extensive alteration of glassy groundmass

Basalt — Section 3, Piece 4D, 41 cm
Texture: intersertal
Phenocrysts: —
Groundmass: plagioclase, 30%, <0.03 mm, laths; clinopyroxene, 30%, <0.02 mm, anhedral and equant; mesostasis, 15%; opaques, 10%
Vesicles: 5%, <0.3 mm, circular
Alteration: brownish green clay fills some vesicles

Shipboard Data
Sample | D | V (t) | V (l) | P
---|---|---|---|---
Section 2, Piece 4C, 41 cm | 2.74 | 4.56 | — | —

SITE 469, CORE 49, SECTIONS 1–2, 403.0–406.3 m

MAJOR ROCK TYPE — BASALT
MINOR ROCK TYPE — BASALTIC BRECCIA, CLAYEY LIMESTONE, CHERT

Macroscopic Descriptions
Basalt — aphyric, moderately altered, and highly fractured. Fractures filled with calcite or reddish brown chert (jasper). Yellowish alteration rinds surround fractures. No glassy margins noted.

Basaltic Breccia — Pieces 2 and 5A–8 in Section 1 are basaltic breccias consisting of angular fragments of aphyric basalt with some palagonite filling spaces between fragments.

Clayey Limestone — Pieces 7A–D in Section 1 are massive, reddish brown clayey limestone. No sedimentary structures.

Chert — Piece 1B in Section 3 is reddish brown chert (spherulitic jasper) cut by small calcite veinlets.

Thin Section Description
Basalt — Section 3, Piece 5, 140–142 cm
Texture: porphyritic with suprathermal groundmass
Phenocrysts: plagioclase, <1%, 0.5–1 mm, euhedral; clinopyroxene, <1%, 0.5–1 mm, euhedral
Groundmass: plagioclase, 40%, <0.03 mm, skeletal; clinopyroxene, 50%, <0.02 mm, anhedral and equant; mesostasis, 17%; opaques, 10%, <0.02 mm
Vesicles: 3%, <0.2 mm, circular
Alteration: brownish green clay fills some vesicles and small calcite veinlets.
Macroscopic Description
Basalt - aphyric, moderately altered, and highly fractured. Fractures filled with calcite, red jasper, or green clay and surrounded by yellowish gray alteration rims. Several pieces (e.g., Section 1, Piece 6; Section 2, Pieces 4A, 4D, and 1F have glassy margins as marked.

SITE 469, CORE 47, SECTIONS 1-3, 414.0-417.5 m
MAJOR ROCK TYPE - BASALT
MINOR ROCK TYPE - ALTERED HYALOCLASTITE
Macroscopic Description
Basalt - aphyric, moderately altered, and highly fractured. Calcite or red jasper fills some fractures; yellowish alterations border fractures. Piece 3A, Section 3, has a glassy margin.

Altered Hyaloclastite - angular fragments of glassy basaltic breccia partially or completely altered to green clay and calcite. Brown basaltic glass preserved in several pieces. Alteration produces soft rock easily scratched with fingernail. Many fragments are concentrically banded. Calcite veins separate basalt and hyaloclastite where they occur in same piece (e.g., Piece 2A, Section 1). Hyaloclastite occurs in Section 1, Pieces 2A and 2B–F and in Section 2, several fragments in Piece 1.

Thin Section Description
Basalt - Section 1, Piece 1, 14–18 cm
Texture: marginally porphyritic with variolitic groundmass
Phenocrysts: < 1%, 0.2 mm, euhedral
Groundmass: Plagioclase, 38%, 0.03–0.1 mm, skeletal needles; Clinopyroxene, 35%, 0.03–0.1 mm, skeletal; Mesostasis, 15%; Opaques, 8%
Vesicles: 4%, 0.05–0.1 mm, circular
Alteration: brownish clays fill some vesicles

Shipboard Data
Sample D V(1) V(2) V(3) P
Section 2, Piece 4A, 14 cm: 2.70 4.40 – 12
SITE 469, CORE 49, SECTIONS 1–2, 432.0–433.7 m
MAJOR ROCK TYPES – ALTERED HYALOCLASTITE, BASALT

Macroscopic Descriptions

Altered Hyaloclastite – glassy basaltic breccia partially or completely altered to green clay. Altered rock easily scratched with fingernail. Many fragments have circular or spherulitic structures with radial patterns. 

Basalt – aphyric, moderately altered, and highly fractured. Some fractures filled with green clay or calcite. Large calcite vein in Section 3, Piece 3. Yellowish gray alteration rind surrounds fractures.

Thin Section Descriptions

Basalt (glassy margin) – Section 1, Piece 9, 113–117 cm
Texture: holohyaline
Phenocrysts: Plagioclase, <1%, 0.2–0.3 mm, euhedral
Groundmass: glass, 99%, partly devitrified
Alteration: traces of zeolitic amygdules

Hyaloclastite – Section 1, Piece 11, 130–133 cm
Texture and Composition: breccia composed of angular fragments of basaltic glass (60%) up to several cm across set in an aphanitic matrix (40%). Both fragments and matrix are altered to green clay.

Shipboard Data

Sample D V(V) V(i) P
Section 3, Piece 2C, 34 cm 2.91 4.85 – 6.9

SITE 469, CORE 46, SECTIONS 1–3, 423.0–426.5 m
MAJOR ROCK TYPES – ALTERED HYALOCLASTITE, BASALT

Macroscopic Descriptions

Altered Hyaloclastite – glassy basaltic breccia partially or completely altered to green clay. Altered rock easily scratched with fingernail. Many fragments have circular or spherulitic structures with radial patterns. 

Basalt – aphyric, moderately altered, and highly fractured. Many fragments have circular or spherulitic structures with radial patterns. Large calcite vein in Section 3, Piece 3. Yellowish gray alteration rind surrounds fractures.

Thin Section Descriptions

Basalt (glassy margin) – Section 1, Piece 9, 103–106 cm
Texture: holohyaline
Phenocrysts: Plagioclase, <1%, 0.5–1 mm, euhedral
Groundmass: brown glass, 95%, partly devitrified
Alteration: clays occur along fractures in glass

Shipboard Data

Sample D V(i) V(i) P
Section 1, Piece 8B, 88 cm 2.84 4.89 – 6.3
### Macroscopic Descriptions

**Basalt** - aphyric, moderately altered, and highly fractured. Pieces 1 and 2 in Section 2 have glassy margins as marked. Calcite and green clay fill some fractures. Yellowish gray alteration rind fills some fractures.

**Altered Hyaloclastite** - basaltic breccia partially or completely altered to green clay. Interiors of altered fragments are concentrically band. Angular fragments of fresh basalt and basaltic glass occur in Section 1, Pieces 7-10.

**Pieces 3A-B** in Section 1 and Pieces 4D-E in Section 2 are basaltic breccias (fresh basalt fragments) with a matrix of green clay. Hyaloclastite marked by breccia pattern.

### Thin Section Descriptions

**Hyaloclastite** - Section 1, Piece 7, 80-82 cm
- **Texture and Composition:** breccia consisting of altered basalt fragments (~60%) set in green clay fine-grained matrix. All minerals and glass have been replaced by green clay.

**Basalt** - Section 2, Piece 5, 107-108 cm
- **Texture:** hyalopilitic to subvariolitic
- **Phenocrysts:**
  - Plagioclase, 30%, <0.05 mm, skeletal
  - Clinopyroxene, 10%, <0.02 mm, skeletal
  - Glass, 47%, devitrified
- **Vesicles:** 3%, 0.1-0.2 mm, circular
- **Alteration:** vesicles partly filled with clay

### Shipboard Data

**Sample:** D V (i) V (ii) P
- Section 2, Piece 4J, 97 cm: 2.78 4.78 – 13
- Section 1, Piece 8, 101-103 cm: 2.82 4.95 – 12

### Core/Section 50/1

**SITE 469, CORE 50, SECTIONS 1–2, 441.0–443.6 m**

**Major Rock Types:** Basalt, Altered Hyaloclastite

**Macroscopic Descriptions**

**Basalt** - aphyric, moderately altered, and highly fractured. Pieces 1 and 2 in Section 2 have glassy margins as marked. Calcite and green clay fill some fractures. Yellowish gray alteration rind fills some fractures.

**Altered Hyaloclastite** - basaltic breccia partially or completely altered to green clay. Interiors of altered fragments are concentrically band. Angular fragments of fresh basalt and basaltic glass occur in Section 1, Pieces 7-10.

**Pieces 3A-B** in Section 1 and Pieces 4D-E in Section 2 are basaltic breccias (fresh basalt fragments) with a matrix of green clay. Hyaloclastite marked by breccia pattern.

**Thin Section Descriptions**

**Hyaloclastite** - Section 1, Piece 7, 80-82 cm
- **Texture and Composition:** breccia consisting of altered basalt fragments (~60%) set in green clay fine-grained matrix. All minerals and glass have been replaced by green clay.

**Basalt** - Section 1, Piece 7, 73-75 cm
- **Phenocrysts:**
  - Plagioclase, 30%, <0.05 mm, skeletal
  - Clinopyroxene, 10%, <0.02 mm, skeletal
  - Glass, 47%, devitrified
- **Vesicles:** 3%, 0.1-0.2 mm, circular
- **Alteration:** vesicles partly filled with clay

**Shipboard Data**

**Sample:** D V (i) V (ii) P
- Section 2, Piece 4J, 97 cm: 2.78 4.78 – 13
- Section 1, Piece 8, 101-103 cm: 2.82 4.95 – 12