HOLE 471

Date occupied: 9 November 1978

Date departed: 15 November 1978

Position: 23°29.78'N, 112°29.78'W

Water depth (sea level; corrected m, echo-sounding): 3101

Bottom felt (m, drill pipe): 3115.5

Penetration (m): 823

Number of cores: 88

Total length of cored section (m): 823

Total core recovered (m): 356.4

Core recovery (%): 43

Oldest sediment cored:

- Depth sub-bottom (m): 741.5
- Nature: Metalliferous sediment

Chronostratigraphy: Middle Miocene (14.5 to 15 m.y. old)

Basement:

- Depth sub-bottom (m): 741.5
- Nature: Altered diabase

Principal results: Hole 471 was drilled on the distal portion of a deep-sea fan west of the foot of the continental slope off Baja California. Five sedimentary units were delineated. Unit 1, from mudline to 63.5 meters, is nannofossil silty clay with minor ash that was deposited during the Quaternary and Pliocene at a rate of 15 m/m.y. Unit 2 is diatomaceous clay and silty clay and claysilaceous diatomaceous ooze to a depth of 155.2 meters. It was deposited principally in the late Miocene at a rate of 35 m/m.y.; the Miocene/Pliocene boundary is in the uppermost part of the unit. Units 1 and 2 have densities of 1.5 g/cm³ and velocities of 1.55 km/s. Unit 3 extends to a depth of 304 meters and is porcellanite and porcellaneous silty claystone with fragments of opal-CT (crystalline) chert and thin beds of clayey dolomite. Core recovery averaged 9% in this unit; the Density and Neutron Logs suggest the presence of softer sediment interbeds in the unit that were not recovered. The top of Unit 3 is a diagnostically marked by a sharp increase in density to 1.6 to 2 g/cm³ for porcellaneite and up to 2.8 g/cm³ for dolomite; velocity increases from 1.0 to 2.8 km/s (porcellaneite) and 4 to 6 km/s (dolomite). Fossils are upper Miocene, but most samples are barren.

Unit 4 comprises the main part of the deep-sea fan and extends from 304 to 735.7 meters depth. It is bioturbated silty claystone with thin interbeds of calcareous sandstone and minor clayey carbonate and vitric ash. Faunal control is poor but indicates that deposition took place during the middle Miocene, with a sharp increase in sedimentation rate from 50 m/m.y. to 200 m/m.y. at about 360 meters depth. The seismic record shows an angular unconformity at this boundary; and the biostratigraphic record is consistent with a hiatus at the Unit 3/Unit 4 boundary. Sediment densities average about 2 g/cm³ with somewhat higher values (2.4–3.3 g/cm³) for carbonates and carbonate-cemented sandstone layers. Velocities are 2 km/s, increasing downslope to 2.3 km/s; carbonate and sandstone layers are as high as 4.9 km/s.

Unit 5 consists of hemipelagic claystone from 735.7 to 741.3 meters depth and altered sediment to the top of the diabase at 741.5 meters depth. The unit is intensely buried and contains microfaults and calcite veins. The altered sediment includes chalcopyrite- and sphalerite-bearing claystone, black quartzite chert, and brown metallic sediment. Velocities and densities are the same as those in Unit 4 but without the high carbonate or sandstone values. Intercalations of metalliferous sediment also occur within the diabase, which is altered and consists of at least two or three sills. Fragmental texture may be the result of emplacement into soft sediment, although slickensides indicate some shearing after consolidation. Density varies from 2.3 to 2.8 g/cm³, and velocity from 3.1 to 5.4 km/s; variability is in part caused by different degrees of alteration. The age of the oldest sediments above basement is 14.5 to 15 m.y., considerably older than the age extrapolated from the nearest stripped magnetic anomalies.

A full suite of downhole logs was run from about the top of Unit 3 (top porcellaneite) to total depth (T.D.). The Density and Sonic Logs clearly show the soft sediment in Unit 3 not recovered by coring; the porcellaneite and dolomite beds are high values on both logs. Metalliferous sediment interbeds in diabase are also clearly indicated. The Density Log may demonstrate a correlation with degree of alteration of diabase. The conductivity curve on the Neutron Log best indicates the resolution of thin sandy beds in Unit 3. The Neutron Log shows considerable character in the diabase and may indicate fracture porosity or degree of alteration. Two Temperature Logs and two heat-probe measurements indicate high geothermal gradient and high heat flow; temperature is 12.5°C at a depth of 95 meters and 24°C at 142.5 meters. Assuming a conductivity of 2.5, heat flow at the site is 1.8 heat flow units (HFU) based on downhole logs and 3.9 HFU based on heat probe.

BACKGROUND AND OBJECTIVES

The Franciscan-like terrain of the California Continental Borderland reappears on Cedros and San Benito islands, westernmost Vizcaino Peninsula, and Magdalena and Santa Margarita islands west of Magdalena Bay (Fig. 1). The rocks of the Magdalena Bay islands include sheared gabbro, serpentinite, and variated thin-bedded chert, an ophiolite assemblage that is highly sheared and locally a melange. Blueschist is rare at Magdalena Bay, although it is fairly abundant in the islands off Vizcaino Peninsula. The terrain is characterized by a strong free-air gravity high, which extends...
south-southeast from Magdalena Bay (Figs. 1 and 2), and high-relief magnetic anomalies, which extend seaward somewhat west of the gravity high (Figs. 1–3).

East of Magdalena Bay, Paleogene shallow-water sandstone (Tepetate Formation) is overlain by Oligocene and Miocene marine strata (San Ysidro and Monterey Formations), which are themselves overlain by the late Tertiary Comondu Volcanics, which form the mountainous backbone of Baja California del Sur, the Sierra Giganta. The Mesozoic batholithic terrain that dominates the high ground of Baja California del Norte may be buried beneath the Comondu. At this latitude, it appears at the surface only in the islands of the Gulf of California. Southeast of La Paz, granitic rocks also compose the Cape massif, a mountainous uplift separated from the Sierra Giganta by a north-south lowland that may be controlled by a fault.

Farther east is the Gulf of California, which underwent most of its rifting from mainland Mexico in the last 4 m.y., although a proto-gulf may have existed.

Figure 1. Bathymetric map of the sea floor west of central Baja California (from Chase et al., 1974) indicating locations of Sites 470 and 471 and seismic profile AA' shown in Figure 4.
earlier. The timing of initial separation of Baja California from the mainland is important to determine, because it would indicate when at this site a large source terrain, including the main Sierra Madre Occidental of Mexico, changed to a more restricted Baja California source terrain.

West of the ophiolitic zone of Magdalena Bay, the continental shelf is underlain by broadly folded Neogene sedimentary rocks (Fig. 4) that may overlie a ductile "Franciscan" or accretionary-wedge basement. The shelf is marked by linear highs and lows on the free-air gravity map and local magnetic highs suggestive of the high-amplitude anomalies of the islands off Magdalena Bay (Figs. 2 and 3). The shelf edge is marked by a linear gravity high that is flanked by a linear gravity low at the foot of the slope (Fig. 2).

A gravity low is associated with the Cedros deep, a feature that is topographically prominent from about 29°N south to about 24°30'N (Figs. 1 and 5). At these latitudes, the deep appears as a graben downfaulted against the continental slope on the east and against the abyssal sea floor on the west. The Cedros deep gravity low persists southeast to the latitude of the site and beyond to 23°N (Fig. 2). However, the topographic low is not present; instead, there is broad topographic bulge underlain by abyssal sea-floor sediments that dip gently to the east. The younger flat-lying sediments of Cedros deep and its southward continuation appear to overlie the pelagic sediments of the abyssal sea floor, but this relationship is not clearly established by reflection profiles. The Cedros deep does not appear to have a magnetic signature.

Site 471 is located in an area that is quiet in terms of gravity and magnetics (Figs. 1 and 3). Striped magnetic anomalies to the southwest were correlated to the geomagnetic time scale by Chase et al., (1970); their magnetic anomaly ages are shown in Figure 3. As Chase et al. (1970) pointed out, anomalies 12 m.y. of age and
Figure 3. Total magnetic-field anomaly map of the western continental margin of southern Baja California from Huehn (1977); contour interval is 100 gammas. (Ages of magnetic stripes are after Chase et al. [1970].)
Figure 4. Line drawing of seismic-reflection profile AA' through Site 471. (Vertical scale in kilometers assumes 1.5 km/s for the velocity of sand in water [from Huehn, 1977]. Deepest short-dashed line below site is basement reflector.)

older trend north-northwest, roughly parallel to the continental slope, but younger anomalies produce a fan pattern—such that those 8 m.y. old and younger are parallel to the present spreading center at the mouth of the gulf. The fan pattern of the magnetics makes estimating the magnetic-anomaly age of the crust at Site 471 somewhat ambiguous; the best guess is 11 m.y.

The thicker sediment section closer to the continental slope must indicate an increase in terrigenous input compared with Site 470. The eastward dip of the basement surface toward the foot of the slope (Fig. 4) suggests that the Sclater age-depth curve may be unusable in this case, because basement slopes downward in the direction of younger crust, the opposite effect of the Sclater age-depth relation. Interestingly, the *Glomar Challenger* track from Site 470 to the Cedros deep shows the basement rising eastward in the direction of younger crust, as predicted by the Sclater curve, reversing only fairly close to the trench. The deepening of the basement toward the continental slope may be the result of the vertical load of the continent, as suggested by the gravity low at the foot of the slope.

Site 471 is located, as are the more northerly sites, near a continental margin that was once a subducting margin, indicated by the “Franciscan” and ophiolite terrain; this would imply that the east slope of the Cedros deep was once a trench slope and that the deep itself is a fossil trench. The orientation of magnetic anomalies swung from north-south to northwest by 12 m.y. ago, an effect that Menard (1978) suggests may have been caused by the Farallon plate subducting only where there was sufficient thermal contrast between the cold, sinking plate and the surrounding asthenosphere for the plate to sink gravitationally. Where the rise crested intersected the trench obliquely, the Farallon plate would have been of near zero age at the time of subduction, and it would not have sunk because of a lack of thermal and density contrast; instead, the plate and its trailing rise cret would have pivoted counterclockwise parallel to the continental slope. The subsequent clockwise swing between 12- and 10-m.y.-old magnetic stripes may have been the result of a triple junction involving a small plate to the north, as Chase et al. (1970) suggested.

Whether the foot of the continental slope was a transform boundary 60 to 10 m.y. ago is not clear, but it is now a passive margin with low seismicity, just as it is farther north off southern California.

The oceanic front migrated approximately 10° of latitude in the northeastern Pacific during the Neogene in response to major climatic oscillations (Ingle, 1973). The location of Site 471, just south of the present-day mixing zone between distal California Current and equatorial waters and about 5° south of Site 470 (Figs. 2, 5), is well-suited for the study of the extent of southward penetration of higher-latitude assemblages during cold pulses in the paleoclimatic history of the area. The 800 meters of sediments overlying the basement were expected to contain a middle Miocene to Holocene planktonic record of mostly temperate elements, with influx of cooler, higher-latitude elements during times of climatic deteriorations and/or intensification of oceanic circulation.

**OPERATIONS**

The track from Site 470 to 471 was designed to determine the relations of both sites to the continental slope off Baja California. Accordingly, we took a slightly zigzag course to cross the Cedros deep twice, then steamed northeast across Site 471 to the continental slope, then returned on our track and dropped the beacon as we headed southwest down the broad apron of a deep-sea fan at the foot of the slope (Figs. 6 and 7).

Continuous coring was routine, with moderate to high recovery to 161.5 meters (Table 1). The heat-flow probe was run twice; the criterion for running the probe was that sediment be firm enough to take weight, but not so hard that the probe would not penetrate it. With a planned 50 meters between probe runs, it was possible to run the probe only twice, once at 95 meters and again at 155 meters. The sand line just above the heat probe was found to be knotted after the second run, requiring that about 150 meters of sand line be cut off before the next core.
Beginning with Core 18 at 161.5 meters, recovery dropped to about 5%, and the coring rate decreased from less than 10 min per core to 20 to 50 min per core. This zone of low recovery corresponds to Lithologic Unit 3, characterized by porcellanite alternating with softer sediments that were not recovered in cores but were identified on downhole logs. Recovery improved beginning with Core 34 at a depth of 313.5 meters, the approximate top of Lithologic Unit 4—the distal turbidite fan sequence. In the past, turbidites have been difficult for DSDP to drill and to recover in cores. Our favorable experience here may have been caused by the low porosity resulting from carbonate cement and to the lack of interbedded cherts or porcellanites. Core recovery was moderately high in Unit 4, with an occasional empty core barrel (Cores 55 and 67) and some recoveries limited to core catchers (in Cores 40, 49, 54, 56, 61, 62, and 68). There is no obvious correlation between core recovery and lithology in Unit 4. Coring rates in Units 4 and 3 were about the same. Other problems included bit plugging: a piece of core would lodge in the throat of the bit, which had to be dislodged with a center bit. Some torquing was noted in Unit 3, probably caused by fractured porcellanite falling in the hole. Frequent mud flushes in this interval cleaned up the hole, and few problems occurred at greater depths in sediment. Small amounts of gas bleeding from the cores were monitored on the Carle and HP gas chromatographs.

Diabase was encountered in Core 79, and coring continued through Core 88. Recovery was fairly good, and cores were close to gauge even at the bottom of the hole. The diabase occurs as altered sills, a lithology that has much higher recovery than pillow basalts, according to experience at previous DSDP sites. The center bit had to be run after Cores 79, 80, and 85, following indications of a plugged bit; otherwise operations were fairly routine. Coring time ranged from 26 minutes for Core 86 to 197 minutes for Core 84; there was no significant decrease in coring rate with depth. Our most trying moments were a stuck core barrel at Core 88, which finally released after once shearing the pin on the fishing neck. “Clay” at the bottom of the hole was in part fill and in part altered, fractured diabase.

The hole was flushed with 30 barrels of gel mud and 20 barrels of guartec in preparation for logging. The hydraulic bit release (HBR) go-devil was pumped down and the bit released at 1600 psi. The hole was filled with 300 barrels of gel mud, and the drill pipe was pulled to 158 meters below the mudline, near the top of Unit 3 (containing porcellanite). We set the pipe this deep to avoid losing the hole in sediments as unconsolidated as those in Units 1 and 2. (We attribute the failure of the logging tool to penetrate the sediment at Site 470 to the fact that sediments below the drill pipe were so unconsolidated that the hole was lost simply by motion of the drill pipe related to heaving of the ship.)

The Sonic, Caliper, and Gamma-Ray Logs were run, and the hole was found to be clean to bottom. The
Figure 6. *Challenger* track approaching and departing Site 471. (Small concentric circles on track lines are satellite fixes. Bathymetry [in meters] was contoured aboard ship on the basis of data from *Baja 75* and *Baja 76* cruises, Oregon State University.)

Figure 7. *Challenger* seismic line approaching Site 471. (See Fig. 6 for location.)
variable Density-Sonic (Wave-Train) Log was then run, followed by the Temperature-Density-Gamma-Ray Log; temperature was logged going down and the Density-Gamma-Ray Log was taken coming up. This was followed by the Guard-Neutron-Gamma-Ray Log, which was followed by the Induction-Gamma-Ray Log. A final Temperature Log was taken after pulling a stand of pipe while the log was in the hole, thereby allowing another 28 meters of open hole to be logged.

The hole was then cemented because of the gas shows monitored in the cores, the pipe was pulled, and we left for the next site at 1327 hours, 18 November, 1978.

**LITHOLOGY**

**Sediments and Sedimentary Rocks**

Site 471 is characterized by a thick section of interbedded silty claystone and sandstone overlain by a thinner section of sediments and sedimentary rocks, including porcellanite, diatomaceous clay, and nannofossil silty clay. We defined five lithologic units above altered diabase at this site (Fig. 8; Table 2).

Unit 1: Nannofossil Silty Clay (0–63.5 m)

Unit 1 is mainly composed of grayish olive green nannofossil silty clay. The abundance of nannofossils ranges from 15% to 40%. Grains of angular silt-size quartz and feldspar are less common, 3% to 12% and 1% to 6%, respectively. Siliceous microfossils are rare. In addition to nannofossil silty clay, this unit also contains layers of olive gray to dark greenish gray silty clay. Angular, silt-size grains of quartz and feldspar average 20% and 8%, respectively. Small patches of pinkish gray vitric ash and dusky yellow green calcareous ooze are scattered throughout this unit. Dark reduction spots and streaks of finely disseminated pyrite are also present. The boundary with the underlying diatomaceous sediment of Unit 2 is gradational, marked by a distinct increase in the abundance of diatoms in Core 6.

Unit 2: Variegated Diatomaceous Clay and Ooze (63.5–155.2 m)

Unit 2 consists of diatomaceous clay, diatomaceous silt clay, and clayey diatomaceous ooze. These sediments vary from dusky yellow green and olive gray to dark yellowish brown and grayish olive green. The darker colors correspond to greater proportions of diatoms in the sediment (e.g., Cores 9–10 and 16–17). Silt-size grains of quartz and feldspar decrease in abundance downhole in this unit, and diatomaceous silt clay grades into the underlying diatomaceous clay and clayey diatomaceous ooze in Core 8. Correspondingly, the abundance of diatoms increases downhole from 15% to 70%. Grayish purple reduction spots and streaks of finely disseminated pyrite as well as dusky yellowish
Figure 8. Lithologic and biostratigraphic summary, Site 471.
Unit 3: Porcellanite and Silty Claystone (155.2-304.0 m)

Unit 3 is olive gray to olive black opal-CT porcellanite and porcellaneous silty claystone. A few fragments of olive black opal-CT chert and several thin interbedded layers of light olive gray silicified dolomite also occur. Recovery was extremely poor in this interval, averaging only 5%. Most cores consist of fragments of hard porcellanite that have been broken and brecciated by drilling. Downhole logs (especially the Density and Neutron Logs) and several pieces of firm silty clay within the sequence (as in Cores 26, 27, and 29-31), however, suggest that these hard siliceous rocks are interbedded with softer sediment. Slabbed surfaces of the porcellanite display abundant burrows.

In thin section, the porcellanite consists dominantly of clay cemented by silica. X-ray diffraction data show the siliceous cement to be opal-CT. Minor chaledony-filled molds of diatoms, radiolarians, and sponge spicules also occur, as well as scattered rhombs of carbonate. Silt-size grains of quartz and feldspar are present in bioturbated silty claystone. Fragments of firm clayey diatomaceous ooze are abundant near base of unit. The dark olive gray claystone, in beds 4 to 15 cm thick, is thoroughly bioturbated. Large lenticular burrows are filled with light olive gray silty claystone. Other burrow forms include Zoophycos and possible Condrites. The claystone is uniform in composition and is composed of angular silt-size grains of quartz (3-15%), and feldspar (2-7%), clay minerals (60-80%), and volcanic ash (2-10%), and scattered white sponge spicules (<1%). The siliceous sponge spicules are cigar-shaped and 2 to 5 mm long, have dark claystone-filled interiors, and are commonly coated with a thin film of dark organic material.

Sandstone interbeds first appear in Core 35 as thin laminae within the bioturbated silty claystone sequence and become thicker and more abundant in Core 47. These persist through Core 77 but are not present in Core 78 immediately above the claystone of Unit 5. Most sandstone layers range from 1 to 4 cm thick, although some attain a maximum thickness of 10 cm. The spacing and thickness of these layers are also variable. Generally, they occur at least 5 to 10 cm apart. A core may contain as many as 30 to 40 thin sandstone beds (e.g., Core 64).

The sandstone is mostly fine-grained and moderately well sorted. It consists of angular grains of polycrystalline and unstrained monocristalline quartz and chert (15-20%), and feldspar (10-20%), and coated pellets (2-10%). Biotite (2%), hornblende (2%), pyroxene (trace), and foraminifers (1%) are accessory components. Rock fragments are chiefly silicic volcanic glasses such as dacite and rhyolite. Some coarse sand-size polycrystalline quartz grains may be metaquartzite. Fine sand-size pelletal grains contain cores of angular quartz or feldspar; the coating is opaque or, less commonly, light brown and may be a mixture of phosphate and manganese oxides-hydroxides. Abundant calcrete, in large, optically continuous patches, is a cement and partially replaces framework grains in these calcreatic sandstones.

Many sandstone layers display Bouma d,e sequences (i.e., parallel lamination gradingly overlain by thicker and finer-grained burrowed, sandy, silty claystone). In some, an intervening layer of micro-cross-laminations (division c) is also present, forming Bouma b,c,d or c,d,e sequences. Commonly, the upper few centimeters of each sandstone bed are intensely bioturbated, creating the appearance of distorted ripple cross-laminations. Compact lenticular concentrations of dark gray, silt- and sand-size faecal pellets are abundant in the burrows in the sandstone and also in the overlying thicker, sandy, silty claystone. It is possible that some of

Table 2. Summary of lithologic units, Site 471.

<table>
<thead>
<tr>
<th>Unit or Sub-unit</th>
<th>Core Number</th>
<th>Depth below Sea Floor (m)</th>
<th>Chronostratigraphy</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1-6, Section 3</td>
<td>6.0-43.5</td>
<td>Quaternary-Recent</td>
<td>Nanoscale silty clay, silty clay, and scattered patches of vitric ash.</td>
</tr>
<tr>
<td>2</td>
<td>6, Section 3-17,CC</td>
<td>63.5-152.5</td>
<td>Miocene</td>
<td>Dolomitic clay, dolomitic silty clay, and clayey dactylic ooze.</td>
</tr>
<tr>
<td>3</td>
<td>17,CC-32</td>
<td>152.5-300.0</td>
<td>Miocene</td>
<td>Porcellanite and porcellaneous silty claystone with a few fragments of opal-CT chert and several clays layers.</td>
</tr>
<tr>
<td>4</td>
<td>33-78 Section 3</td>
<td>304.0-735.7</td>
<td>Miocene</td>
<td>Bioturbated silty claystone with thin interbeds of calcareous sandstone. Sandstone becomes less abundant near base of unit.</td>
</tr>
<tr>
<td>5a</td>
<td>78, Section 3-79, Section 1</td>
<td>732.7-741.3</td>
<td>Miocene</td>
<td>Chalcedony- and spilitic-bearing rock, quartzite, and metagreywollstone.</td>
</tr>
<tr>
<td>5b</td>
<td>79, Section 1</td>
<td>741.3-744.5</td>
<td>Miocene</td>
<td>Clayey carbonate and vitric ash.</td>
</tr>
</tbody>
</table>

Note: The summary of lithologic units, Site 471, includes the following:
- **Unit 1**: Nanoscale silty clay, silty clay, and scattered patches of vitric ash. This unit occurs between Cores 32 and 33, and extends over a distance of about 304 meters, near the base of Core 32.
- **Unit 2**: Dolomitic clay, dactylic ooze, and clays. This unit is placed between Cores 32 and 33, and extends over a distance of about 304 meters, near the base of Core 32.
- **Unit 3**: Porcellanite and porcellaneous silty claystone. This unit is olive gray to olive black opal-CT porcellanite and porcellaneous silty claystone. Fragments of opal-CT chert and several thin interbedded layers of light olive gray silicified dolomite also occur. Recovery was extremely poor in this interval, averaging only 5%. Most cores consist of fragments of hard porcellanite that have been broken and brecciated by drilling.
- **Unit 4**: Interbedded Silty Claystone and Sandstone (304.0-735.7 m)

Unit 4 is a thick, well-bedded sequence of olive gray silty claystone containing numerous thin interbeds of bluish gray calcite-cemented sandstone and light gray, structureless silty claystone. A few beds of light gray altered vitric tuff and several thin layers of clayey dolomite and a limestone (Core 37) occur near the top of the unit. The dark olive gray claystone, in beds 4 to 15 cm thick, is thoroughly bioturbated. Large lenticular burrows are filled with light olive gray silty claystone.

Other burrow forms include Zoophycos and possible Condrites. The claystone is uniform in composition and is composed of angular silt-size grains of quartz (3-15%), and feldspar (2-7%), clay minerals (60-80%), and volcanic ash (2-10%), and scattered white sponge spicules (<1%). The siliceous sponge spicules are cigar-shaped and 2 to 5 mm long, have dark claystone-filled interiors, and are commonly coated with a thin film of dark organic material.

Sandstone interbeds first appear in Core 35 as thin laminae within the bioturbated silty claystone sequence and become thicker and more abundant in Core 47. These persist through Core 77 but are not present in Core 78 immediately above the claystone of Unit 5. Most sandstone layers range from 1 to 4 cm thick, although some attain a maximum thickness of 10 cm. The spacing and thickness of these layers are also variable. Generally, they occur at least 5 to 10 cm apart. A core may contain as many as 30 to 40 thin sandstone beds (e.g., Core 64).

The sandstone is mostly fine-grained and moderately well sorted. It consists of angular grains of polycrystalline and unstrained monocristalline quartz and chert (15-20%), and feldspar (10-20%), and coated pellets (2-10%). Biotite (2%), hornblende (2%), pyroxene (trace), and foraminifers (1%) are accessory components. Rock fragments are chiefly silicic volcanic glasses such as dacite and rhyolite. Some coarse sand-size polycrystalline quartz grains may be metaquartzite. Fine sand-size pelletal grains contain cores of angular quartz or feldspar; the coating is opaque or, less commonly, light brown and may be a mixture of phosphate and manganese oxides-hydroxides. Abundant calcrete, in large, optically continuous patches, is a cement and partially replaces framework grains in these calcreatic sandstones.

Many sandstone layers display Bouma d,e sequences (i.e., parallel lamination gradingly overlain by thicker and finer-grained burrowed, sandy, silty claystone). In some, an intervening layer of micro-cross-laminations (division c) is also present, forming Bouma b,c,d or c,d,e sequences. Commonly, the upper few centimeters of each sandstone bed are intensely bioturbated, creating the appearance of distorted ripple cross-laminations. Compact lenticular concentrations of dark gray, silt- and sand-size faecal pellets are abundant in the burrows in the sandstone and also in the overlying thicker, sandy, silty claystone. It is possible that some of
the sandstone layers may have been ripple cross-laminated and only partially disrupted by burrowing. Some sandstone layers have load structures, and most have sharp basal contacts. The underlying claystone, which has only a few burrows, is generally lighter gray and thinner (<2 cm) than the more extensively burrowed silty claystone that immediately overlies each sandstone layer.

Thin layers of altered vitric tuff occur near the top of Unit 4. In Core 44, a 7-cm-thick, biotite-bearing, light gray tuff is present. It has a sharp basal and gradational upper contact and is graded.

Some sandstone layers are present in Cores 78 and 79 near the base of the unit, although there is a regular alternation of light and dark gray silty claystone beds, especially in Core 78. The boundary between Unit 4 and the underlying claystone of Unit 5 is placed at the last occurrence of calcite-cemented sandstone in Core 78.

**Unit 5: Claystone and Sulfide-Bearing Sediment (735.7-741.5 m)**

Unit 5 is a thin sequence of claystone that is hydrothermally altered at its base. We divide it into two parts: Sub-unit 5a, claystone, and Sub-unit 5b, sulfide-bearing sediment, quartzose black chert, and metalliferous sediment overlying altered diabase.

Sub-unit 5a is greenish gray claystone. It is intensely mottled by burrows and contains abundant microfaults and some calcite-filled veins. Reduction streaks and spots of finely disseminated, dark gray pyrite are common. Except for a few scattered silty layers, the unit contains significantly fewer silt-size grains of quartz and feldspar than the overlying silty claystone of Unit 4. The clay to silt ratio is about 9:1. Nannofossils are present in the claystone at the top of this sub-unit but decrease and finally disappear at its base. Several scattered grayish blue green streaks may be altered vitric ash.

Sub-unit 5b is a potpourri of sediments and sedimentary rocks including chalcopyrite- and sphalerite-bearing claystone, black quartzose chert, and metalliferous sediment. Chalcopyrite- and sphalerite-bearing rocks form the upper part of this unit. Rock fragments recovered in the brecciated base of this sequence consist of claystone, chalcopyrite-sphalerite, and black quartzose chert. The chert is conchoidally fractured and veined by calcite. A thin (2-cm) layer of dusky yellowish brown metalliferous sediment overlying altered diabase forms the base of Unit 5. Clay, X-ray amorphous iron-rich material, and minor carbonate rhombs are dominant components of this sediment. Similar sediment occurs within fractures and between altered diabase in Section 82-1 and Section 88-1. Where metalliferous sediment fills some fractures in the diabase, it has been thermally altered to red brown jasper.

**Igneous Rocks**

Diabase (and its fine-grained equivalent along chilled zones) and brecciated diabase are the two igneous rock types recovered at Site 471. Thin intercalations of claystone at depths of 750.5 meters and 769.5 meters provide convenient boundaries for dividing these rocks into three sequences (Fig. 9). The upper sequence (741.5-750 m) is mainly fine- to medium-grained, aphyric diabase having a chilled margin of aphyric basalt at the upper contact with the overlying sediment. Grain size increases away from this contact. Plagioclase is the only remaining primary constituent in these rocks, occurring as euhedral laths (<2 mm). The texture is intersertal. Clays, calcite, and zeolite are the common alteration minerals; neither primary mafic minerals nor any pseudomorph after them are found.

The middle diabase sequence (750.6-769.6 m) coarsens slightly away from the bounding claystone layers over an interval of about 1 meter. The upper part of this sequence (Core 80) is mostly altered brecciated diabase consisting of angular to subangular fragments of altered diabase and clayey chert generally less than 2 cm across. Slickensides mark the face of one diabase fragment. The lower part of this sequence is highly altered, medium-grained diabase composed of subhedral plagioclase and clinopyroxene with intersertal to subophitic textures. Faint purple pink tints indicate some clinopyroxenes may be titaniferous. Clay, calcite, and an unidentified zeolite are common alteration minerals.

The lower diabase sequence (769.6-820 m) may be further subdivided into two portions. The upper part (Cores 82-83) contains a distinct chilled zone with grain size gradually decreasing in the first 1.5 meters below the claystone. This part is compositionally similar to the middle sequence, except that chert fragments are absent in the brecciated diabase. The lower part is distinct in that it contains significant amounts of biotite, quartz, and K-feldspar(?). In this respect it is similar to the up-
per portion of the diabase sill at Site 469. The mineralogic constituents of this lower part include, in decreasing order of abundance, plagioclase, clinopyroxene, brownish green smectite, opaque minerals, biotite, quartz, K-feldspar(?), colorless amphibole, sphene, calcite, and zeolite. Intersertal to subophitic textures prevail, with euhedral to subhedral plagioclase laths partly embayed into anhedral clinopyroxenes. Plagioclase is strongly zoned and ranges in grain size from 0.5 to 4 mm. Clinopyroxene has faint purple pink tints; several grains are further fringed by pale green clinopyroxene rims. Biotite, quartz, K-feldspar(?), and colorless amphibole all occur in the interstices between plagioclase laths and clinopyroxenes. Intense alteration of K-feldspars to clays precludes their positive identification; however, they appear to be confined to Cores 84 to 86. Despite the distinct mineralogy of this lower part of the lower diabase sequence, we make no further subdivision because of the absence of a chilled zone.

The brecciated diabase could have formed by intense weathering along incipient fractures. In addition, some of these rocks (Core 83) have a laminated fabric similar to cataclastic rocks, although microscopically, constituent minerals do not show such strain effects as marginal granulatation, undulatory extinction, or bending of cleavage cracks or twin lamellae. Some fragmented crystals of plagioclase do occur, however, suggesting minor cataclastic deformation. Possibly these diabase breccias formed by autobrecciation, a fragmentation process whereby portions of the first-consolidated crusts of intrusions or flows are incorporated into the still-molten interior.

Because of the absence of pillow structure, the absence of microscopic quench texture that would indicate rapid chilling of magma against cool water, the coarse grain size, ore mineralization in the overlying sedimentary rocks, and the inclusion of sedimentary rock fragments in the brecciated diabase, the diabase sequence at Site 471 is probably intrusive. This sequence is probably a composite of three or four cooling units, with each unit representing a thin sill or sheet. Alternatively, these cooling units may correspond to offshoots of a single, larger intrusive.

**BIOSTRATIGRAPHY**

Pleistocene through middle Miocene sediments were recovered at Site 471. Planktonic foraminifers and coccoliths are common to abundant and provide stratigraphic control in the upper 45 meters (Cores 1-5) and 58 meters (Cores 1-6) respectively. In Cores 7 through 17, calcareous microfossils are absent, and radiolarians and diatoms provide stratigraphic control (Fig. 10). Microfossils are essentially absent from Cores 18 through 38, although sparse radiolarian assemblages provide some stratigraphic control. Coccoliths reappear in Core 39 and are sporadically present to the bottom of the sedimentary section. Benthic and planktonic foraminifers are present but they are extremely sparse in this interval.

Coccoliths suggest placement of the Pliocene/Quaternary boundary just below Sample 3, CC and the lower Pliocene/upper Pliocene boundary between Cores 5 and 6. Figure 8 summarizes zone determinations for Site 471. The top of the *Sphenolithus heteromorphus* Zone is in Core 78, about 3 meters above the uppermost igneous rock. The age of the oldest sediment at Site 471 is thus estimated to be about 15 m.y.

**Coccoliths**

Coccoliths recovered at Site 471 represent only short intervals of time. In Core 79, just above basalt, the oldest assemblages belong to the upper *Sphenolithus heteromorphus* Zone (approximately 14 m.y. of age; Bukry, 1975). The overlying *Coccolithus miopelagicus* Subzone (approximately 13.4 to 14 m.y. old) extends through a thick interval from Core 39 to Core 78 (368–737 m), but the short time span involved yields an exceptionally high sedimentation rate (383 m/0.6 m.y. = 640 m/m.y.). Reworked Cretaceous and Paleogene coco-
liths occur (Fig. 11) in this interval (Lithologic Unit 4), which is characterized by turbid flow sedimentary structures. An equally thick interval in Cores 6 to 39 (55–368 m) is barren of coccoliths. Pleistocene to lower Pliocene coccoliths are sparse to abundant in the upper cores, Sample 1, CC to Core 6 (9.5–52 m), representing the interval from approximately 0.5 m.y. to 4 m.y. ago. The upper part of Core 1 was not investigated.

All sediment layers intercalated with the igneous rocks of Cores 80 to 88 that were examined for coccoliths are barren. The lower middle Miocene *Sphenolithus heteromorphus* Zone assemblages of Cores 78 and 79 are similar to overlying assemblages, except for the presence of *Sphenolithus heteromorphus* Deflandre and the more common *Cyclocarolithus floridanus* (Roth and Hay); and these assemblages show the only notation for overgrowth (+2 to +3; Bukry, 1973) at Site 471, in Sample 471-79-1, 7 cm (at a depth of 751 m). This sample also contains some fragments of pyritized centric diatoms.

Dark olive clay-rich siltstone directly above blue gray turbiditic sandstones of Cores 39 to 78 are in the *Coccolithus miopelagicus* Subzone and yield the largest, most diverse coccoliths. Lighter-color claystone from higher in the turbidite sequences yields mostly smaller, less diverse coccoliths. Many sediment layers are barren or poor, producing an uneven record of abundance and preservation through the subzone (Fig. 10). Reworked Cretaceous coccoliths in Cores 39 to 79 appear to represent Campanian to Maestrichtian horizons (Fig. 11). Similar coccoliths occur onshore near San Diego, California (Bukry and Kennedy, 1969). Paleocene coccoliths, such as *Discoaster multiradiatus*, are from upper Paleocene strata.

Lower Pliocene coccoliths of Cores 5 and 6 are sparse to common and etched. The assemblages are assigned to the *Sphenolithus neoabies* Subzone, because *Reticulofenestra pseudoumbilica* (Gartner) and *Sphenolithus abies* Deflandre are present and *Discoaster tamalis*
Kamptner and Amaurolithus spp. absent. One reworked A. delicatus Gartner and Bukry occurs in Sample 471-5,CC.

The Pliocene/Pleistocene boundary may be in a condensed section or cut out by a hiatus, because the Gephyrocapsa caribbeana Subzone of Sample 471-4-1, 0 cm (28.5 m depth) overlies the Discoaster surculus Subzone of Sample 471-4-2, 52-53 cm (32 m depth).

Pleistocene assemblages contain Gephyrocapsa oceanica Kamptner with high-angle bars and Coccolithus pelagicus (Wallich), indicating temperate conditions.

**Silicoflagellates**

Lower Pliocene and upper Miocene silicoflagellates are sparse to common and well preserved in Cores 6 to 18. They are absent in the calcareous Quaternary and Pliocene silty clay of Cores 1 to 5 and in the Miocene silt/clay of Cores 19 to 78, although sparse fragments of diatoms Coscinodiscus marginatus Ehrenberg and Thalassiothrix longissima Cleve and Grunow as well as pyritized centric diatoms occur through Cores 20 to 28. The upper silicoflagellate assemblages of Cores 8 and 9 are especially diverse, and some reworking is suggested by the presence of Distephanus mesopithalmus (Ehrenberg) (upper middle to lower upper Miocene, according to Dumitrică, 1973) and the diatom Craspedodiscus coccinodiscus Ehrenberg (lower or middle Miocene). Terrestrial opal addition to the sediment is indicated by the presence of sparse panicoid opal phytoliths in Sample 471-8,CC. Mesocena sp. aff. M. quadrangula Ehrenberg ex Haeckel and Dictyocha sp. (naviculopsoid) in Core 8 suggest correlation with the upper Miocene upper Discosteller quinqueramus Zone of coccoliths at DSDP Site 158 in the eastern equatorial Pacific.
**Figure 11.** Upper Cretaceous and Paleogene reworked coccoliths at Site 471.

(Bukry, 1973). Although silicoflagellates are generally common in Cores 10 to 18, diversity is low and assemblages are composed mainly of *Dictyocha brevispinα* (Lemmermann), *D. fibula* Ehrenberg, and *Distephanus speculum* (Ehrenberg). In most samples *Dictyocha fibula* predominates over *D. brevispinα*, suggesting the warm-water *Dictyocha fibula* Zone of Martini (1971). Samples 471-13,CC and 471-15,CC, however, have more *D. brevispinα* than *D. fibula*, possibly indicating the top of the *D. brevispinα* Zone, a unit correlative with the upper *Discoaster quinqueramus* Zone or upper *D. neohamatus* Zone of coccoliths in the eastern equatorial Pacific (approximately 7 m.y. old) (Bukry and Foster, 1973; Bukry, 1973).

**Radiolarians**

At Site 471, the interval between Cores 1 and 5 is nearly barren of radiolarians. Sections 3 and 5 of Core 1 contain only rare, nondiagnostic radiolarians, and Section 1 yielded *Amphirhopalum ypsilon* and (?)*Ommatartus tetralhamus*, two Quaternary to Pliocene species. Because the latter section does not contain any older radiolarians other than rare individuals of *Stichocorys peregrina*, it is tentatively assigned to the Quaternary. The boundary between the Quaternary and Pliocene is placed immediately above the youngest fossiliferous layers (Core 5, Section 6) with *Lamprocyrtis heteroporos*. It must be emphasized, however, that the true position of that boundary at Site 471 cannot be found by means of radiolarians.

Deposition during the late Pliocene is indicated for Core 5, Section 6 through Core 6, Section 1 by rare occurrences of *L. heteroporos* and the absence of *Eucyrtidium matuyamai*. The extinction of *Stichocorys peregrina* marks the boundary between the upper Pliocene *L. heteroporos* Zone and the lower Pliocene *S. peregrina* Zone (upper part), which comprises the interval between Core 6, Section 3 and Core 10, Section 1. Mostly few to common, moderately to well preserved radiolarians typify the lower Pliocene succession. Its lower limit is indicated by the first appearance of *L. heteroporos*. Besides rare to abundant *S. peregrina*, *Ommartar tus penultimus* is another rare to common species that survived above the Miocene/Pliocene boundary.

The upper Miocene cores of Hole 471 contain a radiolarian assemblage rather rich in species that are almost exclusively warm-water varieties. The equatorial zonation is therefore applicable. The presence of *S. peregrina*, *S. delmontensis*, *S. wolffii*, *O. penultimus*, and *O. antepenultimus* and the absence of *L. heteroporos* suggest that Core 10, Section 3 through Core 17, Section 1 are upper upper Miocene (lower part of the *S. peregrina* Zone). A separation of the upper upper Mio-
cene S. peregrina Zone and the middle upper Miocene O. penultimus Zone is not possible at Site 471, because the first appearances of S. peregrina and O. penultimus nearly coincide, and because the occurrences of S. delmontensis and S. peregrina overlap considerably. There are no radiolarian species remaining to define the upper limit of a possible O. penultimus Zone. The lower boundary can be defined exactly, however, by the extinction of Ommatarius hughesi and the first appearance of O. penultimus and can be placed below Core 17, Section 1, provided that the two events are not affected by dissolution or reworking. Besides several nondiagnostic species, Sample 471-17,CC contains S. delmontensis, S. wolffii, and O. antepenultimus, and Core 23, Section 1 yielded rare to few specimens of O. antepenultimus, O. hughesi, and Cannarius peterssoni (O. antepenultimus Zone). Samples 471-23,CC and 471-28,CC contain very rare and poorly preserved radiolarian assemblages deposited during the early late Miocene. All of the remaining cores of Site 471 lack radiolarians or bear only indeterminable fragments, frequently with heavy crystalline overgrowths.

Diatoms
Few to abundant Plaenocene to upper Miocene diatoms are present in Cores 6 through 18 at Site 471. Nearshore diatoms, such as Actinocyclus ehrenbergii, Rhaphoneis spp., and Thalassiosira spp., are present in Core 1 but are not age-diagnostic. Diagenesis, which is first evident in Cores 17 and 18, removed all but robust, non-age-diagnostic diatoms below Core 18. The first occurrence of Thalassiosira oestrupii in Sample 471-9-1, 58-60 cm is indicative of a horizon slightly higher than the Miocene/Pliocene boundary. Sample 471-10-1, 20-22 cm contains relatively common Dicytocha navicula, a silicoflagellate with an acme penultimus Zone). Samples 471-23,CC and 471-28,CC contain very rare and poorly preserved radiolarian assemblages deposited during the early late Miocene. All of the remaining cores of Site 471 lack radiolarians or bear only indeterminable fragments, frequently with heavy crystalline overgrowths.

Foraminifers
Planktonic foraminifers are common and well to moderately well preserved in the upper 44.8 meters of Hole 471 (Samples 471-1,CC through 471-5,CC, 80 cm). Cores 1 through 3 are assigned to the Quaternary because of the occurrence of Globorotalia truncatulinoides in Sample 471-1,CC, and Neogloboquadridina dutertrei in Samples 471-1,CC through 471-3,CC. An upper Pliocene assemblage containing Neogloboquadridina humerosa, N. aff. N. atlantica, and Globorotalia inflata was recovered from Sample 471-4,CC, whereas Sample 471-5, 80-82 cm, with Globoquadridina altispira and transitional forms between Globorotalia punculata and G. inflata, is considered close to the Zone N21/Zone N19 boundary.

Planktonic assemblages in Samples 471-1,CC through 471-5,CC, 80-82 cm are diverse, and tropical to subtropical taxa such as Pulleniatina obliquiloculata and Sphaeroidinella dehiscens as well as keeled Globorotalia and Globigerinoides occur throughout this interval. Sample 471-5,CC, 80-82 cm yields a sparse, strongly dissolved assemblage, and no foraminifers are present in Sample 471-5,CC. Foraminifers are absent from Cores 6 through 37. From Core 38 to Core 78, occasional foraminifers were seen on cut surfaces of cores. Examination of selected samples from this interval revealed rare, poorly preserved planktonic foraminifers; only long-ranging taxa such as Globigerina bulloides and Globigerinoides trilobus were found.

Benthic foraminifers are sparse but well preserved in the first five cores of Hole 471. Uvigerina senticosa, Pullenia bulloides, and Melonis barleeanus are consistent members of the assemblage in this interval and indicate lower middle to lower bathyal water depths. Benthic foraminifers are absent or extremely rare in Cores 6 through 37.

Below Core 37, representatives of Gyroidina, Pyrgo, Stilostomella, Globalumina and (?)Bolivia were occasionally seen on cut surfaces of cores. Benthic foraminifers are sometimes concentrated toward the top of sandstone layers in the turbidite sequence of Cores 38 to 78, but they are poorly preserved, and most specimens appear to be internal casts. Occasional specimens of Pullenia bulloides and Gyroidina soldanii in samples from fine-grained sediments of Cores 37 to 78 suggest this sequence was deposited in bathyal water depths.

**Sediment Accumulation Rates**
The sediment accumulation rate curve (Fig. 12) for Site 471 was constructed from selected radiolarian (R) and coccolith (C) events. The plot indicates rates of ~20 m/m.y. for the Quaternary into the late Miocene, ~50 m/m.y. for the early late to late middle Miocene, and ~200 m/m.y. for the early middle Miocene. No stratigraphically diagnostic microfossils are present for more than 100 meters above the coccolith control point at 360 meters sub-bottom (Fig. 8). Thus the accumulation rate calculated for the lower portion of Site 471 represents a minimum estimate.

**Geochemical Measurements**

**Interstitial Water**
The salinity, chlorinity, pH, alkalinity, and calcium and magnesium concentrations of interstitial waters from nine depths at Site 471 were determined on board. The results are plotted versus depth at the site in Figure 13. No samples were taken between 125 and 360 meters sub-bottom depth; in this interval, only porcellanites and dolomites were recovered. Although the calcium concentration profile at Site 471 shows a gradual increase downcore, the magnesium concentration profile...
Figure 12. Sediment accumulation rates, Site 471.

shows a marked discontinuity between normal sea water magnesium concentrations above the porcellanites and very low magnesium concentrations below the porcellanites. Salinity and chlorinity also decrease markedly over the same depth interval. The change in magnesium concentrations over the interval from which porcellanites were recovered suggests that the decrease was the result of diagenetic reactions involved in the transformation of biogenic opal to opal-CT porcellanite and/or in the formation of dolomite.

Calcium Carbonate Content

The calcium carbonate concentration in samples from Site 471 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 14. Most of the sediment column at this site is noncalcareous. There, however, a few dolomite interbeds in Unit 3 that had carbonate contents of 99% to 100%. The silty clays of Unit 4 are also noncalcareous, but they are interbedded with calcareous sandstones that contain 14% to 21% CaCO₃.

PHYSICAL PROPERTIES AND DOWNHOLE LOGS

Figure 14 plots the physical-properties data for Site 471, and Table 3 summarizes these data. Figure 15 displays the downhole logs obtained at this site. Relatively constant values of density (~1.5 g/cm³) and velocity (~1.5 km/s) characterize the upper 150 meters of soft nannofossil silty clay and diatomaceous clay. A sharp increase in both parameters occurs at 155 meters, the depth at which soft diatomaceous sediment begins to convert to harder porcellanite. The density of the porcellanite at this depth is about 2.0 g/cm³ but decreases slightly to 1.7 g/cm³ at about 317 meters. Sonic velocities show a similar trend, decreasing in this interval from 3.6 km/s to 2.1 km/s. This change corresponds to a noticeable decrease in the siliceous character of the
Figure 14. Summary of physical properties, Site 471.
ranks—porcellanite changes downhole to less siliceous porcellaneous silty claystone. The Sonic and Density Logs show these variations most clearly. Moreover, all logs demonstrate the occurrence of soft sediment interbedded with porcellanite between 155 and 317 meters. Recovery was only about 5% in this interval, and much of this soft sediment was not recovered.

The thick monotonous sequence of silty claystone below 317 meters has fairly uniform physical-properties profiles, except where it is punctuated by thin layers of clayey dolomite and calcite-cemented sandstone. The Neutron Log gives the best resolution of the thin sandy layers. The two peaks at about 598 meters on this log correspond to thin sandstone layers. The Density and Sonic Velocity Logs also delineate these thin layers. From a physical-properties standpoint, the pelagic claystone at the base of this section of silty claystone is indistinguishable from the overlying unit.

A sharp increase in density and velocity occurs at 741 meters, the top of the altered diabase. These two parameters fluctuate significantly with depth in the diabase and probably correspond to variations in the degree of alteration and fracturing of this unit (see also the Seismic-Spectrum Log, Figure 15). The Neutron Log is also quite variable in this unit. A thin interval of metallocferous sediment occurring at about 780 meters in the diabase shows clearly on the Density, Sonic, and Neutron Logs. Below about 812 meters, neutron, velocity, and density values decrease, perhaps marking an interval of more altered diabase extending to the bottom of the hole.

Table 3 lists impedance contrasts calculated from the laboratory determinations of density and velocity. Clearly the boundary between the porcellanite of Unit 3 and the overlying soft diatomaceous clay is a strong reflector. The carbonate layers should also be good reflectors if numerous or thick enough. The claystone/diabase contact has a high impedance contrast and is a prominent reflector on the seismic profile.

Estimates of in situ temperatures and geothermal gradients at Site 471 come from three sources: (1) heat flow probe measurements made during drilling; (2) two Temperature Logs run about 18 hours apart in the open hole after completion of drilling, and (3) bottom-hole temperatures recorded with a set of three maximum temperature thermometers attached to each logging tool. Figure 16 illustrates the results of the two heat flow probe measurements made at Site 471. The instrument used was the Uyeda/Kinoshita probe first tested on DSDP Leg 60 (see Hussong, Uyeda, et al., in press for details and discussion of this instrument). We made two measurements with the probe in the sediment at 95 meters and 142.5 meters, with additional stations in the pipe at mudline to estimate the temperature of the bottom water. Both runs show a similar pattern of decreasing temperature as the probe is lowered to the sea floor, an increase as it approaches the maximum drilled depth, a plateau corresponding to penetration into the sediment, then cooling and finally warming trends as the probe is pulled from the hole. The interval labeled "on bottom" in each run corresponds to the time the probe was actually in the sediment. Hyndman et al. (1974) note that temperature decreases (cooling curve) when frictional heating affects the temperature measurement. For the measurement at 142.5 meters, the constant temperature (prevailing 42 minutes after the last lowering of the pipe) indicates frictional heating is not important.

In situ sediment temperatures estimated from Figure 16 are about 12.5°C at 95 meters and about 24.0°C at 142.5 meters. Using a bottom-water temperature of 2.0°C, we determined that the geothermal gradients are 110°C/km and 154°C/km, with an average of 132°C/km.

We also estimated the geothermal gradient at Site 471 using the Temperature Logs (Figure 15). Both Temperature Logs show initially steep gradients in the porcellanite, ~40°C/km for the first run and ~74°C/km for the second. A distinct change to lower gradients (30°C/km and 67°C/km, respectively) occurs below about 345 meters. These latter values remain fairly uniform through the thick section of silty claystone, except for an interval between 520 and 570 meters, where gradients decrease slightly. This interval corresponds to the first show of gas in the cores; gas escaping into the open hole and expanding could explain this zone of lower gradients. The second Temperature Log probably more closely approximates the equilibrium gradient than does...
<table>
<thead>
<tr>
<th>Sub-Bottom Depth (m)</th>
<th>Chrono-Stratigraphic Unit</th>
<th>Litho-Logic Units</th>
<th>Caliper Log (hole diameter, in m.)</th>
<th>Gamma Log (API units)</th>
<th>Density Log (density in g/cm$^3$)</th>
<th>Sonic Log (velocity in km/s)</th>
<th>Neutron Log (API units)</th>
<th>Induction Log (resistivity in ohm-m)</th>
<th>Later Log (resistivity in ohm-m)</th>
<th>Temperature Log and Heat Probe Measurements (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quaternary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pliocene</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-100</td>
<td>Unit 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-200</td>
<td>Unit 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-300</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-400</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-500</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-600</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-700</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-800</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 15. Summary of downhole logs, Site 471.
the first run because of the added time between the last circulation and logging. From this reasoning, the average minimum gradient is 70°C/km. This value is lower than the estimates made from heat probe measurements, because the logging tool does not actually penetrate the sediment and because of the thermal disturbance created by the drilling process (Jaeger, 1965). Note that the second Temperature Log recorded lower values than did the first log in the upper 150 meters of open hole and higher values below this, an indication of how the hole re-equilibrates following drilling.

A third estimate of the geothermal gradient at Site 471 comes from extrapolating maximum bottom-hole temperatures recorded during each of the logging runs; this was done according to the method described by Timko and Fertl (1972). Figure 17 illustrates this method for Site 471, and Tables 4 and 5 list the pertinent data. From this method the equilibrium bottom-hole temperature is about 68.5°C. Using a 2.0°C bottom-water temperature and a total depth of 817 meters for the hole, the geothermal gradient is 81°C/km. Again, thermal disturbance resulting from drilling and the lack of penetration of the logging tool tend to make this value a minimum.

From these three methods the range in geothermal gradient at Site 471 is 70°C/km to 154°C/km. These values are approximate because both heat probe data and Temperature Logs suggest a nonlinear gradient. A single value is difficult to estimate, because both methods have significant uncertainties—heat flow data suffer from the effects of frictional heat generated by lowering the probe and drill pipe in the sediment, and logging data are nonequilibrium values influenced by thermal disturbances associated with drilling. The average value from the four estimates is 100°C/km.

We did not measure the thermal conductivity of the sediment cored at Site 471 and therefore can only estimate heat flow. Using the range in gradients listed above and an average thermal conductivity of 2.5 mcal/cm s °C estimated from water content, we deduce that the range in estimated heat flow values at Site 471 is 1.8 to 3.9 HFU.

CORRELATION OF REFLECTION PROFILE WITH DRILLING RESULTS

Figure 18 correlates the seismic-reflection profile obtained by the Glomar Challenger while approaching Site 471 (Fig. 7) with the lithology at Site 471. Above acoustic basement, two acoustic units are recognized:

1) An upper acoustic unit of strong, continuous, evenly spaced, and somewhat indistinct reflectors about 0.19 s thick.
Table 4. Chronology of logging operations.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov. 15</td>
<td>1730</td>
<td>Last circulation of mud.</td>
</tr>
<tr>
<td></td>
<td>2038</td>
<td>Start down with sonic tool.</td>
</tr>
<tr>
<td>Nov. 16</td>
<td>0030</td>
<td>Start down with sonic tool.</td>
</tr>
<tr>
<td></td>
<td>0050</td>
<td>Start up with Wave-Train Log; 1st maximum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>bottom hole temperature (max BHT).</td>
</tr>
<tr>
<td></td>
<td>0325</td>
<td>Tool on deck, log complete.</td>
</tr>
<tr>
<td></td>
<td>0340</td>
<td>Start down with temperature-density tool,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>logging temperature on way down.</td>
</tr>
<tr>
<td></td>
<td>0745</td>
<td>Start up with Density Log; 2nd max BHT.</td>
</tr>
<tr>
<td></td>
<td>1035</td>
<td>Tool on deck.</td>
</tr>
<tr>
<td></td>
<td>1100</td>
<td>Start down with guard Neutron Log.</td>
</tr>
<tr>
<td></td>
<td>1310</td>
<td>Start up with Neutron Log; 3rd max BHT.</td>
</tr>
<tr>
<td></td>
<td>1550</td>
<td>Tool on deck.</td>
</tr>
<tr>
<td></td>
<td>1610</td>
<td>Start down with Induction-Gamma-Ray Log.</td>
</tr>
<tr>
<td></td>
<td>1930</td>
<td>Start up with Induction-Gamma-Ray Log; Gamma-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ray Log run in pipe to mudline.</td>
</tr>
<tr>
<td></td>
<td>1945</td>
<td>Raise pipe 1 stand (28.5 meters) to log soft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sediment above porcellanite; Gamma-Ray Log</td>
</tr>
<tr>
<td></td>
<td></td>
<td>run in pipe to mudline.</td>
</tr>
<tr>
<td></td>
<td>2150</td>
<td>Tool on deck.</td>
</tr>
<tr>
<td></td>
<td>2205</td>
<td>Start down with final Temperature Log.</td>
</tr>
<tr>
<td></td>
<td>2304</td>
<td>Begin recording at 100 meters (water column).</td>
</tr>
<tr>
<td>Nov. 17</td>
<td>0015</td>
<td>Repair cable.</td>
</tr>
<tr>
<td></td>
<td>0050</td>
<td>Continue logging.</td>
</tr>
<tr>
<td></td>
<td>0200</td>
<td>End Temperature Log; final max BHT.</td>
</tr>
<tr>
<td></td>
<td>0406</td>
<td>Temperature tool on deck.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rig down.</td>
</tr>
</tbody>
</table>

Table 5. Bottom-hole temperatures from three maximum reading thermometers mounted on the logging tools, Site 471.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Tool</th>
<th>Distance of Thermometers above Base of Tool (m)</th>
<th>Depth of Measurements below Rig Floor (m)</th>
<th>Depth of Measurements below Sea Floor (m)</th>
<th>Temperature (°F)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov. 16</td>
<td>0050</td>
<td>Wave Train</td>
<td>5.5</td>
<td>3932</td>
<td>817</td>
<td>95, 95, 95</td>
<td>35, 35, 35</td>
</tr>
<tr>
<td></td>
<td>0745</td>
<td>Temperature-Density</td>
<td>3.1</td>
<td>3935</td>
<td>819</td>
<td>122, 122, 122</td>
<td>50, 50, 50</td>
</tr>
<tr>
<td></td>
<td>1310</td>
<td>Neutron</td>
<td>7.3</td>
<td>3933</td>
<td>817</td>
<td>117, 122, 126</td>
<td>47, 50, 52</td>
</tr>
<tr>
<td></td>
<td>1930</td>
<td>Induction</td>
<td>6.1</td>
<td>3932</td>
<td>817</td>
<td>136, 136, 138</td>
<td>58, 58, 59</td>
</tr>
<tr>
<td>Nov. 17</td>
<td>0200</td>
<td>Temperature</td>
<td>5.8</td>
<td>3932</td>
<td>817</td>
<td>144, 145, 146</td>
<td>62, 63, 64</td>
</tr>
</tbody>
</table>
mentation rates. This change reflects a decrease in the supply of terrigenous material, which may have resulted from a change in vertical uplift rates of the adjacent margin or translation of the site away from major river sources. Alternatively, the increase upsection of siliceous sediments may reflect increased productivity in surface waters.

3. Chalcopyrite- and sphalerite-bearing sediments occur at the base of the sediment section; this occurrence may be an ancient analog to sulfide deposits found on the East Pacific Rise Crest and in related fracture zones.

4. The sediments are underlain by 81.5 meters of diabase with two thin intercalations of metalliferous sediment. The diabase is extensively altered, with common brecciated structures that probably resulted from the intrusion of magma into the sediment; this is indicated by the presence of clayey to cherty inclusions in the breccia. Slickensides show some faulting after consolidation. Fracturing in the diabase, as observed in cores, is substantiated by the Sonic Wave-Train Log and the Density Log.

5. The change from diatomaceous ooze to opal-CT porcellanite and porcellaneous rocks occurs at 155 meters at a present subsurface temperature of about 20°C. The transition is reflected in downhole logs and is in agreement with diagenetic changes in siliceous sediments that were observed at other Leg 63 sites (467, 468, 469, and 473).

REFERENCES


LITHOLOGIC DESCRIPTION

Silty Clay and Nannofossil Silty Clay, dark grayish green (5GY 4/2) to light grayish green (5GY 6/2); lighter sections indicate more nannofossil-rich sediments; large bioturbation in Section 5 due to drilling. Several patches of calcite-cemented (5YR 3/1) and dark yellow (5GY 6/2) vitric ash. Section 2. Intense drilling deformation.

ORGANIC CARBON AND CARBONATE
% Organic Carbon: 0.89
% CaCO₃: 3 3

SMEAR SLIDE SUMMARY
TEXTURE:
Sand: 3 10
Silt: 1 3
Clay: 3 3

COMPOSITION:
Quartz: 3 3
Feldspar: 3 3
Mica: 3 3
Heavy minerals: 3 3
Clay: 3 3
Volcanic glass: 3 3
Calc. Nannofossils: 3 3
Radiolarians: 3 3
Sponge spicules: 3 3

Trace of Silty Clay in Core Catcher.

LITHOLOGIC DESCRIPTION

Silty Clay and Nannofossil Silty Clay, dark grayish green (5GY 4/2) to light grayish green (5GY 6/2); lighter sections indicate more nannofossil-rich sediments; large bioturbation in Section 5 due to drilling. Several patches of calcite-cemented (5YR 3/1) and dark yellow (5GY 6/2) vitric ash. Section 2. Intense drilling deformation.

ORGANIC CARBON AND CARBONATE
% Organic Carbon: 0.85
% CaCO₃: 3 3

SMEAR SLIDE SUMMARY
TEXTURE:
Sand: 3 3
Silt: 3 3
Clay: 3 3

COMPOSITION:
Quartz: 3 3
Feldspar: 3 3
Mica: 3 3
Heavy minerals: 3 3
Clay: 3 3
Volcanic glass: 3 3
Calc. Nannofossils: 3 3
Radiolarians: 3 3
Sponge spicules: 3 3

Trace of Silty Clay in Core Catcher.

LITHOLOGIC DESCRIPTION

Silty Clay and Nannofossil Silty Clay, dark grayish green (5GY 4/2) to light grayish green (5GY 6/2); lighter sections indicate more nannofossil-rich sediments; large bioturbation in Section 5 due to drilling. Several patches of calcite-cemented (5YR 3/1) and dark yellow (5GY 6/2) vitric ash. Section 2. Intense drilling deformation.
### Lithologic Description

#### Site 471, Hole 4, Cored Interval 28.5-38.0 m

**Graphic Lithology**
- **0.5 m**
- **1.0 m**
- **VOID**

**Lithologic Description**
- **Silty Clay**, medium greenish gray (5G 5/1), mottled with dark greenish gray streaks. Nannofossils relatively more abundant in Section 5 than rest of core. Intense drilling deformation.

**Organic Carbon and Carbonate**
- % Organic Carbon: 2.4
- % CaCO$_3$: 6.9

**Smear Slide Summary**
- **Texture**: Sand, Silt
- **Composition**: Quartz, Feldspar, Mica, Heavy minerals, Clay, Pyrite, Foraminifers, Calc. Nannofossils, Radiolarians, Sponge spicules

#### Site 471, Hole 5, Cored Interval 38.0-47.5 m

**Graphic Lithology**
- **0.5 m**
- **1.0 m**
- **VOID**

**Lithologic Description**
- **Clay**, medium greenish gray (5G 5/1), silty in places. Nannofossil content 3-4%. Patches of dark gray vitric ash scattered in Sections 4, 5, and 7. Intense drilling deformation.

**Organic Carbon and Carbonate**
- % Organic Carbon: 3.6
- % CaCO$_3$: 3.6

**Smear Slide Summary**
- **Texture**: Sand, Silt
- **Composition**: Quartz, Feldspar, Mica, Heavy minerals, Clay, Pyrite, Foraminifers, Calc. Nannofossils, Radiolarians, Sponge spicules, Silicoflagellates
### Lithologic Description

**SITE 471 HOLE CORE 6 CORED INTERVAL 47.5-58.0 m**

**Lithologic Description**

- **Clay changing downcore to Siliceous Clay, dusky yellow green (5GY 5/2) to greenish gray (5G 5/1), mottled with scattered pyrite-rich streaks. Siliceous microfossils, mainly diatoms, increase in abundance below Section 4.**
- **Intense drilling deformation. No Core-Catcher.**

**Organic Carbon and Carbonate**

<table>
<thead>
<tr>
<th>% Organic Carbon</th>
<th>% CaCO&lt;sub&gt;3&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.86</td>
<td>0.86</td>
</tr>
</tbody>
</table>

**Smear Slide Summary**

- **Texture:** Sand
- **Composition:**
  - **Organic Carbon:** 1.26
  - **Calcite:** 82
  - **Silt:** 77
  - **Clay:** 22

---

**SITE 471 HOLE CORE 7 CORED INTERVAL 57.0-66.5 m**

**Lithologic Description**

- **Diatomaceous Clay, mottled, light grayish olive green (5GY 3/2) and grayish green (10GY 5/2); diatoms more abundant downcore. Scattered dark gray pyrite-rich patches. Possible deformed laminations/lenticular bedding Sections 5-6. Intense drilling deformation.**

**Organic Carbon and Carbonate**

<table>
<thead>
<tr>
<th>% Organic Carbon</th>
<th>% CaCO&lt;sub&gt;3&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.04</td>
<td>0.90</td>
</tr>
</tbody>
</table>

**Smear Slide Summary**

- **Texture:** Sand
- **Composition:**
  - **Organic Carbon:** 1.04
  - **Calcite:**
  - **Silt:**
  - **Clay:**
SITE 471
HOLE
CORE 8 CORED
INTERVAL 66.5-76.0 m

LITHOLOGIC DESCRIPTION
DIATOMACEOUS CLAY, mottled grayish green (10GY 5/2), dusky yellow green (5GY 5/2), and medium olive gray (5Y 4/2! mottling apparently reflects relative amounts of diatoms in ACEOUS OOZE in Section 6. Intense drilling deformation.

ORGANIC CARBON AND CARBONATE
% Organic Carbon
% CaCO
3

SMEAR SLIDE SUMMARY
TEXTURE:
Sand
Silt
Clay

COMPOSITION:

6-13
(D)

65

95

2-78

(D)

63

27

Heavy clay
Mica
Pyrite
Diatoms
Radiolaria
Sponge spicules
Silicoflagellates
SITE 471
HOLE 1
CORE 10
CORED INTERVAL 85.0 - 95.0 m

LITHOLOGIC DESCRIPTION

CLAYEY DIATOMACEOUS Ooze, dark olive brown (5Y 3/4) with subtle yellow-green (5GY 6/2) to green (5GY 5/2) and light green-gray (10GY 5/2) tints. Light brown sediment over mud clasts (clay) chert, internal drilling deformation.

ORGANIC CARBON AND CARBONATE

<table>
<thead>
<tr>
<th>% Organic Carbon</th>
<th>% CaCO₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.53 - 3.133</td>
<td>0 - 0</td>
</tr>
</tbody>
</table>

SMEAR SLIDE SUMMARY

TEXTURE:
- Sand
- Silt
- Clay

COMPOSITION:
- Quartz
- Feldspar
- Mica
- Heavy minerals
- Clay
- Volcanic glass
- Pyrite
- Calcareous ooze
- Ooze
- Radiolarians
- Sponge spicules
- Silicificlackous

SITE 471
HOLE 11
CORE 11
CORED INTERVAL 95.0 - 104.5 m

LITHOLOGIC DESCRIPTION

DIATOMACEOUS CLAY AND CLAYEY DIATOMACEOUS Ooze, dark olive brown (5Y 3/4) to green (5GY 5/2) with scattered dark pyrite-rich streaks. Intense drilling deformation.

ORGANIC CARBON AND CARBONATE

<table>
<thead>
<tr>
<th>% Organic Carbon</th>
<th>% CaCO₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>~3.50</td>
<td>0</td>
</tr>
</tbody>
</table>

SMEAR SLIDE SUMMARY

TEXTURE:
- Sand
- Silt
- Clay

COMPOSITION:
- Quartz
- Feldspar
- Mica
- Heavy minerals
- Clay
- Volcanic glass
- Pyrite
- Calcareous ooze
- Ooze
- Radiolarians
- Sponge spicules
- Silicificlackous
- Plant debris
- Foraminifera
- Diatoms
- Radiolarians
- Sponge spicules
- Silicificlackous
- Plant debris
- Foraminifera
**LITHOLOGY**

**LITHOLOGIC DESCRIPTION**

Diatomaceous clay, dusky yellow green (5GY 5/2) mottled with dark yellowish brown (10YR 4/2) patches. Grayish purple (5P 4/2) pyrite-rich streaks scattered throughout. Intense drilling deformation has homogenized lithology and destroyed sedimentary structures.

**ORGANIC CARBON AND CARBONATE**

<table>
<thead>
<tr>
<th>% Organic Carbon</th>
<th>% CaCO3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.04</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**SMEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>Clay Composition:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy clay</td>
</tr>
<tr>
<td>Calc. Nannofossils</td>
</tr>
<tr>
<td>Radiolarians</td>
</tr>
<tr>
<td>Sponge spicules</td>
</tr>
<tr>
<td>Silicoflagellate</td>
</tr>
</tbody>
</table>

**LITHOLOGY**

Clayey diatomaceous ooze, dusky yellow green (5GY 5/2) to grayish green (10GY 5/2) with some yellowish brown (10YR 4/2) mottles. Structures and lithology homogenized by intense drilling deformation.

**ORGANIC CARBON AND CARBONATE**

<table>
<thead>
<tr>
<th>% Organic Carbon</th>
<th>% CaCO3</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.70</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**SMEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>2-120 4-106</th>
<th>2-120 4-106</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DIATOMACEOUS CLAY, dark yellowish green (5GY 6/2) with fine dark silty spots (5GY 6/2). Structures and lithology homogenized by drilling.

ORGANIC CARBON AND CARBONATE

% Organic Carbon —
% CaCO3 —

SMEAR SLIDE SUMMARY

TEXTURE:
- Sand
- Silt
- Clay

COMPOSITION:
- Quartz
- Feldspar
- Mica
- Heavy minerals
- Clay
- Pyrite
- Carbonate
- Diatoms
- Radiolarians
- Sponge spicules
- Silicoflagellates

LITHOLOGIC DESCRIPTION

DUSKY CLAY, dark yellowish green (5GY 5/2) with some pale green (10G 6/2) patches and streaks, especially Sections 3 and 4. Several bands of dark yellowish green VITRIC ASH in Sections 5 and 8. Structures and lithology homogenized by drilling.

ORGANIC CARBON AND CARBONATE

% Organic Carbon —
% CaCO3 —

SMEAR SLIDE SUMMARY

TEXTURE:
- Sand
- Silt
- Clay

COMPOSITION:
- Quartz
- Feldspar
- Mica
- Heavy minerals
- Clay
Site 471 Hole Core 16 Cored Interval 142.5-152.0 m

Lithologic Description
Diatomaceous Clay, dusky yellowish green (5GY 2/2) with some dark yellow-brown (10YR 4/2) streaks. Structures and bedding homogenized by drilling.

Organic Carbon and Carbonate
- % Organic Carbon: 1.04
- % CaCO₃: 0

Site 471 Hole Core 17 Cored Interval 152.0-161.5 m

Lithologic Description
Clayey Diatomaceous Ooze, mottled dark olive-black (5Y 2/1) to olive-green (10Y 4/2). Common burrows and lenticular bedding. Core-Catcher brecciated by drilling.

Organic Carbon and Carbonate
- % Organic Carbon: 1.0
- % CaCO₃: 0

Site 471 Hole Core 19 Cored Interval 171.0-180.5 m

Lithologic Description
Porcellanite, grayish olive (10Y 4/2) to olive-black (5Y 2/1). Common burrows and some lenticular bedding. Core-Catcher brecciated by drilling.

Organic Carbon and Carbonate
- % Organic Carbon: 1.0
- % CaCO₃: 0
### Site 471

**Hole:** CORE 20, CORED INTERVAL 190.5–190.6 m

#### Lithologic Description

- **Clayey Limestone and Porcellanite:** Limestone is light olive-gray (5Y 5/2) and intensely burrowed. Porcellanite is grayish olive (5Y 4/2) to olive black (BY 5/3), brecciated and fractured by drilling.
  - No Core-Catcher.

#### Organic Carbon and Carbonate

- **% Organic Carbon:** 1.8
- **% CaCO₃:** 78

---

**Hole:** CORE 21, CORED INTERVAL 190.0–190.5 m

#### Lithologic Description

- **Porcellanite:** Medium olive-gray (5Y 4/2), intensely burrowed. Core highly fractured by drilling.
  - No Core-Catcher.

#### Organic Carbon and Carbonate

- **% Organic Carbon:** 1.8
- **% CaCO₃:** 78

---

**Hole:** CORE 22, CORED INTERVAL 199.5–209.0 m

#### Lithologic Description

- **Porcellanite:** Medium olive-gray (5Y 4/2), intensely burrowed. Core consists of Porcellanite fragments brecciated by drilling.
  - No Core-Catcher.

#### Organic Carbon and Carbonate

- **% Organic Carbon:** 1.8
- **% CaCO₃:** 78

---

**Hole:** CORE 23, CORED INTERVAL 209.0–218.5 m

#### Lithologic Description

- **Porcellanite:** Medium olive-gray (5Y 4/2), intensely burrowed. Core highly fractured by drilling.
  - No Core-Catcher.

#### Organic Carbon and Carbonate

- **% Organic Carbon:** 1.8
- **% CaCO₃:** 78

---

**Hole:** CORE 24, CORED INTERVAL 218.5–228.0 m

#### Lithologic Description

- **Porcellanite:** Medium olive-gray (5Y 4/2), intensely burrowed. Core highly fractured by drilling.
  - No Core-Catcher.

#### Organic Carbon and Carbonate

- **% Organic Carbon:** 1.8
- **% CaCO₃:** 78

---

**Hole:** CORE 25, CORED INTERVAL 228.0–237.5 m

#### Lithologic Description

- **Porcellanite:** Olive gray (5Y 3/1) to light olive gray (5Y 5/2), intensely burrowed. Core highly fractured by drilling.
  - No Core-Catcher.
### Site 471 Hole 26 Cored Interval 237.5–257.0 m

<table>
<thead>
<tr>
<th>Time Rock Unit</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textures:</td>
<td>Silt 48 13 Sand</td>
</tr>
<tr>
<td>Siltstone contains some fine sandy laminations.</td>
<td></td>
</tr>
</tbody>
</table>

#### SMEAR SLIDE SUMMARY

- **Texture:**
  - Sand: 20%
  - Silt: 70%
- **Composition:**
  - Clay: 70%
  - Silt: 15%
  - Sand: 15%

### Site 471 Hole 27 Cored Interval 247.0–256.0 m

<table>
<thead>
<tr>
<th>Time Rock Unit</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textures:</td>
<td>Silt 13 Sand</td>
</tr>
<tr>
<td>Claystone is grayish olive gray (5Y 3/2) and burrowed. Porcelaneous rocks are olive gray (5Y 3/2) to greenish gray (5G 6/1), abundant burrows and lenticular bedding. Core brecciated by drilling.</td>
<td></td>
</tr>
</tbody>
</table>

#### SMEAR SLIDE SUMMARY

- **Texture:**
  - Sand: 13%
  - Silt: 37%
  - Clay: 50%
- **Composition:**
  - Clay: 87%
  - Silt: 7%
  - Sand: 6%

### Site 471 Hole 29 Cored Interval 266.0–276.0 m

<table>
<thead>
<tr>
<th>Time Rock Unit</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textures:</td>
<td>Silt 15 Sand</td>
</tr>
<tr>
<td>Claystone is light olive gray (5Y 5/2), abundant burrows and lenticular bedding. Core brecciated by drilling.</td>
<td></td>
</tr>
</tbody>
</table>

#### SMEAR SLIDE SUMMARY

- **Texture:**
  - Sand: 9%
  - Silt: 7%
  - Clay: 85%
- **Composition:**
  - Clay: 85%
  - Silt: 10%
  - Sand: 5%
LITHOLOGIC DESCRIPTION

SITE 471 HOLE
CORE 34 CORED INTERVAL 313.5-333.0 m

SILTY CLAYSTONE, medium silty gray (5Y 4/2), with many thin sandy interbeds. Burrows common, many filled with silt or sandy material. Thin layers of VITRIC ASH mixed with claystone occur in Section 1 as marked. Generalized variations in clayey sandstone noted. Thin sandy intervals marked throughout.

ORGANIC CARBON AND CARBONATE

% Organic Carbon 1.46 -
% CaCO3 0 0

SMEAR SLIDE SUMMARY

TEXTURE:
Sand 48
Silt 43
Clay 9

COMPOSITION:
Quartz 26
Feldspar 26
Mica 1
Heavy minerals 9
Vitric glass 1
Glauconite TR
Pyrite 0
Radiolarian fragments 0
Quartz/TST 10

B B
1 2 3

Fossil Character

SITE 471 HOLE
CORE 35 CORED INTERVAL 323.0-332.5 m

LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium silty gray (5Y 4/2), with many thin sandy interbeds. Burrows common, many filled with silt or sandy material. Thin layers of VITRIC ASH mixed with claystone occur in Section 1 as marked. Generalized variations in clayey sandstone noted. Thin sandy intervals marked throughout.

ORGANIC CARBON AND CARBONATE

% Organic Carbon 1.46 -
% CaCO3 0 0

SMEAR SLIDE SUMMARY

TEXTURE:
Sand 48
Silt 43
Clay 9

COMPOSITION:
Quartz 26
Feldspar 26
Mica 1
Heavy minerals 9
Vitric glass 1
Glauconite TR
Pyrite 0
Radiolarian fragments 0
Quartz/TST 10

B B
1 2 3

Fossil Character

SITE 471 HOLE
CORE 36 CORED INTERVAL 332.5-342.0 m

LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium silty gray (5Y 4/2), with many thin sandy interbeds. Burrows common, many filled with silt or sandy material. Thin layers of VITRIC ASH mixed with claystone occur in Section 1 as marked. Generalized variations in clayey sandstone noted. Thin sandy intervals marked throughout.

ORGANIC CARBON AND CARBONATE

% Organic Carbon 1.46 -
% CaCO3 0 0

SMEAR SLIDE SUMMARY

TEXTURE:
Sand 48
Silt 43
Clay 9

COMPOSITION:
Quartz 26
Feldspar 26
Mica 1
Heavy minerals 9
Vitric glass 1
Glauconite TR
Pyrite 0
Radiolarian fragments 0
Quartz/TST 10

B B
1 2 3

Fossil Character

SITE 471 HOLE
CORE 37 CORED INTERVAL 342.0-351.5 m

LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium silty gray (5Y 4/2), with many thin sandy interbeds. Burrows common, many filled with silt or sandy material. Thin layers of VITRIC ASH mixed with claystone occur in Section 1 as marked. Generalized variations in clayey sandstone noted. Thin sandy intervals marked throughout.

ORGANIC CARBON AND CARBONATE

% Organic Carbon 1.46 -
% CaCO3 0 0

SMEAR SLIDE SUMMARY

TEXTURE:
Sand 48
Silt 43
Clay 9

COMPOSITION:
Quartz 26
Feldspar 26
Mica 1
Heavy minerals 9
Vitric glass 1
Glauconite TR
Pyrite 0
Radiolarian fragments 0
Quartz/TST 10

B B
1 2 3

Fossil Character

SITE 471 HOLE
CORE 38 CORED INTERVAL 351.5-361.5 m

LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE, medium silty gray (5Y 4/2), with many thin sandy interbeds. Burrows common, many filled with silt or sandy material. Thin layers of VITRIC ASH mixed with claystone occur in Section 1 as marked. Generalized variations in clayey sandstone noted. Thin sandy intervals marked throughout.

ORGANIC CARBON AND CARBONATE

% Organic Carbon 1.46 -
% CaCO3 0 0

SMEAR SLIDE SUMMARY

TEXTURE:
Sand 48
Silt 43
Clay 9

COMPOSITION:
Quartz 26
Feldspar 26
Mica 1
Heavy minerals 9
Vitric glass 1
Glauconite TR
Pyrite 0
Radiolarian fragments 0
Quartz/TST 10

B B
1 2 3

Fossil Character
LITHOLOGIC DESCRIPTION

SITE 471 HOLE CORE 38 CORED INTERVAL 361.0–361.0 m

BLYT CLAYSTONE, medium olive gray (5Y 4/2) to
 olive gray (5Y 3/2), intensely bioturbated with many thin
 silt and sandy lenses. Burrows often filled with silt and
 fine sand. Section 3, 34–35 cm, is barren of silt
 clays and shows thin fine lenses of bioturbated
 sandy claystone (as marked) with wavy bedding.
 Graded intervals boundaries are gradational. First
 8 cm of core is mixed altered VITRIC ASH and silt
 clays.

ORGANIC CARBON AND CARBONATE

% Organic Carbon 2-112 3-128
% CaCO3 0 0

TEXTURE
Sand 36
Silt 9
Clay 45

COMPOSITION
Quartz 20
Feldspar 7
Mica TR
Heavy minerals 1
Clay 52
Carbonate unspec. 20
Calc. Nannofossils TR

SITE 471 HOLE CORE 40 CORED INTERVAL 370.5–379.5 m

BLYT CLAYSTONE, medium olive gray (5Y 4/2) to
 light olive gray (5Y 3/2), intensely bioturbated, many
 burrows filled with silt and fine sand. Thin lenses and
 layers of bioturbated silt and fine sand mixed with
 clay (NANNY CLAYSTONES) are scattered throughout
 core (especially Section 3). Sandy layers sometimes
 graded with load cast and wavy bedding (burrowing),
 sharp contacts of clay layers near tops of Sections 1
 and 4 are gradational.

ORGANIC CARBON AND CARBONATE

% Organic Carbon 0.79
% CaCO3 0 0

TEXTURE
Sand 48
Silt 20
Clay 32

COMPOSITION
Quartz 20
Feldspar 7
Mica TR
Heavy minerals 1
Clay 52
Carbonate unspec. 20
Calc. Nannofossils TR

SITE 471 HOLE CORE 41 CORED INTERVAL 379.5–379.5 m

WIGOS MUDSTONE, medium olive gray (5Y 4/2),
 Gum-Grainy only.

LITHOLOGIC DESCRIPTION

TEXTURE
Silty clay 10
Sandy clay 35
Clay 55

COMPOSITION
Quartz 20
Feldspar 7
Mica TR
Heavy minerals 1
Clay 52
Carbonate unspec. 20
Calc. Nannofossils TR
**Lithologic Description**

**SITE 427**

**HOLE 41**

**CORE INTERVAL 379.0–389.5 m**

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>ROCK CHARACTER</th>
<th>SECTION INTERVAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-32</td>
<td>Silty claystone</td>
<td>379.0–389.5 m</td>
</tr>
<tr>
<td>1-33</td>
<td>Silty claystone</td>
<td>389.0–398.5 m</td>
</tr>
</tbody>
</table>

**Organic Carbon and Carbonates**

- **Organic Carbon**: 1-32
- **CaCO₃**: 0

**Smeared Slide Summary**

<table>
<thead>
<tr>
<th>TEXTURE</th>
<th>COMPOSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>Quartz</td>
</tr>
<tr>
<td>Silt</td>
<td>Feldspar</td>
</tr>
<tr>
<td>Clay</td>
<td>Mica</td>
</tr>
<tr>
<td></td>
<td>Heavy minerals</td>
</tr>
<tr>
<td></td>
<td>Clay</td>
</tr>
<tr>
<td></td>
<td>Volcanic glass</td>
</tr>
<tr>
<td></td>
<td>Pyrite</td>
</tr>
<tr>
<td></td>
<td>Carbonate</td>
</tr>
<tr>
<td></td>
<td>Foraminifers</td>
</tr>
<tr>
<td></td>
<td>Calc. Nannofossils</td>
</tr>
<tr>
<td></td>
<td>Lithic fragments</td>
</tr>
</tbody>
</table>

**SITE 427**

**HOLE 42**

**CORE INTERVAL 389.0–398.5 m**

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>ROCK CHARACTER</th>
<th>SECTION INTERVAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-32</td>
<td>Silty claystone</td>
<td>389.0–398.5 m</td>
</tr>
<tr>
<td>1-33</td>
<td>Silty claystone</td>
<td>398.0–407.5 m</td>
</tr>
</tbody>
</table>

**Organic Carbon and Carbonates**

- **Organic Carbon**: 1-32
- **CaCO₃**: 0

**Smeared Slide Summary**

<table>
<thead>
<tr>
<th>TEXTURE</th>
<th>COMPOSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>Quartz</td>
</tr>
<tr>
<td>Silt</td>
<td>Feldspar</td>
</tr>
<tr>
<td>Clay</td>
<td>Mica</td>
</tr>
<tr>
<td></td>
<td>Heavy minerals</td>
</tr>
<tr>
<td></td>
<td>Clay</td>
</tr>
<tr>
<td></td>
<td>Volcanic glass</td>
</tr>
<tr>
<td></td>
<td>Pyrite</td>
</tr>
<tr>
<td></td>
<td>Carbonate</td>
</tr>
<tr>
<td></td>
<td>Foraminifers</td>
</tr>
<tr>
<td></td>
<td>Calc. Nannofossils</td>
</tr>
<tr>
<td></td>
<td>Lithic fragments</td>
</tr>
</tbody>
</table>
ON SITE 471 HOLE 43 CORED INTERVAL 398.5-408.0 m

**LITHOLOGIC DESCRIPTION**

Silty Claystone, medium olive gray (5Y 6/1), burrowed throughout and containing small to medium-sized sand layers. Scattered thin sandy layers throughout Section 1 and upper Section 2. Sandy intervals usually less than 1 cm thick.

**ORGANIC CARBON AND CARBONATE**

- % Organic Carbon: 0.70
- % CaCO₃: 0

**SMEAR SLIDE SUMMARY**

- Sand: 15
- Silt: 30
- Clay: 40
- Organic Carbon: B
- Calc. Nannofossils: T1
- Lithic fragments: 5

---

ON SITE 471 HOLE 44 CORED INTERVAL 408.5-418.0 m

**LITHOLOGIC DESCRIPTION**

Silty Claystone, medium olive gray (5Y 6/1), burrowed throughout, with minor lithic fragments. Some burrows filled with fine sand, others with calcareous clay. Thin sandy layers common in Section 1 as marked.

**ORGANIC CARBON AND CARBONATE**

- % Organic Carbon: 0.40
- % CaCO₃: 0.1

**SMEAR SLIDE SUMMARY**

- Sand: 20
- Silt: 30
- Clay: 40
- Organic Carbon: B
- Calc. Nannofossils: T1
- Lithic fragments: 5

---

ON SITE 471 HOLE 45 CORED INTERVAL 418.0-427.5 m

**LITHOLOGIC DESCRIPTION**

Silty Claystone, medium olive gray (5Y 6/2), burrowed throughout, with minor lithic fragments. Some burrows filled with fine sand, others with calcareous clay. Thin sandy layers common in Section 1 as marked.

**ORGANIC CARBON AND CARBONATE**

- % Organic Carbon: 0.30
- % CaCO₃: 0

**SMEAR SLIDE SUMMARY**

- Sand: 20
- Silt: 30
- Clay: 40
- Organic Carbon: B
- Calc. Nannofossils: T1
- Lithic fragments: 5

---
SITE 471 HOLE CORE 46 CORED INTERVAL 427.5–437.0 m

LITHOLOGIC DESCRIPTION

Scattered thin sandy layers

SILTY CLAYSTONE, medium olive-gray (6Y 4/2), burrowed throughout; scattered thin sandy layers (layer bedding). Some burrows filled with fine sand. Light olive-gray (5Y 5/2) CLAYEY LIMESTONE at base of core is burrowed but contains one interval of fine lamination. Core broken into oblong baskets.

ORGANIC CARBON AND CARBONATE

% Organic Carbon 0.61
% CaCO₃ 0

SMEAR SLIDE SUMMARY

TEXTURE:
Sand 11
Silt 17
Clay 72

COMPOSITION:
Quartz 88
Feldspar 1
Mica 7
Heavy minerals 3
Pyrite 2
Carbonate, unspecified 2
Lithic fragments 2

SITE 471 HOLE CORE 49 CORED INTERVAL 456.0–465.5 m

LITHOLOGIC DESCRIPTION

Scattered thin sandy layers

SILTY CLAYSTONE, olive-gray (5Y 3/2), burrowed throughout. Contains scattered thin sandy layers. Some burrows filled with fine sand. No Core-Catcher.

TEXTURE:
Sand 11
Silt 14
Clay 86

COMPOSITION:
Quartz 5
Feldspar 78
Mica 1
Heavy minerals 4
Pyrite 2
Carbonate, unspecified 3
Lithic fragments 8

SMEAR SLIDE SUMMARY

TEXTURE:
Sand 11
Silt 14
Clay 86

COMPOSITION:
Quartz 5
Feldspar 78
Mica 1
Heavy minerals 4
Pyrite 2
Carbonate, unspecified 3
Lithic fragments 8
LITHOLOGIC DESCRIPTION

SITE 471: HOLE 50: CORE INTERVAL 465.5-475.0 m

INTERBEDDING SILTY CLAYSTONE AND CALCITE-DENTIFIED SANDSTONE AND SILTY SANDSTONE. Calcite is medium olive-gray (5Y 4/2). Interbeds are laminated throughout, and contain scattered thin silty and sandy layers that have been mixed with calcite by burrowing. Sandstones are medium olive-gray (5Y 4/2), quartz-rich and calcite-cemented. Cross and parallel laminations and linearly oriented, parallel sandstone and calcite-cemented, partly homogenized by burrowing. LATERAL AND LAMINAR TRANSLATION

ORGANIC CARBON AND CARBONATE

% Organic Carbon 0.59%
% CaCO3 0

SMEAR SLIDE SUMMARY:

TEXTURE: Sand 62 Silt 29 Clay 15

COMPOSITION:

Quartz 50 Feldspar 10 Mica 20 Heavy minerals 1

ORGANIC CARBON AND CARBONATE

2.00%
% Organic Carbon 0.59%
% CaCO3 0

SITE 471: HOLE 51: CORE INTERVAL 475.0-484.5 m

SILTY CLAYSTONE, medium olive-gray (5Y 4/2), homogeneously interbedded throughout; thin silty and sandy layers are present. Calcite is medium olive-gray (5Y 4/2), quartz-rich and calcite-cemented. Cross and parallel laminations and linearly oriented, parallel sandstone and calcite-cemented, partly homogenized by burrowing. LATERAL AND LAMINAR TRANSLATION

ORGANIC CARBON AND CARBONATE

% Organic Carbon 0.59%
% CaCO3 0

SITE 471: HOLE 52: CORE INTERVAL 484.5-494.0 m

SILTY CLAYSTONE, medium olive-gray (5Y 4/2), homogeneously interbedded throughout; thin silty and sandy layers are present. Calcite is medium olive-gray (5Y 4/2), quartz-rich and calcite-cemented. Cross and parallel laminations and linearly oriented, parallel sandstone and calcite-cemented, partly homogenized by burrowing. LATERAL AND LAMINAR TRANSLATION

ORGANIC CARBON AND CARBONATE

% Organic Carbon 0.59%
% CaCO3 0
**SITE 471 HOLE**

**CORE 53 CORED INTERVAL 494.0-503.5 m**

**LITHOLOGIC DESCRIPTION**

**Silty Claystone,** medium olive gray (5Y 4/2), burrowed throughout. Contains thin calcite-cemented sandy interbeds every ~5-10 cm. Burrowing has partly mixed the two lithologies.

**Organic Carbon and Carbonate**

- % Organic Carbon: 1.00
- % CaCO₃: 0

**SITE 471 HOLE**

**CORE 54 CORED INTERVAL 503.5-513.0 m**

**LITHOLOGIC DESCRIPTION**

**Silty Claystone,** medium olive gray (5Y 4/2), burrowed with scattered sponge fragments. Core-Catcher only.

**NOTE:** Core 55, 513.0-522.5 m: NO RECOVERY

**SITE 471 HOLE**

**CORE 56 CORED INTERVAL 522.5-532.0 m**

**LITHOLOGIC DESCRIPTION**

**Calcite-Cemented Silty Sandstone,** medium bluish gray (5B 5/1) and parallel laminated. Contains thin interbed of olive gray (5Y 4/2) Silty Claystone at ~8 cm pseudofossil intervals.

**Core-Catcher only.**

**SITE 471 HOLE**

**CORE 57 CORED INTERVAL 532.0-541.5 m**

**LITHOLOGIC DESCRIPTION**

**Silty Claystone,** medium olive gray (5Y 4/2), intensely bioturbated throughout. Contains abraded thin interlayer of medium bluish gray (5B 5/1) calcite cemented Silty Sandstone. Layers are ~1-4 cm thick and spaced ~5-10 cm apart. Parallel laminations common in lower part of each layer, tops are burrowed and mixed with overlying claystone (Bouma C-E intervals). Several layers have short basal outsides (degraded).

**Organic Carbon and Carbonate**

- % Organic Carbon: 3.98
- % CaCO₃: 1-2
SITE 471 HOLE CORE 69 CORED INTERVAL 646.0-655.5 m

**Silty Claystone** with abundant thin sandy layers.

LITHOLOGIC DESCRIPTION

- **Silty Claystone** with thin sandy layers.
- Claystone is medium olive gray (5Y 4/2) with light and dark olive gray mottles (5Y 3/2-5Y 5/2) and intensely burrowed throughout. Sections 3 and 5 have rhythmic light olive (10Y 6/2) and dark olive (5Y 4/2) color alternations every 2-4 cm. Each color change marked by thin sandy layers at the base. Sections 3 and 5 have sandy layers as marked.

**Organic Carbon and Carbonate**

<table>
<thead>
<tr>
<th>% Organic Carbon</th>
<th>% CaCO3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-87</td>
<td>0</td>
</tr>
</tbody>
</table>

SMEAR SLIDE SUMMARY

- **Texture:** Sand
- **Composition:** Quartz, Feldspar, Mica, Heavy minerals, Clay, Glass, Foraminifera, Lithic fragments

---

SITE 471 HOLE CORE 70 CORED INTERVAL 655.5-665.0 m

**Silty Claystone** with abundant thin sandy layers.

LITHOLOGIC DESCRIPTION

- **Silty Claystone** with thin sandy layers.
- Claystone is medium olive gray (5Y 4/2) with light and dark olive gray mottles (5Y 3/2-5Y 5/2) and intensely burrowed throughout. Sections 3 and 5 have rhythmic light olive (10Y 6/2) and dark olive (5Y 4/2) color alternations every 2-4 cm. Each color change marked by thin sandy layers at the base. Sections 3 and 5 have sandy layers as marked.

**Organic Carbon and Carbonate**

<table>
<thead>
<tr>
<th>% Organic Carbon</th>
<th>% CaCO3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-87</td>
<td>0</td>
</tr>
</tbody>
</table>

SMEAR SLIDE SUMMARY

- **Texture:** Sand
- **Composition:** Quartz, Feldspar, Mica, Heavy minerals, Clay, Glass, Foraminifera, Lithic fragments

---
**SITE 471**  
**HOLE**  
**CORE**  
**CORED INTERVAL**  
668.5 - 674.5 m

### Lithologic Description

**Silty Claystone** with scattered thin interbeds of calcite cemented *Silty Sandstone*. Claystone shows regular (2-4 cm thick) light and medium olive gray (5Y 5/2), and medium olive gray (5Y 4/2) alternations throughout core and is extensively burrowed. Darker intervals appear to be less bioturbated, lighter zones are more abundant. Burrows change and subdivide in bedding giving a lenticular bedded appearance. Burrows are medium gray (N4) and occur at intervals throughout core. Burrow contacts show sharp and gradational with surrounding core. Two-thick sandstone layers in Sections 1 and 2 are marked by burrows, making them partially laminated zones. Burrow contacts may show partial destratification and burrowing.

### Organic Carbon and Carbonate

- **% Organic Carbon**: 0.41
- **% CaCO₃**: 0

### Smear Slide Summary

<table>
<thead>
<tr>
<th>TEXTURE</th>
<th>MO</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predominant</td>
<td>1</td>
<td>20</td>
<td>10</td>
<td>84</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COMPOSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
</tr>
<tr>
<td>Mica</td>
</tr>
<tr>
<td>Heavy minerals</td>
</tr>
<tr>
<td>Clay</td>
</tr>
<tr>
<td>Glauconite</td>
</tr>
<tr>
<td>Pyrite</td>
</tr>
<tr>
<td>Carbonate</td>
</tr>
<tr>
<td>Lithic fragments</td>
</tr>
</tbody>
</table>

---

**SITE 471**  
**HOLE**  
**CORE**  
**CORED INTERVAL**  
674.5 - 684.0 m

### Lithologic Description

**Silty Claystone** with abundant thin interbeds of calcite cemented *Silty Sandstone*. Claystone has regular light and medium olive gray (5Y 5/2, 4/2) alternations and is extensively burrowed throughout. Abundant burrows give lenticular bedded appearance. Burrows are medium gray (N4) and occur at intervals throughout core. Burrow contacts show sharp and gradational with surrounding core. Burrow contacts may show partial destratification and burrowing. Several thin sandy layers have planar and irregular stratifications, occasional bedding, and indistinct grain size. Burrow contacts sharp, burrowed layers occur every 5 - 10 cm.

### Organic Carbon and Carbonate

- **% Organic Carbon**: 0.41
- **% CaCO₃**: 0

### Smear Slide Summary

<table>
<thead>
<tr>
<th>TEXTURE</th>
<th>MO</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predominant</td>
<td>1</td>
<td>20</td>
<td>10</td>
<td>84</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COMPOSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
</tr>
<tr>
<td>Mica</td>
</tr>
<tr>
<td>Heavy minerals</td>
</tr>
<tr>
<td>Clay</td>
</tr>
<tr>
<td>Glauconite</td>
</tr>
<tr>
<td>Pyrite</td>
</tr>
<tr>
<td>Carbonate</td>
</tr>
<tr>
<td>Lithic fragments</td>
</tr>
</tbody>
</table>
LITHOLOGIC DESCRIPTION

SILTY CLAYSTONE with abundant thin interbeds of calcite-cemented SILTY SANDSTONE. Claystone is alternating light and medium olive gray (5Y 5 1/2-5Y 4 1/2) and intensely burrowed throughout. Sandstone is medium gray (5Y 4) occurring as abundant thin (1-2 cm) interbeds throughout. Thinner sandstone in Section 2 (clayey silt) and micaceous siltstone and broken by microfaults and calcite-filled fractures. Thin interval of calcite-filled fractures also occurs in Section 2 (clayey silt). Sandy layers have sharp basal contacts and parallel, burrowed tops.

SILTY CLAYSTONE with abundant thin interbeds of calcite-cemented SILTY SANDSTONE. Claystone is alternating light and medium olive gray (5Y 5 1/2-5Y 4 1/2) and intensely burrowed throughout. Sandstone is medium gray (5Y 4) and occurs as thin (1-2 cm) interbeds. Thinner sandstone in Section 2 (clayey silt) and micaceous siltstone and broken by microfaults and calcite-filled fractures. Thin interval of calcite-filled fractures also occurs in Section 2 (clayey silt). Sandy layers have sharp basal contacts and parallel, burrowed tops.

ORGANIC CARBON AND CARBONATE

<table>
<thead>
<tr>
<th>% Organic Carbon</th>
<th>% CaCO3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.14</td>
<td>2.80</td>
</tr>
</tbody>
</table>

SMERG SLIDE SUMMARY

TEXTURE:
- Sand: 25
- Clay: 75

COMPOSITION:
- Quartz: 5
- Feldspar: 10
- Mica: 5
- Phyllosilicates: 15
- Heavy minerals: 1
- Calcite: 5
- Pyrite: 5
- Organic matter: 1
- Microfossils: 1
- Lithic fragments: 5

Abundant thin sandy layers.
**SITE 471**  
**HOLE** 75  
**CORED INTERVAL** 712.0-722.0 m

### LITHOLOGIC DESCRIPTION

**SITE 471** with abundant thin interbeds of calcite-cemented **SILTY SANDSTONE**. Color, bedding characteristics and composition of claystone and sandstone identical to previous cores. Thick sandstone layer in Section 3 is microfossiliferous. Sections above show thin, carbonaceous-cemented or limey, micrite-rich intervals. Fracture filled with reddish clay* (47/17).

**ORGANIC CARBON AND CARBONATE**  
% Organic Carbon: 0.51  
% CaCO3: 0

**SMEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>Sample</th>
<th>3-57</th>
<th>5-10</th>
<th>5-13</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TEXTURE:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>20</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>Clay</td>
<td>80</td>
<td>70</td>
<td>60</td>
</tr>
</tbody>
</table>

| **COMPOSITION:** |
| Quartz | 70 | 60 | 50 |
| Feldspar | 30 | 20 | 10 |
| Mica | 10 | 20 | 30 |
| Heavy minerals | TR | TR | TR |
| Glass | 80 | 90 | 80 |
| Glauconite | TR | TR | TR |
| Pyrite | 3 | 2 | 1 |
| Carbonate crystals | 2 | 1 | 1 |
| Foraminifers | 2 | 1 | 1 |
| Plugs | 1 | 1 | 1 |
| Lenticular fragments | 1 | 1 | 1 |
| Silica cemented grains | 1 | 1 | 1 |

*Abundant thin sandy layers

---

**SITE 471**  
**HOLE** 76  
**CORED INTERVAL** 703.0-712.5 m

### LITHOLOGIC DESCRIPTION

**SITE 471** with abundant thin interbeds of calcite-cemented **SILTY SANDSTONE**. Color, bedding characteristics and composition of claystone and sandstone identical to previous cores. Thick sandstone layer in Section 3 is microfossiliferous. Sections above show thin, carbonaceous-cemented or limey, micrite-rich intervals. Fracture filled with reddish clay* (47/17).

**ORGANIC CARBON AND CARBONATE**  
% Organic Carbon: 0.51  
% CaCO3: 0

**SMEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>Sample</th>
<th>3-57</th>
<th>5-10</th>
<th>5-13</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TEXTURE:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>20</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>Clay</td>
<td>80</td>
<td>70</td>
<td>60</td>
</tr>
</tbody>
</table>

| **COMPOSITION:** |
| Quartz | 70 | 60 | 50 |
| Feldspar | 30 | 20 | 10 |
| Mica | 10 | 20 | 30 |
| Heavy minerals | TR | TR | TR |
| Glass | 80 | 90 | 80 |
| Glauconite | TR | TR | TR |
| Pyrite | 3 | 2 | 1 |
| Carbonate crystals | 2 | 1 | 1 |
| Foraminifers | 2 | 1 | 1 |
| Plugs | 1 | 1 | 1 |
| Lenticular fragments | 1 | 1 | 1 |
| Silica cemented grains | 1 | 1 | 1 |

*Abundant thin sandy layers

---

**SITE 471**  
**HOLE** 76  
**CORED INTERVAL** 703.0-712.5 m

### LITHOLOGIC DESCRIPTION

**SITE 471** with abundant thin interbeds of calcite-cemented **SILTY SANDSTONE**. Color, bedding characteristics and composition of claystone and sandstone identical to previous cores. Thick sandstone layer in Section 3 is microfossiliferous. Sections above show thin, carbonaceous-cemented or limey, micrite-rich intervals. Fracture filled with reddish clay* (47/17).

**ORGANIC CARBON AND CARBONATE**  
% Organic Carbon: 0.51  
% CaCO3: 0

**SMEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>Sample</th>
<th>3-57</th>
<th>5-10</th>
<th>5-13</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TEXTURE:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>20</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>Clay</td>
<td>80</td>
<td>70</td>
<td>60</td>
</tr>
</tbody>
</table>

| **COMPOSITION:** |
| Quartz | 70 | 60 | 50 |
| Feldspar | 30 | 20 | 10 |
| Mica | 10 | 20 | 30 |
| Heavy minerals | TR | TR | TR |
| Glass | 80 | 90 | 80 |
| Glauconite | TR | TR | TR |
| Pyrite | 3 | 2 | 1 |
| Carbonate crystals | 2 | 1 | 1 |
| Foraminifers | 2 | 1 | 1 |
| Plugs | 1 | 1 | 1 |
| Lenticular fragments | 1 | 1 | 1 |
| Silica cemented grains | 1 | 1 | 1 |

*Abundant thin sandy layers

---
SITE 471 HOLE CORE 77 CORED INTERVAL 722.0-731.5 m

LITHOLOGIC DESCRIPTION

Silty claystone with thin interbeds of silty sandstone. Color, composition and bedding characteristics as in preceding zones. Sandy layers average < 1 cm thick and are basal parts of 2-5 cm sandstone-claystone cycles. Burrowed zones with offsets up to 2 cm.

ORGANIC CARBON AND CARBONATE

% Organic Carbon
% CaCO₃

SMEAR SLIDE SUMMARY

TEXTURE:
Clastic:
Organic:
Calc. Nannofossils
Lithic fragments

COMPOSITION:
Quartz:
Feldspar:
Mica:
Heavy minerals:
Glauconite:
Plant debris:
Calc. Nannofossils
Lithic fragments:

SITE 471 HOLE CORE 78 CORED INTERVAL 731.5-741.0 m

LITHOLOGIC DESCRIPTION

Silty claystone grading to claystone in Section 2. Both lithologies are dark olive gray (5Y 4/1) to dark greenish gray (5G 3/1). Claystone grades to medium greenish gray (5G 5/1) in Section 5. Intensively burrowed and bioturbated, accumulated throughout, claystone contains several thin (0.5 cm) layers of calcite cementsed silty sandstone in Sections 3-5. Microfaults and fractures scattered throughout, some are calcite-filled. Streaks and small patches of pyrite common in base Section 5, Section 6, and Core-Catcher. Calcareous claystone in Core-Catcher.

ORGANIC CARBON AND CARBONATE

% Organic Carbon
% CaCO₃

SMEAR SLIDE SUMMARY

TEXTURE:
Clastic:
Organic:
Calc. Nannofossils
Lithic fragments

COMPOSITION:
Quartz:
Feldspar:
Mica:
Heavy minerals:
Glauconite:
Plant debris:
Calc. Nannofossils
Lithic fragments:
<table>
<thead>
<tr>
<th>SITE 471</th>
<th>HOLE</th>
<th>CORE</th>
<th>CORED INTERVAL</th>
<th>LITHOLOGIC DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td></td>
<td>741.0-741.9 m</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Calcicarbonaceous Claystone (0-48 cm)** - medium greenish gray (5G 5/1), intensely burr with pyrite-rich patches and seams.
- **Sulfide Bearing Rocks (48-87 cm)** - pyrite-chalcopyrite-galena-rich sediment, also with abundant calcite and dolomite.
- **Metaliferous Sediment (87-90 cm)** - yellowish-brown iron-rich clay.
- **Chert (91-94 cm)** - one piece of black quartzite cemented with thin quartz veins.

Organic Carbon and Carbonate

| Organic Carbon | 1 |
| % CO₂         | 13 |
SITE 471, CORE 79, SECTIONS 1-2, 741.5-745.5 m

MAJOR ROCK TYPE - ALTERED DIABASE

MINOR ROCK TYPES - CLAYSTONE, SULFIDES, METALLIFEROUS SEDIMENT AND DIABASE BRECCIA in Section 3; descriptions on preceding core form.

Macroscopic Description (diabase only)

Medium gray (N5), fine-grained, massive, aphyric diabase. Prismatic Plagioclase crystals up to 2 mm; slight increase in grain size from top to base of Section 1. Badly altered with calcite-filled veins in Piece 1A, Section 1, and Piece 2, Section 2.

Thin Section Descriptions

Diabase - Section 1, Piece 1E, 127-128 cm
Texture: intersertal
Phenocrysts:
Groundmass: Plagioclase, 30%, 0.2-1.0 mm, euhedral, laths; opaque, 5%, 0.05 mm
Alteration: calcite (35%) as vein fill; brownish green clays (20%) replace groundmass between Plagioclase crystals; some Plagioclase (10%) zeolitized

Diabase - Section 2, Piece 2, 40-42 cm
Texture: intersertal
Phenocrysts:
Groundmass: Plagioclase, 20%, 0.5-2 mm, euhedral, laths; opaque, 5%, 0.1-0.2 mm
Alteration: calcite (20%) as vein fill; brownish green clays (20%) between plagioclase; zeolitized (10%) replacing plagioclase

Shipboard Data
Sample D V III) V (j.) P
Section 2, Piece 15, 8 cm 2.47 3.60 - 16

SITE 471, CORE 80, SECTIONS 1-3, 750.5-755.0 m

MAJOR ROCK TYPE - ALTERED DIABASE, DIABASE BRECCIA

MINOR ROCK TYPE - CLAYSTONE

Macroscopic Descriptions

Altered Diabase (Section 1, 0—100 cm; Section 3, 0-45 cm [with breccia] and 60-150 cm) - medium-grained, aphyric and badly altered to greenish clays. Calcite-filled voids in Section 1, 48-19 cm

Diabase Breccia (Section 1, 100-150 cm; Section 2, 0-150 cm; Section 3, 0-60 cm [with altered diabase]) - angular and subangular fragments (<5 cm) of diabase and minor sediment (clayey chert, set in an aphanitic, dark green clayey matrix. Fragments are fine- to medium-grained with Plagioclase crystals up to 2 mm. Some fragments almost completely altered to clays.

Claystone (Section 1, 0-8 cm) - light olive gray (5Y 5/2), laminated, with two dark red (5Y 2/6) lenses or layers - 0.5 cm thick

Thin Section Descriptions

Altered Diabase - Section 1, Piece 49, 85-88 cm
Texture: interstitial
Phenocrysts:
Groundmass: plagioclase, 60%, 0.6-3 mm, euhedral; clinopyroxene, 15%, 0.6-3 mm, euhedral; opaque, 7%, 0.3-1 mm
Alteration: brownish green clays (30%) between plagioclase laths; calcite (3%)

Diabase Breccia - Section 1, Piece 70, 106-109 cm
Texture: clastic
Composition: diabase fragments (40%), <15 mm across, angular to subangular; matrix (10%), zeolites and clays
Alteration: greenish grey clays (20-25%) form matrix and replace groundmass in altered diabase fragments; white mica (TR)

Shipboard Data
Sample D V III) V (j.) P
Section 2, Piece 5A, 60 cm 2.47 3.60 - 16
MAJOR ROCK TYPE - ALTERED DIABASE

MINOR ROCK TYPE - DIABASE BRECIA

MACROSCOPIC DESCRIPTIONS

ALTERED DIABASE - Fine to medium-grained and aphyric. Grain size decreases slightly, 0.03-0.35 cm in Section 1; slight grain size increase from top to base, Section 3. Common alteration to green clays with plagioclase laths to 3 mm long often set in green clay matrix. Clay alteration occurs as irregular patches or along fractures. Apparent layering (>0.5-1 mm thick) in Piece 7, Section 3, caused by alternations of altered igneous rock and less altered diabase. Calcite-filled veins and voids scattered throughout. Pyrite crystals at 22-26 cm, Section 3.

ALTERED DIABASE (Pieces 6-9, Section 1; Pieces 3-6 and 9-11, Section 4) - Angular fragments of altered diabase set in green clay matrix.

THIN SECTION DESCRIPTIONS

ALTERED DIABASE - Section 2, Piece 4, 20-24 cm
Texture: intersertal to subophitic
Phenocrysts: -
Groundmass: clinopyroxene, 25%; plagioclase, 10%, 0.5-3 mm; opaques, 1%; sphene, 1%
Alteration: green clays (25%) and zeolites (?) (10%) replace groundmass

ALTERED DIABASE - Section 4, Piece 4, 53 cm, 2.55 % 4.00 - 12

ALTERED DIABASE - Section 1, Piece 5, 124-127 cm
Texture: intersertal
Phenocrysts: -
Groundmass: plagioclase, 30%, 0.0-3 mm; clinopyroxene, 10%, 0.0-0.2 mm; opaques, 5%; green clays, 20%; zeolites (5%)
Alteration: green clays (30%) and zeolites (5%) replacing groundmass

Shipboard Data
Sample | Section | Lon | Lat | Depth | Age | Type
--- | --- | --- | --- | --- | --- | ---
1 | 1 | 2.55 | 4.00 | 12 | 12 | 12

SITE 471, CORE 81, SECTIONS 1-4, 790.0-766.0 m
MAJOR ROCK TYPE - ALTERED DIABASE

MINOR ROCK TYPES - DIABASE BRECIA. CLAYSTONE

MACROSCOPIC DESCRIPTIONS

ALTERED DIABASE - Fine to medium-grained, massive and aphyric. Grain size decreases, 0.03-0.35 cm, Section 1 then increases from 0.5-16 cm. Extensive green clay alteration of groundmass; plagioclase laths to 2 mm long set in clay matrix. Green clay also fills some fractures. Slickenside on Piece 3, Section 2.

DIABASE (Basaltic?) BRECIA (Section 1, Pieces 6A-B) - Angular fragments of altered basalt (basalt?) set in green clay matrix.

CLAYSTONE (Section 1, Piece 5) - grayish brown (5YR 3/2), massive.

THIN SECTION DESCRIPTIONS

DIABASE (Basaltic?) BRECIA - Section 1, Piece 5A, 65-65 cm
Texture: clastic, interstitial (fragments)
Composition: altered mesosyenitic fragments (originally basaltic glass, 10%), 10% < 1 mm across, angular to subangular; green clay, 11%; plagioclase, 10%, 0.02-0.2 mm, prismatic; clinopyroxene, 10%, 0.05-0.2 mm, prismatic; opaques, 4%, 0.05-0.1 mm, subhedral; zeolites (5%)
Alteration: green clay matrix (5%); zeolite (?) (5%) replacing plagioclase and groundmass

ALTERED DIABASE - Section 1, Piece 5, 124-127 cm
Texture: interstitial
Phenocrysts: -
Groundmass: plagioclase, 30%, 0.0-3 mm; clinopyroxene, 30%, 0.0-0.3 mm; subsalt; clays, 30%; zeolites, 10%; opaques, 5%; green clays, TR
Alteration: green clays (30%) and zeolites (10%) replacing groundmass

Shipboard Data
Sample | Section | Lon | Lat | Depth | Age | Type
--- | --- | --- | --- | --- | --- | ---
1 | 1 | 2.00 | 4.00 | 12 | 12 | 12
SITE 471, CORE 83, SECTIONS 1–3, 779.0–782.1 m
MAJOR ROCK TYPE – DIABASE BRECCIA

Macroscopic Description
Diabase Breccia – angular to subangular fragments of altered, vesicular fine- to medium-grained diabase set in dark gray (N3) aphanitic clayey matrix.
Most fragments are <5 cm across. In Section 2, below 110 cm and in Section 3, the long dimension of fragments is aligned subparallel to core axis (i.e., vertical). Plagioclase laths in diabase fragments are up to 3 mm long.

Thin Section Descriptions
Diabase Breccia – Section 1, Plate 30, 132–133 cm
Texture: clastic, intersertal (fragments)
Composition: plagioclase crystal fragments (angular to subangular, 0.1–0.7 mm) form about 40% of specimen; unbroken plagioclase crystals, 20%, 0.5–3.5 mm, subhedral; clinopyroxene, 3%, 0.5–1 mm, anhedral; clays, 32%; quartz, 3%, 0.2–0.5 mm, spherical, TR; calcite TR
Alteration: greenish clays (32%) replace groundmass; calcite (TR)

Diabase Breccia – Section 2, Piece 5D, 132–133 cm
Texture: clastic
Composition: plagioclase, 30%, 0.1–1.0 mm, subangular, fragmented crystals, clinoxyroxene, TR, 0.2–1.0 mm, subangular, fragmented; opaques, 5%, 0.5–1.0 mm, prismatic; matrix (clays 14%)
Vesicles: 15%, 0.5–2 mm, irregular
Alteration: clays (12%) replace groundmass; calcite (2%)

Shipboard Data
Sample D V (i) V (i) P
Section 3, Piece 1B, 11 cm 2.31 3.19 - 25

SITE 471, CORE 84, SECTIONS 1–2, 787.0–793.5 m
MAJOR ROCK TYPE – ALTERED DIABASE

Macroscopic Description
Altered Diabase – fine- to medium-grained, massive, and aphyric. Scattered dark green to black prismatic pyroxene crystals and plagioclase laths up to 5 mm long.

Thin Section Descriptions
Altered Diabase – Section 1, Plate 6F, 102–106 cm
Texture: intersertal
Phenocrysts: —
Groundmass: plagioclase, 32%, subhedral to euhedral; clinopyroxene, 15%, 0.5–2 mm, subhedral to anhedral; quartz, 3%, 0.1–0.2 mm, subhedral to anhedral; opaques, 15%, 0.5–1.5 mm, anhedral; alkali feldspar, 3%, 0.2–1 mm, anhedral; biotite, TR, 0.1–0.2 mm, platy, brown to dark green
Alteration: clays (30%) and calcite (4%) replace groundmass

Shipboard Data
Sample D V (i) V (i) P
Section 1, Piece 6E, 94 cm 2.67 4.41 - 11

SITE 471, CORE 85, SECTIONS 1–2, 796.0–798.6 m
MAJOR ROCK TYPE – ALTERED DIABASE

Macroscopic Description
Altered Diabase – massive, fine- to medium-grained and aphyric. Scattered dark gray to black prismatic pyroxene crystals and plagioclase laths up to 5 mm long scattered throughout.

Thin Section Descriptions
Altered Diabase – Section 2, Piece 1A, 0–4 cm
Texture: subophitic to intersertal
Phenocrysts: —
Groundmass: plagioclase, 40%, 1–4 mm, subhedral; clinopyroxene, 35%, 1–5 mm, subhedral to anhedral; quartz, 3%, 0.2–1 mm, subhedral; alkali feldspar, 3%, 0.2–1 mm, subhedral; biotite, TR, 0.1 mm, platy, brown
Alteration: clays (16%) and calcite (2%) replace groundmass

Shipboard Data
Sample D V (i) V (i) P
Section 1, Piece 4C, 140 cm 2.78 4.97 - 3
Altered Diabase - massive, fine-to-medium-grained, aphyric, and holocrystalline. Plagioclase laths and black amphibole pyroxene crystal up to 5 mm long scattered throughout.

**Thin Section Description**

**Altered Diabase - Section 1, Piece 1F, 113-117 cm**

**Texture:** subophitic to intersertal

**Phenocrysts:**

- Plagioclase, 40%, 0.5-3 mm, euhedral
- Clinopyroxene, 25%, 0.5-5 mm, anhedral
- Biotite, 10%, 0.3-0.5 mm, platy, brown to dark green
- Hornblende, 5%, 0.1-0.5 mm
- Opaques, 4%, 0.1-0.5 mm

**Groundmass:**

- Plagioclase, 40%, 0.5-2 mm, euhedral to subhedral
- Clinopyroxene, 35%, 0.5-2 mm, anhedral
- Quartz, 2%, 0.1-0.2 mm, euhedral
- Alkali feldspar, 2%, 0.1-0.3 mm
- Opal, 1%, 0.1-0.3 mm
- Calcite, 1%, 0.1-0.5 mm

**Alteration:**

- Clays (17%) and zeolites (1%) replace groundmass

**Shipboard Data**

**Sample**

<table>
<thead>
<tr>
<th>Section</th>
<th>Piece</th>
<th>Depth</th>
<th>Date</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1F</td>
<td>113-117 cm</td>
<td>2.85</td>
<td>5.29</td>
</tr>
</tbody>
</table>

**SITE 471, CORE 87, SECTIONS 1-4, 807.0-819.8 m**

**Major Rock Type - Altered Diabase**

**Macroscopic Description**

- Massive, fine-to-medium-grained, aphyric and holocrystalline aggregates up to 2 mm across of dark green clay are scattered throughout the core.
- Calcite- and green clay-filled fractures and veins common in all sections as marked. Core is fairly homogeneous throughout.

**Thin Section Descriptions**

**Altered Diabase - Section 3, Piece 1H, 83-86 cm**

**Texture:** subophitic to intersertal

**Phenocrysts:**

- Plagioclase, 40%, 0.5-3 mm, euhedral
- Clinopyroxene, 35%, 0.5-5 mm, anhedral
- Biotite, 10%, 0.3-0.5 mm, platy, brown to dark green
- Hornblende, 5%, 0.1-0.5 mm

**Groundmass:**

- Plagioclase, 40%, 0.5-2 mm, euhedral to subhedral
- Clinopyroxene, 35%, 0.5-2 mm, anhedral
- Quartz, 2%, 0.1-0.2 mm, euhedral
- Alkali feldspar, 2%, 0.1-0.3 mm
- Opal, 1%, 0.1-0.3 mm
- Calcite, 1%, 0.1-0.5 mm

**Alteration:**

- Clays (20%) replace groundmass; zeolite (1%) in vein

**Shipboard Data**

**Sample**

<table>
<thead>
<tr>
<th>Section</th>
<th>Piece</th>
<th>Depth</th>
<th>Date</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1F</td>
<td>91 cm</td>
<td>2.85</td>
<td>5.29</td>
</tr>
</tbody>
</table>

**SITE 471, CORE 98, SECTION 1, 866.0-865.7 m**

**Major Rock Type - Altered Diabase**

**Macroscopic Description**

- Massive, fine-to-medium-grained, aphyric and holocrystalline. Plagioclase laths and black amphibole pyroxene crystal up to 5 mm long scattered throughout.

**Thin Section Description**

**Altered Diabase - Section 1, Piece 4C, 57-60 cm**

**Texture:** subophitic to intersertal

**Phenocrysts:**

- Plagioclase, 40%, 0.5-2 mm, euhedral
- Clinopyroxene, 35%, 0.5-2 mm, anhedral
- Biotite, 10%, 0.3-0.5 mm, platy
- Hornblende, 5%, 0.1-0.5 mm

**Groundmass:**

- Plagioclase, 40%, 0.5-2 mm, euhedral
- Clinopyroxene, 35%, 0.5-2 mm, anhedral
- Quartz, 2%, 0.1-0.2 mm
- Alkali feldspar, 2%, 0.1-0.3 mm
- Opal, 1%, 0.1-0.3 mm
- Calcite, 1%, 0.1-0.5 mm

**Alteration:**

- Clays (15%) and calcite (1%) replace groundmass

**Shipboard Data**

**Sample**

<table>
<thead>
<tr>
<th>Section</th>
<th>Piece</th>
<th>Depth</th>
<th>Date</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4C</td>
<td>57-60 cm</td>
<td>2.85</td>
<td>5.29</td>
</tr>
</tbody>
</table>

**SITE 471, CORE 86, SECTION 1, 805.0-805.7 m**

**Major Rock Type - Altered Diabase**

**Macroscopic Description**

- Massive, fine-to-medium-grained, aphyric and holocrystalline. Plagioclase laths and black amphibole pyroxene crystal up to 5 mm long scattered throughout.

**Thin Section Description**

**Altered Diabase - Section 1, Piece 1F, 113-117 cm**

**Texture:** subophitic to intersertal

**Phenocrysts:**

- Plagioclase, 40%, 0.5-3 mm, euhedral
- Clinopyroxene, 35%, 0.5-5 mm, anhedral
- Biotite, 10%, 0.3-0.5 mm, platy
- Hornblende, 5%, 0.1-0.5 mm

**Groundmass:**

- Plagioclase, 40%, 0.5-2 mm, euhedral to subhedral
- Clinopyroxene, 35%, 0.5-2 mm, anhedral
- Quartz, 2%, 0.1-0.2 mm
- Alkali feldspar, 2%, 0.1-0.3 mm
- Opal, 1%, 0.1-0.3 mm
- Calcite, 1%, 0.1-0.5 mm

**Alteration:**

- Clays (15%) and calcite (1%) replace groundmass

**Shipboard Data**

**Sample**

<table>
<thead>
<tr>
<th>Section</th>
<th>Piece</th>
<th>Depth</th>
<th>Date</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1F</td>
<td>113-117 cm</td>
<td>2.85</td>
<td>5.29</td>
</tr>
</tbody>
</table>
Macroscopic Description
Altered Diabase - massive, fine- to medium-grained, aphyric, and holocrystalline. Many calcite- and clay-filled fractures and veins are marked. Large fractured/brecciated zone between 44—73 cm. Section 1, contains many angular fragments of diabase cemented together with calcite. Most veins and fractures are less than 1 cm wide and are bordered by a zone of alteration. Section 4 is a drilling breccia consisting of large diabase fragments and many ground-up small pieces.

Thin Section Descriptions
- Altered Diabase - Section 2, Piece 2A, 89—92 cm
  Texture: subophitic to intersertal
  Phenocrysts: —
  Groundmass: Plagioclase, 35%, 0.5-2 mm, subhedral; clinopyroxene, 30%, 0.5-3 mm, subhedral; biotite, 7%, 0.1-0.5 mm, platy, brown to dark green; opaques, 4%, 0.05-0.01 mm; amphibole, TR, 0.02-0.1 mm, prismatic, colorless
  Alteration: clays (21%) replace groundmass; calcite (2%) and zeolites (1%) in veins

- Altered Diabase - Section 3, Piece 11, 87—91 cm
  Texture: subophitic to intersertal
  Phenocrysts: —
  Groundmass: Plagioclase, 40%, 0.5-2 mm, subhedral; clinopyroxene, 30%, 0.5-3 mm, subhedral; biotite, 7%, 0.1-0.5 mm, platy, brown to dark green; opaques, 4%, 0.05-0.2 mm; amphibole, TR, 0.02-0.1 mm
  Alteration: clays (17%) and zeolites (1%) replace groundmass

Shipboard Data
Sample | D | V (s) | V (i) | P
Section 2, Place 200, 115 cm | 2.68 | 4.72 | 10

SITE 471, CORE 88, SECTIONS 1—4, 814.0—819.8 m
MAJOR ROCK TYPE — ALTERED DIABASE