BACKGROUND AND OBJECTIVES

Drilling at these two sites on the continental slope of the northeastern side of the Guaymas Basin, off the city of Guaymas, Sonora, had three principal objectives:

1) Knowledge of the history of the proto-Gulf of California.

2) The best possible core recovery of the laminated diatomaceous sediments from the oxygen minimum on this continental slope.

3) The first full-scale field test of the newly developed Seroki-Storms-Cameron hydraulic piston corer (HPC).

Moore and Buffington (1968) and Moore (1973) first pointed out that the Gulf is not closed in a reconstruction by taking out the sea floor apparently formed during the past 3.5 m.y. A marine basin of moderate water depth prior to that time is indicated by such a geometric reconstruction, by evidence from surrounding land geology and well information, and by structure and dredge samples from escarpments along the margins of the new basins. An excellent example of such a presumed proto-Gulf remnant lies along the mainland side of the Guaymas Basin, and Moore (1973) reported on a dredge sample (D-5) of Miocene or early Pliocene argillaceous siltstone from this scarp.

Sites 479 and 480 are located approximately on a profile from Moore (1973) (see Fig. 3). The Dredge Sample D-5 is from the scarp below these sites. Site 479 (GCA-29) is in the axis of the syncline above the scarp and was planned to penetrate two unconformities that might reveal some of the history of the present phase of opening and history of the transform fault that forms the scarp. If it had been possible to penetrate well below these unconformities, we might have been able to sample some of the proto-Gulf sediments analogous to the dredge sample and possibly basement of the proto-Gulf. Safety considerations halted our drilling, however, and the nature of this basement rock is not yet known. One hypothesis of the origin of the proto-Gulf is "back-arc" extension and formation either of oceanic crust or thinned continental crust that occurred during the Miocene (Kari and Jensky, 1972). Others have proposed an earlier period of rifting (Moore and Buffington 1978; Jensky, 1974; Mannerick, 1980).

The Guaymas Basin is an area high in organic productivity, with strong diatom blooms generally extending somewhat randomly throughout the year—although there is apparently some tendency for increased numbers of blooms in autumn and spring. The basin also receives a large contribution of terrigenous sediment from major rivers on the mainland flank, especially from the Yaqui. Rains are highly seasonal and concentrated during most years in July, August, and September, although occasionally the area receives some of the winter rains of December and January—more typical of southern California in the climatic zone to the north. The result of these two seasonally influenced sources of sediment is deposition of alternating laminae of diatom-rich layers and layers rich in terrigenous sediment into laminae or varve pairs. Calvert (1964, 1966) concluded that the predominant seasonal influence is the terrigenous sediment supply.

The other environmental factor contributing to formation of these laminated sequences is preferential preservation in the strong oxygen minimum between 300 and 1400 meters (Fig. 1). Essentially the same seasonal sediment supplies are delivered to the slopes and to the basin floors, with the exception of additional turbidite supply to the basin floors, especially during times of lowered sea level. Benthic organisms destroy the laminations above and below the oxygen minimum but not within it (Figs. 2, 3).

Detailed sampling and study of these laminated sequences of sediment thus offer the possibility of gaining information and insight into varying environmental conditions, such as climatic changes and cycles, changes in circulation patterns, changes in depth of oxygen minimum, changes in sea level, and changes in floral and faunal assemblages. Sampling a sufficient thickness of a laminated sequence would furthermore make some study of diagenetic changes and lithification possible.


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Figure 1. A. Cross-section through the water mass of the central Guaymas Basin to show the distribution of dissolved oxygen. The section extends from Mulegé to the mouth of the Río Yaqui (see Fig. 2 for locations). Isopleths of oxygen concentration after Calvert (1964). B. (i) Depth distribution of sediment cores from the Guaymas and San Pedro Mártir basins. Those cores showing laminations to the core surface are indicated by the shaded area on the histogram. The remaining cores are homogeneous, mottled, or partially laminated (homogeneous at the surface, but laminated at some variable depth in the core). (ii) Vertical distribution of dissolved oxygen from 20 hydrographic stations occupied in the Guaymas and San Pedro Mártir basins during October–November 1961. Each point represents a single determination from a Nansen bottle sample at the depth indicated (from Calvert, 1964).
Figure 2. Distribution of sediment cores and their distinguishing structures. Data from *Vermillion Sea* Expedition (1959) and from the *Hugh H. Smith* Expedition (1961) (from Calvert, 1964).
Site 479 was drilled first with conventional drill bit and coring. This site was selected as a compromise between proto-Gulf objectives and laminated sediment objectives. The plan was to then test the HPC at this same site after completion of the first hole if the upper part of the section consisted of good laminated sediments. Our experience on the ship was, however, that because of the excessive disturbance by conventional coring, we could not determine with confidence whether or not this upper section was well laminated. Rather than test the HPC at this site, we moved approximately 7 km to Site 480, where previous oceanographic ship-piston and gravity cores had demonstrated good lamination in the upper few meters of the sediment column.

**PRINCIPAL RESULTS**

These sites were drilled to test the hydraulic piston corer, to obtain a record of laminated diatomaceous sediments from the oxygen minimum, and to penetrate the upper part of the sedimentary section overlying proto-Gulf crust. The HPC test Site 480 was technologically and scientifically successful and obtained almost complete recovery of a 152-meter section of varved sediments. Drilling at Site 479 penetrated several unconformities and terminated in late Pliocene sediments. The correlation with seismic data suggests that uplift of this upper part of the section occurred in the past 1 m.y.

**HOLE 479**

- **Date occupied:** 29 December 1978
- **Date departed:** 31 December 1978
- **Time on hole (hrs.):** 76.75
- **Position:** 27°50.76'N; 111°37.49'W
- **Water depth (sea level; corrected m; echo-sounding):** 747
- **Water depth (rig floor; corrected m; echo-sounding):** 757

**HOLE 480**

- **Date occupied:** 31 December 1978
- **Date departed:** 2 January 1979
- **Time on hole (hrs.):** 39.62
- **Position:** 27°54.10'N; 111°39.34'W
- **Water depth (sea level; corrected m; echo-sounding):** 655

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GUAYMAS BASIN SLOPE SITES

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**Hole 479 and 480**

- **Bottom felt at (m; drill pipe):** 766
- **Penetration (m):** 440
- **Number of cores:** 47
- **Total length of cored section (m):** 440
- **Total core recovered (m):** 272.8
- **Core recovery (%):** 62
- **Oldest sediment cored:**
  - **Depth sub-bottom (m):** 440
  - **Nature:** Laminated mudstone
  - **Age:** Late Pliocene
  - **Measured velocity (km/s):** Not determined
- **Basement:** Not reached

**Principal results:** Hole 479 lies on the northwest continental slope of the Guaymas Basin within the oxygen minimum and over presumed proto-Gulf of California sediments and crust. It was located by a predrilling survey in the axis of a syncline above the scarp of the transform fault of the basin where the drilled section outcrops at the sea floor. The objective was to sample these presumed proto-Gulf sediments as deeply as time would permit and to date the unconformities and folding above the scarp. The lithology of the section was Quaternary to late Pliocene and mainly muddy diatomaceous ooze with alternating sequences of varves and homogeneous, probably bioturbated, zones. Three lithological units were distinguished on the basis of diagenesis, degree of consolidation, and micropaleontology. These correlate rather well with the sediment sections between the unconformities in the seismic reflection records. We conclude that all uplift and folding indicated within the shallow part of the section drilled occurred during the Pleistocene. Drilling was terminated at 440 meters because of gas pressure, increasing C2/C1 ratio, and increase of hydrocarbons in the gasoline range. Heat flow was measured at 2.36 HFU.
0424Z on 31 December, we continuously cored 440 m of the section from Hole 479 with excellent recovery of undisturbed sediments. Rhythmically laminated (varved) sequences alternate with bioturbated sections, perhaps as a function of movement of the oxygen minimum with Quaternary climate and sea-level changes. Study of the varves aboard ship was very limited, because the shipboard scientific party refrained from sampling in order to preserve the cores for shore-based studies, which require intact working halves of the cores. We proposed special curating and sample distribution procedures for the cores.

**SITES 479 AND 480 OPERATIONS**

We departed Site 479 on 29 December at 0512Z on course 350° toward a predrilling reflection seismic survey of the area around proposed Site 479 using Glomar Challenger seismic equipment. Site 479 was selected along an old (1967) C. H. Davis line run before satellite navigation (Fig. 4), and it was, therefore, of uncertain position. We thus needed an area survey to select the desired site in the axis of a syncline, as recommended by the JOIDES Safety Panel. We changed course to 035° at 0115Z on 29 December and began the survey. The survey track and the final sites selected for drilling are shown in Figure 4. Examples of the records (including seismic records) are given in the section on correlation of drilling results. We completed our survey at 1618Z, dropped a beacon, retrieved the profiling gear, hove to in the area, and lowered the positioning hydrophones—but alas, no beacon signals. After awaiting a satellite, we again began profiling in the area at 1755Z and at 1844Z let go a second beacon in 747 meters of water. At 2300Z we were underway for the next site, Site 480, which was selected to complement this site for piston coring.

Although the upper 100 meters of cores at Site 479 were, as usual, badly disturbed, we did not see any convincing evidence for laminated diatomaceous ooze. Site 480 is only about 6.8 km to the northwest and in an optimum locality for coring laminated diatomaceous ooze and mud. No seismic profiling was done on the short traverse from Site 479 to Site 480, because Site 480 is on one of the lines run in the survey for Site 479. We used the 3.5 kHz to record structure in the upper 50 meters. At 0000Z on January 1 we reached our position and dropped a beacon in 655 meters of water. From 0030 to 0230Z we then positioned in automatic over the beacon and ran pipe in the hole. The piston corer was then rigged, and our first core was on deck at 0715Z on 1 January 1979. We then took a very successful series of 31 piston cores, terminating at 1315Z on 2 January at a total depth of 152 meters. Only two cores contained no undisturbed sediments, and recovery was generally 80 to 95%. The cores are remarkably undisturbed, and throughout much of the sequence, finely laminated diatomaceous ooze and silt were recovered. Average time for each core was 1 hr at this depth. This first operational use of the hydraulic piston corer was an unqualified technical and scientific success.

Because this same section had been logged at Site 479, just 6.8 km to the southeast (and since in any case only the lower 90 m could be logged), we opted not to relog, thereby saving time for drilling and logging our next and final site. We therefore pulled out of the hole and were underway for the next site at 1653Z on 2 January 1979.

**SITE 479 SEDIMENTARY LITHOLOGY**

In general, sediments at Site 479 are a uniform, somewhat monotonous, rather disturbed, thick, hemipelagic, Quaternary sequence of muddy diatomaceous ooze to mudstone. Most of the section was originally rhythmically laminated. Sedimentation has been rapid as might be expected from the nearby terrigenous sources and profuse diatom productivity at this locality within the belt of intense upwelling. Discrete, hard, lithified layers of calcareous mudstones to limestone—some laminated—are recurrent at several intervals but are more common with depth. On the composite stratigraphic section (Fig. 5), missing sediments and the position of indurated layers have been slightly modified from core-barrel depths by adjustment with the sonic- and bulk-density logging results.

Although the entire section at Site 479 seems to show a similar environment of deposition, we have decided to use subtle differences to designate three units (see Table 2) to delimit possible breaks in the record. These criteria include indurations, gas, the relative abundance of dia-
Figure 4. Tracks of *Glomar Challenger*, approaching Stations 479 and 480, a multichannel seismic-reflection line from Guaymas Expedition, Scripps Institution of Oceanography, and a 1967 C. H. Davis line.

Unit I: Late Pleistocene (479-1 through 479-26, CC; 0–240.5 m)

The correlation with Hole 480 suggests that the soft and highly disturbed sediments from the upper part of Hole 479 also seem to consist mainly of rhythmically alternating thin layers of moderate olive brown (5Y 4/4) muddy diatomaceous ooze and millimeter-scale laminae of matted pale olive (10Y 6/2) diatomaceous ooze. Some layers are mainly diatomaceous mud or silty clays. Where undisturbed, laminations are subparallel to parallel (see lithology section, Site 480).
Diatoms comprise 20 to 50% of the sediment. Other biogenic components include nannofossils (2-15%), common silicoflagellates, and rare foraminifers or radiolarians. Terrigenous constituents are dominated by silt-sized angular to rounded feldspars, with quartz and minor amounts of opaques and heavy minerals, pyrite, and plant debris.

An H₂S odor is present through Core 479-10, and most of the unit shows a spongy or gelatinous, ruptured surface texture caused by the exhalation of gas (biogenic CO₂ methane) when drilled. Gas is a prominent feature of Unit I and some sediments froth into the core barrel (Fig. 6).

Four hard, decimeter-thick, pale olive (10Y 6/2-5Y 3/2) to grayish olive (10Y 4/2) dolomite-cemented mudstone layers were recovered from 88.5, 110, 170, and 198 meters. Smear slides and thin sections show relict quartz grains and diatom fragments emmeshed in micrite-size, blocky dolomite. The first samples are moderately soft with individual rhombic grains. Some of the pieces are
### Table 2. Lithology, Sites 479 and 480.

<table>
<thead>
<tr>
<th>Site</th>
<th>Unit</th>
<th>Cores</th>
<th>Sub-bottom Depth (m)</th>
<th>Lithology</th>
<th>Paleoenvironment Interpretation</th>
<th>Age</th>
<th>Average Accumulation Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>479</td>
<td>I</td>
<td>1 to 26.CC</td>
<td>0 to 240.5</td>
<td>Moderate olive brown, grayish olive to pale olive muddy diatomaceous ooze to diatom muds; alternations of rhythmically laminated and homogeneous zones; includes some sand and dolomite interlayers and gas-rich zones</td>
<td>Hemipelagic: outer slope episodically intersecting the O₂ minimum beneath zones of upwelling and high productivity</td>
<td>Late Quaternary</td>
<td>Rapid estimates: ~550 m/m.y.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>240.5 to 364.5</td>
<td>Contact: massive sand</td>
<td><strong>Unconformity?</strong></td>
<td>Quaternary (up to ~0.9 m.y.)</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>27-1 to 39.CC</td>
<td>364.5 to 440</td>
<td>Firm to hard, moderate-olive-brown, laminated and homogeneous zones of muddy diatomaceous ooze, includes diagenetic carbonates but few sand, ash, or gaseous layers</td>
<td><strong>Hiatus</strong></td>
<td>Hemipelagic</td>
<td>Late Pliocene (1.8-2.4 m.y.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>364.5 to 440</td>
<td>Contact</td>
<td>Laminated, diatomaceous muds to laminated mudstone; induration increases, diatoms disappear; 7 to 8 hard, diagenetic dolomitic interlayers</td>
<td>Alternations of:</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 to 152.0</td>
<td>Type 1A: Rhythmically laminated, moderate-olive-brown (5Y 4/4), muddy diatomaceous ooze and pale-olive (10Y 6/2) to moderate-yellow (5Y 7/6) diatomaceous ooze</td>
<td>Hemipelagic outer slope; high diatom productivity with upwelling and sediments in O₂ minimum zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>480-31.CC</td>
<td>0 to 152.0</td>
<td>Type 1B: Homogeneous, moderate-olive-brown (5Y 4/4) diatomaceous mud and olive-gray (5Y 3/2) to light-olive-gray (5Y 5/2), diatomaceous, silty clay</td>
<td>Diatom production less; infauna present at ocean floor</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0 to 152.0</td>
<td>Interruptions: sands (Cores 20, 21), dolomitic mudstone (Core 21)</td>
<td>Lowered sea level(?); diagenetic carbonate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a From 16 varves/cm counted.
b From correlation with Site 479.

thinly laminated; others are bioturbated to homogeneous (Fig. 7) (see Kelts and McKenzie, this volume, Pt. 2).

Other minor interlayers include a thin, unaltered, silt-sized, gray (N7) vitric rhyolitic ash in Sections 479-17-3 and 479-17-4 (152 m). Sands are quantitatively unimportant, and where present do not show grading. In Core 479-24-1, a thin gray sand also contains up to 10% pyrite, which suggests winnowing. A medium gray (N5) 50-cm-thick, well-sorted, coarse sand layer occurs at 50.5 meters (Core 479-6). The base of Unit I, however, is marked by a massive, 7-meter-thick, coarse-grained, well-sorted, dark greenish gray (5G 4/1) sand in Core 479-26. These sands seem to be winnowed of fines and have sharp upper and basal contacts. Compositionally, feldspars are more abundant than quartz and volcanic rock fragments with minor heavy minerals and micas (Aguayo, this volume, Pt. 2). Shallow- or deep-water carbonate is rare, although there are a few benthic foraminifers and a trace of reworked coccoliths and diatoms.

**Unit II: Late Pleistocene (479-27 through 479-39.CC; 240.5-364.5 m)**

Below the massive sand (Core 479-26), induration increases, and many sections are not badly disturbed by drilling. These show distinct rhythmic light and dark laminated zones (Fig. 8) between more homogeneous zones. Other differences are also present. The unit is less gaseous, and gas rupturing decreases; there are more abundant silicoflagellates in Cores 479-28, 479-32, 479-34, and 479-35. The frequency of limestone interlayers increases, and some preserve clear evidence of burrowing. Sands are rare. Some phosphate-rich zones occur.

In the laminated sequences, a common couplet type consists of a grayish olive (10Y 4/2) diatomaceous silty clay (dark) and pale olive (10Y 6/2) muddy diatomaceous ooze (light). The couplets seem slightly less diatomaceous with more terrigenous sediment than the upper section. Typical counts range from 22 to 30 couplets per centimeter.

Six hard dolomitic mudstones, several centimeters thick, were encountered in this section. They are thicker than similar Unit-I layers, and cut surfaces commonly show excellently preserved exponential-type burrowing down into a laminated sequence (Kelts and McKenzie, this volume, Pt. 2). Other, more indurated sections also show pervasive burrow structures that must represent the homogenous, clayey units.

Minor beds include fish-scale-rich hard clays (in Sections 479-35-4, 479-38-5) and several 1-cm-thick beds of black sand-sized particles composed of basaltic glass...
Figure 6. Photograph of a section of 479-5-1, showing gas exolution.

Figure 7. Photograph of 479-13-CC, showing fragment of hard, laminated, dolomitic mudstone.

Figure 8. Photograph of 479-35-5, 53–59 cm, showing laminated diatomaceous mudstones of Unit II.

and feldspars coated with manganese oxyhydroxides and some quartz and diatoms (20%) suggesting a possible short time of slowed deposition.

Unit III: Pliocene (479-40 through 47,CC; 364.5–440.0 m)

The contact of Unit II/III is defined by a change in bulk density trends and by a jump to late Pliocene (Mataoba and Oda, this volume, Pt. 2). Most of the section consists of thinly laminated mudstones, which are either grayish olive (10Y 4/2) or pale olive (10Y 6/2) silty clay to diatom mud. Sediments continue to show rhythmic, very fine laminations. Trends continue over a transitional zone that began about in Core 479-35. Diatom frustules diminish and disappear, as do most nannofossils. Once diatom abundance has dropped to minimum values, there is a clear linear increase in induration levels from Cores 479-39 to 479-47, which can be followed on the density log (Fig. 5). Layers rich in fish scales (e.g., Sections 479-40-6, 479-41-1, 479-43-2, 479-46-1, 479-46-2) become prominent. Cores 479-40, 479-42, 479-45, and 479-47 contain a few scattered, paper-thin white laminae that are an almost pure nannofossil ooze, containing a single cosmopolitan species indicative of special blooms.

Nine hard, dolomitic interlayers were counted. One example (Sample 479-47-2, 125–145 cm) shows a progressive change downward from relatively soft, extremely finely laminated claystones to harder limestones (see Kelts and McKenzie, this volume, Pt. 2). Initially parallel structures are completely preserved. Laminations become wavy, then intermittent, then broader and diffuse, mostly as a result of obliteration of the thin dark laminae, rich in organic matter. This suggests a progressive trend in the pattern of lithification of the limestone beds.

Depositional Environment

Sediments at Site 479 show a pattern of an outer-slope hemipelagic depositional environment throughout the time interval drilled.
There is also a good correlation with Site 480, which strongly suggests the upper, highly disturbed 150 meters are similarly composed of alternating zones of fine varve-like diatomaceous rhythmites and homogeneous muddy diatomaceous ooze. Conditions were generally favorable to the preservation of the laminations, which indicate a long-period stable location of the oxygen minimum, similar to that of today. Although some controversy surrounds the nature of the more homogeneous zones (see biostratigraphy, Site 480) in deeper, more indurated sections, pervasive burrowing is conspicuous. This indicates a fluctuating oxygen content in bottom waters during some discrete times.

There is little evidence for major turbidite sedimentation in most of the section at Site 479. We do not observe very silty beds or homogeneous muds typical of a deltaic environment. Sands, particularly graded ones, are rare. This is consistent with its present protected, low gradient, outer-slope location. But, the thick sand bed in Core 479-26 probably defines an unconformity. The composition of coarse-grained (250-600 µm) angular quartz, abundant feldspar, and rounded volcanic rock fragments without carbonates suggests a terrigenous fluviatile source similar to the present Guaymas area. This layer is associated with a low-angle, but distinct unconformity visible on seismic records. These sands could indicate times of lowered sea levels or enhanced bottom currents.

**Diagenesis and Varves**

Based on decreasing drilling disturbance, general consolidation of the sediments begins below about 250 meters or below the zone enriched in biogenic gas. Large amounts of biogenic gas that charge the sediments indicate rather high accumulation rates and low oxidation potentials. These gases may counteract compaction to some degree. Induration is first apparent below Core 479-39 (360 m).

Diatom abundance decreases downhole from generally high levels midsection (45–60%), to intermittently high and low, then generally low below 360 meters. Below 390 meters (Core 479-43) diatoms disappear. This change is parallel to the induration pattern, which suggests silica diagenesis in progress.

Sediments both above and below the claystone boundary are rhythmically laminated with a couplet consisting of a light (A) and a dark (B) lamina. The light laminae lower in the section (Core 479-37) appear to contain more robust types of diatoms.

The last core (479-47) is an example of a claystone showing a continuous succession of very fine rhythmic couplets but containing no frustules (Fig. 9). Light and dark layers, if annual, indicate a span of about 27,000 years. For this core, (about 30–35 couplets per cm). Both light and dark laminae seem to have almost identical bulk compositions at present: dominantly clay (80–85%) with scattered fine carbonate grains.

Close inspection shows that a variety of other laminations or sublaminations are also present. Many of the darker laminations are underlain by a hairline (0.1 mm) reddish brown layer of pure organic matter. This may be a relict of diatom blooms or may instead indicate other seasonal algal productivity.

Successions are interrupted frequently by thin (2–3 mm), gray (N6) silty clays, which may derive from exceptional flood years.

Thin, homogeneous brown to tan silty clay (2–3 mm) bands are less frequent but may indicate burrowing or longer periods of low productivity. A few thin (0.3 mm), creamy white laminations stand out in darker sections. These proved to be a pure nannofossil bloom consisting of one dominant, dissolution-resistant species, *Coccolithus pelagicus*.

Some laminae consist of a single layer of fish scales, which is best detected along parted beds. In some zones, the sediment approaches a fish-scale clay. Commonly, the scales are concentrated at the top of the dark laminae, which appears microburrowed, and below thin organic-rich films occur.

Scattered, grayish orange bands and clumps are phosphate-rich. Both of these latter types of laminae indicate a deeper zone near strong upwelling.

**Recurring Dolomitic Layers**

Hard lithified layers show up on density log records (Fig. 31) as 18 to 20 thin beds, which increase in abundance downhole but show little relation to the overall diagenetic trend. Evidence suggests an *in situ* process cementing host lithologies. This curious recurrent pattern is difficult to explain. Possibly some layers were sedimented with more than a critical amount of carbonate, which would later recrystallize (Kelts and McKenzie, this volume, Pt. 2).

**Volcanic Ashes**

The occurrence of basaltic ash in lower sections of the hole (Cores 479-35–479-39) contrasts with more rhy-
olitic material at the top (Core 479-17). Both appear to have been transported mainly by wind, because the grains are well sorted and silt sized without admixture. These suggest basaltic and rhyolitic volcanism from mainland volcanoes during the Quaternary; some of the possible volcanic sources (weathered volcanoes) were visible 15 km away from the ship. The black coatings on the basaltic ash components may have been acquired before transport, as a rapid burial in anoxic oozes would seem to preclude a manganese coating.

SITE 480 SEDIMENT LITHOLOGY

Table 2 and Figure 5 summarize the lithologies of Sites 479 and 480. Because the hemipelagic environment of deposition changed little during this time, we recognize only one lithological unit that contains two main sediment types on the basis of primary sedimentary structures and biogenic composition. Type 1A consists of alternating dark (rich in terrigenous matter) and light (diatom-rich) laminations. Type 1B consists of homogeneous diatom muds (rich in terrigenous matter) to diatomaceous silt clays that are occasionally bioturbated at the contact with laminated sections. Contacts between these alternating subunits are usually gradational.

Unit I: late Quaternary (Core 480-1 through Section 480-31, CC; 0.0-152.0 m)

Laminated oozes consist of rhythmic couplets of moderate olive brown (5Y 4/4) muddy diatomaceous ooze and pale olive (10Y 6/2) to moderate yellow (5Y 7/6) diatomaceous ooze. The lighter diatomaceous ooze laminas have a consistently narrow compositional range of 70 to 80% diatoms, 15 to 25% clay, 1 to 2% quartz and feldspar, and 1 to 2% silicoflagellates. The darker muddy diatomaceous ooze layers are also consistent in composition with 45 to 50% clay, 25 to 45% diatoms, 1 to 8% quartz, 1 to 3% feldspar, and trace to 10% nanofossils. The laminas are consistently submillimeter to millimeter scale in thickness with rare examples of diatomaceous ooze laminas greater than 1 to 2 mm. Cores 480-1 and 480-2 exhibit a gelatinous consistency in the varved sections because of a very high water content. The laminas are indistinct but visible. At Core 480-3 the laminas consolidate sufficiently for recognition of the boundaries between light and dark layers. The number of dark/light couplets per centimeter is uniform throughout the section. Because of compaction, random counts of laminae give 12 to 15 couplets per centimeter in the top 4 cores and 12 to 20 couplets per centimeter in the bottom 4 cores.

Frequently, the rhythmic couplets have faint or vague boundaries from dark to light laminae. The lighter laminae are mostly pale olive.

Interruptions within the alternation pattern are uncommon. Notable exceptions occur in Cores 480-20 and 480-21. Core 480-20 has three medium gray (N5), massive, well-sorted sand layers in sharp contact with the laminations—in one instance unconformably so (see Fig. 10). Sands are arkosic, with angular to subangular grains. The sand composition seems typical of the Yaqui Province.
GUAYMAS BASIN SLOPE SITES

River province (van Andel, 1964) and consists of quartz and orthoclase with heavy minerals of epidote, hornblende, pyroxene, and minor biotite. A small percentage of the >63µ fraction includes red brown volcanic fragments. Core 480-21 contains a 10- to 15-cm section of well-indurated grayish yellow (SY 8/4) dolomitic mudstone showing bioturbation structures. This was the only indurated sediment recovered in Site 480; we suspect, however, that other hard layers encountered in drilling—but not recovered—were also calcareous mudstones. Immediately below the calcareous mudstone is a 50-cm section of alternating, centimeter-scale, medium bluish gray (SB 5/1) quartz silt-clay layers with millimeter-scale basal sands and pale olive (10Y 6/2) to moderate olive brown (5Y 4/4) muddy diatomaceous ooze. There is grading in each of the quartz silt-clay layers suggesting small-scale turbidite deposition. Wood chips and shell fragments occur rarely within the rhythmic laminations.

Hydrogen sulfide gas is ubiquitous in the sediment section and is manifested by large gas pockets in the cores, gas fractures, cut sediment surfaces, and H₂S odor.

Altered basaltic ash with manganese oxyhydroxide coating on clays (Sample 480-14-1, 110 cm), unaltered rhyolitic ash (Sample 480-28-1, 115 cm), fish scales, and phosphatic material (Samples 480-9-1, 108 cm, 480-26-3, 60-140 cm) are present but rare.

Type IB homogeneous diatomaceous muds consist of moderate olive brown (5Y 4/4) to olive gray (SY 3/2) diatomaceous mud grading to light olive gray (SY 5/2) nannofossil-bearing diatomaceous silty clay. These sediments show no rhythmic laminations or other primary sedimentary structures. Homogeneous sections are uniform in color with some evidence of bioturbation at lower contacts. Type IB can be divided into two distinct textural groups. Diatomaceous silty clays are characterized by 50 to 60% clay, 10 to 15% each of diatoms and calcareous nannofossils, 6 to 10% quartz, 4 to 12% feldspar, and 1 to 3% each of mica, pyrite framboids in diatom frustules, and organic debris. Diatomaceous clays are characterized by 45% clay, 30 to 35% diatoms, 10 to 20% quartz, 2 to 5% feldspar, 1 to 3% pyrite, and 1 to 2% organic debris. Calcareous nannofossils are rare.

These homogeneous sections of the sediment column do not appear to be turbidites or redeposited sediments. There is no evidence of graded bedding or basal sands. In addition, contacts with the rhythmic laminations above and below these sections are gradational.

Sedimentary Processes, Upwelling, and the O₂ Minimum

Alternating zones of rhythmic couplets of dark (rich in terrigenous matter) and light (biogenic-rich) laminae, here interpreted to be annual varves, and the homogeneous diatomaceous mud zones suggest two possible sedimentary histories. Site 480 is in an O₂ minimum zone, which effectively prevents infaunal bioturbation. The O₂ minimum is the result of seasonal upwelling of deep, nutrient-rich bottom waters and concomitant high productivity in the surface waters. The massive pelagic "rain" of organic material depletes the O₂, and the stability of water masses allows the O₂ minimum to sustain its integrity. Consequently, the varve-like rhythms indicate seasonal fluctuation of surface water productivity or terrigenous input controlled by the interaction of oceanographic climatic conditions.

Homogeneous zones perhaps represent times when the O₂ minimum was not in existence or fluctuated (approximately 300-1400 m today). Bioturbation, however, is not readily apparent. Very few burrows are recognized, and these are only seen at the lower gradational contacts with varved zones (Cores 480-8, 480-13, 480-14, 480-19, 480-26).

Correlation of Sites 479 and 480

From smear-slide descriptions the sediment lithologies, textures and colors at Sites 479 and 480 are similar if not identical. Direct correlation of the two sites is, however, somewhat limited by intensive disturbance to the top 150 meters at Site 479. From the logging records at Site 479 (Fig. 31) it is possible to detect the exact location and thickness of indurated beds that may have been cored but not recovered. Two calcareous claystone layers that were recovered at Site 479 show strong jumps on the neutron, resistivity, and bulk density curves. Only one of these layers was recovered at Site 480; however, the drilling record indicates another hard layer drilled very close to the depth of the second calcareous mudstone at Site 479. Similarly, sand layers are present in both sections at approximately the same depth. The most equivocal correlation is that of two occurrences of vitric rhyolitic ash. The differences in depth make this correlation tenuous, and, in fact, the actual correlative ash bed in Site 480 may lie just below the termination depth of 152.0 meters.

SITE 479 ORGANIC GEOCHEMISTRY

The shipboard monitoring program was carried out in harried real-time—as each core arrived on deck it was sampled for gas from voids in the liner (if present) or later from the pressure build-up under the end caps; the core catcher samples were split and examined for fluorescence. The gases were analyzed mainly by the Carle Gas Chromatograph (GC), and spot checks were done with the Hewlett-Packard GC. The maturation of the organic matter was followed by the fluorescence of the toluene–ethanol extract of small sediment samples and microscopic examination of smear slides.

C₁–C₅ Hydrocarbon Analyses

Methane, ethane, carbon dioxide, and hydrogen sulfide were monitored in real-time, and selected samples were further analyzed for C₅–C₆ hydrocarbons. The CH₄ concentration is very scattered, with a general decrease in concentrations with depth, and the normalized data are shown in Figure 11. It shows a decrease (~60%) to about 100 meters sub-bottom, then remains level to about 250 meters. This is followed by a successive increase to 300 meters, a decrease to 450 meters, and an increase again to the bottom of the hole. The upper distribution to 100 meters represents the biogenic respira-
Figure 11. Concentrations of methane (A) and ethane (B) versus depth for Site 479.

Figure 12. Ratio of ethane to methane versus depth at Site 479.

The > C₂ hydrocarbon concentrations were observed to increase, e.g., Section 479-31-5 at 285 meters shows an increase in C₃H₆ and Section 479-47-3 at 435 meters contains isobutane > propane. Thus a series of samples was analyzed to evaluate this hydrocarbon increase, and the results are plotted versus depth in Figure 13 (all the data are normalized to 100% CH₄). The ethane shows considerable scatter versus depth, but an inflection to higher concentration is evident at about 270 meters. The propane shows a steady increase with depth, with a definite minimum at about 270 meters and a decreasing trend below about 400 meters. Isobutane is at background levels to about 270 meters and then shows a rapid increase to a maximum concentration (greater than propane) at about 400 meters—also followed by a decreasing trend below that depth. Both n-butane and n-pentane remain at background levels throughout the hole. Isopentane also shows a rapid increase in concentration from about 270 meters to > 435 meters, however, with some scatter. The maximum concentrations of the C₂–C₅ hydrocarbons are: C₂ = 0.122%, C₃ = 0.010%, C₄ = 0.016%, and C₅ = 0.0015%. The concentrations of C₄ + C₅ hydrocarbons are greater than those observed for the previous Sites 474, 477, and 478. These data indicated that we were approaching a zone with potential liquid hydrocarbons at depths > 430 meters, and the concentration gradients indicate that the more volatile hydrocarbons (C₂–C₄) have migrated upward in the sedimentary column to just below the indurated “cap rock” sequences (~200–250 meters) and accumulated according to their volatility (i.e., boiling points). The propane and isobutane are at a maximum concentration above the isopentane. The absolute amount of thermogenic C₂–C₅ hydrocarbons superimposed on the endogenous hydrocarbons is small.

The carbon dioxide concentration versus depth is shown in Figure 14. The values show an initial increase to about 30% at 90 meters, remain level at that value (with some scatter) to 270 meters, and then increase and decrease with more variability to the bottom of the hole. Normalization of the data did not improve the scatter (cf. Figure 14). The trends of the CO₂ distribution do not follow the calcium concentration or the alkalinity. H₂S was detected by gas chromatography in only two shallow samples, but the odor persisted strongly from about 3 to 50 meters and faintly to about 200 meters.

Fluorescence

Fluorescence data were measured on (1) dried sediment and on tetrachloroethylene extract solutions of (2) dried sediment and (3) pyrolyzed sediment (red heat). None of the dried sediments exhibited any fluorescence, and the real-time fluorescence monitoring of split sections showed only fluorescence along the liners—a result of pipe dope contamination. The extracts of the dried sediments exhibit light orange to orange yellow fluorescence for the shallow and immature samples grading to light yellow, yellow, yellow green with depth,
which indicates some maturation of the lipid material. The extracts from the pyrolized samples exhibit a yellow blue to yellow white fluorescence in the upper sediment section, grading to a strong blue white below about 140 meters. This indicates that this sediment sequence has a petrogenic potential and can yield pyrolisate of a more aliphatic composition in the upper section and more aromatic at depths >140 meters.

Organic Carbon and Organic Nitrogen

The samples were prepared and analyzed as already described, and the results are found in Appendix I, this volume, Pt. 2. The organic carbon and nitrogen contents are plotted in Figure 15. The organic carbon ranges from 3.6% near the surface to 1.2% at hole bottom, with an essentially linear distribution. The organic nitrogen values range from 0.4% near the surface to 0.17% at depth. The C/N ratio data are also found in Figure 15 and the range is from 9 to 16 with a mean value of 14. These values are typical for Recent immature sediments (~12; Ryther, 1956).

Conclusions

The surface sediments of Site 479 (to about 250 meters) are diatomites rich in organic matter (up to 3.6% organic carbon) and contain biogenic gas (CH₄, CO₂, H₂S, minor C₂H₆). Below about 250 meters the sediments become more indurated and the >C₂ hydrocarbon content of the interstitial gas rapidly increases. Propane and isobutane attain a maximum concentration at about 400 meters sub-bottom and isopentane is increasing to a maximum concentration below that depth. These data indicate that at greater depth the higher weight hydrocarbons (>C₅) would be encountered and that the C₃-C₅ hydrocarbons had migrated (diffused or distilled) upward from depth. This rapid increase in the relative concentrations of the C₃-C₅ hydrocarbons with their extent into the gasoline range (coupled with the increase of
the C₂/C₁ to about $20 \times 10^{-4}$) and the uncertainty of the numbers and thicknesses of sand layers that could accumulate these liquid hydrocarbons at greater depths led to the termination of drilling at Site 479.

**SITE 480 ORGANIC GEOCHEMISTRY**

The onboard monitoring program was again carried out in hurried real-time. As each core arrived on deck it was sampled for gas from voids in the liner (if present) or later from the pressure build-up under the end caps; the core catcher samples were split and examined for fluorescence. The gases were analyzed mainly by the Carle GC, and spot checks were done with the Hewlett-Packard GC. The maturation of the organic matter was followed by the fluorescence of the toluene-ethanol extract of small sediment samples.

**C₁-C₄ Hydrocarbon Analyses**

The gases CH₄, C₂H₆, CO₂, and H₂S were monitored, and the normalized CH₄ and C₂H₆ data are plotted versus depth in Figure 16. The methane concentration shows a gradual decrease from 90% at 10 meters to about 75% at 125 meters, followed by a more rapid decrease to the bottom of the hole. The overall gas pressure that developed in the core liners increased with depth. The ethane concentration is low and shows a scattered distribution (cf., Fig. 16). The C₂/C₁ is plotted in Figure 17 with the approximate data distribution for Site 479. The C₂/C₁ shows a more rapid increase than for Site 479, indicating a higher influx of thermogenic hydrocarbons or a higher thermal gradient (assuming that the sedimentation rates are similar). This is further supported by the results of the >C₂ hydrocarbon analyses, where the ethane, propane, and isobutane are present at greater concentrations than at Site 479. The maximum concentrations of the C₁–C₄ hydrocarbons are:

$C_1 = 91.8\%$, $C_2 = 0.035\%$, $C_3 = 0.003\%$, and $C_4 = 0.0003\%$.

The CO₂ concentration shows a gradual increase versus depth (Fig. 18) from about 10% at 10 meters to 50% at 150 meters. The hydrogen sulfide showed a more random distribution with depth. Large concentrations of H₂S were detected by GC (Fig. 18) and by odor through-
GUAYMAS BASIN SLOPE SITES

Normalized CO\textsubscript{2} (%) 0 20 40
Normalized H\textsubscript{2}S (x10\textsuperscript{3}) 5 10 15

Figure 18. Concentrations of CO\textsubscript{2} (A) and H\textsubscript{2}S (B) versus depth at Site 480 (data normalized after correction for air).

Organic Carbon and Organic Nitrogen

The samples were prepared and analyzed as already described, and the results are given in Appendix I, this volume, Pt. 2. The organic carbon and nitrogen contents and C/N ratios are plotted versus depth in Figure 19. The organic carbon ranges from 2.2 to 3.21% with an essentially uniform distribution, and the organic nitrogen content ranges from 0.16 to 0.27% with an analogous distribution to that of carbon and a slight decrease with depth. The C/N data show an increase from 12 to 16 with depth, and these values are typical for immature Recent sediments (~12; Ryther, 1956) and may reflect the onset of maturation.

Conclusion

The sediments of Site 480 are laminated diatomites, rich in organic material, and contain biogenic gas (CH\textsubscript{4}, CO\textsubscript{2}, H\textsubscript{2}S, minor C\textsubscript{2}H\textsubscript{6}). The C\textsubscript{2}/C\textsubscript{1} of Site 480 increases more rapidly than at Site 479, possibly indicating a slightly higher maturation rate caused by a higher thermal gradient.

SITE 479 INORGANIC GEOCHEMISTRY

Interstitial Water Chemistry (Fig. 20)

Alkalinity and phosphate concentrations show large maxima at a depth of 15 meters and are the result of bacterial decomposition of organic carbon in these rapidly accumulated sediments. Of interest is the continuous increase in dissolved ammonia to a maximum of 26 mM at 220 meters. These large increases must be the result of the continued alteration of organic matter, presumably by methane-producing bacteria. Dissolved calcium shows a minimum, and dissolved magnesium shows a complex pattern. The sharp drop in magnesium at about 80 meters can be understood in terms of dolomite formation. Dissolved silica shows a steady state increase to 350 meters; below this depth, concentrations drop as a result of biogenic silica transformation reactions.

SITE 479 BIOSTRATIGRAPHY

The hemipelagic sediments recovered at Site 479 were rich in microfossils. Diatoms and silicoflagellates, generally well preserved, constituted the bulk of the fossil remains as far as Core 479-44; beneath this core, they disappear.

The coccoliths, less well preserved, occur inconsistently and in variable amounts; Cores 479-29 to 479-39 are barren of coccoliths. Radiolarians and benthic and planktonic foraminifers are minor components.

The diatoms and coccoliths indicate that the sediment section recovered at Site 479 is Pleistocene, but the planktonic foraminifers indicate uppermost Pliocene sediments in Core 479-44 to 479-47.

Tentatively, a late Pleistocene age (less than 400,000 y.) is assigned to Cores 479-1 through 479-25. Within the lower Pleistocene sequence, the Mesocena elliptica extinction datum (~0.7 m.y.) does occur in Core 479-32,CC, and the first occurrence datum (~0.93 m.y.) occurs in Core 479-39,CC.

Nannofossils

The late Pleistocene sediments recovered at Site 479 were generally poor in calcareous nannofossils. Because of their poor preservation, scarcity, and low diversity, the coccoliths do not allow a reliable biostratigraphic subdivision at this site. On the basis of the characteristics of the coccolith assemblages, the section is divided...
The diatom assemblages were dominated by a meroplanktonic component consisting of Actinocyclus ehenbergii, Stephanopyxis turris, A. undulatus a.o. Assemblages varied greatly within short intervals, representative of postulated (Schuette and Schrader, 1978a) species succession in sediments underlying coastal upwelling. A laminated section in Section 479-33,CC was sampled in detail and within 5 mm revealed the following assemblages: (1) Thalassiosira oestrupii (over 90%); (2) T. oestrupii (— 50%) and oceanic component (— 20%); and (3) S. turris with almost no Chaetoceros bristle fragments nor spores. Similarly, a high variation within the varved interval at Core 479-36 was observed. An increase in the oceanic component with Pseudoeunotia doliolus and Rhizosolenia bergonii commonly occurred also and will be useful in determining the influence of oceanic Pacific waters at distinct intervals.

Displaced marine benthic species were observed frequently throughout this site, whereas no displaced freshwater diatoms were found. Reworked, older index fossils were observed only in Section 479-35,CC with abundant Rhizosolenia barboi and R. curvirostris. This datum, representing the evolutionary transition, is estab-
lished in the North Pacific near the Pliocene/Pleistocene boundary. Both species do occur only in colder environments, and thus far no clue is in hand to interpret their occurrence.

The *Nitzschia* fossils datum was not observed at this site. The *Mesocena elliptica* extinction datum, which is placed at around 0.7 m.y., did occur in Section 479-32, CC and the first occurrence datum, ~0.93 m.y., in Section 479-39,CC. No other datum levels, either Equatorial Pacific or North Pacific, were observed except the extinction level of *N. reinholdii*, which is time transgressive from high to low latitudes. Thus, the oldest diatom-bearing sediments in Core 479-43 might not be older than about 1.7 m.y. (extinction level of *R. matuyamai*). Other datum levels using abundance of species and bimodal mean diameter size distribution of *Coscinodiscus nodulifer* will be established on shore.

**Radiolarians**

Only seven samples were analyzed from Site 479: Section 479-1,CC, and Cores 479-10, 479-20, 479-31, 479-37, 479-40, and 479-47. Radiolarian remains are strongly diluted by diatom frustules in the sediments.

In the samples *Ommatodiscus* sp. (Benson, 1966), *Teocalyptra davisiann*, *Dictyocoryne truncatum*, *Tetraphyle octacantha*, and *Euchitonia furcata* were among the common species.

In Section 479-31,CC, two incomplete reworked specimens of *Ommatarius avitus* were observed. This species became extinct during the middle Pliocene in the equatorial Pacific.

**Foraminifers**

Two (or three) cooler intervals are seen in the planktonic foraminiferal fauna in the section above Core 479-28. The lowest part of the section at this site, from Core 479-42 to 479-47, is indicated as the latest Pliocene by the co-occurrence of *Globigerinoides obliquus*, *G. bollii*, and *Pulviniatina obliquiloculata* (s.s.). The benthic fauna is characterized by the abundant occurrence of several species of genus *Bolivina* throughout the section; *Bolivina seminuda*, *B. subadvena*, *B. spissa*, *B. argentea*, and so forth. *Buliminella tenuata* and *Cassidulina cushmani* are also abundant.

**SITE 480 BIOSTRATIGRAPHY**

**Nannofossils**

The common occurrence and better preservation of the coccoliths in the detrital clayey laminae at Site 480 is surprising when compared with the absence of nannofossils in the diatomaceous laminae. The latter are interpreted as being accumulations derived from biogenic blooms caused by upwelling. The calcareous nannofossil assemblages at Site 480 are similar to those found in sediments of comparable age (late Pleistocene) at previous sites in the Guaymas Basin.

**Foraminifers**

One or two cooler intervals occur though the occurrence of planktonic foraminifera is scattered. As at Site 479, the benthic foraminifers are dominated by several species of *Bolivina*.

**Diatoms and Silicoflagellates**

A total of 152 meters of hemipelagic sediments were continuously piston cored; recovery was generally greater than 80%. The section can visually be subdivided into finely laminated and homogeneous intervals. The spacing of these intervals seems not to be cyclic. All sediments except for a few narrow sand and turbidite layers are very rich in diatoms and silicoflagellates and offer a unique opportunity to study in detail floral changes and relate them to local and over-regional climatic events.

Since the shipboard scientific party decided not to disturb the collected section by the usual plastic cylinder punching method but rather to postpone detailed sampling to a later shore-lab date, only the core catcher samples, in addition to a few sedimentological smear slides, were available for shipboard study.

The varved sediments present the fortunate opportunity of defining an absolute chronology obtainable by counting the annual laminae pairs. The first test thus was to confirm if indeed laminated sediments in the deeper cores might represent varves as defined by Calvert (1964) and amended later by Baumgartner et al. (1979).

A 0.5-cm-thick piece of laminated diatomaceous mud was used from Section 480-29,CC. We sliced into its white and greenish laminae as accurately as possible and mounted it separately. A total of 26 laminae were separated and microscopically analyzed for their diatom content. The following sequence was observed (Fig. 21).

1) *Greenish with sublaminae* (a); thicker than (b); opal phytoplankton preservation excellent, mostly consisting of *Chaetoceros* spores, meroplanktic species, *Thalassiosira nitzschioides* and to a much lower content of oceanic species, with abundant clay.

2) *White layers without sublaminae* (b); opal phytoplankton preservation poor, mostly consisting of *Coscinodiscus nodulifer*, without clay.

On the basis of sediments underlying recent coastal upwelling areas off Peru (Schuette and Schrader, 1981a) and off southwest Africa (Schuette and Schrader, 1981b) and containing similar flora, the greenish laminae with well-preserved meroplanktic diatoms are interpreted to represent coastal upwelling seasons, whereas the white laminae with poor to moderate, almost monospecific,
assemblages (C. nodulifer in Section 480-29,CC and C. cf. oculus-iridis in Section 480-16,CC) represent non-upwelling seasons. The terms “coastal-upwelling” and “nonupwelling” influenced sediments will be used strictly in the later part of this chapter. An attempt to relate these to climatic patterns will be discussed in detail in the discussion and summary.

The greenish coastal-upwelling laminae (Type a) are generally (in Sections 480-29,CC and 480-16,CC) thicker than the white ones and contain, in addition to the well-preserved diatom component, a substantial amount of clay (up to 60%), whereas the white, nonupwelling laminae (Type b) are thinner and contain almost no clay or silty terrigenous components. Frequently, calcareous nannofossils were observed together with the white laminae (for discussion see below); they should represent times of lower sedimentation.

The higher number of laminae distinguished visually in Core 480-29,CC showed the following separation, using the above-outlined criteria: (1) non-upwelling, (2) upwelling, (3) non-upwelling, (4) upwelling, (5) non-upwelling, (6,7,8) upwelling, (9) non-upwelling, (10,11) upwelling, (12) non-upwelling, (13) upwelling, (14,15) non-upwelling, (16) upwelling, (17) non-upwelling, (18) upwelling, (19) non-upwelling, (20) upwelling, (21,22,23) non-upwelling, and (24,25,26) upwelling. In summary, a total of nine non-upwelling seasons, and a total of nine upwelling seasons could be separated (Fig. 21).

The lamination within the greenish intervals is faint and represents fluctuation and species succession during the highly variable upwelling season. As typical populations within these “upwelling” layers, the following could be separated: (1) Chaetoceros spores (< 80%), meroplanktic component (~ 10%); (2) Pseudoenotia doliolus (40%), Chaetoceros spores (30%); (3) Chaetoceros spores (50%), Thalassionema nitzschioides (thin) (30%), Coscinodiscus nodulifer (10%); (4) Chaetoceros spores (40%), Thalassiosira oestrupii (20%).

The white layers are generally homogeneous and contain only one or two species—Coscinodiscus nodulifer and/or Pseudoenotia doliolus. Because the size distribution of C. nodulifer seems to be climatically controlled, these layers offer a good chance to correlate the unimodal and/or bimodal size distribution in the Gulf to the eastern equatorial Pacific, where it has been tied to the δ18O stratigraphy (Burckle and McLaughlin, 1976).

Four smear slides from a homogeneous section contained the following distinct floras:

1) 480-P4-1, 70 cm: C. nodulifer A, P. doliolus T, no marine benthic forms, and no fresh-water forms, Preservation was poor (representing a non-upwelling season).

2) 480-P4-2, 15 cm: Chaetoceros spores C, P. doliolus F, T. oestrupii F, R. semispina R, marine benthic forms (excellently preserved) ~2%, and fresh-water forms ~1%. Preservation excellent (representing an upwelling season).

3) 480-P4-2, 70 cm: Thalassionema nitzschioides C, Cyclotella striata F, Chaetoceros spores F, P. doliolus F, Coscinodiscus nodulifer R, no fresh-water forms, trace of marine benthic forms, poorly preserved. Preservation moderate (representing a mixture of an upwelling and a non-upwelling season).

4) 480-P4-3, 70 cm: C. nodulifer A, no fresh-water forms, marine benthic forms T (poorly preserved). Preservation poor (representing a non-upwelling season).

It seems that the homogeneous sections do contain a similar upwelling/non-upwelling diatomaceous signal. These signals might be visually disturbed by a rather constant supply of terrigenous material which blurs the lamination. On the other hand, such sharply expressed signals cannot be preserved in a bioturbated record; thus it might be postulated that parts of the homogeneous section are not bioturbated, or only bioturbated in surface layers. Calcareous nannoplankton, because of its oceanic habitat and its controversial environmental requirements compared to diatoms, should be common in those intervals interpreted as non-upwelling based on diatoms. The following percentages were found on the above-mentioned samples: (1) with ~ 10% and (4) with ~ 12% nannofossils, as determined by smear-slide sedimentological description.

Another, ~1-cm-thick slab of Core 480-16,CC revealed 12 distinct white and 11 greenish layers; again, the greenish layers were generally 50% thicker and showed again a sublamination similar to the one found in Core 480-29,CC.

Another distinct feature was the occurrence of a monolayer of fish scales at the bottom of each greenish layer; this became apparent on dry laminated pieces, whereas microscopic tests on the original wet samples did not readily resolve this structure (Fig. 22). The explanation for this type of cyclic occurrence of fish scales might be the depletion of available phytoplankton at the termination of an upwelling cycle, and change to more-uniform, constant oceanic conditions.

Three samples were available from Core 480-14:

1) 480-P14-1, 100 cm: clayey diatomaceous ooze: T. nitzschioides A, Thalassiosira oestrupii F, Chaetoceros spores F, Octactis pulchra R, Cyclotella striata R, preservation of opal phytoplankton excellent, with Skeletomena costatum as one index. Surprisingly, this sample contained about 10% calcareous nannoplankton and seems to be different from other findings (compare discussion above).

Figure 22. Microstructure of couplets of laminae, Cores 480-16 and 29,CC, illustrating monolayer of fish scales on top of pure diatomite layer with oceanic species: Coscinodiscus nodulifer in 29,CC, and C. oculus-iridis(?) in 16,CC.
2) 480-P14-1, 110 cm: dark diatomaceous ooze with volcanic glass: *Thalassionema nitzschioides* A, *Chaetoceros* spores R, *O. pulchra* F, meroplanktic component T, preservation of opal phytoplankton excellent. Again, similar to (1) about 7 to 8% calcareous nanofossil was observed.


The homogeneous interval in Sections 480-14-2 and 480-14-3 again might carry the seasonal upwelling/non-assemblage, probably an upwelling layer. On the other hand, the relatively high percentages of calcareous nano-fossils might serve as an indication of decreased coastal upwelling and a decrease in depth of the upper oxygen-minimum boundary, which ultimately allows for bioturbation.

Another suite of samples was examined:


3) 480-P21-1, 134 cm: calcareous claystone: *Coscinodiscus nodulifer* A, poorly preserved assemblage, representing time of low productivity and warm oceanic conditions, probably a non-upwelling layer.


6) 480-P26-1, 83.4 cm: diatomaceous ooze white(?) layer (70% diatoms): *Thalassionema nitzschioides* A, *P. doliolus* F, *Thalassiosira oestrupii* F, *Chaetoceros* spores few, preservation excellent, probably an upper-layer, with only little terrigenous input (25% clay).

7) 480-P26-1, 83.6 cm: muddy diatomaceous ooze, dark layer: *T. oestrupii* C, *Thalassionema nitzschioides* C, *A. undulatus* F, preservation excellent, probably an upwelling layer (50% clay).

Diatom and silicoflagellate species of equatorial to subtropical habitat (as defined in Baumgartner et al., 1979) were found frequently at distinct horizons (P21, P15, P14) (*O. pulchra*, *P. doliolus*, *Stephanopyxis palmeriana*, *Thalassiosira lineata*); cold-water species such as *Coscinodiscus margina tus*, *T. angust-lineata*, *Dictyo- ocha epidon* were found on the other hand only sporadically.

So far, no trend in an enrichment of cold- or warm-water species has been detected. Biostratigraphic index species were observed only in 480-29,CC, where about 1% of the *P. doliolus* assemblage consisted of *Nitzschia fossils*, which became extinct in the equatorial Pacific around 0.26 Ma, and, if this datum level is synchronous in the Gulf, sediments below 480-29,CC should be older than 0.26 m.y. The exact position of this extinction datum cannot be defined yet, because of the lack of available material uphole. On the other hand, this type of rare occurrence, one individual out of 100 observed specimens, seems to be rather selective, especially in assemblages which do not carry a large number of *P. doliolus*.

**SITE 479 PHYSICAL PROPERTIES**

At Site 479, core disturbance by drilling and expanding gas was more intensive than at the other sites of Leg 64. The following cores were highly disturbed: 479-5 through 7, 479-11, 479-13 through 25. Core 479-34 contained drilling breccia. Small samples were taken for water content, porosity, and bulk density. Cores 479-2, 4, 30, 33, and 46 were empty. Downhole disturbances by gas decreased from Cores 479-28 and 29. Cores 479-38 through 47 were better preserved than those from the middle and upper part of the hole. From Core 479-32 downward it became difficult to use the "cheese cutter," but only the deepest core (479-47) had to be split entirely by the saw. Because of the many disturbed cores, a great part of the GRAPE measurements carried out on one or two sections of about half of all the cores cannot be evaluated.

Near the sea bottom, the partially varved sediments rich in diatoms have very high water contents (~80%) and porosities (~90%), and extremely low bulk densities (1.1 g/cm³; Fig. 23). Down to about 80 meters, the physical properties change more or less in the common way, and then appear to become rather stable downhole to about 380 meters. This signifies that, down to this depth range, the relatively slowly increasing effective overburden pressure (see summary of physical properties, Einsele, this volume, Pt. 2) does not affect the sediments very much. Further evidence for this statement is the observation that varved sediments at 350 to 370 meters depth still have water contents and porosities as high as at 50 meters sub-bottom (55-60% and 70-80%, respectively). These findings are confirmed by the density log, as well as by GRAPE measurements. The scatter of data in the depth range from 0 to 380 meters is caused mainly by changing composition of the sediments. Varved beds rich in biogenic silica have low average grain densities (often between 2.3 and 2.4 g/cm³) and are less compacted than dark mud layers containing higher amounts of terrigenous material (see Fig. 23 and results for Site 480), but because of the bad preservation of most of the cores, the relationship of the samples to one of these two groups often could not be recognized. Therefore, the trend lines shown in Figure 23 represent more or less the average physical properties of the lighter olive-gray varved and darker homogeneous beds.

From about 370 to 390 meters downhole, the physical properties change considerably. These changes may be
Figure 23. Mass physical properties, shrinkage, and content of opaline silica in sediments from Hole 479. The strong change of all properties at about 400 meters is related to an unconformity, as found in the seismic records. Smaller deviations of single data points from the general trend lines are mainly due to sampling from mud turbidites (T), or from layers rich in diatoms (i.e., about 350 to 360 m). Shear strength values marked ? are probably too low. (Closed symbols are cylinder samples. Open symbols are chunk samples.)
related in part to an unconformity in the section at approximately this depth. Water content decreases by 15 to 20% to 30 to 35%, porosity decreases by 10 to 15% to 55 to 60%, and bulk density increases by 0.2 to 0.3 g/cm³ to 1.7 to 1.8 g/cm³. These values correspond to those at 280 to 300 meters depth in Hole 474A, where at 250 to 260 meters depth already the same effective overburden pressure is reached as in Hole 479 at 380 meters depth (see Eisensele, this volume, Pt. 2). The marked change in compaction at Hole 479 probably is caused mainly by the decrease of biogenic siliceous fossils (both in the original composition and by diagenesis), which can be derived also from the average grain densities (Fig. 23). However, other changes in the composition of the sediments also may have some influence. The higher compaction of the sediments in the lowermost part of the hole is confirmed by the density log (although the absolute figures of this log appear to be incorrect), and the GRAPE measurements.

Vane shear strength increases more slowly versus depth than at previous sites. This may be partly due to the low bulk density of the silica-rich varved layers, which cannot build up the same overburden pressure as terrigenous deposits at the corresponding depth. Furthermore, these deposits possibly develop only low cohesion because of their low content in clay minerals. But some of the values measured are certainly too low. At 360 meters and farther downhole, vane shear strength values between 1400 and 1500 g/cm² appear to be “normal.”

From the few values determined for shrinkage it can be seen (Fig. 23) that the resistance of the grain framework against the forces of shrinkage (suction) increases downhole. Low values of shrinkage must be related primarily to diagenetic changes, but to some extent they also reflect the low content of clay minerals in layers rich in biogenic silica.

Some values of laboratory measurements of sonic velocity and bulk density are listed in Table 3.

### SITE 480 PHYSICAL PROPERTIES

By using the newly developed piston corer in combination with the drilling pipe (see above), most of the cores were excellently preserved. Usually only a zone of less than 3 mm along the contact with the core liner was disturbed. It would have been a rare opportunity to determine physical properties on these cores, but they were reserved for special studies on varves. Therefore, we took no samples from the core sections, except from Sections 480-P1-1 and 2. All the other samples came from the core catcher of these piston cores and were rather disturbed and contorted. Therefore, we probed only with small cylinders (5 cm³) and did not carry out vane tests.

Nevertheless, the physical-property data from Hole 480 yielded some information additional to the results at Site 479. In contrast to the badly preserved cores at the previous site, here it was possible to distinguish between relatively light olive-gray varved diatomaceous ooze and more or less homogeneous dark-gray core sections (clay-rich layers or mud turbidites). At all investigated depths, the physical properties of the dark beds differ considerably from those of the varved sections. The trend lines in Figure 24 mainly represent the varved sections, whereas the dark beds show lower water contents and porosities, but higher bulk densities and average grain densities. For that reason, the trend lines for the varved beds of Hole 480 start near the surface at even higher water contents (80-85%) and porosities (90-95%), and lower bulk densities (~1.1 g/cm³) than in Hole 479. Principally, the trend lines of physical properties versus depth are similar in both holes. From 50 to 70 meters downhole, the values appear to become rather stable, as in Hole 479. Shrinkage is rather low in some light-colored varved beds, whereas the darker beds and some turbidites show relatively high shrinkage at the corresponding depth. The content of opaline silica, as determined from average grain densities (see Site 474 report), is plotted in Figure 24.

On a limited number of sections, GRAPE measurements were performed. Because of the small core disturbances, the results are very good. The records reliably show the location of varved or homogeneous dark sections. From Core 479-P8 to the bottom of the hole, the varved sections consistently have GRAPE bulk densities of 1.2 to 1.3 g/cm³ (in the lowermost sections, up to 1.35 g/cm³), whereas the dark beds are considerably denser (1.45-1.6 g/cm³). These measurements agree well with the bulk densities determined by gravimetric methods (Fig. 24).

Laboratory measurements of sonic velocity could not be carried out.

Conclusions for Sites 479 and 480:

1) The varved beds rich in biogenic silica keep up very high water content and porosities in combination with very low bulk densities, down to at least 350 meters below the sediment surface.

2) The gain of shear strength in relation to burial depth appears to be smaller in diatomaceous ooze than in sediments with higher amounts of clay and other terrigenous material.

3) Shrinkage, an indicator of the onset of diagenesis, can drop to 5 to 10% even at shallow depth (<100 m) in sediments rich in biogenic silica.

4) Relatively strong variations in the relationship between physical properties and depth are caused by changing input of terrigenous material into the “host” sedimentation, consisting mainly of diatomaceous ooze. This can be clearly seen on the GRAPE record and the density log (Site 479).
Figure 24. Mass physical properties, shrinkage, and content of opaline silica in sediments from Hole 480. (T) = turbidites, (d) = dark layers rich in clay.

SITE 479 HEAT FLOW

The undisturbed formation temperature at Site 479 was calculated from the final temperatures measured by the two logging runs, using the formula of Dowdle and Cobb (1974). In their notation, the measured temperature

\[ T_{ws} = T_i - C \log \frac{t_k + \Delta t}{\Delta t} \]

where \( T_i \) is the formation temperature, \( C \) a constant to be determined, \( t_k \) is the circulation time, and \( \Delta t \) is the time after circulation ceased. Because we have two sets of values of \( \Delta t \) and \( T_{ws} \), we solve for \( C \) and \( T_i \). For Site 479 these values are

- Run 1: \( T_{ws} = 37.5°C \)
  - \( \Delta t = 2 \) hr
- Run 2: \( T_{ws} = 47.3°C \)
  - \( \Delta t = 12 \) hr

Calculations for circulation time \( t_k \) of 2 hr and 1 hr gave nearly identical results; the bottomhole temperature (BHT) came out \( T_i = 49.5°C \). The temperature at the mudline is 7.9°C, leaving a difference of 41.60°C. Dividing by the length of the hole (434 m) yields a gradient of 95.9°C/km.

Thermal conductivity is calculated from the lithology and some measurements on samples (Table 4). Because the diatomaceous sediments are likely to be more conducting in situ, the value 2.26 was adopted instead of 2.14 for the soft sediments from 0 to 360 meters. From 360 to 440 meters, the sediments become increasingly indurated to claystone, for which we assigned a conductivity of 4.04. The average conductivity for the whole rock column is

\[ <K> = \left(1 + \frac{360}{2.26} + \frac{440}{4.04}\right)^{-1} = 2.46 \text{ mccl/cm s°C} \]

The heat flow in Site 479 thus is 2.36 HFU.

Three temperatures were taken with the Uyeda instrument at this site. When the probe was in the sediment, the one at 98 meters gave a temperature nearly constant with time, the one at 165 meters gave a curve with decreasing slope, and the temperature at the deepest at 231 meters was rising with a constant slope. For the shallowest penetration, the temperature at which the curve leveled off was taken as the formation temperature. In the case of the measurement at 165 meters, it was estimated that the formation temperature was 1°C higher than the last-measured temperature. For the deepest penetration, 2°C was added to the last-measured temperature; the conductivity was taken to be 2.26 for all three measurements. Table 5 gives the details of the calculations. This is 88% of the value given by the bottomhole temperature from logging.

Comparison of the values from the Japanese instrument with those from bottomhole temperatures is essential to establish the best way of interpreting its readings. In any case, all logging tools should be equipped with maximum thermometers according to standard practice.
CORRELATION OF DRILLING RESULTS WITH SEISMIC AND DOWNHOLE LOGGING DATA, SITES 479 AND 480

Site 479 was proposed on the basis of a 1967 survey line, near a new SIO multichannel lines. Figure 4 shows the survey made during the selection of Site 479 with Glomar Challenger. We will return to a discussion of these records shortly.

After completion of Site 479, we transited directly to the preselected location of Site 480, running only the 3.5-kHz echo sounder (Fig. 25). Thus, we could directly correlate the shallow reflectors at the two sites and attempt to correlate with the drilling results. These correlations are listed and explained in Table 6.

Examples of the seismic-reflection records from the Glomar Challenger survey are shown in Figures 26 through 28. Note the important regional unconformity, reflector K, drawn into each section. The overlying strata downlap onto this surface in a progressive manner, indicating that this has been a growth structure uplifted during deposition of much of the overlying section. In Figure 29, this unconformity is tied into the section which passes directly into Site 479, where we penetrated this horizon. An enlargement of the 5-second-sweep record of Line D is shown in Figure 27, marked with some of the unconformities and reflecting horizons discussed below and shown in Table 6. The 2-second-sweep record from the same line is shown in Figure 29. Note that the drill site is not located on Line D; it is shown projected approximately onto the line in order to demonstrate its position with respect to the synclinal axis. Some of the same reflecting horizons are shown carried into Line B (Fig. 30) across the location of Site 480, which penetrated only 152 meters into the same sedimentary sequence drilled at Site 479.

The reflectors are listed in Table 6, but will also be described somewhat more fully below. In making these correlations, we have attempted to assume reasonable seismic velocities and gently to force fits between lithology and the reflecting horizons. We have no reliable velocity information whatsoever here. The uppermost multichannel move-out velocity is calculated for the upper 650 meters; the downhole sonic-log velocities appear at face value to be too low; the sediments were too gassy for reliable laboratory measurements; and we have no sonobuoy data in this vicinity. The velocities we have assumed are indicated in Table 6. Furthermore, these relatively low-frequency seismic records are sometimes ambiguous and permit some license in selecting a recorded horizon phase to measure and correlate, both for the sea floor and sub-bottom reflectors. The correlations are, therefore, to a certain extent what we think they should be.

The shallow reflectors in the 3.5-kHz records correlate well from site to site, but not necessarily as well with lithologies in the holes (Fig. 25). The best correlation is reflectors C and D, which delineate a sandy zone in the cores, and which also match a shallow unconformity in the 2-second records. This is an erosional surface with truncated underlying strata and some shelf-edge (marginal-plateau edge) erosion in Line D. This may represent a Pleistocene low sea-level stand, although the indications of oxygen minimum above and below this level and the present water depth would make subaerial exposure somewhat improbable.

Horizon E (Figs. 25 and 28) is also an erosional surface truncating underlying strata. It appears to correlate with either a sand layer at 96 meters or a dolomitic mudstone at 102 meters at Site 480, and it appears to correlate with a dolomite at Site 479. The mystery regarding

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**Table 4. Measurements of thermal conductivity.**

<table>
<thead>
<tr>
<th>Sample</th>
<th>$K$ (mcal/cm s °C)</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>478-26-1, 114-116</td>
<td>4.54</td>
<td>Basalt</td>
</tr>
<tr>
<td>29-1, 23-26</td>
<td>4.59</td>
<td>Basalt</td>
</tr>
<tr>
<td>41-5, 56-58</td>
<td>4.38</td>
<td>Basalt</td>
</tr>
<tr>
<td>49-3, 56-58</td>
<td>4.31</td>
<td>Basalt</td>
</tr>
<tr>
<td>54-3, 16-</td>
<td>3.80</td>
<td>Basalt</td>
</tr>
<tr>
<td>54-1, 5d</td>
<td>5.42</td>
<td>Basalt</td>
</tr>
<tr>
<td>54-4</td>
<td>4.85</td>
<td>Basalt</td>
</tr>
<tr>
<td>&lt;4.56&gt; ±0.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>479-1-1, 104-107</td>
<td>1.68</td>
<td>Soft sediment</td>
</tr>
<tr>
<td>1,CC</td>
<td>2.40</td>
<td></td>
</tr>
<tr>
<td>1,CC</td>
<td>2.28</td>
<td></td>
</tr>
<tr>
<td>14, bottom</td>
<td>1.73</td>
<td></td>
</tr>
<tr>
<td>23-7, 3-12</td>
<td>1.97</td>
<td></td>
</tr>
<tr>
<td>3-7, 3-12</td>
<td>2.06</td>
<td></td>
</tr>
<tr>
<td>12,CC</td>
<td>2.15</td>
<td></td>
</tr>
<tr>
<td>29-1, 23-26</td>
<td>4.04</td>
<td>Calcified rock</td>
</tr>
<tr>
<td>29-1, 38-43</td>
<td>2.28</td>
<td>Soft sediment</td>
</tr>
<tr>
<td>37-2, 0-10</td>
<td>2.62</td>
<td></td>
</tr>
<tr>
<td>40-2, 62-69</td>
<td>2.21</td>
<td></td>
</tr>
<tr>
<td>&lt;2.14&gt; ±0.29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>481-P2-2, 50-55</td>
<td>1.76</td>
<td>Av. of 3 meas. spongy diatomaceous ooze expanded by gas</td>
</tr>
<tr>
<td>P4-1, 67-74</td>
<td>1.75</td>
<td>Av. of 2 meas. spongy diatomaceous ooze expanded by gas</td>
</tr>
<tr>
<td>P8-3, 94-100</td>
<td>1.94</td>
<td>Av. of 2 meas. spongy diatomaceous ooze expanded by gas</td>
</tr>
<tr>
<td>P11-3,</td>
<td>2.36</td>
<td>Av. of 2 meas. spongy diatomaceous ooze expanded by gas</td>
</tr>
<tr>
<td>1-2, 86-93</td>
<td>1.95</td>
<td>Av. of 6 meas. ±0.15 spongy diatomaceous ooze expanded by gas</td>
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<tr>
<td>481A-6-4, 23-24</td>
<td>2.48</td>
<td>Av. of 2 pieces vesicular basalt</td>
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<tr>
<td>12-6, 45-50</td>
<td>2.58</td>
<td>Firm gray silt, not malleable</td>
</tr>
<tr>
<td>28-2, 36-41</td>
<td>2.46</td>
<td></td>
</tr>
<tr>
<td>22-5, 4-8</td>
<td>2.34</td>
<td></td>
</tr>
<tr>
<td>31-1,CC</td>
<td>3.68</td>
<td></td>
</tr>
</tbody>
</table>

**Table 5. Measured temperatures and heat flow.**

<table>
<thead>
<tr>
<th>Sub-bottom Depth (m)</th>
<th>Measured Temperature (°C)</th>
<th>Estimated Corrected Temperature (°C)</th>
<th>Mudline Temperature (°C)</th>
<th>Heat Flow (HFU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>98</td>
<td>14.0</td>
<td>14.0</td>
<td>6.5</td>
<td>1.73</td>
</tr>
<tr>
<td>165</td>
<td>23.0</td>
<td>24.0</td>
<td>6.4</td>
<td>2.42</td>
</tr>
<tr>
<td>231</td>
<td>26.0</td>
<td>28.0</td>
<td>6.6</td>
<td>2.09</td>
</tr>
<tr>
<td></td>
<td>&lt;2.08&gt; ±0.35</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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GUAYMAS BASIN SLOPE SITES
SITE 479
Water depth 747 m

SITE 480
Water depth 655 m

Figure 25. Correlation of drilling lithology and 3.5-kHz records from Sites 479 and 480. (See Table 6 for reflectors A–F.)
Figure 26. Reflecting Horizon K (Plio/Pleistocene contact) from Line A, *Glomar Challenger*, near Sites 479 and 480.

Figure 27. Correlation of drilling lithologies with 5-sec airgun reflection profile, Line D. Note that Site 479 is projected onto this section. (See Table 6 for reflectors G, H, K.)

Figure 28. Correlation of drilling lithologies and unconformities in 2-sec airgun reflection profile, Line D. (See Table 6 for reflectors D–K.)
Figure 30. Correlation of drilling lithologies, Site 480, with 2-sec air-gun reflection record, Line B; prominent unconformities also shown. (See Table 6 for reflectors D-J.)

Table 6. Correlation of seismic reflectors and lithology.

<table>
<thead>
<tr>
<th>Reflector</th>
<th>Sub-bottom Depth, Hole 479 (m)</th>
<th>Sub-bottom Depth, Hole 480 (m)</th>
<th>Assumed Reflection Velocity (m/s)</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>12</td>
<td>11</td>
<td>1.50</td>
<td>Holocene/Pleistocene contact; laminated-homogenous muds</td>
</tr>
<tr>
<td>B</td>
<td>26</td>
<td>26</td>
<td>1.50</td>
<td>Top of better-laminated muds</td>
</tr>
<tr>
<td>C</td>
<td>48</td>
<td>52</td>
<td>1.50</td>
<td>Top of sandy zone</td>
</tr>
<tr>
<td>D</td>
<td>53</td>
<td>63</td>
<td>1.50</td>
<td>Bottom of sandy and homogeneous zone, over better-laminated section</td>
</tr>
<tr>
<td>E</td>
<td>89</td>
<td>102</td>
<td>1.50</td>
<td>Sandy zone, correlating with erosional unconformity in airgun records, and/or dolomitic mudstone</td>
</tr>
<tr>
<td>F</td>
<td>142</td>
<td>115</td>
<td>1.50</td>
<td>Dolomite in 479, zone of no recovery in 480</td>
</tr>
<tr>
<td>G</td>
<td>140</td>
<td>—</td>
<td>1.50</td>
<td>Increase in gamma ray curve</td>
</tr>
<tr>
<td>H</td>
<td>214</td>
<td>—</td>
<td>1.50</td>
<td>Contact Unit 1/Unit II; Changes in geochemistry</td>
</tr>
<tr>
<td>I</td>
<td>240</td>
<td>—</td>
<td>1.55</td>
<td>Contact Unit II/Unit III; Increase in density log</td>
</tr>
<tr>
<td>J</td>
<td>290</td>
<td>—</td>
<td>1.53</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>364</td>
<td>—</td>
<td>1.55</td>
<td></td>
</tr>
</tbody>
</table>

Figure 29. Correlation of drilling lithologies, Site 479, with 2-sec air-gun reflection profile. (See Table 6 for reflectors D-K.)

This reflector is that in both Lines B and D another reflector appears to cross it at a location somewhat seaward of the site locations (Figs. 28 and 30).

Horizon G appears to subdivide the section into different characters of reflection of strata, but it cannot be related to the lithologies at this time. Horizon H serves the same function, but it can be quite definitely correlated with a jump upward in the trend of the natural-gamma-ray curve.

Horizon I appears to be of considerable significance. It coincides with the boundary between Lithologic Units 1 and 2, and it marks the level of pronounced changes in both organic and inorganic geochemistry. It appears to be an angular unconformity in Line D, but not so in Line B.

Reflector J is an easily recognized horizon in all lines of the survey, because it is a pronounced change in char-
character of reflections, and other strata onlap upon it. Horizon K is the level of the onlap unconformity in the 5-second records and appears to coincide with the boundary between Lithologic Subunits IB and IC (Pliocene/Pleistocene contact) and with a significant change in physical properties and density determined by the logging. We conclude that this horizon indicates the time of initiation of a period of uplift along the transform fault lying to the southwest.

One of the objectives of this pair of sites was structural history and a test of the thesis that it might be related to history of the transition from proto-Gulf to modern Gulf and/or history of movement along this transform. It is premature to come to any final conclusions at this time, but it would appear that this escarpment underwent uplift between the times of Horizons K and E, possibly continuing to the time of Horizon D. This span is from the beginning of Pleistocene time to about 100,000 years (or possibly to as late as 65,000 years). Uplift may have continued past this time, but slowly enough to permit the draping of this marginal plateau with pelagic and hemipelagic sediments.

Finally, it must be emphasized that we are examining here only the latest episodes in a much longer geological history of the proto-Gulf of California. This marine embayment was formed during the Miocene, and the sedimentary section near here may be as much as 3 s. This is discussed by Moore and Curray (this volume, Pt. 2).

**DOWNHOLE LOGGING FOR SITE 479**

Results of Site 479 downhole logging, compared to lithology, calcium carbonate, and physical properties, are shown in Figure 31. (Original tapes are available from storage at the DSDP Information Handling Group.)

**SUMMARY AND CONCLUSIONS, SITES 479 AND 480**

Sites 479 and 480 were selected for two primary objectives: first, to test the proto-Gulf concept and tectonic history of the central Gulf, and, second, to sample and study the varved diatomaceous sediments of the oxygen minimum in the central Gulf. Site 479, the first target, lies on a marginal plateau, above the escarpment of the transform fault bounding the northeast side of Guaymas Basin. This plateau is presumed to overlie proto-Gulf sediments and basement, and although not an ideal drilling target, it was the best which could be located on the basis of the existing survey network and which was acceptable to the Safety Panel. Part of the sediment section could be penetrated, although drilling was restricted to the thickest part of the section in the axis of a syncline, and basement could not be reached. This site, and as a backup, Site 480, lie in the oxygen minimum where piston cores had previously recovered laminated (varved?) diatomaceous sediments.

Only Quaternary sediments were recovered in these two holes, and despite great difference in degree of disturbance, we conclude that the upper 152 meters is duplicated in the two holes. The column is divided into three units which do not differ greatly in lithologies. The first unit, 0 to 250 meters, consists of rhythmically alternating laminae or varves of muddy diatomaceous ooze, with sparse layers of calcareous diatomaceous mudstone and sands. The varved part of the section will be discussed more fully later. The second unit, 250 to 355 meters, consists of the same muddy diatomaceous ooze varves, but with more frequent layers of calcareous mudstone. The third layer, 355 to 440 meters, consists of diatomaceous silty clay with frequent interlayers of calcareous diatomaceous mudstone. The three units are very similar, differing mainly in the proportion of calcareous-mudstone layers and in the relative abundance of diatoms, probably a function of diagenesis and consolidation. These sediments are mainly hemipelagic slope deposits, although a minor proportion of turbidites is also present.

These units can be recognized in a correlation with the seismic-reflection survey of the region of the two sites. The seismic section displays several reflecting horizons, some of which represent either erosional or onlap unconformities that can be related to the section recovered by drilling. Significant changes in geochemical and physical properties also occur across these unit boundaries. The C<sub>2</sub>/C<sub>1</sub> ratio increases sharply at the 250-meter level, and decreases at approximately 355 meters. Propane and isobutane reach maxima at about this latter level but isopentane continues to increase below that depth. These data indicate that at a greater depth the higher weight hydrocarbons (> C<sub>5</sub>) would be encountered and that the C<sub>5</sub>-C<sub>8</sub> hydrocarbons had diffused or distilled upward from below. These increases and further anticipated increases led us to our decision to terminate Hole 479 at 440 meters. Heat flow measured in Hole 479 was 2.36 HFU.

The high sedimentation rates of organic-carbon-rich and siliceous sediments lead to high alkalinities and the highest ammonia concentrations recorded to date, the latter peaking at about 250 meters. Decrease in dissolved-magnesium concentrations suggests uptake into carbonate sediments and dolomitization of nanofossil carbonates at 70 meters, and dolomites occur below this depth. Dissolved silica increases with depth, correlating with disappearance of diatoms and increasing silification of the sediments.

Sediments from these holes have unusually high water contents (~80% near the sea floor) and porosities (~90%), and low bulk densities (1.1 g/cm<sup>3</sup>). These change rapidly with depth and level out between about 80 and 350 meters. Varved sediments at 350 meters still have water contents and porosities of 55 to 60% and 70 to 80%, respectively. From 340 to 380 meters, the depth range of an important unconformity and contact between Lithologic Sub-units IB and IC, there is a zone of even higher water content and porosity and lower bulk density, but below this level they decrease and increase more rapidly as expected.

Hole 480 was the first field test of the newly developed Serocki–Storms–Cameron hydraulic piston corer. This test was an unqualified technical and scientific success. Recovery for the 152-meter section averaged 80%, although it was generally about 90%, with zero or near zero recovery in a few sections now believed to be sands.
The result was recovery of a unique set of almost undisturbed cores of laminated (varved?) diatomaceous sediments previously sampled here in the oxygen minimum only by normal gravity and piston cores. Because this set of cores is so unique and potentially so valuable for study of climatology and other environmental changes in this area, the shipboard scientific party has refrained from sampling more than the core catcher samples in order to preserve the cores for varve studies on shore, which will require intact working halves of the cores. We are furthermore proposing to DSDP and NSF that these cores be curated and samples distributed in a special way.

Origin of these varves has been debated previously in the literature, and the debate has continued aboard Glomar Challenger, this time based on a much longer record, although with only minimal study because of our self-imposed restrictions on sampling. Two principal environmental controls have been responsible for formation and preservation of the laminations, which we believe to be varves, or annual laminae couples. First is a seasonal fluctuation in type of sediment deposited, and second is the oxygen minimum, which limits the number of burrowing organisms.

The laminae couples have dark laminae containing generally >60% clay and <20% diatoms, and light-colored laminae containing >60% diatoms. One seasonal influence is rainfall, concentrated in the drainage areas for this part of the Gulf in July, August, and September, with a minor mode in November and December. The second seasonal influence is the wind system, which controls upwelling, one of the major controls over diatom and silicoflagellate blooms. Upwelling and blooming on this northeast side of the Gulf should occur with the prevailing northerly winds from about November through April. At first examination, these influences would appear to be in phase to produce the observed laminae pairs: the dark layers during the rainy season, and the light layers during the upwelling-bloom season. Detailed observations of the flora, however, appear to contradict this simple explanation, because the species believed to be characteristic of blooms occur predominantly in the dark layers, and the oceanic forms of light-colored layers commonly are almost monospecific. Origin of the varves remains an open question requiring detailed studies we have not yet permitted ourselves to do.

Sequences of varves alternate with homogeneous sections of the cores. We assume that these homogeneous sections may represent bioturbated zones representing times when the oxygen minimum did not impinge on the sea floor, but a final interpretation must await shorebased studies with X-radiographs of the cores. A possible explanation is that the periods of migration or destruction of the oxygen minimum coincide with glacial low stands of sea level.

We have estimated two possible chronologies of the varved and homogeneous sections, based on different assumptions. Direct varve counts appear to give higher rates of sediment accumulation than paleontological zonation boundaries, but either chronology can be forced to fit glacial versus interglacial stages, sea-level fluctuation, and oxygen-isotope curves. Several possibilities occur to us as explanations for the difference between the two chronologies. The "varves" may not strictly represent 1-year periods, and we may not be able to differentiate the very fine laminae deposited during periods of drought. A second possibility is that the homogeneous sections might represent periods of much slower rate of sediment accumulation, although if these are periods of lowered sea level, they should represent higher sedimentation rates. Finally, a third possibility is that significant amounts of section are missing at some of the unconformities distinguished in the seismic-reflection records.

The unconformities in the seismic records are related to uplift associated with the transform fault. Some of them show onlap relations of the overlying strata only, but a few of them show truncation and erosion of a part of the underlying section. We cannot estimate how much removal of section might have occurred, but we judge that it could not have been very much, because neither site is located on the uplifted flank of the syncline above the fault.

Two of the objectives of these sites were accomplished, namely sampling of the varved sediments and dating the folding and uplift. The important objective of learning about the nature and history of the proto-Gulf could not have been accomplished at this site without penetration into the sediment section much deeper than safety would permit. Basement of this part of the proto-Gulf must remain an unknown, pending further work, which might be geophysics, dredging, or drilling.

REFERENCES
Benson, R. N., 1966. Recent Radiolaria from the Gulf of California [Ph.D. diss.]. University of Minnesota.
Figure 31. Results of Site 479 downhole logging, compared to lithology, calcium carbonate, and physical properties.


Figure 31. (Continued).
SITE 479 HOLE
CORE 1 CORED INTERVAL 0.0-3.0 m
LITHOLOGIC DESCRIPTION
Moderate olive brown (5Y 4/4) MUDDY DIATOMACEOUS OOZE with some slightly lighter pale olive (10Y 6/2) layering strongly with H2S odor and gelatinous consistency. Gas rupturing occurs.
SMEAR SLIDE SUMMARY
Feldspar
Clay
Radiolarians
Sponge Spicule
CARBONATE BOMB: 1-130 = 3%
Note: Site 479, Core 2, 3.0-12.5 m: No Recovery.

SITE 479 HOLE
CORE 2 CORED INTERVAL 12.5-22.0 m
C 14 SAMPLE 5Y4/4
LITHOLOGIC DESCRIPTION
Moderately to intensely disturbed, moderate olive brown (5Y 4/4) DIATOMACEOUS MUD with minor traces (10Y 6/2) mm-scale interfering of DIATOM gas pockets and spongy ruptured surface.
SMEAR SLIDE SUMMARY
1-128 3-47 3-75
Silt
Clay
COMPOSITION:
Quartz
Feldspar
Clay
Pyrite
Carbonate unmet
Sponge spicules
Silicoflagellates
CARBONATE BOMB: 2-99 = 3%
Note: Site 479, Core 4, 22.0-31.5 m: No Recovery.

SITE 479 HOLE
CORE 3 CORED INTERVAL 31.5-41.0 m
LITHOLOGIC DESCRIPTION
Intensely disturbed moderate olive brown (5Y 4/4) MUDDY DIATOMACEOUS OOZE TO DIATOM MUD. Generally homogenous layering visible. Surface ruptured, spongy from gas expansion. In Section 3, 90 cm traces of mm-scale matted dusky yellow to white DIATOM OOZE as evidence of rhythmic laminations. Section 4, 15 cm: large pelecypod shell fragment.
SMEAR SLIDE SUMMARY
1-100 3-60 4-91
(D) (D) (M)
TEXTURE:
Silt 10
Clay 90
COMPOSITION:
Quartz 5 4 2
Feldspar 2 4 -
Mica 1
Heavy minerals - - TR
Clay 55 40 20
Pyrite 4 4 1
Carbonate unspec. - - TR
Diatoms 35 40 75
Radiolarians TR
Sponge spicules 2 1
Silicoflagellates - 2 -
Plant debris 2 2 2
terrigenous components only
CARBONATE BOMB: 3-107 = 1%
LITHOLOGIC DESCRIPTION

**C-14 SAMPLE**

Highly disturbed, moderate silt clay (SY 4/2) MUDDY DIATOMACEOUS Ooze with numerous, very small-scale, patchy to discrete, horizontal sand layers. Disturbance types are very phyllosilicous, clayey with hollow clay, and no obvious laminar patterns.

Section 1, 0-5 cm is a lighter grayish clay (10Y 4/2) DIATOMACEOUS Ooze.

SAND layers contain only tenuous, class well-washed of time. May indicate local presence of reworked debris. Slight, non-rectangular. Sand occurs mainly in the form of dispersed sand (SY 4/2) and is not in plug. Feathers (SY 3/2), quartz (SY 6/4), and feldspar (SY 4/2) are the main components. Densely set, translucent and opaque (SY 3/2). Poorly fresh to weathered and rock fragments (SY 3/2).

SMEAR SLIDE SUMMARY

<table>
<thead>
<tr>
<th>TEXTURE:</th>
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<tbody>
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</tr>
<tr>
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</tr>
<tr>
<td></td>
<td>Siliciclastic</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Foraminifers</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Other fossils</td>
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</tr>
<tr>
<td></td>
<td>Total</td>
<td>99</td>
</tr>
</tbody>
</table>

CARBONATE BOMB: 5-100 = 0%

**SY 4/4**

TEXTURE: Silt 11%
Clay 89%
COMPOSITION: Quartz 5%
Feldspar 5%
Clay 46%
Pyrite 2%
Diatoms 4%
Silicoflagellates 2%
Plant debris 1%
Foraminifers 2%
Other fossils 1%

CARBONATE BOMB: 5-100 = 0%

Highly disturbed, very uniform, moderate silt clay (SY 4/2) MUDDY DIATOMACEOUS Ooze with very small-scale, almost imperceptible sand laminae. A disturbed lamina above sand at Section 4, 70 cm is a thin layer of medium gray, silt clay (SY 4/2) with a gradual contrast. In Sections 5 and 6, scattered tufts of plant debris mixed laminae of DIATOM Ooze.

SMEAR SLIDE SUMMARY

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<thead>
<tr>
<th>TEXTURE:</th>
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<td>Quartz</td>
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<td>Feldspar</td>
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<tr>
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<td>Clay</td>
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</tr>
<tr>
<td></td>
<td>Pyrite</td>
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</tr>
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<td></td>
<td>Diatoms</td>
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</tr>
<tr>
<td></td>
<td>Silicoflagellates</td>
<td>2</td>
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<tr>
<td></td>
<td>Plant debris</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Other fossils</td>
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</tr>
</tbody>
</table>

CARBONATE BOMB: 5-100 = 0%
SITE 479 HOLE CORE 9 CORED INTERVAL 69.5–70.0 m

LITHOLOGIC DESCRIPTION

Very deformed, grainy, silty (5Y 6/5) to moderate clay (7.5Y 5/4) diatomaceous ooze to muddy diatomaceous ooze (lithology 7). Multiple gas pockets and coarse surface. No H₂S odor; traces of laminations obliterated. A few faint-relief dark intercalations in sections 2 and 3 and slight darkening down core. Above Section 8, 8 cm of medium gray sand.

SMEAR SLIDE SUMMARY

TEXTURE:
Clay 10
Silt 10
Organic 5
Non-organics 2
Other 1
CARBONATE BOMB: 3.99%
SITE 479 HOLE CORE 10 CORED INTERVAL 79.0–88.5 m

LITHOLOGIC DESCRIPTION

Very deformed, greyish olive (10Y 4/2) to moderate olive brown (10Y 4/4) nannofossil-laminitic MUDDY DIATOMACEOUS Ooze to DIATOMACEOUS MUD.

Sections 1–4 very uniform. Below Section 4, scattered lumps and layers of more indurated olive pale olive (10Y 6/2) diatom ooze. Contains numerous nannofossil carbonate crystals (Section 6, 129 cm) and approximately 20–30% calcareous. Below Section 4, a sharp contact to a 3 cm-thick layer of hard, calcareous diatom mudstone (DIOSILITE) with visible (10Y 6/2) sandy matrix core.

No sand but some scattered large flakes of mica. No H₂S odor.

SMEAR SLIDE SUMMARY

TEXTURE:
Silt 70
Clay 30

COMPOSITION:
Quartz 3
Feldspar 7
Heavy minerals 2
Clay 25
Pyrite 3
Carbonate unsorted 1
Foraminifers 1
Diatoms 3
Silicoflagellates 1
Plant debris 1
Rock fragments 3

CARBONATE BOMB:

6.75–22
Lithology: Sandy ooze
Silt 2.71
Sand 43.88
Clay 51.69

SITE 479 HOLE CORE 11 CORED INTERVAL 88.5–98.0 m

LITHOLOGIC DESCRIPTION

Very deformed, uniform. Dark olive brown (10Y 4/4) MUDDY DIATOMACEOUS Ooze. Faint wisps of firmer pale olive (10Y 6/2) laminae. No H₂S reaction, sand, or varves or H₂S odor. Some evidence for bedding of siltier ooze at Section 4, 80 cm.

SMEAR SLIDE SUMMARY

TEXTURE:
Silt 70
Clay 30

COMPOSITION:
Quartz 3
Feldspar 7
Clay 25
Pyrite 3
Carbonate unsorted 1
Foraminifers 1
Diatoms 3
Silicoflagellates 3

CARBONATE BOMB:

4.65 – 2.24 = 2.42
Lithology: Sandy clay
Silt 2.71
Sand 43.88
Clay 51.69

GUAYMAS BASIN SLOPESITES
SITE 479
HOLE 12
CORED INTERVAL 98.0–107.5 m

LITHOLOGIC DESCRIPTION

Very deformed, mildly modified site brown (5Y 4/4) MUD-DIATOMACEOUS Ooze. Any bedding totally disturbed. Some lighter pale olive (10Y 6/2) DIATOM ooze elliptical. No sand, silt, mica, or H2S odor. Multiple pale – separation indicates base solution. Section 6, 25 cm to Core-Catcher several marine episodic events of gradual ceasing (187 5/6).

SMear slide summary

CARBONATE BOMB: 11–111

SITE 479
HOLE 13
CORED INTERVAL 107.5–117.0 m

LITHOLOGIC DESCRIPTION

Very deformed, moderately brown (5Y 4/4) MUDDY DIATOMACEOUS Ooze. No H2S, sand, or evidence for bedding. No H2S reaction.

Core-Catcher: 2 cm wide slice of hard, greenish olive (10Y 4/2) siliceous mudstone with crackle, fine, very laminated approximately 0.3–1 mm thick, bioturbated structure. Small, 0.01 mm dolomite rhombic, 0.1 µm crystal, very shelly. BCOVERY.

SMear slide summary

TEXTURE:
Silt 75
Clay 20
Porosity 5
Carbonate 5
Dolomite 2
Dolostone 1
Bedform 0.5

CARBONATE BOMB: 6–111–111

11

CARBONATE BOMB: 1–110
### Lithologic Description

**Core 14**

**Interval**: 117.0-126.5 m

*Very deformed, uniform texture. Moderate olive brown (5Y 4/4) to grayish olive (5Y 4/2). Gas seepage, spongy. No HS odor, vent, or indications of laminations.*

**Smear Slide Summary**

- **Texture:** Silt
- **Composition:**
  - Quartz: 70%
  - Clay: 30%
  - Carbonates: 2%
  - Fossils: 1%
  - Pyrite: 1%
  - Silicoflagellates: 1%
  - Diatoms: 60%
  - Sponge spicules: 1%
  - Silicoflagellates: 3%

**Carbonate Bomb:** 2-50 μm

### Lithologic Description

**Core 15**

**Interval**: 126.5-136.0 m


**Smear Slide Summary**

- **Texture:**
- **Composition:**
  - Quartz: 1%
  - Felspar: 2%
  - Clay: 3%
  - Plagioclase: 70%
  - Potash: 10%
  - Pyrite: 1%
  - Carbonates: 1%
  - Oligo: 1%
  - Radiolarians: 1%
  - Concho: 1%

**Carbonate Bomb:** 2-50 μm
### Site 479 Hole 16
#### Core 16 Cored Interval 136.0-145.5 m

**Lithologic Description**


**Section 2, 36 cm and 53 cm:** Pale yellow (10YR 8/2) wisps of submersed mud; possible diatom ooze.

### Site 479 Hole 17
#### Core 17 Cored Interval 145.5-155.0 m

**Lithologic Description**

- Very deformed, moderate olive brown (5Y 4/6) muddy diatom ooze. Bedding suggested by some rare vertical streaks including pale olive (10YR 6/2) and moderate brown (5YR 5/6) clay. Sections 3 and 6: scattered pockets, blebs of gray (7L7) vitric ash, rhyolitic Rl <1.52, uniform, grain size -0.100 mm, well-sorted, very fresh.

**Smear Slide Summary**

- **Texture:** Sand: 3-102, (M1), Silt: 35-65, Clay: 35-65, (M.CF), (D)
- **Composition:** Feldspar: 3-102, Opaques: 3-102, Clay: 35-65, Volcanic glass: 35-65, Pyrite: 3-102, Diatoms: 3-102, Radiolarians: 3-102, Sponge spicules: 3-102, Silicoflagellates: 3-102

---

**Table:**

<table>
<thead>
<tr>
<th>Time-Mineral</th>
<th>Fossil Character</th>
<th>Graphic Lithology</th>
<th>Lithologic Description</th>
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<tr>
<td>HOLE</td>
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<tr>
<td>16</td>
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<tr>
<td>16</td>
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<tr>
<td>Cored Interval</td>
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**Site 479 HOLE:**

- SV 4/6
- R P 1.0
- SV 4/5
- R P 5.0
- SV 4/6
- R P 1.0

---

**Site 479 HOLE:**

- SV 4/6
- R P 1.0
- SV 4/5
- R P 5.0
- SV 4/6
- R P 1.0

---

**Guamas Basin Sites**
**LITHOLOGIC DESCRIPTION**

**SITE 479 HOLE**

**SITE 479 HOLE**

**CORE 18**

**CORED INTERVAL 155.0-164.5 m**

**LITHOLOGIC DESCRIPTION**

Very deformed, uniform, moderately olive brown (5Y 4/4) MUDDY DIATOMACEOUS Ooze, gas trapped, spongy.

Section 1 has 2 small sections (50 cm, 25 cm) of gray (10Y 4/4) vitric, rhyolitic ash?

**SMEAR SLIDE SUMMARY**

**TEXTURE:**

<table>
<thead>
<tr>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
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<td>15</td>
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<td>40</td>
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**COMPOSITION:**

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<th>Heavy minerals</th>
<th>Opaque</th>
<th>Carbonate unspec.</th>
<th>Foraminifers</th>
<th>Calc. nannofossils</th>
<th>Diatoms</th>
<th>Radiolarians</th>
<th>Sponge spicules</th>
<th>Silicoflagellates</th>
<th>Rock fragments</th>
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<td>10</td>
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</table>

**SITE 479 HOLE**

**SITE 479 HOLE**

**CORE 19**

**CORED INTERVAL 164.5-174.0 m**

**LITHOLOGIC DESCRIPTION**

Highly disturbed, uniform MUDDY DIATOM ACEOZE which mixes lighter and darker shades of moderate olive brown (5Y 4/4), and grayish olive (10Y 4/2). Sections in some areas to 5Y 3/2. Grade varies to closer to Sections 3 to 4 with scattered fish scales (e.g. Section 4, 60 cm and Section 7, 48 cm). Slightly calcareous with some sand sized specks.

Section 6, 55 cm changes to more moderate brown to yellowish (10Y 4/4), calcareous, very firm MUDDY DIATOMACEOUS Ooze.

Some rare breccia-like areas may be redissolved. One graded bed at Section 3, 95-100 cm. Extensive separation features from gas pressure.

**SMEAR SLIDE SUMMARY**

**TEXTURE:**

<table>
<thead>
<tr>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
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<td>6</td>
<td>45</td>
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**COMPOSITION:**

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<th>Opaque</th>
<th>Carbonate unspec.</th>
<th>Foraminifers</th>
<th>Calc. nannofossils</th>
<th>Diatoms</th>
<th>Radiolarians</th>
<th>Sponge spicules</th>
<th>Silicoflagellates</th>
<th>Rock fragments</th>
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<tbody>
<tr>
<td>6-7</td>
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<td>3</td>
<td>TR</td>
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<td>TR</td>
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</tbody>
</table>
LITHOLOGIC DESCRIPTION

Completely disturbed, moderate olive brown (5Y 4/4) MUDDY DIATOMACEOUS OOZE with a few scattered patches of more silty grayish olive (10Y 4/2) MUDDY DIATOM OOZE in Section solution.

At Section 2, 100 cm: pale olive DOLOSTONE with regular fir brownish parallel laminations on a sub mm-scale. Mostly doloitic although staining indicates some calcite. Carbonate grains mostly anhedral, 10-40 microns.

SMEAR SLIDE

TEXTURE:
Sand
Silt
Clay

COMPOSITION:

SUMMARY
2-102
ML
70
30

4-70
(DL
2-3
40
35

CARBONATE BOMB:

TR
30
1-2
TR
-65-75

TR
5-110= 1

Highly disturbed, uniform MUDDY DIATOMACEOUS OOZE. Grayish olive (10Y 4/2) in Section 1 then moderate olive brown (5Y 4/4) below. Spongy from strong gas exsolution. A few dusky yellow (5Y 6/4) streaks of diatom ooze occur at Section 5, 90 and 110 cm, Section 6, and Section 7, 0-20 cm. No H₂S odor; and much carbon but s

SMEAR SLIDE SUMMARY

TEXTURE:
Silt
Clay

COMPOSITION:
Quartz
Feldspar
Clay
Pyrite
Opaques
Carbonate unspec.
Foraminifers
Calc. nannofossils
Diatoms
Radiolarians
Silicoflagellates
Rock fragments

CARBONATE BOMB:

TR
30
1-2
TR
-65-75

TR
5-110= 1
**LITHOLOGIC DESCRIPTION**

Section 1 to Section 2, 80 cm: uniform, very disturbed; moderate olive brown (5Y 4/4 to 5Y 5/3). Muddy diatomaceous ooze. Surface gas ruptured, spongy, slight HCl reaction and scattered white specks.

About 80 cm in Section 3, there is a gradual transition to more silt-like cohesive olive gray to grayish olive (10Y 4/2) diatomaceous mud which continues to Section 7. Less gas separa- 

About 50 cm in Section 4, a clump of light brown olive (5Y 4/4) diatomaceous ooze which has a unilateral mantle below of thin gray (N2) sand above 1 mm thick.

**SMAR SLIDE SUMMARY**

1. **TEXTURE:**
- Silt
- Clay

2. **COMPOSITION:**
- Quartz
- Feldspar
- Mica
- Clay
- Pyrite
- Carbonate unspec.
- Calcite
- Dolomite
- Plant debris
- Rock fragments

3. **CARBONATE BOM:**
- 4-73

---

**LITHOLOGIC DESCRIPTION**

Section 1 to Section 2, 80 cm: uniform, very disturbed; moderate olive brown (5Y 4/4 to 5Y 5/3). Muddy diatomaceous ooze. Surface gas ruptured, spongy, slight HCl reaction and scattered white specks.

About 80 cm in Section 2, there is a gradual transition to more silt-like cohesive olive gray to grayish olive (10Y 4/2) diatomaceous mud which continues to Section 7. Less gas separa- 

About 50 cm in Section 4, a clump of light brown olive (5Y 4/4) diatomaceous ooze which has a unilateral mantle below of thin gray (N2) sand above 1 mm thick.

**SMAR SLIDE SUMMARY**

1. **TEXTURE:**
- Silt
- Clay

2. **COMPOSITION:**
- Quartz
- Feldspar
- Mica
- Clay
- Pyrite
- Carbonate unspec.
- Calcite
- Dolomite
- Plant debris
- Rock fragments

3. **CARBONATE BOM:**
- 4-73
**LITHOLOGIC DESCRIPTION**

**CORE INTERVAL: 212.0-221.5 m**

**SITE 479 HOLE HOLE**

**LITHOLOGIC DESCRIPTION:**

- Section 1, 15-120 cm: splotches and patches of gray sand and some minor slightly darker colored zones. Scattered whitish patches which may be parts of former laminae.

**SMEAR SLIDE SUMMARY**

**TEXTURE:**
- Sand 45%
- Silt 45%
- Clay 10%

**COMPOSITION:**
- Quartz: 45%
- Feldspar: 45%
- Mica: 10%
- Clay: 5%
- Pyrite: 3%
- Foraminifers: 2%
- Calc. nanofossils: 1%
- Diatoms: 30%
- Silicoflagellates: 1%
- Rock fragments: 1%

**CARBONATE BOMB: 3-86**

---

**CORE INTERVAL: 221.5-231.0 m**

**SITE 479 HOLE**

**LITHOLOGIC DESCRIPTION:**

Highly disturbed, uniform grayish olive (10Y 4/2) DIATOMACEOUS MUD with a spongy surface from gas expansion and vesicles.

**SMEAR SLIDE SUMMARY**

**TEXTURE:**
- Clay 40%

**COMPOSITION:**
- Mica 2%
- Clay 40%
- Pyrite: 6%
- Carbonate unspec.: 5%
- Calc. nanofossils: 1%
- Diatoms: 30%
- Silicoflagellates: 1%
- Plant debris: TR

**CARBONATE BOMB: 2-131 = 4%**
**SITE 479 HOLE CORE 26 CORED INTERVAL 221.0-245.0 m**

**LITHOLOGIC DESCRIPTION**

Sections 1 and 2: highly disturbed chunks of fine-grained olive-gray (5Y 3/2) silty clay in large blebs and dark greenish gray (5G 4/1) speckled unconsolidated sand, sorted, ungraded. Grain-size is 250—600 µm. Contains angular quartz, abundant feldspars and some rounded rock fragments, little carbonate, some broken diatoms and scattered biotite flakes.

Below Section 2 mostly sand.

**SMEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>TEXTURE</th>
<th>HIGH</th>
<th>MEDIUM</th>
<th>LOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>1-80</td>
<td>65</td>
<td>55</td>
</tr>
<tr>
<td>Silt</td>
<td>60</td>
<td>35</td>
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</tr>
<tr>
<td>Clay</td>
<td>40</td>
<td>15</td>
<td>10</td>
</tr>
</tbody>
</table>

**COMPOSITION:**

- Heavy clay
- Opal
- Silicoflagellates
- Radiolarians
- Sponge spicules
- Rock fragments

**CARBONATE BOMB:** 1-82 =

---

**SITE 479 HOLE CORE 27 CORED INTERVAL 240.0-250.0 m**

**LITHOLOGIC DESCRIPTION**

Couplet (5Y 4/2 - 5Y 6/4)

Light: Dark Disturbed, partings parallel Section 1, 100 cm uniform, moderate olive brown (5Y 4/4) silty clay to diatom ooze. Below Section 1, 100 cm, changes gradually to muddy diatom ooze. Section 1 and 2 defined by a light gray to light gray (5Y 6/4) thin laminae of diatom ooze. Light layer rich in radiolarian, sponge spicules, some broken diatoms and scattered biotite flakes. Core catcher: three pieces of hard lithified aeolitic dolomite with diatoms, shells and partly bored.

**SMEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>TEXTURE</th>
<th>HIGH</th>
<th>MEDIUM</th>
<th>LOW</th>
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</thead>
<tbody>
<tr>
<td>Sand</td>
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</tr>
<tr>
<td>Silt</td>
<td>55</td>
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</tr>
<tr>
<td>Clay</td>
<td>30</td>
<td>25</td>
<td>15</td>
</tr>
</tbody>
</table>

**COMPOSITION:**

- Quartz
- Feldspar
- Clay
- Heavy clay
- Opal
- Silicoflagellates
- Radiolarians
- Sponge spicules
- Rock fragments

**CARBONATE BOMB:** 4-72 = 3%
LITHOLOGIC DESCRIPTION

Section 1, 0-28 cm: Light olive gray (5Y 5/2) to pale gray (5Y 5/3) series of lithified DOLOMITIC BEDS. Burrowed to laminated. Near the base are thin layers of possible quartz. Contacts sharp.

Section 2 to 7: Alternating bands of homogeneous, and zones of thin laminated MUD. Contacts sharp.

SMEAR SLIDE SUMMARY

TEXTURE:
 Sand 10
 Silt 50
 Clay 40
 COMPOSITION:
 Quartz 5
 Feldspar 5
 Clay 55
 Pyrite 3
 Carbonate unsp. 2
 Diatoms 20
 Silicoflagellates 20
 Plant debris 10

Note: Site 479, Hole 29, Core 26, 278.5-279.0 m: No Recovery.
**SITE 479**

**HOLE**

**CORE** 31  
**CORED INTERVAL** 278.5–288.0 m

**LITHOLOGIC DESCRIPTION**

<table>
<thead>
<tr>
<th>Section</th>
<th>Lithologic Character</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Disturbed including many partings from gas expansion.</td>
<td>Section 1-3, 130 cm: uniform, mostly gray (5Y 3/2) firm DIATOMACEOUS CLAYEY SILT. Disks mostly fragmented or melted. Scattered ferruginous, manganese nodules, with small areas of light (BY 5/3) quartz CLAY (e.g. Section 3, 61 cm). Drilled parallel with gas expansion.</td>
</tr>
<tr>
<td>4</td>
<td>Section 3, 100 cm to Section 4, 130 cm: slight color change to moderate olive brown (5Y 4/4) uniform. Distinct but gradational transition. Below Section 4, 130 cm: alternating zones of laminated and homogeneous moderate olive brown (5Y 4/4 + 5Y 3/2) MUDDIY DIATOMACEOUS OSS. Contacts transitional. Laminae from light diatom-rich and dark mud-rich elements. Homogeneous zones appear bioturbated, not graded. Upwelling species dominant.</td>
<td></td>
</tr>
</tbody>
</table>

**SMEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>Texture</th>
<th>Composition</th>
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<td>2/2</td>
<td>5/4</td>
</tr>
<tr>
<td>2/2</td>
<td>5/4</td>
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</tbody>
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**SITE 479**

**HOLE**

**CORE** 32  
**CORED INTERVAL** 288.0–297.5 m

**LITHOLOGIC DESCRIPTION**

<table>
<thead>
<tr>
<th>Section</th>
<th>Lithologic Character</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Light olive gray (5Y 5/2) lithified subparallel; submm, disturbed by some bioturbation.</td>
<td>Section 5, 100–130 cm and Section 6, 130–160 cm: intercalations of rhomboidally laminated zones of moderate olive brown (BY 4/4 + 5Y 3/2) MUDDY DIATOMACEOUS OSS. Some laminations are uniform, with linear features from bioturbation.</td>
</tr>
</tbody>
</table>

**SMEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>Texture</th>
<th>Composition</th>
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<tbody>
<tr>
<td>Sand</td>
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<tr>
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<td>01</td>
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<tr>
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</tr>
<tr>
<td>1/6</td>
<td>01</td>
</tr>
<tr>
<td>1/6</td>
<td>01</td>
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</tbody>
</table>

**Note:** Site 479, Core 32, 297.5–297.5 m: No Recovery.
**SITE 479 HOLE 34 CORED INTERVAL 307.0-318.5 m**

<table>
<thead>
<tr>
<th>GRAPHIC LITHOLOGY</th>
<th>Fossil Character</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Drill brecciated and broken; olive gray (10Y 4/2) to grayish olive (10Y 6/2) mudrocks, carbonaceous, with abundant silicoflagellates (Mesocentra). Gas blown, noted, no visible faecal structures, some induration occurs in Section 6.</td>
</tr>
</tbody>
</table>

**SITE 479 HOLE 35 CORED INTERVAL 316.5-326.0 m**

<table>
<thead>
<tr>
<th>GRAPHIC LITHOLOGY</th>
<th>Fossil Character</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Section 5, 140-150 cm: grayish olive (10Y 4/2) laminated CAL-CAREOUS DIATOMACEOUS MUDSTONE; bioturbated with pale olive green filaments at the base, darker near bottom, but may mask considerable siliceous or clay component. Slightly calcareous, nearly arillate. Calcareous ooze but may mask considerable siliceous or clay component.</td>
</tr>
</tbody>
</table>

**SMEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>TEXTURE</th>
<th>COMPOSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>40</td>
</tr>
<tr>
<td>Silts</td>
<td>60</td>
</tr>
<tr>
<td>Clay</td>
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<tr>
<td>Silt</td>
<td>45</td>
</tr>
<tr>
<td>Fossil</td>
<td>5</td>
</tr>
<tr>
<td>Calcite</td>
<td>5</td>
</tr>
<tr>
<td>Carbonate</td>
<td>50</td>
</tr>
<tr>
<td>Gla.</td>
<td>5</td>
</tr>
<tr>
<td>Fish</td>
<td>0</td>
</tr>
<tr>
<td>Plant</td>
<td>0</td>
</tr>
</tbody>
</table>

**CARBONATE BOMB:**

<table>
<thead>
<tr>
<th>SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-10p</td>
</tr>
</tbody>
</table>

**VOID**

Distorted, grayish olive (10Y 4/2) DIATOMACEOUS MUD TO OOSMOLARITES, fine grained, and replacement zones of more bioturbated character. Concretion transition, Calcareous dark medium gray (5Y 4/2) clastic-plastic layers. Rhythmic laminations on a sub-mm scale very fine. Some dye test shows numerous large fish bones (leg. Section 6, 140 cm). Rhythmically interbedded with dark clayey-silt and light gray (10Y 4/2) massive sediments. Clayey bands on sub-mm scale.

Below Section 4, 140 cm: grayish olive (10Y 4/2) with pale green (10Y 6/2) diatom mud couplets, laminated on a sub-mm scale.}

At Section 2, 125 cm: pyrite-rich (2B1 5Y 3/2) to dark gray (10Y 6/2) with scattered fish bone fragments. Slightly calcareous, bioturbated, fine grained. At Section 3, 145 cm: medium gray (10Y 4/2) clays rich in terrestrial organic debris. At Section 4, 94 cm: couplets rich in monospecific diatoms. At Section 5, 68 cm: pyrite-rich with roots of yucca (5B1).

**SMEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>TEXTURE</th>
<th>COMPOSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>45</td>
</tr>
<tr>
<td>Silts</td>
<td>45</td>
</tr>
<tr>
<td>Clay</td>
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<tr>
<td>Silt</td>
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<tr>
<td>Fossil</td>
<td>5</td>
</tr>
<tr>
<td>Calcite</td>
<td>5</td>
</tr>
<tr>
<td>Carbonate</td>
<td>10</td>
</tr>
<tr>
<td>Gla.</td>
<td>5</td>
</tr>
<tr>
<td>Fish</td>
<td>0</td>
</tr>
<tr>
<td>Plant</td>
<td>0</td>
</tr>
</tbody>
</table>

**CARBONATE BOMB:**

<table>
<thead>
<tr>
<th>SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-10p</td>
</tr>
</tbody>
</table>
SITE 479 HOLE 36 CORED INTERVAL 326.0-355.5 m

**LITHOLOGIC DESCRIPTION**

Grayish olive (10Y 4/2), DIATOMACEOUS MUD (SILTY TO MUDDY Ooze). Entire core uniformly laminated with thin olive (10Y 6/2). At Section 3, 128 cm, a thin black sand laminae is composed of brown, heattreated glass and feldspars coated with supernumerary coatings. Accompanied by some quartz (10%) and clays (50%), glass partially altered.

**SMEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>TEXTURE</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMPOSITION</td>
<td>Quartz</td>
<td>Feldspar</td>
<td>Opaques</td>
</tr>
</tbody>
</table>

**CARBONATE BOMB**

2-78-

SITE 479 HOLE 37 CORED INTERVAL 326.5-345.0 m

**LITHOLOGIC DESCRIPTION**

Numerous voids due to gas entrapment. Grayish olive (10Y 4/2). Entire core uniformly laminated with thin black sand laminae. Accompanied by some quartz (10%) and clays (50%), glass partially altered.

**SMEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>TEXTURE</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMPOSITION</td>
<td>Quartz</td>
<td>Feldspar</td>
<td>Opaques</td>
</tr>
</tbody>
</table>

**CARBONATE BOMB**

3-78 -
SITE 479

HOLE CORE 38 CORED INTERVAL 345.0-354.5 m

VOID

LITHOLOGIC DESCRIPTION

Hard grayish olive 10Y4/2

DIATOMACEOUS MUD AND OOZE with regular, uniform, light-dark rhythmic laminated couplets. Diatom abundance decreases downward.

At Section 1, 30-45 cm: 5 pieces of hard grayish olive 10Y4/2 indurated CARBONATE (DOLOMITIC?) laminated with original varve-like layers some of which appear discontinuous, possibly bioturbated. Carbonate micrite size aphanoritic grains.

At Section 2, 94, 97, and 130 cm are 1 cm-thick BASALTIC ASH beds with sand-size glass and feldspar grains coated with manganese and moderately altered.

SMEAR SLIDE SUMMARY

N1 1-33 2-131 3-70 (M) (Mf) (D)

N1 TEXTURE:

Sand - <10

Silt 80 80 50

Clay 20 10 50

COMPOSITION:

Quartz TR - 11

Feldspar TR 10 9

Heavy minerals TR - 1

Clay 30 20 45

Volcanic glass 30

Pyrite TR - 1

Opaques - 40 -

Carbonate unspec. 70 a

Calc. nannofossils — — TR

Diatoms - 3 35

Sponge spicules TR

Silicoflagellates TR a
dolomite

CARBONATE BOMB:

4-107 = -
SITE 479
HOLE 40
CORE INTERVAL 364.0–373.5 m
LITHOLOGIC DESCRIPTION
Partly crusted, greyish olive (10Y 4/2) DIATOMACEOUS MUD laminated with regular sub-mm light-dark couplets. Some scattered thin grey layers. Diatom abundance continues to decline. Fish scales common on clay laminae partings.

Section 2, 55–145 cm: intercalated homogeneous, greyish olive-green (2Y 4/2) interbedded clay. Upper contact transitional, grades downward from waxy texture to silt. Components include a few broken robust-type diatom frustules and scattered chips (brown, low b.f. clear, no cleavage) of either phosphate or fish debris. Land derived organics abundant. Single dolomite rhombs. May be redeposited.

Section 2, 145 cm to Section 3, 85 cm:

DOLOSTONE.

Shows preserved fine-grained, hard, lithified, not laminated, and manganese rich nodules. 

Section 3, 88 cm: light grey (10Y 6/2) silt comprising altered and fresh sub- to euhedral felt spars and opaques.

SMEAR SLIDE SUMMARY

TEXTURE:

<table>
<thead>
<tr>
<th></th>
<th>Silt</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>70</td>
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</tr>
<tr>
<td>2</td>
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<td>0.8</td>
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<td>4</td>
<td>3.6</td>
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COMPOSITION:

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<thead>
<tr>
<th></th>
<th>Quartz</th>
<th>Feldspar</th>
<th>Heavy minerals</th>
<th>Clay</th>
<th>Pyrite</th>
<th>Carbonate unspec.</th>
<th>Calc. fossils</th>
<th>Diatoms</th>
<th>Silicoflagellates</th>
<th>Plant debris</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>11</td>
<td>&lt;1</td>
<td>2</td>
<td>4</td>
<td>10</td>
<td>1</td>
<td>25</td>
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<td></td>
</tr>
<tr>
<td>2</td>
<td>15</td>
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<td>&lt;1</td>
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<td>10</td>
<td>1</td>
<td>25</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

CARBONATE BOMB: 1-10=

Graupel size (10Y 4/2) DIATOM MUD slightly calcareous, rhythmic parallel laminations, as a sub-mm-scale. Scattered fish scale fragments common. Some zones are badly disturbed by drilling.

Section 1, 135 cm and Core-Catcher: four thin, light greyish DOLOSTONE beds, hard, no visible laminations. Core implanted by diatom mud.

SMEAR SLIDE SUMMARY

TEXTURE:

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<th>Clay</th>
</tr>
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COMPOSITION:

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<th>Pyrite</th>
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<th>Calc. fossils</th>
<th>Diatoms</th>
<th>Silicoflagellates</th>
<th>Plant debris</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>11</td>
<td>&lt;1</td>
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<td>4</td>
<td>10</td>
<td>1</td>
<td>25</td>
<td>1</td>
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</table>

Graupel size (10Y 4/2) DIATOM-BEARING NANNOFOSSIL MUD. Diatoms mostly fragments, Dolomite rhombs (20-40 microns) are common. Core disturbed but evidence for fine-grained laminations.

Core-Catcher: one piece of graupel size (10Y 4/2) hard, fine-grained DOLOSTONE.

SMEAR SLIDE SUMMARY

TEXTURE:

<table>
<thead>
<tr>
<th></th>
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<th>Clay</th>
</tr>
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<tr>
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COMPOSITION:

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<th>Clay</th>
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<th>Carbonate unspec.</th>
<th>Calc. fossils</th>
<th>Diatoms</th>
<th>Silicoflagellates</th>
<th>Plant debris</th>
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<tr>
<td>1</td>
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</table>

Graupel size (10Y 4/2) DIATOM-BEARING NANNOFOSSIL MUD. Diatoms mostly fragments, Dolomite rhombs (20-40 microns) are common. Core disturbed but evidence for fine-grained laminations.

Core-Catcher: one piece of graupel size (10Y 4/2) hard, fine-grained DOLOSTONE.

SMEAR SLIDE SUMMARY

TEXTURE:

<table>
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<th></th>
<th>Silt</th>
<th>Clay</th>
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<tbody>
<tr>
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<td>80</td>
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COMPOSITION:

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<th>Feldspar</th>
<th>Heavy minerals</th>
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<th>Carbonate unspec.</th>
<th>Calc. fossils</th>
<th>Diatoms</th>
<th>Silicoflagellates</th>
<th>Plant debris</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>11</td>
<td>&lt;1</td>
<td>2</td>
<td>4</td>
<td>10</td>
<td>1</td>
<td>25</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>
| TIME INTERVAL | RGB | DIRT | FOSSIL | CHARACTER | GRAPHIC | LITHOLOGY | INTERVAL | BOREHOLE | SITE 479 | CORE 43 | CONTRA INTERVAL 392.5-402.0 m
|---------------|-----|------|--------|------------|---------|-----------|----------|----------|----------|---------|----------------|
| Site 479 HOLE | CORE 43 | INTERVAL | 392.5-402.0 m
| 0.3-1.0 m | | | | | | | | | | |

**Lithologic Description**

Moderately to slightly disturbed grayish olive (10Y 4/2) DIATOMACEOUS MUD, slightly pisolitic with some nannofossils. Slightly calcareous debris, some dolomite. Some showing homogeneous. Source material along layers are rich in fish remains.

Section 2, 46-50 cm: overall thin laminae along laminae are discontinuously laminated with a monospecific large nannofossil, brown, wavy laminations.

**SMEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>TEXTURE:</th>
<th>1-0.5</th>
<th>2-4.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silt</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Clay</td>
<td>65</td>
<td></td>
</tr>
</tbody>
</table>

**COMPOSITION:**

- Quartz: 2
- Feldspar: 1
- Opaque: 1
- Clay: 45
- Pyrite: 5
- Carbonate: 10
- Calcite, dolomite: 10
- Nannofossils: 2
- Radiolarians: TR
- Silicoflagellates: 1
- Fish remains: 3
- Plant debris: 2

**CARBONATE BOMB:** 2-0.2 + 10 mg

---

**Lithologic Description**

Hard, grayish olive (10Y 4/2) CLAY TO SILTY CLAY. Slightly pisolitic. Some areas with cloudy lamination.

Section 1, 60-150 cm: and Section 2, 10 cm: Section 3, 40 cm: muns appear to show fine-grained peloidal lenticel rock with faint lamination.

Section 2, 40 cm: streak of red to light brown (10YR 5/6) possible phosphate concretion (isotropic, high R.I., yellow background).

Section 3, 50 cm and Core-Catcher: thinly laminated, hard, lithified, DONOSTONE. Preservation of primary burrows and laminations by lithification process.

Section 3, 90, 116, and 136 cm: laminae of pure white (10YR 4/4) NANNOFOSSIL OOZE monospecific large types.

**SMEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>TEXTURE:</th>
<th>1-0.5</th>
<th>2-4.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand:</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Silt:</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Clay:</td>
<td>55</td>
<td></td>
</tr>
</tbody>
</table>

**COMPOSITION:**

- Quartz: 2
- Feldspar: 1
- Opaque: 1
- Clay: 30
- Phosphate: 10
- Pyrite: 5
- Carbonate: 10
- Foraminifers: 2
- Calcite, nannofossils: 10
- Radiolarians: TR

**CARBONATE BOMB:** 3-93 + 10 mg
**Very deformed, considerable drill-breccia. Grayish olive (10Y 4/2) CLAY TO SILTY CLAY without evidence of rhythmic features.**

Core-Catcher: grayish olive (10Y 4/2) hard, indurated dolostone,

Section 2, 45 cm: thin pink white (16E) NANNOFOSIL OOZE laminar.

**SMEAR SLIDE SUMMARY**

<table>
<thead>
<tr>
<th>COMPOSITION</th>
<th>Section 1, 0-17 cm: homogeneous yellow grey (10Y 7/3) to light olive grey (10Y 6/3) CLAY TO BILLY CLAY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Section 11 cm: lime white (10Y 3/2) CLAYSTONE, myrtally laminated on a very fine, regular, subparallel, rhythmic layers from compaction. Micro-scale discontinuities is not evident except certain laminar with poor nannofossil core. Sections 1 and 2 rich in fish debris.</td>
</tr>
<tr>
<td></td>
<td>Section 2, 105-150 cm: hard, indurated laminated DOLOSTONE with downward increasing hardness and gradual fining appearance of upward laminations. Seven types of layers occur as distinct laminations including: a) light grey part of couplet; b) dark clay; c) very dark red brown argillaceous lamina; d) thin grey (10Y) bands of calcite; e) and f) thinner white marl oozes. Average couplet thickness: 30 cm. 150 cm section rich in fish debris. More marly layers towards the base.</td>
</tr>
</tbody>
</table>

**TEXTURE:**

<table>
<thead>
<tr>
<th>Texture</th>
<th>Section 1, 0-17 cm: homogeneous yellow grey (10Y 7/3) to light olive grey (10Y 6/3) CLAY TO BILLY CLAY</th>
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<tr>
<td></td>
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<td></td>
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</tr>
<tr>
<td></td>
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</tr>
</tbody>
</table>

**CARBONATE BOMB:** 1.0 - 3%

Note: Site 479, Core 47, 421.0-430.5 m. No Recovery.
### LITHOLOGIC DESCRIPTION

#### Sand
- Composition:
- Textural Character:

#### Diatom Ooze
- Upper to lower unit contact gradational, with nannofossils, bioturbated, upper unit contact gradational, rather silty including BENTHIC FORAMINIFERA. Small pieces of shell scattered throughout.

#### Quartz
- Composition:
- Textural Character:

#### Nannofossil Silt
- Composition:
- Textural Character:

#### Radiolarian ooze
- Composition:
- Textural Character:

#### Radiolaria fossils
- Composition:
- Textural Character:

#### Benthic Foraminifera
- Composition:
- Textural Character:

#### Smear Slide Summary
- Count:
- Size:

#### Bioturbated layers
- Composition:
- Textural Character:

#### Radiolarian ooze
- Composition:
- Textural Character:

#### Radiolaria fossils
- Composition:
- Textural Character:

#### Benthic Foraminifera
- Composition:
- Textural Character:

#### Smear Slide Summary
- Count:
- Size:

#### Lithologic Description

#### Lithologic Character

#### Lithologic Unit

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#### Lithologic Unit
SITE 480 HOLE 5 CORE 5 CORED INTERVAL 19.00–23.75 m

LITHOLOGIC DESCRIPTION

Zones of rhythmically laminated couplets of moderate olive brown (5Y 4/4) muddy diatom ooze and pale olive (10Y 6/2) diatom ooze alternating with zones of homogeneous, moderate olive brown (5Y 4/4) diatom mud. Contacts partly diffuse to gradational. Homogeneous mottles common in laminated zones may be burrows. Strong H2S odor. Section shows transition to unconsolidated ooze zone.

CARBONATE BOMB: CC: 0%

LITHOLOGIC DESCRIPTION

Rhythmically laminated mm-scale couplets of moderate olive brown (5Y 4/4) muddy diatom ooze and pale olive (10Y 6/2) diatom ooze. Varves alternating with zones of homogeneous moderate olive brown (5Y 4/4) diatom mud. Contacts partly diffuse to gradational. Homogeneous mottles common in laminated zones may be burrows. Strong H2S odor.

CARBONATE BOMB: CC: 0%

LITHOLOGIC DESCRIPTION

Rhythmically laminated mm-scale couplets of moderate olive brown (5Y 4/4) grading to olive gray (5Y 3/2) diatomaceous ooze to diatomite with small zone of moderate olive brown (5Y 4/4) diatomaceous ooze and pale olive (10Y 6/2) diatomite rhythmic couplets, some of which appear disturbed. Homogeneous sections show evidence of large (2-3 cm) burrows indicating bioturbation at lower contact to laminated zone. Strong H2S odor.

CARBONATE BOMB: CC: 0%
LITHOLOGIC DESCRIPTION

SITE 480 HOLE
CORE 16 CORED INTERVAL 70.00–80.75 m

At Section 3, 50 cm: some very thin pale olive elastics once laminar.

In Section 3, ten centimeter sections, scattered on surface and along partings. Scattered phosphate, but Section 3, 35 cm.

At Section 3, 85 cm: on thin, pure nannofossil laminae. Some bioturbation in the gradational contact with the varves. Strong H2S odor.

SITE 480 HOLE
CORE 17 CORED INTERVAL 80.75–90.50 m
Very disturbed core mostly laminated, moderate olive brown (5Y 4/4) to grayish olive (10Y 4/2) DIATOM MUDS AND MUDY DIATOMACEOUS Ooze. Light member (diatom-rich) grades in intensity suggesting higher and lower productivity or different microhabitats. Strong H2S odor.

CARBONATE BOMB: CC: 0%
**Lithologic Description**

- **SITE 480 HOLE**
  - **CORE 20**
  - **CORED INTERVAL** 45.00-99.75 m

<table>
<thead>
<tr>
<th>SECTION</th>
<th>GRAPHIC LITHOLOGY</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>CF</td>
</tr>
<tr>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

  Rhythmically laminated moderate olive brown (5Y 4/4) MUD DIATOM Ooze and pale olive (5Y 2/2) DIATOM Ooze couplets.

  At Section 1, 90-99 cm and Section 2, 38-48 cm and 68 cm, medium grey (7.5Y 6/2) well-rounded sand beds interbedded with sharp contacts. Limitations unconformity to the sand layers.

  At Section 1, 80-90 cm SAND has scattered wood chips.

  At Section 2, 120-130 cm unconformities and apparent cross-bedding are observed within laminated zones. Strong H2S odor.

  **CF 1-95**: gray sand; angular to subangular components. Very feldspathic. Well-sorted, grains slightly weathered. Feldspars, mostly plagioclase (60%), angular quartz (25%), gray siltstone rock fragments (15%), fine-grained white (3%), biotite (2%), green hornblende (3%). No calcareous or fossil debris.

- **LITHOLOGIC DESCRIPTION**
  - Interbedding of several lithofacies:
    1. Zone of rhythmically banded couplets of moderate olive brown (5Y 4/4) MUDY DIATOM OOZE and pale olive (5Y 2/2) DIATOM Ooze couplets (5Y 6/2) diatom ooze, oozes, to sub-mm scale. Strong H2S odor.
    2. Several thinner laminations to cm beds of greenish grey (5G 6/4) to medium bluish grey (5B 5/1) SILTY CLAYS TO SANDY SILT, in Section 1, at 41, 90, and 145-150 cm. In Section 2, they are at a sequence of 17 rhythmically banded beds from Section 2, 5-30 cm with 3 more from Section 2, 177-184 cm; these are clearly graded TURBIDITES with a well-sorted, thin- to medium sandstone base. Some are separated by a few thin diatomaceous laminations. Upper and lower contacts are sharp, immediately above the turbidite sequence is a gradational change downward (Section 2, 65-104 cm) from heterogeneous to laminated ooze. Limitations below turbidite units are uncertain above these.
    3. At Section 1, 130-142 cm: a grayish-yellow (5Y 8/4) lithified, DOLOMITIC MUDSTONE is intercalated into homogeneous diatomaceous muds, with some faint layering. This dolomitic bed is homogeneous with some faint burrow mottling. Along the lower contact is a 3-4 cm layer of black grey (5B 4/4) siltstone.

- **SMear Slide Summary**
  - **TEXTURE:**
    - Sand
    - Silt
    - Clay
  - **COMPOSITION:**
    - Quartz
    - Feldspar
    - Mica
    - Clay
    - Pyrite
    - Carbonate
    - Calc. nannofossils
    - Diatoms
    - Silicoflagellates
  - **CARBONATE BOMB:** CC 10%

---

**LATE PLEISTOCENE**

**TEXTURE:**

<table>
<thead>
<tr>
<th>SAND</th>
<th>SILT</th>
<th>CLAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>50</td>
<td>50</td>
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</tbody>
</table>

**COMPOSITION:**

<table>
<thead>
<tr>
<th>QUARTZ</th>
<th>Feldspar</th>
<th>Mica</th>
<th>CLAY</th>
<th>Pyrite</th>
<th>CARBONATE</th>
<th>NANNOSTRONG</th>
<th>DIOGENITES</th>
<th>SILICOFLAGELLATES</th>
<th>PLANT DEBRIS</th>
<th>CARBONATE BOMB</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-5</td>
<td>0-1</td>
<td>0</td>
<td>5-6</td>
<td>0-1</td>
<td>0-1</td>
<td>0-1</td>
<td>0-1</td>
<td>0-1</td>
<td>0-1</td>
<td>0-1</td>
</tr>
</tbody>
</table>

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**U.S.I.A. GEOLOGIC TIMESCATALOG**

**NORTH AFRICAN SITES**

---

**GUAYMAS BASIN SLOPE SITES**
LITHOLOGIC DESCRIPTION

1. Two zones of homogeneous moderate olive brown (5Y 4/4) DIATOM MUD Section 1, 2-89 cm and Section 2, 150 cm to Section 3, 100 cm. Top 30 cm may be drill disturbed.

2. Two zones of rhythmically laminated couplets of sub-mm scale moderate olive brown (5Y 4/4) MUDDY DIATOM Ooze and pale olive (10Y 6/2) DIATOM Ooze. Contacts are transgressive. The lower zone shows a decreased increase in the frequency and number of thick pale olive laminae. There is a secondary rhythmic development on a 0.15 cm scale. At Section 2, 100 cm, laminated ooze and diatom ooze are divided, with about 10 cm each. At Section 3, 110 cm a minor laminated couplet is present. Strong H2S odor.

LITHOLOGIC DESCRIPTION

Intensely then moderately disturbed moderate olive brown (5Y 4/4) DIATOM MUD with minor medium gray (7.5 Y 5/1) sand lenses. Laminations ran in Sections 1 and 2.

At Section 2, 50 cm grade into undisturbed rhythmically laminated MUDDY DIATOM Ooze and pale olive (10Y 6/2) DIATOM Ooze. Light and dark of cm-scale. From Section 2, 95-140 cm: irregular, partly homogeneous moderate olive brown (5Y 4/4) laminae without deformation. Strong H2S odor.

Fish debris is seen in Section 1, 45-50 cm; Section 2, 40 and 100 cm; Section 3, 42, 99, and 122 cm.

SMEAR 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>Opaques</td>
</tr>
<tr>
<td></td>
<td>Coa</td>
</tr>
<tr>
<td></td>
<td>Penta</td>
</tr>
<tr>
<td></td>
<td>Carbonates</td>
</tr>
<tr>
<td></td>
<td>Silicates</td>
</tr>
</tbody>
</table>

CARBONATE BOMB: CC: 0%
### Lithostratigraphic Description

#### Site 480, Hole 26, Core 27, Cored Interval 128.25–123.00 m

<table>
<thead>
<tr>
<th>Section</th>
<th>Lithologic Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rhythmically laminated moderate olive brown (5Y 4/4) and pale olive (10Y 6/2) diatom ooze. Sharp and gradational contacts between laminated zones, indicating sedimentary rhythmites. Higher productivity of benthic diatoms at rhythmically laminated intervals. Sections 1 and 2: laminated couplet brown (5Y 4/4) ooze. Couplet mm/pair. Thicker second order cycle distinctive and rhytromorphic. Higher productivity of the second order cycle. Laminations form marl-like facies. Sections 3 and 4: calcite-rich ooze. Contacts from laminated down to homogeneous. Transition zone Section 5, 80–90 cm long to homogenous diatom ooze with zones showing concentration of phosphatic material and with thin calcite laminae. As Section 2, 52 cm: gray orange (10YR 6/2) and homogeneous diatom ooze. Isolated sharp and gradational contacts between laminated zones, indicating sedimentary rhythmite. Sections 1 and 2: laminated couplet brown (5Y 4/4) ooze. Couplet mm/pair. Thicker second order cycle distinctive and rhytromorphic. Higher productivity of the second order cycle. Laminations form marl-like facies. Sections 3 and 4: calcite-rich ooze. Contacts from laminated down to homogeneous. Transition zone Section 5, 80–90 cm long to homogenous diatom ooze with zones showing concentration of phosphatic material and with thin calcite laminae.</td>
</tr>
<tr>
<td>2</td>
<td>Moderate olive brown (5Y 4/4) homogeneous diatom ooze. Contacts from laminated down to homogeneous. Transition zone Section 5, 80–90 cm long to homogenous diatom ooze with zones showing concentration of phosphatic material and with thin calcite laminae.</td>
</tr>
<tr>
<td>3</td>
<td>Intermediate zone, down to homogeneous to laminated, systemic of burrowing by large animals as dark, homogenous ooze with indications of bioturbation</td>
</tr>
</tbody>
</table>
### Lithologic Description

Complete core comprises undisturbed rhythmic laminations of moderate olive brown muddy diatom ooze and pale olive (10Y 6/2) diatom ooze in varved section. Wood chips are observed with some pumice ash. Varve couples average 16 cm. Transition to homogeneous (bioturbated) zone at the bottom of core. Strong H₂S odor.

#### Section 1
- **0.5 to 1 m**
  - Pumice fragments common

#### Section 2
- **1.0 m**
  - Uniform, rhythmically laminated couplets of moderate olive brown (5Y 4/4) muddy diatom ooze and pale olive (10Y 6/2) diatom ooze. Laminations regular, but have a second order cycle of more and fewer thicker pale olive laminae occurring on a 10-cm scale. In Section 3, decrease in number of pale olive laminae. Counts of 19, 14, 12-15, and 12 couplets/cm.

#### Section 3
- **1.15 m**
  - Several pumice pebbles imbedded as exotics. Friable, rounded and hard.
  - At Section 1, 140—141 cm: several thin white laminae of pure nannofossil ooze, almost monospecific.

#### SMEAR SLIDE SUMMARY

**TEXTURE:**
- Sand: 10%
- Silt: 30%
- Clay: 60%

**COMPOSITION:**
- Quartz: 25%
- Feldspar: 10%
- Volcanic glass: 5%
- Clay: 10%
- Pyrite: 5%
- Detrital: 5%
- Radiolaria: 5%
- Foraminifera: 5%

**PALEOCLIMATE:**
- Complete core comprises undisturbed rhythmic laminations of moderate olive brown muddy diatom ooze and pale olive (10Y 6/2) diatom ooze in varved section. Wood chips are observed with some pumice ash. Varve couples average 16 cm. Transition to homogeneous (bioturbated) zone at the bottom of core. Strong H₂S odor.

At Section 1, 115 cm: several pumice pebbles imbedded as exotics. Friable, rounded and hard.

At Section 1, 26 cm: reddish brown wood fragments.

At Section 1, 140—141 cm: several thin white laminae of pure nannofossil ooze, almost monospecific.
**LITHOLOGIC DESCRIPTION**

**SITE 480, HOLE 30, CORED INTERVAL 142.60–147.25 m**

<table>
<thead>
<tr>
<th>RHYTHMIC CYCLE</th>
<th>BRYO</th>
<th>GRAPHIC LITHOLOGY</th>
<th>FOSSIL</th>
<th>LITHOLOGIC DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td></td>
<td>VOID</td>
<td>Finely laminated, moderate olive brown (5Y 4/4) to grayish brown (10YR 4/2) MUDDIY DIATOM OOZE and pale olive (10YR 4/2) MUDDIY DIATOM OOZE couplet. Fossil nannoplankton less prominent than previous core giving general darker cast. Coasters, tomonts on a sub-mm-scale. End of minor bioturbation at Section 2, 12 cm. Strong H₂S odor.</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td></td>
<td>VOID</td>
<td></td>
</tr>
</tbody>
</table>

**SITE 480, HOLE 31, CORED INTERVAL 147.25–192.00 m**

<table>
<thead>
<tr>
<th>RHYTHMIC CYCLE</th>
<th>BRYO</th>
<th>GRAPHIC LITHOLOGY</th>
<th>FOSSIL</th>
<th>LITHOLOGIC DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td></td>
<td>VOID</td>
<td>Rhythmically laminated moderate olive brown (5Y 4/4) to grayish brown (10YR 4/2) MUDDIY DIATOM OOZE and pale olive (10YR 4/2) MUDDIY DIATOM OOZE couplet. Fossil nannoplankton less prominent than previous core giving general darker cast. Coasters, tomonts on a sub-mm-scale.</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td></td>
<td>VOID</td>
<td></td>
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<tr>
<td>1</td>
<td>3</td>
<td></td>
<td>VOID</td>
<td></td>
</tr>
</tbody>
</table>

**CARBONATE BOMBS: CC: 0%**
GUAYMAS BASIN SLOPE SITES

Site 479

- 0 cm
- 25
- 50
- 75
- 100
- 125
- 150

8-2
8-3
8-4
8-5
8-6
9-1
9-2
9-3
9-4
9-5
10-1
10-2
GUAYMAS BASIN SLOPE SITES

Site 479

0 cm

16, CC 17-1 17-2 17-3 17-4 17-5 17-6 17-7 18-1 18-2 18-3 18, CC 19-1

16

25

50

75

100

125

150

17, CC