7. SITE 331

The Shipboard Scientific Party[1]

SITE DATA

Date Occupied: 13-16 May 1974

Time on Site: 92 hours

Position: 37°53.00'S, 38°06.92'W

Number of Holes: 1

Water Depth: 5077 corrected meters (echo sounding)

Bottom Felt at: 5073.5 meters (drill pipe)

Penetration: 18 meters

Number of Cores: 2

Total Core Recovered: 8.5 meters (47%)

Age of Oldest Sediment: lower Pleistocene

Acoustic Basement: Not reached

Summary: A combination of bad weather—both experienced and forecast—and damage to the drill rig caused the hole to be abandoned after penetrating only 18 meters in 4 days of drilling. None of the major goals was achieved. The recovered sediment consists of lower Pleistocene diatomaceous clay with quartz-silt layers, containing large and robust diatoms and radiolarians endemic to cool, circumpolar waters as well as more temperate forms, suggesting transport of Antarctic Bottom Water. However, some brackish-water diatoms, together with the coarse fraction and heavy minerals in the silt and sandy silt layers, were more probably derived from the continental margin of South America.

BACKGROUND AND OBJECTIVES

Site 331 is located in the east-central part of the Argentine Basin, in 5067 meters of water at 37°53.00'S, 38°06.92'W (Figure 1). The general stratigraphy of Argentine Basin sediments is apparently homogeneous over so wide an area that a single hole such as this can be used to identify seismic reflecting horizons over virtually the entire basin. At the site (Figure 2) thin, highly stratified sediments overlie somewhat more transparent sediments, at the base of which lies a single, rather diffuse reflector, Horizon A. In the North Atlantic a correlative of this reflector has been identified as a chert sequence, the upper members of which are of mid-Eocene age. Coring at Site 328 south of the Falkland Fracture Zone had attributed a similar reflector to an increase in lithification in an otherwise uniform clay sequence, at or near the Cretaceous-Tertiary boundary. Beneath Horizon A are transparent sediments above a rough basement presumed to be the oceanic basaltic layer. At the site the total sediment thickness was 1.2 sec two-way time, equivalent to about 1 km. The site lay midway between magnetic anomalies 33 and 34, and a paleontologic age for the basal sediments was therefore a major site objective, and sufficient time for this had been allowed. Perhaps more realistic, however, were the other aims of sampling continuously the uppermost, Quaternary sequence to examine southern hemisphere climatic variations, acquiring a deep water biostratigraphic section, and sampling Horizon A in some detail.[2] Information on the paleocirculation pattern, particularly the history of Antarctic Bottom Water movement through the basin, was expected also to emerge.

SURVEY AND OPERATIONS

After a long journey northward from the Falkland Plateau, *Glomar Challenger* approached Site 331 along 030° at 9.5 knots, slowing to 6 knots at 2045 on 12 May. A sonobuoy and a 13.5-kHz beacon were dropped simultaneously at 2330. By 0130 on 13 May, the sonobuoy line had been completed, and the ship was positioned over the beacon in 5067 meters of water only 2 km from the proposed site, sufficiently close in this instance.

With at least 3 days of good weather forecast prior to running in the hole, the pipe was spudded in at 1515 on 13 May. The first core came on deck at 1640 (Table 1). After a second core at 1900, the heave compensation, in use for the first time during Leg 36, blew a seal and, after pulling out to the midline, was set back. By this time, despite the forecast, the weather had deteriorated to a point at which it was pointless to spud in again. Pipe was pulled in slowly in the expectation that the weather would soon improve, but instead it worsened, so that by 1200 on 14 May the ship had lost the beacon. By 1500 work on the rig floor had stopped with 2187 meters of pipe still in the water. The ship remained hove to, trying to minimize the stress on the pipe which, after

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[2]This was accomplished during the course of Leg 39 at Site 358.

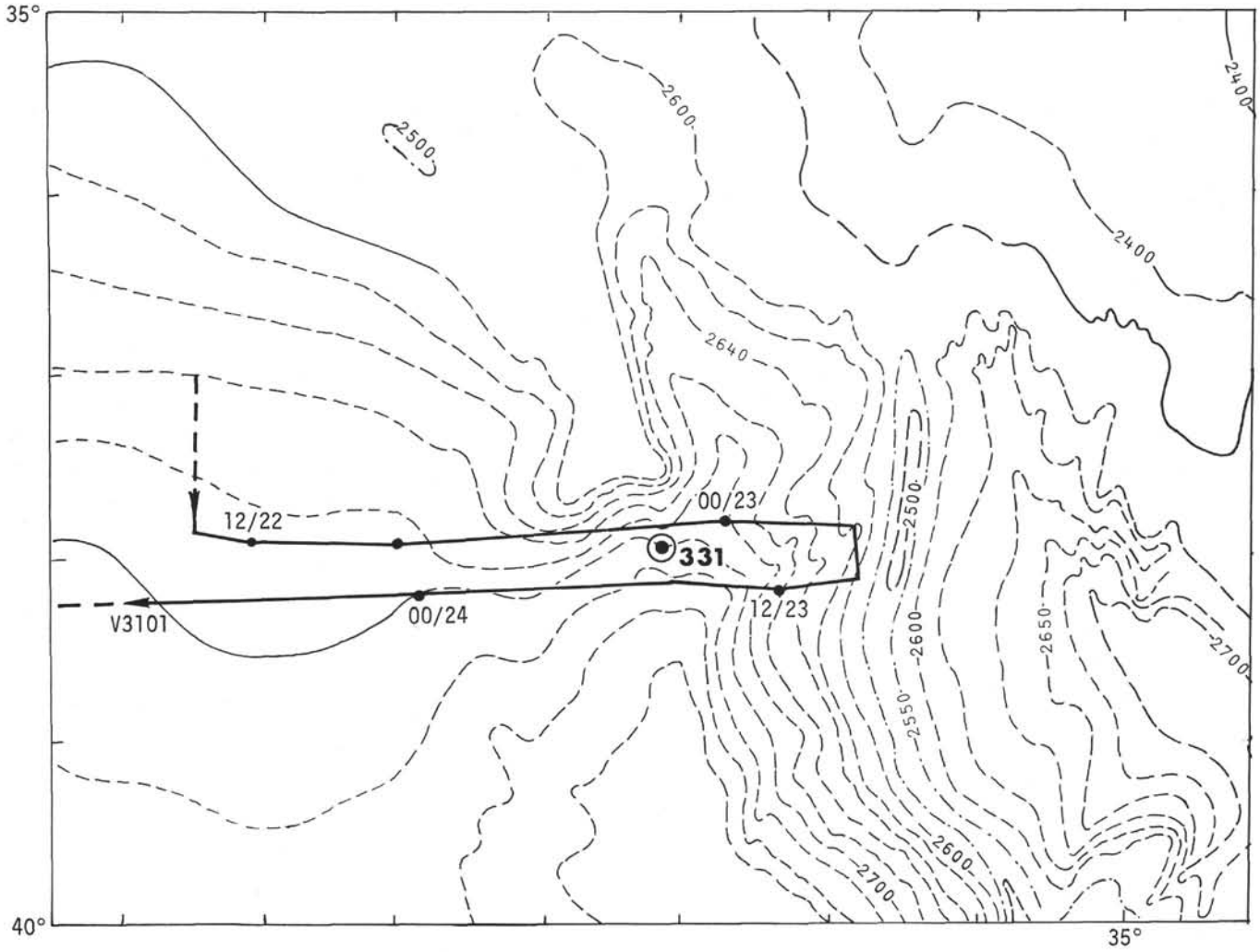

Figure 1. *Bathymetry of the Argentine Basin in the vicinity of Site 331 (after Lonardi and Ewing, 1971), with Vema 3101 track.*

a while, could again be pulled slowly. The weather improved and the remainder of the pipe had been recovered by 1745 on 15 May. Three more days of good weather were forecast, and there seemed still to be time to achieve the major objectives of the site. The ship set out to relocate the beacon, but was hampered by a breakdown of the Sat-Nav computer. This meant that the ship's position was unknown at the time, but could be computed at Scripps after the cruise. The search for the beacon failed, and a fresh beacon was laid at 1950Z. The pipe was run into the hole again, but stopped at 4389 meters when it was learned that a joint of pipe which had slipped out of the elevators at some time during pulling pipe on 14 May, had in falling damaged beyond repair the motor of the manlift. The weather was again becoming rough. Since a harness (the only alternative to use of the manlift for servicing the sandline) would be unsafe in poor weather, the pipe was pulled again, coming on deck at 2045 on 16 May.

More bad weather was now forecast, so the site was abandoned. The ship steamed at 340°T over the beacon at 2130 on 16 May, altered course to 000°T, and increased to 9.5 knots.

An attempt was made, without benefit of satellite fixes, to locate a proposed Site 332 within the Vema Channel, which links the Argentine and Brazil basins. A suitable location was found, and a beacon dropped at 0500 on 20 May, but the site could not be drilled because a breakdown of the power supply to the vertical reference gyros of the automatic positioning system prevented the ship from being positioned stably over the beacon. *Glomar Challenger* sailed directly for Rio de Janeiro, arriving at 1215 on 22 May.

LITHOLOGY

Description

A single surface core, from 0 to 8.5 meters, was taken from Site 331. This core, which is relatively undisturbed and represents 100% recovery, is composed entirely of clay and silt of Quaternary age.

Colors throughout the core are drab hues of green which show only subtle variations. Color units vary in thickness from 10 to 80 cm with the most notable change being an apparently cyclic but diffuse alterna-

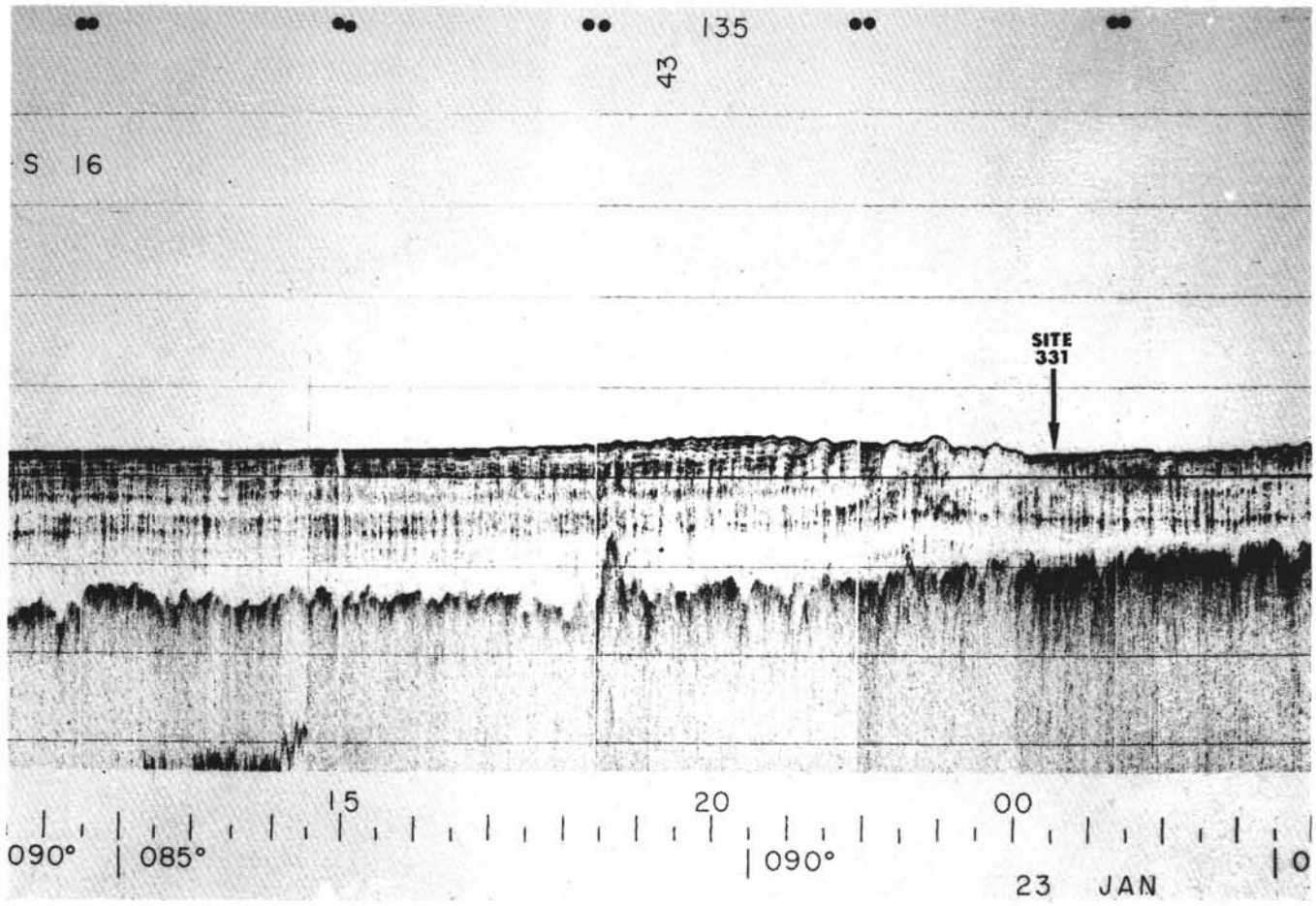

Figure 2. Vema *31-01 reflection profile in the vicinity of Site 331 (see Figure 1 for track).*

tion between olive-gray (5y 4/1) and greenish-gray (5g 6/1).

On the basis of smear-slide descriptions, negligible lithological differences could be detected between the color units in most cases. By far the dominant sediment type is a quartz silt-bearing diatom-rich clay. The bulk of this comprises 40% to 70% clay minerals, 5% to 20% silt-sized quartz and feldspar, and 7% to 20% fragmented diatoms.

Minor constituents include up to 10% fragmented Radiolaria spicules and silicoflagellates. Zeolites are present in amounts varying from 3% to 7% with glauconite and detrital mica occurring throughout as trace components. Volcanic glass is ubiquitous and in one case makes up an estimated 3% of the sediment. An assemblage of heavy minerals is present in amounts which vary from traces to 2%. This heavy mineral fraction, which contains hornblende, tourmaline, sphene, monazite, apatite, and (?) pyroxene, is typical of igneous and metamorphic provenances.

Several zones consisting of well-sorted silt and sandy silt occur throughout the core, particularly in Section 6. In most cases these have been disturbed by the coring process and are present as small (2-5 cm) "pods" within the clay. These pods are considered to represent disrupted thin silt layers. A less disturbed and somewhat thicker (33 cm) silty horizon occurs in Section 6. This comprises an upper 5 cm of silt, with a relatively dis-

TABLE 1
Coring Summary, Site 331

Core	Date (May 1974)	Time (GMT Z)	Depth From Drill Floor (m)	Depth Below Sea Floor (m)	Cored (m)	Recovered (m)	Recovery (%)
1	13	1640	5073.5-5082.0	0-8.5	8.5	8.5	100
2	13	1840	5082.0-5091.5	8.5-18.0	9.5	Tr	0
Total					18.0	8.5	47

tinct upper contact, grading down through a 20-cm-thick disturbed silt and clay interval to a well-defined lower 5-cm sandy silt layer with a relatively distinct lower contact. Smear slides show this to be a well-sorted sandy silt composed of 50% silt and minor sand-sized quartz, 15% feldspar, and 20% altered grains which may be rock fragments or feldspars. Heavy minerals and volcanic glass constitute an important proportion of the sediment (2%-5%), and small amounts of mica, glauconite, zeolite, and siliceous microfossils are present. The >63μm fraction, which is subordinate in amount, comprises 60% glass shards, which are dominantly of rhyolitic composition, some quartz and feldspar sand, and siderite.

Interpretation

Site 331 is situated in an area of well-documented nepheloid-layer deposition (Ewing et al., 1971). Bottom topography is dominated by giant ripples which have been documented in various publications by workers from the Lamont-Doherty Geological Observatory. On the basis of a single 8.5-meter core, it is not possible to state conclusively that a typical sample of material comprising these giant ripples has been obtained. However, the sediment texture and composition indicate that it could be representative of the area.

The dominantly clayey and immature nature of the sediment, along with the presence of some endemic Antarctic diatoms, suggest that the bulk of the material could have settled from the nepheloid layer which in turn has been identified with Antarctic Bottom Water flow. The silts and clays could in part have originated in Antarctic areas; however they may have been largely derived by bottom current erosion of the continental rise and abyssal plain off southeastern South America. The occasional layers of well-sorted silt and sandy silt may represent distal turbidite deposition, originating on the continental margin of South America. The well-sorted nature of these, and the anomalously high (5%) heavy mineral content, however, suggest a more likely process to be current winnowing of the dominant sediment type in the area, which is the slightly silty clay described above. This is in accord with the high-resolution 3.5-kHz seismic profiles collected during cruises of the Lamont-Doherty Geological Observatory (Ewing et al., 1971) which show giant ripple structures which have migrated laterally by current erosion on their "stoss faces" and deposition on their "foresets."

PHYSICAL PROPERTIES

Sonic velocity, wet bulk density, porosity, and water content studies were performed in all six sections of the single core recovered from this site. Velocities were measured using the Hamilton frame method, and other physical properties were determined by gravimetric and GRAPE labratory methods. These values are shown in the site summary graphic log and core summary. Acoustic impedances were calculated from these measurements.

The core consists of 8.5 meters of lower Pleistocene diatom-rich silty clay, becoming more silty toward the bottom. Sediments had moderate to high water contents and showed a relatively plastic condition.

Bulk densities range from 1.25 g/cm^3 to 1.50 g/cm^3 with an average of 1.40 g/cm^3, and porosities from 73% to 56% with an average of 66%. Water contents range from 51% to 38%. Sonic velocities vary moderately with depth, ranging from 1.52 km/sec to 1.55 km/sec and average 1.53 km/sec.

The highest velocity was measured in a more indurated layer, consisting of clayey silt (about 80% silt and 20% clay), the silt fraction consisting mostly of quartz. Here porosity and water content are about 18% lower than the core average.

Average impedance of the core is 2.14×10^5 g/cm^2 sec.

The plotted values are estimated to be accurate to ±7% syringe porosity, ±6% GRAPE porosity, ±0.1 g/cm^3 syringe bulk density, and ±1% velocity.

PALEONTOLOGY

Biostratigraphic Summary

No calcareous fossils were recovered at this site due to deposition below the calcite compensation depth. Siliceous microfossils recovered are all Quaternary in age.

Diatoms

Samples from the core catchers of Cores 1 and 2 were examined for this site. Diatoms are abundant and moderately to well preserved in the samples examined.

A Quaternary age is suggested for these samples by the presence of *Nitzschia kerguelensis, Eucampia balaustium, Charcotia actinochilus, Coscinodiscus lentiginosus, Actinocyclus ingens*, and *Coscinodiscus elliptopora.* All of these species, except *Actinocyclus ingens*, are endemic to the Antarctic. This suggests transportation of the diatoms to Site 331 by current action, probably by the Antarctic Bottom Water.

Radiolaria

The radiolarian assemblages in the two core-catcher samples examined from Site 331 are well preserved and quite diverse. The Radiolaria represent probably about 60% to 70% of the coarse fraction (>63μm). In the samples the coarse fraction itself is very small, not more than 1% of the bulk weight of the sediment.

The fairly common presence of *Stylatractus universus* in both samples indicates a minimum age of 400,000 yr B.P. (extinction datum for this species). This is supported by a few specimens of *Amphirhopalum ypsilon* with two proximal chambers on the forked arm before bifurcation, which according to Nigrini (1971) indicates the lower Pleistocene as more recent species have four or five chambers before bifurcation. There is some evidence of contamination with older fossils in both samples examined as one specimen of *Actinomma tanyacantha* (Miocene) was observed as well as a rare occurrence of *Clathrocyclas bicornis* of Pliocene age.

The assemblages contain the impressions of two distinct oceanographic environments, one indicating temperate waters and the other indicative of the cool cir-

cumpolar waters. The first environment is characterized by the presence of *Lamprocyclas maritales maritales, Lamprocyclas maritales polypora, Theoconus zancleus, Eucyrtidium acuminatum, Pterocanium praetextum, Tetrapyle octacantha, Heliodiscus asteriscus, Tholospyris scaphipes, Siphocampe erucosa*, and *Amphirhopalum ypsilon*. The cool water assemblage is represented by abundant *Antarctissa denticulata* and few specimens of *Spongurus pylomaticus, Lithelius nautiloides, Spongotrochus glacialis, Dictyophimus mawsoni*, and *Pterocanium hirundo*.

The general appearance of the cool-water assemblage is more robust and of a seemingly more uniform size than that of the temperate-water fauna. This can be explained by long-distance transport into this area by bottom currents from the southern end of the Argentine Basin northward. An alternate explanation is to accept only part of the Antarctic assemblage present as being introduced in this area by bottom currents, especially in the smaller size range, and to consider also introduction of the cold-water assemblage this far north by its being endemic to the Antarctic Intermediate Water which moves northward between the underlying North Atlantic Deep Water and the overlying Sub-Antarctic Surface Water. At present it is difficult to determine which of the processes mentioned above is the more important.

SUMMARY AND CONCLUSIONS

Summary

Site 331 is located at 37°53.00'S, 38°06.92'W at a depth of 5067 meters in the Argentine Basin. It was occupied from 0130Z on 13 May to 2130Z on 16 May. The objectives of the site were to investigate the biostratigraphy, major reflectors, and circulation history of the Argentine Basin, and to date magnetic anomalies 33 and 34. The site had to be abandoned before these objectives could be achieved due to continuing bad weather and irreparable damage to the motor that powers the manlift on the drill rig. The damage was sustained when a stand of pipe fell, hitting the motor.

Total penetration was 18.0 meters. Two cores were taken, the first (8.5 m long) being fully recovered, the second obtaining merely a trace of sediment in the core catcher.

The sediment recovered consists of lower Pleistocene drab green diatomaceous clay with quartz silt layers. It consists of 40%-70% clay, 5%-20% silt-size quartz and feldspar, and 7%-20% diatoms in addition to Radiolaria and other siliceous organisms, glauconite, silicic volcanic glass, and a heavy mineral suite indicative of an igneous and metamorphic source. Several species of diatoms are endemic Antarctic species. The apparent dominance of larger diatoms suggests the effects of current action. Radiolarians characteristic of cool circumpolar waters are present together with forms found in more temperate waters. The cool-water species are more robust, again indicating the importance of current winnowing. Diatoms from a brackish water environment are also present.

Conclusions

Seismic reflection profiles in the vicinity of Site 331 reveal the presence of giant sediment ripples which are believed to have advanced along the floor of the Argentine Basin under the influence of a bottom current (Ewing et al., 1971; Ewing and Lonardi, 1971). The material recovered from Site 331 supports this interpretation. The sediment is immature and clay rich. It contains large diatoms and Radiolaria with Antarctic affinities as well as forms characteristic of more temperate waters. The silt and sandy silt layers in the sediment are well sorted and contain a high proportion of heavy minerals.

From the evidence available at Site 331 it is apparent that at least during the lower Pleistocene a deep, sediment-rich current of Antarctic Bottom Water was active in the vicinity of Site 331. This was transporting as a nepheloid layer and winnowing material derived both from the Antarctic region and from the continental margin of South America. As bottom current activity was vigorous in the Quaternary (see Site 328, Summary and Conclusions), it is possible that silt and even sand-sized material was transported into the Argentine Basin by the Antarctic Bottom Current at that time. However, the coarse fraction and heavy minerals were more likely derived, with the brackish water diatoms, from the continental margin of South America.

REFERENCES

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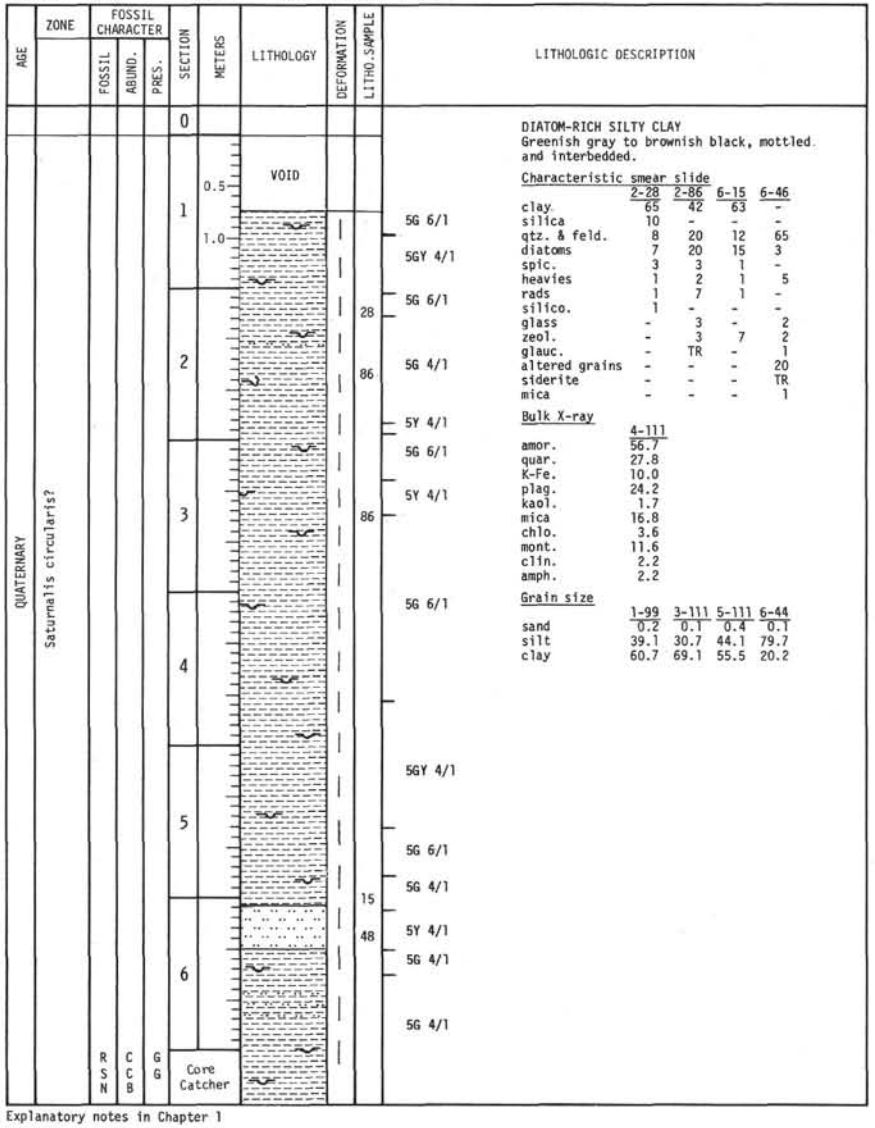
Site 331 Hole Core 1 Cored Interval: 0.0-8.5 m



DIATOM-RICH SILTY CLAY
Greenish gray to brownish black, mottled and interbedded.

Characteristic smear slide

	2-28	2-86	6-15	6-46
clay	65	42	63	-
silica	10	-	-	-
qtz. & feld.	8	20	12	65
diatoms	7	20	15	3
spic.	3	3	1	-
heavies	1	2	1	5
rads	1	7	1	-
silico.	1	-	-	-
glass	-	3	-	2
zeol.	-	3	7	2
glauc.	-	TR	-	1
altered grains	-	-	-	20
siderite	-	-	-	TR
mica	-	-	-	1

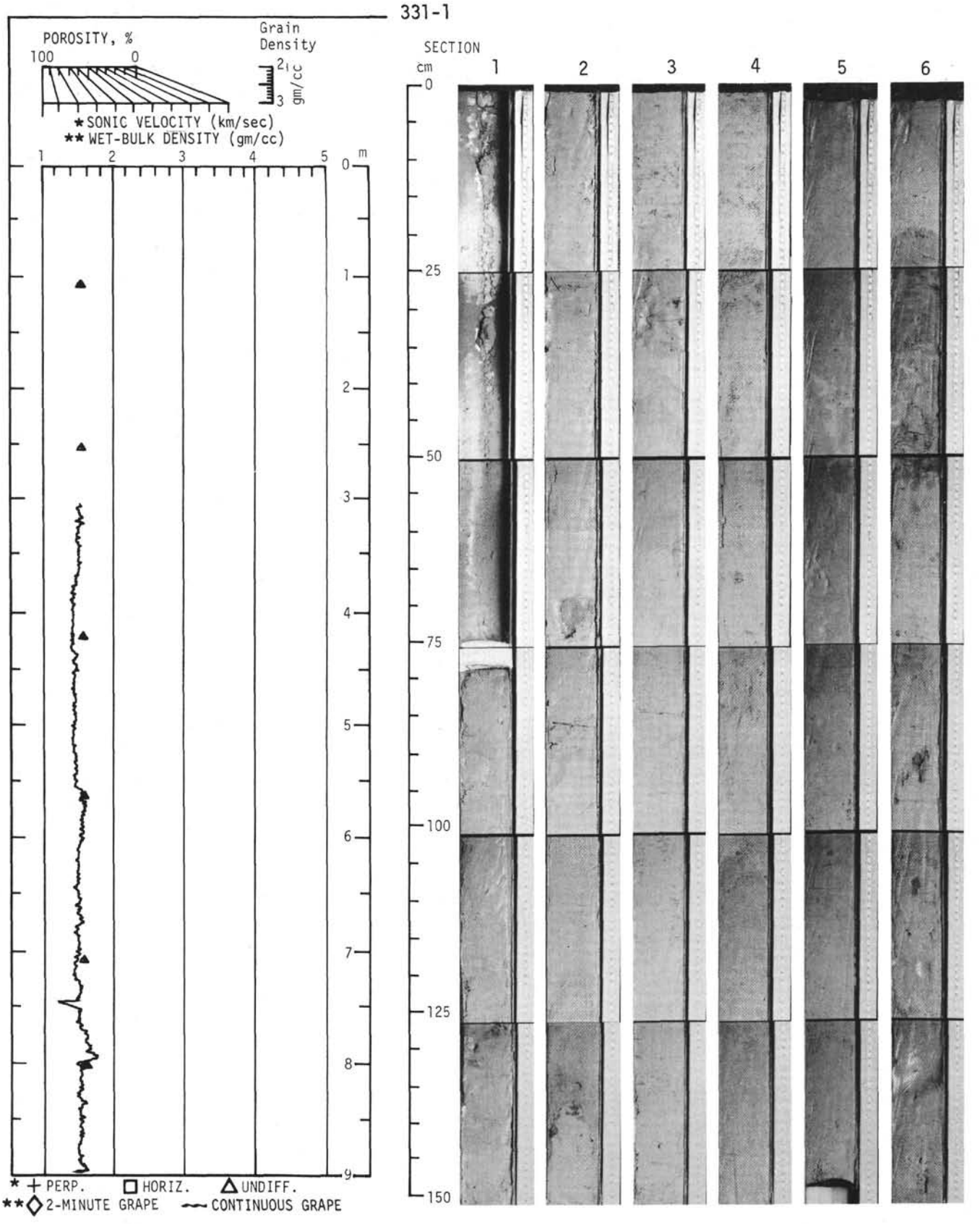
Bulk X-ray

	4-111
amor.	56.7
quar.	27.8
K-Fe.	10.0
plag.	24.2
kaol.	1.7
mica	16.8
chlo.	3.6
mont.	11.6
clin.	2.2
amph.	2.2

Grain size

	1-99	3-111	5-111	6-44
sand	0.2	0.1	0.4	0.1
silt	39.1	30.7	44.1	79.7
clay	60.7	69.1	55.5	20.2

Explanatory notes in Chapter 1


331-1
POROSITY, %
100
0
Grain Density
2
3
gm/cc
*SONIC VELOCITY (km/sec)
**WET-BULK DENSITY (gm/cc)
1
2
3
4
5
m
0
1
2
3
4
5
6
7
8
9
SECTION
cm
1
2
3
4
5
6
0
25
50
75
100
125
150
* + PERP.
HORIZ.
UNDIFF.
** ◇ 2-MINUTE GRAPE
CONTINUOUS GRAPE