4. SITE 320

The Shipboard Scientific Party[1]

SITE DATA

Location: East edge of Nazca plate (Peru Basin)

Dates Occupied: 21-28 January 1974

Time on Site: 157 hours (6.54 days)

Position: 9°00.40′S; 83°31.80′W

Water Depth: 4487 meters (drill pipe)

Penetration: 183.5 meters

Number of Cores: 9

Total length of Cored Section: 84.5 meters

Total Core Recovered: 46.65 meters

Percentage Core Recovery: 55%

Oldest Sediment Cored:
  Depth below sea floor: 155 meters
  Nature: Nanno-foram ooze
  Age: Late Oligocene (N2)
  Measured velocity: 1.58 km/sec

Basement
  Depth below sea floor: 155 meters
  Nature: Basalt
  Velocity: 5.21-5.88 km/sec

Principal Results: At Site 320, the sediment section was spot cored and the basement continuously cored. The top 15.5 meters consist of greenish-gray to olive-green siliceous clay, rich in opaline fossils of Pleistocene age. This is capped by a thin layer of brown ooze with agglutinated forams and rads which may be Holocene in age. The lower sediment section is iron-rich nanno ooze of late Oligocene to early Miocene age (N2 to N8). Sedimentation rates are 5-9 m/m.y. for the Oligocene and Miocene and 7.5-30 m/m.y. for the Quaternary. The high rates for the Quaternary mostly reflect the high organic productivity of the Humboldt (Peru) Current. Basement was cored for a total interval of 28 meters and consists of fine-grained to glassy basalt, probably a series of pillows or thin flows comprising about nine cooling units. Recovery was very poor due to the highly fractured nature of the rocks. Phenocrysts include plagioclase (fresh) and olivine (commonly altered to smectite). Bulk density increases downward from 2.72 to nearly 2.90 g/cc; compressional wave velocity increases from 5.21 to 5.88 km/sec. Paleomagnetic inclinations are normal for the latitude.

BACKGROUND AND OBJECTIVES

Geologic Setting

Information about the early history of the Nazca plate is almost entirely limited to magnetic anomaly data; piston cores have recovered no sediment older than Pliocene along the eastern edge of the plate. Eastward from the fossil Galapagos Rise toward the Peru-Chile Trench, the crust is progressively older. Magnetic anomaly 16 (42 m.y. old) is recognized at the eastern edge of the plate from 12° to 17°S (Herron, 1972) (Figure 1). Based on the Sclater age-depth curve (Sclater et al., 1971), the oldest crust in the Nazca plate north of Nazca Ridge (sometimes called the Peru Basin) should be about 40 m.y. old.

The northwesterly trend of the Galapagos Rise and the magnetic anomalies near the east edge of the Nazca plate (Herron, 1972) suggest that sea-floor spreading from the Galapagos Rise took place in a northeast-southwest direction. Studies of Nazca plate bathymetry by Mammerickx et al. (1975) have confirmed this spreading direction by the discovery of the large, northeast-trending Grijalva and Mendaña fracture zones. The Mendaña Fracture Zone is a narrow region of rugged topography which separates a gently undulating terrain of 4400 to 4800 meters depth on the south from similar terrain of 4000 to 4400 meters depth on the north; Site 320 is located in this northern block. The terrain in both blocks gradually deepens toward the Peru-Chile Trench.

In predicting the age of the crust in this area, an enigma arises. According to the Sclater age-depth curve, the terrain in the south block should be as old as 40 m.y., and the higher terrain to the north about 30 m.y. old. Sediment thicknesses in the southern, presumably older block are less than one-half the thicknesses in the northern block. The increase is gradual: from 0.11 sec south of the Mendaña Fracture Zone at 12°S to 0.15 sec at 10.5°S, 0.20 sec at 9°S, and 0.25 sec at 7.7°S. This thickness is too far south of the equator to be attributed to the zone of equatorial high productivity. Interpretation of magnetic anomalies becomes more difficult north of 12°S, due to the proximity of the magnetic equator, so the problem is one that is best resolved by drilling.

Surface sediments at the site are light to dark brown clay (Rosato et al., in press) or greenish-gray to olive-green clay and mud. Calcareous ooze is generally absent from those parts of the basin deeper than 4000 meters. According to Rosato et al. (1974) and Kulm et al. (this volume), the dominant clay minerals near Site 320 are smectite, illite, and minor amounts of kaolinite and chlorite. There is very little phillipsite (Bonatti, 1963), and little amorphous silica (Rosato et al., in press). The lysocline may be shallower than 3000 meters due to in-

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[1] Robert S. Yeats, Ohio University, Athens, Ohio (Co-Chief Scientist); Stanley R. Hart, Carnegie Institution of Washington, Washington, D.C. (Co-Chief Scientist); James M. Ade-Hall, Dalhousie University, Halifax, Nova Scotia; Manuel N. Bass, Carnegie Institution of Washington, Washington, D.C.; William E. Benson, National Science Foundation, Washington, D.C.; Roger A. Hart, Physical Research Laboratory, Ahmedabad, India; Patrick G. Quilty, West Australian Petroleum Party Ltd., Perth, West Australia, Harvey M. Sachs, Case Western Reserve University, Cleveland, Ohio; Matthew H. Salisbury, National Science Foundation, Washington, D.C.; T.L. Vallier, University of California at San Diego, La Jolla, California. Additional contribution by G. Blechschmidt, University of Washington, Seattle, Washington.

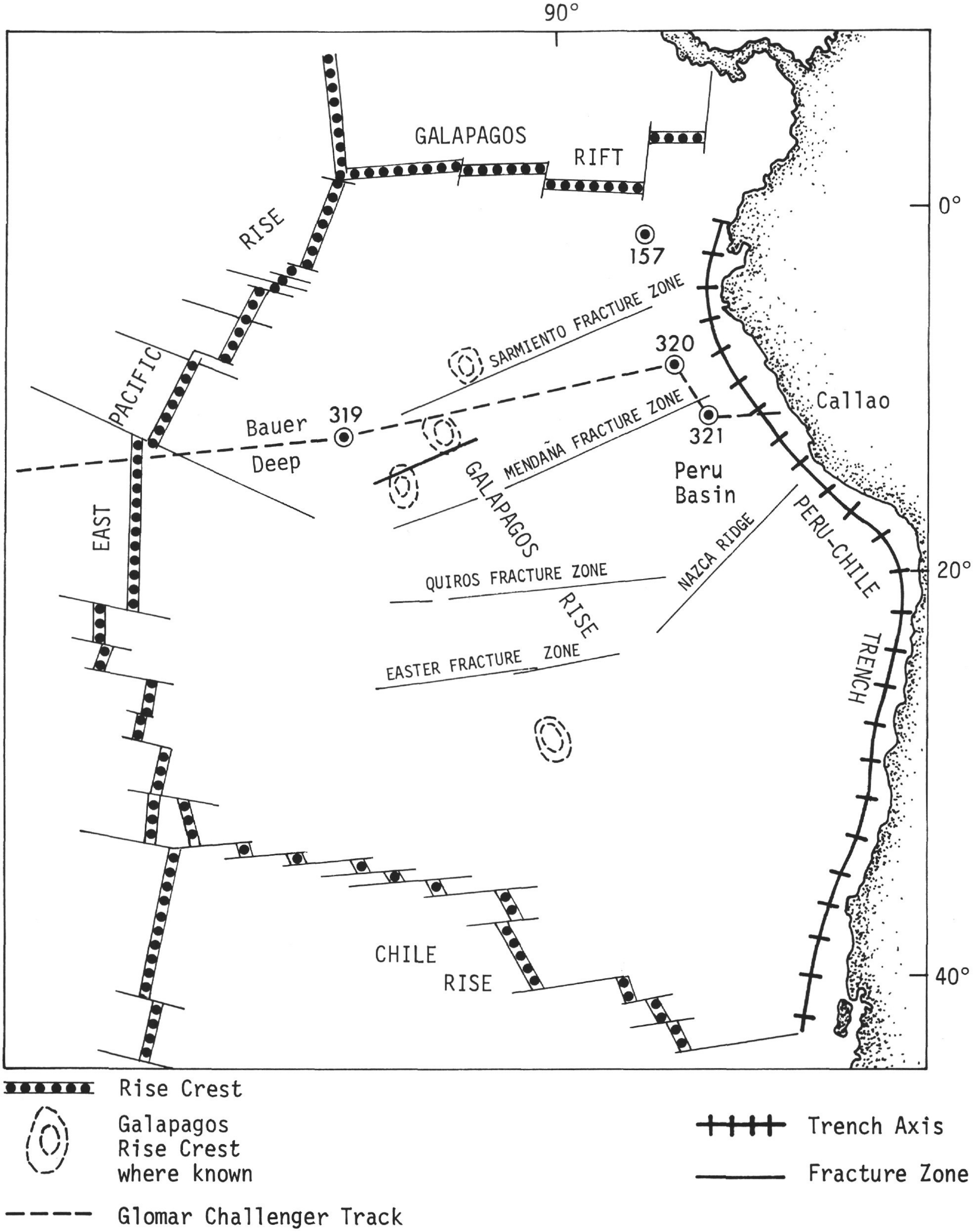

Figure 1. *Location map of sites drilled during Leg 34.*

tense solution effects from the Peru Current (Parker and Berger, 1971).

At 12°S, ASPER data suggest a thrust fault in the Nazca plate west of the Peru-Chile Trench (Hussong et al., 1974). Block faulting within the plate to the north may be tensional in nature. The crustal layering indicated by the ASPER and the two-ship refraction data are in conflict. In many areas, the ASPER data suggest that the sediments are underlain by a 3.1-3.8 km/sec transitional layer 200 meters thick, a 5.2-5.8 km/sec layer 300 meters thick, and a 6.0-6.5 km/sec layer 800+ meters thick. Reversed refraction lines at 8°S show the sediments to be underlain directly by a 5.8-5.9 km/sec layer, 400 to 1000 meters thick, which is underlain by 6.4-6.8 km/sec crust and a lower 7.0-7.3 km/sec crustal layer. The Moho is at 12-13 km, underlain by an 8.5 km/sec mantle. To the south, at 12°S, the Moho is somewhat shallower.

Kelleher (1972) has shown that the continental margin contains a seismic gap between 0° and 10°S, and an absence of historic volcanism from 3° to 16°S (Figure 1). The trench is deformed from 6° to 10°S, corresponding closely to the seismic gap and more generally to the volcanic gap (Kulm et al., 1974).

Site 320 was located from the track of *Kana Keoki* 1971, Leg 8, along 8°S. It is in the area of thickest sediments outside the 200-nautical mile zone west of the South American continent that up to now has been excluded from deep-sea drilling. The relation between sediment overburden thickness and basalt coring rate made sediment thickness an overriding consideration in selecting a site. Part of the *Kana Keoki* profile contains a weak sediment reflector at 0.05-0.1 sec, but this reflector is absent at Site 320.

Objectives

The objectives for Site 320 were (1) to core basalt continuously as deep as possible, with one and possibly two re-entries; (2) to determine the history of the eastern Nazca plate for the last 30 to 40 m.y., particularly changes in depth of the bottom, the CCD, and the lysocline; (3) to determine the effectiveness of the Peru-Chile Trench as a barrier to turbidity current dispersal; (4) to define the stratigraphic column of the eastern Nazca plate so that it could be recognized on the continent side of the trench, if parts of the plate have accreted to the continent in the past; (5) to determine the amount of terrigenous matter in the plate, including volcanic ash from South American volcanoes; and (6) to determine the paleolatitude of the plate from remanent magnetization of basalt.

OPERATIONS

Site Survey

Site 320 was originally planned for latitude 12°S, where an ASPER refraction line gives information about velocities in the crust and upper mantle, and where correlatable magnetic anomalies are found (anomalies 12 through 16, indicating crust as old as 42 m.y.). However, the thinness of sediments at 12°S (80 m, with local pockets up to 120 m) reduced the likelihood of deep penetration of basalt, based on previous DSDP experience in basalt coring. Therefore, the site was moved north to 9°S (Figure 2), where sediment thicknesses up to 160 meters occur, despite the fact that the magnetic structure is of such low amplitude that it cannot be correlated with anomalies elsewhere.

The site was selected from the *Kana Keoki* Leg 8 profile which shows a moderately block-faulted terrain locally broken by small seamounts, all apparently mantled with sediments (Figure 3). As shown on this record, the terrain is a small plateau with less local relief than in other areas, and with a relatively prominent basement reflector at 0.2 sec (Figure 4). There are local

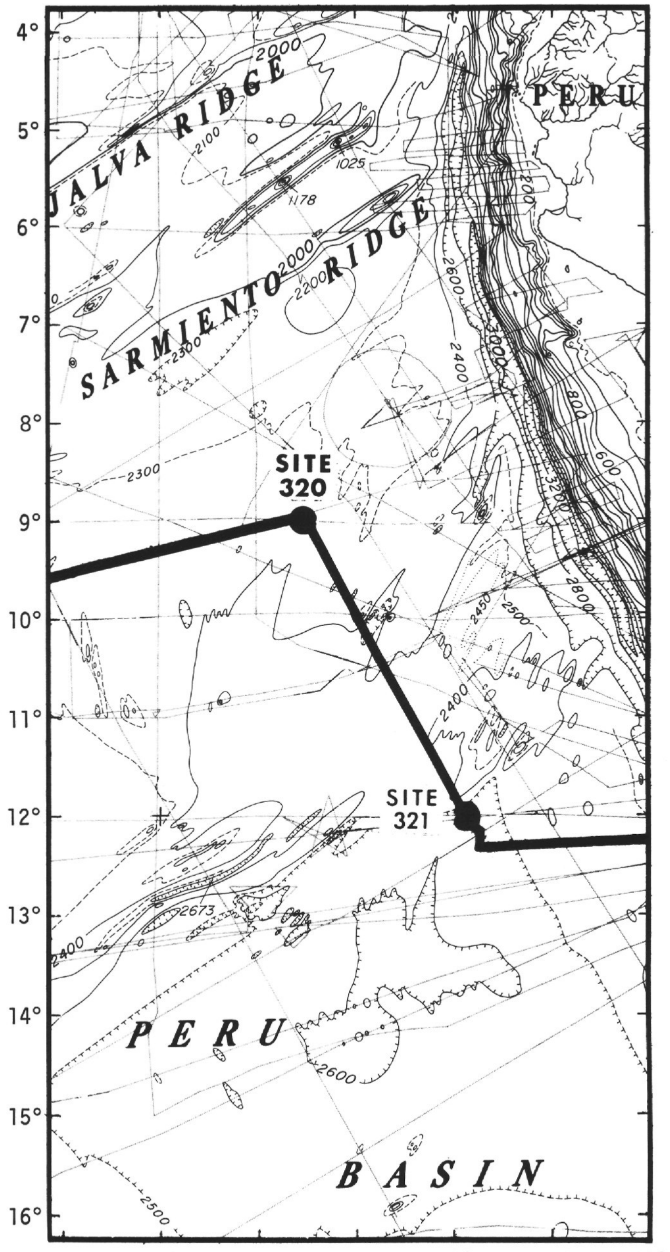

Figure 2. *Bathymetry of Sites 320 and 321 (in fathoms) from Mammerickx et al. (1975).*

weak reflectors in the sediments, but these do not persist, suggesting that a major chert horizon would be unlikely at the site.

We surveyed across the site at 9°02′S to determine the north-south extent of the small plateau, and did not see it, although other features were in common with those on the *Kana Keoki* track. We turned north and then west, directly on the *Kana Keoki* track, and found the plateau, which is about 3 km wide (Figure 3). At the point of beacon drop, the plateau slopes southward, so that water depths at the site are somewhat greater than along the *Kana Keoki* line. The PDR depth stabilized at 4493 meters (corrected); the airgun reading at beacon drop was 4494 ±15 meters (corrected). Sediment thickness is 0.20 sec, or 160 meters at $V_p = 1.6$ km/sec.

Drilling Program

A coring summary for Site 320 is given in Table 1. The operational plan was to take a mudline core, wash to the suggested casing point for a second core, and wash to 100 meters for a third core. The cone would then be keelhauled and the hole drilled into basalt. On 22 January, the first punch core was started at the mudline indicated by PDR, and resulted in full recovery and in the possibility that the mudline was shallower than indicated on the PDR.

The bit was washed down and a core was taken at the casing point, then washed down to 100 meters where a third core was taken. The sediment was quite soft and took weight only near the bottom.

The bit was pulled above the mudline and a new hole (Hole 320A) was spudded at 1100 hr (local time) on 22 January. The coring was started at 4487 meters, 6 meters above the mudline as indicated by PDR, and resulted in full recovery except for a half-meter void at the top. The top of the core consisted of a thin layer of brownish ooze which contains agglutinated forams and Radiolaria less than 0.4 m.y. old, possibly a Holocene fauna. This was taken as good evidence for mudline at 4487 meters.

The drill string was retrieved, the cone keelhauled, and the casing run. The drill string was run in the hole (Hole 320B) and the casing washed in; the cone took 10,000 lb weight at the designated point 2 meters above mudline. The casing was washed from 4487 to 4550 meters, and the hole washed from 4550 to 4623 meters. Two full sediment cores were taken, and basalt was encountered at 4642 meters at the beginning of Core 3. Cores 3 and 4 were cut at relatively rapid coring rates but with low recovery, yielding largely fractured joint blocks of basalt. In both cores, the core catcher was jammed with a piece of basalt which had wedged in the catcher sideways.

Core 5 cut rapidly for 4 meters with some sticking, and very slowly for the last 5 meters with almost continuous minor sticking. The bottom 15 meters of the hole were reamed to bottom and the hole was conditioned with mud so that it was free of sticking. The core barrel for Core 6 was dropped and the bit worked through tight hole to bottom. At this point, the gear box on the Bowen power sub locked up, and the pipe was pulled to permit changeover to the kelly drive. A piece of basalt was found wedged in the throat of the bit.

The kelley was rigged up and pipe was run to a few meters above the cone. After considerable operational problems with the re-entry scanning tool and the Schlumberger winch motor, the cone was entered and the bit was run to within 6 meters of bottom. The next 12 hr were spent trying to get back to bottom using a center bit, working the pipe and adding high-weight mud. The hole would clean up temporarily, then further sticking would occur as additional basalt fell in from the sides of the hole. When bit weight was increased, high torqueing resulted. Finally, the bit reached bottom and became solidly stuck. High-weight mud was added, the pipe worked without attempting to rotate, and the bit became unstuck after several hours.

The hole was abandoned and the ship left station at 0730 hr (local time) 28 January. A sonobuoy was

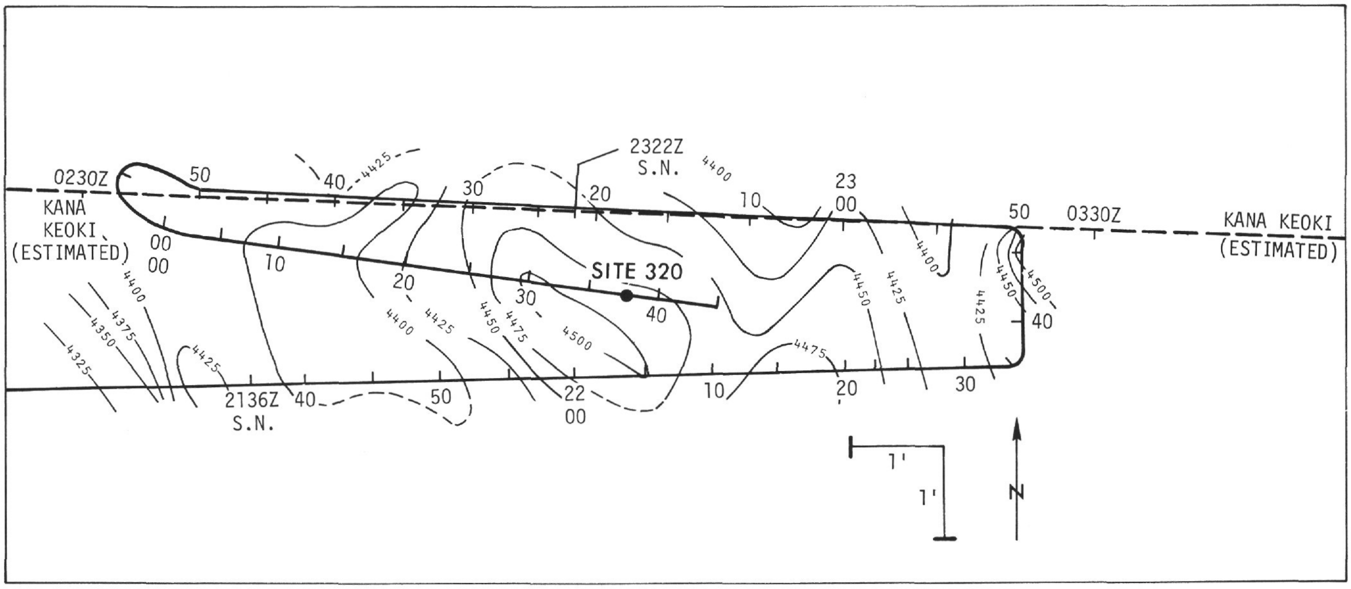

Figure 3. *Detailed bathymetry of Site 320 (in m) based on* Kana Keoki *Leg 8 profiles.*

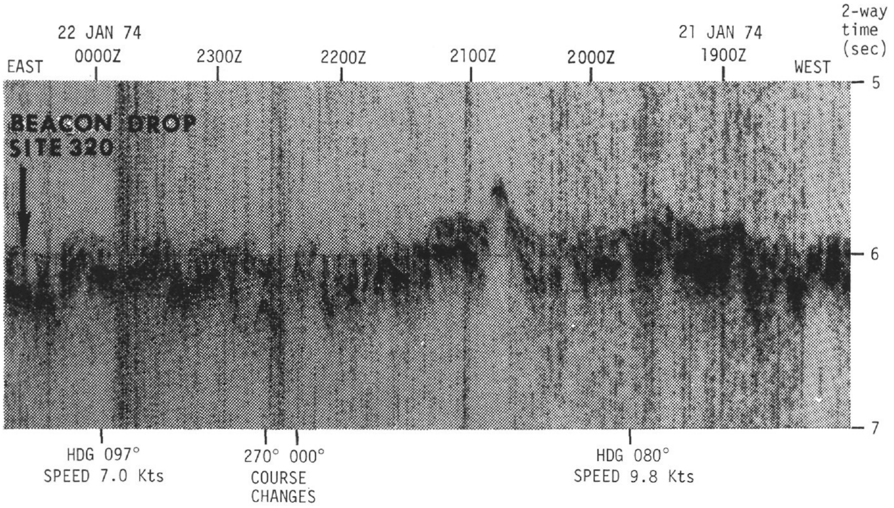

Figure 4. Glomar Challenger *airgun profile (10-sec sweep) approaching Site 320.*

TABLE 1
Coring Summary, Site 320

Core	Time on Deck	Depth from Derrick Floor (m)	Depth Below Mudline (m)	Depth Below Top Basalt (m)	Recovery (m)	(%)	Remarks
Hole 320							
1	0640 (22 Jan)	4493.0-4502.5	6.0-15.5		9.4	99	Punch core, did not take weight
2	0845	4560.5-4570.0	73.5-83.0		1.9	20	Punch core
3	1005	4589.0-4599.0	102.5-111.5		8.1	90	Punch core
Hole 320A							
1	1158 (22 Jan)	4487.0-4496.0	0-9		8.8	98	Punch core
Hole 320B							
1	1657 (23 Jan)	4623.0-4632.5	136-145.5		9.4	99	Had to rotate for 5 min
2	1093	4632.5-4642.0	145.5-155.0		7.5	79	Rotated 45 min
3	2150	4642.0-4651.5	155.0-164.5	0-9.5	0.7	0.07	Rotated 1 hr 25 min, moderate torque
4	0038 (24 Jan)	4651.5-4661.0	164.5-174.0	9.5-19	0.7	0.07	Rotated 1 hr 20 min, high torque
5	0700	4661.0-4171	174.0-183.5	19-29	0.15	0.02	First 4 meters cored rapidly, rest of time intermittent sticking pipe and high torque

dropped on leaving station, but failed 10 min after initiation of airgun recording.

LITHOLOGY

Introduction

Three holes were drilled at Site 320. Hole 320 was spot cored near the surface (6 to 15.5 m) and at depths of 73.5 to 83 meters and 102 to 111.5 meters. Hole 320A, a mudline test, was cored from 0 to 9.5 meters. Hole 320B was designed to recover the lowest sediments above basalt, and was cored continuously from 136 to 155 meters. The core catcher of Hole 320B Core 2 was apparently very close to the basalt contact.

Description of Units: Sediments

From the materials recovered, two sediment units are distinguished which overlie basalt of Unit 3 (Table 2). A stratigraphic column with age and sedimentation rate data is given in Figure 5.

Unit 1: Siliceous Fossil-rich Silty Clay

Unit 1 is a greenish-gray to olive-green siliceous fossil-rich clay and silty clay with a rich and diverse suite of opaline fossils. Accessories include small numbers of silt-sized grains of igneous origin. Calcium carbonate accounts for 2%-3% of the samples by weight and includes rare nannofossils and common fine-grained particles of unknown origin.

In general, 25%-35% of the sediment consists of opaline fossils. In order of decreasing abundance, they are diatoms, radiolarians, sponge spicules, and silicoflagellates, all in pristine condition. In some intervals, these fossils are sufficiently concentrated that the sediment may be considered a siliceous ooze, but clay is dominant in most of the section. All radiolarians examined are Pleistocene in age.

TABLE 2
Lithostratigraphic Units, Site 320

Unit	Hole	Core	Subbottom Depth (m)	Lithology	Age
1	320, 320A	1	0.0-15.5	Siliceous fossil-rich silty clay	Quaternary
2	320 320B	2,3 1,2	73.5-111.5 136.0-155.0	Iron-bearing and iron-rich nanno ooze	Early Miocene and late Oligocene
3	320B	3,4,5	155.0-183.5	Basalt	

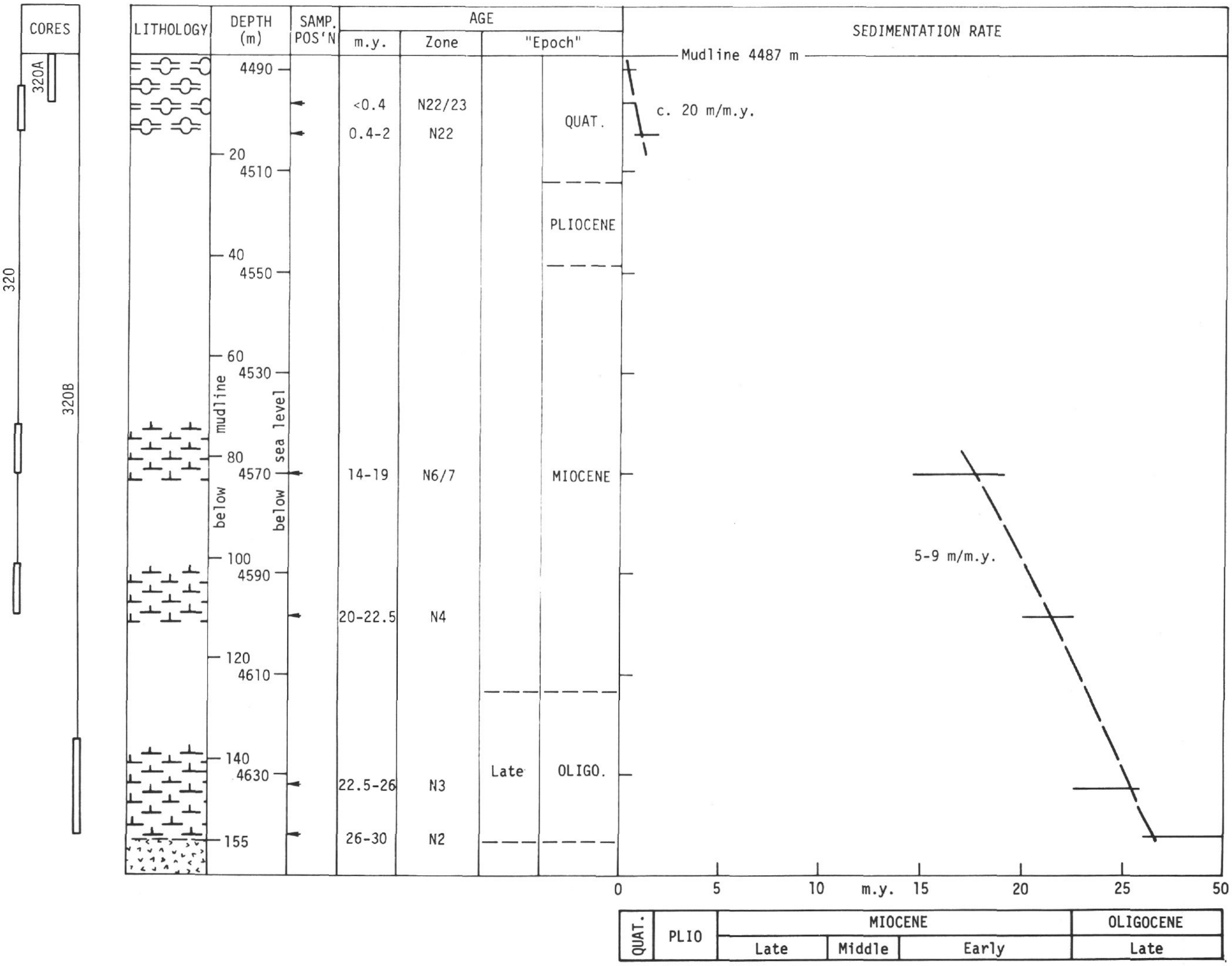

Figure 5. *Stratigraphic column at Site 320 showing age data and sedimentation rates. Horizontal lines on sedimentation rate diagram show precision.*

Volcanic ash is dispersed in low concentrations throughout the unit, and at least one zone (320A-1-4, 65-80 cm) contains several 1-2 cm thick pockets which are greater than 80% glass, with other igneous minerals (feldspars, quartz, and a clear pyroxene), and a few opaline fossils. A single pocket of similar lithology was found at 320-1-2, 70 cm.

Opaque minerals account for less than 1% of the smear slides, including pyrite-filled diatom frustules. Ferruginous particles (our RSOs) are essentially absent; a few yellowish flakes, possibly limonite, were seen in some samples.

Unit 2: Iron-bearing and Iron-rich Nanno Ooze

Unit 2 is a yellow-brown to dark brown nannofossil ooze containing abundant ferruginous grains (RSOs) and a significant but variable foram contribution. This unit comprises at least half the sedimentary section at

Site 320, from some depth shallower than 73.5 meters to the lowest sediments recovered. Ages in this unit range from early Miocene to late Oligocene.

The sediment of Unit 2 is mostly 87%-92% calcium carbonate by weight, except in the uppermost core (Hole 320, Core 2), which is 60%-63% carbonate. The carbonate fraction is dominated by discoasters and coccoliths, which together account for most of the sediment. Fine-grained calcite of unknown origin accounts for 5%-10% of the samples, and foram tests form the remaining carbonate constituent. Foram abundances vary, but generally increase with depth. Calcareous fossil preservation is excellent; but biogenous opal is sparse to absent.

There is less than 15% clay in the uppermost part of Unit 2 (Hole 320, Core 2) and still less in the rest of the unit. The dominant noncarbonate components are the yellow to red ferruginous particles termed RSOs and described in Chapter 3 (this volume). Concentrations (smear slide estimations) of the RSOs are 5%-10% through most of the unit, reaching 15%-20% in occasional darker beds. For sediments of similar color, those from Site 320 tend to have higher RSO concentrations than those from 319. RSO aggregates are distributed throughout Unit 2 at Site 320, although these are limited to the near-surface sediments at Site 319. These aggregates are red to black, nearly opaque, and range in size from 20μ to more than 100μ.

Discussion of Sediments

Given the limited core recovery at Site 320 and the proximity of Site 321, it is not advantageous to discuss and interpret the sedimentary section at this site without reference to Site 321. In terms of sedimentary units, Unit 1 of Site 320 corresponds closely to Unit 1 at Site 321; both are siliceous fossil-bearing clays, somewhat more silty at Site 320. Similarly, the metalliferous nanno (and foram) oozes of Unit 2 (Site 320) lithologically approximate Unit 4 at Site 321.

On the basis of reflection profiles and sediment ages for Sites 320 and 321, the uncored interval at Site 320 (16-73 m) can be inferred, and a reasonable sediment section can be constructed for the site.

While at Site 321 there is a fairly prominent reflecting horizon at about 58 meters, which is the base of the zeolitic brown clay (Chapter 5, this volume), the only reflector at Site 320 is a very weak one at about the same level (60 m). It is inferred that the difference in reflection characteristics indicates a difference in lithologies. Because the lower unit at each site is a similar nannofossil ooze, this implies that the sediment directly above the weak reflector at Site 320 is not zeolitic brown clay like that at Site 321.

Furthermore, the zeolitic brown clay at Site 321 includes the age interval from about 10 to 24 m.y. In contrast, the uppermost nanno ooze recovered at Site 320, at about 73 meters depth, is about 16 m.y. old. Extrapolating the sedimentation rate in the 16 to 73 meter interval (about 2.7 m/m.y.), the interval from 73 meters to the reflector at 60 meters would correspond to about 5 m.y., indicating an age of about 11 m.y. for the sediment at the reflector. From this, two interesting inferences can be drawn: first, if there is a zeolitic brown clay at Site 320, it is not time-correlative with that at Site 321; second, if there is no zeolitic brown clay, then it is likely that terrigenous sedimentation at both Sites 320 and 321 began about 10 m.y. ago. At Site 320, this sediment was deposited on nannofossil ooze, and at Site 321 it accreted on the zeolitic clay.

The differences in RSO concentration between Units 1 and 2 are extreme and probably reflect a cutoff of supply during the deposition of Unit 1. This suggests that the concentration of ferruginous particles is related to proximity to the spreading center. The ferruginous nannofossil ooze of Site 320, Unit 2, is similar to the basal Unit 4 at Site 319, but at Site 320 the average RSO concentration is higher by a factor of 1.5-2.0. Because the sedimentation rate for Site 320, Unit 2, is less than half that of the lower units at Site 319, it is likely that the rate of ferruginous supply to both sites was similar and did not vary over the time intervals represented, but the rate of supply of carbonate to the sediments was higher at Site 319. In this context, it should be noted that the basal sediments at Site 320 are older than those at Site 319, but that the iron-rich sediments overlap in time.

The lowest sediment interval recovered, the core-catcher sample from Hole 320B, Core 2, lies very close to the sediment-basalt contact, inasmuch as Core 3 hit basalt immediately. The core-catcher sample and the sediment immediately above show slightly higher RSO values (15%-20%) than the average for Unit 2, but otherwise are similar to the rest of the unit.

The sedimentary sequence at Site 320 depends mostly on two geographic factors: proximity to a spreading center, and proximity to the South American continent. The metalliferous constituents (Unit 2) are probably related to proximity to a spreading center. Also, the amount of carbonate-bearing sediments is dependent on distance from the spreading center, since the plate is presumed to have subsided through the CCD as it moved away from the center. The second geographic factor, proximity to South America, controls the volcanic ash and opal input into the terrigenous clay of Unit 1. The control on opal input is indirect, being related to the high productivity of the Humboldt (Peru) Current which is in turn controlled by the position of the western continental margin of South America.

Description of Units: Basalt

Unit 3 is basalt. Virtually all of the 28 meters of uniformly fine-grained to glassy basalt from Hole 320B represents pillows or thin flows. At least nine cooling units were sampled, although the poor recovery indicates that additional units may be present. Recovery was in the form of small blocks, each one a natural joint block bounded by stained or vein-coated surfaces. Many of the exposed veins are drusy phillipsite, suggesting that cementation is imperfect and that interpillow spaces are open to some extent. These observations suggest a highly fractured, imperfectly cemented, void-rich pile of pillows composed of relatively small joint blocks, of which only the largest, least cracked, and strongest representatives were recovered.

Considerable amounts of glass are present, both as surfaces on pillow fragments and, in one case, as a large ovoidal mass of solid glass some 3 cm thick. Most natural glass surfaces are altered to palagonite up to 2 mm thick, but commonly thinner than 0.6 mm. The alteration rinds commonly consist of extremely fine-grained aggregates of smectite and are best termed fibropalagonite.

The glass grades inward to a spherulitic layer which alters less readily than the inner, holocrystalline, variolitic rock. Plagioclase and olivine constitute the only phenocrysts, and these are small and very minor (less than 0.5%). Plagioclase is fresh. Olivine is fresh where enclosed in glass and generally altered in the holocrystalline rocks, although even here fresh remnants are found.

The groundmass was originally composed of glass, plagioclase, clinopyroxene, and opaques. Olivine was rare or absent. The clinopyroxene is augite in the holocrystalline rocks and probably pigeonite and subcalcic augite in the spherulitic layer and finer grained variolitic rocks. The opaque minerals are mainly titanomagnetite and small amounts of sulfide and primary ilmenite. The titanomagnetite is typically skeletal and 25μ or smaller in diameter.

The intersertal glass is commonly altered to yellow or brown smectite (never to the nonoxidized green or blue smectite seen at Site 319); surprisingly, fresh intersertal glass survives in the interiors of many specimens (even some altered ones with overall brownish colors). The olivine alters more slowly than the intersertal glass. In the fresher, grayer colored rocks it is pseudomorphed by smectite (rarely green, commonly orange-brown), and in the more altered, browner rocks by earthy red-brown Fe-oxide. Fresh, homogeneous, brown titanomagnetite is present but uncommon. Generally, it shows mottling, cracking, lightening of color, heightened reflectivity, and staining of surrounding minerals indicative of cation-deficient titanomaghemites. Such alteration testifies to extensive, low-temperature halmyrolitic oxidation.

The veins in these basalts vary in three ways: (1) they decrease in overall abundance downward in the core; (2) they change in appearance from the surface of a pillow inward; and (3) they change from the surface of a joint block inwards. Veins in the glassy selvages are massive to drusy phillipsite, often specked with Mn-oxide, and almost always separated from fresh glass by a layer of palagonite. Phillipsite is also the predominant vein material in the interiors of fragments which have glassy surfaces, whereas smectite (both oxidized and nonoxidized types) is the common vein material in the interiors of joint blocks. Tiny vesicles are common in many of the rocks, mainly in the holocrystalline material; many contain thin smectite linings. Amygdules composed of yellow smectite are also present.

BIOSTRATIGRAPHY

General

The faunas and floras and major characteristics are described below for each hole. Faunas are described first, followed by short descriptions of floras. The information from all holes drilled at Site 320 is summarized in Figure 5.

Hole 320

Three cores were taken in Hole 320; faunas vary markedly from core to core and from section to section within one core. In Core 1 fossils are dominantly Radiolaria, but also include rare calcareous nannoplankton, common to abundant diatoms, and some sponge spicules and silicoflagellates. Where calcareous faunas are present, dissolution effects are seldom apparent, and the fauna present is usually very well preserved, even though specimen numbers are always very low.

The foraminiferal faunas of any significance in Core 1 are dominated by *Globigerina dutertrei* and *G. bulloides* with smaller content of *Orbulina universa, Globorotalia cultrata,* and *G. tumida tumida. Globigerina calida praecalida* is present in the core-catcher sample. The age based on foraminifera is late Pliocene to Recent (N20-N23). Foraminiferal faunas lack diversity, and it is probable that the foraminiferal content at the base of the core represents an influence from cool surface waters, certainly cooler than would be expected in the vicinity of Site 319. The radiolarian fauna of this core is abundant, diverse, and well preserved. In Core 2 the samples contain small, though significant, planktonic faunas of low diversity and some contain common benthonic forms. Radiolaria apparently are absent. The deepest sample (Sample 2, CC) contains *Sphaeroidinellopsis seminulina, Globigerinoides quadrilobatus immaturus,* and *Globigerina venezuelana.* In Core 3 all faunas are dominated by *Globigerina venezuelana, G. tripartita,* and *G. binaiensis. Globigerinoides quadrilobatus primordius* occurs in the core-catcher sample and *G. q. immaturus* is present in other section samples. The age of the sample is early Miocene (N4). The samples seem to be low in diversity.

Core 1 is barren of calcareous nannofossils in Sections 1, 2, and 4. A moderately well preserved and fairly diverse Pleistocene assemblage is present in Sections 3, 5, and 6 of Core 1. Early middle Miocene nannofossils were found in Core 2, with *Sphenolithus heteromorphus* being dominant. Core 3 is early Miocene with common *Discoaster druggi, Reticulofenestra abisecta,* and *Sphenolithus conicus.* Preservation of nannofossils in these cores ranges from fair to good.

Hole 320A

A single core (4487 to 4496 m) was taken to find the sediment-water interface. Samples examined from this core include one from the core catcher and one from each of the six sections; that from Section 1 is the surface sample (0.5 cm). All residues are dominantly composed of Radiolaria, diatoms, and silicoflagellates. Ostracodes are present but rare in two samples. Calcareous nannoplankton are absent.

Where planktonic foraminifera are present, the dominant species are, as in Hole 320, *Globigerina dutertrei, G. bulloides,* and lesser numbers of *Globorotalia cultrata.* The fauna from 1-1, 0-5 cm is unique for Leg 34 because it consists almost entirely of agglutinated species of no real age significance. However, the dominant form, identified tentatively as *Botinella labyrinthica* is so delicate that it could not be expected to survive fossilization which may indicate that these faunas are species in situ. Thus, the top of this core is extremely close to the mudline. Other species in this fauna include the spectacular *Bathysiphon filiformis* (to 13 mm long), *Reophax guttifer, R. dentaliniformis, Alveolophragmium globosum,* and *Ammodiscus* (?) *tenuis*. There are no planktonic foraminifera in the sample, and only one calcareous benthonic specimen was recovered. The best foraminiferal fauna in this core is from Sample 1-2, 51-52 cm. Here, foraminifera are more abundant than in other samples, and preservation is excellent. The dominant species are as in the higher two samples, and diversity is still quite low for the latitude.

The foraminiferal faunas in Hole 320A consist entirely of extant species, but the planktonic faunas are of much cooler water aspect than is to be expected at this latitude under normal conditions. The fauna is typical of that normally expected at 35°-45°S latitude in the Pacific Ocean. This must reflect some influence of the Humboldt Current. All warm water forms are absent. In this vicinity, the absence of such warm water indexes renders the normal warm water zonation inoperative, and the closest planktonic foraminifera that can be expected to date the samples is late Pliocene to Recent (N20-N23). Therefore, Radiolaria are useful here.

Core 1 of Hole 320A contains an abundant diverse and well-preserved radiolarian fauna like that of Hole 320. In Hole 320A, samples from the top (Section 1, 0-5 cm) and core catcher (CC) were examined. *Spongaster tetras* was found in the upper sample. Although both samples are Quaternary, 320A-1, CC is distinctly younger than 320-1, CC. First, specimens of *Amphirhopalum ypsilon* from 320A-1, CC generally had four chambers on the forked arm before bifurcating, while those from 320-1, CC had fewer, indicating an older age for the latter sample (Nigrini, 1971). Second, 320A-1, CC had no *Stylatractus universus*, which was seen in 320-1, CC. Since this form became extinct at about 400,000 yr B.P., (Hays, 1970), the one sample is considered younger and the other older than that datum.

Hole 320B

Two sediment cores were taken in Hole 320B. Samples examined include core-catcher and section samples from each of the sections, including six in Core 1 and five in Core 2. Core 2 contains an Oligocene fauna, the first recorded from the Nazca plate. The faunas have very few diagnostic fossils and the critical species identified were recovered only after a long search.

In Core 1 the core-catcher sample is early Miocene (N4) in age as are all the section samples. Included in the fauna are *Globigerina sellii, G. winkleri, Globorotalia kugleri, G. pseudokugleri, G. siakensis, G. obesa,* and *Globigerinita incrusta. Globigerina binaiensis* and *Catapsydrax dissimilis* have been identified in cursory examination of the section samples. A new species of the genus *Clavatorella* occurs in the deeper parts of this core, but it is rare.

In Core 2 the core-catcher sample contains *Globigerina galavisi, G. winkleri, G. ampliapertura, Globorotalia opima opima, G. siakensis, Catapsydrax dissimilis,* and the richest fauna yet seen of *Clavatorella* n. sp. Sample 320B-2-4, 30-32 cm also contains *Globigerina angulisuturalis*. The age at the base of Core 2 is late Oligocene (N2).

Early Miocene nannofossils were recovered in Cores 1 and 2 of Hole 320B. Sections 1 and 2 of Core 1 are assigned to the *Discoaster druggi* Zone with *Discoaster druggi, Triquetrorhabdulus carinatus,* and discoasters of the "*Discoaster deflandre* group" present. Sections 3 through 6 of Core 1 and all of Core 2 contain a flora characteristic of the *Triquetrorhabdulus carinatus* Zone (NN1). Solution-resistant taxa are predominant, and preservation is fair to good.

SEDIMENTATION RATES

The depth-age relationships for the holes drilled at this site are shown on Figure 5. In the early Miocene-late Oligocene interval, nanno ooze accumulated at approximately 5-9 m/m.y. In the Quaternary, evidence to date suggests a much higher sedimentation rate, approximately 7.5-30 m/m.y., although the control on these rates is not particularly good.

The most noteworthy aspect of these rates is that the low rates are in nanno ooze and the higher rates in radiolarian-rich sediments. Despite the depth of the site, the rare foraminifera in the Quaternary do not show significant dissolution effects and are cool water faunas, suggesting an origin in the Humboldt Current. Their overall rarity in the sediments probably reflects dissolution in the water column and dilution by the high abundance of siliceous microorganisms rather than low foram-nannofossil productivity.

GEOCHEMICAL MEASUREMENTS

Sediments

Five "mini-core" samples distributed from 8.9 meters to 152.9 meters were analyzed for *p*H, alkalinity, and salinity of the interstitial waters. The *p*H of the samples was measured by two separate methods. The combination electrode, with a surface seawater *p*H of 8.30, showed a slight decrease in *p*H with depth from near-surface values close to 7.8 near the surface to values of 7.61 to 7.66 near the base of the sediments. In Hole 320, the punch-in electrode gave a surface seawater *p*H of 8.14; the *p*H rises in the surface core (from 7.37 at 9 m, to 7.49 at 13 m), but it has a lower value of 7.29 at 105 meters.

The colorimetric and potentiometric alkalinity values are coincident at most sample depths, varying only at 9 meters (Hole 320), where the respective values were 3.31 meq/kg and 3.63 meq/kg, and at 105 meters, with respective values of 3.52 meq/kg, and 3.85 meq/kg. The sketchy pattern shows a rise in alkalinity between the surface core and 2/3 of the distance down the column, and then a decrease to 2.6 meq/kg at the bottom of the sediment column. Surface seawater alkalinity was 2.44 meq/kg.

The pattern of salinity variation matches that of alkalinity. From 34.6 ⁰/₀₀ near the surface it rose to 35.2 ⁰/₀₀ at 105 meters, then decreased to 34.1 ⁰/₀₀ at 153 meters. Surface seawater salinity was 35.29 ⁰/₀₀.

Basalts

Eight analyses of H_2O and CO_2 of basalts were made at this site and are presented in Table 3. The H_2O values are noticeably higher than those recorded at Hole 319A, reflecting the more highly altered nature of the basement at this site. The CO_2 values are comparable to those in basalts from Site 319. There is a marked decrease of H_2O with depth, but only the very deepest samples are comparable in freshness to those cored at Site 319A.

The H_2O values measured on Hole 320B basalts are generally lower than the average reported for DSDP basalts of this age range. For example, the DSDP basalts of early Oligocene age have an average H_2O content of approximately 2.5% (versus 1.64% for Site 320); however, it is not uncommon to find basalts of Oligocene age and older with H_2O contents as low as those measured at Hole 320B.

PHYSICAL PROPERTIES

Wet-bulk density, porosity, sonic velocity, thermal conductivity, and magnetic property determinations were made in each cored interval in the sediments at Site 320. These measurements, with the exception of thermal conductivity, were continued in cores from the underlying basalt. The results are presented with the core descriptions.

Sediment wet-bulk density, sonic velocity, and thermal conductivity all increase with depth at Site 320 (ranging from 1.25 to 1.82 g/cc, 1.51 to 1.58 km/sec, and 1.65 to 3.00 mcal/cm sec°C, respectively), reflecting a decrease in porosity from 85% to 58% due to compaction with depth. The pronounced increase in carbonate content with depth exerts a secondary control upon sonic velocity and acoustic impedance, contributing to the observed increase in the values of both parameters with depth below the sea floor.

Due to incomplete sampling of the sediment column, it is impossible to determine whether the changes in sediment physical properties occur gradually or abruptly with depth. For this reason, no attempt has been made to subdivide the sediment column at Site 320 into distinctive units on the basis of physical property criteria.

Both the measured bulk densities and seismic velocities of basalts cored at Site 320 display a marked, linear increase with depth, with bulk density ranging from a mean of 2.72 g/cc near the sediment-basalt contact to nearly 2.90 g/cc 20 meters below the contact, and compressional wave velocity (at $P_h = 0$) ranges from 5.21 to 5.88 km/sec over the same interval. This trend of increasing density and velocity with depth is similar to that reported by Christensen et al. (1974) and by Hyndman (1974).

TABLE 3
H_2O and CO_2 Contents of Hole 320B Basalts

Sample (Interval in cm)	CO_2 (%)	H_2O Total (%)
3-1, 54-57	0.35	1.93
3-1, 101-105 (glass)	0.00	0.23
3-1, 120-125	0.25	2.12
4-1, 130-133	0.26	1.94
5-1, 117-123	0.16	1.30
5 (bit sample)	0.12	0.92

MAGNETISM OF THE BASALTS AND SEDIMENTS

Two vertically oriented and four unoriented samples of fine-grained basalt from this site were subjected to paleomagnetic and rock magnetic study (Ade-Hall and Johnson, Paleomagnetism of Basalts, Leg 34, this volume). Shallow inclinations, after remanence cleaning, of -16° and -33° indicate probably that at least two time units were sampled by the drill. The average inclination is close to that anticipated for the present latitude of the site. This agreement is consistent with there having been little latitudinal absolute motion of the Nazca plate since the magnetization of the basalts, a conclusion supported by the magnetization of the overlying sediments (see Ade-Hall and Johnson, Paleomagnetism of Sediments, Leg 34, this volume).

All six samples contain finely divided, highly cation-deficient titanomagnetite produced by low-temperature halmyrolitic alteration. The high degree of cation deficiency is responsible for the relatively low NRM intensity of the basalts of $13 \pm 3 \times 10^{-4}$ emu cm^{-3} (see Ade-Hall et al., Rock Magnetism of Basalts, Leg 34 and Opaque Petrography of Basalts, Leg 34, this volume).

CORRELATION OF REFLECTION PROFILE WITH DRILLING RESULTS

The airgun record shows the presence of 0.20 sec (2-way) of sediments, with perhaps a weak reflector at 0.08 sec, underlain by a diffusely reflective basement displaying high relief. Due to failure of the sonobuoy and incomplete sampling of the sediment column during drilling, correlation of the reflection profile with the drilling record cannot be attempted in any detail. The weak reflector at 0.08 sec may represent a lithologic boundary between the siliceous clays found at the top of the column and the iron-rich nanno oozes sampled at 73.5 meters. The mean sediment velocity, as determined from observed travel times and thickness of the sediment drilled, is in good agreement with the mean of the sediment velocities measured using the Hamilton frame, despite core disturbance during drilling.

SUMMARY AND CONCLUSIONS

Site Survey

Site 320 is located on terrain which is almost entirely mantled by 100 to 150 meters of sediment. High-angle faults apparently are common. A bathymetric map based on the *Glomar Challenger* PDR record shows that the topography trends roughly northwest-southeast, parallel to the old Galapagos Rise crest and at right angles to the Mendaña Fracture Zone.

Sediments

Only six cores were taken in the 155 meters of sediment overlying basalt; the conclusions, therefore, are less certain than those from a continuously cored hole. The cored intervals indicate two major stratigraphic units: siliceous-fossil clay near the surface (0-15.5 m) and iron-rich nanno ooze at depth (73.5-155 m).

The siliceous clay of the top unit has a rich and diverse suite of opaline fossils (diatoms, radiolarians, sponge spicules, and silicoflagellates) together with a subordinate suite of foraminifera. The forams are well preserved. The mudline was recovered in Core 1, Hole 320A, as indicated by the presence of delicate, presumably modern agglutinated forams and an assemblage of radiolarians less than 0.4 m.y. old. Below the mudline, the section is Holocene and/or Pleistocene in age. The lack of diversity of foram faunas and the presence of a cooler water faunal assemblage than is normally found at this latitude indicate that these sediments were deposited under the influence of the Pleistocene ancestor of the strong, north-flowing Humboldt (Peru) Current. Volcanic ash is present in low concentrations throughout the unit; small amounts of sanidine and quartz and proximity to South America suggest a continental provenance.

The iron-rich nanno ooze of the lower unit ranges in age from late Oligocene to early Miocene. As at Site 319, metalliferous components (RSOs) are found throughout the unit; their percentage is generally 5%-10%, although local layers have concentrations up to 20% and rare dark spots up to 90%. The RSOs at Sites 319 and 320 are similar. The absence of RSOs in the siliceous clay and their presence in the older unit at Site 320) and throughout the sediment column at Site 319 suggest that RSO concentration may be related to the proximity to a spreading center, the fossil Galapagos Rise. The foram fauna is of low diversity, particularly in the Miocene, suggesting a cool water regime.

Sedimentation rates are 7.5 to 30 m/m.y. in the Quaternary and 5 to 9 m/m.y. in the early Miocene-late Oligocene. The high sedimentation rates in the Quaternary suggest high organic productivity, particularly for opaline microorganisms. The sedimentation rates in the nanno ooze are less than one-fifth the rates for the nanno ooze in the Bauer Deep, and indicate that the calcareous microfossils grew in less productive waters or that substantial unrecognizable dissolution has taken place. Because the average RSO concentration at Site 320 is 1.5 to 2 times higher than at Site 319, it appears that the rate of ferruginous supply to both sites was similar, and the chief variable was organic productivity.

The oldest sediments above the basalt are late Oligocene in age (about 26-30 m.y.), considerably younger than the magnetic anomaly age of the basement directly across the Mendaña Fracture Zone to the south (39 m.y.), but close to the age of 30 m.y. predicted by the Sclater age-depth curve at the site. Fission-track studies on basalt glass from Hole 320B (Mitchell and Aumento, this volume) give an age of 25 ±3 m.y., in good agreement with the sediment age and only slighly younger than the age derived from the Sclater age-depth relationship. Based on the bathymetric map of Mammerickx et al. (1975), the Galapagos Rise crest north of the Mendaña Fracture Zone lies at approximately 16°S, 98°W, 1735 km southwest of Site 320. Assuming that magnetic anomaly 5 (9.5 m.y. old) occurs at the Galapagos Rise crest, as suggested by Herron (1972), a half spreading rate based on 1735 km in the time interval from 28 ±2 m.y. to 9.5 m.y. is 8.5-10.5 cm/yr., which is in fair agreement with the rate of 7.9 cm/yr based on the distance from magnetic anomaly 12 to anomaly 16 south of the Mendaña Fracture Zone. The suggestion of Mammerickx et al. (1975), based on bathymetry, that the Galapagos Rise is offset right-laterally across the Mendaña Fracture Zone is in agreement with the observation of younger basal sediments and shallower basement to the north of the fracture zone.

Basalt

There is more glass in Site 320 basalts than in those of Site 319 which indicates that the drill penetrated many pillows or several thin flows. The basalts are relatively fresh and have groundmasses composed of glass, plagioclase, clinopyroxene, and opaques, with rare olivine and plagioclase phenocrysts. Opaque minerals are mainly titanomagnetite.

Shore-based chemical studies establish all Site 320 basalts as tholeiites of the type characteristic of spreading ridges, but, as in the case of basals from Site 319, somewhat more fractionated than typical MORB (mid-ocean ridge basalts). Of the five chemical subgroups distinguished among the Leg 34 basalts by the on-shore investigators, two occur in Hole 320B. The more primitive, occurring in Core 3 and most or all of Core 4, overlies the more evolved or fractionated type found in Core 5. Consistent with the chemical indicators, two samples of the more primitive subgroup contain chrome spinel, which would normally not be expected in MORB magmas which have undergone any significant crystal fractionation. The survival of the chrome spinel in these cases is probably related to the rapid quenching of the fine-grained rocks. Despite the occurrence of chrome spinel, however, the more primitive Site 320 subgroup is, by most chemical criteria, not so primitive as the subgroup sampled in Hole 319 and the upper part of the basement in Hole 319A.

The eruption sequence, from less to more primitive, precludes any simple model of magma generation and separation from a single mantle source or of fractionation within a single magma chamber. As in the case of Site 319 basalts, a complex model must be invoked, one probably requiring multiple sources. Consistent with such complexity are the paleomagnetic indicators (inclinations of −16° and −33° in the two vertically oriented samples) of at least two time units, both of which occur in Core 3, near the top of the more primitive magma subgroup. Clearly, a continuous sequence of thin, quenched cooling units, be they pillows or discrete flows, cannot be taken *a priori* as a manifestation of a single eruption nor even a single magma type. Important data regarding petrochemical groups and their rates and sequences of eruption may be brought to light only by careful and extensive sampling and analysis, and these data may in turn be one of our best entrees into understanding the mechanics of spreading at ridge crests. Pending the development of new sampling methods, drilling remains our only source of well-controlled data on the vertical (time) sequence at a single locality, and virtually all such data reside in the DSDP repositories.

Alteration appears to decrease with depth, as indicated by a downhole decrease in water content, an increase in sonic velocity from 5.2 km/sec at the top to 5.8 km/sec at the bottom, and an increase in density from 2.7 g/cc at the top to 2.9 g/cc at the bottom. Extrapolation of these figures to values reasonable for fresh basalt suggests a depth of penetration of weathering at this site of about 40 meters. The alteration state of these basalts is about normal for their age.

The paleomagnetic inclinations for the Site 320 basalts average about -25 ±9°, values reasonable for formation in the Southern Hemisphere at their present latitude in a normal polarity field. The inclinations of the overlying sediments at Site 320, averaging -22°, are in good agreement with the basalt values.

The natural remanence of all Site 320 basalts is stable during AC demagnetization. No large soft components of the types found in the basalts from Site 319 were found in those from Site 320. This difference in remanence is consistent with the uniformly fine grain size of the Site 320 basalts compared to the grain size of those at Site 319. The NRM intensity is lower in Site 320 basalts.

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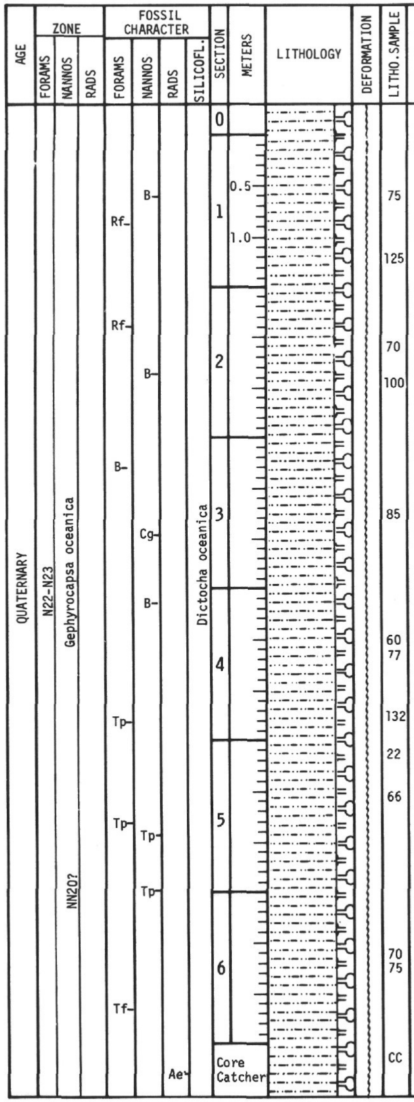
Site 320 Hole Core 1 Cored Interval: 6.0-15.5 m



LITHOLOGIC DESCRIPTION

5GY 4/1 with some 5Y 4/2 and N2

SILICEOUS FOSSIL-RICH DETRITAL SILTY CLAY

Core is dominantly dark greenish gray (5GY 4/1) with streaks, blebs, and beds of olive gray (5Y 4/2) and grayish black (N2). The core is mostly a silty clay, with the coarser component (20-40%) comprised by opaline fossils (diatoms> sponge spicules>rads>silicoflagellates). Accessories include qtz, feldspar, biotite, glass, nannos, and forams. Deformation of the core is extreme. Color variations are due to clay: siliceous fossil fluctuations and to finely disseminated pyrite and carbon(?). Small pocket at 2, 70 cm is a siliceous ash. Micronodules and/or pyrite are present up to 1-2%.

Characteristic Smear Slides

	1-74	2-70	5-66
det. clay	70	25	75
opaques	1	-	T
silic. foss.	25	5	25
nannos	T	T	T
micarb	1	T	T
vol. gls.	-	65	-
quar	2	3	T
feld	1	1	T
mica	T	T	-

Grain Size

	1-72	2-60	3-142	4-30	5-60	6-18
sand	0.3	2.6	0.4	0.2	0.5	0.3
silt	15.6	32.8	43.2	14.1	16.1	16.2
clay	84.1	64.5	56.5	85.7	83.4	83.6

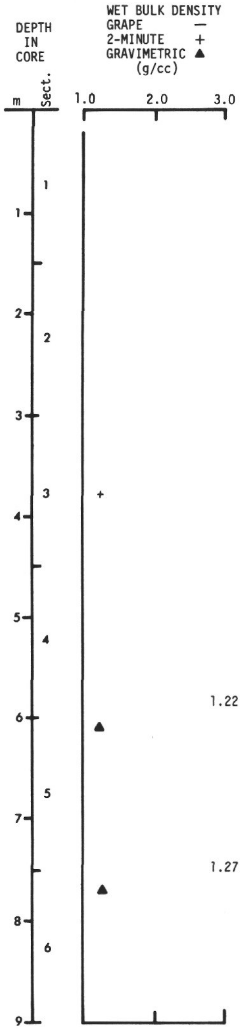
Carbon-Carbonate

	1-50	2-11	3-7	4-39	5-120	6-51
t. carb	1.1	1.8	1.2	0.5	1.4	1.4
o. carb	1.1	1.4	1.2	0.5	1.3	1.2
$CaCO_3$	-	3.0	1.0	-	1.0	2.0

Bulk X-ray

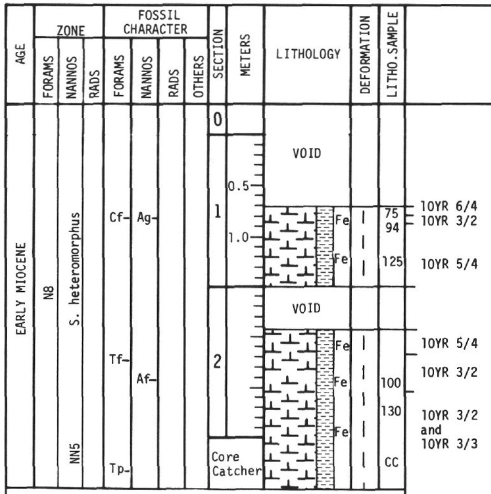
	1-20	4-10
amor	71.7	74.7
quar	28.6	29.0
K-Fe	3.7	3.0
plag	16.7	16.8
kaol	2.9	5.1
mica	29.5	29.7
chlo	1.7	3.4
mont	16.1	12.7
pyri	0.7	-
bari	-	0.3

Explanatory notes in Chapter 2



POROSITY (Vol. %)	SONIC VELOCITY, Vp (km/sec)	ACOUSTIC IMPEDANCE ($X10^5$ g/cm^2sec^1)	THERMAL CONDUCTIVITY (mcal/cm sec°c)±10%	REMANENT INTENSITY, Jo ($X10^4$ emu/cm^3)	MEAN DEMAGNETIZING FIELD (oe)	INCLINATION BEFORE DEMAGNETIZATION (°)	CLEANED INCLINATION (°)	INITIAL SUSCEPTIBILITY, k ($X10^4$ emu/cm^3 oe)	Q RATIO $\frac{Jo}{0.3k}$	VRM ACQUISITION FACTOR $\frac{\text{moment acquired in time } (t_1-t_2)}{\log (t_1/t_2)}$	SATURATION MAGNETIZATION (emu/g)	CURIE POINT (°c)
			1.8									
	1.51	2.02	1.7									
			1.7									
			1.7									
86.7												
82.5												

Site 320 Hole Core 2 Cored Interval: 73.5-83.0 m



LITHOLOGIC DESCRIPTION

IRON/CLAY-RICH NANNO OOZE

Core is only moderately deformed; bedding, though bent, is recognizable. Colors are yellow browns (10YR 6/4, 10YR 5/4) and dark grayish brown (10YR 3/2).

Core predominantly IRON/CLAY-RICH NANNO OOZE, with rare forams and little opal (diatoms, rads, etc.).

RSO and reddish-brown clay are important constituents, with the color variations caused by the (RSO and clay): calc. nanno ratios. One cm bleb in core catcher has about 90% RSO.

Characteristic Smear Slides

	1-94	1-125
clay	15	15
RSO	20	15
nannos	60	65
micarb	5	5
phil	-	T
sp. spic.	-	T
forams	T	T

Grain Size

	1-120	2-118
sand	0.2	0.3
silt	48.4	41.3
clay	51.4	58.4

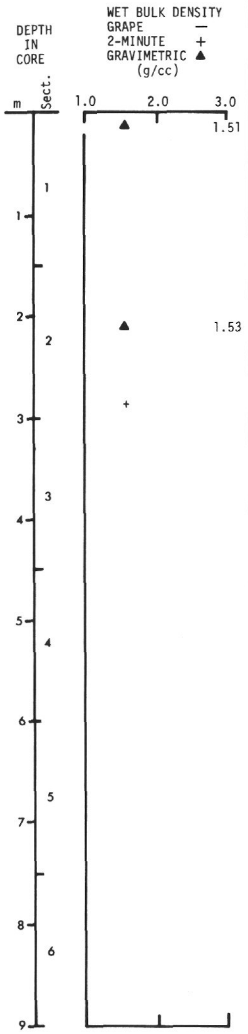
Carbon-Carbonate

	1-106	2-106
t. carb	7.7	7.3
o. carb	0.1	0.1
$CaCO_3$	63.0	60.0

Bulk X-ray

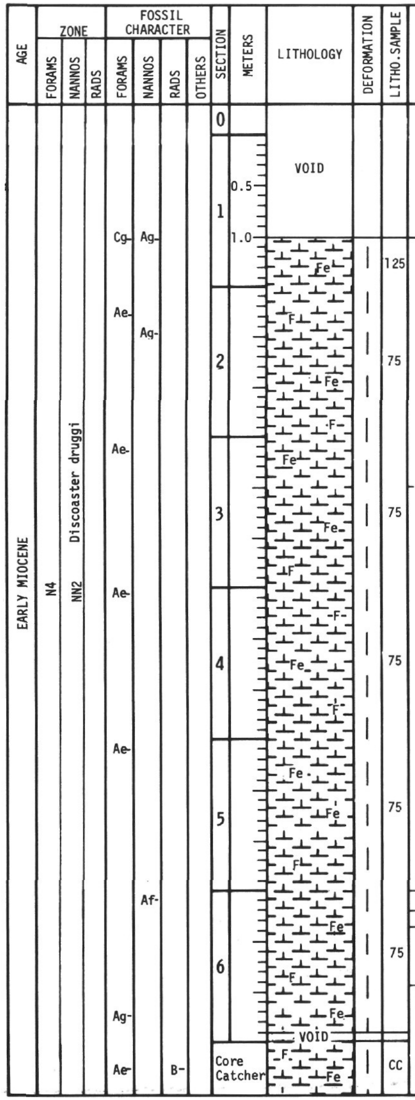
	1-100	2-69
amor	48.1	43.5
calc	82.1	82.4
feld	1.3	2.1
quar	1.2	1.3
kaol	0.5	-
mica	3.1	2.9
chlo	0.5	-
goet	8.9	10.5
clin	1.2	0.8
phil	1.1	-

Explanatory notes in Chapter 2



POROSITY (Vol. %)	SONIC VELOCITY, Vp (km/sec)	ACOUSTIC IMPEDANCE ($X10^5$ g/cm^{2}sec^1)	THERMAL CONDUCTIVITY (mcal/cm sec°c)±10%	REMANENT INTENSITY, Jo ($X10^4$ emu/cm^3)	MEAN DEMAGNETIZING FIELD (oe)	INCLINATION BEFORE DEMAGNETIZATION (°)	CLEANED INCLINATION (°)	INITIAL SUSCEPTIBILITY, k ($X10^4$ emu/cm^3 oe)	Q RATIO $\frac{Jo}{0.3k}$	VRM ACQUISITION FACTOR $\frac{\text{moment acquired in time } (t_1-t_2)}{\log (t_1/t_2)}$	SATURATION MAGNETIZATION (emu/g)	CURIE POINT (°c)
69.7												
71.4				0.04		+06						
			2.2 2.7									
	1.51	2.39										

Site 320 Hole Core 3 Cored Interval: 102.0-111.5 m



10YR 6/4

10YR 6/4 with some 10YR 5/4

10YR 5/5

10YR 4/3

10YR 5/3

10YR 6/4

LITHOLOGIC DESCRIPTION

IRON/FORAM-BEARING NANNO OOZE

Core is only slightly deformed. Colors generally are light yellowish brown (10YR 6/4) with common mottling by 10YR 7/4 and 10YR 5/4. Upper part of Sec. 6 has fairly distinctive dark brown (10YR 4/3) and brown (10YR 5/3) colors. RSO content varies throughout core between about 2 and 10%. Most RSO's are reddish-brown grains; some aggregates occur in Sec. 5 and below. Forams range from 2 to 15%.

Characteristic Smear Slides

	2-75	4-75
clay	5	5
RSO	6	8
nannos	85	75
forams	4	12

Grain Size

	1-128	2-97	3-90	4-93	5-67	6-84
sand	3.0	0.4	1.6	1.4	2.6	0.2
silt	42.0	48.5	46.9	53.0	49.7	49.2
clay	55.0	51.2	51.6	45.7	47.7	50.6

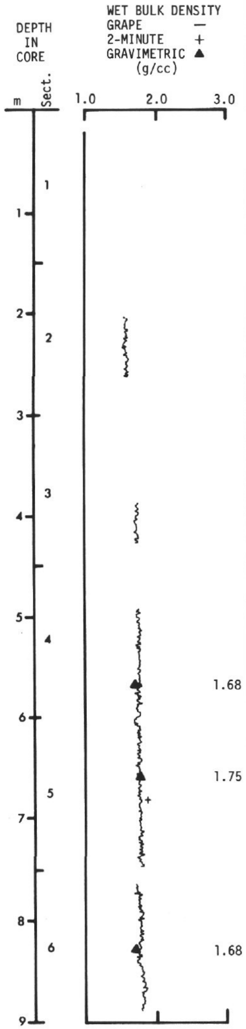
Carbon-Carbonate

	1-140	2-84	3-81	4-57	5-106	6-52
t. carb	11.1	11.0	11.0	11.1	11.0	10.7
o. carb	0.1	0.1	0.1	0.1	0.1	0.1
$CaCO_3$	92.0	91.0	91.0	92.0	91.0	89.0

Bulk X-ray

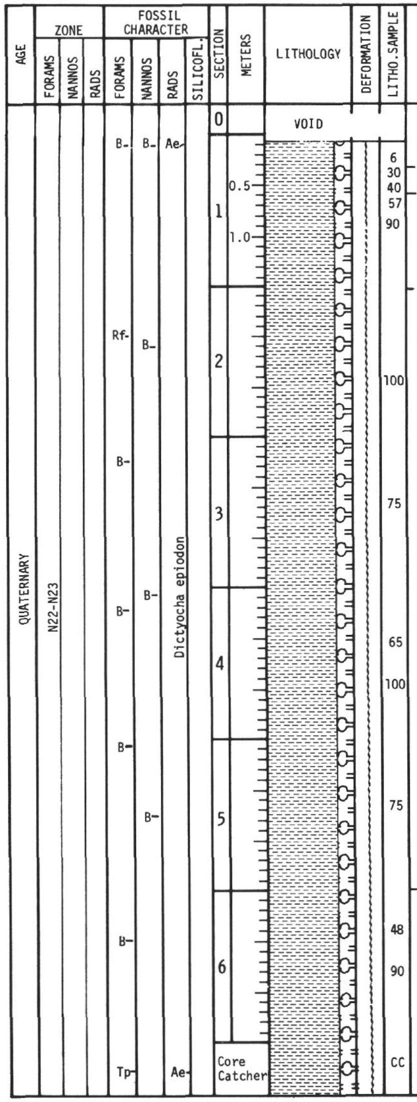
	1-123	5-88	6-59
amor	18.3	20.9	23.9
calc	99.0	98.9	98.1
goet	1.0	1.1	1.9

Explanatory notes in Chapter 2



	POROSITY (Vol. %)	SONIC VELOCITY, Vp (km/sec)	ACOUSTIC IMPEDANCE ($X10^5$ g/cm^2sec^1)	THERMAL CONDUCTIVITY (mcal/cm sec°c)±10%	REMANENT INTENSITY, Jo ($X10^4$ emu/cm^3)	MEAN DEMAGNETIZING FIELD (oe)	INCLINATION BEFORE DEMAGNETIZATION (°)	CLEANED INCLINATION (°)	INITIAL SUSCEPTIBILITY, k ($X10^4$ emu/cm^3 oe)	Q RATIO $\frac{Jo}{0.3k}$	VRM ACQUISITION FACTOR $\frac{\text{moment acquired in time } (t_1-t_2)}{\log (t_1/t_2)}$	SATURATION MAGNETIZATION (emu/g)	CURIE POINT (°c)
1.68	62.6												
1.75	61.6			3.0									
		1.57	2.78										
				2.9	0.01		-05						
				2.9									
1.68	62.4												

Site 320 Hole A Core 1 Cored Interval: 0.0-9.0 m



LITHOLOGIC DESCRIPTION

5Y 4/2
10YR 3/3 and 10YR 3/2
5GY 4/1
5GY 4/2 with some N3 and 5GY 4/1
5GY 3/1 with some 5YR 2/1

SILICEOUS FOSSIL-RICH DETRITAL CLAY

Core is intensely deformed. The interval from 5 to 61 cm of Sec. 1 has colors of dark brown (10YR 3/3) and olive gray (5Y 4/2). Below 61 cm, dominant colors are dark green gray (5GY 4/1 and 5GY 4/2) except in Sec. 6 where colors become somewhat darker (5GY 3/1). Some beds have more siliceous ofssils, thereby forming siliceous fossil clays and clayey siliceous fossil oozes.

At Sec. 4, 65-80 cm, there is a zone of small (1-2 cm) dusky yellow green (5GY 5/1) pockets which are >80% glass, with accessory volcanic minerals and opaline fossils.

Characteristic Smear Slides

	1-30	2-100	5-75
det. clay	75	70	75
nannos	-	T	-
micarb	-	T	2
sil. foss.	23	25	20
vol. gls.	T	1	T
pyrite	T	1	T
quar + feld	2	2	3

Grain Size

	1-100	2-119	3-82	4-114
sand	0.3	0.4	0.2	0.4
silt	21.3	14.4	15.0	15.5
clay	78.4	85.2	84.7	84.1

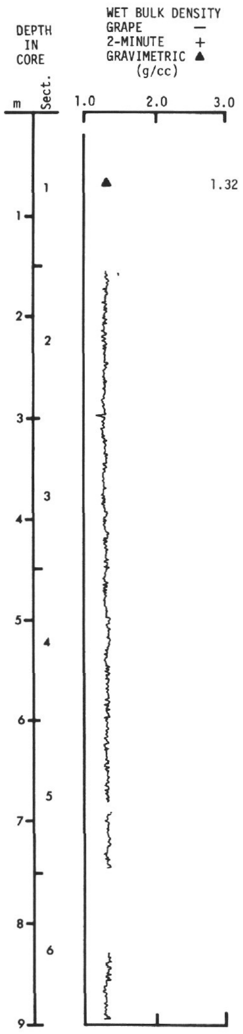
Carbon-Carbonate

	1-130	3-67
t. carb	1.5	1.3
o. carb	1.2	1.1
$CaCO_3$	2.0	2.0

Bulk X-ray

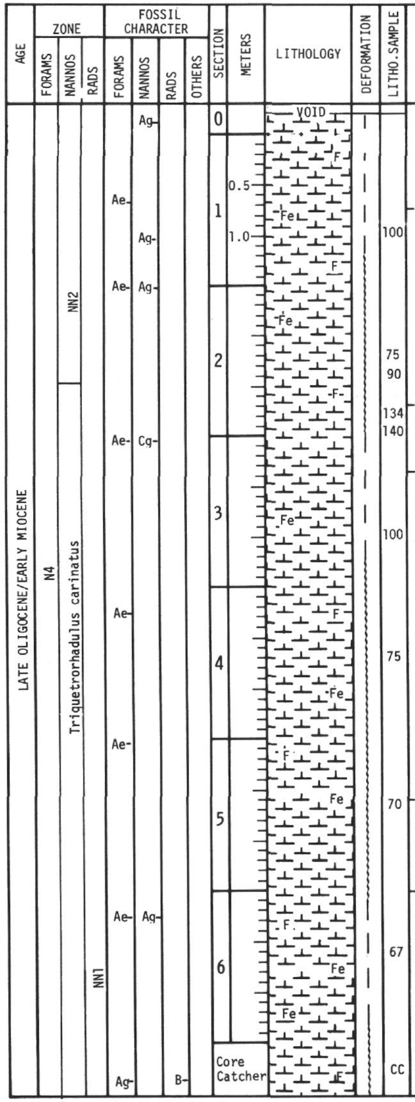
	1-40	3-111	4-89
amor	73.5	69.9	73.5
quar	32.0	29.4	27.0
K-Fe	6.6	3.0	2.9
plag	18.2	16.0	14.5
kaol	5.5	7.6	3.6
mica	24.1	25.5	28.5
chlo	3.3	3.5	2.2
mont	10.4	12.7	20.4
phil	-	2.0	-
bari	-	0.2	0.8

Explanatory notes in Chapter 2



POROSITY (Vol. %)	SONIC VELOCITY, Vp (km/sec)	ACOUSTIC IMPEDANCE ($X10^5$ g/$cm^2$$sec^1$)	THERMAL CONDUCTIVITY (mcal/cm sec°c)±10%	REMANENT INTENSITY, Jo ($X10^4$ emu/cm^3)	MEAN DEMAGNETIZING FIELD (oe)	INCLINATION BEFORE DEMAGNETIZATION (°)	CLEANED INCLINATION (°)	INITIAL SUSCEPTIBILITY, k ($X10^4$ emu/cm^3 oe)	Q RATIO $\frac{Jo}{0.3k}$	VRM ACQUISITION FACTOR $\frac{\text{moment acquired in time } (t_1-t_2)}{\log (t_1/t_2)}$	SATURATION MAGNETIZATION (emu/g)	CURIE POINT (°c)
83.3												
			1.7									

Site 320 Hole B Core 1 Cored Interval: 136.0-145.5 m



LITHOLOGIC DESCRIPTION

IRON-BEARING NANNO OOZE

10YR 5/4

Sediment is stiff, with moderate to intense deformation.

10YR 6/4 and 10YR 7/4

Colors mainly pale brown to dark brown with gradational contacts. Color variatio's are due mainly to the variability of RSO content. Foram concentrations also are variable, ranging from 2 to 10%. Micarb (angular calcite fragments) is conspicuously present in all smear slides.

10YR 5/4

Characteristic Smear Slides

	0-8	1-100	6-67
clay	5	5	5
RSO	5	7	10
nannos	75	75	75
micarb	10	8	5
forams	5	5	5

10YR 4/4

Grain Size

	1-30	2-75	3-94	4-60	5-110	6-110
sand	0.3	0.1	2.6	2.1	0.3	0.5
silt	36.6	38.2	42.5	42.6	37.6	40.8
clay	63.1	61.6	54.9	55.2	62.1	58.7

10YR 6/3

Carbon-Carbonate

	1-18	2-42	3-84	4-21	5-99	6-121
t. carb	10.5	10.8	11.0	10.9	10.7	10.5
o. carb	0.1	0.1	-	0.1	0.1	0.1
$CaCO_3$	87.0	90.0	91.0	90.0	88.0	87.0

Bulk X-ray

	1-10	4-10
amor	26.1	25.6
calc	97.8	95.9
goet	2.2	4.1

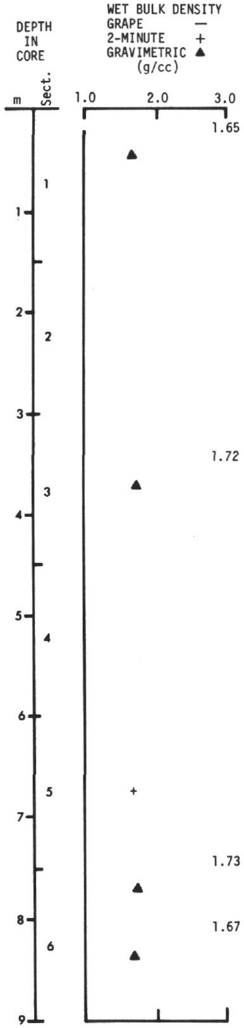
10YR 5/4

10YR 4/4

7.5YR 4/4 and 7.5YR 3/2

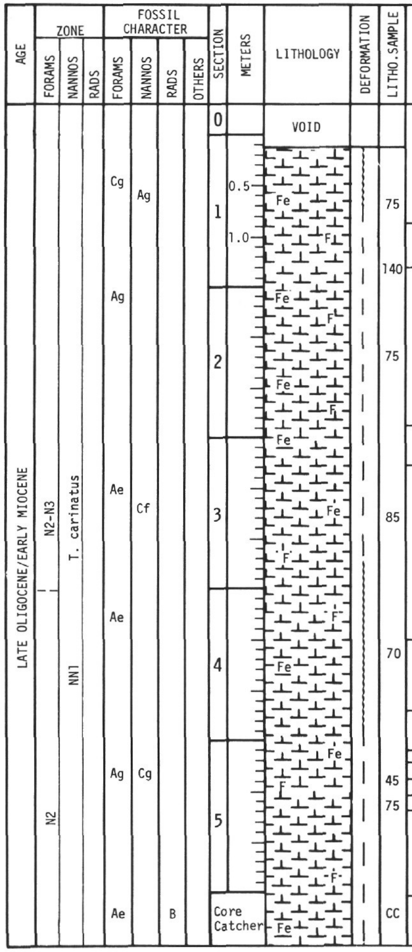
7.5YR 4/4 and 7.5YR 4/2

Explanatory notes in Chapter 2



POROSITY (Vol. %)	SONIC VELOCITY, Vp (km/sec)	ACOUSTIC IMPEDANCE ($X10^5$ g/cm^2sec^1)	THERMAL CONDUCTIVITY (mcal/cm sec°c)±10%	REMANENT INTENSITY, Jo ($X10^4$ emu/cm^3)	MEAN DEMAGNETIZING FIELD (oe)	INCLINATION BEFORE DEMAGNETIZATION (°)	CLEANED INCLINATION (°)	INITIAL SUSCEPTIBILITY, k ($X10^4$ emu/cm^3 oe)	Q RATIO $\frac{Jo}{0.3k}$	VRM ACQUISITION FACTOR moment acquired in time $\frac{(t_1-t_2)}{\log(t_1/t_2)}$	SATURATION MAGNETIZATION (emu/g)	CURIE POINT (°c)
64.6				0.01		-11	-42					
				0.04		-34	-19					
57.7				0.01		00	+05					
				0.01		+06	+24					
			3.5	0.02		-04	-04					
	1.57	2.92	2.9									
			2.8									
57.9												
				0.01		+03						
62.6												
				0.01		-07	+16					

Site 320 Hole B Core 2 Cored Interval: 145.5-155.0 m



10YR 4/3 with minor 10YR 5/4 and 10YR 3/2	
10YR 5/3	
10YR 4/4	
10YR 3/2	
10YR 4/3 ↓ 10YR 4/4	
10YR 3/2	
10YR 6/3	
10YR 4/3	
10YR 3/2	
10YR 4/3	
10YR 3/2	
10YR 4/3	
10YR 3/2	

LITHOLOGIC DESCRIPTION

IRON/FORAM-BEARING NANNO OOZE

Core is firm and fairly dry, generally moderately disturbed. Colors are pale brown to dark brown; darker colors are associated with high RSO content. There is very little clay in the core (<5%).

Foram concentrations range from trace amounts to 10-15%. Seems to be a general increase in RSO content with depth.

Characteristic Smear Slides

	1-75	CC
clay	5	5
RSO	5	10
nannos	80	75
micarb	5	5
forams	5	5

Grain Size

	1-129	3-30	4-70	5-8
sand	0.8	0.6	5.3	5.1
silt	39.9	46.5	48.6	40.8
clay	59.3	52.9	46.1	54.1

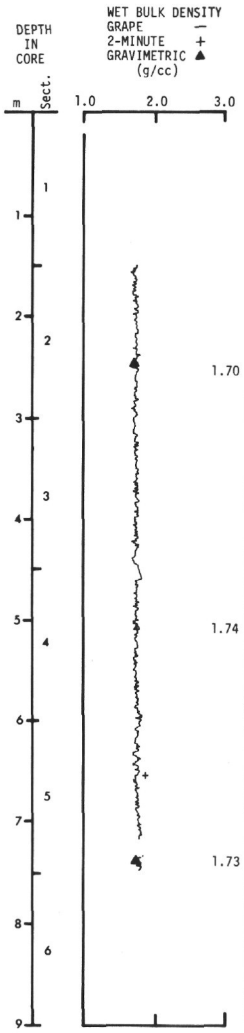
Carbon-Carbonate

	1-140	2-77	3-4	4-120	5-47
t. carb	10.5	10.4	10.5	10.6	10.7
o. carb	0.1	0.1	0.1	0.1	0.1
$CaCO_3$	87.0	87.0	87.0	88.0	89.0

Bulk X-ray

	1-111	2-90	3-10	4-50	5-20
amor	27.5	34.9	27.6	28.6	32.8
calc	97.3	95.8	95.9	95.5	91.4
goet	2.7	4.2	4.1	4.5	8.6

Explanatory notes in Chapter 2



POROSITY (Vol. %)	SONIC VELOCITY, Vp (km/sec)	ACOUSTIC IMPEDANCE ($X10^5$ g/cm^{2}sec^1)	THERMAL CONDUCTIVITY (mcal/cm sec°c)±10%	REMANENT INTENSITY, Jo ($X10^4$ emu/cm^3)	MEAN DEMAGNETIZING FIELD (oe)	INCLINATION BEFORE DEMAGNETIZATION (°)	CLEANED INCLINATION (°)	INITIAL SUSCEPTIBILITY, k ($X10^4$ emu/cm^3 oe)	Q RATIO $\frac{Jo}{0.3k}$	VRM ACQUISITION FACTOR moment acquired in time (t_1-t_2) / log (t_1/t_2)	SATURATION MAGNETIZATION (emu/g)	CURIE POINT (°c)
				0.01		-63	-61					
				0.02		-36	-61					
61.5												
				0.02		+03	-12					
60.6				0.01		+15	+67					
			2.8									
	1.58	3.02	3.1	0.01 0.01		+18	+24					
				0.02		-33	-31					
			2.9									
57.0												

Site 320 Hole B Core 3 Cored Interval: 155.0-164.5 m

AGE	ZONE FORAMS	ZONE NANNOS	ZONE RADS	FOSSIL CHARACTER FORAMS	FOSSIL CHARACTER NANNOS	FOSSIL CHARACTER RADS	FOSSIL CHARACTER OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
								0 1	0.5 1.0	VOID		54 71 82 123 143	BASALT Original recovery was 0.7 meters. Styrofoam spacers, each about 2 cm wide, are used to separate core segments that probably are not part of a continuous core sequence. Therefore, the length portrayed is greater than the actual amount recovered. See the accompanying detailed Section description for petrography and interpretations.

Site 320 Hole B Core 4 Cored Interval: 164.5-174.0 m

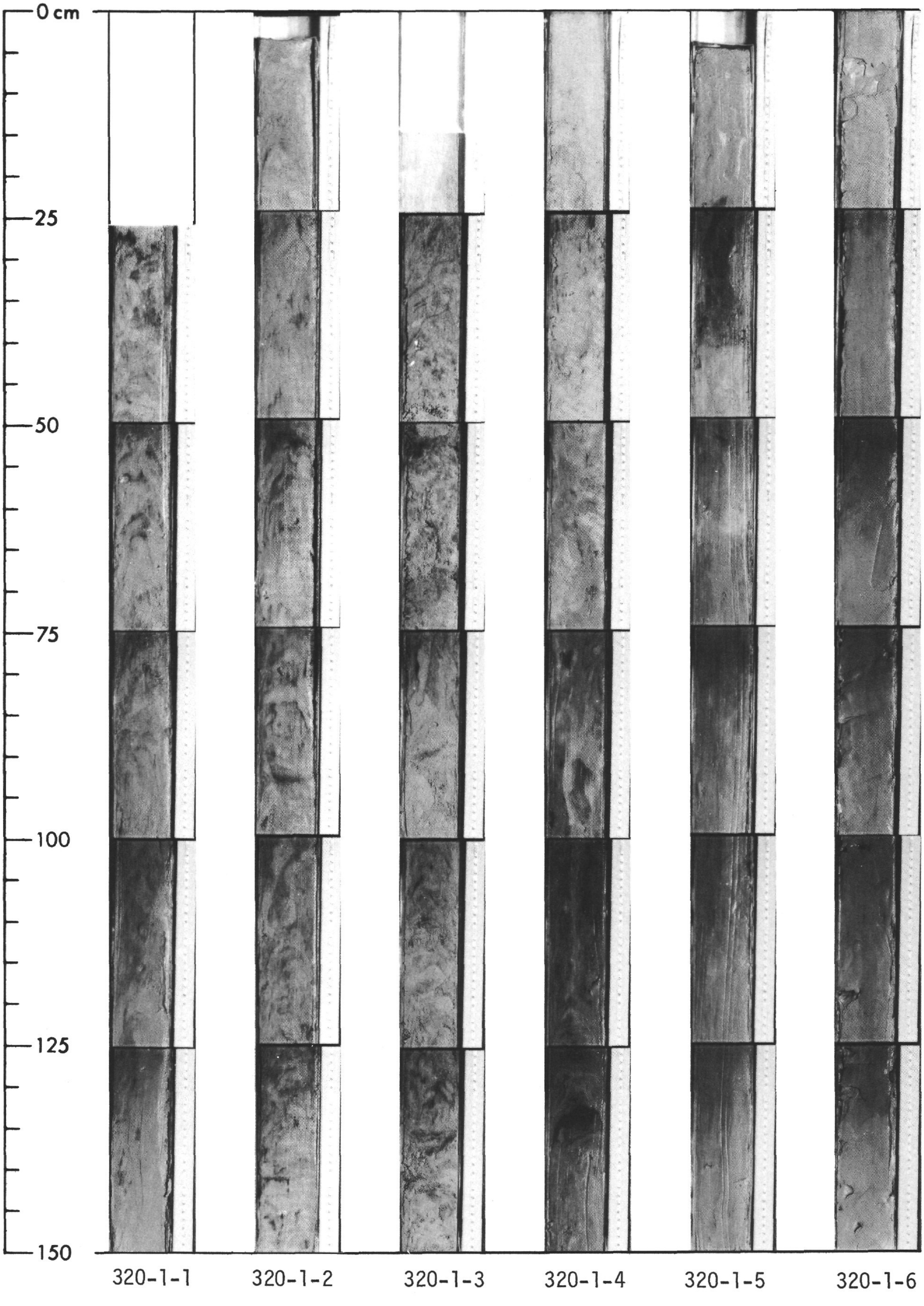
AGE	ZONE FORAMS	ZONE NANNOS	ZONE RADS	FOSSIL CHARACTER FORAMS	FOSSIL CHARACTER NANNOS	FOSSIL CHARACTER RADS	FOSSIL CHARACTER OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
								0 1	0.5 1.0	VOID		89 96 108 123 130 143	BASALT Original recovery was 0.35 meters. Styroforam spacers, each about 2 cm wide, are used to separate core segments that probably are not part of a continuous core sequence. Therefore, the length shown here is greater than the actual amount recovered. See the accompanying detailed Section description for petrography and interpretations.

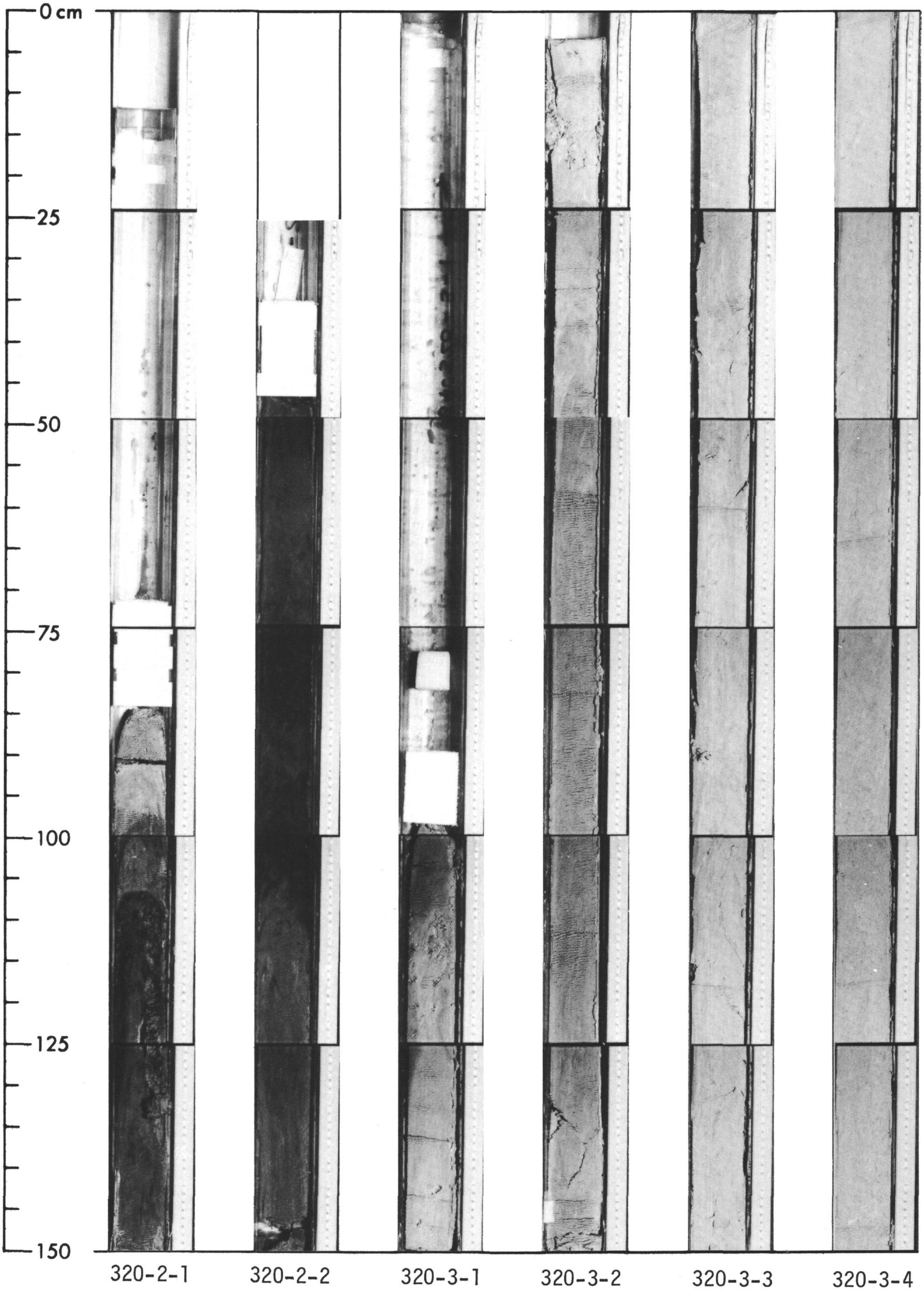
Site 320 Hole B Core 5 Cored Interval: 174.0-183.0 m

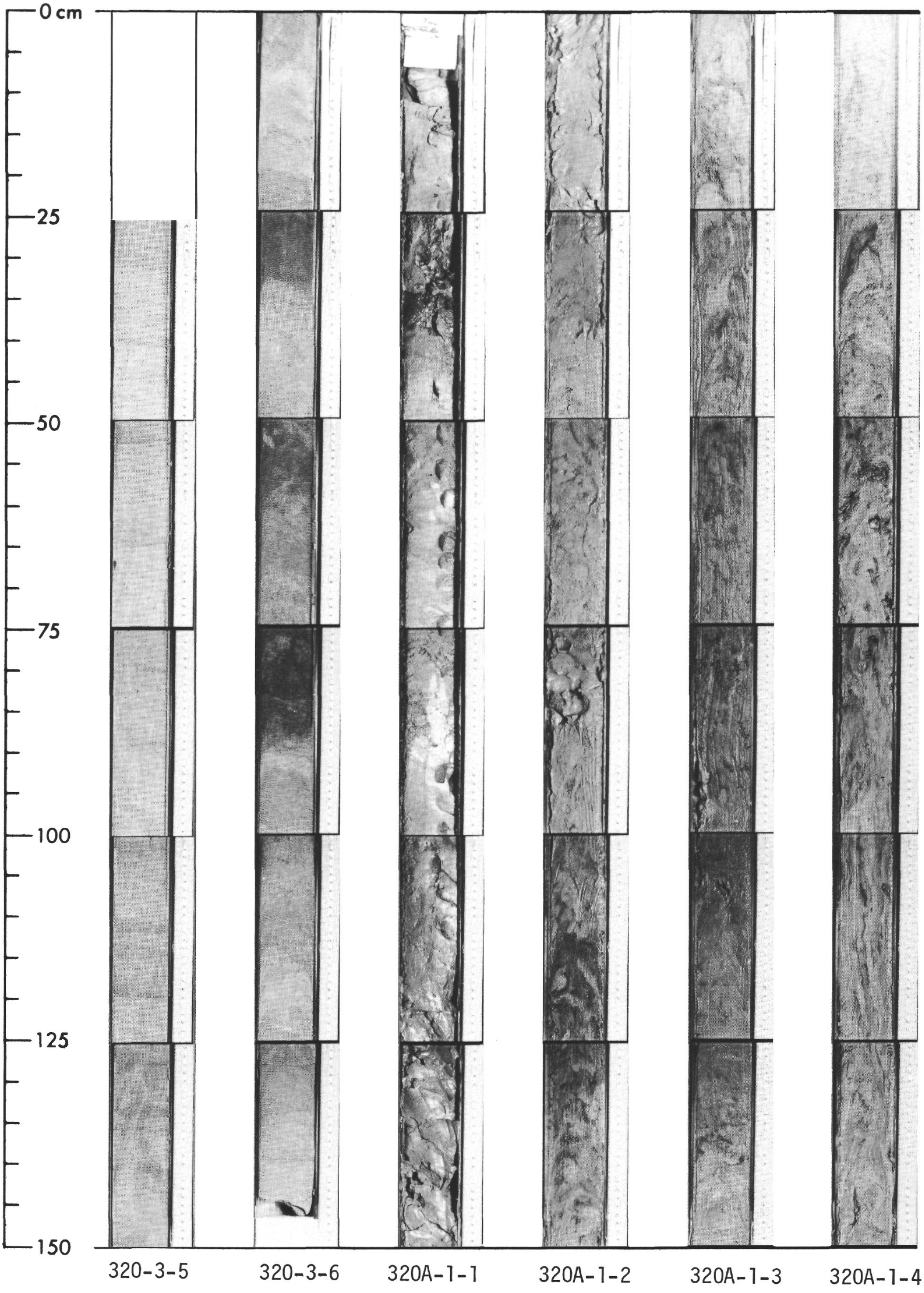
AGE	ZONE FORAMS	ZONE NANNOS	ZONE RADS	FOSSIL CHARACTER FORAMS	FOSSIL CHARACTER NANNOS	FOSSIL CHARACTER RADS	FOSSIL CHARACTER OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
								0 1	0.5 1.0	VOID		118 127 144	BASALT Original recovery was about 0.15 meters. Styrofoam spacers, each about 2 cm wide, are used to separate core segments that probably are not part of a continuous core sequence. Therefore, the length shown here is greater than the actual amount recovered. See the accompanying detailed Section description for petrography and descriptions.

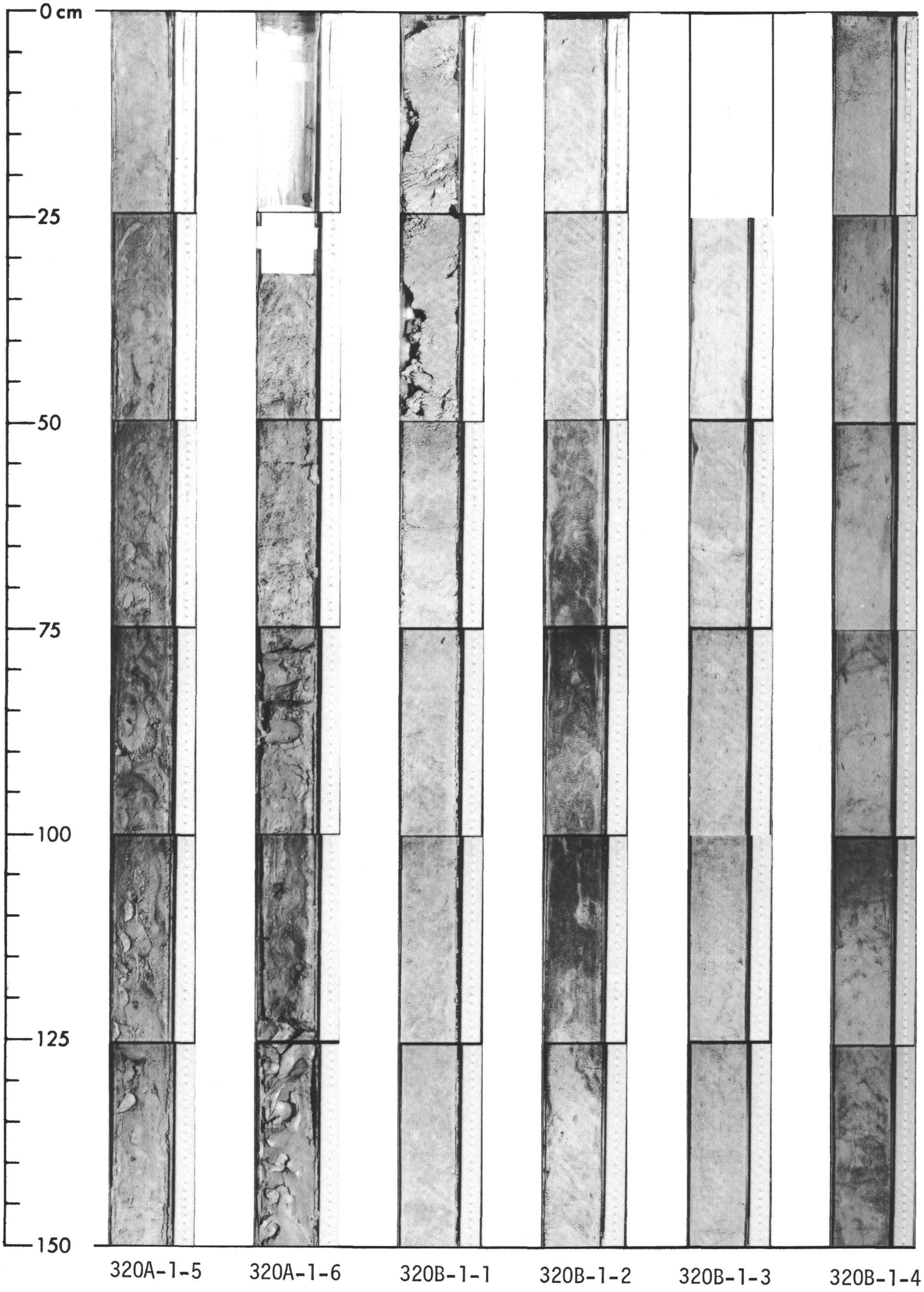
Explanatory notes in Chapter 2

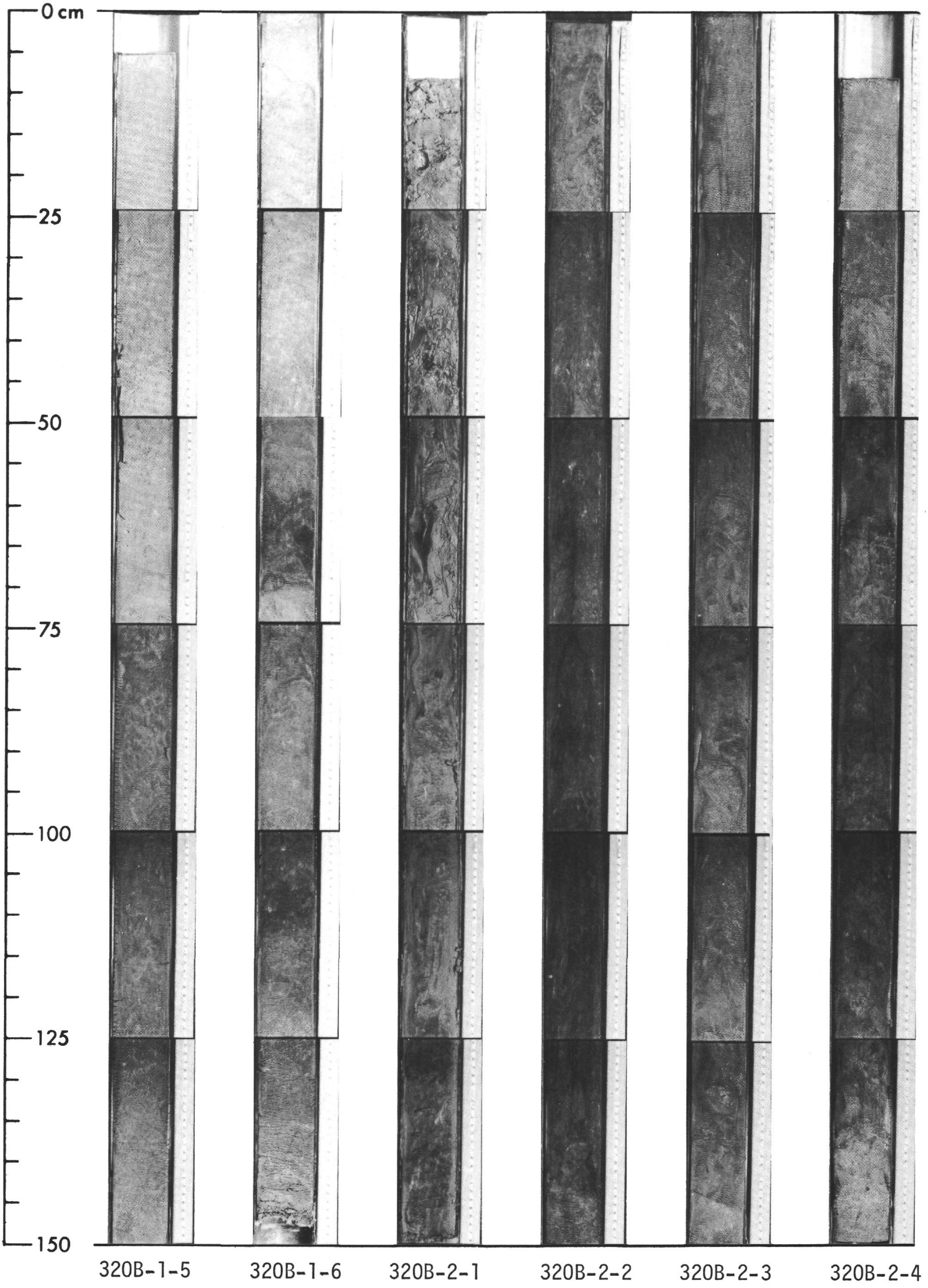
DEPTH IN CORE m	Sect.	WET BULK DENSITY GRAPE — 2-MINUTE + GRAVIMETRIC ▲ (g/cc) 1.0 2.0 3.0	POROSITY (Vol. %)	SONIC VELOCITY, Vp (km/sec)	ACOUSTIC IMPEDANCE $(X10^5\ g/cm^2 sec^1)$	THERMAL CONDUCTIVITY (mcal/cm sec°c)±10%	REMANENT INTENSITY, Jo $(X10^4\ emu/cm^3)$	MEAN DEMAGNETIZING FIELD (oe)	INCLINATION BEFORE DEMAGNETIZATION (°)	CLEANED INCLINATION (°)	INITIAL SUSCEPTIBILITY, k $(X10^4\ emu/cm^3\ oe)$	Q RATIO $\frac{Jo}{0.3k}$	VRM ACQUISITION FACTOR $\frac{\text{moment acquired in time } (t_1-t_2)}{\log (t_1/t_2)}$	SATURATION MAGNETIZATION (emu/g)	CURIE POINT (°c)
1 2	1	2.78 ▲ 2.72 ▲+ 2.66 ▲ 2.74 2.67 ▲+ 2.70 ▲ 2.73		5.28	14.4		4.9 5.06 15.2 4.9	650 1040 >800	-21 -20 -34 -25	-17 -16 -33 -22	1.0 0.50 0.90 1.2	16.1 34 56 13.3		0.06 0.24 0.08	330 374 340
1 2	1	2.77 ▲ 2.84 ▲ 2.85 ▲		5.69	16.2		20.2 22.5	320 115			1.4 3.9	48 19		0.44 0.68	329 373
1 2	1	2.90 ▲ 2.92 ▲ 2.86 ▲		6.06	17.3		8.06	565			1.3	21		0.45	311

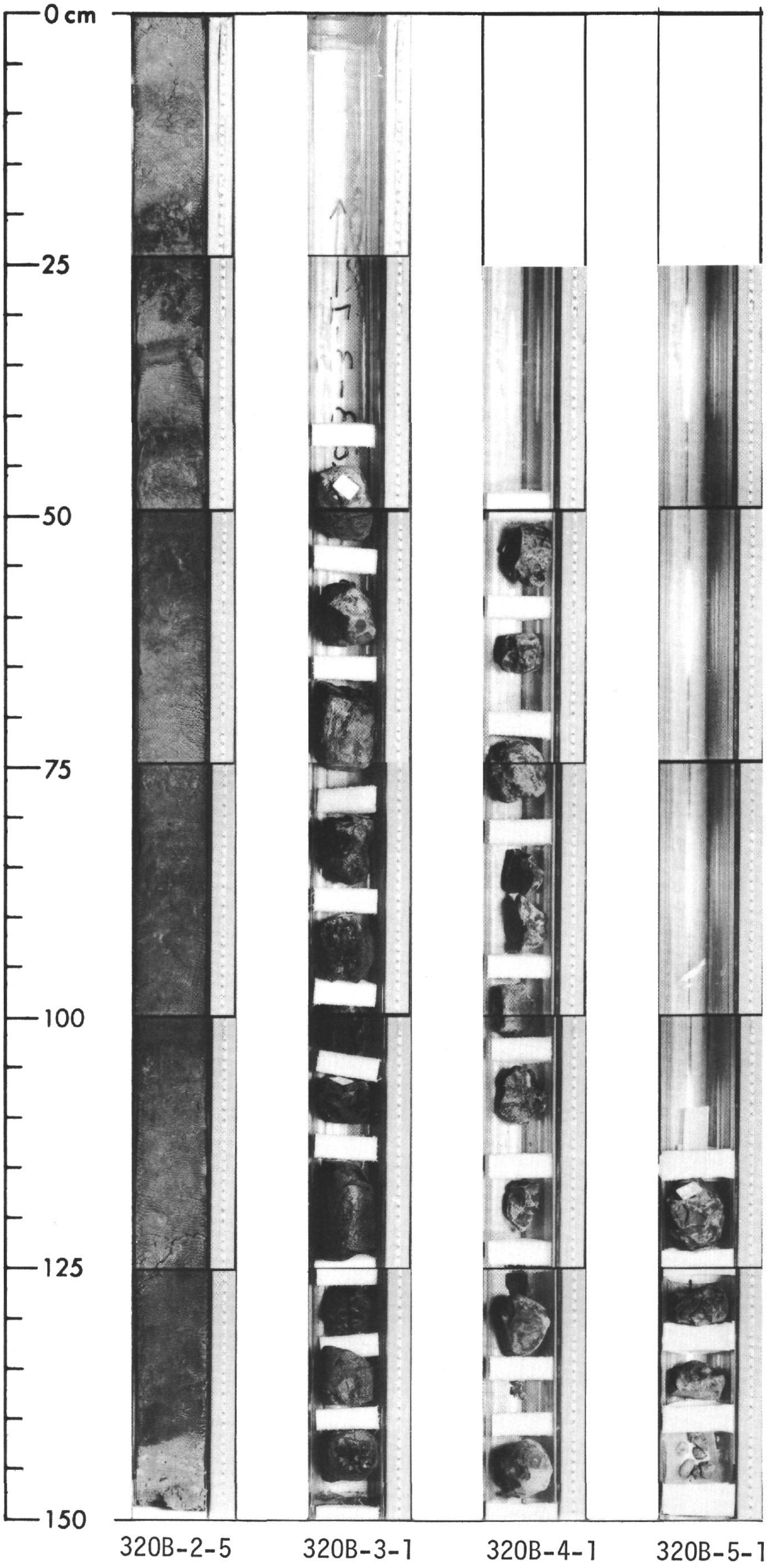

0 cm
25
50
75
100
125
150
320-1-1
320-1-2
320-1-3
320-1-4
320-1-5
320-1-6


0 cm
25
50
75
100
125
150
320-2-1
320-2-2
320-3-1
320-3-2
320-3-3
320-3-4

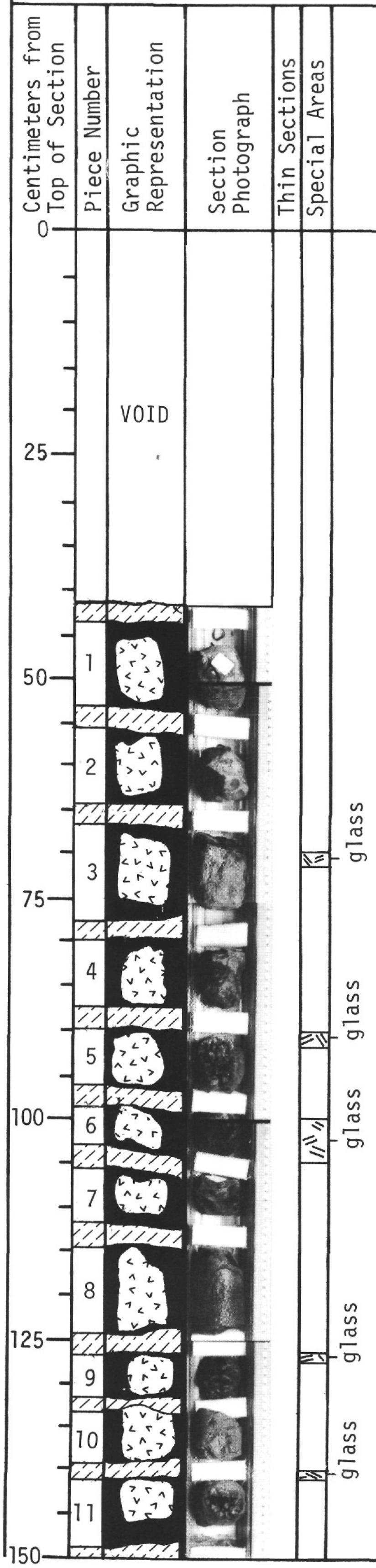

0 cm
25
50
75
100
125
150
320-3-5
320-3-6
320A-1-1
320A-1-2
320A-1-3
320A-1-4


0 cm
25
50
75
100
125
150
320A-1-5
320A-1-6
320B-1-1
320B-1-2
320B-1-3
320B-1-4


0 cm
25
50
75
100
125
150
320B-1-5
320B-1-6
320B-2-1
320B-2-2
320B-2-3
320B-2-4


0 cm
25
50
75
100
125
150
320B-2-5
320B-3-1
320B-4-1
320B-5-1

Site 320 Hole B Core 3 Section 1



Description

Styrofoam spacers, each about 2 cm wide, separate pieces of core that are not part of a continuous core segment. An unknown amount of basalt is missing from the places where the styrofoam has been added.

Eleven glassy to aphanitic to fine-grained fragments. Four fragments have selvages of black glass up to 1 cm thick, but commonly they are broken and only 3 to 8 mm thick. A fifth specimen is entirely glass, 3 cm thick. On oriented specimen 3 (71 to 80 cm) the glass is at the top and dips 20°. In piece 5 (92 to 99 cm) the glass is vertical. The number of glass selvages and the rapid change of their orientations suggest that the fragments are from pillows, and that at least 4 were penetrated. The glass is generally altered to a brown palagonite (uncommonly orange) along fractures. The palagonite is generally altered to an extremely fine-grained aggregate of smectite much like the interstitial smectite in the crystalline portions of the fragments.

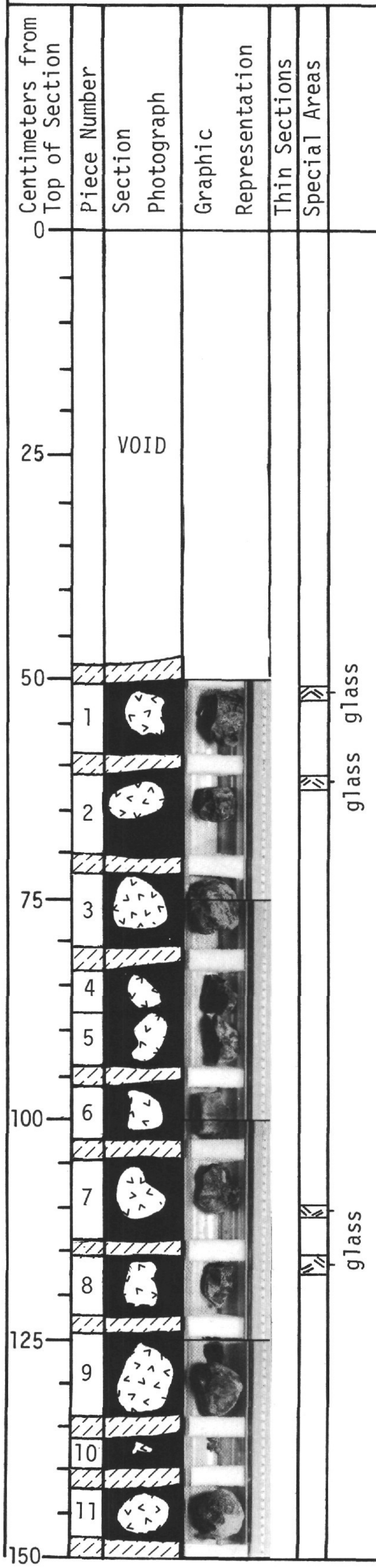
The crystalline rocks are generally aphanitic to very fine-grained in the glass-bearing pieces. In piece 4 (82 to 89 cm), which is from the interior of a pillow, it is very fine- to fine-grained. Colors are most commonly medium brown, but range from light brown to medium or dark brown-gray, and, in local relatively fresh areas (as in piece 1, 53 to 60 cm; piece 11, 143 to 148 cm; and piece 4), to medium gray.

Phenocrysts vary from trace amounts to about 0.5% and generally include both plagioclase and altered olivine. Frequently, the phenocrysts are glomeratic. Olivine is generally altered to earthy red-brown Fe-oxide, but in piece 8 (116 to 126 cm), some olivine is altered to light brown smectite which encloses fresh remnants (Ny slightly less than 1.679, Fo_{87}).

Tiny vesicles from 0.1 to 0.2 mm in diameter occur in the crystalline parts of the pieces. Joints are abundant and nonpenetrative. In glass-bearing pieces they include incipient columnar joints extending 1 to 2 cm into the rock.

The most common vein components are phillipsite and black Mn-oxide, alone or in combination. The phillipsite in the glassy selvage always lies on palagonite and never contacts fresh glass. The Mn-oxide can occur as small nodules, spots, or, in tight joints, as virtually continuous black films, alone or with phillipsite. Smectite is rare; it occurs as linings in some vesicles, but otherwise is only suggested by thin, vague bluish gray, gray and yellow films.

Site 320 Hole B Core 4 Section 1



Description

Styrofoam spacers, each about 2 cm wide, separate pieces of core that are not part of a continuous core segment. *An unknown amount of basalt is missing from the places where the styrofoam has been added.*

Glassy to aphanitic to very fine-grained to fine-grained rock. Pieces 3 through 6 may belong to a single flow unit (pillow). Glass from 2 to 5 mm thick was recovered in 4 pieces, along with the adjacent 2- to 3-mm-thick grayish spherulitic layers (in piece 8, 122 to 126 cm, the spherulitic layer is 5 mm thick, which is unusually thick). The distribution of glass-bearing pieces suggests that at least 3 pillows were penetrated.

The main crystalline rocks are varied in subtle ways. In glass-bearing pieces 1 and 2 the rock is medium brown. In glass-bearing pieces 7 and 8, it is dark brownish gray to dark gray, suggesting that equivalent rock types are fresher with depth.

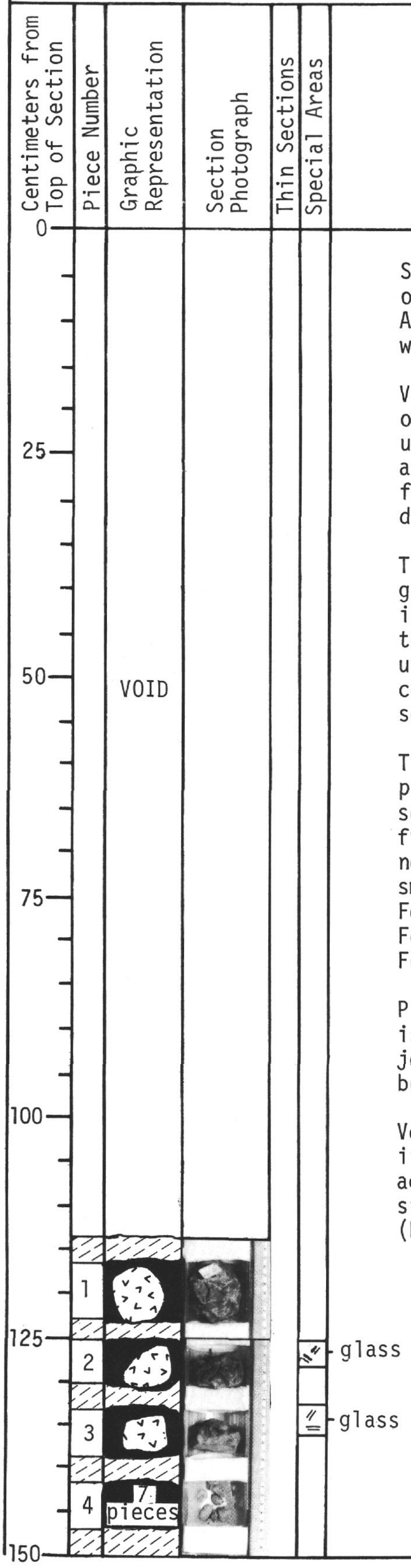
Pieces 1 through 7 have traces of phenocrysts and glomerocrysts. Pieces 8 through 11 are aphyric. Plagioclase phenocrysts are up to 2 x 1 mm in size. Olivine is altered to Fe-oxide and, in the fresher, grayer parts of the two joint blocks furthest removed from a pillow surface (pieces 4 and 5), to light brown or yellow smectite as well.

The most prominent structures are joints. As in 320B-3-1, most are nonpenetrative and all are tight and strong. Those in the glass-bearing pieces include columnar joints, and piece 8 (122 to 126 cm) is in fact an irregular column.

Veins are primarily phillipsite and black Mn-oxide in glass-bearing pieces (1, 2, 7 and 8). Phillipsite is always in contact with palagonite, and never directly with glass. In pieces 7 and 8 very striking pink, very fine-grained phillipsite veins cut brown palagonite.

In joint blocks from pillow interiors there are minor Mn-oxide films or spots in pieces 4 and 9, and phillipsite in piece 6. The main veins in these pieces are, however, smectite. Frequently they are mere films or veneers rather than well developed veins. In the browner, more altered parts of these blocks the smectite is gray, yellowish gray, yellow, brown or red-brown. In the fresher, grayer parts it is green, greenish blue, light gray, bluish gray, blue, white and brown. The smectite veins, vesicle linings and pseudomorphs after olivine are clearly more abundant in or restricted to interior joint blocks, whereas the Mn-oxide and phillipsite veins occur preferentially in glass-bearing blocks from the surfaces of pillows.

Site 320 Hole B Core 5 Section 1



Description

Styrofoam spacers, each about 2 cm wide, separate pieces of core that are not part of a continuous core segment. An unknown amount of basalt is missing from the places where the styrofoam has been added.

Very fine-grained rocks except for the glassy selvages on pieces 2 and 3 and the spherulitic layers immediately underlying them. The glass is black, about 2 mm thick, and altered to orange-brown and brown palagonite along fractures. The 2- and 3-mm-thick spherulitic layers are dark to light gray.

The very fine-grained portions are mainly medium brown-gray. In piece 1, the largest, there is a sharply bounded inner portion with a light brown-gray color, and a 1-mm-thick light grayish brown alteration rind. The rock is unusually massive and homogeneous, breaking with a conchoidal fracture like lithographic limestone. In thin section it is finely variolitic.

Trace amounts of phenocrysts or glomerocrysts include plagioclase up to 2 x 1.5 and 1 x 2.5 mm. Olivine was seen only in piece 1. In the interior of that piece it is fresh (Ny somewhat greater than 1.682, 2V definitely negative; Fo_{84-85}) or altered to green and orange-brown smectite plus Fe-oxide; in the exterior it is altered to Fe-oxide alone. The composition of the olivine is more Fe-rich than that of any olivine from Site 319 and the Fo_{87} from 320B-3-1, 116 to 126 cm.

Piece 1 is a near-surface interior joint block. Piece 2 is almost an entire small column bounded by columnar joints. Tiny holes up to 0.1 mm diameter are found in both the spherulitic and very fine-grained rocks.

Vein constitutents include phillipsite in the glass and in the holocrystalline rock. In piece 1 there are, in addition, black Mn-oxide, red-brown Fe-oxide films and stains, and an irridescent material with metallic luster (Fe-oxide?).

Site 320 Hole B Core 5 Section

Centimeters from Top of Section	Piece Number	Graphic Representation	Section Photograph	Thin Sections	Special Areas	Description
0 25 50 75 100 125 150			NO PHOTOGRAPH AVAILABLE			Bit Sample Very fine-grained, medium gray, massive, homogeneous rock like Core 5, Section 1. The trace amount of phenocrysts is solely plagioclase. One has dimensions of 3 x 1 mm, but all others have maximum dimensions less than 1 mm. Sparse round vesicle range from 0.1 to 0.3 mm in diameter, and somewhat vuggy holes are up to 0.7 mm in maximum dimension. No vein is present. All surfaces are either fresh fractures or irregular polished surfaces with a waxy luster. It is not clear whether the polished surfaces are natural or artificial.