2. SITE 290

The Shipboard Scientific Party[1]

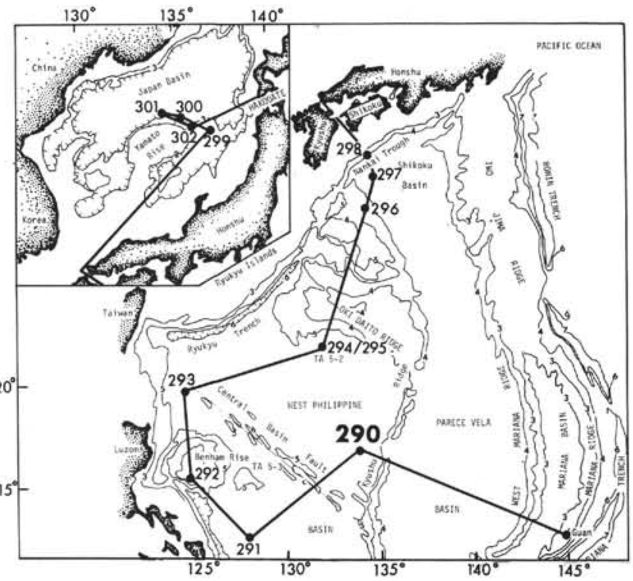

Figure 1. *Location map and track of Glomar Challenger Leg 31 for region around Site 290. From map: "Topography of North Pacific," T. E. Chase, H. W. Menard, and J. Mammerickx, Institute Marine Resources, Geol. Data Center, Scripps Institution of Oceanography, 1971. Contour depths in kilometers; scale 1:6,500,000.*

SITE DATA

Position:
Hole 290: 17°44.85′N; 133°28.08′E
Hole 290A: 17°45.05′N; 133°28.44′E

Water Depth (from sea level): 6062.5 corrected meters (echo sounding)

Bottom Felt At: 6071 meters (drill pipe)

Penetration:
Hole 290: 255 meters
Hole 290A: 140 meters

Number of Holes: 2

Number of Cores:
Hole 290: 9
Hole 290A: 2

Total Length of Cored Section:
Hole 290: 80 meters
Hole 290A: 19 meters

Total Core Recovered:
Hole 290: 38.9 meters
Hole 290A: 1.9 meters

Percentage of Core Recovery:
Hole 290: 48.6%
Hole 290A: 10%

Oldest Sediment Cored:
Depth below sea floor: 255 meters
Nature: Volcanic conglomerate and breccia
Age: Early Oligocene or late Eocene
Measured Velocity: 3.8 km/sec horizontal
4.21 km/sec vertical

Principal Results: The stratigraphic sequence in Hole 290 consists of 90 meters of Quaternary to late Oligocene brown silt-rich clays overlying 49 meters of late Oligocene nannofossil ooze. This transition dates the subsidence of this part of the West Philippine Basin through the CCD. Beneath these units lie more than 80 meters of early Oligocene or late Eocene volcanic silts forming the distal edge of a large sedimentary apron lying west of the Palau-Kyushu Ridge. Apron formation probably extended from the late Eocene to early Oligocene. The basal sediment unit is a late Eocene or very early Oligocene volcanic breccia, over 30 meters thick, formed by slumping from a local topographic high. Basalt fragments and nannofossils in clasts suggest that the basement, which was not reached, is of late Eocene age.

BACKGROUND AND OBJECTIVES

Background

Site 290 is located in the West Philippine Basin at the distal edge of a sedimentary apron along the west flank of the Palau-Kyushu Ridge. It is also just to the northeast of the broken topography associated with the broadly splayed southeast end of the Central Basin Fault. At this end, the Central Basin Fault displaces the apron sediments, but does not appear to cause significant horizontal offset of the Palau-Kyushu Ridge. Basement in the site area has a relief of several hundred meters but until surveying, prior to and following drilling, no basement lineation directions were known.

The Palau-Kyushu Ridge, with its asymmetric profile and sediment distribution, has been identified as a typical remnant arc (Karig, 1972). Its geologic history should have been that of an active arc system until it became abandoned, after which it should display a history of quiescence and subsidence. The sediments,

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west of and derived from the Palau-Kyushu Ridge, should reveal much of its early arc history. Information from similar tectonic settings suggested that these aprons consist of volcaniclastics, transported by wind, current, and density current mechanisms. Source areas are on the associated remnant arcs or in volcanic centers on the arc flank closest to the apron. As the apron grows, coarser clastic material oversteps pelagic sediment which comprises a more distal basin facies. After volcanism ceases, sedimentation in the apron area changes to a much slower accumulation of pelagic clay.

Near Site 290 the pelagic cover over the apron sediments averages 100 meters in thickness, and thickens slightly beyond the distal edge of the apron to 100-150 meters, which is representative of most of the West Philippine Basin.

Objectives

The objectives at Site 290 were largely tectonic with the primary goals of determining the age and nature of the basin crust and obtaining information concerning the history of the Palau-Kyushu Ridge. This information could elucidate the evolution of the Philippine Sea arc complexes. Site 290 was the first in the pattern of holes designed to test various modes of basin origin, and, as such, was placed as close as possible to both the Central Basin Fault and the Palau-Kyushu Ridge (Figure 1). Several factors further limited its location. The site had to be placed beyond the edge of the broadened Central Basin Fault zone to avoid the possibility of testing an anomalous environment, due to minor later spreading or extrusion. It also had to be placed near the distal edge of the apron where basement could be reached in a local trough (Figure 2). DSDP holes on ridges often have shown large unconformities in the critical basal sediment section.

Another high-priority objective was to determine the duration of apron formation. This could be done by dating the transition from apron sediments to overlying pelagic clays, and, hopefully, by locating and dating an underlying section of calcareous ooze. If the age span of this volcanic pulse on the Palau-Kyushu Ridge is similar to that on the Mariana Ridge (Cloud et al., 1956; Tracey et al., 1964), then the concept that the younger intervening marginal basins are of extensional origin would be strengthened. Furthermore, the determination of the timing and duration of arc volcanism and basin extension is necessary to reconstruct evolutionary models of marginal basins.

If the West Philippine Basin were of extensional origin, then the subsequent aging and cooling of the basin lithosphere should be reflected in crustal subsidence. Identifying and dating points on this curve could both substantiate extension and aid in dating it.

OPERATIONS

Presite Survey

The original location of this site was selected on the basis of seismic reflection profiles made during the SIO ANTIPODES 13 expedition. These records suggested that the intersection of the edge of the Central Basin Fault, and the volcaniclastic apron lay near 17°N,

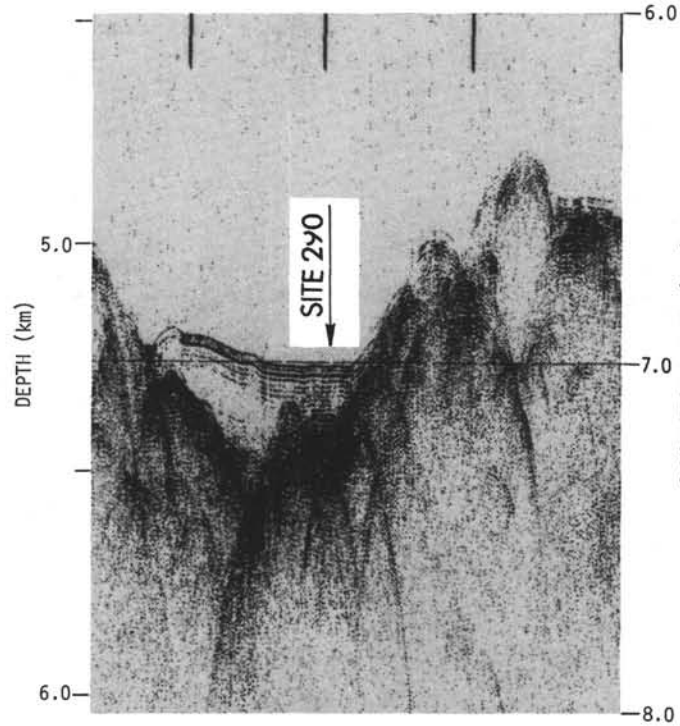


Figure 2. *Seismic reflection profile of D/V* Glomar Challenger's *first crossing over Site 290 area. Profile location is shown in Figure 3.*

133°E. Subsequent, recontouring of all available bathymetric data, together with a desire to avoid structural complexities associated with the Central Basin Fault, necessitated the relocation of Site 290 to the north of the initially proposed site.

The general area of Site 290 was approached from the southeast along bearing 300°T about 19 km (30 miles) north of the Central Basin Fault, and parallel with this feature (Figure 3). Reflection records obtained along this track illustrated that a major portion of the clastic apron and the underlying basement was masked by a very reflective horizon just below a 70-meter-thick interval of transparent sediments. Because of this masking, the ship was slowed to 8 knots, and a detailed presite survey was commenced to search for an area of apron beneath which a basement reflector could be detected. An additional objective of this survey was to locate a site within a topographic low in order to obtain a more complete stratigraphic sequence than might be present on the crest or flank of adjacent highs within the apron area. Therefore, the predrilling survey was focused on the distal portion of the apron.

A favorable area of "ponded" apron sediments was subsequently found between two topographic highs (Figure 2). A relatively thick uppermost transparent layer suggested slumping of pelagic debris from the adjacent highs. A second weak reflector was interpreted as volcaniclastic apron sediments. A strong and steeply dipping basement reflector was apparent in a minor trough along the south side of the apron "pond" (Figure 2), and this subarea was selected as the most promising

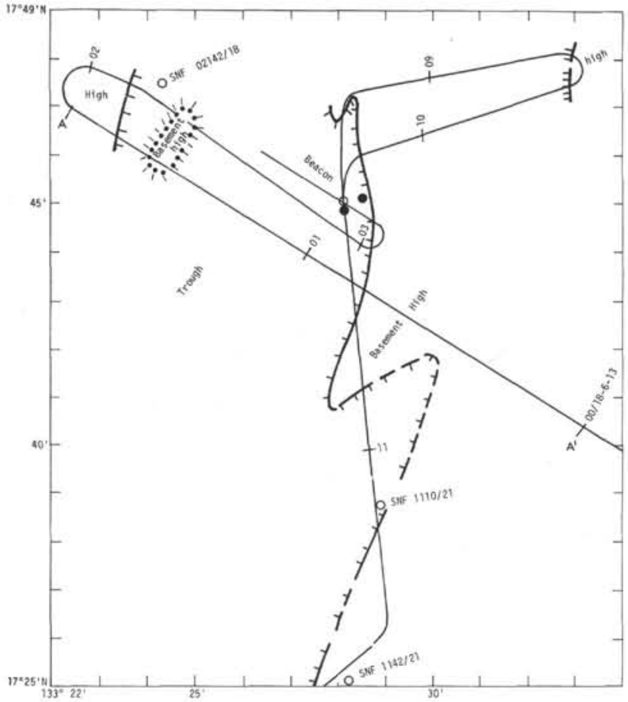


Figure 3. Glomar Challenger *survey tracks in vicinity of Site 290. The hachured line outlines the basement topography in the area.*

site. During additional passes across this site (Figure 3) both PDR and reflection records indicated the ship was moving progressively north across this "pond." The beacon was released at 1230 June 18 in a water depth of 6062 meters (PDR). An additional pass across and beyond the beacon site revealed the encroachment of large side echos on the seismic record, and it was decided to offset the final drilling site 400 meters south of the beacon site to 17°44.85'N, 133°28.08'E.

Drilling Program

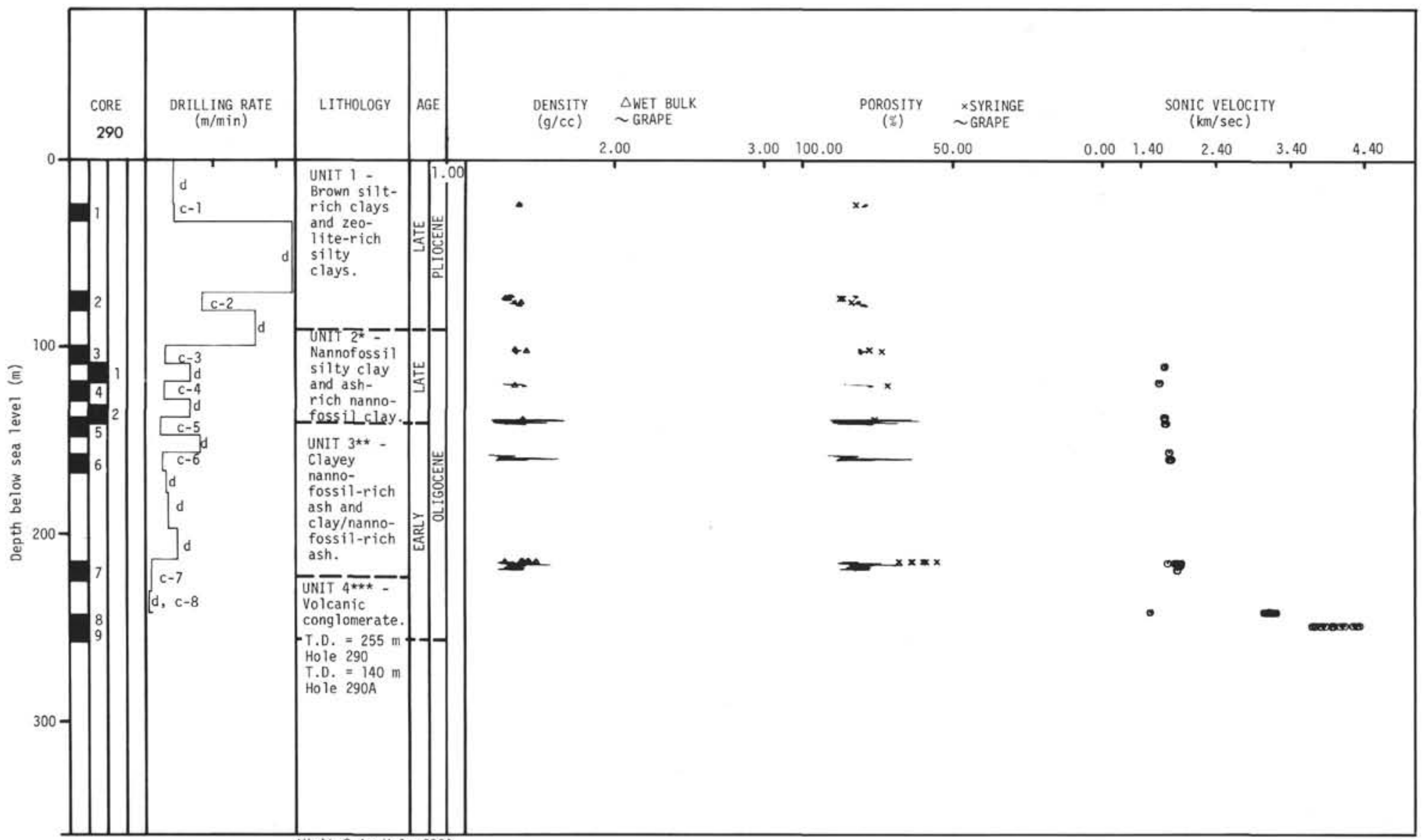
The drill pipe made contact with the sea floor at a depth of 6071 meters as opposed to a PDR depth of 6062 meters. Hole 290 was spudded and interval cored to a total depth of 255 meters below the sea floor. Coring details are found in Table 1.

An abrupt and dramatic decrease in drilling rate (Figure 4) was noted at 225 meters as a 19.5-meter interval was washed following retrieval of Core 7, signaling penetration of Unit 4 consisting of coarse volcanic debris (Table 2). After 5 hr of ever-increasing torque, stalled rotation, and sticking pipe, Core 8 was cut from 241.5 to 251 meters recovering a well-cemented, very hard volcanic grit and conglomerate. The very competent nature of the conglomerate suggests that some of the core actually came from the interval between 225

TABLE 1
Coring Summary, Site 290

Core	Cored Interval Below Bottom (m)	Cored (m)	Recovered (m)	Recovered (%)	Remarks[a]
Hole 290					
Wash	0.0-23.0				
1	23.0-32.5	9.5	5.0	52.6	
Wash	32.5-70.5				
2	70.5-80.0	9.5	8.1	85.0	
Wash	80.0 99.0				Decrease in drilling rate
3	99.0-108.5	9.5	4.5	47.4	
Wash	108.5-118.0				
4	118.0-127.5	9.5	1.7	18.0	
Wash	127.5 137.0				
5	137.0-146.5	9.5	4.0	35.8	Gradational lithologic contact
Wash	146.5-156.0				
6	156.0-165.5	9.5	4.1	43.0	Decrease in drilling rate at 165 meters
Wash	165.5 231.0				
7	213.0-222.5	9.5	4.6	48.0	
Wash	222.5-241.5				Decrease in drilling rate at 325 meters 50 bbls of mud used
8	241.5-251.0	9.5	6.9	72.6	
9	251.0-255.0	4.0	0.0	0.0	
Total	255.0	80.0	38.9		
Hole 290A					
Wash	0.0-108.5				
1	108.5 118.0	9.5	1.9	20.0	
Wash	118.0-130.5				
2	130.5-140.0	9.5	0.0	0.0	
Total	140.0	19.0	1.9		

[a]See Figure 4 for graph of drilling rates and lithologies.



*Unit 2 in Hole 290A occurs from 108.5-118 m.

**Unit 3 - not present in Hole 290A.

***Unit 4 - in Hole 290A occurs from 130.5-140 m.

Figure 4. *Hole summary diagram, Site 290.*

and 241.5 meters. Rounded pieces of this latter unit, including a broken cobble of diabase, apparently caused binding of the bit. Coring continued, but pipe sticking and high torque caused the hole to be abandoned at 0900 (June 19) after recovery of Core 9.

The predrilling site survey suggested that a thinner sediment cover might be found higher on the buried flank of a high adjacent to the sediment "pond" drilled at Site 290 (Figure 3). The ship moved 2000 feet east of the beacon to Hole 290A (17°45.05'N, 133°28.44'E). Water depth at this hole was the same as at Hole 290. Hole 290A was spudded, and the initial core cut at 108.5 to 118 meters below the sea floor. An interval from 118 to 130.5 meters was washed, and a second core was cut from 130.5 to 140 meters recovering only a few fragments of the same hard volcanic conglomerate encountered at the base of Hole 290.

The pipe became stuck in Hole 290A after recovery of the second core, due to caving and a bound bit. Pulling on the stuck pipe was hampered by the water depth and long drill string. An explosive severing tool was run down the hole three times. Following two unsuccessful attempts with the tool, the pipe became free just prior to firing the third charge. The entire drill string was recovered with one bumper sub damaged. About 4 liters of foraminifera-bearing volcanic grit, sand, and pebbles were recovered from the bit and core catcher at the end of the stuck pipe. This latter sediment may represent an uncored interval above the hard volcanic conglomerate and breccia encountered at the base of Hole 290A. A short postsite seismic survey was completed before heading for Site 291.

LITHOLOGY

At Site 290, drilling and coring achieved a total subsurface penetration of 255 meters for Hole 290 and 140 meters for Hole 290A. The ages of the sediment recovered from both holes range from late Pliocene to the early Oligocene. Figure 4 establishes the stratigraphic column for the holes, in which four lithologic units are defined (Table 2).

Unit 1

Unit 1 consists of dark yellow-brown to moderate brown silt-rich clays, locally becoming zeolite-rich silty clays toward the bottom of Core 290-2. Zeolite-rich volcanic ash interbeds also occur. The brown colors are due to goethite. The base of the unit was established at 90 meters in Hole 290, which is in a noncored interval between Cores 2 and 3. Bedding characteristics are not apparent; however, the vertical color streaking due to coring disturbance may indicate a preexisting interbedding of minor lithologies. At the base of Core 290-2, wedge-shaped laminae occur with alternating yellow and brown colors. Sediment constituents include: zeolites (predominately phillipsite, with clinoptilolite); volcanic ash composed of glass, devitrified glass (palagonite), and lithic fragments; minor amounts (to 5%) of quartz, feldspar, and heavy minerals (augite). The biogenic content is low, with trace amounts of nannofossils and sponge spicules. The microfossils of Core 290-1 indicate a late Pliocene age; however, the age of this same unit in Core 290-2 could not be determined due to the lack of indigenous microfossils.

Unit 2

Unit 2 is represented in Cores 3 through 5 to 139 meters in Hole 290, and in Core 1 of Hole 290A. In Hole 290, this unit may be further divided into two subunits, both of a dark yellow-brown to moderate yellow-brown color: the dominant subunit is an ash/radiolarian-bearing nannofossil-rich silty clay containing up to 15%-20% nannofossils, 5%-10% volcanic glass and palagonite, 1%-10% radiolarians, 4%-5% zeolites (clinoptilolite), and 40%-70% clay minerals; a second subunit (Sample 290-4-1, CC) is a volcanic ash-rich nannofossil clay.

Sedimentary features within Unit 2 include: a vague to locally clear lamination defined by color and some grain-size variations, scattered areas of semilithified to lithified nannofossil silty claystone, and burrows. Additionally, the volcanic ash content increases with increasing depth in the unit.

TABLE 2
Unit Descriptions, Depths, Thicknesses, and Ages, Site 290

Unit and Descriptions		Depth (m)	Thickness (m)	Age
1	Brown silt-rich clays and zeolite-rich silty clays	0.0-90.0	≅90(?)	Late Pliocene
2	Ash/radiolarian-bearing nannofossil silty clay, and ash-rich nannofossil clay	90.0-139.0 (290) 108.5-118.0 (290A)	49 9.5	Late Oligocene
3	Clayey nannofossil-rich ash, and clay/nannofossil-rich ash	139.0-222.5 (290) (apparently absent in 290A)	+83.5(?) (290)	Early Oligocene
4	Volcanic conglomerate	222.5(?)-251.0(?) (290) 130.5-140.0(?) (290A)	+28.5(?) (290) +9.5(?) (290A)	Early Oligocene(?)

The unit as represented in Hole 290A (Core 1, Sections 1 and 2) has the color and lithologic characteristics of Unit 2, found in Hole 290. The lithology is predominantly a moderate brown, ash/nannofossil-bearing silty clay with 1%-2% zeolites (phillipsite and clinoptilolite), 5%-8% radiolarians, 3%-6% sponge spicules, and 8%-10% nannofossils. The age of the unit is late Oligocene.

Unit 3

The Unit 3-Unit 2 boundary is defined at 139 meters in Hole 290, with the base of Unit 3 at 222 meters. Unit 3 is apparently absent in the cores from Hole 290A. The unit shows a color change from moderate browns to light olive-grays, and an increasing volcanic ash content (up to 50%). The color change first appeared at 139 meters and lithologic differences do seem to be present. The lithology is characterized as a clayey nannofossil-rich ash grading down-core into a clay/nannofossil-rich volcanic ash, and local zones of clayey nannofossil ooze and nannofossil volcanic ash. Characteristically the volcanic ash content increases from approximately 35% at the top, to 50% at the bottom (Sample 7, CC). Locally in Core 7, the volcanic ash zones have sedimentary volcanic ash clasts up to 7 mm in diameter, which are interbedded within a nannofossil volcanic ash matrix. Other lithologic characteristics of the unit include: a decrease in radiolarian content down-core; zeolites (phillipsite and clinoptilolite); the presence of trace amounts of palagonite and chlorite; incorporated fine gravel (4-5 mm); coarse, medium, and fine sand in the ash zones. Microfossils (nannofossils and radiolarians) indicate an early Oligocene age for the unit.

Unit 4

Unit 4 is a characteristic volcanic conglomerate unit which was found in Holes 290 and 290A. The upper 70 cm (Hole 290, Core 8, Section 1) is an olive-gray subunit with well graded (2-3 mm) subangular-subrounded clasts. The overall texture is bimodal, and the sorting is poor. A second subunit, moderate yellow-brown in color, begins at Sample 290-8-1, 130 cm, and continues to the bottom of Sample 8, CC.

Megascopically the clasts consist of subangular to subrounded diabase, weathered or altered volcanics, palagonite, glass, and devitrified glass and chalk. There is a definite size increase of the clasts down-core, from a diameter of 0.5 to 1 cm in Hole 290, Core 8, Section 2 to a maximum diameter of 6 cm in Hole 290, Core 8, Section 5. Elongate clasts show a long axis orientation in the horizontal plane. Many clasts exhibit a manganese(?), palagonite, and/or weathering rind. The matrix is a recrystallized mixture of carbonate (dolomite), zeolites, and dispersed clay. Zeolites and calcite also occur as amygdaloidal infillings in voids within the matrix. The upper portion of the yellow-brown subunit (Sample 290-8-2, 3 cm) appears more "weathered" than the seemingly fresher, more indurated, lower zone (Sample 290-8-4, 5).

Radiograph studies of the conglomerate in the interval from 242 to 249 meters, illustrate that the sediment components range in size from a gravel through a fine sand. Most gravel sizes are fine (≅6 mm); however, larger pebbles up to 37 mm are found. The unit tends to be homogeneous, but does have indistinct to irregular layering.

At the conclusion of the drilling of Hole 290A, it was found that the bit was blocked by a large quantity of sediment material, which in some degree was unlike the sediment recovered from the two cores. This bit-sediment was a moderate dark-brown color, and a drilling residue of clay to granule size is apparent. The fragments consist of: angular, indurated fragments of igneous lithics, and micrite (this material may represent fragmental material from the volcanic conglomerate of Core 290A-2); rounded, soft, clay to granule size fragments of clay and clayey nannofossil ooze, which contains Pliocene foraminifera, Pliocene and Eocene nannofossils, and Cretaceous foraminifera; and isolated silty to sand-size grains of quartz, feldspar, glass shards, pyroxenes (augite), and amphiboles.

Conglomerate Petrography

The clast to matrix ratio ranges from 50:50 to 40:60. The clasts generally occur in an open framework with some grain-to-grain contacts noted. In thin sections the clast size ranges from an average of 0.6 mm in Section 1, to an average of 5 mm in Section 5. The clasts are subangular to angular, have a moderate to poor sorting, and for the most part consist of manganese(?)-rimmed devitrified glass (palagonite?). Some of the basalt clasts (Section 5, 140-150 cm) show a dark rim which is a crust of palagonite glass, similar to that found around pillow lavas. This crust or rim superficially resembles a weathering rim or manganese crust. The composition of other clasts includes: opaque-brown glass with feldspar microlites; fresh and altered basaltic fragments with feldspar laths and pyroxene crystals; crystals of pyroxene, olivine and feldspar, and chalk. Early Oligocene nannofossils were recovered from the chalk clasts.

The matrix is composed of a micrite mud (calcite) with zeolite and dispersed clay. Voids (up to 10%) in the matrix are lined with calcite and zeolite crystals. Isolated manganese concentrations and Oligocene nannofossils were found within the matrix.

Lithologic Interpretations

Beginning with the lowermost unit (4) and progressing with decreasing age, the following interpretations are proposed:

1) The physical nature of the volcanic conglomeratic (Unit 4) is indicative of deposition via submarine gravity transfer mechanism such as a debris flow. This interpretation is supported by the high matrix content, open framework, subangular to subrounded clasts, bimodal size distribution, and long axis orientation.

   a) The lithology and lithologic nature of the clasts such as: fresh surfaces, manganese(?) or palagonite surfaces; and varying degrees of alteration can be used to denote similar features of the rocks in the provenance area. The distinctive clast lithology of glassy basalts and palagonite are also indicative of an area of pillow basalts.

b) Other characteristics of the unit such as: abrupt color changes (olive-gray to brown; clast size); a general increase in size with increasing depth; sorting of the clasts (moderate to poor with increasing depth); and an overall poorly developed graded bedding may further indicate: (i) normal size grading or pulsations of a single debris flow and chemical reduction of the uppermost sediment layers following deposition; (ii) several pulses or periods of debris flows with a general decrease in the fragment size with time: perhaps from differing provenance areas or over different intervals of time.

c) Nannofossils found in the matrix and chalklike clasts are early Oligocene in age and may indicate the timing of the debris flow and the age of the source area for the conglomerate.

2) The clayey nannofossil-rich ashes of Unit 3 indicate an onset of eruptive volcanism during the early Oligocene. The nannofossil ooze sediment component is indicative of deposition above the regional carbonate compensation depth. Sedimentary volcanic clast zones occur near the base of the unit and depositional characteristics such as interfingering with the finer ash beds show these zones may have been involved in a gravity transfer process concurrent with the ash-nannofossil-clay deposition.

3) Unit 2 illustrates, via a decreasing ash content upwards in the unit, a lessening of an eruptive volcanic cycle for the area. The relative increase in the nannofossil ooze content shows either a return to higher productivity in the overlying waters, or less masking of the biogenous sediment by the pyroclastic deposition. The presence of nannofossils indicates deposition above the regional carbonate compensation depth, but below the lysocline.

4) The brown silt-rich clays comprising Unit 1 contain some volcanic ash, but are relatively devoid of microfossils, particularly foraminifera and nannofossils. These clays were probably deposited near or below the regional carbonate ccompensation depth after the sea floor subsided. The subsidence may have been concurrent with the sedimentation and may have been caused by motion away from a spreading center.

PHYSICAL PROPERTIES

The nature of the sediment cored from Hole 290, with regard to physical properties, varies considerably. Core 1 was too watery to allow any measurements, while Cores 2-6 were so dry that the cutting operation introduced additional microruptures. These microruptures had a serious effect on velocity measurements, as well as on the accuracy of the syringe sampling method for density and water content. Cores 7 and 8 were indurated to such a degree to necessitate band-saw and diamond-saw cutting.

Bulk Density, Porosity, and Water Content

In spite of overlap of densities between the upper three units, a minor increase in average density can be seen between Units 1 and 2, while Units 2 and 3 show a greater difference (Figure 4). The difference between units, based on porosity and water content, has a similar trend, although not so pronounced. Unit 4 shows an increase in bulk density and decrease in porosity suggesting that this unit is acoustic basement. The core catcher of Core 8 (Unit 4) contained a large piece of diabase. GRAPE count calculations indicate a higher density than any other sample from Core 8 (Unit 4).

Vane Shear

The sensitive vane adapter, measuring the 0-0.2 tons per square foot range, was used (see Chapter 1, this volume). The tops of Core 2, Sections 5 and 6 gave a shear strength of 0.13 tons per square foot (126.9 g/cm^2), the top of Core 3, Section 2 yielded a shear strength of 0.15 tons per square foot (146.5 g/cm^2). Further results of the vane shear studies are found in Bouma and Moore (this volume).

Sonic Velocity

The sonic velocity increases slightly with depth from 1.6 km/sec at about 120 meters to 1.9 km/sec at 222 meters. The velocity increases to 3.1 km/sec in the volcanic conglomerate present in Core 8 (Table 3 and Figure 4).

Several slabs were cut in the conglomerate in longitudinal and transverse directions to study possible anisotropy in sonic velocity. These measurements failed to show any significant difference in the two directions for the upper part of Core 8. However, samples from the lower half of Core 8, Section 5 show a discrepancy of more than 1 km/sec, being higher in the stratigraphic direction. A pebble of altered basalt is located in the center of a transverse slab and may be the reason for this higher velocity. Another measurement made on a transverse slab showed a better relationship between vertical and horizontal sonic velocities. However, the

TABLE 3
Sonic Velocity Measurements, Site 290

Sample (Interval in cm)	Hole Depth (m)	Sonic Velocity (km/sec)	Remarks
Hole 290			
4-1, 75	118.7	1.64	Chunk of dry weak sediment
5-1, 30	137.3	1.72	
5-3, 52	140.5	1.73	
6-1, 3	156.0	1 78	
6-3, 77	159.8	1.78	
7-2, 81	215.3	1.89	
7-3. 53	216.5	1.90	
7-4 147	219.0	1.88	
8-1, 3	241.5	3.09	In horizontal direction
8-1, 26	241.8	3.11	In vertical direction
8-5, 126	248.1	4.88	In vertical direction, a pebble of altered basalt is in the center of the sample
8-5 138	248.9	4.21	In vertical direction
8, CC	250.5	5.23	
Hole 290A			
1-2, 5	110.0	1.71	
1-2, 5	110.0	1.70	

velocity was still about 10% higher in the stratigraphic direction. This difference between the sonic velocities in the two directions can be ascribed more to inhomogeneity in the pebble alignment rather than to a real anisotropy in the sonic velocity. The sonic velocity is less dependent upon direction of a pebble than the fabric of the conglomerate.

The diabase sample from Sample 8, CC gave a velocity measurement of 5.2 km/sec.

GEOCHEMICAL MEASUREMENTS

Alkalinity, *p*H, and salinity measurements from Site 290 are summarized in Table 4. Techniques used are described in the Explanatory Notes (Chapter 1, this volume).

Alkalinity

The average alkalinity is 2.72 which is higher than that of the surface seawater reference of 2.30. The lower alkalinities are found in Unit 3. The overall trend for alkalinity is one of a decrease with increasing depth from a high of 3.23 (Core 2, Section 3) to a low of 1.96 (Core 7, Section 1). This may be indicated by postdepositional precipitation in the older sediments.

pH

*p*H values in the cores were all below that of the seawater reference taken at the site. A definite increase in *p*H occurs in Unit 3 at 214 meters. The lithology of Core 7 at this depth is lapilli-size nannofossil volcanic ash in a matrix of nannofossil volcanic ash.

Salinity

Five salinity measurements made were taken with four having the same value as the overlying seawater reference (35.2‰). The highest value of 35.5‰ came from the deepest sample. Little interpretation can be made from these data, although it may be of significance that Units 1 and 2 show the same values, while the lower portion of Unit 3 shows an increase in salinity matching the comparative increase in *p*H and decrease in alkalinity.

PALEONTOLOGIC SUMMARY

Introduction

Cores taken at Site 290 contain late Pliocene and late to early Oligocene calcareous nannoplankton and late Eocene calcareous nannoplankton and radiolarians. No diatoms or silicoflagellates were recovered from any of the samples examined, and only one sample was found to contain foraminifera of early Pliocene age.

A few moderately well-preserved calcareous nannofossils diagnostic of a late Pliocene age were found in Core 1 (23-32.5 m) within a brown silty clay despite the fact that these sediments were deposited well below the calcium carbonate compensation depth. The cored interval between 70.5 and 80 meters (Core 2) is barren of indigenous nannofossils and cannot be dated paleontologically. No other fossils were observed in either of these upper cored intervals.

Cores 3 and 4 (99-137 m) contain a nannofossil ooze with increasing amounts of volcanic ash downward. Calcareous nannofossils indicate a late Oligocene age for these sediments, whereas radiolarians suggest a late Eocene age. This discrepancy in age represents a problem of arbitrary definition of epoch boundaries using these two fossil groups rather than an actual difference in absolute age.[2] Radiolarian zonation indicates all sediments in Cores 3 through 7 (99-222.5 m) are late Eocene in age, whereas late Oligocene calcareous nannofossils are identified in a hard volcanic ash unit in Cores 5 and 6 (137-165.5 m), and early Oligocene species are found in Core 7 (213-222.5 m).

Calcareous nannofossils observed in the matrix material and in a few clasts selected from the coarse volcanic conglomerate recovered from 241.5 to 251 meters (Core 8) suggest an early Oligocene age. Late Eocene calcareous nannofossils were recovered from Sample 9, CC (255 m).

A composite sample of pebbles and sand retained by the drill bit when abandoning Hole 290A (Sample 11, CC; 118 m) contained a mixture of Late Cretaceous and Pliocene foraminifera, late Oligocene and Neogene calcareous nannofossils, late Eocene radiolarians, and fish teeth. It is important to note that although only two abraded and poorly preserved specimens of Late Cretaceous planktonic foraminifera (*Globotruncana* sp.) were recovered in Hole 290A, they represent the oldest fossils recovered to date in the West Philippine Basin.

[2]Epoch and subepoch boundaries appearing on the Hole Summary Diagram (Figure 4) for Site 290 were arbitrarily placed solely on the basis of calcareous nannofossil zonation to facilitate case of definition.

TABLE 4
Summary of Shipboard Geochemical Data, Site 290

Sample (Interval in cm)	Depth Below Sea Floor (m)	*p*H Punch-in	*p*H Flow through	Alkalinity (meq/kg)	Salinity (‰)	Lithologic Unit
Surface seawater reference		8.26	8.26	2.30	35.2	
2-3, 0-6	73.6	7.41	7.35	3.23	35.2	Unit 1
3-3, 0-6	102.1	–	7.27	2.83	35.2	Unit 2
5-1, 144-150	138.5	–	7.41	2.83	35.2	Unit 3
5-2, 143-150	140.0	–	7.56	2.74	35.2	
7-1, 138-150	214.4	–	7.92	1.96	35.5	
Average		–	7.50	2.72	35.3	

This has attendant implications for the age of the adjacent Palau-Kyushu Ridge from which they were most likely derived.

Calcareous Nannofossils

The two samples from Core 1 in Hole 290 contain only very rare specimens of *Discoaster brouweri* and *D. asymmetricus.* The absence of other diagnostic nannofossil species places these samples in the late Pliocene *Cyclococcolithina macintyrei* Subzone of Bukry (1973). The sample from Core 2 contains two specimens of the early Tertiary nannofossil *Marthasterites tribrachiatus* which represent reworking or redeposition in this sample.

Samples from Cores 3, 4, 5, and 6 contain abundant, well-preserved specimens of a diverse late Oligocene floral assemblage. The presence of *Sphenolithus ciperoensis, S. distentus,* and *Cyclicargolithus abisectus* in samples from Cores 3, 4, and Core 5, Section 1 permits the placing of these samples in the *Sphenolithus ciperoensis* Zone as defined by Bukry (1973). The presence of *Sphenolithus distentus* and the absence of *S. ciperoensis* in samples from Core 5, Section 1 and Core 6 refers these samples to the *Sphenolithus distentus* Zone.

Samples from Core 7 also contain an abundant, well-preserved, diverse assemblage; however, the presence of *Reticulofenestra hillae* and *R. umbilica* suggests that this sample can best be assigned to the early Oligocene *Reticulofenestra hillae* Subzone of Bukry (1973).

Core 8 is a conglomerate from which one of the pebbles and some of the matrix from Section 5 (140-141 cm) were examined for nannofossils. Specimens of *Reticulofenestra umbilica* were recovered from both these lithologic components. In addition, specimens of *Dictyococcites scrippsae, Cyclicargolithus floridanus,* and the long-ranging species *Coccolithus pelagicus* were recovered from the matrix sample. The fossils recovered, while sparse, suggest an early Oligocene age.

All of Core 9 consists of very "soupy" mud, and in all probability represents a thorough mixing of sediments from above. Although several species of nannofossils were recovered, they occur in considerably lower abundance than do those present in cores above. The presence of *Discoaster barbadiensis* with the younger species from above suggests a late Eocene age for this sample.

The abundant and diverse nannofossil assemblage recovered from Core 1 samples of Hole 290A contains *Sphenolithus ciperoensis, S. distentus,* and *Cyclicargolithus abisectus* which can be used to recognize the late Oligocene *Sphenolithus ciperoensis* Zone. The assemblage from this sample correlates very well with that recovered from Cores 3, 4 and Core 5, Section 1 in Hole 290. Nannofossils recovered from several pebbles retained in the drill bit upon completion of Hole 290A are also indicative of the *Sphenolithus ciperoensis* Zone.

Foraminifera

The only foraminifera found at Site 290 were recovered from Sample 2, CC (80.0 m). Nevertheless, the fauna is of considerable interest, as species representative of two distinct ages were identified. Two poorly preserved specimens of the Late Cretaceous genus *Globotruncana* were found after an intense search of material in this sample. The umbilical sides of these tests are filled with secondary calcite making species identification impossible. A second assemblage from this same sample can be placed within the early Pliocene N19 Zone as defined by Blow (1969). The diagnostic components of this latter assemblage are *Globorotalia tumida tumida* which has its initial appearance at the base of Zone N18, *Sphaeroidinella dehiscens dehiscens* which initially appears at the base of Zone N19, *Globigerina nepenthes delicatula* which ranges into the basal portion of Zone N19, along with *Globigerinoides obliques* and *G. extremus* which range into the upper part of Zone N19.

Several species of benthonic foraminifera of probable late Pliocene were also recovered from Sample 2, CC. *Amphistegina* sp. and *Elphidium* aff. *E. macellum* characteristic of subtropical neritic environments are rather common and represent evidence of displaced sediment at the lower bathyal depths at Site 290.

Radiolaria and Silicoflagellates

Moderately well-preserved radiolarians were recovered from Core 7, Section 3 (217 m) in Hole 290 and Cores 1 and 2 (100.5-118; 130.5-140.0 m) of Hole 290A; abundance ranges from few to abundant. The assemblages recovered are all assigned to the late Eocene *Thyrsocyrtis bromia* Zone of Dinkleman (1973).

No silicoflagellates or ebridians were observed.

SUMMARY AND INTERPRETATIONS

Summary

Hole 290 sampled 255 meters of pelagic and volcanic sediments from the distal edge of the apron west of the Palau-Kyushu Ridge which could be divided into four units (Figure 4).

Unit 1 (0-90 m): Brown zeolitic, very sparsely fossiliferous to barren. Quaternary to late Oligocene.

Unit 2 (90-139 m): Moderate brown nannofossil ooze, zeolitic near top and becoming ash-rich toward base. Late Oligocene.

Unit 3 (139-225 m): Olive-gray volcanic silt and clay, showing decreasing nannofossil content with depth. Early to late Oligocene.

Unit 4 (225 m—total depth): Volcanic grit and conglomerate, coarsening downward. Both clasts and matrix are very late Eocene or very early Oligocene.

Hole 290A was drilled 800 meters northeast of Hole 290 in the same water depth, but closer to the edge of a local basement trough. In this hole, Unit 1 was about the same thickness as in Hole 290, but Unit 2 was only 30 meters thick and lay directly on Unit 4, a conglomerate, which was reached more than 100 meters above the same contact in Hole 290.

The brown clay of Unit 1 appears to represent the pelagic blanket which overlies the sediment apron on regional reflection profiles. Although these profiles indicate an average pelagic thickness near 60 meters in the vicinity of Site 290, local augmentation of sedimentation from nearby ridges and perhaps from infrequent turbidity-like influx have increased this thickness in Hole 290.

Calculated average sedimentation rates for the brown clay in Site 290 and for nearby, more typical sections range from about 2.5 m/m.y. to 3.5 m/m.y. (Figure 5) and are nearly identical with those obtained in the late Tertiary brown clays in the Parece Vela Basin (DSDP Sites 53 and 54) (Fisher et al., 1971; Karig, 1971). The volcanic ash in Core 2, from 70 to 80 meters, may reflect the eruptive activity related to the opening of the Parece Vela Basin.

If there is no break in deposition between the clay and the underlying nannofossil ooze, this contact is most simply interpreted as reflecting the time at which the region passed through the local calcium carbonate compensation depth.

The upward increase in zeolite content and decrease in volcanic ash is thought to reflect waning volcanic activity and a decrease in sedimentation rate. Unit 2 thus would mark the end of the major volcanic pulse represented by volcaniclastics of Unit 3.

Although only 86 meters of volcanic silts were penetrated in Hole 290, they undoubtedly represent the distal facies of the apron west of the Palau-Kyushu Ridge. The geometry of this unit on reflection records and its absence in Hole 290A attest to some form of lateral transport from the vicinity of the Palau-Kyushu Ridge, but the exact mechanism is not clear. Investigations of similar aprons behind active and remnant arcs (Karig, 1970, 1971; Fisher et al., 1971; Burns et al., 1973) indicate that toward the head of the apron, the clastic material coarsens and the age span of the apron sediments increases, chiefly because the apron expands by overstepping an ooze facies. Thus the initiation of the apron occurred before deposition of the oldest apron sediments cored in Hole 290. Application of growth rates observed in other aprons suggests that the duration of the Paleogene pulse of volcanic activity along the Palau-Kyushu Ridge was from the late Eocene to early Oligocene.

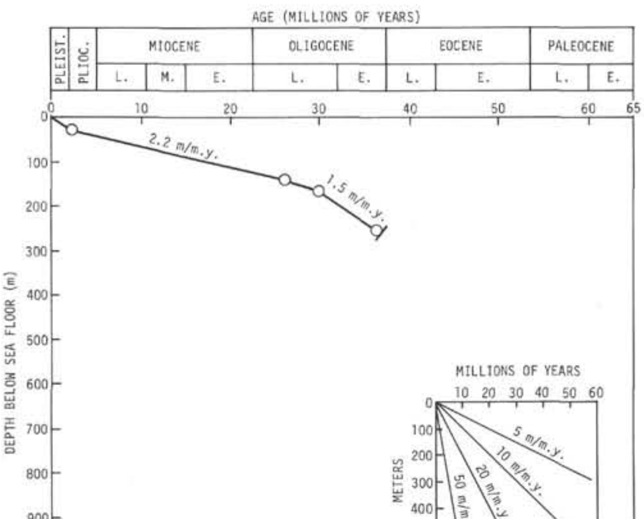


Figure 5. *Estimated sedimentation rate for Site 290 based upon calcareous nannoplankton zonation (Ellis, this volume) and time scale of Berggren (1972). Radiolarian zonation would alternately place the Oligocene-Eocene boundary above Core 7 (213 m) ultimately affecting estimated rate of sedimentation.*

Unit 4, the volcanic conglomerate, probably represents a debris flow, which moved down the adjacent ridge from the north or east, as implied from the steep southwesterly dip component defined by the formation tops in Holes 290 and 290A and from the topography defined by the series of profiles across the trough in which the two holes were located. The predominance of angular basalts clasts, the nannofossil-bearing matrix, and a few clasts of manganese-encrusted sediments all suggest that the entire sediment cover and some basement was involved in the slumping. For this reason it is assumed that the Eocene-Oligocene age of both clasts and matrix is a fair indicator of the local basement age.

It is impossible to differentiate Unit 4, with a seismic velocity of about 4 km/sec, from basaltic basement on reflection profiles. Undoubtedly there is some section beneath the breccias at Site 290 which is coeval with the age of the clasts and matrix of Unit 4, but the downward extrapolation of basement of both ridges flanking the trough does not permit this section to be very thick (Figure 2).

Interpretation

The most likely age of this part of the West Philippine Basin is late Eocene, for the reasons outlined above. It might be argued that this date represents a later phase of basaltic volcanism in the area, but the north-northeast-trending ridges and troughs which comprise the basement, seen both in the site survey (Figure 3) and on a later bathymetric compilation in the region, are similar to that seen in actively extending basins. That these trends are strongly oblique to the Central Basin Fault suggests that this fault zone was not a spreading center at which the basin crust was generated. A more inclusive discussion of the basin origin is presented in Chapter 42 (this volume) where data from all the basin sites are discussed.

The results of Site 290 are also relevant to the history of the Palau-Kyushu Ridge. Reworked Late Cretaceous pelagic foraminifera, recovered from the bit after completion of Hole 290A, demonstrate that crust of that age exists somewhere in an area capable of supplying sediments to the site area. Shallow-water benthonic and pelagic foraminifera of Pliocene age from the same mixed sample suggest that this source is the Palau-Kyushu Ridge, as it is the only sufficiently shallow area anywhere near the site. It can be surmised that crust existed in the Palau-Kyushu Ridge area during the Late Cretaceous, although not necessarily in the form of a ridge. The ridge must have existed by the end of the Eocene and at least sections of it remained at very shallow depths until the early Pliocene. The 125-km distance from the crest of the ridge to Site 290 speaks for a very efficient mode of lateral transport, persisting even into the depositional regime of the brown clay.

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APPENDIX A
Summary of X-Ray, Grain Size, and Carbon-Carbonate Results, Site 290

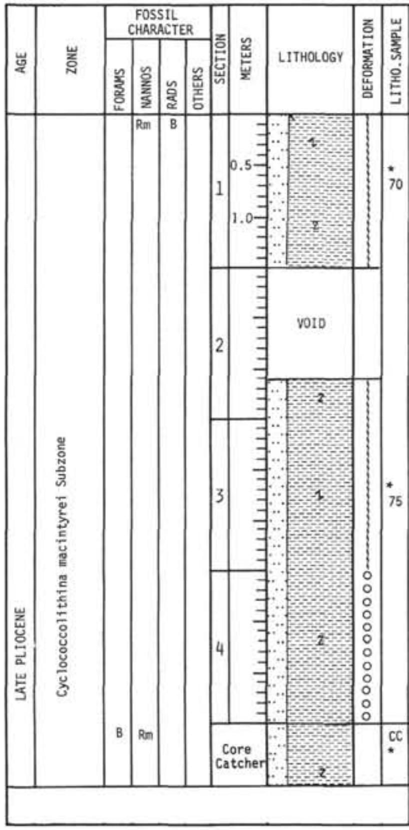
Section	Sample Depth Below Sea Floor (m)	Lithology	Age	Bulk Sample Major Constituent			2-20μm Fraction Major Constituent			<2μm Fraction Major Constituent			Grain Size			Classification	Carbon Carbonate			Comments
				1	2	3	1	2	3	1	2	3	Sand (%)	Silt (%)	Clay (%)		Total (%)	Organic (%)	$CaCO_3$ (%)	
290-1-1	23.7	Unit 1	Quaternary	Mica	Quar.	Plag.	Mica	Quar.	Plag.	Mica	Mont.	Quar.	0.1	16.9	83.0	Clay				
290-2-3	74.3*	Silt-rich Clays	to	Mont.	Plag.	Phil.	No Residue Available			No Residue Available										*From brown clay
290-2-3	74.3*	and zeolite-rich	late	Phil.	Mont.	Plag.	No Residue Available			No Residue Available										*From ash zone in clay
		Silty clays	Oligocene																	Goet. Present (5-25%) in bulk
290-2-4	75.7-75.8			Phil.	Plag.	Mont.	Phil.	Plag.	Quar.	Mont.	Phil.	Mica*	0.1	25.8	74.1	Silty clay				Goet. Present (5-25%) (in bulk and <2μm)
290-3-1	99.7	Unit 2															1.5	0.0	12	
290-3-3	103.4	Ash-radiolarian	Late														1.7	0.0	14	
290A-1-2	111.0-111.1	-bearing		Calc.	Plag.	Mont.	Plag.	Mont.	Phil.	Mont.	Phil.	Plag.					1.0	0.1	8	Augi. in bulk, 2-20μm
		nannofossil-rich	Oligocene																	(6.9 and 10.1%)
290-4-2	120.3	Silty clays															1.5	0.1	12	
290-5-1	138.0																1.7	0.1	13	
290-5-3	140.8	Unit 3	Early	Calc.	Mont.	Plag.	Mont.	Plag.	Phil.	Mont.	Plag.	Phil.					1.7	0.1	13	
290-6-3	159.8	Clayey	to	Clac.	Mont.	Plag.	Plag.	Mont.	Phil.	Mont.	Plag.	Quar.	0.1	62.0	37.9	Clayey silt	1.5	0.1	12	Augi. in 2-20μm (1.3%)
290-7-2	215.2	nannofossil-rich	late	Mont.	Plag.	Calc.	Plag.	Mont.	Phil.	Mont.	Plag.	Phil.	0.6	56.6	42.8	Clayey silt				Phil. and anal. in bulk (11.8% &
		Ash and clay-rich	Oligocene																	1.2%) Augi. in 2-20μm (3.2%)
290-7-4	218.2	nannofossil ash															1.4	0.1	11	
290-8-1	242.3	Unit 4	Very late	Phil.	Augi.	Mont.	No Residue Available			No Residue Available										
290-8-5	248.0	Volcanic	Eocene or	Plag.	Calc.	Phil.	No Residue Available			No Residue Available										
		Conglomerate	very early																	
			Oligocene																	

Note: Complete results of X-ray, Site 290 will be found in Appendix I.

Legend for mineralogical abbreviations: Applies to all Appendices in Site Reports, Chapters 3 to 13.

Quar. = Quartz; Plag. = Plagioclase; K-Fe. = Potash Feldspar; Clin. = Clinoptilolite; Mont. = Montmorillonite; Cris. = Cristobalite; Calc. = Calcite; Amph. = Amphibole; Anal. = Analcite; Mica = Mica; Kaol. = Kaolinite; Trid. = Tridymite; Chlo. = Chlorite; Augi. = Augite; Dolo. = Dolomite; Goet. = Goethite; Pyri. = Pyrite; Hema. = Hematite; Phil. = Phillipsite.

Site 290 Hole Core 1 Cored Interval: 23.0-32.5 m



LITHOLOGIC DESCRIPTION

5YR 3/4

Unit 1. Core is intensely deformed in Sections 1, 2 and 3, to a drilling breccia in Section 4; color is dominately a dark yellow brown (10YR 4/2) with minor moderate brown (5YR 3/4); core generally lithologically consistent throughout all sections.

SILT-RICH CLAY
Smears: 1-70, 3-75, CC

Texture	Composition
83 % Clay	65-71% Clay minerals
16.9% Silt	25-30% Quartz, Feldspar
0.1% Sand	1- 3% Fe-oxides
	1- 5% Zeolite
	1% Mica
	Tr- 2% Volcanic glass
	Tr% Heavy minerals
	Tr% Nannofossils
	Tr% Sponge spicules
	Tr% Foraminifera

Zeolites (phillipsite, clinoptilolite), plus volcanic glass, igneous rock fragments, and heavies (apatite ?), pyroxene; also noted were sponge spicules, and *Asymetricius* discoasters

Grain Size 1-72
0.1, 16.9, 83.0

10YR 4/2

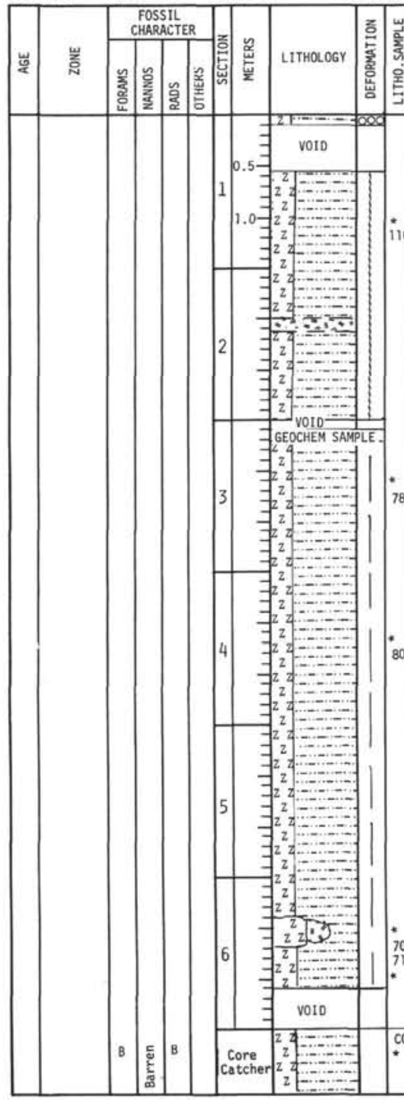
X-ray 1-69 (Bulk)
42.6% Mica
25.2% Quar
18.1% Plag
6.1% Chlo
4.5% Mont
3.6% K-Fe

5YR 3/4

Note: A 0-Section occurred at the top of Section 1 - Smear slides showed the 0-Section to be of the Dominant Lithology.

Explanatory notes in chapter 1

Site 290 Hole Core 2 Cored Interval: 70.5-80.0 m



LITHOLOGIC DESCRIPTION

5YR 3/2

5YR 3/2 and 5YR 3/4 with 5YR 4/4

Core is intensely deformed in Section 1 and 2, moderately deformed in Sections 3 to 6; dominant colors gray brown (5YR 3/2); medium brown (5YR 3/4) and moderate brown (5YR 4/4) with vertical streaking; minor blebs of light brown (5YR 5/6) also occur.

ZEOLITE-RICH (to Zeolitic) SILTY CLAY
Smears: 1-110, 4-80, 6-70, CC

Texture	Composition
74.1% Clay	55-67% Clay minerals
25.8% Silt	20-25% Zeolite
0.1% Sand	5-15% Fe-oxides
	0-10% Quartz, Feldspar
	1% Micronodules
	Tr% Volcanic glass

ZEOLITIC VOLCANIC ASH (Minor Lith)
Smear: 3-78

Texture	Composition
100% Silt	55% Devit. volcanic glass
	45% Zeolite (low. est.)

ZEOLITE-RICH VOLCANIC (Palagonite) ASH (Minor Lith)
Smear: 6-71

Texture	Composition
65% Silt	60% Palagonite
30% Clay	20% Feldspar
5% Sand	10% Devit. glass
	10% Zeolite (low. est.)

5YR 3/2 with 5YR 4/4 and 5YR 3/4

Sand and silt size grains are mainly aggregates of clay; silt fraction of volcanic ash has quartz, feldspar, microcrystalline feldspar in glass; a microphitic texture and quench glasses; zeolites common (phillipsite and clinoptilolite).

Grain Size 4-79
0.1, 25.8, 74.1

X-ray 4-74 (Bulk)	X-ray 3-77 (Bulk)
60.1% Phil	73.9% Phil
11.8% Plag	8.4% Mont
8.9% Mont	8.2% Plag
8.3% Quar	5.3% Quar
6.1% Mica	4.2% Mica
4.1% Chlo	P Goet
0.8% Clin	
P Goet	

5YR 3/4

Explanatory notes in chapter 1

Site 290 Hole Core 3 Cored Interval: 99-108.5 m

AGE	ZONE	FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE OLIGOCENE	Sphenolithus ciperoensis / Thyrsocyrtis bromia (R)		Am	B		1	0.5, 1.0		o o o o o	*16, *76	10YR 4/2 ↕ 10YR 5/4
						2				*70	
			Ag	Cm		3		GEOCHEM SAMPLE			10YR 5/4
		B	Ag	Cm		Core Catcher				CC *	

Unit 2. Core is drilling breccia in Section 1 with moderate slight deformation in Sections 2 to 3; colors alternate dark yellow brown (10YR 4/2), to moderate yellow brown (10YR 5/4) in Section 1, to dominate moderate yellow brown (10YR 5/4) in Sections 2 and 3; some minor lithification to claystone at 145-150 cm in Section 2.

NANNOFOSSIL-RICH SILTY CLAY
Smears: 1-16, 1-76, 2-70, CC

Texture	Composition
50-80% Clay	40-71% Clay minerals
20-50% Silt	15-20% Nannofossils
	5-10% Volcanic glass
	4- 5% Zeolites
	1-10% Radiolarians
	1- 5% Micronodules
	1- 3% Sponge spicules
	1- 2% Feldspar
	1- 2% Foraminifera
	0- 3% Palagonite

Minor lithologic variations include: ash-bearing, radiolarian, ash-rich (2%), nannofossil-rich clay: micronodules noted (5%) at 1-76; color variations seem to reflect changes in clay content (increase clay = darker coloration); zeolites are phillipsite and clinoptilolite; some pyrite staining.

Carbon Carbonate 1-74
1.5, 0.0, 12

Carbon Carbonate 3-143
1.7, 0.0, 14

Explanatory notes in chapter 1

Site 290 Hole Core 4 Cored Interval: 118.0-127.5 m

AGE	ZONE	FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE OLIGOCENE	Sphenolithus ciperoensis / Thyrsocyrtis bromia (R)		Am			1	0.5, 1.0	VOID			
			Am	Cm		2			o o | | |	*49, *75	10YR 5/4 with 10YR 4/2 and 10YR 6/6
		B	Ag	Cm		Core Catcher				CC *	

Top of core is drilling breccia with slight to moderate drilling deformation lower; colors dominant moderate yellow brown (10 YR 5/4), interlayed with dark yellow orange (10YR 6/6) as laminae; (10YR 6/6) = higher volcanic content.

NANNOFOSSIL RICH SILTY CLAY
Smear: 2-75

Texture	Composition
75% Clay	62% Clay minerals
25% Silt	20% Nannofossils
	5-10% Volcanic glass
	5% Radiolarians
	2% Zeolite
	1% Sponge spicules

VOLCANIC (ASH)-RICH NANNOFOSSIL CLAY
(Minor Lith)
Smears: 2-49, CC

Texture	Composition
40-85% Silt	35-70% Clay minerals
15-60% Clay	10-20% Nannofossils
	10-20% Volcanic glass
	5-10% Radiolarians
	3- 5% Palagonite
	2-10% Feldspar

Basic lithology is nannofossil-rich clay with local ash-bearing to rich and radiolarian-bearing zones; laminae of dark layers (10YR 6/6) higher in volcanics; scattered Mn nodules <2 mm; radiolarians common lower in core.

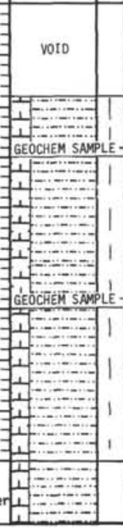
Carbon Carbonate 2-75
1.5, 0.1, 14

Explanatory notes in chapter 1

Site 290 Hole Core 5 Cored Interval: 137.0-146.5 m

AGE	ZONE	FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS
LATE OLIGOCENE	Sphenolithus distentus / Sphenolithus ciperoensis; Thyrsocyrtis bromia (R)	B	Cm, Ag, Ag	Cm, Cm, Fm		1, 2, 3, Core Catcher	0.5, 1.0

LITHOLOGY



LITHO. SAMPLE: * 100, * 36, * 112, * 78, CC *

LITHOLOGIC DESCRIPTION

10YR 7/4

10YR 7/4 → Color Transition → 5Y 5/2

5Y 5/2

Core stiff with slight deformation, however drilling has broken or fragmented core; numerous color laminae, burrows, and shear(?) zones; color dark yellow brown (10YR 4/2), gray orange (10YR 7/4) to 75 cm in Section 2, then transition to light olive gray (5Y 5/2), equals Unit 2-3 boundary.

NANNOFOSSIL-RICH SILTY CLAY
Smears: 2-36, 2-112, 3-78, CC

Texture (1-100)	Composition
20-50% Silt	47-55% Clay minerals
50-80% Clay	15-20% Nannofossils
	13% Feldspar, Quartz
	5-10% Radiolarians
	7-10% Volcanic glass
	2- 5% Sponge spicules
	2- 5% Zeolite
	1% Opaques
	0- 2% Palagonite

Radiolarian content actually very variable throughout core. Zeolites are phillipsite; glass noted throughout.

Carbon Carbonate 1-100
1.7, 0.1, 13

Carbon Carbonate 3-81
1.7, 0.1, 13

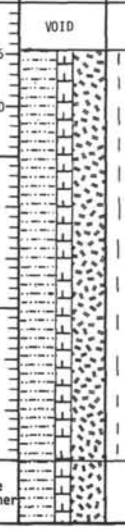
X-ray 3-75 (Bulk)
33.7% Calc
33.4% Mont
21.5% Plag
9.9% Phil
1.5% Quar

Explanatory notes in chapter 1

Site 290 Hole Core 6 Cored Interval: 156.0-165.5 m

AGE	ZONE	FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS
LATE OLIGOCENE	Sphenolithus distentus; Thyrsocyrtis bromia (R)	B	Ag, Ag	Cm, Cm, Fm		1, 2, 3, Core Catcher	0.5, 1.0

LITHOLOGY



LITHO. SAMPLE: * 130, * 60, * CC

LITHOLOGIC DESCRIPTION

5Y 5/2

Core is firm throughout with slight drilling deformation; color is light olive gray (5Y 5/2) throughout; minor burrowing noted in Sections 2-3, (less than 3 mm diameter).

CLAYEY/NANNOFOSSIL-RICH VOLCANIC (ASH)
Smears: 1-130, CC

Texture	Composition
50% Silt	35% Volcanic glass
50% Clay	35% Clay minerals
	14% Nannofossils
	10% Radiolarians
	3% Zeolites
	2% Feldspar
	1% Sponge spicules

NANNOFOSSIL/CLAY-RICH ASH (Minor Lith)
Smear: 3-60

Texture	Composition
50% Silt	45% Volcanic glass
30% Clay	25% Clay minerals
20% Sand	15% Nannofossils
	3- 5% Radiolarians
	3- 4% Feldspar
	2% Palagonite
	1% Heavy minerals

Very definite increase in volcanic glass down the core; chlorite noted; zeolites mostly phillipsite.

Grain Size 3-75
0.1, 62.0, 37.9

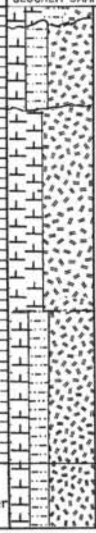
Carbon Carbonate 3-79
1.5, 0.1, 12

X-ray 3-80 (Bulk)
35.3% Calc
30.1% Mont
24.4% Plag
8.0% Phil
2.2% Quar

Explanatory notes in chapter 1

Site 290 Hole Core 7 Cored Interval: 213.0-222.5 m

AGE	ZONE	FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE		LITHOLOGIC DESCRIPTION
EARLY OLIGOCENE	Reticulofenestra hillae Subzone; Thyrsocyrtis bromia (R)		Cm			1	0.5, 1.0	VOID; GEOCHEM SAMPLE				
				Cm		2			|	*110	† Lapilli Zone †	
						3			|		5Y 5/2; Lapilli Zone	
			Ag	Cm		4			|	*63	† 5Y 5/2	
		B	Cg	Fp		Core Catcher				CC *	5Y 5/2	



Core is stiff with slight deformation; consistent light olive gray (5Y 5/2) color throughout core, except for multi-colored variations in "lapilli" zones.

CLAY/NANNOFOSSIL RICH ASH AND NANNOFOSSIL ASH*
Smears: 2-69, 2-110, 4-63, CC

Texture	Composition
56.6% Silt	35-45% Volcanic glass
42.8% Clay	20-27% Clay minerals
0.6% Sand	18-25% Nannofossils
	12% Zeolite
	10% Feldspar
	3-10% Radiolarians
	Tr- 3% Sponge spicules
	Tr- 2% Heavy minerals

*Lapilli of nannofossil volcanic ash (max. of 7 mm) occur within a matrix of nannofossil volcanic ash. The clast zone is ungraded; irregular contacts with the volcanic ash and interfinger as mass flow deposit. Nannofossil volcanic ash very consistent throughout and occurs as the matrix of clast zone. The clasts are rounded, very soft and altered. Zeolites are phillipsite; radiolarians noticeable in smear slides, approaching 10% in Section 4.

Grain Size 2-72
0.6, 56.6, 42.8

Carbon Carbonate 4-74
1.4, 0.1, 11

X-ray 2-68 (Bulk)
31.1% Mont
27.1% Plag
25.6% Calc
11.8% Phil
3.2% Quar
1.2% Anal

Explanatory notes in chapter 1

Site 290 Hole Core 8 Cored Interval: 241.5-251.0 m

AGE	ZONE	FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE		LITHOLOGIC DESCRIPTION
EARLY OLIGOCENE	Reticulofenestra hillae Subzone; Thyrsocyrtis bromia (R)					1	0.5, 1.0	VOID		* TS; * TS	5Y 3/2; 10YR 5/4	
						2				* TS; * TS		
						3					10YR 5/4	
						4				* TS; * TS		
			Rm			5				* TS; * TS; * TS; * TS; * TS; * TS		
				B	B	Core Catcher						

Section 1. VOLCANIC CONGLOMERATE (Unit 4) olive gray (5Y 3/2) to 125 cm moderate yellow brown (10YR 5/4) to 150 cm. Open framework of basaltic, igneous fragments, dark chert, black-dark glass, and some zeolite/calcite-lined voids; clasts (0.2-10 mm) are well sorted in upper portion, moderate to poor in lower; subangular to subrounded fragments in yellow brown matrix.

Section 2. As 125-150 cm in Section 1 with coarser clasts (1-3 cm) moderate sorting; weathering(?) rim noted on large (7 cm) diabase fragment. Faint grading noticed.

Section 3. Moderate yellow brown (10YR 3/4) with darker clasts; average size 3 mm inc. porp. basalt; glassy basalt, feldspar, altered volcanics, palagonite all within a zeolite-micrite matrix; moderately-well sorted and coarser towards bottom. Tendency for a closed framework.

Section 4. Coarser than Section 3 with poor sorting; maximum size is about 6 cm, average 3 mm; closed framework; basalt, chert, weathered volcanics, palagonite fragments. Matrix mud with white zeolite and calcite.

Section 5. Coarser than Section 4 with increase of large diabase fragments down section; clasts including: highly altered basalt, glass, diabase some with Mn crust;

Clast lithologies:	40% pumice
	20% weathered pumice
in Matrix ≈30%	5% minerals including pyroxene crystals
	3% volcanic glass
	2% diabase

DIABASE* - Fragment (Cobble) (Minor Lith)
Thin Section: CC
Medium grained, ophitic texture; tabular to lath-like plagioclase poikilitically enclosed by clinopyroxene. Some alteration of clinopyroxene to brown, chloritic material.

*Fragment below conglomerate unit of core with diabase clasts.

THIN SECTION (DIABASE)
Plagioclase 60% (An_{35-55}) (An cores-Ab rims);
Pyroxenes 36% (Poikilitic clinopyroxene);
Chlorite 4% (alteration of pyroxene edges)
Magnetite-Ilmenite 2%

X-ray 1-77 (Bulk)
70.9% Phil
20.2% Augi
8.9% Mont

X-ray 5-52 (Bulk)
27.8% Plag
27.0% Calc
22.8% Phil
21.8% Augi
0.6% Quar

Explanatory notes in chapter 1

Site 290 Hole Core 9 Cored Interval: 251.0-255.0 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE		LITHOLOGIC DESCRIPTION
EARLY OLIGOCENE OR LATE EOCENE	Helicopontosphaera reticulata or Discoaster barbadiensis	B	Fm	B		Core Catcher				CC *	5YR 3/4	Five sections of moderate brown (5YR 3/4) SILT-BEARING CLAY. Very soupy and flowed from liner upon retrival. Core apparently represents caving sediment representative of Core 1 - Hole abandoned due to collapse, after Core 9 was taken.

SILT-RICH CLAY
Smear: CC

Texture	Composition
86% clay	84% Clay minerals
14% Silt	7-10% Zeolite
	5% Quartz, Feldspar
	1- 2% Nannofossils
	1- 2% Fe-oxides

5 additional smears show: SILT-BEARING/RICH CLAY

Texture	Composition
85-98% Clay	77-86% Iron stained clay minerals
2-15% Silt	12-17% Zeolites (clinoptilolite and phillipsite)
	1- 4% Nannofossils
	1- 2% Quartz, Feldspar

PALEONTOLOGY: Mixture of upper Eocene nannofossils.

Explanatory notes in chapter 1

Site 290 Hole A Core 1 Cored Interval: 108.5-118.0 m

AGE	ZONE	FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
LATE OLIGOCENE	Sphenolithus ciperoensis; Thyrsocyrtis bromia (R)			Am		1	0.5 – 1.0	VOID		
			Am	Am		2			o o o o o o	* 110
		B	Aq	Fm		Core Catcher				CC *

5YR 4/4 to 5YR 3/4

LITHOLOGIC DESCRIPTION

Lithologic material is firm but is drilling breccia occurs within sections; colors are moderate brown (5YR 4/4) to moderate brown (5YR 3/4) and generally uniform. No structures are apparent in the core. Similar to Unit 2 in Hole 290 Core 3.

ASH/NANNOFOSSIL-BEARING SILTY CLAY
Smears: 2-110, CC

Texture	Composition
40-50% Silt	41-45% Clay minerals
50-60% Clay	25% Quartz, Feldspar
	10-12% Zeolites
	8-10% Nannofossils
	6-10% Volcanic glass
	5% Heavy minerals
	3- 6% Sponge spicules
	2% Fe-oxides

The zeolites are phillipsite: some discoasters present. May locally be ash-rich, and zeolite-rich.

Carbon Carbonate 2-104
1.0, 0.1, 8

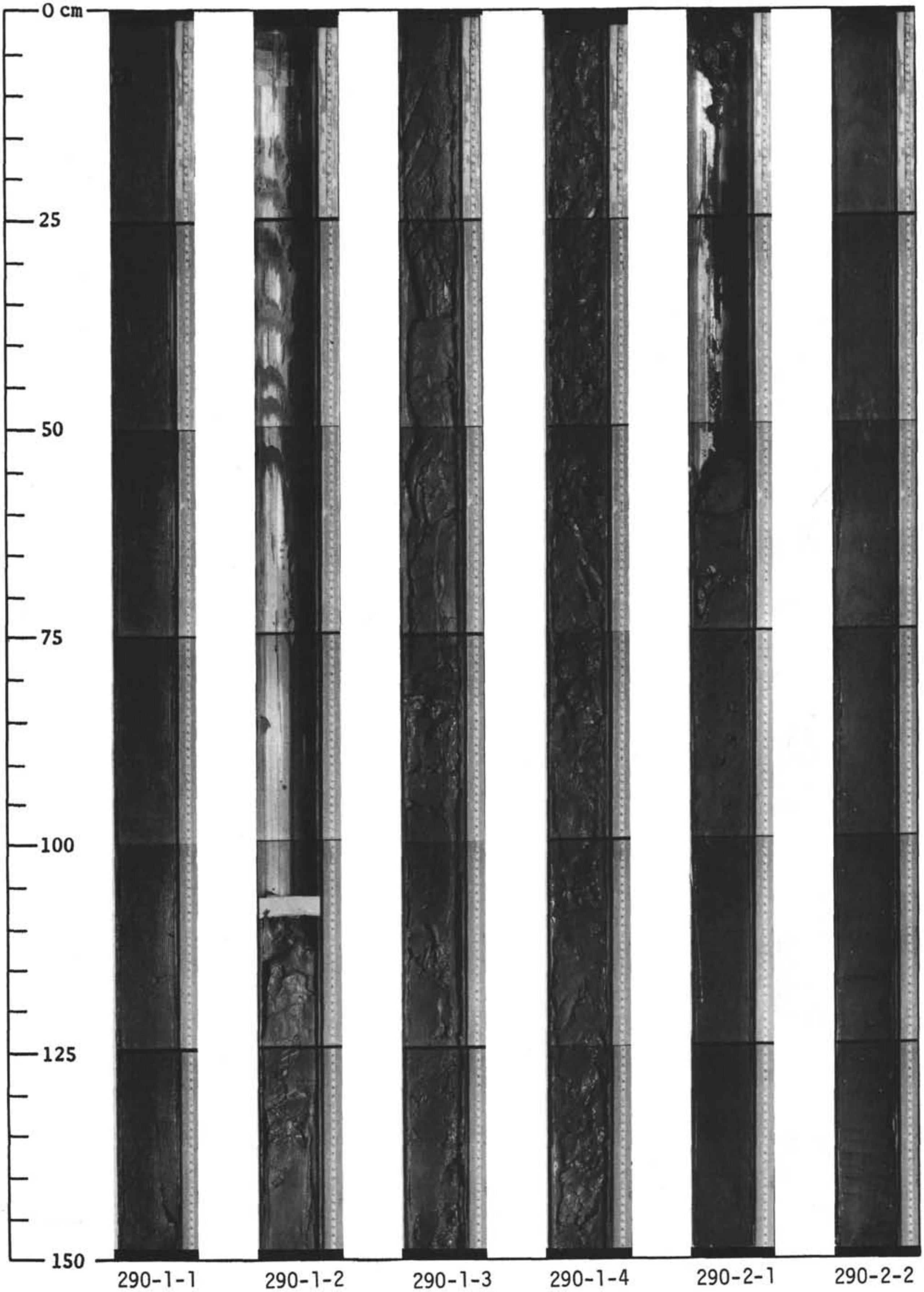
X-ray 2-112 (Bulk)
29.8% Calc
27.4% Plag
19.1% Mont
13.5% Phil
6.9% Augi
3.4% Quar

Explanatory notes in chapter 1

Site 290 Hole A Core 2 Cored Interval: 130.5-140.0 m

AGE	ZONE	FORAMS	NANNOS	RADS	OTHERS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE		LITHOLOGIC DESCRIPTION
LATE OLIGOCENE	Sphenolithus ciperoensis; Thyrsocyrtis bromia (R)	B	Am	Rp		Core Catcher					10YR 5/4	VOLCANIC CONGLOMERATE. Color moderate yellow brown (10YR 5/4); clasts average 3 mm (up to 2-3 cm) including: basalt, glass, chert(?), altered volcanics, palagonite fragments; subangular to subrounded in a matrix of, dolomitized(?) calcite(?), zeolite mud. Unit equivalent to Unit 4 in Core 8 Hole 290.

Explanatory notes in chapter 1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100
125
150
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290-1-2
290-1-3
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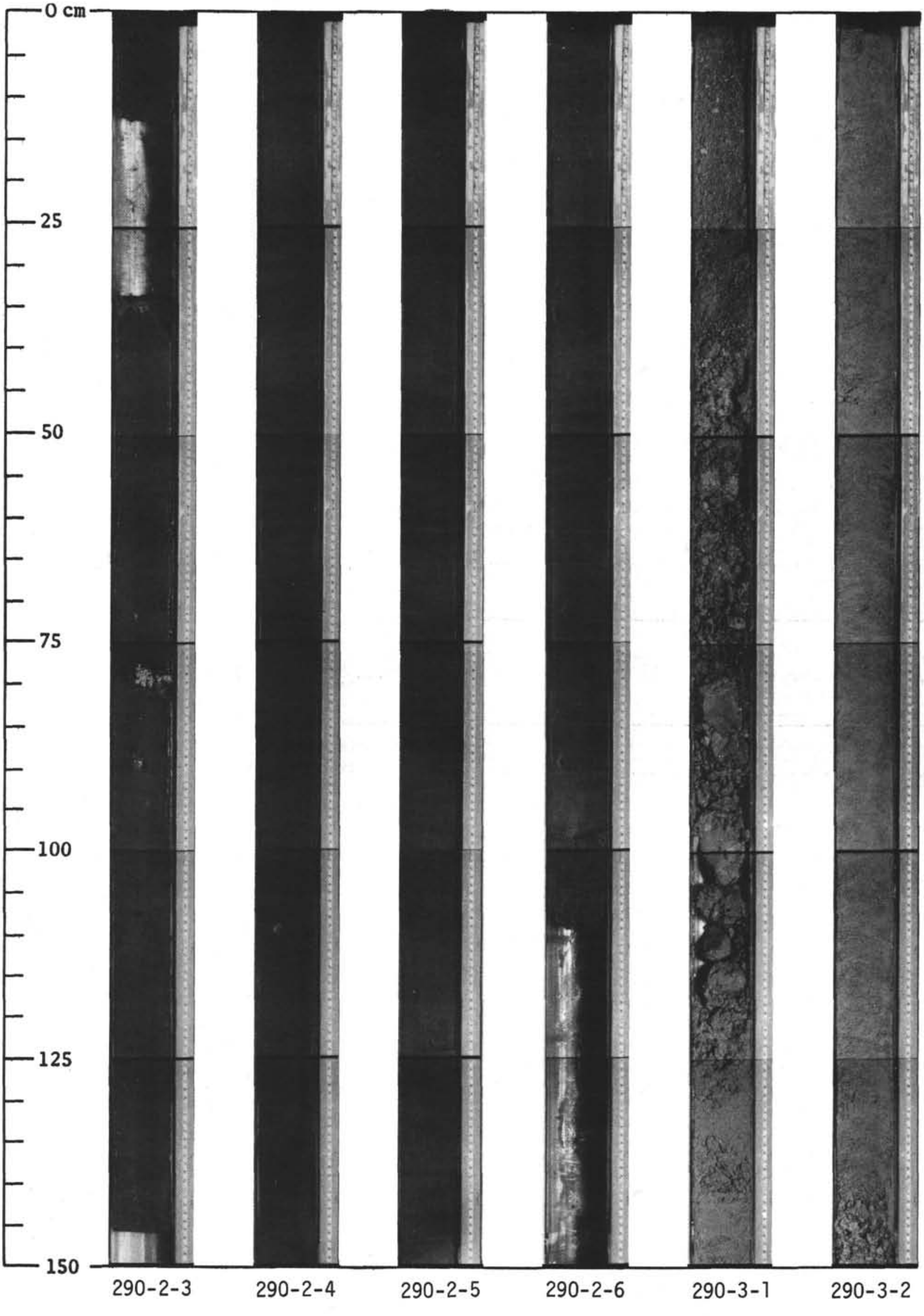
290-2-2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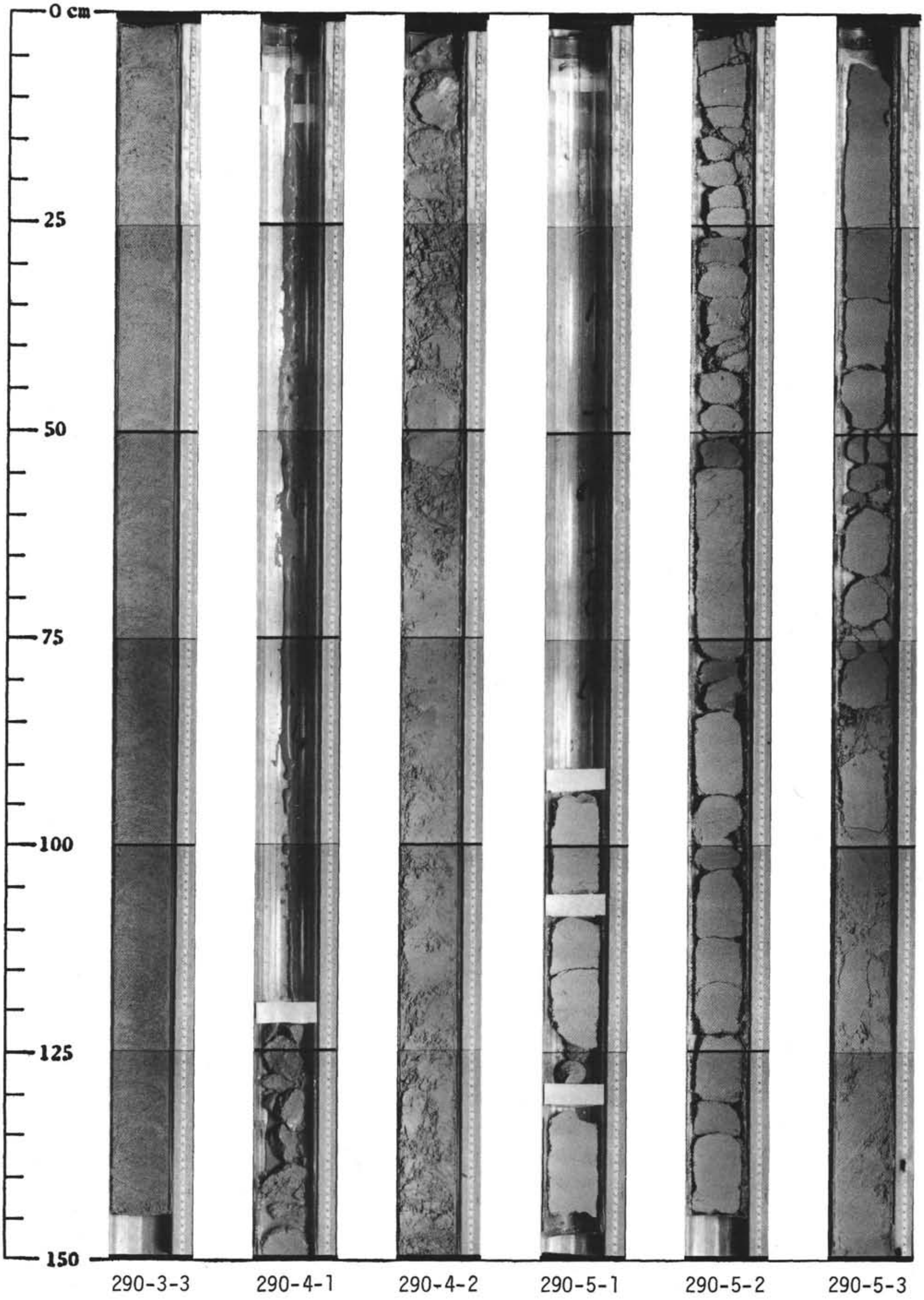
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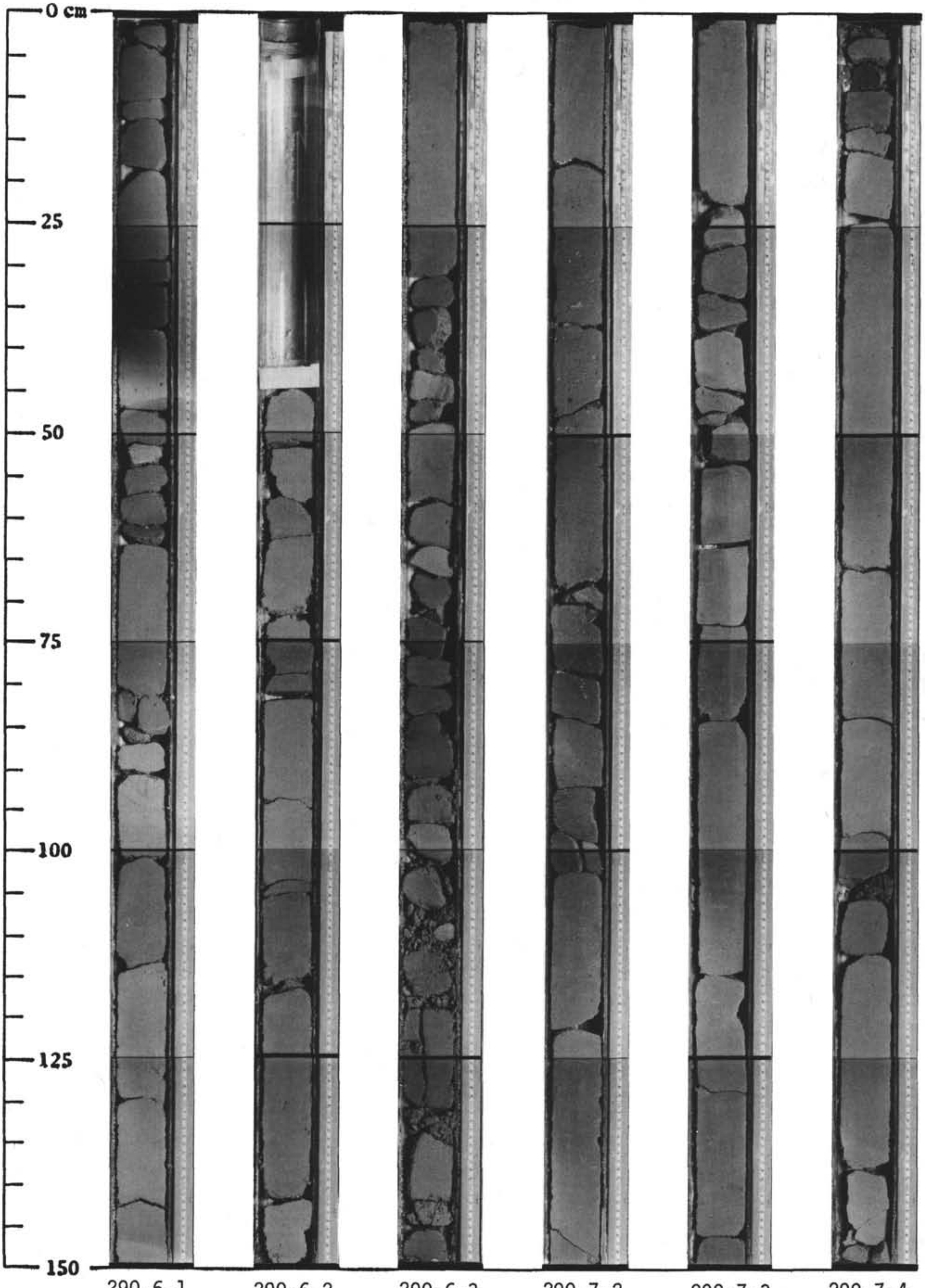
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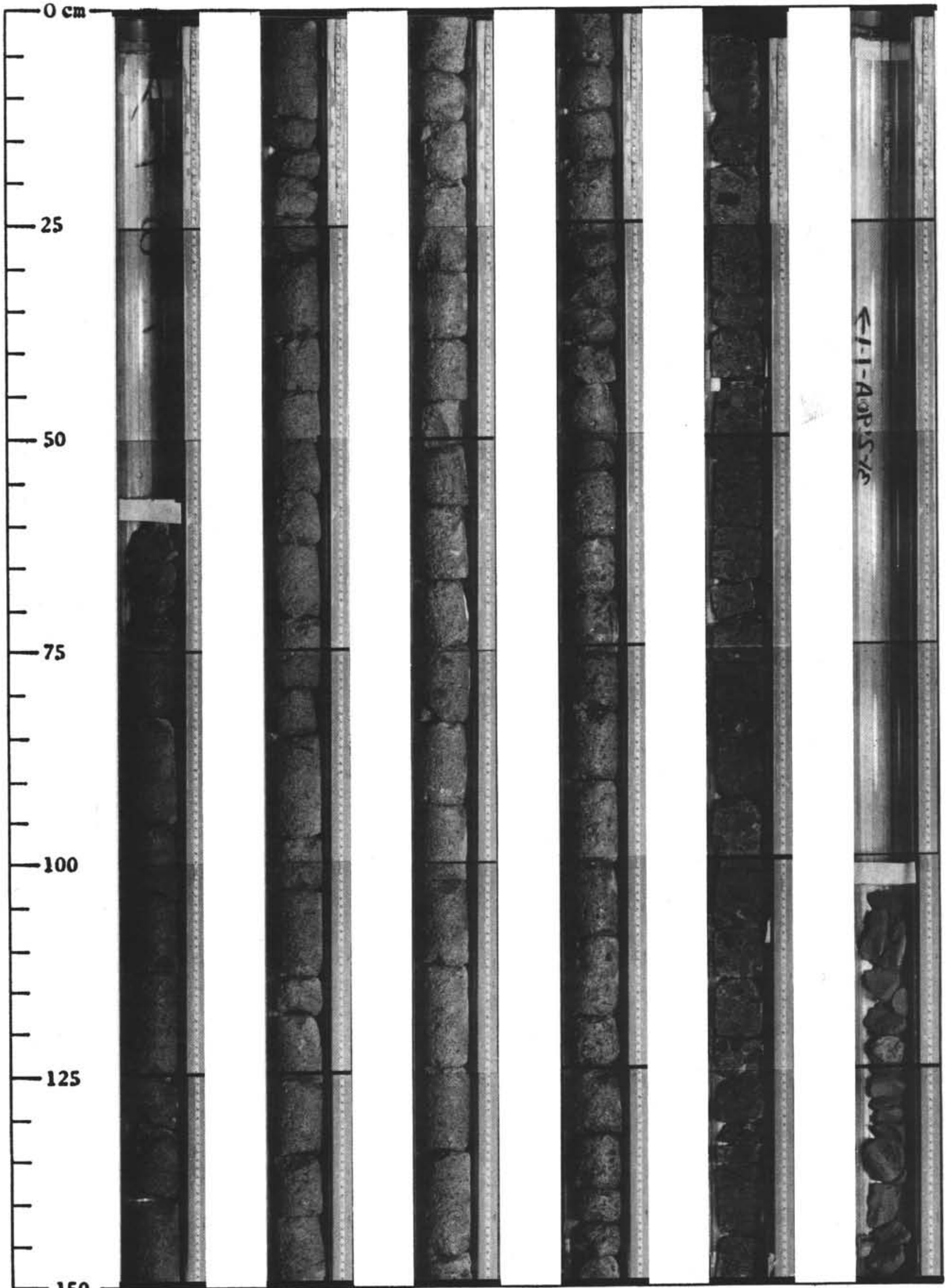

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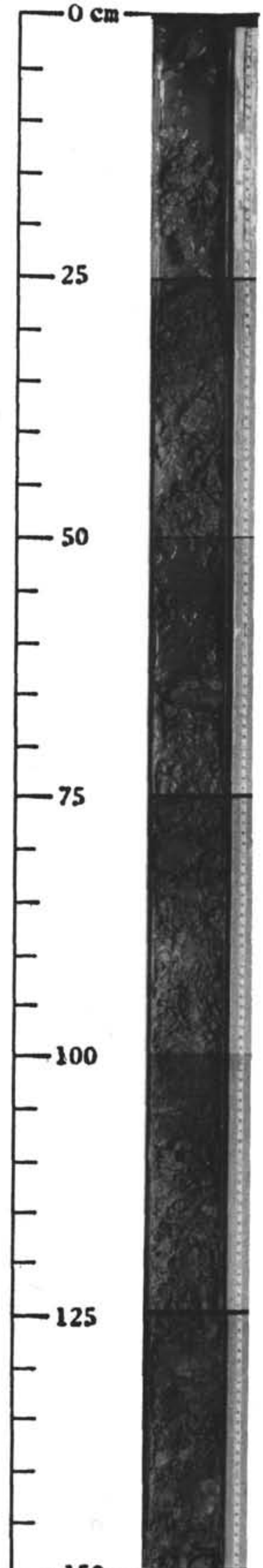

290A-1-2