12. SITE 301

The Shipboard Scientific Party[1]

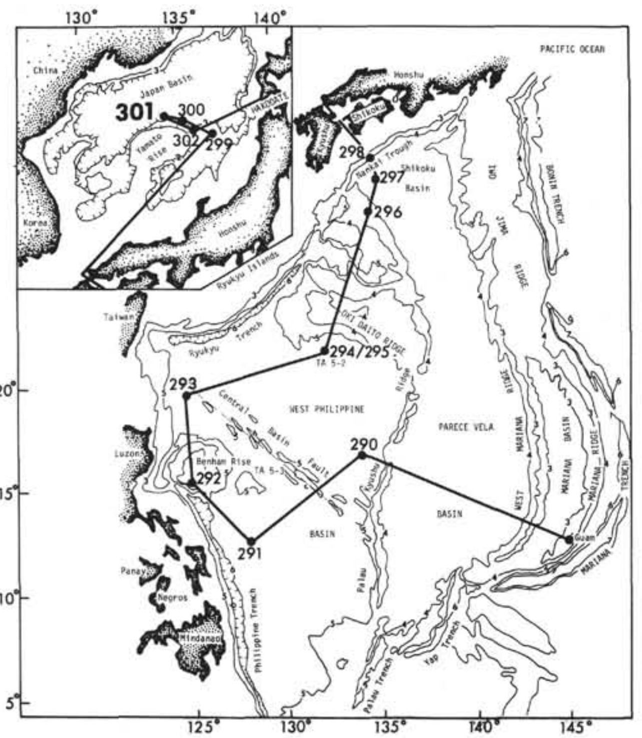


Figure 1. *Location map of DSDP Sites and* Glomar Challenger *sites in the Sea of Japan. From map: "Topography of North Pacific," T. E. Chase, H. W. Menard, and J. Mammerickx, Institute Marine Resources, Geol. Data Center, Scripps Institution of Oceanography, 1971. Contour depths in kilometers. Scale 1:6,500,000.*

SITE DATA

Position: 41°03.75'N; 134°02.86'E

Water Depth (from sea level): 3520 corrected meters (echo sounding)

Bottom Felt At: 3521 meters (drill pipe)

Penetration: 497 meters

Number of Holes: 1

Number of Cores: 20

Total Length of Cored Section: 183.5 meters

Total Core Recovered: 49.9 meters

Percentage of Core Recovery: 27.2%

Oldest Sediment Cored:
Depth below sea floor: 497 meters
Nature: Clayey diatomite
Age: Earliest Pliocene

Principal Results: Site 301 was drilled in the east central portion of the Japan Abyssal Plain in hopes of obtaining objectives originally planned for abandoned Site 300 drilled to the northeast. Stratigraphic section consists of 240.5 meters of Pleistocene distal turbidites, fine sands, silts, silty clays, and clays underlain by 256 meters of Pliocene clayey diatomite and diatomaceous claystone with a few sand interbeds representing two of the later stages of filling of this basin. Unfortunately, the site had to be abandoned before completing objectives due to critically high ethane/methane ratio similar to that found at Site 299.

BACKGROUND AND OBJECTIVES

The premature and unexpected abandonment of Site 300 forced the selection of an alternate unscheduled site in the Japan Abyssal Plain which would hopefully allow the original objectives of Site 300 to be fulfilled. Coarse clastics found in surface and near-surface layers at Site 300 presented striking evidence of the extensive nature of major distributaries from the Toyama Trough. It was decided that an alternate site would be sought in an area to the west along latitude 41°N at a sufficient distance to escape the coarser debris of this major channel-fan system.

Vema-28 (LDGO) seismic records were again used to locate Site 301 and a favorable area was found about 200 km southwest of Site 300, due west of the Yamato Rise (Figures 1 and 2). All indications pointed to the protected nature of this particular area, and both *Vema* records as well as *Glomar Challenger* underway and onsite sonobouy records demonstrated that the area is underlain by about 1.45 sec (1400 m) of sediment (Figures 3 and 4). The sedimentary column was again clearly divisible into an upper 400-500 meter thick reflective unit representing probable Plio-Pleistocene turbidites with a thicker underlying transparent unit beginning at 0.6 to 0.7 sec. The latter is assumed to represent diatom-rich pelagic sediments of Miocene age (Figure 5). Significantly, this latter unit can be traced onto the Yamato Rise, where it emerges from beneath the cover

[1]James C. Ingle, Jr., Stanford University, Stanford, California; Daniel E. Karig, Cornell University, Ithaca, New York; Arnold H. Bouma, Texas A&M University, College Station, Texas; C. Howard Ellis, Marathon Oil Company, Littleton, Colorado; Neville S. Haile, University of Malaya, Kuala Lumpur, Malaysia; Itaru Koizumi, Osaka University, Osaka, Japan; Ian MacGregor, University of California at Davis, Davis, California; J. Casey Moore, University of California at Santa Cruz; Santa Cruz, California; Hiroshi Ujiié, National Science Museum of Tokyo, Tokyo, Japan; Teruhiko Watanabe, University of Tokyo, Tokyo, Japan; Stan M. White, California State University at Fresno, Fresno, California; Masashi Yasui, Japan Meteorological College, Tokyo, Japan; Hsin Yi Ling, University of Washington, Seattle, Washington.

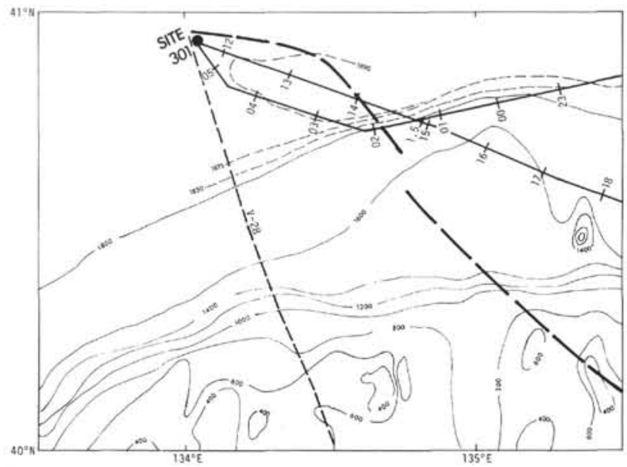


Figure 2. *Bathymetry (in uncorrected meters) in the vicinity of Site 301 updated from Chase and Menard (1969) using* Glomar Challenger *and LDGO* (Vema-28) *data. Note subtle moat at the foot of the Yamato Rise. Heavy track line is illustrated on Figure 4.*

of basin-bottom turbidites and forms a draped pelagic blanket ultimately penetrated at Site 302 (Figure 3).

Objectives and other background information for Site 301 remained the same as outlined in Chapter 11 for abandoned Site 300, namely, dating of acoustic basement, and recovery of a section representative of sedimentologic, paleontologic, and paleoclimatic events in this major basin.

OPERATIONS

Site 300 was abandoned because of the very coarse and unstable surficial sediments. *Glomar Challenger* thus headed west along the northern flank of the Yamato Rise to another location in the Japan Basin Figure 2). The new site, located along a Lamont-Doherty profile (*Vema*-28, 2095-0430), was chosen on the basis of two criteria: first, this area appeared to be furthest from any of the major channels feeding the abyssal plain; and second, this site would put us in position to drill on the Yamato Rise in what time remained if Site 301 had to be abandoned for any reason. Depth to acoustic basement was on the order of 1500 meters, but the lack of reflectors below the 4-500 meter thick turbidite interval suggested that drilling rates should be reasonably high and that the hole conditions would remain favorable.

The ship headed to a point on the ridge flank south of the site in order to profile the basin and follow the basement reflector. However, faulty and noisy hydrophone streamers prevented a good profile recording of this reflector (Figure 4). When the basement reflector became lost on the record, the course was changed to steam directly for the approximate site location determined from the LDGO profile (Figure 3). The speed was decreased to 6 knots, and a 16-kHz beacon was dropped on the first pass over the geographic coordinates. Because of a weak beacon signal and the receiving of a new satellite fix, which altered the dead-reckoning location, it was decided to drop a second, 13-kHz, beacon at that position.

Hole 301 was spudded in a water depth of 3521 meters (drill pipe length) at 2130 30 July. After taking a surface punch core and preparing to interval core, the interfacing between the computer and the stabilizing gyro malfunctioned. Positioning was switched to the semiautomatic mode, requiring that the bottom-hole assembly be buried before further coring was attempted. After the second core was cut at 117 meters, the first of three heat-flow measurements was taken. Two others followed cores at 174-183.5 meters and 212-221.5 meters.

Between 33% and 50% of the section was cored through the first 400 meters of the hole. At 400 meters the ethane content of the generally gassy cores began to increase, and between 400 and 460 meters the methane/ethane ratio decreased sharply. Both these parameters remained about constant during the last three cores, which were cut continuously, but the decision was made to terminate drilling at 497 meters (Table 1). The hole was then plugged with 150 barrels of heavy mud and capped with 40 barrels of cement. The ship left the site toward a favorable location on the lower flank of the Yamato Rise which had been observed along the profile from Site 299 to Site 300.

LITHOLOGY

Site 301 was drilled on the abyssal plain of the Japan Basin in a water depth of 3521 meters. Lithologic analysis of the sediment section recovered indicates that two units may be designated, as shown in Figure 5 and Table 2. The boundary between these units is transitional. Lithologic features found in the cores are noted in Figure 6.

Unit 1

Unit 1 is found in Cores 1-7 (0-240.5 m). It is primarily composed of clay and silty clay. The clay may be silt bearing or rich. Minor lithologies include interbedded silt, sand and silty sand, and volcanic ash zones or beds.

The color of Unit 1 is predominantly in the green-gray, olive-gray, and olive-green hues, with the color variations distinguishing bedding in the unit; bedding thicknesses vary from 1 to 40 cm. The silty clays and clays contain 65%-95% clay-sized particles and 50%-80% clay mineral content. Microfossils include diatoms, radiolarians, sponge spicules, and silicoflagellates in respective order of abundance. The sandy interbeds generally have varying contents of clay and silt. They show poor to good grading. The volcanic ash occurs as isolated zones or as thin interbeds which include 70%-95% volcanic ash. The age of the unit is Pliocene to late Pleistocene-Holocene.

Unit 2

Unit 2 is approximately 256 meters thick occurring in Cores 8 through 20 (240.5-497 m). The dominant lithology is a clayey diatomite or diatomaceous claystone with minor amounts of sand beds in the lower

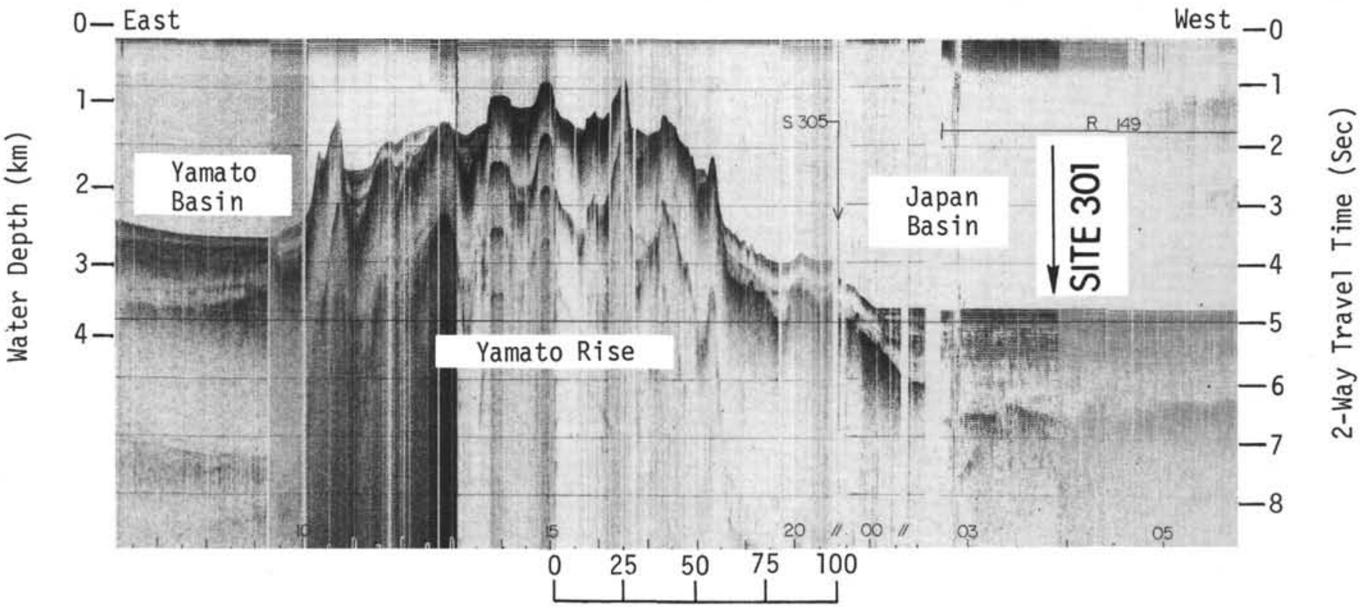


Figure 3. Glomar Challenger *seismic reflection profiles approaching and departing Site 301. Note continuity of deeper pelagic section with the pelagic section on the flank of the Yamato Rise.*

four cores. The colors are predominantly dark greenish-gray and olive-gray.

In the clayey diatomites or diatomaceous claystones, the clay mineral content varies from 30% to 54% and the diatom content, 30%-50%. The olive-gray lithology generally has a higher clay mineral content and a relatively lower diatom content. The olive-gray diatomite also tends to be more indurated and less well bedded, compared to the greenish-gray lithology. Volcanic ash beds are rare. Bioturbation was locally moderate to intense. The micronodule content reached 7% in some cores; they are believed to be pyritic nodules formed within diatom chambers and released upon decay or breakup. Zeolites and carbonate-replaced zeolites occur.

The second lithology occurring in Unit 2 consists predominantly of graded sand-silt-clay and silty sand beds. This lithology first appears interbedded with the diatom claystone in Core 17 (450 m, late Miocene). The maximum concentration of these units is in Core 18 and decreases through Cores 19 and 20. Characteristically these clastic units contain sand-size feldspar (plagioclase), quartz, mica, heavy minerals (pale green augite dominates), and lithic fragments (polycrystalline quartz-microquartzite). Occasional quartzite pebbles were noted in the sand beds, as well as in interbedded diatom claystones. The sand beds contain well-rounded claystone clasts, show sharp basal contacts, and poor to good size grading.

The age of Unit 2 is late Miocene to late Pliocene.

Lithologic Interpretations

The terrestrial clays and silts of Site 301 were probably deposited by grain by grain settling, or from a nepheloid layer from the continental masses surrounding the Japan Sea. Favorable paleooceanographic conditions supported a rich siliceous biota (mostly diatoms) in the water column above the site from late Miocene to late Pliocene. The marked decrease in the proportion of siliceous organisms during the Pleistocene is probably due to dilution by terrestrial sediments.

The poorly sorted sands and silts of Units 1 and 2 were apparently deposited by turbidity currents. The (generally) distal turbidites of Site 301 are consistent with accumulation on the abyssal plain. Some of the coarser, thicker beds may be deposits of small distributary channels. The quartzite and volcanic glass suggest that the turbidites were derived from a varied source terrain which could encompass Asia, Japan, or possibly the Yamato Rise. The Yamato Rise is currently too deep to have been a significant source area even during periods of lowered sea level. However, this feature cannot be eliminated completely as a potential sediment source since it may have had an earlier history of emergence. GDR profiles both approaching and leaving the site (Figure 3) indicate a gentle apparent slope (1/2000) from Asia, suggesting that Pleistocene-Holocene density current deposits were derived from the west.

The Toyama submarine channel currently bypasses the Yamato Basin and feeds directly onto the Japan Abyssal Plain. Since this condition has existed only during the Pleistocene, the Mio-Pliocene turbidites at the site could not have come from Japan via this route. Until more definitive evidence is available, it is assumed that the turbidites were derived from the Asian continent, less than 170 km distant.

Turbidite sands and silts are most abundant in the Pleistocene (Cores 1-7), followed by a secondary maxima in the late Miocene (Cores 18 and 19). Lower sea level, increased precipitation, and increased erosion rates help to explain the Pleistocene turbidites influx. A similar sequence of events associated with the late Miocene global refrigeration may account for the secondary turbidite maxima.

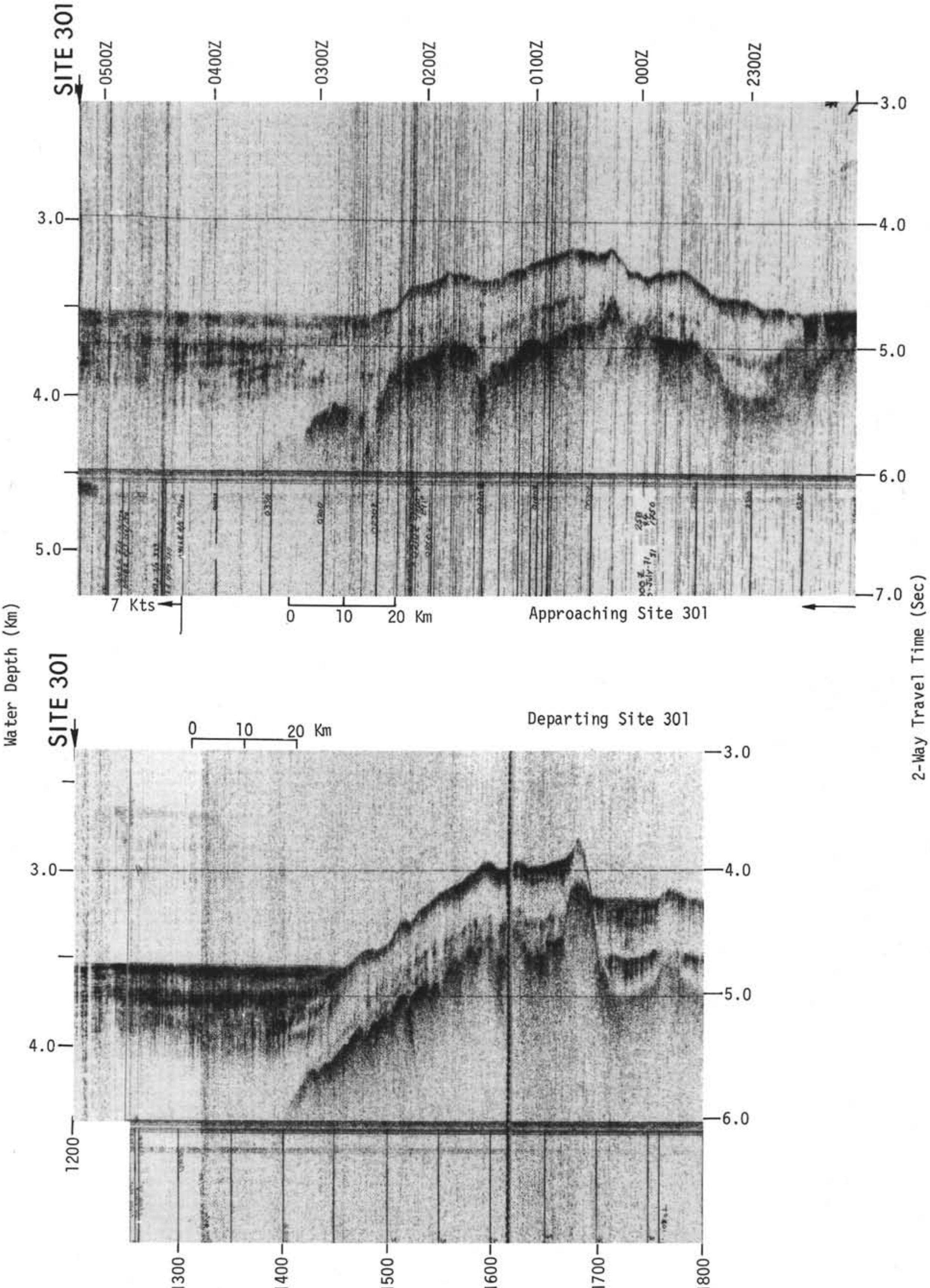


Figure 4. Vema *28 (Lamont-Doherty Geological Observatory) seismic reflection profile across the Yamato Rise and DSDP Site 301. Note flattish acoustic basement which probably marks a volcaniclastic section rather than basalt.*

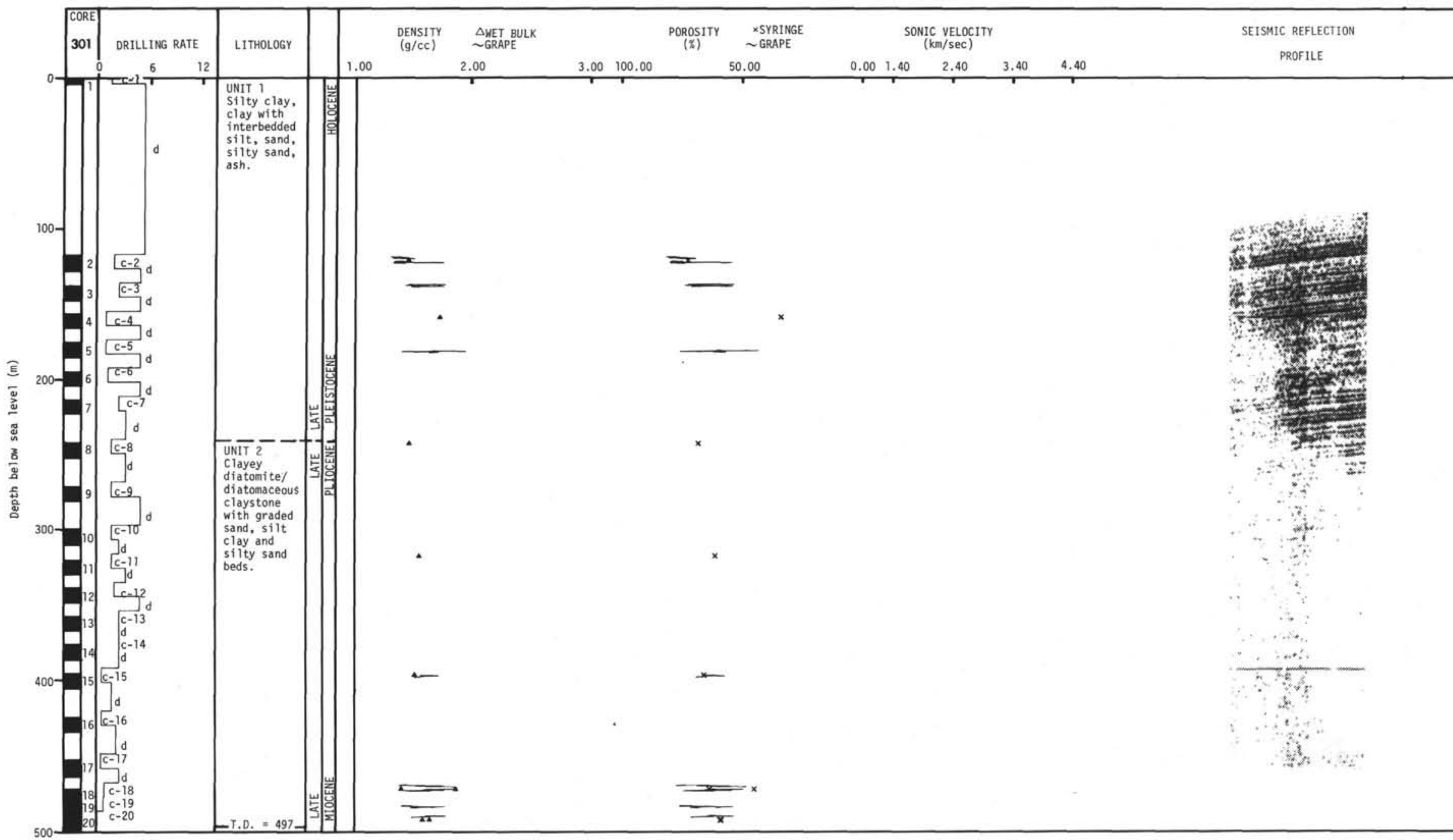


Figure 5. *Hole summary diagram, Site 301.*

TABLE 1
Coring Summary, Site 301

Core	Cored Interval Below Bottom (m)	Cored (m)	Recovered (m)	Recovered (%)	Remarks[a]
1	0.0-3.0	3	0	0	Punch Core
Wash	3.0-117.0				Heat flow at 117 m
2	117.0-126.5	9.5	8.6	91.0	
Wash	126.5-136.0				
3	136.0-145.5	9.5	2.1	22.0	
Wash	145.5-155.0				
4	155.0-164.5	9.5	6.1	64.0	
Wash	164.5-174.0				
5	174.0-183.5	9.5	6.7	71.0	
Wash	183.5-193.0				Heat flow at 183.5 m
6	193.0-202.5	9.5	0 (CC)	0.0	
Wash	202.5-212.0				
7	212.0-221.5	9.5	0.3	3.0	
Wash	221.5-240.5				Heat flow at 221.5 m
8	240.5-250.0	9.5	3.4	36.0	
Wash	250.0-269.0				
9	269.0-278.5	9.5	0.5	5.0	Heat flow
Wash	278.5-297.5				50 bbls mud
10	297.5-307.0	9.5	0.3	3.0	
Wash	307.0-316.5				
11	316.5-326.0	9.5	1.8	19.0	
Wash	326.0-335.5				
12	335.5-345.0	9.5	0 (CC)	0.0	
Wash	345.0-354.5				
13	354.5-364.0	9.5	1.2	13.0	
Wash	364.0-373.5				
14	373.5-383.0	9.5	1.0	11.0	
Wash	383.0-392.5				
15	392.5-402.0	9.5	2.7	28.0	
Wash	402.0-421.0				
16	421.0-430.5	9.5	0.8	8.0	
Wash	430.5-449.5				
17	449.5-459.0	9.5	1.3	14.0	
Wash	459.0-468.5				
18	468.5-478.0	9.5	4.5	47.0	
19	478.0 487.5	9.5	5.2	55.0	
20	487.5-497.0	9.5	3.4	36.0	
Total	497.0	183.5	49.9	27.0	

[a]See Figure 5 for graph of drilling rates and lithologies.

TABLE 2
Unit Descriptions, Depths, Thicknesses, and Ages, Site 301

Unit and Descriptions	Depth (m)	Thickness (m)	Age
1 Silty clay, clay with interbedded silt, sand, silty sand, ash	0-240.5	240.5	Late Pleistocene to Holocene
2 Clayey diatomite/ diatomaceous clay-stone with graded sand-silt clay and silty sand beds	240.5-497.0	≅256	Late Miocene to late Pliocene

PHYSICAL PROPERTIES

The gas content in these cores resulting in many large and small expansion cracks made it difficult to carry out any physical properties measurements. For that reason vane-shear and sonic-velocity measurements were not made; however, a restricted number of GRAPE measurements and thermal-conductivity readings was attempted. It was impossible to obtain a properly filled syringe for water-content measurements. Seven interstitial water samples were collected, and from these the water content was determined.

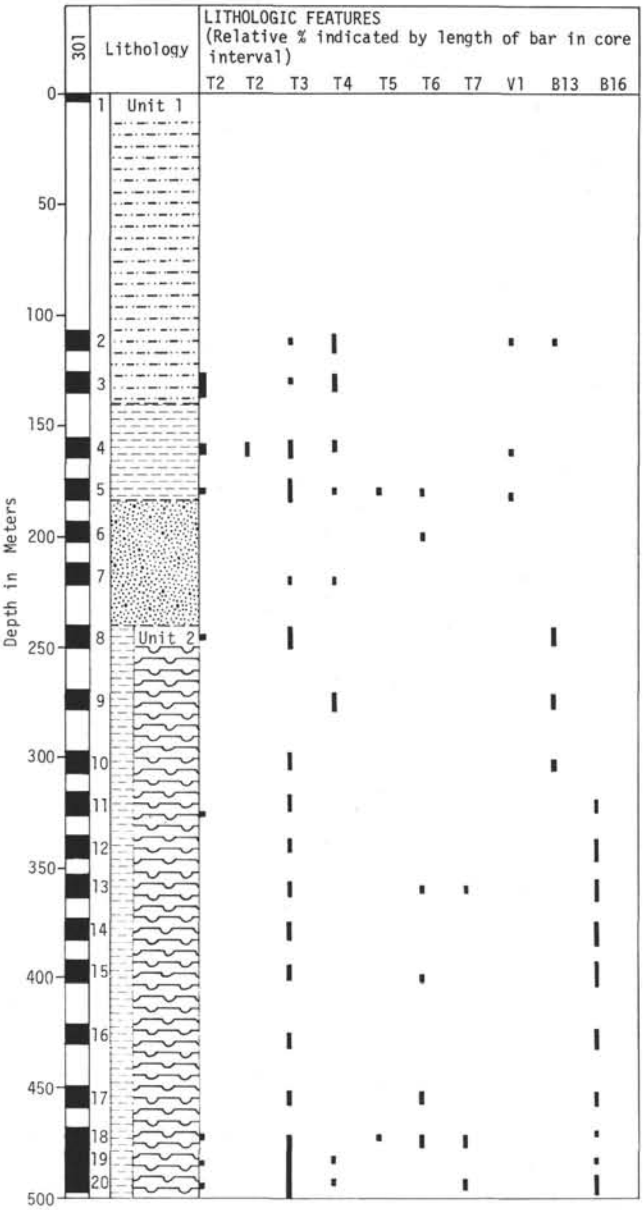


Figure 6. *Lithologic features noted in Cores at Site 301.*

Density, Porosity, and Water Content

The GRAPE analog records are very irregular due to the voids which makes it difficult to judge which values should be used for density. Most core sections had a slight difference between top and bottom. Very often the middle portion was too broken up to allow the analog recorder to respond properly. The readings are presented in Figure 5. A scattering of the limited number of points precludes positive interpretation, but by eliminating the GRAPE readings from Core 5, it can be seen that a minor increase in density occurs in a downward direction.

The laboratory analyses on density and porosity reveal a wide scattering. It is certain that their reliability is out of proportion, due to the inaccuracies obtained when filling the syringes. The water contents consequently also reveal a wide scattering.

Thermal Conductivity

The high gas content which made the cores porous and full of cracks also precluded many attempts to make reliable needle contact for thermal-conductivity measurements. Since most of the sediments obtained an enormous porosity due to hydraulic release of the enclosed gas, no proper syringe samples could be taken for water-content determinations. Therefore, thermal-conductivity measurements derived from water-content ratios may not be any more reliable than the values obtained from needle-probe measurements. The few results obtained are presented in Table 3 and in Figure 7.

Heat-Flow Measurements

Terrestrial heat-flow values at Site 301 represent the product of thermal conductivity and the geothermal

TABLE 3
Thermal-Conductivity Measurements at Site 301

Sample (Interval in cm)	Hole Depth (m)	Thermal Conductivity (10^{-3} cal/cm sec °C) Needle Probe	Average	From Water Content
2-2, 34	119	1.71		
2-2, 78	119	1.65	1.68	
2-3, 144/150	121			1.95 ±0.11
2-4, 115	122	1.81	1.68	
2-4, 66	122	1.55		
3-2, 10	157	1.61	1.56	
3-2, 141	157	1.51		
4-3, 144/150	159			3.21 ±0.22
5-6, 45	183	2.04	1.91	
5-6, 112	183	1.78		

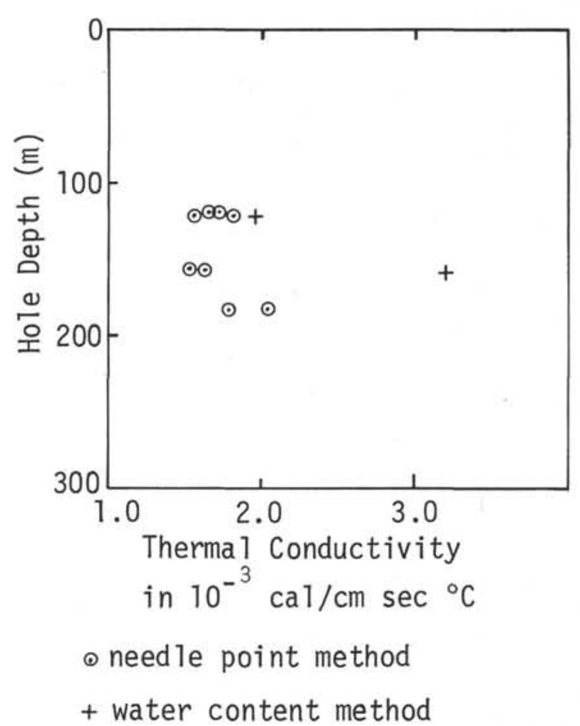


Figure 7. *Thermal conductivity ($\times 10^{-3}$ cal/cm sec °C) versus depth for Site 301.*

gradient. The thermal conductivity was measured from the cores by the needle-probe method and from the geothermal gradient. The geothermal gradient is derived from subbottom temperature measurements using the DHI temperature probe. Three lowerings of the DHI probe were made at subbottom depths of 126.5, 184.5, and 224.5 meters; however, measurements were obtained only at the first two subbottom depths.

126.5 Meters

A good quality of data was attained (Figure 8). The temperature value is 15.5°C, when considering the effect of the initial temperature disturbances due to probe penetration.

184.5 Meters

During this measurement, seawater leaked into the thermistor probe. The record obtained indicates a very high frequency and a low load resistance. The frequency data are shown in Figure 8. Although it may seem erroneous, a test was made to reduce the true temperature value from the record that was apparently affected by seawater. The following four assumptions are made for the data reduction: (1) the frequency of the DHI oscillator is proportional to the square root of the load resistance (R); (2) the effect of the water that leaked in can be replaced by a resistance (Re) parallel to the probe thermistor (R_T); (3) at 126.5 meters, the record shows a remarkable stable temperature until 6 min before the probe did hit bottom (this temperature condition is also applicable to this lowering at 184.5 m); and (4) the record of the above-mentioned stable temperature can be represented by the solid line as shown in Figure 8. However, if this temperature did last throughout the operation, the expected frequency record should be represented as the broken line shown in Figure 8.

Using the assumptions cited, values for R, Re, R_T, and the temperature are 0.874 kohms, 1.069 kohms, 4.787 kohms, and 22.4°C, respectively. The possible error on the temperature should be within 3°C.

Summary

In addition to the above temperature records obtained, it is known that the bottom-water temperature in the Japan Sea is very stable, both periodically and regionally, with a value around 0.3 ±0.1°C. From the temperature values obtained, the subbottom temperature distribution is shown in Figure 9. The preliminary geothermal gradient is 1.20 ±0.10 × 10^{-3}°C/cm. The thermal conductivity obtained by averaging all the measured values, resulted in a value of 1.68 × 10^{-3} cal/cm sec°C. The heat-flow value is 2.0 ±0.3 HFU.

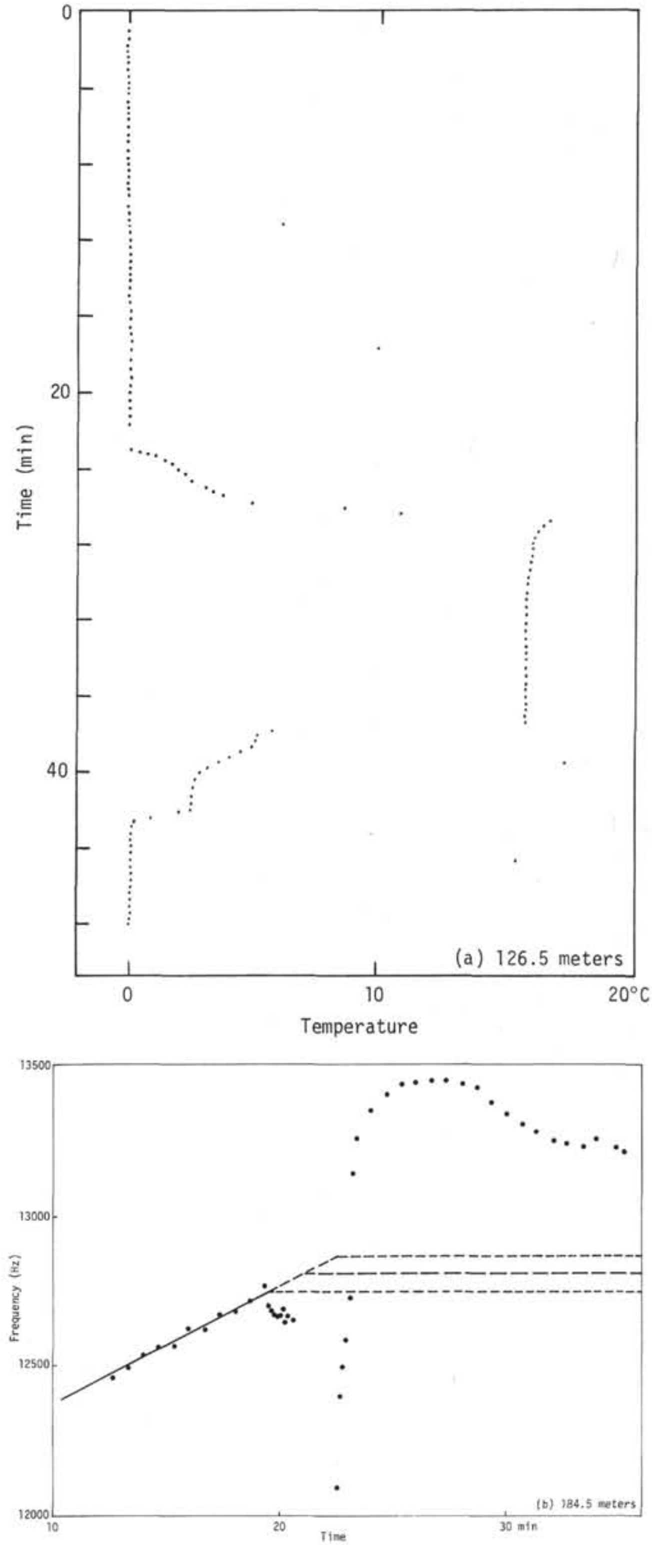


Figure 8. *Heat-flow measurements at Site 301:* (a) *126.5 meters;* (b) *184.5 meters.*

GEOCHEMICAL MEASUREMENTS

Alkalinity

The average alkalinity of the seven samples is 2.28 meq/kg. All values are higher than the surface seawater reference value of 2.28 meq/kg. Very high values occur in Core 2, Section 3 and Core 4, Section 3. Two cores (Core 18, Section 3, Core 20, Section 4) show significant low values of 7.23 and 6.84, respectively (Table 4).

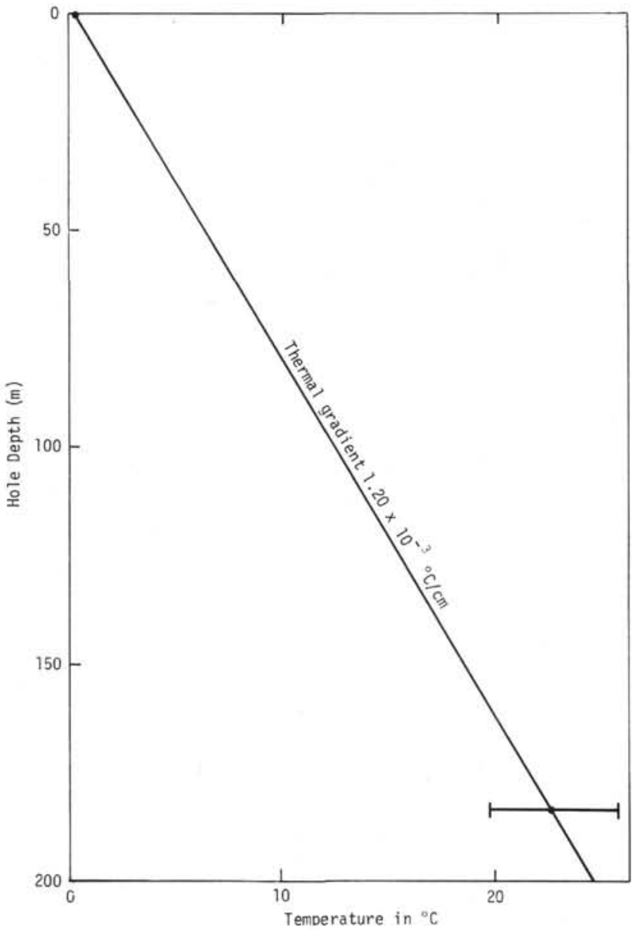


Figure 9. *Heat-flow profile for Site 301.*

pH

The average *p*H values in the cores obtained by punch-in and flow-through methods were all below that of the seawater reference at the site (8.06 and 8.07). The four punch-in *p*H values averaged 7.52, while the seven flow-through values averaged 7.79 (Table 4).

Salinity

Seven salinity measurements averaged 31.6°/oo. A decrease in salinity with depth is present, except for variability in Cores 11, 15, and 18. All seven values and the average were below the overlying seawater reference value of 34.1°/oo (Table 4).

PALEONTOLOGIC SUMMARY

Introduction

Increasing presence of ethane gas ultimately forced abandonment of Site 301 after penetrating 497 meters of Pleistocene through early Pliocene sediments. Cores 1, 2, 4, and 6 contain both calcareous and siliceous microfossils, but sediments below Core 6 (202.5-497 m), contain only siliceous microfossils, with diatoms being the chief component.

The late Pleistocene/early Pleistocene boundary is placed between Cores 2 and 3 (126.5-136 m) based on diatom and silicoflagellate zonations. Calcareous nannofossils belonging to the late Pleistocene *Emiliania huxleyi* and *Gephyrocapsa oceanica* Zones occur within Core 2 (124 m), and an assemblage belonging to the Pleistocene *G. caribbeanica* Subzone occurs in Core 4 (164.5 m).

The Pliocene/Pleistocene boundary cannot be determined precisely due to sparse diatom floras within the critical interval. Nevertheless, this boundary is thought to occur somewhere within the interval represented from the base of Core 5 through Core 7 (183.5-221.5 m). Interestingly, a lithologic change from a silty clay and clay turbidite unit, to an underlying diatomaceous clay with turbidites occurs close to the Plio-Pleistocene boundary between Cores 7 and 8 (221.5-240.5 m).

Cores 8 through 12 (133.0-218.5 m) are late Pliocene in age according to diatom zonation, with Cores 13 through 15 (228-275.5 m) being placed in the early Pliocene. Sediments in Cores 16 through 20 (351.5-497.0 m) would normally be placed within the late Miocene following the traditional view of Japanese biostratigraphers and based on study of Neogene marine sediments exposed in central and northern Honshu. However, if recent reevaluations of North Pacific Neogene diatom biostratigraphy by Burckle

TABLE 4
Summary of Shipboard Geochemical Data, Site 301

Sample (Interval in cm)	Depth Below Sea Floor (m)	*p*H Punch-in	*p*H Flow-through	Alkalinity (meq/kg)	Salinity (°/oo)	Lithologic Units
Surface seawater reference		8.06	8.07	2.28	34.1	
2-3, 144-150	121.5	7.44	7.62	43.60	33.0	Unit 1
4-3, 144-150	178.0	7.64	7.90	47.80	33.3	
8-2, 147-150	243.5	7.71	7.89	21.11	29.7	Unit 2
11-1, 144-150	318.0	–	7.92	18.96	31.9	
15-3, 144-150	396.5	7.29	7.57	17.79	31.1	
18-3, 144-150	473.0	–	7.68	7.23	30.8	
20-4, 144-150	493.5	–	7.84	6.84	31.1	
Average		7.52	7.79	2.28	31.6	

(1971) and Schrader (1973) are followed, then this same interval should be assigned to the early Pliocene. This latter view is arbitrarily followed in this report.

Calcareous Nannofossils

Cold-water conditions are reflected in the sparse nannofossil recovery, which is similar to the other sites in the Sea of Japan. However, an assemblage containing the Holocene-late Pleistocene species *Emiliania huxleyi* was recovered from Core 2, Section 5, and an assemblage referable to the late Pleistocene *Gephyrocapsa oceanica* Zone was recovered from Sample 2, CC. Core 4 contains nannofossils, which place the sample in the early Pleistocene *Gephyrocapsa caribbeanica* Subzone. A nannofossil assemblage, containing *Reticulofenestra pseudoumbilica*, which can probably be best correlated with the late early Pliocene *R. pseudoumbilica* Zone, was recovered from Core 6.

Foraminifera

Foraminifera are rare with the only common and well-preserved specimens found in Core 2. These assemblages are dominated by sinistral coiling populations of "*Globigerina*" *pachyderma* and constitute a subarctic biofacies of probable late Pleistocene age. Rare specimens of poorly preserved benthonic and planktonic species occur in Cores 4, 7, 9, and 13. Framboidal pyrite is present in most samples and is again interpreted as evidence of anaerobic bottom conditions.

Radiolarians and Silicoflagellates

Moderately well-preserved, but generally rare to few, radiolarians were found in samples at Site 301. Initial appearance of *Stylochlamydium venustum* was observed within Core 2. Core 2 through Core 11 presumably encompasses early Pleistocene to late Pliocene ages, and only long-ranging species were recognized. The latest occurrence of *Thecosphaera japonica* was found in the core-catcher sediments of Core 11, and the upper limit ranges from middle Miocene to early Pliocene in age, with their most frequent occurrences within the mid and late Miocene.

Core 2 contains the silicoflagellate *Dictyocha subarctios*, which suggests that the enclosing sediments are slightly older than the Bruhnes-Matuyama paleomagnetic boundary. This species occurs continuously from Core 2 through Sample 4, CC, and this entire interval is placed within the *Dictyocha subarctios* Zone. The youngest occurrence of *Ammodochium rectangulare* is within Core 8. Therefore, the Pliocene-Pleistocene boundary probably falls within the Core 5 through 7 interval. The latest occurrence of *Ebriopsis antiqua* is in Core 10 and is likely marking the top of the *E. antiqua* Zone. However, the occurrence of *Cannopilus hemisphaericus* is too sparse to establish the lower boundary of this zone.

Diatoms

A good subarctic late Pleistocene through late Miocene (?) diatom biostratigraphic section was observed. Pleistocene species which are accompanied by many sublittoral and fresh-water species occur throughout Cores 2 through 5. The boundary between the early and late Pleistocene is placed between Cores 2 and 3 by the upward extinction of *Actinocyclus oculatus* at this level.

Samples 5, CC through 6, CC contain very rare, poorly preserved specimens, and samples from Core 7 are barren. The Plio-Pleistocene boundary is placed in this interval because the occurrences of *Coscinodiscus pustulatus*, *Stephanophyxis innermis*, and *Thalassiosira antiqua* in Samples 5, CC and 6, CC are regarded as reworked specimens of these species. This is based on the presence of many other reworked and living species in these samples, as well as because of the final occurrence of these index species in Core 8.

Since *Denticula seminae* var. *fossilis* and *D. kamtschatica* occur together in Cores 13 through 16, sediments of this interval are considered as early Pliocene age. Cores 17 through 20 are characterized by assemblages composed dominantly of *Denticula kamtschatica*, *Coscinodiscus marginatus*, *Thalassiosira antiqua*, and *T. nidulus*, and the age interpretation of this interval is the same as in the case of Core 35 at Site 299.

SUMMARY AND INTERPRETATIONS

Summary

Site 301 was located in the east central area of the Japan Abyssal Plain (Japan Basin) in hopes of completing the objectives originally sought at Site 300. Drilling at this site penetrated 497 meters into the estimated 1400 meters of sediment blanketing the floor of the abyssal plain. Unfortunately, increasing amounts of ethane gas occurred between 155 meters and 497 meters at this site, ultimately forcing abandonment of the hole prior to penetrating the entire sedimentary column and without reaching acoustic basement. The highest concentrations of ethane occurred at about the same stratigraphic horizon as that at which gas was found at Site 299, specifically, the transition between the seismically reflective unit representing terrigenous clastics and the underlying pelagic blanket as delimited on reflection profiles at both sites.

A major lithologic change was encountered in Core 7 (240.5 m) allowing the sedimentary column to be divided into two discrete units. Unit 1 is 240.5 meters thick, and is composed predominantly of terrigenous clay and silty clay with some sandy interbeds and volcanic ash. These deposits are likely the product of nepheloid layer transport from the adjacent Asian continental mass along with occasional deposition of coarser debris in the form of turbidites. Common diatoms within these sediments indicate Unit 1 ranges in age from late Pliocene through Pleistocene/Holocene.

Unit 2 is composed of 256 meters of earliest Pliocene through late Pliocene clayey diatomite and diatomaceous claystone. Bioturbation is moderate to intense, with pyritic nodules common in some horizons. Graded sand-silt-clay and silty sand beds containing well-rounded claystone clasts and occasional quartzite pebbles occur interbedded with claystones in Cores 17 through 20 (450-497 m) at the base of the hole. The diatomaceous sediments of Unit 2 reflect the extremely high rates of primary productivity in the Sea of Japan, and a relative lack of diluting terrigenous debris in this more isolated portion of the abyssal plain during the interval represented. Volcanic ash forms a minor constituent throughout Unit 2, whereas sands occurring in the early Pliocene portion of the unit apparently mark an earlier pulse of turbidite-contourite deposition.

Only late Pleistocene sediments at this site contain both calcareous and siliceous microfossils, with diatoms providing the principal biostratigraphic control throughout the hole.

Interpretation

The premature abandonment of Site 301 prior to penetrating the full stratigraphic column unfortunately precludes definitive statements regarding the earliest phases in the evolution of this portion of the Japan Sea. However, the two-phase sedimentary sequence sampled provides a detailed view of more recent events in the filling of the Japan Abyssal Plain area, as well as, providing an excellent record of early Pliocene through Pleistocene diatom floras in this part of the sea.

The earliest Pliocene sediments encountered include coarse terrigenous clastics of turbidite origin which likely represent an expression of lowered sea level and consequent increased rate of sediment transport from the shelf margins during the waning stages of a widely recognized late Miocene interval of polar refrigeration (Ingle, 1967; Bandy, 1968; Kennett, 1968). In fact, evidence of subarctic surface temperatures in the Sea of Japan during the latest Miocene-earliest Pliocene interval was previously reported by Asano et al. (1969).

Relatively undiluted diatomaceous sediments continued to accumulate in this area at a rate of about 100 m/m.y. (Figure 10) until the latest Pliocene, when a thin prograding wedge of terrigenous sediments began to cover the underlying biogenous material and dilute the coincident rain of diatom frustules. The rate of sedimentation is somewhat less (85 m/m.y.) during preglacial conditions of higher sea level in the early Pleistocene, but increasing amounts of terrigenous material seriously diluted diatom frustules. A major increase in rate of sedimentation to 140 m/m.y. occurs at the beginning of the late Pleistocene period of sustained glacial climatic conditions about 0.7 to 0.9 m.y.B.P. (Figure 10) in concert with a similar increase noted in the Toyama Trough-Yamato Basin area (Site 299). Again, one can appeal to the initiation of severe climatic effects in terms of lowered sea level, baring of insular and mainland shelves, along with vigorous erosion to explain the relative increase in rates of transport and deposition in the abyssal plain area during this time.

The consistent lack of calcareous microfossils in most pre-late Pleistocene sediments at Site 301 offers supporting evidence of dissolution below an apparently shallow carbonate compensation depth (CCD) within the Sea of Japan as proposed by Ujiié and Ichikura (1973). Depth of deposition at this site has remained at or below 3520 meters for the interval represented, and these latter workers have presented evidence that the CCD is currently at a depth of 2100 meters. Thus, the few calcareous fossils present in the late Pleistocene

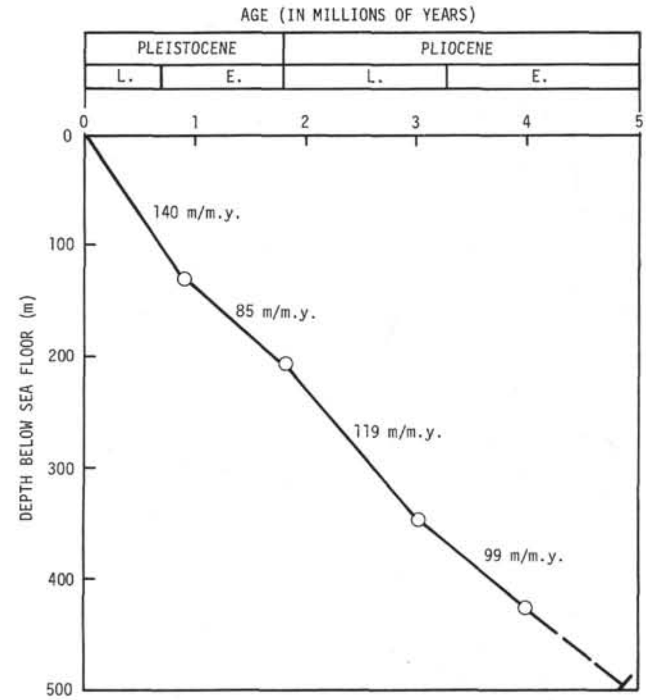


Figure 10. *Estimated rate of sedimentation at Site 301 based upon correlation of diatom zonation with the radiometric and paleomagnetic time scales (Koizumi, this volume). Note that maximum rate of deposition is coincident with the 0.9 m.y.B.P. late Pleistocene period of severe sustained refrigeration.*

deposits at Site 301 most likely owe their existence to rapid deposition of masking terrigenous debris and resultant protection from aggressive bottom water.

Arctic and subarctic diatom floras characterize the early Pliocene through Pleistocene sequence penetrated, attesting to the continual presence of a cool temperate to cold water mass on the western side of the Japan Sea during this period. Scanty late Pleistocene planktonic foraminiferal faunas substantiate the arctic character of surface waters, and point to mean surface temperatures significantly lower than present. In this regard, it is important to note that sea ice currently forms in the marginal northern portion of the Japan Sea in the winter season. Thus, fully glacial conditions can be expected to have created a truly arctic setting in this marginal sea during the late Pleistocene and possibly earlier during the late Miocene.

REFERENCES

Asano, K., Ingle, J.C., Jr., and Takayanagi, Y., 1969. Neogene planktonic foraminiferal sequence in northeastern Japan: Internatl. Conf. Plankt. Microfossils Proc. 1st, v. 1, p. 14-25.

Bandy, O.L., 1968. Cycles in Neogene paleooceanography, and eustatic changes: Paleogeogr., Paleoclimatol., and Paleoecol., v. 5, p. 63-75.

Burckle, L.H., 1971. Correlation of late Cenozoic marine sections in Japan and the Equatorial Pacific. Paleont. Soc. Japan Trans. Proc., v. 82, p. 1-117.

Ingle, J.C., J.r, 1967. Foraminiferal biofacies variations and the Miocene-Pliocene boundary in southern California: Am. Paleontol. Bull., v. 52, p. 217-394.

Kennett, J.P., 1968. Paleooceanographic aspects of foraminiferal zonation in the upper Miocene-lower Pliocene of New Zealand: Comm. Mediterranean Neogene Stratigraphy, Prov. IV Session, Giornale Geol., v. 35, p. 143-156.

Schrader, H. J., 1973. Cenozoic diatoms from the northeast Pacific, Leg 18. *In* Kulm, L.D., von Huene, R., et al., Initial Report of Deep Sea Drilling Project, Volume 18: Washington (U.S. Government Printing Office), p. 673-798.

Ujiié, H. and Ichikura, M., 1973. Holocene to uppermost Pleistocene planktonic foraminifers in a piston core from off Sanin district, Sea of Japan: Palaeontol. Soc. Japan Trans. Proc., N.S., no. 91, p. 137-150.

APPENDIX A
Summary of X-Ray, Grain Size, and Carbon-Carbonate Results, Site 301

Section	Sample Depth Below Sea Floor (m)	Lithology	Age	Bulk Sample Major Constituent 1	2	3	2-20μm Fraction Major Constituent 1	2	3	<2μm Fraction Major Constituent 1	2	3	Grain Size Sand (%)	Silt (%)	Clay (%)	Classification	Carbon Carbonate Total (%)	Organic (%)	$CaCO_3$ (%)	Comments
301-2-3	120.2-120.8	Unit 1 Silty clays and clays with silt sand, silty sand and ash	Late Pleistocene to Holocene	Quar.	Mica	Plag.	Quar.	Plag.	Mica	Mica	Quar.	Mont.	85.5	0.0	15.0	Sand	1.8	1.2	4	Pyri. in bulk, 2-20μm, <2μm (5.9, 4.6, 6.1)
301-2-5	124.0																3.4	1.7	14	
301-3-1	136.9												2.9	75.8	21.3	Silt				
301-4-2	157.3			Quar.	Mica	Plag.	Quar.	Plag.	Mica	Mont.	Quar.	Mica								Pyri. in bulk, 2-20μm (1.5, 2.0%) Kaol in bulk (1.1%)
301-4-2	157.7			Quar.	Mica	Plag.	Quar.	Plag.	Mica	Mont.	Mica	Quar.								Pyri, in bulk, 2-20μm, <2μm (2.4, 4.2, 1.4); Kaol in bulk (3.1%)
301-4-3	158.5												2.6	91.7	5.8	Silt				
301-4-3	158.6												64.6	30.6	4.8	Silty sand				
301-5-3	177.5												0.2	91.9	7.9	Silt				
301-5-3	177.9												1.1	82.6	16.3	Silt				
301-8-4	246.0	Unit 2 Clayey diatomite and diatomaceous claystone with sand-silt clay and silty sand beds	Late Miocene to late Pliocene	Quar.	Mica	Plag.	Quar.	Mica	Plag.	Mica	Quar.	Mont.	0.1	37.6	62.4	Silty clay				Pyri. in bulk, 2-20μm, <2μm (2.7, 4.6, 1.4) Kaol. in bulk (1.0%).
301-9-1	270.3												0.0	31.9	68.1	Silty clay				
301-11-1	317.7												42.5	35.9	21.6	Sand-silt-clay				
301-13-1	355.8-356.0			Quar.	Mica	Plag.	Quar.	Plag.	Mica	Quar.	Mica	Mont.	32.8	45.8	21.4	Sand-silt-clay	1.2	1.1	1	Pyri. in bulk, 2-20μm, <2μm (3.1, 4.2, 3.4)
301-15-2	395.4			Quar.	Plag.	K-Fe.	Quar.	Plag.	Mica	Mica	Mont.	Quar.								Dolo. in bulk (1.7%), Pyri, in bulk, 2-20μm, <2μm (1.8, 3.7, 3.8); Amph. in bulk (1.8), 2-20μm (2.8%).
301-17-1	450.1												21.0	36.7	42.3	Sand-silt-clay				
301-17-1	450.2												13.6	34.1	52.2	Silty clay				
301-17-1	450.2												51.9	29.4	18.7	Silty sand				
301-17-1	450.3			Quar.	Plag.	K-Fe.	Quar.	Plag.	Mica	Mont.	Mica	Quar.	51.7	29.8	18.5	Silty sand				Pyri. in bulk, 2-20μm, <2μm (1.0, 5.5, 1.2)
301-18-3	471.6												45.2	30.9	23.9	Sand-silt-clay				
301-18-3	472.2												45.0	30.7	24.3	Sand-silt-clay				
301-18-4	474.2			Quar.	Mica	Plag.	Quar.	Plag.	Mica	Mont.	Mica	Quar.					0.5	0.5	0	Pyri. in bulk, 2-20μm, <2μm (1.7, 2.6, 1.1).
301-18-4	474.4			Quar.	Plag.	Mica	Quar.	Plag.	Mica	Mont.	Quar.	Mica	0.2	34.1	65.7	Silty clay	1.2	1.1	1	Pyri. in bulk, 2-20μm, <2μm (3.6, 3.6, 1.8%).
301-20-4	492.7												41.0	31.2	27.9	Sand-silt-clay	0.6	0.6	0	
301-20-4	433.4																			

Note: Complete results X-ray, Site 301, will be found in Part V, Appendix I. X-ray mineralogical legend in Appendix A, Chapter 2.

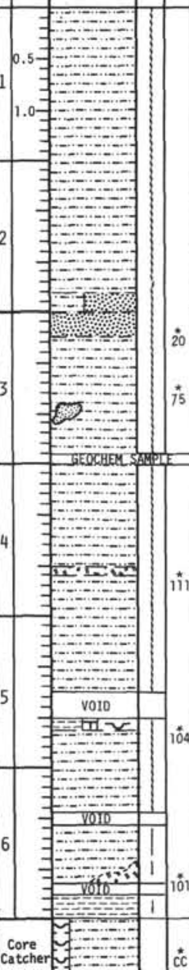
Site 301 Hole Core 1 Cored Interval: 0.0-3.0 m

AGE	ZONE	FORAMS	NANNOS	RADS	SILICO-DIATOMS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
						Core Catcher					Punch core - no recovery; very strong H_2S odor in barrel.

Explanatory notes in chapter 1

Site 301 Hole Core 2 Cored Interval: 117.0-126.5 m

AGE	ZONE	FORAMS	NANNOS	RADS	SILICO-DIATOMS	SECTION
LATE PLEISTOCENE	Distephanus octangulatus (S); Gephyrocapsa oceanica; Dictyocha subarctios (S); Rhizosolenia curvirostris (D)		B	Rm	Fm Fm	1
						2
			Rp	Fm	Fm Fm	3
						4
			Am		Rm Ag	5
			B			6
		Cg	Fm		Rm Ag	Core Catcher



Litho. samples: *20, *75, *111, *104, *101, *CC

5Y 3/2 — Unit 1. Colors: dominant olive gray (5Y 3/2), dark greenish gray (5GY 4/1), olive black (5Y 2/1), grayish olive green (5GY 3/2) and medium olive brown (5Y 4/4); bedding, irregular thicknesses; intense-moderate deformation; soupy, soft to firm; strong H_2S odor.

5GY 4/1

5GY 4/1

SILTY CLAY
Smear: 3-75,CC

Texture	Composition
67% Clay	60% Clay minerals
30% Silt	10% Feldspar
3% Sand	10% Diatoms
	7% Micronodules
	6% Quartz
	4% Micarb
	3% Heavy minerals
	2% Mica
	2% Volcanic glass
	1% Sponge spicules
	Tr% Radiolarians
	Tr% Glauconite

5Y 2/1

5GY 3/2

SAND
Smear: 3-20

Texture	Composition
85% Sand	30% Feldspar
15% Clay	20% Quartz
	10% Clay minerals
	5% Heavy minerals
	5% Micronodules
	5% Micarb
	5% Diatoms
	3% Volcanic glass
	2% Mica
	1% Sponge spicules
	1% Radiolarians
	1% Foraminifera
	1% Glauconite

5Y 4/4

5Y 2/1

Volcanic Ash (Minor Lith)
Smear: 4-111, 6-101
Clay and Foram-Rich Diatom Ooze (Minor Lith)
Smear: 5-104

Grain Size 3-19
85.0, 0.0, 15.0

Carbon Carbonate 3-76
1.8, 1.2, 4

Carbon Carbonate 5-103
3.4, 1.7, 14

X-ray 3-74 (Bulk)
36.0% Quar
24.8% Mica
19.7% Plag
6.0% K-Fe
5.9% Pyri
3.9% Chlo
2.0% Calc
1.9% Mont

5Y 4/4
5Y 3/2

5Y 3/2

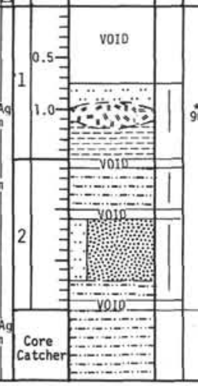
5G 4/1 with 5Y 3/2

5Y 3/2

Explanatory notes in chapter 1

Site 301 Hole Core 3 Cored Interval: 136.0-145.5 m

AGE	ZONE	FORAMS	NANNOS	RADS	SILICO-DIATOMS	SECTION
EARLY PLEISTOCENE	Dictyocha subarctios (S); Actinocyclus oculatus			B	Aq Cm	1
			B	B	Fm	2
		B		Cm	Ag Cm	Core Catcher



Litho. sample: *90

Colors: olive gray (5Y 3/2), olive black (5Y 2/1), light gray (N7), dark greenish gray (5G 4/1); moderate drilling deformation;firm.

5Y 3/2 and 5Y 2/1

SILT
Smear: 1-90

Texture	Composition
76% Silt	58% Quartz
21% Clay	20% Feldspar
3% Sand	7% Heavy minerals
	5% Mica
	5% Opaques
	3% Micarb
	3% Diatoms
	1% Volcanic glass
	1% Radiolarians
	Tr% Foraminifera

5GY 3/2

5Y 3/2

5G 4/1 - 5Y 3/2 — SILTY CLAY

VOLCANIC ASH (Minor Lith)

5Y 3/2

Grain Size 1-90
2.9, 75.8, 21.3

Explanatory notes in chapter 1

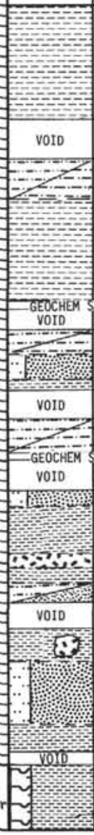
Site 301 Hole Core 4 Cored Interval: 155.0-164.5 m

AGE: EARLY PLEISTOCENE

ZONE: Gephyrocapsa caribbeanica Subzone; Actinocyclus oculatus; Dictyocha subarctios (S)

FOSSIL CHARACTER (FORAMS, NANNOS, RADS, SILICO. DIATOMS): Section 1: B, Cm; Section 2: B, Rm, Rm; Section 4: B, B, Rm, Cg; Core Catcher: Rm-, Cg-, Rm, Cm, Cm-

SECTION / METERS: 1 (0.5, 1.0), 2, 3, 4, 5, Core Catcher



LITHO. SAMPLE: * 80, * 120, * 65, * CC

5G 4/1 with 5Y 3/2 10YR 2/2

5Y 3/2 and 5G 4/1

5G 4/1

5Y 3/2

5GY 4/1

5Y 3/2

10Y 4/2

5Y 3/2

N3

N2 - 5G 3/2

N3

5Y 3/2

5Y 2/1

5Y 3/2

5GY 3/2
5G 4/1

LITHOLOGIC DESCRIPTION

Moderate to intense deformation - stiff; colors: olive gray (5Y 3/2), dark green gray (5G 4/1), dusky yellow brown (10YR 2/2), grayish olive (10Y 4/2); interbedding with varying thicknesses.

CLAY
Smears: 2-120, CC

Texture	Composition
97% Clay	67% Clay minerals
3% Silt	6% Quartz
	5% Feldspar
	5% Zeolite
	5% Diatoms
	4% Sponge spicules
	3% Micronodules
	2% Pyrite
	2% Micarb
	2% Heavy minerals
	Tr- 5% Nannofossils

SILT-RICH SAND
Smear: 3-65

Texture	Composition
92% Silt	40% Quartz
5% Clay	38% Feldspar
3% Sand	8% Heavy minerals
	6% Micronodules
	4% Opaques
	2% Volcanic glass
	2% Micarb

Heavy minerals include brown-green hornblende, zircon, hypersthene.

Grain Size 3-49	Grain Size 3-64
2.6, 91.7, 5.8	64.6, 30.6, 4.8

X-ray 2-80 (Bulk)	X-ray 2-120 (Bulk)
33.7% Quar	30.5% Quar
27.3% Mica	24.7% Mica
21.8% Plag	19.5% Plag
6.6% Mont	10.7% Mont
4.1% Chlo	5.9% K-Fe
4.0% K-Fe	3.1% Kaol
1.5% Pyri	3.1% Chlo
1.1% Kaol	2.4% Pyri

Explanatory notes in chapter 1

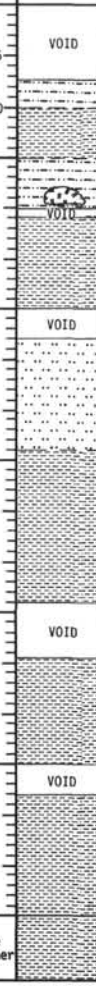
Site 301 Hole Core 5 Cored Interval: 174.0-183.5 m

AGE: EARLY PLEISTOCENE; LATE PLIOCENE

ZONE: Actinocyclus oculatus (D); Thalassiosira zabelinae (D)

FOSSIL CHARACTER (FORAMS, NANNOS, RADS, SILICO. DIATOMS): Section 1: B; Section 2: B, B, Rm; Section 4: B, B, B, B; Core Catcher: B-, Rm, Rm, Rp

SECTION / METERS: 1 (0.5, 1.0), 2, 3, 4, 5, 6, Core Catcher



LITHO. SAMPLE: * 55, * 90

5GY 2/1

5GY 2/1
5Y 3/2
5G 4/1

5G 4/1

5Y 3/2

5G 4/1

5G 4/1
5GY 4/1
5Y 3/2

5GY 2/1
5Y 3/2
5G 4/1

5GY 2/1
5Y 3/2
5G 4/1

5GY 3/2
5G 4/1

LITHOLOGIC DESCRIPTION

Colors: greenish black (5GY 2/1), olive gray (5Y 3/2), dark greenish gray (5G 4/1); moderate-intense drilling deformation, firm; interbedding noted.

CLAY (Dom. Lith)

SILT (Minor Lith)
Smear: 3-55

Texture	Composition
92% Silt	45% Clay minerals
8% Clay	25% Feldspar
	15% Heavy minerals
	5% Opaques
	3% Diatoms
	2% Zeolite
	2% Volcanic glass
	1% Sponge spicules
	1% Mica
	1% Micronodules
	Tr% Silicoflagellates

SILT (Minor Lith)
Smear: 3-90

Texture	Composition
83% Silt	35% Feldspar
16% Clay	30% Quartz
1% Sand	10% Clay minerals
	5% Mica
	5% Opaques
	3% Heavy minerals
	2% Sponge spicules
	Tr% Volcanic glass
	Tr% Diatoms

Grain Size 3-54	Grain Size 3-89
0.2, 91.9, 7.9	1.1, 82.6, 16.3

Explanatory notes in chapter 1

Site 301 Hole Core 6 Cored Interval: 193.0-202.5 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	SILICO. DIATOMS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	*Thalassiosira zabelinae* (D)		Fm	Rm Rm	Rp Rm Rm	Core Catcher				* CC	5Y 3/2

Trace amount recovered in core catcher.

CLAY-RICH SANDY SILT
Smear: CC

Texture	Composition
60% Silt	45% Feldspar
25% Sand	20% Quartz
15% Clay	15% Clay minerals
	10% Pyrite
	3% Micarb
	2% Fe-oxides
	2% Heavy minerals
	1% Glauconite
	1% Diatoms
	1% Radiolarians
	Tr% Sponge spicules
	Tr% Foraminifera

Explanatory notes in chapter 1

Site 301 Hole Core 7 Cored Interval: 212.0-221.5 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	SILICO. DIATOMS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
				B	B B	1	0.5, 1.0	VOID		* 135	
		B	B	B	B B	Core Catcher					5G 4/1

Color dark greenish gray (5G 4/1); intense deformation.

SILT-RICH CLAY
Smear: CC

Texture	Composition
80% Clay	68% Clay minerals
20% Silt	20% Feldspar
	5% Pyrite
	5% Heavy minerals
	2% Mica

CLAYEY SILT
Smear: 1-135

Texture	Composition
55% Silt	45% Clay minerals
40% Clay	25% Feldspar
5% Sand	15% Heavy minerals
	5% Quartz
	5% Volcanic glass
	5% Pyrite

Explanatory notes in chapter 1

Site 301 Hole Core 8 Cored Interval: 240.5-250.0 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	SILICO. DIATOMS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	*Ammodochium rectangulare* (S); *Thalassiosira zakelinde* (D)		B, B, B	Rm	Ag, Rm, Ag	1	0.5, 1.0	VOID			5GY 4/1, 5G 4/1
						2		VOID; GEOCHEM SAMPLE			
						3		VOID; VOID			5GY 4/1 with 5B 5/1
						4		VOID		* 100, * 135	5G 4/1; 5G 4/1 with 5GY 4/1
		B	B	Rm	Rm	Core Catcher					5G 4/1

Unit 2. Dominant color dark greenish gray (5GY 4/1), grayish olive (10Y 4/2), dark greenish gray (5G 4/1); interbedded 1-20 cm intervals; moderate to intense drilling deformation

CLAYEY DIATOM OOZE
Smear: 4-100

Texture	Composition
75% Clay	38% Diatoms
25% Silt	25% Clay minerals
	10% Radiolarians
	8% Quartz
	7% Micarb
	5% Pyrite
	5% Feldspar
	2% Heavy minerals

ZEOLITE CLAY
Smear: 4-135

Texture	Composition
80% Clay	40% Clay minerals
20% Silt	32% Zeolite
	15% Diatoms
	5% Pyrite
	4% Feldspar
	2% Heavy minerals
	2% Radiolarians

Grain Size 4-100 (Silt probably diatoms)
0.1, 37.6, 62.4

X-ray 4-100 (Bulk)
37.3% Quar
28.0% Mica
15.0% Plag
8.1% K-Fe
4.1% Mont
3.9% Chlo
2.7% Pyri
1.0% Kaol

Explanatory notes in chapter 1

Site 301 Hole Core 9 Cored Interval: 269.0-278.5 m

AGE	ZONE	FORAMS	NANNOS	RADS	SILICO. DIATOMS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	Ammodochium rectangulare (S); Thalassiosira zabelinae (D)	BF Rm-	B B-	Rm Rm-	Ag Cm Rm- Cm Fm-	1; Core Catcher	0.5, 1.0	VOID		* 130; * CC	5GY 4/1 (130); 5GY 4/1 and 10Y 4/2 (CC)

Color dark greenish gray (5GY 4/1), moderate burrow mottling; slight deformation; some grayish olive (10Y 4/2) colors noted.

DIATOM SILTY CLAY
Smear: 1-130

Texture	Composition
75% Clay	40% Clay minerals
25% Silt	25% Diatoms
	20% Feldspar
	10% Quartz
	5% Sponge spicules
	Tr% Silicoflagellates

ZEOLITE CLAY
Smear: CC

Texture	Composition
95% Clay	30% Zeolite
5% Silt	27% Clay minerals
	15% Micarb
	15% Diatoms
	5% Pyrite
	5% Quartz
	2% Sponge spicules
	1% Heavy minerals

Grain Size 1-130
0.0, 31.9, 68.1

Explanatory notes in chapter 1

Site 301 Hole Core 10 Cored Interval: 297.5-307.0 m

AGE	ZONE	FORAMS	NANNOS	RADS	SILICO. DIATOMS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	Ammodochium rectangulare (S); Thalassiosira zabelinae		B	B B	Cm Cm; Ag Fm Fm	1; Core Catcher	0.5, 1.0	VOID		* 13; * 18	

Colors: dark greenish gray (5GY 4/1), grayish olive (10Y 4/2); slight drilling deformation.

DIATOM CLAY
Smears: 1-18, 1-13

Texture	Composition
85% Clay	42-45% Clay minerals
15% Silt	35-40% Diatoms
	7-10% Feldspar
	3- 5% Quartz
	3- 5% Pyrite
	2- 3% Sponge spicules

Explanatory notes in chapter 1

Site 301 Hole Core 11 Cored Interval: 316.5-326.0 m

AGE	ZONE	FORAMS	NANNOS	RADS	SILICO. DIATOMS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	Ebriopsis antiqua - cannopilus hemisphaericus (S); Thalassiosira zabelinae (D)	B-	B B-	B Fm-	Cm Cm; Ag Cm	1; 2; Core Catcher	0.5, 1.0	VOID; GEOCHEM SAMPLE; VOID		* 94	5GY 3/2; 5G 4/1 ↕ 5GY 3/2; 5GY 3/2; 5GY 4/1

Colors: grayish olive green (5GY 3/2), dark green gray (5G 4/1); slight deformation; grading in sand zones.

CLAYEY DIATOMITE
Smear: 1-94

Texture	Composition
90% Clay	45% Diatoms
10% Silt	39% Clay minerals
	7% Feldspar
	3% Quartz
	3% Pyrite
	2% Sponge spicules
	1% Micarb
	Tr% Nannofossils
	Tr% Silicoflagellates

Grain Size 1-122
42.5, 35.9, 21.6

Explanatory notes in chapter 1

Site 301 Hole Core 12 Cored Interval: 335.5-345.0 m

AGE	ZONE	FORAMS	NANNOS	RADS	SILICO. DIATOMS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE PLIOCENE	Ebriopsis antiqua - cannopilus hemisphaericus (S); Thalassiosira zabelinae (D)	B-	B-	B	Ag Cm	Core Catcher					5GY 4/1

Core catcher only.

CLAYEY DIATOMITE

Explanatory notes in chapter 1

Site 301 Hole Core 13 Cored Interval: 354.5-364.0 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	SILICO. DIATOMS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
EARLY PLIOCENE	Ebriopsis antiqua - cannopilus hemisphaericus (S); D. seminde-D. kamtschatica (D)		B+	Rm	Ag Cm	1	0.5, 1.0	VOID	o o o o	*132, 143	
		Rm	B+	Rm	Ag Fm	Core Catcher					

Colors: grayish olive (10Y 4/2), dark greenish gray (5GY 4/1); intense-moderate deformation; lower sandy silt bed is graded = turbidite bed.

10Y 4/2 — CLAYEY DIATOMITE
Smear: 1-132

Texture	Composition
96% Clay	50% Diatoms
4% Silt	39% Clay minerals
	5% Pyrite
	3% Feldspar
	1% Quartz
	1% Micarb
	1% Sponge spicules
	Tr% Silicoflagellates

5GY 4/1

SAND-SILT-CLAY (Minor Lith)
Smear: 1-143

Texture	Composition
46% Silt	35% Diatoms
33% Sand	31% Feldspar
21% Clay	20% Quartz
	5% Clay minerals
	3% Pyrite
	2% Radiolarians
	2% Volcanic glass
	1% Sponge spicules
	1% Heavy minerals
	Tr% Glauconite

Grain Size 1-145
32.8, 45.8, 21.4

Carbon Carbonate 1-132
1.2, 1.1, 1

X-ray 1-132 (Bulk)
39.0% Quar
18.9% Mica
18.6% Plag
10.2% Mont
7.5% K-Fe
3.1% Pyri
2.7% Chlo

Explanatory notes in chapter 1

Site 301 Hole Core 14 Cored Interval: 373.5-383.0 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	SILICO. DIATOMS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
	Ebriopsis antiqua - cannopilus hemisphaericus (S); D. seminde-D. kamtschatica (D)		B	Rm	Cm	1	0.5, 1.0	VOID		*82, *140	5G 4/1, 5Y 3/2
		B-	B-	Rm	Ag Fm	Core Catcher				*CC	5GY 4/1

Colors interbedded dark green gray (5G 4/1) and olive gray (5Y 3/2); slight drilling deformation; stiff with fine interbedding.

CLAYEY DIATOMITE OR DIATOM CLAY (Claystone)
Smears: 1-82, 1-140, CC

Texture	Composition
75-93% Clay	30-54% Clay minerals
7-25% Silt	30-50% Diatoms
0- 5% Sand	7-10% Feldspar
	3% Opaques
	2- 5% Quartz
	2- 3% Mica
	1% Heavy minerals
	1% Zeolite
	1% Micarb
	Tr% Radiolarians
	Tr% Sponge spicules
	Tr% Silicoflagellates

Explanatory notes in chapter 1

Site 301 Hole Core 15 Cored Interval: 392.5-402.0 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	SILICO. DIATOMS	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	Ebriopsis antiqua - cannopilus hemisphaericus (S); D. kamtschatica (D)		B	Fm	Fm	1	0.5, 1.0	VOID		*78	5G 4/1
						2		VOID		*100	5Y 4/1
			B	Fm	Fm	3		VOID; GEOCHEM SAMPLE			5G 4/1, 5Y 4/1, 5G 4/1, 5Y 4/1
						4		VOID		*69, *115	N5, 5G 4/1, 5Y 4/1
		B-	B-	Am	Ag Fm	Core Catcher				*CC	5G 4/1

Colors: dark green gray (5G 4/1), olive gray (5Y 4/1); fine laminated - fissile nature; moderate drilling deformation, chunky to soft; bioturbation noted. Some gray (N3-N4 zones); silty zone base Section 4.

CLAYEY DIATOMITE
Smears: 2-100, 1-78, CC

Texture	Composition
70-93% Clay	35-50% Diatoms
7-30% Silt	20-35% Clay minerals
	7-18% Feldspar
	4-10% Silicoflagellates
	1- 5% Micronodules
	1% Opaques
	1- 2% Micarb
	Tr- 2% Sponge spicules
	Tr- 1% Radiolarians
	Tr% Volcanic glass
	Tr- 3% Heavy minerals

SILT-RICH CLAYSTONE (Feldspathic)
Smear: 4-69

Texture	Composition
72% Clay	78% Feldspar
25% Silt	8% Diatoms
3% Sand	4% Clay minerals
	3% Heavy minerals
	3% Silicoflagellates
	2% Micronodules
	1% Opaques
	1% Micarb
	Tr% Sponge spicules

DIATOM SANDY SILTSTONE (Minor Lith)
Smear: 4-115

Texture	Composition
45% Silt	40% Diatoms
30% Sand	25% Feldspar
15% Clay	15% Clay minerals
	10% Quartz
	3% Micronodules
	3% Sponge spicules
	3% Glauconite
	2% Volcanic glass
	1% Mica
	1% Heavy minerals

X-ray 2-142 (Bulk)
37.8% Quar
27.1% Plag
15.7% K-Fe
13.4% Mica
1.8% Pyri
1.8% Amph
1.7% Dolo
0.6% Chlo

Site 301 Hole Core 16 Cored Interval: 421.0-430.5 m

AGE	ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	SILICO. DIATOM	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
LATE MIOCENE	Distephanus quinquangellus (S); D. kamtschatica (D)		B	B	Cm	1	0.5, 1.0	VOID			5Y 4/1, 5G 4/1
		B-	B-	Rm	Ag Fm	Core Catcher					5Y 4/1, 5G 4/1

Colors: olive gray (5Y 4/1) and dark greenish gray (5G 4/1); lithified chunks, slight drilling deformation; bioturbated.

CLAYEY DIATOMITE

Explanatory notes in chapter 1

Site 301 Hole Core 17 Cored Interval: 449.5-459.0 m

AGE: LATE MIOCENE

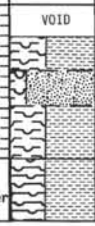
ZONE: Distephanus quinquangellus (S); D. kamtschatica (D)

FOSSIL CHARACTER: FORAMS B–; NANNOS B, B–; RADS Rm, Fm; SILICO. DIATOMS Rm, Ag Fm

SECTION: 1; Core Catcher

METERS: 0.5, 1.0

LITHOLOGY: VOID



LITHO. SAMPLE: *79, *CC

LITHOLOGIC DESCRIPTION

Colors: dark greenish gray (5G 4/1), and olive gray (5Y 4/1); slight drilling deformation, lithified chunks; bioturbation noted.

N3

5Y 4/1

5G 4/1

5Y 4/1

DIATOM-RICH SILTY SAND
Smear: 1-79

Texture	Composition
52% Sand	20% Feldspar
30% Silt	20% Quartz
18% Clay	20% Lithic fragments
	19% Clay minerals
	15% Diatoms
	7% Mica
	2% Sponge spicules
	2% Micronodules
	2% Glauconite
	1% Micarb
	1% Heavy minerals
	1% Pyrite

DIATOMACEOUS CLAYSTONE
Smear: CC

Texture	Composition
80% Clay	53% Clay minerals
20% Silt	30% Diatoms
	10% Zeolite
	2% Sponge spicules
	2% Feldspar
	2% Opaques
	1% Quartz
	Tr% Radiolarians
	Tr% Heavy minerals

Grain Size 1-62
21.0, 36.7, 42.3

Grain Size 1-71
13.6, 34.1, 52.2

Grain Size 1-81
51.7, 29.8, 18.5

Grain Size 1-92
51.9, 29.4, 18.7

X-ray 1-83 (Bulk)
37.0% Quar
27.7% Plag
16.9% K-Fe
11.1% Mica
5.3% Mont
1.0% Chlo
1.0% Pyri

Explanatory notes in chapter 1

Site 301 Hole Core 18 Cored Interval: 468.5-478.0 m

AGE: LATE MIOCENE

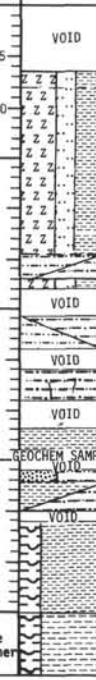
ZONE: Distephanus quinquangellus (S); D. kamtschatica (D)

FOSSIL CHARACTER: FORAMS B–; NANNOS B, B–; RADS Rm, Rm, Rm–; SILICO. DIATOMS Rm, Rm, B Ag

SECTION: 1, 2, 3, 4; Core Catcher

METERS: 0.5, 1.0

LITHOLOGY: VOID; VOID; VOID; VOID; GEOCHEM SAMPLE; VOID; VOID



LITHO. SAMPLE: *78, *128, *124, *73, *118, *138, *CC

LITHOLOGIC DESCRIPTION

Colors: olive gray (5Y 4/1), light green gray (5GY 6/1), dark greenish gray (5GY 4/1); clay clasts and quartzite pebbles noted in silty sand zones; lithified, chunky, bioturbated, and slight drilling deformation.

5GY 6/1

5Y 4/1

5GY 4/1

ZEOLITE SILT-RICH CLAYSTONE
Smears: 1-78, 1-128, 2-124

Texture	Composition
77-85% Clay	34-52% Zeolite
15-20% Silt	40% Carb. unspec.
Tr- 3% Sand	4- 8% Diatoms
	1-14% Feldspar
Zeolites altered	1- 4% Micronodules
to carbonate.	1- 2% Heavy minerals
	1% Volcanic glass
	1% Quartz
	1% Glauconite
	Tr-35% Clay minerals
	Tr% Radiolarians

5Y 4/1

5GY 4/1

5GY-5G 4/1

DIATOMACEOUS CLAYSTONE
Smears: 4-118, 4-138, CC

Texture	Composition
85-88% Clay	35-48% Clay minerals
10-13% Silt	25-35% Diatoms
2% Sand	7-10% Feldspar
	5- 7% Micronodules
	2% Pyrite
	2- 5% Quartz
	1- 5% Radiolarians
	1- 2% Micarb
	1- 2% Sponge spicules
	1% Volcanic glass
	1- 3% Mica

5Y 4/1
+
5G-5GY 4/1

5GY 4/1

SAND-SILT-CLAY
Smear: 3-73

Texture	Composition
45% Sand	25% Quartz
31% Silt	20% Feldspar
24% Clay	11% Clay minerals
	10% Mica
	7% Diatoms
	5% Micronodules
	5% Heavy minerals
	2% Pyrite
	2% Nannofossils
	1% Glauconite
	1% Volcanic glass
	1% Radiolarians

Grain Size 3-70
45.0, 30.7, 24.3

Grain Size 3-11
45.2, 30.9, 23.9

Carbon Carbonate 4-118
0.5, 0.5, 0

Carbon Carbonate 4-137
1.2, 1.1, 1

X-ray 4-117 (Bulk)

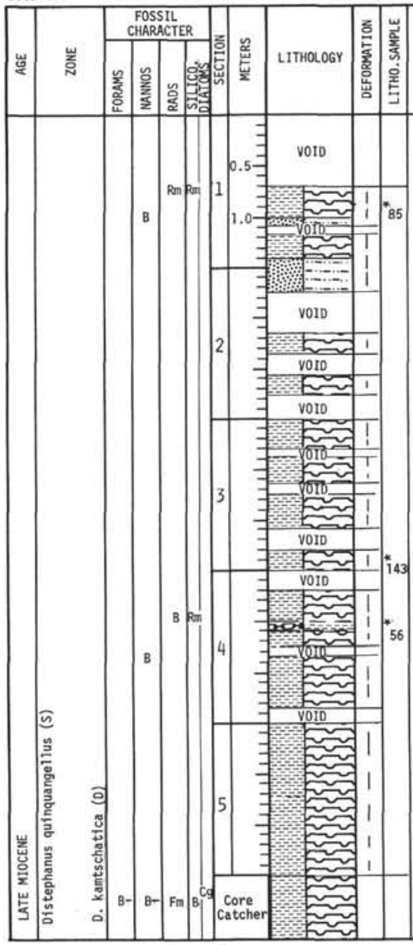
37.5% Quar	5.6% K-Fe
20.8% Mica	2.5% Chlo
18.2% Plag	1.7% Pyri
13.7% Mont	

X-ray 4-136 (Bulk)

29.0% Quar	5.8% K-Fe
20.4% Plag	3.8% Chlo
18.8% Mica	3.6% Pyri
18.5% Mont	

Explanatory notes in chapter 1

Site 301 Hole Core 19 Cored Interval: 478.0-487.5 m



LITHOLOGIC DESCRIPTION

5GY 4/1
5Y 4/1
5GY 4/1
5G 4/1 - 5Y 4/1
5Y 4/1
5GY 4/1
5GY 4/1 - 5Y 4/1
5GY 4/1
5Y 4/1
5Y 6/1
5GY 4/1
5GY 4/1
5G 4/1
5Y 4/1

Colors: dark green gray (5GY 4/1) and olive gray (5Y 4/1). Slight deformation; lithification; bioturbation and interbedded colors.

CLAYEY DIATOMITE
Smears: 1-85, 3-143

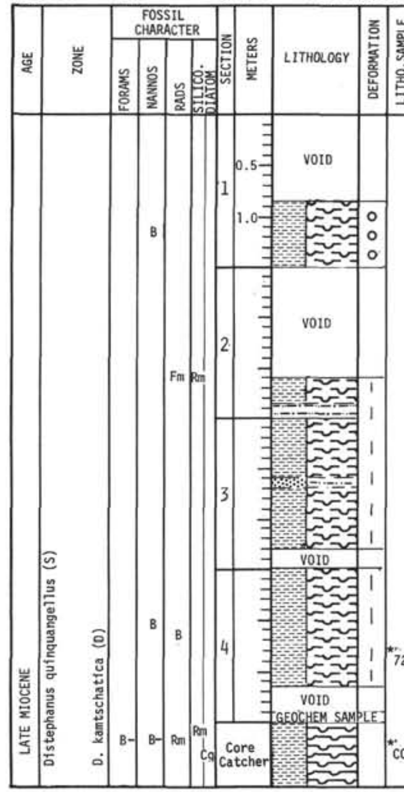
Texture	Composition
90-93% Clay	44% Diatoms
7-10% Silt	35% Clay minerals
	7% Feldspar
	6% Micronodules
	2% Quartz
	2% Radiolarians
	1% Sponge spicules
	1% Micarb
	1% Volcanic glass
	1% Mica
	Tr% Heavy minerals
	Tr% Nannofossils

MICARB CLAYSTONE
Smear: 4-56

Texture	Composition
93% Clay	44% Micarb
7% Silt	40% Clay minerals
	7% Feldspar
	5% Diatoms
	2% Radiolarians
	1% Sponge spicules
	1% Volcanic glass

Explanatory notes in chapter 1

Site 301 Hole Core 20 Cored Interval: 487.5-497.0 m



LITHOLOGIC DESCRIPTION

5GY 4/1
10Y 4/2
5Y 3/2
10Y 4/2
5GY 4/1
5Y 3/2
10Y 4/2
5GY 4/1
5GY 4/1

Colors: dark greenish gray (5GY 4/1), grayish olive (10Y 4/2). Intense-slight deformation: chunky. Bioturbation.

DIATOMACEOUS CLAYSTONE
Smears: 4-72, CC

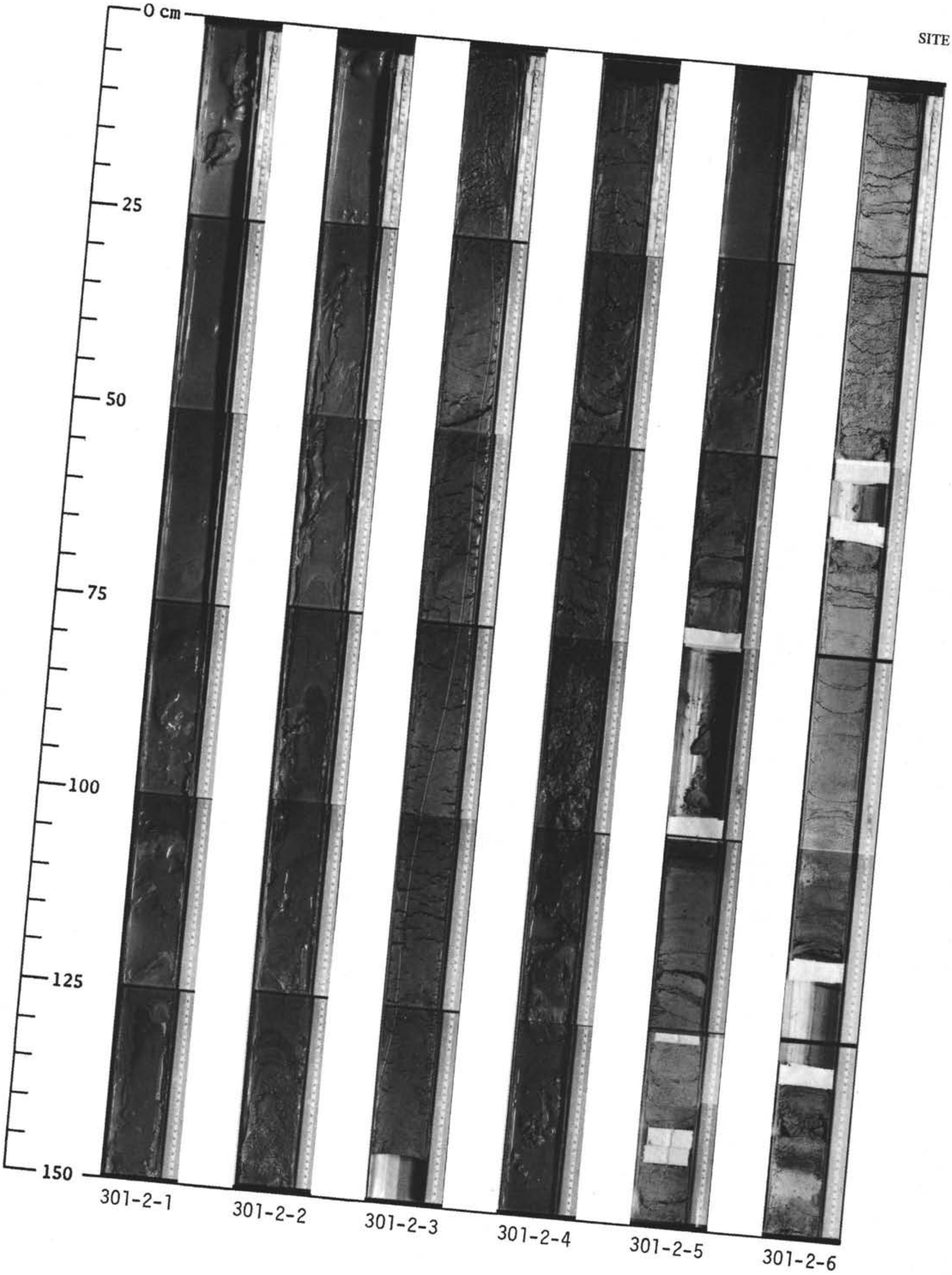
Texture	Composition
90% Clay	43-64% Clay minerals
10% Silt	25-40% Diatoms
	10% Quartz
	3- 4% Pyrite
	3% Feldspar
	2- 5% Sponge spicules
	2- 3% Radiolarians
	1% Silicoflagellates

SAND-SILT-CLAY

Grain Size 2-139	Grain Size 4-72
41.0, 31.2, 27.9	0.2, 34.1, 65.1

Carbon Carbonate 4-72
0.6, 0.6, 0

Explanatory notes in chapter 1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75
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125
150
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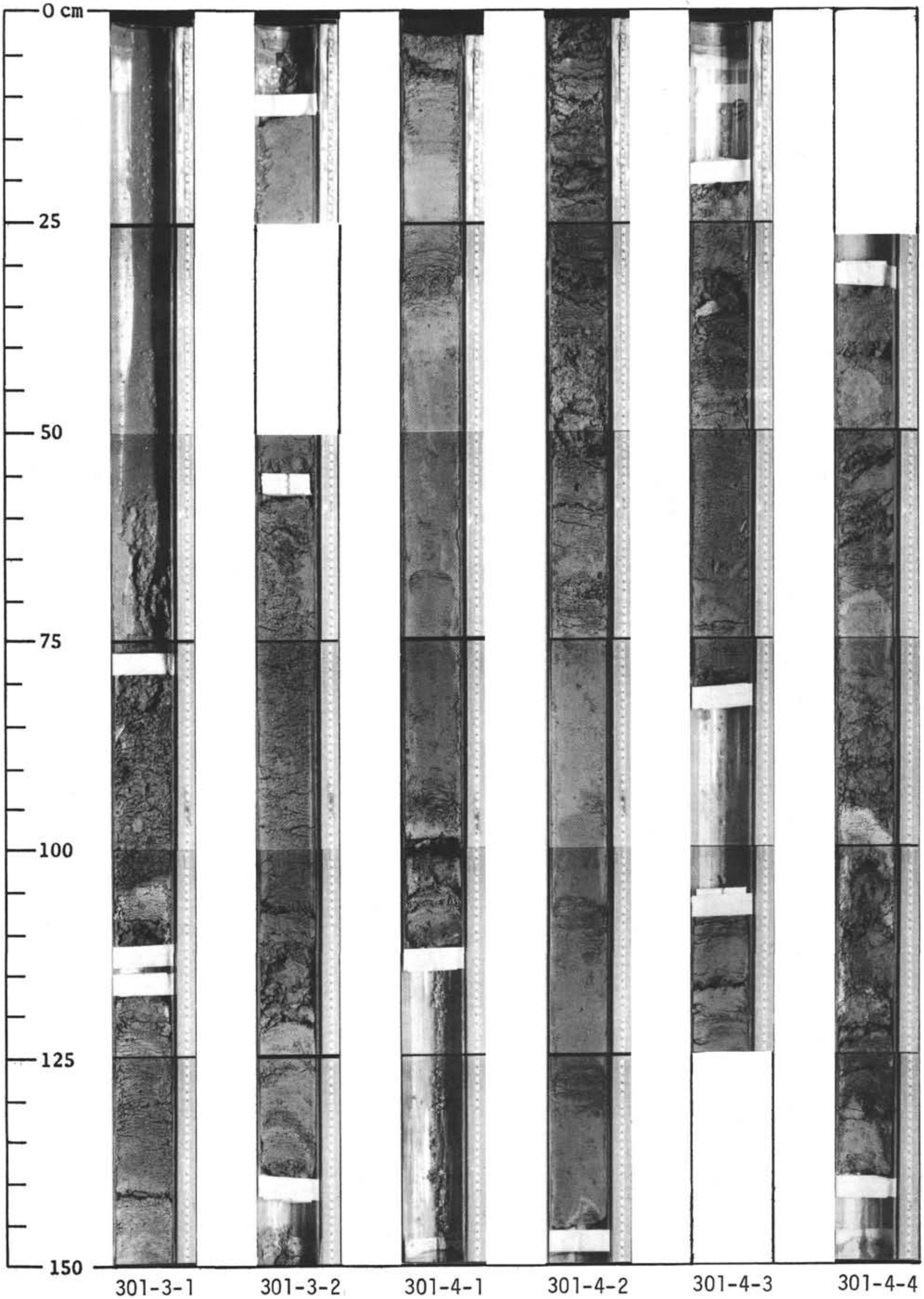
301-2-2
301-2-3
301-2-4
301-2-5
301-2-6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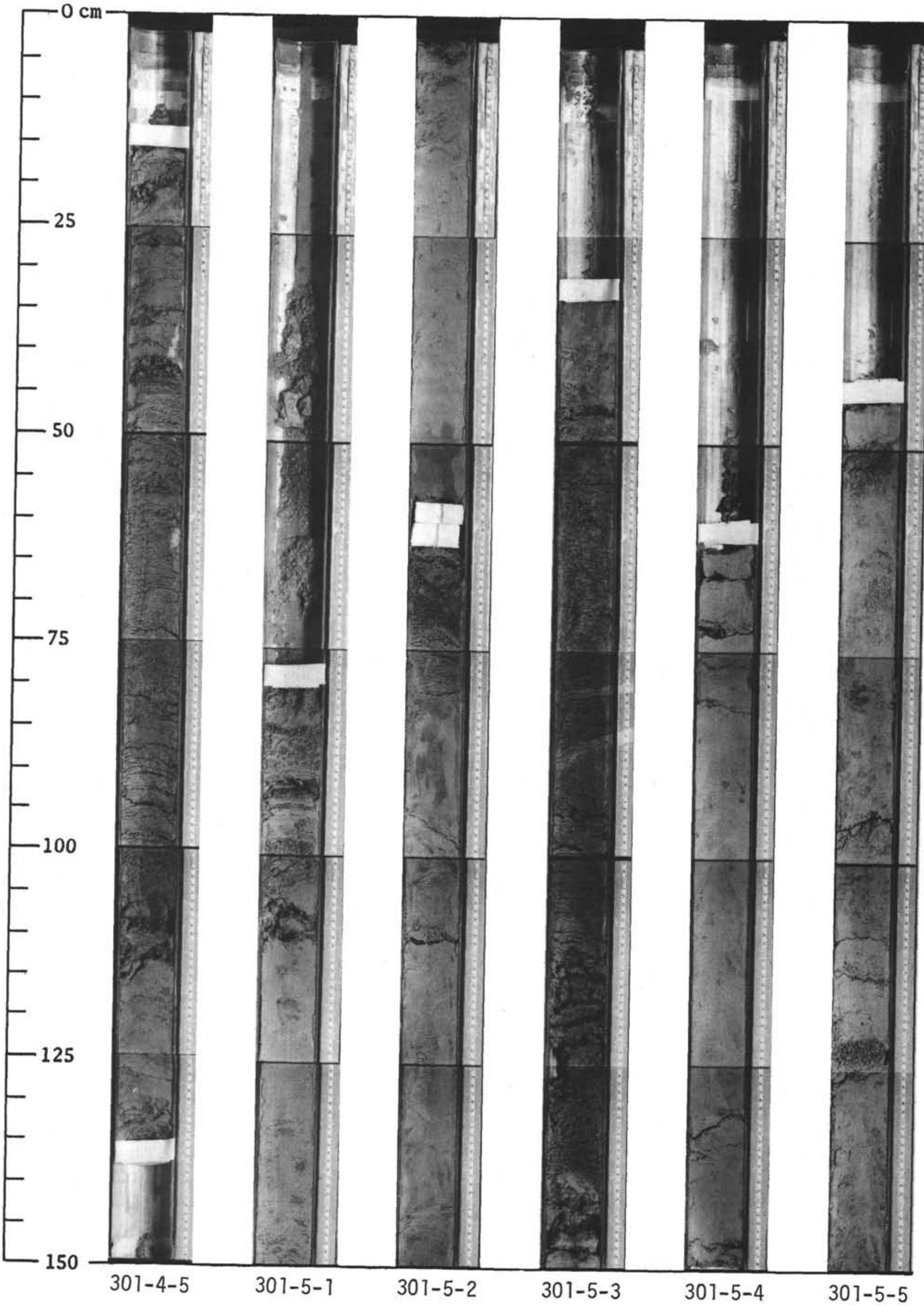
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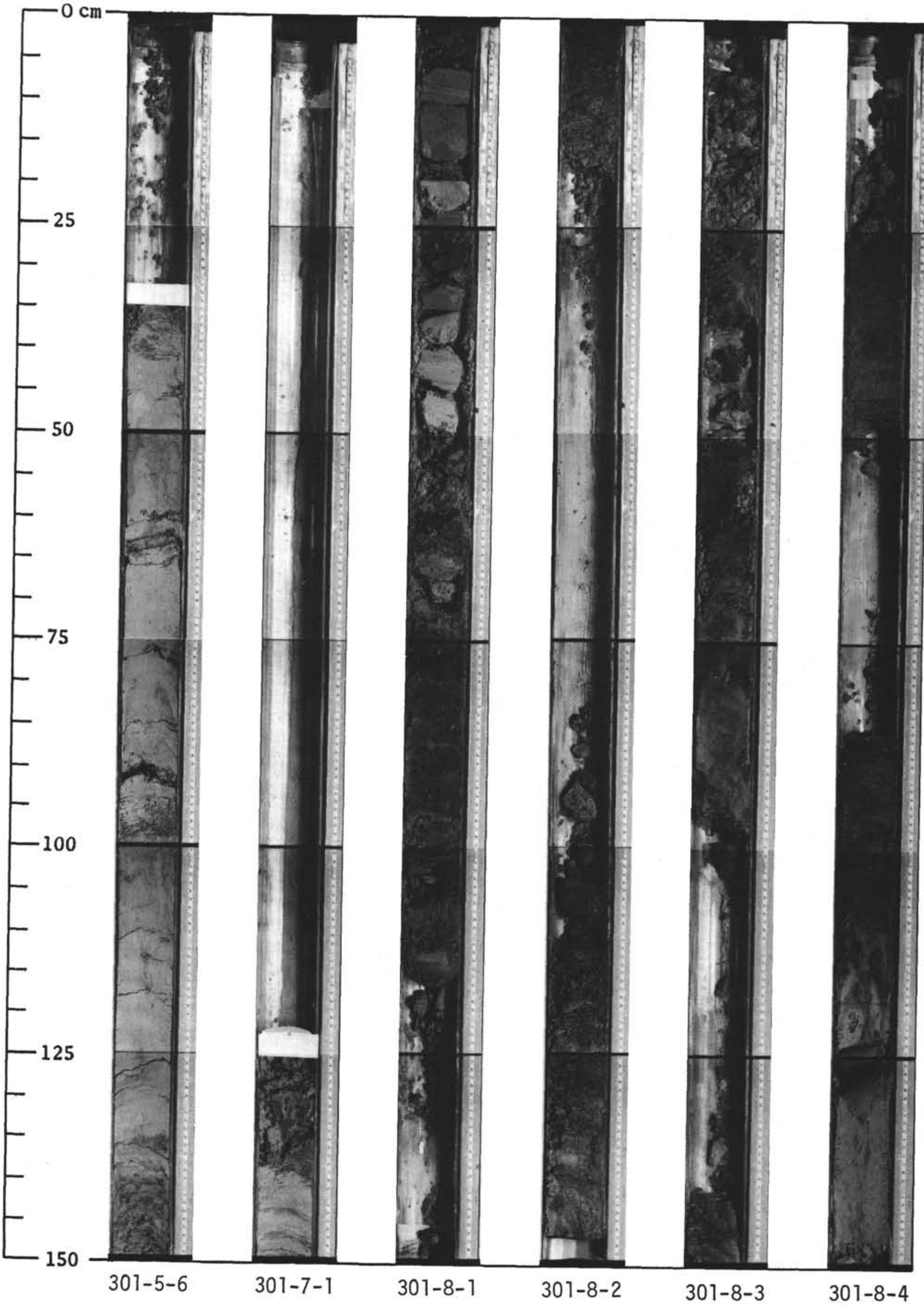
301-5-5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301-8-1
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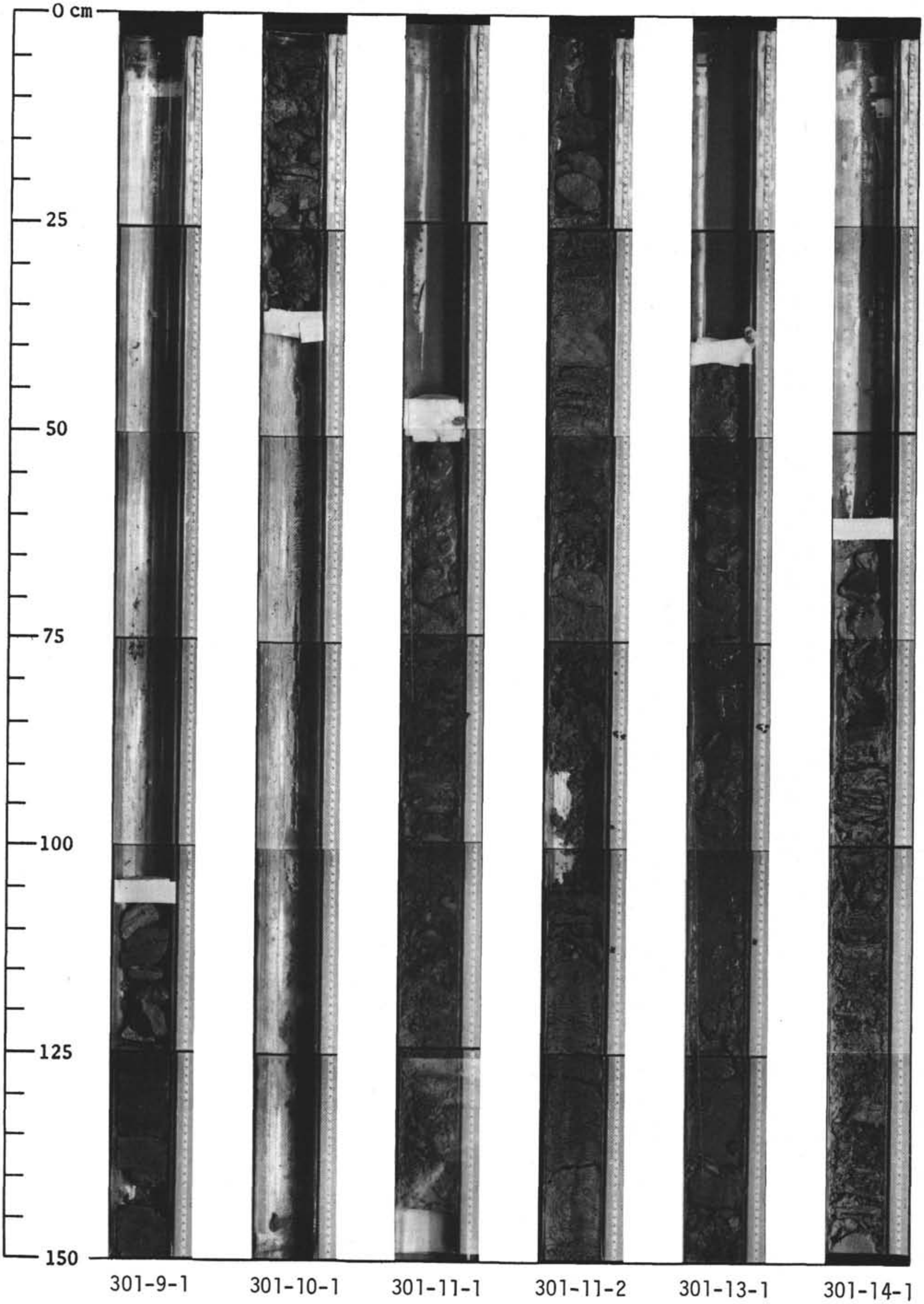
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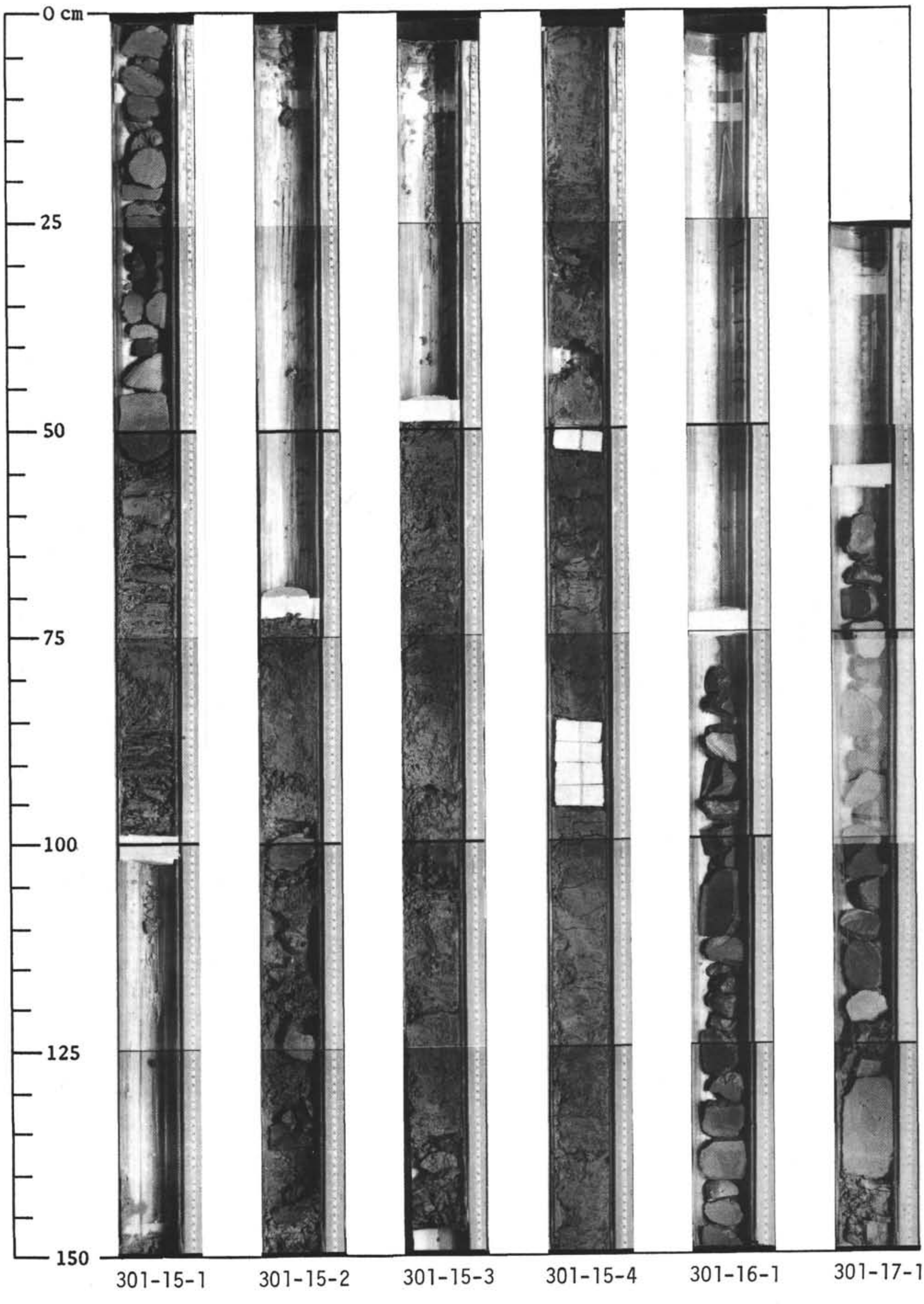
301-13-1
301-14-1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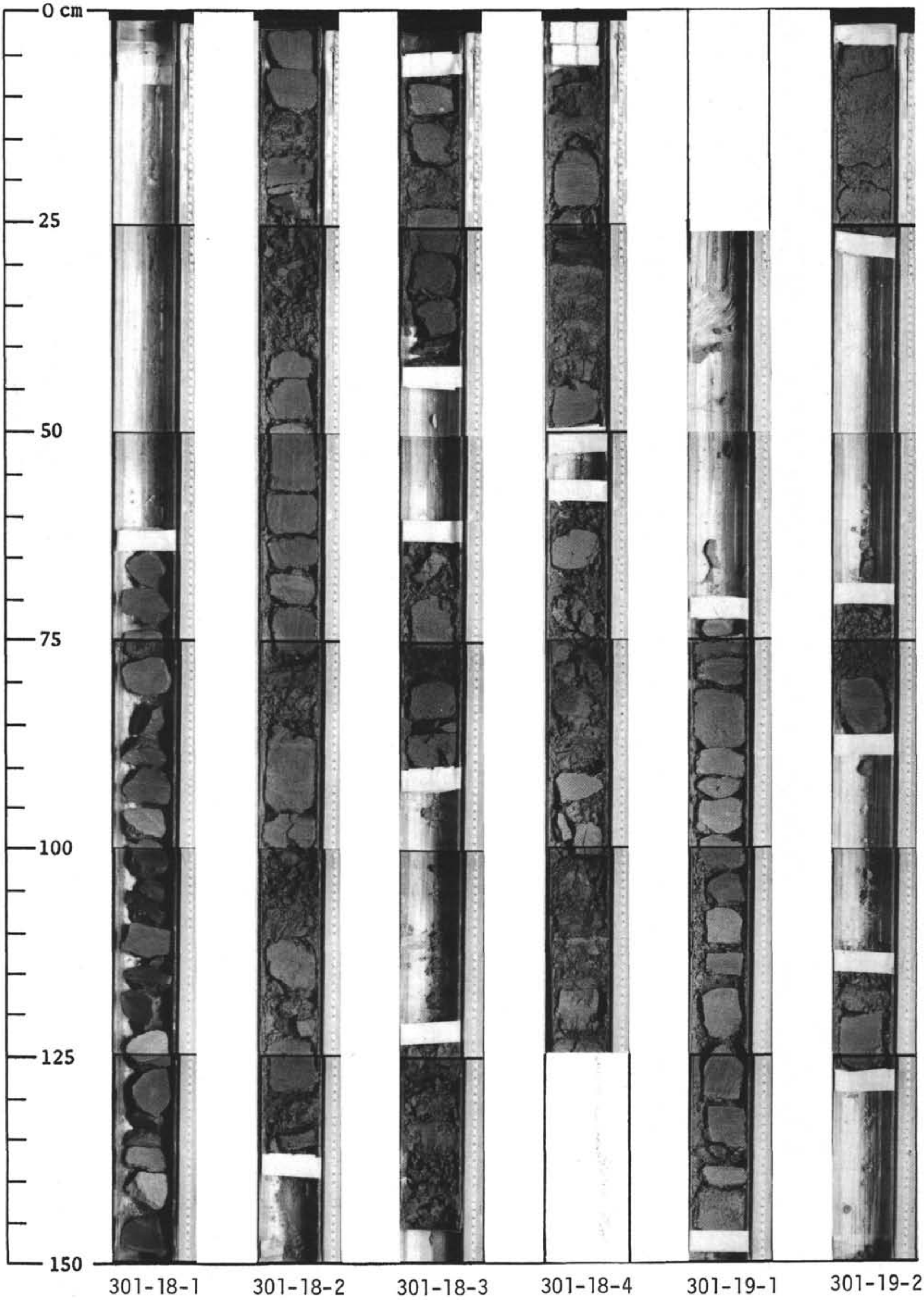
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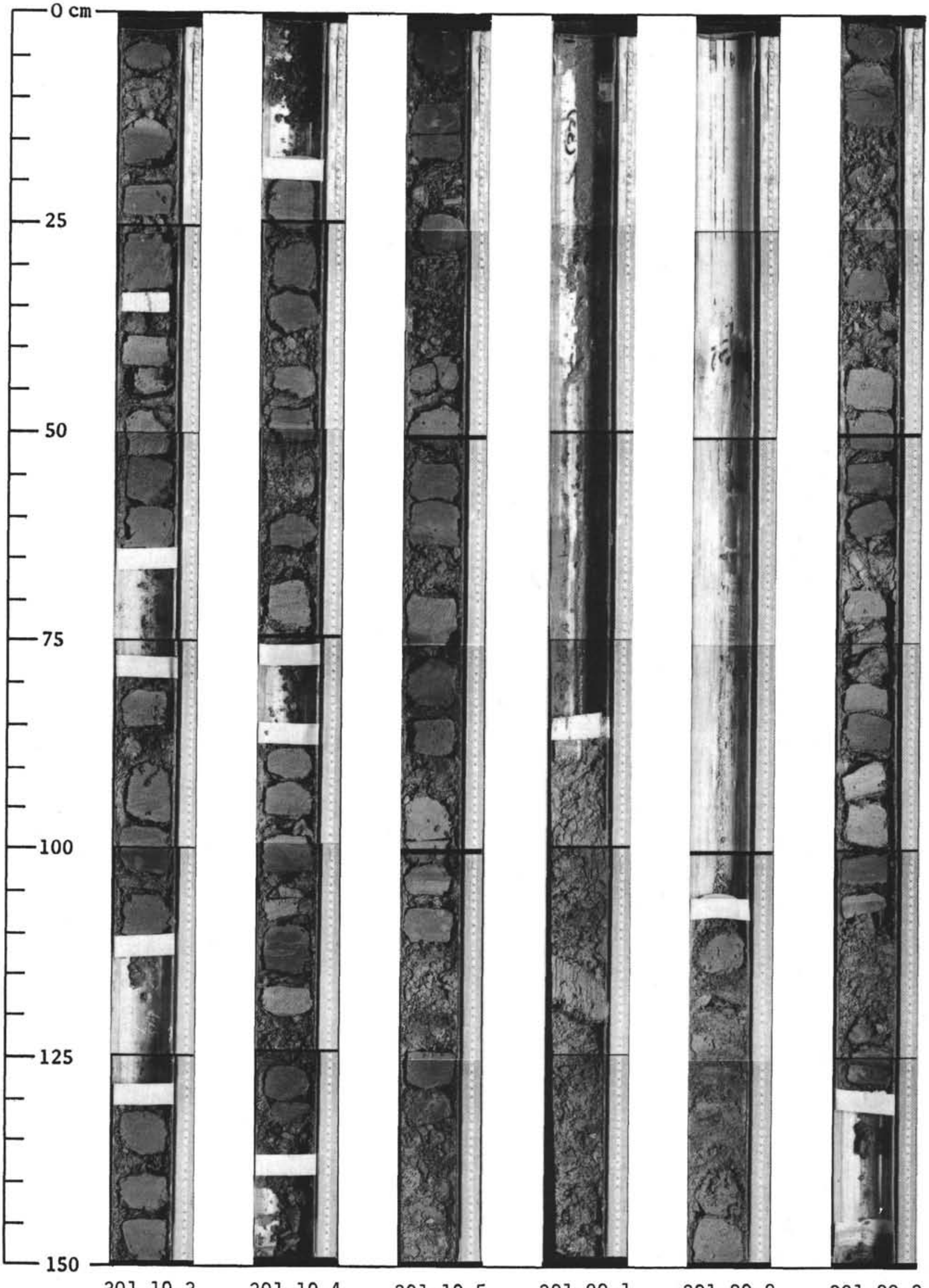
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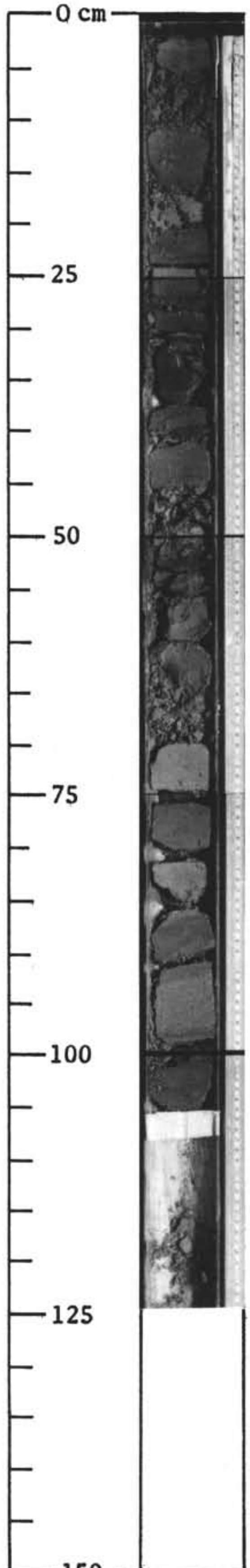

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