6. SITE 318

The Shipboard Scientific Party[1]

SITE DATA

Date Occupied: 13 December 1973 (0757Z)

Date Departed: 16 December 1973 (1300Z)

Time on Site: 77.05 hours

Position:
Latitude: 14°49.63′S
Longitude: 146°51.51′W

Water Depth (sea level): 2641.0 corrected meters, echo sounding

Water Depth (rig floor): 2656.8 corrected meters, echo sounding

Bottom Felt at: 2659.0 meters, drill pipe

Penetration: 745.0 meters

Number of Holes: 1

Number of Cores: 32

Total Length of Cored Section: 298.5 meters

Total Core Recovered: 147.1 meters

Percentage Core Recovery: 49.3%

Oldest Sediment Cores:
Depth below sea floor: 745.0 meters
Nature: Foraminiferal volcanogenic sandstone
Age: Early Eocene
Measured velocity: 2.2 km/sec

Basement: Not reached

Principal Results: The site was drilled in order to determine if the northwest part of the Tuamotu chain is coeval with the Hawaiian-Emperor bend and to study the history of reefal growth and erosion in this area. A simplified geological history at the site may be given as follows:

(1) Eruption of basaltic edifices on older oceanic sea floor at some time prior to 49-51 m.y.B.P.

(2) Deposition of volcaniclastic sandstones and siltstones of shallow water origin at rates averaging 65-70 m/m.y. as these edifices were eroded.

(3) Formation of reefs, at least as old as 49-50 m.y.B.P.

(4) Pelagic sedimentation from early Eocene time to the present, with at least three interruptions. Floods of reefal debris entered the basin as turbidite units during middle Eocene and early Miocene time.

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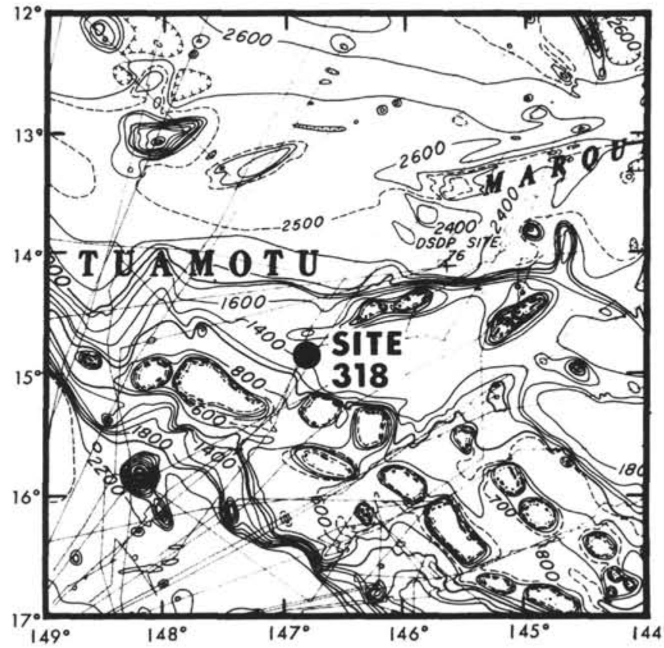

Figure 1. *Location of Site 318 plotted on a portion of the bathymetric chart of the South Pacific of Mammerickx et al. (1973).*

Inasmuch as basaltic basement rocks were not drilled, we can give only minimum ages of edifice construction. Nevertheless, even minimum ages of 49-51 m.y.B.P. are slightly older than recent estimates of the age of the Hawaiian-Emperor bend. Comparison with other ages in the Tuamotu chain suggests that volcanism has been episodic, like that of the Hawaiian chain. Reflectors in the basin are irregular and discontinuous; this irregularity may be due to influx of sediments from ridges bounding it. Comparison of reflectors with drilling results at this site is complex but suggests that the 0.56 to 0.60 (underway) and 0.68 (sonobuoy) sec reflectors, represent an unconformity in the Eocene at a depth of approximately 530 meters and the top of very hard limestones at a depth of about 620 meters, respectively. We continued evaluation of the heave compensator and continued to conclude that its use results in no better core recovery, nor less drill-induced deformation in cores than conventional drilling. Further comparative testing in continuously hard rocks seems indicated.

BACKGROUND AND OBJECTIVES

The original objectives of Site 318 (Figure 1) were (1) to determine the date of cessation of volcanism of near the bend of the putatively continuous Tuamotu/Line Islands seamount chain; (2) to study the petrology of the volcanic rocks that have built the principal Tuamotu edifices; and (3) to attempt to decipher the geological history of the main group of major atolls on the Tuamotu Ridge crest by a study of the sedimentary, presumably turbidite, debris that lies above volcanic rocks. The age of volcanism in this area has direct bearing on Morgan's (1971, 1972) suggestion that this particular area marks a bend in a single Tuamotu/Line Islands chain; a bend that he suggested records a major change in the direction of motion of the Pacific plate. Morgan's bend would therefore be similar to, and coeval with, the bend in the Hawaiian-Emperor chain. Whether the nature of formation of Hawaiian-type chains in linear (Morgan, 1971, 1972) or episodic (Shaw and Jackson, 1973), the age of bends in such chains should be the same according to hypothesis. Clague and Dalrymple (1973) have estimated the Hawaiian-Emperor bend age as about 42 m.y.B.P., although more recent data from Larson, Moberly, et al., (1973), if correct, would lead to estimated bend ages for that chain as being somewhat older. Subsequent to our own drilling in the Line Islands, we believe serious doubt has been cast on the hypothesis that a Line Islands/Tuamotu connection exists; nevertheless, the Tuamotu chain itself has characteristics that resemble the Hawaiian chain (Dana, 1876; Jackson and Shaw, 1975), and it now appears equally important to determine whether or not the birth of the Tuamotu chain coincided with that of the Hawaiian chain. Existing age dates in this area are sparse. Deep Sea Drilling Site 76 (Haws et al., 1972) recovered Eocene reefal debris in Pliocene turbidites along the northern flank of the Tuamotu chain, about 175 km north of our proposed site, but only 27 meters of penetration was achieved. Dredge hauls to the northwest of our proposed site yielded fossil ages in the range 37.5-43 m.y. (Burckle and Saito, 1966) and 37.5-53.5 m.y. (Repelin, 1919), but in terms of basement ages, none of the above data is in any way definitive.

In addition to our interest in basement ages at this site, the Tuamotu Islands in this area form one of the most extensive atoll complexes on earth, and it was hoped to reconstruct a history of atoll formation in this area by drilling reefal debris that presumably lies above basement.

The site considered most likely to meet these objectives was chosen on the *Conrad*-11 refraction profile at 1800, 4 September 1967 (Figure 2) at a position of about 15.2°S; 146.8°N, where a ridge was observed between the major Tuamotu atolls in this area that appeared to contain ponded sedimentary rocks in its basined upper surface. Water depth at this site was measured as about 2600 meters; depth to acoustic basement appeared to be about 0.75 sec.

OPERATIONS

Predrilling Site Surveys

The original site was selected on the basis of a *Conrad*-11 seismic profile that crossed the Tuamotu Ridge on 14 September 1967 (Figure 2). The bathymetry indicated that the *Conrad* line crossed a basin that could have been receiving sediments from five atolls, including Rangiroa, one of the largest in the Tuamotu group.

Glomar Challenger approached Site 318 by attempting to intersect the *Conrad* line before it crossed the north scarp of the Tuamotu Ridge, northwest of Ahe Atoll (Figure 3). This approach was made inasmuch as we were not certain of the location of the *Conrad* line, except that it passed close by Ahe Atoll and passed over the south scarp of the ridge between the Rangiroa and Arutua atolls (Figure 3). In this manner we planned to cross the grain of the structure and be able to navigate on the submarine morphology. The assumed intersection with *Conrad*-11 was made on a course of 100° True and a course change to 215° True was made at 1540 (local), 12 December; shortly afterwards (0140Z, 13 December) Ahe Atoll was picked up on the radar at 16 n. mi. distance, bearing 140°. The north scarp of the Tuamotu Ridge was crossed as well as the perched basin shown on the *Conrad*-11 line (compare Figures 2 and 4). On crossing a high ridge, presumably the northern limit to the trough that we intended to drill, we changed course to 196° True and crossed to the major basin that lies between raised edifices of the Tuamotu Ridge. On the *Conrad*-11 line this basin is 2 hr wide. After steaming for ~1 hr and 15 min, the beginning of another ridge, presumably the one leading up to Rangiroa, appeared. We decided that we were actually east of the *Conrad*-11 line instead of west—the basin being narrower along our line—course was reversed (Figure 5) and we steamed back to a suitable section and dropped the beacon at 2157, 12 December (0757Z, 13 December).

The PDR depth of 1416 fathoms at Site 318 was corrected to 2641 meters (Matthew's tables, Area 41), giving a derrick floor to mudline depth of 2656.8 meters. The bottom proved to be solid in this area, and the drill pipe depth was 2659.0 meters; the latter depth was used for the site.

Reflectors on both the *Conrad*-11 and *Glomar Challenger* lines are irregular and show rapid lateral changes in thickness and strength (Figures 2 and 4). On the *Conrad*-11 line reflectors were noted at 0.08?, 0.20, 0.40, 0.56, and 0.75 sec. On the *Glomar Challenger* line reflectors at roughly 0.1, 0.20, 0.40, 0.60, and 0.75 were noted. The deeper reflectors are quite vague on both lines.

Sonobuoy Survey

Inasmuch as current directions in the general area between the Tuamotu atolls were known to be weak and irregular, a sonobuoy was released at 0535Z, 13 December prior to beacon drop, while underway to the site (see Figure 6); recording on EDO 2 (4-sec sweep). A prominent reflector at 0.69 sec corresponds to the deepest reflector, at approximately 0.71 sec on the profile (Figure 4). Details of the sonobuoy survey are given below.

Drilling Program

Because of the very limited time available at Site 318, the most reasonable drilling strategy appeared to be (1) to take a punch core at mudline to establish the age and erosional character of the surface; (2) to retrieve only every third core drilled, washing the two intermediate intervals until such time as this became impossible due to increasing rock coherence; and (3) to core continuously once such hard formations were reached. We followed this program through Core 21, but, in washing the first and second interval following Core 21,

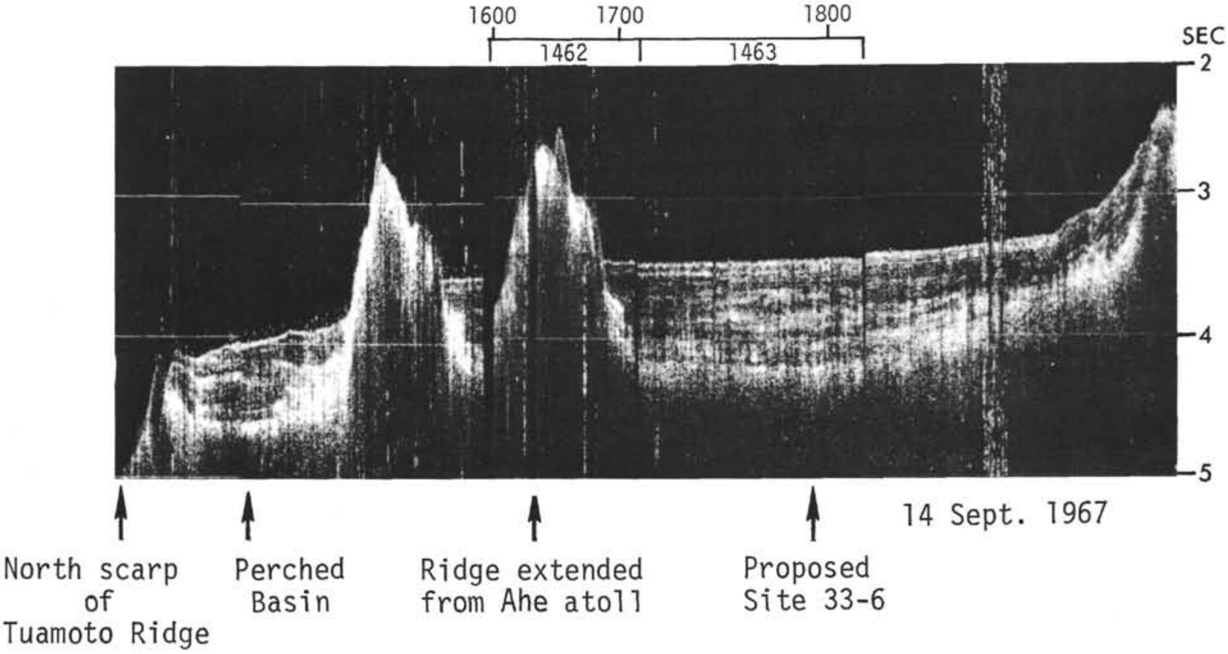

Figure 2. *LDGO* Conrad-*11 seismic reflection profile showing physiographic features used in approach to Site 318.*

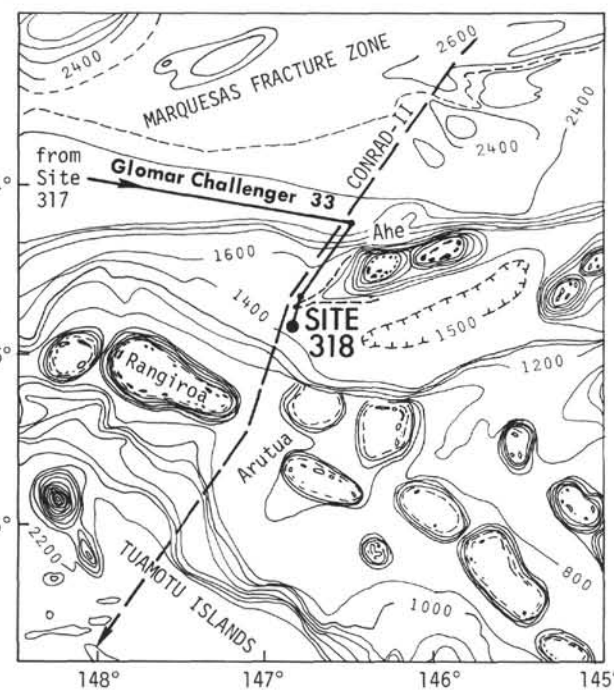

Figure 3. *Location of Site 318, with* Conrad-*11 and* Glomar Challenger *Leg 33 tracks. Bathymetry from Mammerickx et al. (1973).*

washing times became long. We were advised by the Drilling Superintendent that we might have a jammed core catcher. We therefore pulled Core 22 after only one washing interval, and pulled Core 23 immediately following, in response to the Cruise Operations Manager's request for a core at that time. Subsequent to Core 23 we washed as drilling time dictated (in general, washing two cores for one if drilling times were 45 min or less, one for one if drilling times were 1 to 1½ hr, and taking every core that required as long as 1½ hr to drill). Penetration rates became very slow subsequent to Core 21, and the drilling and coring were finally terminated in hole at 2045 (local), 15 December 1973, in order to meet our arrival schedule in Papeete. Bit wear at that time seemed nominal; the final cores were nearly full diameter.

Heave Compensator

Inasmuch as we had accepted the responsibility for a geologic evaluation of the heave compensation device, and since it had previously been operated only in Tertiary rocks, and then with somewhat ambiguous results (see Site 317 report, this volume), we agreed to leave the compensator in the drill string at all times at Site 318, but to take alternate cores with the device locked out and operating throughout the section cored. Thus, in the early portion of the hole 10 even-numbered cores were taken with heave compensation, 10 odd-numbered cores without. During the drilling of Core 22, the Cruise Operations Manager ordered that the heave compensator be left operating for the remainder of the drilling at this site; as a result we are unable to compare results beyond Core 20. Core recovery in holes drilled with the compensator locked out (odd-numbered Cores 1-19) was sensibly the same as recovery in the cores with the compensator operating (even-numbered Cores 2-20). In the former cores recovery averaged 52.9%; in the latter, 53.2% (see Table 1). Recovery in soupy oozes and rocks interbedded with cherts was poor in both modes; firm oozes and chalk gave good recovery in both modes. Recovery time was somewhat slower with the heave compensator operating than without it, no doubt because of its operational complexities (see Site 317 report); the time from delivery of an even core on deck to the arrival of an odd one totaled 11.9 hr versus the

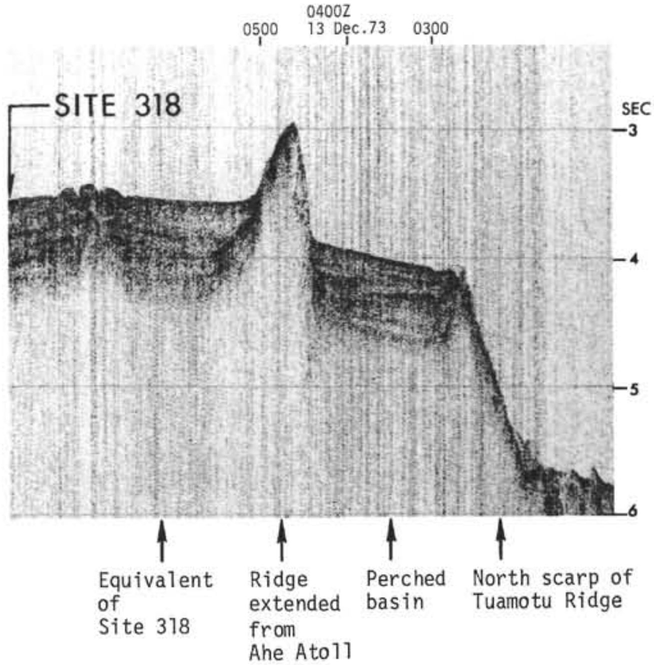

Figure 4. Glomar Challenger *seismic reflection profile on approach to Site 318, showing physiographic features used in locating the site (see Figure 2).*

opposite situation, where the time of delivery of compensator-drilled holes totaled 13.8 h (see Table 1). Deformation was somewhat less severe in cores drilled without the heave compensator (about 24% were intensely deformed) than in cores drilled with it (about 27% were severely deformed).

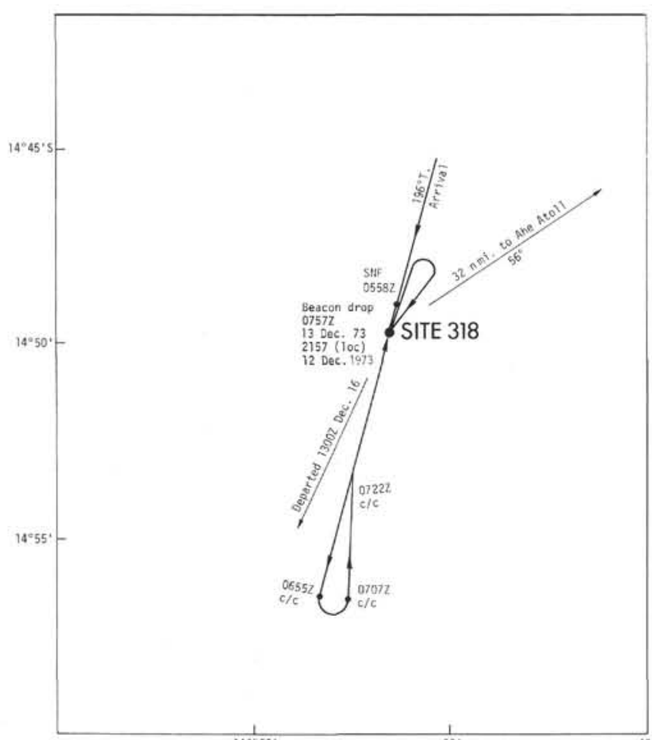

Figure 5. Glomar Challenger *track line on approach to and departure from Site 318.*

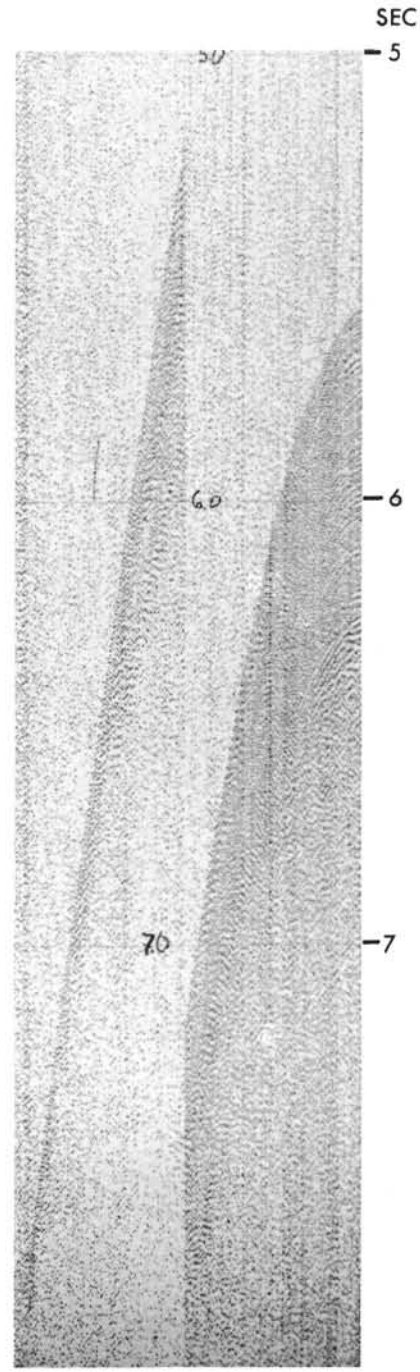

Figure 6. Glomar Challenger *sonobuoy record obtained while underway on approach to Site 318.*

Indeed, we are unable to amend our previous evaluation—it may be that the heave compensator installed on *Glomar Challenger* keeps the bit more firmly in the bottom of the hole than does the conventional drill. If so, returned cores drilled with the compensator show no improved effects, better recovery, time saving, or less severe deformation than those cut with the conventional drill. It is a pity that we were unable to compare the performance of the unit directly in basalt, inasmuch as it was planned for Leg 34 to use it largely in that rock type. On other rock types equally difficult to core, it

TABLE 1
Coring Summary

Core	Date (1973)	Time (local)	Depth From Drill Floor (m)	Depth Below Sea Floor (m)	Length Cored (m)	Length Recovered (m)	Recovery (%)
1	13 Dec	0555	2659.0-2666.5	0-7.5	7.5	7.5	100
2	13 Dec	0740	2695.0-2704.5	26.5-36.0	9.5	2.0	21
3	13 Dec	0845	2723.4-2733.0	64.5-74.0	9.5	1.5	16
4	13 Dec	0945	2752.0-2761.5	93.0-102.5	9.5	9.3	98
5	13 Dec	1055	2780.5-2790.0	121.5-131.0	9.5	9.2	97
6	13 Dec	1205	2809.0-2818.5	150.0-159.5	9.5	9.5	100
7	13 Dec	1310	2837.5-2847.0	178.5-188.0	9.5	9.5	100
8	13 Dec	1420	2866.0-2875.5	207.0-216.5	9.5	4.5	47
9	13 Dec	1530	2894.5-2904.0	235.5-245.0	9.5	2.4	25
10	13 Dec	1650	2923.0-2932.5	264.0-273.5	9.5	5.0	53
11	13 Dec	1810	2951.5-2961.0	292.5-302.0	9.5	9.5	100
12	13 Dec	1930	2980.0-2989.5	321.0-330.5	9.5	2.9	30
13	13 Dec	2105	3008.5-3018.0	349.5-359.0	9.5	2.1	22
14	13 Dec	2230	3037.0-3046.5	378.0-387.5	9.5	4.4	46
15	13 Dec	2355	3065.5-3075.0	406.5-416.0	9.5	2.7	28
16	14 Dec	0120	3094.0-3103.5	435.0-444.5	9.5	3.6	37
17	14 Dec	0250	3122.5-3132.0	463.5-473.0	9.5	2.0	21
18	14 Dec	0445	3151.0-3160.5	492.0-501.5	9.5	2.5	26
19	14 Dec	0625	3179.5-3189.0	520.5-530.0	9.5	1.9	20
20	14 Dec	0750	3208.0-3217.5	549.0-558.5	9.5	7.0	74
21	14 Dec	0955	3236.5-3246.0	577.5-587.0	9.5	3.5	37
22	14 Dec	1405	3255.5-3265.0	596.5-606.0	9.5	5.0	53
23	14 Dec	1625	3265.0-3274.5	606.0-615.5	9.5	3.2	34
24	14 Dec	2025	3274.5-3284.0	615.5-625.0	9.5	6.0	68
25	14 Dec	2245	3284.0-3293.5	625.0-634.5	9.5	4.7	49
26	15 Dec	0100	3293.5-3303.0	634.5-644.0	9.5	6.2	64
27	15 Dec	0310	3303.0-3312.5	644.0-653.5	9.5	2.4	25
28	15 Dec	0645	3322.0-3331.5	663.0-672.5	9.5	3.4	36
29	15 Dec	1020	3341.0-3350.5	682.0-691.5	9.5	2.0	21
30	15 Dec	1430	3360.0-3369.5	701.0-710.5	9.5	4.5	47
31	15 Dec	1800	3379.0-3388.5	720.0-729.5	9.5	2.1	22
32	15 Dec	2045	3398.0-3404.0	739.0-745.0	6.0	5.1	93
Total					298.5	147.1	49.3
Total depth 745.0 meters							

appears to have little other effect than the conventional bumper sub that is removed to allow its operation. In washing cycles it continues to be detrimental because of time loss.

Departure

The Captain of *Glomar Challenger* estimated 26 hr steaming time for the 230 n. mi. from Site 318 to an 0600 rendezvous 17 December with the Papeete pilot boat; the Drilling Superintendent estimated 9 hr were required to pull the string and stow the heave compensator (the bottom-hole assembly had been magnafluxed at Site 317). We therefore planned to have our last core from this site on deck at 1900, 15 December. The final core (Core 32) was on deck at 2040, 15 December. The string was pulled and *Glomar Challenger* got underway at 0300 (local), 16 December on a course of 020°, turned back, passed over the beacon and headed for the pass between Rangiroa and Arutua atolls on a course of 205°. The profiler record (Figure 7) shows the southern edge of the drilled basin, confirming that we drilled near the *Conrad*-11 line.

LITHOLOGIC SUMMARY

The stratigraphic column at Site 318 can be subdivided into five lithologic units (Figure 8):

Unit 1 (0 to between 35.5-64.5 m)—Nannofossil-foraminifer firm ooze that contains some graded beds with shallow water skeletal debris of foraminifers, bryozoans, echinoids, corals, mollusks, and altered volcanogenic material.

Unit 2 (between 35.5-64.5 and between 245 and 264 m)—Foraminifer and nannofossil firm ooze, changing downward to soft chalk, with a few graded beds with sand-sized grains of volcanogènic and shallow water biogenous origin, and a bed of breccia with basalt, chert, and bioclastic debris.

Unit 3 (between 245-264 m and between 416-435 m)—Foraminifer nannofossil chalk, becoming harder with depth, and with chert nodules in the lower part, below 379.5 meters. Thin laminae of sand with rare volcanogenic grains.

Unit 4 (between 416-435 m and between 530-549 m)—Yellowish and greenish nannofossil and foraminifer limestone with chert nodules, clayey laminae and graded beds with volcanogenic and shallow water skeletal debris.

Unit 5 (between 530 to 549-745 m)—Green and greenish-gray clayey limestone, and volcanogenic siltstone and sandstone, mainly as graded beds. Shallow water skeletal debris is abundant in some sandstone layers.

Unit 1—Ooze (0-35.5 m)

Pale orange nannofossil-foraminifer ooze and foraminifer ooze. Interbedded with these calcareous oozes are graded layers 20 to 60 cm in thickness containing sand- to granule-sized grains of volcanogenic and carbonate debris. This debris includes palagonite, greenish

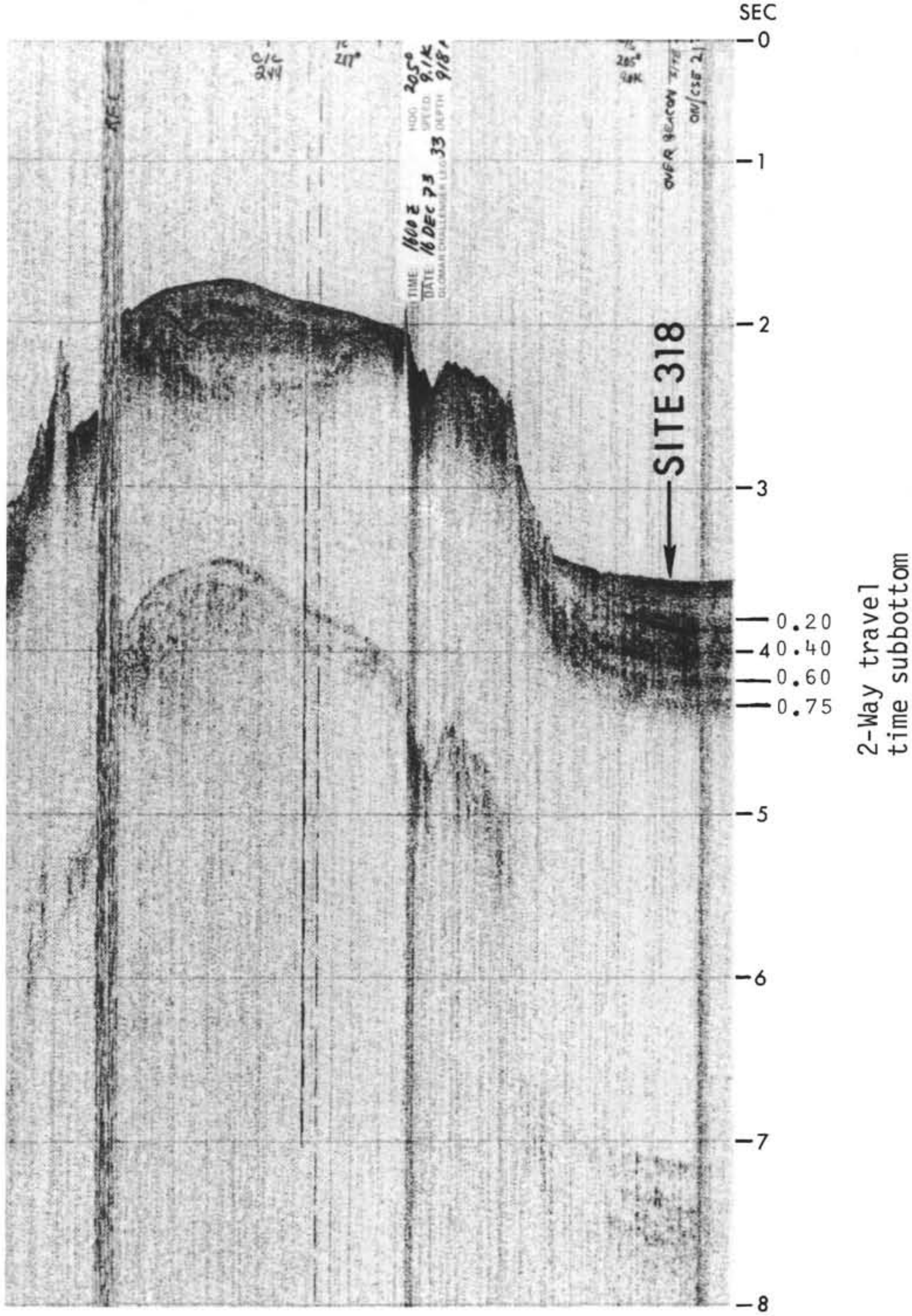

Figure 7. Glomar Challenger *seismic reflection profile on departure from Site 318. Annotated reflectors are correlative with those on the* Conrad-*11 profile shown in Figure 13.*

glass, rock fragments, and, in some layers, shallow water skeletal fragments of bryozoans, mollusks, and large and small foraminifers including *Amphistegina* and *Heterostegina.* The volcanogenic and bioclastic material is mainly concentrated at the base of graded beds; higher parts of the beds consist chiefly of planktonic foraminifers and nannofossils. In thin section, some layers have a packstone texture, with mainly globigerine foraminifers, as whole tests, and a few globorotaliids in a matrix of nannofossils.

Other layers have wackestone textures, with about 50% nannofossils and 50% planktonic foraminifers. The foraminifers are either empty or filled with micrite matrix. (The terms wackestone and packstone are used according to the classification of Dunham, 1962.)

The ooze is vaguely mottled in color shades both slightly lighter and darker than the pale orange host sediment.

As shown by X-ray data (Cook and Zemmels, this volume), some of the transported fossils probably con-

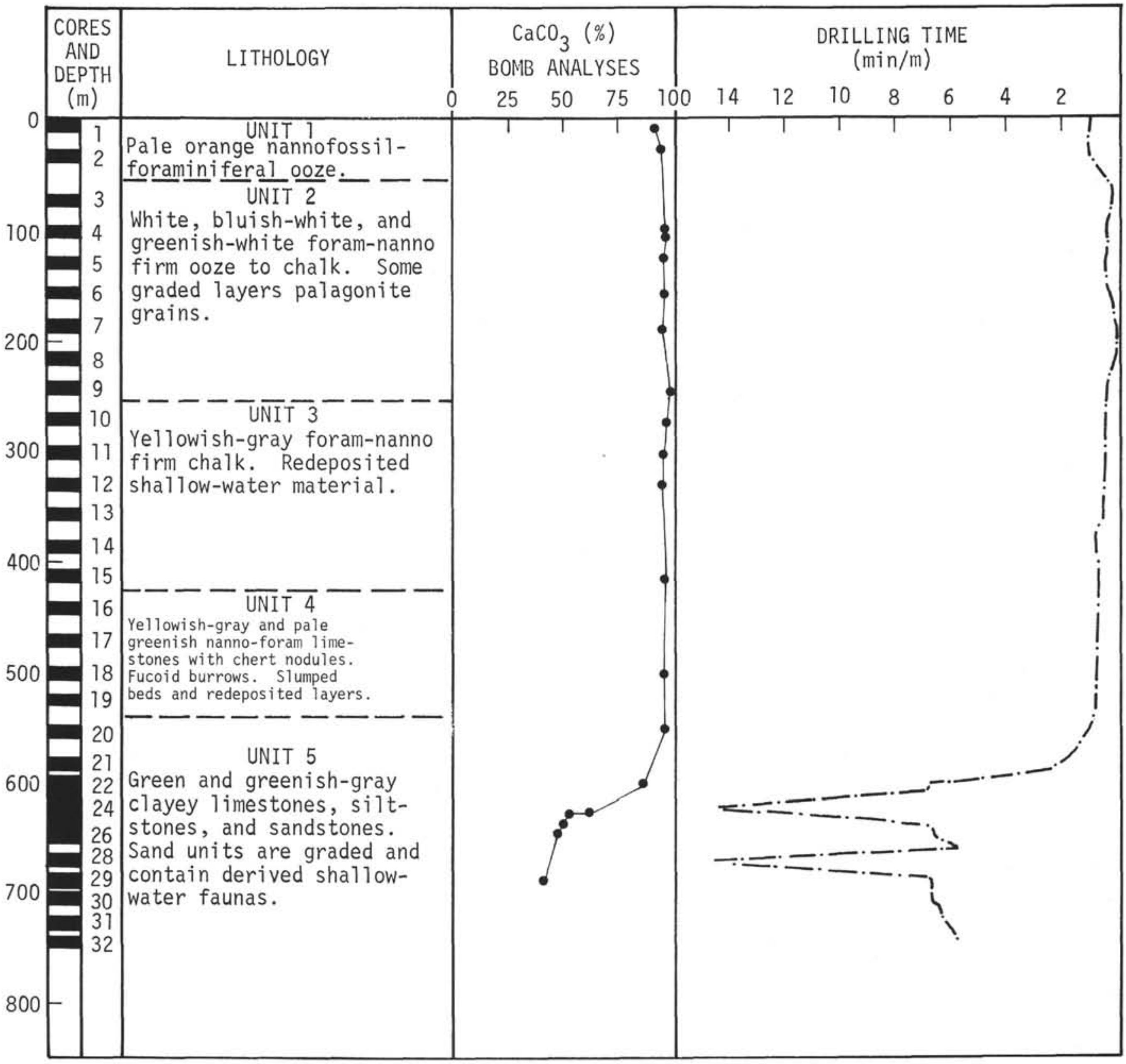

Figure 8. *Graphic log showing lithologic units, carbonate content, and drilling rates at Site 318.*

tain aragonite in their shells. About 1% dolomite and a trace of barite were also detected by X-ray diffraction.

Much of the ooze has the firmness of packed sand, and in Core 2, Section 2, near the base of the unit, the sediments have the induration of chalk.

Unit 2—Ooze and Chalk (64.5-265.5 m)

Foraminifer-nannofossil firm ooze, changing downward to soft chalk. Some layers are foram-rich and contain rare sand-sized grains of palagonite. A few of these layers show graded bedding. Colors range from white at the top of the interval to bluish-white and greenish-white in Cores 6, 7, and 8, and white again near the base of the unit in Core 9. Thin wisps and streaks of gray ooze occur throughout. The foram-rich layers tend to be shades of pale yellowish-gray. At the base of the unit is a thin bed of well-indurated breccia, consisting of pebbles of basalt, chert, and shallow water skeletal debris (Figure 9).

The foram-rich layers in this section have a packstone texture with sand-sized planktonic (99%) and benthonic (1%) foraminifers. Also present in these packstones are very rare fragments of bryozoans, tiny calcareous sponge spicules and grains of palagonite, and feldspar, all set in a matrix of nannofossil micrite. The finer grained sediments, in thin section, have wackestone textures, some with a wide range of sizes of planktonic foraminifers (40-600 μm) set in a matrix of nannofossil micrite. The ratio of matrix to foraminifers ranges from about 1 to 2. Most foraminifers are filled with micrite; some are completely empty. In the lower part of the unit, some of the thinner walled globorotaliid foraminifers have slightly crushed tests.

Figure 9. *Lower Miocene, well indurated, brownish polygenetic breccia from the base of lithologic Unit 2. Diverse fragments include rounded aphyric vesicular basalt clasts with ferruginous halos, gray angular chert clasts, and light yellow skeletal and reef debris (Core 10, Section 1, 137-140 cm; 268 m below the sea floor).*

X-ray data (Cook and Zemmels, this volume) reveal the presence of small amounts of dolomite in gray ooze in Cores 4 and 5, and barite in Cores 4 and 7.

The breccia bed at the base of the unit consists of angular fragments, up to 1 cm in diameter, of a wide variety of clasts. The proportions of clast types are roughly 50% volcanogenic, 40% sedimentary, and 10% biogenic clasts. Volcanogenic clasts consist of basalt, with plagioclase of An_{40-45} composition and augite phenocrysts (15%) in a sideromelane or palagonite groundmass; quartz syenite, containing quartz, orthoclase, minor plagioclase, and aegerine augite; trachyte, composed almost entirely of fine-grained sanidine; oligoclase andesite; holocrystalline basalt, with subcalcic augite microphenocrysts and groundmass pigeonite; palagonite, generally of the gel variety, but also including fibrous types with abundant spherulites; bioclastic debris is composed of mollusks, benthonic and planktonic foraminifers, bryozoans, and sedimentary rock fragments of silicified foraminifer-nannofossil limestone.

Unit 3—Varicolored Chalk, Chert, and Sandstone (265.5-416.0 m)

Foraminifer-nannofossil chalk in shades of yellowish-gray, yellowish-white, pale orange, grayish-orange, pinkish-white, and white with occasional wisps, streaks, laminae, and burrow mottles of light olive-gray and light gray. The induration ranges from soft chalk at the top of the unit to hard chalk at the base. Much of the chalk has been fractured and crushed in the coring process, reducing it to a paste in some intervals. Chert, in the form of olive-gray and yellowish-brown nodules occur very sporadically in the lower part of the unit, beginning at 379.5 meters in Core 14.

Within the chalk are occasional thin laminae of foram-rich sand, with about 1% volcanogenic grains of pale green palagonite and minor feldspar. In thin section, the sands have a packstone texture, with grains of both planktonic (~90%) and benthonic (~10%) foraminifers in a matrix of nannofossil micrite. These tests are commonly fragmental and partly dissolved and recrystallized.

X-ray data show barite and analcite in addition to volcanogenic components in the acid-insoluble fraction.

The bulk of the chalk is wackestone, with planktonic foraminifers of a wide range of sizes (40-500 μm) in a nannofossil micrite matrix. The micrite is commonly charged with tiny calcareous sponge (?) spicules, lying in the bedding plane.

Unit 4—Limestone and Chert (416.0-530.0 m)

Yellowish-gray and pale greenish nannofossil and foraminifer-nannofossil limestone, with common chert nodules. The unit is characterized by darker, more greenish colors than Unit 3 and by the prevalance of laminations, burrows, and mottles. Near the top of the unit these burrows are dark and are set in a lighter host, but lower down the rule is lighter burrows in a darker host. Burrows are generally somewhat flattened parallel to bedding.

Evidence of soft sediment deformation is common, especially in Core 16. Recumbent folding and tiny brittle-fracture step faults occur in Section 2 of Core 16.

Streaks and laminae of foram-rich packstone with greenish palagonite grains occur scattered throughout the unit. These are more numerous, thicker, and coarse grained toward the base of the unit, where they generally form the lower parts of graded beds. The upper parts of these beds consist of nannofossil-foraminifer wackestone with decreasing proportion of foraminifers (mainly planktonic) upward. The limestone is layered on a scale of about 250 μm, marked by changes in foraminifer concentrations in the matrix. Sponge spicules and radiolarians are rare in the upper part of the unit, but become more common near the base. In Core 18, radiolarians are almost as abundant as foraminifers in one thin section.

Chert nodules are scattered throughout the unit, at a frequency of 1 or 2 per meter.

The base of the unit is chosen at the bottom of Core 19, in which an artificial sand or drilling breccia was recovered. This breccia consists of volcanogenic grains (mainly palagonite), chert, and bioclastic debris (planktonic and large benthonic foraminifers including *Nummulites, Heterostegina, Cycloclepeae*?, and *Asterocyclina*, bryozoans, calcareous algae, corals, and mollusks).

Unit 5—Limestone and Volcaniclastic Sediment (549.0-745.0 m)

Green and greenish-gray clayey limestone, siltstone, and sandstone, mainly as graded beds. Hard and cherty in the upper 100 meters (Cores 20 through 24), slightly softer below. The graded beds, which average between 5 and 10 cm thick, generally have siltstone or sandstone at the base, and pass upward into increasingly burrow-mottled limestone and clayey limestone. The colors become increasingly darker towards the base of the unit, except for yellowish-gray silty and sandy layers rich in ash or palagonite. The proportion of $CaCO_3$ decreases regularly toward the base of Unit 5 (see Figure 8). Soft sediment deformation features, such as small step-faults, deformed burrows, inclined beds, and overfolds, are common at many levels within Unit 5.

In thin section, the sand layers have a packstone texture and are seen to consist of mixtures of biogenous and volcanogenic grains with a nannofossil-clay matrix. Most of the sand layers in the upper part of the unit consist chiefly of planktonic foraminifers, with lesser amounts of shallow water bioclastic debris (tests of large foraminifera including *Asterocyclina*, *Nummulites*, and *Heterostegina*, bryozoans, echinoid spines, calcareous algae) and volcanogenic materials (green and brown palagonite, basalt fragments, and feldspars, including both plagioclase and anorthoclase; see Figure 10). In the lower part of the unit, in Cores 30 through 32, the proportions are reversed; these sediments are volcanogenic sandstones, with occasional laminae or beds rich in planktonic foraminifers or shallow water bioclastic debris (especially discocyclinids). Some layers (e.g., Core 30, Section 3, 58-60 cm) consist almost entirely of slightly altered splintery volcanic glass shards. The

Figure 10. *Middle Eocene, light greenish-gray limestone from lithologic Unit 5. Basal part of a graded bed is composed of masses of discocyclinid benthonic foraminifers and a few scattered green palagonite grains (Core 26, Section 1, 137-140 cm; 636 m below the sea floor).*

micrite matrix of the sandstones and the upper, finer grained parts of graded layers are nannofossil rich in the upper part of Unit 5, changing gradually to montmorillonite clay rich in the lower part. X-ray data reveal montmorillonite, clinoptilolite, and volcanogenic minerals at all levels sampled in Unit 5.

GEOCHEMICAL MEASUREMENTS

The results of pH, alkalinity, and salinity analyses of interstitial waters are summarized in Table 2 and Figure 11. Nine samples were analyzed. The shipboard $CaCO_3$ content values for 21 selected sediment samples are shown in Figure 8. Procedures for analysis were those routinely performed aboard ship of *Glomar Challenger*.

pH Values

From 0 to 553 meters, pH values remain consistently below those for surface seawater. They range from 7.20 to 7.39 from 50 to 553 meters. The three methods used to measure pH show corresponding results. A slight increasing trend in Unit 5 may be noted in the lowest (553 m) measurement.

Alkalinity

From 0 to 438 meters, alkalinity values remain uniformly above those for surface seawater which is 8.21 at this site. The alkalinity values show little deviation in this zone, ranging from 2.93 to 3.42 meq/kg. There is a decreasing trend reflected in the lowermost measurement (0.59 meq/kg) at 553.0 meters, which corresponds to the change to lithologic Unit 5.

Salinity

From 0 to 438 meters, salinity values range from 35.5 to 36 ‰ remaining near to, but lower than, the value of 36.3 for surface seawater at this site. Only the lowest measurement (36.6 ‰) at 553 meters in Unit 5 is slightly above that of the surface seawater value.

$CaCO_3$

All of the sediments in Units 1 through 4 have calcium carbonate values between 90% and 100%. Near 600 meters, in Unit 5, as the quantity of volcanogenic clay, siltstone, and sandstone increases, the calcium carbonate content concomitantly decreases (see Figure 8).

PHYSICAL PROPERTIES

The physical properties methods, presentation in hole and core plots, presentation in tables, and definitions are discussed briefly in the Physical Properties section of the Site 315 report and in detail in Appendix I, this volume, and therefore will not be discussed in detail here.

The GRAPE analog data are displayed in the core scale graphs only. Where the sediment was soft and the core liner completely filled, the analog GRAPE shore-based computer program requires no diameter corrections, and the data are plotted as a single solid line. Where the analog GRAPE scans cores of hard rocks with varying diameter, the data are presented as two lines. The solid line is the routine analog data without correction for core diameter and assuming a 6.61-cm

TABLE 2
Summary of Shipboard Geochemical Data

Sample (Interval in cm)	Depth Below Sea Floor (m)	pH Punch-in	pH Flow-through	Colorimetric Alkalinity (meq/kg)	Salinity (°/oo)	Combination Electrode pH	Potentiometer Alkalinity (meq/kg)
Surface Seawater		8.25	8.18	2.44	36.3	8.23	2.39
1-4, 144-150	6	7.85	7.53	3.03	35.8	7.80	3.06
4-4, 144-150	96	7.28	7.20	3.23	35.5	7.38	3.24
6-4, 144-150	156	7.28	6.99	3.42	35.5	7.28	3.38
8-1, 144-150	207.5	7.34	7.20	3.03	35.5	7.40	2.95
10-3, 144-150	268.5	7.30	7.16	3.03	35.5	7.40	3.02
12-1, 142-150	322.5	–	7.32	2.64	36.0	7.45	2.60
14-2, 144-150	381	7.20	7.19	2.93	36.0	7.35	2.79
16-2, 144-150	438	–	7.15	2.05	36.0	–	–
20-3, 144-150	553.5	–	7.39	0.59	36.6	–	–

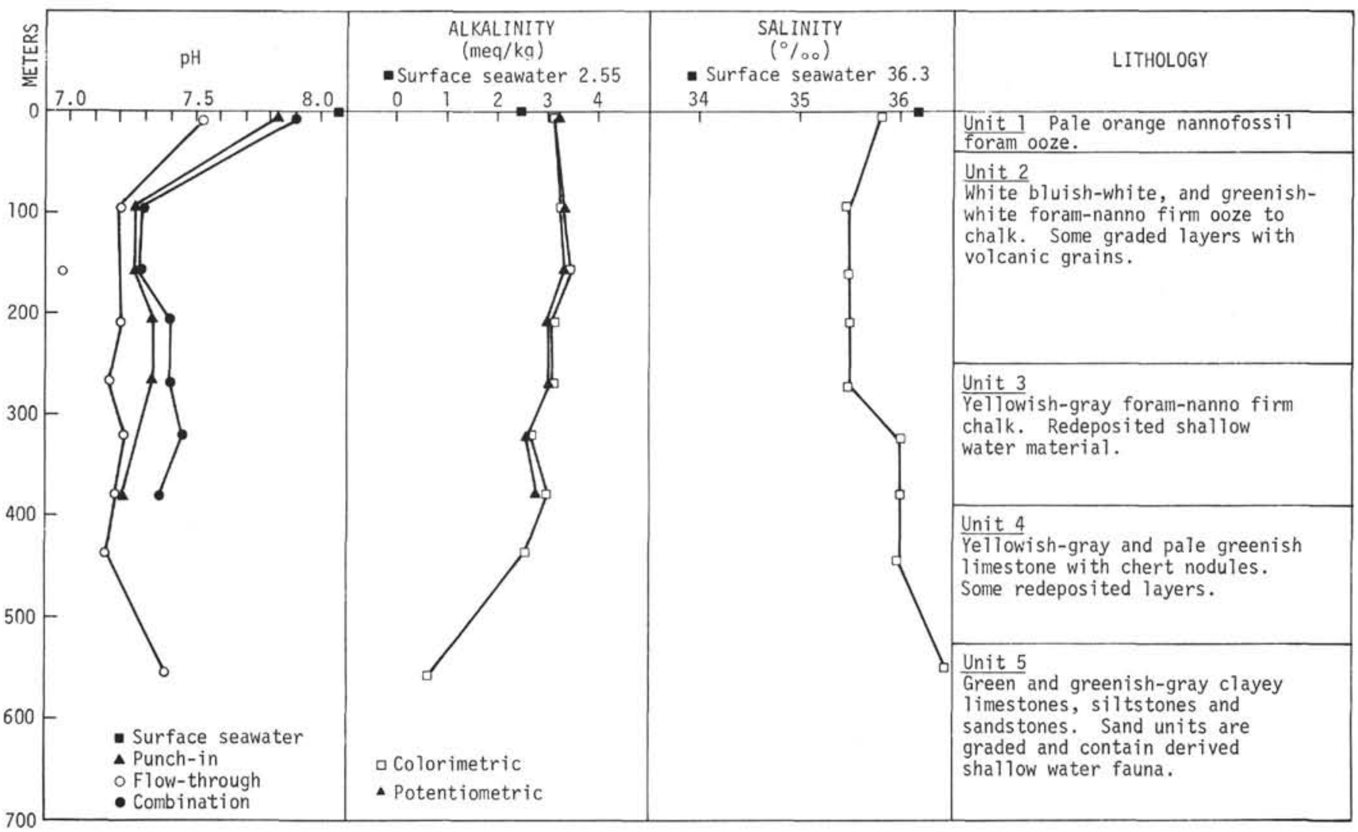

Figure 11. *Graphic log of shipboard* pH, *alkalinity, and salinity measurements at Site 318.*

diameter. This line is presented in case it is felt necessary to consult photographs, measure diameters, and apply other diameter corrections for a discrete interval, or simply for the manipulation of data. The dotted line represents data to which diameter corrections have been applied as described in Appendix I, this volume. Where rock segments were very short, the data appear as a series of peaks; only the maximum density of the peak in these cases represents good density values, and the density values of the shoulders of the analog peaks should be ignored.

The GRAPE Special wet-bulk density, gravimetric wet-water content, porosity, sound velocity (perpendicular and parallel to bedding), absolute velocity anisotropy, percentage velocity anisotropy, acoustic impedance, and reflection coefficients are presented in Table 3, with most of these parameters, graphically displayed in the site plots and core plots.

The physical properties data are primarily presented in tables and graphs and only briefly discussed. Detailed discussion and interpretation about the interrelationships of the laboratory physical property data are treated more thoroughly in Chapter 26, this volume.

Results

Sound velocity, wet-bulk density, wet-water content, porosity, acoustic impedance, and reflection coefficients were measured or calculated from ooze, chalk, limestone, chert, and volcaniclastics, from 0 to 745 meters below the sea floor. The physical properties of the sedimentary rocks recovered at Site 318 are summarized into six stratigraphic groups based primarily on sound velocity, wet-bulk density, wet-water content, and impedance data as shown in Figure 12. The boundaries are indicated by the dashed horizontal lines, and listed in Table 3. This grouping is summarized in Table 4, which lists the lithology, depth interval, and typical values of the characteristic physical properties.

The characteristic physical property intervals at Site 318 are as follows: (1) Quaternary to Miocene foram-nanno ooze and chalk from 0 to 265.5 meters below the sea floor; (2) Miocene to Oligocene foram-nanno chalk from 265.5 to 408 meters; (3) Oligocene to Eocene foram-nanno, nanno-chalk and limestone from ~408 to ~494 meters; (4) Eocene nanno limestone from ~494 to ~540 meters; (5) Eocene nanno limestone with minor interbedded clastics from ~540 to 581.5 meters; and (6) Eocene nanno limestone, clayey limestone, silicified limestone, and volcaniclastics from 581.5 to ~745 meters. The last three units are rather arbitrary and they could be possibly lumped. The last unit could also be arbitrarily subdivided below 700 or 715 meters.

Interval 1, from 0 to 265.5 meters, has variably low velocity wet-bulk density, and impedance with high water content and porosity. The lower boundary is marked by conglomerate and breccia with high velocity clasts.

Interval 2, from 265.5 to ~408 meters, has uniformly low velocity, wet-bulk density, and impedance, and the wet-water content and porosity are high. The lower boundary is marked by a small but significant increase in velocity, wet-bulk density, and impedance, and a corresponding decrease in wet-water content and porosity.

The third interval (3) from ~408 to ~494 meters has fairly uniform parameters, with moderate wet-bulk density and velocity. The lower boundary at 494 meters is marked by an abrupt change to relatively high velocity and relatively high wet-bulk density limestone from ~494 to ~540 meters. However, this fourth (4) interval (~494 to ~540 m) is based only on a few data points and may not exist in situ as represented here. The lower boundary of ~540 meters is distinctly marked by a significant and abrupt decrease in velocity, wet-bulk density, and impedance, with a decrease in porosity and wet-water content.

The fifth (5) interval from ~540 to 581.5 meters has moderate velocity, wet-bulk density, and impedance, probably the result of abundant clastics. Its lower boundary is marked by an abrupt increase in velocity, wet-bulk density, and impedance, and decreases in wet-water content and porosity.

The sixth and last group from 581.5 to ~745 meters is characterized by variably high to low parameters, which tend to decrease with increasing depth (porosity and wet-water content increase). The contrasting parameters in this interval are the result of interbedding of limestone, silicified limestone, clayey limestone, and volcaniclastics.

Discussion

The reflection coefficients calculated are only typical of what may be present at the arbitrary boundaries of major groups of physical properties. The few that are calculated are not any indication of the location or number of such impedance mismatches as are present.

Sound velocity has a tendency to be faster parallel rather than perpendicular to bedding. A few negative anisotropy values were calculated, but it cannot be precluded that these result from error. In general, anisotropy in the Quaternary to Eocene sediments and sedimentary rock above ~540 meters is very slight (0 to 2%), with an occasional high (6%) anisotropy in a few hard layers. Below ~540 meters the Eocene limestone and clastics have significantly higher anisotropy of 0 to 20% with 0 to 12% being typical. See Chapter 26, this volume, for more information.

CORRELATION OF REFLECTION PROFILE WITH DRILLING RESULTS

The reflectors in the basin drilled are not regular; they display lateral changes in strength and "thickness" across the basin (Figures 2 and 4). On the *Conrad*-11 (Figure 13) line, reflectors lie roughly at 0.08, 0.20, 0.40, 0.56, and 0.75 sec; on the *Glomar Challenger* line (Figure 7) reflectors could be discerned, after a fashion, at 0.20, 0.40, 0.60, and 0.75 sec. The deep reflectors are quite vague and are characterized by wavy and indistinct tops. An underway sonobuoy was run (Figure 6) and the only really distinct reflector seen lies at 0.68 sec (Figure 14).

Upon drilling, it was found that the upper reflectors (0.08, 0.20, and 0.40 sec) could not be recognized or correlated with any obvious lithologic breaks. The 0.56-sec reflector of the *Conrad*-11 line and the 0.60-sec reflector of the *Glomar Challenger* line may represent an unconformity in the section at approximately 530 meters. Using a mean velocity of 1820 m/sec from the mudline to 530 meters, a reasonable velocity based on the shipboard data (see Physical Properties section), the two-way travel time to the unconformity should be 0.58 sec, a value that falls between the *Conrad*-11 and *Glomar Challenger* 0.56-sec and 0.60-sec reflectors. The 0.68-sec reflector, or the 0.75-sec reflector of the *Conrad* profile (Figure 13), probably represents the shallowest occurrence of the very hard limestones encountered at approximately 625 to 670 meters depth (Figure 8). The velocity of these limestones is quite high; many are greater than 3 km/sec. If the 0.68-sec reflector lies at a depth of 625 meters, the interval velocity to that depth would be 1.84 km/sec. Figure 14 is an analysis of the sonobuoy record (see Figure 6 for a photograph of the record).

PALEONTOLOGY

Biostratigraphic Summary

Site 318 was cored intermittently between the mudline and 745 meters, except for a portion of the middle Eocene section (Cores 22 to 27; at depths of 596.5 to 653.5 m) which was cored continuously. Nannofossils are present throughout the cored intervals, providing reliable age control for virtually all of the material recovered. Foraminifers are abundant and well preserved in the middle Miocene through Quaternary, but are generally poorly preserved in the Eocene through lower Miocene. Radiolarians of sufficient preservation

TABLE 3
Velocity-Density Parameters, Site 318

Sample (Interval in cm)	Depth in Hole (m)	Compressional Sound Velocity ‖ Beds (km/sec)	⊥ Beds (km/sec)	Anisotropy ‖-⊥ (km/sec)	(‖-⊥) ÷ ⊥ (%)	Temp. (°C)	"Special" Wet-Bulk Density[a] 2-minute count (g/cc) ‖ Beds	⊥ Beds	Wet-Water Content Salt Cor. (%)	Porosity[b] (%)	Acoustic Impedance g 10^5/cm^2 sec	Lithology
2-2, 61-63	28.61	1.968				23.0	1.829		33.14	60.61	3.60[c]	Nanno foram chalk, disturbed lump
3-1, 18-21	64.68	1.612				23.0	1.668		42.69	71.21	2.69[c]	Nanno foram chalk, disturbed lump
6-6, 85-87	158.85	1.620				22.0	1.631		36.23	59.09	2.64[c]	Foram nanno firm ooze, disturbed lump
7-3, 14-18	182.14	1.636				22.0	1.646				2.69[c]	Nanno foram firm ooze
7-4, 119-121	184.69	1.639	1.654	-0.015	- 0.91	22.0		1.674	36.02	60.30	2.77[c]	Nanno foram firm ooze
7-5, 106-108	186.06	1.665	1.669	-0.004	- 0.24	22.0		1.726	39.56	68.28	2.88	Nanno foram firm ooze
8-1, 34-36	207.34	1.698				22.0	1.818		32.11	58.38	3.09[c]	Foram nanno chalk
9-1, 106-108	236.56	1.827	1.839	-0.012	- 0.65	22.0		1.760	31.62	55.65	3.24	Foram nanno chalk
9-2, 50-52	237.50	1.776	1.788	-0.012	- 0.67	22.0		1.726	31.14	53.75	3.09	Foram nanno chalk
10-1, 105-107	265.05	3.222				24.0	2.156		13.97	30.12	6.95[c]	Nanno foram limestone
10-1, 115-117	265.15	2.763				24.0	2.273		25.10	57.05	6.28[c]	Volcanic breccia
10-1, 122-124	265.22	3.956				24.0			12.31			Nanno foram limestone
10-1, 140-142	265.40	4.496				24.0			29.75			Basalt pebble
10-3, 50-52	267.50	1.763				24.0	1.830		30.64	56.07	3.23†	Foram nanno chalk
11-1, 126-128	293.76		1.656			22.0		1.801	31.48	56.70	2.98	Foram nanno chalk
11-3, 45-47	295.95		1.658			24.0		1.805	32.16	58.05	2.99	Foram nanno chalk
12-1, 75-77	321.75	1.786	1.835	-0.049	- 2.67	23.0		1.885	27.13	51.14	3.46	Foram nanno chalk
12-2, 11-13	322.61	1.729	1.700	+0.029	+ 1.71	23.0		1.825	30.38	55.44	3.10	Foram nanno chalk
13-1, 146-148	350.96	1.709	1.713	-0.004	- 0.23	23.0		1.916	27.65	52.98	3.28	Spicule-rich foram nanno chalk
14-1, 41-43	378.41	1.683	1.681	+0.002	+ 0.12	23.0		1.831	28.86	52.84	3.08	Spicule-rich foram nanno chalk
15-1, 124-126	407.74	1.694	1.684	+0.010	+ 0.59	22.0		1.828	29.03	53.06	3.08	Foram nanno chalk
15-2, 106-108	409.06	1.983	1.976	+0.007	+ 0.35	23.0		2.039	20.21	41.21	4.03	Foram nanno limestone
16-1, 95-97	435.95	1.754	1.730	+0.024	+ 1.39	22.0		1.942	26.86	52.16	3.36	Foram nanno limestone
16-2, 77-79	437.27	1.861	1.752	+0.109	+ 6.22	22.0		1.961	25.82	50.82	3.44	Foram-rich nanno limestone
16-3, 120-122	439.20	1.844	1.735	+0.109	+ 6.28	23.0		1.991	25.91	51.59	3.45	Foram-rich nanno limestone
16, CC	439.51		4.997			23.0			0.35			Chert
17-2, 5-10	465.05	5.067				22.0	2.502		1.67	4.18	12.77[c]	Chert
17-2, 26-28	465.26	1.977	1.973	+0.004	+ 0.20	22.0		2.070	20.58	42.60	4.08	Foram-rich nanno limestone
18-1, 92-94	492.92	1.680	1.669	+0.011	+ 0.66	22.0		1.838	29.00	53.30	3.07	Foram-rich nanno limestone
18-2, 46-48	493.96	2.214	2.278	-0.064	- 2.81	22.0	2.009		22.80	45.80	4.58	Nanno foram-rich volcanic silty sandstone
18-2, 65-67	494.15	3.617	3.681	-0.064	- 1.74	22.0		2.301	11.14	25.63	8.47	Nanno foram limestone
19-2, 147-149	523.47	3.161	3.294	-0.133	- 4.04	22.0		2.224	15.50	34.47	7.33	Foram nanno limestone
20-1, 92-94	549.92	1.827	2.034	-0.207	-10.18	22.0		2.140	17.46	37.36	4.35	Foram-rich nanno limestone
20-2, 74-76	551.24	1.902	1.878	+0.024	+ 1.28	22.0		1.961	23.51	46.10	3.68	Foram-rich nanno limestone
20-3, 77-79	552.77	2.116	1.702	+0.414	+24.32	22.0		2.022	21.36	43.19	3.44	Foram-rich nanno limestone
20-4, 92-94	554.42	2.040	1.994	+0.046	+ 2.31	22.0		2.014	22.61	45.53	4.02	Foram-rich nanno limestone
20-5, 87-89	555.87	1.812	1.796	+0.016	+ 0.89	22.0		1.925	24.68	47.51	3.45	Foram-rich nanno limestone
21-2, 34-36	579.34	1.775	1.753	+0.022	+ 1.25	22.0		1.904	25.88	49.28	3.34	Foram nanno limestone
21-3, 84-86	581.34	1.990				22.0	1.613		40.18	64.81	3.21[c]	Nanno- foram-rich volcanic siltstone
21-3, 122-124	581.72	3.507	3.233	+0.274	+ 8.48	22.0		2.454	8.20	20.12	7.93	Foram-rich nanno micritic limestone
22-1, 98-100	597.48	2.700	2.757	-0.057	- 2.07	21.0		2.304			6.35	Nanno limestone, laminated
22-2, 89-91	598.89	2.698	2.783	-0.085	- 3.05	21.0		2.268	11.36	25.76	6.31	Foram-rich nanno limestone, laminated
22-3, 82-84	600.32	2.742	2.696	+0.046	+ 1.71	21.0		2.291	12.34	28.27	6.18	Foram-rich nanno limestone, laminated
22-4, 111-113	602.11	4.114	3.835	+0.279	+ 7.28	21.0		2.370	5.08	12.04	9.09	Micritic limestone, laminated
23-2, 37-39	607.87	3.128	3.037	+0.091	+ 3.00	22.0		2.329	12.03	28.02	7.07	Foram-rich nanno micritic limestone
23-3, 48-50	609.48	2.859				22.0	2.209		15.58	34.42	6.32[c]	Nanno foram silty sandstone
23-3, 52-54	609.52	3.291	3.093	+0.198	+ 6.40	22.0		2.245	10.85	24.36	6.94	Nanno micritic limestone
24-1, 39-41	615.89	2.640				21.0	2.035		14.88	30.28	5.37[c]	Nanno volcanic clayey siltstone
24-1, 143-145	616.93	3.265	3.058	+0.207	+ 6.77	21.0		2.389	8.73	20.86	7.31	Nanno micritic limestone
24-2, 124-126	618.24	4.285	3.963	+0.322	+ 8.13	21.0		2.441	4.44	10.83	9.67	Micritic limestone
24-3, 69-71	619.19	4.262	3.861	+0.401	+10.39	21.0		2.395	4.50	10.78	9.25	Micritic limestone
24-4, 78-81	620.78	4.380	4.194	+0.186	+ 4.43	21.0		2.424	4.77	11.56	10.17	Micritic limestone

25-2, 53-55	627.03	2.857	2.635	+0.222	+ 8.43	21.0		2.360	9.06	21.38	6.22	Foram-rich nanno micritic limestone
25-3, 134-136	629.34	2.979	2.562	+0.417	+16.28	21.0		2.281	12.10	27.60	5.84	Foram-rich nanno micritic limestone
25-4, 116-118	630.66	2.226	1.985	+0.241	+12.14	21.0		1.557	42.30	65.80	3.09	Spicule-rich volcanic siltstone
26-2, 116-118	637.16	3.107	2.635	+0.472	+17.91	21.0		2.280	7.62	17.37	6.01	Foram nanno-rich clayey micritic limestone
26-3, 105-107	638.55	3.579	3.111	+0.468	+15.04	21.0		2.334	10.65	24.86	7.26	Foram-rich nanno micritic limestone
26-4, 106-108	640.06	2.531	2.104	+0.427	+20.29	21.0		2.068	18.88	38.04	4.35	Calcareous volcanic siltstone
26-5, 70-72	641.20	2.148	1.936	+0.212	+10.95	21.0		1.714	35.47	60.80	3.32	Calcareous clayey siltstone
27-1, 122-124	645.22	3.724	3.438	+0.286	+ 8.32	21.0		2.306	7.00	16.14	7.93	Foram-rich nanno micritic limestone
27-2, 126-128	646.76	2.991	2.611	+0.380	+14.55	21.0		2.285	12.03	27.49	5.97	Foram nanno-rich clayey micritic limestone
28-1, 123-125	664.23	3.684	3.376	+0.308	+ 9.12	21.0		2.245	6.39	14.35	7.58	Foram-rich nanno micritic limestone
28-2, 37-39	664.87	2.657	2.427	+0.230	+ 9.48	21.0		2.257	12.25	27.65	5.48	Nanno foram-rich clayey micritic limestone
28-3, 122-124	667.22	3.248	2.942	+0.306	+10.40	21.0		2.273	9.73	22.12	6.69	Nanno foram-rich micritic limestone
29-1, 78-80	682.78	3.523				21.0	2.334		8.70	20.31	8.22	Foram-rich nanno micritic limestone
29-2, 98-100	684.48	4.427	4.074	+0.353	+ 8.66	21.0		2.564	4.93	12.64	10.45	Nanno-rich micritic limestone
30-1, 139-141	702.39	2.186	1.989	+0.197	+ 9.90	22.0		1.587	41.09	65.21	3.16	Volcanic spicule-rich sandy siltstone
30-2, 72-74	703.22	3.027	2.311	+0.716	+30.98	22.0		2.191	14.92	32.69	5.06	Foram-rich clayey micritic limestone, laminated
30-3, 125-127	705.25	3.245	2.724	+0.521	+19.13	22.0		2.279	11.36	25.89	6.21	Foram-rich micritic clayey limestone, laminated
31-1, 105-107	720.55	2.305	2.145	+0.160	+ 7.46	21.0		1.901	27.82	52.89	4.08	Volcanic and carbonate, foram-rich silty sandstone, laminated
31-2, 42-44	721.42	2.924	2.526	+0.398	+15.76	21.0		2.463	11.79	29.04	6.22	Nanno foram-rich clayey limestone, laminated
32-1, 96-98	739.96	2.976	2.518	+0.458	+18.19	21.0		2.047	10.43	21.35	5.15	Nanno foram-rich clayey micritic limestone, laminated
32-1,141-143	740.41	2.228	1.922	+0.306	+15.92	21.0		1.795	29.71	53.33	3.45	Carbonate-rich volcanic silty claystone
32-2, 96-98	741.46	1.898	2.032	-0.134	- 6.59	21.0		1.757	36.50	64.13	3.57	Carbonate-rich volcanic silty claystone, laminated
32-3, 61-63	742.61	2.184	1.935	+0.249	+12.87	21.0		1.701	33.22	56.51	3.29	Volcanic clayey siltstone
32-4, 55-57	744.05	2.461	2.326	+0.135	+ 5.80	21.0		1.944	28.20	54.82	4.52	Volcanic silty sandstone

[a]ρ_g & ρ_{gc} = 2.70 for sed. rocks. 265 for cherts, and 2.86 for basalt.

[b]Porosity = (salt corrected wet-water content) X (wet-bulk density).

[c]Horizontal.

for age determination are present only in the upper Oligocene to upper Miocene, and in a part of the middle Eocene section. Sponge spicules dominate the siliceous fraction of the sedimentary rocks. Diatoms and silicoflagellates appear to be absent.

The sediments recovered range in age from Quaternary to lower Eocene (Zone NP13; approximately 49-51 m.y.B.P.). One major unconformity is present between Cores 9 and 10 (245 to 264 m), and is indicated by the absence of part of the lower and middle Miocene section. Another major discontinuity may be present in the base of Core 15, between mid-Oligocene and upper Eocene; and a hiatus, similar or identical to one at Site 317, was found between the middle and upper Eocene of Cores 20 and 19, respectively.

Mixed faunal assemblages, which contain species whose ranges do not overlap, are characteristic of many of the samples examined. Middle Eocene radiolarians are commonly reworked into Neogene assemblages. Among the Eocene foraminifers, the presence of *Asterocyclina* sp. and a pelagic foraminiferal assemblage showing very little dissolution indicates reworking from a relatively shallow source. Thus, reworked debris from a shallower source area (presumably one or more of the nearby Tuamotu edifices) is present within much of the sedimentary material examined at this site.

Foraminifers

A discontinuous and condensed, richly foraminiferal sequence spanning middle Eocene through Quaternary was cored at Site 318. Foraminifers are abundant and well preserved in middle Miocene to Quaternary rocks; with a few notable exceptions, they are poorly preserved in Eocene to lower Miocene rocks. In the upper Eocene through lower Miocene, poor preservation is a result of dissolution, while in the middle Eocene preservation deteriorates downward with increasing lithification (though foraminifers remain common). The faunas throughout are very similar to those in rocks of similar age at Site 317.

Quaternary

Core 1 is of Quaternary age and contains a typical low-latitude planktonic fauna, dominated by the *Globigerinoides sacculifer* group. *Streptochilus tokelauae* is common and extends into the underlying Pliocene and upper Miocene sediments.

Pliocene

Cores 2, 3, and 4 are of Pliocene age and contain a typical Pliocene faunal sequence, including *Pulleniatina spectabilis*; the occurrence of this species at Site 318 is the southernmost yet reported for this areally restricted species.

Miocene

The upper Miocene (Cores 5 and 6) is probably in depositional continuity with the overlying Pliocene, but a hiatus probably separates the *Globorotalia acostaensis* Zone sediments of Core 6 from the *G. menardii* Zone sediments of Core 7, which in turn probably disconformably overlies middle Miocene sediments of Cores 8

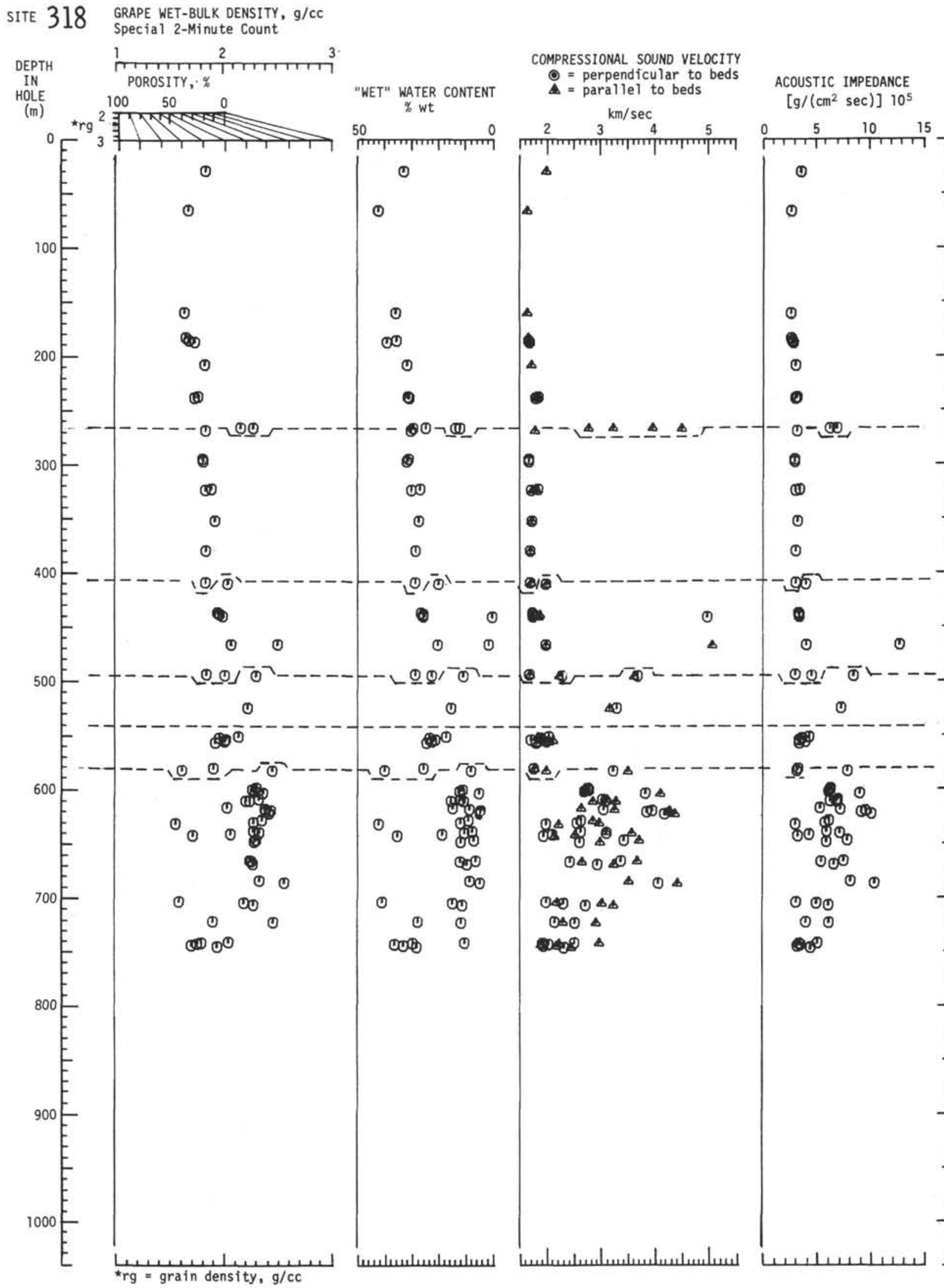

Figure 12. *Summary of physical properties at Site 318. GRAPE analog data, both corrected and uncorrected for actual core diameter, are presented at the end of this chapter.*

TABLE 4
Site 318 Summary of Stratigraphic Grouping on the Basis of Rock Physical Properties (Lab Temperature and Pressure)

Lithology	Depth (m)	Cores	Typical Wet-Bulk Density (g/cc)	Typical Wet-Water Content (wt %)	Typical Porosity (vol %)	Typical Sound Velocity (km/sec)	Typical Acoustic Impedance $\frac{g\ 10^5}{cm^2\ sec}$	Typical Reflection Coefficient at Boundary (no chert)
Foram nanno ooze and chalk; Breccia and conglomerate at base: Quaternary to Miocene	0 to 265.5	1-10	1.63-1.83 (cgl. 2.2-2.3)	31-43 (cgl. 12-30)	53-71	1.61-1.97 (cgl. 2.7-4.5)	2.8 (2.6-3.6)	0.37
Foram nanno chalk: Miocene to Oligocene	265.5 to ~408	10-15	1.83	28	54	1.7	3.1	0.13
Foram nanno, nanno chalk and limestone: Oligocene to Eocene	~408 to ~494	15-18	2.0 (1.83-2.07) (chert 2.5)	24 (20-27) (chert 1.7)	47 (41-53) (chert 4.0)	1.8 (1.6-2.3) (chert 5.1)	3.7 (3.0-4.1) (chert 12)	0.30
Nanno limestone: Eocene	~494 to ~540	18-19	2.25	13	31	3.4	7.9	0.26
Nanno limestone; Minor interbedded clastics: Eocene	~540 to 581.5	20-21	2.0 (1.6-2.1)	21 (17-40)	46 (37-64)	1.8-2.1	3.2-4.4	0.42
Nanno limestone, siliceous limestone, clayey limestone, and volcaniclastic interbeds: Eocene	581.5 to ~745	21-32	1.8 and 2.3 (1.55-2.65) irregularly decreasing downward	32 and 10 (4-42)	(10-65) irregularly increasing downward	1.9-4.4 generally decreasing downward	3.5-10.0	

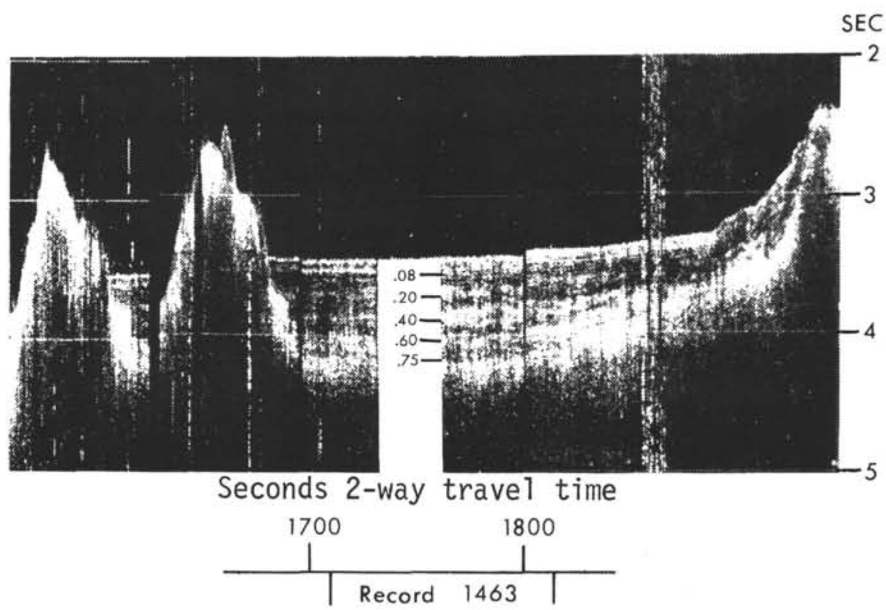

Figure 13. Conrad-*11 seismic reflection profile, showing reflector stratigraphy.*

and 9, which contain *G. fohsi s.l.* Another (more pronounced) hiatus separates the latter from lower Miocene, *Globorotalia kugleri* Zone sediments of Cores 10 through 12, which are in depositional continuity with the underlying upper and middle Oligocene sedimentary rocks of Cores 13-15.

The upper Miocene faunas are monotonous; *Globigerinoides* groups are dominant and *Globorotalia acostaensis* is very scare. *Globorotalia kugleri* is dominant in its zone, along with common specimens of the early *Globigerinoides* lineage.

Oligocene

The Oligocene faunas of Cores 13-15 are poorly preserved and apparently only the *globorotalia opima* and *"Globigerina ciperoensis"* zones are represented. As at Site 317, *Globorotalia opima* is scarce, and *G. ciperoensis* is not present (the zone is here interpreted as the interval between the last *G. opima* and first *G. kugleri*).

Eocene

The upper Eocene (*Globorotalia cerroazulensis* and *Globigerapsis mexicana* zones) are contained in rocks of

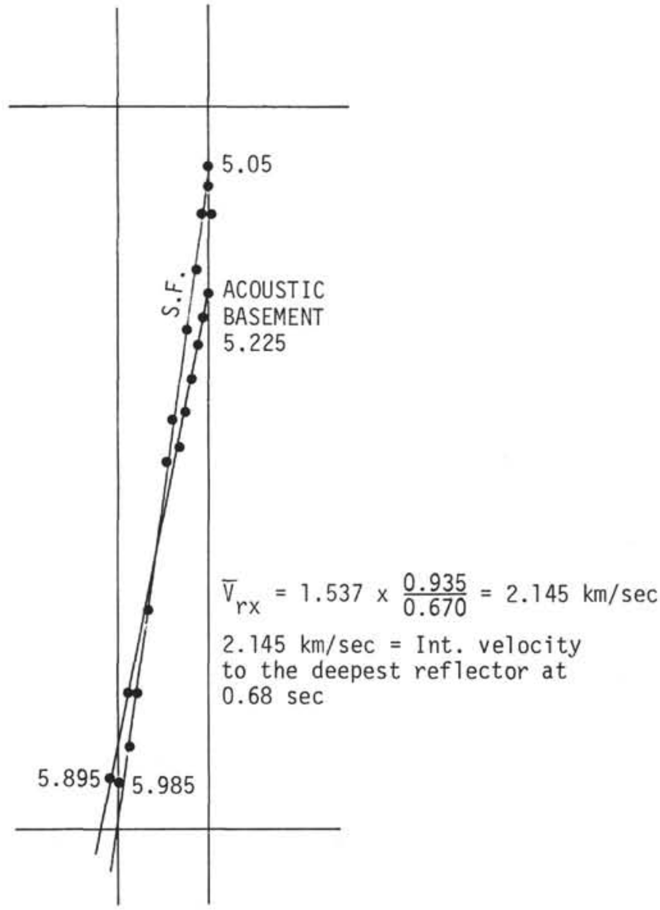

Figure 14. *Analysis of sonobuoy record at Site 318 (preliminary).*

Cores 16-19. Preservation shows a pattern similar to that at Site 317; that is, poor preservation (dissolution) in the uppermost Eocene, with improvement downward into the *G. mexicana* Zone. Also, as at Site 317, the upper Eocene disconformably overlies the middle Eocene *Globorotalia lehneri* Zone.

A remarkably well preserved fauna of the *Globigerapsis mexicana* Zone was found in a graded bioclastic bed in Sections 1 and 2 of Core 19. The upper portion of this bed contains commonly occurring specimens of, among others, *Hantkenina* cf. *H. alabamensis*, and specimens transitional between *Globorotalia centralis* and *G. cerroazulensis*. Test walls are often glassy and without the chalky surface of specimens from typically abyssal sequences. The good preservation, along with the presence of *Asterocyclina* in the coarser parts of the bed, indicates a relatively shallow source for the graded bed. Also, a penecontemporaneous origin is suggested by the lack of elements foreign to a *G. mexicana* Zone assemblage.

The uppermost *G. lehneri* Zone fauna of Core 20 is moderately well preserved, but below this level induration increasingly obliterates the foraminiferal assemblages, which are apparently recrystallized, partially infilled, and deformed by compaction. The lowest, questionably identified assemblages are those of Core 25, which probably belong in the *Hantkenina aragonensis* Zone of the lower middle Eocene, and Cores 30 and 32, which probably are of upper lower Eocene age (*Acarinina densa* Zone).

Large, shore to shelf, tropic to subtropic forms occur erratically but frequently from Cores 2 to 32 (total depth). Amphisteginids, heterosteginids, cycloclypeids (? *Spiroclypeus* sp., Core 2), discocyclinids (*Asterocyclina* sp., Core 19), and others (Core 32) occur often with reefal forms (corals, bryozoans, etc) in turbiditic sands (see Beckmann, this volume).

The age difference between large foraminifers and enclosing sediment is pronounced at the top of the hole (Core 2, Eocene-Oligocene large foraminifers in Pliocene sediment) but decreases to approximate equivalence toward the bottom.

Calcareous Nannoplankton

Cores recovered and nannoplankton zones present seem to indicate that rocks of the Quaternary, Pliocene, and upper Miocene are present without interruption from the sea floor to a depth of approximately 250 meters (Core 9, standard nannoplankton Zone NN9). Reworked middle Eocene nannoplankton species occur in Core 2 (26 to 35.5 m) in layers that contain reefal debris. Between Core 9 (235.5 to 245 m) and Core 10 (264 to 273.5 m) a major unconformity is present, indicated by the absence of nannoplankton Zones NN3 through NN8; the age gap is equivalent to the middle Miocene and part of the lower Miocene. Also, core-catcher samples of Core 9 as well as rocks in the upper part of Core 10 contain a remarkable amount of redeposited nannoplankton from the NP25 and lower NN1 interval, nearly masking their true age. It seems probable that part of Zone NN1 is missing between Cores 10 and 11, inasmuch as upper NN1 nannofossils were not found in Core 11, which should have been present if continuous sedimentation took place. Below Core 11 (at ~300 m) an obviously complete sequence was cored down to the lower Eocene nannofossil Zone NP13. At approximately 690 meters the younger, predominantly calcareous sediments become increasingly rich in green siltstones and limestones, with an increase in accumulation rate. With few exceptions, almost all of these lower rocks are barren of calcareous nannoplankton. From the lower Oligocene downwards (Core 6, at ~440 m) nannoplankton assemblages indicate "near shore environments," as *Zyrghablithus bijugatus* and representatives of the genera *Braarudosphaera, Micrantholithus,* and *Discolithina* occur quite frequently.

In the Quaternary and Pliocene part of the sequence calcareous nannoplankton are well preserved, but become moderate to poorly preserved in the Miocene, and solution effects and heavy overgrowth on discoasters can be seen throughout the Miocene section. In the Oligocene and upper Eocene solution effects are less obvious, but overgrowth is present on all nannoplankton species. With the change toward more silty to sandy sediments in the middle Eocene, preservation of nannoplankton becomes very poor, and species identification at certain levels is extremely difficult or impossible.

Radiolarians

Radiolarians of sufficient abundance and preservation for age determination are present in only two intervals of the sedimentary column cored at Site 318. The upper Miocene through upper Oligocene (Cores 5 through 13; which range in depth from 131 through 359 m) have a siliceous assemblage dominated by sponge spicules, but contain a sufficient number of diagnostic radiolarians for reliable age control. The middle Eocene *Thyrsocyrtis triacantha* Zone is represented in a moderately to poorly preserved radiolarian assemblage in Cores 22 through 25 (depth range 606 to 635 m). The remainder of the cored intervals are barren of radiolarians.

Within the radiolarian-bearing intervals, the following standard radiolarian zones can be recognized: Core 5 (121.5 to 131.0 m) is in the *Stichocorys peregrina* Zone. Core 6 (150.0 to 157.5 m) is in the *Ommatartus penultimus* Zone. Core 7 (178.5 to 188.0 m) is in the *Ommatartus antepenultimus* Zone. Cores 8 and 9 (207.0 to 245.0 m) are in the *Calocycletta costata* Zone. Cores 10 and 11 (264.0 to 302.0 m) are in the *Calocycletta virginis* Zone. Core 12 (321.0 to 330.5 m) is in the *Lychnocanoma elongata* Zone. Core 13 (349.5 to 359.0 m) is in the upper *Dorcadospyris ateuchus* Zone. Cores 14 through 21 are barren of radiolarians, or contain only unidentifiable fragments. Cores 22 through 25 (596.5 to 634.5 m) are in the *Thyrsocyrtis triacantha* Zone. Radiolarians are absent below Core 25.

Reworked radiolarians of middle Eocene age are rare to common in virtually the entire Neogene section (Cores 5 through 13). The physiographic setting of this site is favorable for the accumulation of erosional products from nearby Tuamotu edifices; thus, the extensive reworking of radiolarian debris is not surprising.

ACCUMULATION RATES

As shown in Figure 15, sedimentation rates at Site 318 have been high during the past 50 m.y. Situated in a trough atop a volcanic ridge and surrounded by atolls, the site has been receiving carbonate sediments of both pelagic and reefal origin as well as abundant volcaniclastic debris of clay to pebble size. Thus the high rates are not necessarily indicative of high productivity of plankton in the water column; turbidites are a major component of the section. From early to middle Eocene time the accumulation rate was approximately 65 to 70 m/m.y.; abundant reefal and volcanic material marks this part of the section. For the remainder of Eocene time the rate slowed to approximately 25 m/m.y. Through Oligocene time the rate further slowed to 12 m/m.y. as pelagic sedimentation dominated. After formation of the early-middle Miocene unconformity, the rate increased from about 13 to 25 m/m.y., marked by a heavy influx of reefal and volcanic material.

SUMMARY AND CONCLUSIONS

Site 318 was drilled very close to its preplanned location along the *Conrad*-11 track, in 2659 meters of water. One hole was drilled to a depth of 745 meters; nearly 300 meters were cored, with an average core recovery of more than 49%. It was hoped that the lowest reflector

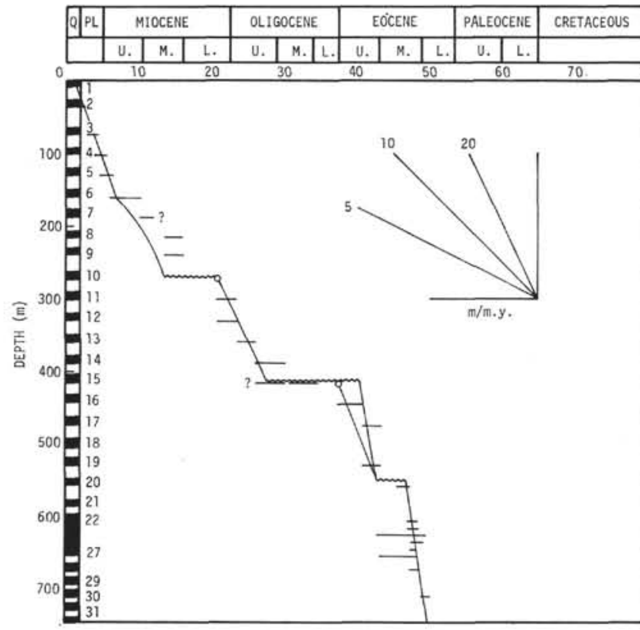

Figure 15. *Graphic log showing age and rate of sediment accumulation at Site 318.*

observed on both the *Conrad*-11 and our own acoustic profiles, which lay at predrilling estimated depths between 650 and 700 meters, was basalt basement. We reached depths exceeding our original estimates, but did not succeed in penetrating or sampling basalt basement rocks at the site, although we used all of our remaining leg time in attempting to do so.

The geologic column drilled at the Tuamotu Ridge site was divided into five lithologic units:

1) Nannofossil-foraminifer ooze that contains some graded beds of shallow water skeletal debris made up of foraminifera, bryozoans, corals, echinoids, and mollusks, and altered volcanogenic material. This unit extends from 0 to between 35.5 and 64.5 meters, and is of Quaternary to upper Pliocene age; large foraminifers of Eocene to Oligocene(?) age are present as redeposited faunal elements.

2) Foraminifer and nannofossil firm ooze, changing downward to soft chalk that contains a few graded beds of sand-sized material of volcanogenic origin. The unit extends from depths of between 35.5 and 64.5 to between 245 and 264 meters, and is late Pliocene to middle Miocene in age. It is separated from Unit 3 by a middle-lower Miocene hiatus between Cores 9 and 10.

3) Foraminifer-nannofossil, yellowish-gray chalk, that contains a breccia bed with pebbles of basalt, chert, and shallow water skeletal debris of reef and near-reef origin. This unit extends from depths of between 245 and 264 meters to between 416 and 435 meters. The unit is of lower Miocene to lower Oligocene age.

4) Nannofossil and foraminifer limestone, generally yellowish-gray to pale green in color, with abundant chert nodules and lenses that include some volcanogenic debris. The base of the unit is a coarse, pebbly sand containing abundant shallow water skeletal debris. The unit occurs between 416 and 435 meters to between 530 and

549 meters, is lower Oligocene through upper Eocene in age, and its base coincides with a minor hiatus and with the 530-meter acoustic reflector discussed below.

5) Green and grayish-green clayey limestone, siltstone, and sandstone, in graded beds as thick as 2.5 meters. The upper 100 meters of the unit contain some chert, and the amount of volcanogenic materials increases downward. The unit occurs between 530 and 549 meters depth to the bottom of the hole at 745 meters, and is of lower to middle Eocene age. At the base of the unit abundant coarse-grained reef debris characterized by large benthonic foraminifers was cored. The unit contains the acoustic reflector at 625 meters, discussed below.

A number of reflectors can be distinguished on the profiler records near Site 318, but all except two are irregular and discontinuous. This irregularity may be due to periodic but not necessarily chronologically equivalent influxes of sedimentary debris from the several edifices that surround the basin. Preliminary analysis of reflector stratigraphy suggests that the 0.56 to 0.60 sec reflector observed in the underway profiles corresponds to an unconformity between middle and upper Eocene strata, and that the 0.68-sec reflector observed in the sonobuoy records corresponds to the appearance of the very hard limestones at a depth of about 625 meters, some 90 meters beneath the unconformity.

The geological history of the general area drilled can be partially derived from bathymetric, profiler, and drill cores retrieved, but the volcanic history must remain largely speculative as a result of our inability to reach basement. The site was chosen near the northwest terminus of the Tuamotu chain, in an open sedimentary trough atop a ridge-like feature that we consider to be a portion of one of the Tuamotu constructional edifices. The basin proved to be filled with more than 745 meters of sedimentary rocks, beginning with an exceedingly heavy influx (as much as 70 m/m.y.) of coarse volcanogenic debris and shallow water foraminifers. Ages derived from several paleontological groups near the bottom of the hole are in close agreement, and yield an age at that depth of 49-51 m.y.B.P. If the basement rocks beneath are a portion of the Tuamotu Ridge, and if the volcanogenic sediments are derived by erosion of higher portions of the ridge or the nearby edifices marked by the coralline islands of Ahe, Rangiroa, and Arutua, then all of the basaltic edifices in the immediate area are older than that date. How much older, we cannot say, except that, considering the sedimentation rate and character and abundance of the volcanogenic debris at the bottom of the hole, it seems unlikely that the cessation of volcanism was prior to early Eocene time. Deep Sea Drilling Site 76 (Hays et al., 1972) also recovered reefal debris of probable lower Eocene age that had been redeposited in Pliocene turbidites on the northern flank of the Tuamotu chain about 175 km north of Site 318, which tends to indicate that most of the edifices in this general area were built; eroded, and capped by reefs by 50 m.y.B.P.

At that time the basin beneath Site 318 was receiving turbidity currents consisting of volcanogenic sandstones and siltstones, intermixed with shallow water foraminiferal debris. This debris arrived at an average rate of 70 m/m.y. through much of lower and middle Eocene time, gradually decreasing in middle Eocene time. Nearly continuous pelagic sediments were deposited in the basin from that time to the present, although depositional hiatuses mark middle and late Eocene time, mid-Oligocene and upper Eocene time, and early through middle Miocene time. During the entire period from middle Eocene through Quaternary, the basin continued to receive small amounts of reefal and volcanogenic debris. Such small pebbles of basaltic rock as are present appear to be of alkaline character (the rocks appear to be of alkalic basalt-hawaiite types). Floods of reefal debris entered the basin in turbidite flows in middle Eocene and early Miocene time; turbidite deposition of reefal material has evidently continued to the present as shown by skeletal debris in Core 1.

Early Eocene edifice ages in this area do not "extrapolate" to Line Islands edifice ages; indeed, at the conclusion of our Line Islands sites we were unable to document a southward younging of the Line Islands. The morphology and available age data in the Tuamotu chain, however, still suggest that it is of Hawaiian aspect and that it does young to the southeast (Dana, 1876; Clague and Jarrard, 1973; Jackson and Shaw, 1975). The age of basement basalt below Muroroa Atoll, approximately 1300 km to the southeast of Site 318 is reported to be 7 ±1 m.y.B.P. (Chevalier, 1974), and the age of Gambier Island, approximately 1800 km from Site 318, if indeed it is a part of the Tuamotu chain, is given between 4.7 and 6.8 m.y. (Brousse, et al., 1972). These rather incomplete data suggest that the Tuamotu chain, like the Hawaiian chain (Shaw, 1973; Shaw and Jackson, 1973) becomes younger to the southeast in an episodic rather than a linear fashion.

Inasmuch as we failed to reach basement at Site 318 we can give only minimum ages for constructional volcanism in this part of the Tuamotu chain. Nevertheless, the minimum age of 49-51 m.y.B.P. is older than Clague and Dalrymple's (1973) estimate of 42 m.y. for the Hawaiian-Emperor bend. Their estimates of this age was in part based on a date of 46 m.y. at Koko Seamount. More recently Leg 32 of Deep Sea Drilling Project (Larson, Moberly, et al., 1973), reported fossil ages at Koko as much as 6 m.y. older than Clague and Dalrymple's radiometric dates on volcanic rocks there. Still more recently, Clague et al. (1975) dated Yuryoku Seamount at the Hawaiian-Emperor bend at 42.3 ±1.6 m.y.B.P. Based on data at hand, it would appear that Tuamotu volcanism preceded Hawaiian-Emperor bend volcanism, at least by a few millions of years.

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Site 318 Hole Core 1 Cored Interval: 0.0-7.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
QUATERNARY	(FORAMS: MIXED U. PLIO. - QUAT.) NN20/21	N	A	G	0					
					1	0.5, 1.0			90, 140	10YR 8/4
					2					10YR 8/3; 10YR 5/4; 10YR 8/3; 10YR 5/4
					3				79	10YR 8/3; 10YR 6/4; 10YR 8/3
					4		VOID			10YR 8/2
		N	A	G	5					10YR 8/2; 10YR 7/3; 10YR 8/2
		R, N, F	—, A, A	—, G, G	Core Catcher				CC, CF	

Very pale orange (10YR 8/2 to 10YR 8/4) NANNOFOSSIL FORAM OOZE. Has texture of firmly packed sand. Darker mottles of moderate yellowish brown (10YR 5/4) NANNO FORAM OOZE at 2.16 and 2.90 m and a layer of dark yellowish orange (10YR 6/4) NANNO FORAM OOZE, from 3.23 to 4.05 m.

A graded foram sand unit has its base at 3.23 m, possibly extending through section 2; another graded unit begins near 4.5 m and probably extends through the dark-colored layer to 3.23 m. Another contact between coarser foram sand above and finer sand below occurs at 6.44 m.

Smear Slides:

Forams	D
Nannos	C
Bryozoans	R
Mollusks	R
Zeolites	R
Fe-Specks	R 2-10µm
Radiolarian fragments	V. Rare
Volc. Glass fragments R. I. >1.57	

Coarse Fraction >177µm:

Forams D

Other constituents include bryozoans, mollusks, zeolite prisms, olivine (ore grain); possible milky white chert fragments; interior walls of foram tests have coarse prismatic calcite crystals; foram test perforations sometimes filled with pyrite(?).

GRAIN SIZE

(3-0 cm):	75.1 Sand, 16.9 Silt, 8.1 Clay
(3-21 cm):	79.7 Sand, 12.9 Silt, 7.4 Clay

Site 318 Hole Core 2 Cored Interval: 26.0-35.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
QUATERNARY	NN19 / G. limbata				0					
					1	0.5, 1.0	VOID			10YR 8/1 to 10YR 8/2
		N	A	G						
		N	A	G	2				67, 82	10YR 7/3; N9; 10YR 8/2; N9; 10YR 8/2; N9
		N	A	G						
UPPER PLIOCENE	NN18	F, N, R	A, A, —	G, G, —	Core Catcher					

Very pale orange (10YR 8/2) NANNO FORAM OOZE and SHELLY FORAM OOZE, consisting of graded layers containing abundant granule-sized skeletal debris of forams, bryozoa, calcareous algae, echinoids, and mollusks. Small pebbles of nanno-bearing zeolitic claystone of Eocene age at 2.36 and 2.49 m.

Interbedded with white (N9) and grayish orange (10YR 7/3) nanno foram soft chalk and firm ooze, preserved as "biscuits" fragmented during drilling.

Smear Slides:

(2-82 cm) Pebble of zeolitic-claystone; may represent altered volcanic sandstone; also present are:

Forams	R
Nannos	R
Fe-Specks	R
Zeolite	A
Clay	A

(2-67 cm):

Forams	A
Nannos	D
Micrite	C
Fe-Specks	R

Core catcher >420µm:

Fragments of:
- Large Forams
- Bryozoans
- Probable Coral
- Halimeda (?)
- Mollusks (pink and white)
- Echinoid Spines (pink)

Explanatory notes in Chapter 1

Site 318 Hole Core 3 Cored Interval: 64.5-74.0 m

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
LOWER PLIOCENE	G. altispira NN15	N	A	G	1	0.5, 1.0			60, 67, 125	N9; 5Y 8/2; N9; N3; N5
		F N R	A A –	G G –	Core Catcher				CC	

White (N9) FORAM NANNO FIRM OOZE to SOFT CHALK.

65-69 cm:
Layer of yellowish gray (5Y 8/2) nanno foram ooze, with rare dark-colored volcanic sand grains.

Medium gray (N3, N5) mottles (pyritic?) at 116 and 125 cm.

Smear Slides:
(1-60 cm):
Nannos D
Forams C
Green Amphibole or Pyroxenes R

(1-67 cm):
Forams D
Nannos C
Green Volcanic Fragments altered to Clay R
Sp. Spic. R

Site 318 Hole Core 4 Cored Interval: 93.0-102.5 m

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
LOWER PLIOCENE	Globorotalia tumida NN13	N	A	G	1	0.5, 1.0			45, 64, 129	N7; N5; N4; N7; N8
					2					
					3					N9; 5B 9/1
					4				80	5B 9/1
					5					5B 9/1; 5G 9/1; 5B 9/1 + 5B 8/1
		N	A	G	6				85	N9; 5B 9/1; 5GY 8/1; 5B 9/1; 5GY 8/1; 5B 9/1
		R N F	R A A	P G G	Core Catcher				CC	N6; 5B 9/1; N9

White (N9), bluish white (5B 9/1) and light gray (N6) FORAM NANNO FIRM OOZE, with thin bands of light greenish gray (5GY 8/1) and medium gray (N5) FORAM NANNO FIRM OOZE.

Smear Slides:
(1-45 cm):
Nannos A to D
Forams C to A
Sp. Spic. R

(1-64 cm):
Nannos A to D
Forams C to A
Rads R

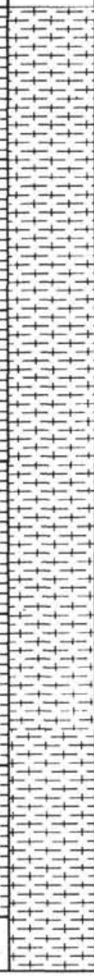
(1-129 cm):
Nannos A to D
Forams C to A
Sp. Spic. R
Foram size appears to be larger in 1-129 cm than in 1-64 cm or 1-45 cm.

(4-80 cm):
Nannos A to D
Forams C to A
Sp. Spic. R
Red Fe-Specks R
Discoasters may be slightly over-calcified.

Explanatory notes in Chapter 1

Site 318 Hole Core 5 Cored Interval: 121.5-131.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
					0					
LOWER PLIOCENE	Pulleniatina primalis NN12 Stichocorys peregrina(?)	N	A	G/M	1	0.5, 1.0			71, 145	N9; N4-N6
		N	A	G/M	2				75	N9
					3				115	N5
					4				38, 50, 121	N9; N5; N9; 5Y 8/2; N9; 5GY 8/2; N5; N9; N5; N5
		N	A	G/M	5					N9
					6				45	N6; N9; N6; N9
		R / N / F	F / A / A	M / G/M / G	Core Catcher					



White (N9) FORAM NANNO FIRM OOZE, with occasional beds of medium gray (N4 to N6) NANNO FORAM and FORAM OOZE. Coarser-grained foram-rich layers are commonly edged by darker (N5) streaks, and contain traces of grayish yellow (5Y 8/2) color.

(1-71 cm):

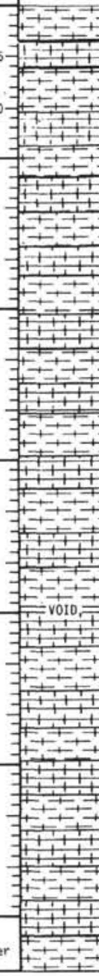
Forams	A to D
Nannos	A
Echinoid Spines	R 100 x 300μm
Pyrite (?)	R
Blocky Calcite	R

(4-121 cm):

Forams	A to D
Nannos	A to D
Echinoid Spines	R
Rads	R
Sp. Spic.	R
Reddish-brown Vesicular Glass	R
Green Clay Fragments	R

Site 318 Hole Core 6 Cored Interval: 150.0-159.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
					0					
UPPER MIOCENE	Globorotalia acostaensis NN11 Ommatartus penultimus	N	A	M	1	0.5, 1.0			75, 91, 100	N9; 5Y 9/1; N9
					2				80	
					3					N9 to 5GY 9/1
					4		VOID			N9 to 5GY 9/1
					5				80	N9; 10G 8/2; 10G 8/2
					6				148	N9
		R / N / F	F / A / A	G / M / G	Core Catcher					



White (N9), and greenish white (5GY 9/1) FORAM NANNO FIRM OOZE and CHALK, with a graded layer of pale grayish yellow (5Y 9/1) NANNO FORAM FIRM OOZE, with its base at 0.91 m, and its top near 0.70 m.

Streaks and thin laminae of medium (N5) to light gray (N7) throughout white ooze and chalk.

Thin laminae of very pale green (10G 8/2) at 6.91-6.97 and 7.21 m.

Smear Slides:

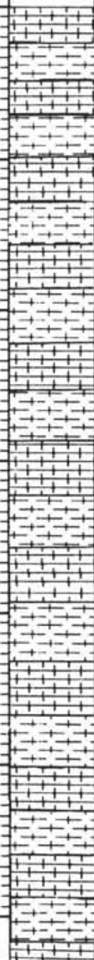
Forams	C
Nannos	D
Rads	R
Sponges	R
Silicofl.	R
Fish Debris	R

In graded bed:

Forams	D
Nannos	C to A
Volc. Glass	R
Micrite	C

Explanatory notes in Chapter 1

Site 318 Hole Core 7 Cored Interval: 178.5-188.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
UPPER MIOCENE	?Globorotalia menardii NN11 Ommatartus antepenultimus	N	A	M	0, 1, 2, 3, 4, 5, 6, Core Catcher	0.5, 1.0			40, 15, 65, 149 2, 108, 10	5G 9/1; N9 to 5G 9/1; N9 to 5B 9/1; N5; 5B 9/1; N9; 5Y 9/1; 5Y 8/1; 5Y 8/1; 5B 9/1 to 5B 7/1; 5G 9/1; N4 to N7; 5B 9/1 and N9
		R N F	F A A	G M G	Core Catcher					

White (N9), greenish white (5G 9/1) and bluish white (5B 9/1) FORAM NANNO FIRM OOZE and CHALK. Mottles, streaks, and wisps of light gray (N7) and medium gray (N5) FORAM NANNO FIRM OOZE throughout, except in graded layer of yellowish white (5Y 9/1) to pale grayish yellow (5Y 8/1) NANNO FORAM to FORAM FIRM OOZE, from 5.58 to 3.66 m. Forams to 500 microns, and ~1% volcanic sand grains in basal part of this graded layer.

Smear Slides:

(1-40 cm):

Nannos	D
Forams	C
Rads	R
Sp. Spic.	R

(3-65 cm):

Nannos	D
Forams	C
Rads	R
Sp. Spic.	R

(3-149 cm):

Forams	D
Nannos	R
Rads	R
Sp. Spic.	R

(4-2 cm):

Dolomite (?) Rhombs	
Forams	D
Nannos	R to C
Rads	R
Sp. Spic.	R

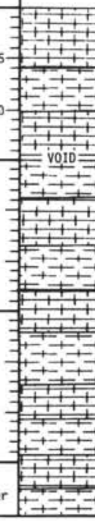
(4-108 cm):

Forams	D
Micrite	C
Nannos	R to C
Rads and Sp. Spic.	R

GRAIN SIZE

(4-3 cm):	29.8	Sand
	55.9	Silt
	14.4	Clay
(4-78 cm):	66.0	Sand
	23.2	Silt
	10.8	Clay
(4-103 cm):	69.3	Sand
	19.6	Silt
	11.0	Clay

Site 318 Hole Core 8 Cored Interval: 207.0-216.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
UPPER MIOCENE	?Globorotalia menardii NN9 Cannartus petterssoni	N	A	M	0, 1, 2, 3, Core Catcher	0.5, 1.0			68, 148, 88, CC	5B 9/1; N9 to 5B 9/1; N9 to 5G 9/1; N9; N9; N7 and N9; N9
		N	A	M						
		F N R	A A F	G M G	Core Catcher					

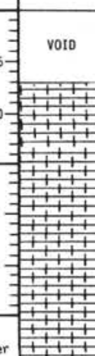
White (N9) and bluish white (5B 9/1) FORAM NANNO FIRM OOZE to CHALK.

A few mm laminae of light gray (N7) color.

Smear Slides:

Forams	C to A
Nannos	D
Rads	R
Sponges	R

Site 318 Hole Core 9 Cored Interval: 235.5-245.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE MIOCENE	?Globorotalia menardii NN9 Calocycletta costata or younger	N	A	M	0, 1, 2, Core Catcher	0.5, 1.0			96 111, 80, CC	N9; → 5G 2/2; N9
		N	A	M						
		F N R	A A C	G M G	Core Catcher					

White (N9) FORAM NANNO CHALK with a few mm-scale laminations.

Rare (1%) sand-sized grains of dark volcanogenic material throughout.

At 2.30 m: a pebble of very dusky green (5G 2/2) palagonitic clay, about 1 cm in diameter.

Smear Slides:

Forams	C
Nannos	D to A
Micrite	R to A
Rads	R
Sponges	R to C

Explanatory notes in Chapter 1

Site 318 Hole Core 10 Cored Interval: 264.0-273.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
					0					
LOWER MIOCENE	Globorotalia kugleri NN2 Calocycletta virginis	N	F	M	1	0.5 1.0	VOID		110 120 125	5Y 9/1 5Y 2/4 5Y 7/2
		N	A	M						
		N	A	M	2				87	
		N	A	M	3				56	5Y 7/2
					4					
		N F	A C	M M	Core Catcher				CC	

Yellowish gray (5Y 7/2) FORAM NANNO CHALK, preserved as "biscuits" separated by intervals of drilling paste. The chalk "biscuits" are shattered by fractures induced by the coring process.

From 1.1 to 1.5 m are pieces of:

A. BRECCIA, consisting of angular fragments of various VOLCANIC ROCKS to 1 cm diam., mainly in shades of very dusky red (5R 2/4, 10R 2/2, etc.), vesicular, altered; SHELLY FORAM LIMESTONE, in shades of yellowish gray (5Y 7/2) and dusky yellow (5Y 6/4); and SKELETAL DEBRIS, up to 5 mm. About 50% volcanic, 40% sedimentary, and 10% shell debris. In T.S., scoria fragments, with plagioclase X'ls, palagonite, large benthonic forams, gastropod (?).

B. BASALT, as rounded cm-size pebbles. Thin sections of 2 of these as follows:

1. Plagioclase augite phyric, fine-grained, sparsely vesicular basalt with fine, ilmenite-rich, glassy groundmass; intersertal texture. Est. mode: vesicles (partly filled), 5%; plagioclase phenocrysts, 15%; augite phen., 5%; replaced augite phen., <5%; groundmass plagioclase, 25%; groundmass augite, 20%, groundmass glass (altered), 25%, groundmass ilmenite, 5%.
2. Vesicular vitrophyric basalt. Est. mode: vesicles (~2 mm), partly filled, 30%; groundmass plagioclase, 25%; groundmass pyroxene, 15%; groundmass glass (altered), 25%; groundmass ilmenite, 5%.

Site 318 Hole Core 11 Cored Interval: 292.5-302.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
					0					
LOWER MIOCENE	Globorotalia kugleri NN1 Calocycletta virginis	N	A	M	1	0.5 1.0			25	5Y 8/1 — N8
					2				81	5Y 8/1 — N9
					3		VOID		30 125	5Y 8/1 — 5Y 9/1
					4					5Y 8/1
					5				63	
					6					
		F N	C A	P M	Core Catcher				CC	

Pale yellowish gray (5Y 8/1) FORAM NANNO CHALK, mottled sparsely with pale gray (N8) and light olive gray (5Y 5/1) small (1-5 mm) burrows.

At 2.8 m, a 5-cm layer of white (N9) FORAM NANNO CHALK, with light gray (N6) mottles. Darker material concentrated at upper and lower contacts.

At 3.3 m, a 5-cm layer of yellowish white (5Y 9/1) NANNO FORAM CHALK, with dark-colored (volcanic) grains making up ~1% of the rock.

At 8.7 to 8.8 m, dark-colored volcanic sand grains constitute ~1% of chalk.

Chalk present as "biscuits", internally fractured by the coring process, and separated by a drilling paste.

Smear Slides:
(1-25 cm):

Nannos	D
Forams	R to C
Rads	R
Sp. Spic.	R
Silicofl.	R

(core catcher):

Forams	A to D
Nannos	C to A
Rads	R
Sp. Spic.	R

Explanatory notes in Chapter 1

Site 318 Hole Core 12 Cored Interval: 321.0-330.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
LOWER MIOCENE	Globorotalia kugleri NN1 Lychnocanoma elongata				1	0.5 1.0	VOID		35	N9; 5Y 8/2 + 5Y 7/2; 5Y 8/1
					2		VOID		10 108	5Y 8/1; N9
		F N	C A	P M	Core Catcher					

White (N9) and pale yellowish gray (5Y 8/1) FORAM NANNO CHALK, with a few sandy foram-rich laminae, with ~1% dark-colored volcanic grains.

Smear Slides:
(1-35 to 40 cm):

Nannos	C to A
Forams	R to C
Micrite	C
Volc. Glass	R

(2-108 cm):

Nannos	D
Forams	R
Rads	R
Sp. Spic.	R

Site 318 Hole Core 13 Cored Interval: 349.5-359.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
UPPER OLIGOCENE	Globigerinia ciperoensis NP25 Dorcadospyris ateuchus	N	A	M	1	0.5 1.0	VOID			5YR 9/1; 5YR 8/1; N9
					2					10YR 8/1
		F N	C A	P M	Core Catcher					

Very pale orange (10YR 8/1), pinkish white (5R 9/1), and white (N9) FORAM NANNO CHALK, with a few mm-scale burrow mottles of medium to light gray (N5 to N7).

At 1.3 m, a 3-cm layer of pale yellowish gray (5Y 8/1) NANNO FORAM CHALK, with ~1% dark-colored volcanic sand grains.

Site 318 Hole Core 14 Cored Interval: 378.0-387.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
UPPER OLIGOCENE	NP25 Globorotalia opima NP25	N	A	M	1	0.5 1.0	VOID		20	N9
		N	A	M	2				123	N9 to N8; 10R 9/1 GEOCHEM
					3				23 140	N9; 10YR 8/4 to 10YR 6/4
		F N	C A	P-M M	Core Catcher					

0.1- 1.5 m:
White (N9) and very light gray (N8) FORAM NANNO FIRM CHALK, with occasional laminae of light gray (N7), and faint white (N9) mottles. Rare dark-colored volcanic sand grains in foram-rich layers.

1.5 m:
Yellowish gray (5Y 8/1) and olive gray (5Y 5/1) CHERT, in a 5-cm chunk.

1.5-2.5 m:
White (N9) to very light gray (N8) FORAM NANNO CHALK, mainly fractured by coring process.

2.5-4.5 m:
A single graded unit, consisting of pinkish white (10R 9/1) NANNO CHALK grading down into white (N9) FORAM NANNO CHALK, grading by gradual increase in proportion of forams into very pale grayish orange (10YR 8/4) to grayish orange (10YR 7/4) to yellowish orange (10YR 6/4) NANNO FORAM CHALK, with dark-colored volcanic grains increasingly abundant towards the base.

Smear Slides:
(1-20 cm; 2-123 cm; 3-23 cm):

Nannos	D
Micrite	C
Forams	R
Rads	R
Sp. Spic.	R

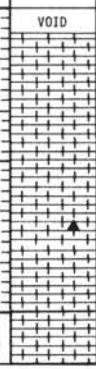
(3-140 cm):

Nannos	A
Forams	A
Micrite	A
Fe-Specks	R to C

Explanatory notes in Chapter 1

Site 318 Hole Core 15 Cored Interval: 406.5-416.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE
					0				
MIDDLE OLIGOCENE	*Globorotalia opima* NP24 / NP23	N	A	M	1	0.5 / 1.0	VOID		55
		N	A	M					
		N	A	M	2				
		N	A	M					137
		F	C	P	Core Catcher				
		N	A	M					



5Y 8/1 and 5Y 6/2
5Y 8/1
5Y 8/2
10YR 5/4
5Y 7/2
5Y 8/2

LITHOLOGIC DESCRIPTION

Pale yellowish gray (5Y 8/1, 5Y 8/2) FORAM NANNO HARD CHALK, with mm-scale mottles of light olive gray (5Y 6/1, 5Y 5/2) and laminae of light olive gray (5Y 5/2).

0.4-0.6 m:
White (N9) NANNO FORAM CHALK, with laminae of pale orange (10YR 8/3) FORAM CHALK, with rare volcanic sand grains.

At 2.2 m:
A 3-cm chunk of moderate yellowish brown (10YR 5/4) CHERT.

Smear Slides:
(1-55 cm):

Nannos	A
Forams	A
Micrite	A

Foram perforations filled with red fe-specks.

(2-137 cm):

Nannos	D
Fe-Specks	R to C
Forams	R

Site 318 Hole Core 16 Cored Interval: 435.0-444.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE
					0				
LOWER OLIGOCENE	*Globorotalia cerroazulensis* NP21	N	A	M	1	0.5 / 1.0	VOID		93 / 107
		N	A	M	2				83
UPPER EOCENE	NP19/20	N	A	M	3				
		N	A	M					
		F	C	P	Core Catcher				
		N	A	M					

5Y 8/1
N9 and N8, N7, N6
N6
5Y 8/1 and N6
5Y 8/1 and N8
5G 9/1
10GY 8/1
10YR 4/2

LITHOLOGIC DESCRIPTION

0.9-2.1 m:
Pale yellowish gray (5Y 8/1) NANNOFOSSIL and FORAM NANNO LIMESTONE, extensively burrowed and mottled by light olive gray (5Y 5/2).

2.1-3.2 m:
Thinly laminated white (N9) and gray (N8, N7, N6, N5) NANNO LIMESTONE. Tiny normal faults displace laminae, and at 2.6 to 2.7 m is a recumbent fold, with minor shear folds on the limbs.

3.2-4.5 m:
Yellowish gray (5Y 8/1), gray (N7, N8), white (N9), greenish white (5G 9/1) and pale yellowish green (10GY 8/1) NANNO LIMESTONE, with darker gray (N5, N6) and grayish green (10GY 5/2) thin laminae.

At 2.3 m:
Two small pebbles of deeply altered volcanic material.

In core catcher:
A 5-cm chunk of dark yellowish brown (10YR 4/2) CHERT.

Smear Slides:
(2-83 cm):

Nannos	A to D	black
Forams	R to C	concre-
Fe-Specks	C	tion

(1-93 cm) white burrowed area:

Micrite	D
Nannos	C
Forams	R to C

(1-107 cm) brownish nonburrowed area:

Nannos	D
Forams	C
Fe-Specks	C ~2µm

Explanatory notes in Chapter 1

Site 318 Hole Core 17 Cored Interval: 463.5-473.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
UPPER EOCENE	Globigerapsis mexicana NP19/20	N	A	M	1	0.5, 1.0	VOID		120	10G 9/1
					2				30	10G 9/2 to 10G 7/2
		F N	C A	G M	Core Catcher					N5 to N7

Greenish white (10G 9/1), very pale green (10G 9/2) to light greenish gray (5G 9/1) to pale green (10G 7/2) NANNO LIMESTONE. Colors become gradually darker toward base of core. Darker colored wisps and laminae of pale green (10G 6/2) to grayish green (10G 4/2). A few foram-rich layers with rare volcanic sand grains.

CHERT at:
<u>1.05-1.08 m</u>: pale yellowish brown (10YR 6/2)
<u>1.41-1.43 m</u>: light olive gray (5Y 4/2)
<u>1.55-1.60 m</u>: light gray (N7)
<u>1.95-2.10 m</u>: medium dark (N4) to medium light (N6) gray.
Chert has ~0.5 cm spots of unsilicified carbonate within.

Smear Slides:
(1-120 cm; 2-30 cm):

Nannos	D
Forams	R

Site 318 Hole Core 18 Cored Interval: 492.0-501.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
UPPER EOCENE	Globigerapsis mexicana NP19/20	F N	C A	G M	1	0.5, 1.0	VOID		90 140	10G 8/1
		N	A	M	2		VOID		30 52	10G 8/2 5P 6/2 5P 6/2 10G 9/1
		N	A	M	Core Catcher					

Pale green (10G 8/2) NANNO LIMESTONE, with darker (10G 6/2) wisps and laminae, and lighter (10G 9/1) burrow mottles. A few pale purple (5P 6/2 to 5P 4/2) laminae and thin layers of yellowish gray (5Y 8/1) VOLCANIC FORAM SANDSTONE. Graded layers (sandy base, burrowed middle, laminated and burrowed top) common. Medium gray (N5) and light olive gray (5Y 6/1) CHERT chunks at 1.0-1.1 m, 2.1, 2.7, and 2.85 m.

Smear Slides:
(1-90 cm):

Nannos	D
Forams	R

(2-30 cm):

Nannos	R
Forams	R
Micrite	D

(1-140 cm, 2-52 cm):

Discocyclinid Forams	A
Nannos	C to A
Volcanic Fragments	R

Site 318 Hole Core 19 Cored Interval: 520.5-530.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
UPPER EOCENE	Globigerapsis mexicana NP17/18	F N	C C	G P	1	0.5, 1.0	VOID artificial			
		F	C	G	2		drilling breccia			
		N F	C C	P G					140	GF
		N	C	P	Core Catcher					

An artificially graded sequence of granule- to fine-grained sand, consisting of volcanogenic (palagonite) grains, cherty grains, and biogenous grains, including planktonic and large benthonic forams, bryozoans, algae, and molluscan fragments.

<u>Core catcher:</u>
Light olive gray (5Y 5/1) CHERT, and pale green (10G 8/1) NANNO LIMESTONE, with thin purplish gray (5P 5/2) laminae.

Smear Slides:
(2-140 cm) coarse fraction >1 mm abraded and rounded allocapics of:

Halimeda	R
Bryozoans	A
Coral(?)	C to A
Mollusks	R
Gastropods	R
Large Forams	R to C
- asterocyclina and other discocyclinids	

Explanatory notes in Chapter 1

Site 318 Hole Core 20 Cored Interval: 549.0-558.5 m

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
					0					
MIDDLE EOCENE	Globrootalia lehneri NP16	N	F	P/M	1	0.5, 1.0	VOID		80	N5, 5Y 4/1; 10GY 8/2
		N	C	M	2		VOID			5GY 8/1 and 10G 7/2; 10G 4/2
					3				130	5GY 2/1; GEOCHEM
					4		VOID		148	10G 6/2, 10G 9/1, 5G 8/1; 10YR 6/2
					5		VOID			10G 8/2, 5GY 4/1, 5GY 2/1; 10G 8/2 to 5G 7/2
		N F	C C	M M	Core Catcher		VOID			

Pale yellowish green (10GY 8/2), pale green (10G 6/2), greenish white (10G 9/1), and light greenish gray (5G 8/1) NANNO LIMESTONE with abundant burrows (of light material in darker).

From 2.7-5.5 m, thinly laminated, on mm-scale, with many low-angle faults and deformed phacoids (burrows), suggesting small-scale slumping.

A few graded layers, most notably at 6.25 to 6.45 m.

CHERT at 1.1 and 1.5 m (moderate yellowish brown, 10YR 5/4), and at 2.1-2.2 m (pale yellowish brown (10YR 6/2). Chert has ~0.5 cm spots of partly silicified limestone within.

Smear Slides:
(1-80 cm, 3-30 cm, 4-148 cm):

Nannos	A
Micrite	A
Forams	R
Fe-Specks	R
Volcanic Fragments	R to C

Site 318 Hole Core 21 Cored Interval: 577.5-587.0 m

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO.SAMPLE	LITHOLOGIC DESCRIPTION
					0					
MIDDLE EOCENE	NP16	N	C	M	1	0.5, 1.0	VOID		126	N4; 10G 8/2 and 5G 7/2; 5G 2/1
					2				30	10G 9/1; 10G 8/2 and 5G 7/2; 5P 4/2; 5Y 7/2; 5P 4/2; 5Y 7/2
		N	C	M	3				53, 83, 89	5G 8/1; 5Y 5/2; 5G 2/1 and 5G 8/1
		F N	C F	P P	Core Catcher		VOID			

Interbedded and interlaminated pale green (10G 8/2) and greenish gray (5G 7/2) NANNO LIMESTONE, and CLAYEY LIMESTONE, with occassional beds and laminae of yellowish gray (5Y 7/2) and olive gray (5Y 5/2, 5Y 4/2) VOLCANIC SILTSTONE and SANDSTONE, rich in forams, and laminae of grayish purple (5P 4/2).

Grayish black (N2) CHERT at 2.6 and 2.9 m, and dark brownish gray (5YR 3/1) CHERT at 3.4, 3.55, 3.8, 4.0, 4.35 m.

Many graded layers, silty or sandy at base, and extensively burrowed near the top.

Smear Slides:
(1-126 cm):

Micrite	D
Nannos	C
Forams	R

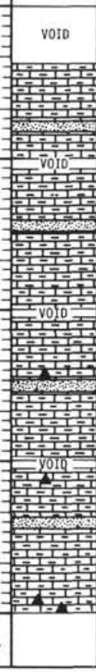
(2-30 cm) dark grainy bed:

Nannos	C
Micrite	D
Forams	R
Green Clay Fragments	R

Explanatory notes in Chapter 1

Site 318 Hole Core 22 Cored Interval: 596.5-606.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
MIDDLE EOCENE	Globigerapsis kugleri NP15	N	C	P	1	0.5, 1.0	VOID		120	alternating 10GY 7/2, 10G 6/2, 10GY 5/2, 5GY 3/2, and 10G 4/2
					2		VOID		77	
					3		VOID			
					4		VOID			
		F N	C C	P P	Core Catcher					



Alternating pale yellowish green (10GY 7/2), pale green (10G 6/2), grayish green (10GY 5/2), grayish olive green (5GY 3/2) and grayish green (10G 4/2) NANNO LIMESTONE and CLAYEY NANNO LIMESTONE.

A few layers of olive black (5Y 2/1) or greenish black (5G 2/1) VOLCANIC SANDSTONE and SILTSTONE.

Prevalent burrowing, of lighter material in darker, and scattered examples of low-angle faulting of laminae. Burrows in some layers internally deformed by post-depositional shear. Recumbant fold at 5.67-5.87 m. Graded sequences common.

At 3.65 m, medium gray (N5) CHERT in pale green limestone.

Chert, blebs at 4.50-4.56, and 5.87-6.0 m.

Smear Slides:

(2-77 cm):

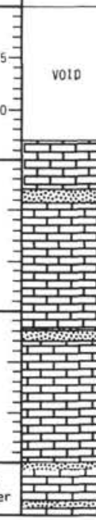
Volcanic ash altering to green clay	D
Nannos	R

(1-120 cm):

Nannos	A to D
Forams	C
Micrite	C

Site 318 Hole Core 23 Cored Interval: 606.0-615.5 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
MIDDLE EOCENE	Globigerapsis kugleri(?) NP15				1	0.5, 1.0	VOID		139, 147	
					2				90, 147	
					3				46, 116	
		N F	F C	P P	Core Catcher					



Graded beds, generally consisting of light greenish gray (5G 8/1) NANNO LIMESTONE or CLAYEY NANNO LIMESTONE, commonly with darker-colored olive gray (5Y 4/1, 5Y 3/1) SILTSTONE or dark greenish gray (5G 4/1) fine-grained SANDSTONE, consisting mainly of volcanic (palagonite) grains and forams, at the base. Sand commonly laminated and x-strat. Burrowing of lighter into darker material becomes more intense towards the top of each graded unit. Occassional purplish gray (5P 4/2) laminae and streaks near the tops of graded units.

Occassional internally deformed burrows.

Graded units 1-15 cmthick, averaging about 5 cm.

Smear Slides:

(1-139 cm):

Volcanic Glass	A
Micrite	C
Nannos	R

(1-147 cm):

Nannos	D
Volcanic Glass	R
Rads	R
Sp. Spic.	R

(2-90 cm):

Micrite	A
Volcanic Glass	C
Feldspar	R
Green Clay	R

(2-147 cm):

Micrite	C
Fe-Specks	C
Feldspar	R
Volcanic Glass	R to C

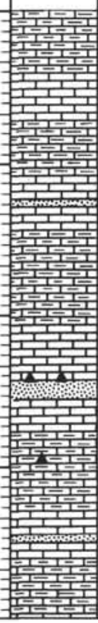
(3-116 cm):

Micrite	A
Forams	C
Nannos	C
Feldspar	R
Volcanic Glass	R
Green Clay	R

Explanatory notes in Chapter 1

Site 318 Hole Core 24 Cored Interval: 615.5-625.0 m

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
					0				
MIDDLE EOCENE	NP15				1	0.5, 1.0			13, 148
					2				62
					3				50 HCL
		N	R	P	4				



LITHOLOGIC DESCRIPTION

Graded beds, from 1-40 cm thick, averaging about 10 cm, generally consisting of light greenish gray (5G 7/1) NANNO LIMESTONE and CLAYEY LIMESTONE, commonly with darker-colored olive gray (5Y 4/1, 5Y 3/1) SILTSTONE or fine-grained FORAM VOLCANIC SANDSTONE at the base, generally laminated or even cross-stratified, with an abrupt contact with the underlying unit. Occassional beds with coarse-grained or granule-sandstone. Middle and upper parts of beds burrowed, with light material in darker host. Burrowing increase in intensity towards top of beds.

Grayish purple (5P 4/2) laminae and wisps near tops of some beds.

Grayish brown (5YR 3/2) and dark greenish gray (5G 4/1) CHERT blebs at 3.75 and 3.80 m, and a very dusky purple (5P 2/2) CHERT splotch at 4.20 m.

Limestone in this core, especially the lighter-colored intervals and the purplish bands, are very hard and siliceous.

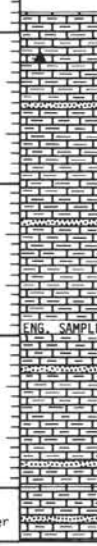
Smear Slides:
(2-62 cm):

Micrite	D
Chert	R to C
Nannos	R

(3-50 cm HCL insolubles):
(1) spheroidal blebs ~100μm diam. coarse chert replacing forams and/or rads.
(2) green clay
(1) + (2) = about 10-20% of rock.

Site 318 Hole Core 25 Cored Interval: 625.0-634.5 m

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE
					0				
MIDDLE EOCENE	Hantkenina aragonensis NP15				1	0.5, 1.0	VOID		
					2				108, 121
					3		ENG. SAMPLE	removed	
					4				130
		N / F	C / C	M / P	Core Catcher				



LITHOLOGIC DESCRIPTION

Graded beds, from 1-40 cm thick, averaging about 10 cm, each bed generally consisting of grayish green (5G 6/1, 5G 6/2, 5GY 6/1, 10GY 5/2) NANNO LIMESTONE, MICRITE LIMESTONE, and CLAYEY LIMESTONE, commonly with darker-colored olive gray (5Y 5/1, 5Y 6/1) SILTSTONE or dark greenish gray (5G 4/1) to greenish black (5G 2/1) VOLCANIC SANDSTONE, generally fine-grained, but occassionally up to granule-size. Sandy layers commonly laminated and cross-stratified, with abrupt, erosional contacts with underlying unit. Middle and upper parts of beds burrowed, with burrowing commonly intense at the top of a bed and decreasing in intensity below; with light-colored material in a darker host. Some mottles internally deformed.

Cherty blebs at 1.74 m.

Smear Slides:
(2-108 cm; 2-121 cm):

Micrite	A
Nannos	A
Forams	R
100μm chert blebs	R to C

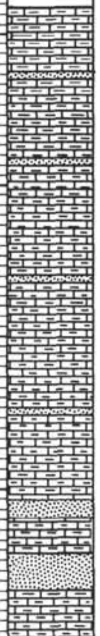
(4-130 cm):

Sp. Spic.	A
Diatoms	C to A
Micrite	C
Rads	C

Explanatory notes in Chapter 1

Site 318 Hole Core 26 Cored Interval: 634.5-644.0 m

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE EOCENE	NP15	N F	F ?	P ?	0, 1, 2, 3, 4, 5, Core Catcher	0.5, 1.0	VOID		140, 24, 70, 95	



Graded beds, from 1-70 cm thick, averaging about 10 cm, each bed generally consisting of grayish green (5G 6/2, 5G 5/1) LIMESTONE or CLAYEY LIMESTONE, commonly with a laminated or cross-stratified basal unit of greenish black (5G 2/1) FORAM-RICH VOLCANIC SANDSTONE (salt and pepper colors), or olive gray (5Y 4/1 to 5Y 2/1) SILTSTONE. Contact with underlying bed abrupt, commonly erosional. Sandstone generally fine-grained, but coarse-grained or even granule-size grains occur at a few levels.

Burrowing intense in upper parts of graded beds, decreasing downward; rarely do burrows cut base of a bed.

Minor low-angle faults and shear folding, and deformed burrows, especially at ~3.0 m.

At 6.3-7.0 m, a single graded bed, with medium-grained foram-voclanic sandstone at base, laminated cross-stratified sandstone in middle and burrowed at top. Greenish black (5G 2/1) at top, dark greenish gray (5GY 4/1) in middle, greenish gray (5GY 6/2) at base.

A pyritized "chevron" burrow at 6.65 m - within graded bed.

Smear Slides:
(1-140 cm):

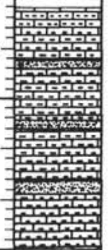
Forams	D
Nannos	R to C

(5-95 cm):

Volcanic Glass	D
Micrite	C

Site 318 Hole Core 27 Cored Interval: 644.0-653.5 m

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE EOCENE	NP14	N F	F ?	P ?	0, 1, 2, Core Catcher	0.5, 1.0	VOID; VOID		142 HCL	



Graded beds, from 1-30 cm thick, averaging about 10 cm, each bed generally consisting of greenish gray (5G 5/1) LIMESTONE or CLAYEY LIMESTONE, commonly with a laminated or cross-stratified basal part of olive gray (5Y 4/1, 5Y 2/1) SILTSTONE or dark greenish gray (5G 4/1) to greenish black (5G 2/1) "salt-and-pepper" FORAM-VOLCANIC SANDSTONE, generally fine-grained, but with a few coarse-grained to granule-bearing units.

Burrowing intense near tops of graded beds, decreasing downwards.

Smear Slides:
(2-142 cm):

Micrite	D
Clay	C
Nannos	R

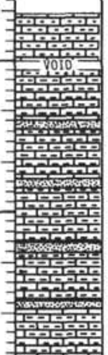
(2-145 cm HCL insoluble residue):

1) clay	D
2) chert blebs ~100μm	C

1) + 2) = 10% of rock

Site 318 Hole Core 28 Cored Interval: 663.0-672.5 m

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
MIDDLE EOCENE	NP14	N F	F ?	P ?	0, 1, 2, 3, Core Catcher	0.5, 1.0	VOID; VOID		110, 15, 15	



Graded bes, from 0.5-15 cm thick, averaging about 10 cm, each bed generally consisting of greenish gray (5G 6/1 to 5G 4/1) LIMESTONE or CLAYEY LIMESTONE, commonly with a basal part of laminated or cross-stratified olive gray (5Y 4/1 to 5Y 2/1) SILTSTONE or greenish black (5G 4/1 to 5G 2/1) "salt-and-pepper" FORAM-BEARING VOLCANIC SANDSTONE, generally fine-grained, but coarse-grained or even granule-bearing in a few beds. Burrowing intense near tops of graded units, decreasing below.

Wackestone textures in some graded units, with volcanic grains and forams suspended in clayey limestone matrix.

From 2.1-2.15 m - laminated grayish blue green (5BG 5/2) CLAYEY LIMESTONE.

Smear Slides:
(1-110 cm):

Micrite	A
Forams	C

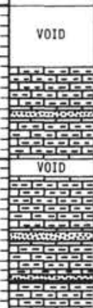
(3-15 cm):

Micrite	A
Nannos	C
Volcanic Glass	A to D
Green Pyroboles	R
Fe-Specks	C

Explanatory notes in Chapter 1

Site 318 Hole Core 29 Cored Interval: 682.0-691.5 m

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
EOCENE					1	0.5, 1.0	VOID		135	
					2		VOID			
		N F	— ?	— ?	Core Catcher		VOID			



Graded beds, from 0.5 to 20 cm thick, averaging about 5 cm, each bed generally consisting of greenish gray (5GY 5/1, 5G 5/1) and dark greenish gray (5GY 4/1 to 5GY 2/1) LIMESTONE and CLAYEY LIMESTONE, commonly with a basal unit of light olive gray (5Y 6/1) or olive gray (5Y 4/1) SILTSTONE or greenish black (5G 2/1) "salt-and-pepper" FORAM-BEARING VOLCANIC SANDSTONE.

A few bands of grayish to dusky blue green (5BG 5/2 to 5BG 3/2) CLAYEY LIMESTONE.

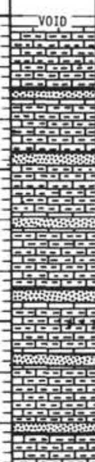
Burrowing intense in upper parts of many graded units, decreasing below.

Smear Slides:
(1-135 cm):

Volcanic Glass	D
Clay	A
Feldspar	C
Nannos	R

Site 318 Hole Core 30 Cored Interval: 701.0-710.5 m

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
MIDDLE EOCENE	*Acarinina densa* NP13				1	0.5, 1.0	VOID		40	
					2				19, 134	
					3					
		N F	F R	P P	Core Catcher		VOID			



Graded bes, from 0.5 to 40 cm thick, averaging about 8 cm, each bed generally consisting of greenish gray (5G 6/1) to dark greenish gray (5GY 4/1) LIMESTONE or CLAYEY LIMESTONE, commonly with a basal unit of olive gray (5Y 6/1 to 5Y 2/1) SILTSTONE, or greenish black (5G 2/1) "salt-and-pepper" FORAM-BEARING VOLCANIC SANDSTONE, commonly laminated or cross-stratified.

A few layers of dusky blue green (5BG 3/2) CLAYEY LIMESTONE.

Burrowing commonly moderate to intense in upper parts of graded beds.

Medium- to coarse-grained sandstone common at bases of beds.

Smear Slides:
(1-40 cm):

Sp. Spic.	C
Volcanic Glass	D
Diatoms	R
Rads	R

(2-19 cm) base of graded bed:

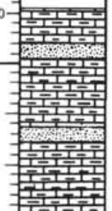
Volcanic Glass	A
Feldspar	A
Clay	C

(2-134 cm) burrowed green limestone:

Micrite	D to A
Nannos	C to A
Clay	C
Fe-Specks	R

Site 318 Hole Core 31 Cored Interval: 720.0-729.5 m

AGE	ZONE	FOSSIL CHARACTER: FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
LOWER EOCENE	NP13				1	0.5, 1.0	VOID		36, 138	
					2					
		N F	C ?	P ?	Core Catcher		VOID			



Graded beds, from 0.5-15 cm thick, averaging about 5 cm, each bed consisting of greenish gray (5G 6/1 through 5G 4/1) and grayish blue green (5BG 5/2) to dusky blue green (5BG 3/2) CLAYEY LIMESTONE, commonly with a basal part of darker-colored to greenish black (5G 2/1) SILTSTONE to SANDSTONE, with forams and volcanic grains. Sandy parts generally laminated, with an abrupt, erosional or load-casted base.

Burrowing common in upper parts of graded layers.

Smear Slides:
(1-138 cm) base of coarse-grained graded bed:

Feldspar	A
Volcanic Glass	A
Clay	C
Micrite	A

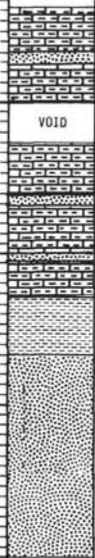
(1-136 cm) top of graded bed:

Micrite	A
Nannos	A
Forams	R

Explanatory notes in Chapter 1

Site 318 Hole Core 32 Cored Interval: 739.0-745.0 m

AGE	ZONE	FOSSIL	ABUND.	PRES.	SECTION	METERS	LITHOLOGY	DEFORMATION	LITHO. SAMPLE	LITHOLOGIC DESCRIPTION
					0					
LOWER EOCENE	Acarinina densa(?) NP13?				1	0.5 1.0	VOID			
					2		VOID			
					3					
					4					
		N F	F R	P P	Core Catcher		VOID			



Graded beds, from 1-250 cm thick, typically 10-15 cm, each bed consisting of greenish gray (5G 6/1 to 5G 4/1) CLAYEY LIMESTONE, with a basal part of olive gray (5Y 4/1) SILTSTONE or greenish black (5G 2/1) "salt-and-pepper" SANDSTONE, commonly laminated or cross-stratified.

Burrowing commonly intense in upper parts of graded units; some burrows deformed by shearing.

At 0.8-0.95 m:
A granule-bearing bed with reverse (?) grading.

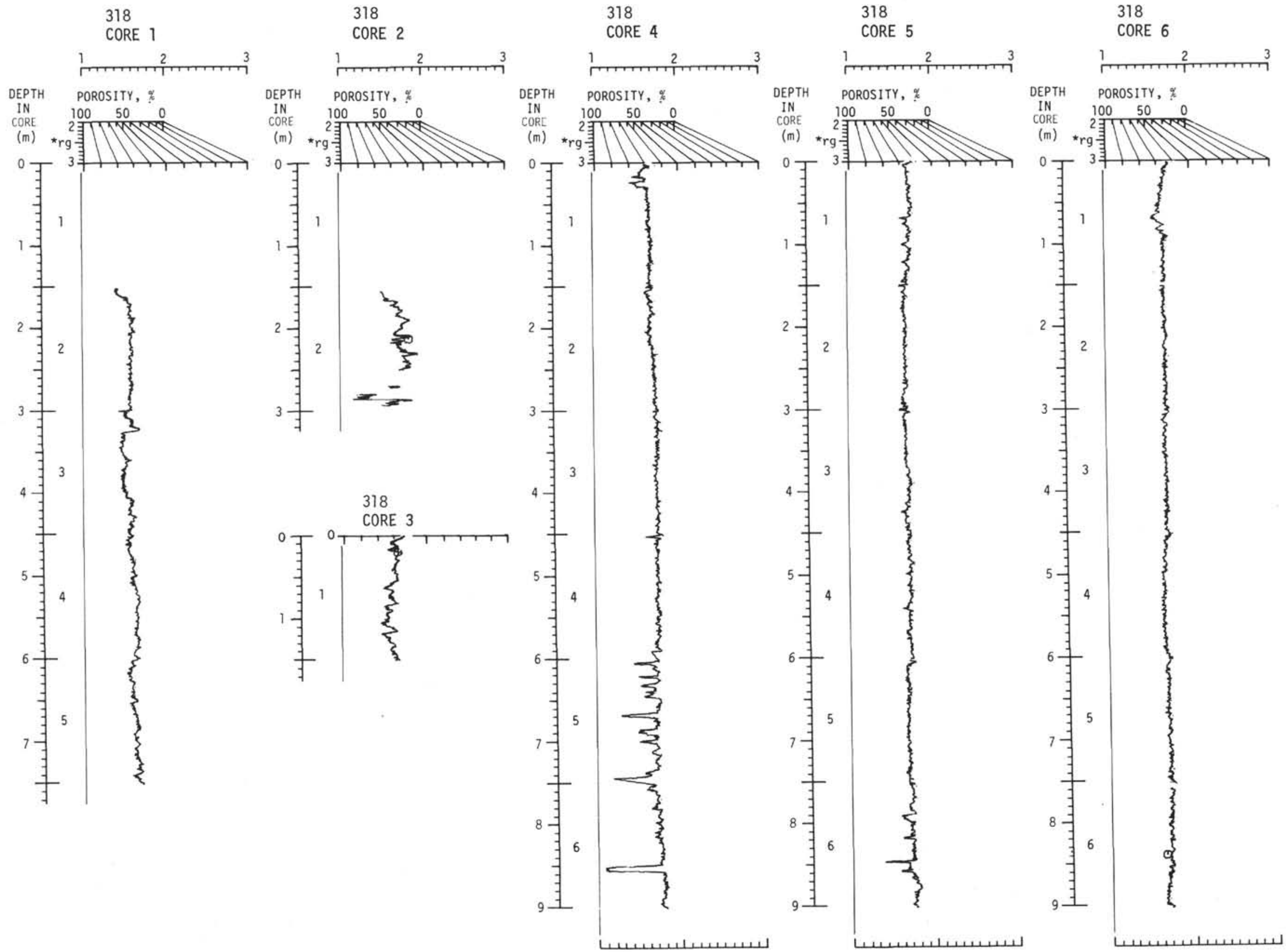
At 1.9-2.4 m:
One graded bed, with coarse-grained sandstone at base.

At 3.45-6.0 m:
One graded bed, with granules (including large benthonic forams) in basal 50 cm, crs. to med. grained next 50 cm, wackestone textures next 50 cm, laminated and cross-stratified next 50 cm, claystone top, with burrows in upper 10 cm only. Base not seen.

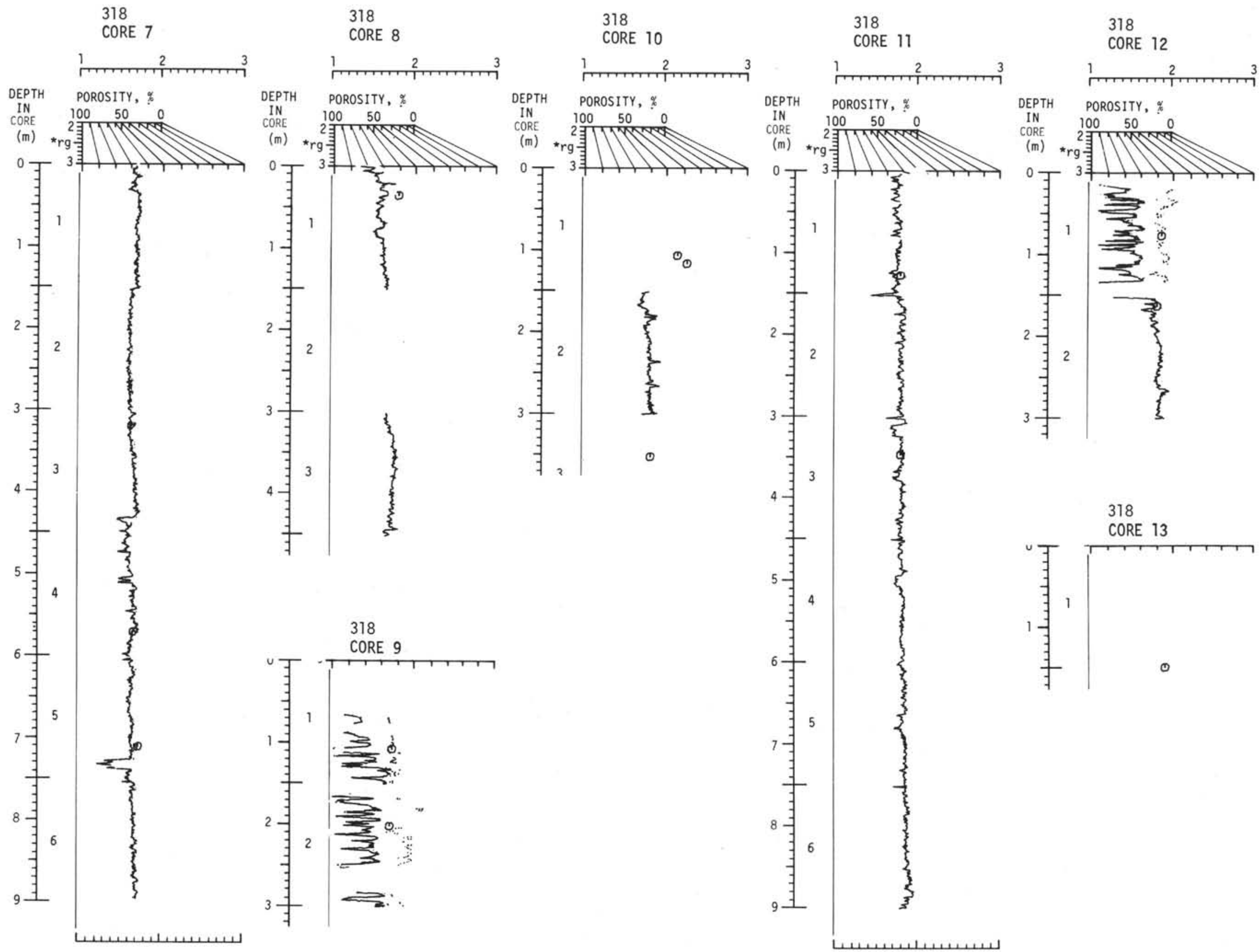
Smear Slides:
(1-100 cm):

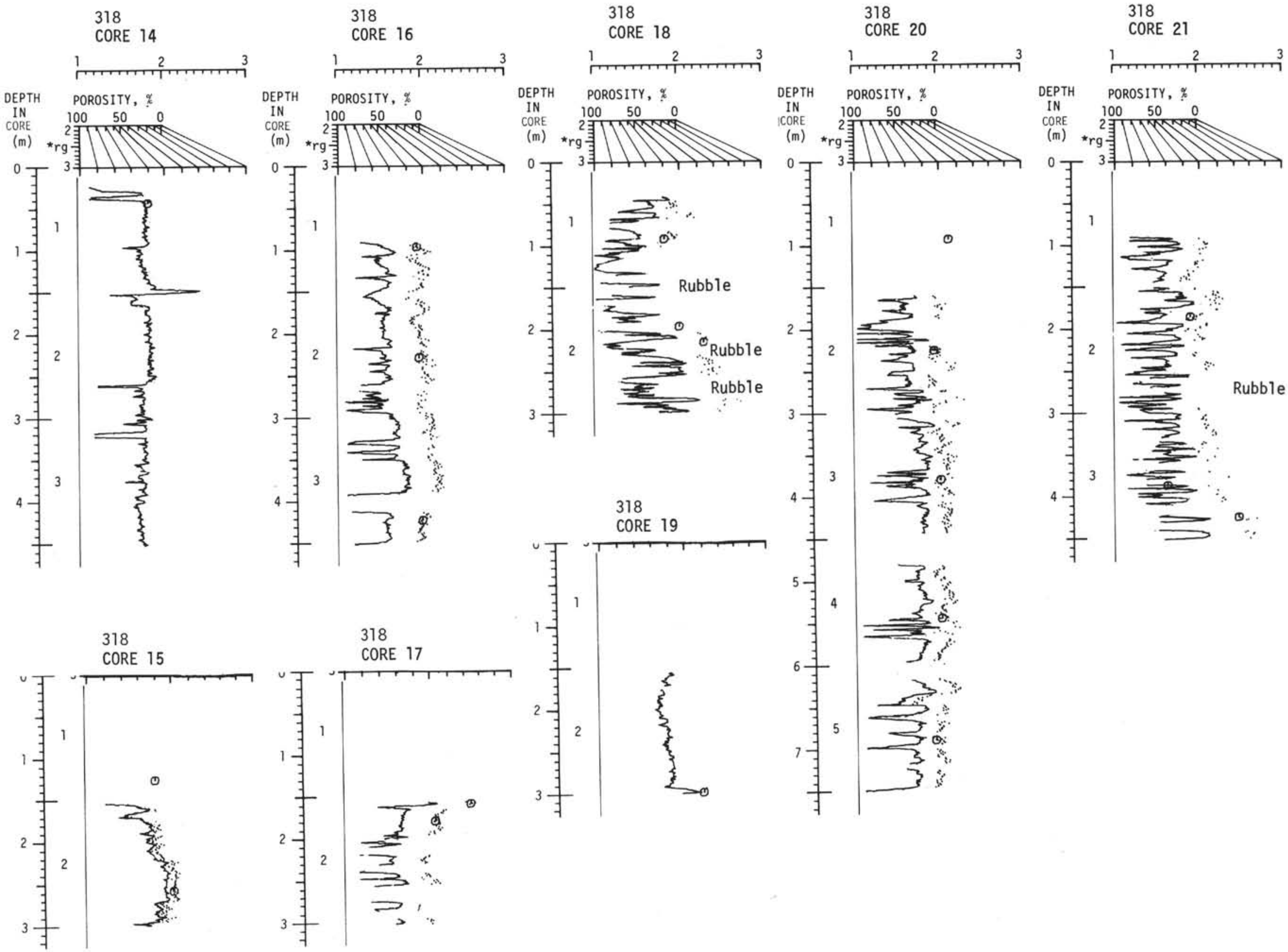
Volcanic Glass	A
Feldspar	C
Clay	A
Micrite	R
Nannos	R

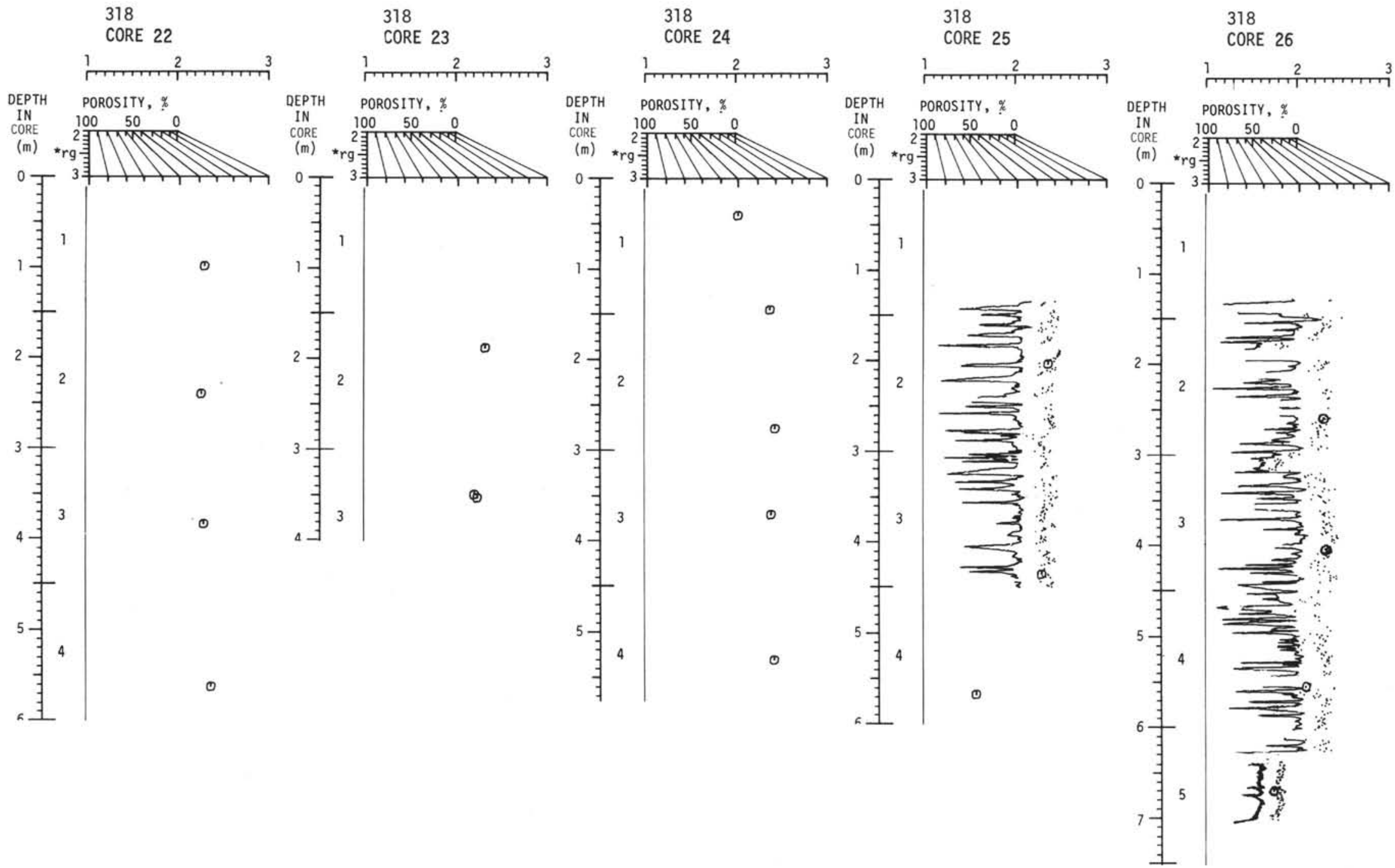
Explanatory notes in Chapter 1



NOTE: The upper scale is GRAPE Wet-Bulk Density (1.0 to 3.0 g/cc): solid lines (——) are GRAPE analog data assuming a 6.61 cm core diameter; dotted lines (. . . . .) are GRAPE analog data adjusted for actual core diameter; circled (ɸ) dots are the wet-bulk density calculated from two-minute counts on a stationary sample; the porosity nomogram allows a porosity scale to be determined by selecting the proper grain density (r_g) and extrapolating horizontally.


318 CORE 7
318 CORE 8
318 CORE 9
318 CORE 10
318 CORE 11
318 CORE 12
318 CORE 13
DEPTH IN CORE (m)
POROSITY, %
100 50 0
*rg


318
CORE 14
318
CORE 16
318
CORE 18
318
CORE 20
318
CORE 21
DEPTH
IN
CORE
(m)
POROSITY, %
100 50 0
*rg
Rubble
Rubble
Rubble
Rubble
318
CORE 19
318
CORE 15
318
CORE 17


318
CORE 22
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CORE 23
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CORE 24
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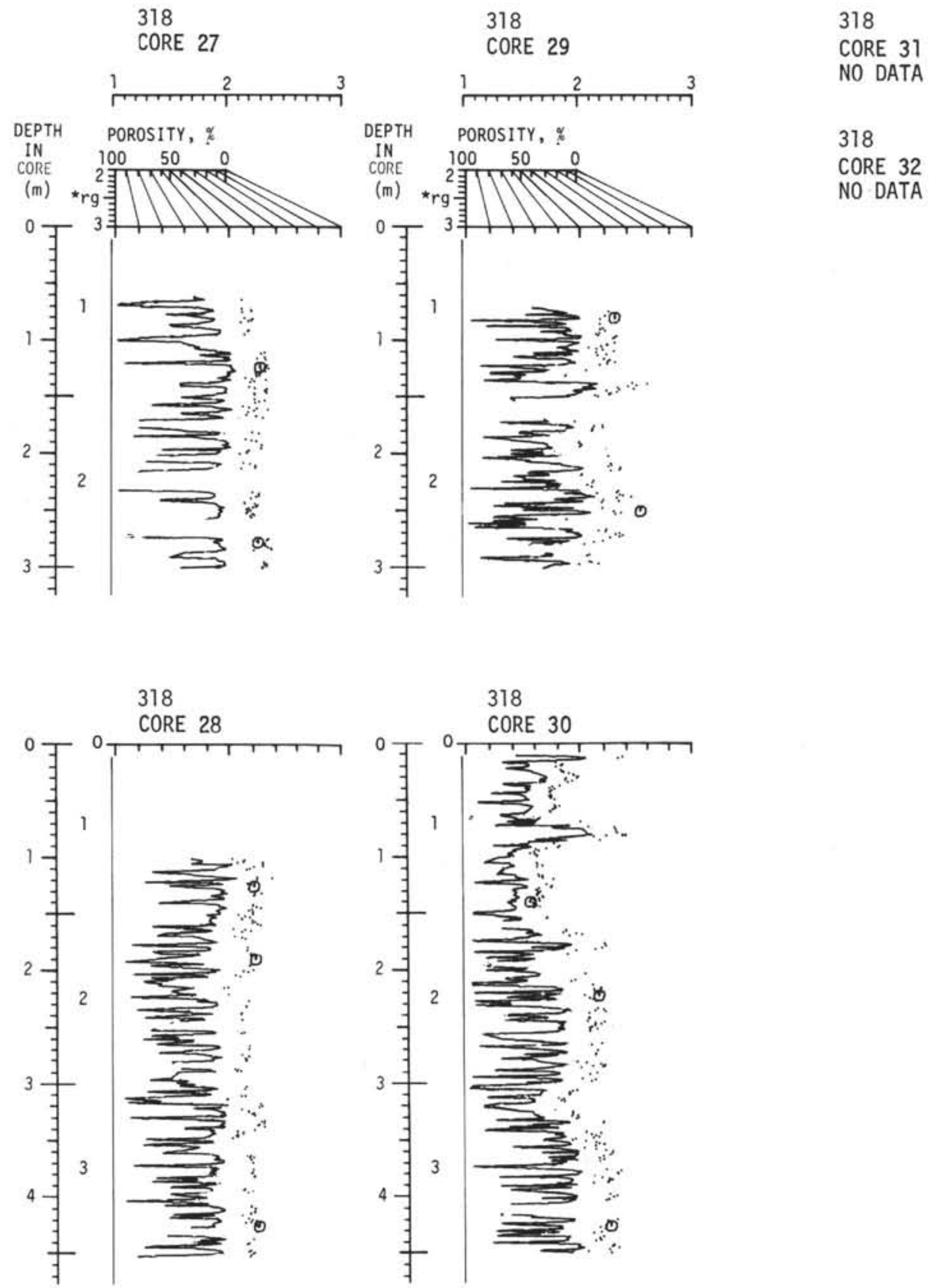
CORE 25
318
CORE 26
DEPTH IN CORE (m)
POROSITY, %
100 50 0
*rg
1 2 3



318
CORE 27
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CORE 29
318
CORE 31
NO DATA
318
CORE 32
NO DATA
DEPTH
IN
CORE
(m)
POROSITY, %
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*rg
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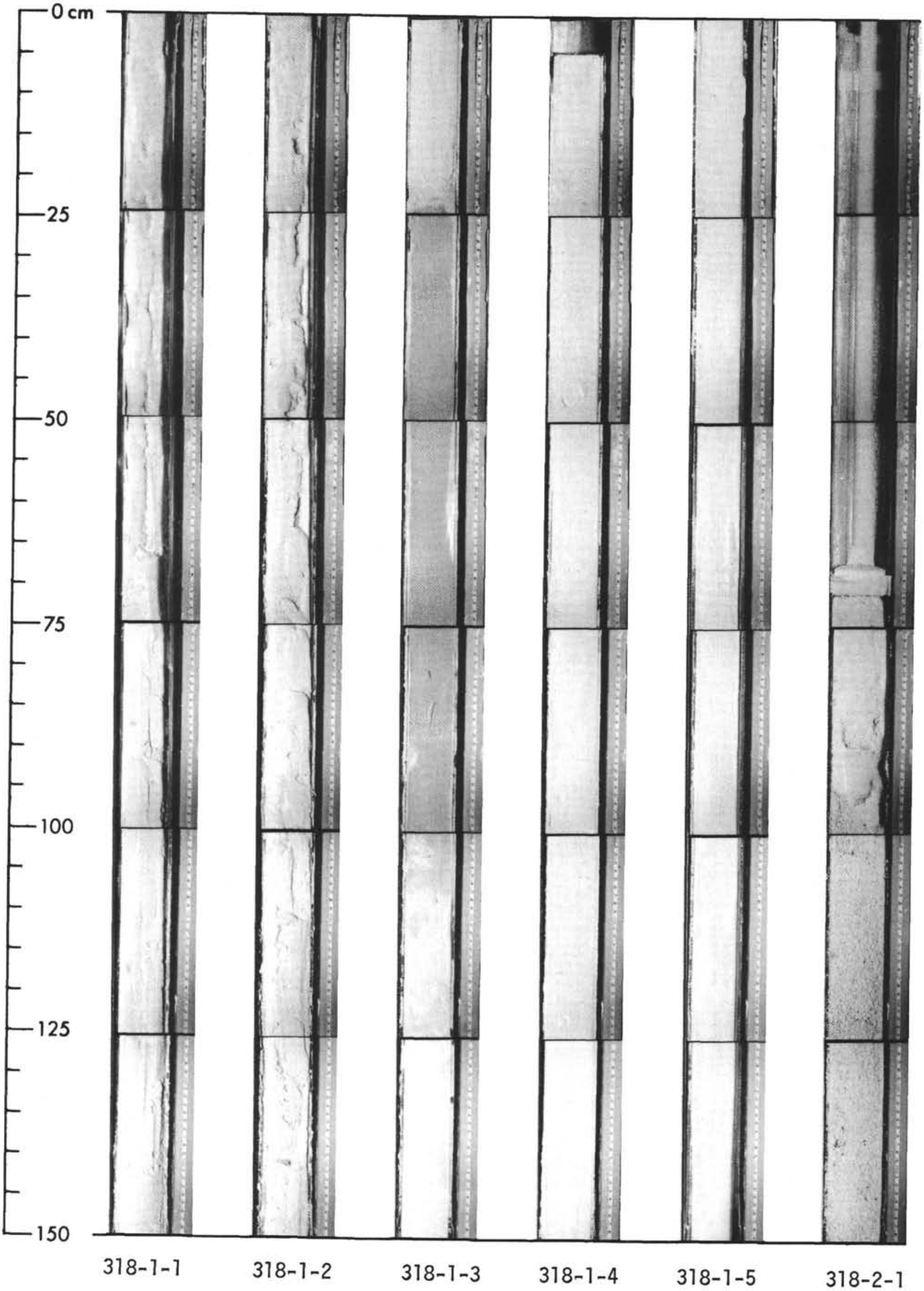
CORE 28
318
CORE 30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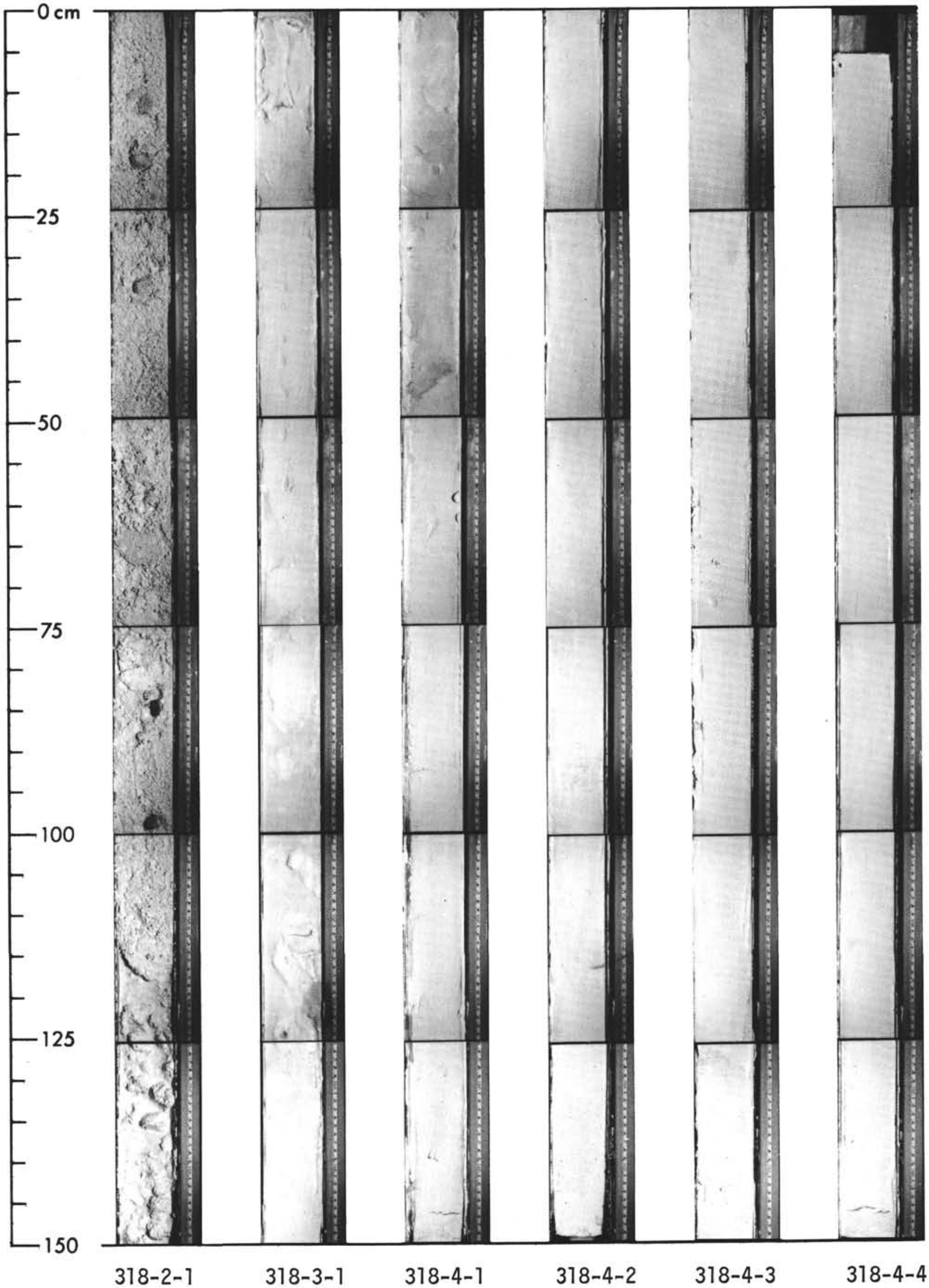
318-1-2
318-1-3
318-1-4
318-1-5
318-2-1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318-4-1
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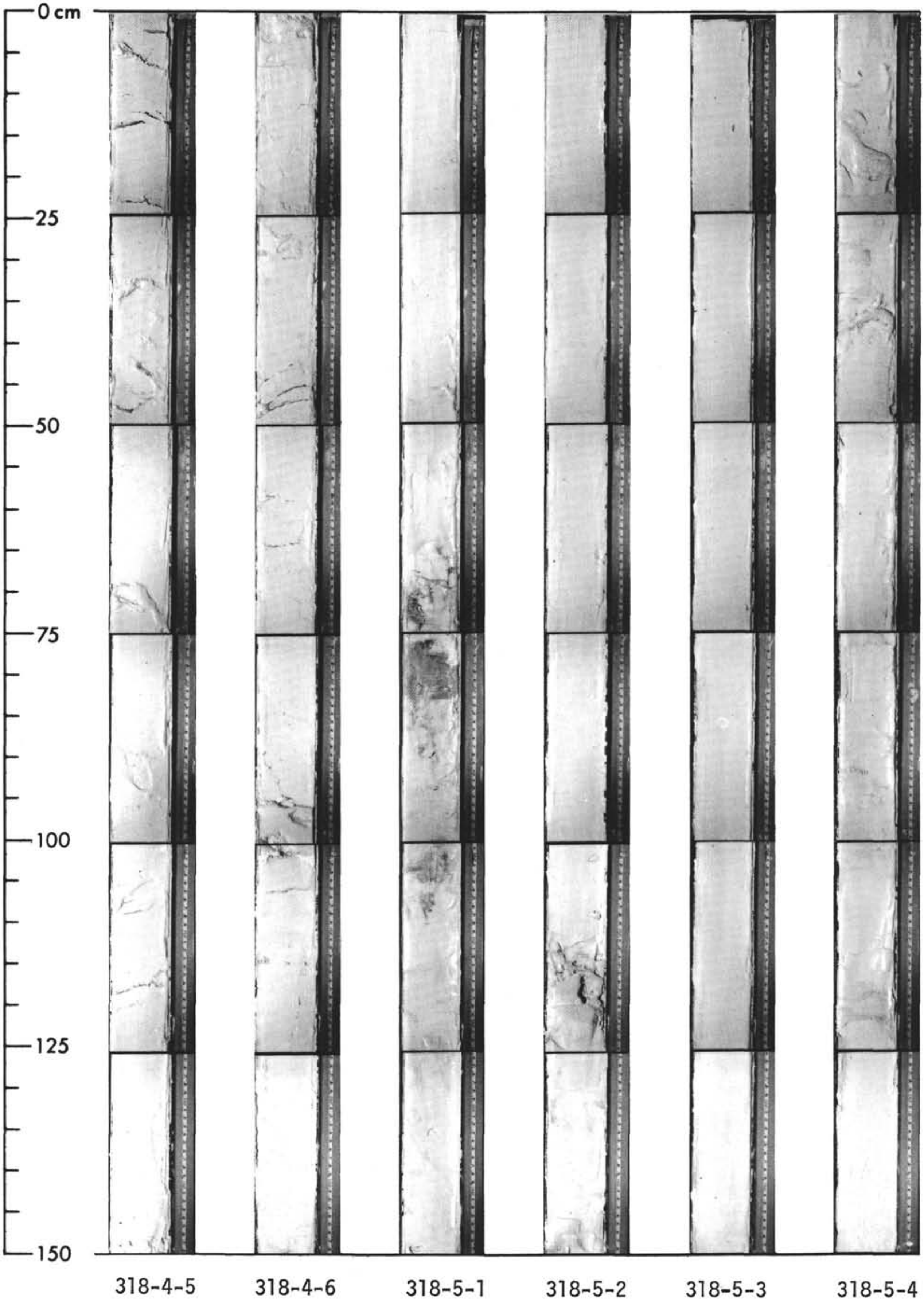
318-4-4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318-4-6
318-5-1
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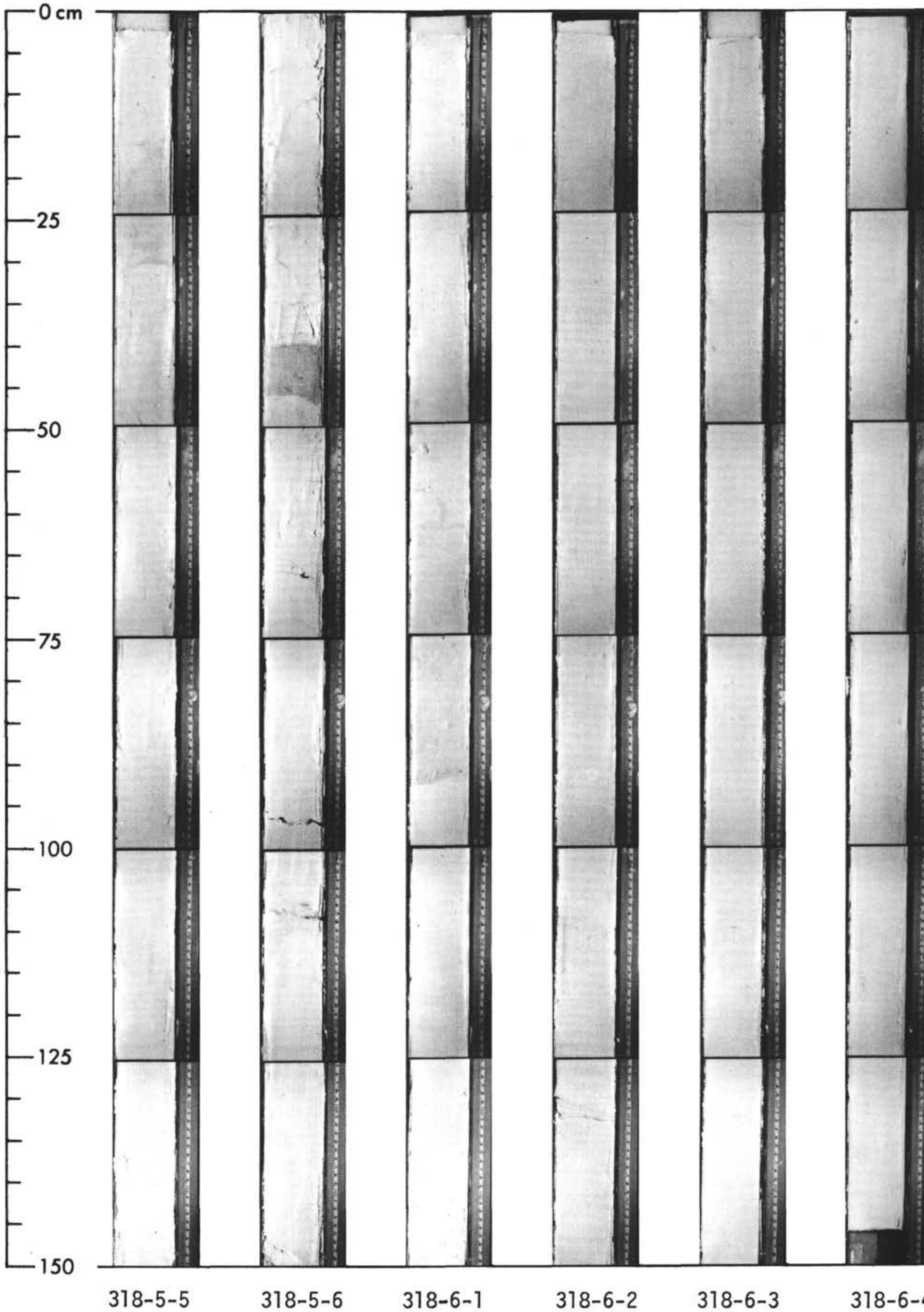
318-5-4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318-6-1
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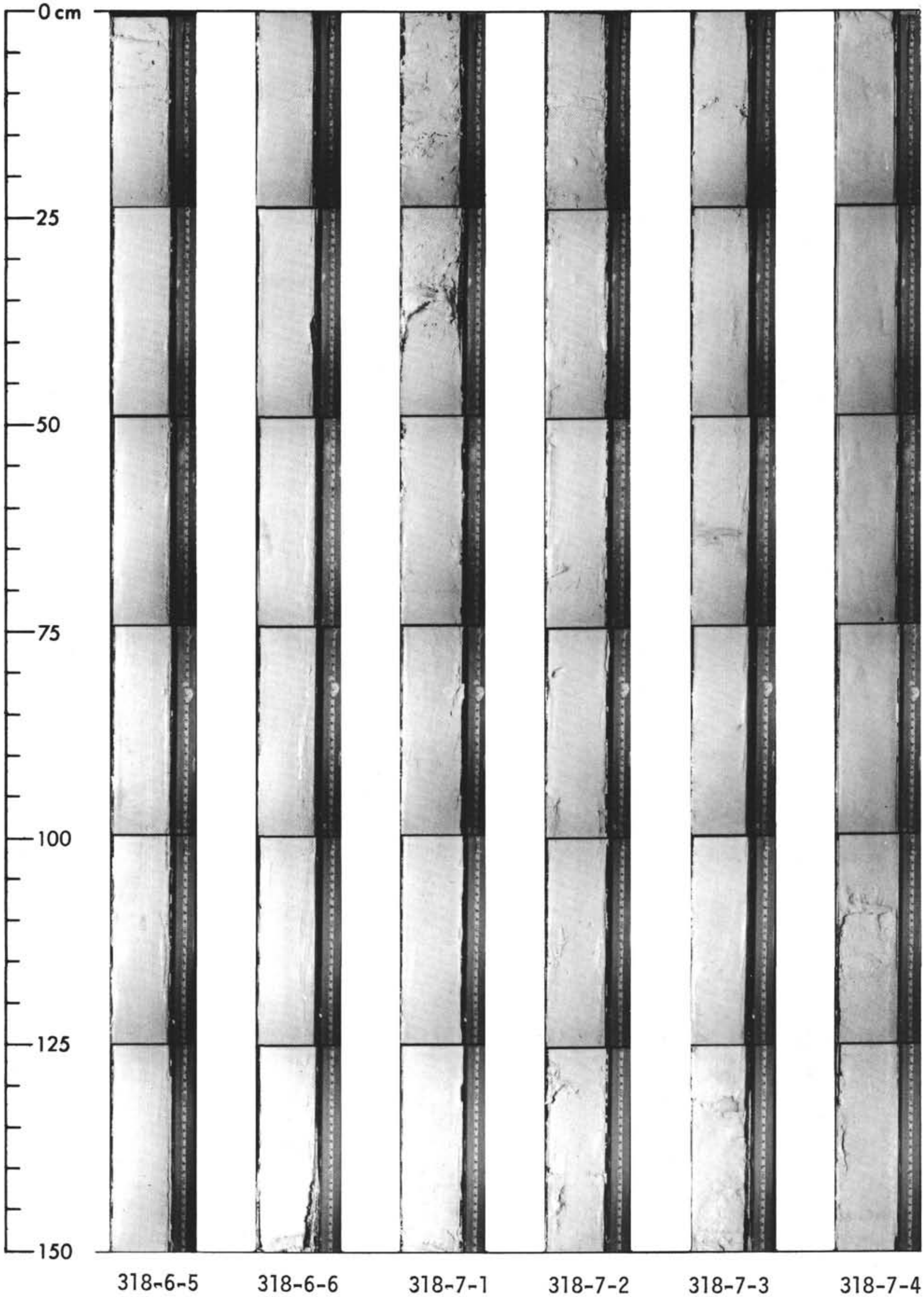
318-6-4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318-6-6
318-7-1
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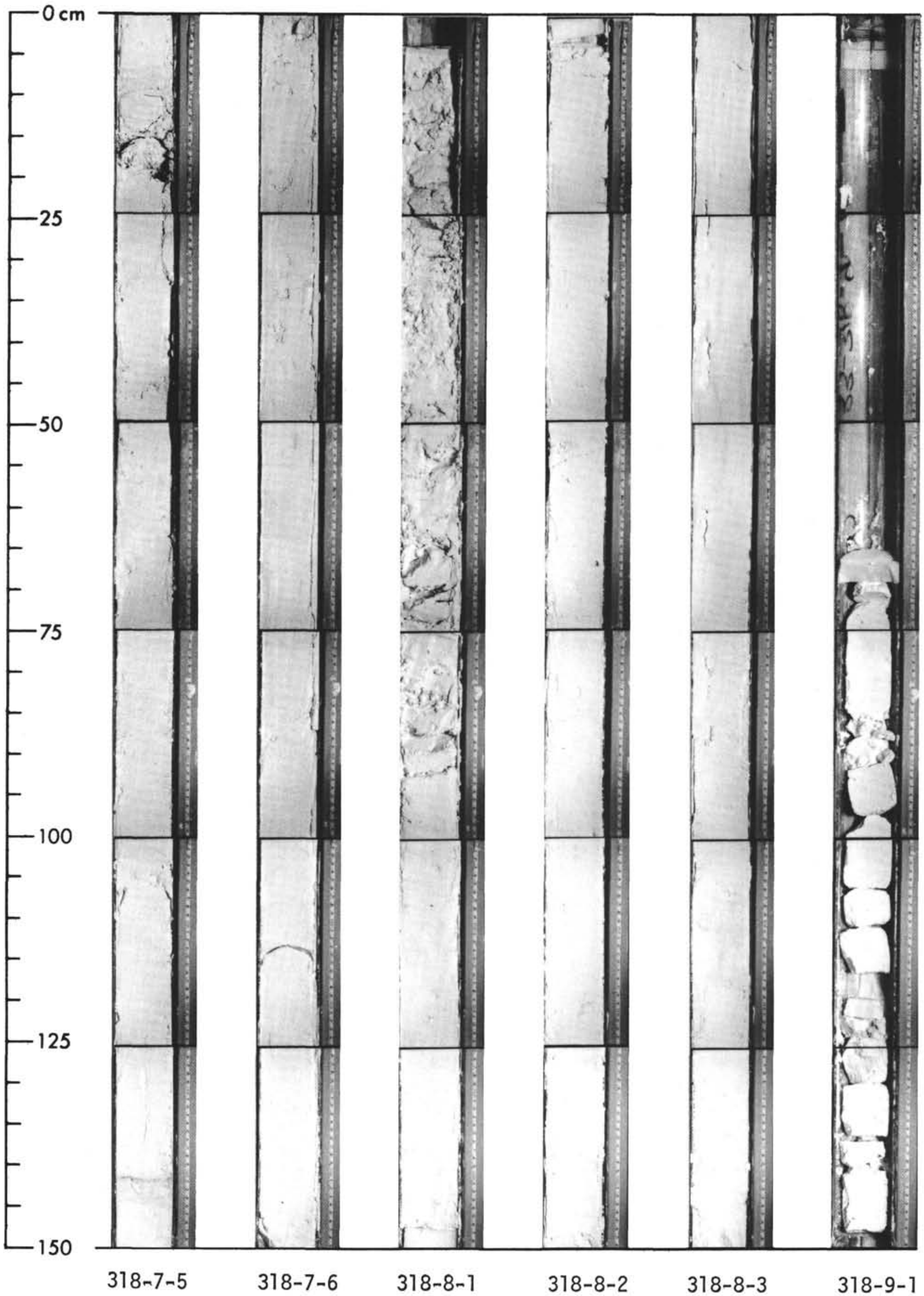
318-7-4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318-7-6
318-8-1
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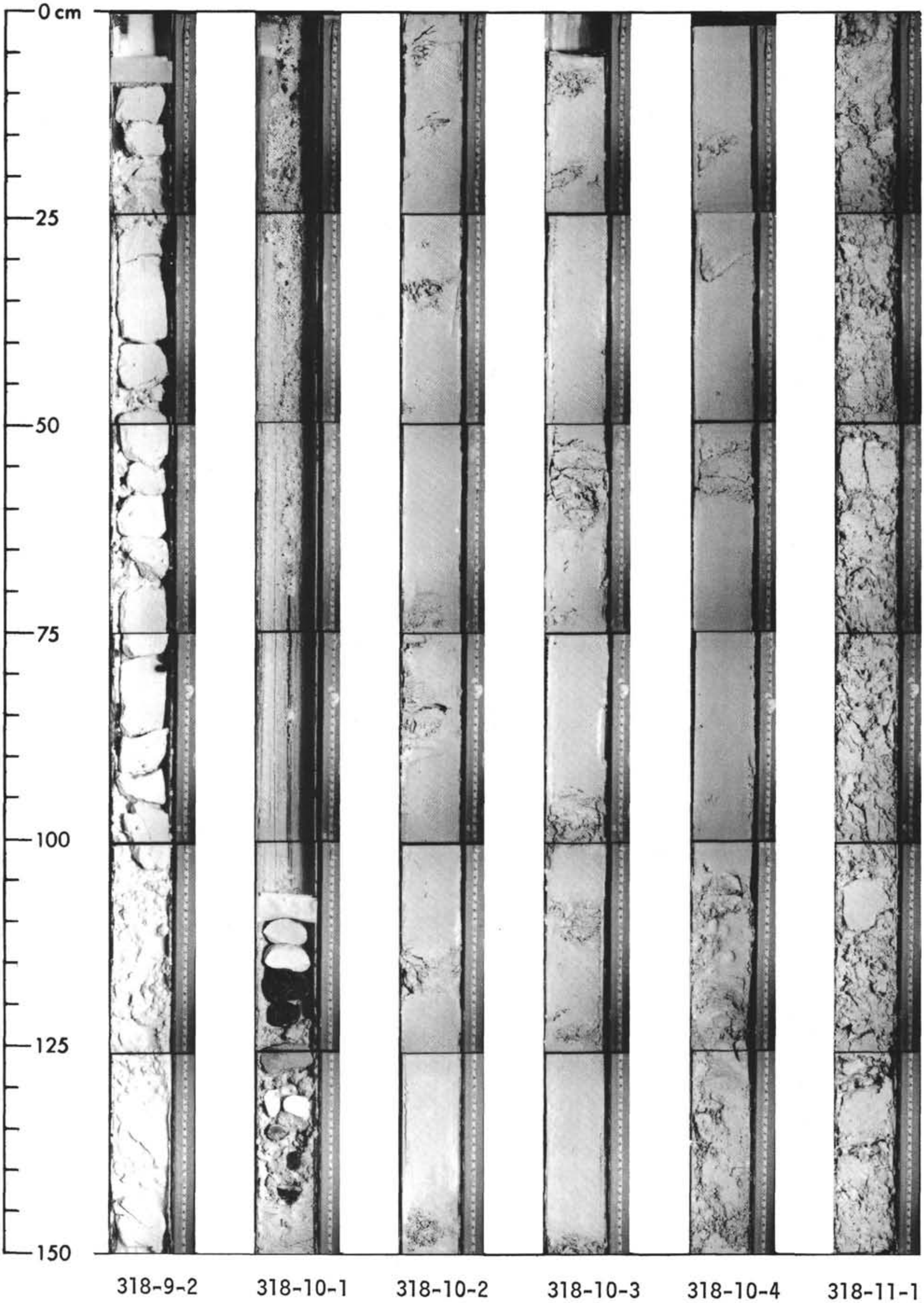
318-8-3
318-9-1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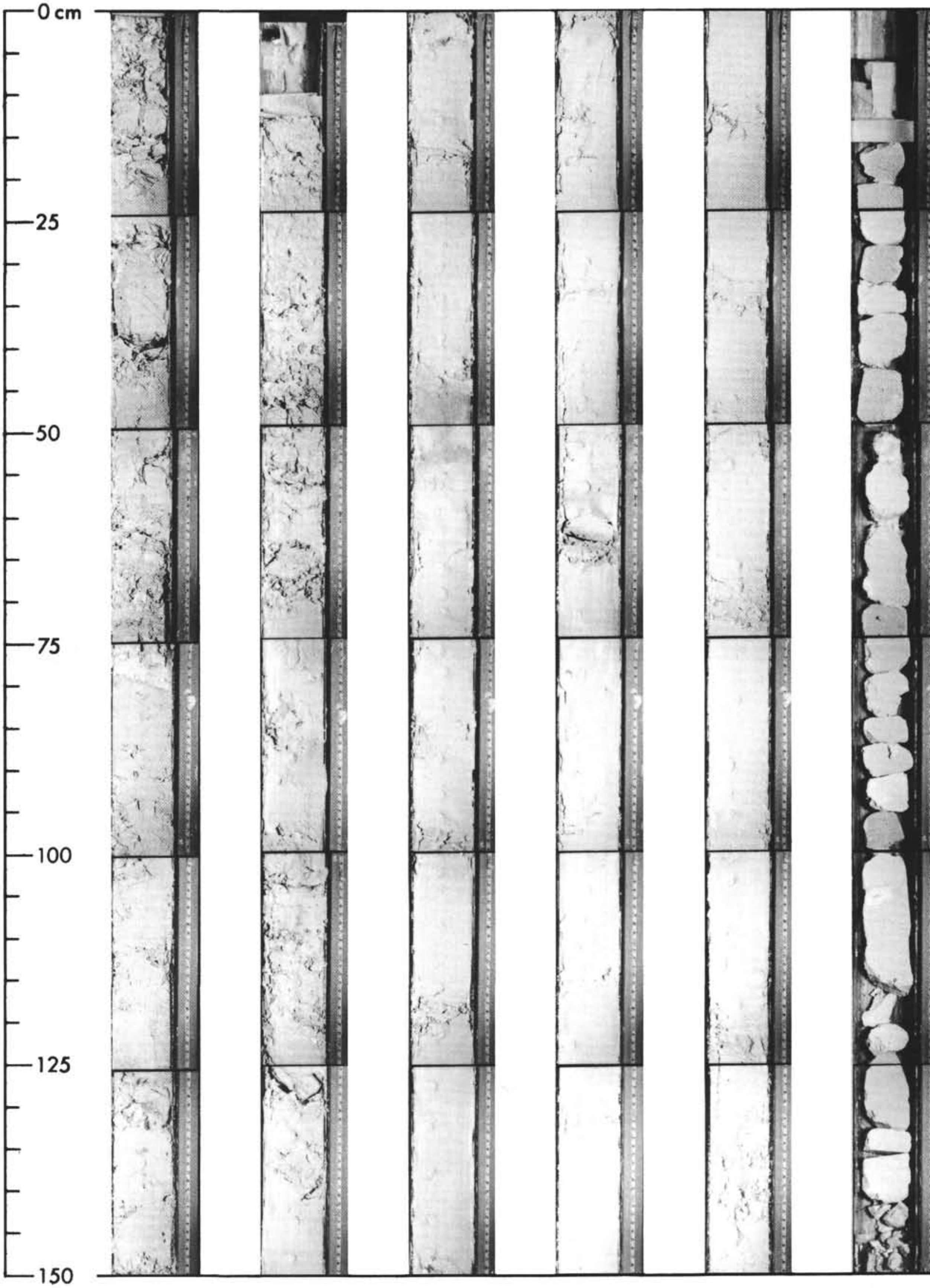
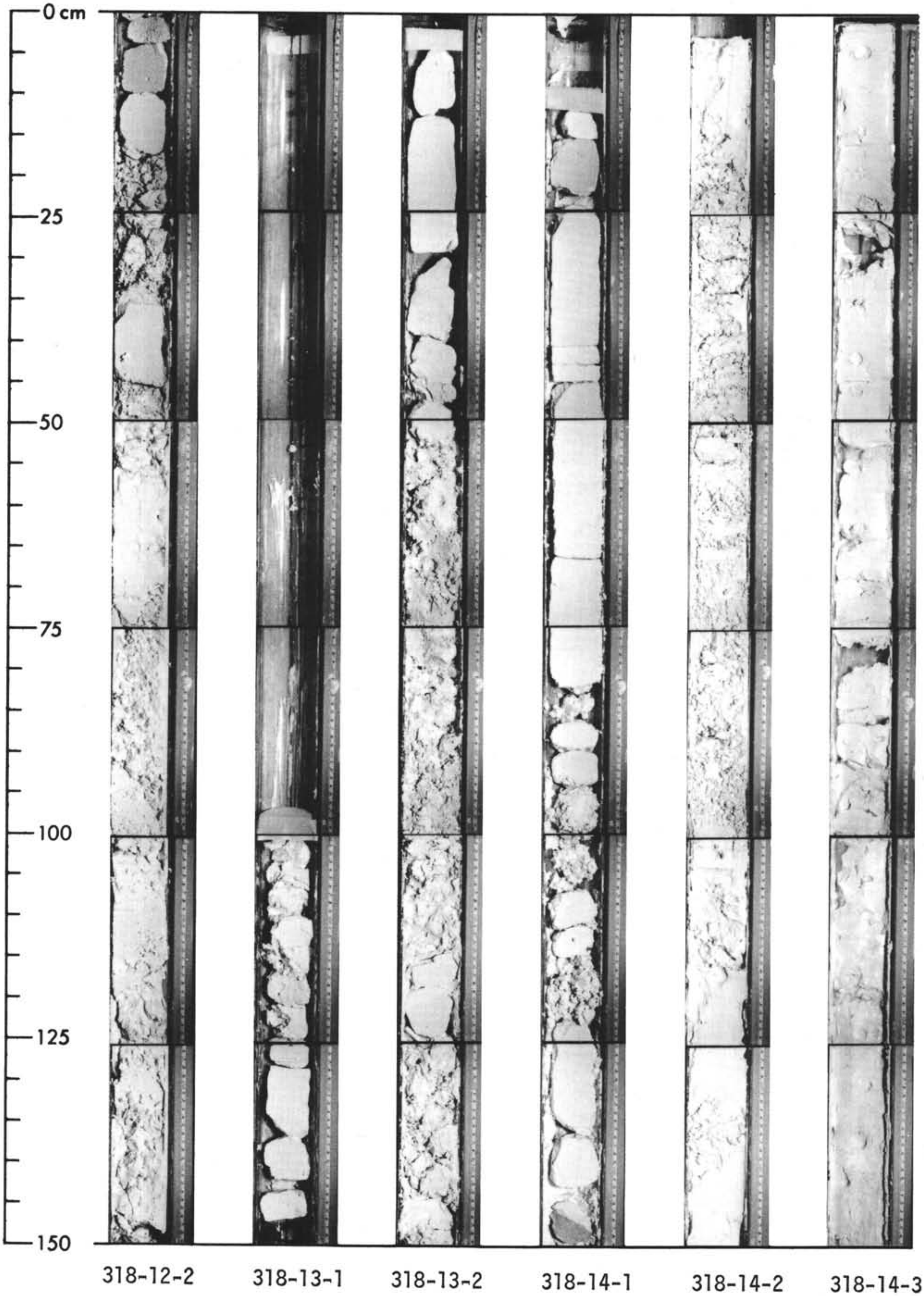
100
125
150
318-9-2
318-10-1
318-10-2
318-10-3
318-10-4
318-11-1



318-11-2 318-11-3 318-11-4 318-11-5 318-11-6 318-12-1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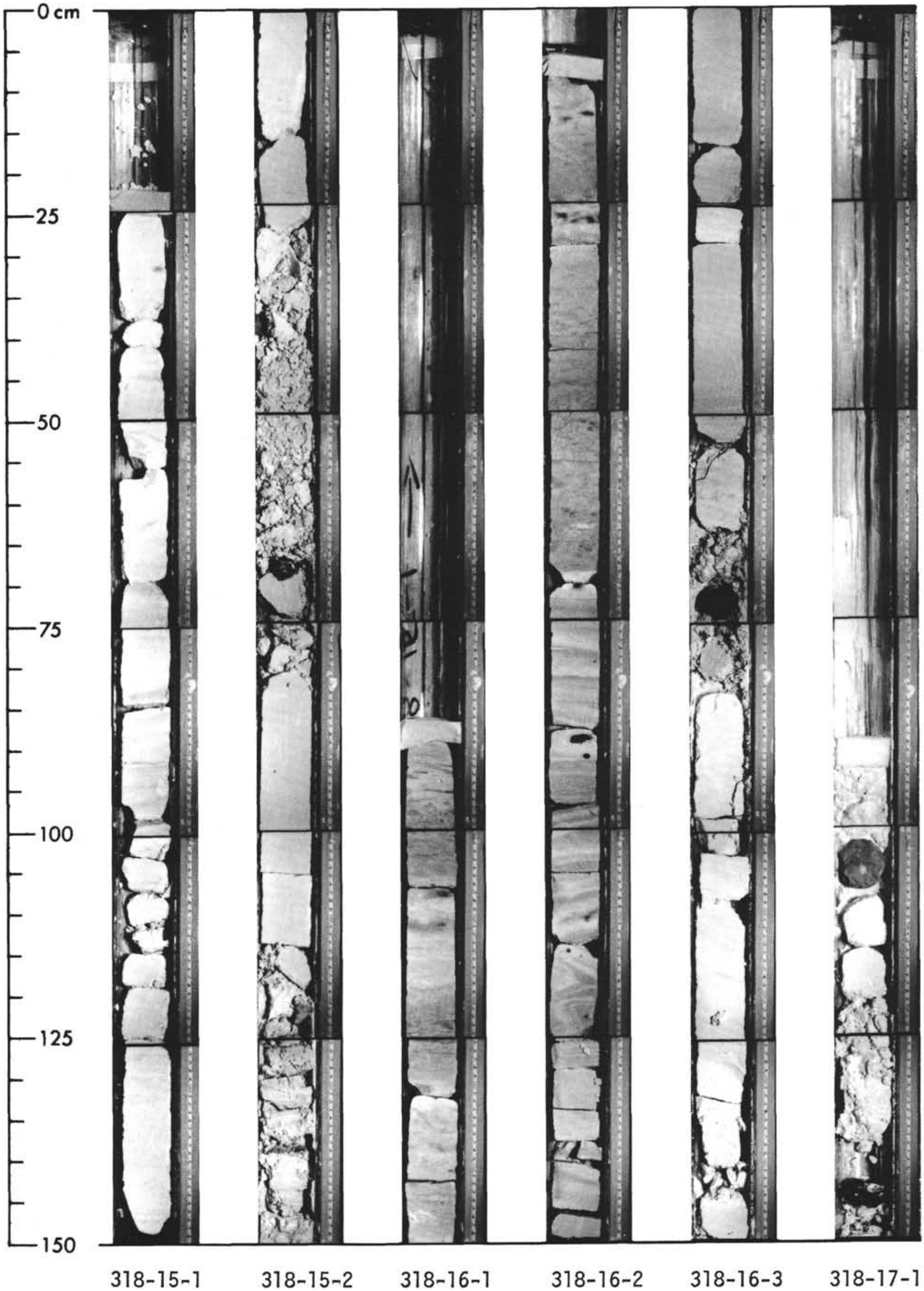
318-13-2
318-14-1
318-14-2
318-14-3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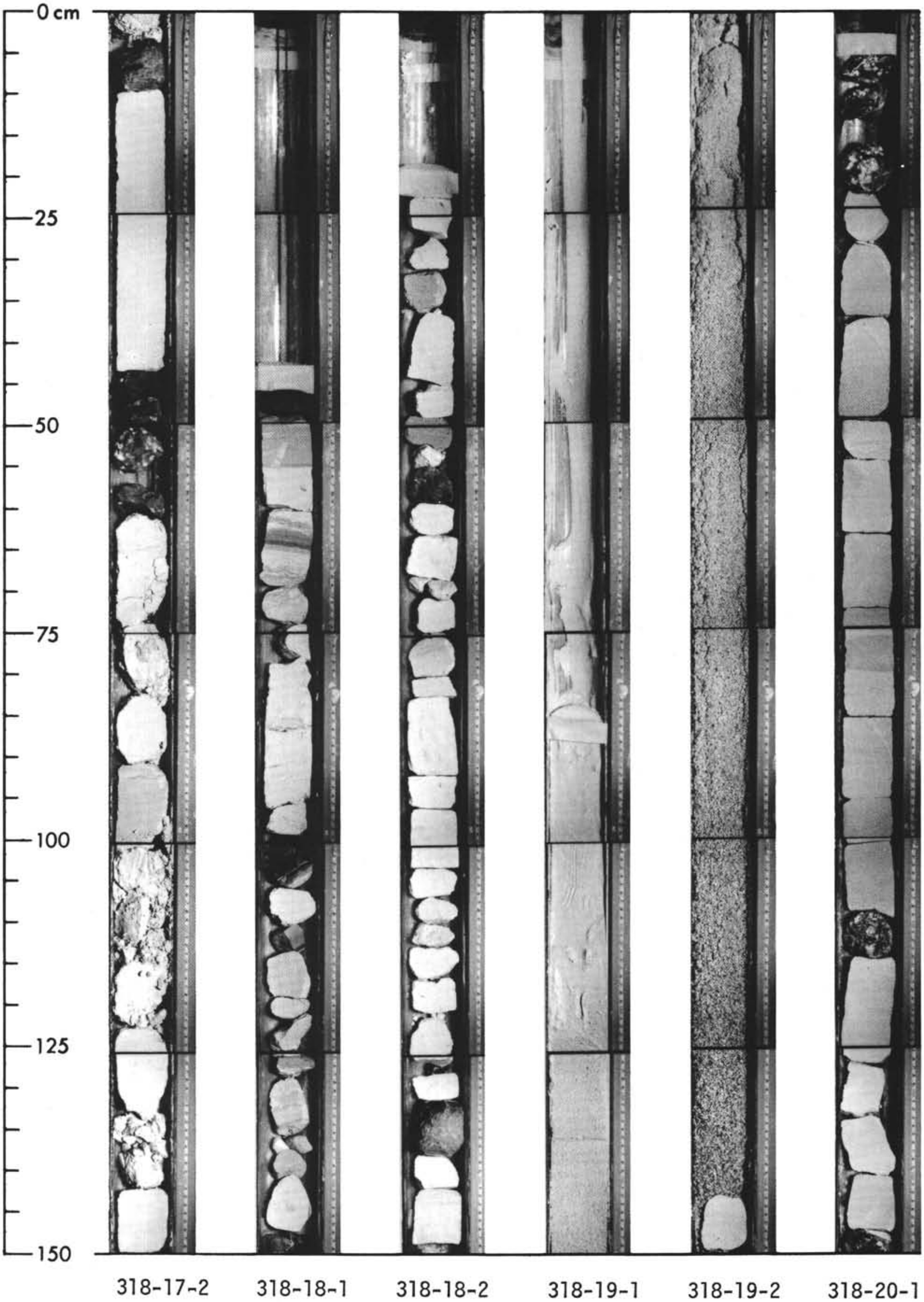
318-15-2
318-16-1
318-16-2
318-16-3
318-17-1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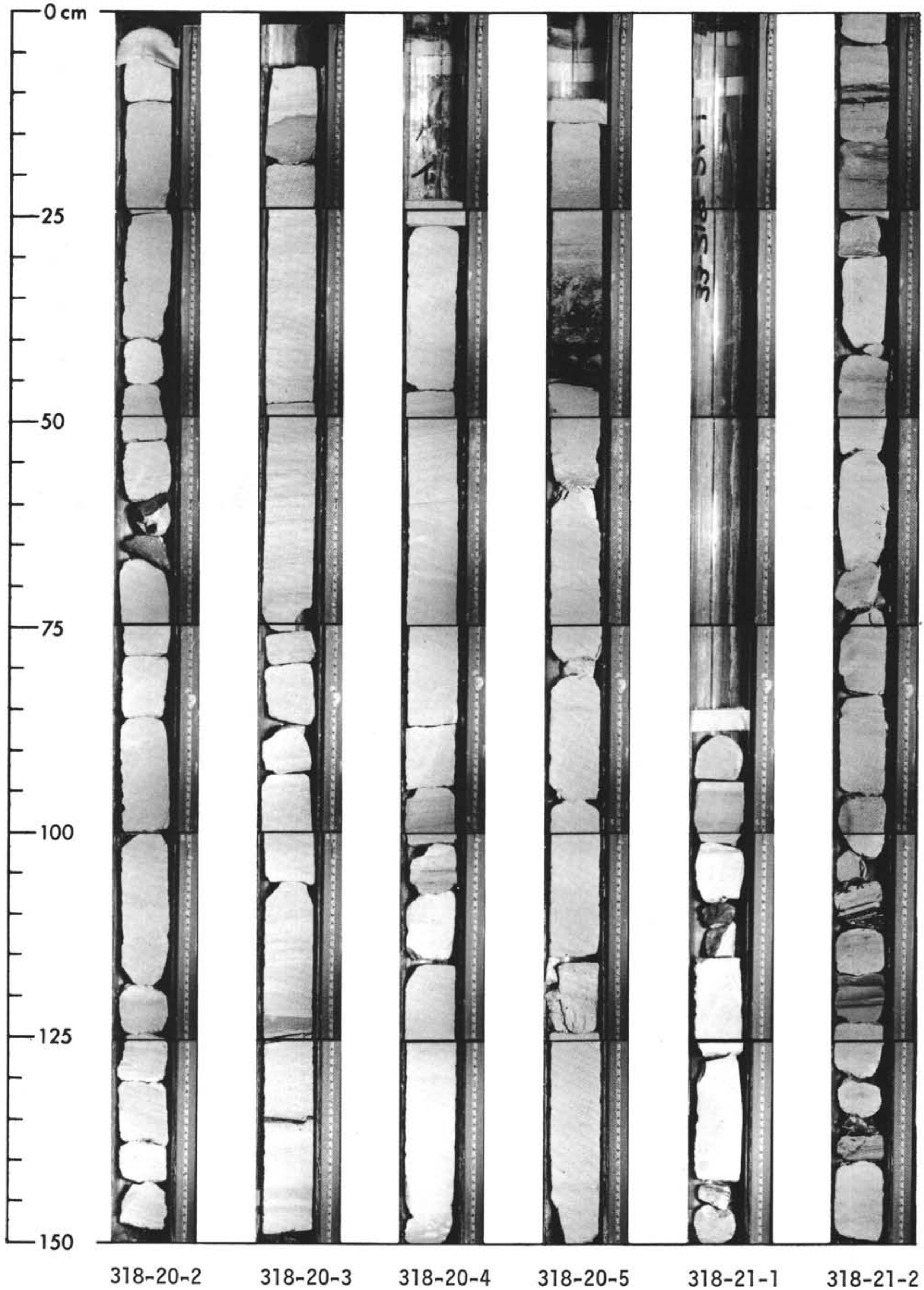
318-17-2
318-18-1
318-18-2
318-19-1
318-19-2
318-20-1


0 cm
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100
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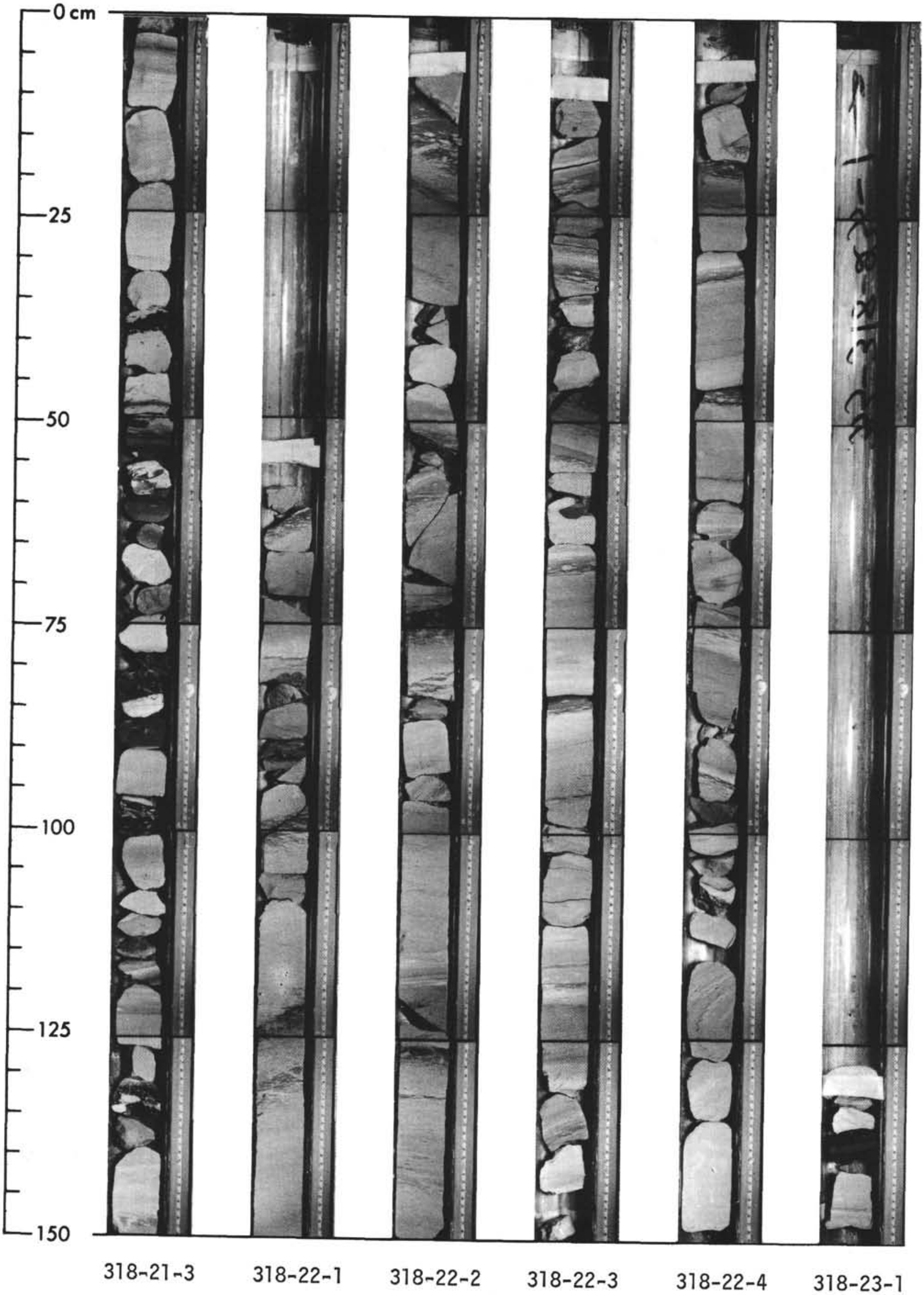
150
318-20-2
318-20-3
318-20-4
318-20-5
318-21-1
318-21-2


0 cm
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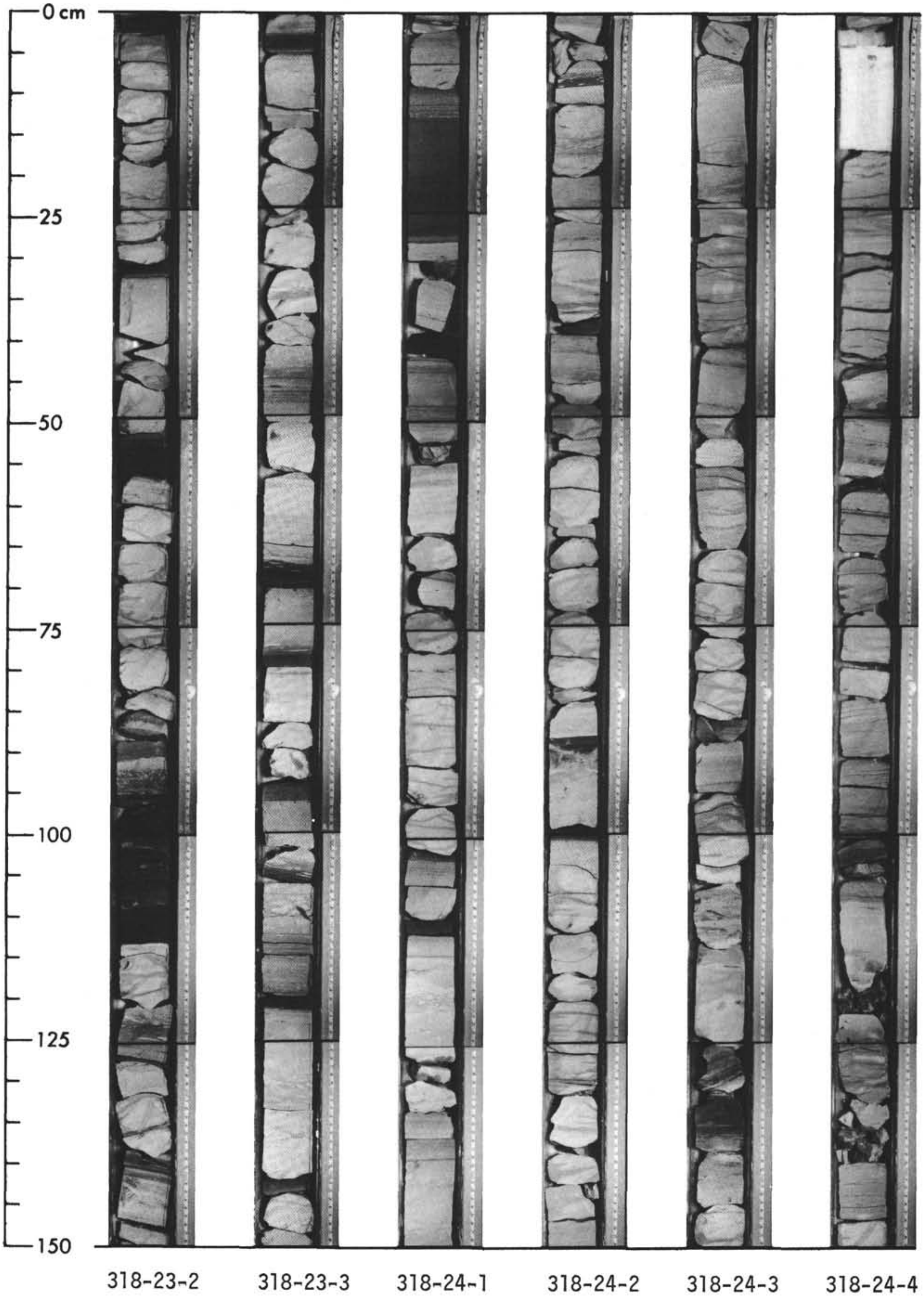
100
125
150
318-21-3
318-22-1
318-22-2
318-22-3
318-22-4
318-23-1


0 cm
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100
125
150
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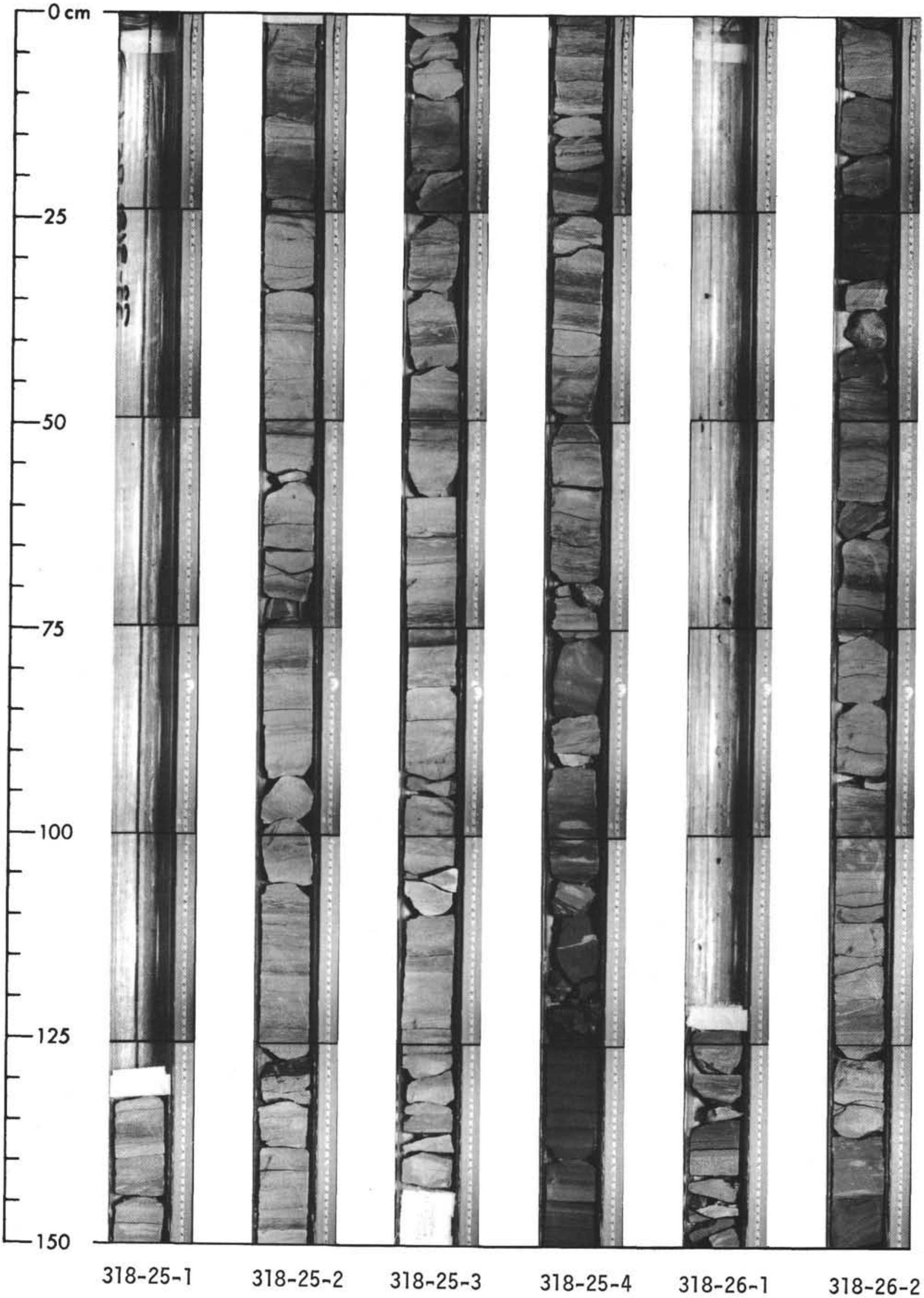
318-23-3
318-24-1
318-24-2
318-24-3
318-24-4


0 cm
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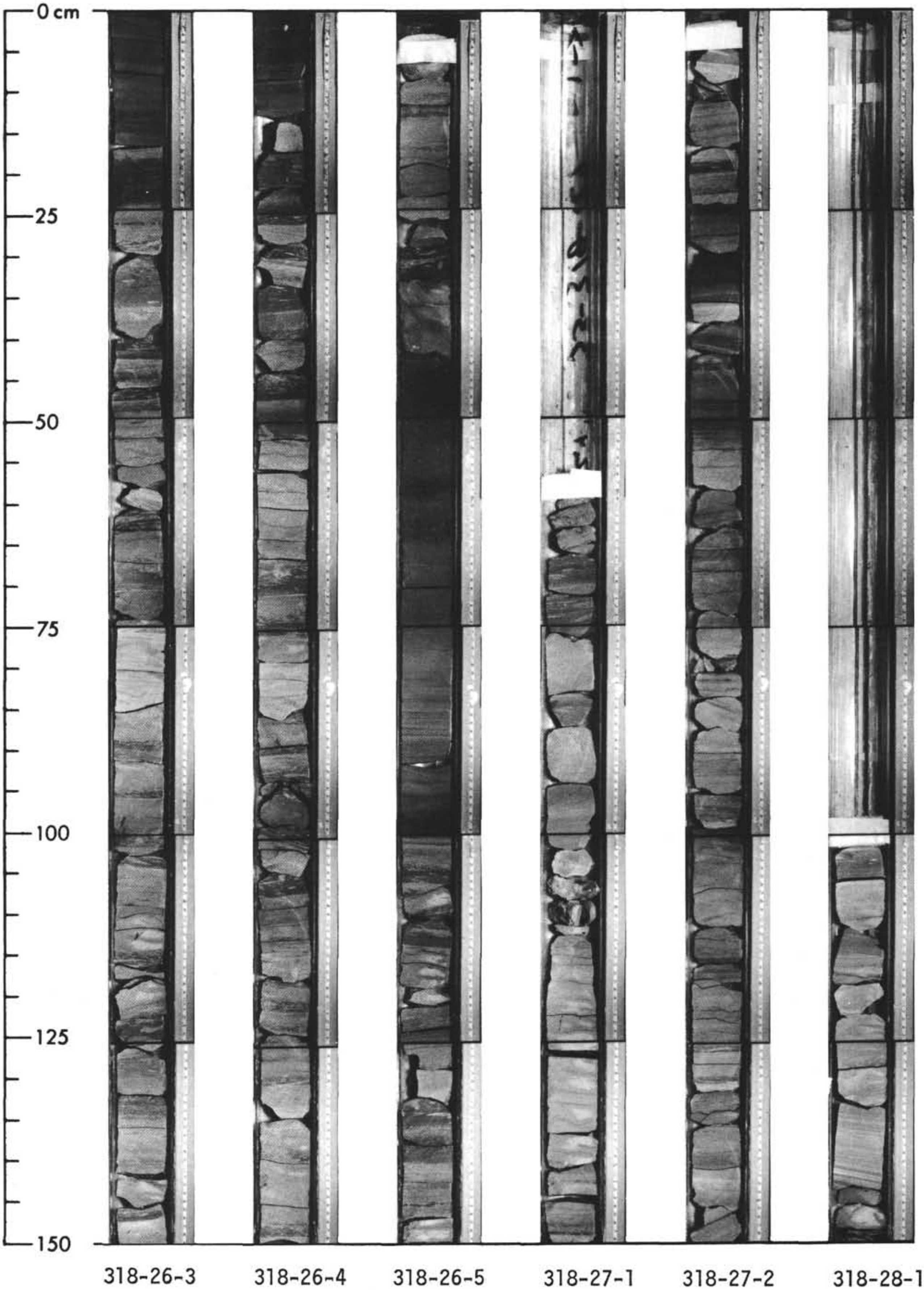
100
125
150
318-25-1
318-25-2
318-25-3
318-25-4
318-26-1
318-26-2


0 cm
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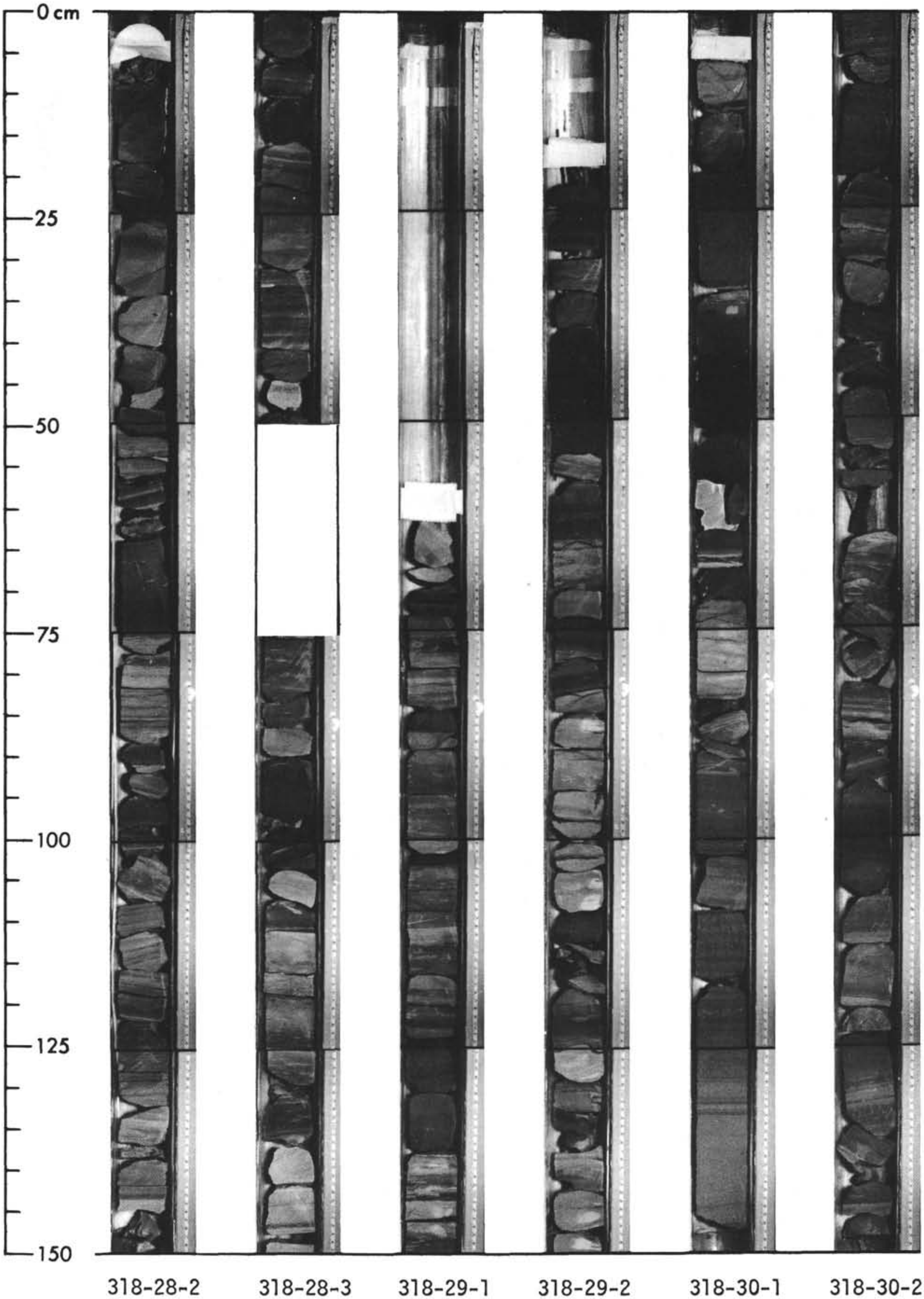
100
125
150
318-26-3
318-26-4
318-26-5
318-27-1
318-27-2
318-28-1


0 cm
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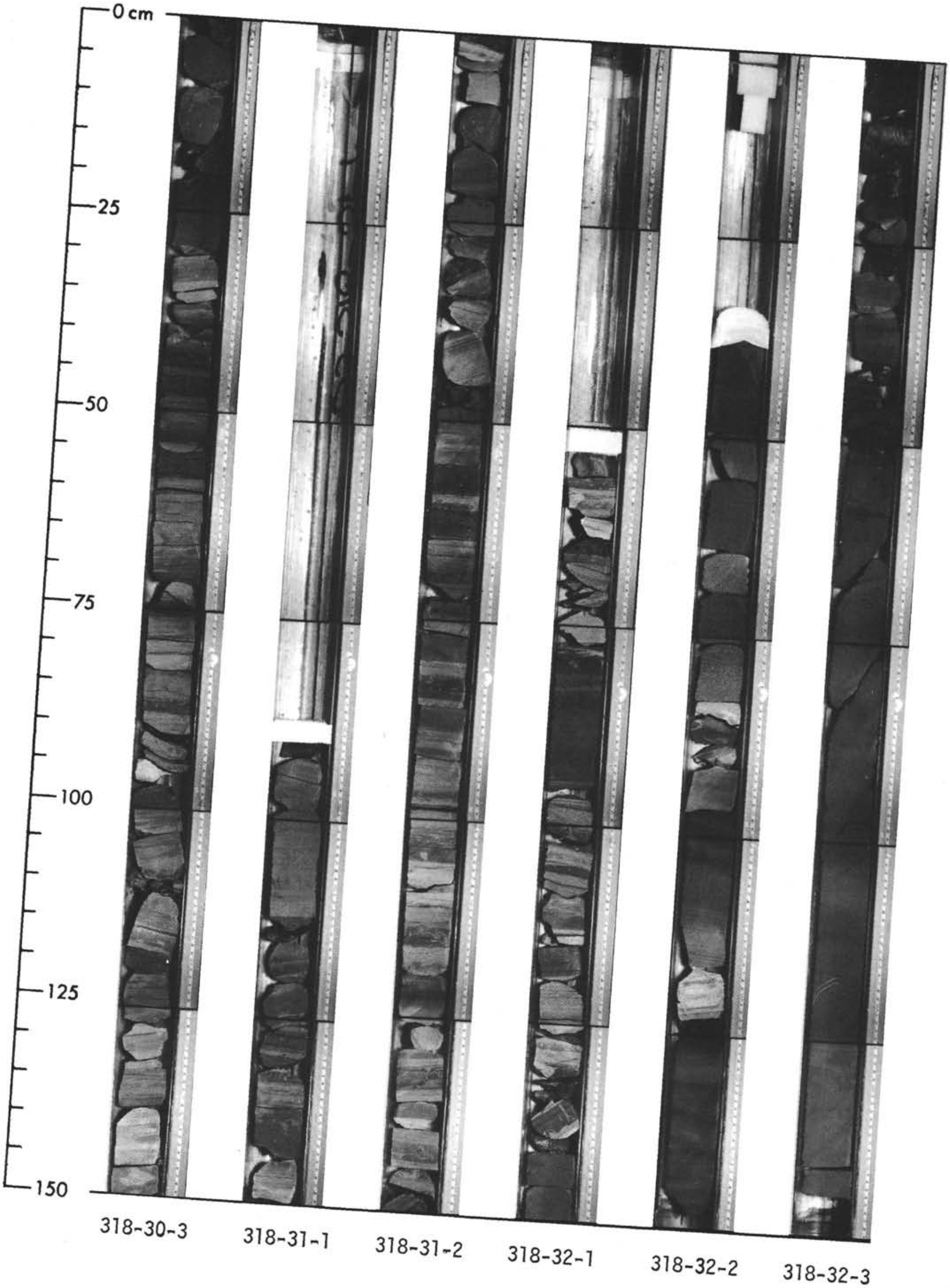
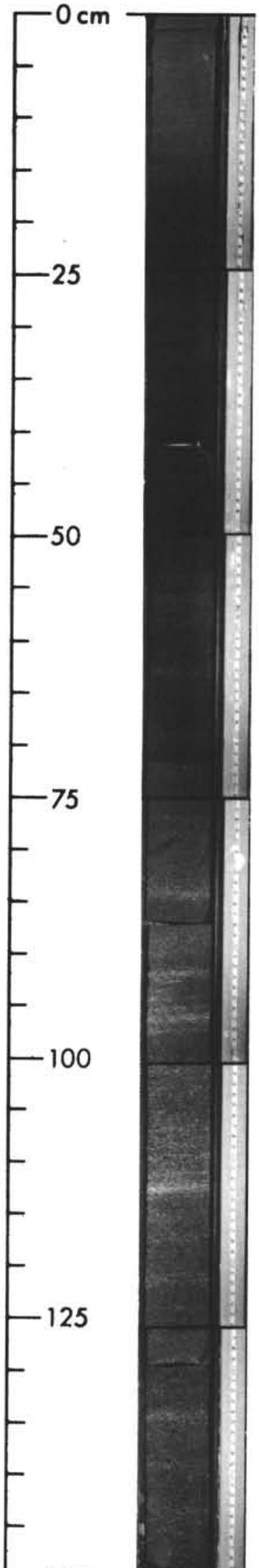
75
100
125
150
318-28-2
318-28-3
318-29-1
318-29-2
318-30-1
318-30-2


0 cm
25
50
75
100
125
150
318-30-3
318-31-1
318-31-2
318-32-1
318-32-2
318-32-3



318-32-4