5. SITE 410

The Shipboard Scientific Party[1]

SITE DATA — HOLE 410

Date Occupied: 1900 13 August 1976

Date Departed: 1800 17 August 1976

Time on Hole: 3 days, 23 hours

Position: Latitude: 45°30.51′N; Longitude: 29°28.56′W

Water Depth (sea level): 2975 corrected meters, echo sounding

Water Depth (rig floor): 2985 corrected meters, echo sounding

Bottom Felt at: 2985 meters, drill pipe

Penetration: 387.5 meters

Number of Holes on Site: 2

Number of Cores: 41

Total Length of Cored Section: 387.5 meters

Total Core Recovered: 232.15 meters

Percentage Core Recovery: 60 per cent

Oldest Sediment Cored:
Depth sub-bottom: 335 meters
Nature: Nannofossil chalk
Chronostratigraphic unit: Upper Miocene
Measured velocity: 1.6 km/s

Basement:
Depth sub-bottom: 340 meters[2]
Nature: Basalt is breccia
Velocity range: 3.88 to 4.32 km/s

Principal Results: Site 410 is on anomaly 5 (8.34 to 9.74 m.y.) on the west side of the Mid-Atlantic Ridge crest. Hole 410 was cored continuously through 340 meters of sediment to end in basalt at 387.5 meters sub-bottom. The hole was abandoned because the core barrel became jammed. Total recovery was 232.15 meters (60%); recovery in basalt was 11.40 meters (24%). The oldest sediment is indurated foraminifer limestone, believed to be upper Miocene, in basalt-limestone breccia within basement.

The youngest unit is 38 meters of Pleistocene marly ooze; this overlies 207 meters of Pleistocene, Pliocene, and upper Miocene nannofossil ooze, below which is 95 meters of upper Miocene nannofossil chalk. Basement is basalt-limestone breccia grading down into basalt lava.

SITE DATA — HOLE 410A

Date Occupied: 1900 17 August 1976

Date Departed: 1800 18 August 1976

Time on Hole: 23 hours

Position: Latitude: 45°30.53′N; Longitude: 29°28.56′W

Water Depth (sea level): 2977 corrected meters, echo sounding

Water Depth (rig floor): 2987 corrected meters, echo sounding

Bottom Felt at: 2987 meters, drill pipe

Penetration: 382.0 meters

Number of Holes on Site: 2

Number of Cores: 6

Total Length of Cored Section: 57.0 meters

Total Core Recovered: 26.91 meters

Percentage Core Recovery: 47 per cent

Oldest Sediment Cored:
Depth sub-bottom: 332 meters
Nature: Nannofossil chalk
Chronostratigraphic unit: Upper Miocene

Basement:
Depth sub-bottom: 331 meters[3]
Nature: Basalt
Velocity range: 3.78 to 4.97 km

Principal Results: Hole 410A was offset 110 meters at 020° from Hole 410 in 2987 meters of water. The hole was washed down through sediment to basalt at 330 meters sub-bottom. The hole was cored to 382 meters with 26.91 meters (47%) recovery, of which 18.55 meters was basalt (38%) recovery). The basalt is homogeneous aphyric pillow lava. The hole was abandoned when the drill string jammed again.

BACKGROUND AND OBJECTIVES

The area around the median valley on the Mid-Atlantic Ridge at 45°N has become one of the best-studied pieces of

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[2]Based on drilling log.

[3]Based on drilling log.

ocean crust. The earliest investigations were made in 1956 (Hill, 1960), when one of the first detailed bathymetric studies of an area of deep ocean crust set out to map a piece of typical median valley. Unfortunately, this small area turned out to be the only place for hundreds of kilometers where the valley was effectively blocked by two large volcanic seamounts from which basalt lavas were dredged (Muir and Tilley, 1964). The area was chosen by the cooperative Canadian project, Hudson Geotraverse, as the place where a planned 1°-wide strip was to be studied across the Atlantic crossed the crest of the Mid-Atlantic Ridge (Aumento et al., 1971). The project started in this area with a detailed survey stretching over several years and covering an area between 45°N and 46°N from the median valley about 2° westward and, on a smaller scale, 1° eastward. The survey included bathymetry, magnetics, gravity, seismic reflection, seismic refraction, dredging, heat flow, and more recently, deployment of the towed deep-ocean side-scan sonar vehicle GLORIA. With this background, the JOIDES Ocean Crust Panel chose to put one of the sites in its proposed longitudinal transect down the length of the Atlantic Ocean in the survey area. The aim of the longitudinal transect was to provide a series of holes on young crust of about the same age between Iceland and 22°N, to complement the increasing amount of information, derived from dredging, about the latitudinal variation in magmas erupted at the Mid-Atlantic Ridge crest. The age chosen was that of anomaly 5 (8.34 to 9.74 m.y.), the readily identifiable anomaly nearest the ridge crest, where sufficient sediment for spudding in would be found at all latitudes. Sites 395 and 396 (Legs 45 and 46), on opposite sides of the ridge axis, were the southernmost holes on this transect, at 22°N. Site 334 (Leg 37) was drilled on anomaly 5 at 37°N. Site 408, originally intended to be on anomaly 5, but moved to the older anomaly 6 (about 20 m.y.) was to have been the farthest north. Site 410 was designed to fill in the gap between 37°N and 63°N, to make an even spread of four sites on the transect. The primary purpose of the site, then, was to provide a point on the longitudinal transect and, in addition, to complement the intensive geophysical and geological survey work in the area.

The sediments at 45°N are expected to be very sensitive to climatic fluctuations in the Northern Hemisphere. In colder periods, cold water masses from the northern part of the Atlantic would be expected to penetrate as far south as this, while in warmer periods warm water masses from subtropical regions would penetrate north to these latitudes. The sediments were expected to contain an important record of climatic changes during the late Tertiary. Special emphasis, consequently, was placed on coring and recovering the complete sedimentary section.

Dr. B. Loncarevic of Bedford Institute made available excellent site survey information, in the form of unpublished Hudson Geotraverse charts (Figure 1). In addition, Dr. R. C. Searle of the Institute of Oceanographic Sciences provided a special site survey involving seismic reflection and GLORIA recordings made during summer 1975 by *R.R.S. Discovery* (Figures 2 and 3). This survey selected three sites, all in sediment-filled ponds and all on anomaly 5, and ranked them in order. After careful examination of the records, we chose the third site (C) as being most likely to contain the complete sedimentary section; also, it lay rather to the west of the crest of anomaly 5, instead of on its eastern edge, and so was most likely to provide crust magnetized during the time of that anomaly. The chief reason for its low ranking was apparently that the sediment in the pond was not flat; to us this seemed outweighed by the other points in its favor.

Figure 4 shows the seismic reflection trace obtained as *Glomar Challenger* came up to drop the beacon. This can be compared with a nearby track from the *Discovery* survey (Figure 5), and shows the form of sediments and basement outcrops along a line approximately perpendicular to the Mid-Atlantic Ridge at this latitude.

OPERATIONS

We approached the site from the north, having come out of Reykjavik. Aiming for a point northwest of the site, we intended to come in along one of the *Discovery* survey lines running northwest-southeast and drop the beacon on the first pass, using the *Discovery* seismic reflection track. Satellite fixes were not numerous, however, and dead reckoning was not as successful as usual, so that we made our turn to the southeast about two miles later than we should have. Thus, though the two seismic reflection tracks show general similarities, in detail they are different. Figure 6 shows the incoming track and the *Discovery* track. Figure 4 shows the *Challenger* profile coming up to beacon drop.

Despite these problems, the records were similar enough to allow a first-time beacon drop, judged from sediment thickness on the seismic reflection record and magnetic anomaly from the magnetometer. We made the drop just as the anomaly identified as anomaly 5 from the Canadian survey flattened out to its peak, thus ensuring a position somewhat northwest of the peak of the anomaly.

We dropped the beacon at 1742Z on 13 August. Pipe was run and the first core came on deck at 0244Z on 14 August. We cored 340 meters of sediment continuously from the mudline. Five in-hole temperature measurements were made for heat flow calculation, and took about 1¼ hours each. The appropriate measurements of thermal conductivity were also made. The *in-situ* pore water sampler was run four times, and took over an hour each time. The sampler appeared to have run each time, but only three samples of water were retrieved, from 45.5, 93.0, and 207 meters sub-bottom. The fourth attempt, at 264 meters, was in hard chalk, which may not have had high enough permeability to respond in the five-minute sampling time. Results are discussed in a later section.

Basement was reached at 340 meters sub-bottom, at 0800 on 16 August. The heave compensator was picked up when basement was reached, and it ran very satisfactorily. The upper unit of basalt-limestone breccia was very hard to drill, but the drilling rate increased again below it. After cutting Core 41 (down to 387.5 m) at about 2100 hours on 16 August, the core barrel became jammed inside the lower collar, and could not be freed (Table 1). The string was pulled, and the core barrel was found to be wedged in by sand.

The ship was offset 110 meters on a bearing 020° from the beacon, and the pipe was run again. It was washed down to basement, at 330 meters sub-bottom, and coring on this

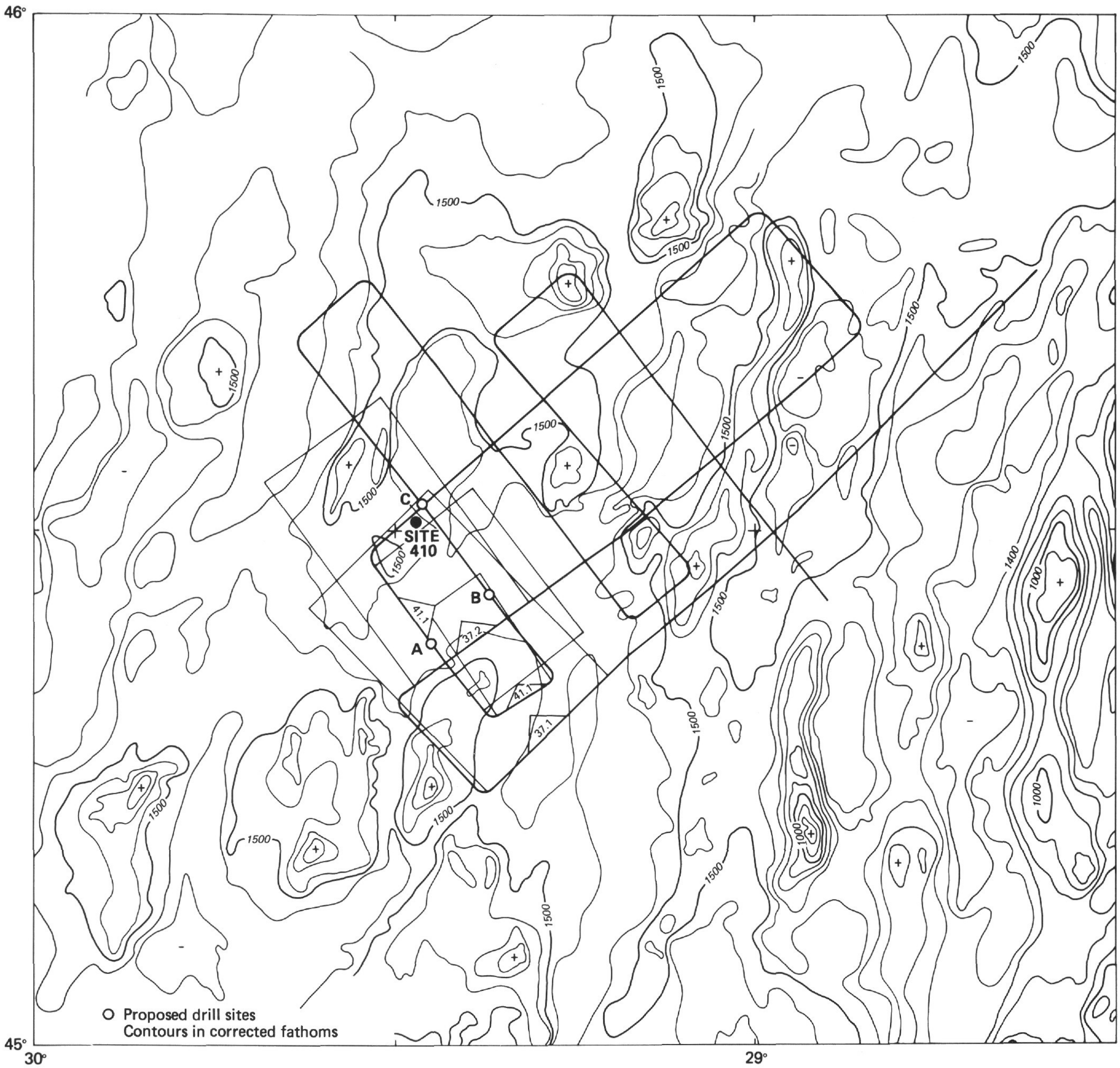


Figure 1. *Bathymetric chart of the vicinity of Site 410, provided by B. Loncarevic of the Bedford Institute of Oceanography. Contours are corrected fathoms. Tracks are of the 1975* Discovery *cruise. Locations A, B, and C are recommended drill sites.*

occasion began without the heave compensator. After 52 meters of rapid penetration into basalt with good recovery, the pipe became jammed so that rotation and circulation were not possible. It was freed after a struggle, and we decided to abandon the site. When the bottom-hole assembly came on deck, one bumper sub was found to be jammed by sand similar to that encountered before.

Because time was short, we made no further attempt to core at this site, and got underway for FAMOUS at about 1800 hours on 18 August. As we left the site, we dropped a sonobuoy. We steamed away northeast, streamed the airguns and hydrophones, and came back past the sonobuoy on our way toward Site 411.

SEDIMENT LITHOSTRATIGRAPHY

Introduction: Hole 410

We recovered sediment at Hole 410 down to the core catcher of Core 36, at 340 meters sub-bottom; recovery rate was 65 per cent. Below this, indurated basalt-limestone breccia occurs to a depth of 380.35 meters. The drill bit jammed at 381.0 meters. We recovered in the drill bit a coarse sand composed of basalt and limestone fragments.

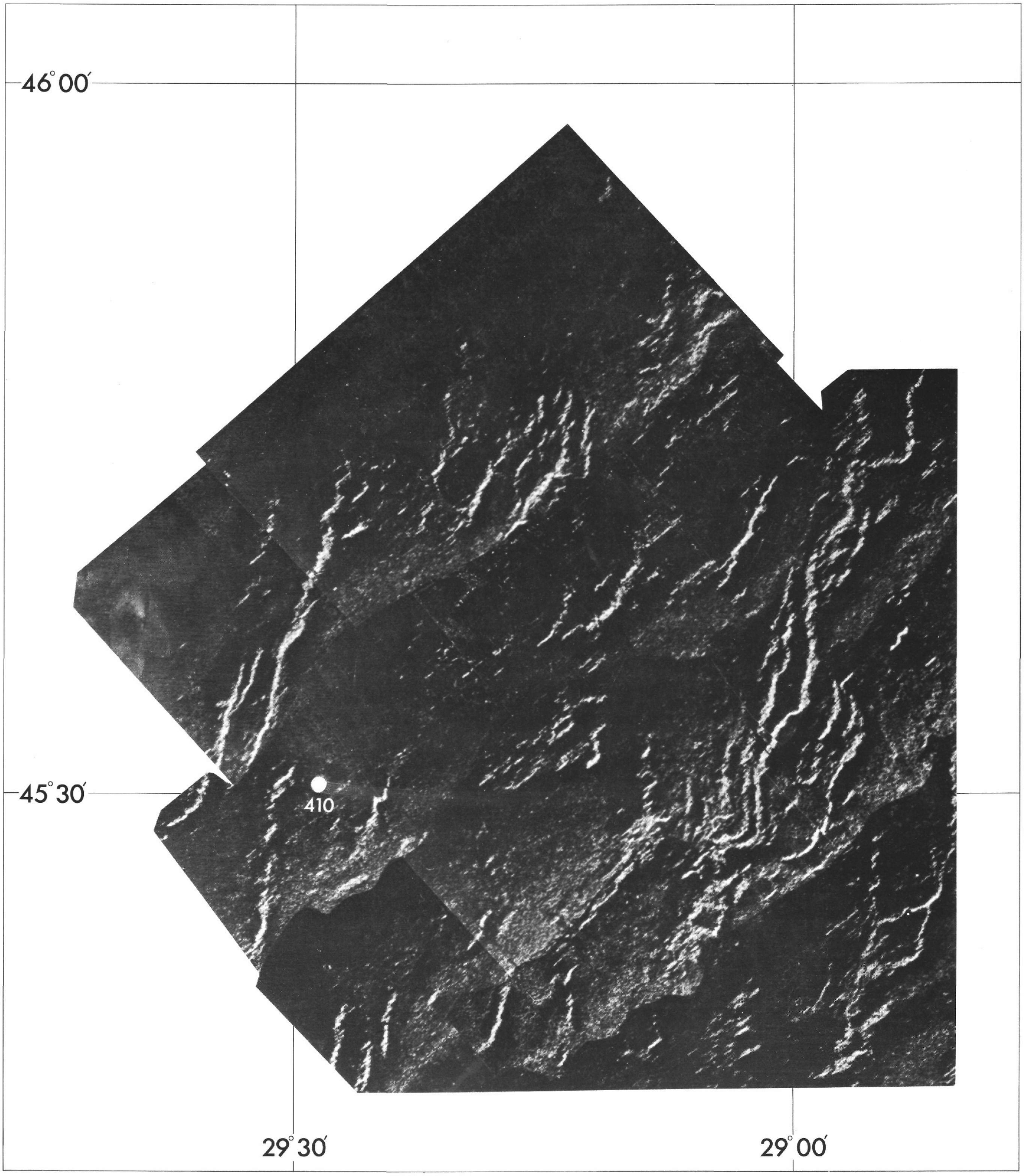


Figure 2. *GLORIA side-scan positive mosaics in the vicinity of Site 410. Provided by Dr. R. C. Searle of the Institute of Oceanographic Sciences, U. K.*

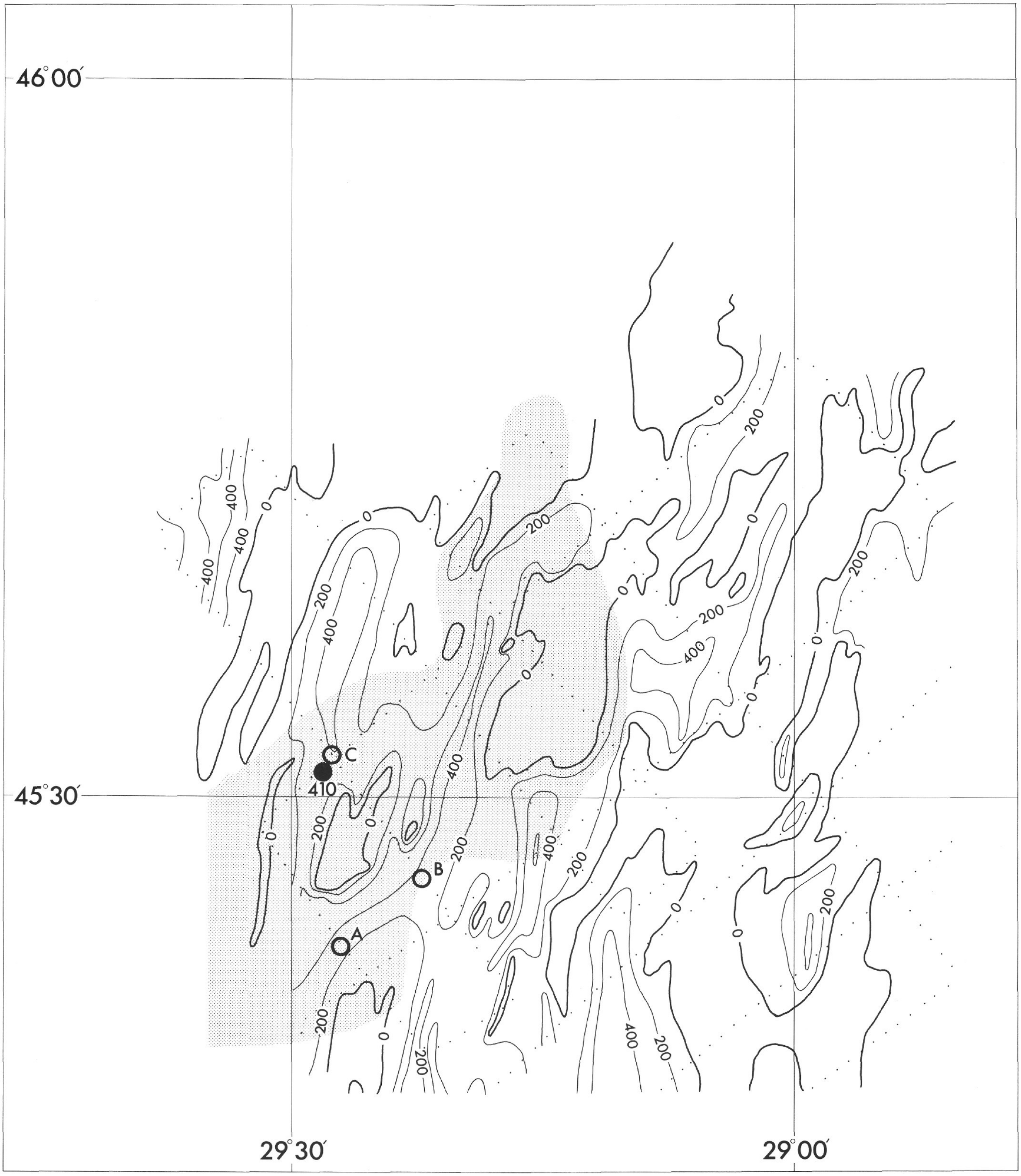


Figure 3. *Sediment isopachs in milliseconds for the vicinity of Site 410. Provided by Dr. R. C. Searle of the Institute of Oceanographic Sciences, U.K. Shaded area is magnetic anomaly 5.*

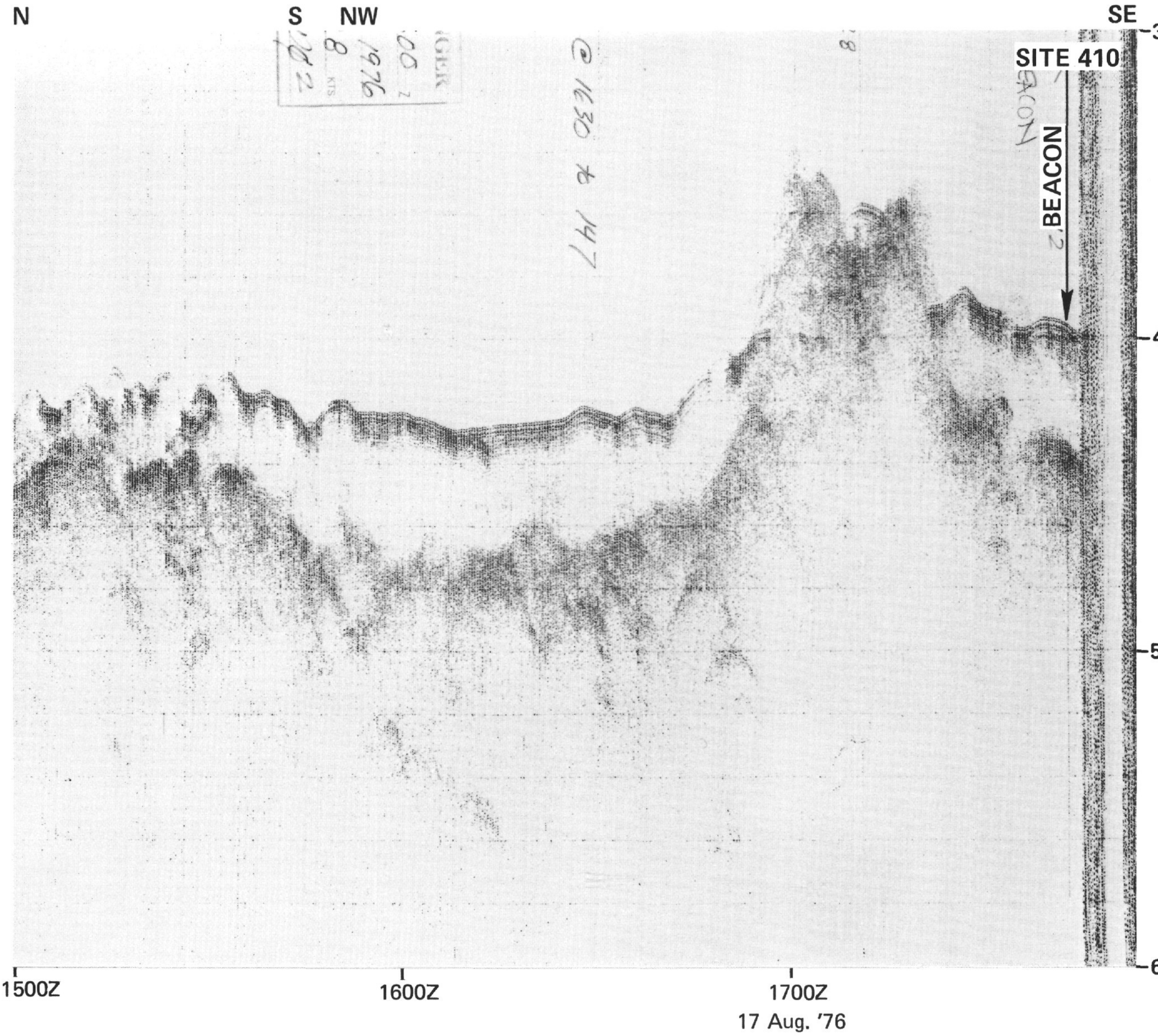


Figure 4. *Seismic profile from* Glomar Challenger *up to the beacon drop for Site 410.*

The sediment above the top of the basalt-limestone breccia can be subdivided into three units, on the basis of lithologic characteristics. The limestone matrix within the basalt-limestone breccia will be described as interlayered sedimentary rock. The sediment units are as follows:

Unit 1 (0 to 36.0 m): Pleistocene, mostly nannofossil ooze with interlayered calcareous muds and marly nannofossil oozes.

Unit 2 (36.0 to 245.0 m): Pleistocene to upper Miocene nannofossil ooze.

Unit 3 (245.0 to 340.0 m): Upper Miocene nannofossil chalk with minor interbedded nannofossil ooze and a thin basaltic sand at the base.

Description of Lithologic Units

Unit 1 (Cores 1 through 4, 0 to 36.0 m)

Cores 1 through 4 (Figure 7) are nannofossil oozes interbedded with marly nannofossil oozes and calcareous muds. A comparison of Munsell color determinations of the sediment with 24 carbonate-bomb results and estimates of detrital silt-size quartz, feldspar, and heavy minerals and clay from 18 smear slides shows good correlation among these characteristics (Figure 8, Table 2). The nannofossil oozes are light gray to very light gray, and contain 60 to 95 per cent $CaCO_3$ and an average of less than 10 per cent detrital minerals (Table 2). Marly nannofossil oozes are gray to light gray, and contain 30 to 60 per cent $CaCO_3$ and an average of less than 30 per cent detrital minerals. Calcareous muds are generally dark gray to olive-gray, and contain 10 to 30 per cent $CaCO_3$, with an average of 60 to 65 per cent detrital minerals (Table 2). The percentage of calcareous ooze increases downhole from approximately 60 per cent in Core 1 to about 70 per cent in Cores 2 and 3, then decreases to 34 per cent in Core 4, owing to a large amount of marly ooze (61% in Core 4) (Table 3, Figure 9).

The calcareous muds and marly nannofossil oozes contain 1 to 10 per cent volcanic glass and biogenic silica;

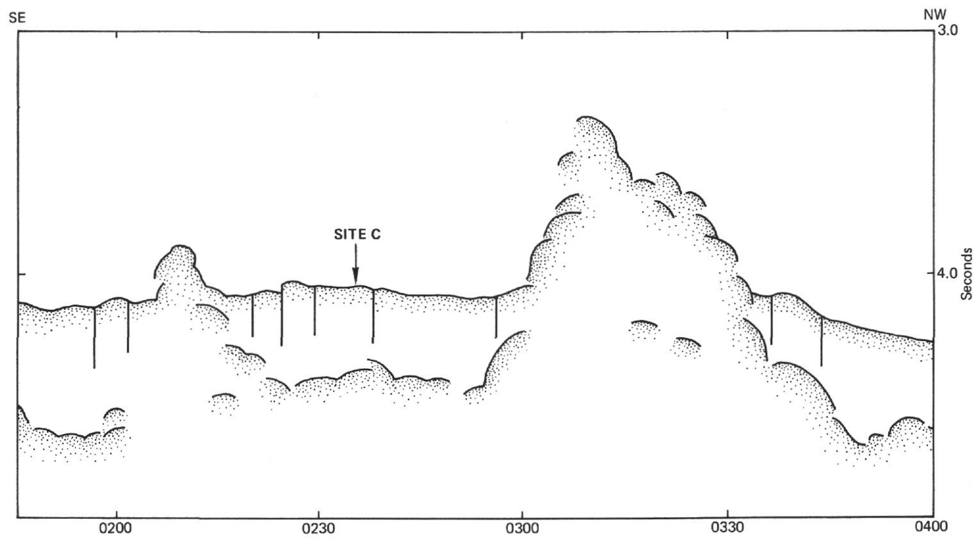


Figure 5. *Line drawing of* Discovery *seismic record near recommended Site C (location on Figure 6).*

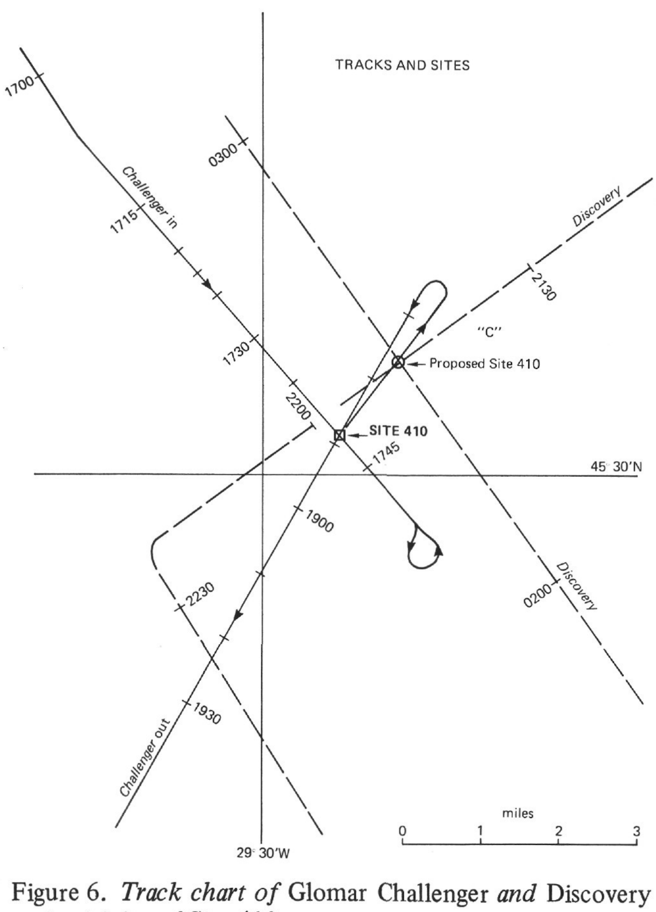


Figure 6. *Track chart of* Glomar Challenger *and* Discovery *in vicinity of Site 410.*

only traces of these constituents occur in the nannofossil oozes. Foraminifers occur in amounts below 5 per cent; maximum values up to 10 per cent occur in only a few samples. In Core 1, Section 1 (80 cm), a pteropod *(Diacria trispinosa)* sandy granule layer 0.5 cm thick contains four whole pteropods and many fragments.

Three erratic pebbles, classified as limestone, hornblende gabbro, and anorthosite, occur in Core 1, and an arkose pebble occurs in Core 2.

Drilling deformation in Cores 1 through 4 was slight to moderate. Minor bioturbation mottling and lamination are present throughout the unit, and graded bedding may occur in Core 1, Sections 1 and 4.

Unit 2 (Cores 5 through 26, 36.0 to 245.0 m)

Cores 5 through 26 (Figure 7) consist of nannofossil ooze; the $CaCO_3$ content (carbonate-bomb results) increases from 75 to 80 per cent near the top of the unit to about 95 per cent at the bottom. Sediment colors grade from light gray to very light gray from top to bottom, reflecting the decreasing detrital content down-section.

Most smear-slide samples are composed almost entirely of nannofossils; nannofossil content ranges between 80 and 95 per cent. The other major biogenic constituent is foraminifers, generally present in amounts between 2 and 5 per cent, but as much as 10 per cent in a few samples. Biogenic silica (diatoms, sponge spicules) is present in very small amounts, from 2 per cent to only a trace, in most samples. Coarse silt-size detrital quartz and feldspar constitutes 2 to 5 per cent of most samples. Sieve separations for micropaleontological study of core-catcher samples in Cores 5 through 15 contain small amounts of fine sand-size ($\sim$150 μm) quartz grains and rock fragments (see Biostratigraphy). Erratic pebbles occur in Cores 5 (chert), 6 (gneiss, basalt), 7 (gneiss), 10 (anorthosite), and 26 (echinoderm biomicrite). The limestone pebble in Core 26 is of special interest, owing to the late Miocene date of that horizon, which presumably would eliminate an ice-rafting origin for the pebble.

All of Unit 2, except the three lowermost cores (24 to 26), is severely deformed. Pyritized burrows, lithified

TABLE 1
Coring Summary, Holes 410 and 410A

Core	Date (Aug. 1976)	Time	Depth From Drill Floor (m)	Depth Below Sea Floor (m)	Length Cored (m)	Length Recovered (m)	Recovery (%)
Hole 410							
1	14	0244	2984.0-2991.5	0.0-7.5	7.5	7.32	98
2	14	0341	2991.5-3001.0	7.5-17.0	9.5	5.32	56
3	14	0446	3001.0-3010.5	17.0-26.5	9.5	5.04	53
4	14	0542	3010.5-3020.0	26.5-36.0	9.5	6.35	67
5	14	0632	3020.0-3029.5	36.0-45.5	9.5	9.20	97
6	14	0840	3029.5-3039.0	45.5-55.0	9.5	4.13	43
7	14	0934	3039.0-3048.5	55.0-64.5	9.5	2.08	22
8	14	1031	3048.5-3058.0	64.5-74.0	9.5	9.46	100
9	14	1220	3058.0-3067.5	74.0-83.5	9.5	trace	0
10	14	1315	3067.5-3077.0	83.5-93.0	9.5	9.54	100
11	14	1535	3077.0-3086.5	93.0-102.5	9.5	9.63	101
12	14	1640	3086.5-3096.0	102.5-112.0	9.5	trace	0
13	14	1740	3096.0-3105.5	112.0-121.5	9.5	2.35	25
14	14	2040	3105.5-3115.0	121.5-131.0	9.5	9.67	102
15	14	2150	3115.0-3124.5	131.0-140.5	9.5	8.96	94
16	14	2300	3124.5-3134.0	140.5-150.0	9.5	9.20	97
17	14	2350	3134.0-3143.5	150.0-159.5	9.5	trace	0
18	15	0104	3143.5-3153.0	159.5-169.0	9.5	7.41	78
19	15	0206	3153.0-3162.5	169.0-178.5	9.5	9.35	98
20	15	0404	3162.5-3172.0	178.5-188.0	9.5	3.57	38
21	15	0515	3172.0-3181.5	188.0-197.5	9.5	9.70	102
22	15	0625	3181.5-3191.0	197.5-207.0	9.5	9.60	101
23	15	0900	3191.0-3200.5	207.0-216.5	9.5	8.60	91
24	15	1005	3200.5-3210.0	216.5-226.0	9.5	9.60	100
25	15	1120	3210.0-3219.5	226.0-235.5	9.5	9.64	101
26	15	1435	3219.5-3229.0	235.5-245.0	9.5	4.19	44
27	15	1550	3229.0-3238.5	245.0-254.5	9.5	4.79	50
28	15	1710	3238.5-3248.0	254.5-264.0	9.5	5.46	57
29	15	2010	3248.0-3257.5	264.0-273.5	9.5	6.75	71
30	15	2138	3257.5-3267.0	273.5-283.0	9.5	9.50	100
31	15	2335	3267.0-3276.5	283.0-292.5	9.5	5.32	56
32	16	0200	3276.5-3286.0	292.5-302.0	9.5	4.97	52
33	16	0306	3286.0-3295.5	302.0-311.5	9.5	2.30	24
34	16	0406	3295.5-3305.0	311.5-321.0	9.5	2.62	28
35	16	0540	3305.0-3314.5	321.0-330.5	9.5	5.13	54
36	16	0715	3314.5-3324.0	330.5-340.0	9.5	4.00	42
37	16	0850	3324.0-3333.5	340.0-349.5	9.5	1.00	11
38	16	1050	3333.5-3343.0	349.5-359.0	9.5	1.50	16
39	16	1718	3343.0-3352.5	359.0-368.5	9.5	6.70	71
40	16	1905	3352.5-3362.0	368.5-378.0	9.5	0.80	8
41	17	0900	3362.0-3371.5	378.0-387.5	9.5	1.40	15
Total					387.5	232.15	60
Hole 410A							
1	17	2330	3312.0-3321.5	325.0-334.5	9.5	8.72	92
2	18	0120	3321.5-3331.0	334.5-344.0	9.5	4.18	44
3	18	0330	3331.0-3340.5	344.0-353.5	9.5	3.95	42
4	18	0532	3340.5-3350.0	353.5-363.0	9.5	3.60	38
5	18	0730	3350.0-3359.5	363.0-372.5	9.5	3.72	39
6	18	0855	3359.5-3369.0	372.5-382.0	9.5	2.74	29
Total					57.0	26.91	47

Note: When pipe was retrieved, sand was found in a bumper sub. This has been counted in Core 6.

enough to withstand the core deformation, and thin, pale green (glauconitic?) laminations occur in some cores above Core 24. Core 24 contains two concentric burrows (1 cm diameter), and Cores 24 to 26 have some pale green laminae and irregularly shaped bioturbation mottling. The presence of pyritized burrows in the severely deformed cores of Unit 2 suggests that bioturbation mottling may have also been common there but was destroyed by disturbance of the soupy sediment.

Unit 3 (Cores 27 through 36, 245.0 to 340.0 m)

This unit is similar in composition and color to Unit 2 above. Most of Unit 3, in contrast to Unit 2, is firm enough to be classified as chalk. Unit 3 is also more uniformly rich

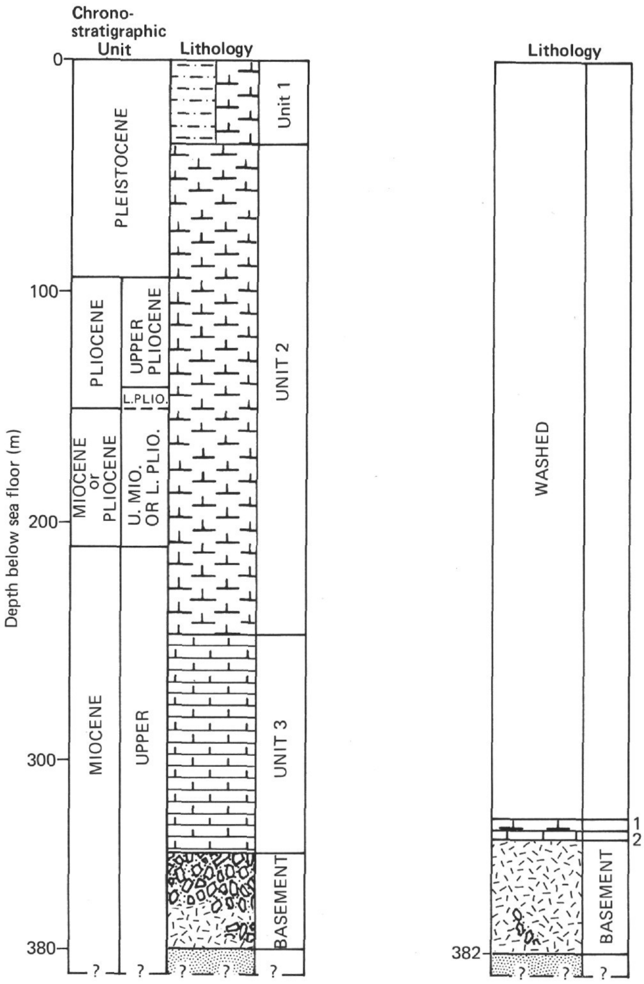


Figure 7. *Generalized stratigraphy of Holes 410 and 410A, Site 410. (Lithologic symbols according to standard DSDP usage.)*

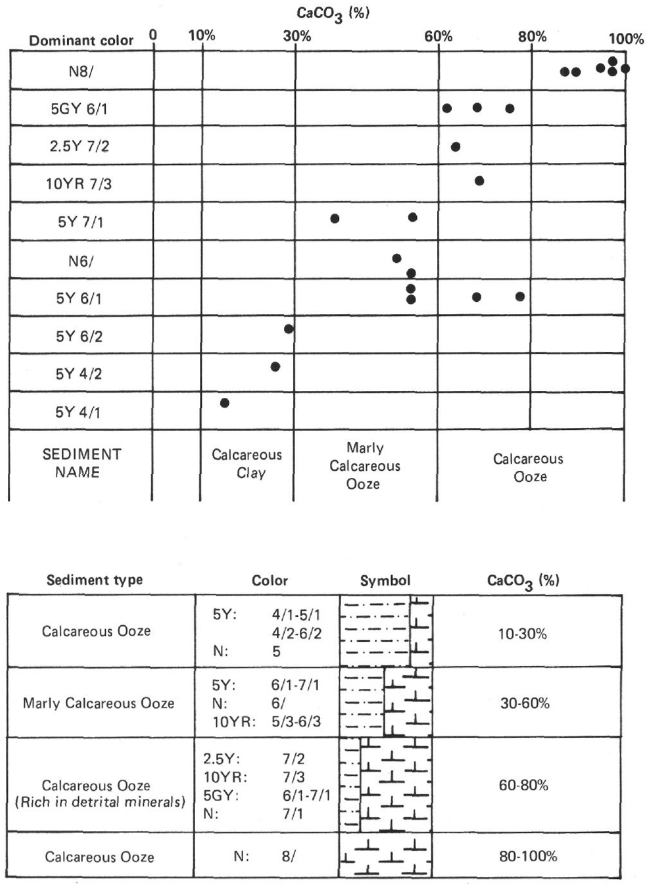


Figure 8. *Classification of sediment type by colors for Hole 410, Cores 1 through 4.*

in $CaCO_3$ (90 to 100%, carbonate-bomb results) than Unit 2, and its color, varying between very light gray and white, except for thin light gray laminations and mottles, is more uniform.

Nannofossils constitute more than 90 per cent of most smear-slide samples; foraminifers and detrital quartz and feldspar silt make up less than 2 to 3 per cent where present. A black lamination composed of pyrite (40%) and nannofossils occurs in Core 28.

A large number and variety of bioturbation features are present in Unit 3. Sub-horizontal, back-filled burrows (*Zoophycos*,) and light gray specks (*Helminthoida*?) and irregularly shaped vertical and randomly oriented light gray mottles are common. Pyritized burrows, some with geopetal fillings of pyrite, are as abundant as in Unit 2. Laminations of thin black pyrite and pale green glauconite-rich ooze occur in most sections. In Core 27, the glauconitic laminations have dips of 5 to 10 per cent, suggesting that they are parts of cross beds. Thin (up to 10 cm), light gray, intensely deformed ooze layers are interbedded with the chalk in most layers.

In Core 34, the color grades downward from very light gray to pale yellow; the color remains pale yellow through

TABLE 2
Correlation of Color and Percentage of Detrital Silt-Size Minerals, Cores 1 Through 4, Hole 410

Number of Samples	Classification	Color Ranges	Minerals (Average %) Quartz and Feldspar	Heavy Minerals	Clay
4	Calcareous mud (10-30% $CaCO_3$)	5Y 4/1 - 5/1 5Y 4/2 - 6/2 N5	24.5	5.5	32.0
6	Marly calcareous ooze (30-60% $CaCO_3$)	5Y 6/1 - 7/1 N6 10YR 5/3 - 6/3	4.7	2.0	19.7
5	Calcareous ooze (Rich in detrital material) (60-80% $CaCO_3$)	2.5Y 5/2 - 7/2 10YR 7/3 5GY 6/1 - 7/1 N7	4.2	1.6	12.0
3	Calcareous ooze (80-100% $CaCO_3$)	N8	1.0	0.3	3.0

Core 36 to the contact with basement. Pyritized burrows in Cores 34 to 36 are covered with an oxidized coating (limonite/goethite?).

The sediment in Core 36 is pale yellow nannofossil ooze, soupy in Sections 1 and 2 and firm in Section 3. Basaltic sand and gravel particles are scattered widely throughout Sections 1 to 3. The core catcher contained two thin (5 to 10

TABLE 3
Sediment Classification, Cores 1 Through 4, Hole 410

Sediment Classification	Core 1 Thickness (m)	Core 1 % of Core	Core 2 Thickness (m)	Core 2 % of Core	Core 3 Thickness (m)	Core 3 % of Core	Core 4 Thickness (m)	Core 4 % of Core
Calcareous mud (10-30% $CaCO_3$)	0.5	7.5	0.2	3.9	0.7	15.0	0.3	4.8
Marly calcareous ooze (30-60% $CaCO_3$)	2.25	33.8	1.25	23.6	0.7	15.0	3.8	61.3
Calcareous ooze Rich in detrital material (60-80% $CaCO_3$)	2.15	32.3	0.1	1.9	0.25	5.4	0.0	0.0
Calcareous ooze (80-100% $CaCO_3$)	1.75	26.3	3.73	70.6	3.0	64.5	2.1	33.9
Total	6.65	99.9	5.28	99.9	4.65	99.9	6.2	100.0

cm) layers of basaltic sand interbedded with 5-cm-thick ooze layers (order from top to bottom: ooze, sand, ooze, sand). The sand layers were well sorted, composed mostly of sub-angular, medium sand-size particles of basalt, limonite, and limestone. A suggestion of slight grading was observed. A serpentine pebble was in the core catcher.

Interlayered Sedimentary Rock (Cores 37 to 41, 340.0 to 381.0 m)

This sequence is mostly a basalt-limestone breccia. Pale orange to pale yellow limestone matrix encloses sand- to cobble-size angular basalt fragments. Cores 37 and 38 consist wholly of the breccia, Core 39 contains interbedded breccia and basalt in about equal proportions, Core 40 contains only basalt, and Core 41 is basalt with only local small patches of breccia.

The limestone matrix is foraminiferal biomicrite with some small areas that appear to be pelleted. Thin veins of sparry calcite pass through the matrix. Most basalt-limestone contacts are sharp, with no apparent alteration of either basalt or micrite. A few fragments are bordered by a thin (1 to 2 mm) palagonitized rim. Angular, irregular glass projects into the micrite in several specimens. The petrography of the basalt is more fully covered in *Basement Lithostratigraphy*. The petrography of the limestone matrix is covered more fully and hypotheses for the origin of the breccia are set forth in a later chapter (Varet and Demange, this volume).

Beneath the lowermost recovered basalt in Core 41 (381.0 m sub-bottom), the core barrel became jammed inside the lower collar. After the string was pulled, the core barrel was found to be wedged in by a basaltic gravelly sand containing also a mixture of mud-size particles (Figure 7). The sand and granule grains are sub-angular to sub-round and are basalt, brown glass, translucent calcite, and pale yellow limestone fragments. These are the same constituents of which the overlying basalt-limestone breccias are composed. Since the sand was recovered after washing, the material is probably downhole contamination. Further discussion of this sand and a similar one recovered at the bottom of Hole 410A will be included at the end of the description of lithologies at Hole 410A.

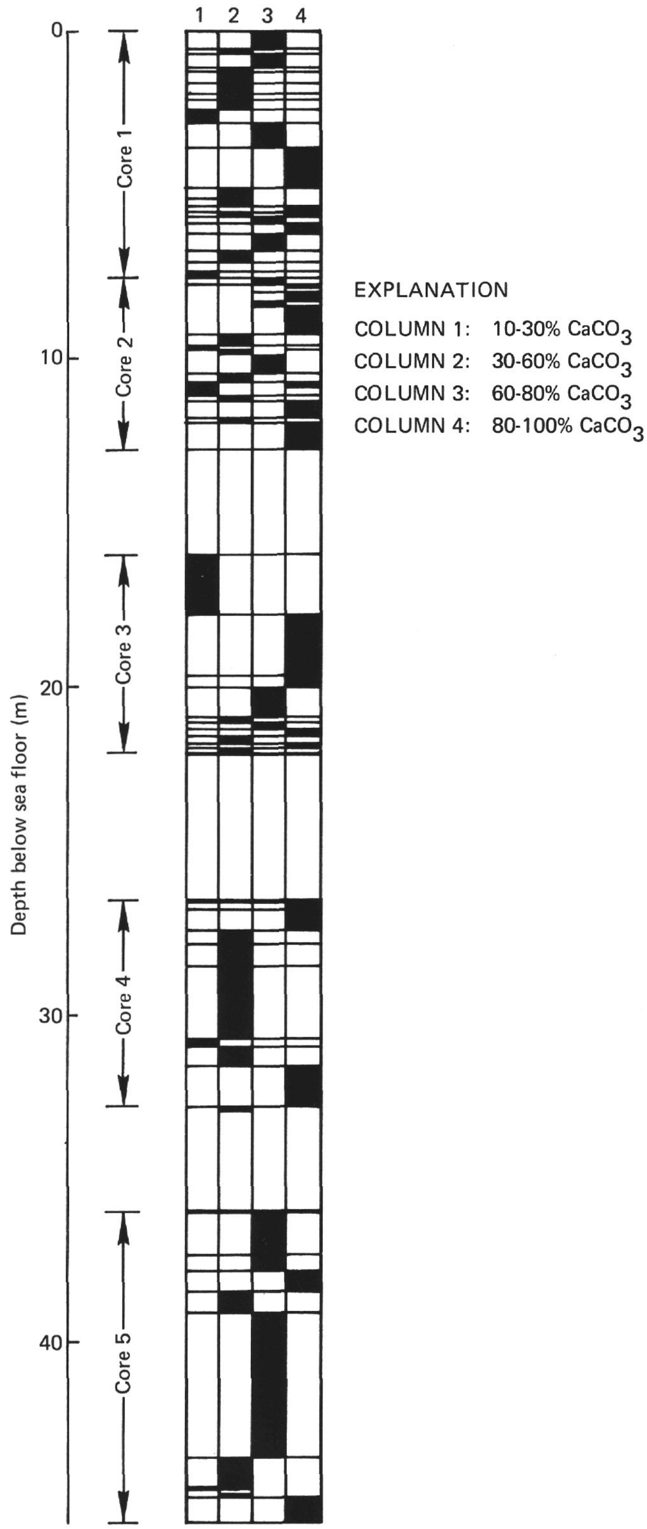


Figure 9. *Carbonate content with depth, Cores 1 through 5, Hole 410.*

Introduction: Hole 410A

The ship was offset 110 meters on a bearing of 020° from the beacon, and drilling was resumed. The sediment was washed down to basement. We recovered one core of sediment, which has been divided into two units on the basis of lithologic characteristics (Figure 7). Small amounts of basalt-limestone breccia, similar to that in Hole 410, occur in Core 2. The drill pipe became jammed after penetration of 51 meters into basement. One bumper sub was clogged with sand similar to that at the base of Hole 410 (Figure 7).

Description of Lithologic Units

Unit 1 (Core 1, Sections 1 to 5, 325.0 to 330.75 m)

This is a moderately deformed sequence of alternating pale brown marly oozes, calcareous muds, and light gray nannofossil oozes. Nannofossils constitute 60 to 70 per cent of most smear-slide samples. Detrital quartz and feldspar silt, volcanic glass, radiolarian fragments and spines, foraminifers, and clay are generally present in amounts up to 5 per cent. Section 1 contains (23 cm) a gastropod shell 5 mm long, and three pteropod tests occur in Section 2. Sections 1 and 2 contain foraminiferal sand layers 10 cm thick; some of these show grading. Rare thin gray and pale brown laminations and what may be bioturbation mottling occur throughout the unit. Since Unit 1 was recovered after washing, it may represent material from several overlying sediment horizons.

Unit 2 (Core 1, Sections 5 and 6, 330.75 to 331.85 m)

Unit 2 is very light gray to light greenish gray nannofossil chalk, composed of about 85 per cent nannofossils, 10 per cent foraminiferal fragments, and less than 5 per cent feldspar. Gray to light gray bioturbation mottling and *Zoophycos* burrows are common. We saw a few pale green laminae. The firmness of the chalk suggests that this material is *in-situ* sediment.

Interlayered Sediment (Core 2, 334 to 344.0 m, and bumper sub, 382.0 m)

Patches of basalt-limestone breccia occur in Core 2. This breccia resembles that in Hole 410, except for somewhat thicker zones of palagonitization around the basalt clasts.

The sand clogging the bumper sub at the bottom of Hole 410A was very similar to the sand recovered at the base of Hole 410. The sand at Hole 410A is medium to coarse, with a mixture of mud and granule components, composed of basalt, brown glass, translucent calcite, and pale yellow limestone fragments. Most constituents are angular to sub-angular.

The following hypotheses are offered to explain the origin of the sands at the bases of both holes: (1) The sands are an accretionary deposit from a moving bed load caused by a change in bottom current; (2) The sands were deposited by turbidity currents; (3) They were formed as a result of lava flowing onto lime ooze; (4) They are drill cuttings, perhaps of a poorly cemented or easily shattered basalt-limestone breccia similar to overlying rocks. These hypotheses are discussed in a later chapter (Roberts, this volume) dealing with textural and mineralogical analyses of the sands.

BIOSTRATIGRAPHY

Sediments ranging from Quaternary to upper Miocene were recovered at Site 410. Hole 410 was continuously cored, whereas only one sediment core was recovered from Hole 410A while washing down to basement. The oldest sediments recovered at both holes are upper Miocene.

Hole 410

At least the upper 93 meters of Hole 410 is Pleistocene. Ice-rafted mineral grains are present throughout this interval, and larger erratics occur sporadically. Ice-rafted mineral grains, but not larger erratics, are present through Sample 15, CC (140 m sub-bottom), which is close to the base of the upper Pliocene. This observation agrees with the results of DSDP Leg 12, which indicated that ice-rafted debris first occurred in the North Atlantic at the beginning of the late Pliocene (~3.0 m.y. ago).

There is a major disagreement over placement of the Miocene/Pliocene boundary in Hole 410. According to the nannofossil evidence, there is probably an unconformity between Cores 17 and 18, since Sample 17, CC is assigned to the middle to upper Pliocene and Sample 18, CC is considered upper Miocene. The foraminifer assemblages, however, suggest placement of the Miocene/Pliocene boundary between Cores 24 and 23. Both sets of data agree that sediments below Core 24 are upper Miocene.

Microfossil assemblages from Sample 36, CC (335 m sub-bottom), recovered about 5 meters above a limestone-basalt breccia, suggest an age of approximately 8.5 m.y. This paleontologic age estimate is within the expected age range for basement.

Sediments above basalt at Hole 410A are upper Miocene.

Planktonic Foraminifers

In general, planktonic foraminiferal assemblages recovered from Hole 410 are diverse and well preserved.

Commonly occurring taxa in the Pleistocene (0 to 93 m) include *Globorotalia inflata, G. crassaformis, Orbulina universa, Neogloboquadrina pachyderma* (sinistral and dextral), and *Globigerina bulloides*. *Globorotalia truncatulinoides* is present in most samples, and *Globorotalia tosaensis* occurs in Sample 9, CC (74.0 m sub-bottom); forms transitional between *G. tosaensis* and *G. truncatulinoides* are present with *G. truncatulinoides,* suggesting a level near the Pliocene/Pleistocene boundary. Since the last *Discoaster brouweri* occurs in Sample 12, CC (~102.5 m sub-bottom), the Pliocene/Pleistocene boundary is placed between these levels.

Upper Pliocene assemblages are similar to Pleistocene assemblages, except for the absence of *Globorotalia truncatulinoides* and reduction in the occurrences of left-coiling *Neogloboquadrina pachyderma*.

Since *Globorotalia puncticulata* is present in Samples 17, CC and 16, CC, the first occurrence of *Globorotalia inflata* in Sample 15, CC (140 m sub-bottom), accompanied by the first occurrence of ice-rafted mineral grains, is judged to closely represent the first evolutionary appearance of this taxon (~3.0 m.y. ago). These data agree with the findings of DSDP Leg 12 (Laughton, Berggren, et al., 1972) that glaciation in the North Atlantic began in the late Pliocene, approximately 3.0 m.y. ago.

The Miocene/Pliocene boundary is tentatively placed at Sample 23, CC (215.5 m sub-bottom), on the basis of the first occurrence of *Globorotalia margaritae* in Sample 22, CC and forms close to *G. tumida* in Sample 23, CC. Taxa commonly present in the lower Pliocene include *Globorotalia scitula, Neogloboquadrina acostaensis, N.* aff. *N. pachyderma, Globigerina woodi,* and *G. bulloides. Globorotalia crassaformis* and *G. puncticulata* are present in the upper portion of this interval, whereas *Globorotalia conomiozea* and *G. margaritae* are fairly common in the lower portion.

Except for Sample 36, CC, the remaining samples examined from Hole 410 are upper Miocene Zone N17.

Taxa such as *Neogloboquadrina acostaensis, Globigerina bulloides, G. woodi, G. nepenthes, Sphaeroidinellopsis* spp., *Globorotalia menardii,* and *G. plesiotumida* are usually present. *Globoquadrina dehiscens* occurs in abundance below Sample 28, CC. Two samples from 36, CC (334.5 m sub-bottom), which yielded *Neogloboquadrina acostaensis* and *Globorotalia continuosa* without *G. plesiotumida,* probably represent foraminifer Zone N16.

A sample taken above the sediment/basalt contact in Hole 410A (Sample 1-6, 85-87 cm; 333.4 m sub-bottom) contained an upper Miocene assemblage which includes: *Neogloboquadrina acostaensis, N.* aff. *N. pachyderma, Globigerinoides sacculifer, G. obliquus, Globigerina bulloides, Globorotalia menardii, G. conoidea,* and *G. scitula.*

Principal planktonic foraminifers found at Site 410 are summarized in Table 4.

Nannofossils

Hole 410 sediments can be characterized here as well-preserved nannofossil oozes. All observations reported here were made only on core-catcher (CC) samples, unless otherwise noted.

Samples 1, CC and 2, CC (7.5 to 12.8 m) contain assemblages of nannofossils indicative of the upper Pleistocene. Abundant occurrences of *Gephyrocapsa aperta, G. caribbeanica,* and *G. oceanica,* together with common occurrences of *Coccolithus pelagicus* and *Helicopontosphaera kamptneri,* account for most of the coccoliths present. Also evident were *Pontosphaera scutellum, Rhabdosphaera clavigera,* and *R. stylifera.*

Samples 3, CC through 11, CC (22.0 to 102.5 m) are lower Pleistocene (Zone NN 19). They commonly contain *C. pelagicus, Cyclococcolithina leptopora, Emiliania annula, Gephyrocapsa* spp., *H. kamptneri, Pontosphaera discopora,* and *R. stylifera.* Samples 5, CC through 11, CC (45.2 to 102.5 m) contain anomalously abundant *Reticulofenestra pseudoumbilica,* which usually does not appear this high in the section. This suggests some mixing of Plio-Pleistocene assemblages, possibly because of turbidites. The Pliocene/Pleistocene boundary is between Samples 11, CC and 12, CC, according to the last occurrence of *Discoaster brouweri* in Sample 12, CC (102.6 m) and the first occurrence of barred *Gephyrocapsa* (*G. aperta* and *G. caribbeanica*) in Sample 11, CC (102.5 m).

Samples 12, CC through 17, CC (102.6 to 150.1 m) are upper Pliocene. They contain *C. pelagicus, E. annula, H. kamptneri, H. sellii, R. pseudoumbilica,* and various discoasters. Samples 12, CC through 15, CC (102.6 to 140.0 m) are placed in Zone NN 18, since they contain *D. brouweri.* Samples 16, CC and 17, CC (149.7 and 150.1 m) contain, in addition, *D. asymmetricus, D. exilis,* and *D. variabilis,* and indicate upper Pliocene Zones NN 16 and NN 17. A hiatus exists between Samples 17, CC (150 m sub-bottom) and 18, CC (167 m sub-bottom), where upper Pliocene sediments rest directly on upper Miocene sediments.

Samples 18, CC through 29, CC (167 to 270.8 m) are placed in Zone NN 11, upper Miocene. They contain *C. pelagicus, C. leptopora, H. kamptneri, D. brouweri, D. variabilis,* and *R. pseudoumbilica.*

Limestone fragments within the basalt breccia of Section 37-1 and Sample 37, CC (340 to 341 m) contain the following nannofossils: *C. pelagicus, H. kamptneri, R. pseudoumbilica,* and *S. abies.* These suggest correlation with the upper Miocene.

Hole 410A

Only one core was recovered at Hole 410A. Sediments at the sediment/basalt contact (Sample 410A-1-6, 86 cm [333.4 m sub-bottom]) are upper Miocene (Zone NN 11), and contain *C. pelagicus, R. pseudoumbilica, C. leptopora, H. kamptneri, H. sellii, S. abies,* and *D. variabilis.*

Principal nannofossils found at Site 410 are summarized in Table 4.

PHYSICAL PROPERTIES OF SEDIMENTS

Hamilton Frame sonic velocity and wet bulk density measurements through the sedimentary section of Site 410 are plotted against sub-bottom depth in Figures 10 and 11.

The sonic velocity profile shows a relatively smooth and very small increase in velocity with depth, less than 0.3 s^{-1}. The smoothness of the profile is in agreement with the absence of internal reflectors within the sedimentary column, as indicated by the seismic reflection profiles.

The wet bulk density data do show an approximately linear increase in density from 1.55 at the sediment/water interface to about 1.80 at 180 meters. From 180 meters to basement at 340 meters, the density does not have a trend, within the uncertainty of the data. There does appear to be a layer of lower densities between 235 meters and 260 meters.

GEOCHEMISTRY

Eight interstitial solution samples were taken from the 345-meter sedimentary succession at this site. Results of the chemical analyses are listed in Table 5 and plotted against sub-bottom depth in Figures 12 and 13. Ca^{++} and Mg^{++} show an overall decrease with depth, although the absolute concentrations vary little. Ca^{++} is significantly lower than its seawater concentration. Alkalinity is high throughout the upper 200 meters of the section, especially between 100 to 200 meters, but decreases rapidly below 200 meters. Conversely, pH is low throughout the upper 200 meters and increases below this point. These unusual trends with depth

TABLE 4
Leg 49 Site 410 Paleo/Biostratigraphic Summary of Core-Catcher Samples (CC)

Core	Depth (m)	Chronostratigraphic Unit	Planktonic Foraminifers	Calcareous Nannofossils
1	7.5	Pleistocene	*Globorotalia inflata* *G. truncatulinoides* *G. hirsuta* *G. scitula* *Globigerina bulloides* *Orbulina universa* *Neogloboquadrina dutertrei* *N. pachyderma* (D) *Turborotalita quinqueloba*	*Gephyrocapsa aperta* *G. oceanica* *G. caribbeanica* *Coccolithus pelagicus* *Helicopontosphaera kamptneri* *Cyclococcolithina leptopora*
2	12.8	Pleistocene	As above plus *N. pachyderma* (S)	As above
3	22.0	Pleistocene	As above plus *Globorotalia crassaformis*	*Helicopontosphaera kamptneri* *Cyclococcolithina leptopora* *C. pelagicus* *Gephyrocapsa oceanica* *G. caribbeanica* *Emiliania annula*
4	32.8	Pleistocene	As above	As above
5	45.2	Pleistocene	As above	*Helicopontosphaera kamptneri* *Cyclococcolithina leptopora* *C. pelagicus* *Reticulofenestra pseudoumbilica* *Gephyrocapsa* spp. *Emiliania annula*
6	49.6	Pleistocene	*Globorotalia inflata* *G. truncatulinoides* *G. crassaformis* *Neogloboquadrina pachyderma* (S+D) *Globigerina bulloides* *Orbulina universa* *Turborotalita quinqueloba*	As above
7	57.1	Pleistocene	As above	As above
8	74.0	Pleistocene	*G. inflata* *G. crassaformis* *G. scitula* *N. pachyderma* (D) *G. bulloides* *O. universa* *T. quinqueloba*	*C. leptopora* *C. pelagicus* *H. kamptneri* *H. sellii* *E. annula* *G. caribbeanica* *R. pseudoumbilica*
9	74.1	Pleistocene	As above plus *G. truncatulinoides* *G. tosaensis*	As above
10	93.0	Pleistocene	*G. inflata* *G. crassaformis* *N. pachyderma* (D) *N. dutertrei* *G. scitula* *Orbulina*	As above
11	102.5	?Pliocene Pleistocene	*G. inflata* *G. crassaformis* *G. scitula* *N. pachyderma* (D) *O. universa* *G. bulloides* *T. quinqueloba*	As above
12	102.6	Pliocene	As above plus *N. pachyderma* (S)	*C. pelagicus* *H. kamptneri* *H. sellii* *E. annula* *R. pseudoumbilica* *Discoaster brouweri* *C. leptopora*

reflect a more complex post-depositional history of the sediments than at the Reykjanes Ridge sites.

The sediments consist mainly of homogeneous white nannofossil ooze with abundant pyrite/marcasite concretions. The succession was deposited fairly rapidly, at about 4 cm/10^3 year, and there were no significant breaks in the sequence. A lithology change is recorded in the last three sediment cores recovered above basement. The sediment here is yellow and the pyrite/marcasite concretions have been oxidized.

TABLE 4 – *Continued*

Core	Depth (m)	Chronostratigraphic Unit	Planktonic Foraminifers	Calcareous Nannofossils
13	114.4	Pliocene	*G. crassaformis* *G. scitula* *G. tosaensis* *G. bulloides* *T. quinqueloba* *N. pachyderma* (D)	As above
14	131.1	Pliocene	*G. crassaformis* *G. inflata* *G. scitula* *G. bulloides* *N. pachyderma* (D) ?*N. atlantica* (S)	As above
15	140.0	Pliocene	As above	As above
16	149.7	Pliocene	*Globorotalia scitula* *G. puncticulata* *G.* aff. *G. inflata* *G. crassaformis* *G. bulloides* *Globigerinoides rubra* ?*Neogloboquadrina atlantica* (S) *N.* aff. *N. pachyderma* (D)	*D. brouweri* *D. asymmetricus* *C. pelagicus* *C. leptopora* *R. pseudoumbilica* *H. kamptneri* *H. sellii* *E. annula*
17	150.1	Pliocene	*Globorotalia scitula* *G. puncticulata* *G. crassaformis* *Sphaeroidinellopsis seminulina* *Globigerina bulloides* *G. woodi* *Globigerinoides obliqua* *G. sacculifer* *S. subdehiscens*	As above plus *D. variabilis*
18	166.9	lower Pliocene/upper Miocene	*Globorotalia margaritae* *G. subscitula* *G.* aff. *G. crassaformis* *Neogloboquadrina acostaensis* *N. pachyderma* (D) *Globigerina bulloides* *G. nepenthes* *G. falconensis* *Globigerinoides obliqua*	*R. pseudoumbilica* *C. pelagicus* *H. sellii* *H. kamptneri* *C. leptopora* *D. quinqueramus* *D. variabilis* *D. brouweri* *Sphenolithus abies*
19	178.4	lower Pliocene/upper Miocene	*Globorotalia margaritae* *G. scitula* *G. conomiozea* (s.l.) *G.* spp. *Neogloboquadrina acostaensis* *N.* aff. *N. pachyderma* *Globigerina bulloides*	*C. pelagicus* *R. pseudoumbilica* *S. abies* *D. variabilis* *H. kamptneri* *H. sellii* *Coronocyclus* sp.
20	182.1	lower Pliocene/upper Miocene	*Globorotalia margaritae* *G. scitula* *G. conomiozea* (s.l.) *G. limbata* *Neogloboquadrina acostaensis* *N.* aff. *N. pachyderma* *Globigerina bulloides* *G. woodi*	*D. variabilis* *D. brouweri* *R. pseudoumbilica* *H. kamptneri* *S. abies* *C. pelagicus*
21	197.7	lower Pliocene/upper Miocene	*Globorotalia margaritae* *G. conomiozea* (s.l.) *G. scitula* *Neogloboquadrina acostaensis* *Globigerina bulloides* *G. woodi*	*R. pseudoumbilica* *C. pelagicus* *D. variabilis* *C. leptopora* *D. brouweri*
22	207.1	lower Pliocene/upper Miocene	*Globorotalia margaritae* *G. conomiozea* *G. menardii* *Sphaeroidinellopsis subdehiscens* *Neogloboquadrina acostaensis* *Globigerina bulloides* *G. nepenthes* *G. woodi*	As above

TABLE 4 – *Continued*

Core	Depth (m)	Chronostratigraphic Unit	Planktonic Foraminifers	Calcareous Nannofossils
23	215.6	upper Miocene/ Pliocene	*Globorotalia limbata* *G.* cf. *G. tumida* *G. plesiotumida* *G. conomiozea* *G. scitula* *G. menardii* *G. conoidea* *Globigerina bulloides* *G. nepenthes* *G. woodi* *Sphaeroidinellopsis seminulina*	As above plus *D. quinqueramus*
24	226.1	upper Miocene	*Globorotalia menardii* *G. subscitula* *G.* cf. *G. margaritae* *Neogloboquadrina acostaensis* *Globigerina bulloides* *G. nepenthes* *G. woodi* *G. apertura*	*D. variabilis* *D. brouweri* *C. pelagicus* *R. pseudoumbilica* *C. leptopora* *H. kamptneri* *D. challengeri* *S. abies*
25	235.6	upper Miocene	*Globorotalia plesiotumida* *G. conoidea* *G. subscitula* *Neogloboquadrina acostaensis* *Globigerina bulloides* *G. woodi* *Sphaeroidinellopsis seminulina*	As above
26	240.0	upper Miocene	*Globorotalia conoidea* *G. plesiotumida* *G. subscitula* *Neogloboquadrina acostaensis* *Globigerina bulloides* *G. woodi* *Sphaeroidinellopsis seminulina* *Globoquadrina dehiscens*	As above
27	249.8	upper Miocene	*Globorotalia limbata* *G. scitula* *Globigerina bulloides* *G. nepenthes* *G. woodi* *Neogloboquadrina acostaensis* *N. humerosa* *Globigerinoides sacculifer*	As above
28	260.0	upper Miocene	*Globorotalia menardii* *G. plesiotumida* *G.* aff. *merotumida* *Neogloboquadrina acostaensis* *Globigerinoides trilobus* *Globigerina bulloides* *G. woodi* *G. apertura*	As above
29	270.8	upper Miocene	*Globorotalia menardii* *G. plesiotumida* *G. scitula* *Sphaeroidinellopsis subdehiscens* *S. seminulina* *Globoquadrina dehiscens* *Globigerina bulloides* *G. woodi* *G. nepenthes* *Neogloboquadrina acostaensis*	As above
30	283.0	upper Miocene	*Globorotalia menardii* *G. plesiotumida* *G. merotumida* *Sphaeroidinellopsis seminulina* *S. subdehiscens* *Globoquadrina dehiscens* *Globigerina bulloides* *G. woodi* *G. nepenthes* *Neogloboquadrina acostaensis*	*R. pseudoumbilica* *C. leptopora* *H. kamptneri* *C. pelagicus* *S. abies* *D. variabilis* *D. brouweri* *D. quinqueramus* *D. pentaradiatus*

TABLE 4 – *Continued*

Core	Depth (m)	Chronostratigraphic Unit	Planktonic Foraminifers	Calcareous Nannofossils
31	288.3	upper Miocene	*Globorotalia menardii* *G. plesiotumida* *G. scitula* *Sphaeroidinellopsis seminulina* *S. subdehiscens* *Globoquadrina dehiscens* *Globigerina bulloides* *G. woodi* *G. apertura* *Neogloboquadrina acostaensis*	As above plus *D. pentaradiatus*
32	297.5	upper Miocene	As above plus *G. nepenthes*	*R. pseudoumbilica* *D. quinqueramus* *S. abies* *H. kamptneri* *C. pelagicus* *D. brouweri*
33	304.3	upper Miocene	As above	As above
34	314.1	upper Miocene	*Globorotalia menardii* *G. plesiotumida* *G. merotumida* *Globigerinoides sacculifer* *Globigerina bulloides* *G. nepenthes* *Neogloboquadrina acostaensis* *N. humerosa*	As above
35	326.1	upper Miocene	As above	*R. pseudoumbilica* *C. leptopora* *H. kamptneri* *C. pelagicus* *S. abies* *D. challengeri* *D. aulakos*
36	334.5	upper Miocene	*Neogloboquadrina acostaensis* *Globorotalia continuosa* *Globoquadrina dehiscens* *Globorotalia merotumida* *Globigerina bulloides* *G. nepenthes* *Globorotalia menardii*	As above
37	341.0	upper Miocene	*Globoquadrina dehiscens* *Neogloboquadrina acostaensis* *Globorotalia continuosa* *Globorotalia menardii*	*H. kamptneri* *R. pseudoumbilica* *C. pelagicus* *S. abies*

The compositional changes of the interstitial solutions of the upper 200 meters of sediments can be explained by post-depositional sulfate reduction processes, indicated by the abundance of sulfide in the sediment. Sulfate reduction is usually attributed to bacterial oxidation of organic matter, and a simplified equation can be used to express this reaction (Sayles and Manheim, 1975):

$$CH_2O + SO_4^{2-} \rightleftharpoons H_2S + 2HCO_3^{-} \quad (1)$$

where CH_2O represents sources of organic carbon. The production of the bicarbonate ion during the sulfate reduction process explains the high alkalinity values obtained at this site (Figure 12). Similarly, the production of hydrogen sulfide explains the low *p*H values and the abundance of sulfide in the sediment. An increase in the HCO_3 concentration of the sediment-solution system will upset the equilibrium of the reaction

$$Ca^{++} + 2HCO_3^{-} \rightleftharpoons CaCO_3 + H_2O + CO_2 \quad (2)$$

and will result in deposition of calcium carbonate; such disequilibrium also explains the absolute depletion in Ca^{++} of the interstitial solutions relative to seawater. There is a small (about 5%) increase in the Ca^{++} concentration between 100 meters and 200 meters sub-bottom depth, whereas the Mg^{++} concentration shows depletion (about 5%) down to 200 meters. These trends indicate that Mg^{++} is substituting for Ca^{++} in a dolomitization reaction (Sayles and Manheim, 1975)

$$CaCO_3 + Mg^{++} + 2HCO_3^{-} \rightleftharpoons CaMg(CO_3)_2 + CO_2 + H_2O \quad (3)$$

This reaction has played a role subordinate to the previous carbonate deposition reaction during the diagenesis of these reactions. It should be noted that both reactions (2) and (3) produce carbonic acid, which tends to solubilize $CaCO_3$ and so one would expect some recrystallization of the carbonate in the sediment as the equilibrium of these reactions shifted in response to the HCO_3^- concentrations in the solutions.

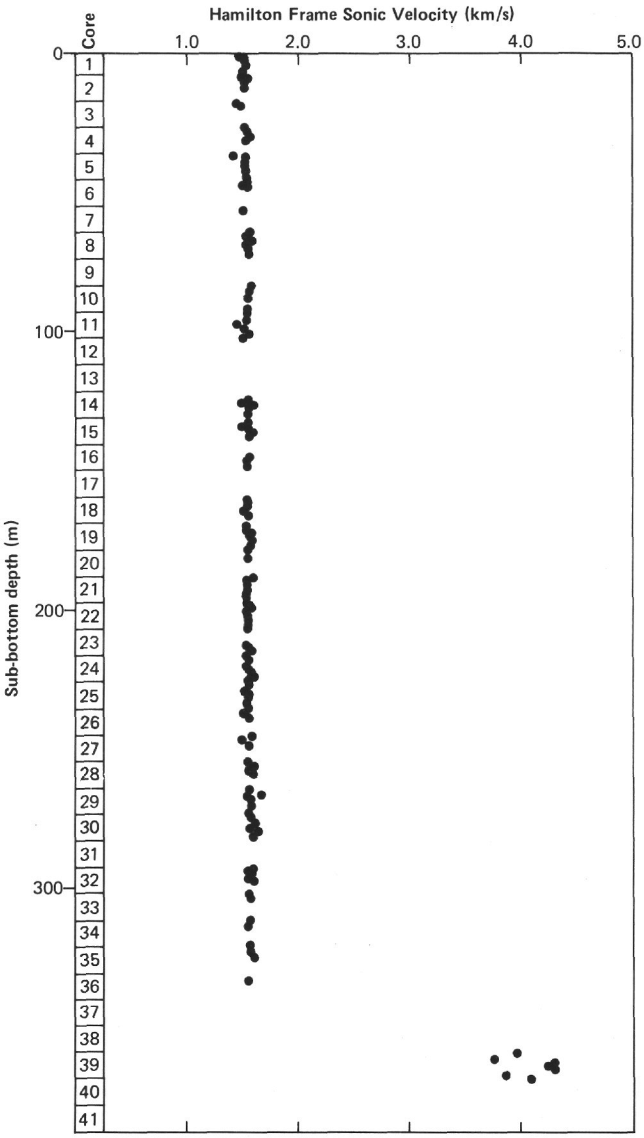


Figure 10. *Sonic velocity versus depth, Site 410.*

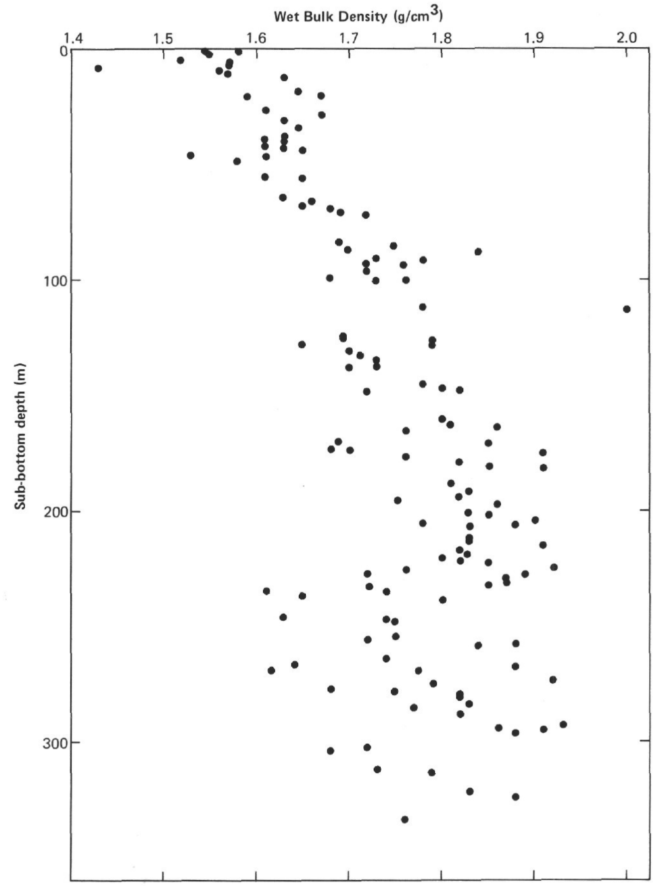


Figure 11. *Wet bulk density versus depth, Site 410.*

However, neither dolomite nor extensively recrystallized ooze was evident in this core.

The composition of the interstitial solutions below 200 meters sub-bottom changes as basement is approached. Alkalinity is reduced by about 50 per cent, *p*H increases by about 10 per cent, Ca^{++} decreases by about 15 per cent and Mg^{++} decreases less rapidly than it did above 200 meters (Figures 12 and 13). These trends suggest that there has been carbonate precipitation and that the equilibrium of reaction (2) has moved further to the right. Also, the decrease in alkalinity and increase in *p*H suggest that sulfate reduction has ceased or at least dramatically decreased. However, pyrite/marcasite concretions occur throughout the sedimentary sequence, although in the lower 50 meters or so they become oxidized, as mentioned above.

The presence of sulfide in the sediment indicates that sulfate reduction has taken place at some stage during the post-depositional history of the sediment below 200 meters, but has subsequently been replaced by oxidizing reactions causing pyrite decomposition and, perhaps related, carbonate deposition. The late oxidation may have been caused by the injection of hot hydrothermal fluids from the basement into the sediment. The temperature increase of the interstitial fluids would move the equilibrium of reaction (2) slightly to the right, causing slight deposition of carbonate. Or more complex reactions involving hydrothermal solutions and interstitial solutions may precipitate calcium carbonate. This can be resolved only by a more detailed

TABLE 5
Leg 49 Summary of Shipboard Geochemical Data, Site 410

Section	*p*H	Alkalinity (meq/1)	Salinity (o/oo)	Ca^{++} (mmoles/1)	Mg^{++} (mmoles/1)	Cl^- (o/oo)
Tap Salt Water	8.470	2.385				
Surface Sea Water	8.174	2.385	35.5	10.55	54.8765	19.3086
1-4	7.481	4.250	35.5	10.4669	52.6546	19.4749
5-6	7.464	4.34	35.5	9.9685	52.4438	19.4749
11-5	7.332	5.72	35.5	10.010	51.757	19.541
16-5	7.325	5.75	35.5	10.259	50.380	19.541
22-6	7.390	5.72	35.2	10.716	49.805	19.375
28-3	7.698	3.06	35.2	8.972	49.3622	19.4249
32-2	7.647	2.86	35.5	9.844	52.805	19.541
410A-1-5	8.102	2.46	35.2	8.9301	48.9904	19.5747

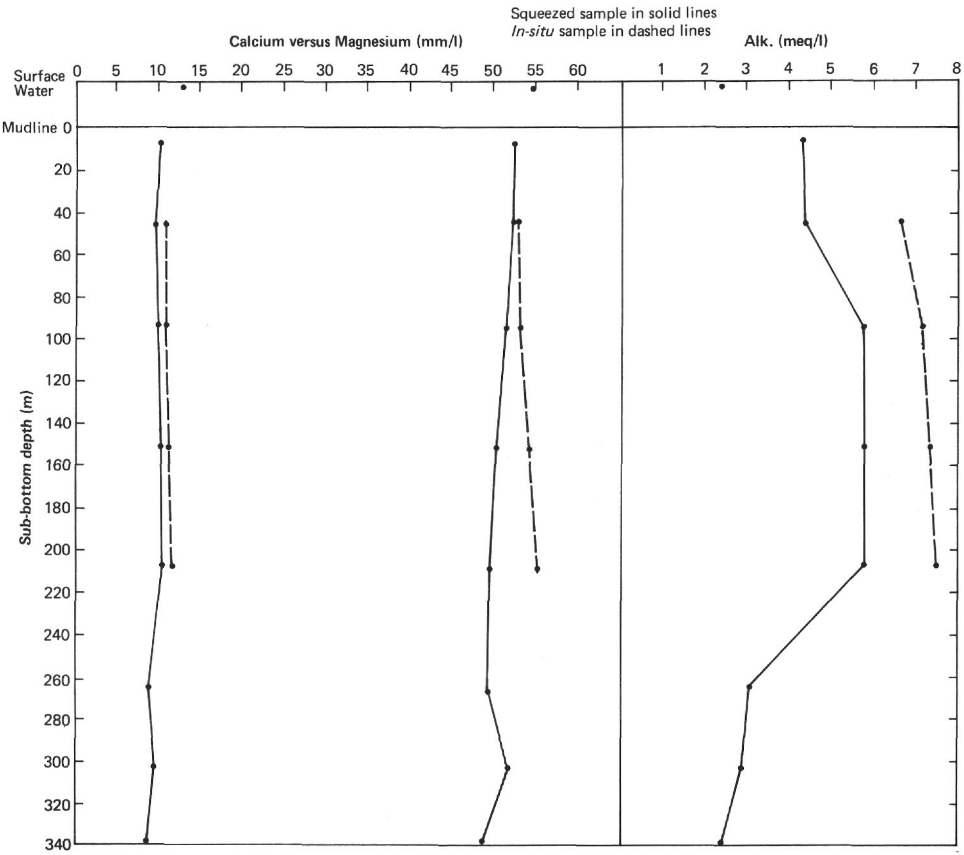


Figure 12. *Plot of interstitial water chemistry versus depth, Hole 410.*

shore-based study. If the involvement of hot hydrothermal fluids in the late diagenetic reactions of the sediments is substantiated by such studies, this would lead to the implication of late, perhaps off-axis, volcanism in the vicinity of this site. The emission of hydrothermal fluids from basement would have to have occurred after enough time had elapsed for the sediments to have first experienced sulfide formation before being oxidized.

The interstitial water chemistry has provided useful data with which to assess post-depositional processes in the sediments of this site, and indicates that follow-up shore-based studies, especially on the lower part of the succession, may provide invaluable information about the volcanic history of the area.

In-Situ Pore Water Sampler

This sampler was tested for the first time at Site 410, where it was run four times, of which three were successful. We planned to use the sampler at 50-meter intervals; the first two samples — at 45 and 93 meters — were successful, but the sediments were highly disturbed, so we took the next sample at 207 meters. The sampler ran but failed to take a sample at 264 meters, and because of the risk of damage while approaching basement we did not use it below this depth.

The squeezed samples described above were taken in the cores preceding the position of the *in-situ* pore samples, so that a comparison of the results could be made. Water from the sample was analyzed immediately on recovery, and the results are plotted in dashed lines on Figures 12 and 13. In Figure 14, the results obtained from the *in-situ* samples are plotted against the squeezed samples. Ca^{++}, alkalinity, and chlorinity show slightly higher values for the *in-situ* samples, but do give the same trends as the squeezed samples. For Mg^{++}, however, the *in-situ* samples give higher values and the opposite trend to the squeezed samples! Suspecting contamination of the *in-situ* samples, we filled the copper tube within which the sample is held in the instrument with surface water for two hours. We then analyzed the sample, and it showed a significant increase in alkalinity (Figure 14).

We conclude from the above results that *in-situ* interstitial water samples can be successfully obtained by the method described here and, by using a more suitable material for the internal barrel which contains the sample, this device may prove useful on subsequent cruises.

CLIMATIC INDICATORS

We interpret the interbedded layers of calcareous mud, marly calcareous ooze, and nannofossil ooze of Cores 1 through 5, Hole 410, to be results of Pleistocene climatic fluctuations. The correlations between sediment color, carbonate content, and detrital mineral content of Cores 1 through 5 (Figures 8 and 9; Tables 2 and 3) show a cyclic fluctuation which corresponds roughly to the northern European glacial stages assigned by Berggren (1972b), with a mean sediment accumulation rate of approximately 65

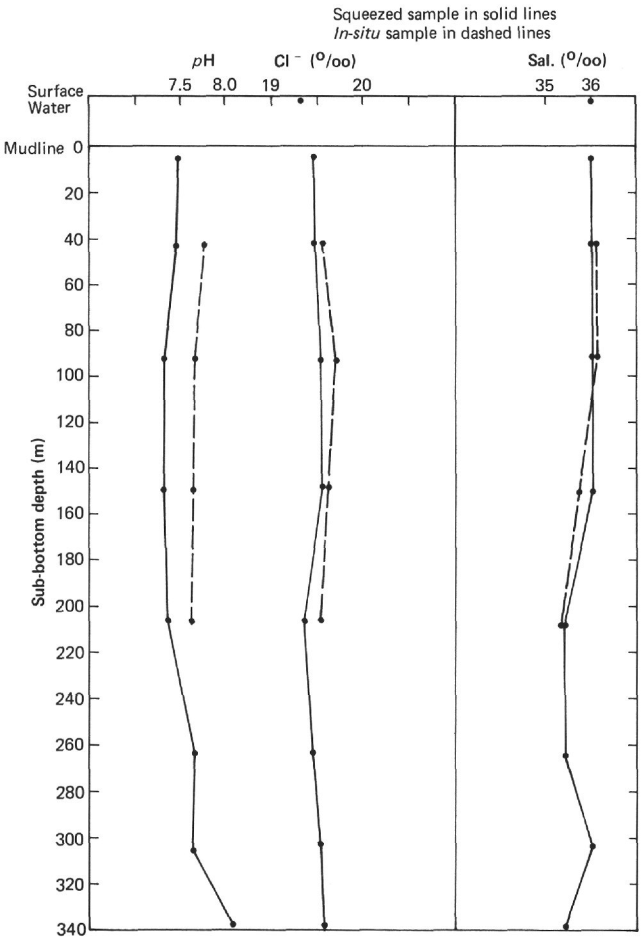


Figure 13. *Plot of interstitial water chemistry versus depth, Hole 410.*

meters/m.y. This topic is discussed more fully in Shor and Poore, this volume.

The Pleistocene sequence below Core 5, Hole 410, is too highly disturbed to permit discrimination among climatic cycles represented by the sediments, even according to sediment color. The association of Pliocene (?) nannofossil assemblages in the core catchers of Cores 5 to 7 with gravel-size erratics of basalt, microgabbro, gneiss (?), and pyrite nodules suggests reworking and mixing of these materials, probably by submarine slumping or turbidity flow, rather than by ice-rafting. The pyrite nodules contain planktonic foraminifers cemented by a pyrite matrix, and are therefore probably products of authigenesis. The association of gneiss, basalt, and authigenic pyrite nodules implies redeposition of material originally deposited by ice rafting, and chemical processes taking place in the sediments and ridge basalts.

A significant characteristic of the sediment column from Cores 1 through 15 (0 to 140 m sub-bottom) is the presence of fine to medium sand-size (> 150 μm) quartz grains and rock fragments in sieve separations of core-catcher samples prepared for paleontological studies. The base of this interval is dated paleontologically as approximately 3.0 m.y. (Berggren, 1972b), since size and mineralogy of these grains suggest an ice-rafting origin. There is a lack of large erratics in the upper Pliocene "glacial" section (Cores 11 to 15) and a relatively low abundance of ice-rafted mineral grains, compared with the Pleistocene section.

SEDIMENT ACCUMULATION RATES

Two accumulation rate diagrams are presented for Hole 410, because of a discrepancy in placement of the Miocene/Pliocene boundary (see Biostratigraphy). Nannofossil age assignments strongly suggest a hiatus between upper Miocene and upper Pliocene sediments, whereas foraminifer assemblages imply continuous deposition through the entire upper Miocene through Quaternary sequence (Figures 15[a] and 15[b]).

Both foraminifer and nannofossil age assignments for sediments immediately overlying basement at Hole 410 are in general agreement with the estimated basement age of 8.34 to 9.74 m.y. assigned to anomaly 5 (La Brecque et al., 1977).

The mean sedimentation rate below 165 meters sub-bottom (Sample 18, CC) is about 40 m/m.y. on the basis of both microfossil groups, although nannofossils suggest that this entire interval is about 1.5 m.y. older than indicated by foraminifers.

Independent dating of the upper 45 meters (Cores 1 through 5) by correlation of carbonate percentage (color) with age assignments of North Europe glacial/interglacial stages indicates a mean accumulation rate of 66 m/m.y. for the Brunhes epoch.

An additional point used to construct Figures 15(a) and 15(b) is the first occurrence of ice-rafted mineral grains in sieved coarse fraction samples (Sample 15, CC), which we correlate with the initiation of North Atlantic glaciation at 3.0 m.y. B.P. (Berggren, 1972a).

SEDIMENT DIAGENESIS

Pyrite nodules, most often as casts of burrows, are common in Cores 6 to 33, Hole 410. In Cores 34 to 36, nodules of geothite/limonite occur. These were presumably composed originally of pyrite, but have since been altered. Cores 34 to 36 are also distinguished from those above by the pale yellow color of the nannofossil ooze.

The presence of pyrite indicates reducing conditions below the sediment/water interface. Following the development of reducing conditions in Cores 34 to 36, a secondary period of oxidation apparently caused the alteration of pyrite nodules to geothite/limonite and the pale yellow color of the ooze. Since the limestone matrix in the underlying basalt-limestone breccia is also pale yellow, the oxidation may be a result of contact with or nearness to the basalt or its associated pore fluids. Further evidence of alteration in the pale yellow sediments is the absence of discoasters (readily susceptible to dissolution), which are present in the nannofossil ooze and chalk above the yellow-gray contact.

Down-core variations in Ca^{++}, Mg^{++}, and alkalinity also suggest diagenetic alterations in the sediment column. Highest alkalinity values occur in the light gray, pyritized nannofossil oozes, and there is a slight decrease in the pale yellow units. Ca^{++} and Mg^{++} contents also decrease slightly with depth (Figure 12).

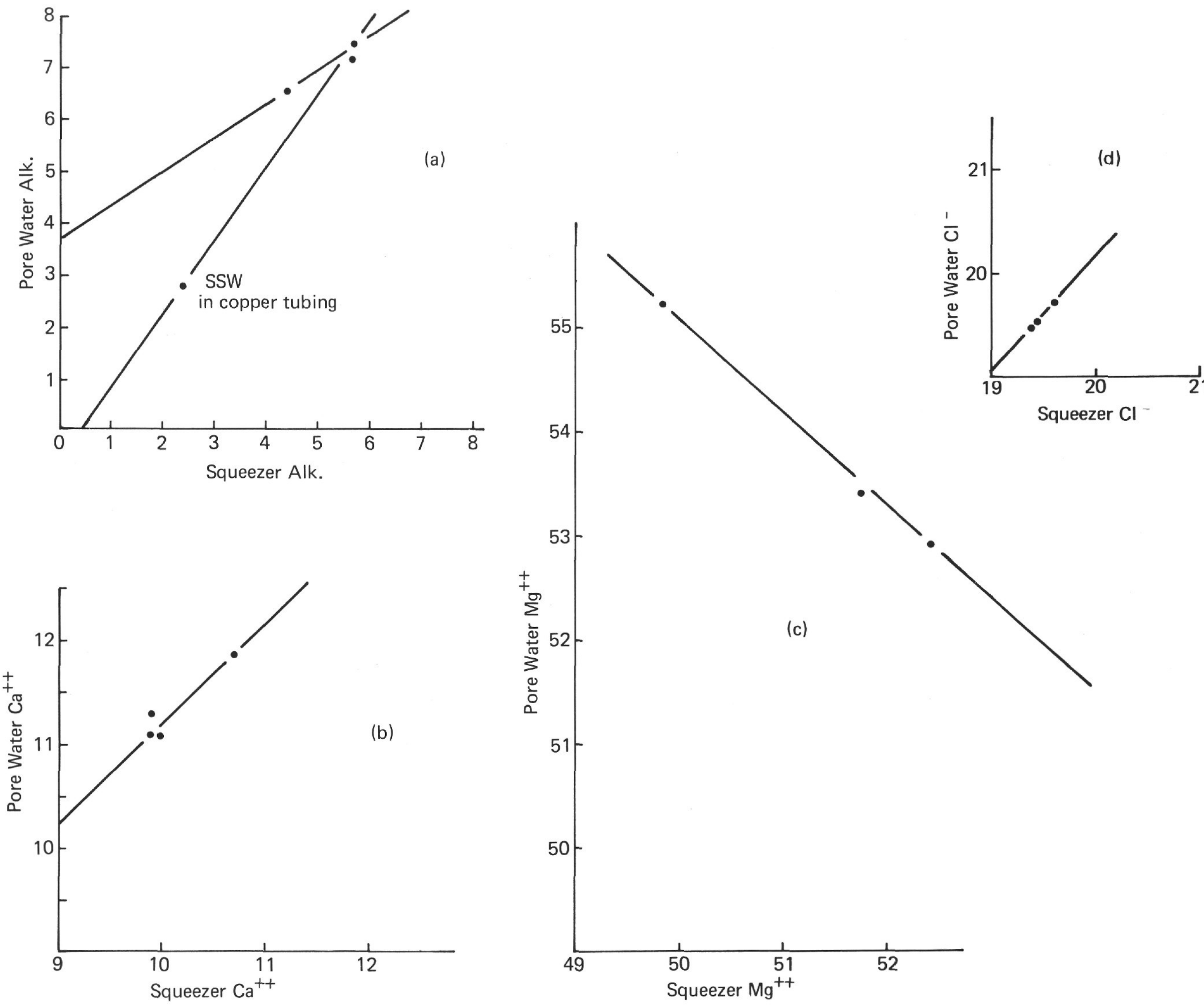


Figure 14. *Plot of interstitial water chemistry for pore-water sampler versus squeezed samples.*

BASEMENT LITHOSTRATIGRAPHY

At Hole 410, acoustic basement was first encountered in Core 37, at a depth of 340 meters[4] below the sea floor. Unlike the previous sites of this cruise, basement at Hole 410 is well-indurated basaltic breccia rather than a coherent lava flow. We drilled 47.5 meters of this breccia, with a recovery rate of 24 per cent, before we had to abandon the hole because of drilling problems.

The breccia is characterized by fragments of basalt in a matrix of limestone. The matrix is described in the sediment section. The basalt fragments range in size from sand to pieces larger than the diameter of the drill core (about 6 cm). Perhaps as much as half of the pebble- to sand-size fragments consist of basaltic glass, generally altered to palagonite. Other fragments are aphyric basalt, some with remnants of glassy selvages but most without such evidence of a chilled margin. In some parts of the section, two or more fragments may be visually reconstructed like pieces of a puzzle, indicating very little relative movement. Most pieces, however, cannot be so reconstructed, and are often suspended in the limestone matrix; this suggests relative movement among fragments. Such suspended fragments also indicate that the basalt was introduced into pre-existing sediment. The mechanism of breccia formation is not clear, but may be tectonic or eruptive. A possible eruptive mechanism is explained later.

The breccia can be subdivided into two lithostratigraphic units by three criteria, the first of which is an irregular but notable decrease in the amount of limestone matrix downhole. In the upper part of the breccia, the carbonate matrix appears to account for about 40 per cent of the recovered core, whereas near and at the bottom of the hole it accounts for no more than a few per cent. Study of thin sections suggests that whereas the upper part of the hole is basaltic, the lower is close to mugearite in composition. This subdivision is apparent in the geochemistry, too: the

[4]Depths refer to drilled intervals calculated.

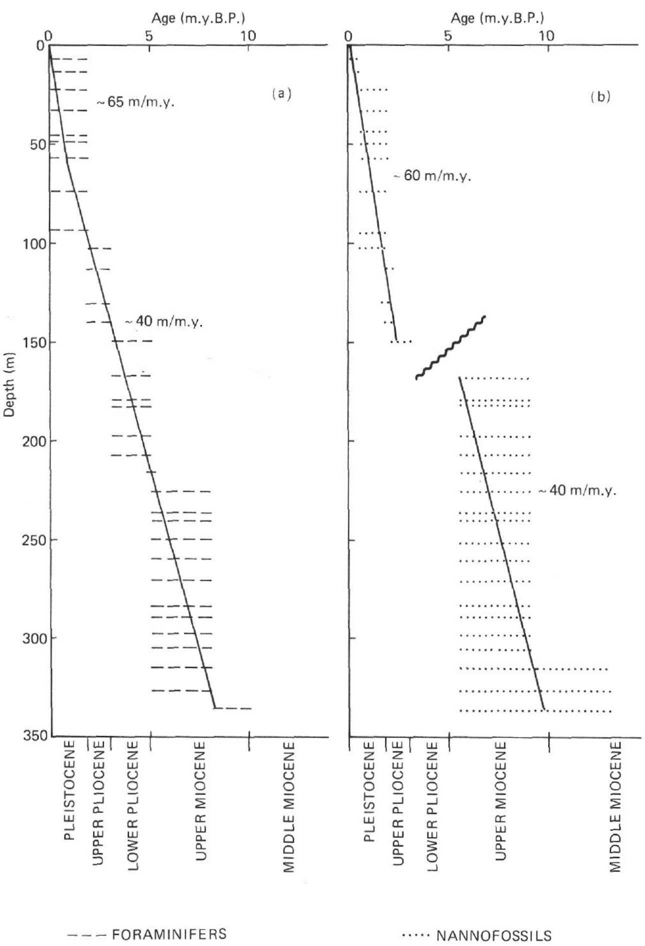


Figure 15. *Sediment accumulation rates, Hole 410.* (a) *Ages for boundaries of foraminifer zones from Berggren (1972b), except for the base of Zone N 17 (from Ryan et al., 1975).* (b) *Age of boundaries of nannofossil zones from Berggren (1972b), except for the base of Zone NN 11 (from Ryan et al., 1975).*

upper unit is poorer in K_2O and richer in MgO than the lower one; in the lower unit, K_2O values reach 1.7 per cent and MgO is below 4 per cent. This is shown in Figure 16(a).

Basement rocks were encountered in Hole 410A at 333 meters beneath the sea floor, 7 meters shallower than at Hole 410, 110 meters to the south. In view of the proximity of the two holes, one might expect a similar sequence of basement rocks, but such is not the case. At Hole 410A, a macroscopically and microscopically homogeneous sequence of basalt was penetrated from its first occurrence at 333 meters to the bottom of the hole at 382 meters. Forty-nine meters of basalt were drilled with a recovery rate of 39 per cent. The recovered core is characterized by vesicularity as great as 25 per cent and by abundant glass selvages. Rare veinlets of limestone and pieces of basalt-limestone breccia were also recovered.

Table 6 summarizes all occurrences of glassy selvages, vesicle-rich zones, and basaltic glass-limestone breccia. On the assumption that these features mark flow boundaries, a minimum of 45 cooling units were penetrated. This suggests an average thickness of about one meter per cooling unit. Such a thin cooling unit thickness, together with the abundance of glass selvages and the presence of some interflow breccia, indicates that the basement consists of a pile of interdigitated pillows. Some easily drilled parts of the sequence (Figures 17 and 18) suggest the presence of interlayered soft ash or sediment, but none was recovered as core. This pair of holes, separated by only 110 meters, provides another striking example of the lateral and vertical variability of the oceanic basement. This variation seems especially marked at this latitude along the Mid-Atlantic Ridge, to judge from the dredge samples of Aumento et al. (1971).

Petrographic observations, as well as the drilling rate changes, allow seven petrographic units to be distinguished, with an average thickness of 7 meters. Geochemical measurements (Figure 16[b]) subdivide the section into two units. The upper unit is more constant in major-element composition, and has a lower Ce/Y ratio than the lower unit. The compositional difference is not great, however, and both units are essentially basaltic.

IGNEOUS PETROGRAPHY

Basaltic basement was reached at similar sub-bottom depths in both holes (340 m at 410, 331 m at 410A), at locations only 110 meters apart. In Hole 410, igneous erratics were recovered at several levels within the upper part of the sedimentary section. No record is available of possible interlayered erratics of magmatic origin in Hole 410A, because sediments there were washed out.

1) *Igneous and metamorphic clasts in the sediments (Hole 410)*

Detrital fragments and non-biogenic components of the sediments in Hole 410 do not consist mainly of volcanic ash, as at Sites 407 and 408, but of fragments of plagioclase and green amphibole without glass, sometimes constituting small pebbles of gabbro up to 1 cm in diameter. Such detrital components average 30 to 50 per cent of the sediment in the uppermost part of Hole 410 (15 upper m at least). They were evident in particular in Samples 1-1, 70 cm; 1-2, 50 cm; 1-5, 30 cm; and 2-1, 30 cm.

Larger fragments of gabbros and sodic anorthosites or diorites were recovered in various levels: Samples 1-5, 30 cm; 6, CC; 7, CC; 10-5, 78 cm — all in the upper 100 meters of the hole (Pliocene to Recent). Erratic fragments of biotite gneiss and coarse-grained granite also occur in association with these. Pyrite or marcasite nodules of sedimentary origin (formed *in situ* in the sediments) are present in the same horizons as the erratics (Samples 6, CC and 7, CC), but elsewhere in the sediments as well.

These kinds of igneous and metamorphic clasts are very abundant in the area, both as pebble- and sand-size fragments, as Aumento et al. (1971) have shown. They also noted that such clasts do not occur in the axial valley, but only within and beyond the crestal mountains.

The gabbros and diorites dredged in the 45°N area on both sides of the crest mountains and around Meta Mound (described by Aumento et al. [1971]), which is still very close to Site 410, are very similar to those found in Hole 410. Thus, the gabbros and sodic anorthosites recovered in Hole 410 may well be "products of residual magmatic liquids," as was suggested by Aumento et al. (1971) for

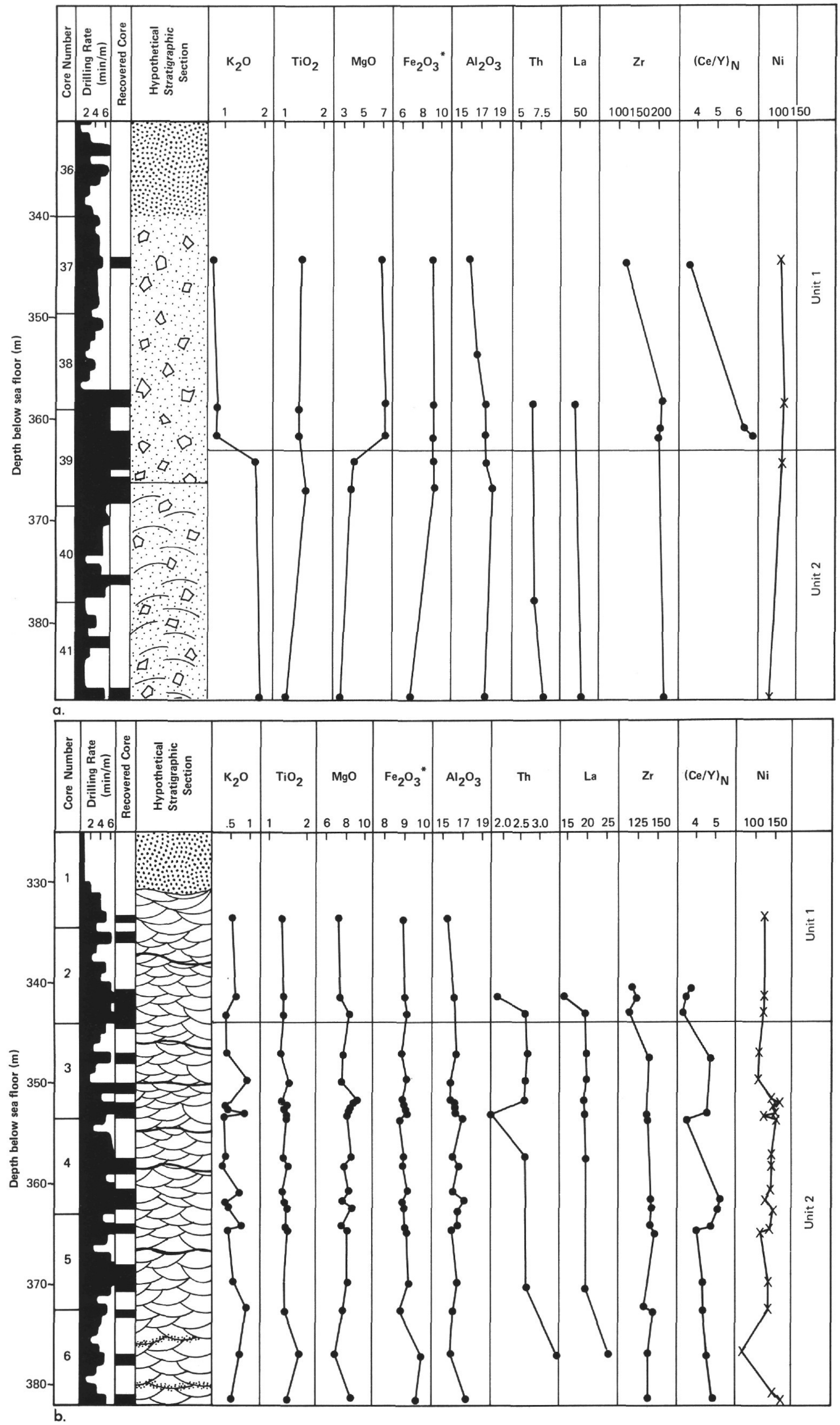


Figure 16. *Subdivision of lithologies, based on geochemistry, for* (a) *Cores 36 through 41, Hole 410;* (b) *Cores 1 through 6, Hole 410A.*

TABLE 6
Hole 410A

Core	Section	Piece Number	Interval (cm)	Evidence of Contact
1	7	1	0-10	Glass
1	7	3	20-25	Glass
1	7	6 and 7	40-55	Glass
2	1	1	0-8	Glass
2	1	3	16-23	Glass
2	1	10 and 11	86-97	Glass
2	2	1	0-13	Glass-carbonate breccia
2	2	2	13-21	Glass
2	2	3	21-27	Glass-carbonate breccia
2	2	8, 9, 10, 11, 12, 13	48-86	Glass
2	2	18	118-128	Glass-carbonate breccia
2	2	19, 20A	128-143	Glass
2	3	2	10-15	Glass
2	3	6 and 7	40-55	Glass
2	4	8	74-81	Glass
2	4	13, 14	114-127	Glass
2	5	2 and 3	11-25	Glass
3	1	6	46-52	Glass
3	1	11, 12, 13	87-115	Glass
3	1	16	130-137	Glass
3	2	3, 4, 5, 7, 8, and 9	25-42, 53-78	Vesicle-rich zone
3	4	1 and 2	0-15	Glass
3	4	5 and 6	29-37	Glass
3	4	14	87-92	Glass
4	1	1 and 2	0-25	Vesicle-rich zone
4	1	6, 7, 8, 9	64-94	Vesicle-rich zone
4	1	14, 15, 16	119-135	Glass
4	2	2	6-10	Glass
4	2	10 and 12	49-53, 63-69	Glass
4	3	2, 4, 5, 6	5-14, 21-40	Glass
4	4	10	100-106	Abrupt decrease in grain size, and highly vesicular
5	1	13, 14, 15	85-105	Glass and high vesicularity
5	1	18, 19, 20	117-136	Glass and high vesicularity
5	2	4, 5	38-50	Vesicle-rich zone
5	3	6, 7	60-75	Vesicle-rich zone
5	3	12, 13, 14	113-135	Glass and high vesicularity
5	4	4	35-41	Glass
6	1	2, 3, 4	6-34	Glass
6	1	8, 9	53-65	Glass
6	1	12, 13, 14, 15, and 16	78-115	Glass and high vesicularity
6	2	3	15-20	Glass
6	2	8, 9, 10, 11 12, 13, 14, 15	50-112	Glass and high vesicularity
6	2	18, 19	134-150	Glass and high vesicularity
6	3	4, 5, 6, 7	25-55	Glass
6	3	11	75-80	Glass

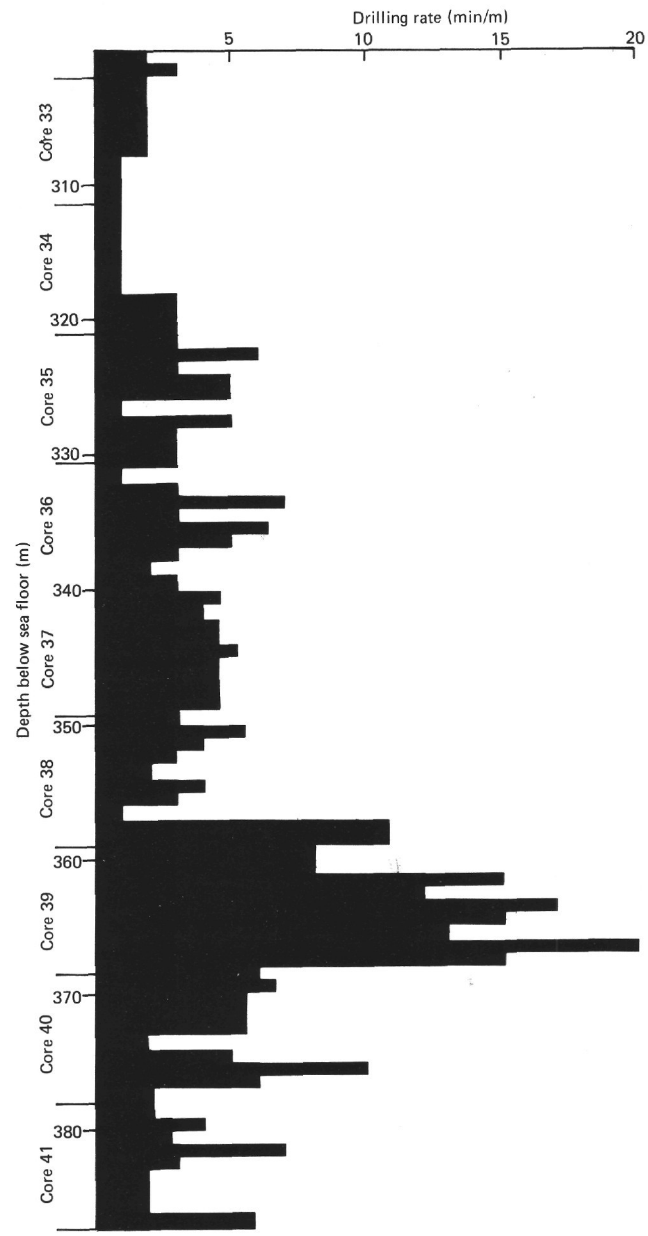


Figure 17. *Drilling rate (min/m) for Cores 33 through 41, Hole 410.*

similar rocks dredged nearby. An ice-rafted origin cannot be ruled out, however.

2) *Volcanic breccias in Hole 410*

All the volcanic rock recovered at Hole 410 is either fractured lava (Figure 19) or loose fragments cemented by indurated recrystallized limestone (Figures 20 and 21). The study of 25 thin sections enabled us to distinguish two major units in the sequence, later confirmed by the geochemistry.

The upper 26 meters (340 to 366 m sub-bottom) consists of a chaotic breccia of sparsely phyric basalt in which olivine is present throughout, associated with plagioclase and with later clinopyroxene in a few cases. The groundmass is either variolitic or glassy, and anorthite content of plagioclase ranges from 70 to 60 per cent.

The lower unit, of mugearitic composition, drilled between 366 and 388 meters sub-bottom, is distinguished by the phenocryst assemblage: clinopyroxene-olivine and plagioclase (up to 10%) in a microcrystalline to glassy groundmass. Clinopyroxene is generally an early phase and colorless. Plagioclase megacrysts are rather calcic ($An_{75 \text{ to } 70}$). Olivine is frequently fresh.

3) *Pillowed complex in Hole 410A*

All the basaltic rocks recovered in Hole 410A are very similar in mineralogy and composition, though it was possible to divide the core into two geochemical units on the basis of trace elements. On the basis of petrographic observations, it is possible, however, to distinguish six flow units, three of which are olivine and plagioclase phyric (331 to 338 m, 355 to 388 m, and 367 to 382 m), two aphyric (346 to 355 m and 358 to 367 m), and one olivine phyric (338 to 346 m). The three lowermost petrographic units correspond to the lower geochemical unit. In thin section,

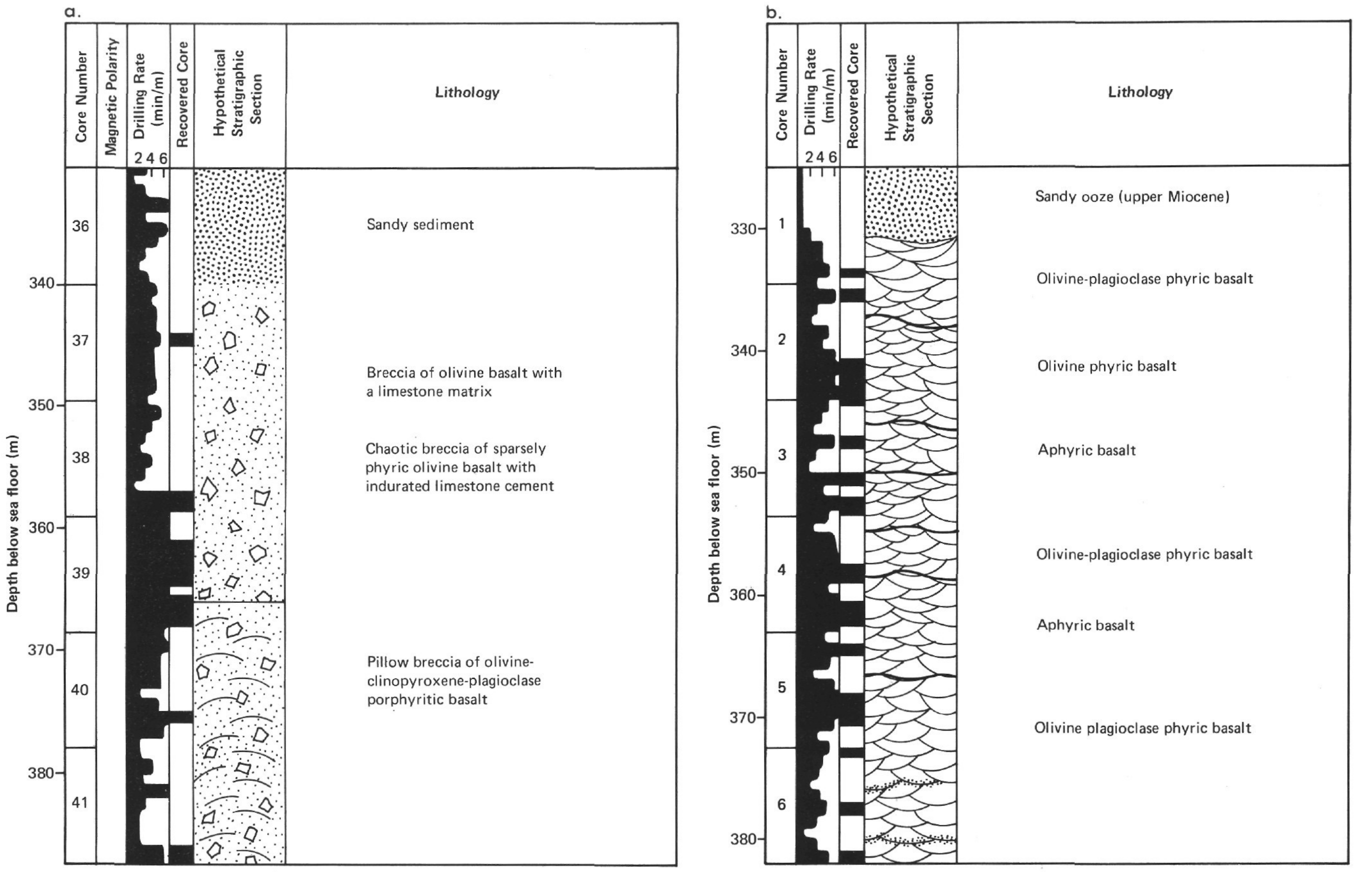


Figure 18. *Drilling rate (min/m) and hypothetical stratigraphic section, Hole 410 (a) and Hole 410A (b).*

all rocks show a rather constant phenocryst mineralogy, with only rare (near 1%) olivine present (up to 3 mm in diameter), associated with later plagioclase that is generally too small for its composition to be determined by optical methods. The groundmass texture ranges from glassy to variolitic, with plagioclase followed by pyroxene. The degree of crystallization is generally too small for opaques to have crystallized; they are therefore limited to the glass, which is generally dusted by thin opaque grains in the most crystalline varieties. Late pyrite may occur together with limited smectite, calcite, and later zeolite.

Rocks are generally rather fresh, and olivine is commonly preserved, especially in the glassy margins. In some of the microcrystalline lavas, olivine was not observed, and it was not possible to ascertain whether this was because it was originally absent, or was altered by magmatic reaction of this mineral in flow interiors. Olivine has been shown to be more stable in the glassy margins of tholeiitic lavas than in flow interiors.

4) *Conclusions*

Although penetration into basaltic crust was limited at this site, a variety of magmatic rocks were recovered. In the basement section, both a variety of basalts and mugearites were found; in the overlying sediments, clasts of plutonic basement were common. The geochemistry shows that this variety is similar to that described by Aumento et al. (1971), and shares the same characteristic enrichment in incompatibles. This enrichment is unusual in mid-ocean ridge basalts, and the lavas from this region may represent one extreme of the variation possible.

ALTERATION PETROGRAPHY

Many of the basalts from Site 410 were very little altered, but some were extensively altered, and showed some interesting features not present in the basalts from earlier sites of Leg 49. The main alteration minerals at Site 410 were a calcium carbonate mineral (most abundant), smectite, several zeolites, palagonite, iron oxide, and pyrite. As usual, the style of alteration in the glassy margins was different from that in holocrystalline rocks. At this site, an extra potential variable was the presence of indurated nannofossil ooze as limestone veins and matrix in the rather brecciated basalts. In only one instance, however, did the type of alteration seem to be related to the presence of the limestone (see below).

In the rocks from Hole 410, those from the first two basement cores (340 to 359 m, Cores 37 and 38) show little alteration of the holocrystalline basalt, and in the glassy margins, veins of palagonite and calcite occur. In Core 39 (359 to 368.5 m) the rocks are more altered. Holocrystalline basalts develop rims of smectite lining vesicles, and smectite and calcium carbonate replace olivine. Carbonate veins are abundant, and zeolites are relatively common. In the basalt-limestone breccias, some of the clasts have the shapes of fragments of basalt glass, but are replaced. The replacement products are calcite and zeolites, forming

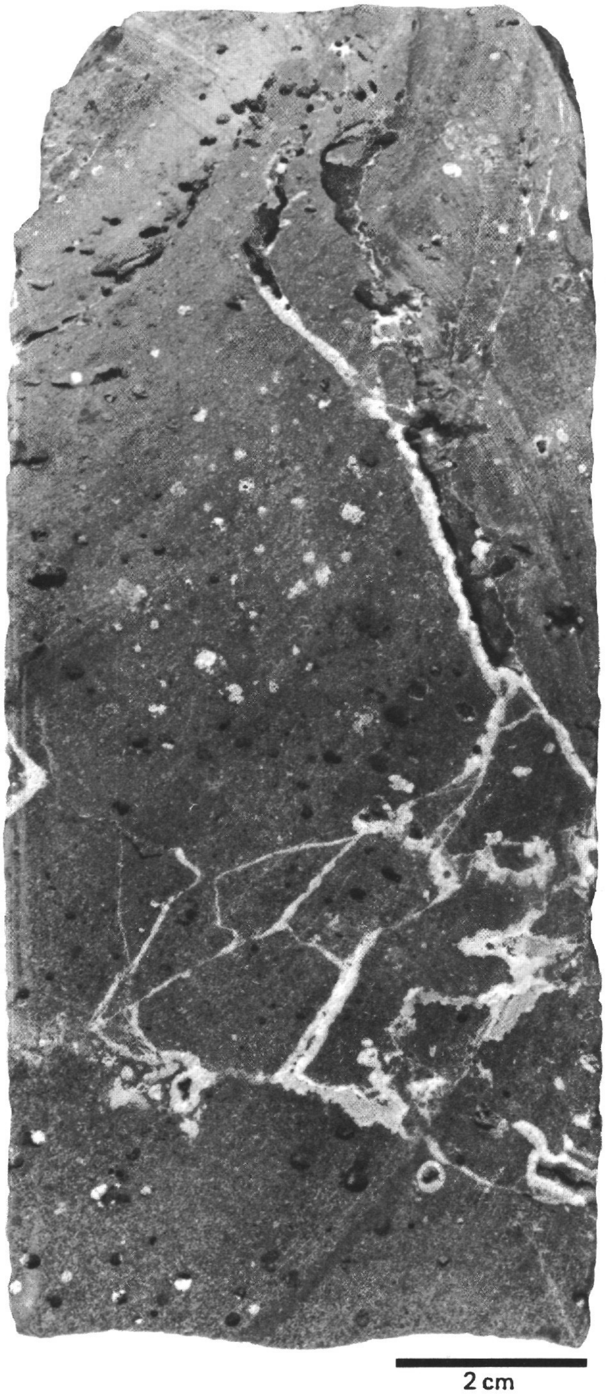


Figure 19. *Fractured basalt, Hole 410.*

Figure 20. *Basaltic breccia. Basaltic fragments are cemented by indurated limestone, Hole 410.*

coarsely crystalline, usually radiating, clusters, and orange iron oxide, forming bands sub-parallel to the margins of the clasts. These bands recall by their shape Liesegang rings, suggesting some diffuse process related to the alteration. Similar banding can be seen in palagonite replacing glass, but the process seems here, in the presence of the limestone, to have gone a stage further with the formation of iron oxides, carbonate, and zeolite in place of palagonite.

In Core 40 (368.5 to 378 m), three of the specimens seem to be the result of basalt erupting into soft ooze, as indicated

Figure 21. *Pillow fragments cemented by a recrystallized limestone matrix, Hole 410.*

by the lobate shapes of the lava/ooze contact. One of these was sectioned (piece number 9), and in this zeolites and calcite are well developed; in places, calcite has partly replaced plagioclase phenocrysts — this is the only time such alteration occurs at Site 410. In the lowermost core from this hole, Core 41 (378.0 to 387.5 m), zeolites and calcite fill veins and vesicles in the basalts.

In Hole 410A, the lavas fall into three groups, based on alteration. The upper group (Cores 1 and 2, 330 to 344 m), and the lower group (lower Core 5 and Core 6, 366 to 382 m) are all very fresh, with fresh olivine in the holocrystalline basalts. The alteration minerals are calcite (as veins and vesicle fillings) and some smectite (rimming vesicles) in the holocrystalline lavas, and palagonite, calcite, and some zeolites in the glassy margins. Within the middle group of lavas (344 to 366 m), the glassy margins are altered in the same way, but the alteration of the holocrystalline basalts is much more extensive. Smectite is developed very abundantly as a dark green, highly birefringent variety. With it are calcite and some zeolites. When one of the smectite-rich rocks is drilled, a slimy expanded cream-like material results, very different from the normal rock cuttings.

It is not clear why there should be such variation in the degree of alteration of the basalts within such a shallow hole. Perhaps it is related to the presence of channels for reactive fluids that pass through some parts of the rock and not through others. Or the rock may react differently to the same solutions in different parts of the sequence.

BASEMENT PALEOMAGNETISM

We here describe each of the two holes separately in terms of sampling, experimental procedure, and results, but frequently compare them. The holes were drilled into anomaly 5, about 10 m.y. old.

Hole 410

At Hole 410, we took 16 standard cores (2.54 cm diameter, 2.40 cm length) from the basalt chunks of the basalt-limestone breccia making up Cores 36 through 41. Only Cores 39, 40, and 41 contained pieces large enough to be oriented for paleomagnetic sampling. The specimens taken were rather unevenly distributed between depths of 350 meters and 380 meters; 10 of them were from Core 39, 7 from separate basalt chunks within the breccia, 2 from the limestone matrix, and 1 of limestone with basalt cobbles.

The state of the recovered material placed great restrictions on further sampling, particularly of the limestone. In an attempt to explain the inclinations we found and elucidate the mode of formation of the breccia, we also took samples in the overlying chalk and carried out conglomerate tests on small component chunks of basalt in two recovered pieces of intact breccia. In Section 39-1, we took four small cores (1 cm diameter, 1 cm length) from pieces 10A and 10B; these two pieces were oriented correctly to within 15° to 20° of each other. Each core was from a separate basalt chunk in the breccia. In Section 39-2, we sampled five separate basalt chunks. All the basalt chunks sampled are much smaller than those sampled with the standard-size core specimen. Measurement was carried out by inserting the small cores in a somewhat imprecise hole of 1 cm diameter, cut in the center of a 2.5-cm-long styrofoam plug, which fitted the specimen holder of the Digico magnetometer.

The NRM intensities of the basalts sampled encompassed a wide range, from 2.48×10^{-6} emu cm^{-3} to almost 1.5×10^{-2} emu cm^{-3} (Figure 22). Seven of the 10 standard-size specimens had NRM intensities above 10^{-2} emu cm^{-3}, which brought the mean value to 1.08×10^{-2}. The limestone specimens had NRM intensities of 1.5 and 2.9×10^{-5} emu cm^{-3}, and the basalt-limestone mixture 4.68×10^{-4} emu cm^{-3}.

The NRM inclinations of the basalt chunks were varied. The large pieces (greater than the diameter of the DSDP core) showed two very shallow negative inclinations (−2°), another less shallow negative inclination (−26°), and ten positive inclinations ranging from 22° to 47°. Of the three limestone matrix samples taken, two were not free of small basalt cobbles and one was; NRM inclinations were −52°, −24°, +35° respectively. After the enclosed basalt chunks were sawed out of the second one, its NRM inclination changed to +38° (Table 7).

The nine small basalt chunks sampled introduced more diversity into the inclination values. The four pieces in Section 39-1 all had negative inclinations which range from −55° to −16° (Table 7). The five pieces 1.5 meters downhole (Section 39-2) had four positive values from 0° to 78° and a negative (−61°) value.

Magnetic directions from the four small cores of Section 39-1 are shown in Figure 23. The directions seem non-random, all being on the upper hemisphere (Figure 23). This non-randomness is again suggested by the second piece of basalt breccia. This time the four smallest cores plot on the lower hemisphere with about the same directional

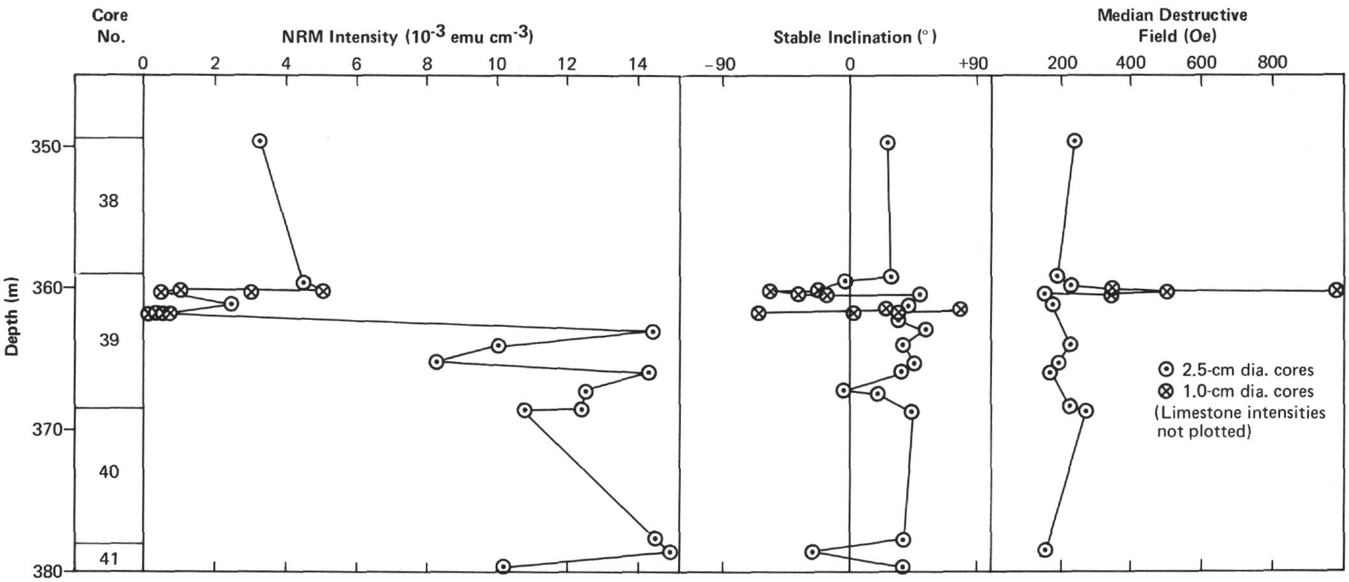


Figure 22. *Downhole plot of paleomagnetics, Hole 410.*

TABLE 7
Paleomagnetism – Hole 410

Sample (Interval in cm)	Sub-Bottom Depth (m)	NRM Intensity (10^{-3} emu cm^{-3})	Initial Inclination (°)	Stable Inclination (°)	MDF (Oe)	Comments
410-33-1, 23-25	342.2	0.007		+59.3	150	Sediments
410-33-1, 67-69	342.7	0.004		+53.0	360	overlying
410-33-1, 84-86	342.8	0.006		+69.1	210	basement
410-38-1, 20-22	349.7	3.338	+26.6	+26.2	240 (Leeds)	Basalt –
						limestone:
410-39-1, 18-21	359.2	0.052	-23.6			with basalt
		0.029	+37.7	+29.2 (150 Oe)	190	without basalt
410-39-1, 76-78	359.8	4.503	- 1.6	- 2.1	230	Basalt
410-39-1, 110	360.10	0.980		-55.5	355	First
410-39-1, 115	360.15	5.176		-21.9	505	basalt
410-39-1, 122.5	360.225	0.585		-34.6	900	breccia
410-39-1, 123	360.23	3.014		-16.4	345	group
410-39-1, 135-137	360.4	0.015	+51.8	+50.0	150 (Leeds)	Limestone
410-39-2, 68-70	361.2	2.484	+42.5	+41.0	165	Basalt
410-39-2, 124	361.74	0.295	+24.9			
410-39-2, 125	361.75	0.705	+78.3			Second
410-39-2, 129	361.79	0.148	+ 0.4			basalt
410-39-2, 133	361.83	0.098	+34.7			breccia
410-39-2, 136	361.86	0.476	-61.5			group
410-39-3, 22-25	362.2	0.047	+35.4			Limestone/
						basalt
410-39-3, 103-106	363.0	14.404	+21.6	+52.6	(thermal demag.)	Basalt
410-39-4, 45-46	364.0	10.062	+42.0	+38.8	235	Basalt
410-39-5, 21-23	365.2	8.260	+47.3	+45.2	195	Basalt
410-39-5, 101-104	366.0	14.405	+36.0	+35.9	170	Basalt
410-39-6, 64-66	367.1	12.498	- 1.9	- 3.9	(thermal demag.)	Basalt
410-40-1, 42-44	368.4	14.404	+21.6	+18.6	225	Basalt
410-40-1, 58-60	368.6	10.771	+46.1	+46.2	270 (Leeds)	Basalt
410-41-1, ~70	377.7	14.536	+38.4	+38.9	(thermal demag.)	Basalt
410-41-1, 145-150	378.5	14.873	-26.3	-28.4	160	Basalt
410-41-2, 43-45	379.9	10.227	+38.8	+38.6	(thermal @ Leeds)	Basalt

dispersion as those from the first breccia tested (Figure 24). The large chunk at the bottom of piece 10B is reversed with respect to the smaller ones above; but its volume is six times greater than theirs. Therefore, if any heating and remagnetization (discussed later) has occurred, this large chunk may have been affected differently.

In all cases, very high directional stability was observed upon A.F. or thermal demagnetization (Figure 25), so that the stable inclinations plotted in Figure 22 are very close to the NRM inclinations. Since the specimens were taken from blocks in a breccia, the measured inclinations were not expected to agree with each other. It was therefore

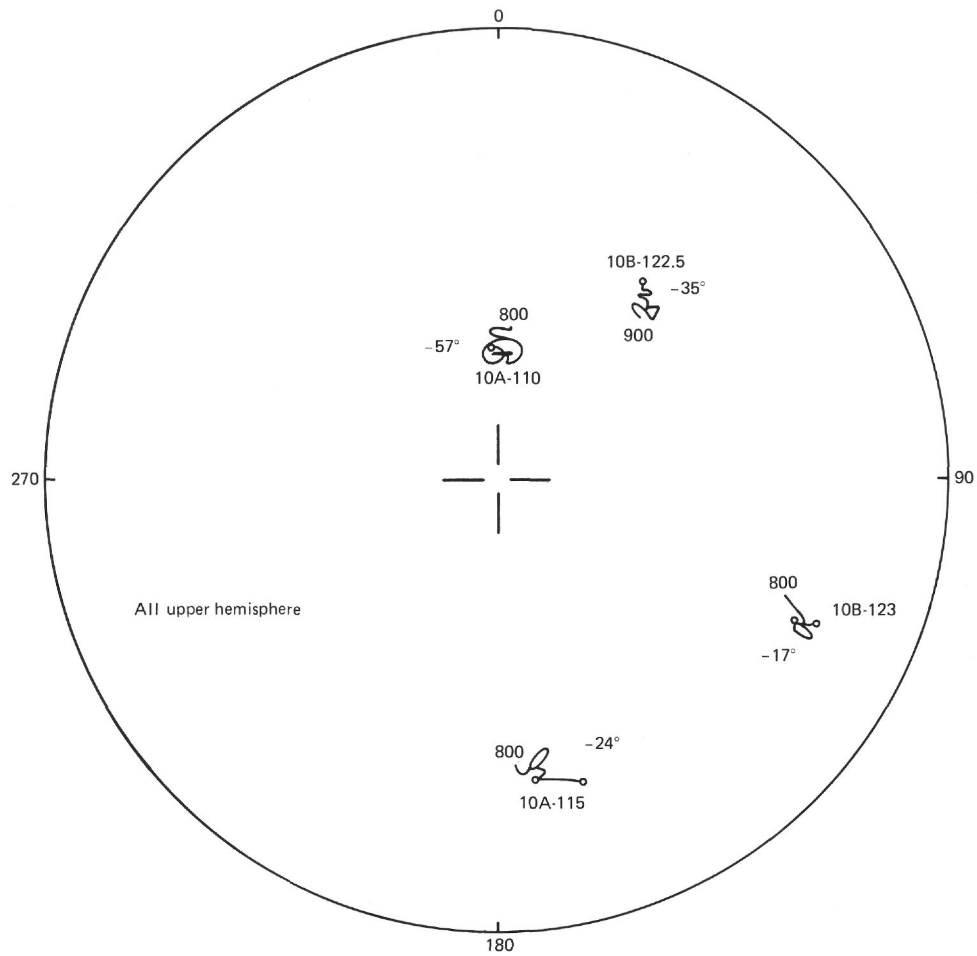


Figure 23. *AF demagnetization of four blocks in basaltic breccia, Section 410-39-1, Pieces 10A and 10B.*

surprising to find that a majority of specimen inclinations have positive values which, although low in comparison with the 64° predicted by the axial dipole model for latitude 45°N, were in a range similar to those found at Hole 410A, where flows were sampled at comparable depth (Figures 22, 26, and 27). Computation of a mean direction is not appropriate, since the specimens are chunks within a breccia. It is interesting, however, that most of the large basalt chunks have positive inclinations, often between 30° and 50°. The predominantly positive inclinations are consistent with the sign of the magnetic anomaly (anomaly 5) at this site. In other words, there is a suggestion that we may have measured magnetic inclinations reflecting the geomagnetic field, or that a partial remagnetization has occurred subsequent to lava solidification and breakup.

The intensity decay upon A.F. demagnetization of the standard-size specimens of basalt from Hole 410 was characterized by median destructive fields (MDF) between 160 and 270 Oe (Figure 28). In two of the basalts (Samples 39-1, 76 cm, and 39-2, 68 cm), there was a 6 per cent increase in intensity between 0 and 50 Oe (Figure 28). Specimen 39-1 had very shallow negative initial inclination, and Specimen 39-2 had positive initial inclination of 42°. A striking characteristic of all specimens is the uniformity of the shapes of the A.F. demagnetization remanence decay curves, and also the closeness of the MDFs. This is in contrast to observations at all other sites on this cruise.

On the small cores, A.F. demagnetization to 800 and 900 Oe caused no systematic change in direction beyond what was probably caused by handling difficulties. In this respect, then, the small cores show behavior similar to the standard cores. But intensity change with increasing alternating fields is markedly different from the standard cores (Figure 29). The small specimens are initially more stable; they either are constant in intensity or show slight increase to 100 Oe. Thereafter, intensities drop sharply, mimicking somewhat the standard cores, to 200 or 300 Oe. At higher fields, the extremely high stability of the small cores is clearly evident (Compare Figures 28 and 29). The remanence decay curves may suggest at least two magnetic carriers.

The second group of small cores was not demagnetized, since, judging from the results of demagnetization of the first group, the directions would not change. The variation of saturation magnetization with temperature for the small cores will be carried out on shore and compared to that of the standard cores. Although both sets of breccia samples are indicated to be random at the 95 per cent confidence level (using the table of values compiled by Irving [1964] from Watson [1956] and Vincenz and Bruckshaw [1960]),

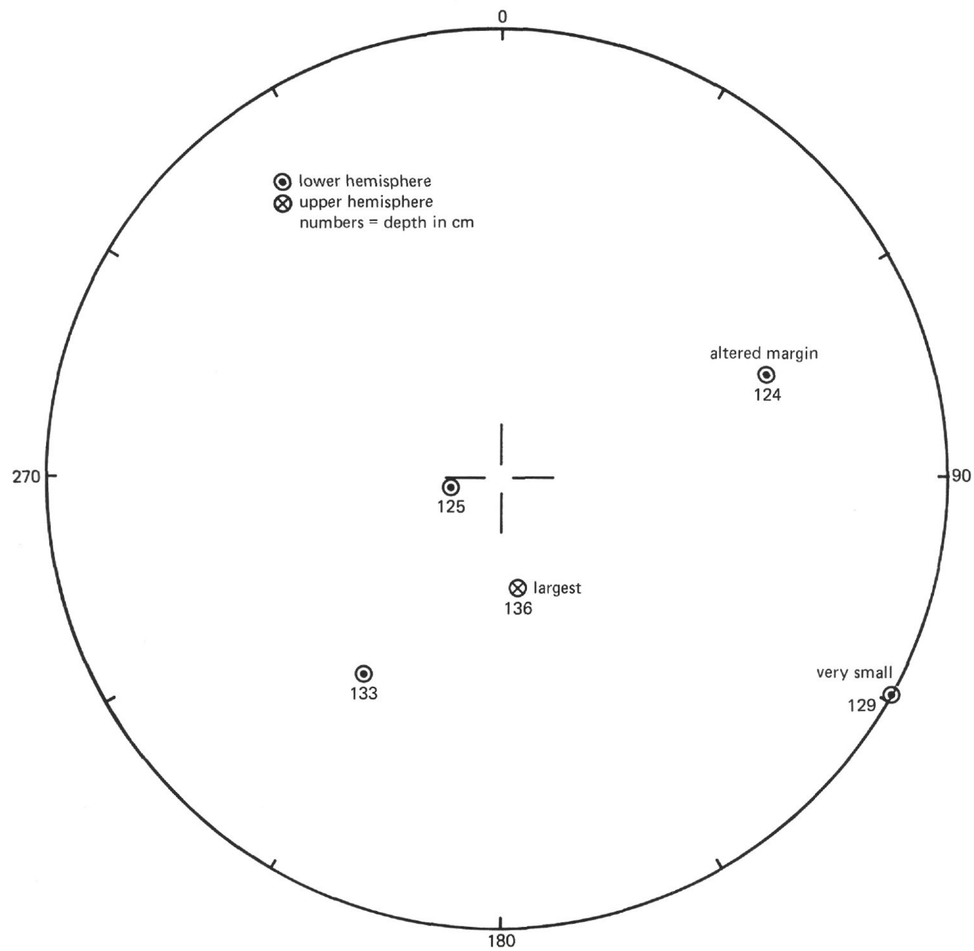


Figure 24. *Breccia block test, Section 39-2, Piece 10B. NRM directions.*

they are non-random at a lower confidence level — pieces in Section 39-1 at the 90 per cent level and Section 39-2 at a lower level.

For comparison with the limestone matrix, three specimens were taken from the chalk overlying basement at about 35 meters above the sediment/basement interface. These have NRM intensities ,of about 6×10^{-6} emu cm^{-3}. Their stability is indicated by multiple storage tests in the laboratory and partial A.F. demagnetization. Their inclinations are between 69° and 55°, comparable to the predicted inclination of 64° at this site.

The intensities of the limestone matrix samples from the breccia are 5 times greater than the chalk specimens. Their inclinations lie within the range of values of the basalts. Furthermore, they have the same stability characteristics as those of the basalt (Figure 30). Both these facts suggest that their remanence has been influenced since deposition, or that the lava was still hot when brecciated and that its residual heat was sufficient to overprint the original remanence of the lime mud matrix and of the enclosed basalt chunks.

Figure 31 shows the thermal demagnetization (in air) curves of three basalt specimens, 410-39-4, 39-6, and 41-1. The blocking temperatures range from 530°C to 600°C, although a minor phase with blocking temperatures above 600° is also apparent. Specimens 39-6 and 41-1 show no appreciable change at temperatures around 300°C, which has been reported as the Curie temperature of the primary magnetic phase before thermal decomposition of several dredged rocks from the 45°N Mid-Atlantic transect (Irving et al., 1970a; Irving et al., 1970b). Specimen 39-4 has a small decrease in intensity (less than 10% of NRM) after heating at 300°C, followed by a slight increase on further heating at 350°C, as though a minor phase with blocking temperature about that value may have been removed. The effect of heating in air, and resulting oxidation, may be masking any information to be gained by thermal demagnetization. But the thermal behavior may suggest that these basalts contain nearly stoichiometric magnetite as a major constituent of the ferromagnetic phase, possibly formed by oxidation of titanomagnetite at temperatures above 300°C.

Discussion

Several characteristics of Site 410 specimens are noteworthy. Their inclinations are not random as would be expected from a breccia. Most of their inclinations are similar to those of the presumed *in-situ* lavas of Hole 410A (see later discussion). The small cores from smaller breccia pieces do not seem to be random, and show extremely high

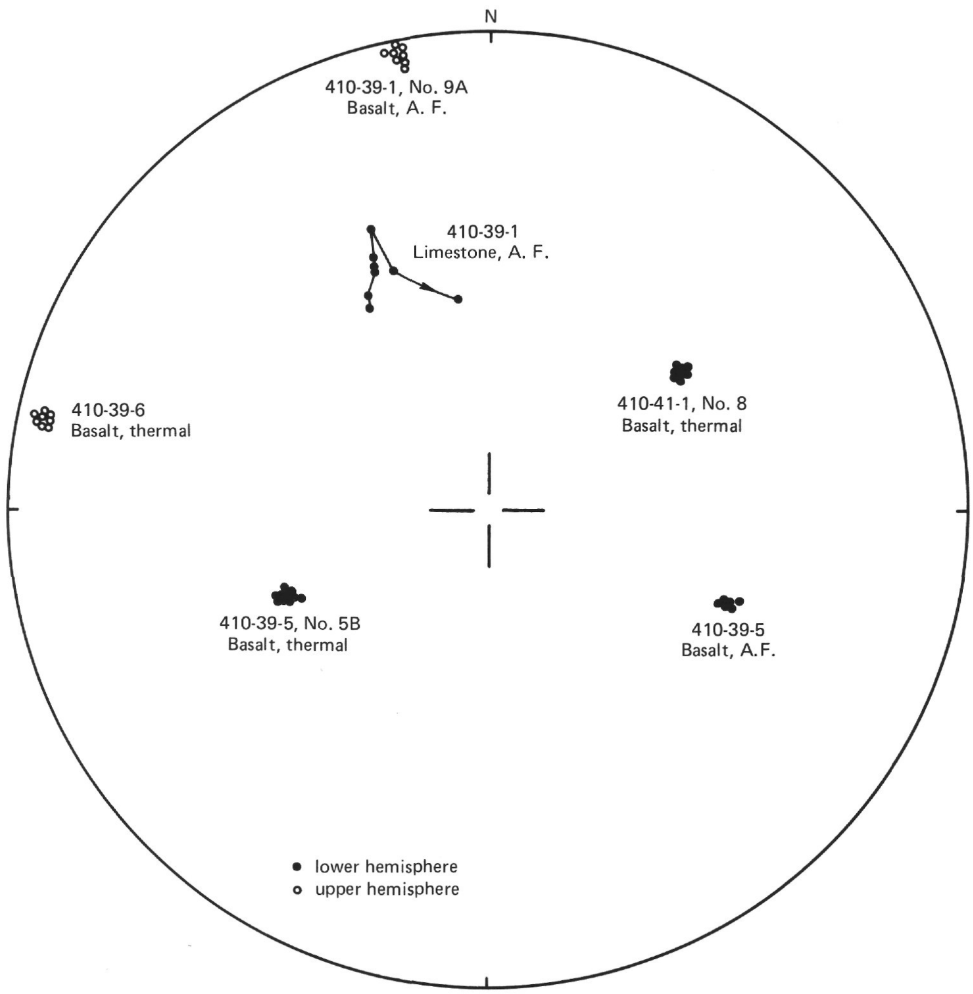


Figure 25. *Directional changes upon stepwise demagnetization, Hole 410.*

A.F. stability. The basalts have NRM intensities higher than those from the flows of Hole 410A, and the A.F. decay curves and the MDFs are unusually uniform. The matrix carries a remanence similar to those of the enclosed basalt pieces. The basalt blocking temperatures are rather high, and another phase may have an even higher blocking temperature.

The intensity and the blocking temperature may together indicate magnetite. The high A.F. stability and very high blocking temperature could suggest hematite. The lack of complete randomness of the basalt chunks from the breccia, the high remanence of the limestone matrix specimens and their similar stability to the basalts, the similarity of most inclinations to those of flows at Hole 410A, and the high blocking temperatures, all suggest something different from our previous sites in the acquisition of the remanent magnetization. The remanence of these basalts may reflect brecciation of a hot lava flow, with imprinting of a coherent remanence when the breccia came to rest, or remagnetization at a later time.

Hole 410A

At Hole 410A, we took 27 standard cores from basalt, sampling Cores 2 through 6 (sub-bottom depth 334 to 376 m) which appear to be from a sequence of thin flows. (We also took two samples from the chalk cored just before reaching basement.) NRM basalt intensities range from 1.6×10^{-3} emu cm^{-3} to 7.9×10^{-3} emu cm^{-3}, with a mean of 3.2×10^{-3} emu cm^{-3}, and there is no obvious correlation between NRM intensity and depth. The intensities are more uniform than at previous sites on the cruise, and significantly lower than those of the basalts at Hole 410.

The inclinations are all positive, in agreement with the sign of the anomaly, and become shallower with depth. Values around 40° occur down to 345 meters sub-bottom (11 m into basement); then inclinations center around 20°. The steepest inclination, 49°, belongs to the uppermost specimen (410A-1-7), at 334 meters, and the shallowest, +1°, occurs at 364 meters (of 375 m total depth), in specimen 410A-5-1, which also has the second highest NRM intensity, 6.4×10^{-3} emu cm^{-3}. As at Hole 410, all the specimens demagnetized showed extremely high directional stability (Figure 32). Again, even the highest of the stable inclinations is appreciably lower than the axial dipole prediction of 64° for the site latitude of 45°N. An arithmetic mean of all specimens ($N=27$) is 22°, $\sigma=4.70°$. However, since there seems to be a change in inclination downhole, a mean was calculated for the upper five specimens (see Table

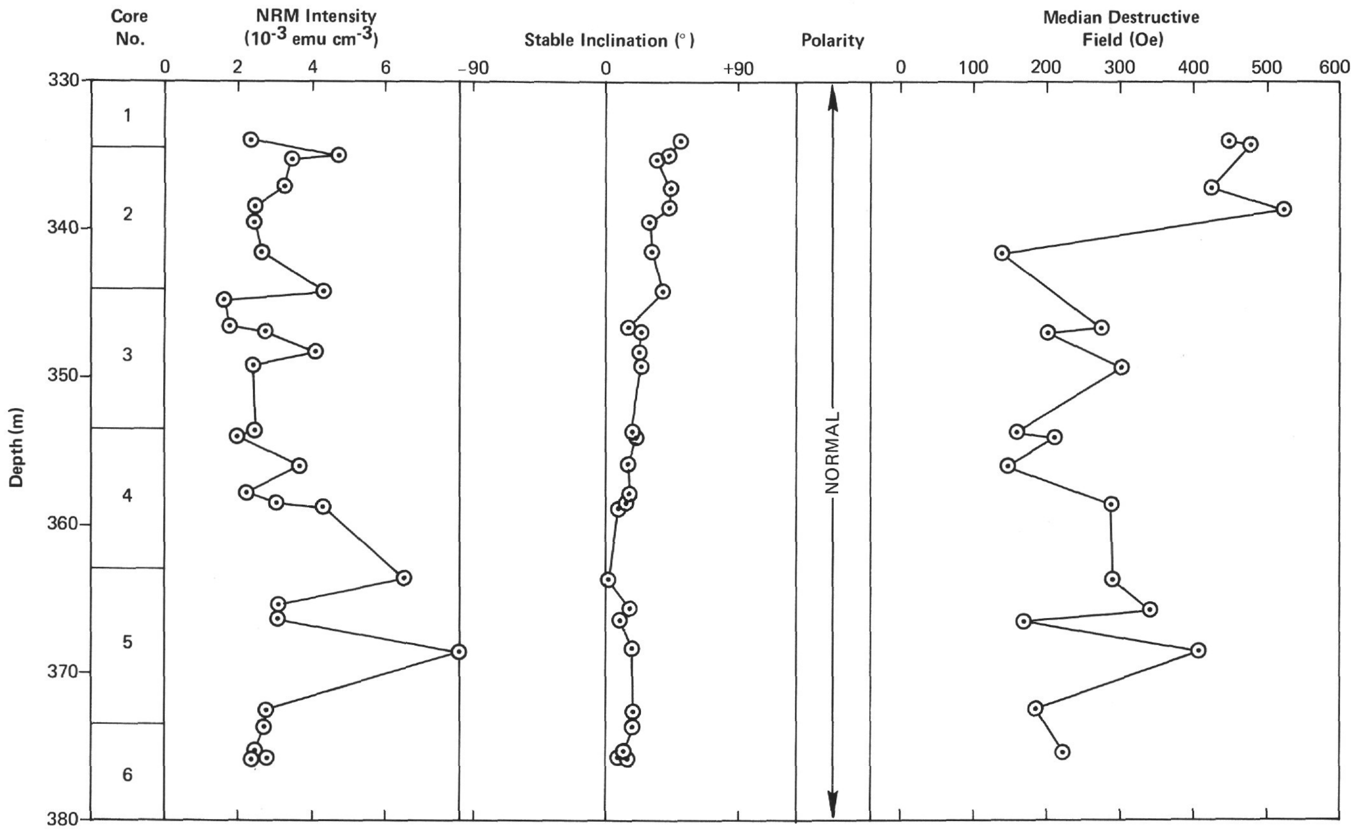


Figure 26. *Downhole plot of paleomagnetics, Hole 410A.*

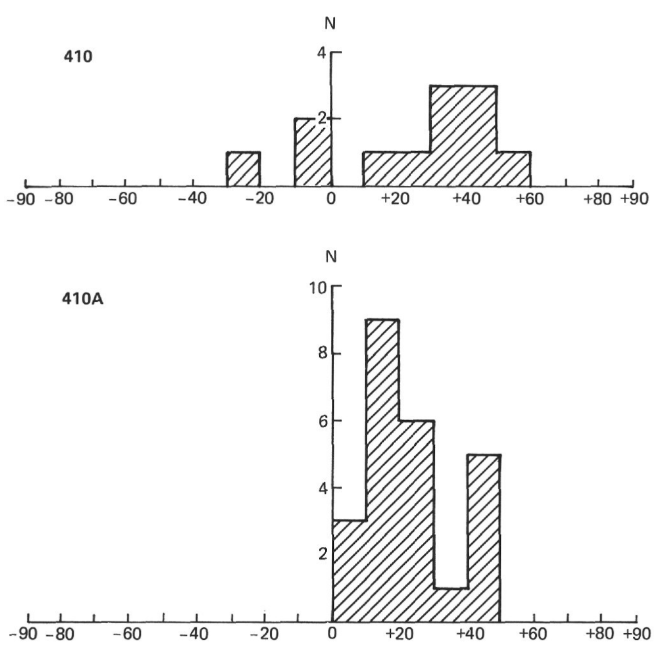


Figure 27. *Histogram of stable inclinations at Holes 410 and 410A.*

8) and the lower 19 (excludes the sixth, seventh, and eighth samples, see table). These two means are, respectively, 42.6°, $\sigma=6.53°$ ($N=5$) and 15.3°, $\sigma=3.91°$ ($N=19$).

The A.F. demagnetization of specimens from Hole 410A produced a spectrum of MDFs between 140 Oe and 450 Oe, although most were between 140 Oe and 300 Oe (Figure 33), very similar to Site 410. The uppermost four specimens had high MDFs and displayed high resistance to A.F. demagnetization similar to the small cores from Section 410-39-1 (compare Figures 33 and 28). These samples also have higher inclinations than the rest of the samples at Hole 410A. It is interesting, although perhaps fortuitous, that the specimen with the highest NRM intensity (5-4, 7.9 × 10^{-3} emu cm^{-3}) was also the most stable to A.F. demagnetization (Figure 33). The uniformity of the A.F. demagnetization curves is greater than at our previous sites, though not as pronounced as at Hole 410.

Thermal demagnetization of seven specimens from Hole 410A showed tendencies similar to those at Hole 410 (Figure 34). The blocking temperature at Hole 410A seems slightly lower (~500°C) than at Hole 410 (~530°C to 600°C), which might indicate a lower degree of oxidation. A blocking temperature above 600°C is also suggested. All the thermally demagnetized specimens from Holes 410 and 410A have significantly higher blocking temperatures than those from the Reykjanes Ridge sites, where the blocking temperature was 400°C. The ferromagnetic minerals in the basalts from Hole 410A may have undergone high-temperature oxidation, as has been suggested for Hole 410. Because the grain size of the opaque minerals is very small, shipboard microscope examination has not proved very informative, and a thorough examination of polished sections must be carried out on shore. If Holes 410 and 410A have undergone high-temperature oxidation as suggested by the blocking temperatures, Hole 410 may have

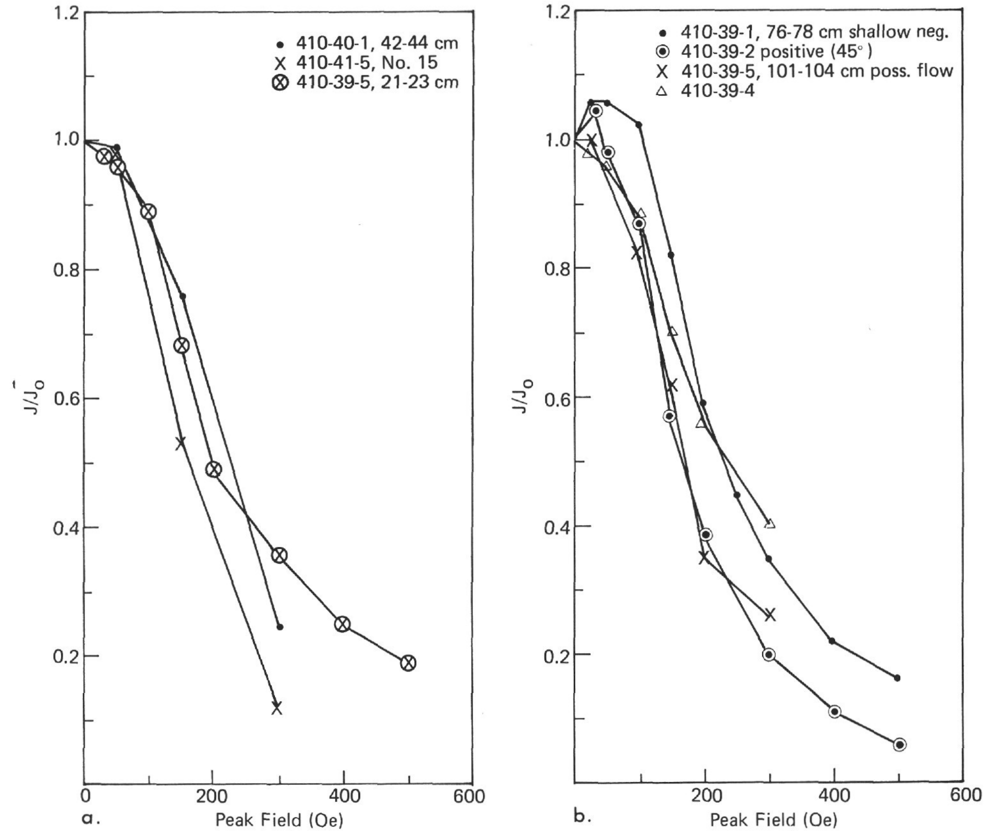


Figure 28. *AF demagnetization results, Hole 410.*

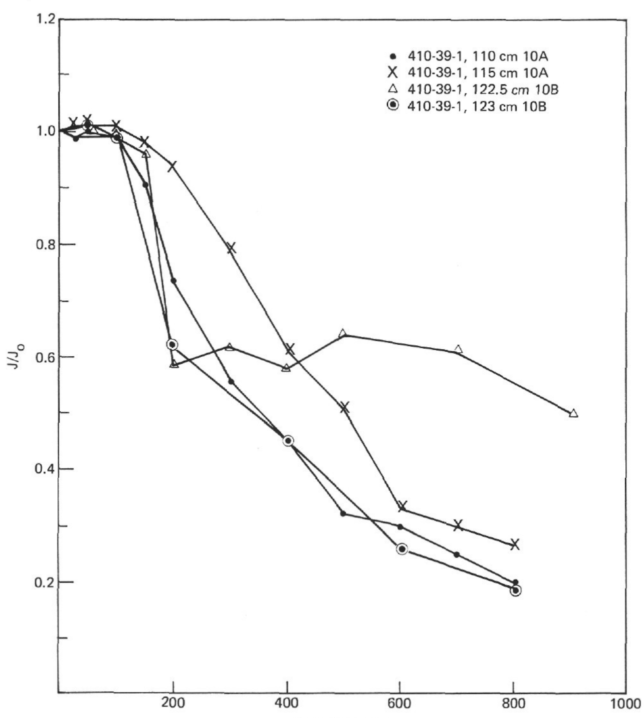


Figure 29. *Small-core AF demagnetization, Hole 410.*

undergone slightly more oxidation than Hole 410A. This is supported by the higher NRM intensities, greater uniformity of MDFs and A.F. demagnetization curves, and higher blocking temperatures of specimens from Hole 410, compared with those from Hole 410A.

The two samples of chalk overlying basement had stable inclinations reversed relative to the basalt below and the positive anomaly of the magnetic anomaly pattern. Both specimens had low intensities, 1 to 3×10^{-6} emu cm^{-3}. One, the more consolidated, was stable to storage tests, whereas the other, physically much softer, was less stable. The first had an initial NRM inclination of about $-50°$, and after subjection to a 50-Oe field, it was $-57°$. The second had a positive 70° NRM inclination, and after 50 Oe, a negative $-37°$, although 24- to 48-hour storage tests caused this to fluctuate widely ($-20°$ to $-50°$). However, storage in a zero field and remeasurement on shore showed both to have high negative inclinations, $-67°$ and $-51°$, respectively. The negative inclinations are consistent with the paleontological determination that the sediments of Sections 1-5 and 1-6 of Hole 410A are from positions considerably uphole from the basaltic basement (Poore, this volume).

In summary, Hole 410A is notable for shallow inclinations, high MDFs, and high apparent blocking temperatures. The differences in inclinations and MDFs near the top of the hole indicate at least two magnetic units (Figure 26).

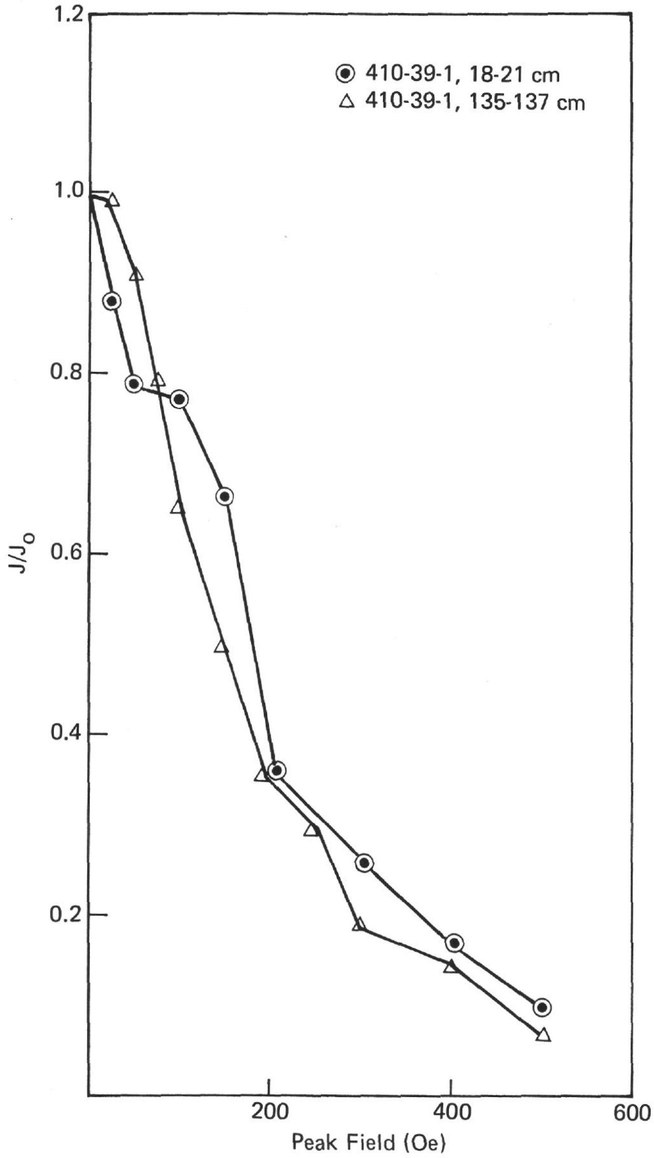


Figure 30. *AF demagnetization of limestone matrix, Hole 410.*

PHYSICAL PROPERTIES OF BASEMENT ROCKS

Less than 50 meters of basement was drilled before Hole 410 was terminated because of drilling problems. The wet bulk density and Hamilton Frame sonic velocity measurements for this interval are plotted in Figures 35, 36, and 37. Sonic velocities have a sample mean of 4.07 km/second (s = 0.24), with no detectable trend. The wet bulk density by gamma-ray attenuation and by weight agree, within their uncertainties. The trend suggested by the weighed wet bulk densities is not reliable, owing to the small sample size.

Hole 410A penetrated 57 meters of basalt before drilling problems caused termination of this hole as well. With somewhat higher recovery, more measurements were made on Hole 410A samples. Sonic velocity, wet bulk densities, and water content are plotted against depth in Figures 38, 39, 40, and 41. Sonic velocity measurements still show no trend, but do show a significantly higher mean (4.41 km/second, s = 0.39) than the Hole 410 rocks. The wet bulk densities by weight and by gamma-ray attenuation agree, within the scatter, but show no trend. The same is true with the water content values. Basically, the data sample set at this site was quite small.

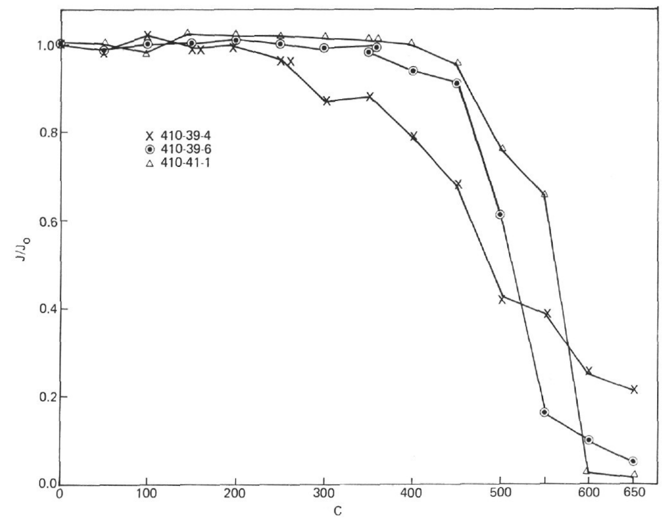


Figure 31. *Thermal demagnetization results, Hole 410.*

CORRELATION OF SEISMIC REFLECTION WITH DRILLING RESULTS

At Site 410, seismic reflection profiles were available from a survey by *R.R.S. Discovery* and from the beacon-drop approach made by *Glomar Challenger*. In addition, a wide-angle reflection profile was shot over the site on an azimuth of 200°T. No reflection data are available immediately for Hole 410A, but because it was displaced only 110 meters northeast from Hole 410, it is not likely that the results here would be much different on the scale of our measurement.

Two-way reflection time at the site is 370 ms, and no internal reflectors are evident. Assuming a linear velocity gradient of 1.0 s^{-1} and a bottom water sound velocity of 1500 m/s, basement is predicted at 305 meters. This is 10 per cent short of the drilled depth of 340 meters at Hole 410.

The wide-angle reflection profile was run to about 10 km south of the site. The direct water wave was not received (Figures 42 and 43), and distances were estimated from satellite fixes and the closest point of approach to the beacon. The interval velocity for the sediments was determined to be 1.58 km/s from a $T^2 - x^2$ plot (Figure 44). This gives a basement depth of 295 meters versus 331 meters drilling depth, an error of 12 per cent. A refracted arrival was also determined from the basement interface. This return was extremely weak, but a velocity of 4.54 to 4.76 is indicated for the basalt basement, which agrees with laboratory measurements, and a tangent point was found at 2 km which agrees well with a critical angle determination. The intercept time is 4.19 s, and gives a sediment layer of 366 meters, assuming flat layering. Considering that the sonobuoy sampled reflections from a wide area, the velocity and layer determinations are surprisingly accurate.

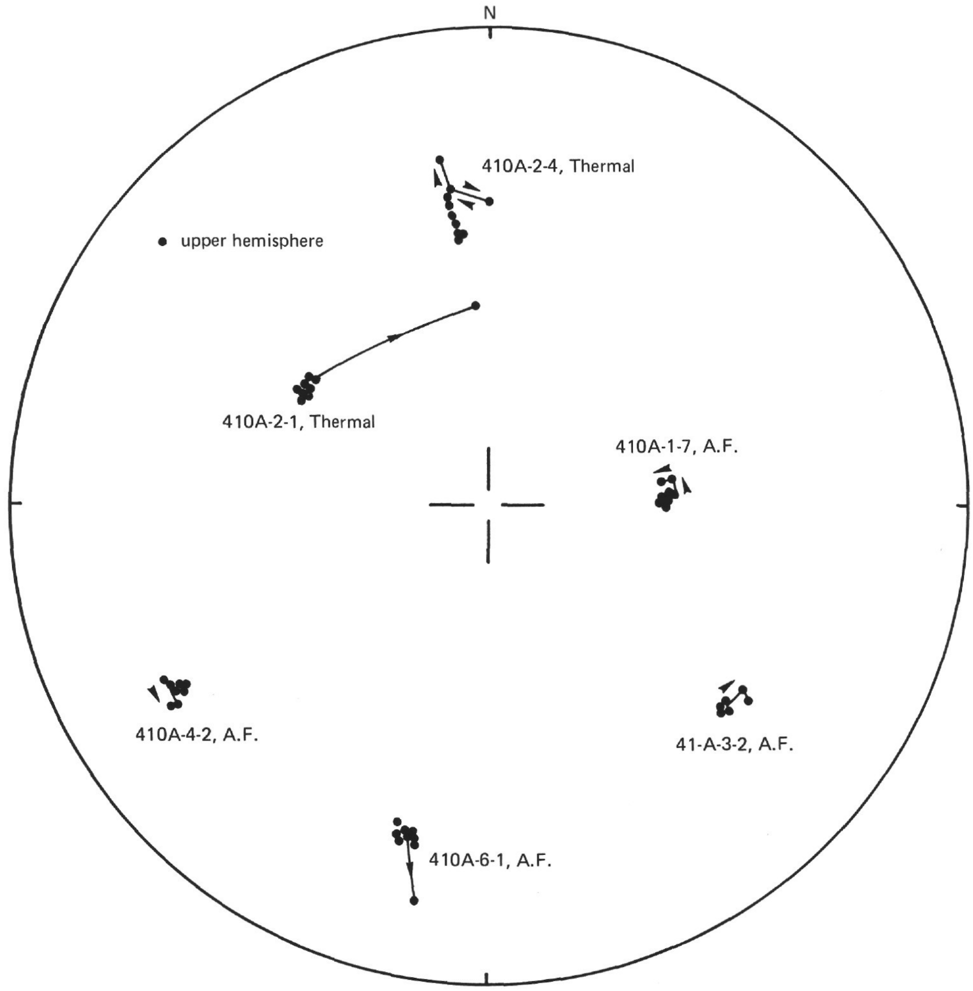


Figure 32. *Directional changes upon stepwise demagnetization, Hole 410A.*

THERMAL CONDUCTIVITY

Five downhole sediment temperatures were measured at sub-bottom depths of 74, 121.5, 178.5, 235.5, and 292 meters by the same method as used in Holes 407 and 408. The results have not been analyzed, however, because of machine trouble with the tape reader.

Sixteen analog thermal conductivity measurements were made with seven unsplit sections of cores. Results are shown in Figure 45 as a downhole plot. Thermal conductivity varies within a range from 2.59 to 3.35; the average is 3.02 ± 0.28 mcal/cm s°C. No systematic variation in thermal conductivity with sub-bottom depth is apparent. The values are much higher than those obtained at Sites 407 and 408.

Figure 46 shows the relationship between thermal conductivity and water content in sediment measured on the present cruise. Results are consistent with the empirical curve given by Ratcliffe (1960) for bottom-surface sediments measured in widespread oceans.

SUMMARY AND CONCLUSIONS

Our prime objective in drilling at Site 410 was to provide a data point on the longitudinal traverse of the Mid-Atlantic Ridge recommended by the JOIDES Ocean Crust Panel. The site is in an area of the western flank of the ridge which has been extensively surveyed over the years by the Bedford Institute. We drilled two holes here in 3000 meters of water in a broad sedimentary basin between northeast-trending mountains, on the older (NW) edge of anomaly 5. At both holes we penetrated slightly over 330 meters of sediment and about 50 meters of basement. We had to abandon both holes when the drill string jammed in the hole. We attempted continuous coring of sediment only at Hole 410.

The sediments at Hole 410 are 340 meters of calcareous ooze and chalk. The upper unit is 38 meters of Pleistocene nannofossil ooze (mostly) interbedded with calcareous muds and marly nannofossil ooze. A second unit extends down to 245 meters and is Pleistocene through upper Miocene light gray nannofossil ooze. This unit is notable for its high content of nannofossils (80 to 95%), the occurrence of pyritized burrows, and light green glauconitic laminae near its base. The third unit is 95 meters of upper Miocene nannofossil chalk which is 99 to 100 per cent carbonate. This unit has a great amount and variety of bioturbation features. Pyritized burrows are as common as in Unit 2. The unit is light gray and grades to pale yellow for the section below about 315 meters. Above the basement rocks is 20 cm of interlayered basalt sand and nannofossil chalk.

TABLE 8
Paleomagnetism – Hole 410A

Sample (Interval in cm)	Sub-bottom Depth (m)	NRM Intensity (10^{-3} emu cm^{-3})	Initial Inclination (°)	Stable Inclination (°)	MDF (Oe)	Comments
410A-1-5, 130-132	332.2	0.001		-57.3 (–66.8)		Sediments
410A-1-6, 47-49	333.0	0.003		-37.3 (-51.2)		
410A-1-7, 21-24	334.0	2.352	+88.6	+48.8	450	
410A-2-1, 51-54	335.0	4.710	+43.5	+42.3	(thermal demagnetization)	
410A-2-1, 68-70	335.2	3.375	+39.7	+35.4	475	(Leeds)
410A-2-2, 110-113	337.1	3.172	+43.9	+43.5	425	
410A-2-3, 87-90	338.4	2.284	+44.5	+42.9	525	(Leeds)
410A-2-4, 53-56	339.5	2.411	+30.4	+22.9	(thermal demagnetization)	
410A-2-5, 95-99	341.5	2.560	+38.4	+31.7	140	
410A-3-1, 23-25	344.2	4.336	+38.0	+39.5	(thermal @ Leeds)	
410A-3-1, 76-78	344.8	1.598	+40.8	(not demagnetized)		
410A-3-2, 111-113	346.6	1.670	+17.7	+16.5	275	
410A-3-2, 143-145	346.9	2.693	+22.7	+21.8	205	
410A-3-3, 122-124	348.2	4.090	+20.3	+20.8	(thermal demagnetization)	
410A-3-4, 73-75	349.2	2.386	+26.2	+24.3	300	(Leeds)
410A-4-1, 11-13	353.6	2.387	+21.5	+18.8	160	
410A-4-1, 52-54	354.0	2.114	+20.8	+20.4	210	
410A-4-2, 87-93	355.9	3.634	+16.8	+15.1	150	
410A-4-3, 130-137	357.8	2.175	+18.2	+16.7	(thermal demagnetization)	
410A-4-4, 43-45	358.4	3.138	+14.7	+13.5	290	(Leeds)
410A-4-4, 65-70	358.7	4.331	+10.3	+ 8.6	(thermal demagnetization)	
410A-5-1, 69-76	363.7	6.470	+ 3.0	+ 0.7	290	
410A-5-2, 105-119	365.6	3.132	+16.4	+15.9	340	(Leeds)
410A-5-3, 38-45	366.4	3.106	+14.4	+10.3	170	
410A-5-4, 95-106	368.5	7.989	+19.1	+18.2	410	
410A-6-1, 8-16	372.6	2.663	+20.2	+18.2	185	
410A-6-1, 118-126	373.7	2.693	+19.9	+16.9	(thermal demagnetization)	
410A-6-2, 122-132	375.3	2.489	+15.5	+11.8	220	
410A-6-3, 2-8	375.6	2.386	+11.0	+ 8.6	(thermal demagnetization)	
410A-6-3, 28-30	375.8	2.775	+13.7	+13.2	?[a]	(Leeds)

[a]No decay of intensity up to 800 Oe.
(Leeds) = Samples measured at Leeds University, not on shipboard.

A microfossil assemblage 5 meters above the basement at Hole 410 gives an age of about 8.5 to 9.5 m.y. Anomaly 5 has been estimated by LaBrecque et al. (1977) to be between 8.34 and 9.74 m.y. old. Because we drilled on the old side of anomaly 5, we expected the age of the basement to be about 9.5 m.y. Total carbonate in the upper Pleistocene section can be related to climate changes. About six or more carbonate maxima are tentatively correlated with known upper Pleistocene glacial cycles. Pteropods were also present in the uppermost meter of the Pleistocene section; this suggests downslope transport from depths less than 3000 meters.

Glacial erratics are present to the Pliocene/Pleistocene boundary, and ice-rafted mineral grains are present down to about 140 meters sub-bottom (3 m.y.). This finding supports the interpretation of Leg 12 workers that late Neogene glaciation in the northern hemisphere dates from this time. Some of the erratics (gabbros, anorthosites) could be of local origin, and not glacial.

The occurrence of pyrite nodules from 46 to 311 meters sub-bottom indicates reducing conditions through most of the section. At the base of the section, secondary oxidation has altered them to goethite and limonite. The oxidized sediment is yellowish, and is also notable for the absence of delicate discoasters.

The basement rocks at Hole 410 are 25 meters of a basalt-limestone breccia over 27 meters of basalt pillow breccia; the 53 meters drilled at Hole 410A are predominantly pillow basalt breccia. At Hole 410, the limestone matrix constitutes up to 40 per cent of the core. The basalt fragments are of variable size, and most of the smaller ones are palagonitized glass. Some pieces can be fitted together like a puzzle, indicating little transport after fracture, but this is not generally so. Many pieces are suspended, and not in contact, indicating a flow into sediment rather than a layer of fragments buried by sedimentation. The remanent magnetism measurements of several basalt pieces within the breccia show no coherent direction, but surprisingly they seem to have the same polarity, suggesting a degree of nonrandomness. Possibly the flow was emplaced within the blocking temperature range (450 to 560°C). The lower basalt unit has much less limestone matrix. It has clinopyroxene-olivine and plagioclase phenocrysts, frequently fresh, whereas the upper basalt is very sparsely phyric. The pillow breccias at Hole 410A are often highly vesicular and glassy. Up to 45 pillow skins may have been penetrated. Six units were distinguished by petrographic grouping, and two were distinguished on geochemical grounds. The rocks frequently have fresh olivine, and range from sparsely phyric to aphyric.

The basalt section at both holes is normally magnetized and uncharacteristically stable. Samples show high remanence of 10^{-2} -10^{-3} emu cm^{-3}, but are somewhat lower at

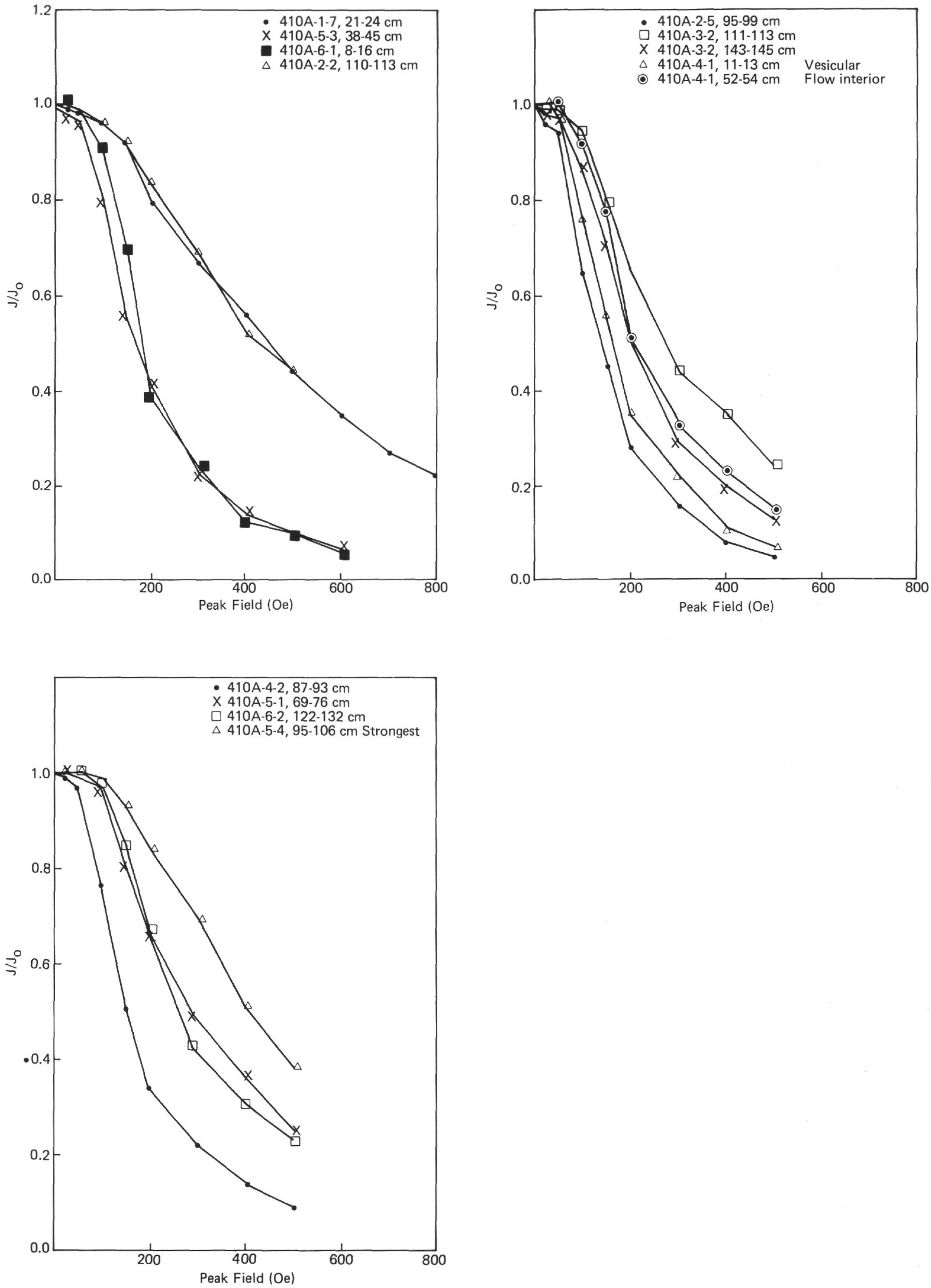


Figure 33. *AF demagnetization results, Hole 410A.*

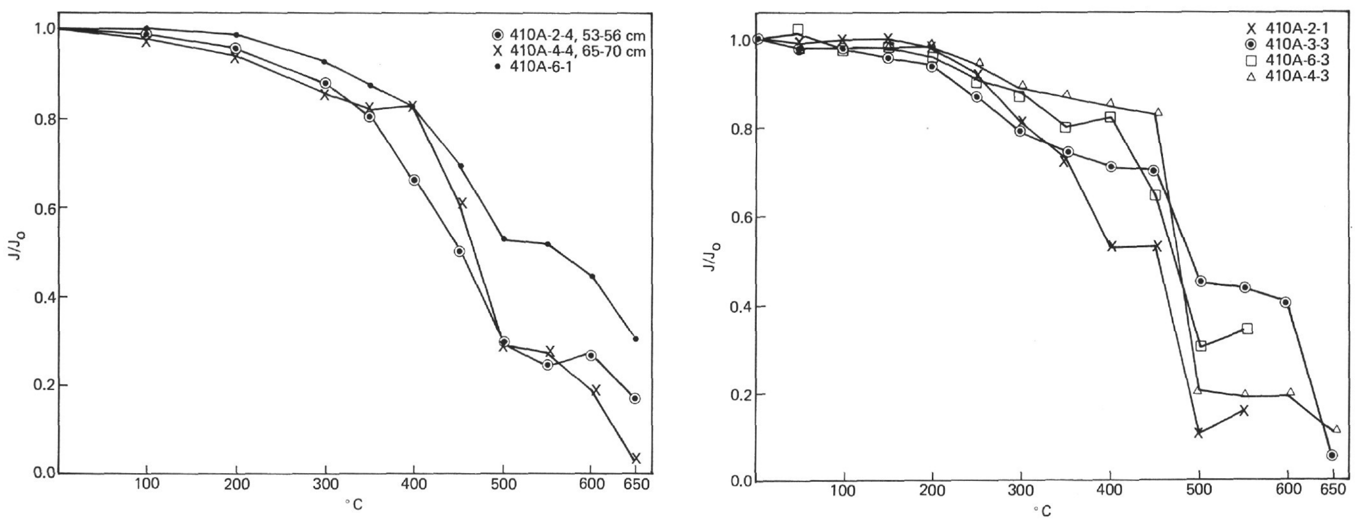


Figure 34. *Thermal demagnetization results, Hole 410A.*

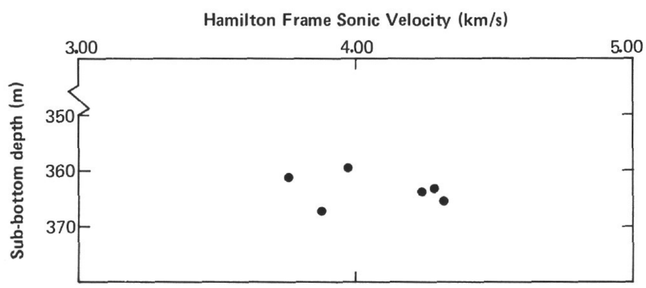


Figure 35. *Sonic velocity versus depth, Hole 410.*

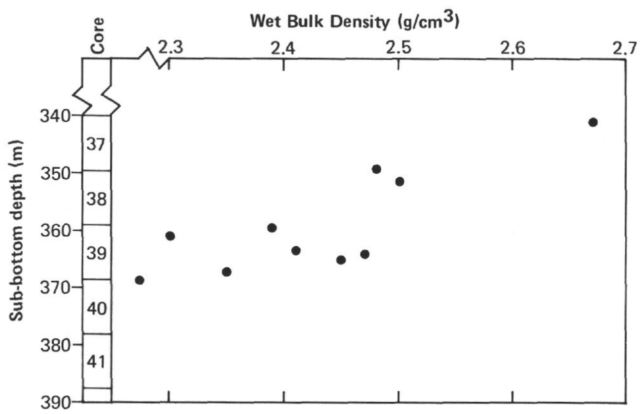


Figure 36. *Wet bulk density versus depth, Hole 410.*

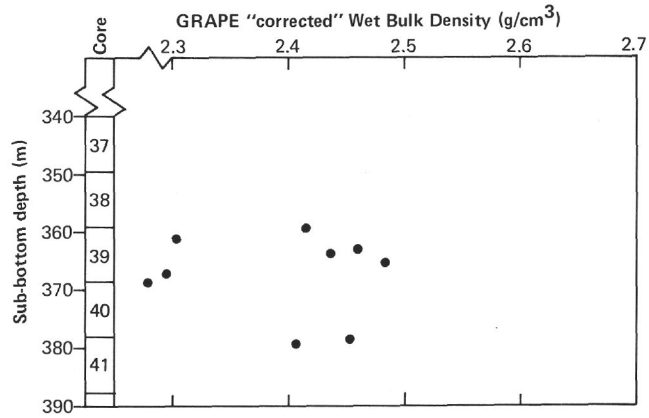


Figure 37. *GRAPE "corrected" wet bulk density versus depth, Site 410.*

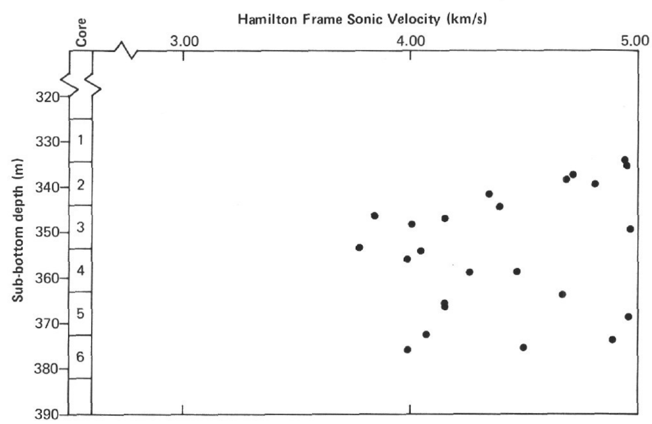


Figure 38. *Sonic velocity versus depth, Hole 410A.*

Hole 410A than at Hole 410. The inclinations are much shallower than expected, even taking secular variation into account. The section at Hole 410 has two magnetic cooling units which are repeated in the top of Hole 410A, where there are a total of seven. It is interesting that the inclinations at Hole 410A steepen up-section. This can be interpreted as secular variation, or as growth tilting (successive addition of lava flows while the section is steadily tilting).

Drilling had to be terminated at both holes when the string became jammed by basaltic gravelly sand. Some of this material was recovered; it is sand composed of basalt, limestone, brownish glass, and calcite fragments. Mud is also admixed. In Holes 410 and 410A, the sand grains are angular to sub-angular. These sands are probably drill cuttings (Roberts, this volume).

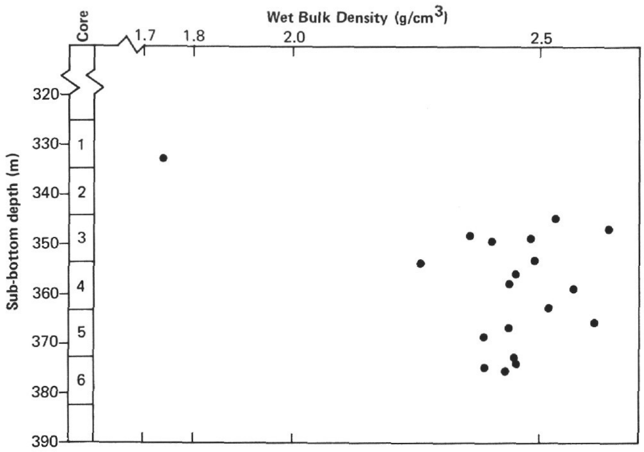


Figure 39. *Wet bulk density versus depth, Hole 410A.*

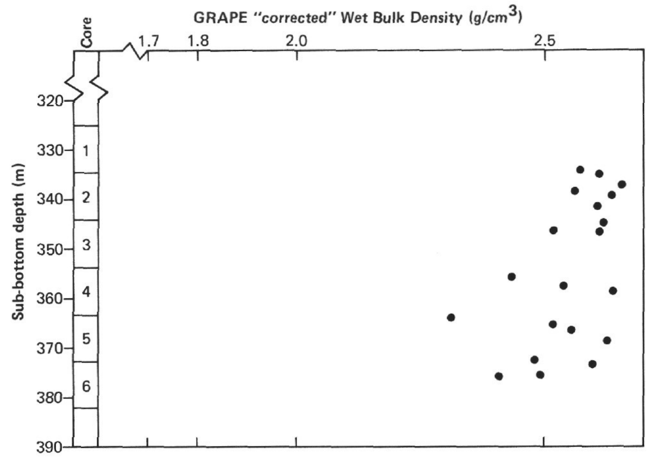


Figure 40. *GRAPE "corrected" wet bulk density versus depth, Hole 410A.*

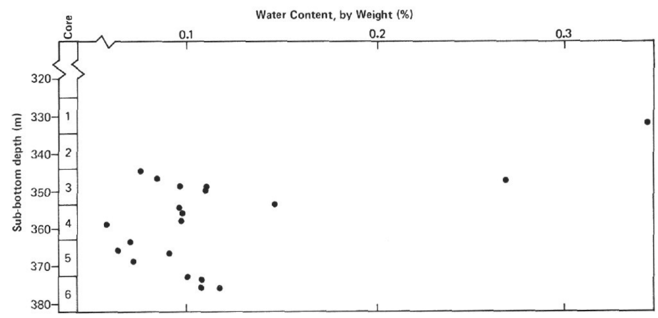


Figure 41. *Water concent versus depth, Hole 410A.*

REFERENCES

Aumento, F., Loncarevic, B.D., and Ross, D.I., 1971. Hudson Geotraverse: geology of the Mid-Atlantic Ridge at 45°N, *Phil. Trans. Roy. Soc. London,* v.268A, p.623-650.

Berggren, W.A., 1972a. Late Pliocene-Pleistocene glaciation. *In* Laughton, A.S., Berggren, W.A., et al., *Initial Reports of the Deep Sea Drilling Project,* v.12: Washington (U.S. Government Printing Office), p.953-963.

———, 1972b. A Cenozoic time-scale — some implications for regional geology and paleobiogeography, *Lethaia,* v.5, p.195-215.

Irving, E., 1964. *Paleomagnetism:* New York (John Wiley and Sons), p.63.

Irving, E., Park, J.K., Haggerty, S.E., Aumento, F., and Loncarevic, B., 1970a. Magnetism and opaque mineralogy of basalts from the Mid-Atlantic Ridge at 45°N, *Nature,* v.228, p.974.

Irving, E., Robertson, W.A., and Aumento, F., 1970b. The Mid-Atlantic Ridge near 45"N. VI remanent intensity, susceptibility, and iron content of dredged samples, *Canadian J. Earth Sci.,* v.7, p.226.

Jung, P., 1973. Pleistocene pteropods — Leg 15, Site 147, Deep Sea Drilling Project. *In* Edgar, N.T., Saunders, J.B., et al., *Initial Reports of the Deep Sea Drilling Project,* v.15: Washington (U.S. Government Printing Office), p.753-767.

Laughton, A.A., Berggren, W.A., et al., 1972. *Initial Reports of the Deep Sea Drilling Project,* v.12: Washington (U.S. Government Printing Office).

LaBrecque, J.L., Kent, D.V., and Cande, S.C., 1977. Revised magnetic polarity time scale for Late Cretaceous and Cenozoic time, *Geology,* v.5, p.330.

Muir, I.D. and Tulley, C.E., 1964. Basalts from the northern part of the Rift Zone of the Mid-Atlantic Ridge, *J. Petrol.,* v.5, p.409.

Ratcliffe, E.H., 1960. The thermal conductivities of ocean sediments, *J. Geophys. Res.,* v.65, p.1535-1544.

Ryan, W.B.F., Cita, M.B., Rawson, M.D., Burkle, L.H., and Saito, T., 1975. A paleomagnetic assignment of Neogene stage boundaries and the development of isochronous datum planes between the Mediterranean, the Pacific and Indian oceans in order to investigate the response of the world ocean to the Mediterranean "salinity crisis," *Rivista Italiana Paleontologia e Stratigraphia,* v.80, p.631-688 (1974).

Sayles, F.L. and Manheim, F.T., 1975. Interstitial solutions and diagenesis in deeply buried marine sediments: results from the Deep Sea Drilling Project, *Geochim. Cosmochim. Acta.,* v.39, p.103.

Vincenz, S.A. and Brockshaw, J.McG., 1960. Note on the probability distribution of small number of vectors, *Proc. Camb. Phil. Soc.,* v.56, p.21.

Watson, G.S., 1956. A test for randomness of directions, *Mon. Not. Roy. Astr. Soc. Geophys. Supp.,* v.7, p.160.

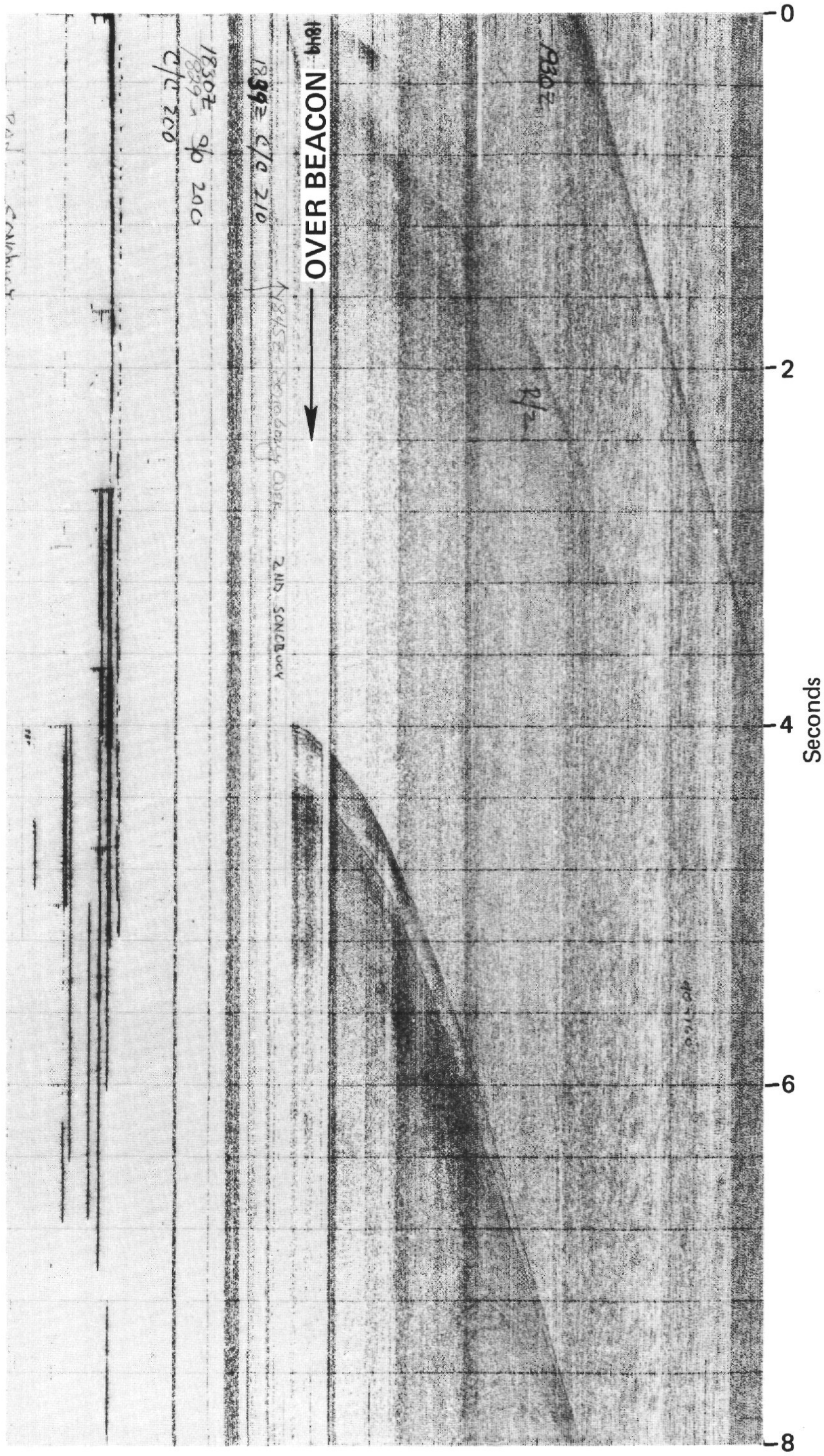


Figure 42. *Sonobuoy profile taken at Site 410.*

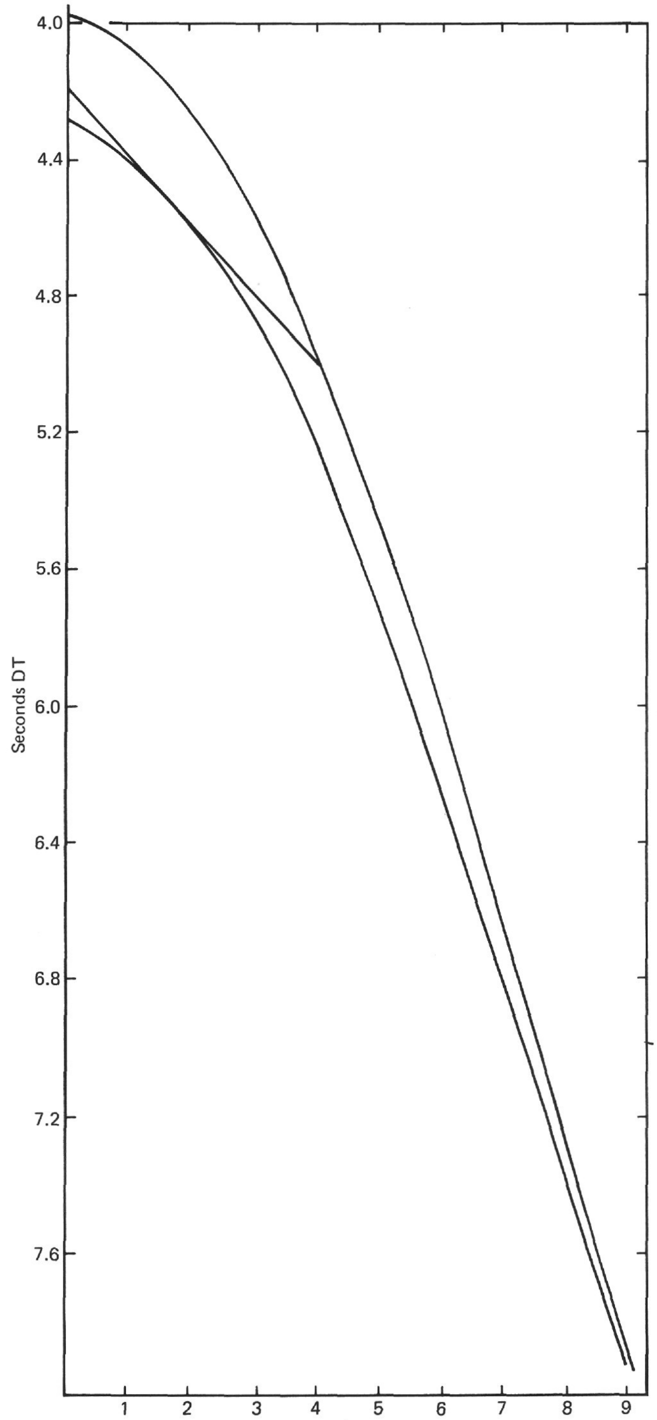


Figure 43. *Line drawing of sonobuoy profile, Site 410.*

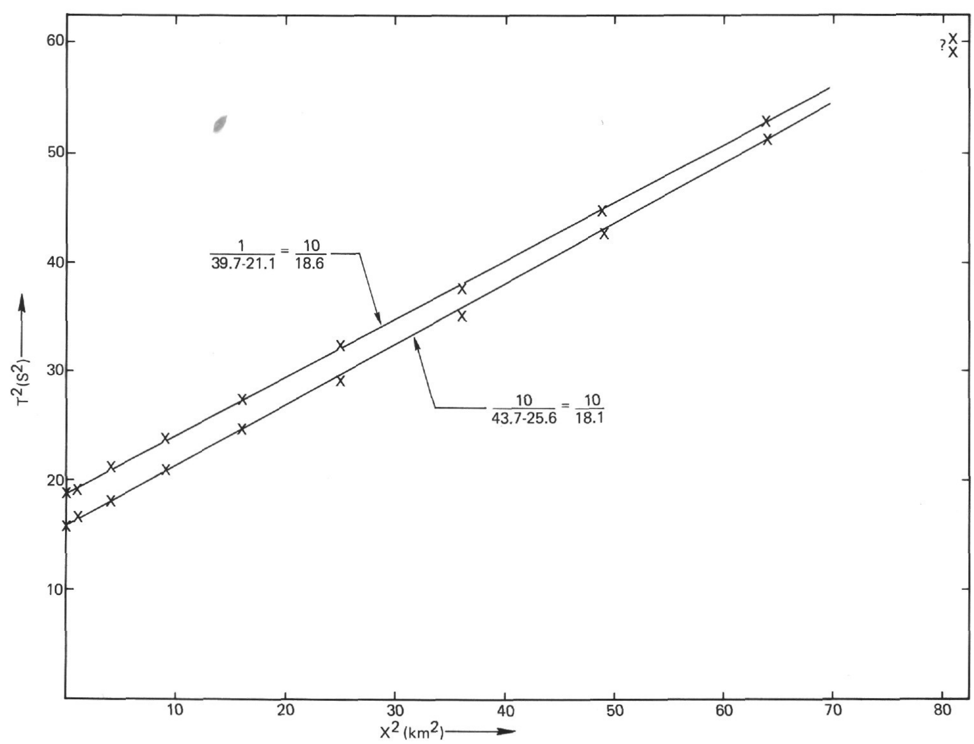


Figure 44. x^2 -T^2 *plot of Hole 410 sonobuoy.*

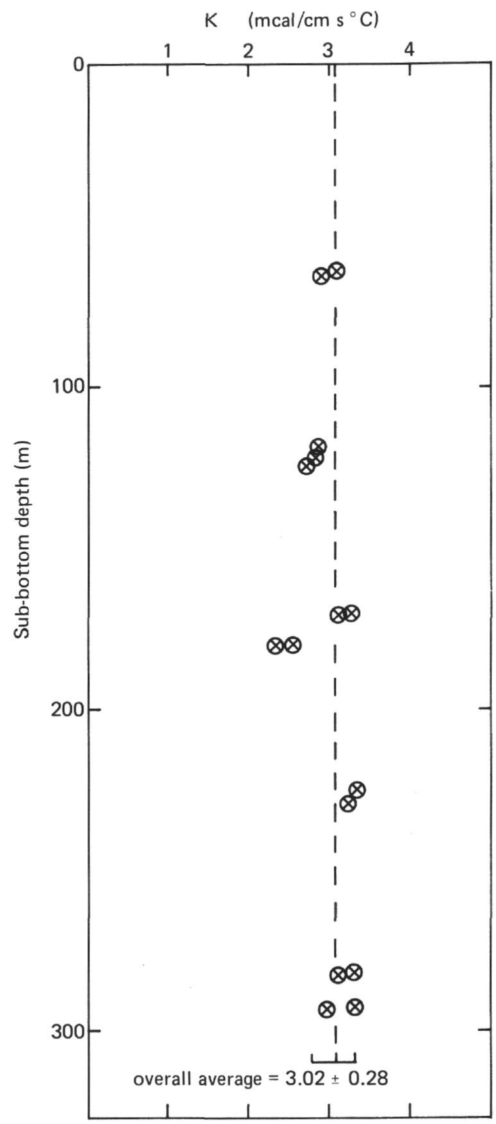


Figure 45. *Variations in thermal conductivity with depth sub-bottom, Hole 410.*

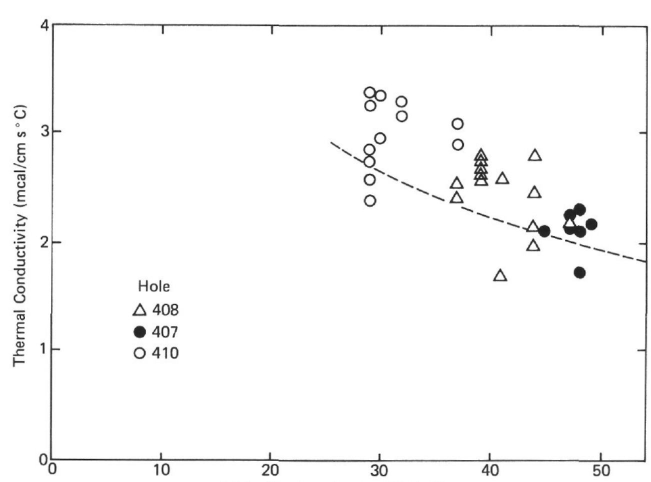


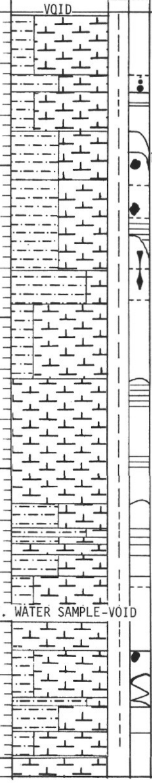
Figure 46. *Relation between thermal conductivity and water content. Broken line is after Ratcliffe (1960).*

SITE 410 **HOLE** **CORE** 1 **CORED INTERVAL:** 0.0-7.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS
PLEISTOCENE	N22/N23 NN20/21	Ag	Ag		1, 2, 3, 4, 5	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / LITHOLOGIC SAMPLE

VOID



INT. WATER SAMPLE-VOID

CC=20 cm

LITHOLOGIC DESCRIPTION

4 very pale brown (10YR 7/3)
70 brown (10YR 5/3)
very pale brown (10YR 7/3)
brown to pale brown (10YR 5/3-6/3)
140 light gray (N7)
6 +
olive gray (5Y 5/2)
gray (5Y 6/1)
light gray (5Y 7/1)
80 greenish gray (5GY 6/1) & light gray (N7)
gray (5Y 5/1)
olive gray (5Y 5/2)
gray (5Y 6/1)
light gray (5Y 7/1) & very light gray (N8)
laminations:
gray (N6),
90 greenish gray (5GY 7/1)
very light gray (N8)
gray (5Y 6/1)
+
light gray (5Y 7/1)
64 olive gray (5Y 5/2)
gray (5Y 6/1)
very light gray (N8)
light gray (5Y 6/1)
light gray (N7)
+
very light gray (N8)
very light gray (N8)
47 greenish gray (5GY 6/1)
gray (5Y 5/1)
80 medium gray (N5)
light gray (5Y 6/1)
light gray (N7)
1
very light gray (N8)

NANNOFOSSIL OOZE interlayered with marly calcareous ooze and some calcareous clay. Glacial(?) erratics at 1-145 cm (hornblende gabbro), 2-45 cm (micritic limestone) and 5-30 cm (anorthosite). Pteropods (Diacria trispinosa) found whole at 1-16 cm and one .50 cm.layer with >10 specimens at 1-80 cm. Pteropod fragments scattered throughout 0-100 cm. Colors are highly variable, ranging from pale brown (upper 132 cm) to grays, olive grays, and very light grays. Mottling and laminations are scattered throughout. Soft, sandy ooze is most common texture.

Smear Slides (Major lithology)

	1-4	3-90	5-47
qtz. & fspr.	2	5	5
H. min.	3		5
volc. glass + palagonite	Tr?		1
zeolite	Tr	1	Tr
unsp. carb.	3	1	20
forams	5	10	5
nannos	60	80	40
diatoms	3	2	Tr
rads	1	1	Tr
silicoflag.	Tr		
sp. spic. + fine spines (silica)	3	1	
clay	20	--	26

Smear Slides (Minor lithology)

	1-70	1-140	4-64
qtz. & fspr.	5	10	
H. min.	4	5	
volc. glass + palagonite	2	3	
zeolite	2	Tr	
unsp. carb.	20	15	
forams	3	5	
nannos	20	35	
diatoms		1	
rads		1	
silicoflag.			
sp. spic. fine spines (silica)	Tr	1	
clay	44	26	
	marly ooze		calc. clay

Carbonate Bomb

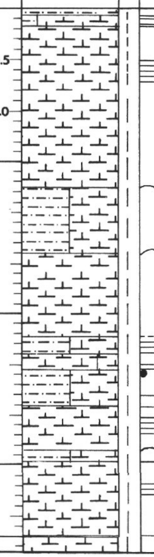
1-99	69%	3-35	87%
1-143	52%	5-47	62%
2-69	39%	5-49	68%
2-87	75%		

Explanatory notes in Chapter 1

SITE 410 **HOLE** **CORE** 2 **CORED INTERVAL:** 7.5-17.0 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS
PLEISTOCENE	N22 NN20	Ag	Ag		1, 2, 3, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / LITHOLOGIC SAMPLE



CC=13 cm

LITHOLOGIC DESCRIPTION

3 gray (5Y 5/1)
10 2.5Y 5/2 & 7/2 mixed
Black (Mn-oxide encrusted) bryazoa
very light gray (N8) with N7 intermixed
15
50 light gray (5Y 6/1) with light gray (5Y 7/1) mottling
mainly very light gray (N8)
5Y 5/2, N6, 5GY 6/1,
34 5Y 7/1 mixed
45 dark gray (5Y 4/1)
gray (N5)
light olive gray (5Y 6/1) to olive gray (5Y 4/1)
light gray (5Y 7/1)
very light gray (N8)
5Y 6/1
very light gray (N8)
47

NANNOFOSSIL OOZE interbedded with marly calcareous ooze and some calcareous clay. Glacial erratic at 56 cm (arkosic sandstone). Laminations and mottles common throughout. Soft, sandy ooze most common texture.

Smear Slides (Major lithology)

	1-10	2-15	4-47
qtz. & fspr.	2		
H. min.			
clay	10		
volc. glass + palagonite			
zeolite	1		
unsp. carb.	5		
forams	10	7	10
nannos	70	90	90
biogenic silica		3	Tr
glauconite	2		

Smear Slides (Minor lithology)

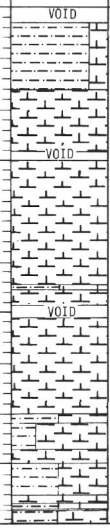
	1-3	2-50	3-45
qtz. & fspr.	25	4	40
H. min.	7	1	8
clay	43	20	10
volc. glass + palagontie			
zeolite			
unsp. carb.	20	3	40
forams	5	7	2
nannos		63	
biogenic silica		2	
glauconite			

Carbonate Bomb

1-9	64%
1-66	89%
2-54	55%
2-50	55%
3-102	97%

SITE 410 **HOLE** **CORE** 3 **CORED INTERVAL:** 17.0-26.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE
PLEISTOCENE	N22 NN19	Ag	Ag		1, 2, 3, CC	0.5, 1.0	VOID, VOID, VOID			50, 70, 70, 121, 18



LITHOLOGIC DESCRIPTION

light olive gray (5Y 6/2)

very light gray (N8)

light gray (5Y 6/1)

light gray (5Y 6/1) over greenish gray (5GY 6/1)

light gray (N7)

very light gray (N8)

light gray (5Y 6/1)

very light gray (N8)

light gray (5Y 6/1)

light gray (5Y 6/1)

NANNOFOSSIL OOZE with interbedded marly calcareous ooze and calcareous clay. Dominantly very light gray, but with light gray to light olive gray units also present. No coarse erratics observed. Soft ooze is dominant texture.

Smear Slides (Major lithology)

	2-70	3-70	3-121
qtz. & fspr.		1	2
H. min.			
clay	3	3	4
volc. glass + palagonite		1	
zeolite			1
unsp. carb.		5	2
forams	10	12	12
nannos	87	80	85
biogenic silica	Tr	3	3
glauconite			1

Smear Slides (Minor lithology)

	1-50	4-18
qtz. & fspr.	13	6
H. min.	4	1
clay	35	5
volc. glass + palagonite	16	
zeolite		
unsp. carb.	5	3
forams	3	12
nannos	20	70
biogenic silica	4	3
glauconite		

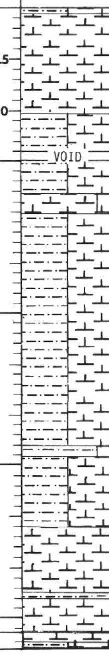
Carbonate Bomb

1-52	29%
1-129	97%
3-38	100%
4-15	69%

Explanatory notes in Chapter 1

SITE 410 **HOLE** **CORE** 4 **CORED INTERVAL:** 26.5-36.0 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE
PLEISTOCENE	N22 NN19	Ag	Ag		1, 2, 3, 4, CC	0.5, 1.0	VOID			70, 45, 70, 80



LITHOLOGIC DESCRIPTION

olive gray (5Y 4/2)

very light gray (N8)

light gray (5Y 7/1)

gray (5Y 6/1)

dark gray (5Y 4/1)

gray (5Y 6/1) & olive gray (5Y 6/2)

olive gray (5Y 4/2-5/2)

light gray (5Y 7/1)

very light gray (N8)

dark gray (5Y 4/1)

CC=15 cm

MARLY NANNOFOSSIL OOZE interbedded with nanno ooze and calcareous clay. Dominantly gray to light gray, soft, sandy ooze, highly disturbed by coring. No glacial erratics (coarse) noted in visual descriptions. Mottled throughout.

Smear Slides	(Major lith.) 3-70*	(Minor lith.) 1-70	2-45	1-80
qtz. & fspr.	3	1	20	1
H. min.	1		3	1
clay		3	40	3
volc. glass + palagontie				
zeolite				
unsp. carb.	5	2	12	
forams	20	5	5	12
nannos	68	83	20	80
biogenic silica	3	5	1	3

*Clay should be ~20-30%, nannos similarly less.

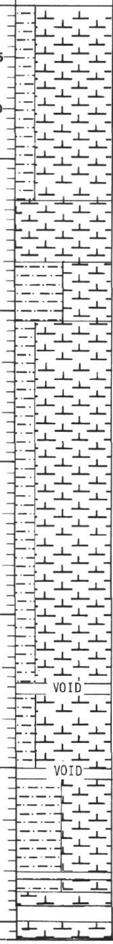
Carbonate Bomb

1-39	94%	3-140	26%
2-45	16%	4-50	55%
3-48	78%		

SITE 410 HOLE CORE 5 CORED INTERVAL: 36.0-45.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	LITHOLOGIC SAMPLE
PLEISTOCENE	N22 NN19				1	34, 70
					2	70
					3	70
					4	70
					5	80
					6	100
		Ag	Ag		CC	

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

very light gray (N8); olive gray (5Y 4/2); light gray (5Y 7/1)

very light gray (N8)

light brownish gray (10YR 6/2)

olive gray (5Y 4/2); very light gray (N8); gray (5Y 6/1)

light gray (5Y 6/1); gray (5Y 5/1); olive gray (5Y 5/2)

olive gray (5Y 5/2)
gray (5Y 6/1)

very light gray (N8)

NANNOFOSSIL OOZE
interbedded with marly nanno ooze and calcareous clay. Highly disturbed core, mainly light gray sandy ooze (soft). Glacial erratics (coarse) at 1-99 cm (basalt) and 4-82 cm (chert).

Smear Slides (Major lithology)

	1-70	2-70	4-70
qtz. & fspr.	4	2	
H. min.	3		
clay	10	5	
zeolite			
unsp. carb.	5	3	4
forams	7	5	10
nannos	70	82	80
biogenic silica		3	6

Smear Slides (Minor lithology)

	6-100	1-34
qtz. & fspr.	10	2
H. min.	2	2
clay	20	50
zeolite		1
unsp. carb.	2	1
forams	5	30
nannos	60	--
biogenic silica	1	3

Carbonate Bomb

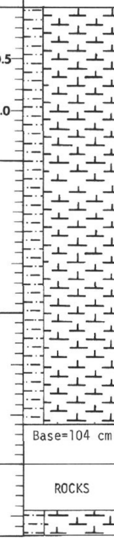
3-71	86%
4-?	70%
5-38	59%
6-88	50%

Explanatory notes in Chapter 1

SITE 410 HOLE CORE 6 CORED INTERVAL: 45.5-55.0 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	LITHOLOGIC SAMPLE
PLEISTOCENE	N22 NN19				1	70
					2	70
					3	70
		Ag	Ag		CC	

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

Highly mixed: very light gray (N8); light gray (N7); gray (5Y 6/1); medium gray (N5)

NANNOFOSSIL OOZE
Highly disturbed core of gray to very light gray nannofossil ooze containing pyritized burrows in Section 2 and erratic pebbles in Sections 2 and CC. Pyrite/foram concretions are also observed in CC. The following lithologies are noted:

1) Fine-grained basalt, not vesicular.
2) Gneiss or altered granite with large crystals of feldspar, hornblende and biotite, encrusted in small regions with pyrite.
3) "Microgabbro", or basic igneous rock with millimeter-size crystals of plagioclase, clinopyroxene and amphibole.
4) Pyrite nodules with planktonic forams in a pyrite (marcasite?) matrix.

Smear Slides

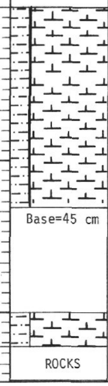
	1-70	2-70	3-70
qtz. & fspr.	5	--	3
H. min.	1	--	
clay	--	5	2
glass + palagonite	1	2	--
glauconite	2	--	--
zeolite	--	--	--
unsp. carb.	3	--	2
forams	7	5	12
nannos	80	85	80
biogenic silica	1	--	1

Carbonate Bomb

1-89	84%
2-41	77%
3-49	77%

SITE 410 HOLE CORE 7 CORED INTERVAL: 55.0-64.5 m

TIME-ROCK UNIT: PLEISTOCENE
BIOSTRAT ZONE: N22 NN19
FOSSIL CHARACTER: FORAMS Ag; NANNOS Ag; RADS
SECTION: 1, 2, CC
METERS: 0.5, 1.0



LITHOLOGIC SAMPLE: 70, 95

LITHOLOGIC DESCRIPTION

Mixed:
very light gray (N8); light gray (N7); gray (5Y 6/1)

streaks of olive (5Y 4/3)

NANNOFOSSIL OOZE
with pyritized burrows and gneiss or altered granite in Core Catcher. Highly disturbed, like previous core.

Smear Slides

	1-70	1-95
qtz. & fspr.	3	2
H. min.	--	1
clay	--	15
glauconite	2	--
zeolite	1	--
forams	6	4
nannos	77	77
unsp. carb.	--	1
biogenic silica	1	--

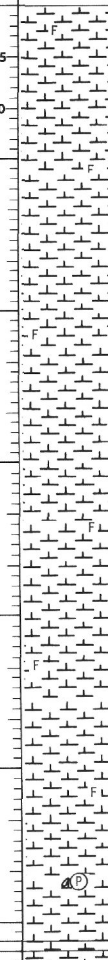
Carbonate Bomb

1-37	84%
2-20	81%

Explanatory notes in Chapter 1

SITE 410 HOLE CORE 8 CORED INTERVAL: 64.5-74.0 m

TIME-ROCK UNIT: PLEISTOCENE
FOSSIL CHARACTER: FORAMS Ag; NANNOS Ag; RADS
SECTION: 1, 2, 3, 4, 5, 6, 7, CC
METERS: 0.5, 1.0



LITHOLOGIC SAMPLE: 70, 70, 70, 70, 70, 55, 6

LITHOLOGIC DESCRIPTION

Extremely deformed mixture of very light gray (N8), gray (5Y 6/1 and 5Y 5/1), grayish green (5G 6/1), pale olive (5Y 6/3)

light olive gray (5Y 6/2), greenish gray (5G 6/1), light gray (N7)

light gray (N7) with mottling of dark gray (N3)

mostly very light gray (N8) to greenish gray (5G 6/1) with mottles of dark gray (N3)

dark gray streaks (N3)
light gray (10YR 7/1) with greenish gray (5GY 6/1) tinge CC=17 cm

FORAMINIFERA-RICH NANNOFOSSIL OOZE
Dominantly gray to light gray, very deformed. Two pyrite-filled burrows in Section 6. Samples mostly nannofossils with some (5-20%) forams. Other components rare (Tr to 3%). Dark gray streaks and wisps of volcanic ash, some greenish gray tint to some layers.

Smear Slides

	1-70	2-70	3-70	4-70
nannos	67	80	80	70
forams	20	10	10	5
diatoms	--	2	--	2
rads	--	1	--	1
sp. spic.	--	2	--	2
qtz. & fspr.	1	1	5	1
H. min.	Tr	1	1	2
clay	10	2	--	10
carb. unsp.	2	--	2	2
zeolite	--	1		--
volc. glass	--	--	2	3
palagonite	--	--	Tr	--

	5-70	6-55	7-6
nannos	90	90	78
forams	5	5	10
diatoms	--	--	--
rads	--	--	--
sp. spic.	2	--	1
qtz. & fspr.	--	Tr	1
H. min.	--	Tr	Tr
clay	--	3	--
carb. unsp.	--	2	--
zeolite	--	--	--
volc. glass	3	--	--
palagonite	--	--	--

Site 410, Core 9, Cored interval: 74.0-83.5 m: NO RECOVERY

SITE 410 HOLE CORE 10 CORED INTERVAL: 83.5-93.0 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	LITHOLOGIC SAMPLE
PLEISTOCENE	NN19	Ag	Ag		1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0	23, 52, 120, 13, 59

LITHOLOGIC DESCRIPTION

Entire core a mixture of intermixed irregular lumps of very light gray (N8), light gray (N7), dark greenish gray (5GY 4/1), light olive gray (5Y 6/1), yellowish gray (5Y 8/1) with scattered wisps and clots of dark gray (N3, N2)

NANNOFOSSIL OOZE
Dominantly light gray, highly deformed core. Darker gray clumps appear finer grained than light gray areas (possible disturbed turbidite sequences?). Pyrite-filled burrow at 1-55, anorthosite pebble at 5-77. Lithology quite uniformly nannofossils with very small amounts other components except for dark clot at 4-13 (see smear slide below).

Smear Slides (Major lithology)

	1-23	2-52	3-120	5-59
nannos	90	90	85	90
forams	1	5	3	3
qtz. & fspr.	5	2	7	2
H. min.	Tr	--	Tr	Tr
carb. unsp.	2	2	2	3
sp. spic.	Tr	--	--	--
volc. glass	2	Tr	3	1
clay	--	--	--	1
zeolite				
glauconite				

Smear Slides (Minor lithology)

	4-13
nannos	5
forams	2
qtz. & fspr.	60
H. min.	5
carb. unsp.	--
sp. spic.	--
volc. glass	5
clay	22
zeolite	Tr
glauconite	1

Explanatory notes in Chapter 1

SITE 410 HOLE CORE 11 CORED INTERVAL: 93.0-102.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	LITHOLOGIC SAMPLE
?PLIOCENE-PLEISTOCENE	N21? NN19	Ag	Ag		1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0	53, 79, 17, 4, 9

LITHOLOGIC DESCRIPTION

Mostly very light gray (N8) with clumps of light gray (5Y 6/1 and 5Y 7/2), dark gray (N3), medium gray (N5), greenish gray (5GY 6/1)

NANNOFOSSIL OOZE
Mostly light gray, very deformed core. Lighter gray portions coarser grained with more forams, darker gray finer grained, possibly indication of disturbed turbidite? sequences. Except for radiolarian-rich portion of section one, core is uniformly nannofossil ooze, with small amounts (<5%) other constituents.

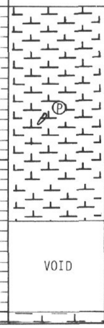
Smear Slides (Minor lithology)

	1-53	3-79	5-17	7-4	7-9	CC
nannos	63	90	88	88	85	89
forams	7	5	5	5	10	5
rads	20	--	Tr	--	--	--
diatoms	1	--	--	--	--	--
sp. spic.	1	--	Tr	--	1	--
qtz. & fspr.	Tr	3	1	5	1	1
carb. unsp.	2	1	3	2	3	2
clay	5	--	--	--	--	--
silicoflag.	1	--	Tr	--	--	--
volc. glass	Tr	--	1	--	Tr	3
H. min.	--	1	1	Tr	--	Tr

Site 410, Core 12, Cored interval: 102.5-112.0 m: NO RECOVERY

light gray (5Y 6/1), very light gray (N8) with dark gray (N3), greenish gray (5GY 6/1) at bottom

SITE 410 HOLE CORE 13 CORED INTERVAL: 112.0-121.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	GRAPHIC LITHOLOGY	LITHOLOGIC DESCRIPTION
PLIOCENE	N21 NN18	Ag	Ag		1, 2, CC	0.5, 1.0	 VOID	Light gray with scattered wisps of dark gray (N3)

NANNOFOSSIL OOZE
Light gray, extremely deformed ooze one pyrite-filled burrow at 1-105.

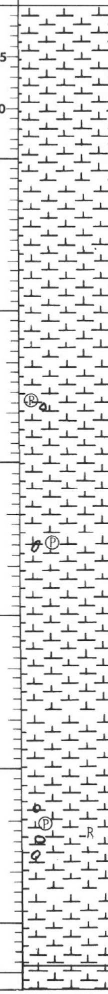
Smear Slides

	2-29
nannos	90 (some discoasters)
forams	3
carb. unsp.	2
volc. glass	5

CC=10 cm

Explanatory notes in Chapter 1

SITE 410 HOLE CORE 14 CORED INTERVAL: 121.5-131.0 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	GRAPHIC LITHOLOGY	LITHOLOGIC SAMPLE
PLIOCENE	N21 NN18	Ag	Ag		1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0		63, 59, 22, 107, 137, 116, 145, 5, 44

LITHOLOGIC DESCRIPTION

very light gray (N8) with patches of light gray (5Y 6/1)

light gray (N7)

intermixed light gray (N7 and 5Y 6/1), greenish gray (5GY 6/1), rare streaks of brownish black (5YR 2/1)

mottling of very light gray (N8), light gray (5Y 6/1), medium dark gray (N4), greenish gray (5GY 6/1), very dusky purple (5P 2/2)

very light gray (N8) with streaks of very dusky purple (5P 2/2) and very dark red purple (5RP 2/2) at 6-143 greenish gray (5GY 6/1) and light gray (5Y 6/1) 134-143

greenish gray (5G 6/1), dark greenish gray (5GY 6/1), light gray (N7) olive gray (5Y 5/2), gray (5Y 6/1), dusky purple (5P 2/2)

NANNOFOSSIL OOZE
Dominantly light gray, mostly highly deformed core. Except for siliceous sample 6-116 (see smear slides) all samples 80-90 percent nannofossils, few forams and other components (<5%). Pyrite pebbles (up to 3 cm long) and many small (sand-size) probable pyrite grains scattered throughout (esp. Section 4); these are probable burrow fillings. Possible burrow mottling in lower, less disturbed part of core.

Smear Slides (Major lithology)

	1-63	3-59	4-22	4-107
nannos	90	82	95	90
forams	3	6	2	2
carb. unsp.	2	2	1	2
rads	--	--	--	2
diatoms	--	--	--	--
sp. spic.	--	--	--	Tr
qtz. & fspr.	4	2	1	3
H. min.	--	1	1	--
volc. glass	1	4	--	1
glauconite	--	Tr	--	--
palagonite				
silicoflag.				

	5-137	6-145	7-44	(Minor lith.) 6-116
nannos	90	88	90	64
forams	3	5	3	10
carb. unsp.	2	3	3	3
rads	1	--	--	15
diatoms	--	--	--	1
sp. spic.	--	1	--	1
qtz. & fspr.	3	1	2	2
H. min.	1	1	Tr	1
volc. glass	--	1	2	2
glauconite	--	--	--	--
palagonite			Tr	--
silicoflag.				1

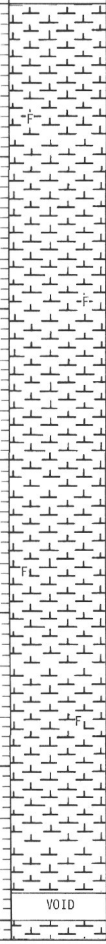
CC=21 cm

SITE 410 HOLE CORE 15 CORED INTERVAL: 131.0-140.5 m

TIME-ROCK UNIT: PLIOCENE
BIOSTRAT ZONE: N21 NN18
FOSSIL CHARACTER: FORAMS Ag; NANNOS Ag; RADS

SECTION: 1, 2, 3, 4, 5, 6, CC
METERS: 0.5, 1.0

GRAPHIC LITHOLOGY:



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / LITHOLOGIC SAMPLE

LITHOLOGIC DESCRIPTION

6-11 greenish gray (5GY 6/1)

very light gray (N8) and light gray (N7)

very light gray (N8) and light gray (N7) with wisps of very dusky purple (5P 2/2), greenish gray (5GY 6/1), light olive brown (2.5Y 5/4), light gray (5Y 6/1) scattered throughout

CC=20 cm lt. gray (5Y 6/1)

FORAMINIFERA-RICH NANNOFOSSIL OOZE
Dominantly light gray, highly deformed, mostly nannofossil ooze with 5-15% foraminifera. Darker smeared laminations scattered trhoughout, probable volcanic ash layers.

Smear Slides

	1-80.5	3-17	5-96
nannos	90	83	79
forams	5	10	15
carb. unsp.	2	5	5
qtz. & fspr.	3	2	1
volc. glass	Tr	--	Tr
palagonite			Tr
H. min.			Tr

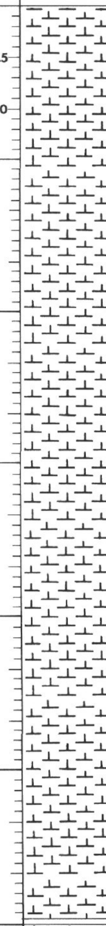
Explanatory notes in Chapter 1

SITE 410 HOLE CORE 16 CORED INTERVAL: 140.5-150.0 m

TIME-ROCK UNIT: PLIOCENE
BIOSTRAT ZONE: N19 NN16/17
FOSSIL CHARACTER: FORAMS Ag; NANNOS Ag; RADS

SECTION: 1, 2, 3, 4, 5, 6, CC
METERS: 0.5, 1.0

GRAPHIC LITHOLOGY:



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / LITHOLOGIC SAMPLE: 65, 80, 70, 72

LITHOLOGIC DESCRIPTION

light gray (N7) and very light gray (N8) mixed

NANNOFOSSIL OOZE
Highly disturbed core of light gray nannofossil ooze with up to 10% forams.

Smear Slides

	1-65	3-70	5-72
H. min.*	Tr	3	3
clay	3	5	3
zeolite	Tr	Tr	Tr
forams	3	10	3
nannos	94	82	91
silic. micro.	Tr	Tr	--

*Note: "Heavy minerals" are opaques and colored mineral grains in fine silt-size range, and may be fine pyrite grains which are seen under the binocular scope in gray streaks in several cores.

Site 410, Core 17, Cored interval: 150.0-159.5 m: NO RECOVERY

SITE 410 HOLE CORE 18 CORED INTERVAL: 159.5-169.0 m

TIME-ROCK UNIT | BIOSTRAT ZONE | FOSSIL CHARACTER (FORAMS, NANNOS, RADS) | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | LITHOLOGIC SAMPLE | LITHOLOGIC DESCRIPTION

Time-rock unit: late MIOCENE / early PLIOCENE

Biostrat zone: N19, NN11

Fossil character: Forams Ag, Nannos Ag

Sections: 1, 2, 3, 4, 5, CC (meters 0.5, 1.0)

Lithologic samples: 70 (Sections 1–5)

light gray (N7) and very light gray (N8) with gray (N5) streaks

NANNOFOSSIL OOZE

Soft, disturbed light gray nannofossil ooze with pyritized burrow fillings up to 3 cm long scattered throughout. Forams up to about 10%. Section 5 lacks obvious burrow fills, but has streaks of dark gray which is finely crystalline pyrite.

Smear Slides

	1-70	3-70	5-70
H. min.	3	3	2
clay	Tr	3	5
zeolite	Tr	--	Tr
forams	7	3	3
nannos	90	91	90
silic. micro.	Tr	Tr	Tr

Explanatory notes in Chapter 1

SITE 410 HOLE CORE 19 CORED INTERVAL: 169.0-178.5 m

TIME-ROCK UNIT | BIOSTRAT ZONE | FOSSIL CHARACTER (FORAMS, NANNOS, RADS) | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | LITHOLOGIC SAMPLE | LITHOLOGIC DESCRIPTION

Time-rock unit: late MIOCENE / early PLIOCENE

Biostrat zone: N19, NN11

Fossil character: Forams Ag, Nannos Ag

Sections: 1, 2, 3, 4, 5, 6, 7, CC (meters 0.5, 1.0)

Lithologic samples: 70 (Sections 1–6)

light gray (N7) and very light gray (N8)

very light gray (N8) with dark gray (N4) mottling and faint greenish gray (5G 6/1) laminations

22 cm Sect. 7
CC=12 cm

NANNOFOSSIL OOZE

Very light gray, firm nannofossil ooze with grayish mottles and streaks (fine-grained pyrite or marcasite). Two pyritized burrows seen on split surface. Upper 69 cm of Section 1 is soft and highly disturbed as in Core 18; remainder is only moderately deformed and considerably firmer.

Smear Slides

	2-70	3-70	5-70
H. min.	5	10	3
clay	--	4	3
zeolite	Tr	1	Tr
forams	2	5	3
nannos	92	80	91
unsp. carb.	1	Tr	Tr
silic. micro.	Tr	--	

SITE 410 HOLE CORE 20 CORED INTERVAL: 178.5-188.0 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	LITHOLOGIC SAMPLE		LITHOLOGIC DESCRIPTION
late MIOCENE / early PLIOCENE	N19 NN11	Ag	Ag		1	0.5, 1.0	70	very light gray (N7) and light gray (N8) mixed	NANNOFOSSIL OOZE
					2		70		
					3				
					CC				

NANNOFOSSIL OOZE

Soft, very light gray nannofossil ooze with dark gray mottling and streaks in Section 3. Very badly disturbed. Four pyridized burrows in Core Catcher (apparently two, each broken, originally).

Smear Slides

	1-70
H. min.	3
clay	5
zeolite	Tr
forams	3
nannos	89
unsp. carb.	Tr

Explanatory notes in Chapter 1

SITE 410 HOLE CORE 21 CORED INTERVAL: 188.0-197.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	LITHOLOGIC SAMPLE		LITHOLOGIC DESCRIPTION
late MIOCENE / early PLIOCENE	N19 NN11	Ag	Ag		1	0.5, 1.0	70	light gray (N7) to very light gray (N8)	NANNOFOSSIL OOZE
					2		70		
					3		70		
					4		70	very light gray (N8) with mottling of dark gray (N4) to gray (N5)	
					5		70		
					6		70		
					7			CC=15 cm	
					CC				

NANNOFOSSIL OOZE

Very light gray nannofossil ooze throughout, with one pyritized burrow at 5 cm (Section 1). Soft and disturbed from top to 3-30 cm; firmer below with gray streaks and mottles (fine-grained pyrite). Faint pale green and gray laminations in Sections 4-7.

Smear Slides

	1-70	3-70	5-70
total detrital (mainly clay-size)	5	8	5
forams	2	5	2
nannos	93	86	92
unsp. carb.	Tr	Tr	Tr
zeolite	Tr	1	1
biogenic silica		Tr	

Carbonate Bomb

1-60	100%
3-91	100%
4-80	100%
5-80	100%
6-80	97%
7-19	100%

SITE 410 HOLE CORE 22 CORED INTERVAL: 197.5-207.0 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	LITHOLOGIC SAMPLE
late MIOCENE / early PLIOCENE	N14 NN11	Ag	Ag		1	0.5, 1.0	70
					2		70
					3		70
					4		70
					5		70
					6		70
					7		
					CC		CC=20 cm

LITHOLOGIC DESCRIPTION

light gray (N7) to very light gray (N8) with mottling of dark gray (N4)

NANNOFOSSIL OOZE

Light gray to very light gray nannofossil ooze, badly disturbed to 5-120 cm; somewhat less so below. Three pyritized burrows observed, the largest approx. 2x2x6 cm with large crystals identified as marcasite on habit (rhombohedral). Smears and mottles of gray (fine-grained pyrite) are common from Section 4 to the base.

marcasite burrow cast (6-35 cm)

Smear Slides

	2-70	4-70	6-70
total detrital (mainly clay-sized)	8	8	4
forams	2	2	3
nannos	90	90	92
unsp. carb.	Tr	Tr	Tr
zeolite	Tr	Tr	1
biogenic silica			Tr

Explanatory notes in Chapter 1

SITE 410 HOLE CORE 23 CORED INTERVAL: 207.0-216.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	LITHOLOGIC SAMPLE
late MIOCENE / early PLIOCENE	N18-N19 NN11	Ag	Ag		1	0.5, 1.0	70
					2		70
					3		70
					4		70
					5		70
					6		45
					CC		CC=20 cm

LITHOLOGIC DESCRIPTION

light gray (N7) to very light gray (N8)

few streaks of gray (N5) in Section 5

NANNOFOSSIL OOZE

Light gray to very light gray nannofossil ooze with occasional pyrite/marcasite concretions and streaks. One nodule in Section 3 is flat and contains forams, some altered to pyrite (internal molds), some perfectly preserved. The upper 3 sections are entirely homogenized by drilling - slightly firm ooze is found only in Section 6 and Core Catcher. The Core Catcher contains several nodules (burrow fills).

Smear Slides

	1-70	3-70	5-70
total detrital (mainly clay-sized)	5	7	4
forams	3	3	2
nannos	92	89	93
unsp. carb.	Tr	Tr	1
zeolite	Tr	1	Tr
biogenic silica		Tr	

SITE 410 HOLE CORE 24 CORED INTERVAL: 216.5-226.0 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	LITHOLOGIC SAMPLE
late MIOCENE	N17 NN11				1	0.5, 1.0	70
					2		70
					3		70
					4		70
					5		70
					6		70
		Ag	Ag		7		
					CC		CC=20 cm

LITHOLOGIC DESCRIPTION

light gray (N7) to very light gray (N8)

NANNOFOSSIL OOZE

Very light gray to light gray nannofossil ooze ranging from very soft at top to nearly chalk in Sections 4-7. Pyrite streaks and mottles plus occasional small burrow fills from top to upper Section 5. Burrows in Section 4 show fine structure nearly undisturbed-homogeneity of this ooze otherwise makes determining degree of deformation difficult. A few very faint laminations (few mm thick) are seen in Section 5.

2 cm

burrow at 4-75 cm

Smear Slides

	1-70	3-70	5-70
total detrital (mainly clay-sized)	4	11	12
forams	3	1	3
nannos	93	88	85
unsp. carb.	Tr	Tr	Tr
zeolite	Tr	Tr	Tr
biogenic silica			

Explanatory notes in Chapter 1

SITE 410 HOLE CORE 25 CORED INTERVAL: 226.0-235.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	LITHOLOGIC SAMPLE
late MIOCENE	NN11				1	0.5, 1.0	70
					2		62
					3		
					4		
					5		55, 92
					6		
		Ag	Ag		7		
					CC		CC=15 cm

LITHOLOGIC DESCRIPTION

very light gray (N8) with rare streaks of gray (N4) or dark gray (N3)

greenish gray laminae (5G 6/1)

NANNOFOSSIL OOZE

Highly to moderately deformed in Sections 1-4, undeformed in 5-7. Uniformly nannofossils with 2-5% discoasters. Thin greenish gray laminae in Section 5 contain partially glauconized foraminifer. Small (2 cm long) pyrite-filled burrow at 6-139.

Smear Slides	(Major lithology) 1-70	3-62	5-92	(Minor lith.) 5-55
nannos	92	93	93	87
forams	5	3	3	8
carb. unsp.	1	2	2	2
qtz.	2	1	2	1
H. min.	--	1	Tr	1
volc. glass	--	--	--	1
glauconite	--	--	--	Tr

SITE 410 HOLE CORE 26 CORED INTERVAL: 235.5-245.0 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	GRAPHIC LITHOLOGY	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
late MIOCENE	N17 NN11	Ag	Ag		1, 2, 3, CC	0.5, 1.0	VOID	30, 52	very light gray (N8); CC=20 cm

NANNOFOSSIL OOZE

Mostly light gray soft ooze with some thin chalk horizons. Nannofossils predominate, few forams and other components (<5%). Limestone nodule (6x3 cm) at 1-55 to 1-60, fossil hash of pelecypod, crinoid fragments with some foraminifera, ostracods, matrix micrite. Possible brachiopods.

Smear Slides

	1-30	3-52
nannos	90	93
forams	5	3
carb. unsp.	3	3
qtz.	2	1
fspr.	--	
H. min.	Tr	--
sp. spic.	--	Tr

SITE 410 HOLE CORE 27 CORED INTERVAL: 245.0-254.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	GRAPHIC LITHOLOGY	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
late MIOCENE	N17 NN11	Ag	Ag		1, 2, 3, CC	0.5, 1.0	P	52, 143, 78	very light gray with much mottling of light gray (5Y 6/1), and greenish gray (5GY 5/1), and dusky purple (5P 2/2); CC=25 cm

NANNOFOSSIL CHALK

Predominantly light gray, nannofossils more than 90 percent, few (<5%) forams, carb. unspecified. Much burrow mottling, *Zoophycos* burrows in Section 2, 103-127. Pyrite filled burrow (1 cm diameter) in Section 1 (80 cm), shows geopetal structure. Grayish green cross-laminae in Section 2. Small sand-size patches may be *Helminthoida?*

Smear Slides

	1-52	2-143	3-78
nannos	94	90	91
forams	3	5	5
carb. unsp.	2	2	2
qtz. fspr.	1	1	1
H. min.	Tr	--	--
volc. glass	--	--	1

Explanatory notes in Chapter 1

SITE 410 HOLE CORE 28 CORED INTERVAL: 254.5-264.0 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	GRAPHIC LITHOLOGY	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
late MIOCENE	N17 NN11	Ag	Ag		1, 2, 3, 4, 5, 6, CC	0.5, 1.0	VOID	80, 26, 90	very light gray (N8) with soft light gray (N7) patches; black (N1) lamination; CC=12 cm

NANNOFOSSIL CHALK

Light gray, mostly firm chalk with several thin ooze laminations denoted by lines on sed. struct. column. These patches may be drilling disturbances between chalk sections. One thin lamination with 40 percent pyrite sand in Section 3 (90 cm). Much vertical as well as horizontal (*Zoophycos?*) and very small sand-size patches (*Helminthoida?*).

Smear Slides

	Major lith. 1-80	Major lith. 3-27	Minor lith. 3-89
nannos	90	88	54
forams	5	5	3
carb. unsp.	2	4	2
volc. glass	1	2	--
qtz. fspr.	1	2	1
H. min.		Tr	--
pyrite			40

SITE 410 **HOLE** **CORE** 29 **CORED INTERVAL:** 264.0-273.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	SECTION	METERS	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
late MIOCENE	N17 NN11	Ag	Ag		1, 2, 3, 4, CC	0.5, 1.0	100, 10, 22	see below

very light gray (N8) with mottles and inter-laminations, disturbed zones which are light gray (N7)

NANNOFOSSIL CHALK
Light gray with slightly darker mottling and deformed areas. Pyrite burrow-filling at 1-55, Zoophycos(?) in places, possibly Helminthoida burrowing. ALternating zones of firm chalk and intensely deformed ooze. Predominantly nannofossils (85-95%), few forams, others (<5%). Black spot (1 mm diameter) at 2-123 (see smear slides).

Smear Slides (Major Lithology)

	1-100	3-10	5-22
nannos	95	90	86
forams	3	3	5
carb. unsp.	1	5	7
qtz. fspr.	1	1	2
H. min.	Tr	Tr	Tr
volc. glass	--	Tr	--
zeolite	--	1	--

Smear Slides (Minor lithology)

	2-123
nannos	82
forams	12
carb. unsp.	3
qtz. fspr.	Tr
H. min.	3 (opaque silt)
volc. glass	
zeolite	

CC=22 cm

Explanatory notes in Chapter 1

SITE 410 **HOLE** **CORE** 30 **CORED INTERVAL:** 273.5-283.0 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	SECTION	METERS	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
late MIOCENE	N17 NN11	Ag	Ag		1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0	25, 60, 78	see below

very light gray (N8) with mottles and laminations of light gray (N7)

NANNOFOSSIL CHALK
Very light to light gray, chalk pieces vary from 10-30 cm in length, separated by intensely deformed ooze. Laminations seen are probably deformed ooze squeezed between chalk pieces during drilling. Samples almost wholly nannofossils.

Smear Slides

	1-24	3-61	5-77	7-7
nannos	91	93	91	88
forams	5	3	2	5
carb. unsp.	2	2	5	5
qtz.			2	
fspr.	2	1		2
H. min.		Tr		
volc. glass		Tr		
sp. spic.			Tr	

CC=5 cm

SITE 410 **HOLE** **CORE** 31 **CORED INTERVAL:** 283.0-292.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
late MIOCENE	N17 NN11	Ag	Ag		1, 2, 3, 4, CC	0.5, 1.0	VOID	(undeformed)		70, 70, 70, 40	very light gray (N8) with gray (N5) to light gray (N7) mottles and laminations; CC=20 cm

NANNOFOSSIL CHALK

Firm nannofossil chalk with gray laminations (opaques) and *Zoophycos* burrows in lower sections. Slightly sandy, very light gray, undeformed except top section. Pyritized burrow fill in Section 3. Slight burrowing throughout.

Smear Slides	(Major lith.) 1-70	2-70	3-70	(Minor lith. dark laminations) 4-40
forams	5	5	4	3
nannos	95	93	92	90
unsp. carb.			2	5
opaques				Tr
zeolite		1	1	1
qtz.		1	1	1

SITE 410 **HOLE** **CORE** 32 **CORED INTERVAL:** 292.5-302.0 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
late MIOCENE	N17 NN11	Ag	Ag		1, 2, 3, CC	0.5, 1.0				70, 70, 139	light gray (N7) to very light gray (N8) with greenish gray (5G 6/1) and gray (N5) laminations; very light gray (N8); CC=20 cm

NANNOFOSSIL CHALK

Firm very light gray nannofossil chalk with several pyritized burrows, gray and grayish green fine laminations and groups of laminations (1-2 mm each) and burrow mottles. Much softer in upper 50 cm of Section 1, probably due to drilling.

Smear Slides (Major lithology)	1-70	2-70
nannos	92	91
forams	5	5
H. min.		
zeolite	1	1
qtz.		1
sp. spic.	1	1
unsp. carb.	1	1

Smear Slides (Minor lithology, green laminations)	3-139
nannos	92
forams	4
H. min.	1
zeolite	2
qtz.	1
sp. spic.	
unsp. carb.	

Explanatory notes in Chapter 1

SITE 410 **HOLE** **CORE** 33 **CORED INTERVAL:** 302.0-311.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
late MIOCENE	N17 NN11	Ag	Ag		1, CC	0.5, 1.0				70, 81, 40	light gray (N7) to very light gray (N8) with light gray (N6) laminations

NANNOFOSSIL CHALK

Firm nannofossil chalk with a zone (Section 1, 60-85 cm) of numerous fine laminations and burrowing. One good *Zoophycos* burrow. Zeolites up to ~3% in silt laminae. Fine-grained pyrite scattered throughout as small mottles.

Zoophycos burrow

Smear Slides (Major lithology)	1-70	2-40
clay	--	--
zeolite	1	1
unsp. carb.	2	2
forams	5	7
nannos	92	90

Smear Slides (Minor lithology-silt laminations)	1-81
clay	1
zeolite	3
unsp. carb.	1
forams	5
nannos	90

SITE 410 **HOLE** **CORE** 34 **CORED INTERVAL:** 311.5-321.0 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
late MIOCENE	N17 NN9-NN11	Ag	Ag		1, 2, CC	0.5, 1.0	VOID			70, 70	white (2.5Y 8/2) to pale yellow (2.5Y 8/3); CC=18 cm

NANNOFOSSIL CHALK

Pale yellow nannofossil chalk showing signs of secondary oxidation. Burrow fill at 1-78 cm (1x1x3 cm) is stained with iron-oxide (rusty brown) and most of discoasters present in cores above are missing in this core. Light gray mottling is present in the upper 70 cm of Section 1 and in Section 2, 20-65 cm. Firm. Some nannofossils appear partially recrystallized.

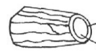
Smear Slides	1-70	2-70
limonite	2	1
zeolite	2	2
forams	6	7
nannos	90	88
qtz.		1
unsp. carb.		1

SITE 410 HOLE CORE 35 CORED INTERVAL: 321.0-330.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
late MIOCENE	N17 NN9-NN11	Ag	Ag		1, 2, 3, 7, CC	0.5, 1.0				70, 70, 70	white (2.5Y 8/2) to pale yellow (2.5Y 8/3); CC=20 cm

NANNOFOSSIL CHALK
Firm, pale yellow nannofossil chalk grading towards firm ooze with chalk interbedded in Sections 3 and 4. Oxidized burrow fills present in Sections 1 and 2.

Oxidized burrow fill?



Smear Slides

	1-70	2-70	3-70
limonite	T	T	T
zeolite	2	2	1
unsp. carb.	1	2	2
forams	7	6	6
nannos	88	88	90
volc. glass	1(?)	1(?)	

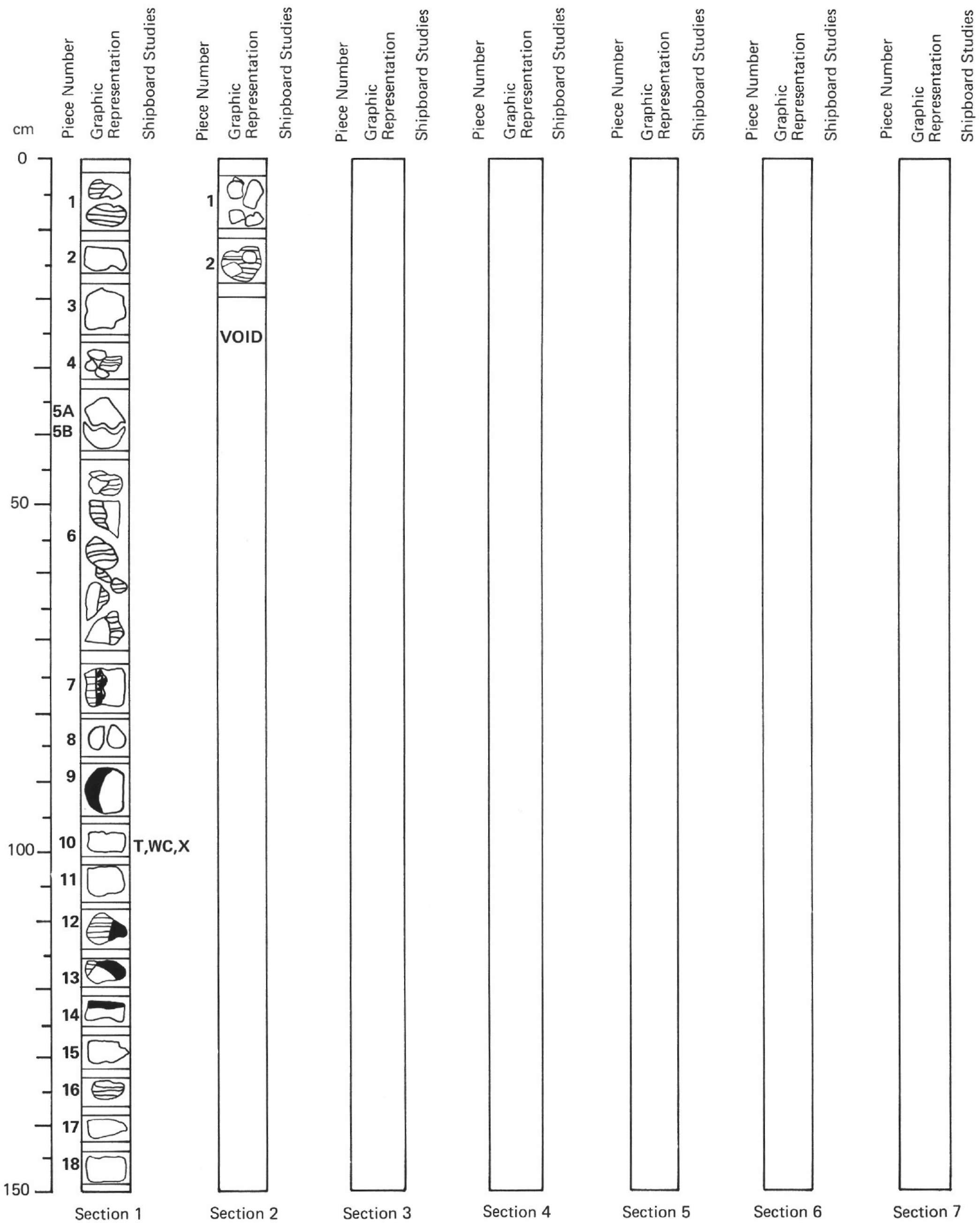
SITE 410 HOLE CORE 36 CORED INTERVAL: 330.5-340.0 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FORAMS	NANNOS	RADS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
late MIOCENE	N16 NN9-NN11	Cg Cm	Ag		1, 2, 3, CC	0.5, 1.0	VOID			70, 70, 40, 5	white (10YR 8/2) to pale yellow (10YR 8/3); sand 2.5Y 4/4

NANNOFOSSIL OOZE
Pale yellow nannofossil ooze, highly disturbed in upper 2 sections (soupy). Basaltic sand grains and gravel scattered through. Two thin (5-10 cm) sand layers in Core Catcher, composed primarily of subangular basalt fragments, iron-oxide and calcite (medium sand, well sorted). Possibly slight grading in sand layers. One serpentine pebble was found in the core liner above the cut with other basalt and carbonate sand grains.

Explanatory notes in Chapter 1

LEG **49** SITE **410** HOLE CORE **37** DEPTH **340.0-349.5 m**



Original basalt recovery was 1.0 meters. Styrofoam spacers make the length shown here greater than the amount recovered.

Mixed basaltic breccia and vesicular fine-grained aphyric basalt.

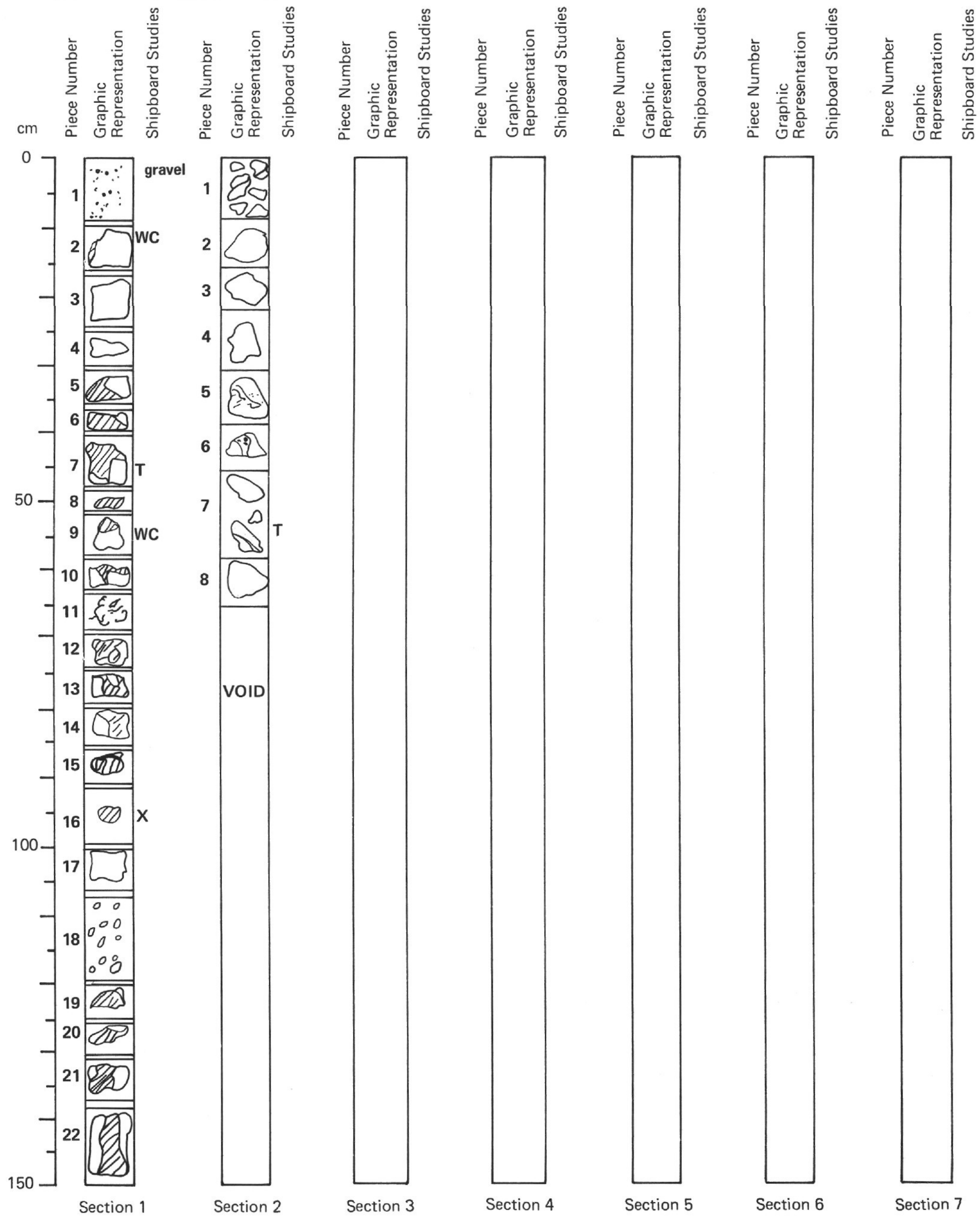
Breccia: clasts of red-brown palagonitized glass and vesicular aphyric basalt in a matrix of lithified carbonate-rich clay (nanno ooze?).

Basalt: vesicles uneven distribution, maximum 10-15%, 0.5-3.0 mm, some partially filled with zeolites; local glass selvages.

Petrography: texture variolitic to glassy (vitrophyric) with <10% crystals fresh olivine, plagioclase and minor clinopyroxene (some resorption). Trace sub-ophitic. Plagioclase An_{55-60}. Opaque microlites in glass. Microphenocrysts occasionally in clots. Glass fresh or altered to smectite and minor palagonite.

Limestone is foraminiferal biomicrite with some pelleted areas.

LEG 49 SITE 410 HOLE CORE 38 DEPTH 349.5-359.0 m



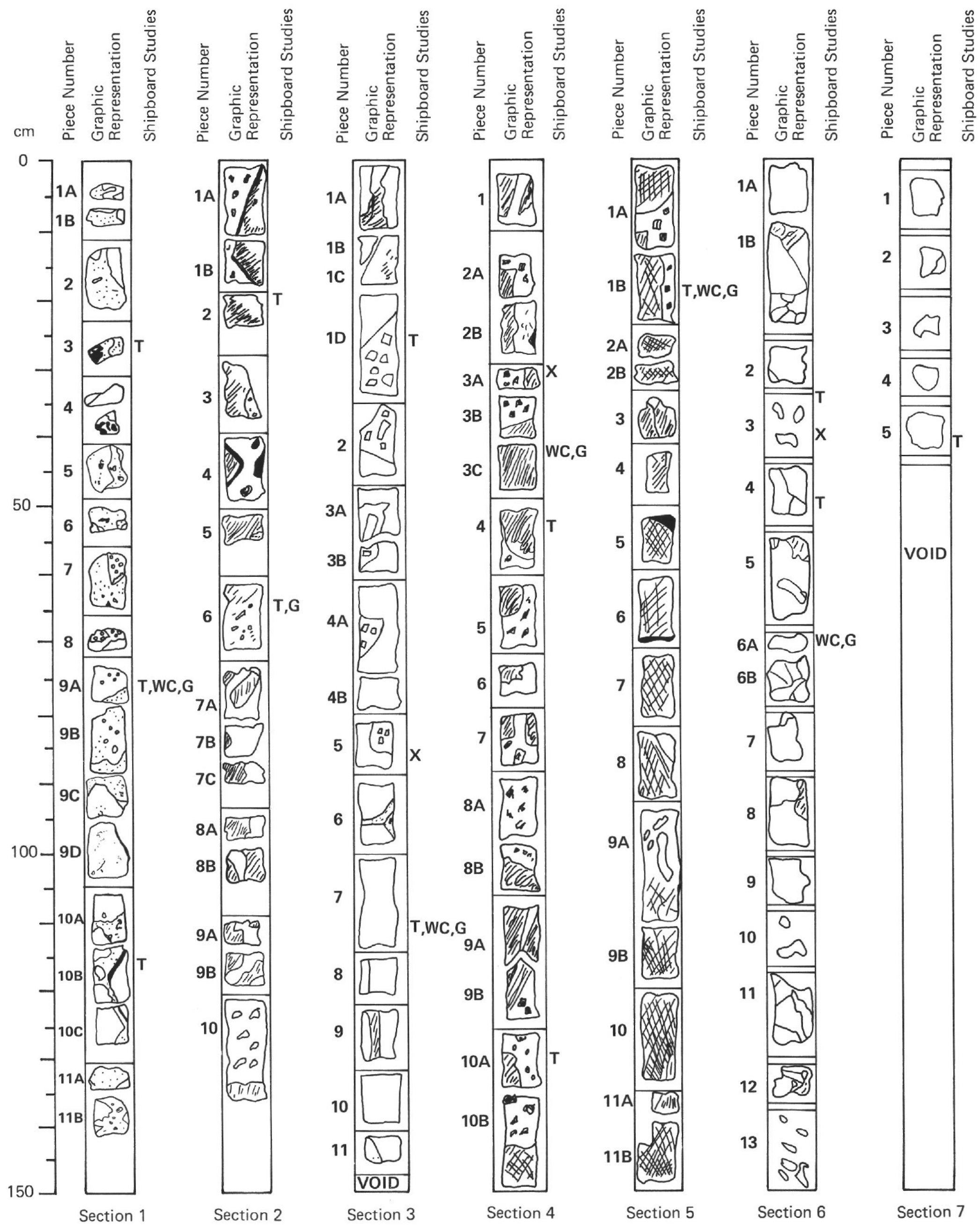
Original basalt recovery was 1.50 meters. Styrofoam spacers make the length shown here greater than the amount recovered.

Limestone basalt breccia (basalt clasts in limestone matrix). Glass selvages present but rare, most basalt-limestone contacts not chilled. Probably represents cold basalt talus deposit. Basalt clasts: fine-grained, aphyric and vesicular, vesicles maximum 10%, partially filled with calcite and zeolites(?). Variolitic texture evident. Many small palagonitized glass fragments in the limestone.

Petrography texture: glassy (vitrophyric) microphenocrysts olivine (fresh and altered), plagioclase (An_{70}) and lesser clinopyroxene total .50-5%. Glomeroporphyric costs of plagioclase and olivine glass highly altered. Abundant carbonate in groundmass.

Limestone-foraminiferal biomicrite, some pellets.

LEG **49** SITE **410** HOLE CORE **39** DEPTH **359.0-368.5 m**



Original basalt recovery was 6.70 meters. Styrofoam spacers make the length shown here greater than the amount recovered.

Basalt and Basaltic Breccia: top of core almost 100% cobbles of basaltic breccia. This grades gradually downward to a mix of 90% basalt and 10% breccia at base of core.

Basalt: very fine-grained aphyric variolitic vesicular basalt (aphanitic in Section 5). Plagioclase and olivine (fresh) microphenocrysts in Sections 5-7). Glass selvages uncommon. Vesicles vary 5-20%, to 10 mm. Partially or entirely filled with calcite zeolites and palagonitized glass (Section 7). Two populations vesicules (Sections 6-7). Rare pipe vesicles to 4 cm (Sections 1 and 5). Trace amounts orange Fe-oxides(?) top of core increases to 40% in Sections 4-7.

Breccia: clasts angular basalt identical to above and numerous fragments angular to subrounded palagonitized red-brown glass in a lithographic limestone matrix (5YR 8/1). Glassy rinds on approximately .25-.33 of the basalt clasts.

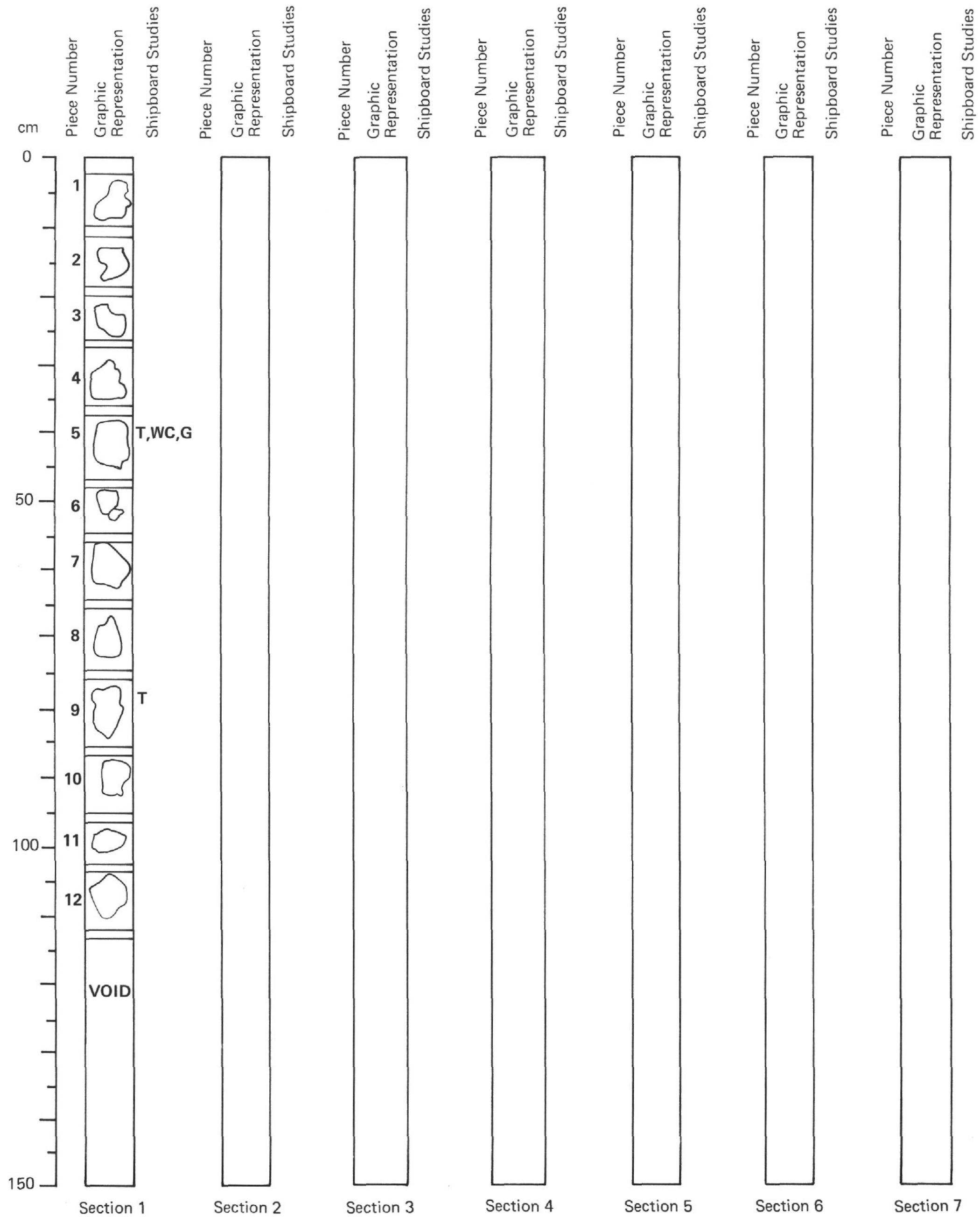
Petrography: Texture largely glassy (vitrophyric) to variolitic with microphenocrysts plagioclase, olivine and/or clinopyroxene sub-ophitic (Section 3), intergranular-intersertal (top Section 6), hyaloclastite with skeletal olivine (Section 7). Glass occasionally fresh, often altered smectite ± palagonite. Olivine occasionally fresh, usually partially or completely altered to calcite ± iddingsite. Trace groundmass olivine (base Section 3 - top Section 4). Plagioclase An_{70-50}. Clinopyroxene brown color, skeletal to variolitic (base Section 3 - top Section 5), colorless elsewhere, sector zoned (top Section 6). Elongate or skeletal opaques concentrated in glass.

Limestone: foraminiferal biomicrite.

Shipboard Data

	Vp	NRM	Inc.
Sect. 1, 15 cm:	––	11	+30°
Sect. 1, 80 cm:	3.97	––	?
Sect. 2, 65 cm:	3.75	1413	+41°
Sect. 3, 105 cm:	4.28	10336	+53°
Sect. 4, 50 cm:	4.24	4227	+39°
Sect. 5, 20 cm:	4.30	6021	+45°
Sect. 6, 70 cm:	3.88	––	?
Sect. 6, 100 cm:	––	11824	+35°

LEG **49** SITE **410** HOLE CORE **40** DEPTH **368.5-378.0 m**



Original basalt recovery was 0.80 meters. Styrofoam spacers make the length shown here greater than the amount recovered.

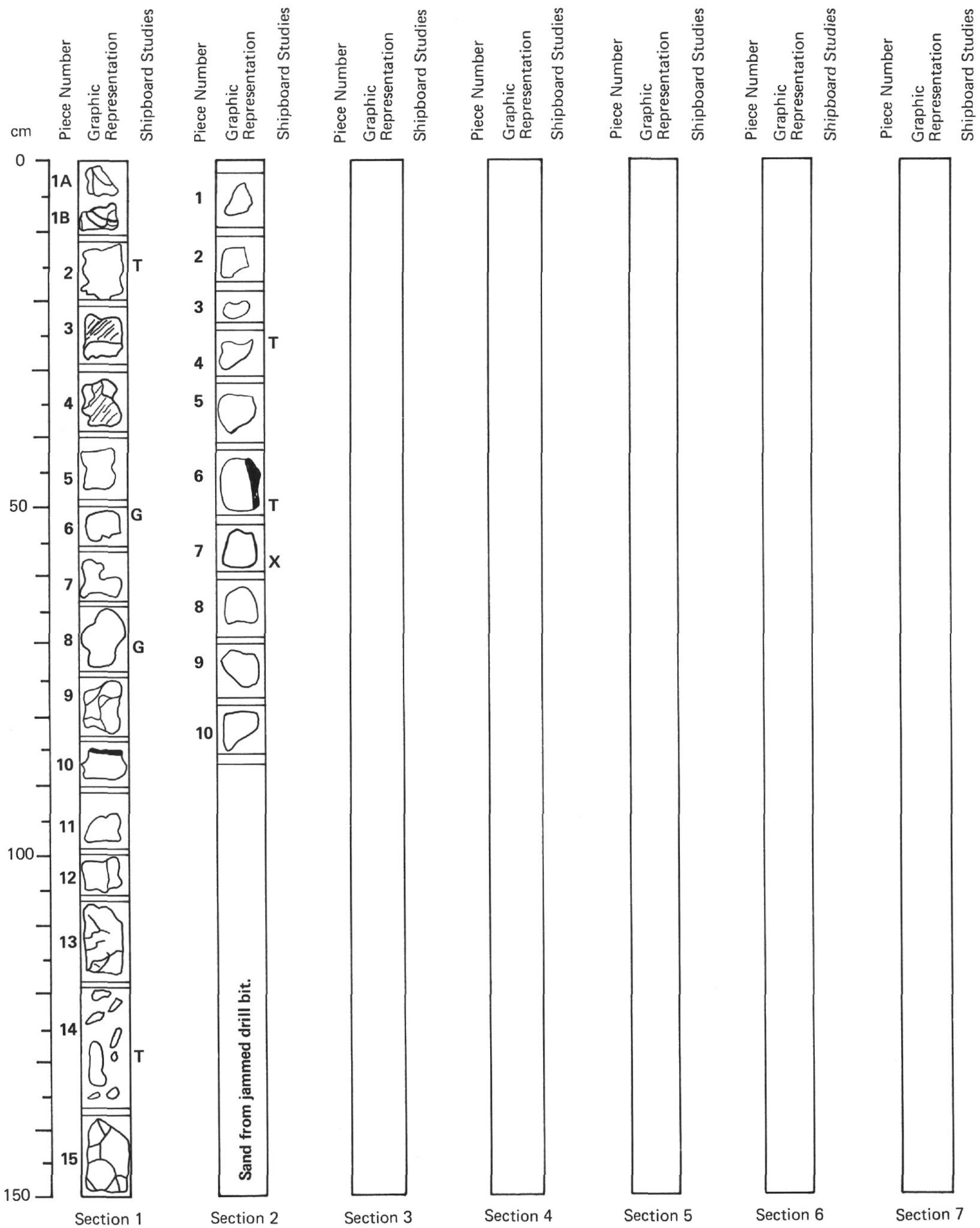
Vesicular fine-grained aphyric basalt with rare microphenocrysts of plagioclase and olivine (fresh and altered). Vesicles unevenly distributed, maximum 5-10%, 0.5-2 mm, filled with calcite and zeolites, some rimmed with palagonite. Numerous calcite or calcite-clay veins. Local glass selvages altered to palagonite.

Petrography: intersertal texture, microphenocrysts of augite (2%) and fresh olivine (1%). Very fine-grained groundmass contains plagioclase laths and highly oxidized glass.

Shipboard Data

	Vp	**NRM**	**Inc.**
Sect. 1, 40 cm:	4.08	3643	+19°

LEG **49** SITE **410** HOLE CORE **41** DEPTH **378.0-387.5 m**



Original basalt recovery was 1.40 meters. Styrofoam spacers make the length shown here greater than the amount recovered.

Top to Section 2, 88 cm: vesicular aphyric basalt and local basaltic breccia. Most pieces laced with calcite veins. Vesicles partially or entirely filled with calcite and zeolites. Two populations of cross-cutting vesicles (unevenly distributed). Maximum 20%, 0.5-3 mm. Rare glass selvages altered to palagonite.

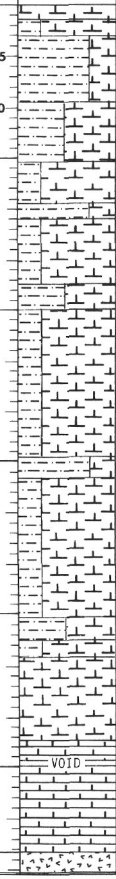
Section 2, 88 cm to base: basaltic sand from jammed drilled bit with subangular to subrounded basalt, glass, limestone and calcite fragments.

Petrography: texture, glassy (vitrophyric) to intergranular-intersertal with microphenocrysts of olivine (2-3%) altered to calcite and iddingsite, augite (1-5%) and plagioclase (~12%), An_{75}. Glass fresh or altered to smectite.

Shipboard Data

	Vp	NRM	Inc.
Sect. 1, 60 cm:	––	9624	+37°

SITE 410 **HOLE** A **CORE** 1 **CORED INTERVAL:** 325.0-334.5 m

TIME-ROCK UNIT	BIOSTRAT ZONE	FOSSIL CHARACTER: FORAMS	NANNOS	RADS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	LITHOLOGIC SAMPLE	LITHOLOGIC DESCRIPTION
late MIOCENE	N16-N17 NN11	Ag	Ag		1, 2, 3, 4, 5, 6, CC	0.5, 1.0				70, 70, 70, 70, 20, 70, 70	see below

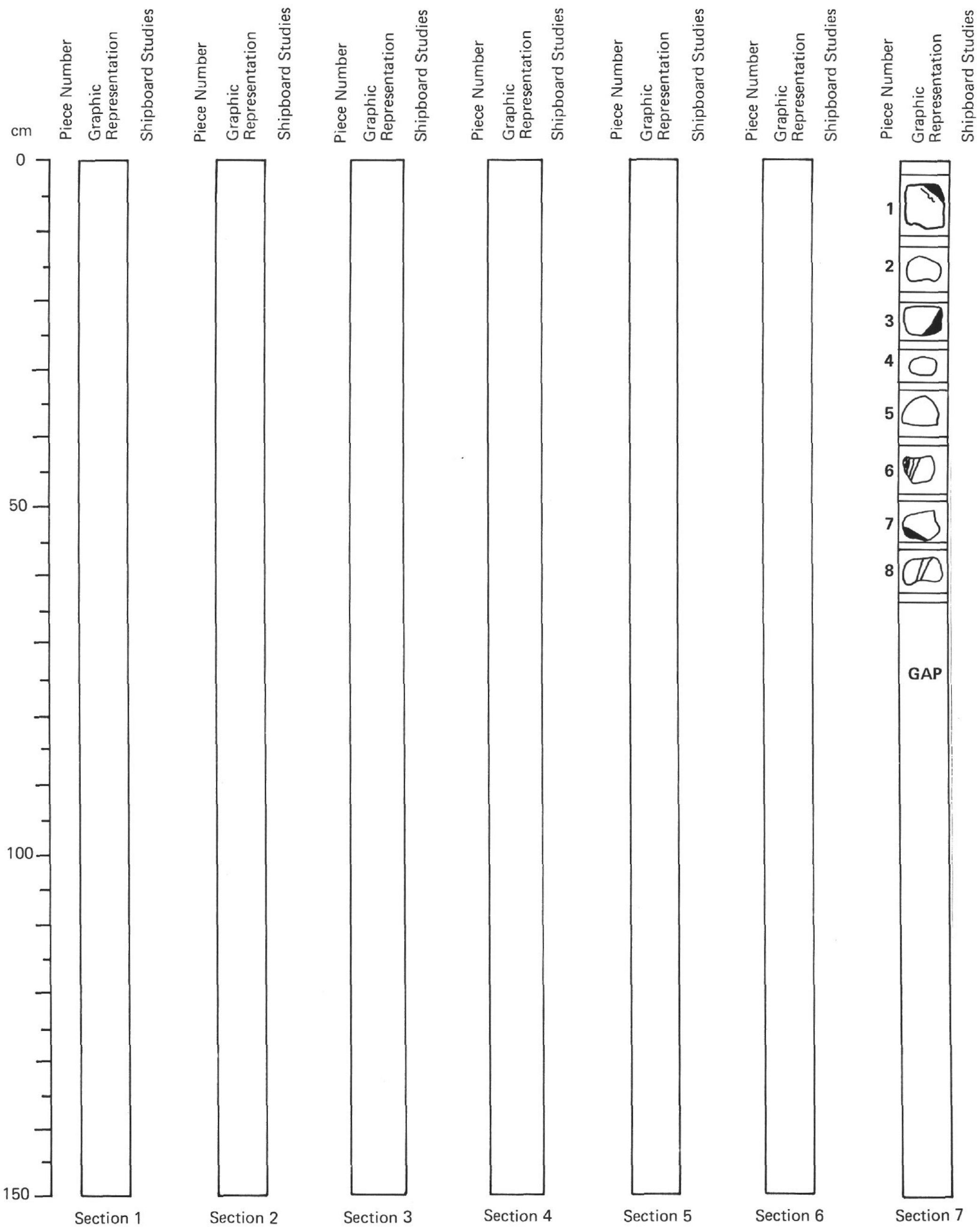
foram sand
very pale brown (10YR 7/4)
gray (5Y 5/1)
olive gray (5Y 5/2)
foram sand
light gray (5Y 7/1)
gray (5Y 6/1)
white (5Y 8/1)
light gray (5Y 7/1)
foram sand
gray (5Y 5/1) to dark gray (5Y 4/1)
very pale brown (10YR 7/4)
yellowish brown (10YR 5/4)
brownish yellow (10YR 6/4)
very pale brown (10YR 7/4)
gray (5Y 5/1), 5Y 6/1)
very pale brown (10YR 7/4)
10YR 5/2
10YR 5/3
very pale brown (10YR 7/4)
very light gray (N8)
VOID
light greenish gray (5GY 8/1)
CC=20 cm

NANNOFOSSIL OOZE
with intermixed marly ooze and calcareous clay (0-642 cm) and nannofossil chalk (725-836 cm). This core appears to contain one or more mudline penetrations (brown to gray, soft, sandy, 0-642 cm) and one penetration of basal sediments and basalt (disturbed nanno ooze, very light gray, 642-727 cm; nanno chalk to 836 cm, basalt to base of core. The chalk unit (light greenish gray) is extensively laminated and burrowed.

Vesicular, fine-grained aphyric basalt with rare fresh olivine microphenocrysts, vesicles 1-10%, 0.2-1.5 mm. Partially or entirely filled with calcite or blue-gray smectite. Local palagonitized glass selvages. Carbonate veins with palagonitized glass fragments. Overall alteration moderate-weak. Petrography-variolitic basalt with fresh olivine and plag. (An_{65-70}). In a completely palagonitized glass groundmass.

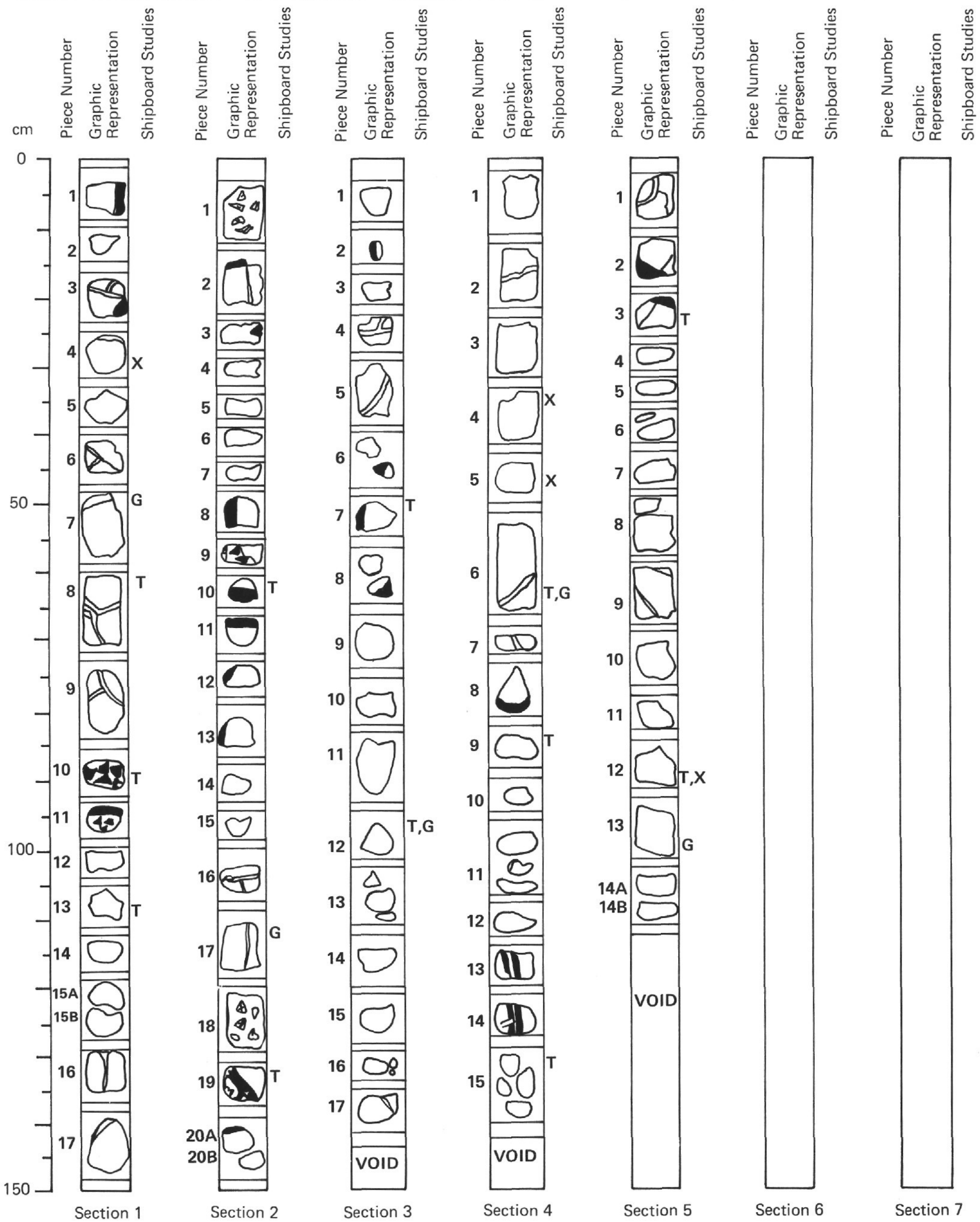
Explanatory notes in Chapter 1

LEG 49 SITE 410 HOLE A CORE 1 DEPTH 325.0-334.5 m



Vesicular, fine-grained aphyric basalt with rare fresh olivine microphenocrysts, vesicles 1-10%, 0.2-1.5 mm. Partially or entirely filled with calcite or blue-gray smectite. Local palagonitized glass selvages. Carbonate veins with palagonitized glass fragments. Overall alteration moderate-weak. Petrography-variolitic basalt with fresh olivine and plagioclase (An_{65-70}). In a completely palagonitized glass groundmass.

LEG 49 SITE 410 HOLE A CORE 2 DEPTH 334.5-344.0 m



Original basalt recovery was 4.18 meters. Styrofoam spacers make the length shown here greater than the amount recovered.

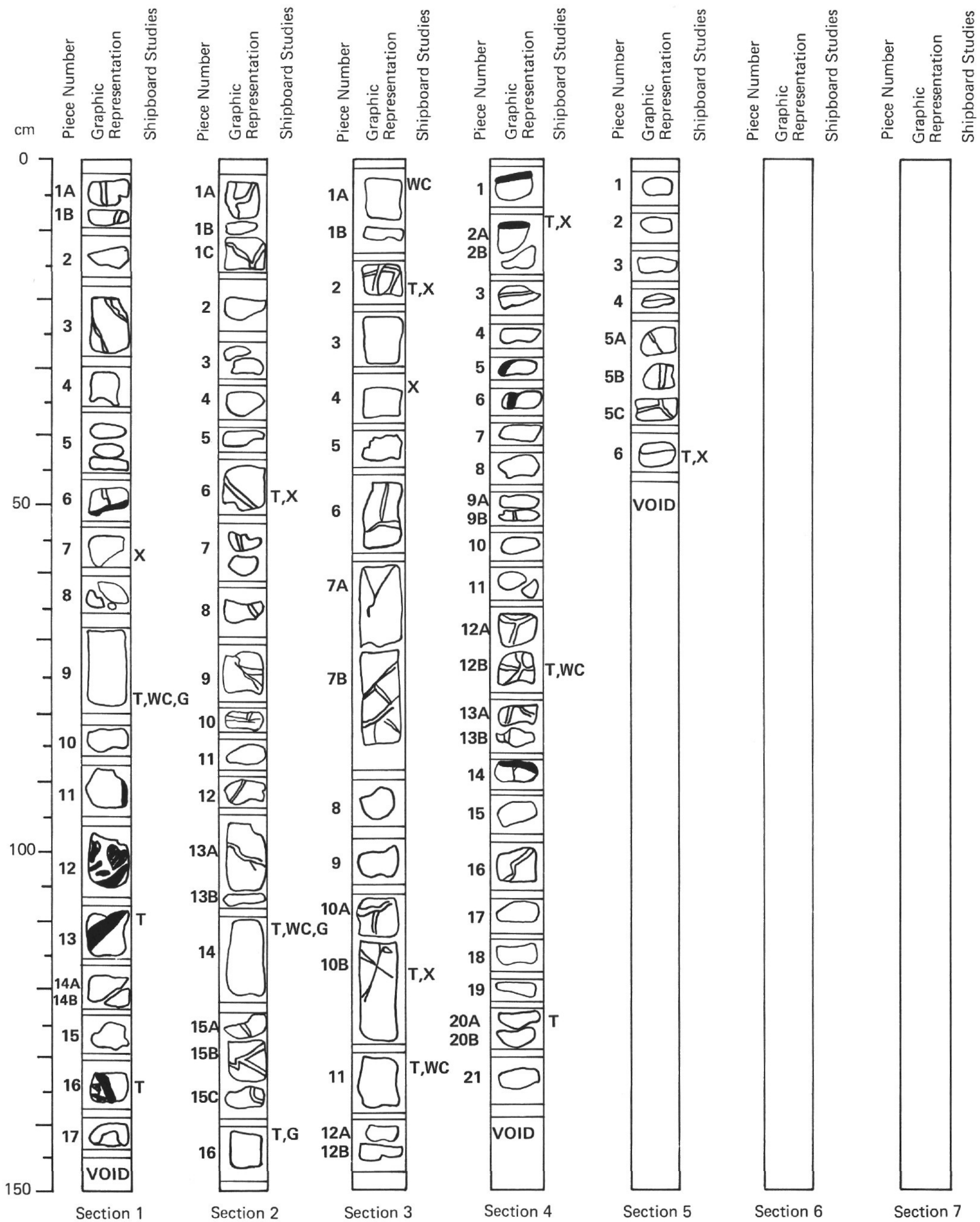
Vesicular fine-grained aphyric basalt. Vesicles unevenly distributed, from 1% and <.50 mm to 10-15%, 1-3 mm, partially or entirely filled with calcite, zeolites or glass. Common calcite veins near which adjacent rock is more highly altered. Overall basalt alteration weak to moderate. Partially palagonitized glass selvages abundant, glass often fractured and inpregnated with calcite. Patches of breccia common (basalt clasts and partially palagonitized glass fragments in a limestone matrix).

Petrography: texture - glassy (vitrophyric) to variolitic, occasionally intersertal, all gradations exist from glassy flow margins into partially crystalline basalt. Glass contains microphenocrysts, olivine, plagioclase and minor clinopyroxene. Glass fresh to altered (palagonite and minor smectite). Olivine generally fresh but some carbonate alteration, more abundant and larger than plagioclase. Plagioclase (An_{70}). Local glomeroporphyritic clots olivine and plagioclase. Opaque microlites. Carbonate and chloropharite(?) veins.

Shipboard Data

	Vp	NRM	Inc.
Sect. 1, 60 cm:	5.12	2649	+42°
Sect. 1, 70 cm:	––	––	Normal
Sect. 2, 100 cm:	4.71	1676	+44°
Sect. 3, 95 cm:	4.69	1589	+43°
Sect. 4, 65 cm:	4.81	1229	+24°
Sect. 5, 100 cm:	4.37	440	+32°

LEG **49** SITE **410** HOLE **A** CORE **3** DEPTH **344.0-353.5 m**



Original basalt recovery was 3.95 meters. Styrofoam spacers make the length shown here greater than the amount recovered.

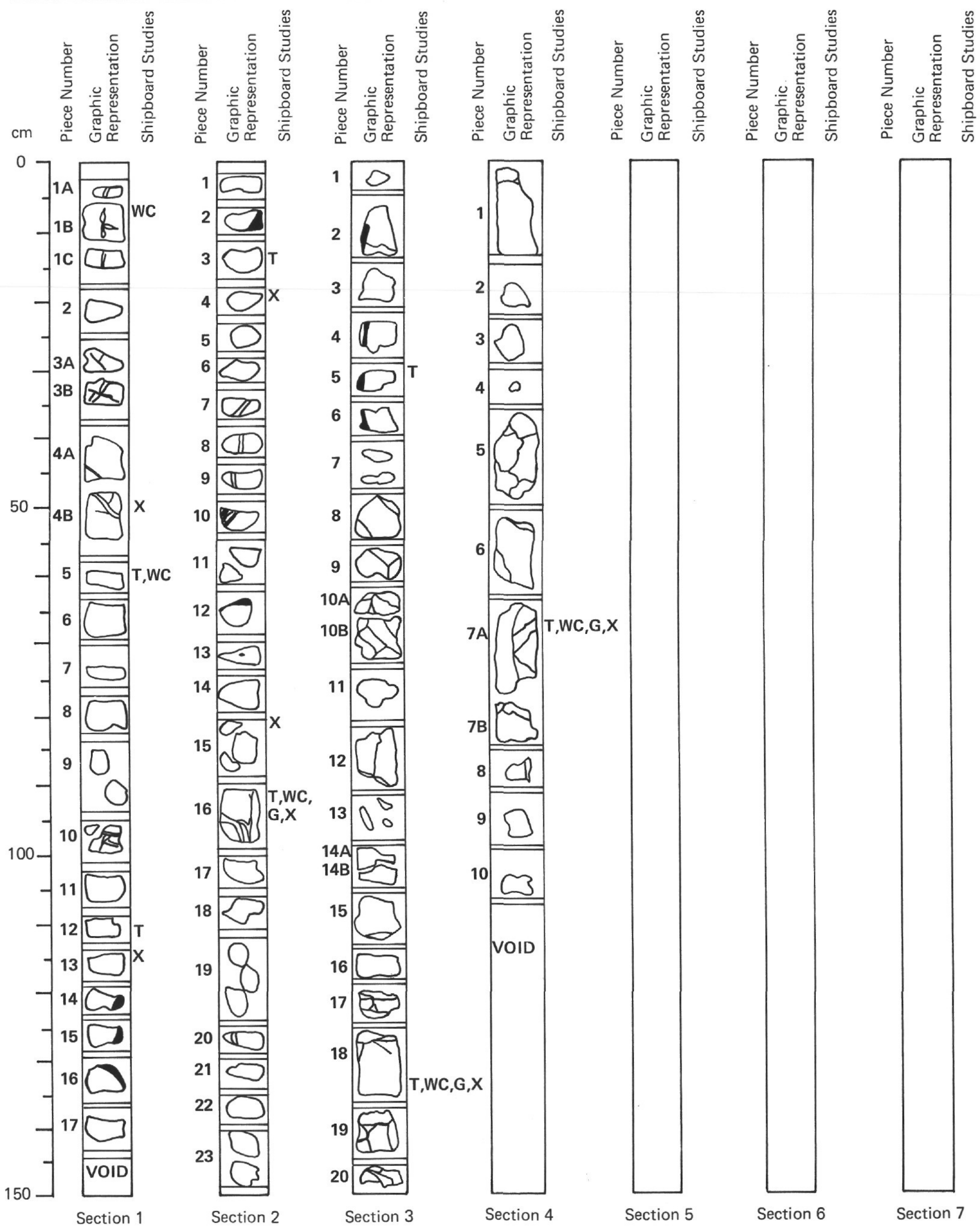
Vesicular fine-grained aphyric basalt. Very rare microphenocrysts olivine (Section 1). Vesicles unevenly distributed from 1%, 0.2 mm to 10-15%, .50-2 mm, partially filled wtih calcite, blue-gray smectite or zeolites (Section 4). Palagonitized glass selvages common and often fractured and impregnated with calcite. Numerous calcite veins (most abundant in Section 3). Basalt more altered near these veins. Overall alteration varies from weak to moderate.

Petrography: texture glassy (vitrophyric) to variolitic and subaphyric with microphenocrysts of olivine, plagioclase laths, plagioclase quench crystals and minor clinopyroxene in fresh pale brown glass. Olivine fresh except in Section 4 where pseudomorphed by smectite. Section 5 texture intersertal with varioles of olivine and skeletal dendritic pale brown clinopyroxene.

Shipboard Data

	Vp	NRM	Inc.
Sect. 1, 70 cm:	4.39	––	––
Sect. 2, 110 cm:	3.84	1018	+16°
Sect. 2, 145 cm:	4.15	––	Normal
Sect. 3, 120 cm:	4.00	1952	+18°
Sect. 4, 85 cm:	4.97	1003	+24°

LEG 49 SITE 410 HOLE A CORE 4 DEPTH 353.5-363.0 m



Original basalt recovery was 3.60 meters. Styrofoam spacers make the length shown here greater than the amount recovered.

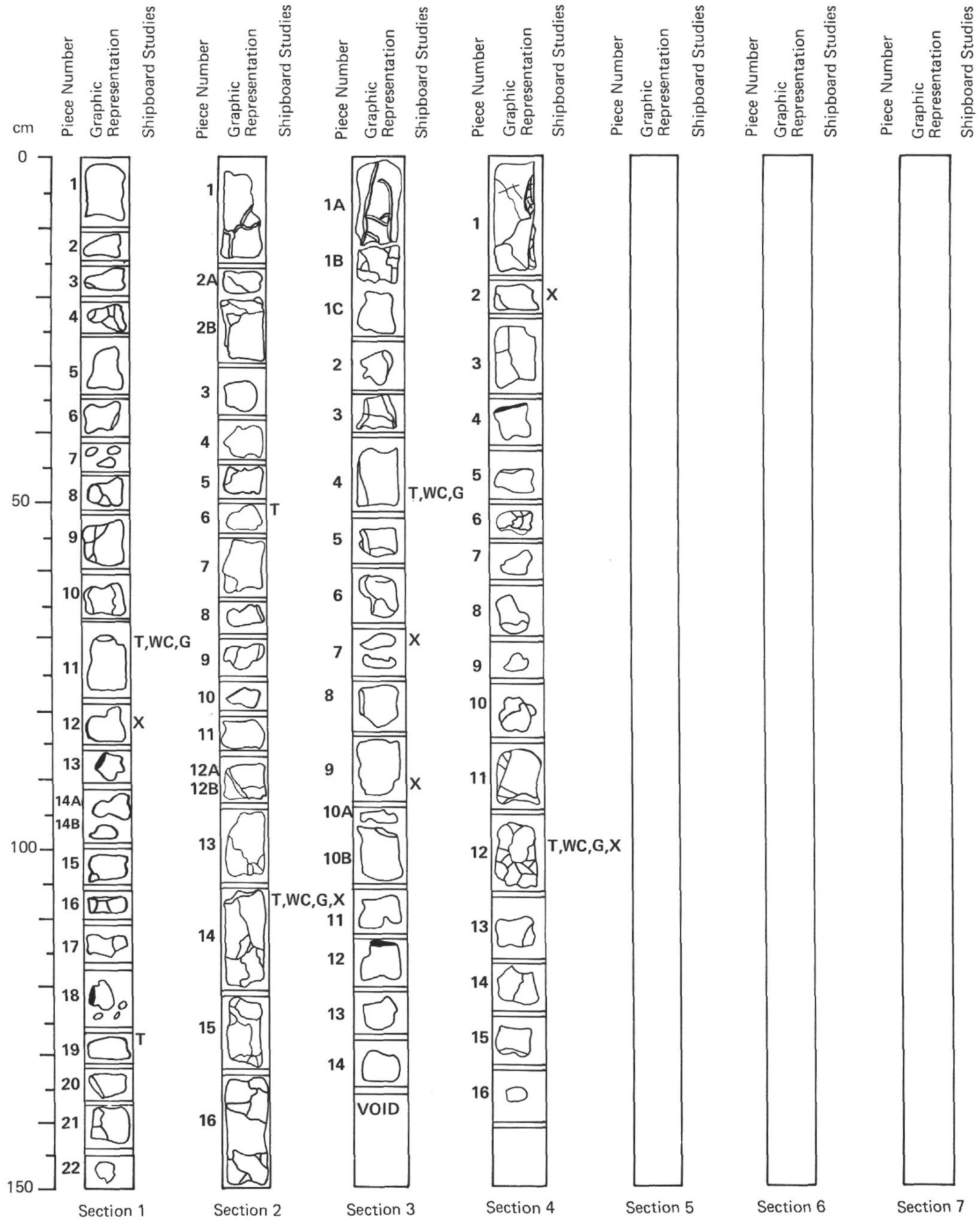
Vesicular fine-grained aphyric basalt. Vesicles unevenly distributed from 1%, .50 mm to 10-15%, 0.3-2 mm. Partially filled with calcite, blue-gray smectite or zeolites. Partially palagonitized glass selvages common. Calcite veins common. Overall basalt alteration weak to moderate, strongest adjacent to calcite veins. Decrease in vesicularity and increase in grain size downward in Section 3 indicates gradation from glassy top of flow into less vesicular coarse-grained flow interior. This continues into Section 4 where finer-grained more vesicular base of flow occurs near base of recovered interval. Variolitic plagioclase to 1 mm in lower Section 3 and upper Section 4. Some second generation vesiculation on first generation vesicle walls in Section 3.

Petrography: texture glassy to variolitic, occasionally intersertal. Glass partially replaced by palagonite or smectite. Microphenocrysts of fresh olivine, plagioclase and minor clinopyroxene olivine occasionally skeletal, occasionally in glomeroporphyritic clots.

Shipboard Data

	Vp	NRM	Inc.
Sect. 1, 10 cm:	3.78	––	+20°
Sect. 1, 50 cm:	4.04	1369	Normal
Sect. 2, 90 cm:	4.00	1862	+16°
Sect. 3, 130 cm:	4.26	1805	+11°
Sect. 4, 50 cm:	4.47	1924	+13°

LEG **49** SITE **410** HOLE **A** CORE **5** DEPTH **363.0-372.5 m**



Original basalt recovery was 3.72 meters. Styrofoam spacers make the length shown here greater than the amount recovered.

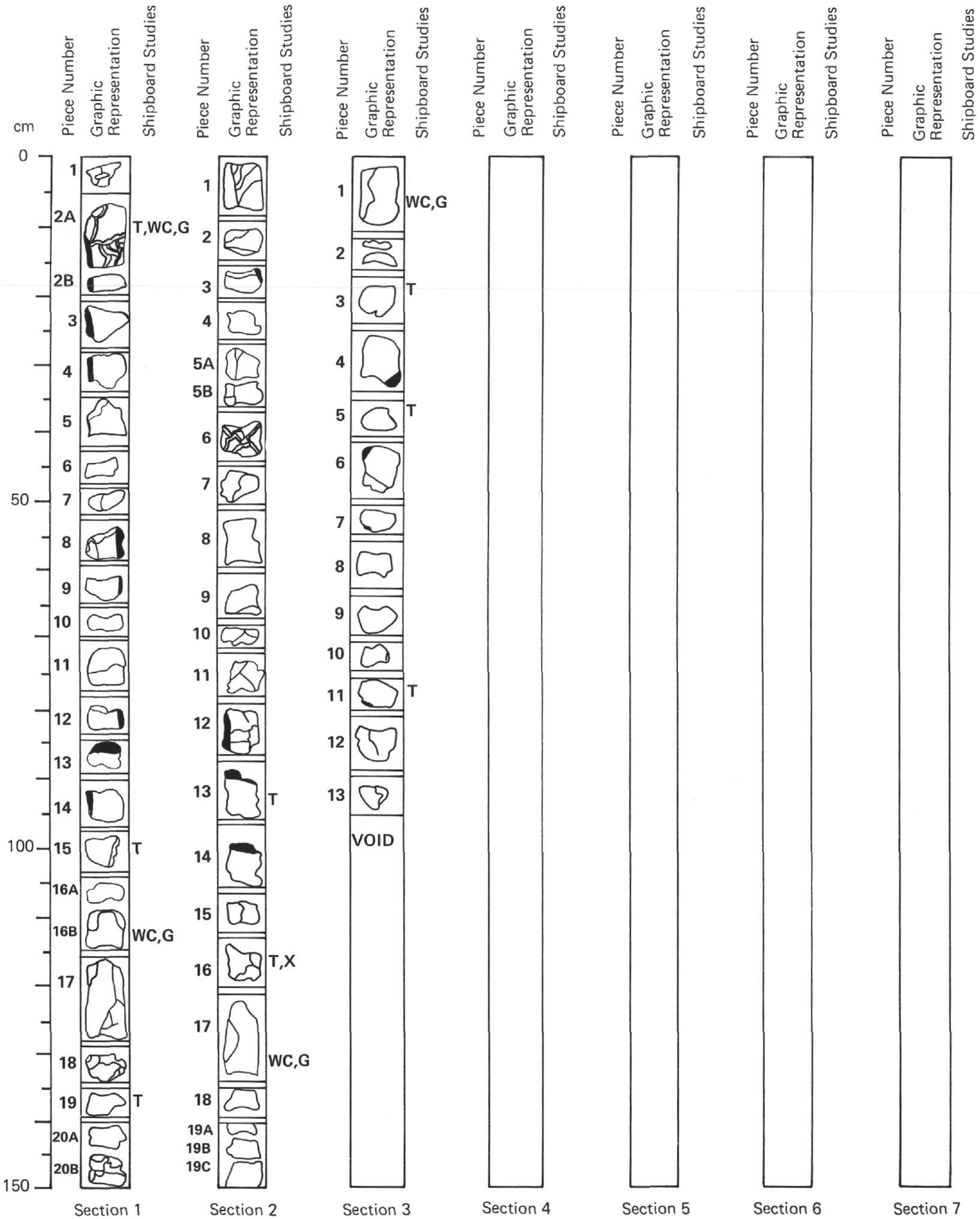
Fine-grained aphyric variolitic basalt. Glass selveges present but uncommon. Calcite veins common. Vesicle-rich zones (5-10%, 1-3 mm) common. Remainder of core has 1% vesicles (0.2 mm), partially filled with calcite and smectite. If vesicle-rich zones represent flow margins this core contains 5-8 flows of similar composition.

Petrography: glassy to variolitic, 50-99% glass with rare microphenocrysts, plagioclase and fresh to altered olivine. Glass highly altered.

Shipboard Data

	Vp	NRM	Inc.
Sect. 1, 75 cm:	4.67	––	?
Sect. 2, 105 cm:	4.15	1627	+16°
Sect. 3, 50 cm:	4.15	1703	+11°
Sect. 4, 100 cm:	4.96	4059	+18°

LEG 49 SITE 410 HOLE A CORE 6 DEPTH 372.5-382.0 m



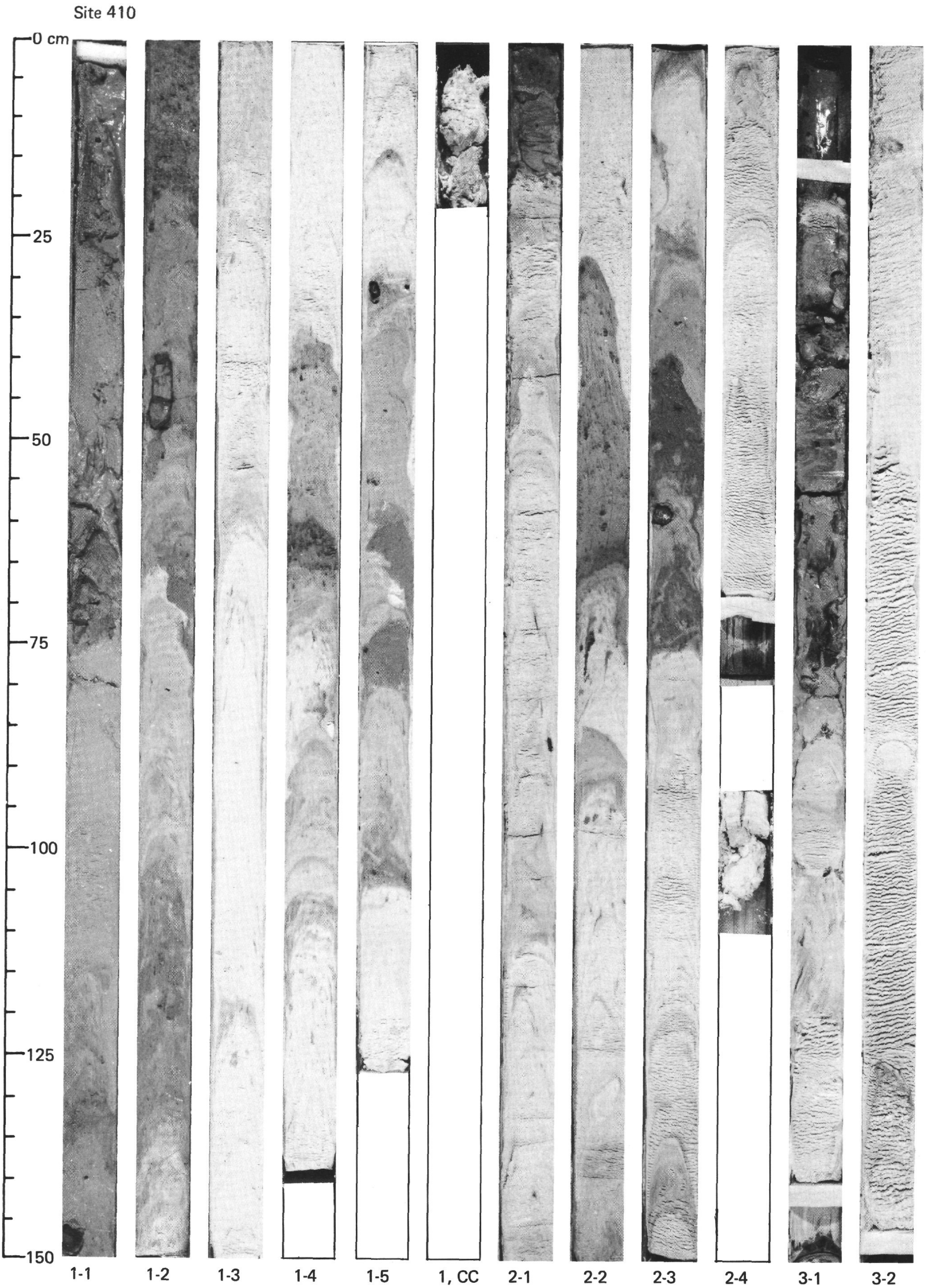
Original recovery = 2.74 m, etc.

Fine-grained, aphyric basalt. Many pieces have glassy selvages, 5-10% vesicles partly filled with smectite.

Glass is hydrated to gray color.

Shipboard Data

	Vp	NRM	Inc.
Sect. 1, 10 cm:	4.07	––	––
Sect. 1, 120 cm:	4.89	1358	+18°
Sect. 2, 120 cm:	4.50	1067	+12°
Sect. 3, 10 cm:	3.99	1561	+ 6°
Sect. 3, 35 cm:	––	––	Normal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0 cm
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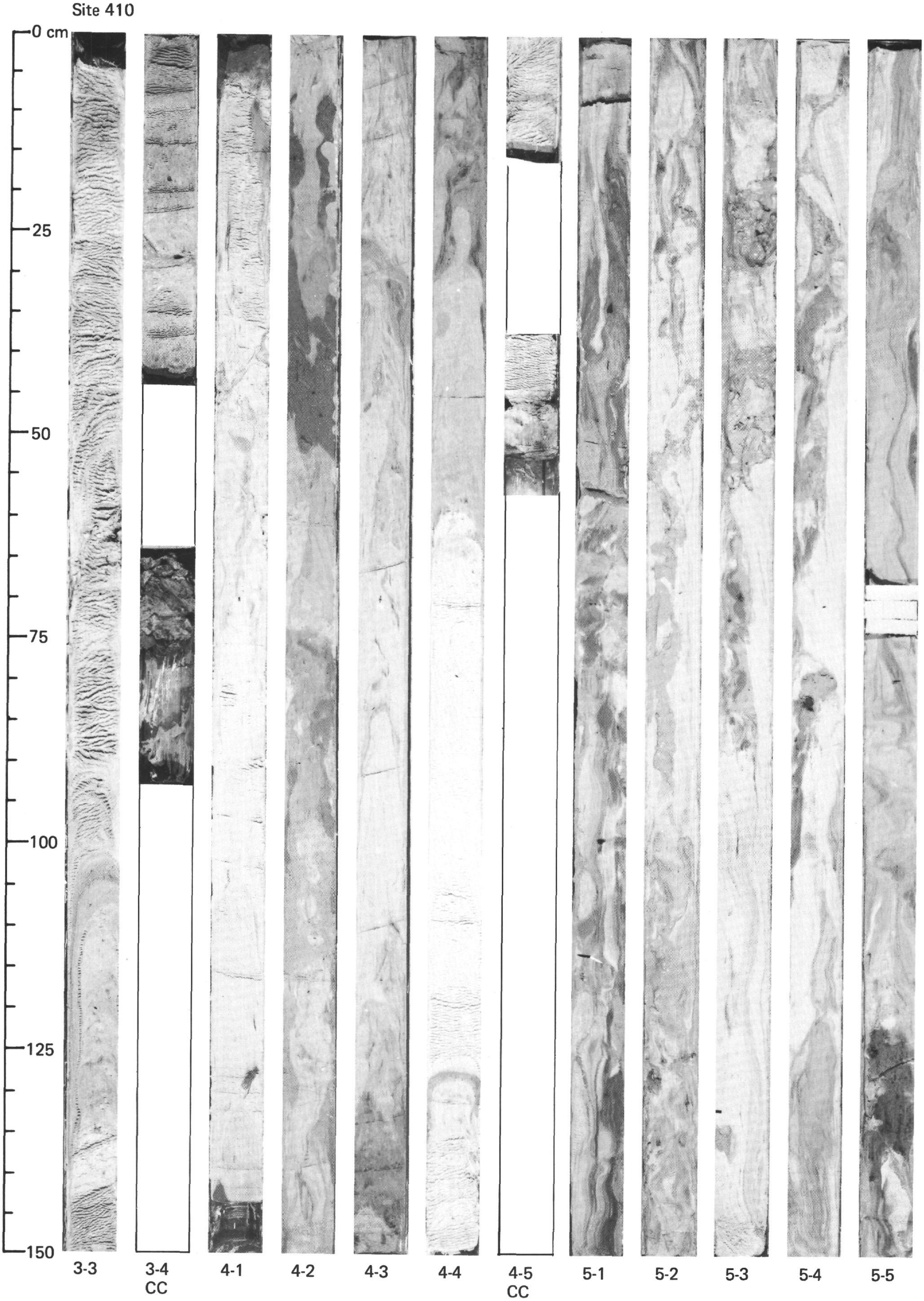
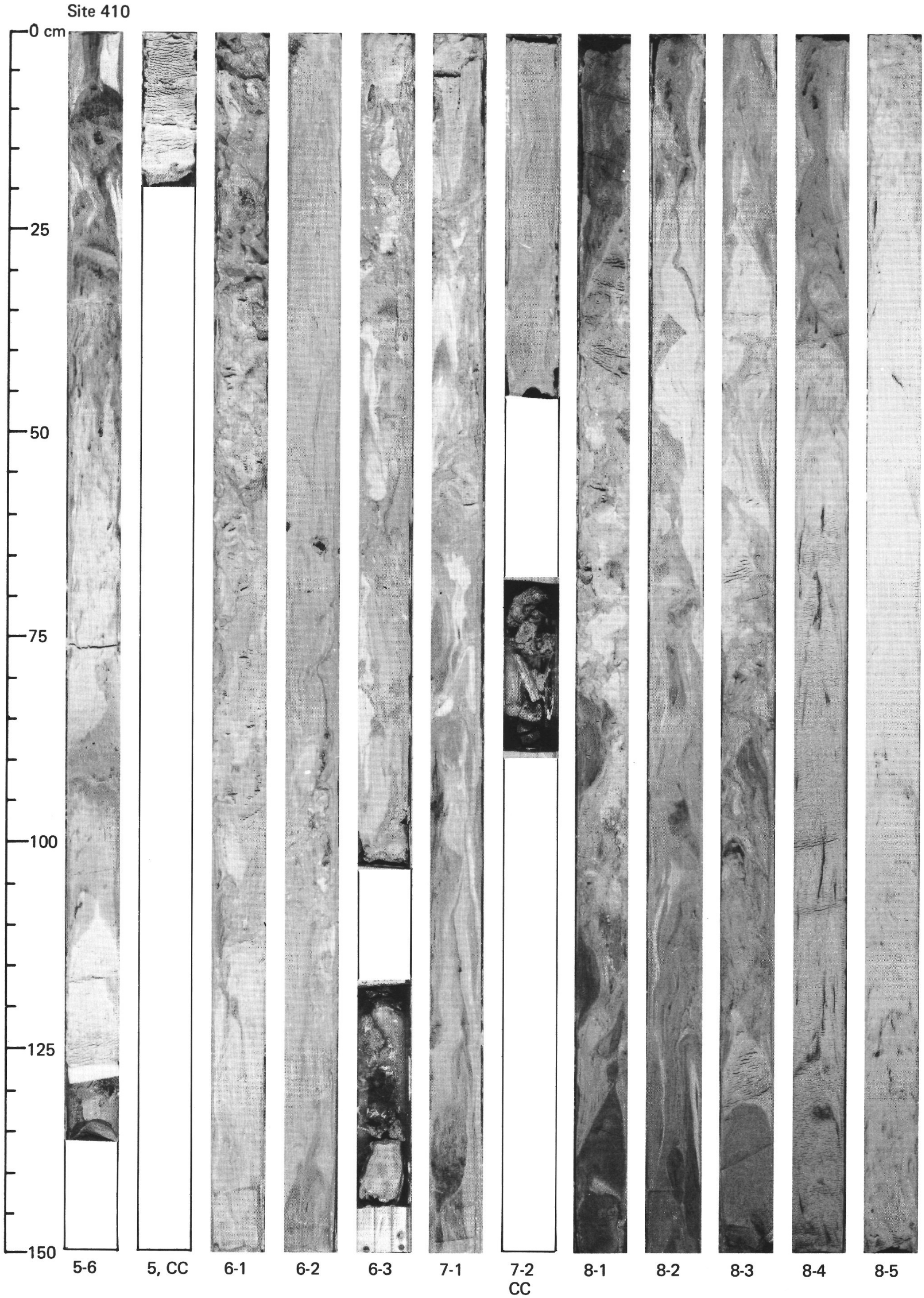
50
75
100
125
150
1-1
1-2
1-3
1-4
1-5
1, CC
2-1
2-2
2-3
2-4
3-1
3-2


Site 410
0 cm
25
50
75
100
125
150
3-3
3-4
CC
4-1
4-2
4-3
4-4
4-5
CC
5-1
5-2
5-3
5-4
5-5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125
150
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7-1
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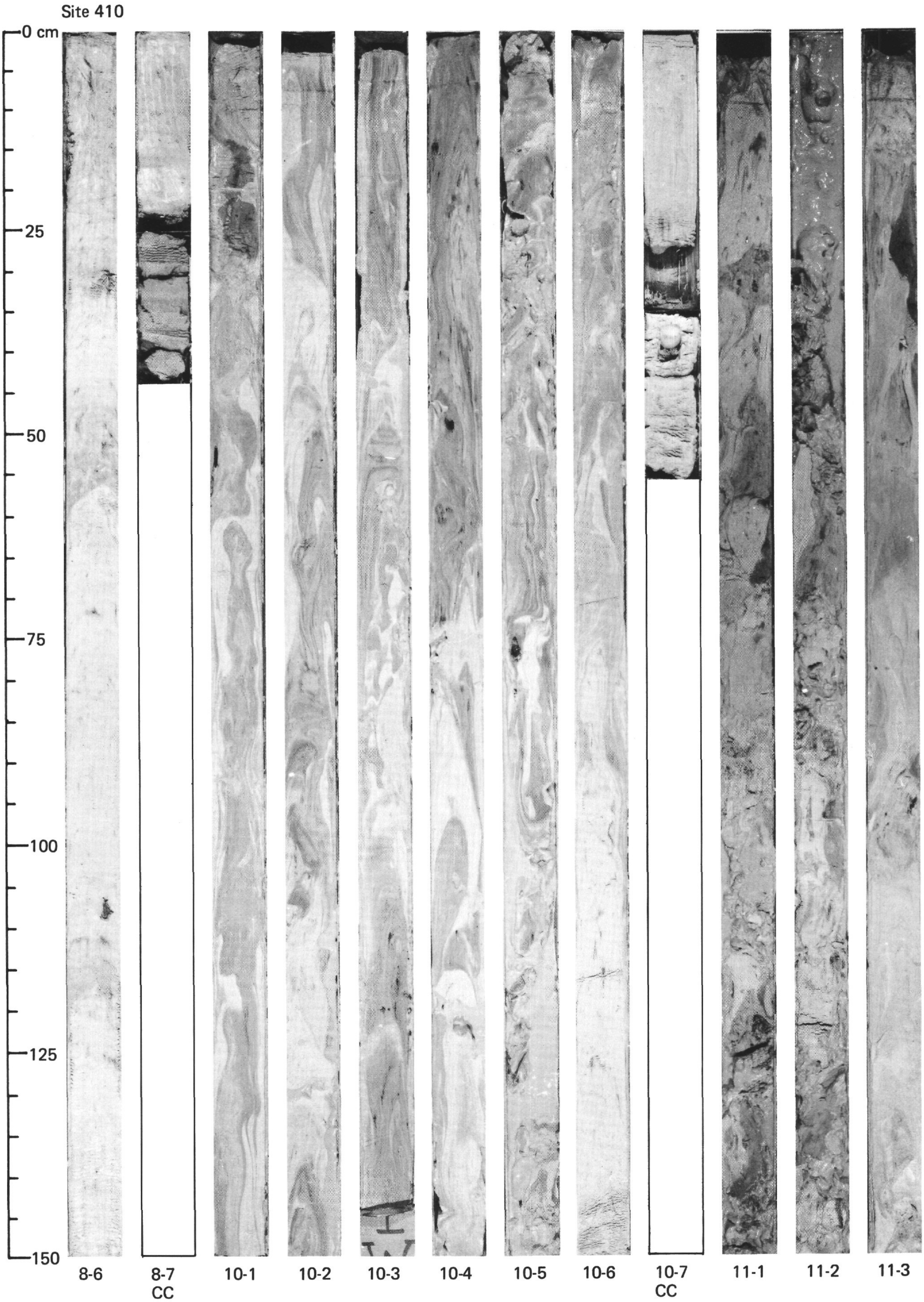
8-2
8-3
8-4
8-5


Site 410
0 cm
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50
75
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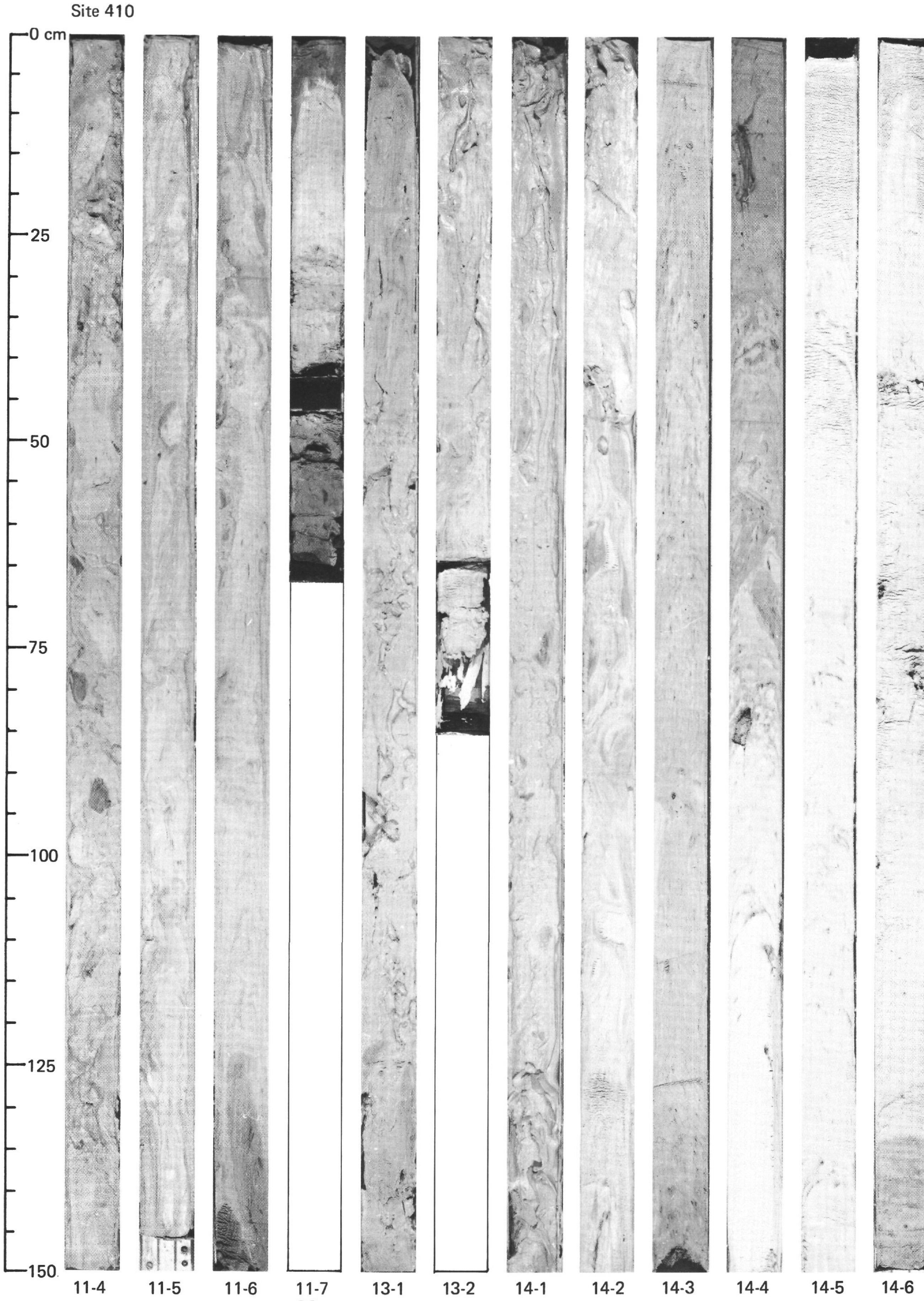
125
150
8-6
8-7
CC
10-1
10-2
10-3
10-4
10-5
10-6
10-7
CC
11-1
11-2
11-3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0 cm
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125
150
11-4
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11-6
11-7
CC
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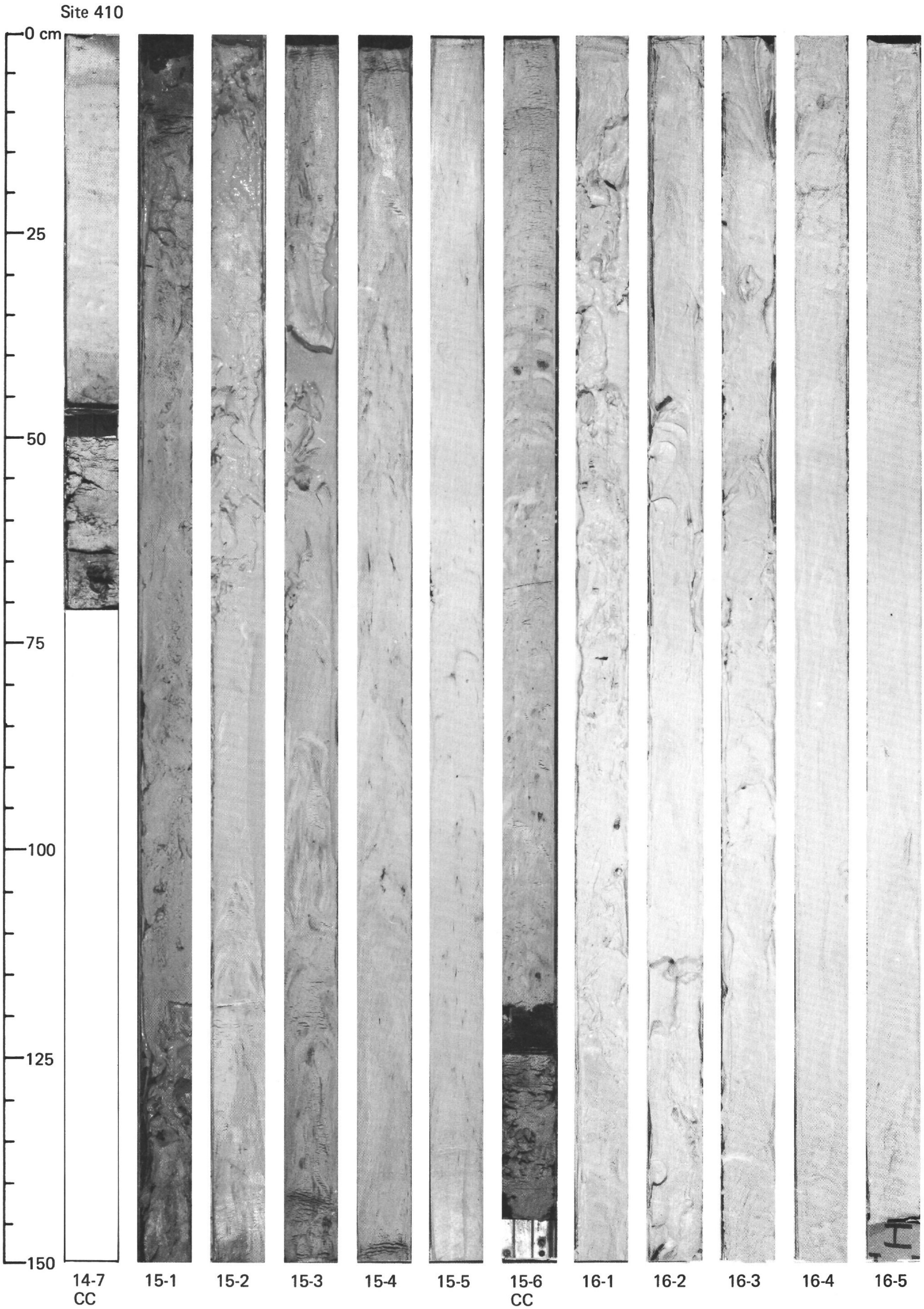
13-2
14-1
14-2
14-3
14-4
14-5
14-6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125
150
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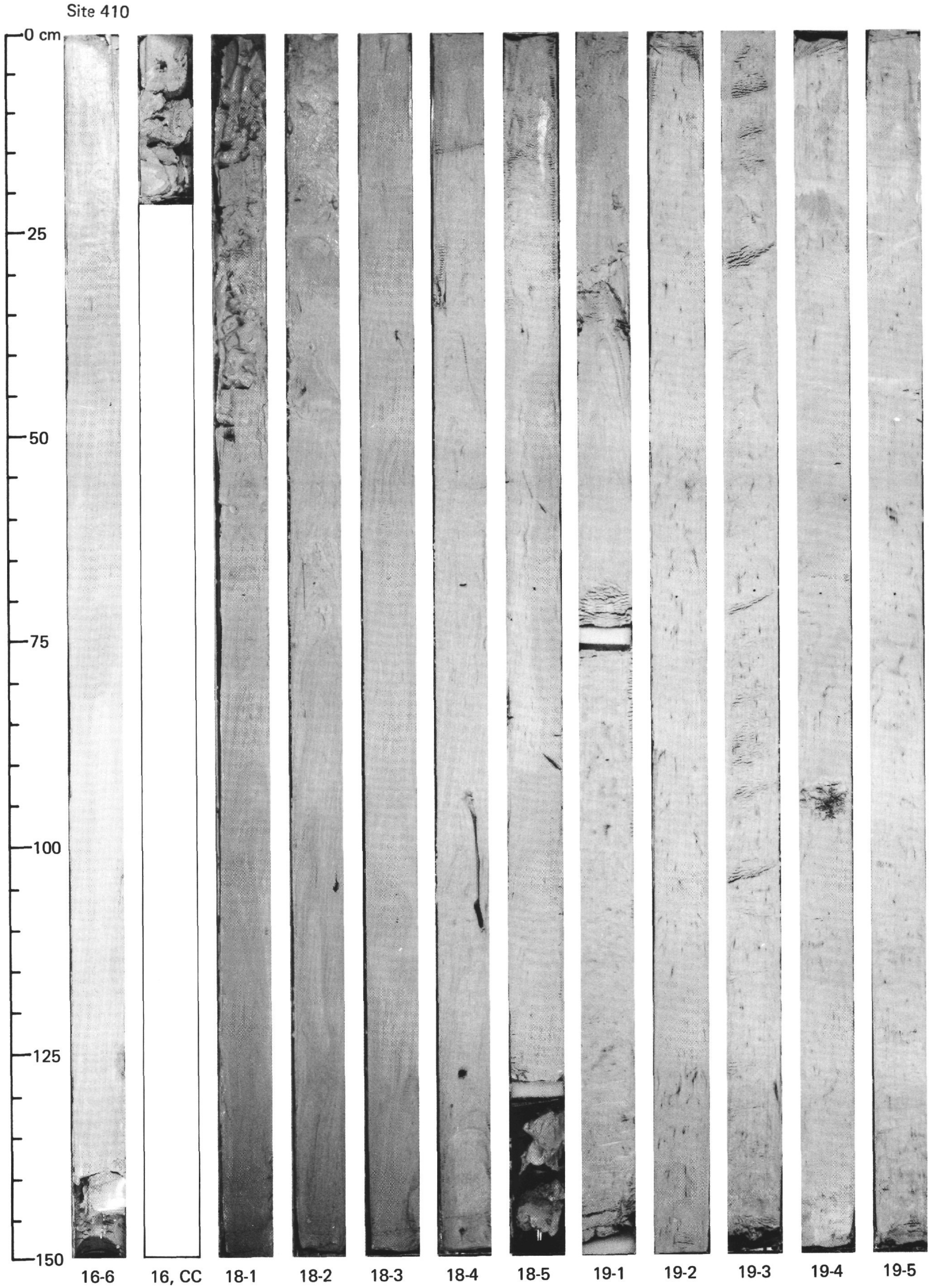
15-4
15-5
15-6 CC
16-1
16-2
16-3
16-4
16-5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100
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18-4
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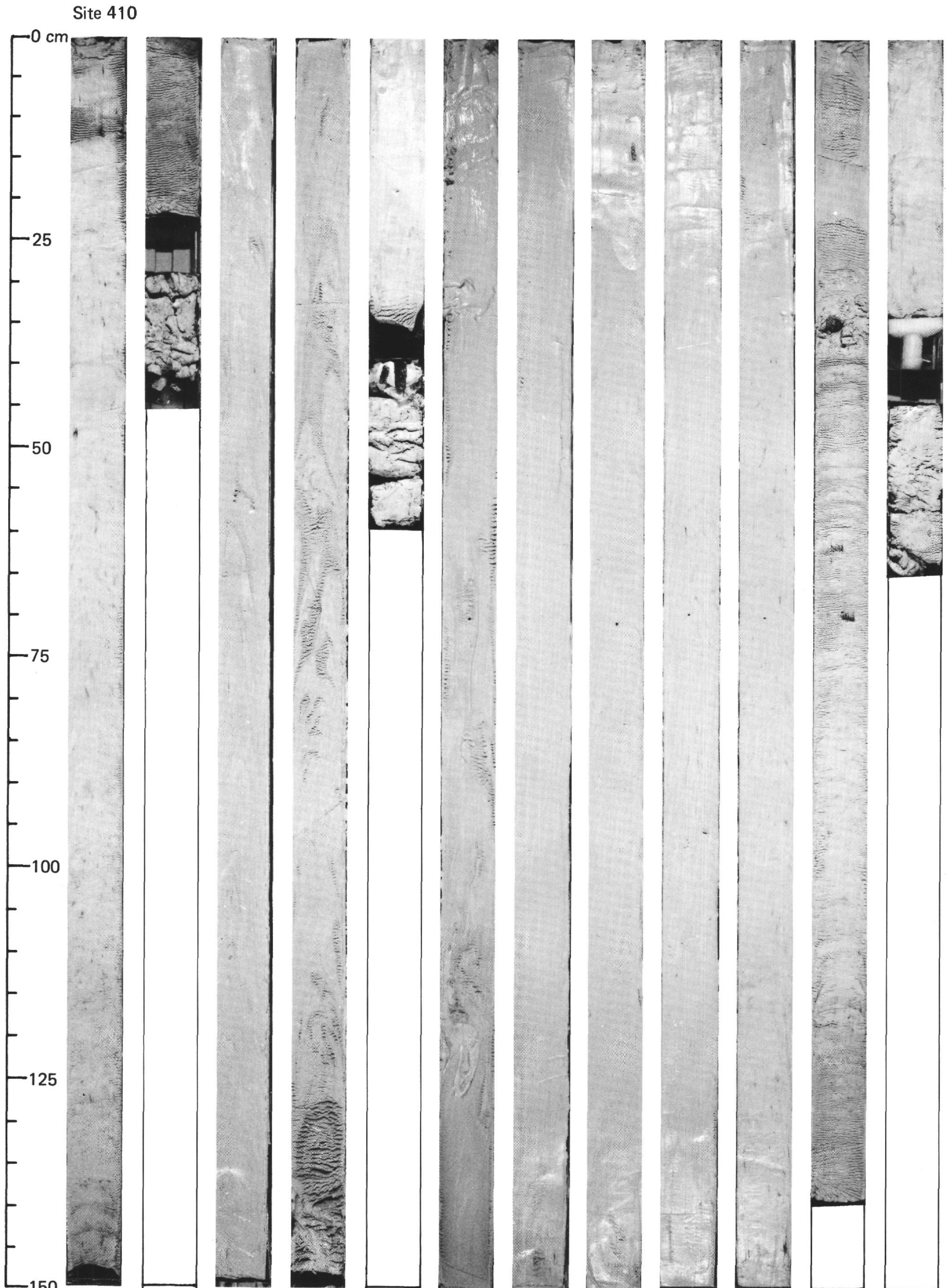
19-3
19-4
19-5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19-7
20-1
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21-1
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21-3
21-4
21-5
21-6
21-7


Site 410
0 cm
25
50
75
100
125
150
22-1
22-2
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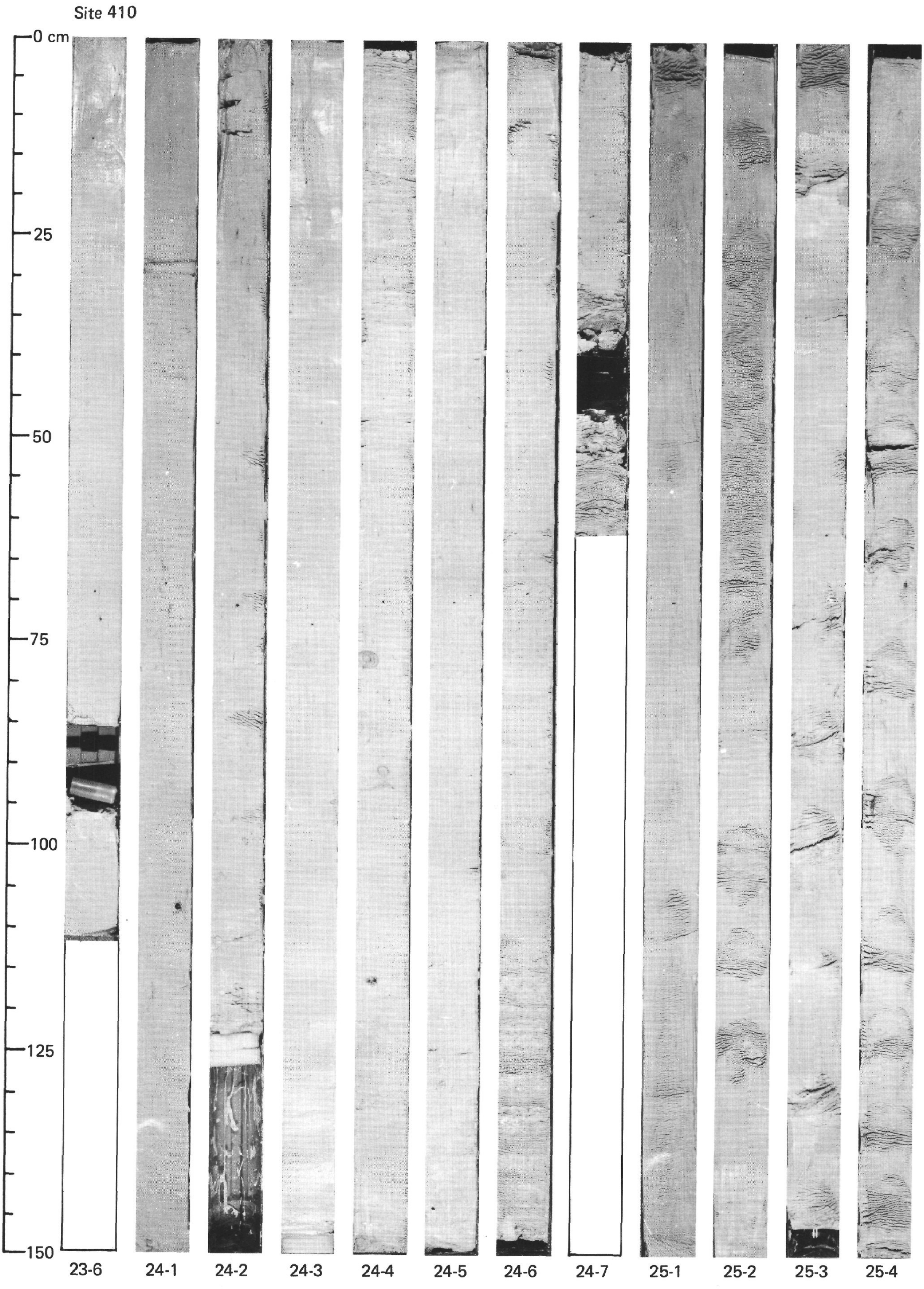
22-4
22-5
22-6
22-7
23-1
23-2
23-3
23-4
23-5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24-4
24-5
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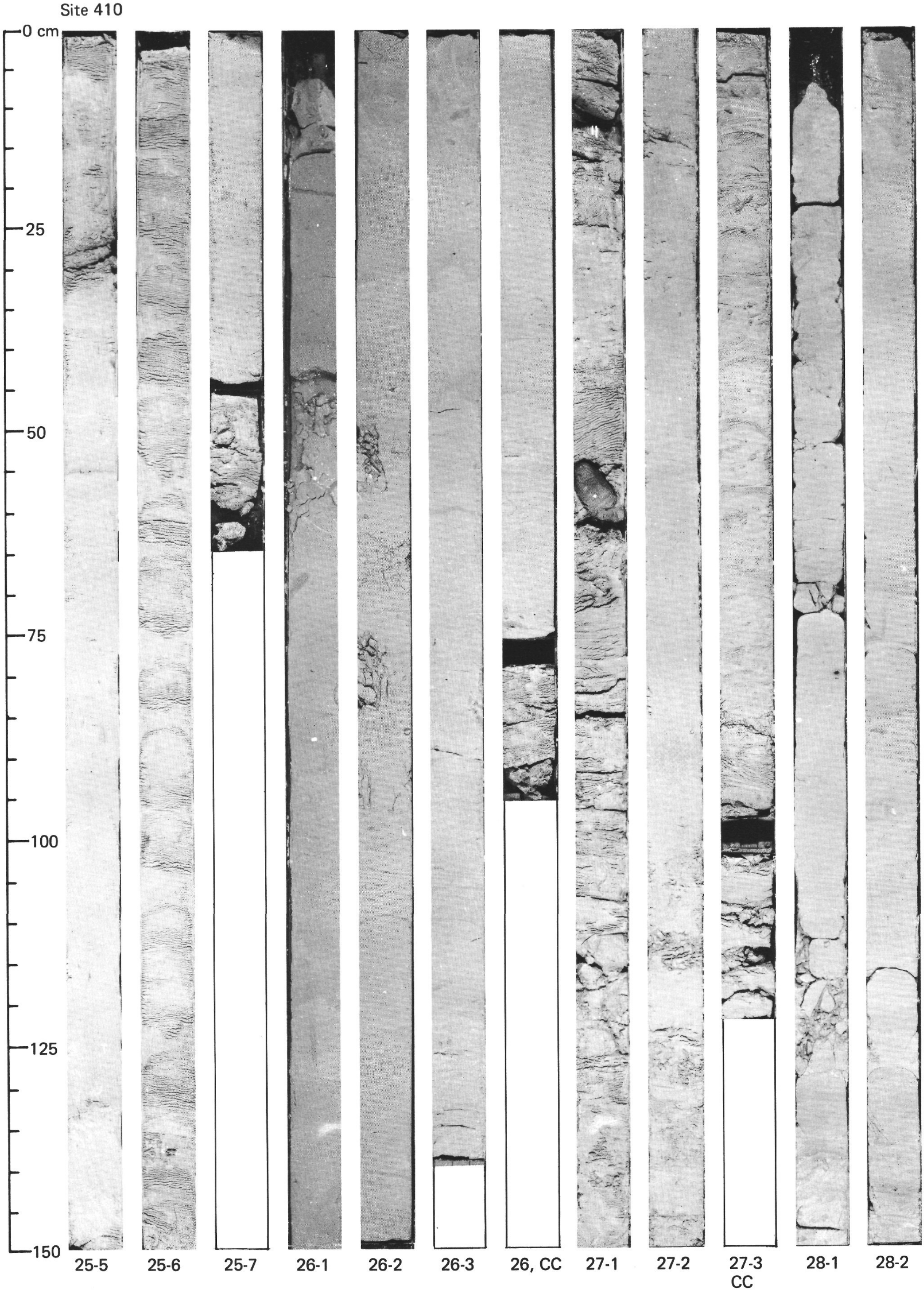
24-7
25-1
25-2
25-3
25-4


Site 410
0 cm
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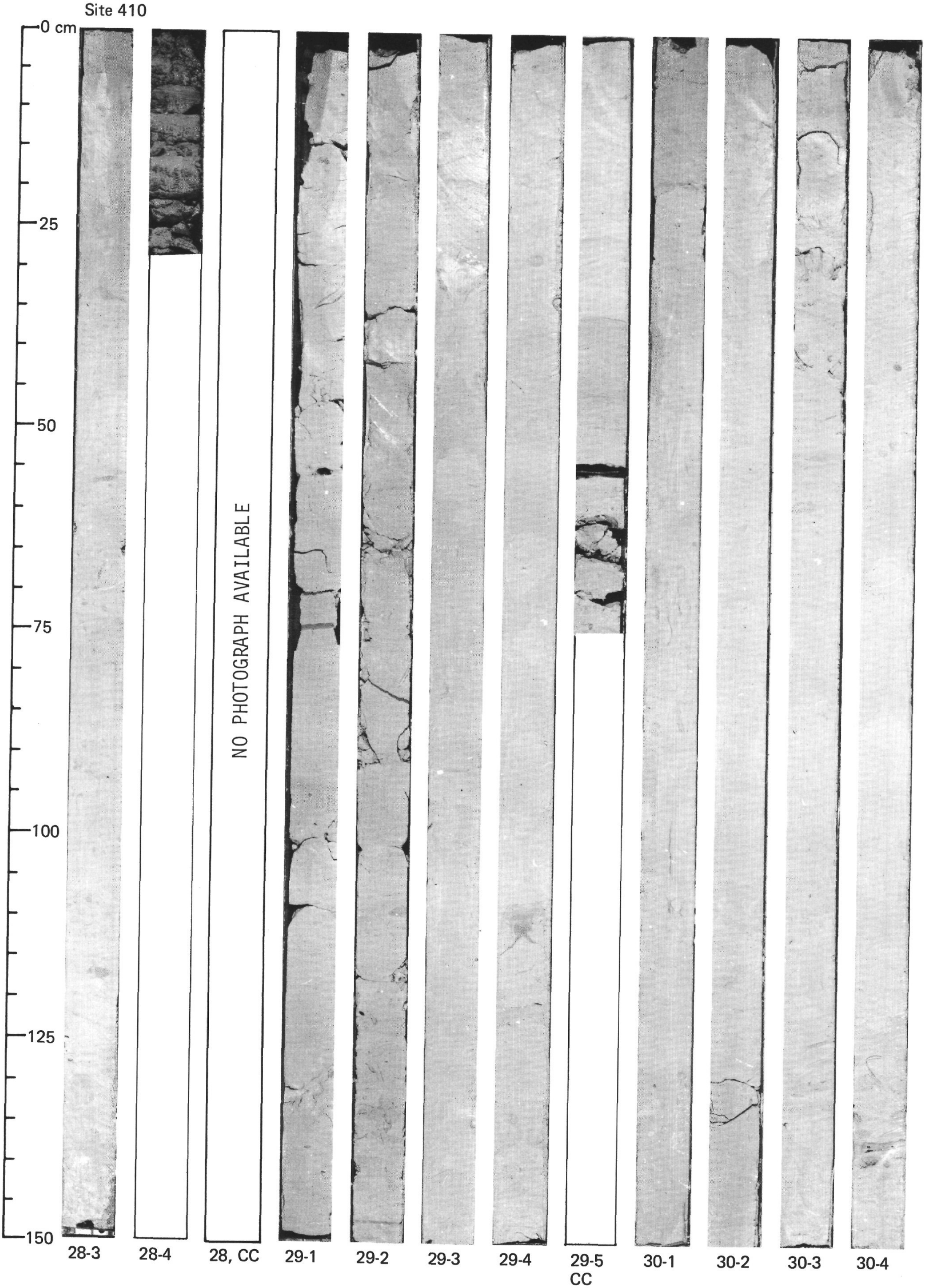
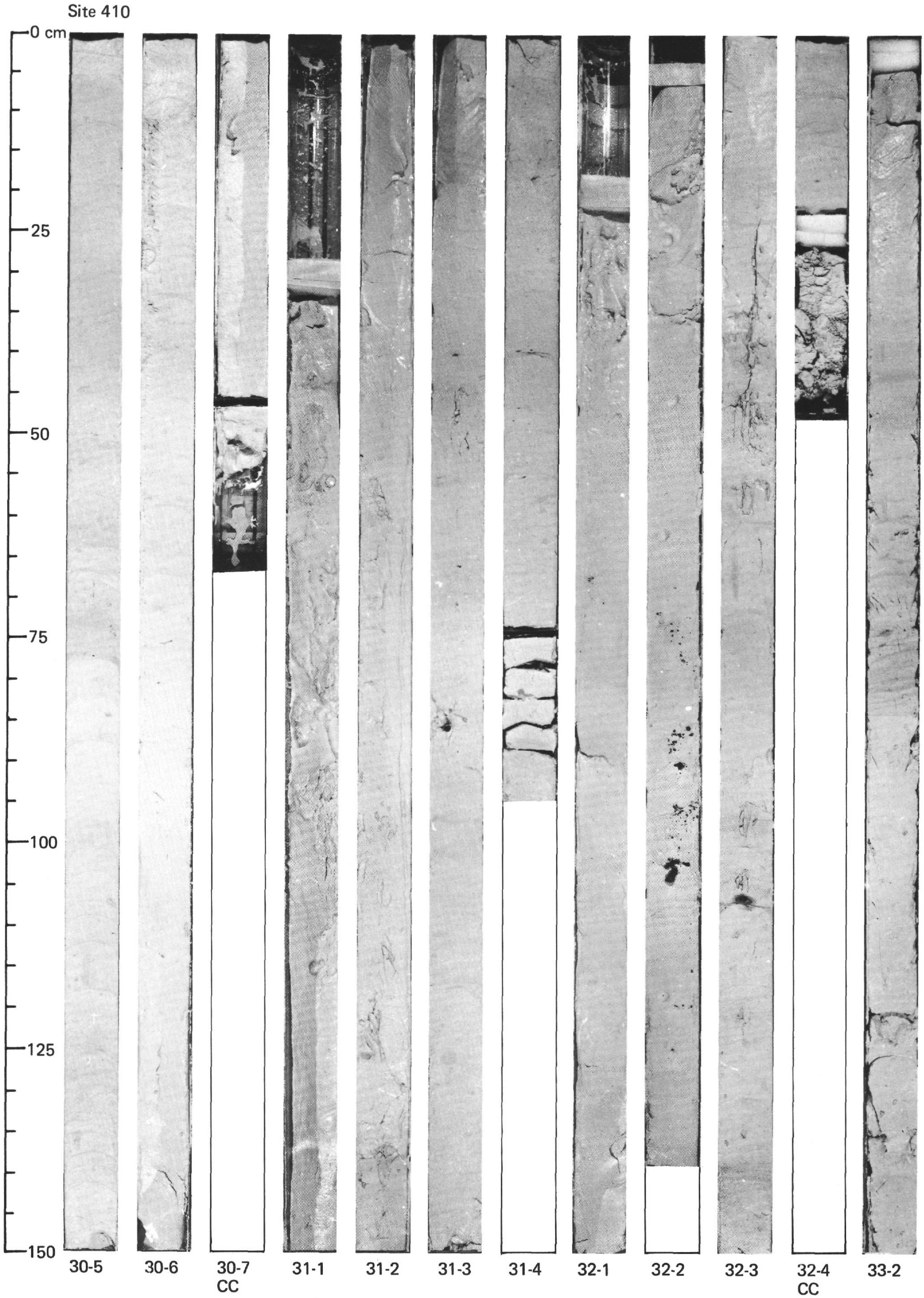
50
75
100
125
150
25-5
25-6
25-7
26-1
26-2
26-3
26, CC
27-1
27-2
27-3
CC
28-1
28-2


Site 410
0 cm
25
50
75
100
125
150
NO PHOTOGRAPH AVAILABLE
28-3
28-4
28, CC
29-1
29-2
29-3
29-4
29-5
CC
30-1
30-2
30-3
30-4


Site 410
0 cm
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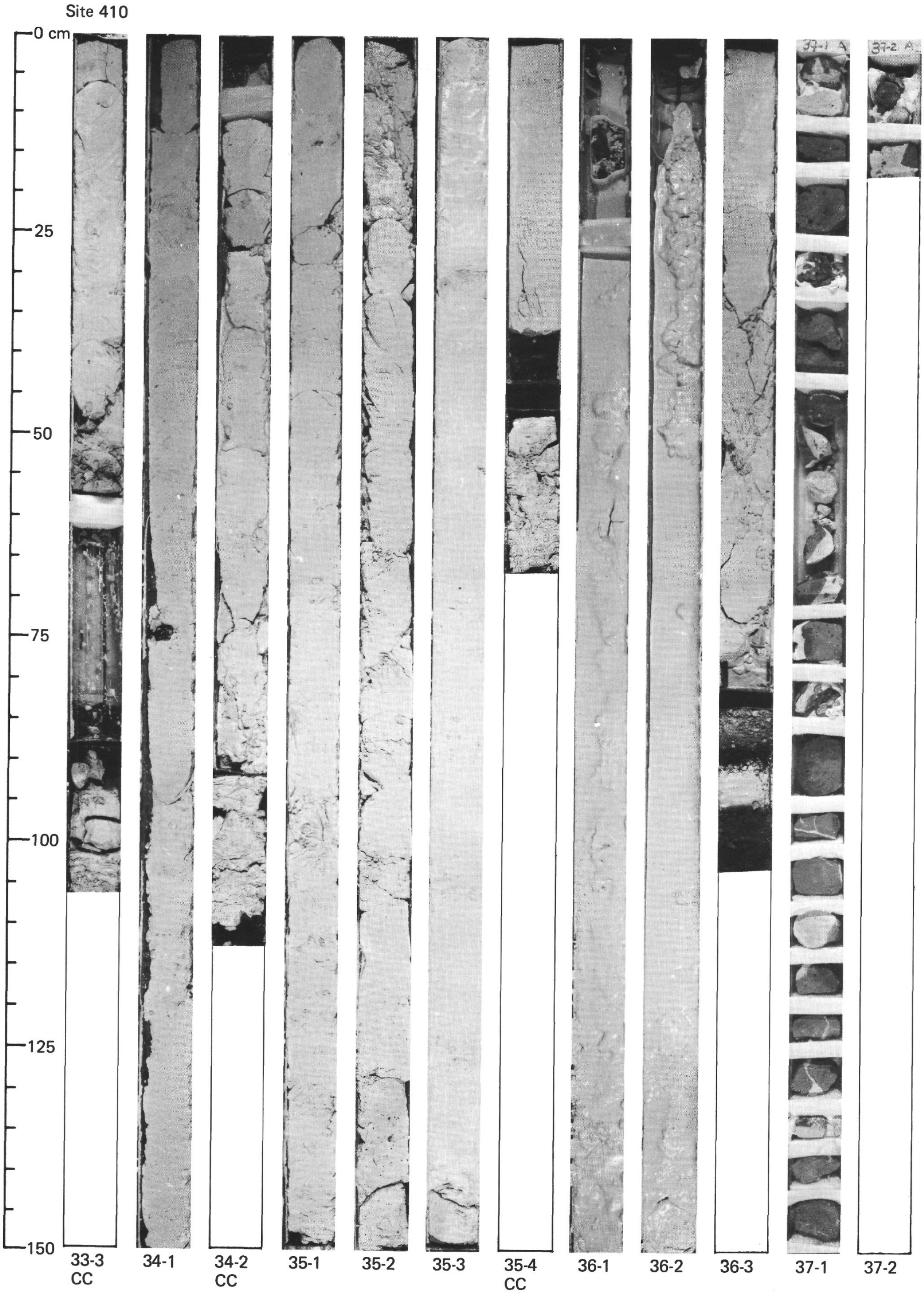
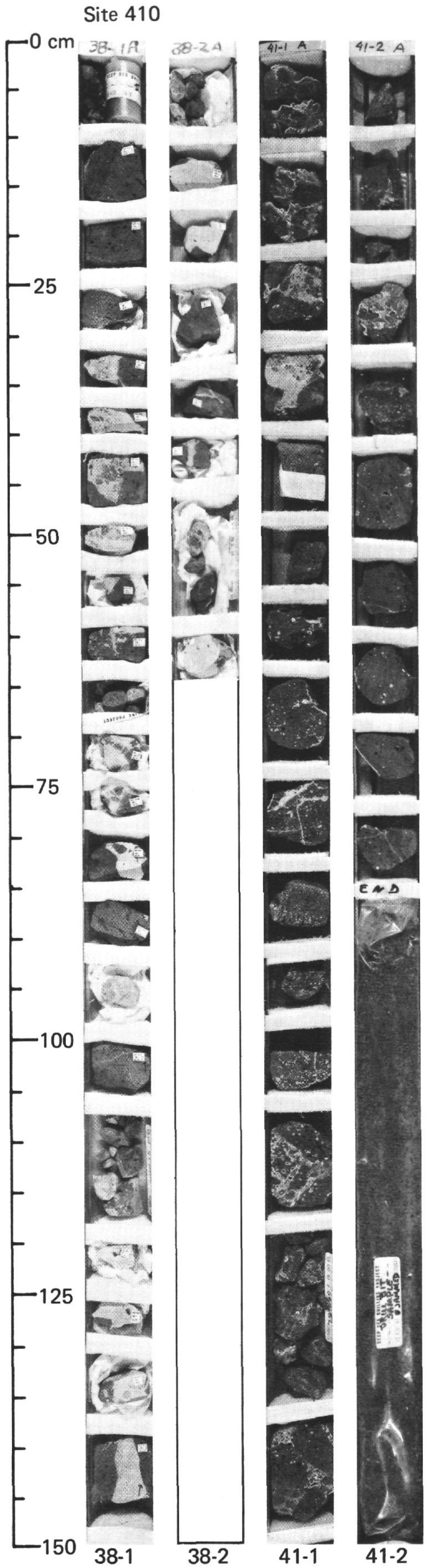
75
100
125
150
30-5
30-6
30-7
CC
31-1
31-2
31-3
31-4
32-1
32-2
32-3
32-4
CC
33-2


Site 410
0 cm
25
50
75
100
125
150
33-3
CC
34-1
34-2
CC
35-1
35-2
35-3
35-4
CC
36-1
36-2
36-3
37-1
37-2


Site 410
0 cm
25
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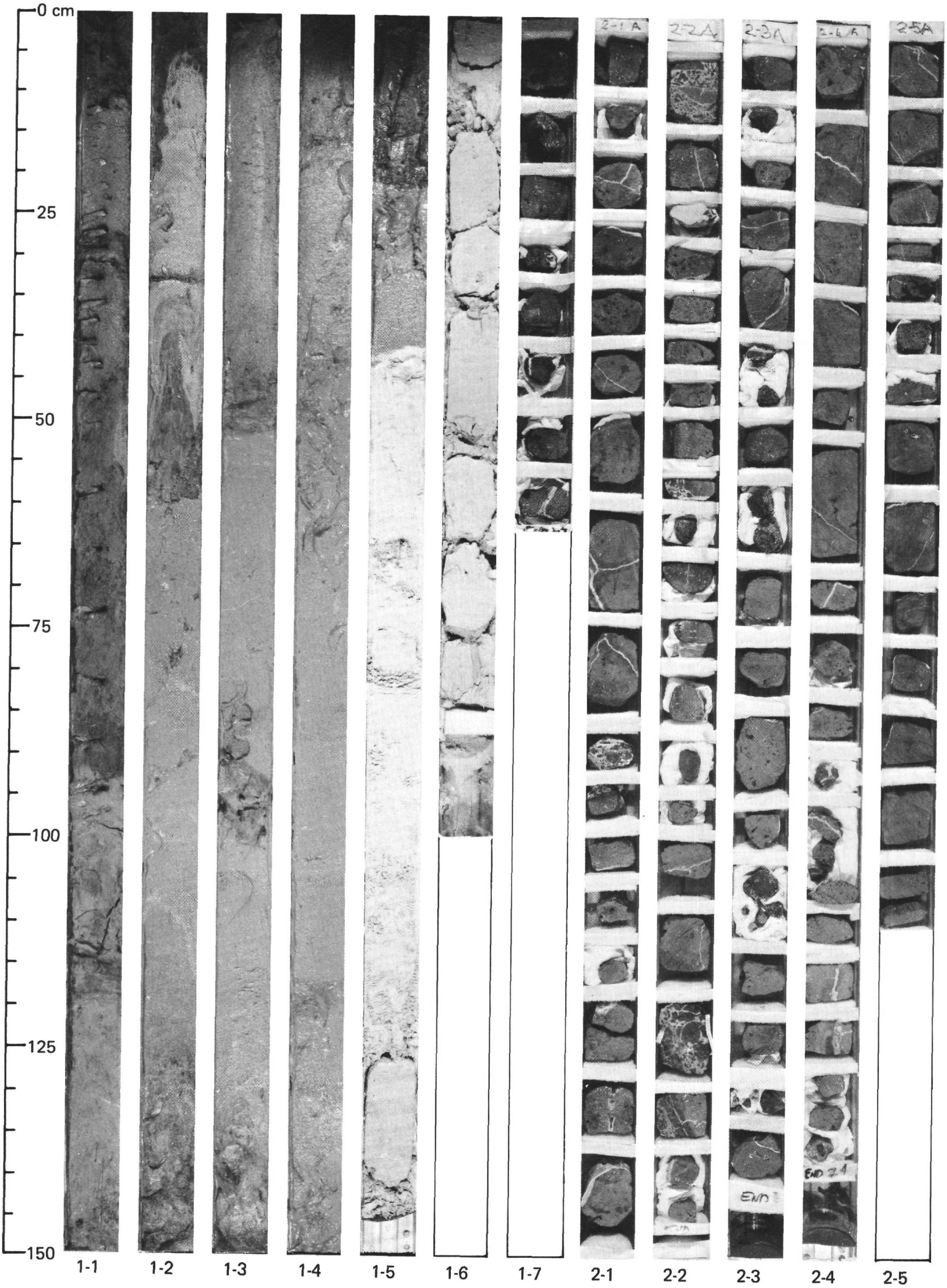
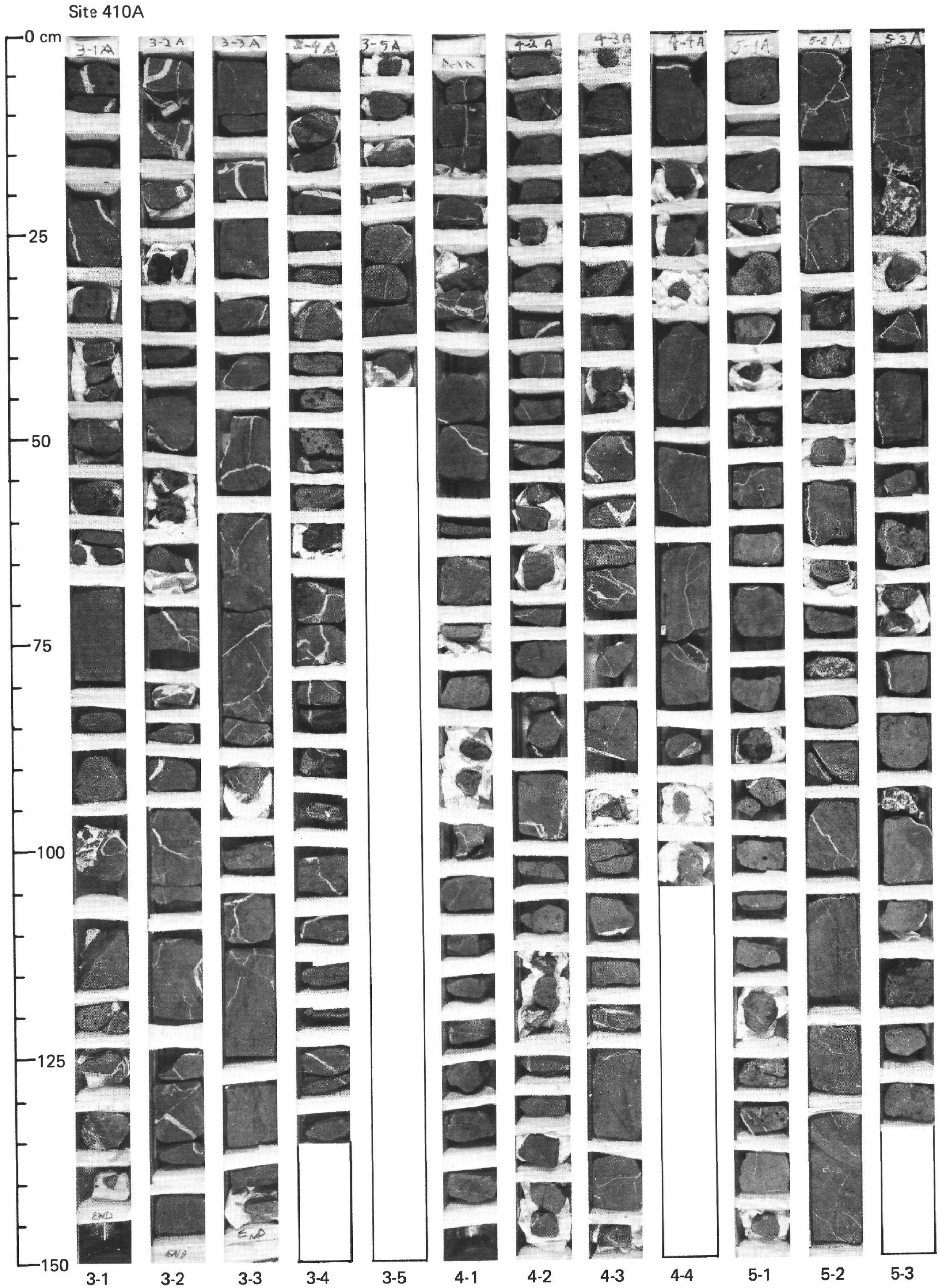
75
100
125
150
38-1
38-2
41-1
41-2

Site 410A




Site 410A
0 cm
25
50
75
100
125
150
3-1
3-2
3-3
3-4
3-5
4-1
4-2
4-3
4-4
5-1
5-2
5-3

Site 410A