The descriptions of sites, cores, and data included in these site reports were completed within one year of the cruise, but many of the topical chapters that follow were completed at a later date. More data were acquired and authors' interpretations matured during this interval, so readers may find some discrepancies between site reports and topical papers. The timely publication of the *Initial Reports* series, which is intended to report the early results of each leg, precludes incurring the delays that would allow the site reports to be revised at a later stage of production.

2. SITE 603[1]

Shipboard Scientific Party[2]

HOLE 603

Date occupied: Beacon drop 0411 hr., 5 May 1983

Date departed: Bit on deck 0450 hr., 11 May 1983

Time on hole: 6 days, 49 min.

Position: 35°29.66′N; 70°01.70′W

Water depth (sea level; corrected m, echo-sounding): 4633

Water depth (rig floor; corrected m, echo-sounding): 4643

Bottom felt (m, drill pipe): 4644

Penetration (m): 832.6

Number of cores: Cored 41; washed 13

Total length of cored section (m): Cored 393.0; washed 439.6

Total core recovered (m): Cored 226.38; washed 90.3

Core recovery (%): Cored only, 58

Oldest sediment cored:
Depth sub-bottom (m): 832.6
Nature: Hemipelagic claystone
Age: early middle Miocene
Measured velocity (km/s): 1.8

Basement: Not reached

Principal results: Hole 603 was drilled as an exploratory hole to test the substrate for reentry and to gather data on the lower continental rise and on late Cenozoic reflection horizons. It was spot- and wash-cored at the top, but the bottom half was nearly continuously cored.

Fair amounts of methane gas with a trace of H_2S were present throughout the section. The consistently low methane/ethane ratios suggest a biogenic rather than thermogenic origin for the gases. Because of this and because of the absence of permeable layers we considered it safe to continue drilling. There was no evidence that gas occurred in clathrate form.

Located just east of the lower continental rise terrace, the hole penetrated 832.6 m of Pleistocene to middle Miocene dark green gray, silty, micaceous, burrowed clays and claystones with a few sporadic, thin, silt turbidites below 700 m. Sedimentation rates (uncorrected for compaction) are estimated to be high, averaging about 51 m/Ma for the entire sequence. Siderite is locally common below 200 m as burrow fills, nodules, and disseminated particles. The rather homogeneous lithologic section can be assigned to the Blake Ridge Formation. It is divided into Subunits IA through IC according to the differing amounts of biogenic components in the sediments.

Subunit IA (Cores 603-1 through -19) is composed of upper Miocene to lower Pleistocene nannofossil-bearing clays and claystones, with significant amounts of quartz and mica, and trace amounts of plant debris. The preservation and abundance of calcareous microfossils decrease downward, and they are almost absent in Subunit IB.

Subunit IB (Cores 603-20 through -41) consists of middle and upper Miocene quartz- and mica-bearing hemipelagic claystones, with sporadic trace amounts of calcareous nannofossils and foraminifers. Subunits IA and IB are faintly banded but do not show discrete bedding or evidence of slumping. The dark clays and claystones are surprisingly lean in organic carbon, which averages about 0.35% in Units IA and IB.

Subunit IC (Cores 603-42 through -54) consists of middle Miocene biogenic-silica-bearing claystones; calcareous microfossils are sporadically preserved, and an agglutinated foraminiferal *Rhabdammina* fauna is present. Subunit IC sediments have rare instances of preserved laminations and in two cores show centimeter-scale Bouma sequences. The organic carbon content is higher in Subunit IC, averaging about 0.5%.

The *Glomar Challenger* seismic profile, recorded on approach to Site 603, clearly shows that the turbidite-built lower continental rise terrace (acoustic Unit 1) is dammed by the crest of the Hatteras outer ridge, which extends eastward as the lower continental rise hills. We dropped the beacon in the first small "valley" immediately next to the lower continental rise terrace, prior to crossing the continental rise hills. The reflection pattern and the fact that we spudded in Pleistocene sediments older than 1.2 Ma suggest that crest and hill growth kept ahead of turbidite accumulation while spillover fines were entrained by the Western Boundary Undercurrent, leaving the southeast face of the crest largely without sediment deposition. Seismic profile *Conrad* 2101-77, on which Site 603 is located, shows that the lower continental rise hills are surface expressions of migrating wave reflector configurations at depth. Apparently, the spillover material accreted on the northwest faces of the hills. We consider the hills to be constructional features formed as large mud waves (antidunes) under the Western Boundary Undercurrent, whereas the ridge crest formed more as a natural levee along its flank. It is important to note that the Hatteras outer ridge continued to grow until at least 1.2 Ma ago, rather than 2.8 Ma as has been previously suggested.

Horizon X, a prominent seismic boundary which in the past has been recognized regionally, was cored at about 750 m and dated by radiolarians as early late Miocene (about 10 Ma, correlative at this site with the TM2.3/TM3.1 standard sequence boundary of Vail et al., 1980). It separates the climbing wave pattern of the Outer Hatteras Ridge (acoustic Unit 2) from a hummocky and parallel pattern below (acoustic Unit 3), and is interpreted as marking the onset of the deposition under the influence of the Western Boundary Undercurrent. Acoustic Unit 3 is considered to consist of distal turbidites (lithostratigraphic Subunit IC).

HOLE 603A

Date occupied: 0450 hr., 11 May 1983

Date departed: 1345 hr., 12 May 1983

[1] van Hinte, J. E., Wise, S. W., Jr., et al., *Init. Repts. DSDP*, 93: Washington (U.S. Govt. Printing Office).

[2] Addresses: Dr. Jan E. van Hinte (Co-Chief Scientist), Instituut voor Aardwetenschappen, Vrije Universiteit, 1007 MC Amsterdam, The Netherlands; Sherwood W. Wise, Jr. (Co-Chief Scientist), Department of Geology, Florida State University, Tallahassee, Florida 32306; Brian N. M. Biart, Department of Earth Sciences, Open University, Milton Keynes MK7 6AA, United Kingdom (present address: Exploration Consultants, Ltd., Highlands Farm, Greys Road, Henley-on-Thames, Oxon RG9 4PS, United Kingdom); James M. Covington, Department of Geology, Florida State University, Tallahassee, Florida 32306 (present address: Texaco USA, P.O. Box 60252, New Orleans, LA 70160); Dean A. Dunn, Deep Sea Drilling Project, La Jolla, CA 92093 (present address: Department of Geology, University of Southern Mississippi, Hattiesburg, Mississippi 39406); Janet A. Haggerty, Department of Geosciences, University of Tulsa, Tulsa, Oklahoma 74104; Mark W. Johns, Department of Oceanography, Texas A&M University, College Station, Texas 77843 (present address: Tetra Tech, Inc., 11820 Northup Way, Suite 100, Bellevue, WA 98005); Philip A. Meyers, Department of Atmospheric and Oceanic Science, University of Michigan, Ann Arbor, Michigan 48109; Michel R. Moullade, Centre de Recherches Micropaléontologiques, Université de Nice, 06034 Nice, Cedex, France; Jay P. Muza, Department of Geology, Florida State University, Tallahassee, Florida 32306; James Ogg, Department of Geology and Geophysics, University of Wyoming, Laramie, Wyoming 82071 (present address: Department of Geosciences, Purdue University, West Lafayette, Indiana 47904); Makoto Okamura, Department of Geology, Kochi University, Kochi City, Kochi Prefecture 780, Japan; Massimo Sarti, Instituto di Geologia, Universitá di Ferrara, 44100 Ferrara, Italy; Ulrich von Rad, Bundesanstalt für Geowissenschaften und Rohstoffe, 3 Hannover 51, Federal Republic of Germany.

Time on hole: 1 day, 9 hr., 55 min.

Position: 35°29.69′N; 70°01.69′W

Water depth (sea level; corrected m, echo-sounding): 4633

Water depth (rig floor; corrected m, echo-sounding): 4643

Bottom felt (m, drill pipe): N/A

Penetration (m): 0.0

Number of cores: 0

Total length of cored section (m): 0.0

Total core recovered (m): 0.0

Core recovery (%): 0

Oldest sediment cored: N/A

Basement: N/A

Principal results: No sediment was recovered during the attempt to establish reentry Hole 603A. Failure of the unlatching mechanism to release the reentry cone from the drill string made it impossible either to emplace or to recover the reentry cone and casing assembly, which were jettisoned to the seafloor about one mile southeast of the drill site.

HOLE 603B

Date occupied: 1345 hr., 12 May 1983

Date departed: 1545 hr., 31 May 1983

Time on hole: 19 days, 2 hr.

Position: 35°29.71′N; 70°01.71′W

Water depth (sea level; corrected m, echo-sounding): 4633

Water depth (rig floor; corrected m, echo-sounding): 4643

Bottom felt (m, drill pipe): 4644 (after casing set)

Penetration (m): 1585.2

Number of cores: Cored 75; washed 8

Total length of cored section (m): Cored 683.60; washed 718.50

Total core recovered (m): Cored 484.44; washed 58.11

Core recovery (%): 71

Oldest sediment cored:
Depth sub-bottom (m): 1576.2
Nature: Limestone
Age: Early Cretaceous (Valanginian)
Measured velocity (km/s): 2.420 km/s vertical; 2.954 km/s (horizontal)

Basement: Not reached

Principal results: Reentry Hole 603B penetrated most of the Cenozoic and Mesozoic section beneath the lower continental rise off Cape Hatteras. This allowed us to identify and date important seismic reflection horizons and to characterize Mesozoic sedimentation along this passive margin at the interface between continental and deep-sea environments. A major discovery was a turbiditic deep-sea fan complex within the Lower Cretaceous.

The hole was terminated at 1576 m, just 200 m short of basement when the drill string parted just below the power sub. Recovery was excellent throughout the section, which was divided into the five lithologic units outlined here (correlations to regional oceanic formations are given in parentheses).

Unit I (Blake Ridge Formation) consists of 960 m of lower Pleistocene to middle (lower?) Miocene hemipelagic silty claystone, dark gray except for a thin, barren, brown clay layer at the base. Reflection Horizon X separates Subunit IC, which contains occasional turbidites, from Unit IB, which marked the beginning of deposition under the influence of the Western Boundary Undercurrent.

Unit I is separated by Reflection Horizon A^u from Unit II (Bermuda Rise Formation). The latter consists of 62 m of lower Eocene to upper Paleocene radiolarian claystone. Middle to upper Eocene units were removed at this site by the Oligocene erosional event which produced Reflector A^u, an erosional surface that cut through to Reflection Horizon A^t and A^c at this location. Unit II correlated with supercycle Ta of Vail et al., 1980. An inverse impedance contrast characterizes Reflection Horizon A*, between Unit II and Unit III.

Unit III, 96 m of Upper Cretaceous (and lower Paleogene?) variegated claystone (Plantagenet Formation), contains turbidites, including black carbonaceous mud turbidites, as do all of the underlying units. It is separated from Unit IV by a truncating reflection horizon, here referred to as Km, and equates with the upper two-thirds of supercycle K of Vail et al., 1980.

Unit IV (Hatteras Formation) consists of 96 m of mid-Cretaceous (Aptian–Turonian) black carbonaceous claystones, mostly emplaced as mud turbidites.

Unit V is composed of 362 m of Berriasian–Aptian interbedded nannofossil claystone and limestone with sandstone and claystone turbidites. Coarse terrigenous sands, largely unconsolidated, are the preponderant lithology at the top of Unit V, between 1224 and 1252 m. Their base correlates with Reflection Horizon β. Sandstone turbidites compose 47% of the section over a 218-m interval in Subunit VA. The deep-sea fan complex was deposited in conjunction with a major progradation of terrestrial deltas across the adjacent continental shelf. These occurred despite the once-presumed existence of extensive shelf-edge reef or carbonate-bank complexes, a presumption which should be re-examined in light of the new data from Hole 603B. The top sandstones of Unit V together with Unit IV are correlated with cycle K1.3, all the rest of Subunit VA with cycle K1.2, and Subunit VB with cycle K1.1 of Vail et al. (1980).

HOLE 603C

Date occupied: 1545 hr., 31 May 1983

Date departed: 2330 hr., 6 June 1983

Time on hole: 5 days, 7 hr., 15 min.

Position: 35°29.78′N; 70°01.86′W

Water depth (sea level; corrected m, echo-sounding): 4643

Water depth (rig floor; corrected m, echo-sounding): 4653

Bottom felt (m, drill pipe): 4649.5

Penetration (m): 366.0

Number of cores: 40 (12 HPC, 28 XCB)

Total length of cored section (m): 366.0

Total core recovered (m): 314.44

Core recovery (%): 86

Oldest sediment cored:
Depth sub-bottom (m): 366.0
Nature: Hemipelagic clay
Age: late Miocene–early Pliocene
Measured velocity (km/s): 1.592

Basement: Not reached

Principal results: The upper portion of lithologic Unit I, which was spot- and wash-cored in Hole 603, was continuously cored in Hole 603C using the hydraulic piston corer (HPC) down to 91 m, and thence using the extended core barrel (XCB) down to 366 m. This considerably improved the stratigraphic record for lithologic Subunit IA (nannofossil-bearing to nannofossil-rich clay and claystone). The lower Pleistocene was found to extend down to 30 m, and all four subzones of the nannofossil *Discoaster brouweri* Zone could be recognized. A discrepancy was noted in the position of the Miocene/Pliocene boundary located by certain calcareous nannofossils and by planktonic foraminifers, respectively. We suspect that sedimentation rates during the Messinian at this site were exceptionally high, so that slight differences in the calibration of the Miocene/Pliocene boundary between these two microfossil groups may have been considerably magnified here. The shore-based paleomagnetic record provides a more refined calibration for this boundary.

INTRODUCTION

Site 603 was initially occupied on Leg 93, which drilled Holes 603 to 603C. Failure to achieve the objectives of sampling Jurassic strata and the underlying oceanic basement on Leg 93 led to the reoccupation of this site on Leg 93, when Holes 603D to 603F were drilled in an unsuccessful attempt to complete drilling through the Jurassic section. Weather conditions at 603D and bit failures at 603E and 603F prevented drilling of these holes below 1585.2 m, the total depth of Hole 603B, so that no significant scientific results were gained by Leg 95 drilling efforts at Site 603. A discussion of the Leg 95 results of drilling Holes 603D to 603F follows the Leg 93 results for Holes 603 to 603C.

BACKGROUND AND OBJECTIVES

Background

It is now recognized that a single, carefully placed hole in the North American Basin can sample a nearly complete section, dating from shortly after the initial opening of the Atlantic to the present. Such a section should record the response of the basin to enlargement and deepening through seafloor spreading and crustal cooling, to the influx of sediments from the crest, and to the major current reorganization which took place during the Oligocene. Hoping for such results, the JOIDES Passive Margin Panel recommended that a hole be drilled to Jurassic basement in deep water near the western edge of the basin, if a site could be identified in which the youngest Jurassic reflector, J_1, and the underlying basement were within reach of the *Challenger*'s 6800-m drill string.

Site 603 is located about 435 km east of Cape Hatteras, in 4633 m of water, near the western edge of the Hatteras Abyssal Plain of the North American Basin (Fig. 1). The site occupies a position on the Hatteras outer ridge (Rona et al., 1967), just off the continental rise terrace in the first valley of the continental rise hills (Figs. 2, 3) at the distal end of the "New Jersey Transect." The location was selected after an extensive multichannel survey by *Knorr* in 1980, on multichannel seismic profile *Conrad* 2101-77. The profile shows a 10-km-

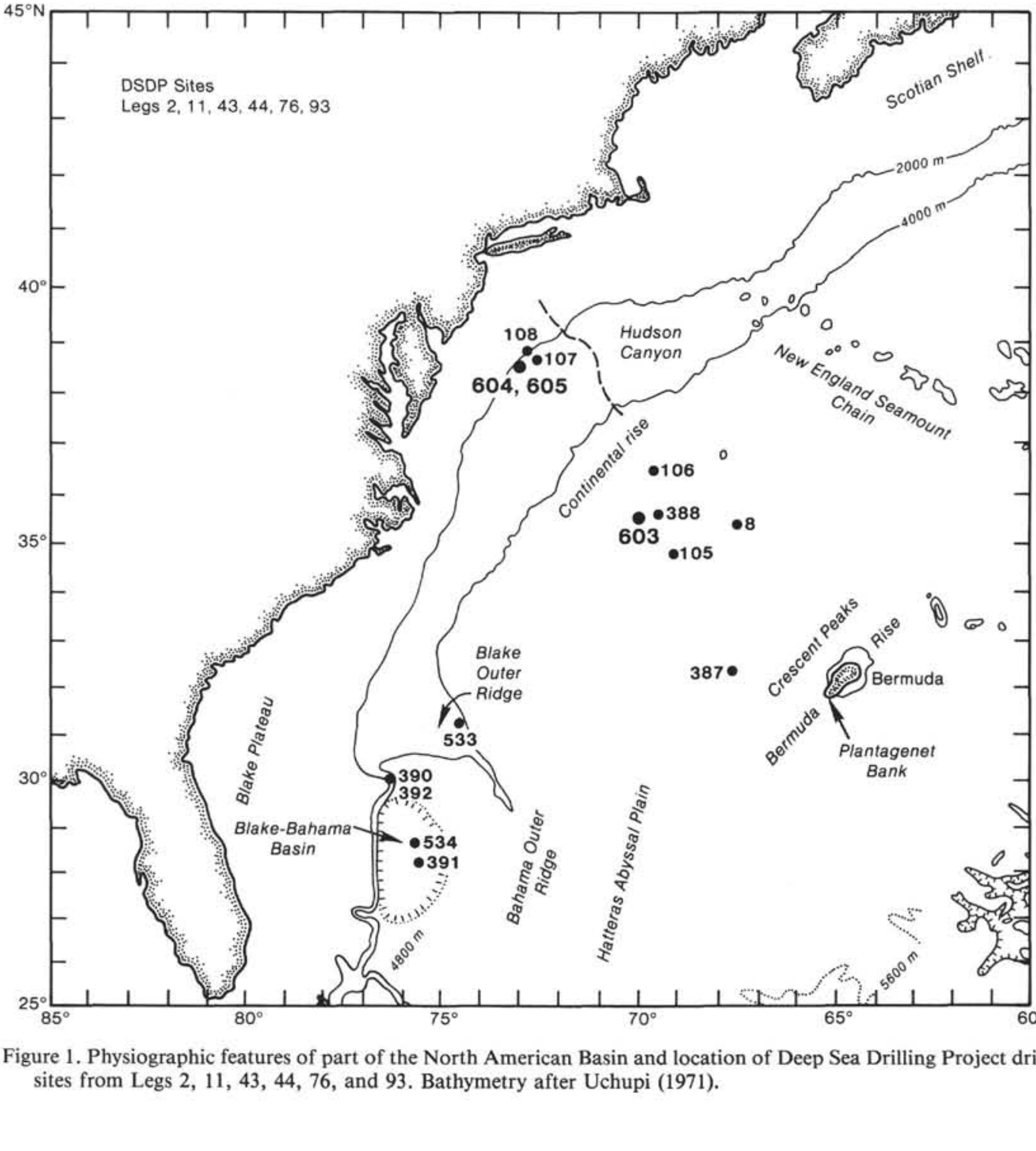

Figure 1. Physiographic features of part of the North American Basin and location of Deep Sea Drilling Project drill sites from Legs 2, 11, 43, 44, 76, and 93. Bathymetry after Uchupi (1971).

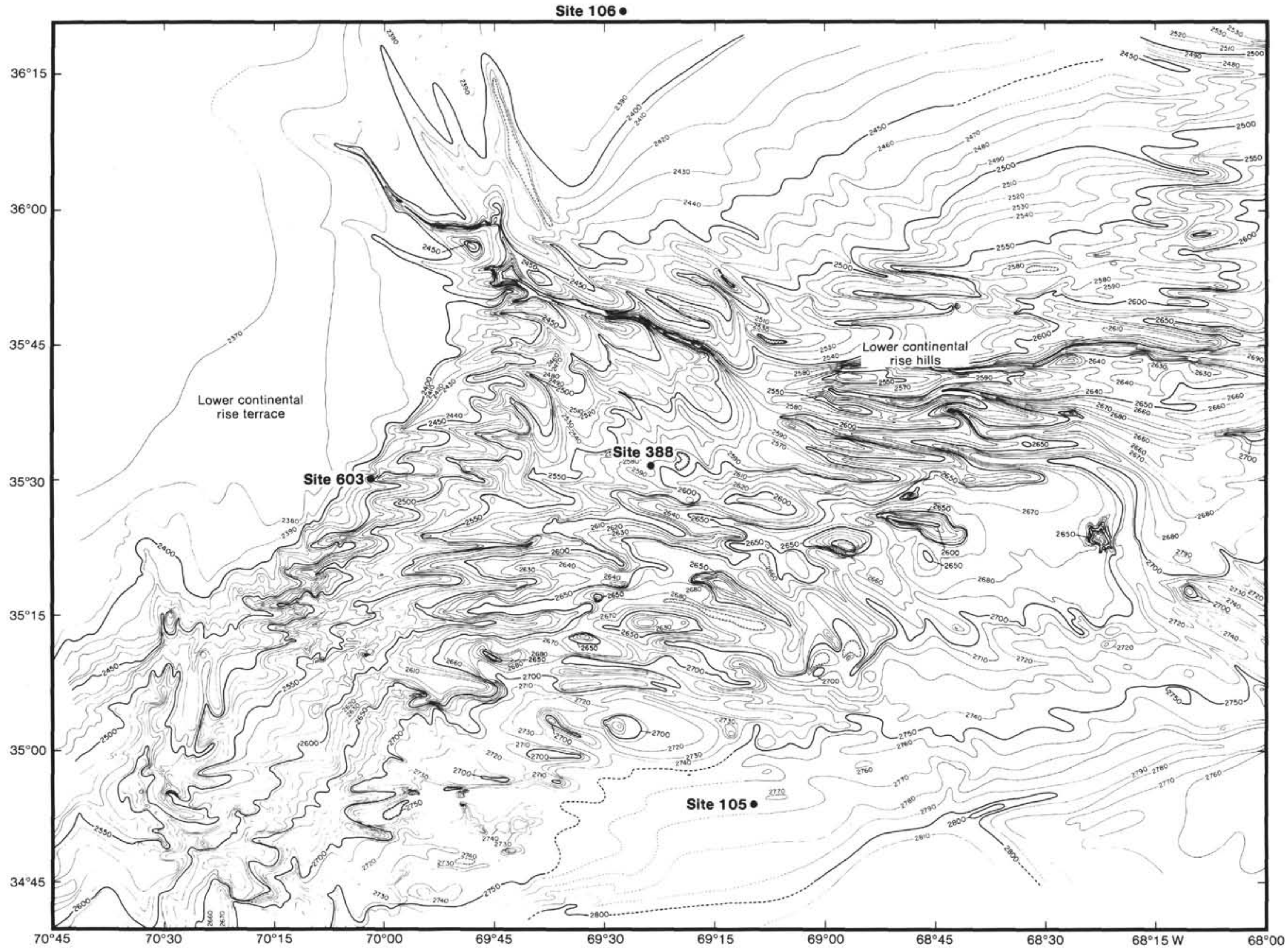

Figure 2. Bathymetric map from Asquith (1979) showing location of Site 603 along boundary between the lower continental rise terrace and the lower continental rise hills. Also shown are locations of previous DSDP sites in the area.

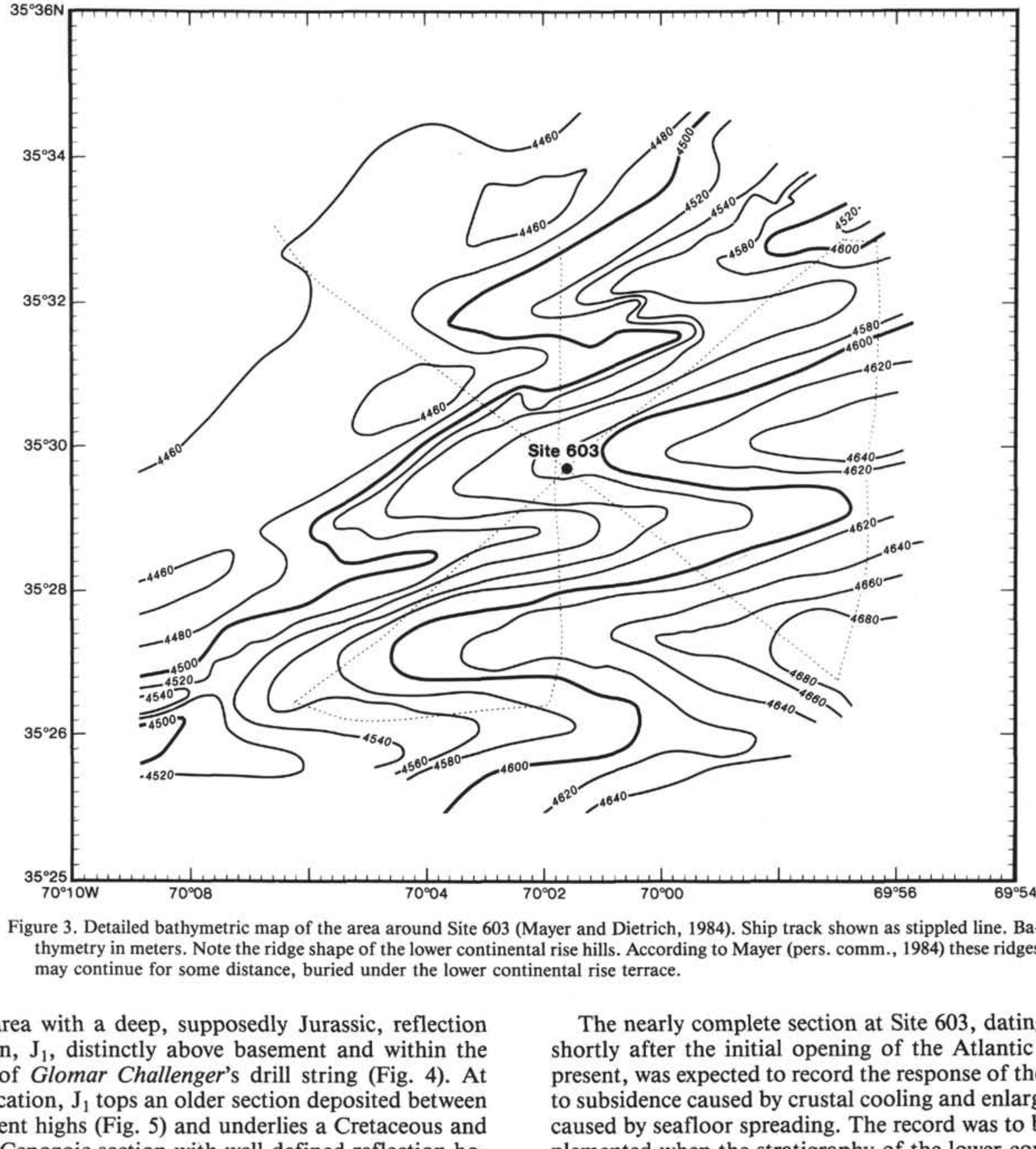

Figure 3. Detailed bathymetric map of the area around Site 603 (Mayer and Dietrich, 1984). Ship track shown as stippled line. Bathymetry in meters. Note the ridge shape of the lower continental rise hills. According to Mayer (pers. comm., 1984) these ridges may continue for some distance, buried under the lower continental rise terrace.

wide area with a deep, supposedly Jurassic, reflection horizon, J_1, distinctly above basement and within the reach of *Glomar Challenger*'s drill string (Fig. 4). At this location, J_1 tops an older section deposited between basement highs (Fig. 5) and underlies a Cretaceous and upper Cenozoic section with well-defined reflection horizons that can be traced across much of the basin and beyond.

The site is located in the "Jurassic magnetic quiet zone" about 80 km west of magnetic Anomaly 25. The age of basement here can be estimated by westward extrapolation of the magnetic anomaly pattern, assuming a constant spreading rate. The age of the crust is 151.35 Ma, or 1.35 Ma before the end of the Callovian, if the scale of Van Hinte (1976a) is used, and 157.20 Ma, or 2.20 Ma before the end of the Callovian using the Cande et al. (1978) scale, which places Site 603 on their Anomaly M29. Ogg and Steiner (in press) place M25 at the Oxfordian/Kimmeridgian boundary, which is younger than on the other scales and implies an early Oxfordian age for the oceanic basement.

The nearly complete section at Site 603, dating from shortly after the initial opening of the Atlantic to the present, was expected to record the response of the basin to subsidence caused by crustal cooling and enlargement caused by seafloor spreading. The record was to be supplemented when the stratigraphy of the lower continental rise Site 603 could be compared with the results of drilling a series of holes on the upper continental rise in the vicinity of DSDP Sites 107 and 108: the New Jersey Transect. Further, the information on the continental rise can be integrated with published knowledge of the U.S. eastern coastal plain, continental shelf, and continental margin to complete the geohistoric picture of a passive continental margin.

Successful drilling at Site 603 and the New Jersey Transect was expected to allow us to determine the age and nature of unconformities or their conformable extension toward the basin. It was expected to delineate not only important events in margin history but also sequence boundaries, thus calibrating the seismostratigraphic framework for practical purposes.

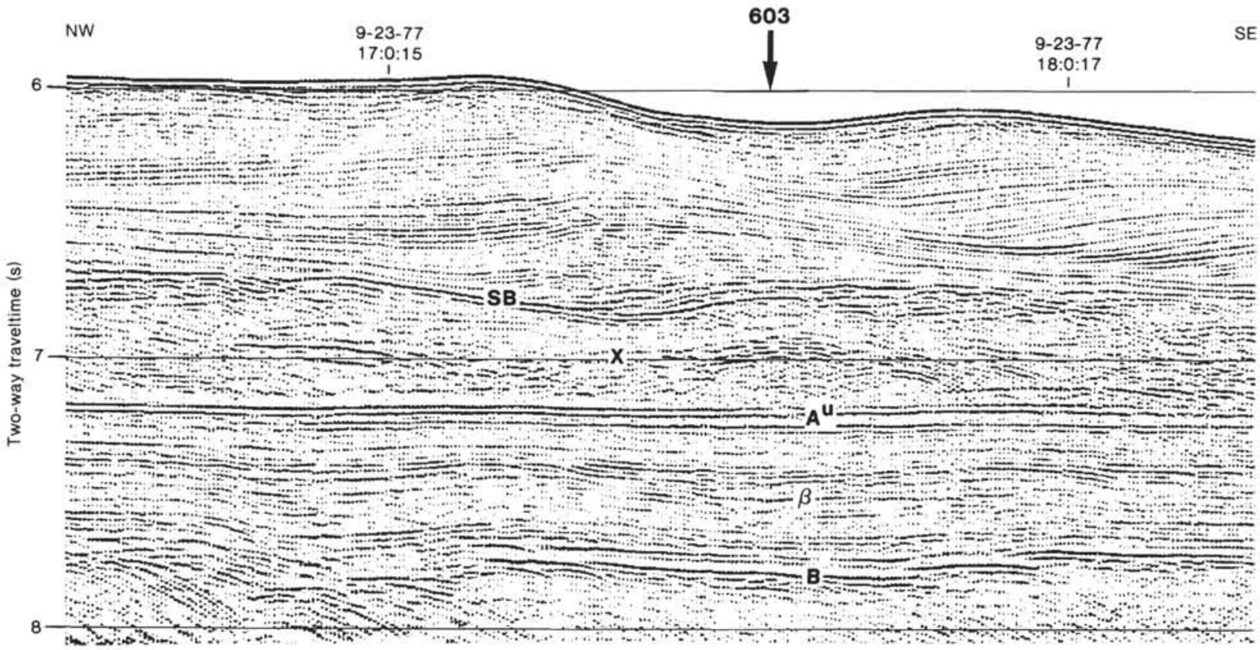

Figure 4. A. Portion of seismic profile *Conrad* 2101-77 showing location of Site 603. For location of seismic line, see Figure 6. SB, X, A^u, β, and B are prominent reflectors identified by Tulcholke et al. (1982).

The location of Site 603 is unique, in the sense that its depositional history has been influenced by coastal events as well as by oceanic events. For instance, changes in sea level that strongly influenced the shallow-marine realm have had an effect on continental rise sedimentation, but so have changes in deep ocean circulation such as the initiation of massive overflow of Norwegian Sea water into the Atlantic. It was hoped that good recovery of the sedimentary record at Site 603 would make it possible to correlate the different realms and to contribute significantly to an integrated geologic history. It was also expected to provide material for improving paleobathymetric interpretation and biostratigraphic correlation across facies boundaries as well as for studies of the evolution of microfossils and microfacies.

Objectives

The principal objectives of drilling at Site 603 (ENA-3), as set forth by the Passive Margin Panel, were to:

1. Identify and sample prominent seismic reflectors and sequence boundaries in the Cretaceous and Cenozoic sedimentary section (β, A*, A^u, and X) and to determine their age and nature;
2. Sample as much of the upper sedimentary section as possible with the HPC in order to understand the active, current-controlled depositional processes which predominated in the area throughout much of the Neogene;
3. Determine the age and nature of Reflection Horizon J_1;
4. Determine the age, nature, and depositional environment of the oldest sediment deposited on oceanic crust at a location landward of Site 105 and not situated on a basement high.

Achievement of the first objective would test two hypotheses. The first one, that of Vail et al. (1980), states that deep-sea reflection horizons are chronostratigraphic boundaries that correlate with eustatic seismic-sequence boundaries on the continental shelf and slope. The second, that of Tucholke (1981), states that deep-sea reflection horizons are caused by impedance contrasts at lithologic boundaries that relate to surface and bottom circulation, productivity patterns, and the position and attitude of the CCD. Such boundaries may or may not have chronostratigraphic significance: "Depth dependent lithologic boundaries (e.g., CCD dependent) are likely to be diachronous in seafloor regions with significant paleoslope" (Tucholke, 1981, p. 35). Tucholke also remarks that "a consistent relationship between sea level lowstands and intensified abyssal circulation (and unconformities) as suggested by Vail, et al. (1980) has not been observed in the deep basin" (Tucholke, 1981, p. 35).

The following considerations also counted as strong arguments in favor of drilling Site 603 (ENA-3).

1. Achievement of the second objective was expected to yield a continuous, high-resolution upper Cenozoic section, with high sediment accumulation rates, that would facilitate detailed correlation of fossil zones, magnetostratigraphy, and stable isotope stratigraphy. This would improve the resolution of the time scale and accurately date paleoceanographic events in the western North Atlantic, such as the onset of deposition caused by the Western Boundary Undercurrent.
2. Successful, continuous coring to Jurassic (Callovian) basement would provide an undisturbed, complete mid-Cretaceous to Upper Jurassic section. The Cretaceous portion of this profile should contain the record of changing ocean modes, and an important drilling objective was to recover alternating carbon-rich and other beds to sample for organic and inorganic geochemical analysis (see Schlanger and Cita, 1982; de Boer, 1983).

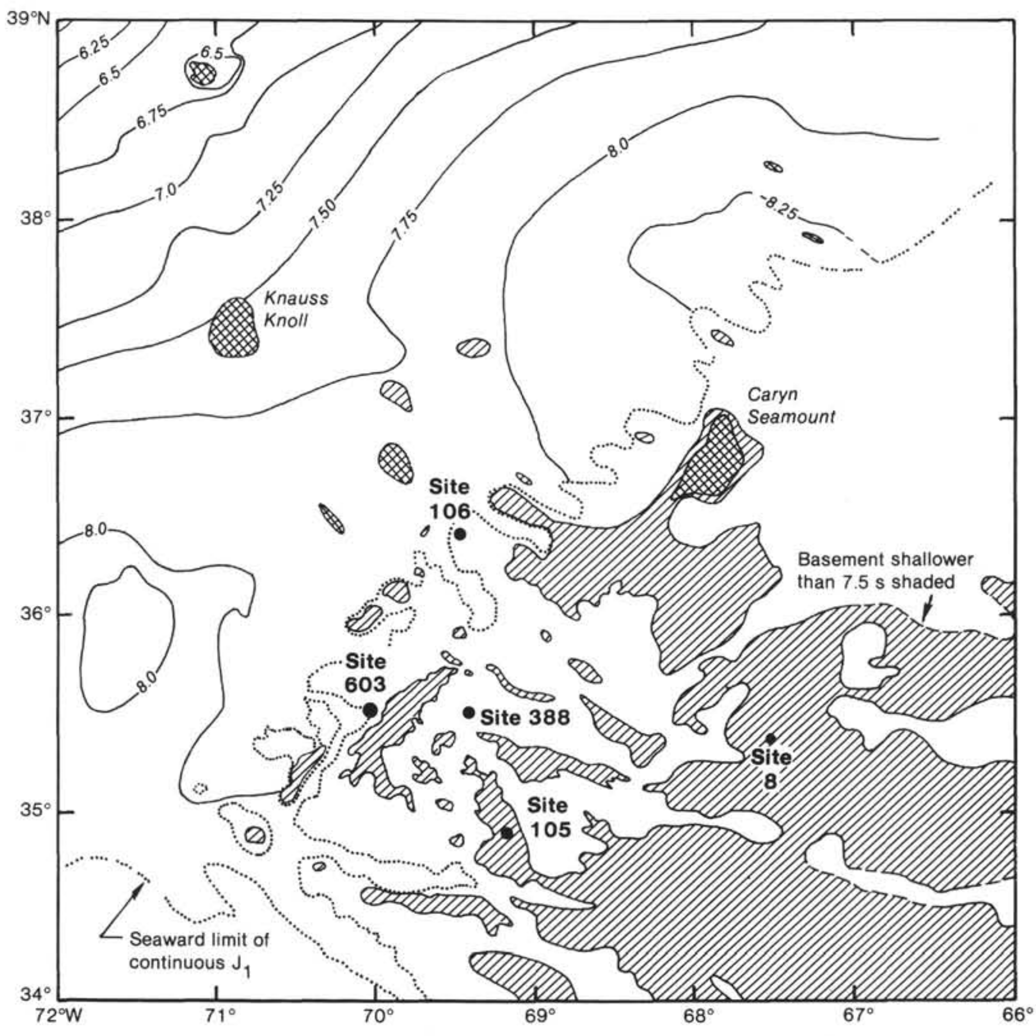

Figure 5. Location of Site 603 with respect to basement highs (hachured) and seaward limit of J_1 reflector. Numbers indicate depths to Horizon J_1 in seconds (two-way traveltime) below sea level. From Tucholke et al., 1982.

3. The Neocomian–Jurassic section at Site 603 would be especially valuable, for oceanic sediments of that age exposed on land are almost always tectonically disturbed and have an imperfectly preserved remanent magnetic signal. Offshore, the older Cretaceous and Jurassic had previously been drilled by DSDP at very few locations, mostly on basement highs where the record is likely to be incomplete. At Site 603 the Neocomian–Jurassic was expected to be deposited above the CCD and to be well suited for tying biostratigraphic results to the magnetic polarity reversal stratigraphy, an essential step in the construction of a Mesozoic time scale (van Hinte, 1976a, b). The Site 603 data were expected to complement and substantiate recent geomagnetic results obtained ashore (Ogg and Steiner, in press; Channell et al., 1982) and at DSDP Site 534 (Ogg, 1983).

4. The Mesozoic at Site 603 was also expected to contain a well-preserved record of rhythmic oceanic sedimentation, a subject of high interest (Schwarzacher and Fischer, 1982).

5. Finally, there was general interest in evaluating the sediments of the lower continental rise as a hydrocarbon source and for its reservoir potential (Jansa and Macqueen, 1978; Mattick et al., 1978). Certainly, at Site 603 the section would be immature, but elsewhere similar sediments might occur at greater burial depth.

OPERATIONS

Following a six-day port call, *Glomar Challenger* left Norfolk, Virginia, at 1456 hr. on 3 May and proceeded on an east–southeasterly course over the continental shelf toward Site 603 (ENA-3D). This site was the primary objective of the leg and is located about 434 km east of Cape Hatteras, North Carolina, and 499 km northwest of Bermuda. Speed averaged about 9 knots through reasonably good seas and weather. Geophysical gear was streamed at 0700 hr. on 4 May.

During the 531-km transit, speed was adjusted so that we could take advantage of scheduled satellite fixes during the final approach to the site. Within 39 km of the site, the vessel was slowed to about 7 knots and, 8 km later, course was adjusted slightly to retrace a reference seismic profile (*Conrad* 2101-77, see Fig. 6), approaching from the northwest. Two satellite fixes were recorded during the approach, with a third coming just as a 16-kHz double-life acoustic beacon was dropped while

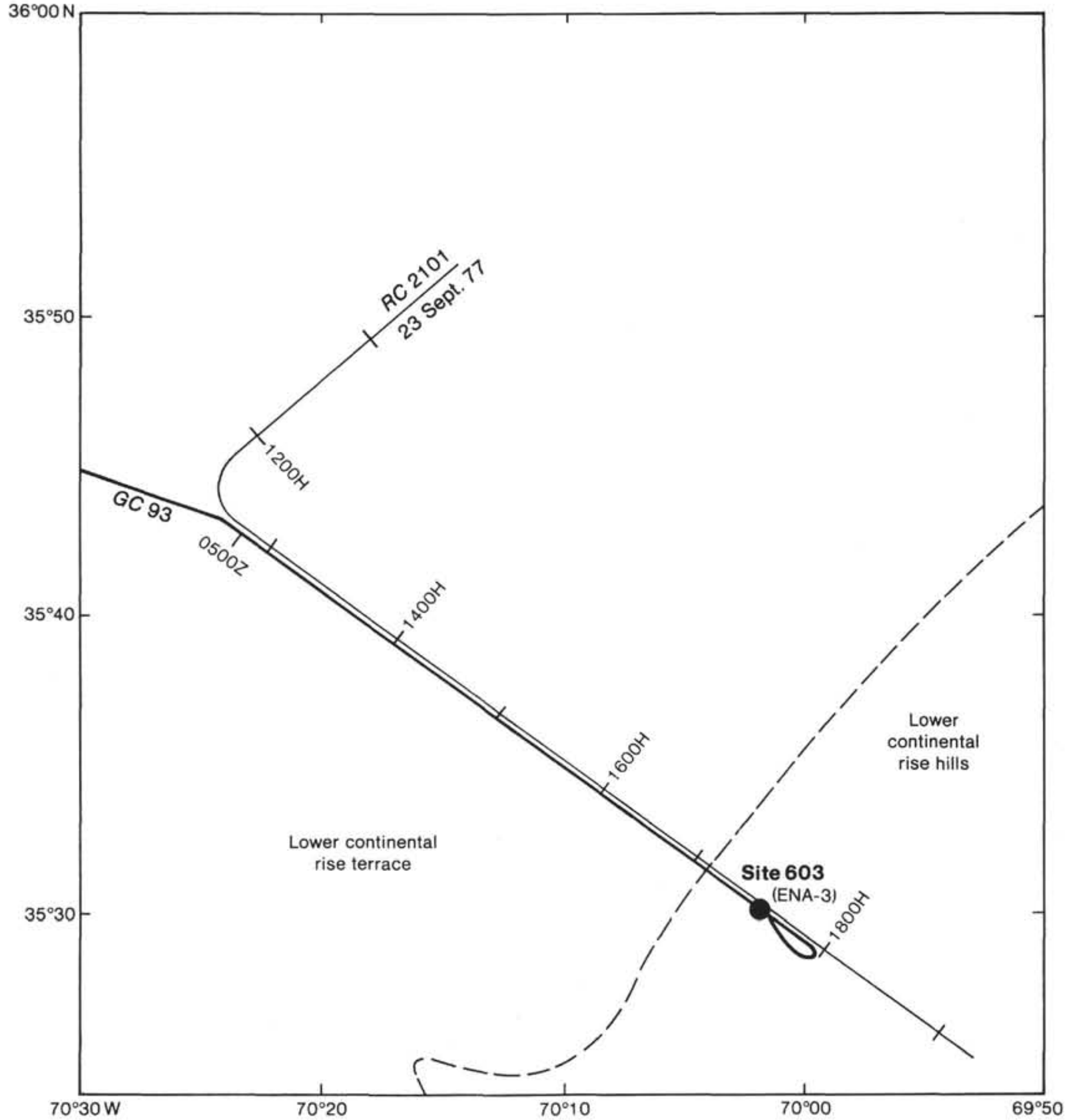

Figure 6. Cruise track of *Glomar Challenger* during Leg 93 (*GC* 93), retracing previous seismic profile *Conrad* 2101-77. Location of Site 603 is shown, at the landward edge of the lower continental rise hills. Dotted line shows location of the Hatteras outer ridge crest, which marks the edge of the lower continental rise terrace.

the vessel passed over the site for the first time at 0411 hr., 5 May. *Challenger* continued on course 3 km, extending her seismic profile in order to confirm the site position, which had been targeted within the first trough beyond the eastern margin of the lower continental terrace, just at the beginning of the "badlands" of the lower continental rise hills (Figs. 2 and 7). Both the A^u and J_1 reflectors were noted on the *Challenger* seismic profile across the site (Fig. 7).

Upon retrieving the geophysical gear and bringing the ship back on station, we determined from bottom topography and satellite fixes that the beacon had drifted 0.5 km south during its hour-long descent to the bottom. The ship, therefore, was offset an appropriate distance from the beacon prior to spudding the first hole of the reentry series. The coring strategy called for an exploratory hole to be washed and spot-cored through Cenozoic sediments down to about 550 m, then continuously cored to about 700 m. Next, the reentry cone and casing would be set in an offset hole, which would then be cored continuously from the top of the Mesozoic section down to basement. Last, if time remaining permitted, a third hole would be cored continuously down from the mudline to recover the upper Cenozoic section using the HPC and XCB.

Hole 603

Exploratory Hole 603 was spudded at 2021 hr. on 5 May in 4633 m of water (PDR depth corrected to surface; 4643 m PDR depth corrected to rig floor). Site position was 35°29.66′N, 70°01.70′W. A seafloor punch core was attempted in order to ascertain the water depth by measured drill string. The core barrel, however, returned full, so one joint of pipe was removed from the string and a second mudline core (to 4643.3 m) was attempted. The second try resulted in a water core (no

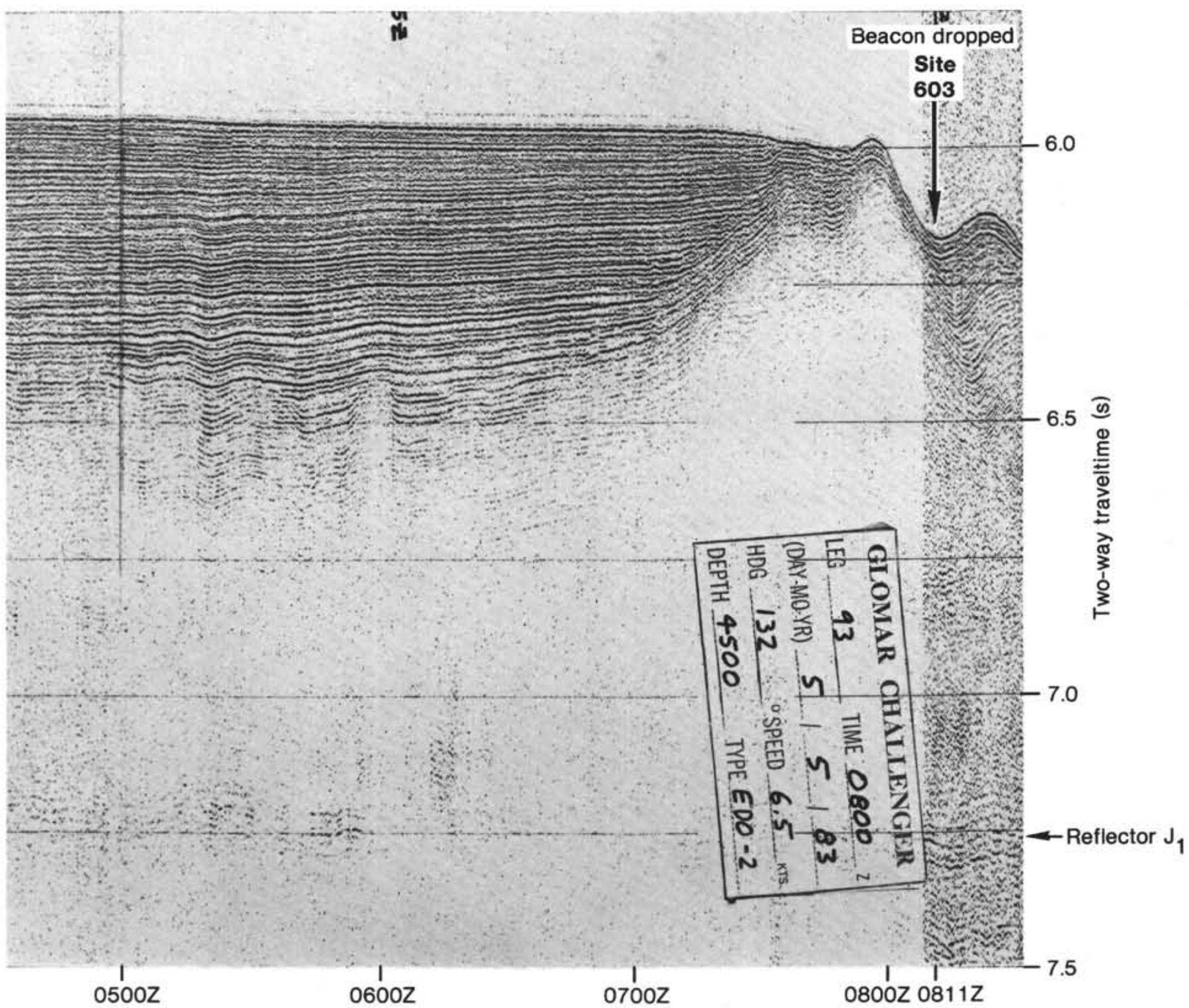

Figure 7. *Glomar Challenger* seismic profile *GC* 93 and position of Site 603. Note that reflector J_1 is apparent at the location of Site 603. For location of line *GC* 93, see Figure 6.

trace of sediment) which indicated that the mudline lay just at the top of the first core, and this value (4644 m) was taken for the water depth at which the drill string felt bottom. The soft sediment had produced no deflection of the weight indicator.

A core barrel was reinserted in the string and the drilling crew proceeded with a jet-in test to determine the casing point for the 16-in. conductor string which would support the reentry cone assembly. The bit was jetted without rotation to about 76 m below seafloor (BSF) before firm resistance was felt. The core barrel was retrieved with 7.02 m of sediment accumulated from the interval of the wash run; this was designated a "wash core." Following a suggestion from the Data Processing Section of DSDP, the shipboard party decided to retain all wash cores and to number them in sequence with the fixed-interval drill cores. Wash cores were distinguished by an "M" (for "miscellaneous") following the core number (Table 1).

An instrumented probe for temperature data and *in situ* pore water samples was then run into the hole. No heat flow reading was obtained, however, probably because the instrumented core barrel did not latch down properly.

The hole was then drilled through clay and soft claystone to 573.4 m BSF, with spot and wash cores taken at intervals not greater than 48 m for stratigraphic control and hydrocarbon safety. The sediments contained considerable amounts of methane. Spaced through this interval were four additional heat flow-interstitial water probe runs taken after fixed-interval cores. Valid temperature measurements were obtained at 131.8, 179.8, 227.8 and 323.8 m. The rather impermeable sediments at these levels yielded only meager pore-water samples.

Minor hole problems occurred on two occasions during this interval. They were attributed to the adherence of sticky clay to the bottom-hole assembly (BHA). After poor recovery in Core 27, the next core barrel failed to reach its position at the bit and the drill string was raised a short distance while a center bit was pumped down to clear the bit throat. After a core barrel was reinserted, proper "seating pressure" indicated that the obstruction had been cleared. The barrel which had failed to seat was recovered containing 48 cm of core from within the

Table 1. Coring summary, Site 603, Holes 603 to 603C.[a]

Core no.	Date	Time (hr.)	Depth from drill floor (m) Top Bottom	Depth below seafloor (m) Top Bottom	Length cored (m)	Length recovered (m)	Percentage recovered
Hole 603 (May 1983)							
1	5	2116	4644.0–4653.0	0.0–9.0	9.0	9.49	+100
2M	6	0110	4653.0–4727.8	9.0–83.8	—	—	Wash
3M	6	0420	4727.8–4766.2	83.8–122.2	—	—	Wash
4	6	0540	4766.2–4775.8	122.2–131.8	9.6	9.82	+100
5	6	0935	4775.8–4814.2	131.8–170.2	—	—	Wash
6	6	1145	4814.2–4823.8	170.2–179.8	9.6	0.00	0
7M	6	1515	4823.8–4843.0	179.8–199.0	—	—	Wash
8	6	1619	4843.0–4852.6	199.0–208.6	9.6	3.87	40
9	6	1735	4852.6–4862.2	208.6–218.2	9.6	5.93	62
10	6	1900	4862.2–4871.8	218.2–227.8	9.6	9.69	+100
11M	7	0034	4871.8–4910.2	227.8–266.2	—	—	Wash
12	7	0235	4910.2–4919.8	266.2–275.8	9.6	4.31	45
13M	7	0425	4919.8–4958.2	275.8–314.2	—	—	Wash
14	7	0610	4958.2–4967.8	314.2–323.8	9.6	6.30	66
15M	7	1011	4967.8 5006.2	323.8–362.2	—	—	Wash
16	7	1150	5006.2–5015.8	362.2–371.8	9.6	6.39	67
17M	7	1415	5015.8–5054.2	371.8–410.2	—	—	Wash
18	7	1555	5054.2–5063.8	410.2–419.8	9.6	1.42	15
19M	7	1755	5063.8–5092.6	419.8–448.6	—	—	Wash
20	7	2045	5092.6–5102.2	448.6–458.2	9.6	6.50	68
21	7	2225	5102.2–5111.8	458.2–467.8	9.6	5.29	55
22M	8	0055	5111.8–5150.2	467.8–506.2	—	—	Wash
23	8	0238	5150.2–5159.8	506.2–515.8	9.6	6.30	66
24M	8	0445	5159.8–5188.6	515.8–544.6	—	—	Wash
25	8	0610	5188.6–5198.2	544.6–554.2	9.6	9.92	+100
26	8	0750	5198.2–5207.8	554.2–563.8	9.6	8.32	87
27	8	0925	5207.8–5217.4	563.8–573.4	9.6	0.21	2
28M	8	1048	5207.8–5217.4	563.8–573.4	—	—	Wash
29	8	1355	5217.4–5227.0	573.4–583.0	9.6	7.68	80
30	8	1531	5227.0–5236.6	583.0–592.6	9.6	5.94	62
31	8	1712	5236.6–5246.2	592.6–602.2	9.6	4.35	45
32	8	1856	5246.2–5255.8	602.2–611.8	9.6	2.68	28
33	8	2058	5255.8–5265.4	611.8–621.4	9.6	8.66	90
34	8	2253	5265.4–5275.0	621.4–631.0	9.6	5.66	59
35	9	0035	5275.0–5284.6	631.0–640.6	9.6	8.77	91
36	9	0225	5284.6–5294.2	640.6–650.2	9.6	5.98	62
37	9	0430	5294.2–5303.8	650.2–659.8	9.6	3.38	35
38	9	0615	5303.8–5313.4	659.8–669.4	9.6	3.42	36
39	9	0800	5313.4–5323.0	669.4–679.0	9.6	2.44	25
40	9	0950	5323.0–5332.6	679.0–688.6	9.6	8.86	92
41	9	1126	5332.6–5342.2	688.6–698.2	9.6	9.52	99
42	9	1312	5342.2–5351.8	698.2–707.8	9.6	6.58	69
43	9	1507	5351.8–5361.4	707.8–717.4	9.6	2.54	26
44	9	1656	5361.4–5371.0	717.4–727.0	9.6	6.09	63
45	9	1855	5371.0–5380.6	727.0–736.6	9.6	7.76	81
46	9	2330	5380.6–5390.2	736.6–746.2	9.6	6.13	64
47	10	0435	5390.2–5399.8	746.2–755.8	9.6	1.92	2
48	10	0647	5399.8–5409.4	755.8–765.4	9.6	1.64	17
49	10	0850	5409.4–5419.0	765.4–775.0	9.6	3.93	41
50	10	1040	5419.0–5428.6	775.0–784.6	9.6	5.93	62
51	10	1230	5428.6–5438.2	784.6–794.2	9.6	3.00	31
52	10	1430	5438.2–5447.8	794.2–803.8	9.6	6.43	67
53M	10	1707	5447.2–5467.0	803.8–823.0	—	—	Wash
54	11	0442	5467.0–5476.6	823.0–832.6	9.6	3.33	35
Total					393.0	226.38	58
Hole 603B (May 1983)							
1M	14	1235	4644.0–4929.0	0.0–285.0	—	—	Wash
2M	15	0140	4929.0–5061.1	285.0–417.1	—	—	Wash
3M	15	2035	5061.1–5123.0	417.1–479.0	—	—	Wash
4M	20	1810	5176.1–5282.3	532.1–638.3	—	—	Wash
5	22	1543	5465.4–5475.0	821.4–831.0	9.6	7.35	77
6M	22	1800	5475.0–5494.2	831.0–850.2	—	—	Wash
7M	22	2005	5494.2–5513.4	850.2–869.4	—	—	Wash
8M	22	2243	5513.4–5536.0	869.4–892.0	—	—	Wash
9	23	0020	5536.0–5542.2	892.0–898.2	6.2	0.55	9
10	23	0235	5542.2–5551.8	898.2–907.8	9.6	7.66	80
11M	23	0510	5551.8–5571.0	907.8–927.0	—	—	Wash
12	23	0710	5571.0–5580.6	927.0–936.6	9.6	7.68	80
13	23	0925	5580.6–5590.2	936.6–946.2	9.6	4.90	51
14	23	1100	5590.2–5599.8	946.2–955.8	9.6	9.78	+100

Table 1 (continued).

Core no.	Date	Time (hr.)	Depth from drill floor (m) Top	Bottom	Depth below seafloor (m) Top	Bottom	Length cored (m)	Length recovered (m)	Percentage recovered
Hole 603B (May 1983) (Cont.)									
15	23	1255	5599.8	5609.4	955.8	965.4	9.6	7.23	75
16	23	1540	5609.4	5619.1	965.4	975.1	9.7	8.96	92
17	23	1738	5619.1	5628.6	975.1	984.6	9.5	6.71	71
18	23	1948	5628.6	5637.6	984.6	993.6	9.0	5.20	58
19	23	2154	5637.6	5646.6	993.6	1002.6	9.0	4.93	55
20	24	0016	5646.6	5655.6	1002.6	1011.6	9.0	4.36	48
21	24	0240	5655.6	5664.6	1011.6	1020.6	9.0	7.86	87
22	24	0440	5664.6	5673.6	1020.6	1029.6	9.0	6.36	71
23	24	0700	5673.6	5682.6	1029.6	1038.6	9.0	2.10	23
24	24	0900	5682.6	5691.6	1038.6	1047.6	9.0	2.23	25
25	24	1130	5691.6	5700.6	1047.6	1056.6	9.0	5.25	58
26	24	1335	5700.6	5709.6	1056.6	1065.6	9.0	5.08	56
27	24	1640	5709.6	5717.2	1065.6	1073.2	7.6	1.22	16
28	24	1830	5717.2	5724.8	1073.2	1080.8	7.6	5.86	77
29	24	2042	5724.8	5734.4	1080.8	1090.4	9.6	6.62	69
30	24	2326	5734.4	5744.0	1090.4	1100.0	9.6	6.37	66
31	25	0330	5744.0	5753.5	1100.0	1109.5	9.5	6.79	71
32	25	0535	5753.5	5762.5	1109.5	1118.5	9.0	2.51	28
33	25	0740	5762.5	5771.5	1118.5	1127.5	9.0	4.55	51
34	25	0955	5771.5	5780.5	1127.5	1136.5	9.0	8.00	89
35	25	1155	5780.5	5789.5	1136.5	1145.5	9.0	5.96	66
36	25	1405	5789.5	5798.5	1145.5	1154.5	9.0	4.68	52
37	25	1640	5798.5	5807.5	1154.5	1163.5	9.0	7.37	82
38	25	1850	5807.5	5816.5	1163.5	1172.5	9.0	7.46	83
39	25	2045	5816.5	5825.5	1172.5	1181.5	9.0	7.65	85
40	25	2326	5825.5	5834.5	1181.5	1190.5	9.0	8.60	96
41	26	0250	5834.5	5841.2	1190.5	1197.2	6.7	6.26	93
42	26	0400	5841.2	5848.8	1197.2	1204.8	7.6	8.32	+100
43	26	0645	5848.8	5858.4	1204.8	1214.4	9.6	8.46	88
44	26	0840	5858.4	5868.0	1214.4	1224.0	9.6	5.69	59
45	26	1020	5868.0	5877.6	1224.0	1233.6	9.6	1.22	13
46	26	1212	5877.6	5887.2	1233.6	1243.2	9.6	5.10	53
47	26	1350	5887.2	5896.8	1243.2	1252.8	9.6	0.87	9
48	26	1615	5896.8	5906.4	1252.8	1262.4	9.6	3.00	31
49	26	1914	5906.4	5916.0	1262.4	1272.0	9.6	7.03	73
50	26	2115	5916.0	5925.6	1272.0	1281.6	9.6	1.35	14
51	27	0200	5925.6	5935.2	1281.6	1291.2	9.6	9.45	98
52	27	0427	5935.2	5944.8	1291.2	1300.8	9.6	9.57	+99
53	27	0615	5944.8	5954.4	1300.8	1310.4	9.6	8.22	86
54	27	0805	5954.4	5964.0	1310.4	1320.0	9.6	7.60	79
55	27	1010	5964.0	5973.6	1320.0	1329.6	9.6	7.54	79
56	27	1210	5973.6	5983.2	1329.6	1339.2	9.6	4.50	47
57	27	1410	5983.2	5992.8	1339.2	1348.8	9.6	9.00	94
58	27	1615	5992.8	6002.4	1348.8	1358.4	9.6	8.56	89
59	27	1815	6002.4	6012.0	1358.4	1368.0	9.6	7.41	77
60	27	2020	6012.0	6021.6	1368.0	1377.6	9.6	5.92	62
61	27	2245	6021.6	6031.2	1377.6	1387.2	9.6	8.02	84
62	28	0100	6031.2	6040.2	1387.2	1396.2	9.0	7.20	80
63	28	0315	6040.2	6049.7	1396.2	1405.7	9.5	9.55	+100
64	28	0530	6049.7	6058.7	1405.7	1414.7	9.0	7.74	86
65	28	0740	6058.7	6067.7	1414.7	1423.7	9.0	8.10	90
66	28	1000	6067.7	6076.7	1423.7	1432.7	9.0	8.01	89
67	28	1200	6076.7	6085.7	1432.7	1441.7	9.0	8.60	96
68	28	1350	6085.7	6094.7	1441.7	1450.7	9.0	7.96	88
69	28	1600	6094.7	6103.7	1450.7	1459.7	9.0	9.60	+100
70	28	1825	6103.7	6112.7	1459.7	1468.7	9.0	7.94	88
71	29	0720	6112.7	6121.7	1468.7	1477.7	9.0	9.14	+100
72	30	1110	6121.7	6126.7	1477.7	1482.7	5.0	1.58	32
73	30	1325	6126.7	6136.3	1482.7	1492.3	9.6	7.56	79
74	30	1620	6136.3	6145.9	1492.3	1501.9	9.6	9.44	98
75	30	1826	6145.9	6155.5	1501.9	1511.5	9.6	6.77	71
76	30	2045	6155.5	6165.1	1511.5	1521.1	9.6	6.83	71
77	30	2316	6165.1	6174.7	1521.1	1530.7	9.6	9.78	+100
78	31	0215	6174.7	6184.2	1530.7	1540.2	9.5	5.43	57
79	31	0520	6184.2	6193.2	1540.2	1549.2	9.0	9.23	+100
80	31	0805	6193.2	6202.2	1549.2	1558.2	9.0	8.16	91
81	31	1050	6202.2	6211.2	1558.2	1567.2	9.0	7.97	89
82	31	1337	6211.2	6220.2	1567.2	1576.2	9.0	6.93	77
83	31	—	6220.2	6229.2	1576.2	1585.2	9.0	0.00	0
Total							683.6	484.44	71

Table 1 (continued).

Core no.	Date	Time (hr.)	Depth from drill floor (m) Top Bottom	Depth below seafloor (m) Top Bottom	Length cored (m)	Length recovered (m)	Percentage recovered
Hole 603C (June 1983)							
1	3	1045	4649.5–4651.5	0.0–2.0	2.0	1.96	98
2	3	1311	4651.5–4661.1	2.0–11.6	9.6	9.44	98
3	3	1432	4661.1–4670.7	11.6–21.2	9.6	9.48	99
4	3	1550	4670.7–4680.3	21.2–30.8	9.6	9.78	+100
5	3	1700	4680.3–4689.9	30.8–40.4	9.6	8.64	90
6	3	1813	4689.9–4699.4	40.4–49.9	9.5	9.32	98
7	3	1940	4699.4–4708.9	49.9–59.4	9.5	9.31	98
8	3	2110	4708.9–4717.3	59.4–67.8	8.4	8.51	+100
9	3	2220	4717.3–4726.8	67.8–77.3	9.5	9.60	+100
10	3	2330	4726.8–4734.3	77.3–84.8	7.5	7.66	+100
11	4	0404	4734.3–4740.5	84.8–91.0	6.2	6.07	98
12	4	0550	4740.5–4746.7	91.0–97.2	6.2	0.00	0
13	4	0755	4746.7–4756.3	97.2–106.8	9.6	2.75	29
14	4	1135	4756.3–4765.9	106.8–116.4	9.6	9.42	98
15	4	1350	4765.9–4775.5	116.4–126.0	9.6	9.37	98
16	4	1530	4775.5–4785.1	126.0–135.6	9.6	9.44	98
17	4	1720	4785.1–4794.7	135.6–145.2	9.6	8.35	87
18	4	2102	4794.7–4804.3	145.2–154.8	9.6	9.46	99
19	4	2240	4804.3–4813.9	154.8–164.4	9.6	8.48	88
20	5	0018	4813.9–4823.5	164.4–174.0	9.6	9.42	98
21	5	0230	4823.5–4833.1	174.0–183.6	9.6	9.63	+100
22	5	0410	4833.1–4842.7	183.6–193.2	9.6	7.89	82
23	5	0557	4842.7–4852.3	193.2–202.8	9.6	9.39	98
24	5	0745	4852.3–4861.9	202.8–212.4	9.6	9.55	99
25	5	0930	4861.9–4871.5	212.4–222.0	9.6	9.51	99
26	5	1100	4871.5–4881.1	222.0–231.6	9.6	9.48	99
27	5	1245	4881.1–4890.7	231.6–241.2	9.6	9.59	99
28	5	1420	4890.7–4900.3	241.2–250.8	9.6	8.48	88
29	5	1620	4900.3–4909.9	250.8–260.4	9.6	2.83	29
30	5	1815	4909.9–4919.5	260.4–270.0	9.6	3.10	32
31	5	2000	4919.5–4929.1	270.0–279.6	9.6	8.70	91
32	5	2200	4929.1–4938.7	279.6–289.2	9.6	1.95	20
33	5	2335	4938.7–4948.3	289.2–298.8	9.6	9.10	95
34	6	0130	4948.3–4957.9	298.8–308.4	9.6	1.71	18
35	6	0330	4957.9–4967.5	308.4–318.0	9.6	9.49	99
36	6	0510	4967.5–4977.1	318.0–327.6	9.6	9.58	99
37	6	0705	4977.1–4986.7	327.6–337.2	9.6	9.51	99
38	6	0935	4986.7–4996.3	337.2–346.8	9.6	9.56	99
39	6	1135	4996.3–5005.9	346.8–356.4	9.6	9.50	99
40	6	1310	5005.9–5015.5	356.4–366.0	9.6	9.43	98
Total					366.0	314.44	86

[a] Note that no sediment was recovered at Hole 603A.

pipe. This was designated a miscellaneous core (28M) from the same interval as Core 27.

Continuous coring then proceeded to 5390 m in claystone which became gradually more indurated with depth. Weather continued good until 9 May when, with most of the objectives for the hole achieved, an approaching weather front prompted the decision to stop coring and to pull out of the hole for the safety of the drill string. The hole was filled with weighted mud and the pipe trip was started. Before the bit was pulled from the hole, it became apparent that the weather front was dissipating. The previous core was retrieved from the pipe while the weather continued to improve. Since the rate of penetration (ROP) was still about 30 m/hr. and the hole and core bit were in good condition, further coring was a compelling option.

The bit was then run back to total depth and coring operations were resumed. At about 800 m BSF, the ROP decreased to the point where there was little advantage in continued coring through a section that would have to be penetrated again in the reentry hole. Coring was terminated at 832.6 m BSF. The hole was again displaced full of weighted mud, and the drill string was pulled. About 30,000 to 50,000 lb. overpull or "drag" was noted through much of the hole on the pipe trip, probably because clay in the hole wall was swelling in reaction to the fresh water of the drilling mud. The core bit arrived on deck at 0450 hr., 11 May (Fig. 8).

Hole 603A

With the successful completion of the exploratory hole, the rig was quickly prepared for the deployment of the preassembled reentry cone. The keelhaul lines were passed from the moonpool under the hull and the cone was in the water only 2½ hr. after the bit had been brought on deck. When the cone had been hung off beneath the moonpool, a 71.8-m string of 16-in. casing was made up and hung off beneath the rig floor. The BHA, incorporating the casing running tool, was then assembled and lowered to engage the casing string. The casing was, in turn, lowered until it latched into the reentry cone. The final slings were cut and the entire assembly was lowered toward the seafloor as the drill string was made up.

Hole 603A was spudded at 2058 hr., 11 May, and jetting-in proceeded smoothly with only moderate resistance to about 30 m BSF. Then several meters were drilled at an increased rate with very little resistance, and it was noted that about 30,000 lb. of hanging weight had been lost (approximately that of the cone and casing). Premature shifting of the release sleeve or failure of the casing running tool was suspected. It was soon confirmed that the drill string was free to move downward without the cone–casing assembly, but our inability to rotate the drill string indicated that a normal full release had not occurred. Low circulating-pump pressure was also a sign that the system had lost integrity. It was found that the BHA could move down through the casing, but not upward, as the latch sleeve remained attached to the casing hanger. There was no way to complete the jetting-in operation, and two attempts were made to retrieve the shifting tool with the sand line and release the assembly. The shifting tool was found to be stuck somewhere in the BHA and the overshot safety shearpin failed on both occasions. A third try was made with a backup shifting tool, but the sleeve was not engaged, indicating that the other tool was lodged at or above the sleeve.

As the cone–casing assembly could neither be emplaced nor released, the drill string was recovered to the BHA. Adverse sea conditions and the risks of open-ocean diving made it infeasible to use divers to attempt to unlatch the cone from the casing. The 7¼ in. drill collar was laid out and drill pipe was made up loosely at the lowest accessible BHA connection. The assembly was then lowered by one stand, the pipe was set in slips and the rotary table was turned to the left to back off and release the BHA–cone–casing assembly. The hardware was dropped about 1 mi. southeast of the drill site. The pipe was recovered at 1345 hr., 12 May, and reentry system preparations began again from scratch. No sediment was recovered during the attempt to establish reentry Hole 603A.

Hole 603B

About 18 hr. were required to assemble a new BHA, reentry cone, and casing running tool and to test the latching of the casing hanger into the cone. The cone was then keelhauled and another seven-joint string of 16 in. casing was run and latched up. Following a routine pipe trip, Hole 603B was spudded at 0136 hr., 14 May (Fig. 8) on positioning offsets 30 m west of Hole 603.

Jetting-in was much more difficult in this case than at Hole 603 or 603A. It was necessary to raise and lower the pipe repeatedly and to use maximum pump circulation for most of the interval. No further progress could be made after the mud skirt of the cone reached a depth of 4642.5 m below the rig floor, and this was established as seafloor depth. The drill string was disengaged from the cone–casing assembly at 0438 hr.

A 14⅞ in. hole was then drilled to the intended depth of the surface casing shoe at 5123 m. The drilling rate was much slower than expected, and the inner barrel was pulled twice when a full barrel was suspected of slowing penetration. This measure, which produced wash Cores 1M to 3M, had little effect. Wiper trips for hole conditioning were made at 4956 m and at total depth. The hole was found to be clean after each trip and was thoroughly flushed with bentonite mud before the pipe trip was made for the surface casing string. The 14⅞ in. bit was brought on deck at 2100 hr. 15 May.

First Reentry: Surface Casing

The rig's complete inventory of 53 joints of 11¾ in. range two 54-lb. casing, plus three expansion joints, was made up and hung off in the moonpool. Next, a special BHA was assembled which was designed to make it easier to cement the casing by directing the slurry through the casing's float shoe. A sealing nipple was held in the top of the shoe by the weight of the BHA. After the carefully measured BHA was lowered into the casing, the casing string was found to be 9 m too long, apparently the result of a systematic error in measurement. As the string was too long for the existing hole, it was necessary to remove one joint of casing before the string could be attached to a new BHA by means of the casing running tool. The entire assembly was then suspended at the moonpool at 1615 hr., 16 May.

The wind and seas of an approaching weather system were producing vessel motion and positioning conditions that prevented us deploying and reentering with the heavy (425,000 lb.) combined drill pipe–casing string. A delay of 28 hr. ensued before weather conditions abated sufficiently. Maximum sustained winds of 35 knots were recorded and vessel roll reached 6°.

The drill string was then run to put the casing shoe at reentry depth, and the reentry sonar tool was lowered. Although the primary (8°) transducer was found to be inoperative, the reentry cone target was acquired at a distance of 80 ft. (24 m) with the 45° transducer, and a successful reentry stab was made after 95 min. of scanning.

The casing was then run into the hole until resistance was felt at 4993 m. The casing was circulated to within 1 m of total depth before progress was arrested. Fairly constant resistance of 30 to 40,000 lb. was encountered for the entire distance.

When the entire weight of the casing string had been taken up by the hole, the drill string was raised to check that the casing hanger had latched in. No extra weight was regained, indicating that the snap ring of the casing hanger had not engaged the reentry cone. The shoe was again landed and the string was alternatively lowered to the next hub of the drilling joint, set down on elevators, and torqued with the rotary table until the casing running tool was slacked enough to rotate and release the casing. This occurred at about 1.5 to 2 m below the calculated point, indicating that the weight of the upper casing string had pulled the conductor pipe and reentry cone by this amount. (Two expansion joints had been placed near the center of the surface casing string so that half the weight of the heavy string would rest on the bottom of the hole while only the upper part would be suspended from the cone.) This information, along with

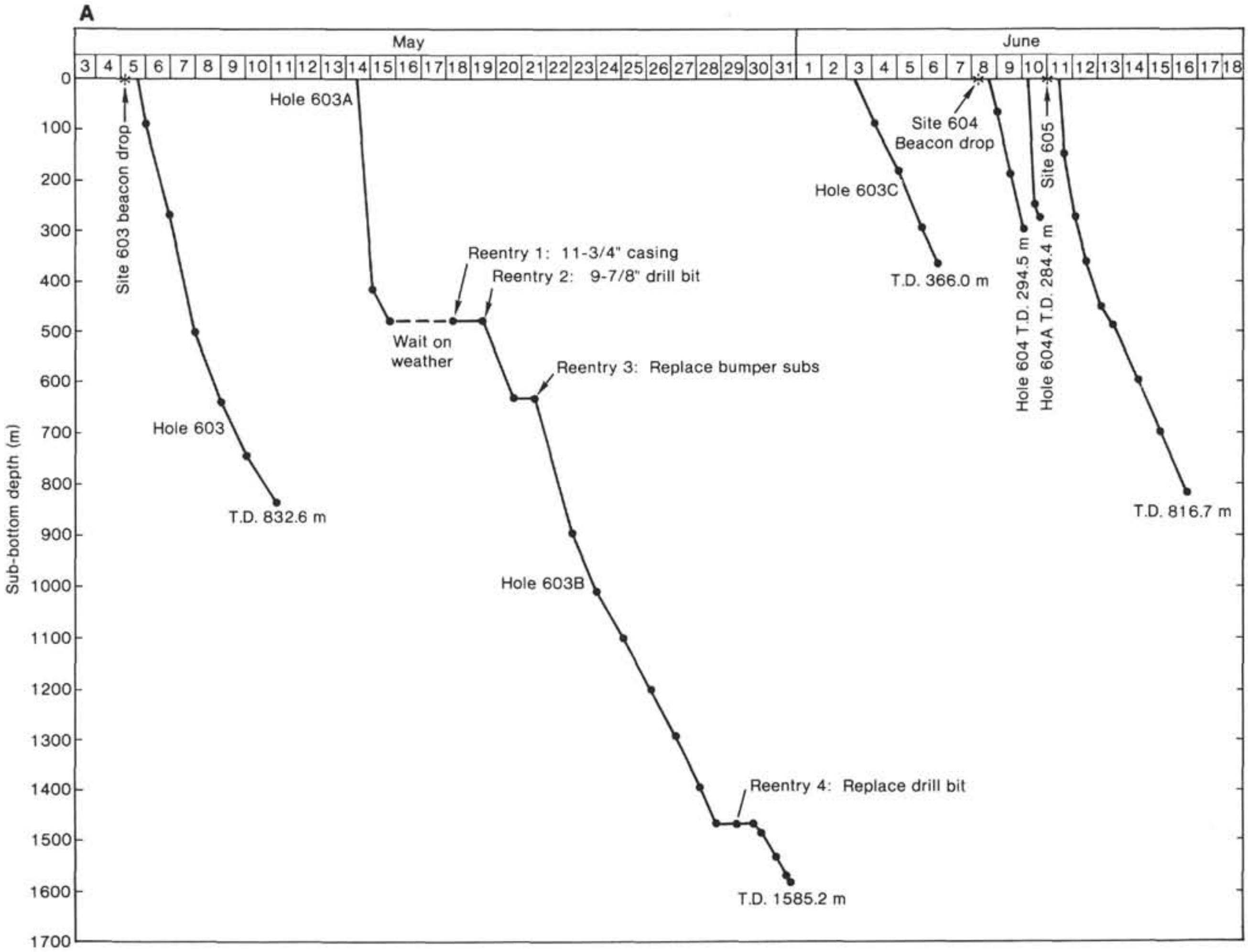

Figure 8. A. Station activity summary for Leg 93. B and C. Photographs taken on May 31, showing power sub and remainder of 6229.2 m of drill string held by Global Marine's Irv Renfro (B) and close-up of the Kelly Cock sub at the failed box connection (C). Arrow points to the largest fatigue zone. A number of shallower zones were observed essentially all the way around the root of the last engaged thread.

the seafloor range reading from the reentry sonar, was used to revise the water depth measurement for the hole from 4642.5 to 4644 m.

The drill string was then raised completely clear of the casing and lowered until the BHA seal nipple landed in the casing shoe. The float valve was closed and 180 barrels of 15 lb./gal. cement slurry were pumped into the drill string. Next, a latch-down displacement plug was launched, followed by 10 barrels of slurry and 10 barrels of fresh water, and displaced with seawater to the shoe. The plug failed to land and block circulation, however, after an adequate amount of water had been pumped. Pumping was stopped to avoid displacing cement from the hole. The cementing equipment was rigged down and the drill string was recovered. At this point, the reentry cone-casing assembly was situated in the hole.

Second Reentry: Coring BHA

A standard 9⅞ in. coring bit and BHA were run to reentry depth, but the reentry sonar tool failed shortly after being lowered down the pipe and had to be replaced. The second reentry was accomplished after a scanning and maneuvering time of 104 min.

An inner core barrel equipped with a center bit was pumped into place and the core bit was lowered until cement was contacted at 5094 m. (The volume of cement inside the casing corresponded quite closely with the 10 barrels pumped behind the plug.) The cement, plug, and shoe were then drilled out with somewhat more difficulty than had been anticipated.

Even after the bit was well beyond the casing shoe, difficulty was experienced in drilling a new hole. Torquing, slow penetration, and erratic pump pressure plagued drilling efforts. The only difference in the drilling assembly from that of Hole 603 was the center bit. It was replaced with a standard inner barrel, but little improvement was noted and the ROP remained well below that of Hole 603. The cause of the problems was suspected to be sticky clay adhering to the drill collars and "balling" the bit, but maximum pump pressure and RPM improved the ROP only slightly until a depth of about 5205 m had been reached. Drilling rate then improved considerably for about 55 m. After another abrupt drop in ROP, it was suspected that the inner barrel had filled up. The barrel was stuck in place, however, and two attempts to retrieve it resulted only in sheared overshot

B

C

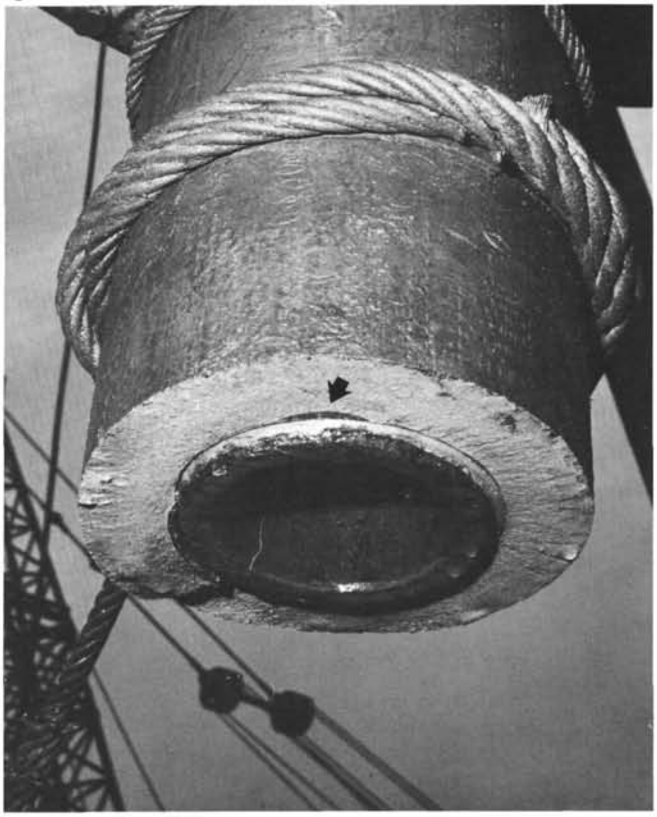

Figure 8 (continued).

pins. Another joint was drilled down (requiring 1 hr.) and a third retrieval attempt was made. This time the barrel was found to be free. It was recovered filled with claystone (Core 4M) and an empty barrel was pumped down the pipe. Anomalously low pump pressure had been noted when pumping down the previous core barrel, and this barrel gave no pressure indication of landing at the bit.

A review of the problems and the phenomena experienced in Hole 603B led to the conclusion that a bumper sub had probably failed or (less likely) that a washout existed somewhere in the drill string. The string was pulled, and the washpipe of the second bumper sub was found to be loose inside the body of the telescoping sub. This had permitted drilling circulation to pass around the packing of the bumper sub and out through the vented body. A large vertical crack in the top (threaded) part of the washpipe was found to be responsible for the failure of the threaded connection. The bit was brought on deck at 0415 hr., 21 May (Fig. 8).

Third Reentry: Core Bit

The BHA was reassembled with a new core bit and three rebuilt bumper subs. A 9⅞ in. stabilizer was added 22 m above the bit in an attempt to alleviate a possible "dogleg" situation in the hole as indicated by a 5½° single-shot survey reading at 5270 m (Fig. 9). A successful reentry stab was made after 59 min. of scanning, and the bit was washed down to total depth at 5282 m without undue difficulty after the power sub was deployed at 5157 m.

Drilling (without cores) then proceeded to 5337 m. At that point a malfunction in the dynamic positioning system resulted in loss of control of the vessel's heading. When the system was shifted to the manual mode of operation, there was no response from the stern thrusters. It was, therefore, necessary to return to the semiautomatic mode and to try to hold station without heading control. With beam winds gusting to 20 knots, the thrusters were barely able to hold position and the order was given to pull the drill string above the seafloor. There was little hope of accomplishing this, however, with 700 m of pipe in the hole and both the power sub and heave compensator deployed. By the time the power sub had been set back, heading control had been regained and full automatic positioning resumed. The maximum excursion off station had been about 170 m. The stern thruster problem was eventually rectified and drilling recommenced after a delay of 6¾ hr.

The hole was then drilled to the total depth of Hole 603 before the center bit was replaced with an inner core barrel. Alternate drilling and spot coring proceeded to 5571 m, where continuous coring began. About 300 m of claystones, siliceous claystones, and carbonaceous shales were then penetrated at an excellent rate and with generally good recovery. Hole conditions were good, but the hole angle had increased at a rather alarming rate to 17½° (Fig. 9), despite the addition of the stabilizer to the BHA. Beginning at about 5870 m, approximately 30 m of unconsolidated to semiconsolidated turbiditic sand was encountered. The presence of loose, flowing sand in

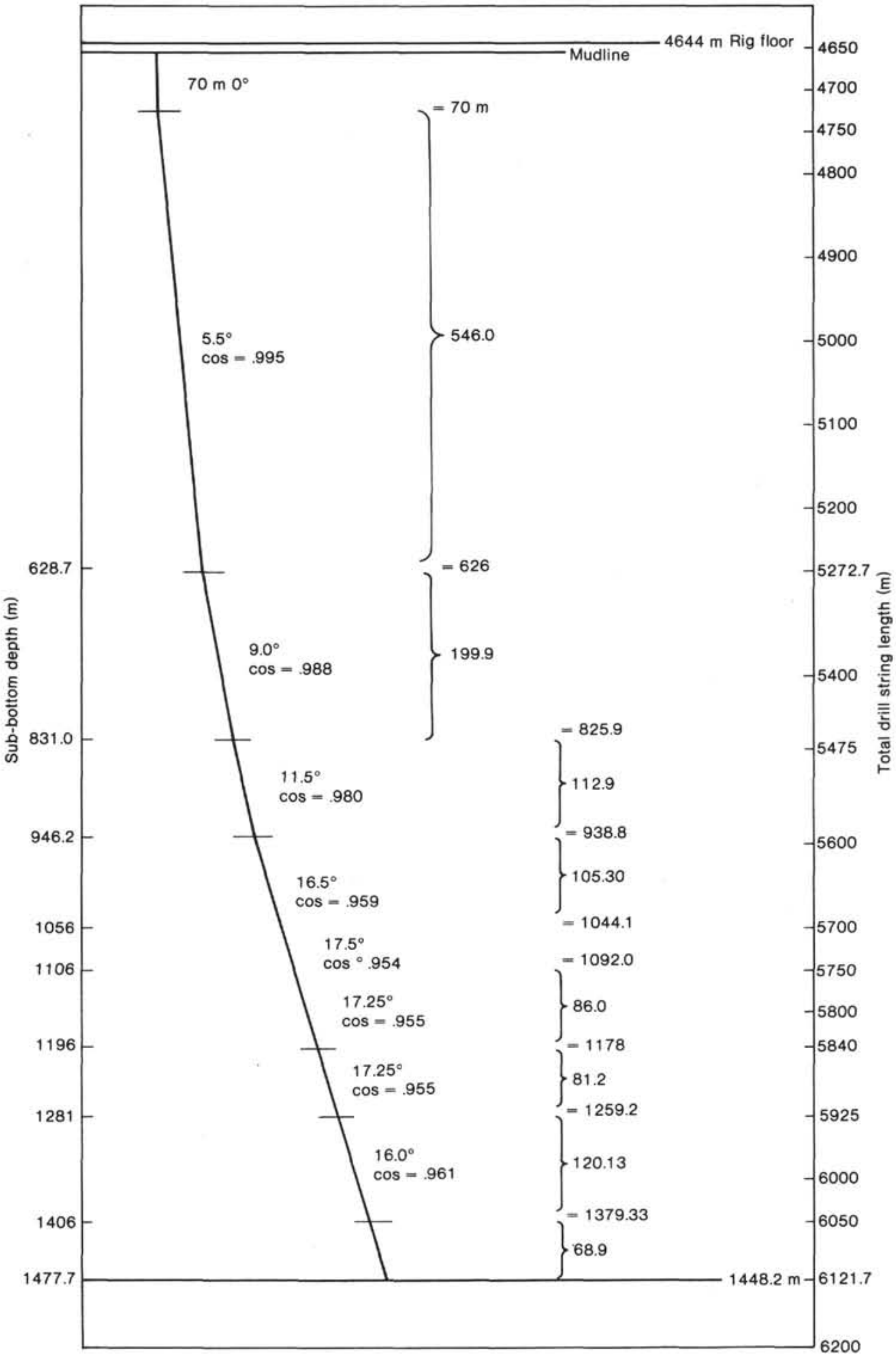

Figure 9. Deviation of Hole 603B from vertical drilling.

the core barrel caused considerable concern because of the rig's minimal hole-cleaning capabilities. Minor torquing and sticking tendencies did occur, but the hole stabilized after a few additional cores had been cut. The sandstone, interbedded with siltstone, claystone and marl, continued for over 100 m more but became better cemented with depth. Around 6100 m, the turbidite sequence gradually gave way to a lithology of chalk, laminated limestone, and dark carbonaceous claystone. The material was quite well indurated, but the ROP remained high. The cores began to show signs of bit bearing wear, however, and the core bit was retired at a depth of 6122 m (1478 m BSF) after an excellent run.

Prior to pulling pipe, the hole was cleaned with a flush of bentonite and guar gum mud slugs. The pipe dragged up to 50,000 lb. over its hanging weight for the first 13 stands before it came free in the hole, probably because the hole was crooked. The bit, which arrived on deck at

0725 hr., 29 May (Fig. 8), was found to have one loose cone.

Fourth Reentry: Core Bit

The fourth reentry was accomplished in 94 min. of scanning time. The bit was run to the surface casing shoe where an attempt to measure hole deviation was unsuccessful because the single-shot instrument malfunctioned. The trip then continued smoothly until resistance was encountered at 5530 m (886 m sub-bottom). The pipe was "worked" against heavy drag, using the circulating head, to about 5900 m, where the power sub and heave compensator were picked up. The bit finally reached total depth at 0915 hr., 30 May, and coring resumed with high hydrostatic back pressure, which indicated a considerable amount of material suspended in the annulus of the hole.

Hole cleaning conditions improved after three or four cores, and coring continued through Lower Cretaceous chalk, laminated limestone, and diminishing amounts of carbonaceous claystone. The ROP remained high to about 1525 m BSF, where an increased limestone content reduced the penetration rate to about 8 m/hr. On Core 83 the rate dropped further to 6 m/hr. This interval had just been cored, and the bit was being raised off the bottom of the hole in preparation for retrieving the core when disaster struck.

The drill string parted just below the power sub (about 12 m above the rig floor) and the entire drilling assembly was lost. Fortunately the falling pipe struck nothing between the break and the vessel's keel and there were no injuries. The failure at the box connection of the Kelly Cock sub was caused by brittle cleavage along fatigue cracks propagating from corrosion pits that had developed over the 14-yr. life of the sub. The string was lost at 1545 hr., 31 May, at a total drill string depth of 6229.2 m.

Hole 603C

After the accident, the rig was inspected and minor damage was repaired. At this time, only 24 stands of drill pipe remained on the pipe racker, and the major task of assembling a new drill string had to be accomplished before drilling/coring operations could continue. Nearly two days were required to remove the contents of the casing hold and to assemble the drill pipe and drill collars into stands (Fig. 8). The work was slowed further by inclement weather and vessel motion. Finally, at 1400 hr. on 2 June, enough pipe was on the racker to spud the final hole of Site 603. The ship was then positioned 305 m west-northwest of Hole 603B (but still on the *Conrad* 2101 seismic line) so as to avoid the area where the lost drill string had fallen.

The initial pipe trip was slowed by the need to measure the pipe, to remove rubber protectors from the lower (used) portion of the string, and to make up the tool joints of the new pipe twice. The power sub was picked up in preparation for spudding, and the Kelly Cock sub was removed from the assembly. (The Kelly Cock, a blowout prevention safeguard, was removed on the recommendation of Global Marine management because it had been in use as long as the failed unit and its risks were perceived to outweight its safety benefits.) The combination HPC and XCB assembly was then deployed and run to the bit. Hole 603C was spudded at 1027 hr., 3 June.

A shallow penetration at Site ENA-3 (603) had been planned from the beginning for detailed stratigraphic and paleontological work. The HPC system was utilized in the relatively soft clay section and provided excellent recovery of undisturbed cores from the seafloor to 91 m BSF. At this point, full stroke of the 9.5-m corer was no longer achieved and overpull of 35,000 lb. was noted when the core barrel was withdrawn.

The XCB system was then substituted for the HPC and coring continued. Core recovery was at first low until the proper combination of drilling parameters was found. Excellent recovery of relatively undisturbed core was then enjoyed to about 250 m BSF. Recovery remained good in the underlying soft claystone, but rather severe rotational disturbance prevailed after the extended barrel retracted in the stiff sediment to the point that it began operating in the rotating mode.

Runs were made with a modified core barrel for temperature measurements at 85 and 146 m BSF. The self-contained shoe was used in lieu of the probe, and the special runs reduced the risk of equipment failure that had been experienced in the past when the shoe was attached to the HPC barrel. Excellent data were recorded at both points to supplement the Hole 603 data.

Coring was terminated at 366 m BSF to provide enough time to complete another drill site before returning to Norfolk. The vessel got under way for Site 604 at 2330 hr., 6 June (Fig. 8). A postsite seismic survey was run before course was set for the next drill site, located about 160 km southeast of Atlantic City, New Jersey. This concluded an occupation by *Glomar Challenger* of Site 603 which had lasted some 33 days.

LITHOLOGIC SUMMARY

The sedimentary section recovered at Site 603 is divided into five lithologic units (I through V) based on composition, color, and degree of lithification.

Lithologic Unit I (0–960 m, early Pleistocene–middle [early?] Miocene) contains sediments recovered in Holes 603 and 603C and those from Cores 603B-1 to 603B-15-4, 45 cm. This unit, which is composed primarily of hemipelagic clay–claystone, has four subunits (Table 2). All other lithologic units were recovered only in Hole 603B. Unit II (960–1023 m) is composed predominantly of radiolarian claystone of late Paleocene to early Eocene age. Unit III (1023–1119 m) contains Senonian variegated claystone and organic-matter-rich claystone. Turonian–Aptian carbonaceous claystones, variegated claystones, and terrigenous silt turbidites compose Unit IV (1119–1215 m). Unit V (1215–1576 m, Aptian–Berriasian) contains interbedded claystone, laminated and bioturbated clayey nannofossil limestones, and sandy turbidites.

Unit I: Hemipelagic Clay–Claystone (early Pleistocene–middle (early?) Miocene

This unit (Fig. 10, backpocket; Table 2) extends from the sediment/water interface to the total depth of 832.6 m in Hole 603 and 960 m sub-bottom in Core 603B-15. This

Table 2. Site 603 lithostratigraphy.

Unit/Subunit	Lithology	Core level	Sub-bottom depth (m)	Age
Unit I	Hemipelagic clay/claystone	603-1 to 603-54,CC 603B-1M to -15-4, 45 cm 603C-1 to -40,CC 603D-1 603E-1 603F-1M to -2M	0-960.75 (603B)	Pleistocene—middle Miocene
Subunit IA	Nannofossil-bearing clay/claystone	603-1 to 603-19M,CC 603B-1M to 603B-2M,CC 603C-1 to -40,CC 603D-1 603F-1M	0-419.8/448.6 (603)	early Pleistocene Pliocene/late Miocene
Subunit IB	Quartz-mica-bearing claystone	603-20 to 603-41,CC 603B-3M to 603B-4M-5 603F-2M	448.6-698.2 (603)	late Miocene
Subunit IC	Biogenic-silica-bearing clay/claystone and silt-bearing or silt-rich claystone	603-42 to 603-54,CC 603B-4M-5 to 14-3, 65 cm 603E-1	698.2 (603)-949.85 (603B)	late Miocene-middle Miocene
Subunit ID	Silt-rich claystone	603B-14-3, 65 cm to -15-4, 45 cm	949.85-960.75[a]	middle Miocene?-middle early Eocene
Unit II	Radiolarian claystone	603B-15-4 45 cm to -22-2, 68 cm 603F-3M	960.75-1022.78	middle early Eocene late Paleocene
Unit III	Variegated claystone	603B-22-2, 68cm to -33-1, 60 cm	1022.78-1119.1	Cenomanian-Coniacian
Subunit IIIA	Variegated claystone without carbonaceous claystone	603B-22-2, 68 cm to -23,CC	1022.78-1038.6	?
Subunit IIIB	Variegated claystone (with greenish gray, mostly reddish brown) and some carbonaceous claystone	603B-24 to -29-2	1038.6-1083.8	Santonian-Senonian
Subunit IIIC	Variegated claystone (with reddish brown, greenish gray) and no carbonaceous claystone	603B-29-3 to -33-1, 60 cm	1083.8-1119.1	Cenomanian? to Turonian
Unit IV	Black carbonaceous claystone	603B-33-1, 60 cm to -44-1, 32 cm	1119.1-1214.72	Turonian-Aptian
Subunit IVA	Black carbonaceous and pelagic greenish gray claystone, lacking any reddish brown color	603B-33-1, 60 cm to -38-2	1119.1-1166.5	Turonian-Albian
Subunit IVB	Less black carbonaceous, more pelagic (greenish gray and reddish brown) claystone	603B-38-3 to -41-4	1166.5-1196.5	Albian
Subunit IVC	Black carbonaceous and pelagic (greenish gray only) claystone	603B-41-5 to -42,CC	1196.5-1204.8	Albian
Subunit IVD	Pelagic greenish gray, reddish brown with less black carbonaceous claystone	603B-43-1 to -44-1, 32 cm	1204.8-1214.72	Aptian
Unit V	Interbedded laminated marl and bioturbated limestone with sandstone to claystone turbidites	603B-44-1, 32 cm to -82,CC 603E-2M to -4M 603F-4M to -9,CC	1214.72-1576.2	Aptian-late Berriasian
Subunit VA	As above with the turbidites	603B-44-1, 32 cm to -76-1, 120 cm 603E-2M to -4M 603F-4M to -5M	1214.7-1512.3	Aptian-Valanginian
Subunit VB	As above without the turbidites	603B-76-1, 120 cm to -82,CC 603F-6 to -9,CC	1512.3-1576.2	Valanginian-late Berriasian

[a] All sub-bottom depths hereafter are from Hole 603B.

unit is composed of nannofossil-bearing (to nannofossil-rich) clays, terrigenous silt-bearing (to silt-rich) and nannofossil-bearing (to nannofossil-rich) clays and claystones, and biogenic silica-bearing claystones, all with differing but significant amounts of quartz, mica, siderite, and pyrite. Although the lithologic terms from our sediment classification scheme are purely descriptive, we have selected here the genetic term "hemipelagic" to characterize the lithologic unit as a whole. Biogenic and detrital sediments settling and accumulating on the surface of the continental rise are termed "hemipelagic," because they are a mixture of continentally derived terrigenous detritus and pelagic sediments that comprise the accumulations of the deep ocean basins (Field, 1978).

Subunit IA: Nannofossil-bearing Clay-Claystone (Pleistocene-lower Pliocene/upper Miocene)

The uppermost 19 cores (0-419.8 m; 0-448.6 m sub-bottom depth) of Hole 603 and the uppermost two cores (0-285 m; 0-417.1 m sub-bottom depth) of Hole 603B contain greenish gray (5BG 5/1-5GY 5/1) to dark grayish green (5G 4/1-5GY 4/1) clay to claystone, with differing but significant amounts of calcareous nannofossils, such that these sediments range from nannofossil-bearing (1-10%) to nannofossil-rich (10-30%). Compared to Hole 603B, the basal boundary of Subunit IA is deeper in Hole 603 because Core 603-19M is a wash core taken from 419.8 to 448.6 m sub-bottom (Fig. 10). This subunit, like all of the hemipelagic clay–claystone unit, is slightly to moderately bioturbated, with well-preserved burrow structures, primarily Planolites. Subunit IA contains quartz and mica in amounts ranging from trace quantities (quartz- and mica-bearing) to 10–15% (quartz- and mica-rich).

Subunit IA cores range from clays and claystones to silt-rich clays and claystones, with rare (1–5%) to common (5–25%) silt-sized particles. In addition, trace to rare amounts of heavy minerals, pyrite, glauconite, and micronodules of framboidal pyrite are found. Trace to rare amounts of radiolarians, sponge spicules, fish remains, and plant debris are present, and foraminifers are found in rare (1–5%) amounts. Siderite is found in cores from Subunit IA; the uppermost occurrences are in the core catcher of 603B-1 and in 603-10.

The transition from clay to claystone occurs in Subunit IA between cores 603-9 and -14 (208.6–323.8 m). The base of the clay to claystone transition was marked by the need to use a diamond saw instead of a wire to split core sections in the laboratory. This "transition" occurs in Hole 603B below 638.3 m sub-bottom depth (below Core 603B-4).

The base of Subunit IA is marked by the first appearance of calcareous microfossils within the claystone, except for rare layers of more carbonate-rich material within the underlying Subunit IB. Other than the lack of carbonate, there is no color or textural difference between Subunit IA claystone and the underlying claystone of Subunit IB.

Subunit IA has better stratigraphic resolution in Hole 603C (Fig. 10) through the use of the HPC and the XCB to sample the sedimentary column. Hole 603C recovered a total depth of 366.0 m sub-bottom, with the uppermost 91.0 m sampled by the HPC, and the remainder of the section cored by the XCB. Eight spot cores separated by washed intervals were taken in Hole 603, compared to the 40 cores obtained by a continuous coring procedure in Hole 603C over the same depth interval.

Hole 603C recovered greenish gray (5BG 5/1, 5G 5/1, to 5GY 5/1) to dark greenish gray (5BG 4/1 to 5G 4/1) hemipelagic clays to claystones, with differing but significant amounts (1–77%, usually 5–30%) of calcareous nannofossils, ranging from nannofossil-bearing and nannofossil-rich to nannofossil clay/claystone. These sediments were slightly to moderately bioturbated, demonstrating clear burrow-mottling in well-preserved cores. Hole 603C sediments contained rare quartz (1.5%), rare to common mica (1–10%, usually 3–5%), trace amounts of heavy minerals, feldspar, glauconite, palagonite, and opaque minerals. Pyrite was found in cores in trace to rare (4%) quantities, as burrow fills, nodules, and disseminated grains. Siderite was sporadically present, in trace quantities, in Cores 3, 11 to 13, 23, and 35 to 38 of Hole 603C. Trace quantities of plant debris, fish remains (mostly fish scales), and diatoms were found in the sedimentary section. Trace amounts of radiolarians were found in smear slides from Cores 3, 5, and 13. Rare amounts (1–2%) of foraminifers were found throughout the section.

The transition from clay to claystone in Hole 603C appeared to occur over a longer range than that seen in Hole 603, possibly because of the improved stratigraphic record at 603C. The beginning of the transition to claystone occurred in Core 603C-31 (270.0–279.6 m), whose lowermost two sections had to be split with a diamond saw. Indurated layers of stiffer claystone, divided by thicker soft clay intervals, extend up to Core 603C-9 (67.8–77.3 m sub-bottom). In comparison, a narrow transition from claystone to clay occurred in Hole 603 between 227.8 and 266.2 m sub-bottom, in Wash Core 11. Cores 37 to 40 in Hole 603C (327.6–366.0 m sub-bottom,) contained greenish gray claystone that expanded noticeably when exposed to fresh water during the core-splitting process. Similar expanding claystone was noticed in Hole 603, but at considerably greater depth (Cores 21 to 23 of Hole 603; 458.2–515.8 m sub-bottom).

In Hole 603C the abundances of foraminifers and nannofossils present in the cores appear to be cyclic. The changes from darker-colored nannofossil-bearing clay to lighter-colored nannofossil clay appeared to occur over intervals of 4 to 8 m.

Subunit IB: Quartz–Mica-bearing Claystone (lower Pliocene/upper Miocene–middle Miocene)

Cores 603-20 to -41 (448.6–698.2 m sub-bottom depth) and Core 603B-3 down through Section 603B-4-5 (417.1–532.1/638.3 m sub-bottom depth) contain sediments of Subunit IB, consisting of dark greenish gray (5GY 4/1) to very dark greenish gray (5G 3/1–5G 5/1) claystone, ranging from mica- and quartz-bearing to mica- and quartz-rich claystone. Because drilling deformation is severe the sediments of Core 603B-3 display no apparent primary sedimentary structure. The sediments are observed to be slightly to severely bioturbated in the remainder of this subunit from Hole 603B and in the full interval of the subunit in Hole 603. The greater apparent amount of bioturbation in Subunit IB sediments may be an artifact resulting from better preservation of burrow structures in more indurated sediments. This hemipelagic claystone is slightly to severely disturbed by the drilling process; drilling disturbance ranges from slight fracturing of the sediment, to "drilling biscuits," to complete deformation into drilling breccia.

Subunit IB cores are primarily claystones and silt-bearing clay–claystones, but below Core 603-37 (650.2–659.8 m) the amount of silt-sized terrigenous material increases and there is more silt-rich and silty claystone. Mica and quartz are found in rare (1–5%) to common (5–25%) amounts; mica is generally more abundant than quartz in the sediment. Trace to rare amounts of heavy minerals, palagonite, glauconite, and micronodules of framboidal pyrite are found. Radiolarians, sponge spicules, fish remains, and plant debris are infrequently present, in trace to rare (1–5%) amounts. Calcareous microfossils are almost completely absent from Subunit IB, except for extremely rare, thin laminae of nannofossil-bearing to nannofossil-rich claystone in Cores 603-26 to -31 and 603-33 to -41. Most of the carbonate that is found in Subunit IB of Holes 603 and 603B is in the form of siderite nodules, burrow fills, and layers (Fig. 11).

In Hole 603B, Subunit IB commonly contains siderite nodules of less than 1 cm in diameter, whereas in Hole 603 there are several very large concretions of siderite-bearing limestone that are 1 cm in diameter or larger (see later). Sample 603-21-1, 41–45 cm, shows a portion of a large burrow filled with light olive gray (5Y 6/2) limestone (Fig. 12A). The outside of this concretion shows an interesting surface pattern of an aggregate of pellets (Fig. 12B).

The uppermost sediments of Subunit IB (Cores 603-20 to -25; 448.6–554.2 m sub-bottom depth) contain dark grayish green claystone that swelled noticeably when exposed to fresh water during the core-splitting process.

The base of Subunit IB is placed at the uppermost occurrence of radiolarians. There is no significant textural or color difference between the claystone of Sub-

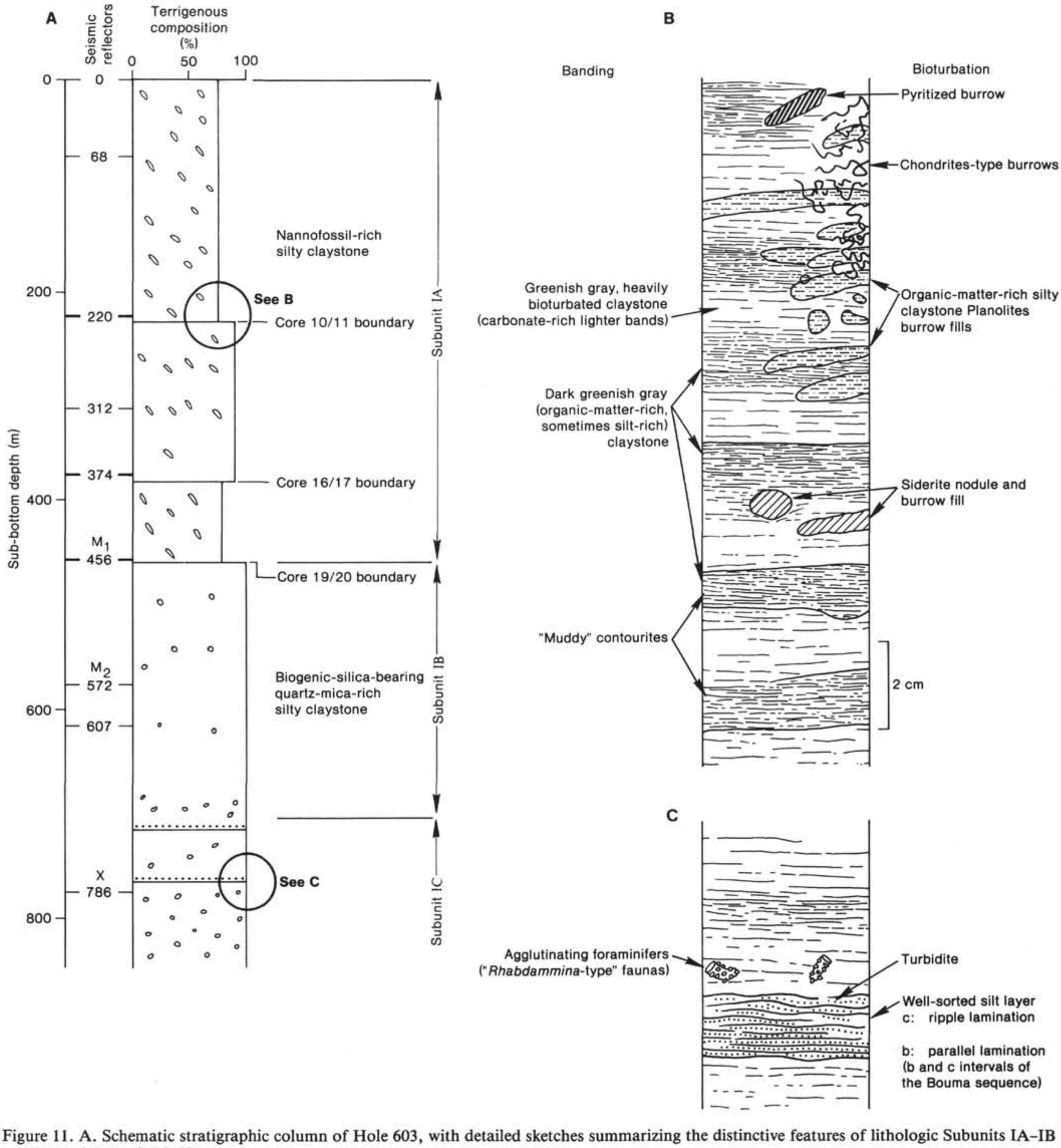

Figure 11. A. Schematic stratigraphic column of Hole 603, with detailed sketches summarizing the distinctive features of lithologic Subunits IA–IB (B), and Subunit IC (C).

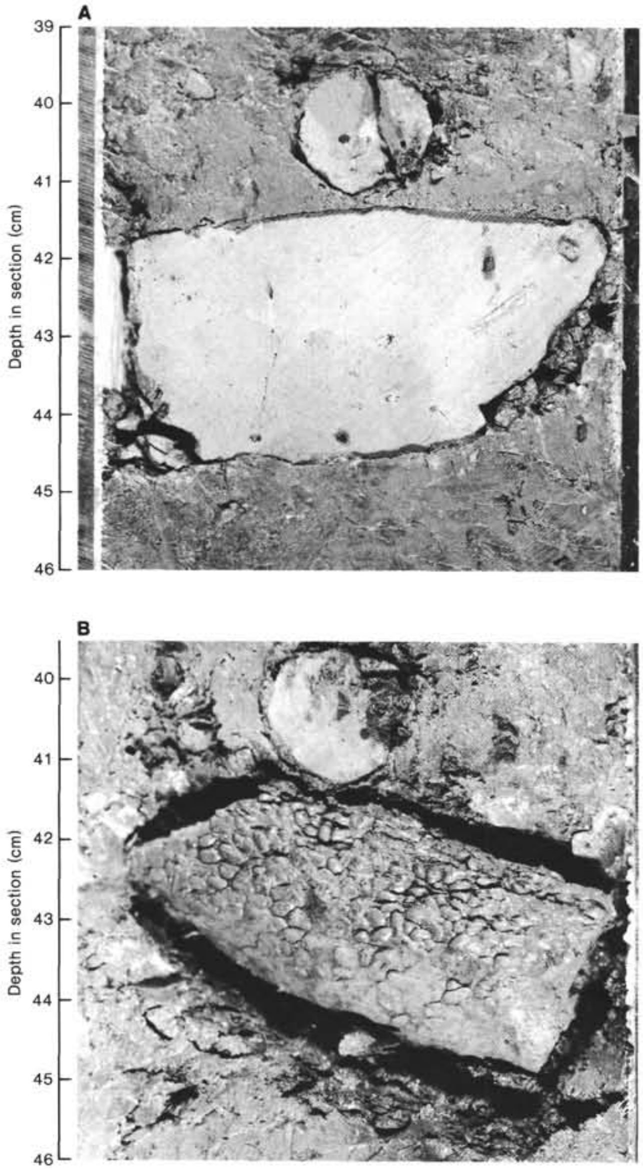

Figure 12. A. Siderite-bearing limestone nodules in Section 603-21-1 (lithologic Subunit IB). Nodule at 41–45 cm appears to be a burrow fill. B. Reverse side of limestone nodule, showing the knobby-botryoidal surface of this limestone burrow concretion.

unit IB and the underlying biogenic-silica-bearing claystone of Subunit IC.

Subunit IC: Biogenic Silica-bearing Clay–Claystone and Silt-bearing or Silt-rich Claystone (middle Miocene)

This subunit completes the stratigraphic record drilled at Hole 603, extending from Core 42 to 54 (698.2–832.6 m sub-bottom depth). In Hole 603B, the top of this unit is at the base of Section 603B-4M-5 (wash core) and the unit extends to Sample 603B-14-3, 65 cm (636–950 m sub-bottom depth). The top of Subunit IC is set at the uppermost occurrence of a discrete sand layer (Hole 603), which coincides closely in depth with the uppermost occurrence of biogenic-silica-bearing claystone (Hole 603B). Biogenic-silica-bearing claystone composes only the upper portion of the subunit (603-42 to 54; 603B-4M). This dark greenish gray to grayish green (5G 4/1–5GY 4/1) biogenic-silica-bearing claystone shows faint banding, is moderately bioturbated and contains up to 10% siliceous organisms (by smear slide analysis). The more siliceous material is slightly paler green than the less siliceous claystone.

The claystone of Subunit IC also contains 5–25% of terrigenous silt of quartz and mica; generally, mica is slightly more abundant than quartz. In addition to significant amounts of biogenic silica, Subunit IC contains occasional trace amounts of calcareous nannofossils, trace to rare amounts of feldspar, heavy minerals and opaque minerals, glauconite, pyrite, and micronodules. Siderite is rare to common (1–25%) in these cores, and discrete mm- to cm-thick laminae of abundant (more than 50%) siderite are seen. Pyrite and siderite burrow fills are common, as are siderite nodules. A spectacular concretion of light olive gray (5Y 6/2) siderite-bearing limestone is found in Core 603-46-2, 48–66 cm (Fig. 13).

Cores from this subunit emit methane from the cut surfaces, a phenomenon which is most apparent when the cores are still wet. Gas voids are partly filled with micronodules of framboidal pyrite. Gas escaped over periods of up to 1 hr. after the core was split in Cores 603-43 to -44 and 603-48 to -53, coinciding with decreased sonic velocities in these cores (see Physical Properties section in this report). In some cores, escaping gas fractured the sediments along horizontal planes (compaction surfaces?).

Subunit IC also contains cores with evidence of turbidite or sandy contourite deposition at Site 603 during the middle Miocene (Fig. 14). These thin, laminated deposits are uncommon but characteristic of Subunit IC—a total of 12 occurrences in 11 cores—and are interpreted as either turbidites or sandy contourites.

Near the base of Subunit IC (Core 603B-14), dark gray (5Y 4/1) and dark greenish gray (5GY 4/1) claystone with horizontal burrows and banding changes to a greenish gray (5GY 5/1) siderite-bearing and mica-rich claystone with horizontal burrows and rare, streaky dark gray (N4) laminae. In Sample 603B-14-3, 20–47 cm composition again changes to a quartz-bearing, mica- and unspecified carbonate-rich claystone, texturally a sandy claystone. The unspecified carbonate may be recrystallized radiolarians and/or foraminifers. At the very base of Subunit IC, in Sample 603B-14-3, 47–65 cm, greenish gray (5GY 5/1) changes to grayish brown (2.5Y 5/2) color and clay content increases.

Subunit ID: Silt-rich Claystones (middle or early? Miocene)

In Hole 603B, this subunit extends from 603B-14-3, 65 cm to 603B-15-4, 45 cm (950–961 m sub-bottom depth) and is predominantly composed of yellow brown (10YR 5/4) and brown (10YR 5/3) terrigenous silt-rich claystone. Bioturbation is rare to absent. Manganese nodules/concretions occur in Sections 603B-14-3 at 90 cm and 603B-14-6 at 7 and 65 cm. The last occurrence is a concretion or burrow fill which appears to contain a center of brown clay that has not been completely impregnated by iron-manganese oxides.

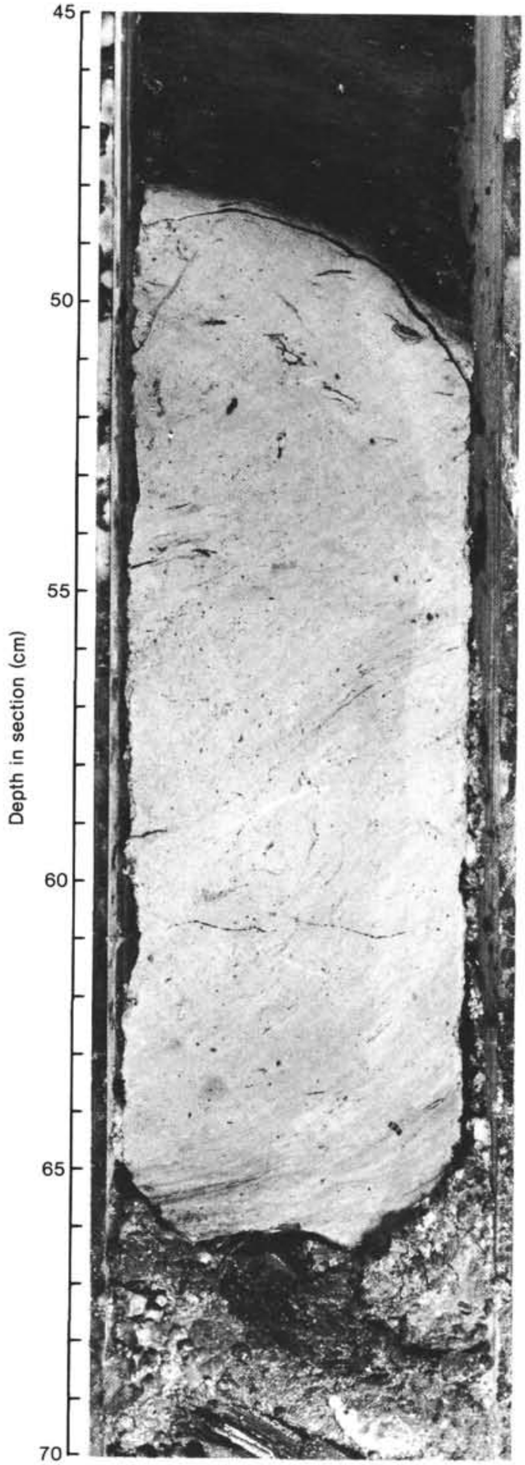

Figure 13. Siderite-bearing limestone concretion in lithologic Subunit IC. Sample 603-46-2, 45–70 cm.

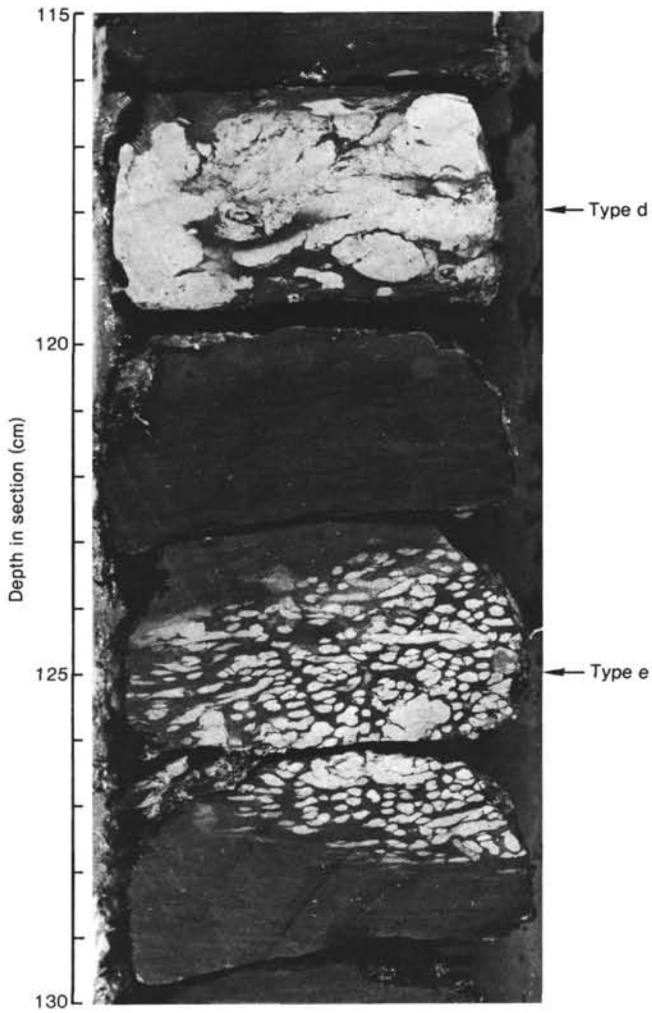

Figure 14. Burrowed siderite layer (type d, top) and layer of small scattered siderite concretions (type e, bottom) in Sample 603-50-3, 115–130 cm. A thin turbidite is also present in the lower part of this figure.

Smear slide analysis of the silt-rich claystones reveals that mica content ranges from 5 to 10%, quartz from 2 to 15%, and feldspar from 0 to 7%. Trace amounts of heavy minerals, glauconite, zeolites, siderite, and fish remains are found at some levels. From analysis by carbonate bomb, the carbonate content is typically less than 1%, with a rare pocket of 6% carbonate present in Sample 603B-14-4, 80–81 cm. The organic carbon content is less than 0.1% throughout the subunit.

Sections 5, 6, and 7 of Core 603B-14 contain bluish gray (5BG 6/1) reduction zones in the oxidized brown claystone. In Core 603B-15, these reduction zones are less abundant and are greenish gray (5GY 6/1). This subunit appears to be more highly oxidized and has a lower sedimentation rate than the overlying subunits of dark greenish gray (5GY 4/1) claystones.

The age of Subunit ID is problematic because it is barren of any age-diagnostic microfossils. Radiolarians are absent, and foraminifers are rare and very poorly preserved. Nannofossils are rare and poorly preserved and are also considered to be a product of downhole contamination. The age of middle to early (?) Miocene is therefore derived from that of contiguous Subunit IC (middle Miocene) and from the early Miocene age assigned fish teeth contained in a similar lithology in nearby Hole 603E.

Near the base of Subunit ID (Core 603B-15), there is a slight color change from a yellowish brown (10YR 5/4) to brown (10YR 5/3), with rare, scattered mottles of greenish gray (5G 6/1). Thin (1 mm) laminations of red (10R 4/6) appear. Smear slide analysis shows a trace amount of zeolites as a new component in these silt-rich claystones. Unit II is easily differentiated from the base of Unit I by the dramatic color change from brown (7.5YR 5/4) to pale green (5G 6/2) and the lithology change from silt-rich claystone to radiolarian claystone (see Frontispiece).

Siderite

Siderite nodules, burrow fills, and beds occur at Site 603 in Subunits IA, IB, and IC. Figure 10 shows that it becomes more abundant at a burial depth below 410 m (i.e., below Core 603-18), when $CaCO_3$ percentages (carbonate bomb) approach zero. Two rather indistinct maxima can be noted, one from 430 to 580 m (Cores 603-19M to -29, upper Miocene) and one between about 700 and 800 m (Cores 603-41 to -52, middle Miocene). There is also a distinct negative correlation between the abundance of siderite and pyrite nodules. Scattered silt-sized siderite crystals also occur as minor admixtures in the silty claystones which are the dominant lithology of this section.

Siderite occurs as (a) tiny specks or micronodules (1-3 mm in diameter), more or less compressed by compaction (possibly prior to siderite replacement); (b) nodules or burrow fills (sometimes associated with pyrite), about 1-3 cm in diameter, often concentrated in discontinuous layers (Figs. 12, 15); (c) large concretions 15-20 cm in diameter (only in Cores 603-46 to -48) (Fig. 13); (d) discrete, more or less burrowed ("marbled") layers (Fig. 14); (e) layers of many individual, small (1-3 mm), scattered concretions (Fig. 14).

A thin section of the 15-cm concretion in Section 603-46-2 (Fig. 13), shows that the siderite concretion contains many "streaked-out," elongate, clay-filled burrows, well-preserved planktonic foraminifers, and radiolarians "ghosts." There are all gradations from pure silt-sized siderite stone to siderite stone completely mixed with claystone by bioturbation. A large siderite concretion (Sample 603-21-1, 41-44 cm, Fig. 12A) shows a knobby-botryoidal surface (Fig. 12B). Possibly this nodule developed from a large burrow filled by fecal pellets from crustaceans.

Analyses indicate that the concretions contain abundant, well-sorted, silt-sized (2-10 μm diameter) carbonate rhombs and irregular crystals. Shipboard XRD analysis of a small nodule from Sample 603-17M-3, 136 cm showed the typical siderite peaks at 53°, 25.1°, and especially at about 32.0° 2θ (Cu Kα). Geochemical analysis (carbonate bomb) of the pure siderite sample (603-46-2, 59 cm) showed that with cold, concentrated HCl, CO_2 was liberated (85% siderite was calculated). This means that the carbonate bomb "$CaCO_3$" values also include siderite, unless diluted HCl is applied. Thin-section analysis of six siderite concretions indicated the following composition:

1%	Quartz (silt-sized, angular, 20-60 μm diameter)
tr	Mica (tiny flakes, mostly biotite)
tr-10%	Clay minerals (depending on amount of bioturbation), partial aggregate polarization
tr	Glauconite grains (50 μm)
1-5%	Framboidal pyrite spherules, often lining or filling burrows
81-96%	Siderite (silt-sized crystals, 2, 4, 10 μm, larger toward open cavities)
tr-2%	Well-preserved planktonic (globigerinid-type) foraminifers in some cores, recrystallized (sideritized?) foraminiferal chambers in others
tr-5%	Siliceous organisms (mostly radiolarians), partly original opal-A skeletons, partly sideritized, partly dissolved and replaced or filled by authigenic opal-CT lepispheres (beginning of early-diagenetic silicification)

Bottom Current Deposits

Surficial sediments from the western North Atlantic continental rise, described by Heezen et al. (1966), Schneider et al. (1967), Heezen and Schneider (1966), Rona (1969), and Asquith (1979), are though to be present-day contourites. Monotonous sequences of bioturbated claystones, acoustically transparent and of Miocene to Pleistocene age, which occur at many North Atlantic DSDP sites, are interpreted to be ancient analogs (e.g., Site 105, Leg 11: Hollister, Ewing, et al., 1972; Sites 112, 114 and 116, Leg 12: Laughton, Berggren, et al., 1972; Site 388, Leg 44: Benson, Sheridan, et al., 1978a).

Middle Miocene to Pleistocene sediments cored in the lower continental rise off the United States at Site 603 are a monotonous succession, more than 900 m thick, of homogeneous, gray green silty claystone, faintly banded and heavily bioturbated. Faint banding is the most significant of the sedimentary structures recognized in Unit I and seems to be due to slight changes in biogenic carbonate, quartz silt, and organic matter content, and perhaps in clay mineralogy. Centimeter-thick bands of claystone of different shades of greenish gray color alternate in a rhythmical fashion throughout the succession. These bands have gradational boundaries and in rare instances show evidence of a sharp base and top (Fig. 14).

Bioturbation (mostly horizontal Planolites-type burrows) has commonly disrupted the banding or completely churned the sediment; banding is always poorly preserved. A later generation of Chondrites-type burrow also occurs, and predominates in the lower half of the section. Vertical burrows (escape traces) are rare. Planolites-type burrows, cut along their axis, frequently mimic horizontal layering. Layers of well-sorted quartz silt, a few cm thick, were observed in Subunit IC (Figs. 4, 15). Some of these layers show well-developed turbiditic structures, namely a parallel-laminated interval grading upward in a ripple-laminated top (intervals T_b and T_c of the Bouma sequence) (Fig. 15). The silt layers have a sharp base and a gradational upper contact, and are distinctive features of Unit IC. Some of the silt layers appear to have been reworked by bottom currents, and may be considered as sandy contourites (Lovell and Stow, 1981).

Unit II: Radiolarian Claystone (Eocene)

This lithologic unit extends from 961 to 1023 m sub-bottom depth in Hole 603B (Sample 603B-15-4, 45 cm to 603B-22-2, 68 cm) (Fig. 16, Table 2). Unit II is composed of claystone containing variable quantities of ra-

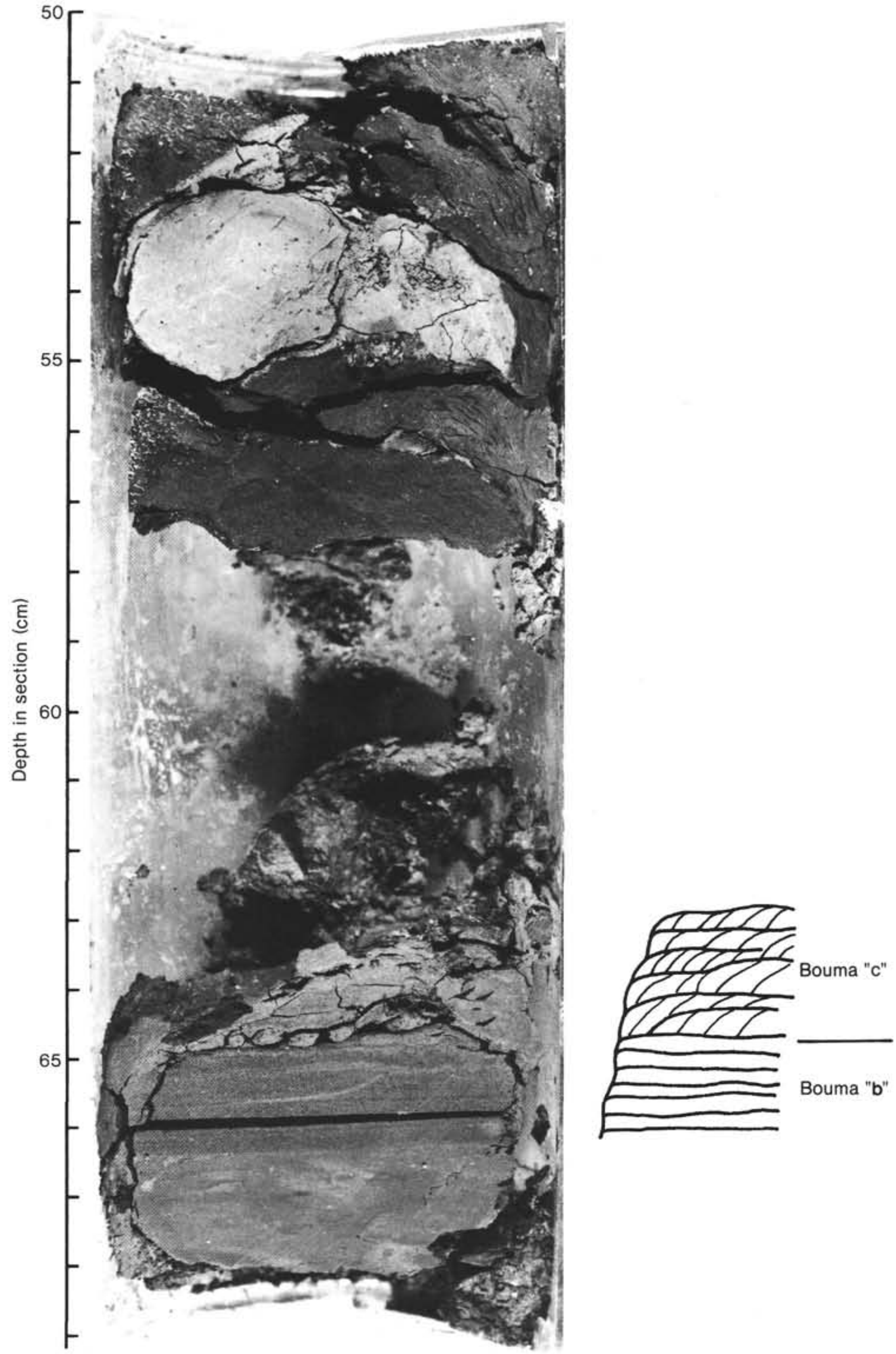

Figure 15. Turbidite of Subunit IC, in Sample 603-48,CC, between 64.5 and 66.5 cm. "Drill biscuit" in core catcher contains the turbidite sequence, and also a siderite nodule above this sequence.

diolarians, ranging from radiolarian-bearing (less than 10%) and radiolarian-rich (10-30%) to radiolarian claystone (30-50%). In Cores 603B-17 through -21, the zeolite content ranges from trace to common amounts (1-15%) to constitute zeolite-bearing and zeolite-rich claystone. Rare (1-5%) amounts of quartz, mica, and heavy minerals are found. Glauconite, pyrite, sponge spicules, fish debris, and nannofossils are found in trace amounts. From analysis by carbonate bomb the carbonate content is less than 1%, although one siderite nodule was noted in Core 603B-18.

The uppermost 10 m of this unit are extremely colorful. The radiolarian claystone in the base of Core 603B-15 contains distinct color bands of pale green (5G 6/2) and reddish brown (5Y 4/4). The top of Core 603B-16 (the "Halloween core") is pale orange (yellowish red, 5Y 4/6) with rare mm-thick black streaks. Going downcore, the color changes to a dark reddish brown (5YR 3/2) with common black layers and yellowish red horizontal burrows. The lower portion of the core is predominantly green (5GY 6/2), alternating with yellow brown (7.5YR 4/4). There is a decrease in color variation and banding in the remaining cores. The colors are shades of yellow brown (10YR 5/4) and grayish green (5GY 4/1) at the base of the unit.

Bioturbation is rare. Fine laminations throughout this unit below Core 603B-16 contain concentrations of radiolarians. By Core 603B-21 these laminations are faint, and layers of claystone containing abundant recrystallized radiolarians alternate with layers almost devoid of recrystallized radiolarians. In Core 603B-17, many of these laminations have become lenses (3–5 mm in length) filled with radiolarians, and they are abundant in Section 603B-17-3, at 977 m sub-bottom, as stringers. In Section 603B-17-4, these laminations and lenses are very distinct; white stringers containing the initial stages of porcellanite development appear, with diffuse boundaries. At 603B-17-4, 49 cm, a 2-mm layer of siliceous cement is found. A similar diagenetic trend is also noted in Core 603B-19, with similar white stringers. The percentage of zeolites from smear slide analysis is also very high in these ranging cores, from 5 to 7% in Core 603B-17 and from 6 to 15% in Core 19, with white lenses of zeolitic silt at 70%. Thin sections from Core 16, of typical radiolarian claystone, appear as porcellaneous mudstone.

Thin-section analysis revealed that the black streaks which appeared in Core 603B-16 are claystone impregnated with iron manganese. In Core 603B-18, two crenulated layers of dark brown appear as discrete manganese crusts.

The only evidence of turbidity-current deposition occurs at the base of this unit. In Section 603B-22-2, two graded siltstone layers are found overlain by radiolarian-rich claystone.

The contact with Unit III is immediately below these graded layers at 603B-22-2, 68 cm. The boundary may also be defined by the lithology change, from a radiolarian claystone of Unit II to a clayey, silty sandstone in Unit III. There is a color change from the greenish gray (5G 5/1) of Unit II to the alternating dark brown (7.5YR 3/2) and dusky blue-green (5BG 3/2) of Unit III.

Unit III: Variegated Claystone (Senonian; possibly also early Paleogene)

The boundary between the mid-Eocene radiolarian claystones (Unit II) and the barren, variegated claystones (Unit III) at 603B-22-2, 68 cm is a conspicuous lithological and biostratigraphic break (Fig. 16). Lithologically, we put the boundary at the base of two turbidites overlain by greenish gray radiolarian claystone and underlain by barren terrigenous silt-rich claystone which, for the first time, displays reddish brown and greenish gray colors.

It is more difficult to define the base of Unit III. Tentatively, we place the boundary between Unit III and the underlying Unit IV at 603B-33-1, 60 cm, because below this level carbonaceous "black shales" are abundant and brown claystones are absent. Figure 16, however, shows that there is a lithological gradation between both units, since the uppermost "black shales" are in Section 603B-32-1.

Subdivision of Unit III is possible by the relative abundance of brown (oxidized) and greenish gray (reduced) claystone and the appearance of dark gray, slightly carbonaceous claystone (Fig. 16). Three subunits are tentatively defined in Unit III (Table 2).

Unit III is barren, except for a few zeolite-filled or silicified radiolarian "ghosts" and a "*Rhabdammina*-like" agglutinated foraminiferal assemblage in Cores 603B-30 to -33 (Fig. 16). Pock-marked pits in the variegated claystone were probably formed by the postdepositional dissolution of radiolarians (e.g., in Cores 603B-29 and -30).

Variegated (greenish gray to reddish brown) claystones compose the most abundant lithology of the unit. The sediments are predominantly greenish gray (5GY 5/1–6/1) to dark greenish gray (5GY 4/1–5G 4/1) in the reduced state and are dark reddish brown (5YR 3/4) to dark brown (10YR 3/3) to red (5YR 4/6) in the oxidized state. Subordinate are gray (N5) to dark gray (10YR 3/1, 5Y 4/1), dark reddish gray (5Y 4/2-3), yellowish brown (10YR 5/4), and moderately yellow (5Y 7/6) hues. Tiny streaks of (?organic-matter-rich) black material are ubiquitous in burrowed greenish gray claystones and probably represent compacted burrow fills.

The composition of these claystones, as estimated from smear slides, varies from terrigenous-silt-bearing (less than 10%) to silt-rich (more than 10%) claystones with Fe- and Mn-oxides (reddish brown) and pyrite (greenish gray) as opaque minerals. Mica is usually more frequent than silt-sized quartz. Glauconite and heavy minerals occur in trace amounts. Organic matter (coalified plant debris?) makes up several percent of the dark gray to greenish gray claystones. Zeolites (probably clinoptilolite) were recognized only in some smear slides (trace amounts to 1%), except for Cores 603B-26, -28, -29, -31, and -33, where 2 to 10% were reported in smear slides. Zeolite-filled radiolarian "ghosts" were observed in Cores 603B-24 and -30. Manganese-stained thin laminae and a few angular iron manganese concretions were noted in Cores 603B-28 and -30, suggesting very slow sedimentation rates.

The greenish gray and reddish brown claystone is either homogeneous or color-banded to irregularly color-mottled. The greenish gray to dark gray claystone is commonly laminated and alternates with laminated carbonaceous claystone. Bioturbation is rarely observed in the organic-matter-poor reddish brown claystone, but is more frequent in the greenish gray varieties. There, burrows filled by siderite are observed (Core 603B-26).

Figure 16 indicates four occurrences of dark gray (to black), more or less carbonaceous claystone in Unit III: (a) Core 603B-24, (b) Cores 603B-26 to -27 (with up to 1.9% C_{org}), (c) Sections 603B-28-4 to -29-2, and (d) Core 603B-32 to Section 603B-33-1 (gradation to black carbonaceous claystone, Unit IV). They consist of undetermined clay minerals, organic matter (plant material, up to 10%), pyrite, quartz, and mica (together about 5–10%), and trace amounts of zeolite. Tentatively, we sug-

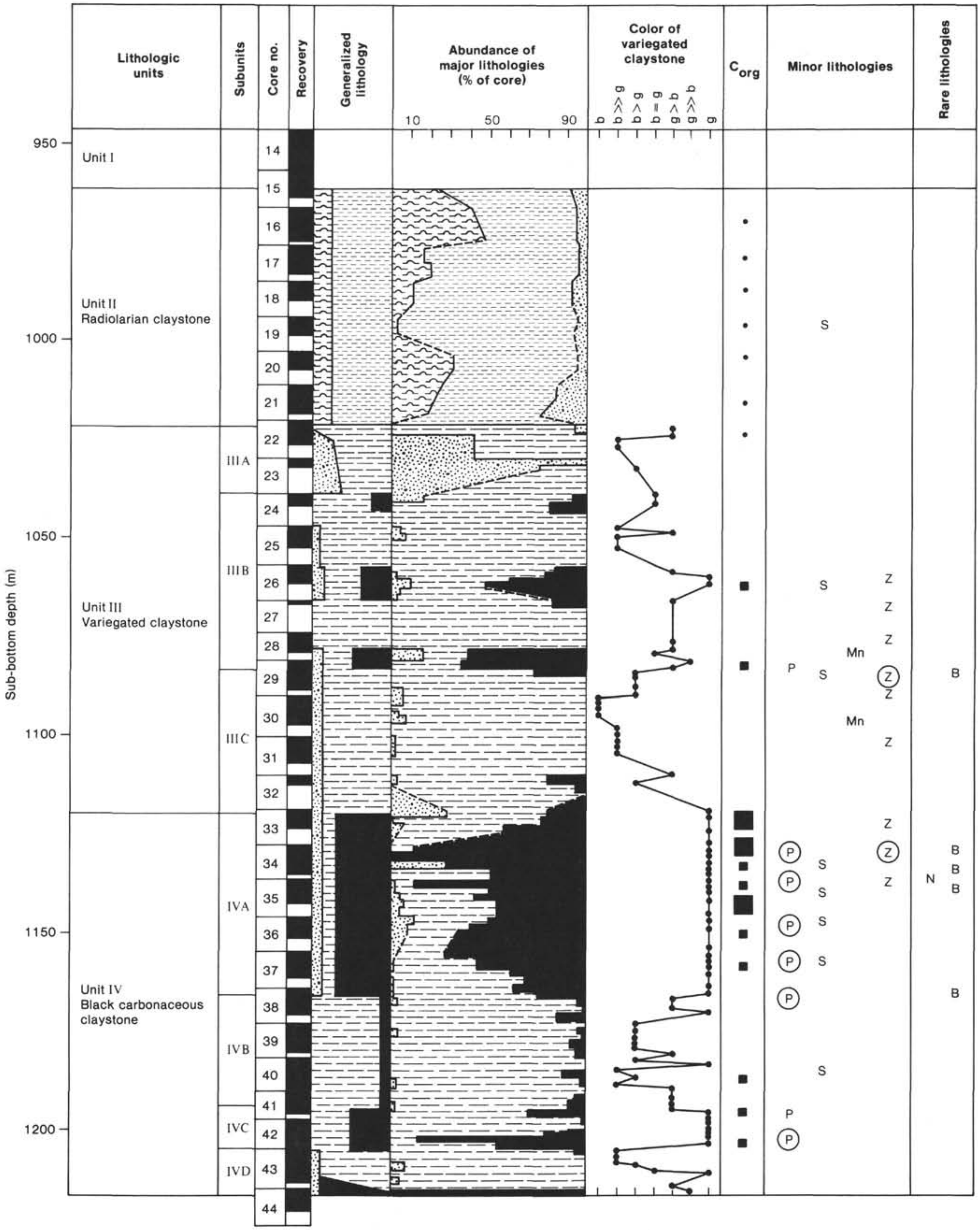

Figure 16. Stratigraphic summary of lithologic Units II to IV, Hole 603B, indicating cored intervals, core recovery, lithology, age, and biostratigraphy of recovered material. Relative abundance (%) of greenish gray versus reddish brown pelagic claystones gives an approximate indication of bottom-water oxygenation. Radiolarian zonation after Nishimura (this volume).

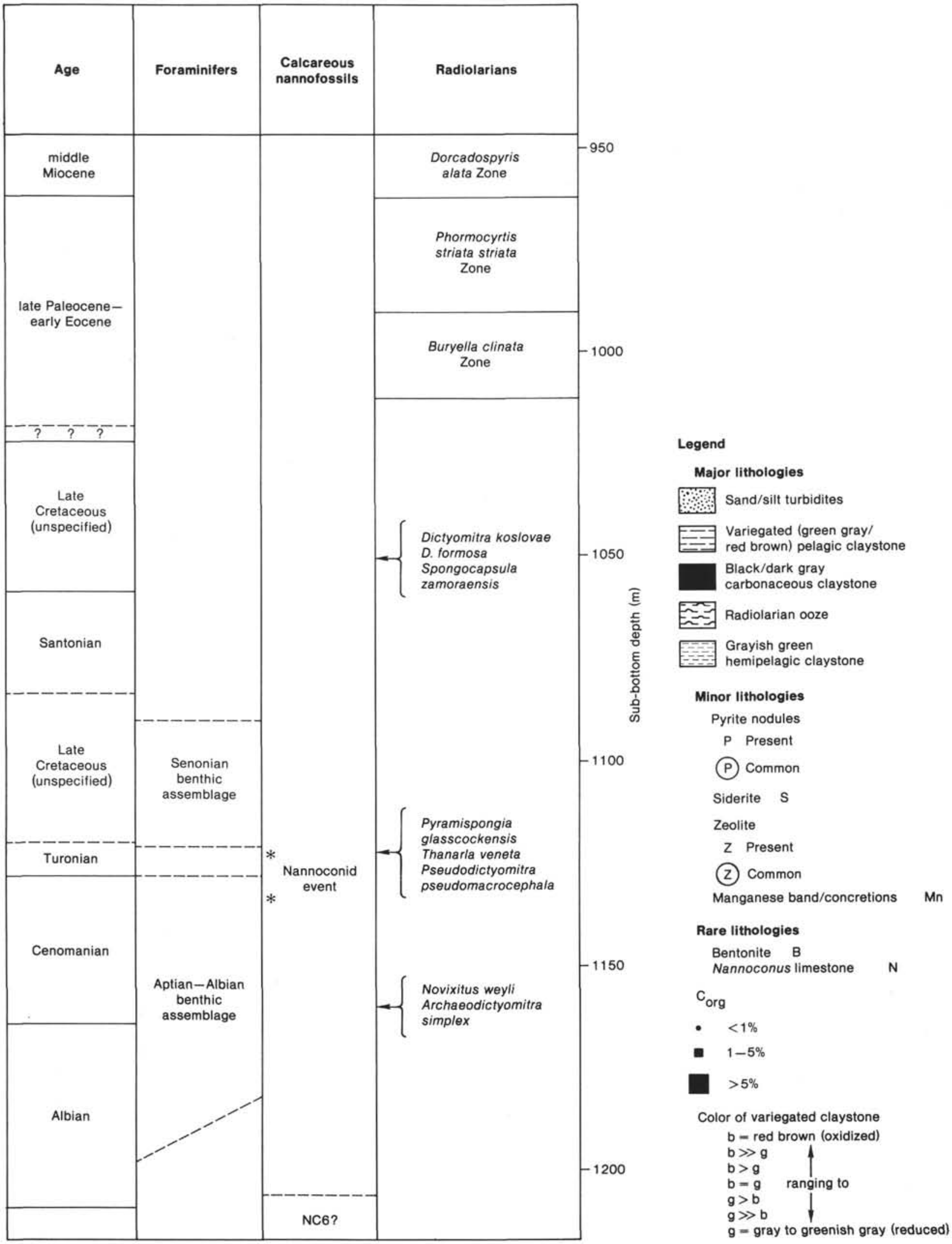

Figure 16 (continued).

gest that at least the homogeneous to faintly graded, dark gray carbonaceous claystones with a basal silt layer are mudstones deposited by turbidity currents (Fig. 17). The origin of the laminated carbonaceous claystone is less clear.

In almost all cores, 1-10% of each section consists of thin layers of gray to medium gray (5Y 6/1 to N4), laminated, terrigenous silt turbidites (Fig. 16). Massive to graded, partly laminated sand layers occur only in Sections 603B-23-1 and 603B-23-2 (more than 145 cm thick, with the rest washed away by the drilling procedure), in Sections 603B-24-1 (25 cm thick), 603B-28-4 (6 cm thick, laminated), and 603B-33-1 (more than 45 cm thick). These layers consist of glauconite and mica-bearing to mica-rich, silty, fine- to medium-grained quartz sandstone.

The majority of the terrigenous coarse layers interbedded with the greenish gray and black claystones consists, however, of thin (cm-scale) to very thin (mm-scale)

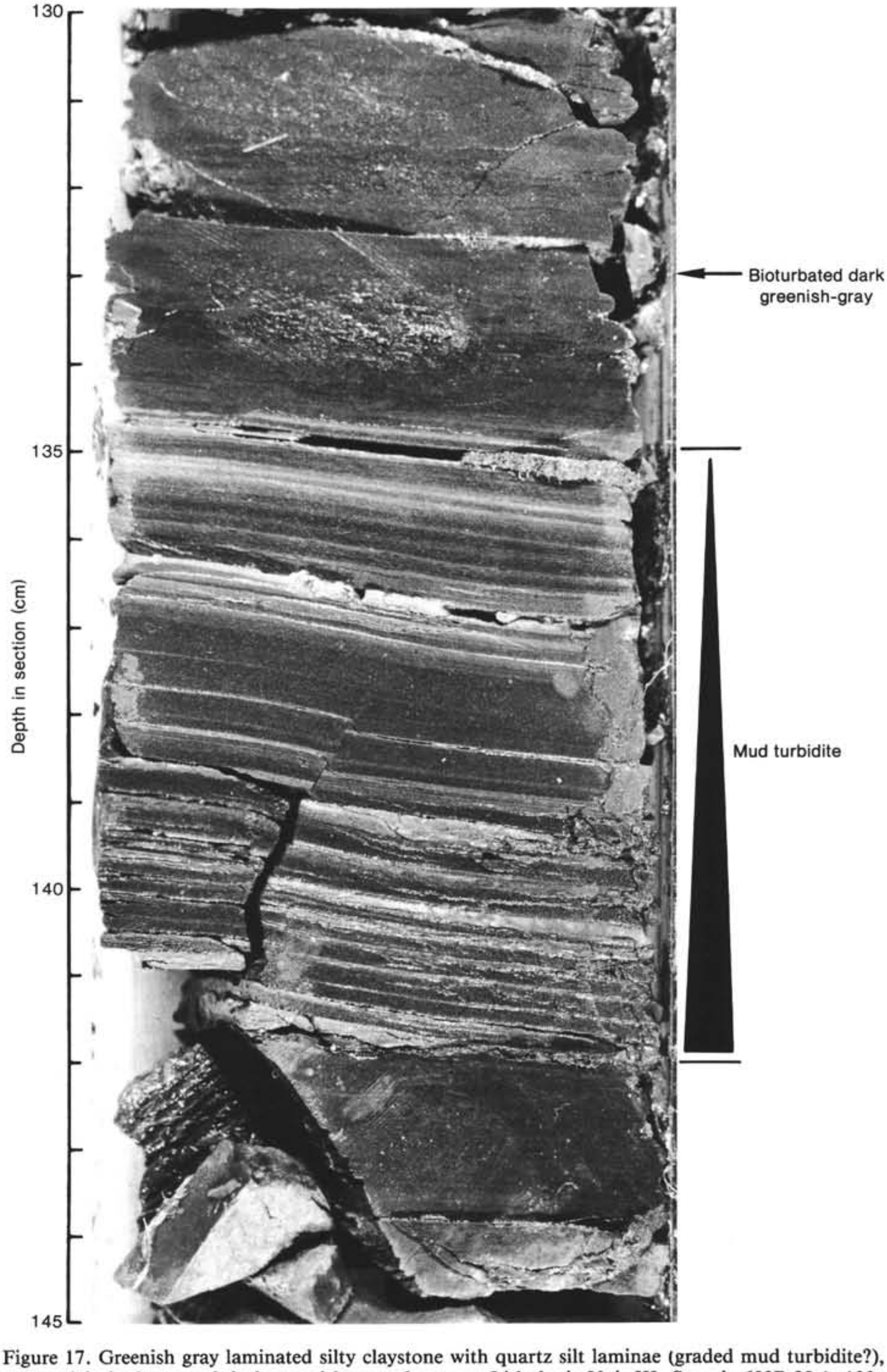

Figure 17. Greenish gray laminated silty claystone with quartz silt laminae (graded mud turbidite?), overlain by burrowed dark greenish gray claystone. Lithologic Unit III, Sample 603B-29-1, 130–145 cm.

layers, laminae, and lenses (burrow fills?) of light gray, moderately sorted, mica-rich quartz siltstones (Fig. 17). The siltstones generally show parallel, current-ripple, and convolute lamination (T_b and T_c intervals of the Bouma cycle) and can be explained as either distal turbidites or bottom-current deposits.

A cemented, 3-mm thick, light gray (5Y 7/1) layer of siderite stone was discovered in Core 603B-29-2, 39 cm, and siderite-rich claystone was found in burrows within dark gray claystone in Section 603B-26-3.

A 5-cm thick distinct layer of light gray (N7), zeolite-rich, smectite(?) claystone occurs in Sample 603B-29-2, 87–92 cm (Fig. 18); it may represent an altered volcanic ash layer.

Unit IV: Black Carbonaceous Claystone (Aptian–Turonian)

The upper boundary of Unit IV at 603B-33-1, 60 cm is set at the uppermost occurrence of black carbonaceous claystone as a major lithology (Fig. 16). We define the lower boundary of Unit IV by the lowermost occurrence of black carbonaceous claystone and the uppermost appearance of nannofossil claystones (marlstones) at 603B-44-1, 32 cm. Layers of "black shale" (mostly carbonaceous mud turbidites), however, occur also in the overlying Senonian Unit III, and the underlying Neocomian Unit V. This means that there are Berriasian to lower Aptian, Aptian to Turonian, and mid-Upper Cretaceous (at least Santonian) "black shales" at Site 603.

Unit IV may be subdivided using the occurrence or relative abundance of pelagic, reddish brown claystones in the core sections (see Fig. 16). Four subunits can be distinguished (Table 2), based on their dominant lithologies:

1. *Black Carbonaceous Claystone.* Although black carbonaceous claystone is the name-defining, most conspicuous lithofacies of Unit IV, it is only in Unit IVA (and part of IVC) that it becomes the most abundant lithology (Fig. 16).

The color of the carbonaceous claystone ranges from black (N1) to grayish black (N2–3), greenish black (5G 2/1, 5G 3/1), olive black (5Y 2/1), and dark olive black (5Y 3/1–2). The claystone contains up to 15% organic matter (mainly particulate coalified plant fragments and small organic spherules) according to smear slide estimates. The shipboard C_{org} contents of black claystones are summarized for Units IVA to IVD below.

Subunit	Range (%) (*N*)	Average (%)
IVA	0.7–13.6 (*17*)	4.24
IVB	1.4 (*1*)	1.37
IVC	0.7–2.5 (*3*)	1.45
IVD	2.2 (*1*)	2.15
Unit IV	0.7–13.6 (*22*)	3.64

Other components observed in the smear slides include quartz, mica, and pyrite. Zeolite (probably clinoptilolite, which is commonly associated with carbonaceous mudstones) is common (up to 12%) in Core 603B-34.

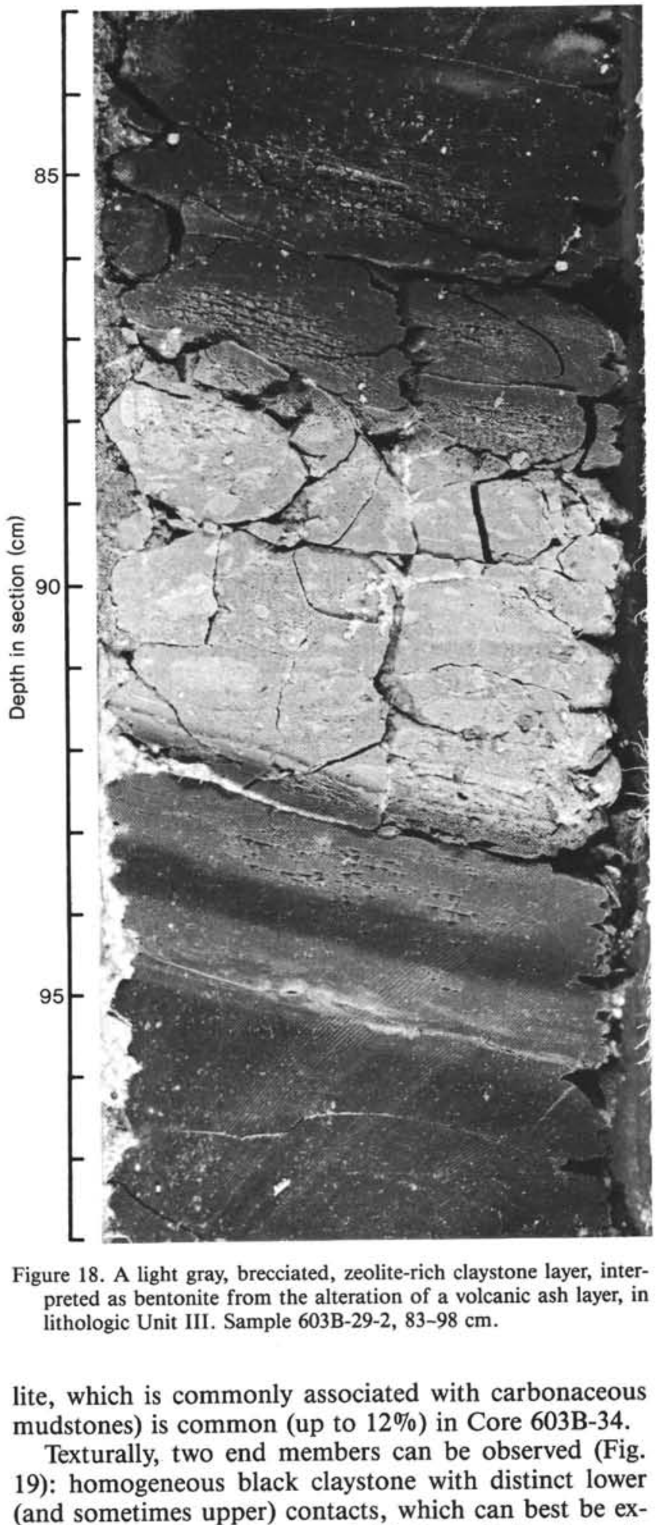

Figure 18. A light gray, brecciated, zeolite-rich claystone layer, interpreted as bentonite from the alteration of a volcanic ash layer, in lithologic Unit III. Sample 603B-29-2, 83–98 cm.

Texturally, two end members can be observed (Fig. 19): homogeneous black claystone with distinct lower (and sometimes upper) contacts, which can best be explained as mud turbidites, and faintly to distinctly laminated carbonaceous claystones with pyrite or thin (sub-mm) quartz silt laminae. These claystones are devoid of bioturbation, except for a few local, upward-pointing "escape burrows." The laminations are parallel or rippled, indicating some reworking by bottom currents (Fig. 19). Thin sections show that the lamination is due

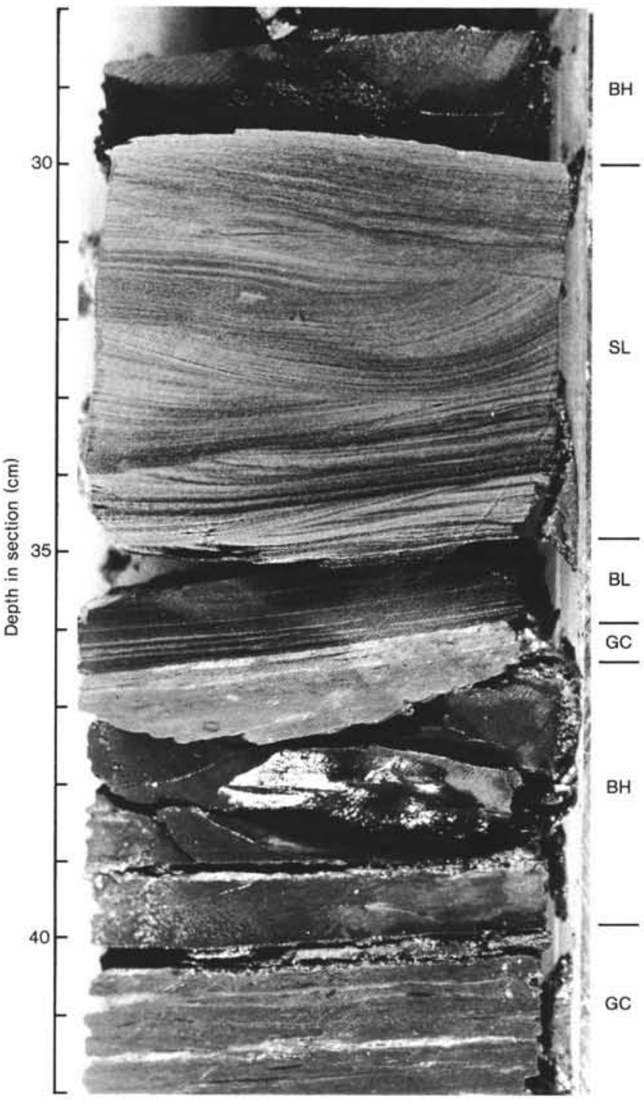

Figure 19. Typical aspect of Subunit IVA carbonaceous claystones. Abbreviations indicate different lithologies within this subunit: BH = homogeneous black claystone (mud turbidites?), SL = parallel and cross-laminated quartz siltstone layer (in this case, cemented by siderite), BL = laminated black claystone, and GC = faintly laminated to slightly bioturbated greenish gray claystone (pelagic sediments). Sample 603B-36-1, 28–42 cm.

to concentrations of (1) quartz silt (light-colored), (2) mica, clay, and organic matter (dark-colored laminae), (3) pyrite microplacers, or (4) mica only.

Pyrite lenses and nodules are especially common in Cores 603B-33, -37, and -41, siderite-rich claystone in Cores 603B-34, -36, and -40 (see Fig. 16).

2. *Silt Turbidites.* About 1 to 10% of most core sections of Unit IV consist of thin layers and lenses of light to medium gray (N4–6) laminated silt. Three maxima of terrigenous silt input can be identified (Fig. 16): at the upper boundary of Unit IV (Cores 603B-33, -34), from Section 603B-34-4 to 603B-36,CC, and from Sections 603B-43-4 through 603B-43-6, near the lower unit boundary. Only locally do the silt layers reach thicknesses of 10–15 cm (Sections 603B-33-3, 603B-35-4, 603B-36-1 to 603B-36-3) and display parallel and/or ripple laminations (Fig. 19), and (rarely) cross and convolute laminations. There is generally a sharp truncational boundary toward the underlying claystone; often the upper contact is also distinct, indicating some reworking. In most cases the layers are less than 1 cm thick. Often these parallel-laminated silt layers are the basal part of a homogeneous black claystone turbidite (sometimes overlain by a laminated carbonaceous claystone). However, all other combinations are possible.

The composition of these layers varies from glauconite-bearing quartz siltstone to mica- and organic-matter-bearing, clay-mineral-rich, quartz siltstone (sandy and clayey coarse siltstone). Variations in quartz silt, mica, clay, and pyrite concentrations are responsible for the laminations. A thin section of the base of a silt turbidite (603B-43-5, 64–66 cm) shows that a mica-bearing quartz siltstone, rich in clay minerals and organic matter, was cemented by large calcite crystals enclosing quartz grains.

3. *Variegated (greenish gray to reddish brown) claystone.* This mica-rich claystone, which has been discussed in the section on Unit III, is the pelagic background sediment for the black claystone and silt turbidites. The greenish gray claystones are intimately interbedded on a cm-to-dm scale with the black claystones and quartz silt layers, lenses, and stringers. In some cases an upward gradation from greenish gray into black claystone was noted. The major colors are (in order from oxidizing to reducing conditions) (dark) reddish brown (5YR 3–4/4); dark brown (7.5Y 3/2) to dark reddish brown (5YR 3/3); dusky red (2.5YR 3/2); light greenish gray (5BG 7/1–6/1); greenish gray (5GY 5/1, 5G 5/1–5G 4/1); dark greenish gray (5GY 4/1); gray (5Y 5/1); dark gray (5Y 4/1).

The color changes can be gradual or sharp. In claystones underlying silt and mudstone turbidites, the original brown color has been reduced to green. The color column of Figure 16 shows some trends of oxidizing versus reducing conditions which lead us to subdivide Unit IV into Subunits A–D.

Smear slides show that the composition of the claystones is characterized by undetermined clay minerals with subordinate mica, traces of zeolites, pyrite, and organic matter occurring in the greenish gray varieties. Generally, the brown claystone is less bioturbated than the greenish gray mudstone, which commonly is slightly burrowed and irregularly laminated, especially if it is associated with carbonaceous black claystones.

4. *Smectite Claystone.* Highly swelling smectite (?) claystone (volcanogenic bentonite) is observed in Sections 603B-34-2, 603B-35-1, and 603B-38-1.

5. *Siderite Claystone.* A thin section (603B-37-2, 0–5 cm) shows a completely sideritized silty claystone with large, more or less euhedral siderite crystals.

Unit V: Interbedded Nannofossil Claystone and Limestone with Sandstone to Claystone Turbidites (Berriasian–Aptian)

The lowest unit recovered in Hole 603B is a Neocomian carbonate-rich sequence of alternations of gray, laminated, nannofossil claystone ("marl") and light gray, bioturbated, nannofossil chalk to limestone. These pelagic sediments are interbedded with abundant turbidites of terrigenous sandstone and organic-matter-bearing claystone in the upper part of the unit (Fig. 20). The contact between Units IV and V was placed at the top of the abundant turbidites of nannofossil-rich claystone at 603B-44-1, 32 cm. Unit V is subdivided into two subunits, VA and VB, respectively by the presence or absence of turbidites (Fig. 20; Table 2). The contact is placed at the base of the lowest claystone turbidite, in Sample 603B-76-1, 120 cm. This is also the approximate location of the Valanginian/Hauterivian boundary.

The pelagic sediments of alternating laminated marl and bioturbated limestone are very similar between the two subunits, which will be described uniformly. The turbidites distinguishing Subunit VA will be examined separately.

Pelagic Sedimentation

The *in situ* pelagic sediments of Unit V consist of alternations of gray, laminated, nannofossil claystone (marl) and of light gray, bioturbated limestone (Fig. 21). Laminated zones are nannofossil-rich claystone (10–30% nannofossils) to nannofossil marl (30–50% nannofossils). The most common color is medium gray with a brownish tint (5Y 5/1), though the color can range from dark gray (N3, 5Y 3/1) to light gray (N7, 5Y 7/1) depending on clay and organic matter content. In general, the color becomes darker and the clay and organic matter become more abundant in progressively younger cores, but this is not a uniform trend. The organic matter content (mostly land plant debris) averages about 5% in smear slide analyses. The microfossils (5% average abundance; calcified radiolarians, calcispheres, and foraminifers) are generally calcite-filled after partial flattening. Laminations are due to small variations in the abundance of clay and fine-grained mica minerals and appear to average about 50/cm. Curiously, the laminations are difficult to distinguish in thin sections, perhaps owing to a reduced contrast between clay- and micrite-rich layers when using transmitted light. The terrigenous silt component, primarily fine-grained mica, is minor. Within the laminated zones are wood fragments, ammonite aptychi (especially in the lower half of the unit), rare ammonites, *Inoceramus* shells (in Cores 603B-70 to 603B-80), and a fish jaw (Core 603B-80).

Bioturbated zones are clayey nannofossil chalk ("marly limestone") to clay-rich limestone. Color is generally light gray (N7, 5GY 7/1) with a range from medium gray (N5, N6) to nearly white (N8, N8.5). Radiolarians are common (5–15%) and are more abundant in the lower (and usually more carbonate-rich) part of the unit. The radiolarians are generally sparry calcite molds; pyrite replacement also occurs. Nannofossils are more abundant but also more recrystallized than those in the laminated zones. Pyrite nodules and iron sulfide streaks are common.

The bioturbated and laminated zones exhibit gradational contacts with partially bioturbated, vaguely laminated gray marl as a brief intermediate stage in most cases (Fig. 21). These alternations do not exhibit a regular cyclicity and quite often are between darker, densely laminated sediments and lighter, less laminated sediments, or are between laminated and partially bioturbated sediments. The frequency of the main alternations (after subtracting the turbidite episodes from the section) seems to average 1.0 to 1.5 "cycles"/m. However, there are more subtle variations in color darkness or degree of bioturbation on the 10–20-cm scale. In addition, the ratio of laminated versus bioturbated sediment is variable through the unit (Fig. 20). Laminated intervals are dominant in Cores 603B-49 to -57 and 603B-76 to -80, bioturbated intervals are dominant in Cores 603B-66 to -70, and laminated intervals are slightly dominant in the rest.

Turbidite Intervals

Core 603B-44 through Section 603B-76-1 is characterized by the abundance of claystone, siltstone, and sandstone turbidites, and this interval was designated as Subunit VA (Sample 603B-44-1, 32 cm through 603B-76-1, 120 cm; 1214.7–1512.3 m depth; thickness 297.6 m). These turbidites are of two main types: siltstone–sandstone and organic-matter-rich claystone. The presence of intermediate types and of graded sandstone-to-claystone sequences indicates that these two textural types are related.

Terrigenous siltstone–sandstone turbidites are most abundant in Cores 603B-45 to -67, with a peak in Cores 603B-45 to -48, where they comprise nearly all of the recovered sediment (Fig. 20). Within these 23 cores (218 m), siltstone-sandstone turbidites comprise about half of the recovered section. The composition of these dark gray to dark greenish gray (N4, 5GY 4/1) turbidites is dominated by subangular quartz, with abundant feldspar (up to 15% in some thin sections), mica (muscovite and biotite), heavy minerals, and opaques, plus a significant content of plant debris, shell fragments, and glauconite. (In some cases, wood fragments comprise 20% of local zones within a turbidite.) The bioclastic debris (ammonite and other shell fragments, gastropods, echinoids, pelecypods, epistominid foraminifers, fish debris) and wood fragments (now carbonized) in part indicates a shallow-water source of some of the material. The interstices between the loosely packed grains are generally filled by clay, though calcite cementation is common in the basal portion of beds when the turbidite overlies a carbonate-rich pelagic sediment. The thick, sandy turbidite beds of Cores 603B-44 to -48 are unconsolidated sand in several cases.

Some turbidites exhibit the entire range of structure of the Bouma cycle (divisions T_a to T_e), though the uppermost fine-laminated (T_d) and homogeneous intervals (T_e) are recognizable only when a sufficiently thick claystone layer overlies the sandstone bed. The thickest sandstone beds contain a relevant proportion of clayey matrix (up to 30–35%). They are massive or display either faint convolute or parallel, thick laminae (dewatering structures). They do not develop a Bouma sequence or, if they do, it is incomplete (sandy debris flow deposits) (Fig. 22). Conspicuous features are massive basal layers (divisions T_a and T_b of the Bouma sequence) and intraclast-rich intervals in the medial portion ("slurried beds"). The intraclasts are generally of flattened dark claystone, but can include plastically deformed blocks of laminated

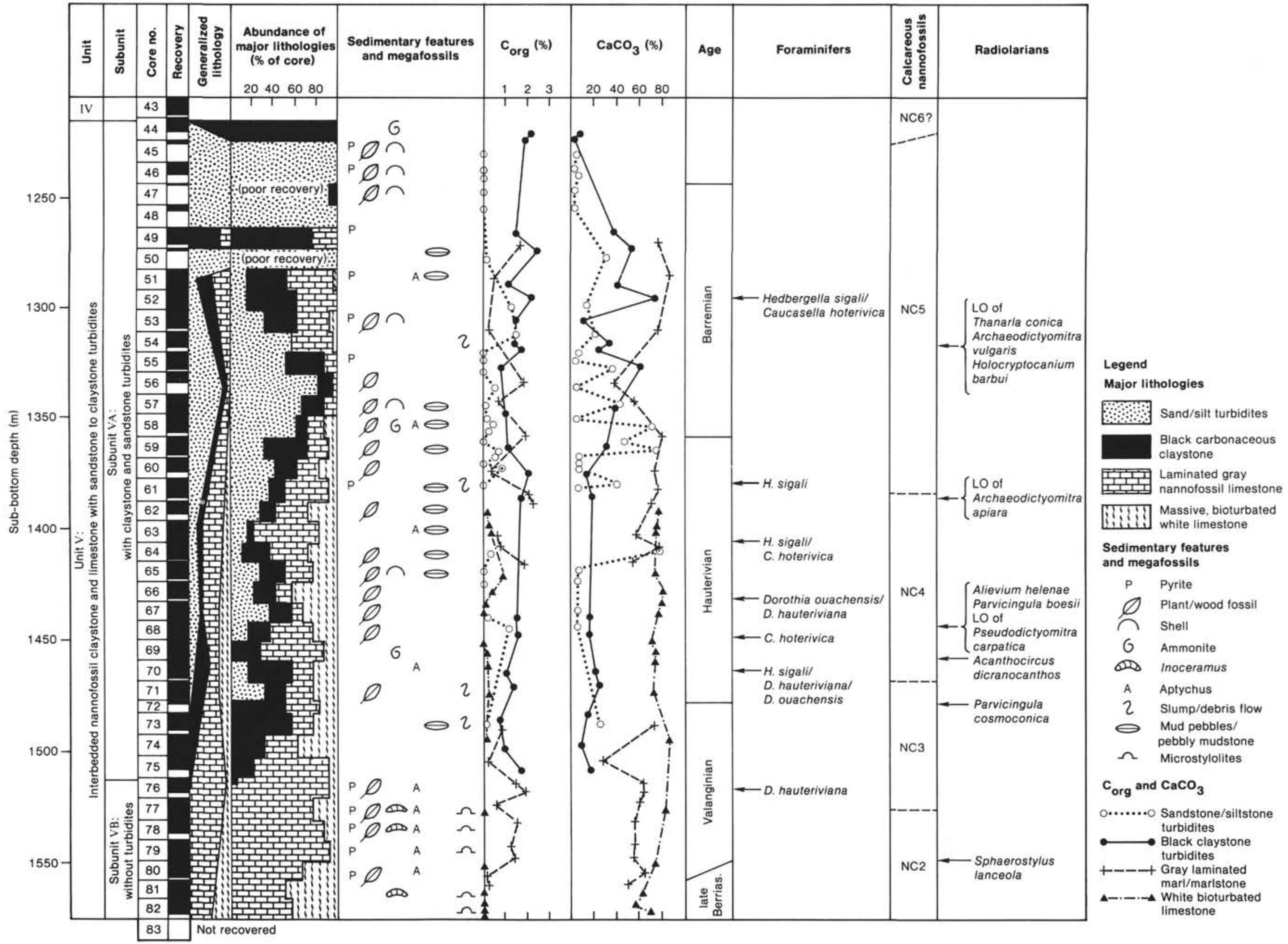

Figure 20. Stratigraphic summary of lithologic Unit V, Hole 603B, indicating cored intervals, core recovery, lithology, age, and biostratigraphy of recovered sedimentary rocks. LO = last occurrence.

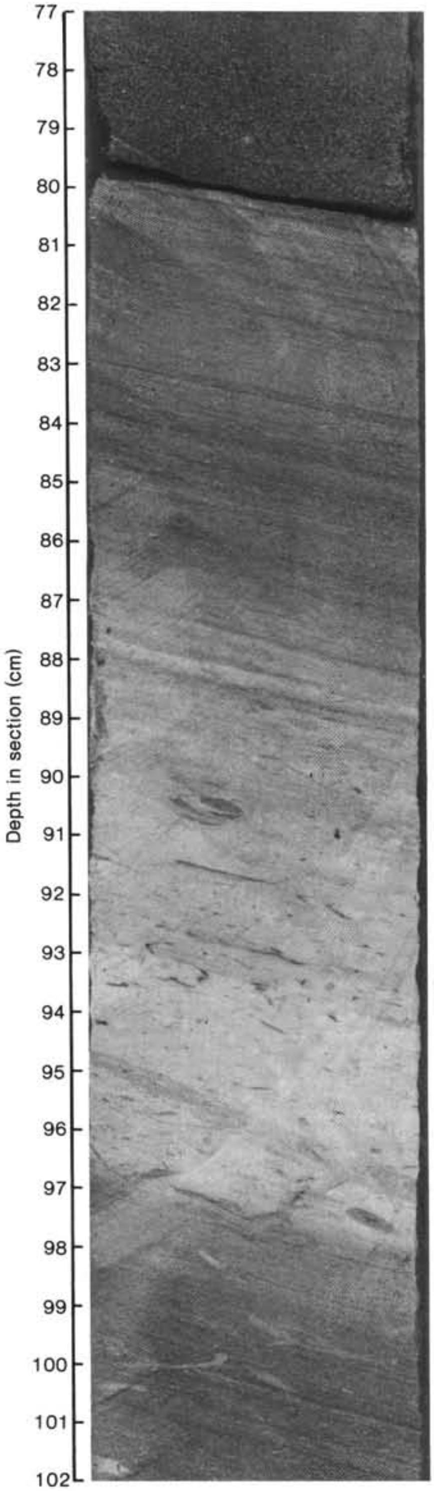

Figure 21. Typical cycle, showing gradational changes of laminated marl-bioturbated chalk-laminated marl in lithologic Unit V of Site 603. A silty sandstone turbidite overlies the laminated marl, in the top of the figure. Sample 603B-59-2, 77–102 cm.

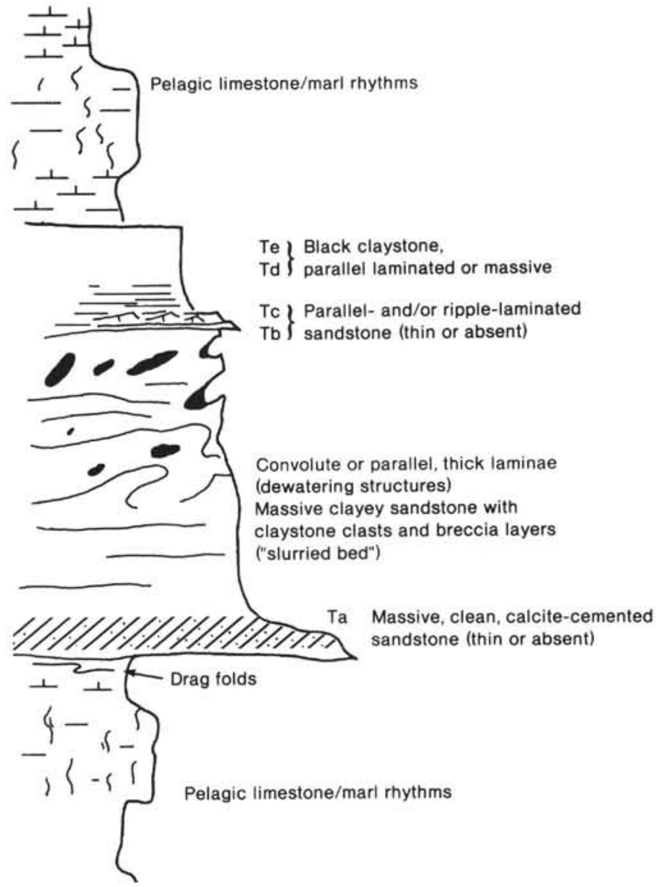

Figure 22. Sketch showing the main features of some Lower Cretaceous turbidites at Site 603. Individual members of the Bouma sequence are labeled, and the Bouma sequence is supplemented by a thick debris-flow interval.

and bioturbated pelagic sediments. In addition, the sediments below the turbidite can be partially disrupted (drag structures). These turbidites range from 20 cm to 2 m thick; 50 to 100 cm is typical.

Organic-matter-rich claystone turbidites occur from Core 603B-44 through Section 603B-76-1. These comprise an average of 25% of the recovered section of this interval. The usual composition is claystone, with 5 to 10% well-preserved nannofossils, 5–10% organic material, and minor mica and quartz silt. Color is always very dark gray (N2, N3). They are typically homogeneous in texture, but there are numerous exceptions which exhibit features indicative of a turbidite origin: ripple-laminated, basal silt layer, upward decrease in the silt content, bioturbation in the uppermost centimeter, and rare evidence of reworked older nannofossils. In addition, these black claystones are inserted spasmodically into the rhythm of the alternating laminated and bioturbated pelagic sediments without affecting the pattern. In rare cases, there is an entire sandstone–siltstone–claystone turbidite sequence, but normally the claystone beds are more numerous and distinct from the thicker, coarser turbidites. The black claystone beds typically are 2–20 cm thick, with a trend toward thinner beds in the upper part of the subunit. Overall, claystone and siltstone–sandstone turbidites comprise more than half of Subunit VA.

BIOSTRATIGRAPHY[3]

Hole 603 Summary

Hole 603 recovered 54 spot and washed cores through an 832.6-m Neogene hemipelagic clay and claystone section which became progressively more indurated with depth. The first 19 cores of nannofossil-bearing clay and claystone (lithologic Subunit IA) contained common to abundant, moderately to well-preserved calcareous microfossils, particularly in the top 170 m (Cores 603-1 to -5), where plankton dominated the foraminiferal assemblages. Siliceous microfossils were rare or absent in Subunit IA, which was deposited well above the calcium carbonate compensation depth.

Calcareous microfossils diminish in numbers and diversity from Core 20 downward, indicating deposition in the vicinity of a fluctuating CCD. Calcareous benthic foraminifers are rare or absent below Core 603-18, where the sporadic benthic assemblages which are present are represented by a few agglutinated species. Nannofossil assemblages, where present, are generally dominated by discoasters, which are more dissolution-resistant than placoliths. Authigenic siderite is present in the section below Core 603-10 (see Lithology section, Hole 603), and it is possible that its formation may have been achieved at the expense of calcareous microfossils. Biogenic calcite may have been dissolved *in situ* to provide carbonate ions for siderite formation, thereby depleting further the already sparse calcareous assemblages in the lower half of the hole.

Samples from 603-24,CC to 603-30-1 contained few radiolarians, with poor to moderate preservation. No age-diagnostic species were found in this interval.

No appreciable numbers of siliceous microfossils were encountered until the bottom of the section in Cores 603-41 to -54 (lithologic Subunit IC), which contained radiolarians from the middle Miocene *Diartus petterssoni* Zone.

The calcareous microfossil sequences in the more fossiliferous upper part of the sequence (lithologic Subunit IA) seem to reflect rather continuous deposition (Fig. 10). Suspected hiatuses are few and of short duration (Zone PL4 among the planktonic foraminifers; Subzones CN10a and 11a among the coccoliths), and may be an artifact of washed intervals in the coring sequences. The suspected hiatus in the coccolith sequence is at the Miocene/Pliocene boundary as defined by those fossils. In lithologic Subunits IB and IC, intermittent barren intervals preclude positive detection of any biostratigraphic hiatuses.

An apparent discrepancy exists between the planktonic foraminiferal and nannofossil zonations in the placement of the Miocene/Pliocene boundary. In the former, this boundary is placed at the base of Core 603-19M (Fig. 10) based on the FAD of *Globorotalia margaritae*. Downhole contamination does not seem to be a factor here because this species consistently occurs over the preceding six cores. The boundary, however, is placed by nannofossils at the base of Core 603-13M if the LAD of *Triquetrorhabdulus rugosus* is used following the correlations of Bukry (1973) and Okada and Bukry (1980). Here the LAD of *Discoaster quinqueramus* is used (Fig. 10) following the correlation of Haq (1984). *Triquetrorhabdulus rugosus* is consistently present from Cores 603-17M through -13M. Regardless of which nannofossil datum is used, there is still a discrepancy of at least 100 m between the "nannofossil" and "planktonic foraminiferal" Miocene/Pliocene boundaries. We are left with the conclusion, therefore, that in the rather expanded section in this hole we may be seeing a need to revise the stage correlations of the planktonic foraminiferal and coccolith zonations being applied. Other possibilities are diachrony of some of the datums used or reworking of some of the nannofossil marker species. The same problem is noted in Hole 603C (later) where the boundary can be better defined using magnetostratigraphy (Canninga et al., this volume).

The sporadic distribution of calcareous microfossils allows the upper/middle Miocene boundary only to be approximated somewhere in the depth range of Cores 603-33 or -34 (according to planktonic foraminifers). Calcareous microfossils would place the bottom of the hole in the upper middle Miocene, but this pick is based partly on material in Core 603-54,CC which is apparently not in place, but has partly caved from higher in the hole. Radiolarians, on the other hand, place the interval from 603-42-1 to 603-52-1 in the middle Miocene *Diartus petterssoni* Zone.

Hole 603B Summary

Neogene (Cores 603B-1M through -14)

Hole 603B was washed (Cores 1M–4M) to a depth of 821 m, the approximate depth of the last stratigraphically significant core from exploratory Hole 603. Core 603B-5 is age-equivalent to 603-54. Cores beyond 603B-5 represent the older section not reached in Hole 603 (Fig. 10).

Within the Neogene section of Hole 603B, which consists of hemipelagic clays and claystones, calcareous foraminifers become less abundant and preservation decreases down through Core 603B-7M. In Cores 603B-7M through -14, calcareous foraminifers are absent and are replaced by a few agglutinated species ("*Rhabdammina*-like" fauna).

Neogene calcareous nannofossils also become less abundant downcore (Cores 603B-1M through -13) as diversity decreases and dissolution increases. Assemblages are generally dominated by discoasters, which are more resistant to dissolution than placoliths. By Core 603B-14, Neogene nannofossils have disappeared because of the rise in the CCD.

Moderately preserved Neogene radiolarians are rarely present in Cores 603B-4M through -13. These cores contain middle Miocene (Cores 603B-4M to -12) to upper lower Miocene (Core 603B-13) radiolarian assemblages.

[3] For convenient cross-reference among chrono-, bio-, and seismostratigraphy we used the time scale of Vail and Mitchum (1979), unless otherwise stated. The majority of shipboard scientists decided to make an exception for the Plio-Pleistocene stratonomy to bring it in accordance with common paleoceanographic usage (Berggren, 1977b), although the position of the Plio/Pleistocene boundary is not universally agreed upon.

Eocene (Cores 603B-15 through -22)

Sections 603B-15-4 to 603B-22-2 of Hole 603B recovered a 51.5-m Eocene variegated or laminated claystone section (lithologic Unit II; Fig. 16). The core-catcher samples contained common to few, well to poorly preserved radiolarians. Calcareous planktonic microfossils were rare or absent in Unit II, which was deposited below the calcium carbonate compensation depth. Calcareous benthic foraminifers are also absent in this unit, but a few agglutinated fragments are present in Sample 603B-18,CC.

Sample 603B-14,CC is barren of microfossils. According to radiolarians, the Miocene/Eocene unconformity may be placed between Samples 603B-14,CC and -15,CC. Authigenic zeolite-filled radiolarians are commonly present in Samples 603B-17,CC through 603B-22-2. Some centric diatoms are found in Samples 603B-19,CC and 603B-20,CC, Samples from Cores 603B-15,CC to 603B-19,CC contain early Eocene radiolarian assemblages from the *Phormocyrtis striata striata* Zone to the *Bekoma bidartensis* Zone, and a new late Paleocene *Bekoma campechensis* Zone has been defined (Nishimura, this volume) based on the radiolarian assemblage present from Section 603B-20-1 to Sample 603B-21,CC. Rare radiolarians presumed to be of middle to late Paleocene age were found in samples from Core 603B-22.

Cretaceous (Cores 603B-23 through -82)

Calcareous and siliceous microfossils appeared to be distributed irregularly through the 450-m-thick Cretaceous sequence that was continuously cored in Hole 603B (Figs. 16 and 20). In the upper part of the series, foraminifers are either absent (cores 603B-22 to -29) or exclusively represented by low diversity and "primitive" agglutinated assemblages (Cores 603B-30 to -40; Fig. 16); then rare and tiny benthic and planktonic forms occur sporadically from Cores 603B-42 to -76 (Fig. 20). In the interval which comprises Cores 603B-44 to -58 and corresponds to the coarser turbiditic intercalations of lithologic Unit IV and Subunit VA, foraminiferal assemblages are composed mainly of rare and poorly preserved, shallow-water, mid-shelf benthics, and are associated with a few invertebrate remains (gastropods, pelecypods, bryozoans). From Cores 603B-52 to -76, these shallow-water organisms are progressively replaced by deeper-water calcareous and agglutinated foraminifers. All these forms appear to have been transported and redeposited downslope close to or below the CCD, at greater depths than their original biotope.

Indigenous calcareous nannofossils are almost absent from Cores 603B-22 to -43, with the exception of two very thin *Nannoconus* layers in Cores 603B-35. Beyond this barren interval, coccoliths are consistently present but are more diverse and better preserved in the clay-rich black interbeds (thought to be turbiditic) than in the limy units. Taking into account the foraminiferal record, the question arises as to whether even the calcareous nannofossils in the limestones represent an *in situ* flora. The contacts of these nannoconid layers with the adjacent rock, however, suggest that they are *in situ*.

Rare calcitized and/or pyritized, moderately to poorly preserved radiolarians were present in many Cretaceous intervals, i.e., in Cores 603B-21, -26, -30, -33 to -35, -37, -48, -51, -53 to -55, -57, -59, -61 to -81. In addition, rare ammonites were found in several cores (603B-44, -58, -69) of the lower part of lithologic Unit IV and from Subunit VA, as well as a few aptychi (Core 603B-79).

Because of the scattered distribution and poor preservation of the recovered microfossils in lithologic Units III and IV, their age resolution above Core 603B-44 is generally mediocre. For that part of the column, we rely on the dinoflagellate stratigraphy (Habib and Drugg, this volume) for determining stage boundaries.

The coarsest and thickest turbiditic intercalated sequence (lithologic Subunit VA) is Hauterivian–early Aptian in age. The Hauterivian/Barremian boundary (Fig. 20) is located at the top of Core 603B-59, based on the calcareous nannofossil (Covington and Wise, this volume) and dinoflagellate stratigraphy (Habib and Drugg, this volume). Foraminifers definitely point to a late Hauterivian age down to Core 603B-71, and a late Valanginian age down to Core 603B-76, an attribution which is more or less consistent with the nannofossil findings. Nannofossil data (Covington and Wise, this volume) and dinoflagellate data (Habib and Drugg, this volume) indicate that the Valanginian/Hauterivian boundary is at the top of Core 603B-72 (Fig. 20). The Berriasian/Valanginian boundary lies between the top of Core 603B-80 and the top of Core 603B-81. These age assignments imply a much slower Valanginian–early Hauterivian sedimentation rate, in comparison with late Hauterivian–Barremian times. Fragmentary foraminiferal and macrofossil evidence (Moullade, this chapter; Hoedemaker, this volume) suggests somewhat younger ages (late Valanginian for Cores 603B-76 and 603B-79).

Hole 603C Summary

Hole 603C was cored to 91 m using the HPC and then to 366 m with the XCB (40 cores total). Because Holes 603, 603B, and 603C are within 1000 m of each other, there is essentially no difference in the microfossil assemblages found among the holes (Fig. 10). Apparent differences in the ranges of certain species of microfossils result from better resolution of the holes that recovered a more complete section (e.g., Hole 603C).

Both planktonic and benthic foraminifers occur in the cores from Hole 603C. They are moderately to well preserved. Planktonic foraminifers are common to rare; benthics (predominantly calcareous) are few. Diversity decreases downhole as dissolution increases.

Calcareous nannofossils are few to abundant in the Hole 603C cores. Abundance is generally high near the top (first 27 cores) of the section. As with the foraminifers, diversity decreases and dissolution increases in cores deeper than Core 603C-27.

There were no radiolarians in the cores from Hole 603C.

The top of the section at Hole 603C (Core 1, top) is early Pleistocene, based on both foraminifers and nannofossils. Some watery mud collected from the core liner above Core 603C-1 is Holocene and/or Recent. The "nannofossil Pliocene/Pleistocene boundary" is found in Section 603C-4-5, between 32 and 110 cm, based on the LAD of *Discoaster brouweri*. With foraminifers, the boundary is placed in Sample 603C-5,CC.

The Miocene/Pliocene boundary at Site 603 is difficult to determine because of the major discrepancy between the datums provided by the nannofossils and foraminifers that was noted previously (see Hole 603). The "nannofossil Miocene/Pliocene boundary" is placed about 300 m sub-bottom, well above the "foraminiferal Miocene/Pliocene boundary" at 450 m. Possible reasons for this discrepancy include diachrony of some of the datums used or systematic reworking of some of the nannofossil index species. Fortunately, the excellent recovery in Hole 603C and the high rate of sediment accumulation allow for an accurate magnetostratigraphy which may help solve the problem (Canninga et al., this volume) and improve the calibration of the foraminiferal and nannofossil zonations.

Foraminifers

Hole 603

Fifty-three core-catcher samples were processed and examined for preliminary shipboard study. With respect to the abundance of foraminifers, the 832.6-m section in Hole 603 can be divided into three major intervals.

The first interval comprises Cores 603-1 to -5 (there was no recovery in Core 603-6) and is characterized by abundant to common, mostly planktonic foraminifers. The second interval includes Cores 603-7, to -19M, where, compared with sediments above, foraminifers appear to be more diluted. In the last interval (Cores 603-20 to -54), few to very rare foraminifers were found in 24 samples; 10 core-catcher samples were totally barren.

Preservation of the foraminiferal tests is generally good to moderate in the first two intervals; the change from a generally good to a consistently moderate preservation takes place in Core 603-12. The deeper interval (Cores 603-20 to -54) yielded poor to moderately preserved foraminifers, with obvious signs of dissolution, particularly among the planktonics.

The percentage of calcareous benthic foraminifers increases among the total foraminiferal microfauna (in the >177 μm size fraction) from the top of the hole to Core 603-13M, then decreases slowly until they suddenly disappear below Core 603-18. In fact, below this core the benthic component of the recovered foraminiferal assemblages is either absent or represented by rare to few "primitive" agglutinated foraminifers. They become more abundant in Core 603-41, where it is thus possible to use the term of "*Rhabdammina*-like" fauna (Brouwer, 1965). Rare to very rare agglutinated forms were then found down to the bottom of the hole and rare calcareous benthics were present only in Cores 603-34 and -37.

Considering the progressive downward decrease in recovered microfauna, the biostratigraphic subdivision of the cored interval in Hole 603, particularly for the lower part, remains problematic (see Blanc-Vernet and Moullade; Gervais, and Ma'alouleh and Moullade, all this volume).

Two samples from Core 603-1 were investigated, one from the core catcher and one from an extruded part of the core between Sections 2 and 3. Both yielded common *Globorotalia truncatulinoides* and rare *G. tosaensis*, plus a few *Pulleniatina obliquiloculata* and *Sphaeroidinella dehiscens*. Thus this core is unambiguously Pleistocene in age (*G. truncatulinoides* Zone); the co-occurrence of *G. truncatulinoides* and *G. tosaensis* restricts this attribution to the early Pleistocene.

Cores 603-3M and -4 yielded an assemblage including rare to few *G. miocenica* plus *S. dehiscens, G. crassaformis*, and others, which correspond to Zone PL5 (= lower part of the upper Pliocene) of Berggren (1973, 1977b). Sample 603-2,CC furnished a relatively nondiagnostic foraminiferal microfauna with *G. hirsuta, Neogloboquadrina dutertrei, N.* sp. cf. *N. acostaensis-humerosa*, common *Globigerinoides ruber*, and rare *G.* sp. cf. *G. obliquus*. The absence of *Globorotalia truncatulinoides* in this sample could be interpreted as negative evidence of a possible Pliocene age, but *G. tosaensis*, which ranges from the late Pliocene to the early Pleistocene, is also missing. We suspect that these two keeled globorotaliids could be absent because of local climatic restrictions.

The interval comprising Cores 603-5 to -11M seems to be biostratigraphically well defined near the top (Sample 603-5,CC) by the last appearance datum (LAD) of *Sphaeroidinellopsis seminulina* and at the bottom by the LAD of *G. margaritae*, thus corresponding to the lower part of the middle Pliocene (= PL3 Zone). However, the presence of the PL4 Zone (= the upper part of the middle Pliocene) cannot be demonstrated, probably because of spot coring over 40-m intervals. The zone proved to be present in Hole 603 (see later).

In addition to the marker species, the middle Pliocene interval yielded few to common *Globoquadrina* sp. cf. *G. altispira* (LAD in Core 603-7M), *Globorotalia crassaformis, G. praehirsuta*, rare *G. puncticulata*, and very rare *S. paenedehiscens*.

Cores 603-12 to -19M have been given an early Pliocene age on the basis of the continuous occurrence of *G. margaritae*. Core 603-12, which contains *G. margaritae* but no *Globigerina nepenthes*, is more precisely attributed to Zone PL2 (cf. Berggren, 1977a). Cores 603-13M to -19M belong to the long-ranging Zone PL1, which cannot be subdivided here into its three usual subzones, owing to the small number of samples investigated and also to the progressive downward impoverishment of the foraminiferal microfauna.

The Miocene/Pliocene boundary has been tentatively set just below Core 603-19M on the basis of:

1. The apparent first appearance datum (FAD) of *G. margaritae* at this level;

2. The co-occurrence in Core 603-19M of both *G. margaritae* and its immediate phylogenetic ancestor, *G. juanai;* and

3. The presence in Sample 603-19M,CC of some specimens which are intermediate, from an evolutionary point

of view, between the two species. This evolutionary event has been dated at or very close to the Miocene/Pliocene boundary (Kennett and Srinivasan, 1983). Despite the sudden decrease in foraminifers below Core 603-19M, the shipboard foraminiferal specialist believed this event could be used as evidence to denote this important boundary. Others (cf. Berggren, 1985) place the beginning of *G. Margaritae* within the Miocene. In accordance with this and with magnetostratigraphic evidence gained from Hole 603C (Canninga et al., this volume), Gervais (this volume) draws the Miocene/Pliocene boundary immediately above Core 603-16 on the basis of a climatic change and the first appearance of *Globigerinoides conglobatus*.

Below Core 603-19M, the biostratigraphic data extracted from the remaining cored interval are rather scattered. Age-diagnostic foraminiferal microfaunas have been found only as follows:

Core 603-25: rare *Neogloboquadrina acostaensis*, predominantly sinistrally coiled, rare *Globorotalia conomiozea*, and few *G. conoidea.*

Core 603-31: few *G. conoidea*. Both of the above assemblages indicate a possible Zone N16.

Core 603-34: few *G. conoidea*, rare *G. praemenardii, Globigerina nepenthes;* these correspond to Zone N14.

Cores 603-38 to -41: rare *G. nepenthes, Globorotalia* sp. cf. *G. praemenardii;* these indicate Zone N14 of middle Miocene age.

The boundary between the upper and middle Miocene has thus been tentatively located within the interval from Cores 603-31 to -34, more precisely just below Core 603-31, considering that (1) Sample 603-34,CC shows the first evidence of a definitive N14 assemblage; (2) Sample 603-31,CC still belongs to Zone N16; and (3) the interval comprising Cores 603-32 and -33, which yielded only nondiagnostic foraminifers, may partly or totally represent Zone N15, i.e., may still be of middle Miocene age.

Dating of the bottom of the hole is rather uncertain. Cores 603-42 to -53 are barren or have yielded only extremely rare and very long-ranging (mostly agglutinated) foraminifers. Sample 603-54,CC provided rare *Globigerinoides trilobus, G.* sp. gr. *G. obliquus*, and *Globigerina nepenthes*, leading us to the same N14 attribution as above. However, taking into account the process of recovery for this last core, the possibility of caving and downhole contamination for this sample cannot be excluded. As a result, a middle Miocene age for this horizon is still questionable and must be confirmed by further coring of the same interval.

Hole 603B

Except for the two uppermost cores, which correspond to a washed interval 417.1 m thick and contain rich and well-preserved assemblages, the core-catcher samples which were examined from Cores 603B-3M to -82 for preliminary shipboard study either yielded only rare, moderately to poorly preserved foraminifers or, frequently, were barren. Figure 23 summarizes the main biostratigraphic results.

Lithologic Unit I (Cores 603B-1M to -15)

The hemipelagic silty claystones from the upper part of Hole 603B yielded two distinct foraminiferal assemblages. Cores 603B-1M to -7M contain common to rare, mostly planktonic foraminifers (= Assemblage I, Fig. 23). Their preservation is moderate (Cores 603B-1M to -3M) to poor (Cores 603B-4M to -7M). Cores 603B-7M to -14 are characterized by a "*Rhabdammina*-like" foraminiferal microfauna (= Assemblage II, Fig. 23) and Cores 603B-8M to -14 are completely devoid of any calcareous forms.

On the basis of the co-occurrence of a few *Globorotalia tosaensis, Globoquadrina altispira*, and *Sphaeroidinellopsis seminulina*, and the presence of rare specimens intermediate between *Globorotalia praehirsuta* and *G. hirsuta*, Sample 603B-1M,CC is given a late Pliocene (Zone PL4) age. Sample 603B-2M,CC contains few *G. margaritae* s.s., *Globigerina nepenthes*, and one specimen of *Globorotalia juanai.* We agree with Kennett and Srinivasan (1983), who demonstrated that *G. margaritae primitiva* is a junior synonym of *G. juanai.* Thus we reconsider the data from DSDP Leg 47A published by Salvatorini and Cita (1979) on the basis of this taxonomic emendation, which leads us to restrict the range of *G. margaritae* s.s. to the lower Pliocene. As a result, Samples 603-19M,CC (see above, Hole 603) and 603B-2M,CC were attributed to the basal part of Zone PL1 (lowermost Pliocene).

Sample 603B-3M,CC yielded very rare and poorly diagnostic planktonic foraminifers (*Globigerinoides trilobus, Globigerinita naparimaensis*, and *Globigerina nepenthes druryi*). Sample 603B-4M,CC was devoid of foraminifers. In the interval which includes Cores 603B-5 and -6M, rare, poorly preserved *Globorotalia conoidea*, plus some evolved specimens from the *G. fohsi* (Sample 603B-5,CC) and *G. zealandica–G. praescitula* (Sample 603B-6M,CC) lineages, lead us to attribute Cores 603B-5 to the middle part (= Zone N12) and -6 to the lower part (= Zones N9 to N12) of the middle Miocene.

Sample 603B-7,CC yielded very rare and poorly preserved specimens of *G. zealandica, G.* sp. gr. *fohsi*, and *G. panda* that point to an age close to the early/middle Miocene (Zones N8/N9) boundary. In addition, we noticed in this sample the occurrence of a few "primitive" agglutinated benthic foraminifers (*Bathysiphon* sp.). A similar but more diverse "*Rhabdammina*-like" microfauna was then regularly found from Cores 603B-7M to -14 downward.

Lithologic Unit II (Core 603B-16 to the upper part of Core 603B-22)

This interval was found to be devoid of foraminifers except for the occurrence of very rare and unidentifiable debris of primitive agglutinated forms in Sample 603B-18,CC. These radiolarian claystones were certainly deposited below the CCD.

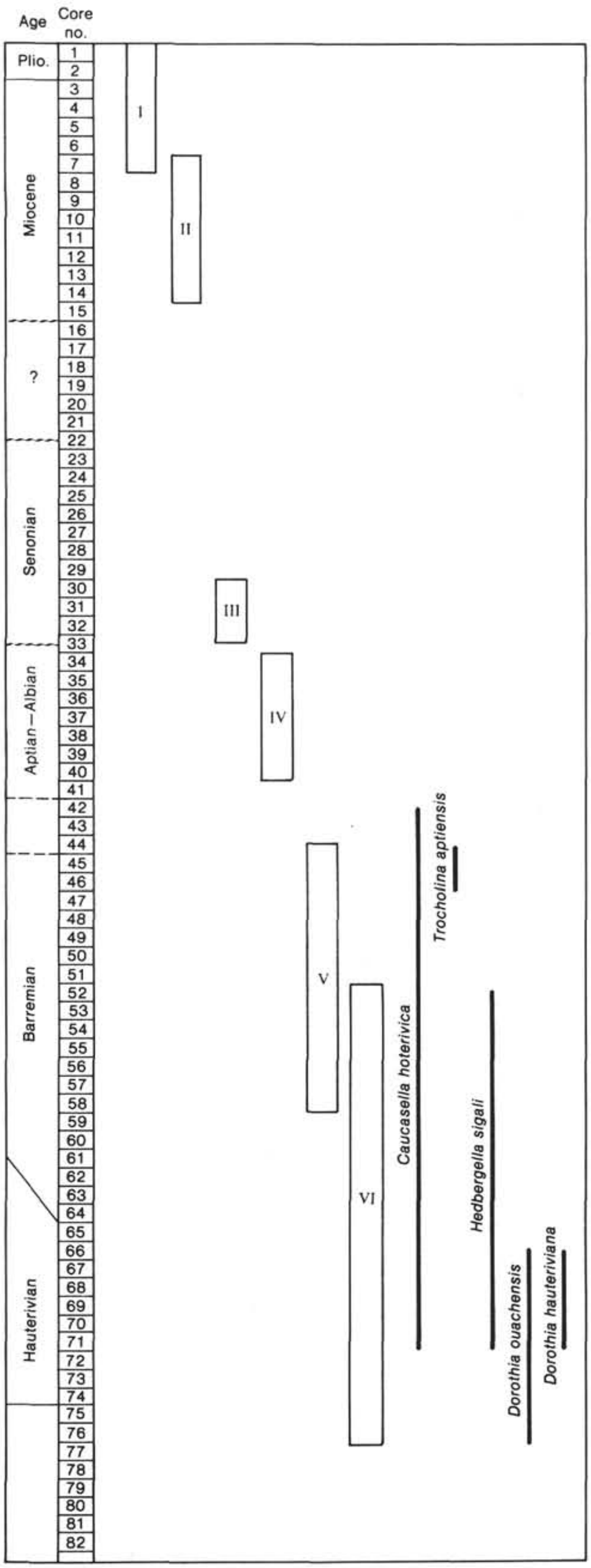

Figure 23. Stratigraphic distribution of six foraminiferal assemblages and some Lower Cretaceous marker species in Hole 603B. I, Mio–Pliocene more or less diverse assemblage; II, Miocene, "*Rhabdammina*-like" agglutinated assemblages; III, Senonian, and IV, Aptian–Albian V, shallow-water turbidite-transported Barremian assemblage; and VI, deep-water residual calcareous Valanginian–Barremian assemblage.

Lithologic Unit III (lower part of Core 603B-22 to upper part of 603B-33)

The upper part (Cores 603B-22 to -29) of the variegated claystones was found to be totally barren of foraminifers. Samples taken from the lower part (Cores 603B-30 to -33) yielded few to rare agglutinated forms (*Trochammina gyroidinaeformis, Ammodiscus cretaceus, Plectina* cf. *conversa, Bolivinopsis* sp., *Haplophragmoides* sp., etc.) which compose Assemblage III (Fig. 23). A similar but more diverse assemblage was described by Krashenninikov (1974) from Upper Cretaceous sediments of the Indian Ocean (DSDP Leg 27) and compared (but not found to be identical) with Cretaceous agglutinated faunas mentioned by many authors from the central eastern European Carpathian flysch. This agglutinated microfauna was given a late Turonian–Coniacian to Campanian age by Krashenninikov (1974), and was then reported by McNulty (1979) as underlying Maestrichtian chalks in Site 387 (near the present area of study). We have therefore attributed a Senonian age to Assemblage III. Consequently, lithologic Unit III is of the same age as the Plantagenet Formation, first described by Jansa et al. (1979) from the western North Atlantic Ocean.

Lithologic Unit IV (lower part of Core 603B-33 to 603B-43)

This predominantly black, shaly interval (cf. Hatteras Formation of Jansa et al., 1979) yielded practically no calcareous foraminifers, but in Cores 603B-33 to -40 a few moderately to poorly preserved agglutinated forms are present; these compose Assemblage IV (Fig. 23). This microfauna comprises *Trochammina vocontiana, Trochammina* sp., *Haplophragmoides concavus, Verneuilinoides neocomiensis, Dorothia filiformis, Ammodiscus cretaceus, Glomospira* spp., etc., and seems to represent more of a residual assemblage, from which calcareous forms were dissolved, than a real abyssal "*Rhabdammina*-like" fauna like Assemblages II and III. All these species listed above are more commonly found in the upper part of the bathyal Lower Cretaceous deposits of southeastern France (Moullade, 1960, 1966) and could suggest an Aptian–Albian age for Assemblage IV. Sample 603B-42,CC yielded a single, poorly preserved, very tiny, presumably planktonic specimen, tentatively referred to *Caucasella hoterivica*. This species is usually mentioned from Hauterivian–Barremian shelf deposits, and was probably transported downslope.

Lithologic Unit V (Cores 603B-44 to -82)

This interval yielded two different foraminiferal assemblages, which overlap from Cores 603B-52 to -58; the interval was found to be barren in its lowermost part (Cores 603B-76 to -82). Cores 603B-44 to -58 correspond to the coarser and thicker sandy turbiditic levels here interbedded with and superimposed on an alternating claystone and marlstone sequence. They often contain shallow-water, larger invertebrate debris (a few gastropods, pelecypods, rare bryozoans) and also few and poorly preserved (frequently eroded and broken) mid- and/or outer-shelf foraminifers (Assemblage V, Fig. 23), e.g., epistominids from the *Epistominella ornata–E. caracolla* group, *Dorothia kummi, D.* sp. gr. *hechti subtrochus*, large and smooth lenticulinids. In addition, rare neritic (inner-shelf) forms, such as *Trocholina aptiensis* (but, surprisingly, no orbitolinids) were found in Cores 603B-44 to -46. Rare *Caucasella hoterivica* also occur in Cores 603B-46 and -52. The co-occurrence of this species with *Epistominella* sp. gr. *E. ornata–E. caracolla* and *T. aptiensis*, if both were *in situ*, would allow one to delineate a Barremian age for the part of the sequence which is located just below Core 603B-44.

All these shallow-water forms (larger invertebrates and foraminifers) were certainly transported from the shelf by some turbiditic processes and then redeposited in the paleofan sediments at much greater depths, where rapid burial preserved them from the effects of the CCD. Among them, the notable absence of reef or near-reef organisms (as rudistids, orbitolinids) should be pointed out.

The last foraminiferal assemblage (VI, Fig. 23) occurs from Core 603B-52 and extends to Core 603B-76 downward. *Caucasella hoterivica* is still sporadically present; rare and tiny *Hedbergella sigali, Lenticulina subangulata, L. eichenbergi*, rare agglutinated forms with calcareous cement, like *Dorothia ouachensis* and *D. hauteriviana*, plus rare *Ammodiscus gaultinus*, "*Ammodiscus*" *minimus*, and *Gaudryinella eichenbergi*, were found in a few samples. The strong impoverishment of these "assemblages," compared with those, much richer and diverse, which were described from bathyal areas of the Tethyan realm (Moullade, 1966; Neagu, 1975), and the small size of these sporadic specimens lead us to suggest that here even the deep-water calcareous and possibly also the agglutinated foraminifers were transported from their original biotope and redeposited into the eastern North American Basin at depths very close to or below the CCD.

As a result, the possibilities of dating these beds by means of foraminifers are limited. In the Tethyan realm *H. sigali* is known to appear first in the upper Hauterivian, *D. ouachensis* in the middle part of the lower Hauterivian and *D. hauteriviana* (which ranges up to the Hauterivian/Barremian boundary) in the upper Valanginian (Moullade, 1966, 1974, 1979, 1983; Magniez-Jannin, et al., in press). Consequently, Core 603B-76 may not be older than late Valanginian, Core 603B-71 may not be older than late Hauterivian, and the Hauterivian/Barremian boundary should be in an interval including Cores 603B-61 to -64 (Fig. 23).

Because of the sporadic distribution of foraminifers in Hole 603B, no sedimentary hiatuses were detectable, other than a possible mid-Cretaceous gap located in Core 603B-33, where a Turonian/Coniacian to Campanian agglutinated foraminiferal fauna overlies an Aptian–Albian assemblage.

Hole 603C

The uppermost 366 m of the Cenozoic section of Site 603 were continuously cored with HPC and then with the XCB (Hole 603C) in order to recover undisturbed sedimentary structures and obtain better age control.

Forty cores were taken and, for the purpose of the site report, their foraminiferal content was examined in all the core-catcher samples (size fraction >177 μm only).

These samples yielded common to rare, well- or, more often, moderately well preserved, mostly planktonic foraminifers. A few benthics, predominantly calcareous, were frequently present. The assemblages become progressively impoverished and their preservation slowly deteriorates downhole. Signs of stronger dissolution began to be more apparent from Core 603C-27 downward.

The main foraminiferal datums can easily be recognized, with no major discrepancies when compared to the results which were obtained by Leg 76 drilling in the northwestern Atlantic Ocean (Moullade, 1983). *Globorotalia truncatulinoides* first appears in the hole in Sample 603C-4,CC, locating the Pliocene/Pleistocene boundary just below Core 603C-4. By the co-occurrence of *G. tosaensis*, Cores 603C-1 to -4 can be attributed to the early Pleistocene. Nannofossils from a sample taken at the top of Core 603C-1 already point to an early Pleistocene age. However, some mud and water from the core liner above the sediments were recovered for foraminiferal analysis and yielded a warm-water, presumably Recent and/or Holocene assemblage that contains abundant *G. truncatulinoides*, few to common *G.* sp. gr. *G. menardii–G. tumida, G. hirsuta, Pulleniatina obliquiloculata, P. finalis*, rare *G. ungulata*, and *Globigerinoides ruber* (pink specimens). This leads us to assume that in this area a thin layer of Recent/Holocene mud may lie on a lower Pleistocene series about 30 m thick. The missing part of the Pleistocene was eroded or not deposited.

On the basis of their foraminiferal content, Cores 603C-5 to -40 appear to belong to the Pliocene, and the usual six zonal subdivisions which have been defined by Berggren (1973, 1977a, b, 1985) can be easily identified in Hole 603C.

The lower boundary of Zone PL6 was located in Core 603C-9, which coincides with the extinction of *Globorotalia miocenica*. The lower limit of Zone PL5 appeared to be in Core 603C-15, where the last specimens of *Globoquadrina altispira* were encountered. The PL4 Zone, the lower limit of which is defined by the last appearance of *Sphaeroidinellopsis seminulina*, extended from Sample 603C-15,CC to Sample 603C-19,CC. The lower limit of the next standard zone is classically defined by the LAD of *Globorotalia margaritae*. This species last appears in Sample 603C-28,CC together with *Globigerina nepenthes*, the LAD of which is said to define the lower boundary of Zone PL2. In that case *Globorotalia margaritae* should be also found in Core 603C-27, but was not present in our samples. Therefore we tentatively assume that the lower part of Core 603C-27 and the upper part of Core 603C-28 belong to Zone PL2.

Cores 603C-28 (lower part) to 603C-40 can be attributed to the PL1 Zone, taking into account that *G. margaritae* was found there almost regularly, in Samples 603C-29,CC, -30,CC, -32,CC, -34,CC, -38,CC, -39,CC and 40,CC. This species is particularly well represented in these three last cores.

Based on the first appearance of *G. crassaformis* (in Sample 603C-30,CC), the upper subzone (PL1c) of Zone PL1 has also been identified. There was in this interval no specimen of *G. juanai*, (which is the phylogenetic ancestor of *G. margaritae*, see Hole 603B) and which has been reported to disappear close to the Miocene/Pliocene boundary (Kennett and Srinivasan, 1983). On the basis of the planktonic foraminiferal evidence the shipboard foraminiferal specialist suggests that the lowermost part of Zone PL1 and consequently also the Miocene/Pliocene boundary were not reached in Hole 603C. This is also in agreement with the foraminiferal evidence for Hole 603 (Ma'aloueh and Moullade, this volume) which suggests that the Miocene/Pliocene boundary was located in Core 603-19M, a wash core taken from 419.8–448.6 m. However, there is a disagreement in the placement of the Miocene/Pliocene boundary based on foraminiferal data and based upon calcareous nannofossil data, as previously noted.

In summary, continuous coring of Hole 603C confirmed that about 30 m of early Pleistocene series overlies 335 m of the approximately 400-m-thick Pliocene hemipelagic claystone which was discontinuously cored in Holes 603 and 603B. No hiatuses can be depicted nor suspected in this Pliocene–Pleistocene section, which was characterized by an exceptionally and constantly high sediment accumulation rate.

Calcareous Nannofossils

Hole 603

Calcareous nannofossils are rare to common and sometimes absent in the upper Cenozoic of Hole 603. Diversity is relatively high in Cores 603-1 to -19M, reflecting deposition significantly above the CCD. Preservation there is generally moderate to good. Relatively low diversity, zones barren of calcareous microfossils, and poor to good preservation in Cores 603-20 to -54 reflect deposition near a fluctuating CCD.

A rather continuous Pliocene–Pleistocene section is represented by Cores 603-1 to -13M (Fig. 10). Except for the Pleistocene, all biostratigraphic zones used are from Okada and Bukry (1980). Core 603-1 contains abundant *Gephyrocapsa* sp., *Pseudoemiliania lacunosa, Calcidiscus leptopora*, relatively common *Helicosphaera sellii*, and a few *Ceratolithus cristatus*. This assemblage is assigned to the early Pleistocene *H. sellii* Zone of Gartner (1977).

Core 603-2M contains abundant *Discoaster brouweri* in addition to those species mentioned in Core 603-1. Core 603-2M belongs to the Pliocene *D. brouweri* Zone (CN12), which is not further subdivided here because this was a wash core accumulated over an interval of 75 m.

Cores 603-3M through -7M belong to the *D. tamalis* Subzone (CN12a) of the *D. brouweri* Zone. Species generally common to abundant in these cores include *D. tamalis, D. brouweri, D. asymmetricus, D. pentaradiatus, D. surculus, H. sellii, C. cristatus, Calcidiscus macintyrei*, and *P. lacunosa*. Core 603-6 had no sediment recovery.

Rotary Cores 603-8 through -10 contain an assemblage similar to the above plus generally common to abundant

Reticulofenestra pseudoumbilica (greater than 8μm) and the LAD of *Sphenolithus* sp. in Section 603-9-2. Thus these cores can be assigned to the *R. pseudoumbilica* Zone (CN11).

The LAD of *Amaurolithus delicatus* in Section 603-11M-1, the FAD of *D. tamalis*, and an abundance peak of *D. asymmetricus* in Sample 603-10,CC are three co-occurring datums which suggest a possible hiatus between Cores 603-10 and -11M. Specifically, the co-occurrence of *C. cristatus* (= *Ceratolithus rugosus*) and *A. delicatus* (range about = *A. primus*) in Core 603-11M, and the FAD of *D. tamalis* in Core 603-10,CC may indicate the absence of the *Sphenolithus neoabies* Subzone (CN11a), placing Core 603-11M in the *C. rugosus* Subzone (CN10c). However, it must be noted that Core 603-11M was washed over an interval of 38 m.

The common occurrence of *R. pseudoumbilica, D. pentaradiatus, D. surculus, Sphenolithus* sp., *A. delicatus, C. cristatus, Calcidiscus macintyrei*, and *P. lacunosa*, as in Core 603-11M, also places Cores 603-12 and -13M in the *Ceratolithus rugosus* Subzone (CN10c).

The uncertainty results from not knowing the exact position of the cored material within the 40-m washed interval of Core 603-13M. The LAD of *Triquetrorhabdulus rugosus* in Section 603-14-4 and the LAD of *Discoaster quinqueramus* in Sample 603-16-1, 100–102 cm place this interval in the *T. rugosus* subzone (CN10a).

The LAD of *D. quinqueramus* also marks the Miocene/Pliocene boundary in this section. *Ceratolithus acutus* is absent in Hole 603. Sample 603-16-1, 100–102 cm through Core 603-19M are assigned to the *Amaurolithus primus* Subzone (CN9b) based on the interval from the datums discussed above to the first occurrence of *A. delicatus.* Other diagnostic species in the interval include *D. quinqueramus* and *D. berggrenii.*

An essentially barren interval exists from Cores 603-20 to -24M. *D. berggrenii* occurs sporadically in this interval but becomes common to abundant in Cores 603-25 and -26, respectively. The interval can be assigned to the *D. berggrenii* Subzone (CN9a), but the upper extent of the subzone cannot be determined because nannofossil recovery in the section above was very poor. Cores 603-27 through -35 offered little or no useful biostratigraphic information. Sample 603-31-1, 95 cm, however, yielded a very peculiar assemblage, including discoasters reminiscent of *D. deflandrei, D. aulakos*, and *D. kugleri*, and other large (15 to 20 μm) forms. It is believed that a major stratigraphic boundary, corresponding to the change in fauna, was crossed in this interval. The *D. neorectus* Zone (CN8b) appears to be absent, implying a possible hiatus.

Abundant *D. bollii* in Core 603-36 indicate an early late Miocene age (*D. bellus* Subzone [CN8a]). *Discoaster neohamatus, D. calcaris*, and *D. neorectus* are also present, but are few in number. The lower extent of the subzone could not be determined because of the numerous barren intervals below (Cores 603-37 through -46). Common *Catinaster coalitus* in Cores 603-39 through -41 aid in restricting the lower limit of that interval to the *C. coalitus* Zone (CN6) of middle Miocene age.

Cores 603-47 through -50 were essentially barren of nannofossils, but forms tentatively attributed to *D. kugleri* were encountered in Cores 604-51 and -52. The total range of this species defines the *D. kugleri* Subzone (CN5b) and represents the oldest diagnostic nannofossil datum in Hole 603. Cores 603-53 and -54 yielded confusing assemblages. Small chunks recovered in Sample 603-54,CC were probably cavings from above, as they contained nannofossils (such as broken specimens reminiscent of *Discoaster quinqueramus*) that apparently represent much younger assemblages. Hole 603 is tentatively assigned a maximum age of middle Miocene by nannofossils.

Hole 603B

The calcareous nannofossils in the top four cores from Hole 603B do not provide stratigraphically significant information because these are from wash cores taken over approximately 831 m of section. Nevertheless, Sample 603B-1M,CC is assigned to the *Discoaster brouweri* Zone (CN12); Samples 603B-2M,CC through -4M,CC are assigned to the *D. quinqueramus* Zone (CN9). This same 831 m of section was previously cored in Cores 603-1 through -51, which offers a more precise biostratigraphy.

Core 603B-5 (821.5–831 m sub-bottom) is age-equivalent to Core 603-52 (*Discoaster kugleri* Subzone, CN5b). Common *D. kugleri, D. variabilis, D. intercalcaris, D. exilis*, and D. deflandrei, as well as a few *Helicosphaera carteri* and *Calcidiscus leptopora*, occur within this interval.

Wash Cores 603B-6M through -8M represent approximately 60 m of cored sediment (831–892 m sub-bottom). These sediments contain a middle Miocene assemblage (CN5b) represented by relatively common *D. exilis*, few *D. deflandrei, D. kugleri*, and *Reticulofenestra pseudoumbilica*, and rare *Helicosphaera bukryi* in Core 603B-8-1.

A thin turbidite layer in Core 603B-6M,CC contains a relatively unmixed nannofossil assemblage of late Eocene age. Included in this pristine assemblage are *D. tani nodifer, R. bisecta, Cyclococcolithina formosa, Chiasmolithus oamaruensis, D. saipanensis, Zygrhablithus bijugatus, R. umbilica, R. reticulata, D. barbadiensis, Coccolithus pelagicus*, and *Sphenolithus* sp., in generally common abundance. Sample 603B-9,CC is barren.

Core 603B-10 contains an assemblage dominated by common *D. exilis, D. intercalcaris*, and a few forms tentatively identified as *D. kugleri.* With the exception of a few *R. pseudoumbilica*, placoliths are not present.

Core 603B-11M was cored over a 20-m interval. The occurrence of *D. kugleri, D. exilis, R. pseudoumbilica*, and *Calcidiscus macintyrei* assigns this core to the *D. kugleri* Subzone (CN5b), the same as Core 603B-10. *Cyclicargolithus floridanus* is not present.

Unidentifiable discoasters are present only in Core 603B-12-4. The rest of Core 12 is barren, as is all of Core 13.

Core 603B-14 is barren with the exception of Section 2, which contains few to rare specimens of *D. exilis, D.*

bellus, D. braarudii, D. intercalcaris, R. pseudoumbilica, and pristine *C. leptopora*. These apparently represent downhole contaminants, since a mixture of Pleistocene through middle Miocene specimens seems to be present. Also present are species similar to *D. woodringi* and variants; these may all be in place.

In summary, no Tertiary assemblages below Core 603B-11M are considered stratigraphically significant. The oldest autochthonous assemblage, in Core 603B-11M, is assigned to the *D. kugleri* Subzone (middle Miocene).

With the exception of Core 603B-35, Cores 603B-15 through -43 are barren of indigenous calcareous nannofossils (Fig. 16). Occasional downhole contaminants from the Neogene were sometimes noted, for example in Section 603B-18-1 and Sample 603B-18,CC. The absence of datable Cenozoic coccolith assemblages below that level resulted from deposition below the CCD. In Core 603B-35, a 1-cm-thick chalk was noted at 103–104 cm in Section 2, and a 4-mm lamina was found in the core catcher. The top and bottom contacts of the chalks were graded into the adjacent rock, and both chalks were considered allochthonous deposits (the section here contained an appreciable amount of turbiditic material). The chalks were composed entirely of nannoconids, mostly if not entirely *Nannoconus truitii*. The occurrence of a monogeneric assemblage of this kind indicates an extremely restricted surface-water environment. On the basis of dinoflagellates, Habib and Drugg (this volume) date Core 35 as Cenomanian.

Below Core 603B-35, abundant, diverse, and unusually well preserved nannofossils appear quite suddenly in Core 603B-44-1, 56–57 cm. The nannofossils persist through the section to Core 603B-75 in soft, black clays which are thought to be turbiditic. Interbedded with the black clays are gray chalks and limestones which are thought to be *in situ* deposits. In this lithology nannofossils are much less diverse and preservation is poor. Though some degree of reworking most likely occurred, the assemblages of the clay and limestone seem similar and the well-preserved nannofossils recovered from the black clays have generally been used for age determinations. These determinations are made here with strong reliance on Roth's (1983) scheme from nearby Site 534. Roth based his work in general on Thierstein (1971, 1973), Roth (1973, 1978), Bukry (1975), Perch-Nielsen (1979), and Taylor (1982).

Important nannofossils that range throughout Cores 603B-44 through 82 (Fig. 20) are *Parhabdolithus asper, Reinhardtites fenestratus*, and *Lithraphidites carniolensis*. Core 603B-44 contains fossils with strong affinities to *Rucinolithus irregularis, Chiastozygus litterarius*, and *Rhagodiscus angustus* which are considered by most workers to be of Aptian age. Many of the Hole 603B species, however, appear to be forms ancestral to these last three species. This assessment is underscored by the fact that forms that resemble the latter two species are found sporadically downhole as far as Core 603B-57. Also present in Core 603B-44 are *Nannoconus colomii, Micrantholithus hoschultzii*, and *M. obtusus*. These species are generally thought to be no younger than latest Barremian. We presume, however, that these taxa are reworked in that they occur in turbiditic silts.

Calcicalathina oblongata was first consistently encountered in Sample 603B-53,CC. Roth (1983) places the LAD of that species within the upper Barremian. The lower Barremian LAD of *Speetonia colligata* is found within Sample 603B-55,CC, so Cores 603B-53 through -55 are probably early to late Barremian in age. *Cruciellipsis cuvillieri* was encountered several cores below in Section 603B-60-1 and persisted through Core 603B-82. The LAD of *Cyclagelosphaera deflandrei* is found in Section 603B-66-3. If reliable, this would approximate the top of the Valanginian (Roth, 1983). The accurate identification of this form, however, is complicated by its state of preservation, which is in turn a function of the lithology in which it is found.

The middle Valanginian LAD of *Rucinolithus wisei*, the next datum used, occurs in Section 603B-79-4. The earliest occurrences of *C. oblongata, Tubodiscus verenae*, and *Diadorhombus rectus* are assigned to Sections 603B-77-4, 603B-79-4, and 603B-80-5, respectively. This triad appears nearly contemporaneously in Roth's (1983) scheme, and he assigns that group datum to the lower Valanginian.

Taxonomic problems involving the *Retacapsa* group hamper accurate age determination for the remainder of Hole 603B, but the lowermost core, 603B-82, is believed to be early Valanginian (at the youngest) to possibly late Berriasian in age.

Hole 603C

Calcareous nannofossils from Hole 603C (Fig. 10) are generally very similar to the assemblages found at correlative horizons in Holes 603 and 603B. This is to be expected, since Hole 603C was offset from 603B by only 300 m. Because Hole 603C was hydraulic piston cored to 91 m and then XCB-cored to 366 m, the entire sedimentary section here was recovered essentially intact and appears to be continuous. Consequently, the biostratigraphy from Hole 603C is much more precise than that from either Hole 603 or Hole 603B.

Sample 603C-1-1, top, to Sample 603C-2-3, 30–32 cm contains an abundant, well-preserved assemblage that belongs to the *Helicosphaera selli* Zone (Gartner, 1977). Species dominant in this interval are *Pseudoemiliania lacunosa, H. sellii, Calcidiscus leptopora, Gephyrocapsa* spp., and *Reticulofenestra haqii*, to cite just a few.

The *C. macintyrei* Zone (Gartner, 1977) extends from Sample 603C-2-4, 30–32 cm to Sample 603C-4-6, 30–32 cm. Species dominant in this well-preserved assemblage include *C. macintyrei, Ceratolithus cristatus*, and *Helicosphaera carteri* as well as those species listed for the overlying zone. Reworked Upper Cretaceous microfossils are evident in this interval, particularly in Cores 3 and 4. This reworked Cretaceous assemblage includes *Eiffellithus eximius, E. turriseiffeli, Tetralithus gothicus, Zygodiscus* sp., and *Micrantholithus* sp.

The Pliocene/Pleistocene boundary is present in Section 603C-4-5 between 32 and 110 cm, based on the LAD of *Discoaster brouweri*. The *D. brouweri* Zone (CN12) consists of four subzones which are all present in the cored interval from Hole 603C.

The *Calcidiscus macintyrei* Subzone (CN12d) is present from Sample 603C-4-5, 110 cm to 603C-9-5, 30–32 cm. Species dominant in this interval include well-preserved *Ceratolithus cristatus, Calcidiscus leptopora, C. macintyrei, H. sellii, H. carteria, P. lacunosa, Pontosphaera* spp., *R. haqii, Gephyrocapsa* spp., *Coccolithus pelagicus, D. brouweri*, and *D. triradiatus*.

Extending from Sample 603C-9-5, 30–32 cm to Sample 603C-10-2, 30–32 cm is the *Discoaster pentaradiatus* Subzone (CN12c). This assemblage is differentiated from the overlying assemblage of CN12d only by the added presence of *D. pentaradiatus*.

Preservation remains good and abundances are high between Sample 603C-10-4, 110–112 cm and Sample 603C-13-2, 30–32 cm. This interval is representative of the *D. surculus* Subzone (CN12b). Species prevalent in this interval include *D. surculus, D. brouweri, D. pentaradiatus, P. lacunosa, H. sellii, C. macintyrei, C. leptopora, C. pelagicus, R. haqii, Pontosphaera* sp., and *Scyphosphaera* spp.

The interval from Sample 603C-13-2, 30–32 cm to 603C-22-1, 30–32 cm is placed in the *Discoaster tamalis* Subzone (CN12a). Nannofossil preservation in this zone is poor to good, and species are common to abundant. Species prevalent in this interval are similar to the subzone above (CN12b), with the added presence of *D. tamalis, D. asymmetricus*, and *D. variabilis*. Intervals of high dissolution that may represent upward CCD excursions are prevalent in Core 603C-15.

The *R. pseudoumbilica* Zone (CN11) can be divided into two subzones (CN11b and CN11a), both of which are present in Hole 603C. The LAD of *Sphenolithus* spp. defines the top of the *R. pseudoumbilica* Zone and also the top of CN11b, the *D. asymmetricus* Subzone. The *D. asymmetricus* Subzone is present from Sample 603C-22-1, 30–32 cm to Sample 603C-25-3, 30–32 cm. Preservation in this interval is poor to moderate, but becoming increasingly better downcore. Prevalent species in this interval include those species found in the overlying CN12a interval, with the addition of *Sphenolithus abies, S. neoabies*, and *R. pseudoumbilica*.

The top of Subzone CN11a, the *S. neoabies* Subzone, is recognized by the first appearance of abundant *D. asymmetricus* (the *D. asymmetricus* acme), in Sample 603C-23-6, 30–32 cm. It is possible that the increase in abundance of *D. asymmetricus* between Sample 603C-23-6, 30–32 cm and Sample 603C-25-3, 30–32 cm is a function of preservation, which is better in the lower part of the *R. pseudoumbilica* Zone, beginning in Sample 603C-23-6, 30–32 cm. CN11a is present from Sample 603C-25-3, 30–32 cm to Sample 603C-30,CC.

The *Amaurolithus tricorniculatus* Zone (CN10) is present from Sample 603C-30,CC to Sample 603C-36-6, 30–32 cm. It is possible to separate this interval into three subzones. The *Ceratolithus rugosus* Subzone (CN10c) is present from Sample 603C-30,CC to Sample 603C-33-6, 30–32 cm. Sample 603C-33,CC is barren. The *Ceratolithus acutus* Subzone (CN10b) is present in Sample 603C-34-1, 40–42 cm. It is the only sample in which *C. acutus* has been observed. Thus, Subzone CN10b is placed somewhere between 603C-34-1, 40–42 cm and 603C-34,CC, where the LAD of *Triquetrorhabdulus rugosus* is observed. The *T. rugosus* Subzone (CN10a) is observed in the interval from Sample 603C-34,CC through Sample 603C-36-5, 30–32 cm.

The entire *A. tricorniculatus* Zone is marked by intervals of moderate, poor, and barren preservational characteristics. Overgrown discoasters and etched placoliths are common throughout this interval. Nannofossils are generally less abundant by at least an order of magnitude than those observed upsection, and many intervals are barren of calcareous microfossils.

The *D. quinqueramus* Zone (CN9) is present from Sample 603C-36-6, 30–32 cm to Sample 603C-40,CC at the base of the hole. Zone CN9 can be subdivided into two subzones. From Sample 603C-36-6, 30–32 cm through Sample 603C-39-5, 30–32 cm, the *A. primus* Subzone (CN9b) is present. Preservation is moderate to poor and nannofossil abundances are much the same as in Zone CN10. Species which dominate this interval are *T. rugosus, R. haqii, R. pseudoumbilica, S. abies, S. neoabies, D. surculus, D. quinqueramus, D. pentaradiatus, D. brouweri, D. variabilis*, and *C. leptoporus. A. primus, H. sellii*, and *C. macintyrei* are generally present to a lesser degree.

The absence of *A. primus* from Sample 603C-39-6, 30–32 cm to the bottom of the hole suggests that this interval might be placed in the *Discoaster berggrenii* subzone (CN9a). Preservation is poor in this interval, however, and because of overgrowth and excessive breakage, the six-rayed discoasters generally cannot be readily identified at the species level. Six-rayed discoasters are, nevertheless, relatively abundant, as are *R. haqii, C. leptopora, C. pelagicus, S. abies, S. neoabies, R. pseudoumbilica, D. berggrenii, D. quinqueramus*, and *D. variabilis*.

It is interesting to note that the Miocene/Pliocene boundary based on nannofossils from this hole does not agree with the planktonic foraminifer data (Moullade, this volume) or the paleomagnetic data (Canninga et al., this volume), both of which indicate that the Miocene/Pliocene boundary was not reached in Hole 603C (see also site summary for Hole 603). It is doubtful that the Miocene/Pliocene boundary datum based on the LAD of *D. quinqueramus* by Haq (1984) is in error. Thus, assuming no fundamental error in placing the foraminiferal Miocene/Pliocene boundary (Moullade; Gervais; both this volume) or in the paleomagnetic correlation (Canninga et al., this volume), it would seem possible that the nannofossil assemblages in Hole 603C have been systematically reworked in this part of the section (cf. reworked foraminifers in Gervais, this volume). This seems even more plausible when one considers the depositional setting (antidunal sediment drifts) and possible mechanisms for such systematic reworking.

Radiolarians

Cenozoic

Three hundred and sixty samples were examined from three holes at Site 603 for their radiolarian content. Samples were washed through a 250-mesh sieve in water with hydrogen peroxide. Samples from Holes 603 and 603B contained radiolarians, but all samples examined from Hole 603C were barren.

Hole 603

Radiolarians are absent in samples from Cores 1 to 24 of this hole. Samples from 603-24,CC to 603-40,CC contained few radiolarians, with poor to moderate preservation, but no zonal marker species were found. Sections 603-41-1 to 603-54-1 contained rare to common radiolarian assemblages, with poor to moderate preservation. Samples from Sections 603-46-4, 603-49-1, 603-53-1, and 603-53-2 contained abundant, well-preserved radiolarians (Fig. 10).

Sections 603-42-1 through 603-52-1 contained middle Miocene radiolarians from the *Diartus petterssoni* Zone, as indicated by the presence of *Didymocyrtis laticonus, Stichocorys delmontensis, Cyrtocapsella cornuta*, and *C. japonica*.

Samples from Sections 603-52-3 and 603-54-1 contained rare to very rare assemblages of moderately-preserved radiolarians, but could not be assigned a definite age because zonal marker species were missing.

Hole 603B

Cores 1M to 3M of this hole were barren of radiolarians. Cores 4M to 21 contained rare to common assemblages of radiolarians, most of them moderately preserved, although certain intervals contained well-preserved specimens.

Sample 603B-4M,CC contained specimens of *Didymocyrtis antepenultima, Stichocorys peregrina*, and *Acrosphaera* spp. aff. *A. spinosa*, and is assigned to the middle to late Miocene *D. antepenultima* Zone.

The middle Miocene *Diartus petterssoni* Zone is recognized in samples from Sections 603B-5-1 to 603B-7M-4, which contained specimens of *D. petterssoni, Cyrtocapsella japonica, C. cornuta, C. tetrapera*, and *Stichocorys wolffii*. Samples from 603B-7M,CC to 603B-12,CC were also of middle Miocene age, and contained Radiolaria from the *Dorcadospyris alata* Zone, including *D. alata, Calocycletta* cf. *robusta*, and *Amphymenium* sp. aff. *A. splendiarmatum*. The late early Miocene *Cyrtocapsella costata* Zone was recognized in samples from Section 603B-13-2 and 603B-13,CC, by the presence of *C. costata, C. virginis*, and *C. tetrapera*.

No radiolarians were found in samples from Sections 603B-14-2 to 603B-15-2. Paleogene radiolarians were found from Section 603B-15-4 to Sample 603B-21,CC, with rare to common assemblages of varying preservation. Sections 603B-15-4 to 603B-17-3 contained well-preserved early Eocene radiolarians from the *Phormocyrtis striata striata* Zone.

Moderately preserved to well-preserved radiolarians were recovered from 603B-15-4 through 603B-17,CC by the use of weak hydrofluoric acid solution. Samples from 603B-15-4 to 603B-17-3 contained early Eocene radiolarians from the *P. striata striata* Zone, as characterized by the presence of *Buryella clinata, Calocycloma ampulla, Theocotyle ficus*, and *Lamptonium incohatum*. Included in these samples were specimens of *Eusyringium fistuligerum*, which has been reported as being limited to the late Eocene. However, these samples lack the characteristic middle Eocene marker species *Dictyoprora montgolfieri* and *Thyrsocyrtis triacantha*, so they are considered to be early Eocene in age.

The early Eocene *Buryella clinata* Zone is represented by samples from 603B-17,CC to 603B-18-3, as indicated by the co-occurrence of *B. clinata* and *Bekoma bidartensis*, along with specimens of *B. divaricata, P. turgida*, and *P. cubensis*.

Previously, the early Eocene *B. bidartensis* Zone was defined by Foreman (1973) as sediments containing *B. bidartensis*, prior to the FAD of *Buryella clinata*. Hole 603B contains sediments with rare to common assemblages of poorly to moderately preserved radiolarians in Cores 18 to 21, and a new late Paleocene radiolarian zone is defined here by Nishimura (this volume). The *Bekoma campechensis* Zone is defined by the total range of the nominate species, which occurs in sediments older than the FAD of *B. bidartensis*. Therefore, samples from 603B-18,CC to 603B-19,CC are assigned to the early Eocene *B. bidartensis* Zone, and samples from Section 603B-20-1 to 603B-21,CC are assigned to the late Paleocene to earliest Eocene *B. campechensis* Zone.

Samples from Cores 22 to 24 of Hole 603B are barren of radiolarians.

Mesozoic Radiolarians: Hole 603B

Samples from Hole 603B contain poorly to moderately preserved Coniacian to Albian radiolarians and Barremian to Valanginian radiolarians replaced by pyrite.

Samples 603B-24,CC to 603B-25,CC contain rare to common assemblages of poorly to moderately preserved radiolarians which are tentatively assigned a Coniacian age, based on the general aspect of the fauna. These samples contained *Dictyomitra formosa, D. koslovae, Pseudoaulophacus* spp., *Protostichocapsa stocki*, and *Spongocapsula zamoraensis*. *Dictyomitra formosa* ranges from lower Coniacian to lower Campanian (Pessagno, 1976), whereas *Spongocapsula zamoraensis* is Albian to Coniacian (W. Riedel, personal communication), so their co-occurrence indicates a Coniacian age for these sediments.

Samples from Cores 603B-27 to -32 were barren. Samples 603B-33-1, 38–42 cm, 603B-33-2, 120–122 cm, 603B-33,CC, and 603B-34-1, 36–38 cm contained common, moderately well preserved Cenomanian to Turonian radiolarians. These specimens include *Pyramispongia glascockensis* (early Cenomanian to Coniacian; Pessagno, 1976), *Thanarla veneta* (early Cenomanian to late Turonian), *Pseudodictomitra pseudomacrocephala* s.s. (late Aptian to early Cenomanian; W. Riedel, personal communication), and *Hemicryptocapsa polyhedra* (Turonian; Dumitrică, 1970). The co-occurrence of these species indicates a Cenomanian to Turonian age for these sediments.

Samples from Cores 603B-34 to -36 were barren. Core 37 contained moderately to poorly preserved radiolarians replaced by pyrite, including *Acanthocircus* spp., which is found in Albian strata of the Great Valley Sequence of California (Pessagno, 1977), and *Archaeodic-*

tyomitra simplex, which has an Albian to Cenomanian age. Consequently, this core is assigned an Albian age.

Samples from 603B-37,CC to 603B-51-1 are barren, except for 603B-48,CC which contains a poor assemblage of siliceous shells. Sample 603B-51-2, 67–69 cm contains abundant, very poorly preserved radiolarians, including some calcified forms extracted from nannofossil limestone.

Cores 603B-54 to 603B-80 contain rare, but well-preserved pyritized radiolarian faunas (see Fig. 20). These cores are well dated by nannofossils as Barremian to Hauterivian in age, so Hole 603B contains the first preserved radiolarian faunas of this age in the Atlantic basin. It may be possible to extend the stratigraphic ranges of early Cretaceous radiolarian taxa found in the Atlantic region, by shore-based study of these sediments.

SEDIMENT ACCUMULATION RATES

Hole 603

Sediment accumulation rates (uncorrected for compaction) are calculated using the numeric ages assigned by the authors of the zonations employed for the planktonic foraminifers, nannofossils, and radiolarians aboard ship (see Biostratigraphy section). Where more specific information was lacking, the determinations compiled by Vail et al. (1979) were used. Figure 24 was constructed using the following sequence of biohorizons (numeric ages assigned [in Ma] are given in parentheses):

FAD *Globorotalia truncatulinoides* (1.9);
Helicosphaera sellii Zone (1.22–1.51)
LAD *G. miocenica* (2.2)
LAD *Globoquadrina altispira* (2.8);
Reticulofenestra pseudoumbilica (3.0)
LAD *Globorotalia margaritae* (3.3)
LAD *Triquetrorhabdulus rugosus* (5.0)
FAD *G. margaritae* (Atlantic) (4.8)
Crossover point between foraminiferal and nannofossil curves (6.3)
FAD *D. berggrenii* (7.0)
N16/N15 foraminiferal boundary (10.0)
Error box defined by the LAD of *Discoaster bollii* (7.5) to the FAD of *Catinaster coalitus* (13.2)
LAD *Liriospyris parkerae* (greater than 15)
LAD *Dorcadospyris alata* (17)
LAD *Discoaster kugleri* Zone (13.2–13.4)

The sedimentation curve in Figure 24 has not been corrected for compaction and is divided into three segments. Over the first 200 m of the hole, coccolith and foraminiferal dates are in close agreement and yield a rate of 11.1 cm/10^3 years. Below 200 m, separate curves drawn for these two fossil groups diverge slightly and then cross at 500 m. This segment of the curve yields an accumulation rate of 6.7 cm/10^3 years based on the end points. Below 500 m, the curve based on foraminifers is connected with two lower points based on radiolarians to yield a rate of 2.8 cm/10^3 years for the last 300 m. A rate based on coccolith biohorizons over this interval gives a rate of 4.2 cm/10^3 years

The discrepancy in the curves results from uncertainty about core depth arising from wash cores whose exact intervals cannot be fixed precisely, varying opinions about the numeric ages which may be assigned to the biohorizons, and, in the base of the hole, poor fossil recovery. The lowest point on the nannofossil curve in particular is not considered very reliable. For the present, however, these curves are presented to show the possible range of rates which can be expected from this sequence.

Hole 603B

Sediment accumulation rates determined by shipboard data for the early Miocene through the Aptian are rather generalized for Hole 603B because during that time sediments at the site were deposited below the CCD, and age control by planktonic calcareous microfossils is essentially lacking. No early Miocene nannofossil or planktonic foraminiferal assemblages were positively identified and ichthyoliths and the few radiolarians present at the base of lithologic Unit I could range in age from early Miocene to early middle Miocene. Although there is some discrepancy among the ages indicated by the various microfossil groups for the base of Unit I, the loss of section attributed to erosion along the A^u unconformity is evident in Figure 24 as well as the difference in sedimentation rate between the Miocene and the Eocene. The early Eocene–late Paleocene rate of less than 1 cm/10^3 years for lithologic Unit II is an estimate determined from preliminary radiolarian studies. The lowest rate in the section, 0.32 cm/10^3 years recorded for lithologic Unit III, a largely barren, variegated claystone of Late Cretaceous (Coniacian?) to Paleocene(?) age, denotes a period of sediment starvation at the site. This calculated rate would be even lower if a suspected hiatus were not included in the diagram. This hiatus, inferred from benthic foraminiferal and radiolarian data, is marked by a sand and a lithology change at the Unit III/IV boundary, and an unconformity is apparent on the seismic reflection profile (Reflection Horizon Km).

A large error box bounds the interval for the black shales of lithologic Unit IV, which are also largely devoid of calcareous fossils; the dates here are based on displaced benthic foraminifers and a short-lived monogeneric bloom of calcareous nannofossils.

Calcareous nannofossils again appear consistently in the section beginning at 1220 m. These suggest an average accumulation rate of 2.0 cm/10^3 years for the remainder of the section (lithologic Unit V). Rates are highest in the Barremian and Hauterivian, where the input of turbiditic material (terrestrial clastics and carbonaceous claystones) is the greatest. The rates begin to taper off in the Valanginian (below 1500 m) where the section consists almost exclusively of pelagic carbonate.

GEOCHEMISTRY

Geochemical measurements were made on interstitial gas compositions, organic and inorganic carbon concentrations, and interstitial water of samples from Site 603 in the shipboard laboratories.

Hole 603

Interstitial Gases

Release of interstitial gases was evident in nearly every core from Hole 603. Gas could be seen bubbling

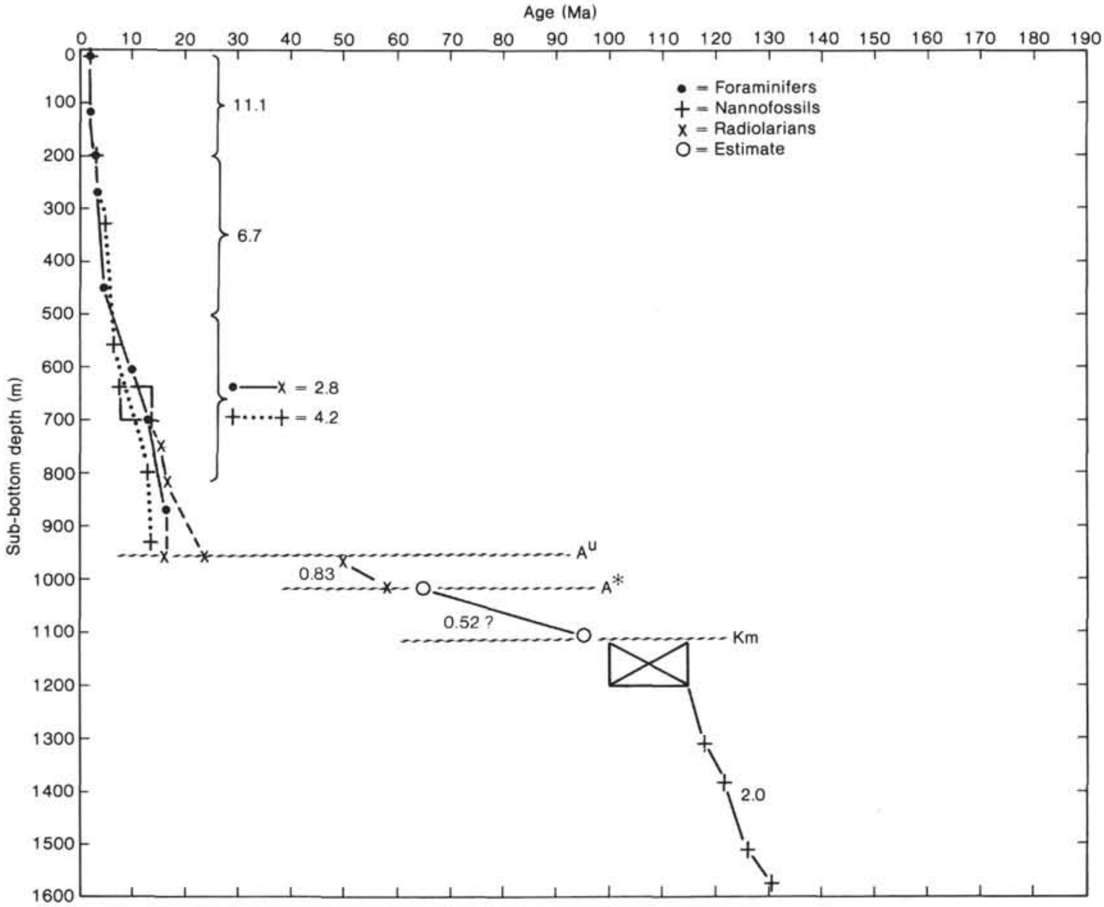

Figure 24. Sediment accumulation rates (cm/10^3 years) in Holes 603 and 603B. Reflectors A^u, A*, and Km located on figure.

from nonlithified sediments through core liners. Slow, spontaneous extrusion of muds from core sections was common, and moderate gas cracking often occurred. In a few cases, plastic caps were forced off core sections that awaited splitting in the core laboratory. In deeper, lithified cores, gases continued to escape from opened cores with a sizzling sound, and internal pressures caused multiple microfracturing of core sections. The odor of the escaping gases, especially in the upper ~500 m of this section, was similar to that of cooking gas, but a strong sulfide odor was never encountered.

Gas compositions were dominated by methane in all cores from Hole 603. Concentrations of ethane and heavier hydrocarbons were usually too small to provide C_1/C_2 ratios. In Cores 603-29 to -40, such ratios could be measured and were between 1000 and 3000. The lowest C_1/C_2 ratio, ~700, was found in Core 603-46. Carbon dioxide was also present, usually at less than 1% of the total. The composition of these interstitial gases suggests that they probably originated from microbial activity.

Although methane was relatively abundant in Hole 603 cores, there was no evidence of methane hydrates. No cores were especially cool as a result of hydrate decomposition, and no sediment voids which might have been filled by hydrates were encountered.

Organic Carbon and Nitrogen

Concentrations of organic carbon are relatively low in samples from throughout Hole 603 (Appendix II). The values of 120 determinations average 0.35 ± 0.12 wt.%, which is quite close to the mean organic carbon concentration of 0.3% calculated by McIver (1975) from data from DSDP Legs 1 through 31. Ratios of organic carbon concentration to organic nitrogen concentration, C/N, have a mean value of 8.5 ± 1.4, calculated on the basis of atomic weights. This C/N value is in the range found in marine plankton (Müller, 1977) and is similar to the values found in Pleistocene and Pliocene sediments from DSDP Leg 58 (Waples and Sloan, 1980).

The amount of organic carbon present in deep-sea sediments is a fraction of the material originally available from marine production and continental runoff. Microbial and oxidative processes degrade sinking organic matter, and further losses are large during the early stages of burial in the seafloor. The importance of the latter phase of degradation is diminished by rapid burial in areas of high sedimentation rates, with the result that concentrations of organic carbon are enhanced, but still higher rates of sediment accumulation act to dilute, as well as to preserve, organic matter in the sea bottom.

The relatively low concentrations of organic carbon present in the Neogene samples from Hole 603 reflect deposition beneath waters lacking high productivity, and in an environment having a high rate of sediment accumulation that appears to have enhanced preservation but diluted concentrations of the modest supply of organic matter.

Both organic carbon concentrations and C/N values decrease slightly over the upper 700 m of Hole 603. These parameters are generally above their mean values in samples from the top 230 m, close to their means between 230 and 580 m, and below their mean values from 580 to 700 m. Waples and Sloan (1980) report decreases in concentrations of organic carbon and in C/N ratios with depth in Neogene sediments from DSDP Leg 58 in the western North Pacific. They attribute these downhole decreases to continued microbial degradation of organic matter, with preferential losses occurring to carbon, rather than nitrogen. Such microbial activity would result in the evolution of microbial gases, which are indeed abundant in Hole 603 cores.

In the bottom 100 m of Hole 603, concentrations of organic carbon and atomic C/N ratios are similar to those present in the upper parts of this section and are substantially higher than those from 580 to 700 m sub-bottom. These higher values are contrary to what would be expected from continued diagenetic alteration of material deposited under uniform conditions, and hence they signal some sort of change in the paleoceanographic setting. Because biogenic silica also increases in the 700- to 800-m portion of this section, it is possible that biological productivity was greater during this period of sediment deposition than at later times and that this is recorded in the silica, organic carbon, and C/N values.

Rock-Eval pyrolysis was used in an attempt to characterize the type of organic matter in seven samples selected at ~100-m intervals throughout Hole 603. Because these sediments contain so little organic matter, their S_2 and S_3 values are too low to be useful for source identification. Temperatures of S_2 maxima are between 395° and 405°C (Meyers, this volume) and indicate that the organic matter is immature. In general, it appears that the processes which have reworked these bottom current deposits have also provided opportunities for the organic matter in these sediments to be reworked.

Carbonate Carbon

Concentrations of calcium carbonate are 21% or less in this section (Fig. 10; Appendix I). Samples from sub-bottom depths of 1 to 425 m have concentrations varying randomly between 0 and 21%; below 425 m concentrations are seldom greater than 5%, thus limiting variability. It is probable that the 425-m sediment depth records the former CCD depth at this location, and the variability in $CaCO_3$ below this sediment depth indicates a fluctuating CCD (cf. Gervais, this volume).

Siderite ($FeCO_3$) concretions and granules were frequently encountered deeper in this section and contributed carbonate to the $CaCO_3$ determinations. One sample (603-46-2, 59 cm), which appeared to contain abundant siderite and no calcium carbonate, was treated with concentrated HCl. Based upon the amount of generated CO_2, the sample is 85% siderite by weight. On the basis of weight loss (a less accurate determination), siderite makes up 77% of the sample. The organic carbon concentration is 0.35%, very similar to surrounding sediments, and suggests that inorganic diagenetic processes which form siderite have little influence on organic matter concentrations, although a C/N ratio of 15.8 indicates that this material has lost nitrogenous components.

Interstitial Water

Interstitial water samples were obtained from sediments from 15 levels in Hole 603. Figure 25 shows the downhole values of pH, salinity, alkalinity, chlorinity, and concentrations of Ca^{++} and Mg^{++} of these water samples. Minor variations occur in pH, salinity, alkalinity, and chlorinity; they may be due to random contamination of samples by drilling fluids, to analytical uncertainty, or to mineralogical and diagenetic effects. For example, lower salinities between 448 and 640 m sub-bottom suggest dilution by fresh water, but chlorinity values hold steady at standard concentrations through this depth range and hence preclude such dilution.

Effects of diagenesis are evident in the downhole concentrations of calcium and magnesium. Calcium doubles in concentration between 84 and 717 m while magnesium drops to less than half its concentration between sub-bottom depths of 84 and 449 m. Release of calcium is probably due to postburial dissolution of calcium carbonate, possibly accompanied by dolomitization. Removal of dissolved magnesium from interstitial waters is much greater than is addition of calcium and is unlikely to be solely due to dolomitization. Diagenetic uptake by detrital clays may be responsible for the large decrease in concentration of dissolved magnesium.

Concentrations of dissolved Li^+ and K^+ are shown in Figure 26. Lithium was present in trace amounts in samples from the upper 250 m of this section, but concentrations were too low to be quantified. This trace component of interstitial waters evidently is released by diagenesis from the solid phase of sediments and increased in concentration fairly rapidly with age. The pattern of potassium concentrations is complicated, first decreasing and then increasing with depth. Because potassium is one of the cations commonly exchanged with clay minerals, the pattern seen here in Hole 603 may be related to subtle changes in clay mineralogy as the sediments age.

Sulfate concentrations in interstitial water change drastically from 28.3 mM at 84 m sub-bottom to 7 mM at 132 m (Fig. 26), evidently as a result of sulfate reduction in these sediments. Pyrite is commonly found throughout Hole 603 and is further evidence of reduction of sulfate to sulfide. Concentrations of sulfate, however, do not disappear entirely but remain generally between 3 and 10 mM to the bottom of Hole 603. This residual amount of sulfate, plus the absence of abundant hydrogen sulfide, indicates that reductive processes were not strong in these sediments, probably as a consequence of their relatively low concentrations of organic matter.

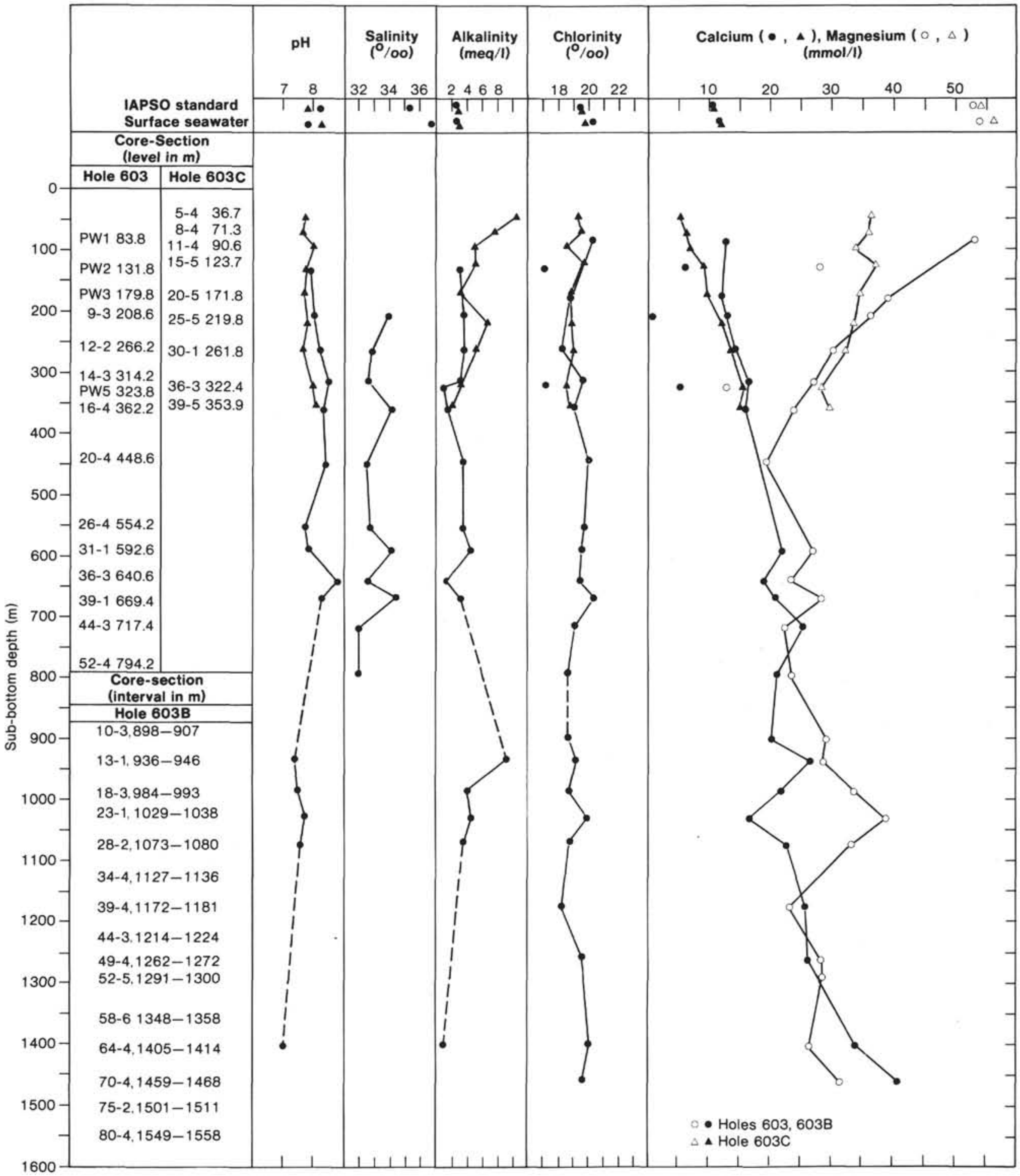

Figure 25. Values of pH, salinity, alkalinity, chlorinity, and dissolved calcium and magnesium in interstitial water samples squeezed from sediments and sedimentary rocks from Holes 603, 603B, and 603C. Data points not connected by the line segments represent questionable data.

Hole 603B

Interstitial Gases

Samples of interstitial gas were taken from 26 cores in Hole 603B, starting with Core 603B-4M (at 585 m sub-bottom) and ending with 603B-42 (1200 m sub-bottom), where concentrations of gases had become too low to warrant their continued monitoring with shipboard equipment. In general, concentrations of gases were low throughout this hole, even in black shale and sandstone sequences. Hydrogen sulfide could not be smelled in any samples. Ratios of methane to ethane were ~2000 in

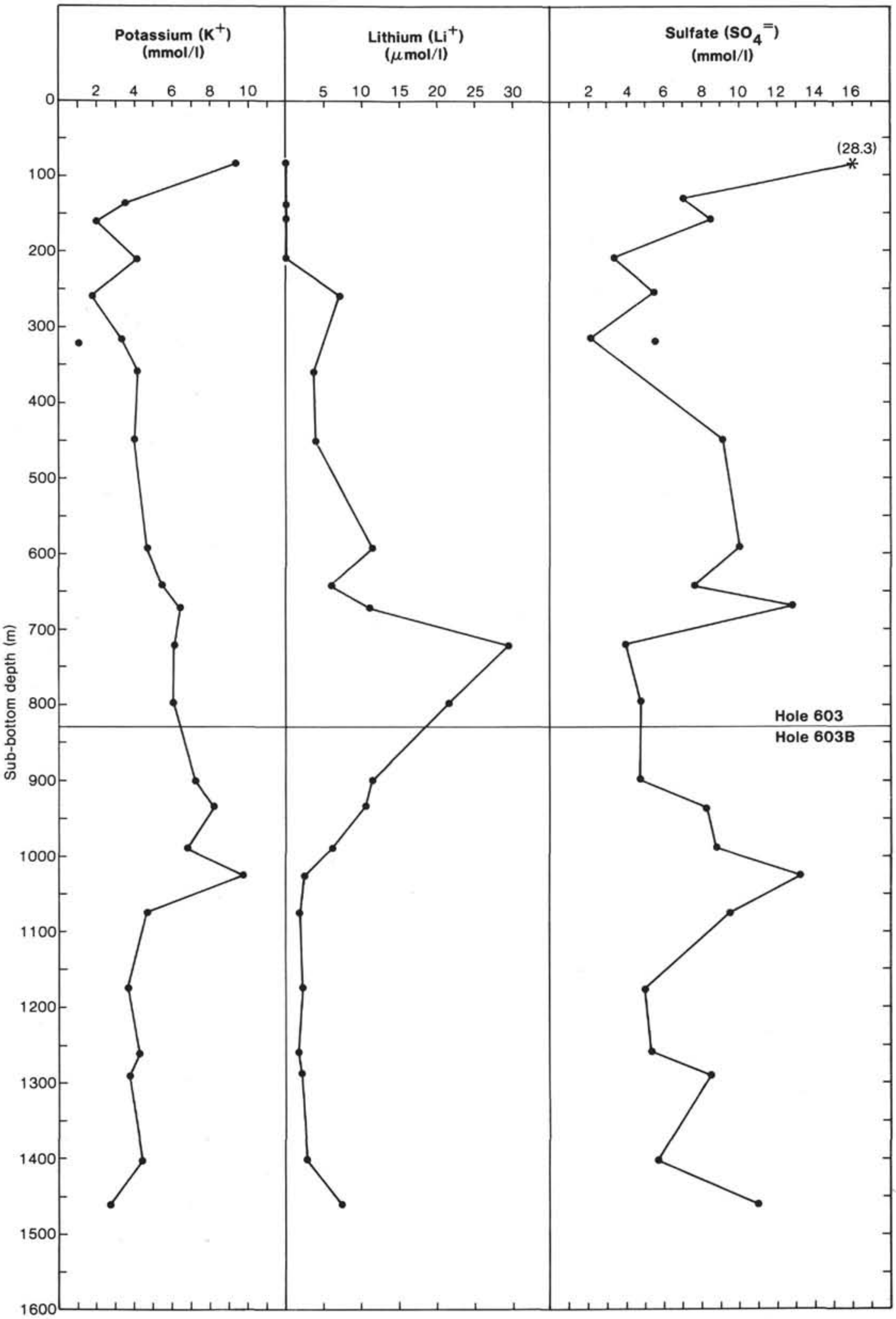

Figure 26. Values of dissolved potassium, lithium, and sulfate concentrations in interstitial water samples squeezed from Site 603 sediments and sedimentary rocks. Data points not connected by the line segments represent questionable data.

Core 603B-4M, reached a minimum between 600 and 700 in Cores 603B-5 through -10 (820 to 908 m sub-bottom), and then were 1000 and higher in the deeper samples. Contributions of propane, butanes, and pentanes were minor. The interstitial gases in these samples are evidently biogenic in origin and indicate that sediments at this site have experienced little heating.

Organic Carbon and Nitrogen

Concentrations of organic carbon were determined routinely in two samples from each core from Hole 603B and at closer intervals in sections of special interest. A total of 238 determinations from Hole 603B are listed in Appendix II. These values can be divided into three groups by sub-bottom depth and organic matter characteristics.

The first group consists of samples from depths between ~820 and 1050 m sub-bottom (Cores 603B-5 to -25). Organic carbon concentrations decrease with greater depth from 0.5% to levels below the detection limit of the shipboard Hewlett-Packard 185 CHN Analyzer (0.1%). Between 820 and 925 m, concentrations of 0.4 to 0.5% organic carbon are similar to values found between 700 and 800 m in Hole 603 and probably represent the early phase of a Miocene period of enhanced productivity. In samples below 925 m, the extremely low organic carbon values indicate little input of organic matter from marine or continental sources and deposition under oxygenated conditions, giving poor preservation of organic matter. C/N ratios change from values of around 10 in samples between 820 and 940 m to values of 5 or less between 940 and 1050 m sub-bottom. Like the organic carbon concentrations, the C/N ratios continue the pattern of higher values found in Hole 603 between 700 and 800 m sub-bottom, and their abrupt decrease at 950 m indicates a paleoceanographic change, probably in productivity.

The second grouping of organic matter values extends from 1050 m to 1220 m sub-bottom (Cores 603B-26 to -44) and is obtained from a series of red, green, gray, and black claystones. The black-colored claystones are rich in organic matter; the range of 22 samples is 0.7 to 13.6%, with a mean of 3.8%. These relatively high percentages contrast with those of the green, red, and gray claystones, which are quite low (<0.1%). Atomic C/N ratios of the black claystones average 33, whereas the values of interbedded organic-carbon-lean strata average ~10. Similar contrasts in organic carbon contents and C/N ratios have been observed in Cenomanian black shales and adjacent green claystones (Meyers et al., 1983) and have been interpreted as resulting from enhanced preservation of organic matter by rapid burial (the black shales) in a normally oxic depositional environment (the green claystones).

Highest organic carbon values are concentrated in Cores 603B-33 to -35 in Aptian–Albian claystones. These values, from 4.1 to 13.6%, are significantly higher than most previously reported values from similar strata in the North American Basin (cf. Erdman and Schorno, 1978; Deroo et al., 1980; Summerhayes and Masran, 1983), which have 10.4% as a maximum. Shipboard Rock-Eval analyses show that these Hole 603B black shales have high hydrogen indices (Meyers, this volume), representative of type II kerogen of marine origin. Although most previous studies have concluded that the majority of the organic matter contained within North Atlantic Cretaceous black shales is from continental sources, Summerhayes and Masran (1983) suggest that samples with higher organic carbon concentrations contain proportionately more marine organic matter. Moreover, some Cenomanian sediments from Site 105 are unusually rich in marine organic matter (Summerhayes, 1981) and Albian–Aptian sediments from Sites 417 and 481 are dominated by marine material (Deroo et al., 1980). The predominance of marine organic matter in Aptian–Albian sediments rich in organic carbon at Hole 603B is therefore not unexpected and represents short episodes of enhanced preservation of marine material superimposed upon a low background amount of terrigenous organic matter.

The third grouping consists of limestones and interbedded claystones, siltstones, and sandstones of Barremian to Valanginian age present between 1220 and 1575 m sub-bottom (Cores 603B-45 to 603B-82). Organic carbon concentrations vary from <0.1 to over 2.6% in samples from this depth range (Appendix II) and are independent of lithology. The mean organic carbon concentration of samples from this group is 0.8%, which is considerably greater than the DSDP average of 0.3% (McIver, 1975). C/N ratios are also high in these samples, ranging between 11.0 and 75.1, and they suggest that much of the organic matter in the rocks in this group originated from land plants (cf. Müller, 1977). Coaly stringers and pyritized wood fragments were abundant in strata below 1220 m and support the likelihood that continental inputs dominate the sources of the organic matter in these rocks. Rock-Eval results showed that three of the five samples analyzed contain heavily reworked, detrital material, although two samples (603B-61-5, 89–90 cm and 603B-49-2, 72–74 cm) had high hydrogen indices (Meyers, this volume). The abrupt change from a predominantly terrigenous to a predominantly marine type of organic matter between Barremian and Aptian times, concurrently with the disappearance of limestones, is curious, since it indicates that transport of vast amounts of continental organic material to the North Atlantic stopped at the end of the Barremian age at the same time that the CCD became shallower.

As part of the Rock-Eval analyses performed on organic-carbon-rich claystones and limestones from Hole 603B, temperatures of S_2 maxima were recorded as indicators of the maturity of the organic matter in these rocks (Meyers, this volume). All of the samples gave readings between 380° and 415°C, indicative of low thermal maturity (Espitalié et al., 1977). Values of the limestones were generally in the higher half of this range and reflect the detrital character of the mostly continental organic matter in these rocks.

Carbonate Carbon

Concentrations of $CaCO_3$ as determined by shipboard carbonate bomb are listed in Appendix II for samples from Hole 603B. Values are about 10% between 820 and

940 m sub-bottom. These sediments also contain higher than expected concentrations of organic carbon, and hence enhanced productivity may have depressed the CCD during this part of the Miocene epoch. Samples between 940 and 1210 m contain virtually no $CaCO_3$ and evidently were deposited below the CCD. Limestones and calcareous claystones, siltstones, and sandstones appear between 1215 m and the bottom of Hole 603B at 1575 m. Their carbonate content varies between 3 and 91%, with most samples having more than 50% by weight $CaCO_3$.

Interstitial Water

Samples of interstitial water were squeezed from sediments from ten depths in Hole 603B; rocks from five other depths yielded no water upon squeezing, because they were too lithified to be compressed. As in Hole 603, values of pH, alkalinity, and chlorinity vary little with sub-bottom depth (Fig. 25). Calcium concentrations increase, most obviously where limestones are present between 1260 and 1460 m sub-bottom (Cores 603B-49 to -70), whereas magnesium concentrations show no downhole trend and fluctuate around 28 mM. The increase in concentrations of Ca^{++} continues the pattern seen in samples from Hole 603 and is probably due to continuing diagenetic dissolution of calcium carbonate.

Concentrations of Li^+ and K^+ are highest between 900 and 1030 m sub-bottom (Cores 603B-10 to -23) (Fig. 26) and then decrease deeper in Hole 603B. As noted in Hole 603, the concentrations of these monovalent cations are greatest in lithologic Subunit IC, which is continued in the topmost part of Hole 603B. Changes in clay mineralogy may provide sources of lithium and potassium to be released by diagenesis. Alternatively, these cations may be trace components of biogenic opal and may be released during postburial dissolution and reprecipitation of opal (Gieskes et al., 1982). Siliceous microfossils are important components of Subunit IC and are not abundant elsewhere in Holes 603 and 603B.

Sulfate concentrations are low but do not fall to zero in water samples from Hole 603B (Fig. 26). The generally low amounts and the detrital character of organic matter evidently do not constitute a sufficiently strong oxygen demand to develop highly reducing conditions throughout this section.

Hole 603C

Hole 603C was cored by HPC and XCB continuously from the mudline to 366 m sub-bottom. Samples from Hole 603C provide a more detailed geochemical description of sediments over this interval than is available from Hole 603, yet their downhole patterns agree well. Organic carbon concentrations average around 0.35% (Appendix II), and C/N ratios of organic matter decrease somewhat with depth because of preferential loss of nitrogenous material (cf. Waples and Sloan, 1980). Calcium carbonate concentrations range between 1 and 30%, and they tend to be highest in the upper 60 m of sediment. As seen in Figure 25, Ca^{++} and Mg^{++} concentrations in interstitial water show the effects of diagenetic cation exchange which are continued in Holes 603 and 603B. Other inorganic constituents also fit into the patterns seen before at Site 603. The only notable difference in geochemical characteristics is that interstitial gases in Hole 603C sediments were not so abundant as in Hole 603 sediments. Although some gas pressure developed in the capped sections while they were awaiting opening in the core laboratory, no cores exhibited the sediment extrusion or cap bulging seen before. This difference in gassiness may be because HPC and XCB procedures disturb sediments less than rotary coring, or it may reflect patchy benthic microbial populations.

PHYSICAL PROPERTIES

Sonic Velocity

Compressional wave velocity was measured with the Hamilton Frame at intervals of approximately 1.5 m (once per section) in Holes 603 and 603B and in the first five sections of cores from 603C. Both rotary and wash cores were measured, although results from unlithified sections should be treated with caution. Cores 603-1 to 603-3M and all cores from 603C were measured in the split liner parallel to bedding.

Measurements performed in the liner showed less variation. Velocities are close to the velocity of seawater. Deviations appear to be a result of drilling disturbance: poor signal propagation results in variable measurements, especially for samples removed from the core liner.

Sediments from Core 603-4 and below, and all sections from 603B, were measured using samples removed from the core liner. Because of the strong signal attenuation, sample thickness had to be reduced to about 1 cm. The presence of gas increased attenuation of the signal and was noted by reductions in the calculated sonic velocities.

Sonic velocities for Cores 603C-29 through -32 could not be measured as the samples disintegrated during extraction. This interval represents the clay to claystone transition: the sediments were too hard for the extended core barrel to push ahead of this bit, but too soft to allow the bit to cut properly. As a result, the recovered sediments were fractured and crumbly.

The measured values were corrected with reference to the shipboard reference standards (Boyce, 1976); all calculations of velocities were performed using either the routine SVENT on the ship's HP 1000 computer (Hole 603) or programmable calculator (Holes 603B and 603C).

Chunk samples from Hole 603B were trimmed on the diamond saw to produce flat, parallel surfaces. In general, the samples were sufficiently indurated to permit trimming both parallel and perpendicular to bedding so that velocity measurements were performed in both the vertical (bedding normal) and horizontal (bedding parallel) directions. This was not possible for Cores 603B-45 to -49, where only loose sand was recovered, and for Cores 603B-12 to -15, where the cores were highly fractured by drilling. Where possible, samples were taken once per section between 70 and 90 cm below the top of each section. Representative samples of different lithologies were taken from cores that contained variable lithologies. This leads to sampling bias in favor of minor

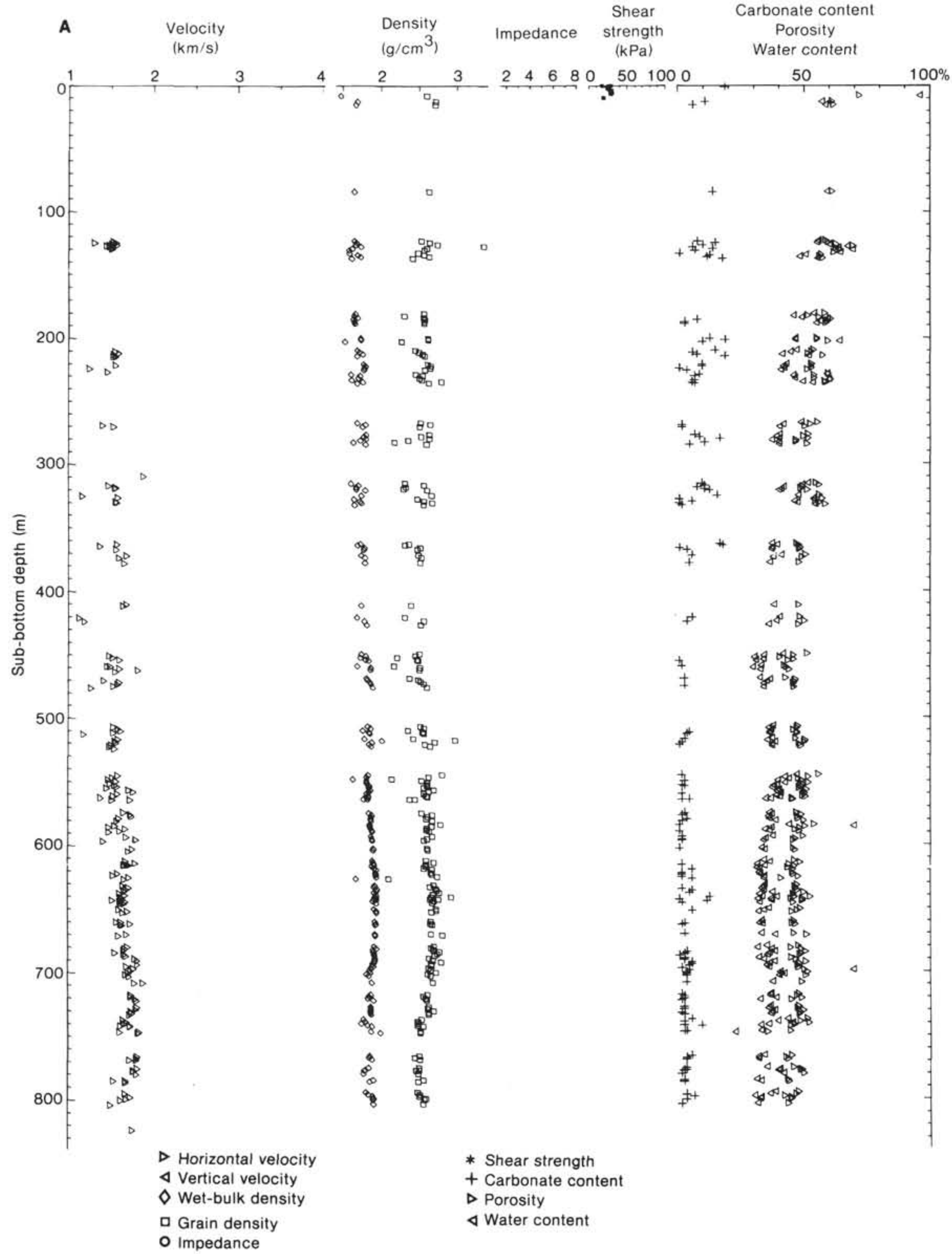

Figure 27. Physical properties of Site 603. A. Hole 603. B. Hole 603B. C. Hole 603C.

lithologies and to greater variance of the grouped data, when both major and minor lithologies are analyzed together.

All results are presented in Figure 27 and Appendix I. The overall increase in velocity with depth generally appears to be a function of consolidation and lithification for the clay to claystone section (0–960 m sub-bottom). Below 960 m, lithologic type and state of lithification of the sediments control the sonic velocity results.

Physical properties are correlated with sedimentology and seismic units in the section on Seismic Stratigraphy that follows the Physical Properties section.

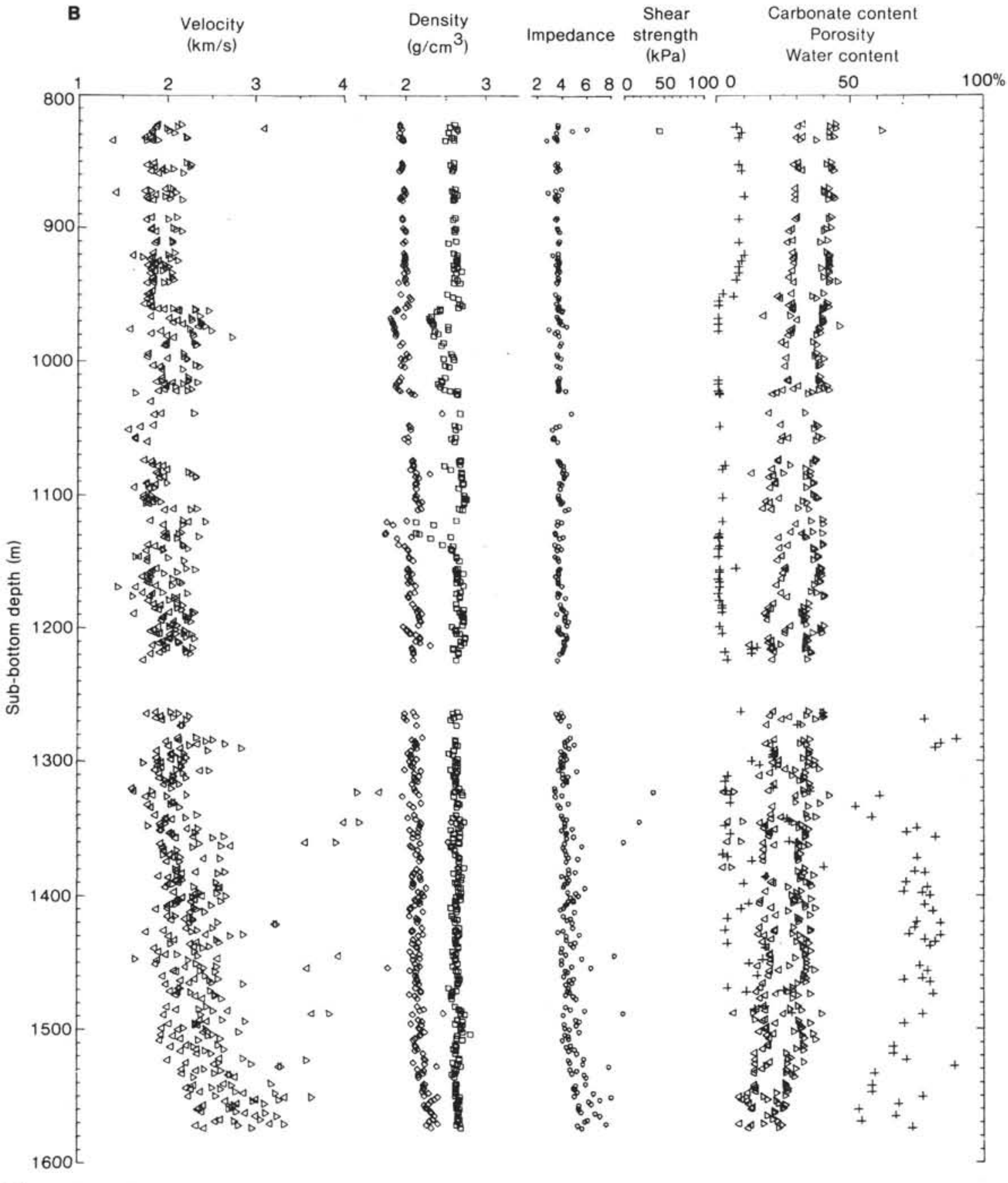

Figure 27 (continued).

Shear Strength

Shear strength measurements were routinely performed with a handheld Soiltest Torvane for sediments with strengths of approximately 20 kPa or less. For stronger sediments, a handheld Soiltest Pocket Penetrometer (Model CL-700) was utilized to measure unconfined strength. Shear strengths were measured parallel to bedding on split cores and normal to bedding where possible. Shear strengths are usually measured normal to bedding; thus, measurements made parallel to bedding generally result in lower measured shear strengths. Shear strength measurements were taken, when possible, adjacent to bulk physical property and sonic velocity measurements.

Hole 603 shear strength measurements were possible only through Core 15 (0–332 m sub-bottom depth). A sharp increase in strength was observed between Cores 603-8 and -11M (200–250 m sub-bottom depth), even though degassing in this region is likely to have reduced the absolute strength. At a few intervals below 250 m sub-bottom, shear strength exceeded the range of the penetrometer. Shear strength data were plotted versus depth (Fig. 27).

The Torvane shear strength measuring device was used on Cores 603C-1 through -16 (Fig. 27). Below this depth the pocket penetrometer was used until it failed to penetrate in Section 603C-37-3 because the sediments were highly indurated. The shear strength profile shows in-

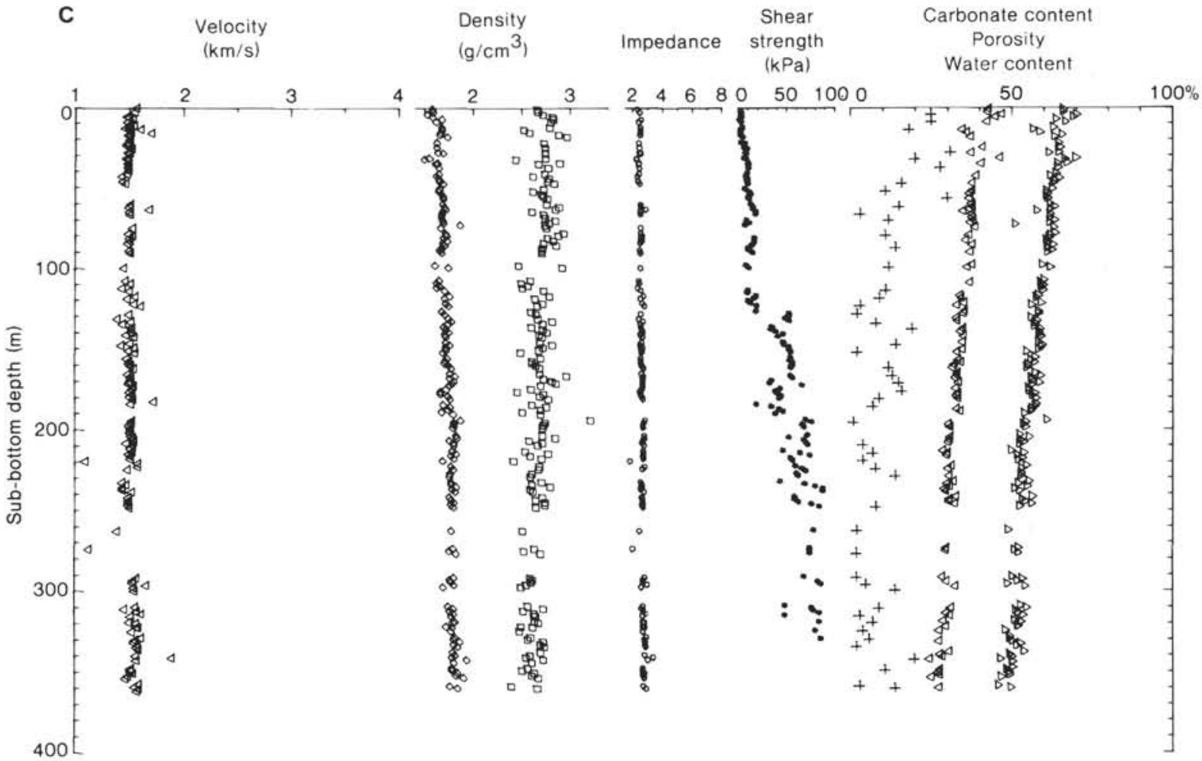

Figure 27 (continued).

creasing strength with depth, with a marked increase in values when the pocket penetrometer was used (Fig. 27).

Bulk Physical Properties

Bulk density, grain density, water content, porosity, and weight percent calcium carbonate (see Geochemistry section) were determined from samples taken at intervals of approximately 1.5 m (once per section). The Boyce cylinder technique was used on soft sediments and the Boyce gravimetric chunk technique (Boyce, 1973) was utilized for indurated sediments. All values have been corrected for salt content (Hamilton, 1974). The results are listed in Appendix I and shown in Figures 27 and 28.

The lithology of the sediments of Hole 603B is highly variable. The following points are worth noting:

1. The upper sequence of clay/claystone (0–960 m sub-bottom) shows very general trends: increasing bulk density and decreasing porosity and water content with depth. Grain density shows very little change, with an overall decrease from ~ 2.75 g/cm^3 to 2.60 g/cm^3.

2. The cored interval of Hole 603C is thought to represent a seismic sequence which resembles large-scale climbing ripple lamination. This pattern has been suggested as being characteristic of contourites. Approximately 12 reflectors should have been penetrated. There is no obvious cause for these reflections to be seen in the physical properties. However, such lateral coherency of reflection character implies a systematic variation in acoustic impedance which, in turn, is a function of the sediment physical properties.

3. The highest compressional wave velocities were found in the cemented sands. However, these sands account for only a minor percentage of the total sand thickness (see Lithology section, this chapter).

4. Velocities through the laminated sediments vary with the percentage of carbonate present and coincide with a change in color from dark gray (slow) to light gray (fast). Destruction of the laminations by bioturbation is reflected by a further increase in the sonic velocity.

5. Marked anisotropy (horizontal velocity/vertical velocity) exists throughout the sediment column (Table 3). The laminated carbonates and black shale sequences exhibit the highest anisotropy ratios (Fig. 28). Anisotropy is greatest in the shale and laminated carbonates but low in the bioturbated carbonates and sandstones. This suggests that the anisotropy is due to primary sedimentary alignment of grains forming the framework structure.

6. Bulk densities increase with increasing degree of cementation.

7. Compressional wave velocity and bulk density increase with depth whereas water content decreases with depth.

Lithologic Units II through V show a considerable range of physical properties. In contrast to the homogeneity of Unit I, they have intercalated lithologies. Table 3 summarizes the velocity data for each lithology. If velocity is considered to be dependent on processes of deposition and diagenesis, then differences in these explain the variation in acoustic anisotropy (Fig. 28).

On the basis of physical properties, the sedimentary column may be divided into distinct units (Fig. 27). When analyzing physical property data, it is essential to consider how measurements were made. Breaks in a particular property may reflect *in situ* boundaries or may only

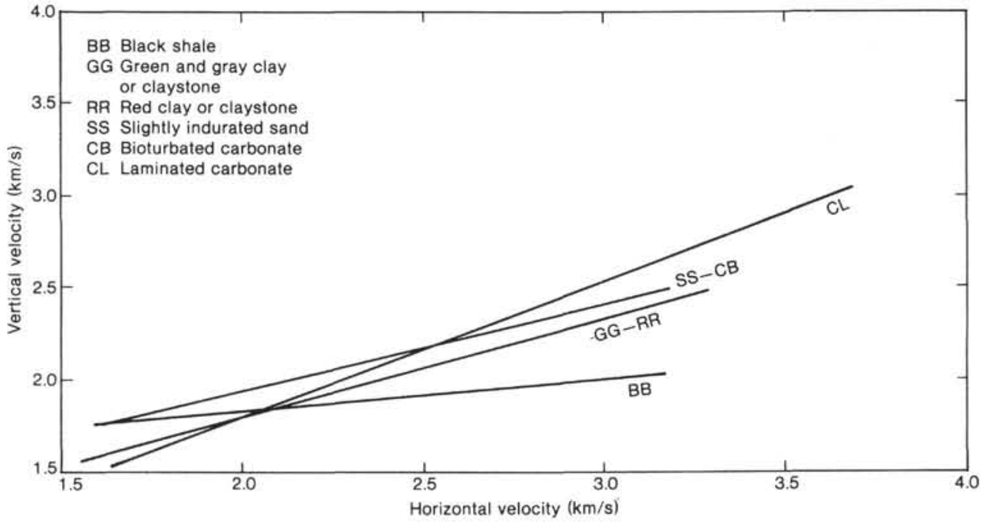

Figure 28. Acoustic anisotropy for various sediment types of Hole 603B.

Table 3. Average vertical and horizontal velocities (in km/s) with anisotropy ratios for samples from cores 603B-54 to 603B-64.

Sediment type	*V* Average vertical velocity	*H* Average horizontal velocity	*H/V* Average anisotropy
Cemented sand	4.059	4.153	1.02
Slightly indurated sand	2.030	1.996	0.97
Black shale	1.844	2.202	1.19
Laminated carbonate	2.056	2.274	1.11
Bioturbated carbonate	2.370	2.539	1.07

testify to excessive damage caused by the mechanical process of core recovery and analysis. Thus even small changes represent differences in the physics (*sensu lato*) of the samples. By analysis of all physical properties data for all three holes drilled, twenty-six physical properties units were recognized:

Unit 1 (0–65 m sub-bottom): This unit is marked by regular physical property trends with increased compaction resulting from increasing overburden. These trends include increasing wet-bulk density and shear strength and decreasing water content and porosity with depth.

Unit 2 (65–109 m sub-bottom): Shear strength remains fairly constant in this interval. Water content decreases by only 2% and thus wet-bulk density and porosity show only slight decreases with depth.

Unit 3 (109–190 m sub-bottom): Shear strength rises abruptly at the upper portion of this unit but thereafter exhibits a generally constant trend with depth. Velocity and bulk density are highly variable within this interval. Porosity and water content gradually decrease. The lower 15 m of this unit may represent a distinct unit with lower shear strength, lower density, and loss of velocity data.

Unit 4 (190– ~270 m sub-bottom): The top of this unit is again marked by an increase in shear strength. Wet-bulk density shows a marked increase, but the remaining parameters are relatively constant.

Unit 5 (~270–370 m): Velocity increases with increasing depth, whereas porosity and water content decrease with depth. The shear strength profile is very erratic in this region. As previously mentioned, the vague boundary between Units 4 and 5 appears to be a result of the clay-to-claystone transition.

Unit 6 (370–450 m): Bulk density and sonic velocity increase and porosity decreases. (Core recovery was low, making definition of this unit only tentative.)

Unit 7 (450–552 m): Sonic velocity decreases, wet-bulk density and grain density increase because of compositional variation.

Unit 8 (552–560 m): This unit is defined by higher wet-bulk density than in units above and below. Other properties show no significant variation from Unit 7.

Unit 9 (560–620 m): Sonic velocity is higher over this unit. The top is defined by low wet-bulk and grain density and low porosity. These latter properties increase downward over the upper 20 m of the unit so that wet-bulk density is slightly higher than in Unit 8.

Unit 10 (620–690 m): Wet-bulk density is higher because of the grain density. Carbonate content is elevated for the upper 30 m. Sonic velocity is lower than in adjacent units.

Unit 11 (690–705 m): This unit is characterized by a downward decrease in wet-bulk density and a rise in carbonate content. Sonic velocity is higher than Unit 12, although no change is seen in grain density.

Unit 12 (705–735 m): All properties are relatively constant compared to Unit 11 above.

Unit 13 (735–755 m): Sonic velocity, wet-bulk, and grain density are all lower. Porosity decreases downward throughout the unit so that wet-bulk density recovers to values nearer those of Unit 12.

Unit 14 (755–780 m): This unit is defined by higher sonic velocity than adjacent units, perhaps because of slightly higher carbonate content. Other properties have values similar to those of the unit above.

Unit 15 (780–960 m): Velocity is low. No change in other properties is visible.

Unit 16 (960–1020 m): A change in composition (inferred) resulted in a decrease in grain density, whereas both velocity and acoustic anisotropy increased (i.e., greater rise in horizontal velocity). This implies that the structure of the sedimentary framework is now important for the transmission of sound, which, in turn, is a function of composition and consolidation (water loss).

Unit 17 (1020–1120 m): At 1120 m there is a sharp rise in grain density accompanied by a decrease in porosity. Only a small increase in vertical velocity is seen, but this is probably an artifact of drilling disturbance—the samples could not be properly trimmed to allow reliable measurement.

Unit 18 (1120–1197 m): At 1120 m there is a sudden and marked decrease in grain density accompanied by an increase in porosity. These then recover with increasing depth—sharply at first and then more gradually. Horizontal velocity is variable.

Unit 19 (1197–1216 m): Both bulk and grain density exhibit a decrease followed by a transitional increase. Velocity and grain density compare closely with each other and exhibit less change, suggesting sound transmission by framework is important.

Unit 20 (1216–1265 m): Data lost because of poor recovery.

Unit 21 (1265–1324 m): Variable bulk physical properties. Generally, wet-bulk density rises as porosity is lost. This may be due to consolidation or cementation. (There is also a possible break at 1309 m.)

Unit 22 (12324–1381 m): This unit is characterized by cemented sandstones which exhibit very high velocity (greater than 4 km/s), and low porosity. There is an overall slight increase in grain density. The sandstones are probably too thin to give a seismic expression.

Unit 23 (1381–1455 m): High variability in wet-bulk density, grain density, and porosity. No cemented sandstones.

Unit 24 (1455–1490 m): Porosity decreases and grain density increases slightly. Bulk density (and consequently velocity) remain constant.

Unit 25 (1490–1525 m) and Unit 26 (1525–1575 m): Transitional increase in velocities caused by a marked reduction in porosity. Anisotropy decreases. Subunit 26 is distinguished by greater variation in velocity.

Units 24–26 show a general variability of properties although grain density is comparatively constant. This suggests that composition is similar, but that grain size and/or structure vary. Lowered acoustic anisotropy suggests that the framework is important but because the structure is equally rigid in the horizontal and vertical directions, randomly oriented cementation is suggested as the cause. Lithologically, these units are characterized by interbedding of laminated and bioturbated nannofossil limestone.

See Biart (this volume) for further elaboration on this physical property stratigraphic approach.

GRAPE

During the recovery of material from Holes 603, 603B, and 603C, the cores were routinely scanned by the Gamma Ray Attenuation Porosity Evaluator (GRAPE) which has an accuracy of $\pm 10\%$ (Boyce, 1976). This accuracy can be improved after the cores are split if corrections are made for core thickness. Owing to problems with the magnetic tape drive, however, this was not possible on Leg 93, and only uncorrected analog records were available for subsequent analysis.

Continuous GRAPE measurements were performed on most complete sections at Hole 603C. The upper cores completely filled the liner and should give a reliable density profile. Lower down, the tungsten carbide tooth, which trims hard formations to allow them to pass through the core catcher, began to cut a helical groove around the core. Consequently, GRAPE values are unreliable for this section because of the variation in the core diameter. Evaluation was continued because it was hoped that a maximum value on each section's profile might correspond to a "full-liner" reading, which could be used as a check on the Boyce cylinder density measurement. Lower still, the helical groove became continuous, so that the diameter of the core was nearly constant within the liner—the separation being filled by drilling mud.

Working with uncorrected analog records is not at all productive. The most obvious feature on the GRAPE record is the core thickness. Before any real sense can be made of the record, the thickness correction must be carried out. There is evidence of a gradual increase in bulk density from around 1.6 to over 2.0 g/cm^3 for Hole 603. The lithology is defined as relatively constant clay to claystone, so there is not likely to be much variation in density other than in response to consolidation and cementation. The gassy nature of many of the recovered cores (Cores 603-43, -44, -48 to -53) degraded results. Gas may be in solution at depth (or even hydrated). Pressure within the core liner stretches the liner, and gas expansion causes large voids with concomitant compaction of adjacent material.

Downhole Temperature Measurements

Seven attempts to measure the *in situ* temperature of the upper sediments using the downhole pore water/temperature probe were made at Holes 603 and 603C (Table 4). Valid results were obtained from only four measurements.

From these measurements a temperature profile was produced in order to determine the heat flow (see discussion of thermal conductivity) from the equation: q

Table 4. Site 603 temperature probe data.

Probe no.	Depth below seafloor (m)	Temperature (°C)
1[a]	83.8	—
6	84.8 (Hole 603C)	5.8
2	131.8	11.6
7	145.2 (Hole 603C)	8.5
3[b]	179.8	8.1
4	227.8	12.2
5	323.8	15.8

Note: Hole 603 unless otherwise noted. Dash indicates that no reading was obtained.
[a] Not emplaced in sediment
[b] Affected by drill string motion

= $-K$ grad T, where K = thermal conductivity, q = heat flow, T = temperature.

The temperature gradient for these sediments, calculated using the data of probes 4, 5, 6, and 7, was 4.18°C per 100 m (Table 4, Fig. 29). The probe was programmed to sample at 5 s intervals. Probes 1, 2, and 3 encountered difficulties.

During the first trip, the probe lodged in the in the pipe and could not be emplaced in the sediment. The temperature measured during emplacement of the third probe appears to have been lowered by seawater that was infused by the pumping action of the drill string as it moved up and down in the drill hole because the heave compensator was not working.

The time/temperature curve for probe number 5 (323.8 m sub-bottom) also exhibits the effects of drill string motion and appears to have yielded a low value. Additionally, Probe 2 at Hole 603, 131.8 m sub-bottom, appears to have measured an erroneously high value.

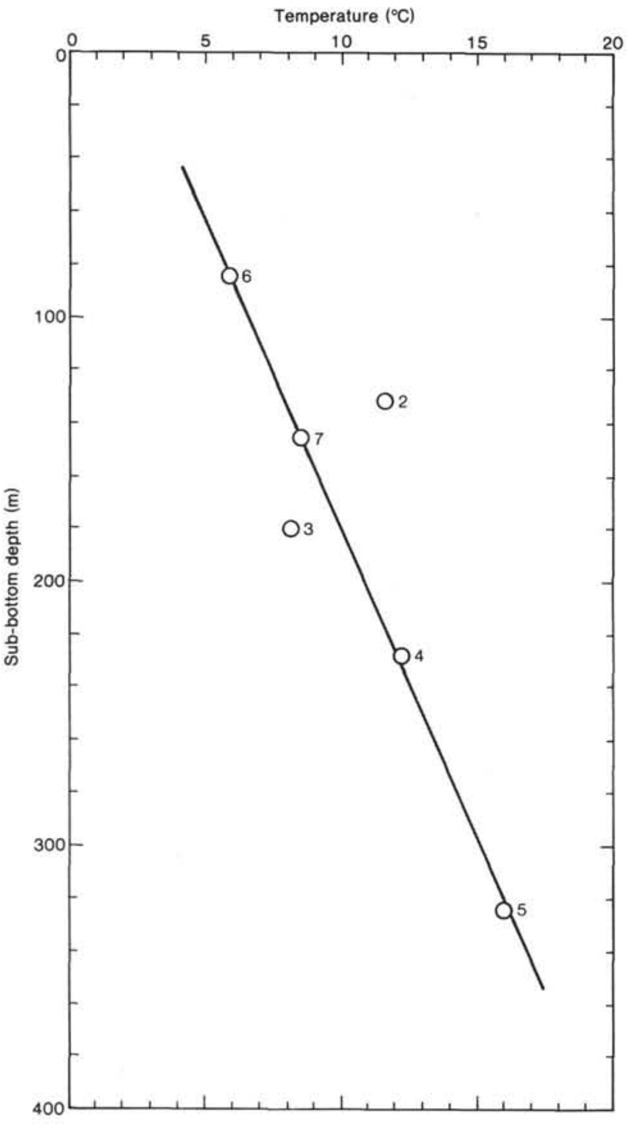

Figure 29. Downhole temperature profile for Holes 603 and 603C. Probe no. indicated.

SEISMIC STRATIGRAPHY

The eastern North American Basin has been studied longer and in greater detail by marine geophysicists than any other basin in the world. Yet before Site 603 was drilled, no regional seismic stratigraphic analysis had been published other than the pioneer identification of prominent reflectors in an alternation of reflective and transparent zones on large-scale, low-resolution seismic reflection profiles (Tucholke, 1979). Modern, higher-resolution multichannel seismic reflection records reveal that the section is quite complex, consisting of units with changing internal reflection patterns that terminate at unit boundaries. These boundaries constitute most of the reflection horizons that have been traced over much of the basin, most of which have been identified in the literature. The nature of the boundaries and of the units they delineate is just beginning to be described (Tucholke, 1981; Sheridan et al., 1983) and mapped (Mountain and Tucholke, 1985).

To prepare for Leg 93 drilling, it proved necessary to unravel the seismostratigraphy of the multichannel sections made available to us. We followed the approach outlined by Vail et al. (1977), distinguishing local units bounded by reflection pattern changes ("unconformity-bound units"). We will refer to reflection Units and reflection Horizons. Thus natural, genetic depositional units are recognized that can be related to time-stratigraphic units or standard sequences (Vail and Mitchum, 1979; Vail et al., 1980).

Stratigraphy

The stratigraphic succession of the *Conrad* and *Knorr* multichannel profiles can readily be subdivided into three major units. At Site 603 (Fig. 4) we see (a) basement, below 1.73 s under the mudline, (b) a section topped at 1.06 s by a few prominent subhorizontal reflectors referred to as the A-complex (Tucholke, 1979), and (c) a thick section between A and the seafloor. The reflection configuration within the two upper units allows for a further subdivision, which we numbered in order of penetration from the top down (Fig. 30, Table 5).

The *Conrad* 2102-77 seismic reflection profile (Fig. 4) shows three major seismic facies units between Horizon A and the seafloor:

Unit 3: a rather chaotic, hummocky pattern with transparent base (A–X), followed by:

Unit 2: a migrating-wave configuration (A–seafloor), succeeded by:

Unit 1: a pattern of strong, parallel reflectors to the west of Site 603.

Reflection Unit 1

This unit consists of a package of strong, parallel reflectors that build the so-called lower continental rise terrace (LCRT) behind the Hatteras outer ridge crest (HORC) which has the lower continental rise hills (LCRH) to its east. This situation is also clearly shown on the *Glomar Challenger* seismic profile recorded while approaching Site 603 (Fig. 7). Even though our record does not allow an unambiguous correlation across the

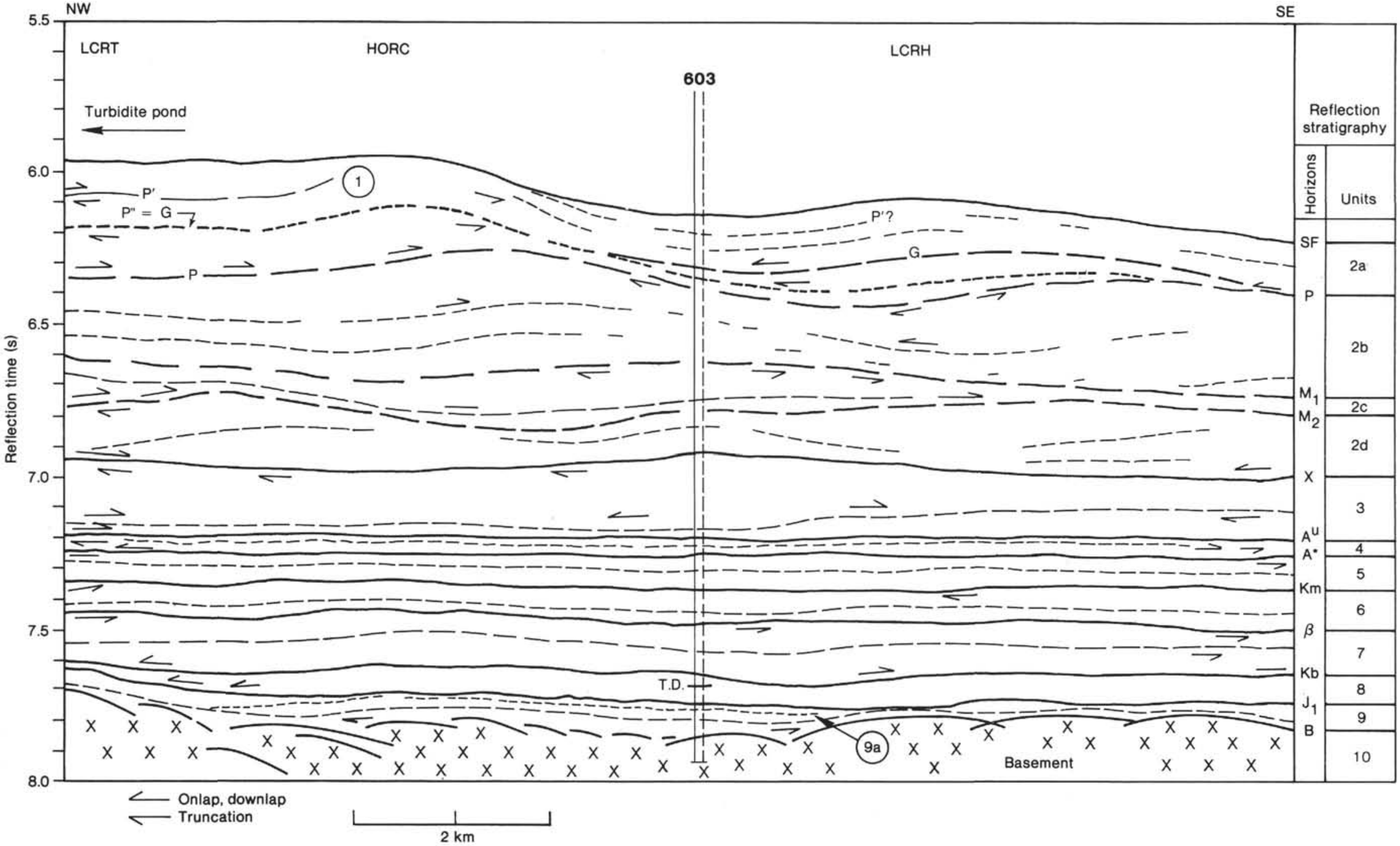

Figure 30. Stratigraphic interpretation of multichannel seismic reflection profile *Conrad* 2101-77 (Fig. 4), partly after Tucholke et al. (1982). Continuous and broken heavy lines delineate sequence boundaries. Reflection stratigraphy, indicating units divided by reflection horizons, is shown in the right-hand columns. Unit 1 lies to the northwest of the Hatteras outer ridge crest (HORC). LCRT = lower continental rise terrace, LCRH = lower continental rise hills.

Table 5. Stratigraphic summary of seismic profile *Conrad* 2101-77 at Site 603, listing depths of reflection horizons, predicted depth, local seismostratigraphic units and boundaries, reflection configurations at unit boundaries and for seismic facies, and drilling results.

0.01 (s BSF)	Predicted depth (m BSF): Sonobuoy	Predicted depth (m BSF): Coring	Reflection stratigraphy[a]: Unit	Horizon	Boundaries	Facies	Drilling results, Site 603[b]: Depth (m)	Velocity (km/s)	Standard sequences		Time of event (Ma)	Formation
					Td	Parallel even (High Amplitude)		1.63	Q_2	Q		
8	68	74		P′	O C / Te		65		Q_1		1.7	
12	104	112	2a		O / Td O							
16	138	148		G	Te	Sigmoid (Low Amplitude)	128	1.60	TP3		2.8	
21	183	195			O / Td O							
25	219	233		P	Te	Oblique parallel	200		TP2	Tf	3.8	
35	312	326	2b		O O / C			2.00	TP1		4.2	
41.5	374	386			C / Td	Hummocky clinoform	369		TM3.3 TM3.2		5.2	
50	456	465		M_1	O / Te	Hummocky clinoform	450	1.87	TM3.1		6.6	Blake Ridge Formation
61.5	571	572	2c		O / C	Onlap fill						
65	607	605		M_2	O O / Te	Shingled	590	2.00	TM2.3	Te	9.8	
70	659	651	2d		O–D / C Td	Lenticular						
80	765	744		X	O / Te	Shingled and disrupted lenticular	740	1.69	TM2.2		13.0	
			3									
104	1003	967			O / To	Parallel and transparent			TM2.1—Td?	Td?	15.5?	
106	1053	986		$A^u/A^T/A^c$	O C / Te	Onlap fill	960	1.91	TE1 / TP2	Ta	22.5 + 29	Bermuda Rise
109	1088	1014	4		C						53.5	
112.5	1129	1046		A*	O / Te C	Disrupted parallel	1022	1.85		Kb	60	Plantagenet Formation
117	1181	1088	5 (a / b)		C	Transparent						
123	1253	1144		Km	D O / Te	Low-amplitude disrupted parallel	1119	2.26	K1.3		84 (+97)	Hatteras Formation
131	1355	1223	6 (a / b)		C / O C_C O	Fan complex mound	1215	2.80				unnamed
135	1398	1256		β	Te	Disrupted wavy parallel	1264	2.90	K1.2	Ka	"112"	Blake-Bahama Formation (Sandy facies)
143		1376	7 (a / b)		O / Te	Transparent to disrupted wavy parallel and onlap fill			K1.1?			
153		1526		Kb	O / C–Td	Even wavy parallel	1525		J3.2?		131?	
			8				T.D. 1585.2 m					
161		1646		J_1	O / Td	Onlap fill						
167		1736	9a	$J_{2(?)}$	O / Te	Disrupted wavy parallel						
173	1996	1826	9b	B	C / C	Hyperbolic						
			10									

Note: Reflection horizons (seismic sequence boundaries) in s (TWTT) below seafloor; predicted depths using velocity criteria derived by Tucholke et al. (1982) from sonobuoy recordings and from previous borehole data.

[a] Boundaries β, A*, A^u, and X preassigned in the site prospectus by the Passive Margin Panel. folowing Tucholke et al. (1982). Descriptions of reflection configurations at unit boundaries and of seismic facies follow terminology of Vail et al. (1977). C= concordance, D= downlap, O= onlap, 0= offlap, Td= depositional truncation, Te= erosional truncation, To= toplap.

[b] Drilling results and interpretation in terms of the sequence stratigraphy of Vail and Mitchum (1979) and the regional lithostratigraphy of Jansa et al. (1979).

ridge crest, it is apparent that ridge growth and turbidite accumulation are simultaneous (compare Tucholke and Laine [1982], who consider the ridge and hills to be older than the turbidites). The ridge crest could be roughly mapped with the seismic records we had at our disposal as background information (VEMA, *Conrad, Knorr;* Fig. 6).

Unit 1 has been spot-cored at nearby DSDP Site 106 (Fig. 1), where it consists of Pleistocene terrigenous sand turbidites and clays (Hollister, Ewing, et al., 1972), constituting the upper portion of the type section for the Blake Ridge Formation as defined by Jansa et al. (1979).

Unit 1 and Subunit 2a are seismic facies units that are partly time-equivalent. Provisionally, we correlated two seismic horizons across the HORC (Fig. 30): reflection Horizon G, the truncating base of Unit 1, and reflection Horizon P′, the most prominent of a number of internal sequence boundaries within Unit 1 (see Fig. 38 in Wise and van Hinte, this volume). Shore-based age determination (Ma'alouleh and Moullade; Canninga et al,; both this volume) showed that G marked the beginning of glacial times (basal Pleistocene, or within the Pliocene, according to others) and that it correlates with the P1.3/Q1 cycle boundary of Vail and Mitchum (1979), whereas P′ may correlate with their Q1/Q2 cycle boundary. The G event is expressed as a major cooling event in the stable isotope record (boundary between isotope units II and III in Ganssen, this volume).

Reflection Unit 2

This unit was spot-cored in the lower continental rise hills area at DSDP Site 388; its edge was cored at DSDP Site 105. The unit at those sites consists of hemipelagic, silty micaceous clay with some siderite and plant debris. It forms part of the Blake Ridge Formation as defined by Jansa et al. (1979).

Unit 2 incorporates various prominent reflectors or depositional pattern boundaries that can be followed across the profile and allow for further subdivisions into subunits. To delineate natural subunits we identified changes in depositional patterns, i.e., sequence boundaries (Vail et al., 1980). The result of our shipboard interpretation of the seismic profile is given in Figure 30.

Our reflection Horizons M_1 and M_2 probably correlate with Horizon M of the Blake-Bahama Basin (Dillon et al., 1976; Benson, Sheridan, et al., 1978b; Sheridan et al., 1978). Horizon M appears in multichannel data as a double horizon (Sheridan et al., 1981) and has been dated at Site 391 as late Miocene. Without further discussion, Jansa et al. (1979) and Vail et al. (1980) place Horizon M at the Miocene/Pliocene boundary and the "basal middle Tortonian," respectively. The latter may refer to our reflection Horizon M_2, which had been labeled "SB" by Tucholke et al. (1982) and "Merlin" by Mountain and Tucholke (in press), who conclude it to be of late middle Miocene age. It correlates with a reflection horizon at 0.3 s at Site 388 (referred to as Horizon X by Benson, Sheridan, et al., 1978a) that has been assigned a late Miocene age (N16/17 and NN11 above, N14/15 and NN10 below). See discussion of reflection Horizon X.

Unit 2 was successfully sampled during Leg 93 in Holes 603, 603B, and 603C. The results are summarized in Table 5.

The migrating-wave pattern which characterizes reflection Unit 2 is of a type which appears to be formed by current action in deep water (Mitchum et al., 1977). In our case, the current would have been the south-flowing Western Boundary Undercurrent (WBUC) (Heezen and Hollister, 1971). Multichannel seismic reflection profiles clearly show that the LCRHs are the seafloor expression of the migrating sediment waves. North–south lines show a north-dipping internal reflection configuration of the hills and of the underlying units, revealing their antidune nature. The migrating mounded-to-transparent internal reflector configuration of the ridge crest has, since its initiation, been different from the prograding clinoform pattern of the hills. The ridge crest seems to be a natural levee of the WBUC rather than an accumulation of antidunes.

Thus, judging from the deeper-seated, larger-scale, climbing, wavy reflection pattern, we agree with authors who have proposed a constructional origin for the ridge (Fox et al., 1968; Rona, 1969; Heezen and Hollister, 1971; Ewing and Hollister, 1972; Benson, Sheridan, et al., 1978a; Jansa et al., 1979; Tucholke and Mountain, 1979). Consequently, the hypotheses of Ballard (1966) and Schlee et al. (1976) that explain the seafloor topography as a result of mass movements can be rejected for this area.

The reflection seismic data at our disposal also contradict part of the hypothesis of Asquith (1979), who suggests that the hills are remnants of a once smoother Miocene–Pliocene HOR which had been formed by the WBUC parallel to the continental margin and which was eroded by sediment gravity flows during glacial low stands of sea level. According to Asquith (1979), the remnants were subsequently plastered with fine sediment by the WBUC to produce an apparent, superficial antidune structure.

We do agree, though, with Asquith (1979) that the HORC is a constructional product of the WBUC, forming a wall behind which turbidites ponded. The glacial input of terrigenous material obviously also loaded the WBUC, thus increasing sediment outfall at its edges. However, we do not see the presumed channel cuts in the HORC. To the contrary, the *Glomar Challenger* record (Fig. 7) clearly shows that the ridge crest and hills continued growing while turbidites ponded behind them and built the outer rise terrace.

The reflection configuration of Unit 2 suggests that similar processes have been active since Horizon X time. However, prior to Horizon P, the turbidite buildup must have been considerably less as compared with the ridge growth, leaving the proto-HORC a more prominent drift feature on the seafloor. The northwest termination of the wavy pattern lies at and under the HORC where it merges, either in a package of high-amplitude parallel reflectors that level with the crest (acoustic Subunit 2a and lower part of 2c), or in a relatively thinner bundle of low-amplitude parallel reflectors that stay below the ridge crest (Subunits 2b, 2d, and upper part of 2c). The

P event is expressed in the stable isotope record as a cooling event (Ganssen, this volume).

Reflection Unit 3

This unit, the section between reflection Horizons X and A^u, was sampled at nearby Site 106 (Cores 106B-5 through -8), where it consists of hemipelagic, gray silty mudstone with siliceous microfossils. Siliceous induration of Cores 106B-7 and -8 is attributed to reprecipitation of opal from the microfossils. These lowest cores contain late Oligocene–early Miocene and reworked Eocene microfossils (Hollister, Ewing, et al., 1972). As the hole bottomed just above Horizon A^u (Tucholke, 1979, fig. 8), the reworking confirms the postulated erosional nature of this widespread reflection horizon.

The upper part of Unit 3 at Site 106 (Cores 1-6B) forms part of the type section of the Blake Ridge Formation as defined by Jansa et al. (1979). Jansa et al. (1979) cite an Eocene age for Cores 106-7B and -8B and assign them to the "sediments enriched in biogenic silica and chert" of their Bermuda Rise Formation. However, the lithology does not fit the Bermuda Rise Formation (cf. sediment description by Lancelot et al., 1972), nor are the cores of Eocene age (Hollister, Ewing, et al., 1972, sections on nannoplankton and radiolarians; Wilcoxon, 1972). The two cores should have been included in the Blake Ridge Formation.

Unit 3 wedges out before reaching Site 105, but is present at Site 388. At Site 105, merged Horizons A and X are overlain by upper Miocene sediments (Ewing and Hollister, 1972). Hole 388 did not reach Horizon X. The horizon at 0.30 s, referred to as Horizon X by Benson, Sheridan, et al. (1978a), correlates with our Horizon M_2 (seismic profiles *Conrad* 2101-77, *Knorr* 80-5 and 80-30).

Vail et al. (1980, p. 140) assign an earliest Langhian age to Horizon X based on "good correlation to continental shelf wells—estimated from sea level chart." Tucholke and Laine (1982) and Mountain and Tucholke (in press) agree on a middle middle Miocene age.

See Table 5 and Figure 31 for the preliminary results of drilling at Site 603.

Below Unit 3 the general reflection pattern is parallel, with varying degrees of continuity, described below. This general configuration would suggest that the section consists largely of pelagic sediments and/or turbidites—as one would expect, of course, on an outer continental rise.

Reflection Unit 4

This unit is characterized by two strong, parallel reflection horizons that stand out like a railroad track on most seismic profiles. At the location of Site 603 the upper and lower reflectors have been labeled A and A*, respectively, on VEMA profile 23 by Ewing and Hollister (1972). Horizon A has later been referred to as A^u (Tucholke, 1979), and A^u and A* have been identified at our location on *Conrad* profile 2101-77 by Tucholke and Mountain (1979) and Tucholke et al. (1982).

This unit has been delineated and described as "Horizon A–Horizon A*" by Ewing and Hollister (1972) and Lancelot et al. (1972). According to these authors it was cored at Site 105, where it consists of varicolored volcanogenic clays. The section is barren and could be of Turonian to Eocene age, as it is underlain by Cenomanian red/green/black shales and is correlated with Site 7, where it underlies middle Eocene turbidites. Tucholke (1979), however, considers A^u and A* to have merged at Site 105. He places the varicolored unit below A*, which implies a Late Cretaceous age, because at Sites 386 and 387 Horizon A* has been found to correlate with a top Cretaceous chalk (Tucholke, Vogt, et al., 1979a, 1979b). It also implies that our Unit 4 is early Tertiary in age, because it lies above A*. We agree with the latter implication, but not with the former, since we consider Unit 4 to be present and cored at Site 105. Jansa et al. (1979) consider that this interval of Site 105 (Cores 105-5 through -9) belongs to their Plantagenet Formation, but do not decide whether it belongs to the Tertiary upper part of the formation or to the Cretaceous lower part. Tucholke et al. (1982) and Sheridan et al. (1983) observed that Reflection Horizon A^c, associated with early Eocene porcellanites, can be "merged by convolution interference" with Horizon A^u. Therefore, at Site 603, Unit 4 may represent the Bermuda Rise Formation and/or the upper Plantagenet Formation of Jansa et al. (1979). Reflection Horizon A^u is generally considered to reflect a regional, erosional surface, the time of its formation being between late Eocene and Miocene (see review in Tucholke, 1981). Vail et al. (1980) equate the erosional A^u event with a major late Oligocene sea level drop.

Leg 93 drilling showed reflection Unit 4 to consist of lower Eocene—upper Paleocene multicolored radiolarian claystone (Hole 603B, Cores 15 through 22). For further information, see Table 5 and Figure 31.

Reflection Unit 5

This sequence is bounded by two truncating reflection horizons, A* and Km (mid-Cretaceous). The stratigraphic position of reflection Horizon A* has been estimated by Jansa et al. (1979) and Schlee and Grow (1980) to be basal Tertiary, and by Vail et al. (1980) to be basal Thanetian. Observations at Sites 386 and 387 by Tucholke and Vogt (1979a, b) leave the question open, because upper Paleocene overlies Maestrichtian.

Single-channel seismic records lack the resolution of the *Conrad* 2101-77 line and show a transparent zone between Horizons A* and β. Therefore Horizon Km has not been described from the oceanic part of the North American Basin. However, Schlee and Grow (1980) did identify two sequence boundaries between Horizons A* (= T/K, fig. 51 of Schlee and Grow, 1980) and β on the continental slope and upper continental rise: Horizon CON(iacian) and Horizon CENO(manian). It seems possible that our disrupted reflector in the middle of Unit 5 correlates with CON, and it seems likely that Horizon Km correlates with Horizon CENO (Vail et al., 1980, also expect a basal middle Cenomanian oceanic sequence boundary). Shipboard and postcruise age determination showed that Km separates Senonian from Albian–Turonian sediments. Further confirmation of these ages would determine a Km–CON correlation (Fig. 31).

The Horizon A*–Horizon β interval has been cored at various locations (Sites 105, 386, 387, 391), where its sediments have been classified as lower Plantagenet and

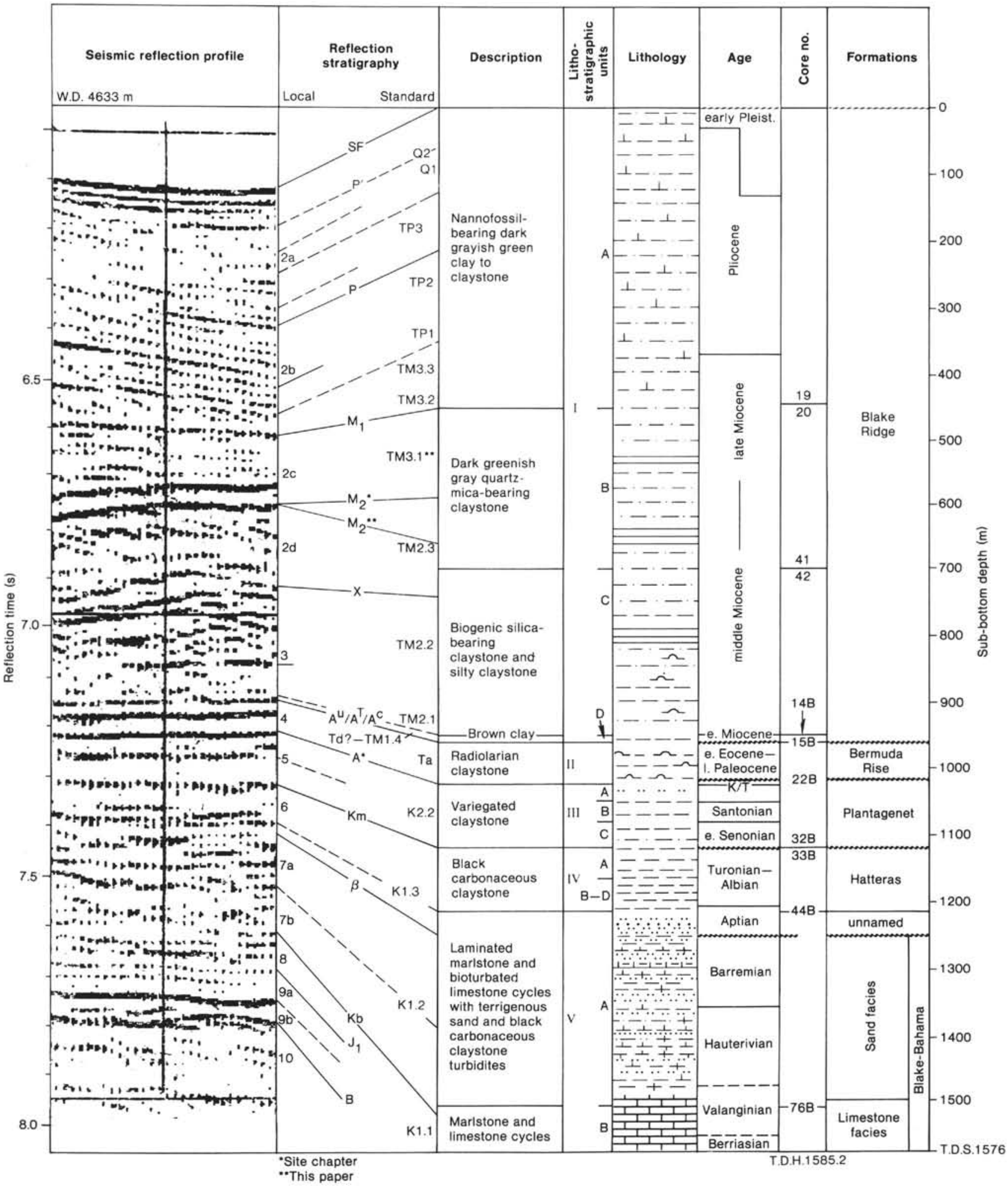

Figure 31. Stratigraphic summary of Site 603. See Explanatory Notes (this volume) for lithologic symbols. Standard seismic sequence symbols after Vail and Mitchum (1979), except K2.2, which is the upper half of their K2.

Hatteras formations (Jansa et al., 1979). It is tempting to correlate Horizon Km with the boundary between these formations, for this would be consistent with a mid-Cenomanian age. Thus, Unit 5 would be part of the Plantagenet Formation and would largely consist of variegated (gray, green, brown, red) claystone. This prediction was confirmed by Site 603 drilling, which showed reflection Unit 5 to be equatable with the variegated claystone of lithologic Unit III (Cores 603B-22 through -33) of Senonian to earliest Paleocene age. This result not only correlates Km with Horizon CON (Schlee and Grow, 1980) but also confirms the Vail et al. (1980) prediction of a basal Thanetian position of Horizon A*.

Reflection Unit 6

Horizon Km and Horizon β are two truncating surfaces delineating this unit. Horizon Km has been described above. Horizon β has been identified at the Site 603 location on *VEMA* profile 23 by Hollister, Ewing, et al., 1972, and on *Conrad* profile 2101-77 by Tucholke and Mountain, 1979, and Tucholke et al., 1982.

Horizons A and B, and later α above A and β above B, have been recognized on low-resolution seismic profiles of the 1960s. Horizon B in our area is smooth acoustic basement (sediment and/or basalt) and Horizon β forms the top of a stratified unit overlying basement (Ewing and Hollister, 1972; Tucholke, 1979). Horizon β has been penetrated at DSDP Sites 5, 101, 105, 387, 391 and 534, where it coincides with the boundary between Neocomian limestones and an overlying argillaceous section (Lancelot et al., 1972; Tucholke, 1979; Jansa et al., 1979; Sheridan, Gradstein, et al., 1983). The youngest age of the limestone recovered from these sites is Barremian. The oldest age of the overlying section, however, is uncertain, because different fossil groups suggest ages ranging from Barremian to Albian. Since Horizon β shows truncation, the differences in age assignments probably are due to reworking and we would give highest value to the youngest ages. At all locations, the section above Horizon β seems to be Aptian or younger. Jansa et al. (1979) formally named the argillaceous section above Horizon β the Hatteras Formation, with which our Unit 6 probably correlates (see discussion of Unit 5). Their predictions were confirmed by Site 603 drilling as the age of the lowest sediment (a massive, unconsolidated sand) above Horizon β and higher shales proved to be early Aptian in age (Covington and Wise; Habib and Drugg; both this volume). Our results also confirm the correlation of Horizon β with a "basal middle Aptian" unconformity of the continental shelf and margin produced by a marked sea-level low stand. Further confirmation of our age assignment will suggest that the low stand occurred somewhat earlier during the earlier Aptian than indicated by Vail and Mitchum (1979).

Reflection Unit 7

This unit comprises the interval between reflection Horizons β and Kb. At Site 603, the section below Horizon β shows two surfaces that record depositional truncation. The lower has been identified as J_1 by Klitgord and Grow (1980, Line FAY 20-4) and more precisely by Tucholke et al. (1982). The upper one is here referred to as reflection Horizon Kb (basal Cretaceous). This horizon more or less drapes basement topography over most of the *Conrad* 2101-77 profile, but on occasion truncates underlying units at a few local basement highs. The draping, parallel reflection pattern suggests pelagic sedimentation, whereas local onlap fill and the more hummocky configuration in the west might indicate turbidite contributions.

The pre-Horizon β section of the North American Basin has been formally classified as the Blake-Bahama Formation (Jansa et al., 1979). Reflection Unit 7 probably forms part of this formation.

Reflection Horizon C′, distinguished by Sheridan et al. (1983) in the Blake-Bahama Basin, might well be compatible with Kb, as might be the basal Valanginian "Horizon 131" of Vail et al. (1980, fig. 9). Horizon C′ was cored at Sites 391 and 534 and proved to be of Berriasian age.

Horizon Kb was penetrated in Hole 603B and proved to be of late Valanginian age. The correlation of Kb with the reference chart of Vail et al. (1980) as given in Figure 31 and Table 5 must remain uncertain until further paleontologic studies allow for a more precise age assignment, and until the criteria for an earliest Valanginian age of the "Horizon 131" event have been made public.

Reflection Unit 8

Reflection Horizons J_1 and Kb enclose Unit 8, one of the most distinct units of *Conrad* profile 2101-77. Although Unit 8 has not been described as such from this area, it seems to be of more than local importance. A group of parallel reflectors also appears above J_1 on profiles U.S.G.S. 25 and nearby FAY 20-4 published by Klitgord and Grow (1980). Unit 8 may also compare with the Horizon C′-Horizon C (= J_1) unit in the Blake-Bahama Basin (Sheridan et al., 1983), which has been shown at Site 534 to consist of a Berriasian massive turbidite sequence (Sheridan, Gradstein, et al., 1983). The seismic profile at Site 391 (Benson, Sheridan, et al., 1978b, fig. 25) shows onlap on a transparent unit that is concordant with Horizon C (= J_1) and seems to be the same distinct sequence that is equivalent to our Unit 8. It has a late Tithonian–early Berriasian age. Altogether, we expected Unit 8 to be the basal part of the Blake-Bahama Formation as defined by Jansa et al. (1979). Unfortunately, accidental loss of the drill string prevented Leg 93 from reaching Horizon J_1.

Reflection Unit 9

Little can be said with certainty about Reflection Unit 9 between Horizon B(asement) and Horizon J_1 because the unit is present in only a few basement depressions along *Conrad* profile 2101-77.

The section below J_1 has been drilled at Sites 99, 100, 105, 391, and 534. It consists of interbedded, varicolored limestones and claystones of pelagic and density-current origin. Jansa et al. (1979) named this rock unit the Cat Cap Formation, designating nearby Site 105 as its type locality. The facies would agree well with the internal reflection configuration at Site 603. Horizon J_1 marks the top of this formation. Its age has been determined at Sites 391 (Benson, Sheridan, et al., 1978b) and 534 (Sheridan, Gradstein, et al., 1983) and would correlate with Horizon 141 identified in the Western Atlantic by Vail et al. (1980).

The questionable truncation of Subunit 9b could be considered as an indication for the presence of Horizon J_2 (Klitgord and Grow, 1980) or of Horizon D′ (Sheridan et al., 1983). Both horizons were drilled at Site 534 and have been interpreted to mark the base and the top, respectively, of the Oxfordian. In view of the predicted age of basement, each of the horizons can be present at

Site 603. Considering the implied rate of sediment accumulation (1.1 versus 4.5 cm/10^3 years), we would guess it is J_2, the older one, even though, according to Klitgord and Grow (1980), Horizon J_2 does not reach so far east as Site 603. Unfortunately *Glomar Challenger*'s drill string was lost before reaching J_1 and this part of the section remains to be sampled by later drilling.

Seismic Reflectors and Physical Properties

Reflectors penetrated at Site 603 are summarized in Table 6. Also tabulated are the correlations with the physical property units.

Horizons P′ through X all represent reflections from layers of minor compositional and diagenetic variation. Lithologic Unit I is relatively homogeneous compared to the section below. It is likely that the upper boundary of lithologic Unit II contributes to the seismic signal and, therefore, that some of the reflectors represent an interference of individual reflections.

The occurrence of Horizon A^u is well documented over the North American Basin (Tucholke, 1981). It is correlated with the top of physical property Unit 16, which is marked by an unconformity between lower Eocene and Miocene.

Horizon β is normally the top of a lithified limestone overlain by black claystones of Aptian–Albian age. This has been interpreted as a single, albeit diachronous event: a rise in the calcite compensation depth (Tucholke, 1979). The occurrence of sandy turbidites at this boundary introduces problems of definition and, therefore, of correlation with nearby sites.

All correlations given are preliminary and require detailed modeling to verify them (see Biart, this volume).

SUMMARY AND CONCLUSIONS

Site 603 consisted of seven holes drilled in 4634 to 4642 m of water on the lower continental rise 435 km east of Cape Hatteras, North Carolina. Four holes (603 to 603C) drilled during DSDP Leg 93 are described here. Three additional holes drilled by DSDP Leg 95 (603D to 603F) are described in the following section of this chapter. All holes are correlated in Figure 32. The principal objectives at Site 603 were to:

1. Sample and identify reflection Horizons β, A*, A^u, and X and other prominent seismic reflectors in the Mesozoic and Cenozoic sedimentary section;

Table 6. Seismic reflection horizons drilled at Site 603.

Horizon	Predicted depth	Amplitude	Physical properties unit boundary	Depth (m)
P′	68	Minor	1/2	65
P″	112	Minor	2/3	109
P	183	Minor	3/4?	190
Unnamed	219	Minor	?	270–370
M_1	312	Major	6/7	450
X	765	Major	10/11	690
A^u	1053	Major	15/16	960
A*	1129	Major	16/17	1020
Km	1253	Major	17/18	1120
β	1398	Major	20/21	1265
Kb		Major	25/26	1525

2. Sample the upper sedimentary section with the HPC in order to understand the active, current-controlled depositional processes which predominated in the area during the Neogene;

3. Sample the oldest sediments deposited on oceanic crust at a location landward of the nearby DSDP Site 105, where Upper Jurassic sediments had been cored over a prominent basement high;

4. Sample and determine the age and nature of oceanic basement.

The sediments were sampled in three phases. First, an exploratory hole (Hole 603) was washed and spot-cored through Cenozoic sediments down to 573 m, continuously cored to 803 m, then wash and rotary-cored to 833 m. Next, an attempt was made to set a reentry cone in Hole 603A. This cone, however, was lost when the unlatching mechanism failed to release the cone from the drill string and the reentry assembly had to be jettisoned. No sediment was recovered from that hole. The next attempt to set a cone was successful, and reentry Hole 603B was then washed and drilled down to 821 m, wash and rotary-cored over short intervals to 927 m, and then continuously cored to a total depth of 1585.2 m. The hole and the last core were lost just 200 m short of our basement objective, when the drill string parted at the Kelly Cock sub (a blowout prevention link just below the power sub at the top of the drill string). Following that mishap, Hole 603C was continuously cored from the surface via HPC down to 91 m, and then via XCB down to 366 m, where the hole was terminated to allow time to drill the remaining sites on the leg.

Despite the accident at Hole 603B, which robbed us of our final objective (sampling Jurassic strata and dating the underlying oceanic basement), Leg 93 occupation of Site 603 was successful: an excellent lower Pleistocene to Lower Cretaceous section was obtained, with outstanding recovery in all three holes. The 1025.26 m of total sediment recovery is a DSDP record for any one site. This has allowed us to identify and date important seismic reflection horizons and to characterize Mesozoic and late Cenozoic sedimentation along this passive margin at the interface between continental and deep-sea environments. A major discovery was the coring of a deep-sea fan complex within the Lower Cretaceous, described below.

Lithology

The lithologic units penetrated at Site 603 between 0 and 1576 m sub-bottom are outlined in Table 2 and depicted in Figures 10, 16, and 20. Despite facies differences because of the influx of terrigenous sediments from the nearby continent, these units can be correlated with the oceanic formations erected for the North American Basin (Jansa et al., 1979) as well as with standard seismic sequences (Vail et al., 1980) (Fig. 31). In descending order, these units and their correlations are:

Unit I: 960 m of lower Pleistocene to lower–middle Miocene hemipelagic clay and claystone (Blake Ridge Formation).

The unit is subdivided on the basis of lithology and color into four subunits. The dark green clays of Sub-

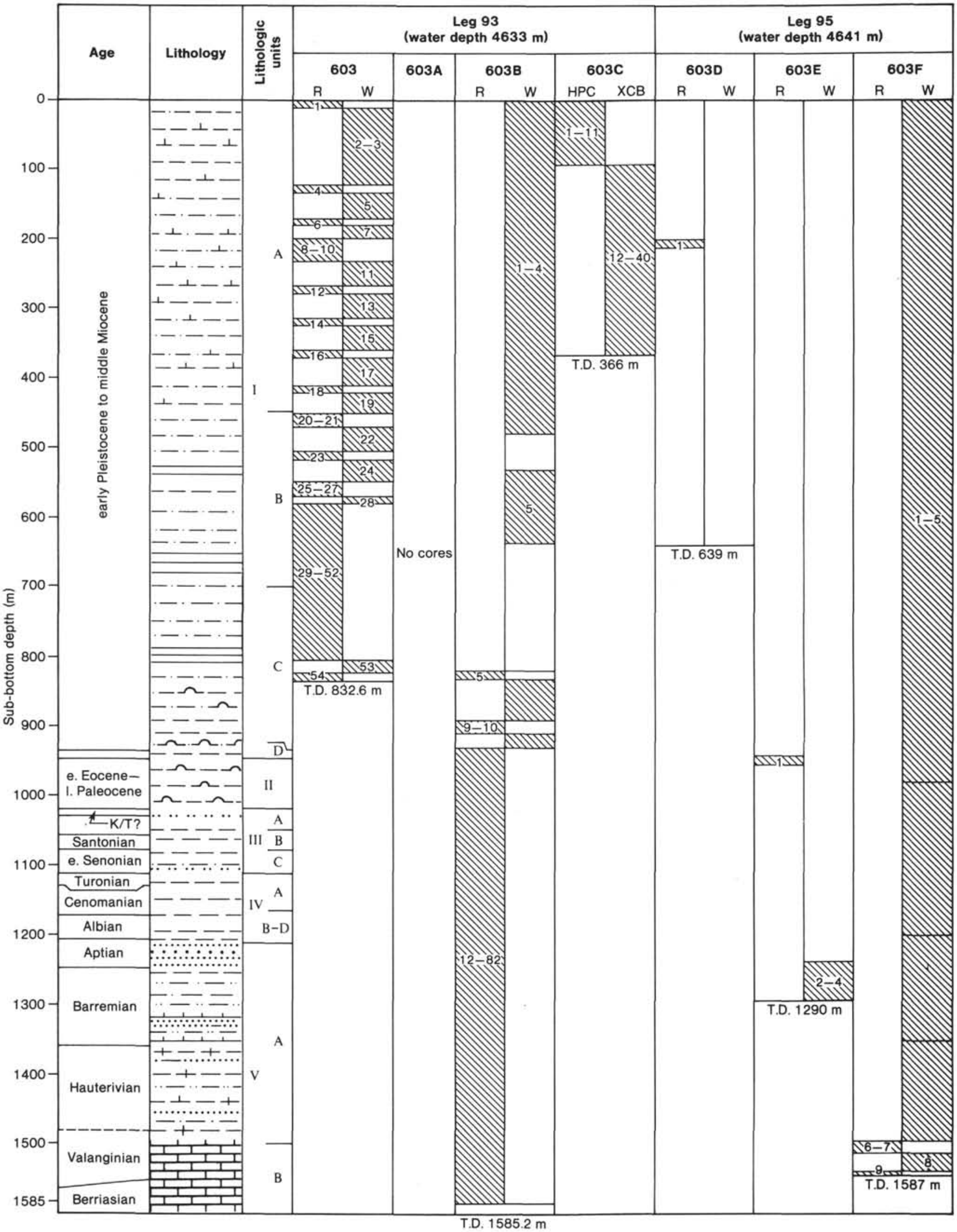

Figure 32. Correlation of Leg 93 and Leg 95 holes drilled at Site 603, indicating Holes 603 to 603C (Leg 93), Holes 603D to 603F (Leg 95), and composite stratigraphic column for this site. Hachures indicate cored intervals. R = rotary core, W = wash core, HPC = hydraulic piston core, XCB = extended core barrel. See Explanatory Notes (this volume) for lithologic symbols.

unit IA contain nannofossils and planktonic foraminifers deposited above the calcite compensation depth. Greenish gray clays of Subunits IB and IC are largely devoid of calcareous microfossils except for the more dissolution-resistant discoasters. Subunit IC contains radiolarians in some numbers at selected intervals, as well as the first unambiguous evidence of sporadic silt and sand turbidites below 720 m. In contrast to the green clays above, Subunit ID is composed of yellowish brown to brown clays, barren of calcareous and siliceous microfossils but containing fish teeth of early Miocene age (Cores 603B-14 and -15, Section 603E-1-1; see Hart and Mountain, this volume).

Unit II: 62 m of variegated lower Eocene and upper Paleocene radiolarian claystone (Bermuda Rise Formation). The unit is extremely colorful at the top, with hues ranging from pale green, grayish green, reddish brown, yellow brown, to pale orange. Radiolarian content varies from 50 to less than 10%. Incipient diagenesis has converted some of the biogenic opal to opal-CT, but not in quantities exceeding 50% of the rock. Thus the sediment is not porcellanitic "chert" in the strict sense. A lithium spike noted in interstitial water samples may be due to the dissolution of biogenic opal.

Unit III: 96 m of mostly Senonian and lowest Paleocene variegated claystone (Plantagenet Formation).

This unit is subdivided into three subunits based on the relative abundance of dark gray carbonaceous claystone. These organic-matter-rich clays first appeared in Subunit IIIB and were subsequently encountered in the underlying section (Units IV and V). Carbonaceous claystones are not present in sediments from Subunits IIIA or IIIC. Nearly all cores of Unit III contain 1 to 10% terrigenous silt and sand. Considered turbiditic in origin, these are also found in all underlying lithologic units. This comparatively landward locality, however, is the only DSDP site in which terrigenous clastics have been reported from the Plantagenet Formation.

Near the top of Unit III at Sample 603B-22-3, 73 cm (1023.3 m) is a 4.5-cm-thick, current-bedded sandy layer which contains black spherules about 1 mm in diameter. These possibly record the Cretaceous/Tertiary boundary event (see Klaver, this volume).

Unit IV: 96 m of mid-Cretaceous Aptian–Turonian black carbonaceous claystones (Hatteras Formation).

This unit is subdivided on the occurrence or relative abundance of pelagic reddish brown claystones which are present in Subunits IVB and IVD. This unit contains the highest concentration of "black shales" in the section. Organic carbon contents, which range from 4.1 to 20% in these rocks, are the highest yet reported from the North American Basin. Sharp basal contacts and graded silts at the bases of some of the black claystones suggest that these were emplaced as mud turbidites.

Unit V: 362 m of upper Berriasian–Aptian, interbedded, nannofossil clays and limestones with sandstone to claystone turbidites (Blake-Bahama Formation plus an unnamed sand unit at the top of the sequence).

This unit is distinguished from Unit IV by the presence of calcareous nannofossils, which are abundant throughout. It is subdivided into two units by the presence or absence of turbidites. Subunit VA (Blake-Bahama Formation, sandy facies) is characterized by an abundance of claystone, siltstone, and sandstone turbidites. These are of two main types: siltstone–sandstone and organic-matter-rich claystone. The presence of intermediate types and complete sandstone to claystone graded sequences indicate that the two textural types are related. The upper 30 m of this subunit consists of very poorly consolidated sand that could be considered a unit on its own. Subunit VB (Blake-Bahama Formation, limestone facies) consists of *in situ* pelagic carbonates which consist of alternations of laminated and bioturbated nannofossil chalks and limestones. These lithologies also occur in Subunit VA.

Depositional History

Better than at any other site yet drilled on the North American passive margin, Site 603 records the interplay between allochthonous and pelagic sedimentation at the interface between continental and deep ocean environments. Over the 130 Ma of time represented by the section, the largely continuous, quiescent background of hemipelagic and pelagic sedimentation was interrupted by pulses ranging from light touches to violent bursts of turbidites. Only in its later history did bottom currents become the dominant force in shaping the character of the sedimentary deposits.

The oldest sediments recovered at Site 603 are characterized by carbonate cycles consisting of laminated marls that alternate with well-bioturbated homogeneous chalks and limestones. These represent alternating periods of oxic and anoxic bottom conditions, perhaps caused by climate-driven, periodic changes in the intensity of ocean circulation, upwelling, and oxygen replenishment in a somewhat narrow, restricted, incipient North Atlantic ocean basin. This pelagic sequence is first interrupted in the upper Valanginian by organic-matter-rich claystone turbidites, which contain exceptionally well preserved calcareous nannofossils, probably derived from the slope or upper rise, where deposition was taking place within a broad oxygen-miminum zone. Whole ammonites and aptychi from unsplit cores provide additional biostratigraphic control for this part of the section. One specimen collected aboard ship and originally thought to be an aptychus has since been found to be the lower jaw of a fish (Hoedemaker, this volume).

Silt and sandstone turbidites appear in the upper Hauterivian, reaching a peak in the Barremian and disconformably topped by 30 m of Aptian sand, then continuing intermittently into the Senonian (Unit III). Over a 218-m interval of Subunit VA, they comprise about 47% of the section. Below the Aptian sand, individual turbidites range up to 2 m in thickness and are dominated by subangular quartz with abundant feldspar, mica, heavy minerals, opaques, wood fragments (locally up to 20%), glauconite and shallow-water bioclastics. Poorly cemented except at the base of some beds, the sand cores can usually be split under the pressure of a fingernail. They exhibit the entire range of Bouma structures, with the basal sequences dominant (T_a to T_c). Included are intraclast-rich debris flows and plastically deformed blocks of fine-grained sediments up to 25 cm across. The latter could represent slumped overbank deposits, which would indicate the presence of well-defined fan channels (similar features have recently been cored in the middle/lower Mississippi fan; see Leg 96 Scientific Party, 1984). Apparently Hole 603B intersected a complex of one or more deep-sea fans which perhaps form part of an apron of clastic-rich sediments of this age along the lower continental margin of eastern North America.

The construction of this fan complex culminated in massive, deep-sea, sand deposition which we interpret to be the effect of an Aptian eustatic low stand (Vail et al., 1980). With the subsequent rapid rise in sea level, coarse clastic deposition ceased, the dominance of terrigenous over marine organic matter reversed, and the CCD shoaled rapidly, as recorded by the abrupt loss of calcareous nannofossils. During the Cenomanian-Turonian, fleeting blooms of calcareous nannofossils represented only by the genus *Nannoconus* suggest highly restricted surface-water environments at the peak of "black shale" (carbonaceous claystone) deposition (Subunit IVA). Reddish lithologies and the absence of any organic matter at some intervals indicate that the deep basin environment itself was, at least at times (Subunits IVB and IVC), strongly oxidizing.

Dark carbonaceous turbidites continued into the overlying Senonian of Unit III. This lithology accumulated over a longer period of time (Hauterivian to Santonian) at this landward site than at any other DSDP site drilled to date.

Despite the influx of sand, silt, and mud turbidites, starved sedimentation during the Late Cretaceous was only 5 m/Ma, by far the lowest rate for the section. There may well be hiatuses which could not be detected because of the lack of microfossils. For instance, the striking Cretaceous/Tertiary boundary sand with its small spherules represents high-energy event and seems to have an eroded base. The interval of sediment starvation was followed by the deposition of the lower Eocene biosiliceous claystones of Unit II. Erosion along the A^u disconformity following deposition of Unit II and the subsequent lack of deposition account for the sharp contact between Units II and I. Middle to upper Eocene units were removed at this site, and the entire Eocene may be absent just to the south and east of this locality (Jansa et al., 1979, fig. 15).

After starved lower-middle Miocene pelagic clay deposition, dark clays and occasional sand or silt turbidites began to accumulate at a rapid rate during the middle Miocene (nannofossil zone CN5 of Okada and Bukry, 1980; 10.9 to 14.4 Ma, according to Berggren et al., in press), fed by the outflow of terrigenous material, including wood debris, mica, and the like, from the shelf. Generally flat-lying to mounded at first (Subunit IC), these sediments began to be caught and shaped into large-scale (50 × 500 km), elongate, drift deposit by the Western Boundary Undercurrent (WBUC), thereby signaling a change in Atlantic bottom circulation (Subunit IB). This marked the birth of the feature now called the Hatteras outer ridge (HOR) (see Tucholke and Laine, 1982). As the material was built up above the level of the CCD, which was falling at an increased rate by the end of middle Miocene times, appreciable numbers of calcareous microfossils began to accumulate, the first since the site passed beneath the CCD following the Barremian.

A relatively constant northeast-southwest bottom current and a west-east turbidite input from the margin led to the formation of antidunelike sediment waves which grew to form the present lower continental rise hills (Fig. 2). The crest of the HOR grew apace where the turbidity currents were intercepted by the WBUC, forming a dam behind which coarse terrigenous turbidites have been ponded, particularly during glacial times (DSDP Site 106). No coarse clastics bypassing the pond were deposited with the clays of the HOR at our locality. As a result, sediments of the HOR are monotonously uniform, consisting of a homogeneous mixture of clay and silt (muddy contourites of Stow and Lovell, 1979). No sandy contourites are present in our section. Our stratigraphic analysis suggests that the system grew contemporaneously and steadily at a high rate of sedimentation (111 m/Ma) through the Pliocene and at least into the early Pleistocene (*Calcidiscus macintyrei* Zone of Gartner, 1977; 1.88 to 1.45 Ma, according to Backman and Shackleton, 1983). Its accretion was not terminated at any time during the Pliocene: rather, the ridge crest grew concurrently with coarse clastic deposition in the turbidite pond to the west.

Seismic Stratigraphy

In analyzing seismic reflection profile *Conrad* 2101-77, we first identified sequence boundaries and the units they delineate, then recognized the interval reflection configuration (seismic facies) of the units. Most sequence boundaries correlate with "reflectors" of oceanic geophysical literature and can be named accordingly (reflection Horizon X, reflection Horizon A*, etc.). The sequence boundaries proved to correlate with lithologic and biostratigraphic boundaries, changes in physical and chemical properties of the sediment, and/or changes in drilling rate. Several reflection units correlate with regional formations (Jansa et al., 1979).

Our drilling results strongly suggest that deep-sea seismic sequence boundaries (reflection horizons) on multichannel records are chronostratigraphic boundaries that correlate with the eustatic events of the Vail and Mitchum (1979) coastal onlap curve.

No two units are alike at Site 603. The sedimentary record consists of natural units, representing times of relative stability, separated by horizons left by events that drastically changed the scene. Although their effect differed in different physiographic settings, they can be correlated. A preliminary correlation of oceanic reflection horizons and continental margin ("standard") reflection stratigraphy is given for Site 603 in Figure 31 and Table 5. Thus the first of our principal objectives—to identify and sample the prominent reflection horizons—was achieved. We identified and sampled Horizons β, A*, the $A^u/A^T/A^c$ complex, and X. In addition, we identified the following horizons of regional importance: Kb, basal Cretaceous—Valanginian; Km, mid-Cretaceous—Coniacian; M_2, basal upper Miocene; M_1, upper upper

Miocene; P, upper Pliocene; G, basal glacial (Pleistocene); and P′, lower Pleistocene (Pliocene and Pleistocene as used by Vail and Mitchum, 1979).

Drilling at Site 603 was to test the hypothesis of Vail et al. (1980) versus that of Tucholke (1981) (see Background and Objectives section, this chapter). It confirmed Vail et al. (1980), but the conflict is more apparent than real. Vail et al. (1980), who worked for many years in the petroleum industry, have multichannel, high-resolution data in mind when they make their statements. Tucholke (1981), in contrast, used single-channel oceanic seismic profiles as the basis for his statements. Often, the latter allow correlations of only the strongest reflectors, that is, zones of high amplitude that relate to high impedance contrasts and lithology. The reflection horizons or sequence boundaries correlated by Vail et al. (1980), however, do not necessarily follow the highest amplitudes in a reflection configuration and may cross lithologic boundaries.

The Lower Cretaceous "Cape Hatteras" Deep-sea Fan Complex: Correlations, Significance, and Implications

The intersection of a major Lower Cretaceous passive margin deep-sea fan complex consisting of up to 47% sand over a 218-m interval and located some 320 km seaward of the Cretaceous shelf break came as a surprise. The possibility that coarse clastics may have bypassed the Early Cretaceous shelf to accumulate at the foot of the slope had only been suggested speculatively in recent assessments of the stratigraphy and petroleum potential of the eastern North American continental margin (Jansa and Macqueen, 1978; Mattick, et al., 1978). No such clastic sediments were found in rocks of this age cored at DSDP Site 105 just 97 km southeast of Site 603, and the possibility of coarse clastics in any quantity reaching these distant localities was not anticipated. The only firm indication that such a deposit might exist was given by the presence of coeval coarse turbidites at DSDP Sites 391 and 534 to the south (Blake-Bahama Basin; Sheridan, Gradstein, et al., 1983). Interestingly, the deposition of deep-sea clastics at Sites 603, 391, and 534 coincides with a major progradation of terrestrial deltas along the adjacent continental shelf of the eastern seaboard of North America (Libby-French, 1984). A similar phenomenon has been recorded in the southern Wessex Basin of England (Wealden Beds), and deep-sea fans of this age have been cored off northwest Africa at DSDP Sites 370 and 416 (Lancelot, Winterer, et al., 1980). Hallam (1984) attributes the initiation of this widespread siliciclastic deposition to climatic change (from arid to humid conditions). We attribute its termination in our study area to the late Aptian sea-level rise.

Until recently, it was believed that an extensive reef/carbonate bank complex existed along the outer continental shelf from Mexico to Nova Scotia during the Early Cretaceous. This reef/carbonate-bank system, plus a presumed eustatic rise (Vail et al., 1980), were thought to have effectively confined most terrigenous clastics to the inner continental shelf (particularly in depressions such as the Baltimore Canyon Trough). Presumably, little clastic material would have bypassed the reefs to the deep-sea environment. Schlee et al. (1976), however, noted the absence of evidence for reefs on their multichannel line 3 across the southern Baltimore Canyon Trough, and Mattick et al. (1978) commented that carbonate deposition there might be incompatible with the prograding deltas in that region. More recently, Poag (1982) and Libby-French (1984) have suggested that deltaic clastics probably did overstep the shelf edge during the Hauterivian–Barremian in both the Georges Bank and Baltimore Canyon areas, thereby shedding detrital sediments down the slope beyond.

Our drilling results at Site 603 clearly show that large amounts of terrigenous Hauterivian–Aptian sands did bypass the outer shelf to spread over the abyssal plain hundreds of kilometers beyond. They were deposited interbedded with organic-matter-rich claystones in deep-sea fan complexes along the continental rise and abyssal plain, later to be covered by younger deposits consisting predominantly of clays. Among other things, this demonstrates that many of the ingredients considered favorable for petroleum accumulation are present in this passive margin, deep-sea environment. Although no mature hydrocarbons were found at the relatively shallow burial depths of Site 603, these might be present under deeper burial conditions of the kind that would exist at more landward localities such as along the nearby Carolina Trough.

The implications of the above are complex and are dealt with elsewhere in this volume. It was apparent to us at the outset, however, that:

1. Large deep-sea fan complexes can be present along the older passive margin of eastern North America.
2. The continental rise environment of passive margins should not be neglected as potential petroleum provinces.
3. A progressive but slow worldwide sea-level rise from the Hauterivian to the mid-Aptian did not prevent the outpouring of terrestrial clastics along the shelves and rises of the North American Atlantic margin. The presumption by Vail et al. (1980) of an Aptian drop and subsequent rapid rise in sea level appears to be supported and recorded in a massive sand deposit followed by the cessation of sand turbidite deposition and a sharp rise in the CCD at this site. Consequently, reflection Horizon β is equated with the Aptian sea-level event.
4. The extent of Lower Cretaceous reef development should be reassessed, particularly considering the turbid water conditions which must have prevailed on the shelf during that period and which should have inhibited reef development. We question whether any significant reef development occurred along the mid-eastern seaboard of the United States after the Valanginian.
5. The absence of sand turbidites at Site 105 is probably due to its location on a basement high; the density currents would have flowed around it.
6. Lateral and vertical sedimentary facies changes are far more rapid and complex beneath the continental rise than in the more seaward environments traditionally explored by deep-sea drilling. More deep-penetration holes will be necessary to understand this important province at the boundary between deep-marine and continental environments.

LEG 95, SITE 603: SUPPLEMENTARY REPORT[1]

HOLE 603D

Date occupied: 1 September 1983

Date departed: 3 September 1983

Time on hole: 53 hr.

Position: 35°29.98′N; 70°01.41′W

Water depth (sea level; corrected m, echo-sounding): 4641

Water depth (rig floor; corrected m, echo-sounding): 4651

Bottom felt (m, drill pipe): 4652

Penetration (m): 639.7

Number of cores: 1

Total length of cored section (m): 9.6

Total core recovered (m): 9.47

Core recovery (%): 98.6

Oldest sediment cored:
Depth sub-bottom (m): 208.6
Nature: Nannofossil silty mud to silty clay
Age: middle Pliocene

Basement: Not reached

HOLE 603E

Date occupied: 3 September 1983

Date departed: 10 September 1983

Time on hole: 157.8 hr.

Position: 35°29.98′N; 70°01.37′W

Water depth (sea level; corrected m, echo-sounding): 4641

Water depth (rig floor; corrected m, echo-sounding): 4651

Bottom felt (m, drill pipe): 4652

Penetration (m): 1290

Number of cores: Cored 1; washed 3

Total length of cored section (m): Cored 9.6; washed 1280.4

Total core recovered (m): Cored 0.58; washed 12.9

Core recovery (%): 6.0 (cored only)

Oldest sediment cored:
Depth sub-bottom (m): 946
Nature: Mudstone
Age: (?)-middle Miocene

Basement: Not reached

HOLE 603F

Date occupied: 10 September 1983

Date departed: 15 September 1983

Time on hole: 138.9 hr.

Position: 35°29.87′N; 70°01.36′W

Water depth (sea level; corrected m, echo-sounding): 4640

Water depth (rig floor; corrected m, echo-sounding): 4650

Bottom felt (m, drill pipe): 4650

Penetration (m): 1545.7

Number of cores: Cored 3; washed 6

Total length of cored section (m): Cored 24.1; washed 1521.6

Total core recovered (m): Cored 17.8; washed 50.3

Core recovery (%): 73.8 (cored only)

Oldest sediment cored:
Depth sub-bottom (m): 1545.7
Nature: Nannofossil limestone, marly nannofossil limestone to nannofossil marl
Age: Valanginian
Measured velocity (km/s): 2.4

Basement: Not reached

Site summary and principal results. The Leg 95 scientific party spent 14 days unsuccessfully attempting three times to drill a single-bit uncored hole to 1576 m, the point at which coring was terminated when Leg 93 lost its drill string. The objective was to core continuously from 1576 m to basement and log this seaward termination site of the New Jersey Transect.

The first attempt with the new, specially designed polycrystalline diamond compact (PDC) bit failed when gale force winds interfered with our stationkeeping ability. The second attempt was terminated when the bit wore out in sand turbidites at 1290 m. The third attempt failed when the standard rotary core bit wore out in limestones at 1546 m. Logging during another gale was not successful.

There were no significant scientific results from these efforts.

SITE APPROACH AND OPERATIONS

Hole 603D

Challenger approached Site 603 from the northwest, utilizing satellite fixes at 0924 and 1001 hr., 1 September, which brought the vessel on course along the track of *Conrad* line 2201-77, upon which Site ENA-3 was originally located. The beacon was dropped at 1107 hr., ap-

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proximately 5.5 n. mi. (10.1 km) east of Hole 603C. The ship continued on a northeastward track for two more miles before retrieving the seismic gear and returning to the beacon. Subsequent satellite fixes showed that the beacon had drifted 0.4 n. mi. to the south during descent, requiring a reciprocal offset to place the *Challenger* over the intended site for Hole 603D. This particular location was chosen, in part, to avoid a possible encounter with Leg 93's lost drill pipe or reentry cones, which were believed to lie somewhere within a 1 to 2 n. mi. radius southwest of Hole 603C.

With the vessel so located, the BHA was made up with an all-new Polycrystalline Diamond Compact (PDC) bit, specially designed for DSDP by Pressure Coring, Inc., of Midland, Texas. Two bits had been purchased (at a cost of about $20,000 each) specifically for use at this site in hopes that the high penetration rates credited to the new PDC bit technology would allow drilling to reach basement with a single bit—thus eliminating the time required to place a reentry cone and casing and significantly reducing the time to reach the objective at this site.

The bit was run to the seafloor and a PDC center bit was pumped to the bit. The Bowen Sub was picked up and washing-in began, with first resistance felt at 4652 m. PDR depth was 4651 m. Spud-in occurred at 8717 hours, September 1. Washing down proceeded rapidly to 4851 m (199 m BSF). The center bit was then retrieved, an empty core barrel was dropped and a spot core was taken (Table 7) to correlate stratigraphy with Holes 603B and 603C and to check the ability of the new bit to take a core. More pumped flow than normal was used when cutting a core in soft material to avoid "balling up" the bit. In spite of this, a full core barrel was retrieved with a somewhat gassy, soupy core. The center bit, showing absolutely no signs of wear, was again pumped to the bit and washing down again proceeded at the greatest possible rate. The goal was to wash through most of the section already cored at Hole 603B and begin coring at about 1530 m BSF.

During the morning of September 3, an unexpected, localized storm began to build up in the vicinity of the vessel. By the time the hole had been deepened to 640 m BSF, the heave motions began to increase to the point that a steady weight on the bit, said to be critical when using PDC bits, could not be maintained. To combat this problem, the Heave Compensator was picked up. At this point, the ship's dynamic positioning system began to lose the acoustic signal from the beacon. This was apparently due to a blanketing effect caused by bubbles swept under the ship by the waves and current as the weather deteriorated into a moderate gale. With only intermittent acoustic signals stationkeeping had to be maintained in semimanual or manual mode.

With the situation steadily worsening the Heave Compensator was set back so that the pipe could be pulled quickly if the positioning problem did not improve. The weather continued to deteriorate and, after about three hours of positioning with great difficulty in semiautomatic mode with no sign of improvement, the hole was abandoned for the safety of the drill string. The bit cleared the mudline at 1604 hr. and the pipe was hung off on three knobby drilling joints.

By 0300 hr. on September 4, the seas had moderated so that vessel motion was once again within prescribed operational limits. Hole 603E was spudded at 0502 hr. at a depth of 4652 m.

Hole 603E

The bit was washed down again at the highest penetration rate possible using two pumps to produce a flow of greater than 600 gpm. Washing with the center bit

Table 7. Coring Summary, Site 603, Holes 603D to 603F.

Core no.	Date (Sept. 1983)	Time (hr.)	Depth from drill floor (m) Top–Bottom	Depth below seafloor (m) Top–Bottom	Length cored (m)	Length recovered (m)	Percentage recovered
Hole 603D							
1	2	1600	4851.0–4860.6	200.0–209.6	9.6	9.47	99
Hole 603E							
1	6	0215	5588.4–5598.0	936.4–946.0	9.6	0.58	6
2M	8	1240	5910.0–5923.4	1258.0–1271.4			Wash
3M	8	2320	5929.0–5931.0	1277.0–1279.0			Wash
4M	9	1540	5931.0–5941.7	1279.0–1289.7			Wash
Hole 603F							
1M	10	1700	4650.0–4682.6	0.0–32.6			Wash
2M	12	0230	4682.6–5630.5	32.6–980.5			Wash
3M	12	1445	5630.5–5850.1	980.5–1200.8			Wash
4M	13	0820	5850.8–6023.2	1200.8–1373.2			Wash
5M	13	1745	6023.2–6147.8	1373.2–1497.8			Wash
6	13	2140	6147.8–6157.3	1497.8–1507.3	9.5	9.84	104
7	14	0115	6157.3–6166.4	1507.3–1516.4	9.1	5.0	55
8M	14	0920	6166.4–6190.2	1516.4–1540.2			Wash
9	14	1245	6190.2–6195.7	1540.2–1545.7	5.5	2.95	54

[a] Drilled on Leg 95.

continued to 936 m BSF, where a spot core was taken (Table 7) to correlate stratigraphy between this hole and the 603B reference cores. Core 603E-1 retrieved about half a meter of firm but disturbed claystone. Core-catcher failure apparently accounted for the minimal recovery. A drift angle recorded by two Kuster shots showed 1.25° off vertical. The center bit, displaying virtually no wear, was reinserted and washing ahead was resumed.

During this period a single joint encountered firm resistance in sediments that required nearly 2 hr. to drill through, so the four heavy-wall "knobby" drilling joints left on the ship were added to the drill string, one by one. They were used routinely for the remainder of the hole.

At 1400 hr. September 7, with the bit at 1238 m BSF, a drilling break announced the penetration of an anticipated zone of turbiditic sand that had been reported at Hole 603B. The rate of penetration soon dropped to 2-4 m/hr. Actual penetration was at a zero rate for many minutes and even hours, with advances made in sudden spurts. After the drill string was picked up to make connections, the hole was usually found to have taken a meter or so of fill, indicating that the loose sand was caving in whenever the pumps were stopped.

Progress for the next two days was extremely slow, because the bit appeared unable to make any headway in the loose sand. Several gel mud slugs were introduced into the hole, but had no effect. The center bit was replaced with a core barrel twice, both to examine the bit cutters and to see if a core barrel present at the bit would improve penetration. No damage to the center bit's cutting structure was found and no improvement in penetration was achieved.

Both wash cores contained mostly loose, coarse sand with some clay and shalelike material. It was the presence of the clay constituents that enabled the 8-fingered core catchers to trap any sand at all. The second core, 603E-3, actually contained some 6–8 inch sections of solid claystone, suggesting that the sand interval had been penetrated at about 1287 m BSF.

At 1430 hr. on September 9, just as the decision was being made to abandon continued drilling efforts, instructions from DSDP in La Jolla were received to do so and to trip the pipe in order to change to an F93CK roller cone bit for one last, desperate attempt to reach basement at this site. We were also instructed not to log the hole at this time.

Estimates indicated that the 1800-m penetration objective could be reached in as little as 9 days if the bit lasted so long. Since that was within the operating time remaining for the voyage, it was decided to go ahead on that basis until the objective was reached or until progress fell a full day behind a projected progress curve. If the goal then appeared unobtainable in the time allotted, operations would be aborted.

Thus, the hole was filled with barite mud and the PDC bit was pulled out, clearing the mudline at 2015 hr. September 9 and arriving on deck at 0554 hr. September 10. The condition of the PDC bit quickly explained why penetration had dropped to less than 1 m/hr. The cutting structure, Stratapax buttons mounted on steel studs, was 90% destroyed. Only the innermost ring of cutters surrounding the core opening remained. The face of the bit had been worn away to a depth of up to ¾ inch.

An F93CK bit was made up to a new Mechanical Bit Release and refurbished BHA, and the pipe was run to the seafloor for the final attempt to recover Jurassic basement.

Hole 603F

The mudline was detected at 4650 m, coinciding with the PDR reading, and the hole was officially spudded at 1547 hr. September 10. An initial wash core was taken to a sub-bottom depth of 32.6 m BSF, primarily to allow for possible gas sampling (Table 7). This task accomplished, an empty core barrel was pumped to the bit and washing down commenced. Two pumps were used, which produced a continuous flow of more than 600 gpm. All drilling parameters were set to achieve the maximum rate of penetration while helping the bit to do the least possible work in the hope of extending the depth that would be reached before the inevitable failure of the bit. The Heave Compensator was not used during this period, both to speed up the operation and because the seas were especially calm. At about 970 m BSF the previously noted hard, siliceous limestone layer was penetrated. The overall net rate of penetration to that depth had been in excess of 30 m/hr—much better than the projected progress curve.

Following the firm limestone layer, the wash barrel was pulled as a routine precaution. The barrel was found to be stuck in the bit and the overshot shear pin failed on the first retrieval attempt. Before the second wireline run to retrieve the barrel, an extra meter was drilled down. The barrel came free with moderate line overpull on the second attempt.

At the same time the stuck barrel was being dealt with, an error was discovered in the offsets being read by the dynamic positioning computer. The problem was a common hardware failure involving one circuit board within the positioning computer and was quickly remedied, but it left some doubt as to the exact offsets being used by the computer at the time the hole was spudded in. No further difficulties were experienced, however, and the operations at the site were not adversely affected.

After the wash barrel was retrieved from 980.5 m BSF, a redressed barrel was pumped to the bit and washing ahead continued to 1200.8 m BSF. The wash barrel was again retrieved and a 50-bbl mud slug was pumped into and out of the hole in preparation for penetrating the turbiditic sand that destroyed the PDC bit in Hole 603E. The sand was detected by a distinct drilling break at 1214 m BSF and was drilled through with anticlimactic ease. A second gel mud slug was pumped through the system for good measure and routine washing ahead continued as before.

By midnight of September 12 the bit had been washed to 1335 m BSF. Drilling was an amazing 36 hr. ahead of the optimistic projected schedule. Use of the Heave Compensator was attempted for one joint but the Antislingshot Valve would not close, so the Heave Compensator was drained and set back for repairs.

At 1373.2 m BSF the wash barrel was again pulled. The core, made up of sandstone but no loose sand, showed obvious signs of nonhorizontal layering, suggesting that the hole had kicked off vertical during or after the sand interval. A Kuster Single-Shot photo failed to turn out, so the drift angle could only be estimated at 8–10°.

At 1497.8 m BSF the wash barrel was retrieved once more. Again sandstone and claystone were recovered with clear signs that the hole had drifted off vertical. This time a Kuster measurement confirmed the visually apparent drift to be 10.75°.

The next core was a standard 9.5-m rotary core. While cutting it, the bit began to exhibit signs of excessive torque when more than 10,000 lb. weight on the bit were used, giving the first hint that it was nearing its end. The core, 603F-6, had an average diameter of 2⅛ in., which also suggested that at least one of the four roller cones was getting loose enough on its bearing to wobble—thus overtrimming the core and accounting for the torque problems.

Three more cores were taken, 603F-7 to -9, before the bit was declared too far gone to have even the remotest chance of reaching basement—at least 200 m deeper. The final core of 5.5 m took 80 min. to cut and had an average diameter of 1⅞.

To compound matters, the weather, which had been excellent for 12 days, was rapidly deteriorating into a moderate gale. To preserve the chance of logging the hole already drilled, preparations for logging were made immediately. The MBR rotary shifting tool was deployed and the bit was released in textbook fashion. The hole was then filled with barite weighted mud and the string was pulled to the logging depth. It would have been preferable to leave the fresh water mud out of the hole until after completing the logging exercise, since it was assumed that fresh-water-sensitive clays present in the hole would swell and possibly close it. This alternative was not feasible, however, because the rapidly worsening weather made even logging somewhat risky. If dynamic positioning could not keep the ship on station as the seas became rougher, it would have been necessary to abandon the site before a proper mud plug could be pumped into the hole.

This consideration proved to be academic, however, when the logging routine failed. Two attempts were made to lower the first assembly of logging tools into the hole. Both times the sonde could not be induced to advance into the hole below the open-ended pipe. A severe mud and/or clay ball built up at the pipe end as a result of the ship's heave motions was presumed to be the problem. It was even possible that the barite mud in the hole had worsened the situation. Whatever the case, the first run ended in a kinked logging cable, which severed two of the seven internal conductors. The second run was equally futile in spite of a 2-hr. flush with seawater between runs to wash away any mud ball.

All attempts to improve the situation were frustrated by an apparent abundance of sticky clay in the BHA, so logging tools were rigged down and the pipe was pulled out of the hole. The rig was made secure for sea and the vessel was underway for Site 613 at 2355 hr., September 15.

LITHOLOGY

Site 603 is located in the western North Atlantic Basin on the lower continental rise hills, near the boundary with the lower continental rise terrace in 4616 m water depth. Three holes were drilled at Site 603 on Leg 95: 603D, 603E, and 603F. From Hole 603D only one core was recovered, 603D-1, and the site had to be abandoned because of bad weather. Hole 603E afforded four cores, 1, 2M, 3M, and 4M, the last three being washcores, before it was abandoned because the bit failed. From Hole 603F, 9 cores were obtained, 1M through 5M (wash), 6, 7, 8M (wash), and 9; it also was abandoned because the bit failed. All these cores were taken intermittently through the section and do not give stratigraphic continuity. Only Cores 603F-6 and 7 were taken consecutively, so that this report serves only as a supplement to a few of the lithologic units recognized in the Leg 93, Site 603 report.

A graphic representation of the stratigraphy and lithology of Holes 603 through 603F is given in Figure 32. The column given at the far right hand side of the figure illustrates a composite of the approximate stratigraphic core positions from Leg 95, based upon the Leg 93 Site Report. Of the five basic lithologies identified by the scientific party of Leg 93, we actually recovered material of lithologic Subunits IA, IB, IC, Unit II, and Subunits VA and VB.

Hole 603D

Core 603D-1 was taken from the interval 199.0 to 208.6 m. It is entirely dark greenish gray (5GY 4/1) and ranges from a nannofossil-bearing silt-rich clay in the upper 35 cm to a clay (5GY 4/1) from 603D-1, 75 cm to the bottom of the core. Both the clay and the silt-rich clay are massive, nearly uniform, and unburrowed throughout. A small, unstructured nodule of calcite or possibly of siderite was noted at 603D-1, 2–25 cm. Both the clay and the silt-rich clay contain quartz sand and silt grains (6–19%) which are angular to subangular. Most of the sediment contained gas, which formed large bubbles on exposure to the lower pressure and higher temperature of surface conditions. The sediment was very homogeneous and contained no burrows or bedding. When the core photograph is scrutinized, Sections 1 to 3 have an apparent bedding, but this seems to be an artifact of coring and splitting and does not reflect true bedding.

Except for the lack of burrowing, this core is representative of Leg 93 lithologic Subunit IA. An earlier regional study by Jansa et al. (1979) recognized this lithology as having mappable regional extent and considered it as the upper part of the Blake Ridge Formation.

Hole 603E

Four cores were recovered in Hole 603E. The first was a rotary core taken a few meters above a basinwide seismic unconformity, marked by Reflector A^u (Tucholke and Mountain, 1979), whose presence was predicted from multichannel seismic reflection profile *Conrad* line 2101-77 and from data in Hole 603B. The next three cores were wash cores taken in order to clear the bit, which appeared to be clogged while in unlithified sands. After the fourth core it was determined that the bit was incapable of penetrating any farther, and the hole was abandoned.

Core 603E-1 consists of 55 cm of greenish gray (5GY 5/1) and grayish brown (2.5Y 5/2) silty clay, brecciated during coring. The core was taken from the depth interval between 936.4 and 946.0 m BSF. Rare burrow mottling is observed in the greenish gray interval and very dark gray pyrite granules are found in the grayish brown intervals. Glauconite, ranging in size from coarse sand to granules, occurs in the top 5 cm. The core is apparently barren of microfossils except for fish teeth, which were used to establish an early Miocene age (see Biostratigraphy section). Fine sand-sized pits, seen on cut surfaces, were caused by spherical inclusions plucked during splitting of the core. The insoluble residue of this core contains sucrose-textured spheres that are thought to be composed of dolomite. A more detailed study (X-ray) is needed to establish their composition. This core belongs to lithologic Subunits IC and ID, cored and described on Leg 93 at Site 603. It correlates in stratigraphic position with the basal portion of the Blake Ridge Formation (Jansa et al., 1979).

Core 603E-2M is almost entirely composed of unlithified, terrigenous sand which was severely disturbed by coring. A few "biscuits" of siderite-rich mudstone are found in Sections 1 and 2. Both lithologies are uniformly dark olive gray (5Y 3/2). The core was taken from between 1258.9 and 1271.4 m (Barremian). The sands are composed of extremely fresh, unaltered quartz, feldspar, and heavy minerals indicative of metamorphic origins. The siderite-cemented nodules are laminated on a millimeter-scale and contain organic fragments (wood). This core is clearly correlative to lithologic Subunit VA from Hole 603B.

Cores 603E-3M (1277.0–1279.0 m) and 603E-4M (1279.0–1290.0 m) are composed of black to very dark gray (5Y 2.5/1 to 5Y 3/1) nannofossil claystone to clayey nannofossil limestone, with intervals of loose, dark olive gray (5Y 3/2) terrigenous sand. The sand was probably washed in during coring. The claystones range from finely laminated to bioturbated. Graded bedding may be present as well.

These cores correspond to lithologic Subunit VA from Hole 603B (see Fig. 32) both in age and in lithology. Cores 603E-2M, -3M, and -4M all belong to the Blake-Bahama Formation (Jansa et al., 1979). Terrigenous sand dominates at this site, however, far more than in the "sandy limestone" reported at DSDP Hole 391C, the type locality for the Blake-Bahama Formation. Seismic evidence (Mountain and Tucholke, in press) demonstrates that, along the rise adjacent to the Baltimore Canyon Trough, terrigenous contribution to the Blake-Bahama Formation is especially significant.

Hole 603F

Nine cores were recovered in Hole 603F. The first five were wash cores, the sixth and seventh were rotary, the eighth was wash, and the ninth was again rotary. Before the bit failed, 1545.7 m were drilled in this hole. The site was abandoned before the Jurassic was reached. The first core was taken in Pleistocene sediments and the last was in the Valanginian (Lower Cretaceous).

Core 603F-1M (0.0–32.6 m) is a gray to greenish gray nannofossil and silt-rich claystone (5G 5/1 to 5G 4/1), which is extensively burrowed. Spherical foraminifers (*Orbulina*) are seen on the core surface as sand-sized specks and are enriched in burrows and isolated layers. Small, olive-colored specks (5Y 5/3) and black streaks (5Y 2.5/2) are also common. This core has been dated as Pleistocene (see Biostratigraphy section).

This core apparently belongs to lithologic Subunit IA, Leg 93, Site 603, which is described as a gray to dark greenish gray, nannofossil-bearing claystone which is extensively burrowed. This subunit is Pliocene–Pleistocene in age, extends from the seafloor down to 448 m, and correlates with the Blake Ridge Formation (Jansa et al., 1979).

Core 603F-2M (32.6–980.5 m) is a grayish olive green (5GY 3/2) to dark greenish gray (5G 4/1), silt-rich claystone. The claystone is extensively burrowed, the burrows being sideritic and sporadically pyritic. The burrows are generally flattened, but the sideritic ones are quite rounded or only slightly flattened, indicating early lithification. Some of the burrows are filled with well-preserved discoasters. This core is of late Miocene age (see Biostratigraphy section).

Lithologic Subunit IB, Leg 93, Site 603 has been described as a dark greenish gray quartz- and mica-bearing claystone, middle to late Miocene in age, with rare laminae of nannofossil accumulation and with siderite-rich burrows and laminae in some zones. Core 603F-2M, taken somewhere in the depth range of 34.6 to 980.5 m, apparently originated in the zone from 400 to 600 m BSF, in the upper Miocene sedimentary zone of lithologic Subunit IB; it correlates with the Blake Ridge Formation (Jansa et al., 1979).

Core 603F-3M was taken in the interval of 980.0 to 1200.8 m and is of Paleocene to early Eocene age (see Biostratigraphy section). It is an unbedded to weakly bedded porcellanitic to zeolitic claystone of grayish green color (10GY 5/2). X-ray diffraction (Fig. 33) shows that although the general appearance of the core remains rather similar through its length, the composition of the cement changes from opal-CT in the upper three sections of the core to a zeolitic composition (clinoptilolite) in the lower three sections (4, 5, and 6).

Thin, off-white stringers and layers of radiolarian sands (5Y 8/1) are present in the upper half of the core and sporadic streaks and nodules of zeolite-replaced radiolarians are seen in the lower part. Flattened burrows of greenish gray (5GY 4/1) and black (5Y 2/1) colors are noted in Cores 603F-2, -3, and -6. Pervasive layers of a dark brown color (7.5YR 4/4) are noted in Sections 603F-3M-5 and 603F-3M-6 and, additionally, sporadic layers of a light olive brown (2.5Y 5/4) are present in Section 603F-3M-6.

Core 603F-3M is representative of Unit II of the Leg 93 lithology and from comparison of age, color, lithology, and mineralogy it is probably equivalent to the sec-

Hole	Core-Section (level in cm)	Bulk (B) Residue (R)	Quartz	Feldspar	7Å Clays	10Å Clays	14Å Clays	Opal CT	Zeolites	Ankerite	Siderite	Lithology	Age	
Hole 603E	1,CC	B	O	?	△		O					ID	lower Miocene?	Sand-sized spherules
	1,CC	>63 µm	△							O				
Hole 603F	2-3, 65	B								?	O	IB	u. Mio.	Burrow
	3-1,30	R	O					O	X			II	lower Eocene	
	3-3,49	R	O		X	X		X	O					
	3-6,36	B	O		△				X					
	5-1,35	R	O	△	X	△	O					VA	Valanginian	
	5-1,150	R	O	?		△	O							
	8-3,57	R	O	?	X	△	O					VB		

Figure 33. Mineral content of sediment samples from Holes 603E and 603F as determined by shipboard X-ray diffraction.

tion represented by Leg 93 Cores 603B-17 to -19. On the basis of stratigraphic position, composition and diagenetic porcellanite, this core represents the Bermuda Rise Formation (Jansa et al., 1979).

Core 603F-4M is a wash core taken during drilling between 1200.8 and 1373.2 m. It is late Hauterivian to early Barremian in age (see Biostratigraphy section). The sedimentary sequence is fairly complex and is composed of five interrelated lithologies: silty claystone, sandstone, siltstone, silt-rich nannofossil claystone, and sandy nannofossil limestone. These lithologies interfinger without a repetitive pattern, except that the upper part of the core contains little carbonate (down to Section 5). But beginning at about Sample 603F-4M-5, 70 cm, the $CaCO_3$ content rises rapidly toward the bottom of the core, and the silty claystone and the sandy nannofossil limestone first appear. Plant debris (lignitic?) is common throughout the core, particularly in Section 603F-4M-6. The two samples, taken at 603F-4M-6, 16 and 70 cm, contain 2.49 and 1.90% organic carbon, respectively.

The sands and silts within the core are quartz-rich (40–70%) and have a fairly high heavy-mineral content (2–20%). The especially significant feature of these sand and silt zones is their fine assemblage of bedding structures. These include laminar, cross-bedded, and climbing ripple features. Two examples of well-developed bedding are illustrated in Figure 34. The beds themselves are not clearly turbiditic but rather have the appearance of levee or crevasse splay deposits, which commonly form at the border of and outside turbidite channels in a distributary fan network. It may be, of course, that these laminar and cross-bedded deposits are T_b or T_c members of a turbidite Bouma sequence, but this small sampling (one core) of the entire, thick, depositional package lacks convincing proof of simple turbidite deposition.

The lithologic assemblage and age of Core 603F-4M correspond to lithologic Subunit VA, outlined in Leg 93, Site 603; the unit also corresponds to the Blake-Bahama Formation of Jansa et al. (1979). This core clearly contains deep-sea clay and carbonate pelagic sedimentation interspersed with a turbidite-related package.

Cores 603F-5M, -6, -7, -8M, and -9 were recovered from 1373.2 to 1545.7 m below the seafloor. Cores 603F-5M and -8M are wash cores so their exact depth is not known, but the possible intervals are restricted to 1373.2 to 1497.8 m for 603F-5M and to 1515.4 to 1540.2 m for Core 603F-8M. The similar lithology exhibited by all five cores suggests a single lithologic unit for the interval of 1489.1 to 1545.7 m BSF (lithologic Unit V).

This unit consists of a monotonous series of sedimentary cycles, but mainly of two different lithologies. The first is a light gray (5Y 6/1 to 5Y 7/2), highly lithified nannofossil limestone (Fig. 35). The limestones are extensively burrowed, particularly in the lower third of each bank, and the average thickness of these beds is somewhat less than 40 cm. The burrow structures are mostly oblique, gray to dark gray in color and rarely flattened, so that early lithification is suggested. The second lithology consists of finely laminated (mm-thick) clay-rich nannofossil limestones to nannofossil claystone (Fig. 36). Color ranges from dark gray (N4) through dark olive gray (5Y 3/2) to olive gray (5Y 5/2 to 4/2). White, mm-thick streaks of flattened radiolarians and foraminifers accentuate the laminar character of the sediment. Some radiolarians escaped compaction because of early pyritization. Pyrite appears in amounts up to 2% throughout this lithology as framboids and idiomorphic crystals, and nodules of several cm in size are seen sporadically. The pyrite nodules have irregular internal structure or, more rarely, are aggregates of large idiomorphic crystals (603F-9-1, 100 cm). Organic carbon content ranges up to 19% and consists mainly of lignitic plant debris and of dark brown spherules (spores?). Large lignitic fragments and coaly layers were found in 603F-5M, more rarely in 603F-6 and -8M.

Ammonite aptychi are ubiquitous but are especially common in Samples 603F-8M-2, 100–130 cm and 603F-8M-3, 70–80 cm (Fig. 36). Layers of thin *Inoceramus* shells are especially frequent in Cores 603F-7 and -9.

The bedding laminae are very even and of amazingly uniform thickness, except for rare intercalations of a somewhat thicker, massive silt-rich claystone and a single surface with distinct current ripples in 603F-7-3, 147 cm. The lack of bioturbation, the very high organic carbon and pyrite contents, and the lack of benthic foraminifers all indicate deposition under anoxic bottom conditions.

These two main facies types exhibit a clear cyclic repetition. From the bottom up, the cycles start with the burrowed limestone, often with a scoured, sharp basal surface (Fig. 37). In one instance, at 603F-8M-3, 55–58 cm, there was a green gray basal layer with appreciable amounts of colorless glass shards of volcanic origin. The lower portions of each limestone layer are often flasered and weakly burrowed. The central part is massive and strongly burrowed (Fig. 34). The upper centimeters of the limestone grade through a zone of faintly laminated gray and grayish brown limestone into the carbonaceous

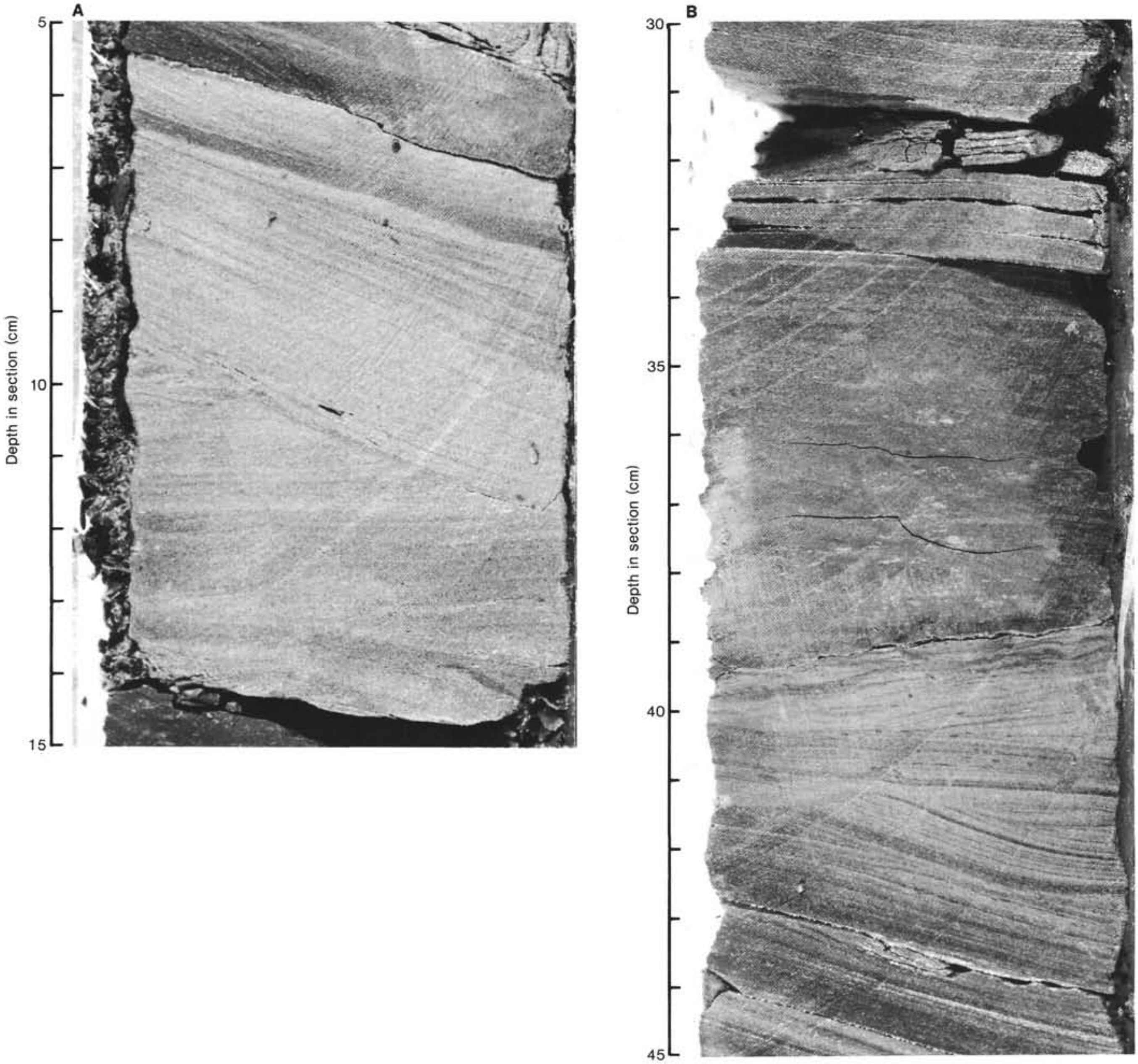

Figure 34. Lithologic Subunit VA. A. Sample 603F-4M-4, 5–15 cm shows festoon cross-bedding in a fine, sandy mudstone. The lower "contact" is an artifact of the drilling process. B. Sample 603F-4M-4, 30–45 cm is composed of mudstone to sandstone, and shows laminar, cross-bedded, and rippled (climbing) structures. Note that this core was drilled 11° from vertical.

laminites of the uppermost part of the cycle (Fig. 37). The same sort of gradational transition may also occur between the laminar facies and the limestone, although this is rare.

The uppermost core of this sequence, 603F-5M, contains several well-developed, sandy, turbidite beds which delimit the fairly tranquil cyclic alternation displayed in Cores 603F-6, -7, -8M, and -9 (see Figs. 38, 39).

The Valanginian age of Cores 603F-5M through -9 and their characteristic lithology allow us to identify them with lithologic Unit V of Site 603B and with the Blake-Bahama Formation (Jansa et al., 1979). Core 603F-5M with its turbidite layers fits into Subunit VA (or a transition to VB) and Cores 603F-6 to -9 are all clearly part of Subunit VB.

BIOSTRATIGRAPHY

Hole 603E

Calcareous Nannofossils

Sample 603E-1,CC is barren of nannofossils. Sediment recovered from the same depth in Hole 603B during Leg 93 is also barren and lies between strata dated as Eocene below and middle Miocene above. Cores 603E-2M, -3M, and -4M contain unconsolidated sand

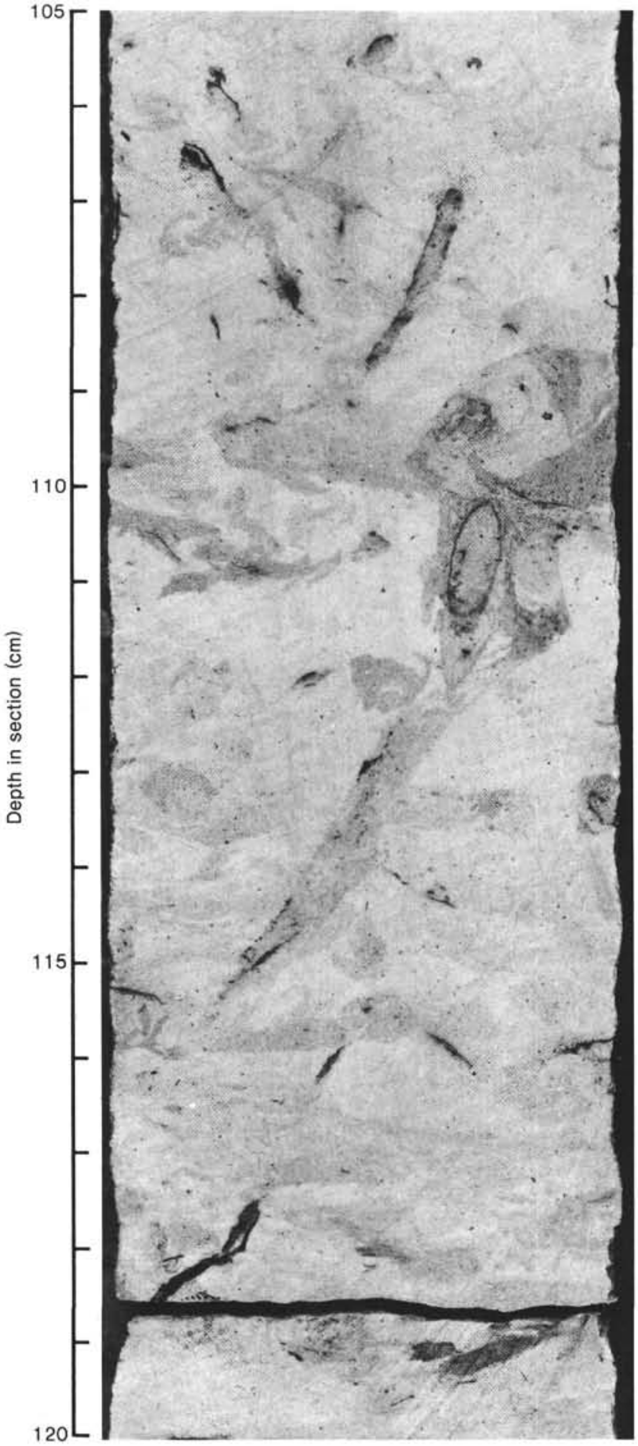

Figure 35. Lithologic Subunit VB. Sample 603F-6-1, 105–120 cm consists of heavily burrowed, light gray to white nannofossil limestone (facies 1 of Unit V cycles).

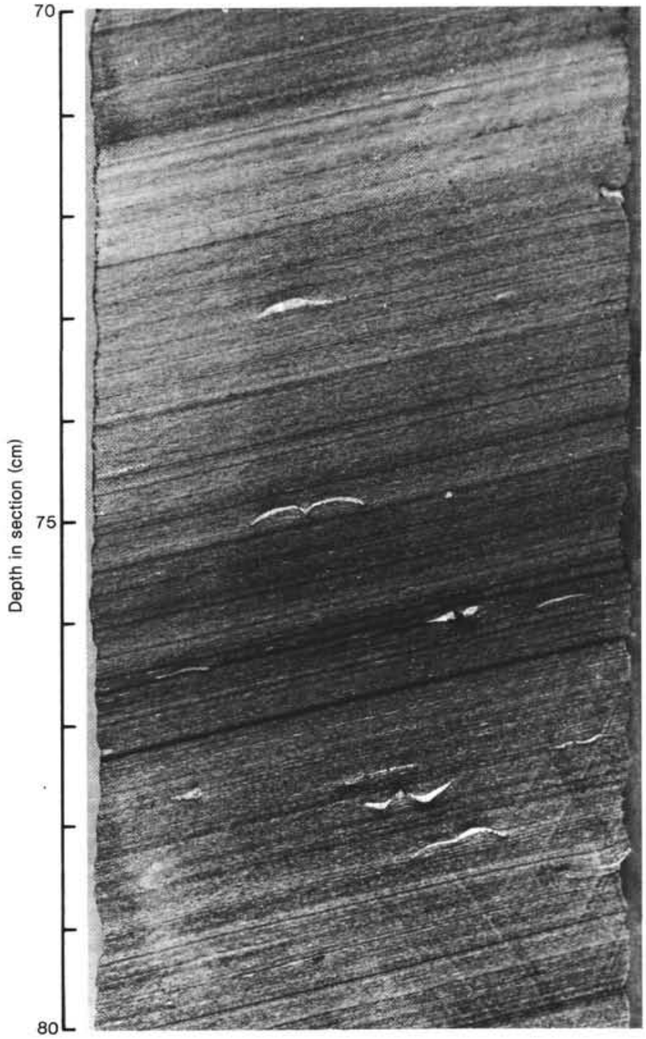

Figure 36. Lithologic Subunit VB. Sample 603F-8M-3, 70–80 cm consists of finely laminar, dark olive gray to olive gray nannofossiliferous marl (facies 2 of Unit V cycles), with ammonite aptychi in the core.

and some fragments of dark gray calcareous silt. Fragments of silt from Samples 603E-2M,CC (1271.4 m), 603E-3M,CC (1279.0 m), and 603E-4M,CC (1289.0 m) contain abundant and well-preserved nannofossils of Hauterivian to early Barremian age. The flora includes the following species: *Calcicalathina oblongata, Conusphaera mexicana, Cretarhabdus conicus, C. striatus, Cyclagelosphaera margerelii, Flabellites biforaminis, Lithraphidites carniolensis, Micrantholithus hoschulzii, Micrantholithus* sp., *Nannoconus bucheri, N. colomii, N. grandis, Parhabdolithus asper, P. embergeri, P. infinitus, Reinhardtites fenestratus, Watznaueria barnesae*, and *W. communis.*

Radiolarians

Sample 603E-1,CC contained no well-preserved radiolarians. Some ovoid mineral aggregates were found in the sieved fraction (greater than 63 μm); these may be the alteration products of radiolarian tests.

Hole 603F

Hole 603F penetrated 1545.7 m of strata previously recovered by DSDP Leg 93 from Holes 603, 603B, and 603C. Five wash cores were taken from the seafloor to a depth of 1497.8 m and dated as early Pleistocene (Core 603F-1M), late Miocene (Core 603F-2M), possible Paleocene to early Eocene (Core 603F-3M), late Hauterivi-

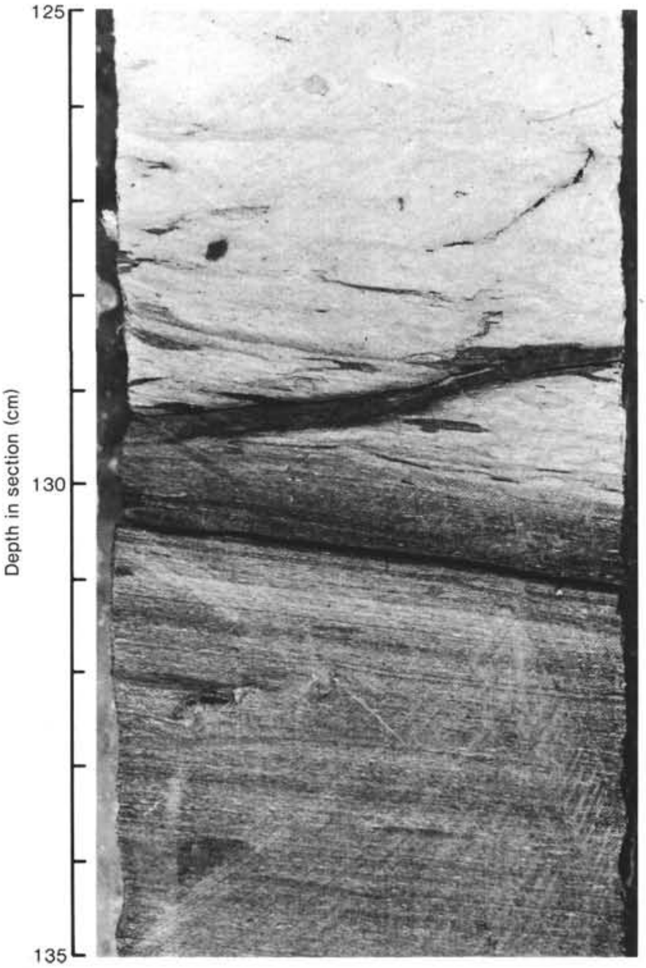

Figure 37. Lithologic Subunit VB. Sample 603F-6-1, 125–135 cm shows a sharp transition from laminated marl to limestone. The base of the limestone contains abundant, flattened, burrow structures. A pyritized bone is seen at 132 cm.

an to early Barremian (Core 603F-4M), and Valanginian (Core 603F-5M). Three rotary cores and one wash core were recovered in the interval from 1497.8 m to the bottom of the hole at 1545.7 m, and those strata are Valanginian in age.

Foraminifers are present in Core 603F-1M but are poorly preserved or absent in the other cores. Nannofossils are present in all the cores recovered, except for Core 603F-3M. Radiolarians are present in most cores, but they are very badly corroded and often pyritized.

The biostratigraphy of the strata penetrated by Hole 603F is in general agreement with that determined for Hole 603B.

Foraminifers

Sample 603F-1M,CC comprised a pale clay that contained a diverse, rich, well-preserved lower Pleistocene fauna. This contained very early *Globorotalia truncatulinoides, Orbulina universa, Sphaeroidinella dehiscens, Pulleniatina obliquiloculata*, and *Globigerinoides sacculifer.*

The Cenozoic clay recovered in Sample 603F-2M,CC was barren, as were Samples 603F-3M,CC and 603F-

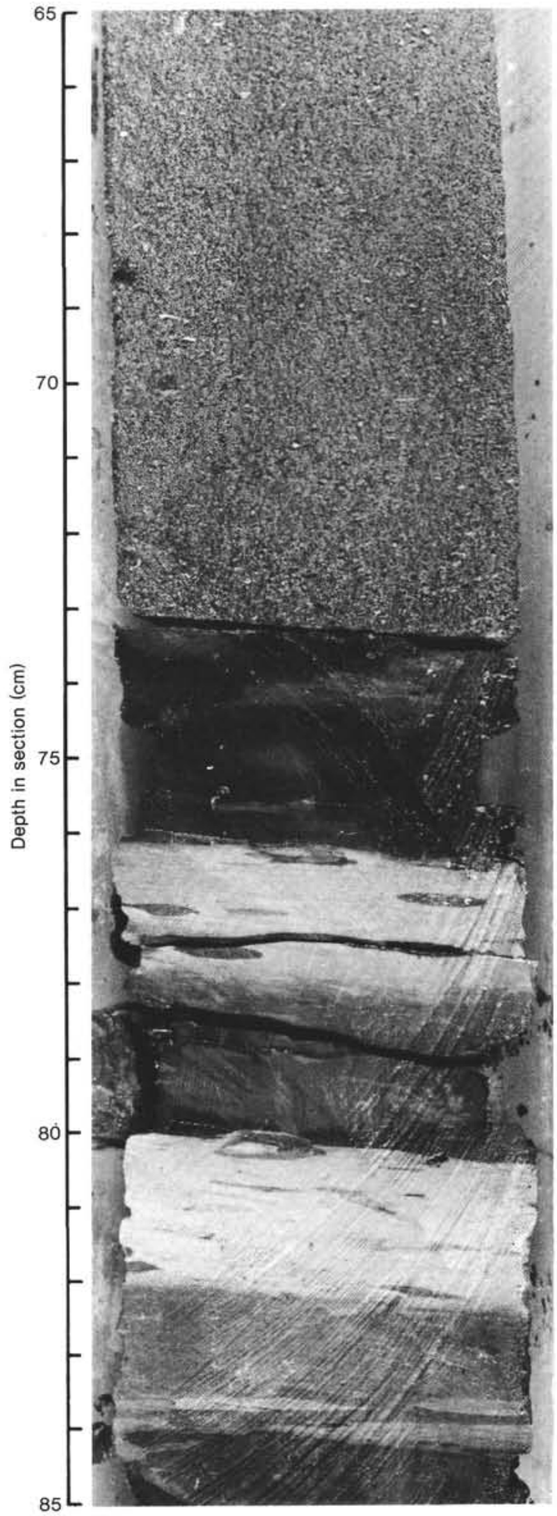

Figure 38. Lithologic Subunit VB. Sample 603F-5M-1, 65–85 cm consists of a sandy turbidite overlying an alternation of marly nannofossiliferous limestones with flattened burrows and dark gray to black organic-matter-rich mudstones.

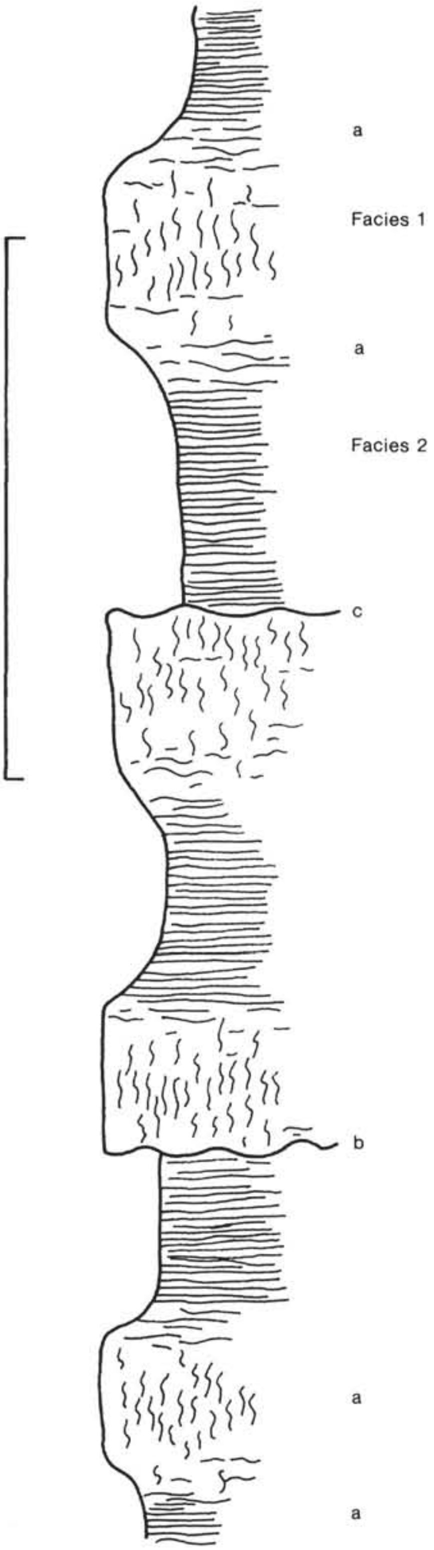

Figure 39. Diagram showing Cores 603F-6 to -9, with cyclic alternations of light gray, massively burrowed, microspar nannofossil limestone (facies 1), with dark olive gray, laminar nannofossil marls (facies 2). Gradual transitions between both facies types are most common (case a), but sharp transitions (case b) are also present. Sharp, scoured erosional surfaces overlain by the laminar marl facies are rare (case c). Facies 1 strata are shown in Figure 35, Facies 2 strata in Figure 36. A sharp transition (case b) is shown in Figure 37.

4M,CC. An undiagnostic Lower Cretaceous fauna was recovered from Sample 603F-5M,CC; it included *Lenticulina* spp., *L. muenster*, and occasional fish teeth.

Lower Cretaceous Samples 603F-6,CC, 603F-7M,CC and 603F-8M,CC were barren of foraminifers, although all three contained relatively abundant, pyritized radiolarians. Core 603F-6,CC contained a crushed specimen of the bivalve *Inoceramus* sp.

Calcareous Nannofossils

Core 603F-1M recovered lower Pleistocene nannofossiliferous mud. Samples were examined from 603F-1M-3, 69–70 cm and from 603-1M,CC. The nannofossil flora is abundant and well-preserved and includes *Calcidiscus macintyrei, Ceratolithus cristatus, Crenalithus doronicoides*, rare, small *Gephyrocapsa* spp., *Helicosphaera sellii, Pseudoemiliania lacunosa*, and *P. ovata.*

Core 603F-2M contained upper Miocene silty mudstone that is assigned to the upper Miocene *Discoaster quinqueramus* Zone (CN9). Samples 603F-2M-1, 25–26 cm and 603F-2M,CC contain few nannofossils, and preservation is moderate to good. Discoasters are the best represented element of the flora. The following species are present: *Cyclococcolithina leptopora, Discoaster berggrenii, D. bollii, D. brouweri, D. calcaris, D. challengeri, D. hamatus, D. intercalaris, D. neorectus, D. pansus, D. prepentaradiatus, D. quinqueramus, D. signus, D. variabilis*, and *Reticulofenestra pseudoumbilica.*

Core 603F-3M was barren of calcareous nannofossils. Samples from 603F-3M-3, 16–17 cm, 603F-3M-6, 16–17 cm, and 603F-3M,CC were examined.

Core 603F-4M recovered mudstone rich in upper Hauterivian–lower Barremian nannofossils. Sample 603F-4M,CC contains a diverse assemblage that includes *Calcicalathina oblongata, Chiastozygus striatus, Cretarhabdus conicus, Flabellites biforaminis, Lithraphidites carniolensis, Manivitella pemmatoidea, Micrantholithus hoschulzii, Nannoconus colomii, Polypodorhabdus madingleyensis, Reinhardtites fenestratus, Watznaueria barnesae*, and *W. communis.*

The interval from the top of Core 603F-5M to the bottom of the hole at 1545.7 m is a nannofossil limestone and chalk 172.5 m thick. Two wash cores and three rotary cores were taken, ending with Core 603F-9 (1540.2 to 1545.7 m). The nannofossil flora is abundant and preservation is moderate to poor. Samples were examined from 603F-5M-6, 74–75 cm; 603F-5M,CC; 603F-6.CC, (1507.3 m); 603F-7,CC, (1516.4 m); 603F-8M-3, 10–12 cm; 603F-8M,CC; and 603F-9-2, 136–137 cm (1544.8 m). The nannofossil assemblage in these beds contains *Cruciellipsis cuvillieri, Cyclagelosphaera deflandrei, Rucinolithus wisei, Speetonia colligata*, and *Tubodiscus verenae*, indicative of a Valanginian age. Other species present include *Cretarhabdus conicus, Cruciplacolithus salebrosus, Diazomatolithus lehmanii, L. carniolensis, P. asper, P. embergeri, P. infinitus, Polypodorhabdus madingleyensis, R. fenestratus, W. barnesae, W. bioporta*, and *W. communis.*

Radiolarians

Radiolarians were sparse and poorly preserved in the sediments at Site 603F. Sample 603F-1M,CC was barren of radiolarians. Six samples and the core catchers were examined from Core 603F-2M. Samples 603F-2M-1, 110–112 cm, 603F-2M-6, 110–112 cm, 603F-2M-4, 110–112 cm, 603F-2M-5, 110–112 cm, and 603F-2M-6, 110–112 cm were barren of radiolarians. Sample 603F-2M,CC contained some very badly corroded radiolarian fragments.

Six samples plus the core catcher were studied from Core 603F-3M. Samples 603F-3M-1, 30–31 cm, 603F-3M-2, 30–31 cm, and 603F-3M-3, 30–31 cm contained very badly corroded radiolarians. Sample 603F-3M-4, 30–31 cm contained abundant but very poorly preserved radiolarians. Single specimens of *Buryella tetradica* and *Bekoma bidartensis* were tentatively identified in this sample, and these taxa would indicate the *Bekoma bidartensis* zone of Paleocene to earliest Eocene age.

Six samples plus the core catcher were examined from Core 603F-4M. Samples 603-4M-1, 90–91 cm, 603F-4M-2, 90–91 cm, 603F-4M-3, 90–91 cm, 603F-4M-4, 90–91 cm, 603F-4M-5, 90–91 cm, and 603F-4M-6, 90–91 cm, and 603F-4M,CC were all barren of radiolarians. Two samples were examined from Core 603F-5M. Samples 603F-5M-5, 59–60 cm and 603F-5M,CC contained a few badly corroded and pyritized radiolarian fragments. Sample 603-6,CC contained numerous pyritized radiolarians, and Sample 603F-7,CC contained a few fragments of pyritized radiolarians.

ORGANIC GEOCHEMISTRY

Hole 603E

The shipboard Girdel Rock-Eval apparatus was used to pyrolyze sediment samples from Hole 603E. Table 8 shows values for S_2 (mg hydrocarbon/g sediment), the temperature maximum (T_{max}) for S_2 (°C) and organic carbon values in percentage.

S_2 is proportional to the hydrocarbon-generating potential of the sediment. T_{max} the temperature at which S_2 is evolved, is an indicator of the maturity of the sediment (Espitalié et al., 1977). S_1 peaks were so small that they were not measurable. S_3 peaks (mg CO_2/g sediment) were not reported because the values were unreproducible owing to problems with the CO_2 trapping system.

Table 8. Pyrolysis data for Holes 603E and 603F.

Sample (interval in cm)	Sub-bottom Depth (m)	S_2 (mg HC/g sediment)	T_{max} (°C)	Organic carbon (%)
Hole 603E				
2M-1, 97	1259.87	10.1	425	3.42
3M-2, 12	1278.62	1.3	418	0.68
3M-2, 55	1279.05	1.7	422	1.89
Hole 603F				
4M-1, 26–28	1201.06	2.4	430	1.93
4M-6, 15–17	1208.45	2.1	432	2.49
		2.9	430	
4M-6, 70–72	1209.20	4.3	426	1.90
5M-1, 77–79	1373.97	1.7	430–460 (very broad peak)	1.55
8M-2, 56–58	1516.20	0.8	425	1.33
8M-2, 131–132	1518.95	30.3	413	19.05

The percentage of organic carbon was measured using the shipboard LECO carbon analyzer.

S_2 values (mg hydrocarbon/g sediment) show that Sample 603E-2M-1, 97 cm has a good potential for hydrocarbon generation: 10.1 mg hydrocarbon/g sediment (Tissot and Welte, 1978). The percentage of organic carbon for this sample is the highest of all three samples in Hole 603E and all six samples in 603F, except for 603F-8M-2, 132 cm. T_{max} for 603E-2M-1, 97 cm (425°) indicates that the organic material is immature. The other two samples in Hole 603E (1278.62 and 1279.05 m sub-bottom depth) show a substantial decrease in S_2 with core depth. The percentage of organic carbon is also lower: 0.68% for 603E-3M-2, 12 cm and 1.89% for 603E-3M-2, 55 cm. T_{max} values also indicate that the organic material is immature.

No S_1 peak (free hydrocarbons) was measurable for any of the samples and no visible evidence of gas was observed.

Hole 603F

Table 8 also summarizes S_2 (mg hydrocarbon/g sediment), T_{max}, and the percentage of organic carbon for Hole 603F. Samples 603F-4M-6, 70–72 cm and 603F-8M-2, 131–132 cm show higher S_2 values (4.3 and 30.3 mg/g, respectively) than the rest of the samples. In addition, the percentage of organic carbon is also higher (1.90 and 19.05%, respectively). Sample 603F-4M-6, 70–72 cm has a fair potential for hydrocarbon generation. Sample 603F-8M-2, 131–132 cm has a very good potential for hydrocarbon generation. The remaining samples have poor potential. T_{max} values for all the samples measured are indicative of immature organic matter. T_{max} for 603F-5M-1, 77–79 cm is an artifact of the broadness of the S_2 peak.

Sample 603F-4M-6, 70–72 cm contains lignin. This could be the reason for both the higher S_2 value and the percentage of organic carbon. Sample 603F-8M-2, 131–132 cm contains a large amount of coal, producing the high S_2 value and the percentage of organic carbon. The presence of coal is also reflected by the lower T_{max} value.

No visible gas was obtained in any of the cores recovered. S_1 values obtained from pyrolysis were so small that they were not measurable. S_3 values were not reported because of problems with the CO_2 trapping system.

PHYSICAL PROPERTIES

Eleven sonic velocities and four water-content–bulk-density samples were processed during the second occupation of Site 603. Results are listed in Table 9.

SUMMARY AND CONCLUSIONS

Three attempts failed to reach 1576 m, at which point continuous coring to basement was to have begun. A few wash and spot cores corroborated the findings of Leg 93, but otherwise no significant scientific results were derived from our efforts.

Table 9. Bulk physical properties data, Hole 603F.

Core-Section (interval in cm)	Sub-bottom depth (m)	Wet-bulk density (g/cm^3)	Water content (%) Wet	Dry	Porosity (%)	Void ratio	Grain density (g/cm^3)
5-1, 147–149	1374.7	2.23	11.4	12.9	25.5	0.34	2.66
5-5, 69–71	1379.3	2.15	13.5	15.6	28.9	0.41	2.61
7-1, 90–92	1507.4	2.28	9.8	10.8	22.3	0.29	2.65
7-2, 77–80	1508.9	2.18	12.4	14.1	27.0	0.37	2.61

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Date of Acceptance: 10 July 1985

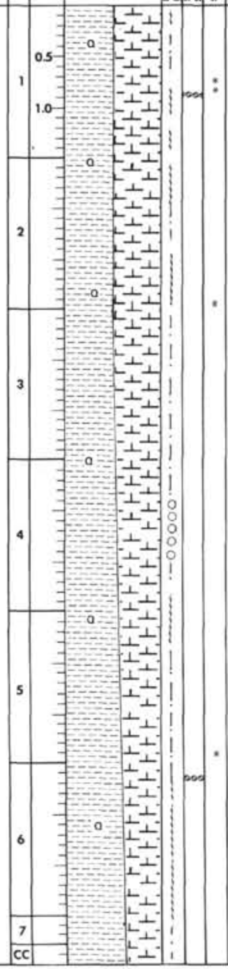
SITE 603 HOLE CORE 1 CORED INTERVAL 0.0–9.0 m

TIME – ROCK UNIT: early Pleistocene

BIOSTRATIGRAPHIC ZONE — FOSSIL CHARACTER — FORAMINIFERS: *G. truncatulinoides* Zone–*G. tosaensis* Subzone

NANNOFOSSILS: *Helicosphaera sellii* Zone

RADIOLARIANS — DIATOMS — SECTION — METERS — GRAPHIC LITHOLOGY — DRILLING DISTURBANCE — SEDIMENTARY STRUCTURES — SAMPLES



LITHOLOGIC DESCRIPTION

QUARTZ-BEARING NANNOFOSSIL-RICH CLAY, homogeneous, greenish-gray (5GY 6/1) colored, with vertically-streaked black specks (organic matter?). Moderate to severe drilling disturbance.

SMEAR SLIDE SUMMARY (%):

	1, 75	1, 85 M	2, 150	5, 144
Texture:				
Silt	2	5	10	5
Clay	98	95	90	95
Composition:				
Quartz	2	2	7	4
Heavy minerals	1	1	1	1
Clay	55	65	55	65
Micronodules	–	–	1	–
Carbonate unspec.	2	–	1	3
Foraminifers	–	2	TR	TR
Calc. nannofossils	40	30	35	30
Sponge spicules	–	–	–	TR
Fish remains	TR	–	TR	–
Opaques	–	TR	–	1

Information on core description sheets, for ALL sites, represents field notes taken aboard ship under time pressure. Some of this information has been refined in accord with post-cruise findings, but production schedules prohibit definitive correlation of these sheets with subsequent findings. Thus the reader should be alerted to the occasional ambiguity or discrepancy.

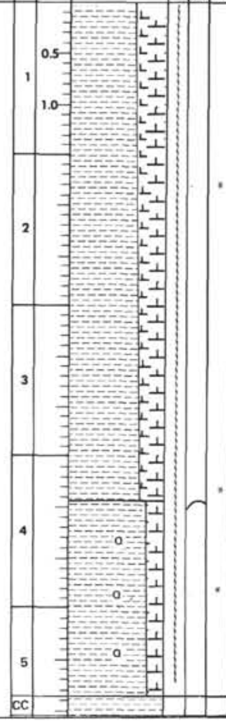
SITE 603 HOLE CORE 2M CORED INTERVAL 9.0–83.8 m

TIME – ROCK UNIT: late Pliocene

BIOSTRATIGRAPHIC ZONE — FOSSIL CHARACTER — FORAMINIFERS: PL6

NANNOFOSSILS: *Discoaster brouweri* Zone (CN12)

RADIOLARIANS — DIATOMS — SECTION — METERS — GRAPHIC LITHOLOGY — DRILLING DISTURBANCE — SEDIMENTARY STRUCTURES — SAMPLES



LITHOLOGIC DESCRIPTION

WASH CORE

Upper 4.95 m of core is NANNOFOSSIL-RICH CLAY, bluish gray (5B 5/1) to greenish gray (5G 4/1–5BG 4/1) in color, with severe drilling deformation and scattered pyrite nodules.

Lower part of core is QUARTZ-BEARING NANNOFOSSIL-RICH CLAY, dark greenish gray to bluish gray (5G 4/1–5B 4/1), with severe drilling deformation.

SMEAR SLIDE SUMMARY (%):

	2, 31	4, 31	4, 130
Texture:			
Silt	–	–	16
Clay	100	100	84
Composition:			
Quartz	1	1	10
Mica	–	–	TR
Heavy minerals	1	1	1
Clay	70	75	72
Pyrite	–	–	1
Micronodules	1	1	–
Carbonate unspec.	2	11	3
Foraminifers	TR	–	TR
Calc. nannofossils	25	10	12
Fish remains	–	1	–
Plant debris	–	–	1

SITE 603 HOLE CORE 3M CORED INTERVAL 83.8–122.2 m

TIME – ROCK UNIT: late Pliocene

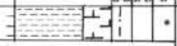
BIOSTRATIGRAPHIC ZONE: *G. miocenica* Zone (PL5); *D. brouweri* Zone (*D. tamalis* Subzone) (CN12a)

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS

SECTION: 1

METERS

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE, SEDIMENTARY STRUCTURES, SAMPLES

LITHOLOGIC DESCRIPTION

WASH CORE

NANNOFOSSIL-RICH CLAY, in centimeter-wide color bands of medium bluish gray (5B 5/1) and greenish gray (5G 6/1–5GY 5/1), with moderate drilling deformation.

SMEAR SLIDE SUMMARY (%):

	1, 17
Texture:	
Silt	1
Clay	99
Composition:	
Quartz	3
Mica	2
Heavy minerals	2
Clay	68
Carbonate unspec.	10
Foraminifers	TR
Calc. nannofossils	15
Sponge spicules	TR
Fish remains	TR
Fe-oxides	TR

SITE 603 HOLE CORE 4 CORED INTERVAL 122.2–131.8 m

TIME – ROCK UNIT: late Pliocene

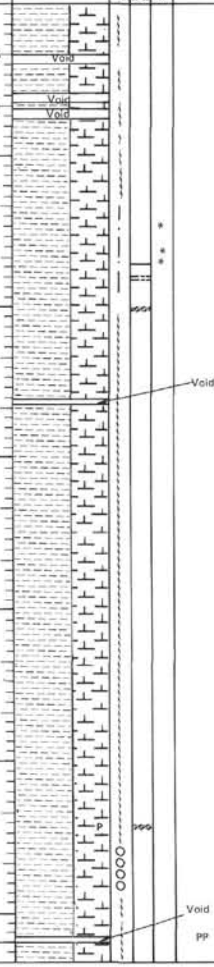
BIOSTRATIGRAPHIC ZONE: *G. miocenica* Zone (PL5); *D. brouweri* Zone; *D. tamalis* Subzone (CN12a)

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS

SECTION: 1, 2, 3, 4, 5, 6, 7, CC

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE, SEDIMENTARY STRUCTURES, SAMPLES

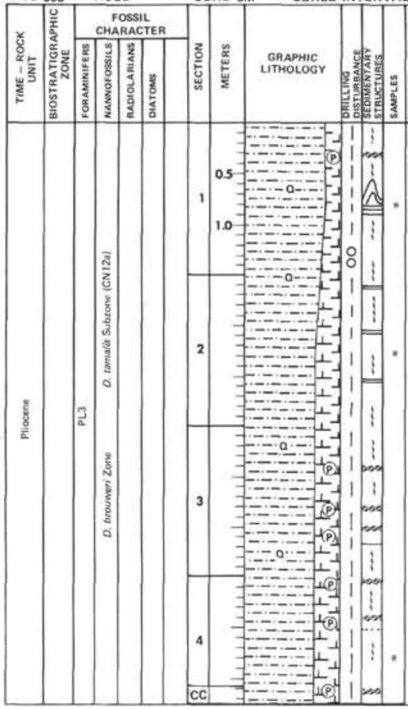
LITHOLOGIC DESCRIPTION

NANNOFOSSIL-RICH CLAY, medium bluish-greenish gray (5BG 5/1), with streaks of bluish gray (5B 5/1), greenish gray (5G 5/1), and dark bluish gray (5B 4/1–5B 3/1). Very disturbed from drilling. Core contained pockets of methane gas (voids).

SMEAR SLIDE SUMMARY (%):

	2, 74	2, 93	2, 104
Texture:			
Clay	100	100	100
Composition:			
Quartz	–	1	1
Mica	–	–	1
Heavy minerals	1	1	1
Clay	60	60	62
Micronodules	1	–	TR
Carbonate unspec.	3	3	5
Calc. nannofossils	35	35	30
Fish remains	–	TR	–

SITE 603 HOLE CORE 5M CORED INTERVAL 131.8–170.2 m



LITHOLOGIC DESCRIPTION

WASH CORE

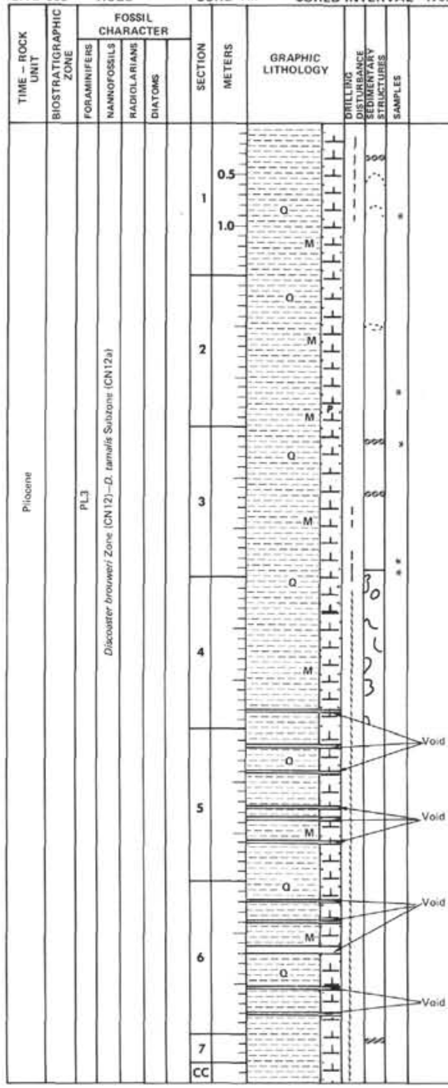
QUARTZ-BEARING NANNOFOSSIL-RICH SILTY CLAY, dark greenish gray to greenish gray (5G 4/1, 5G 5/1–5GY 5/1, 5BG 4/1), with evident bioturbation and slight drilling disturbance.

SMEAR SLIDE SUMMARY (%):

	1, 80	2, 80	4, 80
Texture:			
Sand	TR	TR	–
Silt	15	15	20
Clay	85	85	80
Composition:			
Quartz	5	5	3
Feldspar	TR	TR	–
Mica	3	3	5
Heavy minerals	TR	TR	TR
Clay	69	54	45
Pyrite	–	3	2
Carbonate unspec.	2	2	2
Foraminifers	3	3	3
Calc. nannofossils	15	30	30
Fe-oxides	3	–	–
Dolomite	–	–	TR

Core 6, 170.2–179.8 m: no recovery

SITE 603 HOLE CORE 7M CORED INTERVAL 179.8–199.0 m



LITHOLOGIC DESCRIPTION

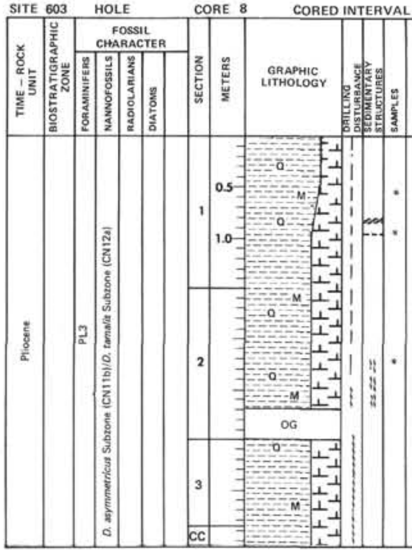
WASH CORE

QUARTZ-MICA-BEARING NANNOFOSSIL-RICH CLAY, greenish-gray (5Y 5/1) to dark greenish gray (5GY 4/1), with severe drilling deformation in Sections 4 to 6. Burrows, bioturbation, and pyrite burrow fills are common. Many voids due to methane gas in the lower half of the core.

SMEAR SLIDE SUMMARY (%):

	1, 91	2, 115	3, 20 M	3, 136	3, 142
Texture:					
Silt	2	4	100	10	10
Clay	98	96	–	90	90
Composition:					
Quartz	1	–	100	5	5
Mica	TR	1	–	5	4
Heavy minerals	TR	–	TR	–	TR
Clay	70	80	–	80	85
Glauconite	TR	TR	–	TR	–
Pyrite	TR	–	–	–	–
Carbonate unspec.	3	2	–	–	–
Foraminifers	TR	–	–	–	–
Calc. nannofossils	25	15	–	10	5
Fish remains	–	–	–	TR	–
Plant debris	TR	TR	–	–	–
Opaques	1	1	–	TR	TR

SITE 603 HOLE CORE 8 CORED INTERVAL 199.0–208.6 m



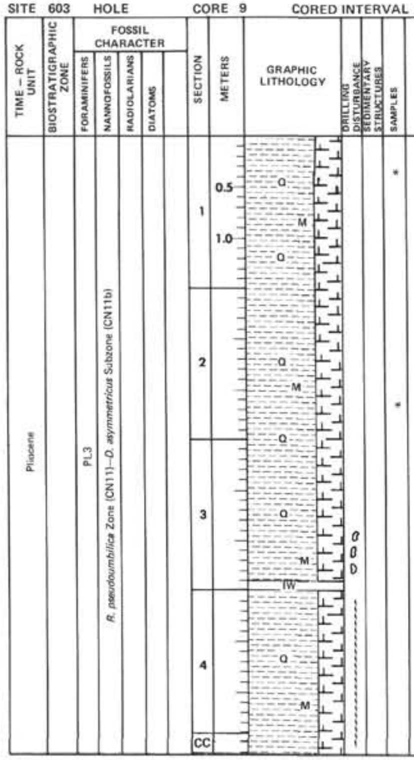
LITHOLOGIC DESCRIPTION

QUARTZ-MICA-NANNOFOSSIL-BEARING CLAY, dark greenish gray to greenish gray (5GY 4/1–5G 5/1), with slight to severe drilling disturbance. Faint laminations and burrow-mottling are seen. Core contains methane gas.

SMEAR SLIDE SUMMARY (%):

	1, 58	1, 98	2, 77
Texture:			
Silt	5	3	2
Clay	95	97	98
Composition:			
Quartz	3	2	2
Feldspar	–	–	TR
Mica	5	1	5
Heavy minerals	1	–	TR
Clay	66	65	58
Pyrite	–	–	1
Zeolite	TR	–	–
Carbonate unspec.	2	2	2
Foraminifers	3	–	2
Calc. nannofossils	20	30	30
Fish remains	TR	–	–
Opaques	–	TR	–

SITE 603 HOLE CORE 9 CORED INTERVAL 208.6–218.2 m



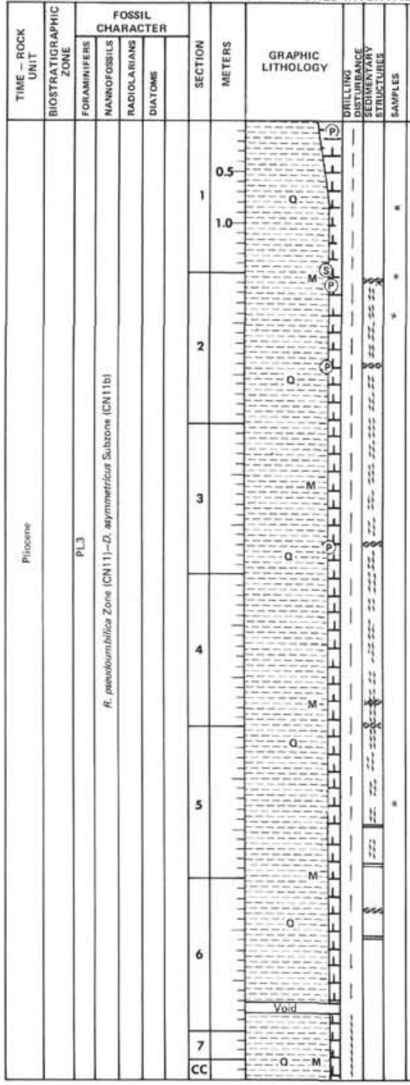
LITHOLOGIC DESCRIPTION

QUARTZ-MICA-NANNOFOSSIL-BEARING CLAY, greenish-gray (5G 5/1) to dark greenish-gray (5GY 5/1). Lower half of core shows severe drilling disturbance, and methane gas cracks and voids.

SMEAR SLIDE SUMMARY (%):

	1, 36	2, 114
Texture:		
Silt	8	30
Clay	92	70
Composition:		
Quartz	3	4
Mica	4	15
Clay	65	75
Glauconite	–	TR
Pyrite	TR	1
Micronodules	TR	–
Carbonate unspec.	2	3
Foraminifers	TR	–
Calc. nannofossils	25	1
Plant debris	–	TR
Opaques	–	1

SITE 603 HOLE CORE 10 CORED INTERVAL 218.2–227.8 m



LITHOLOGIC DESCRIPTION

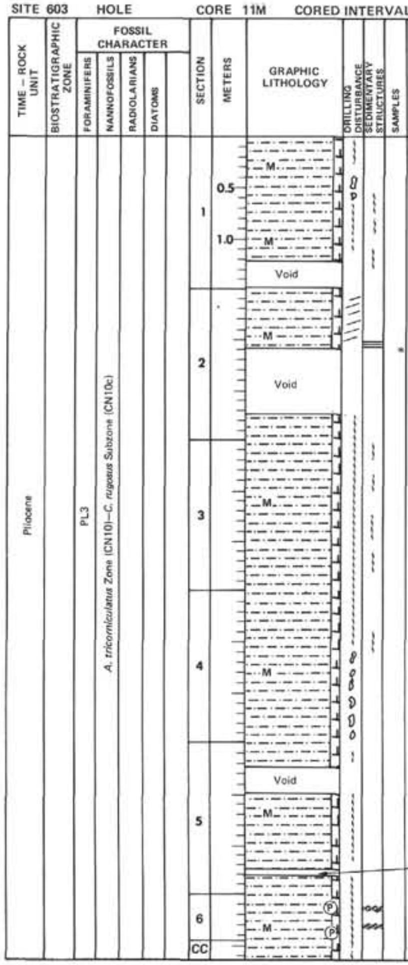
MICA-NANNOFOSSIL-RICH CLAY, dark greenish gray (5G 4/1–5BG 4/1), with centimeter-thick laminations, bioturbation and pyritized burrows. Slight drilling disturbance seen in core, and methane gas voids and cracks in lower two sections.

Core contains nodules and discontinuous layers of siderite.

SMEAR SLIDE SUMMARY (%):

	1, 84	2, 6 M	2, 45 M	5, 79
Texture:				
Silt	30	–	97	20
Clay	70	100	3	80
Composition:				
Quartz	4	TR	6	4
Mica	16	–	–	8
Heavy minerals	–	–	–	1
Clay	76	–	3	70
Glauconite	TR	–	–	–
Pyrite	1	–	–	TR
Carbonate unspec.	–	100	91	2
Calc. nannofossils	1	–	–	15
Fish remains	TR	–	–	–
Plant debris	–	–	–	TR
Opaques	1	–	–	–
Siderite	1	–	–	–

SITE 603 HOLE CORE 11M CORED INTERVAL 227.8–266.2 m



LITHOLOGIC DESCRIPTION

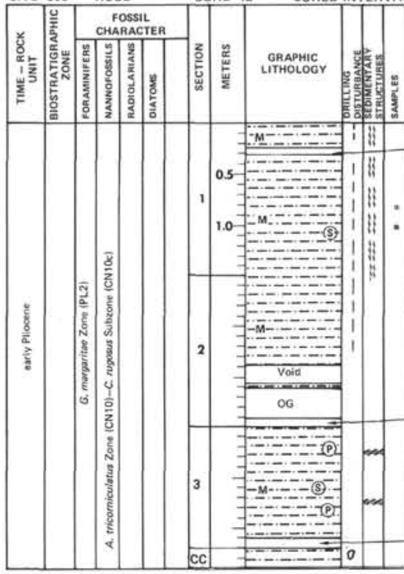
WASH CORE

NANNOFOSSIL BEARING, MICA-SILT-RICH CLAY, grading to CLAYSTONE in Sections 3–4. Dark gray (5Y 4/1) to dark greenish gray (5GY 4/1), with vertical black streaks and faint mottling due to bioturbation. Some pyritized burrows occur in Section 6.

SMEAR SLIDE SUMMARY (%):

	2, 61	2, 61 M
Texture:		
Sand	–	3
Silt	20	22
Clay	80	75
Composition:		
Quartz	3	3
Feldspar	1	1
Mica	8	6
Heavy minerals	1	–
Clay	76	62
Glauconite	TR	–
Pyrite	1	TR
Micronodules	–	2
Carbonate unspec.	1	2
Foraminifers	–	2
Calc. nannofossils	9	20
Radiolarians	–	1
Fish remains	–	1
Plant debris	TR	TR
Dolomite	–	TR

SITE 603 HOLE CORE 12 CORED INTERVAL 266.2–275.8 m



LITHOLOGIC DESCRIPTION

MICA-BEARING SILT-RICH CLAYSTONE, greenish-gray (5G 5/1), with mottles of dark bluish black (5B 2/1). Slight drilling disturbance and moderate bioturbation are seen. Some pyritized burrows are seen in Section 3.

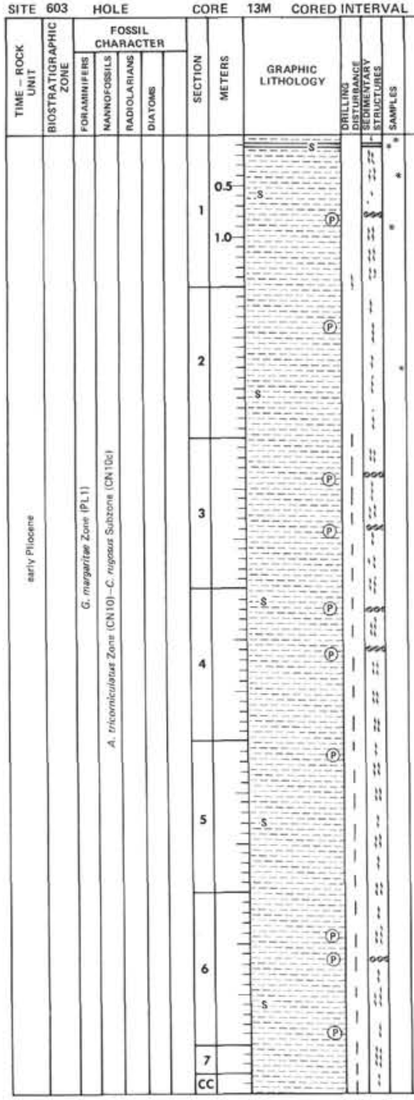
Gas voids occur in Sections 1 and 2.

Core contains siderite nodules.

SMEAR SLIDE SUMMARY (%):

	1, 83	1, 105 M
Texture:		
Silt	17	1
Clay	83	99
Composition:		
Quartz	2	1
Mica	11	–
Heavy minerals	1	–
Clay	82	15
Glauconite	TR	–
Pyrite	TR	–
Micronodules	1	–
Calc. nannofossils	1	–
Plant debris	1	–
Siderite	1	84

SITE 603 HOLE CORE 13M CORED INTERVAL 275.8–314.2 m



LITHOLOGIC DESCRIPTION

WASH CORE

SIDERITE-BEARING CLAYSTONE, dark greenish-gray (5G 4/1–5BG 4/1) to greenish-gray (5BG 5/1–5G 5/1), with mottling of bluish black (5B 2/1) and olive gray (5Y 5/2–5Y 3/1). Common bioturbation and pyrite nodules.

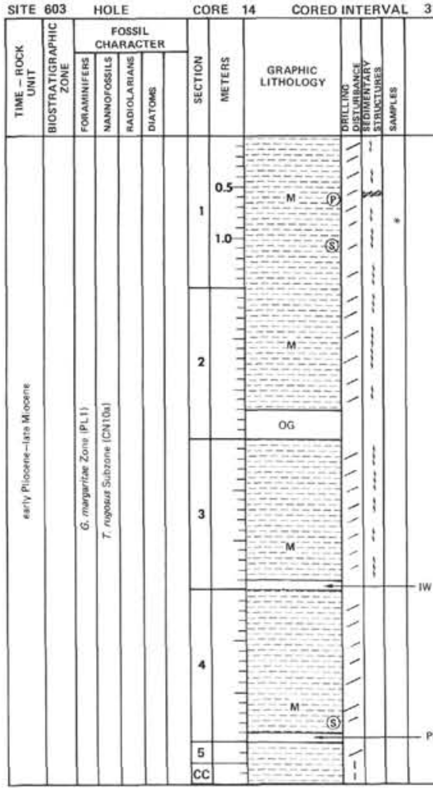
Slight drilling deformation in Sections 3–7.

A siderite layer occurs in Section 1, 8–9 cm.

SMEAR SLIDE SUMMARY (%):

	1, 8 M	1, 12	1, 44	1, 96 M	2, 82
Texture:					
Silt	2	1	4	1	4
Clay	98	99	96	99	96
Composition:					
Quartz	2	2	2	1	2
Feldspar	–	–	TR	–	TR
Mica	2	1	2	2	2
Heavy minerals	–	–	–	1	1
Clay	30	80	81	54	87
Pyrite	–	2	1	–	–
Micronodules	–	2	1	1	–
Calc. nannofossils	5	8	TR	40	–
Sponge spicules	–	TR	–	–	–
Fish remains	–	TR	–	–	–
Siderite	61	5	3	1	8

SITE 603 HOLE CORE 14 CORED INTERVAL 314.2–323.8 m



LITHOLOGIC DESCRIPTION

MICA-RICH CLAYSTONE, dark greenish gray (5G 4/1) with mottles of bluish black (5B 2/1). Slight bioturbation evident. Core is broken up into drilling biscuits.

Tiny spots of clay-rich chalk seen in Sections 1 and 4 (1, 63 cm; 4, 134 cm).

Siderite nodules occur throughout the core.

SMEAR SLIDE SUMMARY (%):

	1, 82
Texture:	
Silt	10
Clay	90
Composition:	
Quartz	4
Mica	10
Clay	80
Micronodules	1
Zeolite	TR
Carbonate unspec.	3
Calc. nannofossils	2
Diatoms	TR

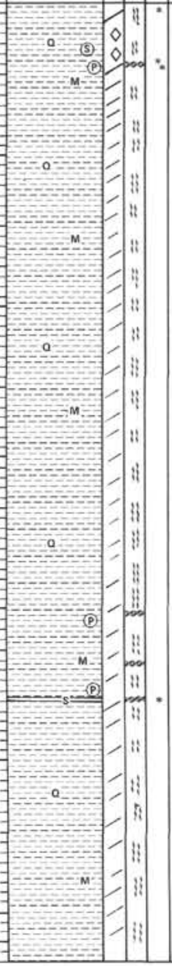
SITE 603 HOLE CORE 15M CORED INTERVAL 323.8–362.2 m

TIME-ROCK UNIT: early Pliocene–late Miocene

BIOSTRATIGRAPHIC ZONE / FOSSIL CHARACTER — FORAMINIFERS: *G. margaritae* Zone (PL1); NANNOFOSSILS: *T. rugosus* Subzone (CN10a)

SECTION: 1, 2, 3, 4, 5, 6, 7, CC — METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

WASH CORE

QUARTZ-MICA-BEARING CLAYSTONE, dark greenish-gray (5G 4/1–5BG 4/1), with mottles of bluish black (5BG 2/1) and greenish gray (5GY 5/1–5BG 5/1), faintly banded.

Core is broken up into drilling biscuits.

Moderate bioturbation, with common *Chondrites* and other burrows, and some pyritized burrows.

Core contains siderite nodules and burrow fills.

SMEAR SLIDE SUMMARY (%):

	1, 8	1, 60 M	1, 62 M	5, 88 M
Texture:				
Sand	–	20	–	–
Silt	18	13	3	–
Clay	82	67	97	100
Composition:				
Quartz	5	4	2	–
Mica	3	4	TR	2
Heavy minerals	TR	–	–	–
Clay	82	65	67	–
Glauconite	–	TR	–	–
Pyrite	2	–	–	–
Calc. nannofossils	TR	2	30	–
Opaques	–	TR	TR	3
Siderite	8	25	1	95

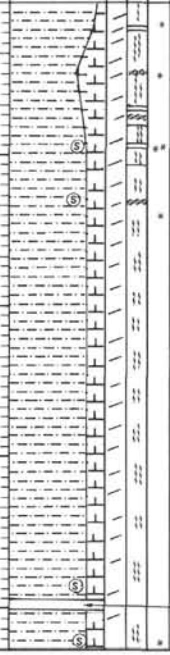
SITE 603 HOLE CORE 16 CORED INTERVAL 362.2–371.8 m

TIME-ROCK UNIT: early Pliocene–late Miocene

BIOSTRATIGRAPHIC ZONE / FOSSIL CHARACTER — FORAMINIFERS: *G. margaritae* Zone (PL1); NANNOFOSSILS: *D. quinqueramus* Zone (CN9)–*A. primus* subzone (CN9b)

SECTION: 1, 2, 3, 4, 5 — METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



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LITHOLOGIC DESCRIPTION

SIDERITE-NANNOFOSSIL-BEARING SILTY CLAYSTONE, with laminations of dark greenish gray (5G 4/1), greenish gray (5G 5/1), and gray (5Y 5/1).

Entire core is broken up into drilling biscuits.

Moderate bioturbation, with *Chondrites*, and pyritized burrows.

Core is faintly banded, with sharp to gradational boundaries, and contains siderite nodules and burrow fills.

SMEAR SLIDE SUMMARY (%):

	1, 26	1, 72	1, 146	1, 147 M	2, 61 M	5, 36
Texture:						
Silt	3	30	20	8	70	20
Clay	97	70	80	92	30	80
Composition:						
Quartz	2	2	1	1	TR	8
Mica	TR	1	2	2	1	5
Heavy minerals	–	TR	–	–	–	TR
Clay	88	58	83	62	4	79
Pyrite	–	3	TR	TR	TR	–
Zeolite	–	TR	–	–	–	–
Foraminifers	–	3	TR	–	–	–
Calc. nannofossils	5	30	4	5	5	3
Fish remains	–	–	–	–	–	TR
Siderite	5	3	10	30	90	5

SITE 603 HOLE CORE 17M CORED INTERVAL 371.8–410.2 m

TIME-ROCK UNIT: early Pliocene–late Miocene

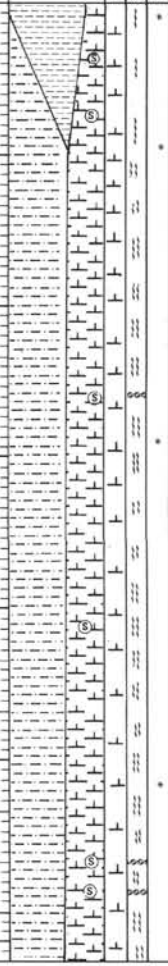
BIOSTRATIGRAPHIC ZONE: *G. margaritae* Zone (PL1); *D. quinqueramus* Zone (CN9)–*A. primus* Subzone (CN9b)

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS

SECTION: 1, 2, 3, 4, 5, 6, 7, CC

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE, SEDIMENTARY STRUCTURES, SAMPLES

LITHOLOGIC DESCRIPTION

WASH CORE

NANNOFOSSIL CLAYSTONE to NANNOFOSSIL SILTY CLAYSTONE, dark greenish-gray (5G 4/1–5GY 4/1) to gray (5Y 5/1).

Core is moderately fragmented into harder drilling biscuits separated by softer sediments.

Moderately burrowed (*Chondrites*), with pyrite and siderite burrow fills and nodules.

SMEAR SLIDE SUMMARY (%):

	1, 14	1, 146	3, 136 M	6, 27
Texture:				
Silt	10	40	50	–
Clay	90	60	50	100
Composition:				
Quartz	5	1	–	TR
Mica	2	2	–	TR
Clay	75	55	–	58
Glauconite	TR	–	–	–
Pyrite	–	2	–	–
Carbonate unspec.	1	5	100	2
Foraminifers	–	TR	–	–
Calc. nannofossils	15	35	–	40
Fish remains	TR	–	–	TR
Plant debris	–	–	–	TR
Opaques	2	–	–	TR

SITE 603 HOLE CORE 18 CORED INTERVAL 410.2–419.8 m

TIME-ROCK UNIT: late Miocene–early Pliocene

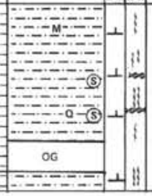
BIOSTRATIGRAPHIC ZONE: *G. margaritae* Zone (PL1); *D. quinqueramus* Zone (CN9)–*A. primus* Subzone (CN9b)

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS

SECTION: 1, 2, CC

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE, SEDIMENTARY STRUCTURES, SAMPLES

LITHOLOGIC DESCRIPTION

MICA-BEARING QUARTZ-RICH SILTY CLAYSTONE, dark greenish-gray (5BG 4/1) to dark bluish-gray (5B 4/1).

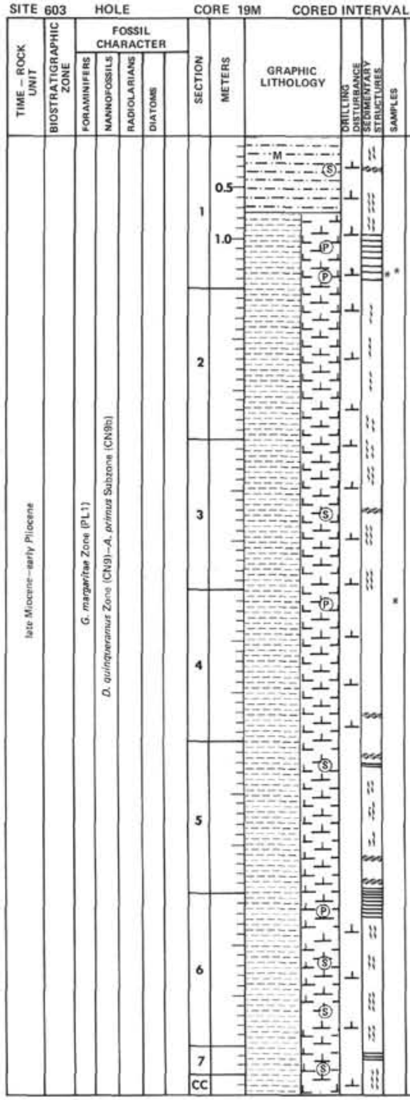
Moderately bioturbated.

Core is broken up into drilling biscuits, and contains siderite nodules and burrow fills.

SMEAR SLIDE SUMMARY (%):

	1, 88
Texture:	
Sand	5
Silt	35
Clay	60
Composition:	
Quartz	10
Mica	5
Clay	70
Pyrite	1
Carbonate unspec.	5
Foraminifers	TR
Calc. nannofossils	8
Plant debris	1

SITE 603 HOLE CORE 19M CORED INTERVAL 419.8–448.6 m



LITHOLOGIC DESCRIPTION

WASH CORE

Top 0.75 m is MICA-BEARING SILTY CLAYSTONE, greenish gray (5Y 4/1–5G 4/2).

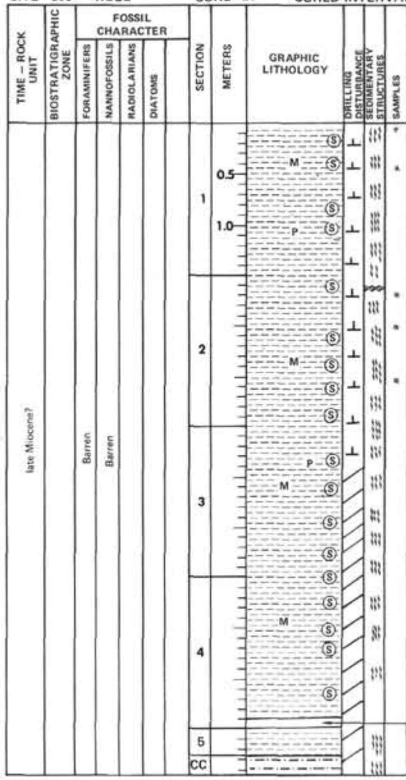
Rest of core is *NANNOFOSSIL CLAYSTONE*, greenish-gray (5GY 5/1), laminated to intensely burrow-mottled, with pyrite and siderite burrow fills.

Entire core is broken up into drilling biscuits.

SMEAR SLIDE SUMMARY (%):

	1, 132	1, 136	4, 12
Texture:			
Sand	3	2	8
Silt	32	3	2
Clay	65	95	90
Composition:			
Quartz	2	2	2
Mica	13	3	3
Heavy minerals	TR	–	TR
Clay	78	55	60
Glauconite	TR	TR	–
Pyrite	1	TR	TR
Carbonate unspec.	5	–	5
Foraminifers	–	–	TR
Calc. nannofossils	1	40	30
Fish remains	–	TR	TR
Plant debris	–	–	TR

SITE 603 HOLE CORE 20 CORED INTERVAL 448.6–458.2 m



LITHOLOGIC DESCRIPTION

MICA-BEARING CLAYSTONE, dark greenish-gray (5G 4/1).

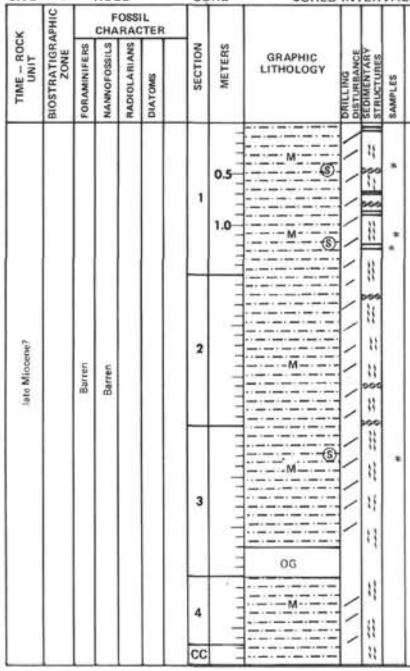
Intensity bioturbated, with pyrite and many siderite-filled burrows, and greenish-black (5GY 3/1–5G 2/1) and gray (5Y 6/1) burrow fills.

First two sections broken up into drilling biscuits.

SMEAR SLIDE SUMMARY (%):

	1, 6 M	1, 47	2, 20 M	2, 51 M	2, 106 M
Texture:					
Sand	1	–	1	–	–
Silt	35	30	35	10	30
Clay	64	70	64	90	70
Composition:					
Quartz	15	2	1	2	5
Feldspar	–	TR	–	–	–
Mica	20	10	25	8	10
Heavy minerals	–	3	–	1	–
Clay	60	83	62	83	70
Pyrite	3	2	2	–	–
Micronodules	–	–	1	1	–
Carbonate unspec.	TR	TR	–	2	15
Calc. nannofossils	–	–	–	3	–
Fish remains	TR	TR	TR	–	TR

SITE 603 HOLE CORE 21 CORED INTERVAL 458.2–467.8 m



LITHOLOGIC DESCRIPTION

MICA-RICH SILT-RICH CLAYSTONE, dark greenish-gray (5G 4/1).

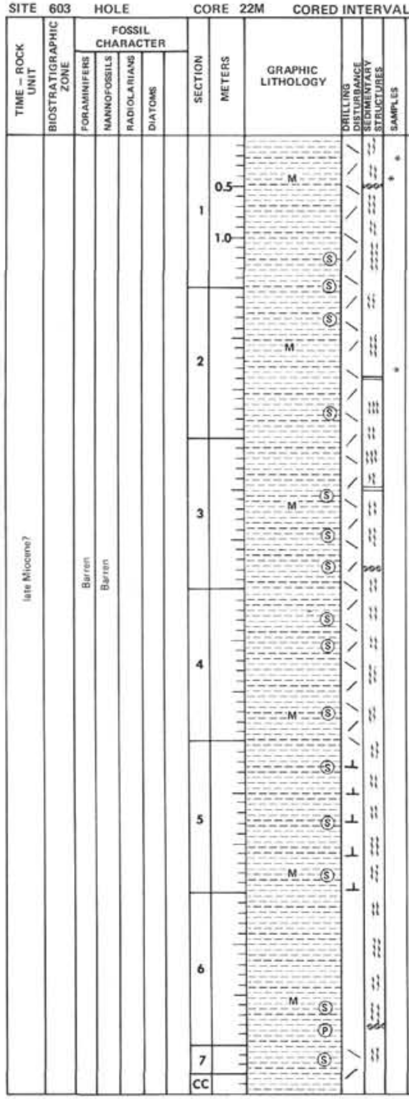
Heavily bioturbated, with greenish-black (5GY 3/1–5G 2/1) burrow fills, and siderite nodules and burrow fills.

Entire core is broken into drilling biscuits.

SMEAR SLIDE SUMMARY (%):

	1, 45 M	1, 116 M	1, 128	3, 32 M
Texture:				
Sand	—	2	1	—
Silt	30	45	19	10
Clay	70	53	80	90
Composition:				
Quartz	—	10	3	3
Mica	—	20	12	2
Heavy minerals	—	1	1	—
Clay	5	53	81	33
Pyrite	—	1	1	TR
Micronodules	—	TR	TR	1
Carbonate unspec.	95	—	2	—
Fish remains	—	—	—	1
Plant debris	TR	TR	TR	—
Siderite	—	15	—	65

SITE 603 HOLE CORE 22M CORED INTERVAL 467.8–506.2 m



LITHOLOGIC DESCRIPTION

WASH CORE

MICA-BEARING CLAYSTONE, dark greenish gray (5G 4/1–5BG 4/1). Moderately bioturbated, with siderite nodules and clasts, and dark greenish gray (5GY 3/1) to greenish black (5GY 2/1) burrow fills.

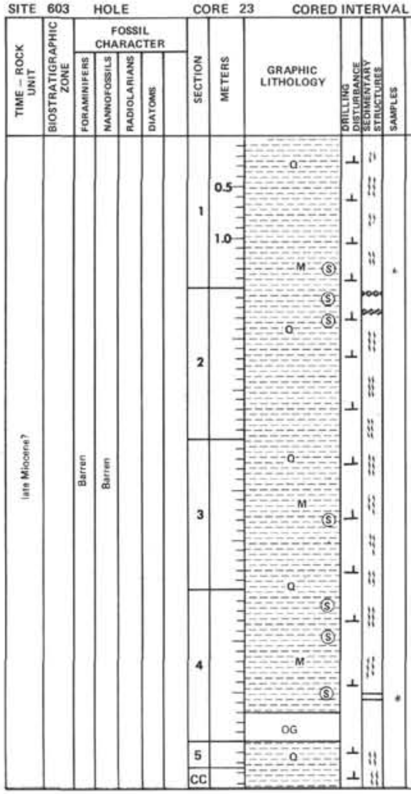
Core broken up into drilling biscuits and drill breccia.

Core has siderite-filled *Chondrites* burrows.

SMEAR SLIDE SUMMARY (%):

	1, 26	1, 44 M	2, 83 M
Texture:			
Silt	10	7	—
Clay	90	93	100
Composition:			
Quartz	2	—	—
Mica	10	7	3
Clay	86	83	77
Glauconite	1	—	20
Micronodules	1	—	TR
Zeolite	TR	TR	—
Siderite	—	10	—

SITE 603 HOLE CORE 23 CORED INTERVAL 506.2–515.8 m



LITHOLOGIC DESCRIPTION

QUARTZ-MICA-BEARING CLAYSTONE, dark greenish-gray (5BG 4/1) with dark gray (5Y 4/1) burrow mottles.

Entire core moderately bioturbated, with siderite nodules and clasts.

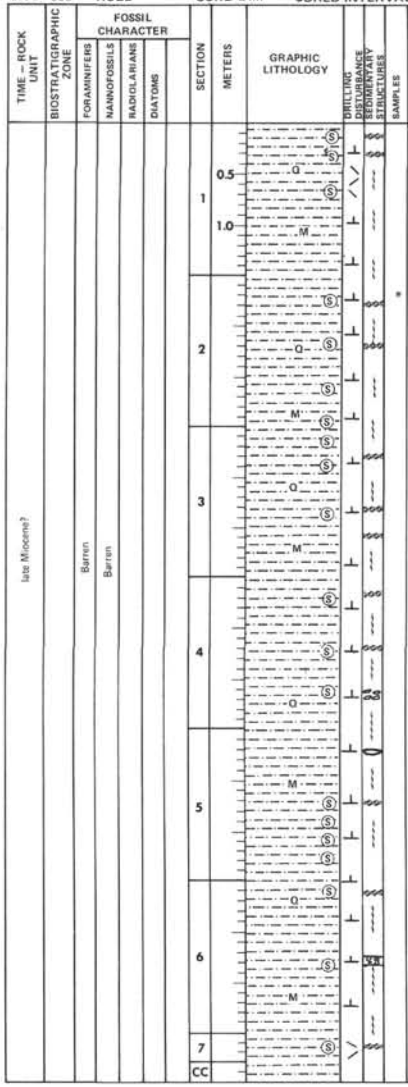
Core broken up into drilling biscuits.

Core has faint parallel banding.

SMEAR SLIDE SUMMARY (%):

	1, 131	4, 107 M
Texture:		
Silt	10	60
Clay	90	40
Composition:		
Quartz	6	TR
Mica	4	2
Heavy minerals	TR	–
Clay	82	–
Pyrite	TR	2
Carbonate unspec.	5	–
Calc. nannofossils	3	–
Siderite	–	96

SITE 603 HOLE CORE 24M CORED INTERVAL 515.8–544.6 m



LITHOLOGIC DESCRIPTION

WASH CORE

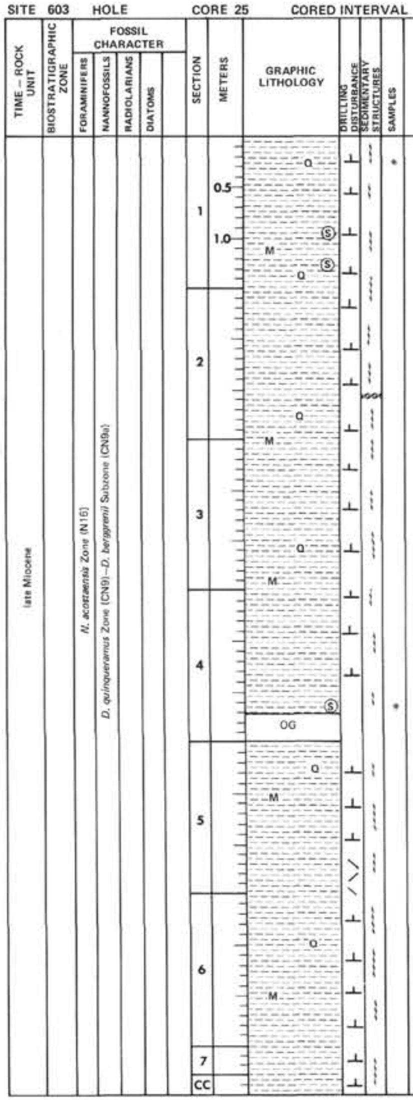
QUARTZ-MICA-BEARING SILT-RICH CLAYSTONE, dark greenish gray (5GY 5/1–5GY 4/1), with siderite nodules, concretions, and burrow fills.

Entire core moderately bioturbated, and broken up into drilling biscuits with horizontal burrows.

SMEAR SLIDE SUMMARY (%):

	2, 20
Texture:	
Silt	20
Clay	80
Composition:	
Quartz	10
Mica	6
Clay	80
Glauconite	TR
Pyrite	4

SITE 603 HOLE CORE 25 CORED INTERVAL 544.6–554.2 m



LITHOLOGIC DESCRIPTION

QUARTZ-MICA-BEARING CLAYSTONE, dark greenish-gray (5G 4/1–5BG 4/1), with burrow mottling and slight bioturbation throughout the core, mainly *Chondrites* burrows.

Siderite nodules and concretions are present.

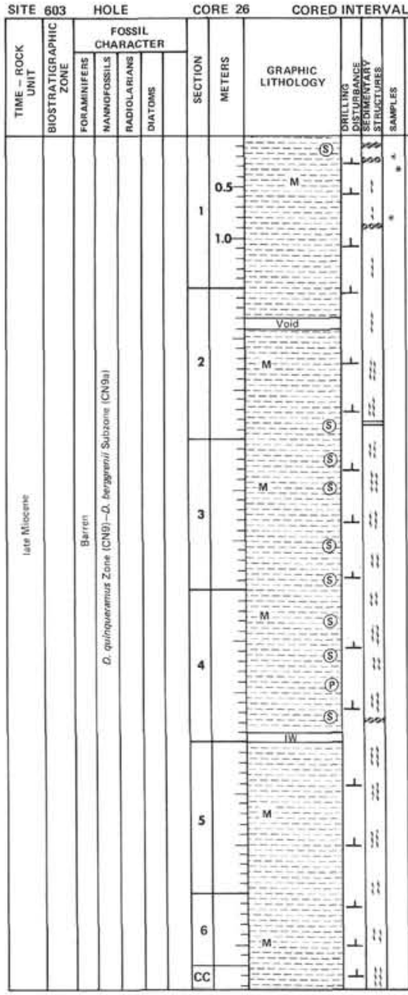
Entire core is broken up into drilling biscuits.

Pyritized burrows are also present.

SMEAR SLIDE SUMMARY (%):

	1, 28	4, 113
Texture:		
Silt	10	15
Clay	90	85
Composition:		
Quartz	3	5
Mica	8	8
Clay	78	77
Pyrite	3	3
Carbonate unspec.	3	3
Foraminifers	TR	–
Calc. nannofossils	5	3
Radiolarians	–	TR
Sponge spicules	TR	1
Plant debris	–	TR

SITE 603 HOLE CORE 26 CORED INTERVAL 554.2–563.8 m



LITHOLOGIC DESCRIPTION

MICA-RICH CLAYSTONE, dark greenish gray (5GY 4/1).

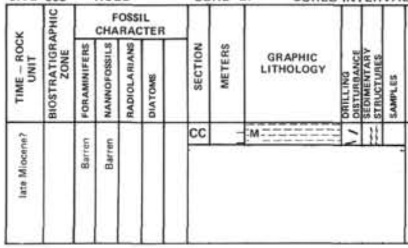
Entire core moderately bioturbated, with black (5G 3/1–5G 2/1) burrow fill, siderite and pyrite burrow fills, and siderite nodules.

Entire core is broken up into drilling biscuits.

SMEAR SLIDE SUMMARY (%):

	1, 24 M	1, 35	1, 82 M
Texture:			
Silt	10	15	–
Clay	90	85	100
Composition:			
Quartz	–	1	–
Mica	10	15	–
Clay	88	83	7
Micronodules	1	1	–
Calc. nannofossils	1	–	–
Siderite	–	–	93

SITE 603 HOLE CORE 27 CORED INTERVAL 563.8–573.4 m

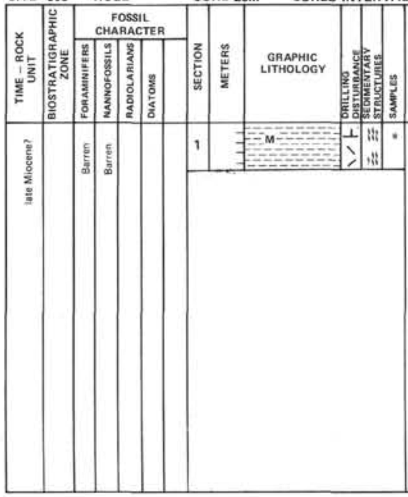


LITHOLOGIC DESCRIPTION

MICA-RICH CLAYSTONE, dark greenish gray (5GY 4/1), with evidence of bioturbation.

Only 26 cm of highly-fragmented drilling breccia recovered in Core Catcher.

SITE 603 HOLE CORE 28M CORED INTERVAL 563.8–573.4 m



LITHOLOGIC DESCRIPTION

WASH CORE

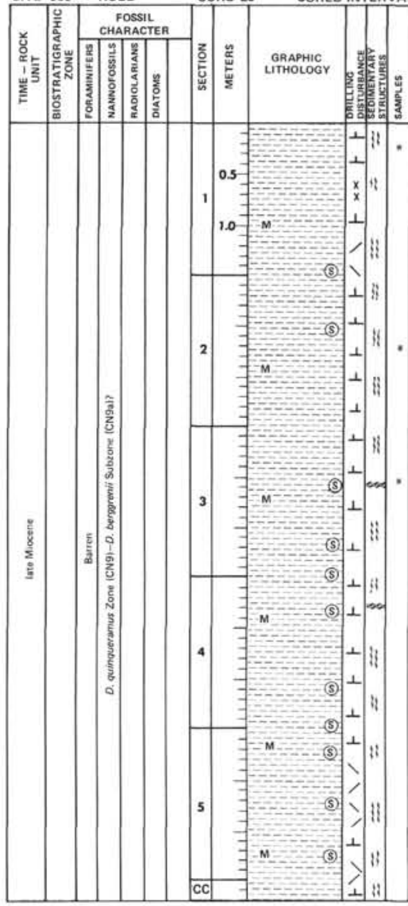
Core recovery is 48 cm of drilling biscuits and breccia.

SPONGE SPICULE-BEARING MICA-RICH CLAYSTONE, dark greenish gray (5GY 4/1). Heavily bioturbated with dark green to black (5G 2/2) streaks.

SMEAR SLIDE SUMMARY (%):

	1, 14
Texture:	
Silt	40
Clay	60
Composition:	
Quartz	5
Mica	21
Clay	65
Glauconite	1
Pyrite	1
Micronodules	1
Sponge spicules	4
Plant debris	TR
Siderite	2

SITE 603 HOLE CORE 29 CORED INTERVAL 573.4–583.0 m



LITHOLOGIC DESCRIPTION

MICA-RICH CLAYSTONE, dark greenish gray (5GY 4/1), with very dark greenish gray (5G 3/1–5G 5/1) and siderite (olive, 5Y 5/3–5Y 6/3) burrow fills.

Entire core moderately bioturbated, and broken up into drilling biscuits.

SMEAR SLIDE SUMMARY (%):

	1, 22	2, 78 M	3, 59 M
Texture:			
Silt	15	16	100
Clay	85	84	–
Composition:			
Quartz	1	1	–
Feldspar	TR	–	–
Mica	15	16	TR
Heavy minerals	81	80	–
Clay	–	–	TR
Micronodules	1	1	–
Carbonate unspec.	–	2	–
Calc. nannofossils	TR	TR	–
Sponge spicules	1	–	–
Siderite	1	–	100

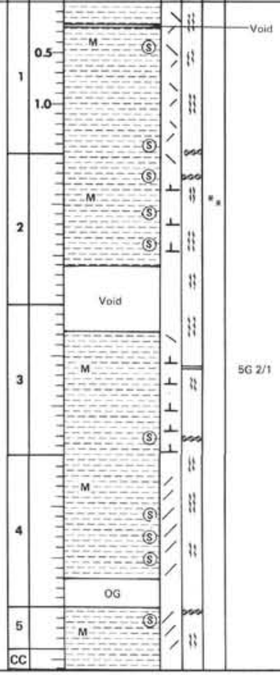
SITE 603 HOLE CORE 30 CORED INTERVAL 583.0–592.6 m

TIME – ROCK UNIT: late Miocene

BIOSTRATIGRAPHIC ZONE: D. neorectus Subzone (CN8b)/D. berggrenii Subzone (CN9a)

FOSSIL CHARACTER: FORAMINIFERS: Barren; NANNOFOSSILS; RADIOLARIANS; DIATOMS

SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES



LITHOLOGIC DESCRIPTION

MICA-RICH CLAYSTONE, dark greenish gray (5G 4/1–5G 5/1) with greenish black (5GY 3/1) burrow fills and siderite (olive, 5Y 6/2–6/3) burrow fills. Entire core is moderately bioturbated, with slight to moderate drilling disturbance.

Siderite becomes less abundant from Core 28 to Core 30, and traces of nannofossils begin to reappear.

SMEAR SLIDE SUMMARY (%):

	2, 48 M	2, 50
Texture:		
Silt	10	10
Clay	90	90
Composition:		
Quartz	1	–
Mica	10	10
Clay	88	89
Pyrite	–	TR
Micronodules	1	1
Calc. nannofossils	–	TR
Fish remains	TR	–

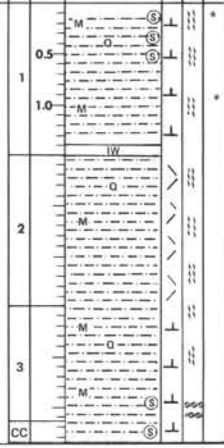
SITE 603 HOLE CORE 31 CORED INTERVAL 592.6–602.2 m

TIME – ROCK UNIT: late Miocene

BIOSTRATIGRAPHIC ZONE: N. acostaensis Zone (N16); D. neohamatus Zone (CN8)–D. neorectus Subzone (CN8b)

FOSSIL CHARACTER: FORAMINIFERS; NANNOFOSSILS; RADIOLARIANS; DIATOMS

SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES



LITHOLOGIC DESCRIPTION

MICA-QUARTZ-BEARING SILTY CLAYSTONE, faintly banded, dark bluish gray (5B 4/1–5BG 4/1) and dark greenish gray (5G 4/1), with moderate to heavy bioturbation, by *Chondrites* burrows.

Core moderately to highly fragmented by drilling.

Lighter bands are more siderite-rich.

Core contains siderite nodules and burrow fills.

SMEAR SLIDE SUMMARY (%):

	1, 11	1, 98
Texture:		
Silt	15	35
Clay	85	65
Composition:		
Quartz	10	8
Mica	5	3
Clay	76	63
Pyrite	3	2
Zeolite	TR	TR
Calc. nannofossils	2	3
Plant debris	1	1
Siderite	3	20

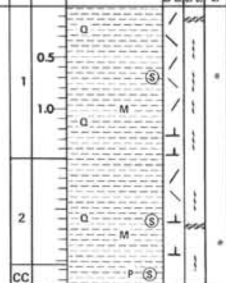
SITE 603 HOLE CORE 32 CORED INTERVAL 602.2–611.8 m

TIME – ROCK UNIT: middle–late Miocene

BIOSTRATIGRAPHIC ZONE: N14–N16; D. neohamatus Zone (CN8)–D. neorectus Subzone (CN8b)

FOSSIL CHARACTER: FORAMINIFERS; NANNOFOSSILS; RADIOLARIANS; DIATOMS

SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES



LITHOLOGIC DESCRIPTION

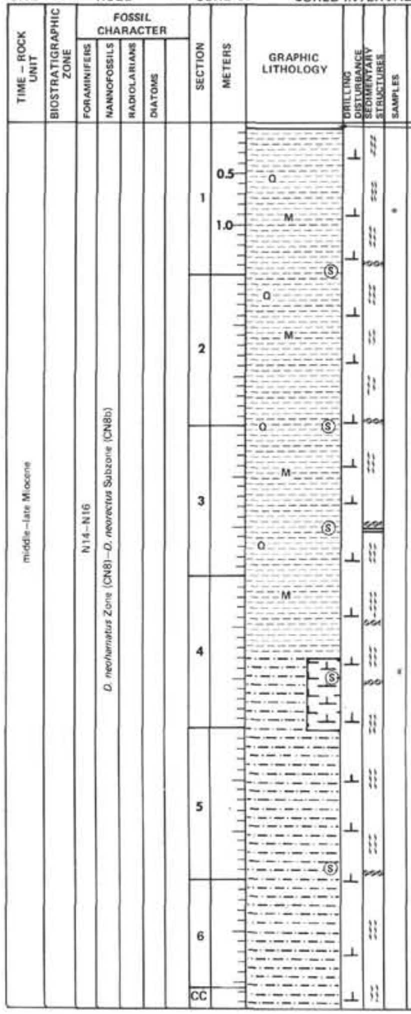
QUARTZ-MICA-BEARING SIDERITE-RICH CLAYSTONE, dark greenish gray (5GY 4/1), with siderite burrow fills.

Entire core slightly bioturbated, and moderately to severely disturbed by drilling.

SMEAR SLIDE SUMMARY (%):

	1, 70	2, 81
Texture:		
Sand	23	12
Silt	4	28
Clay	73	60
Composition:		
Quartz	3	5
Mica	3	3
Heavy minerals	TR	–
Clay	73	60
Pyrite	1	TR
Carbonate unspec.	–	7
Calc. nannofossils	–	TR
Siderite	20	25

SITE 603 HOLE CORE 33 CORED INTERVAL 611.8–621.4 m



LITHOLOGIC DESCRIPTION

QUARTZ-MICA-BEARING CLAYSTONE (Top 5.3 m), dark greenish gray (5G 4/1–5GY 4/1), faintly banded with slightly lighter and darker green layers.

Below this is NANNOFOSSIL-BEARING SILTY CLAYSTONE, lighter greenish gray (5G 5/1) in lower Section 4.

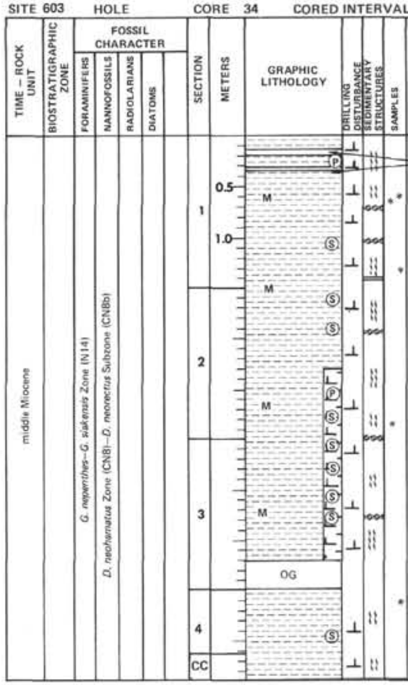
Entire core is moderately bioturbated, with siderite burrow fills.

Core is moderately fragmented by drilling, and contains siderite nodules and layers.

SMEAR SLIDE SUMMARY (%):

	2, 85	4, 93 M
Texture:		
Silt	22	5
Clay	78	95
Composition:		
Quartz	15	4
Mica	7	TR
Clay	75	54
Pyrite	TR	1
Calc. nannofossils	–	35
Fish remains	TR	–
Plant debris	–	3
Siderite	3	3

SITE 603 HOLE CORE 34 CORED INTERVAL 621.4–631.0 m



LITHOLOGIC DESCRIPTION

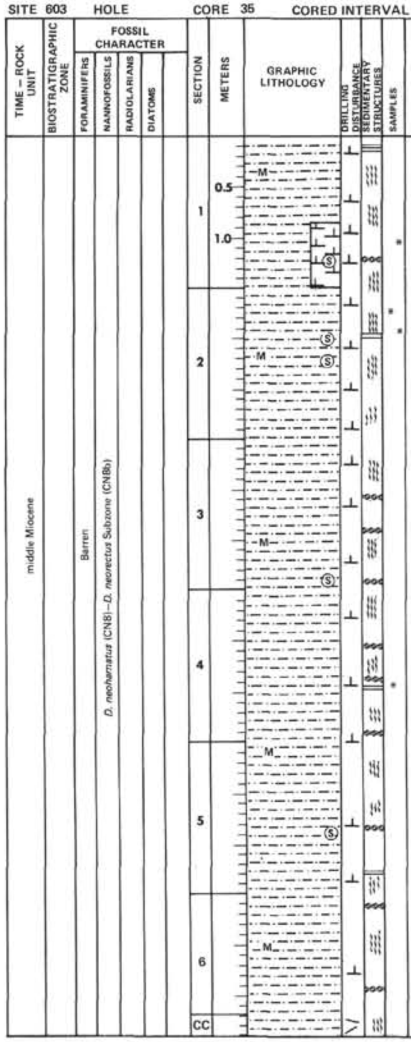
MICA-BEARING CLAYSTONE, dark greenish gray (5G 4/1), with gray (5Y 6/1) to greenish black (5G 3/1) burrow fills, and siderite and pyrite concretions.

Core is moderately bioturbated and moderately disturbed by drilling.

SMEAR SLIDE SUMMARY (%):

	1, 61	1, 68 M	1, 139 M	2, 136	4, 14
Texture:					
Silt	5	10	14	6	7
Clay	95	90	86	94	93
Composition:					
Quartz	1	1	–	1	–
Mica	4	7	12	5	7
Clay	95	89	84	76	91
Micronodules	TR	1	1	TR	1
Carbonate unspec.	–	–	–	1	1
Foraminifers	–	–	1	–	–
Calc. nannofossils	TR	–	TR	17	TR
Fish remains	TR	TR	–	–	TR
Siderite	TR	2	2	–	–

SITE 603 HOLE CORE 35 CORED INTERVAL 631.0–640.6 m



LITHOLOGIC DESCRIPTION

MICA-BEARING SILT-RICH CLAYSTONE, dark greenish gray (5G 4/1), heavily bioturbated, with black (5Y 2/2), dark olive (5Y 3/2) and gray (5Y 6/1) streaks and burrow fills.

Entire core has moderate drilling disturbance, with drilling biscuits separated by softer material.

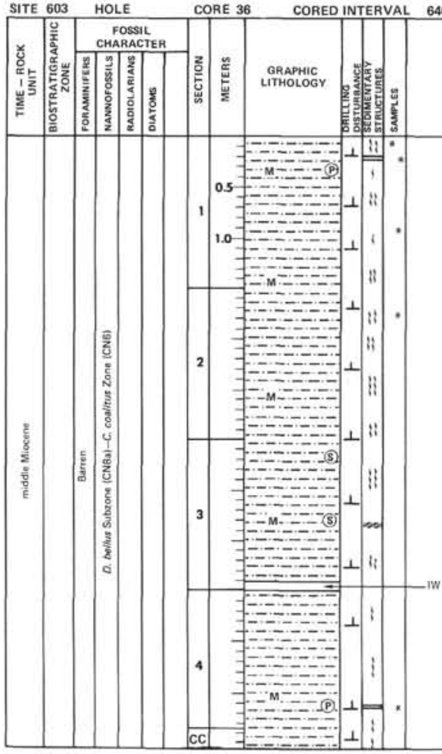
Core contains siderite layers and burrow fills.

Nannofossil-rich silty claystone occurs in the lower part of Section 1.

SMEAR SLIDE SUMMARY (%):

	1, 103	2, 27	2, 45 M	4, 92 M
Texture:				
Silt	35	20	70	80
Clay	65	80	30	20
Composition:				
Quartz	2	3	1	1
Feldspar	–	1	–	–
Mica	3	8	2	3
Heavy minerals	TR	–	–	–
Clay	61	78	30	15
Pyrite	1	TR	TR	1
Micronodules	1	1	2	–
Calc. nannofossils	26	3	15	TR
Plant debris	–	1	TR	–
Siderite	6	5	50	80

SITE 603 HOLE CORE 36 CORED INTERVAL 640.6–650.2 m



LITHOLOGIC DESCRIPTION

MICA-BEARING SILTY CLAYSTONE, cycles of lighter (5GY 5/1) and darker (5G 4/1) greenish gray layers.

Siderite nodules and layers, and pyrite nodules are present. Entire core is moderately bioturbated, and broken up into drilling biscuits.

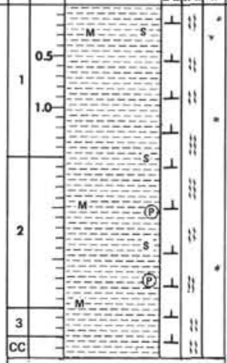
SMEAR SLIDE SUMMARY (%):

	1, 4	1, 22 M	1, 93	2, 28	4, 116 M
Texture:					
Silt	12	92	9	17	–
Clay	88	8	91	83	100
Composition:					
Quartz	1	–	–	2	–
Mica	10	1	2	15	1
Clay	86	7	50	79	50
Glauconite	TR	–	–	–	–
Micronodules	1	–	–	1	–
Carbonate unspec.	–	–	7	–	–
Calc. nannofossils	1	3	41	1	–
Radiolarians pyritized	–	–	–	–	49
Fish remains	TR	–	–	–	–
Siderite	1	89	–	2	–

SITE 603 HOLE CORE 37 CORED INTERVAL 650.2–659.8 m

TIME – ROCK UNIT: middle Miocene
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER: FORAMINIFERS: Barren; NANNOFOSSILS: *D. neohamatus* Zone (CN8)–*C. coalitus* Zone (CN6); RADIOLARIANS; DIATOMS

SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES



LITHOLOGIC DESCRIPTION

MICA-SIDERITE-RICH CLAYSTONE, dark greenish gray (5GY 6/1–5GY 5/1), with moderate bioturbation and gray (5Y 4/1) burrow mottling. Some pyritized burrows are seen.

Entire core is broken up into drilling biscuits.

Core is banded, with lighter colored beds being nannofossil-rich.

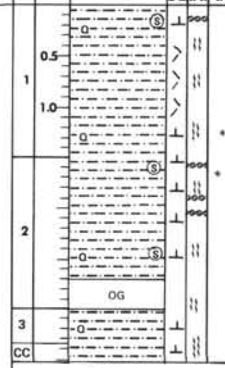
SMEAR SLIDE SUMMARY (%):

	1, 18	1, 34 M	1, 114 M	2, 116
Texture:				
Silt	30	8	2	25
Clay	70	92	98	75
Composition:				
Quartz	4	1	–	3
Feldspar	–	TR	–	–
Mica	15	7	2	12
Heavy minerals	3	–	–	1
Clay	68	76	50	72
Glauconite	TR	TR	–	1
Pyrite	1	–	–	1
Micronodules	–	1	1	–
Calc. nannofossils	3	–	45	–
Radiolarians	2	–	–	–
Sponge spicules	1	–	–	–
Fish remains	TR	TR	–	TR
Plant debris	TR	TR	–	–
Siderite	3	15	2	10

SITE 603 HOLE CORE 38 CORED INTERVAL 659.8–669.4 m

TIME – ROCK UNIT: middle Miocene
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER: FORAMINIFERS: N14; NANNOFOSSILS: *D. neohamatus* Zone (CN8)–*C. coalitus* Zone (CN6); RADIOLARIANS; DIATOMS

SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES



LITHOLOGIC DESCRIPTION

QUARTZ-BEARING SILTY CLAYSTONE, dark greenish gray (5GY 4/1) to greenish gray (5G 5/1), with pyritized burrows, and siderite nodules.

Core is moderately bioturbated, and shows moderate to severe drilling disturbance.

Claystone expands when exposed to fresh water.

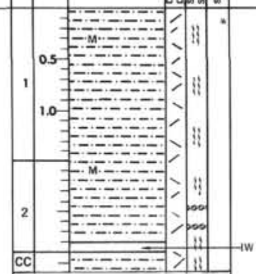
SMEAR SLIDE SUMMARY (%):

	1, 129	2, 20 M
Texture:		
Silt	25	35
Clay	75	65
Composition:		
Quartz	10	20
Feldspar	3	5
Mica	3	3
Clay	75	65
Glauconite	TR	–
Pyrite	2	2
Zeolite	TR	–
Calc. nannofossils	TR	TR
Fish remains	–	TR
Plant debris	2	TR
Siderite	5	5

SITE 603 HOLE CORE 39 CORED INTERVAL 669.4–679.0 m

TIME – ROCK UNIT: middle Miocene
BIOSTRATIGRAPHIC ZONE
FOSSIL CHARACTER: FORAMINIFERS: Barren; NANNOFOSSILS: *D. neohamatus* Zone (CN8)–*C. coalitus* Zone (CN6); RADIOLARIANS; DIATOMS

SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES



LITHOLOGIC DESCRIPTION

MICA-RICH SILTY CLAYSTONE, dark greenish gray (5BG 4/1–5G 4/1), with moderate bioturbation, including *Chondrites* and *Planolites* burrows.

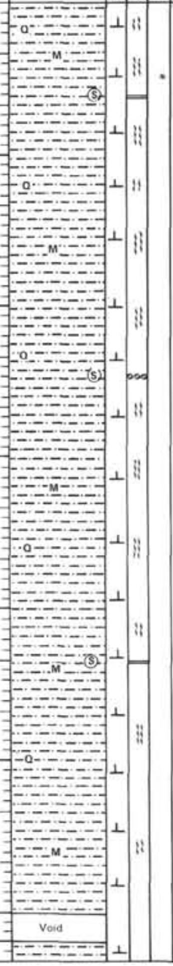
Entire core is severely disturbed by drilling.

SMEAR SLIDE SUMMARY (%):

	1, 12
Texture:	
Silt	25
Clay	75
Composition:	
Quartz	1
Mica	15
Heavy minerals	1
Clay	78
Pyrite	2
Plant debris	TR
Siderite	3

SITE 603 HOLE CORE 40 CORED INTERVAL 679.0–688.6 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
middle Miocene		N14	*D. neohamatus* Zone (CN8)–*C. coalitus* Zone (CN6)			1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0



LITHOLOGIC DESCRIPTION

QUARTZ-MICA-BEARING SILTY CLAYSTONE, dark greenish gray (5G 4/1–5BG 4/1), with lighter bands of more carbonate-rich sediment.

Entire core moderately bioturbated, with siderite burrow fills.

Core disturbed by drilling, occurs as drilling biscuits separated by drill breccia.

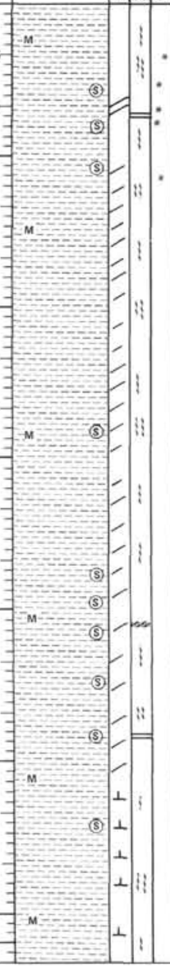
Core contains siderite layers and nodules.

SMEAR SLIDE SUMMARY (%):

	1, 78
Texture:	
Silt	30
Clay	70
Composition:	
Quartz	10
Feldspar	2
Mica	5
Heavy minerals	TR
Clay	75
Pyrite	1
Calc. nannofossils	TR
Plant debris	2
Siderite	5

SITE 603 HOLE CORE 41 CORED INTERVAL 688.6–698.2 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
middle Miocene		*G. nepenthes*–*G. siakensis* Zone (N14)	*D. neohamatus* Zone (CN8)–*C. coalitus* Zone (CN6)			1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0



LITHOLOGIC DESCRIPTION

MICA-BEARING CLAYSTONE, bands of dark greenish gray (5G 4/1) and dark grayish green (5GY 4/2).

Core is slightly disturbed by drilling, with Sections 6 and 7 moderately disturbed.

Entire core is slightly to moderately bioturbated, with siderite burrow fills and layers.

SMEAR SLIDE SUMMARY (%):

	1, 56 M	1, 80 M	1, 104 M	1, 119	2, 32 M
Texture:					
Silt	12	12	4	8	–
Clay	88	88	96	92	100
Composition:					
Quartz	1	1	–	TR	–
Mica	12	12	3	8	–
Clay	85	84	86	91	–
Glauconite	1	1	–	–	–
Micronodules	1	1	–	1	–
Calc. nannofossils	–	–	2	–	–
Radiolarians	–	–	TR	TR	–
Fish remains	–	–	TR	–	–
Siderite	1	1	9	TR	100

SITE 603 HOLE CORE 42 CORED INTERVAL 698.2–707.8 m

TIME-ROCK UNIT: middle Miocene

BIOSTRATIGRAPHIC ZONE: *D. exilis* Zone (CN5)–*C. coalitus* Zone (CN6)

FOSSIL CHARACTER: Foraminifers: Barren

Sections: 1, 2, 3, 4, 5, CC

Graphic lithology: OG; 5Y 4/2

LITHOLOGIC DESCRIPTION

MICA-BEARING CLAYSTONE, dark greenish gray (5GY 4/1).

Core moderately to severely bioturbated, with some siderite burrow fills.

A clay layer at Section 3, 89–90 cm appears to be altered volcanic ash.

Sections 1 and 3 are moderately fragmented by drilling.

SMEAR SLIDE SUMMARY (%):

	1, 131	2, 81	3, 85	3, 88
	M	–	M	M
Texture:				
Sand	–	–	–	10
Silt	15	18	15	20
Clay	85	82	85	70
Composition:				
Quartz	1	2	2	8
Feldspar	–	–	TR	3
Mica	6	10	8	12
Heavy minerals	1	1	–	1
Clay	83	82	86	73
Glauconite	–	TR	–	–
Pyrite	2	2	1	1
Micronodules	TR	–	–	–
Calc. nannofossils	1	–	–	–
Radiolarians	1	TR	–	–
Sponge spicules	1	TR	TR	1
Fish remains	1	TR	–	–
Siderite	3	3	3	1

SITE 603 HOLE CORE 43 CORED INTERVAL 707.8–717.4 m

TIME-ROCK UNIT: middle Miocene

BIOSTRATIGRAPHIC ZONE: *D. exilis* Zone (CN5)–*C. coalitus* Zone (CN6)

FOSSIL CHARACTER: Foraminifers: Barren

Sections: 1, 2

Graphic lithology: Void

LITHOLOGIC DESCRIPTION

MICA-BEARING CLAYSTONE, dark grayish green (5G 4/2), with moderate bioturbation.

Section 1 is broken up into drilling biscuits that slowly outgas over an hour interval – Section 2 is a drilling breccia. Holes of outgassing vents contain pyrite framboidal micronodules.

SMEAR SLIDE SUMMARY (%):

	1, 18	1, 58
		M
Texture:		
Silt	7	–
Clay	93	100
Composition:		
Quartz	TR	–
Mica	7	–
Clay	91	–
Pyrite	–	98
Micronodules	1	–
Carbonate unspec.	TR	–
Calc. nannofossils	1	–
Diatoms	TR	–
Radiolarians	TR	1
Sponge spicules	TR	1
Fish remains	TR	–

SITE 603 HOLE CORE 44 CORED INTERVAL 717.4–727.0 m

TIME-ROCK UNIT: middle Miocene

BIOSTRATIGRAPHIC ZONE: *D. exilis* Zone (CN5)–*C. coalitus* Zone (CN6); *Didymocyrtis antepenultima* Zone

FOSSIL CHARACTER: Foraminifers: Barren

Sections: 1, 2, 3, 4, CC

Samples: IW

LITHOLOGIC DESCRIPTION

QUARTZ-PYRITE-MICA-BEARING SILTY CLAYSTONE, faintly banded with shades of dark greenish gray (5G 4/1–5BG 4/1–5GY 4/1).

Moderate to heavy bioturbation, with *Planolites, Cylindrichnus* (halo burrows), and pyrite and siderite-filled burrows.

Core is moderately to slightly disturbed by drilling.

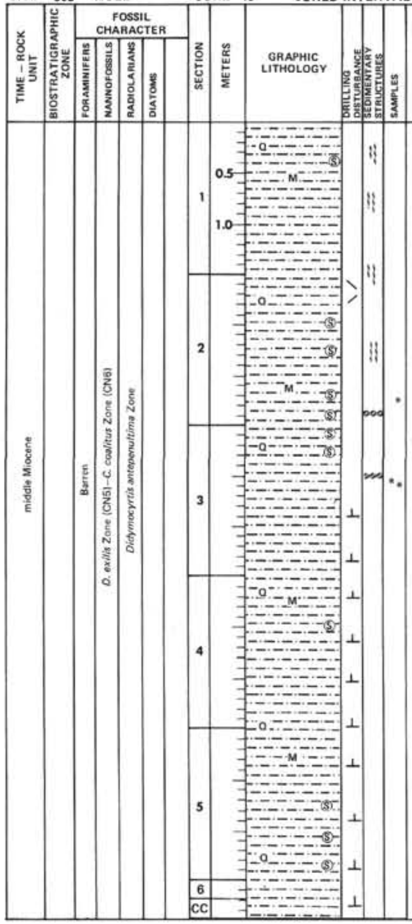
Core outgassed (methane?) upon opening, with pyrite-rich nodules the apparent source of the gas.

A coarse silt layer at 62–63 cm (Section 2) appears to be a distal turbidite with sharp base, a rippled basal layer grading upward to parallel-laminated claystone (Bouma C–D sequence):

SMEAR SLIDE SUMMARY (%):

	2, 48	2, 62.5	2, 63	3, 28
		M	M	M
Texture:				
Silt	30	90	90	100
Clay	70	10	10	–
Composition:				
Quartz	7	84	80	–
Feldspar	3	2	2	–
Mica	5	3	3	–
Heavy minerals	–	–	TR	–
Clay	80	5	5	–
Glauconite	–	2	3	–
Pyrite	5	3	7	100
Zeolite	–	–	TR	–
Carbonate unspec.	TR	1	–	–

SITE 603 HOLE CORE 45 CORED INTERVAL 727.0–736.6 m



LITHOLOGIC DESCRIPTION

QUARTZ-MICA-SIDERITE-BEARING SILTY CLAYSTONE, layers of dark greenish gray (5GY 4/1) alternating with greenish gray (5G 4/1) in undeformed sections.

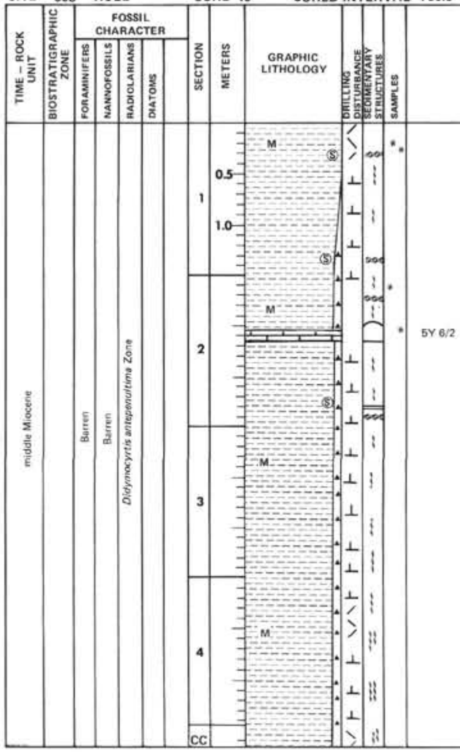
Lower sections moderately deformed into drilling biscuits.

Core is moderately bioturbated, with siderite nodules and concretions.

SMEAR SLIDE SUMMARY (%):

	2, 129 M	3, 57	3, 60
Texture:			
Silt	–	40	20
Clay	–	60	80
Composition:			
Quartz	TR	3	2
Mica	TR	8	10
Heavy minerals	–	1	1
Clay	–	82	79
Glauconite	–	–	TR
Pyrite	–	1	2
Calc. nannofossils	–	–	1
Radiolarians	–	TR	TR
Fish remains	–	–	TR
Plant debris	–	TR	TR
Siderite	100	5	5

SITE 603 HOLE CORE 46 CORED INTERVAL 736.6–746.2 m



LITHOLOGIC DESCRIPTION

SIDERITE-MICA-RICH CLAYSTONE, dark greenish gray (5G 4/1), grading from 43 to 150 cm in Section 1 to:

BIOGENIC SILICA-RICH CLAYSTONE, dark greenish gray (5GY 4/1) that is present to Core Catcher.

Entire core is slightly to moderately bioturbated, with siderite burrow fills.

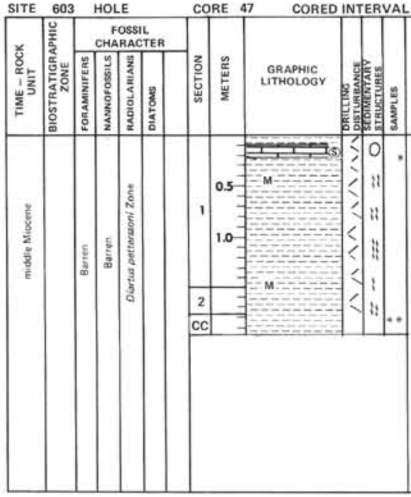
A concretion of SIDERITE-BEARING LIMESTONE occurs at Section 2, 48–65 cm, light olive gray (5Y 6/2) in color.

Entire core is moderately to severely disturbed by drilling.

SMEAR SLIDE SUMMARY (%):

	1, 21	1, 25 M	2, 16	2, 57 M
Texture:				
Sand	–	3	–	–
Silt	30	27	30	90
Clay	70	70	70	10
Composition:				
Quartz	2	1	–	TR
Feldspar	TR	–	–	–
Mica	12	15	10	TR
Heavy minerals	1	TR	–	–
Clay	70	70	68	7
Glauconite	–	TR	–	–
Pyrite	3	–	2	3
Micronodules	–	3	–	–
Carbonate unspec.	1	–	–	80
Calc. nannofossils	–	–	2	–
Diatoms	–	–	3	–
Radiolarians	TR	TR	5	TR
Sponge spicules	1	1	8	TR
Fish remains	TR	TR	–	–
Siderite	10	10	2	10

SITE 603 HOLE CORE 47 CORED INTERVAL 746.2–755.8 m



LITHOLOGIC DESCRIPTION

MICA-BEARING CLAYSTONE, greenish gray (5G 5/1–5BG 5/1) unoriented pieces in drilling breccia. Individual pieces show evidence of burrow mottling.

A concretion of SIDERITE-BEARING LIMESTONE occurs at Section 1, 21–29 cm – this may be due to downhole contamination.

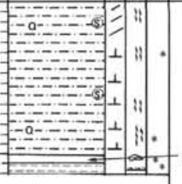
SMEAR SLIDE SUMMARY (%):

	1, 27 M	CC, 10	CC, 11
Texture:			
Silt	–	7	12
Clay	100	93	88
Composition:			
Quartz	–	1	4
Mica	–	8	8
Clay	–	90	86
Glauconite	–	–	TR
Micronodules	–	TR	1
Carbonate unspec.	95	1	–
Radiolarians	–	TR	TR
Sponge spicules	TR	2	1
Siderite	5	–	–

SITE 603 HOLE CORE 48 CORED INTERVAL 755.8–765.4 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
middle Miocene		Barren	Barren	*Diartus petterssoni* Zone		1, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

QUARTZ-BEARING SILTY CLAYSTONE, dark greenish gray (5G 4/1), with moderate bioturbation, seen by semi-horizontal burrows (*Chondrites*).

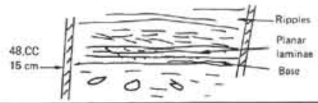
Core disturbed into drilling biscuits in breccia.

Core outgassed (methane?) immediately after splitting – seen by fizzing of wetted cut surfaces.

Core Catcher has a SIDERITE concretion at 5 cm, and at 15 cm shows a 3–5 mm thick turbidite sequence, with a flat, sharp base below parallel-laminated quartz silt, then above this are ripples of quartz silt.

SMEAR SLIDE SUMMARY (%):

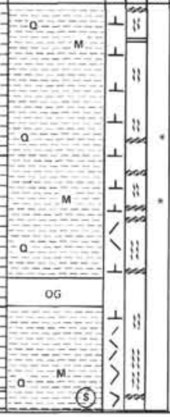
	1, 58	1, 136	CC,5 M	CC,15 M
Texture:				
Sand	–	–	–	10
Silt	8	30	65	50
Clay	92	70	35	40
Composition:				
Quartz	5	5	1	55
Feldspar	1	TR	–	1
Mica	3	4	TR	–
Heavy minerals	TR	TR	–	TR
Clay	85	86	TR	30
Glauconite	–	TR	–	2
Pyrite	2	2	–	5
Zeolite	–	–	–	TR
Carbonate unspec.	3	3	–	2
Foraminifers	–	–	–	TR
Calc. nannofossils	TR	TR	–	TR
Diatoms	–	–	–	TR
Radiolarians	TR	–	–	3
Sponge spicules	–	TR	–	2
Plant debris	1	TR	–	–
Siderite	–	–	99	–



SITE 603 HOLE CORE 49 CORED INTERVAL 765.4–775.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
middle Miocene		Barren	Barren	*Diartus petterssoni* Zone		1, 2, 3, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

QUARTZ-MICA-BIOGENIC SILICA-BEARING CLAYSTONE, dark greenish gray (5G 4/1–5GY 4/1).

Moderately bioturbated.

Core produces gas (methane?) from cut surfaces.

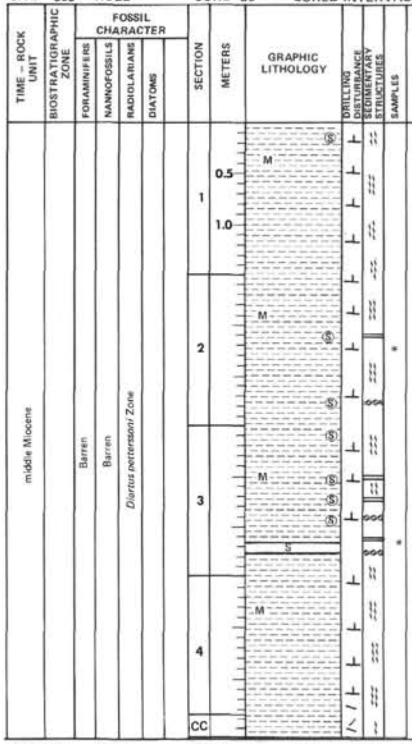
Entire core broken up into drilling biscuits.

Core contains trace to 5% siliceous microfossils.

SMEAR SLIDE SUMMARY (%):

	1, 134	2, 43
Texture:		
Silt	10	9
Clay	90	91
Composition:		
Quartz	3	5
Mica	5	4
Clay	88	86
Glauconite	–	TR
Calc. nannofossils	3	–
Diatoms	–	TR
Radiolarians	1	5
Sponge spicules	TR	TR
Fish remains	–	TR
Siderite	–	TR

SITE 603 HOLE CORE 50 CORED INTERVAL 775.0–784.6 m



LITHOLOGIC DESCRIPTION

MICA-BEARING CLAYSTONE, faintly banded shades of dark greenish gray (5G 4/1–5GY 4/1) to dark gray (5Y 4/1).

Moderately to heavily bioturbated, with some siderite-filled *Planolites* and *Chondrites* burrows.

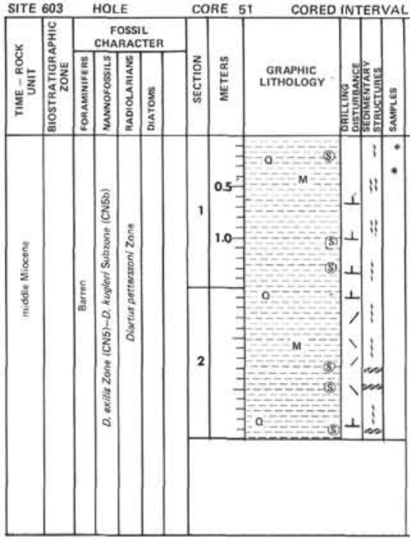
Core emits gas (methane?) from cut surfaces.

Entire core moderately disturbed by drilling.

SMEAR SLIDE SUMMARY (%):

	2, 71	3, 118 M
Texture:		
Sand	2	–
Silt	28	20
Clay	70	80
Composition:		
Quartz	1	1
Feldspar	–	1
Mica	6	1
Heavy minerals	TR	–
Clay	81	5
Glauconite	TR	1
Pyrite	2	1
Calc. nannofossils	1	–
Diatoms	1	–
Radiolarians	5	–
Sponge spicules	1	–
Fish remains	TR	–
Siderite	2	90

SITE 603 HOLE CORE 51 CORED INTERVAL 784.6–794.2 m



LITHOLOGIC DESCRIPTION

QUARTZ-MICA-BEARING CLAYSTONE, faintly banded shades of dark grayish green (5GY 4/1–5G 4/1).

Slightly to moderately bioturbated, with gray (N4–5Y 5/1) siderite burrow fills, rare shell fragments, and agglutinated benthic foraminifera.

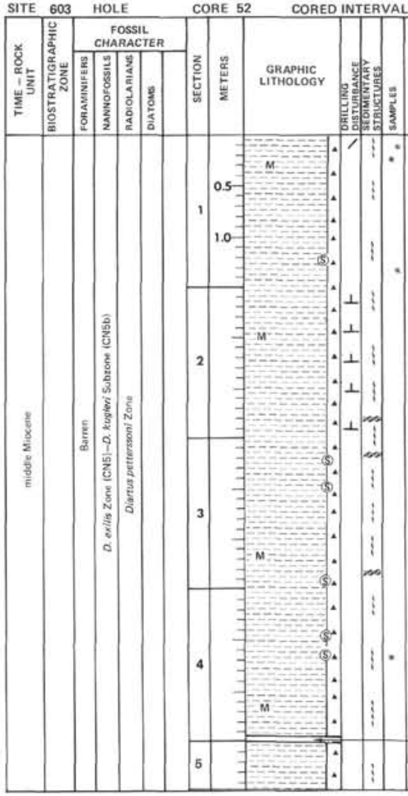
Core moderately to severely disturbed by drilling.

Core emits gas (methane?) from cut surfaces.

SMEAR SLIDE SUMMARY (%):

	1, 10	1, 35
Texture:		
Silt	7	6
Clay	93	94
Composition:		
Quartz	2	TR
Mica	5	6
Clay	92	91
Micronodules	TR	TR
Diatoms	TR	–
Radiolarians	TR	–
Sponge spicules	1	1
Fish remains	TR	TR
Siderite	TR	2

SITE 603 HOLE CORE 52 CORED INTERVAL 794.2–803.8 m



LITHOLOGIC DESCRIPTION

BIOGENIC SILICA and MICA-BEARING CLAYSTONE, dark greenish gray (5GY 4/1–5G 4/1).

Slightly to moderately bioturbated, with siderite burrow fills.

Section 2 broken up into drilling biscuits.

Core emits gas from cut surfaces.

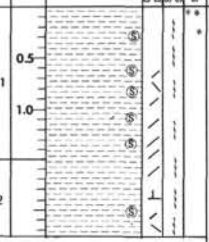
Core contains siderite nodules and layers.

SMEAR SLIDE SUMMARY (%):

	1, 19 M	1, 25	1, 136	4, 69
Texture:				
Silt	4	9	4	3
Clay	96	91	96	97
Composition:				
Quartz	TR	1	TR	1
Mica	2	8	2	2
Heavy minerals	–	–	TR	TR
Clay	86	76	82	94
Glauconite	TR	TR	TR	–
Micronodules	TR	1	TR	1
Calc. nannofossils	–	–	–	TR
Diatoms	TR	1	I	–
Radiolarians	8	8	10	1
Sponge spicules	3	3	3	1
Siderite	1	2	2	TR

SITE 603 HOLE CORE 53M CORED INTERVAL 803.8–823.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION
middle Miocene		Barren	D. exilis Zone (CN5)–D. kugleri Subzone (CN5b)			1, 2



LITHOLOGIC DESCRIPTION

WASH CORE

SIDERITE-BIOGENIC SILICA-BEARING CLAYSTONE, dark grayish green (5G 4/1–5GY 4/1) in faint bands, with slight bioturbation.

Some siderite nodules and burrow fills are present.

Core is slightly to severely disturbed by drilling.

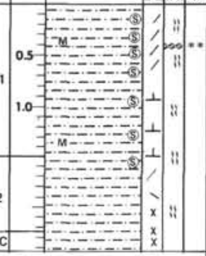
Core biscuits emit gas (methane?) from cut surfaces.

SMEAR SLIDE SUMMARY (%):

	1, 2 M	1, 3 M	1, 28
Texture:			
Silt	4	10	1
Clay	96	90	99
Composition:			
Quartz	TR	2	1
Feldspar	TR	–	–
Mica	4	4	1
Heavy minerals	–	–	TR
Clay	91	73	95
Glauconite	TR	1	–
Micronodules	TR	1	TR
Calc. nannofossils	–	–	TR
Radiolarians	1	6	1
Sponge spicules	1	2	1
Siderite	3	11	1

SITE 603 HOLE CORE 54 CORED INTERVAL 823.0–832.6 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION
middle Miocene		G. nepenthes–G. siakensis Zone (N14)	D. exilis Zone (CN5)–D. kugleri Subzone (CN5b)	D. alata Zone		1, 2, CC



LITHOLOGIC DESCRIPTION

MICA-RICH SILTY CLAYSTONE, dark grayish green (5G 4/1–5BG 4/1) bands of darker and lighter color.

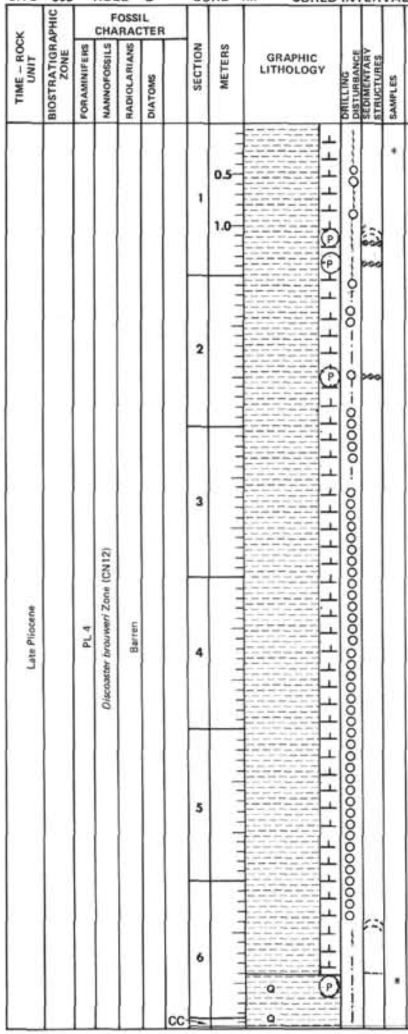
Moderately bioturbated, with siderite burrow fills and concretions.

Core becomes progressively more disturbed from drilling, from Section 1 to Core Catcher.

SMEAR SLIDE SUMMARY (%):

	1, 40	1, 41
Texture:		
Sand	–	3
Silt	12	35
Clay	88	62
Composition:		
Quartz	2	4
Mica	5	15
Heavy minerals	1	1
Clay	88	71
Glauconite	TR	1
Pyrite	1	2
Calc. nannofossils	1	–
Radiolarians	–	1
Sponge spicules	–	TR
Fish remains	–	TR
Plant debris	TR	TR
Siderite	2	5

SITE 603 HOLE B CORE 1M CORED INTERVAL 0.0–285.0 m



LITHOLOGIC DESCRIPTION

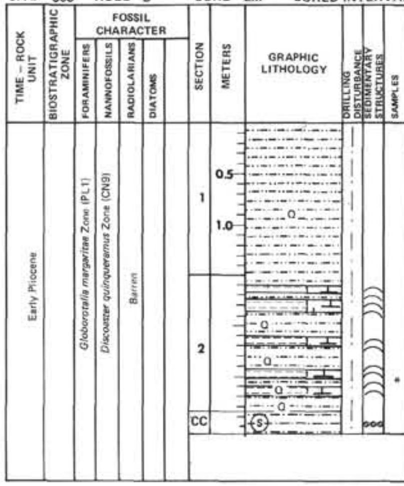
WASH CORE:
NANNOFOSSIL-RICH CLAY,
predominantly greenish gray (5GY 5/1) with moderate to severe drilling disturbance. No bioturbation observed, possibly due to severity of drilling disturbance. Faint yellowish-brown gray (5Y 5/1) bands and pyritized burrows in the upper portion of the core. 50-90 cm interval of Section 6 contains scattered dark gray (N3) pyrite?-rich clusters.

QUARTZ-BEARING CLAY,
greenish gray (5G 5/1 to 5GY 5/1) with rare small pyritized? burrows? in the lower portion of the core.

SMEAR SLIDE SUMMARY (%):

	1,24 D	6,95 D
Texture:		
Silt	40	40
Clay	60	60
Composition:		
Quartz	3	5
Mica	TR	TR
Clay	69	92
Pyrite	3	1
Carbonate unspec.	3	2
Foraminifers	2	–
Calc. nannofossils	20	TR
Sponge spicules	TR	–

SITE 603 HOLE B CORE 2M CORED INTERVAL 285.0–417.1 m



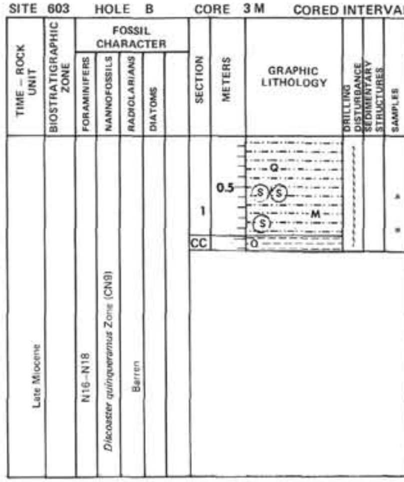
LITHOLOGIC DESCRIPTION

WASH CORE:
QUARTZ-RICH CLAY
dark greenish gray (5G 4/1) with layers of moderately disturbed greenish gray (5G 5/1)
NANNOFOSSIL CLAY in the lower portion of the core.
Rare siderite nodule (1 cm: diameter) in the core catcher.

SMEAR SLIDE SUMMARY (%)

	2,101 M	CC,7 D
Texture:		
Silt	40	20
Clay	60	80
Composition:		
Quartz	2	15
Feldspar	–	TR
Mica	TR	2
Heavy minerals	–	TR
Clay	60	78
Glauconite	–	TR
Pyrite	–	2
Carbonate unspec.	3	3
Foraminifers	TR	TR
Calc. nannofossils	35	TR
Fish remains	–	TR

SITE 603 HOLE B CORE 3 M CORED INTERVAL 417.1–479.0 m



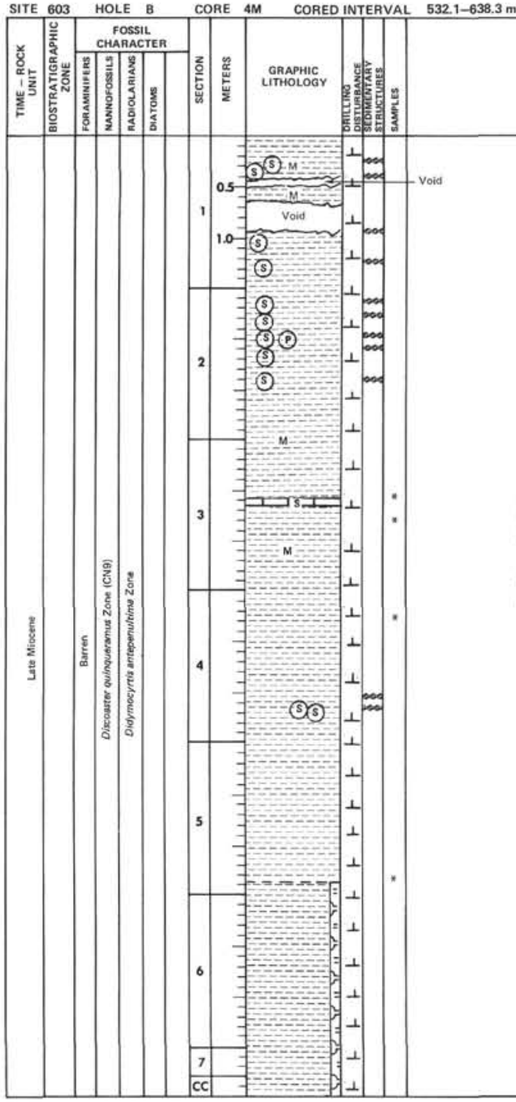
LITHOLOGIC DESCRIPTION

WASH CORE:
QUARTZ-AND MICA-BEARING CLAY.
dark greenish gray (5G 4/1) to a darker gray green (5BG 4/1) in the core catcher.
No structures or bioturbation observed, possibly due to severity of drilling deformation. Rare sideritic nodules.

SMEAR SLIDE SUMMARY (%):

	1,80 D	1,88 M
Texture:		
Silt	12	–
Clay	88	100
Composition:		
Quartz	4	–
Feldspar	TR	–
Mica	8	TR
Heavy minerals	TR	–
Clay	87	–
Palagonite	TR	–
Glauconite	TR	–
Pyrite	TR	–
Fish remains	1	–
Other Siderite	–	100

SITE 603 HOLE B CORE 4M CORED INTERVAL 532.1–638.3 m



LITHOLOGIC DESCRIPTION

WASH CORE:
MICA-BEARING CLAY
dark greenish gray (5G 4/1), no structure apparent. Siderite infilling of burrows (usually < 1 cm diameter) more abundant in the upper portion of the core. A 1 cm thick layer of siderite occurs in the middle of the core.

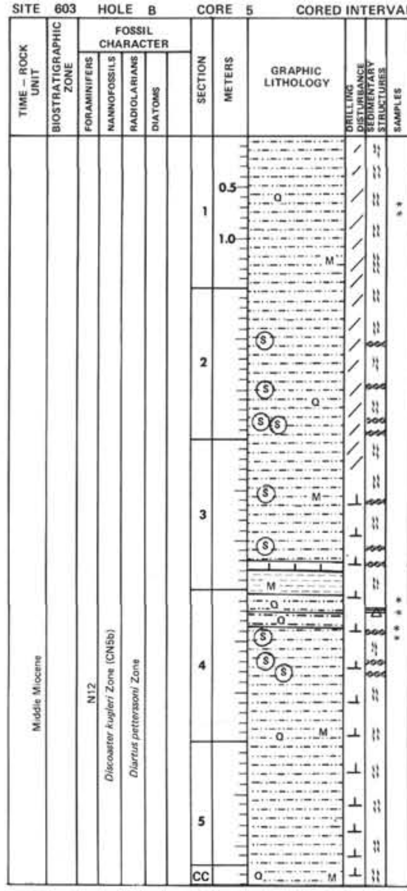
In the lower portion of the core the lithology changes to BIOGENIC SILICA-BEARING CLAY, with no change in color or structure.

NOTE: Section 1 had been continuous. Void observed during formations; core liner punctured and gas released.

SMEAR SLIDE SUMMARY

	3, 63 M	3, 75 D	4, 25 D	5, 143 D
Texture:				
Sand	–	–	–	1
Silt	15	15	25	19
Clay	85	85	75	80
Composition:				
Quartz	–	1	1	1
Feldspar	–	TR	TR	–
Mica	–	7	8	3
Heavy minerals	–	1	2	1
Clay	2	87	83	84
Pyrite	1	TR	3	1
Carbonate unspec.	–	2	2	2
Calc. nannofossils	–	2	1	3
Diatoms	–	–	–	1
Radiolarians	–	–	–	3
Sponge spicules	–	–	TR	1
Fish remains	–	TR	TR	–
Plant debris	–	TR	TR	–
Other Siderite	97	–	–	–

SITE 603 HOLE B CORE 5 CORED INTERVAL 821.4–831.0 m



LITHOLOGIC DESCRIPTION

QUARTZ- AND MICA-BEARING SILT-RICH CLAYSTONE
The majority of the core is composed of 1 to 2 cm-thick bands of slightly bioturbated dark greenish gray (5G 4/1–5GY 4/1) silt-rich claystone and of heavily bioturbated, darker greenish gray (5Y 4/1) silt-rich claystone (containing less mica but more quartz than the lighter green bands). Bioturbation of the darker bands is mostly *Planolites*-type horizontal burrows that frequently are associated with *Chrondrites*-type burrows. White specks of calcareous benthic foraminifers? are scattered throughout the core. In Section 4, 12–32 cm, is a turbidite layer composed of parallel-laminated, graded bed of quartz silt and wavy laminations (sediment-starved ripples) underlain by parallel laminations of silty claystone.

Core emitted gas upon splitting.

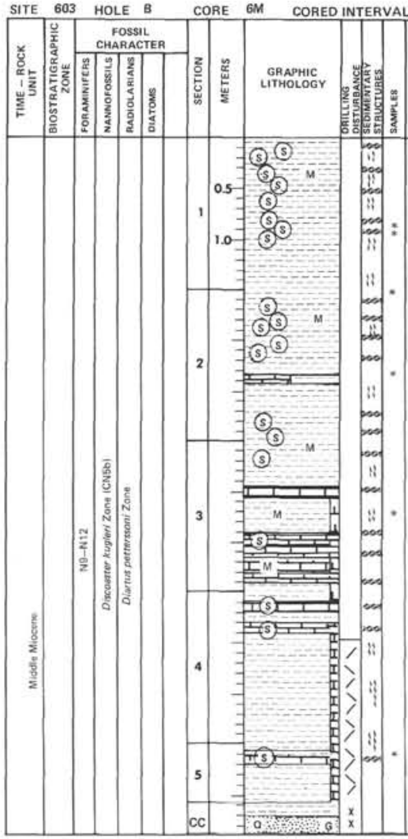
SMEAR SLIDE SUMMARY (%)

	1, 61 D	1, 63 D	4, 12 D	4, 19 M	4, 26 M	4, 31 M
Texture:						
Sand	–	2	–	–	5	10
Silt	20	18	15	15	85	60
Clay	80	80	85	85	10	30
Composition:						
Quartz	4	3	1	3	75	15
Mica	6	8	5	4	5	10
Heavy minerals	1	TR	1	–	3	2
Clay	81	80	84	85	10	65
Glauconite	TR	1	–	–	2	2
Pyrite	3	2	2	4	3	3
Calc. nannofossils	2	–	1	1	TR	–
Diatoms	TR	TR	–	–	–	TR
Radiolarians	–	1	–	–	–	TR
Sponge spicules	–	–	TR	TR	–	TR
Plant debris	TR	TR	1	TR	TR	TR
Other Siderite	3	5	3	3	2	3

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2 75-77	5 75-77
Organic carbon	0.48	0.58
Carbonate	7	9
C/N	10.5	11.3

SITE 603 HOLE B CORE 6M CORED INTERVAL 831.0–850.2 m



LITHOLOGIC DESCRIPTION

Gas emitted
WASH CORE:
Irregularly banded (1 to 2 cm thick) dark greenish gray CLAYSTONE (5G 4/1-5BG 4/1, slightly brown) and MICA-BEARING CLAYSTONE (5GY 4/1, slightly olive green). The claystone is more bioturbated horizontally and contains less mica than the greener, mica-bearing claystone (very similar to Core 5R). Some burrows are filled by siderite and are highly compacted perpendicular to the bedding plane and are abundant enough to compose layers in the core.
In the lower portion of the core catcher is a GLAUCONITE-QUARTZ-RICH SILTY SAND, poorly consolidated (possibly the lower graded interval of a turbidite). All sedimentary structures, lower contact, and upper portion are washed away. Split core emitted gas.

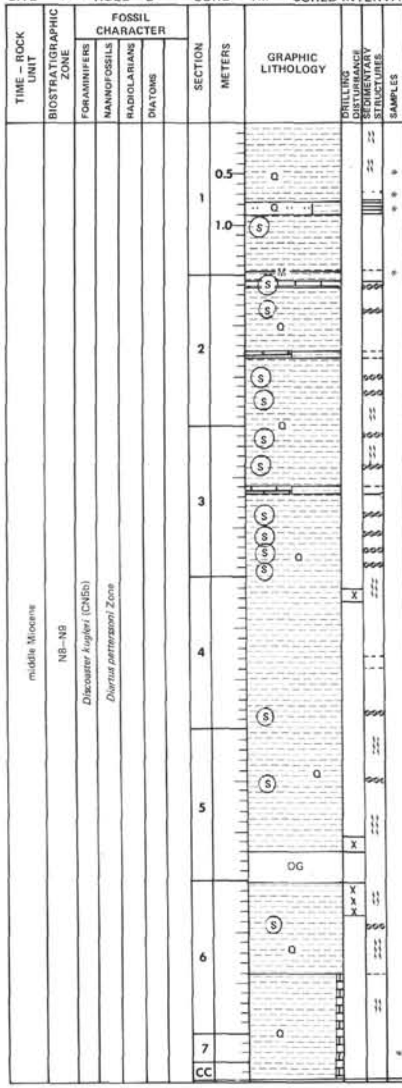
SMEAR SLIDE SUMMARY (%)

	1, 88 D	1, 90 D	2, 5 M	2, 87 M	3, 73 D	5, 15 D	CC, 18 M
Texture:							
Sand	–	–	–	–	–	–	58
Silt	8	10	9	50	9	12	27
Clay	92	90	91	50	91	88	15
Composition:							
Quartz	1	2	2	–	1	2	28
Mica	2	5	6	1	3	3	5
Heavy minerals	TR	–	TR	–	TR	TR	TR
Clay	92	90	91	50	90	88	15
Glauconite	–	TR	TR	–	–	–	25
Pyrite	1	TR	TR	–	1	2	–
Zeolite	–	–	–	–	TR	TR	–
Foraminifers	–	–	–	–	–	–	TR
Calc. nannofossils	1	–	TR	TR	2	–	7
Radiolarians	–	–	–	–	TR	–	–
Fish remains	–	1	–	–	–	–	–
Other Siderite	3	3	1	49	3	5	20

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2 75-77	5 20-22
Organic carbon	0.33	0.42
Carbonate	8	10
C/N	9.4	10.4

SITE 603 HOLE B CORE 7M CORED INTERVAL 850.2–869.4 m



LITHOLOGIC DESCRIPTION

Emitted gas
WASH CORE.
Irregularly banded dark greenish gray (5GY 4/1) and a darker greenish gray (5G 4/1) QUARTZ-BEARING CLAYSTONE, similar to Cores 5 and 6M, with moderate bioturbation. Many burrows are filled with siderite and compacted. Several 1-2 cm bands contain a concentration of silt-size siderite specks in the clays tone. In the lower portion of the Core, a gradual change in color to dark olive gray (5Y 3/2) with less obvious banding in a SIDERITE-QUARTZ-BEARING CLAYSTONE. In Section 1, 70-87 cm, is a turbidite layer composed of parallel-laminations of CLAY-RICH QUARTZ SILTSTONE overlain by a pelitic division of ORGANIC MATTER AND QUARTZ-BEARING CLAYSTONE. In Section 2, 0-6 cm, is a mud-turbidite? composed of MICA-BEARING CLAYSTONE with a sharp basal contact. See figure below. Split core emitted gas.

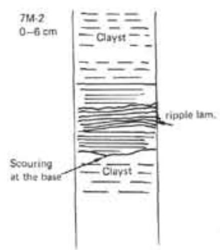
SMEAR SLIDE SUMMARY (%)

	1, 59 D	1, 74 M	1, 86 M	2, 6 M	7, 36 D
Texture:					
Sand	–	–	10	–	–
Silt	15	10	70	8	5
Clay	85	90	20	92	95
Composition:					
Quartz	8	3	60	2	3
Feldspar	–	–	TR	–	–
Mica	2	TR	2	6	2
Heavy minerals	TR	–	TR	–	TR
Clay	83	89	30	86	85
Glauconite	1	–	3	–	–
Pyrite	3	1	4	3	2
Calc. nannofossils	–	TR	–	–	–
Radiolarians	–	TR	–	–	–
Org. matter	–	5	–	1	3
Other Siderite	3	2	1	2	5

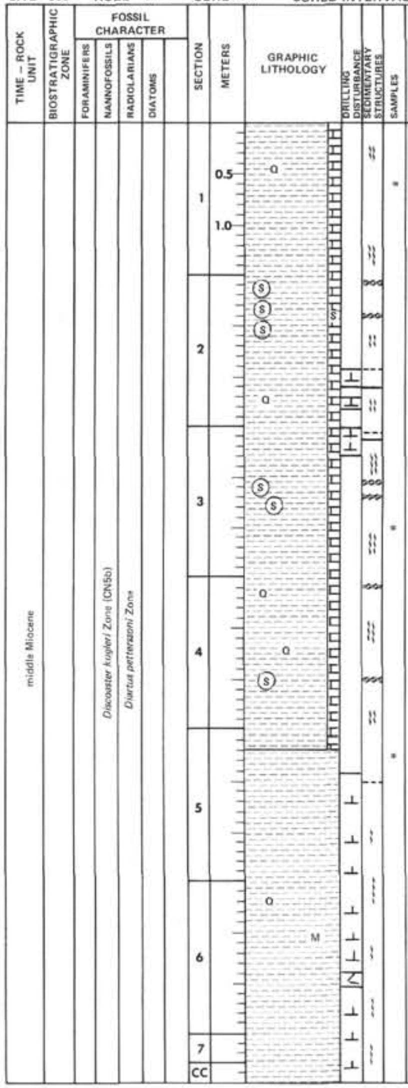
ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	1 72-74	2 70-72	5 70-72
Organic carbon	1.32	0.24	0.39
Carbonate	<1	8	9
C/N	16.4 black	8.3	9.9

7M-2
0–6 cm



SITE 603 HOLE B CORE 8M CORED INTERVAL 869.4–892.0 m



LITHOLOGIC DESCRIPTION

WASH CORE

SIDERITE- AND QUARTZ-BEARING CLAYSTONE, irregularly banded (mm to cm scale) dark greenish gray (5GY 4/1 and 5BG 4/1) with rare streaks of greenish gray (5G 5/1). Siderite filling of burrows is less abundant than in previous cores. In the lower portion of the core there is a transition to a MICA AND QUARTZ-BEARING CLAYSTONE, dark gray (5Y 4/1) and less obvious banding and bioturbation. In Section 2, 94–103 cm, and Section 3, 4–6 cm are? mud turbidities?, that are dark gray (5Y 4/1) and have distinct lower contacts. Split core emitted gas.

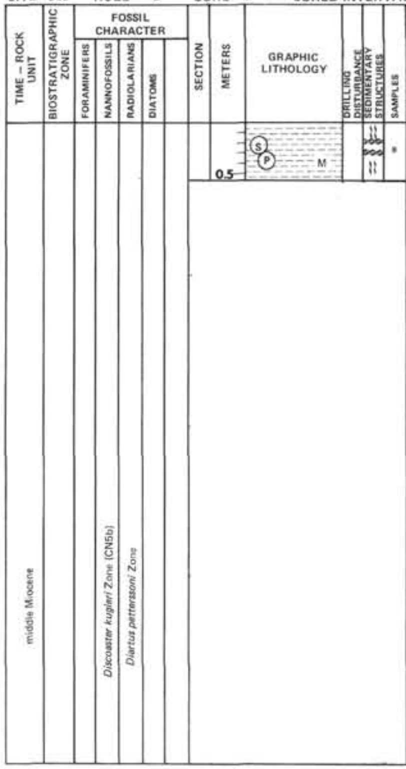
SMEAR SLIDE SUMMARY (%)

	1, 64	3, 106	5, 36
	D	M	D
Texture:			
Silt	15	10	15
Clay	85	90	85
Composition:			
Quartz	6	5	4
Mica	3	5	6
Clay	75	90	84
Glauconite	TR	–	–
Pyrite	6	–	4
Zeolite	–	TR	–
Diatoms	TR	–	–
Radiolarians pyritized	–	–	TR
Fish remains	TR	–	–
Other Siderite	8	–	2

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2	5
	80-81	82-84
Organic carbon	0.34	0.55
Carbonate	9	10
C/N	9.4	11.8

SITE 603 HOLE B CORE 9 CORED INTERVAL 892.0–898.2 m



LITHOLOGIC DESCRIPTION

MICA-BEARING CLAYSTONE

dark greenish gray (5GY 4/1), moderately bioturbated. Rare siderite and pyrite filled burrows.

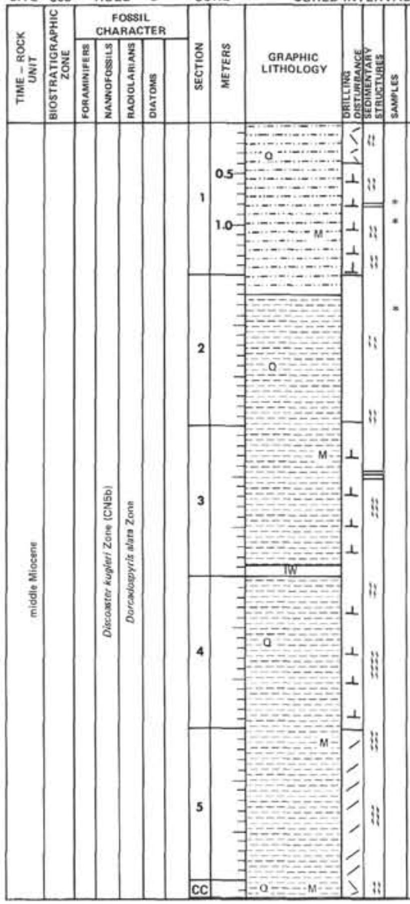
SMEAR SLIDE SUMMARY (%)

	1, 27
	D
Texture:	
Silt	6
Clay	94
Composition:	
Quartz	1
Mica	5
Clay	94
Pyrite	TR
Fish remains	TR

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	1
	20-22
Organic carbon	0.52
Carbonate	8
C/N	12.3

SITE 603 HOLE B CORE 10 CORED INTERVAL 898.2–907.8 m



LITHOLOGIC DESCRIPTION

SILT-RICH CLAYSTONE TO SILT-BEARING CLAYSTONE
all dark greenish gray (5GY 4/1 and 5BG 4/1), moderately bioturbated and faintly banded. At 83 cm, in Section 1 occurs a bluish black 2 mm thick band/horizontal burrow composed of BIOGENIC SILICA BEARING, SILT-RICH CLAYSTONE. At 46-48 cm, in Section 3, occurs slightly wavy parallel laminae of greenish gray and black organic-rich laminae.
White specks of benthic foraminifers? throughout Core.

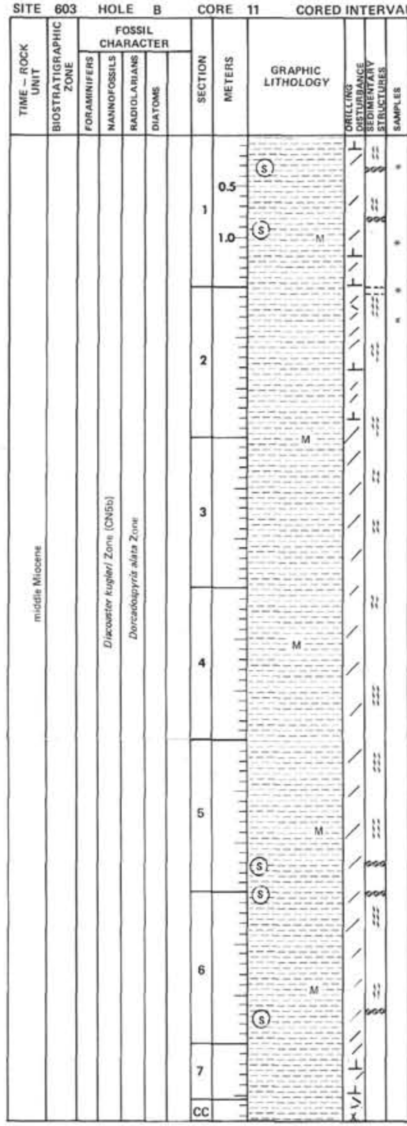
SMEAR SLIDE SUMMARY (%)

	1, 83 M	1, 96 D	2, 35 D
Texture:			
Silt	30	30	15
Clay	70	70	85
Composition:			
Quartz	6	8	2
Mica	3	3	4
Heavy minerals	1	1	1
Clay	80	83	89
Glauconite	1	TR	TR
Pyrite	2	1	1
Diatoms	2	1	TR
Radiolarians pyritized	1	TR	TR
Sponge spicules	–	TR	–
Plant debris	–	TR	TR
Other Siderite	4	3	3

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2 82-84	5 77-79
Organic carbon	0.31	0.35
Carbonate	9	8
C/N	9.5	9.8

SITE 603 HOLE B CORE 11 CORED INTERVAL 907.8–927.0 m



LITHOLOGIC DESCRIPTION

WASH CORE
MICA-BEARING CLAYSTONE
dark greenish gray (5GY 4/1 to 5G 4/1) moderately bioturbated, and irregularly banded with very dark gray (N4, 5Y 3/1). Rare siderite nodules/burrow fills. White specks of benthic foraminifers? are common.
Color banding is accompanied by variations in degree of bioturbation with the darker green being more intensely burrowed. Narrow bands or lenses of siderite-rich, and siderite-bearing claystone (5Y 4/1 dark gray) also occur in the core. Split core emitted gas.

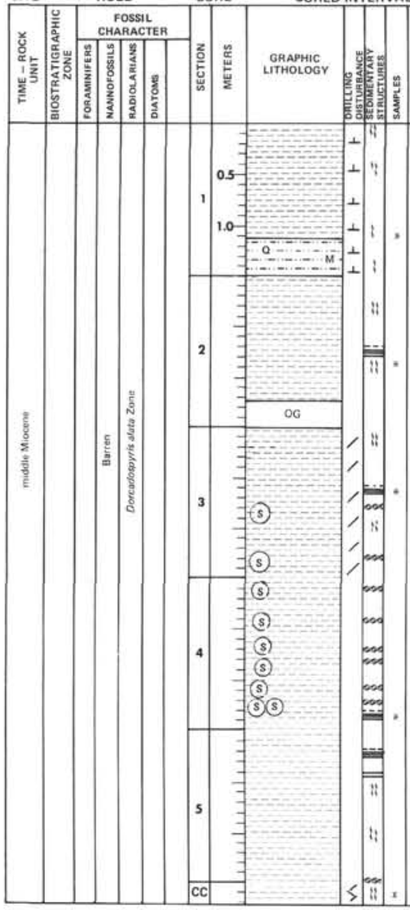
SMEAR SLIDE SUMMARY (%)

	1, 32 M	1, 103 D	2, 2 M	2, 57 D
Texture:				
Silt	15	12	12	12
Clay	85	88	88	88
Composition:				
Quartz	3	2	TR	1
Feldspar	2	2	–	–
Mica	7	5	–	1
Clay	85	88	88	87
Glauconite	TR	TR	–	–
Pyrite	2	2	–	TR
Calc. nannofossils	TR	–	TR	1
Radiolarians	TR	TR	–	–
Fish remains	TR	TR	TR	–
Plant debris	TR	–	–	TR
Other Siderite	1	1	12	10

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2 78-80	5 81-82
Organic carbon	0.37	0.24
Carbonate	10	9
C/N	10.7	8.6

SITE 603 HOLE B CORE 12 CORED INTERVAL 927.0–936.6 m



LITHOLOGIC DESCRIPTION

CLAYSTONE

grayish green (5G 4/2) with dark gray (5G 4/1) burrows changing to SILT-RICH CLAYSTONE in the lower portion of Section 1. Section 2 is moderately bioturbated dark greenish gray (5G 4/1) CLAYSTONE with an interval of dark gray (5G 3/1) parallel laminations with a sharp base and gradational top at 78 cm. and a similar feature occurs in Section 3 at 65 cm, Section 4 at 135 cm, and Section 5 at 20 and 42 cm. Section 3 also has faint banding throughout. Sections 3, 4, and 5 contain siderite nodules/burrow infills.

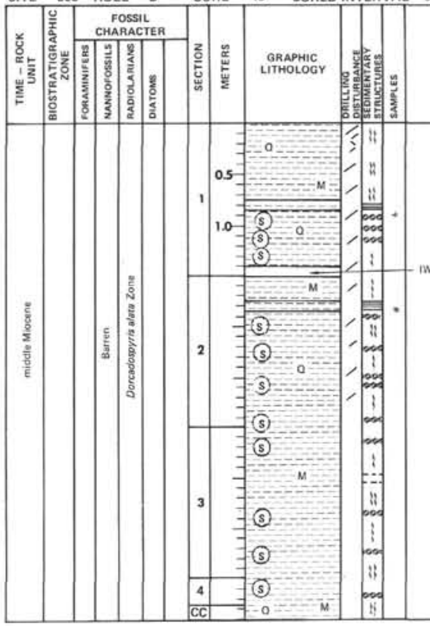
SMEAR SLIDE SUMMARY (%)

	1, 116	2, 82	3, 65	4, 135	6, 10
	D	D	M	M	D
Texture:					
Sand	5	–	–	–	–
Silt	30	20	10	70	8
Clay	65	80	90	30	92
Composition:					
Quartz	5	2	1	–	1
Mica	6	4	5	–	2
Heavy minerals	1	–	–	–	–
Clay	86	88	89	25	93
Glauconite	–	1	–	–	TR
Pyrite	1	2	2	–	TR
Zeolite	1	–	–	–	–
Diatoms	TR	TR	TR	–	1
Radiolarians	–	TR	–	–	1
Fish remains	–	2	1	–	–
Plant debris	–	TR	TR	–	TR
Other Siderite	–	1	1	75	2

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2	5
	80-82	80-82
Organic carbon	0.14	0.29
Carbonate	8	8
C/N	8.4	10.0

SITE 603 HOLE B CORE 13 CORED INTERVAL 936.6–946.2 m



LITHOLOGIC DESCRIPTION

SILT-BEARING CLAYSTONE

dark greenish gray (5GY 4/1 to 5G 3/2) with varying degrees of bioturbation. Burrows are usually dark gray (N4) to dark bluish gray (5B 4/1) in color. Siderite burrow fillings/nodules occur in scattered horizons. Faintly laminated, dark bands of CLAYSTONE with a sharp basal contact occur in Section 1 at 79-82 cm, and Section 2 at 41-46 cm. In Section 3, 46-49 cm is greenish gray (5GY 5/1 to 5Y 6/1) with a gradual transition to bordering darker claystone, has a low burrow abundance, and is probably siderite enriched.

Split core emitted gas.

SMEAR SLIDE SUMMARY (%)

	1, 83	2, 44
	D	M
Texture:		
Silt	7	4
Clay	93	96
Composition:		
Quartz	2	1
Feldspar	2	–
Mica	3	3
Clay	93	96
Glauconite	TR	TR
Pyrite	TR	TR
Radiolarians	TR	TR
Fish remains	TR	TR

ORGANIC CARBON AND CARBONATE (%)

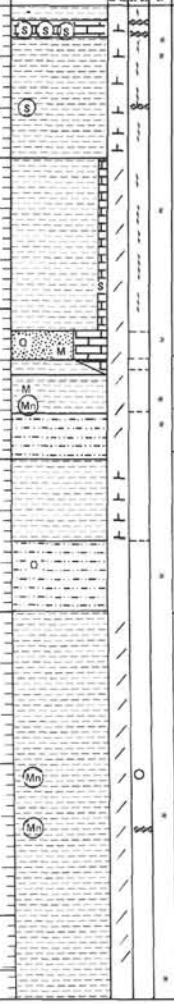
Section-Interval (cm)	2
	85-87
Organic carbon	0.20
Carbonate	7
C/N	8.9

SITE 603 HOLE B CORE 14R CORED INTERVAL 946.2–955.8 m

TIME – ROCK UNIT | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION

Nannofossils: Barren. Diatoms: Barren.

Sections: 1, 2, 3, 4, 5, 6, 7, CC. Meters: 0.5, 1.0



5G 5/1
5GY 5/1
2.5Y/2
10YR 4/3
10YR 5/4
2.5Y 5/4
10YR 5/3
10YR 5/5

CLAYSTONE

dark gray (5Y 4/1) and dark greenish gray (5GY 4/1) with horizontal burrows and banding. Section 1, 20-30 cm: band of burrow fills of CLAY-RICH SIDERITE. Section 2 is similar in appearance but with streaky dark gray (N4) laminae and horizontal burrowing in SIDERITE-BEARING, MICA-RICH CLAYSTONE. Section 3, 20-47 cm composed of QUARTZ-BEARING, MICA AND UNSPECIFIED CARBONATE RICH CLAYSTONE, texturally a sandy claystone. (The unspecified carbonate may be recrystallized microfossils). A transition in color from greenish gray (5GY 5/1) to grayish brown (2.5Y 5/2) and an increase in clay content occurs from 47-65 cm. The last appearance of nannofossils occurs at 64 cm (Biostratigraphy data). The remainder of Section 3 is mica-rich claystone, no bioturbation below 105 cm. Sections 4, 5, and 6 are yellow brown and brown SILT-RICH CLAYSTONES. Fe-Mn nodules in Section 3 and 6.

Split core emitted gas.

SMEAR SLIDE SUMMARY (%)

	1, 30 M	1, 47 M	2, 62 D	3, 34 M	3, 90 M	3, 113 D	4, 124 M	6, 65 M	CC,10 D
Texture:									
Sand	–	2	–	30	–	–	–	–	–
Silt	70	18	20	60	9	14	20	5	3
Clay	30	80	80	10	91	86	80	95	97
Composition:									
Quartz	2	5	3	7	–	2	15	1	TR
Mica	3	3	10	15	9	12	5	1	3
Heavy minerals	TR	–	–	–	–	TR	–	–	–
Clay	24	80	80	43	90	85	80	–	97
Glauconite	–	15	–	–	–	–	TR	–	–
Pyrite	1	1	TR	–	–	–	–	–	–
Zeolite	–	–	TR	–	–	TR	–	–	TR
Radiolarians	–	1	TR	–	–	–	–	–	–
Sponge Spicules	–	–	TR	–	–	–	–	–	–
Fish remains	–	TR	1	–	1	1	–	–	–
Other Siderite	70	–	6	35	–	TR	–	9	–
Fe-Mn Oxides	–	–	–	–	–	–	–	98	–

ORGANIC CARBON AND CARBONATE (%)

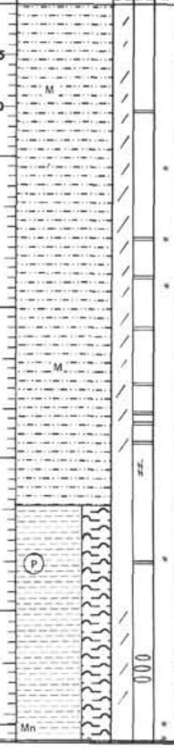
Section-Interval (cm)	1 80-81	2 80-81	3 10-11	3 80-81	4 80-81	5 80-81	6 80-81
Organic carbon	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Carbonate	0	0	2	0	6	<1	<1
C/N	6.8	6.5	3.4	2.3	1.1	1.2	1.6

SITE 603 HOLE B CORE 15 CORED INTERVAL 955.8–965.4 m

TIME – ROCK UNIT | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION

Time-rock unit: early Eocene. Foraminifers: Barren. Radiolarians: *Phormocyrtis striata striata* Zone

Sections: 1, 2, 3, 4, 5, CC. Meters: 0.5, 1.0



5G 6/2
5Y 4/4
5G 6/2
5Y 4/4
5G 6/2
5Y 4/4
5Y 4/4

SILT-RICH CLAYSTONE

yellowish brown (10YR 5/4) to brown (10YR 5/3) with scattered mottles of greenish gray (5G 6/1). In Sections 1, 2, and 3 are thin laminae (1 mm) of red (10R 4/6) as indicated. The upper portion of Section 4 is still silt-rich claystone but olive (5GY 5/3) to yellowish red (5YR 5/6) at 30 cm to brown (7.5YR 5/4) at 45 cm with reddish brown to brownish red (5YR 5/4 to 2.5YR 4/4). At 45 cm in Section 4 is a change in lithology to RADIOLARIAN CLAYSTONE, pale green (5G 6/2) with subhorizontal streaks and lenticular spots of both light pale green (5G 7/2) and bluish gray (5B 5/1). Clusters of pyrite abundant at 97-98 cm, Section 4. Section 5 has alternating pale green (5G 6/2) and reddish brown (5Y 4/4) bands. The upper portion of the reddish brown has lenses/mottles of pale green. Apparent dip of laminae is 8-10° and the hole dip is measured as 11.5°. Black nodules in base of core catcher.

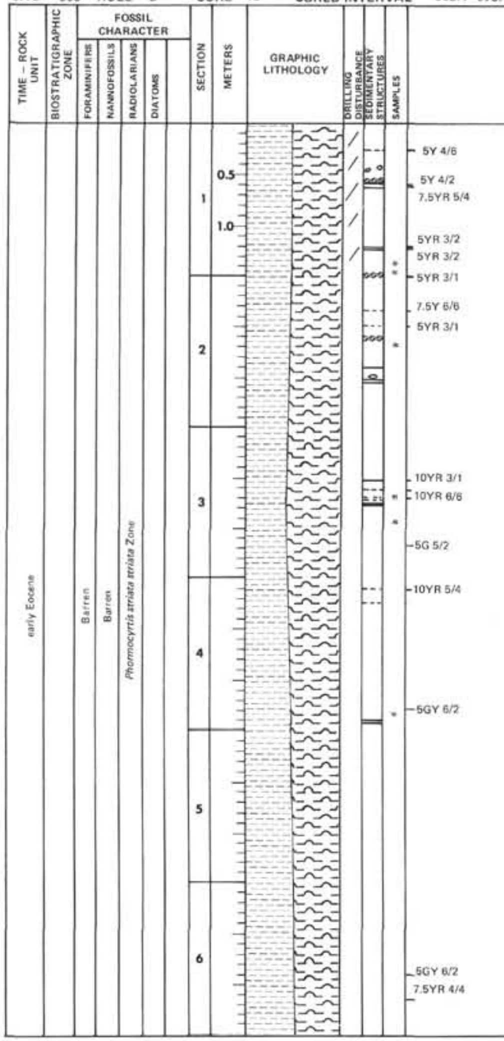
SMEAR SLIDE SUMMARY (%)

	2, 26 M	2, 79 M	2, 132 D	4, 93 D	CC,4 D	CC,15 M
Texture:						
Silt	20	20	19	25	37	5
Clay	80	80	81	75	63	95
Composition:						
Quartz	2	2	2	–	TR	–
Feldspar	3	3	7	–	–	–
Mica	5	5	10	–	2	5
Heavy minerals	TR	–	–	–	–	–
Clay	80	80	81	75	63	30
Glauconite	TR	–	–	–	–	–
Radiolarians	–	–	–	25	35	–
Fish remains	–	TR	TR	–	TR	–
Other Fe Mn Oxide		–	–	–	–	65

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2 81-82	5 66-67
Organic carbon	<0.1	<0.1
Carbonate	<1	<1
C/N	1.8	1.7

SITE 603 HOLE B CORE 16 CORED INTERVAL 965.4–975.1 m



LITHOLOGIC DESCRIPTION

RADIOLARIAN CLAYSTONE,

Amazingly colorful! Section 1 begins yellowish red (5YR 4/6) with some mm thick black streaks. At 26 cm the color gradually begins to change to dark reddish gray (5YR 4/2) and dark reddish brown (5YR 3/2) by 60 cm with common black layers and nodules (2-5 mm diameter) and yellowish red horizontal burrows. 60-65 cm, and 120-121 cm are brown (7.5YR 5/4) bands. From 65-132 cm, below each brown band there is a gradual change to dark reddish brown (again) with very dark gray (5YR 3/1) and black (5YR 2/1) 5-8 mm streaks and rare yellowish red horizontal burrows. From 132 cm, Section 1 to 47 cm, Section 2 is very dark gray (5YR 3/1) with a few lenses/burrows of reddish yellow (5YR 6/6). In 47-62 cm are very thin irregular bands (70 total) of which 30% are reddish yellow. The remainder of Section 2 is very dark gray with rare laminae, and burrows in shades of yellow. Section 3 is predominantly yellow brown with abundant radiolarians at 50-60 cm, and found in small 3 mm lenses throughout the Section. The remainder of the Core is composed of cyclic alternations, 10-20 cm, from green (5GY 6/2) to yellow brown (7.5YR 4/4) with gradual transitions. By Section 6, the brown bands are 15-20 cm alternating with green bands that are 5-10 cm thick.

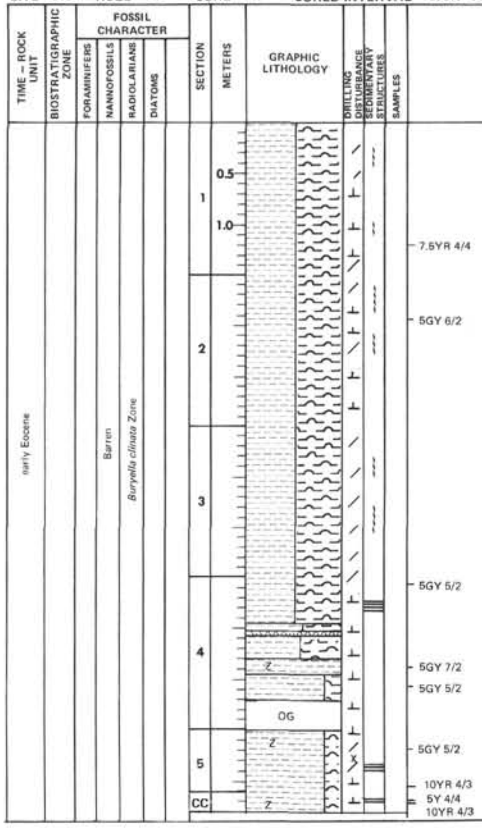
SMEAR SLIDE SUMMARY (%)

	1, 87 D	1, 90 M	2, 60 M	3, 71 D	3, 80 M	4, 137 D
Texture:						
Sand	5	–	–	–	–	–
Silt	45	33	–	50	10	50
Clay	50	67	100	50	90	50
Composition:						
Quartz	1	1	–	–	–	1
Mica	2	1	–	TR	2	3
Clay	51	67	–	50	88	50
Pyrite	1	1	–	TR	–	–
Carbonate unspec.	–	–	–	–	TR	–
Calc. nannofossils	–	–	–	–	TR	–
Radiolarians	45	30	–	50	10	46
Sponge spicules	–	–	–	–	TR	–
Fish remains	–	–	–	–	TR	–
Other Fe Mn Oxides	–	–	99	–	–	–
silica	–	–	1	–	–	–

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2 70-72	5 70-72
Organic carbon	<0.1	<0.1
Carbonate	<1	<1
C/N	4.2	5.3

SITE 603 HOLE B CORE 17 CORED INTERVAL 975.1–984.6 m



LITHOLOGIC DESCRIPTION

RADIOLARIAN CLAYSTONE,

alternating bands of brown (7.5YR 4/4) and light olive green (5GY 6/2). Section 1 has faint laminations throughout with green bands of 1-5 cm in thickness and brown bands usually 8-20 cm thick and rarely 2-4 cm thick. In Section 2 the banding is not as distinct with an overall green tone. Brown bands typically are 3-5 cm thick, and green bands typically are 5-10 cm thick. Lenses (3-5 mm length) appear to be filled with radiolarians, and some laminations are concentrations of radiolarian skeletons. In Section 3 these lenses become stringers and are abundant. In Section 4, the laminations and banding are distinct. At 44-78 cm white stringers of porcellanite with diffuse boundaries appear. At 49 cm is a 1-2 mm layer of siliceous cement. From 78-93, ZEOLITE-BEARING CLAYSTONE of grayish yellow green (5GY 7/2) ZEOLITE-BEARING AND RADIOLARIAN-RICH CLAYSTONE that changes to dark brown with laminations of red brown containing concentrations of radiolarians.

SMEAR SLIDE SUMMARY (%)

	4, 49 M	4, 83 D	5, 14 D	5, 40 D
Texture:				
Silt	–	10	15	25
Clay	–	90	85	75
Composition				
Quartz	–	2	3	2
Mica	–	TR	2	3
Heavy minerals	–	TR	–	TR
Clay	–	83	85	75
Glauconite	–	–	TR	–
Zeolite	5	7	5	5
Radiolarians	–	3	5	15
Sponge spicules	–	TR	–	–
Fish remains	–	–	TR	–
Other Opal CT	95			
Fe Oxide Pigment	–	5	–	–

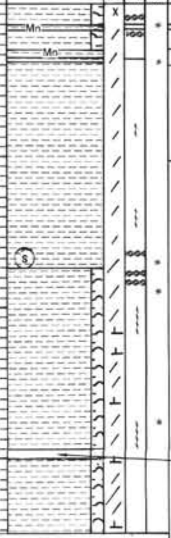
ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2 70-72	5 53-55
Organic carbon	<0.1	<0.1
Carbonate	<1	<1
C/N	4.6	2.5

SITE 603 HOLE B CORE 18 CORED INTERVAL 984.6–993.6 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
early Eocene		Barren	Barren	*Bekoma bidartensis*		1, 2, 3, 4	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



2.5Y 6/6
5GY 4/1
5Y-5GY 5/1
IW

LITHOLOGIC DESCRIPTION

RADIOLARIAN-BEARING CLAYSTONE
with Fe oxide staining yielding an olive yellow (2.5Y 6/6–8) coloration in the upper 46 cm of Section 1. Elongate burrows lined with Fe/Mn occur at 18, 22, and 33 cm. Discrete Mn(Fe?) oxide crusts occur at 25 cm and 53 cm. The remainder of the Core is dark green gray (5GY 4/1) in color with varying content of radiolarians from CLAYSTONE at the base of Section 1, to RADIOLARIAN-RICH CLAYSTONE in the lower portion of Section 2 through Section 4. A siderite filled burrow occurs in Section 2 at 95 cm. Laminations occur throughout the Core that contain concentrations of radiolarians. In Section 2, 116-147 cm are sandy lenses of radiolarians overlain by material with elongated black tiny burrows.

SMEAR SLIDE SUMMARY (%)

	1, 7 D	1, 52 M	2, 97 M	2, 134 D	3, 105 D
Texture:					
Sand	–	–	–	9	13
Silt	14	6	100	4	4
Clay	86	94	–	87	82
Composition:					
Quartz	4	3	–	3	3
Mica	2	5	–	1	1
Clay	86	12	–	85	82
Glauconite	TR	–	–	TR	–
Pyrite	–	–	–	TR	–
Zeolite	TR	TR	–	TR	1
Calc. nannofossils	TR	TR	–	–	–
Radiolarians	8	–	–	11	13
Sponge spicules	–	–	–	–	TR
Other Fe Mn Oxide	–	80	–	–	–
Siderite	–	–	100	–	–

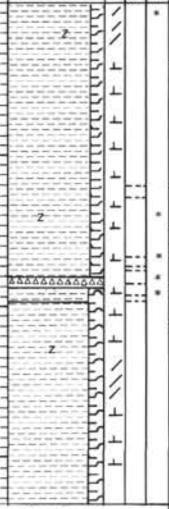
ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2 75-77
Organic carbon	0.1
Carbonate	1
C/N	4.1

SITE 603 HOLE B CORE 19 CORED INTERVAL 993.6–1002.6 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
early Eocene			Barren	*Bekoma bidartensis Zone*		1, 2, 3, 4	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



5GY 4/1
5YR 4/4
7.5YR 4/2
5Y 4/1
5YR 4/4
5Y 4/1
5YR 4/4
5Y 4/1
2.5YR 6/6
5GY 4/1
5Y 4/1

LITHOLOGIC DESCRIPTION

RADIOLARIAN-BEARING AND ZEOLITE-RICH CLAYSTONE,
dark gray (5GY 4/1) or dark green gray (5Y 4/1) with tiny white concretions (siderite?) in Section 1. Section 2 is varicolored with varying abundance of radiolarians and laminations. The colors are dark gray alternating with red brown (7.5YR 4/2). The red brown intervals within 50-105 cm contain recrystallized radiolarians, white lenses of zeolitic silt, and generally less zeolites in the matrix than the dark gray alternating claystone. By the lower portion of Section 2 the red brown becomes RADIOLARIAN-BEARING (Fe oxide stained) ZEOLITE RICH CLAYSTONE, and the green gray contains silicified stringers. From 138-142 cm there is an olive yellow (2.5YR 6/6) layer of RADIOLARIAN-MICA and ZEOLITE BEARING CLAYSTONE.
The remainder of the Core is mostly dark gray Claystone with brown at 0-5, 14-16, 77, and 120 cm in Section 3.

SMEAR SLIDE SUMMARY (%)

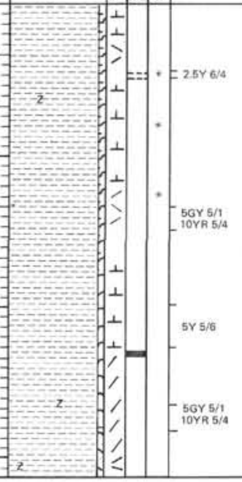
	1, 12 D	2, 55 D	2, 104 M	2, 120 D	2, 140 D
Texture:					
Silt	50	20	70	15	12
Clay	50	80	30	85	88
Composition:					
Quartz	3	3	–	TR	2
Mica	–	2	–	TR	3
Clay	66	83	30	70	80
Glauconite	1	–	–	–	–
Zeolite	10	12	70	15	6
Calc. nannofossils	–	TR	–	–	–
Radiolarians	10	TR	–	5	8
Fish remains	–	TR	–	–	TR
Other Fe oxide pigment	–	–	–	10	8

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2 105-106
Organic carbon	0.1
Carbonate	1
C/N	2.5

SITE 603 HOLE B CORE 20 CORED INTERVAL 1002.6–1011.6 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
late Paleocene			Barren	*Bekoma campechensis* Zone		1, 2, 3, CC	0.5, 1.0



LITHOLOGIC DESCRIPTION

ZEOLITE-BEARING RADIOLARIAN CLAYSTONE

greenish gray (5GY 5/1) and yellow-brown (10YR 5/4) with gradational color changes, faint laminations, and rare bioturbation). Section 3, 0–46 cm contains a slight color change to yellowish red (5Y 5/6) with a 2 mm bluish black sharp laminae at 46 cm.

SMEAR SLIDE SUMMARY (%)

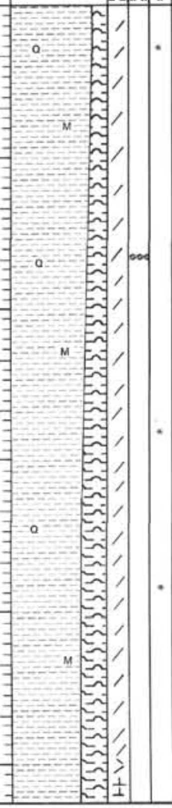
	1, 72 M	1, 134 D	2, 35 D
Texture:			
Silt	–	60	35
Clay	–	40	65
Composition:			
Quartz	–	2	4
Mica	2	2	3
Heavy minerals	–	–	2
Clay	36	40	63
Pyrite	–	TR	TR
Zeolite	2	5	3
Carbonate unspec.	–	1	–
Calc. nannofossils	TR	–	TR
Radiolarians	60	40	25
Sponge spicules	–	–	TR

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2 78-79
Organic carbon	0.1
Carbonate	1
C/N	3.8

SITE 603 HOLE B CORE 21 CORED INTERVAL 1011.6–1020.6 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
late Paleocene		Barren	Barren	*Bekoma campechensis* Zone		1, 2, 3, 4, 5, 6	0.5, 1.0



LITHOLOGIC DESCRIPTION

SILT-BEARING RADIOLARIAN-RICH CLAYSTONE

dark greenish gray (5GY 4/1) with faint parallel laminations and recrystallized radiolarians throughout the Core. Concentrations of recrystallized radiolarians occur at 55 and 120 cm in Section 4. Split core emitted gas.

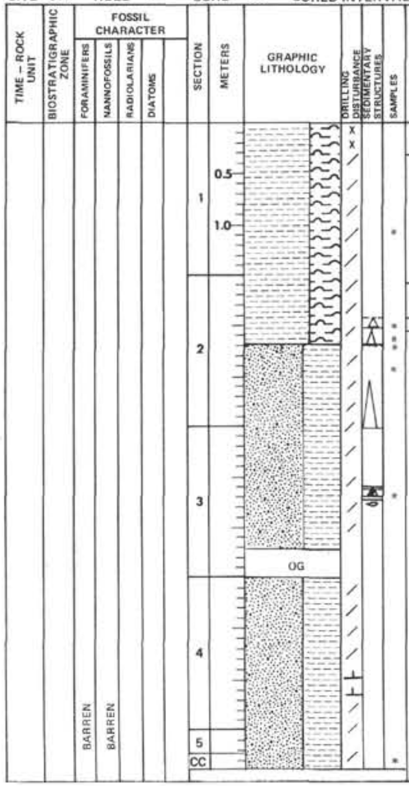
SMEAR SLIDE SUMMARY (%)

	1, 46 D	3, 122 D	4, 123 M
Texture:			
Sand	–	–	15
Silt	25	32	22
Clay	75	68	63
Composition:			
Quartz	4	2	2
Mica	4	4	5
Heavy minerals	1	1	–
Clay	75	68	63
Glauconite	1	–	–
Pyrite	TR	TR	TR
Zeolite	1	–	–
Carbonate unspec.	2	–	20
Radiolarians	12	25	10
Sponge spicules	–	TR	–

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2 75-77	5 77-79
Organic carbon	<0.1	<0.1
Carbonate	<1	<1
C/N	3.8	3.7

SITE 603 HOLE B CORE 22 CORED INTERVAL 1020.6–1029.6 m



LITHOLOGIC DESCRIPTION

5GY 5/1

5G 4/1

5G 5/1

RADIOLARIAN CLAYSTONE
greenish gray (5GY 5/1) with faint laminations, and variations in the abundance of radiolarians. Section 1, 49–50 cm, is a zone with abundant white sand-sized grains. Section 2, 56–58 cm, contains two *fining-upward sequences* of greenish gray (5G 5/1) basal silt layers overlain by wavy laminations or current ripples of radiolarian-rich claystone. Below 68 cm in Section 2 is CLAYEY SILTY SANDSTONE alternating from dark brown (7.5YR 3/2) to dusky blue green (5BG 3/2). Section 3 begins grayish blue green (5BG 5/2) and darkens to 5BG 4/2 in the lower part of a turbidite at 70 cm. At 67–72 cm occurs parallel laminations and a coarse sand-sized base of 0.5–1.0 mm grains. Below this, the core is dark reddish brown with irregular bands and mottles of greenish gray clayey silty sandstone.

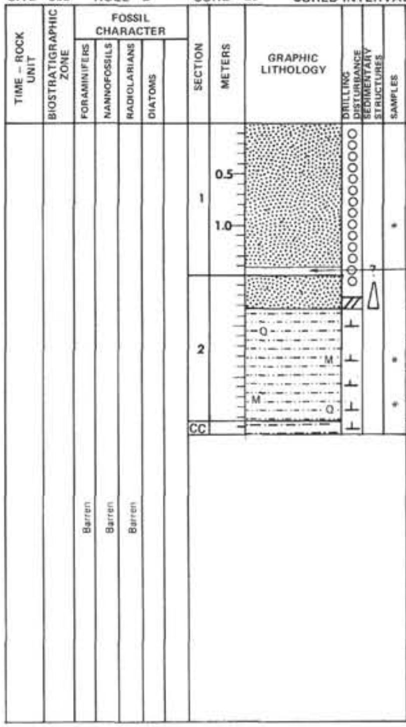
SMEAR SLIDE SUMMARY (%)

	1, 109 D	2, 57 D	2, 68 M	2, 71 D	2, 90 D	3, 72 M	CC,4 M
Texture:							
Sand	30	–	35	50	40	–	15
Silt	5	35	24	15	17	–	45
Clay	65	65	41	35	43	–	40
Composition:							
Quartz	1	–	25	18	25	–	–
Feldspar	–	–	20	7	20	–	5
Mica	2	–	5	10	5	–	15
Heavy minerals	–	TR	–	TR	TR	–	2
Clay	65	65	41	35	43	–	40
Glauconite	TR	TR	TR	TR	TR	–	4
Pyrite opagues	TR	5	1	–	21	–	–
Zeolite	–	TR	–	–	–	–	–
Carbonate unspec.	2	30	5	30	5	–	1
Radiolarians	30	–	–	–	–	–	3
Fish remains	–	TR	TR	–	–	–	–
Plant debris	–	–	TR	–	TR	–	–
Other Qtz. Microx-alline	–	–	–	–	–	100	–
Silicified Microfossils	–	–	3	–	–	–	–
Qtz. + Chert	–	–	–	–	–	–	

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2 54-55	2 101-103	3 47-48	3 90-91
Organic carbon	<0.1	<0.1	<0.1	<0.1
Carbonate	<1	<1	1	1
C/N	4.0	2.4	2.5	5.6
	lt. gray	red		red

SITE 603 HOLE B CORE 23 CORED INTERVAL 1029.6–1038.6 m



LITHOLOGIC DESCRIPTION

IW sample

(1)
(2)
(1)
(1)/(2)
(1)
(1)/(2)

MICA- AND GLAUCONITE-RICH QUARTZ SANDSTONE
dark greenish gray (5GY 4/1)

Upper 185 cm of core may be a turbidite, but only the lowermost 5 cm was undeformed by drilling.

Lower part of Section 2 is TERRIGENOUS SILT-RICH CLAYSTONE, alternations of
(1) greenish-gray to dark green-gray (5GY 5/1–5GY 4/1) with
(2) dark reddish-brown (5YR 3/4) color bands with sharp and gradational contacts

Radiolarians dissolved and filled by zeolites?

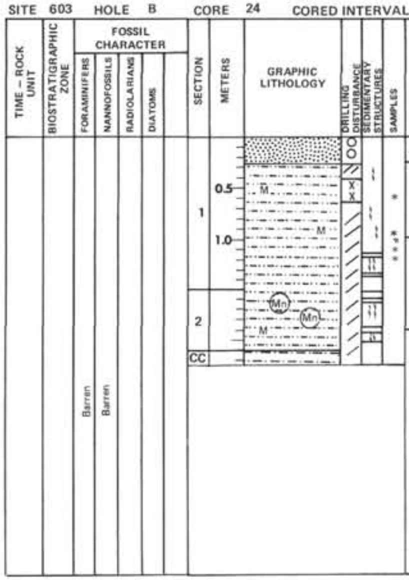
SMEAR SLIDE SUMMARY (%)

	1, 99 D	2, 72 M	2, 137 D
Texture:			
Sand	70	20	5
Silt	20	40	30
Clay	10	40	65
Composition:			
Quartz	40	15	18
Feldspar	10	10	2
Mica	20	15	10
Heavy minerals	5	1	1
Clay minerals	8	42	65
Glauconite	15	2	1
Pyrite	2	TR	–
Fe oxides	TR	TR	1
Carbonate unspec.	TR	–	–
Radiolarians ± silicified	–	5	2
Plant debris	TR	–	–

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2(14)
Organic carbon	<0.1
Carbonate	–

SITE 603 HOLE B CORE 24 CORED INTERVAL 1038.6–1047.6 m



LITHOLOGIC DESCRIPTION

(1) GLAUCONITE- AND MICA-RICH SAND greenish gray (5GY 5/1)

(2) TERRIGENOUS SILT-BEARING CLAYSTONE ferruginous (?metalliferous) reddish-brown (5YR 4/3), ±homogeneous, with thin layers of lenses of yellow, red, and black

(3) MICA-BEARING TO MICA-RICH CLAYSTONE

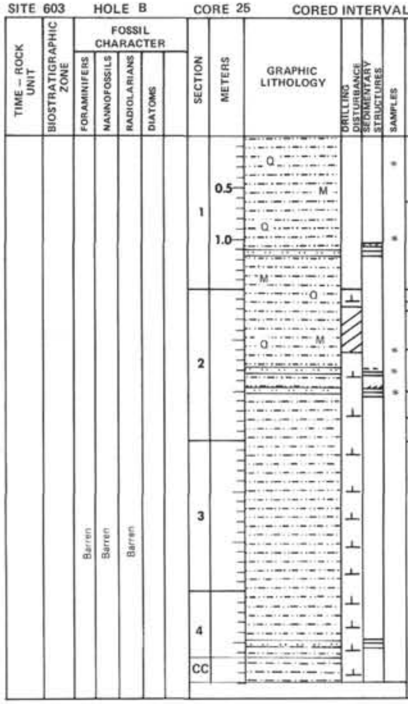
dark reddish gray (5YR 4/2-5/2) to

(4) dark gray (5Y 4/1) with abundant black streaks (?burrows) creating a laminated appearance in some zones

SMEAR SLIDE SUMMARY (%)

	1, 63 M	1, 97 D	1, 98 M	1, 99 M	1, 112 D
Texture:					
Silt	–	7	–	–	11
Clay	100	93	100	100	89
Composition:					
Quartz	–	2	–	–	1
Mica	–	3	–	–	10
Heavy minerals	–	TR	–	–	–
Clay minerals + aggr.	95	93	70	70	89
Glauconite	–	–	–	–	TR
Fe-Mn oxides	5	–	30	30	TR
Zeolite	–	–	–	–	TR
Carbonate unspec.	–	2	–	–	–
Fish remains	–	–	–	–	TR

SITE 603 HOLE B CORE 25 CORED INTERVAL 1047.6–1056.6 m



LITHOLOGIC DESCRIPTION

TERRIGENOUS SILT-RICH CLAYSTONE, varicolored:

(1) dark gray (5Y 4/1)
(2) dark reddish gray (5Y 4/2-3)
(3) reddish brown (5YR 4/3)
(4) gray (N5)
(5) yellowish-brown (10YR 5/4)

With four thin layers of mica-rich QUARTZ SILTSTONE greenish-gray (5G 5/1), moderately sorted very fine sandy, coarse siltstone, parallel and small-scale cross-laminated (distal turbidites?, Tb/Tc-interval)

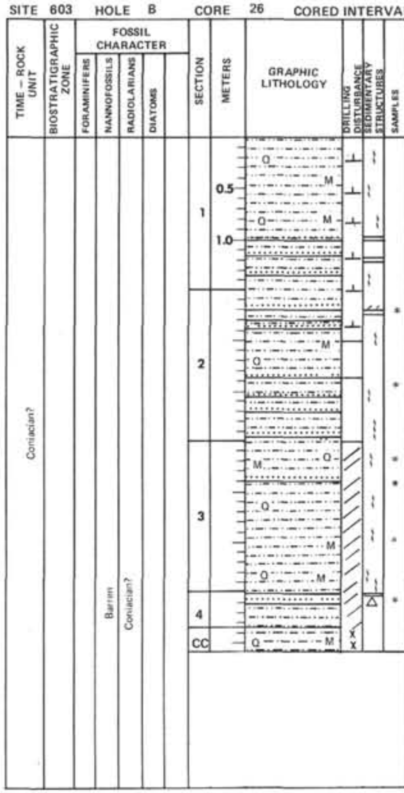
SMEAR SLIDE SUMMARY (%)

	1, 24 D	1, 99 D	2, 60 D	2, 80 M	2, 99 M
Texture:					
Sand	2	–	–	30	–
Silt	15	10	12	70	96
Clay	83	90	88	–	4
Composition:					
Quartz	5	5	8	90	87
Feldspar	TR				
Mica	10	4	4	4	9
Heavy minerals	1	–	1	–	1
Clay minerals & aggregates	83	90	86	2	–
Glauconite	TR	–	TR	3	TR
Pyrite	TR	TR	2	1	2
Fe oxides	–	–	TR	TR	–
Zeolite	1	1	1	–	1
Radiolarians	–	–	TR	–	–
Fish remains	TR	–	–	–	–
Plant debris	TR	TR	–	–	–

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2 (70)
Organic carbon	0.1
Carbonate	1

SITE 603 HOLE B CORE 26 CORED INTERVAL 1056.6–1065.6 m



LITHOLOGIC DESCRIPTION

TERRIGENOUS SILT-RICH CLAYSTONE, variegated, with color bands of:

(1) dark gray (10 YR 3/1) with lenses and streaks of black material (? compacted burrows)
(2) dark-brown (10YR 3/3)
(3) dark greenish gray (5G 4/1, 5Y 4/1 to 5GY 4/1), mottled with siderite-rich burrow fills
(4) gray (5Y 6/1) with parallel or convolute laminations = sand rich silty claystone (base of mud turbidites?)
(5) gray (5Y 5/1) - med. gray (N4) - olive gray (5Y 4/1), mottled

Many 5–15 cm thick laminated mica-rich QUARTZ SILTSTONE layers (distal turbidites), parallel-, cross- and convolute-laminated; overlain by laminated and burrowed claystones.

Claystones disintegrate upon exposure to fresh water.

SMEAR SLIDE SUMMARY (%)

	2, 35 M	2, 93 M	3, 18 M	3, 40 M	3, 46 M	3, 99 M	4, 9 D
Texture:							
Sand	100	–	–	–	20	–	–
Silt	–	27	20	30	7	100	10
Clay	–	73	80	70	73	–	90
Composition:							
Quartz	24	20	7	21	20	97	4
Feldspar	15	–	3	7	5	–	–
Mica	30	1	2	4	2	1	7
Heavy minerals	1	TR	TR	TR	TR	–	–
Clay minerals and aggr.	30	77	79	70	–	–	89
Glauconite	–	–	TR	TR	TR	1	–
Pyrite	–	TR	–	–	–	1	–
Fe oxides	TR	TR	1	–	TR	TR	TR
Zeolite	–	2	TR	1	TR	TR	TR
Radiolarians	–	TR	–	TR	–	–	–
Fish remains	–	–	–	–	TR	–	TR
Plant debris & org. matter	–	–	8	–	–	–	–

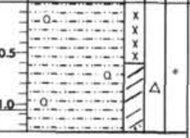
ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	4(28)	4(26)	2(61)
Organic carbon	1.95	0.1	0.1
	6	9	1
	black	lt. gray	

SITE 603 HOLE B CORE 27 CORED INTERVAL 1065.6–1073.2 m

TIME – ROCK UNIT | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION

Nannofossils: Barren
Radiolarians: Barren
Sections: 1, CC



TERRIGENOUS SILT-RICH CLAYSTONE, variegated bands of dark gray (5Y 4/1), dark greenish gray (5G 4/1) and dark reddish brown (5YR 3/4) color.

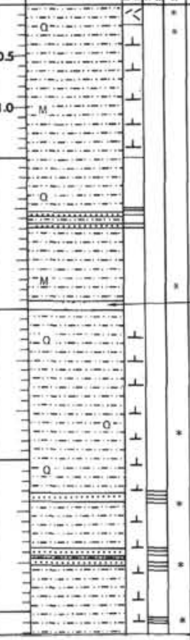
SMEAR SLIDE SUMMARY (%)

	1, 70 D
Texture:	
Sand	–
Silt	8
Clay	92
Composition:	
Quartz	7
Mica	1
Heavy minerals	TR
Clay minerals	92

SITE 603 HOLE B CORE 28 CORED INTERVAL 1073.2–1080.8 m

TIME – ROCK UNIT | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION

Nannofossils: Barren
Radiolarians: Barren
Sections: 1, 2, 3, 4, CC



IW

TERRIGENOUS SILT-BEARING CLAYSTONE mainly dark greenish gray (5G 4/1), with some red (5YR 4/6) bands.

Clays expand and disintegrate after being wetted with fresh water (?smectite)

Thin layers of laminated siltstone

Zeolite-replaced radiolarians

Below Section 4, 30 cm is ORGANIC MATTER AND QUARTZ-BEARING MICA-RICH CLAYSTONE, gray (N5) to black, with 6–10 cm thick layers of GLAUCONITE-BEARING, TERRIGENOUS SAND AND CLAY-RICH MICA SILTSTONE (?distal turbidite).

SMEAR SLIDE SUMMARY (%)

	2, 124 D	3, 124 D	4, 40 M	4, 106 D	CC, 12 M	1, 9 M	1, 26 D
Texture:							
Sand	–	2	10	–	10	–	–
Silt	30	28	80	20	30	14	25
Clay	70	70	10	80	60	86	75
Composition:							
Quartz	4	5	20	6	4	5	1
Feldspar	–	–	5	–	1	–	–
Mica	5	1	57	10	20	4	7
Heavy minerals	–	1	2	1	1	1	1
Clay minerals + aggregates	86	88	10	75	58	86	87
Glauconite	–	1	3	1	2	2	–
Pyrite	1	TR	1	TR	2	1	1
Fe oxides	–	–	TR	–	–	TR	1
Zeolite	–	1	–	–	–	TR	2
Carbonate unspec.	–	1	–	–	–	–	–
Radiolarians (± silicified)	1	2	–	–	–	1	–
Fish remains	–	–	–	TR	–	TR	–
Plant debris + org. matter	2	–	2	7	10	TR	1

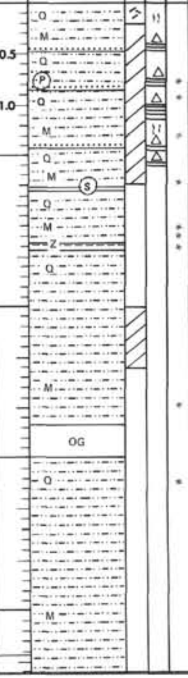
ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2(81-82)	4(76-78)
Organic carbon	<0.1	<0.1
Carbonate	2	3

SITE 603 HOLE B CORE 29R CORED INTERVAL 1080.8–1090.4 m

TIME – ROCK UNIT | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION

Nannofossils: Barren
Radiolarians: Barren
Sections: 1, 2, 3, 4, 5, CC



TERRIGENOUS SILT-RICH CLAYSTONE greenish gray (5G 5/1) with thick turbiditic layers of laminated, partly graded, black, ORGANIC-RICH CLAYSTONE to CLAY-RICH QUARTZ SILTSTONE, probably turbidites (silt layer at base, convolute laminations), 20 episodes per m.

Below Section 2, 32 cm is TERRIGENOUS SILT- AND ZEOLITE-BEARING CLAYSTONE.

Reddish brown (4YR 4/4 to 5Y 3/4), and greenish gray (5G 5/1 to 5GY 5/1) probably reduced version of reddish brown (4YR 4/4 to 5Y 3/4), no apparent bioturbation, center of these bands is usually silt layer surface of claystones is pock-marked (?molds of dissolved radiolarians).

A ZEOLITE-RICH CLAYSTONE (? bentonite, ??ash), light gray (N7) is in Section 2, 85–95 cm.

A cemented 3 mm-thick siderite stone (or dolomite) layer occurs in Section 2 at 32–37 cm.

SMEAR SLIDE SUMMARY (%)

	2, 88 M	2, 90 M	2, 91 D	3, 98 D	4, 24 M	1, 82 D	1, 93 D	1, 137 D	2, 39 M
Texture:									
Sand	–	–	–	–	–	–	10	–	–
Silt	10	20	18	7	17	20	65	95	–
Clay	90	80	82	93	83	80	25	5	100
Composition:									
Quartz	5	8	5	4	10	6	65	95	3
Feldspar	–	1	TR	–	2	–	2	TR	–
Mica	3	–	3	3	3	4	–	–	–
Heavy minerals	–	1	TR	–	TR	–	TR	TR	–
Clay minerals	90	74	82	82	83	78	24	2	3
Glauconite	–	–	–	–	–	TR	3	–	–
Fe oxides	–	10	–	10	–	–	–	–	–
Zeolite	TR	6	10	1	2	2	TR	–	–
Carbonate unspec. (sid./dol.)	2	TR	–	–	–	–	–	–	94
Radiolarians (recryst.)	–	–	TR	–	–	–	–	–	–
Fish remains	–	–	–	–	–	TR	–	–	–
Plant debris + org. matter	–	–	–	–	–	10	6	3	–

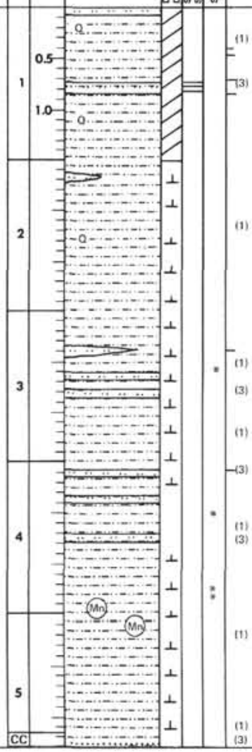
ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	1(70-72)	2(70-72)	5(25-27)
Organic carbon	1.34 <	0.1 <	0.1
Carbonate	2 < (black)	1 (red) <	1

SITE 603 HOLE B CORE 30R CORED INTERVAL 1090.4–1100.0m

TIME-ROCK UNIT: Coniacian–Campanian

BIOSTRATIGRAPHIC ZONE / FOSSIL CHARACTER: Foraminifers: Coniacian–Campanian; Nannofossils: Barren; Radiolarians: Coniacian–Campanian



LITHOLOGIC DESCRIPTION

VARIEGATED QUARTZ-BEARING CLAYSTONE
(1) dark reddish brown (2.5Y 3/4)
(2) greenish-gray (5GY 6/1)

with layers and lenses (?burrow fills) of
(3) terrigenous silt- and sand-
(QUARTZ, GLAUCONITE, MICA) BEARING
CLAYSTONE or SILTSTONE (turbidites?)

Sect. 4 (140 cm): black Mn-stained layer
Sect. 5 (3a): Mn concretions (angular, 2–15 mm diameter).

The core contains clays that expland when exposed to fresh water.

SMEAR SLIDE SUMMARY (%)

	3, 60 M	4, 52 D	4, 121 M	4, 137 M
Texture:				
Sand	10	–	50	–
Silt	20	11	40	10
Clay	70	89	10	90
Composition:				
Quartz	30	4	20	5
Feldspar	2	–	7	–
Mica	3	2	50	2
Heavy minerals	–	–	2	1
Clay minerals	64	88	10	89
Glauconite	1	1	10	–
Fe oxides	–	1	–	2
Radiolarians recryst.	TR	3	–	–
Plant debris	–	–	1	–

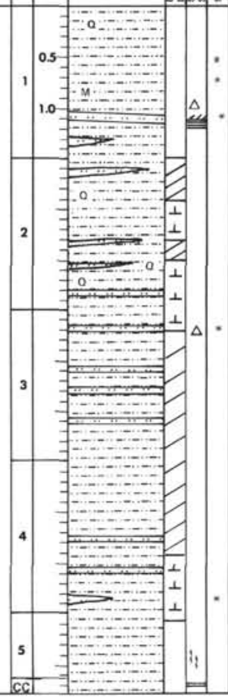
ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2(68-70)
Organic carbon	<0.1
Carbonate	4
	red

SITE 603 HOLE B CORE 31 CORED INTERVAL 1100.0–1109.5 m

TIME-ROCK UNIT: Coniacian–Campanian

FOSSIL CHARACTER: Foraminifers: F/M; Nannofossils: Barren; Radiolarians: Barren



LITHOLOGIC DESCRIPTION

VARIEGATED QUARTZ AND MICA-BEARING CLAYSTONE, dark reddish brown (2.5YR 3/4) and light gray (5Y 7-6/1), more silty, zeolite-bearing, with burrow fills and thin layers of SANDY SILTSTONE, sometimes current-ripple laminated.

Locally (Sect. 5, 50–60 cm) *Chondrites*-burrow-mottled layers (dark gray).

SMEAR SLIDE SUMMARY (%)

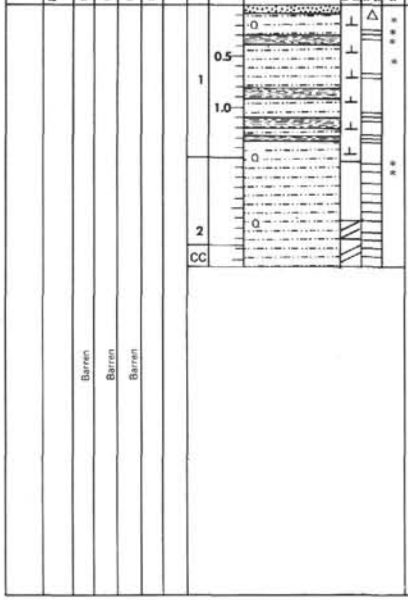
	1, 55 D	1, 70 M	1, 115 M	3, 19 M	4, 138 M
Texture:					
Sand	–	–	100	–	30
Silt	18	20	–	11	70
Clay	82	80	–	89	–
Composition:					
Quartz	8	7	–	2	47
Mica	6	13	–	9	47
Heavy minerals	1	1	–	–	–
Clay minerals	78	67	–	81	–
Glauconite	–	2	–	1	2
Pyrite	TR	1	–	2	–
Fe-oxides	7	–	–	–	1
Zeolite	1	2	–	4	–
Carbonate unspec.	–	–	100	–	3

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2(81-83)	5(38-40)
Organic carbon	<0.1	<0.1
Carbonate	2	<1
	red	red

SITE 603 HOLE B CORE 32 CORED INTERVAL 1109.5–1118.5 m

TIME – ROCK UNIT | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION



VARIEGATED TERRIGENOUS SILT-RICH CLAYSTONE, predominantly reddish brown (5YR 3/3), with 1–5 mm thick layers of dark greenish gray (5GY 4/1) and layers of moderate yellow (5Y 7/6), and grayish black (N2) = organic-rich layers. Color banding due to oxidation/reduction variations?

Color lamination changes from light to dark greenish gray on a millimeter scale. Mottling of gray in red material due to bioturbation.

Dark gray layers have distinct upper and lower contacts (turbidites?), while reddish brown layers have sharp basal contacts.

SMEAR SLIDE SUMMARY (%)

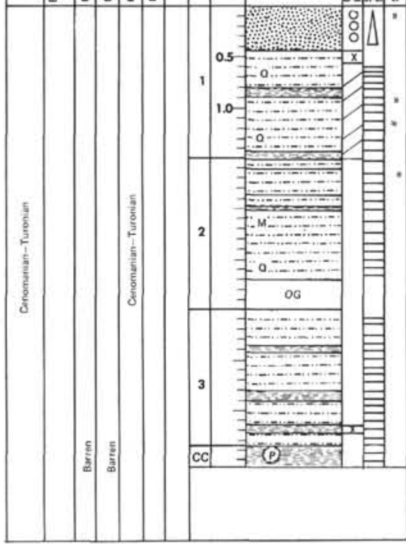
	1, 15 M	1, 22 D	1, 27 M	1, 56 D	2, 4 M	2, 11 D
Texture:						
Silt	30	25	10	23	30	4
Clay	70	75	90	77	70	96
Composition:						
Quartz	15	10	1	10	5	2
Feldspar	–	10	–	10	–	–
Mica	15	5	1	1	2	2
Heavy minerals	1	–	TR	TR	–	–
Clay minerals	62	–	88	77	93	96
Glauconite	–	TR	TR	TR	–	–
Pyrite	2	1	–	2	TR	–
Zeolite	1	–	–	–	TR	–
Fish remains	–	TR	–	–	–	TR
Plant debris/org. matter	4	–	10	–	–	–

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2(33-34)
Organic carbon	0.1
Carbonate	2
	red

SITE 603 HOLE B CORE 33 CORED INTERVAL 1118.5–1127.5 m

TIME – ROCK UNIT | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION



GLAUCONITE-QUARTZ-MICA-RICH CLAYEY-SILTY SAND in uppermost 42 cm. Rest of core is CLAYSTONE, dark greenish gray (5GY 4/1), and greenish black (5G 2/1). Some (light) greenish gray (5BG 7/1–6/1) very thin (0.2 mm) laminae, occur mostly in greenish-gray claystone.

Greenish gray grades upwards into dark gray and black (faintly laminated) claystone

Some pyrite laminae and 1–3 mm thick black lenses are present in the core.

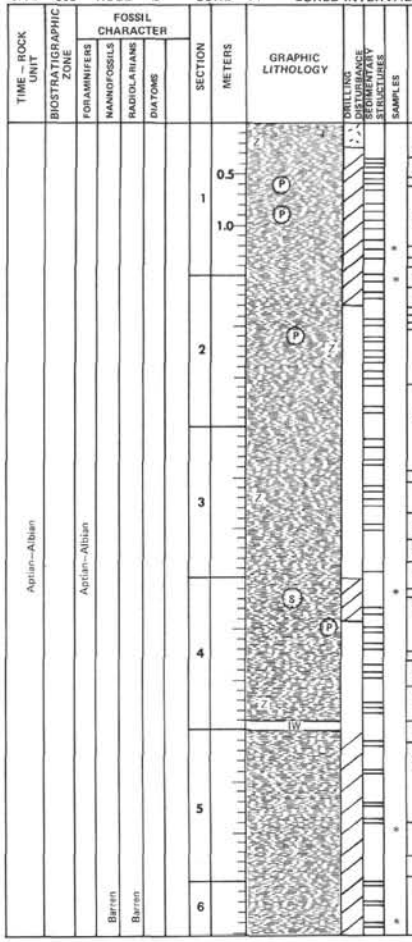
SMEAR SLIDE SUMMARY (%)

	1, 10 D	1, 99 D	1, 122 M	2, 20 D
Texture:				
Sand	30	–	–	–
Silt	30	15	100	15
Clay	40	85	–	85
Composition:				
Quartz	20	5	98	8
Mica	15	6	2	7
Heavy minerals	4	TR	TR	–
Clay minerals	45	89	–	66
Glauconite	12	–	–	–
Pyrite	3	TR	–	3
Zeolite	1	–	–	4
Plant debris/org. matter	–	–	–	12

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2(26-28)	3(10-11)
Organic carbon	6.03	4.14
Carbonate	1	2
	black	black

SITE 603 HOLE B CORE 34 CORED INTERVAL 1127.5–1136.5 m



LITHOLOGIC DESCRIPTION

BLACK CARBONACEOUS CLAYSTONE

(1) LAMINATED ZEOLITE-BEARING ORGANIC MATTER-RICH CLAYSTONE, olive black (5Y 2/1) to grayish black (N2). Silt concentrated in submillimeter laminae. Pyrite nodules. Organic carbon content up to 13.5%.

(2) ORGANIC-RICH CLAYSTONE, grayish black (N2), *silt laminae not apparent.*

(3) SILT-RICH CLAYSTONE, dark greenish gray (5GY 4/1) to greenish black (5GY 3/1), slightly bioturbated and irregularly laminated.

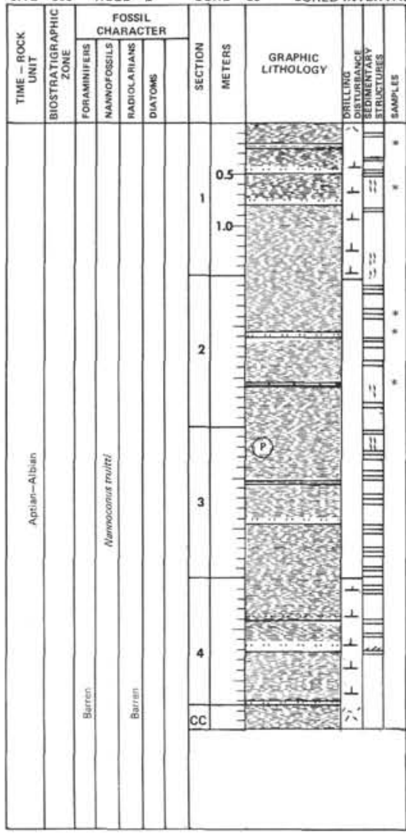
SMEAR SLIDE SUMMARY (%)

	1, 119	2, 6	4, 15	5, 105	6, 38
	D	M	M	D	D
Texture:					
Sand	—	—	—	—	—
Silt	15	5	95	24	13
Clay	85	95	5	76	87
Composition:					
Quartz	1	1	72	5	5
Mica	1	1	3	4	3
Heavy minerals	—	—	TR	TR	TR
Clay minerals	81	93	5	76	87
Glauconite	—	—	2	—	TR
Pyrite	2	2	15	3	2
Zeolite	10	—	TR	12	TR
Plant debris/org. matter	10	3	3	5	3

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	1(51-53)	2(135-137)	1(72-74)
Organic carbon	10.54	13.59	11.59
Ca Carbonate	<1	<1	<1
	2(78-80)	4(76-78)	5(78-80)
Corg	6.86	1.35	0.93
$CaCO_3$	1	<1	<1

SITE 603 HOLE B CORE 35 CORED INTERVAL 1136.5–1145.5 m



LITHOLOGIC DESCRIPTION

BLACK CARBONACEOUS CLAYSTONE, consisting of alternations of

(1) black to very dark gray/dark olive gray (5Y 3/1-2) ORGANIC MATTER-RICH CLAYSTONE massive, parallel or flat ripple laminated; only locally burrow-mottled, pyrite laminae, lenses and micronodules;

(2) dark greenish-gray (5G 4/1), quartz-mica-and Zeolite bearing CLAYSTONE, (faintly) laminated to massive, burrow-mottled with

(3) light-gray (?turbiditic) parallel and current-ripple cross-laminated SILTSTONE layers (only 2-10 mm thick!)

Banding between (1) and (2), parallel lamination deformed around burrows. Common cycles are from base to top: (3)—(1, massive)—(2, bended)

Minor lithologies:

(4) Swelling ?SMECTITE CLAYSTONE (2-5 cm)

(5) gray (5Y 5/1) NANNOFOSSIL LIMESTONE layer (1 cm), monospecific *Nannoconus* blooms (restricted surface water conditions!)

(Cycles too thin to be graphically represented at this scale.)

SMEAR SLIDE SUMMARY (%)

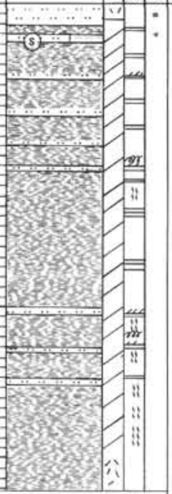
	1, 23	1, 67	2, 35	2, 69	2, 105
	M	D	D	M	M
Texture:					
Sand	—	—	—	—	—
Silt	—	6	10	100	—
Clay	100	94	90	—	100
Composition:					
Quartz	—	3	4	41	—
Feldspar	TR	—	—	—	—
Mica	TR	3	6	41	—
Heavy minerals	—	1	1	6	—
Clay Aggregates	97	78	82	—	4
Pyrite + Opaques	3	7	4	10	—
Zeolite	—	1	3	2	1
Carbonate unspec.	—	—	—	—	50
Calc. nannofossils	—	—	—	—	45
Plant debris/org. matter	—	13	—	—	—

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	3(132-135)	1(25-26)	2(147-148)
	0.89	0.92	0.1
Organic carbon	<1	<	<1
	black	black	gray
	2(70-72)	4(55-57)	2(19-20)
Corg	0.66	5.5	4.16
CaCO3	1	1	2

SITE 603 HOLE B CORE 36 CORED INTERVAL 1145.5–1154.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
			Barren	Barren		1, 2, 3, CC	0.5, 1.0



LITHOLOGIC DESCRIPTION

Interbedded (cm-dm-scale)

(1) BLACK ORGANIC-RICH CLAYSTONE (N2-3, 5G 2/1), homogenous or banded (silt laminae separating bands);

(2) laminated BLACK ORGANIC-RICH CLAYSTONE (sub-mm fine silt laminae);

(3) mica-and organic matter bearing CLAYSTONE, dark greenish-gray (5G 4/1), generally with light bioturbation;

(4) pyrite-bearing clay mineral-rich QUARTZ SILTSTONE layers (<1 to 17 cm thick) with parallel, convolute and current-ripple cross-laminations (Tb, Tc_2, Tc_1). Medium gray (N4-5) laminae due to alternations of quartz silt-rich (light), mica-, clay-, and plant material-rich (dark), pyrite and mica-rich layers. Sharp boundaries (truncation) to underlying black claystone and overlying lithologies.

(3) is probably pelagic background sediment;
(4/1) pairs are major turbidites, (2) might be explained as more distal mud turbidites
(5) Minor lithology: quartz-bearing CLAYEY ?SIDERITE-STONE

SMEAR SLIDE SUMMARY (%)

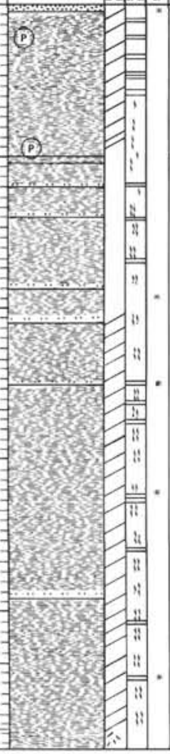
	1, 15 M	1, 33 M
Texture:		
Sand	20	–
Silt	–	70
Clay	–	30
Composition:		
Quartz	64	8
Feldspar	2	–
Mica	3	1
Heavy minerals	1	–
Clay	20	30
Glauconite	2	TR
Pyrite	5	1
Carbonate unspec.	–	60
Radiolarians	TR	–
Plant debris	3	–

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	1(71-72)	2(71-72)
Organic carbon	1.45	0.82
Carbonate	1	1

SITE 603 HOLE B CORE 37 CORED INTERVAL 1154.5–1163.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
Aptian – Albian	Aptian–Albian	Barren	Barren			1, 2, 3, 4, 5, CC	0.5, 1.0



LITHOLOGIC DESCRIPTION

Interbedded (cm-dm-scale)

(1) ORGANIC-RICH CLAYSTONE, black (N1–2) or greenish black (5G 2/1), massive or faintly laminated with pyrite lenses and concretions,

(2) LAMINATED ORGANIC-RICH CLAYSTONE with thin silt layers (quartz, mica), and

(3) CLAYSTONE, dark greenish gray (5G 4/1), generally bioturbated with only vague, disrupted lamination. This lithology more dominant than (1) and (2) in Sect. 3-5, also bioturbation.

Minor lithologies:

(4) lenses and layers of mica and organic matter bearing clay mineral-rich QUARTZ SANDSTONE/SILTSTONE (2 cm thick, associated with (1) and (2)

(5) SIDERITE-STONE (recrystallized nannofossil limestone).

SMEAR SLIDE SUMMARY (%)

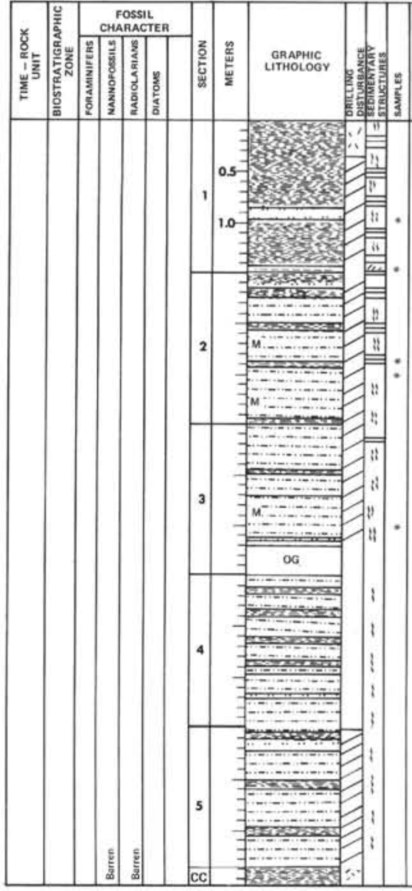
	1, 5 M	2, 138 D	3, 75 M	4, 30 D	5, 65 D
Texture:					
Sand	70	–	–	–	–
Silt	30	20	95	12	15
Clay	10	80	5	88	85
Composition:					
Quartz	50	10	76	2	8
Feldspar	–	–	3	–	–
Mica	2	5	4	1	2
Heavy minerals	1	TR	2	TR	–
Clay	12	80	5	88	80
Glauconite	2	TR	2	TR	TR
Pyrite	3	2	2	1	3
Zeolite	–	–	–	TR	–
Carbonate unspec.	–	TR	3	TR	TR
Plant debris/org. matter	5	3	3	8	7

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	1(70-72)	2(71-72)	3(70-72)
Organic carbon	1.13	0.21	1.53
Carbonate	7	1	1

	5(70-72)
Corg	0.28
$CaCO_3$	1

SITE 603 HOLE B CORE 38 CORED INTERVAL 1163.5–1172.5 m



LITHOLOGIC DESCRIPTION

Interbedded
(1) GREENISH GRAY MICA-RICH CLAYSTONE, homogeneous to bioturbated;
(2) LAMINATED GREENISH GRAY CLAYSTONE (quartz silt laminations);
(3) BLACK ORGANIC-RICH HOMOGENEOUS CLAYSTONE with distinct basal contact;
(4) GLAUCONITE-BEARING QUARTZ SILTSTONE layers (< 10 mm thick), parallel and current-ripple cross-laminated, always below (3) as base of turbidite;
(5) LAMINATED BLACK (N3) ORGANIC-RICH CLAYSTONE, more silty

Major lithology is (1) and (2); more bioturbation. Black claystone is slightly burrowed.

Minor lithologies are:
Homogeneous, gray, waxy SMECTITE CLAYSTONE, and

MICA-RICH VARIEGATED CLAYSTONE, (dark) reddish-brown (5YR 3-4/4) and greenish gray (5GY 5/1) color.

SMEAR SLIDE SUMMARY (%)

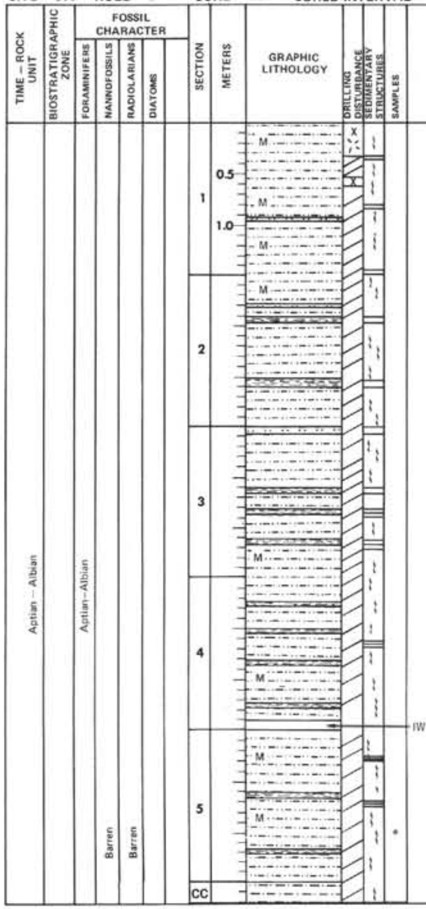
	1, 97	1, 148	2, 92	2, 101	3, 103
	M	M	D	D	D
Texture:	1	1	2	2	3
Sand	10	—	—	—	—
Silt	85	5	23	20	15
Clay	5	95	77	80	85
Composition:					
Quartz	69	2	3	2	2
Mica	15	—	15	2	10
Heavy minerals	3	1	2	1	1
Clay	5	95	77	78	85
Glauconite	3	—	—	—	1
Pyrite	3	2	1	1	1
Zeolite	—	—	—	1	—
Carbonate unspec.	2	—	—	—	—
Plant debris	—	—	2	15	—

	4(50-52)	5(52-54)
Corg	< 0.1	0.12
$CaCO_3$	1	1

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	1(50-52)	2(52-54)	3(50-52)
Organic carbon	0.1	0.12	≤0.1
Carbonate	<1	1	≤1

SITE 603 HOLE B CORE 39 CORED INTERVAL 1172.5 – 1181.5m



LITHOLOGIC DESCRIPTION

MICA-RICH CLAYSTONE (in order of abundance):
(1) VARIEGATED CLAYSTONE, dark brown (7.5YR 3/2) to dark reddish-brown (5YR 3/3) → greenish gray (5G 5/1), if locally reduced; lightly bioturbated to vaguely laminated; silt laminae (?current-laminated)
(2) CLAYSTONE, greenish gray (5G 5/1–5G 4/1), moderately bioturbated to vaguely laminated, with darker, silt-filled burrows; abundant silt stringers
(3) ORGANIC-RICH BLACK CLAYSTONE, black (N1–2) to greenish black (5G 2/1) color, usually 1–2 cm bands with silt layer at base, grading upwards into (2)

General trend is less black shales and more greenish gray claystone than in Core 38.

SMEAR SLIDE SUMMARY (%)

	5, 101
	D
Texture:	
Silt	25
Clay	75
Composition:	
Quartz	1
Mica	10
Heavy minerals	1
Clay	85
Glauconite	1
Pyrite + opaques	1
Plant debris	1

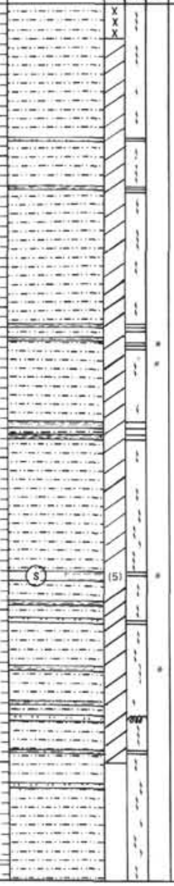
ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2(80-82)	5(77-79)
Organic carbon	< 0.1	< 0.1
Carbonate	< 1	1

SITE 603 HOLE B CORE 40 CORED INTERVAL 1181.5–1190.5m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
Barremian–Aptian/Albian;	Barremian–Aptian/Albian?		Barren	Barren		1, 2, 3, 4, 5, 6, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

MICA-RICH CLAYSTONE (in order of abundance):
(1) VARIEGATED CLAYSTONE, dusky red (2.5YR 3/2) and dark gray (5Y 4/1)
Colors interbedded and intermottled, moderate bioturbation; stripes of ?current-transported silt.
(2) GREENISH GRAY (5GY 5/1) to GRAY (5Y 5/1) CLAYSTONE, texture as (1), bioturbated
(3) DUSKY RED (2.5Y 3/2) to DARK REDDISH-BROWN (2.5Y 3/4) CLAYSTONE with abundant mottles of greenish-gray, less silt and more oxidized than (1).
(3) → (1) → (2) is a transition from oxidation to reduction
(4) BLACK TO GREENISH-BLACK (N1-5G 2/1) ORGANIC-RICH CLAYSTONE, homogeneous to faintly laminated by fine quartz silt laminae. Occurs only in (2)

Minor lithology:
(5) Quartz and mica-bearing SIDERITE CLAYSTONE with large euhedral siderite crystals (XRD and thin-section)

SMEAR SLIDE SUMMARY (%)

	3, 36 M	3, 54 D	4, 115 M	5,52 D
Texture:				
Silt	20	50	50	25
Clay	80	50	50	75
Quartz	1	2	3	3
Mica	5	15	15	11
Heavy minerals	1	1	1	2
Clay	75	80	50	80
Fe Ox	—	—	—	1
Glauconite	tr	tr	—	1
Pyrite	3	1	—	tr
Opaques	—	—	1	1
Carbonate unspec.	—	—	30	—
Plant debris	15	1	—	1

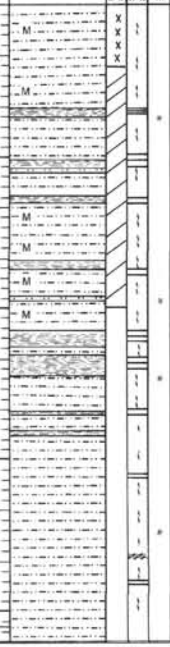
ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2(26-29)	2(42-43)	5(80-82)
Organic carbon	< 0.1	1.37	0.08
Carbonate	2	2	2
	red	black	

SITE 603 HOLE B CORE 41 CORED INTERVAL 1190.5 – 1197.2m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
			Barren	Barren		1, 2, 3, 4, 5, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

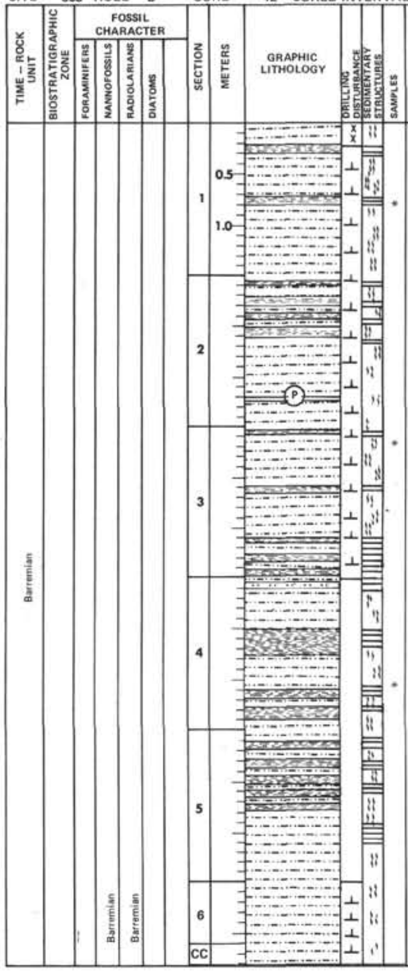
Mainly variegated
Dark reddish brown (5YR 3/4), MICA-RICH CLAYSTONE, usually bioturbated, with silt lenses and burrow fills; banded with dark greenish-gray (5GY 4/1), extensively bioturbated (*Chondrites* burrows) CLAYSTONE.

Minor lithologies are dark greenish gray, parallel laminated bands of quartz-bearing mica-rich sandy QUARTZ SILTSTONE and BLACK QUARTZ AND MICA-BEARING ORGANIC-RICH CLAYSTONE. Frequently silt laminae at base of (?turbiditic) black claystone horizons.

SMEAR SLIDE SUMMARY (%)

	1, 111 D	2, 142 M	3,66 D	4, 70 D
Texture:				
Sand	—	20	—	—
Silt	15	40	15	10
Clay	85	40	85	90
Composition:				
Quartz	6	7	4	4
Mica	15	15	15	12
Heavy minerals	—	tr	—	tr
Clay	76	70	69	80
Glauconite	2	5	3	2
Pyrite	tr	3	1	1
Opaques	tr	tr	tr	tr
Zeolite	1	tr	1	1
Carbonate unspec.	—	—	tr	—
Fish remains	—	tr	—	—
Plant debris/organics	tr	tr	7	tr

SITE 603 HOLE B CORE 42 CORED INTERVAL 1197.2 – 1204.8m



LITHOLOGIC DESCRIPTION

Interbedded (cm to dm-scale)

(1) Dark greenish gray (5GY 4/1) MICA-BEARING CLAYSTONE, heavily bioturbated (horizontal *Chondrites* vertical *Planolites* burrows) alternating with black to dark gray (N1, 2), laminae, and

(2) BLACK ORGANIC-RICH CLAYSTONE, mm-laminated, with very thin pyrite laminae and micronodules and dark greenish gray bioturbated interbeds, partly MICA-BEARING, ORGANIC-RICH CLAYEY SILTSTONE.

(1) is approx. 60-70% of core
(2) 30-40% (i.e., more than core 41)

SMEAR SLIDE SUMMARY (%)

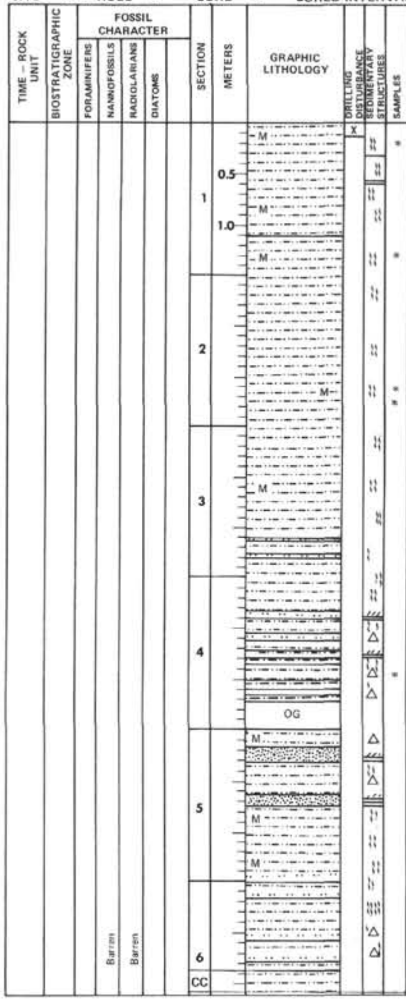
	1,81 D	2,20 D	4,107 M
Texture:			
Sand	–	10	–
Silt	13	60	25
Clay	87	30	95
Composition:			
Quartz	4	3	15
Mica	9	6	5
Heavy minerals	1	–	–
Clay	80	74	77
Glauconite	4	1	2
Pyrite	1	3	1
Fe-Ox	1	–	–
Zeolite	–	1	tr.
Radiolarians	–	–	tr.
Plant debris/Org. matter	tr.	12	–

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2(80–82)	3(78–80)	3(42-45)
Organic carbon	2.45	1.17	0.74
Carbonate	1	<1(0)	2

Section-Interval (cm)	5(85-87)
Organic carbon	<0.1
Carbonate	1

SITE 603 HOLE B CORE 43 CORED INTERVAL 1204.8 – 1214.4m



LITHOLOGIC DESCRIPTION

Upper 110 cm of core is MICA- and QUARTZ-BEARING CLAYSTONE, dark brown (10YR 3/2) to very dark grayish brown. Irregularly banded and heavily bioturbated (*Chondrites*, etc.), gradual color changes.

Lower part of core is Fe oxide-stained SILT-RICH (MICA >QUARTZ) CLAYSTONE, dark reddish brown (5YR 3/3) homogeneous to locally faintly laminated with thin quartz silt lenses (burrow fills), white, CLAYSTONE, dark greenish gray (5G 4/1) burrow-mottled throughout, usually associated with silt-rich zone at base (graded mud turbidites), and graded (*Ta*) parallel (Tb), and festoon-type cross-laminated (Tc) SANDY SILTSTONES (turbidites), up to 9 cm thick.

Reduction of claystone color from brown to green-gray is frequent at base of silt and mud turbidites.

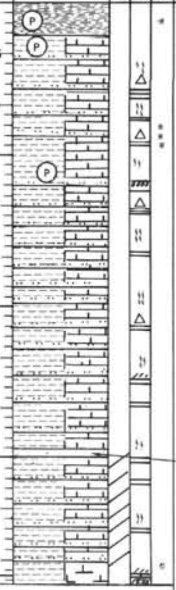
SMEAR SLIDE SUMMARY (%)

	1, 23 D	1,138 D	2,113 M	2,126 D	4, 96 D
Texture:					
Sand	2	–	–	–	7
Silt	17	35	95	12	84
Clay	81	65	5	88	4
Composition:					
Quartz	5	5	56	4	40
Feldspar	1	–	–	1	–
Mica	10	30	16	7	60
Heavy minerals	1	1	–	–	2
Clay	81	60	5	80	4
Glauconite	1	tr	12	–	4
Pyrite	1	–	4	1	–
Hemalite	tr	5	–	64	7
Radiolarians	–	–	tr	–	–
Plant debris:Organics	tr	–	7	–	5

SITE 603 HOLE B CORE 44 CORED INTERVAL 1214.4 – 1224.0m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
Barremian		R/P	NC 5b (ROTH)/6 (SISSINGH)	Barren		1, 2, 3, 4, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

Black ORGANIC-RICH CLAYSTONE (N1) in upper 31 cm. Rest of core consists of alternations of:

ORGANIC MATTER-RICH NANNOFOSSIL CLAYSTONE TURBIDITES dark gray (N3) to medium gray (N4). Base of each cycle is laminated, 5–20 mm thick silt-rich layer (CLAY-RICH QUARTZ-MICA SAND to sandy/silty CLAYSTONE), sometimes convolute lamination. About 13 cycles per 1 m section. *Chondrites*-type bioturbation in upper portion of some cycles. Pyrite concretions common.

SILT-RICH NANNOFOSSIL CLAYSTONE, dark greenish gray (5G 4/1), heavily burrowed is very rare and apparently pelagic background sediment.
(Indicated silt layers and sed. structures are generalized and schematic.)

Plant debris-bearing siltstone, current-ripple cross-laminated occurs at base of Section 4.

SMEAR SLIDE SUMMARY (%)

	1, 20 D	1,120 D	1, 128 M	1,131 M	4, 103 M
Texture:					
Sand	–	–	–	20	8
Silt	–	40	50	40	92
Clay	100	60	50	40	–
Composition:					
Quartz	–	–	1	30	66
Mica	–	–	tr	20	22
Heavy minerals	–	–	–	–	1
Clay	60	40	51	38	–
Glauconite	–	–	–	–	5
Pyrite	10	–	3	2	–
Carbonate unspec.	–	–	–	5	–
Foraminifers	–	–	tr	–	–
Calc. nannofossils	–	40	40	2	1
Plant debris/Organics	30	20	5	3	5
Other Bryozoans	–	–	tr	–	–

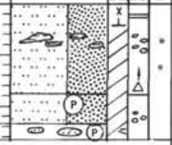
ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2(79-81)
Organic carbon	2.15
Carbonate	13
	black

SITE 603 HOLE B CORE 45 CORED INTERVAL 1224.0–1233.6m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
Late Barremian		Barren	*Micrantholithus hoschulzii* Zone/*M. obtusus* Zone			1, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

PLANT DEBRIS-BEARING SANDY SILTSTONE, dark gray (5Y 4/1–N4). Contains shallow-water shell fragments and echinoderm fragments. Vague upward grading in the two main beds recovered. Generally homogeneous; except for zones containing plastically deformed clasts of silt- and organic-bearing nannofossil-rich CLAYSTONE in Sect 1, 29-44 cm and 105-115 cm.

At 98 cm is a wood fragment, black, 4 cm long flattened shape, with pyrite nodule along base.

SMEAR SLIDE SUMMARY (%)

	1, 35 M	1, 68 D
Texture:		
Sand	–	30
Silt	–	70
Composition:		
Quartz	–	43
Feldspar	–	2
Mica	–	43
Heavy minerals	–	2
Glauconite	–	2
Pyrite	–	1
Calc. nannofossils	–	1
Plant debris	–	5

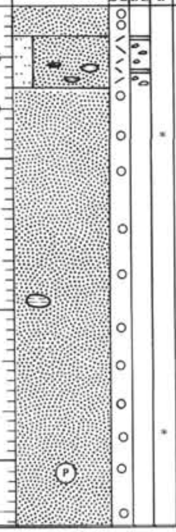
ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	1-70/71
Organic carbon	0.3
Carbonate	4

SITE 603 HOLE B CORE 46 CORED INTERVAL 1233.6–1243.2m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
late Barremian		F/P	A/G *M. obtusus* Zone/*M. hoschulzii* Zone	Barren		1, 2, 3, 4, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

SILT-RICH SAND, dark gray (N4–5Y 4/1), fine-grained mainly quartz and mica with shallow-water shell fragments and plant debris.
Unconsolidated texture in general, only a few fragments of consolidated sandstone recovered. Contains angular clasts of claystone ("mud chips").
Pyrite nodule, 2 cm diameter, Sect. 4-15 cm.

SMEAR SLIDE SUMMARY (%)

	1, 127 D	3, 119 D
Texture:		
Sand	100	80
Silt	–	20
Composition:		
Quartz	60	47
Feldspar	18	10
Mica	20	27
Heavy minerals	tr	2
Glauconite	tr	1
Pyrite	2	1
Carbonate unspec.	/	6
Calc. nannofossils	tr	tr
Plant debris	tr	6

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-70/61	4-15/16
Organic carbon	<0.1	0.1
Carbonate	6	8

SITE 603 HOLE B CORE 47 CORED INTERVAL 1243.2–1252.8m

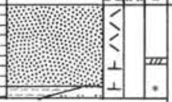
TIME – ROCK UNIT: late Barremian

BIOSTRATIGRAPHIC ZONE: *M. obtusus* Zone/*M. hoschulzii* Zone

FOSSIL CHARACTER: FORAMINIFERS: Barren; NANNOFOSSILS; RADIOLARIANS: Barren; DIATOMS

SECTION: 1

METERS: 0.5



LITHOLOGIC DESCRIPTION

SANDSTONE, fine-grained, dark gray (5Y 4/1), homogeneous, poorly-cemented, contains shell fragments and plant debris.

81–92 cm NANNOFOSSIL-BEARING, PLANT DEBRIS-RICH CLAYEY SILTSTONE grading upward to CLAYSTONE. Probably upper portion of turbidite.

SMEAR SLIDE SUMMARY (%)

	1,90 M
Texture:	
Silt	65
Clay	35
Composition:	
Quartz	22
Feldspar	2
Mica	20
Clay	35
Glauconite	1
Calc. nannofossils	5
Plant debris	15

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	1-60/61
Organic carbon	<0.1
Carbonate	2

SITE 603 HOLE B CORE 48 CORED INTERVAL 1252.8 - 1262.4m

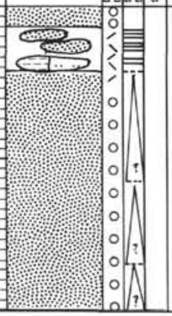
TIME – ROCK UNIT: Late Barremian

BIOSTRATIGRAPHIC ZONE: *M. obtusus* Zone/*M. hoschulzii* Zone

FOSSIL CHARACTER: FORAMINIFERS: R/P; NANNOFOSSILS; RADIOLARIANS: Barren; DIATOMS

SECTION: 1, 2

METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

SAND, quartz-feldspar-mica with wood fragments and shell debris; dark greenish gray (5GY 4/1). Loose unconsolidated slurry with only a few blocks of poorly-cemented laminated fine-grained sandstone and one of laminated plant-debris-rich clayey siltstone. Three possible graded zones having a decrease in average grain size from 1 mm to 100μ

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-70/71
Organic carbon	0.2
Carbonate	4

SITE 603 HOLE B CORE 49 CORED INTERVAL 1262.4 - 1272.0m

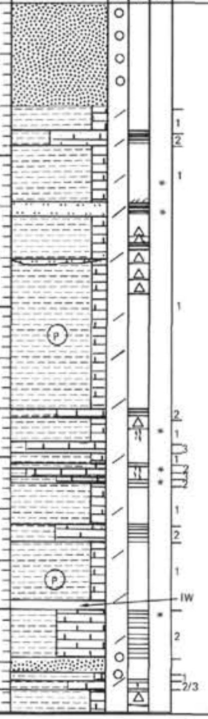
TIME – ROCK UNIT: Late Barremian

BIOSTRATIGRAPHIC ZONE: *M. obtusus/hoschulzii* Zones

FOSSIL CHARACTER: FORAMINIFERS; NANNOFOSSILS: A/G; RADIOLARIANS: R/P; DIATOMS

SECTION: 1, 2, 3, 4, 5, CC

METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

(1) ORGANIC MATTER-BEARING NANNOFOSSIL-RICH CLAYSTONE, homogeneous, dark gray (N3, 5Y 3/1). Commonly have a layer of clay- and mica-bearing quartz siltstone (laminated, cross-laminated, and/or ripple laminated) immediately below. Probably these claystone-siltstone couplets are distal turbidites. This is the dominant lithology.

(2) Laminated CLAYEY NANNOFOSSIL CHALK (Marl), medium to dark gray (N5, 5Y 5/1, N4, 5Y 4/1, N3).

(3) Bioturbated CLAY-RICH NANNOFOSSIL CHALK, light greenish gray (5GY 8/1, 5GY 7/1).

Interbedding is on 10 cm scale, therefore only dominant lithology is indicated.

Rare pyrite nodules.

Sand slurry at top of Sect. 1 and in Sect. 5, 45-60 cm.

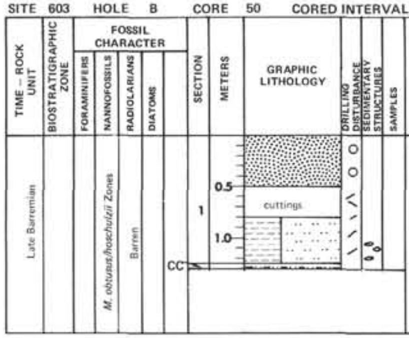
SMEAR SLIDE SUMMARY (%)

	5, 5 D	2, 30 M	2,64 D	3, 126 D	4,12 D	4,15 M
Texture:						
Sand	–	25	5	–	–	–
Silt	40	60	80	20	30	70
Clay	60	15	15	81	70	30
Composition:						
Quartz	tr	5	43	21	1	tr
Feldspar	–	5	3	–	–	–
Mica	1	25	20	1	1	tr
Heavy minerals	–	tr	2	1		
Clay	59	9	15	71	68	30
Pyrite		3	2	2	2	–
Fe-Ox	2					
Carbonate unspec.		2	4	–	–	tr
Calc. nannofossils	30	tr	8	15	25	70
Plant debris/org mat (5/5)	8	5	3	8	3	–

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-72/74	5-32/34	4-60/63
Organic carbon	1.4	1.8	2.6
Carbonate	40	78	56

SITE 603 HOLE B CORE 50 CORED INTERVAL 1272.0 - 1281.6m



LITHOLOGIC DESCRIPTION

ORGANIC MATTER-BEARING, CLAYEY SILTSTONE, dark gray (N5). Contains plastically deformed clasts of laminated NANNOFOSSIL CLAYSTONE (MARL) (dark gray, *N4*) near base.

0–50 cm: Slurry of sand, fine-grained, dark gray; probably downhole contamination

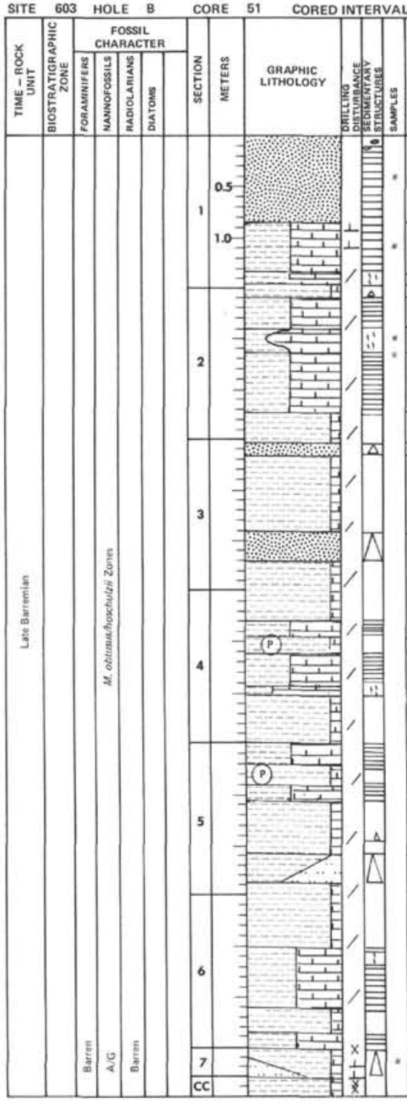
50–80 cm: cuttings of siltstone and claystone

Core Catcher: mud slurry

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	1-95/97
Organic carbon	1.0
Carbonate	30

SITE 603 HOLE B CORE 51 CORED INTERVAL 1281.6–1291.2 m



LITHOLOGIC DESCRIPTION

INTERBEDDED NANNOFOSSIL CLAYSTONE (MARL) AND CLAYSTONE

(1) Laminated NANNOFOSSIL CLAYSTONE (Marl), gray (*N4*, N5, 5Y 5/1 - 5Y 3/1).

(2) ORGANIC- and NANNOFOSSIL-BEARING CLAYSTONE, dark gray (N2, N3), homogeneous. SILTSTONE layer below in some cases.

(3) Bioturbated CLAYEY NANNOFOSSIL CHALK, light gray (N5, N6 N7); minor lithology in this core.

Types (1) and (2) are interbedded on a 5-15 cm scale, therefore only the dominant lithology is drawn.

SANDSTONE to SILTY SANDSTONE

Turbidites, dark greenish gray (5GY 4/1), are in Sect. 1, 0-85 cm and Sect. 2, 7-16 and 190-120 cm.

Laminated, graded, and with claystone intraclasts.

Rare pyrite nodules.

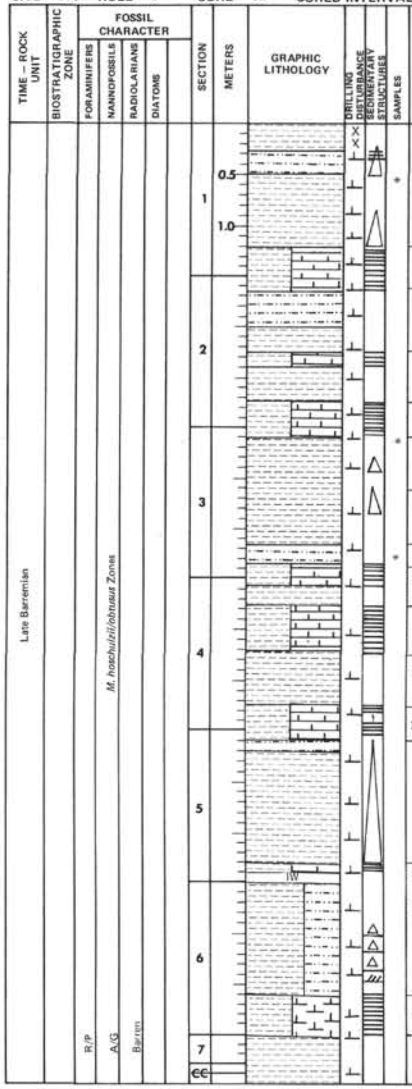
SMEAR SLIDE SUMMARY (%)

	1, 43 D	1, 108 D	2, 52 D	2, 68 M	7, 15 D
Texture:					
Sand	1	–	–	–	–
Silt	31	30	8	35	15
Clay	68	70	92	65	85
Composition:					
Quartz	12	–	–	–	–
Feldspar	1	–	–	–	–
Mica	7	–	tr	tr	1
Clay	66	69	92	65	79
Pyrite	tr	tr	tr		
Zeolite	–	–	–	–	tr
Carbonate unspec.	–	–	–	5	
Calc. nannofossils	8	28	7	30	11
Plant debris	4	–	–	–	3
Other Organics	2	3	1	–	6

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-89/91	5-82/83
Organic carbon	0.5	1.2
Carbonate	90	39

SITE 603 HOLE B CORE 52 CORED INTERVAL 1291.2–1300.8 m



LITHOLOGIC DESCRIPTION

INTERBEDDED CLAYSTONE AND NANNOFOSSIL CLAYSTONE (MARL)

(1) NANNOFOSSIL-BEARING CLAYSTONE, very dark gray (5Y 2/1); homogeneous but in many cases grades downward into organic- and silt-bearing Nannofossil CLAYSTONE (gray, 5Y 4/1). Probably distal turbidities.

(2) Laminated ORGANIC-BEARING NANNOFOSSIL CLAYSTONE (Marl), gray (5Y 4/1, 5Y 5/1, N4, N5).

Minor lithology: NAKNOFOSSIL-BEARING SILT-RICH CLAYSTONE, dark gray (5Y 4/1), to SILTY CLAYSTONE. Graded. Turbidite origin.

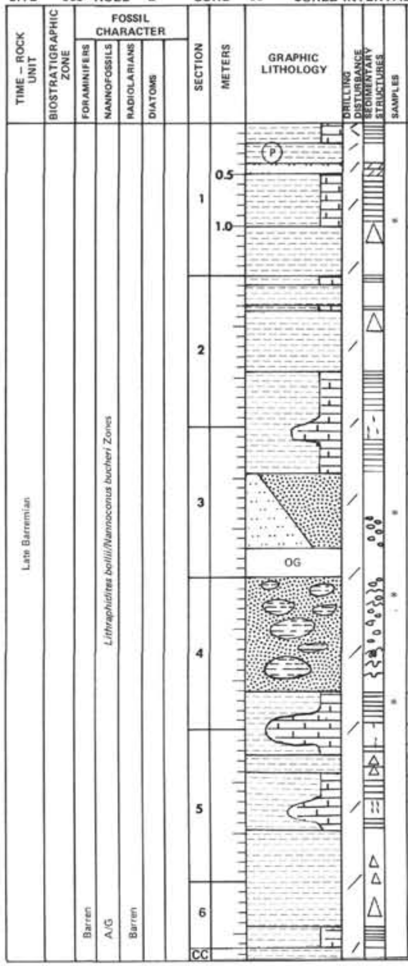
SMEAR SLIDE SUMMARY (%)

	1, 56 M	3, 13 M	3,124 D
Texture:			
Sand	—	—	—
Silt	31	12	21
Clay	69	88	79
Composition:			
Quartz	3	1	6
Mica	6	2	8
Heavy minerals	—	—	1
Clay	69	83	76
Glauconite	—	—	tr
Pyrite	—	tr	1
Zeolite	tr	—	—
Calc. nannofossils	17	9	6
Plant debris	1	21	1
Organics	4	21	1

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-79/81	5-76/78
Organic carbon	2.1	1.0
Carbonate	76	15

SITE 603 HOLE B CORE 53 CORED INTERVAL 1300.8–1310.4 m



LITHOLOGIC DESCRIPTION

INTERBEDDED CLAYSTONE, SILTY SANDSTONE, AND NANNOFOSSIL-BEARING CLAYSTONE

Major Lithologies:

(1) CLAYSTONE, homogeneous, very dark gray (N2, N3, 5YR 2/1) usually grading downward into NANNOFOSSIL-BEARING CLAYSTONE, dark gray (N3, 5YR 3/1). Underlain in some cases by silty claystone. Distal turbidite origin indicated.

(2) Quartzose SILTY SANDSTONE to SANDY SILTSTONE, medium dark gray (N4, 5YR 4/1, 5GY 4/1). Contains plant debris and shell fragments. Turbidite origin indicated. Center portion can be debris flow containing claystone and laminated marl intraclasts.

(3) Laminated NANNOFOSSIL-BEARING TO NANNOFOSSIL RICH CLAYSTONE (Marl), dark to medium gray (N3, 5Y 3/1, N4, 5Y 4/1, 5Y 5/1).

Minor Lithology:

(4) Bioturbated CLAY-RICH NANNOFOSSIL LIMESTONE, medium gray (5Y 4/1, 5GY 5/1).

Due to extensive interbedding, only the dominant lithology is drawn.

Scattered pyrite nodules.

SMEAR SLIDE SUMMARY (%)

	1, 94 M	3, 84 M	4, 18 M	4, 120 D
Texture:				
Sand	—	30	—	—
Silt	—	60	—	25
Clay	100	10	100	25
Composition:				
Quartz	—	60	—	—
Mica	tr	20	tr	
Clay	99	88	93	25
Glauconite	—	1	—	—
Pyrite	—	2	1	—
Zeolite	—	2	—	—
Carbonate unspec.	—	—	—	25
Calc. nannofossils	1	5	5	50
Other Organics	—	2	1	—

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-77/79	5-76/78
Organic carbon	1.5	0.2
Carbonate	16	79
	3-64/66	
	1.4	
	22	

SITE 603 HOLE B CORE 54 CORED INTERVAL 1310.4–1320.0 m

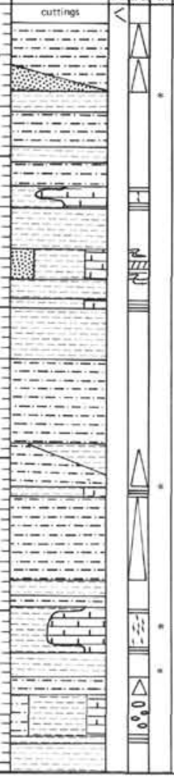
TIME-ROCK UNIT: Early Barremian

BIOSTRATIGRAPHIC ZONE: *L. bollii/N. bucheri* Zones

FOSSIL CHARACTER: FORAMINIFERS R/P; NANNOFOSSILS A/C; RADIOLARIANS Barren; DIATOMS

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

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

INTERBEDDED CLAYSTONE, SILTSTONE, NANNOFOSSIL-RICH CLAYSTONE (MARL), AND CHALK

(1) Laminated NANNOFOSSIL-RICH CLAYSTONE (Marl), gray (N3–N6, 5Y 4/1, 5Y 5/1).
(2) Bioturbated Clay-rich NANNOFOSSIL CHALK, light gray (N7, 5Y 7/1).
(3) ORGANIC MATTER- and NANNOFOSSIL-BEARING CLAYSTONE, homogeneous, very dark gray (N3–N4); can have silt-rich basal layer.
(4) SILTY CLAYSTONE TO SILTSTONE, medium gray (5Y 5/1, N4, 5Y 4/1), organic matter and nannofossil-bearing mica-rich, quartzose; contains shell fragments.

Due to interbedding, only dominant lithology is drawn.

Sect. 5, 95-120 cm – slump or debris flow of disrupted laminated marl with siltstone interblock fill.

SMEAR SLIDE SUMMARY (%)

	1, 91 D	4, 28 D	5, 12 M	5, 56 D
Texture:				
Sand	–	15	–	–
Silt	–	35	40	34
Clay	100	50	60	60
Composition:				
Quartz	tr	15	tr	1
Feldspar	–	2	–	–
Mica	tr	8	40	1
Clay	94	52	–	66
Pyrite	1	1	–	–
Carbonate unspec.	–	10	tr	tr
Calc. nannofossils	5	8	57	25
Radiolarians	–	–	–	tr
Fish remains	–	–	–	tr
Plant debris	–	5	2	7
Other Organics	tr	–	–	–

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-89/91	3-87/90	5-71/73
Organic carbon	1.4	0.0	1.1
Carbonate	34	6	25

SITE 603 HOLE B CORE 55 CORED INTERVAL 1320.0–1329.6 m

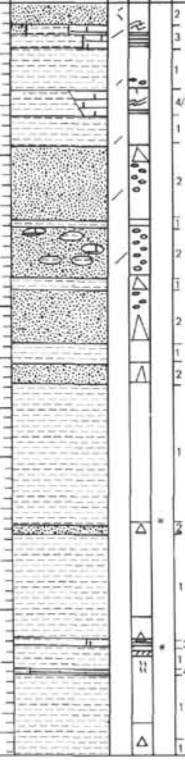
TIME-ROCK UNIT: Early Barremian

BIOSTRATIGRAPHIC ZONE: *L. bollii/N. bucheri*

FOSSIL CHARACTER: FORAMINIFERS; NANNOFOSSILS A/G; RADIOLARIANS Barren; DIATOMS

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

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

INTERBEDDED CLAYSTONE, SANDY SILTSTONE, NANNOFOSSIL-RICH CLAYSTONE (MARL) AND NANNOFOSSIL LIMESTONE

(1) NANNOFOSSIL-BEARING to RICH CLAYSTONE, homogeneous, dark gray (N3, N4); *Chondrites* burrows at top of some layers and silt-rich zone at base.
(2) SANDY SILTSTONE, QUARTZOSE, ORGANIC MATTER and MICA-BEARING; shades of gray (5Y 3/1, 5Y 4/1, N4); upward graded. Can include intraclasts of other lithologies.
(3) Laminated NANNOFOSSIL-RICH CLAYSTONE (Marl), gray (5Y 4/1–5Y 6/1, N5–N6).
(4) Bioturbated CLAY-RICH NANNOFOSSIL LIMESTONE. Light gray with greenish tints (N6, 5Y 7/1, 5GY 7/1).

Types (3) and (4) have transitional contacts.
Due to interbedding, only dominant lithology is drawn.
Section 1, 70–76 cm: claystone layer with angular siltstone intraclasts.
Rare pyrite nodules.
Sandy siltstone turbidites are carbonate cemented at base in many cases.

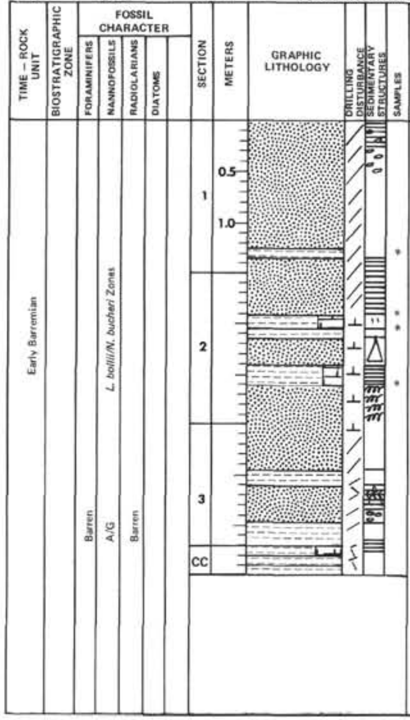
SMEAR SLIDE SUMMARY (%)

	4, 64 D	5, 32 D
Texture:		
Sand	–	–
Silt	2	16
Clay	98	84
Composition:		
Quartz	tr	–
Mica	tr	–
Clay	81	84
Pyrite	1	tr
Zeolite	–	tr
Carbonate unspec.	–	1
Calc. nannofossils	17	15
Plant debris	1	–
Other Organics	–	tr

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-70/72	3-69/71	5-90/92
Organic carbon	0.1	<0.1	0.7
Carbonate	3	35	61

SITE 603 HOLE B CORE 56 CORED INTERVAL 1329.6–1339.2 m



LITHOLOGIC DESCRIPTION

INTERBEDDED SANDSTONE, CLAYSTONE, AND NANNOFOSSIL-RICH CLAYSTONE (MARL)

Major Lithologies:

(1) SANDSTONE, quartzose, rich in wood fragments; medium to fine-grained with grading; dark greenish gray (5GY 3/1). Claystone intraclasts are abundant in central portion of these turbidite beds. General sequence is massive base, intraclast zone, then laminated fine-grained upper portion.

(2) NANNOFOSSIL-BEARING CLAYSTONE, homogeneous to vaguely upward graded, very dark gray (N2, N3).

Minor Lithologies:

(3) Laminated ORGANIC MATTER-BEARING NANNOFOSSIL-RICH CLAYSTONE (Marl), gray (N4, N5).

(4) Bioturbated NANNOFOSSIL-RICH CLAYSTONE (Marl), medium gray (5Y 4/1–5Y 6/1).

Only dominant lithologies are drawn.

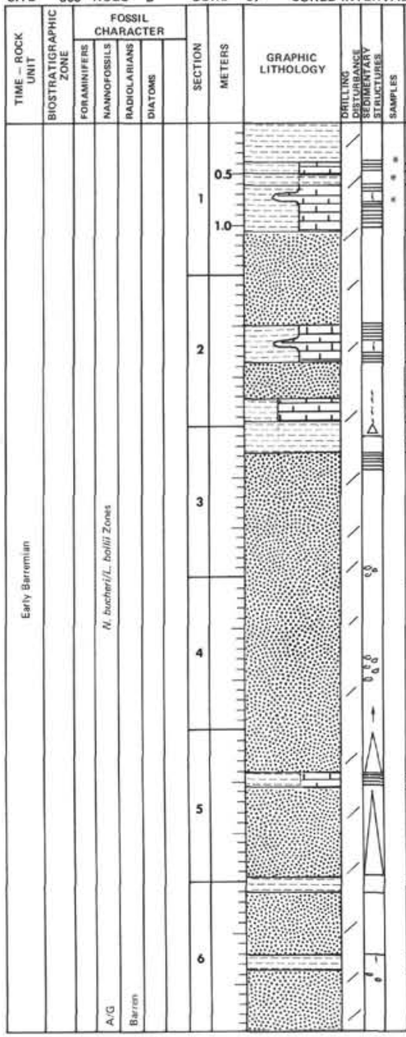
SMEAR SLIDE SUMMARY (%)

	1, 129 D	2, 50 M	2, 56 M	2, 104 D
Texture:				
Sand	–	–	–	–
Silt	8	12	26	30
Clay	92	88	74	70
Quartz	tr	–	1	1
Mica	3	4	–	2
Clay	82	86	74	70
Pyrite	2	1	–	2
Zeolite	–	3	–	–
Calc. nannofossils	10	8	25	20
Plant debris	1	–	–	–
Other Organics	–	–	–	5

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-95/97	1-70/72
Organic carbon	1.8	0.4
Carbonate	37	5

SITE 603 HOLE B CORE 57 CORED INTERVAL 1339.2–1348.8 m



LITHOLOGIC DESCRIPTION

INTERBEDDED SANDSTONE, CLAYSTONE, AND NANNOFOSSIL CLAYSTONE (MARL)

Major Lithologies:

(1) SANDSTONE, quartzose, dark gray to dark greenish gray (N4, 5GY 4/1), contains angular quartz, mica, heavy minerals, opaques, plant debris and shell fragments. Fine-grained, coarser at base of beds. Contains claystone intraclasts. Coarse basal portion is calcite-cemented in several cases. Turbidite origin.

(2) ORGANIC MATTER- and NANNOFOSSIL-BEARING CLAYSTONE, very dark gray (N2, N3), homogeneous or faintly graded with minor quartz silt.

(3) Laminated NANNOFOSSIL CLAYSTONE (Marl), gray (N5, N6) to slightly brownish gray (5Y 5/1, 5Y 6/1, 5YR 4/1).

Minor Lithologies:

(4) Bioturbated CLAYEY NANNOFOSSIL LIMESTONE (Marly Limestone), light gray (N7, N6, N5), can be vaguely laminated.

(5) NANNOFOSSIL-BEARING CLAYSTONE, dark greenish gray (5G 4/1), homogeneous.

Only dominant lithologies are drawn.

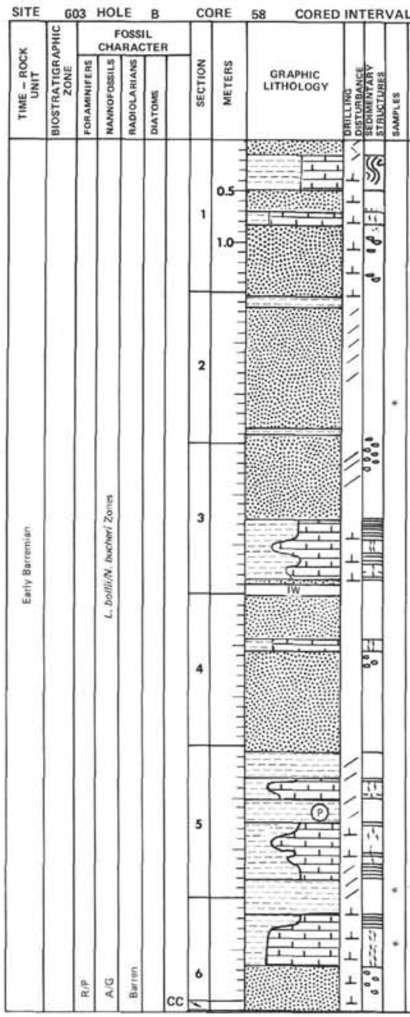
SMEAR SLIDE SUMMARY (%)

	1, 32 M	1, 53 M	1, 70 D
Texture:			
Sand	–	–	–
Silt	42	7	–
Clay	58	93	100
Composition:			
Quartz	–	5	–
Mica	tr	1	tr
Heavy minerals	tr	tr	–
Clay	58	52	40
Glauconite	tr	tr	–
Opaques	1	1	tr
Zeolite	–	–	tr
Carbonate unspec.	40	–	–
Calc. nannofossils	–	40	60
Plant debris	1	1	–

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-68/70	5-44/46
Organic carbon	0.6	0.8
Carbonate	58	39
	3-89/190	4-67/69
	0.9	<0.1
	26	21

SITE 603 HOLE B CORE 58 CORED INTERVAL 1348.8 - 1358.4



LITHOLOGIC DESCRIPTION

INTERBEDDED SANDSTONE, NANNOFOSSIL CLAYSTONE (MARL), LIMESTONE, AND CLAYSTONE

(1) SILT-RICH SANDSTONE, QUARTZOSE, FELDSPAR- and MICA-RICH; brownish gray (10YR 5/1, 5Y 4/1); medium-grained, massive or slightly graded, contains claystone intraclasts and plant debris.

(2) Laminated NANNOFOSSIL CLAYSTONE (Marl), light brownish gray (5Y 5/1, 10YR 6/1).

(3) Bioturbated CLAY-RICH NANNOFOSSIL LIMESTONE, light gray (N7, N8) with gray burrow mottling.

(4) ORGANIC MATTER- and NANNOFOSSIL-BEARING CLAYSTONE, very dark gray (N2, N3, N4, 10YR 3/1), homogeneous.

Rare ammonite aptychi in laminated marl intervals. Nautiloid shell at Sect. 3, 145 cm.

Sect. 1, 14-49 cm – slump (?) in laminated marl, perhaps caused by basal shear of overlying sandstone turbidite.

Only dominant lithologies are drawn.

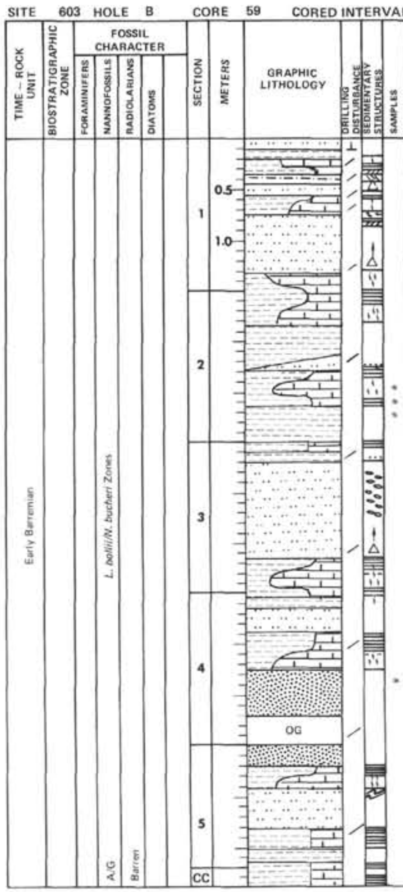
SMEAR SLIDE SUMMARY (%)

	2, 107 D	5, 141 D	6, 42 D
Texture:			
Sand	80	–	–
Silt	15	20	30
Clay	5	80	70
Composition:			
Quartz	50	1	1
Feldspar	3		
Mica	35	5	1
Heavy minerals	4	1	–
Clay	–	76	60
Glauconite	1	–	–
Opaques	3	tr	1
Carbonate unspec.	1	–	10
Calc. nannofossils	–	10	25
Plant debris	3	7	2

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-75/77	5-91/93
Organic carbon	0.1	0.2
Carbonate	3	79

SITE 603 HOLE B CORE 59 CORED INTERVAL 1358.4–1368.0 m



LITHOLOGIC DESCRIPTION

INTERBEDDED CLAYSTONE, SILTY SANDSTONE, NANNOFOSSIL-RICH CLAYSTONE, AND CLAYEY NANNOFOSSIL CHALK

(1) ORGANIC MATTER-RICH and NANNOFOSSIL-BEARING CLAYSTONE, very dark gray (N3, N4), homogeneous. *Chondrites* burrows at top of some layers.

(2) SILTY SANDSTONE, quartzose; dark greenish gray (5GY 4/1); fine- to medium-grained, generally graded with intraclasts of the other lithologies in center portion of bed. Contains wood fragments and plant debris.

(3) Laminated NANNOFOSSIL-RICH CLAYSTONE (Marl), gray (10YR 5/1 mainly; also 10YR 4/1, 10YR 6/1, N6).

(4) BIOTURBATED NANNOFOSSIL CHALK (Marly chalk), very light greenish gray (5GY 7/1, 5GY 8/1).

Lithologies (3) and (4) grade into each other.

Only dominant lithologies are drawn.

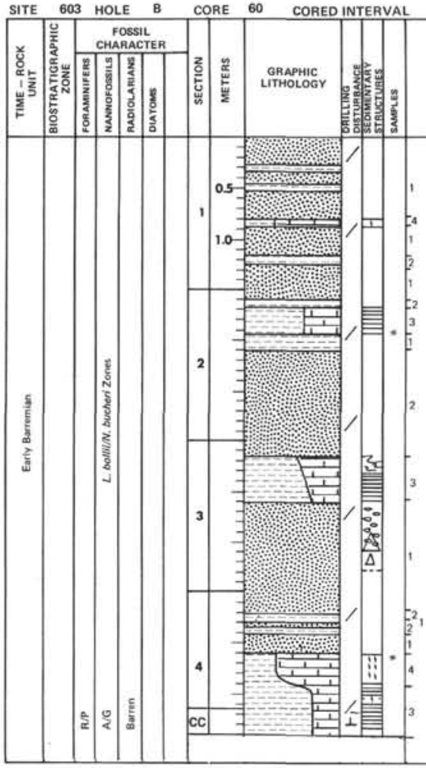
SMEAR SLIDE SUMMARY (%)

	2, 95 M	2, 103 D	2, 118 D	4, 86 D
Texture:				
Sand	–	–	–	70
Silt	65	20	28	30
Clay	35	80	72	–
Composition:				
Quartz	tr	tr	tr	50
Feldspar	–	–	–	5
Mica	1	tr	tr	20
Heavy minerals	–	–	–	5
Clay	35	75	72	8
Pyrite	tr	–	tr	–
Carbonate unspec.	2	5	3	5
Calc. nannofossils	60	20	20	–
Plant debris	2	tr	5	7

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-114/116	5-56/58
Organic carbon	1.1	0.5
Carbonate	30	6
	1-108/111	4-35/38
	0.01	0.6
	27	79

SITE 603 HOLE B CORE 60 CORED INTERVAL 1368.0 - 1377.6 m



LITHOLOGIC DESCRIPTION

INTERBEDDED SANDSTONE, CLAYSTONE, NANNOFOSSIL CLAYSTONE, AND CLAYEY CHALK

(1) SANDSTONE, QUARTZOSE, MICA-RICH; brownish gray (5Y 4/1, 5Y 5/1); massive base, intraclast-rich central portion, and other turbidite features; plant debris-beariing.

(2) NANNOFOSSIL-BEARING CLAYSTONE, dark gray (N3, N4); homogeneous. Organic-bearing.

(3) Laminated NANNOFOSSIL CLAYSTONE (Marl), gray (5Y 5/1, 5Y 6/1).

(4) Bioturbated CLAYEY NANNOFOSSIL CHALK, light greenish gray (5G 6/1, 5G 7/1, 5G 8/1).

Lithologies (3) and (4) grade into each other.

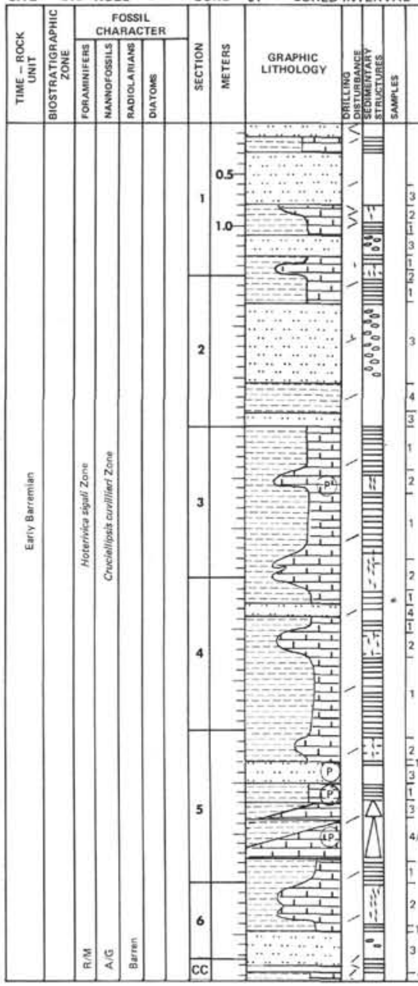
SMEAR SLIDE SUMMARY (%)

	2, 45 D	4, 66 M
Texture:		
Sand	–	–
Silt	15	50
Clay	85	50
Composition:		
Quartz	1	1
Feldspar	tr	
Mica	2	1
Heavy minerals	–	tr
Clay	80	45
Pyrite	1	–
Carbonate unspec.	2	2
Calc. nannofossils	10	50
Plant debris	3	1

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-70/73	1.71/73	3-40/42	4-40/42
Organic carbon	0.8	<0.1	0.2	2.0
Carbonate	4	2	75	13

SITE 603 HOLE B CORE 61 CORED INTERVAL 1377.6 - 1387.2 m



LITHOLOGIC DESCRIPTION

INTERBEDDED NANNOFOSSIL CLAYSTONE (Marl), SILTY SANDSTONE, CLAYSTONE, AND CLAYEY LIMESTONE

(1) Laminated NANNOFOSSIL CLAYSTONE (Marl), brownish gray (5Y 4/1, 5Y 5/1)

(2) Bioturbated CLAYEY NANNOFOSSIL LIMESTONE/CHALK (Marly Linestone), gray (N5, N6, N7); minor lithology.

Lithologies (1) and (2) grade into each other.

(3) SILTY SANDSTONE, quartzose; dark greenish gray (5GY 4/1, 5Y 4/1); feldspar, mica, and plant debris rich; can contain intraclasts and rip-up blocks of the other lithologies; carbonate-cemented coarse base.

(4) ORGANIC MATTER- and NANNOFOSSIL-BEARING CLAYSTONE, dark gray (N3, N4), homogeneous, with silty base in some cases.

Only the locally dominant lithology is drawn.

Pyrite nodules are scattered through core.

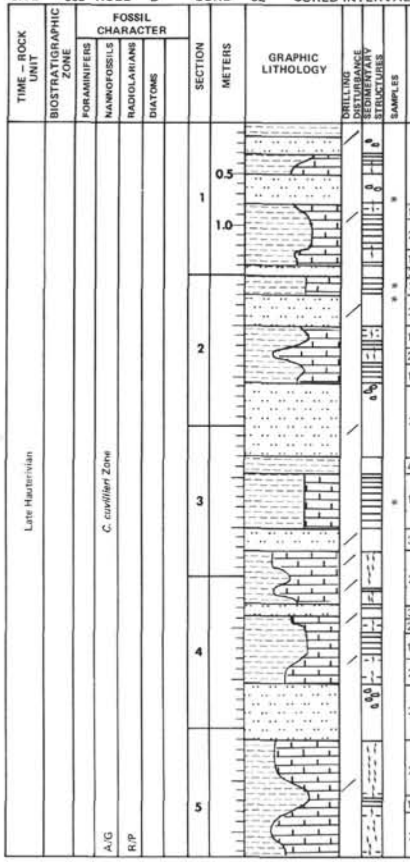
SMEAR SLIDE SUMMARY (%)

	4, 21 M
Texture:	
Sand	–
Silt	–
Clay	–
Plant debris	100

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-92/94	5-89/90	1-78/80	4-102/104
Organic carbon	0.2	1.7	<0.1	2.0
Carbonate	7	19	40	78

SITE 603 HOLE B CORE 62 CORED INTERVAL 1387.2–1396.2 m



LITHOLOGIC DESCRIPTION

INTERBEDDED NANNOFOSSIL CLAYSTONE (MARL) CLAYEY CHALK, CLAYEY SILTSTONE, AND CLAYSTONE

(1) Laminated NANNOFOSSIL CLAYSTONE (Marl), brownish gray (5Y 4/1 - 5Y 6/1).

(2) Bioturbated CLAYEY NANNOFOSSIL CHALK (Marly Limestone), gray (N6, N7).

These two lithologies grade into each other.

(3) CLAYEY SILTSTONE to SANDSTONE, quartzose; rich in mica, feldspar, and plant debris; dark greenish gray (5GY 4/1, 5Y 4/1); in some cases contains claystone intraclasts; coarse basal layer of turbidite often calcite cemented.

(4) NANNOFOSSIL-BEARING CLAYSTONE, brownish black (5YR 2/1) to dark gray (5Y 4/1, N3), homogeneous.

Only the locally dominant lithology is drawn.

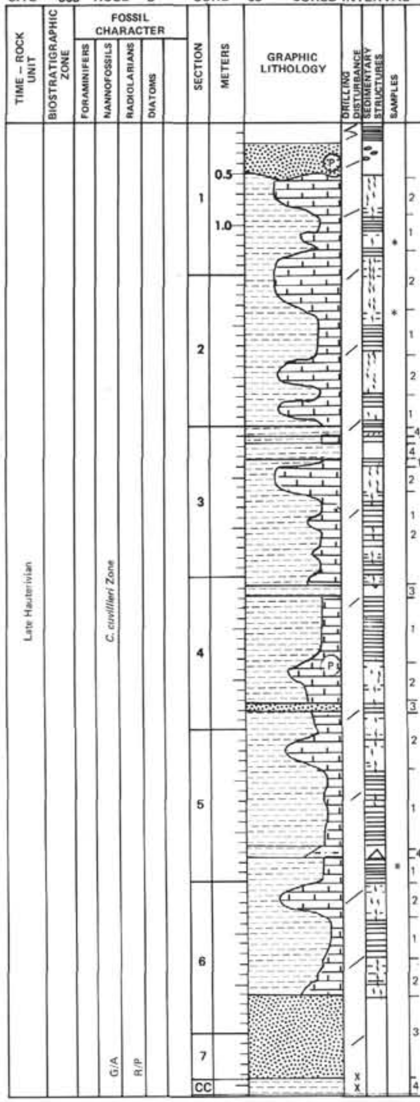
SMEAR SLIDE SUMMARY (%)

		1, 75 D	2, 16 D	2, 20 D	3, 76 D
	Texture:				
	Sand	15	–	–	–
	Silt	19	–	6	–
	Clay	66	100	94	100
Composition:	Quartz	15	–	5	–
	Feldspar	15	–	–	–
	Mica	2	tr	1	tr
	Heavy minerals	1	–	tr	–
	Clay	36	58	50	98
	Opaques	tr	1	–	–
	Glauconite	tr	–	–	–
	Pyrite	–	–	tr	–
	Calc. nannofossils	30	40	43	2
	Plant debris	1	1	1	–

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-85/88	5-85/88
Organic carbon	2.1	0.1
Carbonate	71	79

SITE 603 HOLE B CORE 63 CORED INTERVAL 1396.2 – 1405.7 m



LITHOLOGIC DESCRIPTION

INTERBEDDED NANNOFOSSIL CLAYSTONE (MARL), CHALK, SILTSTONE, AND CLAYSTONE

(1) Laminated ORGANIC MATTER-BEARING NANNOFOSSIL CLAYSTONE (Marl), brownish gray (5Y 4/1, 5Y 5/1, N6).

(2) Bioturbated CLAYEY NANNOFOSSIL CHALK (Marly Limestone), rich in radiolarians, light gray (N5 - N7).

Lithologies (1) and (2) grade into each other.

(3) SILTSTONE to SILTY CLAYSTONE, quartzose; dark greenish gray (5GY 4/1, 5Y 4/1); contains claystone intraclasts in many cases. Turbidite origin.

(4) NANNOFOSSIL- and ORGANIC MATTER-BEARING CLAYSTONE, very dark gray (N2, N3), homogeneous.

Rare *Inoceramus* and ammonite aptychi in laminated marl intervals.

Only the locally dominant lithology is drawn.

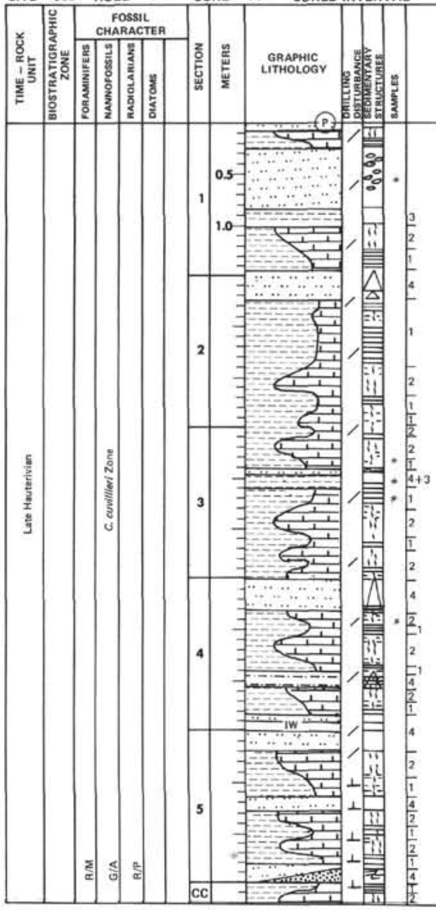
SMEAR SLIDE SUMMARY (%)

	1, 121 M	2, 37 M	5, 136 D
Texture:			
Sand	–	–	–
Silt	20	–	30
Clay	80	100	70
Composition:			
Quartz	tr	–	tr
Mica	–	tr	tr
Clay	80	69	64
Opaques	–	tr	–
Zeolite	–	tr	–
Carbonate unspec.	tr	1	1
Calc. nannofossils	20	30	30
Plant debris/Organics	–	–	5

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-85/87	5-78/80
Organic carbon	0.2	0.5
Carbonate	77	58

SITE 603 HOLE B CORE 64 CORED INTERVAL 1405.7–1414.7 m



LITHOLOGIC DESCRIPTION

INTERBEDDED NANNOFOSSILS-RICH CLAYSTONE (MARL), CLAY-RICH LIMESTONE, CLAYSTONE, AND SILTY SANDSTONE

(1) Laminated Nannofossil-Rich CLAYSTONE (Marl), organic matter-bearing, gray (5Y 5/1, N5, 5Y 4/1)
(2) Bioturbated Clay-rich NANNOFOSSIL LIMESTONE, rich in radiolarians, light gray (N6, N7) to light greenish ray (5GY 6/1).

Lithologies # 1 and # 2 grade into each other.

(3) CLAYSTONE; organic matter- nannofossil-mica-bearing, very dark gray (N2, N3), homogeneous.
(4) SILTY SANDSTONE to SANDSTONE or SILTSTONE; quartzose, minor mica and glauconite; dark greenish gray (5GY 4/1, 5Y 4/1); contains plant debris and abundant claystone intraclasts. Turbidite origin.

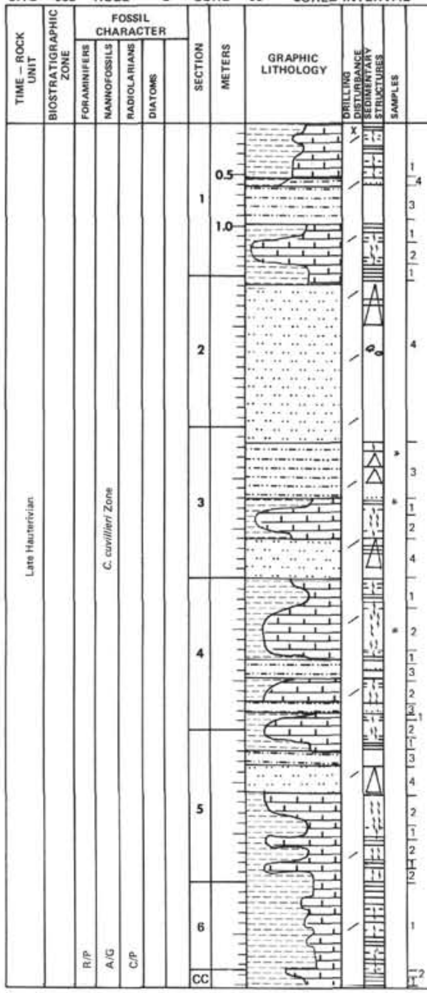
SMEAR SLIDE SUMMARY (%)

	1, 58 D	3, 32 D	3, 53 D	3, 72 D	4, 39 D
Texture:					
Sand	–	–	–	–	–
Silt	44	12	76	13	20
Clay	56	88	24	87	80
Composition:					
Quartz	20	–	–	–	–
Feldspar	10	–	–	–	–
Mica	5	5	–	–	tr
Heavy minerals	tr	–	–	–	–
Clay	51	84	24	87	80
Glauconite	tr	–	–	–	–
Pyrite + opaques	1	–	–	–	–
Zeolite	–	tr	tr	tr	tr
Carbonate unspec.	7	–	70	4	tr
Calc. nannofossils	5	7	6	6	20
Plant debris + Organics	1	4	–	3	1

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-80/82	5-76/79
Organic carbon	0.7	0.2
Carbonate	78	79

SITE 603 HOLE B CORE 65 CORED INTERVAL 1414.7–1423.7 m



LITHOLOGIC DESCRIPTION

INTERBEDDED NANNOFOSSIL CLAYSTONE (MARL), LIMESTONE, CLAYSTONE, AND SILTY SANDSTONE

(1) Laminated NANNOFOSSIL CLAYSTONE (Marl), brownish gray (5Y 4/1, 5Y 5/1, N5).
(2) Bioturbated RADIOLARIAN-BEARING NANNOFOSSIL LIMESTONE, very light gray (N6, N7, N8).

Lithologies (1) and (2) grade into each other.

(3) SILT-BEARING NANNOFOSSIL-RICH CLAYSTONE, very dark gray (N2, N3), homogeneous or with silt-rich base. In many cases it is underlain by cross-laminated or laminated siltstone.
(4) SILTY SANDSTONE, quartzose, rich in mica, with shell fragments and plant debris; dark gray (N4, 5GY 4/1); Turbidite sedimentary structures including claystone intraclasts.

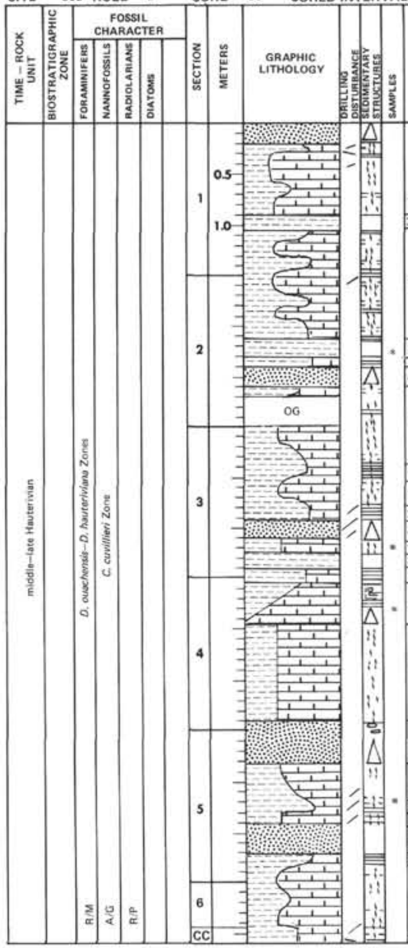
SMEAR SLIDE SUMMARY (%)

	3, 28 D	3, 75 D	4, 48 D
Texture:			
Sand	–	–	–
Silt	16	–	–
Clay	84	100	100
Composition:			
Quartz	5	–	–
Feldspar	5	–	–
Mica	3	tr	–
Clay	49	70	–
Pyrite + opaques	1	–	–
Carbonate unspec.	–	30	60
Calc. nannofossils	35	–	40
Fish remains	tr	tr	–
Plant debris	2	–	–

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-84/86	4-70/73
Organic carbon	0.1	0.8
Carbonate	4	75
	1-27/30	
	1.8	
	55	

SITE 603 HOLE B CORE 66 CORED INTERVAL 1423.7 - 1432.7 m



LITHOLOGIC DESCRIPTION

INTERBEDDED CLAYEY LIMESTONE, NANNOFOSSIL CLAYSTONE (MARL), CLAYSTONE, AND SANDSTONE

(1) Bioturbated CLAYEY NANNOFOSSIL LIMESTONE (Marly Limestone), very light gray (N8, N7)

(2) Laminated NANNOFOSSIL CLAYSTONE (Marl), gray (10YR 5/1 most common, also N5, N6, N7, 10YR 4/1, 10YR 6/1)

Lithologies (1) and (2) grade into each other.

(3) NANNOFOSSIL and ORGANIC MATTER-BEARING CLAYSTONE, dark gray (N3, N4); homogeneous, but many layers have silty bases and bioturbated tops.

(4) SILTY SANDSTONE, CLAY-RICH, QUARTZOSE, with feldspar, mica, and plant debris; dark greenish gray (5GY 4/1, 5Y 4/1); often calcite cemented in basal part.

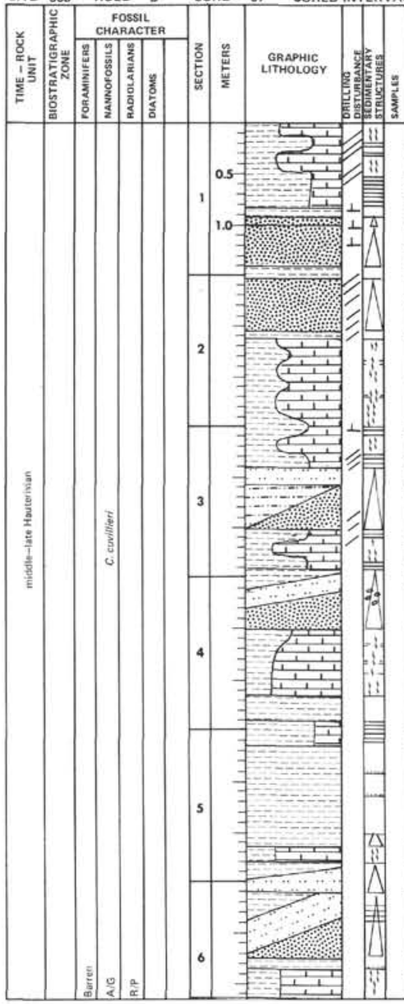
SMEAR SLIDE SUMMARY (%)

	2, 74 D	3, 122 D	4, 30 D	5, 70 M
Texture:				
Sand	–	–	70	–
Silt	15	60	15	2
Clay	85	40	5	98
Composition:				
Quartz	tr	–	57	tr
Feldspar	–	–	10	–
Mica	1	tr	5	tr
Heavy minerals	–	–	3	–
Clay	84	40	20	90
Carbonate unspec.	–	tr	–	–
Calc. nannofossils	8	60	–	8
Plant debris + org matt	7	–	5	2

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-93/95	5-81/83
Organic carbon	< 0.1	0.3
Carbonate	3	84

SITE 603 HOLE B CORE 67 CORED INTERVAL 1432.7 - 1441.7 m



LITHOLOGIC DESCRIPTION

INTERBEDDED CLAYEY LIMESTONE, SANDSTONE, CLAYSTONE, AND NANNOFOSSIL CLAYSTONE

(1) Bioturbated CLAYEY NANNOFOSSIL LIMESTONE, very light gray (N7, N8), calcified radiolarian-rich

(2) Laminated CALCIFIED RADIOLARIAN- and ORGANIC MATTER-BEARING NANNOFOSSIL CLAYSTONE (Marl), light gray (5Y 6/1, 5Y 7/1, *N6, N5*).

Lithologies (1) and (2) grade into each other.

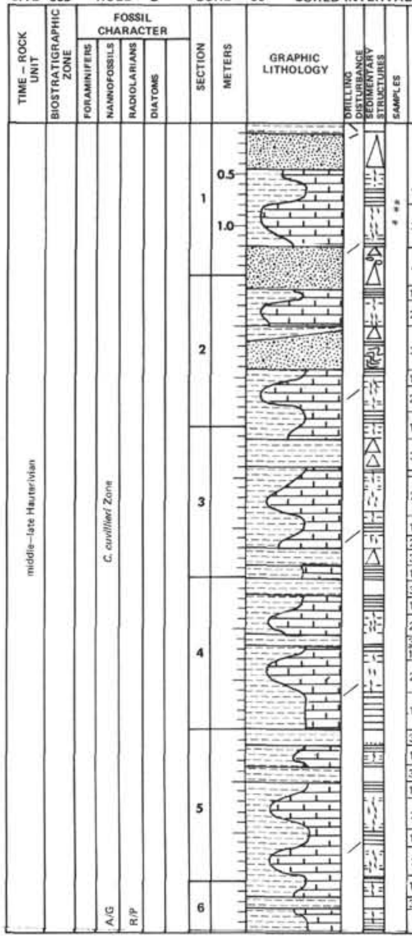
(3) SANDSTONE, quartzose, with mica, clay and plant debris; dark greenish gray (5GY 4/1, 5Y 4/1); fine to medium grained with grading and other turbidite texture sequences.

(4) NANNOFOSSIL-BEARING, ORGANIC MATTER-BEARING CLAYSTONE, dark gray (N3, N4), homogeneous but often has silt-rich basal layer.

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-80/82	5-74/76
Organic carbon	0.2	1.5
Carbonate	82	18
	3-72/74	4-63/65
	< 0.1	0.2
	4	80

SITE 603 HOLE B CORE 68 CORED INTERVAL 1441.7–1450.7 m



LITHOLOGIC DESCRIPTION

INTERBEDDED NANNOFOSSIL CLAYSTONE (MARL), LIMESTONE, CLAYSTONE, AND SANDY SILTSTONE

(1) Laminated NANNOFOSSIL CLAYSTONE (Marl), brownish gray (5Y 4/1, 5Y 5/1, 5Y 6/1).
(2) Bioturbated CLAY-RICH LIMESTONE, light gray (N7), rich in radiolarians.

Lithologies (1) and (2) grade into each other.

(3) ORGANIC MATTER-MICA-NANNOFOSSIL-BEARING CLAYSTONE, dark gray (N3, N4), homogeneous or fining upward.
(4) SANDY SILTSTONE, quartzose, with mica, clay, and plant debris; dark greenish gray (5GY 4/1, 5G 3/1, 5Y 4/1); turbidite origin.

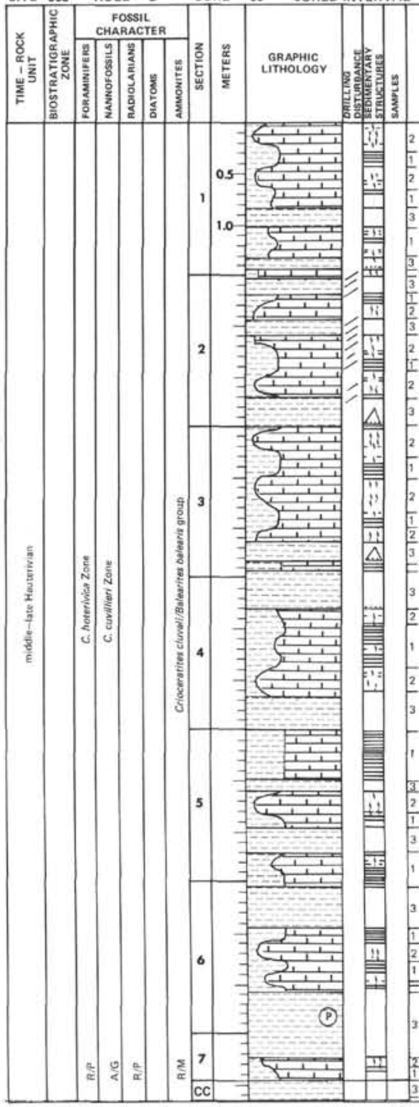
SMEAR SLIDE SUMMARY (%)

	1, 74 D	1, 85 D	1, 95 D
Texture:			
Sand	–	–	–
Silt	14	–	20
Clay	86	100	80
Composition:			
Quartz	4	–	–
Mica	–	–	5
Clay	84	20	80
Zeolite	–	–	1
Carbonate unspec.	2	84	–
Calc. nannofossils	8	6	10
Plant debris + Organics	2	–	4

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-71/73	5-50/52
Organic carbon	1.1	1.5
Carbonate	6	17

SITE 603 HOLE B CORE 69 CORED INTERVAL 1450.7–1459.7 m



LITHOLOGIC DESCRIPTION

INTERBEDDED CLAYEY CHALK, LIMESTONE, AND CLAYSTONE

(1) Laminated CLAYEY NANNOFOSSIL CHALK (Marly Limestone), medium brownish gray to gray (5Y 5/1, N5, N6)
(2) Bioturbated LIMESTONE, light gray (N6, N7), rich in calicified or pyrite replaced radiolarians.

Lithologies (1) and (2) grade into each other.

(3) ORGANIC MATTER- and NANNOFOSSIL-BEARING CLAYSTONE, very dark gray (N2, N3), homogeneous, mica silt-rich basal layer common.

A *Criocerdites-Balearites*-type ammonite was found in laminated marly limestone interval at Sect. 5, 14 cm.

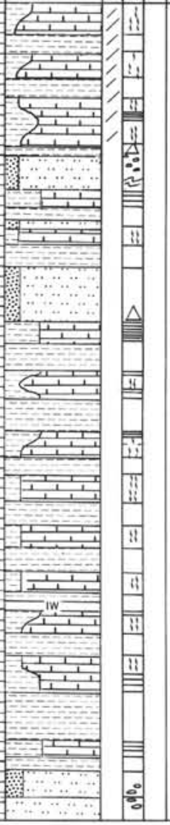
ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-70/72	5-68/70
Organic carbon	0.1	0.2
Carbonate	76	79

SITE 603 HOLE B CORE 70 CORED INTERVAL 1459.7–1468.7 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION
middle–late Hauterivian			*C. cuvillieri* Zone			1, 2, 3, 4, 5, 6, CC
			A/G	R/P		

METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

INTERBEDDED CLAYSTONE, LIMESTONE CLAYEY NANNOFOSSIL CHALK, AND SILTSTONE

(1) ORGANIC MATTER- and NANNOFOSSIL-BEARING CLAYSTONE, dark gray (N3, N4), homogeneous. Has a silt-rich graded base and bioturbated top (in many cases), indicating a turbidite origin.

(2) Laminated CLAYEY NANNOFOSSIL CHALK (Marly Limestone), light brownish gray (5Y 5/1, 5Y 6/1), contains scattered Aptychi

(3) Bioturbated CLAY-RICH NANNOFOSSIL LIMESTONE, rich in calcified radiolarians, very light gray (N7, N8).

Lithologies (2) and (3) grade into each other.

(4) CLAY-RICH SAND-RICH SILTSTONE, quartzose, dark greenish gray (5GY 4/1), poorly-sorted, contains plant debris and claystone intraclasts, turbidite origin with debris flow.

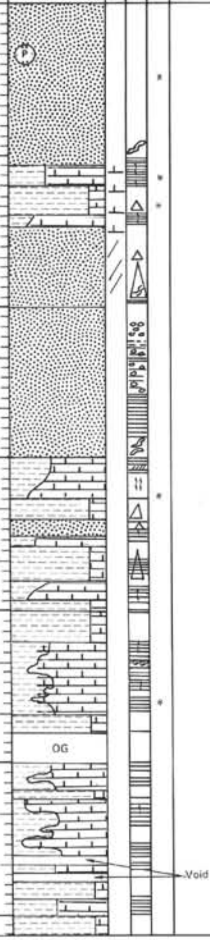
ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-83/85	5-83/85
Organic carbon	0.1	1.0
Carbonate	77	22

SITE 603 HOLE B CORE 71 CORED INTERVAL 1468.7–1477.7 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION
Late Hauterivian		*D. ouachensis–H. sigali* Zones	*C. cuvillieri* Zone			1, 2, 3, 4, 5, 6, CC
		R/M	A/G	R/M		

METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

INTERBEDDED SILTY SANDSTONE, CLAYEY NANNOFOSSIL LIMESTONE, LIMESTONE, AND CLAYSTONE

(1) SILTY SANDSTONE, QUARTZOSE; MICA- and NANNOFOSSIL-RICH, PLANT DEBRIS-BEARING; medium gray (N5); massive to laminated turbidite origin. Can have debris flow layer.

(2) Laminated CLAYEY NANNOFOSSIL LIMESTONE (Marly Limestone), light brownish gray (5Y 5/1).

(3) Bioturbated CLAY-RICH NANNOFOSSIL LIMESTONE, rich in calcified radiolaria, very light gray (N7, 5GY 7/1).

Lithologies (2) and (3) grade into each other.

(4) SILT-BEARING NANNOFOSSIL-RICH CLAYSTONE, very dark gray (N3, N2), homogeneous or slightly graded.

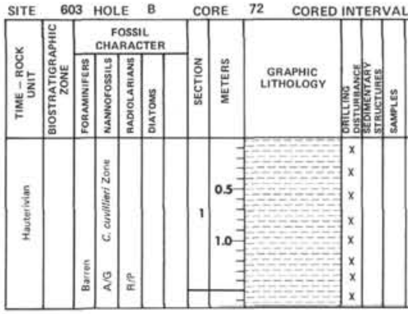
SMEAR SLIDE SUMMARY (%)

	1, 70 D	2, 28 M	2, 50 D	4, 41 D	5, 92 X
Texture:					
Sand	60	–	–	5	–
Silt	30	60	40	30	35
Clay	10	40	60	65	65
Composition:					
Quartz	40	TR	5	8	3
Mica	10	1	7	5	1
Heavy minerals	TR	–	TR	TR	–
Clay	20	7	46	43	39
Glauconite	TR	1	–	1	–
Pyrite	TR	–	1	TR	TR
Calc. nannofossils	30	90	40	42	55
Diatoms	–	–	–	TR	–
Radiolarians	–	–	–	TR	–
Plant debris	TR	1	1	1	2

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-83/86	5-80/83
Organic carbon	1.3	0.3
Carbonate	25	77

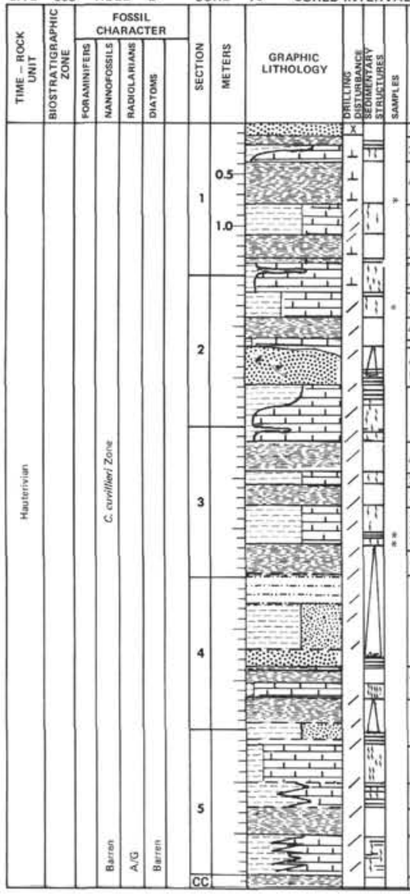
SITE 603 HOLE B CORE 72 CORED INTERVAL 1477.7–1482.7 m



LITHOLOGIC DESCRIPTION

DRILLING BRECCIA cuttings are mostly dark greenish gray to greenish black (5Y 3/1) CLAYSTONE with minor amount of parallel laminated ORGANIC-RICH NANNOFOSSIL CLAYSTONE and SILTY SANDSTONE.

SITE 603 HOLE B CORE 73 CORED INTERVAL 1482.7–1492.3 m



LITHOLOGIC DESCRIPTION

INTERBEDDED CLAYSTONE, SILTY SANDSTONE AND CLAYEY TO CLAY-BEARING NANNOFOSSIL LIMESTONE, with alternation of:

(1) White to grayish white (N8–N7) with greenish shades, heavily bioturbated, CLAY-BEARING NANNOFOSSIL LIMESTONE.
(2) Light gray mottled (N6–N5) bioturbated and laminated, CLAYEY NANNOFOSSIL LIMESTONE.
(3) Dark gray (5Y 4/1) to gray (5Y 5/1), slightly greenish, laminated ORGANIC MATTER-BEARING CLAYEY NANNOFOSSIL LIMESTONE/CHALK.
(4) Very dark gray (N2–N3) homogeneous NANNOFOSSIL- and ORGANIC MATTER-BEARING CLAYSTONE. It coarsens downward to silty claystone and it is usually associated with turbiditic sandstone.
(5) Fine to very fine QUARTZOSE SANDSTONE-SILTY SANDSTONE, sometime clay-rich, or clayey, parallel or convolute laminated. It may contain claystone intraclasts deposited by turbidity currents and associated debris flows.

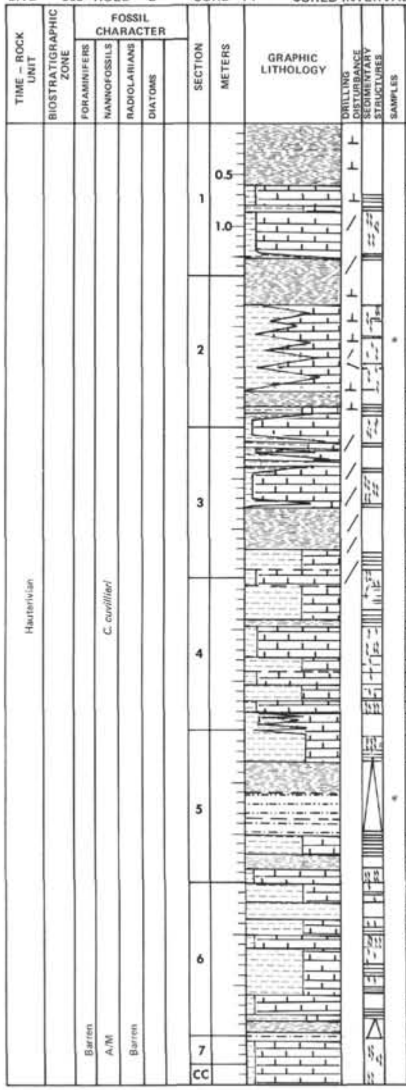
SMEAR SLIDE SUMMARY (%)

	1, 70	2, 24	3, 104	3, 114
	D	D	D	D
Texture:				
Sand	–	–	–	–
Silt	15	30	30	30
Clay	85	70	70	70
Composition:				
Quartz	1	tr	–	–
Mica	3	–	–	–
Clay	80	10	30	34
Pyrite	1	–	–	–
Zeolite	–	–	–	tr
Carbonate unspec.	–	50	36	35
Calc. nannofossils	10	40	30	30
Plant debris	5	tr	4	1

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2(78-80)	4(75-78)	5(63-65)
Organic carbon	0.7	<0.1	0.7
Carbonate	14	28	77

SITE 603 HOLE B CORE 74 CORED INTERVAL 1492.3–1501.9 m



LITHOLOGIC DESCRIPTION

INTERBEDDED CLAYSTONE, SILTY CLAYSTONE, FINE SANDSTONE AND CLAYEY TO CLAY-BEARING NANNOFOSSIL LIMESTONE

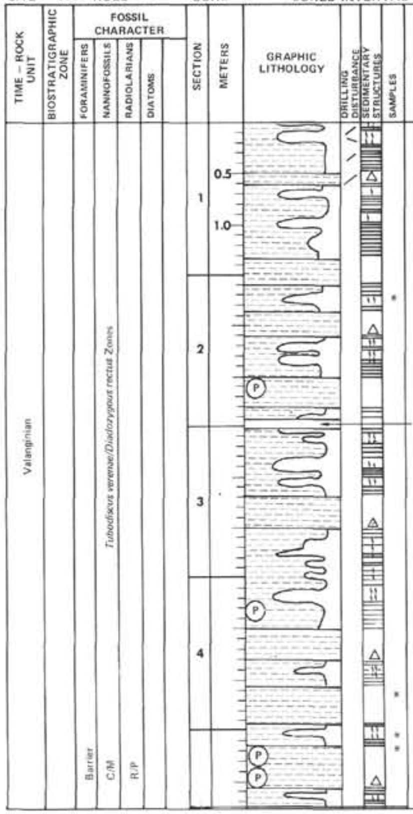
Alternating lithologies:

(1) CLAY-BEARING NANNOFOSSIL LIMESTONE, white to grayish white (N8–N7) with greenish shades, heavily bioturbated.
(2) CLAYEY NANNOFOSSIL LIMESTONE, light gray (N6–N5) color mottled, laminated and moderately bioturbated.
(3) LAMINATED ORGANIC MATTER-BEARING CLAYEY NANNOFOSSIL LIMESTONE/CHALK, dark gray (5Y 4/1) to gray (5Y 5/1) slightly greenish.
(4) NANNOFOSSIL- and ORGANIC MATTER-BEARING CLAYSTONE, homogeneous, very dark gray to grayish black (N3–N2). It coarsens downward to SILT-RICH and SILTY CLAYSTONE.

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-67/69	5-70/72
Organic carbon	0.1	0.8
Carbonate	91	10

SITE 603 HOLE B CORE 75 CORED INTERVAL 1501.9–1511.5 m



LITHOLOGIC DESCRIPTION

INTERBEDDED NANNOFOSSIL CLAYSTONE, NANNOFOSSIL LIMESTONE, AND CLAYSTONE

Major Lithologies:

(1) Laminated, organic matter-bearing NANNOFOSSIL CLAYSTONE (Marl), gray (N5-N7, 5Y 5/1).

(2) Bioturbated CLAY-BEARING NANNOFOSSIL LIMESTONE, light gray (N7, N8).

Minor lithology is ORGANIC MATTER- and NANNOFOSSIL-BEARING CLAYSTONE; homogeneous, very dark gray (N2, N3). In several cases the layers are silt-rich at the base, implying a distal turbidite origin.

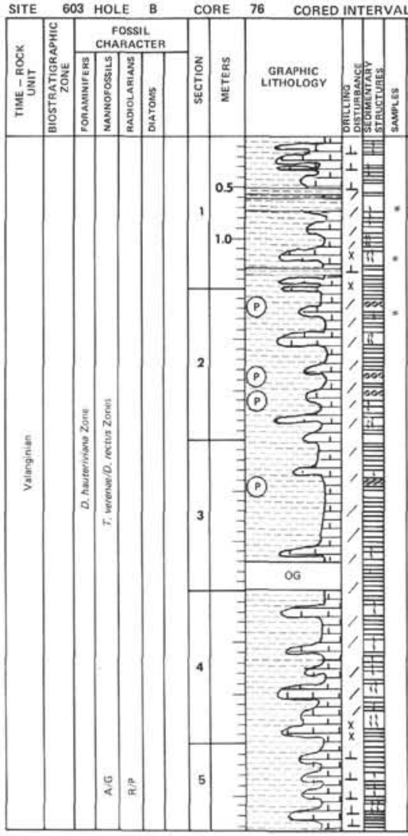
SMEAR SLIDE SUMMARY (%)

	36, 2	121, 4	8, 5	14, 5
	M	D	D	D
Texture:				
Silt	20	20	30	8
Clay	80	80	70	92
Composition:				
Quartz	TR	–	TR	–
Clay	79	10	54	85
Pyrite	5	–	–	–
Zeolite	1	–	–	–
Carbonate unspec.	–	80	20	–
Calc. nannofossils	15	10	30	8
Plant debris + Organics	–	–	6	7

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-70/72	5-41/42
Organic carbon	1.0	1.6
Carbonate	28	18

SITE 603 HOLE B CORE 76 CORED INTERVAL 1511.5–1521.1 m



LITHOLOGIC DESCRIPTION

INTERBEDDED NANNOFOSSIL CLAYSTONE AND LIMESTONE

Major Lithologies:

(1) Laminated NANNOFOSSIL CLAYSTONE (Marl), gray with brownish tint (5Y 4/1 – 5Y 5/1)

(2) Bioturbated NANNOFOSSIL-RICH LIMESTONE, light gray (N6, N8).

These alternate with gradational contacts.

Minor Lithology:

ORGANIC MATTER- and NANNOFOSSIL-BEARING CLAYSTONE, homogeneous, dark gray (N2, N3). Occurs only as two beds in Sect. 1.

Aptychi common in laminated marl.

Rare pyrite nodules and fragments of wood.

Laminations in marl are about 50 per centimeter.

SMEAR SLIDE SUMMARY (%)

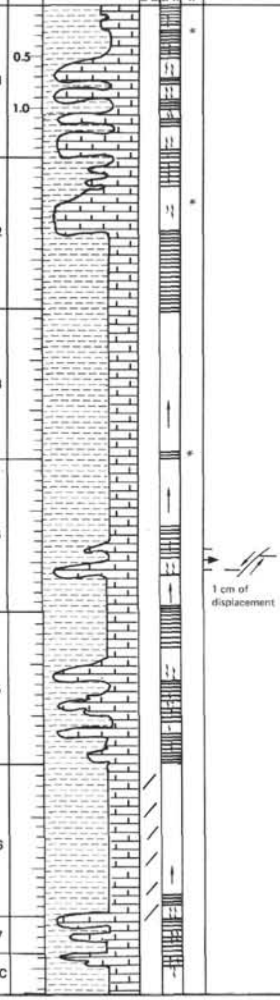
	1, 68	1, 136	2, 24
	D	M	D
Texture:			
Silt	15	22	30
Clay	85	78	70
Composition:			
Quartz	1	1	TR
Mica	4	6	
Heavy minerals	–	TR	
Clay	85	77	65
Glauconite	–	TR	–
Pyrite	2	1	1
Carbonate unspec.	–	–	3
Calc. nannofossils	8	10	30
Plant debris	5	5	1

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-67/70	5-71/72
Organic carbon	1.5	1.9
Carbonate	66	66

SITE 603 HOLE B CORE 77 CORED INTERVAL 1521.1–1530.7 m

TIME-ROCK UNIT: Valanginian
BIOSTRATIGRAPHIC ZONE: *T. verenae/D. rectus* Zones
FOSSIL CHARACTER: Foraminifers: Barren; Nannofossils: C/M; Radiolarians: R/P
SECTIONS: 1, 2, 3, 4, 5, 6, 7, CC



LITHOLOGIC DESCRIPTION

INTERBEDDED NANNOFOSSIL-RICH CLAYSTONE AND LIMESTONE

(1) Laminated ORGANIC MATTER-BEARING NANNOFOSSIL-RICH CLAYSTONE to NANNOFOSSIL CLAYSTONE, mainly brownish gray (5Y 5/1) but also gray (5Y 4/1–5Y 7/1, N5–N7).

(2) Bioturbated CLAY-BEARING LIMESTONE, very light gray (N7–N8.5). Commonly contains bluish gray streaks, pyrite nodules, micro clay seams. Calcified radiolarians are abundant.

These alternate with gradational contacts.

Aptychi common in laminated marl to claystone beds.

Inoceramus fragments are rare (Sect. 3, 126 cm is best example).

Belemnite in Sect. 1, 50 cm.

Large wood fragments at Sect. 3, 64 and 98 cm, Sect. 4, 98 cm; and Sect. 6, 59 cm.

SMEAR SLIDE SUMMARY (%)

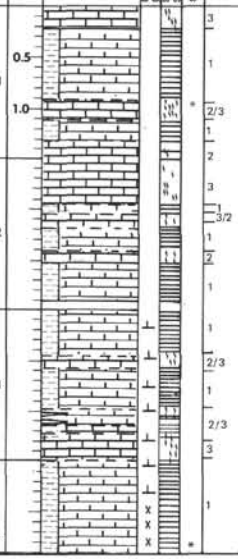
	1, 26	2, 59	3, 144
	D	D	D
Texture:			
Silt	28	90	85
Clay	72	10	15
Composition:			
Quartz	TR	–	TR
Feldspar	–	–	TR
Mica	–	–	TR
Clay	72	10	15
Palagonite	–	–	TR
Pyrite	1	–	TR
Micronodules	TR	–	–
Carbonate unspec.	7	85	76
Calc. nannofossils	15	5	7
Radiolarians	–	–	1
Plant debris + Organics	5	–	–

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-79/82	5-77/79
Organic carbon	0.4	0.04
Carbonate	71	89

SITE 603 HOLE B CORE 78 CORED INTERVAL 1530.7–1540.2 m

TIME-ROCK UNIT: Valanginian
BIOSTRATIGRAPHIC ZONE: *T. verenae/D. rectus* Zones
FOSSIL CHARACTER: Foraminifers: Barren; Nannofossils: A/M; Radiolarians: R/P
SECTIONS: 1, 2, 3, 4



LITHOLOGIC DESCRIPTION

CYCLIC ALTERNATION OF

(1) ORGANIC MATTER- and PLANT DEBRIS-BEARING CLAY-RICH NANNOFOSSIL CHALK, shading from greenish gray (5Y 5/1) to dark greenish gray (5Y 4/1), varve-like laminated. Aptychus and *Inoceramus* shells, as well as pyrite nodules up to 1 cm in diameter, are common.

(2) NANNOFOSSIL LIMESTONE, rarely CLAY-BEARING, light gray to very light gray (N6–N7) slightly greenish, faintly laminated and moderately bioturbated.

(3) NANNOFOSSIL LIMESTONE, white to greenish white (N8) slightly greenish, heavily bioturbated.

Microstylolite-rich horizons, grayish green (5Y 4/2) occur in Sections 2 and 3.

SMEAR SLIDE SUMMARY (%)

	1, 97	4, 87
	D	D
Texture:		
Sand	–	–
Silt	–	35
Clay	100	65
Composition:		
Quartz	–	2
Mica	tr	–
Clay	–	20
Carbonate unspec.	100	20
Calc. nannofossils	–	50
Plant debris + organics	–	8

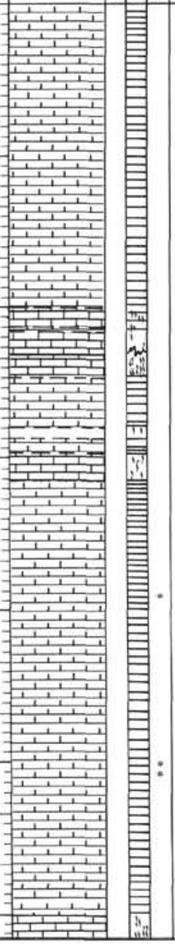
ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-74/76
Organic carbon	1.4
Carbonate	59

SITE 603 HOLE B CORE 79 CORED INTERVAL 1540.2–1549.2 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
Valanginian	*T. verenae/D. rectus* Zones	Barren	A/P	R/P		1–7	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

(1) ORGANIC MATTER-BEARING NANNOFOSSIL CHALK, varve-like laminated, dark greenish gray (5Y 4/1) to greenish gray (5Y 5/1), bearing abundant Aptychus and pyrite nodules with intercalations of

(2) NANNOFOSSIL LIMESTONE, very light gray (N8) to light gray (N7) sometime greenish (5B 8/1), heavily to moderately bioturbated and laminated. Some grayish green (5Y 4/2), stylolite horizons occur.

SMEAR SLIDE SUMMARY (%)

	4, 130 D	6, 5 M	6, 6 M
Texture:			
Sand	–	–	–
Silt	35	30	20
Clay	65	70	80
Composition:			
Clay	30	10	30
Pyrite + opaques	–	–	tr
Carbonate unspec.	30	30	20
Calc. nannofossils	35	60	50
Plant debris	5	–	–

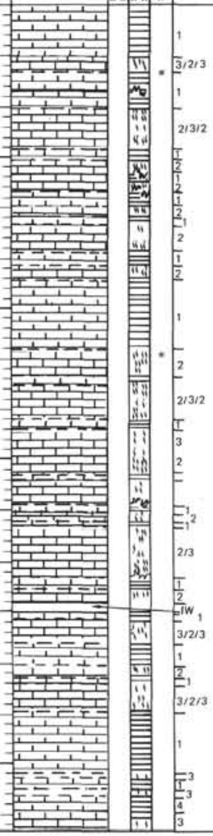
ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-84/84	5-84/86
Organic carbon	1.1	1.3
Carbonate	58	58

SITE 603 HOLE B CORE 80 CORED INTERVAL 1549.2–1558.2 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
Berriasian–Valanginian	*Retacapsa neocomiana* Zone		A/P	C/M		1–6	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

Cyclic alternations of:

(1) ORGANIC MATTER and PLANT DEBRIS-BEARING NANNOFOSSIL LIMESTONE/CHALK, varve-like laminated, shading from dark, greenish gray (5Y 4/1) to greenish gray (5Y 5/1) and medium gray (N5), bearing commonly Inoceramus shell fragments, Aptychus. Rare Belemnites and scattered pyrite nodules occur.

(2) NANNOFOSSIL LIMESTONE, heavily bioturbated and color mottled, white to very light gray (N7), slightly greenish (5G 8/1) in places.

(3) NANNOFOSSIL LIMESTONE moderately bioturbated and faintly laminated, shading from light gray (N7) to medium light gray (N6) slightly greenish (5B 8/1) in places.

(4) A coarse coalified wood fragment occurs in Section 6.

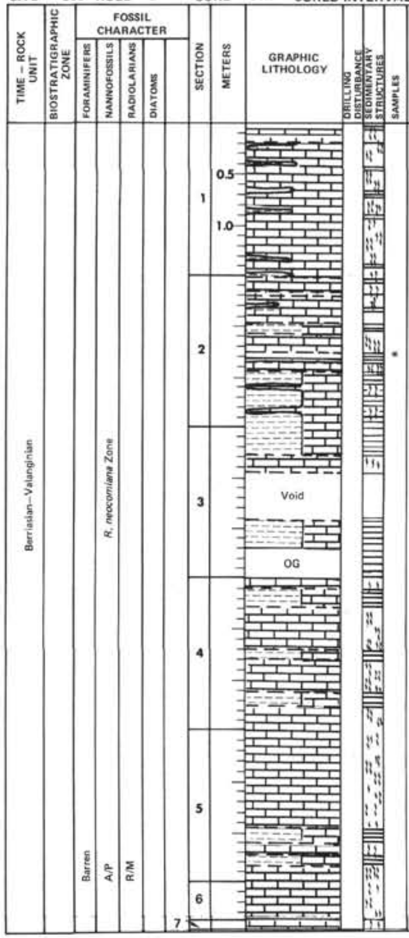
SMEAR SLIDE SUMMARY (%)

	1, 68 D	3, 50 D
Texture:		
Sand	–	–
Silt	30	40
Clay	70	60
Composition:		
Quartz	1	tr
Mica	tr	tr
Clay	9	5
Pyrite	tr	–
Zeolite	tr	–
Carbonate unspec.	20	45
Calc. nannofossils	61	50
Plant debris	9	tr

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-79/81	5-71/73
Organic carbon	0.04	0.1
Carbonate	77	68

SITE 603 HOLE B CORE 81R CORED INTERVAL 1558.2–1567.2 m



LITHOLOGIC DESCRIPTION

Cyclic alternation of:

(1) NANNOFOSSIL CLAYSTONE (Marl), varve-like laminated, greenish to dark greenish gray (5Y 5/1–5Y 4/1) and medium gray (N5–N6).

(2) NANNOFOSSIL LIMESTONE, heavily bioturbated light to very light gray (N7–N8) with greenish shades and medium gray (N5–N6) burrow-mottles.

(3) Intermediate textures between (1) and (2) occur. Bright grayish green (5G 4/2) clay seams occur in (2) and (3).

A 5 mm clay layer of Smectite-Bentonite? expanding with fresh water probably represents an altered ash layer, in Section 2, 79 cm.

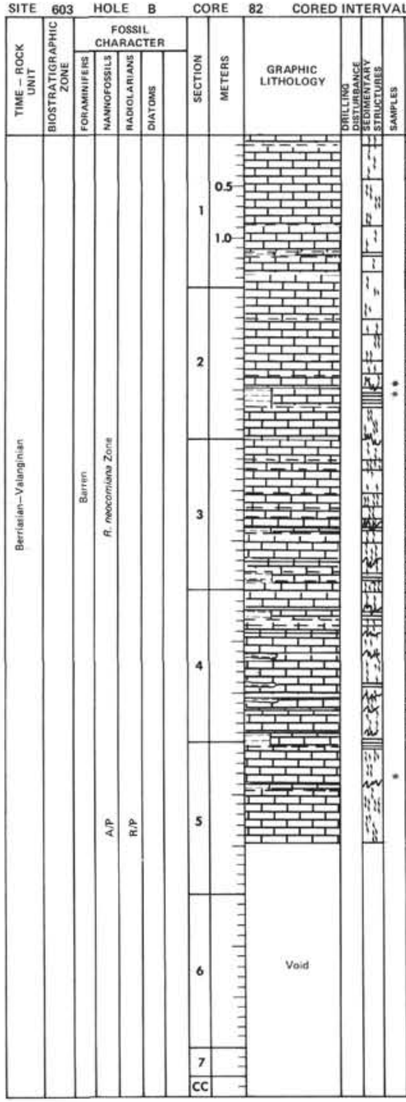
SMEAR SLIDE SUMMARY (%)

	2, 79
	M
Texture:	
Sand	–
Silt	13
Clay	87
Composition:	
Quartz	1
Clay	87
Opaques	6
Zeolite	tr
Carbonate unspec.	2
Calc. nannofossils	4
Radiolarians	tr

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-62/63	5-62/63
Organic carbon	0.2	0.0
Carbonate	53	67

SITE 603 HOLE B CORE 82 CORED INTERVAL 1567.2–1576.2 m



LITHOLOGIC DESCRIPTION

Cyclic alternations of:

(1) NANNOFOSSIL LIMESTONE, white to greenish white (N8) and light gray (N7) with greenish shades. Medium gray (N5–N6) burrow mottles.

(2) NANNOFOSSIL LIMESTONE, medium gray (N5) to medium light gray (N6) faintly laminated and moderately bioturbated.

(3) CLAY-RICH LIMESTONE/CHALK, varve-like laminated; shades from dark greenish gray (5Y 4/1) – greenish gray to medium dark gray (N4) – medium gray (N5).

(4) Green clay-rich horizons 1 to 1.5 cm thick, are frequent in Sections 3, 4, and 5 (microstylolites).

Alternations (1) (2), with lithofacies (1) prevailing, occur in Sections 1, 2, and partly 3.

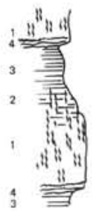
Asymmetric cycles (3) (2) (1) (4) (see figure below) are common in Section 3 (bottom), 4, and 5.

SMEAR SLIDE SUMMARY (%)

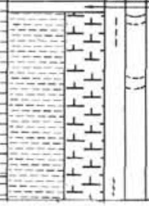
	2, 95	2, 105	5, 35
	M	D	D
Textures:			
Sand	–	–	–
Silt	–	–	–
Clay	100	100	100
Composition:			
Clay	–	25	–
Pyrite	100		
Carbonate unspec.	–	75	95
Calc. nannofossils	–	–	5
Plant debris	–	tr	–

ORGANIC CARBON AND CARBONATE (%)

Section-Interval (cm)	2-75/76	5-73/74
Organic carbon	0.1	0.1
Carbonate	54	73



SITE 603 HOLE C CORE 1 CORED INTERVAL 0.0–2.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
Early Pleistocene	G. truncatulinoides Zone N22 (G. tosaensis subzone)	A/G, C/M	H. sellii Zone; A/G, A/G			1, 2, CC	0.5, 1.0				IW, *, *

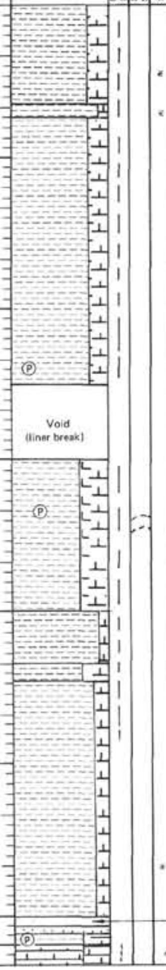
LITHOLOGIC DESCRIPTION

NANNOFOSSIL-RICH CLAY, Section 1, 10–13 cm: Grayish orange (10YR 7/4). Section 1, 13 cm to the end of the core the color is predominantly greenish gray (5GY 5/1) with a slight gradual change at the base to gray (5Y 5/1). In Section 1 from 80–90 cm there is a band of light gray.

SMEAR SLIDE SUMMARY (%):

	1, 12	1, 48
	M	D
Texture:		
Silt	20	31
Clay	80	69
Composition:		
Quartz	2	1
Mica	4	2
Heavy minerals	1	TR
Clay	73	63
Pyrite	1	1
Carbonate unspec.	2	6
Foraminifers	2	2
Calc. nannofossils	15	25
Diatoms	TR	–
Fish remains	TR	–
Hematite	–	TR

SITE 603 HOLE C CORE 2 CORED INTERVAL 2.0–11.6 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
early Pleistocene	G. truncatulinoides N22 (G. tosaensis subzone)		H. sellii Zone			1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0				1, 2, 1, 1, 1, 2, 1, 2, IW

LITHOLOGIC DESCRIPTION

1) NANNOFOSSIL-RICH CLAY, gray (5Y 5.5/1)–dark green gray (5G 4/1–5G 5/1) with slight brownish tint (10YR 5.5/1). Black specks of Fe sulfide.

2) NANNOFOSSIL-BEARING CLAY, brown (7.5YR –dark reddish gray (5YR 4/2), homogeneous to faintly banded (reddish gray ?5YR 5/2]) dark grayish brown (10YR 4/2–5/2).

A thin (2 mm) lens or layer of ?laminated planktonic foraminiferal (+ quartz?) sand (?contourite) occurs in Section 7, 40 cm.

Local pyrite (+ siderite?) nodules.

Core Catcher: hard micritic limestone (XRD: calcite), probably ice-rafted pebbles?

O-ring disturbance in Section 5.

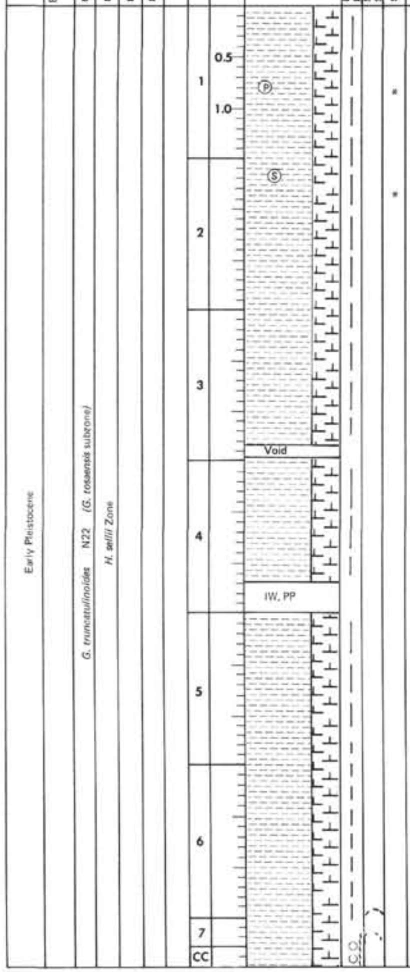
Section 7 is 101 cm in length, possibly due to 75 cm void in Section 3.

SMEAR SLIDE SUMMARY (%):

	1, 70	1, 105	6, 100	CC,10
	D	D	D	M
Texture:				
Sand	4	–	–	–
Silt	30	15	18	100
Clay	66	85	82	–
Composition:				
Quartz	2	2	2	TR
Mica	3	1	1	–
Heavy minerals	1	–	–	–
Clay	61	–	82	–
Glauconite	TR	–	–	–
Pyrite	TR	–	–	–
Fe-oxides	–	3	5	–
Carbonate unspec.	3	6	4	100
Foraminifers	5	–	–	–
Calc. nannofossils	25	4	6	–

SITE 603 HOLE C CORE 3 CORED INTERVAL 11.6–21.2 m

TIME–ROCK UNIT | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER (FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS) | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES



LITHOLOGIC DESCRIPTION

NANNOFOSSIL-RICH CLAY, greenish-gray (5G 5/1).

Faintly banded.

Pyrite nodules (up to 1 cm diameter), rare, scattered.

Section 2, 36 cm: Small unconsolidated siderite "precursor nodules" (crystals ~2–4 μ diameter).

Strong H_2S odor, upon splitting.

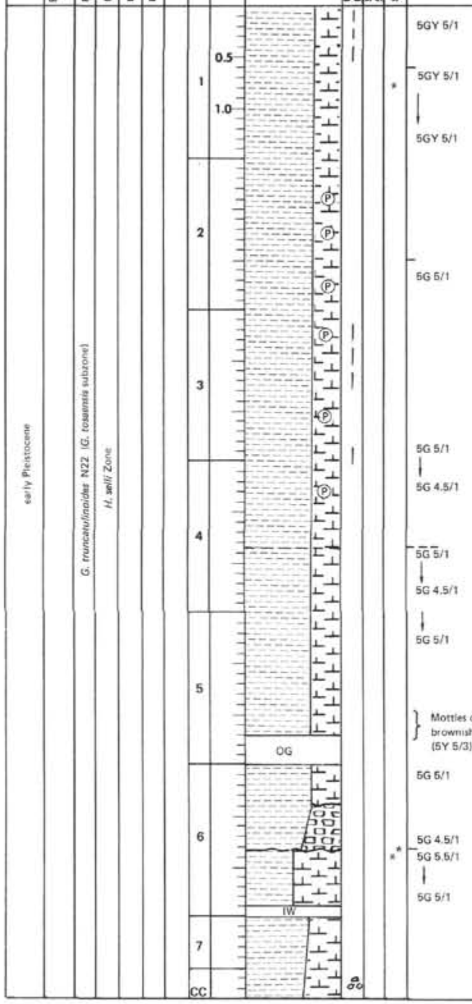
Section 7 is 66 cm in length.

SMEAR SLIDE SUMMARY (%):

	1, 84	2, 35
	D	M
Texture:		
Silt	5	70
Clay	95	30
Composition:		
Quartz	4	TR
Feldspar	TR	–
Mica	TR	–
Clay minerals	65	20
Glauconite	TR	–
Pyrite and opaques	TR	–
Carbonate unspec. (siderite)	1	70
Calc. nannofossils	30	10
Radiolarians	TR	–
Fish remains	TR	TR
Plant debris	TR	–

SITE 603 HOLE C CORE 4 CORED INTERVAL 21.2–30.8 m

TIME–ROCK UNIT | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER (FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS) | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES



LITHOLOGIC DESCRIPTION

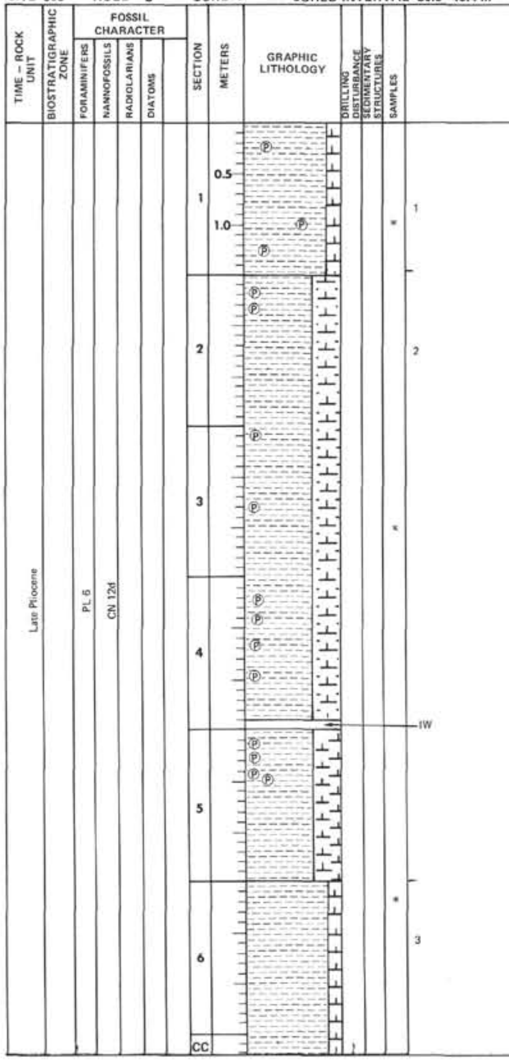
NANNOFOSSIL-RICH CLAYSTONE, greenish gray (5GY 5/1–5G 5.5/1) with small scattered dark gray (N4) splotches and mottles. Also scattered narrow bands of bluish, purplish, brownish, and dark grays; <1 cm wide. Pyrite (burrow replacements) is rare. Strong H_2S odor when split.

At Section 6, 85 cm, there is a sharp change from CALCAREOUS CLAYSTONE to CLAYEY NANNOFOSSIL OOZE (lighter shade of gray).

SMEAR SLIDE SUMMARY (%):

	1, 80	6, 85	6, 92
	D	M	M
Texture:			
Silt	29	40	70
Clay	71	60	30
Coposition:			
Quartz	1	–	–
Mica	–	1	TR
Clay	71	–	20
Palagonite	–	1	–
Pyrite	1	–	–
Carbonate unspec.	7	40	8
Foraminifers	TR	–	–
Calc. nannofossils	20	–	60
Opaques	–	3	2

SITE 603 HOLE C CORE 5 CORED INTERVAL 30.8–40.4 m



LITHOLOGIC DESCRIPTION

1) PYRITE-BEARING, NANNOFOSSIL-RICH CLAY, gradual change from bluish gray (5BG 5/1) at the top to a lighter bluish gray at the base of Section 1. Small (<1 mm) speckles (pyrite?) throughout the core. Faint banding and mottling begins below 125 cm of Section 1.

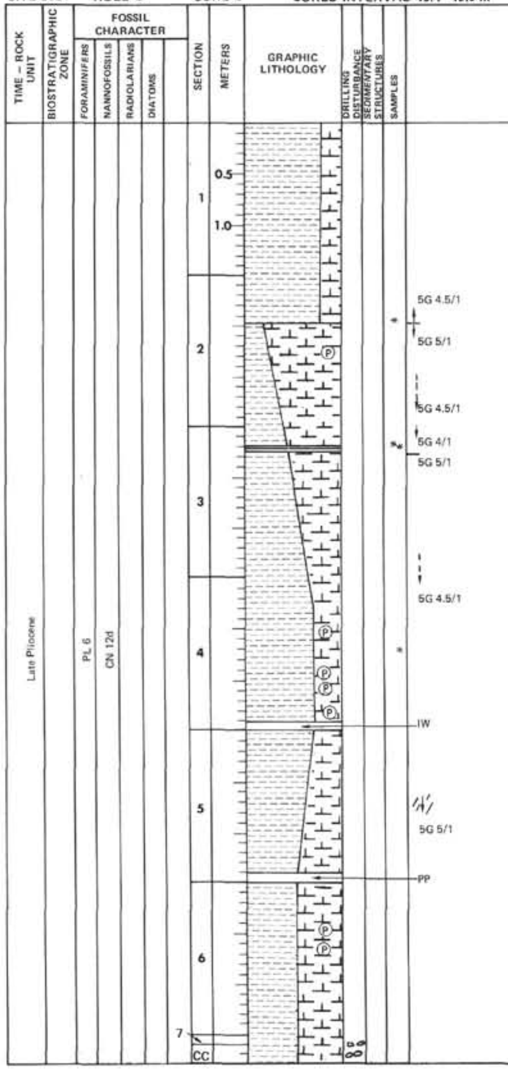
2) NANNOFOSSIL CLAY, bluish gray (5BG 6/1) with rare mottles of gray (5Y 5/1), and faint 0.5 cm bands of greenish gray (5G 5/1). Rare pyrite nodules as indicated.

3) NANNOFOSSIL-RICH CLAY, dark greenish gray (5BG 4/1) to gray (N5.5). No banding or mottling.

SMEAR SLIDE SUMMARY (%):

	1, 100	3, 100	6, 20
	D	D	D
Texture:			
Silt	20	30	20
Clay	80	70	80
Composition:			
Quartz	TR	1	2
Mica	1	1	2
Clay	68	59	73
Glauconite	1	1	1
Pyrite framboids	6	–	–
Carbonate unspec.	5	3	5
Foraminifers	–	2	–
Calc. nannofosils	15	30	15
Diatoms	2	2	1
Radiolarians	1	–	–
Plant debris	1	1	2

SITE 603 HOLE C CORE 6 CORED INTERVAL 40.4–49.9 m



LITHOLOGIC DESCRIPTION

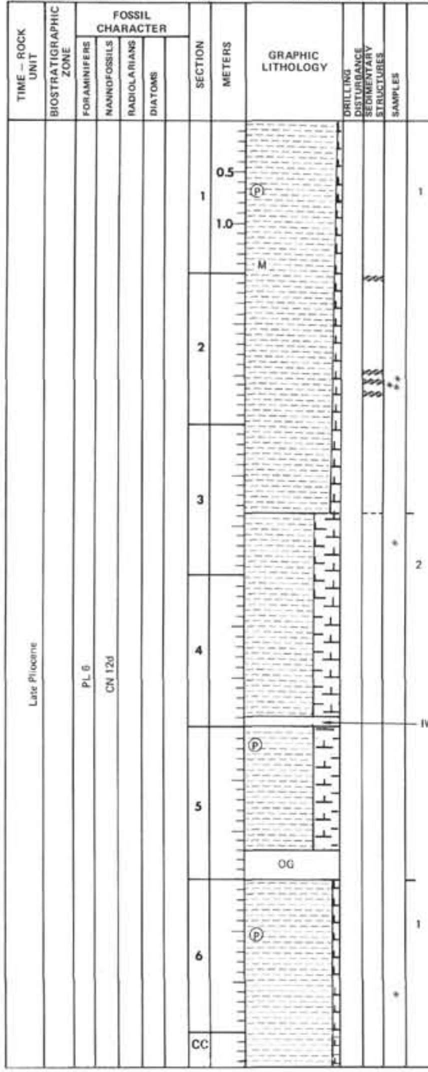
NANNOFOSSIL-RICH CLAY to CLAYEY NANNOFOSSIL OOZE, dark greenish gray to greenish gray (5G 4.5/1–5G 5/1), with vague banding of bluish gray, scattered dark gray streaks, and varicolored mottles. Some oval yellowish gray mottles are dark rimmed. Scattered pyrite clusters and pyritized burrows.

At Section 3, 20 cm is a 2 mm layer of quartz and siderite SILT. Below is dark (5G 4/1) QUARTZ-RICH SIDERITE CLAYEY SILT.

SMEAR SLIDE SUMMARY (%):

	2, 48	3, 20	3, 21	4, 71
	D	M	M	D
Texture:				
Silt	90	100	63	24
Clay	10	–	37	76
Composition:				
Quartz	2	30	11	–
Mica	–	–	2	–
Heavy minerals	TR	–	–	–
Clay	11	–	36	76
Palagonite	–	1	–	–
Pyrite	2	2	1	–
Carbonate unspec.	7	67	50	4
Calc. nannofossils	77	–	–	20
Diatoms	TR	–	–	–

SITE 603 HOLE C CORE 7 CORED INTERVAL 49.9–59.4 m



LITHOLOGIC DESCRIPTION

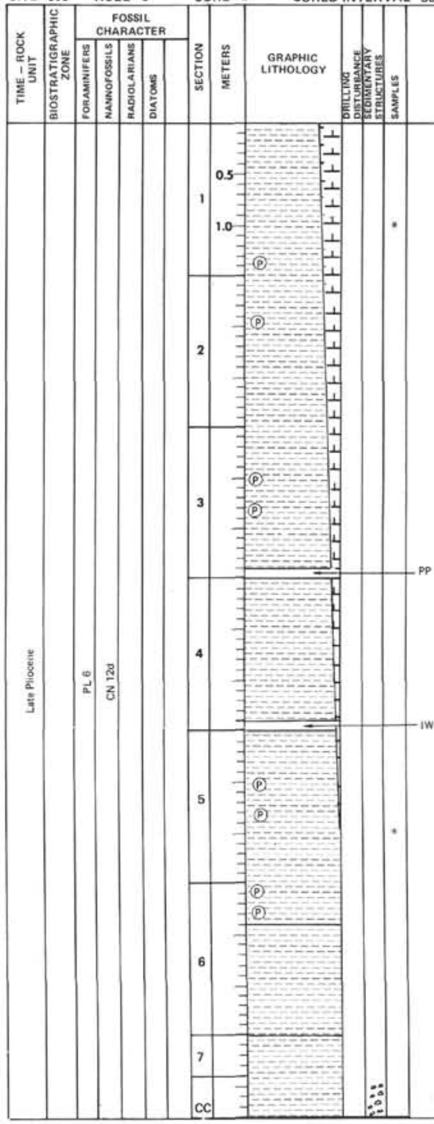
1) MICA- and NANNOFOSSIL-BEARING CLAY, dark greenish gray (5GY 4/1–5G 4/1) with vague banding and mottling. Burrows are infilled with NANNOFOSSIL CLAY, greenish gray (5GY 5/1), and outlined by gray MICA-RICH CLAY.

2) NANNOFOSSIL-RICH CLAY, greenish gray (5GY 5/1) with faint banding and mottling.

SMEAR SLIDE SUMMARY (%):

	2, 107	2, 108	2, 109	3, 118	6, 116
	D	M	M	D	D
Texture:					
Silt	15	20	30	25	10
Clay	85	80	70	75	90
Composition:					
Quartz	1	1	3	2	1
Mica	5	10	1	2	3
Heavy minerals	–	–	TR	–	–
Clay	83	76	63	68	87
Pyrite	–	2	TR	TR	TR
Carbonate unspec.	4	6	2	2	3
Foraminifers	–	–	1	–	–
Calc. nannofossils	6	4	30	25	5
Fish remains	TR	–	–	–	–
Plant debris	1	1	TR	1	1

SITE 603 HOLE C CORE 8 CORED INTERVAL 59.4–67.8 m



LITHOLOGIC DESCRIPTION

SILT-RICH NANNOFOSSIL-RICH CLAY to CLAY, dark greenish gray (5G 4/1) with vague banding. Scattered dark bluish gray (5B 3/1) irregular streaks and small mottles. Slight trend toward a darker shade in lower portion. Rare pyrite nodule, either as burrow fillings or wood fragment(?) replacements.

SMEAR SLIDE SUMMARY (%):

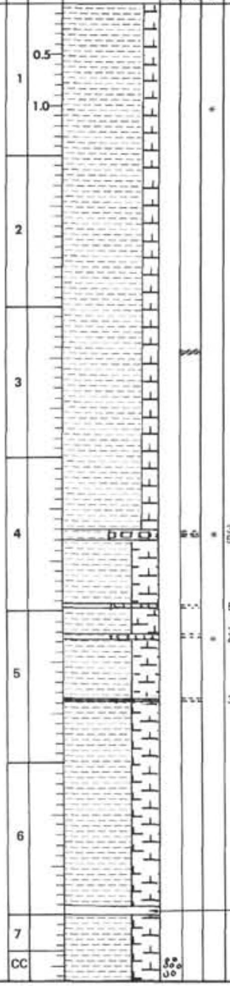
	1, 100	5, 100
	D	D
Texture:		
Silt	37	–
Clay	63	100
Composition:		
Quartz	4	2
Feldspar	–	1
Mica	6	2
Heavy minerals	TR	–
Clay	63	92
Glauconite	TR	–
Carbonate unspec.	7	2
Calc. nannofossils	18	1
Plant debris	2	–

SITE 603 HOLE C CORE 9 CORED INTERVAL 67.8–77.3 m

TIME-ROCK UNIT: Late Pliocene

BIOSTRATIGRAPHIC ZONE / FOSSIL CHARACTER: FORAMINIFERS: PL 6; NANNOFOSSILS: CN 12c; RADIOLARIANS; DIATOMS

SECTION / METERS / GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

1) NANNOFOSSIL-RICH CLAY, dark greenish gray to greenish gray (5BG 4.5/1–5G 5/1) with scattered speckles (pyrite) and faint mottling.

This gradually changes to:
2) NANNOFOSSIL CLAY, greenish gray (5G 5/1) and is similar in appearance to 1). Rare distinct banding occurs in Section 4, 74–76 cm and 143–145 cm, and Section 5, 24–26 cm and 84–85 cm. Bands are composed of the following:
Minor Lithologies:
3) QUARTZ AND SIDERITE SILT, gray 5Y 6/1,

4) QUARTZ-RICH, SIDERITE CLAYEY SILT, gray (5Y 5/1), and

5) CLAYEY CALCAREOUS OOZE, dark gray (5Y 4/1).

SMEAR SLIDE SUMMARY (%):

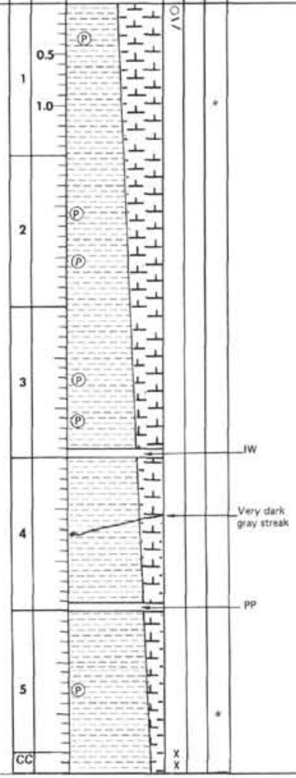
	1, 100	4, 77	5, 28
	D	M	D
Texture:			
Silt	20	50	35
Clay	80	50	65
Composition:			
Quartz	TR	1	–
Mica	2	2	2
Clay	79	45	60
Pyrite	TR	–	–
Carbonate unspec.	3	51	5
Foraminifers	–	–	2
Calc. nannofossils	15	–	30
Plant debris	1	1	1

SITE 603 HOLE C CORE 10 CORED INTERVAL 77.3–84.8 m

TIME-ROCK UNIT: Late Pliocene

BIOSTRATIGRAPHIC ZONE / FOSSIL CHARACTER: FORAMINIFERS: *G. miocenica* PL 5; NANNOFOSSILS: CN12b–CN12c; RADIOLARIANS; DIATOMS

SECTION / METERS / GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

SILT-BEARING NANNOFOSSIL-RICH CLAY, dark greenish gray (5GY 4/1 at top with general trend to 5G 4/1 at base), with vague bands and mottles of a slightly yellowish or bluish gray. Abundant dark bluish gray (5B 3/1) irregular streaks. Scattered pyrite nodules.

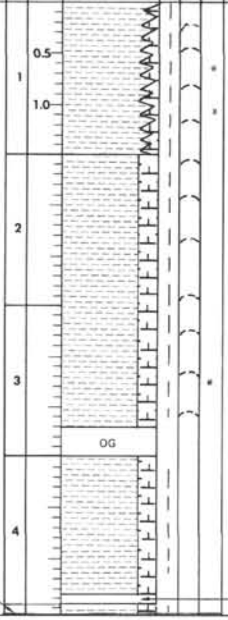
SMEAR SLIDE SUMMARY (%):

	1, 100	5, 100
	D	D
Texture:		
Silt	–	30
Sand	–	70
Composition:		
Quartz	–	3
Mica	–	5
Clay	–	70
Pyrite	–	1
Carbonate unspec.	–	5
Foraminifers	–	1
Calc. nannofossils	–	15

SITE 603 HOLE C CORE 11 CORED INTERVAL 84.8–91.0 m

TIME – ROCK UNIT: Late Pliocene

BIOSTRATIGRAPHIC ZONE / FOSSIL CHARACTER: *G. miocenica* PL 5 (FORAMINIFERS); CN 12b (NANNOFOSSILS)



LITHOLOGIC DESCRIPTION

MICA AND QUARTZ-BEARING CLAY (more greenish bands) and

NANNOFOSSIL-RICH CLAY (more grayish bands), dark greenish gray (5G 4/1 to 5BG 4/1). Sections 2 and 3: greenish gray (5G 5/1). Faintly banded.

Pyritized burrows (1–2 cm long, 4 mm diameter) with spiny surface and pyrite nodules.

Faint burrow mottling, black Fe sulfide specks.

SMEAR SLIDE SUMMARY (%):

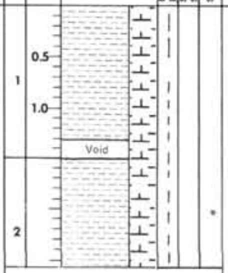
	1, 106	3, 78	1, 62
	D	D	
Texture:			
Silt	10	15	–
Clay	90	85	100
Composition:			
Quartz	5	TR	TR
Mica	2	TR	TR
Heavy minerals	TR	–	TR
Clay minerals	90	83	75
Glauconite	–	–	TR
Pyrite and opaques	1	TR	TR
Carbonate unspec. (siderite)	2	2	TR
Calc. nannofossils	TR	15	25
Sponge spicules	–	–	TR
Fish remains	TR	TR	–

Note: Core 12, 91.0–97.2 m: no recovery.

SITE 603 HOLE C CORE 13 CORED INTERVAL 97.2–106.8 m

TIME – ROCK UNIT: Late Pliocene

BIOSTRATIGRAPHIC ZONE / FOSSIL CHARACTER: *G. miocenica* PL 5 (FORAMINIFERS); CN 12b (NANNOFOSSILS)



LITHOLOGIC DESCRIPTION

NANNOFOSSIL CLAY, dark greenish gray (5G 5/1), faintly banded.

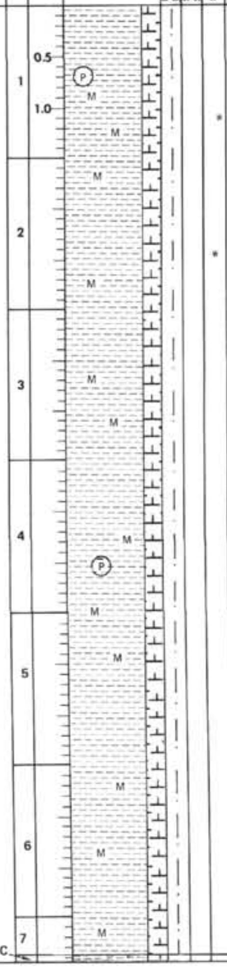
SMEAR SLIDE SUMMARY (%):

	2, 54
	D
Texture:	
Silt	1
Clay	99
Composition:	
Quartz	TR
Mica	1
Clay	69
Pyrite and opaques	TR
Carbonate unspec. (siderite)	TR
Calc. nannofossils	30
Radiolarians	TR
Fish remains	TR

SITE 603 HOLE C CORE 14 CORED INTERVAL 106.8–116.4 m

TIME – ROCK UNIT: Late Pliocene

BIOSTRATIGRAPHIC ZONE / FOSSIL CHARACTER: *G. miocenica* PL 5 (FORAMINIFERS); CN 12b (NANNOFOSSILS); FM (FORAMINIFERS, CC); CG (NANNOFOSSILS, CC)



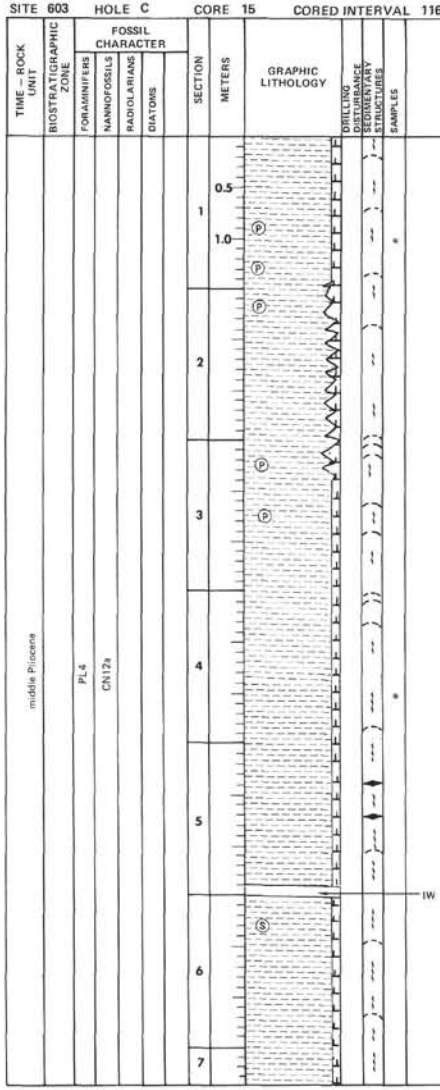
LITHOLOGIC DESCRIPTION

MICA- and NANNOFOSSIL-RICH CLAY, greenish gray to dark greenish gray (5G 5/1–5G 4/1), with vague mottling (disrupted bands?) of darker or greener shades. Rare white specks. Otherwise homogeneous. Pyritized burrow at Section 1, 70 cm. Pyrite cluster at Section 4, 103 cm.

SMEAR SLIDE SUMMARY (%):

	1, 110	2, 95
	D	M
Texture:		
Silt	36	12
Clay	64	88
Composition:		
Quartz	3	–
Feldspar	1	–
Mica	10	
Heavy minerals	–	TR
Clay	64	87
Palagonite	TR	TR
Glauconite	TR	–
Pyrite	–	TR
Carbonate unspec.	5	2
Foraminifers	TR	–
Calc. nannofossils	15	11
Plant debris	TR	TR

SITE 603 HOLE C CORE 15 CORED INTERVAL 116.4–126.0 m



LITHOLOGIC DESCRIPTION

1) NANNOFOSSIL-BEARING CLAY, dark greenish gray (5GY 4/1–5G 4/1) with scattered speckles (pyrite?) throughout core. Rare pyritized (?)burrows. Faint banding.

2) NANNOFOSSIL-RICH CLAY, gray (5GY 5/1), only small mottles, lenses and bands only in Section 3 and top of Section 4.

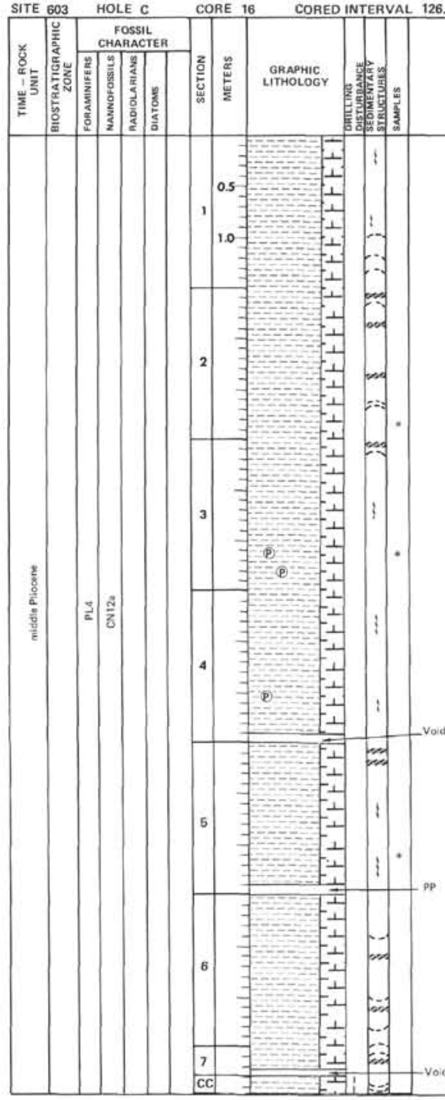
3) Few scattered semiconsolidated siderite nodules.

Section 7 is 37 cm in length.

SMEAR SLIDE SUMMARY (%):

	1, 100	4, 100
	D	D
Texture:		
Silt	10	10
Clay	90	90
Composition:		
Quartz	TR	1
Mica	3	4
Heavy minerals	TR	TR
Clay minerals	87	87
Pyrite	TR	–
Carbonate unspec.	2	2
Calc. nannofossils	8	6
Fish remains	–	TR
Plant debris	TR	TR

SITE 603 HOLE C CORE 16 CORED INTERVAL 126.0–135.6 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL-RICH CLAY, greenish gray (5G 5/1) to gray (N5) (bluish hue).

Faintly mottled and only locally banded (slightly darker or more olive hues = dark gray (5Y 4.5/1) (these areas are less nannofossil-rich).

Tiny (<2 mm) burrows or lenses filled by white quartz silt (100% quartz) (or agglutinated foraminifera?). Pyrite nodules (small, scattered).

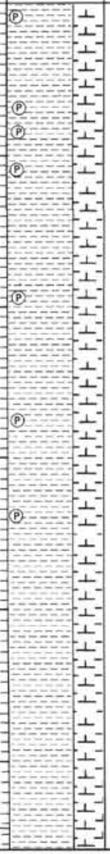
Few distinct burrows (5–10 mm diameter) filled by darker (5Y 4.5/1) material.

SMEAR SLIDE SUMMARY (%):

	2, 137	3, 115	5, 110
	M	D	M
Texture:			
Silt	8	8	100
Clay	92	92	–
Composition:			
Quartz	5	4	100
Mica	2	2	–
Heavy minerals	TR	–	–
Clay minerals	72	62	–
Pyrite and opaques	1	1	–
Carbonate unspec.	TR	TR	–
Foraminifers	–	1	–
Calc. nannofossils	20	30	–
Plant debris	–	TR	–

SITE 603 HOLE C CORE 17 CORED INTERVAL 135.6–145.2 m

TIME – ROCK UNIT: middle Pliocene | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER: FORAMINIFERS PL4; NANNOFOSSILS CN 12a; RADIOLARIANS; DIATOMS | SECTION: 1, 2, 3, 4, 5, 6, CC | METERS: 0.5, 1.0 | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES



LITHOLOGIC DESCRIPTION

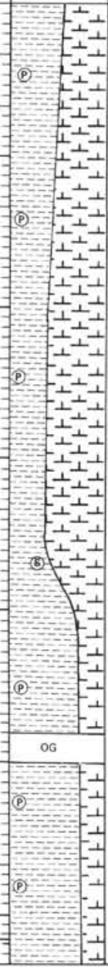
NANNOFOSSIL CLAY, grayish green (5G 5/1–5BG 5/1) with scattered speckles (pyrite?) throughout the core. Faint mottles. Rare pyritized burrows?/wood? as indicated. Between 60–110 cm, Section 5 occur carbonate nodules (<1 mm diameter) with a fibrous texture in smear slide analyses.

SMEAR SLIDE SUMMARY (%):

	1, 100	5, 90
	D	M
Texture:		
Silt	30	–
Clay	70	–
Composition:		
Quartz	TR	–
Mica	1	–
Clay	68	–
Palagonite	TR	–
Carbonate unspec.	1	100
Calc. nannofossils	30	–
Plant debris	TR	–

SITE 603 HOLE C CORE 18 CORED INTERVAL 145.2–154.8 m

TIME – ROCK UNIT: middle Pliocene | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER: FORAMINIFERS PL4; NANNOFOSSILS CN 12a; RADIOLARIANS; DIATOMS | SECTION: 1, 2, 3, 4, 5, 6, 7, CC | METERS: 0.5, 1.0 | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES



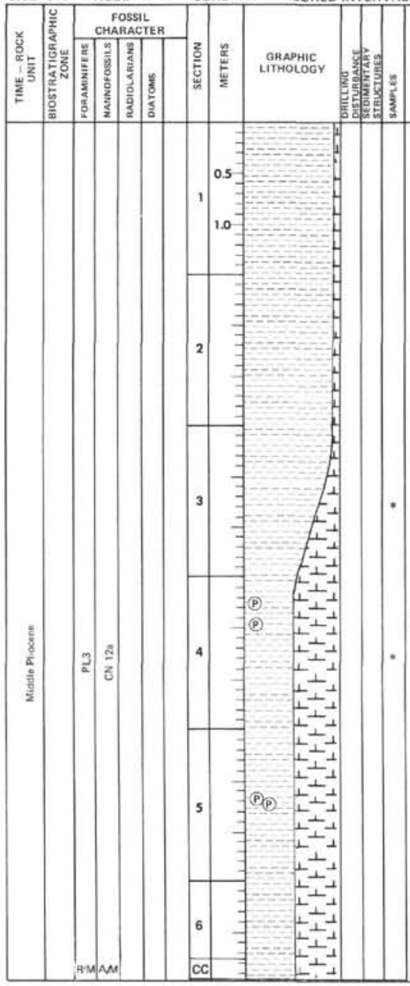
LITHOLOGIC DESCRIPTION

CLAYEY NANNOFOSSIL OOZE to NANNOFOSSIL-RICH CLAY, medium dark greenish gray (5G 4.5/1), becoming greenish gray (5G 5/1) in Section 2, then gradually dark greenish gray (5G 4/1) in Section 4 and below. Mottles and streaks of dark bluish gray (5B 3/4 pyrite-rich?) and rarer yellowish green gray. Rare scattered pyrite nodules (burrow replacements or plant debris replacement??) and white specks of quartz silt clusters (agglutinated foraminifera?). Siderite nodule in Section 4, 101 cm.

SMEAR SLIDE SUMMARY (%):

	4, 80	6, 57	6, 80
	D	M	D
Texture:			
Silt	70	100	29
Clay	30	–	71
Composition:			
Quartz	1	100	1
Mica	2	–	3
Clay	30	–	71
Glauconite	1	–	–
Pyrite	–	–	1
Carbonate unspec.	2	–	1
Foraminifers	1	–	TR
Calc. nannofossils	63	–	23
Diatoms	–	–	TR
Sponge spicules	–	–	TR
Silicoflagellates	TR	–	–
Fish remains	–	–	TR

SITE 603 HOLE C CORE 19 CORED INTERVAL 154.8–164.4 m



LITHOLOGIC DESCRIPTION

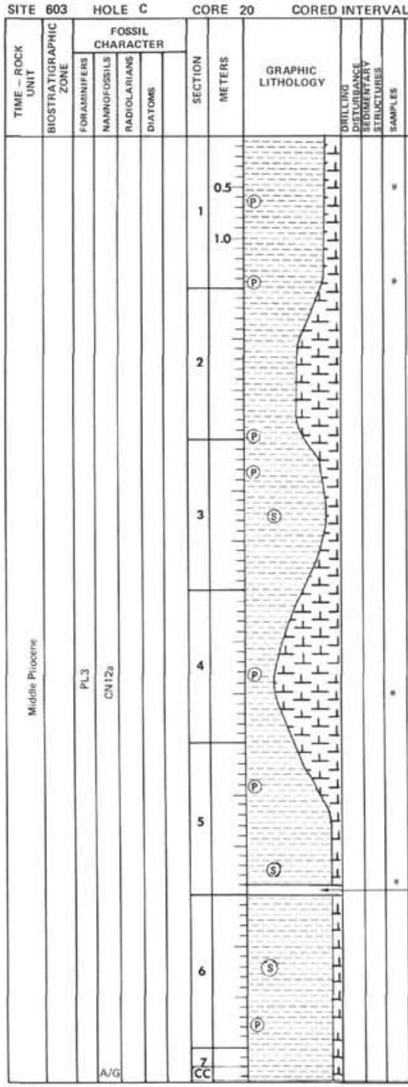
1) CLAY, dark gray (5G 5/1–5G 4/1), homogeneous with speckles (pyrite?) throughout the core. Section 1, 34–36, 110–115, 120–123 cm, and Section 3, 38–40, 93–94 cm are areas in which the clay is stiffer.

2) CLAYEY NANNOFOSSIL OOZE, gray (5G 5/1), slightly lighter than previous section of core. Otherwise similar in appearance with some pyrite nodules/burrow infills(?).

SMEAR SLIDE SUMMARY (%):

	3, 80	4, 80
	D	D
Texture:		
Silt	10	50
Clay	90	50
Composition:		
Quartz	1	1
Mica	4	3
Clay	88	42
Pyrite	1	–
Carbonate unspec.	3	3
Calc. nannofossils	3	50
Fish remains	–	TR
Plant debris	TR	1

SITE 603 HOLE C CORE 20 CORED INTERVAL 164.4–174.0 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL-RICH CLAY to CLAYEY NANNOFOSSIL OOZE to NANNOFOSSIL-BEARING MICA-BEARING CLAY, dark greenish gray (5G 4/1) with slight variations: Sections 2 and 4 are slightly lighter, Sections 5 and 6 are slightly darker. Very faint banding. Dark streaks throughout. Rare white specks (agglutinated foraminifera?), pyrite nodules and clusters, and siderite clusters (small). Lighter colored sections are considerably richer in nannofossils.

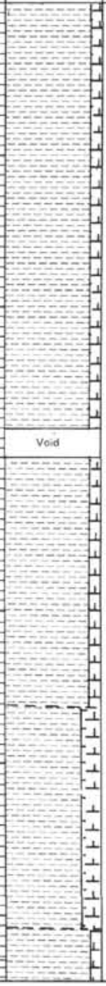
SMEAR SLIDE SUMMARY (%):

	1, 50	1, 145	4, 100	5, 137
	D	M	D	D
Texture:				
Silt	19	100	70	26
Clay	81	–	30	74
Composition:				
Quartz	1	–	1	1
Mica	2	–	1	9
Heavy minerals	1	–	–	–
Clay	81	–	30	74
Glauconite	TR	–	–	–
Pyrite	1	100	1	4
Zeolite	–	–	–	1
Carbonate unspec.	1	–	3	4
Foraminifiers	TR	–	–	–
Calc. nannofossils	11	–	64	7
Opaques	2	–	–	–

SITE 603 HOLE C CORE 21 CORED INTERVAL 174.0–183.6 m

TIME-ROCK UNIT: Middle Pliocene
BIOSTRATIGRAPHIC ZONE: Foraminifers PL3; Nannofossils CN 12a
FOSSIL CHARACTER: FM (Foraminifers), AG (Nannofossils)

SECTIONS: 1, 2, 3, 4, 5, 6, 7, CC
METERS: 0.5, 1.0



LITHOLOGIC DESCRIPTION

1) NANNOFOSSIL-BEARING CLAY, greenish gray (5G 5.5/1), slightly mottled, more or less homogeneous (no bandings) tiny (1–3 mm) white specks of silt-sized quartz (?burrow fills). Burrows in more olive hues.

2) NANNOFOSSIL-RICH CLAY, slightly lighter-colored than 1) about greenish-gray (5G 6/1).

Possibly represents interglacial?

Color changes between 1) and 2) are gradational.

Section 7 is 42 cm in length.

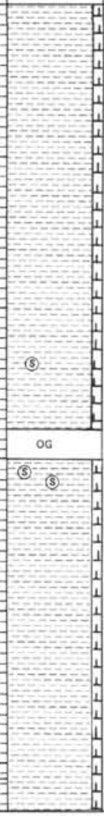
SMEAR SLIDE SUMMARY (%):

	1, 100 D	6, 50
Texture:		
Silt	15	25
Clay	85	75
Composition:		
Quartz	3	1
Mica	2	TR
Clay minerals	85	74
Pyrite and opaques	TR	–
Zeolite	–	1
Carbonate unspec.	1	3
Foraminifers	1	1
Calc. nannofossils	8	20

SITE 603 HOLE C CORE 22 CORED INTERVAL 183.6–193.2 m

TIME-ROCK UNIT: Middle Pliocene
BIOSTRATIGRAPHIC ZONE: Nannofossils CN11

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



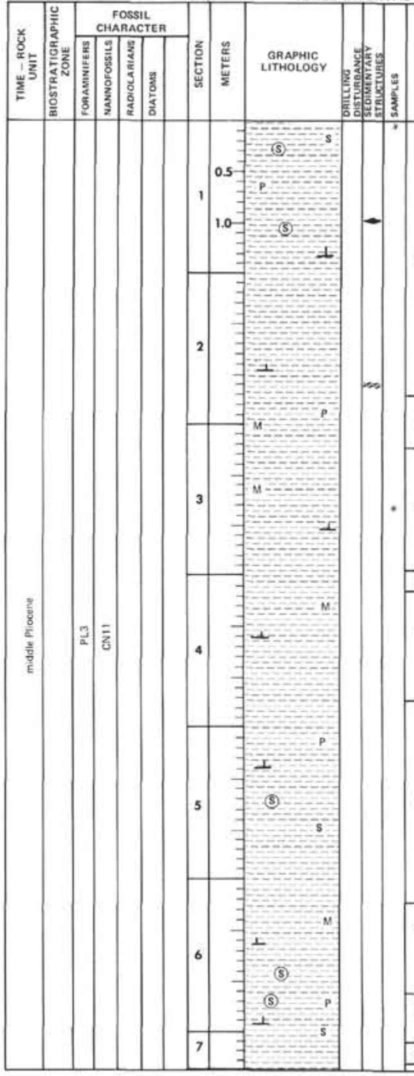
LITHOLOGIC DESCRIPTION

NANNOFOSSIL-BEARING CLAY,
1) darker colored = green gray (5G 5/1) and
2) lighter colored = 5GY 5.5/1.
Very subtle color gradations. Faintly mottled and banded (more olive hues). Few scattered siderite nodules.

SMEAR SLIDE SUMMARY (%):

	2, 88 D	3, 15 D
Texture:		
Silt	10	8
Clay	90	92
Composition:		
Quartz	1	1
Mica	TR	2
Clay minerals	89	92
Pyrite and opaques	1	TR
Zeolite	TR	–
Carbonate unspec.	1	TR
Foraminifers	1	TR
Calc. nannofossils	8	5
Fish remains	–	TR

SITE 603 HOLE C CORE 23 CORED INTERVAL 193.2–202.8 m



LITHOLOGIC DESCRIPTION

1) *SIDERITE-PYRITE-NANNOFOSSIL-BEARING CLAY*, 5G 4.5/1 [slightly darker than 2)].

2) MICA and NANNOFOSSIL-BEARING CLAY, 5GY 5/1 with mottles of 5G 5/1.

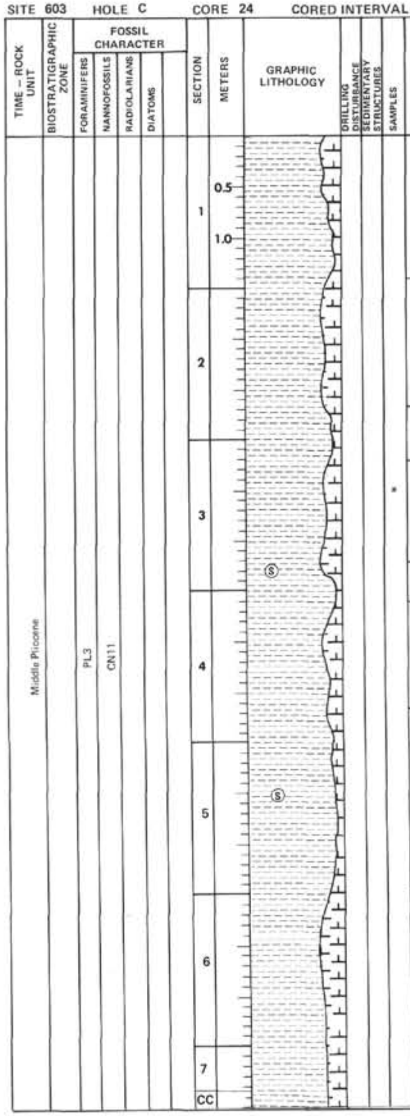
Homogeneous to highly mottled. Yellowish siderite nodules. Tiny quartz silt-filled burrows. Gradational color changes between (1) and (2).

Section 7 is 37 cm in length.

SMEAR SLIDE SUMMARY (%):

	1, 5	3, 80
Texture:		
Silt	13	15
Clay	87	85
Composition:		
Quartz	1	2
Mica	2	4
Clay minerals	87	86
Pyrite	3	1
Carbonate unspec. (siderite)	5	3
Foraminifers	TR	—
Calc. nannofossils	2	4
Plant debris	TR	TR

SITE 603 HOLE C CORE 24 CORED INTERVAL 202.8–212.4 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL-RICH CLAY, greenish-gray (5G 5/1 to 5BG 5/1) with black burrow mottles, highly mottled and homogenized.

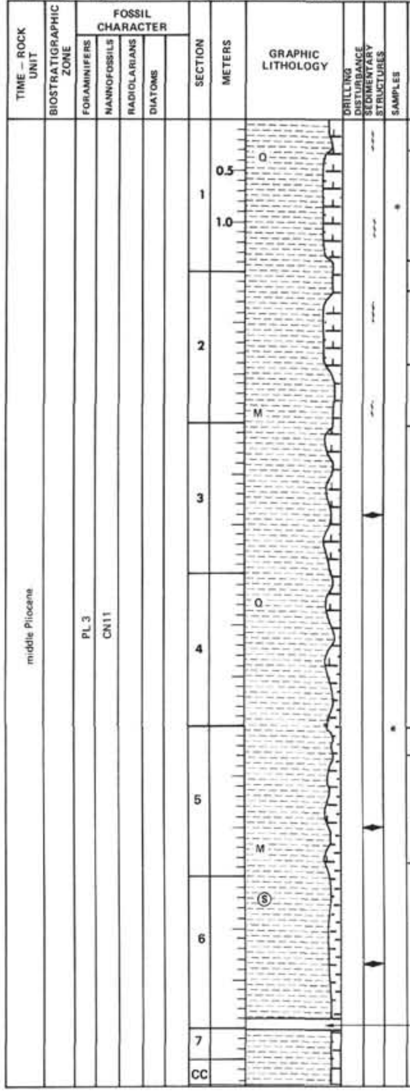
1) slightly darker colored than 2).

Section 7 is 41 cm in length.

SMEAR SLIDE SUMMARY (%):

	3, 50
Texture:	
Silt	25
Clay	75
Composition:	
Quartz	1
Mica	2
Clay minerals	75
Pyrite and opaques	1
Carbonate unspec.	TR
Foraminifers	2
Calc. nannofossils	20
Plant debris	TR

SITE 603 HOLE C CORE 25 CORED INTERVAL 212.4–222.0 m



LITHOLOGIC DESCRIPTION

1) NANNOFOSSIL-BEARING CLAY, darker colored greenish gray (dark) (5G 4.5/1), stiff.

2) NANNOFOSSIL-RICH CLAY, lighter colored gray (5Y 6/1), less stiff.

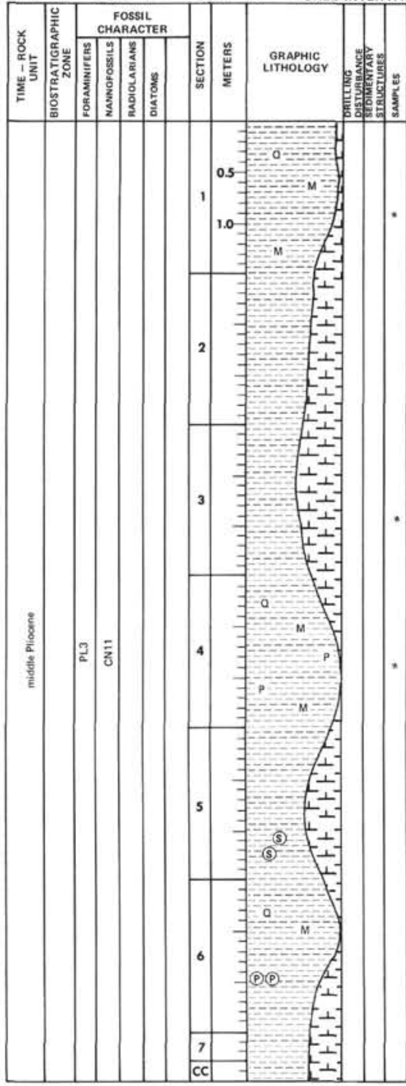
Mottled to approximately homogeneous. Locally burrows filled with lighter (2.5Y 6/2) material, partly siderite.

Section 7 is 31 cm in length.

SMEAR SLIDE SUMMARY (%):

	1, 83	5, 5
	D	D
Texture:		
Silt	23	20
Clay	77	80
Composition:		
Quartz	1	3
Mica	2	3
Heavy minerals	–	TR
Clay minerals	77	81
Pyrite and opaques	TR	2
Carbonate unspec.	2	2
Foraminifers	1	1
Calc. nannofossils	17	7
Plant debris	–	1

SITE 603 HOLE C CORE 26 CORED INTERVAL 222.0–231.6 m



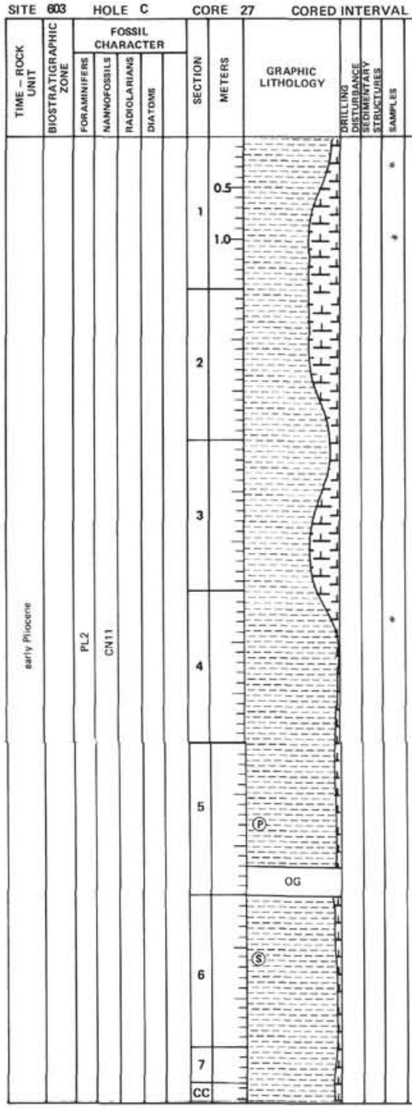
LITHOLOGIC DESCRIPTION

SILT-BEARING CLAY to NANNOFOSSIL CLAY, dark greenish gray (5G 4/1) to greenish (5G 5/1) depending on nannofossil content. These fluctuations are drawn schematically. Diffuse mottles of slightly darker, bluish, greenish, or yellowish grays. Scattered white specks. Rare siderite and pyrite clusters in Sections 5 and 6. PYRITE-BEARING and SILT-BEARING CLAY is typical lithology of Section 4 (darker shade of dark greenish gray).

SMEAR SLIDE SUMMARY (%):

	1, 90	3, 90	4, 90
	D	D	D
Texture:			
Silt	20	48	10
Clay	80	52	90
Composition:			
Quartz	3	TR	3
Mica	5	1	7
Clay	80	52	86
Pyrite	2	1	4
Zeolite	TR	–	–
Carbonate unspec.	6	1	–
Calc. nannofossils	4	45	–

SITE 603 HOLE C CORE 27 CORED INTERVAL 231.6–241.2 m



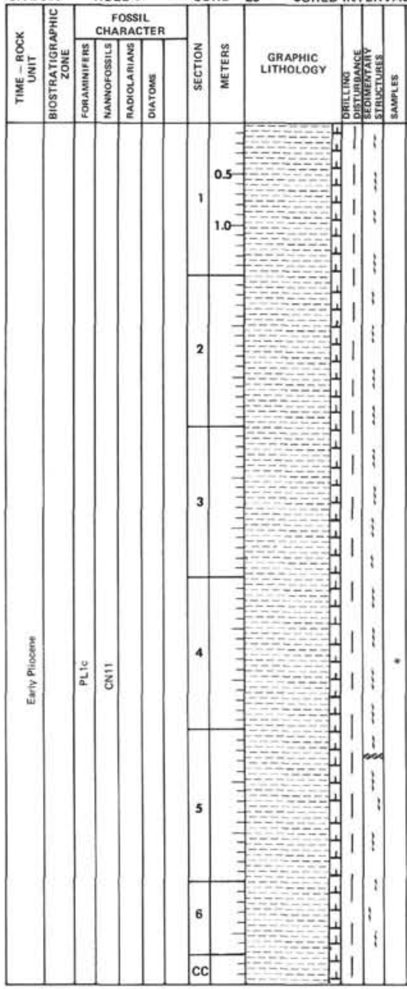
LITHOLOGIC DESCRIPTION

CLAY, dark greenish gray (5G 4/1) to NANNOFOSSIL-BEARING CLAY, dark greenish gray (5G 4.5/1), to NANNOFOSSIL CLAY, greenish gray (5G 5/1). Variations in color due to nannofossil content. Overall the cores are homogeneous with dark speckles of pyrite throughout the core. Rare pyrite and siderite nodules as indicated.

SMEAR SLIDE SUMMARY (%):

	1, 30	1, 100	4, 30
	D	D	D
Texture:			
Silt	15	35	10
Clay	85	65	90
Composition:			
Quartz	2	1	1
Mica	3	1	3
Heavy minerals	TR	–	TR
Clay	83	60	90
Glauconite	–	1	–
Pyrite	3	1	1
Carbonate unspec.	3	3	2
Foraminifers	–	1	–
Calc. nannofossils	5	30	2
Diatoms	–	1	–
Plant debris	1	1	1

SITE 603 HOLE C CORE 28 CORED INTERVAL 241.2–250.8 m



LITHOLOGIC DESCRIPTION

NANNOFOSSIL-BEARING CLAY, very stiff, dark greenish gray (5G 4/1). Heavily bioturbated. Pyritized burrow, 5–7 cm in diameter occurs in Section 5, 25 cm.

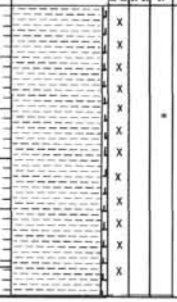
SMEAR SLIDE SUMMARY (%):

	4, 87
	D
Texture:	
Silt	10
Clay	90
Composition:	
Quartz	1
Mica	2
Pyrite	1
Zeolite	TR
Carbonate unspec.	2
Calc. nannofossils	4
Plant debris	TR

SITE 603 HOLE C CORE 29 CORED INTERVAL 250.8–260.4 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
Early Pliocene		PL1c	CN11			1, 2, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

NANNOFOSSIL-BEARING CLAY, dark greenish gray (5G 4.5/1). All DRILLING BRECCIA; cut surface smoothed from cutting wire.

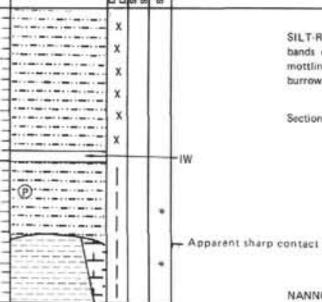
SMEAR SLIDE SUMMARY (%):

	1, 100
	D
Texture:	
Silt	11
Clay	89
Composition:	
Quartz	TR
Mica	3
Clay	89
Carbonate unspec.	3
Calc. nannofossils	5
Fish remains	TR

SITE 603 HOLE C CORE 30 CORED INTERVAL 260.4–270.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
Early Pliocene		PL1c	CN10c			1, 2	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

SILT-RICH CLAY, dark greenish gray (5G 4/1) with vague bands of dark bluish gray (5B 3/1) and faint burrow(?) mottling. White "specks" are cross-cuts of quartz-silt lined burrows (well exposed at base of Section 2).

Section 1 is mainly breccia produced by drilling.

NANNOFOSSIL-RICH CLAY, greenish gray (5G 4.5/1) becoming darker and less nannofossil-rich toward base of core. Otherwise same appearance and features as the overlying silt-rich clay.

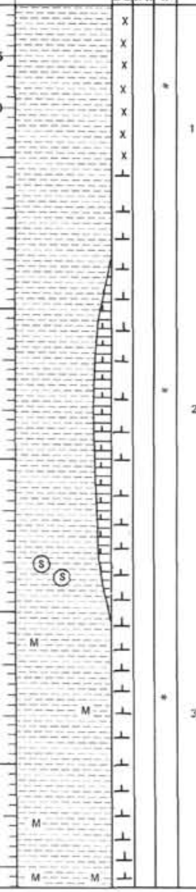
SMEAR SLIDE SUMMARY (%):

	2, 50	2, 100
	D	D
Texture:		
Sand	2	–
Silt	15	30
Clay	83	70
Composition:		
Quartz	3	2
Mica	9	6
Heavy minerals	TR	TR
Clay	81	66
Pyrite	3	1
Carbonate unspec.	3	4
Calc. nannofossils	–	20
Fish remains	–	TR
Plant debris	1	1

SITE 603 HOLE C CORE 31 CORED INTERVAL 270.0–279.6 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
Early Pliocene		*G. margaritae* (PL1a–b)	CN10c			1, 2, 3, 4, 5, 6, CC	0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

1) CLAYSTONE, dark greenish gray (5BG 4/1) with severe disruption from coring and cutting. No structure apparent. In Section 2, at 8 cm is a discontinuous layer of siderite.

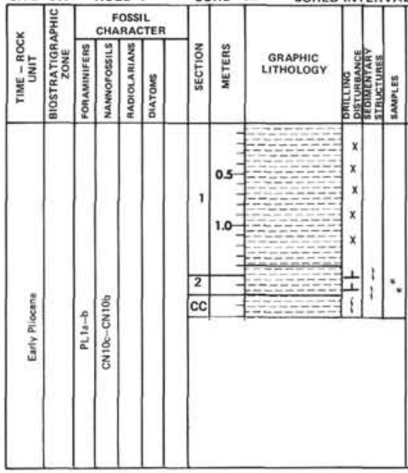
2) NANNOFOSSIL-BEARING CLAYSTONE, dark greenish gray (5G 4/1). In Section 4, 90–115 cm, are abundant 1–2 mm siderite nodules/fragments.

3) MICA-RICH CLAYSTONE, dark greenish gray (5G 4/1–5BG 4/1). No structure apparent due to coring deformation. (Cut by the saw.) Biscuits are highly fractured and flaking apart.

SMEAR SLIDE SUMMARY (%):

	1, 80	3, 80	5, 80
	D	D	D
Texture:			
Silt	10	15	13
Clay	90	85	87
Composition:			
Quartz	TR	1	1
Mica	2	3	11
Heavy minerals	TR	TR	–
Clay and aggregates	95	85	87
Pyrite	1	1	TR
Carbonate unspec.	1	2	1
Calc. nannofossils	–	8	TR
Plant debris	11	TR	TR

SITE 603 HOLE C CORE 32 CORED INTERVAL 279.6–289.2 m



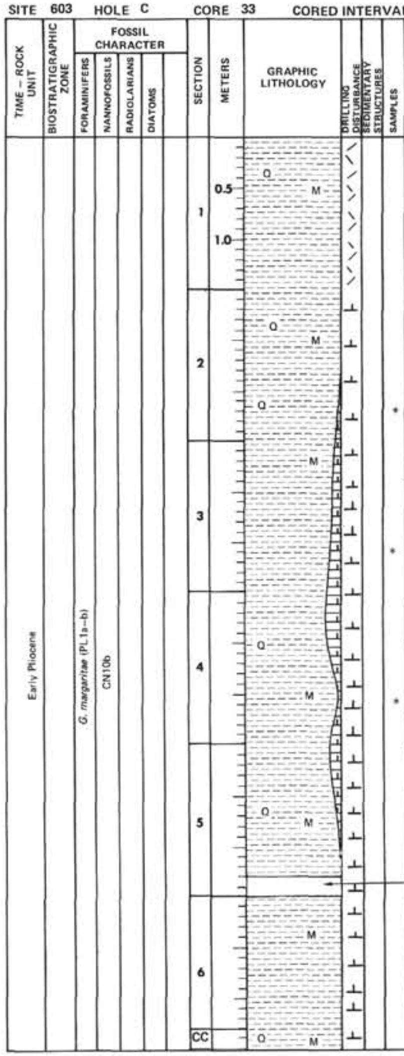
LITHOLOGIC DESCRIPTION

MICA-BEARING and SIDERITE-RICH CLAYSTONE, dark greenish gray (5G 4/1) with elongate lenticular burrow mottles of greenish gray (5G 5/1) rimmed by dark bluish gray (5B 3/1). Scattered pyrite grains. Burrow fill (Section 2, 16 cm) is mica-rich claystone. Section 1 is DRILLING BRECCIA.

SMEAR SLIDE SUMMARY (%):

	2, 6	2, 16
	M	D
Texture:		
Silt	17	20
Clay	83	80
Composition:		
Quartz	1	1
Mica	9	5
Heavy minerals	1	–
Clay, clay aggregates	83	80
Zeolite	1	1
Carbonate unspec.	5	12

SITE 603 HOLE C CORE 33 CORED INTERVAL 289.2–298.8 m



LITHOLOGIC DESCRIPTION

1) NANNOFOSSIL-BEARING, SILT-RICH CLAYSTONE, dark greenish gray (5G 4/1).

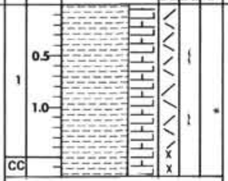
2) NANNOFOSSIL-RICH CLAYSTONE, greenish gray (5G 5/1).

3) SILT-BEARING CLAYSTONE, dark greenish gray (5G 4/1).

SMEAR SLIDE SUMMARY (%):

	2, 120	3, 110	4, 110
	D	D	D
Texture:			
Silt	20	15	10
Clay	80	85	90
Composition:			
Quartz	2	TR	2
Feldspar	1	–	–
Mica	9	3	5
Heavy minerals	TR	–	TR
Clay and aggregates	82	84	89
Pyrite	1	TR	1
Carbonate unspec.	2	2	1
Calc. nannofossils	3	10	1
Plant debris	–	1	1

SITE 603 HOLE C CORE 34 CORED INTERVAL 298.8–308.4 m

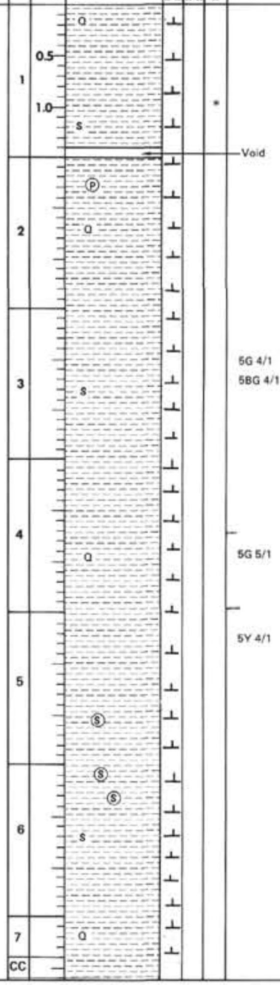
TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION / METERS / GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES	LITHOLOGIC DESCRIPTION
Early Pliocene		PL1a–b	CN 10a				see below

Pieces of NANNOFOSSIL CLAYSTONE, dark greenish gray (5G 4/1, 5GY 4/1) to greenish gray (5G 4.5/1). Mottles and irregular bands of greenish gray (5GY 5/1).

SMEAR SLIDE SUMMARY (%):

	1, 107
	D
Texture:	
Silt	33
Clay	67
Composition:	
Quartz	2
Mica	1
Heavy minerals	TR
Clay	67
Pyrite	TR
Carbonate unspec.	2
Calc. nannofossils	30

SITE 603 HOLE C CORE 35 CORED INTERVAL 308.4–318.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION / METERS / GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES	LITHOLOGIC DESCRIPTION
Early Pliocene		*G. margaritae* (PL1a–b) RM	CN 10a AM				see below

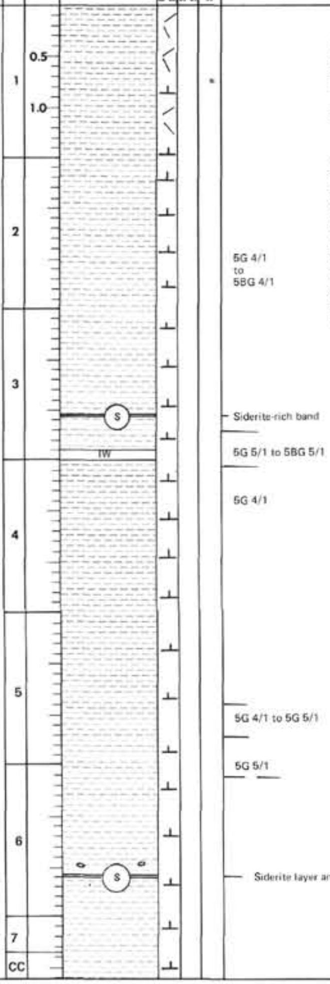
QUARTZ- and SIDERITE-BEARING CLAYSTONE with traces of nannofossils, dark greenish-gray (5G 4/1–5BG 4/1), heavily burrowed, faintly banded (or streaky lamina due to compacted burrows). Pyritic (+ siderite?) burrow fills and siderite-rich bands. Lighter yellowish band at Section 2, 100 cm.

SMEAR SLIDE SUMMARY (%):

	1, 44
	D
Texture:	
Silt	7
Clay	93
Composition:	
Quartz	3
Clay minerals	93
Pyrite	1
Fe-oxides	2
Zeolite	TR
Carbonate unspec. (siderite)	2
Foraminifers (fragments)	1
Calc. nannofossils	TR

SITE 603 HOLE C CORE 36 CORED INTERVAL 318.0–327.6 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
early Pliocene–late Miocene		PL1a–b	CN10a–CN9b		



LITHOLOGIC DESCRIPTION

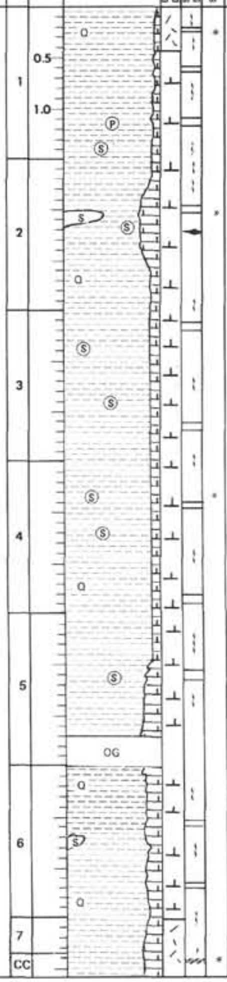
QUARTZ- and MICA-BEARING CLAYSTONE, dark greenish gray (5G 4/1 to 5BG 4/1) to greenish gray (5Y 5/1) faintly banded and heavily bioturbated (horizontal bluish black streaks due to *Planolites*-type burrows).

SMEAR SLIDE SUMMARY (%):

	1, 77
	D
Texture:	
Silt	10
Clay	90
Composition:	
Quartz	6
Feldspar	1
Mica	2
Clay	90
Glauconite	TR
Zeolite	TR
Calc. nannofossils	TR
Fish remains	TR

SITE 603 HOLE C CORE 37 CORED INTERVAL 327.6–337.2 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS
late Miocene		*G. margaritae* (PL1a–b)	CN 9b		



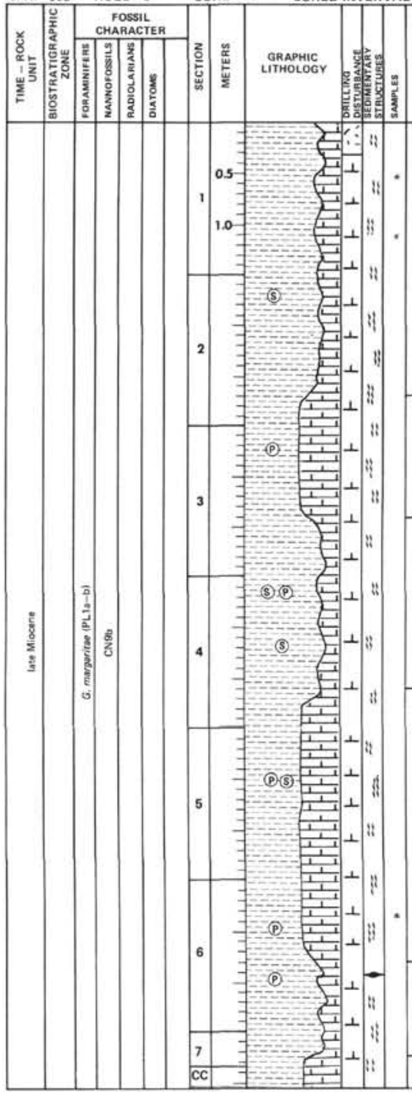
LITHOLOGIC DESCRIPTION

NANNOFOSSIL-RICH CLAYSTONE to NANNOFOSSIL-BEARING CLAYSTONE, dark gray to dark greenish gray (5GY 4/1–5Y 4/1) to greenish gray (5G 5/1 = more nanno-rich). Faintly banded, few distinct, many indistinct, flattened elongate burrows (fill more olive, darker halo). Several bands of yellowish (2.5Y 6/2) siderite nodules and concretions (burrow fills). Few isolated pyrite (+ siderite?) nodules. Claystone swelling! Burrow fills are very nannofossil-rich to nannofossil claystone (40%!).
Core swells when exposed to fresh water.

SMEAR SLIDE SUMMARY (%):

	2, 53	4 35	1, 28	CC.5
	D	M		
Texture:				
Silt	–	100	8	40
Clay	100	–	92	60
Composition:				
Quartz	TR	–	7	–
Feldspar	–	–	TR	–
Mica	TR	5	–	–
Heavy minerals	–	–	TR	–
Clay minerals	35	–	25	60
Glauconite	–	–	TR	–
Zeolite	TR	–	–	–
Carbonate unspec. (siderite)	TR	95	1	–
Calc. nannofossils	15	–	7	40
Fish remains	TR	–	–	–

SITE 603 HOLE C CORE 38 CORED INTERVAL 337.2–346.8 m



LITHOLOGIC DESCRIPTION

1) NANNOFOSSIL-BEARING CLAYSTONE, dark greenish-gray (5G 4/1–5GB 4/1). Moderately burrowed (flat *Planolites*-type) and spreiten-burrow fills (Section 6, 92 cm).

2) NANNOFOSSIL CLAYSTONE, greenish-gray (5G 5/1), significantly lighter-colored than 1).

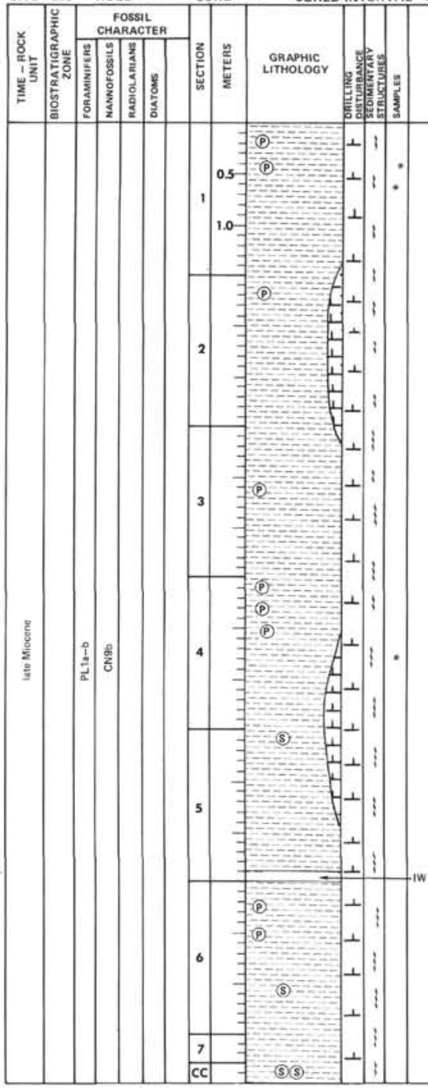
Faintly banded throughout. Light olive. Pyritic burrow fills.

Pyrite + siderite burrow fills S+P.

SMEAR SLIDE SUMMARY (%):

	1, 54 D	1, 111 M	6, 36 D
Texture:			
Silt	22	5	40
Clay	78	95	60
Composition:			
Quartz	1	TR	TR
Mica	1	TR	TR
Clay minerals and aggregates	78	55	60
Glauconite	TR	–	–
Pyrite	TR	–	–
Carbonate unspec. (siderite)	TR	40	–
Foraminifers	–	TR	–
Calc. nannofossils	20	5	40
Fish remains	TR	–	–

SITE 603 HOLE C CORE 39 CORED INTERVAL 346.8–356.4 m



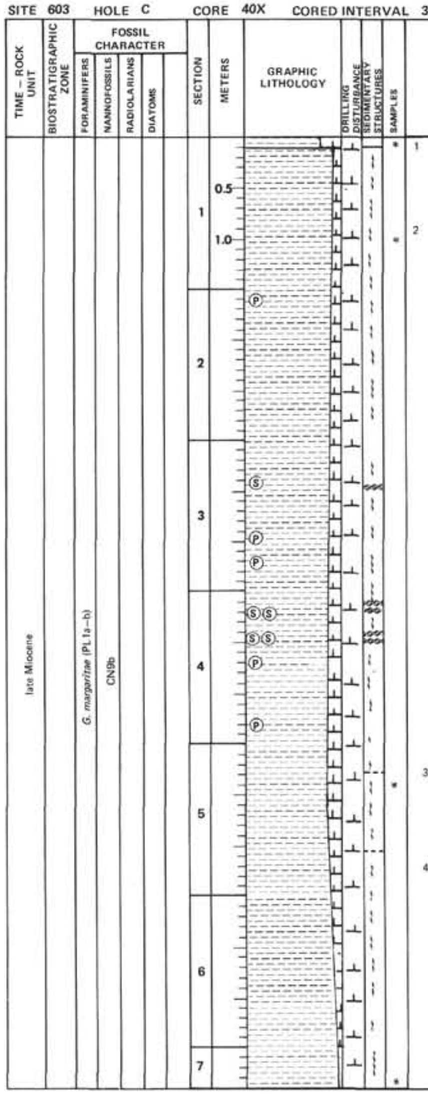
LITHOLOGIC DESCRIPTION

CLAY to NANNOFOSSIL-BEARING CLAY, dark greenish gray (5G 4/1) to greenish gray (5G 4.5/1, 5G 5/1), lighter shades in Section 2 and Section 4/5. Moderate bioturbation of elongate lenticular burrow mottles and *Chondrites*. Some burrows are filled with brownish siderite-rich clay. Abundant pyrite nodules, rare siderite concretions.

SMEAR SLIDE SUMMARY (%):

	1, 48 M	1, 63 D	4, 80 D
Texture:			
Silt	80	5	12
Clay	20	95	88
Composition:			
Quartz	1	TR	1
Feldspar	–	TR	–
Mica	–	1	–
Clay	20	95	88
Pyrite	–	TR	1
Zeolite	–	1	TR
Carbonate unspec.	78	2	1
Calc. nannofossils	1	1	9

SITE 603 HOLE C CORE 40X CORED INTERVAL 356.4–366.0 m



LITHOLOGIC DESCRIPTION

1) NANNOFOSSIL-RICH CLAYSTONE, greenish gray (5G 5/1). One drilling biscuit and slurry in uppermost 10 cm of core.

2) NANNOFOSSIL-BEARING CLAYSTONE, dark greenish gray (5G 4/1) with burrows infilled with CLAY-RICH SIDERITE, dark greenish gray (5GY 4/1). At 40–41 cm, Section 3, and 21, 24, 52 and 54 cm of Section 4, burrows are infilled with SIDERITE, gray (5GY 6/1).

3) SIDERITE AND NANNOFOSSIL-RICH CLAYSTONE, dark greenish gray (5G 4.5/1) with slight to moderate bioturbation.

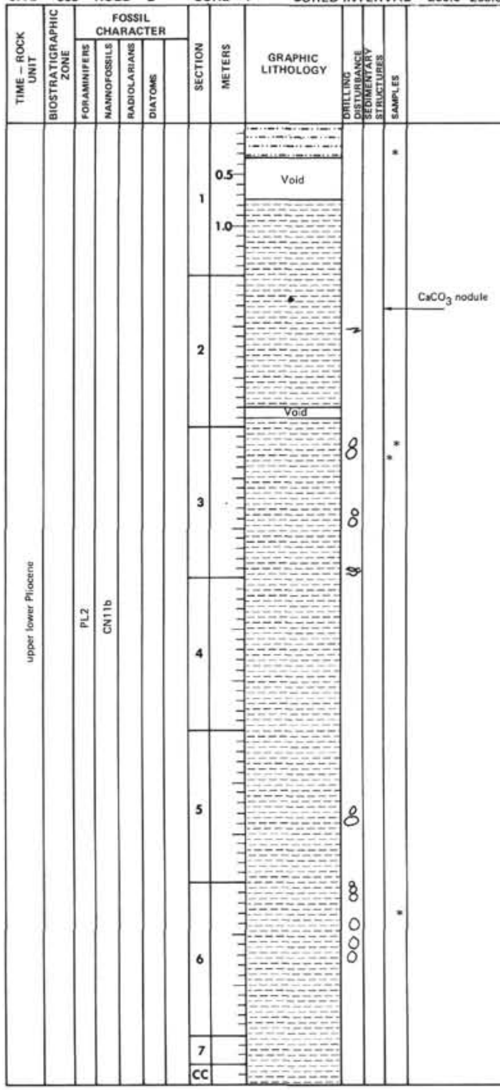
4) CLAYSTONE, dark greenish gray (5GY 4/1–5G 4/1) with rare burrowing and bioturbation.

Rare pyrite filled burrows.

SMEAR SLIDE SUMMARY (%):

	1, 4	1, 100	5, 40	7, 40
	M	D	D	D
Texture:				
Silt	20	10	30	5
Clay	80	90	70	95
Composition:				
Quartz	–	1	1	TR
Mica	TR	3	2	2
Heavy minerals	TR	1	TR	1
Clay	80	88	66	93
Pyrite	TR	TR	TR	TR
Carbonate unspec.	2	2	10	2
Calc. nannofossils	18	5	90	1
Plant debris	TR	–	1	1

SITE 603 HOLE D CORE 1 CORED INTERVAL 200.0–209.6 m



LITHOLOGIC DESCRIPTION

SILTY NANNOFOSSIL MUD to CLAY (near bottom), dark greenish gray (5GY 4/1), uniform massive structureless silty mud to mud. The upper part of the core contains nannofossil silt (~5% or less) which disappears toward the base. A few foraminifer fragments were present in the smear slides.

Sediment is unburrowed but was very gassy and self extruded.

SMEAR SLIDE SUMMARY (%):

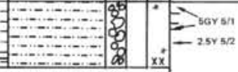
	1, 30	3, 20[a]	3, 30	6, 30
Texture:				
Sand	4	–	3	1
Silt	15	–	8	5
Clay	81	–	89	94
Composition:				
Quartz	4	–	2	1
Mica	1	–	2	3
Heavy minerals	1	–	2	2
Clay	81	–	88	94
Glauconite	1	–	–	–
Pyrite	3	–	2	–
Carbonate unspec.	1	95	1	–
Calc. nannofossils	5	5	3	4
Discoasters	3	–	–	–

[a] Nodule

SITE 603 HOLE E CORE 1 CORED INTERVAL 936.4–946.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	ICHTHYOLITHS	SECTION	METERS
		Barren	Barren	Barren		lower Miocene; 6 diagnostic morphological types	1	0.5
							CC	

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

MUDSTONE, greenish gray (5GY 5/1) and grayish brown (2.5Y 5/2). Sharp contacts between colors. Sporadic burrow mottles of grayish brown in greenish gray interval. Large glauconite grains (coarse sand to granule) at 0–5 cm. Rare, very dark gray granules (pyrite?) in the grayish brown intervals. Numerous pits on split surface of core indicate medium sand-sized grains plucked from core; dolomite?

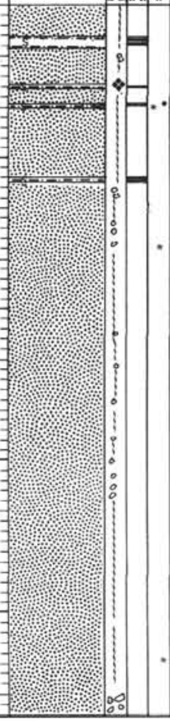
SMEAR SLIDE SUMMARY (%):

	1, 2	1, 52
	M	D
Texture:		
Silt	50	50
Clay	50	50
Composition:		
Quartz	44	44
Mica	5	5
Heavy minerals	TR	TR
Clay	50	50
Glauconite	TR	–
Pyrite	TR	TR
Zeolite	1	1

SITE 603 HOLE E CORE 2W CORED INTERVAL 1258.0–1271.4 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
		Hauterivian–lower Barremian	upper Hauterivian–lower Barremian			1	0.5, 1.0
						2	
						3	
						4	
						5	
		RM	AG	B		CC	

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

SAND with siderite-rich MUDSTONE INTERBEDS. The entire core is dark olive gray (5Y 3/2) and is very much disturbed by coring (wash). The sands are medium to coarse grained quartz plus a great deal of heavy mineral sand. The heavies are fresh (extremely so) and unabraded, of metamorphic origins.

The silty-clay (mudstones) are mm lamina with considerable muscovite on bedding. Nannofossils are well preserved. Fine organic fragments (?wood?) are also present.

SMEAR SLIDE SUMMARY (%):

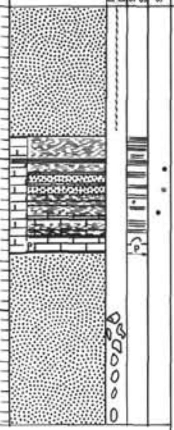
	1, 100	2, 92	5, 45
Texture:			
Sand	1	80	70
Silt	59	19	30
Clay	40	1	TR
Composition:			
Quartz	3	70	60
Feldspar	–	10	10
Mica	–	–	2
Heavy minerals	–	18	26
Clay	25	–	–
Pyrite	2	–	–
Zeolite	TR	–	–
Carbonate unspec.	40	–	–
Calc. nannofossils	–	1	1
Fish remains	TR	–	–
Plant debris	30	–	–
Opaques	–	1	1

ORGANIC CARBON AND CARBONATE (%):

	1, 97
Organic carbon	3.42
Carbonate LECO	54.81
+ (siderite) BOMB	43.00

SITE 603 HOLE E CORE 3W CORED INTERVAL 1277.0–1279.0 m

TIME–ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
	Lenticulina spp.	Hauterivian–lower Barremian	upper Hauterivian–lower Barremian			1, 2, 3	0.5, 1.0				
		RP	AG	B							



LITHOLOGIC DESCRIPTION

General color: 5Y 4/1 sands and black (5Y 2.5/1) for limestone to shale sections.

Sands, coarse fairly well sorted, very fresh angular grains with coring artifacts, breccias of limestone to shale fragments (coring) and LIMESTONE is less laminar to massive. The shale to limestones range from finely laminar shale (mm) to somewhat burrowed, to small slump sections (pyrite cemented). One segment in Section 2 has an elegant fine scoured surface overlain by a 3 cm weakly graded bed (silty).

SMEAR SLIDE SUMMARY (%):

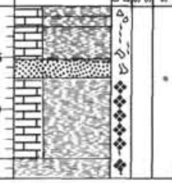
	2, 35
Texture:	
Sand	8
Silt	26
Clay	66
Composition:	
Quartz	3
Mica	1
Clay	66
Pyrite	TR
Zeolite	TR
Carbonate unspec.	5
Calc. nannofossils	25

ORGANIC CARBON AND CARBONATE (%):

	2, 12	2, 55
Organic carbon	—	—
Carbonate LECO	91.13	20.16
+ (siderite) BOMB	78.0	20.0

SITE 603 HOLE E CORE 4W CORED INTERVAL 1279.0–1289.7 m

TIME–ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
			upper Hauterivian–lower Barremian			1, CC	0.5, 1.0				
		B	AG	B							



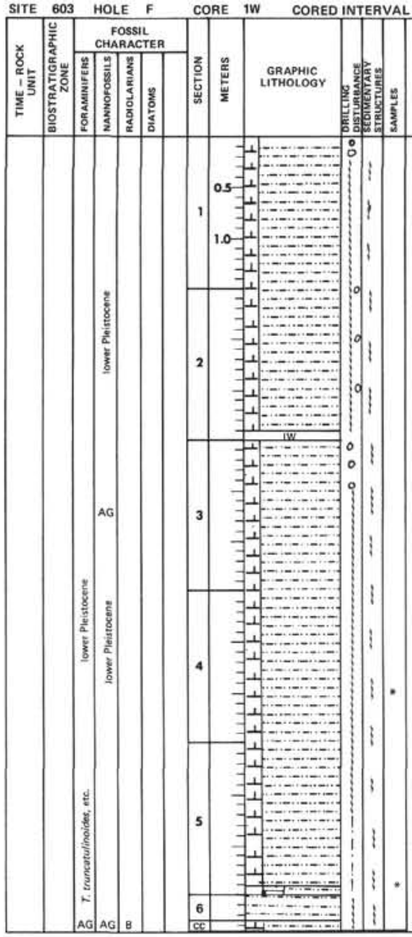
LITHOLOGIC DESCRIPTION

Black (5Y 2.5/1) to very dark gray (5Y 3/1) NANNOFOSSIL SHALE (~ 20% carbonate) to MARLY NANNOFOSSIL LIMESTONE, laminar to burrowed organic-rich, pyritiferous.

SMEAR SLIDE SUMMARY (%):

	1, 75
Texture:	
Sand	2
Silt	40
Clay	58
Composition:	
Quartz	1
Mica	2
Clay	58
Pyrite	TR
Zeolite	1
Calc. nannofossils	35
Plant debris	3

SITE 603 HOLE F CORE 1W CORED INTERVAL 0.0–32.6 m



LITHOLOGIC DESCRIPTION

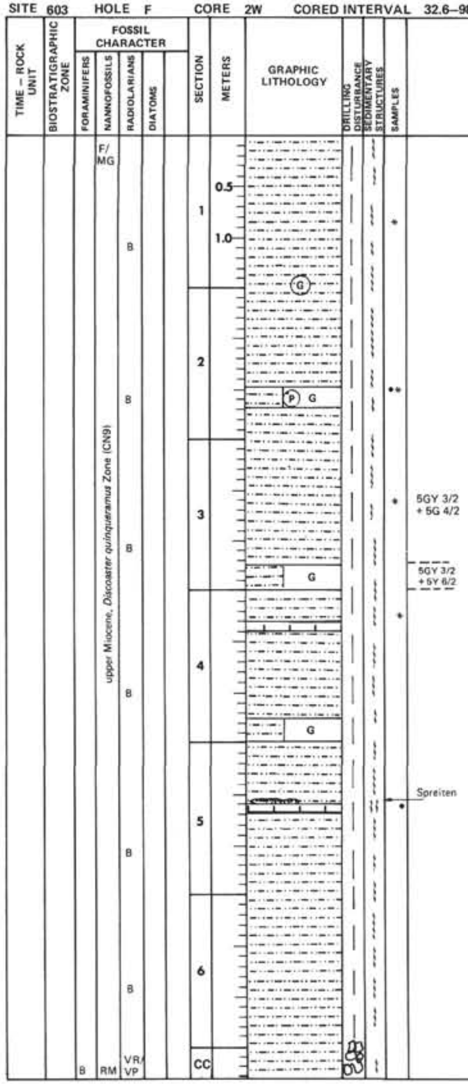
NANNOFOSSILIFEROUS MUD, gray (5G 5/1) with dark gray (5G 4/1) thin layers and mottles (burrows). Upper sections soupy and strongly disturbed by drilling. Below 50 cm of Section 3 less disturbed. Thin silty layers. Throughout the sections up to mm large spherical foraminifera, enriched in burrows and layers (Section 5, 140–145 cm). Rare pyritized well preserved burrows (vertical with 5 mm long horizontal spicules).

Uppermost 15 cm of core olive (5Y 5/3) color by oxidation of ubiquitous fine dispersed sulfides.

SMEAR SLIDE SUMMARY (%):

	4, 100	5, 142
	D	M
Texture:		
Sand	1	20
Silt	29	50
Clay	70	30
Composition:		
Quartz	20	15
Mica	TR	TR
Heavy minerals	TR	TR
Clay	58	30
Pyrite	2	5
Zeolite	TR	–
Carbonate unspec.	5	20
Foraminifers	TR	5
Calc. nannofossils	15	25

SITE 603 HOLE F CORE 2W CORED INTERVAL 32.6–980.5 m



LITHOLOGIC DESCRIPTION

Grayish olive green (5GY 3/2) to dark greenish gray (5G 4/1) with burrows of greenish black (5GY 2/1) to greenish black (5G 2/1) (SILTY) MUDSTONE extensively burrowed. Sideritic burrows are grayish brown (2.5Y 5/2) and contain small light specks. Smear slide of burrow shows discoasters (well preserved).

Most burrows are flattened but the grayish brown ones are quite rounded or only slightly compacted (early lithification).

Sporadic interlayered (Section 3, 125–150 cm) grayish olive green MUDSTONE and light olive gray (5Y 6/2) SIDERITE.

SMEAR SLIDE SUMMARY (%):

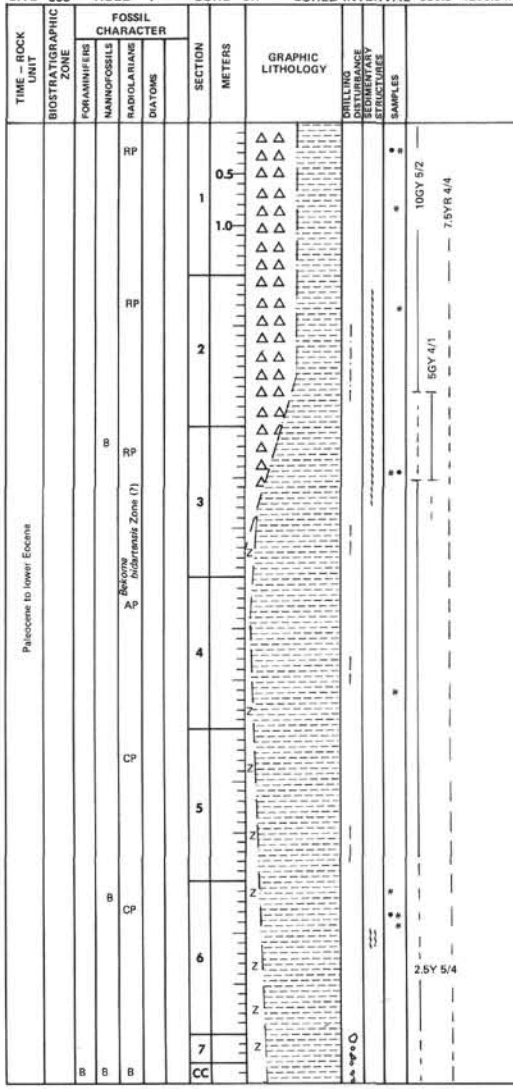
	1, 85	2, 103[a]	4, 25
Texture:			
Sand	–	–	50
Silt	20	90	50
Clay	80	10	–
Composition:			
Quartz	10	3	5
Mica	1	1	TR
Heavy minerals	TR	TR	TR
Clay	80	10	42
Pyrite	2	–	1
Zeolite	–	–	TR
Carbonate unspec.	5	86	2
Foraminifers	–	–	TR
Calc. nannofossils	2	–	50
Plant debris	TR	–	TR

[a] Siderite

ORGANIC CARBON AND CARBONATE (%):

	2, 102	5, 64
Organic carbon	0.3	0.48
Carbonate LECO	26.74	9.50
Carbonate BOMB	20	6

SITE 603 HOLE F CORE 3W CORED INTERVAL 980.5–1200.8 m



LITHOLOGIC DESCRIPTION

PORCELLANITIC CLAYSTONE to ZEOLITIC CLAYSTONE

Unbedded or irregularly thin laminated, grayish green (dominant color: 10GY 5/2) porcellanitic claystone.

Thin layers with white (5Y 8/1) punctuated radiolarians(?).

Sporadic white stringers and nodules of zeolites at Section 4, 5, and 6.

Dark greenish gray (5GY 4/1) with black (5Y 2/1) flattened burrows at Section 2, 25 cm and Section 3, →80 cm. Other burrows at Section 6.

Pervasive or diffuse dark brown (7.5YR 4/4) color, especially at Section 5, 120 cm and Section 6, → 60 cm.

Sporadic light olive brown (2.5Y 5/4) layers at Section 6, 80–90 cm.

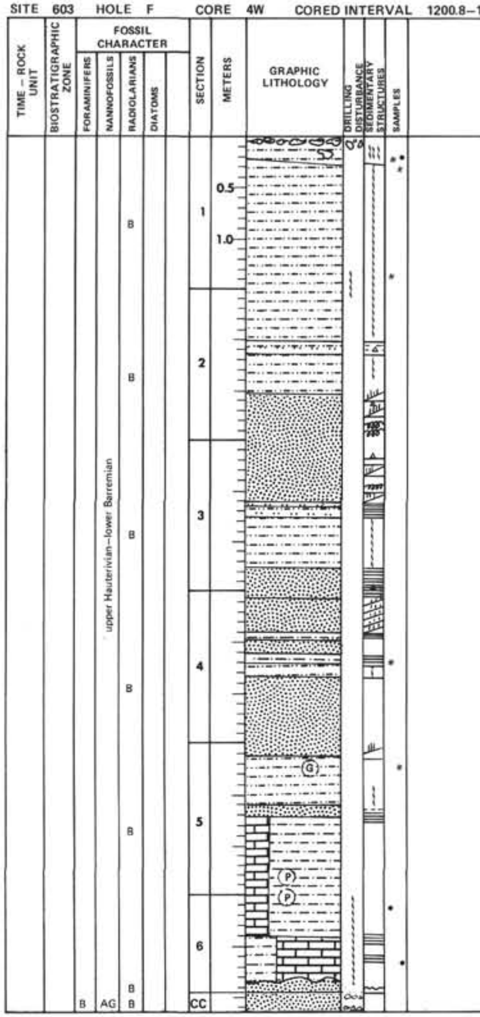
SMEAR SLIDE SUMMARY (%):

	1, 80	2, 35	4, 115	6, 10	6, 45
	D	M	D	M	D
Texture:					
Silt	10	10	20	–	20
Clay	90	90	80	–	80
Composition:					
Quartz	3	2	2	TR	2
Mica	2	1	2	–	2
Clay and silica	93	92	92	–	80
Pyrite	TR	3	1	–	1
Zeolite	2	2	3	100	15
Radiolarians	–	–	–	TR	–
Fish remains	–	–	TR	TR	–

ORGANIC CARBON AND CARBONATE (%):

	1, 30	3, 49	6, 36
Organic carbon	0.15	0.12	0.10
Carbonate LECO	0.42	1.00	1.00
Carbonate BOMB	0.00	0.00	0.00

SITE 603 HOLE F CORE 4W CORED INTERVAL 1200.8–1373.2 m



LITHOLOGIC DESCRIPTION

Three major lithologies and two minor ones:

(1) MUDSTONE – dark brown (7.5YR 4/4) with minor burrow mottling of very light brown; with no compositional change this sediment grades into greenish gray (5GY 5/1) intervals in a) haloes around burrows; b) adjacent to laminae; and c) downwards towards slightly coarser intervals; this lithology is most common in Sections 1 and 2.

(2) SANDSTONE – greenish gray to dark greenish gray (5GY 6/1, 5/1, 4/1); never burrowed; good examples of cross-stratification, parallel/convolute laminae, intraclasts of gray mudstone, possible dewatering structures and rare graded bedding; this lithology is dominant in Sections 3 and 4.

(3) NANNOFOSSIL MUDSTONE – black (N2.5) very faintly laminated with very dark gray (N3) at 70–90 cm, Section 5; nearly structureless below this except for rare pyrite fragments.

(4) At bottom of Section 6, SANDY NANNOFOSSIL LIMESTONE is found as a single representation of this lithology.

(5) Siltstone; much as (2) sandstone but fine grained.

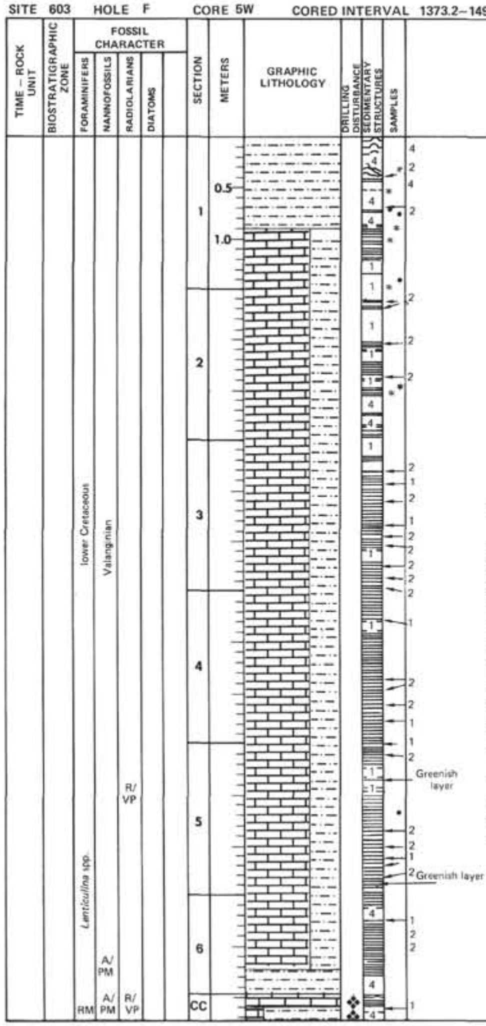
SMEAR SLIDE SUMMARY (%):

	1, 25	1, 35	3, 140	4, 70	5, 29	6, 120
	D	D	D	D	M	D
Texture:						
Sand	5	3	50	30	10	3
Silt	45	60	45	50	60	57
Clay	50	37	5	20	30	40
Composition:						
Quartz	40	51	70	46	40	5
Feldspar	TR	3	5	3	3	–
Mica	5	3	3	7	–	3
Heavy minerals	2	3	10	20	10	2
Clay	50	35	5	20	30	35
Glauconite	TR	TR	–	–	10	–
Pyrite	TR	–	–	–	TR	5
Carbonate unspec.	–	–	2	1	TR	–
Calc. nannofossils	–	–	–	–	–	25
Fish remains	–	–	–	TR	5	TR
Plant debris	3	5	5	3	2	20

ORGANIC CARBON AND CARBONATE (%):

	6, 16	6, 70	1, 26
Organic carbon	2.49	1.90	1.93
Carbonate LECO	20.16	25.07	23.74
Carbonate BOMB	19.0	47	17

SITE 603 HOLE F CORE 5W CORED INTERVAL 1373.2–1497.8 m



LITHOLOGIC DESCRIPTION

The three important components in this core are: MUDSTONE, LIMESTONE, and COALY MATTER.

Core is made up of four lithologies:

1. NANNOFOSSIL LIMESTONE, light gray (5Y 7/1) to gray (5Y 5/1). Intensely burrowed (see smear slide Section 1, 105 cm).
2. MARLY to COALY NANNOFOSSIL CHALK to MUDSTONE, grayish black (N2), massive to rarely laminar. Varies from nearly all nannofossil ooze to nearly all coaly components (see smear slide Section 2, 90 cm).
3. MARLY NANNOFOSSIL LIMESTONE, millimetric laminated limestone, olive gray (5Y 4/2) to dark olive gray (5Y 3/2) (See smear slide Section 1, 92 cm).
4. NANNOFOSSIL SANDY MUDSTONE, unbedded to somewhat bedded, dark olive gray (5Y 3/2) to olive gray (5Y 4/2). See upper section of Section 1 for slumps and bedding structure (see smear slide, Section 1, 57 cm). Most zones are about 10.3% $CaCO_3$ but top of sandy section may be about 20%. There are a few stringers of an indeterminant gray green color. Cause of color unknown.

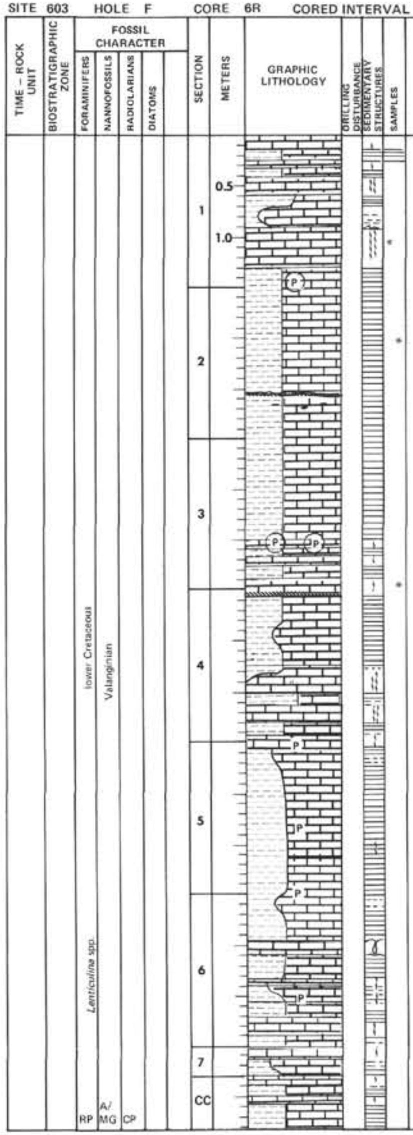
SMEAR SLIDE SUMMARY (%):

	1, 57	1, 92	1, 105	2, 90	2, 103
Texture:					
Sand	40	0	2	TR	15
Silt	35	70	68	50	55
Clay	25	30	30	50	30
Composition:					
Quartz	55	2	2	–	30
Feldspar			–	–	
Heavy minerals	3	TR	TR	TR	3
Clay and silica	25	28	25	42	32
Volcanic glass	–	–	TR?	–	–
Zeolite	–	–	TR?	–	–
Calc. nannofossils	12	65	70	50	30
Sponge spicules	–	–	TR	–	–
Plant debris	5	5	3	8	5
Lithology	4	3	1	2	4

ORGANIC CARBON AND CARBONATE (%):

	1, 74	1, 148	1, 77	5, 70
Organic carbon	0.20	0.16	1.55	1.04
Carbonate LECO	7.08	78.64	10.33	84.72
Carbonate BOMB	3	84	7	67

SITE 603 HOLE F CORE 6R CORED INTERVAL 1497.8–1507.3 m



LITHOLOGIC DESCRIPTION

5Y 7/1
5Y 4/2

5Y 7/1
5Y 4/2
5Y 6/2

5Y 4/2
+ 5Y 3/2

NANNOFOSSIL LIMESTONE, light gray (5Y 6/1–5Y 7/1), more or less intensely burrowed. Passes to the top over a more laminated greenish gray part into a homogeneous, fine laminated MARLY NANNOFOSSIL LIMESTONE, olive gray (5Y 4/2) to dark olive gray (5Y 3/2), lamination mm-thick or less. Many white streakes (mm) flattened? microfossils? Many fish remains (bones = vertabrae, teeth et al.), aptychi, and some pyritized radiolaria all throughout the core. Streaks and thin layers of coal.

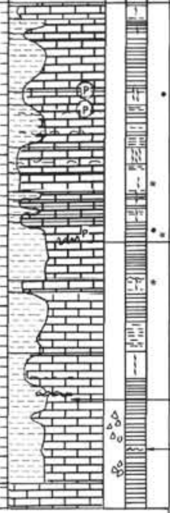
SMEAR SLIDE SUMMARY (%):

	1, 105	2, 56	3, 140
	D	D	M
Texture:			
Sand	–	–	40
Silt	60	40	50
Clay	40	60	10
Composition:			
Quartz	10	3	–
Clay	30	40	–
Glauconite	–	–	1
Pyrite	TR	–	–
Carbonate unspec.	50	30	1
Calc. nannofossils	10	25	–
Plant debris	–	–	88

SITE 603 HOLE F CORE 7R CORED INTERVAL 1507.3–1516.4 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
	Valanginian					1	0.5, 1.0
						2	
						3	
						4	
		B	A/PM	FP		CC	

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

5Y 7/1

5Y 4/2 + 5Y 3/2

Folded pyrite band

5Y 6/1

Large collapsed shell?

Small-scale ripples

Cycles (see Core 6R) of:
1) Fine laminated MARLY NANNOFOSSIL LIMESTONE, light gray to gray (5Y 7/1 to 5Y 6/1), more or less intensely burrowed, grading over gray (5Y 6/1) faintly laminated parts into
2) Fine laminted (mm or less) MARLY NANNOFOSSIL LIMESTONE, olive gray (5Y 4/2) to dark olive gray (5Y 3/2) throughout, with disseminated pyrite and fish remains, aptychi, and layers of large *Inoceramus* shells.

At the bottom of Section 3 small-scaled current ripples on bedding surface.

Cycles cut on top of laminated facies or transition into limestone.

In laminated facies much organic matter.

SMEAR SLIDE SUMMARY (%):

	2, 30	2, 82	2, 130
	D	D	D
Texture:			
Silt	60	50	60
Clay	40	50	40
Composition:			
Quartz	–	TR	–
Clay	40	50	40
Pyrite	TR	2	TR
Carbonate unspec.	55	15	50
Calc. nannofossils	5	30	10
Plant debris	–	3	–

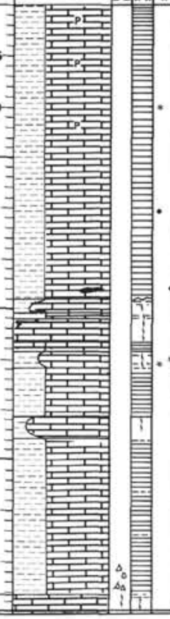
ORGANIC CARBON AND CARBONATE (%):

	1, 90–92	2, 77–80
Organic carbon	0.18	1.25
Carbonate LECO	60.23	61
Carbonate BOMB	78	64.64

SITE 603 HOLE F CORE 8W CORED INTERVAL 1516.4–1540.2 m

TIME-ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
						1	0.5, 1.0
						2	
			A/PM				
	Valanginian					3	
						4	
		B	A/PM	VR/VP		CC	

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

5Y 4/2
5Y 3/2

Aptychi

5Y 7/1

N6

Aptychi

5Y 4/2 + 5Y 3/2

5Y 7/1

1) Fine laminated MARLY NANNOFOSSIL LIMESTONE, olive gray (5Y 4/2) to dark olive gray (5Y 3/2), (mm laminae) (disseminated pyrite) growing occasionally into
2) Light gray (5Y 7/1) to gray (N6) NANNOFOSSIL LIMESTONE, more or less burrowed.

IN LAMINATED FACIES over all the core aptychi (especially in Section 2, 100–130 cm and Section 3, 70–80 cm). In Section 2, 135 cm large incoaled plant stem with pyrite nodules. Much organic matter and plant debris.

SMEAR SLIDE SUMMARY (%):

	1, 100	3, 56
	D	D
Texture:		
Sand	2	TR
Silt	48	30
Clay	50	70
Composition:		
Quartz	8	TR
Clay	42	67
Carbonate unspec.	–	10
Calc. nannofossils	45	20
Plant debris	5	3

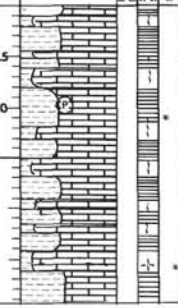
ORGANIC CARBON AND CARBONATE (%):

	2, 57	2, 131
Organic carbon	1.33	19.05
Carbonate LECO	64.56	9.00
Carbonate BOMB	52	4.00

SITE 603 HOLE F CORE 9R CORED INTERVAL 1540.2–1545.7 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
			Valanginian			1	0.5				*
							1.0				
			AM			2					*

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS



5G 5/2

5G 5/2

5G 5/2

5G 5/2

5Y 7/1
N2 → N4

LITHOLOGIC DESCRIPTION

Interbedded:

a) Light gray (5Y 7/1) massive or irregularly thin laminated NANNOFOSSIL LIMESTONE, intensely burrowed.

b) Medium gray (N5) to medium dark gray (N4) even thin laminated MARLY NANNOFOSSIL LIMESTONE.

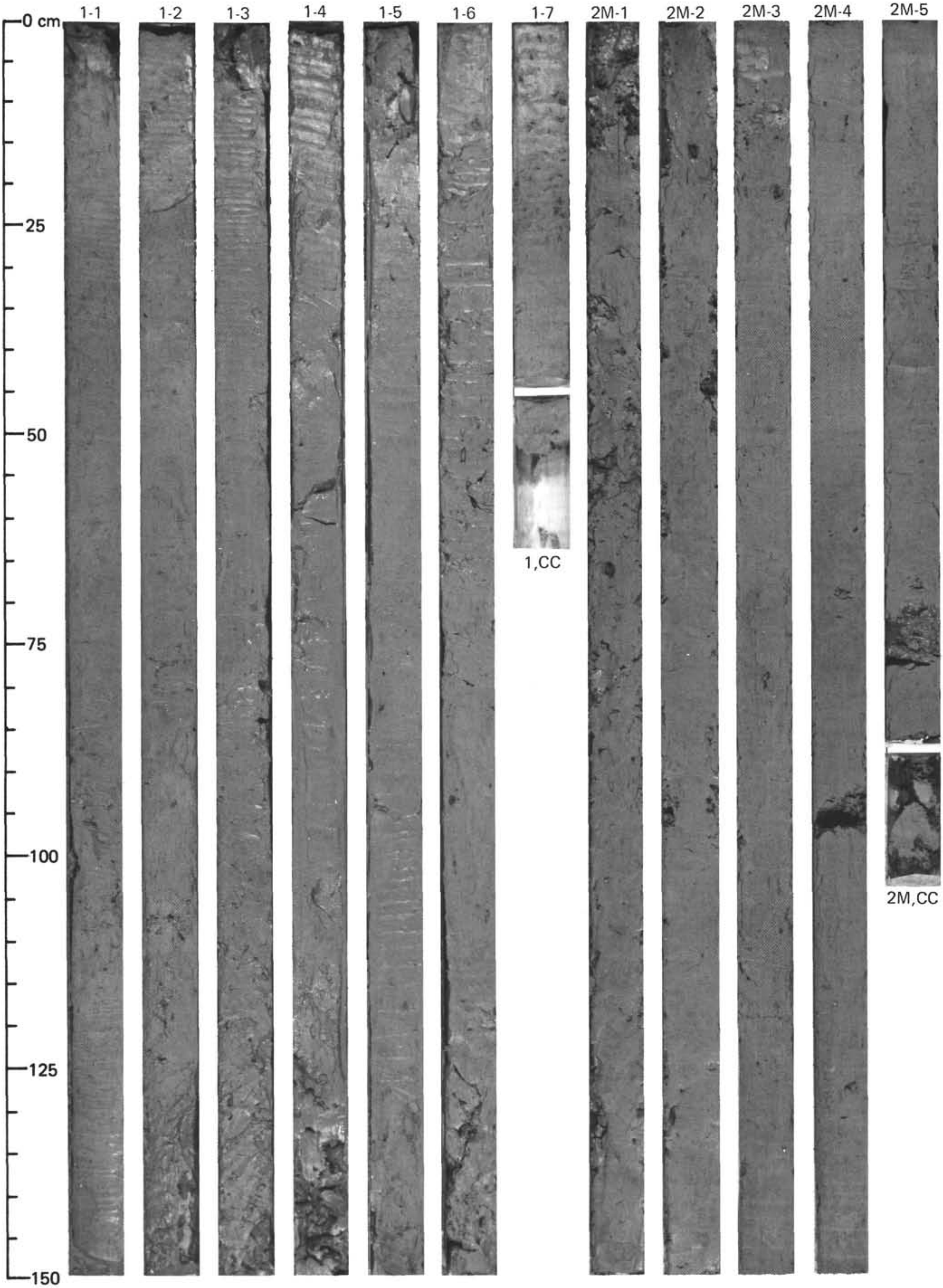
Contact a) → b) is gradual

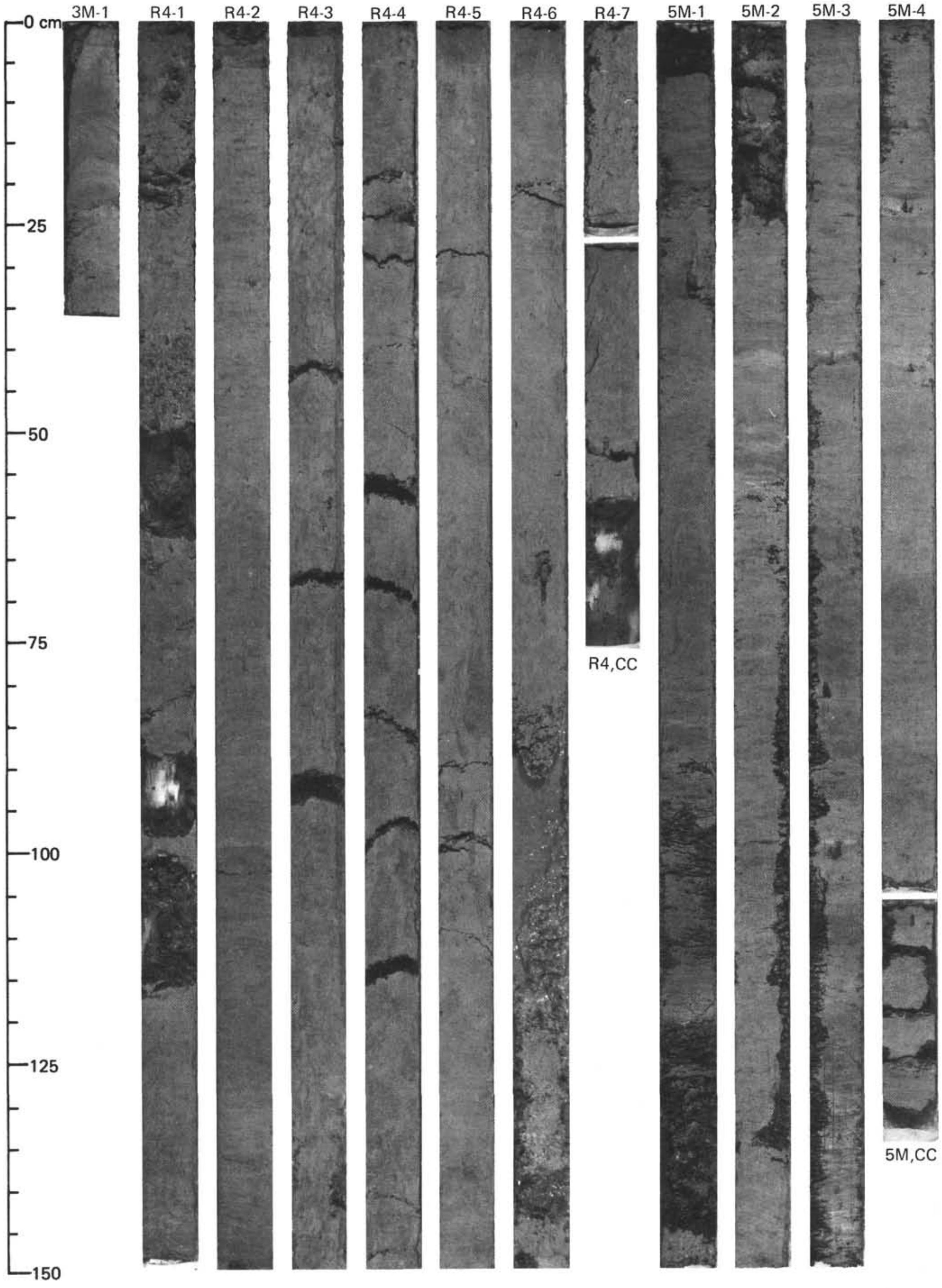
Contact b) → a) is often sharp (with thin grayish green (5G 5/2) layers at Section 1: c)

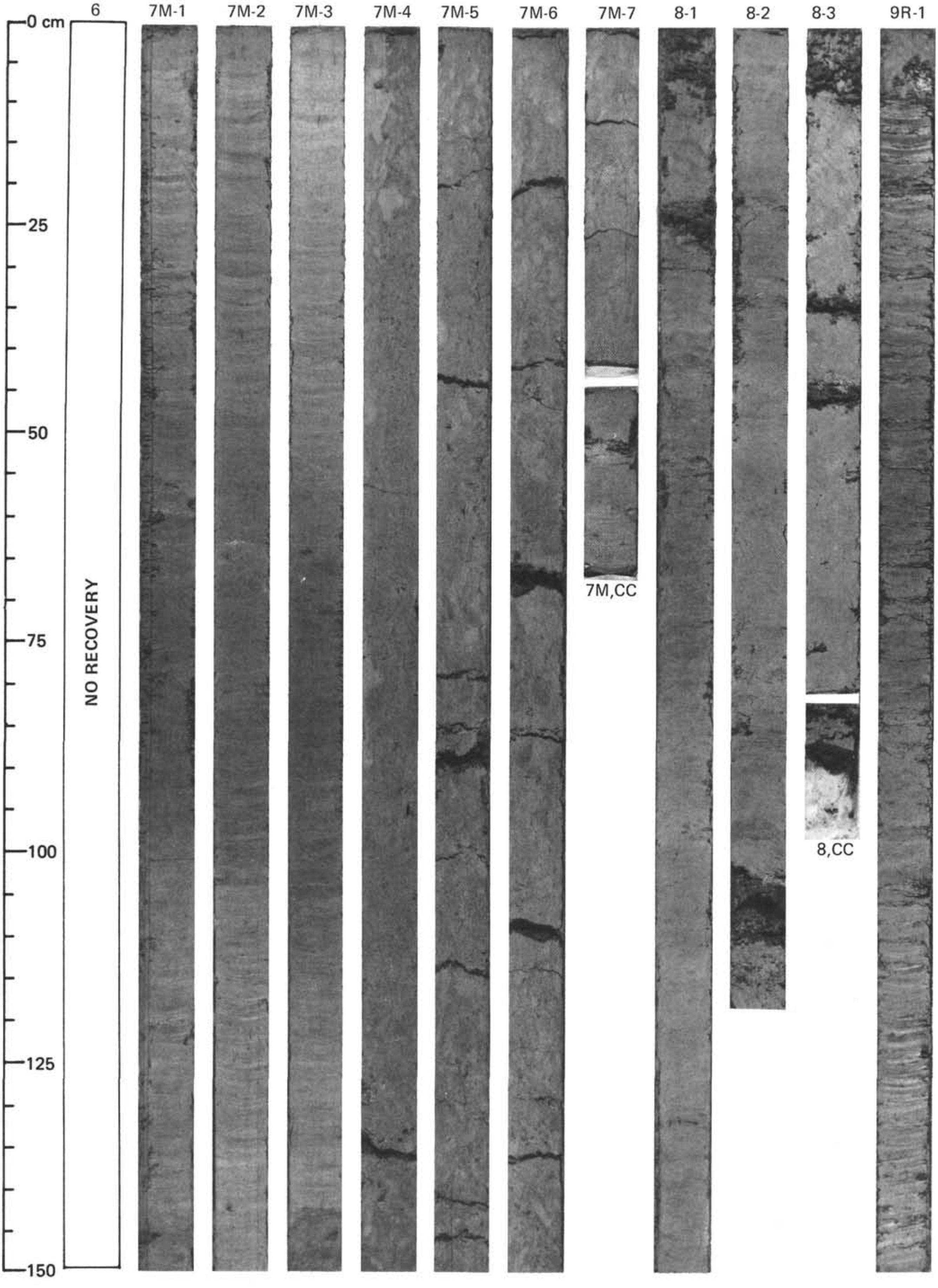
Inoceramus shells (Section 2, 110 cm)

SMEAR SLIDE SUMMARY (%):

	1, 111 M	2, 110 M
Texture:		
Sand	–	40
Silt	40	50
Clay	60	10
Composition:		
Clay	57	10
Carbonate unspec.	5	80
Calc. nannofossils	35	10
Plant debris	3	–


0 cm
25
50
75
100
125
150
1-1
1-2
1-3
1-4
1-5
1-6
1-7
1,CC
2M-1
2M-2
2M-3
2M-4
2M-5
2M,CC


3M-1
R4-1
R4-2
R4-3
R4-4
R4-5
R4-6
R4-7
5M-1
5M-2
5M-3
5M-4
0 cm
25
50
75
100
125
150
R4,CC
5M,CC


0 cm
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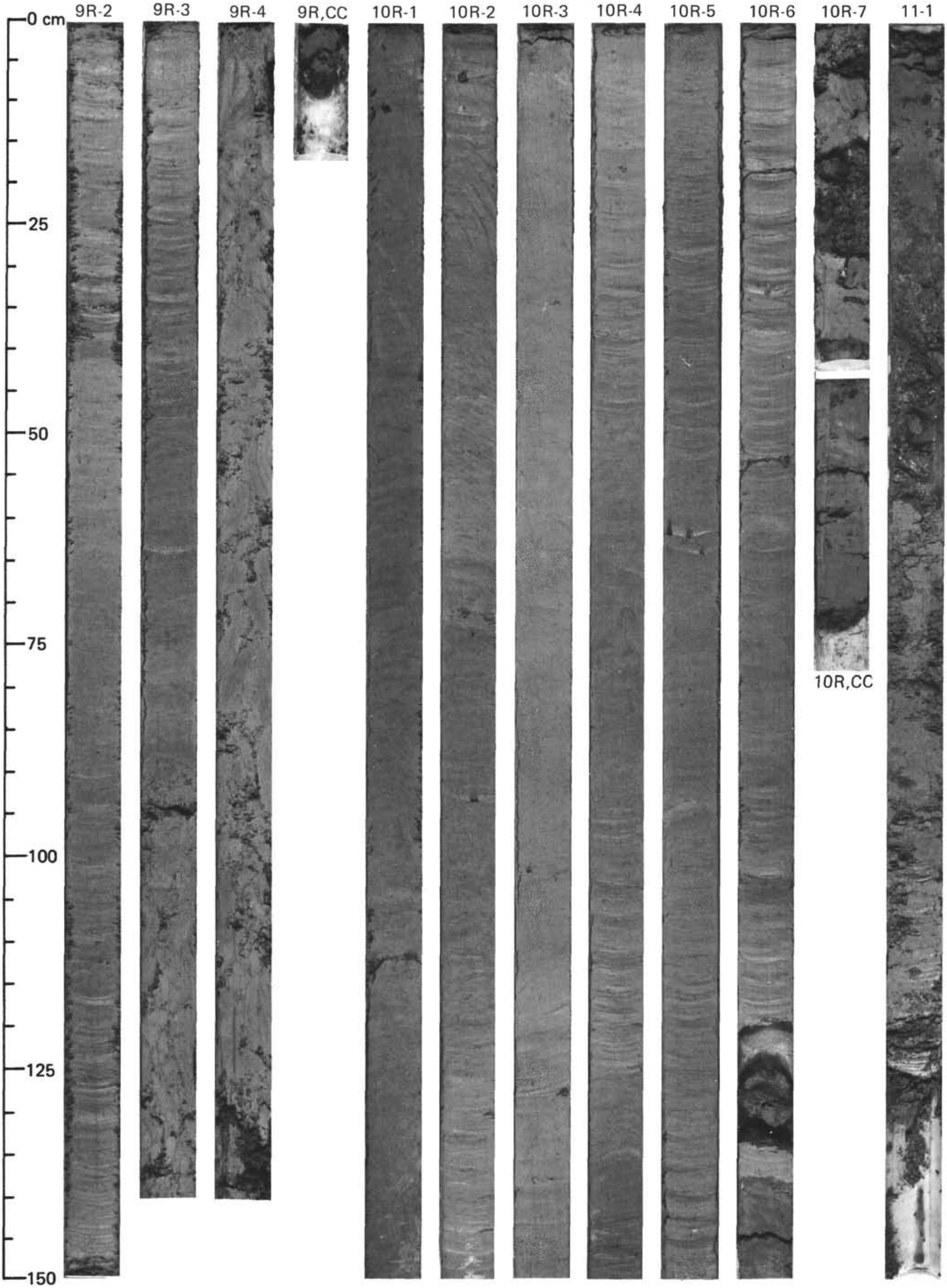
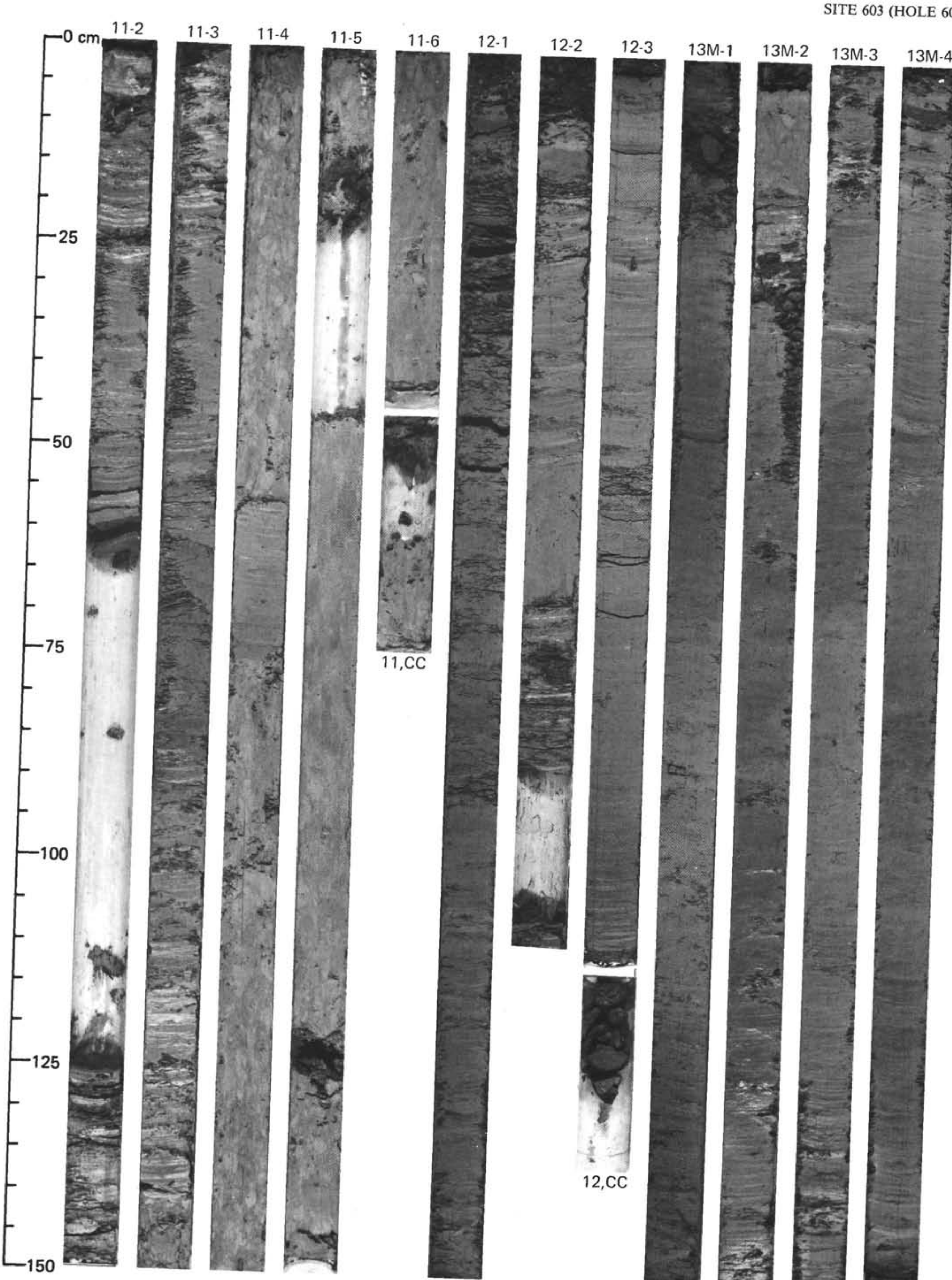
50
75
100
125
150
6
NO RECOVERY
7M-1
7M-2
7M-3
7M-4
7M-5
7M-6
7M-7
7M,CC
8-1
8-2
8-3
8,CC
9R-1


0 cm
25
50
75
100
125
150
9R-2
9R-3
9R-4
9R,CC
10R-1
10R-2
10R-3
10R-4
10R-5
10R-6
10R-7
11-1
10R,CC


0 cm
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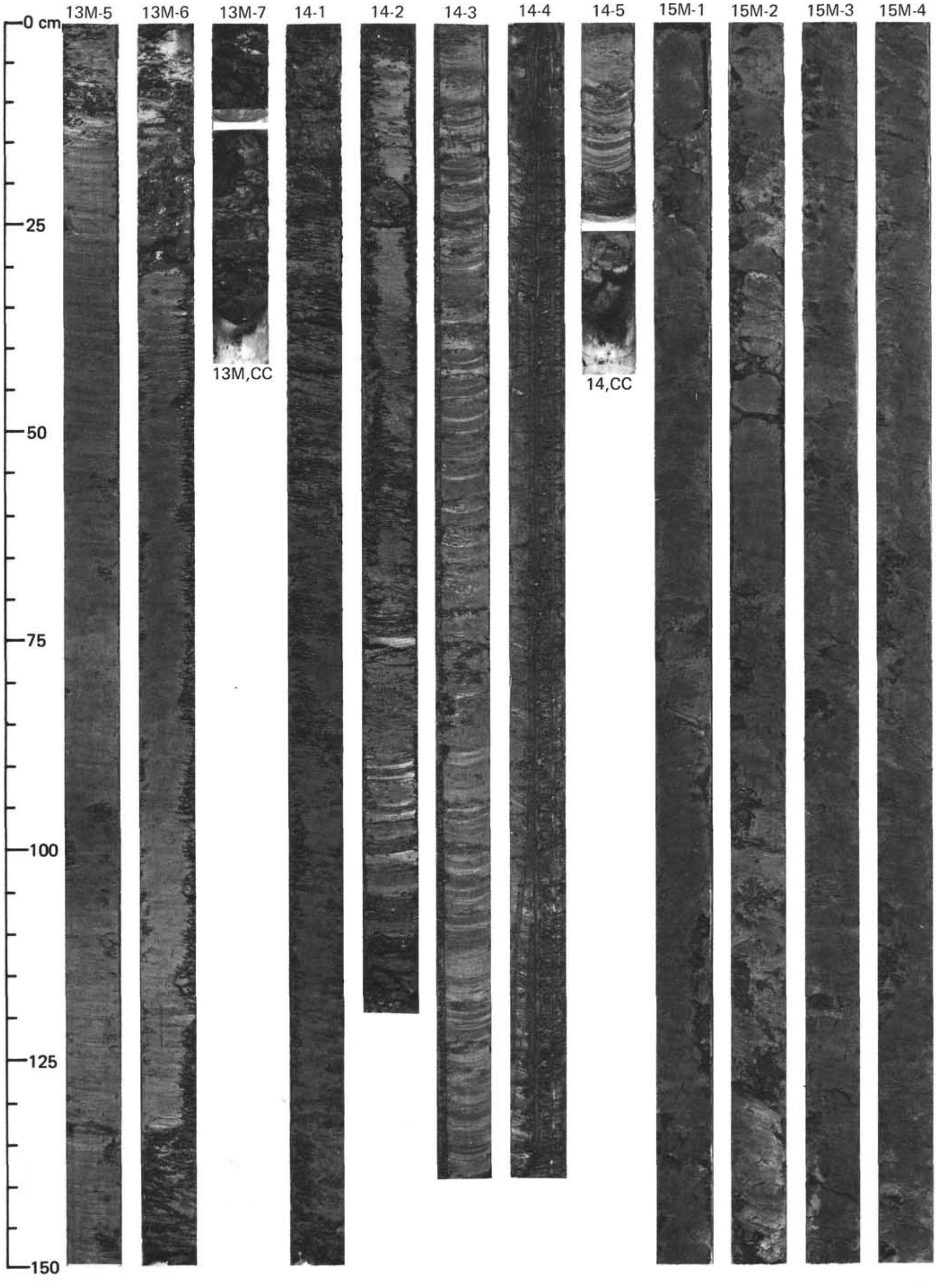
50
75
100
125
150
11-2
11-3
11-4
11-5
11-6
12-1
12-2
12-3
13M-1
13M-2
13M-3
13M-4
11,CC
12,CC


0 cm
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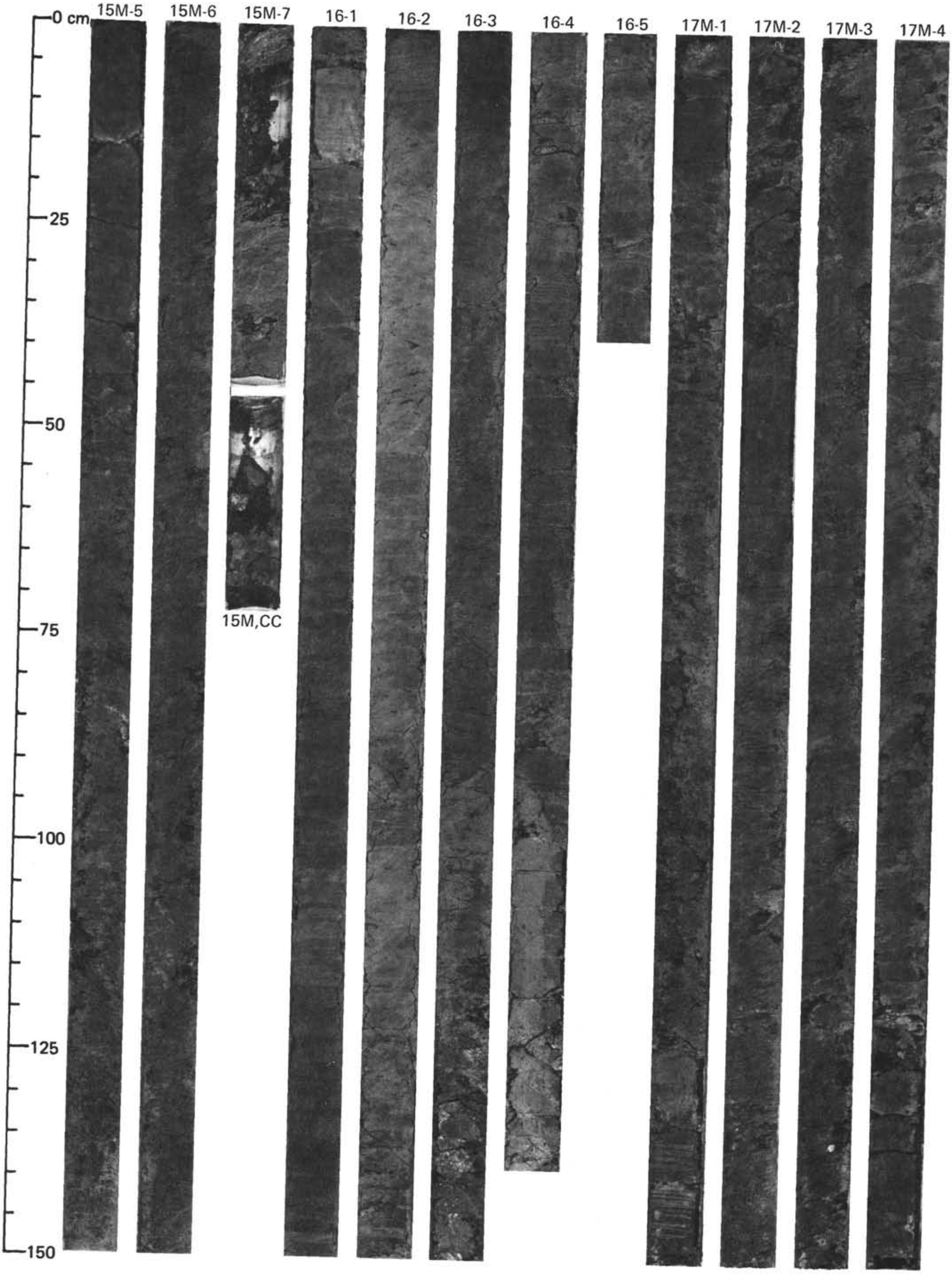
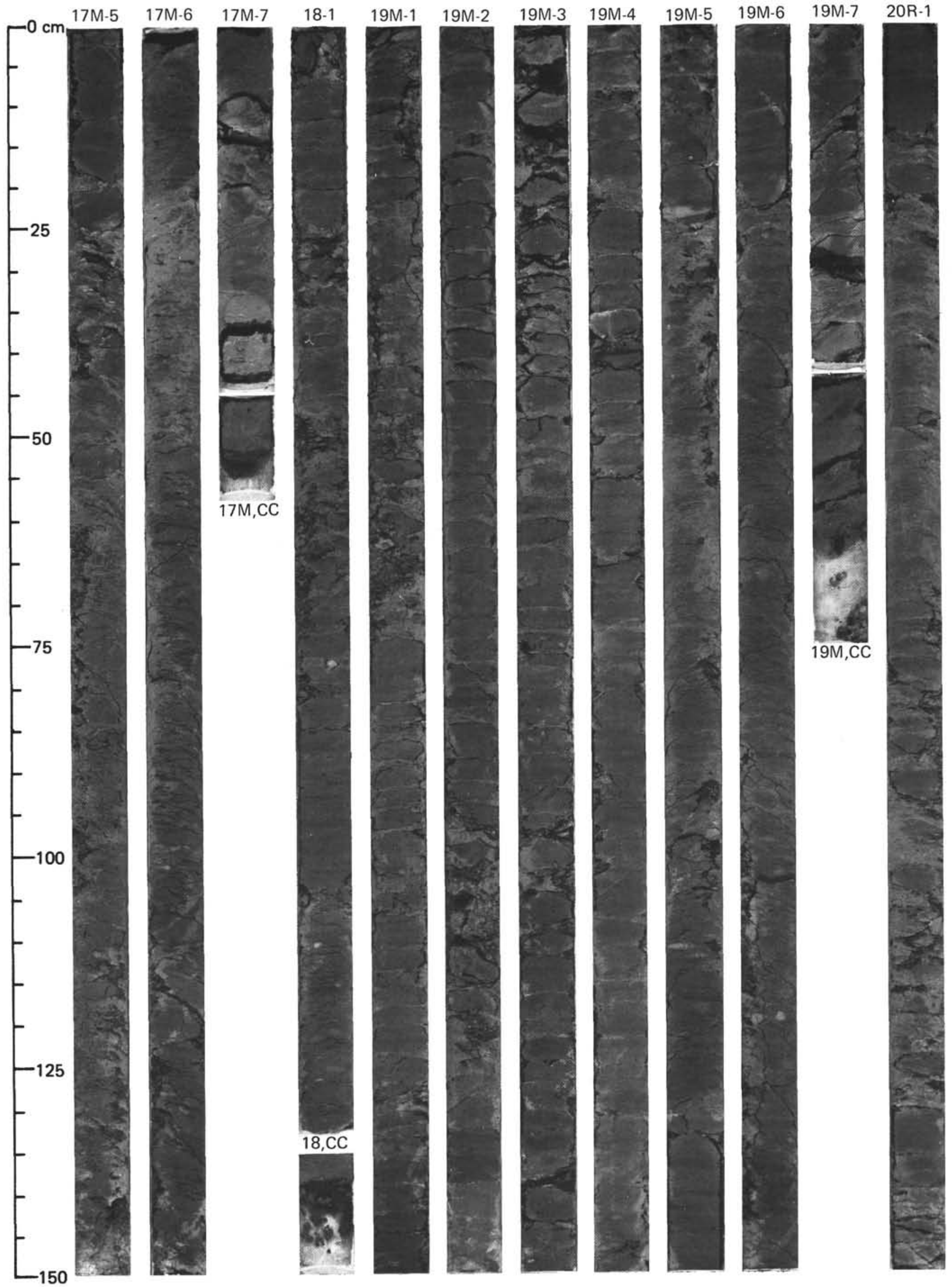
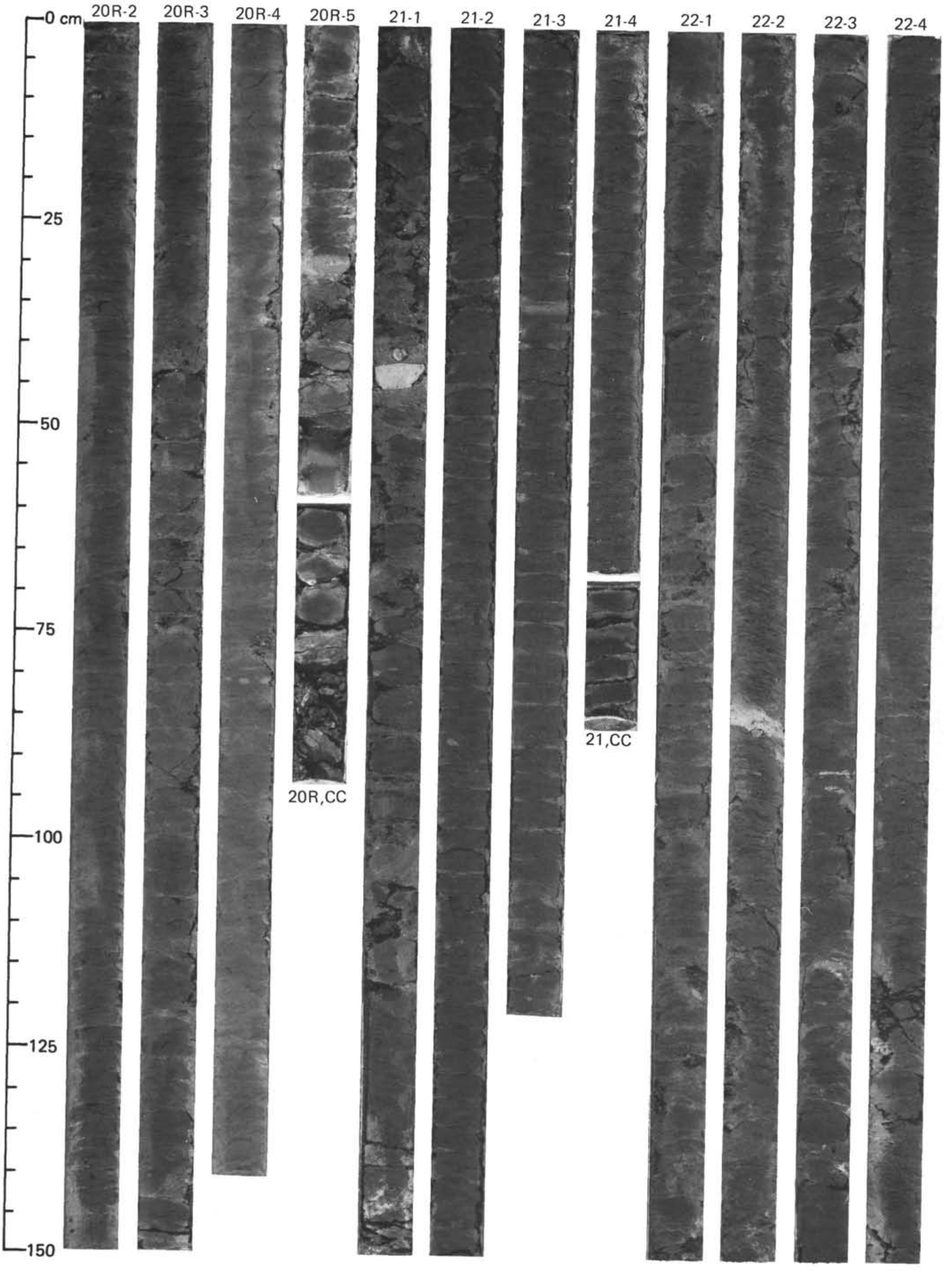
75
100
125
150
13M-5
13M-6
13M-7
13M,CC
14-1
14-2
14-3
14-4
14-5
14,CC
15M-1
15M-2
15M-3
15M-4


0 cm
25
50
75
100
125
150
15M-5
15M-6
15M-7
15M,CC
16-1
16-2
16-3
16-4
16-5
17M-1
17M-2
17M-3
17M-4


17M-5
17M-6
17M-7
18-1
19M-1
19M-2
19M-3
19M-4
19M-5
19M-6
19M-7
20R-1
0 cm
25
50
75
100
125
150
17M,CC
18,CC
19M,CC


0 cm
25
50
75
100
125
150
20R-2
20R-3
20R-4
20R-5
21-1
21-2
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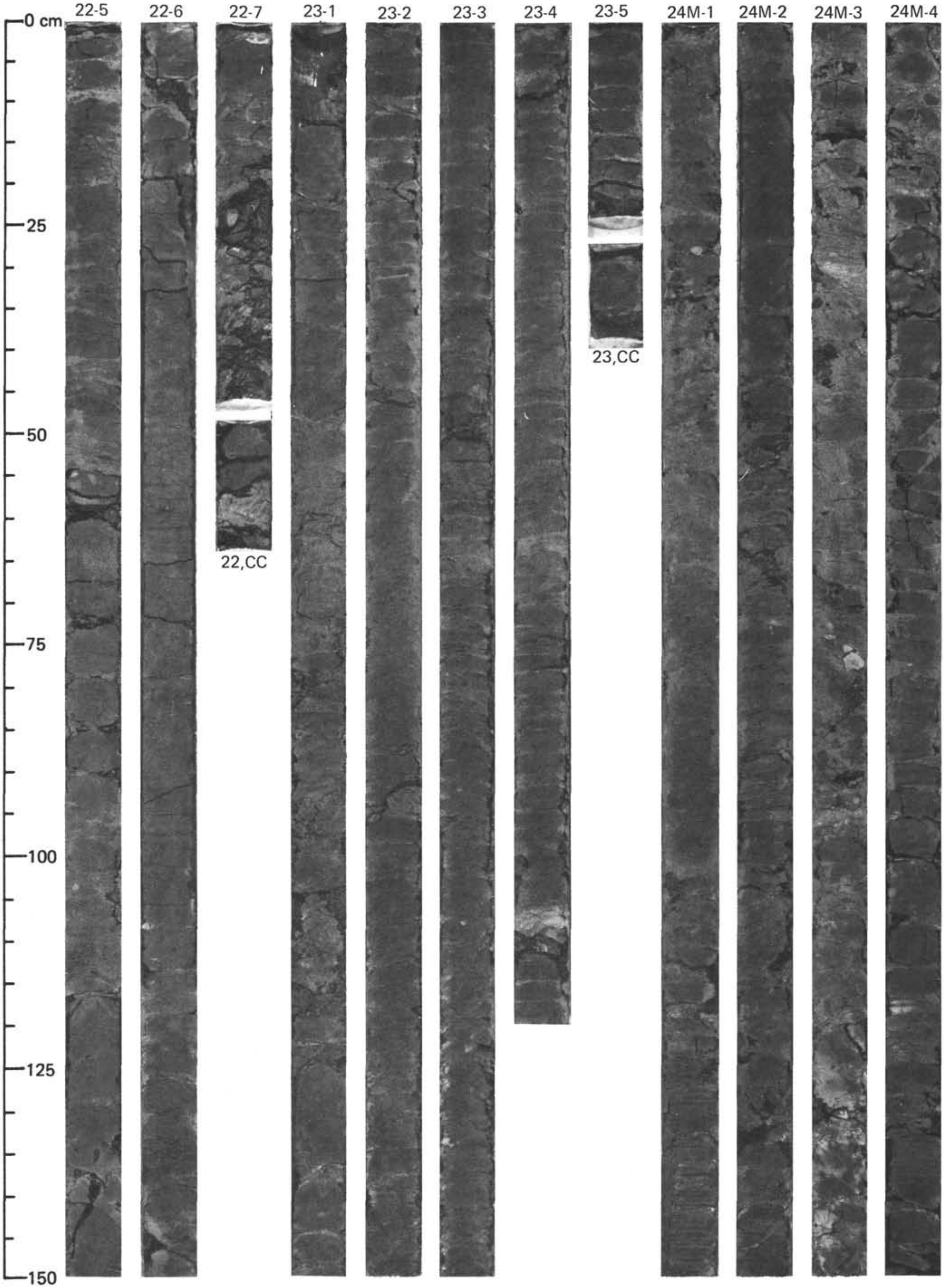
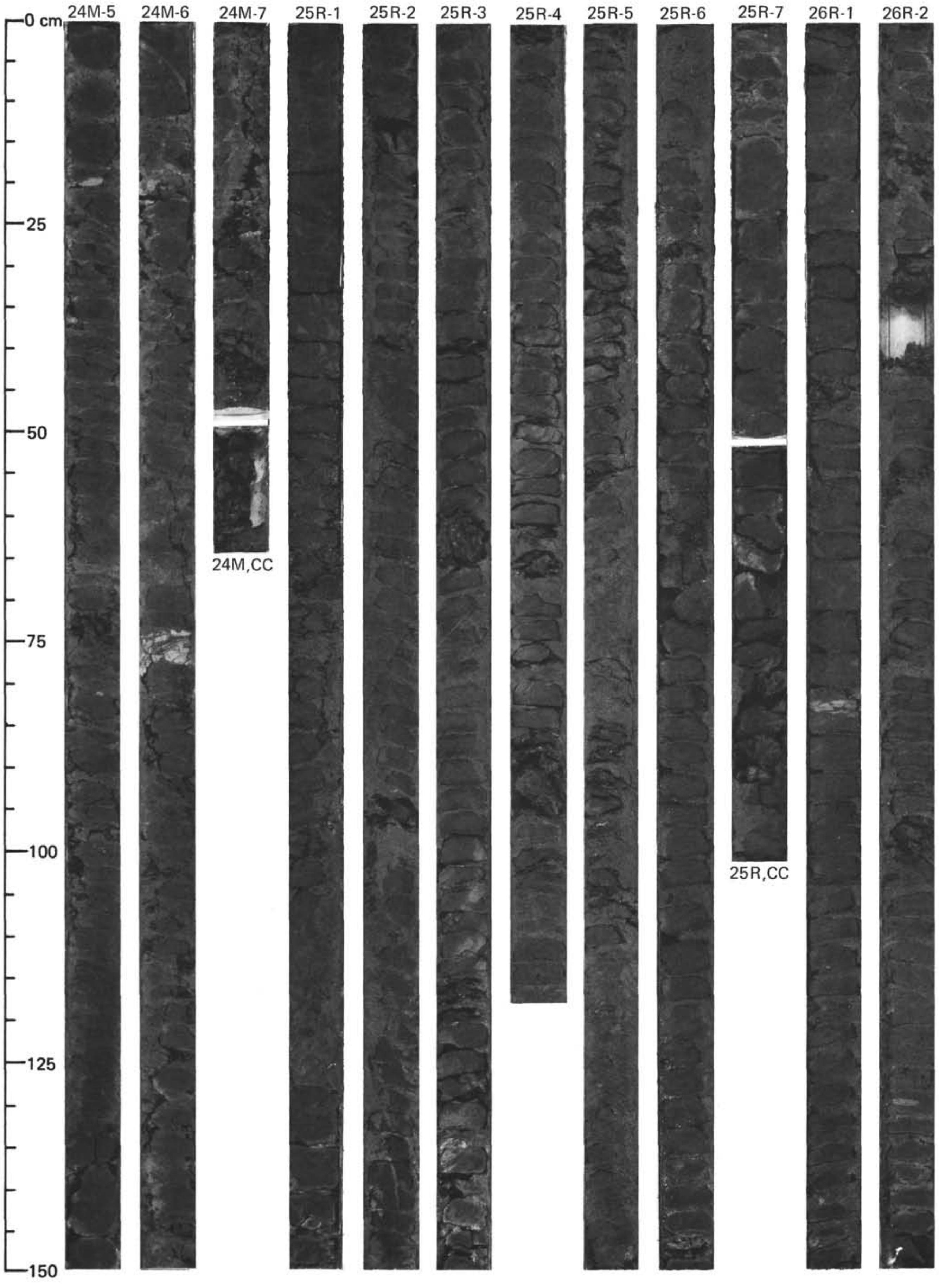
21-4
22-1
22-2
22-3
22-4
20R,CC
21,CC


22-5
22-6
22-7
23-1
23-2
23-3
23-4
23-5
24M-1
24M-2
24M-3
24M-4
0 cm
25
50
75
100
125
150
22,CC
23,CC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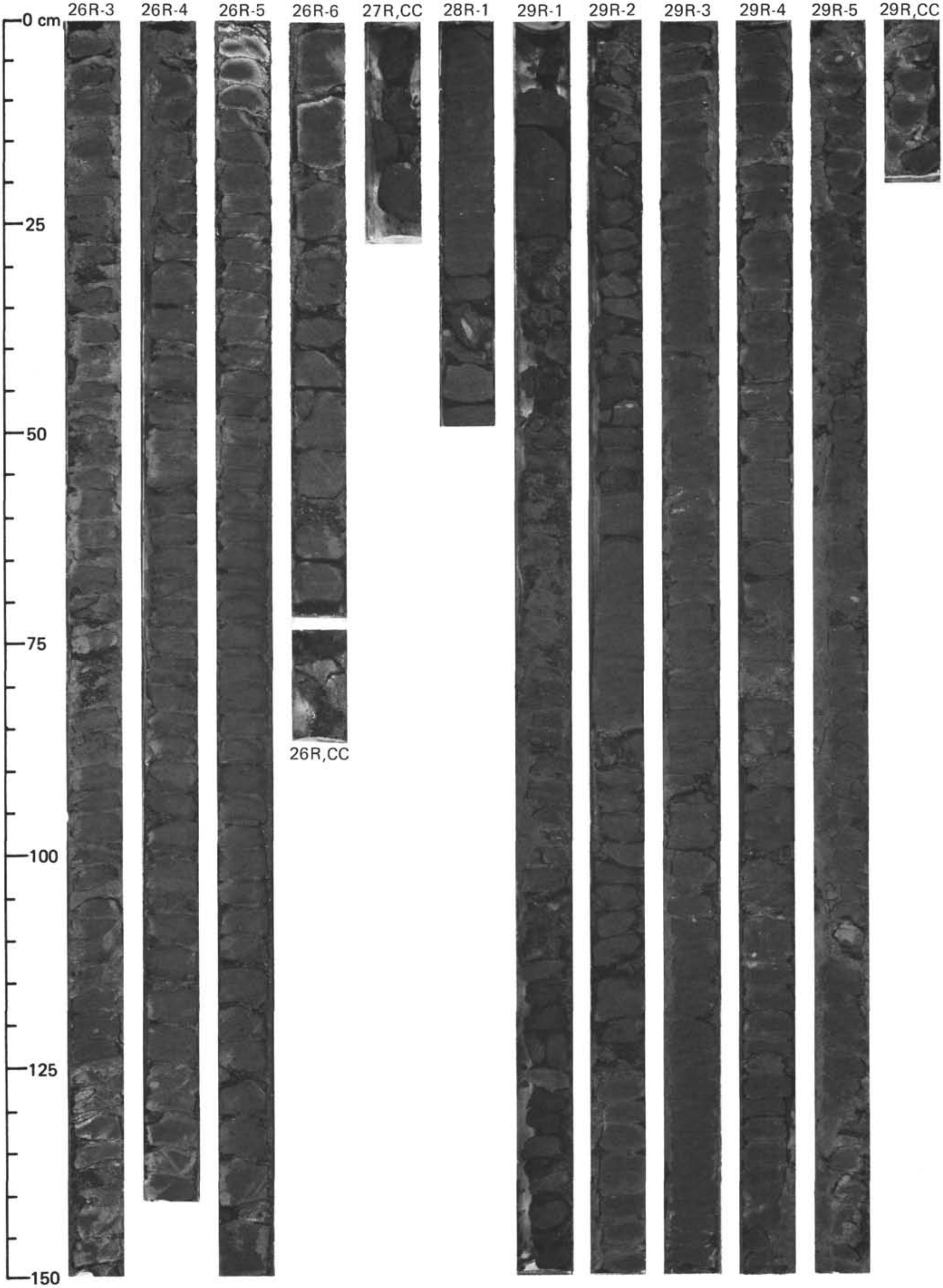
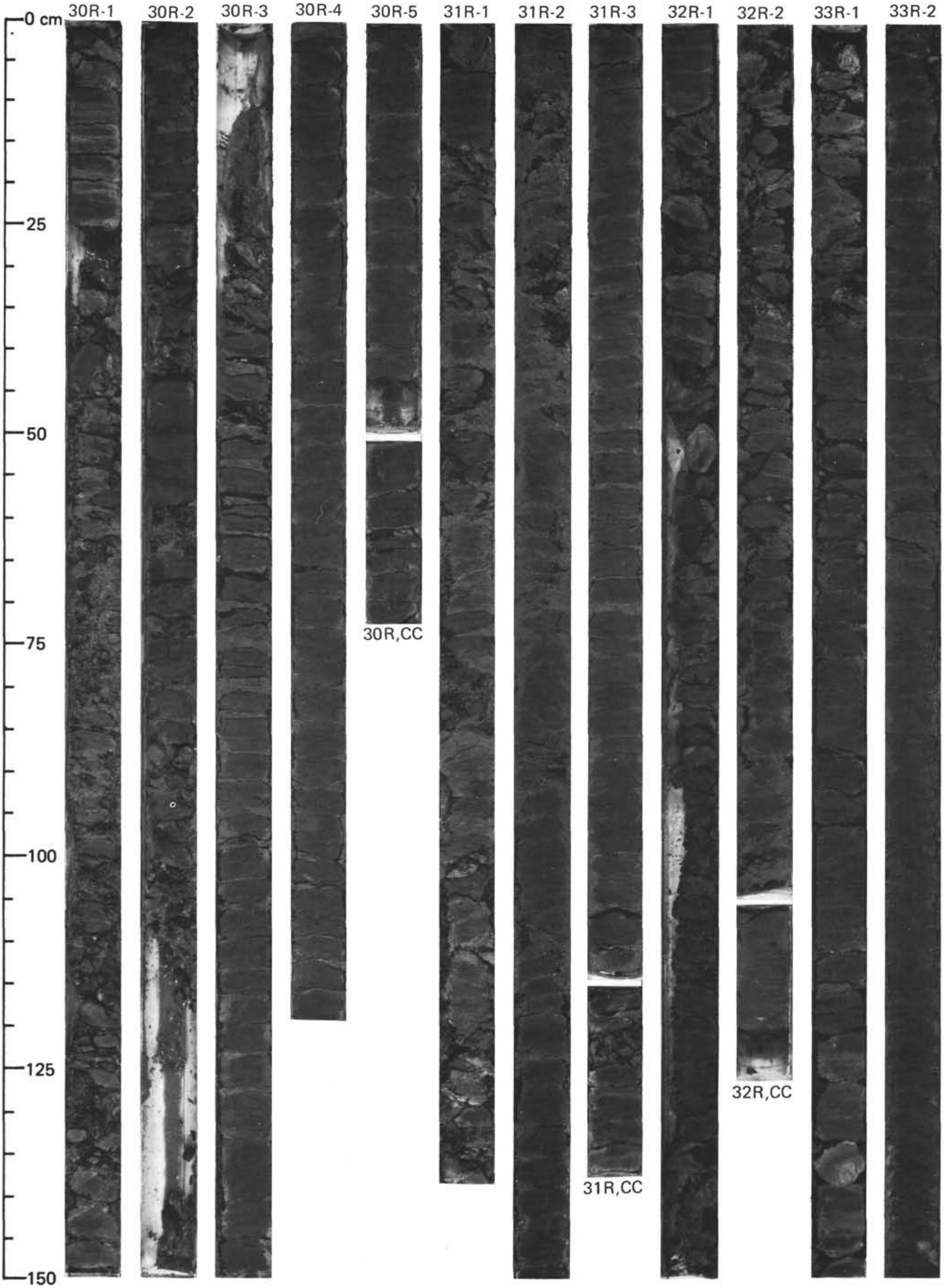
25
50
75
100
125
150
24M-5
24M-6
24M-7
25R-1
25R-2
25R-3
25R-4
25R-5
25R-6
25R-7
26R-1
26R-2
24M,CC
25R,CC


0 cm
25
50
75
100
125
150
26R-3
26R-4
26R-5
26R-6
26R,CC
27R,CC
28R-1
29R-1
29R-2
29R-3
29R-4
29R-5
29R,CC


0 cm
25
50
75
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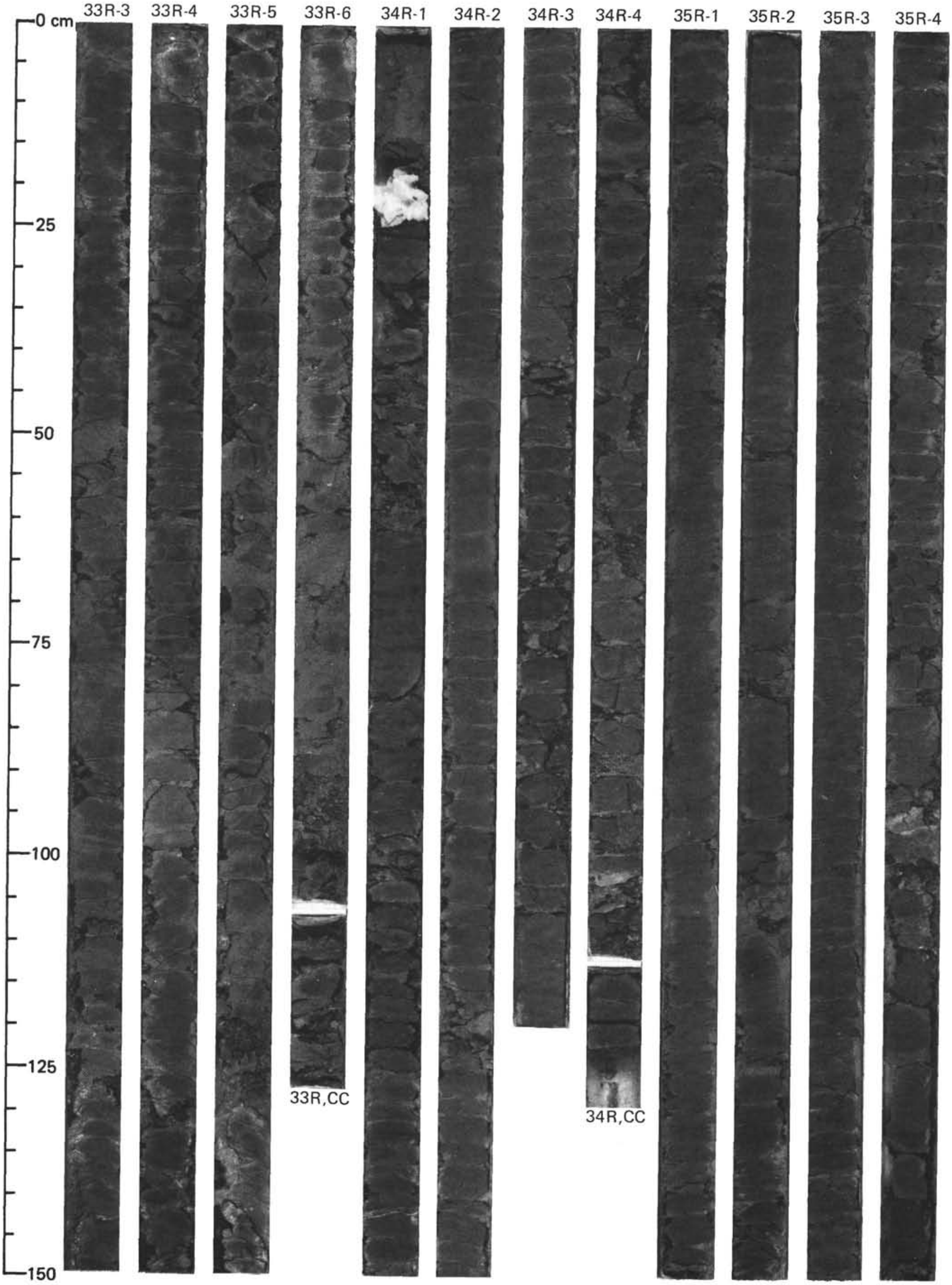
125
150
30R-1
30R-2
30R-3
30R-4
30R-5
31R-1
31R-2
31R-3
32R-1
32R-2
33R-1
33R-2
30R,CC
31R,CC
32R,CC


0 cm
25
50
75
100
125
150
33R-3
33R-4
33R-5
33R-6
34R-1
34R-2
34R-3
34R-4
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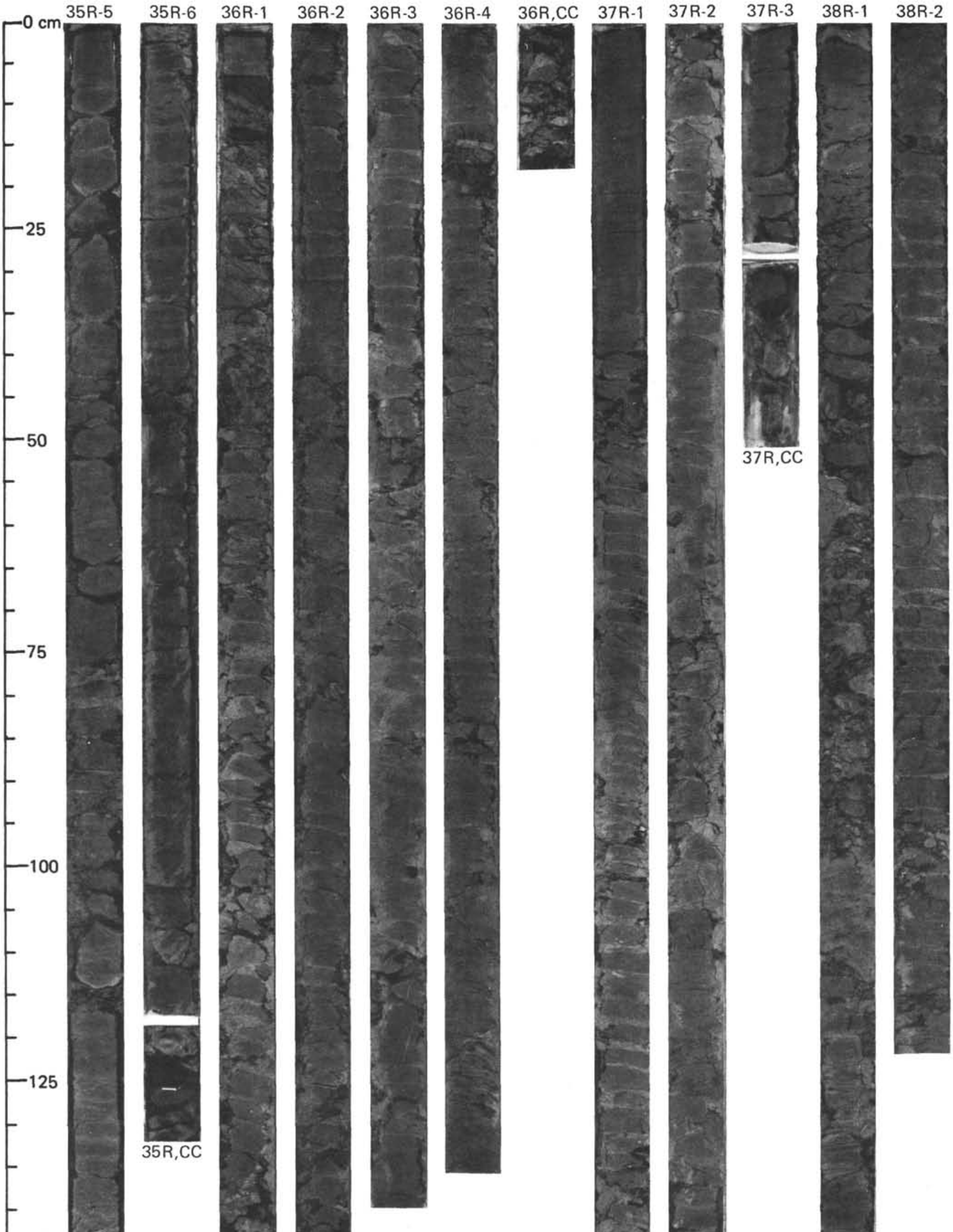
33R,CC
34R,CC


0 cm
25
50
75
100
125
150
35R-5
35R-6
35R,CC
36R-1
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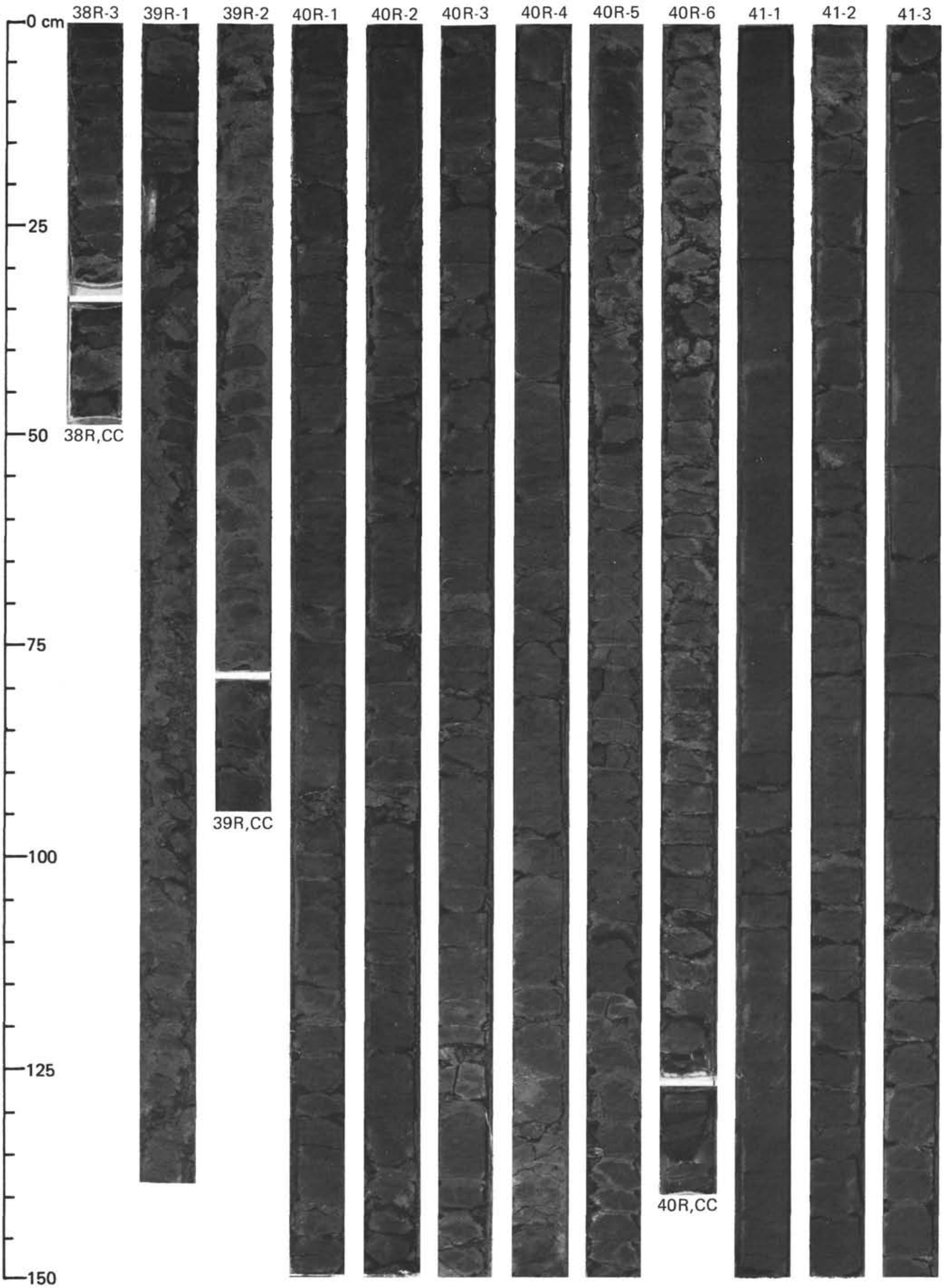
38R-1
38R-2


0 cm
25
50
75
100
125
150
38R-3
39R-1
39R-2
40R-1
40R-2
40R-3
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40R-5
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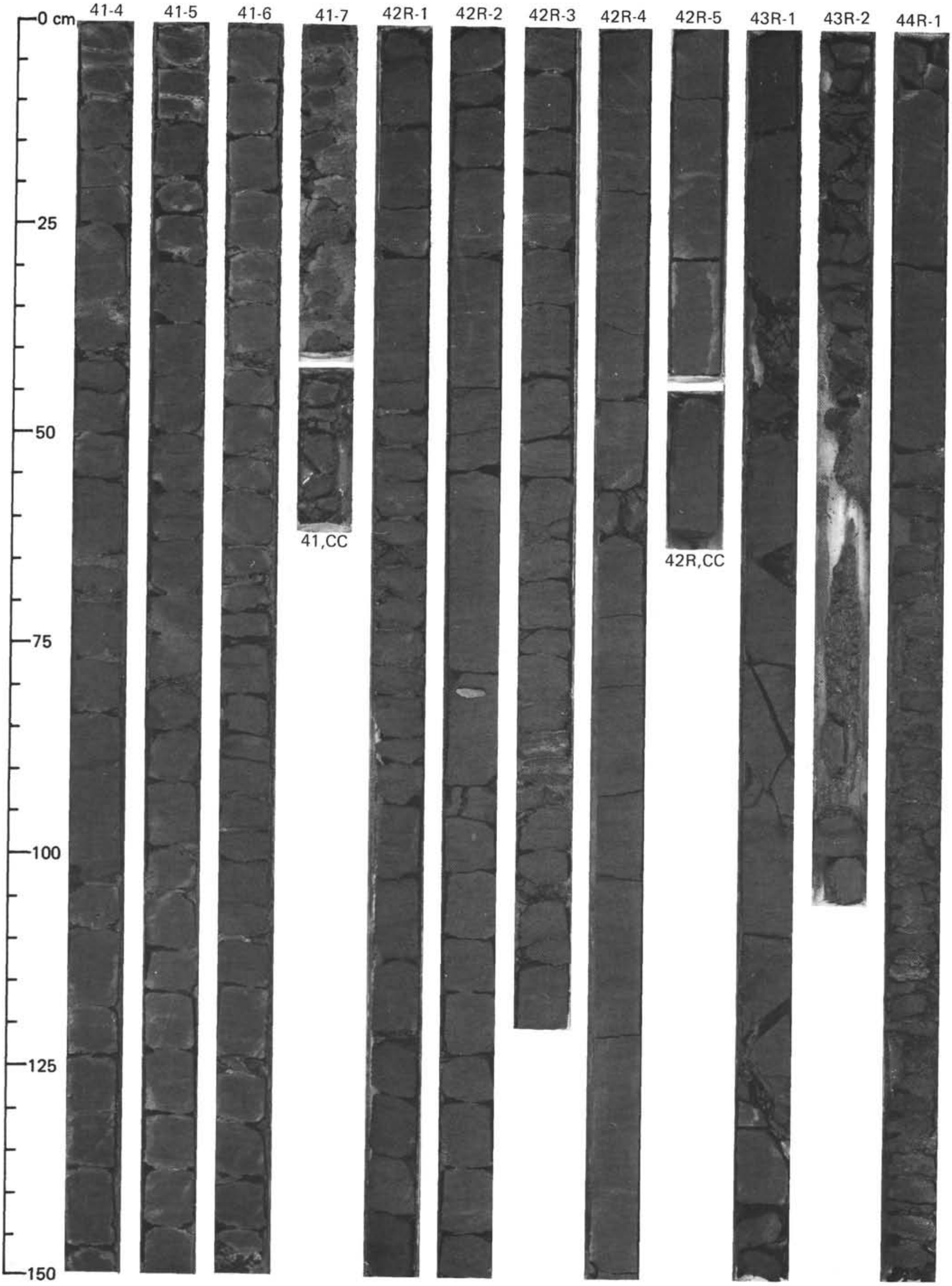
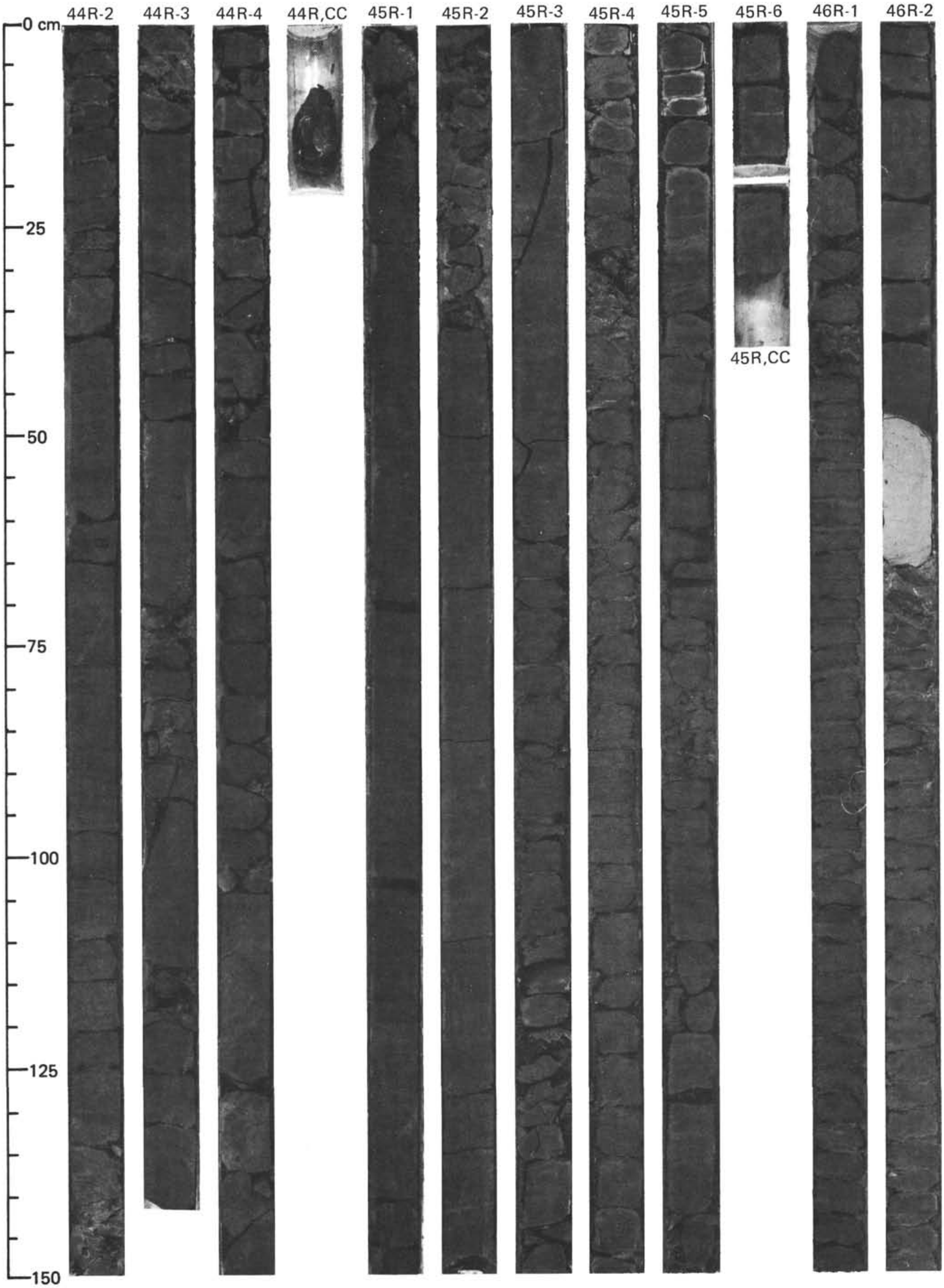
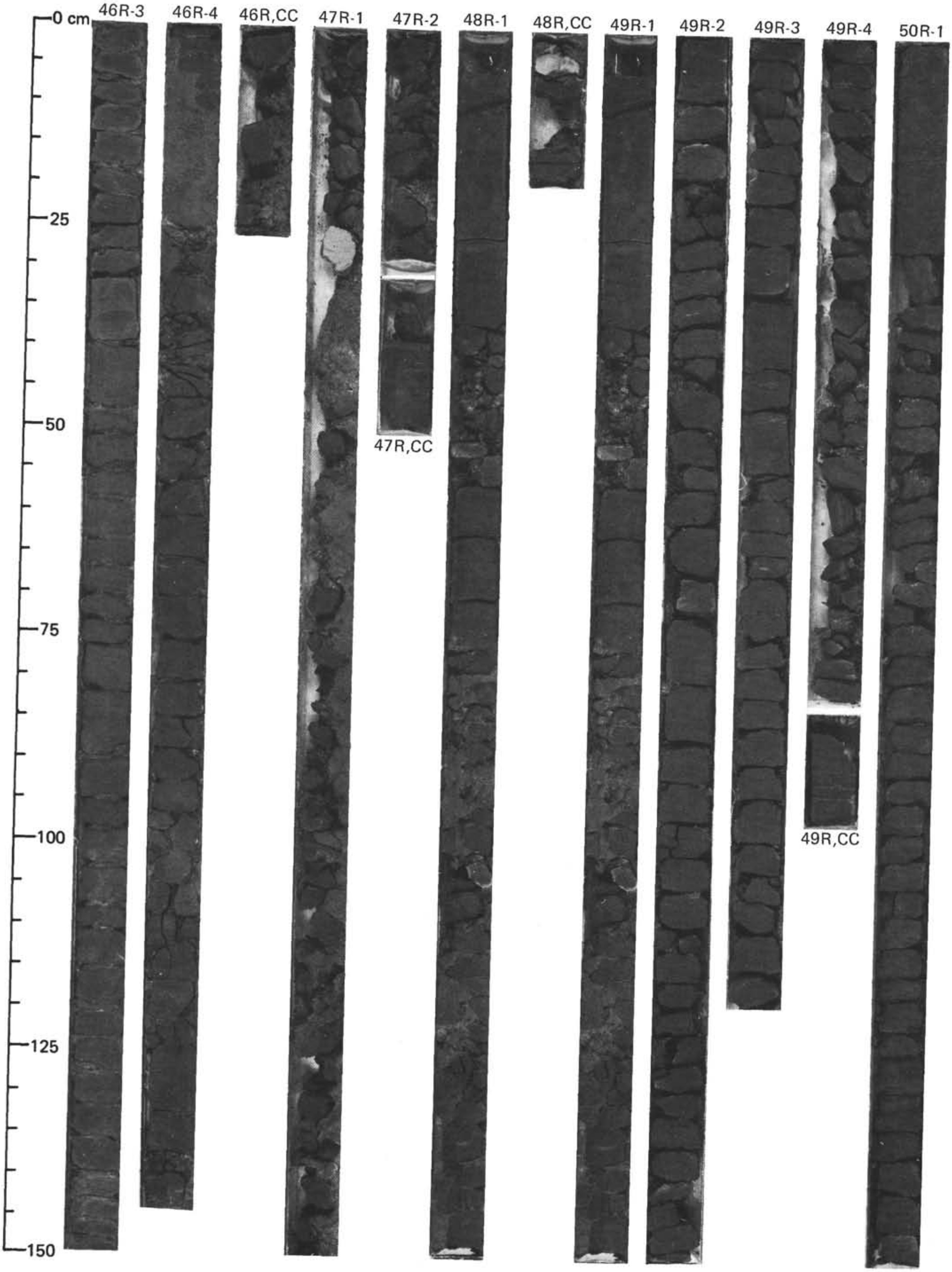
41-1
41-2
41-3
38R,CC
39R,CC
40R,CC


0 cm
25
50
75
100
125
150
41-4
41-5
41-6
41-7
41,CC
42R-1
42R-2
42R-3
42R-4
42R-5
42R,CC
43R-1
43R-2
44R-1


44R-2
44R-3
44R-4
44R,CC
45R-1
45R-2
45R-3
45R-4
45R-5
45R-6
45R,CC
46R-1
46R-2
0 cm
25
50
75
100
125
150


0 cm
25
50
75
100
125
150
46R-3
46R-4
46R,CC
47R-1
47R-2
47R,CC
48R-1
48R,CC
49R-1
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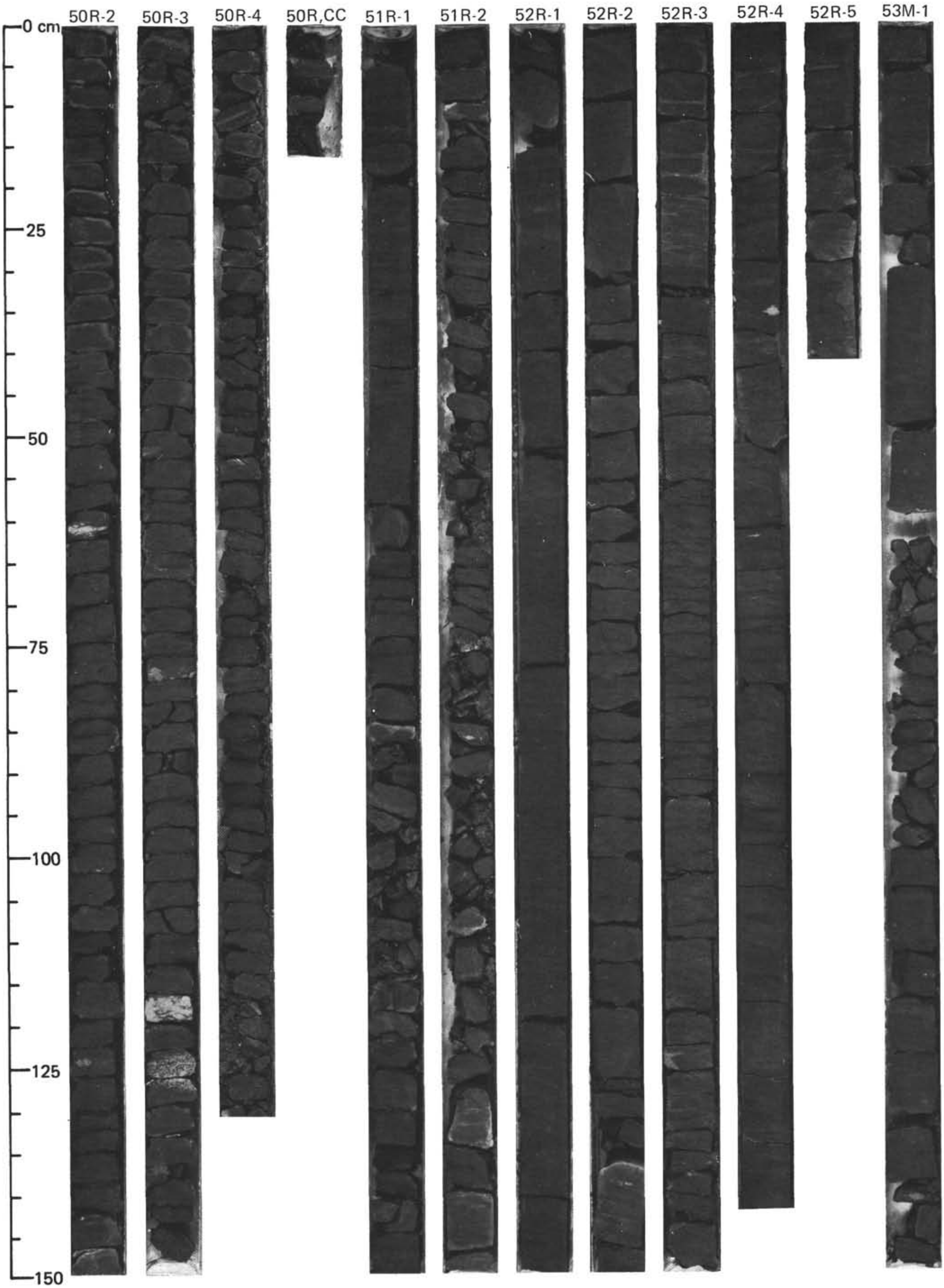
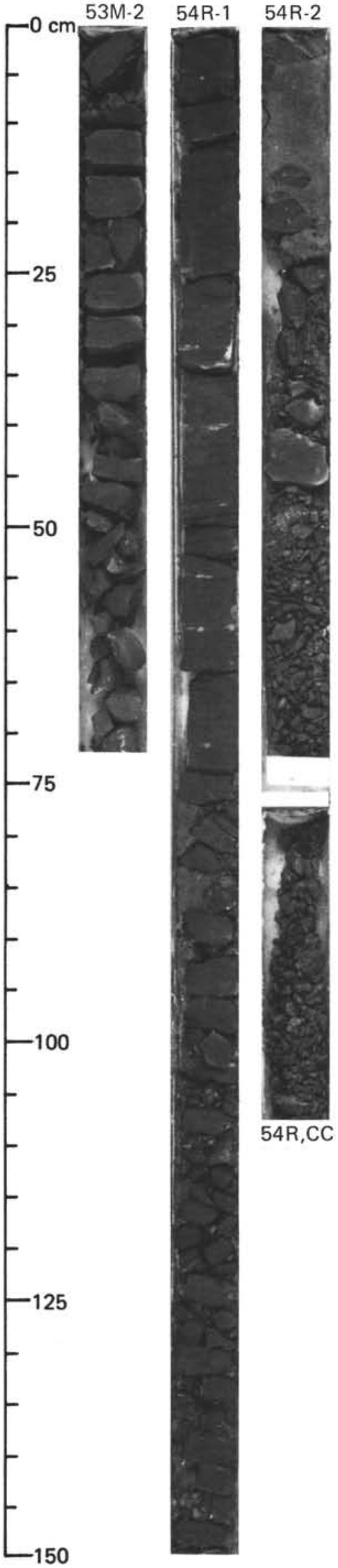
49R-3
49R-4
49R,CC
50R-1


50R-2
50R-3
50R-4
50R,CC
51R-1
51R-2
52R-1
52R-2
52R-3
52R-4
52R-5
53M-1
0 cm
25
50
75
100
125
150


0 cm
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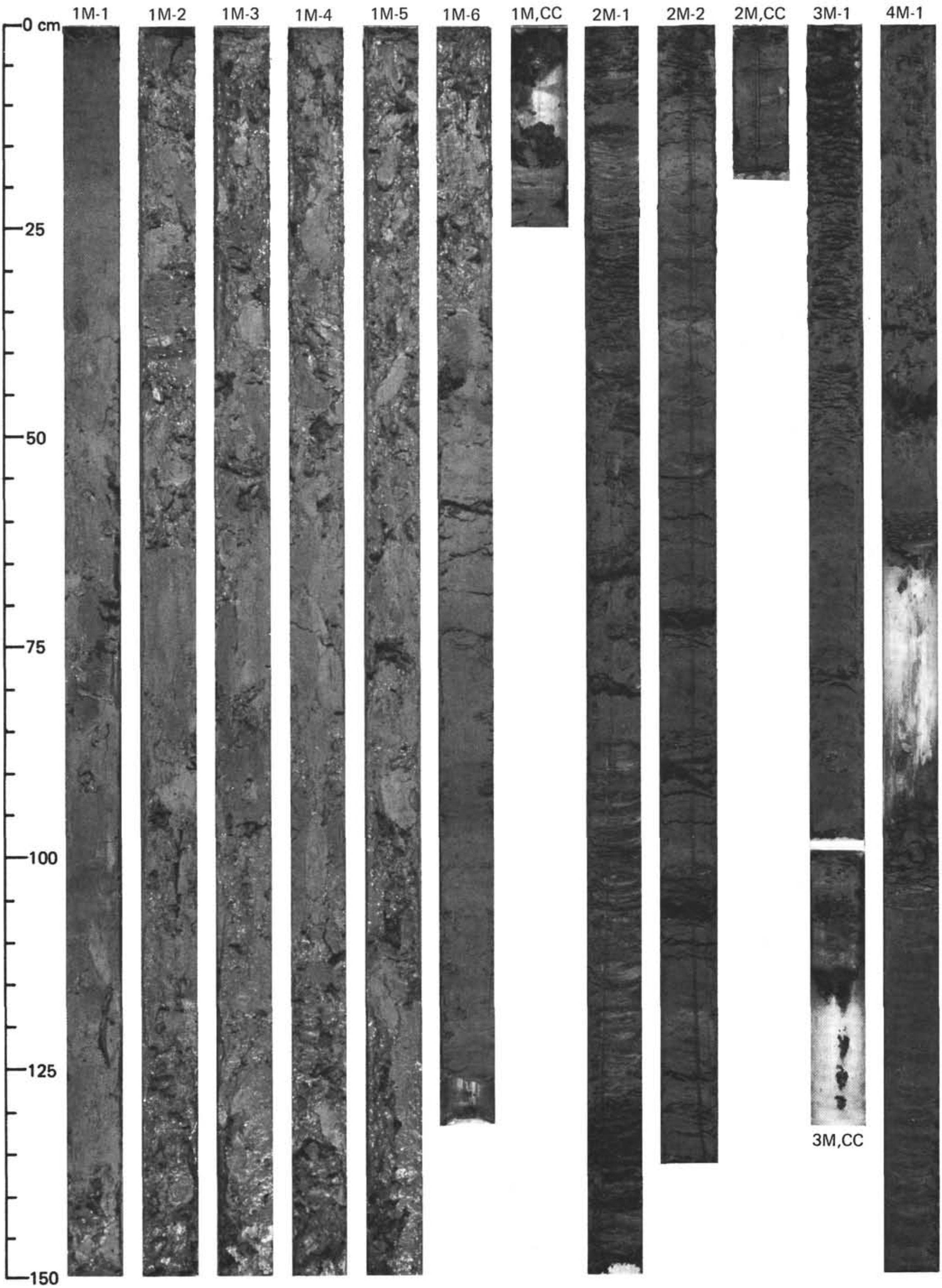
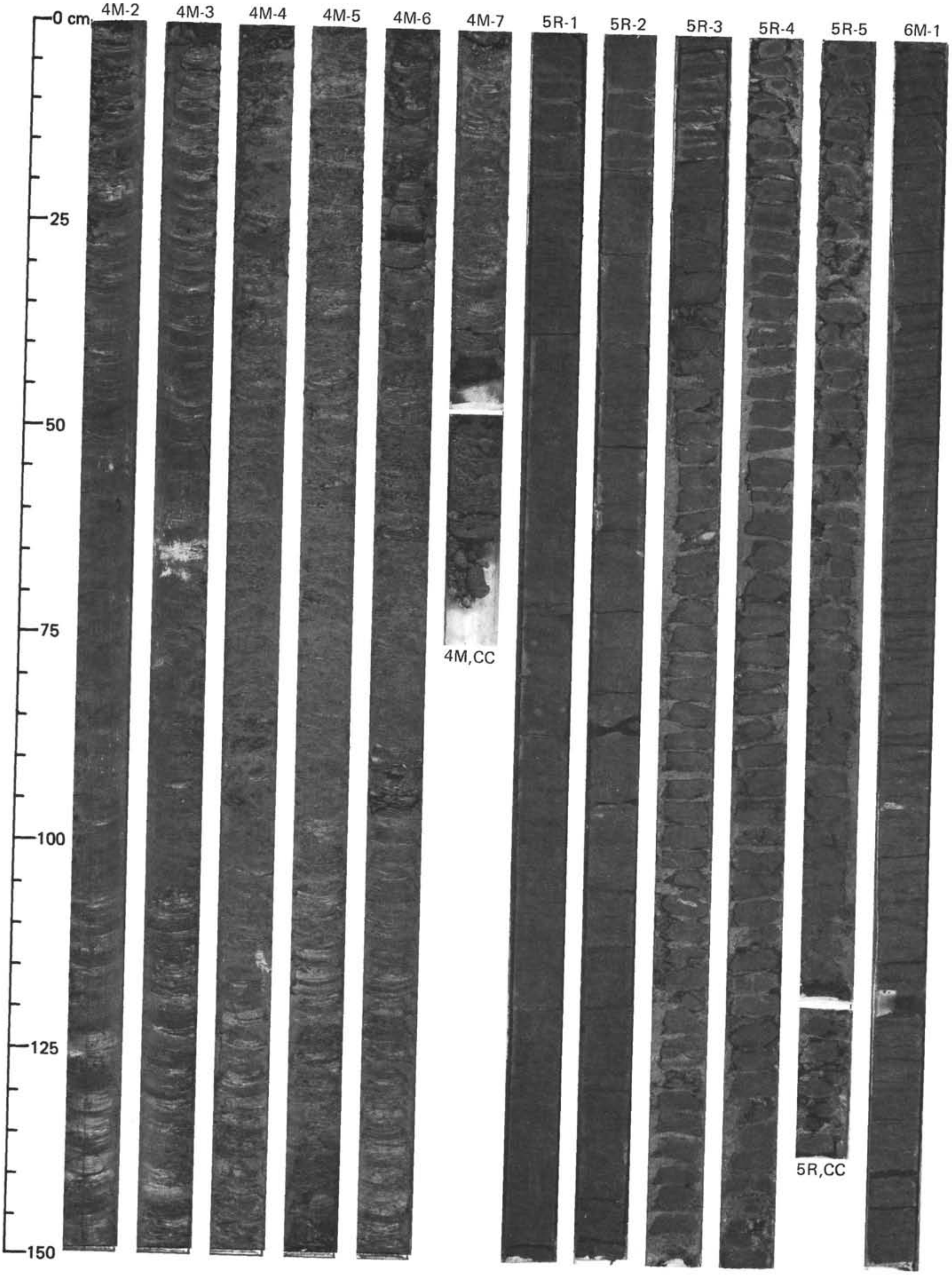
75
100
125
150
53M-2
54R-1
54R-2
54R,CC


1M-1
1M-2
1M-3
1M-4
1M-5
1M-6
1M,CC
2M-1
2M-2
2M,CC
3M-1
4M-1
0 cm
25
50
75
100
125
150
3M,CC


0 cm
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75
100
125
150
4M-2
4M-3
4M-4
4M-5
4M-6
4M-7
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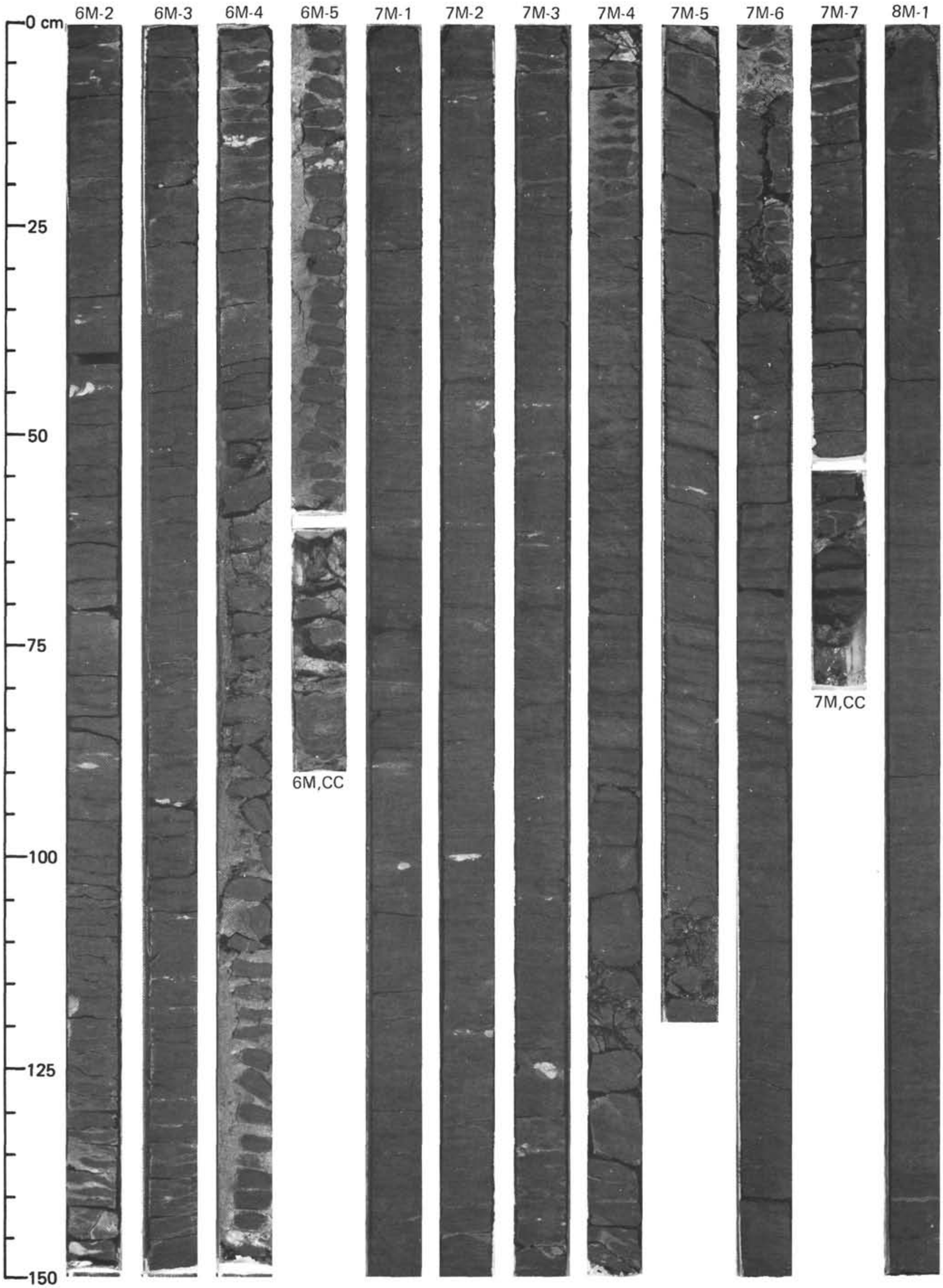
5R-2
5R-3
5R-4
5R-5
5R,CC
6M-1



0 cm
25
50
75
100
125
150
6M-2
6M-3
6M-4
6M-5
6M,CC
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7M-2
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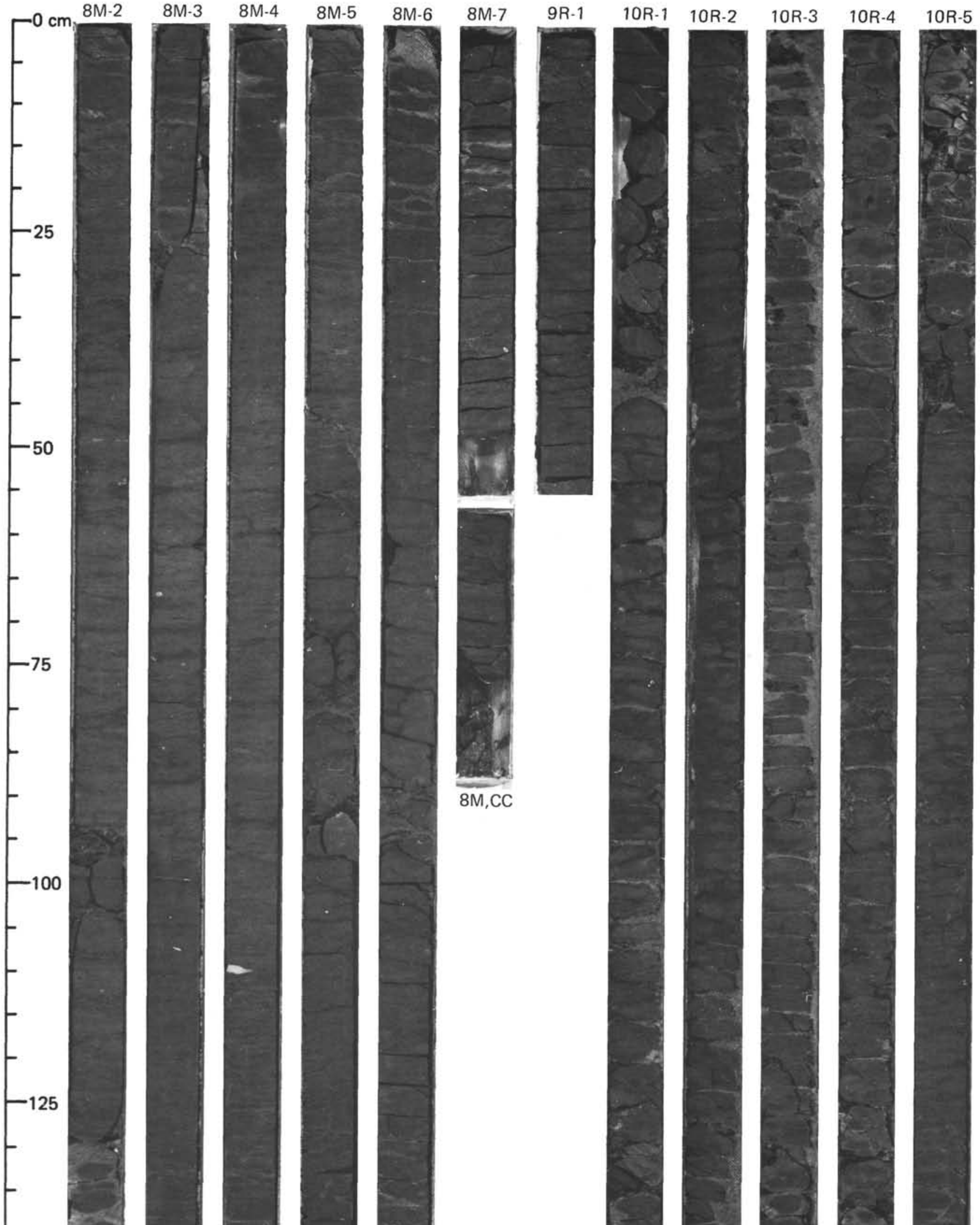
7M-5
7M-6
7M-7
7M,CC
8M-1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25
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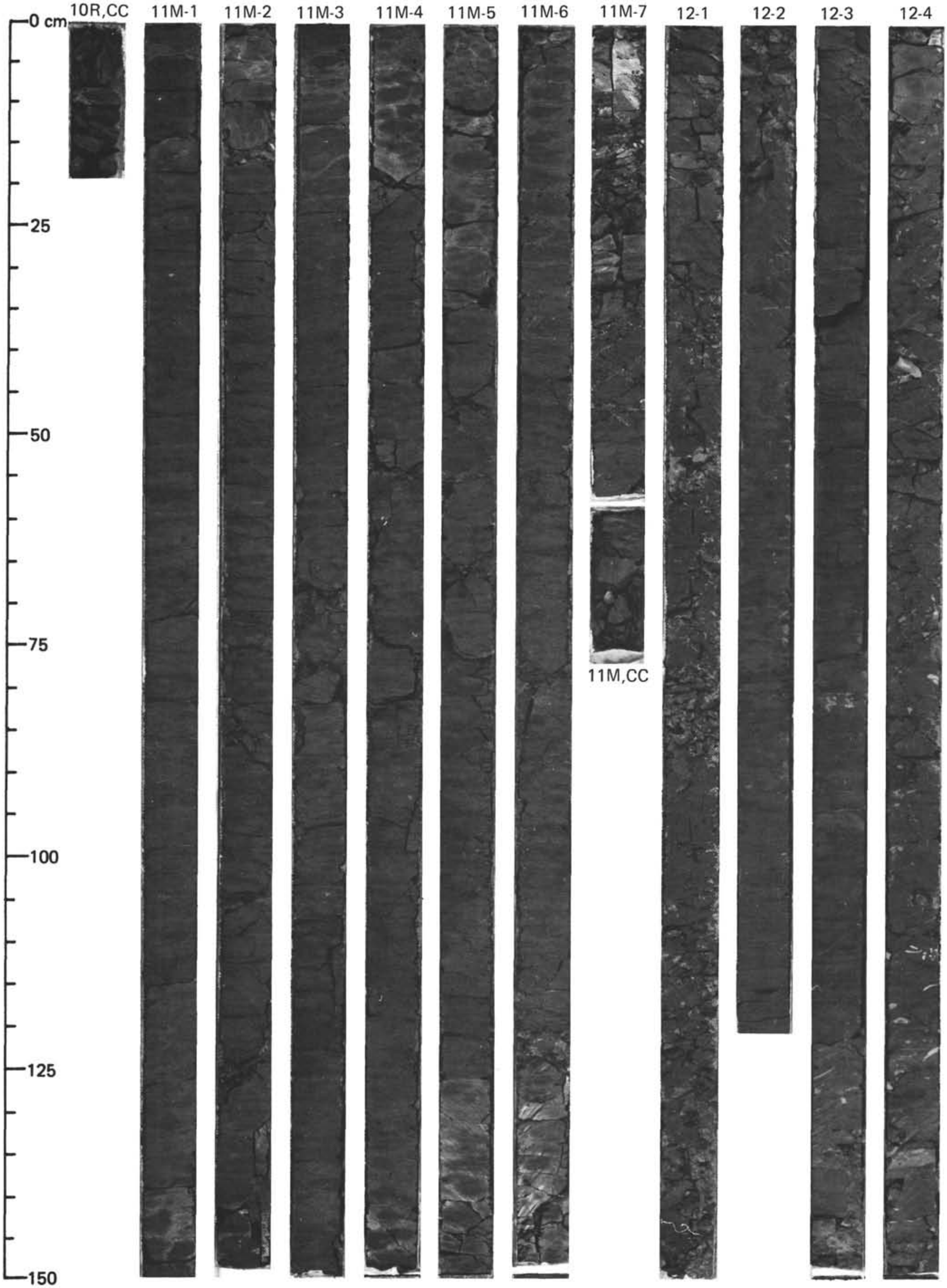
100
125
150
8M-2
8M-3
8M-4
8M-5
8M-6
8M-7
8M,CC
9R-1
10R-1
10R-2
10R-3
10R-4
10R-5


0 cm
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150
10R,CC
11M-1
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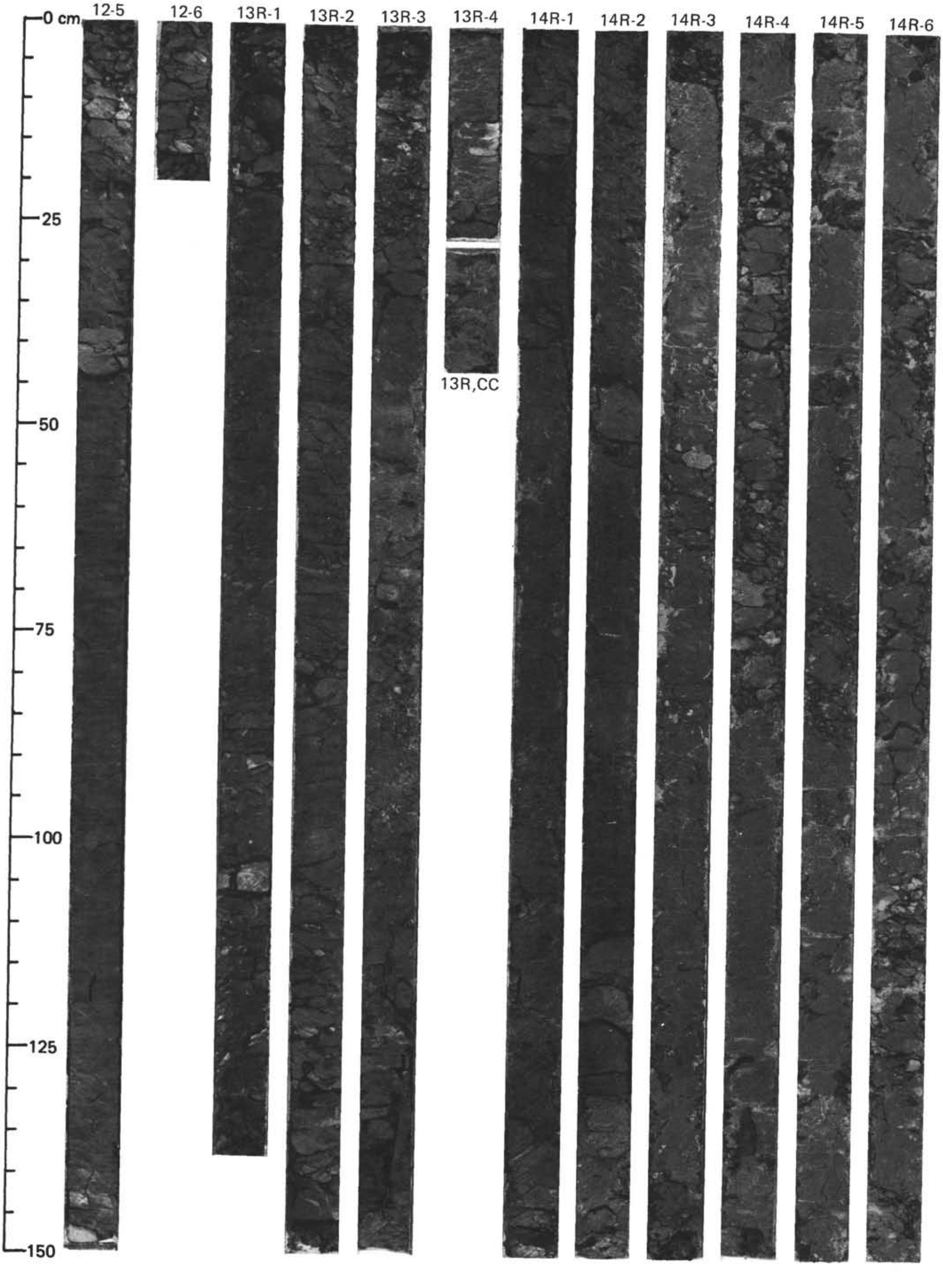
12-4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12-6
13R-1
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14R-3
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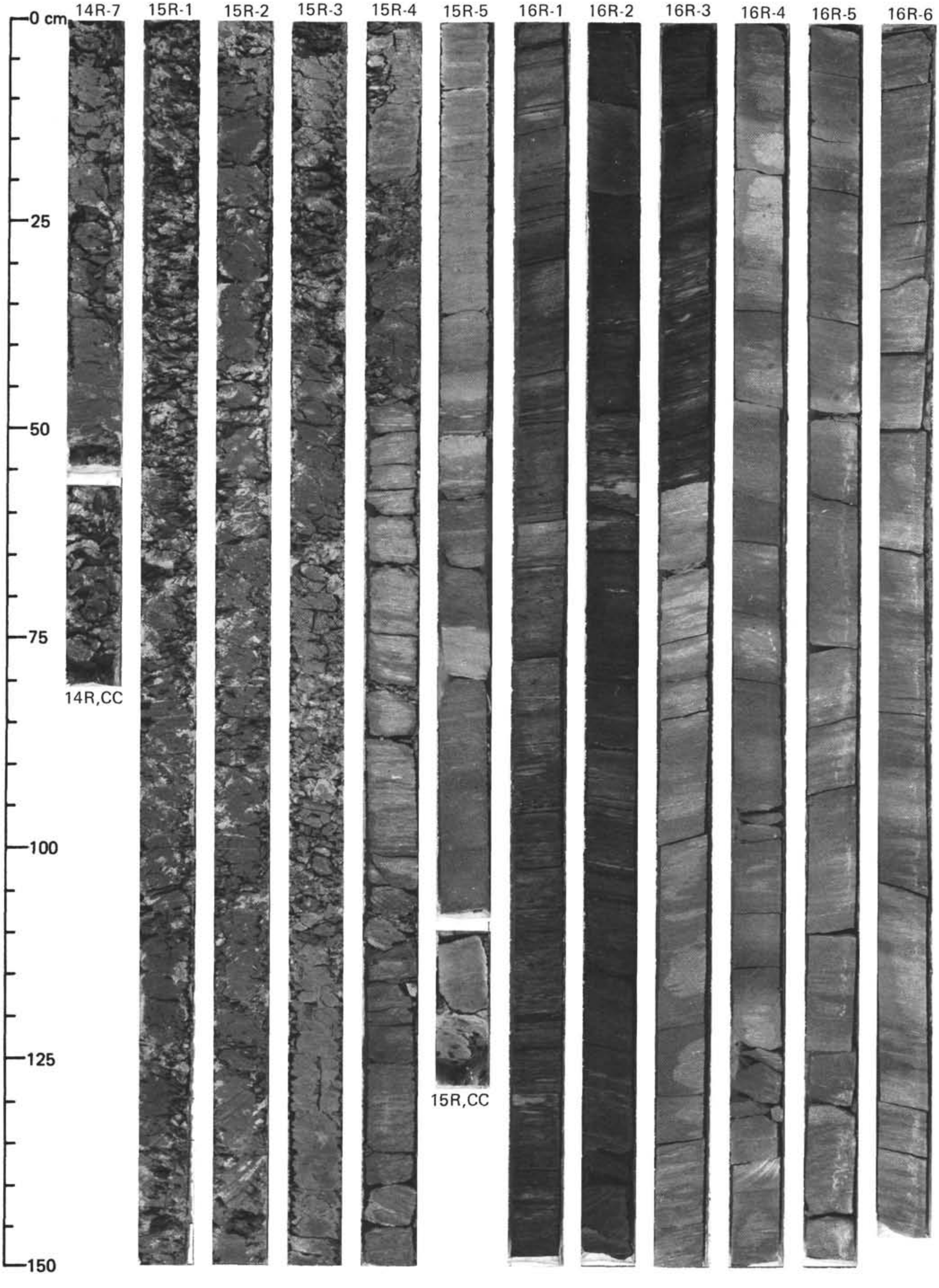
14R-5
14R-6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125
150
14R-7
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15R-3
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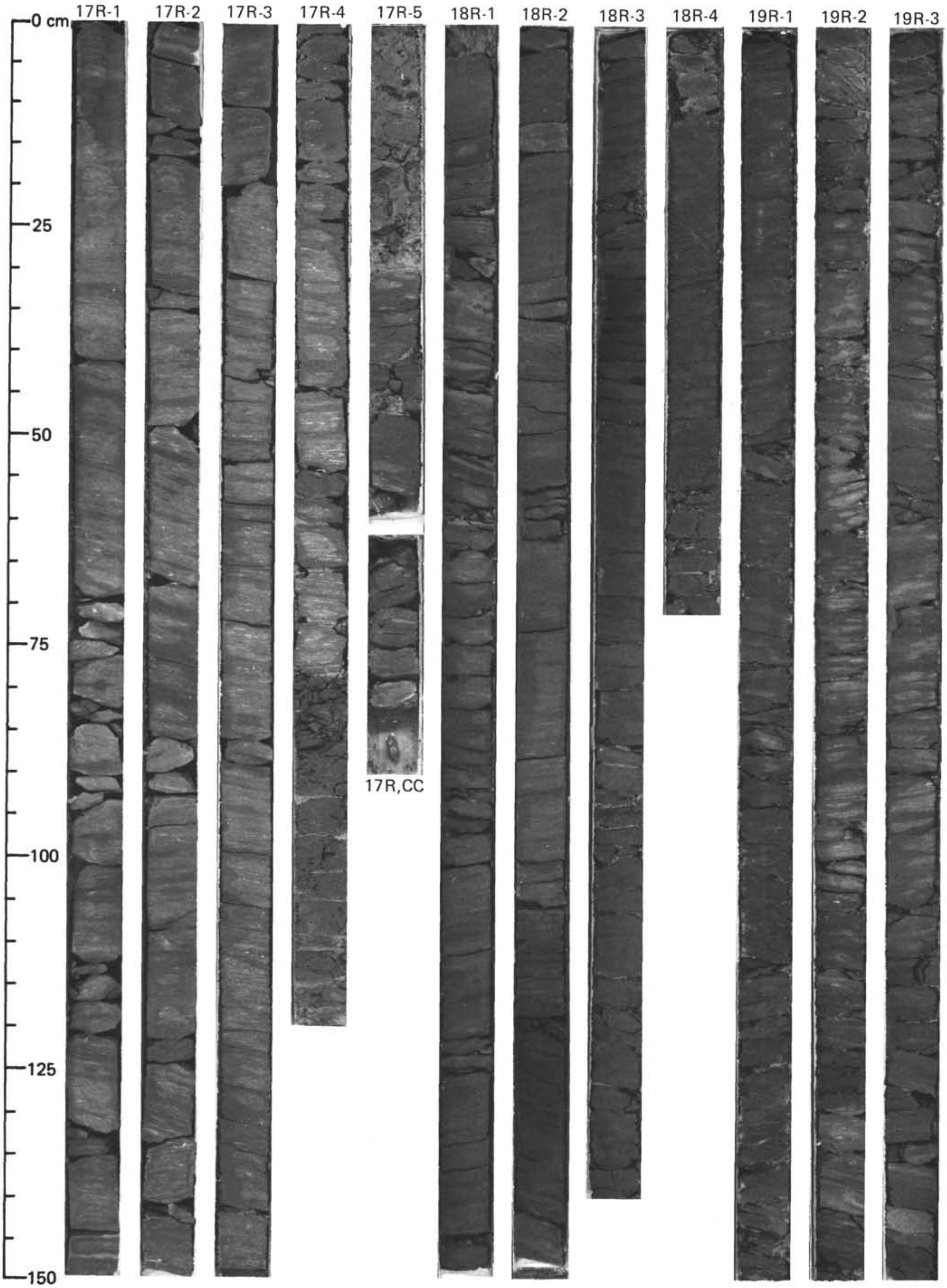
14R,CC
15R,CC


0 cm
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50
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125
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17R-1
17R-2
17R-3
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18R-4
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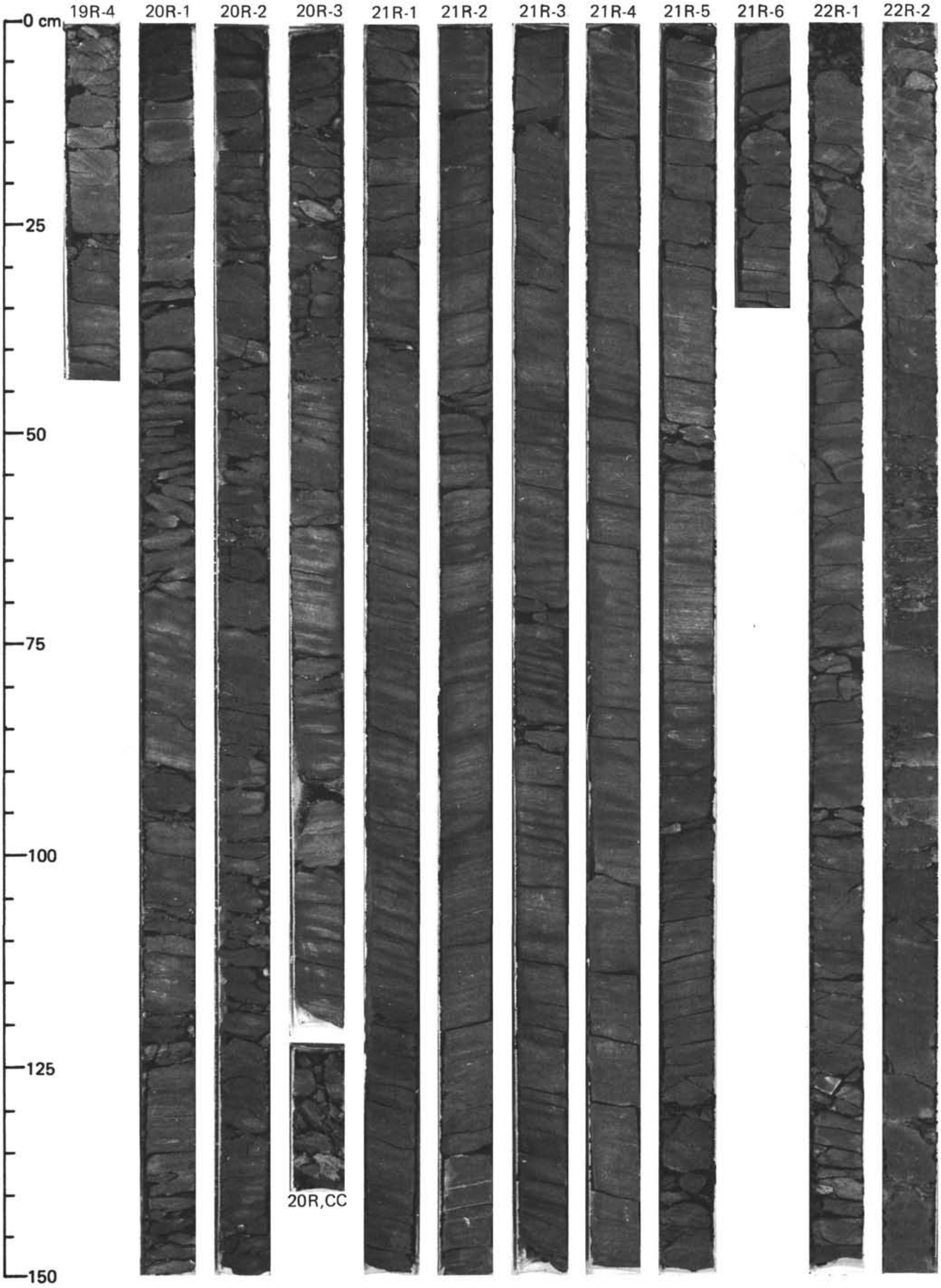
19R-2
19R-3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125
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19R-4
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20R-3
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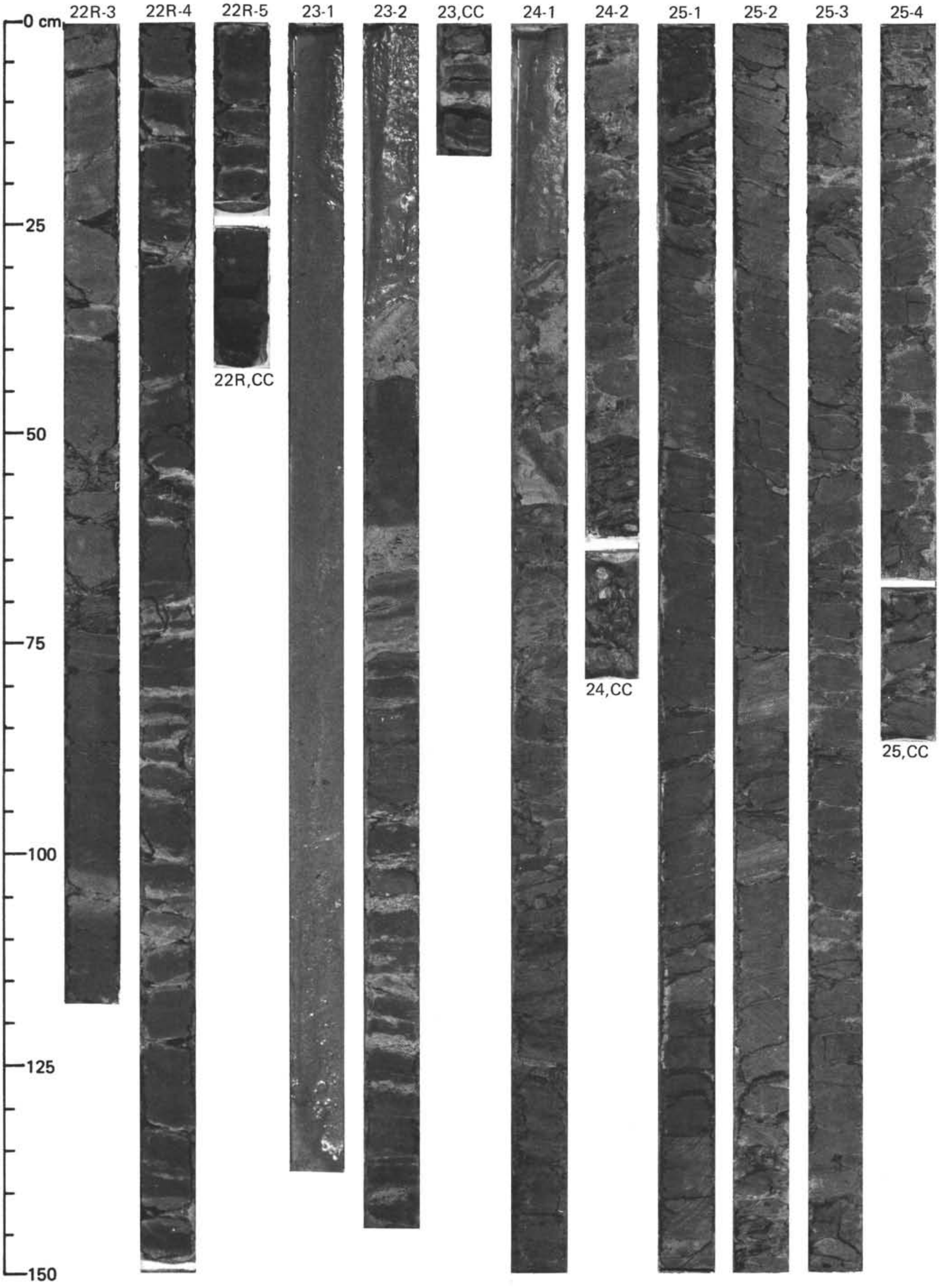
21R-3
21R-4
21R-5
21R-6
22R-1
22R-2


0 cm
25
50
75
100
125
150
22R-3
22R-4
22R-5
22R,CC
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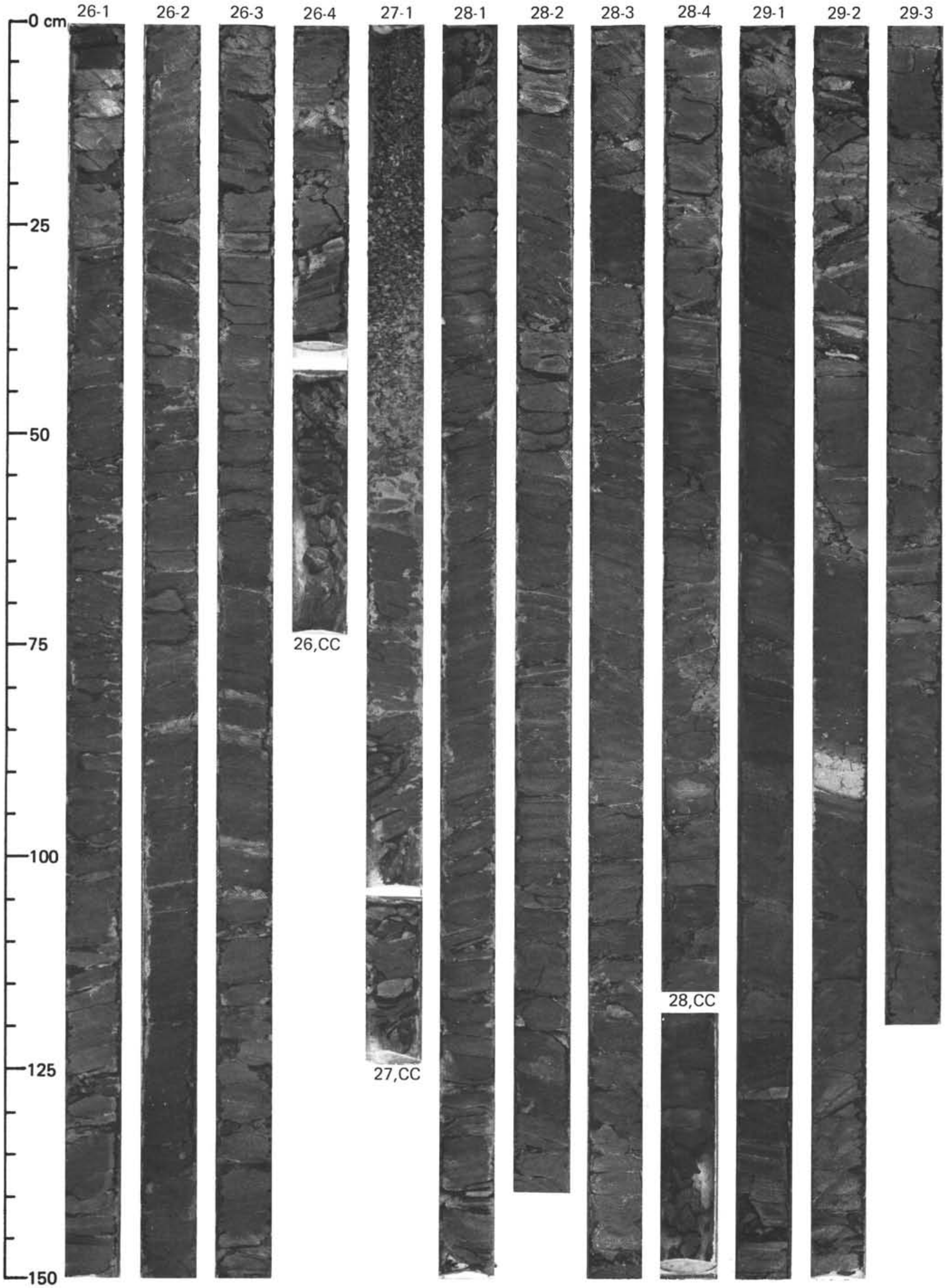
25-3
25-4
25,CC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75
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125
150
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26-2
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27,CC
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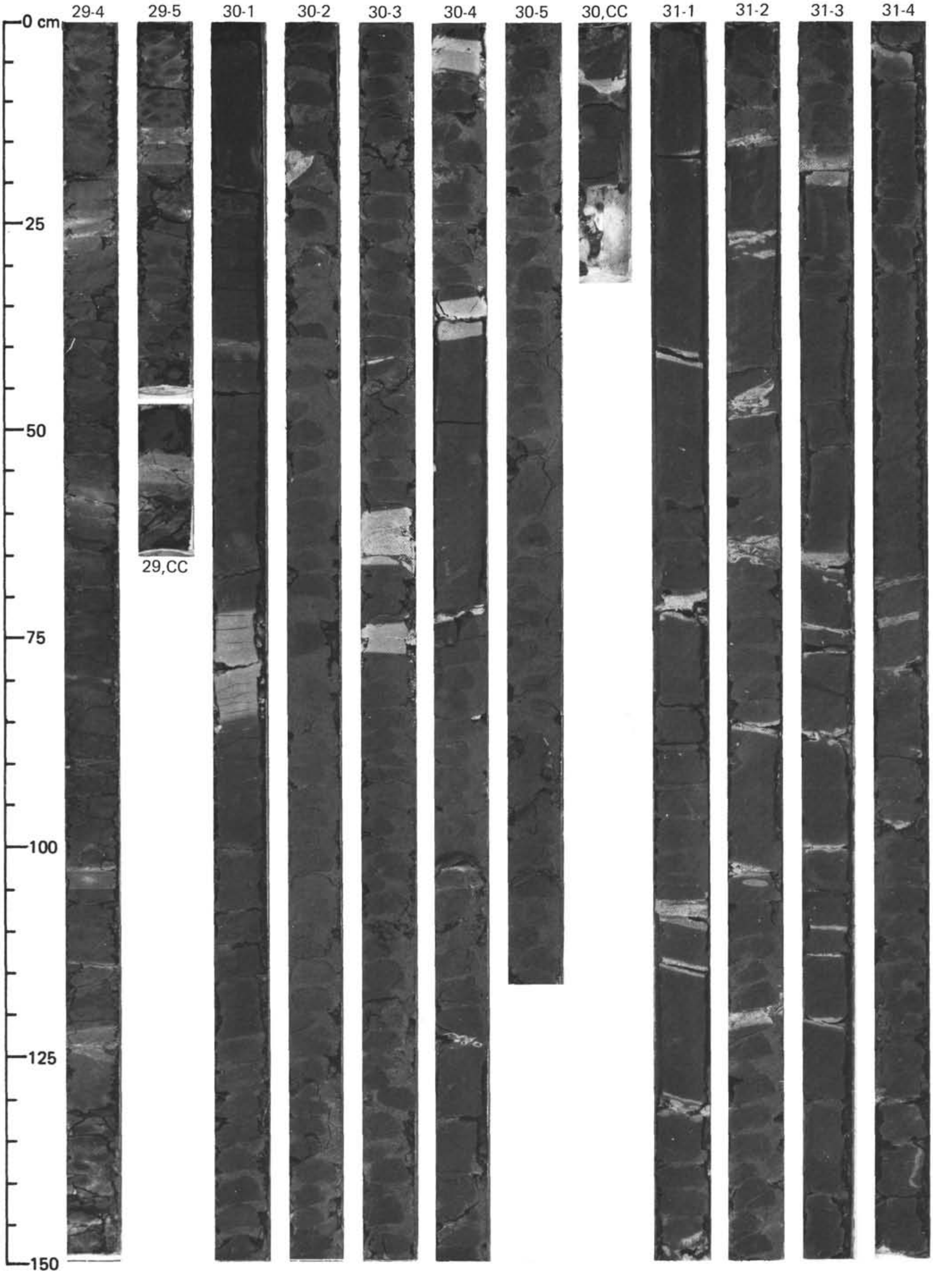
28-2
28-3
28-4
28,CC
29-1
29-2
29-3


29-4
29-5
30-1
30-2
30-3
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31-1
31-2
31-3
31-4
0 cm
25
50
75
100
125
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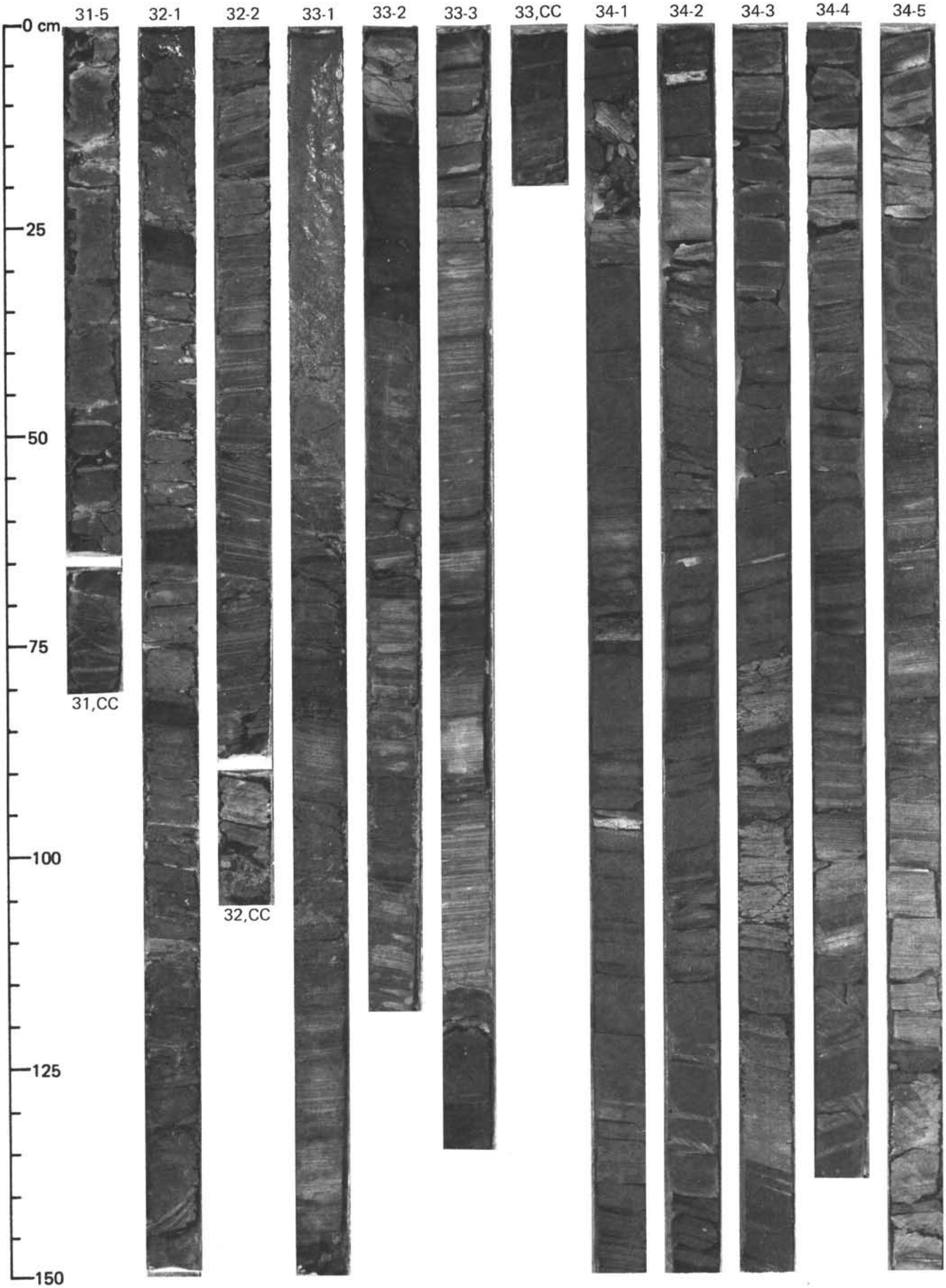
29,CC


31-5
32-1
32-2
33-1
33-2
33-3
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34-5
0 cm
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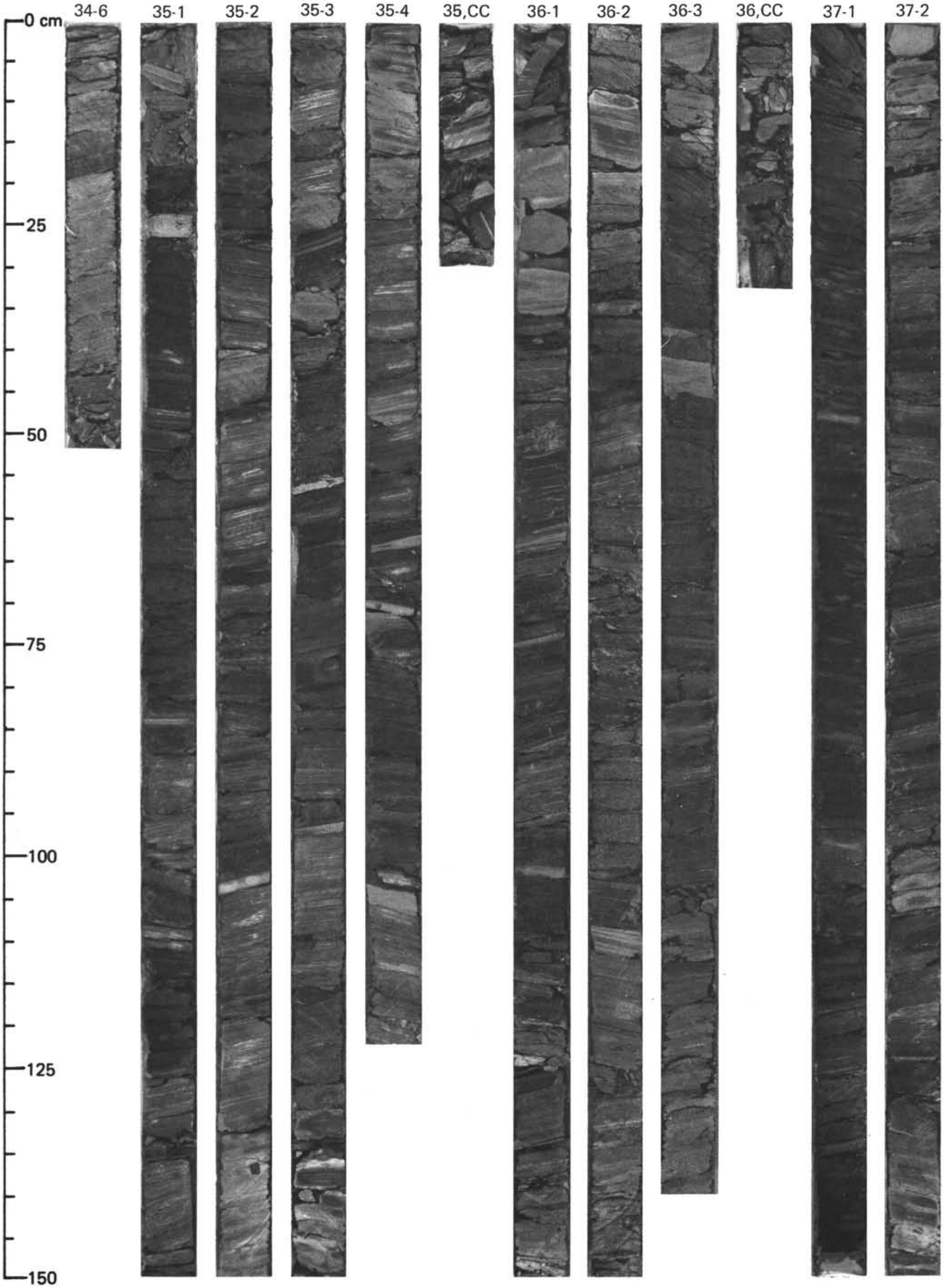
50
75
100
125
150
31,CC
32,CC



0 cm
25
50
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125
150
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35-4
35,CC
36-1
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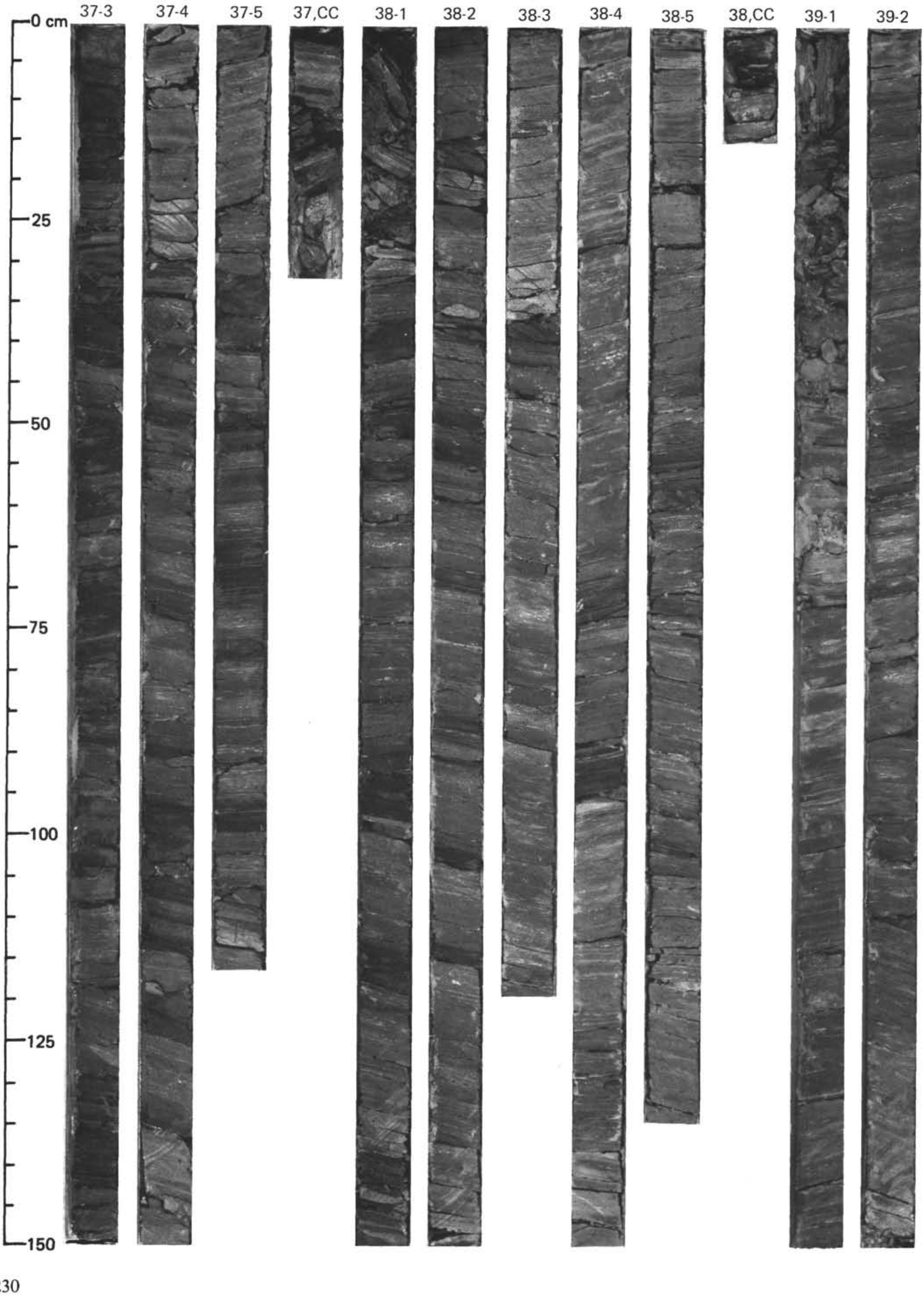
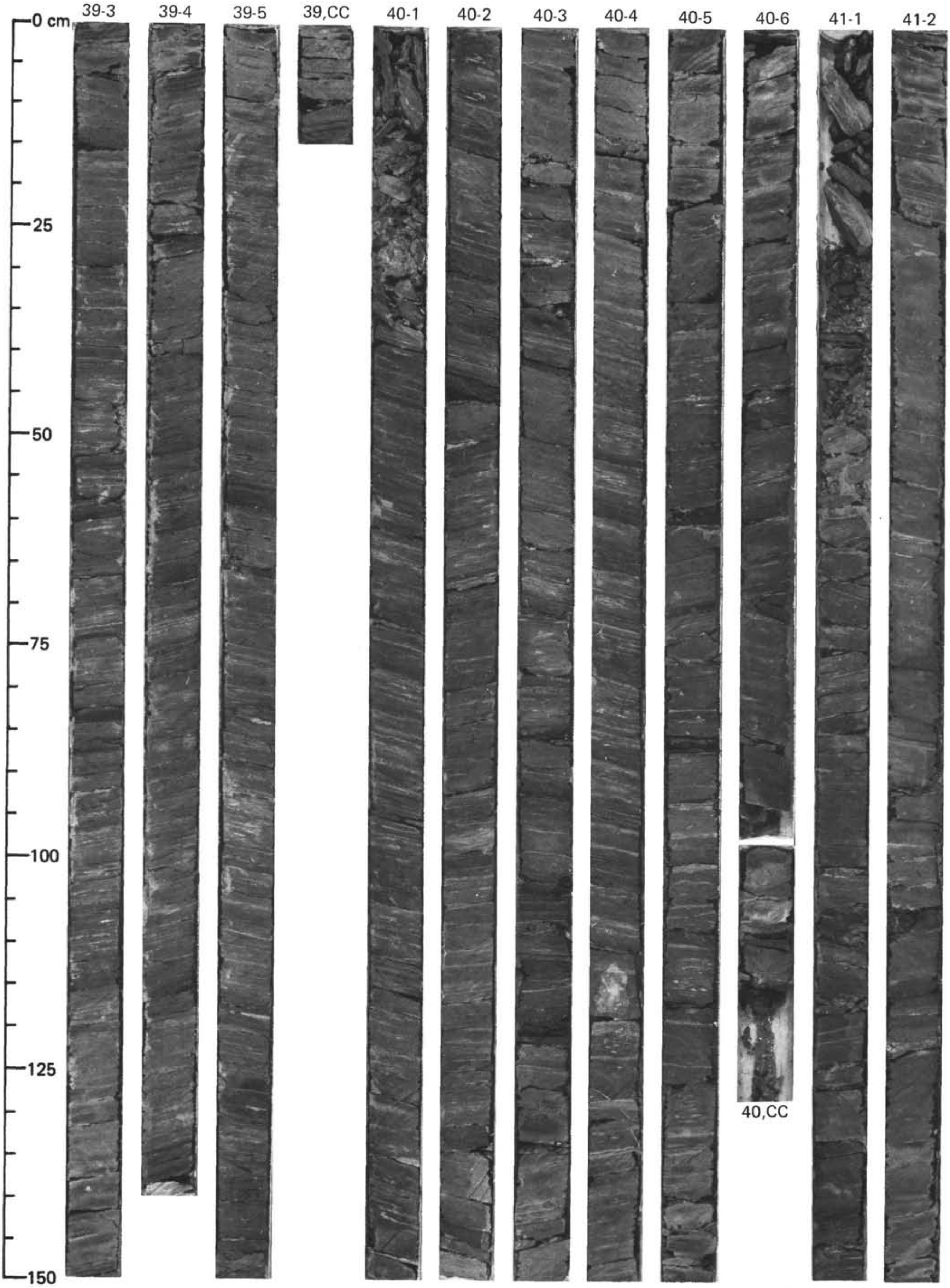
36,CC
37-1
37-2


37-3
37-4
37-5
37,CC
38-1
38-2
38-3
38-4
38-5
38,CC
39-1
39-2
0 cm
25
50
75
100
125
150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50
75
100
125
150
39-3
39-4
39-5
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40-1
40-2
40-3
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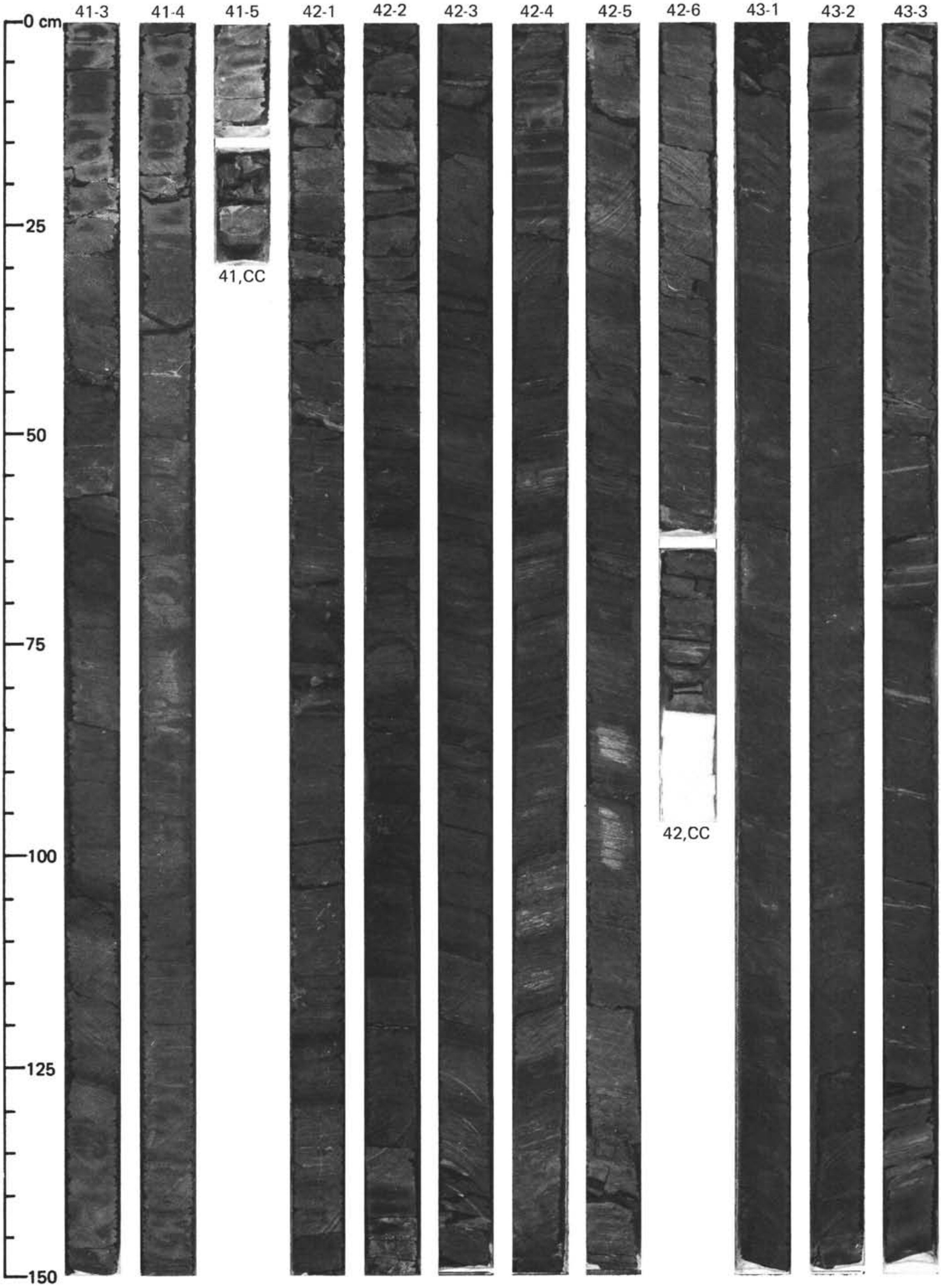
40-5
40-6
40,CC
41-1
41-2



0 cm
25
50
75
100
125
150
41-3
41-4
41-5
41,CC
42-1
42-2
42-3
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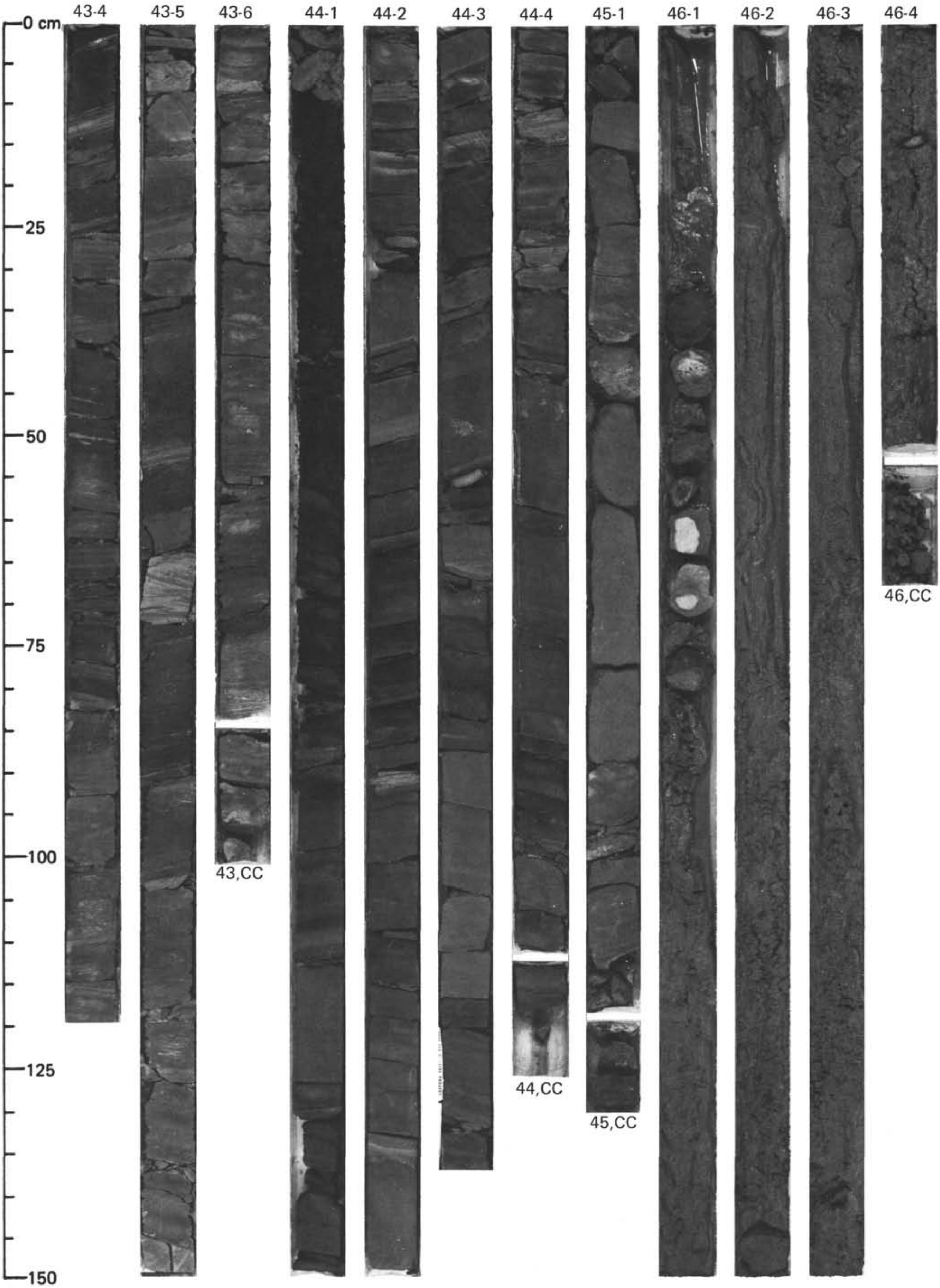
42-5
42-6
42,CC
43-1
43-2
43-3


0 cm
25
50
75
100
125
150
43-4
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43-6
44-1
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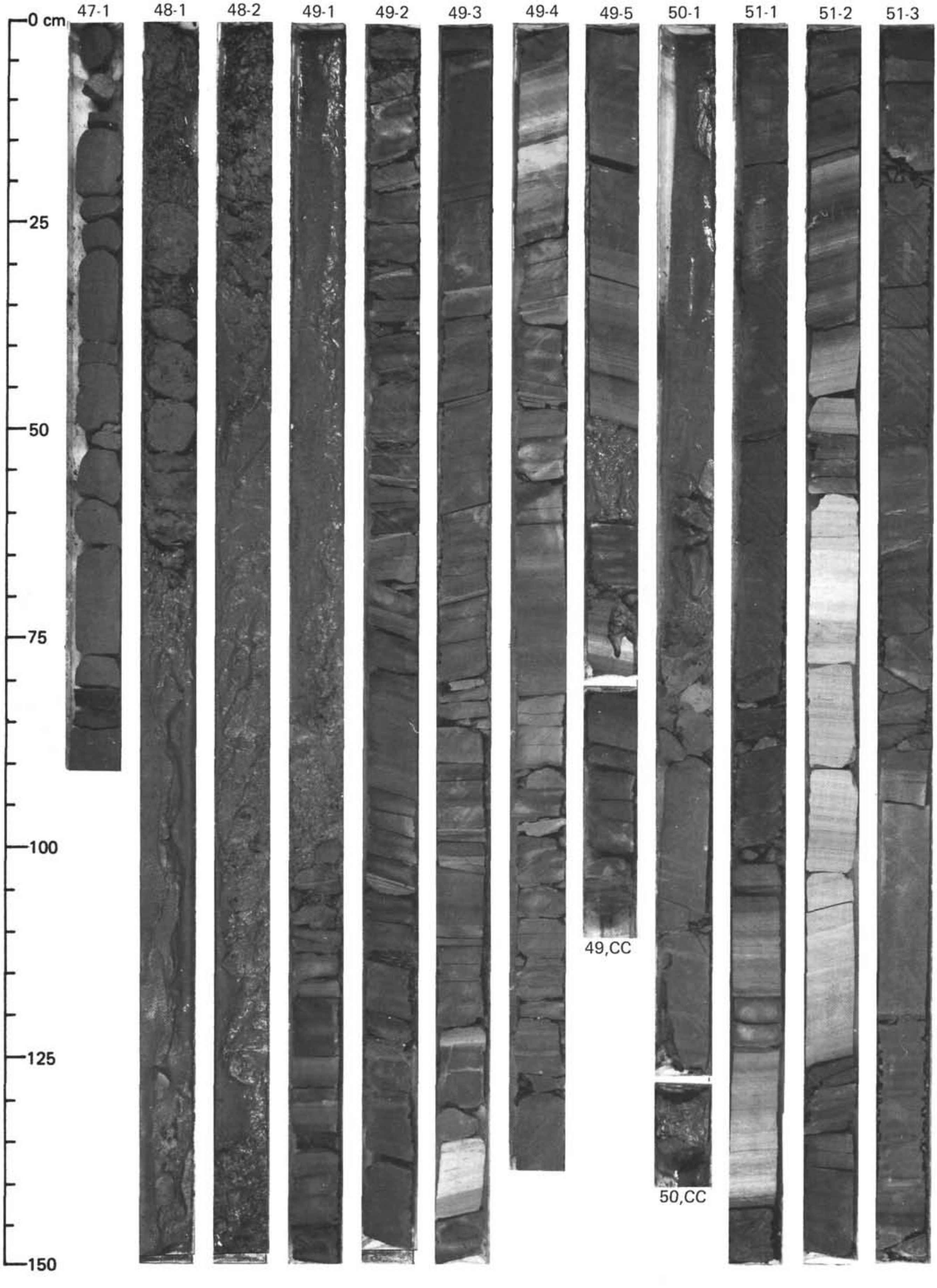
44,CC
45,CC
46,CC


0 cm
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50
75
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125
150
47-1
48-1
48-2
49-1
49-2
49-3
49-4
49-5
50-1
51-1
51-2
51-3
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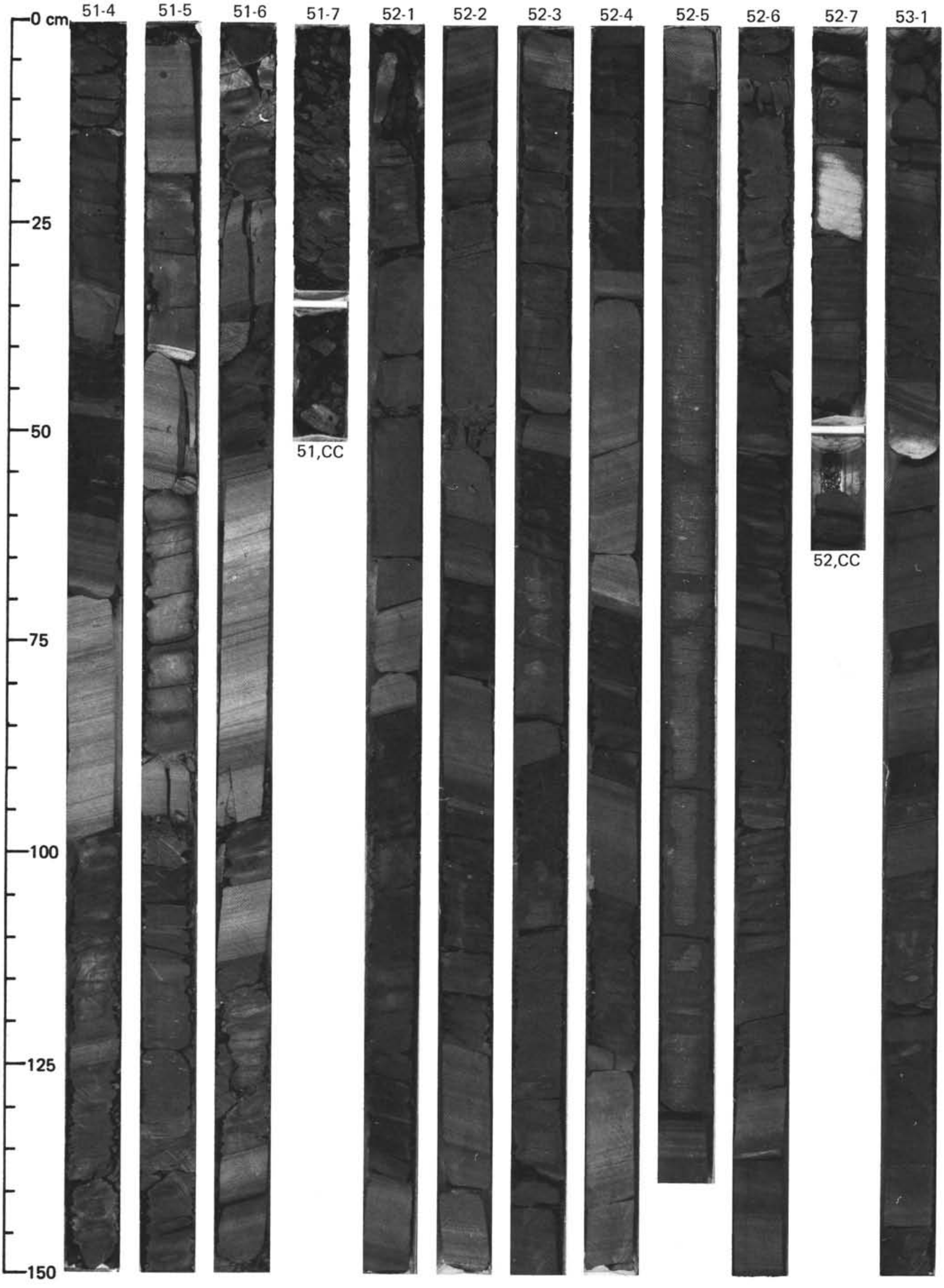
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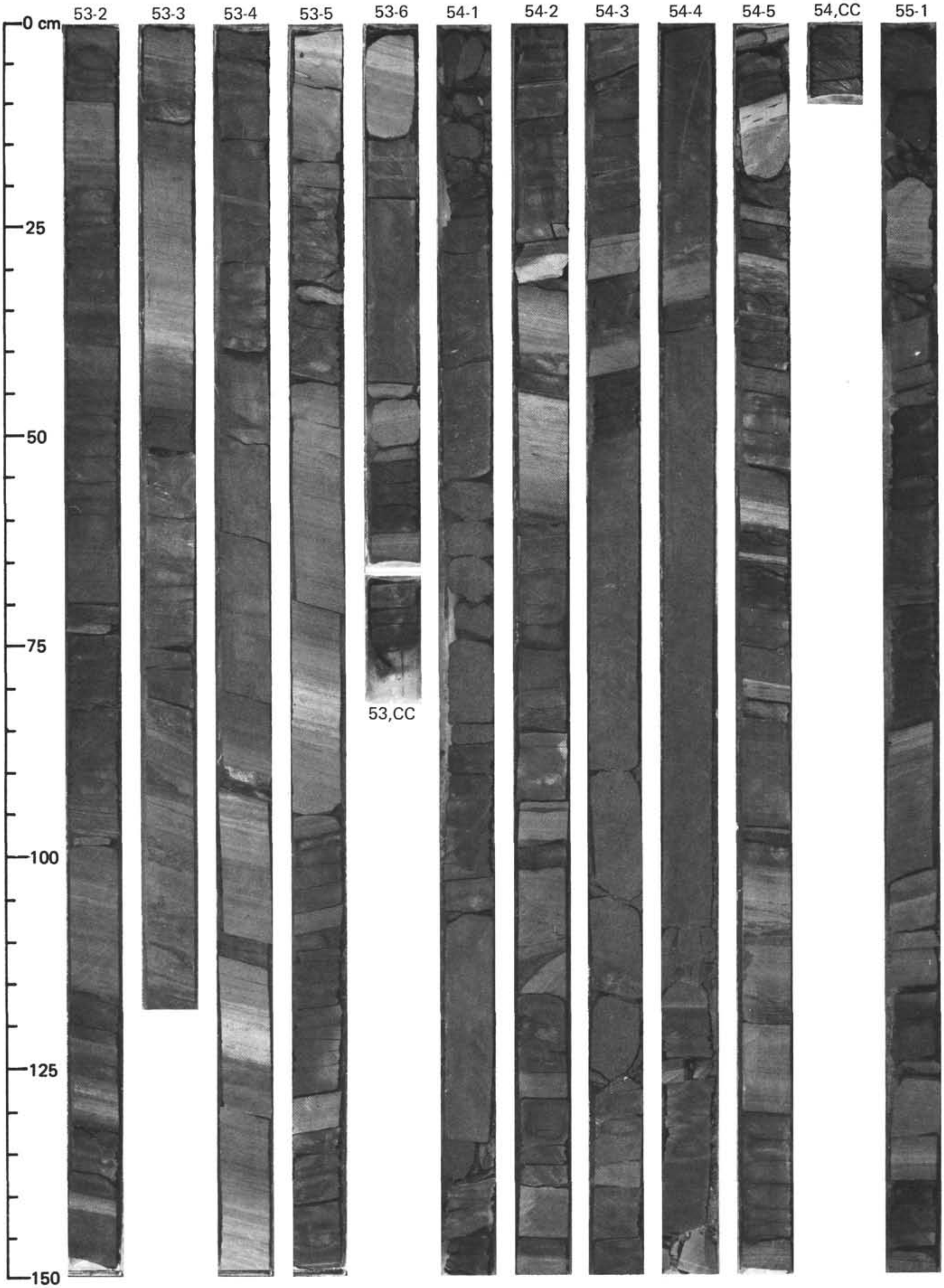
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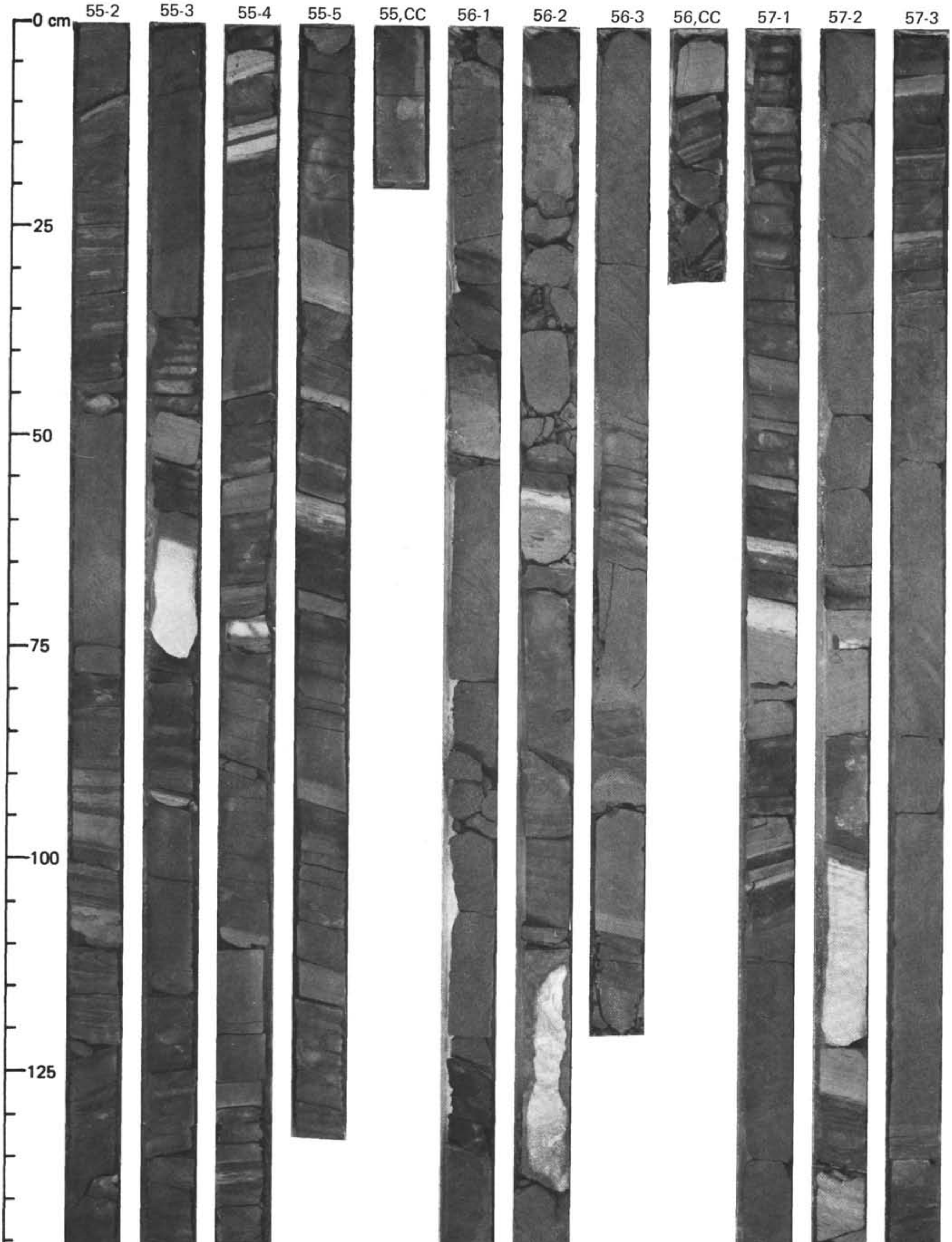
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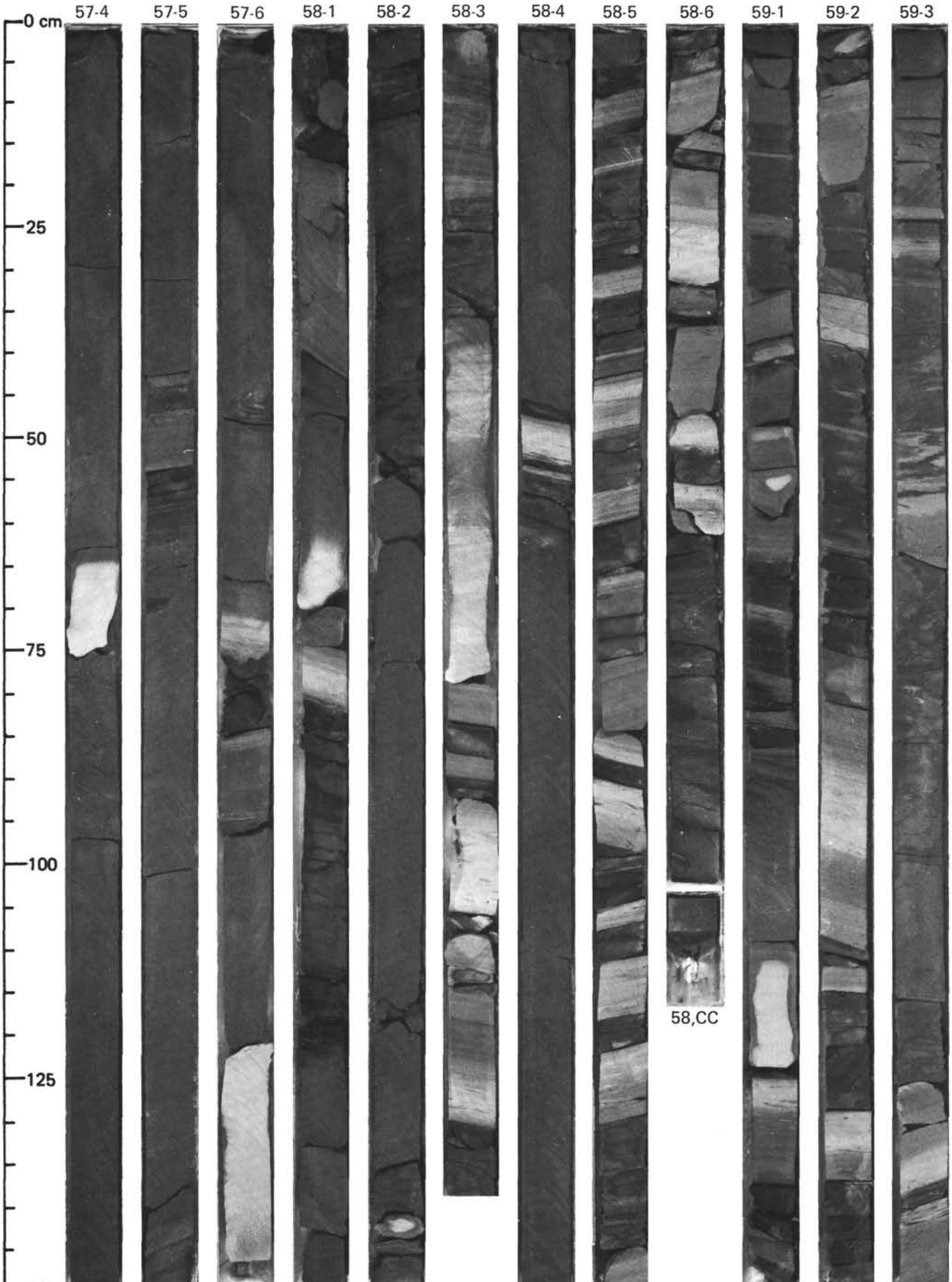
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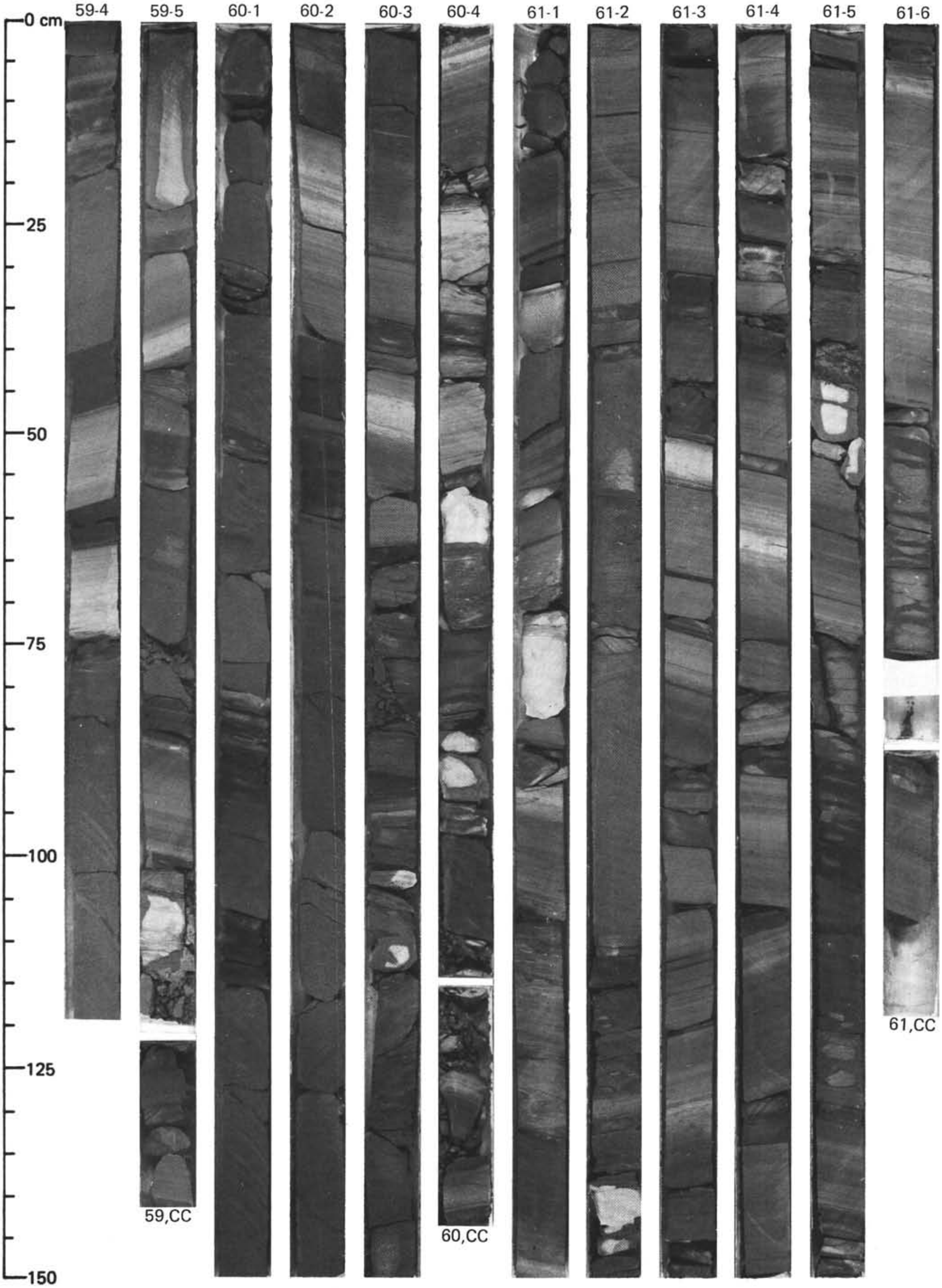
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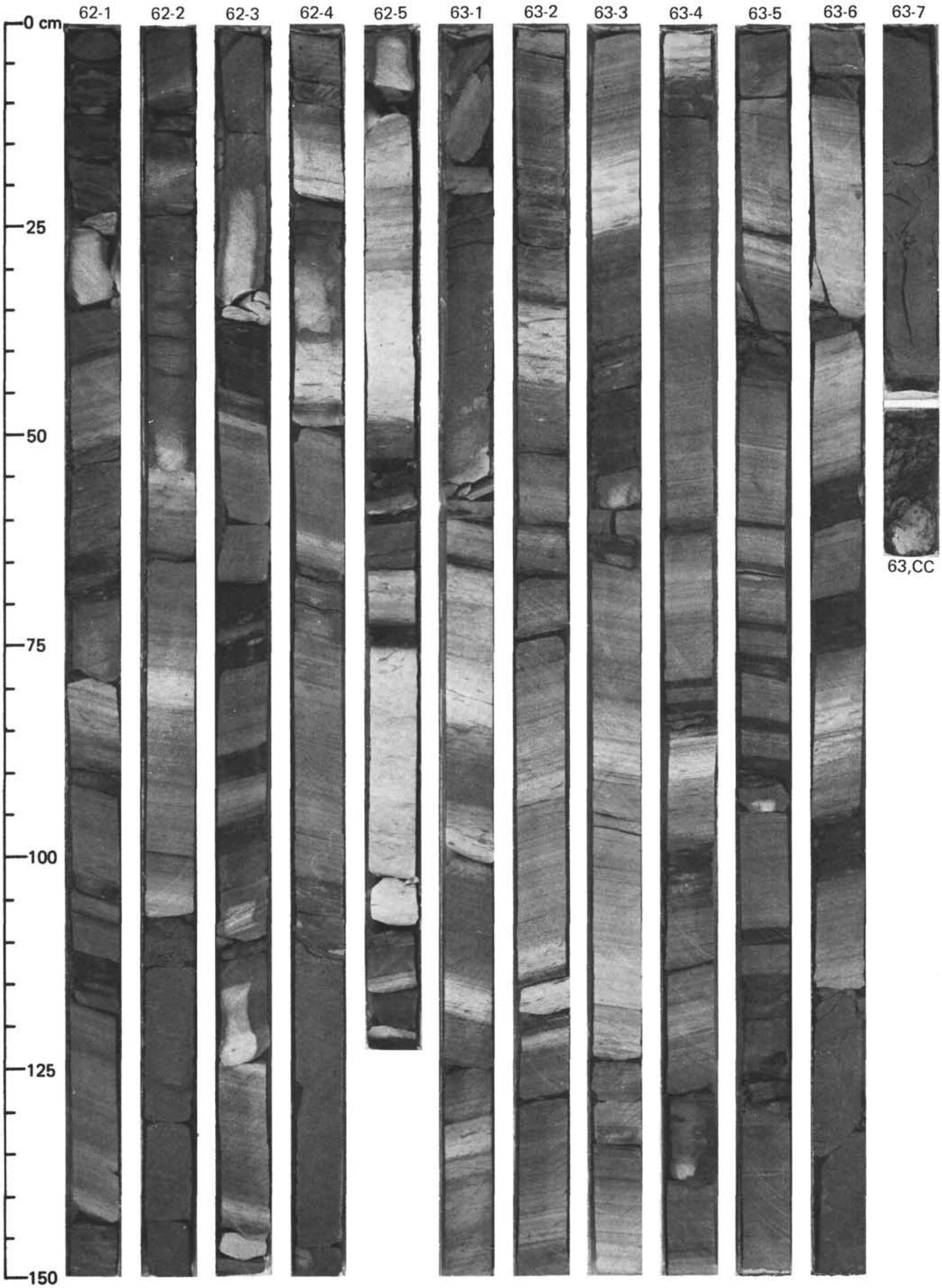
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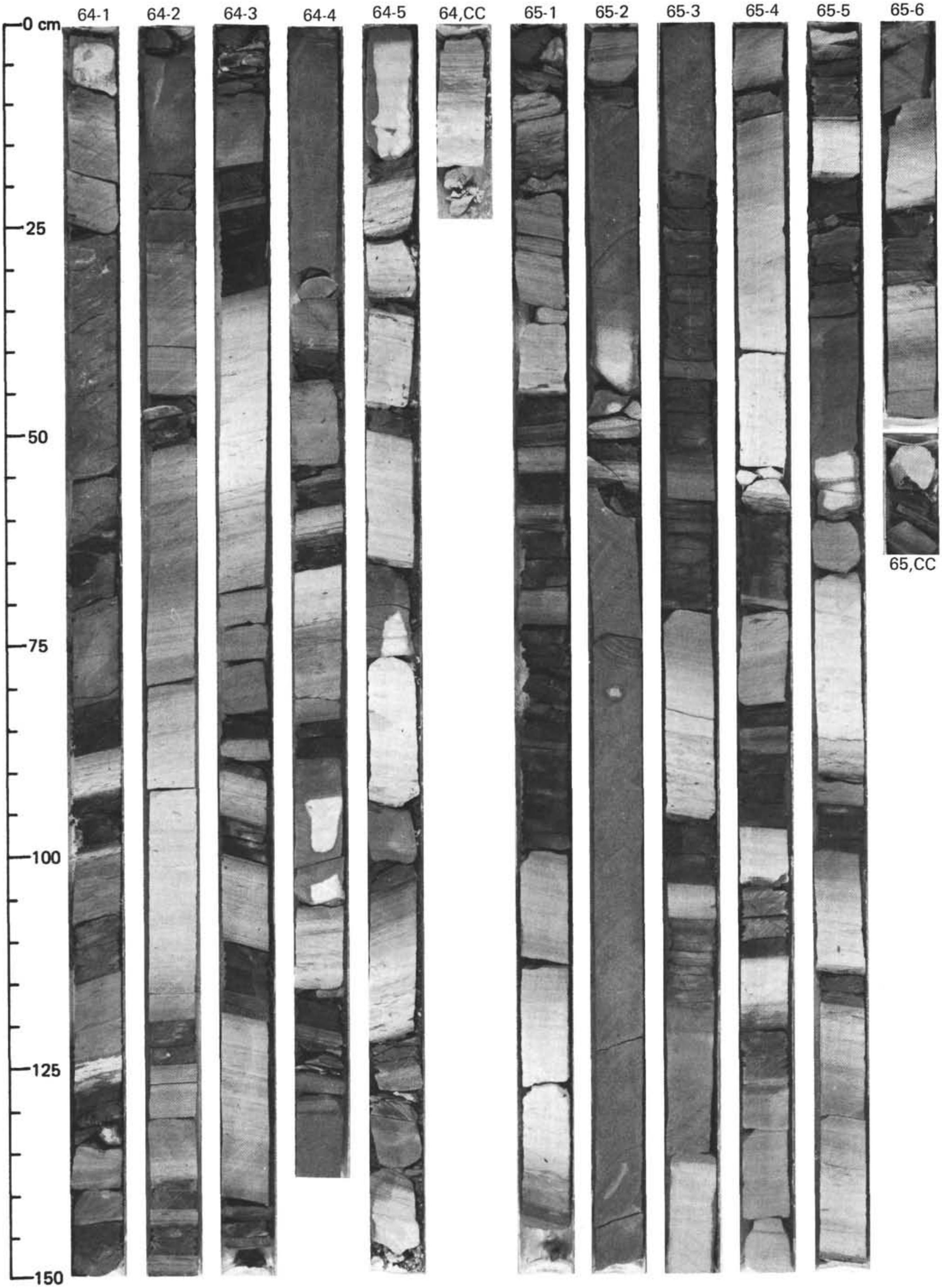

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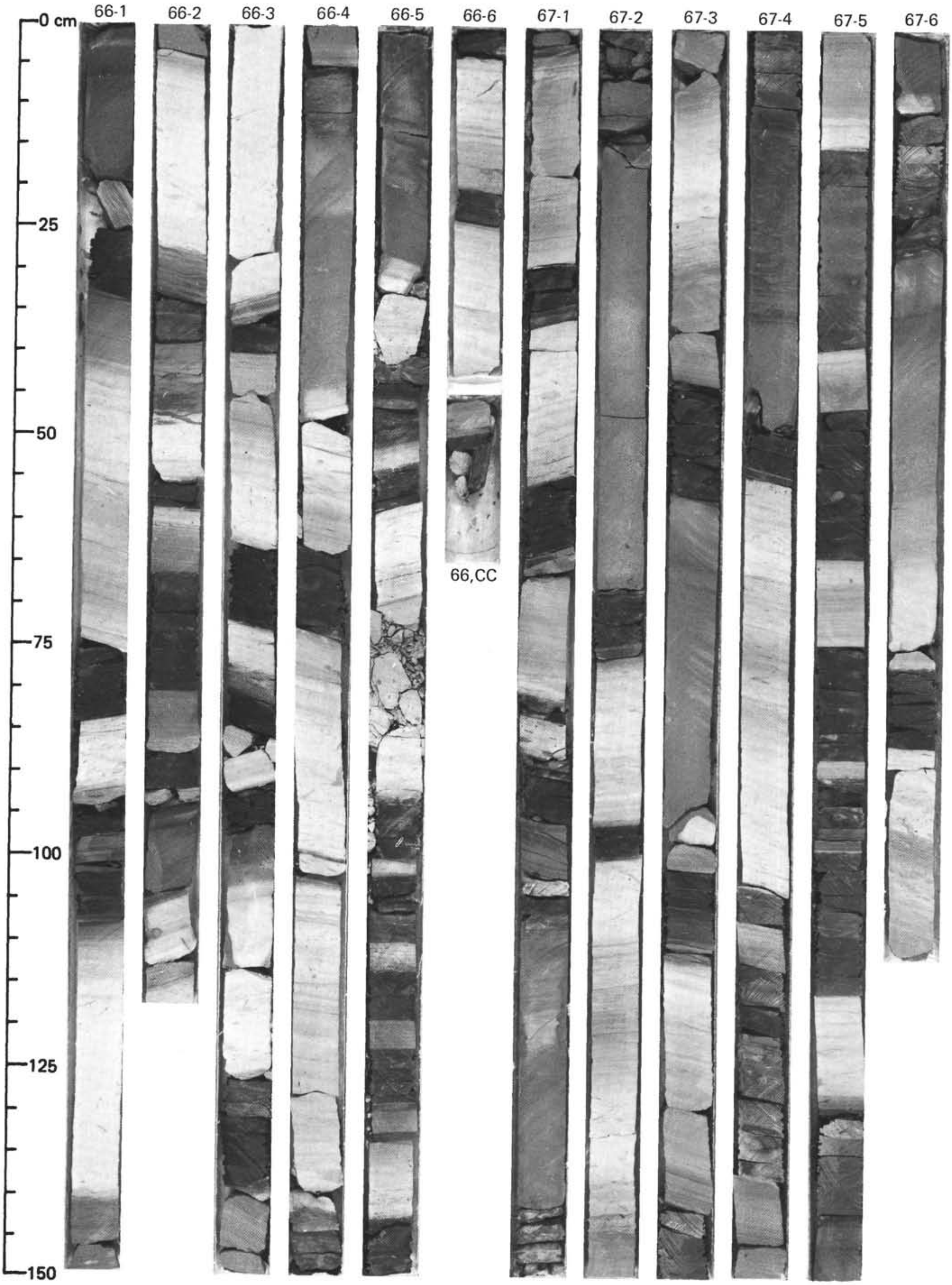
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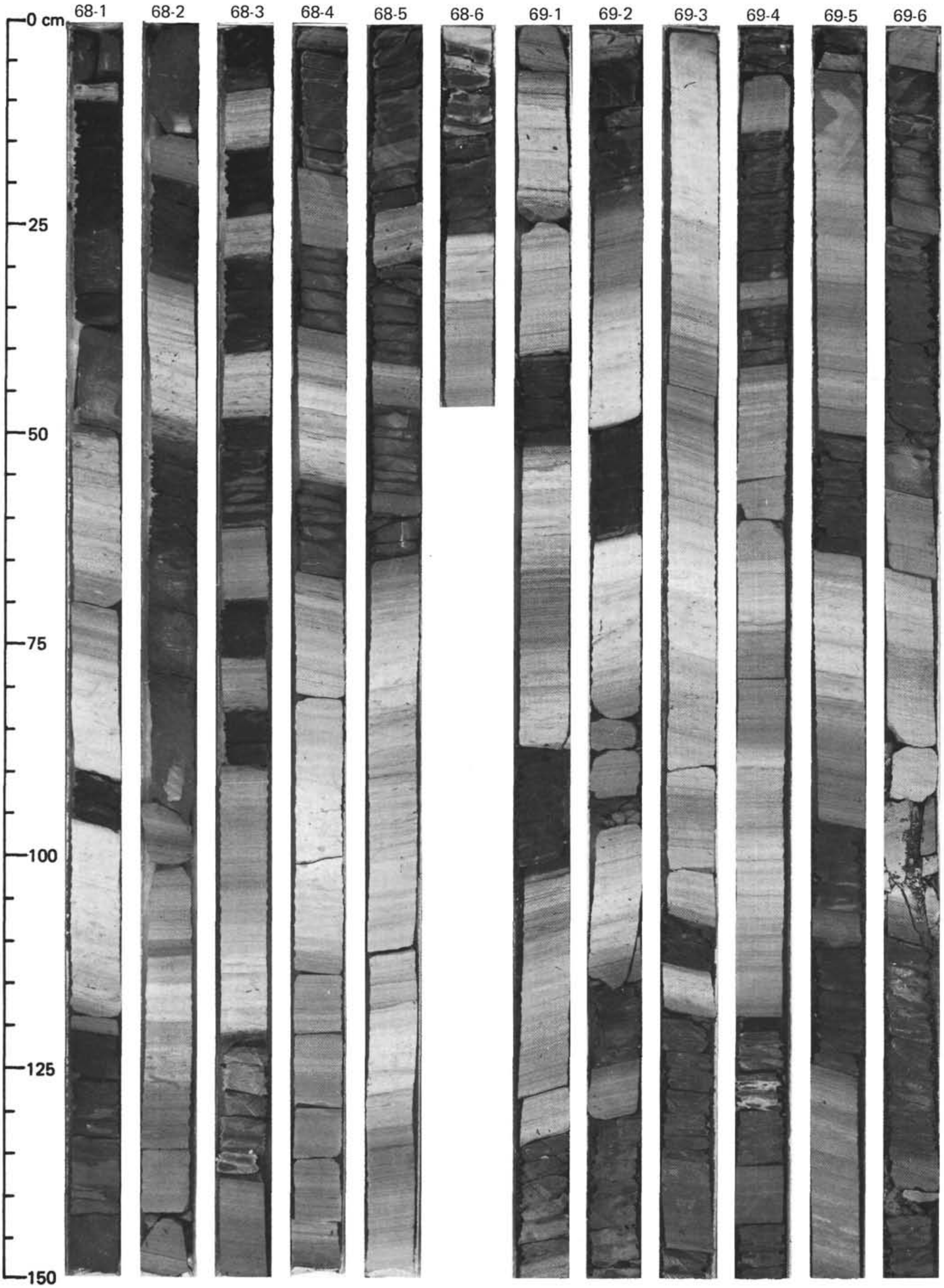
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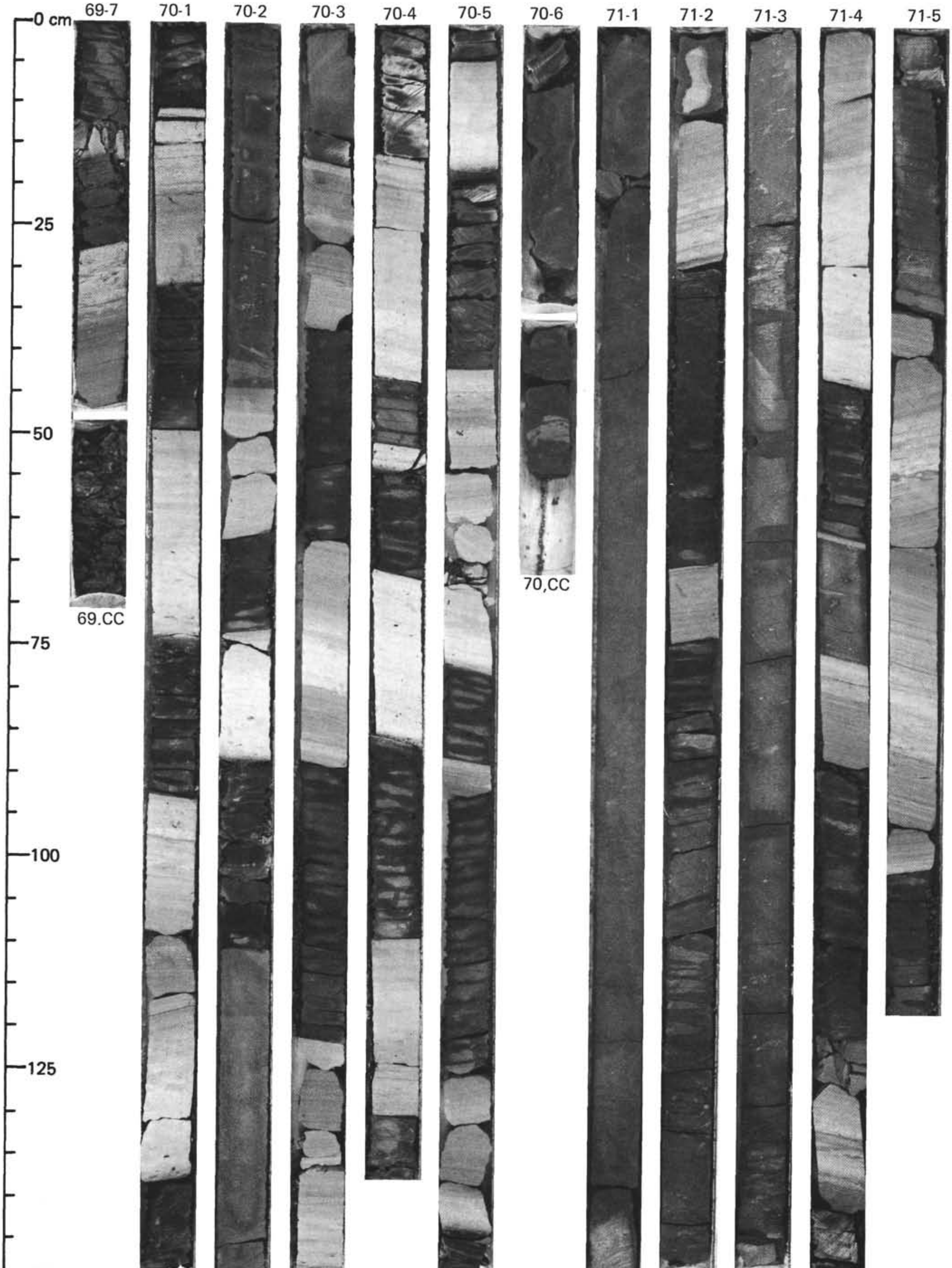
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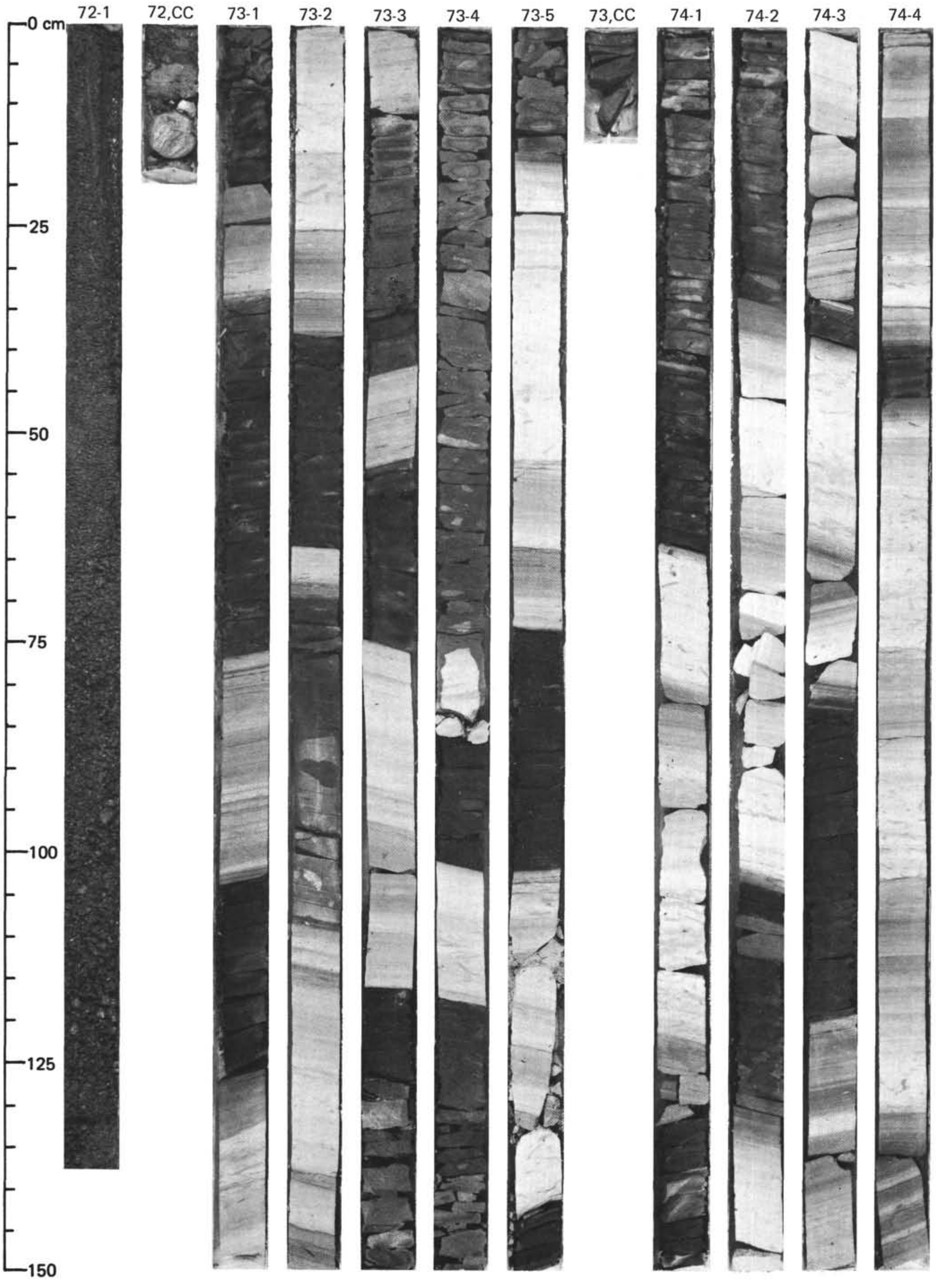
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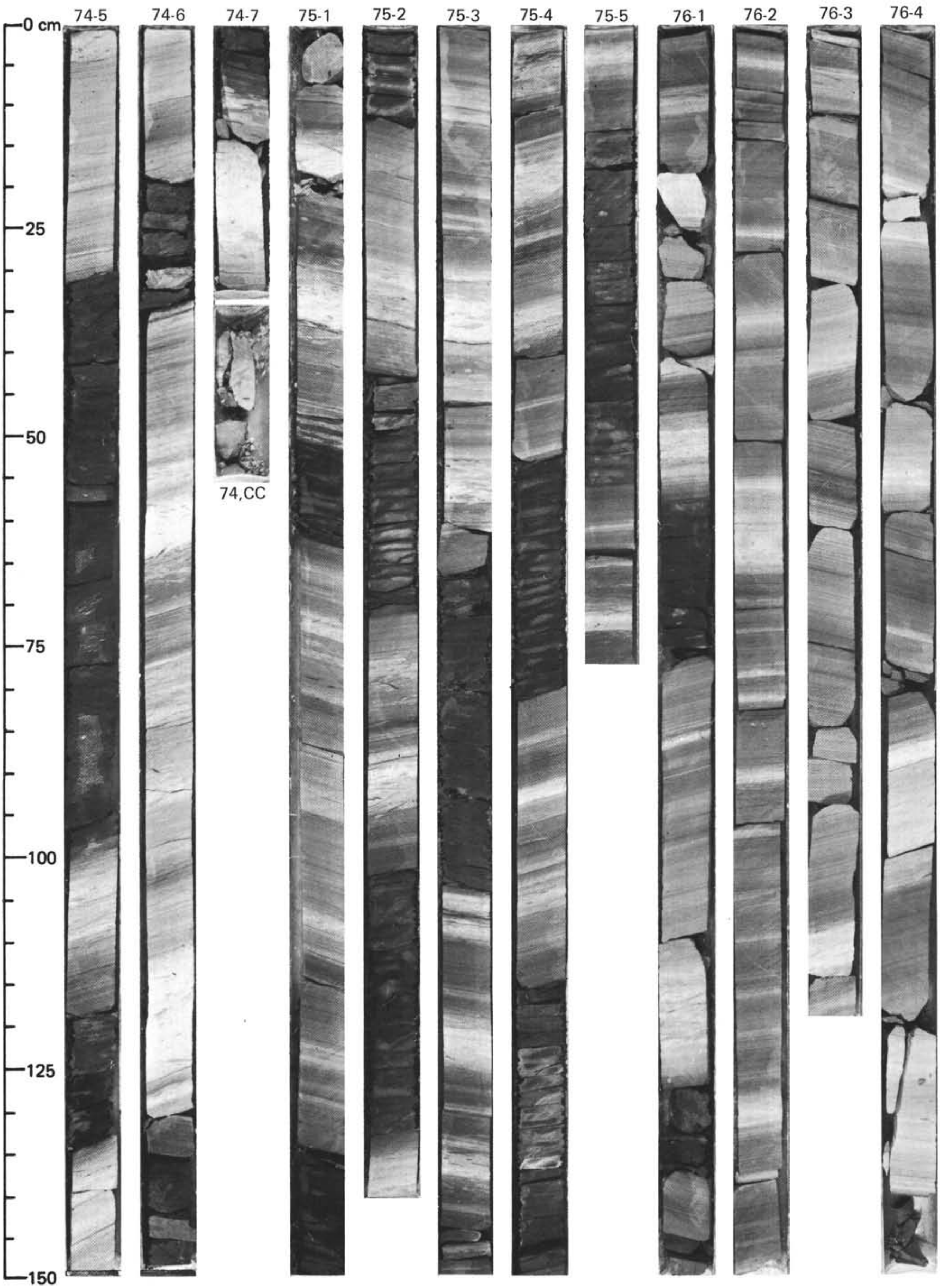
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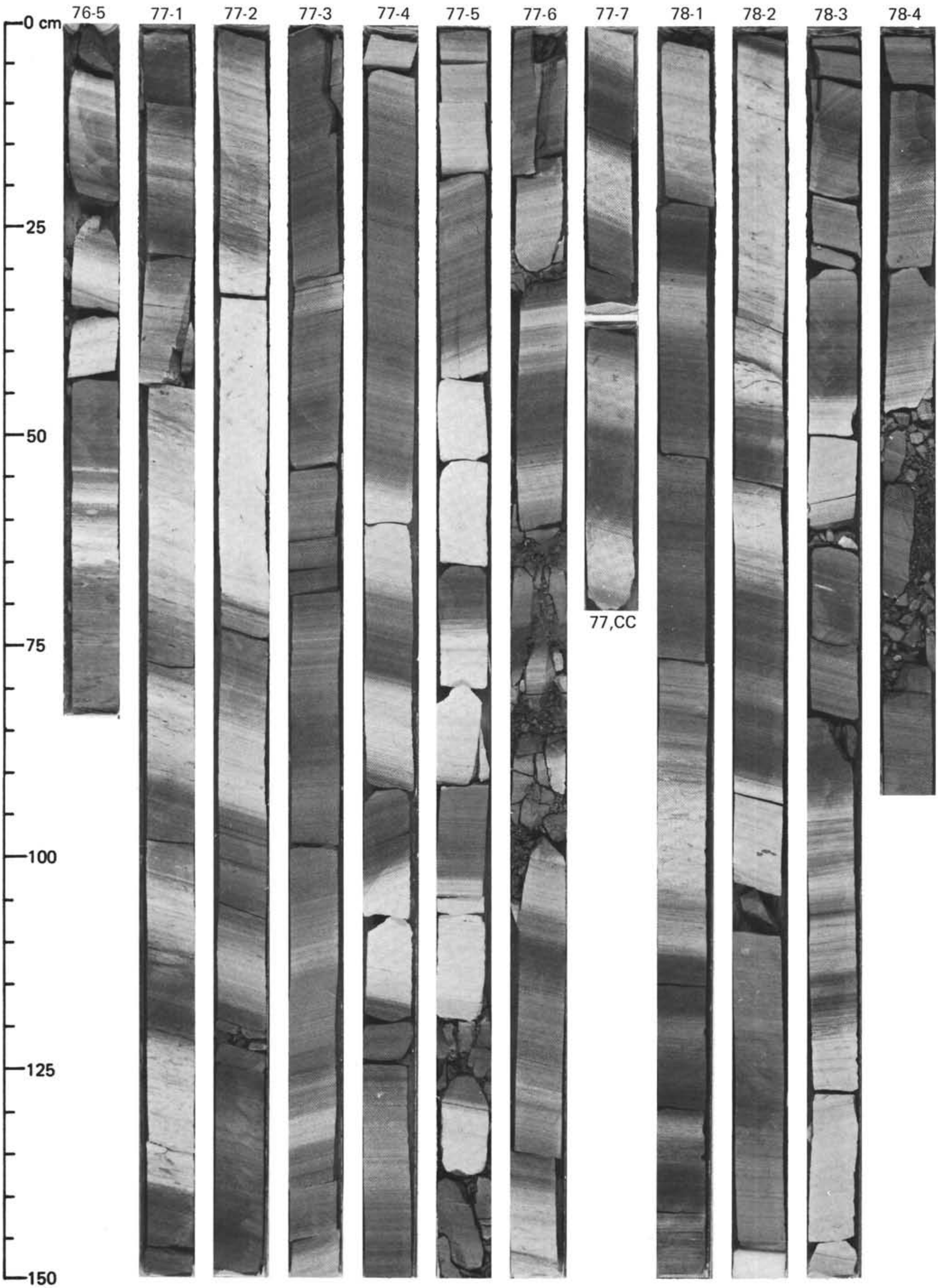
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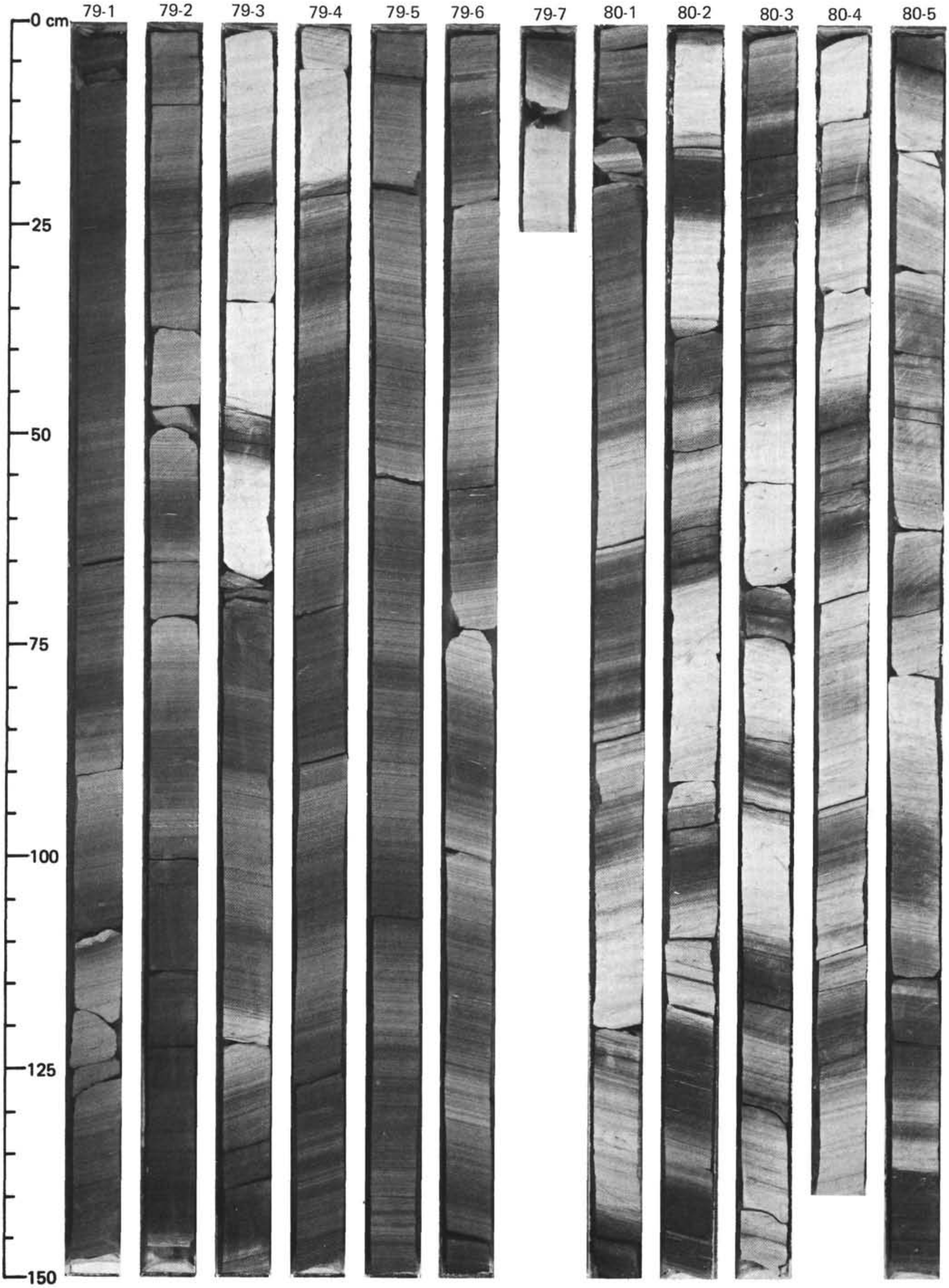
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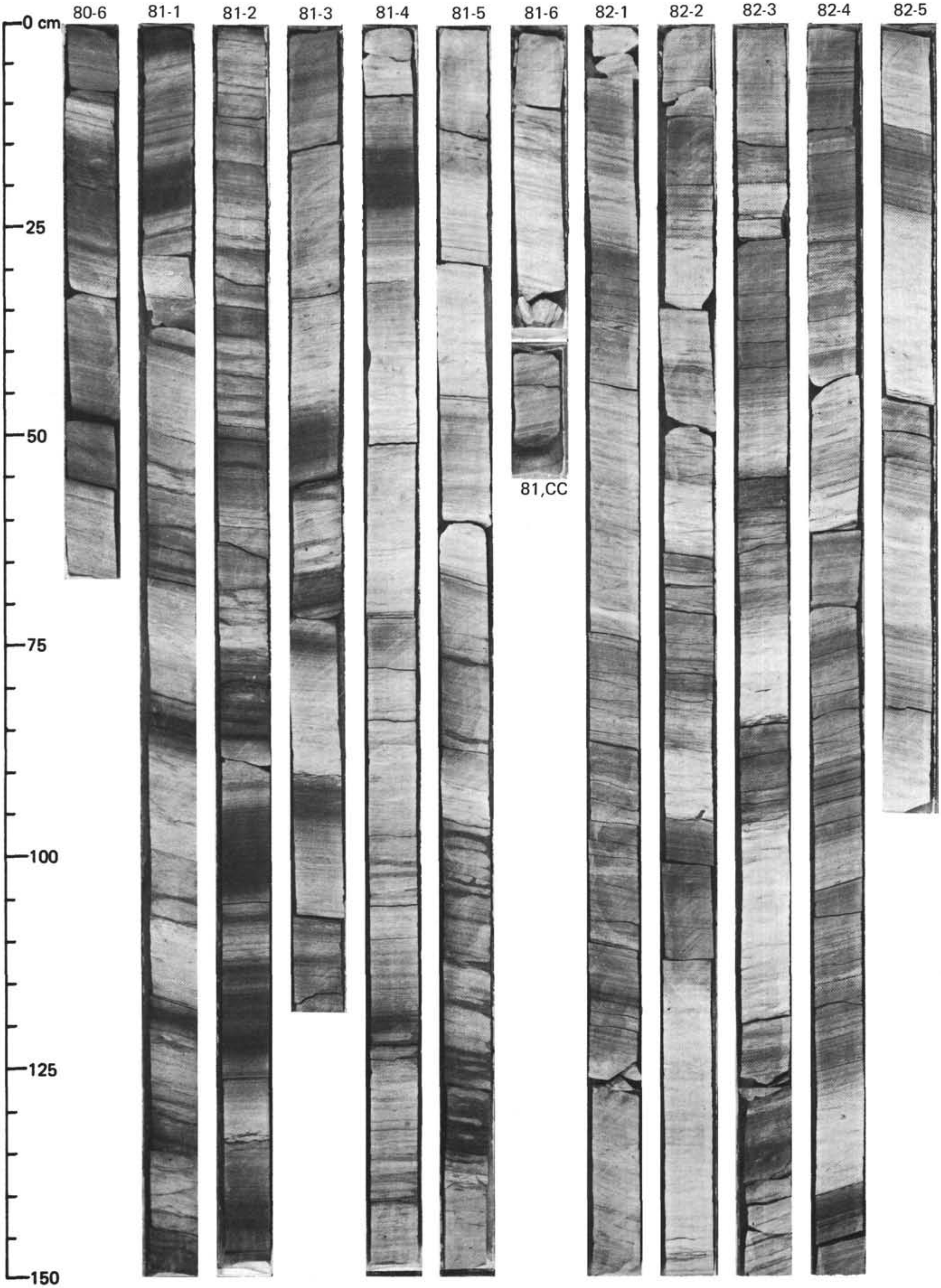
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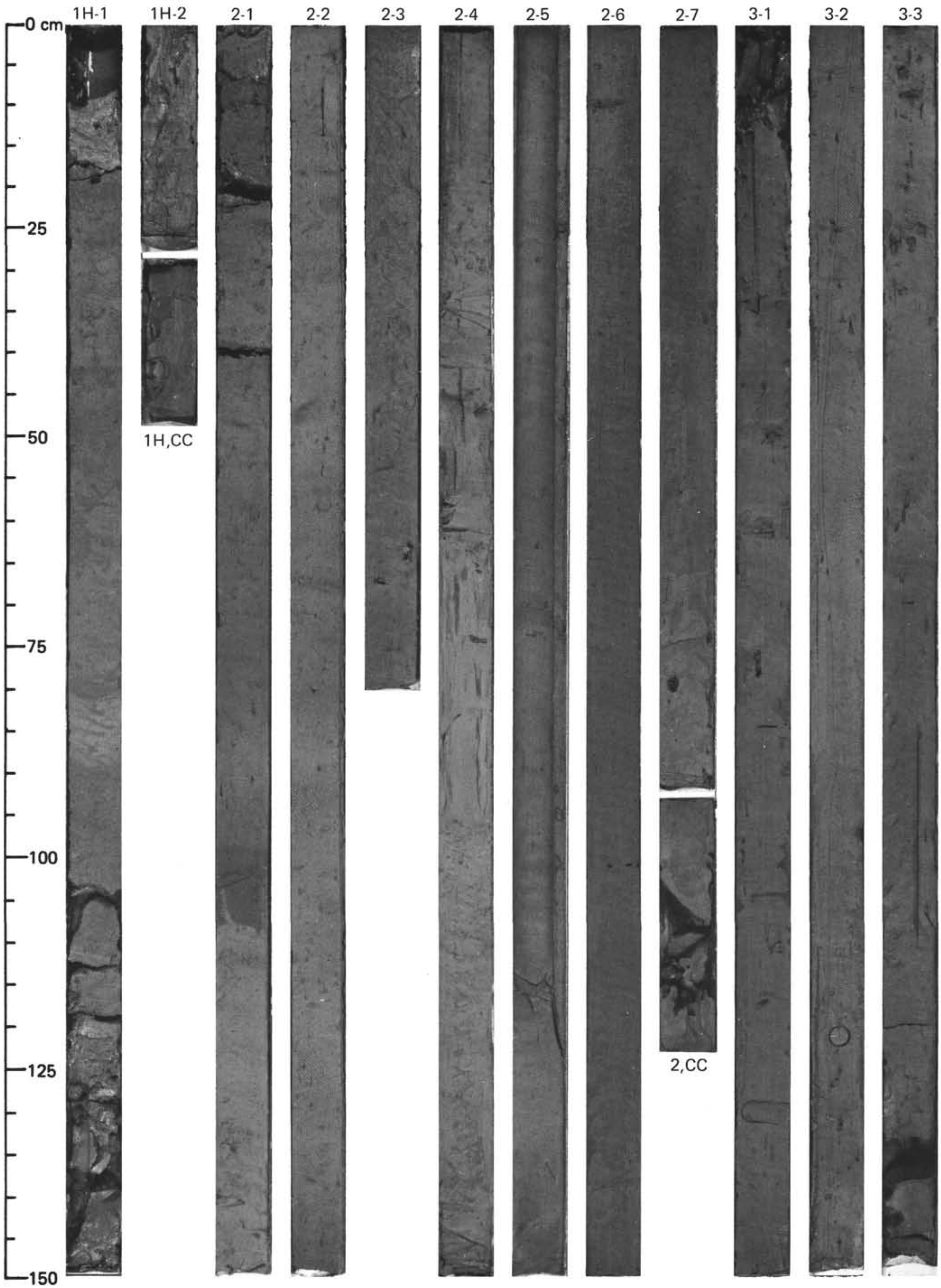
1H-1
1H-2
2-1
2-2
2-3
2-4
2-5
2-6
2-7
3-1
3-2
3-3
0 cm
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75
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125
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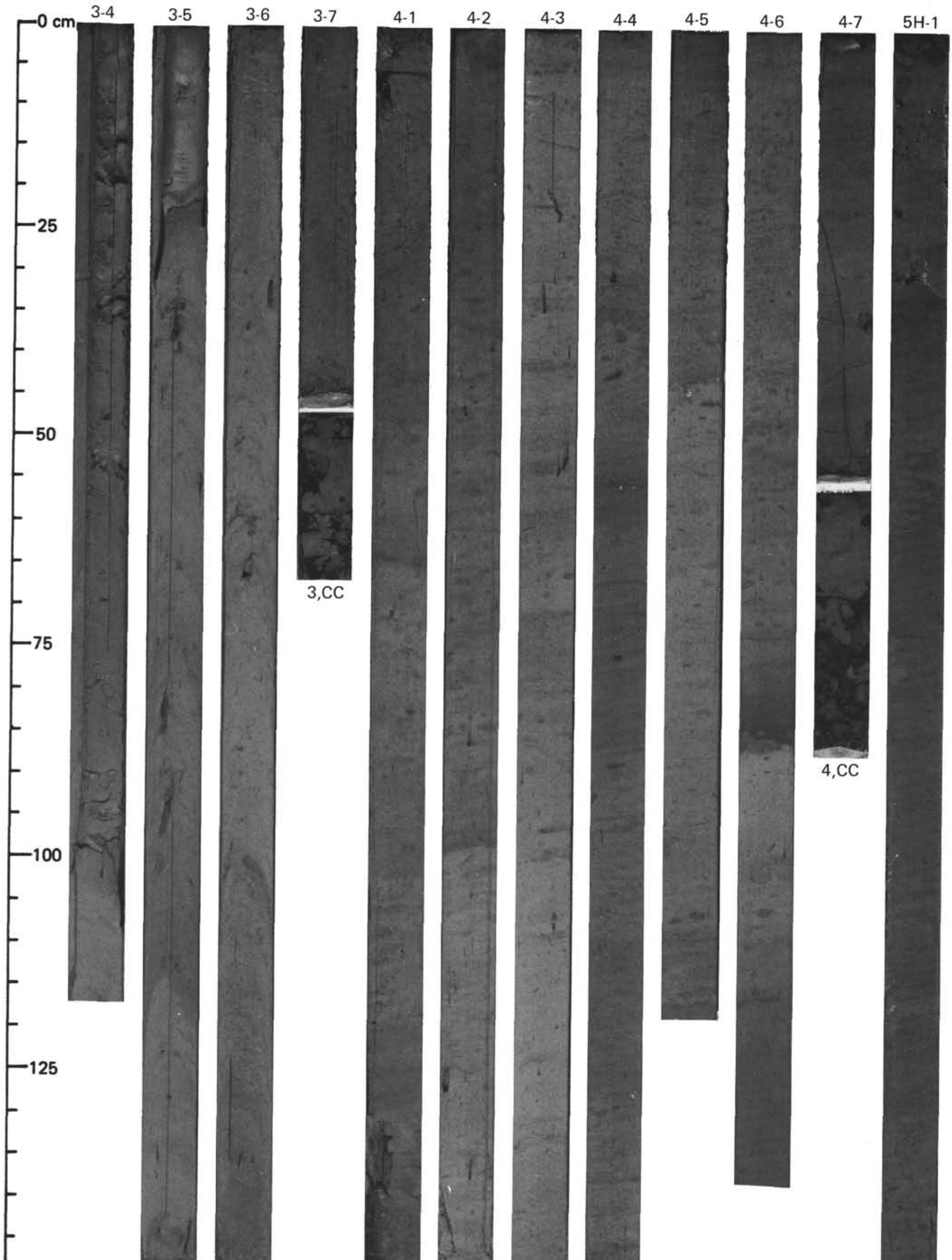
1H,CC
2,CC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3-5
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4-1
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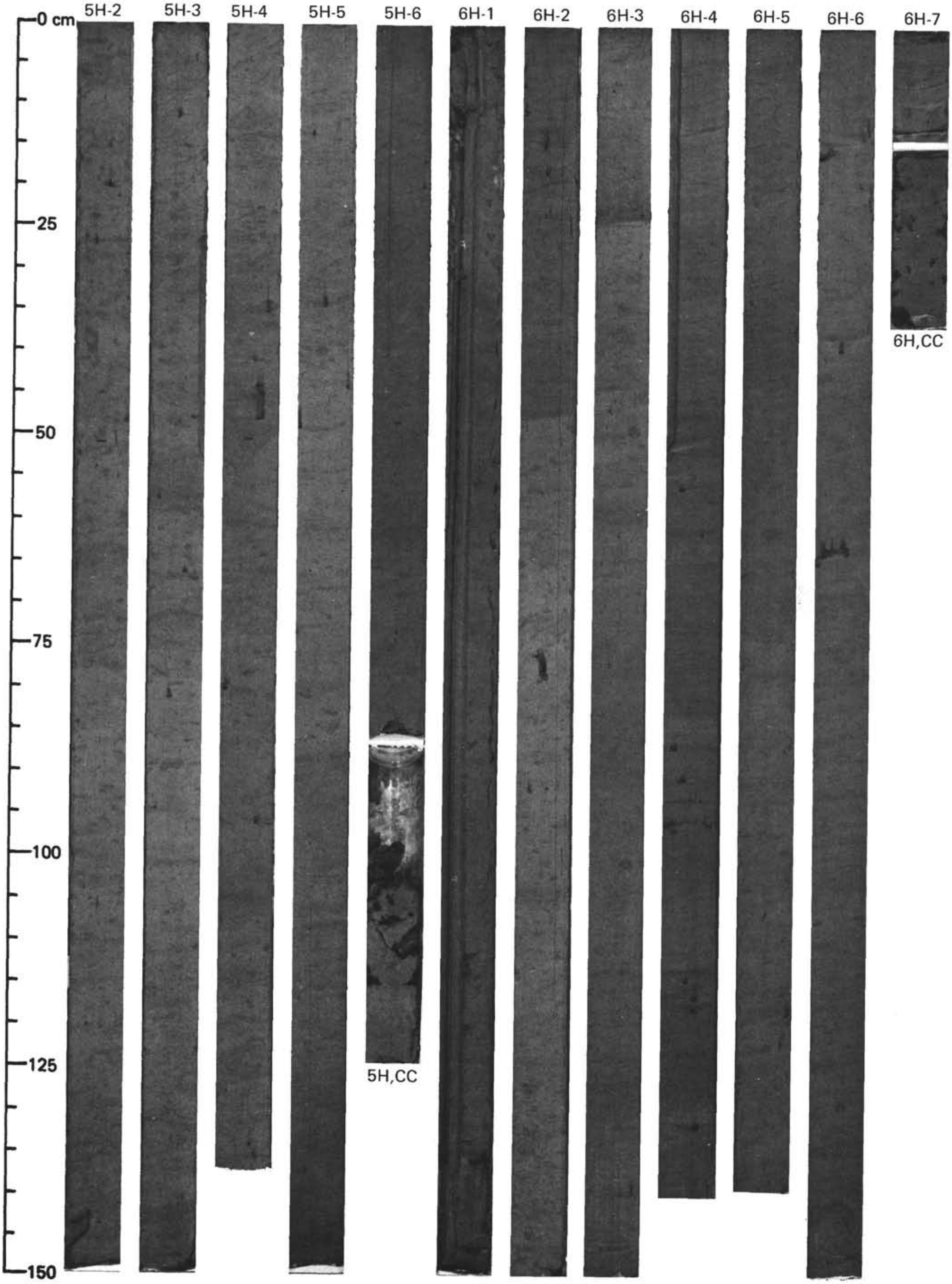
4-3
4-4
4-5
4-6
4-7
4,CC
5H-1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5H-3
5H-4
5H-5
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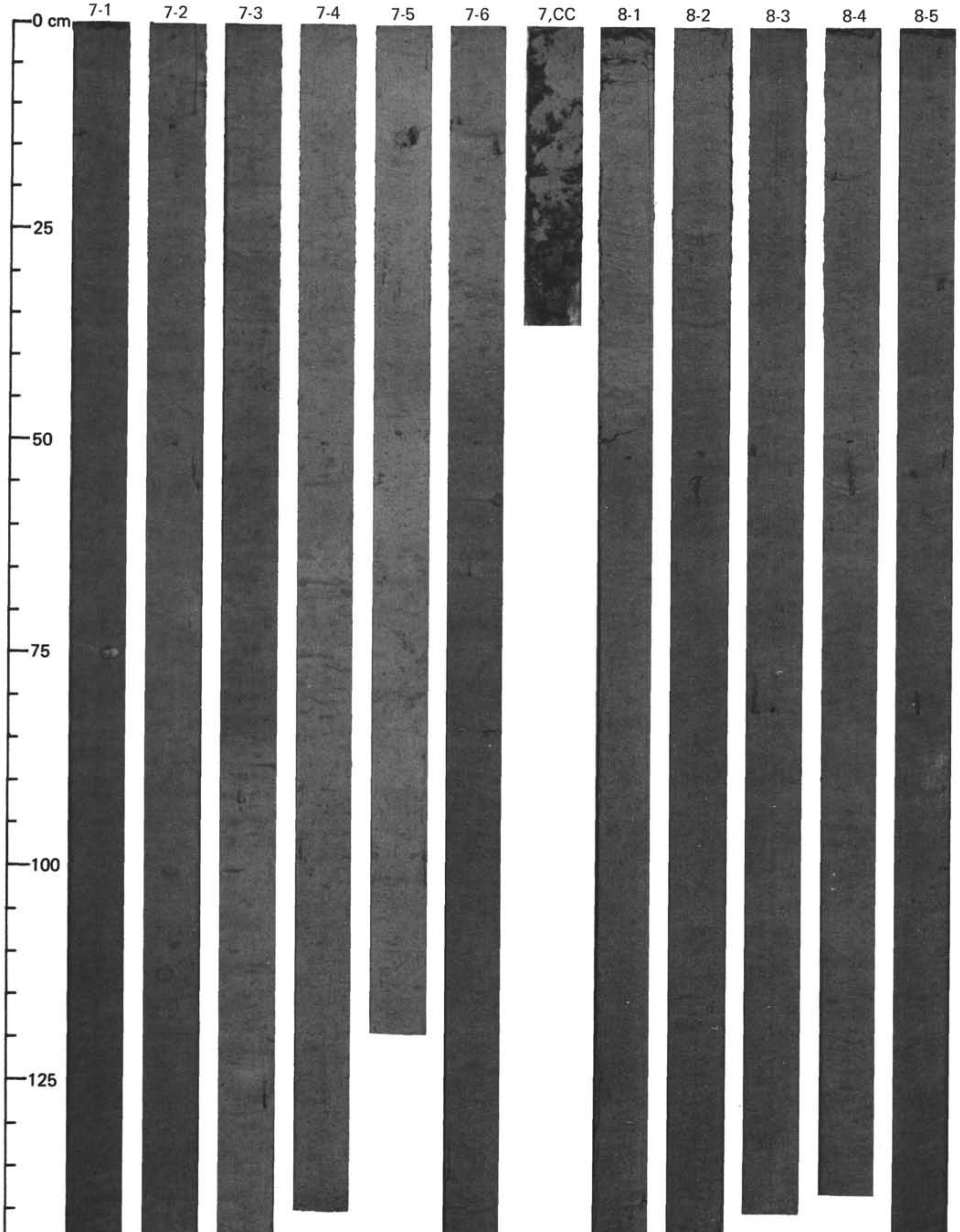
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7-3
7-4
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8-1
8-2
8-3
8-4
8-5
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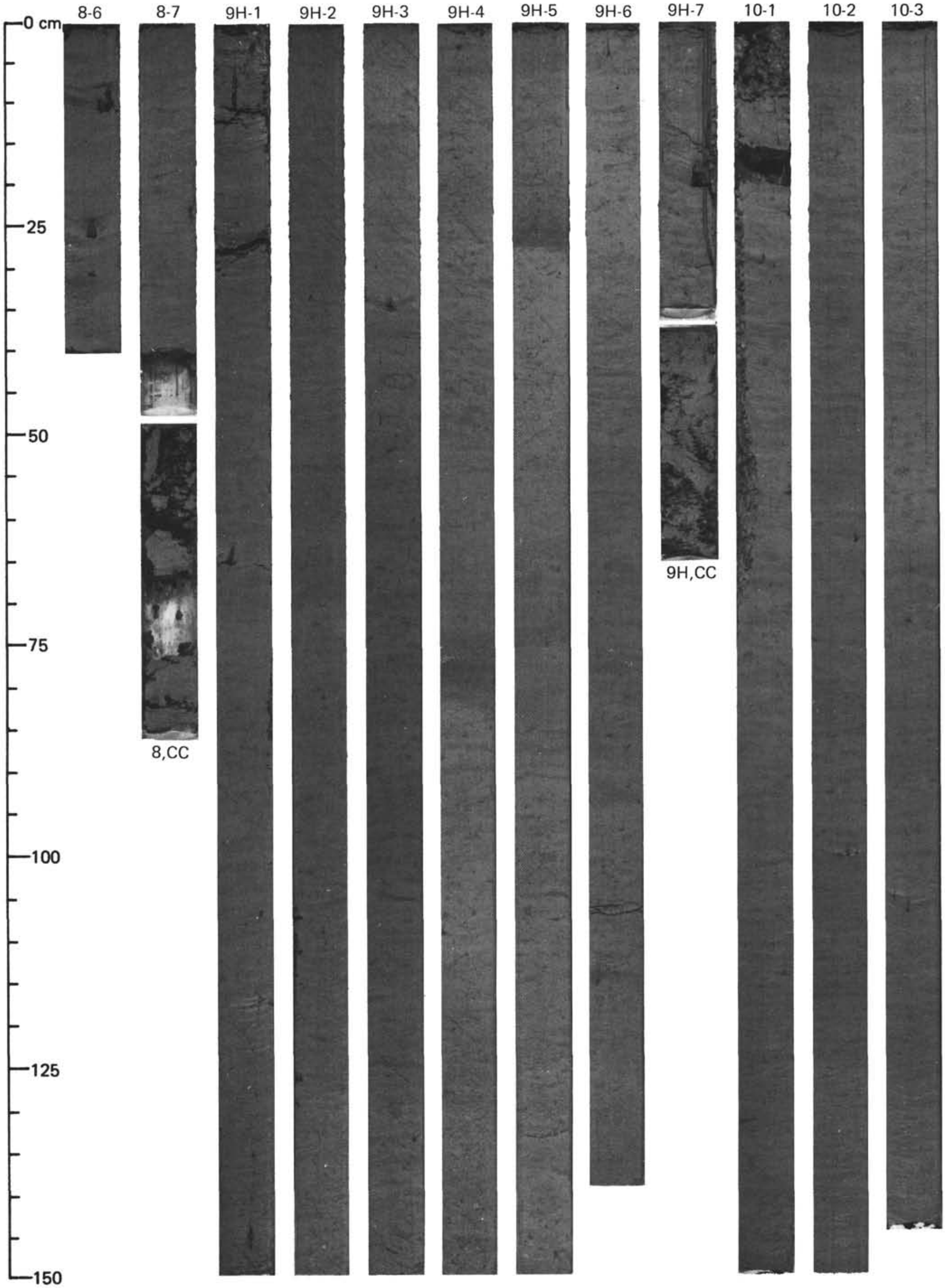
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9H-1
9H-2
9H-3
9H-4
9H-5
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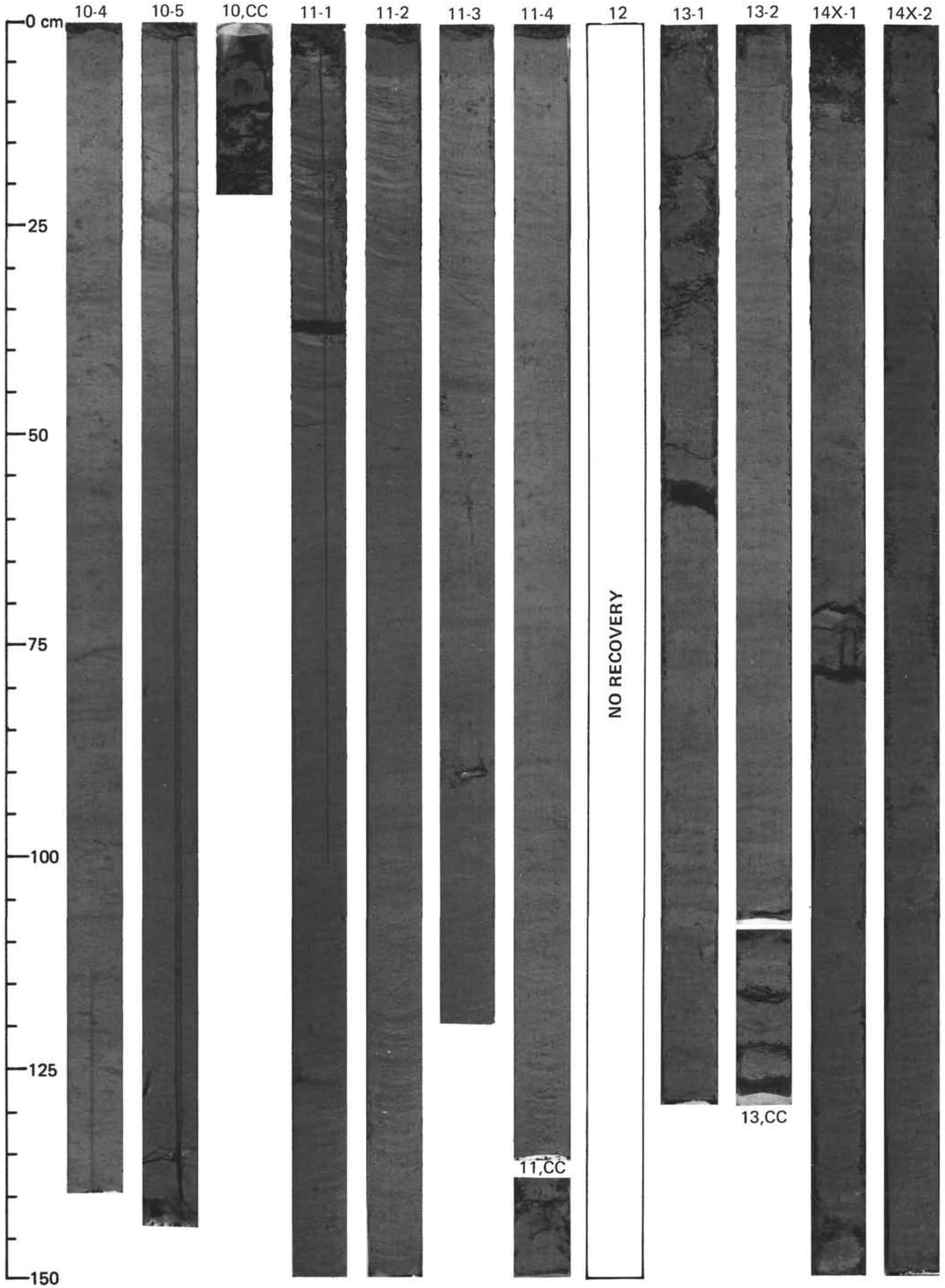
9H,CC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13-2
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14X-2
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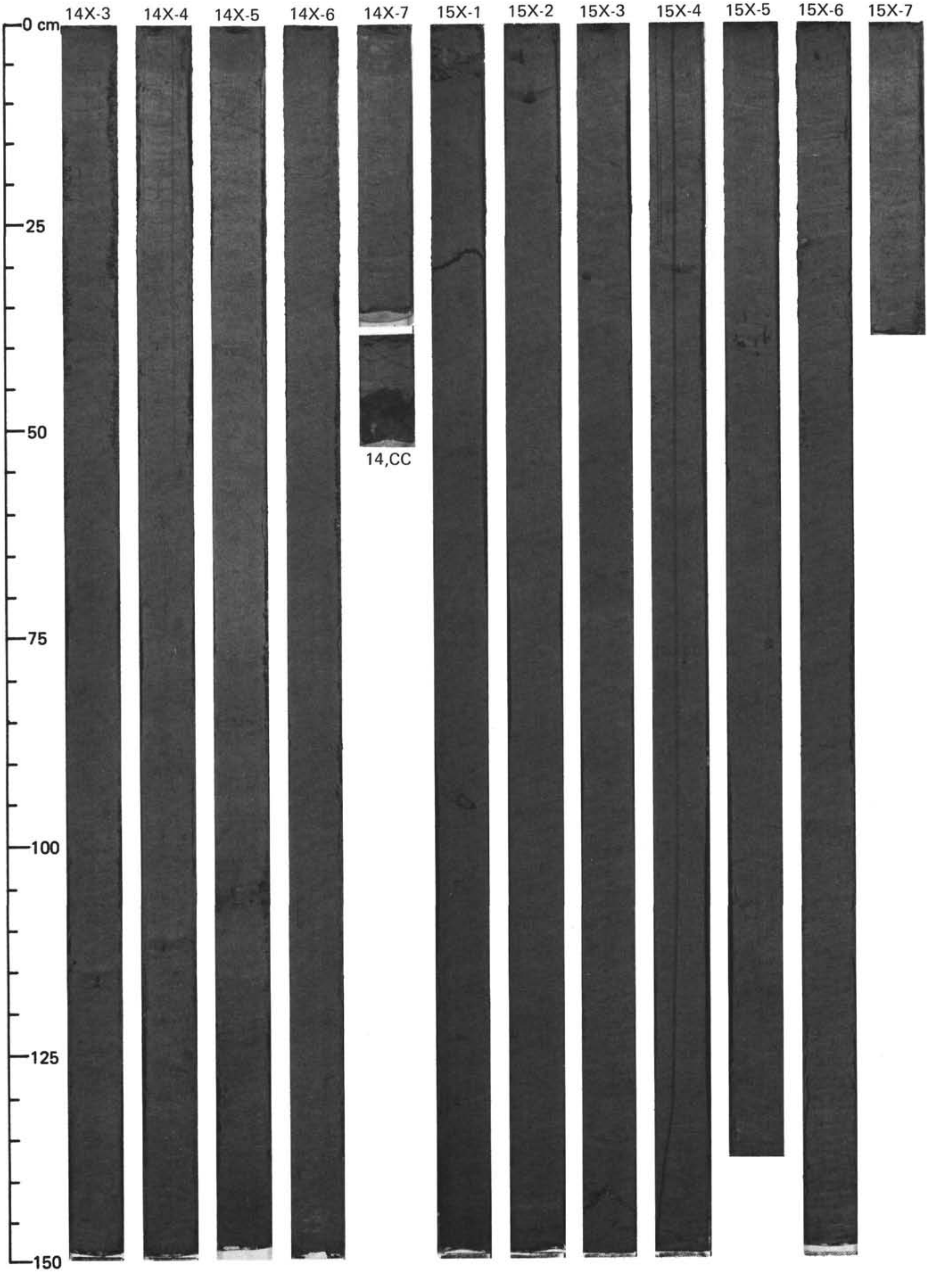
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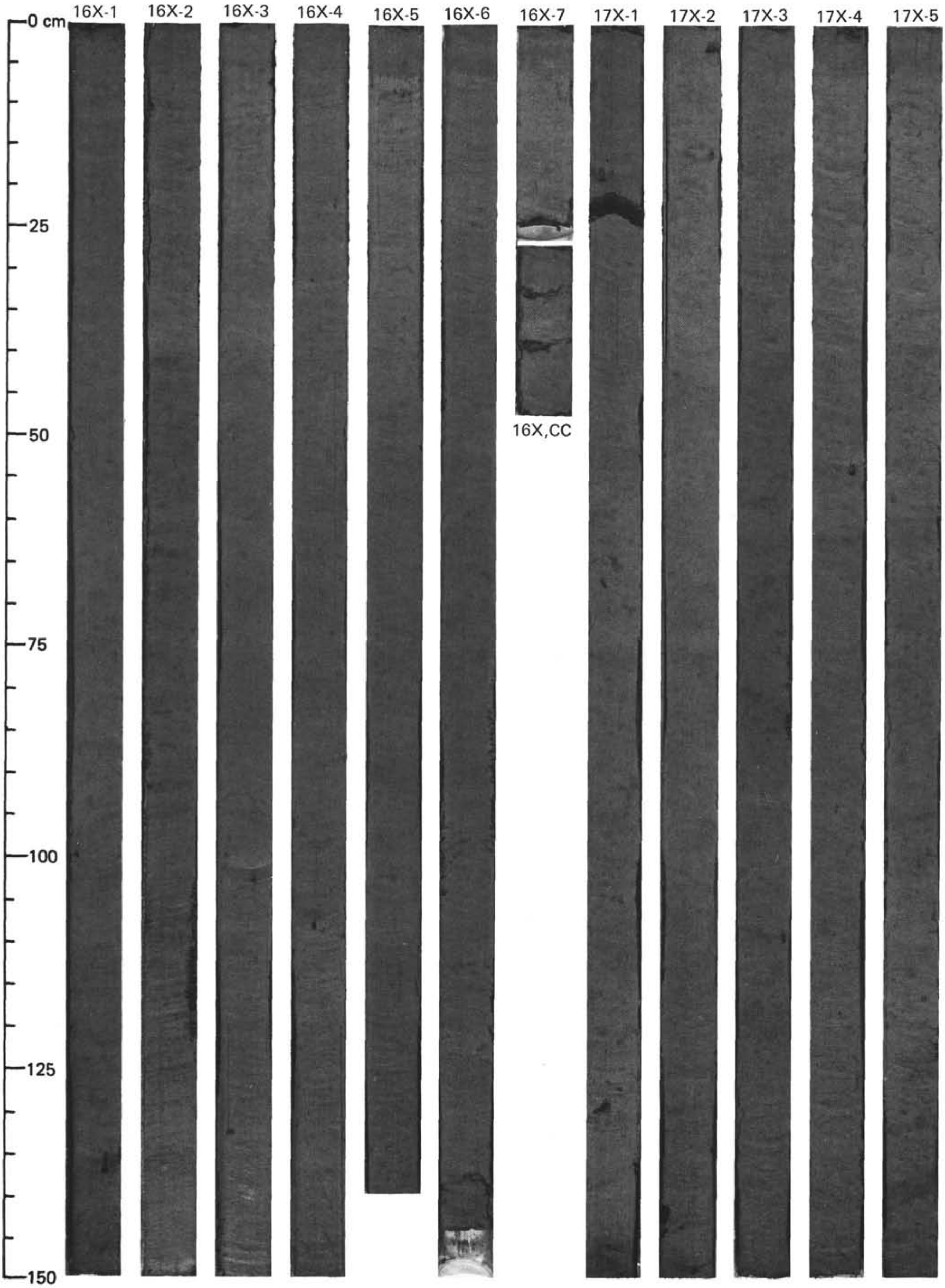
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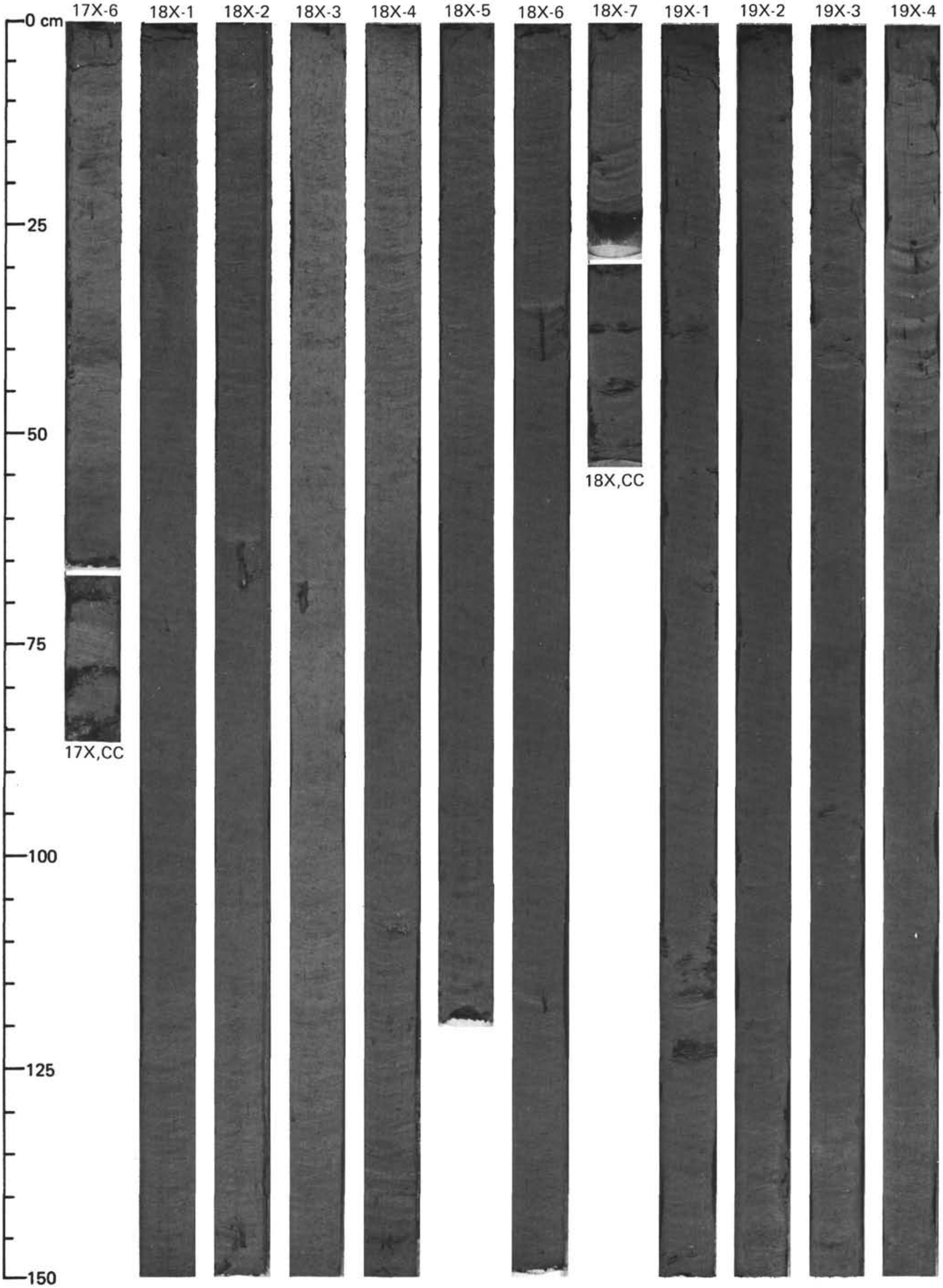
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18X-1
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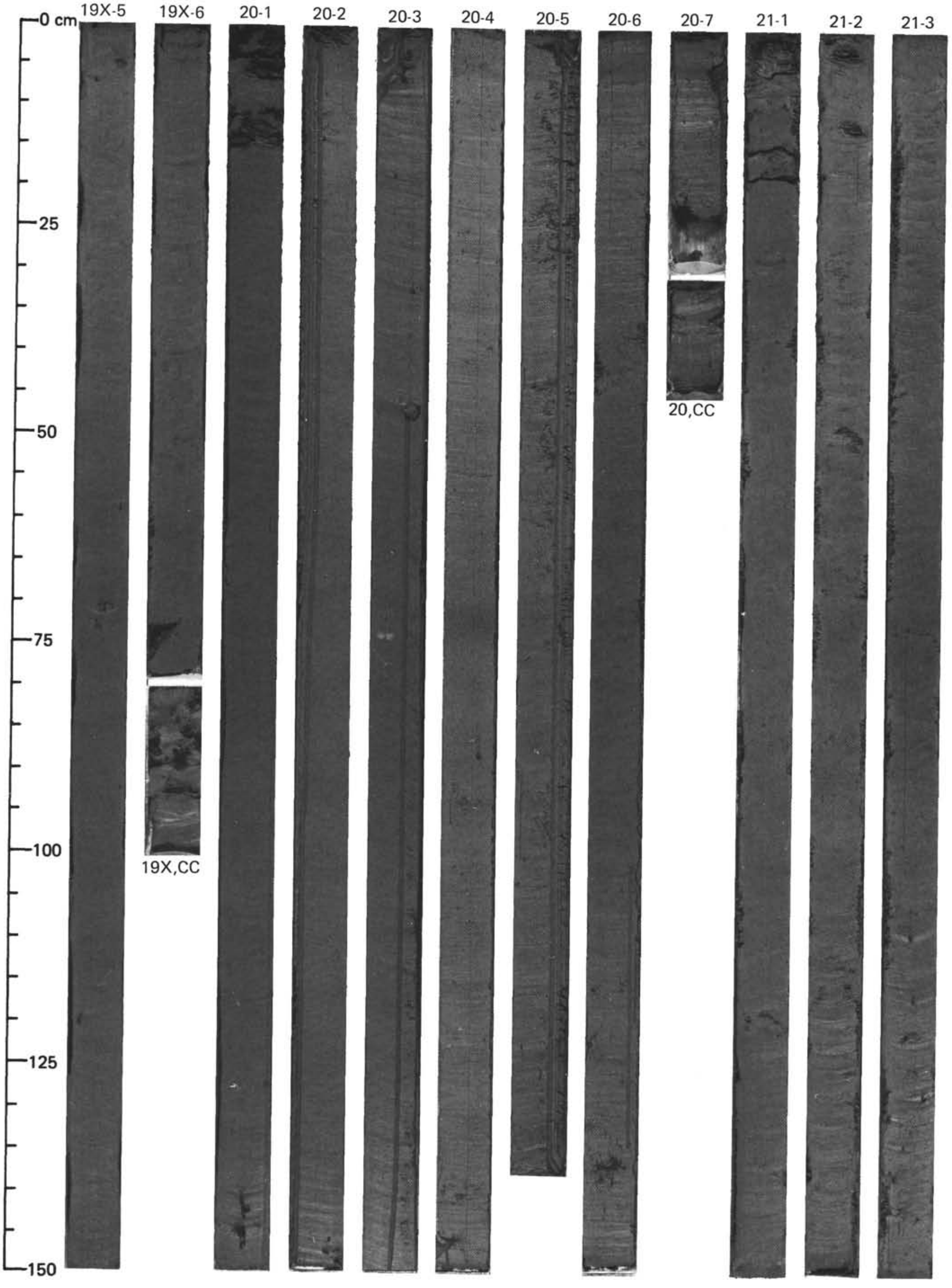
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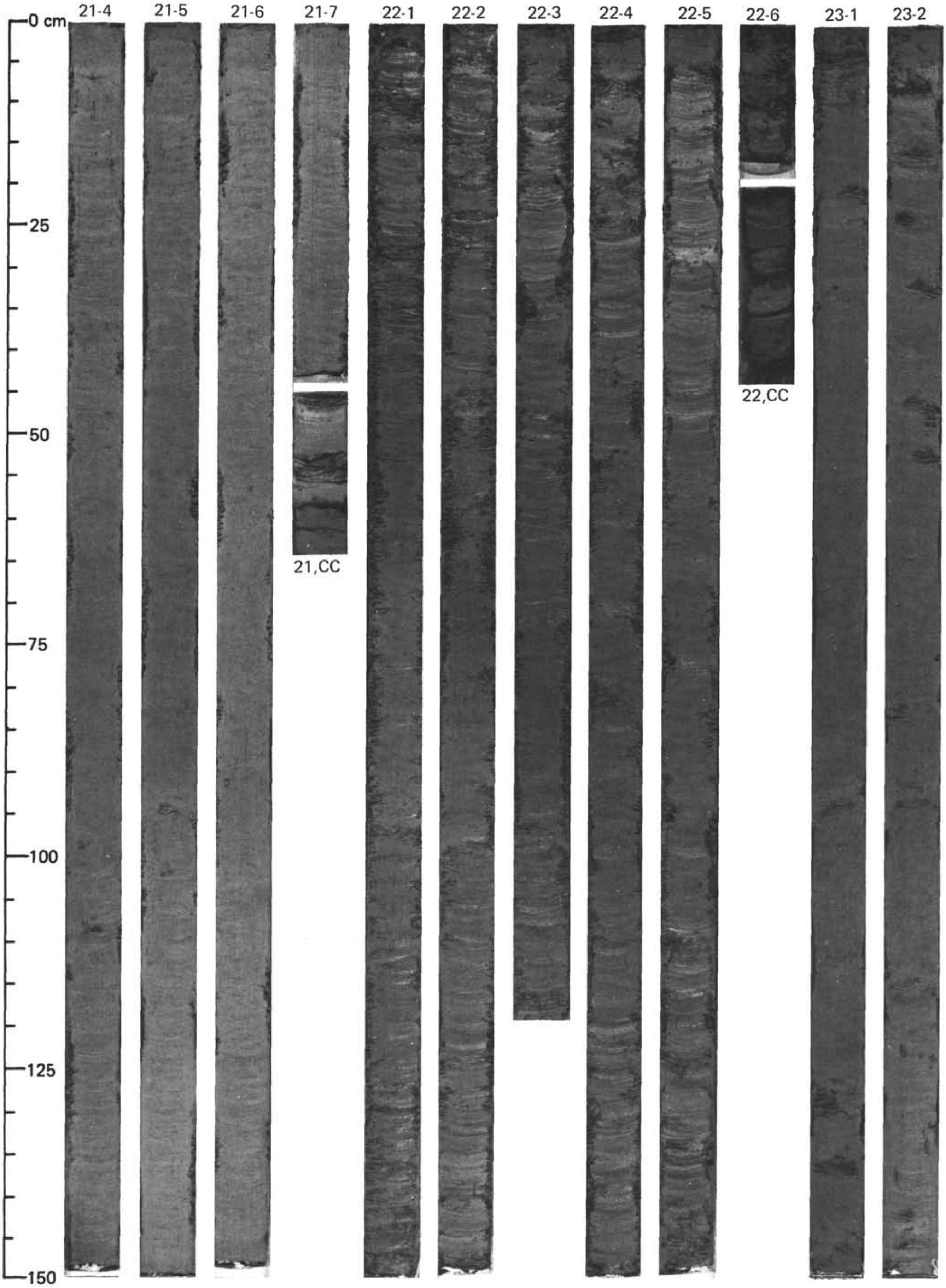
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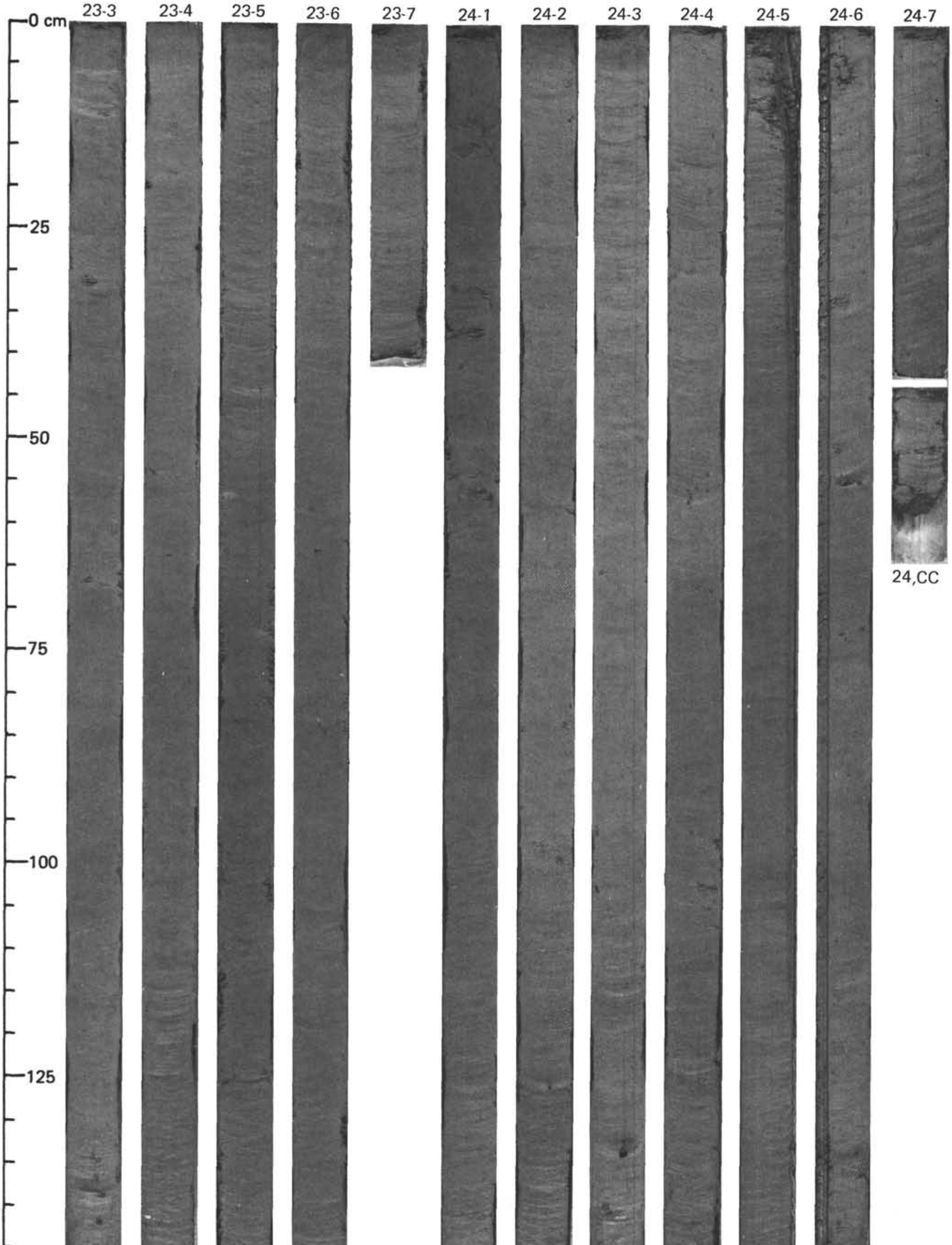

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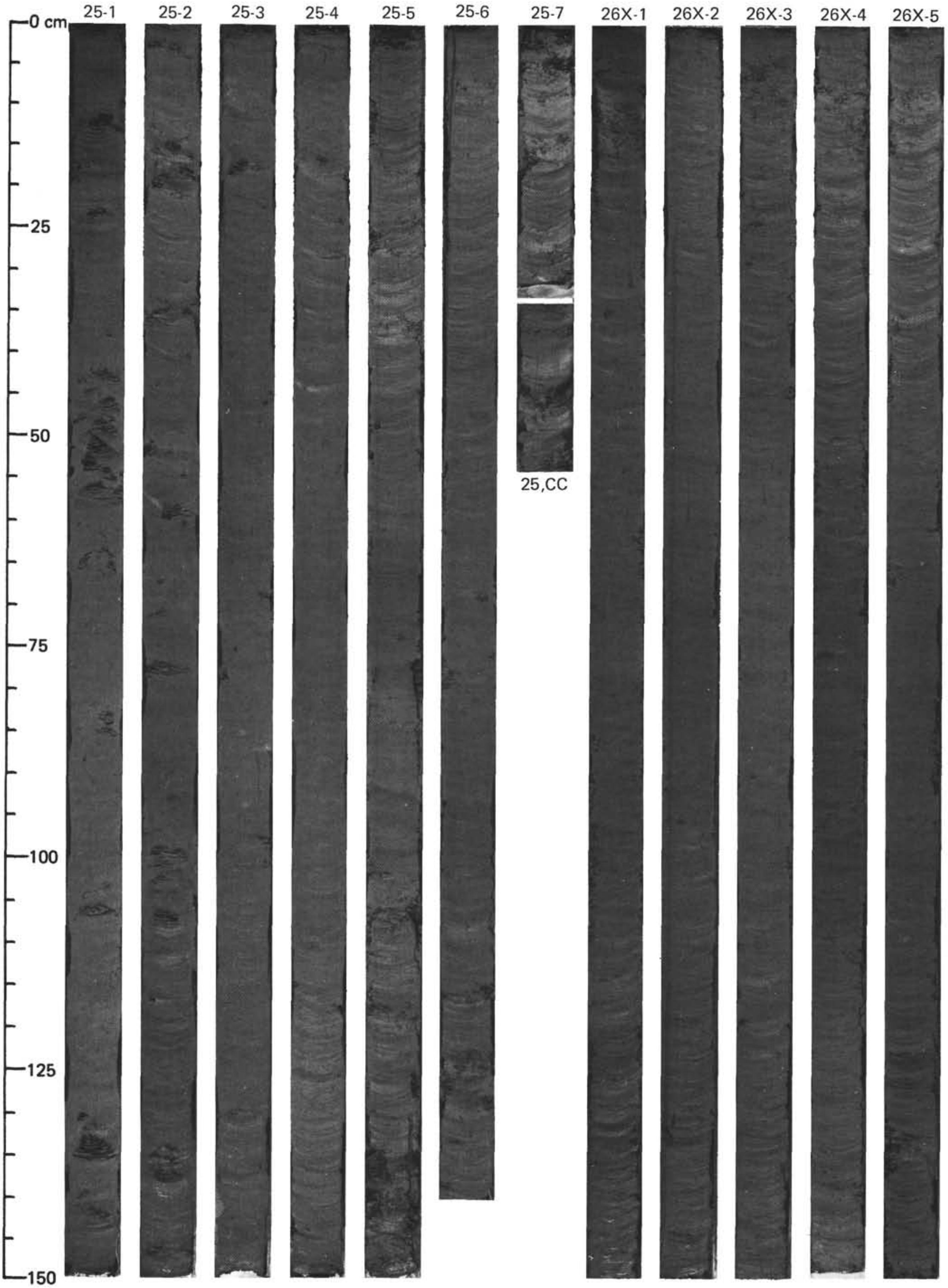
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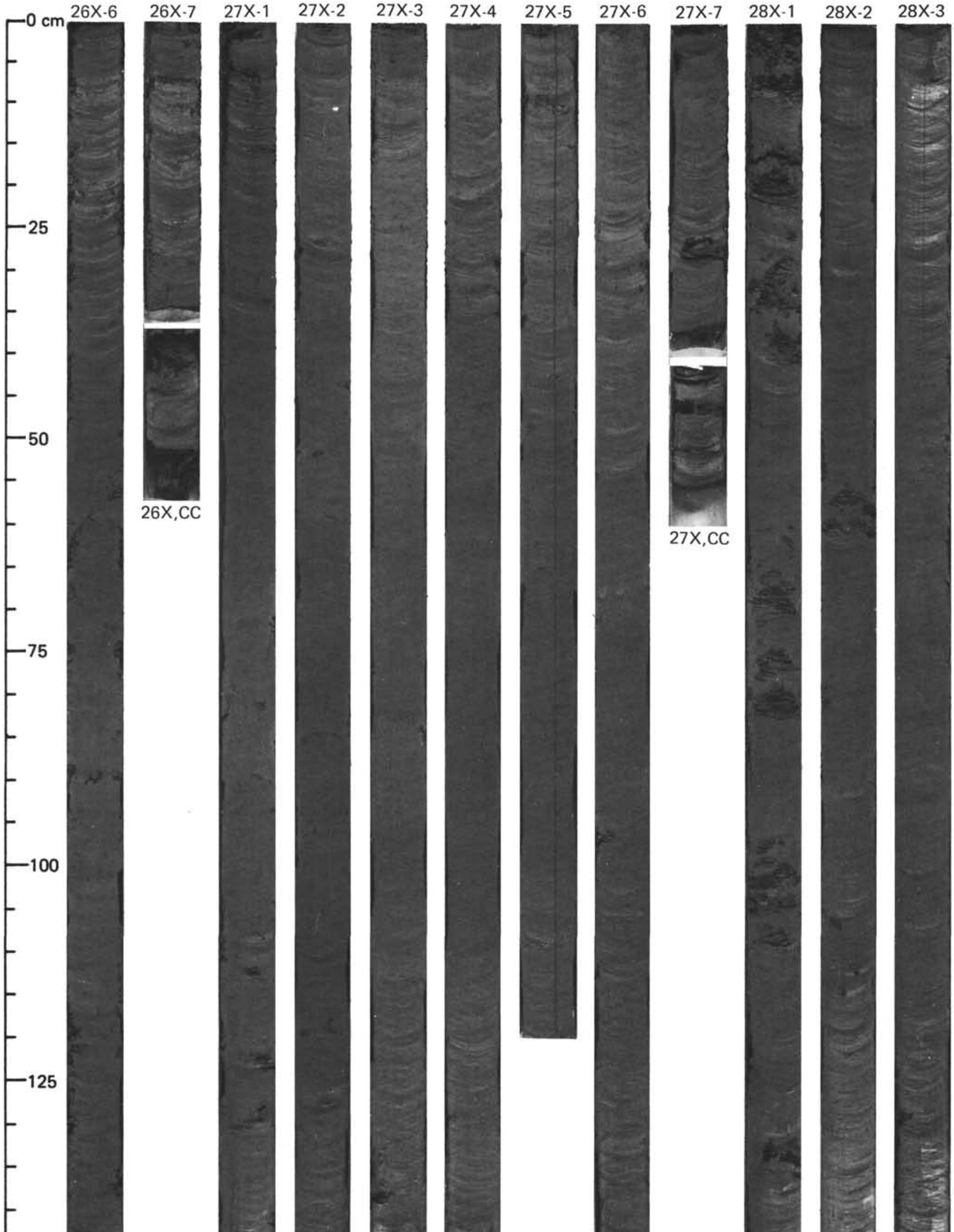
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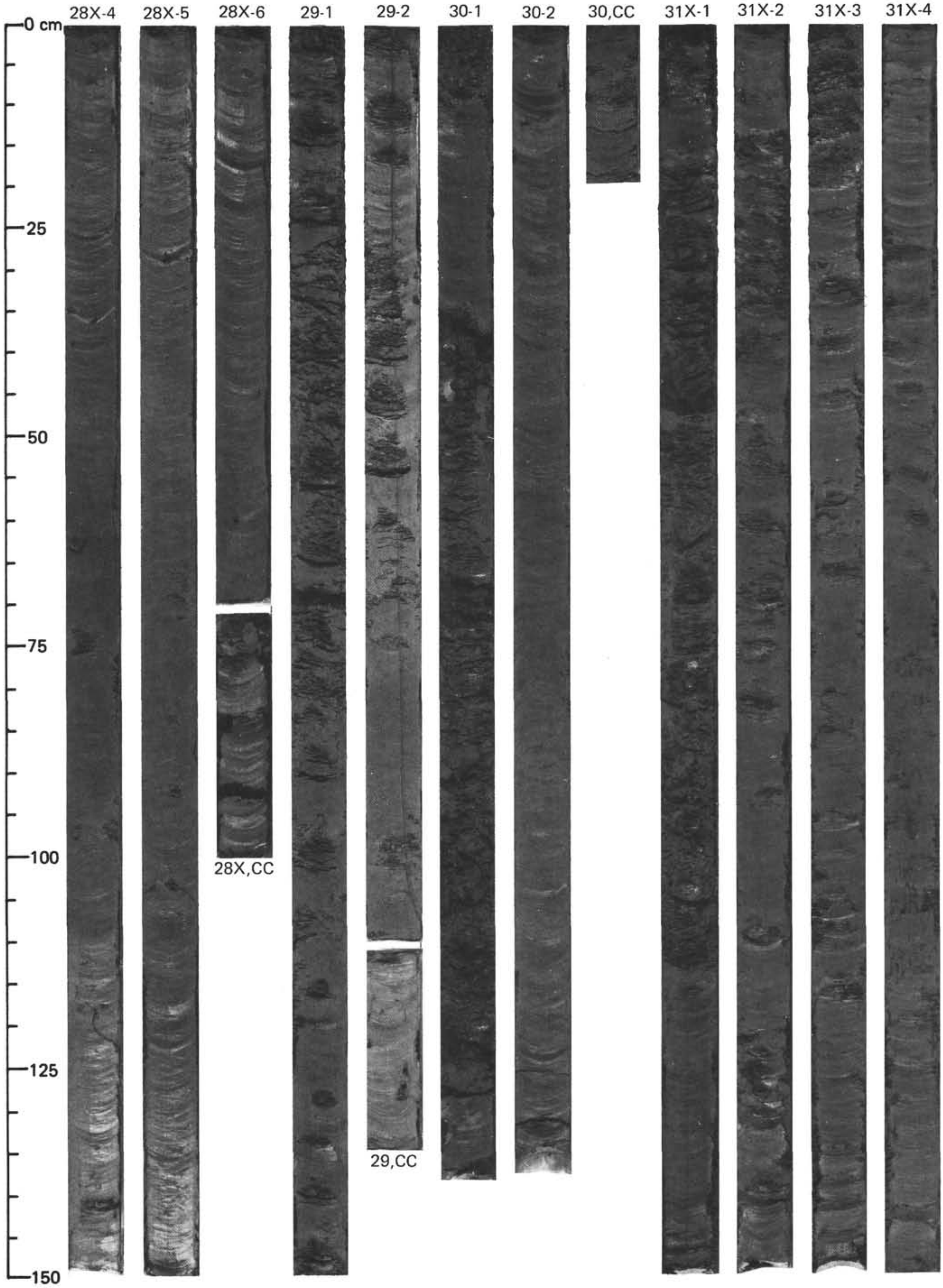
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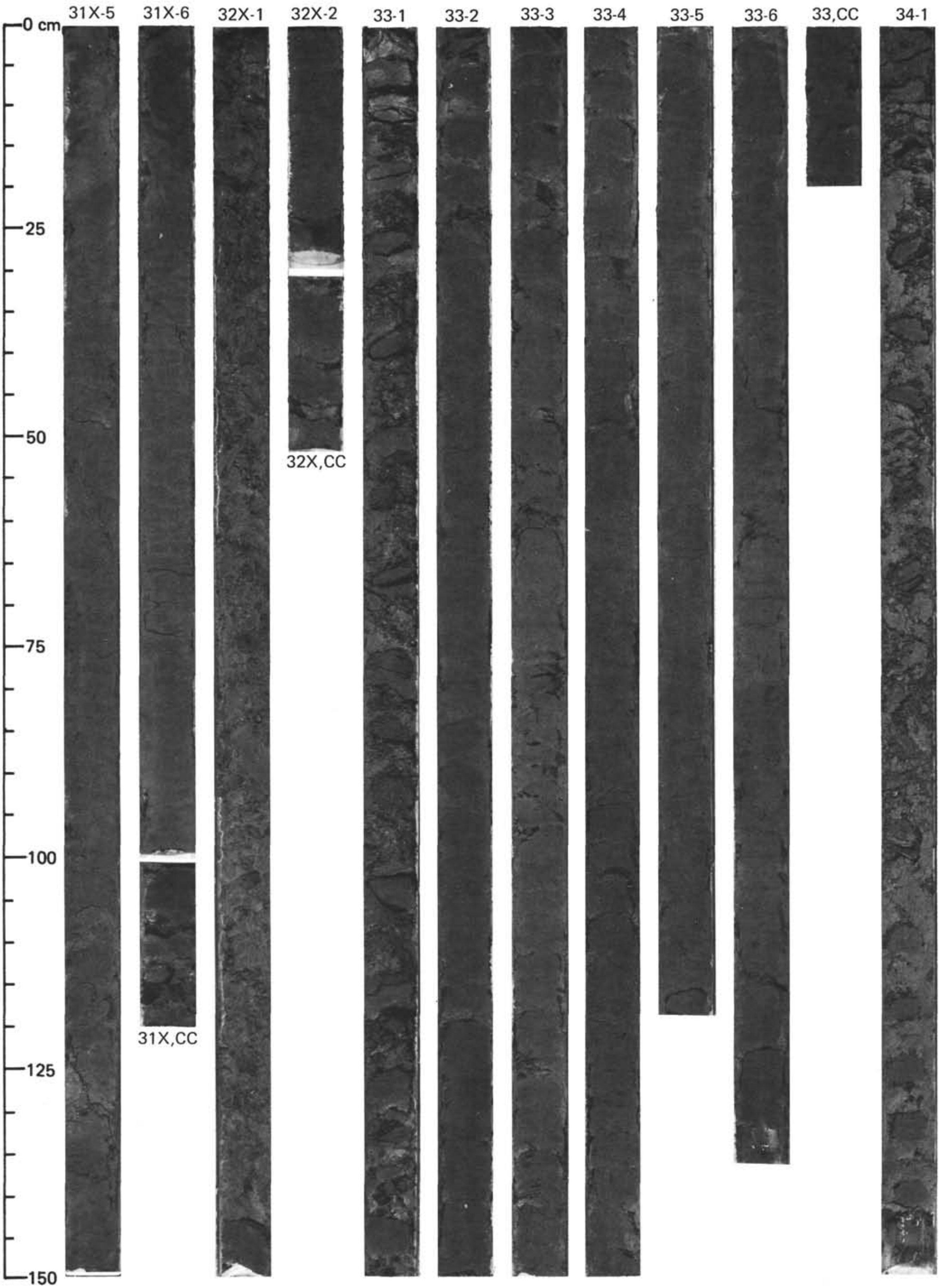
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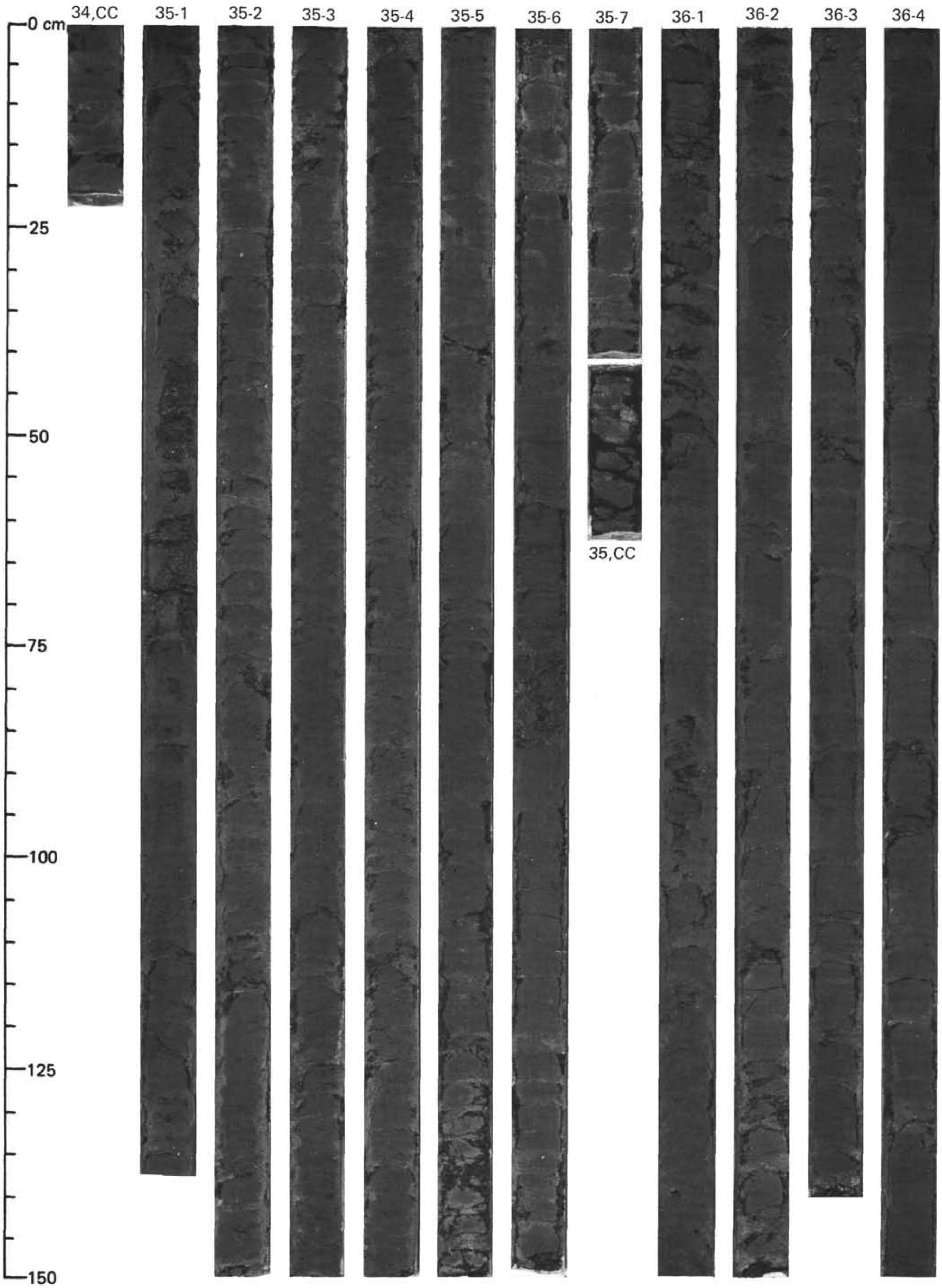
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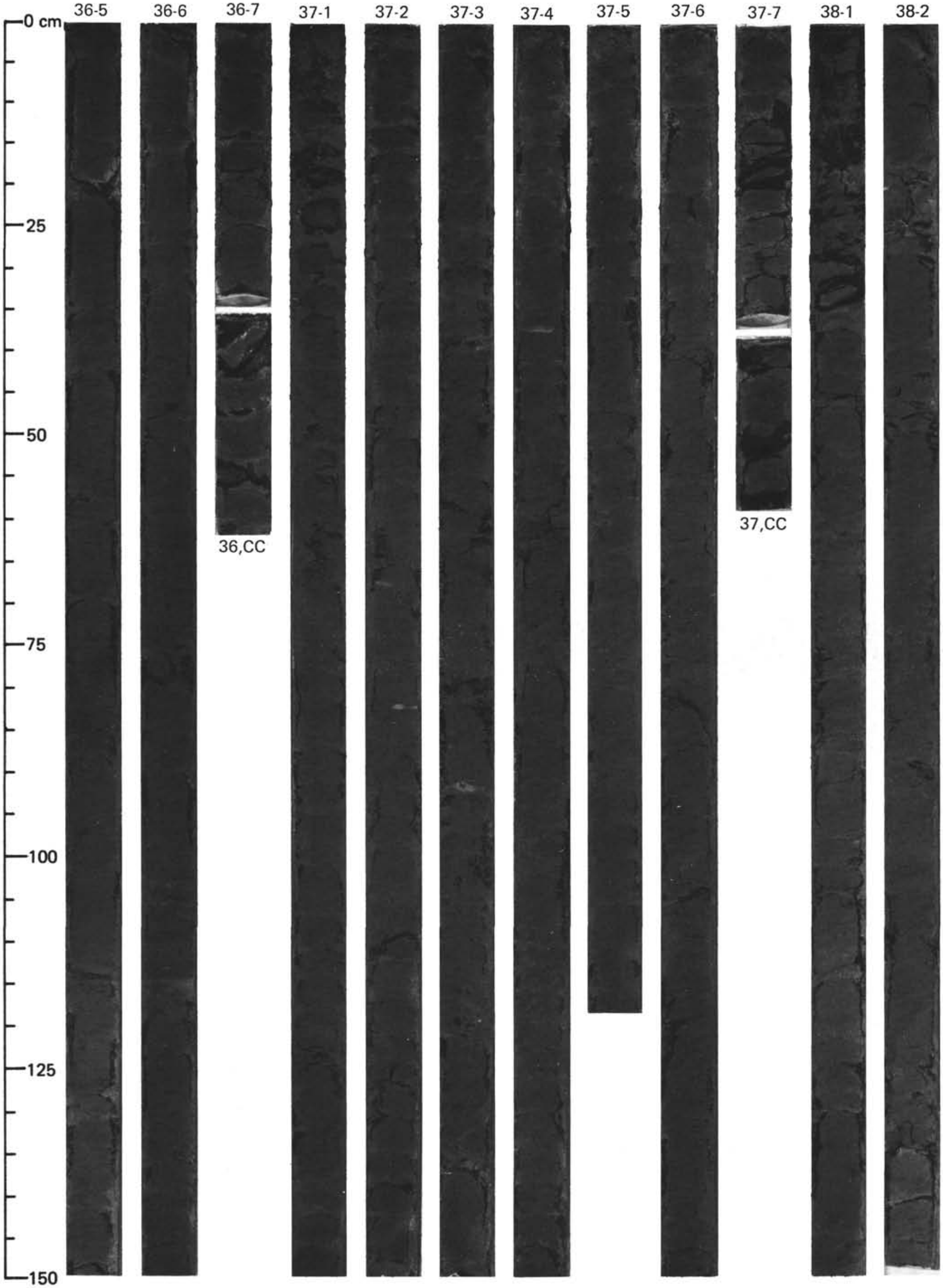
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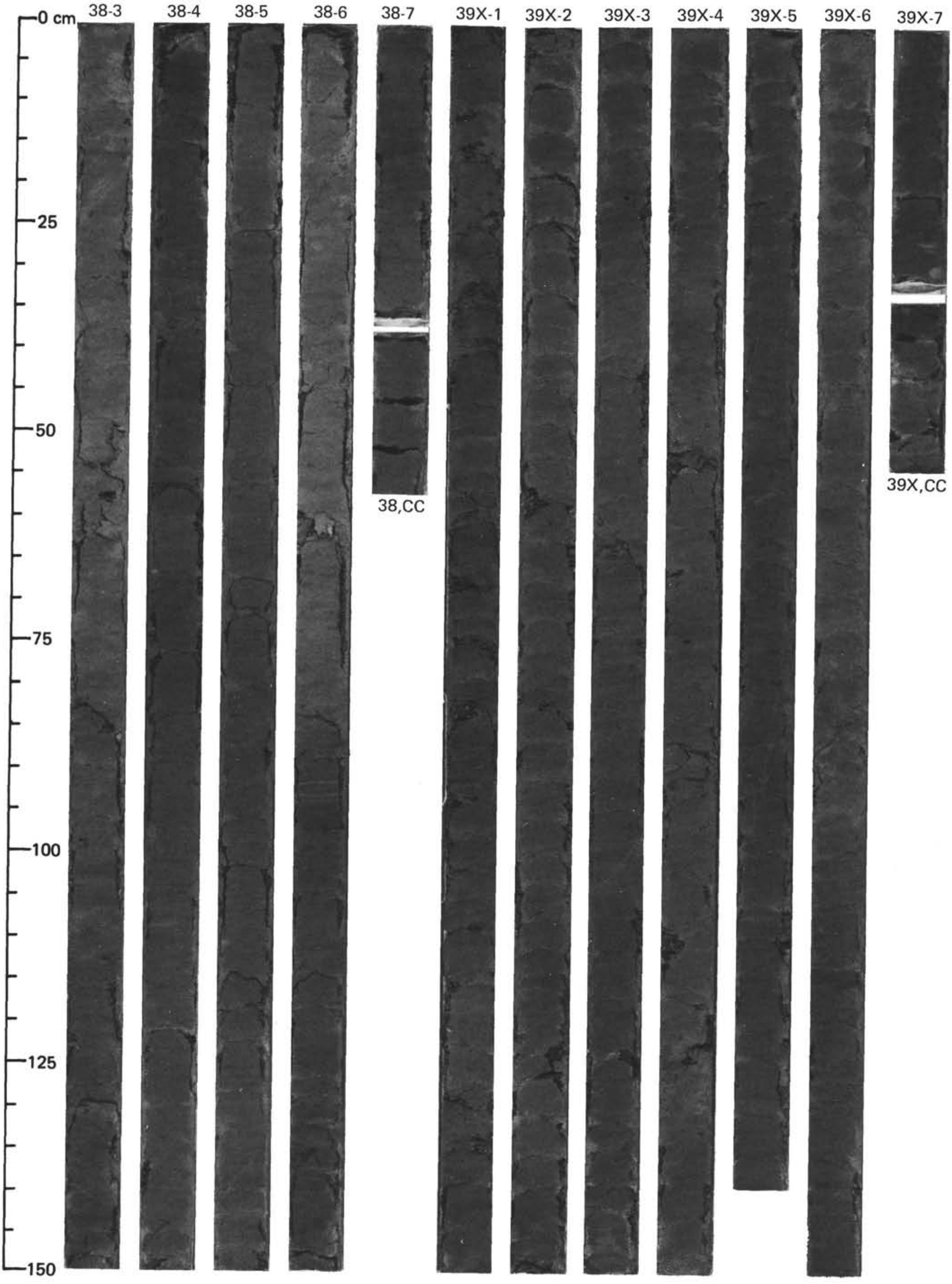
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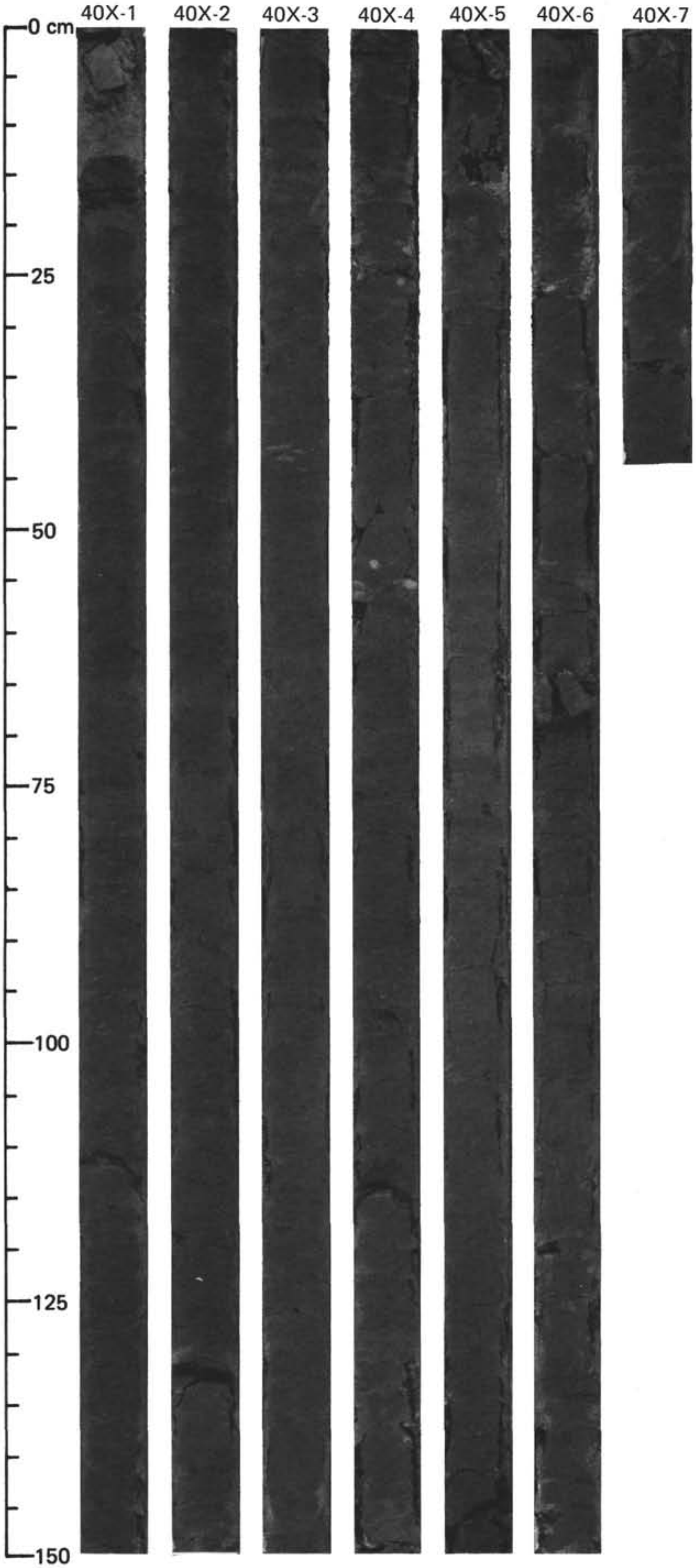
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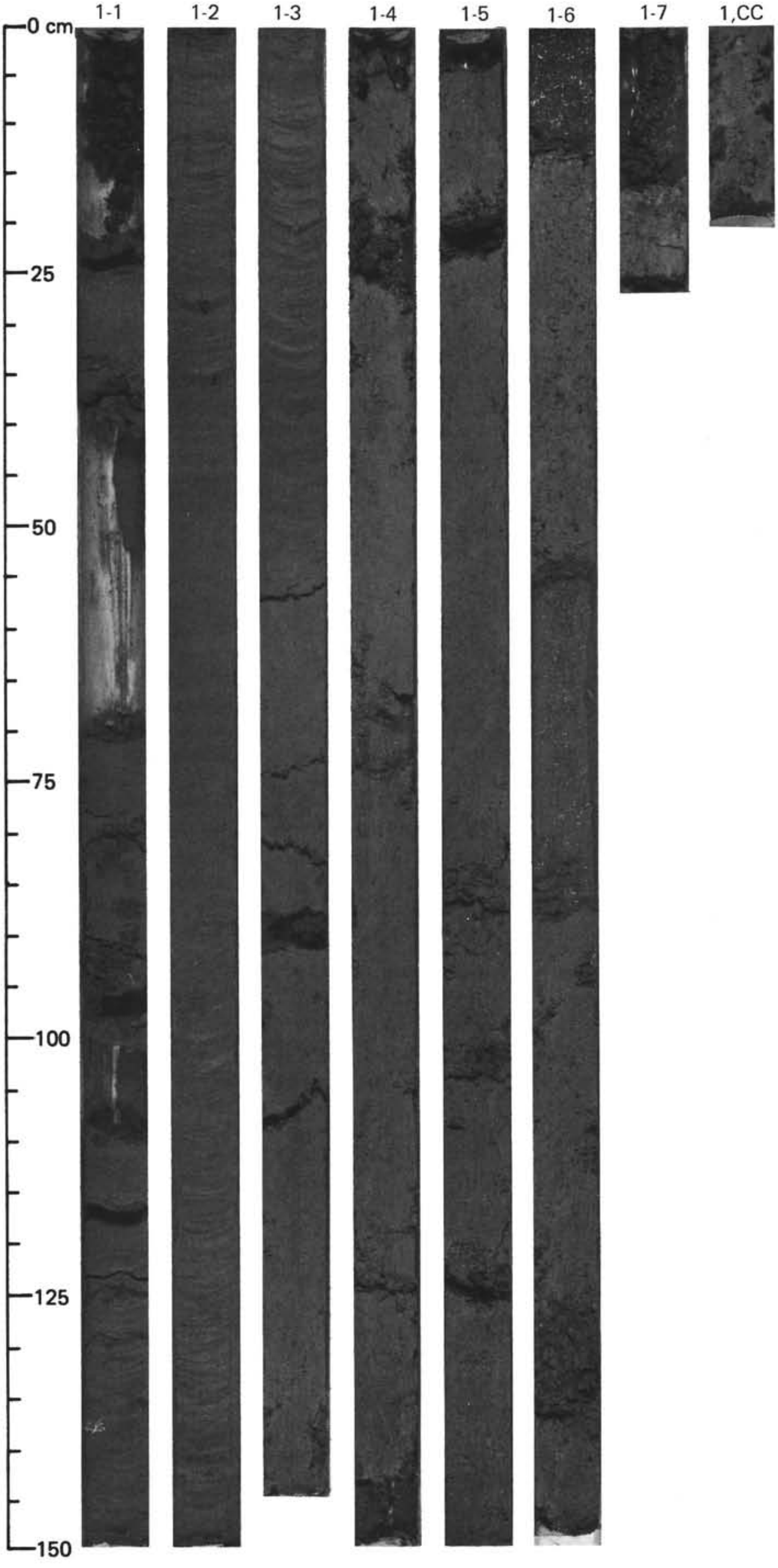
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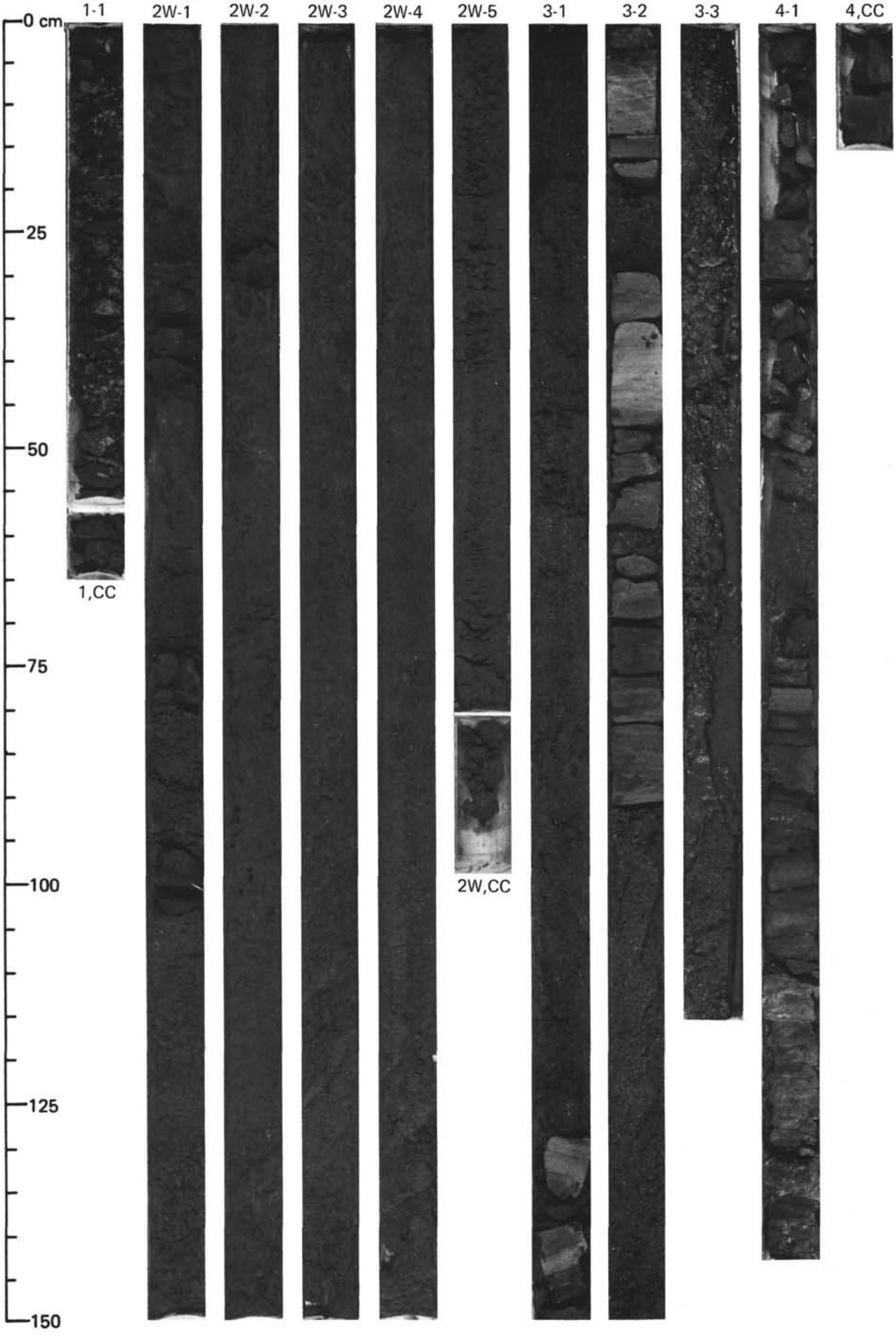
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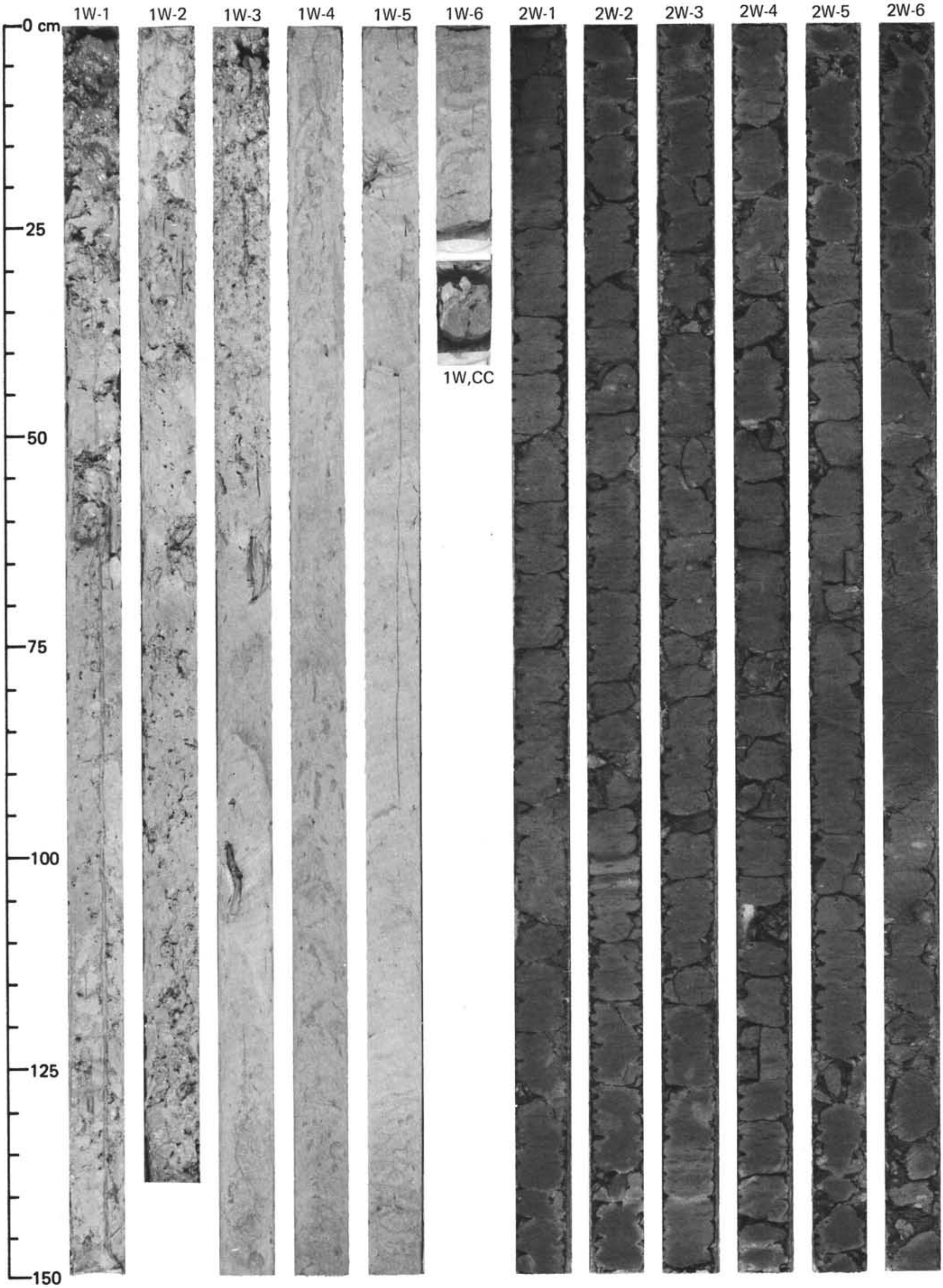
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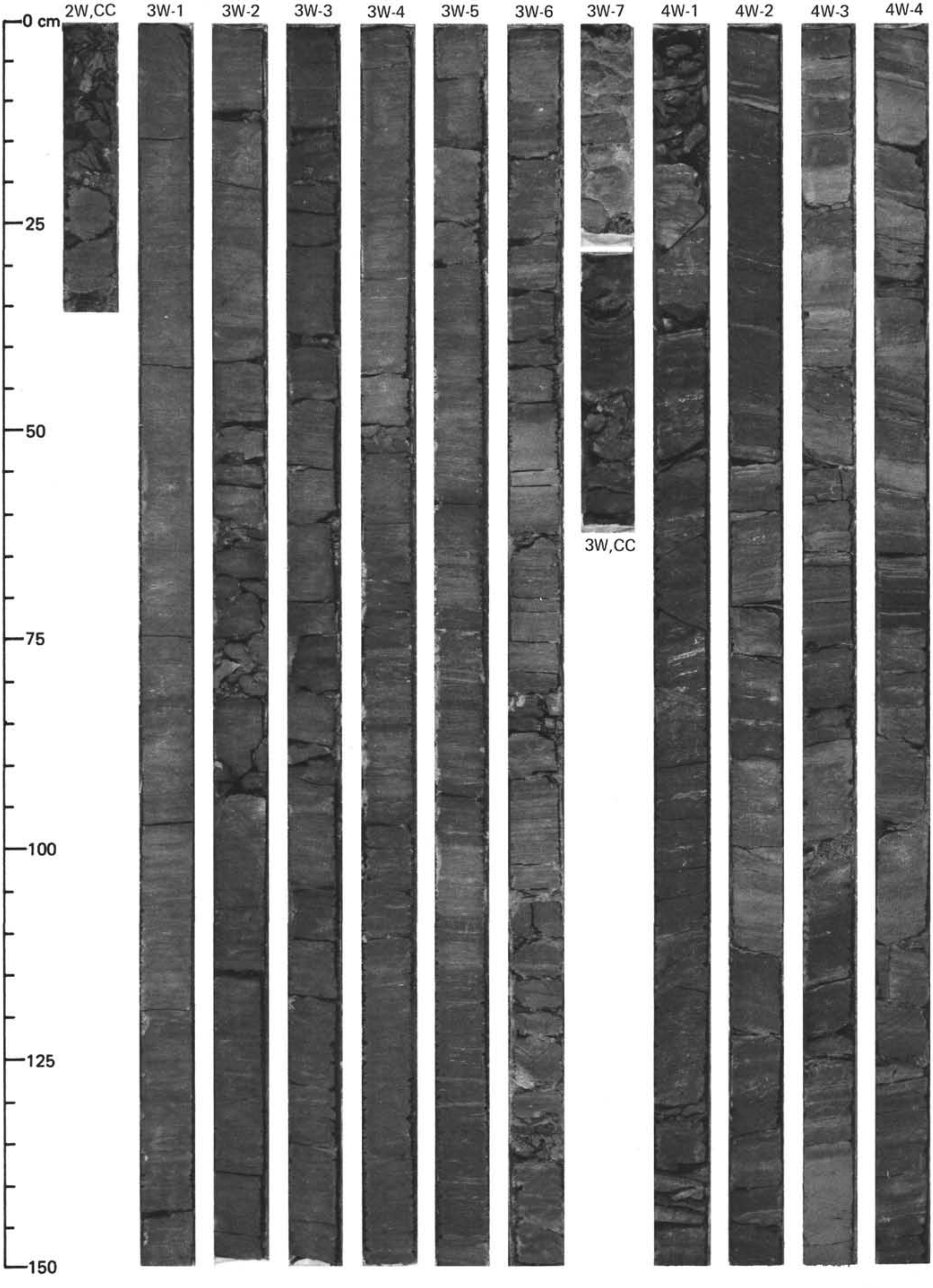
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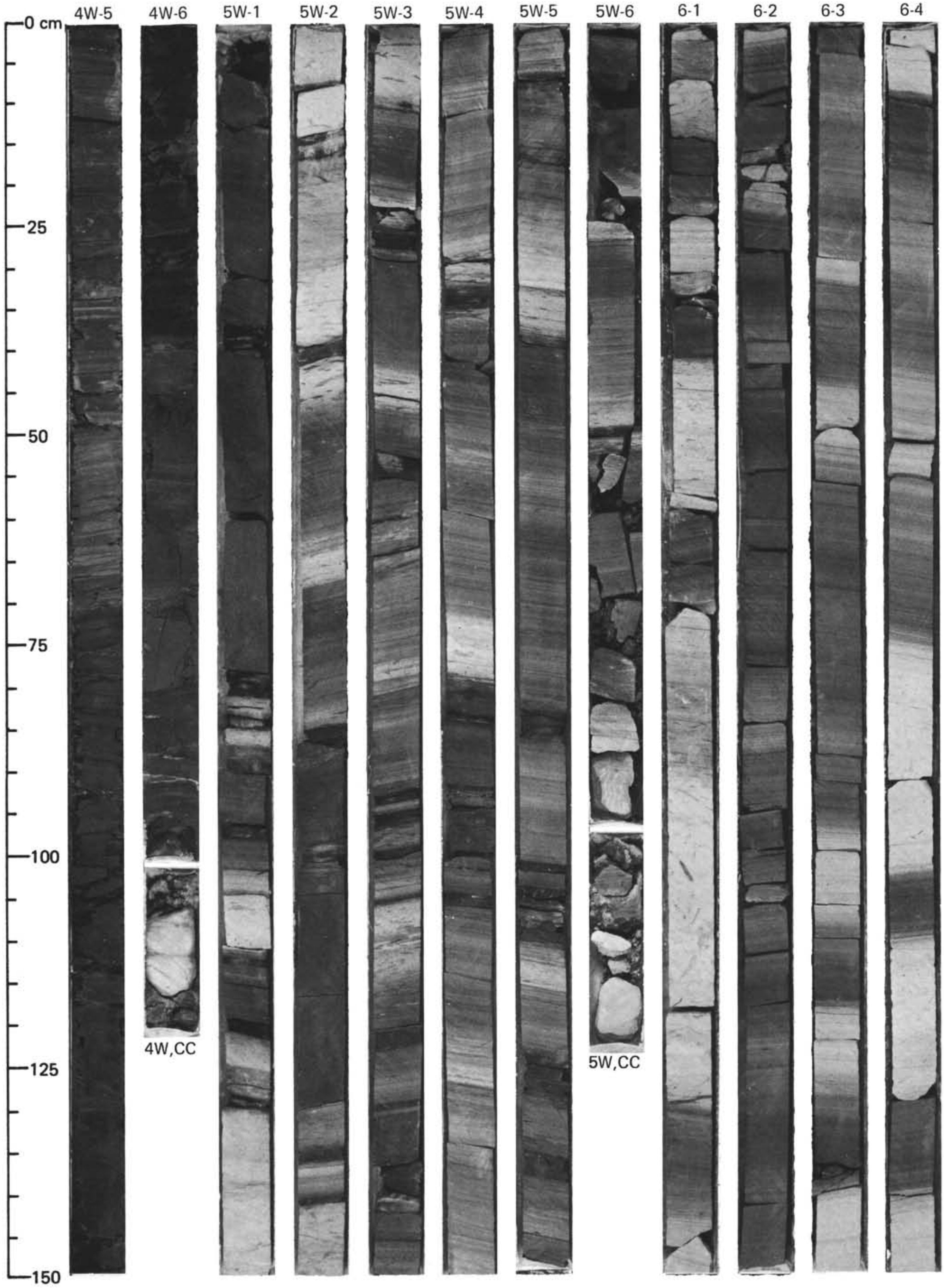
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5W-3
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5W-5
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6-1
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6-3
6-4
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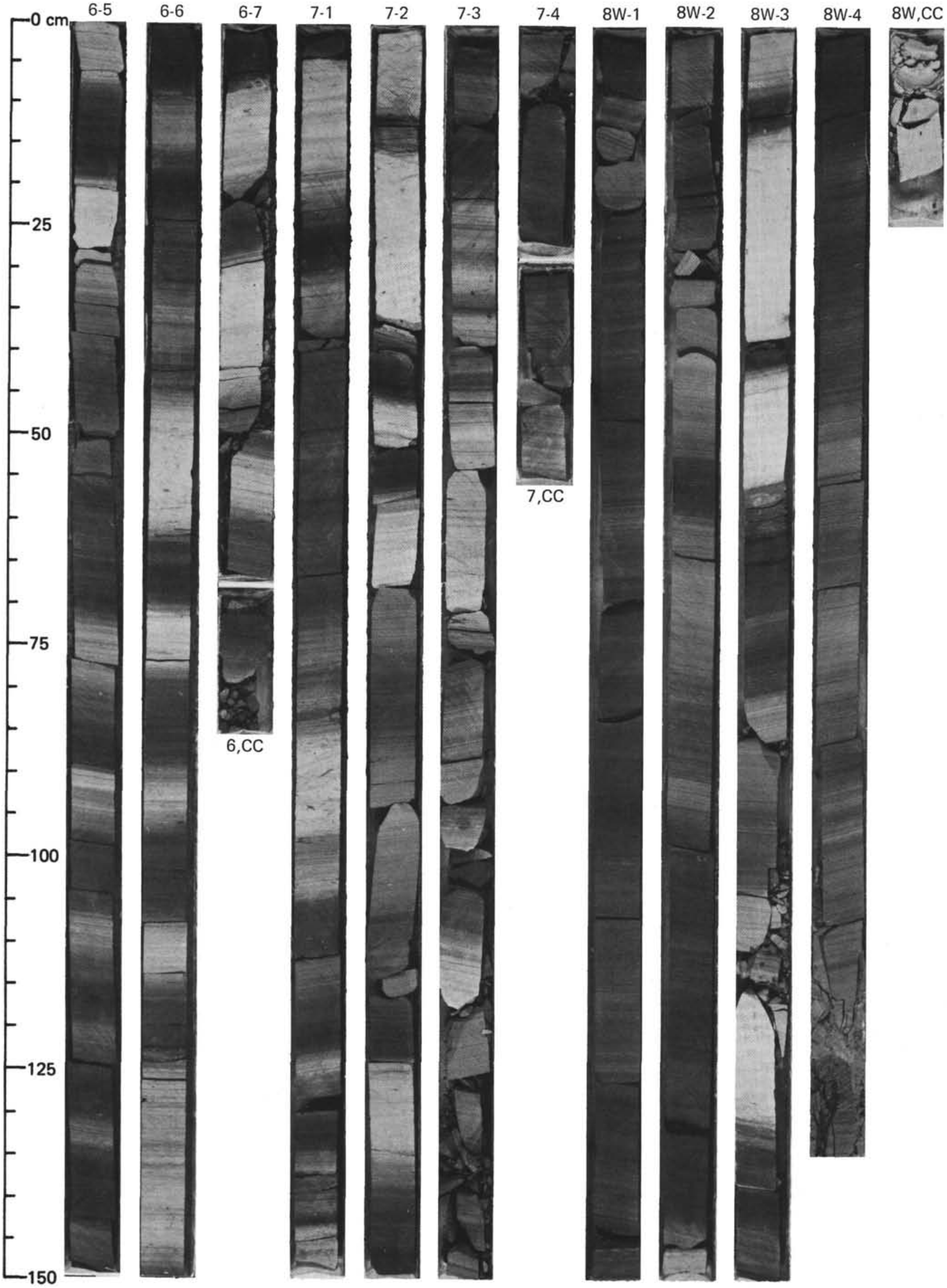
5W,CC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8W-4
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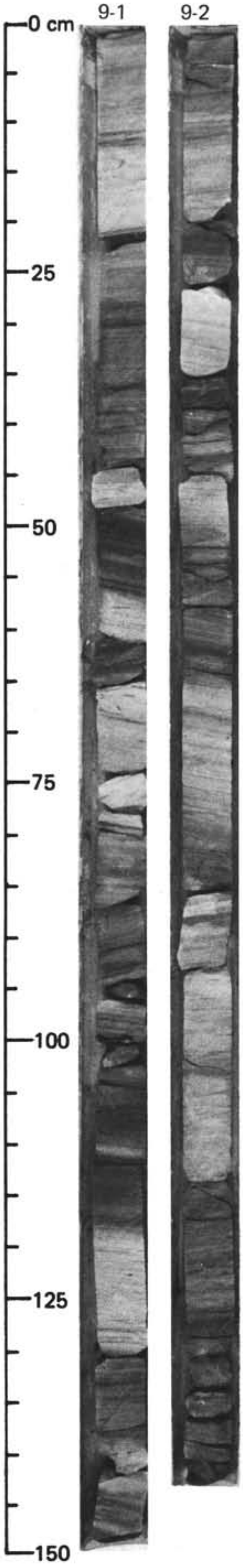
6,CC
7,CC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