5. SITE 489[1]

Shipboard Scientific Party[2]

HOLE 489

Date occupied: 3 April 1979

Date departed: 5 April 1979

Time on hole: 39.2 hours

Position: 16°16.19′N; 99°01.13′W

Water depth (sea level; corrected m, echo-sounding): 1240

Water depth (rig floor; corrected m, echo-sounding): 1250

Bottom felt (m, drill pipe): 1268.5

Penetration (m): 34.5

Number of cores: 4

Total length of cored section (m): 34.5

Total core recovered (m): 22.6

Core recovery (%): 66

Oldest sediment cored:
Depth sub-bottom (m): 34.5
Nature: Green mud
Age: Early Miocene

Principal results: Hole terminated because of leaking bumper sub.

HOLE 489A

Date occupied: 5 April 1979

Date departed: 7 April 1979

Time on hole: 52.4 hours

Position: 16°16.19′N; 99°01.13′W

Water depth (sea level; corrected m, echo-sounding): 1240

Water depth (rig floor; corrected m, echo-sounding): 1250

Bottom felt (m, drill pipe): 1266.5

Penetration (m): 327

Number of cores: 34

Total length of cored section (m): 298.5

Total core recovered (m): 164.5

Core recovery (%): 55

Oldest sediment cored:
Depth sub-bottom (m): 302
Nature: Green silt and siltstone
Age: Early Miocene

Basement:
Depth sub-bottom (m): 303
Nature: Schist

Principal results: Site 489 cores demonstrated the existence of schistose continental crust in close proximity (~10 km) to inferred accretionary zone sediments. The cores also provided data regarding the late presubduction and early synsubduction history of the margin at this site. These are the first such data obtained so close to the oceanic/continental basement suture in an actively subducting region.

Suprabasement sediments consisted of approximately 300 meters of lower Miocene muddy silt or siltstone, unconformably underlying a thin (2–5 m) veneer of Quaternary muddy silt (Table 1). Faunal assemblages indicate a marine transgression approximately 22.5 Ma, followed by rapid subsidence of the site below the carbonate compensation depth approximately 21 Ma. The site has subsequently risen to its present depth, but evidence regarding the nature of this rise is largely missing because of the early Miocene-Quaternary unconformity. Overcompaction of early Miocene sediments suggests the prior existence of a thicker overburden and subsequent erosion as the reason for the unconformity.

Remanent magnetizations of both sediments and igneous rocks were unusually low. Low sediment magnetization suggested a provenance different from that of previously drilled sites, and low basement rock magnetization suggested that regional magnetic anomalies derive from a deeper source, probably subducting oceanic crust beneath the site.

Small amounts of ethane and higher hydrocarbons were observed with greatest amounts in the lowermost part of the section. The immaturity of the cored section implies that these gases were sourced at greater depth and migrated into their present position.

Figure 1 summarizes data from Site 489 cores.

BACKGROUND AND OBJECTIVES

Although the reality of subduction is widely accepted, we know little about its beginnings. Does the crust buckle in compression before rupturing to form the subduction surface? Does it sag gravitationally before rupture carries one block beneath the other? Or does it do something entirely different? Answers to these questions are fundamental to an understanding of the mechanism of subduction.

In the region of Leg 66 drilling, ignorance of the late presubduction history of the margin further complicates the study of early subduction history. Mesozoic and Tertiary igneous and metamorphic complexes extend to the shoreline, giving the impression of once belonging to a more extensive terrain whose seaward part has been forcibly removed. Did this missing terrain slide northward and westward as is now the case with Baja Califor-

[1] *Initial Reports of the Deep Sea Drilling Project*, Volume 66.
[2] Joel S. Watkins (Co-Chief Scientist), Gulf Research and Development Company, Houston, Texas (present address: Geology and Interpretation Department, Exploration and Production Division, Gulf Science and Technology Company, Pittsburgh, Pennsylvania); J. Casey Moore (Co-Chief Scientist), Earth Sciences Board, University of California, Santa Cruz, California; Steven B. Bachman, Department of Geology, University of California, Davis, California (present address: Department of Geological Sciences, Cornell University, Ithaca, New York); Floyd W. Beghtel, Phillips Petroleum Company, Bartlesville, Oklahoma; Arif Butt, Institut und Museum für Geologie und Paläontologie, Universität Tübingen, Tübingen, Federal Republic of Germany; Borys M. Didyk, Research and Development Laboratory, Empresa Nacional del Petróleo (ENAP), Concon, Chile; Glen Foss, Deep Sea Drilling Project, Scripps Institution of Oceanography, La Jolla, California; Jeremy K. Leggett, Department of Geology, Imperial College of Science and Technology, London, United Kingdom; Neil Lundberg, Earth Sciences Board, University of California, Santa Cruz, California; Kenneth J. McMillen, Geophysics Laboratory, Marine Science Institute, University of Texas, Galveston, Texas (present address: Geology and Interpretation Department, Exploration and Production Division, Gulf Science and Technology Company, Pittsburgh, Pennsylvania); Nobuaki Niitsuma, Institute of Geosciences, Shizuoka University, Oya, Shizuoka, Japan; Les E. Shephard, Department of Oceanography, College of Geosciences, Texas A&M University, College Station, Texas (present address: Sandia National Laboratories, Division 4536, Albuquerque, New Mexico); Jean-François Stephan, Département de Géotectonique, Université Pierre et Marie Curie, Paris, France; Thomas H. Shipley, Scripps Institution of Oceanography, University of California at San Diego, La Jolla, California; and Herbert Stradner, Geologische Bundesanstalt, Vienna, Austria.

Table 1. Coring summary, Holes 489 and 489A.

Core	Cored Interval below Bottom (m)	Cored (m)	Recovered (m)	Recovered (%)	Remarks
Hole 489					
1	0.0-6.0	6.0	5.60	93	
2	6.0-15.5	9.5	8.82	93	
3	15.5-25.0	9.5	5.10	54	
4	25.0-34.5	9.5	3.10	33	
		34.50	22.62	66	
Hole 489A					
1	0.0-8.0	8.0	8.00	100	
2	36.5-46.0	9.5	2.82	30	
3	46.0-55.5	9.5	1.29	14	
4	55.5-65.0	9.5	7.96	84	
5	65.0-74.5	9.5	7.48	79	
6	74.5-84.0	9.5	4.97	52	
7	84.0-93.5	9.5	6.88	72	
8	93.5-103.0	9.5	4.86	51	
9	103.0-112.5	9.5	3.54	37	
10	112.5-122.0	9.5	4.20	44	
11	122.0-131.5	9.5	7.19	76	
12	131.5-141.0	9.5	3.03	32	
13	141.0-150.5	9.5	4.66	49	
14	150.5-160.0	9.5	0.12	1	
15	160.0-164.5	4.5	1.95	43	
16	164.5-169.5	5.0	5.09	102	
17	169.5-179.0	9.5	2.57	27	
18	179.0-183.0	4.0	4.68	117	
19	183.0-188.5	5.5	4.15	75	
20	188.5-198.0	9.5	2.13	22	
21	198.0-207.5	9.5	7.05	74	
22	207.5-217.0	9.5	7.14	75	
23	217.0-226.5	9.5	7.90	83	
24	226.5-236.0	9.5	8.55	90	
25	236.0-245.5	9.5	7.96	84	
26	245.5-255.0	9.5	6.55	69	
27	255.0-264.0	9.5	4.84	51	
28	264.0-273.5	9.5	5.03	53	
29	273.0-282.0	9.0	9.14	102	
30	282.0-291.0	9.0	7.26	81	
31	291.0-300.0	9.0	2.85	32	
32	300.0-309.0	9.0	0.85	9	gneiss fragments
33	309.0-318.0	9.0	0.28	3	
34	318.0-327.0	9.0	0.28	3	
		298.50	163.25	55	

nia and the block west of the San Andreas fault? Did it slide southeastward as suggested by reconstructions of the Cayman Trough? Or was it perhaps consumed by tectonic erosion, to disappear into the subduction zone? Answers to these questions are fundamental to our understanding of the geologic history of the region.

Among the most likely places to look in rock records for evidence of late presubduction and early synsubduction history are in the sediments deposited on or immediately seaward of the lip of the continental crust where it joins oceanic crust. These sediments are difficult to sample, however. In most subduction zones the edge of the continental crust cannot be identified with confidence. In other areas, rocks of the continental/oceanic crust transition zone are beyond the reach of the *Challenger*'s drill. The Leg 66 area may be unique in that these sediments are accessible. The edge of continental crust can be placed in a zone less than 10 km wide. Sediments on the lip are completely penetrable, as are the upper part of sediments deposited on oceanic crust.

Specific objectives at Site 489 (Fig. 2) were penetration of a strong seismic reflector at an estimated depth of 290 meters (Fig. 3) and recovery of samples of sediment from overlying sediments. The strong reflector, thought to be continental basement, rises irregularly southeastward beneath rising seafloor. Seaward, it becomes progressively more irregular, loses continuity, and dies out a few kilometers southwest of Site 489.

Site 490 (Fig. 3), discussed in the following chapter, is a companion site drilled into accretionary zone sediments immediately seaward of the edge of the continental crust. The common objective at Sites 489 and 490 was to obtain data concerning the evolution of the margin during the late presubduction to early synsubduction period.

OPERATIONS

The move of 35 km north from Site 488, including minor profiling, was made in 4¼ hours. The beacon drop point was only approximate because of the unavailability of good satellite fixes during transit. The position was considered adequate, however, and the pipe trip was begun.

Fixes indicated that the beacon was within offsetting distance of the intersection of two reference profiles and the vessel was offset about 460 meters to the west-southwest prior to spudding.

Owing to the 20% (approx.) slope of the seafloor, two "water cores" were taken before sediment was found at 1268.5 meters, 24.5 meters deeper than the PDR reading. Hole 489 was spudded at 1205 hours, April 3.

Firm Miocene clay, 3 meters below seafloor, slowed initial penetration, because only limited weight could be applied. Five and one-half hours after spudding, core barrel number 5 failed to produce the pump pressure "kick" indicative of proper seating at the core bit. After retrieving the core barrel, we twice attempted unsuccessfully to clear a possible obstruction from the bit. We then retrieved the string to check for a downhole mechanical malfunction.

Inspection of the bottom hole assembly revealed that the internal washpipe of the lower bumper sub was unscrewed, permitting drilling fluid to escape through the bumper sub. The bumper sub was replaced and the drill string was run back for respudding.

Hole 489A

Hole 489A was spudded into sediments 1266.5 meters deep at 1205 hours, April 4. Uppermost sediments were recored to sample a paleontological break. We then "washed" to the depth at the bottom of Hole 489 and began continuous coring.

Coring continued without significant incident through moderately indurated claystones and siltstones. Relatively slow penetration rates and good hole conditions

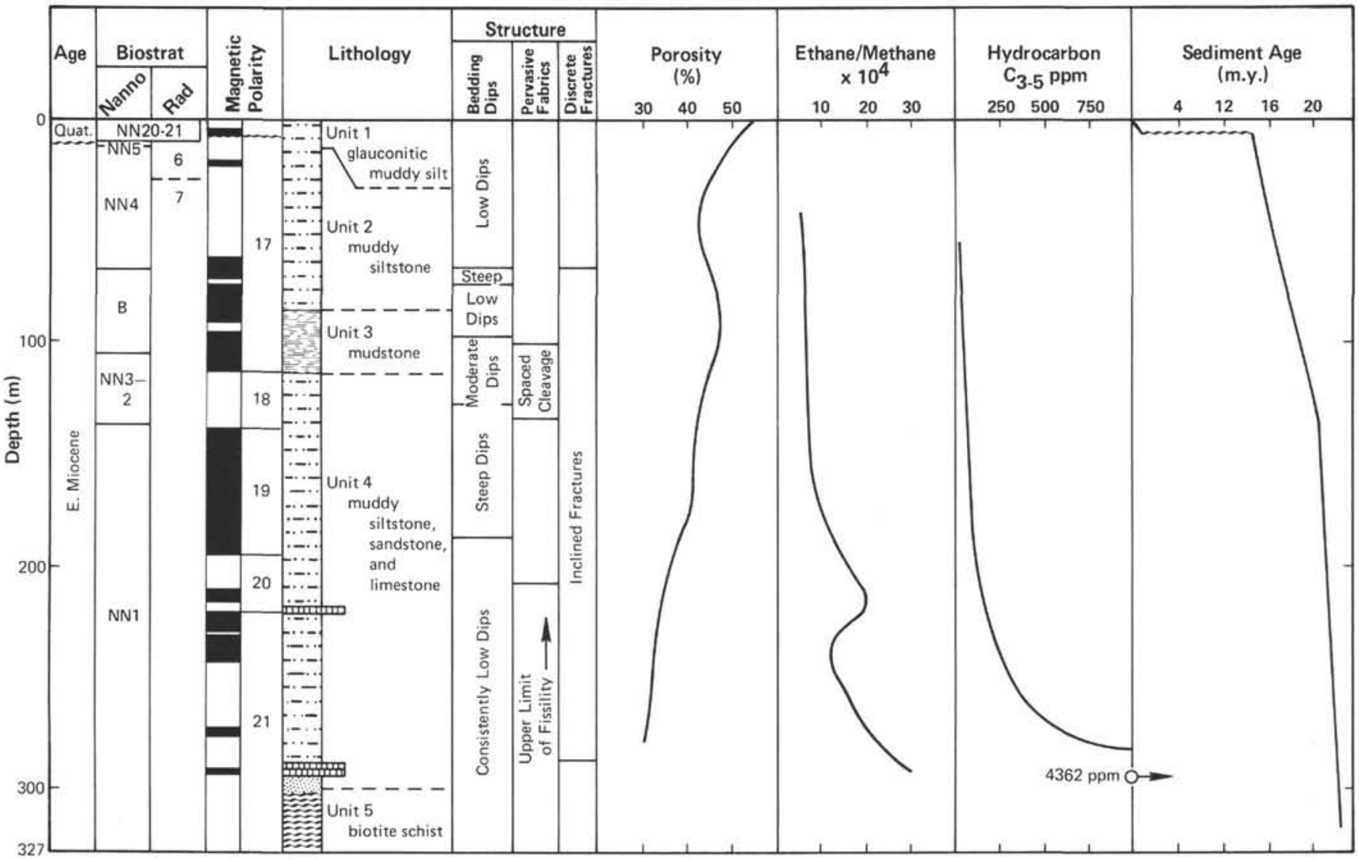


Figure 1. Summary of age, nannofossil and radiolarian zones (6 = *Calocycletta costata*, 7 = *C. virginis*, B = barren), magnetic polarity zones (black = normal, white = reversed, slashes = no data), lithology, lithologic units, structure porosity, C_2/C_1, total C_{3-5}, and age vs. depth.

prevailed throughout the section. We penetrated broken schist basement at about 303 meters sub-bottom and terminated drilling at 327 meters because of sticking.

The hole was flushed with mud, an inner core barrel pumped down with a shifting tool attached, and wireline run to retrieve the barrel and actuate the mechanical bit release. The release sleeve resisted shifting and the safety shear pin failed after several minutes. A second attempt produced the same result. The third attempt resulted in parting of the sand line about 25 meters above the sinker bars. We cut off about 150 meters of sand line and rigged a new sinker bar assembly, then ran a wireline fishing spear in a final attempt to clear the pipe and release the bit for logging. The broken wire was engaged by the spear, but the fish jammed. We sheared the pin on the new overshot, left the spear in the pipe, and pulled the pipe.

We abandoned the hole after filling it with 110 barrels of barite-weighted drilling mud. Although hydrocarbon gases had been encountered in the hole, cementing was not feasible because of the unrecovered core barrel and fishing tool. The vessel departed for Site 490 at 1630 hours, April 7.

LITHOLOGIC SUMMARY

At Site 489 we penetrated 327 meters and recovered 38 cores, which we divided into 5 units (Fig. 4; Chart 1, back pocket). The two holes, 489 and 489A, are considered together because of their overlapping stratigraphy and proximity. Quaternary and lower Miocene sediments were found in cores as well as metamorphic basement of probable pre-Tertiary age.

Unit 1, Quaternary (Core 489-1, 0–5.5 m; Core 489A-1, 0–2.1 m), consists of muddy silt. In Hole 489A, the silt is glauconitic and foraminifer-rich. Woody debris, mud balls, and mud fragments are common. Microfossils suggest an upper slope environment.

Unit 2, early Miocene (Cores 489-1–489-4, 5.5–34.5 m; Cores 489A-1–489A-6, 7.1–84.0 m), is comprised of muddy silt that grades into muddy siltstones near the base. Thin ash layers are common. Limestone clasts in the upper half of the unit contain microfauna of the same age as the enclosing rock, suggesting that the clasts are either concretions or primary deposits. Bioturbation ranges from light to intense; several burrows represent *Chondrites*. Preserved bedding shows apparent dips of 25° to 54°, and minor fractures dip from 12° to 60°. The upper part of Unit 2 is siliceous, with concentrations of radiolarians, diatoms, and sponge spicules. Scarce foraminifers are characterized by small forms and a few benthic varieties suggesting water depths of 300 to 1000 meters. Calcareous nannofossils have been partially dissolved.

Unit 3, early Miocene (Cores 489A-7–489-9, 84.0–112.5 m). This mudstone unit is differentiated from the overlying and underlying units by an increase in the clay-size fraction. Intense bioturbation has destroyed most primary sedimentary features. Several intervals

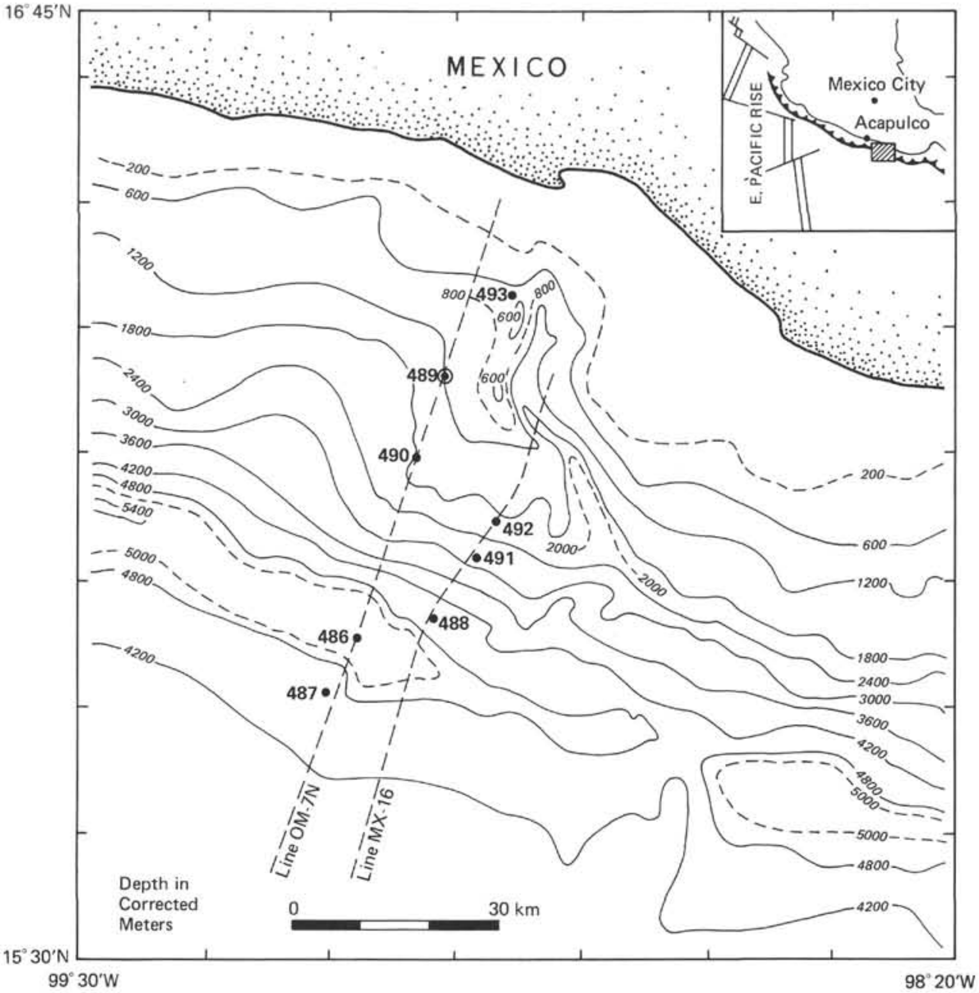


Figure 2. Site location map and index.

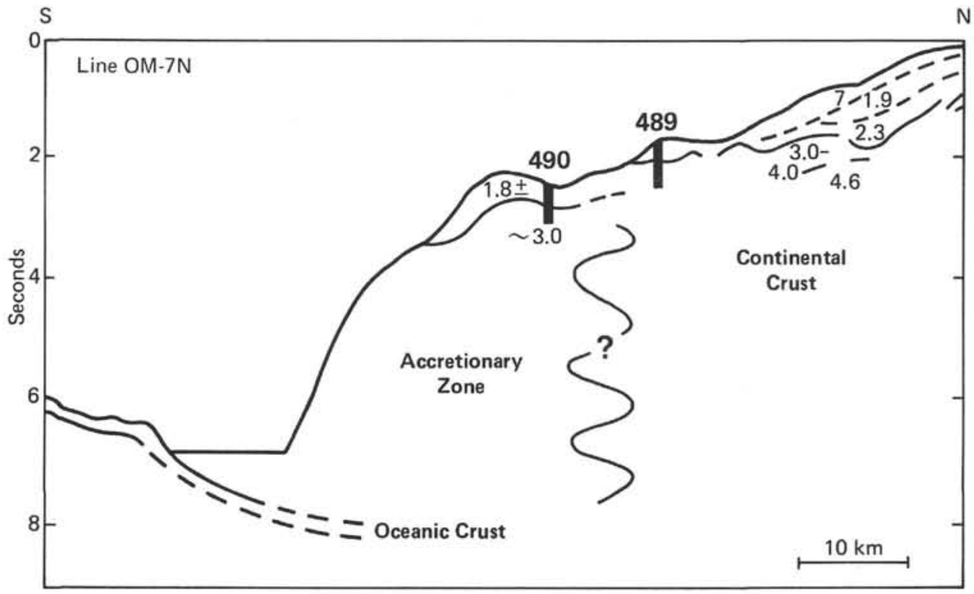


Figure 3. Schematic cross section of UTMSI multichannel Line OM-7N showing Sites 489 and 490, their relationship to the seaward edge of the continental crust, and seismic velocities observed in the area.

contain thin ash pods. Small fractures offset burrows and remnants of bedding. Microfauna resemble those in Unit 2.

Unit 4, early Miocene (Cores 489A-10–489A-31, 112.5- 300.0 m), consists primarily of muddy siltstone, similar to Unit 2. Two fine- to medium-grained calcareous sandstone beds with thicknesses of 32 cm and 10 cm occur near the base of the unit. The maximum thickness of the sandstones could be 2.2 meters, depending on the lithology of unrecovered core. Pods and thin layers of very fine to fine sand increase in volume from the middle of Unit 4 to its base. A few limestones occur regularly throughout the unit, with an 8-cm-thick limestone layer at 291 meters. Calcareous content in the unit increases with depth in the lower half. Scattered glauconite grains occur near 220 meters (Core 489A-23), and zeolite fills veins below 281 meters (Cores 489A-29–489A-31).

Moderate to intense bioturbation characterizes most of the sequence. *Chondrites* and other unidentified burrow forms are evident at several intervals, and *Zoophycos* is present at 185 meters (Core 489A-19). Above 226 meters, foraminifers are scarce and siliceous fauna abundant. Benthic foraminifers indicate an upper to upper-mid bathyal (300–1000 m water depth) environment and occur with dwarf planktonic species (see Biostratigraphy). Below 226 meters, benthic foraminifers suggest deep shelf (<200 m) environments, and the abundance of siliceous fauna decreases. Articulated bivalves, scaphopods, and echinoids are abundant several meters above the sandstones at 289 meters.

Unit 5 (Cores 489A-32–489A-34, 300.0–327.0 m) is a basal unit for which onshore geology suggests a pre-Tertiary age. It consists of schist with biotite-hornblende-quartz, garnet-muscovite-quartz, biotite-muscovite-quartz associations, and muscovite–chlorite-bearing quartzite. Section 489A-32,CC contains a subrounded schist pebble.

Lithologic Interpretation

Site 489 is located above the edge of the continental crust and adjacent to the accretionary zone to the southwest. The sediments cored at Site 489 may reflect the tectonic trends in both the underlying continental crust and nearby subduction complex.

The basal metamorphic rocks probably represent continental crust correlative with outcrops along the nearby Mexican coast (de Czerna, 1971). The subrounded pebble of schist within the first basement core may represent a period of exposure of basement rocks within or above wave base sometime preceding or during earliest Miocene. The upper part of the lower Miocene section is finer grained and contains more discrete ash layers. Its microfauna suggests deposition in deeper water than does fauna of the basal section. This relationship suggests a transgressive sequence from near-shore to deeper-water environments. Because the early Miocene sea level rise probably did not exceed 150 meters (Vail et al., 1977), some of the bathymetric changes suggested by microfaunal assemblages (minimum of several hundred meters in the early Miocene) must be due to subsidence.

A period of erosion and deformation between early Miocene and Quaternary is suggested by (1) the Pleistocene through middle Miocene hiatus in the section; (2) the steeper dips of the lower Miocene rocks compared to the flat overlying Quaternary beds; (3) the truncation of seismic reflectors in what is probably a Miocene section by the overlying slope apron; and (4) overconsolidation of subunconformity sediments. Seismic data suggest possible erosional events in the Pliocene–Miocene and a major erosional event in the Quaternary. Along the Mexican coast, folding along a north–south trending axis occurred at the end of the Miocene (Tardy, 1977), an event that may be related to the tilting of beds at Site 489. Glauconitic silts suggest slow deposition in the Quaternary.

The Cenozoic tectonic history of southwestern Mexico is poorly understood. The Precambrian to Mesozoic metamorphic complexes appear to be truncated at the continental margin (Kesler and Heath, 1970), and the Mesozoic magmatic arc appears to be too close to the present margin (Karig, 1974). Several models have been proposed to account for possible truncation of pre-Cenozoic rocks along the southwestern Mexico margin: (1) tectonic erosion of the continental margin by subduction (Karig et al., 1978); (2) left lateral transform movement (de Czerna, 1971, Malfait and Dinkelman, 1972); and (3) right lateral transform movement (Karig, 1974).

The documentation of early Miocene subsidence on the upper slope does not limit the mechanism for possible margin truncation but may help delineate the timing of such an event. Subsidence of the upper slope could be related to subduction, normal or oblique, or to transform motion.

BIOSTRATIGRAPHY

Figure 1 shows the biostratigraphic summary of Site 489, based on nannofossils, radiolarians, and some foraminifers. Alternating periods of calcareous and siliceous dissolution, which occur in the upper half of Site 489, hamper biostratigraphic dating of the sediments. Siliceous microfossils occur abundantly in the upper portion of Site 489 but have been dissolved below Core 489A-18 (180–300 m). Sporadic preservation of calcareous nannofossils permits the most complete zonation. Planktonic foraminifers are useful only in Core 1 and below Core 27.

Calcareous Nannoplankton

Sediments consist mainly of lower Miocene, capped by a thin layer of upper Quaternary to Holocene. Middle Miocene to lower Quaternary sediments are missing.

Late Quaternary to Holocene

Emiliania huxleyi, which is found in Cores 489-1 (0–5.5 m) and 489A-1 (0–8.5 m), is indicative of later Quaternary to Holocene. According to Geitzenauer (1972) this species appears about 0.15 m.y. ago in the geological record. The nannoflora included here are *Ceratolithus simplex, Coronocyclus nitescens, Cyclococcolithus leptoporus, Emiliania huxleyi, Gephyro-*

capsa doronoicoides, G. oceanica, Helicosphaera carteri, Pontosphaera syracusana, Syracosphaera pulchra, and *Thoracosphaera heimi*.

Miocene

At Holes 489 and 489A, the lower few centimeters of Core 1 and the rest of the cores at these sites contain Miocene age sediments. The upper part of the Miocene sediments contains more siliceous microfossils than the overlying Quaternary.

Nannoflora from Sample 489-1,CC indicate an uppermost early Miocene to earliest middle Miocene age (NN5, the *Sphenolithus heteromorphus* nannoplankton zone), with abundant *Discoaster exilis* and *Sphenolithus heteromorphus*. The species of the nannoflora are *Coccolithus miopelagicus, Cyclicargolithus bukryi, C. floridanus, Coronocyclus nitescens, Discoaster exilis*, and *D. trinidadensis*.

Foraminifers

The sedimentary section contains variable sediment facies. Cores 489-1 and 489A-1 contain glauconitic mud with abundant and well-preserved foraminifers. Cores 489-2 through 489-5 and 489A-2 through 489A-31 consist of light greenish gray siliceous mud and underlying silty mud and sandstone facies containing rare to common foraminifers. Relatively abundant benthic foraminifers occur in the lower part of the sedimentary sequence, but several core catcher samples such as 489-3,CC, 489A-2,CC, 489A-7,CC through 489A-10,CC, 489A-20,CC, and 489A-26,CC are barren of foraminifers. Planktonic foraminifers in the lower Miocene section are small and dwarfish. Both Cores 489-1 and 489A-1 encompass a middle Miocene through Quaternary hiatus.

Planktonic foraminifers in Cores 489-1 and 489A-1, exclusive of the core catcher, indicate a late Quaternary age of the sediment. The assemblage includes *Globorotalia tumida, G. menardii, G. scitula, Globigerinoides ruber, G. sacculifer, G. triloba, Pulleniatina obliquiloculata*, and *Orbulina universa*.

In Cores 489-2 through 489-5 and 489A-2 through 489A-23, planktonic foraminifers indicate an upper early Miocene age (N5–N8). The species include *Globorotalia peripheroronda, Globigerinoides subquadratus, G. triloba, G. primordius, Globoquadrina altispira, Globigerina obesa*, and *G. venezuelana*.

Cores 489A-24 through 489A-31 comprise the early part of the early Miocene fauna and include *Globorotalia siakensis, G.* aff. *kugleri*, and small specimens of genus *Globigerinoides*.

Depositional Environment

At Site 489 the terrigenous sequence above the basement rock marks an initial lower Miocene transgression of the sea. The middle Miocene through Quaternary hiatus may indicate submarine erosion. Benthic foraminifers in the entire sedimentary section reveal assemblages related to subsidence from the lower Miocene through upper Quaternary. The following three assemblages are represented:

Assemblage I (lower Miocene silty mud and sandstone)

In Cores 489A-31 through 489A-24 the benthic foraminifers indicate a relatively deep shelf environment. Terrigenous facies here were deposited in less than 200 meters water depth. The assemblage includes *Quinqueloculina, Lenticulina, Nodosaria, Gavelinella, Hanzawaia, Siphonogerina, Unicosiphonia*, and *Stilostomella*. The following small-sized specimens also occur: *Cassidulina laevigata, Uvigerina* sp. *Hoeglundina*, and *Sphaeroidina* aff. *bulloides*. The assemblage is also associated with small *in situ* mollusks.

Assemblage II (upper part of lower Miocene; clastic and siliceous mud facies)

Assemblage II could indicate bathyal environment (1000–2000 m) in Cores 489A-20 through 489A-2 or subsidence below the CCD. The assemblage includes benthic foraminifers such as *Dentalina, Nodosaria, Lenticulina, Vaginulina, Hoeglundina* cf. *elegans, Melonis* aff. *affinis, Oridorsalis* aff. *umbonatus, Pullenia bulloides, Cassidulina subglobosa, Gyroidina, Pleurostomella, Siphonodosaria, Sphaeroidina bulloides, Uvigerina aculeata, U.* cf. *peregrina, Pyrgo murrhina, Vulvulina spinosa*, and *Pseudonodosaria*. The occurrence of common siliceous microfossils such as radiolarians and diatoms together with scarce and dwarfish planktonic foraminifers in the sand fraction of the samples may suggest a local upwelling along the upper slope region and indicate a change in the oceanographic conditions as the slope subsided to a greater depth. Upwelled cold water may have suppressed productivity of the calcareous plankton and resulted in a bloom of siliceous plankton. Similar phenomena of siliceous blooms related to upwelling have been documented in some modern coastal shallow basins. For instance, in coastal basins along the Gulf of California, the sediments contain abundant diatoms at a shallower depth (DSDP Leg 64).

Assemblage III (upper Quaternary glauconitic mud facies)

Assemblage III represents a Quaternary foraminiferal assemblage. Benthic foraminifers are abundant, diverse, and include large specimens. They include *Lenticulina* (large specimen), *Stilostomella, Cassidulina subglobosa, C.* aff. *lomitensis, C. teretis, Planulina* cf. *renzi, Gyroidina soldanii, Hoeglundina elegans* (very large specimen), *Uvigerina peregrina, U. proboscidea, Pyrgo murrhina, Bulimina striata, Laticarinina, Cibicidoides*, and *Bolivina*. This assemblage corresponds to the modern mid-bathyal depth environment. Thus Assemblages I through III suggest that the slope basin subsided to more than a thousand meters since the initial phase of transgression at Site 489.

Radiolarians

Abundant, well-preserved radiolarians occur in the upper part of Site 489, along with centric diatoms. Hole 489 contains a good radiolarian fauna in all five cores, whereas Hole 489A contains radiolaria in Cores 1 to 3 and 5 to 18. The rest of the section is barren of radiolarians owing to silica dissolution.

Two recognizable zones, the *Calocycletta costata* (early-middle Miocene) and the *C. virginis* (early Miocene), have a boundary between the middle and lower part of Core 2 in Hole 489. At Site 489 these zones are separated by the appearance of *C. costata* and *Cannartus mammiferus* at the zone boundary and the disappearance of *C. tubarius* just before the boundary (Riedel and Sanfilippo, 1971).

Correlation of radiolarian and nannoplankton zones is problematical at Site 489. The boundary between the *C. costata* and *C. virginis* zones, near the base of Core 2, correlates with the NN4 nannoplankton zone, yet Berggren and Van Couvering (1974) place this zonal boundary within the NN3 zone. Accordingly, we use the correlation scheme of Martini (1971) for this site because it places the *C. costata/C. virginis* boundary within NN4, about one-third of the way down within the zone. If we accept boundary dates of 14.3 Ma for the upper limit and 17.7 Ma for the lower limit of NN4 (Berggren and van Couvering, 1974), then the *C. costata/C. virginis* boundary occurs at roughly 15.5 rather than at 18.1 Ma.

Carbonate-Nodule Fauna

Zones of carbonate-cemented mudstone in the upper part of Site 489 could be reworked from nearby outcrops or cemented in place. Two thin sections made from these rocks show pelagic fauna identical to that of the surrounding mud. One sample from the wash interval between Cores 1 and 2 in Hole 489 contains radiolarians that can be etched out of the rock. *Stichocorys delmontensis* and *Calocycletta virginis* show that the lithified sediment comes from the *C. virginis* zone, the same as the hemipelagic mud adjacent to the nodule. One sample from Core 3 in Hole 489 contains what are probably lower Miocene planktonic foraminifers.

SEDIMENT ACCUMULATION RATES

The age-depth curve (Fig. 5) has been based on relatively few biostratigraphic ranges. A thin Quaternary layer in the NN21-NN20 nannofossil zones unconformably overlies lower Miocene sediments. Only two different accumulation rates can be recognized for the lower Miocene: a lower rate of 21.5 m/m.y. from 20.7 to 14.5 Ma and a higher rate of 106 m/m.y. in sediments older than 20.7 m.y.

PALEOBATHYMETRY

Drilling at Site 489 penetrates a complete lower Miocene transgressive sedimentary sequence deposited over eroded hornblende-biotite schist. This sedimentary sequence can be used to reconstruct the early Miocene paleobathymetric history of the margin (Fig. 5), which involves subsidence after the initial transgression either to depths near the CCD of 3 km or to shallower depths (1 km) by the end of the early Miocene time, depending on whether one focuses on carbonate preservation rather than foraminifera data. If the margin had subsided to depths of 3 km, it was considerably below the present-day water depth (1275 m), and a period of uplift must have followed the early Miocene. Basal sediments at Site 489 consist of sand and sandstone containing bivalves, scaphopods, and echinoids, as well as benthic foraminifers indicating neritic to upper bathyal depths (less than 300 m), with upper to middle bathyal benthonic foraminifers (water depths of 300-1000 m). We propose two bathymetric interpretations for sediments above 200 meters core depth. Benthic foraminiferal data alone indicate that water depths never exceeded 1 to 2 km. However, the near absence of calcareous benthic and planktonic foraminifers in the upper portion of Site 489 suggests deposition near, or in excess of, the CCD at the end of the early Miocene. This latter interpretation is supported by the occurrences of the trace fossil *Zoophycos* in the middle part of Site 489, as this trace fossil has been found mainly in deep-water post-Paleozoic sediments (Ekdale, 1978). If these sediments were deposited at such a great water depth, those benthic foraminifers found in Cores 2 to 20 of Hole 489 must have been transported from shallower water and buried before they dissolved, as is the case in some deep California basins (Ingle, 1973).

PALEOMAGNETISM

Forty-four oriented samples were collected for paleomagnetic investigation from the sedimentary sequence. Stability of remanent magnetization of selected samples was checked with stepwise AF demagnetization (Niitsuma, this volume). All samples were cleaned routinely with 15 mT AF demagnetization. Average intensity is $10^{-7.2 \pm 0.8}$ emu/cc after 15 mT AF demagnetization, relative to a noise level of $10^{-8.1 \pm 1.2}$ emu/cc. This intensity is two orders lower than the intensity measured in sediments from Hole 487 ($10^{-5.6 \pm 0.3}$) and Hole 488 ($10^{-5.3 \pm 0.6}$).

Because the intensity of remanent magnetization correlates with the content of magnetic mineral in sediments, the weak remanent magnetization of sediments in Holes 489 and 489A suggests that the clastic materials were derived from outcrops containing significantly lower magnetic mineral content than sources for Sites 487 and 488. Thus the intensity change indicates a change in sediment provenance.

Although paleomagnetic intensities are insufficient for magnetostratigraphy, there are five recognizable magnetozones. These are correlated with Epochs 17 to 21 on the basis of associated nannoplankton and foraminiferal fossil data.

Remanent magnetization was measured on five metamorphic rock samples taken from cores of metamorphic rocks in Hole 489A. Average and standard deviation of NRM intensity is $10^{-6.9 \pm 0.5}$ emu/cc. Intensity increased during stepwise AF demagnetization, and direction of remanent magnetization was unstable (Niitsuma, this volume).

The weak remanent magnetization observed in the rocks is inadequate to produce the magnetic anomaly of ± 150 gamma as observed by Shipley et al. (1980). On the contrary, the rough parallelism of the magnetic anomaly with magnetic anomalies seaward of the trench

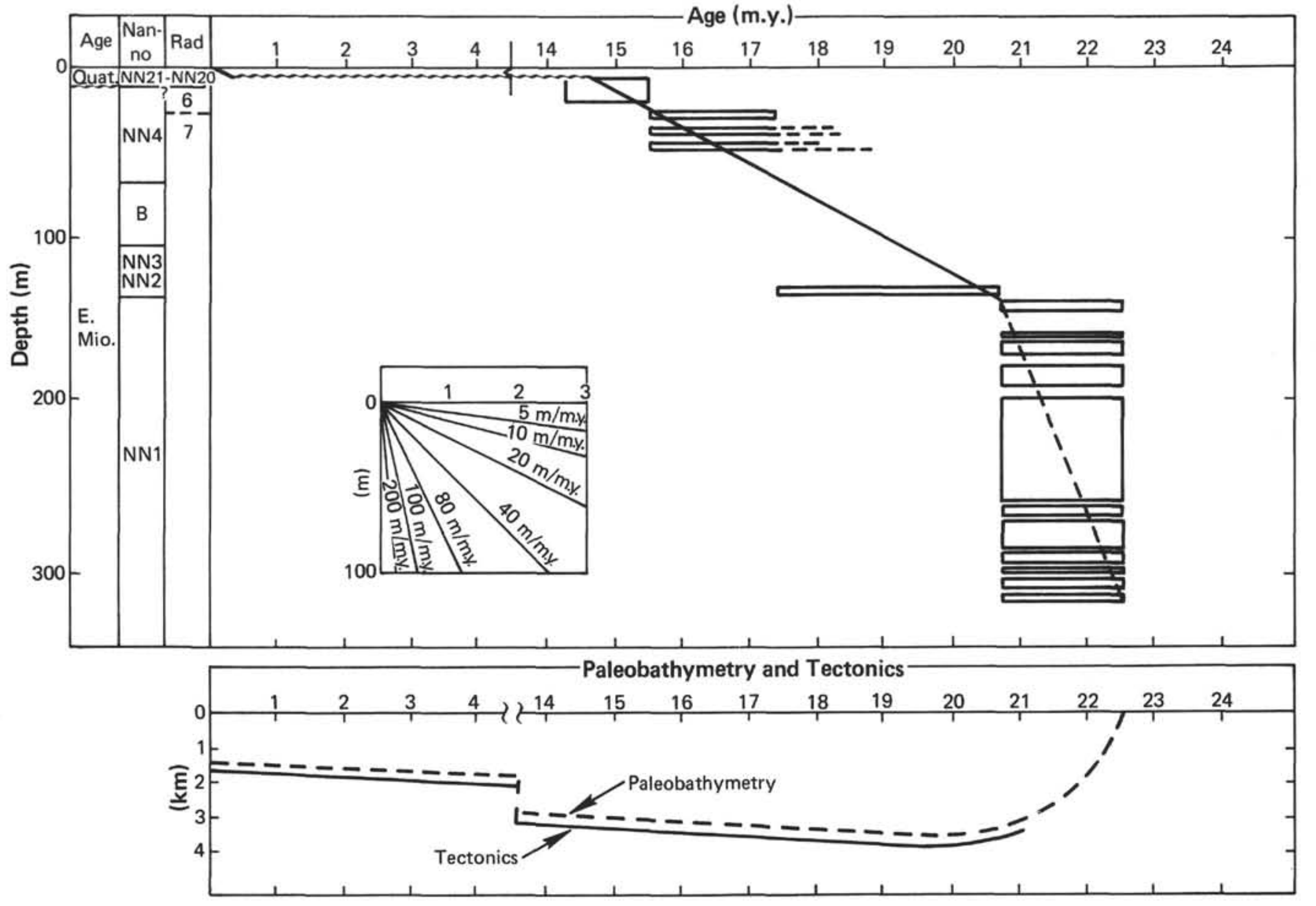


Figure 5. Depth vs. age and paleobathymetry of Site 489 sediments. Boxes indicate formal ranges.

suggests that the magnetic anomaly originated in subducting oceanic crust below the overriding continental basement.

ORGANIC GEOCHEMISTRY

At Site 489 the shipboard organic geochemistry program consisted of monitoring gases released in core liners, visual inspection for fluorescence in the split core, and analyses of selected core samples for carbon, nitrogen, and hydrogen.

Gases

The upper 50 meters of sediments contained small amounts of H_2S and CO_2. The H_2S was below the detection limit of the Carle gas chromatograph but was released in sufficient concentrations during splitting of the core to give a slight odor. CO_2 was present in concentrations of 0.02–0.04% in this section of the hole. Release of H_2S indicates the presence of sulfate-reducing bacteria, which do not usually occur with methane-producing organisms (Claypool and Kaplan, 1979).

For the section below 50 meters, release of moderate amounts of gas in the core liner indicated that pore fluids were above gas saturation at surface conditions. Analysis of this gas showed no H_2S but varying amounts of CO_2 and hydrocarbons in the C_1 to C_5 range as shown in Figure 6.

Throughout the cored sequence the methane content of the core liner gas decreased with depth (Fig. 6), whereas the ethane content remained fairly constant except for two small peaks at 180 meters and near the contact with metamorphic basement. C_2:C_1 parallels the ethane distribution, peaking in the 180 to 250 meter interval and again near the metamorphic basement. C_{3-5}, present at low levels in the upper part of the sedimentary sequence, increased significantly in the lowermost 20 meters. The distribution of these constituents shows an exponential increase with depth, reaching a level of 4362 ppm with 968 ppm of pentanes in the vicinity of the contact with the metamorphic basement (Fig. 6). The source of this mature gas is not known, but sediment downdip to the northwest of this site is a possibility (see Fig. 9). Gases migrating along the contact with the metamorphic basement could cause the anomaly.

Fluorescence

Split cores showed no evidence of crude oil and/or bitumen impregnation. Sporadic fluorescent (white) droplets and superficial fluorescent stains observed on the surface of the cores and the core liners were probably due to contaminants from drilling fluids.

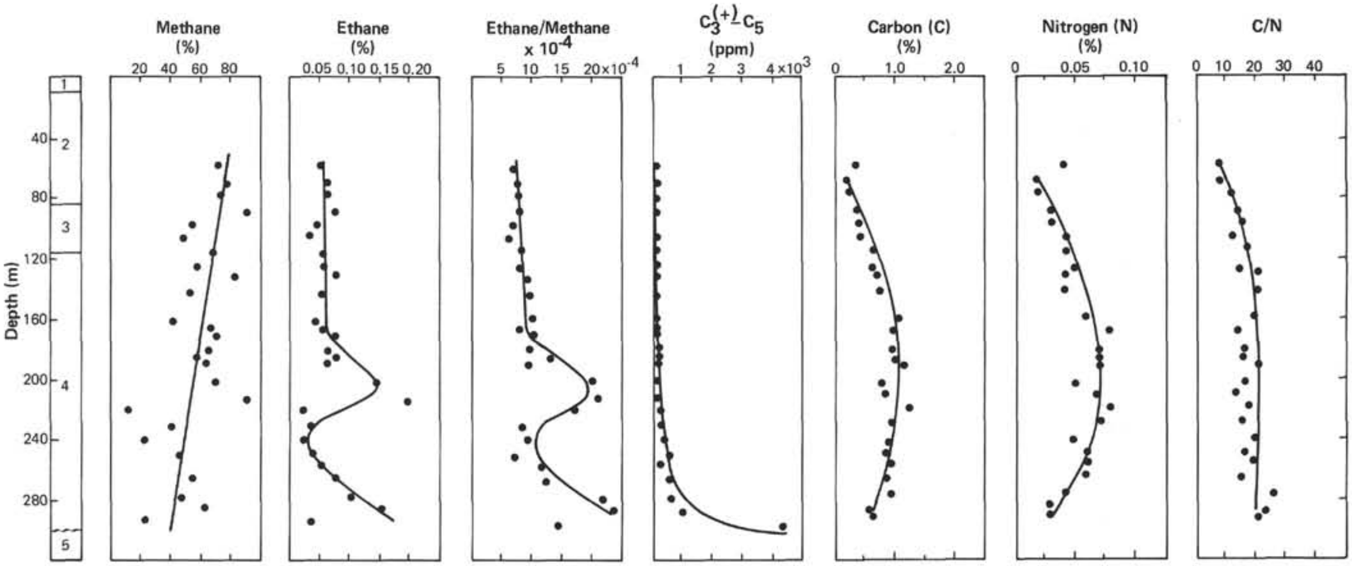


Figure 6. Core liner gas analyses.

Organic Carbon, Hydrogen, Nitrogen, and Carbonates

A sample from each core was taken for CHN analysis. The organic carbon content varied from 0.21% to 1.24% and the total nitrogen content from 0.02% to 0.08% (Fig. 6). The organic potential of the sediments was low in the upper 100 meters and intermediate in the lower section. Both carbon and nitrogen contents show a relative maximum at about 200 meters and decrease near the contact with the metamorphic basement. C/N, which varied from 8.4 to 26.2 (Fig. 6), is within the range of organic matter associated with recent sediments (Fairbridge, 1972) and suggests a low degree of geothermal maturity. C/N increases up to about 17 at 140 meters, then remains approximately constant through the remainder of the hole.

Conclusions

Hydrocarbon gases in the C_1 to C_5 range occur throughout the cored sequence and cause low to moderate degassing of cores. The organic potential of the cored sediments varied from low to intermediate, and C/N suggests a low degree of geothermal maturation. Hydrocarbon gases in the C_1 to C_5 range occur throughout the cored sequence and cause low to moderate degassing of cores. C_{3-5} content increases exponentially near the contact with the metamorphic basement without evidence of increased organic potential or thermal maturity. The origin of these gases is not known, but their source may possibly be more mature sediments downdip.

PHYSICAL PROPERTIES

Site 489 physical property analyses included porosity, water content, wet bulk density, compressional sound velocity, and undrained shear strength, using standard DSDP procedures (Boyce, 1976).

Three main factors influenced the physical properties of Site 489 sediments. (1) Carbonate precipitation within the pore spaces resulted in varying stages of lithification and greatly affected the variability of these properties with depth (Fig. 7). (2) Removal of overburden by submarine currents, mass movements, or subaerial exposure has resulted in overconsolidated sediments at shallow depths (see Shephard et al., this volume). (3) Slow sediment accumulation rates during the early Miocene and attendant dewatering resulted in relatively high values of bulk density and low values of water content and porosity.

General trends of these properties, based on gravimetric and rock chunk data, are summarized in the following.

Porosity, Water Content, Bulk Density

Porosity decreases from 61% at 1.5 meters to 30% at 285 meters. Fluctuations in the porosity–depth profile appear related to carbonate precipitation within the voids. Water content decreases from 34% to 1.5 meters to 13% at 285 meters. Bulk density increases from 1.70 Mg/m^3 at 3.15 meters to 2.16 Mg/m^3 at 289 meters (Fig. 7). These gradually changing index properties result in a relatively transparent section on the seismic profiles (Shipley, this volume).

Compressional Sound Velocity

Velocity increases with depth from 1.60 km/s at 12 meters to 1.90 km/s at 237 meters. Measured velocities are much lower than those needed to predict accurately basement at 300 meters sub-bottom (1.90 km/s maximum value measured versus 2.0 km/s average predicted from velocity analyses of multichannel seismic data; Shipley, this volume). This discrepancy results in part from gas coming out of solution and partially attenuating the sonic signal when the core is brought onboard ship and from core disturbance and variations in carbonate precipitation.

Shear Strength

Shear strength increases rapidly from 11.7 kPa at 3.75 meters to 173.8 kPa at 22 meters (Fig. 7). Below 22

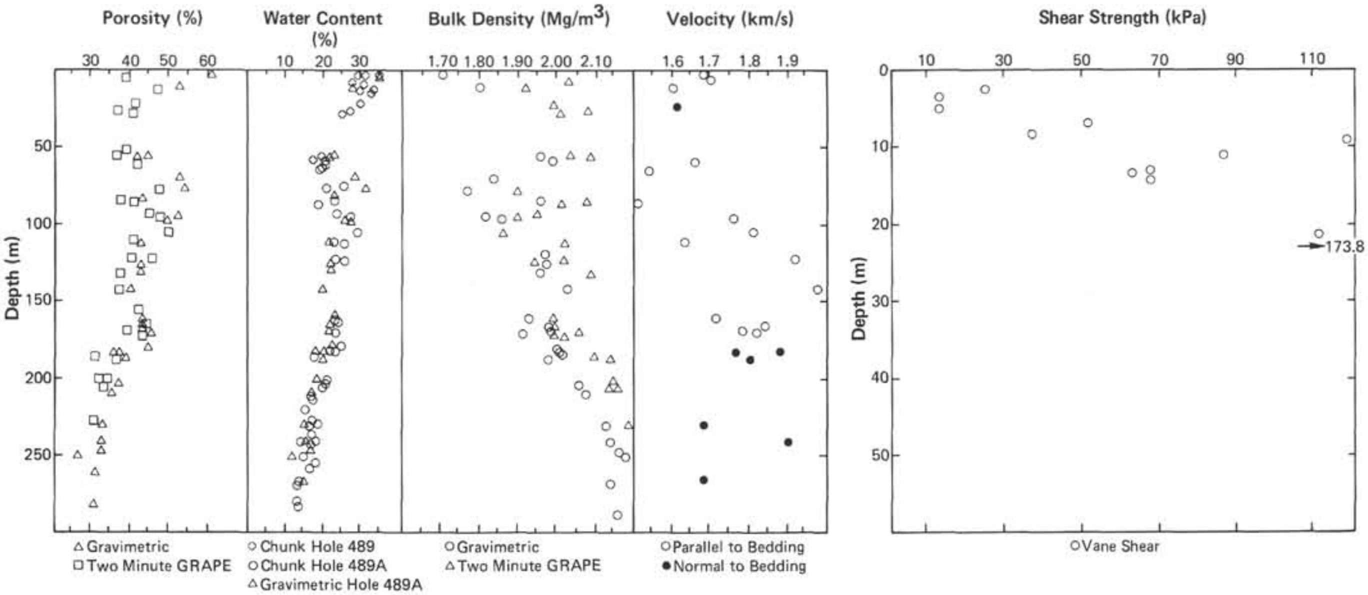


Figure 7. Physical properties summary profiles, Site 489.

meters sediment failure by cracking precluded further measurements. The high shear strengths measured at shallow depths for this site (60 kPa) further suggest removal of previous overburden from this area.

CORRELATION OF SEISMIC REFLECTION DATA AND DRILLING RESULTS

A multichannel seismic reflection line essentially through Site 489 reveals a thin (0.27 s) acoustically transparent interval overlying a high-amplitude reflection doublet which is the acoustic basement (Fig. 8). Seismic Line MX-11 parallel to the trench axis (about 600 m to the northeast) illustrates the position of this site relative to the acoustic basement high to the southeast and thick sedimentary accumulation to the northwest (Fig. 9). The predrilling site survey suggested that the reflection at the base of the sedimentary section was the top of the Paleozoic to Precambrian metamorphic rocks. This conclusion was based on high seismic velocities from refraction data (3.3 to 4.0 km/s), nearly dredge samples of hornblende-biotite gneiss, and extrapolation from onshore geology (Shipley et al., 1980; Shipley, this volume).

The seismic velocity estimated for Site 489 from velocity analysis of multichannel seismic data (2.0 km/s) predicted basement at about 270 meters sub-bottom. Foliated metamorphic rocks encountered at 300 meters correlates well with the basement reflection at 1.86 s. The fairly reflection-free nature of the overlying section records the rather slowly changing physical properties and lack of significant lithologic changes at the resolution of the reflection data. Two poorly defined and discontinuous reflections (Fig. 8) mixed with the receiver ghost occur at 0.08 and 0.12 sub-bottom (80 and 120 m). These may be related to the slightly more indurated nature of the section between about 75 and 110 meters.

The seismic reflection data shoreward of Site 489 record a complex history of sedimentation and erosion (Shipley, this volume). Basal reflection onlap basement highs with simple basin filling as opposed to coastal onlap or offlap. Thus the relief on the basement surface existed prior to deposition of the first sediments in the early Miocene. The sequence recorded in the seismic data landward of the site is a tectonically undeformed section containing depositional cycles separated by erosional events. Reflection terminations define two major and several minor unconformities. The major unconformities bound three major depositional sequences.

Although correlation with core data is difficult, the youngest depositional sequence and the younger part of the middle depositional sequence do appear to be truncated, possibly by subsea current erosion during Pleistocene lower sea level stands. A single basal reflection termination and correlation to seismic velocity data suggest that the basal part of the oldest sequence may have been drilled at Site 489.

SUMMARY AND CONCLUSIONS

Site 489 includes two holes, 489 and 489A, drilled to verify the existence of continental crust located approximately 10 km from inferred accretionary zone rocks and to document the subsidence history of the margin prior to and during the subduction process.

Hole 489A bottomed in a schist basement of pre-Tertiary(?) age. Pronounced irregularities of the basement surface predate transgression of marine sediment in the early Miocene.

Overlying sediments consist of three lower Miocene lithologic units, all of muddy silt or siltstone with varying amounts of clay, and an uppermost Quaternary unit of muddy silt. Fracturing, steeply dipping fracture planes, and tilted bedding planes in the lower Miocene

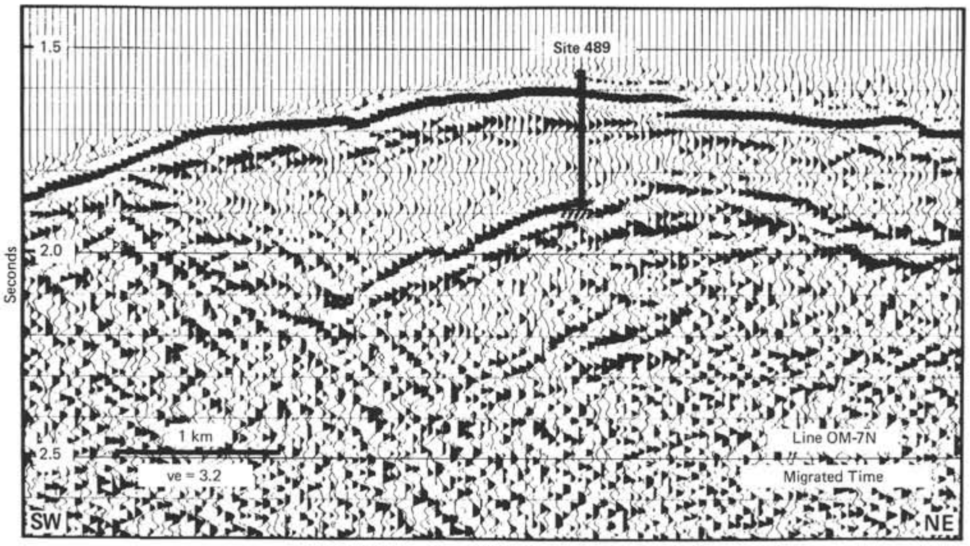


Figure 8. Multichannel seismic reflection profile through Site 489 parallel to regional dip.

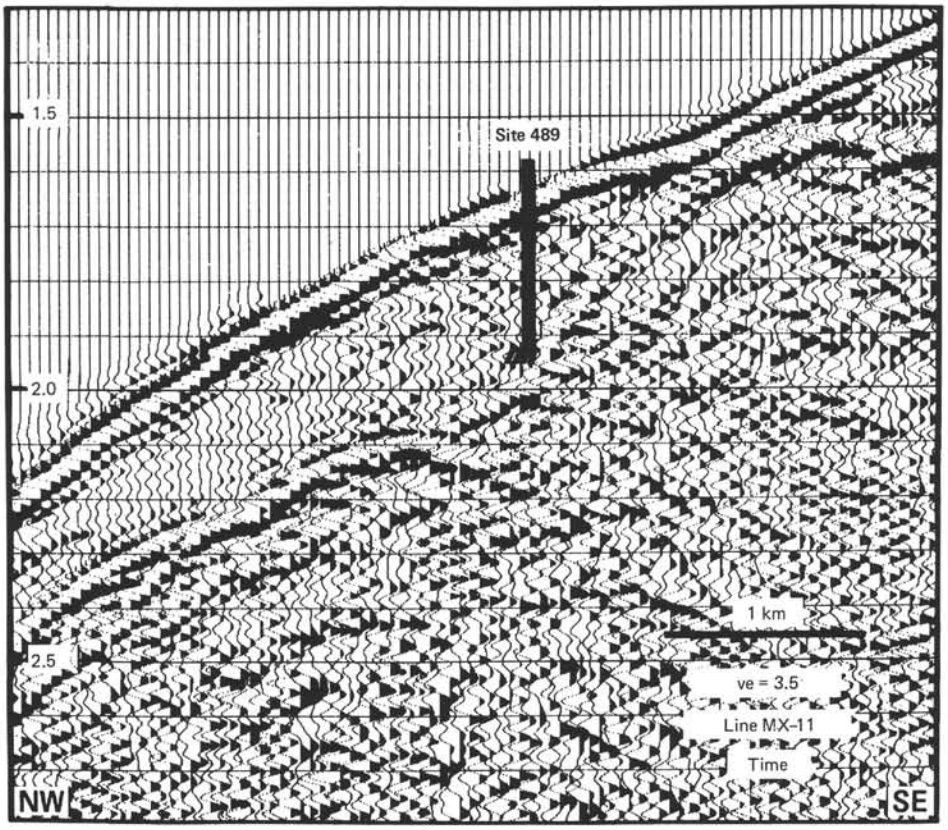


Figure 9. Multichannel seismic profile through Site 489 parallel to regional strike. Bottom topography reflects local basin to northwest of site.

units suggest deformation, uplift, and erosion prior to deposition of the flat-lying Quaternary silts.

The site subsided rapidly following a marine transgression about 22.5 Ma. Pronounced carbonate dissolution in sediments deposited 21 Ma indicates a colder, deeper slope environment in contrast to an outershelf environment indicated by faunal assemblages in lowermost Miocene sediments. Cores from Site 489 tell little of post-early Miocene history because of the unconformity, but it probably rose gradually from about 19 Ma to present, as was the case at Site 493.

Two mechanisms could account for observed carbonate dissolution: (1) subsidence below the CCD or (2) upwelling of cold waters. These mechanisms lead to different interpretations of paleobathymetric history of Site 489. Subsidence below the CCD requires (1) transgression, (2) subsidence to depths of 2000 to 3000 meters during the Miocene and Pliocene, (3) uplift and erosion, and (4) deposition of Quaternary sediments. Upwelling cold water requires (1) transgression, (2) subsidence to 1000 to 1500 meters, (3) erosion, and (4) deposition of Quaternary sediments.

It is not clear whether the unconformity represents erosion at the wave base or erosion on the slope by deep-water currents. Erosion at one or the other depth seems the best explanation, because overconsolidation of early Miocene sediments suggests a thicker overburden than presently extant.

Geochemical analysis of Site 489 samples revealed small amounts of higher (C_2, C_3, . . .) hydrocarbons. These are thought to have migrated from deeper, more mature sediments to their present position.

Magnetic properties investigation showed that magnetization of Site 489 sediments was two orders of magnitude lower than magnetization of sediments recovered at Sites 488 and 487. Either the source Site 489 sediments differs from that of Sites 487 and 488, or magnetic minerals have been winnowed out of Site 489 sediments. Remanent magnetization of cored metamorphic rock is inadequate to account for regional magnetic anomalies. Consequently these anomalies must originate deeper in the continental crust or, more probably, in oceanic crust being subducted beneath Site 489.

REFERENCES

Berggren, W. A., and Van Couvering, J. A., 1974. *The Late Neogene:* Amsterdam (Elsevier).

Boyce, R. E., 1976. Definitions and laboratory techniques of compressional sound velocity parameters and wet water content, wet bulk density and porosity parameters by gravimetric and gamma ray attenuation techniques. *In* Schlanger, S. O., Jackson, E. D., et al., *Init. Repts. DSDP*, 33: Washington (U.S. Govt. Printing Office), 931-958.

Claypool, G. E., and Kaplan, I. R., 1979. The origin and distribution of methane in marine sediments. *In* Kaplan, I. R. (Ed.), *Natural Gases in Marine Sediments:* New York (Plenum Press), pp. 99-139.

de Czerna, Z., 1971. Precambrian sedimentation, tectonics and magmatism in Mexico. *Geol. Rundsch.*, 60:1488-1511.

Ekdale, A. A., 1978. Trace fossils in Leg 42A cores. *In* Hsü, K., Montadert, L., et al., *Init. Repts. DSDP*, 42, Pt. 1: Washington (U.S. Govt. Printing Office), 821-827.

Fairbridge, R. M., 1972. *The Encyclopedia of Geochemistry and Environmental Sciences:* New York (Van Nostrand), pp. 136-141.

Geitzenauer, K. R., 1972. The Pleistocene calcareous nannoplankton of the subantarctic Pacific Ocean. *Deep Sea Research* (Vol. 19): New York (Pergamon Press), 45-60.

Ingle, J. C., Jr., 1973. Biostratigraphy and paleoecology of early Miocene through early Pleistocene benthonic and planktonic foraminifera, San Joaquin hills-Newport Bay-Dana Point, Orange County, California: *SEPU Guide Book,* 1973 annual meeting, Anaheim, California, pp. 18-38.

Karig, D. E., 1974. Tectonic erosion at trenches. *Earth Planet. Sci. Lett.*, 21:209-212.

Karig, D. E., Cardwell, R. K., Moore, G. F., et al., 1978. Late Cenozoic subduction and continental margin truncation along the northern Middle America Trench. *Geol. Soc. Am. Bull.*, 89: 265-276.

Kesler, S. E., and Heath, S. A., 1970. Structural evidence for Precambrian rocks in the Xolapa complex, Guerrero, Mexico. *Geol. Soc. Am. Abstracts with Programs,* 2:287. (Abstract)

Malfait, B. T., and Dinkelman, M. G., 1972. Circum-Caribbean tectonic and igneous activity and the evolution of the Caribbean plate. *Geol. Soc. Am. Bull.*, 83:251-272.

Martini, E., 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. *In* Farinacci, A. (Ed.), *Proc. Second Plankt. Conf., Roma, 1970,* 2: Rome (Edizeoni Tecno-Scienza), 739-785.

Riedel, W. R., and Sanfilippo, A., 1971. Cenozoic radiolaria from the western tropical Pacific, Leg 7, Deep Sea Drilling Project. *In* Winterer, E. L., Riedel, W. R., et al., *Init. Repts. DSDP*, 7, Pt. 2: Washington (U.S. Govt. Printing Office), 1529-1672.

Shipley, T. H., McMillen, K. J., Watkins, J. S., et al., 1980. Continental Margin and lower slope structures of the Middle America Trench near Acapulco. *Mar. Geol.*, 35:65-82.

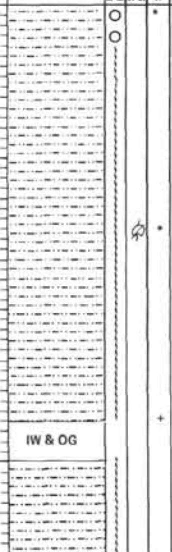
Tardy, M., 1977. Essai sur la reconstitution de l'évolution paléogéographique et structurale de la partie septentrionale du Mexique au cours du Mésozoïque et du Cénozoique. *Bull. Soc. Geol. Fr.*, 7:1297-1308.

Vail, P. R., Mitchum, R. M., Jr., and Thompson, S. III, 1977. Seismic stratigraphy and global changes of sea level. *In* Payton, C. E. Ed.), Seismic stratigraphy-applications to hydrocarbon and exploration. *Am. Assoc. Pet. Geol. Mem.*, 26:49-213.

SITE 489 HOLE CORE 1 CORED INTERVAL 0.0–6.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
QUATERNARY	NN 20/NN 21	AG	AG	AG		1	0.5, 1.0
						2	
						3	
LOWER MIOCENE	*Calocycletta costata* NN 4					4	
		AG	AG	AG		CC	

GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES



LITHOLOGIC DESCRIPTION

5GY 3/2

10GY 3/2

MUDDY SILT, grayish olive green (5GY 3/2) to dusky yellowish green (10GY 3/2) and siliceous vitric silt, grayish olive green (5GY 3/2). Woody chips and reworked 1–2 mm mud balls.

SMEAR SLIDES

	Muddy silt	Muddy silt	Siliceous vitric silt
	1-10 (D)	2-70 (D)	CC (D)
TEXTURE:			
Sand	3	5	5
Silt	72	75	85
Clay	25	25	10
COMPOSITION:			
Quartz	60	60	20
Feldspar	5	8	TR
Mica	–	1	1
Pyrite	3	3	7
Clay	25	25	10
Glass	–	–	30
Glauconite	5	7	–
Foraminifers	TR	–	–
Nannofossils	1	–	–
Radiolarians	TR	TR	7
Diatoms	TR	–	10
Sponge spicules	TR	TR	4
Plant fragments	1	1	1

ORGANIC CARBON AND CARBONATE

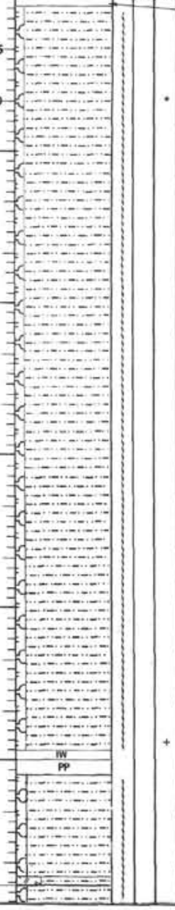
	3-106
% Organic Carbon	1.4
% $CaCO_3$	6

Siliceous, vitric silt

SITE 489 HOLE CORE 2 CORED INTERVAL 6.0–15.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
LOWER MIOCENE	*Calocycletta costata/Calocycletta virginis* NN 4					1	0.5, 1.0
						2	
				AG		3	
						4	
						5	
						6	
		FP	RM	AG		CC	

GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES



LITHOLOGIC DESCRIPTION

VOID

Siliceous MUDDY SILT, grayish green (5G 5/2) and vitric muddy silt, mottled.

SMEAR SLIDES

	Siliceous muddy silt
	1-100 (D)
TEXTURE:	
Sand	2
Silt	63
Clay	30
COMPOSITION:	
Quartz	40
Feldspar	4
Mica	3
Heavy minerals	TR
Pyrite	5
Clay	30
Radiolarians	5
Diatoms	5
Sponge spicules	2
Plant fragments	1

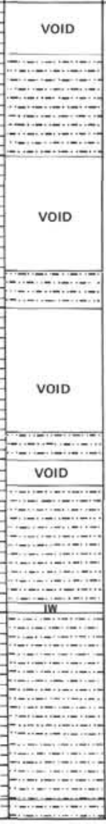
ORGANIC CARBON AND CARBONATE

	5-130
% Organic Carbon	0.2
% $CaCO_3$	1

SITE 489 HOLE CORE 3 CORED INTERVAL 15.5–25.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
LOWER MIOCENE	NN 4 / *Calocycletta virginis*		RM	CG		1, 2, 3, 4, 5, 6, CC	0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

Thin ash layers

LITHOLOGIC DESCRIPTION

MUDDY SILT, grayish green (5G 5/2), mottled.

SMEAR SLIDES

	Muddy silt
	3-135 (D)
TEXTURE:	
Sand	1
Silt	59
Clay	40
COMPOSITION:	
Quartz	43
Feldspar	5
Mica	2
Heavy minerals	TR
Pyrite	3
Clay	40
Radiolarians	5
Diatoms	TR
Sponge spicules	2

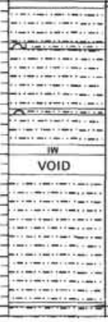
ORGANIC CARBON AND CARBONATE

	4-130
% Organic Carbon	0.4
% $CaCO_3$	2

SITE 489 HOLE CORE 4 CORED INTERVAL 25.0–34.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
LOWER MIOCENE	NN 4 / *Calocycletta virginis*	RM	RP	FG		1, 2, CC	0.5, 1.0

GRAPHIC LITHOLOGY



VOID

VOID

LITHOLOGIC DESCRIPTION

MUDDY SILT, mottled, dark greenish gray (5G 4/1). Thin siliceous muddy silt layers. Indurated limestone clasts, pyritized and fractured, diameter 3 mm–5 cm.

SMEAR SLIDES

	Siliceous muddy silt	Muddy silt
	1-42 (M)	2-80 (D)
TEXTURE:		
Sand	1	2
Silt	70	63
Clay	29	35
COMPOSITION:		
Quartz	42	45
Feldspar penetration twin	7	14
Mica	–	TR
Pyrite	5	3
Clay	24	35
Glass	5	–
Radiolarians	7	TR
Diatoms	2	TR
Sponge spicules	5	TR
Plant fragments	TR	1

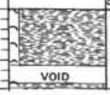
ORGANIC CARBON AND CARBONATE

	2-75
% Organic Carbon	0.2
% $CaCO_3$	3

SITE 489 HOLE CORE 5X CORED INTERVAL —

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
LOWER MIOCENE	NN 4 / *Calocycletta virginis*	RP	RM	AG		1	0.5

GRAPHIC LITHOLOGY



LITHOLOGIC DESCRIPTION

Washed into core barrel as bit was rotated near base of Core 4 for several hours. Structureless mud, grayish green (5G 5/2), mixed with radiolarian mud.

SMEAR SLIDES

	Mud	Radiolarian mud
	1-2.5 (D)	1-49 (D)
TEXTURE:		
Sand	–	–
Silt	20	20
Clay	80	80
COMPOSITION:		
Quartz	7	5
Feldspar	3	2
Mica	4	3
Heavy minerals	1	2
Pyrite	2	2
Clay	74	73
Glass	1	1
Foraminifers	TR	TR
Nannofossils	1	1
Radiolarians	6	10
Diatoms	TR	TR
Sponge spicules	1	1
Silicoflagellates	TR	TR

SITE 489 HOLE A CORE 1 CORED INTERVAL 0.0–8.0 m

TIME – ROCK UNIT: QUATERNARY; LOWER MIOCENE
BIOSTRATIGRAPHIC ZONE: NN 20/NN 21; NN 5 *Calocycletta costata*
FOSSIL CHARACTER: FORAMINIFERS CG; NANNOFOSSILS FP; RADIOLARIANS AG; DIATOMS; MOLLUSCS
SECTION: 1, 2, 3, 4, 5, CC
METERS: 0.5, 1.0
GRAPHIC LITHOLOGY: VOID; IW

LITHOLOGIC DESCRIPTION

Glauconitic foraminiferal MUDDY SILT, dusky yellowish green (10GY 3/2). Firm clay fragments. Minor vitric siliceous muddy silt, grayish green (5G 5/2).

SMEAR SLIDES

	Foraminiferal muddy silt	Vitric siliceous muddy silt
	1-15 (D)	CC (M)
TEXTURE:		
Sand	15	2
Silt	50	70
Clay	35	28
COMPOSITION:		
Quartz	28	30
Feldspar	5	2
Mica	TR	2
Pyrite	5	5
Clay	35	28
Glass	–	15
Glauconite	5	–
Carb. unspec.	1	2
Foraminifers	15	–
Nannofossils	1	–
Radiolarians	2	8
Diatoms	TR	3
Sponge spicules	2	5
Plant fragments	1	TR?

SITE 489 HOLE A CORE H-1 CORED INTERVAL 0.0–36.5 m

FOSSIL CHARACTER: CM CG
SECTION: 1, 2, CC
METERS: 0.5, 1.0

LITHOLOGIC DESCRIPTION

Wash sample: MUDDY SILT, dusky yellowish brown (10YR 2/2). Core-Catcher: grayish green (5G 5/2) MUDDY SILT, well-lithified angular limestone fragment.

SITE 489 HOLE A CORE 2 CORED INTERVAL 36.5–46.0 m

TIME – ROCK UNIT: LOWER MIOCENE
BIOSTRATIGRAPHIC ZONE: NN 4 *Calocycletta virginis*
FOSSIL CHARACTER: FORAMINIFERS FG; NANNOFOSSILS CP; RADIOLARIANS RM, RP; DIATOMS; MOLLUSCS
SECTION: 1, 2, CC
METERS: 0.5, 1.0

LITHOLOGIC DESCRIPTION

1.5 cm limestone clast

Burrow filled with grayish olive green muddy silt (5GY 3/2)

MUDDY SILT, dark greenish gray (5G 4/1), soupy to firm.

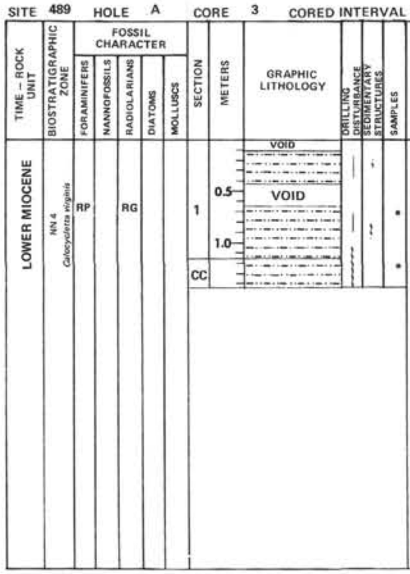
SMEAR SLIDES

	Muddy silt
	2-30 (D)
TEXTURE:	
Sand	3
Silt	77
Clay	20
COMPOSITION:	
Quartz	57
Feldspar	5
Mica	5
Pyrite	3
Glass	5
Carb. unspec.	1
Nannofossils	TR
Radiolarians	1
Diatoms	1
Sponge spicules	2

ORGANIC CARBON AND CARBONATE

	2-100
% Organic carbon	0.3
% $CaCO_3$	2

SITE 489 HOLE A CORE 3 CORED INTERVAL 46.0–55.5 m



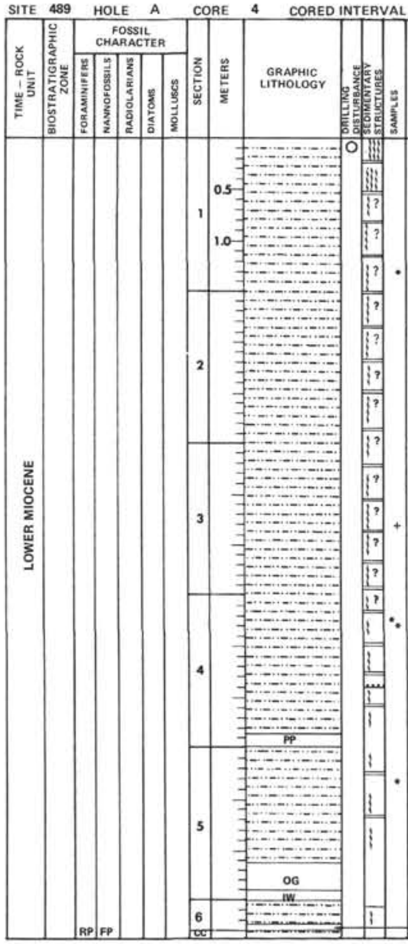
LITHOLOGIC DESCRIPTION

MUDDY SILT, dark greenish gray (5G 4/1), watery to firm. Rounded clasts (2–4 cm diameter) of firm muddy silt. At 20–35 cm, slightly mottled with grayish olive green (5GY 3/2) muddy silt. Very firm in Core-Catcher.

SMEAR SLIDES

	Muddy silt	Muddy silt
	1-73 (D)	CC (D)
TEXTURE:		
Sand	1	2
Silt	59	68
Clay	40	30
COMPOSITION:		
Quartz	50	58
Feldspar	3	6
Mica	2	3
Pyrite	3	2
Clay	40	30
Glass	–	TR
Carb. unspec.	1	1
Foraminifers	–	TR
Nannofossils	1	TR
Diatoms	TR	–
Sponge spicules	TR	TR
Plant fragments	TR	–

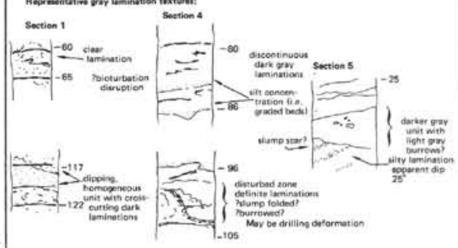
SITE 489 HOLE A CORE 4 CORED INTERVAL 55.5–65.0 m



LITHOLOGIC DESCRIPTION

MUDDY SILTSTONE, dark greenish gray (5G 4/1). Moderately to intensely mottled (bioturbated). Streaks of medium bluish gray (5B 5/1) and minor olive gray (5Y 4/1) mudstone. Common 1–2 mm bluish gray mudstone laminations above 1, 52 cm. Below 1, 52 cm, sporadic dark gray sub-horizontal drilling laminations, 1.5–4 cm spacing, often discontinuous (obliterated by bioturbation?).

Representative gray lamination textures:



Dark gray laminations thicken (1 cm), become diffuse and wavy

SMEAR SLIDES

	Muddy siltstone	Muddy siltstone	Muddy siltstone	Muddy siltstone
	1-138 (D)	4-27 (M)	4-30 (D)	5-32 (M)
TEXTURE:				
Sand	1	7	–	–
Silt	64	78	85	85
Clay	35	15	15	15
COMPOSITION:				
Quartz	50	75	75	83
Feldspar	7	10	7	2
Mica	5	7	3	1
Heavy minerals	–	1	1	TR
Pyrite	3	1	–	1
Clay	35	5	5	10
Glass	–	–	5	–
Glauconite	–	–	3?	3?
Carbonate unspec.	TR	–	–	–
Foraminifers	TR	–	–	–
Nannofossils	TR	–	TR	–
Sponge spicules	TR	–	–	–
Plant fragments	TR	1	1	–

ORGANIC CARBON AND CARBONATE

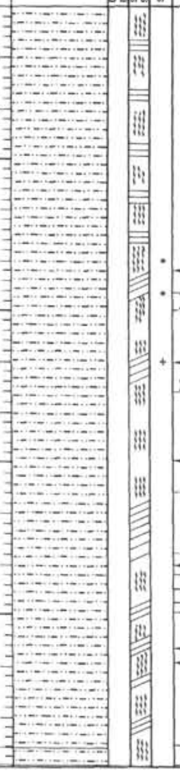
	3-89
% Organic Carbon	0.3
% $CaCO_3$	2

VOID

SITE 489 HOLE A CORE 5 CORED INTERVAL 65.0–74.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	MOLLUSCS	SECTION	METERS
LOWER MIOCENE		RP					1	0.5 / 1.0
							2	
							3	
							4	
							5	
		RP		FP			CC	

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



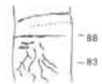
LITHOLOGIC DESCRIPTION

- Last recognizable horizontal bed
- Bedding (discontinuous color and silt concentrations) apparent 38° dip
- Inclined dark gray laminations (discontinuous) have 54° apparent dip
- Large circular burrows, 12 mm maximum dimension
- Gray laminations no longer present
- Inclined bedding (45° apparent dip) trunated by layers of different color or silt concentrations
- Fault, 55° apparent dip, sense not clear
- 30° apparent dip beds. Micrite concretion, 3 cm x 5.5 cm, irregular burrows
- At 140 cm, 25° apparent dip
- Fracture zone, 2 crudely conjugate sets, 55–60°
- 30° apparent dip
- 12° apparent dip
- Sub-horizontal true bedding

MUDDY SILTSTONE, dark greenish gray (5G 4/1) (locally soft to firm silt), moderately to intensely mottled (bioturbated). Streaks of medium bluish gray (5B 5/1) and minor olive gray (5Y 4/1) areas. Common 1–2 mm bluish gray mudstone laminations, sub-horizontal, but often diffuse – possibly smeared out by bioturbation.

Deviation 1.6 degrees.

Section 4



Chondrite-like ?burrows... in the section appearing to be planar

SMEAR SLIDES

	Muddy siltstone	Mudstone
	2-101 (D)	2-137 (M)
TEXTURE:		
Sand	1	2
Silt	51	38
Clay	48	60
COMPOSITION:		
Quartz	25	30
Feldspar	5	5
Mica	1	2
Heavy minerals	TR	1
Pyrite	–	1
Clay	48	65
Glauconite	–	2
Plant fragments	1	1
Apatite?	20	3

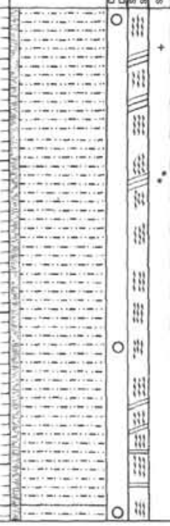
ORGANIC CARBON AND CARBONATE

	3-50
% Organic Carbon	0.2
% $CaCO_3$	3

SITE 489 HOLE A CORE 6 CORED INTERVAL 74.5–84.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	MOLLUSCS	SECTION	METERS
LOWER MIOCENE							1	0.5 / 1.0
							2	
							3	
							4	
		RP		RP			CC	

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



LITHOLOGIC DESCRIPTION

- 25° apparent dip
- 8° apparent dip
- 20° apparent dip, diffuse beds of alternating 5G 4/1 and 5GY 4/1
- 5° apparent dip
- 28° apparent dip
- 5–10° apparent dip, 1 mm laminations of medium bluish gray (5B 5/1) muddy siltstone

MUDDY SILTSTONE and MINOR MUDSTONE, predominantely dark greenish gray (5G 4/1) with minor dark greenish gray (5GY 4/1). Intensely bioturbated. Bedding traces occasionally evident (as shown).

SMEAR SLIDES

	Muddy siltstone	Mudstone
	2-13 (D)	2-21 (M)
TEXTURE:		
Sand	10	1
Silt	70	19
Clay	20	80
COMPOSITION:		
Quartz	78	15
Feldspar	5	5
Mica	3	3
Heavy minerals	2	1
Pyrite	1	1
Clay + clay size	10	73
Glauconite	TR?	–
Apatite?	1	2

ORGANIC CARBON AND CARBONATE

	1-40
% Organic Carbon	0.2
% $CaCO_3$	3

SITE 489 HOLE A CORE 7 CORED INTERVAL 84.0–93.5 m

TIME – ROCK UNIT: LOWER MIOCENE

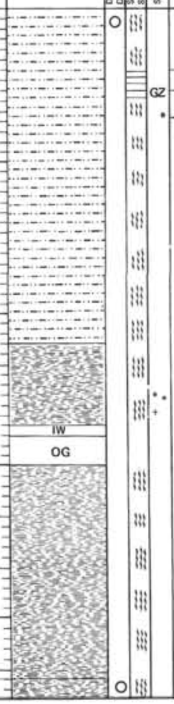
BIOSTRATIGRAPHIC ZONE: *Calocycletta virginis*

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS (FM), DIATOMS, MOLLUSCS

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



1 mm medium bluish gray (5B 5/1) mudstone laminations

Ash fragments

Vague horizontal laminations in places – may be drilling deformation.

Vague horizontal laminations

LITHOLOGIC DESCRIPTION

MUDDY SILTSTONE underlain by MUDSTONE, greenish gray (5G 6/1) to dark greenish gray (5G 4/1). Intensely bioturbated. Vague horizontal bedding.

SMEAR SLIDES

	Ash	Muddy sand (burrow filling)	Mudstone
	1-107 (M)	3-87 (M)	3-88 (D)
TEXTURE:			
Sand	–	50	1
Silt	100	30	29
Clay	–	20	70
COMPOSITION:			
Quartz	–	44	76
Feldspar	–	2	7
Mica	–	3	2
Heavy minerals	TR	1	1
Pyrite	–	45	1
Clay	–	–	10
Glass	100	–	–
Glauconite?	–	–	3
Apatite?	–	5	–

GRAIN SIZE

	1-80
Sand	3.0
Silt	49.6
Clay	47.4

ORGANIC CARBON AND CARBONATE

	3-92
% Organic Carbon	0.4
% $CaCO_3$	3

SITE 489 HOLE A CORE 8 CORED INTERVAL 93.5–103.0 m

TIME – ROCK UNIT: LOWER MIOCENE

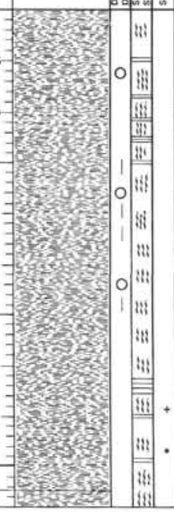
BIOSTRATIGRAPHIC ZONE: *Calocycletta virginis*

FOSSIL CHARACTER: FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS (CM, CM), DIATOMS, MOLLUSCS

SECTION: 1, 2, 3, 4, CC

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY / DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES



Bedding truncated by 1 mm mudstone laminations, medium bluish gray (5B 5/1). Occasionally diffuse and thicker (to 8 mm).

8 mm gray mudstone with "microflaser" texture

LITHOLOGIC DESCRIPTION

MUDSTONE, greenish gray and dark greenish gray (5G 6/1 to 5G 4/1 and 5GY 4/1). Intensely bioturbated. Primary bedding destroyed except as indicated.

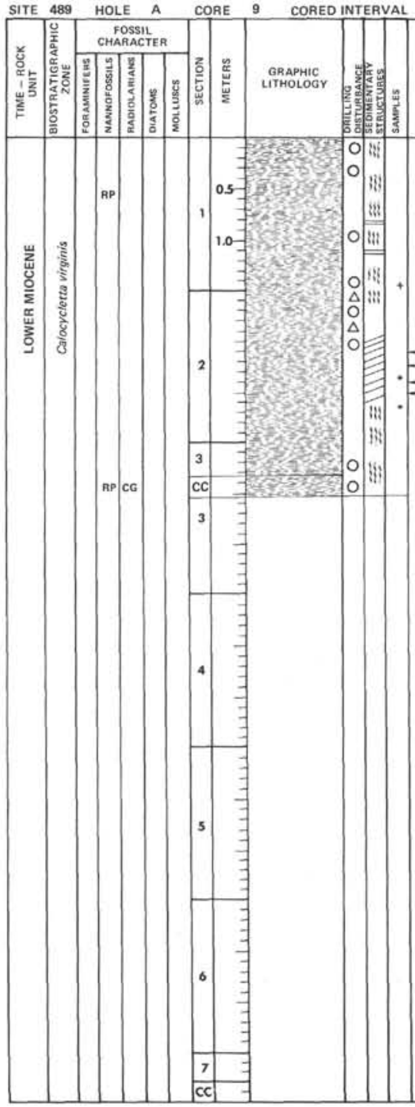
SMEAR SLIDES

	Mudstone
	3-133 (D)
TEXTURE:	
Sand	–
Silt	10
Clay	90
COMPOSITION:	
Quartz	8
Feldspar	2
Mica	1
Heavy minerals	1
Pyrite	TR
Clay	87
Radiolarians	1
Sponge spicules	TR
Plant fragments	TR

ORGANIC CARBON AND CARBONATE

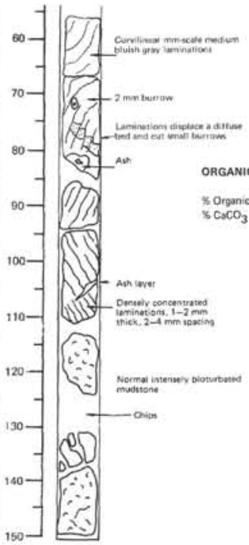
	3-92
% Organic Carbon	0.4
% $CaCO_3$	1

SITE 489 HOLE A CORE 9 CORED INTERVAL 103.0–112.5 m



75° apparent dip of laminations
75° apparent dip
60° apparent dip
54° apparent dip

Details of Part of Section 2:



LITHOLOGIC DESCRIPTION

MUDSTONE, dark greenish gray (5G 4/1). Intensely bioturbated. Bedding indicated where visible, comprising 1 mm medium bluish gray (5B 5/1) laminations. Soupy zones contain small, irregular chips of the surrounding rock. At 1, 125–134 cm, congugate shears dipping 60–70 degrees. At 2, 55–110 cm, core is broken into large pieces (see detail below). Millimeter medium bluish gray (5B 5/1) laminations dip steeply and occasionally cut features such as small burrows. At 2, 84 and 105 cm, ash layers.

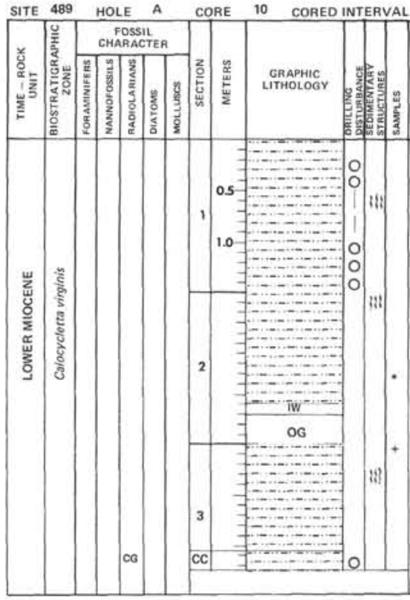
SMEAR SLIDES

	Ash 2-84 (M)	Mudstone 2-116 (D)
TEXTURE:		
Sand	–	1
Silt	100	29
Clay	–	70
COMPOSITION:		
Quartz	–	15
Feldspar	–	5
Mica	TR	2
Heavy minerals	TR	1
Pyrite	–	1
Clay	–	72
Glass	100	–
Radiolarians	–	1
Diatoms	–	TR
Sponge spicules	–	1
Apatite?	–	1

ORGANIC CARBON AND CARBONATE

	1-145
% Organic Carbon	0.4
% $CaCO_3$	3

SITE 489 HOLE A CORE 10 CORED INTERVAL 112.5–122.0 m



LITHOLOGIC DESCRIPTION

MUDDY SILTSTONE, dark greenish gray (5G 4/1). Where internal details are evident, there is intense burrowing. No clear bedding details. Core broken into large blocks.

SMEAR SLIDES

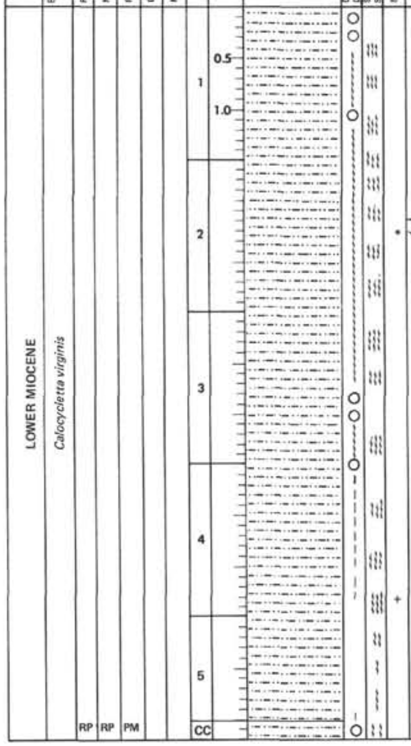
	Muddy siltstone 2-83 (D)
TEXTURE:	
Sand	2
Silt	65
Clay	33
COMPOSITION:	
Quartz	45
Feldspar	18
Mica	3
Heavy minerals	1
Pyrite	1
Clay	30
Foraminifers	TR
Radiolarians	1
Sponge spicules	1
Plant fragments	TR

ORGANIC CARBON AND CARBONATE

	3-5
% Organic Carbon	0.6
% $CaCO_3$	3

SITE 489 HOLE A CORE 11 CORED INTERVAL 122.0–131.5 m

TIME – ROCK UNIT | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER (FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS, MOLLUSCS) | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION



Two cross-cutting fractures: a) 52° true dip, slickensides 20°, very smooth; b) 20° true dip, irregular.

55° true plunge of slickensides

MUDDY SILTSTONE, dark greenish gray (5G 4/1) with minor soft to very firm muddy silt. Intense bioturbation. Drilling biscuits of 3–5 cm discrete blocks of muddy siltstone separated by very soft muddy silt, apparently formed by rotation of the blocks during drilling.

Section 3: irregularly fractured throughout, with conjugate sets of 40–50 degrees apparent dips.

Section 4: bedding dips 48 degrees true. Cleavage, true dip 29–48 degrees (average 40 degrees) with slickensides at 28–47 degrees. *Zero to very slight* (< 1 *mm*) offset of bedding and burrows. Bedding and cleavage strike subparallel, but dip in opposite directions. Cleavages spaced 0.5–2 cm, en echelon, healed. Some cleavages are open and more widely spaced (2–8 cm) – may have been opened by drilling or handling.

In Section 5, cleavage is less regular and somewhat folded below an inclined healed fracture at 5, 12–18 cm.

SMEAR SLIDES

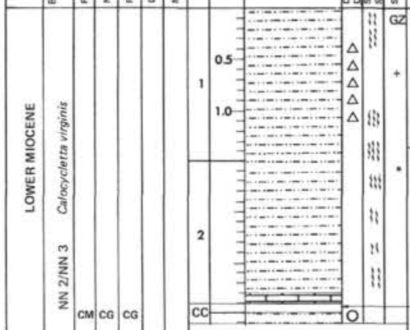
	Muddy siltstone 2-70 (D)
TEXTURE:	
Sand	2
Silt	60
Clay	38
COMPOSITION:	
Quartz	50
Feldspar	3
Mica	3
Pyrite	3
Carbonate unspec.	TR
Radiolarians	TR
Diatoms	1
Sponge spicules	2

ORGANIC CARBON AND CARBONATE

	4-134
% Organic Carbon	0.6
% $CaCO_3$	2

SITE 489 HOLE A CORE 12 CORED INTERVAL 131.5–141.0 m

TIME – ROCK UNIT | BIOSTRATIGRAPHIC ZONE | FOSSIL CHARACTER (FORAMINIFERS, NANNOFOSSILS, RADIOLARIANS, DIATOMS, MOLLUSCS) | SECTION | METERS | GRAPHIC LITHOLOGY | DRILLING DISTURBANCE | SEDIMENTARY STRUCTURES | SAMPLES | LITHOLOGIC DESCRIPTION



Probable bedding with 60° apparent dip

VOID

Soft MUDDY SILT to MUDDY SILTSTONE, grayish olive green (5GY 3/2), bioturbation. At 1, 25–100 cm, probable bedding 60 degree apparent dip, planar fractures with 40–70 degree apparent dip, slickensides up to 47 degrees. Fractures subparallel to bedding. Below 2, 14 cm, soft to very firm MUDDY SILT, moderate bioturbation. Dark laminations, sub-horizontal, as in Core 4, scattered throughout section. At 2, 20 cm, set of horizontal and concave upward laminations. Full round of LIMESTONE, bioturbated, dark greenish gray (5G 4/1) in Section 2, 140–150 cm. Core-Catcher same as above MUDDY SILT, 4x8 cm rounded fragment of LIMESTONE, as above.

SMEAR SLIDES

	Muddy siltstone 2-10 (D)
TEXTURE:	
Sand	2
Silt	68
Clay	30
COMPOSITION:	
Quartz	52
Feldspar	8
Mica	3
Pyrite	2
Glass	TR
Nannofossils	TR
Radiolarians	1
Diatoms	1
Sponge spicules	3
Plant fragments	TR?

GRAIN SIZE

	1-10
Sand	5.4
Silt	66.6
Clay	27.9

ORGANIC CARBON AND CARBONATE

	1-66
% Organic Carbon	0.7
% $CaCO_3$	1

SITE 489 HOLE A CORE 13 CORED INTERVAL 141.0–150.5 m

TIME-ROCK UNIT: LOWER MIOCENE

BIOSTRATIGRAPHIC ZONE: NN 1 *Calocycletta virginis*

FOSSIL CHARACTER: FORAMINIFERS RP; NANNOFOSSILS FM; RADIOLARIANS CG; DIATOMS; MOLLUSCS

SECTION: 1, 2, 3, CC

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY: OG

DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

Burrows

Burrow

LITHOLOGIC DESCRIPTION

MUDDY SILT, firm, grayish olive green (5GY 3/2). Moderate to intense bioturbation, common to abundant thin (1–2 mm) laminations of gray black (N2) mud (drilling biscuits). Mottling is above colors with dark greenish gray (5G 4/1) mud. Laminations cross-cut the mottling. Below 1, 99 cm, dark greenish gray (5GY 4/1) muddy siltstone, moderately bioturbated. Fractures dip 50–77 degrees true, slickensides 51–77 degrees true plunge.

Section 2, infrequent fractures, 22 degrees to near 90 degrees apparent dips.

Section 3, more abundant fractures, 28–90 degrees apparent dips, slickensides plunge up to 90 degrees. Much burrowing. Wood fragments.

SMEAR SLIDES

	Muddy silt	Mud
	1-57 (D)	1-86 (M)
TEXTURE:		
Sand	–	1
Silt	55	34
Clay	45	65
COMPOSITION:		
Quartz	47	28
Feldspar	3	TR
Mica	2	2
Heavy minerals	–	TR
Pyrite	1	2
Clay	45	–
Carbonate unspec.	TR	2
Nannofossils	–	TR
Radiolarians	TR	TR
Diatoms	TR	TR
Sponge spicules	2	1
Plant fragments	–	TR

ORGANIC CARBON AND CARBONATE

	2-16
% Organic Carbon	0.7
% $CaCO_3$	2

SITE 489 HOLE A CORE 14 CORED INTERVAL 150.5–160.0 m

BIOSTRATIGRAPHIC ZONE: *Calocycletta virginis* - NN 1

FOSSIL CHARACTER: FORAMINIFERS RP; NANNOFOSSILS CM; RADIOLARIANS RM; DIATOMS; MOLLUSCS

SECTION: CC

LITHOLOGIC DESCRIPTION

MUDDY SILT, soft, grayish olive green (5GY 3/2), structureless.

SMEAR SLIDES

	Muddy silt
	CC (D)
TEXTURE:	
Sand	2
Silt	60
Clay	38
COMPOSITION:	
Quartz	49
Feldspar	2
Mica	3
Heavy minerals	TR
Pyrite	3
Clay	38
Carbonate unspec.	TR
Nannofossils	TR
Radiolarians	TR
Sponge spicules	5

SITE 489 HOLE A CORE 15 CORED INTERVAL 160.0–164.5 m

TIME-ROCK UNIT: LOWER MIOCENE

BIOSTRATIGRAPHIC ZONE: *Calocycletta virginis* - NN 1

FOSSIL CHARACTER: FORAMINIFERS RP; NANNOFOSSILS FM; RADIOLARIANS CG; DIATOMS; MOLLUSCS

SECTION: 1, 2, CC

METERS: 0.5, 1.0

LITHOLOGIC DESCRIPTION

MUDDY SILTSTONE (below Section 1, 1–12 cm), color grayish olive green (5GY 3/2), abundant fractures (true dips 38–62 degrees, crudely conjugate, slickenside indistinct, plunging 35–60 degrees with MUDDY SILT, soft, same color, bioturbated in Section 1, 0–12 cm, 101–107 cm and Core-Catcher.

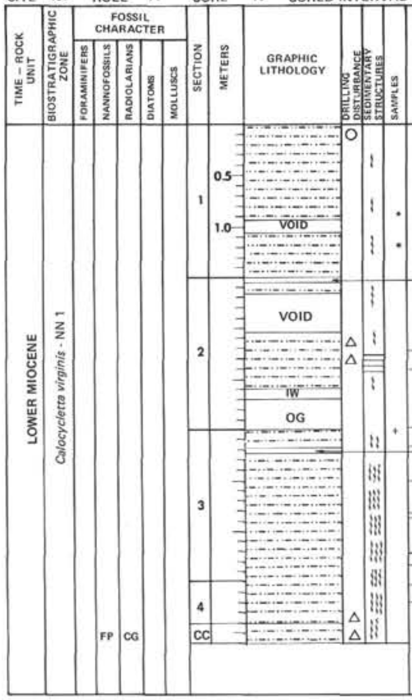
SMEAR SLIDES

	Muddy siltstone
	1-120 (D)
TEXTURE:	
Sand	2
Silt	68
Clay	30
COMPOSITION:	
Quartz	60
Feldspar	5
Mica	5
Heavy minerals	TR
Pyrite	4
Clay	30
Carbonate unspec.	TR
Nannofossils	TR
Radiolarians	1
Diatoms	TR
Sponge spicules	5
Plant fragments	TR?

ORGANIC CARBON AND CARBONATE

	2-16
% Organic Carbon	1.0
% $CaCO_3$	2

SITE 489 HOLE A CORE 16 CORED INTERVAL 164.5–169.5 m



VOID

1 mm subhorizontal grayish black (N2) mud every 3–4 cm
Not clear if original bedding

Very firm

VOID

Horizontal to vertical fractures

Burrows

Fractures, true dip approximately 30 degrees

Burrows

LITHOLOGIC DESCRIPTION

MUDDY SILT, grayish olive green (5GY 3/2), with subrounded clasts of MUDDY SILTSTONE, dark greenish gray (5G 4/1). High concentration of clasts at top of core may be remnants of earlier lithology that caved into hole while retrieving Core 15. Slightly mottled. Muddy silt is firmer in Section 2. Below Section 3, 23 cm, MUDDY SILTSTONE, same color.

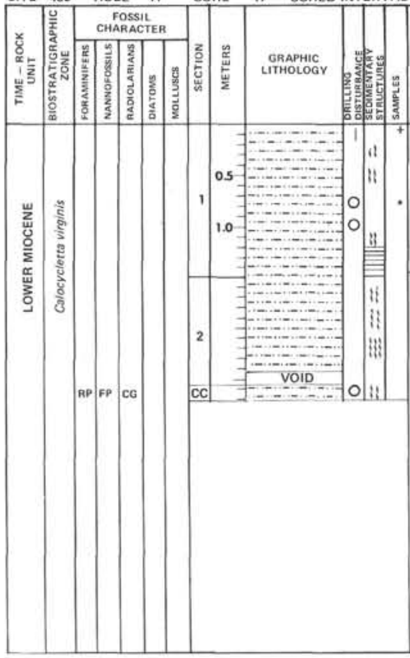
SMEAR SLIDES

	Mud	Muddy silt
	1-90 (M)	1-120 (D)
TEXTURE:		
Sand	–	2
Silt	40	53
Clay	60	45
COMPOSITION:		
Quartz	30	42
Feldspar	2	5
Mica	36	5
Heavy minerals	–	TR
Pyrtie	3	2
Clay	60	40
Carbonate unspec.	TR	TR
Nannofossils	TR	TR
Radiolarians	TR	TR
Diatoms	TR	–
Sponge spicules	2	1
Plant fragments	–	TR

ORGANIC CARBON AND CARBONATE

	3-0
% Organic Carbon	1.0
% $CaCO_3$	3

SITE 489 HOLE A CORE 17 CORED INTERVAL 169.5–179.0 m



Thin black horizontal laminations

LITHOLOGIC DESCRIPTION

MUDDY SILT, very soft to firm, grayish olive green (5GY 3/2), with subrounded clasts, up to diameter of core barrel, of bioturbated MUDDY SILTSTONE, same color. Muddy silt becomes firmer and more mottled with depth. Below Section 2, 40 cm, becomes muddy siltstone, same color. Moderate to intense bioturbation.

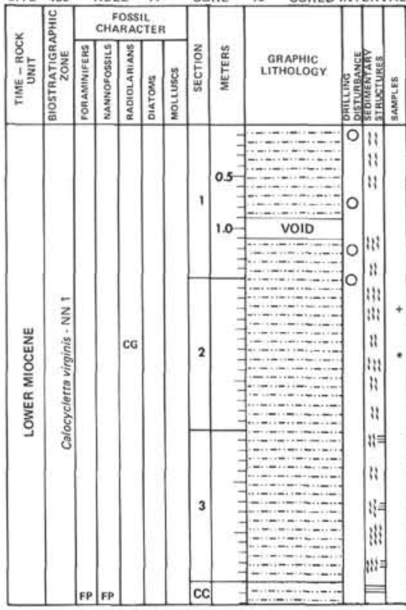
SMEAR SLIDES

	Muddy silt
	1-81 (D)
TEXTURE:	
Sand	1
Silt	69
Clay	30
COMPOSITION:	
Quartz	59
Feldspar	4
Mica	2
Heavy minerals	TR
Pyrite	3
Clay	30
Carbonate unspec.	TR
Nannofossils	TR
Radiolarians	TR
Diatoms	TR
Sponge spicules	2
Plant fragments	TR

ORGANIC CARBON AND CARBONATE

	1-0
% Organic Carbon	0.5
% $CaCO_3$	2

SITE 489 HOLE A CORE 18 CORED INTERVAL 179.0–183.0 m



Consistant fractures, 16–19 degrees true dip

Irregular fractures up to 55 degrees true dip, slickensides plunging 20–50 degrees.

Thin dark mud laminations

Thin dark mud laminations

Thin dark mud laminations

LITHOLOGIC DESCRIPTION

MUDDY SILTSTONE, grayish olive green (5GY 3/2), bioturbated. Core-Catcher: siltier at base.

SMEAR SLIDES

	Muddy siltstone
	2-80 (D)
TEXTURE:	
Sand	2
Silt	58
Clay	40
COMPOSITION:	
Quartz	47
Feldspar	5
Mica	3
Pyrite	2
Clay	40
Carbonate unspec.	1
Foraminifers	TR
Nannofossils	TR
Radiolarians	TR
Diatoms	TR
Sponge spicules	2

ORGANIC CARBON AND CARBONATE

	2-30
% Organic Carbon	1.0
% $CaCO_3$	2

SITE 489 HOLE A CORE 19 CORED INTERVAL 183.0–188.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	MOLLUSCS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
LOWER MIOCENE	NN 1	FM	FM				1, 2, 3, CC	0.5, 1.0	IW, OG			

Chondrites trace fossil

Well preserved zoophycos trace fossil

MUD, grayish olive (10Y 4/2)

LITHOLOGIC DESCRIPTION

MUDDY SILTSTONE, grayish olive green (5GY 3/2) moderate to intense bioturbation. Fractures prevalent, planes dip 20–76 degrees true. Slickenside on 76 degree dipping fracture has 76 degree true plunge. Sections 2 and 3, thin dark drilling laminations. Moderate bioturbation.

SMEAR SLIDES

	Muddy siltstone
	2-50 (D)
TEXTURE:	
Sand	1
Silt	55
Clay	44
COMPOSITION:	
Quartz	48
Feldspar	3
Mica	2
Pyrite	3
Clay	44
Sponge spicules	TR

ORGANIC CARBON AND CARBONATE

	3-0
% Organic Carbon	1.0
% $CaCO_3$	2

SITE 489 HOLE A CORE 20 CORED INTERVAL 188.5–198.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	MOLLUSCS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
LOWER MIOCENE	NN 1	RP	RP				1, 2, CC	0.5, 1.0	VOID, VOID			

VOID

Dark thin drilling laminations

LITHOLOGIC DESCRIPTION

MUDDY SILT, grayish olive green (5GY 3/2), firm to very firm. Moderate bioturbation. Section 2, soft to firm.

SMEAR SLIDES

	Muddy silt
	CC (D)
TEXTURE:	
Sand	1
Silt	59
Clay	40
COMPOSITION:	
Quartz	50
Feldspar	7
Mica	1
Pyrite	2
Glass	40
Carbonate unspec.	TR
Nannofossils	TR
Sponge spicules	TR
Plant fragments	TR?

ORGANIC CARBON AND CARBONATE

	1-100
% Organic Carbon	1.2
% $CaCO_3$	3

SITE 489 HOLE A CORE 21 CORED INTERVAL 198.0–207.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	MOLLUSCS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
LOWER MIOCENE	NN 1	FM	FP				1, 2, 3, 4, 5, 6, 7, CC	0.5, 1.0	VOID, VOID, VOID			GZ

VOID

VOID

VOID

LITHOLOGIC DESCRIPTION

MUDDY SILTSTONE, grayish olive green (5GY 3/2), with angular clasts of more lithified material of the same lithology (as shown). Generally structureless.

In Section 4, below 109 cm, muddy siltstone becomes firmer, horizontal drilling laminations are visible in places. Moderately bioturbated. Laminations are millimeter-scale MUD, medium bluish gray (5B 5/1).

At Section 5, 25 cm, diffuse, calcareous area: discoloration, dark greenish gray (5GY 4/1) to dusky yellow green (5GY 5/2) – incipient concretion? At Section 5, 37–41 cm, greenish gray LIMESTONE, possible bioturbation.

At Section 6, 12 cm, diffuse concentration of very fine sand grains.

SMEAR SLIDES

	Very fine sand	Muddy siltstone	Muddy siltstone
	6-12 (M)	6-20 (D)	6-124 (D)
TEXTURE:			
Sand	55	7	2
Silt	38	73	65
Clay	7	20	33
COMPOSITION:			
Quartz	77	67	65
Feldspar	10	15	10
Mica	3	2	2
Heavy minerals	3	TR	1
Pyrite	1	1	2
Clay	5	15	20
Sponge spicules	–	–	TR
Plant fragments	1	–	TR

GRAIN SIZE

	5-14
Sand	6.0
Silt	62.5
Clay	31.4

ORGANIC CARBON AND CARBONATE

	4-110
% Organic Carbon	0.8
% $CaCO_3$	3

SITE 489 HOLE A CORE 22 CORED INTERVAL 207.5–217.0 m

TIME – ROCK UNIT: LOWER MIOCENE

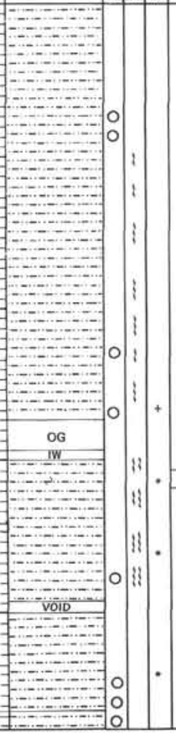
BIOSTRATIGRAPHIC ZONE

FOSSIL CHARACTER: FORAMINIFERS; NANNOFOSSILS: CM; RADIOLARIANS; DIATOMS; MOLLUSCS

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



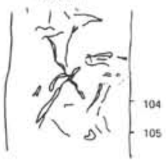
DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

Diffuse concentration of sand grains

LITHOLOGIC DESCRIPTION

MUDDY SILTSTONE, grayish olive (10Y 4/2). Section 1, 0–81 cm, closely fractured, friable, almost shaly. Structureless. From 81–113 cm, diffuse, anastamosing permeations, possibly too straight to be bioturbation (see drawing). From 130–150 cm, closely fractured, almost shaly.

Section 1



SMEAR SLIDES

	Siltstone	Muddy siltstone	Muddy siltstone
	4-22 (M)	4-92 (D)	5-60 (D)
TEXTURE:			
Sand	40	3	2
Silt	50	62	73
Clay	10	35	25
COMPOSITION:			
Quartz	61	83	62
Feldspar	15	12	10
Mica	5	2	4
Heavy minerals	2	1	1
Pyrite	2	1	1
Clay	5	–	20
Nannofossils	–	–	1
Plant fragments	10	1	1

ORGANIC CARBON AND CARBONATE

	3-100
% Organic Carbon	0.8
% $CaCO_3$	2

SITE 489 HOLE A CORE 23 CORED INTERVAL 217.0–226.5 m

TIME – ROCK UNIT: LOWER MIOCENE

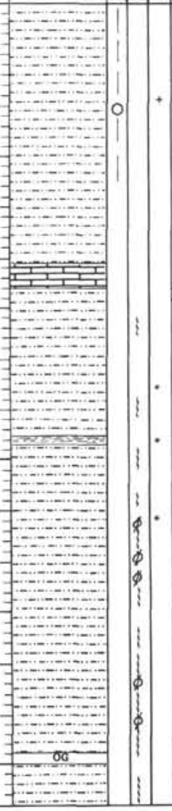
BIOSTRATIGRAPHIC ZONE: NN 1

FOSSIL CHARACTER: FORAMINIFERS: RP; NANNOFOSSILS: FM; RADIOLARIANS; DIATOMS; MOLLUSCS

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

METERS: 0.5, 1.0

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

Fractures, apparent dip 38 degrees

Apparent dip 15 degrees

LITHOLOGIC DESCRIPTION

MUDDY SILT, grayish olive (10Y 4/2), soft, no internal structure. Section 2, 105–130 cm LIMESTONE, micritic, olive gray (5Y 3/2). Section 3, 127–132 cm MUD, light bluish gray (5B 7/1). Sections 3 and 4, concentrations of dark, fine to coarse sand-sized material (glauconite). Bioturbation.

SMEAR SLIDES

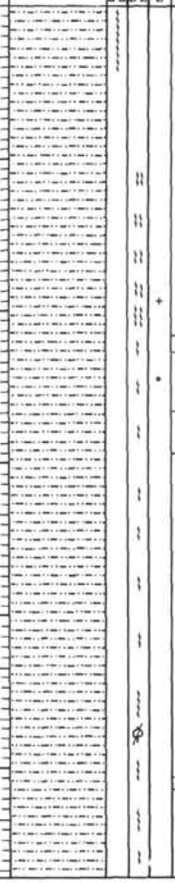
	Muddy silt	Mud	Muddy silt
	3-80 (M)	3-130 (M)	4-60 (M)
TEXTURE:			
Sand	30	–	2
Silt	50	40	63
Clay	20	60	35
COMPOSITION:			
Quartz	55	41	58
Feldspar	15	10	10
Mica	4	2	3
Heavy minerals	2	1	2
Pyrite	1	1	1
Clay	15	45	25
Glass	3	–	–
Glauconite	3	–	–
Nannofossils	1	TR	TR
Plant fragments	1	TR	1

ORGANIC CARBON AND CARBONATE

	1-95
% Organic Carbon	1.2
% $CaCO_3$	4

SITE 489 HOLE A CORE 24 CORED INTERVAL 226.5–236.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	SECTION
LOWER MIOCENE	NN 1	RP	CP	1, 2, 3, 4, 5, 6



Fissile zone is subhorizontal

Fissile zone dips 30 degrees true

Microfault displaces mm-scale mud lamination, apparent dip of fault 70 degrees true.

LITHOLOGIC DESCRIPTION

MUDDY SILT, grayish olive green (5GY 3/2) and MUDDY SILTSTONE below 63 cm, incipient fissility, prominent planes dipping 20 degrees true. Structureless otherwise. Color becomes grayish olive (10Y 4/2) in Section 2.

SMEAR SLIDES

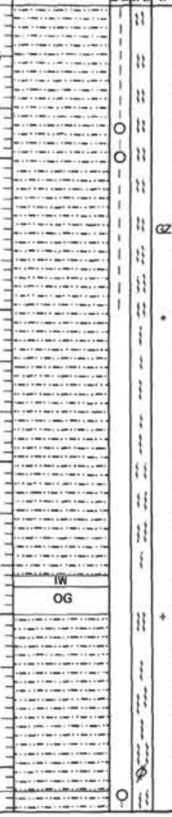
	Muddy siltstone 3-70 (D)
TEXTURE:	
Sand	1
Silt	79
Clay	20
COMPOSITION:	
Quartz	69
Feldspar	10
Mica	3
Heavy minerals	1
Pyrite	1
Clay	15
Nannofossils	TR
Plant fragments	1

ORGANIC CARBON AND CARBONATE

	2-140
% Organic Carbon	0.9
% $CaCO_3$	5

SITE 489 HOLE A CORE 25 CORED INTERVAL 236.0–345.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	SECTION
LOWER MIOCENE	NN 1	FP	CM	1, 2, 3, 4, 5, 6, CC



Thin, horizontal dark drilling laminations every 2–3 cm

Minor irregular pods and layers of fine sand

Gradual color change to dark greenish gray (5GY 4/1)

Sediment becomes very firm. Small wood fragments

LITHOLOGIC DESCRIPTION

MUDDY SILT, grayish olive (10Y 4/2), soft to firm structureless. Slight to moderate bioturbation.

SMEAR SLIDES

	Muddy silt 3-10 (D)
TEXTURE:	
Sand	2
Silt	73
Clay	25
COMPOSITION:	
Quartz	60
Feldspar	8
Mica	3
Heavy minerals	TR
Pyrite	3
Clay	25
Nannofossils	TR
Sponge spicules	TR
Plant fragments	1

GRAIN SIZE

	2-70
Sand	6.2
Silt	70.5
Clay	23.3

ORGANIC CARBON AND CARBONATE

	5-0
% Organic Carbon	0.9
% $CaCO_3$	4

SITE 489 HOLE A CORE 26 CORED INTERVAL 245.5–255.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	MOLLUSCS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
LOWER MIOCENE	NN 1		CM				1, 2, 3, 4, 5, CC	0.5, 1.0				

LITHOLOGIC DESCRIPTION

MUDDY SILT, olive gray (5Y 3/2), soft to firm. No internal features present except moderate bioturbation.

At Section 2, 42–56 cm, MUDDY SILTSTONE.

Section 3, firm to very firm.

Section 4: smooth, planar fractures common, sub-horizontal to 58 degree true dips. At 4, 50–120 cm, increase then decrease in degree of lithification. Corresponding color changes to light olive gray (5Y 5/2) and return to 5Y 3/2.

SMEAR SLIDES

	Muddy silt
	2-10 (D)
TEXTURE:	
Sand	2
Silt	73
Clay	25
COMPOSITION:	
Quartz	65
Feldspar	3
Mica	3
Heavy minerals	1
Pyrite	2
Clay	25
Carbonate usnpec.	TR
Nannofossils	1
Sponge spicules	TR
Plant fragments	TR

ORGANIC CARBON AND CARBONATE

	1-30
% Organic Carbon	0.8
% $CaCO_3$	3

SITE 489 HOLE A CORE 27 CORED INTERVAL 255.0–264.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	MOLLUSCS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
LOWER MIOCENE	NN 1	FM	CM				1, 2, 3, CC	0.5, 1.0				

LITHOLOGIC DESCRIPTION

MUDDY SILT, dark greenish gray (5GY 4/1), soft to very firm, moderate bioturbation. At Section 1, 110–150 cm, faint thin (1–2 mm) black (N2) drilling? laminations, horizontal or sub-horizontal.

SMEAR SLIDES

	Muddy silt
	2-10 (D)
TEXTURE:	
Sand	2
Silt	63
Clay	35
COMPOSITION:	
Quartz	56
Feldspar	3
Mica	2
Heavy minerals	TR
Pyrite	3
Clay	35
Carbonate unspec.	TR
Nannofossils	1
Sponge spicules	TR

ORGANIC CARBON AND CARBONATE

	2-58
% Organic Carbon	0.9
% $CaCO_3$	4

SITE 489 HOLE A CORE 28 CORED INTERVAL 264.0–273.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	MOLLUSCS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
LOWER MIOCENE	NN 1	RM	CM				1, 2, 3, 4, CC	0.5, 1.0	IW, OG			

Burrows

Muddy siltstone, light olive gray (5Y 5/2), veined

Bioturbated limestone, 3x3 cm, grayish olive green (5GY 3/2)

Burrow

LITHOLOGIC DESCRIPTION

MUDDY SILT, grayish olive green (5GY 3/2), soft to firm. Slight to moderate bioturbation. Irregularly oriented straight fractures dipping 35–80 degrees true.

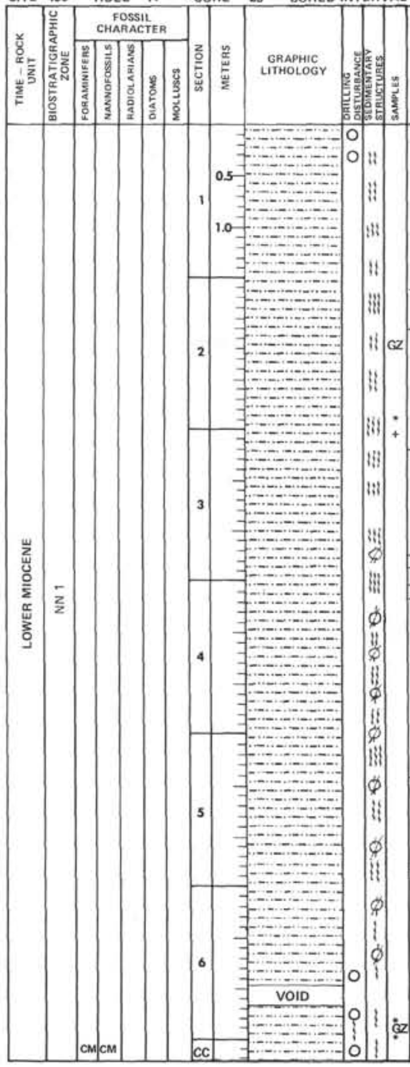
SMEAR SLIDES

	Muddy silt
	2-100 (D)
TEXTURE:	
Sand	–
Silt	65
Clay	35
COMPOSITION:	
Quartz	52
Feldspar	6
Mica	3
Pyrite	2
Clay	35
Nannofossils	TR
Sponge spicules	TR
Plant fragments	2

ORGANIC CARBON AND CARBONATE

	1-140
% Organic Carbon	0.8
% $CaCO_3$	3

SITE 489 HOLE A CORE 29 CORED INTERVAL 273.0–282.0 m



Apparent dip of bedding is 23 degrees

Burrows

Chondrites trace fossils

Coral? fragment

Burrows

Fracture, 31 degree true dip, small bivalve shells

Articulated bivalve

Sediment-filled, zeolite-lined planar fracture, 52 degree apparent dip

1 mm zeolite-filled fault

Discontinuous layer of zeolite grains

LITHOLOGIC DESCRIPTION

MUDDY SILT, dark greeenish gray (5GY 4/1), soft at top of Section 1, becoming firmer with depth, very firm by middle of Section 2. Slight to intense bioturbation.

In Section 2, smooth planar fractures, true dip 28–73 degrees. Sand fraction increases downward.

SMEAR SLIDES

	Muddy silt	Zeolite	Muddy silt
	2-140 (D)	6-134 (M)	6-144 (D)
TEXTURE:			
Sand	15	–	30
Silt	70	–	55
Clay	15	–	15
COMPOSITION:			
Quartz	64	–	66
Feldspar	10	–	5
Mica	3	–	5
Heavy minerals	2	–	–
Pyrite	2	–	2
Clay	15	–	15
Carbonate unspec.	2	–	2
Zeolite	–	100	–
Foraminifers	TR	–	TR
Nannofossils	2	–	1
Diatoms	TR	–	1
Sponge spicules	TR	–	1
Plant fragments	TR	–	2

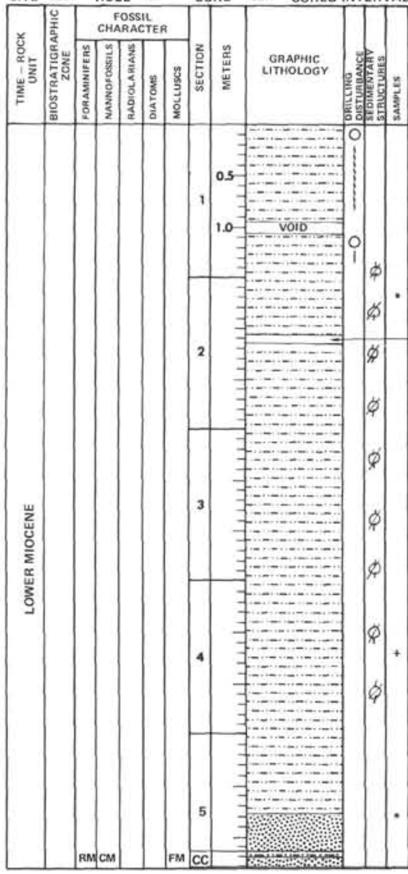
GRAIN SIZE

	2-64	6-139
Sand	10.3	35.1
Silt	66.7	44.0
Clay	23.0	20.9

ORGANIC CARBON AND CARBONATE

	3-8
% Organic Carbon	0.9
% $CaCO_3$	5

SITE 489 HOLE A CORE 30 CORED INTERVAL 282.0–291.0 m



VOID

Sand content decreases

LITHOLOGIC DESCRIPTION

MUDDY SILT, dark greenish gray (5GY 4/1), soft, slightly sandy and fine- to medium-grained SANDSTONE, olive gray (5Y 3/2), carbonate cement, with irregular dark, finer grained zones. Occasional shell fragments.

In Section 5, zeolite filled and unfilled fractures, apparent dips 40–90 degrees.

SMEAR SLIDES

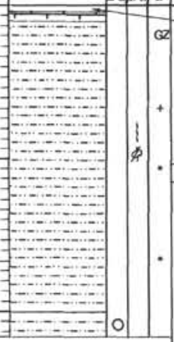
	Muddy silt	Muddy silt
	2-20 (D)	5-80 (D)
TEXTURE:		
Sand	20	7
Silt	50	73
Clay	30	20
COMPOSITION:		
Quartz	55	64
Feldspar	3	5
Mica	3	2
Heavy minerals	TR	–
Pyrite	2	2
Clay	30	30
Carbonate unspec.	3	2
Foraminifers	TR	1
Nannofossils	1	1
Radiolarians	TR	TR
Diatoms	1	TR
Sponge spicules	TR	TR
Plant fragments	3	3

ORGANIC CARBON AND CARBONATE

	4-70
% Organic Carbon	0.5
% $CaCO_3$	6

SITE 489 HOLE A CORE 31 CORED INTERVAL 291.0–300.0 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FOSSIL CHARACTER: FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	MOLLUSCS	SECTION	METERS	GRAPHIC LITHOLOGY	DRILLING DISTURBANCE	SEDIMENTARY STRUCTURES	SAMPLES
LOWER MIOCENE		RM	FM				1, 2, CC	0.5, 1.0				GZ



LITHOLOGIC DESCRIPTION

VOID

Vague burrows

Diffuse, well-indurated calcareous area

At 8–25 cm: vein with zeolite filling

SANDY MICRITIC LIMESTONE, grayish olive green (5GY 3/2). MUDDY SILTSTONE, grayish olive green (5GY 3/2).

SMEAR SLIDES

	Zeolite	Muddy siltstone
	2-12 (M)	2-100 (D)
TEXTURE:		
Sand	–	15
Silt	–	70
Clay	–	15
COMPOSITION:		
Quartz	–	65
Feldspar	–	15
Mica	–	4
Heavy minerals	–	2
Pyrite	–	1
Clay	–	10
Carbonate unspec.	–	TR
Zeolite	100	–
Nannofossils	–	1
Plant fragments	–	2

GRAIN SIZE

	1-30
Sand	7.2
Silt	73.1
Clay	19.7

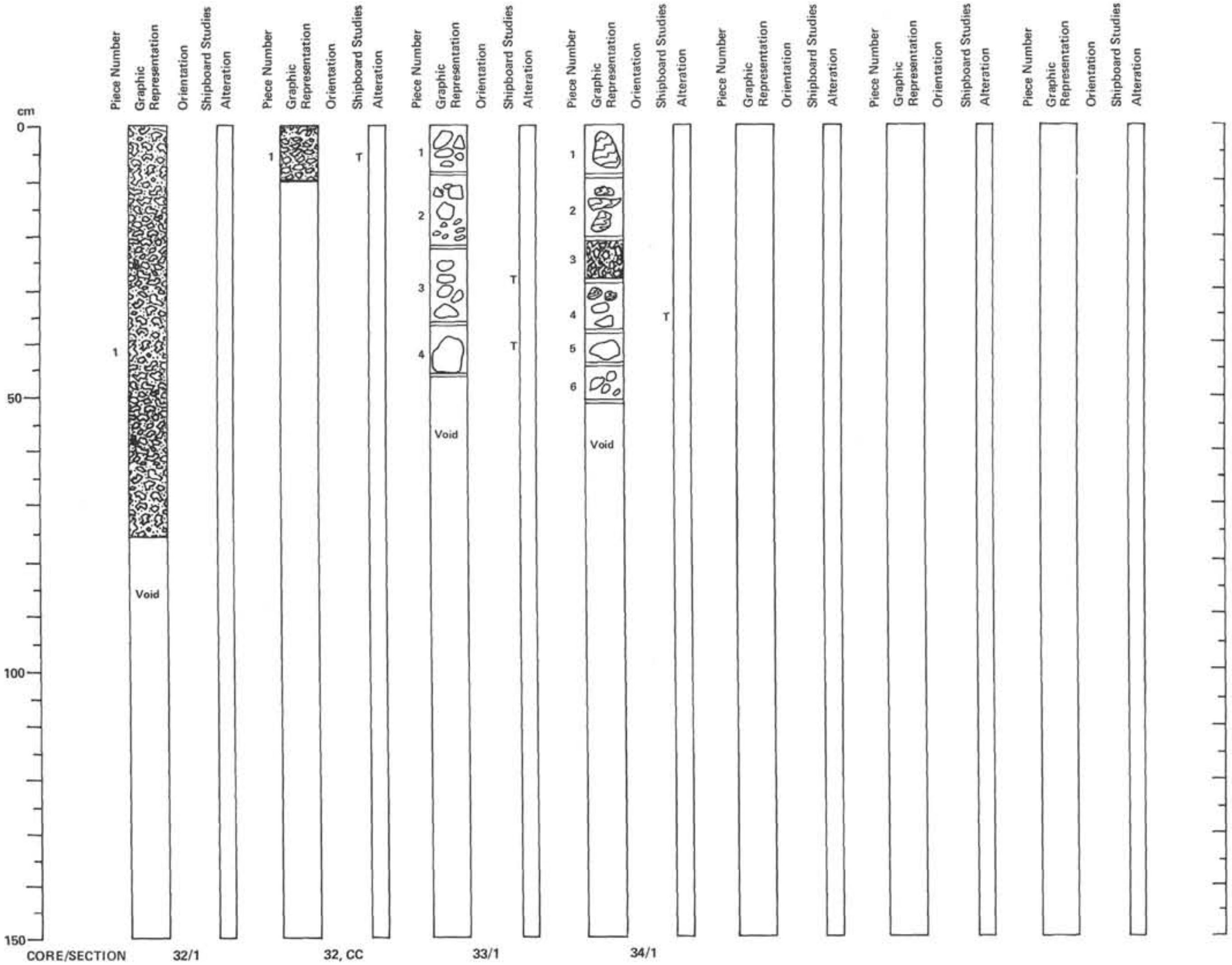
ORGANIC CARBON AND CARBONATE

	1-104
% Organic Carbon	0.6
% $CaCO_3$	4

THIN SECTION

Section 1, 5–6 cm

Sandy micritic limestone
Quartz 20–30%
Pelagic foraminifers ~5%
Muscovite < 1%



SITE 489A, CORE 32, SECTION 1 and CORE-CATCHER, 300.0–309.0 m

Macroscopic Description

Drilling breccia, fragments of BIOTITE-MUSCOVITE-QUARTZ SCHIST up to 2x3 cm. In upper 50 cm, rubble enclosed in medium light gray (N7) MUD. Schist is greenish black (5G 2/1) to medium bluish gray (5B 5/1). Subrounded schist pebble in Core-Catcher.

Thin Section Description

Core-Catcher: Biotite-Muscovite-Quartz Schist

Biotite = common
Muscovite = common

SITE 489A, CORE 33, SECTION 1, 309.0–318.0 m

Macroscopic Description

BIOTITE-HORNBLENDE-QUARTZ SCHIST, with angular blocks of MUSCOVITE-CHLORITE-BEARING QUARTZITE. Crenulation feliation, dark gray (N3).

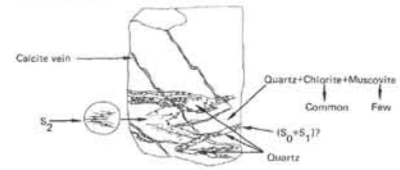
Thin Section Descriptions

Section 1, 26–28 cm: Biotite-Hornblende-Quartz Schist

Biotite = common
Hornblende = abundant

Section 1, 40–42 cm: Muscovite-Chlorite-bearing Quartzite

Chlorite = common
Muscovite = few



SITE 489A, CORE 34, SECTION 1, 318.0–327.0 m

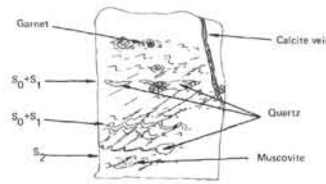
Macroscopic Description

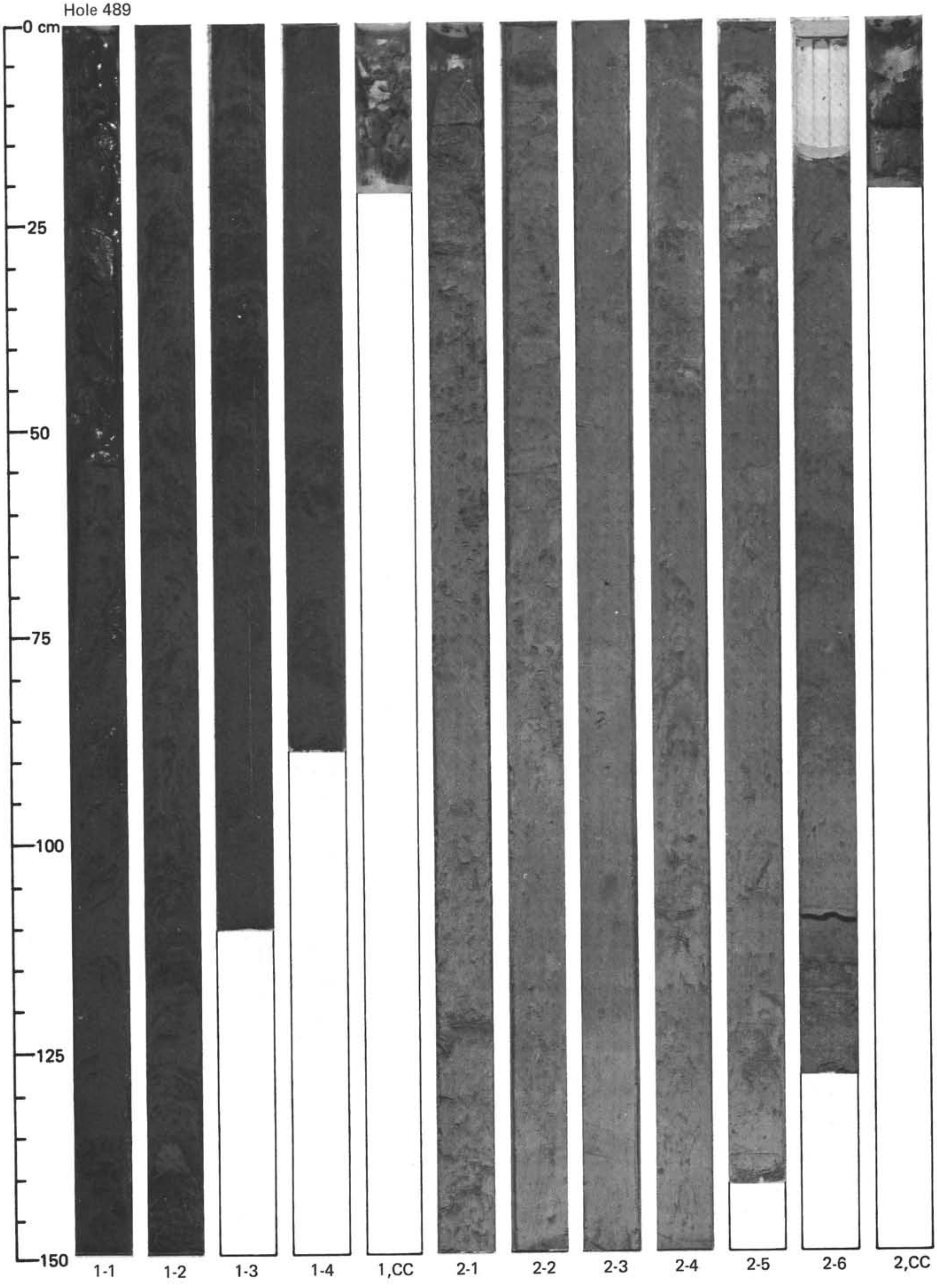
GARNET-MUSCOVITE-QUARTZ SCHIST, dark gray (N3). Crenulation foliation. Pyrite-bearing. Smaller siliceous fragments, probably same as Core 33 (muscovite-chlorite-bearing quartzite).

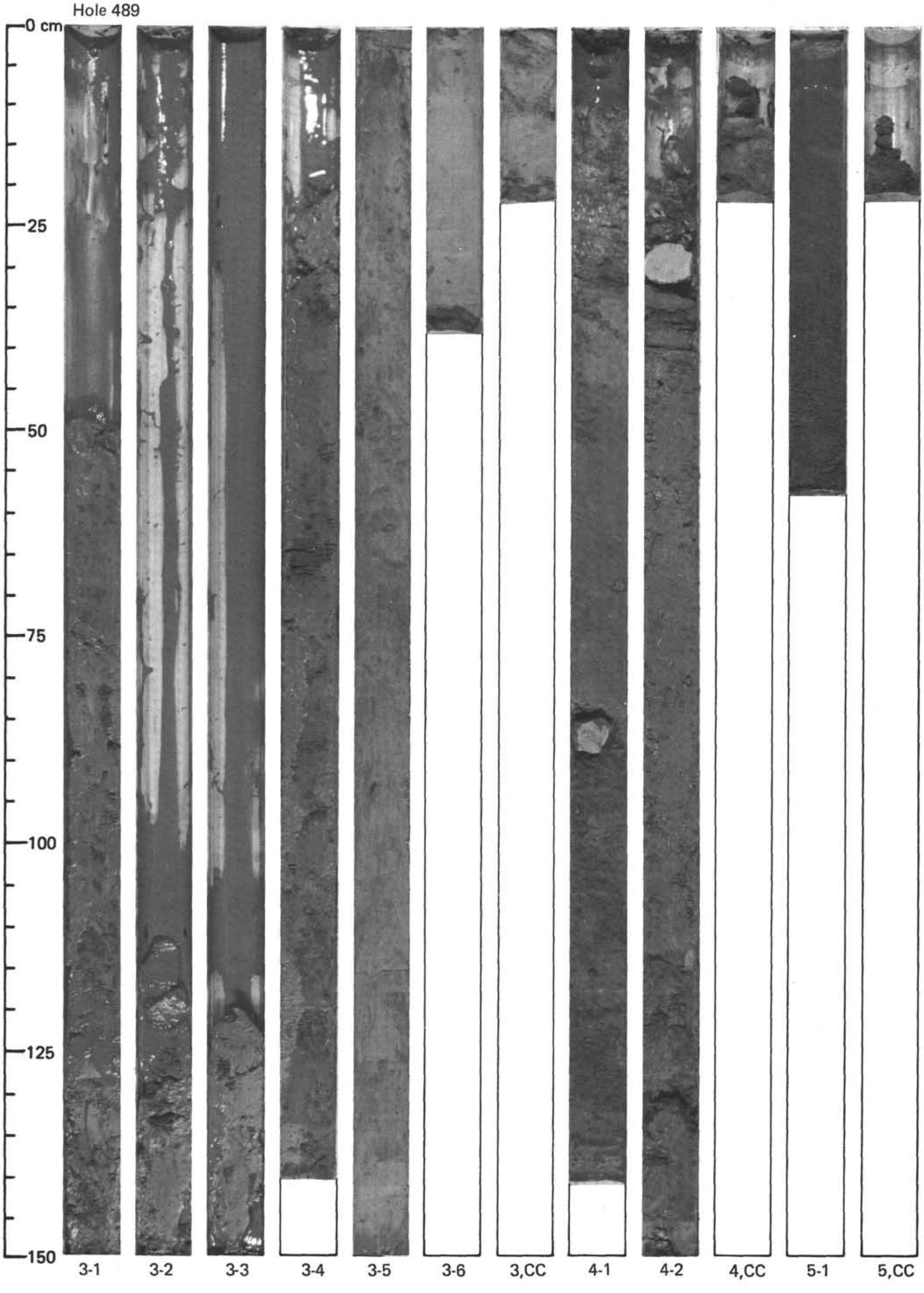
Thin Section Description:

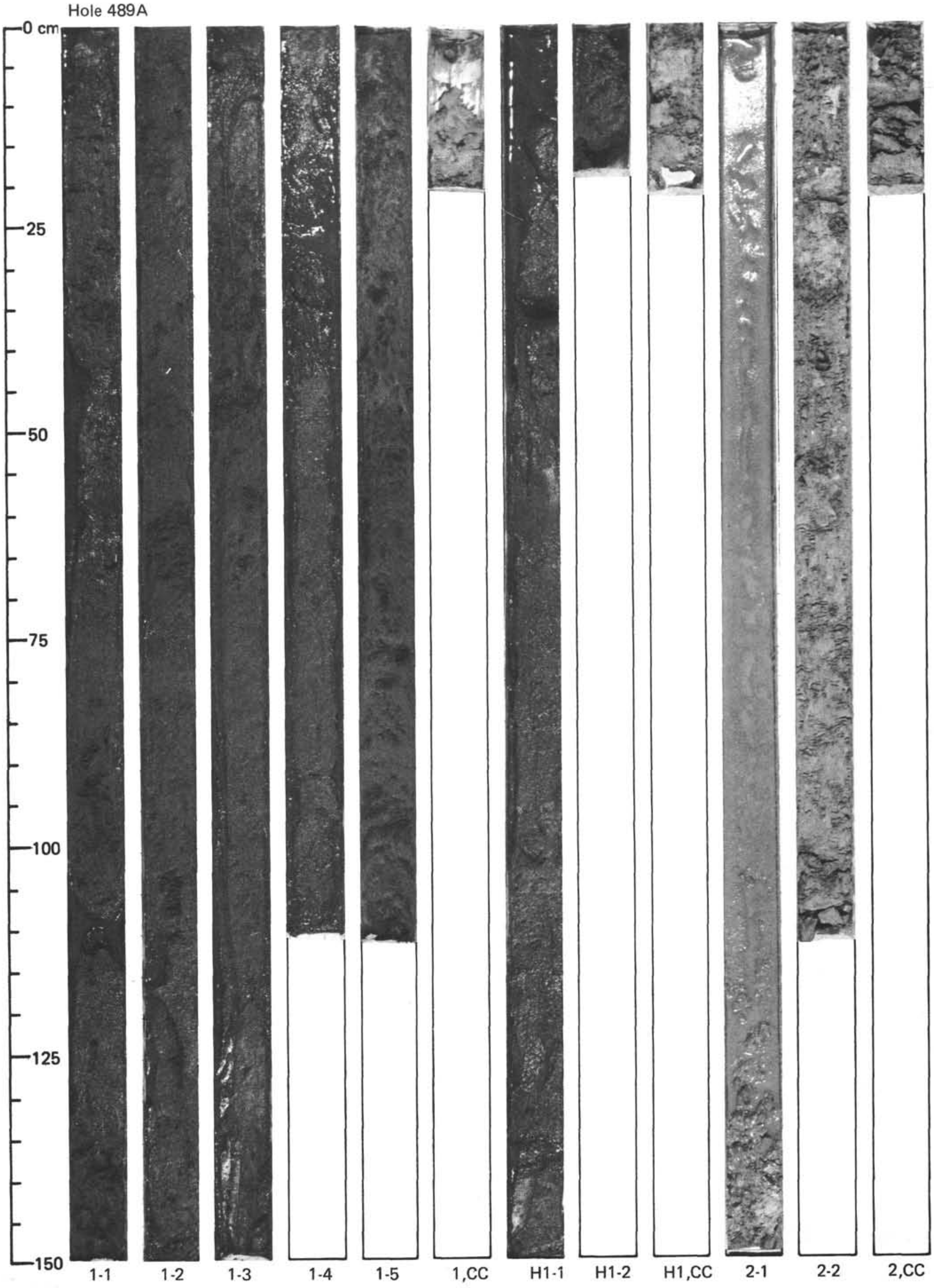
Section 1, 35–37 cm: Garnet-Muscovite-Quartz Schist

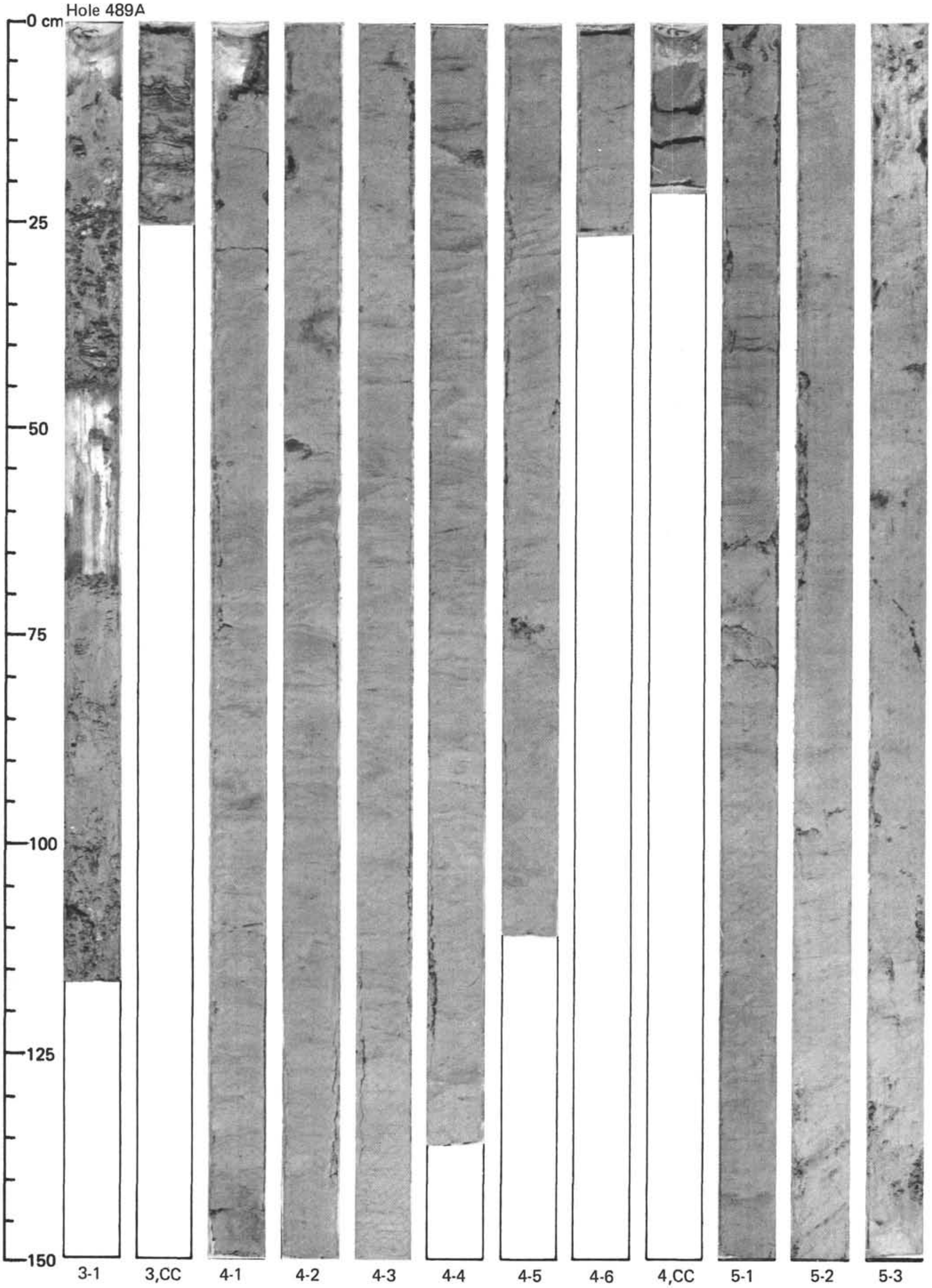
Garnet = common
Muscovite = abundant

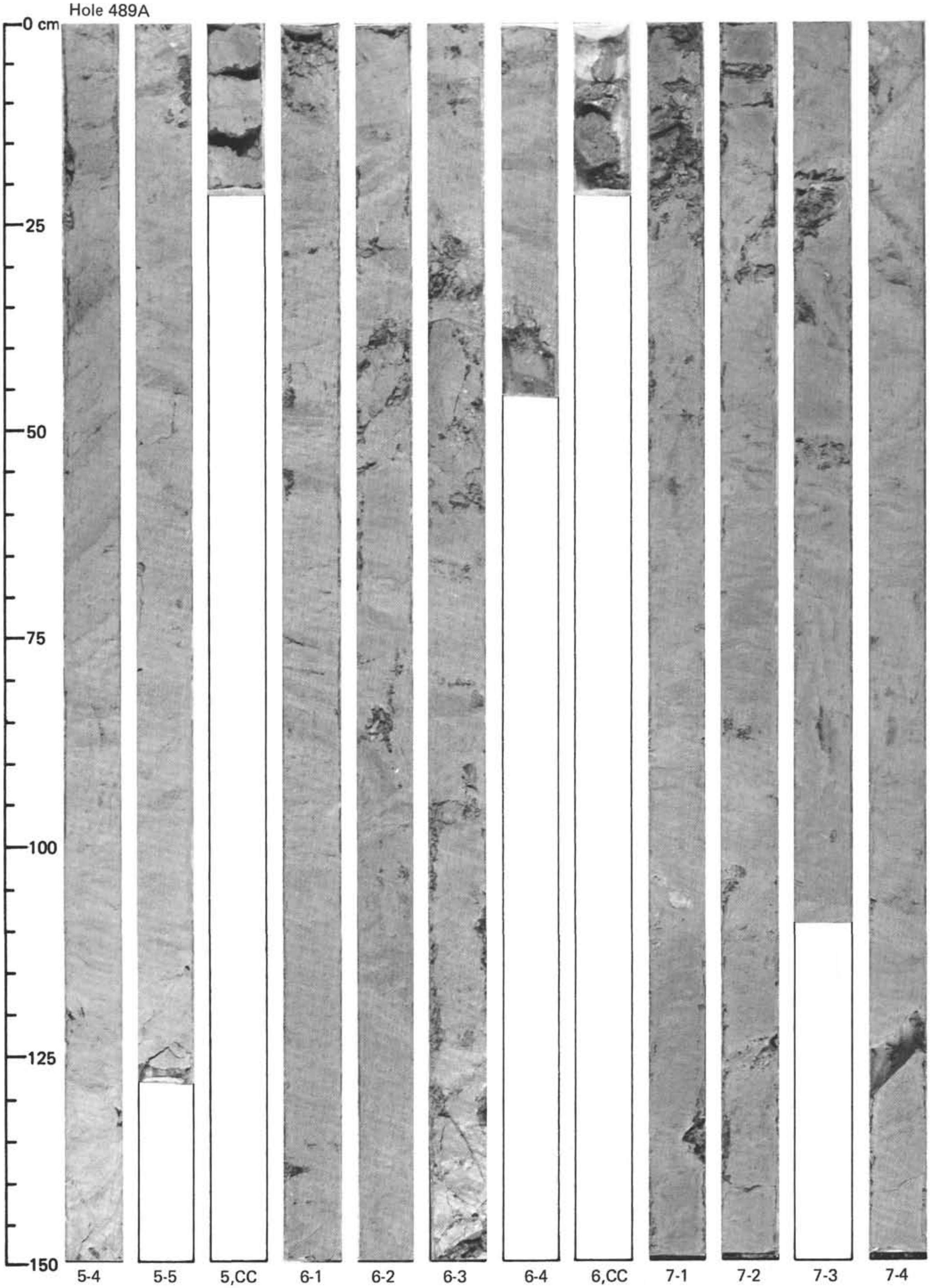


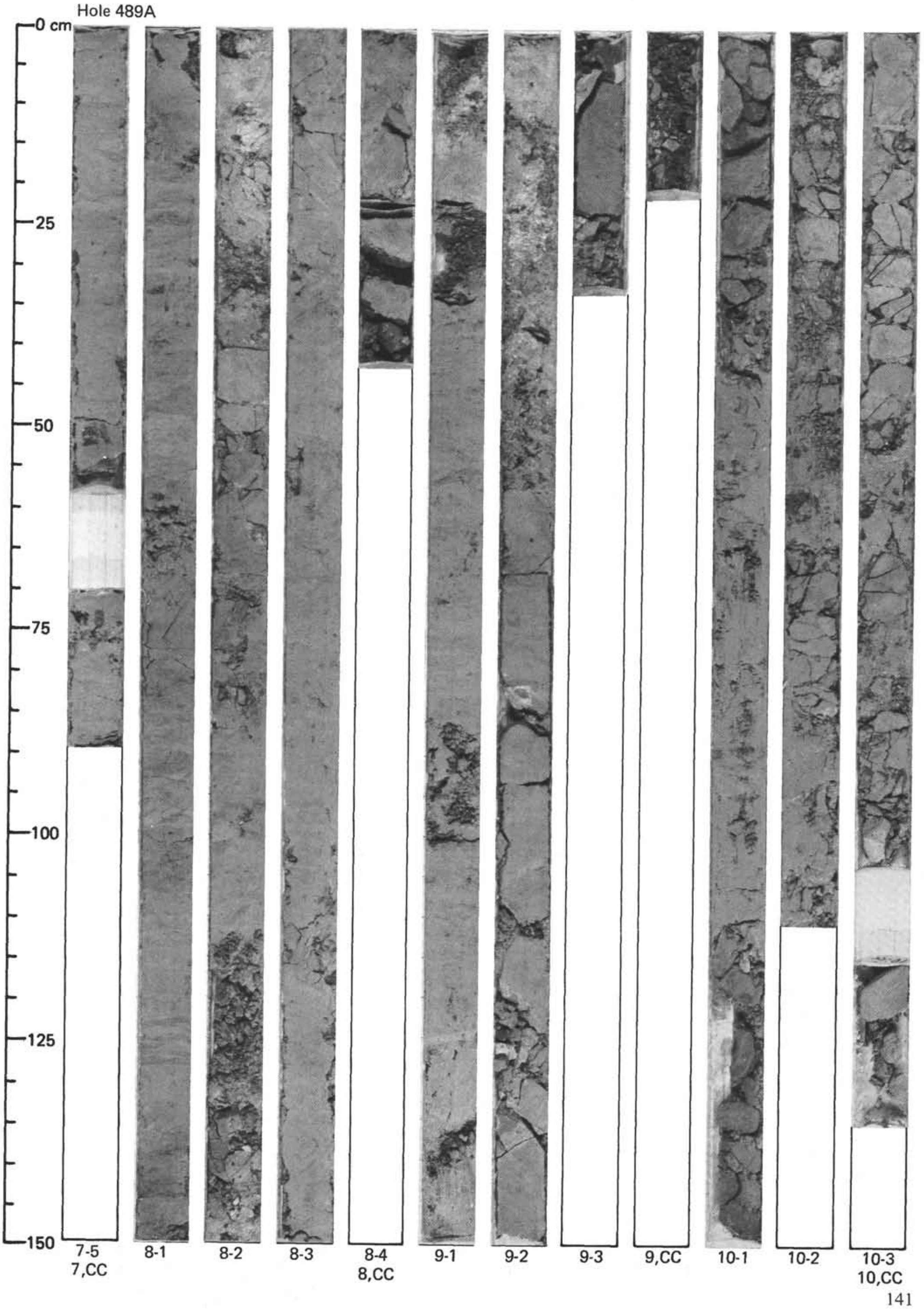

Hole 489
0 cm
25
50
75
100
125
150
1-1
1-2
1-3
1-4
1,CC
2-1
2-2
2-3
2-4
2-5
2-6
2,CC

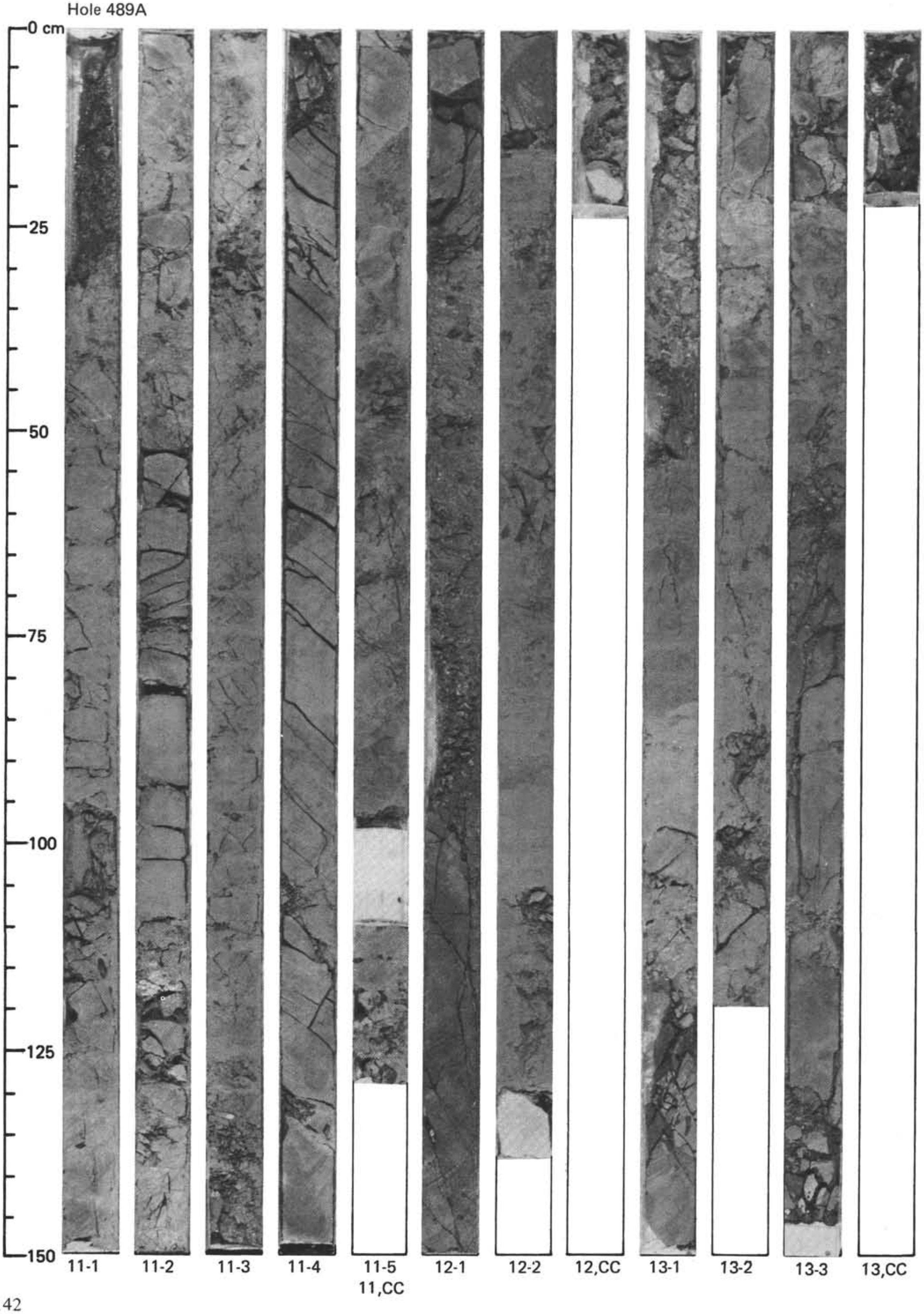

Hole 489
0 cm
25
50
75
100
125
150
3-1
3-2
3-3
3-4
3-5
3-6
3,CC
4-1
4-2
4,CC
5-1
5,CC

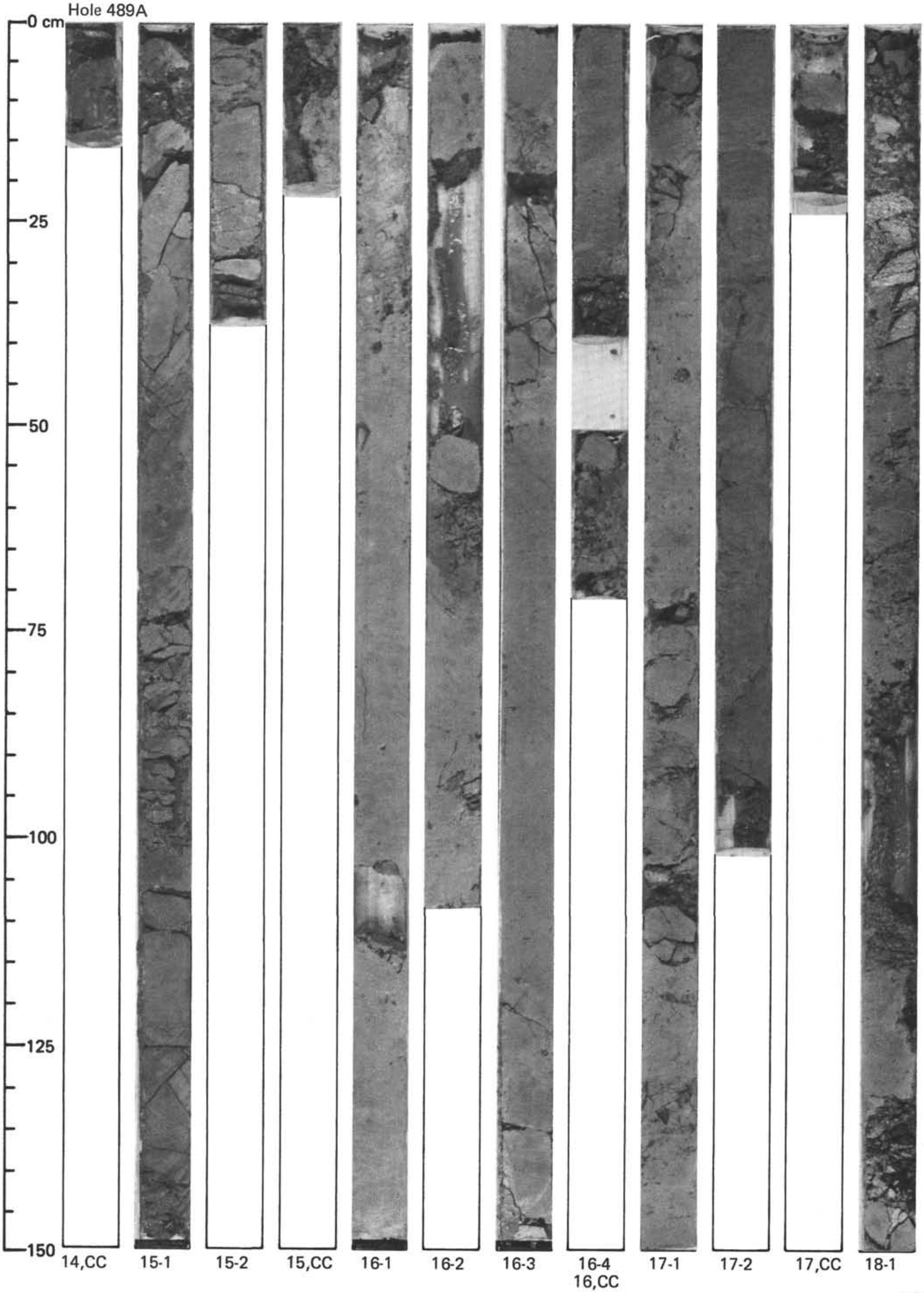

Hole 489A
0 cm
25
50
75
100
125
150
1-1
1-2
1-3
1-4
1-5
1,CC
H1-1
H1-2
H1,CC
2-1
2-2
2,CC

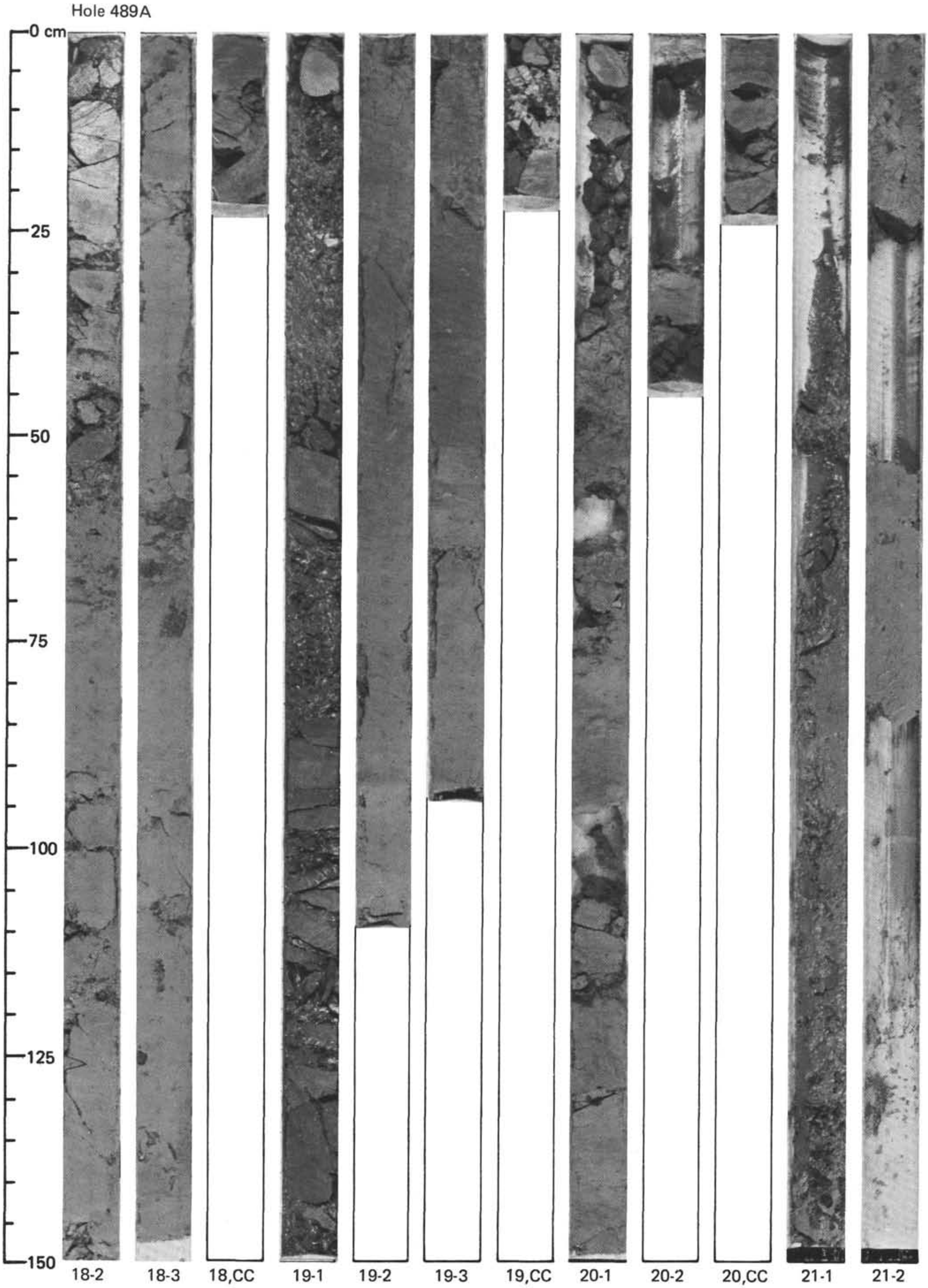

Hole 489A
0 cm
25
50
75
100
125
150
3-1
3,CC
4-1
4-2
4-3
4-4
4-5
4-6
4,CC
5-1
5-2
5-3

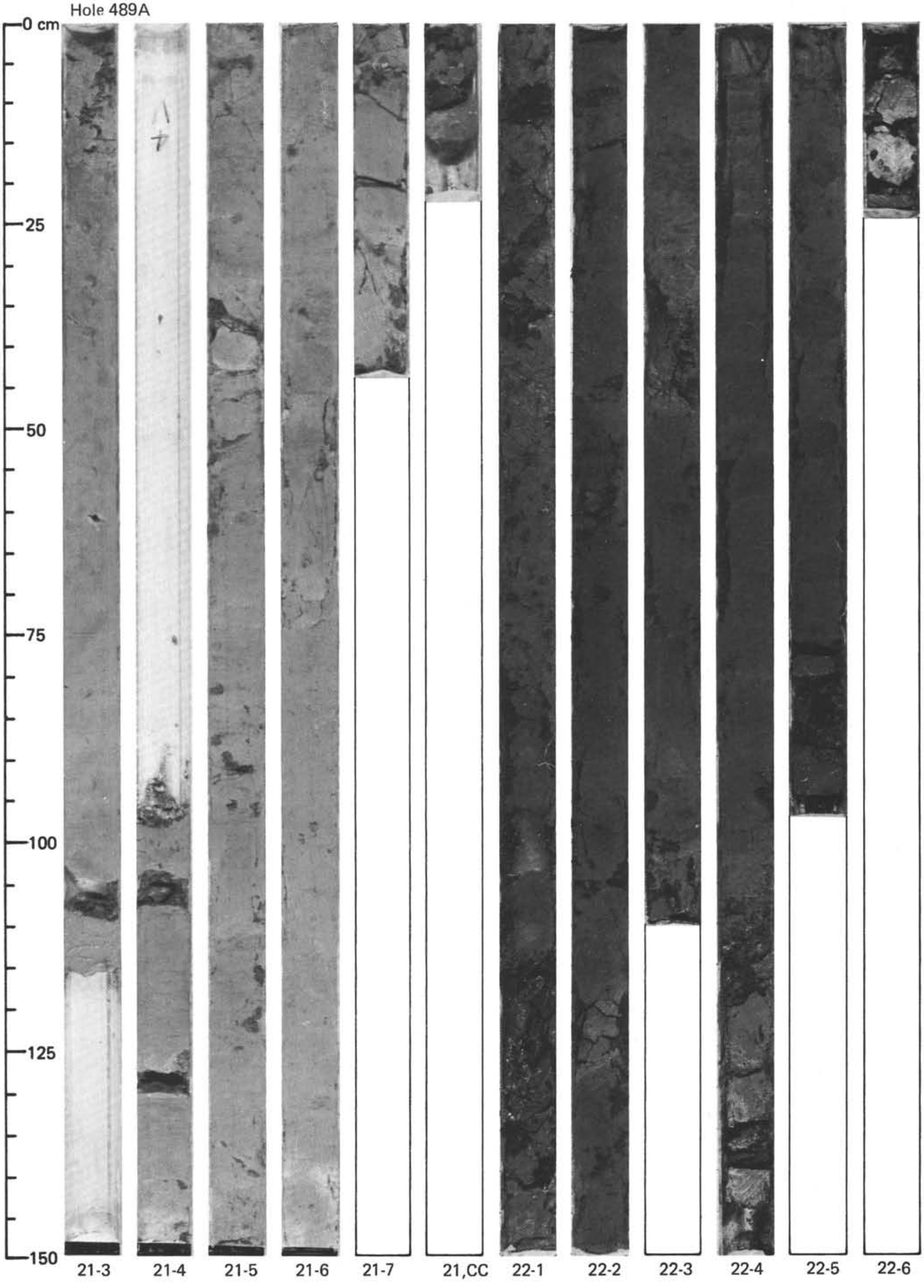

Hole 489A
0 cm
25
50
75
100
125
150
5-4
5-5
5,CC
6-1
6-2
6-3
6-4
6,CC
7-1
7-2
7-3
7-4

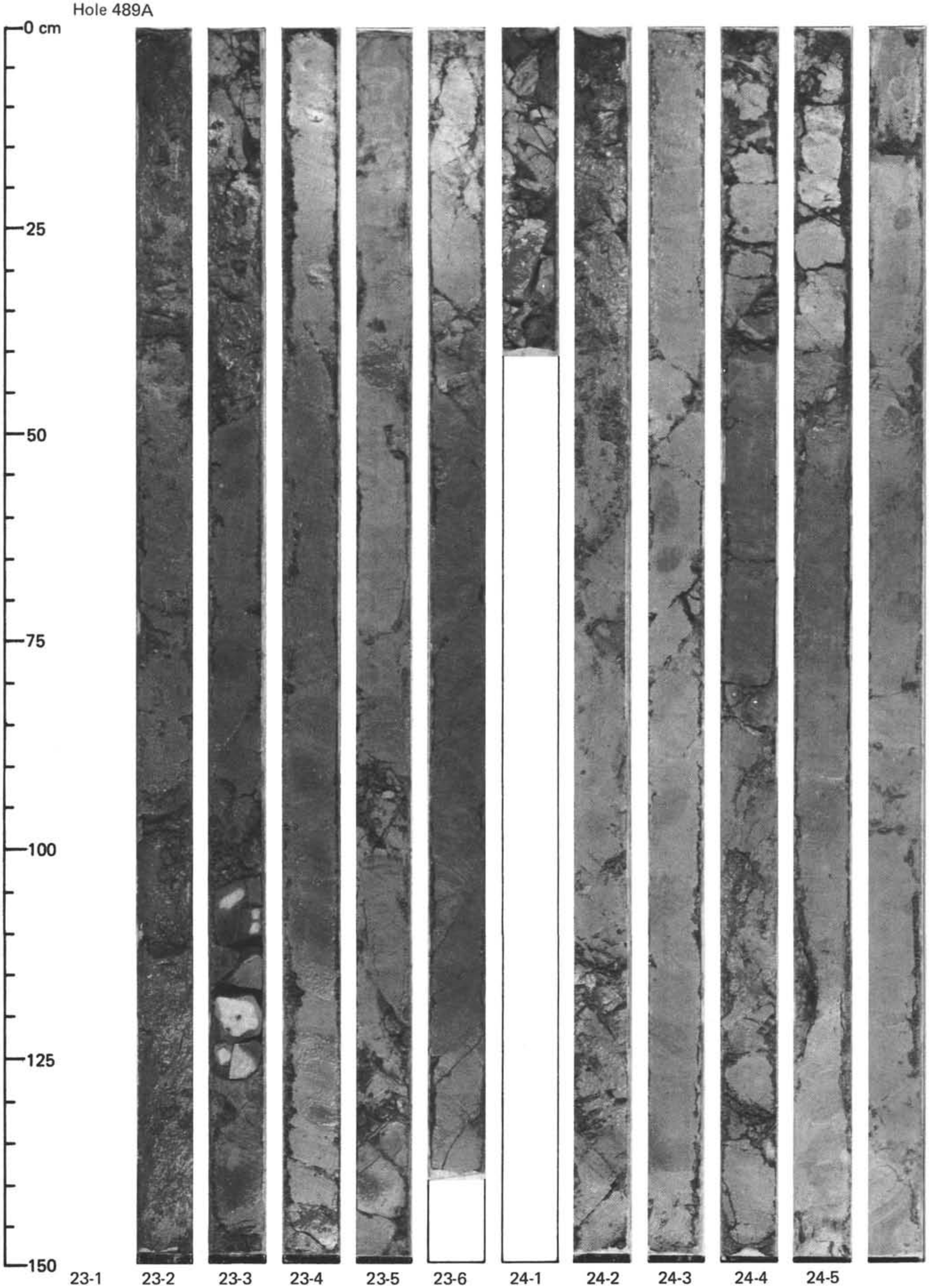

Hole 489A
0 cm
25
50
75
100
125
150
7-5
7,CC
8-1
8-2
8-3
8-4
8,CC
9-1
9-2
9-3
9,CC
10-1
10-2
10-3
10,CC

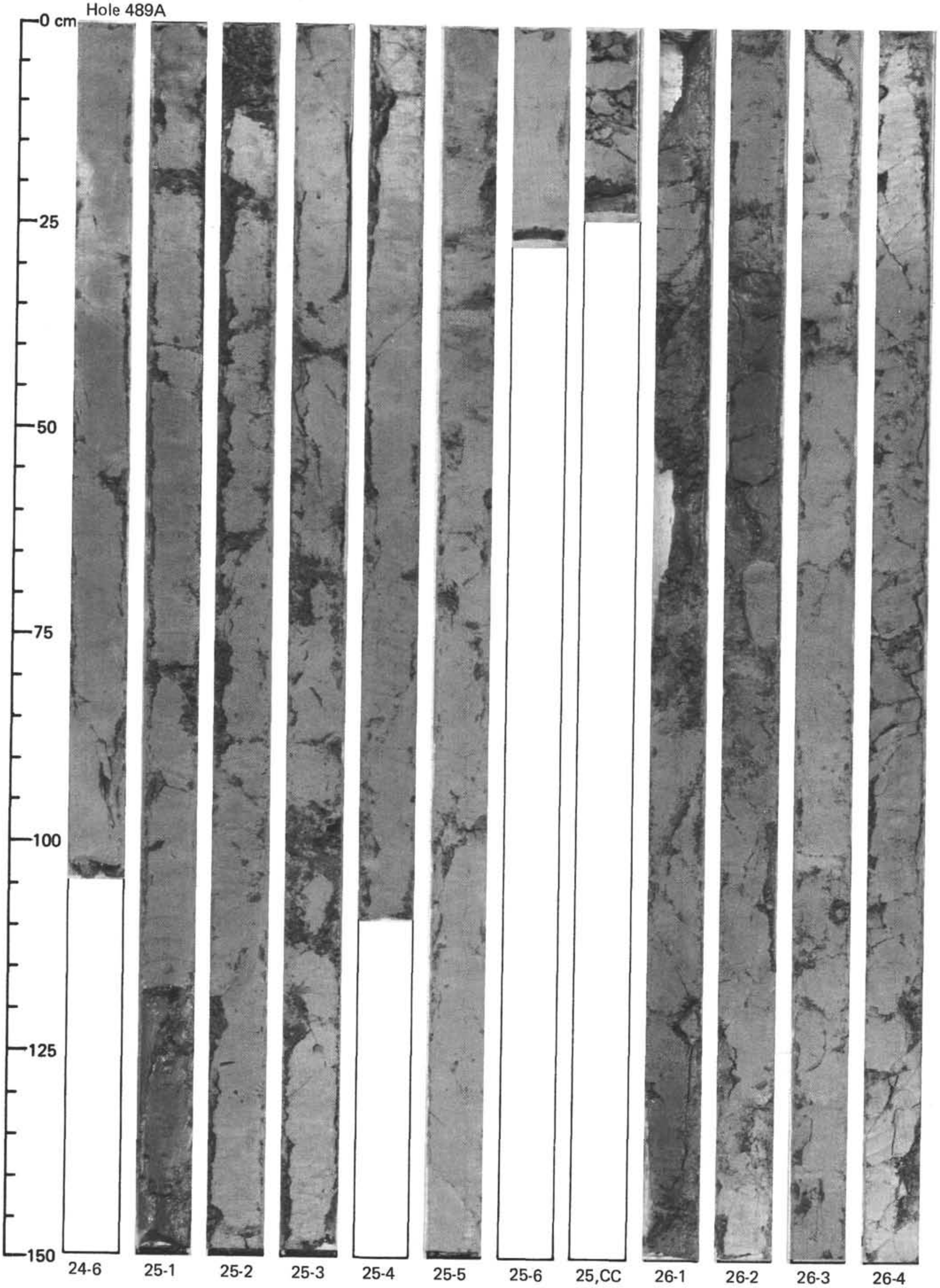

Hole 489A
0 cm
25
50
75
100
125
150
11-1
11-2
11-3
11-4
11-5
11,CC
12-1
12-2
12,CC
13-1
13-2
13-3
13,CC

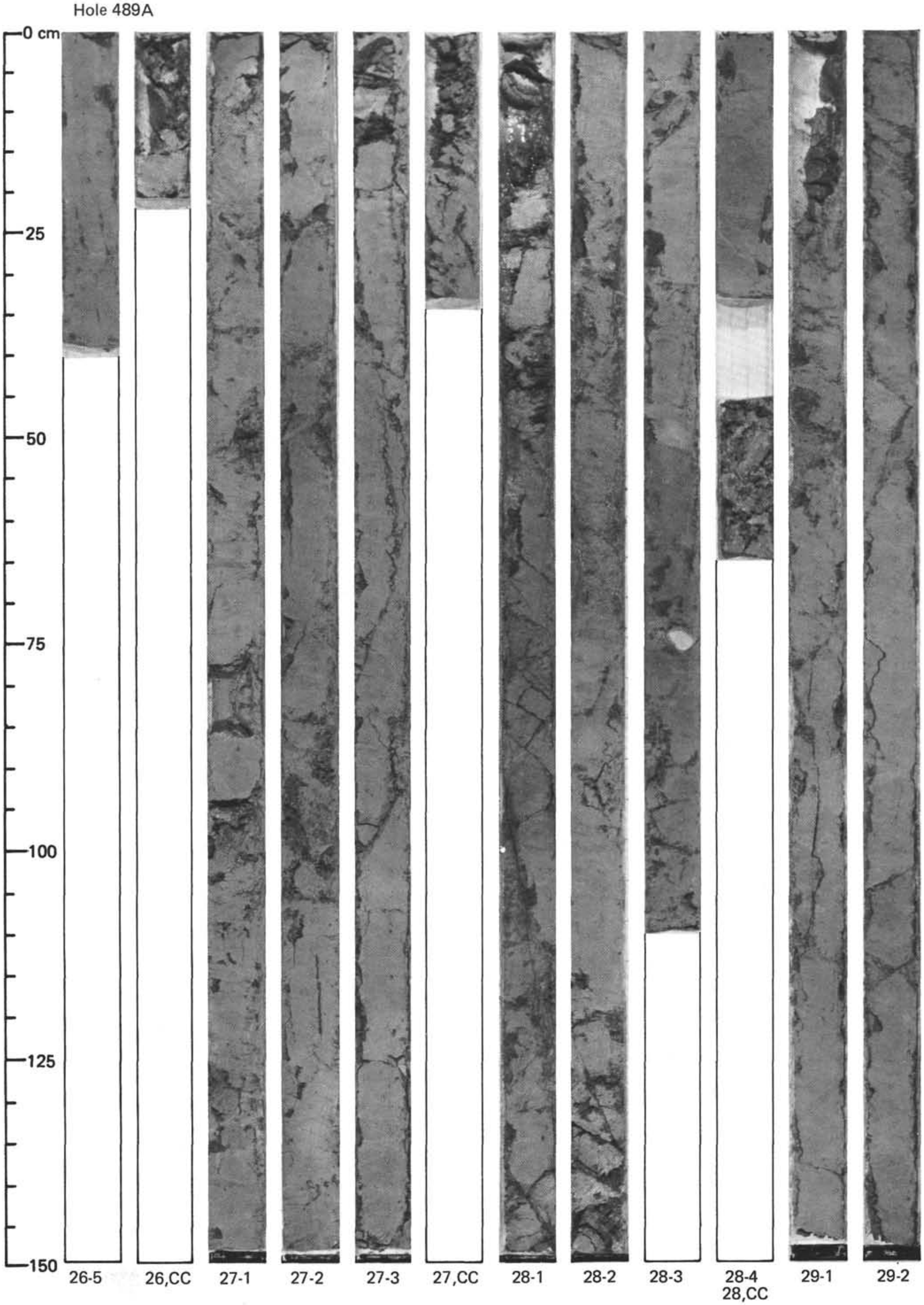

Hole 489A
0 cm
25
50
75
100
125
150
14,CC
15-1
15-2
15,CC
16-1
16-2
16-3
16-4
16,CC
17-1
17-2
17,CC
18-1


Hole 489A
0 cm
25
50
75
100
125
150
18-2
18-3
18,CC
19-1
19-2
19-3
19,CC
20-1
20-2
20,CC
21-1
21-2

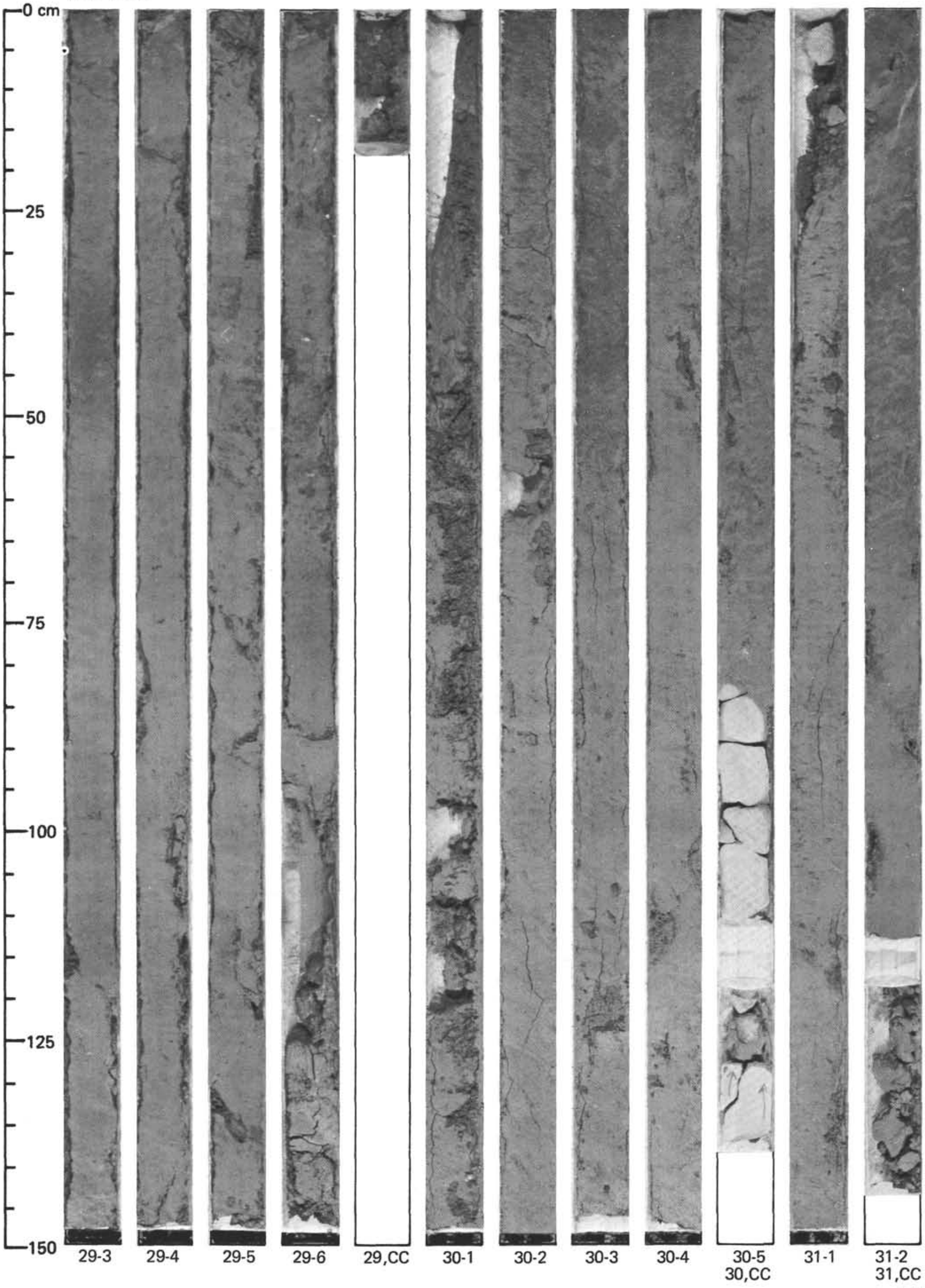

Hole 489A
0 cm
25
50
75
100
125
150
21-3
21-4
21-5
21-6
21-7
21,CC
22-1
22-2
22-3
22-4
22-5
22-6

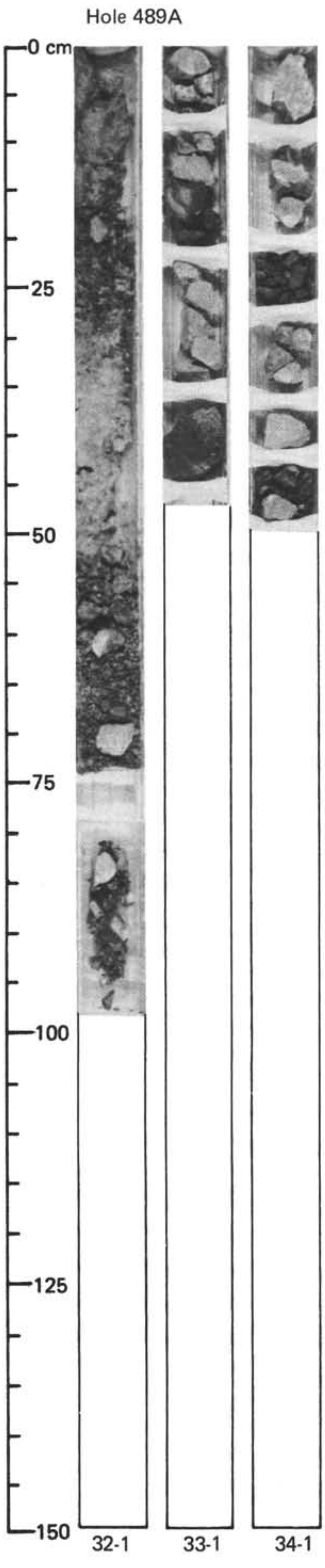

Hole 489A
0 cm
25
50
75
100
125
150
23-1
23-2
23-3
23-4
23-5
23-6
24-1
24-2
24-3
24-4
24-5


Hole 489A
0 cm
25
50
75
100
125
150
24-6
25-1
25-2
25-3
25-4
25-5
25-6
25,CC
26-1
26-2
26-3
26-4


Hole 489A
0 cm
25
50
75
100
125
150
26-5
26,CC
27-1
27-2
27-3
27,CC
28-1
28-2
28-3
28-4
28,CC
29-1
29-2

Hole 489A


0 cm
25
50
75
100
125
150
29-3
29-4
29-5
29-6
29,CC
30-1
30-2
30-3
30-4
30-5
30,CC
31-1
31-2
31,CC


Hole 489A
0 cm
25
50
75
100
125
150
32-1
33-1
34-1