6. SITE 551[1]

Shipboard Scientific Party[2]

HOLE 551

Position: 48°54.64′N; 13°30.09′W

Water depth (sea level; corrected m, echo-sounding): 3887

Water depth (rig floor; corrected m, echo-sounding): 3897

Bottom felt (m, drill pipe): 3909

Penetration (m): 201

Number of cores: 14

Total length of cored section (m): 125

Total core recovered (m): 80.95

Core recovery (%): 64.8

Oldest sediment cored:
Depth sub-bottom (m): 142
Nature: Chalk
Age: late Cenomanian
Measured velocity (km/s): 1.9

Basement:
Depth sub-bottom (m): 142–201
Nature: Basalt
Velocity range (km/s): 4.4 to 5.5

Principal results: Site 551 is at the seaward edge of the Goban Spur (3909 m water depth) and lies over the flat top of a raised basement block (Fig. 1). This site was drilled to enable us to determine the nature and age of the basement at the oceanmost edge of the continental crust. Spot cores were taken in the upper 100 m, and continuous cores were taken from 100 to 201 m below seafloor (BSF) (Tables 1, 2).

The most significant achievements at the site are as follows:

1. Finding 58.6 m of basaltic flows and pillows as basement beneath bathyal upper Cenomanian chalks.

2. Finding the most organic-carbon-rich black shale yet reported in the northeastern Atlantic (Table 3).

The following seven lithologic units were recognized (Table 4):

Unit 1: 0–>9 m BSF. Marly ooze and calcareous mud. Sediment is Holocene–Pleistocene in age and abyssal in nature. The lower limit of the unit is not known because of the spot coring.

Unit 2: >9–100.9 m BSF. Yellow to light brown nannofossil ooze and calcareous mudstone. The sediment is late Paleocene to middle Eocene in age. The upper limit of the unit is not known because of the spot coring. The lower limit of the unit is an unconformity.

Unit 3: 100.9–132.5 m BSF. Light gray nannofossil ooze and chalk with white mottling. The sediment is early Maestrichtian to late Campanian in age. There is an unconformity (about 20 m.y. hiatus) at the base of Unit 3; the middle and lower Campanian, the entire Santonian and Coniacian, and the upper Turonian are missing.

Unit 4: 132.5–134.6 m BSF. White to pale green nannofossil chalk and siliceous mudstone. The sediment is early Turonian in age.

Unit 5: 134.6–138.5 m BSF. Black, organic-carbon-rich shale, early Turonian in age.

Unit 6: 138.5–142.4 m BSF. White and pale yellow nannofossil chalks, late Cenomanian in age. The chalk rests unconformably on basalt.

Unit 7: 142.4–201.0 m BSF. Altered pillow basalts with calcareous sediment filling in fractures. The age of the basalt is unknown.

Site chapter results are based chiefly on shipboard analysis and interpretation. The specialty chapters reflect postcruise revisions and additional data. Where discrepancies arise, the specialty chapters should be considered correct.

SITE APPROACH AND OPERATIONS

The final drill site was located about 265 mi. (424 km) southwest of Cobh, Ireland and 25 mi. (40 km) north of Site 550 (Fig. 1). Guided by satellite navigation, the vessel passed north of the proposed site, turned sharply back to parallel reference Profile CM 10, and approached the site from the southwest (Fig. 2). The approach from deep water helped us to identify submerged physiographic features, and we dropped the positioning beacon on the first pass.

Drilling at a location with exactly the right characteristics was critical if the drilling objectives for the site were to be attained. The site was supposed to be near the top of an escarpment. When the ship had taken station over the beacon, the depth indicated by the precision depth recorder (PDR) was checked against the bathymetry of reference profiles to determine the optimum position for drilling, which meant minimum slope and soft sediments that were thick enough to support the bottom hole assembly (BHA). Only 3 operating days remained in the voyage, so it was also necessary to drill where the total sediment section was thin enough to enable us to penetrate to basement in that amount of time. The position of the ship was offset 245 m to the east and 122 m to the north as the pipe was being lowered; the ship began station keeping at that position because the depth indicated on the PDR (3897 m) coincided with the depth of a physiographic bench in the profiles.

The coring program called for taking a punch core at the seafloor to determine water depth. Some PDR error

[1] Graciansky, P. C. de, Poag, C. W., et al., *Init. Repts. DSDP*, 80: Washington (U.S. Govt. Printing Office).

[2] Pierre C. de Graciansky (Co-Chief Scientist), École Nationale Supérieure des Mines, Paris, France; C. Wylie Poag (Co-Chief Scientist), U.S. Geological Survey, Woods Hole, Massachusetts; Robert Cunningham, Jr., Exxon Production Research Company, Houston, Texas; Paul Loubere, Oregon State University, Corvallis, Oregon (present address: Northern Illinois University, DeKalb, Illinois); Douglas G. Masson, Institute of Oceanographic Sciences, Wormley, United Kingdom; James M. Mazzullo, Texas A & M University, College Station, Texas; Lucien Montadert, Institut Français du Pétrole, Rueil Malmaison, France; Carla Müller, University of Frankfurt, Frankfurt, Federal Republic of Germany; Kenichi Otsuka, Shizuoka University, Shizuoka, Japan; Leslie Reynolds, U.S. Geological Survey, Woods Hole, Massachusetts (present address: University of South Carolina, Columbia, South Carolina); Jacques Sigal, Vincennes, France; Scott Snyder, East Carolina University, Greenville, North Carolina; Hilary A. Townsend, University of Southampton, Southampton, United Kingdom; Stephanos P. Vaos, Florida State University, Tallahassee, Florida; and Douglas Waples, Mobil Research & Development Corporation, Dallas, Texas.

Table 1. Coring summary, Leg 80.

Hole	Latitude	Longitude	Water depth (m)	Number of cores	Cores with recovery	Percent of cores with recovery[a]	Meters cored	Meters recovered	Percent recovered[b]	Meters drilled	Total penetration (m)	Average penetration rate (m/hr.)[c]	Time on hole or site (hr.)
548	48°54.95′N	12°09.84′W	1256	35	35	100.0	211.0	210.9	99.9	0	211.0		45.2
548A	48°54.93′N	12°09.87′W	1256	38	38	100.0	346.0	246.5	71.2	205.5	551.5	42.4	82.9
			Total for site	73	73	100.0	557.0	457.4	82.1	205.5	762.5		128.1
549	49°05.28′N	13°05.88′W	2533	99	93	93.9	812.5	369.7	45.5	189.0	1001.5	7.9	301.2
549A	49°05.29′N	13°05.89′W	2535.5	42	41	77.6	196.0	144.4	73.7	0	198.5		54.2
			Total for site	141	134	95.0	1008.5	514.1	51.0	189.0	1200.0		355.4
550	48°30.91′N	13°26.37′W	4432	48	46	95.8	442.5	262.6	59.3	94.0	536.5	36.4	115.3
550A	48°30.91′N	13°26.39′W	4432	0	0	0	0	0	0	95.0	95.0	170.6	19.2
550B	48°30.96′N	13°26.32′W	4432	30	30	100.0	264.5	177.9	67.3	456.0	720.5	14.2	150.3
			Total for site	78	76	97.4	707.0	440.5	62.3	645.0	1352.0	34.0[d]	284.8
551	48°54.64′N	13°30.09′W	3909	14	13	92.9	125.0	81.0	64.8	76.0	201.0	9.1	75.2
			Total for leg	306	296	96.7	2397.5	1493.0	62.2	1115.5	3515.5		843.5

Note: Blanks signify that quantities are unknown.
[a] Total for site is calculated from total number of cores and total cores with recovery.
[b] Total for site is calculated from total meters cored and total meters recovered.
[c] Rotary coring only.
[d] Total meters penetrated divided by number of rotating hours.

Table 2. Coring summary, Site 551.

Core	Date (July 1981)	Time (hr.)	Depth from drill floor (m)	Depth below seafloor (m)	Length cored (m)	Length recovered (m)	Recovery (%)
1	17	1029	3909.0–3918.0	0.0–9.0	9.0	5.21	58
—	17	—	3918.0–3956.0[a]	9.0–47.0	—	—	0
H1	17	1245	3956.0–3965.5	47.0–56.5	9.5	5.67	60
—	17	—	3965.5–4003.5[a]	56.5–94.5	—	—	0
H2	17	1435	4003.5–4013.0	94.5–104.0	9.5	7.93	83
2	17	1550	4013.0–4022.5	104.0–113.5	9.5	4.49	47
3	17	1703	4022.5–4032.0	113.5–123.0	9.5	4.63	49
4	17	1825	4032.0–4041.5	123.0–132.5	9.5	6.06	64
5	17	1945	4041.5–4047.5	132.5–138.5	6.0	2.91	49
6	17	2245	4047.5–4053.0	138.5–144.0	5.5	4.76	87
7	18	0445	4053.0–4060.0	144.0–151.0	7.0	0	0
8	18	1143	4060.0–4061.5	151.0–152.5	1.5	1.28	85
9	18	1612	4061.5–4069.0	152.5–160.0	7.5	7.15	95
10	18	1812	4069.0–4078.0	160.0–169.0	9.0	3.41	38
11	18	2331	4078.0–4087.0	169.0–178.0	9.0	9.13	100
12	19	0825	4087.0–4097.0	178.0–188.0	10.0	6.84	68
13	19	1424	4097.0–4106.5	188.0–197.5	9.5	8.30	87
14	19	1259	4106.5–4110.0	197.5–201.0	3.5	3.18	91

[a] Drilled interval.

Table 3. Pyrolysis properties of black shales from Leg 80.

Site	Cores	Average hydrogen index (mg HC/g TOC)	Average oxygen index (mg CO_2/g TOC)	TOC	T_{max} (°C)
549	27	317	38	3.4	423
550	16–25	239	70	1.8	420
551	5	393	34	9.5	413

due to slope was anticipated, and so the bit was lowered to 3908.5 m before the barrel was retrieved. This core barrel was empty, and it was necessary to add a joint of pipe and to repeat the procedure before a core was recovered. The depth was then determined to be 3909 m.

The upper portion of the hole (to 104 m BSF) was drilled through soft oozes. Two spot cores were taken in order to check sediment age and to monitor for hydrocarbons. Chalk was then cored continuously to 142 m BSF, where basalt was encountered. Coring in the basalt was slow, but recovery was good.

While basalt was being cored, one core barrel apparently did not latch into place properly and was recovered empty. The seating pressure of the following barrel indicated a partial obstruction, and it was necessary to clear the bit with a core breaker before proceeding. Four cores later, the bit was found to be completely plugged after the core barrel was retrieved. All efforts to establish circulation failed, and the bit was pulled about halfway to

Table 4. Lithologic summary, Site 551. Water depth: 3909 m.

Unit	Hole-Core-Section (level in cm)	Depth (m BSF)	Main lithology	Age
1	551-1	0->9 (mudline core; lower limit unknown)	Foraminifer-nannofossil ooze and calcareous mud	Holocene to Pleistocene
2	551-H1, 551-H2-5 (40 cm)	>9-100.9 (sampled only in wash Cores H1 and H2; upper boundary unknown)	Yellow to light brown calcareous ooze and calcareous mudstone	middle Eocene to late Paleocene
3	551-H2-5 (40 cm) to 551-4	100.9-132.5	Light gray calcareous ooze to chalk with white mottling	early Maestrichtian to late Campanian
4	551-5-1 to 551-5-2 (60 cm)	132.5-134.6	White to pale green nannofossil chalk and siliceous mudstone	Turonian?
5	551-5-2 (60 cm) to 551-5,CC	134.6-138.5	Black, organic-carbon-rich shale	early Turonian
6	551-6-1 to 551-6-3 (92 cm)	138.5-142.4	White and pale yellow chalks	late Cenomanian
7	551-6-3 (92 cm) to 551-14	142.4-201.0	Altered pillow basalts with calcareous sediment infillings	Unknown

Notes: There is a 1-2 cm layer of dark brown mud (late Paleocene) at the contact of Units 2 and 3. In this table, cross rules denote changes in lithology; wavy lines denote unconformities; dashed line denotes boundary present in washed interval (not cored).

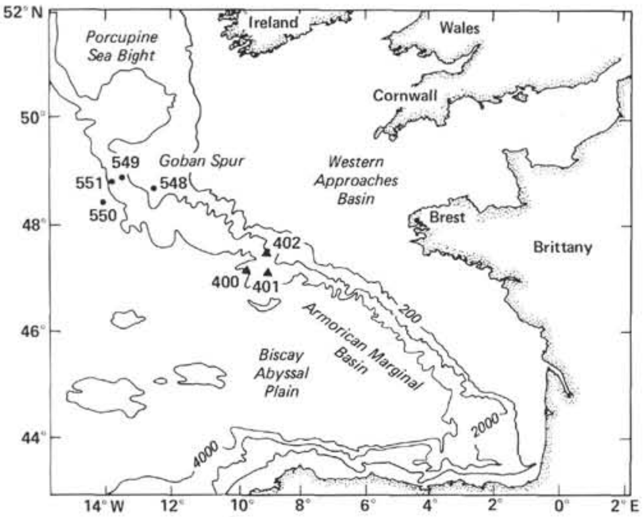


Figure 1. Location of Leg 80 drill sites. Three Leg 48 drill sites (400–402) are also shown.

the seafloor before a final attempt was made. The surging action of pulling pipe had apparently cleared the cuttings from the bit, and circulation was regained. The bit was then run back to total depth, and three more cores were taken before time expired. The drill string was then recovered, and *Glomar Challenger* departed for Southampton.

SEDIMENT LITHOLOGY

Despite the relatively thin sedimentary section, seven lithologic units were identified at Site 551 (Table 4).

Unit 1

Unit 1 consists of marly foraminifer–nannofossil ooze, marly nannofossil ooze, calcareous ooze, and calcareous mud. It was sampled in Core 1 (0–9 m BSF) and is Holocene–Pleistocene in age.

Core 1, which was taken at the mudline, contains bands of pale-colored marly calcareous ooze intercalated with dark, more terrigenous, calcareous muds. The top few centimeters of the core are made up of a pale brown (10YR 7/4), marly foraminifer–nannofossil ooze that is presumed to be of Holocene age. Below this layer there is a rapid transition to olive gray (5Y 5/2) homogeneous mud, which contains scattered small, dark pebbles and probably contains many smaller (submillimeter-sized) rock fragments. A smear slide taken from Section 1 of the core shows that the sediment contains 25% quartz, 35% clay, 15% carbonate fragments, and 20% nannofossils. This dark sediment passes gradually into a white (10YR 8/1) calcareous ooze in Section 2. A smear slide taken in the white ooze contains 15% quartz, 40% clay, 10% carbonate fragments, 20% foraminifers, and 15% nannofossils. Below the white ooze, across a rapid lithologic transition, there is more calcareous mudstone of brown (10YR 5/3), olive (5Y 5/3), gray (5Y 5/1), olive gray (5Y 5/2), and dark gray (5Y 4/1) intergrading colors. This sediment contains small rock fragments and occasional pebbles; one 3.5 cm quartzite fragment was found in the core catcher.

No sedimentary structures were observed, but they may be absent as a result of extensive drilling disturbance. Carbonate values range from 16% in the darkest sediments to 62% in the white ooze (carbonate bomb). The lithology is similar to the Pleistocene sediments cored

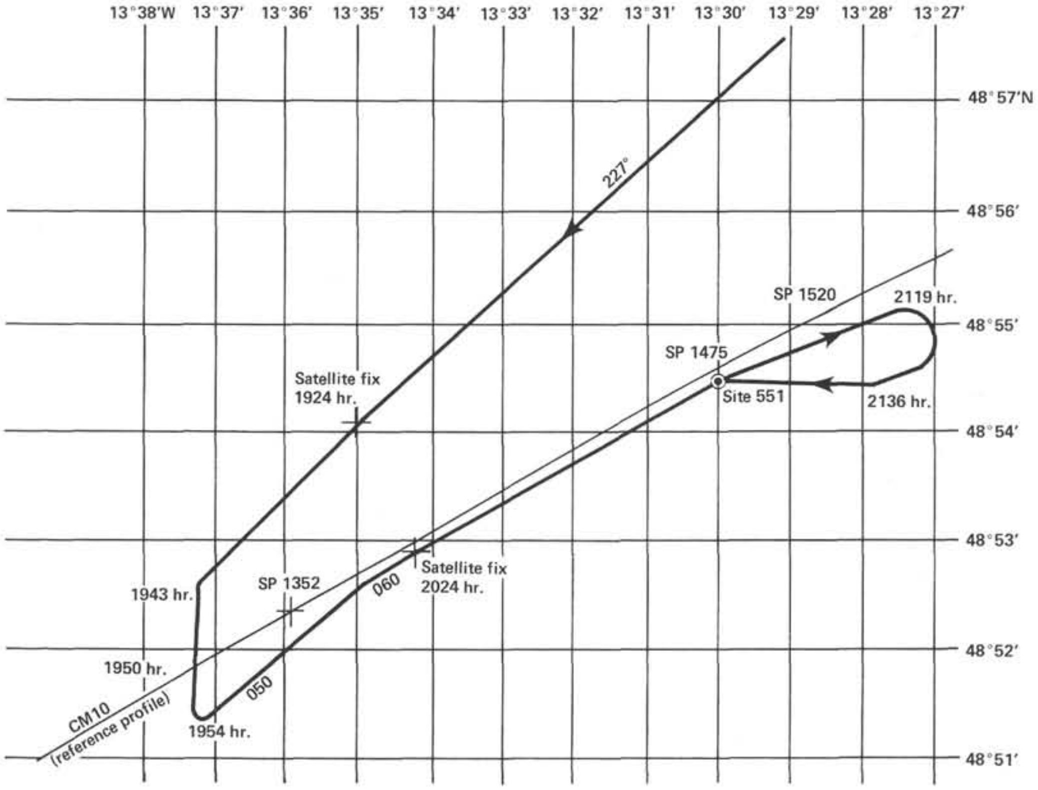


Figure 2. Approach to Site 551 (16 July 1981). SP = shot point.

at the other Leg 80 sites. Paleoclimatic fluctuations are probably primarily responsible for the variations in the sediment.

Unit 2

Unit 2 consists of nannofossil ooze and calcareous mudstone. It was sampled in wash Core 551-H1 and from Section 551-H2-1 to 551-H2-5 (40 cm) (47–56.5 and 94.5–100.9 m BSF). The unit is late Paleocene to middle Eocene in age.

Core H1 contains a yellow (2.5Y 7/6) to light olive brown (2.5Y 5/4), soft, moderately bioturbated nannofossil ooze containing scattered yellow (2.5Y 7/4) mottles and fine black flecks. Sections 4 and 5 in the core contain dark bands a few centimeters wide and zones of scattered, small, dark nodules as large as 5 mm in diameter. Section 1 contains several chunks of caved sediments, including a pale green mud of early middle Miocene age (nannofossil Zone NN5). A single carbonate bomb analysis in Section 4 gave a value of 63% carbonate. Nannofossils indicate early and middle Eocene ages, depending on the sampling position within this highly deformed material.

Core H2 contains yellow brown (10YR 7/4–5/6) calcareous mudstone of various shades. The sediment is homogeneous, with occasional color banding on the scale of centimeters and some burrow mottling in the darker units. The contacts between colors are generally sharp, but they do not appear to be accompanied by textural variations. Carbonate values range from 18 to 64%; they are not obviously related to the color changes. Fossils indicate a late Paleocene to early Eocene age for this sediment.

Unit 3

Unit 3 consists of light gray nannofossil ooze and chalk with white mottling. It occurs from 100.9 to 130.5 m BSF (551-H2-5, 40 cm to Core 4) and is early Maestrichtian to late Campanian in age.

The contact between Units 2 and 3 is an unconformity marked by a 1–2 cm band of brown mud containing dark green flecks. The upper and lower contacts of the brown mud band are sharp. Unit 3 is a light gray (2.5Y 7/1) nannofossil ooze and chalk containing scattered mottles and streaks of white sediment up to several centimeters in size. The composition of the gray and white sediments is similar: 50 to 70% nannofossils, 5 to 15% foraminifers, 5 to 20% unspecified carbonate fragments, 5% clay (X-ray), and small quantities of quartz (smear slides). Carbonate bomb values range from 86 to 93% carbonate. Euhedral grains of calcite are common. The white chalk contains shallow-water nannofossil species and occurs as highly deformed fragments included within a slump deposit. Not all of Unit 3 is chaotic, inasmuch as thin laminae occur in Sections 551-4-1 and 551-4-3.

Unit 3 appears to be correlative with the upper Campanian portions of Unit 4 (Core 23) at Site 549, where there are similar slump features and the calculated sedimentation rate is comparable.

Unit 4

Unit 4 consists of white to pale green nannofossil chalk and siliceous mudstone. It occurs from 132.5 to 134.6 m BSF (Core 5, Sections 1 and 2) and is early Turonian in age.

The contact between Units 3 and 4 was not recovered but is presumed to be an unconformity on the basis of biozonation. Unit 4 consists of white (2.5Y 8/2) to pale green (5GY 7/1) nannofossil chalk that is either homogeneous or faintly laminated. Quartz, clay minerals, foraminifers, and volcanic glass are common in these sediments. Carbonate bomb values range from 50 to 70%. Section 551-5-1 contains an irregular 2–3 cm band of olive (5Y 5/6) cryptocrystalline material that may be oxidized pyrite; X-ray determination on a bulk sample has shown only mixed-layer clay. Below this material there is a 5 cm section with fine laminae 1 mm or less in thickness that consist of accumulations of planktonic foraminifers and radiolarians. A carbonate value for this sediment is 36%; that for clay is 30% (smear slides). Foraminifers and biosiliceous fragments are common. The presence of low cristobalite and clinoptilolite indicates that the siliceous tests have been diagenetically altered. Smectite is the dominant clay mineral over illite. The remainder is clinoptilolite and barite (Graciansky and Bourbon, this volume). Two gritty, 2–3 cm layers occur in Section 551-5-2. These layers are rich in biosiliceous fragments that include radiolarians and zeolites. The layers are similar in color to the rest of Unit 4 and are faintly laminated near the top.

Unit 5

Unit 5 consists of black shale. It occurs from 134.6 to 138.5 m BSF (Section 551-5-2, 60 to 120 cm and in the core catcher) and is early Turonian in age.

Unit 5 consists of black shale that was recovered as part of a drilling breccia in Core 5. The black shale was mixed with gray and white chalks of uncertain stratigraphic position. The contact between Units 4 and 5 may be represented by a thin band of green and black cherty mud that appears in Section 551-5-2. The black shale fragments are massive to faintly laminated. They have low concentrations of calcium carbonate (less than 1%) and are rich in biosiliceous material, zeolites, and phillipsite. Thus, part of these black shales could have originated in the alteration of pyroclastic debris (Otsuka, this volume). This black shale is the richest organic sediment recovered during Leg 80. It has no precise correlatives in terms of organic geochemistry in the sediments recovered at Sites 548 and 550, but it can be compared with black shales of Turonian age recovered at Site 549 (Waples and Cunningham; and Waples, "Anoxia," this volume).

Unit 6

Unit 6 consists of white, yellow gray, and pale yellow orange nannofossil chalk. It occurs from 138.5 to 142.4 m BSF (Section 551-6-1 to 551-6-3, 92 cm) and is late Cenomanian in age.

The contact between Units 5 and 6 was not recovered. The upper part of Unit 6 is composed of white, massive, nannofossil chalk with occasional zones of yellow gray laminations and black (manganese oxide) staining. Some bedding on a centimeter scale appears in the middle part of this portion of Unit 6, and the sediment coarsens to a sandy foraminifer–nannofossil chalk within Section 551-6-2. Sandier parts consist of laminated accumulations of planktonic foraminifers and/or *Inoceramus* prisms. Part of the lamination is at a slight angle to the horizontal. In Section 2 at 106 cm, there is a sharp transition back to fine white nannofossil chalk, which grades downward into a light green chalk (5GY 9/1) and then to a pale yellow orange, sandy, foraminifer–nannofossil chalk. Black-stained bands (manganese dendrites?) are scattered throughout. X-ray analysis of the residue from acid leaching again shows the presence of low cristobalite and clinoptilolite, which is characteristic of the diagenesis of sediments relatively rich in radiolarians. The clay-mineral assemblage comprises smectite, illite, and mixed-layer clays in similar proportions, reflecting a stronger detrital influence than in upper parts, where smectites are dominant (Graciansky and Bourbon, this volume).

Unit 7

Unit 7 consists of basalt with intercalated sediments. It is described in more detail below.

BASALT LITHOLOGY

Fifty-nine meters of basaltic rocks were recovered at the bottom of Hole 551 (142–201 m BSF; Fig. 3). They constitute lithologic Unit 7, below the upper Cenomanian chalks that make up Unit 6 (see Sediment Lithology). These basalts are more altered than those at Site 550.

The section displays two main subunits. The upper one, from 142 to 188 m BSF, comprises mainly pillow lavas and their fragments. The pillow lavas are supported by a hyaloclastic and calcareous matrix. The lower one, from 188 to 201 m BSF, consists of two massive lava flows separated by fragmented and highly altered debris of lava pillows.

Visual inspection shows the various rock types to have moderately phyric texture, with plagioclases occurring as phenocrysts up to 0.5 cm in size and constituting 2 to 15% of the rock. No olivine phenocrysts are visible to the eye. Chilled edges contain vesicles from 0.5 to 1 cm in diameter that are filled with calcite or green smectite. The coarser-grained parts have subophitic texture.

Two aspects of these basalts are of particular interest: the types of alteration and the presence of calcareous material within them.

Every rock type is deeply fractured. Fractures in the fresher rocks are bordered by rust-colored fringes, a feature that suggests oxidation by late deuteric circulation. In brecciated parts, and at pillow edges, the whole rock has lost its original color and has become reddish brown. In some places the rock is noticeably friable. Some fractures are still open, and walls are blanketed by dogtooth calcite. In some places the net of fractures is so dense that the basalt has been replaced nearly completely by more or less sparry calcite. Spaces between pillows are also filled by sparry calcite, or by calcareous microbrec-

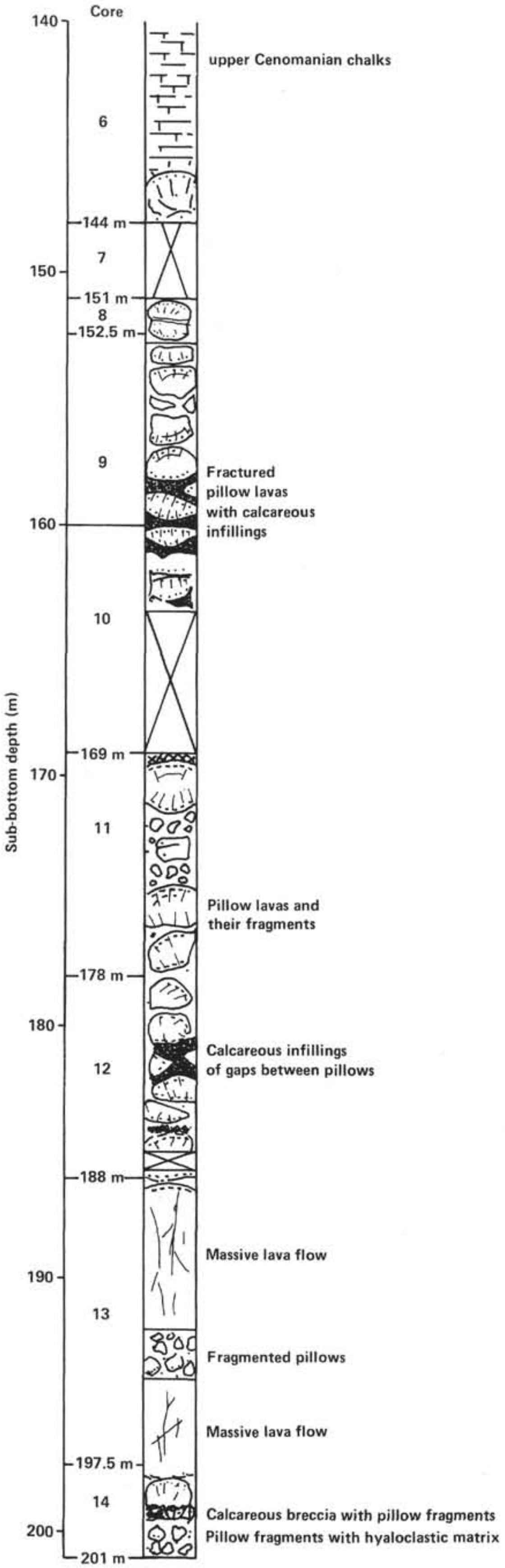


Figure 3. Basalts recovered at Site 551.

cias, some of which are graded and laminated fragments that have spalled from the hyaloclastic cortex.

In the uppermost part of the pile, cracks and fissures within the pillows are filled with both sparry calcite and pink micrite containing planktonic foraminifers. These sediments can be found at least 10 m below the top of the basalt section, and in some places they fill the spaces between the lava pillows. Such pink limestones become increasingly more recrystallized at greater depths in the hole, which makes their origin difficult to understand. Presumably, some of these carbonates were deposited on the basaltic surface of the seafloor, later filtering into the matrix of the pillows and filling in the cracks. Other carbonates probably recrystallized later and compacted into microsparite and sparite. Some of the carbonates were micritic calcites of hydrothermal origin and became stained by iron oxide during several phases of dissolution and recrystallization. Some of the better preserved limestones contain a few globigerinidlike microfossils, but no forms of stratigraphic value have yet been identified.

Thin sections of the pillow lavas show nearly aphyric to phyric textures. Phenocrysts are olivine (which has been replaced by calcite and/or chlorite) and fresh plagioclase. The groundmass comprises skeletal microlitic plagioclases, small granular clinopyroxenes, opaque granular minerals, and devitrified glass replaced by chlorite and/or calcite. Numerous fractures are filled by calcite or smectite.

Typical thin sections of the massive lava flows display phyric textures with phenocrysts of calcic (An > 60) plagioclases and poikilitic clinopyroxenes; microphenocrysts are mainly olivine. The microcrystalline groundmass comprises olivine, clinopyroxene, plagioclase, magnetite, and chlorite.

The characteristics of these basalts are those of oceanic tholeiites (as at Site 550) that are somewhat altered in their upper parts and frequently in the "brownstone facies" (Maury et al., this volume). The basalts probably originated as magmatic material during rifting and have formed a so-called basement outer-high that is located on thinned continental crust.

BIOSTRATIGRAPHY

Summary

Rotary coring at Site 551 penetrated approximately 142 m of sediments that range in age from Quaternary to late Cenomanian (Fig. 4). The Pleistocene sediments in the mudline core contain abundant well preserved microfossils that were deposited under climatic conditions and at water depths similar to those that exist at present.

Except for a thin layer of grayish white chalk in Section 1, which is early to middle Miocene in age, the sediments in Core H1 (47–56.5 m BSF) are of Eocene age. Both the foraminifer and nannoplankton assemblages are rich and well preserved, and both indicate a biostratigraphic position at or near the boundary between the early and middle Eocene.

A continuous lower Eocene–upper Paleocene sequence is present in Core H2 (94.5–104 m BSF). Most of the

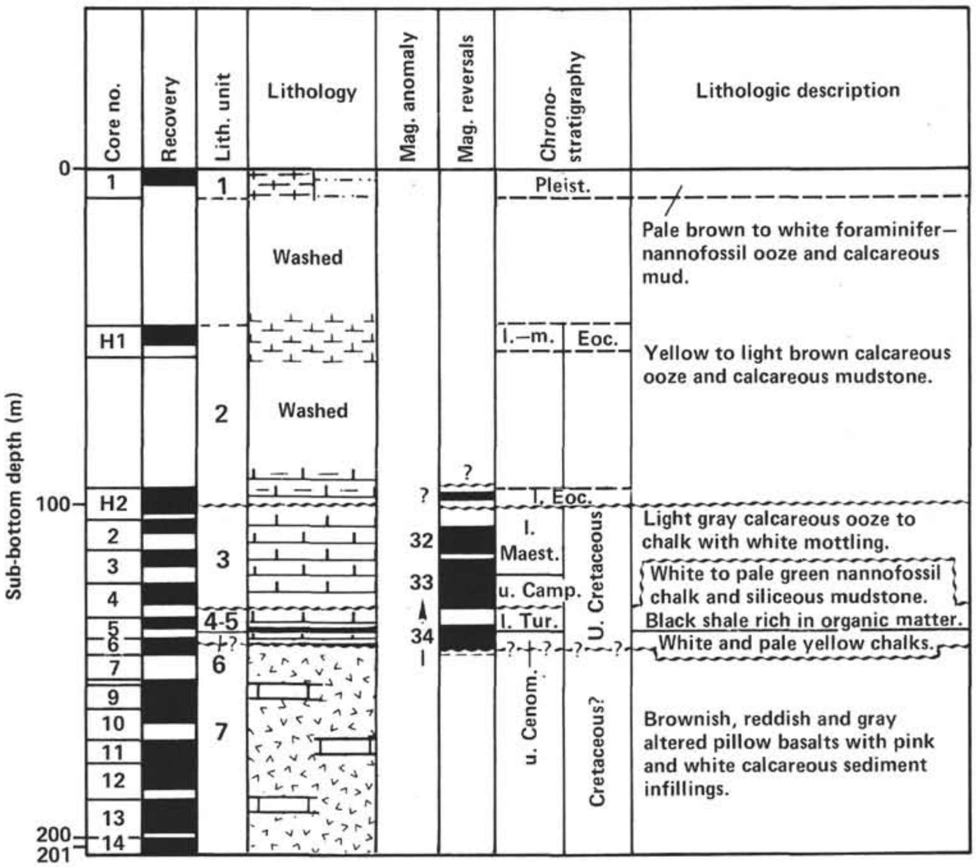


Figure 4. Stratigraphic section at Site 551. Approximately 2 cm of upper Paleocene sediment is present between the lower Eocene and Maestrichtian. Legend as in Explanatory Notes (this volume). The limestone symbols within the basement indicate scattered thin intervals.

core (Section 1 to Section 5, 35 cm) is lower Eocene sediment. Nannoplankton Zones NP10–NP13 have been recognized, and a sample at the base of the Eocene section contains a planktonic foraminifer fauna that can be assigned to Zone P6 (basal Eocene). Immediately below (Section 5, 36–38 cm) there is a thin layer of dark brown upper Paleocene sediment. Although preservation is generally good, the Paleocene layer and the dark brown, manganese-rich zones that appear occasionally within the Eocene display the effects of carbonate dissolution.

The Cretaceous sediments can be divided into two chronostratigraphic units. The uppermost sediments lie in Section 551-H2-5 immediately below the Paleocene sediments. The upper unit (the base of Core H2 to the lower part of Core 4) ranges in age from early Maestrichtian to late Campanian. Both planktonic foraminifers and nannoplankton are abundant, but fragmentation and dissolution are a problem, especially in the part of the unit interpreted as Maestrichtian. Although nannoplankton assemblages can be confidently identified throughout the unit, foraminiferal evidence is conclusive only for the unit's late Campanian portion (Core 4).

The lower chronostratigraphic unit within the Cretaceous ranges in age from early Turonian (Core 5) through late Cenomanian (Core 6). An unconformity representing a hiatus of about 20 m.y. appears to be present between the early Turonian and late Campanian sediments, although the contact was not recovered. The sediments in Section 551-5-1 contain rich calcareous microfossil assemblages that can be confidently assigned to the early Turonian. The underlying sequence of black shale (most of Cores 5 and 6), which is capped by light greenish sediments, is characterized by severe to complete carbonate dissolution, much of the shale evidently having been deposited below the calcite compensation depth (CCD). This sequence is tentatively included within the lower Turonian section. The lower part of Core 6, which contains abundant and well preserved foraminifers and nannoplankton, is interpreted as late Cenomanian in age. The Cenomanian section extends from 138.5 to 142.5 m, where it lies directly upon basaltic basement.

Foraminifers

Cenozoic

Sample 551-1-1, 4–6 cm contains an assemblage of Holocene planktonic foraminifers that is moderately well preserved (minor recrystallization). The most abundant species are *Globigerina bulloides, Globorotalia inflata*, and *G. truncatulinoides*. Species of secondary abundance include *Neogloboquadrina pachyderma, Orbulina universa, Hastigerina siphonifera, Globorotalia scitula*, and *G. hirsuta*. Except for the increased relative abundance of *Neogloboquadrina pachyderma* and a corresponding decrease in *Globorotalia truncatulinoides*, the Pleistocene assemblage from Section 551-1,CC is similar to that from the surface sediments. These minor faunal differences suggest that the sediments of Section 551-1,CC, although deposited in slightly cooler waters than those of the Holocene, accumulated during an interglacial when climatic conditions were similar to those of today. The similarity in generic composition of benthic foraminifer assemblages from these samples (*Pyrgo, Cibicides, Uvigerina*) indicates deposition within the same general bathymetric setting.

Section 551-H1,CC, which was taken at 52.6 m BSF (Fig. 14), has an abundant, moderately well preserved planktonic foraminifer assemblage that indicates an age of early middle Eocene (Zone P10). *Globigerina linaperta* and *G. eocaena*, both long-ranging Eocene forms, are numerically dominant. Less abundant, but more stratigraphically restricted species include *Acarinina pseudotopilensis, A. pentacamerata, A. bullbrooki, Truncorotaloides collactea*, and *Planorotalites renzi*.

The lower Eocene sediments, which occur in Core H2 (94.5–104 m BSF), are similar in general lithology and color to those of Section 551-H1,CC. In Sample 551-H2-5, 33–35 cm, which is at a depth of 100.8 m BSF and comes from the base of this lithic unit, *Globigerina linaperta* is again the most abundant species; taxa of lesser abundance include *Acarinina broedermanni, A. soldadoensis soldadoensis, A. primitiva, Morozovella aequa, M. wilcoxensis, M. subbotinae*, and *M. marginodentata*. Because the ranges of these species overlap, the assemblage is assigned to the latter part of Zone P6 (lower Eocene). The rarity of benthic foraminifers in the sediments of both wash cores suggests deposition in lower bathyal to abyssal environments.

Sample 551-H2-5, 36–38 cm, which lies immediately below the sample just described, was taken from a thin (about 2 cm), darker unit. This unit belongs to the upper Paleocene, but the poor preservation of the assemblage hinders precise zonal assignment. The sample contains the lower contact with white Cretaceous chalks, and many of the best preserved specimens belong to Cretaceous species. Forms indigenous to the Paleocene unit include *Pseudohastigerina wilcoxensis* and *Chiloguembelina* sp., both of which are common, and rare specimens of *Subbotina triloculinoides, S. pseudobulloides, Acarinina* cf. *A. praecursoria*, and *A.* aff. *A. primitiva*. There is, obviously, faunal mixing involving the Cretaceous and portions of the lower and upper Paleocene. Species from lower stratigraphic levels are either reworked or present because of contamination. Benthic foraminifers are common, largely because planktonic foraminifers have been preferentially destroyed by dissolution. The benthic generic composition (*Nodosaria, Lenticulina, Pullenia, Lagena*) suggests deposition in a bathyal environment.

Cretaceous

The 44 m thick Cretaceous sequence, which lies between upper Paleocene sediments and basalt, comprises two chronostratigraphic units separated by a major unconformity (Fig. 4).

Cores H2, 2, and 3 are of early Maestrichtian age and contain pelagic sediments that were deposited in a lower bathyal to abyssal environment. Shallower-water benthic foraminifer species appear to have been displaced into this sequence from higher up on the Goban Spur. Diagnostic species include *Globotruncana stuarti, G. elevata, G. stuartiformis, G. arca, G. ventricosa, G. tricarinata, G. fornicata, G. caliciformis, G. stuartiformis, Schackoina multispinata, Biglobigerinella algeriana, Rugoglobigerina rotundata, Globigerinelloides bollii, G. yaucoensis, Guembelina plummerae, G. pulchra, Ventilabrella austinana, Pseudoparella texana, Aragonia ouezzanensis, A. velascoensis, Reussella szajnochae*, and primitive forms of *G. contusa*.

The sediments in Core 4, which were derived from similar paleoenvironments, are of late Campanian age (*Globotruncana calcarata* or MCs 8 Zone), as indicated by the presence of the key form, *Globotruncana calcarata*.

The second chronostratigraphic unit includes Turonian and Cenomanian strata. The foraminifer assemblages are very rich, but benthic foraminifer specimens are rare. The sediments in Core 5 belong to the lowest Turonian (base of *Globotruncana helvetica* or MCs 3 Zone); although the zonal marker was not identified, the planktonic foraminifer association is made up primarily of *Globotruncana stephani, G. turbinata, G. gibba, G. praehelvetica, G. algeriana, G. imbricata, Whiteinella paradubia*, and primitive forms of *G. schneegansi*. The specimens in the assemblage are affected by calcite dissolution. Black shale is intercalated within Core 5; it yielded no fossils other than fish debris. A late Cenomanian association (late *Rotalipora cushmani* or MCs 2 Zone) is identified in Core 6 by the presence of *Rotalipora cushmani, R. deecykei, R. greenhornensis*, the *Globotruncana stephani* group, and *Hedbergella brittonensis*. The sparsity of benthic specimens seems to indicate a lower bathyal or abyssal paleoenvironment.

Nannoplankton

Quaternary

The Pleistocene sequence encountered was thin and incomplete. Core 1 (0–9.0 m) contains a nannoplankton assemblage belonging to Zone NN21 (*Emiliania huxleyi* Zone). There is an alternation of layers rich in diverse, indigenous nannoplankton assemblages (deposited during warm periods) and layers poor in nannoplankton but rich in detrital material (deposited during cool periods). The sediments deposited during the warm periods (interglacials) are light-colored nannofossil oozes with common *Emiliania huxleyi, Gephyrocapsa ericsonii*, and *Coccolithus pelagicus*. Also present, but rare, are *Cyclococcolithus leptoporus, Helicosphaera carteri, Discolithina japonica, Syracosphaera pulchra*, and *Rhabdosphaera stylifer.* Terrigenous detritus and reworked nannoplankton are also scarce.

The glacial deposits consist of calcareous mudstones that are poor in autochthonous nannoplankton, containing chiefly *Emiliania huxleyi* and *Geophyrocapsa ericsonii.* These sediments are characterized by common terrigenous detritus (carbonates, quartz) and reworked Cretaceous and Tertiary specimens.

Tertiary

Sediments of earliest middle Eocene age (nannoplankton Zone NP14) are present in Section 551-H1-1 from 4 to 16 cm (47.0–56.5 m BSF) (Fig. 4). The nannoplankton are abundant and slightly etched. The assemblage consists of *Chiasmolithus solitus, C. grandis, Coccolithus pelagicus, Discoaster barbadiensis, D. sublodoensis, D. lodoensis, Rhabdosphaera inflata, Ericsonia disticha*, and *Helicosphaera seminulum*.

A few centimeters of grayish white nannofossil ooze (Section 551-H1-1, 12–15 cm) yielded a nannoplankton assemblage belonging to Zone NN5 (middle Miocene); it contained *Sphenolithus heteromorphus, Cyclicargolithus abisectus, Discoaster exilis*, and *Helicosphaera carteri.* The nannofossils are small and strongly affected by dissolution.

A very condensed lower Eocene sequence was recovered from Section 551-H1-2 and from Section 551-H2-2 (94.5–104.0 cm). The *Discoaster lodoensis* Zone (NP13) of the lower Eocene is present from Section 551-H1-2 to 551-H2-2, 20 cm; the *Marthasterites tribrachiatus* Zone (NP12) occurs from 551-H2-2, 40 cm to 551-H2-4, 80 cm; and the *Marthasterites contortus/Discoaster binodosus* Zone (NP10/NP11) occurs from 551-H2-4, 100 cm to 551-H2-5, 40 cm. The nannofossils are abundant, but they are slightly to strongly etched and broken from dissolution. The species associations are diverse, and characteristic species for each zone are present.

Below this lower Eocene section, the upper Paleocene (Zone NP9) is represented by 4 to 5 cm of dark brown calcareous mudstone rich in well preserved nannoplankton, including *Discoaster multiradiatus, Fasciculithus tympaniformis, Toweius eminens, T. craticulus, Ellipsolithus macellus*, and *Chiasmolithus bidens.*

Cretaceous

Lower Maestrichtian sediments (upper part of the *Tetralithus trifidus* Zone) are separated from upper Paleocene sediments by an unconformity representing a hiatus of at least 14 m.y. (Fig. 4). These Cretaceous rocks are rich in nannoplankton that show signs of slight dissolution and fairly strong fragmentation, probably as a result of diagenesis. The species are diverse and include *Broinsonia parca, Reinhardtites anthophorus, Cribrosphaerella ehrenbergi, Prediscosphaera cretacea, Manivitella pemmatoidea, Arkhangelskiella cymbiformis, Micula staurophora, Eiffellithus turriseiffeli, Kamptnerius magnificus, Microrhabdulus decoratus, Tetralithus aculeus, T. gothicus, T. trifidus*, and *Lucianorhabdus cayeuxii. Lucianorhabdus cayeuxii* is rare in most of the samples, but it is common in several pebbles of white nannofossil ooze that are included in the beige ooze of the lower Maestrichtian–upper Campanian sequence. The common occurrence of this species in the pebbles indicates that the sediments have been displaced from a shallower environment. The idea that the sediments are displaced is supported by the high accumulation rate (11 m/m.y.) during the 2 m.y. when the sediments belonging to the *Tetralithus trifidus* Zone were deposited. *Tetralithus trifidus* itself is always rare, whereas *T. gothicus* is more frequent, as in Hole 548A. The abundance of *Kamptnerius magnificus* may indicate temperate waters.

Upper Campanian sediments (lower part of the *T. trifidus* Zone) are present in Core 4 (123.0–135.0 m), as determined by the simultaneous occurrence of *Eiffellithus eximius, Tetralithus gothicus, T. trifidus*, and *Broinsonia parca.* The nannoplankton are preserved about as well as in the lower Maestrichtian sediments. Core 5 yielded a nannoplankton assemblage of Turonian age. This suggests that an unconformity representing a hiatus of about 20 m.y. separates the Turonian and late Campanian. Typical Turonian species are *Gartnerago obliquum, Lithastrinus floralis, Eiffellithus turriseiffeli*, and *Prediscosphaera cretacea.* The nannoplankton are abundantly recrystallized and broken as a result of diagenesis. Core 5 contains greenish sediments above and black shales below; fragmentation and dissolution are stronger in the greenish sediments than in the black shales. The greenish sediments were deposited in a region of high productivity, as indicated by the abundance of radiolarians, which have been partially destroyed by diagenesis. As a result of the high production of siliceous microfossils, nannoplankton make up a smaller proportion of the fossil assemblage than in younger strata. At the same time, the dissolution of the calcareous micro- and nannofossils is stronger as a result of the undersaturation of the water with respect to calcium carbonate. Conditions are similar where Holocene sediments are deposited in areas of upwelling.

The underlying organic-carbon-rich black shales of probably earliest Turonian age are almost barren of nannoplankton; only a few dissolution-resistant specimens were found. According to the calculated subsidence curve for oceanic basement, these sediments were deposited at water depth of about 2000 m. If the explanation for the dissolution is that the black shales were deposited below the CCD, the CCD rose to significantly higher levels during a relatively short time within the early Turonian. The strong carbonate dissolution within the black shales might be related to organic enrichment and diagenetic processes, however (Waples, "Anoxia," this volume).

The lowermost Turonian section is underlain by upper Cenomanian sediments found in Core 6. The age of these sediments is based on the presence of *Podorhabdus albianus, Corollithion signum, Lithraphidites* cf. *alatus*, and the absence of *Gartnerago obliquum.* The sediments are rich in nannoplankton that have been slightly recrystallized and heavily broken by diagenesis; zeolites (clinoptilolite) are abundant in several layers.

The upper Cenomanian rocks overlie the basaltic pillow lavas of the basement (Fig. 4). Thin sediment layers are interbedded in the basalt, but they are barren of nannoplankton, probably because of the strong recrystallization of the carbonates.

SEDIMENT ACCUMULATION RATES

The average rate of sediment accumulation at Site 551 (142.4 m, 90 m.y.) is 1.6 m/m.y. The rate has been remarkably uniform during the Mesozoic (1.7 m/m.y.)

and Cenozoic (1.8 m/m.y.) in view of the sporadically preserved sedimentation at this site. However, the erratic accumulation rates become more obvious when the record is analyzed in smaller increments.

During the earliest phase of sedimentation, when late Cenomanian nannofossil chalks were being deposited on top of the basalts, the accumulation rate was low (about 1.3 m/m.y.). It increased to approximately 2.7 m/m.y. during the early Turonian, and it accelerated again in the late Campanian and early Maestrichtian (to as much as 7.4 m/m.y.).

During the early Tertiary (late Paleocene to early Eocene), the rate increased even more, reaching 10.8 m/m.y. The final 47 m section of Tertiary and Quaternary sediments accumulated at the much lower rate of 1.1 m/m.y.

ORGANIC GEOCHEMISTRY

Fifty-three samples were analyzed for total organic carbon (TOC) content; 102 samples were analyzed for carbonate content; 16 samples were analyzed for total nitrogen; and 15 samples were analyzed by Rock-Eval pyrolysis. The results are tabulated in Waples and Cunningham (this volume).

Total Organic Carbon, Carbonate, and Nitrogen

The Holocene-Pleistocene section (Core 1) was analyzed for TOC and carbonate content at closely spaced intervals. The results which are shown in the diagenesis profile in Figure 5, are similar to those at Site 548.

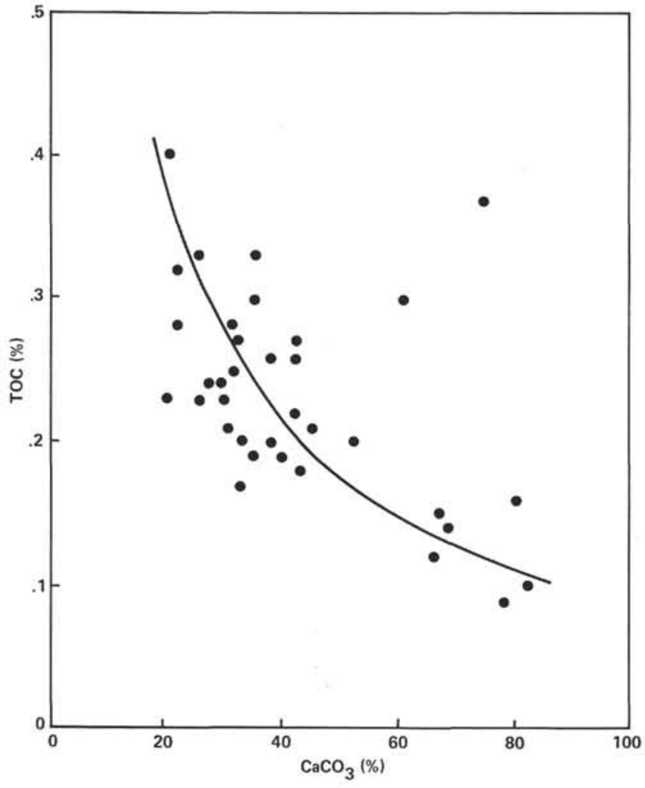


Figure 5. TOC and carbonate content of Holocene–Pleistocene (Core 1) sediments at Site 551.

TOC values for the continuously cored section (Cores H2–6, upper Cenomanian to upper Paleocene) are plotted in Figure 6. Except for the black shales in Core 5, the TOC values are extremely low (<0.23%). The 11% value obtained for one black shale sample is the highest yet reported for Cretaceous sediments from the Biscay margin (the maximum values encountered at Sites 400 and 402, Leg 48, were approximately 4%). However, a sediment nearly as rich in TOC (approximately 8%) was found on Vigo Seamount during Leg 47 in a coeval bed close to a coeval unconformity.

Carbonate contents are variable throughout the Holocene–Pleistocene section and in Unit 2 (Waples and Cunningham, this volume). Unit 3 is highly calcareous. Unit 4 is generally less calcareous, with some intervals that are highly siliceous. The black shales and some overlying light-colored horizons are faintly calcareous or noncalcareous and are enriched in silica. Unit 6 is quite calcareous, averaging about 80% $CaCO_3$.

The nitrogen contents of the black shales (Unit 5) indicate that the organic matter is similar in source to that of the nearly coeval black shales at Site 549. The atomic C/N ratios are 19 and 29 for the two samples analyzed, in comparison to 25 and 27 for the Site 549 black shales.

The black shales are carbonaceous claystones rich in silica and zeolites. The silica is believed to be of biogenic origin, because recrystallized radiolarians are abundant. Zeolite is present as clinoptilolite, which often replaces siliceous tests and is also indicative of the diagenesis of amorphous silica. Most sediments in the lithologic units above and below the black shale are rich in carbonate, but the carbonate contents in the blackest, densest intervals of the black shales are negligible.

Rock-Eval Pyrolysis

The hydrocarbon source potential, S_2, of organic-carbon-lean samples from Units 1 to 4 and 6 was not detectable because of the units' extremely low TOC values. The black shales of Unit 5, however, have moderately

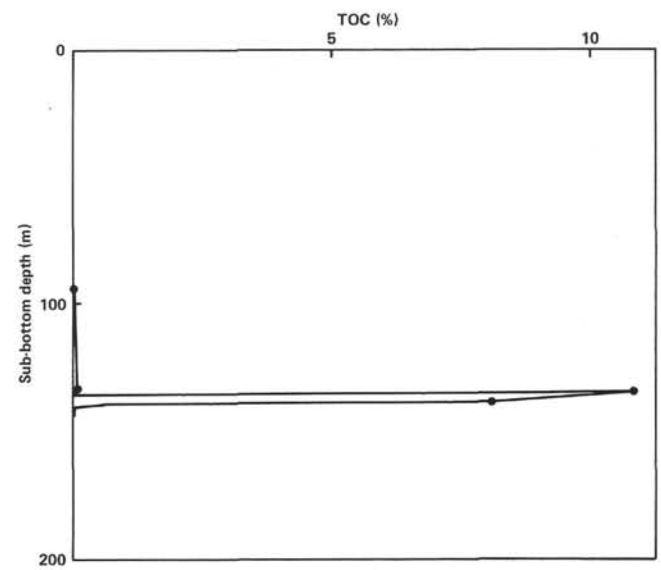


Figure 6. TOC values for Cores H2 to 6 at Site 551.

high hydrogen indices (358 and 427 mg HC/g TOC, indicative of mixed Type II and III kerogens), which, coupled with the extremely high TOC values (8%, 11%), indicate excellent oil source potential. The T_{max} values are low (413°C), however, indicating that the black shales are thermally immature.

The Rock-Eval results indicate that the organic matter in the black shale at Site 551 is more like that in the black shale recovered at Site 549 than that recovered from Site 550 (Table 3). The hydrogen and oxygen indices for the Site 549 and 551 black shales are similar, averaging 355 mg HC/g TOC and 36 mg CO_2/g TOC, respectively. The average hydrogen index for black shales from Site 550 is considerably lower (239 mg HC/g TOC), and the average oxygen index is higher (70 mg CO_2/g TOC).

Organic Facies

All the sediments recovered at Site 551 except the black shales were deposited under highly oxidizing conditions. The influx of terrestrial organic matter was moderate, and it consisted of finely divided material. Degradation of most terrestrial organic matter and virtually all marine organic matter during or shortly after deposition left only refractory residues of mainly terrestrial origin in the nonblack intervals.

Similar ages, lithologies, TOC values, and organic matter types suggest that the black shales from Sites 549 and 551 were deposited under similar conditions (marine productivity was high, the influx of organic and inorganic terrestrial material was low, and the bottom water was low in oxygen). At Site 551, deposition occurred in water depths of around 2000 m, probably well within an expanded oxygen-minimum layer. At Site 549, in contrast, deposition was probably on the upper to middle slope, nearer the upper limit of the oxygen-minimum zone. The relationships among the various black sediments encountered on Leg 80 are discussed in more detail in Waples ("Anoxia"); Waples and Cunningham; and Cunningham and Gilbert (all this volume).

PALEOMAGNETISM

Approximately 40 samples were collected from the Cretaceous sediments at Site 551. The results from these samples indicate the presence of three normal polarity intervals which may represent Anomalies 32, 33, and the upper part of 34 (Fig. 4).

SUMMARY AND CONCLUSIONS

Site 551 was drilled on the seaward edge of Goban Spur (3909 m water depth) over the flat top of a raised basement block (Fig. 7). To minimize coring time we decided to drill in a location different from that originally proposed; we spudded in close to the seaward edge of the block, where no more than 200 m of sediments were estimated to be present.

The "basement" is not Hercynian sandstones, as at Site 549, but basaltic flows and pillows at least 59 m

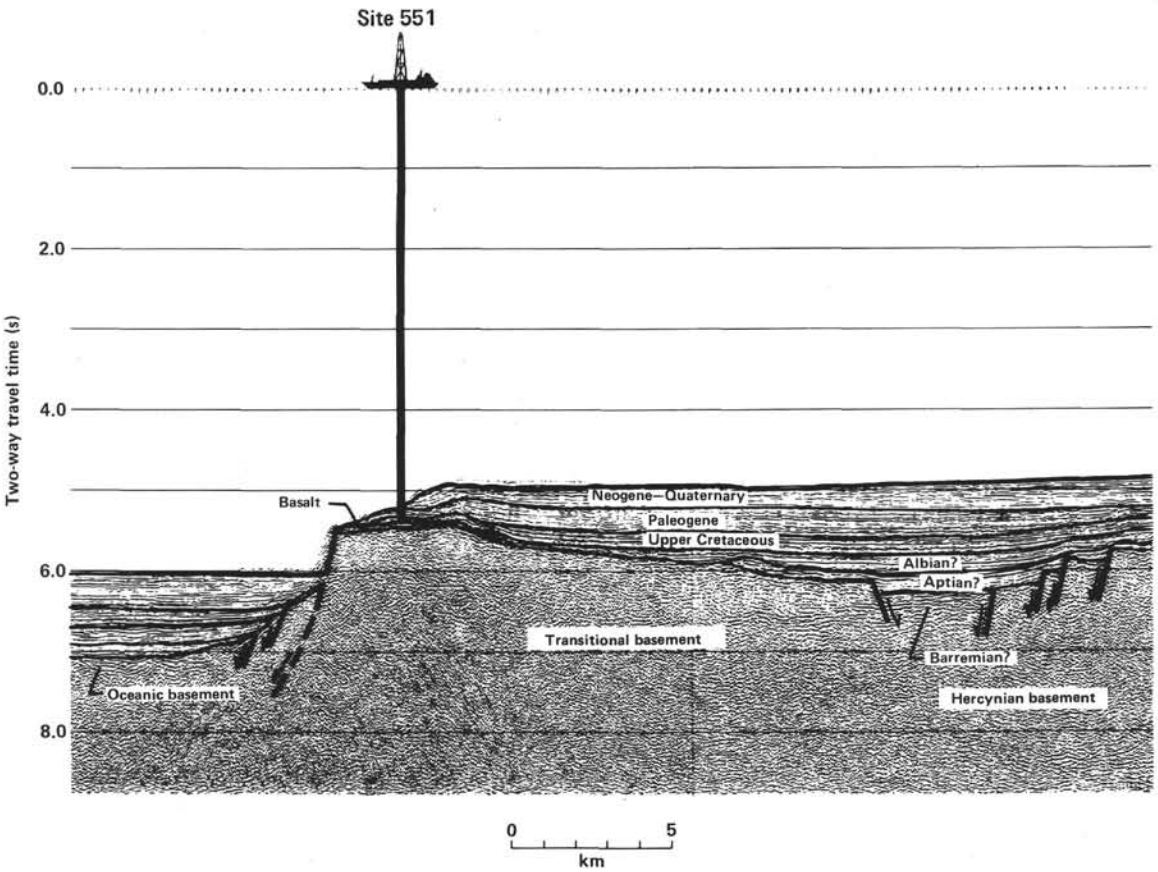


Figure 7. Segment of multichannel seismic Profile CM 10 across Site 551.

thick (our total penetration), which are overlain by bathyal upper Cenomanian strata. Thus, the flattened top of the block corresponds to the top surface of lavas emplaced at bathyal depths. The presence of basalt at this location seems to indicate that the seaward edge of the continental crust was complexly intruded and covered by oceanic crust during the initial phase of seafloor spreading, as predicted by Scrutton (1979, and Scrutton, this volume). The deeply altered state of the basalts may indicate that they were exposed on the seafloor for a long period of time before burial by sediments. This raises the possibility that this layer was emplaced much earlier, during rifting. Middle Jurassic extrusives and intrusives have been reported from the Celtic Sea region (Kamerling, 1979; Robinson et al., 1981), and the emplacement of synrift volcanics in some of the half-grabens of the Goban Spur has been postulated (Masson et al., this volume). Nevertheless, this hypothesis seems unlikely, because basalts at Sites 550 and 551 are very similar, and both are typical oceanic tholeiites. They are clearly different from the continental tholeiites or flood basalts emplaced during the prerift magmatic, or possibly synrift, stages. Unfortunately, the mobility of K during the late stages of deuteric alteration prevented us from establishing dates which could have given a partial answer to the discussion (Maury et al., this volume). Regardless of the time of emplacement, however, the basement block beneath Site 551 can be considered as transitional between oceanic and continental basement. Documenting oceanic basalts at a place like Site 551, where topographic, gravimetric, and magnetic anomalies have been found is one of the principal achievements of Leg 80.

The thin sedimentary section at Site 551 is the result, in part, of unconformities, several of which correspond to those documented at other Leg 80 sites. Unconformities are only part of the story, however. In relative terms some of the units at Site 551 are thicker than they are at other sites. For example, the Campanian–Maestrichtian section at Site 551 is one-quarter as thick as at Site 550 (25 vs. 105 m), a relationship that is approximately in keeping with the 1 to 5 ratio of the total sediment thickness at the two sites. Yet the thickness of the lower Eocene units is nearly identical (50 and 53 m, respectively). A consideration of silica diagenesis suggests that a 300-m-thick pile of post-Cretaceous sediments could have been removed by erosion (Otsuka, this volume).

Another way in which the sediments at Site 551 differ is that the thin (4–5 m) interval of light-colored upper Cenomanian chalks there does not contain the dark carbonaceous interbeds that characterize Site 550. The beds are believed to have formed in an oceanic basin, where the circulation of bottom waters was restricted. The absence of such beds at Site 551 puts some important constraints on the size of this basin in its early stage of development.

Another significant feature of the sediments at Site 551 is the presence of carbonaceous Turonian black shale (equivalent to that at Site 549), which is unusually enriched in marine organic matter. The carbonate contents of the black shales at Sites 551 and 549 show that the CCD lay at a depth intermediate between the sites during the Turonian. The respective present depths of the shales are 4041 and 2975 m BSF. The interpretation of such lithologies is discussed by Waples ("Anoxia," this volume); they are known for their oceanwide occurrence at this particular age (Graciansky et al., 1984).

A major (about 20 m.y.) hiatus appears to separate lower Turonian from upper Campanian deposits. The hiatus corresponds to a period when the sediment accumulation rates at the other Leg 80 sites were low. The sediments that accumulated during the Late Cretaceous at Site 551 are chalks displaced from shallower water sites. This depositional style is comparable to that at Sites 549 and 550, although only 25 m of sediments were deposited at Site 551.

The recovery of Cenozoic strata was insufficient to reconstruct the depositional history of that period. However, spot coring revealed that the complete upper Paleocene–lowest Eocene nannofossil zonation was recorded in only 5 m, whereas the remaining lower to middle Eocene sediments are at least 50 m thick. As at the other Leg 80 sites, the sediments in the short upper Pleistocene core display variations associated with climatic change.

REFERENCES

de Graciansky, P. C., Deroo, G., Herbin, J. P., Montadert, L., Müller, C., Schaaf, A., and Sigal, J., 1984. Ocean-wide stagnation episode in the Late Cretaceous. *Nature (London)*, 308:346–349.

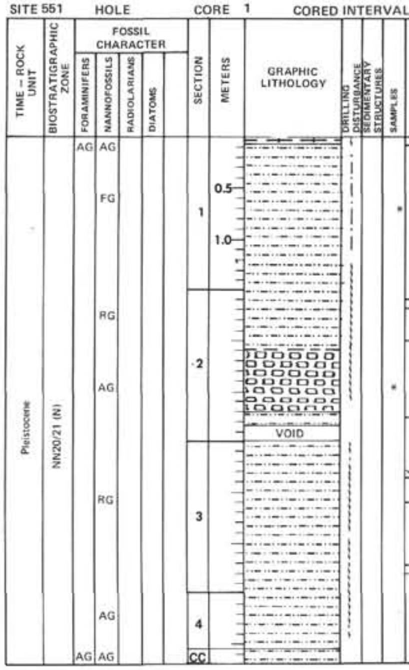
Kamerling, P., 1979. The geology and hydrocarbon habitat of the Bristol Channel Basin. *J. Petrol. Geol.*, 2:75–93.

Robinson, K. W., Shannon, P. M., and Young, D. G. D., 1981. The Fastnet Basin: an integrated analysis. *Proc. Conf. Petroleum Geology of the Continental Shelf of Northwest Europe, 1980*, pp. 444–454.

Scrutton, R. A., 1979. Structure of the crust and upper mantle at Goban Spur, southwest of the British Isles—Some implications for margin studies. *Tectonophysics*, 59:201–215.

Date of Initial Receipt: September, 6, 1983
Date of Acceptance: November 9, 1983

SITE 551 HOLE CORE 1 CORED INTERVAL 0.0–9.0 m



10YR 7/4
5Y 5/2
5Y 5/2
5Y 6/1
5Y 5/4
Olive & white streaked
10YR 8/1 white
10YR 6/3
10YR 5/3
White pebble
5Y 5/3
5Y 5/1
10YR 5/3
5Y 5/2
5Y 4/1
5Y 5/2

LITHOLOGIC DESCRIPTION

Unit 1
Foram-nannofossil ooze or calcareous ooze, pale brown (10YR 7/4) to white (10YR 8/1), soft to soupy
Foraminifera are common
White beds contain more calcareous fragments than nannofossils, quartz is common

Unit 2
Calcareous mud, olive (5Y 5/4) to dark gray (5Y 4/1), soft to soupy
Silty, probably contains common rock fragments, scattered small dark pebbles, Section 3 contains small white pebble, Core-Catcher contains 3.5 cm size piece of quartzite

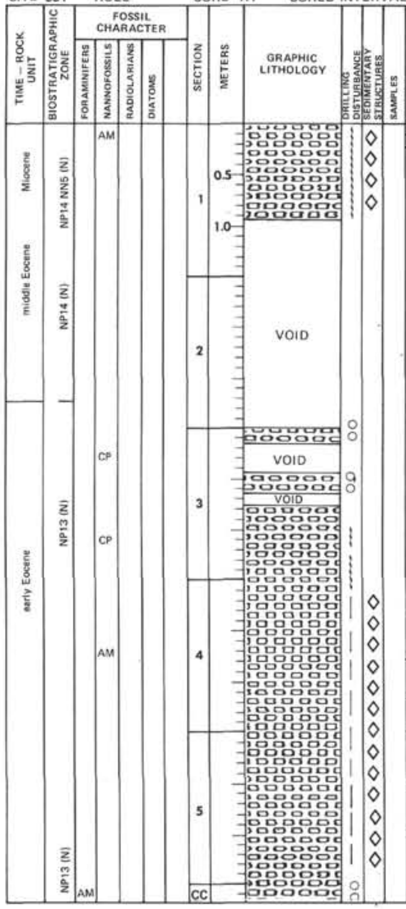
SMEAR SLIDE SUMMARY (%):

	1, 70	2, 98
	D	D
Texture:		
Sand	5	20
Silt	35	30
Clay	60	50
Composition:		
Quartz	25	15
Heavy minerals	5	–
Clay	35	40
Carbonate unspec.	15	10
Foraminifers	–	20
Calc. nannofossils	20	15

ORGANIC CARBON AND CARBONATE (%):

	1, 77	2, 105	3, 51	4, 52
Carbonate	16	62	29	20

SITE 551 HOLE CORE H1 CORED INTERVAL 47.0–56.5 m



5Y 7/3
Mixed colors
5Y 7/3
2.5Y 6/4
2.5Y 5/4
2.5Y 5/4
2.5Y 5/4
2.5Y 6/4
Darker band
Darker & small nodule
2.5Y 7/4
2.5Y 8/4
2.5Y 7/4
2.5Y 8/4
2.5Y 5/4
2.5Y 6/4
Dark nodules
2.5Y 7/6
10YR 6/6

LITHOLOGIC DESCRIPTION

Unit
Calcareous ooze, yellow (2.5Y 7/6) to light olive brown (2.5Y 5/4), soft
Scattered mottles of yellow (2.5Y 7/4) and fine black flecks
Sections 4 and 5 contain darker bands and zones of scattered black nodules (up to 5 mm size)
Section 1, 10–20 cm is zone of mixed greens, browns, and yellows

ORGANIC CARBON AND CARBONATE (%):

	4, 50
Carbonate	63

SITE 551 HOLE CORE H2 CORED INTERVAL 94.5–104.0 m

TIME – ROCK UNIT: early Eocene; late Paleocene; early Maestrichtian

BIOSTRATIGRAPHIC ZONE: NP13 (N); early Maestrichtian or early Campanian; NP12 (N); NP10–11 (N); NP9 (N); *T. trifidus* (N)

FOSSIL CHARACTER — FORAMINIFERS: AG, CP, AG, AG; NANNOFOSSILS: CM, CM, CM, AM, AM, AM, AM, AP, AM, AM, AM, CM, CM, AG, AP

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

GRAPHIC LITHOLOGY — DRILLING DISTURBANCE — SEDIMENTARY STRUCTURES — SAMPLES

LITHOLOGIC DESCRIPTION

Mixed browns
10YR 7/4
2.5Y 6/2, brown gray band
10YR 7/4
10YR 6/8
Darker mottling
Darker
Darker
10YR 5/6
10YR 5/3
10YR 5/4
Banding
Brown + yellow brown
10YR 5/6
Yellow spots
10YR 6/8
Gradational contact
10YR 7/6
10YR 5/4
10YR 6/6
10YR 6/3
10YR 7/4
Brown band, dark green flecks
2.5Y 7/2
2.5Y 7/2

Unit

Calcareous mud, shades of yellow brown (10YR 7/4 to 10YR 5/6). Below Section 5, 45 cm is light gray (2.5Y 7/2) calcareous ooze, firm

Above Section 5 sediment is fairly homogeneous with occasional banding in shades of main colors, contacts are generally sharp

Below Section 5, 45 cm sediment is mottled with irregular shaped white ooze, could be natural or a drilling induced sediment breccia. Probably a slump mixture of sediments

ORGANIC CARBON AND CARBONATE (%):

	1, 124	2, 124	3, 124	4, 114	4, 27
Carbonate	56	36	36	64	18

	4, 134	5, 124
$CaCO_3$	37	88

SITE 551 HOLE CORE 2 CORED INTERVAL 104.0–113.5 m

TIME – ROCK UNIT: early Maestrichtian

BIOSTRATIGRAPHIC ZONE: early Maestrichtian or late Campanian (F); *T. trifidus* (N)

FOSSIL CHARACTER — FORAMINIFERS: AG, AG, AG; NANNOFOSSILS: AM, AG, AM, AM

SECTION: 1, 2, 3, CC — METERS: 0.5, 1.0

GRAPHIC LITHOLOGY — DRILLING DISTURBANCE — SEDIMENTARY STRUCTURES — SAMPLES

LITHOLOGIC DESCRIPTION

2.5Y 7/2
Slides of gray and white sediment
VOID
Dark brown clay clast
Thin white horizontal band
2.5Y 7/2

Unit

Nannofossil chalk or firm ooze, light gray (2.5Y 7/2)

Scattered mottles and streaked fragments of white sediment, mm to cm size

Upper part of core sediment is soupy or in small fragments surrounded by strongly deformed material

White and gray sediments do not appear to be very different compositionally, both are rich in nannofossils

SMEAR SLIDE SUMMARY (%):

	2, 63 D (white)	2, 63 D (gray)
Texture:		
Sand	Tr	10
Silt	5	50
Clay	95	40
Composition:		
Quartz	—	Tr
Mica	—	Tr
Clay	7	10
Pyrite	Tr	—
Carbonate unspec.	20	5
Foraminifers	Tr	10
Calc. nannofossils	73	70

ORGANIC CARBON AND CARBONATE (%):

	1, 135	2, 135	3, 127
Carbonate	89	89	88

SITE 551 HOLE CORE 3 CORED INTERVAL 113.5–123.0 m

TIME – ROCK UNIT: early Maestrichtian

BIOSTRATIGRAPHIC ZONE: early Maestrichtian or late Campanian (F); *T. trifidus* (N)

FOSSIL CHARACTER — FORAMINIFERS: AG, AG, AG, AG; NANNOFOSSILS: AM, AM, AP, CP

SECTION: 1, 2, 3, CC — METERS: 0.5, 1.0

GRAPHIC LITHOLOGY — DRILLING DISTURBANCE — SEDIMENTARY STRUCTURES — SAMPLES

VOID

LITHOLOGIC DESCRIPTION

10YR 8/2–8/3
10YR 7/1
Thin white band
2.5Y 7/2

Unit

Nannofossil chalk, very pale brown (10YR 8/3) to light gray (10YR 7/1–2.5Y 7/2), firm, soupy at top of core

Mottled with scattered white sediment, mottles mm to cm size

Sediment is broken into chunks, surrounded by flow-in, in upper part of core

SMEAR SLIDE SUMMARY (%):

	1, 60 D
Texture:	
Sand	20
Silt	40
Clay	40
Composition:	
Quartz	Tr
Clay	10–15
Carbonate unspec.	20
Foraminifers	15
Calc. nannofossils	50

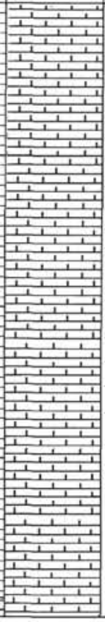
ORGANIC CARBON AND CARBONATE (%):

	1, 96	2, 96	3, 96
Carbonate	87	90	93

SITE 551 HOLE CORE 4 CORED INTERVAL 123.0–132.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
late Campanian	latest Campanian (MCs 8 zone) (F) *T. trifidus* (N)	AG	AP, AM			1	0.5, 1.0
		AG	AP			2	
		AG	AP			3	
		AG	AP			4	
		AG				CC	

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

LITHOLOGIC DESCRIPTION

10YR 7/2
Band of white lenses
Gray laminae
10YR 7/2
10YR 8/3
Faint laminae
10YR 8/2
10YR 7/2

Unit
Nannofossil chalk, light gray (10YR 7/2) to very pale brown (10YR 8/3), firm
Scattered white mottles, ovoid to subangular in shape, mm to rare cm in size
Deformed sediment clasts
White sediment contains shallow water nannofossils
Faint variations in gray show deformed sediment within gray beds, either drilling and/or syn-depositional
Gray sediment contains common nearly euhedral grains of carbonate

SMEAR SLIDE SUMMARY (%):

	2, 70
	D
Texture:	
Sand	10
Silt	40
Clay	50
Composition:	
Quartz	Tr–5
Clay	10
Carbonate unspec.	15
Foraminifers	5
Calc. nannofossils	60

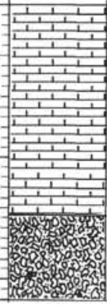
ORGANIC CARBON AND CARBONATE (%):

	1, 119	2, 119	3, 144	4, 116
Carbonate	87	87	88	86

SITE 551 HOLE CORE 5 CORED INTERVAL 132.5–138.5 m

TIME – ROCK UNIT	BIOSTRATIGRAPHIC ZONE	FORAMINIFERS	NANNOFOSSILS	RADIOLARIANS	DIATOMS	SECTION	METERS
early Turonian	early Turonian (early MCs 3 zone) (F) early Turonian (N)		CM, RP, CP, AM			1	0.5, 1.0
			AM, AM, RP, RP, AM			2	
						CC	

GRAPHIC LITHOLOGY



DRILLING DISTURBANCE / SEDIMENTARY STRUCTURES / SAMPLES

LITHOLOGIC DESCRIPTION

2.5Y 8/2
5Y 5/6 band
2.5Y 8/2
5Y 7/4
2.5Y 8/2
Gradual contact
5Y 8/2
5G 7/2 band, silty
5GY 7/1
5G 7/2, silty base
Chert pebbles
Black shale
Green, gray, white chalk
Calcareous black shale
Black shale

Unit 1
Nannofossil chalk, white (2.5Y 8/2) to pale green (5GY 7/1), firm, massive to faint laminae
Color transitions are gradational except in laminated beds and silty horizons
Laminae in Section 1 are distinct in shades of white and very pale green, mm or less width, laminated sediments contain more clay and forams than surrounding chalk, sponge spicules also present, all sediment contains volcanic glass
Silty beds enriched in radiolaria and silica fragments

Unit 2
Black shale mixed with drilling breccia top of unit marked by fragments of green and black chert, black shale poor in carbonate, appears partly laminated in some fragments. Contains zeolites and silica by XRD.

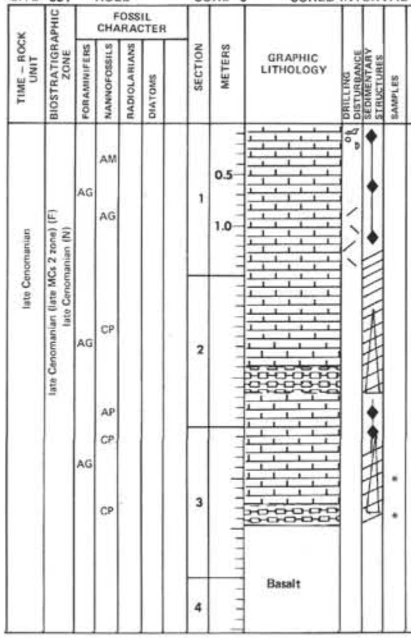
SMEAR SLIDE SUMMARY (%):

	1, 14	1, 29	1, 47	2, 5	CC
	D	D	D	D	D
Texture:					
Sand	–	–	10	5	Tr
Silt	–	–	30	15	50
Clay	–	–	60	80	50
Composition:					
Quartz	Tr	–	Tr	Tr	5
Feldspar	–	–	–	Tr	–
Mica	–	–	–	Tr	Tr
Heavy minerals	–	–	–	Tr	Tr
Clay	–	–	30	15	30
Volcanic glass	Tr	Tr	5–10	Tr	–
Unspec. silica	–	–	–	50	–
Micronodules	–	–	–	–	5
Zeolite	–	–	–	5	30
Carbonate unspec.	–	–	10	–	10
Foraminifers	–	Tr	5	5	Tr
Calc. nannofossils	Tr	Tr	30	15	20
Radiolarians	–	–	–	10	–
Sponge spicules	–	–	Tr	–	–
Amorphous dark brown	–	Tr	10	–	–

ORGANIC CARBON AND CARBONATE (%):

	1, 20	1, 28	1, 33	1, 48	1, 50
Carbonate	75	8	71	36	60
	2, 3	2, 5	2, 7	2, 12	2, 49
Carbonate	40	9	18	54	4
	2, 80				
Carbonate	59				

SITE 551 HOLE CORE 6 CORED INTERVAL



LITHOLOGIC DESCRIPTION

NANNOFOSSIL AND FORAM-NANNOFOSSIL CHALK

White (N8), yellow gray (5Y 8/1), grayish yellow (5Y 8/4) chalks

Occasional Mn-rich laminae and blebs

Occasional lamination, at acute angle to drilling (⫽) – cross bedding??? or slump??

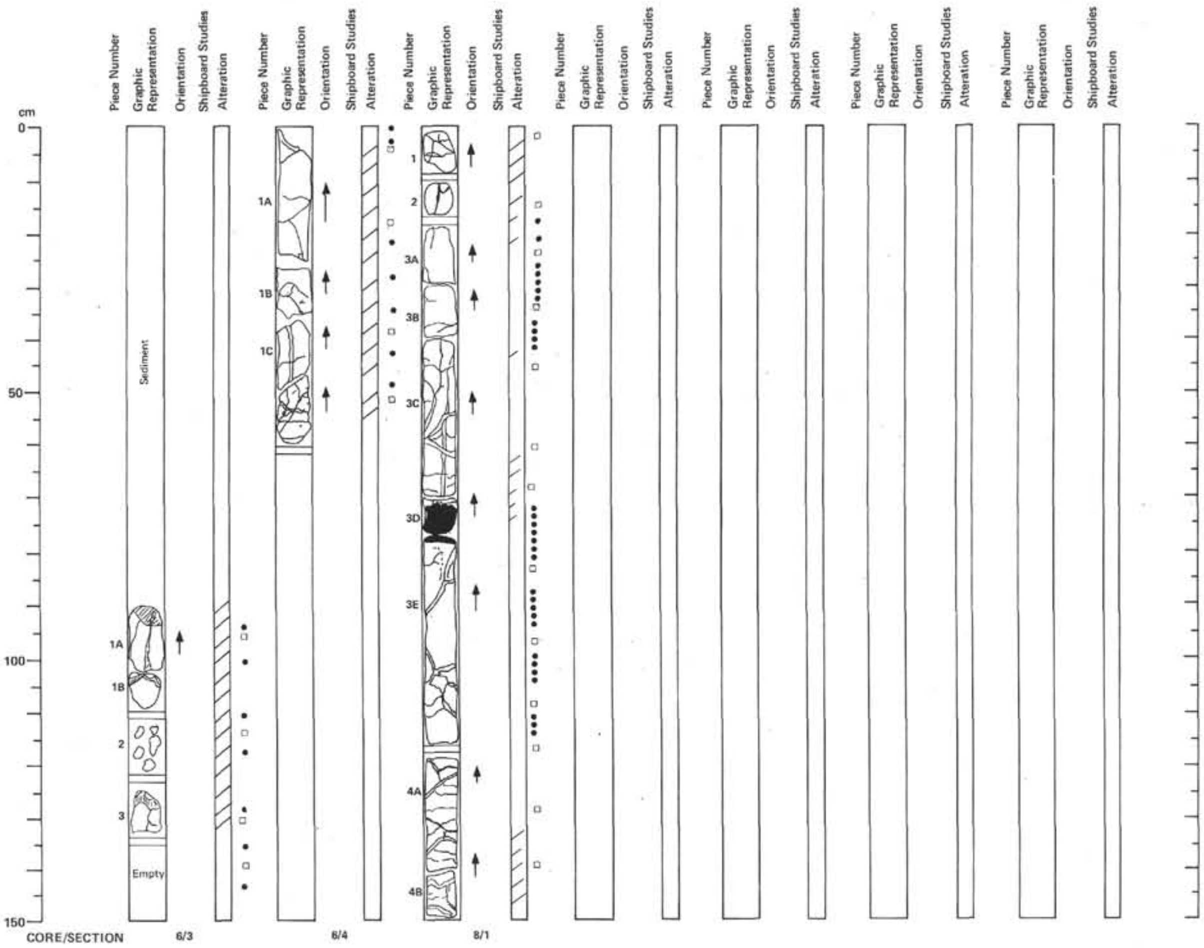
Two turbidites(?) grading from white or pale yellowish orange (10YR 8/6) and very pale orange (10YR 8/2) into white and very light gray (N8) or greenish white (5GY 4/1) chalk

Microfaulting in Section 1, 5–16 cm and 29–42 cm

Basalt at base

SMEAR SLIDE SUMMARY (%):

	3, 50
	D
Composition:	
Quartz	10
Clay	10
Foraminifers	10
Calc. nannofossils	60
Diatoms	<5
Sponge spicules	Tr



LEG 80, SITE 551, CORE 6

Core 6, Section 3, 90–130 cm and Section 4

Visual Description: Very fine-grained (chilled) moderately phyric basalt, veins filled with carbonate sediments. Alteration follows the veins. Color is moderate brown (5YR 4/4) in altered parts and dark (10YR 2/2) elsewhere. Calcitic vesicles. Plagioclase phenocrysts, 2–3 mm, 5–10%.

LEG 80, SITE 551, CORE 7

Core 7: No recovery.

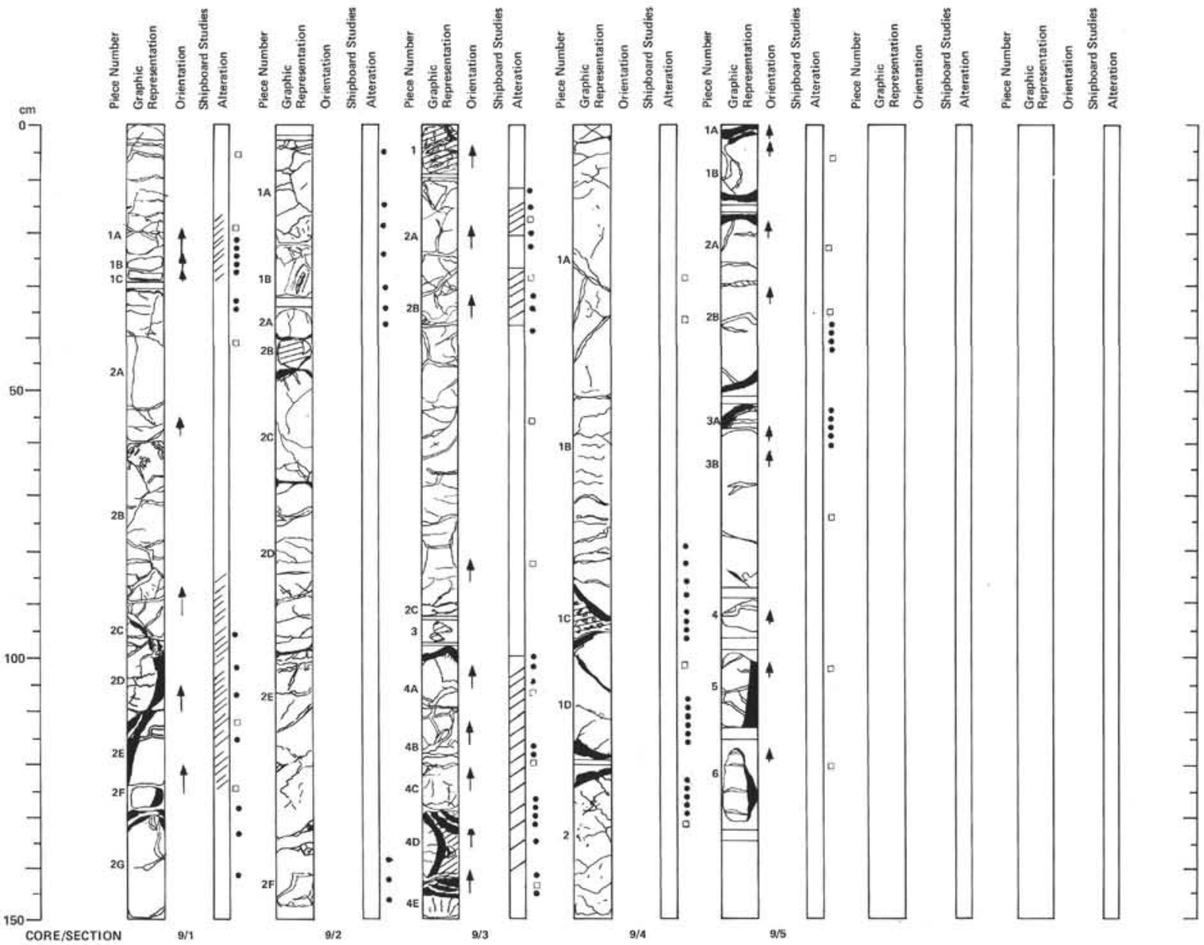
LEG 80, SITE 551, CORE 8

Core 8, Section 1

Visual Description: Two lava flows of phyric basalt separated at 78 cm by devitrified volcanic glass; boundary is marked by chilled margins on both sides. Color: dusky brown 5YR 2/2–10YR 2/2) except in the most altered parts (5YR 5/6); calcite- and smectite-filled vesicles; plagioclase 4–5 mm, 15–20%; calcite veins throughout.

Thin Section Description

Location: 129–132 cm
Texture: Altered subaphyric
Phenocrysts: Rare olivines replaced by associated calcite plus chlorite and fresh calcic plagioclase
Groundmass: Microlithic plagioclase, small granular anhedral clinopyroxene; devitrified glass
Alteration: Numerous calcitic veins; replacement of olivine; devitrification of glass



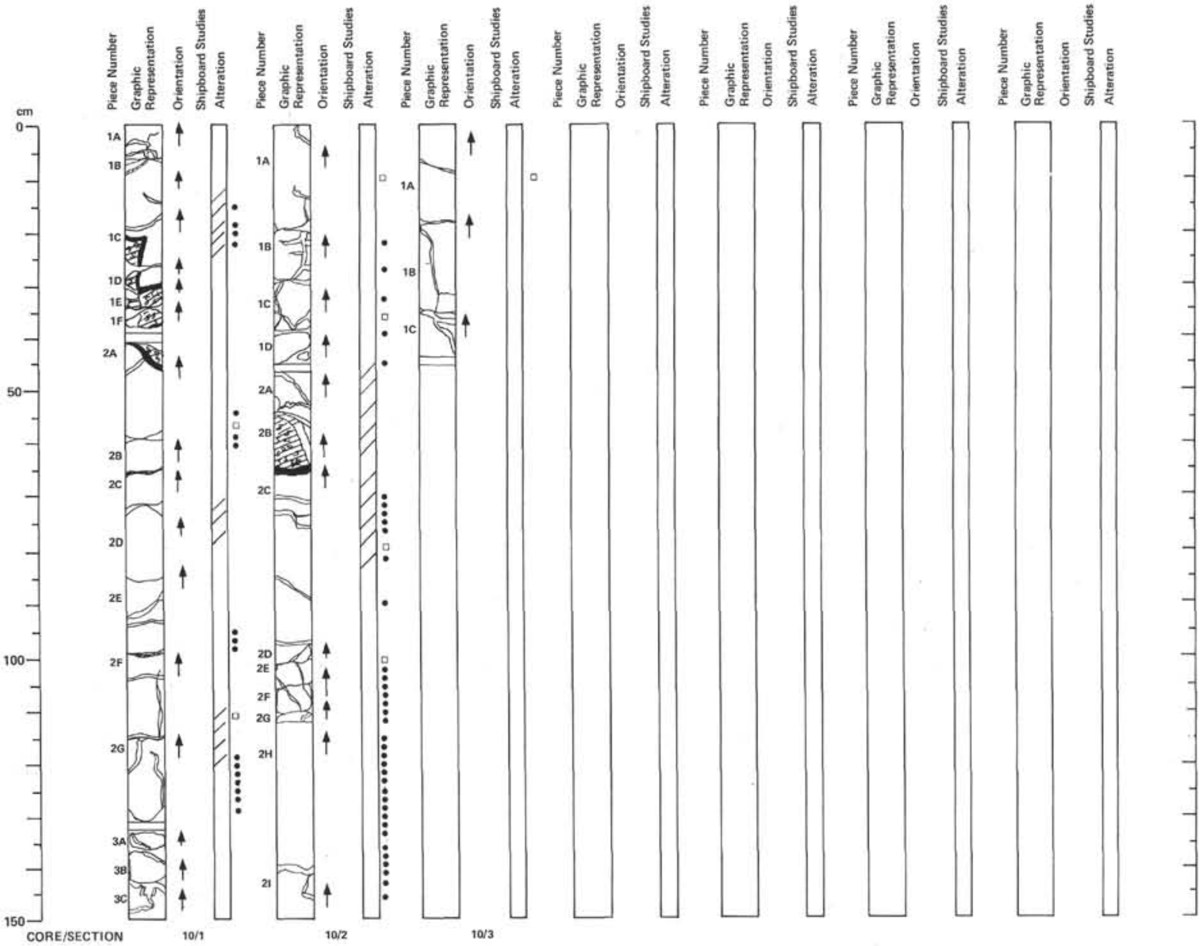
LEG 80, SITE 551, CORE 9

Core 9 – Accumulation of 15 main fragments or entire basaltic pillows separated by reddish calcareous or dark colored hyaloclastite breccia

Visual Description: Altered nearby aphyric pillow basalts. Color: 2.5YR 6/0–2.5YR 6/2 or 5YR 5/3–5YR 5/1 in brownish to reddish hues as a result of alteration. Scattered millimeter-size vesicles of calcite are larger and more abundant at the border of pillows, but vanish inside. Calcite veins are abundant and bounded by an alteration fringe of basalt. In completely filled geodes with dog-tooth calcite at Section 2, Piece 1B. Chilled margins of pillows recognizable by their shapes, finer grain, and disposition of vesicles. Spaces between pillows are filled with hyaloclastite breccia in Section 1, lower part of Section 4, and Section 5 and with red calcareous mudstone supporting volcanic fragments in Sections 2, 3, and 4, 1–100 cm. This calcareous material contains small planktonic foraminifers.

Thin Section Description:

Location: Core 9, Section 4, 47–52 cm. Altered nearly aphyric basalt. Rare phenocrysts are olivine replaced by associated calcite and chlorite and fresh plagioclase. Groundmass comprises microlithic plagioclases, small granular clinopyroxenes, and devitrified glass. Numerous calcitic veins.



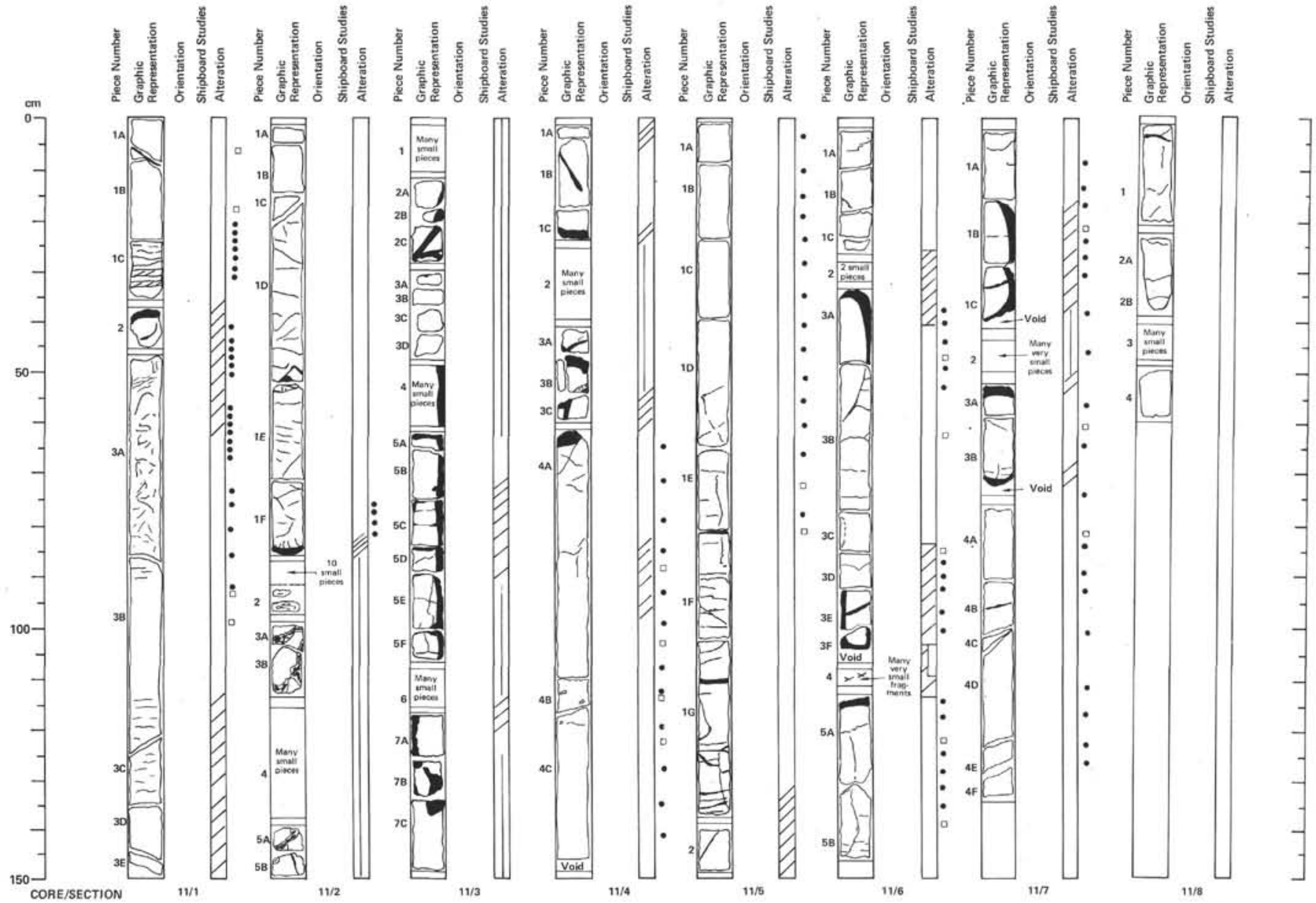
LEG 80, SITE 551, CORE 10

Core 10 – Accumulation of three large basaltic pillow fragments linked by red calcareous breccia.

Visual Description: Fairly fresh phyric, vesicular pillow basalt. Color ranges from blue gray (2.5Y 6/0) in fresh parts to rusty red (5YR 5/1) in the more altered ones. Millimeter-size plagioclase phenocrysts. Abundant vesicles filled with calcite, 0.5–0.1 cm in size. Chilled pillow margins not as conspicuous as in Core 9 except at contact with sediment. Numerous calcite veins associated with red calcareous mudstone including volcanic debris at Section 1, 20–45 cm and Section 2, 55–65 cm.

Thin Section Description:

Location: Section 3, 35–39 cm. Fairly fresh phyric basalt. Numerous phenocrysts of zoned plagioclase clusters; microphenocrysts of olivine. Groundmass shows microcrystalline olivine, clinopyroxene, plagioclase, magnetite, and chloritized glass.



LEG 80, SITE 551, CORE 11

MAIN SUBDIVISIONS

I. Sections 1, 2, 3, and Section 4, 0–60 cm: Three large pillow sections and volcanoclastic breccia
II. Section 4, 60–150 cm and Section 5: Massive phyric basaltic lava flow
III. Sections 6, 7, and 8: Five connected pillow fragments with interlocular volcanoclastic breccia

I) Three Large Pillow Sections

Visual Description: Aphyric to moderately phyric pillow fragments and volcanoclastic breccia.

The upper pillow (Section 1, 50 cm–Section 2, 90 cm) shows typical bottom and top chilled borders and is probably complete. Calcite vesicles are concentrated in the upper 60 cm and in the lower 20 cm. Plagioclase phenocrysts are more abundant at Section 1, 100–110 cm, rare elsewhere.

The middle pillow (Section 3, 60–110 cm) has been intersected by the drill pipe along its chilled border. Aphyric basalt nearly without vesicles.

The lower fragment (Section 4, 0–20 cm) is the bottom chilled border of a pillow. Vesicles are small (<1 mm) and rare. Aphyric basalt. Numerous calcite veins fringed by severe alteration. Color is brownish red (10YR 4/3–10YR 4/1 or 7.5YR 5/0–2.5YR 3/2) in the more altered areas and dark gray in fresher parts.

Pillows are supported by a breccia composed of recognizable (centimeter to decimeter size) pillow fragments, smectitic, devitrified hyaloclastite, and numerous calcitic veins. No sediment.

II) Massive Phyric Basaltic Lava Flow

Visual Description: Thickness, 2 m; color, gray (N5) in the fresher parts to light brown gray (2.5Y 6/2) elsewhere. Calcite- and/or smectite-filled vesicles throughout. Plagioclase phenocrysts more numerous toward the base of Sections 4 and 5; net of calcite veins not very dense; no strong alteration except in the lower 50 cm of unit; chilled border at the top.

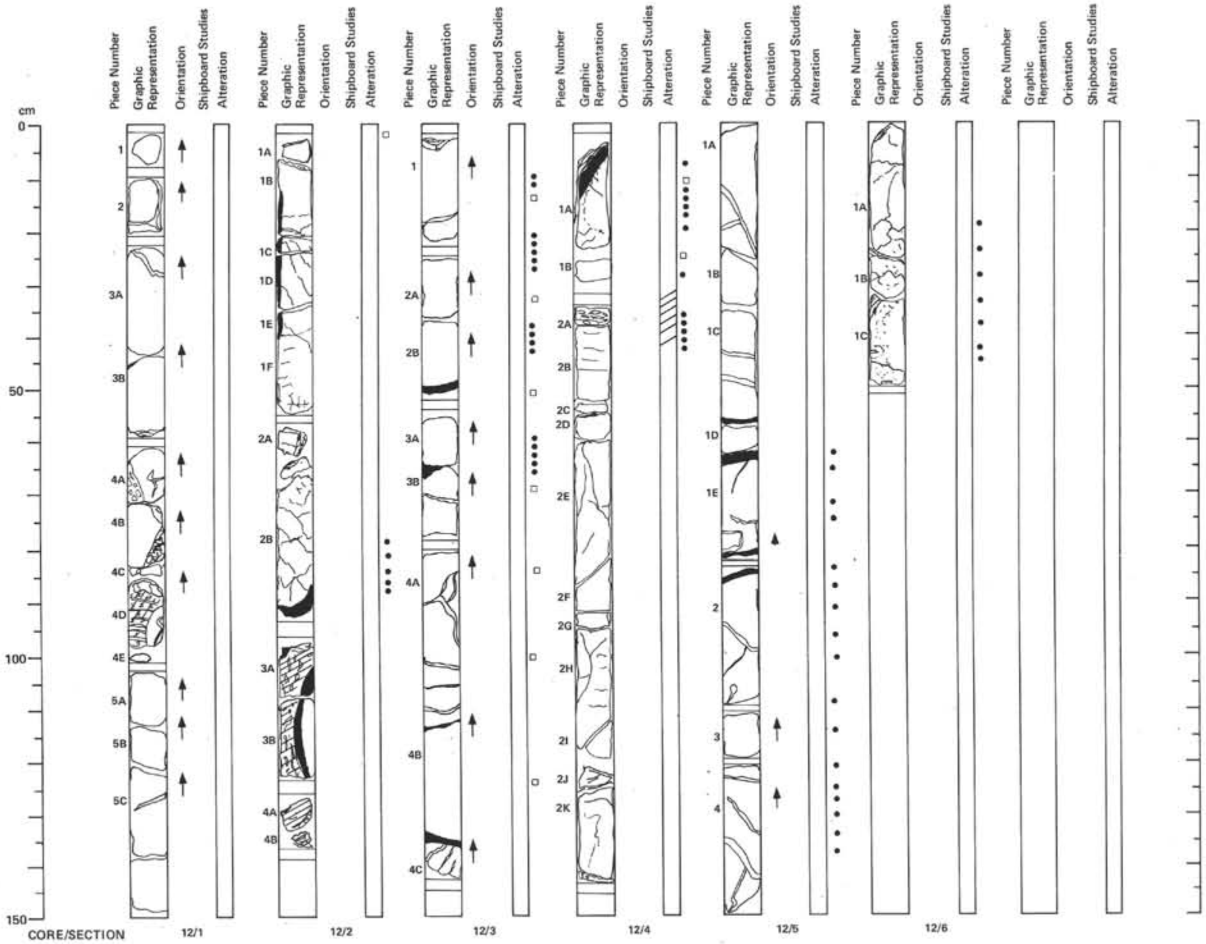
Thin Section Description:

Location: Section 5, 98–102 cm, 40–50 cm above the foot of the lava flow. Unaltered aphyric basalt with groundmass comprising microlithic olivine, plagioclase, clinopyroxene, magnetite, and chloritized glass.

III) Five Connected Pillow Fragments with Interlocular Volcanoclastic Breccia

Visual Description: A complete pillow section (Section 6, 30–110 cm) and a large pillow fragment (Section 7, 15–40 cm) consist mostly of phyric basalt. Euhedral to subhedral plagioclase clusters, 2–3 mm, 15%. Vesicles and alteration fringe concentrated along conspicuous chilled border. Other pillows are aphyric to nearly aphyric, with widespread small vesicles; severe alteration along the borders and along calcitic vein boundaries. A very fresh basaltic block at Section 7, 70–130 cm.

Volcanoclastic breccia infills the spaces between connected pillows. Small amount of pink calcareous mudstone at Section 6, 110 cm.



LEG 80, SITE 551, CORE 12

MAIN SUBDIVISIONS

I. Sections 1, 2, 3, and Section 4, 0–20 cm: Seven main fragments of pillows supported by a calcareous and volcanoclastic breccia

II. Section 4, 20–150 cm, Sections 5 and 6: Two main basaltic lava flows

I) Seven Main Fragments of Pillows Supported by a Calcareous and Volcanoclastic breccia

Visual Description: No complete pillow sections but huge fragments 60–80 cm maximum in size. Aphyric to nearly aphyric in Sections 1 and 2; moderately phyric in Sections 3 and 4. Unequal alteration according to pieces. Fresher fragments are at Section 2, Piece 1. Altered parts are dull red-brown (2.5YR 3/0) and fresher ones are gray to yellowish gray (7.5YR 6/4–2.5YR 6/4). Calcite- and/or smectite-filled vesicles scattered throughout, 1–2 mm in size, more numerous along the drilled borders. Net of calcite fractures bounded by more altered fringes. Space between two pillow fragments at Section 1, 80–110 cm with a graded and laminated calcareous sandstone supporting volcanic debris. Disposition suggests infilling from above of sedimentary material within the vugs that separated the pillows through a relatively thick pile of already emplaced lava flows. A wide space between pillows at Section 2, 95–140 cm is infilled by a reddish (10R 6/1) calcareous mudstone, including sand-size basaltic debris.

Thin Section Description:

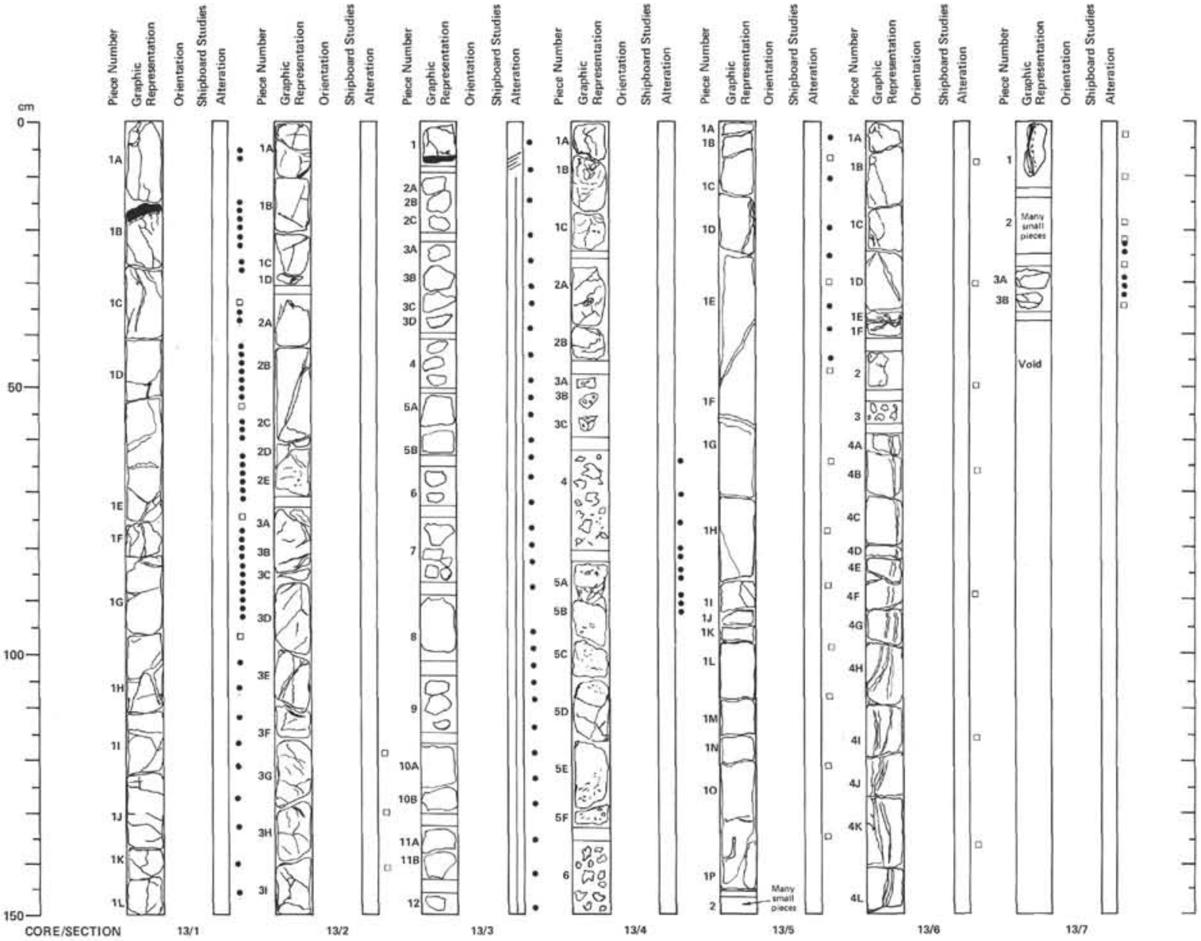
Location: Section 3, 99–103 cm. Nearly basalt with sparse phenocrysts of calcic plagioclase. Groundmass comprises skeletal microliths of olivine together with plagioclase, clinopyroxene, and magnetite. Alteration limited to devitrification of residual interlocular glass.

II) Two Main Basaltic Aphyric to Nearly Aphyric Lava Flows (millimeter-size subophitic texture at the middle of individual flows)

Visual Description: Boundary between two flows at Section 5, 20–30 cm across a displaced pillow fragment. Base of the lower flow at Core 13, Section 1, 20 cm.

Upper flow: Section 4, 20–150 cm–Section 5, 20 cm. Upper part is altered (reddish to yellowish gray [7.5YR 6/4–2.5Y 6/4]) with many calcitic veins and fractures and calcite-filled or empty vesicles (Section 4, 0–60 cm). Main part of upper flow very fresh and dark gray (2.5Y 2/0) to black in color. Scattered calcitic veins.

Lower flow: Section 5, 30–150 cm and Section 6. Nearly aphyric basalt, vesicular nearly from bottom to top; alteration more pronounced at the top than at the bottom.



LEG 80, SITE 551, CORE 13

MAIN ROCK TYPES

I. Core 13, Sections 1, 2, and Section 3, 0–7 cm: Massive lava flows
II. Section 3, 7–150 cm and Section 4, 0–100 cm: Volcanoclastic breccia
III. Section 4, 100–150 cm and Sections 5, 6, and 7: Massive lava flow

I) Section 1, 0–20 cm: Bottom of the Lowermost Lava Flow of Core 12.
Remainder of Section 1 and Section 2 is a single 2.80 m-thick flow. Aphanitic borders at the boundaries. Aphyric to nearly aphyric subophitic textures at the center. 1–2 mm calcite- and/or smectite-filled vesicles present in the upper 100 cm, but missing elsewhere. Euhedral 2–3 mm plagioclase phenocrysts, more abundant at the base (Section 2, 110–150 cm). Color is gray (2.5Y 5/0) in unaltered parts and gray yellow (2.5Y 6/2) or dark green (5G 3/2) along calcitic fractures.

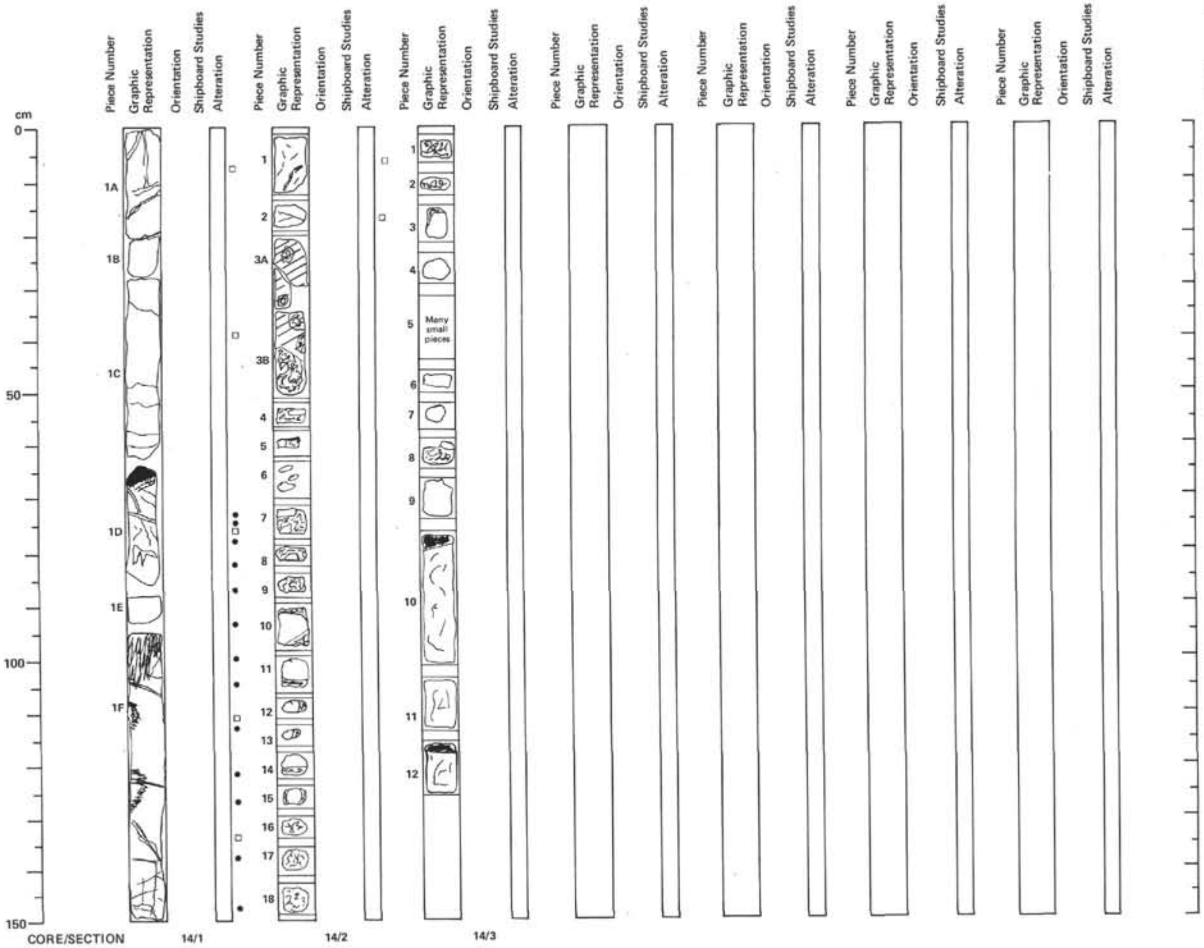
II) Volcanoclastic Breccia
Much alterated pillow fragments within hyaloclastic matrix. Rust (7.5YR 3/2–7.5YR 5/2), brownish to reddish yellow (7.5YR 5/4), greenish olive (5Y 5/4), black or dark gray (2.5Y 3/0) colors. Many calcite fractures. Vesicular pillow borders recognizable.

III) An Individual Massive Lava Flow (3.35 m thick)

Visual Description: Nearly phyric unaltered basalt. Vesicular in the upper 50 cm and in the lowermost 10 cm. Vesicles decrease in size from 4–1 mm from the outside to the inside of flow; infillings of calcite and/or smectite. Subophitic texture in the middle and lower part. Color, olive gray (5Y 5/2) to dark gray (N3–N4). Slight alteration only at the borders of calcitic veins, 1 mm–4 mm in width; very fresh elsewhere even friable. Clusters of subhedral plagioclase, 1–4 mm, <5%.

Thin Section Description:

Location: Section 5, 72–75 cm. Phyric basalt with phenocrysts of plagioclases and poikilitic clinopyroxenes. Microphenocrysts of olivine. Microcrystalline groundmass with olivine, clinopyroxene, plagioclase, magnetite, and chlorite.



LEG 80, SITE 551, CORE 14

MAIN SUBDIVISIONS

I. Section 1, Section 2, 0–20 cm: Two massive phyric basaltic flows
II. Section 2, 20–50 cm: Pink calcareous breccia
III. Section 2, 50–150 cm, Section 3: Volcanoclastic breccia

I) Two Massive Phyric Basaltic Flows

1. Section 1, 0–60 cm

Visual Description: Fresh, gray (N3), phyric basalt of subhedral, 1–4 mm, plagioclase (less than 10%) and rarer olivine phenocrysts. No vesicles.

Thin Section Description:

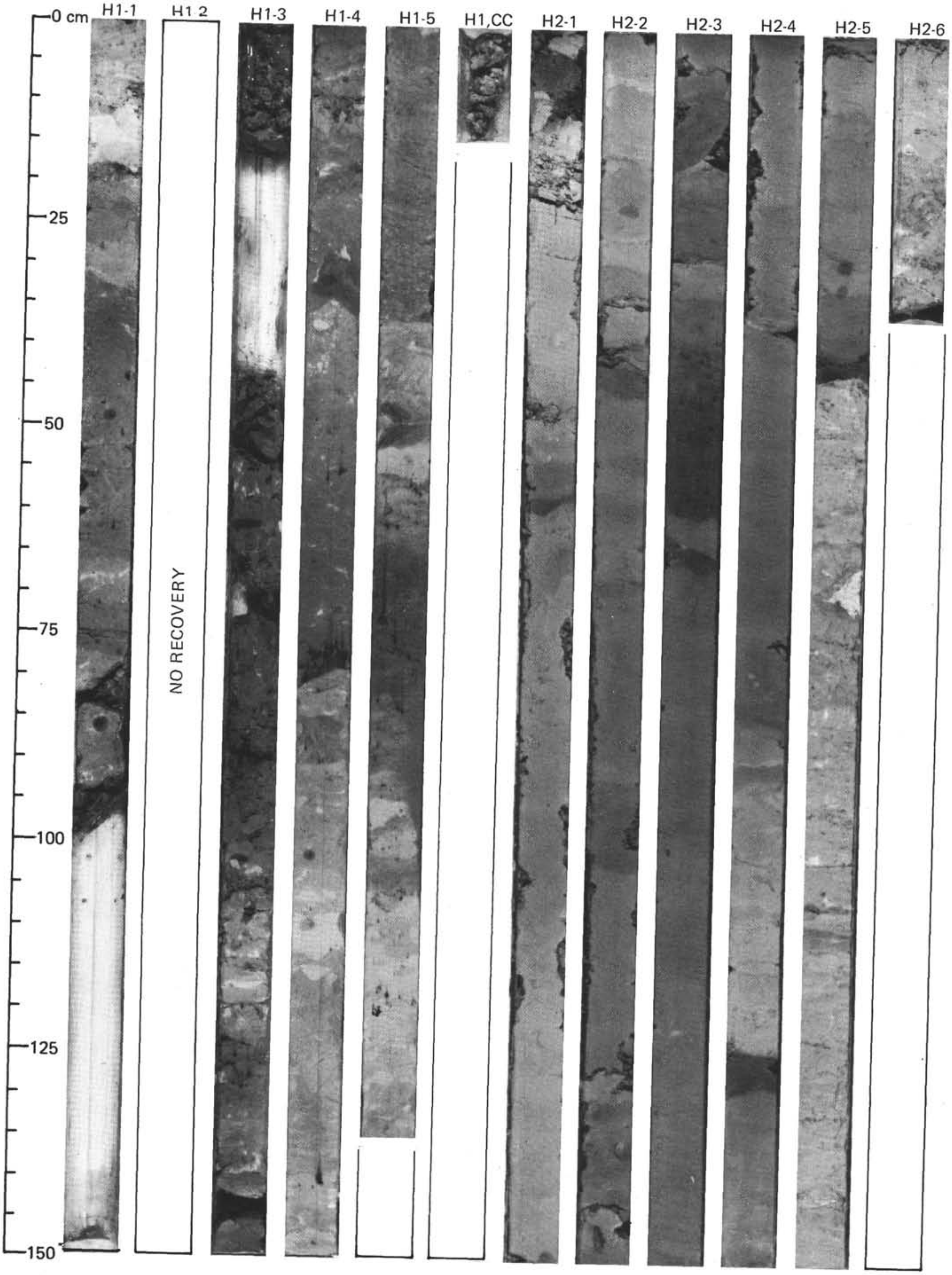
Location: Section 1, 23–27 cm. Phyric basalt comprising numerous phenocrysts of calcic plagioclase and of rarer olivine replaced by chlorite. Microlithic groundmass of skeletal plagioclases, clinopyroxenes, and replaced olivine. Alteration limited to chloritization of olivine.

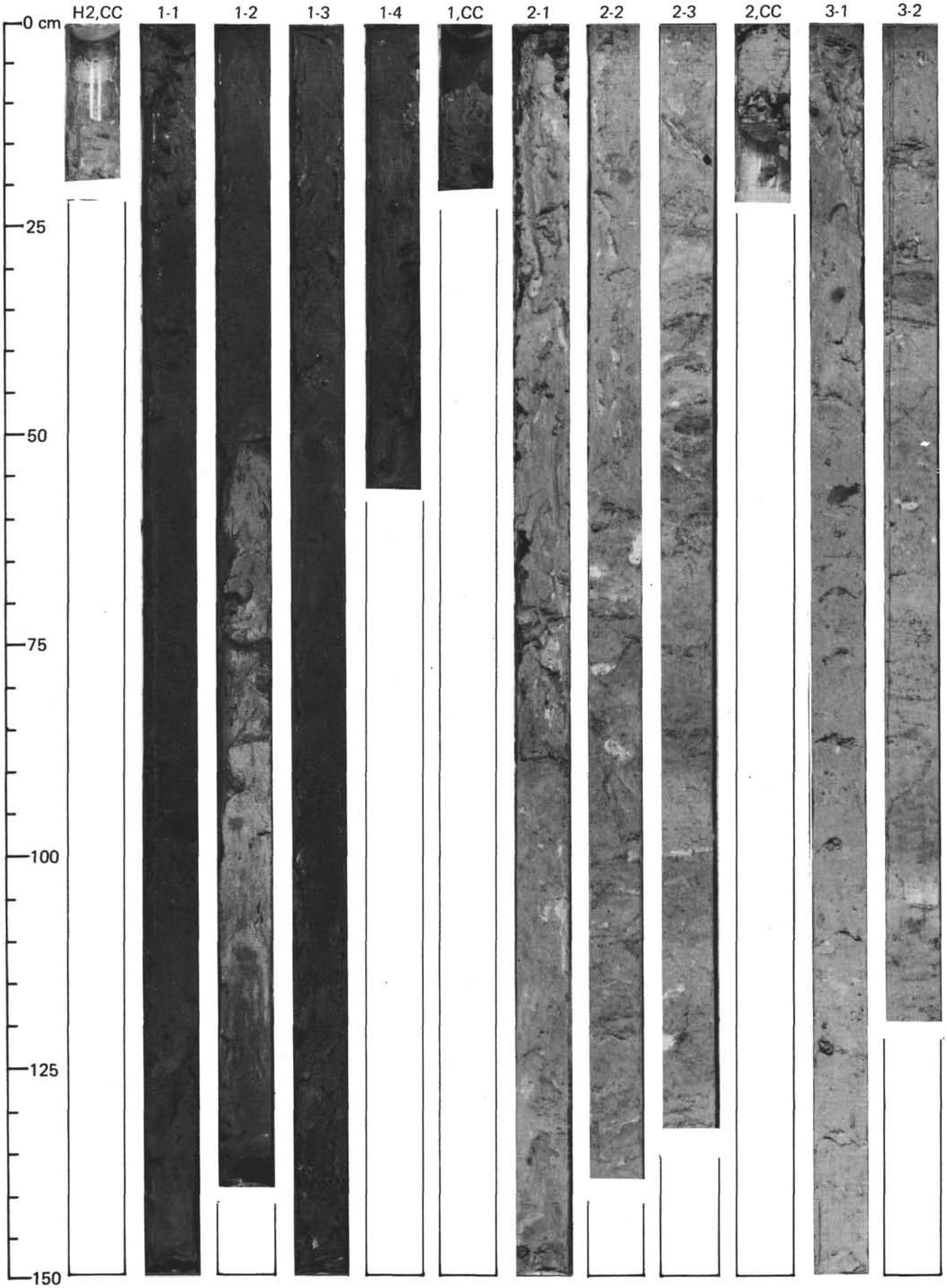
2. Section 1, 60 cm–Section 2, 20 cm

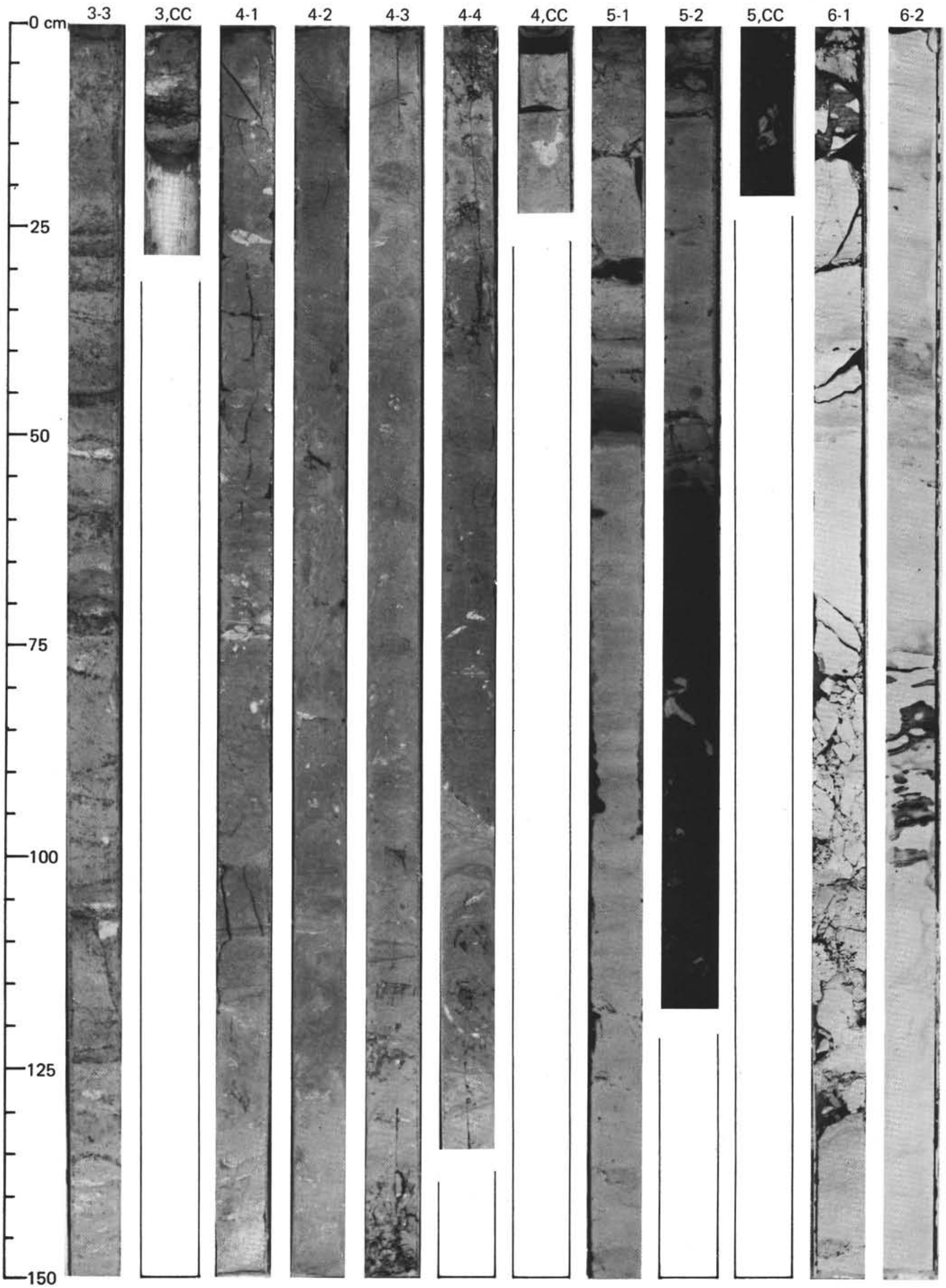
Visual Description: Vesicular phyric basalts. Characteristics comparable to those of overlying flow except for the presence of calcite and/or smectite vesicles and for a deeper alteration.

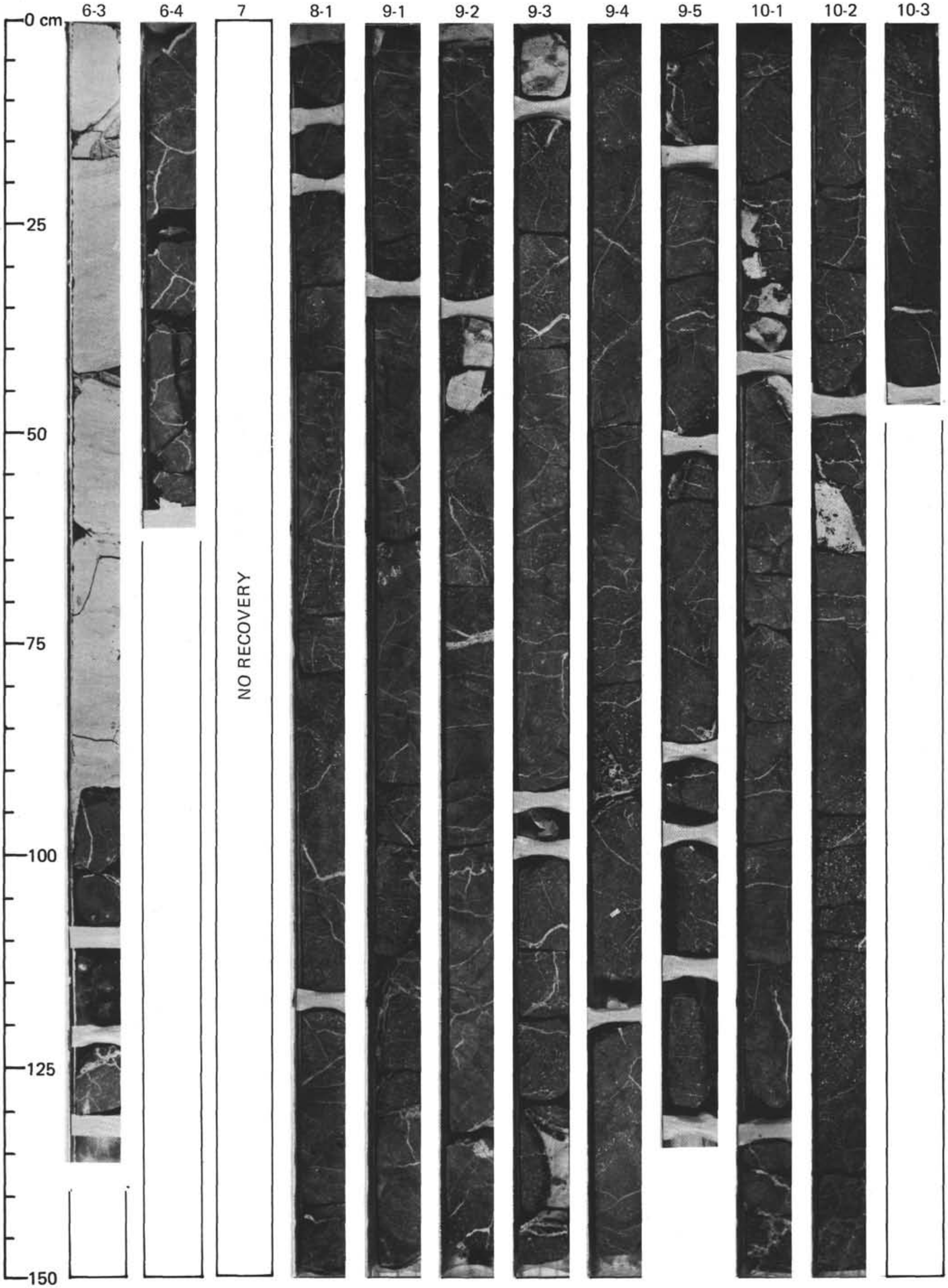
II) Greenish-Pink Calcareous Mudstone, including dark-green altered basaltic fragments. Clasts are rounded to highly angular. Extensive white veining calcite. Calcareous material disappears progressively toward the bottom.

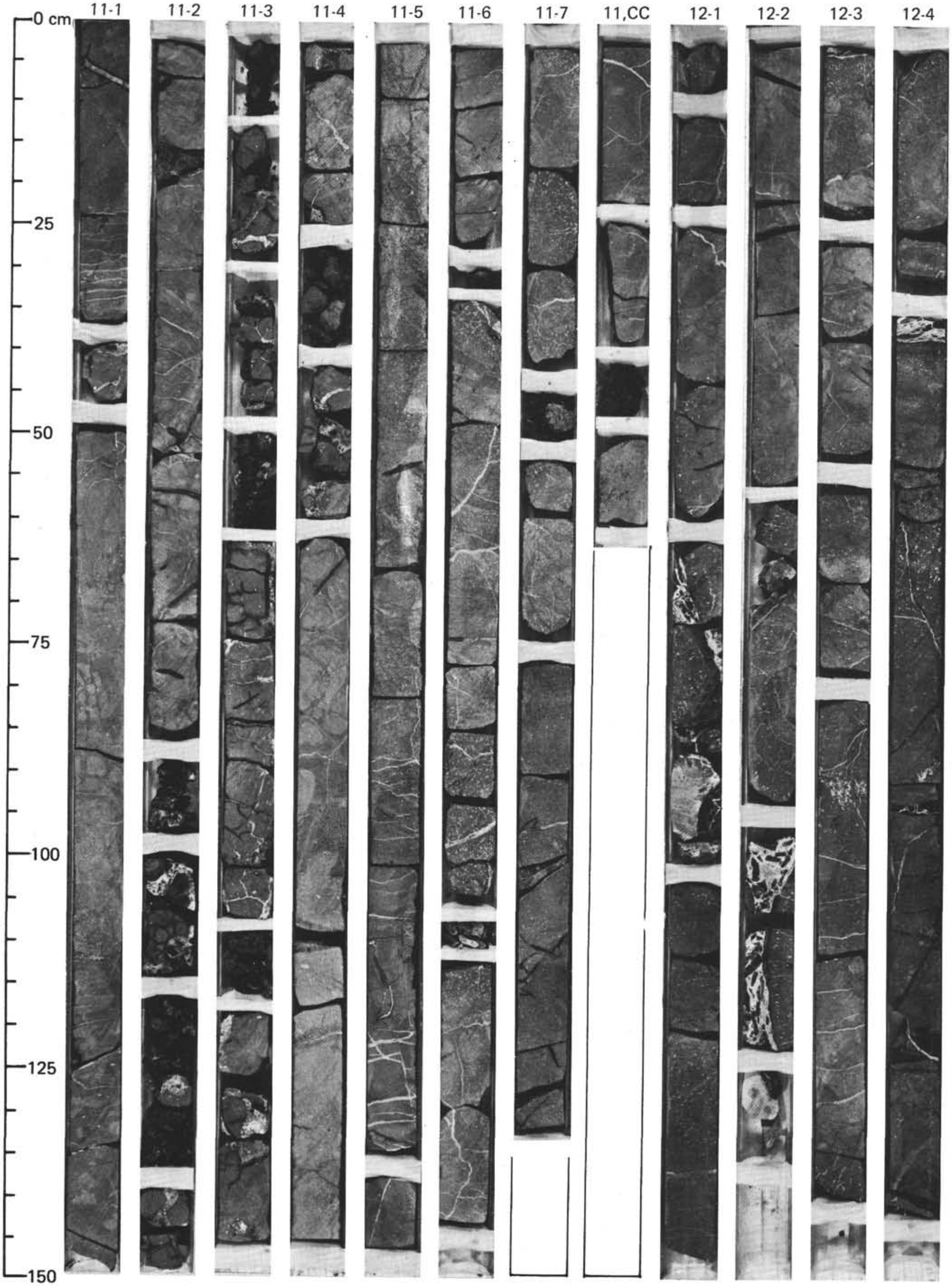
III) Volcanoclastic Breccia
Clasts are angular, massive, indurated, olive-brown pillow fragments, 10–50 cm maximum in size. Matrix hyaloclastite (probably replaced by smectite and/or chlorite) including smaller clasts; appears to be deeply altered. Occasional calcitic veins.

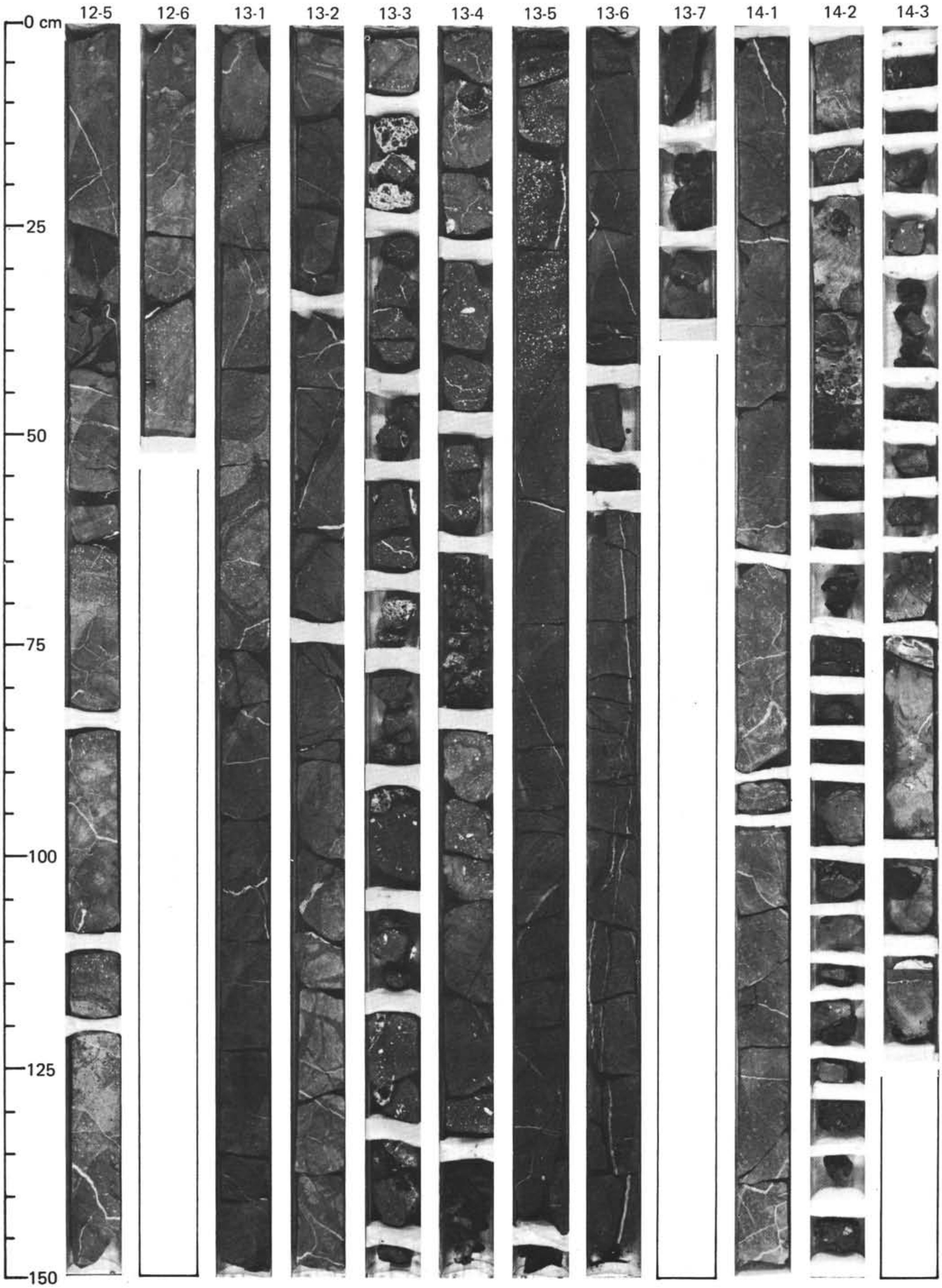

0 cm
25
50
75
100
125
150
H1-1
H1-2
H1-3
H1-4
H1-5
H1,CC
H2-1
H2-2
H2-3
H2-4
H2-5
H2-6
NO RECOVERY


H2,CC
1-1
1-2
1-3
1-4
1,CC
2-1
2-2
2-3
2,CC
3-1
3-2
0 cm
25
50
75
100
125
150


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


0 cm
25
50
75
100
125
150
6-3
6-4
7
8-1
9-1
9-2
9-3
9-4
9-5
10-1
10-2
10-3
NO RECOVERY


0 cm
25
50
75
100
125
150
11-1
11-2
11-3
11-4
11-5
11-6
11-7
11,CC
12-1
12-2
12-3
12-4


0 cm
25
50
75
100
125
150
12-5
12-6
13-1
13-2
13-3
13-4
13-5
13-6
13-7
14-1
14-2
14-3