5. SITE 138

The Shipboard Scientific Party[1]

ABSTRACT

Site 128 lies about 870 km west of Cap Blanc and 130 km east of Site 137 at the foot of the continental rise.

About 200 to 250 meters of Tertiary clay, silt, and sand rest on 190 to 240 meters of Upper Cretaceous sediment. The Cretaceous lithology is mainly mudstone and shale with thin chert layers at 255 meters, clay at 332 meters, and dolomite silt and dolomite clay cyclically interbedded with carbonaceous mud at 425 meters. A 50-cm thick layer of fine grained altered basalt lies within one dolomite-clay sequence. At a subbottom depth of 437 meters the hole bottomed in coarse grained slightly altered basalt with alkalic affinities. If this unit represents the basement reflector at about 0.50 second on the *Challenger* seismic profile, then average compressional wave velocities (~1.75 km/sec) for the complete sedimentary succession are lower than expected. Also, the age of sediment above the basalt appears younger than at Site 137 (nearer the ridge crest), suggesting the basalt at Site 138 is an intrusive sill and not the top of oceanic layer 2. One of the intermediate reflectors on the *Challenger* profile may be caused by the indurated shale and chert in Core 4 (~255 meters).

Calcareous fossils are very rare or absent throughout the entire succession at Site 138. Radiolaria are moderately common throughout, and diatoms and microplankton occur in places.

SITE DATA

Time: 1850 October 24, 1970
0745 October 26, 1970

Position: 25° 55.37'N
25° 33.79'W

Water Depth: 16,584 feet
2,794 nominal fathoms
5,288 meters

Total Penetration: 422 meters

Cores Taken: Seven cores

BACKGROUND, SURVEY, OPERATIONS

Site 138 lies close to the foot of the lower continental rise off West Africa, about 870 km west of Cap Blanc, in a water depth of 5288 meters (Figure 1, Chapter 4).

The main purpose of drilling at this site was to compare its sedimentary sequence with that penetrated at Site 137, located only 130 km to the west in an area of abyssal hills at a water depth of 5361 meters. *Vema* 27 seismic reflection profiles provide the main source of data from which these two site selections were made. The profiles (Chapter 4, Figure 2) show a striking contrast in acoustic character despite the proximity of the two sites. At Site 138, about 0.50 second of mostly well layered continental rise sediments overlie acoustic basement in contrast to <0.40 second of mostly transparent sediment with weak reflectors at Site 137. A more detailed description of the seismic records for Sites 137 and 138 is given in Chapter 4. An enlargement of the seismic profile at Site 138 is given in the composite diagram as Figure 1.

It can be seen from the profiles (Chapter 4, Figure 2) that there is a pronounced topographic feature of approximately 1800 meters relief between Sites 137 and 138. Bathymetric data made available by Lattimore, *et al.* (1971), and reproduced as a schematic diagram in the insert in Figure 1, Chapter 4, reveal that this feature trends ENE. Other fracture zones and lineaments off this part of West Africa trend more WNW and several, such as the Atlantic Fracture Zone, extend out to the mid-Atlantic Ridge axis. The topographic feature between Sites 137 and 138, could well be important in influencing the sediment disposition between the two sites particularly with respect to continentally derived material.

Seismic Reflection Data:	*Vema* 27	*Challenger*
Intermediate Reflectors	0.16-0.23 sec	0.23-0.27 sec
Basement Reflector	0.50-0.40 sec	0.50 sec

The drilling and coring records are given in Table 1 and Figure 2.

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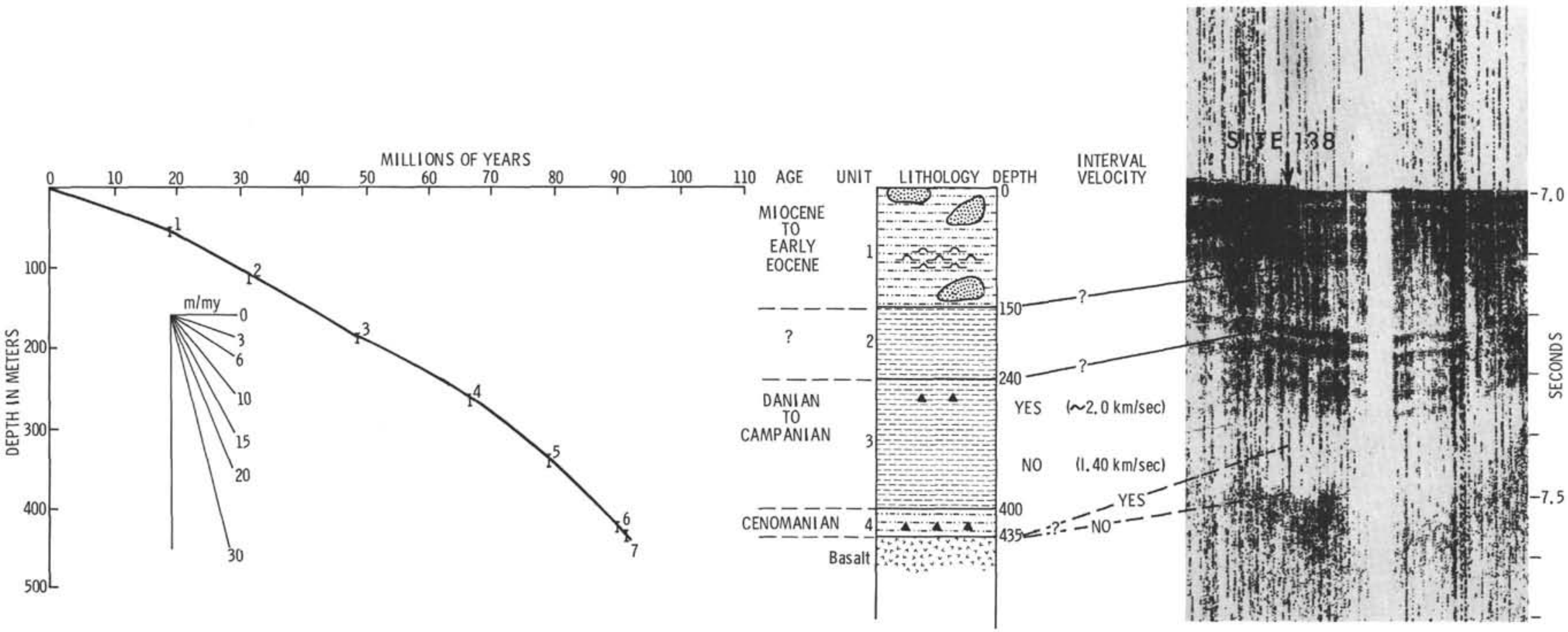


Figure 1. *Geologic synthesis at Site 138. Two hypothetical correlations between the cored section and seismic record are shown. The correlation designated "NO" yields unrealistically low interval velocity for Unit 3. There is no seismic reflector corresponding to the correlation marked "YES" which is based on an assumed velocity of 2.0 km/sec for Unit 3.*

TABLE 1
Drilling and Coring Record for Site 138

Description	Interval Below Sea Floor (m)	Core Recovery (m)	Drilling Rate (m/min)
Drill	0-52		5.0
Core 1	52-61	8.8	
Drill	61-82		4.2
	82-101		3.2
	101-110		1.8
Core 2	110-119	9.0	
Drill	119-156		1.7
	156-175		1.0
	175-183		0.5
Core 3	183-190	0.2	
Drill	190-212		0.8
	212-230		1.0
	230-249		1.0
	249-255		0.7
Core 4	255-264	0.6	
Drill	264-265		0.5
	265-286		1.0
	286-304		1.1
	304-323		1.3
	323-332		1.0
Core 5	332-341	0.5	
Drill	341-360		0.9
	360-382		1.1
	382-397		1.0
	397-415		1.0
	415-425		0.6
Core 6	425-431	3.1	
Core 7	437-442	0.9	
Drill	442-448		0.1
	448-453		

BIOSTRATIGRAPHY

General

The upper part of this hole contains rich Radiolaria and diatom assemblages indicating an early Miocene age for Core 1 and an early Oligocene age for Core 2. Calcareous fossils are absent from this hole except for a few admixed Quaternary foraminifera in Core 1 and rare Cretaceous nannofossils in Core 5. Cores 3 and 4 lack fossils. Radiolaria indicate a Campanian age for Core 5 and a Cenomanian age for Core 6.

Foraminifera

The foraminifera in this hole are very scarce and not age-diagnostic; they are represented only by a few deep-water species of the Astrorhizidae and Lituolidae. The presence of a few specimens of *Globorotalia truncatulinoides* and *Pullenia* sp. as contamination in Core 1 may indicate that the hole penetrated Quaternary calcareous sediments near the sea floor.

Nannoplankton

The cores recovered from this hole are barren of nannoplankton except for Core 5 which contains rare long ranging Cretaceous coccoliths.

Diatoms

Determinations listed below were made by Hans Schrader.[2]

Strongly etched diatoms are found in the core catcher of Core 1, but more abundant and better preserved assemblages occur in Core 2. Cores 3, 4, 5 and 6 do not contain diatoms except for a few remains in the core catcher of Core 3.

A list of important species follows:

Core 1, Core Catcher:
Few diatoms, strongly etched.
Chaetoceros sp., Coscinodiscus sp., Actinoptychus undulatus, Actinoptychus splendens, Stephanopyxis sp.

Core 2, Section 1, 30 cm:
Pyxilla sp., Pyxillagracilis, Trinacria simulacrum var. grossepunctate, Melosina sulcata, Coscinodiscus superbus
Age: Late Eocene-Paleocene

Core 2, Section 1, 100 cm:
Melosira sulcata, Actinocyclus ehrenbergi, Liostephania sp., Triceratium exiguum, Pyxilla sp., Hemiaulus sp., Syedra sp., Raphoneis sp., Coscinodiscus marginatus
Age: Late Eocene to Oligocene

Core 2, Section 2, 75 cm:
Few diatoms.
Pyxillia sp., Actinoptychus undatus

Core 2, Section 4, 75 cm
Abundant and well-preserved diatoms.
Pyxilla sp., Coscinodiscus marginatus, Cocconeis sp., Pyxilla reticulata
Age: Late Eocene

Core 2, Section 6, 25 cm:
Abundant and well preserved diatoms.
Hyalodiscus sp., Asterolampra marylandica, Synedra sp., Stephanopyxis turris, Pyxilla sp., silicoflagellates and Ebriaceae.

Core 2, Section 6, 100 cm:
Silicoflagellates: Dictyocha lamellifera, Naviculopsis bipiculata
Diatoms: *Grammatophora sp., Hemiaulus sp., Pyxilla sp., Melosia sp.*
Age: Eocene, perhaps Early Eocene.

Organic Microfossils

Determinations made by
D. O. J. Diederix, R. de Haan, and W. O. Tichler[3]

Core 4 Section 1: 105-125 cm:
No sporomorphs found.
Microplankton flora consists of *Senoniasphaera rotundata, Trithirodinium evittii, Danea mutabilis* (Morgenroth

[2]Geologisch-Palaeontologisches Institut der Universitar, Kiel.

[3]Koninklijke/Shell Exploratie en Produktie Laboratorium, The Hague.

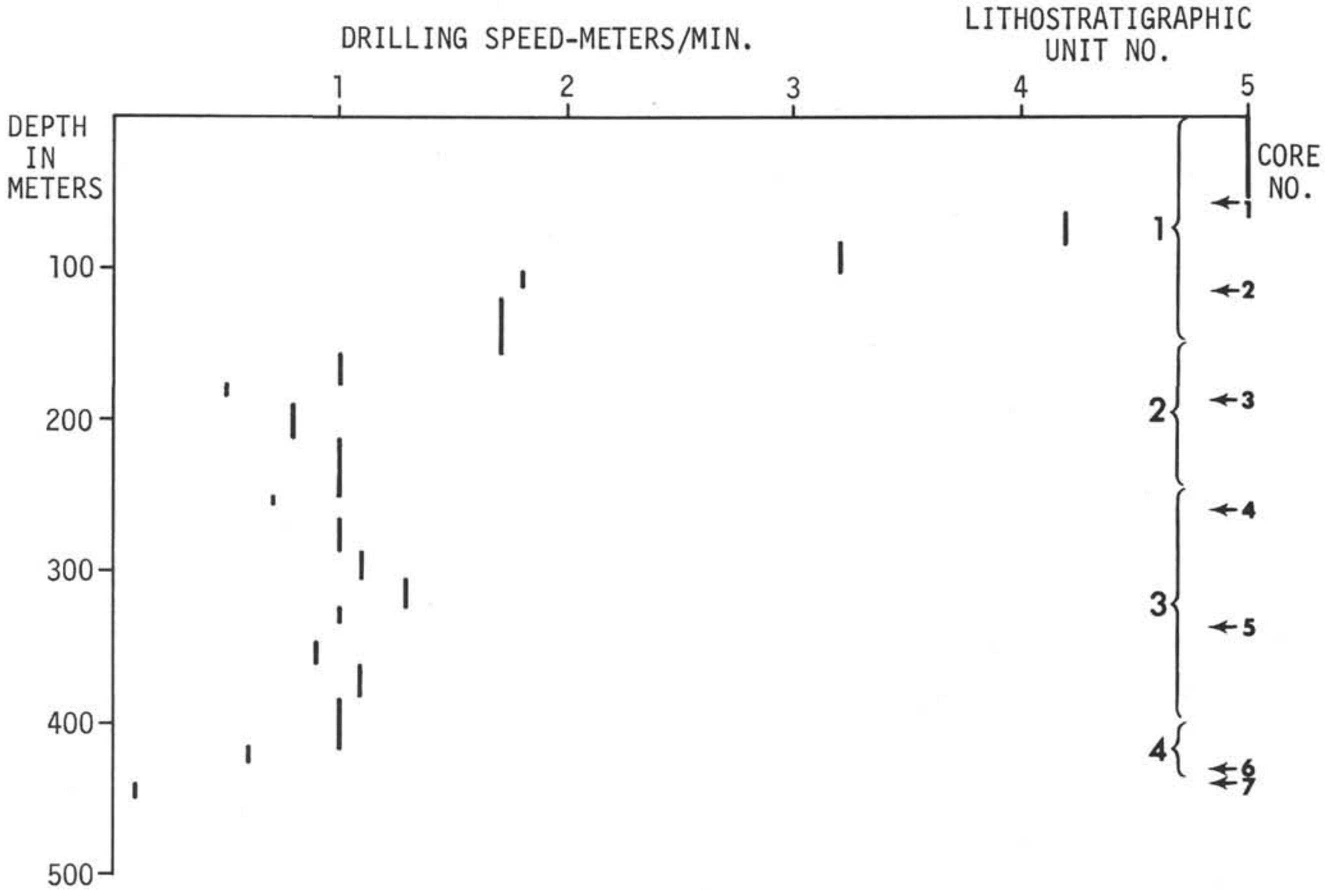


Figure 2. *Drilling and coring summary at Site 138.*

TABLE 2

CORE	DIAGNOSTIC FOSSILS HOLE 138		
	FORAMINIFERA	NANNOPLANKTON	AGE
1	Fragments of agglutinated foraminifera?	None	
2	None	None	
3	None	None	
4	None	None	
5	Ammodiscus sp. (1 frag.)	Only very rare coccoliths including *Watznaueria barnesae Cretarhabolus surirellus, Eiffelithus turriseiffeli*. Age: Probably Upper Cretaceous.	
6	Rare thin-walled agglutinated foraminifera *(Bathysiphon, Lituotuba, Reophax)*.	None	

1968), *Spinidinium essoi, Conyaulacysta cf. wetzeli, cf. Areoligera penicillata, cf. Palynodinium grallator, cf. Leiofusa lidiae, Deflandrea cf. pannucea.*

Age: Maestrichtian to Danian, possibly only Danian.

Core 6 Section 2: 41-43 cm, and Section 3: 97-99 cm: No sporomorphs or microplankton recovered.

LITHOSTRATIGRAPHIC SUMMARY

At Site 138, one hole was drilled to a depth of 442 meters. Seven cores were recovered at intervals of approximately 50 to 70 meters. Although total core recovery was poor (only 23.4 m), a wide variety of different sedimentary and igneous rocks was encountered.

These can, tentatively, be classified into four lithostratigraphic units.

Unit	Cores	Lithology	Depth Below Sea Floor (m)	Age
1	1 & 2	Green silty clay w/ sand layers, in part radiolarian	0-150	Early Eocene-Miocene
2	3	Barren gray & brown Clay	150-240	?
3	4 & 5	Greenish & Black indurated mudstone with chert layers and greenish/brown clay	240-400	Campanian to Danian
4	6	Dolomite silty clay, carbonaceous pyritiferous black mud with basalt layer	400-435	Cenomanian
	7	Theoleiitic basalt	437	?

UNIT 1 – Green Silty Clay with Sand Layers (Cores 1, 2)

If this sequence extends to the surface sediments, it is about 150 meters thick and is of Early Eocene to Quaternary age. It consists of pale yellowish green and pale yellowish brown silty and sandy clay and is interbedded with grayish green sand layers which comprise about 5 to 10 per cent of the recovered sediment. These sand layers are completely deformed by coring and occur as irregular patches partly mixed with the surrounding clay. The sand is fine-grained, well-sorted and consists of about 85 per cent quartz, 5 per cent feldspar (K-feldspar > plagioclase), 5 per cent chlorite, 2 per cent pyroxene, 1 per cent other heavies (zircon, rutile, apatite, hornblende, magnetite) and traces of chert fragments and foraminifera.

The clays contain appreciable amounts of quartzose silt (15-30%) along with chlorite, mica, Fe-oxides, and traces of feldspar. In a brown silty layer (Core 1, Section 6), a volcanogenic heavy mineral suite was found with several percent of pyroxene, ?aegirine, olivine, ?iddingsite, and biotite-chlorite. A basaltic tephra is suggested as the source of this silt fraction.

In Core 2, Section 5, 20 per cent siliceous tests of Radiolaria (and diatoms) occur, and this part of Unit 1 can be termed a radiolarian silty clay. Sedimentation rates are near 4m/my. Drill rates range from 5 to 1 meters per minute.

UNIT 2 – Barren Gray and Brown Clay (Core 3)

Unit 2 consists of approximately 90 m of unfossiliferous varicolored clay of which only 27 cm were recovered in Core 3. It can be distinguished from Unit 2 by its higher degree of induration and by the lack of fossils. The age is probably Early Tertiary. The boundary between Unit 1 and Unit 2 was put at about 150 meters (below sea floor), where the first abrupt break in the drilling rate (from 4 to 1 m/min) occurred. Drill rates range from 1 to 0.5 meter per minute.

UNIT 3 – Greenish and Black, Indurated Mudstone with Chert Layers and Greenish Brown Clay (Core 4, 5)

This unit is approximately 150 meters thick (recovery in Cores 4 and 5 only 120 cm) and has a Late Cretaceous to Early Tertiary age. The main sediment types are a dark greenish gray and reddish brown semi-consolidated clay (Core 5) and an indurated homogeneous massive mudstone (Core 4). Core 4 contains only fragments of mudstone and chert. The original thickness of the interbedded greenish black chert layers can only be roughly estimated as 5-10 cm. The "chert" is a very fine-grained silica-cemented clayey siltstone with recrystallized cross-sections of radiolarians and sponge spicules (?), and small amounts of chlorite, mica, pyrite (framboidal spherules) and traces of authigenic carbonate and quartz. A fine parallel lamination is produced by dark concentrations of pyrite cubes and spherules.

The semi-consolidated varicolored clay of Core 5 contains about 2 to 5 per cent zeolite (?clinoptilolite), a few percent of chlorite, hematite, and heavy minerals (hornblende), but characteristically no quartz. Sedimentation rates are near 5m/my. Drill rates range from 0.5 to 1.1 meters per minute.

UNIT 4 – Dolomite Silt and Clay, Pyritiferous Carbonaceous Black Mud with Basalt Layer (Core 6)

This unit is probably about 35 meters thick although only 3.23 meters was recovered. The sediments are characterized by cyclical alternations of greenish-gray dolomitic lutites with very dark brown carbonaceous silty muds. A 50-cm thick basalt sill, or flow, and two thin ash layers were observed in Core 6 (Section 2). The age of this unit is Cenomanian. Sedimentation rates are near 9m/my. Drill rates range from 0.6-1.1 meters per minute

A cyclic deposit observed in Core 6 (Sections 2 and 3) consists of six symmetrical dolomite/black mud cycles within an interval of about 200 cm. The average individual cyclic bed is about 20 to 30 cm thick. The light greenish gray sediment in the middle of each cycle consists of a pure dolomite silt or indurated dolostone (Core 6, Section 2) with only about 5 per cent clay and detritals and 5 per cent framboidal pyrite. The dolomite rhombs occur in two size classes: small euhedral rhombs 2-10μ; and large euhedral rhombs between 20 and 50μ, a small proportion of which has irregular borders and small primary dolomite nuclei. This pure dolomite appears to grade upwards and downwards into a laminated darker lutite containing more clay and organic matter. The dark end member is a black mud consisting of about 50 per cent discrete round brown (isotropic) grains of palynomorphs (5-20$\mu\phi$), 10 per cent pyrite, and only 5 per cent small dolomite rhombs (5$\mu\phi$). One thin sandy layer (Core 6, Section 2, cm 118) contains a few per cent of large chert grains (up to 100$\mu\phi$). A large pyrite nodule 5 mm ϕ) was found in Core 6 (1).

The typical cycle appears to be characterized by the following sequence (GRAPE-densities correlate with the cyclic alternation, see Physical Properties Chapter 18).

A basalt layer, 50 cm thick, is interbedded with these cyclical sediments. Neither of the basalt-sediment boundaries show evidence of thermal metamorphism. Since no baked lower contact was found (necessary for sill or flow), and as basalt fragments extended upward as much as 5 cm into the unconsolidated sediment we conclude the original igneous-sedimentary contact was lost in drilling.

End Member	(Sharp Contact)	GRAPE-Density (gm/cm^3)
A	Dark-brown carbonaceous mud (Sandy mud with chert fragments)	low (1.6)
	Gradation into gray carbonaceous mud	transition
	Transition Zone (streaky alternations of A and B)	
	Greenish gray dolomitic silty clay	
B	Light greenish gray dolomite lutite (90% dolomite)	high (1.95)
	Greenish gray dolomitic clay	transition
	(Sharp Contact)	
A		low (1.6)

The original texture of the altered basalt was intergranular. The feldspars (?labradorite) are highly saussuritized. The pyroxenes are chloritized and serpentinized. Secondary minerals include natrolite, stilbite, biotite and hornblende. No grain size differences were noted over the 50 cm interval. The original composition was probably that of an alkalic basalt.

Two thin light-colored *tephra layers*, 2 to 6 mm thick, consisting of highly altered vitreous and crystal ash, were found 40 cm below the intrasedimentary basalt.

Basalt (Core 7)

Core 7 recovered about 95 cm of a coarse-grained inter-granular alkalic basalt with about 5 to 10 per cent altered glass and 10 per cent iron oxides in the groundmass; 50 per cent fresh to slightly altered labradorite; and about 30 per cent pyroxene (augite), altered to chlorite and serpentine; plus minor biotite, and hornblende. Secondary minerals include: natrolite, ?stilbite, and calcite. The basalt at the base of the core is less altered and contains a few unaltered pyroxene and olivine grains.

PHYSICAL AND CHEMICAL PROPERTIES

Some physical property measurements on Cores 1 through 3 are unreliable due to deformation caused by the coring process. There is a pronounced lithology change at approximately 240 meters which is well illustrated by the physical property measurements. These consolidated and indurated sediments below 240 meters were mostly undeformed during coring though the percentage of recovery was low.

Penetrometer Measurements (units of mm + 10^{-1}) range from about 50-112 in the soft silty clays and sand layers at about 50 meters, to essentially zero in the sediments below 250 meters. Because of drilling deformation in Core 1, the minimum values are probably the closest to *in situ* conditions. The Oligocene silty clay (and sand) of Core 2 (110-119 m) is considerably more compacted and has mean values of about 20. Cores 3, 4, 5 and 6 contain well indurated mudstones, dolomitic and zeolitic clays, shales, and chert layers with penetration values being practically zero.

Bulk density measurements (gm/cc) measured in the GRAPE do not show any significant changes from Core 1 to Core 5 (Table 3). The densities vary from about 1.35 to about 1.8, with average values between 1.5 and 1.6. The porosities (%) are also uniform from Core 1 to Core 5 with relatively high values between 60 and 75. These values are highly questionable since the more indurated clays of Core 2 and Core 5 should have higher density and lower porosity values.

In contrast Core 6 (Section 3) is a good example of how useful the GRAPE density values can be in interpreting undisturbed unsplit sediment cores. Both bulk density and porosity curves show a sinusoidal trend that can be directly correlated with the presence of carbonaceous black shale (density minima around 1.6; porosity maxima about 66) cyclically interbedded with light greenish-gray dolomite-rich clays. The purest portions of this dolomitic clay have the highest densities (1.95) and lowest porosities (46). Upward and downward these light-colored clays grade continuously into a black shale; a graduation which is directly reflected in the GRAPE records.

Density and porosity calculated from water content measurements correlate roughly with GRAPE densities and porosities (Table 3). However, because of drilling deformation many of the values are not considered representative of *in situ* conditions.

Natural gamma radiation counts in the silty clay and sand layers of Core 1, 2, and 5 range from about 1000 to 1700. A significant peak, with a maximum count of 2600, can be noted in quartzose sandy clay with a relatively high proportion of quartz, feldspar, heavy minerals and mica (2%) occurring in Core 2.

Sonic velocity measurements on samples from Site 138 are listed in Table 4.

Two samples were taken for chemical property measurements as follows: 138-1-5, 0-5 cm pH 7.34, Eh+167, salinity 34.7 ppt; 138-2-5, 0-5 cm pH 7.35, Eh+173, salinity 33.6 ppt.

DISCUSSION AND CONCLUSIONS

Site 138 lies at a water depth of 5298 meters on the lower continental rise in an area of gently undulating sea floor (about 870 km west of Cap Blanc). It contains a 437 meters-thick Upper Cretaceous to Recent sequence of pelagic to hemipelagic sediments overlying basalt.

The geological history appears to be as follows: In the Cenomanian, symmetrical cycles of alternating cherty black muds and dolomitic clayey silts were deposited. The origin of these 20 to 30 cm thick cycles is difficult to explain. They may indicate a fluctuating chemical environment, or alternatively, the cyclicity may be due to intermittent resedimentation processes. The origin of the dolomite is critical to an understanding of these cycles. Some of the larger rhombs contain, as nuclei, pre-existing smaller rhombs which are less perfect crystals than the outer ones. The outer rhombs might have grown *in situ*, since they show no evidence of transport. The irregular boundaries of the inner rhombs may be due to redeposition from elsewhere or partial dissolution of *in situ* dolomite before the second generation of dolomite was formed. A 50-cm layer of basalt was recovered within these cycles. Basalt was also recovered in the next core immediately below, and evidence that this basalt is a sill is given below. We suggest,

TABLE 3
Summary of Density, Porosity and Water Content Data for Site 138

			GRAPE			Sediment Sample			
Hole	Core	Section	Depth Below Sea Floor (m)	Density (gm/cc)	Porosity (%)	Depth Below Sea Floor (m)	Water Content (%)	Density (gm/cc)	Porosity (%)
138	1	1	52.75	1.51	61	52.30	39	1.56	61
138	1	2	54.25	1.56	57	53.64	43	1.43	62
138	1	3	55.75	1.67	48	55.14	34	1.56	54
138	1	4	57.25	1.61	52	56.64	41	1.48	60
138	1	5	58.75	1.59	54	–	–	–	–
138	1	6	60.25	1.50	61	59.79	42	1.50	63
138	2	1	110.75	1.65	49	110.14	43	1.55	66
138	2	2	112.25	1.53	60	111.64	42	1.47	61
138	2	3	113.75	1.49	62	113.14	44	1.45	63
138	2	4	115.25	1.48	63	114.64	46	1.43	66
138	2	5	116.75	1.44	66	116.14	47	1.38	65
138	2	6	118.25	1.47	64	117.64	50	1.35	67
138	3	1	–	–	–	184.22	68	1.13	77
138	5	1	332.75	1.50	60	333.00	33	1.57	53
138	6	2[a]	427.25	–	–	–	–	–	–
138	6	3[a]	428.75	–	–	428.50	34		

[a]Variable lithology–for details see Chapter 18.

TABLE 4
Microtran Sonic Velocity Measurements

Site	Core	Section	Interval	Lithology	Velocity (m/sec)
138	3	1	140	Clay	1823
	6	3	23	Dolo silt	2314
	6	3	28	Carbonaceous mud	2224
	6	3	39	Dolo silt	2569
	7[a]	1	70	Basalt	4358
	7[a]	1	115	Basalt	3982
	7[a]	1	145	Basalt	4181

[a]Compare with results of Chapter 24.

therefore, that the second generation dolomite may possibly be due to metamorphic effects.

In the Campanian, essentially carbonate free mudstones, bedded cherts, and slightly zeolitic clays represent pelagic and in part volcanogenic deposition below the compensation depth without much terrigenous influence (almost no quartz). The radiolarian fauna generally is poorly preserved. The cherts were laminated radiolarian muds before they were silicified by mobilization of SiO_2 from siliceous organisms.

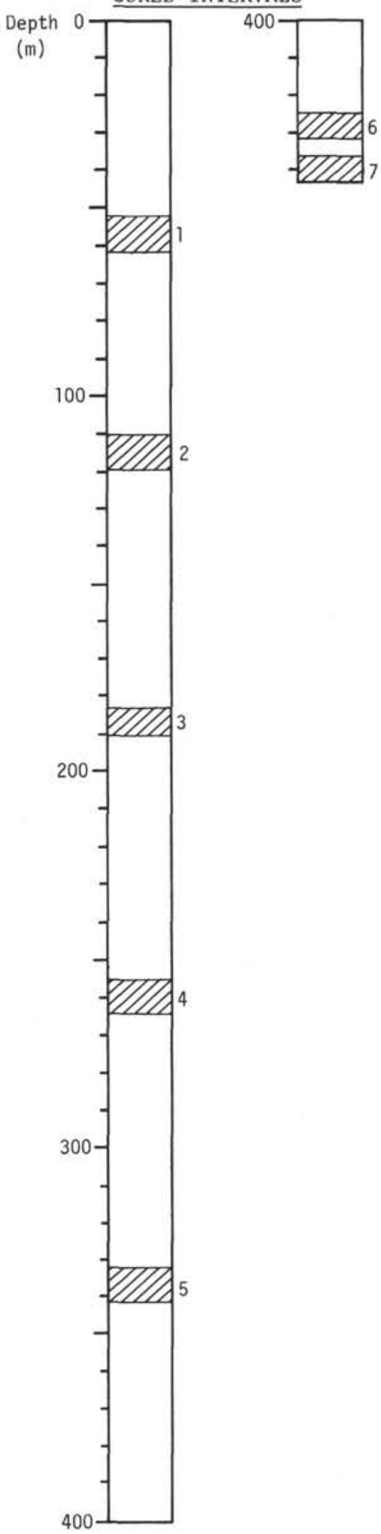
Since Late Cretaceous time, the area of deposition remained below the calcite compensation depth in a well-oxygenated environment. An absence of long hiatuses is suggested by the "normal" sedimentation rate of about 5 meters/m.y. (see Chapter 27). Radiolarian and diatom clays were deposited during the Oligocene (Core 2). Within the Early Miocene (Core 1) the influence of a terrigenous supply from the African continent is significant. This influx of terrigenous material may be correlated with mountain building events on land. The suggested mechanism by which the sand reached this area is turbidity currents flowing westward down the steepest slope. The seismic sections of the continental rise in this area show a continuity of intermediate reflectors over considerable distances and a gradual thinning of individual sediment units to the west (See Chapter 4 Figure 2). The abundance of siliceous fossils in a few places only, may also indicate redeposition from areas closer to shore (see Chapters 26, 27).

The coarse-grained basalt recovered at 437 meters is believed to be a sill and not the true oceanic layer 2. A detailed discussion of this subject is presented in Chapter 27. Briefly, the main reasons for this conclusion are: the age of sediments adjacent to the basalt appear to be younger than basal sediments in Site 137 which lies closer to the mid-Atlantic ridge axis; if the basalt is correlated with the basement reflector at Site 138 then an average velocity for all sediments above is only 1.76 km/sec compared with an average at Site 137 of 2.00 km/sec; the Cenomanian to Late Albian calcareous oozes seen in Site 137 were not penetrated at Site 138.

A zone of several reflectors occurs between 0.16 and 0.33 second. Only one core of clay (with a very low recovery) was recovered in the upper portion of this interval. However, it is quite possible that these reflectors are unsampled sand beds. The lower portion of this reflective zone might be correlated with the Late Cretaceous shale, mudstone and chert beds.

SITE 138–SUMMARY

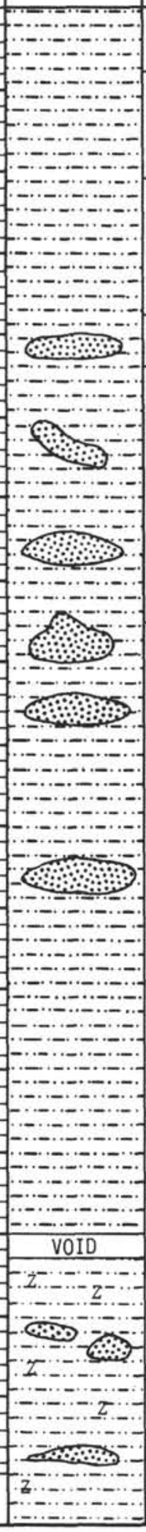
CORED INTERVALS



CORE	LITHOLOGY	AGE
1	SILTY CLAY and SAND	EARLY MIOCENE
2	SILTY CLAY, SILICEOUS	OLIGOCENE
3	CLAY	UNKNOWN
4	SHALE, MUDSTONE, CHERT	UNKNOWN
5	CLAY	EARLY CAMPANIAN
6	DOLOMITE SILTY CLAY, CARBONACEOUS CHERTY BLACK MUD, BASALT SILL	CENOMANIAN
7	BASALT	UNKNOWN

SITE 138 **CORE** 1 **DEPTH (m)** 52-61

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE
EARLY MIOCENE			*Calocycletta veneris*	1, 2, 3, 4, 5, 6, CC	1–8		40, 105, 40, 70, 75, 90



LITHOLOGIC DESCRIPTION

CLAY, SILTY 30 cm $CaCO_3$ 0
Pale yellowish green (10GY 7/2), pale green (10G 6/2), and pale yellow brown (10YR 6/4) with layers of SAND, grayish green (5G 6/2)

Smear Slide Average (40-105 cm):

Clay	70%
Chlorite	5%
Quartz	20%
Mica	2%
Opaques	1%

GZ 0-27-73 $CaCO_3$ 1

Some areas more silty, generally as streaks, silty layers

Smear Slide (40 cm, Sec. 2)		Smear (70 cm, Sec. 2)	
Clay	~70%	Quartz	55%
Quartz	20%	Clay	40%
Chlorite	3%	Chlorite	5%
Opaques	3%	Feldspar	2%
Feldspar	Tr.	Biotite	Tr.

$CaCO_3$ 0

GZ 32-47-21

Sand composition (Smear 75 cm):

Quartz (coated, some have needles or heavy minerals)	~80%
Chlorite	5%
Pyroxene	2%
Biotite and Muscovite	4%
Heavy minerals (hornblende, zircon, rutile, apatite, magnetite or ilmenite)	3%
Zeolite	5%
Pyrite	3%
Chert, pelagic forams	Tr.

40 cm GZ 7-29-64 sec.4, 14 cm $CaCO_3$ 2

Coarse Fraction:
Quartz, claystone fragments, fish debris, tr. benthonic forams, tr. glauconite

Blebs of grayish brown (10YR 5/2), mostly between 80-110 cm, 45-55 cm

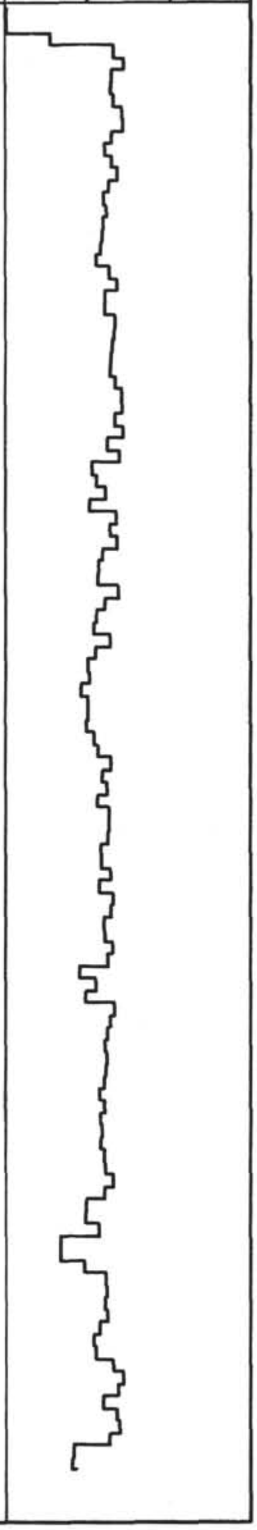
Smear (90 cm grayish brown): 29 cm $CaCO_3$ 0

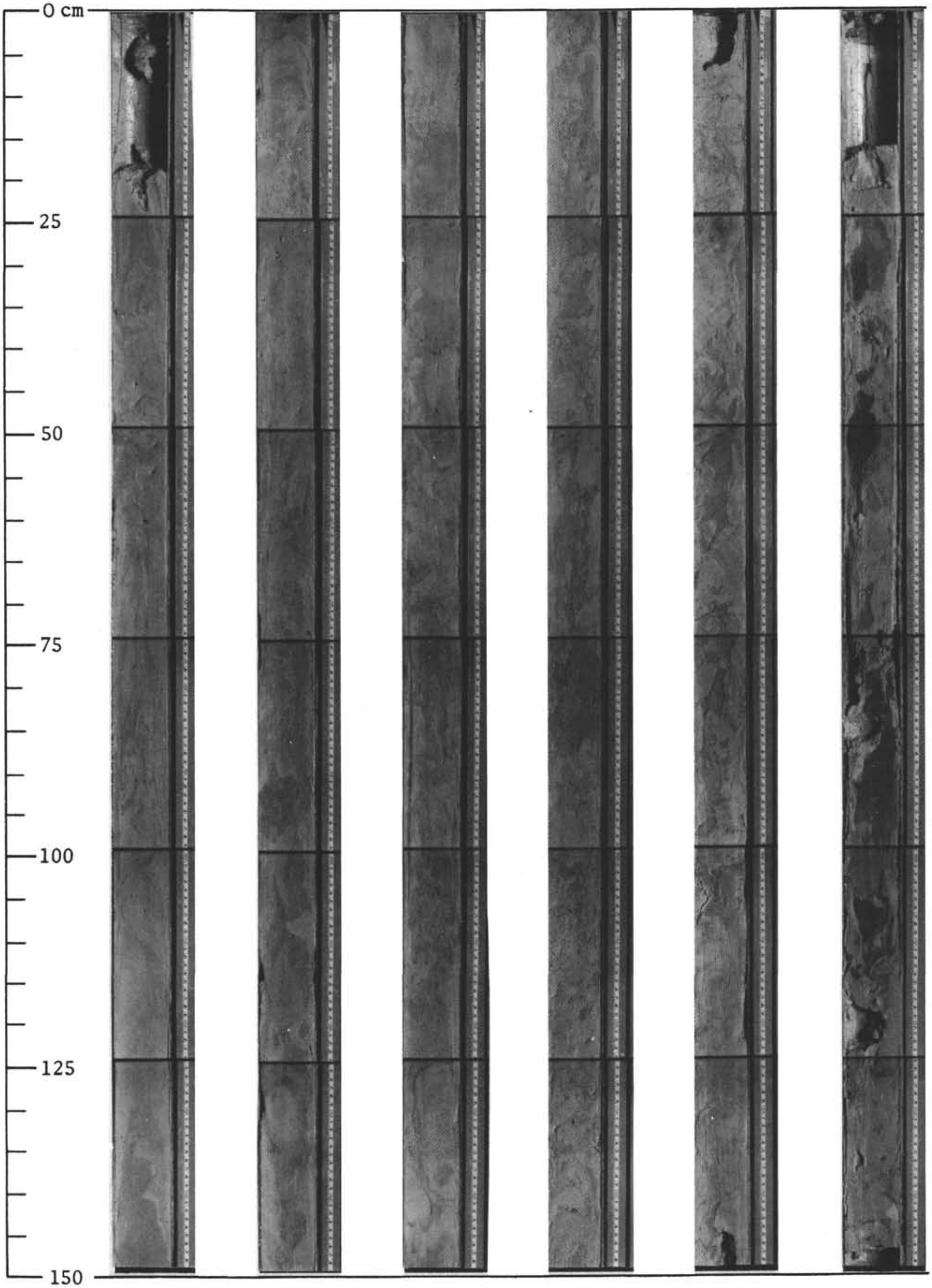
Clay	60%
Zeolite	~15%
Pyroxene plus biotite plus chlorite	2-3%
Opaques plus	2-3%
Quartz	15%
Fe oxide	2%

25 cm GZ 6-35-59

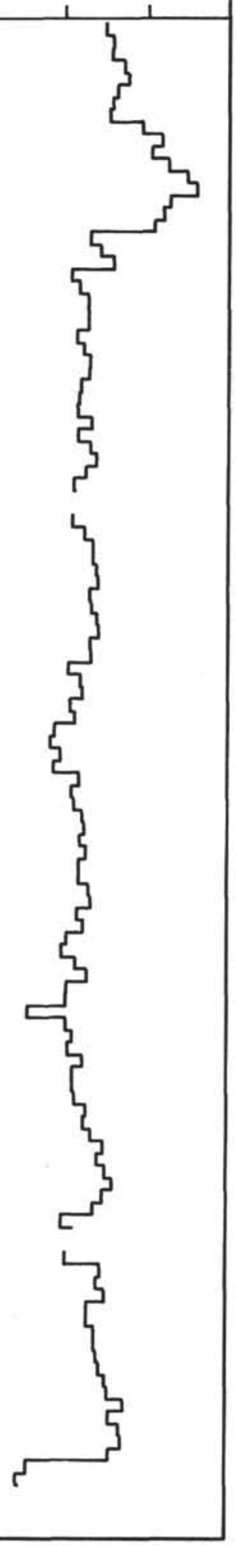
NATURAL GAMMA RADIATION

COUNTS/7.6 cm/1.5 min




0 cm
25
50
75
100
125
150
138-1-1
138-1-2
138-1-3
138-1-4
138-1-5
138-1-6

SITE 138 CORE 2 DEPTH (m) 110-119

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE	LITHOLOGIC DESCRIPTION	NATURAL GAMMA RADIATION (COUNTS/7.6 cm/1.5 min; 1000, 2000)
EARLY OLIGOCENE			*Calocycletta tuberosa*	1, 2, 3, 4, 5, 6, CC	1–8		30, 80, 100, 75, 25, 110	see below	

SILTY CLAY, locally rich in Radiolaria; greenish gray (5G 6/1), dark greenish gray (5G 6/2), pale green (10G 6/2)

Smear Slide (30 cm):

Clay	~70%
Radiolaria	20%
Quartz	10%
Micas, opaques	2%

Sand layer, olive gray (6Y 4/2)

Smear Slide (80 cm):

Quartz	65%
Clay	10%
Biotite	5%
Feldspar	5%
Rads	3%
Diatoms	3%
Zeolite	3%
Pyrite	3%

14 cm $CaCO_3$ 0

$CaCO_3$ 0

100-150 cm; Section 1, sandy clay, dark grayish green (5G 6/2)

Smear Slide (75 cm):

Clay	~85%
Quartz	10%
Radiolaria	5%
Chlorite	1%
Mica	1%

Smear Slide (100 cm):

Quartz	~50%
Clay	40%
Radiolaria	5%
Mica	2%
Feldspar	1%

30 cm. GZ 0-29-71

14 cm $CaCO_3$ 0

Pale green (10G 6/2)

GZ 0-30-70

$CaCO_3$ 0

Smear Slide (75 cm):

Clay	~65%
Radiolaria	35%
Quartz	2%

$CaCO_3$ 0

GZ 0-48-52

Section 5 disturbed by coring

Dark olive gray (5Y 3/2)

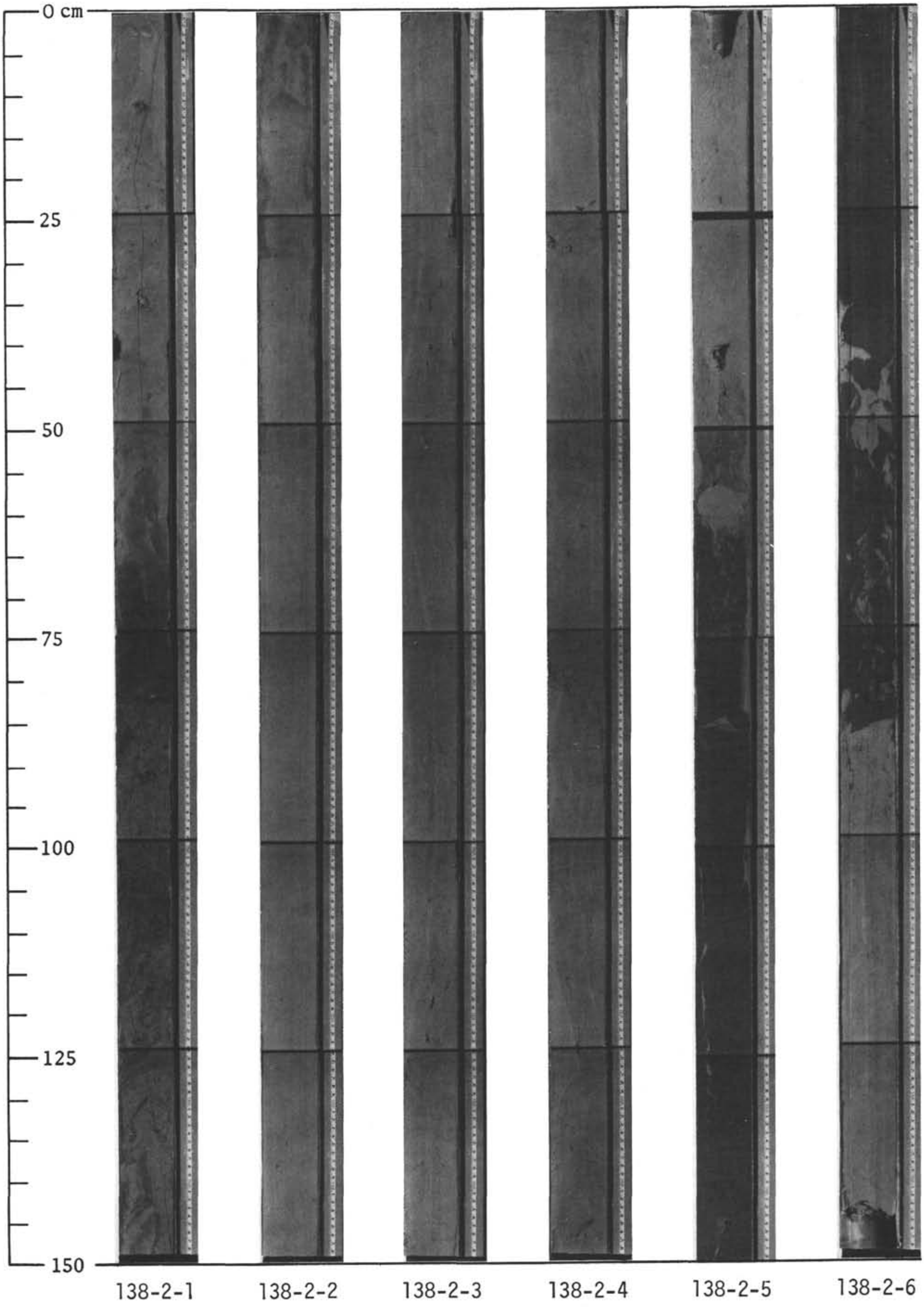
40 cm. GZ 0-48-52

$CaCO_3$ 4

Smear Slide Average:

Clay	80-90%
Radiolaria	5-10%
Quartz	5%
Zeolites and mica	Tr.

Greenish gray (5G 6/1)

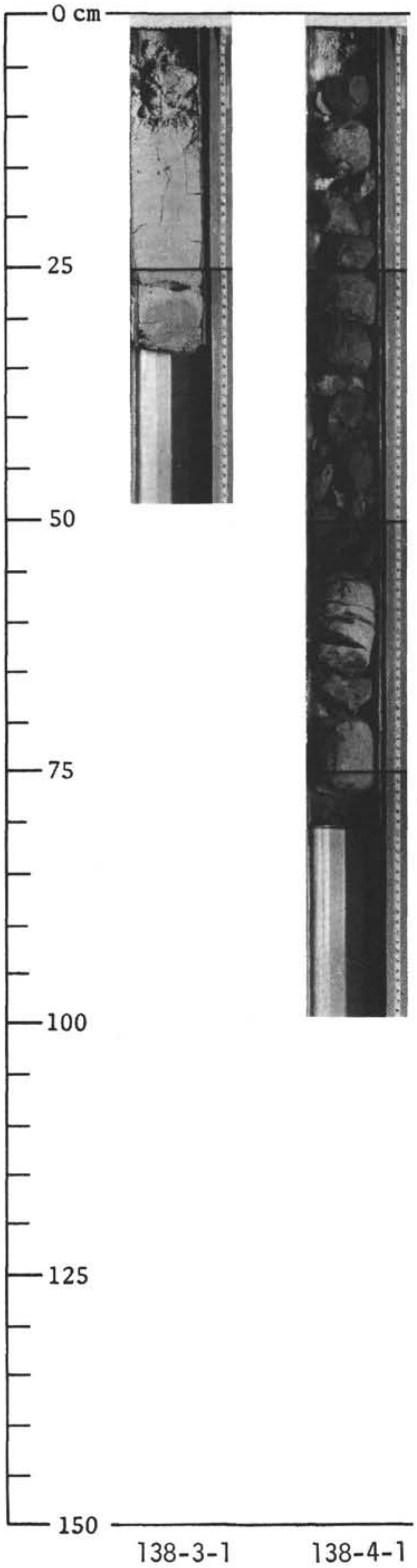

0 cm
25
50
75
100
125
150
138-2-1
138-2-2
138-2-3
138-2-4
138-2-5
138-2-6

SITE 138 **CORE** 3 **DEPTH (m)** 183-190

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE	LITHOLOGIC DESCRIPTION	NATURAL GAMMA RADIATION COUNTS/7.6 cm/1.5 min 1000 2000
UNKNOWN				1	1	VOID	127 148	CLAY 120-146 cm: light bluish gray (5B 7/1) 146-150 cm: light reddish brown (5YR 6/3) Friable with shaly partings from 120-135 cm, firm and stiff from 135-146 cm Both Smear Slides Show: Clay ∿95% Rest is quartz, zeolite, mica, hornblende X-Ray (121-123 cm): Palygorskite A $CaCO_3$ 0 Quartz, mica, montmorillonite C Chlorite (?), siderite Tr.	
				CC					

SITE 138 **CORE** 4 **DEPTH (m)** 255-264

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE	LITHOLOGIC DESCRIPTION	NATURAL GAMMA RADIATION COUNTS/7.6 cm/1.5 min 1000 2000
MAESTRICHTIAN TO DANIAN				1	1	VOID	T.S.	SHALE, MUDSTONE and CHERT Greenish gray (5G 6/1) to greenish black (5G 2/1) MUDSTONE: Homogeneous, indurated, no bedding, streaks and small blebs of pyrite SHALE: Slightly fissile, black streaks of manganese or organic material CHERT: Fragmented, maximum probable thickness of beds ∿10 cm. Very fine clayey siltstone, cement is strained silica in optical continuity. ∿80% Silica, 10% Clay, 5% Quartz, 3% Radiolaria and sponge spicules, rest pyrite, chlorite, mica Thin Section (90 cm): Silica 60% Clay minerals 15% Carbonaceous matter 10% Carbonate fragments 5% Quartz 5% Fe oxide 4% Siliceous organisms, carbonate rhombs Tr. X-Ray (cc) (CHERT): (?) Tridymite A Quartz, dolomite Tr. Coarse Fraction: Claystone and chert fragments, quartz	
				CC					


0 cm
25
50
75
100
125
150
138-3-1
138-4-1

SITE 138 CORE 5 DEPTH (m) 332-341

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE	LITHOLOGIC DESCRIPTION
CAMPANIAN				1	1	VOID		
				CC				

CLAY
Greenish gray (5G 5/1-6/1) and reddish brown (5YR 5/3) in alternating bands 1-5 cm. thick
Smears of both colors (from core catcher) show:

Greenish gray:		Reddish brown:	
Clay	~95%	Clay	~95%
Zeolite (?Clinoptilolite)	2%	Zeolite (?Clinoptilolite)	5%
Biotite, chlorite, hornblende, quartz rutile, zircon	2%	Hematite, biotite, chlorite, hornblende, quartz	Tr.

$CaCO_3$ 0

X-Ray (cc):
Montmorillonite, palygorskite A
Quartz, feldspar, mica, akolinite C
Coarse Fraction:
(?) Zeolite

NATURAL GAMMA RADIATION
COUNTS/7.6 cm/1.5 min
1000 2000

SITE 138 CORE 6 DEPTH (m) 425-431

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE	LITHOLOGIC DESCRIPTION
CENOMANIAN				1	1	VOID		
				2*	2			
				3*	3, 4			
				CC				

DOLOMITIC SILTY CLAY
Greenish gray (5G 6/1) and light bluish gray (5B 7/1) laminae
Intercalations of CARBONACEOUS CHERTY BLACK MUD; ALTERED BASALT layer; thin ASH layer

130 cm GZ 4-35-61

Dolomite as well developed rhombs showing two growth stages

Coarse Fraction:
Pyrite, dolomite, calcite, zeolite

30 cm GZ 1-19-80

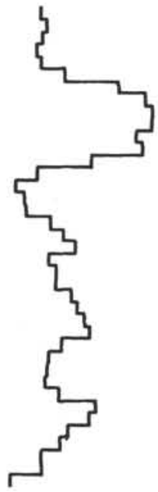
Dolomitic silty clays and carbonaceous black muds alternate cyclically in Section 3. $CaCO_3$ 0

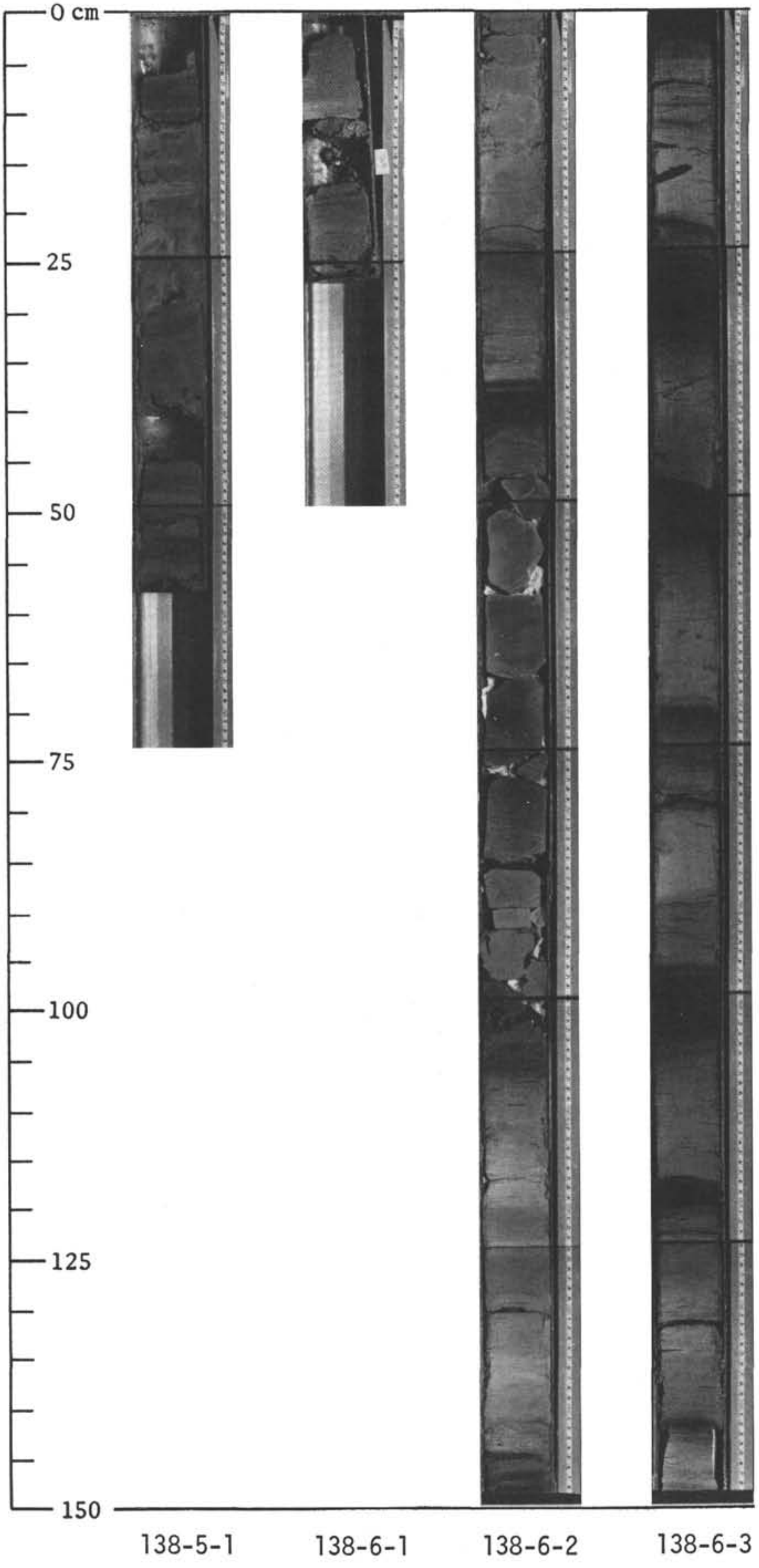
GZ 1-48-51

GZ 0-22-78
GZ 0-14-86

* See Section Summary

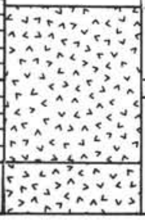
NATURAL GAMMA RADIATION
COUNTS/7.6 cm/1.5 min
1000 2000




0 cm
25
50
75
100
125
150
138-5-1
138-6-1
138-6-2
138-6-3

SITE 138 CORE 7 DEPTH (m) 437-442

AGE	ZONE: FORAM	ZONE: NANNO	ZONE: RAD	SECTION	METERS	LITHOLOGIC SYMBOLS	SMEAR SLIDE	LITHOLOGIC DESCRIPTION	NATURAL GAMMA RADIATION COUNTS/7.6 cm/1.5 min 1000 2000
UNKNOWN				1	1	VOID	T.S.1 T.S.2	See below	
				CC					



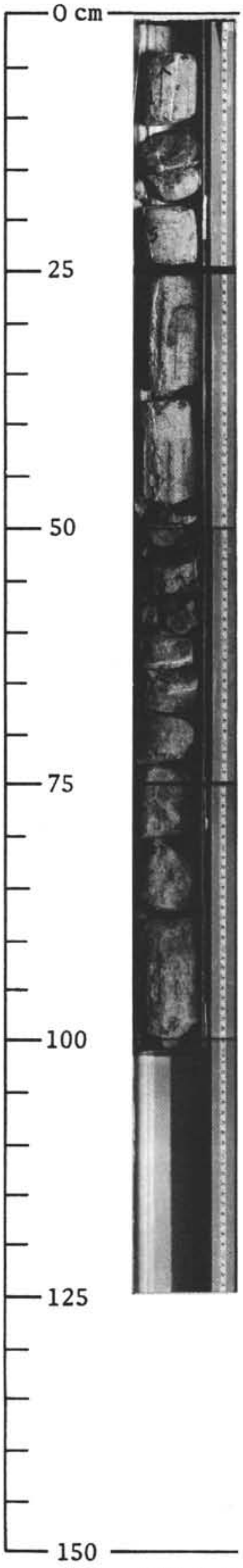
BASALT, coarse grained and highly altered
Dark gray to olive green, with white vertical Calcite veins

Thin Section 1: Doleritic with only 5-10% altered glass. Original Feldspar laths .1-.5 mm long

FELDSPAR - ∿50% is fresh to slightly altered Labradurite (∿A_n55). ∿50% badly to completely altered to Saussurite, Sericite, and Calcite. Numerous long laths have long needles of Clinozoisite, some Epidote plus Albite. Some late Feldspar may be orthoclasi.

PYROXENE - almost all altered to Chlorite, Antigorite (and Chrysotile?), Biotite and Hornblende. Stilbite possibly present. Iron oxides up to 10%, Calcite less than 5%.

Thin Section 2: Similar to above, but finer grained and more altered. Much late (replacement) fibrous Albite, also Zeolites (Natrolite and Etilbite). Calcite comprises 20-25% of the slide as irregular masses, veins and a replacement of Feldspar and Pyroxene. Feldspars mostly altered, Pyroxenes nearly entirely so. Hornblende occurs as lath-like crystals, but is minor compared to Biotite and Chlorite



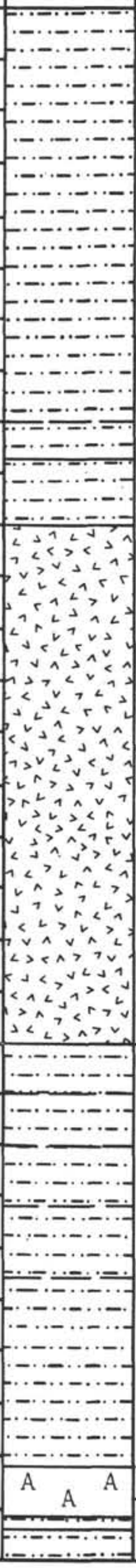
138-7-1

SITE 138 CORE 6 SECTION 2

AGE	SECTION PHOTO	cm	LITHO	SMEAR SLIDE	DESCRIPTION

AGE: SENONIAN

cm: 25, 50, 75, 100, 125, 150



SMEAR SLIDE: 100, 144

DOLOMITIC SILTY CLAY
Greenish gray (5G 6/1), streaky and lensy laminae, semi-indurated

X-Ray (46-47 cm):
Feldspar, montmorillonite A
Mica, dolomite C

X-Ray (144 cm):
K feldspar, montmorillonite, pyrite A
Quartz, mica, palygorskite C

Carbonaceous black mud, sharp lower contact, transitional upper

Original contact between dolomitic silty clay and basalt probably lost in drilling

ALTERED THOLEIITIC BASALT, original texture doleritic, thin section shows feldspar was originally probably labradorite (A_n55), in laths <.1 to .5 mm long, now altered to saussurite, sericite, albite. Pyroxenes are completely altered to chlorite, ? serpentine, biotite and hornblende. Iron oxides (ilmenite, hematite, magnetite) occur as rectilinear grains and as 'dust' in chloritic replacements of pyroxenes.

At 100 cm. in a thin black shale, a silty clay with high organic content. Probably not the original contact

Greenish gray (5G 6/1)

Dark gray zone

Greenish gray

Lighter greenish gray (5GY 6/1)

Greenish gray

ASH LAYERS, white, grains up to 0.3 mm

146-148 cm: greenish gray black carbonaceous clay

Smear Slide (100 cm):

Clay	65%
Fe oxide and organic	25%
Quartz	5%
Biotite	5%
Zeolite, chlorite, biotite, dolomite	Tr.

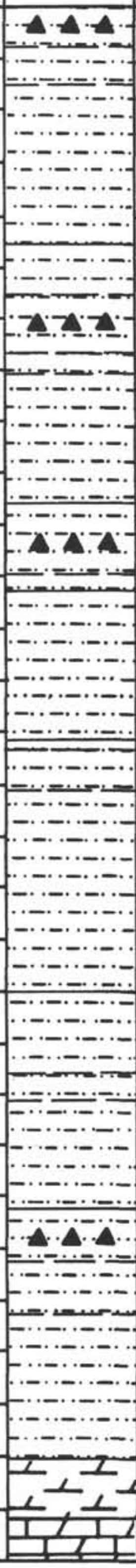
Smear Slide (120 cm):

Dolomite	85%
Clay	10%
Pyrite	5%
Quartz	Tr.

Smear Slide (144 cm):

Clay	65%
Feldspar	10%
Pyrite	10%
Zeolite	8%
Biotite	5%
Quartz	3%
Dolomite	3%
Fe oxide, glass	Tr.

SITE 138 CORE 6 SECTION 3

AGE	SECTION PHOTO	cm	LITHO	SMEAR SLIDE	DESCRIPTION
SENONIAN		25, 50, 75, 100, 125, 150		20, 50, 70, 120, 150	B, T, G, T, B, T, G, B, T, G, B, G, B, T, G, B, T, G(L)

Cyclic alternations of dolomitic SILTY CLAY and carbonaceous black MUD containing CHERT. The carbonaceous muds average about 5 cm. in thickness and are spaced at about 25 cm. intervals. Upper boundaries of dolomitic layers tend to be sharper than lower ones (more transition zones below the carbonaceous muds than above).

B) BLACK CARBONACEOUS CLAY LAYERS, actually very dark brown (10YR 2/2). Sandy layers of CHERT fragments present.

G) Dolomitic SILTY CLAYS, greenish grey (5GY 6/1) to locally light greenish grey (5GY 6/1 to 8/1).

T) Transition zones between B and G. Generally intermediate color, but streaky laminae apparent.

Composition:

G) Smear Slides (20, 70 cm)(Dolosilts):

Clay	~50%
Dolomite	40%
Pyrite	6%
Biotite	3%
Quartz	2%

B) Smear Slides 50, 120 cm:

Dark brown organic looking material of Mn stained limonite spherules	~50%
Clay	20-30%
Pyrite plus other opaques	10%
Dolomite (small rhombs)	5%
Quartz	2%
Chert fragments	1% up to 20%

The sandy layers (estimated 30% sand, 50% silt, 20% clay) are composed of chert fragments in the sand fraction, mostly organic or limonitic grains, dolomite rhombs, pyrite and quartz in the silt fraction, and clay and organic material in the clay fraction

Thin Section: (150 cm)
Ankerite 90%, Pyrite 6%, Clay 3%, Biotite 1%

X-Ray (0-2 cm)(Black Mud):

Quartz	A
Montmorillonite, pyrite, palygorskite	C
Feldspar, mica	Tr.

X-Ray (10 cm)(Dolosilt):

Dolomite, quartz, montmorillonite	A
Feldspar, pyrite	C
Mica, palygorskite	Tr.

X-Ray (142-143 cm)(Dolostone)

Ankerite, montmorillonite	A
Quartz	C
Biotite	Tr.

X-Ray (149-150 cm)(Dolostone)

Ankerite	A
Quartz, montmorillonite, pyrite	Tr.