30. X-RAY MINERALOGY OF SITES 558 AND 563[1]

C. Latouche and N. Maillet, Institut de Géologie du Bassin d'Aquitaine, Université de Bordeaux I[2]

ABSTRACT

Downhole bulk-sample and clay-mineral analytical results for Sites 558 and 563 are presented in this chapter. These results show a Tertiary climatic and hydrologic evolution similar to that at other DSDP drill sites in the northeastern Atlantic Ocean (Sites 398, 403–406, 548–550, 552–555). The sediments recovered at both sites are primarily calcareous and chalky oozes characterized by >90% carbonate and minor quartz and plagioclase feldspar. Clay minerals smectite, kaolinite, illite, and chlorite are present throughout the cores; upsection, illite increases at the expense of smectite. The clay mineralogy suggests climatic cooling and increased ocean circulation during the Miocene. Intervals rich in very fine grained (<2 μm) quartz suggest times of increased eolian input. This could have resulted from development, during Oligocene and late Miocene time, of an arid, desertlike sediment provenance that lasted until the present day.

INTRODUCTION

Analysis of the Leg 82 sediments, collected on the western side of the Mid-Atlantic Ridge, south of the Azores, served to find out more about the North Atlantic Tertiary environments (climate, hydrology), which were directly implicated in the evolution of the sedimentation pattern. We chose to investigate Site 558 (near the Pico Fracture Zone) and Site 563 (south of the Hayes Fracture Zone) (Fig. 1) because the Tertiary sediments recovered at these sites were complete; very little Tertiary sediment was found at the other sites. Tertiary sediments from this region consist mainly of calcareous and chalky oozes.

X-ray diffraction was used in the mineralogic analysis of 65 samples recovered during Leg 82. The distribution of samples is as follows. Site 558: 43 samples (lower Oligocene to upper Miocene from Hole 558 and upper Miocene to Pleistocene from Hole 558A). Site 563: 22 lower Oligocene to upper Miocene samples. Two other samples were also analyzed, one from Site 560 (upper Miocene) and the other from Site 564 (middle Miocene–lower Oligocene).

METHODS

A Philips diffractometer was used, and operating conditions were as follows: nickel-filtered copper $K\alpha$ radiation at 40 kV, 20 mA.

Total Sediments

Total sediments were analyzed according to the powder diffractogram method; that is, sediments were dried, crushed, and, after being set in powder on a support, X-rayed. To determine the minerals involved, we used their characteristic peaks (Torre de Assunçâo and Garrido, 1953): quartz at 3.35 Å; plagioclase feldspar between 3.20 and 3.15 Å, calcite at 3.03 Å, and dolomite at 2.883 Å.

Semiquantitative concentrations of minerals: The peak height characterizing each mineral was transcribed on a standard curve, and mineral concentrations were evaluated. Calibration was based on four synthetic reference standards, formed of variable weight mixtures of quartz, feldspar, calcite, and dolomite. Clay quantity, occurrence of heavy minerals, and content of amorphous components were not taken into consideration.

Clay Fraction (<2 μm)

Total sediments were dispersed in deionized water, using mechanical agitation. Samples with high carbonate contents were first treated with *N*/10 HCl. After several (2–3) washings in deionized water, <2 μm subfractions were separated by gravity settling. After the <2 μm portion of the suspension was centrifuged, the resulting thick paste was spread across 3 slides, as follows: slide one was scanned untreated; slide two was saturated with ethylene glycol; slide three was heated at 550°C for an hour.

Minerals were identified on the basis of their typical reactions to classical treatment (Brown, 1961; Thorez, 1975). Percentages of the different minerals were estimated from the glycolated samples. The heights of the 001 peaks were used to determine smectite (17 Å), illite (10 Å), and kaolinite and chlorite (7.1 Å). Chlorite was distinguished from kaolinite on the basis of the difference between their reflections: 002 for kaolinite (3.57 Å) and 004 for chlorite (3.55 Å). Results are given in percentage values; these percentages are evaluated only with regard to the crystallized clay minerals in the <2 μm fraction. In this fraction several minerals such as zeolite and quartz were observed. The heulandite group in zeolites was identified (7.90 and 8.90 Å). After heating, a distinction was drawn between heulandite and clinoptilolite. Quartz, within the fine-grained fraction, was identified at 4.24 Å. The 3.35-Å peak, usually used to determine quartz, was superimposed on the illite 003 peak. The 4.24-Å peak—measured in millimeters—was used not to quantify quartz accurately, but to give it a relative value. All mineralogic analyses were carried out under the same operating conditions.

RESULTS

The major mineralogic characteristic at all sites studied is the dominance of carbonates (calcite) and the poor representation of coarse detrital elements such as quartz and feldspars within total sediments. Clay minerals are represented mainly by smectites within the Oligocene and upper Miocene. They are rich in illite at the base of the Miocene and in the Pliocene and Pleistocene. Quartz is often linked to this clayey fraction.

Site 558

The sediments studied are upper Oligocene and lower, middle, and upper Miocene (Hole 558) and upper Miocene, Pliocene, and Pleistocene (Hole 558A). Our results are given in Table 1 and Figure 2.

[1] Bougault, H., Cande, S. C., et al., *Init. Repts. DSDP*, 82: Washington (U.S. Govt. Printing Office).

[2] Address: Institut de Géologie du Bassin d'Aquitaine, Université de Bordeaux I, 351 Cours de la Libération, 33405 Talence Cedex, France.

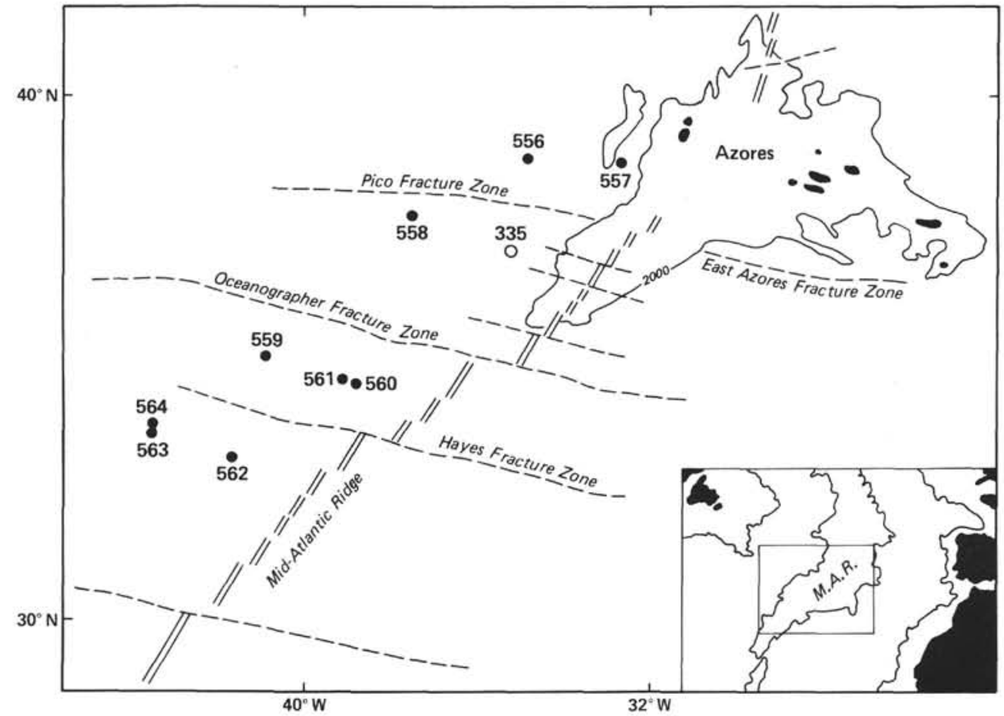

Figure 1. Locations of Leg 82 drill sites.

Upper Oligocene and undifferentiated Oligocene/Miocene (558-27-1, 51–55 cm to 558-17-1, 110–115 cm; nannofossil ooze). Sediment is carbonate, always calcite except at the base of the lower Oligocene, where dolomite was noted. Quartz is absent or present in trace amounts and plagioclase feldspars are rare (~3%). Clay minerals are represented mainly by abundant smectites (57–76%), illites (11–23%), kaolinites (7–13%), and chlorites (4–9%). Traces of zeolite (heulandite) are associated with the clay fraction.

Lower and middle Miocene (558-16-3, 110–115 cm to 558-12-1, 110–115 cm; nannofossil ooze). Sediment is dominantly carbonate (calcite), quartz is absent or present in trace amounts, and plagioclase feldspars are present (3–4%). Clay minerals are very rich in smectites (74–100%); illites, kaolinites, and chlorites are less common than in the underlying Oligocene/lower Miocene section. Zeolites (heulandite and clinoptilolite) are present in the clay fraction. Quartz decreases (in relative abundance) in the same fraction.

Middle and upper Miocene (558-11-1, 110–115 cm to 558-1-2, 120–125 cm; nannofossil ooze). Sediment is very rich in carbonates (calcite). In bulk samples, quartz is scarce and plagioclase feldspars are present (2–3%). Clay minerals are represented mainly by smectites (49–89%) and illites (6–28%); kaolinites occur in more dominant proportions (5–20%) than chlorite (trace to 7%). In this fine-grained fraction, quartz increases toward the top of the Miocene.

Upper Miocene, Pliocene, and Pleistocene (558A-1-1, 59–62 cm to 558A-16-1, 110–115 cm; nannofossil ooze). The carbonate content decreases slightly at the top of the Hole 558A. Quartz is present in traces, and plagioclase feldspars are present (3%). The composition of clay minerals varies. In Samples 558A-16-1, 110–115 cm to 558A-14-5, 110–115 cm (upper Miocene), clay minerals are dominated by illites (33–46%). In Samples 558A-13-1, 110–113 cm to 558A-9-2, 110–114 cm (Miocene, Pliocene), smectites constitute the most important component (41–55%). In Samples 558A-8-2, 120–123 cm to 558A-1-1, 59–62 cm (Pliocene, Pleistocene), the main clay mineral is illite (32–51%), and kaolinite and chlorite are well represented. Quartz is abundant in this clay fraction.

Site 563

The major mineralogic characteristics are the dominance of carbonates (calcite), the extreme paucity of plagioclase, and the scarcity of quartz. The clay fraction is rich in smectites from the base to the top of the sediment studied. Illite, kaolinite, and chlorite are well represented. Traces of zeolite (heulandite) are associated with the clay fraction in the Oligocene and middle-lower Miocene sediments. In this fine-grained fraction, quartz increases toward the top of the core (563-1-1, 110–115 cm).

Our results for Site 563 are given in Table 2 and Figure 3.

Site 560

This site is between the Oceanographer and Hayes fracture zones. The sample studied is upper Miocene (560-1-1, 28–30 cm; nannofossil ooze). The major characteristics are the dominance of carbonates (calcite), the presence of very few feldspars, and traces of quartz. Clay minerals are represented mainly by smectites (58%), accompanied by some illites (29%), kaolinites (20%), and chlorites (13%). Quartz is abundant in the clay fraction.

Table 1. X-ray diffractometry mineralogic analyses (%), Site 558 (Holes 558 and 558A).

	Bulk sample				<2 μm fraction					
Hole-Core-Section (interval in cm)	Calcite	Dolomite	Quartz	Plagio-clase feldspars	Smectite	Illite	Kaolin-ite	Chlorite	Presence or absence of zeolite	Quartz (4.24 Å) (height in mm)
558A-1-1, 59–62	83		1	3	16	46	19	19		14
558A-2-1, 110–114	71		2	3	25	40	21	14		15
558A-2-4, 56–59	88		1	3	40	32	14	14		23
558A-3-1, 110–115	80		2	3	22	41	13	24		26
558A-4-1, 110–115	88		1	3	13	51	18	18		28
558A-5-1, 110–115	86		1	3	23	43	23	11		30
558A-6-2, 120–123	83		1	3	21	45	17	17		26
558A-8-2, 120–123	80		1	3	34	33	19	14		35
558A-9-2, 110–114	91		Tr	3	43	28	15	15		24
558A-10-1, 110–115	95		Tr	3	44	32	12	12		20
558A-11-1, 110–115	93		Tr	3	41	33	13	13		12
558A-12-1, 110–115	94		Tr	3	51	25	16	8		30
558A-13-1, 110–113	94			3	55	23	11	11		17
558A-14-5, 110–113	92		1	3	19	46	22	13		29
558A-15-1, 110–115	89		1	3	16	52	16	16		21
558A-16-1, 110–115	92		1	2	33	33	17	17		30
558-1-2, 120–125	91			2	49	28	19	4		16
558-2-1, 50–56	91			2	53	23	20	4		16
558-3-1, 110–115	91			2	60	19	14	7		6
558-4-1, 110–115	91			2	66	19	15			12
558-5-1, 110–116	90		Tr	2	69	17	17	Tr		Tr
558-6-1, 110–115	90		Tr	2	89	6	5	Tr		Tr
558-7-1, 70–76	91			2	55	27	18	Tr		Tr
558-8-1, 110–115	91			2	67	15	18	Tr		Tr
558-9-2, 110–115	91			3	62	24	14	Tr		10
558-10-1, 110–115	93			3	63	19	14	4		8
558-11-1, 110–115	90		Tr	3	64	16	16	4		15
558-12-1, 110–111	94		Tr	4	100		Tr			Tr
558-13-1, 110–115	91		Tr	4	82	9	9		H	Tr
558-14-1, 110–115	91		Tr	3	81	8	11			
558-15-1, 98–104	91			3	82	10	8		C	15
558-15-6, 23–28	88		Tr	3	74	13	9	4	C	15
558-16-3, 110–115	91			3	75	14	8	3	H	8
558-17-1, 110–115	91			3	76	11	9	4	H	6
558-18-1, 110–115	93		Tr	3	69	14	12	5	H	17
558-19-1, 110–114	91		Tr	3	65	16	12	7	H	10
558-20-1, 110–115	91		Tr	3	66	19	9	6	H	12
558-21-1, 110–115	91		1	3	62	20	10	8	H	10
558-22-1, 110–115	93		Tr	3	57	21	13	9		18
558-24-1, 84–89	88		Tr	3	58	20	14	8	H	17
558-25-1, 68–74	91		Tr	3	74	13	8	5		7
558-26-1, 110–115	81	Tr		3	61	23	10	6		4
558-27-1, 51–55	56	32		1	71	15	7	7		Tr

Note: H = heulandite; C = clinoptilolite; Tr = trace.

Site 564

This site is on the west flank of the Mid-Atlantic Ridge, south of the Hayes Fracture Zone. The sample studied (564-H1-7, 43–47 cm; nannofossil ooze) is undifferentiated lower Oligocene–middle Miocene. Carbonates predominate (calcite); quartz (3%) and plagioclase feldspars (3%) are present. Clay minerals are dominated by smectites (68%), accompanied by illites (16%) and kaolinites and chlorites (8% each).

SYNTHESIS AND DISCUSSION

The overall evolution of clay-mineral assemblages throughout the Tertiary and Quaternary shows very similar trends to the sediment evolution at sites previously studied in the North Atlantic: Leg 47B (Chamley et al., 1979), Leg 48 (Latouche and Maillet, 1979), Leg 78 (Latouche and Maillet, in press), Leg 80 (Chennaux et al., in press), and Leg 81 (Latouche and Maillet, in press). There exist, however, differences attributable mainly to the geographic and climatic environment.

Interpretation of the mineral assemblages recovered during Leg 82 was based on previous publications, the majority of which suggest that marine clays are of detrital origin. Particular attention was given to the work by Millot (1964), Yeroschev-Shak (1964), Griffin et al. (1968), Paquet (1969), Tardy (1969), Latouche (1975), Courtois and Chamley (1978), Chamley (1979), Latouche and Maillet (1982), Sarnthein and Erlenkeuser (1982), and Grousset et al. (1983). All these authors assume that the kaolinites and smectites are derived from humid tropical regions and that smectite genesis is favored by the presence of basic volcanic parent-rock. Illites and chlorites are thought to be located generally within intermediate- and high-latitude zones and/or to originate from acid rock dismantling. Illites and chlorites also occur in desert zones, and evidence of their inputs within a marine environment was attributed to atmospheric circulation.

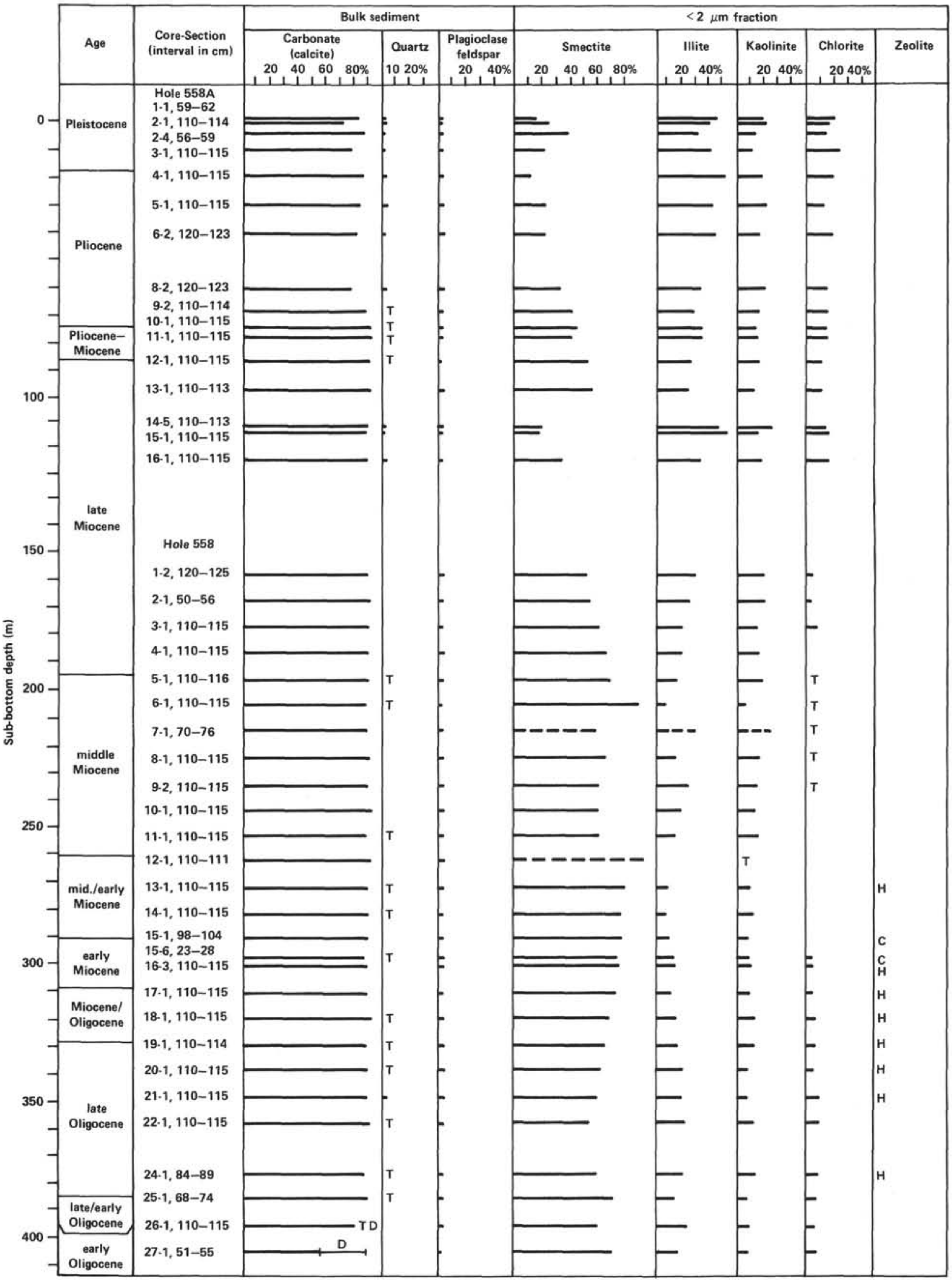

Figure 2. Mineralogic log, Site 558 (Holes 558 and 558A). D = dolomite, T = trace, C = clinoptilolite, H = heulandite. Dashed lines indicate very poorly crystallized. The following age ranges are undifferentiated: Pliocene-Miocene, middle/early Miocene, Miocene/Oligocene, and late/early Oligocene.

Table 2. X-ray diffractometry mineralogic analyses (%), Site 563 (Hole 563).

	Bulk sample				< 2μm fraction					
Core-Section (interval in cm)	Calcite	Dolomite	Quartz	Plagio-clase feldspars	Smectite	Illite	Kaolin-ite	Chlorite	Presence or absence of zeolite	Quartz (4.24 Å) (height in mm)
1-1, 110-115	92		Tr	3	45	31	12	12		23
2-1, 110-115	94		Tr	3	71	16	8	5		28
3-1, 110-114	92		Tr	3	52	26	11	11		18
4-1, 110-114	96		Tr	Tr	50	28	13	9		8
5-1, 110-114	94			3	62	20	12	6		19
6-1, 110-114	97			Tr	54	21	15	10		19
7-1, 110-114	96		Tr	Tr	67	21	8	4		12
8-1, 110-114	97			Tr	70	15	9	6		Tr
9-1, 110-114	96		Tr	Tr	59	20	16	5		15
10-1, 120-125	91		Tr	2	62	16	13	9	H	20
11-1, 120-124	94		Tr	Tr	70	12	12	6		10
12-1, 127-132	94			Tr	63	17	13	7	H	14
13-2, 110-112	94			Tr	63	19	11	7	H	15
14-2, 124-128	96			Tr	67	15	18		H	20
15-1, 110-114	96			Tr	79	11	5	5		4
16-1, 110-114	96			Tr	64	21	8	7		10
17-1, 110-114	94			Tr	70	16	7	7	H	4
19-1, 108-112	91		Tr	Tr	51	18	31	Tr		8
20-1, 70-74	94			Tr	60	20	12	8		10
21-2, 107-111	96			Tr	68	18	11	3		8
22-1, 74-78	91	Tr		Tr	84	8	4	4		6

Note: H = heulandite; Tr = trace.

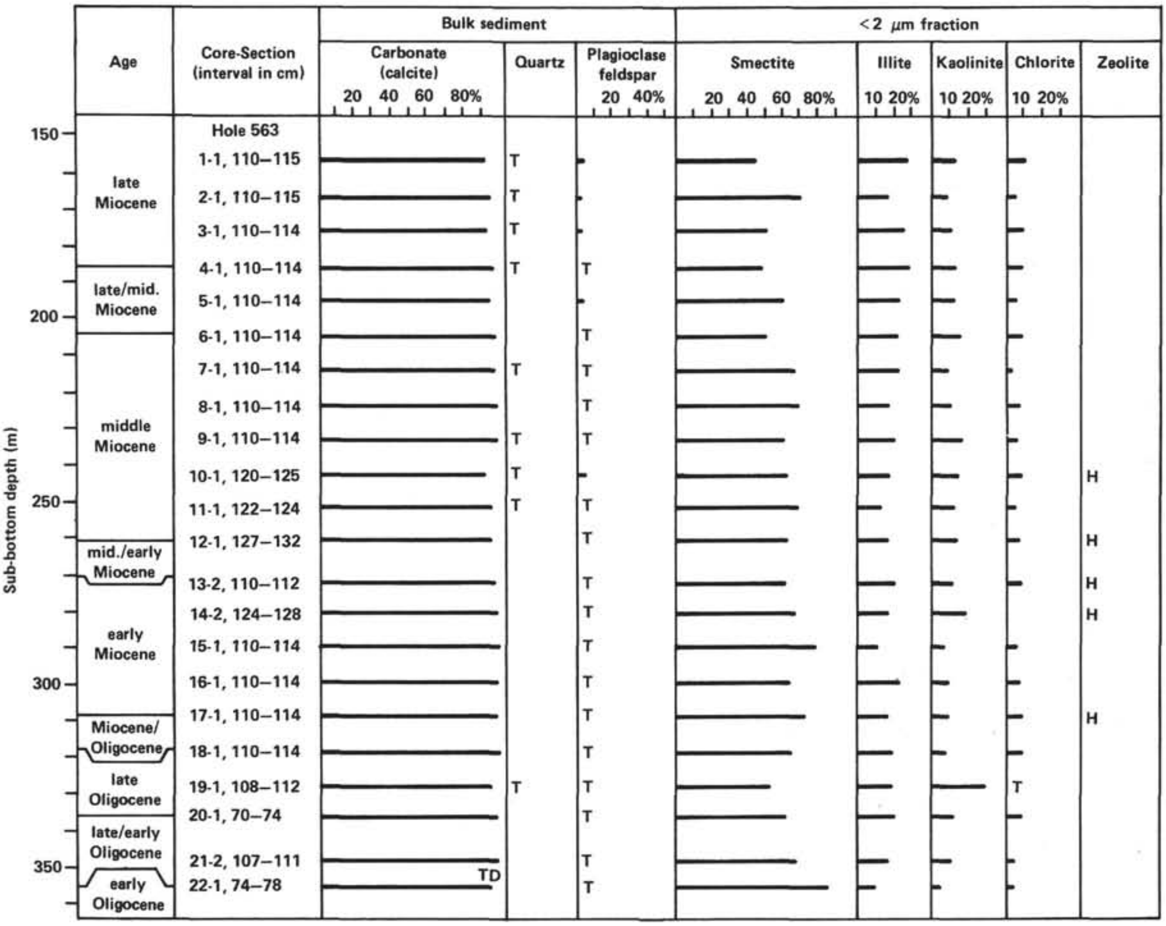

Figure 3. Mineralogic log, Site 563. D = dolomite, T = trace, and H = heulandite. The following age ranges are undifferentiated: late/middle Miocene; middle/early Miocene; Miocene/Oligocene; and late/early Oligocene.

Common General Evolution in the North Atlantic

In the North Atlantic, the major characteristic of this evolution, during the Cenozoic, was the smectite-group decrease and, from the middle late Miocene to the Quaternary (Fig. 2), the illite increase. Latouche and Maillet (1979, 1980) explained the occurrence of illites and chlorites by a northern water circulation that took form in the second half of the Tertiary. Although using different analytical methods, Vergnaud Grazzini et al. (1978) and Roberts and Montadert (1979) certified the same water circulation source. In the equatorial region studied herein, illite and chlorite contents tended to increase during the Miocene. This increase coincided with that in the North (Latouche and Maillet, 1979,1980), and can similarly be linked to north-south water circulations, as well as to climatic alterations already known. This mineralogic change, observed in the sediment record throughout the Atlantic, is somewhat different in this region because of the geographic location (low latitudes).

Regional Characteristics

The constant occurrence of smectite, illite, kaolinite, and chlorite in the examined sediments from all sites suggests varied input origins and, consequently, water circulation courses (initiated at the beginning of the Tertiary) enabling communication of the zone studied with regions at different latitudes. Further, the constant occurrence of illite and chlorite suggests the existence of other than northern input origins. This suggestion is enforced by the presence of very fine grained quartz, which presents two maxima (Fig. 4), one in the upper Oligocene and the other from the upper Miocene to the Pleistocene. This vertical distribution coincides fairly well with the illite variations observed mainly from the upper Miocene to the Quaternary. Just like clay minerals (Turekian, 1965; Gillette, 1974, 1981; Blifford and Gillette, 1971; Gillette and Walker, 1977), quartz associated with the fine-grained fraction is often considered to be the result of eolian phenomena. Consequently, the relative abundances of these mineral assemblages (quartz, illite, chlorite) could add to the information on climatic modifications, as in the example given by Janecek and Rea (in press) for the Pacific during the Cenozoic. This assemblage could also indicate, in this part of the Atlantic, dry and continental desert periods. In accordance with the assumptions of Janecek and Rea, there existed two dry periods: a less humid period in the late Oligocene (quartz abundant in Holes 558 and 558A) and a distinctly arid period in the Miocene and accentuated in the Pliocene and Pleistocene (quartz, illite, and chlorite are abundant).

ACKNOWLEDGMENTS

Special thanks are extended to H. Bougault for providing the samples analyzed. The manuscript has benefited from critical reviews by G. Chennaux and A. Desprairies. This investigation has been funded by the Action Thematique Programmée, Géologie et Géophysique des Océans.

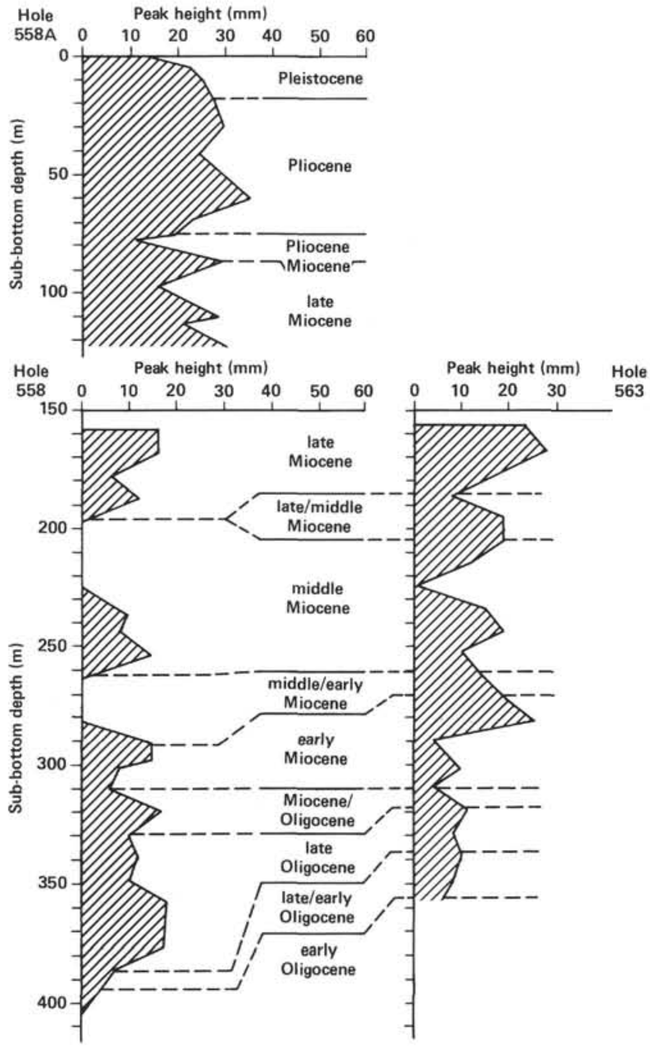

Figure 4. Quartz-associated with fine-grained (<2 μm) fraction. Identical analysis conditions were applied to all samples. (Peak at 4.24 Å.)

REFERENCES

Blifford, I. H. J., and Gillette, D. A., 1971. Applications of the log normal frequency distribution of the chemical composition and size distribution of naturally occurring atmospheric aerosols. *Water, Air, Soil Pollution*, 1:106-114.

Brown, G., 1961. *The X-ray Identification and Crystal Structures of Clay Minerals:* London (Mineralogical Society).

Chamley, H., 1979. North Atlantic clay sedimentation and paleoenvironment since the late Jurassic. *In* Talwani, M., and Ryan, W. B. F. (Eds.), *Deep Drilling Results in the Atlantic Ocean: Continental Margins and Paleoenvironments:* Washington (Am. Geophys. Union), pp. 342-361.

Chamley, H., Debrabant, P., Foulon, J., Giroud d'Argoud, G., Latouche, C., Maillet, N., Maillot, H., and Sommer, F., 1979. Mineralogy and Geochemistry of Cretaceous and Cenozoic Atlantic sediments off the Iberian Peninsula (Site 398, D.S.D.P. Leg 47B). *In* Sibuet, J.-C., Ryan W. B. F., et al., *Init. Repts. DSDP*, 47, Pt. 2: Washington (U.S. Govt. Printing Office), 429-449.

Chennaux, G., Esquevin, J., Jourdan, A., Latouche, C., and Maillet, N., in press. X-ray mineralogy and mineral geochemistry of Cenozoic strata (Leg 80). *In* Graciansky, P. C., de Poag, C. W., et al., *Init. Repts. DSDP*, 80: Washington (U.S. Govt. Printing Office).

Courtois, C., and Chamley, H., 1978. Terres rares et minéraux argileux dans le Cretacé et le Cénozoique de la marge atlantique ori-

entale. *C. R. Hebd. Seances Acad. Sci.* (Paris), t. 286, Ser. D: 671–674.
Gillette, D. A., 1974. On the production of soil wind erosion aerosols having the potential for long range transport. *J. Rech. Atmospheriques*, 8:735–744.
________, 1981. Production of dust that may be carried great distances. *In* Péwé, T. L. (Ed.), *Desert Dust: Origin, Characteristics and Effect on Man*. Spec. Pap. Geol. Soc. Am., 186:11–26.
Gillette, D. A., and Walker, T., 1977. Characteristics of airborne particles produced by wind erosion of sandy soil, high plains of west Texas. *Soil Sci.*, 123:94–110.
Griffin, J. J., Wondom, H., and Goldberg, E. D., 1968. The distribution of clay minerals in the world ocean. *Deep-Sea Res.* (Oxford), 15:433–459.
Grousset, F., Latouche, C., and Maillet, N., 1983. Clay minerals as indicators of wind and current contribution to postglacial sedimentation on the Azores-Iceland Ridge. *Clay Miner.*, 18:65–75.
Janecek, T. R., and Rea, D. K., in press. Eolian deposition in the northeast Pacific Ocean: Cenozoic history of atmospheric circulation. *Geol. Soc. Am. Bull.*
Latouche, C., 1975. Les minéraux argileux des sédiments actuels de l'Atlantique nord-oriental et du sud de la Mer de Norvège. *Proc. Internat. Clay Conf.* (Mexico, July 16–23): Wilmette, Illinois (Applied Publ. Ltd.), pp. 45–54.
Latouche, C., and Maillet, N., 1979. X-ray mineralogy studies, Leg 48, Rockall Region (Sites 403, 404, 405 and 406). *In* Montadert, L., Roberts, D. G., et al., *Init. Repts. DSDP*, 48: Washington (U.S. Govt. Printing Office), 665–676.
________, 1980. Minéraux argileux et évolution des environnements sédimentaires du domaine atlantique nord-oriental durant le Paleogène. *Bull. Soc. Geol. Fr.*, 22(5):757–761.
________, 1982. Essai sur l'utilisation des argiles comme temoins des climats néogènes dans la province atlantique nord-orientale. *Bull. Soc. Geol. Fr.*, 24(3):482–496.
________, in press. X-ray mineralogy study of Tertiary deposits, Leg 81 (Sites 552, 553, 554, and 555). *In* Roberts, D. G., Schnitker, D., et al., *Init. Repts. DSDP*, 81: Washington (U.S. Govt. Printing Office).
Millot, G., 1964. *Géologie des Argiles:* Paris (Masson et Cie), p. 499.
Paquet, H., 1969. Evolution géochimique des minéraux argileux dans les altérations et les sols des climats méditerranéens et tropicaux à saisons contrastées. *Mem. Serv. Carte Geol. Alsace Lorraine*, 30: 1–212.
Roberts, D. G., and Montadert, L., 1979. Margin paleoenvironments of the northeast Atlantic. *In* Montadert, L., Roberts, D. G., et al., *Init. Repts. DSDP*, 48: Washington (U.S. Govt. Printing Office), 1099–1118.
Sarnthein, M., and Erlenkeuser, H., 1982. Termination I: the response of continental climate in the subtropics as recorded in deep-sea sediments. Actes Colloque Internat. C.N.R.S. (Bordeaux, Sept. 1981), *Bull. Inst. Geol. Bassin d'Aquitaine* (Bordeaux), 31:393–497.
Tardy, Y., 1969. Géochimie des altérations. Etudes des arènes et des eaux de quelques massifs cristallins d'Europe et d'Afrique. *Mem. Serv. Carte Geol. Alsace Lorraine* (Strasbourg), 31:1–199.
Thorez, J., 1975. *Phyllosilicates and Clay Minerals. A Laboratory Handbook for Their X-ray Diffraction Analysis*: Dison (G. Le Lotte).
Torre de Assunçâo, C., and Garrido, J., 1953. Tables pour la détermination des minéraux au moyen des rayons X. *Bull. Musee Lab. Mineral. Geol. Fac. Sci. Lisbonne*, Ser. 6, no. 20–21.
Turekian, K., 1965. Some aspects of the geochemistry of marine sediments. *In* Riley, J. P., and Skirrow, G. (Eds.), *Chemical Oceanography*, Vol. 2: London (Academic Press), 81–126.
Vergnaud Grazzini, C., Pierre, C., and Létolle, R., 1978. Paleoenvironment of the northeast Atlantic during the Cenozoic: oxygen and carbon isotope analyses at DSDP Sites 398, 400A and 401. *Oceanol. Acta*, 1(3):381–390.
Yeroschev-Shak, V. A., 1964. Clay minerals of the Atlantic Ocean. *Soviet Oceanogr.* (Moscow/Washington), 30-2:90–106.

Date of Initial Receipt: 2 December 1983
Date of Acceptance: 20 April 1984