10. MINERALOGY OF CENOZOIC SEDIMENTS CORED DURING DEEP SEA DRILLING PROJECT LEG 79 AS DETERMINED BY X-RAY DIFFRACTION[1]

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INTRODUCTION

Four sites in the region of the Mazagan Plateau off northwest Africa were drilled during Leg 79 of the Deep Sea Drilling Project. Bulk mineralogy and clay mineralogy were analyzed from the Cenozoic sediments recovered from the four sites.

METHODS

Eighty-eight sediment samples from six boreholes were examined by semiquantitative X-ray diffraction (XRD) methods (see Mann and Müller, 1980). Carbonate contents were determined by the "Karbonat-Bombe" method (Müller and Gastner, 1971) and clay minerals were X-rayed after carbonate was removed with dilute acetic acid.

RESULTS AND DISCUSSION

Site 544

Site 544 is located in a water depth of approximately 3581 m on the northwest flank of a structural high from which granitic fragments had been dredged during a presite survey.

Five lithological units were described by the shipboard scientific party: I, foraminiferal-nannofossil ooze of Pleistocene to early middle Miocene age; II, clayey foraminiferal nannofossil ooze of early Miocene age; III, pale reddish brown limestone of Middle to Late Jurassic age; IV, grayish red to moderately red-orange calcareous sandy mud (IVA) underlain by mudstone (IVB) and poorly sorted sandy gravel (IVC) on pinkish gray granitic gneiss (IV).

We have analyzed only the samples of Unit I, Holes 544A and 544B (0–102 m; Pleistocene to early middle Miocene). They belong to the clayey foraminiferal-nannofossil ooze suite. Calcium carbonate is the main constituent (≥65%, except for Sample 544A-3-2, 110–112 cm; see Table 1) with minor detrital minerals (quartz, feldspar, clay minerals). All samples contain small amounts of tiny clear dolomite crystals. Quartz is usually rounded and some samples contain minor amounts of opaques (pyrite?) or hydrous Fe-minerals.

The clay mineral suite is dominated by illite, indicating a terrigenous supply, whereas the origin of the fibrous silicates palygorskite and sepiolite is unclear. Chamley et al. (1980) ascribe the fibrous clays in sediment samples from the Moroccan coast to the presence of alkaline marginal basins where they were formed and later redeposited in turbidites off the African continent. A notable feature in some samples was the shape of the fibers that obviously were broken during transport. Electron optical investigation of the Leg 79 fibrous clays also could help in elucidating their origin.

Site 545

Site 545 is located in a water depth of 3142 m at the foot of the Mazagan Escarpment. The "target" was Mesozoic sediments that were reached 252 m sub-bottom. They consist of Cenomanian to Aptian green pelagic claystones that rest unconformably on Jurassic carbonates (skeletal intraclast grainstones, packstones, wackestones with algal fragments, echinoderms, benthic foraminifers, and bivalves) of shallow water origin. The lowermost 66 m consist of dolomitized sandy limestone with ammonites.

Our samples were confined to the upper 252 m (Units I and II). Unit I (0–181 m) was subdivided into Subunits IA (0–85.6 m; Pleistocene) and IB (85.6–181 m; middle Miocene to late Pliocene).

Subunit IA is described as muddy or clayey foraminiferal nannofossil ooze that was deposited above the foraminifer lysocline and is generally richer in terrigenous components than Pleistocene sediments of Site 544 (see Table 1). Terrigenous input, however, decreases downsection but increases again in the lower part of Subunit IB (Sample 545-19-4, 50–52 cm). This sample also contains volcanic glass in minor amounts.

Unit II (181–252 m; early to middle Miocene) is a green gray clayey nannofossil ooze/chalk, whose color points to a mildly reducing sedimentary environment. Consequently, pyrite is more abundant than in Unit I, and glauconite is a typical constituent. All samples (except Sample 545-21-1, 130–132 cm) contain up to 7% dolomite; some crystals exhibit zoning (Sample 545-27-3, 83–84 cm). In the same sample there are also pyritized discoasters.

Illite again is the main clay mineral with smectite present sometimes only in minor amounts (especially in the lower part of Unit II) or not detectable. In nearly all samples mixed-layer minerals (illite and chlorite/smectite) and again fibrous clays (palygorskite ± sepiolite) could be found. Clay minerals in the upper part of Subunit IB and in the lowermost part of Unit II are poorly crystallized.

Site 546

Site 546 was drilled in a water depth of 3958 m on a structural high that supposedly was either a fault block

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[1] Hinz, K., Winterer, E. L., et al., *Init. Repts. DSDP*, 79: Washington (U.S. Govt. Printing Office).
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Table 1. Mineralogy of Leg 79 sediments analyzed by X-ray diffractometry.

		Bulk mineralogy (100%)							Clay mineralogy (100%)							
Litho-logical Unit/ Subunit	Sample (interval in cm)	Clay minerals and amorphous materials	Quartz	Feldspar	Calcite	Dolomite	Halite	Others	Smectite	Illite	Kaolinite	Chlorite	Chlorite and Kaolinite[a]	Sepiolite	Paly-gorskite	Others
Hole 544A																
I	1-3, 30–32	9	9	2	73	2	4		3	78	6	9		3		ML? Gyp.
	3-2, 110–112	44	7	2	43	1	3		15	58	6	13		8	?	ML? Gyp.
	4-2, 50–52	12	8	3	70	3	3		9	50	17	12		5	7	ML? Gyp.
	5-1, 130–132	14	11	4	65	3	4		6	69	11	10		2	2	ML? Gyp.
	6-4, 35–37	18	7	—	69	2	3		6	74	13	10		4	3	ML?
	7-2, 80–82	15	7	—	68	5	5		11	58	12	16		3	m	ML?
	8-2, 50–52	12	7	2	71	5	2		8	69	9	11		m	3	
	9-2, 50–52	9	8	2	69	5	7		8	56	11	12		7	6	ML? Gyp.
	10-3, 70–72	10	7	1	73	4	6		2	92			4		2	
Hole 544B																
I	1-2, 20–22	7	11	3	69	3	8		6	73	7	14		?		ML?
	2-2, 102–104	13	12	3	63	3	5	Apa. 1	9	64	11	14				ML?
	3-1, 110–112	14	14	2	68	2	6		7	70	10	13				
	4-1, 140–142	13	13	4	64	3	4		8	65	9	12			6	
	5-2, 41–43	10	14	4	64	2	6		5	73	10	12		m	m	ML?
	6-3, 52–54	15	7	2	70	2	4		4	73	11	12				
	7-2, 89–90	8	6	1	77	3	4		4	71	11	14		?	m	ML?
	8-2, 60–62	11	5	1	77	3	3		5	65	12	12			6	ML?
	9-2, 100–102	12	7	2	74	3	3		2	57	12	12			6	
	10-1, 90–91	8	8	2	76	3	2		2	76	11	11			m	
	11-1, 70–72	15	9	3	70	3	—		2	69	14	12			3	
	12-2, 29–31	8	10	3	70	5	4		1	65	13	18			3	
Hole 545																
IA	2-3, 58–60	40	14	4	35	3	4		4	64	12	14		?	6	ML?
	3-2, 58–60	42	13	4	33	4	4		4	63	10	14		5	4	ML? Gyp.
	4-1, 30–32	11	18	4	52	6	18		29	48	9	10		2	2	ML
	8-4, 50–52	21	14	4	54	3	4		—	58	10	16			6	ML
IB	10-2, 98–100	2	12	4	69	7	6		—	79	7	10			4	ML
	11-2, 20–22	7	8	—	76	5	4		9	66	9	10			4	ML? Gyp.
	12-4, 25–27	10	10	?	71	4	5		m	31	9	16				ML
	13-6, 50–52	7	7	—	77	3	5		5	73	11	11		?		ML
	14-4, 50–52	6	9	2	77	2	4		14	57	8	11			?	ML
	15-1, 53–55	24	13	2	57	4	—		9	74	8	9			?	ML
	19-4, 50–52	24	12	4	52	4	4		4	61	13	16			6	ML
II	20-1, 59–61	11	5	—	77	3	4		5	79	4	9			3	ML
	21-1, 130–132	17	5	—	75	—	3		20	64	7	7			?	ML
	23-4, 140–142	23	5	2	65	2	3		pr	76			14		10	ML
	24-2, 15–17	20	9	2	60	5	5		pr	74	5	16			5	ML
	26-3, 72–74	33	11	2	43	4	5	Pyr. pr	pr	91			9		?	ML
	27-1, 70–72	17	14	3	50	5	9	Pyr. 2	pr	88			12		?	ML
	27-3, 83–85	42	15	2	27	7	2	Pyr. pr	pr	84			11		5	ML
Hole 546																
I	1-1, 77–79	35	20	3	38	2	2	Pyr. pr	?	66	8	21			5	
	2-2, 75–77	29	15	6	45	3	2	Pyr. 2	?	69	8	18			5	
	3-2, 100–102	18	7	2	69	2	2		?	76	7	17				ML?
	4-2, 75–77	18	7	2	67	2	4		4	62	17	17			?	ML?
	6-2, 130–132	25	17	3	49	2	4	Pyr. pr	pr	65	12	23				ML
	7-3, 10–12	35	13	3	40	2	7		pr	79	5	16				ML?
	8-4, 10–12	10	12	4	62	4	7		4	80	4	12				ML
	9-1, 10–12	14	10	3	62	5	6		2	72	10	18				ML?
	10-1, 10–12	24	10	2	55	2	7		7	80	7	6				ML
	11-1, 10–12	21	8	3	58	3	7		8	65	18	17				
	12-2, 100–102	18	6	2	67	3	4		2	75	6	12				ML?
	13-2, 100–102	10	6	2	68	3	11		7	72	10	11				
	14-2, 50–52	12	6	2	65	3	12		—	76			24			
II	16-2, 14–16	7	8	3	60	17	5		—	84	16					
	16-2, 33–35	7	8	2	63	12	8		—	86			14			
	16-2, 39–41	50	22	1	14	7	6	Pyr. 2	—	39	61					
	16-2, 50–52	27	17	3	40	5	8		—	92			8			
Hole 547																
	1-2, 30–32	33	18	5	35	4	5		?	88			12			
Hole 547A																
I	1-2, 33–35	18	16	4	52	3	7			76	10	14				
	2-4, 50–52	27	15	3	49	3	3			75	10	15				
	3-1, 37–39	23	10	3	56	2	6		4	78	6	12				ML?
	5-4, 50–52	13	9	2	71	2	4		3	79	10	8				ML?
	6-2, 25–27	19	9	3	64	2	4		4	75	7	7			7	ML
	7-1, 40–42	12	5	3	74	3	3		4	73	13	10			?	ML?
	8-3, 57–59	17	7	2	68	2	4		?	86	7	7		?		
IIA	8-4, 90–94	19	7	2	67	2	3		7	81	5	7				ML?
	8-5, 57–59	18	10	2	62	3	4		15	63	12	10				ML?
	9-2, 50–52	14	8	—	68	4	7		21	51			19		9	
	10-2, 50–52	13	8	2	71	2	4		10	77			11		2	ML?
	11-2, 50–52	14	7	2	68	4	5		6	71	7	14				
	12-2, 50–52	12	4	1	77	2	4		15	59	5	7			4	ML?
	13-2, 50–52	6	10	2	75	3	5		22	64	7	7			?	
	14-4, 86–88	19	8	1	65	2	4		31	58		6			5	
	15-1, 10–12	19	12	—	62	3	4		30	62		4			4	

of continental crust or a salt structure. At 155.5 m subbottom the *Glomar Challenger* cored banded halite, which is the third and lowermost sedimentary unit of Site 546.

Samples of Unit I and the upper part of Unit II were analyzed with the XRD. The lower part of Unit II (below Core 546-17) was described by the shipboard scientists as claystone with gypsum-rich layers.

Samples of Unit I (0–125.7 m; Pleistocene to late Miocene) consist of clayey to slightly clayey foraminiferal nannofossil ooze. They are relatively rich in detrital min-

Table 1. (Continued).

Litho-logical Unit/ Subunit	Sample (interval in cm)	Bulk mineralogy (100%) Clay minerals and amorphous materials	Quartz	Feldspar	Calcite	Dolomite	Halite	Others	Clay mineralogy (100%) Smectite	Illite	Kaolinite	Chlorite	Chlorite and Kaolinite[a]	Sepiolite	Paly-gorskite	Others
Hole 547A (Cont.)																
IIB	16-2, 70–72	36	7	1	48	5	3		46	45		4			5	
	17-2, 70–72	37	16	2	40	3	3		56	38		4			2	
III	19-1, 47–49	50	8	2	30	8	2		89	8			2		1	
	19-1, 109–111	26	18	2	47	4	2		?	96	1	3			?	ML?
	19-2, 23–25	12	6	1	70	6	5		?	41	3			33	23	
	20-1, 99–101	34	7	—	50	6	3		94	4	1				1	
	20-3, 80–82	24	6	3	55	7	5		83	15	2					2 Dolom. var
	21-2, 100–102	9	16	2	63	6	4		?	67			2			
	21-4, 100–102	70	7	?	21	2	0		96		4					
	22-2, 62–66	18	4	3	62	8	5		?	40			6	21	33	
IVA	23-2, 100–102	30	2	2	52	3	5	Opal-CT 6	11	25				14	40	
	24-1, 119–121	31	2	—	58	1	3	Opal-CT 5	94	16				34	6	
	25-4, 20–22	19	1	—	73	2	4	Opal-CT 1	38	18				39	5	
	26-1, 42–44	54	3	—	36	1	2	Opal-CT 5	100					?		
	27-2, 100–102	41	3	1	36	11		Opal-CT 5	100						pr.	2 Dolom. var

Note: Apa. = Apatite; Gyp. = gypsum; m = minor; ML = mixed-layer mineral; Pyr. = pyrite; — = not detected; pr = is present.
[a] Not separated due to small amounts.

erals (mainly quartz, some feldspar; see Table 1), and again palygorskite is a constituent of the clay fraction, but could not be positively identified below Core 546-2. Smectite is scarce to absent in this part of the sedimentary column, but occurs in early Pleistocene to Pliocene samples that also are characterized by low contents of terrigenous material, the latter gradually decreasing from Core 546-8 (middle Pliocene) to Core 546-14 (late Miocene) with quartz (12–6%), feldspar (4–2%), and very few clay minerals.

Sample 546-2-2, 75–77 cm contains measurable quantities of pyrite that is probably due to the presence of pyritized burrows (see site report, this volume).

Unit II (125.7–155.5 m; middle Miocene) comprises greenish and reddish brown calcareous sediments and grayish red claystone, the latter being richer in detrital minerals and the former showing increased dolomite percentages, possibly due to diagenesis under the influence of highly saline pore waters that are derived from the underlying salt (see site report, this volume). High values for halite were found in two samples *above* the dolomite-rich part of Unit II (see Table 1). A characteristic component of the clay fraction in both types of sediments is kaolinite, which is the main clay mineral in Sample 546-16-2, 39–41 cm and is well crystallized here. Kaolinite also was found as a major constituent in clays interlayered with the halite of Unit III (see site report, this volume).

Reworking is indicated by the occurrence of Cretaceous microfossils and mixing of various lithologies (Section 546-16-2).

Site 547

Site 547 (water depth 3938 m) is located on the northeastern flank of the granitic gneiss block of Site 544.

Three holes were drilled. The 1030-m sedimentary sequence is divided into seven units (we analyzed samples of Unit I to Subunit IVA).

Unit I (0–141.1 m; Pleistocene to late Miocene) is a pale yellowish brown clayey foraminiferal nannofossil ooze, which is rich in detrital minerals in its upper part (see Table 1).

The main component is calcite; minor amounts of dolomite occur throughout Unit I. Again, as at the previous sites, illite dominates the clay fraction, whereas smectite is absent in the Pleistocene samples but present in Pliocene and Miocene samples with an illite/smectite mixed-layer minerals (± palygorskite).

Subunit IIA (141.1–204.3 m; early Miocene to middle Miocene) comprises a greenish gray, slightly clayey nannofossil ooze and has a composition similar to that of Unit I; however, the feldspar contents are sometimes below the detection limit of XRD (~1% in carbonate-rich samples). Microscopic investigations—also by shipboard scientists—showed quartz (+ feldspar) to be rare, but samples examined with the XRD yielded higher percentages of both.

Siliceous biogenetic debris (radiolarians) have been found in Cores 547-13 and 547-14 of middle Miocene age.

Subunit IIB (204.3–225.7 m; late Eocene–early Oligocene) has a thickness of 21.4 m and is separated by an unconformity with Subunit IIA. It is also a clayey nannofossil ooze to nannofossil clay, but is somewhat finer and less bioturbated.

The two samples from this unit (Samples 547A-16-2, 70–72 cm; 547-17-2, 70–72 cm) yielded less carbonate, but higher contents of pyrite, partly as overgrowths of radiolarians (547A-17-2, 70–72 cm). Some dolomite crystals exhibit zoning.

In the lower part of Subunits IIA and IIB smectite becomes an important constituent of the clay mineral suite. Kaolinite could not be detected, its absence probably reflecting a different climate and sedimentary environment in the hinterland at that time (Eocene/Oligocene to early Miocene).

Unit III (225.7–279.0 m; late Eocene) is a conglomeratic sequence of debris flows. The "matrix" consists of light olive-gray clayey nannofossil claystone, clayey nannofossil (± foraminiferal) chalk, and porcellanite.

Sample 547A-19-1, 47–49 cm is a smectite-rich calcareous claystone with only minor illite contents. Sample 547-19-1, 109–111 cm is a clayey nannofossil chalk for which illite is again the main clay mineral. Sample

547A-19-1, 47–49 cm is richer in opaques and dolomite; the latter also contains pyrite inclusions.

Sample 547A-19-2, 23–25 cm, a clayey nannofossil chalk, is characterized by a relatively high content of fibrous clays.

Samples 547A-20-1, 99–101 cm and 547A-20-3, 80–82 cm are clayey nannofossil chalks with $CaCO_3$ contents of 50–55%, respectively. Opaques (pyrite) and clay minerals are more abundant in Sample 547A-20-1, 99–101 cm, and dolomite again has pyrite inclusions.

Sample 547A-21-2, 100–102 cm, once again a clayey nannofossil chalk, is from a clast-free interval of Unit III.

Sample 547A-21-4, 100–102 cm is a calcareous claystone.

Subunit IVA (279.0–364.5 m; early Paleocene to early Eocene), a (mostly hemipelagic) clayey nannofossil chalk to nannofossil claystone (Cores 547A-26 and 547A-27), is characterized by high smectite contents and the occurrence of opal-CT ± fibrous clays, which in this interval are most probably authigenic. Porcellanite and chert have been noted during core descriptions by the shipboard scientists.

The other units (below 326 m sub-bottom) were not examined.

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