22. X-RAY MINERALOGY OF SEDIMENTS, DSDP LEG 38

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INTRODUCTION

Semiquantitative determinations of the mineral composition by X-ray are tabulated on the core forms in the appropriate Site Report Chapters and Tables 1-4 (this paper) as reported by the laboratories of the Phillips and British Petroleum companies. Analytical procedures and method of data reporting are summarized in the discussion to follow.

TABLE 1
Clay Mineralogy (X-Ray), Sites 338, 340, and 341

Sample (Interval in cm)	Montmorillonite	Illite	Kaolinite	Chlorite
Site 338				
7-1, 122-124	18	45	21	17
8-4, 80-82	16	38	22	24
9-1, 80-82	20	47	20	13
10-2, 128-130	27	44	17	12
11-4, 133-135	22	48	15	15
12-3, 70-72	19	51	17	13
13-4, 70-72	15	59	12	14
14-3, 89-91	32	44	13	12
15-6, 79-81	28	36	36	
16-6, 79-81	40	25	19	16
17-4, 79-81	40	20	21	19
18-2, 129-131	34	24	25	16
19-5, 119-121	49	42	9	
28-2, 102-104	P ml?	Tr	a	
29-3, 24-26	P ml?	Tr	a	
30-2, 106-110	P	Tr	a	
30-5, 1-3	P	Tr	a	
31-2, 128-130	43	35	22	
32-2, 86-88	42	38	6	14
33, CC	28	45	8	19
34, CC	33	38	29	
34, CC	81	19	Tr	
35-2, 86-88	30	46	24	
36-1, 125-127	Tr ml?	55	45	
37-2, 108-110	18	58	2	22
38-1, 49-51	83	11	3	3
39-1, 129-131	28	55	6	11
40-1, 63-65	76	11	5	8
41-2, 75-77	66	25	3	6
42-1, 80-82	82	13	2	3
Site 340				
2-2, 80-82	P	-	-	-
3-2, 130-132	P	-	-	-
4-2, 80-82	P	-	-	-
5-2, 80-82	P	-	-	-
6-2, 80-82	P	-	-	-
7-1, 71-73	P	Tr	Tr	
8-3, 80-82	P	Tr	Tr	
9-1, 80-82	P	Tr	Tr	
10-5, 80-82	P	Tr	Tr	
11-4, 50-52	P	Tr	Tr	

TABLE 1 – *Continued*

Sample (Interval in cm)	Montmorillonite	Illite	Kaolinite	Chlorite
Site 341				
26-4, 100-102	26	39	22	13
26-5, 100-102	30	35	21	14
26-6, 100-102	20	46	20	14
27-6, 50-52	31	33	20	16
28-3, 50-52	33	37	17	13
28-6, 50-52	44	29	13	14
29-6, 79-81	22	36	42	
30-5, 98-100	42	25	18	14
31-5, 65-67	36	34	15	15
32-5, 80-82	32	38	17	13
33-6, 68-70	25	39	18	18
34-3, 64-66	32	30	20	18

Note: Determined by British Petroleum Laboratories. P = present (abundant); Tr = trace; a = absent; ml = mixed layer of montmorillonite/illite. Percentages quoted are of the clay mineral component only, not of the total sediment composition.

British Petroleum Co. Data (Sites 338, 340, 341, and 343 to 345)

Preparation

Three groups of clay minerals (term restricted to phyllosilicates in the <5μm fraction) are relatively easily identified by X-ray diffraction from their basal (00*l*) spacings. These are montmorillonites, illites, kaolinites, and chlorites. Biscaye's (1965) method was used to determine the relative abundance of these groups. A fourth group of clay minerals, the mixed-layer clays, can also be recognized, although there is not a satisfactory method for determining its relative abundance.

The diagnostic basal reflections are enhanced by the preparation of slides of oriented clays from aqueous suspensions of clay minerals. Leg 38 samples consisted almost exclusively of muds. These were first dry ground to a very fine powder, and then ground further in a very weak solution of dispersing agent using a "micronizing" mill. Each suspension was allowed to settle for 36 min after which a volume was extracted from a depth of 5 cm. This sample, representing the <5μm fraction, was spread onto three glass slides and air dried. One slide was then heated at 550°C for 3/4 hr, while a second was placed in ethylene glycol vapor for at least 12 hr. The third slide was retained in an untreated state. Each of the slides was subsequently examined on a diffractometer over the range 3.5° 2Θ to 30° 2Θ. This preparation method can lead to the preferential concentration of clay minerals, particularly montmorillonite. This enhancement is unavoidable but is probably most

TABLE 2
X-Ray Mineralogy, Sites 343, 344, and 345[a]

	Clay Minerals ($<5\ \mu$m)[b]					Other Components ($<5\ \mu$m)[b]			
Sample (Interval in cm)	Mont. (%)	Illite (%)	K/C (%)	Kaol.	Chlor.	Quartz	Micas	Plag.	Other Minerals
Site 343									
2-3, 7-9	22	40	37	16	21	A	P	A	Calcite (P)
2-4, 38-40	20	50	28	15	13	A	P	P	Orthoclase (P) Calcite (Tr)
3-5, 81-83	74	13	11			A	P	P	
4-3, 19-21	17	25	56	28	28	A	P	P	Calcite (P)
5-2, 74-76	63	32	18			P	P	P	
6-0, 129-131	P	a	a	a	a	Tr	a	a	
7-1, 120-122	73	2	23	11	11	P	Tr	P	Dolomite (Tr?)
11-2, 40-42	12	32	55	19	36	A	P	P	Dolomite (Tr?)
15-2, 39-41	a	77	22			A	P	P	
15-2, 86-88	13	8	77			P	P	Tr	
16-3, 24-26	81	13	5			A	P	Tr	
16-1, 146-148	79	2	18	8	10	P	Tr	a	Calcite (Tr)
Site 344									
2-2, 70-72	30	28	40	16	24	A	P	P	
3-3, 110-112	19	40	40	18	22	A	P	P	
5-3, 110-112	34	30	35	18	17	A	P	P	
6-3, 90-92	29	36	34	17	17	A	P	P	Dolomite (Tr)
7-4, 86-88	22	42	34	16	18	A	P	P	Orthoclase (Tr) Calcite (Tr?)
8-4, 49-51	24	28	47	23	24	A	P	Tr	
9-3, 68-70	17	37	44	19	25	A	P	P	Orthoclase (Tr)
10-3, 19-21	31	48	19	9	10	A	P	P	
12-3, 49-51	41	31	27	13	13	A	P	P	Calcite (Tr?)
13-1, 50-52	25	43	31	14	17	A	P	P	Calcite (Tr?)
14-1, 50-52	39	31	28	11	17	A	P	A	
15-3, 50-52	45	31	22	11	11	A	P	P	
16-2, 50-52	34	35	29	14	15	A	P	P	Dolomite (Tr)
17-1, 50-52	15	62	21	5	16	A	P	A	Dolomite (Tr)
18-1, 50-52	59	25	15	7	7	A	P	P	Gypsum (Tr?)
18-1, 60-62	40	19	40	20	20	A	P	P	
21-2, 50-52	48	33	17	8	9	A	P	P	
23-2, 50-52	54	27	17	7	10	A	P	P	Orthoclase (Tr) Calcite (Tr)
24-1, 120-122	65	26	8	4	4	A	P	P	
25-1, 70-72	42	33	23	10	13	A	P	P	Siderite (Tr?)
26-1, 140-142	42	11	31	14	17	A	P	P	Dolomite (Tr?)
27-2, 90-92	48	43	39	20	19	A	P	P	
28-2, 50-52	26	40	30	13	17	A	P	P	Calcite (Tr?)
31-3, 83-85	ml	40	60	24	36	A	P	P	
32-2, 78-82	ml	43	57			A	P	P	
33-2, 65-67	ml	34	65			A	P	P	
Site 345									
1-2, 110-112	14	53	33	15	18	A	P	P	Siderite (Tr?) Orthoclase (Tr) Calcite (P) Dolomite (Tr)
2-3, 10-12	18	45	36	16	20	A	P	Tr	Siderite (Tr)
3-2, 55-57	12	47	40	16	24	A	P	P	Calcite (P)
4-2, 74-76	6	40	53	20	33	A	P	P	
5-2, 119-121	36	14	49	25	24	A	P	P	
6-2, 12-14	45	13	41	25	16	P	P	a	
7-2, 59-61	36	20	43	22	21	A	P	Tr	
8-3, 75-77	29	38	32	16	16	A	P	Tr?	Siderite (Tr)
9-3, 74-76	47	21	31	16	15	A	P	Tr?	Siderite (Tr)?
10-3, 89-91	28	37	34	17	17	P	P	Tr	Siderite (Tr?)
11-3, 89-91	71	13	14	8	6	A	P	Tr	
14-3, 30-32	67	23	9	4	5	P	P	Tr	Gypsum (?)
16-4, 44-46	49	30	19	11	8	A	P	Tr	Calcite (Tr?)
17-3, 74-76	68	16	14	8	6	A	P	Tr	
19-2, 75-76	50	30	18	5	13	A	P	P	
20-3, 14-16	59	26	13	6	7	A	P	P	

TABLE 2 – *Continued*

Sample (Interval in cm)	Clay Minerals (<5 μm)[b] Mont. (%)	Illite (%)	K/C (%)	Kaol.	Chlor.	Other Components (<5 μm)[b] Quartz	Micas	Plag.	Other Minerals
21-3, 6-8	78	9	12	6	6	A	P	Tr	
22-3, 53-55	83	12	5			P	a	a	Siderite (A)
23-3, 88-90	87	8	3			A	P	Tr	
24-3, 124-126	86	8	4			A	P	Tr	
25-2, 42-44	35	28	35	17	18	A	P	Tr	
26-3, 57-59	83	16	a			Tr	Tr	a	
27-2, 78-80	75	17	6			A	P	Tr?	
28-2, 64-66	91	5	2			A	P	Tr	
28-2, 149-150	60	31	7			A	P	Tr	Gypsum (Tr)
30-4, 7-9	55	20	24	10	14	A	P	Tr	
30-5, 82-84	68	19	11			A	P	P	Calcite (Tr?)
31-3, 44-46	41	33	24	12	12	A	P	Tr	Dolomite (Tr?)
31-6, 2-4	85	6	7			A	P	Tr	
32-2, 123-125	89	8	1			P	Tr	Tr?	

[a]Determined by British Petroleum Laboratories

[b]Mont. = Montmorillonite, Kaol. = Kaolinite, Chlor. = Chlorite, Plag. = Plagioclase, K/C = kaolinite/chlorite, ml = mixed-layer of montmorillonite/illite, P = present, a = absent, A = Abundant, Tr = Trace. Percentages quoted are of the clay mineral component only, not of the total composition.

significant with samples which have >60% montmorillonite.

Identification

It is important to appreciate that clay minerals are not distinguished solely on d-spacings, but also by characteristic changes with different treatments. There are a number of problems associated with this method, particularly dealing with the distinction between kaolinite and chlorite, and the mixed-layer clays.

Calculation

Results have been calculated using Biscaye's (1965) method, which involves the use of a planimeter to calculate peak area measurements. These measurements (integrated intensities) are preferable to methods using only peak heights (model intensities). The intensity of the basal reflections is a function of relative abundance, chemical composition, and structural character of the clay minerals. All quantitative methods make assumptions about some of these variables, and therefore the percentages quoted can never be regarded as more than semiquantitative (Tables 1, 2).

Phillips X-ray data (Sites 346 to 349)

Bulk Samples

To determine bulk mineralogy, a representative aliquot of each sample was washed with distilled water to remove seawater, dried at room temperature, crushed to a fine particle size in a mortar and pestle, and prepared as a randomly oriented sample packing material in a standard aluminum holder prior to X-ray diffraction analysis. The concentration of mineral components of the bulk samples reported were based on the following criteria:

Trace (Tr): Diffraction pattern was weak and identification was made on the basis of two major diagnostic peaks.

Present (P): A number of peaks of the mineral are visible in the diffraction pattern.

Abundant (A): Diffraction peaks of the mineral are prominent in the total diffraction pattern, but the peaks of other minerals are of an equivalent intensity.

Major (M): The diffraction peaks of the mineral dominate the diffraction pattern.

The concentrations reported are relative and in no way reflect absolute quantities (Tables 3, 4).

<2μm fraction

The following procedure was used to obtain aliquots of the <2μm fraction of the samples for clay mineral analysis. Each sample was washed with distilled water to remove seawater and disaggregated by ultrasonic treatment. The sand fraction was removed by wet sieving through a 62μm (230 mesh) sieve and the <2μm fraction segregated by standard sedimentation methods. Each clay sample was mounted with a preferred orientation by vacuum filtering onto porous ceramic plates. Four X-ray diffraction patterns were obtained for each prepared slide: first, untreated at room temperature; second, after exposure to ethylene glycol vapor for 2 hr; third, after heating the glycolated slides at 375°C for 1/2 hr; and fourth, after heating the slides at 550°C for 1 hr.

Determination of the relative amounts of specific clay minerals in the <2μm fraction was made according to the technique devised by Biscaye (1965) using the following peaks and weighting factors: (1) the area of the 17Å glycolated peak for montmorillonite and mixed-layer clay; (2) four times (4×) the 10Å peak area (glycolated trace) for mica; (3) twice (2×) the 7Å peak for chlorite and kaolinite. The 7Å peak was divided between kaolinite and chlorite in proportion to the fraction of each mineral in the total area under the 3.5Å kaolinite-chlorite doublet. It is to be emphasized that the "percentages" reported reflect the method used in their determination, i.e., it is not implied that a concentration of 1% chlorite in a clay fraction can be detected and measured.

TABLE 3
X-Ray Diffraction Analysis of Samples from Sites 346, 347, 348, and 349: Bulk Samples[a]

Sample (Interval in cm)	Lithology[b]	Quartz	Plagio-clase	Pyrite	Mica	Kaolinite and/or Chlorite	Other Minerals[c]
Site 346							
1-3, 90-92	Sandy mud, mudstone	M	P	ND[d]	Tr	Tr	Calcite (P)
2-3, 59-61	Sandy mud, mudstone	M	P	ND	Tr	Tr	Calcite (Tr)
3-5, 39-41	Sandy mud, mudstone	M	P	ND	Tr	Tr	
4-3, 40-42	Sandy mud, mudstone	M	P	ND	Tr	Tr	
5-2, 30-32	Sandy mud, mudstone	A	A	ND	Tr	Tr	
6-3, 54-56	Sandy mud, mudstone	M	P	ND	Tr	Tr	
7-4, 140-142	Mud/sandy mud, mudstone	M	P	ND	Tr	Tr	
8-3, 30-32	Sandy mud, mudstone	M	P	ND	Tr	Tr	
9-4, 74-76	Sandy mud, mudstone	M	P	Tr	Tr	Tr	
10-3, 14-76	Sandy mud, mudstone	M	Tr	Tr	Tr	Tr	
11-3, 74-75	Sandy mud, mudstone	M	P	Tr	Tr	Tr	Calcite (Tr)
12-3, 73-75	Sandy mud, mudstone	M	P	ND	Tr	Tr	
13-2, 74-76	Mud/mudstone	M	P	ND	Tr	Tr	
14-2, 50-52	Sandy mud, mudstone	M	Tr	Tr	Tr	Tr	Clinoptilolite-heulandite (P)
14-3, 76-76	Sandy mud, mudstone	M	P	ND	P	P	
17-1, 71-73	Sandy mud, mudstone	M	P	Tr	P	P	
18-3, 50-52	Sandy mud, mudstone	M	P	ND	P	P	
19-1, 51-53	Sandy mud, mudstone	M	P	ND	P	P	
20-2, 96-98	Sandy mud, mudstone	M	P	ND	P	P	
Site 347							
1-2, 115-117	Mud/sandy mud, mudstone	M	P	ND	Tr	Tr	Calcite (P)
2-2, 97-99	Mud/sandy mud, mudstone	M	P	ND	P	P	
Site 348							
1-2, 40-42	Sandy mud, mudstone	M	P	ND	Tr	Tr	Calcite (P)
1-6, 120-122	Sandy mud, mudstone	A	P	ND	Tr	Tr	Calcite (A)
2-2, 40-42	Mud/sandy mud, mudstone	M	P	ND	Tr	Tr	Calcite (P)
3-3	Mud/sandy mud, mudstone	M	P	ND	P	P	
6-2, 104-106	Clay/claystone, mud/mudstone	M	P	ND	Tr	Tr	
7-3, 60-62	Mud/mudstone	M	P	ND	Tr	Tr	
8-3, 39-41	Mud/mudstone	M	P	Tr	Tr	Tr	
9-3, 50-52	Mud/mudstone	M	P	ND	Tr	Tr	
11-3, 60-62	Mud/mudstone	A	A	ND	ND	ND	
15-2, 50-52	Mud/mudstone	M	P	P	Tr	Tr	Gypsum (Tr)
16-3, 50-52	Mud/mudstone	M	P	P	Tr	Tr	
19-5, 20-22	Mud/mudstone	P	Tr	ND	ND	ND	Clinoptilolite-heulandite (P)
20-2, 50-52	Clay/Claystone	P	P	ND	ND	ND	
21-2, 124-126	Clay/claystone	A	P	ND	ND	ND	
24-3, 99-101	Mud/mudstone	M	P	Tr	P	Tr	
26-3, 29-31	Mud/mudstone	M	P	Tr	P	P	
27-2, 116-118	Mud/sandy mud, mudstone	M	P	Tr	P	Tr	
30-3, 48-50	Mud/sandy mud, mudstone	M	P	Tr	P	Tr	Gypsum (Tr)
Site 349							
1-3, 100-102	Sandy mud, mudstone	M	P	Tr	Tr	Tr	Calcite (P)
2-3, 50-52	Mud/sandy mud, mudstone	M	P	ND	Tr	Tr	Amphibole (Tr)?
3-2, 120-122	Mud/sandy mud, mudstone	M	P	ND	P	P	
4-1, 90-92	Sandy mud, mudstone	M	P	ND	P	P	
5-3, 80-82	Mud/sandy mud, mudstone	M	P	ND	P	P	

TABLE 3 – *Continued*

Sample (Interval in cm)	Lithology[b]	Quartz	Plagio-clase	Pyrite	Mica	Kaolinite and/or Chlorite	Other Minerals[c]
6-3, 50-52	Mud/sandy mud, mudstone	M	P	Tr	Tr	Tr	Clinoptilolite-heulandite (Tr)
9-2, 33-35	Sandy mud, mudstone	M	P	Tr	Tr	Tr	Clinoptilolite-heulandite (Tr) Amphibole (Tr)?
10-4, 62-64	Mud/mudstone	M	P	Tr	Tr	Tr	Clinoptilolite-heulandite (Tr) Amphibole (Tr)?
11-3, 59-63	Mud/sandy mud, mudstone	P	P	Tr	Tr	Tr	Clinoptilolite-heulandite (P)
12-5, 50-52	Mud/mudstone	P	P	Tr	Tr	Tr	Clinoptilolite-heulandite (Tr)
13-3, 118-120	Sandy mud/mudstone sand/sandstone	P	P	ND	Tr	Tr	Clinoptilolite-heulandite (Tr)?

[a]Determined by Phillips Petroleum Laboratories.

[b]From preliminary data of samples from Leg 38.

[c]Amphibole tentatively identified from a peak at 8.4Å.

[d]ND = Not Detected.

The percentages of montmorillonite layers in the mixed-layer clay, reported were estimated to the nearest tenth percentile by the method of Reynolds and Hower (1970). Those samples in which the expandable interlayer component exhibited moderate thermal stability are noted with an asterisk.

REFERENCES

Biscaye, P.E., 1965. Mineralogy and sedimentation of recent deep-sea clay in the Atlantic Ocean and adjacent seas and oceans: Geol. Soc. Am. Bull., v. 76, p. 803-832.

Reynolds, R.C., Jr., and Hower, J., 1970. The nature of interlayering in mixed-layer illite-montmorillonite: Clays Clay Minerals, v. 18, p. 25-36.

TABLE 4
X-Ray Diffraction Analysis of Samples from Leg 38: Clay Mineralogy of the < 2 μm Fraction[a]

	Relative Concentration of Clay Minerals, Percent					
Core-Section	Mica	Kaolinite	Chlorite	Mixed-Layer[b]	Other	Percentage of Montmorillonite Layers in Mixed-Layer Clay
Site 346						
1-3	44	12	12	32	–	60
2-3	28	20	12	40	–	50
3-5	32	9	9	50	–	50
4-3	34	8	7	51	–	70
5-2	5	–	–	93*	Kaolinite and/or chlorite (2)	60
6-3	15	5	4	76*	–	50
7-4	25	10	6	59	–	80
8-3	15	8	7	70	–	60
9-4	23	7	7	63*	–	60
10-3	29	11	9	51*	–	60
11-3	22	10	8	60*	–	70
12-3	22	9	8	61*	–	50
13-2	16	10	9	65*	–	70
14-2	17	6	6	71*	–	80
14-3	21	–	20	59	–	60
17-1	46	–	37	17	–	50
18-3	42	–	41	17	–	50
19-1	37	–	45	18	–	50
20-2	37	–	47	16	–	50
Site 347						
1-2	44	–	19	37	–	60
2-2	14	–	21	65	–	70
Site 348						
1-2	52	9	10	29	–	60
1-6	47	10	10	33*	–	60
2-2	46	8	8	38	–	60
3-3	42	10	14	34*	–	50
6-2	23	9	9	59*	–	50
7-3	30	9	8	53*	–	60
8-3	11	5	3	81*	–	60
9-3	24	9	6	61*	–	70
11-3	19	8	4	69*	–	50
15-2	15	9	3	78*	–	60
16-3	20	6	6	68*	–	60
19-5	–	–	–	–	Montmorillonite (100)	–
20-2	–	–	–	100	–	80
21-2	–	–	–	100*	–	80
24-3	9	4	4	83*	–	90
26-3	4	–	–	94*	Kaolinite and/or chlorite (2)	60
27-2	2	–	–	97*	Kaolinite and/or chlorite (1)	80
30-3	1	–	–	98*	Kaolinite and/or chlorite (1)	70
Site 349						
1-3	28	11	9	52	–	50
2-3	19	6	6	69	–	60
3-2	6	–	–	91*	Kaolinite and/or chlorite (3)	50
4-1	13	8	5	74*	–	70
5-3	23	10	9	58*	–	50
6-3	6	–	–	90*	Kaolinite and/or chlorite (4)	60
9-2	2	2	1	95*	–	90
10-4	6	2	2	90	–	80
11-3	–	–	–	99	Kaolinite and/or chlorite (1)	60

TABLE 4 – *Continued*

	Relative Concentration of Clay Minerals, Percent					
Core-Section	Mica	Kaolinite	Chlorite	Mixed-Layer[b]	Other	Percentage of Montmorillonite Layers in Mixed-Layer Clay
12-5	4	–	–	94*	Kaolinite and/or chlorite (2)	60
13-3	6	–	–	92*	Kaolinite and/or chlorite (2)	80

[a]Determined by Phillips Petroleum Laboratories.

[b]Samples with an asterisk contain an expandable interlayer component of moderate thermal stability.