13. X-RAY MINERALOGY OF SEDIMENTS RECOVERED DURING DSDP LEG 65[1]

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INTRODUCTION

During Leg 65, four sites were drilled near the mouth of the Gulf of California where high sedimentation rates made it possible to sample young oceanic crust near the ridge crest. The oldest sediments cored were upper Pliocene siltstones (Site 483); the samples at the other sites (482, 484, and 485) were all Quaternary in age. A series of 80 sediment samples, most of them hemipelagic clays, were examined by semiquantitative X-ray diffraction and Carbonate Bomb techniques to determine their mineralogy and carbonate contents (Table 1). The results of this study may be used to determine their provenance and diagenesis.

METHODS

The methods used were essentially those described in Mann and Müller (1980). They consist of measuring the peak heights or areas of X-ray diffraction peaks associated with individual minerals and relating these to the percentages present. Carbonate contents have been determined by the "Karbonat-Bombe" method of Müller and Gastner (1971).

Most of the bulk samples contained gypsum (up to ~10 percent), which probably developed during transport and storage from Fe-sulfides and calcite. Gypsum was not taken into consideration in computing the percentages of the minerals present.

RESULTS

Site 482 (Fig. 1)

A total of seven holes were drilled at Site 482 in an attempt to drill a deep hole in the basement. The site is located on 0.5-m.y.-old crust about 12 km east of the axis of the East Pacific Rise and 15 km south of its intersection with the Tamayo Fracture Zone in 3 km of water.

The sediments overlying the basement are about 150 meters thick. Those in the upper part (0–84 m sub-bottom) consist of olive gray silty clays with some sandy mud or diatomaceous layers. The main constituents are clay minerals of which smectite predominates. Two samples contain palygorskite. The ratio of smectite to illite varies between 3:1 and 1:1. Quartz and feldspar are common, and calcite is present in minor amounts (foraminifers, nannofossils). The whole mineralogical assemblage mostly reflects continental weathering, transport, and some redeposition of sedimented material (turbidite layers are common). Clinoptilolite, for example, probably did not form *in situ* but is allochthonous in origin. Its association with palygorskite in this part of the sedimentary column with only rare volcanogenic constituents points to a distant (continental) source for both. Displaced diatoms with pyrite fillings are signs of sediment recycling.

The sediments in the lower part of Site 482 are olive gray silty sands and muds (partly sandy) which become increasingly fissile or shaley with depth. The section between about 84 m to 135 meters sub-bottom is characterized by a higher ratio of smectite to illite (up to 20:1) and, in many samples, chlorite is the only phyllosilicate mineral present. Kaolinite has been positively identified in a shale and in a silty sand which is also relatively rich in feldspars; all other samples yielded combined chlorite and kaolinite which could not be resolved. One sample (no. 24)—an olive black to brownish black muddy nannofossil ooze—is smectite-free.

Site 483 (Fig. 2)

At Site 483—about 52 km west of the East Pacific Rise in a water-depth of 3088 meters—four holes were drilled.

Sediment thickness above basement is about 105 meters, the lowermost sediments being between 1.51 m.y. and 1.65 m.y. old. In Hole 483 three sedimentary units were defined above the basalts based on composition:

Unit I (0–36.5 m) consists of muddy nannofossil marl and radiolarian ooze with some clayey silty sand and silty clay.

Unit II (36.5–52 m) is composed of clayey silt, nannofossil marl, siliceous mud, and turbiditic fine-grained silty sand.

Unit III consists of silty clay and clayey silt with few siliceous fossils.

The top of Unit I consists of marl and olive gray clayey silt (sample no. 1). Calcite may be present in this sample but could not be identified positively. Samples in the middle part of the unit (1.5 to 23 m) may be characterized by minor amounts of calcite, pyrite, and (in the <2 μm fraction) clinoptilolite. Sample 483-5-3, 72–74 from the lower part of Unit I is an olive gray calcareous marl and thus has more carbonate, but otherwise is similar in composition to the other samples. The kaolinite to chlorite ratio varies with depth, perhaps indicating different source areas or reworking. Unit II is represented by three samples: a muddy siliceous ooze, a vitric silty clay, and a diatomaceous ooze. The vitric clay is relatively rich in feldspar (plagioclase) and clinoptilolite is present in both the bulk sample and the clay fraction. The siliceous oozes display similar mineralogies, with amor-

[1] Lewis, B. T. R., Robinson, P., et al., *Init. Repts. DSDP*, 65: Washington (U.S. Govt. Printing Office).

Table 1. Mineralogy of Leg 65 sediments.

			Bulk Mineralogy = 100%						Clay Mineralogy = 100%							
Sample (interval in cm)	Lab. Sample	Depth (m)	Clay Minerals and Amorphous Material	Quartz	Feld-spar	Carbonate	Clino-ptilolite	Others	Smectite	Illite	Chlorite	Kaolinite	Chlorite and Kaolinite[a]	Clino-ptilolite	Others[b]	Remarks
Site 482																
482A-1-2, 26–28	1	1.77	75	14	8	3	—	—	54	25	—	—	18	3	palygorskite?	
482-1-2, 53–55	2	2.04	76	14	8	2	—	—	56	21	6	15	—	2	—	
482A-2-2, 25–27	3	7.76	72	16	9	3	—	—	61	31	1	4	—	4		Smectite with shoulder
482A-3-1, 114–116	4	16.65	55	21	19	3	2	—	38	32	—	—	27	2	palygorskite 1	
482A-4-2, 35–37	5	26.86	63	15	7	3	2	—	51	18	27	—	—	3	palygorskite 1	
482A-5-2, 38–40	6	36.39	55.5	23	16	3.5	2	—	38	36	22	—	—	4	—	
482B-1-2, 26–28	7	45.77	65	19	16	—	?	—	49	18	31	—	—	2	—	
482B-2-2, 28–28	8	55.27	71.5	16	9	2.5	1	pyrite?	69	23	5	—	—	3	—	
482D-1-2, 115–117	9	74.16	66.5	14	7	2.5	—	pyrite 2	67	20	—	—	11	2	—	
482B-4-2, 26–28	10	74.27	68	14	14	4	—	pyrite?	60	22	17	—	—	1	—	
482D-2-2, 116–118	11	83.67	76	13	9	2	—	—	51	32	—	—	14	3	—	
482D-2-3, 135–137	12	85.36	59	22	13	4	2	pyrite 2	79	8	11	—	—	2	barite?	
482D-3-2, 65–67	13	92.66	59	17	17	5	2	—	76	6	16	—	—	1	barite?	
482B-6-2, 15–17	14	93.16	50.5	23	20	5.5	1	pyrite?							palygorskite 1	
482D-4-2, 21–23	15	101.72	67	16	7	6	2	—	84	4	10	—	—	2		
482B-7-2, 23–25	16	102.74	67	17	9	5	2	pyrite 2	77	17	4	—	—	2	—	
482D-5-2, 111–113	17	112.12	45.5	26	24	4.5	—	—	74	5	15	—	—	6	—	Smectite with shoulder
482D-6-4, 27–29	18	113.28	66.5	23	8	2.5	—	—	81	11	4	4	—	—	—	
482B-8-3, 116–118	19	114.67	75.5	19	10	3.5	2	pyrite 2	32	44	24	—	—	—	talc?	
482F-2-2, 55–57	20	115.56	65.5	14	20	1.5	—	—	74	10	14	—	—	2	—	Smectite with shoulder
482B-9-3, 66–68	21	123.67	75	16	9	—	?	pyrite 2	71	14	—	—	15	m	palygorskite?	
482C-7-4, 51–53	22	125.02	72	18	8	2	—	—	88	5	3	3	—	1	—	
482F-3-2, 55–57	23	125.06	74.5	15	8	2.5	—	—	86	10	4	—	—	—	—	
482D-7-3, 28–30	24	131.79	64.5	23	9	3.5	—	—	81	11	—	—	7	—	—	
482F-4-2, 56–58	25	134.07	64	16	18	2	—	—	—	68	32	—	—	—	—	
482B-10-4, 112–114	26	135.12	71.5	19	8	1.5	—	—	65	18	17	—	—	—	—	
Site 483																
483-1-1, 21–23	1	0.22	87	9	7	?	—	—	64	17	—	—	19	—	—	
483-2-3, 106–108	2	5.07	75	10	10	3	—	pyrite 2	74	17	5	4	—	—	—	
483-3-2, 56–58	3	12.57	77	11	7	3	—	pyrite 2	63	24	—	11	—	2	—	
483-4-2, 91–93	4	22.42	84	9	7	—	—	—	63	20	—	—	13	4	—	
483-5-3, 72–74	5	33.23	69	12	6	11	—	pyrite 2	66	20	5	7	—	—	—	
483-6-2, 15–17	6	40.66	79.5	11	8	15	—	pyrite?	65	18	15	—	—	2	—	
483C-1-3, 131–133	7	42.87	83	9	6	2	—	—	53	24	12	10	—	1	—	
483-7-2, 80–82	8	50.82	63	13	20	2	2	pyrite?	65	22	—	12	—	1	barite?	
483-8-2, 66–68	9	60.17	78.5	11	8	2.5	—	—	64	17	9	9	—	1	—	Smectite with shoulder
483-9-2, 76–78	10	69.77	76	12	10	2	m	—	69	14	—	—	15	2	—	
483-10-2, 91–93	11	79.42	59	22	14	3	2	—	55	29	9	6	—	1	—	
483-11-2, 25–27	12	88.26	82	11	7	—	m	—	55	20	—	—	21	—	—	
483C-2-4, 107–109	13	91.58	82	10	8	—	m	—	74	13	—	10	—	—	barite?	
483B-1-4, 107–109	14	97.08	81.5	10	7	1.5	—	—	74	11	—	10	—	4	—	
483C-3-2, 36–38	15	97.37	78	14	8	—	—	—	78	12	—	10	—	?	talc? barite?	
483-12-3, 85–87	16	99.86	81	11	7	1	m	—	62	24	10	—	—	4	—	
483C-4-1, 9–11	17	105.10	81	12	7	—	m	—	39	41	2	12	—	—	—	
483-13-2, 84–86	18	107.85	68	19	11	?	m	pyrite 2	71	17	—	—	11	1	—	
Site 484																
484-1-2, 21–23	1	1.72	74	12	8	6	—	—	56	36	—	—	8	—	—	
484A-1-2, 115–117	2	2.66	79.5	11	8	1.5	—	—	45	24	—	—	28	3	—	
484A-2-2, 131–133	3	10.82	83	10	7	—	—	—	59	21	—	—	17	3	—	
484A-3-2, 24–26	4	19.25	84	9	7	?	—	—	26	48			20	6	—	
484A-4-2, 15–17	5	28.66	73	11	9	7	?	—	59	21	—	—	17	4	—	
484A-5-2, 125–127	6	39.26	84	8	6	2	—	—	57	25	—	—	14	4	—	
Site 485									52	34	—	—	8	6	—	
485-1-2, 6–8	1	1.58	77	12	6	5	m	—	58	20	—	—	18	3	palygorskite 1	
485-2-1, 33–35	2	3.34	75	15	7	3	m	—	39	28	—	—	29	4	—	
485-3-3, 46–48	3	15.97	64	20	11	5	?	—	59	14	—	—	23	4	—	
485-4-2, 16–18	4	23.67	68.5	14	9	8.5	?	—	65	17	—	—	13	5	—	
485-5-3, 57–59	5	35.08	71	19	10	—	?	—	27	39	—	—	22	12	—	
485-6-2, 21–23	6	42.72	73	16	10	1	—	—	61	21	—	—	14	4	—	
485A-1-2, 26–28	7	52.27	73	14	11	2	m	pyrite	78	10	—	—	10	2	—	
485A-1-2, 47–49	8	52.48	69	20	9	2	3	—	62	19	—	—	11	8	—	
485A-2-2, 22–24	9	67.73	75	15	10	3	2	pyrite?	67	15	—	—	15	3	—	
485A-3-2, 35–37	10	71.36	71.5	15	10	3.5	?	pyrite?	58	21	—	—	14	7	—	
485A-4-1, 58–60	11	79.59	72.5	13	8	2.5	m	pyrite?	59	17	—	—	20	4	—	
485A-5-3, 17–19	12	91.68	69	17	9	3	2	—	57	23	—	—	14	6	—	
485A-6-2, 25–27	13	99.76	70	18	9	3	m	—	66	12	—	—	14	8	—	
485A-8-2, 25–27	14	118.76	75	14	8	3	m	—	79	7	—	—	9	5	—	
485A-9-2, 85–87	15	128.86	47	24	20	2	7	—	68	17	—	—	5	10	—	
485A-10-2, 33–35	16	137.84	77.5	12	8	2.5	—	—	80	11	—	—	7	2	—	
485A-11-2, 90–92	17	147.91	57	20	17	3	3	—	76	16	—	—	4	4	—	
485A-18-1, 101–103	18	184.52	56.5	24	17	2.5	—	—	92	7	—	—	1	m	—	
485A-19-2, 67–69	19	190.18	64.5	18	13	4.5	—	—	82	12	—	—	6	m	—	
485A-20-1, 10–13	20	192.62	73.5	15	8	3.5	—	—	82	9	—	—	9	—	—	
485A-22-1, 53–55	21	202.04	73.5	14	8	4.5	—	—	80	10	—	—	10	m	—	
485A-22-6, 36–38	22	209.37	69	18	10	3	—	—	87	9	—	—	4	m	—	
485A-27-1, 101–105	23	231.53	73.5	16	7	3.5	—	—	86	7	—	—	6	—	palygorskite 1	
485A-36-2, 25–28	24	296.77	77.5	13	6	3.5	—	—	86	6	—	—	8	—	—	
485A-37-1, 96–98	25	304.97	71.5	17	7	4.5	—	—	75	10	—	—	15	—	—	
485A-38-1, 5–7	26	313.06	73	17	7	3	—	—	87	7	—	—	6	?	—	
485A-38-1, 73–75	27	313.74	72	17	8	3	—	—	92	5	—	—	3	—	—	

Note: m = minor.
[a] Not resolved (small amounts only).
[b] Most <2 μm samples contain quartz.

phous material as the main component, quartz and feldspar as common constituents, and smectite dominating over illite; kaolinite and chlorite are present in equal amounts ($\sim 10\%$). All samples had low $CaCO_3$ values. The samples from Unit III consist of hemipelagic silty clays and clayey silts with minor turbidite layers and a low $CaCO_3$ content (0–1.5%). Amorphous material and clay minerals are again the main constituents, quartz and feldspar are common with quartz being the more abundant, and clinoptilolite is present in both the bulk and <2 μm samples. In many samples, smectite predominates over illite (the ratios vary between 1.6:1 and 6.7:1 except in Sample 483-12-3, 85–87—a homogeneous gray olive soft mud—where the ratio is about 1:1).

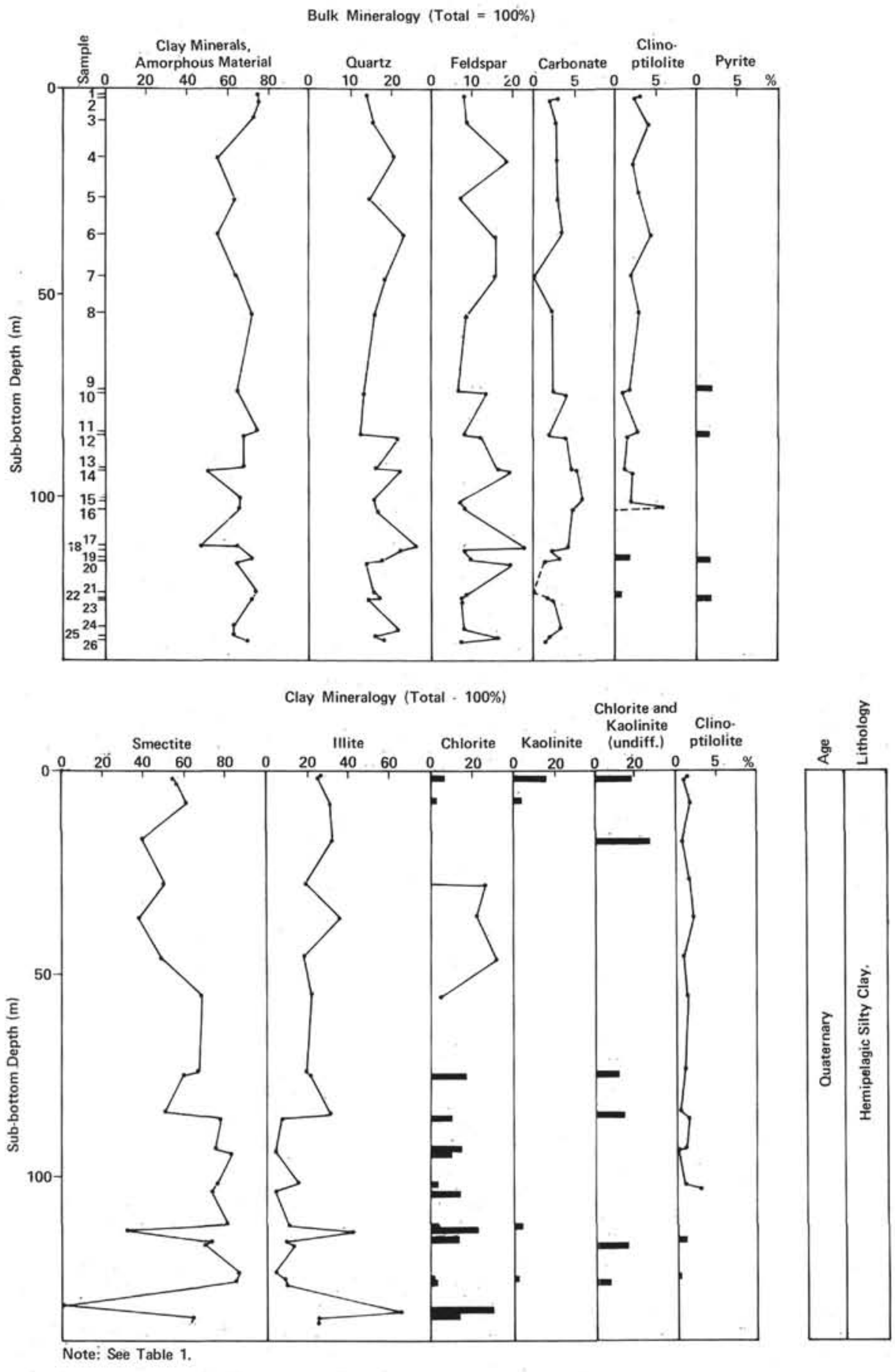


Figure 1. X-ray mineralogy versus sub-bottom depth, Site 482.

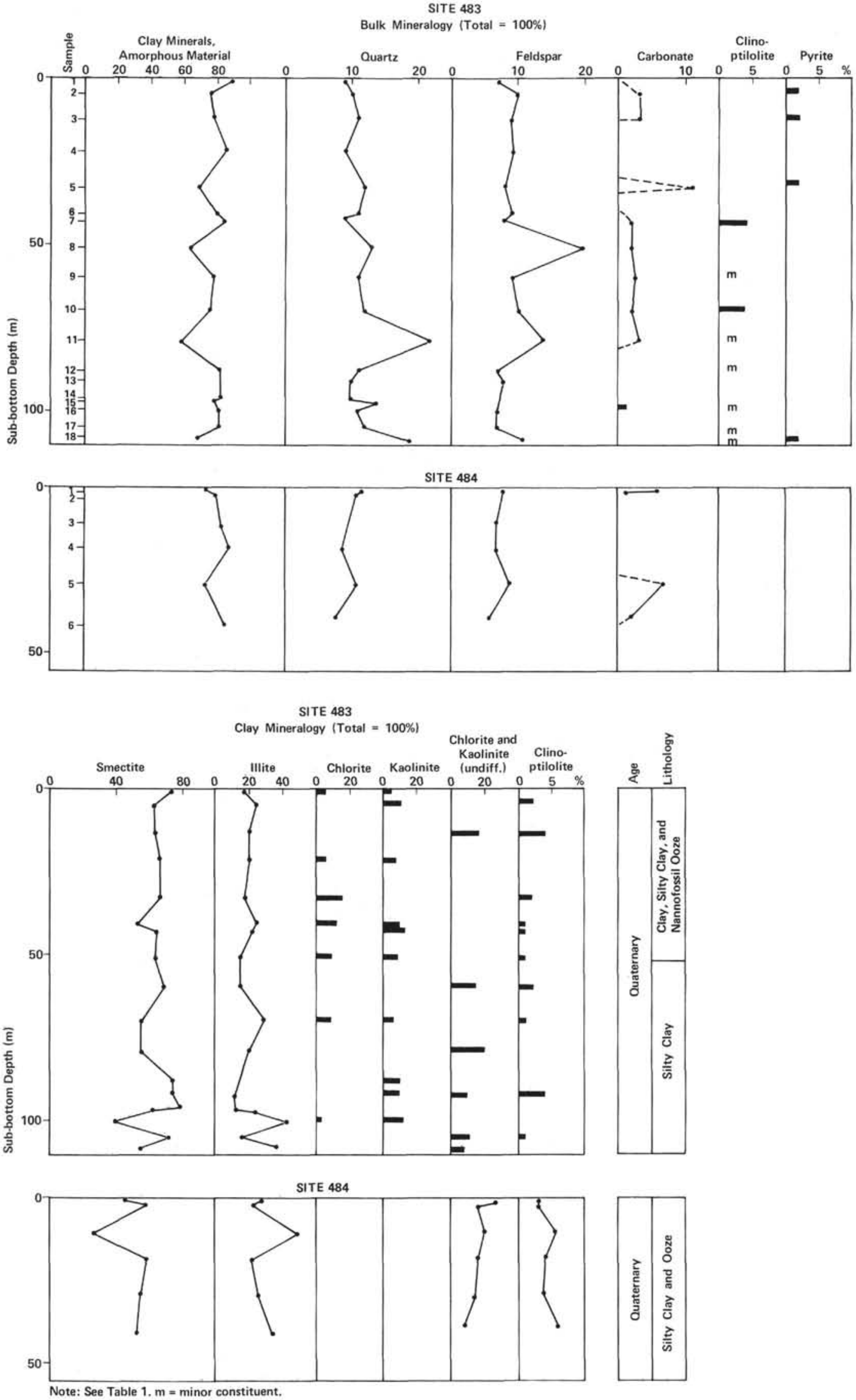
The whole sedimentary sequence reflects a hemipelagic environment with less input of terrigenous material than at Site 482. Sediments between basaltic units were not examined.

Site 484 (Fig. 2)

Site 484 was drilled in 2898 meters of water on a small topographic high displaying a 3000 γ magnetic anomaly. In the first hole (484), only 4.9 meters of hemipelagic sediments (soft greenish gray nannofossil and diatomaceous ooze, mud, and sandy silty clay with interbedded sand layers) were recovered above basement. The only sample studied (484-1-2, 21–23) was a nannofossil-bearing clay with a high content of amorphous material, 6% $CaCO_3$, and a low detrital content. The smectite to illite ratio was ~1.9:1.

At Hole 484A, 55 meters of sediments on top of basement were drilled, and two sedimentary units were distinguished:

Unit I (0–14.5 m) is a soft grayish olive siliceous clay with numerous turbidite layers. Two samples have been analyzed: both are rich in amorphous material; detritals and clay minerals are minor.



Note: See Table 1. m = minor constituent.

Figure 2. X-ray mineralogy versus sub-bottom depth, Sites 483 and 484.

Unit II (14.5–55 m) is a firm, homogeneous grayish olive, hemipelagic siliceous clay which grades downward to a calcareous nannofossil clay. The analyzed samples are olive gray siliceous clays from the upper two-thirds of Unit II.

Amorphous material predominates over detritals and clay minerals at Site 484. Smectite and kaolinite + chlorite decrease with depth and illite increases whereas other values scatter. Again clinoptilolite has been found in all $< 2\ \mu m$ samples. It is not clear whether this clinoptilolite formed authigenically or is allochthonous since the sediments at Site 484 include significant proportions of silt and sand of probable turbidite origin (Site 484 report, this volume).

Site 485 (Fig. 3)

At Site 485 hemipelagic sediments were recovered. Above the uppermost basaltic unit (at 153.5 m) two sedimentary units were recognized, both of which show signs of diagenesis (only the uppermost 35 m of Unit I are unconsolidated):

Unit I (0–79.5 m) is composed of soft to firm grayish olive clay with intercalated turbidite layers (mostly silty clays or clayey silts). Amorphous material is the main constituent but detritals—mainly quartz and feldspar—are common, and clinoptilolite is rare to common. Smectite to illite ratios vary between about 0.7:1 and 8:1, the average being 3.4:1.

Unit II (79.5–153.5 m) is similar to the upper unit except that the amount of silt-size material increases (35–40 vs. 5–15%). Amorphous material is again abundant, and quartz and feldspar are present in about the same percentages as above (~16 and ~10%, respectively). Sample 485A-9-2, 85–87 cm, which displays a relatively high feldspar content (~20 percent) is from a silty sand layer. Smectite is more abundant in Unit II than in Unit I, and the average smectite to illite ratio is ~5.5:1.

At Site 485, the sediments within the basaltic pile differ from those cored above in several ways. They consist of olive gray sandy silty clays, muds, olive gray nannofossil marls, chalks, black mudstones, and claystones. Some of these layers are turbiditic. All of the samples analyzed yielded higher smectite contents than those from Unit II, but the illite was lower. The average smectite to illite ratio is approximately 10:1. Smectite crystallinity appears to increase downward, suggesting diagenetic alteration.

SUMMARY AND CONCLUSIONS

The semiquantitative mineralogical studies presented here confirm that the sediments drilled on Leg 65 at the mouth of the Gulf of California consist largely of hemipelagic silty clays with interbedded turbidites. The clays consist of smectite with subordinate illite, chlorite, and kaolinite and minor clinoptilolite. Quartz and feldspar are invariably present in the silt fraction and carbonate is present at all sites. Differences in sediment composition and induration indicate that Site 482 was more strongly influenced by terrigenous sources than the other sites and that the sediments at Site 485 have undergone mild diagenesis.

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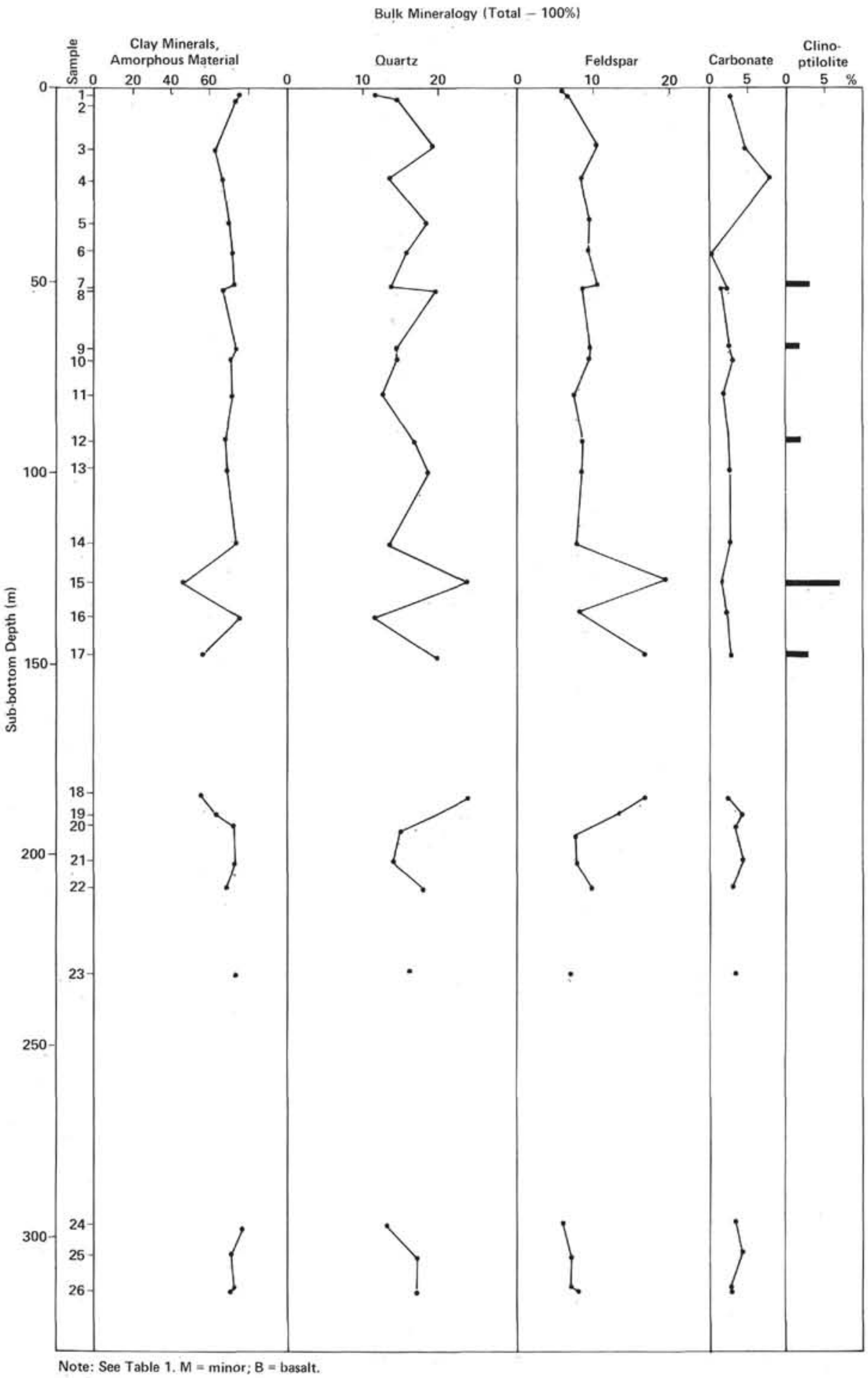

Figure 3. X-ray mineralogy versus sub-bottom depth, Site 485.

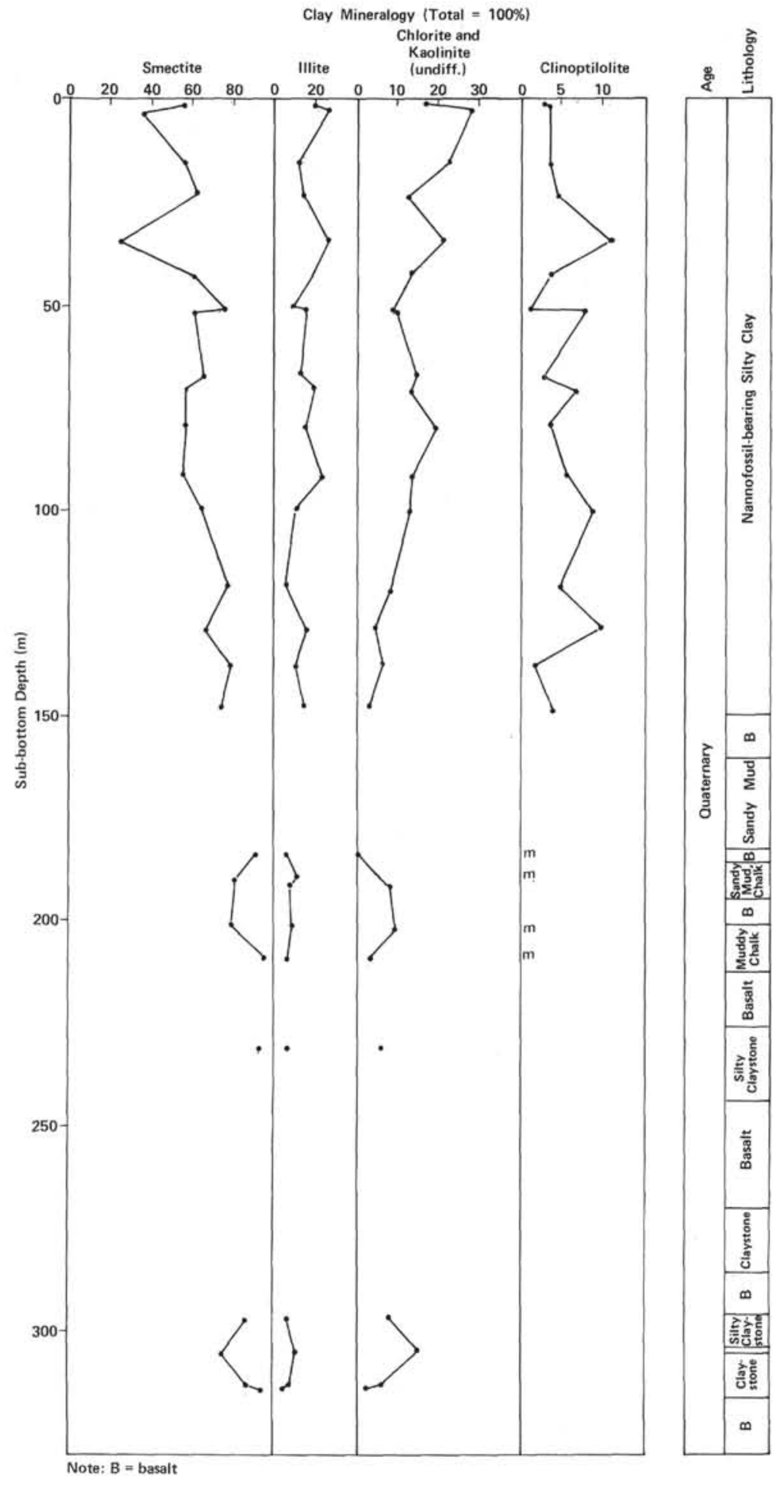

Figure 3. (Continued).