APPENDIX I. X-RAY MINERALOGICAL ANALYSIS[1]

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INTRODUCTION

During Leg 66 eight sites on an active margin transect off southern Mexico were drilled in order to determine the nature of ocean-continent transition across a subduction zone. Present outcrops of Mesozoic to Precambrian basement at the coast intruded by Mesozoic magmas within only 65 km of the Middle America Trench axis indicate truncation of the continental margin, tectonic removal of an accretionary zone, and consumption of ocean sediments and crust by subduction.

METHODS

Sediment samples were analyzed by X-ray diffraction (XRD) according to the methods described in Mann and Müller (1980); essentially they consist of measuring peak heights (bulk mineralogy) and peak areas (clay mineralogy) of individual minerals. Carbonate contents were determined by the "Karbonat Bombe" method of Müller and Gastner (1971).

RESULTS

Site 486

At Site 486, in a small trench floor sediment pond (water depth ~5140 m), 38 meters (Hole 486) and 22 meters (Hole 486A) of fine to medium muddy sand and coarse sand were drilled. Sample 486-5-3, 0–2 cm, at the transition point from fine-to-medium sand to sandy mud, contains abundant quartz and feldspar in addition to clay minerals (illite, chlorite), hornblende, and gypsum, which probably formed during transport and storage.

Site 487

At Site 487, 10 km seaward of Site 486 at a water depth of 4764 meters, we penetrated about 170 meters pelagic and hemipelagic sediments. Two units were distinguished.

The upper unit, about 115 meters thick, comprises Pleistocene gray mud of which the top part (Unit IA, 0–40 m, late Pleistocene) is relatively rich in silt. Two muds and one ash-bearing silt (Sample 487-3-3, 92–94 cm) were examined. The latter is somewhat poorer in quartz and feldspar than the mud samples (see Table 1).

The bulk mineralogy of Subunit Ib (early Pleistocene) is similar to that of Subunit Ia. Smectite contents increase, however, whereas illite decreases (muds, Samples 5–12). Sample 13 (487-13-3, 4–6 cm) is a clay but is richer in illite than the previous samples. Roughly equal amounts of chlorite and kaolinite seem to be present throughout Subunit Ib but could not be distinguished in samples below about 92 meters.

Unit II is composed mainly of brown clay (late Miocene to Pliocene); ash layers were identified in Cores 14 and 16. Quartz, feldspar, and barite rarely occur; amorphous material and clay minerals predominate. Smectite is the most important crystalline component of the clay fraction; its crystallinity increases from Samples 14 to 18 (Cores 14–18). One firm pinkish gray sample—part of a nodule, 487-19-1, 82–84 cm)—was tentatively identified as zeolite but consists of fine crystalline rhodochrosite and amorphous material.

Samples 20 and 21 are rich in amorphous constituents; quartz and feldspar are present in minor amounts only. Sample 21 (487-19-5, 145–146 cm) also contains small amounts of calcite and apatite as well as volcanic glass.

Site 488

At Site 488, on the first ridge landward of the Middle America Trench at a water depth of 4254 meters, about 429 meters of early or middle to late Quaternary sediments were penetrated. Two lithostratigraphic units were distinguished.

Unit I (0–313 m sub-bottom) is a hemipelagic dark greenish gray to greenish black, frequently laminated sediment rich in silt-size material (see site chapter). Its mineralogy is relatively uniform. Quartz and clay minerals are the main crystalline constituents; illite dominates the clay mineralogy (ratio smectite/illite $\leq$ 0.1). $CaCo_3$ was found by XRD in only two samples from Unit I. Volcanic glass and other volcanic material were also rare except for the uppermost meter, which consists of vitric clay to clayey ash. Feldspar increases from <10% to >10% (avg.) at the base of Unit I, probably because of higher sand content (which is higher still in Unit II). This points to a change in morphology after deposition of Unit II sediments, which probably accumulated in a turbidite channel or depositional basin (see site chapter).

The two Unit II samples we examined are a grayish olive green muddy silt (Sample 12) and an olive black laminated muddy silt. They have similar mineralogies, comprising common quartz and feldspar and a clay suite dominated by illite. The last sample (488-44-2, 7–9 cm) contains more crystalline material than the previous ones, which accords with the incipient fissility of the muddy silt observed on board.

[1] *Initial Reports of the Deep Sea Drilling Project*, Volume 66.

Site 489

Site 489 is on the upper slope of the Middle America Trench off southwestern Mexico. Water depth is about 1240 meters. Five sedimentary units were distinguished.

Unit I (Hole 489, 0–5.5 m) is a Quaternary grayish olive green (glauconitic) muddy silt. Sample 489-1-4, 28–36 cm comprises common quartz and feldspar in addition to some $CaCO_3$, pyrite, and hornblende. Clay minerals make up about 60% of the material, with smectite > illite and some chlorite + kaolinite.

Unit II (Hole 489, 5.5–34.5 m; Hole 489A, 7.1–84.0 m) is an early Miocene muddy silt which becomes firm near the base. Our samples are a grayish green siliceous muddy silt which is richer in quartz and feldspar and contains some clinoptilolite in addition to the "normal" clay mineral suite, a dark grayish green muddy silt with less feldspar, minor pyrite, illite > smectite, and clinoptilolite in the $< 2\ \mu m$ fraction.

Unit III (Hole 489A, 84.0–112.5 m) early Miocene mudstone with thin ashlayers, is represented by Sample 489A-7-3, 93–95 cm which contains quartz and feldspar, minor clinoptilolite, and clay fraction dominated by smectite.

Unit IV (Hole 489A, 112.5–300.0 m) also an early Miocene muddy siltstone with a few limestones occurring regularly throughout, has a bulk and clay mineralogy similar to Unit III; the smectite/illite ratio decreases from about 2 (Sample 489A-16-1, 10–12 cm) to about 0.5 (Sample 489A-31,CC, 18–20 cm), however, and the lowermost samples are higher in quartz, indicating increasing volumes of fine (terrigenous) sand (= higher sedimentation rates; see site chapter).

The basal unit, below 300 meters, consists of schist and quartzite (continental crust), probably of pre-Tertiary age, according to shipboard investigations.

Compared to Site 488, Site 489 clay mineral ratios are quite different, suggesting different source rocks. Paleomagnetic measurements on shipboard also indicated different sources (see site chapter), as clastic material in Site 489 sediment contain lower percentages of magnetic minerals than those at Sites 487 and 488.

Site 490

Site 490 is on the lower slope in a water depth of about 1761 meters. About 589 meters of argillaceous sediments were drilled and were divided into three units.

Unit I (0–123 m) is an olive green to olive gray mud which becomes olive black in the lowermost 25 meters. Quartz and feldspar contents are lower than in Hole 489A, which corresponds to the greater distance to shore of Site 490, compared to Site 489. Smectite/illite ratios are between 0.2 and 0.1. The lower part of the unit is diatom-bearing. Glauconite, which was identified during microscopy investigations, was not detected by XRD. Calcite is an important constituent locally, either as concretions with borings or occasional diffuse moderate olive brown spots (see site chapter).

Unit II (~123 m–~399 m) is a Pliocene to late Pleistocene olive gray muddy siltstone. Quartz and feldspar contents are somewhat lower than in Unit I, except for two gray olive mudstone samples (490-32-6, 50–52 cm and 490-34-2, 90–92 cm). Two samples contain Mg-calcite, one from a diffuse calcareous area near a concretion (490-17-2, 5–7 cm), the other from Core 25 (490-25-2, 110–112 cm), which is foraminifer- and nannofossil-bearing and contains some plant material. This suggests that Mg-calcite formed after the decomposition of organic material, which causes a decrease in carbonate solubility, an increase of *p*H, and partial precipitation from interstitial solutions (e.g., Müller, 1967). The lowermost sample of Unit II has "normal" calcite.

Unit III, Pliocene, is variable in feldspar, but otherwise its mineralogy and sedimentary characteristics are similar to Unit II. All samples analyzed are muddy siltstones, with quartz and feldspar common to abundant and minor amounts of pyrite. Zircon and hornblende were detected by microscopy in some samples. Both occur in different shapes and colors, suggesting at least two different source rocks.

Site 491

Site 491 is on the inner slope of the Middle America Trench at a water depth of about 2900 meters. We drilled 542 meters of lower Pliocene to upper Quaternary argillaceous to sandy sediments and divided them into three units.

Unit I (0–57.5 m sub-bottom) is a grayish olive green mud of late Pliocene to late Quaternary age. During shipboard investigations pyrite nodules and calcareous concretions were observed which probably caused gypsum to develop during transport.[2] Our Unit I sample contains common quartz and feldspar; the clay mineral suite is dominated by illite.

Unit II extends from 57.5 to 437.5 meters and is made up of grayish olive green early to late Pliocene mud with some fine sand layers.

Unit III, muddy silt and siltstone with interbedded fine to coarse pebbly sand, was cored to a depth of 542 meters.

Our samples are from Unit II. All are muddy silts and —except for Sample 491-16-2, 130–131 cm—carbonate-free. The exception is from a laminated silt which contains minor "unspecified" carbonate (no detectable foraminifers or nannofossils). Clay samples are rich in illite and kaolinite + chlorite, which could not be separated and identified in some cases. The smectite/illite ratio is low, as at Site 490 (Table 1), suggesting similar depositional environments and/or similar source rocks—perhaps comparable to the schistose basement (mica schists) drilled at Site 489.

Site 492

The *Glomar Challenger* drilled Quaternary to late Miocene sediments at Site 492 in the midslope region of the Middle America Trench. Water depth here is about 2000 meters. Two lithologic units were defined.

Unit I (0–247 m in Hole 492) consists of grayish olive green muddy silts and muddy siltstones of Quaternary

[2] Gypsum was not taken into account in computing mineral percentages.

to late Miocene age. The main components are clay minerals (illite, chlorite, kaolinite; some smectite; and glauconite); quartz and feldspar are common. Calcite is present in some samples as idiomorphic crystals or, mainly, as clay-size material. In Sample 492-12-3, 90–92 cm (micritic chalk) replaced radiolarians (now composed of $CaCO_3$) occur in trace amounts, which accords with the shipboard observation that carbonate is probably of diagenetic origin. Gypsum occurs in some samples, probably as a product of decomposition and oxidation of calcite and pyrite.

Unit II is muddy siltstone with interbedded fine sand to granular gravel (see site chapter). This unit is represented only by Sample 492-29-4, 98–100 cm. Its grayish green muddy siltstone has a fissile structure, breaking into many small (several cubic millimeters) irregular pieces which have a "polished" surface.

Site 493

At the final drill site of Leg 66, on the Mexican continental margin at a water depth of about 645 meters, we penetrated 652 meters of sediment before reaching basement (diorite). The sedimentary sequence was divided into three units.

Unit I is a Quaternary muddy silt with wood debris, ash, and foraminifer layers and shell fragments. Samples are from Holes 493A and 493B (Nos. 16–19, Table 1). Compared to those from Unit I at Site 492, they are somewhat low in quartz and feldspar; all yield a few percent carbonate. Clay mineral ratios resemble those of Unit I, Site 492, though smectite occurs in smaller quantities.

Unit II is composed of late Miocene and Pliocene muddy silt(-stone) and mud(-stone) with intercalated beds of thin ash beds, siliceous mudstone, and limestone. There were no samples for Unit III.

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Table 1. Bulk and clay mineralogy, Sites 486–493.

Sample (interval in cm)	Sample No.	Sub-bottom Depth (m)	Bulk Mineralogy = 100%: Clay minerals + Amorphous Material	Quartz	Feldspar	Carbonate	Other Carbonates	Hornblende	Others	Clay Mineralogy = 100%: Smectite	Illite	Chlorite	Kaolinite	Chlorite + Kaolinite	Others	Remarks
486																
5-3, 0–2	1	15.50	11	51	35	?		3			65	35				
487																
2-2, 30–32	1	2.80	76	15	9	?					53			47	palygorskite?	mainly amorphous
3-3, 92–94	2	14.42	94	1	5					11	51	18	20			mainly amorphous
5-2, 90–92	3	31.90	83	11	6					14	48	25	13			
6-3, 55–57	4	42.55	81	12	7					11	66	10	13			
7-2, 60–62	5	50.60	82	10	8					24	38			36		
8-1, 70–73	6	58.70	79	10	7			2	apatite2	29	36	16	19			
9-2, 104–106	7	70.04	82	10	8					24	38	17	21			
9-5, 34–36	8	73.84	81	13	6					37	31	14	18			
10-4, 63–65	9	82.13	83	10	7					61	25	6	6		{clinoptilolite2 sepiolite?	
11-4, 77–79	10	91.77	86	9	5				pyrite?	40	36			24		mainly amorphous
12-4, 70–74	11	101.20	85	9	6					56	24			20		mainly amorphous
13-1, 4–6	12	105.54	88	7	5					64	16			20		
13-3, 4–6	13	108.54	68	7	18	3		4		34	51			14		mainly amorphous
									barite?	97	1			2	clinoptilolite?	mainly amorphous
14-2, 19–21	14	116.69	94	3	3											
15-2, 24–26	15	126.24	95	2	3				barite?	91	7			2		+ smect. well cryst.
16-1, 58–60	16	134.58	88	4	5				barite3	84	10			6	talc?	+ smect. well cryst.
16-1, 102–104	17	135.02	92	4	2				barite2	81	17			2		+ smect. well cryst.
18-6, 103–105	18	161.53	97	1					barite2	99				1	{clinoptilolite talc ?	+ smect. well cryst.
19-1, 82–84	19	163.32	20			rhodochrosite80										
19-2, 26–28	20	164.26	93	1	4				barite2	99				1		mainly amorphous
19-5, 145–146	21	169.95	87	1	8				apatite2	69	31					mainly amorphous
488																
1-1, 44–64	1	0.44	77	17	5			1		4	38			58		
2-4, 140–142	2	10.40	69	22	9					5	54	16	25			
5-4, 140–142	3	35.40	74	17	6	calcite3		?	apatite?	4	65			31		
7-1, 103–105	4	49.03	75	23	7				phillipsite	3	59			38		
9-3, 34–36	5	70.84	67	20	13					5	53			42		
13-3, 34–36	6	109.84	69	20	9				pyrite2	3	66			31	mixed layer?	
16-2, 60–62	7	136.10	72	18	10					4	62			34		
18-5, 50–52	8	159.50	63	21	16					4	66			30		
20-1, 87–89	9	172.87	69	18	11	dolomite?		2	pyrite?pyroxene?	3	70			27		
29-1, 13–15	10	257.63	67	23	10					2	55			43		
33-3, 30–31	11	297.30	83	11	6	calcite?				1	48			51		
37-1, 137–139	12	335.37	66	24	10					2	55			43		
44-2, 7–9	13	401.57	65	23	12					3	69			28		
489																
1-4, 28–30	1	4.78	62	19	10	calcite5		2	pyrite2	60	15			25		
2-3, 50–52	2	9.50	58	25	17					49	36			9	clinoptilolite6	
489A																
3-1, 90–97	3	46.90	67	22	9				pyrite2	31	47			19	clinoptilolite3	
7-3, 93–95	4	87.93	62	25	12				clinoptilolite1	45	35			19	clinoptilolite Tr.	
12-1, 50–52	5	132.02	62	20	16			2		28	62			10		
16-1, 10–12	6	164.60	57	21	20			2		54	27	10	9			
21-4, 0–2	7	202.50	62	23	15				clinoptilolite?	53	33			14	clinoptilolite Tr.	
25-2, 10–12	8	237.60	43	25	20			2		32	38			30		
31,CC, 18–20	9	300.18	50	26	24					24	51			25		
490																
1-3, 90–92	1	3.90	67	12	8	calcite13				5	63			32		
5-1, 80–82	2	38.30	78	15	7			1		8	47			45		
9-1, 120–122	3	76.70	67	20	13					5	63	14	18			
12-2, 123–125	4	106.23	76	15	7	calcite2				7	55	19	19			
15-4, 83–85	5	137.83	71	12	9	magnesium calcite8				12	44	21	23			
17-2, 5–7	6	153.05	75	15	8	calcite?			pyrite2	6	59	15	20			
21-3, 70–72	7	193.20	85	15	10				pyrite?	9	51	16	24			
25-2, 110–112	8	230.10	75	15	6	magnesium calcite4				5	50			45		
32-6, 50–52	9	298.00	18	36	46					13	53			34	mixed layer?	
34-2, 90–92	10	305:90	48	40	12					8	57			35		

Table 1. (Continued).

Sample (interval in cm)	Sample No.	Sub-bottom Depth (m)	Bulk Mineralogy = 100%: Clay minerals + Amorphous Material	Quartz	Feldspar	Carbonate	Other Carbonates	Hornblende	Others	Clay Mineralogy = 100%: Smectite	Illite	Chlorite	Kaolinite	Chlorite + Kaolinite	Others	Remarks
490 (cont)																
38-6, 39–40	11	349.39	73	19	8					12	65	10	13			
42-3, 28–29	12	382.78	66	23	8	calcite1			pyrite2	7	72	9	12			
48-1, 30–32	13	427.30	69	21	10					24	44			32		
49-1, 28–30	14	436.78	64	23	8	calcite3			pyrite2	10	58			32		
54-1, 89–90	15	484.89	46	35	17			1	pyrite1	10	53			37		
58-3, 62–64	16	524.62	54	21	25					13	62	10	15			
62-4, 28–29	17	564.78	67	19	14					30	37			33		
491																
3-7, 20–21	1	28.70	72	20	8					12	48			40		
7-3, 80–82	2	61.30	75	16	9					8	52			40		
11-3, 72–74	3	99.22	62	21	17					2	64			34		
15-2, 80–82	4	126.30	62	20	18					2	55			43		
16-2, 130–131	5	136.30	61	23	12	calcite4			apatite?	2	72	10	15			
20-1, 72–74	6	172.22	66	23	9			2		2	65	13	20			
30-3, 110–112	7	261.10	69	21	10					9	54	17	20			
40-2, 98–100	8	354.48	67	22	11						71			29		
492																
1-1, 134–136	1	1.34	66	20	8	calcite4			apatite2	12	46			42		
3-2, 88–90	2	15.38	70	16	10			2	clinoptilolite2; pyrite?	13	35	26	26			
5-5, 2–4	3	38.02	71	18	9	calcite2				5	67	12	16			
7-1, 90–92	4	51.90	73	18	8				apatite1	12	54			36		
(9?)-1, 40–42	5	70.40	75	16	9				pyrite?	18	54			28		
11-2, 10–12	6	96.60	70	21	9					7	70	10	13			
12-3, 90–92	7	102.40	42	8		calcite50				5	62	13	20			
14-1, 50–52	8	118.00	71	18	11				pyrite?	12	56	13	19			
15-2, 112–114	9	129.62	72	17	11					24	40			36		
17-4, 41–43	10	150.91	72	16	12				pyrite?	14	60			26		
20-3, 95–97	11	138.45	73	16	11					26	45			29		
23-1, 80–82	12	203.80	50	22	28					4	70			26		
25-1, 120–122	13	223.20	53	21	16					14	62	10	14			
29-4, 98–100	14	265.48	75	16	9					12	75	7	6			
493																
6-1, 131–133	2	139.31	72	16	11	calcite1				1	74			25		
10-1, 70–72	3	196.70	73	15	8	calcite4				3	61	19	17			
14-1, 70–72	4	234.70	76	14	6	calcite3			apatite1	6	66			28		
18-3, 81–83	5	275.81	77	13	8		dolomite1			3	65	11	21			
21-3, 2–3	6	303.52	69	9	10		siderite6		pyrite6	4	69			27		
22-3, 24–26	7	313.24	77	11	6	calcite6	siderite?			5	70			25		
27-3, 105–107	8	361.55	76	14	8	calcite2				7	68	8	17			
31-4, 49–50	9	400.49	73	19	9					77	17			5	clinoptilolite1	
34-2, 109–110	10	426.59	61	21	12	calcite21			clinoptilolite2	73	11			7	clinoptilolite1	
38-2, 140–142	11	464.90	58	22	18				clinoptilolite2	59	26			13	clinoptilolite2	
41-2, 98–100	12	492.98	60	24	12				clinoptilolite2	68	22			9	clinoptilolite1	
46-3, 55–56	13	541.55	55	26	16				clinoptilolite?	60	29			11	clinoptilolite?	mixed layer
50-1, 12–13	14	576.12	54	19	14				clinoptilolite1	44	39			16	clinoptilolite1	
54-2, 12–12	15	615.62	48	22	27	calcite3				22	57	11	10			
493A																
1-1, 145–147	16	1.45	73	15	6	calcite4			pyrite2	4	52			40		
1-1, 70–72	17	12.70	68	19	5	calcite3		2		7	38			55		
2-2, 80–82	18	23.80	72	15	5	calcite3				5	51			44		
2-2, 101–106	19	24.04	70	10	8		siderite?		pyrite3	5	47			48		
10-1, 41–42	20	97.91	42	6	2		dolomite50			3	62	15	20			

Note: Data is after Mann and Müller, 1980. Tr. = trace.