APPENDIX I. SEDIMENT XRD DATA, LEG 64[1]

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INTRODUCTION

During Leg 64, eight sites were drilled on a transect from young ocean crust to continental crust off Baja California, in the central part of the Gulf of California, where high sedimentation rates have prevailed over a currently active spreading center, and on the continental slope where hemipelagic sediments overlie continental crust.

METHODS OF INVESTIGATION

Methods (semiquantitative X-ray-diffraction procedures) are essentially those described in Mann and Müller (1980). They consist of measuring peak heights and peak areas of individual minerals and relating them to "percentages" present. Carbonate values have been determined by the "Karbonat-Bombe" method of Müller and Gastner (1971).

RESULTS (Table 1)

Site 474

Site 474 belongs to the Baja California–Continental Margin Transect and is located on oceanic crust overlain by about 500 meters of sediments containing biogenic gas (methane).

The sedimentary sequence was divided into five units. Unit I consists of late Pleistocene hemipelagic diatomaceous muds, oozes, and nannofossil marls.

Main constituents are clay minerals and amorphous material. Feldspar, quartz, and calcite are common; pyrite is rare. Samples of the <2-μm fraction contain abundant amorphous material, smectite, and illite (ratio $\sim 1{:}1$), as well as clinoptilolite and chlorite + kaolinite.

Unit II samples (Nos. 4–8) are diatomaceous muds, oozes (silts), and arkosic granitic sands. Thus, the mineralogy of samples 4 through 6 (ooze, diatomaceous clayey silts) is not different from that of Unit I. Amorphous material is especially abundant in samples 3, 4, and 5. The ratio of smectite to illite is variable (0.6–1.0) for the upper three samples of Unit II, and ~ 0.5 for the granitic sands. Samples 7 and 8 (sands), however, are richer in quartz and feldspar, and much lower in clay minerals and amorphous material. All samples of Unit II are relatively carbonate-rich, partly in the form of nannofossils (oozes, muds), or in the form of mollusks, bryozoans, and shallow-water carbonates.

Unit III—Pleistocene to early Pleistocene—begins with a siliceous clayey silt which is also rich in amorphous constituents. Below follow diatomaceous, clayey silts, with some arkosic sand layers and pebbles of igneous and metamorphic rocks. Most are, however, nannofossil-bearing, clayey silts (partly mud turbidites). Siliceous, clayey silts are characterized by variable amounts of clay minerals and amorphous material. Feldspar and quartz are common to abundant, and calcite is present in most samples. Minor constituents include apatite, gypsum (detrital?), and pyrite. Samples 13 and 14—a diatomaceous nannofossil-bearing silt and a clayey silt—are the only ones *without* clinoptilolite in the clay fraction. Some samples may also contain palygorskite or siderite (see Table 1). Clays usually are not well crystallized except for Sample 474-2-1, 108–110 cm, from a sandy layer within a muddy turbidite sequence.

Unit IV is late Pliocene to early Pleistocene mud turbidites (grayish olive silty claystones and clayey siltstones). Quartz and feldspar are common, and all samples contain calcite. Again we found clinoptilolite in every <2-μm-fraction sample. Between 329 and 368 meters (Cores 19–23), we note a high smectite crystallinity; samples from this interval were described by shipboard scientists as silty claystones with (arkosic) sands. Clay-fraction samples from olive-gray claystones between ~ 406 and 422 meters exhibit also increasing smectite crystallinity, which becomes lower for samples 47 and 48 (~ 443 and ~ 456 m), and increases again (sample 49; ~ 461 m). Samples 50 and 51 belong to Unit V, which consists of Pliocene clayey siltstones, sands, mud flows, and one dolerite sill. Our samples—silty claystones—came from Cores 36 and 39 (above dolerite) and consist of quartz, feldspar, and calcite; pyrite was detected in Sample 474-36-2, 105–107 cm. Our clay-fraction samples lack clinoptilolite, and smectite is less crystallized than in previous samples.

Site 475

Site 475 is at a water depth of 2631 meters, on the lower continental slope; here, predominantly hemipelagic sediments (diatomaceous muds) were penetrated. These are underlain by a glauconitic, dolomitic mudstone, which in turn overlies a conglomerate (cobbles of metamorphic rocks).

Unit I sediments—late Pleistocene to late Pliocene—are olive-brown, diatomaceous muds (silty clays), with occasional sand layers (e.g., sample 2). Quartz and feldspar are common constituents, and calcite (= nannofossils, foraminifers) is present in all samples. The clay-mineral suite is dominated by smectite, except for the two uppermost samples, where illite is the main clay mineral. We also found abundant amorphous material

[1] Curray, J. R., Moore, D. G., et al., *Init. Repts. DSDP*, 64: Washington (U.S. Govt. Printing Office).

Table 1. Sediment XRD data.

			Bulk Mineralogy (% of rock)								Clay Mineralogy (% of Clays)					
Sample (interval in cm)	Sample No.	Sub-bottom Depth (m)	Clay Minerals + Amorphous Material	Quartz	Feld-spar	Calcite	Other Carbonates	Pyrite	Horn-blende	Others	Smec-tite	Illite	Chlorite	Kaolin-ite	Chlorite + Kaolinite[a]	Others[b]	Ratio Smectite/ Illite
474-1-2, 42–44	1	1.9	55	15	22	6		2			43	38			14	Cpt 5	1.1
2-2, 51–53	2	4.0	58	15	10	12	Sid?	3	2		37	52			10	Cpt 1	0.7
3-2, 46–48	3	13.5	42	13	19	20	Sid?	2	4		48	35			14	Cpt 3	1.4
4-2, 83–85	4	23.3	51	17	8	22		2			35	34			28	Cpt 3/Talc?	1.0
5-3, 44–46	5	33.9	52	16	11	16		3	2		33	51			13	Cpt 3/Pal?	0.6
6-4, 66–68	6	45.1	46	10	18	23	Sid?	2			50	36			11	Cpt 3	1.4
7-5, 107–109	7	56.6	6	24	35	31		4			26	69			4	Cpt 1	0.4
8-2, 48–50	8	61.0	20	23	36	19		2		Pyx?	31	53			12	Cpt 4/Pal?	0.6
11-2, 118–120	9	90.2	71	13	10	4		2		Talc?/Palyg?	61	28			10	CPT 1	2.1
12-1, 42–44	10	97.4	70	11	8	8		3			43	39			16	Cpt 2/Pal?	1.1
13-1, 52–54	11	107.0	39	23	21	8		3	4	Gyp?	46	49			6	Cpt 1/Pal?	0.9
16-3, 6–8	12	138.0	18	30	38	10		2	2		12	82			6	Pal?	0.1
17-1, 72–74	13	145.2	30	26	15	23		2		Pyx 4	18	72			10		0.3
474A-1-4, 66–68	14	168.7	44	22	18	8			2		52	38			8		1.4
1-4, 82–84	15	168.8	72	15	10	3		?			49	34			14	Cpt 3	1.4
1-4, 100–102	16	169.0	16	24	39	14			5	Palyg?/Cpt 2	63	23			13	Cpt 1	2.7
2-1, 108–110	17	174.1	38	30	20	7			5		6	91			2	Cpt 1	0.1
2-1, 134–136	18	174.3	25	28	38	5			4		46	48			6	Cpt m	1.0
3-5, 35–37	19	188.8	64	16	10	6		?		Apat 2/Cpt 2/Sid 1	48	28			21	Cpt 3	1.7
3-5, 81–83	20	189.3	61	19	11	6	Sid?	?		Cpt 2	46	28			21	Cpt 5/Pal?	1.6
3-5, 111–113	21	189.6	22	33	36	9		?			31	48			18	Cpt 3	0.6
3-5, 134–136	22	189.8	50	19	20	11	Sid?				44	43			9	Cpt 4	1.0
4-4, 73–75	23	197.2	78	12	10		Sid?			Palyg?	58	27			14	Cpt 1	2.1
6-1, 99–101	24	212.0	64	12	8	16				Sep?	54	35			10	Cpt 1	1.5
6-1, 145–147	25	212.5	30	32	18	18				Talc?/Cpt 2	43	56			5	Cpt 2	0.8
7-2, 47–49	26	222.5	72	15	10	3					55	26			15	Cpt 4	2.1
9-3, 60–61	27	243.1	67	9	9	13		2			49	34			15	Cpt 2	1.4
			66														
10-2, 63–65	28	251.1	66	18	11	5				Apatite m	58	21			17	Cpt 4	2.8
12-3, 64–66	29	271.6	62	18	8	12				Sep?	57	27			13	Cpt 3	2.1
13-4, 120–122	30	283.2	74	9	7	10				Talc?	57	29			12	Cpt 2	2.0
14-2, 50–52	31	289.0	76	11	10	3				Talc?	55	28			15	Cpt 2	2.0
16-3, 1–3	32	309.0	58	8	14	20					38	55			6	Cpt 1	0.7
16-3, 69–71	33	309.7	62	10	18	10					55	37			7	Cpt 1	1.5
17-4, 84–86	34	320.8	74	10	10	4	Rhod 2			Sep?	52	40			8	Cpt 1	1.3
19-2, 49–51	36	329.0	70	13	10	5				Cpt 1-2	77	14			7	Cpt 2/Pal?	5.5
19-2, 92–94	37	329.4	64	20	8	6				Cpt 2/Sep?	55	32			11	Cpt 2	1.7
21-5, 81–83	38	350.8	51	21	20	4		?	4		54	38			5	Cpt 3	1.4
23-1, 90–92	39	363.9	67	16	12	3		?		Cpt 2	71	17			9	Cpt 3	4.2
23-4, 89–91	40	368.3	64	15	12	7		2			70	23			6	Cpt 1	3.0
25-1, 59–61	42	382.6	38	17	34	7		3		Cpt 1-2	67	27			4	Cpt 2	2.5
27-4, 85–87	43	406.4	44	13	28	13		2			66	26			7	Cpt 1	2.5

28-4, 72–74	44	415.7	60	20	11	6		3			58	34			8	Cpt m	1.7
29-2, 114–116	45	422.6	57	16	17	7		3			67	27			6	Cpt m	2.5
30-3, 70–72	46	433.2	70	16	8	6		?		Cpt?	80	14			6	Cpt m/Talc?	5.7
31-3, 58–60	47	442.6	63	17	9	7		2		Cpt 2	81	12			6	Sep 2/Talc 2/Cpt 1	6.8
32-5, 111–113	48	455.6	59	20	14	6			1		82	10			8	Cpt m	8.2
33-3, 85–87	49	460.9	56	14	12	6		2			78	15			7	Cpt 1	5.2
36-2, 105–107	50	489.1	61	12	6	19		2			78	16			5		4.9
39-1, 60–62	51	515.6	71	14	10	5					79	18			3		4.4
477-3-2, 5–7	1	12.1	53	16	22	3				Cpt 6/Apa m	55	33				Cpt 12	1.7
3-2, 111–113	2	13.1	81	7	5	5	Rhod 2				100						—
4-1, 85–87	3	20.9	80	7	7	6					65	35					1.9
5-1, 82–84	4	30.3	74	11	7	7				Cpt 1/Gyp?	68	23			9		3.0
7-1, 24–26	5	48.7	80	6	6	8					70	24			6	Talc m	2.9
7-2, 56–58	6	49.0	33	25	38	1	Rhod 3			Hor m	96	2			1		48.0
15-1, 15–17	7	105.2	68	17	6	1	Dol 7			Apa 1/Anh m	34	38	28				0.9
16-2, 32–34	8	116.8	73	22	5		Dol?					55	45				1.2
17-3, 27–29	9	127.8	67	23	10							59	41				1.4
19-2, 140–142	10	145.4	59	25	14	2		1		Apa 1/Anh 2		30	70				0.4
20-1, 90–92	11	153.9	62	19	16	3				Apa?/Anh? Talc m		25	73			Talc 2	0.3
478-1-1, 17–19	1	0.2	62	15	15	3	Dol 1/Mg-C′			Cpt 1/Gyp?	100				m		—
2-3, 69–71	2	7.2	76	7	5	12					33	45		17		Cpt 5	0.7
2-3, 83–85	3	7.3	78	10	8	4					48	40	5	5		Cpt 2	1.2
7-6, 73–75	4	58.2	34	25	28	4				Cpt 9	42	41			15	Cpt 2	1.0
15-3, 81–83	5	130.8	73	11	10	4				Cpt 2	42	42		12		Cpt 2	1.0
16-3, 58–60	6	140.1	77	10	9	3	Dol?			Cpt 1	62	29		7		Cpt 2	2.1
17-3, 64–66	7	149.6	66	14	12	3				Cpt 5	45	52		3		Cpt 5	0.9
20-5, 104–105	8	170.0	77	10	9	4					53	31			16	Cpt m	1.7
21-3, 51–53	9	178.0	75	10	8	7					49	39	3		10	Cpt m	1.2
28-6, 38–40	10	249.9	78	8	6	8					45	40			15	Pal?/ML?	1.1
32-1, 43–45	11	269.9	68	11	13	5				Cpt 3	51	35			13	Cpt 1/ML?	1.4
32-1, 113–115	12	270.6	62	13	20	3		?		Cpt 2	41	39			13	Cpt 7	1.0
36-1, 129–131	13	308.8	58	21	22	?		1		Cpt 4	45	33	12	4		Cpt 6	1.4
39-3, 59–61	14	330.1		10	7	4				Opal-CT m	35	45	10	6		Cpt 4	0.8
479-6-2, 68–70	1	43.2	66	10	7	15		2		Cpt?	56	35			9		1.6
10-6, 29–31	2	86.8	57	22	12	4		5		Cpt 2	51	43			6		1.2
21-2, 93–95	3	185.9	80	10	5	1	Dol3	2		Pyx?	31	55			14		0.6
36-4, 90–92	4	331.4	77	16	5	?	Dol?	2			37	47			16		0.8
44-5, 26–28	5	408.3	68	15	5	5	Dol4	3			62	30			8		2.1
481-P3-2, 72–74	1			4	4	8				Opal-CT m	45	—			55		—
P9-1, 51–53	2			13	9	6					36	48	m	16			0.8
481A-10-1, 58–60	3	128.1		13	9	3	Mg-C?				30	51			19		0.6
27-2, 43–45	4	290.9		13	12	4	Mg-C?/Dol?				54	32			11	Cpt 3	1.7
30-6, 10–12	5	325.1		12	8	3		2			48	36		12	12	Cpt 4	1.3

Notes: Abbreviations: Sm, smectite; Il, illite; Ch, chlorite; Kao, kaolinite; Qtz, quartz; Fsp, feldspar; Pyx, pyroxene; Hor, hornblende; Carb, carbonates; Ct, opal-CT; Cpt, clinoptilolite; An, analcime; Cb, cristobalite; Rhod, rhodochrosite; Mg-C, high-Mg calcite; Dol, dolomite; Sep, sepiolite; Pal, palygorskite; Sid, siderite; Anh, anhydrite; ML, mixed-layer; Apa, apatite.

[a] Not resolved (only small amounts).

[b] m = minor, + = most <2-μm samples contain quartz.

in the <2-μm fraction. Almost all <2-μm samples of Unit I contain clinoptilolite.

Unit II consists of early Pliocene olive-gray or olive-brown, diatomaceous muds. Our silty clay samples (11–14) evolved H_2S after HCl treatment for carbonate analysis.

Feldspar and quartz are common; calcite is rare to absent, but the lowermost sample contains dolomite, which becomes a major consistent in Unit III. The ratio of smectite to illite increases to about 8 (less input of detrital material?). All <2-μm samples contain clinoptilolite. The main constituent of the clay fraction, however, is amorphous material. Samples of Unit II and IV have not been received.

Hole 475B recovered 9.5 meters of late Pleistocene diatomaceous mud grading downward into nannofossil mud to ooze. Our sample is a nannofossil-bearing diatomaceous mud with quartz, feldspar, and calcite as common minerals. Amorphous constituents predominate both bulk and clay mineralogy; in the latter we found some smectite, illite, and kaolinite + chlorite.

Site 477

Site 477 (water depth 2003 m) is located in the Guaymas Basin, in a spreading rift. Drilled sediments are Quaternary and include partly turbiditic diatomaceous silts, clays, and oozes, which were found to be hydrothermally altered below a dolerite intrusion. This was drilled between 58 and 105.5 meters. Relatively high amounts of clay minerals and amorphous material were found in Unit I samples—mostly olive-brown or grayish-olive diatomaceous oozes—above dolerite. Calcite (nannofossils) is rare to common; quartz and feldspar are common. Sample 477-7-2, 56–58 cm represents a part of the sedimentary section where diatomaceous ooze with silt blebs grades into turbiditic sand; our sample is rich in feldspar and clay minerals (smectite and some illite and chlorite) which are well crystallized. It seems probable that sediments above the dolerite also have been influenced by the intrusion. Below the dolerite, brownish-gray to gray or grayish-black "hydrothermal" sediments were encountered; they consist of clays, claystones, and siltstones. The main constituents are clay minerals, quartz, and feldspar; typical admixtures include dolomite, pyrite, and anhydrite. Dolomite rhombs are rich in clayey inclusions. We could not detect smectite in samples from ~ 117 to 154 meters sub-bottom; the clay-mineral suite is dominated by chlorite and illite. In sample 477-20-1, 90–92 cm, we found some talc, which also reflects hydrothermal alteration from below. Chlorite crystallinities increase downward from sample 7 to sample 11.

Site 478

Site 478 is 12 km northwest of Site 477, in the Guaymas Basin. Oldest sediments above a dolerite intrusion are $\sim 260{,}000$ years old. The whole sedimentary sequence, which was divided into three units and several sub-units, measures 342.5 meters.

Unit IA (0–127 m) consists of olive-brown, diatomaceous oozes with intercalated turbiditic layers, mainly pale-olive-gray to gray, silty sands. Our samples—muddy diatomaceous oozes—consist of roughly equal amounts of quartz and feldspar, and some carbonate. Sample 4, 478-7-6, 73–75 cm comes from a turbidite sand layer and is rich in quartz and feldspar; here we also found clinoptilolite. Clay minerals vary: on top (Sample 478-1-1, 17–19 cm) only smectite is found, whereas all other samples also yielded abundant illite. A minor but characteristic constituent of the <2-μm fraction is clinoptilolite.

Unit IB (127–188.2 m)—grayish-olive, diatomaceous, silty mud—is characterized by relatively constant amounts of calcite, quartz, and feldspar (table). All Unit I samples yielded low percentages of crystalline material.

Unit II (188.2–260 m) consists of muddy diatom oozes to diatomites, and some dolomitic siltstones. Our sample (10) is from a diatomaceous claystone sequence and is relatively low in quartz and feldspar. Clay minerals include smectite, illite, and possibly palygorskite, plus a mixed-layer mineral. Between 220 and 232 meters and between 253 and 257 meters two sills (dolerites) were drilled. According to shipboard investigations, they caused some alteration in the sediments immediately above and below. Our samples, however, are confined to other parts of the sedimentary column.

Unit III—diatom mudstone—was divided into two sub-units. Unit IIIA (260–288 m) consists of moderate-olive brown diatomites or diatomaceous claystones; Unit IIIB consists of laminated diatomites, dolomitic siltstone, and a contact zone with a dolerite intrusion; the latter forms the basement at this site. Samples from this unit are characterized by moderate to abundant quartz and feldspar, and minor calcite. Shipboard microscopic investigations revealed a remobilization of silica caused by the dolerite intrusion. We found opal-CT in Sample 478-39-3, 59–61 cm (nannofossil-bearing claystone), which is in accordance with this observation.

Site 479

At Site 479, on the northern flank of the Guaymas Basin (water depth 756 m), 440 meters of Quaternary hemipelagic sediments were drilled. Thinly laminated muddy diatomaceous oozes to mudstones with intercalated calcareous (limestone) layers make up most of the section, which was divided into three units, though only minor differences in composition and induration were noticed.

Unit I (0–259 m; late Pleistocene) is a diatomaceous ooze of moderate olive-brown color, with rhythmically alternating thin (millimeter-scale) lighter-colored layers. Our samples (1–3; table) comprise characteristic pyrite and common to rare calcite (foraminifers, nannofossils), with or without dolomite.

Unit II (259–364.5 m)—early Pleistocene, partly indurated, muddy, diatomaceous ooze—is represented by only one sample (479-36-4, 90–92 cm), a grayish-olive, diatomaceous clay, which comprises again some pyrite in addition to detrital minerals. Calcite and dolomite possibly are present. The clay fraction is dominated by amorphous constituents.

Unit III (364–440 m; Quaternary laminated mudstones) is also represented by only one sample (479-44-5, 26–28 cm). It is a silty clay and contains about equal amounts of calcite and dolomite (altogether about 9%), and again we found pyrite, which is a typical constituent at Site 479. (According to smear-slide investigations on board, it is present in every sample analyzed).

Site 480

(No samples were received.)

Site 481

Site 481 lies in the northern rift of the Guaymas Basin at a water depth of 1998 meters. The oldest sediment cored is a late Quaternary claystone at 364 meters sub-bottom. Our five samples cover a depth range from ~12 to ~325 meters, and are we hope representative.

The sedimentary column is divided into the following types (see also site report, this volume): turbidites (two types differentiated), mass flows, and laminated sediments. Turbidite type 1 has less terrigenous material than type 2 (according to shipboard investigations), which is in accordance with our data (compare samples 1 and 2; these two samples—diatomaceous oozes—are from a piston-cored section). Sample 3 (481A-10-1, 58–60 cm) is an olive-gray diatomaceous (turbiditic?) mud, and has a composition similar to that of Sample 481P-9-1, 51–53 cm (= turbidite type 2). A mass flow is represented by sample 4 (481-27-2, 43–45 cm; a clayey siltstone) the laminated sediment sequence, by sample 5 (481-30-6, 10–12 cm; diatomaceous mudstone).

We found similar mineralogies for both samples, clinoptilolite being the characteristic component of the clay fraction. This suggests the influence of a dolerite intrusion which was cored from 328 to about 333 meters. Altogether, four complexes of basalt (partly flows), dolerite, and gabbro sills occur at Site 481.

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