35. COURSE-SILT-FRACTION MINERALOGY OF JAPAN TRENCH SEDIMENTS, DEEP SEA DRILLING PROJECT LEGS 56 AND 57

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INTRODUCTION

Soviet sedimentologists use the term "coarse silt" to denote the size fraction 0.1 to 0.05 mm (50–100 μm). Petelin (1961) has shown that this fraction is most diagnostic for terrigeneous and volcanogenic mineral assemblages and provinces in Recent deep-sea sediments, because of its greatest variability of both heavy and light non-opaque minerals, which may be easily identified by the common immersion method. We believe that the fraction is suitable for mineralogical study of unconsolidated and friable sediments from DSDP cores as well, if the objective is to investigate their source area and transporation tracks. In the case of fine-grained oceanic sediments, mineral composition of the coarse silt does not differ markedly from that of the "coarse fraction" (>62 μm).

We studied the coarse-silt fraction from Japan Trench sediments drilled during DSDP Legs 56 and 57, to determine the origin of clastic minerals, which are supposed to be both volcanic and terrigeneous. Some authigenic minerals were also found, and we discuss them briefly in this chapter.

We separated the 0.1 to 0.05 mm fraction by wet sieving, after dispersion of sediment samples in water with tripolyphosphate solution. Heavy and light fractions were separated using bromoform with specific gravity 2.9. We then studied both heavy and light fractions by the immersion method, counting 300 to 500 grains in each, if available. The results are represented as grain-frequency percentages in Table 1. We also recalculated the data on the basis of non-opaque heavy minerals and characteristic ratios (Table 2).

The studied set of samples comprises most of the Neogene to Quaternary lithologic units, distinguished on both legs, as well as a minor amount of Miocene turbidites and upper Oligocene shallow-water deposits from Site 439. The coarse-silt fraction is too scarce to be counted in the pelagic clay drilled at Site 436, and the Cretaceous shales (Site 439) and cherts (Site 436) are not friable enough to be dispersed.

HEAVY MINERALS

The heavy fraction ranges from traces to about 10 per cent of the coarse silt. Opaque minerals and rock fragments make up 25 to 92 per cent of the total heavy fraction; non-opaque minerals constitute the rest. Authigenic pyrite is commonly a prevalent opaque constituent of the fraction in hemipelagic sediments, as well as in turbidites and in shallow-water sandstones, but it is absent in the Miocene radiolarian–diatomaceous claystone, transitional from hemipelagic to pelagic, as well as in the pelagic clay drilled at Site 436 on the oceanic slope. In several samples of Pliocene and Miocene sediments from the inner trench slope, pyrite constitutes 65 to 86 per cent of the heavy fraction, masking relations among non-opaque minerals.

The non-opaque heavy minerals are mainly clastic, except for two samples from the Miocene transitional beds at Site 436, where we found 66 and 94 per cent of authigenic rhodochrosite (identification confirmed by X-ray), as well as the upper Oligocene sandstone unit at Site 439, where rhodochrosite constitutes 2 to 71 per cent. The heavy fraction from a single upper Miocene hemipelagic diatomaceous vitric silty claystone sample from Site 434 also contains 17 per cent authigenic carbonate, probably rhodochrosite.

In the Neogene to Quaternary hemipelagic sediments, pyroxenes and hornblende strongly predominate over other clastic non-opaque minerals, constituting together 73 to 98 per cent of the total (Table 2). Pyroxenes are more abundant than hornblende, and orthopyroxene commonly prevails over clinopyroxene. The orthopyroxene is mainly pleochroic hypersthene in elongated grains and euhedral crystals, some with glassy rims. Clinopyroxenes are represented by light-brown augite with minor amounts of diopside and other varieties. Euhedral augite is common. Amphiboles are represented both by green and brown hornblende, with a minor admixture of dark-reddish-brown oxyhornblende.

The other minerals identified in the heavy fraction of hemipelagic sediments are epidote, garnet, zircon, apatite, sphene, barite, anatase, and rutile. We found the epidote group minerals in a great majority of samples. Their frequency in some samples is comparable with that of hornblende. Others are rather scarce or sporadic.

The two-pyroxene and hornblende assemblage of heavy minerals apparently represents island-arc andesitic belt volcaniclastic material, but it does not necessarily represent ash falls at the site: more or less prolonged reworking may have occurred before deposition in the deep-sea environment. Hornblende is only partly of volcanic origin, the rest being associated with a terrigenous mineral assemblage which in the hemipelagic sediments contains epidote, garnet, zircon, apatite, sphene, and rutile. The epidote + hornblende (+ pyroxene) terrigenous

TABLE 1
Mineralogy of the Coarse-Silt (0.1–0.05 mm) Fraction (% of total)

	Heavy Fraction																				Light Fraction															
Sample (interval in cm)	Black Opaques	Pyrite	Fe-oxides	Leucoxene	Garnet	Hornblende	Orthopyroxene	Clinopyroxene	Epidote Group	Actinolite	Zircon	Apatite	Sphene	Barite	Olivine	Biotite	Anatase	Rutile	Rhodochrosite	Unidentified	Quartz	Feldspar ($n < 1.54$)	Plagioclase ($n > 1.54$)	Chlorite	Zeolite	Glauconite	Chalcedony	Volc. Glass, Acidic	Volc. Glass, Basic	Org. Carbonate	Org. Silica	Org. Phosphate	Unidentified	Quartz/Feldspars	Feldspars	Volc. Glass/Feldspars + Quartz
434-1-2, 64–69	2	22	1	–	+	3	48	14	1	–	+	+	–	–	–	–	–	–	–	–	4	5	23	1	–	+	–	29	–	8	+	–	29	0.1	4.0	0.9
7-2, 55–59	–	80	+	–	–	4	10	6	+	–	+	+	–	–	–	–	+	–	–	–	7	7	15	2	–	–	–	26	1	1	2	–	40	0.3	2.4	0.9
9-1, 100–105	4	53	1	–	1	11	16	7	2	–	+	–	–	–	–	–	–	–	–	6	17	5	14	2	–	–	–	28	–	–	2	–	32	0.9	2.7	1.1
15-1, 67–81	2	22	1	–	1	15	35	10	3	–	1	–	–	–	–	–	–	–	–	10	12	12	13	+	–	+	–	36	+	–	2	–	23	0.5	1.4	1.0
19-1, 50–54	–	42	19	–	+	7	19	9	3	–	–	–	+	1	–	–	–	–	–	–	9	3	14	9	–	–	–	35	–	5	3	–	22	0.5	4.1	1.3
24-1, 78–82	1	20	62	–	+	5	2	3	1		+	1	–	–	–	–	–	–	–	4	5	2	5	–	–	–	–	30		6	8	–	44	0.7	3.2	2.5
25-2, 62–65	–	14	78	–	–	1	3	3	1	–	–	–	–	+	–	–	–	–	–	–	2	+	9	3	1	–	–	26	+	25	2	–	30	0.2	26.0	2.4
434A-1-2, 56–60	7	25	3	–	1	14	28	13	3	–	1	–	–	–	–	–	1	–	–	6	5	2	14	2	–	–	–	32	–	–	4	–	40	0.3	6.0	1.5
434B-4-1, 30–34	7	42	7	–	–	21	11	4	–	–	1	+	–	–	–	–	–	–	–	6	4	1	5	5	–	+	3	36	–	–	6	–	39	0.7	4.7	3.6
8-1, 40–44	10	25	1	–	–	26	19	10	1	1	–	–	+	–	–	–	–	–	–	6	7	+	13	3	–	–	–	48	–	4	4	–	20	0.5	38.0	2.4
25-2, 140–144	8	31	9	–	+	13	10	4	3	–	1	1	–	–	–	–	–	–	17	4	4	1	8	2	1	–	–	21	–	–	1	–	63	0.4	9.5	1.6
435-1-1, 50–54	20	8	5	–	+	8	30	12	5	+	1	+	+	–	–	–	–	+	–	–	9	4	1	6	1	–	–	36	–	1	–	–	31	0.6	3.0	2.6
-2-3, 123–127	32	8	3	+	1	7	24	12	3	–	1	1	1	+	+	–	–	+	–	7	8	4	11	7	–	–	1	38	–	2	1	–	30	0.5	2.5	1.6
6-4, 46–50	12	12	2	–	+	10	32	11	4	–	+	1	+	–	–	–	–	–	–	10	6	3	14	10	–	–	–	34	–	–	2	–	29	0.3	5.1	1.5
6-6, 60–64	14	17	1	–	2	12	16	18	9	1	1	1	1	–	–	–	–	+	–	10	12	6	8	6	–	+	–	29	–	1	2		37	0.9	1.4	1.1
8-1, 61–64	49	5	3	–	–	6	22	12	–	–	1	–	–	–	–	–	–	–	–	3	8	1	19	4	–	–	–	39	–	–	3	–	26	0.4	21.0	1.4
10-1, 71–78	4	32	2	–	1	6	18	16	7	–	1	1	1	–	–	–	–	+	–	12	10	5	8	4	–	–	–	43	–	1	1	–	27	0.8	1.5	1.9
12-1, 27–29	11	14	–	1	–	3	33	31	1	–	–	–	–	–	–	–	–	–	–	6	+	1	18	12	–	–	–	50	–	1	1	–	17		24.0	2.6
14-3, 16–20	4	39	2	–	+	16	13	7	5	1	1	1	1	–	–	–	–	+	–	9	7	3	8	6	–	–	–	43	1	–	5	–	27	0.6	2.4	2.4
16-1, 82–86	1	70	+	–	1	8	4	7	1	1	+	1	+	–	–	–	–	–	–	5	6	2	3	3	–	–	–	60	–	–	7	–	18	1.2	1.3	5.4
435A-1-2, 123–127	6	29	5	–	–	4	25	22	2	+	1	–	–	–	–	–	–	–	–	6	4	2	9	3	–	–	–	34	–	4	20	–	24	0.4	4.6	2.3
1-4, 130–133	3	29	1	–	+	13	19	21	3	–	–	1	–	–	–	–	–	–	–	10	9	5	11	7	1	–	–	28	–	3	1	–	36	0.6	2.2	1.1
8, CC	29	14	34	–	1	2	14	5	1	–	–	–	–	–	–	–	–	–	–	–	4	+	5	3	–	–	–	15	–	–	54	–	19	0.8	14.0	0.8
436-2-1, 100–106	19	61	2	–	+	8	34	14	5	–	–	2	–	–	–	–	–	–	–	9	7	6	17	4	1	–	–	34	–	1	+	–	27	0.3	3.2	1.1
3-4, 72–76	26	3	4	–	4	30	21	3	–	–	+	1	–	–	–	–	–	–	–	8	7	2	12	–	–	–	–	61	–		3	–	17	0.5	6.0	2.9
5-3, 57–61	12	9	2	–	1	7	32	18	5	+	1	+	+	–	–	–	–	–	–	14	9	5	7	4	–	+	–	36	–	–	4	–	39	0.8	1.5	1.7
7-6, 59–61	15	57	1	+	+	3	13	5	1		+	–	–	–	–	–	–	–	–	4	5	1	6	2	–	–	–	73	–	–	1	–	11	0.7	6.0	6.1
8-3, 60–64	6	61	2	–	1	8	9	7	3	–	1	1	+	–	–	–	–	–	–	3	4	2	6	2	–	–	–	70	–	–	1	–	14	0.5	3.3	5.8
10-1, 118–122	5	21	1	–	1	21	24	15	3	–	1	1	–	–	–	–	–	–	–	7	10	2	12	3	–	–	–	47	–	–	5	–	21	0.7	5.7	2.0
13-2, 46–50	12	23	18	–	–	7	16	11	4	+	+	–	–	–	+	–	–	–	–	9	4	1	10	2				58			5		20	0.4	26.0	3.9
14-3, 54–56	18	18	4	–	+	40	5	5	3	–	1	1	–	–	–	–	–	–	–	6	9	4	5	5	–	–	–	68	–	+	–	–	9	1.0	1.2	3.8
17-4, 40–44	11	36	23	–	+	6	7	10	1	–	+	+	–	–	–	–	–	–	–	4	1	2	12	2	–	–	–	58	–	–	3	–	23	0.1	7.8	3.9
22-1, 75–78	3	66	16	–	–	3	2	9	1	–	–	+	–	–	–	–	–	–	–	–	2	–	3	2	–	–	–	66	–	–	7	–	18	0.7	–	13.2
23-4, 60–64	5	42	25	–	–	8	5	4	2		+		+	–	–	–	–	–	–	9	6	1	8	–	–	–	–	54	–	–	7	–	25	0.7	6.0	3.6
26-1, 8–12	4	75	2	–	6	5	3	2	–	–	+	–	–	–	–	–	–	–	–	4	1	+	2	1	–	–	–	72	–	–	14	–	10	0.5	7.0	24.0
29-1, 52–54	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	1	1	–	–	–	–	73	–	–	5	–	16	2.0	2.0	12.2
31-2, 60–64	10	–	4	–	–	8	2	6	4	–	–	1	–	–	–	–	–	–	66	–	4	1	7	1	–	–	–	79	+	–	4	–	9	0.4	7.0	6.6
37-1, 80–84	1	–	+	–	–	–	+	1	2	–	–	–	–	–	–	–	–	–	94	–	–	+	15	–	–	–	–	42	7	–	7	3	26	–	30.0	2.6
438-2, 274–278	5	8	1	–	1	25	19	24	6	–	1	1	+	–	–	–	–	–	–	12	9	2	9	7	–	–	–	24	–	11	–	–	39	0.8	4.5	1.2
5-4, 100–104	5	22	+	–	+	14	21	20	7	+	+	–	–	–	–	1	–	–	–	9	6	2	11	17	–	–	–	45	–	–	2	–	17	0.5	6.0	2.6
10-2, 112–116	7	14	–	–	1	16	20	22	3	2	–	2	+	–	–	3	–	–	–	9	7	4	8	4	1	–	–	14	–	–	24	–	39	0.6	2.3	0.7
12-4, 28–30	8	6	4	–	1	15	8	6	5	1	1	1	–	+	–	3	–	–	–	10	8	+	4	6	2	–	–	26	–	–	32	–	23	1.7	11.0	2.1
438A-2-2	8	7	1	–	1	21	16	23	7	1	1	1	1	–	1	1	–	–	–	12	10	4	11	3	–	–	–	22	–	5	1	–	46	0.7	2.8	0.9
4-2, 30–34	6	17	1	–	–	14	17	26	9	2	+	1	–	–	–	1	–	–	–	7	9	5	16	6	1	–	–	26	–	+	–	–	37	0.4	3.2	0.9
14-2	9	34	2	–	1	16	10	9	5	2	+	1	+	–	–	2	–	–	–	10	9	4	8	3	–	–	–	35	–	–	12	–	31	0.8	2.0	1.7
18-2, 65–69	7	62	5	–	1	7	4	4	6	2	–	1	1	–	–	–	1	–	–	–	4	1	4	2	–	–	–	23	–	–	34	–	32	0.8	6.0	2.6
28-2, 80–82	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9	7	4	5	–	–	–	12	–	–	18	–	45	0.8	0.6	0.6
34-2, 9-13	13	26	1	–	–	7	11	14	14	1	1	–	1	–	–	–	–	–	–	11	7	3	9	3	–	+	–	19	–	–	21	–	38	0.6	3.3	1.0
40-2, 106–110	18	37	3	–	2	13	1	4	14	–	1	1	+	–	+	–	–	–	–	5	7	2	6	5	–	+	–	30	–	–	11	–	39	0.9	2.8	2.0
48-2, 30–32	4	81	3	–	1	2	+	4	5	–	+	+	–	–	–	–	–	–	–	–	10	5	–	5	–	–	–	8	–	–	45	–	27	2.0	0	0.5
54-1, 83–85	7	50	8	–	+	14	1	5	8	1	1	1	–	–	–	–	–	–	–	4	3	2	3	2	–	–	–	9	–	–	66	–	15	1.0	0.4	1.1
60-2, 115–117	1	86	1	–	1	3	1	4	3	–	1	–	–	–	–	+	–	–	–	–	8	1	3	4	1	2	–	18	–	–	25	–	39	2.0	3.0	1.5
82-2, 100–102	3	82	1	–	+	9	+	1	2	–	+	–	–	–	–	–	–	–	–	–	1	1	24	–	–	–	–	8	18	–	6	–	42	0.1	36.0	0.3
439-12-1, 146–148	24	9	1	–	2	20	+	5	27	1	1	1	+	–	–	–	+	–	–	9	10	20	6	2	–	–	–	15	–	–	18	–	51	0.4	0.3	0.4
16-2, 114–116	22	28	1	–	1	9	–	4	22	1	1	2	–	+	–	–	–	–	–	9	14	12	2	1	–	–	–	–	–	–	2	–	68	1.0	0.2	0
22-2, 15–18	52	17	1	–	2	6	1	2	7	–	2	4	1	–	–	–	–	–	2	4	14	12	10	1	–	–	2	–	–	–	–	–	61	0.6	0.8	0
24-1, 84–87	13	76	–	–	–	9	–	2	1	–	1	1	–	–	–	–	–	–	–	2	11	16	12	–	–	–	–	–	–	–	+	–	60	0.4	0.8	0
28-1, 87–90	10	49	12	–	2	1	–	1	3	–	2	4	1	–	–	+	–	–	7	6	5	10	22	–	–	–	–	–	–	–	1	–	60	0.2	2.2	0
32-1, 146–148	6	9	–	–	7	1	–	1	1	1	3	2	–	–	–	–	–	–	71	–	6	3	–	–	–	–	2	–	–	23	–	–	68	2.1	0	0
440-2-1, 51–55	8	46	2	–	2	5	23	12	1	–	1	–	–	–	+	–	+	–	–	–	6	1	14	4	–	–	–	23	–	–	6	–	45	0.4	14.0	1.1
440A-4-1, 20–24	2	26	7	–	–	22	13	14	6	4	1	1	1	–	–	1	–	–	–	2	7	–	5	1	–	1	–	61	–	–	3	–	22	1.4	–	5.1
440B-3-1, 80–84	6	13	5	–	1	14	21	19	7	2	+	1	–	–	–	–	–	–	–	10	8	+	8	1	–	–	–	40	–	–	15	–	28	1.0	23.0	2.5
6-1, 135–139	14	–	2	–	1	32	19	12	7	2	1	1	1	–	–	–	–	–	–	7	6	3	5	3	–	–	–	65	–	–	+	–	17	0.7	1.5	5.0
10-1, 71–75	5	12	1	–	+	25	17	19	4	1	1	+	–	–	–	3	–	–	–	12	13	9	9	3	–	–	–	20	–	–	16	–	28	0.7	1.0	0.6
16-1, 129–131	3	61	1	–	+	3	14	13	2	–	1	1	+	–	–	–	–	–	–	2	4	–	6	1	–	–	–	77	–	–	4	–	8	0.7	–	7.7
42-1, 110–112	5	33	10	–	3	23	7	12	6	–	–	1	1	–	1	–	–	1	–	–	6	1	5	1	–	–	–	33	–	–	4	–	51	1.0	5.0	2.8

assemblage is widespread in the Recent circum-Pacific mineral megaprovince (Petelin and Alexina, 1970; Murdmaa et al., 1979).

Comparing the heavy minerals in the Japan Trench hemipelagic sediments from different sites and of different ages, we observed rather indistinct changes. The proportion of the two-pyroxene assemblage is greatest on the lower inner trench slope (Site 434), decreasing both toward upper slope (Sites 435, 438) and on the outer slope (Site 436), where epidote, hornblende, and other terrigenous minerals tend to increase in frequency with respect to pyroxenes.

Another trend is an increase in the proportion of the terrigenous assemblage with increasing age of sediments. This trend is slight on the lower trench slope (Site 434) and on the outer slope (Site 436), but it is particularly apparent on the terrace edge (Site 438). In Quaternary and upper-Pliocene sediments at Site 438, pyroxenes predominate, whereas in the lower Pliocene and, even more, in the upper and middle Miocene, epidote +

TABLE 2
Non-opaque Heavy Minerals in Coarse (0.1–0.05 mm) Fraction (% of total)

Sample (interval in cm)	Sub-bottom Depth (m)	Clinopyroxene	Orthopyroxene	Hornblende	Epidote Group	Garnet	Zircon	Apatite	Sphene	Biotite	Anatase	Rutile	Actinolite	Barite	Olivine	Rhodochrosite	Number of Grains
434A-1-2, 56–60	2.0	22	47	24	4	1	1	1	–	–	–	–	–	–	–	–	301
434-1-2, 64–69	2.1	21	73	4	1	+	+	+	–	–	–	–	–	–	–	–	288
7-2, 55–59	56	27	48	18	2		2	1	–	–	1	–	–	–	–	–	95
9-1, 100–105	74.0	19	44	30	4	1	1	+	–	–	–	–	–	–	–	–	144
15-1, 67–81	130.5	15	53	24	5	1	2	–	–	–	–	–	–	–	–	–	254
19-1, 50–54	168.5	22	48	17	8	1	–	–	1	–	–	–	–	3	–	–	161
24-1, 78–82	216.5	24	15	43	8	3	3	4	–	–	–	–	–	–	–	–	67
25-2, 62–65	225.5	33	43	12	9	–	–	–	–	–	–	–	–	3	–	–	33
434B-4-1, 30–34	315.0	10	30	56	–	–	3	1	–	–	–	–	–	–	–	–	144
8-1, 40–44	353.0	17	33	46	1	–	–	–	1	–	–	–	2	–	–	–	320
25-2, 140–144	517.0	13	30	40	9	1	3	3	–	–	–	–	–	–	–	–	149
435-1-1, 50–54	0.5	21	52	14	8	1	1	+	1	–	–	–	1	–	–	–	271
435A-1-2, 123–127	2.7	41	46	8	4	–	1	–	–	–	–	–	1	–	–	–	193
1-4, 130–133	6.0	38	33	23	5	+	–	1	–	–	–	–	–	–	–	–	283
8, CC, 0–4	206.5	20	62	10	5	3	–	–	–	–	–	–	–	–	–	–	39
435-2-3, 123–127	12.0	24	49	15	5	2	1	1	1	–	–	+	–	+	1	–	204
6-4, 46–50	51.0	19	56	17	6	+	+	1	+	–	–	–	–	–	–	–	240
6-6, 60–64	54.0	30	27	20	14	3	1	2	1	–	–	+	1	–	–	–	234
8-1, 61–64	65.5	27	58	14	–	–	1	–	–	–	–	–	–	–	–	–	165
10-1, 71–78	84.5	33	36	11	14	2	1	1	1	–	–	+	–	–	–	–	208
12-1, 27–29	103.0	46	48	4	2	–	–	–	–	–	–	–	–	–	–	–	367
14-3, 16–20	125.0	16	30	36	11	+	2	3	1	–	–	+	1	–	–	–	192
16-1, 82–86	142.0	30	18	35	3	2	1	3	1	–	–	–	6	–	–	–	88
436-2-1, 102–106	9.0	22	54	12	9	1	–	2	–	–	–	–	–	–	–	–	290
3-4, 72–76	22.5	35	51	7	4	1	1	1	–	–	–	–	–	–	–	–	270
5-3, 57–61	40.0	28	50	11	8	1	1	+	+	–	–	–	+	–	–	–	254
7-6, 59–61	63.5	21	57	14	5	1	2	–	–	–	–	–	–	–	–	–	130
8-3, 60–64	68.5	24	31	27	11	2	2	2	1	–	–	–	–	–	–	–	126
10-1, 118–122	85.0	23	36	32	5	1	1	1	–	–	–	–	–	–	–	–	281
13-2, 46–50	114.5	28	41	19	9	–	1	–	–	–	–	–	1	–	1	–	140
14-3, 54–55	125.5	9	10	74	5	+	1	1	–	–	–	–	–	–	–	–	272
22-1, 75–78	199.0	60	14	19	5	–	–	2	–	–	–	–	–	–	–	–	42
17-4, 40–44	155.5	40	28	24	5	1	1	1	–	–	–	–	–	–	–	–	93
23-4, 60–64	212.5	18	26	41	12	–	1	–	1	–	–	–	–	–	–	–	78
26-1, 8–12	236.0	20	31	37	10	–	2	–	–	–	–	–	–	–	–	–	49
29-1, 50–54	265.5	28	10	35	22	–	–	5	–	–	–	–	–	–	–	–	40
31-2, 60–64	285.5	7	2	9	4	–	–	1	–	–	–	–	–	–	–	77	248
37-1, 80–84	341.5	1	1	–	3	–	–	–	–	–	–	–	–	–	–	96	278
438A-2-2	25	31	23	28	10	1	1	1	+	2	–	–	2	–	1	–	313
4-2, 30–34	44	38	25	20	12	–	+	–	–	2	1	–	2	–	–	–	309
14-2	185	20	23	34	12	2	+	2	1	3	–	–	3	–	–	–	238
18-2, 65-69	223	17	14	28	24	3	3	2	–	–	2	–	7	–	–	–	58
28-2, 80–82	318	17	21	17	28	–	4	2	–	–	–	–	11	–	–	–	53
34-2, 9–13	374	27	22	14	27	–	2	–	2	–	–	–	5	–	–	–	55
40-2, 106–110	432	10	3	34	37	5	1	6	3	–	–	–	–	–	1	–	147
48-2, 30–32	509	32	3	12	40	8	2	2	–	–	–	–	+	–	–	–	40
54-1, 83–85	557	16	2	46	25	2	2	4	2	–	–	–	2	–	–	–	56
60-2, 115–117	624	30	6	24	24	6	6	–	–	3	–	–	–	–	–	–	33
82-2, 100–102	833	9	3	64	17	3	3	–	–	–	–	–	–	–	–	–	64
438-2-2, 74–78	7	31	25	33	8	1	1	1	+	–	–	–	–	–	–	–	308
5-4, 100–104	39	31	33	22	10	1	1	–	–	1	–	+	1	–	–	–	308
10-2, 112–116	84	32	29	22	5	1	–	3	+	4	–	–	3	–	–	–	224
12-4, 28–30	105	16	18	37	13	3	–	2	–	7	–	–	3	+	–	–	232
439-12-1, 146–148	917	9	+	35	46	3	2	2	1	–	+	–	1	–	–	–	301
16-2, 114–116	947	10	–	22	56	2	2	4	–	–	–	–	3	1	–	–	180
22-2, 15–18	1003	10	2	23	28	9	10	15	2	–	–	–	–	–	–	–	106
24-1, 84–87	1023	8	–	9	24	15	11	26	4	2	–	–	–	–	–	–	53
28-1, 87–90	1059.4	17	–	69	4	–	4	6	–	–	–	–	–	–	–	–	52
32-1, 108–109	1097.5	3	–	3	7	50	20	13	–	–	–	–	3	–	–	–	60
440-2-1, 51–55	7	28	52	12	3	4	1	–	–	–	+	–	–	–	+	–	193
6-1, 135–139	46	16	24	43	9	1	1	1	1	–	–	–	3	–	–	–	294
440A-4-1, 20–24	102	22	22	37	9	–	1	2	–	1	–	–	6	–	–	–	278
440B-3-1, 80–84	159	29	33	22	10	1	1	–	1	–	–	–	3	–	–	–	226
10-1, 71–75	226	27	24	35	6	1	1	1	–	4	–	–	1	–	–	–	308
16-1, 127–131	283	38	43	10	5	1	1	1	1	–	–	–	–	–	–	–	146
42-1, 110–112	530	24	12	43	11	5	–	1	–	–	–	1	–	–	2	–	81

hornblende prevails over pyroxenes, with a corresponding increase in garnet and zircon frequencies.

The lower-Miocene turbiditic sequence and the upper Oligocene sandstones and siltstones at Site 439 appear to continue this trend, showing apparent predominance of the terrigenous assemblage. Pyroxenes, especially hypersthene, are rather scarce in heavy fractions from these deposits. The epidote group prevails over other non-opaque minerals, constituting up to 55 per cent of the total (Table 2). Garnet, zircon, and apatite show relatively high frequencies; sphene, tourmaline, and biotite occur sporadically. The data show that silt-size volcaniclastic products occur as minor constituents in lower Miocene turbidites and are likely absent in upper Oligocene shallow-water deposits. Our conclusion corresponds with that of Miki and Takahashi (this volume), but is even more categorical.

LIGHT FRACTION

The light fraction of the coarse silt, along with clastic grains, contains considerable biogenic opal (large diatoms, radiolarians, and sponge spicules), and occasionally some biogenic or authigenic calcite. "Unidentified" grains, mainly rock fragments and lithic ash, constitute 8 to 68 per cent of the fraction, in most samples ranging from 20 to 40 per cent (Table 1).

Plagioclase, quartz, and volcanic glass are the dominant identified clastic grains in all samples; however, their quantitative interrelations vary widely. We expressed these variations by ratios: quartz to feldspar, labradoritic plagioclase (index of refraction > 1.54) to other feldspars, and volcanic glass to quartz + feldspar.

The quartz-to-feldspar ratio in terrigenous mineral assemblages of the deep-sea sediments is generally indicative of the relative influence of acidic and basic rocks in source areas, and it is also sensitive to "maturity" of terrigenous clastic material, rising with repeated reworking and weathering cycles. Because island-arc andesitic volcanic products contain very little quartz and much plagioclase, their quartz-to-feldspar ratio is extremely low, far below unity, so andesitic, dacitic, or basaltic volcaniclastic material results in decreasing values of the ratio in heterogeneous coarse fractions. High values of the labradoritic to alkaline feldspars ratio are indicative of unaltered andesitic-belt volcanic products or basic parent rocks, whereas low figures appear if albitized greenstones or granitic or alkaline rocks supply the clastic material. The glass to crystalline matter ratio indicates the proportion of vitric tephra or pumice. It is very high in vitric-ash interbeds, and decreases to zero in terrigenous sediments, as well as in coarse-grained, reworked lithic-crystal volcaniclastic material (Murdmaa et al., 1979).

In the Japan Trench Neogene to Quaternary hemipelagic sediments, the quartz-to-feldspar ratio is less than 1.0 throughout, except for a few samples where it increases up to 2.0. These exceptions belong to samples in which both feldspar and quartz show low concentrations relative to abundant volcanic glass or biogenic opal, so the grain counts may be not representative. Hence, the ratio is indicative of a predominant andesitic-belt volcaniclastic assemblage, but we assume that there is some enrichment in quartz relative to primary pyroclastic matter.

The calcic to alkaline feldspars ratio in the hemipelagic sediments is variable, ranging from 1.1 to 28.0. In the great majority of the samples, labradoritic plagioclase apparently predominates over silicic plagioclase (with trace amounts of potassium feldspar), indicating an andesitic-belt mineral assemblage.

The vitric to crystalline matter ratio in the light fractions from hemipelagic sediments ranges from 0.5 to 24, showing wide variations in relative abundances of both constituents. Rather low values (commonly 0.9 to 2.6) occur at inner-slope sites, except for vitric-ash interbeds. At Site 436 on the oceanic slope, predominance of vitric silt is much more apparent, especially in the lower part of the hemipelagic section, where the ratio ranges from 3.8 to 24. We assume that the difference is caused by gravity sorting of the primary volcaniclastic material, so that lighter vitric particles tend to be transported farther from island-arc source areas as compared with heavier crystalline material. Also, floating pumice may carry the vitric components to any distance. Furthermore, the inner-slope sediments probably contain a considerable proportion of terrigenous quartz and feldspar, carried by near-bottom gravity transport, which does not reach the oceanic slope.

The light fractions in lower Miocene turbidites and upper Oligocene shallow-water deposits at Site 439 differ markedly from those of the hemipelagic sediments. Rock fragments and altered minerals make up more than 50 per cent of the fraction. Volcanic glass is absent (except for one sample), and the vitric to crystalline matter ratio is zero. The quartz-to-feldspar ratio is variable (0.2–3.0), thus showing both "mafic" and "acidic" composition of the source material. The ratio of feldspars ranges from 0 to 2.2; in most samples it is below unity, indicating metamorphic or acidic igneous parent rocks. The data indicate that the clastic silt is terrigenous.

Rare grains of authigenic (?) zeolite and glauconite occur occasionally in the light fraction.

DISCUSSION

We recognized two clastic mineral assemblages in the Cenozoic sediments drilled during legs 56 and 57 in the Japan Trench. The index minerals for the first are hypersthene, augite (± hornblende) in the heavy fraction, and labradorite to andesine plagioclase + colorless volcanic glass in the light fraction. This assemblage is apparently derived from andesitic-belt volcanic products, which may be deposited either directly, just after subaerial volcanic eruptions on nearby island arcs, or as a result of post-eruptive reworking of tephra and older volcaniclastic rocks. The assemblage utterly dominates in Recent deep-sea sediments surrounding such volcanically active island arcs as the Kurile, Aleutian, Idzu–Bonin, Mariana, Tonga, and others, where the contribution of clastic minerals from continental sources is minimized (Murdmaa, 1971; Murdmaa et al., 1979). Ujie et al. (1977) have found a similar assemblage of clastic minerals in late Cenozoic sediments in northwestern Hokkaido.

Another terrigenous mineral assemblage is marked by epidote + hornblende with minor garnet, zircon, apatite, sphene, and tourmaline in heavy fraction, and by quartz + alkaline feldspars (albite–oligoclase and potassium feldspar) in the light fraction. Some pyroxenes and labradorite may also be associated with the assemblage, but unaltered volcanic glass is absent. This terrigenous assemblage is likely derived from low-grade metamorphic rocks such as greenstones or greenschists, but with an essential contribution from acidic rocks, which may be either granitic or high-grade metamorphic rocks. The epidote + hornblende assemblage is widespread in the Recent sediments on Pacific Ocean margins, where it is probably related to Cenozoic and Mesozoic orogenic source provinces (Murdmaa et al., 1979).

Along with non-opaque minerals, the Oligocene and lower Miocene clastic rocks at Site 439 contain abundant lithic fragments, which are mainly silicic (quartzose and feldspathic). In smear slides, we detected altered leucocratic volcanic rocks and possibly hydrothermal metamorphic rocks, including those composed of mosaic quartz with mica. Thus, the nearby source area was not merely a volcanic island arc: certain metamorphic basement rocks likely have been exposed on the hypothetical Oyashio landmass. Moreover, we have not found in these sediments any unaltered volcaniclastic matter, which might indicate synsedimentary volcanic activity on nearby islands. Thus, it seems likely that the volcanism which produced the dacitic rocks found as boulders in conglomerates at Site 439 ceased completely before the late Oligocene shallow-water sandstones began to accumulate.

In the Japan Trench Neogene to Quaternary hemipelagic sediments, the andesitic-belt volcaniclastic assemblage apparently predominates, although the terrigenous assemblage is also present in minor quantities. On the deep terrace edge, at Sites 438 and 439, we observed a gradual downward increase in the proportion of the terrigenous assemblage, so that in the lower Miocene turbidites it prevails over the volcaniclastic assemblage, and in the Oligocene shallow-water deposits it makes up the whole coarse-silt fraction.

The Neogene to Quaternary two-pyroxene + hornblende + labradorite + colorless volcanic glass assemblage (scarce quartz, alkaline feldspars, and accessory minerals) is apparently associated with young volcaniclastic products derived from the Japanese andesitic-belt volcanoes. The volcanic activity, however, was not necessarily synsedimentary, but may have been somewhat older. Most of the volcaniclastic material probably is epiclastic and was carried from subaerial tephra deposits together with some non-volcaniclastic terrigenous particles. The terrigenous admixture in the coarse silt seems to decrease with time from the Miocene to the Recent; however, we hesitate to interpret this as evidence of increasing volcanic activity. Vitric-tephra interbeds ("ash layers") likely are much more reliable for reconstruction of volcanic events than is the coarse-silt mineralogy, because the volcaniclastic assemblage is epiclastic.

Comparing the coarse-silt mineral composition in correlative hemipelagic sediments from different sites, we found some evidence of sorting during offshore transportation. The volcanic-glass content relative to feldspar and quartz increases at the outer trench slope (Site 436), and is lowest on the upper part of the inner slope. These changes correspond to the total silt and the coarse silt clastic content in sediments, as indicated by grain-size analyses, if coarse biogenic constituents are excluded: the higher the clastic silt and sand content, the lower volcanic glass in coarse silt. The same patterns were recognized in Recent sediments along two transects across the Kurile Trench (Murdmaa, 1971), interpreted as evidence of mechanical differentiation of andesitic-belt volcaniclastic material.

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