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Quaternary argillaceous sediments in the northern Japan Trench and slope areas: with special reference on chemical composition of cored sediments

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Abstract : Most sediments in the northern Japan Trench and slope areas are diatomaceous silty clay intercalated with volcanic ash. This feature is traced throughout the continental slope, the inner trench slope and the trench bottom. The chemical composition of the sediments is between averaged composition of onshore granites and Quaternary volcanics. This indicates that the sediments were supplied from the land west of the slope area. However, some major elements show a clear variation trend with increasing water depth. Silica and Mn increase with depth. In contrast, silica decreases with depth in the Southwest Japan forearc slope. The increase of silica in the northern Japan Trench area is ascribed to the regional enrichment of volcanic ash or to that of diatom.

Small amount of carbonates exists even in samples from the trench, the depth of which seemingly exceeds the carbonate compensation depth. The pelagic sediments in the east side of the trench suggests almost the same chemical composition as that in the continental slope area. The sediment in this region is enriched in SiO_2 and impoverished in Al_2O_3 and MnO in comparison with typical pelagic sediments.

1. Introduction

Analyses of sedimentary basins in the Tohoku Forearc based on seismic reflection surveys suggest the presence of Neogene sediments in the shelf and continental slope areas up to several kilometer thick (Ishiwada and Ogawa, 1976; Honza, 1979; Komatsu, 1979). Most works on these sediments have been restricted to the analysis of sedimentary basin and have not dealt with origin and supply of the sediments, except for some works on the drilled cores of the DSDP Japan Trench Transect (Scientific Party, Legs 56, 57, 1980).

In this paper, we discuss the supply and depositional environments of the sediments based on their chemical composition. The analyzed samples are the cored material of the geological and geophysical survey carried out in the Japan and Kuril Trench and slope areas during the Hakurei-maru GH 76-2 cruise (Honza ed., 1977, Honza, 1978) and a detailed survey in the north-

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ern area during the GH76-3 cruise (Arita and Kinoshita, 1978; Tamaki, 1978) (Fig. 1, Table 1).

2. Geological background of the sample cores

Most cores for this study consist of dark olive gray to olive gray homogeneous diatomaceous silty clay intercalated by volcanic ash layers (Inouchi *et al.*, 1977) (Fig. 2). This feature is observed throughout the continental slope, inner trench slope and trench bottom, except the upper slope and shelf. All cores are suggested to be the Quaternary in age on the basis of the seismic profiling and dredged results (Hasegawa *et al.*, 1977; Honza, 1978). The upper slope cores are generally enriched in sand which is usually diffusely distributed in the sediment due to intense bioturbation (Sample No. P81, P82, P83, P88, P89, P92 and P93). Silty sand turbidites are observed in some cores (Sample No. P82, P83, P85 and P86). In the northern Pacific slope area, turbidites are transported through deep sea channels such as those observed off Shimokita (Sakurai *et al.*, 1974). According to detailed survey in the shallower part off Sanriku area (Arita and Kinoshita, 1978, 1984), medium and fine sands cover the surface of the wider shelf and upper slope. Silty sediments are dominant in the narrower shelf. The surface sand consists of transparent quartz, volcanic and sedimentary rock fragments. Pumiceous fragments are commonly observed. Dredged surface sand is mostly volcanic in origin and some are granitic and carbonaceous in the northern upper continental slope (Yuasa and Tamaki, 1978).

On the contrary, parallel laminations are preserved throughout the cores on the trench floor. This reflects the near-absence of bottom life in the sediment of the trench floor. This suggests that bottom waters in the deepest parts of the trench are semi-stagnant and poor in oxygen though not entirely O_2-depleted (Hesse, 1977). Mud turbidites are observed in the cores of the trench floor.

The sample cores for chemical analyses were selected from the trench area as wide as possible to represent the local feature of chemical compositions of sediments.

P81 (750 m D) was sampled from the mid-slope gently dipping toward the southeast in the upper continental slope off Tomakomai. P82 (1,150 m D), P88 (1,223 m D), P89 (1,295 m D), P92 (938 m D) and P93 (671 m D) were from the upper continental slope off Hachinohe dipping eastward and P83 (1,650 m D) was from the foot of the upper slope forming a narrow depression between the western slope and the eastern uplifted block. P86 (1,850 m D) was from a gently uplifted mid-slope of the continental slope off Kesen-numa. P85 (4,770 m D) was from a narrow bench in the inner trench slope where is a ponded sediment. P75 (7,300 m D), P77 (7,400

Table 1 Sampled sites of cores used in this study.

Station No.	Sample No.	Latitude(N)	Longitude(E)	Depth(m)	Area
438	P75	36°42.7'	143°13.0'	7,300	Japan Trench
442	P76	37°51.0'	145°35.4'	5,400	oceanic floor
447	P77	38°25.8'	144°05.6'	7,400	Japan Trench
449	P78	43°09.4'	148°36.9'	8,805	Kuril Trench
450	P79	41°37.3'	147°54.2'	5,180	oceanic floor
455	P80	41°31.1'	145°40.9'	7,050	Kuril Trench
464	P81	42°10.0'	141°41.6'	750	off Tomakomai
467	P82	40°53.7'	142°16.7'	1,150	off Hachinohe
470	P83	40°40.7'	142°47.0'	1,650	off Hachinohe
471	P84	40°07.0'	144°21.9'	7,330	Japan Trench
476	P85	39°23.7'	143°53.3'	4,770	off Kamaishi
479	P86	39°11.2'	142°58.8'	1,850	off Kesen-numa
506	P88	40°54.0'	142°21.5'	1,223	off Hachinohe
508	P89	40°39.9	142°34.5'	1,295	off Hachinohe
626	P92	40°40.3'	142°20.2'	938	off Hachinohe
659	P93	40°50.4'	142°04.9'	688	off Hachinohe

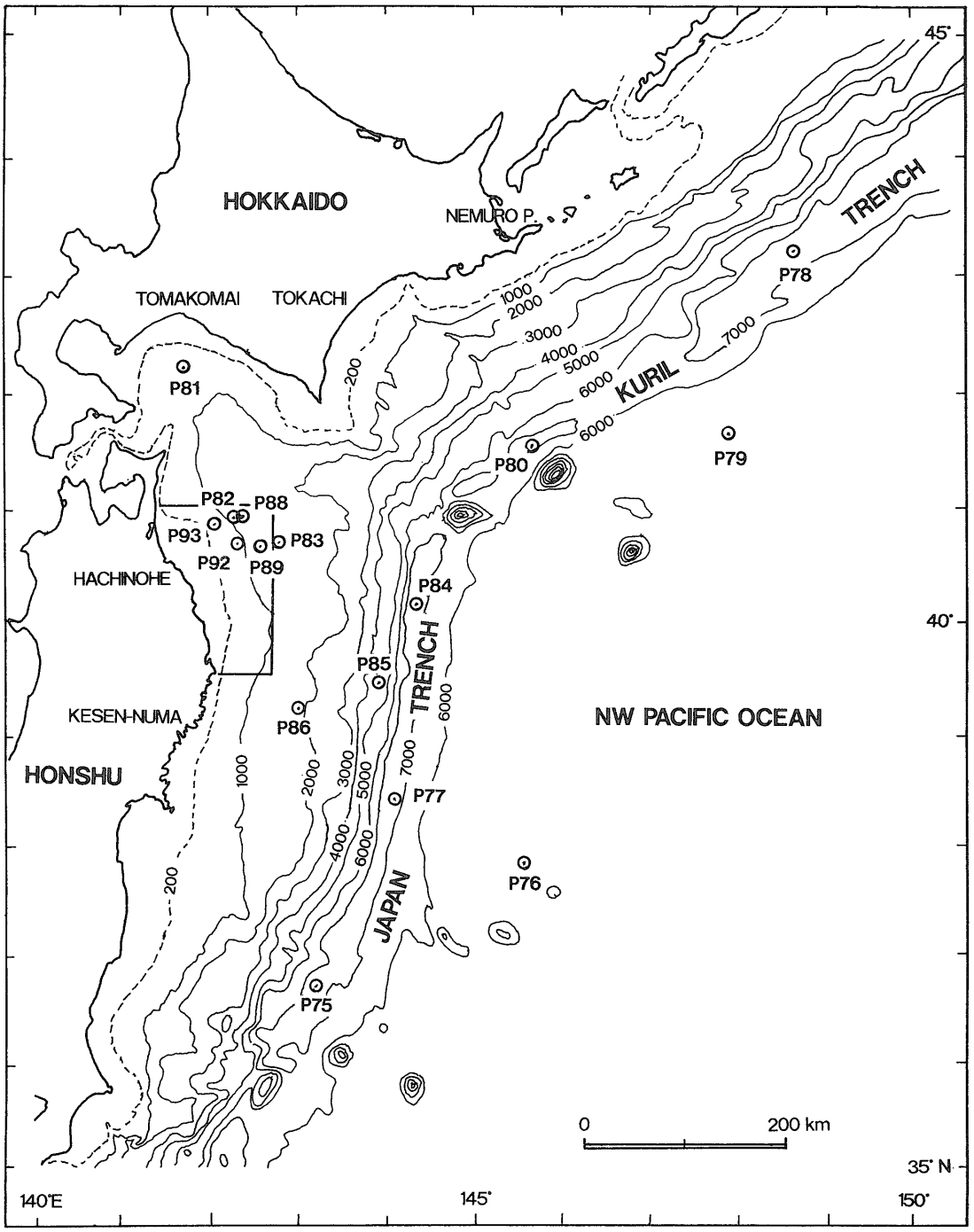

Fig. 1 Cored sites of the GH76-2 cruise. The area surrounded by thick lines east of Hachinohe is the surveyed area of the GH76-3 cruise.

Table 2 Chemical composition of argillaceous sediments in weight percent. Sampled locations are listed as depth from the top of core in centimeter.

Sample No.	P75-1	P75-2	P75-3	P75-4	P76-1	P76-2	P76-3	P77-1	P77-2	P77-3	P78-1	P78-2	P78-3	P79-1	P79-2	P80-1
Location	70	140	255	330	70	270	377	60	150	220	70	210	450	100	255	70
SiO2	60.61	59.96	60.32	60.07	60.04	64.67	59.30	60.34	61.07	64.57	63.92	63.62	64.19	59.18	60.23	66.78
TiO2	0.60	0.60	0.63	0.66	0.64	0.47	0.63	0.49	0.49	0.44	0.44	0.45	0.44	0.56	0.64	0.40
Al2O3	13.74	13.64	14.29	14.52	14.40	13.15	14.36	11.42	11.20	9.48	10.25	9.93	9.77	12.62	13.64	9.38
Fe2O3	1.46	2.31	2.10	2.33	2.72	1.96	4.17	1.95	2.41	0.85	2.15	2.12	2.31	3.33	3.75	0.80
FeO	3.56	3.15	3.17	3.12	2.59	2.18	1.87	2.33	2.18	2.74	1.94	1.98	1.87	2.01	2.44	2.81
MnO	0.066	0.080	0.084	0.095	0.050	0.057	0.064	0.058	0.056	0.046	0.140	0.120	0.110	0.071	0.082	0.077
MgO	3.09	2.79	3.00	2.99	3.33	2.27	2.90	2.62	2.87	2.76	2.32	2.33	2.36	3.17	2.95	2.09
CaO	1.31	1.65	1.50	1.61	1.74	1.52	2.69	1.23	1.14	1.65	1.28	1.49	1.28	2.02	1.94	0.61
Na2O	3.30	3.69	3.52	3.30	3.44	3.32	3.27	3.67	3.53	3.69	3.96	3.51	2.63	4.42	3.30	3.25
K2O	2.39	2.24	2.38	2.45	2.52	2.39	2.24	2.03	1.95	1.65	1.77	1.69	1.64	1.45	2.09	1.65
P2O5	0.10	0.10	0.11	0.12	0.10	0.077	0.094	0.10	0.11	0.11	0.098	0.096	0.088	0.10	0.11	0.091
H2O(+-)	5.66	5.17	6.42	7.17	6.87	4.96	5.74	8.81	7.91	5.81	3.23	7.38	4.54	6.06	5.50	8.11
CaCO3	0.43	0.27	0.43	0.13	0.33	0.61	0.00	0.31	0.43	0.13	0.71	0.00	0.44	0.00	0.77	1.25
Res.	2.76	3.71	1.97	1.28	0.22	1.94	0.42	2.86	1.61	4.27	6.14	2.61	4.64	3.52	2.23	0.063
Salts	1.28	0.93	0.97	1.17	1.58	1.40	1.40	2.50	2.38	2.06	1.56	2.42	2.02	1.25	1.32	2.33
Total	100.351	100.289	100.884	100.997	100.572	100.970	99.135	100.724	99.321	100.256	99.912	99.748	99.340	99.750	100.991	99.158

Table 2 (continued)

P80-2	P80-3	P81-1	P81-2	P81-3	P81-4	P81-5	P82-1	P82-2	P82-3	P82-4	P82-5	P82-6	P82-7	P83-1	P83-2	P83-3
235	400	55	100	200	240	305	60	120	165	215	260	315	350	70	80	165
63.38	65.04	61.52	61.36	60.27	61.34	60.73	60.94	56.67	57.85	58.42	58.77	59.70	59.38	61.86	61.49	57.32
0.50	0.43	0.55	0.50	0.54	0.56	0.58	0.53	0.61	0.66	0.66	0.64	0.62	0.60	0.53	0.55	0.58
11.18	10.16	11.61	10.71	11.02	11.45	12.28	12.17	13.42	14.02	13.91	13.62	13.68	13.46	10.88	12.99	12.42
1.91	1.91	2.54	0.77	1.11	1.31	1.04	1.73	2.64	2.81	2.57	3.59	0.077	3.32	1.72	2.56	2.01
2.46	2.12	2.10	3.38	3.21	3.22	3.65	2.78	2.96	2.78	2.68	1.82	4.96	2.07	2.57	2.52	2.85
0.078	0.078	0.053	0.042	0.036	0.039	0.051	0.050	0.068	0.062	0.059	0.066	0.052	0.070	0.047	0.061	0.050
2.18	2.37	3.18	2.72	2.91	3.13	3.08	3.09	3.00	3.30	3.16	2.79	2.79	2.60	2.79	2.86	3.01
2.52	1.58	2.15	1.23	2.38	2.17	2.64	2.27	3.35	1.89	2.13	2.81	3.37	2.43	1.98	0.74	3.18
3.29	3.36	3.78	3.97	3.14	3.90	3.36	3.56	3.23	3.03	2.92	3.17	3.13	3.16	3.25	3.73	3.28
1.65	1.67	1.78	2.13	1.81	1.86	1.90	1.86	2.06	2.14	2.20	1.85	1.98	2.10	1.68	2.06	1.81
0.11	0.097	0.13	0.11	0.13	0.13	0.14	0.12	0.16	0.12	0.11	0.13	0.13	0.12	0.12	0.10	0.13
7.06	6.96	5.60	6.50	6.10	4.06	4.21	7.46	4.77	5.92	7.08	2.54	2.59	4.53	6.28	8.11	6.32
0.29	0.00	0.00	0.40	0.44	0.00	0.48	0.46	2.32	2.10	0.98	1.96	1.71	2.61	0.90	1.72	1.64
2.76	1.94	4.21	3.45	4.43	6.79	5.20	2.18	2.83	3.00	3.06	4.33	3.79	1.70	2.78	0.51	5.11
1.37	1.91	1.79	1.80	2.15	0.98	1.56	1.53	1.03	1.04	1.03	1.02	0.88	0.93	1.64	0.90	1.21
100.734	99.627	100.980	99.071	99.676	100.759	100.895	100.742	99.114	100.723	100.967	99.095	99.459	99.077	99.024	100.894	100.920

Table 2 (continued)

P83-4	P83-5	P84-1	P84-2	P84-3	P84-4	P84-5	P84-6	P84-7	P84-8	P85-1	P85-2	P86-1	P86-2	P86-3	P88-1	P88-2
215	350	30	100	163	233	368	423	493	558	130	500	30	115	215	20	165
57.83	57.06	61.63	63.51	63.99	61.45	63.21	63.10	60.34	64.38	64.99	61.04	58.38	59.41	63.98	58.43	59.71
0.58	0.58	0.50	0.54	0.49	0.53	0.49	0.51	0.55	0.45	0.43	0.50	0.57	0.58	0.53	0.59	0.53
12.51	12.39	11.03	11.42	11.36	12.58	11.34	11.23	11.87	10.15	9.02	10.75	12.18	12.48	12.61	12.20	10.45
2.41	2.23	2.30	0.85	2.10	2.30	2.28	2.42	2.58	1.33	1.68	2.36	2.40	2.13	1.74	7.34	2.64
2.70	2.80	2.16	3.49	2.20	2.36	1.99	2.06	2.38	2.54	2.14	2.09	2.46	2.72	2.40	2.71	1.95
0.060	0.049	0.056	0.058	0.056	0.066	0.050	0.055	0.046	0.038	0.033	0.051	0.062	0.064	0.054	0.066	0.048
2.84	3.11	2.91	2.82	2.73	2.93	2.72	2.88	2.83	2.55	2.43	2.60	2.26	2.39	1.99	3.70	2.11
2.83	2.51	1.04	1.78	1.51	1.74	1.44	1.53	3.07	0.76	1.09	2.99	6.57	2.93	3.80	2.67	3.39
2.73	3.95	3.79	3.50	3.54	3.56	2.89	3.38	2.63	4.06	3.24	3.23	2.09	3.00	2.29	2.84	2.70
1.88	1.85	1.90	1.89	1.92	2.13	2.01	1.88	1.78	1.57	1.47	1.43	1.86	1.89	2.03	2.45	1.63
0.13	0.13	1.06	0.11	0.10	0.12	0.10	0.11	0.13	0.11	0.11	0.12	0.098	0.11	0.084	0.12	0.17
5.98	5.92	8.34	6.30	6.63	6.35	6.36	5.09	6.32	5.13	4.77	5.53	4.74	2.89	3.29	3.53	4.85
3.10	4.08	0.56	0.00	0.00	0.00	0.00	0.00	0.13	1.77	0.85	1.26	1.28	7.96	1.74	1.07	6.24
2.24	1.16	0.59	2.06	1.18	3.28	4.10	3.96	2.45	3.25	5.37	4.76	2.97	1.45	1.81	1.63	1.55
3.07	1.50	2.07	1.68	1.69	1.53	1.99	1.72	1.96	1.13	1.97	2.07	1.88	0.66	0.65	0.59	1.31
100.890	99.301	99.935	100.008	99.484	100.935	100.965	99.198	99.068	99.209	99.606	100.787	99.799	100.650	99.010	99.930	99.282

Table 2 (continued)

P88-3	P88-4	P89-1	P89-2	P92-1	P92-2	P92-3	P92-4	P92-5	P92-6	P92-7	P92-8	P93-1	P93-2	P93-3
217	330	40	206	30	55	85	125	145	175	215	245	45	170	265
56.97	61.16	60.07	60.33	61.00	61.96	59.90	61.18	62.19	60.26	62.10	58.34	63.02	62.73	59.85
0.59	0.59	0.59	0.61	0.48	0.48	0.51	0.49	0.53	0.53	0.53	0.58	0.52	0.57	0.60
13.41	13.89	12.77	13.03	10.57	10.33	10.99	10.43	11.35	11.33	11.85	12.53	11.53	12.63	13.35
1.89	2.34	2.74	1.87	0.98	1.38	1.23	1.79	1.62	1.74	2.39	1.43	1.58	2.17	2.59
3.78	2.23	2.38	3.38	2.85	2.49	2.78	2.32	2.54	2.72	2.09	3.48	2.61	2.37	2.32
0.078	0.072	0.068	0.058	0.037	0.037	0.047	0.035	0.041	0.042	0.037	0.056	0.043	0.048	0.063
2.38	2.10	2.73	3.03	2.72	2.77	2.91	2.86	2.58	3.03	3.21	2.79	2.68	2.66	2.60
4.44	4.76	3.57	2.20	1.55	0.78	1.70	0.59	2.19	2.47	2.30	3.18	1.14	1.69	2.42
2.64	3.53	3.42	3.06	3.72	3.97	3.87	3.62	3.12	3.35	3.28	3.19	3.30	3.04	3.05
1.55	1.71	1.81	1.44	1.67	1.84	1.77	1.69	1.74	1.80	0.89	1.82	1.91	1.85	1.74
0.11	0.10	0.12	0.12	0.13	0.11	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12
3.07	3.07	4.09	3.28	0.69	5.29	5.32	4.76	5.57	5.14	6.06	5.72	5.35	0.55	3.56
6.92	1.94	2.49	1.16	0.85	2.00	0.25	2.46	0.65	1.16	0.00	3.27	1.05	0.75	4.99
0.63	1.97	1.31	4.24	9.88	3.25	5.37	4.76	3.06	3.59	3.62	1.40	2.90	7.10	1.65
0.60	0.85	0.92	1.04	2.27	2.32	2.32	1.97	1.72	1.77	1.32	1.12	1.37	1.10	0.74
99.053	100.319	99.066	98.853	99.394	99.013	99.102	99.097	99.020	99.060	99.795	99.016	99.122	99.369	99.645

Table 3 Chemical composition of recalculated by excluding carbonates, water, residual materials and salts in Table 2.

Sample No.	P75-1	P75-2	P75-3	P75-4	P76-1	P76-2	P76-3	P77-1	P77-2	P77-3	P78-1	P78-2	P78-3	P79-1	P79-2	P80-1
SiO2	63.21	62.87	61.85	61.03	60.99	66.66	60.93	63.48	64.35	68.84	69.86	67.17	69.60	62.31	62.31	69.54
TiO2	0.63	0.63	0.65	0.67	0.65	0.48	0.65	0.52	0.52	0.47	0.48	0.48	0.48	0.59	0.66	0.42
Al2O3	14.33	14.30	14.65	14.75	14.63	13.55	14.75	12.02	11.80	10.11	11.20	10.48	10.59	13.29	14.11	9.77
Fe2O3	1.53	2.42	2.15	2.37	2.77	2.02	4.29	2.05	2.54	0.90	2.35	2.34	2.51	3.50	3.88	0.83
FeO	3.71	3.30	3.25	3.17	2.63	2.25	1.92	2.45	2.30	2.92	2.12	2.09	2.03	2.12	2.52	2.93
MnO	0.069	0.084	0.086	0.097	0.051	0.059	0.066	0.061	0.059	0.049	0.15	0.13	0.12	0.075	0.085	0.080
MgO	3.22	2.92	3.08	3.03	3.38	3.34	2.97	2.76	3.02	2.95	2.54	2.46	2.56	3.33	3.05	2.17
CaO	1.37	1.73	1.54	1.63	1.76	1.57	2.76	1.29	1.20	1.76	1.40	1.57	1.39	2.13	2.01	0.63
Na2O	3.44	3.87	3.61	3.35	4.50	3.42	3.36	3.86	3.72	3.94	4.33	3.71	3.94	4.65	3.42	3.38
K2O	2.49	2.35	2.44	2.49	2.56	2.46	2.30	2.14	2.06	1.76	1.93	1.78	1.78	1.53	2.16	1.72
P2O5	0.10	0.11	0.11	0.12	1.10	0.079	0.097	0.11	0.12	0.12	0.11	0.10	0.095	0.11	0.11	0.095
H2O(+)	5.90	5.42	6.58	7.29	6.98	5.11	5.90	9.27	8.34	6.19	3.53	7.79	4.92	6.38	5.69	8.45

Table 3 (continued)

P80-2	P80-3	P81-1	P81-2	P81-3	P81-4	P81-5	P82-1	P82-2	P82-3	P82-4	P82-5	P82-6	P82-7	P83-1	P83-2	P83-3
65.81	67.91	64.77	65.68	65.05	65.96	64.84	63.11	60.98	61.16	60.92	64.03	64.14	63.28	66.02	62.89	61.66
0.52	0.45	0.58	0.54	0.58	0.60	0.62	0.55	0.66	0.70	0.69	0.70	0.67	0.64	0.57	0.56	0.62
11.61	10.61	12.22	11.47	11.89	12.31	13.11	12.60	14.44	14.82	14.51	14.84	14.70	14.35	11.61	13.29	13.36
1.98	2.00	2.67	0.83	1.20	1.22	1.11	1.79	2.84	2.97	2.68	3.91	0.083	3.54	1.84	2.62	2.17
2.55	2.21	2.21	3.62	3.46	3.46	3.90	2.88	3.19	2.94	2.80	1.98	5.33	2.21	2.74	2.58	3.07
0.081	0.081	0.056	0.045	0.039	0.042	0.054	0.052	0.073	0.066	0.062	0.072	0.056	0.075	0.050	0.062	0.054
2.26	2.47	3.35	2.91	3.14	3.37	3.29	3.20	3.23	3.49	3.29	3.04	3.00	2.77	2.98	2.92	3.24
2.61	1.65	2.26	1.31	2.57	2.33	2.82	2.35	3.60	2.00	2.22	3.06	3.62	2.59	2.11	0.75	3.42
3.42	3.51	3.98	4.25	3.39	4.20	3.59	3.69	3.48	3.21	3.05	3.45	3.36	3.37	3.64	3.82	3.53
1.71	1.74	1.87	2.28	1.95	2.00	2.03	1.93	2.22	2.26	2.29	2.03	2.13	2.24	1.79	2.11	1.95
0.11	0.10	0.14	0.12	0.14	0.14	0.15	0.12	0.17	0.13	0.12	0.14	0.14	0.13	0.13	0.10	0.14
7.33	7.27	5.90	6.96	6.58	4.37	4.50	7.73	5.13	6.26	7.38	2.77	2.78	4.83	6.70	8.30	6.80

Table 3 (continued)

P83-4	P83-5	P84-1	P84-2	P84-3	P84-4	P84-5	P84-6	P84-7	P84-8	P85-1	P85-2	P86-1	P86-2	P86-3	P88-1	P88-2
62.53	61.64	63.72	65.97	66.23	63.93	66.62	66.96	63.84	69.18	71.10	65.85	62.32	65.59	67.48	60.46	66.21
0.63	0.63	0.52	0.56	0.51	0.55	0.52	0.54	0.58	0.48	0.47	0.54	0.61	0.64	0.56	0.61	0.59
13.53	13.38	11.40	11.86	11.76	13.09	11.95	11.92	12.56	10.91	9.87	11.60	13.00	13.78	13.30	12.62	11.59
2.61	2.41	2.38	0.88	2.17	2.39	2.40	2.57	2.72	1.43	1.84	2.54	2.56	2.35	1.84	7.59	2.93
2.92	3.03	2.23	3.63	2.28	2.46	2.10	2.19	2.52	2.73	3.41	2.26	2.63	3.00	2.53	2.80	2.16
0.065	0.053	0.058	0.06	0.058	0.069	0.053	0.058	0.049	0.041	0.036	0.055	0.066	0.071	0.057	0.068	0.053
3.07	3.35	3.01	2.93	2.82	3.05	2.87	3.05	3.00	2.74	2.66	2.81	2.41	2.64	2.10	3.83	2.34
3.06	2.71	1.07	1.85	1.56	1.81	1.52	1.62	3.25	0.81	1.20	3.23	7.02	3.23	4.01	2.76	3.76
2.95	4.26	3.92	3.64	3.66	3.71	3.04	3.59	2.78	4.36	3.55	3.49	2.24	3.31	2.42	2.94	2.99
2.03	2.00	1.96	1.96	1.99	2.22	2.12	2.00	1.88	1.69	1.61	1.54	1.99	2.09	2.14	2.54	1.81
0.14	0.14	1.10	0.11	0.10	0.13	0.11	0.12	0.14	0.12	0.12	0.13	0.11	0.12	0.089	0.12	0.19
6.47	6.40	8.62	6.54	6.86	6.61	6.70	5.40	6.69	5.51	5.22	5.97	5.06	3.19	3.47	3.65	5.38

Table 3 (continued)

P88-3	P88-4	P89-1	P89-2	P92-1	P92-2	P92-3	P92-4	P92-5	P92-6	P92-7	P92-8	P93-1	P93-2	P93-3
62.67	64.00	63.67	65.29	70.60	67.76	65.71	68.05	66.45	65.12	65.47	62.58	67.19	69.38	64.86
0.65	0.62	0.63	0.66	0.56	0.53	0.56	0.55	0.57	0.57	0.56	0.62	0.55	0.63	0.65
14.75	14.54	13.53	14.10	12.23	11.30	12.06	11.60	12.13	12.24	12.49	13.44	12.29	13.97	14.47
2.08	2.45	2.90	2.03	1.14	1.51	1.35	1.99	1.73	1.88	2.52	1.54	1.68	2.40	2.81
4.16	2.33	2.52	3.66	3.30	2.72	3.05	2.58	2.71	2.94	2.20	3.73	2.78	2.62	2.51
0.086	0.075	0.072	0.063	0.043	0.040	0.052	0.039	0.044	0.045	0.039	0.060	0.046	0.053	0.068
2.61	2.20	2.89	3.27	3.14	3.03	3.19	3.18	2.75	3.28	3.38	2.99	2.85	2.94	2.82
4.88	4.98	3.79	2.38	1.80	0.85	1.87	0.66	2.34	2.67	2.43	3.41	1.22	1.87	2.62
2.91	3.70	3.62	3.32	4.31	4.35	4.25	4.03	3.34	3.62	3.46	3.42	3.52	3.36	3.31
1.71	1.79	1.92	1.56	1.93	2.01	1.94	1.88	1.86	1.95	0.94	1.95	2.04	2.05	1.89
0.12	0.11	0.13	0.13	0.15	0.12	0.14	0.15	0.14	0.14	0.13	0.13	0.13	0.13	0.13
3.38	3.21	4.34	3.55	0.80	5.79	5.84	5.30	5.95	5.55	6.39	6.14	5.70	0.61	3.86

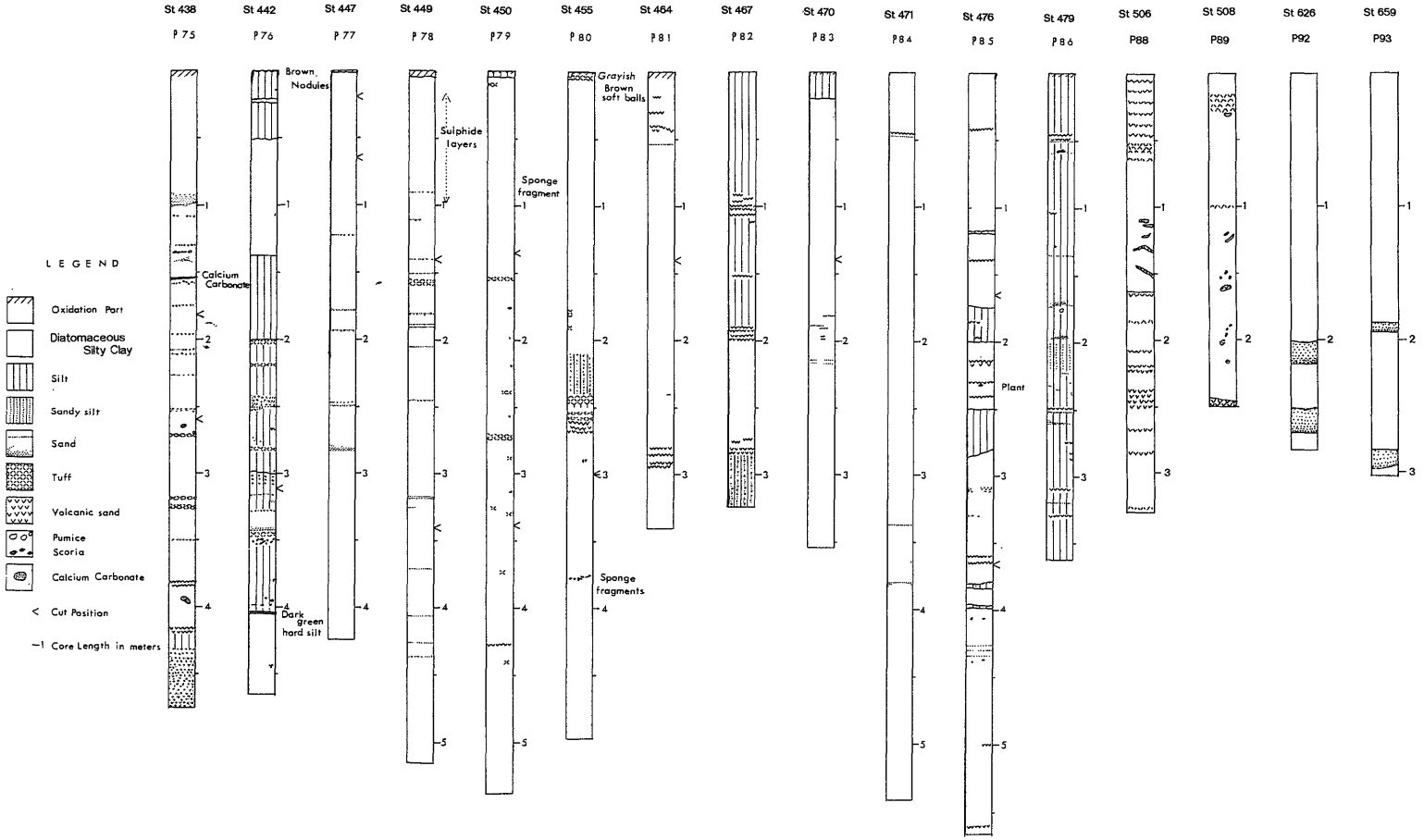

Fig. 2 Columnar sections of piston cores in the GH76-2 and GH76-3 cruises. Revised after Inouchi *et al.*, 1977.

m D) and P84 (7,330 m D) were from the floor of the Japan Trench. P78 (8,805 m D) and P80 (7,050 m D) were from the floor of the southwestern Kuril Trench. P76 (5,400 m D) and P79 (5,180 m D) were from the oceanic floor in the eastern Japan Trench and from that in the southern Kuril Trench, respectively (Table 1).

3. Chemical composition of argillaceous sediments

The materials for this analysis (65 samples) were selected from 16 piston cores in cruises GH76-2 and GH76-3 (Table 1). The samples were dried at 110°C and subsequently ground. Each sample was analyzed with an X-ray fluorescence spectrometer JOEL-JSX-100S for Si, Ti, Al, Fe, Mn, Mg, Ca, K, Na, and P. The details of the method have been published by Sugisaki *et al.* (1977). The analytical methods for other constituents are as follows;

1) $H_2O(+)$ was gravitationally determined by the method of Shapiro and Brannock (1955a).

2) $CaCO_3$ was calculated from CO_2 content which was manometrically measured by the method of Shapiro and Brannock (1955b).

3) Residual materials were calculated by subtracting CO_2 and $H_2O(+)$ from ignition loss. They may contain sulfur, organic materials and others.

4) Salts were calculated from water soluble chlorine by assuming that pore water has the same composition as that of sea water.

The analytical results are listed in Table 2. The silicate composition of the samples were recalculated by excluding carbonates, salts, and residual materials (Table 3). These recalculated data are mainly used in the following discussion.

The average chemical composition and the deviation of the samples analyzed in this work are shown in Table 4. The small standard deviation from the average value of each composi-

Table 4 Average chemical compositions (%) and standard deviations of sediments. 1) This study (GH76-2), 2) Sugisaki (1978), 3) Sugisaki (1981).

	Japan Trench 1)	Nankai Trough2)	Northern Central Pacific Basin3)
Number of samples	65	29	34
SiO2	68.84±2.78	66.68±1.99	62.83±6.34
TiO2	0.62±0.07	0.72±0.06	0.84±0.26
Al2O3	13.60±1.47	16.51±0.64	15.91±1.53
Total Fe as Fe2O3	5.67±0.92	6.01±0.65	8.26±2.64
MnO	0.07±0.02	0.09±0.06	0.85±0.24
MgO	3.11±0.37	2.29±0.36	3.25±0.41
CaO	2.38±1.19	1.51±0.93	2.19±1.29
Na2O	3.77±0.49	3.29±0.36	1.38±0.64
K2O	2.12±0.30	3.09±0.41	3.48±0.71
P2O5	0.15±0.13	0.14±0.01	1.05±0.70

tion indicates homogeneity of the present sediments. The average values of 34 pelagic sediments collected from the northern central Pacific basin during GH79-1 and those of 29 argillaceous sediments collected from the Pacific margin of Southwest Japan during GH 75-4 are also listed in the table for comparison.

The following aspects emerge from the present data: (1) A small amount of carbonates exists even in samples from the trench, the depth of which seemingly exceeds the carbonate compensation depth. (2) The sediments in this region are enriched in SiO_2 and impoverished in Al_2O_3 and MnO compared with typical pelagic sediments.

Figure 3 illustrates the relationship among SiO_2, TiO_2, and Al_2O_3. The mutual abundance of these elements tends to remain stationary during sedimentary processes, because these elements are hardly soluble in natural water at pHs of 5 to 9. Hence, the diagram is helpful in examination of sediment sources. The compositional points from Southwest Japan are located along a line connecting point G of averaged Japanese granites and point V of averaged Japanese Quaternary volcanics, indicating that the sediments were derived mostly from the Japanese Islands and that the original materials from the islands were chemically homogenized during sedimentary processes (Sugisaki, 1978). On the other hand, some points from Northeast Japan on the diagram deviate towards the SiO_2

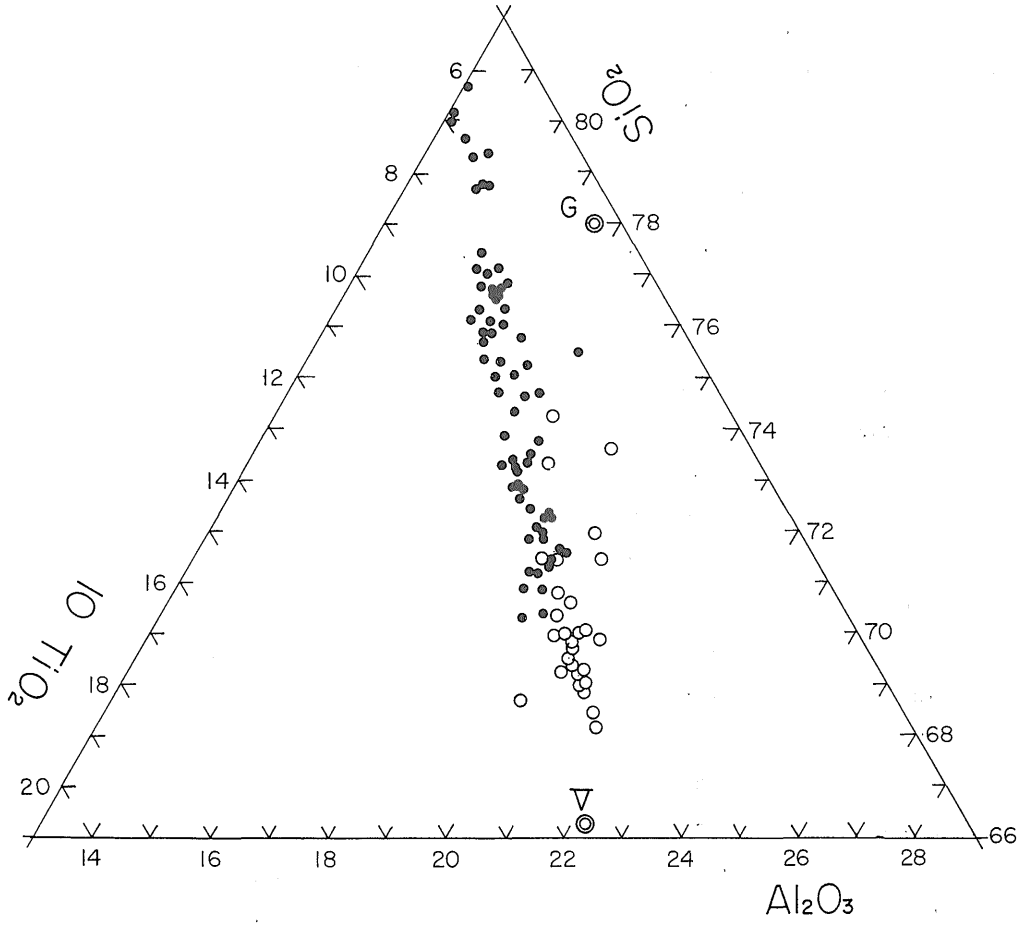

Fig. 3 Relationship of SiO_2-TiO_2-Al_2O_3 of piston cores. Closed circles = cores from the northern Japan Trench and Slope areas. Open circles = cores from the Nankai Trough and slope areas. G and V are average composition of onshore granites and Quaternary volcanics, respectively.

apex beyond the point of granites (Fig. 3). These points represent trench deposits. This suggests the contribution of siliceous materials to the sediments, and the materials can be regarded as siliceous organisms and/or acidic tuffs, as discussed below.

As shown in Figure 4, SiO_2 is negatively correlated with Al_2O_3 and TiO_2. These inverse correlations are also observed in other marine sediments recovered from the Japan Trench and its environs at DSDP Legs 56 and 57 (Sugisaki, 1980), and in Triassic bedded cherts in central Japan (Sugisaki *et al.*, 1982). In these areas, the regression line calculated by the least square method passes through a point of SiO_2= 100 % and Al_2O_3= 0 %. The regression line is regarded as a mixing line indicating simple mixture of normal clastic sediments and siliceous organisms such as radiolaria and diatom, because these sediments and sedimentary rocks contain many siliceous organisms regarded as pure silica; the point at SiO_2= 100 % and Al_2O_3= 0 % indicates pure silica in the figure. In contrast, the present regression line crosses at a point of a little lower than 100 % on the SiO_2 ordinate (Fig. 4a). This feature is the same for SiO_2 versus TiO_2 relation (Fig. 4b). This suggests that the excess silica in the present samples is derived not only from siliceous organisms but also from another source. The source can be acidic tuffs, because the distribution patterns in Fig. 4 are observed in acidic tuffs from Tertiary Setogawa Formation (Yamamoto, 1984). The regression line for the present relation is expressed as follows (in wt. %).

$$SiO_2 = 94.7 - 1.91\ Al_2O_3$$

That for Setogawa acidic tuff is reported as below (Yamamoto, 1984).

$$SiO_2 = 96.2 - 1.45\ Al_2O_3$$

Both regression lines are approximately identical, and this suggests the contribution from acidic tuff to the present samples.

However, another criterion for discrimination of silica sources in sediments does not unequivocally show the role of acidic tuff in the sediment genesis. On the plot of Al_2O_3/TiO_2 versus SiO_2/TiO_2, acidic volcanics generally show a linear trend exemplified by a line for circum-Pacific acidic volcanics (Fig. 5). If sediments are derived from acidic volcanics, their compositional points should be located on this line. Whereas, if sediments are a simple mixture of siliceous organisms and a clastic material,

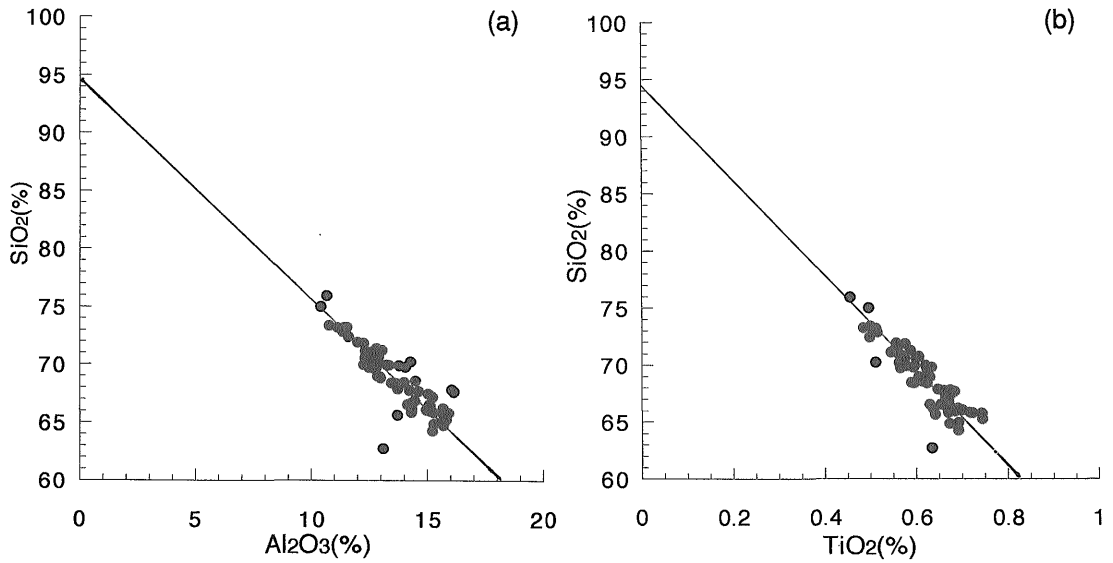

Fig. 4 Plots of SiO_2 against Al_2O_3 (a) and TiO_2 (b). The regression lines are drawn by least square method as follows; SiO_2= 94.7 - 1.91Al_2O_3. SiO_2= 94.5 - 41.79TiO_2.

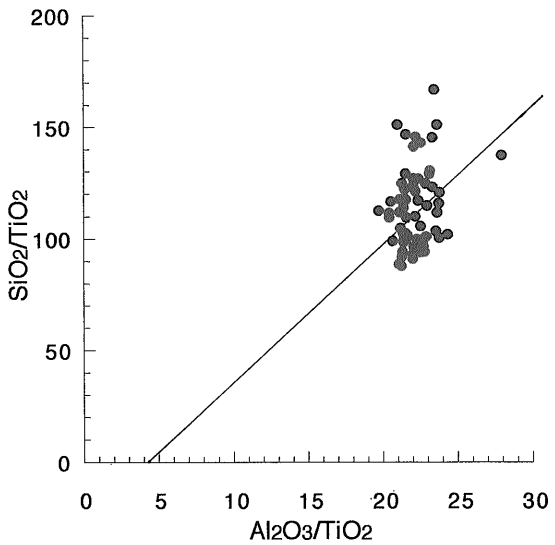

Fig. 5 Plots of SiO_2/TiO_2 vs. Al_2O_3/TiO_2. The line in the figure shows the relation for acidic volcanic rocks from circum-Pacific regions (Yamamoto *et al.*, 1986).

their points plot along a vertical line (Yamamoto *et al.*, 1986). The point distribution of the present samples on the plot (Fig. 5) is not so regular as that expected from both cases. The compositional points cluster around the acidic trend and also are vertically distributed; but both aspects are ambiguous. This suggests that siliceous contribution from acidic tuffs was not predominant over that from siliceous organisms, and vice versa. Both sources may have evenly been responsible for the high silica content in some samples. The sources of the excess silica are also shown by the sediment description in the earlier section.

Some major components show clear variation trends with increasing water depth of cores (Figs. 6a, b). The concentrations of Mn and Si in the present samples increase with increasing core depths. This can be attributed to a decrease of the sedimentation rate of clastic materials towards the trench. If we assume that the input rates of siliceous organisms and / or acidic tuffs and the precipitation of hydrogenous Mn remain stationary and that the supply of clastic materials from the Japanese Islands declines towards the trench, the proportions of Si and Mn in the sediments should gradually increase (Sugisaki, 1984).

As noted earlier, carbonates are present even in deep sediments such as trench samples. The amount of CO_2 expelled by acid treatment of samples was measured and the CO_2 was assumed to be derived from $CaCO_3$ for convenience of data display (Table 2). This may not be a suitable assumption, because Mn often occurs as manganese carbonates ($MnCO_3$) in hemipelagic regions of suboxic or reducing environments (Sugisaki *et al.*, 1991). A part of Mn in the present samples must occur as manganese carbonates, and the amount as $CaCO_3$ listed in Table 2 should contain both $CaCO_3$ and $MnCO_3$. In fact, manganese carbonate bands (Sugisaki *et al.*, 1991) and manganese carbonate nodules (Okada, 1980) have been reported to occur within the Japan Trench sediments. This reducing environment where manganese carbonates deposite may result from water stagnant on the trench bottom as described earlier. If a part of the analyzed Mn is assumed to occur as $MnCO_3$, the increase in Mn contents with increasing water depth of the cores (Fig. 6) could be ascribed to the environmental change towards the reducing condition in the trench bottom. Thus, both effects — decrease in clastic input rate and reducing condition in the trench bottom — may have enhanced the Mn contents in cores of deeper sites.

4. Conclusion

The following conclusions are noted in the sediments and sedimentary sequences in the northern Japan Trench and Slope areas.

1. Most sediments cored are diatomaceous silty clay intercalated with volcanic ash.

2. Chemical composition of the cored sediments suggests that major elements have a clear variation trend with increasing water depth. Silica increases with depth, which is ascribed to the regional enrichment of volcanic ash or to that of diatom.

3. In the SiO_2-TiO_2-Al_2O_3 diagram the composition of the sediments is between compositions of averaged onshore granites and Quaternary volcanics indicating supply from the land

area west of the slope area and enrichment in silica by diatom and acidic tuff.

4. Small amount of carbonates exists even in samples from the trench, the depth of which seemingly exceeds the carbonate compensation depth.

5. The pelagic sediments in the east side of the trench suggests almost the same chemical composition as that in the continental slope area. The sediments in this region are enriched

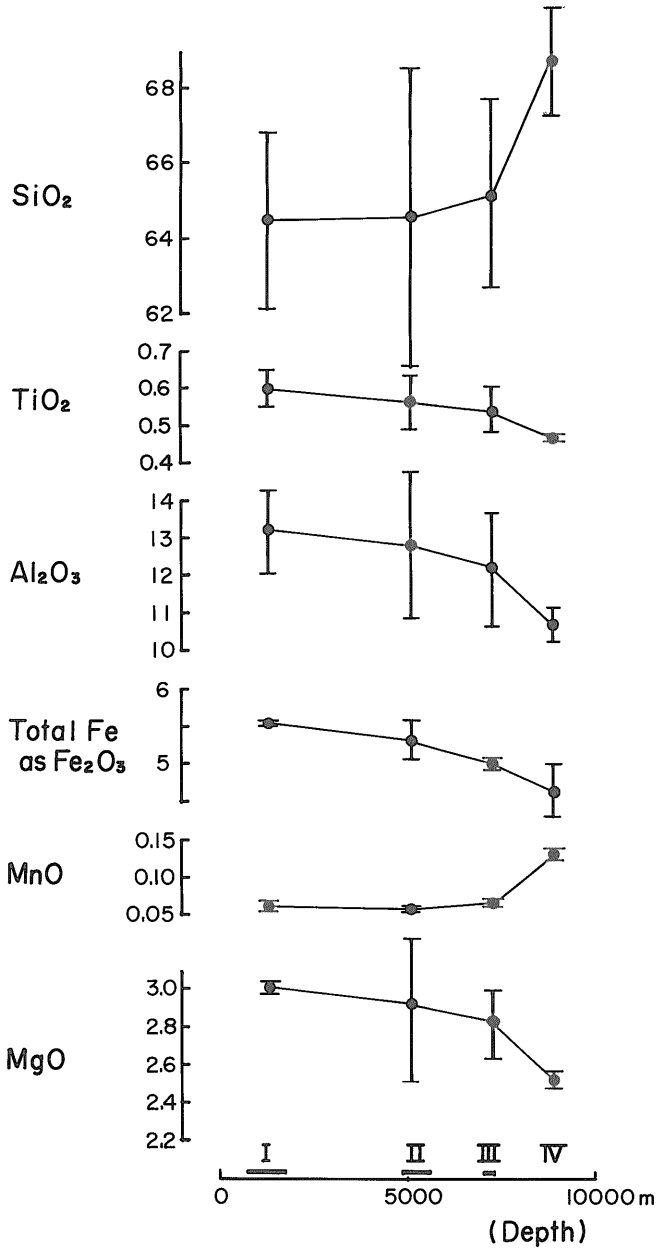

Fig. 6a Ranges of chemical composition of cored samples with sampled water depth. The composition suggests that major elements show a clear variation trend with increasing water depth.

in SiO_2 and impoverished in Al_2O_3 and MnO in comparison with typical pelagic sediments and ferrous content is observed in each sample.

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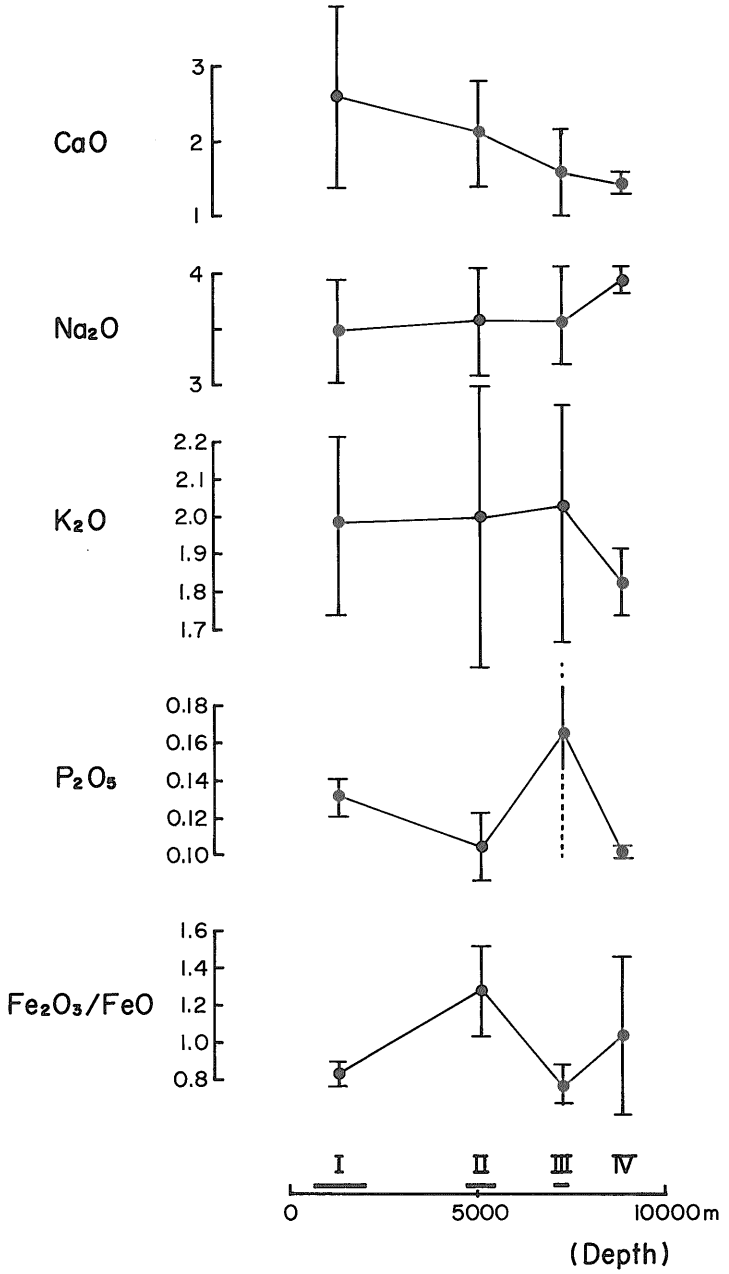

Fig. 6b Continued from Fig. 6a.

rators on board and of crews of Hakurei-maru during the GH76-2 and GH76-3 cruises.

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北部日本海溝及び斜面域の新第三系・第四系粘土質堆積物：特に採取コアの堆積物の化学組成について

杉崎隆一・本座栄一

要　旨

日本海溝及び南西千島海溝周辺の大陸斜面，内側海溝斜面，海溝底にかけて，広く分布する堆積物は，大部分火山灰が介在する珪藻を含んだシルト質粘土が主体となっている．しかしながら採取されたコアの堆積物の化学分析から主要元素が水深により明瞭に変化する様子が読み取れた．シリカは深くなると増加する．一方西南日本沖では深くなるとシリカは減少する．日本海溝周辺でのシリカの増加は火山灰あるいは珪藻の増加に起因すると考えられる．日本海溝及びその斜面域の堆積物の化学組成は陸域の花崗岩と第四紀火山岩の平均的化学組成を結ぶ線上にあり，西の陸域からの供給を示唆し，更にそれが珪藻などの有機物に富んでいることが判断される．少量の炭酸塩が海溝底の試料にも見うけられるが，ここはCCDを越えているところである．海溝東側の遠洋性堆積物は大陸斜面域と同様の化学組成から成っているが，典型的な遠洋性堆積物に比べてSiO_2に富み，Al_2O_3とMnOが減少している．