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Sulfur and Carbon Contents in Recent Sediments and Their Relation to Sedimentary Environments

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Abstract: Two hundred and sixty-seven samples of Recent sediments were analyzed for total sulfur, total carbon and organic carbon in order to examine their relationship to sedimentary environments. These samples were collected from the different environment, i.e., regions of nine lakes and six sea areas around the Japanese islands. Average content of total sulfur in fresh-water sediments is lower than that of both brackish and marine sediments in reduced condition. However, there is no clear difference of total sulfur contents between sediments of marine bays of ra her oxidized conditions and those of the eutrophic fresh-water lakes. The contents of organic carbon are higher in lake sediments than those of marine ones, whereas those of the carbonate-carbon are more abundant in marine sediments than in lacustrine ones. As for the chemical form of sulfur, 50% or more of the total sulfur existed in the form of sulfide except in deep-sea sediments which sulfide-sulfur was not detected. A close positive correlation between total sulfur and organic carbon contents appeared only in the sediments deposited under rather oxidized conditions in most cases. Total sulfur, organic carbon and sulfate-sulfur seem to be more abundant in Recent sediments than those of old sedimentary rocks. Although the content of total sulfur is useful for estimation of depositional environment of sedimentary rocks, the concentration ratio of non-carbonate carbon against total sulfur provides a much better indication to distinguish sedimentary rocks of marine origin from non-marine sediments.

Introduction

Content of sulfur is a good geochemical indicator for the discrimination between marine and non-marine sedimentary environments (KEITH and DEGENS, 1959). The sulfide-sulfur in Recent sediments derives mainly from bacterial reduction of sulfate (BERNER, 1970, JφRGENSEN, 1977, and GOLDHABER *et al.*, 1975 and 1977). The contents of sulfate-sulfur in the pore water of marine sediments are clearly higher than those of non-marine ones. The bacterial reduction of sulfate occurs very actively in organic dominant sediments, thus the contents of sulfur and organic matter in the sediments are generaly correlated each other.

Generally saying on sedimentary rocks, total sulfur is more abundant in marine ones than in non-marine ones (KEITH and DEGENS, 1959, ITIHARA, M. and ITIHARA, Y., 1971, KOMA, 1974 and 1978, KOMA *et al.*, 1974, TANAKA *et al.*, 1981). In some cases, however, the contents of total sulfur in the sedimentary rocks of marine origin have been reported to be with an average of 0.105% (n=67, TERASHIMA *et al.*, 1981) which is nearly the same or rather lower than the total sulfur contents of some sedimentary rocks of fresh-water origin (0.15±0.13%, KEITH and DEGENS, 1959). TANAKA *et al.* (1981) pointed out that the clear positive correlation between sulfur and carbon contents in sedimentary rocks may arise in the sediments

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deposited in relatively stable environments, but the conclusion has not been certified in the variety of Recent sediments. Although the contents of carbonate-carbon and sulfate-sulfur in sedimentary rocks seem to be closely related to the sedimentary conditions (TERASHIMA *et al.*, 1981), there are few data on Recent sediments as to the contents of carbonate-carbon and sulfate sulfur, and details of the geological distribution of both elements have not been discussed.

In this study, 267 samples of Recent sediments were collected from lakes and sea areas. Total sulfur, total carbon, and organic carbon were analyzed in these samples. In order to know the chemical form of the sulfur, sulfate-sulfur and water leachable chlorine were also analyzed in some selected samples. The relationship between distribution of these elements and sedimentary environments and the correlation of total sulfur to organic carbon, particularly in the comparison of the Recent sediments with the sedimentary rocks of geologic time will be discussed.

Samples and Analytical Methods

Lake sediments

The lake sediments were collected in the period of 1961 to 1965 for the study of geochemistry of Recent lake sediments, and 90 samples were selected from 30 gravity cores, which are

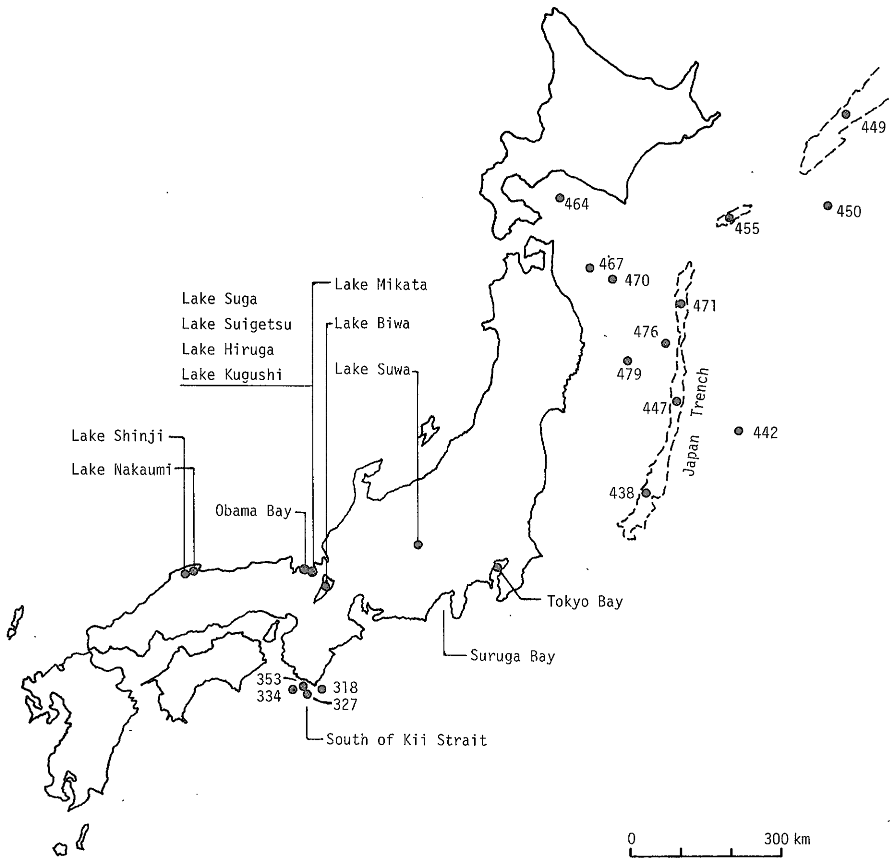

Fig. 1 Sampling locations of Recent sediments. Digitals by the circles are station number of the references in the text. Off Northeast Japan means station Nos. 464, 467, 470, 476 and 479, and the Nos. 438, 442, 447, 449, 450, 455 and 471 belong Around the Japan Trench.

20 to 140 cm long, mostly 70 cm. From these samples, 51 fresh-water sediments were selected from three lakes of different types (Lake Biwa, Lake Suwa, and Lake Mikata), and 39 brackish-water sediments from six lakes of two regions (Fig. 1). Localities of the sampling stations of the lake sediments are shown in Fig. 2 to 5, and outline of the sedimentary environments are given below.

Lake Biwa is the largest (area: 674.4 km^2, max. depth: 96 m) and a typical fresh-water and oligotrophic lake of Japan. Lake Suwa (14.5 km^2, 7.0 m) and Lake Mikata (3.6 km^2, 5.8 m) are rather small and eutrophic fresh-water lakes. Lake Mikata, Lake Suga, Lake Suigetsu, Lake Hiruga and Lake Kugushi are called Mikata Five Lakes, and these are connected mutually with the rivers and/or channels. Lake Kugushi had been polyhaline lake having direct connections to the Wakasa Bay. Lake Hiruga, Lake Suigetsu and Lake Suga were originally fresh-water, but these lakes have been changed to brackish about 300 years ago by the completion of the channels. Recently, small amounts of saline water flows backward into the Lake Mikata in the extremely dry seasons. Lake Shinji (80 km^2, 6.4 m) is connected by a river to Lake Nakaumi (104 km^2, 9.0 m), which is connected to the Miho Bay directly. The areas of the latter two lakes are evidently larger than those of Mikata Five Lakes (0.9 to 5.02 km^2). More details of the geochemical characteristics of the sediments and lake water and sampling method with locations in these lakes have been reported by YONETANI (1967) and OMORI (1968, 1969 and 1971).

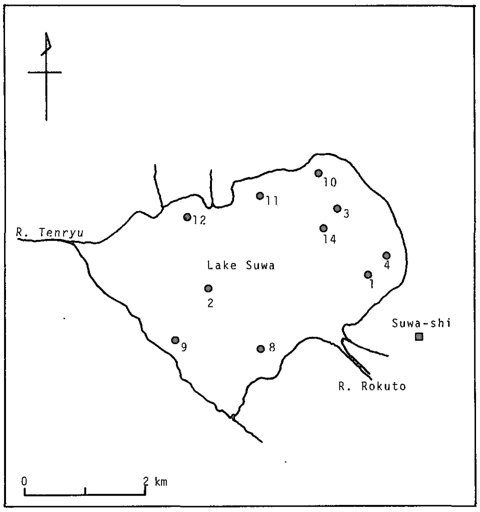

Fig. 3 Localities of the sampling stations in Lake Suwa.

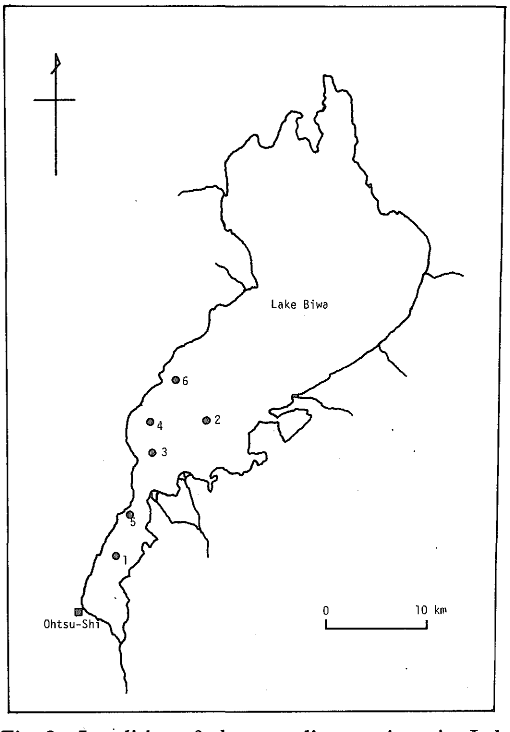

Fig. 2 Localities of the sampling stations in Lake Biwa.

Marine sediments

The 177 samples of marine mud sediments were collected from several different regions in the Japanese off-shores and in the Pacific (Fig. 1) in the period of 1971 to 1979.

Tokyo Bay has an area of 1000 km^2 and a mean depth of 17 m. The bay is surrounded by the densely populated and highly industrialized areas. The bottom sediments are black silty clays containing hydrogen sulfide in the pore water. The sediment core (65 cm, Stn. No. 79–2, MATSUMOTO, 1981) was taken by a

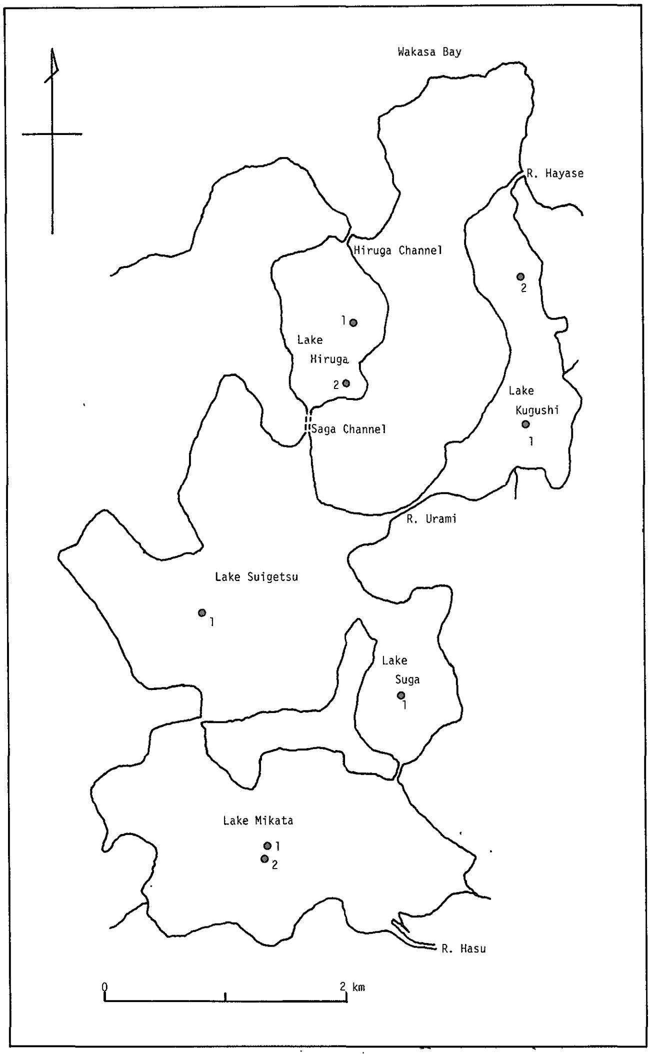

Fig. 4 Localities of the sampling stations in Lakes Mikata, Suga, Suigetsu, Kugushi and Hiruga.

gravity corer. The area of Obama Bay is small (60 km²), and the water depth (max. 35 m) decreases conversely with the distance from the bay entrance. The bottom sediments seem like sandy silt or silty clay, and the sedimentary environment is rather oxidized conditions. Twenty three surface sediments were collected from 4 to 26 m of the water depth with a freefall grab (OBARA *et al.*, 1973). Suruga Bay is a typical open type bay in oxidized conditions. There are various types of sediments from gravel to clay, mainly silty clay. Samples of surface sediments have been obtained from the 20 locations (Stn. Nos. 39–47, 73–78 and 106–110, MATSUMOTO and KINOSHITA, 1978) using the Smith-McIntyre grab.

The core sediments from the South of Kii Strait (INOUCHI and KINOSHITA, 1977, core length: 300–580 cm) and from the Northeast Japan-Japan Trench region (HONZA, 1977, core length: 130 to 550 cm, mostly 500 cm) were collected by a piston corer equipped to the Hakurei-maru, the research vessel of the Geological Survey of Japan. The South of Kii Strait have been affected by the Kuroshio current which has relatively warm tempera-

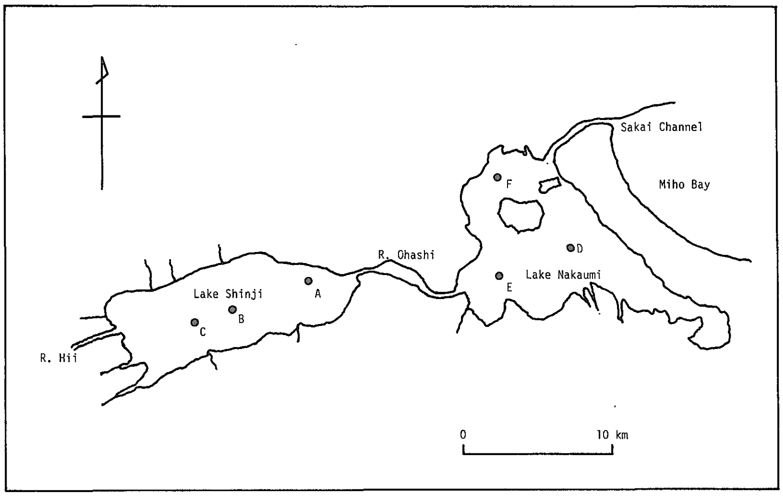

Fig. 5 Localities of the sampling stations in Lakes Shinji and Nakaumi.

ture. On the other hand, the Northeast Japan-Japan Trench is in the region of the cold Oyashio current. Ditails about the marine samples have been described in the above-mentioned references.

Analytical Methods

The samples were dried at room temperature, and ground to under 150 mesh after noticeable plant pieces, shells and anthropogenic matters had been picked out, then kept in plastic bottles.

Total sulfur, total carbon and organic carbon were analyzed by an infrared absorption photometry after combustion with a high-frequency induction furnace (TERASHIMA, 1978 and 1979). The contents of carbonate-carbon were calculated by subtracting organic carbon content from the total carbon. Sulfate-sulfur was analyzed by a conventional gravimetric method following the digesting sample with diluted hydrochloric acid, and water soluble chlorine by titrimetric method (TERASHIMA *et al.*, 1982).

In Recent sediments, sulfur seems to exist in various forms such as sulfide, sulfate, elemental and others (KAPLAN *et al.*, 1963). In this study, amount of sulfide sulfur was estimated by subtracting sulfate-sulfur content from the total sulfur for both Recent sediments and sedimentary rocks.

Results and Discussion

The analytical results for total sulfur, organic carbon and carbonate-carbon are listed in Table 1 to 3, and the contents of sulfide and sulfate-sulfur in 121 selected samples are given in Table 4.

The means and ranges of total sulfur, organic carbon and carbonate-carbon contents are summarized in Table 5 with the concentration ratio of organic carbon to total sulfur (R_1 and R_2). The concentration ratio of R_1 is calculated from the mean values for each areas, whereas the R_2 means the average of individual ratios.

Total sulfur

Average content of total sulfur in the fresh-water sediments is 0.23%, and the values of Lake Biwa (Av. 0.05%) are clearly lower than those of Lake Suwa (0.35%) and Lake Mikata (0.20%). The data of brackish-water sediments vary from 0.55% (Lake Shinji) to 2.21% (Lake Hiruga) with the average of 1.40%. For marine sediments, total sulfur ranges from 0.15% (Suruga Bay) to 2.85% (Tokyo Bay), and the average is 0.58%. The results indicate that the total sulfur is more abundant in the brackish-water sediments and

Table 1 Analytical results of total sulfur, organic carbon and carbonate carbon for fresh-water sediments in weight percent.

Sample No.	Station No.	Location (cm)	Total sulfur	Organic carbon	Carbonate carbon	Sample No.	Station No.	Location (cm)	Total sulfur	Organic carbon	Carbonate carbon
	Lake Biwa					26		80–101	0.29	2.77	0.00
1	1	0–15	0.12	2.19	0.02	27	3	0–15	0.23	3.94	0.00
2		15–30	0.07	1.04	0.06	28		15–30	0.32	3.24	0.00
3		30–45	0.05	1.00	0.03	29		30–60	0.31	3.20	0.00
4		60–68	0.08	1.69	0.07	30		60–80	0.34	3.80	0.00
5	2	0–13	0.05	1.20	0.03	31	4	127–140	1.16	5.76	0.00
6		13–28	0.03	0.80	0.12	32	8	13–25	0.29	4.01	0.00
7		28–36	0.02	0.55	0.00	33		60–72	0.65	4.72	0.00
8	3	0–15	0.03	0.60	0.00	34	9	2–20	0.33	2.60	0.00
9		15–23	0.02	0.46	0.00	35	10	5–25	0.38	3.39	0.35
10	4	0–5	0.08	1.38	0.05	36		40–55	0.38	1.60	0.00
11		20–35	0.04	0.90	0.02	37		85–95	0.26	2.10	0.00
12		35–50	0.04	0.89	0.00	38	11	25–35	0.53	1.52	0.00
13		65–73	0.05	1.16	0.08	39		80–92	0.26	1.58	0.00
14	5	35–50	0.08	1.55	0.13	40	12	20–35	0.16	1.41	0.00
15		65–75	0.04	0.77	0.05	41		50–65	0.25	1.93	0.00
16	6	21–36	0.04	1.07	0.03	42	14	25–40	0.28	2.42	0.00
17		60–69	0.05	1.75	0.00	43		70–85	0.28	3.08	0.00
	Lake Suwa						Lake Mikata				
18	1	15–30	0.37	4.86	0.00	44	1	0–10	0.28	4.28	0.00
19		40–50	0.29	3.96	0.00	45		20–30	0.25	2.47	0.00
20		60–70	0.37	4.32	0.00	46		40–50	0.09	2.91	0.00
21	2	0–15	0.35	4.17	0.00	47		60–70	0.09	3.02	0.00
22		15–30	0.22	3.25	0.00	48		80–90	0.17	4.48	0.00
23		30–45	0.23	2.56	0.00	49		100–110	0.21	4.64	0.00
24		45–60	0.22	2.52	0.00	50		120–130	0.24	5.30	0.00
25		60–75	0.30	2.88	0.00	51	2	35–50	0.29	3.10	0.00

the marine bay sediments of relatively reduced condition than in the fresh-water ones. The oligotrophic lake sediments are especialy poor in total sulfur. There is no clear difference in the total sulfur content between the sediments of the marine open bays in rather oxidized conditions and those of the eutrophic fresh-water lakes.

The vertical distributions of total sulfur contents in typical cores from the nine lakes are given in Fig. 6. The profiles of Lake Suga, Lake Hiruga and Lake Suigetsu show remarkable decrease of total sulfur contents against increasing depth. However, there is no vertical variation of the total sulfur contents in the other lake sediments. The vertical change in the three lakes may be referred to the sea water intrusion to these lakes by excavation of the canals. The same interpretation for total sulfur contents in Lake Suigetsu had been made by MATSUYAMA (1974). Influence of recent environmental pollutions by sulfur in the lake sediments is estimated to be almost negligible, because there is no increasing tendency of sulfur contents toward surface except for the above mentioned three lakes.

The history of environmental pollution and some geochemical characteristics in the Tokyo Bay sediments have been reported by MATSUMOTO and YOKOTA (1977), KITANO *et al.*

Table 2 Analytical results of total sulfur, organic carbon and carbonate carbon for brackish-water sediments in weight percent.

Sample No.	Station No.	Location (cm)	Total sulfur	Organic carbon	Carbonate carbon
	Lake Suga				
52	1	20–30	1.67	3.97	0.00
53		40–48	0.53	5.50	0.00
54		50–55	0.40	6.15	0.00
	Lake Suigetsu				
55	1	0–10	3.48	5.12	0.00
56		35–50	1.33	4.10	0.00
57		50–65	0.32	3.48	0.00
58		90–105	0.16	4.14	0.00
	Lake Kugushi				
59	1	30–40	1.95	2.64	0.00
60		60–70	2.06	5.20	0.00
61		70–85	2.24	5.80	0.00
62	2	30–40	1.73	2.65	0.00
63		40–50	2.24	2.86	0.00
64		50–60	2.42	3.40	0.00
65		60–70	2.48	4.52	0.00
	Lake Hiruga				
66	1	5–25	3.00	3.46	0.00
67		25–40	1.71	3.82	0.00
68		55–62	0.30	5.50	0.00
69	2	0–15	2.92	3.08	0.00
70		15–30	3.80	2.68	0.00
71		30–45	2.81	3.93	0.00
72		45–60	1.52	3.52	0.00
73		60–70	0.92	3.16	0.00
	Lake Shinji				
74	A	12–30	0.28	0.76	0.00
75		40–55	0.87	0.90	0.00
76	B	Surface	0.78	1.55	0.00
77		33–48	0.68	0.76	0.04
78		66–76	0.50	0.95	0.00
79	C	0–15	0.47	1.40	0.00
80		36–46	0.50	0.82	0.05
81		61–67	0.35	0.98	0.02
	Lake Nakaumi				
82	D	0–15	1.24	1.61	0.00
83		60–75	1.44	1.52	0.00
84		80–100	1.52	1.64	0.00
85	E	0–15	1.26	1.50	0.26
86		15–30	1.14	1.16	0.22
87		30–40	1.18	1.15	0.13
88	F	Surface	0.68	1.87	0.33
89		40–65	0.82	1.15	0.37
90		70–80	0.86	1.20	0.42

(1980), and MATSUMOTO (1981). The results indicate that sulfur, organic carbon, and some heavy metals are enriched in surface sediments by the pollution. The original content of total sulfur prior to pollution in the Tokyo Bay sediments is estimated to be about 1% or less. In the South of Kii Strait, Northeast Japan-Japan Trench, total sulfur is not enriched in the upper stratum of the sediments, and there is rather increasing tendency with depth as shown in Fig. 7. These facts imply that the subsurface sediments are more abundant in total sulfur than the surface sediments in the case where pollutions are negligible. The total sulfur contents of the Stn. No. 442, east of the Japan Trench, vary significantly from 1.5 to 3 m below surface. These sediments consist mainly of silt with tuff and sand beds about 5–10 cm thick, and total sulfur tends to be abundant near the boundaries of these lithologic units.

The sulfur content in deep-sea sediments from the north and south Central Pasific has been reported by TERASHIMA *et al.* (1982). The content of total sulfur ranges from 0.16 to 0.51% with an average of 0.33%. About 80% of total sulfur is considered to have been derived from the sea salts, and barite may be considered to be the main source for the rest of the sulfur. Sulfied sulfur was not detected in the analyzed deep-sea samples.

Organic and Carbonate-Carbon

The content of organic carbon in the lake sediments varies from 1.02 (Lake Shinji) to 5.21% (Lake Suga), and there is no clear difference between the fresh-water (2.56%) and the brackish-water (2.81%) sediments.

Table 3 Analytical results of total sulfur, organic carbon and carbonate carbon for marine sediments in weight percent.

Sample No.	Station No.	Location (cm)	Total sulfur	Organic carbon	Car-bonate carbon
	Tokyo Bay				
91	79–2**	0–2	3.00	4.82	n.d.
92		4–6	3.62	5.10	n.d.
93		8–10	3.60	3.68	n.d.
94		12–14	3.30	3.62	n.d.
95		16–18	3.21	3.00	n.d.
96		20–22	3.02	2.81	n.d.
97		26–28	2.47	2.40	n.d.
98		32–34	2.29	2.23	n.d.
99		40–45	2.00	1.97	n.d.
100		60–65	1.99	1.96	n.d.
	Obama Bay				
101	1–1	Surface	0.06	0.23	0.00
102	1–2	do.	0.11	0.81	0.00
103	1–4	do.	0.17	1.33	0.00
104	2–2	do.	0.09	0.42	0.17
105	2–3	do.	0.10	0.63	0.26
106	2–4	do.	0.20	1.13	0.00
107	3–3	do.	0.26	1.90	0.00
108	4–3	do.	0.21	0.82	0.74
109	4–4	do.	0.17	0.76	0.86
110	4–5	do.	0.17	1.11	1.17
111	4–6	do.	0.17	1.19	1.11
112	5–2	do.	0.21	1.27	0.53
113	5–3	do.	0.23	1.13	0.93
114	6–2	do.	0.21	1.35	0.25
115	6–3	do.	0.25	1.34	0.31
116	6–5	do.	0.24	1.01	0.67
117	7–1	do.	0.18	1.08	0.18
118	7–2	do.	0.30	1.23	0.13
119	8–1	do.	0.25	1.26	0.16
120	10–2	do.	0.20	1.59	0.00
121	10–3	do.	0.04	0.20	0.00
122	10–4	do.	0.15	1.18	0.00
123	10–5	do.	0.29	1.53	0.16
	Suruga Bay				
124	39	Surface	0.06	0.13	0.31
125	40	do.	0.12	0.69	0.36
126	41	do.	0.12	0.80	0.17
127	42	do.	0.13	0.89	0.44
128	43	do.	0.08	0.34	2.07
129	44	do.	0.22	0.84	0.16
130	45	do.	0.20	1.31	0.51
131	46	do.	0.15	1.21	0.86
132	47	do.	0.19	0.37	4.61
133	73	do.	0.16	1.10	0.21
134	74	do.	0.17	1.01	0.56
135	75	do.	0.14	0.82	0.44
136	76	do.	0.15	0.85	0.13
137	77	do.	0.16	0.85	0.99
138	78	do.	0.21	1.23	1.48
139	106	do.	0.21	1.12	0.91
140	107	do.	0.13	1.06	0.03
141	108	do.	0.17	1.07	0.14
142	109	do.	0.15	1.03	0.16
143	110	do.	0.08	0.36	0.04
	South of Kii Strait				
144	334	20–32	0.18	1.32	0.91
145	(1355 m)*	84–94	0.33	1.27	1.39
146		164–172	0.34	1.02	1.16
147		244–253	0.40	1.14	0.89
148		342–350	0.39	0.74	0.34
149		423–432	0.35	0.54	0.27
150	327	37–44	0.13	0.92	1.23
151	(1566 m)*	106–116	0.23	0.80	1.00
152		210–220	0.30	0.78	0.75
153		350–360	0.30	0.62	0.48
154		440–444	0.34	0.62	0.54
155		570–580	0.35	0.66	0.46
156	318	17–25	0.20	1.20	1.43
157	(2070 m)*	97–107	0.26	0.92	1.02
158		196–205	0.54	0.74	0.82
159		288–298	0.52	0.70	0.53
160	353	393–402	0.34	0.66	0.54
161	(1645 m)*	55–64	0.24	1.30	1.05
162		94–103	0.33	1.24	1.04
163		220–230	0.39	1.00	1.07
164		290–295	0.26	0.47	0.61
	Off Northeast Japan				
165	464	28–33	0.49	1.68	0.00
166	(750 m)*	78–82	0.70	1.92	0.00
167		127–132	0.85	2.03	0.00
168	467	6–20	0.89	1.93	0.14
169	(1150 m)*	37–50	0.91	1.67	0.14

Table 3 Continued

Sample No.	Station No.	Location (cm)	Total sulfur	Organic carbon	Car-bonate carbon
170		77–90	0.86	1.74	0.20
171		127–140	1.36	1.08	0.58
172		157–175	1.36	0.86	0.29
173		200–215	1.31	1.23	0.72
174		235–250	1.33	0.93	0.29
175		290–306	1.16	1.16	0.92
176		324–342	1.42	0.88	0.17
177		358–372	1.52	1.00	0.31
178	470	6–17	0.79	1.70	0.18
179	(1650 m)*	40–50	0.86	2.00	0.16
180		75–88	0.88	1.84	0.30
181		110–120	0.87	1.93	0.15
182		154–164	0.81	1.65	0.16
183		190–200	0.95	1.19	0.26
184		227–237	0.91	1.48	0.29
185		274–284	0.89	1.32	0.37
186		310–320	0.90	1.61	0.42
187		353–363	0.89	1.61	0.49
188		383–393	0.91	1.61	0.50
189	479	18–22	0.60	1.92	0.40
190	(1850 m)*	98–102	0.49	0.68	0.36
191		168–172	0.78	1.09	0.31
192		248–252	0.46	0.52	0.48
193	476	48–52	0.37	2.15	0.00
194	(4770 m)*	98–102	0.39	1.86	0.00
195		188–192	0.45	1.45	0.00
196		298–302	0.53	1.77	0.47
197		448–452	0.60	1.95	0.67
198		548–552	0.73	2.11	0.29
	Around the Japan Trench				
199	450	18–22	0.47	0.96	0.00
200	(5180 m)*	98–102	0.34	0.90	0.00
201		198–202	0.42	0.83	0.00
202		298–302	0.51	0.78	0.00
203		398–402	0.28	0.72	0.00
204		498–502	0.38	0.78	0.00
205	442	40–55	0.18	0.87	0.00
206	(5400 m)*	80–95	0.20	0.67	0.00
207		137–150	0.25	0.74	0.00
208		172–185	0.58	0.55	0.48
209		180–195	0.27	0.78	0.00
210		200–215	0.92	0.59	0.47
211		220–235	0.23	0.59	0.07
212		240–255	0.56	0.82	0.63
213		260–275	0.14	0.37	0.00
214		270–285	0.66	0.86	0.64
215		295–308	0.15	0.42	0.00
216		320–335	0.12	0.36	0.02
217		360–370	0.14	0.28	0.00
218		400–415	0.12	0.19	0.02
219		450–462	0.16	0.30	0.00
220	445	0–20	0.17	0.51	0.00
221	(7050 m)*	40–60	0.40	1.24	0.00
222		85–100	0.40	1.11	0.00
223		120–135	0.60	1.57	0.00
224		160–180	0.63	1.19	0.00
225		210–230	0.50	0.88	0.05
226		255–269	0.33	0.35	0.15
227		300–315	0.30	1.00	0.00
228		340–355	0.39	0.94	0.00
229		385–400	0.43	1.07	0.00
230		430–455	0.40	1.11	0.04
231		480–495	0.50	1.30	0.00
232	438	0–15	0.69	1.20	0.00
233	(7300 m)*	30–45	0.80	1.13	0.00
234		65–80	0.66	1.20	0.00
235		96–116	0.76	1.13	0.00
236		130–150	0.76	0.88	0.22
237		181–195	0.68	0.96	0.00
238		220–240	0.77	0.86	0.00
239		270–285	0.77	0.97	0.00
240		300–315	0.74	0.97	0.00
241		340–355	0.71	0.99	0.00
242		423–435	0.39	0.11	0.04
243		460–475	0.40	0.15	0.04
244	471	0–15	0.43	1.35	0.00
245	(7330 m)*	40–60	0.47	1.00	0.00
246		85–105	0.39	1.26	0.00
247		120–139	0.44	1.26	0.00
248		139–152	0.39	1.16	0.00
249		180–194	0.51	1.18	0.00
250		220–235	0.43	1.19	0.00
251		260–275	0.50	1.20	0.00
252		300–315	0.57	1.56	0.00
253		340–355	0.54	1.31	0.00
254		380–395	0.57	1.20	0.00

Table 3 Continued

Sample No.	Station No.	Location (cm)	Total sulfur	Organic carbon	Carbonate carbon
255		420–435	0.42	1.17	0.00
256		470–485	0.42	1.05	0.00
257	447	18–22	0.22	1.22	0.00
258	(7400 m)*	98–102	0.31	1.31	0.00
259		198–202	0.58	1.10	0.00
260		298–302	0.56	1.28	0.00
261		398–402	0.54	1.16	0.00
262	449	48–52	0.17	0.53	0.00
263	(8805 m)*	98–102	0.20	0.74	0.00
264		198–202	0.18	0.67	0.00
265		298–302	0.18	0.50	0.00
266		398–402	0.41	0.68	0.00
267		498–502	0.13	0.76	0.00

*Water depth n.d.: Not determined.
**Sulfur analyzed by combustion-titrimetric method.

Table 4 Contents of sulfide and sulfate sulfur for selected 121 samples in weight percent (Sample numbers are same as the Table 1 to 3).

Sample No.	Sulfide sulfur	Sulfate sulfur	
		Total	Sea salt origin*
Lake Biwa			
1	0.10	0.02	0.00
2	0.07	0.00	0.00
4	0.08	0.00	0.00
8	0.03	0.00	0.00
10	0.07	0.01	0.00
13	0.05	0.00	0.00
16	0.04	0.00	0.00
Lake Suwa			
18	0.27	0.10	0.00
20	0.26	0.11	0.00
23	0.13	0.10	0.00
26	0.17	0.12	0.00
27	0.17	0.06	0.00
30	0.26	0.08	0.00
33	0.43	0.22	0.00
36	0.36	0.02	0.00
38	0.51	0.02	0.00
42	0.18	0.10	0.00
Lake Mikata			
45	0.21	0.04	0.00
46	0.09	0.00	0.00
48	0.15	0.02	0.00
50	0.19	0.05	0.00
Lake Suga			
52	0.77	0.90	0.02
54	0.12	0.28	0.07
Lake Suigetsu			
55	1.40	2.08	0.17
56	0.51	0.82	0.13
58	0.13	0.03	0.01
Lake Kugushi			
59	0.62	1.33	0.03
61	1.13	1.11	0.06
62	0.77	0.96	0.07
65	1.28	1.20	0.09
Lake Hiruga			
66	1.32	1.68	0.04
67	0.95	0.76	0.03
68	0.26	0.04	0.04
70	1.42	2.38	0.12
72	0.35	1.17	0.12
Lake Shinji			
76	0.11	0.67	0.03
78	0.43	0.07	0.02
79	0.12	0.35	0.02
80	0.34	0.16	0.02
81	0.22	0.13	0.01
Lake Nakaumi			
82	0.62	0.62	0.15
83	0.43	1.01	0.11
84	0.42	1.10	0.10
86	0.99	0.15	0.10
88	0.50	0.18	0.16
89	0.61	0.21	0.09
90	0.67	0.19	0.08
Obama Bay			
103	0.12	0.05	0.04

Table 4 Continued

Sample No.	Sulfide sulfur	Sulfate sulfur	
		Total	Sea salt origin*
106	0. 11	0. 09	0. 08
108	0. 15	0. 06	0. 05
110	0. 13	0. 04	0. 05
112	0. 09	0. 12	0. 10
113	0. 14	0. 09	0. 08
115	0. 13	0. 12	0. 12
116	0. 15	0. 09	0. 08
117	0. 14	0. 04	0. 06
123	0. 25	0. 04	0. 03
Suruga Bay			
127	0. 05	0. 08	0. 08
128	0. 05	0. 03	0. 03
129	0. 11	0. 11	0. 11
132	0. 09	0. 10	0. 07
134	0. 06	0. 11	0. 12
137	0. 08	0. 08	0. 08
138	0. 11	0. 10	0. 08
139	0. 12	0. 09	0. 09
141	0. 04	0. 13	0. 13
South of Kii Strait			
145	0. 25	0. 08	0. 09
149	0. 30	0. 05	0. 04
151	0. 20	0. 05	0. 06
155	0. 28	0. 07	0. 05
156	0. 09	0. 11	0. 10
160	0. 28	0. 06	0. 05
161	0. 14	0. 10	0. 10
164	0. 17	0. 09	0. 05
Off Northeast Japan			
165	0. 20	0. 29	0. 14
167	0. 13	0. 72	0. 14
169	0. 64	0. 27	0. 12
171	1. 13	0. 23	0. 08
174	1. 10	0. 23	0. 08
177	1. 27	0. 25	0. 06
178	0. 59	0. 20	0. 11
181	0. 64	0. 23	0. 12
183	0. 81	0. 14	0. 07
186	0. 74	0. 16	0. 10
189	0. 15	0. 45	0. 19
191	0. 50	0. 28	0. 09
192	0. 29	0. 17	0. 05
193	0. 09	0. 28	0. 21
196	0. 28	0. 25	0. 11
197	0. 20	0. 40	0. 14
198	0. 35	0. 38	0. 16
Around the Japan Trench			
199	0. 10	0. 37	0. 13
201	0. 24	0. 18	0. 10
204	0. 22	0. 16	0. 09
206	0. 05	0. 15	0. 11
208	0. 50	0. 08	0. 04
210	0. 78	0. 14	0. 04
212	0. 47	0. 09	0. 06
214	0. 53	0. 13	0. 05
216	0. 03	0. 09	0. 08
219	0. 07	0. 10	0. 10
220	0. 03	0. 14	0. 10
222	0. 24	0. 16	0. 15
225	0. 35	0. 15	0. 09
228	0. 25	0. 14	0. 11
230	0. 23	0. 17	0. 13
233	0. 58	0. 22	0. 10
235	0. 48	0. 28	0. 09
237	0. 40	0. 28	0. 09
240	0. 51	0. 23	0. 09
243	0. 30	0. 10	0. 04
245	0. 39	0. 12	0. 12
248	0. 28	0. 11	0. 15
252	0. 43	0. 14	0. 15
256	0. 26	0. 16	0. 12
257	0. 01	0. 21	0. 16
259	0. 11	0. 47	0. 15
261	0. 06	0. 48	0. 14
262	0. 01	0. 16	0. 15
264	0. 05	0. 13	0. 10
266	0. 18	0. 23	0. 15

* Figures were estimated from water soluble chlorine by assuming that pore water has the same composition as that of sea water.

Table 5 Means and ranges of total sulfur, organic carbon and carbonate carbon contents, and organic carbon/total sulfur ratio in Recent sediments.

Area	n	Total sulfur, %		Organic carbon, %		Carbonate carbon, %		Ratio(org. C/tot.S)	
		Mean	Range	Mean	Range	Mean	Range	R_1	R_2
Fresh-water									
Lake Biwa	17	0.05	0.02-0.12	1.12	0.55-2.19	0.04	0.00-0.13	22.4	22.4
Lake Suwa	26	0.35	0.16-1.16	3.14	1.41-5.76	0.01	0.00-0.35	9.0	9.9
Lake Mikata	8	0.20	0.09-0.29	3.87	2.47-5.30	0.00	0.00	18.9	22.4
Average		0.23		2.56		0.02		11.1	16.0
Brackish-water									
Lake Suga*	3	0.87	0.40-1.67	5.21	3.97-6.15	0.00	0.00	6.0	9.1
Lake Suigetsu*	4	1.32	0.16-3.48	4.21	3.48-5.12	0.00	0.00	3.2	10.4
Lake Hiruga*	8	2.21	0.30-3.80	3.64	2.68-5.50	0.00	0.00	1.7	3.8
Lake Kugushi	7	2.16	1.73-2.48	3.87	2.64-5.80	0.00	0.00	1.8	1.8
Lake Shinji	8	0.55	0.28-0.87	1.02	0.76-1.55	0.01	0.00-0.05	1.9	2.0
Lake Nakaumi	9	1.13	0.68-1.52	1.42	1.15-1.87	0.19	0.00-0.42	1.3	1.4
Average		1.40		2.81		0.05		2.0	3.6
Sea-water									
Tokyo Bay	10	2.85	1.99-3.62	3.16	1.96-5.10	n.d.		1.1	1.1
Obama Bay	23	0.19	0.04-0.30	1.07	0.20-1.90	0.33	0.00-1.17	5.6	5.8
Suruga Bay	20	0.15	0.06-0.22	0.85	0.13-1.31	0.73	0.03-4.61	5.7	5.7
South of Kii strait	21	0.32	0.13-0.54	0.89	0.47-1.32	0.83	0.27-1.43	2.8	3.2
Off Northeast Japan	34	0.86	0.37-1.52	1.52	0.52-2.15	0.30	0.00-0.92	1.8	2.1
Around the Japan Trench	69	0.43	0.12-0.92	0.90	0.11-1.57	0.04	0.00-0.64	2.1	2.4
Average		0.58		1.16		0.32		2.0	3.2

R_1: Calculated from the mean values for each areas. R_2: The average of individual ratios. *These lakes were fresh-water before 1630(Lake Hiruga) and 1665(Lake Suga & Lake Suigetsu). n.d.: Not determined.

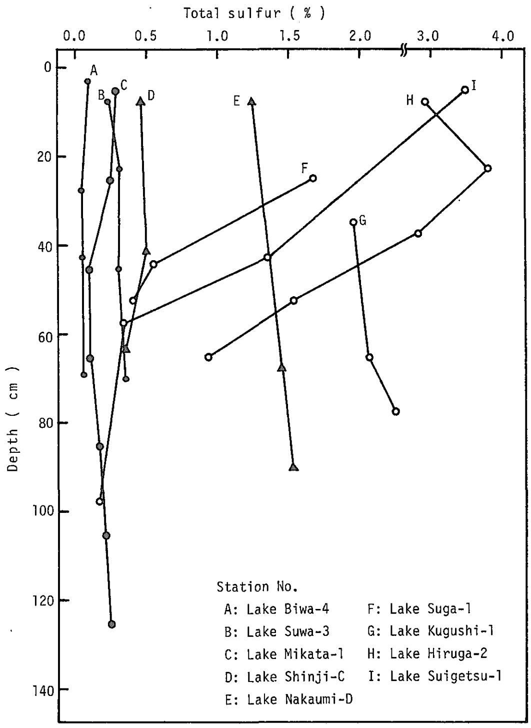

Fig. 6 Vertical distribution of total sulfur contents in the lake sediment cores.

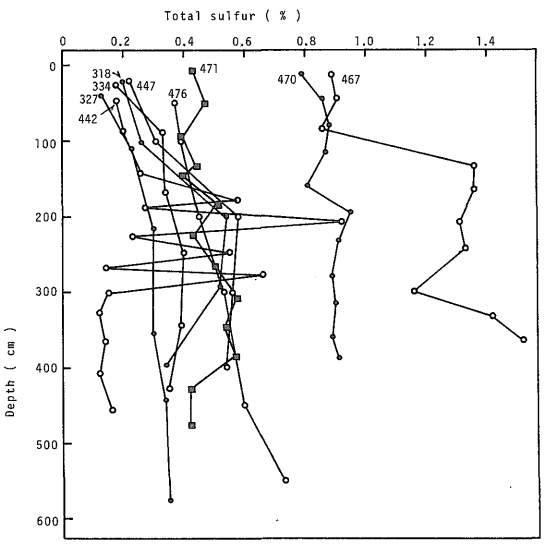

Fig. 7 Vertical distribution of total sulfur contents in the open ocean sediment cores. Digitals mean the station numbers.

In the marine sediments, organic carbon ranges from 0.85% (Suruga Bay) to 3.16% (Tokyo Bay). The average of 1.16% is clealy lower than that of the lake sediments. The vertical distribution of organic carbon for some representative core samples are illustrated in Fig. 8. It shows that organic carbon is more abundant in surface than in subsurface sediments. This may arise from the decomposition of organic matter. The similar decreasing tendency of organic carbon in the sediments of the Central Pacific has been reported by TERASHIMA *et al.* (1982).

The contents of carbonate-carbon in the sediments of fresh-water (0.02%) and brackish-water (0.05%) are far lower than those of marine sediments (0.32%). This fact implies that the carbonate-carbon exists in the form of calcium carbonate in these sediments, and the calcium carbonate is more stable in the marine environments.

The relationship between the water depth of sampling locations, and organic carbon and carbonate carbon contents in the marine

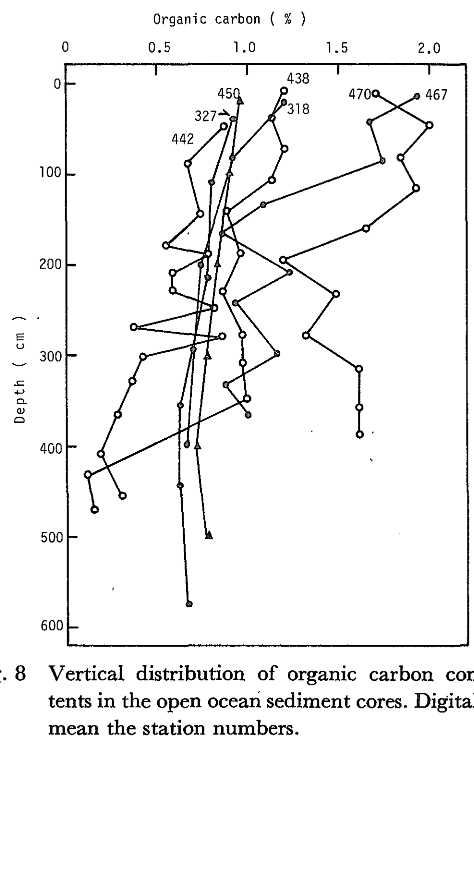

Fig. 8 Vertical distribution of organic carbon contents in the open ocean sediment cores. Digitals mean the station numbers.

Table 6 Relationship between water depth of the sampling locations and organic and carbonate carbon contents (%).

Water depth (m)	n	Organic carbon		Carbonate carbon		Sea area
		Mean	Range	Mean	Range	
0-10	9	1.02	0.20-1.59	0.06	0.00-0.18	(1)
10-20	10	0.89	0.13-1.35	0.27	0.00-0.67	(1), (2)
20-100	8	1.10	0.69-1.90	0.83	0.00-1.48	(1), (2)
100-1000	15	1.08	0.34-2.03	0.77	0.00-4.61	(2), (4)
1000-2070	50	1.15	0.47-2.00	0.54	0.03-1.43	(2), (3), (4)
4770-5400	27	0.91	0.19-2.15	0.14	0.00-0.67	(4), (5)
7050-7400	42	1.07	0.11-1.57	0.01	0.00-0.22	(5)
8805	6	0.65	0.50-0.76	0.00	0.00	(5)
2950-5960	115	0.20	0.07-0.63	0.34	0.00-10.23	(6)

(1) Obama Bay, (2) Suruga Bay, (3) South of Kii Strait, (4) Off Northeast Japan, (5) Around the Japan Trench, (6) Central Pacific(After TERASHIMA *et al.* 1982).

sediments are listed in Table 6. The mean contents of organic carbon vary within a relatively narrow range (mostly 0.65 to 1.15%). Comparing organic carbon with carbonate carbon, organic carbon content is generally higher than carbonate carbon unrelated to the water depth except in the Central Pacific. The content of carbonate carbon varies systematicaly depending upon the water depth, and 20 to 1000 m of water depth is the most dominant region of carbonate carbon. The results may be related to the compensation depth of calcium carbonate in the surveyed area. The compensation depth of calcium carbonate in some marine areas have been discussed in SUGISAKI (1978, 1979), and SUGISAKI and KINOSHITA (1981 and 1982).

Sulfide sulfur and sulfate sulfur

The means and ranges of sulfide and sulfate sulfur contents are summarized in Table 7. The mean content of sulfide sulfur varies from 0.06 to 0.79% with the average of 0.342%. As for the sulfate sulfur, the range and average are from 0.004 to 1.05% and 0.275% respectively. The regional distribution patterns of both sulfide and sulfate sulfur are nearly the same as that of total sulfur. There is a clear tendency that the sulfate sulfur is more abundant in the sediments from brackish-water (Av 0.753%) than those from marine (0.170%) and fresh-water (0.051%). The estimated values of sulfate sulfur from sea salt varies from 0.02% (Lake Shinji) to 0.12% (Off Northeast Japan) with an average of 0.092%. The results indicate that 90% or more of sulfate sulfur was derived from the sea salts in marine sediments, which deposited under relatively oxidized conditions as Obama Bay, Suruga Bay and South of the Kii Strait.

Correlation between sulfur and carbon contents

It is generally accepted that main portion of sulfide-sulfur in the coastal marine sediments is produced by bacterial reduction of sulfate. The bacterial reduction of sulfate occurs very actively in organic dominant sediments, and the sulfur and organic matter contents are positively correlated each other in most cases. However, total sulfur in Recent sediments seems to be rather abundant in the subsurface zone (Fig. 7), whereas organic carbon is rich in the surface samples (Fig. 8). This fact implies that the total sulfur and organic carbon are correlated inversely in some cases.

Table 7 Means and ranges of sulfide and sulfate sulfur contents in selected Recent sediments.

Area	n	Sulfide sulfur		Sulfate Sulfur Total		Sulfate Sulfur Salt origin**	
		Mean	Range	Mean	Range	Mean	Range
Lake Biwa	7	0.06	0.03-0.10	0.004	0.00-0.02	n.d.	
Lake Suwa	10	0.27	0.13-0.51	0.09	0.02-0.22	n.d.	
Lake Mikata	4	0.16	0.09-0.21	0.03	0.00-0.05	n.d.	
Lake Suga & Others*	14	0.79	0.12-1.42	1.05	0.03-2.38	0.07	0.01-0.17
Lake Shinji	5	0.24	0.11-0.43	0.28	0.07-0.67	0.02	0.01-0.03
Lake Nakaumi	7	0.61	0.42-0.99	0.49	0.15-1.10	0.11	0.08-0.16
Obama Bay	10	0.14	0.09-0.25	0.074	0.04-0.12	0.069	0.03-0.12
Suruga Bay	9	0.08	0.04-0.12	0.092	0.03-0.13	0.089	0.03-0.13
South of Kii Strait	8	0.21	0.09-0.30	0.076	0.05-0.11	0.068	0.04-0.10
Off Norhteast Japan	17	0.54	0.09-1.27	0.29	0.14-0.72	0.12	0.05-0.21
Around the Japan Trench	30	0.27	0.01-0.78	0.18	0.08-0.48	0.11	0.04-0.16
Fresh-water	21	0.182		0.051		n.d.	
Brackish-water	26	0.634		0.753		0.073	
Sea-water	74	0.285		0.170		0.098	
All the samples	121	0.342		0.275		0.092	

*Lake Suigetsu, Lake Hiruga and Lake Kugushi. ** Same as in Table 4. n.d.: Not determined.

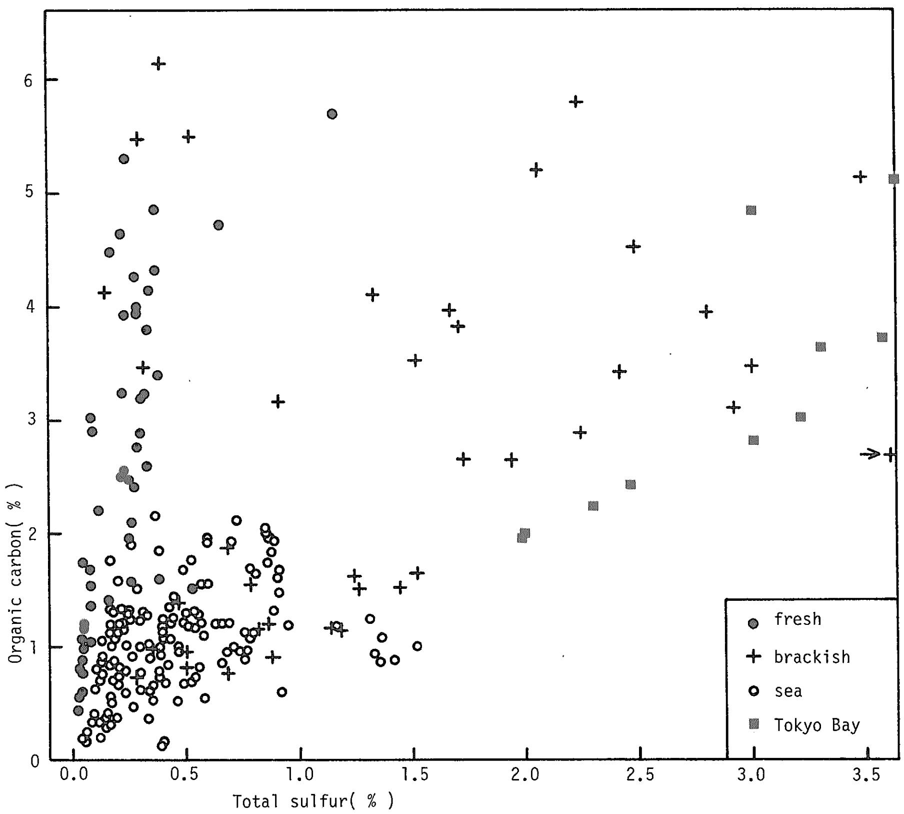

Fig. 9 Relationship between total sulfur and organic carbon contents.

In order to show the correlation between total sulfur and organic carbon contents in various sedimentary environment, all the data are plotted in Fig. 9, and the calculated correlation factors and coefficients for different regions are listed in Table 8. The clear positive correlation between total sulfur and organic carbon contents is seen in the three lakes (Lake Biwa, Lake Suwa and Lake Suigetsu), and in the four marine areas, i.e., Tokyo Bay, Obama Bay, Suruga Bay and the central Japan Sea (KINOSHITA, 1981). For the other regions, however, the correlation coefficient varies from −0.98 to 0.49, and the results indicate no clear positive correlation. The inverse correlation observed in Lake Suga and Lake Hiruga may not have particular meaning, because the sedimentary environments of these lakes have been very unstable and the number of samples is small. The inverse correlation in South of the Kii Strait and Off Northeast Japan seem to be reasonable. The sediments were taken from the whole cores of more than 4 m in length, in most cases. In order to clarity the correlation between total sulfur and organic carbon in the upper parts of sediments (less than 50 cm), 22 samples were selected from open marine areas, and the results are listed in Table 8. There is clear positive correlation.

The close positive correlation between total sulfur and organic carbon contents given in Table 8 is found in the sediments deposited under rather oxidized conditions in most cases. If the sedimentary environment has relatively oxidized condition, the influence of organic carbon contents may be much important to the bacterial reduction of sulfate.

Table 8 Linear regression for total sulfur and organic carbon in 293 Recent sediments. Org. C=a(tot.S)+b; c: Correlation coefficient.

Area	n	a	b	c
Lake Biwa	17	15.90	0.29	0.89
Lake Suwa	26	3.26	2.00	0.56
Lake Mikata	8	3.23	3.12	0.25
Lake Suga	3	-1.57	6.57	-0.98
Lake Suigetsu	4	0.40	3.69	0.89
Lake Hiruga	8	-0.48	4.67	-0.68
Lake Kugushi	7	1.92	-0.28	0.39
Lake Shinji	8	0.38	0.81	0.26
Lake Nakaumi	9	0.11	1.30	0.12
Tokyo Bay	10	1.47	-1.02	0.81
Obama Bay	23	4.86	0.17	0.81
Suruga Bay	20	4.99	0.11	0.68
South of Kii Strait	21	-0.84	1.16	-0.31
Off Northeast Japan	34	-0.63	2.06	-0.44
Around the Japan Trench	69	0.83	0.54	0.49
The Central Japan Sea*	26	0.65	0.64	0.56
Selected 22 samples**		1.28	0.67	0.67
All the samples	293	0.79	1.12	0.46

*After KINOSHITA(1981). **Selected surface sediments(upper 50 cm) collected from south of the Kii Strait, Off Northeast Japan, Around the Japan Trench and the central Japan Sea.

Table 9 Contents of total sulfur, non-carbonate (organic) carbon, carbonate carbon in Paleozoic to Cenozoic sedimentary rocks and Recent sediments.

Age	Area	n	Total sulfur, % (A)	Non-carbonate carbon, % (B)	Carbonate carbon, %	Ratio(B/A) R_1	R_2
Paleozoic	Chugoku, Marine	67	0.105	0.57	0.15	5.4	17.5
	Shikoku, Marine	10	0.186	0.39	0.23	2.1	15.6
Mesozoic	Chugoku, Non-marine	28	0.028	1.52	0.28	54.3	92.8
	Chugoku, Marine	41	0.370	1.05	0.04	2.8	37.1
	Shikoku, Marine	22	0.226	0.60	0.28	2.7	15.7
	Koshiki-jima, Non-marine	6	0.039	0.74	0.10	19.0	52.8
	Koshiki-jima, Marine	17	0.684	1.02	0.41	1.5	3.3
Cenozoic	Shikoku, Marine	12	0.320	0.46	0.05	1.4	3.5
	All non-marine	34	0.030	1.38	0.25	46.0	85.8
	All marine	169	0.263	0.72	0.16	2.7	19.5
Recent	Fresh-water	51	0.23	2.56	0.02	11.1	16.0
	Brackish-water	39	1.40	2.81	0.05	2.0	3.6
	Sea-water	177	0.58	1.16	0.32	2.0	3.2

Data for sedimentary rocks were taken from TERASHIMA *et al.*(1981) and TANAKA *et al.*(1981).
R_1 and R_2: See Table 5.

Application to sedimentary rocks of geologic ages

Analytical results of total sulfur, non-carbonate carbon, carbonate carbon and sulfate sulfur in about 200 sedimentary rocks of Paleozoic to Cenozoic age from Chugoku, Shikoku and Kyushu (Koshiki-jima) have been reported by TERASHIMA *et al.* (1981) and TANAKA *et al.* (1981). The results are summarized in Table 9 for comparison with the Recent sediments. The content of total sulfur in the sedimentary rocks varies widely from 0.001 to 1.90% with the average of 0.22% (n=203). Although the content of total sulfur in the marine pelitic rocks from the Chugoku Paleozoic terrain seems to be very low (0.105%, n=67), the average of marine shales are relatively higher than those of non-marine ones. In comparison with the Recent sediments, total sulfur seems not to be so concentrated in both the marine and non-marine sedimentary rocks. The average contents of non-carbonate carbon in the sedimentary rocks are lower than the contents of organic carbon in the Recent sediments. Assuming a constant supply of organic matter to the sediments since late Paleozoic, the difference between the contents of non-carbonate carbon for sedimentary rocks and organic carbon of Recent sediments may be due to the loss of organic carbon during the diagenesis. Loss of carbon in some sedimentary rocks in the process of regional metamorphisms had been discussed by KATADA *et al.* (1964).

Sulfate sulfur was found in 95% of Recent sediments (n=121), but only in 24% of sedimentary rocks (n=126). Moreover the average content is markedly higher in the Recent sediments (0.275%) than the sedimentary rocks (0.034%). These facts imply that the sulfate sulfur were lost or changed to sulfide sulfur during the formation of sedimentary rocks. There was clear inverse correlation between sulfate sulfur and carbonate carbon contents in sedimentary rocks (TERASHIMA *et al.*, 1981). As shown in Fig. 10, the similar tendency is observed in the Recent sediments. In Recent sediments,

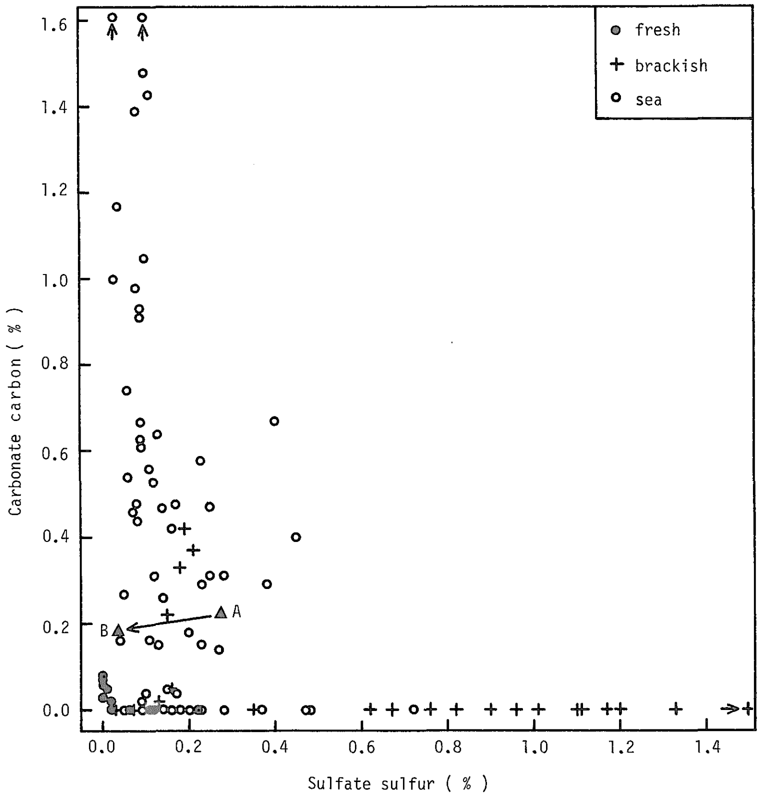

Fig. 10 Relationship between sulfate sulfur and carbonate carbon contents. Solid triangle means average content for Recent sediments (A), and sedimentary rocks (B).

the sulfate sulfur is most abundant in brackish-water sediments, whereas carbonate carbon predominate in marine sediments under rather oxidized conditions.

Average carbonate carbon content of the sedimentary rocks is 0.18% (n=203), whereas that of the Recent sediments is 0.22% (n=257). This may suggest that the formation of carbonate minerals during diagenesis tends to be restricted to relatively narrow regions and conditions.

Concentration ratio of organic carbon to total sulfur

Although the content of total sulfur is partly useful to indicate the environment of deposition of sedimentary rocks, there is no clear difference in the total sulfur contents between some Recent fresh-water sediments and marine sediments (Table 5). Concentration ratio of organic (or non-carbonate) carbon against total sulfur seems to be a more suitable geochemical indicator to distinguish marine and fresh-water sediments.

The concentration ratios (organic carbon/total sulfur) of fresh-water sediments are clearly higher than those of the marine sediments as shown in Fig. 11. As to the marine sediments, the concentration ratios seem to decrease from the coastal side to the oceanic side except those of the Tokyo Bay.

There is no marked difference in the concentration ratios between R_1 and R_2 in Recent sediments (Table 5), but for the sedimentary rocks, R_2 values are significantly higher than R_1 values as listed in Table 9. This indicates that the concentration ratio of total sulfur to non-carbonate carbon in sedimentary rocks varies widely due to many effects as diagenesis, metamorphism and so on. The R_1 values of

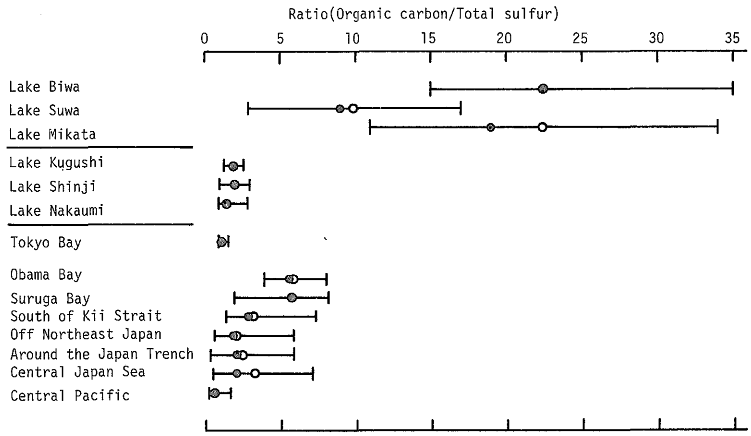

Fig. 11 Variation of organic carbon/total sulfur ratio in recent sediments. Solid circle, R_1; Open circle, R_2.

both the marine and non-marine sedimentary rocks seem to be nearly the same as those of the Recent sediments. Thus, R_1 value should be a better geochemical indicator to distinguish marine and non-marine sedimentary environments.

The close correlation between the concentration ratio of organic (or non-carbonate) carbon to total sulfur and the sedimentary environments may be related to the source, reaction and preservation of both elements in the sediments. The principal source of sulfur in sediments is sulfate in surface and/or pore water, and the content of sulfate sulfur in sea water (2,649 mg SO_4^{2-}/kg) is greatly higher than the average of river water (11.2 mg SO_4^{2-}/l, LIVINGSTONE, 1963).

The organic carbon tends to be rather abundant in the coastal side than the oceanic side (Table 5–6). These facts imply that the sulfur predominates in the sediments of marine environments, whereas non-carbonate carbon is richer in the sediments of lands and near shore regions. The concentration ratio of non-carbonate carbon against total sulfur should therefore be more suitable for the geochemical indicator of sedimentary environments.

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* in Japanese with Engilish abstract.

現世堆積物中の硫黄・炭素含有量と堆積環境

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要　旨

本研究は，堆積環境の異なるいくつかの湖沼及び海域から採取した現世堆積物中の硫黄と炭素の含有量とその存在状態を明らかにし，堆積環境との関係を明確にすることを目的とした．

全硫黄は，淡水堆積物で低いとされているが，貧栄養湖の琵琶湖では明らかに低いが，諏訪湖，三方湖では小浜湾，駿河湾等酸化環境の海底堆積物と比較して有意差は認められなかった．汽水湖や還元環境の海底堆積物では明らかに高い．有機炭素は，湖沼に比べて海域で低い傾向があり，また沿岸堆積物よりも遠洋堆積物で低い．炭酸塩炭素は，湖沼に比べて海域で高く，硫酸塩硫黄は淡水及び海底堆積物よりも汽水堆積物に多く含有される．全硫黄と有機炭素の相関については，淡水湖や海域の表層堆積物では良好な正の相関を示すが，汽水湖や海域の深層堆積物では逆相関を示す場合もあった．

現世堆積物中の各成分の含有量と古い時代の堆積岩のそれを比較すると，全硫黄，有機炭素，硫酸塩硫黄は現世堆積物に多く含有される．本研究結果によれば，全硫黄の含有量のみによって海成—非海成の判別を行なうと，誤りをおかす場合が予想される．そこで，有機炭素が海域に比べて湖沼に多い点に着目し，有機炭素/全硫黄の比を求めた．その結果，その比の平均値は淡水堆積物では9以上，海底堆積物では6以上となった．また，古生代—新生代の堆積岩試料についても非炭酸塩炭素/全硫黄の比を求めた結果，海成層と非海成層の間に明確な差があることがわかった．

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