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Suspended Matter, Turbidity, and Bottom Sediment in Harding Lake, Alaska, U.S.A.*

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Abstract

Concentrations, microscopic observations of the suspended matter, vertical distributions of turbidity and temperature, size frequency distributions and microscopic observations of the bottom sediment were studied to clarify the sedimentary process at the present time in Harding lake, Alaska. Both the suspended matter in lake water and the bottom surface sediment had almost the same compositions. They were transparent and colorless or light brown corpuscles, crystal minerals, fragments of dead planktons, and detritus from the terrestrial sources. Planktons were abundant in lake water but scarce in the bottom sediment. Most of corpuscles and assemblages which were a major constitution both in the suspended matter and the bottom sediment seemed to be from the terrestrial origin. They might be supplied and transported from the western side of the lake, as was estimated by the cumulative frequencies in the bottom sediment.

Introduction

Harding lake, situated about 160 km to the south of the Arctic Circle at latitude 64°25'N and longitude 146°50'W, is a closed lake, having neither inlet nor outlet rivers. The morphometric features of the lake are 9.88 km^2 in area, 43 m in maximum depth (mean: 16 m). Air temperature in the area is characterized as a continental climate with the large difference in temperature between the summer and the winter season. Hence, although the lake surface is covered with ice of over 1 m thick in winter, its temperature rises to about 20°C in summer.

On July 10 to 16 in 1978, surveies for the research on suspention and sedimentation were performed in the lake. This is a part of the joint project of the oversea scientific researches on the subject of "The Scientific Research on Climatic Changes on the Postglacial Age in the Arctic Circle" (Nakao, edited, 1980)[1]. The purpose of this report is an attempt to investigate the sedimentary process in Harding lake at the present time.

Fig. 1 shows a map of location sites in our measurement, which crossed the deepest basin of the lake.

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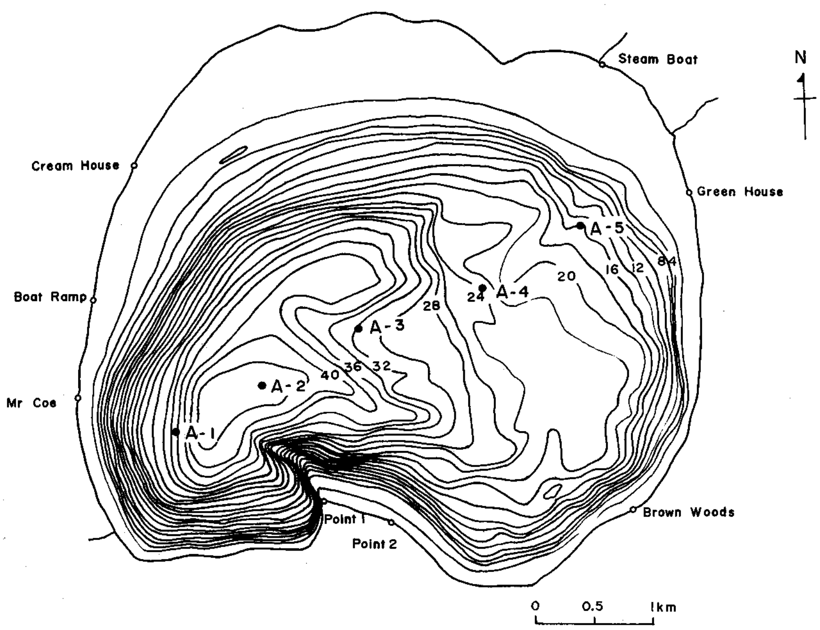

Fig. 1 A map of location sites

Suspended matter

Dry weight

Samples of lake water were taken by a Vandorn bottle in layers determined by referring to results of the turbidity measurement preliminarily performed before water sampling, and then the total suspended matter was gravimetrically analyzed after filtration. In the experiment, two types of Millipore filters: HAWP (pore size, 0.45 μm) and SSWP (pore size, 3.0 μm) were prepared, but only the SSWP type was finally used to obtain the dry weight of the total suspended matter, because of difficulty of filtrating a large bulk of water by the HAWP type. The procedures employed in the study are as follows. Before use, filters were boiled, and dried in a decicator until the weight of each filter reached to a constant value within $\pm$0.2 mg. After the filtration done under a vacuum by a Millipore pump, the filters were rinsed twice with about 30 ml of 5% ammonium formate solution. Filters placed in plastic petri dishes were taken to the laboratory and dried again in the same method as mentioned above. In the experiment, two to three blank filters at each site were prepared to correct the effect of humidity on the filter weight. Total weights of the suspended matter on the filter were determined using the difference in weight before and after filtration with corrections being made by blank filters. The type of a balance used for the measurement was a METLLER-B.

Results shown in Table 1 are the concentrations of the suspended matter in water, ranging from 0.18 to 1.09 (mg/l). With respect to vertical profiles,

Table 1. *Concentrations of suspended matter*

SITE	A–1		A–2		A–3		A–4		A–5	
DEPTH (m)	V.F.W.	C.S.M.	V.F.W.	C.S.M.	V.F.W.	C.S.M.	V.F.W.	C.S.M.	V.F.W.	C.S.M.
0	5.2	0.25	3.9	0.39	5.2	0.52	5.2	0.18	5.2	0.30
5	5.2	0.18	4.6	0.42	5.2	0.49	5.2	0.62	5.2	0.48
10	5.2	0.49	3.8	0.62			5.2	0.58	5.2	0.54
13									5.2	0.51
15	5.2	0.70	5.2	0.54	5.2	0.64	5.2	0.63		
22	5.2	1.09	5.2	0.78	5.2	0.85	5.2	0.70		
25	5.2	1.04								
30	5.2	0.93	5.2	0.90	5.2	0.61				
35			5.2	0.85						
40			5.2	0.73						

V.F.W.: volume of filtered water (*l*)
C.S.M.: concentration of suspended matter (mg/*l*)

high concentrations are seen in 22 m depths at sites A–1, A–3 and A–4 and in 30 m depths at site A–2, though each value is different.

At site A–5, the layer of high concentration is not clear, which may be due to the shallow water at the site. Generally, surface water has a tendency to show a low concentration in the vertical profile.

Microscopic observation

To examine the composition of materials suspended in lake water, remains on the filter were directly observed by a microscope. In this case, the filter used was the HAWP type and the amount of filtered water was about 100 m*l*. A piece of the dried filter was put on a micro slide glass and made clear with drops of ceder oil. Under the microscope, miscellaneous materials were seen: living planktons, detritus materials, minerals, corpuscles of transparent, light brown and black, their assemblages, organic aggregates and unknown materials. Zooplankton of full shape was recognized in the sampled water before filtration, but not observed under the microscope, since it was crushed during the processes of vacuuming and drying. Mineral crystals when they are large, were clearly distinguished through polarized light and their shapes. However, some of remains of zooplankton and organic aggregates were illuminated by polarizers, thus it was difficult to clarify the distinction between these materials and minerals, when the fragments were small.

Compositions of the material were almost the same in the location site but different in depth. A major part of suspended matter in surface water in which the concentration of the suspended matter was low, consisted of corpuscles and their assemblages. Other materials mentioned above were rarely observed. When water depth become deeper than 10 m, diatoms of *Navicula*, *Diatoma*, *Tabellaria* and *Melosira* appeared, of which the distributions seemed to depend on the depth of water. Layers of the maximum concentration in dry weight may be caused by dense distribution of cyanophyceae.

Vertical distributions of turbidity and temperature

As one of the ways to investigate the sedimentary process, the attenuation coefficient in water was measured as an index of the turibidity in lake water using an *in situ* transmittance meter. The attenuation of light is the result from the combined actions of scattering and absorption both by water and the suspended matter, and of absorption by the dissolved matter in water. Thus, the attenuation coefficient does not mean physically the index of the concentration of the supended matter. But, in comparison with the gravimetric method which is complicated in the procedure and time-consuming, it is easy to obtain the fine vertical profile of the trubidity using the *in situ* transmittance meter.

The transmittance meter used in this study has 0.5 m in water path length. A light flux from a tungsten lamp (6V, 1A) paralleled by collimator lenses through the water path, and then reaches the receiver which consists of collimator lenses, a diaphragm having a pinehole, a filter peaking at 650 *n*m and Cds photocell. The immerged unit of the transmittance meter, on which a thermistor probe is attached, is connected with a deck control unit and a two pens recorder by a cable. The instrument was lowered to the bottom by a wire with a constant speed and the water depth in each 5 m was marked on the recorder by a depth gauge. An inclination correction was not necessary, since the instrument was lowered down perpendicularly. The attenuation coefficient was calculated from the following equation,

$$\alpha = 2\,ln\,(R_A/R_W) + 0.230 \qquad (\mathrm{m}^{-1})$$

where α is the attenuation coefficient, R_A and R_W are readings of the record in air and in water respectively, and 0.230 is a constant for compensating the difference of the reflection of light on the window surface in air and in water. Since the turbidity measurements were carried out on different days with water and sediment core sampling, location sites for the measurement of turbudity deflected a little from ones shown in Fig. 1.

Vertical profiles of the attenuation coefficient are shown in Fig. 2, in which solid cricles denote the concentration of the suspended matter described above. In the profiles, distribution patterns of the turbidity are almost the same at A–1, A–2 and A–3, where turbid layers are ranging from 15 to 30 m depths. On referring to microscopic observations, the turbid layers appear to be caused from the distribution of phytoplanktons. There are little changes in the vertical values of the attenuation coefficient among the three sites, however looking in detail, A–1 is the clearest in the upper layer and also the most turbid in the lower layer among them. Both values of the attenuation coefficient in the upper and in the lower layer at A–2 and A–3 show almost the same. On the whole, turbidity distributions are similar to the concentration of the suspended matter except for results in some depth. At A–2, concentrations of the suspended matter in 30 and 35 m depths are larger compared with values of the attenuation coefficient, while in surface layers at A–4 and A–5 concentrations of the suspended matter are smaller against the attenuation coefficient. As described above, the attenuation coefficient mainly depends on the suspended matter, and concentrations of the suspended matter in the study

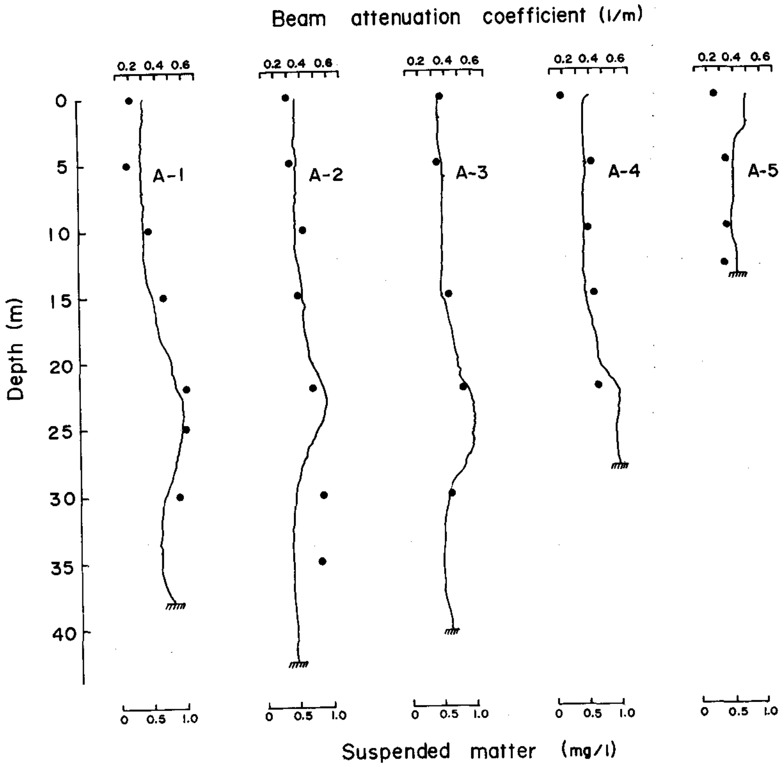

Fig. 2 Profiles of attenuation coefficient

are obtained by the gravimetrical method using the SSWP filter which has the pore size of 3.0 μm. So, in principle, particles smaller than the pore size of the filter cannot be captured onto the filter. On the other hand, as is evident in microscopic observations in the suspended matter which are filtrated by the HAWP filter having the pore size of 0.45 μm, there are lots of particles under 3.0 μm in size. Thus, provided that the fairly small value of the concentration of the suspended matter in the surface layer at A–4 is not due to the experimental error, the smaller particles passed through the filter may be abundant in the layer. The attenuation coefficient in the surface water at A–5 is larger, in spite of the same concentration of the suspended matter with that of other sites. Although we cannot conclude only from our data, this may be caused by the absorption of the dissolved matter originating from the biological sources in and around the lake. The turbidity near the bottom, especially at A–1, A–3 and A–4 has an increasing tendency toward the bottom. The profiles denote evidently not only the upward transport of the bottom sediment but also the existence of water movement near the bottom. While, at A–2 of the deepest site and A–5 of the western shallow water, the upward transport of the bottom sediment is not clear. Besides, values of the attenuation coefficient are smaller than those of other sites. The profiles show that there is no water movement or, if any, it may be very weak.

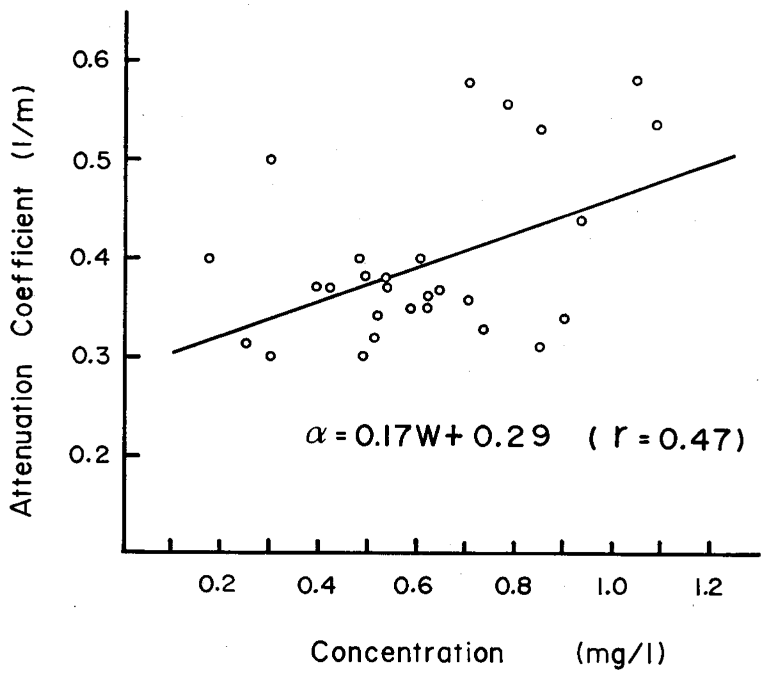

Fig. 3 Relation between attenuation coefficient and concentration of suspended matter

Fig. 3 shows the relation between the attenuation coefficient and the concentration of the suspended matter. Using the least square method, the relation is obtained as, $\alpha=0.17W+0.29$ where α is the attenuation coefficient and W is the concentration of the suspended matter. The result shows a somewhat large scatter of points and a correlation between them is not fine ($r=0.47$). The main factors affecting the scatter in the result may have been caused by qualitative differences of the suspended matter in depth, the absorption of the dissolved matter in lake water, and the SSWP filter used for the determination of the dry weight. However, on the whole, the attenuation coefficient increases in proportion to the concentration of the suspended matter. When the concentration of the suspended matter is zero, the attenuation coefficient is 0.29. This is the same value of the attenuation coefficient of pure water at wavelength 650 *nm* (Jerlov, 1968)[2]. However, our value may be small, if the absorption of the dissolved metter in lake water is considered. The slope given by the equation is also smaller than that of the suspention of mud (Jones & Wilis, 1955)[3]. But, if we consider that both ranges of the concentration and the attenuation coefficient in our data are smaller compared to data of Jones & Wilis, and also the qualitative difference of the suspended matter between ours and theirs, it may not be adequate to discuss the slope in the equation. Fig. 4 shows the vertical temperature profiles obtained simultaneously with the turbidity measurements. As is obvious in the figure, clear thermocline is formed. A temperature inversion of 0.6°C appears in the layer close to the lake surface at A–5, and structures of "steps" form are observed

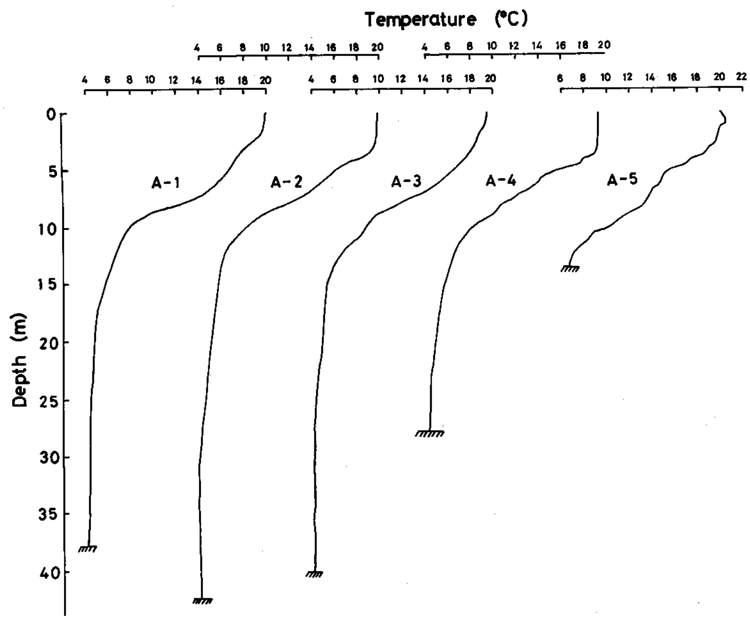

Fig. 4 Temperature profiles in the lake

in both profiles at A–4 and A–5. In general, when the clear thermocline is formed, it is often observed that the vertical profiles of the suspended matter and the turbidity have the peak concentration near the thermocline, which may be raised by the change of the sinking rate of suspended particles due to the differences of water density and the eddy diffusivity over and below the thermocline. Comparing the results of the temperature profiles with the turbidity profiles, there is no significant relation. This implies that the primary productivity and associated detritus in Harding lake, especially over the thermocline and the suspended particles to be supplied from the terrestrial soruce in the summer season, are minimal.

Sediments in the lake bottom

Particles size in the lake sediments

Samples of sediments were taken by a gravity corer and kept in plastic tubes after cutting. The size frequency distribution was made by a granulometric analysis with mechanical sieving, using a microsieving equipment for samples finer 74 μm. The equipment consists of an ultrasonic vibrator, an electromagnetic vibrator, and a reciprocating pump by which pressure and vacuum are applied to a microsieving, which ranges in eleven classes from 63 to 5 μm.

Results of cumulative frequency are shown in Table 2 and their profiles against distance from the lake floor are shown in Fig. 5.. Vertical distributions of the cumulative frequency at each site do not have the same tendency. Especially, at site A–1, near the western side in Harding lake, cumulative frequencies for the

Table 2. *Cumulative frequencies in the bottom sediment*

Site no. A–1 Cumulative Frequency %

Depth cm / Grain Size μm	0.5 ~2.5	1.5 ~4.0	3.0 ~7.0	7.0 ~9.0	8.0 ~12.0	12.0~ 18.0	18.0~ 22.0	22.0~ 26.0	26.0~ 30.0	30.0~ 34.0
74	0.61	3.80	7.54	3.37	4.36	9.09	9.93	5.44	11.45	8.44
63	4.65	5.05	10.70	8.19	6.83	25.36	13.52	9.89	15.85	12.59
45	15.19	23.01	27.39	27.73	22.60	30.95	20.18	16.24	24.60	18.42
32	26.66	26.99	42.74	33.36	25.86	47.04		31.91	36.57	34.65
20	43.15	30.82	55.26	48.72	32.04	55.02	32.24	44.25	49.29	46.92
12.5	53.38	50.45	69.68	70.32	53.18	68.16	53.35	62.37	64.64	66.10
8	64.09	65.76	78.24	77.52	73.14	78.49	68.15	76.03	78.55	77.19
5	66.61	69.61		79.41	75.39	81.02	70.00	78.06	81.29	80.03

Site no. A–2 Cumulative Frequency %

Depth cm / Grain Size μm	0	4.0~ 6.0	9.0~ 10.0	10.0~ 14.0	14.0~ 18.0	18.0~ 22.0	22.0~ 26.0	26.0~ 30.0	30.0~ 33.0
74	1.53	2.55	2.26	2.72	3.50	2.95	5.90	5.97	3.38
63	7.48	4.22	5.37	5.31	5.33	8.24	10.48	9.26	10.71
45	19.24	14.44	8.33	10.92	13.31	14.36	20.10	14.96	16.45
32	25.35	20.99	15.08	17.38	20.58	19.60	30.25	29.36	28.23
20	34.60	33.22	33.90	27.18	36.44	31.94	43.84	52.93	42.48
12.5	46.97	50.48	50.35	45.24	52.74	49.09	62.30	67.38	59.25
8	56.96	66.84	63.64	59.61	67.89	66.27	74.02	78.45	72.08
5	59.71	69.07	67.96	62.82	70.74	70.18	75.55	79.88	

Site no. A–3 Cumulative Frequency %

Depth cm / Grain Size μm	0	6.0~ 10.0	10.0~ 14.0	14.0~ 18.0	18.0~ 22.0	22.0~ 26.0	26.0~ 30.0	30.0~ 33.0
74	2.66	1.71	2.01	1.03	4.06	8.44	2.05	3.33
63	5.89	4.43	3.48	3.83	6.75	9.93	3.37	6.55
45	19.11	8.77	6.37	6.85	16.67	15.43	10.80	14.63
32	25.98	16.37	10.94	15.01	19.44	26.11	15.57	24.83
20	32.79	36.91	20.28	31.85	43.69	38.59	24.60	41.34
12.5	47.68	48.19	45.42	50.17	62.35	58.79	48.19	55.04
8	58.91	62.19	63.08	69.32	74.82	72.25	63.93	68.29
5	61.99	65.66	67.67	72.27	78.29	75.46	67.42	

Site no. A–4 Cumulative Frequency %

Depth cm / Grain Size μm	0	4.0~ 8.0	8.0~ 12.0	12.0~ 16.0	16.0~ 20.0	20.0~ 24.0	24.0~ 28.0	28.0~ 32.0
74	0.48	1.26	1.14	2.92	1.91	2.19	1.00	1.46
63	2.59	2.10	2.89	4.65	4.12	3.07	5.68	2.27
45	5.05	10.43	7.38	10.38	13.68	8.25	12.22	7.61
32	7.90	16.02	13.19	20.97	22.58	14.36	19.17	13.54
20	12.37	24.60	26.91	37.78	33.64	27.38	32.89	30.84
12.5	26.83	40.11	40.96	58.86	54.37	50.28	57.28	47.33
8	48.83	64.30	61.37	70.88	70.24	66.32	70.82	63.29
5	54.51	68.41	67.03	74.96	74.73	69.02	74.20	

Table 2. *Continued.*
Site no. A-5 Cumulative Frequency %

Depth cm / Grain Size μm	0	3.0~6.0	6.0~10.0	10.0~14.0	14.0~18.0	18.0~22.0	22.0~25.0
74	2.88	1.11	1.46	1.18	1.85	2.66	3.24
63	4.56	3.21	3.38	2.07	3.22	9.83	8.48
45	12.09	8.15	6.60	13.02	7.26	19.84	12.81
32	17.35	14.75	17.87	15.74	18.90	34.23	19.56
20	22.93	25.82	34.29	21.01	39.85	51.95	35.43
12.5	35.00	39.42	46.54	45.63	56.56	64.72	50.73
8	55.62	59.59	63.50	63.49	70.70	74.75	62.64
5	61.04	63.89	65.44	68.85	74.63	75.05	68.38

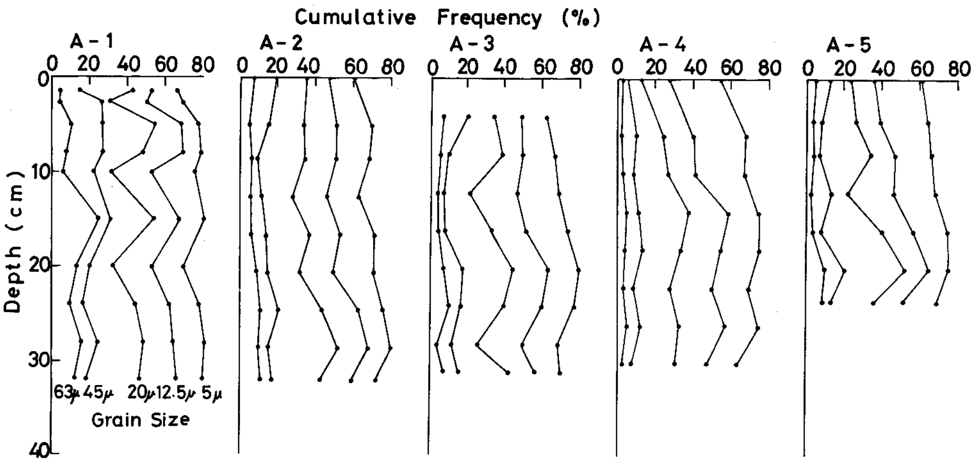

Fig. 5 Distributions of cumulative frequency in the bottom

particle size show large fluctuations with distance from the lake floor, and at A–2 the deepest site in the lake, fluctuations of the cumulative frequency are small. On the whole, size distributions of sediments are coarser at site A–1 than those of other sites, and accordingly when approaching the eastern side, sediment particles show the tendency to be finer.

Microscopic observation

Since some samples of sediments were coagulated when offered for microscopic observation, we prepared two kinds of the slide for the microscope: one was made by dried powdery sample and the other was made by crushing of coagulated particles after wetting. However, according to the microscopic observation, there was essentially no difference between the two kinds of the slide, though microscopic observations have made only the samples of the lake floor.

Under the microscopic observation, the tendency of the size frequency distribution in each site is similar to results indicated in Table 2. However, observing particles under high magnification, most of particles are not single solids but the assemblages of fine particles. Materials consisting of particles are transparent and colorless or light brown corpuscles, crystal minerals, fragments of dead planktons and detritus from the terrestrial source. Both the composition of materials in lake water and in the lake sediment are the same. But it should be noted that in the lake sediment, fragments of dead planktons are minimal. Though we need more detailed analyses, it may be conclude that most of corpuscles and assemblages which are a major constitution of the suspended matter and that the lake sediments seem to be from the terrestrial origin, and that they are mainly supplied and transported from the western side of the lake, as is estimated by cumulative frequencies in the bottom sediments.

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