PALEOHYDROLOGY OF LAKE VANDA IN WRIGHT VALLEY, ANTARCTICA INFERRED FROM GRANULOMETRIC ANALYSIS OF DVDP 14 CORE

Kinshiro NAKAO,

Department of Geophysics, Faculty of Science, Hokkaido University, Sapporo 060

Tetsuya TORII

Chiba Institute of Technology, Tsudanuma, Narashino 275

and

Kyoko TANIZAWA

Department of Geophysics, Faculty of Science, Hokkaido University, Sapporo 060

***Abstract*:** The sediment core DVDP 14 of 28 m in length was drilled at the center of the dry basin in North Fork located 1.5 km from the western edge of Lake Vanda, which is marked by a great fluctuation in water level during the past lake history, as has been pointed out by the previous studies.

Preparing 35 samples from the core at different depths and subjecting them to sieving (mechanical and micro), size frequency distributions were investigated and depositional environments were analyzed by their vertical profiles, whereby it was inferred that the lucustrine and the aeolian deposition alternated with each other, corresponding to the pluvial condition (warm climate; higher water level) and the dry condition (cold climate; lower water level) in the lake area.

1. Introduction

Located in the ice free Wright Valley in an arid climate, Lake Vanda is fed only by the Onyx River gathering meltwater during summer from the Lower Wright Glacier. Its origin is a glacial scour basin in a fjord.

The previous studies of the lake have disclosed that it passed two typical stages in water level in its hydrological history (Fig. 1).

One is represented by the highest lacustrine terrace 52 m above the present lake level (NAKAO *et al.*, 1972), which accounts for the existence of the so-called Great Lake Vanda with the shoreline shown by MCGINNIS *et al.* (1973) and the area four times as large as the present one. The ^{14}C datings of remains of algae collected from this shoreline by YOSHIDA *et al.* (1975) indicate that a great fluctuation has taken place from the highest to the present level since 3000 to 2000 years B.P.

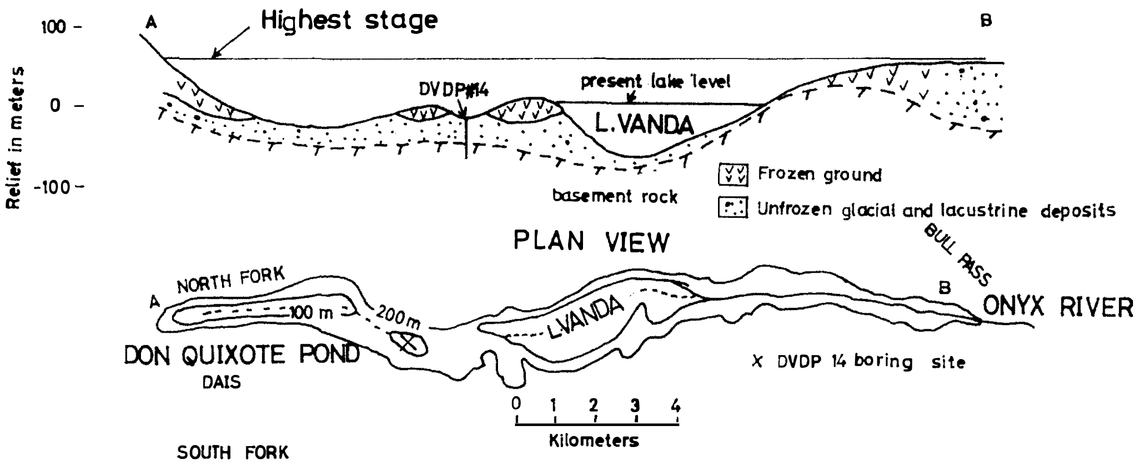

Fig. 1. Sedimentary structure in Lake Vanda area. A contour line of 200 m on the plan view indicates the shoreline of Great Lake Vanda in the highest stage.

The other is represented by the stage lowermost in water level at the time when the lake dried up lastly in 1200 years B.P. (WILSON, 1964).

As the water level of the ancient lake lowered, a mound emerged in the middle part, preventing the water from flowing westward and giving rise to a dry depression area in the west side of the mound, the top of which stands 1 m above the present lake level. Hence, the area has dried up to the extent that the basin floor is lower than the lake level.

For drilling a core from the surface to the depth of 78 m, with a sediment 28 m in thickness and a basement rock below it, the site DVDP 14 was selected at the center of the basin 1.5 km west from the western edge of the lake, the ground level of the site being 15 m below the water level of the lake.

The hydrological history of Lake Vanda is summarized in Fig. 2. The analyses of electrical depth sounding (NAKAO *et al.*, 1972; MCGINNIS *et al.*, 1973) indicate the existence in the east side of the lake of a scour basin which has been almost buried by fluvioglacial deposits, causing the ancient Bull Lake to reduce in area and depth into a shallow depression which is called Bull Lake at present.

This deposition is supported by a similar fluvioglacial event which has left such traces in part of the southern shore of Lake Vanda as are observed in the disruption of lacustrine terraces evidently by another fluvioglacial inflow from a different glacier.

It is speculated that the ancient Bull Lake had a larger capacity of meltwater discharged by the Onyx River than the capacity flowing into Lake Vanda because of the controlling effect of the present Bull Lake on the discharge of meltwater into it and that the burying of the ancient Bull Lake took place after Lake Vanda lastly dried up.

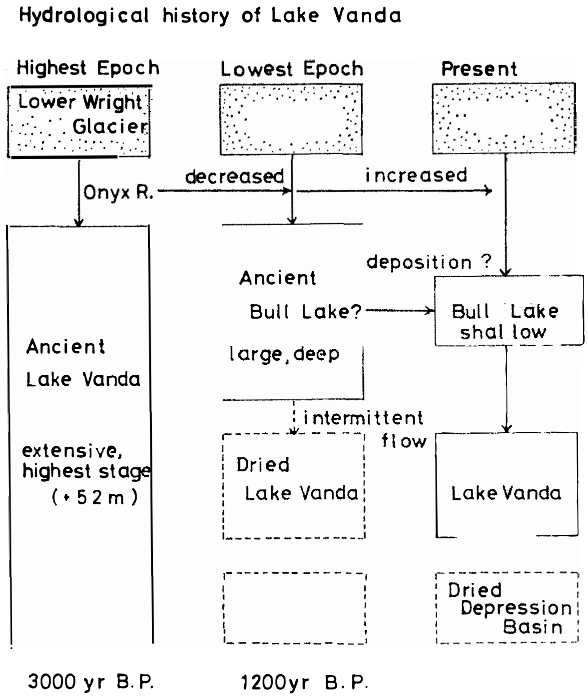

Fig. 2. Hydrological history of Lake Vanda.

Grain size frequency distributions of the core were examined by the granulometric analysis, whereby it is confirmed that the hydrological environments of the basin have frequently repeated the dry and the lacustrine conditions alternately in company with fluctuations in lake level during the past lake history.

2. Method of Granulometric Analysis

Thirty-five samples, each 5 cm in length, were prepared from different strata of the sediment of the DVDP 14 core.

The size frequency distributions were investigated to clarify a depositional environment corresponding to each of the 35 core samples of DVDP 14. Granulometric analyses were made by mechanical sieving, using a Ro-Tap shaker for samples coaser than 74 μ in grain size, and a microsieving equipment for samples finer than 74 μ.

The equipment consists of an ultrasonic vibrator, an electromagnetic vibrator, and a reciprocating pump by which pressure and vacuum are applied to a microsieve, which ranges in eleven classes from 63 μ to 5 μ. Then, the unity method of sieving can be applied to the granulometric analysis for a very wide range from 10^4 to 10^0 microns in particle size.

3. Interpretation of Size Frequency Distributions

3.1. Relation between content of water soluble salt and grain size

The relation between vertical profiles of median grain size and contents of water soluble salt throughout the entire sediment core is shown in Fig. 3 in which the median grain size changes in a wide range from 2 μ to 0.5 mm, namely from silt to coarse sand. The vertical profile of median grain size in a phi scale coincides precisely with the variation of water soluble salt content in an inverse proportion between grain size and salt content.

If the content of water soluble salt is in proportion to the total surface area (S) of grain in a unit mass, it is in proportion to $(d\rho)^{-1}$ as in the following relations.

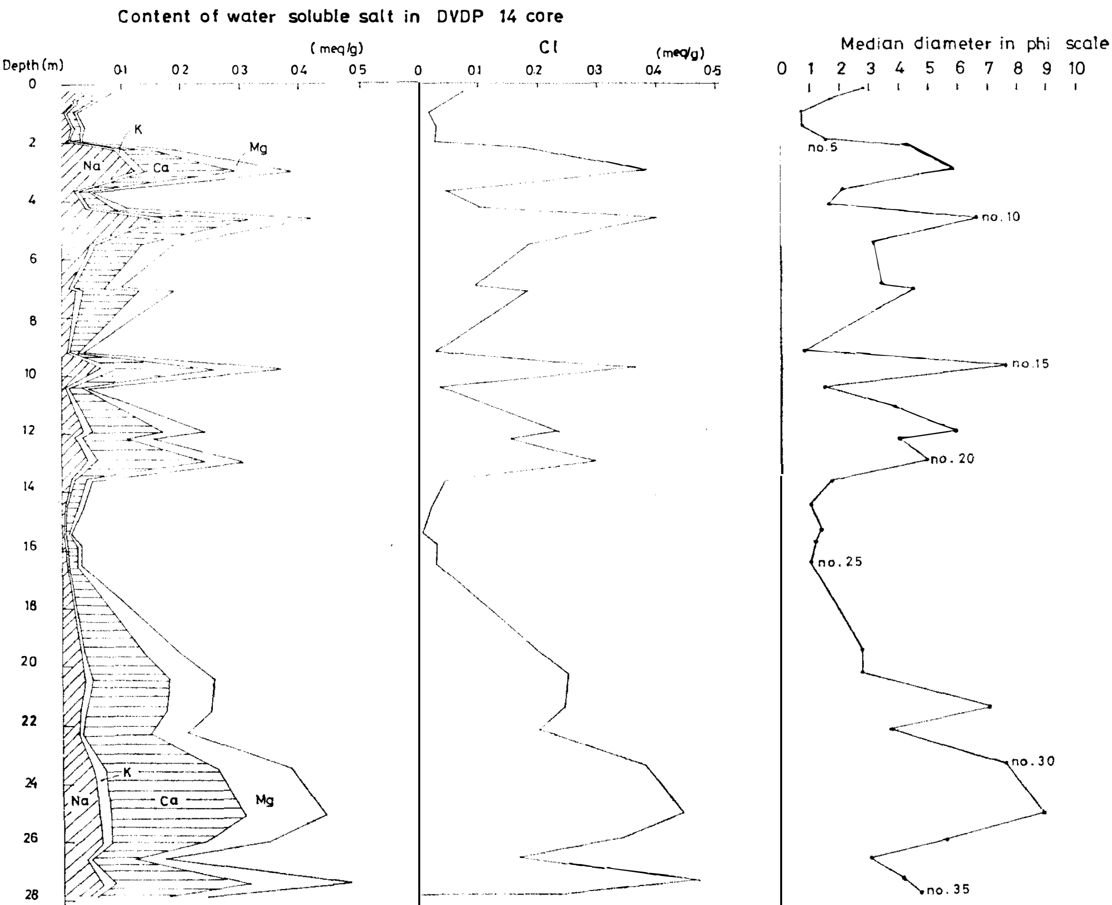

Fig. 3. Vertical profiles of median grain size and content of water soluble salt in DVDP 14 core.

$$n=\frac{3}{4}\left(\frac{d}{2}\right)^{-3}(\pi\rho)^{-1} \tag{1}$$

Table 1. Median diameter d_{50} and grain density of 35 samples.

Sample No.	Depth interval (cm)	Median diameter d_{50} (mm)	Grain density (g/cm^3)
1	25- 28	0.144	2.87
2	60- 65	0.308	2.87
3	100- 105	0.615	2.87
4	150- 155	0.615	2.83
5	200- 205	0.330	2.83
6	220- 225	0.055	2.69
7	300- 305	0.019	2.77
8	373- 378	0.233	2.75
9	420- 425	0.330	2.77
10	461- 466	0.010	2.75
11	550- 555	0.117	2.70
12	695- 700	0.095	2.78
13	700- 705	0.044	2.66
14	920- 925	0.574	2.67
15	970- 975	0.006	2.63
16	1040-1045	0.353	2.79
17	1110-1115	0.067	2.77
18	1190-1195	0.017	2.79
19	1210-1215	0.063	2.74
20	1290-1295	0.034	2.69
21	1357-1362	0.308	2.85
22	1440-1445	0.500	2.76
23	1540-1545	0.379	2.83
24	1580-1585	0.436	2.75
25	1647-1652	0.500	2.82
26	1946-1951	0.154	2.65
27	2040-2050	0.144	2.71
28	2145-2150	0.008	2.75
29	2220-2225	0.082	2.76
30	2340-2345	0.006	2.77
31	2500-2505	0.002	2.77
32	2600-2605	0.024	2.85
33	2640-2645	0.134	2.83
34	2738-2743	0.063	2.71
35	2781-2786	0.039	2.60
			mean 2.76

where n: the number of grains in a unit mass, ρ: grain density, d: grain diameter, and π: the ratio of the circumference to its diameter.

$$S=4\pi\,(d/2)^{-2}n, \tag{2}$$

$$S=6\,(d\rho)^{-1}. \tag{3}$$

Then, the salt content depends on the grain diameter, because the grain densities of 35 samples varied little as shown in Table 1, their mean value being 2.76 g/cm^3.

A linear relation holds generally between content of Cl^- and $(d_{50})^{-1}$, in which d_{50} expresses median diameter in mm, as shown in Fig. 4. But, as for fine sediments of silt and clay, their relations deviated from the general tendency toward the smaller contents, whereas in coase sediments, the relations deviate conversely to the larger contents, reflecting environmental changes.

The sediments of the smaller and larger contents of salt may respectively correspond to a lacustrine environment under a pluvial condition and an aeolian environment under a condition in which the salt content increases as lake water continues to dry up.

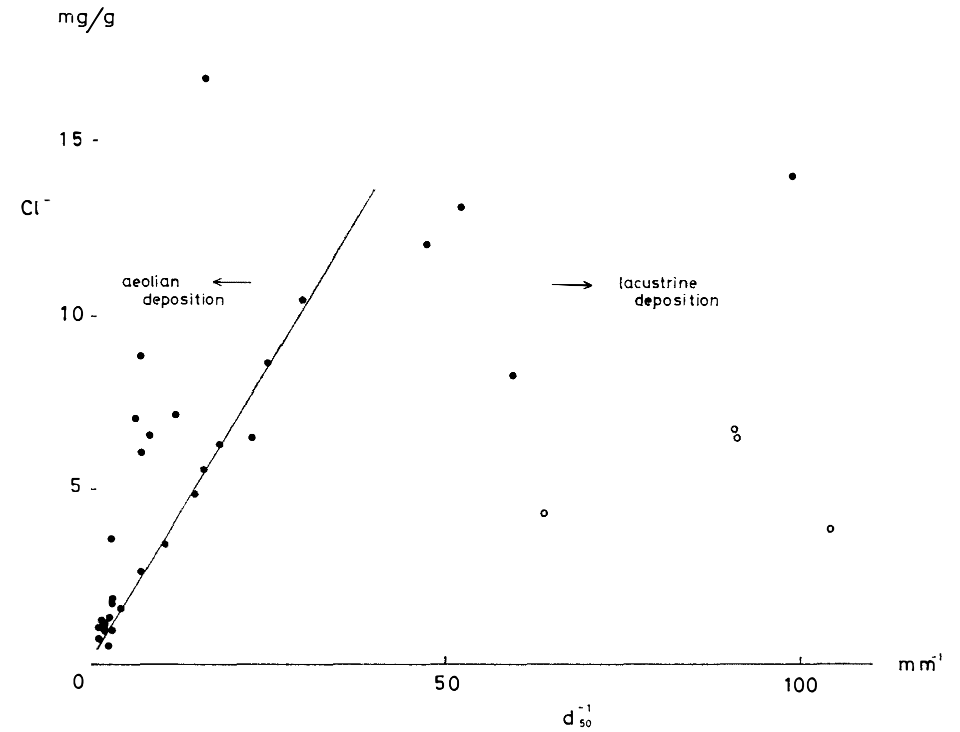

Fig. 4. Relation between Cl^- content and $(d_{50})^{-1}$, d_{50} expressing median diameter in mm. Open circles represent plots scaled down.

3.2. Size frequency distributions

Size frequency distributions throughout the entire sediment core distinguish themselves by three types; namely, the first type represents such a relation in log-probability paper that consists of three straight lines (three sub-populations), the second type of two straight lines (two sub-populations), and the third type of one straight line (one sub-population).

The first type results from three depositional processes, as shown in Fig. 5:

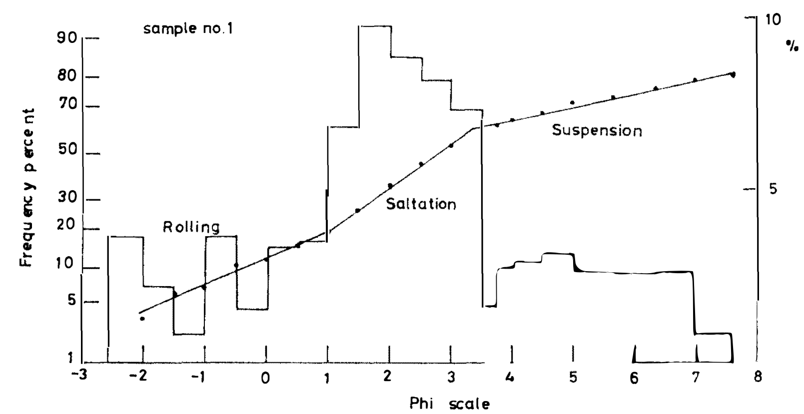

Fig. 5. Cumulative frequency in log-probability paper and frequency of grain size of sample No. 1 (3 sub-populations).

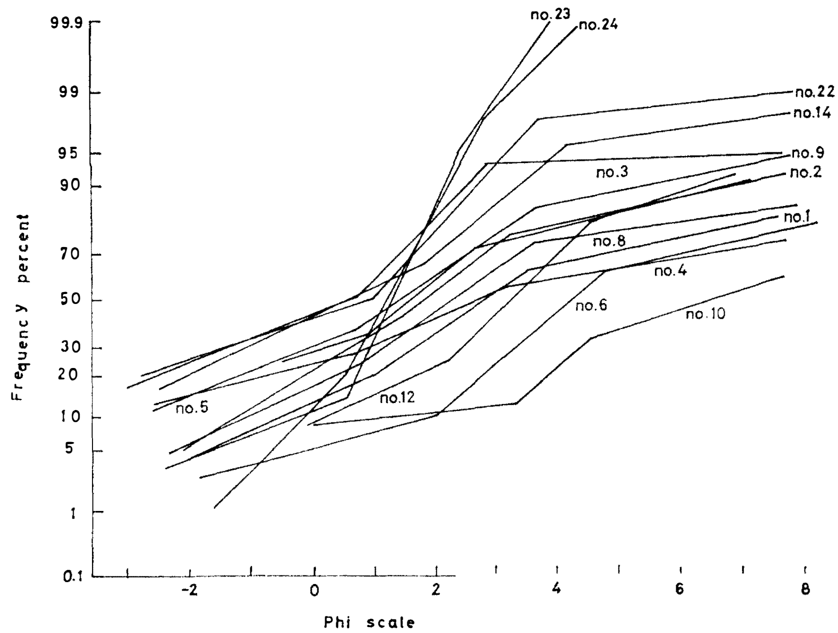

Fig. 6. Size frequency distributions of samples (3 sub-populations) in log-probability paper.

suspension (fine grains); saltation (medium grains); rolling (coarse grains). This type is produced by the aeolian deposition in a dry basin. Relations of the aeolian type throughout the entire sediment core are shown in Figs. 5 and 6.

The third type may correspond to the lacustrine sediment deposited when the dry basin was submerged as the result of a rise in water level of Lake Vanda, forming

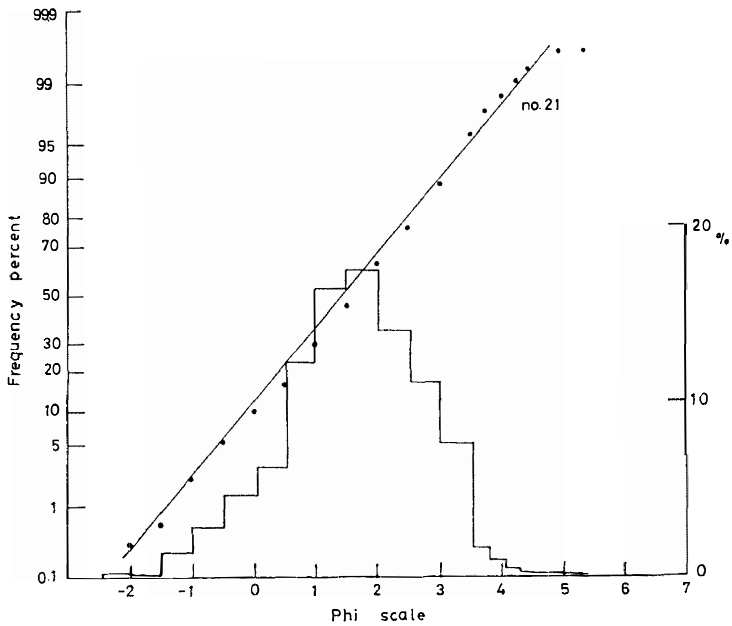

Fig. 7. Cumulative frequency in log-probability paper and frequency of grain size of sample No. 21 (one sub-population).

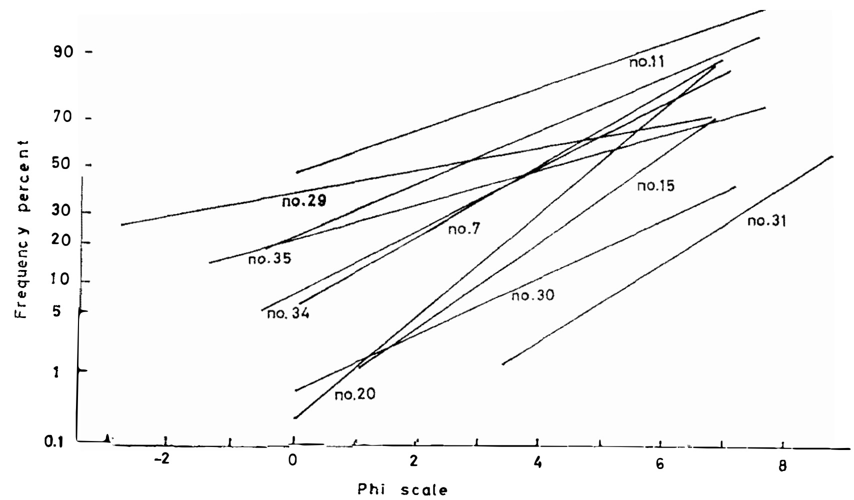

Fig. 8. Size frequency distributions of samples (one sub-population) in log-probability paper.

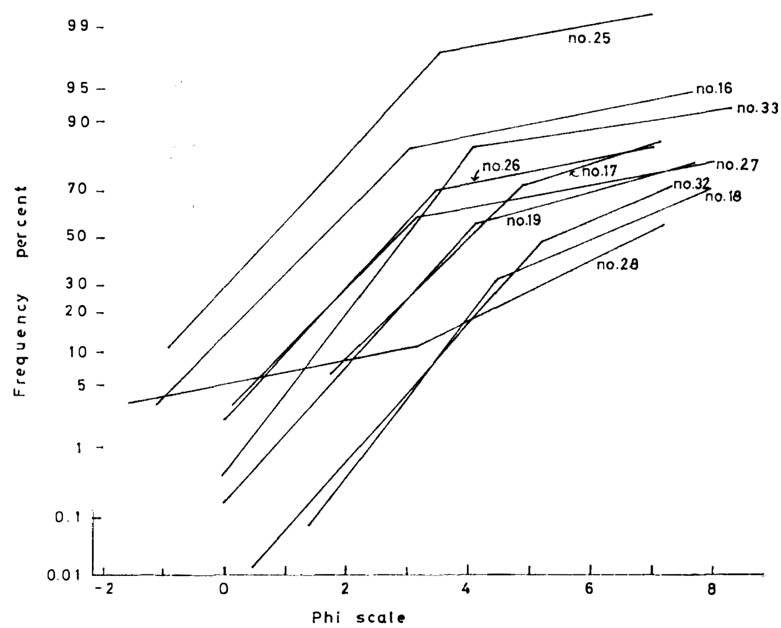

Fig. 9. Size frequency distributions of samples (two sub-populations) in log-probability paper.

a relation expressed in a log-probability curve in Figs. 7 and 8. The sediment accumulates as the complex suspended matter originating from fluvial and aeolian sedimentation deposits complicatedly through lake water or lake ice.

The second type represents the intermediate process in sedimentation, marked by two sub-populations, as shown in Fig. 9.

4. Change in Depositional Environment and Paleoclimate

The conclusion reached from the examination of size frequency distributions throughout the entire sediment core (28 m in thickness) in the depression basin is that Lake Vanda underwent an alternation of the pluvial and dry epochs, four each, with one another. The pluvial and the dry epochs correspond respectively to the period of lacustrine sedimentation having one sub-population and to the period of aeolian sedimentation having three sub-populations.

The nearly accepted general tendency is that the lacustrine sediment is poor in chemical content, whereas the aeolian sediment formed in the period of continuous drying up of the basin and condensation of soluble salt take place, is rich in chemical content.

It is indicated from the examination of the sediment of three sub-populations in this basin that the present dry condition has continued from the age corresponding to a depth of 2.25 m in sedimentation, and that the last pluvial epoch took place in 3000 years B.P., as pointed out by the previous studies. Accordingly, the rate of sedimentation is 1 m in thickness per 1000 years.

On the assumption that the same rate holds throughout the sediment layer 28 m in thickness on top of the basement rock, it is inferred that sedimentation began in this scour basin in 30000 years B.P. along with glacier regression.

Moreover, the pluvial and the dry conditions represent respectively the warm and the cold climates which control the discharge of meltwater from a glacier. The paleoclimates from 30000 years B.P. to date are shown in Fig. 10, in which longer among the variations are the cold and the warm climates lasting from 22000 to 14000 and to 4000 years B.P. respectively.

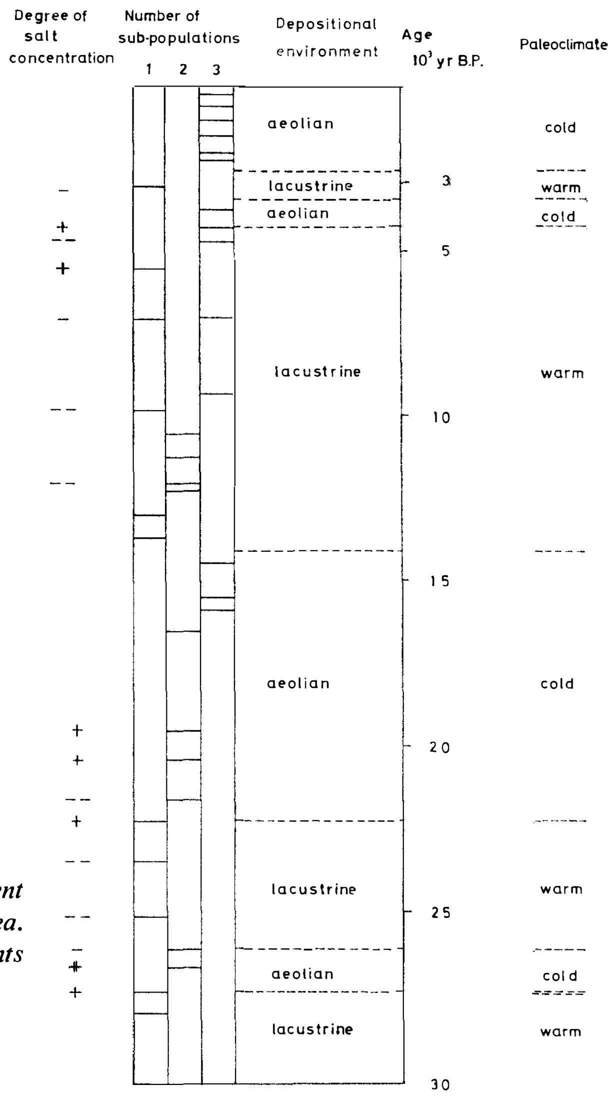

Fig. 10. Changes in depositional environment and paleoclimate in Lake Vanda area. Figure in age column also represents depth in meters.

References

NAKAO, K., NISHIZAKI, Y. and NAKAYAMA, K. (1972): Report of the Japanese Summer Parties in Dry Valleys, Victoria Land, 1971–1972. XI. Sedimentary structure near the saline lakes in three ice-free valleys, Victoria Land, Antarctica, inferred from electrical depth sounding. Nankyoku Shiryô (Antarct. Rec.), **45**, 89–104.

McGINNIS, L. D., NAKAO, K. and CLARK C. C. (1973): Geophysical identification of frozen and unfrozen ground, Antarctica. Permafrost: North Am. Contrib. Second Int. Conf., Yakutsk, ed. by Organizing Committee of Canada and U.S. Planning Committee. Washington, Natl. Acad. Sci., 136–146.

WILSON, A. T. (1964): Evidence from chemical diffusion of a climatic change in the McMurdo Dry Valleys 1,200 years ago. Nature, **201**, 176–177.

YOSHIDA, Y., TORII, T., YUSA, Y., NAKAYA, S. and MORIWAKI, K. (1975): A limnological study of some lakes in the Antarctic. R. Soc. N. Z., Bull., **13**, 311–320.

(*Received September 18, 1978*)