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Limnological Studies of Lake Yogo-ko (I)

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Abstract

In the first chapter of this paper, the writer stresses the significance of the limnological study of Lake Yogo-ko. As this lake has been a closed lake, it is an appropriate subject for the study of water budgets. It is also expected to yield valuable information for the investigation of paleolimnology. In the second chapter, the writer discusses some of the geological and geographical features around the lake.

Introduction

On the surface of the earth there are numerous lakes, each of which constitutes a microcosmic sphere. This consists of four elements: the lithosphere (i. e. the lake basin), the hydrosphere (i. e. the body of lake water), the biosphere (i. e. the organisms in the lake) and, of course, the atmosphere which covers these three spheres. The last-named is not a direct object of limnological study though its influence has a great bearing on the other spheres. Limnologists have mainly confined their attention to the hydrosphere and the biosphere, on which they have made numerous studies. It is, however, unfortunate that study of the lithosphere has lagged behind. This situation may be due to the background of most modern limnologists who have come from zoology, botany, physics or chemistry. A few geologists and geographers are interested in the study of lake basins but their chief interest lies not in limnological but in geological and geographical problems. Halbfass's[1)2)] study is therefore remarkable. His morphometric work is of great value to all limnologists since the morphology of lake basins is important in the determination of the trophic conditions of lakes. But such a study entirely depends on present morphology and is therefore only useful for the discussion of present-day limnogical conditions. Each lake has an independent history though its duration may vary. In so far as the present-day morphology of lake basins is the main determinable factor for the trophic conditions of a lake, it seems true that these conditions in the past have been controlled by the morphology of a lake basin as it existed at any given time. It is, however, impossible to reconstruct the paleomorphology of a lake basin by the geographical method, even if we wish to deduce the trophic history of a lake, because the paleomorphology of lake basins has been buried under lake sediments. For this purpose, geological methods are certainly useful. When we can obtain core samples from the bottom of a lake and have succeeded in analysing them from various angles, it will be possible to deduce the past trophic conditions of that lake and even the paleomorphology of the lake basin. The limnologists who are interested in the time factor, e. g. the developmental history of such a microcosmic sphere as a lake, must study the lake sediments from both geological and limnological view-points. Moreover, we must pay regard to the location of lakes. Lake basins have various origins but it is certain that a lake is situated in land which is low in comparison with its neighbourhood and for any lake to continue to exist for a long time, there must be a geological reason. For instance, the fault movement or downwarping of the earth's crust are possible causes. Hutchinson[3] has enumerated under this head the following so-called ancient lakes: Lake Baikal, the Caspian and Aral seas, Lakes Tanganyika, Ohrid, Prespa, and Titicaca. Evidence around Lake Tahoe[4] and Lake Khanka also suggests the considerable length of its existence. Having discussed the history of Lake Biwa-ko, the writer included it into the above-mentioned group of ancient lakes. These ancient lakes which date back to the Tertiary period must have a geological reason for their continued existence.

During the summer of 1961, having visited the Limnological Institute of Lake Baikal, U.S.S.R., the writer observed Lake Baikal, the deepest and most typical oligotrophic lake in the world. In 1965 he went there again and also visited three other ancient lakes, namely Lakes Ohrid and Prespa in the Balkan Peninsula, and Lake Tahoe in the U.S.A. As regards Lake Baikal, the writer discovered that it had appeared during the Miocene epoch, continuing its existence through the Pliocene epoch and the Pleistocene epoch, and that it is located in an unstable section of the earth's crust which is proved by the occurrence of frequent severe earthquakes and the conspicuous subsidence of the lake shore. Similar features to those of Lake Baikal may be found in the other three ancient lakes; the fact that Lake Biwa-ko is very similar to them furnishes strong support for the writer's theory that the continuation of the existence of ancient lakes through an immense length of time is due to the downwarping of the lake basin.[5] On account of such crustal deformation, ancient lakes will probably remain indefinitely as deep and clear as they are at present.

In the case of Lake Biwa-ko, if we could succeed in obtaining deep core samples from its center, we would derive information of two kinds. The first, of course, would be in the paleolimnological field, because we might be able to reconstruct the lake's developmental process since the Tertiary period by analysing the huge amount of lake sediments which could have been deduced on the basis of the striking Bouguer anomaly[6] and of Sparker's data.[7] The second is in the field of Pleistocene geology. As the writer has already discussed[9] on the basis of his own field survey, glaciation in the Japanese Islands seems to have fluctuated six times during the late Pleistocene epoch. It is, however, impossible to determine the glacial oscillations during the earlier Pleistocene epoch, since the high mountains of Japan give no proof of earlier glacial morphology. Because of the absence of ice sheet glaciation in the Japanese Islands, the reconstruction of the earlier Pleistocene climate of Japan is more difficult than in the case of the continents of North America and Europe. The only way to reconstruct the entire Pleistocene climate of Japan is by studying the ancient lake sediments which have preserved the traces of past events. By studying these deposits, particularly pollen stratigraphy, we may for example deduce the old atmosphere which covered Lake Biwa-ko and thereby the former Pleistocene climate of Japan. Afterwards we would be able to compare the synchrony or non-synchrony of the Pleistocene climatic changes of the three continents of North America, Europe, and Asia.

With this in mind, the writer began his paleolimnological work in Lake Yogo-ko in which core sampling is easier than in Lake Biwa-ko. As will be mentioned in the next chapter, Lake Yogo-ko was part of a former Lake Biwa-ko; accordingly, investigation of the history of Lake Yogo-ko is not part of a single and independent study of a tiny lake but an actual step towards the paleolimnological investigation of Lake Biwa-ko with which Lake Yogo-ko shared the same limnetic history for a considerable length of time. However, together with such paleolimnological work, we must study the present limnological situation and hydrography of this lake which will furnish fundamental data respecting its past features. One characteristic feature of this lake is that it is a closed lake as stated below; it has been sensitive to lake level fluctuation owing to such water budgets as precipitation, evaporation, and seepage inflow and outflow. Consequently, Lake Yogo-ko also seems to be appropriate for the investigating of water resources conservation.

Geological and Geographical Features of Lake Yogo-ko

Lake Yogo-ko is located to the north of Lake Biwa-ko; the shortest horizontal distance between them is only 1,300 m. Both lakes are separated by the small mountain range of Shizu-ga-take (422.5 m. above sea level), but from the geological point of view they were connected through the valley of Yogo-gawa and were a single lake during the Pleistocene eproch.

According to the writer's calculation,[9] the morphometric features of Lake Yogo-ko are as follows:

Latitude	35°31′N
Longitude	136°12′E
Altitude	134 m. above sea level
Length	2.3 km.
Maximum Breadth	1.2 km.
Length of Shoreline	6.0 km.
Area	1.63 km^2.
Shore Development	1.32
Maximum Depth	14.5 m.
Mean Depth	7.4 m.
Volume	0.012 km^3.

The horizontal distance between Lake Yogo-ko and the glaciated district in the central Japanese mountains is about 170 km., and the difference in altitude between them is approximately 2,000 m. Although no meteorological observatory is located near Lake Yogo-ko, when we refer to the data recorded during the years from 1921 to 1950 at the two stations of Hikone, 30 km. south and Tsuruga, 20 km. northwest of the lake, we may estimate a mean annual temperature of 14°C. and a total annual precipitation of 2,200 mm at Lake Yogo-ko. A considerable proportion of the precipitation is snow.[10] According to the meteorological data, in the glaciated district of the central Japanese mountains the mean annual temperature and the total annual precipitation are 6-8°C. and 1,880～

2,750 mm respectively. These are basic data for the discussion of the paleolimnology of Lake Yogo-ko and the fluctuation of its past climate.

Geologically speaking, Lake Yogo-ko occupies the northernmost part of the Lake Biwa Tectonic Basin. It is surrounded by paleozoic mountains with steep slopes except for its northern shore which is cultivated as rice fields. In its natural state the lake has no inflowing rivers; its water is probably derived from seepage and also from springs. The main stream of the Yogo-gawa River flows down near the lake, then finally pours into Lake Biwa-ko. On the eastern side of the Yogo-gawa River, there lie conspicuously high mountains showing fault scarp morphology. The course of the Yogo-gawa River traces a straight line along this scarp, indicating that it is a fault valley. Both scarp and valley are regarded as typical examples of the morphology caused by tectonic movements such as have been cited in many papers. The southern part of the scarp may be connected with the so-called "Ōmi-Iga Great Fault"[11] and may extend for more than 200 km. in all. The estern limit of the Lake Biwa Tectonic Basin is formed by the steep scarp which deformed the Ancient Lake Biwa Group.[12] Apparently, the scarp has been growing; in other words, its western part has been subsiding.[13] Thus the basin of Lake Yogo-ko is regarded as a fault angle depression.[14] Matsushita[15] noticed that the paleozoic strike on the eastern side of the tectonic line showed a N-S direction, while that on the western side indicated an E-W direction. Okayama[16] discovered that "Yanagase Fault", a part of that greater fault, is a reversed fault, not a normal fault structure.

In the writer's opinion the limnetic history of Lake Yogo-ko probably has a close connection with such features of structural geology. The shortest distance between the shore of Lake Yogo-ko and the so-called "Yanagase Fault Scarp" is only 1 km., and during the growth of the scarp a group of steep fans appeared; consequently the piedmont plain became lower towards the west. However, we must consider the other important factor of the crustal deformation in this district. As the writer has discussed already,[5][7] the Lake Biwa basin has long been continuing its downwarping crustal movements. In consequence, in this district of the northernmost section of the Lake Biwa Tectonic Basin, the earth's crust is tilting towards the south. As a result of these two components, namely the western subsidence and the southward inclination of the earth, water covers the southern or southwestern corner of this district. As explained before, this corner is surrounded by a mountain range; even at the lowest pass it is about 100 m. higher than the present level of Lake Yogo-ko. The writer is of the opinion that Lake Yogo-ko continued to exist for a considerable length of time after it was separated from Lake Biwa-ko by reason of the effect of that crustal deformation. It may continue its existence for many years until its level finally reaches the lowest pass as a result of this southwestward tilting of the earth's crust.

On the basis of his field work the writer has classified the terraces around Lake Yogo-ko (Fig. 1); they are T-2, T-3, T-4, T-5, T-6, and T-X. Although the details of such a system of terraces will be discussed in another paper dealing with the geomorphology of Lake Biwa-ko, it should be mentioned here that T-1 is the writer's "Ancient Lake Biwa Terrace"; T-2, 3, 4, (5, 6) are terraces that appeared after minor drops in the level of Lake Biwa-ko.[5]

Presumably, the upper part of each is a stream terrace, while the lower part is a lacustrine terrace. On account of the gradual transition from stream terrace to lacustrine terrace, it is not easy to discriminate between them. The nature of T-X is still unknown, and must be dealt with not in this small district, but in the whole complex of the Lake Biwa-ko basin. It is of interest that Lake Yogo-ko might have been connected with Lake Biwa-ko during the building of T-2, 3, 4 ; afterwards it was separated from the latter and its independent limnetic history began. This interpretation is based on a consideration of geomorphological factors such as the distribution of the above-stated terraces. A piece of wood which was discovered by the writer in December, 1959 in the deposits of T-3 at the other locality in the Lake Biwa basin verified that the age of T-3 was 28,500±2,500 years B. P.[17] Accordingly, the remarkable time gap[5] between T-1 and T-2* might extend over the whole Pleistocene epoch.

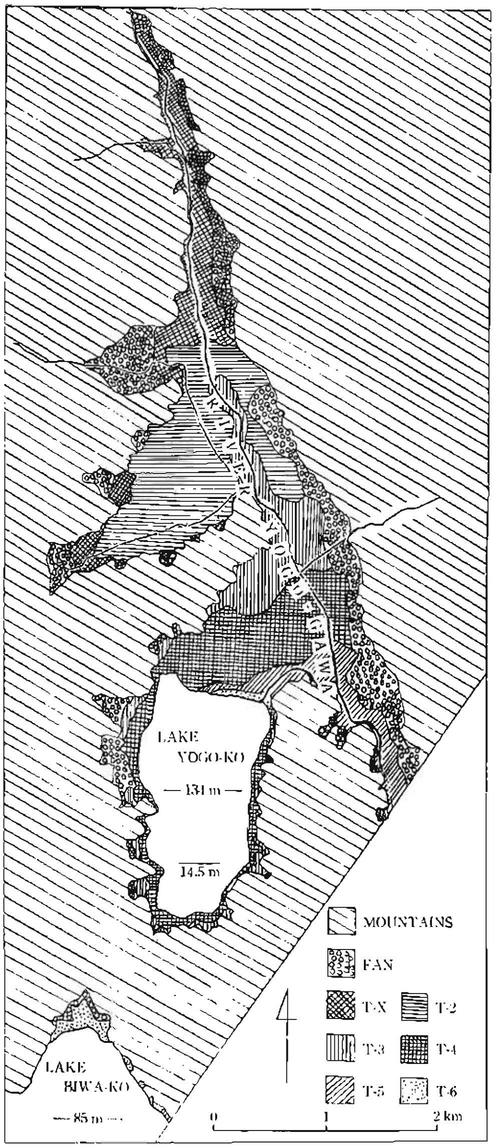

Fig. 1. Geomorphological map of the area around Lake Yogo-ko based on S. Horie's field data.

The other noticeable feature is the age of the wood contained in T-5 deposits. Wood was obtained by the writer in January, 1961 from the floor of the artificial channel on the northern shore of Lake Yogo-ko. There were many buried plant roots *in situ* and fortunately they were discovered as a result of the excavation of the channel. They were 2 m. below the rice fields and were contained in the lacustrine sediments, not in the fluvial deposits. A piece of this wood has been identified by Dr. Shimaji as *Diospyros* sp. ; its age was 3,180±180 years B. P.[18] Presumably, the level of Lake Yogo-ko at that time was lower than before ; afterwards it rose to a somewhat higher altitude than the present level and then dropped again

* Geomorphologically, T-2 is slightly older than T-3.

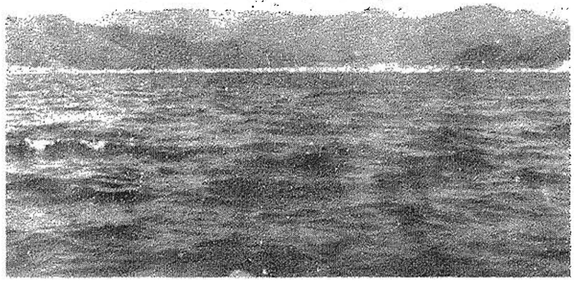

Fig. 2. Lake Yogo-ko and the Yanagase Fault Scarp.

to the T-6 level. As it is probable from a consideration of the geomorphology of the surrounding area Lake Yogo-ko was naturally a closed lake, the main cause of such fluctuation of level seems to have been the former climate. At any rate, T-5 and T-6 terraces were connected with the lake level fluctuation, though T-5 of Lake Yogo-ko at present is continuous with T-5 of Lake Biwa-ko as a result of later erosion caused by streams. In view of the fact that the separation of Lake Yogo-ko from Lake Biwa-ko occurred post-T-4 but pre-T-5,

TABLE 1
Numerical data on the profile of River Yogo-gawa calculated by S. Horie.

Contour line	Horizontal distance between each contour line	Contour line	Horizontal distance between each contour line
86– 90m	3450m	220–230m	600m
90– 95	2525	230–240	425
95–100	3200	240–250	200
100–110	2625	250–260	1100
110–115	975	260–270	550
115–120	825	270–280	450
120–130	575	280–290	425
130–140	2575	290–300	275
140–150	850	300–310	475
150–155	600	310–320	350
155–160	500	320–330	275
160–165	400	330–340	275
165–170	475	340–350	250
170–175	350	350–360	300
175–180	400	360–370	200
180–190	825	370–380	150
190–200	700	380–390	150
200–210	725	390–400	100
210–220	250		

its own age is somewhere between 28,500±2,500 years B. P. and 3,180±180 years B. P.

Finally, an additional noteworthy factor is the profile of the Yogo-gawa River. Table 1 gives numerical data on the horizontal distance between each contour line along that river. It is apparent that the river has five knick points at altitudes of 130 m., 150 m., 220 m., 250 m., and 300 m. above sea level; it suggests that each knick point corresponds to each terrace, T-2, 3, 4, 5, 6. If so, the minor drop of level caused by relatively severe crustal movement as well as the drop of lake level which is similar to the eustatic shift of sea level is also verified in this point. Such a phenomenon observed around Lake Yogo-ko may be found in the whole area of the Lake Biwa-ko basin. Accordingly, this tiny lake of Yogo is certainly a model which illustrates the type of crustal deformation and climatic change that affected the ancient lake of Biwa (to be continued).

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