30. *Concentrations of Total Lipids and their Significance as an Index of Paleoclimates in the 200 m Long Core Sample of Lake Biwa*

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Lipids in sediments refer to substances soluble in benzene, chloroform, petroleum, diethyl ether, or similar organic solvents, and include hydrocarbons, chlorinoid pigments, fatty acids and esters, carotenoid pigments, resin alkaloids, heterocyclic compounds and others. Lipids in lake sediments are derived from not only aquatic biota (autochthonous) but also wax of higher plants (allochthonous) in the drainage area in that age. Lipids in surface sediments are abundant in an eutrophic lake than in an oligotrophic lake, and show the productivity of the lake, but the high productivity in the lake may not always coincide with the high temperature. Furthermore, they are subject to degradations at early age by microorganisms and, sometimes, to reproductions arising from other substances such as kerogens in deeper sediments. In the 200 m core sample, the latter case cannot be observed at the present time.

Swain (1970) has listed the lipid materials in non-marine source organisms expected to occur in sediments, and also shown the benzene methanol (8:2) extractable matters in peat deposits, oligotrophic lakes and eutrophic lakes of the glaciated region (6.5%, 0.30% and 0.83% respectively in weight). Smith (1954) has reported on the organic matters extracted from the fresh water sediments of Stony Lake and Lake Wapalann NJ, (11,200 and 2,230 ppm in weight, respectively). As the carbon contents of the organic materials mentioned above are estimated to be 50%, the lipids of the sediments are about 5,600 and 1,100 $\mu\text{g/g}$ in carbon. In Japan, the lipids materials in the sediments of Lake Haruna are about 3,000–1,000 $\mu\text{g-C/g}$ and about 5.0–2.0% of total organic carbons.

Lipids concentrations were determined in the sediments of the 200 m long core sample of Lake Biwa, which had been extracted with chloroform and methanol (2:1) at intervals of 25 cm and partly at intervals of 50 cm. In this study, to estimate the paleoclimate, the relation between the lipids and total numbers of fossils, such as diatoms and pollens, carbon isotopic ratios and other organic com-

pounds is to be discussed. The details of the analytical method used on lipids were previously described (Ogura and Ishiwatari, 1975).

In Fig. 1 the vertical changes of total lipids concentrations at every one meter observed in the 200 m long core sediments and total numbers of diatoms (Mori, 1974) and pollen (Fuji, personal communication) are shown.

The relation of diatoms and total lipids are shown in Fig. 2a. The value of lipids are chosen from the one meter average concentrations nearest to the depth in which fossils, carbon isotopic com-

Fig. 1. The variation of average lipids carbon in one meter, cells of diatoms (After Mori (1974)) and absolute number of pollens (After Fuji) with depth in the 200 m core sample of Lake Biwa.

Fig. 2

Fig. 2. The relationship between cells of diatoms (After Mori (1974)) and lipids carbon in the upper figure a and the ratio of lipids carbon to total organic carbon (L-C/TOC) in the lower figure b.

Fig. 3

Fig. 3. The relationship between absolute number of pollens (After Fuji) and lipids carbon in the upper figure a and the ratio of lipids carbon to total organic carbon (L-C/TOC) in the lower figure b.

positions and other organic compounds were analysed. In the upper part of the core sample from 10 m to 79 m, an approximately linear relationship exists between them (closed circle in the figure), but that relationship cannot be observed below the depth of 83 m. The relationship between the percentages of total lipids to total organic carbon (L-C/TOC) and the numbers of diatoms is plotted in Fig. 2b. No marked correlation between them can be observed as a whole. However, it seems that two groups can be distinguished in the figure. One group shows relatively low and constant L-C/TOC as against the change of numbers of diatoms. Another group shows a negative correlation between L-C/TOC and numbers of diatoms.

The relation between numbers of pollens and total lipids are also shown in Fig. 3a. Lipids concentrations were not noticeably affected by large amounts of pollens. The same pattern is observed in the relation of L-C/TOC with pollens as in the case of diatoms. These two kinds of fossils may be part of the sources of lipids, but this result indicates that the contributions of these fossils on the lipids must be considered as to the species, sizes, lipids contents and the differences

of rates of degradation between fossils and lipids in addition to the numbers.

The relationship between L-C/TOC and carbon isotopic composition of organic carbon $\delta^{13}\text{C}$ is shown in Fig. 4 (Nakai, 1972). The low value of $\delta^{13}\text{C}$ must be derived from materials which contain lipids components. If the carbon isotopic composition shows the paleotemperature as described by Nakai (Nakai, 1973), the L-C/TOC may play an important role in the estimation of the paleotemperature.

In his review (1970) of the lipids in marine water, Jeffery reports that the chloroform extracts from the semi-tropical water contain 10–20% of total dissolved organic carbon. On the other hand, the chloroform extracts from the Antarctic oceanic water contain 40–50% of total dissolved organic carbon and 0.28–0.32 mg-C/litter as a lipid material. The oceanic lipid concentrations in the Gulf of Mexico are about half of those in the Antarctic where 0.12–0.16 mg-C/litter, constitutes 15–20% of total dissolved organic carbon. Plankton samples from the Gulf of Mexico contain 10–20% lipids on the dry weight basis, while Antarctic plankton samples contain 20–40% lipids in dry weight. High concentrations of lipids in such cold waters are due not only to the total productivities but to the lipid percentages of biomass in the waters. In addition, the rate of degradation of lipids is considered to be low in such cold waters.

Fig. 4. The relationship between carbon isotopic composition of total organic carbon (After Nakai (1972)) and the ratio of lipids carbon to total organic carbon (L-C/TOC) in the 200 m core sample of Lake Biwa.

If the observation that the lipids contents in organic carbon are high in a cold region can be applied to the sediments of Lake Biwa and if the organic materials that remain in the sediments reflect the paleo-environments which are unchanged in their relative abundance, L-C/TOC should show the paleoclimates. However, total organic carbon in lake sediments comes from terrestrial higher plants for the most part. For this reason, the summation of carbohydrates and proteins carbon, which are the chemical fossils of biological production, is a factor more suitable than total organic carbon. The ratios of lipids carbon to the summations of carbohydrates and proteins carbon are calculated with the data of carbohydrates and proteins carbon being used in accordance with the results of Handa (Handa, 1972, 1973). The vertical profiles of the ratios of lipids carbon to the summations of carbohydrates and proteins carbon L-C/CP and L-C/TOC with depth are shown in Fig. 5. The ratios of Σ organic carbon, which includes lipids, carbohydrates and proteins, to total organic carbon in the 200 m core sample have been discussed by Handa previously (Handa, 1973), but the present author proposes the ratio of lipids/carbohydrates and proteins as a more reasonable factor of the paleo-temperature. The value of L-C/CP increases with increasing depth because of the differences of rates of degradations between lipids and carbohydrates and proteins. The relatively high values of L-C/CP, which shows the cold climates, in the 200 m long core sample, are obtained from the depth of 19 m, 49 m, 85 m, 104 m, 110 m, 130 m,

Fig. 5. The vertical variation of the ratio of lipids carbon to the summation of carbohydrate and protein carbon (L-C/C+P) (After Handa (1972) and (1973)) compared with the variation of the ratio of lipids carbon to total organic carbon (L-C/TOC) in the 200 m core sample.

151 m, 160 m, 186 m and 190 m. A comparison of this data with carbon isotopic composition and the data of granulometry (Yamamoto, 1974) produces a good agreement between them, but some ambiguities are found below the depth of 151 m. It is expected that, in the near future, the analysis of the sediments at the same depth will eliminate this discrepancy.

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