Paleoenvironmental reconstruction using algal biomarkers in brackish lacustrine sediments from Lake Nakaumi, Japan, with special reference to the alkenone paleothermometry

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Algal species is more diverse in coastal and brackish areas, and their assemblages more sensitively respond to environmental changes. Algal biomarker have been used for evaluating ecology and response for the algae to environmental changes. In particular, long-chain alkenones, haptophyte-derived biomarkers, is useful as strong tools for reconstructing sea surface temperature. Recently, the alkenones have been also identified in lacustrine environments such as continental saline and freshwater lakes. In Japan islands, the alkenones were clearly detected from only Lake Toyoni, Erimo Town, Hokkaido. We firstly identified the alkenones from brackish lake, Lake Nakaumi, in Japan. In the present study, we comprehensively analyzed multiple algal biomarkers in the sediments from Lake Nakaumi to evaluate distribution of algal assemblages and their variations. Especially, we examine the applicability and reliability for the alkenone paleothermometry in the brackish lake environmnent.

In Lake Nakaumi, the lake environment was strongly affected by artificial rearrangements during the high economic growth in Japan, especially land reclamation by drainage and replacement of salt water by fresh water from 1960s to 1980s. The sediment core were collected from central area of the lake (Nk3C) during May 2017. The ages were determined by Cs and Pb isotopes, and the lowermost horizon was estimated to be about 600 years ago. For the biomarker analysis, the extractions of freeze-dried sediments were fractionated using silica-gel column and analyzed by GC-MS and GC-FID.

The long-chain alkenones and alkyl diols as well as steroids were detected in all samples from the Nk3C core. The alkenone compositions are clearly different between the samples above and below the horizons affected by the artificial rearrangements during 1960s. Below the horizons in 1960s, the di-unsaturated alkenones such as $C_{37:2}$ alkenones are dominant, and the alkenone unsaturation indices ($U^{K'}_{37}$) are higher. On the other hand, the $C_{37:4}$ and C_{40} alkenones are relatively abundant and the $U^{K'}_{37}$ and U^{K}_{37} values are lower above the horizons in 1960s. We presume that the main alkenone producers in sediments below and above the horizons in 1960s were typical marine haptophyte species such as *Emiliania huxley* and *Gephyrocapsa oceanica* and lacustrine species including *Chrysotila lamellosa*, respectively. The compositions of long-chain alkyl diols are also different between the sediments above and below the horizons in 1960s; C_{30} 1,15-diol, which is synthesized by marine eustigmatophyte algae, is dominant below the horizons, but C_{32} 1,15-diol, biomarker for fresh water eustigmatophyte algae, is dominant above the horizons in 1960s. These trends for alkyl diols are concordant with those for the alkenones. Concentrations of dinoflagellate-derived steroid, dinosteroid, is higher in deeper horizons of the core. From these results, it is suggested that in haptophyte, dinoflagellate, and marine eustigmatophyte were mainly produced under shallow marine environment in the Lake Nakaumi by the middle 20th century, and subsequently, the fresh water species for the haptophyte and eustigmatophyte flourished as the dominant producers under brackish environment in the lake after the artificial rearrangements during 1960s.

Keywords: brackish waters, Lake Nakaumi, algal biomarker, alkenone, alkyl diol, paleoenvironmental reconstruction

