Paleoecological variations reconstructed by organic matter derived from lichens and fungi across the Cenomanian/Turonian boundary in the Tomamae area, northern Hokkaido, Japan

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The Cretaceous period is known as the extreme greenhouse period due to active magmatism caused by superplume. Especially in the mid-Cretaceous, the Oceanic Anoxic Events (OAEs) occurred in several times, and had a great impact on marine and terrestrial ecosystems. Moreover, many animals and plants in the terrestrial ecosystem likely have undergone rapid diversification since the mid-Cretaceous (e.g. Dilcher, 2000; Meredith et al., 2011). Noticeably, the lichens have acquired strong light tolerance and undergone rapid diversification, and fungi have gained new symbiotic relations with trees through the appearance of ectomycorrhizal fungi since the mid-Cretaceous (e.g. Gaya et al., 2015; Taylor et al., 2011). However, these researches are limited to molecular phylogenetic analysis and numerical simulations, and few fossil records have been reported. In the present study, we analyzed biomarkers and organic fossils (palynomorph) derived from the lichen and fungi in the sediments deposited across the Cenomanian/Turonian boundary (CTB) from the northern Hokkaido, Japan to evaluate paleoecology during environmental disturbance event.

We analyzed sedimentary rocks across the CTB in the Saku Formation, Yezo Group, were collected from the Omagari-zawa sections of the Tomamae area, northern Hokkaido, Japan. The sediments used correspond to the OAE2 intervals (1st build-up, Trough, 2nd build-up and Plateau phases), determined by $\delta^{13}C$ stratigraphy (Omatsu et al., 2014). For the biomarker analysis, lipids were extracted from freeze-dried sediments, subsequently fractionated using silicagel column, and analyzed by GC-MS. For palynomorph analysis, kerogens were separated by HCl and HF from the extraction residue, and observed under a fluorescent light microscope.

Based on sterane and hopane ratios, we confirmed the high contribution of terrigenous matter input and low maturity of organic matter (vitrinite reflectance ca. 0.4% level; lignite to subbituminous coal rank) in the Omagari-zawa section. Recently, a perylene is thought to be fungal biomarker. In our study, we tentatively defined that the ratio of perylene to plant-derived aromatic terpenoids is useful as indicator of fungal biomass in terrestrial flora i.e. fungal activity. On the other hand, it has known that the lichens produce dibenzofuran (DBF). In particular, we suggested that specific isomers of alkyl DBF such as 1-methyl DBF are useful for the lichen biomarkers. Here, we established the ratio of 1-methyl DBF to plant wax *n*-alkanes (C_{27}-C_{31}), and it assumed to reflect relative contribution of lichens among terrestrial plants. These results implied that the fungi constantly flourished, and their activities declined during environmental disturbances such as before and after the 1st build-up and before the 2nd build-up stages. On the other hand, the variations in lichen-derived biomarker index are synchronous with those of the angiosperm/gymnosperm ratio (ar-AGI), indicating that the lichen increased during the angiosperm expansion period. The coniferous vegetation index such as Higher Plant Parameter (HPP) increased during the 1st build-up and 2nd build-up stages, implying that the conifer has expanded under arid condition. However, the HPP values declined during the Trough and Plateau stages. These results suggest that, in the eastern margin of the Asian continent during the CTB, fungal activity was affected by arid/humid fluctuation, while lichen contribution on terrestrial ecosystem was greatly affected by angiosperm/gymnosperm vegetation changes.

Keywords: paleoecology, lichen, fungi, biomarker, palynomorph, Cretaceous

