

Change in precipitation pattern in Kyusyu during the middle Eocene recorded in freshwater carbonate

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The evolution of the Asian monsoon system during the Cenozoic has been suggested to have been affected by the uplift of the Himalaya and Tibetan Plateau, which was attributed to the collision between the Indian subcontinent and Eurasian continent at ca. 50 Ma (e.g., Manabe and Terpstra, 1974). Although the East Asian monsoon system (EAM) has been conventionally interpreted to have appeared in the late Oligocene or the early Miocene, recent research suggested the existence of the EAM during the late Eocene (Licht et al., 2014). In the low-latitude coastal areas in the southern China, Xie et al. (2020) suggested the shift from a dry condition in the early Eocene to a wet condition in the middle Eocene is suggested based on the lithological and palynological analyses (Xie et al., 2020). However, this climatic change in the low-latitude areas could have resulted from the shift of the Intertropical Convergence Zone (ITCZ) and it is necessary to investigate the Eocene climatic conditions at mid-latitudes.

In this study, we examined the depositional environments of the lower Eocene Akasaki Formation and the upper Eocene Yoshinotani Formation distributed in Kyusyu based on the sedimentological and mineralogical studies of freshwater carbonate. We performed the XRD analysis, microfacies observation, and stable isotope analyses of freshwater carbonate samples taken from two formations. In addition, we conducted for the U-Pb dating of zircon grains in three tuff samples from the Yoshinotani Formation. The XRD profiles show that carbonate nodules of the Akasaki Formation mostly consist of calcite, dolomite, and quartz. The $\delta^{13}\text{C}$ values of most samples are in a narrow range of -10 ± 1 ‰, suggesting the mixing source of pedogenic organic carbon and atmospheric CO_2 . A positive correlation is observed between the $\delta^{18}\text{O}$ and the carbonate mineralogy (ratio of calcite to dolomite), which likely reflects the evaporitic conditions. Based on these results, Carbonate nodules found in red mudstone of the lower Eocene Akasaki Formation is interpreted to be pedogenic carbonate formed under semi-arid climate with a distinct seasonal contrast of rainy and dry seasons.

Based on the XRD profiles, carbonate nodules of the Yoshinotani Formation is mainly composed of siderite, quartz, and feldspar with minor pyrite and iron oxides. Distinctively positive $\delta^{13}\text{C}$ values are likely caused by $\delta^{13}\text{C}$ -enriched CO_2 from a byproduct of methanogenesis. The $\delta^{18}\text{O}$ values range from -5.6 to -1.7 ‰, which is interpreted to reflect $\delta^{18}\text{O}$ values of meteoric water. These results suggest that nodules of the upper Eocene Yoshinotani Formation were developed on wetlands covered by poorly drained soils under temperate climate with stable rainfall throughout a year.

Our reconstruction of the depositional environments suggests the shift in precipitation pattern in Kyusyu during the middle Eocene. This might be related to the appearance of the monsoon system in east Asia related with the uplift of the Himalaya and Tibetan Plateau.

Keywords: freshwater carbonate, Eocene, East Asian monsoon