Alkenone paleotemperature proxy is applicable to marine sedimentary rocks exposed on land: the lower Pleistocene Otadai Formation, Kazusa Group, Japan

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Long Chain Alkenones (LCAs), a class of C_{35}-C_{42} unsaturated ketones produced by Isochrysidales haptophytes, have been widely used as proxies for sea surface temperatures based on alkenone unsaturation indices ($U^{K'}_{37}$). Application of the alkenone paleotemperature proxy for lithified and uplifted marine sequences exposed on land is usually constrained by the poor preservation due to denaturation and subaerial weathering. Therefore, it is rare that LCAs are discovered in terrestrial outcrops, and only one previous study in Vrica outcrops, Italy has clearly shown that $U^{K'}_{37}$ reflected temperature variations between glacial and interglacial periods.[1]

In this study, we discovered that LCAs are well preserved in the lower Pleistocene Otadai Formation of the Kazusa Group, Boso Peninsula, Japan. The Kazusa group is well-exposed marine sequences consisting of hemipelagic siltstones interbedded by sandstone beds, which has been studied for stratigraphy and paleoenvironment using microfossils and pollen analysis. Detailed oxygen isotope stratigraphy to determine the marine isotope stage (MIS) from the drilled core is available for the upper Otadai Formation, which can be correlated to the outcrops along the Yoro River using the intercalated tephra layers [2]. We collected siltstones from the outcrops along the Yoro River covering from MIS 29 to 33.

LCAs can be detected from all collected samples, probably because they have never been exposed to high temperatures or consolidation stress in the process of burial and uplift [3]. Possible LCAs producers should be *Pseudoemiliania lacunosa* and *Reticulofenestra asanoi*, because modern alkenone producers *Gephyrocapsa* spp. and *Emiliania huxleyi* are almost absent in this section [2]. In spite of the difference in production species, LCA distributions in the Otadai Formation are quite similar to those in modern marine settings, i.e. di- and tri- unsaturated C_{37} and C_{38} dominate with a ratio of almost 1:1. On the assumptions that $U^{K'}_{37}$-temperature calibrations of ancient alkenone producers were the same as those of *G. oceanica* and *E. huxleyi*, the temperatures between MIS 29 and 33 fluctuated between 23.15 ˚C and 26.60 ˚C, which were perfectly synchronized with the glacial-interglacial cycles. Although we need to carefully consider whether the modern $U^{K'}_{37}$-temperature calibration can be applied because these temperatures seem to be slightly high compared to the present (MIS 1) alkenone temperatures around the Boso Peninsula [4, 5], the $U^{K'}_{37}$ in the Otadai formation certainly record the paleotemperature information.

[1] Cleaveland and Herbert, (2009) *Geology* 37(2), 179-182. [2] Tsuji et al. (2005) *Journal of Geological Society of Japan* 111(1), 1-20. [3] Kamiya et al. (2017) *Tectonophysics* 710-711, 69-80. [4] Yamamoto et al. (2004) *Geophysical Research Letters* 31, L16311. [5] Kajita et al. (2020) *Quaternary Science Reviews* 230, 106160.

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