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Sclerochronological study of the gigantic inoceramids *Sphenoceramus schmidti* and *S. sachalinensis* from Hokkaido, northern Japan

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Here, we present the first sclerochronological investigation of shells of the gigantic inoceramids *Sphenoceramus schmidti* and *S. sachalinensis* from the middle Campanian cold seep carbonate-bearing strata of the Yezo Basin in Hokkaido (northern Japan). Stable carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotope values were measured in the aragonitic and calcitic shell layers of both species and compared to those of other co-occurring benthic (mainly bivalves and gastropods) and demersal molluscs (ammonites). Sedimentological and stable isotope data suggest that these bivalves lived near cold seeps and were exposed to high H_2S level in the seawater. The inoceramid shells exhibited higher $\delta^{13}C$ and lower $\delta^{18}O$ values than the coeval non-cold seep molluscs. We ascribed the anomalous isotopic pattern to a combination of vital and environmental effects determined by the hosting of chemosymbionts and the exposure to warm interstitial waters. Inoceramid $\delta^{13}C$ minima coincided with growth lines and likely reflect changes in nutrient supply by the chemosymbionts. Absolute temperatures estimated from $\delta^{18}O$ values of *Sphenoceramus schmidti* and *S. sachalinensis* were, on average, ca. 4–5°C warmer than those reconstructed for the non-seepage environment (19.3 ± 0.7°C). Short-term $\delta^{18}O$ fluctuations of the inoceramid material indicate local temperature ranges of up to 5.2°C, that is four times larger than those reconstructed from the benthic and demersal fauna (1.3°C). In general, our data suggest that the stable carbon and oxygen isotope values of the studied *Sphenoceramus* spp. were strongly affected by short-term fluctuations in seepage activity and do not reflect seasonal fluctuations. □ *Campanian, chemosymbiosis, cold seep, oxygen and carbon isotopes, sclerochronology.*

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Inoceramid shells provide an exceptional geochemical archive for Late Cretaceous high-resolution palaeoclimate reconstructions (Jiménez Berrocoso *et al.* 2008; Walliser *et al.* 2018). However, their $\delta^{13}C$ values are usually higher, and sometimes (but not always), $\delta^{18}O$ values are lower than expected from isotopic equilibrium fractionation with the Cretaceous seawater (Tourtelot & Rye 1969; Pirrie & Marshall 1990; MacLeod & Hoppe 1992; Ludvigson *et al.* 1994; Elorza & García-Garmilla 1996; Fisher & Arthur 2002; He *et al.* 2005; Henderson & Price 2012; Zakharov *et al.* 2012). Remarkably, inoceramids exhibit such stable isotope pattern when found embedded in ^{13}C-depleted carbonate concretions with high amounts of microcrystalline pyrite (Tourtelot & Rye 1969; Whittaker *et al.* 1987; Wright 1987; Carpenter *et al.* 1988; Pirrie & Marshall 1990; Ludvigson *et al.* 1994; Henderson & Price 2012; Zakharov *et al.* 2012). Such concretions are diagnostic features for bacterially mediated anoxic oxidation of methane (AOM) and are often associated with ancient cold seeps (Aharon & Fu 2000; Peckmann & Thiel 2004; Angeletti *et al.* 2015; Reitner *et al.* 2015), that is sites at which hydrocarbon-loaded fluids vent out of the seafloor.

Methane seepages are habitats that are depleted in ^{12}C and enriched in H_2S which can only be colonized by a highly specialized chemosymbiotic fauna (Levin

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