Belemnites, clumped isotopes and oxygen fractionation

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Belemnite calcite has been used extensively for Jurassic and Cretaceous stable oxygen isotope temperature reconstructions since the 1950s. However, with the advent of clumped isotope thermometry, a consistent offset between reconstructed δ¹⁸O temperatures vs Δ⁴⁷ temperatures from the same belemnites has been observed. We investigate the causes of this offset by analyzing samples from the aragonitic phragmacone and calcitic rostrum from the same Cylindroteuthis belemnites, along with other aragonitic benthos, from the Callovian-aged Christian Malford Lagerstätte, U.K. Our new clumped isotope data suggest that the water-calcite ¹⁸O-fractionation factor in belemnite calcite was larger than that of the commonly used δ¹⁸O thermometry equations (e.g. Kim and O’Neil, 1997), and which is currently observed in other marine calcifiers. Our reconstructions suggest that the oxygen isotope fractionation is compatible with that observed in slow-forming abiotic calcites (e.g. Coplen, 2007) and in rapidly precipitating Travertines (Kele et al. 2015). The application of more established δ¹⁸O thermometry equations (Kim and O’Neil, 1997) to belemnite calcite for temperature reconstructions has resulted in a consistent underestimation of belemnite calcification temperatures, which has led to erroneous conclusions about belemnite life habits, and underestimation of global temperatures during these greenhouse times. We therefore advocate the use of calcite equations based on low precipitation rate experiments (e.g. Coplen, 2007; Kele et al., 2015) for belemnite rostrum temperature reconstructions.