



Early Cretaceous latitudinal seawater temperatures and oxygen isotope gradient from clumped isotope data

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In this study, we have investigated Valanginian (Early Cretaceous) sub-arctic, boreal, and sub-tropical fossil belemnites (Mollusca: Cephalopoda). Combined carbonate clumped isotope and oxygen isotope data provide new palaeotemperature estimates as well as a constraint on the oxygen isotope composition of seawater. Our belemnite data reveal balmy high-latitude marine temperatures (ca. 22 degrees C) and warm sub-tropical temperatures (ca. 31 degrees C). Supplementing our clumped isotope-based temperature estimates with TEX86 data, we reconstructed a latitudinal temperature gradient that is reduced compared to modern conditions. We find that modelling efforts are close to reproducing tropical temperatures when high carbon dioxide levels and polar amplification are taken into account. Warm polar temperatures, as suggested by our data, imply that we may be underestimating future climate change in such regions. Early Cretaceous seawater oxygen isotope values show a modern profile and are much more positive (up to 1.5 permil SMOW) than typically assumed. The occurrence of less depleted high-latitude seawater is a possible consequence of the reduced temperature gradient.