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High-resolution stable isotope (oxygen and carbon) sclerochronology in belemnites: implications for Early Cretaceous seasonality

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In order to fully comprehend the nature of the Cretaceous greenhouse climate, research into the seasonality of palaeotemperatures is essential. Understanding seasonality, should provide valuable insights into the equator-to-pole temperature gradient, and should also be strongly indicative of the presence or absence of polar ice sheets. Unfortunately to date, Cretaceous sea surface temperatures have predominantly been reconstructed using δ^{18}O values from organisms such as foraminifera, fish teeth, and more recently using membrane lipids. The problem with this approach is that the palaeotemperatures derived from such biological materials can only represent annual averages, since they do not provide usable information on sub-annual time scales. Belemnites are eminently suitable for stable isotope investigations and they have been utilized for many years in Jurassic and Cretaceous palaeoclimate research. However, high-resolution belemnite seasonality studies have never before been published. The belemnite animal is commonly believed to have lived for several years and to have secreted its calcite in isotopic equilibrium with surrounding seawater. It should therefore be possible to identify seasonal fluctuations in temperature by analyzing isotopic changes across the belemnite rostrum. This study presents high-resolution δ^{18}O and δ^{13}C data obtained from transects across well-preserved Early Cretaceous belemnite rostra. The data indicate that significant fluctuations are indeed preserved in the biogenic calcite and that they can be intimately linked with seasonality. Data from the Pechora Basin in Arctic Russia show that during the Early Ryazanian tzikwinianus ammonite zone, belemnite δ^{13}C ratios recorded an annual signal of positive values during the summer period (related to high productivity) and more negative values during the winter period. Since the δ^{13}C data can clearly be linked to environmental factors it seems likely that the δ^{18}O data is also similarly affected. We therefore interpret the δ^{18}O oscillations recorded here as being of environmental origin. The belemnite δ^{18}O ratios fluctuated between –1‰ in the summer period and +1.5‰ in the winter. Assuming a $\delta^{18}O_{seawater}$ value of –1‰ and only minimal variations in salinity, this δ^{18}O range potentially corresponds to Early Ryazanian Arctic palaeotemperatures of approximately 16˚C in the summer months and 6˚C in the winter months.