Ordovician spatial patterns of climate change inferred from isotope thermometers

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Ordovician was an extremely turbulent period for the Earth system, where the Great Ordovician Biodiversification Event (GOBE) occurred in the early-middle Ordovician. Many hypotheses were proposed, taking into account both biotic and abiotic factors. One such hypothesis posits that global cooling led to a transition from greenhouse to icehouse climate systems, which further triggered feedback mechanisms such as increased oceanic circulation, bio-productivity, and oxygenation during the middle Ordovician. Direct evidence, however, is still scarce. Here, we have compiled a comprehensive dataset of $\delta^{18}O$ (10,636) from carbonate rocks and fossil shells as well as clumped isotope temperature data (Δ_{47}; 88) spanning the entire Ordovician. Our study investigates climate change from both temporal and spatial perspectives.

We assessed the effects of the late diagenesis alteration, lithological differences, different depositional environments and water depths on the carbonate $\delta^{18}O$, and corrected the latitudinal effect of the $\delta^{18}O$ in seawater. The latitudinal temperature gradient (LTG) was introduced to account for the spatial patterns of climate change, which here refers to the difference in sea-surface temperature between low (<20°) and low-to-middle (20–40°) latitudes. We observed a gradual increase in the LTG from Tremadocian to Dapingian, indicating an amplified thermal contrast between low and low-middle latitudes. It suggested a remarkable climate cooling and shift towards an icehouse climate state, coinciding with the GOBE. From Darriwilian to Sandbian, the LTG weakens significantly and the temperature difference decreases, which is consistent with the plateau of global temperatures and the slow change in species diversity. After Sandbian, a progressive steepening of LTG was observed, which provides the first evidence for low paradoxical atmospheric CO_2 at the Late Ordovician. Our study supports the global cooling hypothesis and sheds light on the links between climate change and biological evolution across the Ordovician.

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