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Ordovician climate changes in the northern subtropics: The $\delta^{18}O$ record from the Tunguska Basin, Siberia

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Oxygen isotopes from bioapatite (conodonts) have been used for several decades to reconstruct the Palaeozoic climate history. During the Ordovician, conodont-based $\delta^{18}O_{phos}$ studies have revealed a general cooling trend throughout the system. The $\delta^{18}O_{phos}$ data from Estonia confirm this long-term shift but also demonstrate that against the background of a generally cooling climate in the pre-Hirnantian, the Late Ordovician was quite unstable, with several episodes of sea surface temperature (SST) decrease and increase of different magnitude and duration. In the sedimentary sequence, these cooling events are reflected by major sea-level lowstands. Several of these are also recognizable in the Tunguska Basin of Siberia. We have recently studied the $\delta^{18}O_{phos}$ record from two Middle and Upper Ordovician sections in Siberia. Comparisons of the results with data from the Baltic region have revealed differences but also some similarities in the $\delta^{18}O_{phos}$ trends, even though these two regions were located on different palaeocontinents, Siberia and Baltica. Both were geographically separated and display different Early Palaeozoic histories with respect to their environmental conditions. Siberia was located in low equatorial latitudes from the Cambrian onwards and remained there through the Ordovician and Silurian, whereas Baltica drifted from high southern latitudes to low latitudes from the late Cambrian and reached the southern subtropics in the Late Ordovician (late Sandbian–early Katian).

Despite Siberia's location at low northern subequatorial latitudes, the upper Middle (starting from the Darriwilian) and the Upper Ordovician in the Tunguska Basin are assumed to be represented by cool-water deposits (various calcareous siltstones with interbeds of micritic and/or bioclastic limestone). The onset of cool-water conditions is explained by plate-tectonic reorganization, resulting in the upwelling of cold oceanic waters along the southern margin of the palaeocontinent and their penetration into the epicontinental seas. Our $\delta^{18}O_{phos}$ data generally fluctuate around 17.5‰ (VSMOW), indicating that SST was relatively stable. This general state is interrupted by six cooling episodes, but unlike in Baltica, no general trend of SST change in any direction (decrease or increase) is evident. In the Baltic region, a general cooling trend prevailed, and SST decreased continuously during the pre-Hirnantian Late Ordovician. In addition to this general trend, seven cooling events (CE) are observed, named (from the oldest upwards) the Late Kukruse, Haljala, Keila, Early Nabala, Vormsi, Early Pirgu, and Middle Pirgu CEs. Comparison of the $\delta^{18}O_{phos}$ curves from the Tunguska and Baltoscandian basins shows that five of these CEs are reflected by brief intervals of higher $\delta^{18}O_{phos}$ values also in the former one. The Keila CE is identified in the lower Mangazea Formation (Fm), the Early Nabala CE in the upper Mangazea Fm, and the Vormsi CE in the uppermost Mangazea Fm. In addition, the Haljala CE probably corresponds to an interval in the lowermost Mangazea Fm and the Early Pirgu CE to a small $\delta^{18}O_{phos}$ peak in the lowermost Dolbor Fm. The most pronounced CE in Siberia is recorded in the upper Darriwilian, in the lower Ust'Stolbovaya Fm, and apparently reflects the Middle-Darriwilian Ice Age. The recognition of the same CEs in successions on two different palaeocontinents is clear evidence that they are not some regional phenomena but the result of global climatic perturbations.

The recently acquired $\delta^{18}O_{phos}$ data allow an improvement in the dating of the Siberian strata and their correlation with successions on other palaeocontinents. Previously, the MDICE, Upper Kukruse Low, GICE, and an interval probably including Rakvere (KOPE) and Saunja carbon isotopic events (CIE) were recognized in the Siberian $\delta^{13}C_{carb}$ record. Now, the position of the Keila CE just below an increase in $\delta^{13}C_{carb}$ in the Tunguska Basin confirms the identification of this CIE as GICE and allows the correlation of this level (lower Baksian Regional Stage) with the Keila Regional Stage in Estonia. In addition, the prolonged CIE between the Early Nabala and Vormsi CEs as identified in the Tunguska Basin apparently corresponds to the Saunja (Waynesville) CIE. This also means that the small peak in the $\delta^{13}C_{carb}$ curve below this CIE correlates with the Rakvere CIE.

ABSTRACT

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