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The Early Palaezoic climate – a control of macroevolutionary changes, major radiations and extinction events

LEHNERT, O.

Universität Erlangen, Geozentrum Nordbayern, Schlossgarten 5, D-91054 Erlangen, Germany c/o Czech Geological Survey, Klárov 3/131, 118 21 Prague 1, Czech Republic; *lehnert@geol.uni-erlangen.de*

The marine faunal evolution, as shown by SEPKOSKI'S (1984) Palaeozoic and Modern Evolutionary Faunas, during the time of the "Cambrian Explosion" and the "Great Ordovician Biodiversification Event" (GOBE), was triggered by long-lasting physico-chemical and biological processes such as changes in palaeogeography (e.g., VALENTINE & MOORES 1972) and intensity of volcanism, climate and trophic networks (SERVAIS *et al*. 2008).
Palaeoclimate is certainly a major parameter influencing primary production in the World oceans, the long-term rise and demise of ecosystems, as well as abrupt evolutionary events. Since parallel trends for $\delta^{18}O$ and $\delta^{13}C$ across the Hirnantian glaciation and several Silurian isotope events have a postulated, positive excursions in the $\delta^{13}C$ record have been used in recent years to suggest glacial events this sentence is lacking some words, it make no sense right now (e.g., KALJO *et al*. 2003, SALTZMAN & YOUNG 2005). However, in these cases the datasets may have not provided the temporal biostratigraphic resolution necessary to identify offsets (e.g., CALNER 2008). Some examples, such as the Early Silurian "Ireviken Event", are given to demonstrate that carbon and oxygen isotope records across several events are obviously diachronous. For this reason, only $\delta^{18}O$ data provide a reliable parameter to infer climate changes. $\delta^{18}O$ values are also used to recalculate palaeosea-water temperatures. Long-term as well as short-term shifts in the $\delta^{18}O$ record are applied to climate reconstructions and interpreted to display waning and waxing of continental ice in higher latitudes. Extensive $\delta^{18}O$ data from biogenic apatite have been collected by our working group in Erlangen in cooperation with other colleagues working on early Palaeozoic conodonts. These data show that there is not a simple linear trend in the Ordovician triggering the GOBE as proposed by TROTTER *et al*. (2008), but a series of longer term climate changes reflected by the oscillating "isotopic background" data. These trends provide evidence for successive long cooler and warmer periods, interrupted by a number of short-term glaciations. Based on comparison of the sedimentary record, this type of climate changes may extend down into the Cambrian, although it needs to be proved by larger sets of stable isotope data
The existence and timing of Early Palaeozoic glaciations, other than the well-established Hirnantian glaciation, has been much debated over the last few years. The oldest record of a dramatic shift in $\delta^{18}O$ which is used as an evidence of a short-term glacial in the uppermost Sandbian is the Deicke Glaciation (BUGGISCH *et al*. 2008). Expressions of the younger Mid-Katian Slandrom Glaciation on Baltica, Laurentia and Gondwana were first discussed by CALNER *et al*. (submitted). The interpretation of the classic curve on Ordovician biodiversity by SEPKOSKI (1995) together with diversity curves for specific faunal groups across the GOBE (WEBBY *et al*. 2004) indicates that diversity peaks compare well with the Late Ordovician cold periods or glacials and diversity apparently drops during the warmer intervals or 'interglacials'. The cold intervals in the Upper Ordovician also coincide with the establishment of highly complex reef communities and extensive reef development (WEBBY 2002). As an example, the time slice for the Slandrom Glaciation is discussed corresponding to a major peak in the diversity in Sepkoskis's Palaeozoic as well as in his Modern Fauna. Cooling of the climate was presumably the main trigger for this interval of maximum biodiversity in several groups. In general, many groups, like brachiopods and gastropods, appreciated cooler conditions and seem to flourish during colder periods. Such effects of cooler periods and that faunas seem to be strongly affected during warmer climates or intervals of unstable conditions are seen in different time periods, with notably good examples from the Silurian and Devonian. During the Devonian different groups (e.g.

brachiopods) decline in their diversity during warm periods and major reef crises and extinctions are connected to global warming (JOACHIMSKI *et al*. 2009). In contrast to interpretations of an Devonian super-greenhouse for times when Emsian through Givetian stromatoporoid-coral mega-reef complexes covered up ten times larger areas than todays' reefs, $\delta^{18}O$ data display an interval of major cooling (JOACHIMSKI *et al*. 2009). In conclusion, there is no doubt that palaeoclimate changes strongly influenced macro-evolution and played a major role in early Palaeozoic extinction and radiation events.

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