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Assessing mechanisms of environmental change: Palynological signals across the Late Ludlow (Silurian) positive isotope excursion ($\delta^{13}C$, $\delta^{18}O$) on Gotland, Sweden

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Abstract

The Silurian is characterised by strong environmental changes, as indicated by several pronounced positive $\delta^{13}C$ and $\delta^{18}O$ excursions. The mechanisms responsible for these isotopic shifts are a matter of much debate. The purpose of the present study is a quantitative high-resolution evaluation of the palynomorph distribution across the Late Ludlow (Ludfordian) isotope excursion on Gotland. Marine and terrestrial palynomorphs have been chosen as palaeoenvironmental indicators because they are widely distributed and exceptionally well preserved. Moreover, the combined analysis of marine and terrestrial palynomorphs allows the reconstruction of contemporaneous palaeoenvironmental change in the marine and terrestrial realms. To correlate our results with the carbon isotope stratigraphy, we have sampled only localities with published isotope data from diagenetically unaltered brachiopod shells. Our results show that fluctuations in the composition of the acritarch assemblages are closely correlated with the stable isotope development. Low abundances of acritarchs occur in times of high stable isotope values and vice versa, indicating that an increase in marine productivity cannot have been the reason for the positive $\delta^{13}C$ excursion. The results are in good agreement with climatic models for the Silurian assuming alternating humid and arid climatic conditions in low latitudes. Times of high stable isotope values correspond to arid climatic conditions in low latitudes, with low input of terrestrial nutrients resulting in impoverished acritarch and conodont communities, whereas times of low stable isotope values correlate with humid climate, high nutrient input, and abundant and diverse acritarch communities. The major change in acritarch communities took place during the increase of the stable isotope values after hemipelagic planktonic or nektonic organisms (graptolites, conodonts) have been affected. This indicates that environmental changes connected with the stable isotope excursion first affected deeper-water settings and later the photic zone. The absolute abundance of terrestrial spores

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closely mirrors the marine $\delta^{13}C$ and $\delta^{18}O$ development, showing that both the marine and the terrestrial realm were synchronously affected by the climatic changes. The high abundance of spores during the isotope excursion might be explained by increased aeolian input.

Keywords: Palynomorphs; Acritarchs; Spores; Gotland; Silurian; Ludlow; Stable isotopes; Bioevents; Productivity

1. Introduction

Over the last decade, the Silurian has been increasingly recognised as a time of pronounced environmental change. Several distinct positive oxygen and carbon isotope excursions have been identified on various low-latitude palaeo-continents (e.g., Andrew et al., 1994; Samtleben et al., 1996, 2000; Wenzel and Joachimski, 1996; Kaljo et al., 1997, 1998, 2003; Wigforss-Lange, 1999; Bourque et al., 2001; Saltzman, 2001; Lehnert et al., 2003, Cramer and Saltzman, 2005). These isotope excursions coincide with distinct lithological and biotic changes. Although each of these events has its own characteristics, their conspicuous similarities indicate similar controlling mechanisms (Munnecke et al., 2003). The amplitudes of the Silurian stable isotope excursions are extremely high compared to Mesozoic and Cenozoic excursions. Classical interpretations such as productivity changes (for $\delta^{13}C$) and temperature changes and/or glacial effects (for $\delta^{18}O$) therefore fail to account for the extreme amplitudes observed (see discussion in Bickert et al., 1997). The identification of the strongest $\delta^{13}C$ excursion of the entire Phanerozoic in this time interval (Ludfordian; Samtleben et al., 1996; Munnecke et al., 2003; Fig. 1) with up to 4‰ for $\delta^{18}O$ and 12‰ for $\delta^{13}C$ values appears especially surprising given the fact that the Silurian previously had been considered a time of relatively stable environmental conditions (Bassett and Edwards, 1991).

To explain the Silurian $\delta^{13}C$- and $\delta^{18}O$-isotope excursions, different models have been proposed. Periods of high $\delta^{13}C$ values on Gotland have been interpreted as being characterised by high productivity resulting from high nutrient supply caused by continental runoff during times of low sea level (Wenzel and Joachimski, 1996). Kump et al. (1999) proposed a “weathering hypothesis” as explanation for the isotope excursion of the Late Ordovician glaciation, and from the similarity between the Late Ordovician and the Silurian events Kump et al. (1999) and Kaljo et al. (2003) inferred the existence of glaciations also in the Silurian. Other authors attributed the repeated shifts from low to high C- and O-isotope values in the Late

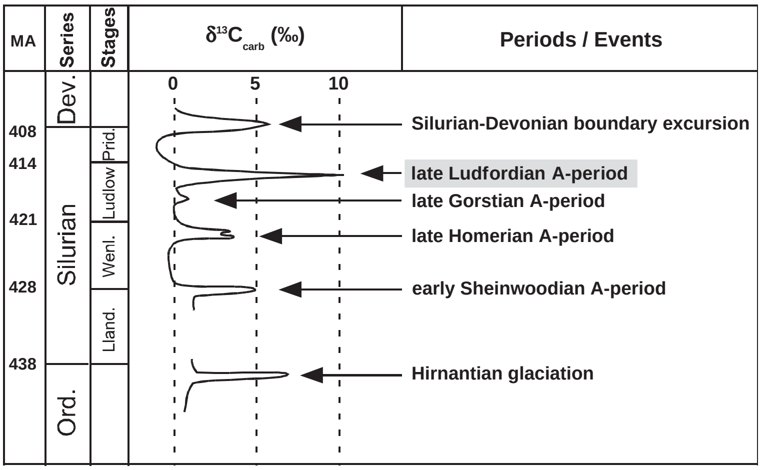

Fig. 1. Compilation of positive $\delta^{13}C$ excursions in the Late Ordovician, Silurian, and Early Devonian (adapted from Munnecke et al., 2003; excursion in the Early Devonian after Hladiková et al., 1997; Saltzman, 2002).