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Research paper

Dynamics of phytoplankton in relation to the upper Homerian (Lower Silurian) *lundgreni* event – An example from the Eastern Baltic Basin (Western Lithuania)

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ABSTRACT

The Silurian period was a time of significant environmental change punctuated by a series of bioevents. The mid-Homerian *lundgreni* event was one of the most severe extinction episodes of the mid-Paleozoic, which mostly affected pelagic organisms, while simultaneously sparing benthos. Despite the great importance of phytoplankton in determining the causal mechanisms of ecosystem collapse, there are very few studies on the effects of the *lundgreni* event on this ecological super-guild.

Here we present a detailed quantitative paleoecological analysis of the green algae and acritarchs of the upper Wenlock of the Viduklė-61 section (Western Lithuania). Independent high-resolution graptolite biostratigraphic and $\delta^{13}C$ chemostratigraphic control ensures accurate calibration of the micro-phytoplankton diversity and community compositional trends. The constrained clustering and assemblage zoning revealed five distinct assemblages separated by sharp changes in genus diversity and sample taxonomic composition. The statistically estimated local genus richness curves revealed similarity with previously determined 4th order sedimentary cycles. Interestingly, though, it appears that the *lundgreni* (mid-Homerian) biotic event had a significantly smaller effect on the studied ecological super-guild than the subsequent mid-upper Homerian regression.

1. Introduction

The Silurian period was a time of large-scale geobiological changes in the functioning of the Earth's ecosystems. There was a series of sudden extinction and radiation events which were causally related to changes in the oceanic states and sea level (Aldridge et al., 1993; Cramer et al., 2015; Jeppsson, 1987, 1993, 1998; Loydell, 2007; Melchin et al., 2012; Munnecke et al., 2003; Spiridonov et al., 2015). One of the most significant perturbations of this time interval was the so-called mid-Homerian “big crisis” or the *lundgreni* event of graptolites (Jaeger, 1991; Koren', 1987) which was approximately contemporaneous with the Mulde conodont extinction event (Calner et al., 2012; Jeppsson et al., 1995; Jeppsson and Calner, 2002), and which preceded the subsequent upper Homerian Mulde positive carbon isotopic excursions (CIEs) (Cramer et al., 2012; Samtleben et al., 1996; Wenzel and Joachimski, 1996).

It was determined in earlier studies that this perturbation left a strong mark on the graptolite clade, forcing extinction magnitudes at the species level to reach the 95% mark (Lenz and Kozlowska-Dawidziuk, 2002; Porębska et al., 2004). This event was followed by the highest reduction in graptolite species richness since the Floian epoch (Cooper et al., 2014). This event also influenced microevolutionary regimes, causing a phyletic size reduction in some surviving graptolite lineages (the so-called “Lilliput effect” (Urbanek, 1993)) and enabling subsequent macroevolutionary iterative speciation events (Urbanek et al., 2012). Other organic groups were affected as well – the conodont diversity of the Silurian Baltic basin dropped to a few remaining species due to permanent extinctions and long-term regional extirpations (Jarochowska and Munnecke, 2015; Jeppsson, 1998; Radzevičius et al., 2016; Radzevičius et al., 2014c). Comparable patterns have been determined in other paleocontinents and regions (Jeppsson et al., 1995; Slavík, 2014). This demonstrates the global extent of perturbation. The chitinozoans – a form of microplankton of disputed phylogenetic affinities – during the discussed mid-Homerian event apparently experienced the largest single drop in diversity during the whole Silurian period (Nestor, 1997; Paluveer et al., 2014). Similar patterns have been observed in the radiolarian fossil record – similar to other pelagic groups they were heavily affected, with just two species (out of the 28) recorded in the Arctic Canadian record surviving the perturbation (Lenz et al., 2006).

Coarse grained synoptic studies of Gotland material show that acritarchs were also to some extent affected by the *lundgreni* mass extinction event (Kaljo et al., 1996). There are indications based on the qualitative studies of the Polish, Swedish and Canadian sections that during the *lundgreni* event the acritarch paleocommunities experienced

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a sudden reorganisation in their species composition and dominance patterns (Calner et al., 2006; Lenz and Kozlowska-Dawidziuk, 2002; Porębska et al., 2004). However, in general the quantitative patterns of the impact of the mid-Homerian event on the acritarchs and green algae – one of the most important components of the Silurian phytoplankton – are definitely underexplored.

In this article we present the first to date detailed quantitative description of palynomorph (acritarchs and green algae) diversity and compositional change in relation to the *lundgreni* geobiological event in the Viduklė-61 core. The studied section has so far yielded one of the richest arrays of information on the mid- to late Homerian global change, which includes the stratigraphic distribution of graptolites, conodonts, lithology, stable carbon isotopic trends and also the cyclic patterns of sedimentary succession (Martma et al., 2005; Radzevičius et al., 2014a, 2014b). This enables us to precisely correlate the revealed changepoints in the acritarch paleoecological dynamics to the regional and ultimately to the global time scales.

2. Material and methods

2.1. Geological setting

The studied section is located in Lithuania. This territory corresponds to the western part of Baltica palaeocontinent and the eastern part of the Baltic Silurian sedimentary Basin (Fig. 1). During the Late Wenlock, the Silurian Baltic Basin was located in the southern hemisphere near the equator (Cocks and Torsvik, 2002).

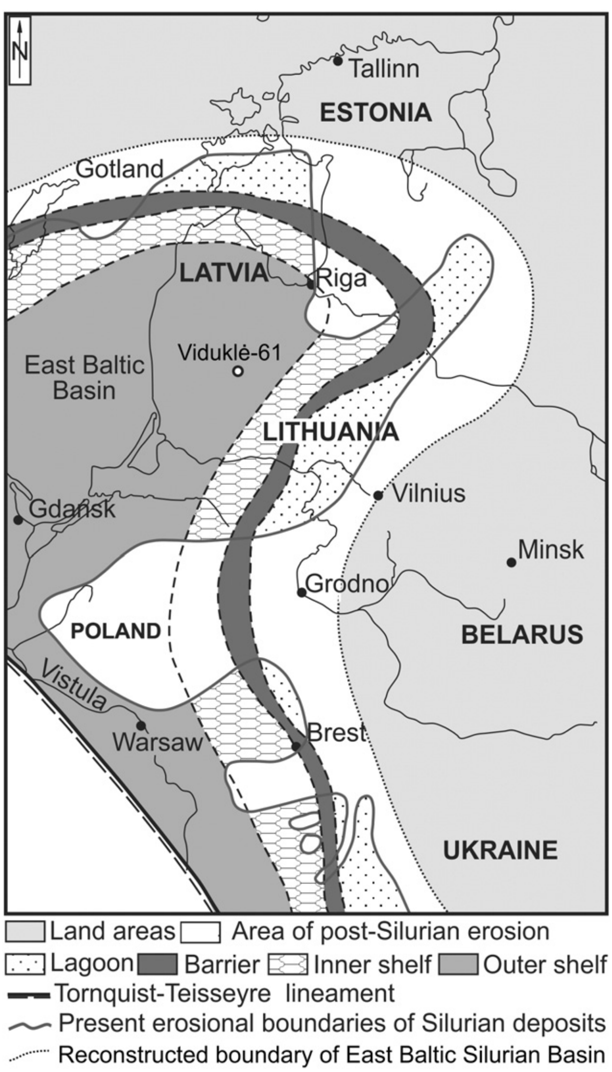

Fig. 1. Paleogeographic location of the studied well site. After (Einasto et al. (1986).

The facies of the basin vary from shallow marine carbonatic in the eastern part of Lithuania to a deep water clayey facies in the western part (Fig. 1). The Viduklė-61 borehole is located in the western part of Lithuania. The upper Wenlock geological section is represented by carbonatic rocks with a varying clay content. Two formations are distinguished in the investigated interval: the upper part of the Riga Formation (with the Ančia Member at the top) and the Siesartis Formation. The Grötlingbo bentonite is present in the upper part of the Ančia Member (Kiipli et al., 2008). This bentonite is widespread in the whole Silurian Baltic Basin, and according to radiometric dating its age is 428.5 $\pm$ 0.7 Ma (Cramer et al., 2012). Also distinguished were the *lundgreni* (upper part), *parvus*, *nassa*, *praedeubeli*, *deubeli*, and *ludensis* graptolite biozones (Radzevičius et al., 2014b). In the Gėluva regional Stage two zonal conodont species – *Ozarkodina bohemica longa* and *Kockelella ortus absidata* – have also been detected (Radzevičius et al., 2014b). This further supports the conclusion that this regional stage is of upper Wenlock age since the same species are to be found in this time interval in the Gotland sections (Calner and Jeppsson, 2003). According to the graptolite data, the geological section of the upper Wenlock of the Viduklė-61 core is complete without any detectable stratigraphical or sedimentation gaps in it. The stable carbon isotopes ($\delta^{13}C$) record is also characteristic of the upper Wenlock (Cramer et al., 2011), with two positive excursions (Martma et al., 2005). In the investigated interval two 4th and five 5th order sedimentary cycles most probably of Milankovitch origin have been distinguished (Radzevičius et al., 2014a).

2.2. Palynomorph extraction and analysis

The studied material comes from 56 samples from the Viduklė-61 core. We sampled the depth interval from 1312.8 to 1276.1 m, which corresponds to the middle and upper parts of the Homerian Stage. Laboratory palynomorph extraction was achieved by means of standard palynological processing (Green, 2001). The rock samples were initially treated separately with concentrated HF and HCl (30%). Sodium pyrophosphate (decahydrate) was used as a dispersant. The dispersed organic material was washed and separated using heavy liquid (KJ + CdJ) – 2.1 g/ml. Two slides were made foreach sample. The palynomorphs were studied on conventional smear slides using transmitted light microscopy. All samples were used for quantitative analysis. All the palynomorphs which fell into a designated slide view were counted. For each sampled level, the arithmetic mean was calculated from two slides. The slide view of the majority of the slides equalled 18 $\times$ 18 mm. Two samples at depths of 1281.1 and 1280.7 m had a slide view of 22 $\times$ 22 mm. Therefore, we rescaled the acritarch abundance from these two samples to the 18 $\times$ 18 mm standard (up to the integer numbers) by dividing the number of found individuals by the ratio of the areas of the larger and smaller slides. Thus, the differences in counting area should have little effect on the final results of the compositional and diversity analysis - The sampling variability was addressed directly in diversity estimates using statistical techniques (see the next section).

Photomicrographs of the palynomorphs were made using a Nicon Coolpix digital camera. All slides are housed in the Nature Research Centre Institute of Geology and Geography, Vilnius, Lithuania. Additionally, the microphotographs of the important taxa were made using a scanning electron microscope at the Nature Research Centre (Vilnius, Lithuania).

2.3. Statistical techniques

In order to reveal structural similarities of relative abundance and diversity change we performed four kinds of analysis. The first approach