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Ooid-stromatolite association as a precursor of bioevents (Silurian, Timan–northern Ural Region)

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Abstract

This study reports the frequent occurrence of ooid-stromatolite association levels at the starting of bioevents at various Silurian stratigraphical boundaries in the Timan–northern Ural region. Five genetic types of ooids show various depositional settings and environments of their formation. The important feature of studied ooids is the fact that calcite crystals of their cortex have the distinct traces of dissolution formed by organic acids of embedded microorganisms. A honeycomb-like pattern of subpolygonal to subspherical pits and walls is interpreted as calcified extracellular polymeric substance (EPS) within stromatolite fabrics and some microscopic ooids (less than 0.1 mm in size) in the beginning of their microbial cortex formation are locally visible. This is important observation because well-preserved different fabrics seen in ancient ooids and stromatolites have previously been interpreted to represent paleoenvironmental conditions brought about by different scale changes in benthic assemblages. Results from this study suggest that it is possible that the connection of ooids with stromatolites at these time-levels depends on their genetic relationship to abundance microbial habitats in the Silurian shallow water marine basin of the region.

Keywords: Ooid-stromatolite association; Environments; Silurian; Timan–northern Ural region

1. Introduction

The association of stromatolites and ooids dates back to the Archean. One of the oldest occurrences of the association is known from the Late Archaean Ghaap Group of South Africa (Wright and Altermann, 2000). Some of the first described stromatolites are associated with oolitic limestones in the Cambrian Hoyt Formation of Saratoga Springs, New York State (Paul et al., 2011). Such facies have been discussed in association with the major crises such as the end-Permian extinction (Pruss et al., 2004). Separate evidence for regarding certain oolites as "disaster deposits" comes from the Silurian of Sweden, where widespread oolites occur in a close stratigraphic proximity to Wenlock–Ludlow extinction events (Calner, 2005). Well-known terms "Oolith", "Stromatolith", and "Ooid" have been commonly recorded in the geological literature on the Lower Triassic in the north of Germany. This region is a classic area for stromatolites and stromatolite-ooid/oolite associations (Reitner et al., 2008). Well-preserved, abundant stromatolitic/microbial carbonates in the Paleozoic of the Timan–northern Ural region represent a wide range of depositional environments from subtidal to supratidal facies (Antoshkina, 1999). Ooids in the Silurian deposits occur in association with stromatolites or stromatolite-like microbial limestones (Antoshkina, 2011). These beds are important for the interpretation of the impact of the faunal overturns at stratigraphic boundaries on Silurian benthic ecosystems evolution in the region under study. Therefore, it is of interest to have an overview of the ooid-stromatolite associations and the environments in which they grew and to compare our observations and interpretations with Kalkowsky's (Paul et al., 2011). This paper represents the first results of study on the Silurian ooid-stromatolite associations and reports on the significance in paleoenvironmental reconstruction, including studies of relative sea-level change, bathymetry, salinity, and hydrodynamic level.

2. Materials and methods

Samples of ooid-stromatolite rocks were studied from sections of the Wenlock (outcrop 479) on the Iz'yayu River of the

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Chernyshev Swell and on the Kozhym River (outcrop 212) of the Subpolar Urals; from Ludlow successions on the Iz'yayu River (outcrops 479–481) and on the Shar'yu River (outcrop 64) of the Chernyshev Swell, and on the Padimejtyvis River (outcrop 1) of the Chernov Swell; from the uppermost Silurian beds on the Kozhym River (outcrop 236) of the Subpolar Urals and on the Iz'yayu River (outcrop 481) of the Chernyshev Swell. Samples were used to make polished slabs, thin sections, and fresh broken surfaces for various studies, which were conducted in the Institute of Geology, Komi Science Center, Ural Branch of the Russian Academy of Sciences. Thin sections were studied under petrographic and binocular microscopes. Determinations of the isotopic composition of carbon and oxygen in carbonates were made on a Delta V Advantage mass-spectrometer. Values of $\delta^{13}C$ are given in per mil deviation from the PDB standard; $\delta^{18}O$ from the SMOW standard calibrated to NBS19 (TSlimestone). The standard deviation of $\delta^{13}C$ and $\delta^{18}O$ does not exceed ±0.1‰ (1σ). About 40 samples of ooid and stromatolite host rocks for stable isotope analysis were collected using a microdrill from sites of rocks with the least recrystallization, dolomitization, and porosity. Twenty-four samples of ooids from various types of limestones were analyzed. Polished slabs and fresh broken surfaces were examined to reveal the structure and elemental composition of ooids and their host rocks using a JSM6400 Scanning Electron Microscope with an X-ray spectral microprobe. Trace element contents in Silurian carbonate rocks were measured by emission spectrographic analysis.

3. Geological setting

The Timan–northern Ural region represents the northeastern margin (in modern co-ordinates) of the East European (Baltica) continent. Eastern Baltica (western slope of the present-day Ural Mountains) was a passive continental margin until the onset of Uralide orogenesis in the Late Paleozoic, and the easternmost zone of the margin is formed by the western structural zone of the Ural Mountains (Fig. 1a). Westwards, the north of the Urals is separated from the Pre-Urals Foredeep by the Major West-Urals Thrust. In the west, the Pre-Urals Foredeep is bordered by the Pechora Syneclise. From the Ordovician to Early Devonian, the evolution of the Timan–northern Ural sedimentary basin was closely related to the development of the Paleo-Uralian Ocean, under geodynamic conditions that evolved from a passive margin, intraplate depressions, and uplifts. Their structural plan mainly inherited the landscape of the Riphean basement (Malyshev, 2002). The paleogeographic position of the region during the Silurian Period lay within the equatorial realm (Puchkov, 2010; Cocks and Torsvik, 2011). Silurian sedimentation took place on an extensive carbonate platform, generally, under conditions of a gradually subsiding continental margin. An epicontinental sea was shallow, with a nearly flat bottom that sloped very gently eastward, toward the Paleo-Uralian Ocean (Fig. 1b). The Silurian carbonates appear to have been constructed mainly by benthic microbial and metazoan communities, which formed a laterally continuous facies tract. Periodically, they developed into reef barriers, which restricted the shelf circulation and initiated facies differentiation, and in some cases, sedimentation of lagoonal evaporates. From the late Telychian to the early Ludfordian time reefs appeared on the shelf margin (= the Northern, Subpolar and Polar Urals). The back-reef basin was characterized by lagoonal and tidal flat environments. The low-diversity fauna and flora in these facies are represented by taxa typical of shallow-water, low energy conditions (Antoshkina, 1999).

4. Stratigraphical, genetic, and construction characteristics of the silurian ooid-stromatolite associations

4.1. Silurian stratigraphy

Most stratigraphical subdivisions now in use for the succession in the Timan–northern Ural region were proposed by Antsygin et al. (1993), although the rank of the subdivisions has changed over the years. Conodont biostratigraphy and stable isotopic data, however, have now solved most uncertainties in lateral correlations, and the stratigraphic subdivision can be based on firm knowledge about the zonal affinity of the strata at different localities (Mel'nikov, 1999; Männik et al., 2000; Mel'nikov and Zhemchugova, 2000). Eustatic sea level variations respond sensitively to climatic changes due to the growth and retreat of continental ice sheets at high latitudes (Fig. 1c). Sea level falls and rises are well observed during the Silurian period in the lithology, facies movements, breaks in sedimentation, and changes in faunal communities in the Timan–northern Ural region sedimentary basin (Männik and Martma, 2000; Antoshkina, 2008). A summary of major events known from Silurian times in the region has been presented (Antoshkina, 2007; Shebolkin and Männik, 2014).

4.2. Stratigraphical and facies description of ooid-stromatolite associations

Successions of beds with an ooid-stromatolite association in various sections range from 0.25 to 9 m in thickness. At present, the association levels have been recognized in the mid-Wenlock, uppermost-Homerian, within the Gorstian, in the uppermost-Gorstian, top-lower Ludfordian, and in the uppermost-Silurian. It is possible the stromatolite-ooid association in the mid-Wenlock corresponds to the Sheinwoodian–Homerian boundary and one in the upper part of the lower Ludfordian successions can be compared with the start of the Lau Event.

The mid-Wenlock ooid-stromatolite association level. This level is well illustrated in the Ust'Durnayu Formation on the Iz'yayu River where the Wenlockian succession is represented in full (Shebolkin and Männik, 2014). The association as a whole is up to 2 m in thickness and includes some thin layers with wackestones, packstones, and gravelstones. Presence of unsorted bioclasts, lithoclasts, and siliciclastics (5–15%) is characteristic. Vadose cements are present in some packstones with ooids. The ooid-stromatolite beds of 0.2–0.5 m in thickness are widespread in the middle part of the Wenlock in the Iz'yayu River section of the Chernyshev Swell. It is very interesting that lithological study of these limestones shows that they have been