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GEOLOGY

Ultrastructures of Stromatolites from the Wenlockian of Chernov Swell

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Abstract—The morphology of fossilized biogenic particles and the elemental composition of biogenic formations, discovered for the first time in Lower Silurian deposits within the Timan–Northern Urals region, are considered. The diversity of biogenic formations identified in stromatolites indicates a high level of activity of microorganisms forming the cyanobacterial mat and confirms the microbial origin of the Wenlockian stromatolite buildups.

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The exposures of Early Paleozoic carbonate sequences comprising stromatolite buildups in the Bezymyannyi Creek valley (a tributary of the Padimeytyvis River) on Chernov Swell were first established and described by G.A. Chernov in 1941 (Fig. 1). During a repeat examination in 1961 of these Silurian sediments, Chernov paid special attention to the characteristic surface of limestone beds that were identified as stromatolites [8].

The Bezymyannyi section is represented by the Llandovery, Wenlockian, and Ludlowian deposits with a total thickness of 198 m. The 40-m interval of the section enclosing stromatolite buildups is composed of alternating ostracod–pelecypod, brachiopod, and stromatolite limestone with mud cracks and dolomitic bituminous marls. Stromatolite buildups are common in the upper part of the section occupying the lower and middle parts of elementary cyclites, which are crowned by surfaces with mud cracks [4]. The interval studied was subdivided into three stromatolite-containing levels. In terms of morphology, stromatolite buildups are attributed to three main morphological types: bun-shaped, dome-shaped, and stratiform. Bun-shaped and dome-shaped buildups are confined to the lower beds of the interval (first and second levels). Bun-shaped stromatolites are of 0.6 m in diameter and 0.4 m in height. Colonies with dome-shaped buildups are up to 1.4 m in diameter and 0.25 m in height. Stratiform stromatolites from 3 to 8 cm thick are confined to the upper strata of the third level. The difference between the basic forms of stromatolite buildups is associated with periodic changes

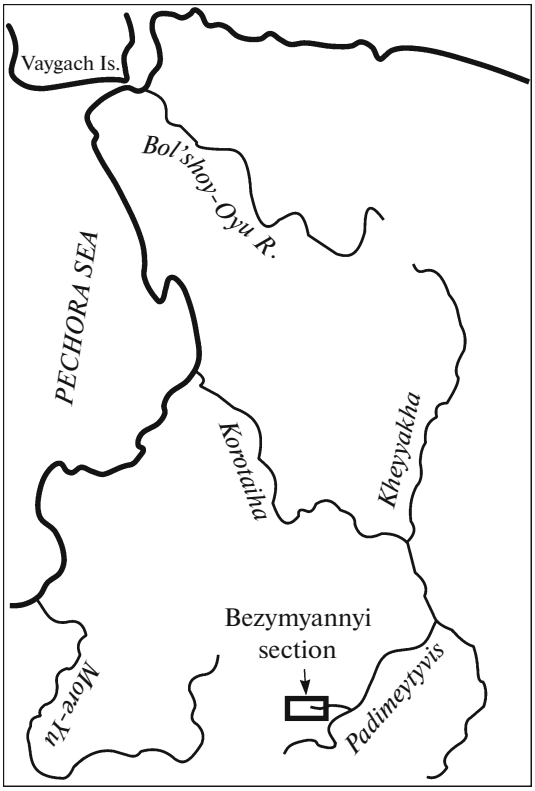

Fig. 1. Location scheme of the Bezymyannyi section.

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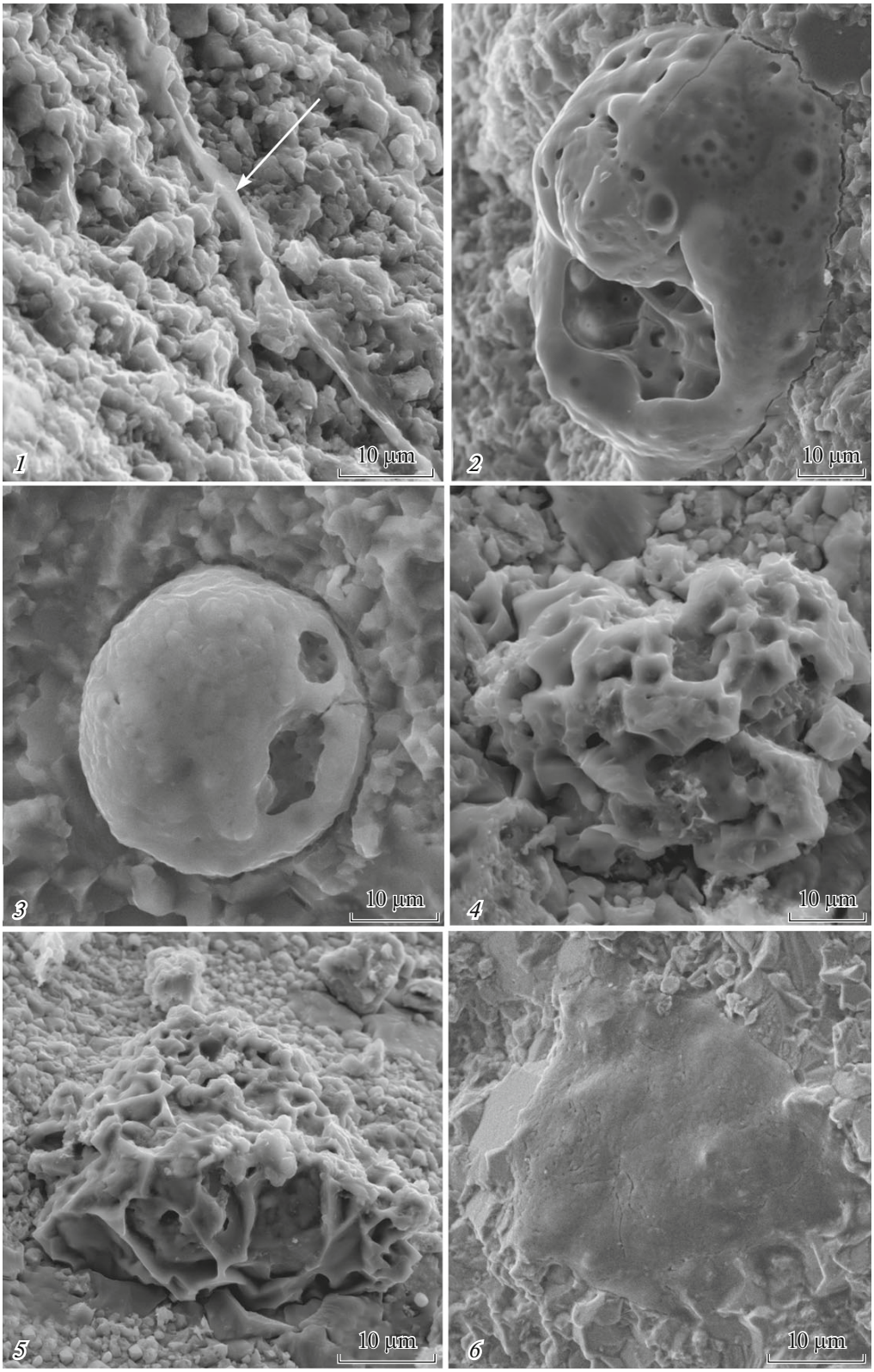

Fig. 2. Biogenic formations of Wenlockian stromatolites: *1*, mineralized covers of tubular filamentary structures, possibly cyanobacteria; *2–4*, globular fossils; *5*, dome-shaped fossils; *6*, a fragment of a microbial biofilm.

Elemental composition of biogenic formations

Sample no.	Forms of fossils	Units	Elements							Total
			O	S	Ca	Fe	Si	Na	Cl	
1	Globular	Wt. %	14.97	16.74	3.56	16.96				100
		Atm. %	50.58	28.23	4.8	16.38				
2		Wt. %	22.05	13.3	7.29	15.78				100
		Atm. %	60.98	18.48	8.04	12.5				
3	Dome-shaped	Wt. %	63.5		0.75		50.45			100
		Atm. %	68.62		0.32		31.06			
4	Biofilm	Wt. %	7.13		21.47			3.32	0.91	100
		Atm. %	38.69		46.54			12.53	2.24	

in the water level in the water basin. At the transgression stage, the conditions were more favorable for development of bun-shaped and dome-shaped stromatolite buildups. At the regression stage, stratiform stromatolite buildups were mainly formed [5, 7].

It is known that stromatolites are formed due to interaction of microorganisms, mostly cyanobacteria, which can adapt to extreme living conditions, associated with processes of sedimentation [2].

Currently, electron microscopy is widely used for studying microbial formations. This method allows us to identify various groups of fossilized bacterial structures. Of particular importance are the role of bacteria in the development of life on Earth, formation of the biosphere and soils, and in active participation in rock formation and accumulation of various mineral resources [1, 2].

The ultrastructures of stromatolite samples collected in the Bezymyannyi section were studied on a Tescan Vega 3 LMH scanning electron microscope with an X-MAX energy dispersive spectrometer (OXFORD Instruments); carbon coating (analyst S.S. Shevchuk, Institute of Geology, Komi Science Center, Ural Branch, Russian Academy of Sciences, Syktyvkar). Fresh chip surfaces of stromatolite buildups were analyzed. In order to eliminate surface contamination of samples before the study, they were washed successively with distilled water and alcohol and treated with hydrochloric acid. As a result, biogenic formations, which were first discovered in Silurian stromatolites in the study area, are subdivided into four main groups of fossils. The first group includes mineralized covers of tubular filamentous formations, likely cyanobacteria, of up to 60 μm in length, with a wall thickness of 1 μm (Fig. 2, *1*). The second group includes globular fossils (Fig. 2, *2–4*). The third group is represented by dome-shaped fossils (Fig. 2, *5*). The fourth group includes fragments of a microbial biofilm (Fig. 2, *6*). Analysis of the elemental composition of biogenic formations of the second, third, and fourth groups of fossils has shown that all groups studied contain calcium (Ca) and oxygen (O). The highest Ca content and the lowest O content were recorded in the fourth group (a biofilm). The globular fossils contain Fe and S, as well. Only dome-shaped stromatolite buildups are characterized by a Si content. Microbial biofilms contain Na and C (see the table).

The diversity in the elemental composition of biogenic formations is possibly due to the metabolic processes of different bacteria occupying the cyanobacterial mat and accumulating certain chemical elements in the process of life, as well as due to varying degrees of fossilization [1, 2].

The unique preservation of biogenic formations found in stromatolite-generating biota can be explained by the instantaneous dumping of stromatolite buildups. This assumption is confirmed by occurrence in the same section of previously discovered vital burials of Wenlockian brachiopods *Spirinella* with preserved elements of the internal structure, thin annulus layers, and thin spines on the shell surface. Storms, during which there was burial of the benthic assemblage, are considered to be one of reasons for such burials [3].

Thus, the diversity of biogenic formations established in stromatolites indicates the high level of activity of microorganisms forming the cyanobacterial mat and confirms the biological nature of Wenlockian stromatolite buildups on Chernov Swell.

At present, the locality of fossilized biogenic formations discovered among stromatolites of the Bezymyannyi section is the only currently known locality of such a type in the Timan–Northern Urals region.

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