Wenlock-Ludlow boundary sediments on Chernov uplift (Arctic region of Russia)

VLADIMIR A. MATVEEV • Institute of Geology Komi SC UB RAS, Syktvykar • matveev@geo.komisc.ru
TATIANA M. BEZNOsoVA • Institute of Geology Komi SC UB RAS, Syktvykar • beznosova@geo.komisc.ru
LÁSZLÓ Á. GÖMZE • Institute of Ceramics and Polymer Engineering, University of Miskolc, Hungary, IGREX Engineering Service Ltd • fengomze@uni-miskolc.hu

Abstract

The article presents the results of a study of Wenlock-Ludlow boundary sediments in the river Padimeityvis basin at Chernov uplift using paleontological, lithological and chemostratigraphic methods. The results of paleontological studies allowed attributing to Wenlock the carbonate stratum of the upper part of the section along the stream Bezymyanny and establishing Wenlock-Ludlow boundary only in the river Padimeityvis. The results of studying the isotope δ13C in Wenlock-Ludlow boundary sediments are also presented. In the upper part of the section along the stream Bezymyanny a positive C-isotopic shift of the curve which possibly marks the late Wenlock global biotic event of Mulde was observed.

Key words: Ludlow, Wenlock, conodonts, brachiopods, Arctic region, Timan-Northern Ural region, isotope δ13C

Kulcsszavak: Ludlow, Wenlock, conodont, brachiopoda, Arctic region, Timán-Northern Ural region, δ13C izotóp.

1. Introduction

The study of the stratigraphy of the paleozoic sediments of Chernov uplift began in 1921 by the Northern Scientific and Trade Expedition where G. A. Chernov worked. The results of the study of Silurian sediments and collections of fossil fauna are given in field diaries, thematic reports and published works by G. A. Chernov [1-3], S. A. Knjazev [4], A. I. Ljashenko [5], N. I. Timonin [6], A. I. Antoshkina, T. M. Beznosova [7], T. L. Modzalevskaya [8], T. M. Beznosova [9-11], P. Mannik, V. A. Matveev [12-13], N. V. Maidl [14], V. Y. Lukin [15]. In these works, the conditions for the formation of sediments composing the section, their age are considered, and their own stratigraphic dissection schemes are proposed. Issues of stratigraphy of Wenlock deposits in the Podimeityvis River basin have been reviewed repeatedly. A variety of conclusions about the age of Wenlock-Ludlow boundary stratum in the section of Chernov uplift testifies to the complexity of its structure and biostatigraphic differentiation, as shown by our subsequent detailed studies. The history of the study of Silurian strata at Chernov uplift is given in publications [9-12].

In the sections of the Mikhailov-Vaigach structural-facies zone and the Timan-Northern Ural region the Wenlock-Ludlow boundary is determined with considerable relativity since it has an indistinct paleontological and lithological characteristic [16]. According to the stratigraphic scheme of the Urals, the regional Wenlock-Ludlow boundary between in the Timan-Northern Ural region is relatively established in a lithologically homogeneous member by the appearance of the ostracods Schreckia uralensis Abush. at the base of the Podimeityvis horizon [17].

The newly conducted studies of sedimentation conditions of Silurian sediments at Chernov uplift made it possible to substantiate the stormy mode of sedimentation in Wenlock. A study of the collected fauna collections - the tabulate corals of brachiopods, ostracods, conodonts, vertebrates, the nature of changes in the behavior of isotope δ13C served to justify the Wenlock age of the Bezymyanny section and the Wenlock-Ludlow boundary in the section of the Podimeityvis River (Fig. 1). The established total thickness of Wenlock sediments at Chernov uplift is 300 m.
On the whole, this is a near-thrust rootless structure formed as a result of the leaf-by-leaf stripping exposure in the cover of the Korotakhinsky depression, confined to the incompetent Upper Ordovician member [6, 18].

3. Materials and methods

The material for this article was the collections of leaf-by-leaf samples collected by V. A. Matveev and P. Myannik during field work in 2010 and 2017. The collection of samples includes more than 53 samples with the remains of fossil macro- and microfauna, 44 samples for the isotope $\delta^{13}$C_carb.

The Wenlock section is opened along the Bezymyanny stream and continues with a gap on the river Padimeytyvis (left tributary of the Korotakh River), where the Ludlow deposits are exposed. The studied Wenlock-Ludlow sections are located in the central part of the Chernov uplift in the Arctic part of the European North-East of Russia (Fig. 1). Organic remains were investigated by: T. M. Beznosova (brachiopods), P. Mannik (conodonts), V. Y. Lukin (tabulate corals), L. L. Shamsutdinova (ostracods), P. Mannik, L. V. Sokolova (conodonts), T. Márs (vertebrates). Lithological samples were studied by T. V. Maidl, stromatolites – by V. A. Matveev. Conclusions about the age of ostracods by A. F. Abushik [19] and stromatoporoids by O. V. Bogovavlenskaya [7] were also taken into account.

The isotope $\delta^{13}$C_carb in carbonate rocks was determined at the “Geoscience” of the Institute of Geology Komi SC UB RAS using a DELTA V Advantage mass spectrometer. The values of the isotope coefficients were determined in ppm (%) according to the PDB standards NBS18 and NBS19 (TS-limestone) for carbon. The error in determining both coefficients did not exceed ± 0.1 %o. The isotope $\delta^{13}$C_carb was determined in 98 samples (sampling step 50 cm). The material for the isotope analysis was carbonate rocks, the least subjected to secondary transformations. Samples were obtained using a diamond drill with a diameter of 3.5 mm. Collections of fossil fauna remains are stored in the Museum named after A. A. Chernov of the Institute of Geology Komi SC UB RAS named after Academician N. P. Yushkin.

4. Results and discussion

The Wenlock-Ludlow boundary sediments are represented by the alternation of light brown to dark brown thin-layer limestones, platy with cracks of sediment drying, stromatolitic, clay, bioturbated limestones, containing numerous remains of ostracod shells, pelecipods, brachiopods, corals and other organisms.

The studied section thickness with a total capacity of 205 m was divided by us into six benches, three benches were identified along the Bezymyanny stream and three benches - along the Podymeityvis River. The first five benches belong to Wenlock, the sixth bench to Ludlow (Fig. 2).

5. Brief description of the section on the Bezymyanny stream

Unit 1 (thickness 36 m) is composed of interbedded brownish limestones and fine-grained and microgranated and limestones, dolomitic bituminous limestones, limestone with flat pebble conglomerate, ostracodic and brachiopodic limestones, which also contain fragments of trilobites, gastropods, peliocids. Defined: brachiopods Spirinella nordensis (Ljashenko), conodonts Ozarkodina kozhimica Melnikov, Panderodus ex gr. greenlandesis Armstrong, Oulodus kozimicus Melnikov, ostracods Cytherellina aff. inornata (Abushik), Lichwinia silurica (Neckaja). The upper boundary of the bench is carried out at the base of the first layer of stromatolite limestones.

Unit II (thickness 32 m) is represented by the interbedded brown, dark brown, fine-, micro-grained argillaceous limestones with silty shaly limestones, alternating with light lumpy spotted and micro-laminated microbial-algal and fenestrian limestones with leaf-by-leaf silty and argillo-dolomitic with lithoclasts and desiccation fissures at different levels. A tectonic disturbance 1.8 m thick is observed in the lower part of the bench.

In the bench, a stratum with organogenic structures is developed, which is represented by stromatolithic structures and coral-stromatoporate biostromes with a total thickness of 31 m (Fig. 3, A). In the lower part of this stratum, limestones with stromatolites of various morphological structures occur: bunched, dome-shaped and beds, reaching a diameter of 55 cm and a height of 25 cm (Fig. 3, B). Similar Wenlock stromatolite structures are known in the north of the Urals, Chernyshev uplift, Dolgyi Island and Saaremaa Island in Estonia [8, 11, 15].
Fig. 3: Coral-stromatoporoid biostrome (A (II. egység)); 1а - colony of stromatoporoid; B - brachiopod Lingula sp.; C - peloid limestone with thin bioclastic interbeds (Unit II); D - limestone biomorphic with subrounded chaotic storm cone (Unit III).

Fig. 4: Wenlock-Ludlow boundary deposits in the section of the Padimeityvi River. A - Wenlock mészkő a mésztartalmú pala beékelődésekkel (IV. egység); B - tungó tabulatkorall Aulocystella aseptata (Barskaja, 1967); C - peloid limestone, bioturbated (Unit IV); E - pelitomorphic limestone with /f_lat introclasts (Unit II); 1b - Aulocystella aseptata táblák (Barskaja, 1967); B - dome-shaped stromatolite (II. egység); С - peloid mészkő lapos belső törmelékekkel (II. egység);

Coral-stromatoporoid biostromes with stromatoporoids Syringostromella elegestica Riab., Ec. Faustigiatum (Fig. 3, 1a and 1b), tubular tabulate corals Aulocystella aseptata Barskaja and dendritic tabulate corals Rhipheolelites lamelliformis Klaaumann lie above.

Thin-bedded limestones with ostracods and brachiopods Atrypoidea linguata (Bush) cover the biostrom with desiccation fissures and signs of undulation ripples lie above.

A similar structure of the Upper Wenlock section gap, comprising coral-stromatoporate and stromatolite biostroms, was described by D. K. Patrunov et al. on the Dolgyi island [20]. The conodonts Ozarkodina kozhimica Melnikov, Ctenognathodus sp. are defined in the bench. The upper boundary of the bench is the biostrome roof.

Unit III (thickness 17 m) is composed of brown and light brown fine- and medium-grained limestones with interbeds of limestone bioclastic, micro-layered, argillaceous. The lower part of the bench is composed of unsorted-detrital, biomorphic limestones, in which ostracods predominate, and interbeds of limestone with flat-pebble conglomerate (tempestites?) (Fig. 3, C and D) and signs of undulation ripples are also observed. Brown, micro-fine-grained, aphonite limestones with interbeds of unsorted-detrital limestones, mainly ostracodic, prevail above. Brachiopods Atrypoidea linguata (Bush), ostracods Eukloedenella, Hermanina insignis Abushik., conodonts Ozarkodina kozhimica Melnikov, Ctenognathodus sp. are defined.

The lithological structure features of this part of the Wenlock section (Benches I-III) suggest that its formation occurred in open shallow shelf conditions at low sea levels, with the prevalence of storm sedimentation and the general regressive orientation of the basin development [11].

Further, after a 100-110 m break, the section continues along the Podymeityvis River.

Unit IV (thickness 50 m) is composed of interbedded limestones of light brown pelitomorphic thin-bedded limestones (Fig. 4, A) containing a small amount of bioclastic material (Fig. 4, C), dark brown shaly limestones, argillaceous (1-5 cm) limestones and thin interbeds of calcareous argillaceous – shales. No visible fauna remains are found. When the rocks were dissolved on conodonts in the samples, the brachiopods Lingula sp. (Fig. 4, B) were found along with the conodonts of Ozarkodina kozhimica Melnikov.

Unit V (thickness 30 m) is composed of interbedded limestones of light brown micro-grained, thin-bedded to shaly with light brown massive, cryptocrystalline limestones, with semi-shelly fracture, and bioturbated limestones (Fig. 4, D). In the bench, single shells of brachiopods, gastropods, ostracods, and orthoceratide (1-5 cm) were found (Fig. 4, E). Brachiopods Lingula, conodonts Ozarkodina kozhimica Melnikov, Ozarkodina anika Viira et Einasto, 2003, Ozarkodina cf. soegina Viira et Einasto, 2003 were defined.

In the roof of this bench, the contact of thin-bedded limestones to shaly and bioturbated limestones is revealed. We consider this contact as the lithological Wenlock-Ludlow boundary. The paleontological boundary was drawn along the disappearance of the inarticulate brachiopods Lingula sp. and the appearance of the Ludlow brachiopods Greenfieldia uberis and numerous ostracods (Fig. 4, F).
Unit VI (40 m thick) is composed of interbedded lumpy light brown limestones, thin-bedded limestones, dark gray bioclastic, pelitomorphic, bioturbated limestones with interbeds of dark brown shaly argillaceous. Four interbeds with stromatolithic dome-shaped structures of a diameter of 35 cm and a height of up to 15 cm are observed in the bench. On the weathered surface, it can be seen that the buildings are formed of a series of small dome-shaped structures of a diameter of 35 cm and a height of up to 6 cm. Brachiopods G. iberis, G. dissecta, M. attenuatae, Atrypoidea linguata Buch, Lingula sp., Wenlock-Ludlov conodonts O. kozhimica, O. segoine, O. cf. anika (Viira et Einasto, 2003) and vertebrates Thelodus visvaldi Karatajutė-Talimaa et Märrs, 2002, are defined in the bench limestones.

6. Biota of Wenlock-Ludlov boundary sediments

The sea basin level increase in the late Wenlock (Shenwudian) contributed to the taxonomic diversity of the biota. The benthic communities were based on the brachiopods represented by the Atrypoidea linguata atrypids and the first in Silur sparifrids of the Spirinella nordenis, which are known in Wenlock of the Dolgy and Gotland Islands, in Great Britain, Bohemia, Mongolia, Southern China, in Llandovery and Wenlock of North America and Ludlov of Estonia. Along with brachiopods the ostracod species Hermanna insignis (Abushik), Eukloedenella grandifabae Abushik, as well as gastropods, pelecipods, coral and stromatoporoid communities that formed the biostromes [11, 19] were developed at that time. The gradual shallowing of the basin, the development of stromatolith-forming organisms negatively affected the existence of the Spirinella brachiopods belonging to the third benthic complex (B.C. 3) and Atrypoidea belonging to B.C. 2 [21]. The increase in stromatolith interbeds observed upstream of the section, as well as desiccation fissures, indicates a progressive regression, as a result of which stromatoporoids, ostracods, pelecipods, ostracods disappeared.

Wenlock deposits (thickness about 100 m), which are opened in the section along the Podymytvis River, represented by thin-bedded, argillaceous limestones, do not contain visible fauna remains. When dissolving conodont samples in this section, the isotope δ13C values are in the range from -9.51 to 1 ‰, and in Ludlov from -3 to 0 ‰.

As for the vertebrates, the remains of the vertebrates Thelodus visvaldi were discovered in the section, which until now were known only on the Severnaya Zemlya [22].

The section interval of Wenlock-Ludlov boundary sediments with a thickness of 13.7 m is characterized by a mixed complex of the Ludlov benthic fauna and the Wenlock complex of conodonts. In Fig. 2, this section interval is highlighted in gray. Examples of joint finds of fauna remains of different ages are known at the Llandovery-Wenlock boundary at the Chernov uplift, as well as at the Ludlov-Pridoli boundary in the section of the western slope of the Subpolar Urals [23, 24, 11].

7. C_carbon Isotope Analysis

The results of the isotope analysis, sequentially tied to the intervals of the section, showed the possibility of identifying four intervals with characteristic isotopic values that are consistent with paleontological and lithological data (Fig. 2).

Isotope characteristics of carbonates of the Wenlock-Ludlov boundary deposits in the river Padimutvis basin showed that in Wenlock δ13C_carbon values are in the range from -9.51 to 1 ‰, and in Ludlov from -3 to 0 ‰.

In interval I, composed mainly of pelitomorphic, bioclastic, stromatolitic limestones, the isotope δ13C_carbon is characterized by negative values. The average value of the isotope coefficient for carbon is δ13C_carbon = -5.15 ‰. Up the section, the isotope δ13C_carbon has wave-like oscillations; first, the carbon values fall from -4.35 to -7.5 ‰, which then increase to -3.8 ‰ and fall to -7.0 ‰.

In interval II, a sharp weighting of the isotope δ13C_carbon is observed, which begins at the base of the coral-stromatoporate biostrome (bed 101) δ13C_carbon = -6.3 ... -0.6 ‰ and continues to the very top of the section, where it reaches maximum values + 1 ‰ (bed 109). The average isotope δ13C_carbon value for this interval is -1.18 ‰. A sharp shift of the isotope curve towards positive δ13C_carbon values may correspond to the Early Wenlock biotic and isotopic Mulde event. This event is characterized by the extinction of the graptolite and conodont fauna, as well as a double positive excursion of carbon isotopes, which lies in many sections of the world [25-28].

In interval III, the average value of the isotope coefficient for carbon is -4.48 ‰. The interval is characterized by two abnormal negative values δ13C_carbon = -9.51 ... -9.10 ‰.

Interval IV. The average value of the carbon isotope coefficient for this interval is δ13C_carbon = -2.98 ‰. In the lower part of the interval, two peaks of negative values of carbon isotopes = -6.29 ... -6.93 ‰ are recorded. Above the section, the interval is characterized by a gradual weighting of the isotope δ13C_carbon = -6.93...-0.13 ‰, which sets the trend in the positive direction of the curve.

Considering the extremely shallow deposits of the studied Wenlock-Ludlov boundary deposits, it can be assumed that the isotope-facilitated fresh water from the continent saturated with dissolved soil carbon dioxide during climate humidization periods and a corresponding increase in terrigenous runoff could influence the isotope values changes. A sharp weighting of the isotope δ13C_carbon at the base of the coral-stromatoporate biostrome, unlike the lying above and below values, may indicate a change of water in the sedimentation basin from desalted to
normal marine [29, 30]. Such an effect is also associated with an increase in the biological productivity of the reservoir, due to warming and an increase of the sea level, which is correlated with lithological data (sequential change of layers with stromatolithic structures to coral-stromatoporote biostromes and then to limestones with diverse benthic fauna). Sharp spasmodic shifts of the isotopic curve in the studied section indicate significant changes in the characteristics of the middle of Wenlock-Ludlov boundary sedimentation in the Timan-Northern Ural Sea Basin.

8. Conclusions

The conducted studies supplemented the paleontological and sedimentological characteristics of Wenlock-Ludlov boundary deposits. For the first time, Wenlock-Ludlov boundary deposits received paleontological and chronostratigraphic evidence. The established thickness of Wenlock sediments at the Chernov uplift is 300 m. Two intervals were traced in the boundary deposits in which the brachiopod communities change from benthic complex 1 in Wenlock to benthic complex 2 in Ludlov. The established anomalous excursions of carbon isotopes in the section can serve as reliable chronostatigraphic benchmarks for regional and global correlation of Wenlock sections. The results of the study confirm and complete the conclusions of G. A. Chernov on the links of the Timan-Northern Ural Sea Basin with the Baltic and Western Europe basins.

Acknowledgements

The authors are grateful to P. Mannik, who was the first to study the collection of conodonts from the Bezmyanny section at the Chernov uplift, T. Märs for determining vertebrates and L. V. Sokolova for determining the conodonts of the Padimeytvis section, L. V. Shamsutdinova for identifying ostracods of Wenlock-Ludlov boundary sediments, N. A. Matveeva for a discussion of the results, I. V. Smolova, an engineer at the “Geoscience”, Institute of Geology Komi SC UB RAS for determining the isotope Δ13C in carbonate rocks, S. O. Kulikov, V. A. Radaev for helping in conducting expeditionary work.

The work was conducted within the framework of the projects FAAAA-A17-11712170038-1 of the Institute of Geology, Federal Research Centre Komi Scientific Centre, UB, RAS.

References

[1] Chernov, G. A. (1964): Silurian deposits of the Chernov uplift // Doklady Earth Sciences. SSSR, pp. 843–846.
[2] Chernov, G. A. (1966): Silurian stromatolites of the Chernov uplift (Bolshemizelmaya Tundra). Stratigraphy and Paleontology of North-West European Region of the USSR. Moscow, Leningrad: Nauka, pp. 90–105.
[3] Chernov, G. A. (1972): Paleozoic of the Bolshemizelmaya tundra and the prospects of its oil and gas bearing sections. Moscow: Nauka, 318 p.
[4] Knyazev, S. A. (1965): Silurian Deposits of the Central Part of the Chernov Uplift // Materials on the Geology and Minerals of Northeastern Eurasia, USSR. Syktyvkar, No. 5, pp. 112–120.
[5] Lyashenko, A. I. (1964): New species of Devonian brachiopods of the Russian platform and the Western slope of the Ural // Fauna of the Paleozoic of the Volga-Ural region of the oil and gas province. Moscow: Nauka, pp. 3–57.
[6] Timonin, N. I. (1998): Pechora Plate: History of Geological Development in the Phanerozoic. Ekaterinburg, 240 p.
[7] Antoshkina, A. I. – Beznosova T. M. (1988): New data on stratigraphy Wenlock deposits of the Bolshemizelmaya tundra. Bull. MOIP Otdelenie geo, Vol. 63. No. 6. pp. 32–39.