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Lithological and biostratigraphic characteristics of the Upper Silurian and Lower Devonian deposits of the southwestern part of the field named after Roman Trebs

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Abstract. A conodont sequence from the Przhidolian stage of the Upper Silurian and almost the entire Lokhkovian stage of the Lower Devonian has been established in the sections of the Upper Silurian-Lower Devonian on the southwestern part of the field named after Roman Trebs (Timano-Pechora oil and gas province). According to the conodonts, two biostratigraphic subdivisions are distinguished in the rank of layers with fauna in the Upper Silurian and three of them in the Lokhkovian stage of the Lower Devonian. The layers can be compared with the standard conodont zonal scale. The Silurian-Devonian boundary has a complex rationale for biostratigraphic data (conodonts), cyclostratigraphy, and logging data (electrical and radioactive methods). The Lower Devonian deposits are overlain by terrigenous packs of the Timanian horizon of the Frasnian stage. The break in the sedimentation covers the interval from the Praghian stage of the Lower Devonian to the Dzhierskian horizon of the Frasnian stage of the Upper Devonian inclusively. The regularity of the placement of reservoir rocks in the section of wells is analyzed and their relation to the cyclicity of sedimentation is noted.

Key words: Silurian, Devonian, conodonts, logging, lithology, cyclicity

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Introduction

The field named after Roman Trebs is located within the Timan-Pechora oil and gas province, tectonically associated with the northeastern slope of the Bolshezemelsky Arch. Geological studies of the Lower Paleozoic in the northern part of the Timan-Pechora province have been carried out since the last century by many researchers: D.V. Nalivkin, V.V. Menner, N.V. Taninskaya, A.I. Antoshkina, V.N. Puchkov, S.V. Melnikov, T.M. Beznosova, Z.P. Yuryeva, Iyu. Valiukevichus, Yu.V. Deulin, G.A. Chernov, A.I. Pershina, N.B. Rasskazova, V.S. Tsiganko and others. As a result of these studies, stratigraphic dismemberment of Paleozoic deposits was carried out, paleogeographic reconstructions were made, geological and facial maps were created, sedimentation models were constructed, which allowed reconstructing the stages of paleobasin evolution and reconstructing sedimentation conditions for individual periods of time.

This article is devoted to the dismemberment of the Silurian and Devonian deposits discovered by a series of wells, the determination of their stratigraphic volume and identification of the position and nature of the boundary based on the results of biostratigraphic (by conodont), cyclostratigraphic, geophysical studies of wells. Two wells A and B were taken as the basis, which characterize the most completely the section under consideration.

As a stratigraphic basis, the Stratigraphic Scheme for the Middle and Upper Paleozoic of the Russian Platform (1990) was used in the dismemberment.

Lithological characteristics of the Upper Silurian and Lower Devonian section in the wells A and B

The deposits of the Upper Silurian and the Lower Devonian of the Bolshezemelsky Arch are related to the formations of the shallow-marine paleoshelf of the epicontinental sea. They have a cyclic structure reflecting the transgressive-regressive sedimentation.

As a rule, the lower elements of the cyclites are composed of dark-colored clayey and clay-carbonate rocks, for which, according to the logging data, high indications of gamma ray logging with relatively low

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values of neutron logging and specific electric resistance (Fig. 1). When the sea level rises, they are usually the first to form in the submerged parts of the coastal zones under the reducing environment.

The average elements of the cyclites in many cases are represented by limestones the micrite and nodular-layered, distinguished by low indications of gamma-ray logging and high indications of neutron logging and high specific electric resistance. They are formed during stagnation in an open sea basin with normal salinity in the zone of lower sublittoral, in a more calm hydrodynamic situation.

Biogermic, organogenous-detrital dolomitic limestones and porous dolomites are the upper members of the cyclites, which correspond to low gamma-ray logging indications and mean values of neutron logging, high values of specific electric resistance in oil-saturated intervals and low in water saturated ones. They are formed in shallow conditions in the zone of upper sublittoral.

The replacement of biogermal limestones or porous dolomites with argillaceous rocks reflects the beginning of a new transgressive stage. Important reference points are packs of basal conglomerates, whose sign according to the logging data are the increased values of natural radioactivity in the gamma-ray logging. They are formed during the erosion of the underlying strata at the onset of a new transgression of the sea.

The Lower Devonian deposits occur in a clinoform on the eastern slope of the Bolshezemelsky Arch, the thickness of the sediments decreases from east to west and southwest to complete wedging (Yur'eva, Valiukevichus, 2014).

Well A is west of the Central Block of the field named after R. Trebs, in the zone of wedging and reduction of D_1 stratum thickness, and well B is located in the south-eastern part of the Central Block, almost at the eastern boundary of the Khoreyversky depression. In the context of the latter, a comparative increase in the volume of the Lower Devonian deposits is observed.

The Upper Silurian. Przhidolian stage. Grebenskian horizon. In the well A, two cyclites are identified in the sediments of the Grebenskian horizon (Fig. 2). The first cyclite includes the packs 1-3. It is represented by a complete set of elements of the cyclite: clayey rocks in the base (pack 1), layered limestones with interlayers of bioclastic and organogenic differences in the middle part (pack 2) and dolomites porous and clayey in the upper part (pack 3). In a pack of limestones of the middle part conodonts were found: *Coryssognathus* aff. *dubius* (Rhodes), *Oulodus (= Delotaxis)* cf. *elegans* (Walliser), *Ozarkodina* aff. *cornidentata* (Branson et Mehl), *Ozarkodina* cf. *eosteinhornensis* (Walliser), characteristic of the Przidolian stage of the Upper Silurian. In the porous dolomites oil saturation is noted. The total thickness of the cyclite in well A is 25.9 m.

The second cyclite contains packs 4-6. It begins with nodular-layered limestones (pack 4), overlapping with a clear contact underlying porous dolomites. ,The following conodonts were found in the limestones: *Oulodus* cf. *elegans detortus* (Walliser), *Oulodus* cf. *elegans elegans* (Walliser), *Ozarkodina* cf. *confluens* (Branson et Mehl), common in the Przhidolian stage, the conodontic zone detorta. Organogenic-detrital and biohermous bryozoan limestones with intercalations of clayey and oolitic limestones are more developed (pack 5). In organogenic-clastic limestones, the Upper-Przhidolian conodonts were encountered: *Oulodus* cf. *elegans detortus* (Walliser), *O.* cf. *elegans elegans* (Walliser), *Ozarkodina* aff. *nasuta* (Viira), *Oz.* cf. *denticulata* (Viira), *Oz.* cf. *siluricus (*Branson et Mehl), *Oz.* cf. *swetlanae* (Mashkova). The cyclite ends with dolomites dense massive, alternating with dolomite clayey thin-layered (pack 6), the formation of which took place in the lagoon environment.

In the section of well B, Silurian deposits are represented by two sedimentation cyclites. At the base of the first cyclite (packs 1-6) mudstones lie, which are replaced by clayey limestones with argillite interlayers (pack 1). The latter in turn overlap with limestones unevenly-clayey micro-grained, nodular-layered (packs 2,3). In the limestones of packs 1 and 3, conodonts of the Upper Silurian *Coryssognathus* aff. *dubius* (Rhodes), *Ozarkodina* cf. *confluens* (Branson et Mehl), *Oz.* cf. *denticulata* (Viira) are found. Cyclite is completed with clayey dolomite that is not clearly-layered, porous, porous-cavernous, with areas of relic organogenic structure (packs 4-6). The porous-cavernous dolomites are characterized by oil saturation.

The second cyclite is represented by packs 7-9. The lower part of it is composed of interbedded mudstones and clayey dolomites (pack 7). The middle part (pack 8) is composed of dolomites micro-grained and cloddy, unevenly clayey, in places with a relic organogenic structure. In the upper part of the cyclite there are dolomites porous, porous-cavernous, oil saturation is noted (pack 9).

Lower Devonian. Lokhkovian stage. Ovinparmian horizon. In the well A, three cyclites are distinguished in the deposits of the Ovinparmian horizon (Fig. 2).

Packs 7-10 are included in the first cyclite. It begins with basal conglomerates (pack 7). In the debris there are conodonts of the Grebenskian horizon of the Upper Silurian: *Oulodus* cf. *siluricus* (Branson et Mehl), *Ozarkodina* sp., *Panderodus* sp., *Wurmiella* sp. In addition to the large carbonate debris, clastic and argillaceous material is present in the rocks that came from erosion of rocks from the adjacent land. On the conglomerates there are mudstones (pack 8), which are replaced by limestones clotted, cloddy, clayey (pack 9).

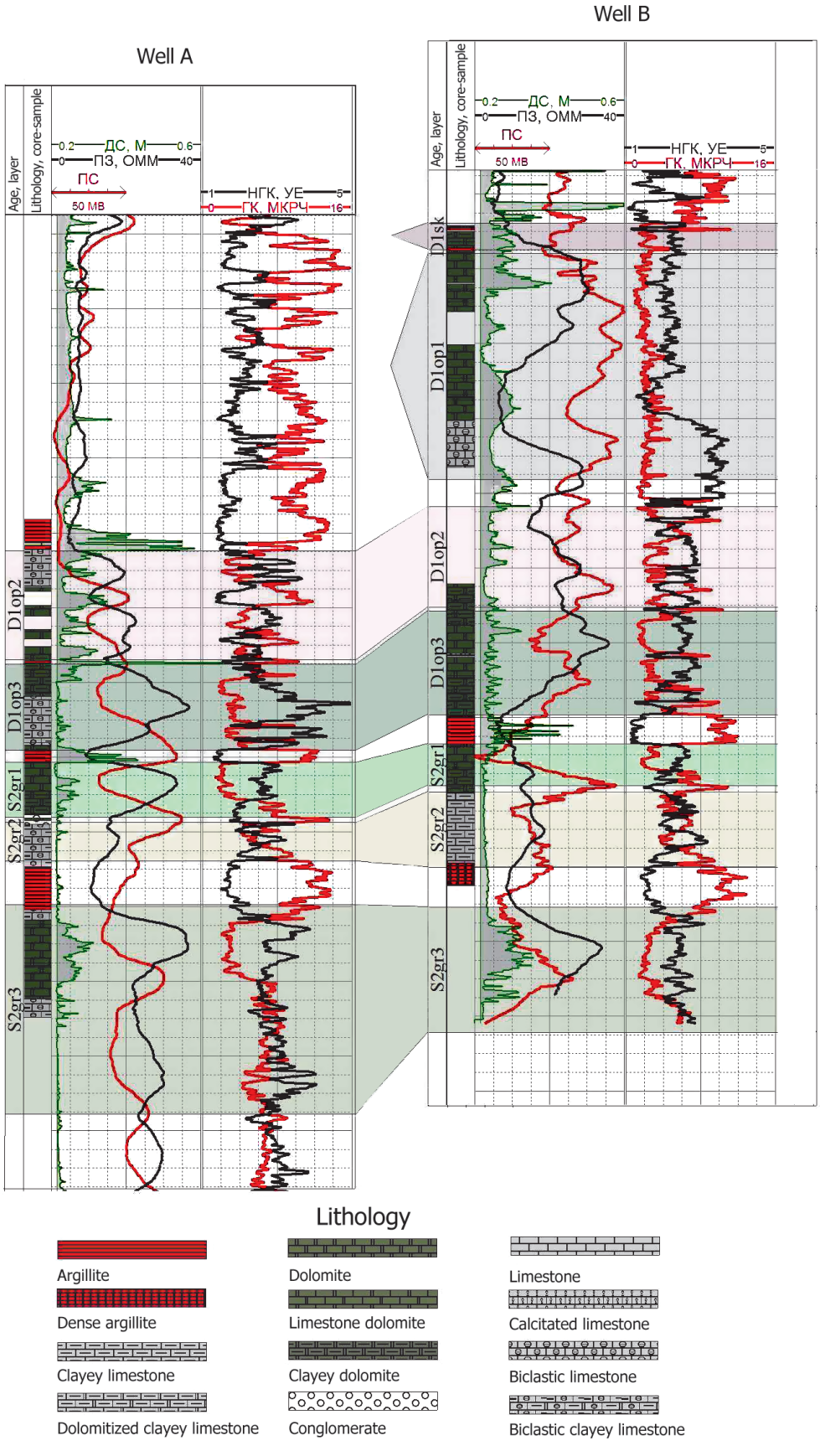

Fig. 1. Correlation scheme for wells A and B

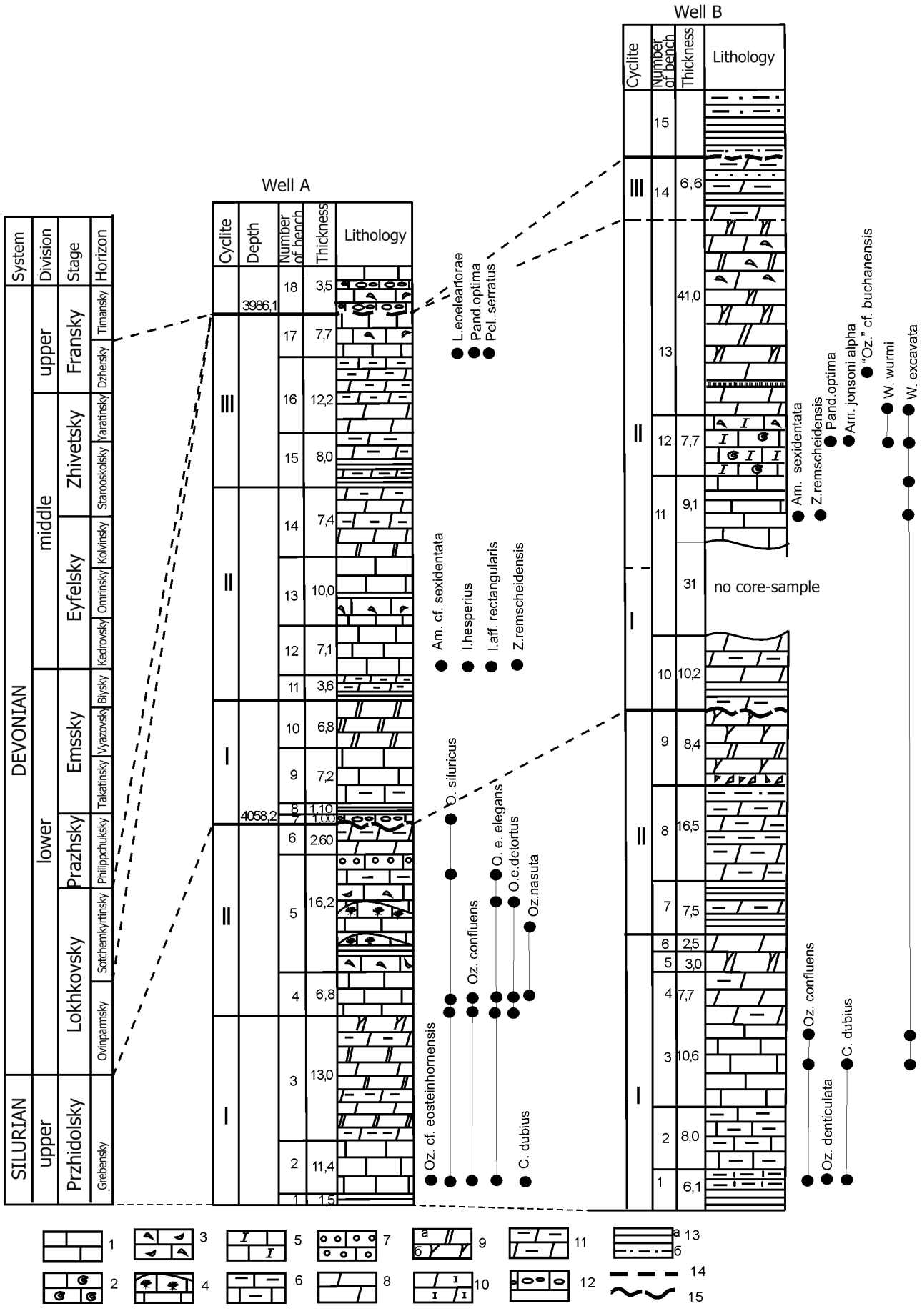

Fig. 2. Correlation of geological sections along wells A and B. Conodont distribution in sections. 1-6 – limestones: 1 – layered, 2 – organogenic, 3 – bioclastic, 4 – biohermic, 5 – dolomite, 6 – clayey; 7 – oolitic; 8-11 – dolomites: 8 – dense, 9a – porous, 9b – cavernous, 10 – calcareous, 11 – clayey; 12 – conglomerates, 13 – a) mudstones, b) siltstones, 14-15 – assumed boundaries: 14 – conformable, 15 – non-conformable.

In limestones, there are structures of landslides, which allow us to assume their formation in shallow-water conditions on the slopes of organogenic structures. Cylite is completed by porous dolomites with significant oil saturation. The thickness of the cyclite is 16.1 m.

The second cyclite contains packs 11-14. Clay-carbonate rocks are laid at its basis (11). They overlap limestones nodular-layered (pacl 12) with conodonts *Icriodus* cf. *hesperius* (Klapper et Murphy), *Icriodus* aff. (Branson et Mehl), *Panderodus unicostatus* (Branson et Mehl), *Zieglerodina remscheidensis remscheidensis* (Ziegler), characteristic of the Lower Lokhkovian of the Lower Devonian. Above the section, limestones are microgranular with interlayers of bioclastic (pack 13). The upper part of the cyclite is represented by alternating dolomites, porous, dense and clay (pack 14), with single interbeds of dolomites with relic biogermic algal texture. The thickness of the second cyclite is 34.0 m.

The third cyclite is incomplete, it includes packs 15-17. The lower part of it is composed of interbedded mudstones and clayey dolomites (pack 15). The upper layers (pack 16) are represented by dolomites as nodular-layered and clayey, ending with clayey limestones interbedded with limestone nodular-layered. In the latter, conodonts of *Amydrotaxis* sp., *Lanea* cf. *eoeleanorae* Murphy et Valenzuela-Ríos, *Pandorinellina optima* (Moskalenko), *Pelekysgnathus* cf. *serratus Jentzsch* are found, common in the Middle Lokhkovian of the Lower Devonian.

The limestones of the Middle Lokhkovian are covered by a pack of intermingling limestone conglomerates and limestones with organogenic detritus, 1.35 m thick. They contain a pack of red-colored terrigenous-carbonate rocks of the Timanian horizon.

In the well B, three cyclites are determined in the Lower Devonian sediments, (Fig. 2). The section of the first cyclite is characterized by a core in an incomplete volume. There is a core of only the lower element of the cyclite. It is represented by dolomites, microgranular dense slightly calcareous, unevenly clayey, with thin interlayers of dark gray clay material. The fragments of the recrystallized shell fauna (pack 10) are found in some places. The second cyclite includes packs 11-13. Pack 11 is composed of limestones microgranular, dense with fragments of shell fauna. As a result of leaching, which occurred along organic residues, a thin porosity is observed. Conodonts *Amodrotaxis* cf. *sexidentata* Murphy et Matti, *Oulodus* sp., *Pelekysgnathus* sp., *Zieglerodina* cf. *remscheidensis* (Ziegler) have been found in limestones, characteristic for the upper part of the Lower Lokhkovian. The upper pack 12 is represented by organogenic limestones. In them conodonts of the Middle Lokhkovian *Amydrotaxis* cf. *jonsoni* (Klapper) *morphotype alpha* Klapper et Murphy, *Pandorinellina* cf. *optima* (Moskalenko) are found. In the next pack 13 – dolomites are unevenly oil-saturated, fine-grained, porous-cavernous with lens-like inclusions of sulfates; silicification is observed. In the fine-grained dolomites, rare conodonts are represented by *Wurmiella wurmi* (Bischoff et Sannemann), and *'Ozarkodina'* cf. *buchanensis* (Philip), *Oulodus* sp. The species '*Ozarkodina' buchanensis* is widespread in the Upper Lokhovian deposits of the Lower Devonian of the Southern Tien-Shan (Bardashev, Ziegler, 1992). The third cyclite completes the Lower Devonian section. It is represented only by the first element of the cyclite, which is formed by dolomite clayey with thin interlayers of mudstone (pack 14).

Taking into account the lithological characteristics of the pack 14 (well B), and also taking into account the findings of the Upper Lokhkovian conodonts *'Ozarkodina' buchanensis* in the pack 13, we can assume the presence of sediments of the lower stratum of the Sochkyrtinskian horizon in the section of well B. This assumption is confirmed in the interpretation results of geophysical data (Fig. 1). The red-colored terrigenous rocks of the Timanian-Sargaevian horizon of the Frasnian stage of the Upper Devonian lie above.

Biostratigraphic dismemberment of well sections by conodonts

Distribution of conodonts in the Silurian-Lower Devonian section of wells A and B is extremely uneven. It largely depends on the facial composition of the rocks. The conditions for the formation of the Silurian and Lower Devonian deposits in the epicontinental Timan-Pechora paleobasin varied from the lagoon to the lower sublittoral of the high sea (Taninskaya, 2010). Changes in sedimentation environments were controlled by sea level fluctuations. The main finds of conodonts are made in layered limestones formed in the conditions of the lower sublittoral. Conodonts are not found in clayey rocks and porous dolomites. The taxonomic diversity of conodonts is small. But they are represented by stratigraphically important species, allowing the dismemberment of the section and its correlation with the standard conodont scale.

Biostratigraphic dismemberment was performed according to the section of the most representative well A and supplemented with materials obtained from well B.

In well A there are biostratigraphic subdivisions in the rank of layers with fauna containing species-indices of the standard conodont scale.

In the Upper Silurian sediments, the following biostratigraphic sequence is established:

Layers with *Ozarkodina* cf. *eosteinhornensis* (Walliser) respond to pack 2. Along with the nominal species in the conodont complex, *Coryssognathus* aff. *dubius* (Rhodes), *Oulodus (= Delotaxis)* cf. *elegans* (Walliser), *Ozarkodina* aff. *cornidentata*

(Branson et Mehl) are found. Species *Ozarkodina* cf. *eosteinhornensis* (Walliser) is a zonal standard conodont zone of the eosteinhornensis of the Przhidolian stage of the Upper Silurian (Melchin et al., 2012).

Layers with *Oulodus* cf. *elegans detortus* (Walliser) are highlighted in packs 4-5. *Oulodus* cf. *elegans* (Walliser), *Ozarkodina* cf. *confluens* (Branson et Mehl), *O.* aff. *nasuta* (Viira), *Oz.* cf. *denticulata* (Viira), *Oz.* cf. *swetlanae* (Mashkova) are also found here. The lower boundary of the layers is determined by the appearance of *O. e. detortus*, a zonal species of the detortus zone – the upper conodont zone of the Przidololian stage of the Upper Silurian (Melchin et al., 2012).

In zone B, zonal species of *Ozarkodina eosteinhornensis*, *Oulodus elegans detortus* have not been identified. But the presence of typical Silurian species *Ozarkodina* cf. *confluens* and *Coryssognathus* aff. *dubius* in a section and features of its structure allow us to make a comparison with Przhidolian deposits of well A.

The Lower Devonian sequence includes:

Layers with *Icriodus hesperius* (Klapper et Murphy), *Icriodus* aff. *rectangularis* (Carls et Gandl) are allocated in pack 12. In the conodonts complex, *Zieglerodina remschedensis* (Ziegler) and elements of *Amydrotaxis* cf. *sexidentata* Murphy et Matti are also present. Finds here of the early species of *Icriodus* define the lower reaches of the Lokhkovian stage of the Lower Devonian. *Icriodus hesperius* is a zonal species of the conodont zone of the same name, which is the lowest zone of the Lower Lokhkovian of the Lower Devonian (Becker et al., 2012). Types of *Icriodus* aff. *rectangularis* (Carls et Gandl) and *Amydrotaxis* cf. *sexidentata* Murphy and Matti appear somewhat later at the end of the I. hesperius zone. The joint finding of these taxa shows that the given interval of the section is not the basis of the Devonian. The layers are compared with the upper part of the hesperius zone of the Lower Lokhkovian of the Lower Devonian. A complex of conodonts with *Amydrotaxis* cf. *sexidentata* Murphy et Matti, *Zieglerodina remschedensis* (Ziegler) was found in the well B in the pack 11 (Fig. 2), which can be compared with the upper part of the zone hesperius – the woschmidti zone of the Lower Lokhkovian.

Layers with *Lanea* cf. *eoeleanorae, Pandorinellina optima* are identified in the pack 17. The identified cosmopolitan conodonts, their presence in the complex, determines the assignment of these layers to the Middle Lokhkovian of the Lower Devonian (the conodont zones of the omoalpha-eleanorae of the standard scale). Based on the conodont data, the volume of the Lower Devonian in the well A corresponds to the Lower-Middle Lokhkovian. In the well B, Middle Lokhkovian beds are characterized by the species *Amydrotaxis* cf. *jonsoni* (Klapper), *alpha morphotype* Klapper et Murphy, *Pandorinellina* cf. *optima* (Moskalenko). Species have a wide geographical distribution and are characteristic of the Middle Lokhkovian of the Lower Devonian. In the section of the well, an evolutionary sequence of species of Amydrotaxis is observed (Murphy, Matti, 1982).

In the well B, younger layers with *'Ozarkodina'* cf. *buchanensis* (Philip). This species was encountered at the top of the Middle and Upper Lokhov formations of the Shishkat section in the Southern Tien Shan (Bardashev, Ziegler, 1992). The Lower Devonian deposits cover the red-colored terrigenous deposits of the Upper Devonian.

Characteristics of the Silurian-Lower Devonian boundary

In accordance with the developed models of sedimentogenesis for the Late Silurian - Early Devonian time, the Silurian-Lower Devonian boundary within the Bolshezemelsky Arch is of a transgressive nature. A sharp drop in sea level at the end of Przhidolian time led to a partial erosion of the deposits of the Przhidolian stage, expressed in the development of erosion surfaces in the dolomites, a reduction in their capacity. The beginning of the transgressive stage is reflected in the formation of dark-colored clay rocks at the base of the Lower Devonian deposits; sometimes basal conglomerates are noted (Yur'eva, Valiukevichus, 2014; Taninskaya, 2010).

Since the sections of the wells do not have a layered faunistic characteristic, the boundary is established with some degree of conventionality. Lithologically, it is expressed by a sharp change in the porous, clayey and cavernous dolomites lying in the roof of the Grebenskian horizon, dark-colored clayey rocks at the base of the lower Devonian, sometimes with basal conglomerates, as in well A. Biostratigraphically, the boundary is characterized by the disappearance of characteristic Silurian fauna species and the appearance of the Lower Devonian conodontic fauna in overlying layers.

Conclusion

As a result of the conducted studies, it was established that the Upper Silurian-Lower Devonian and Upper Devonian structural complexes participating in the section of wells A and B are separated by a surface of deep erosion non-conformity covering the interval from the Praghian stage of the Lower Devonian to the Djierian horizon of the Frasnian stage of the Upper Devonian inclusively.

In sections of the Grebenskian horizon of the Przhidolian Stage of the Upper Silurian and the Ovinparmian horizon of the Lokhovian Stage of the Lower Devonian, a conodont sequence is established in the wells, comparable to the standard conodont scale. Two biological subdivisions with layers of fauna in the Grebenskian horizon and two in the Ovinnparmian horizon were identified.

The Silurian-Devonian boundary, discovered by the investigated wells, has a transgressive character, expressed by a sharp change in porous and cavernous dolomites by argillites and clay-carbonate rocks. In the well A at the level of the Silurian-Lower Devonian boundary, there is a layer of basal conglomerates.

The deposits of the Upper Silurian, the Lower Devonian, are cyclical. The presence of reservoir rocks - porous and porous-cavernous dolomites formed during regression, screened by layers of impenetrable clay rocks formed in transgressive stages, creates favorable conditions for the accumulation of oil.

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