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BRACHIOPODS AS INDICATORS OF THE UPPER DEVONIAN FRASNIAN SEDIMENTATION IN THE TIMAN-PECHORA OIL AND GAS PROVINCE

Bakulina L.P., Dovjikova Y.G.
Ukhta State Technical University, Russia
Komi Republic, Ukhta, Pervomaiskaya str., 13: luda5200@bk.ru, dovzh57@yandex.ru

Summary. The paper describes faunal complexes formed in the north of the European part of Russia under different facies conditions during the Frasnian stage of the Upper Devonian period. The main inhabitants of the Frasnian sea basin were cephalopods – ammonoids and bactritoids, characterized by a rich species diversity of brachiopods, ostracods, bivalves, echinoderms, conodonts, coniconchians and radiolarians. These complexes are somewhat similar to the Frasnian complexes of the Russian Platform and the Western slope of the Ural Mountains. A particularly important role in the division of the Frasnian sections played brachiopods – inhabitants of the 30-200 m depth intervals of the warm shallow-water basins with normal salinity. Characterized by characteristic bi-valve, bilaterally symmetrical shells with different relief, these brachiopods are the most important indicator of the physicochemical conditions of sedimentation. To date, more than sixty brachiopod species with different shapes, sizes and shell surface structures have been detected and described in the Upper Devonian Frasnian stagsse of the Timan-Pechora oil and gas province.

Each substage, horizon and formation of the Frasnian stage is characterized by its own set of brachiopod species distinguished for their specific morphological features. It brings to a conclusion that the studied rocks had been formed under different facies conditions during four major sedimentation cycles – the Timan (Timan formation), Khvorostan (Ustyarega formation), Semiluk (Domanik and Vetlasyan formations) and Don (Sirachoy and Ukhta formations).

Keywords: *the Frasnian stage, the Timan-Pechora oil and gas province, facies conditions, faunal complexes, brachiopods, sedimentation cycles*

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I. Introduction

The Timan-Pechora oil-gas province is located in the Northeast of the European part of Russia and is one of the most investigated regions of the country (Fig. 1). Hydrocarbon traps of the province are often related to the Frasnian deposits of the Upper Devonian period. These rocks are especially important for investigation, as they often constitute oil and gas bearing strata or serve as collectors for the accumulation of hydrocarbons.

The Frasnian stage of Timan-Pechora oil-gas province represents a structurally complicated strata built by rhythmically interchanging deposits with diverse marine fauna formed in different facies environment. The stage is divided into the Lower, Middle and Upper Frasnian substages.

The Lower Frasnian substage unconformably overlies the older rocks dating back to the Middle Devonian-Upper Silurian and even Proterozoic periods. The substage consists of the Yaran, Dzhierskian and Timanian horizons in the volume of Velyurian, Dzhierskian and Timanian formations (Fig. 2). The Middle Frasnian substage includes Sargayev and Domanik horizons in the volume of Ustyareg and Domanik formations. The Upper Frasnian substage includes Vetlasyan, Sirachoy, Evlanov and Livenian horizons in the volumes of Vetlasyan, Sirachoy and Ukhta formations (Yudina, Moskalenko, 1997).

Main results

The transgression had begun in the Velyurian age, spread from the east and gradually covered vast territories. During the Dzhierskian age, sedimentation was accompanied by the outpouring of basaltic lava and the formation of strata with considerable ash material content. The basin stabilized in the Domanik age. Then it reached the maximum depth of ~100 m in depressions and started to get shallower. The Upper part of the Frasnian sections is constituted by behind-rifting, rifting and continental slope facies, as well as clayey-sulphate strata.

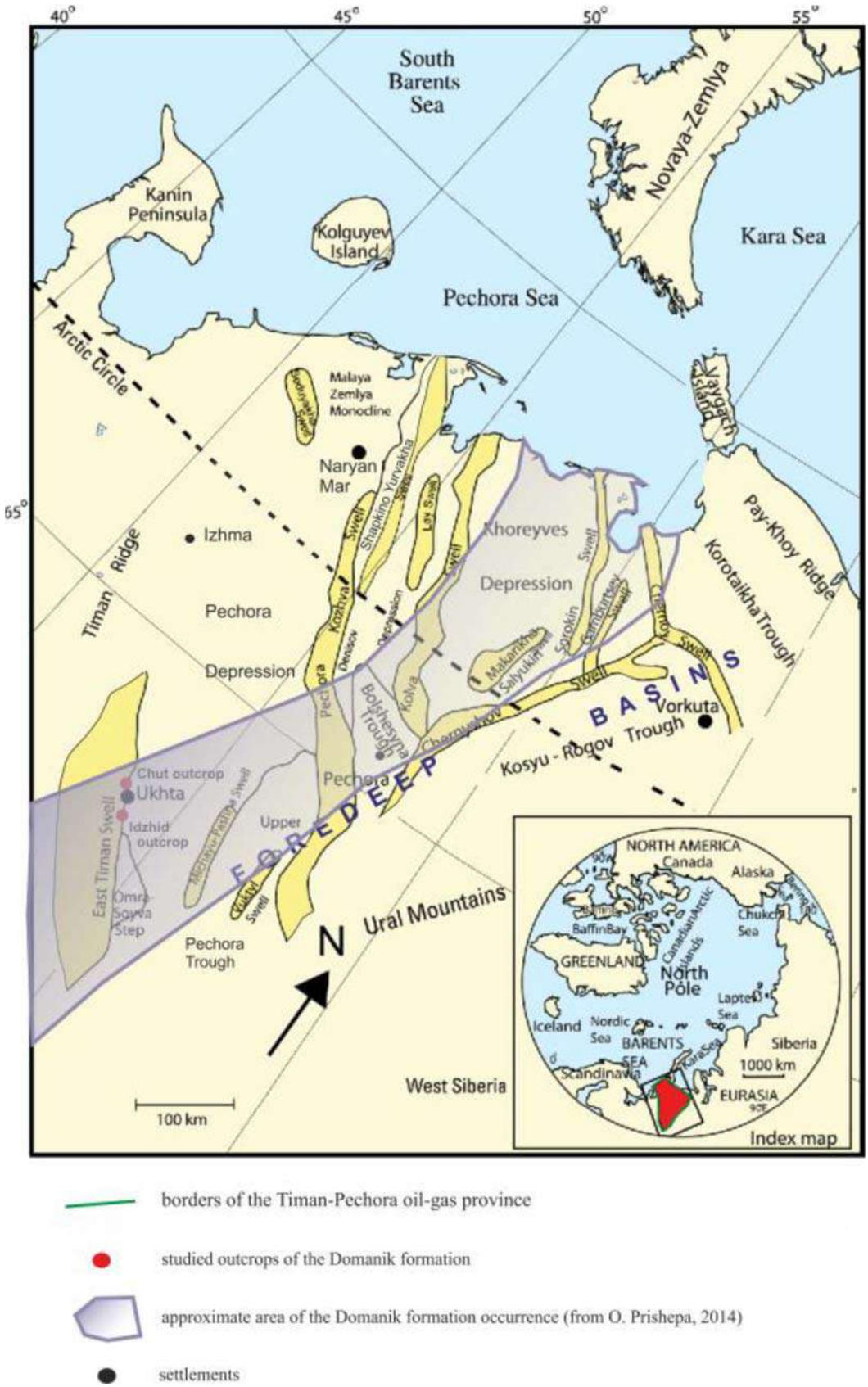

Fig. 1. Location map of the Timan-Pechora basin with indication of the studied outcrops (the map is from Schenk, 2011)

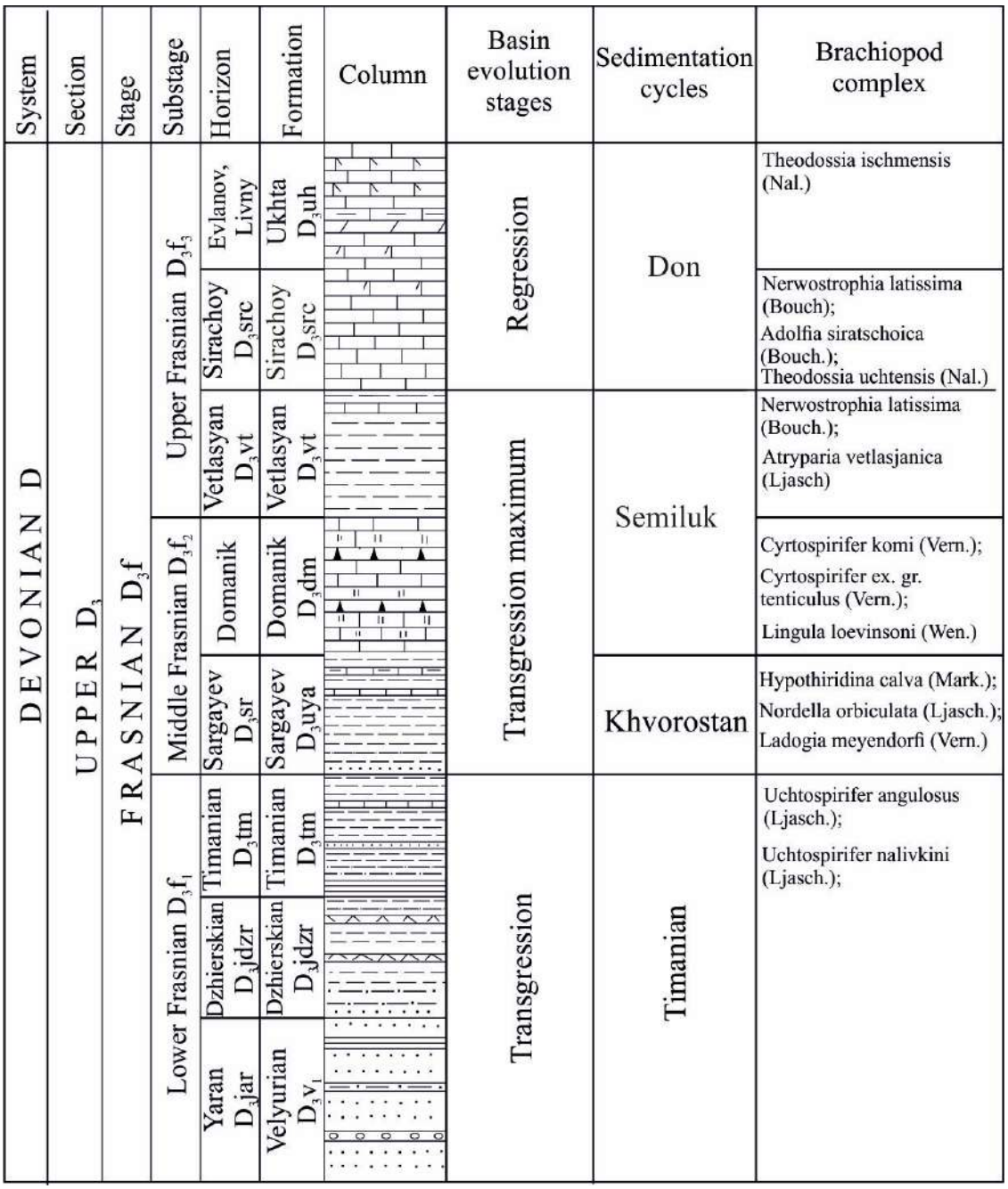

Fig. 2. Schematic structure of Frasnian stage of Timan-Pechora oil-gas province

Faunistic complexes of the stage are very diverse and somewhat similar to the complexes of the Russian platform and the Eastern slope of the Ural Mountains (Yudina, Moskalenko, 1997). There are more than 20 species of ammonoidea, ostracods, bivalves, brachiopods, echinoderms and other organisms identified in these sediments (Fig. 3).

Particularly interesting are brachiopods – the most important archistratigraphic group of the Devonian deposits serving as an indicator for physicochemical conditions of sedimentation. The first ever collections of the Timanian brachiopods were gathered back in 1843 by A.A.Keyserling – outstanding geologist, palaeontologist, traveller and public figure of the 19th century (Keyserling, Krusentern, 1843). It was the brachiopod studies that helped dating the Devonian outcrops of Ukhta as the Late Frasnian series.

Brachiopod ("brachon" – hand, "podos" – leg) is a bivalve symmetrical animal with soft body surrounded by a mantle enclosed in a bivalve shell. The brachiopods are the sessile inhabitants of shallow-water basins with normal salinity and lead an attached lifestyle.

The jointed (articulate) brachiopods – representatives of the class Articulata were the most widespread in the territory of the province. In addition to muscles, the valves of such brachiopods were connected by a lock – a pair of teeth located on the ventral valve symmetrically to the delthyrium – a triangular hole for the leg to exit. On the dorsal valve they corresponded to depressions – dental sockets.

There are more than 60 brachiopod species from 6 orders (Orthida, Pentamerida, Productida, Rhynchonellida, Atrypida, Spiriferida) identified and described in the Frasnian formations. These brachiopods inhabited the sea basin in the Timanian, Ustyareg, Domanik, Vetlasyan, Sirachoy and Ukhta stages of the Late Devonian period (Fig. 3).

It was established that formation of the Frasnian series took place during four large sedimentation cycles (Parmuzina, Borovinsky, 2012), each corresponding to a certain fauna complex and certain brachiopod species.

The first sedimentation cycle (the Timanian cycle) was characterized by a prevalence of Uchtospirifer genus from the order of Spiriferida. The Timanian formation contains fossils of two species, namely Uchtospirifer angulosus (Ljasch.) and Uchtospirifer nalivkini (Ljasch.) (Figs 4, 5).

Fauna / horizon	D_3dzh	D_3tm_1	D_3tm_2	D_3ujr	D_3dm	D_3vt	D_3src	D_3uh
Ammoniidea								
Conodonts								
Brachiopods								
Bivalves								
Ichthyofauna								
Ostrocods								
Konikonh								
Entomozoids								
Stromatoporoidea								
Tabulate corals								
Rugose corals								
Crinoidea								
Gastropods								
Pelecypods								

Fig. 3. Frasnian fauna complex

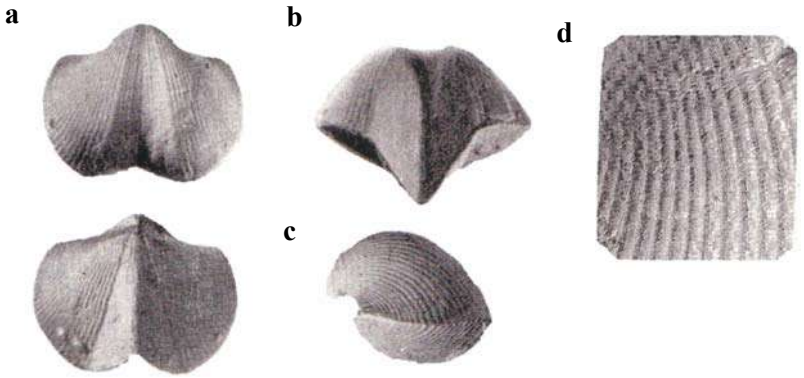

Fig. 4. Uchtospirifer angulosus (Ljasch.) genus:
a – abdominal cusp view;
b – dorsal cusp view;
c – side view; **d** – sculpture of abdominal cusp (40x zoom)

Fig. 5. Uchtospirifer nalivkini (Ljasch.) genus
a – abdominal cusp view;
b – dorsal cusp view;
c – shape of sinus

Representatives of the Uchtospirifer genus have large shells (up to 34 mm) with relatively small pointed top. The sinus is deep, triangular, sharply confined, the saddle is angular, high. They have deep triangular, sharply confined sinus, angular and high saddle. The surface of the lateral slopes is covered with flat rounded radial ribs separated by much narrower gaps.

The Uchtospirifer nalivkini genus is also distinguished by large shells (up to 30-40 cm). But differs in the shape of the sinus – the sinus is trapezoidal-rounded with a flattened bottom in the front part (Fig. 5).

The second sedimentation stage (Khvorostan cycle) corresponding to the formation of the Ustyareg formation is marked by a predominance of the genuses Hypothiridina calva (Mark.), Nordella orbiculata (Ljasch.) and Ladogia meyendorfi (Vern.). All cited forms have large biconvex shells (Fig. 6). The genus Hypothiridina calva (Mark.) is characterized by a broad sinus with a high flat uvula with rough sculpture in the form of ribs and furrows (a), Ladogia – by a large sinus ending in a high angular uvula with numerous thin ribs (b). In the genus Nordella the surface of the shell is almost smooth, at a detailed study the lamellar lines of accretion covered with concentric rows of elongated tubercles are traced (c). In the genus Nordella, the surface of the shell is almost smooth, during detailed study plate lines of growth covered with concentric rows of elongated tubercles are traced (c).

The biconvex shape of shells with rough ribs is characteristic for inhabitants of the sandy bottom, smooth surface and thin ribs – for brachiopods living among thin sediments. During the Timanian and Ustyareg time, there was a shallow-water sea basin with normal salinity where mainly sand-clay sediments were accumulated. The Semiluk sedimentation stage corresponds to the formation of the Domanik and Vetlasyan formations. The Domanik formation is built by bitumen-siliceous-carbonate rocks emerged under the conditions of uncompensated sedimentation in the isolated Domanik depression (Bakulina, Dovjikova, 2021; Максимова, 1979) located far enough from the seacoast.

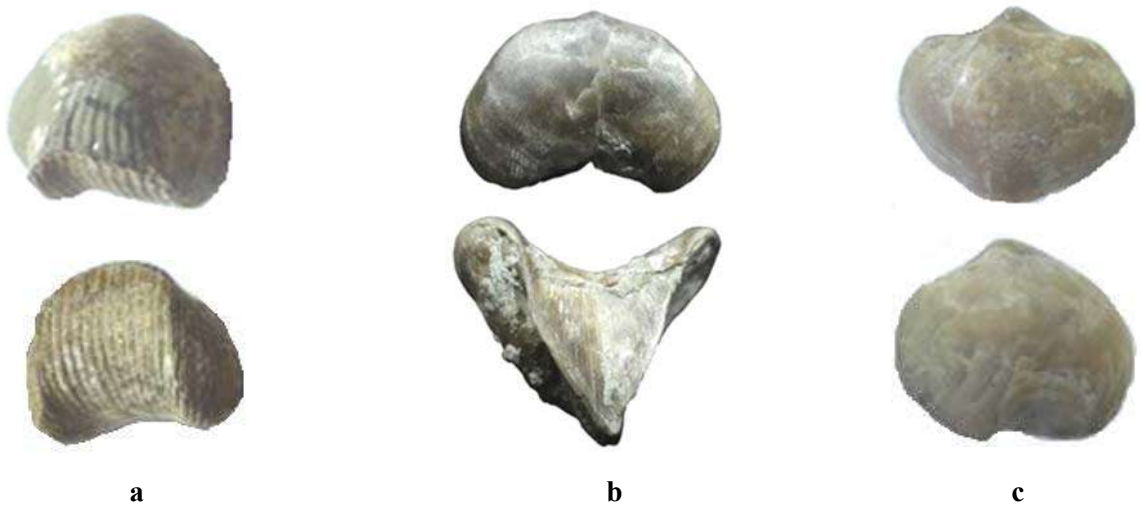

Fig. 6. Dominant brachiopods during Khvorostan sedimentation cycle:
a. Hypothiridina calva Mark. with wide sinus and pronounced sculpture;
b. Ladogia meyendorfi (Vern.) with tall angular sinus;
c. Nordella orbiculata with smooth surface

Typical fauna of the stage are the representatives of the Spiferida order, the genus Cyrtospirifer komi (Ljasch.) and the genus Cyrtospirifer ex. gr. tenticulus (Vern.), inhabitants of the enviroment with thin sediment.

The limestones of the Domanik formation also contain the inarticulate brachiopods – the genus Lingula loevinsoni (Wen.), belonging to the Lingulida order of the class Inarticulata. In the limestones of the Domanic formation they form numerous accumulations along the bedding planes (Fig. 7). These are inhabitants of shallow waters, littoral zone and upper part of sublittoral – from the water's edge to a depth of about 20-25 m, in exceptional cases they reached a depth of 100 m. The appearance of the genus Lingula loevinsoni (Wen.) in limestones indicates a change in the salinity of the sea basin. A special condition of the Domanik basin – an increased concentration of silicic acid – had depressing effect on the fauna and caused mass extinctions of organisms during sedimentation.

Fig. 7. Chitinous-phosphate shells of Lingula loevinsoni (Wen.) genus enclosed in limestone of the Domanik formation (10x zoom)

The Vetlasyan deposits correspond to the regressive stage of evolution of the Frasnian basin, when, under conditions of low sea level, clayey and silty material was carried out, filled the depression, smoothing the relief. The Vetlasian formation is a typical clinoform with a poor brachiopod complex, corresponding to the Nerwostrophia (Stropheodonta) latissima (Bouch.) – Adolfia siratschoica (layers with Atryparia vetlasjanica) zone. The brachiopods are accumulated mainly in the upper part of the formation.

The Sirachoy and Ukhta formations are the result of the Donian stage of sedimentation, allocated in the territory of the Timan-Pechora province. The stage is characterized by discontinuous reduction of the sedimentation area and the area of the sea with normal salinity.

The Sirachoy formation represents predominantly carbonate strata built by limestones, clayey limestones with the interlayers of sandstones and clays. The upper part of the formation is dolomitized, forming typical backreef shallow-shelf facies. According to the brachiopod complex, the formation is divided into the following two components: 1) the lower subformation corresponding to the zone of Nerwostrophia latissima (Bouch.) – Adolfia siratschoica (layers with Atryparia siratschoica); 2) the upper subformation corresponding to the zone of Theodossia (layers with Theodossia uchtensis).

The Ukhta formation corresponds to the final phase of the Donian regressive cycle. The lower part of the formation is built by carbonate rocks with the interlayers of clays and sandstones, and the upper – by sulphides. The brachiopod complex is poor, corresponding to the zone of Theodossia with the layers of Theodossia ischmensis (Nal.).

Most of the Theodossia genus representatives is characterized by smaller shells. A decrease in the size of the shell can be caused, firstly, by a change in the temperature of the basin water, and secondly, by a change in its salinity. It is known that in conditions of relatively high water temperature, the development and all life processes of bionts proceed most intensively. Inhabitants of warm seawaters early reach their sexual maturity due to rapid development and the growth of these organisms stops or sharply slows down. Therefore, specimens living in cold seas have larger shells than those living in tropical waters. More or less significant deviations from the normal seawater salinity in the direction of its increase or decrease also cause a decrease in the sizes of marine organisms. Reduction in sizes of the invertebrates and, respectively, their shells is conditioned by less intensive metabolism under desalting and salinization environment.

Conclusion

Therefore, each formation corresponds to a certain complex of brachiopods with well-defined shapes and surface sculpture, characterizing different conditions of the sedimentation.

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БРАХИОПОДЫ – ИНДИКАТОРЫ ОСАДКОНАКОПЛЕНИЯ ФРАНСКОГО ЯРУСА ВЕРХНЕГО ДЕВОНА ТИМАНО-ПЕЧОРСКОЙ НЕФТЕГАЗОНОСНОЙ ПРОВИНЦИИ

Бакулина Л.П., Довжикова Е.Г.

Ухтинский государственный технический университет, Россия

Республика Коми, Ухта, Первомайская ул., 13: luda5200@bk.ru, dovzh57@yandex.ru

Резюме. В работе рассмотрены комплексы фауны франского яруса верхнего девона севера Европейской части России, сформировавшиеся в различной фациальной обстановке. Отложения франского возраста на территории провинции характеризуются стратиграфической полнотой и представлены сложными по литологическому составу осадочными породами морского генезиса, содержащими большое количество ископаемых остатков хорошей сохранности. Основными обитателями франского морского бассейна были головоногие моллюски – аммоноидеи и бактритоидеи, отличающиеся значительным многообразием видов; брахиоподы, остракоды, двустворки, иглокожие, конодонты, кониконхии и радиолярии. Эти комплексы несколько похожи на франские комплексы Русской платформы и Западного склона Урала. Особенно важную роль для расчленения разрезов франских отложений играют брахиоподы, обитатели теплых мелководных бассейнов нормальной солености в интервалах глубин 30-200 м, обладавшие характерной двустворчатой двухсторонне-симметричной раковиной с различным рельефом. Они также являются наиболее важным индикатором физико-химических условий осадконакопления. На сегодняшний день во франском ярусе верхнего девона Тимано-Печорской нефтегазоносной провинции диагностировано и описано более шестидесяти видов брахиопод, которые различаются формой, размером и структурной поверхностью раковины.

Для каждого подъяруса, горизонта и свиты франского яруса характерен свой видовой набор брахиопод с их специфическими морфологическими особенностями. Это позволяет сделать выводы, что породы сформированы в различной фациальной обстановке в течение четырех крупных циклов осадконакопления. Каждому циклу соответствует свой фаунистический комплекс, отвечающий определенной обстановке. Это тиманский цикл (тиманская свита), хворостанский (усть-ярегская свита), семилукский (доманиковая и ветласянская свиты) и донской (сирачойская и ухтинская свиты). В работе показано соответствие каждого комплекса брахиопод определенному циклу осадконакопления франского времени.

Ключевые слова: *франский ярус, Тимано-Печорская нефтегазоносная провинция, фациальная обстановка, фаунистические комплексы, брахиоподы, циклы осадконакопления*

TİMAN-PEÇORA NEFT-QAZLI VİLAYƏTİNİN FRAN MƏRTƏBƏSİNİN ÜST DEVON ÇÖKÜNTÜTOPLANMANIN İNDİKATORLARI – BRAXİOPODLAR

Bakulina L.P., Dovjikova Y.Q.

Uxta Dövlət Texniki Universiteti, Rusiya

Komi Respublikası, Uxta şəhəri, Pervomayskaya küç., 13: luda5200@bk.ru, dovzh57@yandex.ru

Xülasə. Hazırkı məqalə Rusiyanın Avropa hissəsinin şimalında, müxtəlif fasial şəraitlərdə formalaşmış Üst Devon dövrünün Fran mərtəbəsinin fauna komplekslərinə həsr olunmuşdur. Timan-Peçora neft-qazlı vilayətində aşkar edilmiş Fran dövrünün çöküntüləri stratiqrafik kəsilişin tamamlığı ilə xarakterizə edilərək litoloji tərkibinin mürəkkəbliyi ilə seçilən və özündə çoxlu sayda yaxşı qorunmuş fauna qalıqlarını saxlayan dəniz mənşəli çöküntü süxurları ilə təmsil olunur. Fran dövrünün dəniz hövzəsinin əsas sakinləri sefalopodlar idi ki, onlar zəngin növ müxtəlifliyi ilə səciyyələnən ammonoid və baktritoidlərlə (braxiopodlar, ostrakodlar, ikiqapaqlılar, exinodermlər, konodontlar, konikonlar və radiolarilər) təmsil olunmuşdur. Sözü gedən komplekslər bir qədər Rusiya Platformasının və Uralın qərb yamacının Fran komplekslərinə bənzəyir. Fran çöküntülərinin kəsilişlərinin bölünməsində normal duzluluqlu isti dayaz su hövzələrinin 30-200 m dərinlik intervallarında yaşayan, səciyyəvi iki qapaqlı, ikitərəfli simmetrik qabığa və müxtəlif relyefə malik braxiopodlar oynayır. Onlar həm də çöküntütoplanma prosesinin fiziki-kimyəvi şəraitinin ən mühüm göstəricisidir. Bu günə qədər Timan-Peçora neft-qazlı vilayətinin Üst Devon Fran mərtəbəsində altmışdan çox braxiopod növü aşkar və təsvir edilmişdir ki, onlar qabığın forması, ölçüsü və struktur səthi ilə fərqlənir. Fran mərtəbəsinin tərkibində hər bir yarımmərtəbə, horizont və lay dəstəsi özünəməxsus morfoloji xüsusiyyətlərə malik braxiopod

kompleksləri ilə xarakterizə olunur. Bu, süxurların dörd əsas sedimentasiya tsiklləri ərzində müxtəlif fasial şəraitdə yaranma qənaətinə gəlməyə imkan verir. Hər bir tsiklin müəyyən bir mühitə uyğun olan öz fauna kompleksi vardır. Bunlar Timan (Timan lay dəstəsi), Xvorostan (Ust-Yareq lay dəstəsi), Semiluk (Domanik və Vetlasyan lay dəstələri) və Don (Siraçoy və Uxta lay dəstələri) tsiklləridir. Məqalədə hər bir braxiopod kompleksinin Fran mərtəbəsinin müəyyən çöküntütoplanma tsiklinə uyğunluğu göstərilir.

Açar sözlər: *Fran mərtəbəsi, Timan-Peçora neft-qaz vilayəti, fasial şərait, faunistik komplekslər, braxiopodlar, çöküntütoplanma tsikli*