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CORAL BIOSTROMES OF THE UPPER FRASNIAN VORONEZH FORMATION OF THE PRYPIAT TROUGH (BELARUS)

Yu. Zaika
State Enterprise "GEOSERVICE"
53 Yanki Maura St, 220015, Minsk, Belarus
E-mail: cyrtophyllum@gmail.com

This article presents a schematic model of zoogenic sedimentary deposits common in the Voronezh Formation (Upper Frasnian, Upper Devonian) of the Prypiat Trough. Layered carbonate bodies, in which limestone intervals with abundant ramose Tabulate and fasciculate Rugose corals alternate with intervals devoid of coral remains, represent them. These structures are considered multilayered coral biostromes. Certain features of the deposits and the preservation of coral skeletons within them indicate an active sedimentation environment, particularly the influence of hydrodynamic and, likely, seismic factors. It is suggested that the multilayered biostromes may have been confined to active fault zones of the Voronezh time.

Keywords: subframework coral bank, multilayered coral biostrome, Tabulata, Rugosa, Upper Frasnian, Devonian, Prypiat Trough.

INTRODUCTION

Carbonate sedimentary formations in which rock-forming organisms play an important role are of considerable interest in the Upper Devonian of the Prypiat Trough (southeastern Belarus), both for biostratigraphic purposes and in terms of their potential reservoir properties. They have been studied with varying detail, and the least studied are the zoogenic deposits of the Frasnian Stage. This topic is the subject of this article, which partially complements and expands on the rather brief information provided by previous authors.

According to Makhnach et al. [1], zoogenic sedimentary bodies were uncovered by drilling in the Upper Frasnian Voronezh Formation in the Prypiat Trough, the main rock-forming organisms in which are corals. They were confined mainly to the lower part of the Voronezh Formation. Their most common varieties were characterized as "subframework banks" and "multilayered biostromes", formed under conditions of seabed transformation caused by early rift processes during the formation of the Prypiat Trough.

The deposits of the subframework banks contain accumulations of ramose and fasciculate Rugose and Tabulate corals, which generally remain isolated and do not form a coherent framework. This does not allow the term "coral buildups" to be fully applied to these formations.

The multilayered biostromes are represented by vertical alternation of probably the same subframework coral banks, forming up to seven or more intervals up to 0,5 m thick each, separated by "empty" limestone intervals without coral skeletons [1]. The incompleteness of the borehole core recovery does not allow an exact assessment of the thickness of the biostromes; apparently it reached a maximum of a few meters. It is also difficult to estimate their horizontal dimensions.

The study of this type of organogenic deposits based on core materials allowed the author to supplement the knowledge of rock-forming organisms, paleoecology and the structure of coral communities of the Voronezh time.

MATERIAL AND METHODS

The studied material comes from the boreholes Khobninskaya-3R, Khobninskaya-4R, Barovichskaya-1, Marmovichskaya-1, Karpovichskaya-1 and Prudokskaya-1, drilled in the central and northern parts of the Prypiat Trough (South East of Belarus). The core material obtained in previous decades has only partially survived to the present day, so studying the entire sequence of cores from these wells is no longer possible.

The available core samples were studied mainly on their longitudinal sections. To improve visibility, the sections were polished and coated with varnish.

A rough estimate of the ratio of the volume of coral skeletons to the total volume of the enclosing cores is based on measuring the cross-sectional area of the coral skeletons relative to the total longitudinal cross-sectional area of the cores.

RESULTS OF THE STUDY

Brief description of the deposits. The deposits are represented by bluish- and greenish-gray clayey limestone and brown dolomitized limestone. They usually have a "lumpy" texture and sporadically contain inclusions of bituminous argillaceous material. Some samples consist of dark-gray argillite-like bituminous limestone with foliated texture.

The limestones are characterized by numerous skeletons of fasciculate and ramose corals: Rugosa (0,4–0,6 cm in diameter), and Tabulata: *Alveolitella* (up to 0,5–1,5 cm in diameter) and *Aulopora*. The latter are both scattered in the sediment as well as overgrow the skeletons of other corals. Corals altogether make up a maximum of 35 % of the core volume (as measured on the cross-sectional area of the corals on borehole core sections). Among them Rugose corals predominate.

The sediment matrix consists of micritic material with scattered remains of invertebrate skeletons. Debris also forms lenses and other accumulations, in which fragments of brachiopods and other shell fauna are distinguishable. Comparatively complete brachiopods also occur.

In general, the limestone is classified as floatstone and bafflestone (*sensu* [2] and [5]). The latter term is used because the corals do not grow together to form a solid framework, so the term "framestone" is not entirely appropriate.

Rock-forming organisms. The prevailing faunal component is Rugose corals, represented mainly by *Peneckiella minima* (Roemer), *P. fascicularia* (Soshkina) and *P. jevlanensis* Soshkina (plate 1, figs. 1–9). Systematic position of one more representative of the Rugose corals, previously conditionally attributed to *Ivdelephyllum* sp. [6], will be clarified in another publication.

In the subframework coral banks, Rugose corals appear to form clusters consisting predominantly of one species.

Among Tabulata, *Alveolitella fecunda* (Salée) (plate 1, figs. 2, 5) and *Aulopora* sp. (plate 1, figs. 7, 9) are identified. *Alveolitella* colonies are represented by sparsely branched and unbranched subcylindrical coralla of comparatively small size.

Aulopora corals are an abundant component of the considered biostromal coral community. They are attached to detrital particles and grow onto surfaces of Rugose and *Alveolitella* corals. In addition, a scattered presence of *Aulopora* in the sediment is characteristic: these are probably microcolonies consisting of several corallites attached to small particles of debris, as well as sparse chains of corallites spreading along the surface of the soft bottom. *Aulopora* overgrowing corallites of Rugosa in some cases forms *Mastopora*-like pseudocolonies up to 0,7 cm in diameter (plate 1, fig. 7). Apparently, the *Aulopora* from the studied core samples is represented by a single species, which is highly variable. It is not certain whether it belongs to any of the already known *Aulopora* species.

Overturned *Alveolitella* and Rugose corals oriented in different directions dominate the studied core samples. This is especially noticeable by the variable orientation of the long axes of *Peneckiella* and "*Ivdelephyllum*" corallites. Together with the lumpy texture of the limestone, this may indicate increased activity of the environment. Makhnach and al. [1] expressed a similar opinion. The cited research also indicates that in the subframework banks of the Voronezh Formation, the proportion of coral skeletons preserved in life position does not exceed 25 %. Nevertheless, there are core samples with all corals in life positions as well (plate 1, fig. 4). The small size of the corallites of such corals, however, indicates a short duration of episodes of stable conditions. The influence of active hydrodynamics may be evidenced by accumulations of skeletal debris (plate 1, fig. 6), the occurrence of which is explained by water sorting.

The effect of the seismic factor on the sedimentation conditions, which could be associated with processes of formation of the Prypiat Trough, cannot be ruled out as well. This factor is considered as one of the possible reasons for the observed inverted occurrence of coral skeletons in the sediment. The probable seismic impact may also be indicated by the "suspended" in the sediment occurrence of coral skeletons oriented in all directions. Such an occurrence could have arisen because of liquefaction of the sediment.

Depositional environment and facies. The relatively small size of corals and their prevailing overturned occurrence indicates their short lifespan in unstable conditions. Inclusions of coral-bearing limestone embedded in foliated bituminous limestone (plate 1, fig. 1) – apparently, displaced fragments of coral biostromes – are a possible sign of sediment slumping or sediment removal from relatively elevated areas occupied by biostromes. The cause of this could be either hydrodynamic or seismic, or both. Significant hydrodynamic activity is also indicated by oriented arrangement of isolated brachiopod valves in bituminous limestone (plate 1, fig. 1) (according to [4]). The listed features probably denote frequent and irregular sediment supply, its removal from protruding areas of the bottom, and the stirring up of the settled material. The preceding authors [1; 3] have already made some of these assumptions.

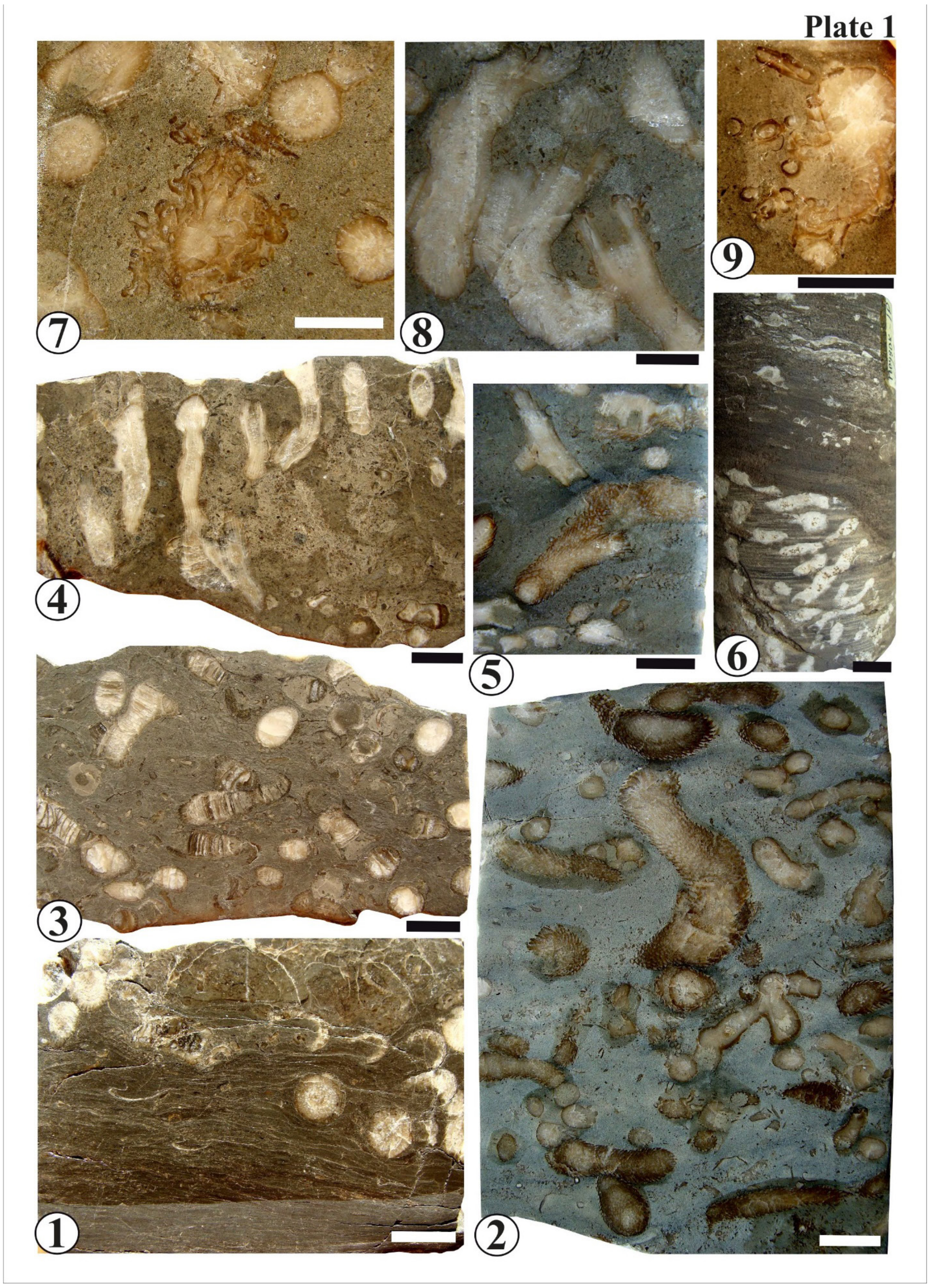


Plate 1 – Drill core material of the subframework coral banks of the Upper Frasnian Voronezh Formation (Prypiat Trough, South East of Belarus)

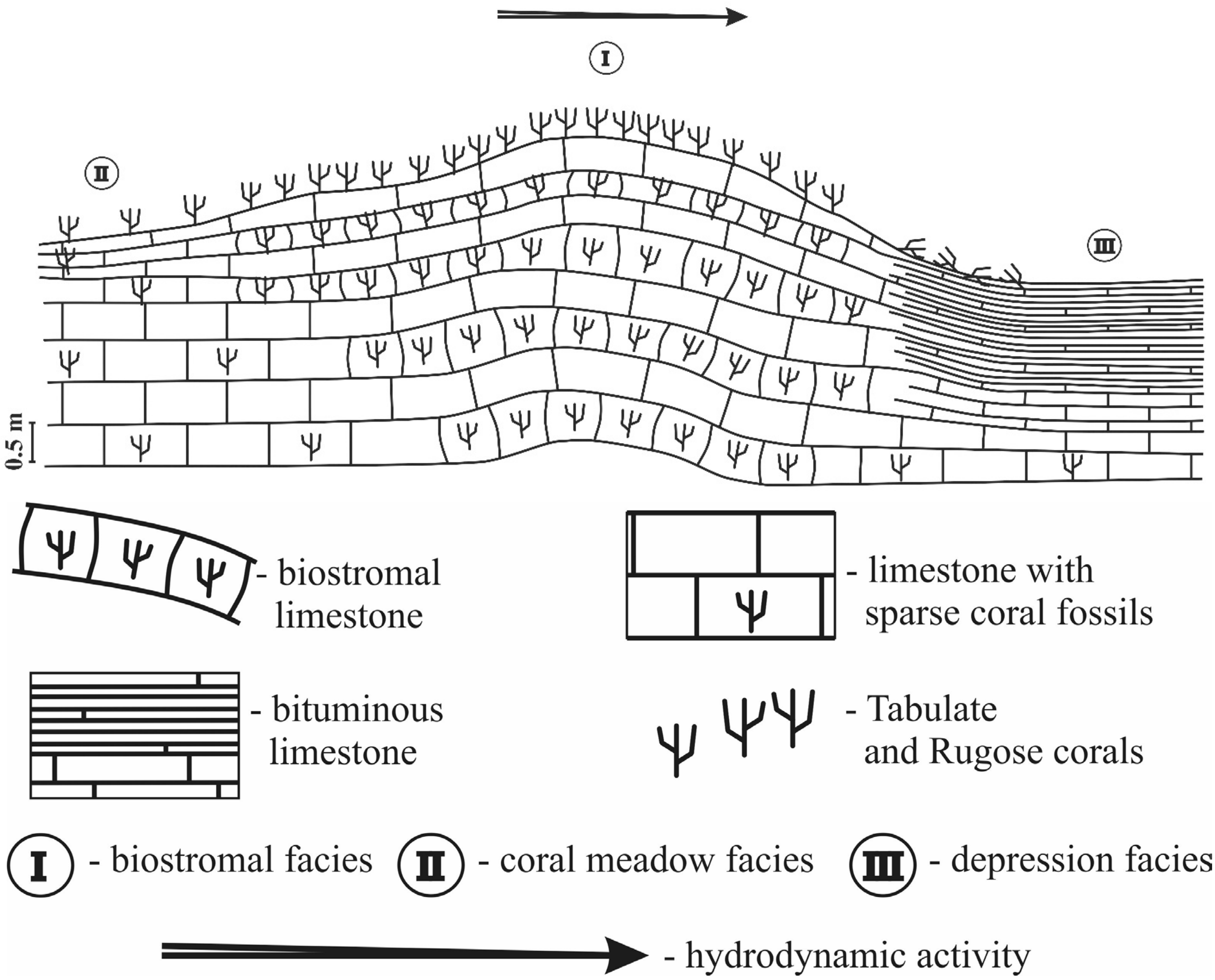
1 – Foliated bituminous limestone with inclusions of fine-detrital limestone, overturned corallites of *Peneckiella fascicularia* (Soshkina) deforming the sediment foliation and enveloped by it, and brachiopod valves oriented parallel to the foliation (left central part of the figure), Karpovichskaya-1 borehole, depth 4624–4630 m. **2** – Clayey micritic limestone with skeletal detritus accumulations, with *Alveolitella fecunda* (Salée), *Aulopora* sp. and *Peneckiella minima* (Roemer), Khobninskaya-3R borehole, depth 3223–3225 m. **3** – Clayey limestone with scattered skeletal detritus, with *Peneckiella jevlanensis* Soshkina and *Aulopora* sp., Marmovichskaya-1 borehole, depth 3910–3923,5 m. **4** – Fine-detrital limestone with *Peneckiella fascicularia* (Soshkina) (Rugosa) in life position, Marmovichskaya-1 borehole, depth 3896–3910 m. **5** – Clayey micritic limestone with skeletal detritus accumulations, with *Alveolitella fecunda* (Salée) and *Aulopora* sp. attached to it (central part of the figure), *Peneckiella minima* (Roemer) overgrown by the lamellar form of *Alveolitella fecunda* (Salée) (upper part of the figure), Khobninskaya-4R borehole, depth 3378–3393 m. **6** – Dolomitized argillaceous limestone, in the lower part – lumpy limestone with Rugosa enveloped by thin-layered limestone in the center of the core sample, accumulation of skeletal detritus and scattered *Aulopora* sp. in the upper part of the core sample, Prudokskaya-1R borehole, depth 4119–4145 m. **7** – *Aulopora* sp. on Rugosa corallite, Khobninskaya-4R borehole, depth 3378–3393 m. **8** – Longitudinal section of Rugosa corallum and a Rugosa corallite with *Aulopora* sp. on the surface of its calice, Khobninskaya-4R borehole, depth 3378–3393 m. **9** – *Aulopora* sp. pseudocolony on Rugosa corallite, Barovichskaya-R1 borehole, depth 1524–1528 m. **1–5, 7–9** – Longitudinal sections of cores, **6** – external surface of core sample. Scale bars: 1,0 cm (**1–6**), 0,5 cm (**7–9**).

Thus, a typical "multilayered coral biostrome" is a layered sedimentary body composed of coral-bearing bands alternating with intervals of sediment were corals are lacking. Such a layered formation reflects the discontinuity of sedimentation and periodic alterations in its intensity.

Apparently, in a subframework coral bank fasciculate and ramose Rugosa and Tabulata formed dense thicket-like populations that fixed the accumulating sediment. This could have led to the formation of a small elevation due to the development of new coral individuals on the retained accumulations. With the influx of large amounts of sediment or with its acceleration, the coral populations could have been partially or completely buried. Subsequently, this relatively elevated area of the bottom, fixed by the skeletons of corals, served as a place for their new settlement and formation of a new subframework coral bank.

Previously, a community type of the "coral meadow" was indicated from the Voronezh Formation of the Prypiat Trough [6]. These were comparatively sparse coral populations, consisting mostly of *Aulocystis tikhyi* Sokolov (Tabulata) and several species of *Peneckiella* (Rugosa). Apparently, in suitable conditions, the coral meadows could transition into the subframework coral banks. It is characteristic that *Alveolitella fecunda* (Salée) is confined specifically to coral biostromes, and not to coral meadows.

Text-figure 1 shows a schematic representation of the proposed model of the multilayered coral biostrome of the Voronezh Formation.



Text-figure 1 – Hypothetical schematic section of a multilayered coral biostrome

Taking into account the above data, it is possible to assume the occurrence of the following three facies associated with coral biostromes in the Prypiat Trough during the Voronezh time.

I – coral biostrome facies: massive and argillaceous detrital limestones with lumping textures, with a large number of fasciculate Rugose, ramose and auloporoid Tabulate corals. Coral thickets trapped the accumulating sediment, probably creating a slight rise above the bottom.

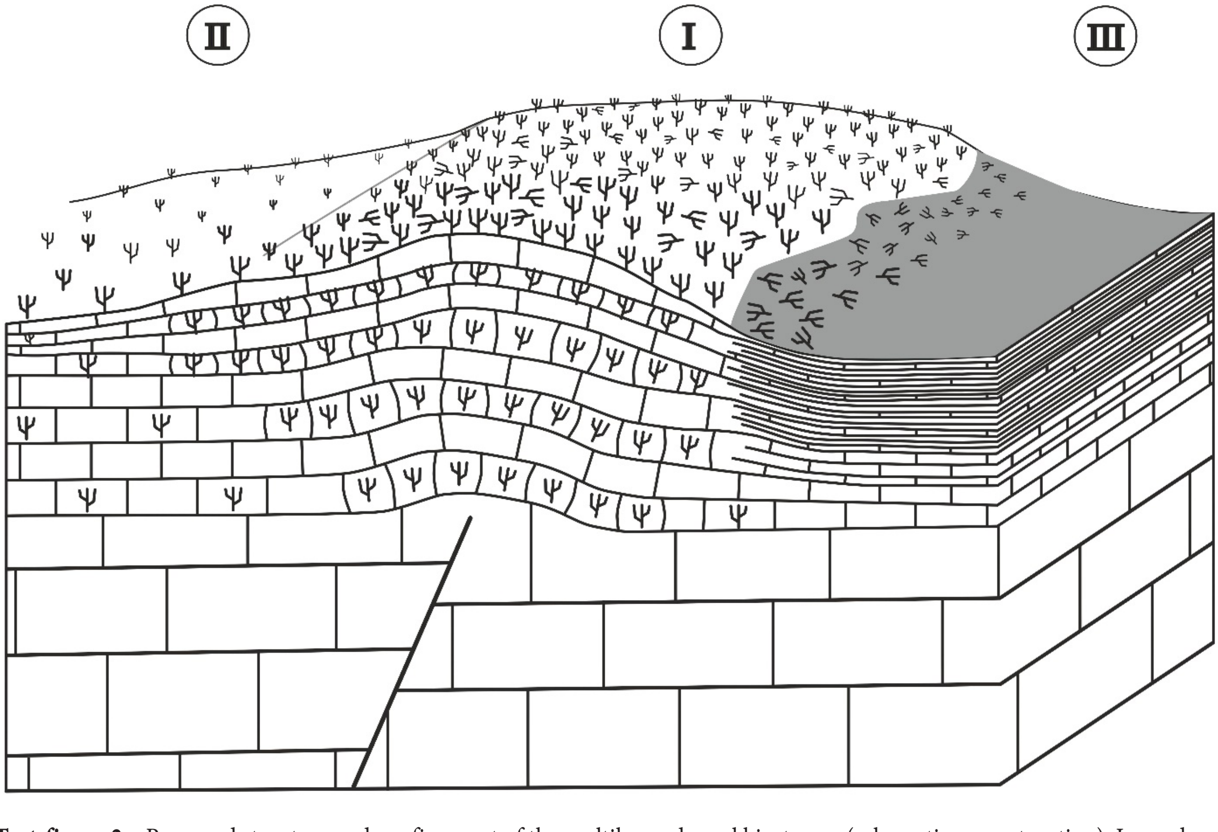
II – coral meadow facies: clayey limestones with detrital inclusions, with comparatively sparse fasciculate Rugosa and with Auloporids (Tabulata).

III – depression facies: bituminous argillaceous carbonate deposits with inclusions of reworked limestone fragments and corals, probably removed from adjacent coral biostromes. The supposed proximity of this facies to biostromes may be not only spatial, but also genetic. Namely, the coral thicket could retain larger sediment particles, while the smallest fraction accumulated in the adjacent depression.

This reconstruction of the facies sequence is largely tentative, since it is based on the study of discrete borehole material. It also remains unclear what was the initial cause of the formation of the biostromes, and what the initial stage of their growth looked like.

When considering the answers to these questions, the following assumptions can be made. It is quite possible that the coral banks, which hardly projected significantly above the bottom level, could not create an effective filter by which the bituminous deposits of the depression facies (III) could separate and accumulate. However, coral banks, confined to an existing bottom elevation initially expressed to a sufficient degree in the bottom relief, could have become such a filter. Coral thickets on this elevation could have captured organic detritus and soil particles carried by water, passing only the finest suspension further. This suspension, including organic matter, settled in the depression of the bottom, where bituminous carbonate sediment was formed behind the coral biostrome.

Considering the active processes of transformation of the bottom relief at the early phase of rifting in the Prypiat Trough, such a supposed elevation could be confined to a fault zone (text-fig. 2). In this case, the vertical alternation of coral bands with intervals of "empty" sediment could reflect vertical movements of the bottom of a tectonic nature. The activation of this section of the bottom, accompanied by seismic events, led to the disturbance of the sediment and the cessation of the existence of a coral bank. The overturning of coral skeletons and the burial of the coral bank under the "empty" sediment accompanied this. A subsequent rise in the sea floor or the onset of a relatively stable episode created the opportunity for the development of a new coral bank.



Text-figure 2 – Proposed structure and confinement of the multilayered coral biostrome (schematic reconstruction). Legend: see text-figure 1

Further study of more material should show how close this version is to reality. If this hypothesis is correct, then the coral biostromes and subframework coral banks described above could have had a significant spatial extent, possibly measured in kilometers. This scale is indirectly evidenced by previously published indications of the "reefogenic" nature of the deposits to which the largest oil fields in the Voronezh Formation of the Prypiat Trough are confined [1].

CONCLUSIONS

The impossibility of making direct observations of the objects under study makes all conclusions to a certain extent conditional. The studied deposits in the Prypiat Trough occur at a depth of several kilometers and can only be reached by boreholes.

It should be assumed that the occurrence of massive coral framework structures in the Upper Frasnian Voronezh Formation of the Prypiat Trough is unlikely, which is due to the sedimentation environment. Instead, multilayered zoogenic sedimentary bodies were formed, in which the rock-forming significance belongs to fasciculate Rugose and ramose Tabulate corals. These bodies could have arisen as a result of the rhythmic development of dense coral thickets.

It is not possible to accurately estimate their size and shape based on the available discrete core materials. Supposedly, such sedimentary structures could reach several meters in thickness, while the thickness of a single coral band is several tens of centimeters. If, as can only be speculated for now, such biostromes were confined to active faults, they could extend over rather large distances.

The study of the multilayered coral biostromes, in addition to its significance for the reconstruction of the paleogeographic environment and its dynamics in the Prypiat Trough, is of interest for several practical reasons.

First, they are a convenient biostratigraphic indicator of the lower part of the Voronezh Formation, since they differ significantly both from the coral-stromatoporoid buildups of the underlying Semiluki Formation [6] as well as from sparse coral settlements occurring in the upper part of the Voronezh Formation [1].

In addition, multilayered coral biostromes, subject to postsedimentary dolomitization, leaching and fracturing, are potential reservoir rocks. Considering that coral skeletons are subject to selective leaching, the host rock can acquire significant porosity. This is confirmed by previous indications on confinement of oil deposits in the Voronezh Formation to the "reefogenic strata" [1]. Therefore, the macroscopic voidage associated with leached coral skeletons in biostromal rocks can reach high values. These characteristics require further study.

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КАРАЛАВЫЯ БІЯСТРОМЫ ВАРОНЕЖСКАГА ГАРЫЗОНТУ (ВЕРХНІ ФРАН) У ПРЫПЯЦКІМ ПРАГІНЕ (БЕЛАРУСЬ)

Ю. У. Заіка

Дзяржаўнае прадпрыемства «ГЕАСЕРВІС»,
вул. Янкі Маўра, 53, 220015, Мінск, Беларусь
E-mail: cyrtophyllum@gmail.com

Верхнедэвонскія карбанатныя адклады Прыпяцкага прагіну, сфарміраваныя з удзелам арганізмаў-пародаўтваральнікаў, выклікаюць цікавасць не толькі ў сувязі з іх біястратыграфічным значэннем, але і як патэнцыяльныя пароды-калектары. Гэтыя адклады вывучаны з неаднолькавай дэталёвасцю: заагенныя пабудовы франскага яруса сярод іх даследаваны ў найменшай ступені. У артыкуле прапануецца схематычная мадэль заагенных асадкавых утварэнняў, пашыраных у варонежскім гарызонце (верхні пад'ярус франскага яруса) Прыпяцкага прагіну. Яны прадстаўлены пласцістымі карбанатнымі целамі, у якіх інтэрвалы парод, перапоўненыя караламі – галінчатымі Tabulata і кусцістымі Rugosa, чаргуюцца з інтэрваламі без рэштакаў каралаў. Каралавыя інтэрвалы – гэта ўтварэнні субкаркасных банак, у якіх шкілеты каралаў не зрастаюцца паміж сабой у такой ступені, каб сфарміраваць суцэльныя працяглыя каркасы. Каралавыя шкілеты складаюць да 35 % ад агульнага аб'ёму пароды, што сведчыць пра іх істотны ўдзел у якасці пародаўтваральнікаў. У сукупнасці субкаркасныя банкі, якія паўтараюцца ў разрэзе адна над адной, раздзеленыя інтэрваламі пустых вапнякоў, складаюць шматпластавыя каралавыя біястромы. Субкаркасныя банкі былі ўтвораны біяцэнозамі каралавых зарасцей. Большасць каралаў у субкаркасных банках належыць да радоў Peneckiella (Rugosa), Alveolitella і Aulopora (Tabulata). Некаторыя асаблівасці будовы адкладаў і захаванасці ў іх каралавых шкілетаў даюць падставы для высноў аб істотнай актыўнасці асяроддзя асадканакаплення, у прыватнасці, аб уплыве гідрадынамічнага і, верагодна, сейсмічнага фактараў. Каралавыя шкілеты маюць параўнальна невялікія памеры і ў пераважнай большасці знаходзяцца ў перакуленым стане, што ўказвае на зменлівасць і нестабільнасць асяроддзя. Выказваецца гіпотэза аб магчымай прымеркаванасці шматпластавых біястромаў да ўчасткаў актыўных разломаў варонежскага часу. З'яўленне і спыненне існавання кожнай чарговай каралавай банкі (каралавага пласта ў шматпластавым біястроме) магло быць звязана з чаргаваннем эпізодаў разломнай актывізацыі і прамежкаў часу з адносна стабільнымі ўмовамі. Тэарэтычна такія біястромы маглі распасцірацца на вялікія адлегласці. У залежнасці ад асаблівасцей дна, біястромы межавалі з біяцэнозамі каралавых лугоў (параўнальна разрэджаныя папуляцыі каралаў), а таксама з участкамі дэпрэсій – паніжэннямі, у якіх акумуляваліся глеістыя бітумінозныя асадкі, дзе сустракаюцца пераадкладзеныя рэшткі каралаў, знесеныя з каралавых банак. Своеасаблівасць каралавых адкладаў варонежскага гарызонту робіць іх маркёрам пэўнага прамежку эвалюцыі Прыпяцкага прагіну і, адпаведна, зручным біястратыграфічным індыкатарам. У выпадках другаснай даламітызацыі, з якой нярэдка звязана высокая порыстасць і кавернознаць парод, такія адклады могуць уяўляць сабой натуральныя калектары для вуглевадародаў, вады, расолаў і інш. Рэканструкцыя каралавых банак і шматпластавых біястромаў, а таксама іншых каралавых біяфацый з улікам глыбокага залягання адкладаў ускладняецца дыскрэтнасцю кернавых матэрыялаў, непаўнатой выхаду керну, знішчэннем керну старых свідравін. Па гэтых прычынах для ўдасканалення ведаў аб памерах і будове шматпластавых біястромаў, складзе арганізмаў-пародаўтваральнікаў, выяўлення заканамернасцей іх прасторавага пашырэння і высвятлення іх практычнага значэння неабходны дадатковыя матэрыялы свідравання.

Ключавыя словы: субкаркасныя каралавыя банкі, шматпластавыя каралавыя біястромы, табуляты, ругозы, верхнефранскі пад'ярус, дэвон, Прыпяцкі прагін.

КОРАЛЛОВЫЕ БИОСТРОМЫ ВОРОНЕЖСКОГО ГОРИЗОНТА (ВЕРХНИЙ ФРАН) ПРИПЯТСКОГО ПРОГИБА (БЕЛАРУСЬ)

Ю. В. Заика

Государственное предприятие «ГЕОСЕРВИС»,
ул. Янки Мавра, 53, 220015, Минск, Беларусь
E-mail: cyrtophyllum@gmail.com

Верхнедевонские карбонатные отложения Припятского прогиба, сформированные с участием организмов-породообразователей, вызывают интерес не только в связи с их биостратиграфическим значением, но и как потенциальные породы-коллекторы. Эти отложения изучены с неодинаковой детальностью: зоогенные постройки франского яруса среди них исследованы в наименьшей степени. В статье предлагается схематическая модель зоогенных осадочных образований, распространенных в воронежском горизонте (верхний подъярус франского яруса) Припятского прогиба. Они представлены слоистыми карбонатными телами, в которых интервалы пород, переполненные кораллами – ветвистыми Tabulata и кустистыми Rugosa, чередуются с интервалами без остатков кораллов. Коралловые интервалы – это образования субкаркасных коралловых банок, где скелеты кораллов не срастаются между собой в такой степени, чтобы сформировать целостные протяженные каркасы. Коралловые скелеты составляют до 35 % от общего объема породы, что свидетельствует об их большом значении в качестве организмов-породообразователей. В совокупности субкаркасные коралловые банки, которые повторяются в разрезе одна над другой, разделенные интервалами пустых известняков, составляют многослойные коралловые биостромы. Субкарскасные коралловые банки были образованы биоценозами коралловых зарослей. Большинство кораллов в субкаркасных банках составлют представители родов Peneckiella (Rugosa), Alveolitella и Aulopora (Tabulata). Некоторые особенности отложений и сохранности в них коралловых скелетов дают основания для выводов о существенной активности среды осадконакопления, в частности, о влиянии гидродинамического и, вероятно, сейсмического факторов. Коралловые скелеты имеют сравнительно небольшие размеры и преимущественно залегают в перевернутом состоянии, что указывает на изменчивость и нестабильность среды. Высказывается гипотеза о возможной приуроченности многослойных биостромов к участкам активных разломов воронежского времени. Возникновение и прекращение существования каждой очередной коралловой банки (кораллового пласта в многослойном биостроме) могло быть связано с чередованием эпизодов разломной активизации и промежутков времени с относительно стабильными условиями. Теоретически такие биостромы могли простираться на большие расстояния. В зависимости от особенностей дна, биостромы граничили с биоценозами коралловых лугов (сравнительно разреженные популяции кораллов), а также с участками депресий, где встречаются переотложенные остатки кораллов, снесенные с коралловых банок. Своеобразие коралловых отложений воронежского горизонта делает их маркером определенного промежутка эволюции Припятского прогиба, и, соответственно, удобным биостратиграфическим индикатором. В случае вторичной доломитизации, с которой нередко связана высокая пористость и кавернозность пород, такие отложения могут представлять собой природные коллекторы углеводородов, воды, рассолов и т. д. Реконструкция коралловых банок и многослойных биостромов, а также других коралловых биофаций с учетом глубокого залегания отложений осложняется дискретностью керновых материалов, неполнотой выхода керна, уничтожением керна старых скважин. По этим причинам для усовершенствования знаний о размерах и строении многослойных биостромов, составе организмов-породообразователей, выявления пространственных закономерностей их распространения и выяснения их практического значения необходимы дополнительные материалы бурения.

Ключевые слова: субкаркасные коралловые банки, многослойные коралловые биостромы, табуляты, ругозы, верхнефранский подъярус, девон, Припятский прогиб.