

**ГЕОЛОГО-МИНЕРАЛОГИЧЕСКИЕ РЕСУРСЫ**  
**GEOLOGICAL AND MINERALOGICAL RESOURCES**  
**ГЕОЛАГА-МІНЕРАЛАГІЧНЫЯ РЭСУРСЫ**

UDC 551.734.5; 567 (476)

**D. P. Plax<sup>1</sup>, Yu. V. Zaika<sup>2</sup>**<sup>1</sup>*Belarusian National Technical University, Minsk, Belarus, e-mail: agnatha@mail.ru*<sup>2</sup>*Unitary Enterprise "Geoservice", Minsk, Belarus, e-mail: yu\_z@tut.by*

**ON THE ZHELON DEPOSITS (FRASNIAN, UPPER DEVONIAN) OF THE LATVIAN SADDLE  
IN THE BASINS OF THE SARYANKA AND ROSITSA RIVERS (BELARUS)**

**Abstract.** Detailed lithological and stratigraphic characteristics of typical outcrops of the Zhelon Regional Stage, exposed in basins of the Saryanka and Rositsa Rivers, are provided in the paper. A new local stratigraphic unit, the Degtyarevo Formation, is distinguished. Its composite section, consisting of a series of exposures, is given. In some of outcrops of the Degtyarevo Formation the deposits enclose abundant palaeontological material: skeletal elements of various representatives of ichthyofauna and sparse invertebrates (scolecodonts, fragmentary inarticulate brachiopods, and fine carbonified plant remains). On the basis of palaeontological data and lithological composition it was possible to clarify the geological age of the studied deposits and suggest a precise correlation of the Degtyarevo Formation (Zhelon Regional Stage). The provided data will be applicable for the future refinement of the current Stratigraphic Chart of the Devonian deposits of Belarus (2010).

**Keywords:** Belarus, Upper Devonian, Frasnian, Zhelon Regional Stage, Degtyarevo Formation, Latvian Saddle, fossil ichthyofauna

**Д. П. Плакс<sup>1</sup>, Ю. В. Заика<sup>2</sup>**<sup>1</sup>*Белорусский национальный технический университет, Минск, Беларусь,  
e-mail: agnatha@mail.ru*<sup>2</sup>*Унитарное предприятие «Геосервис», Минск, Беларусь,  
e-mail: yu\_z@tut.by*

**О ЖЕЛОНСКИХ ОТЛОЖЕНИЯХ (ФРАНСКИЙ ЯРУС, ВЕРХНИЙ ДЕВОН) ЛАТВИЙСКОЙ СЕДЛОВИНЫ  
В БАСЕЙНАХ РЕК САРЬЯНКА И РОСИЦА (БЕЛАРУСЬ)**

**Аннотация.** Приводятся детальные литолого-стратиграфические описания типовых обнажений желонского горизонта, выходящих на дневную поверхность в бассейнах рек Сарьянка и Росица. Выделяется новое местное стратиграфическое подразделение – дегтярёвская свита. Дается ее сводный разрез, составленный из серии надстраивающих друг друга обнажений. Отложения дегтярёвской свиты желонского горизонта в некоторых обнажениях достаточно хорошо охарактеризованы палеонтологически. Они содержат в основном скелетные элементы представителей различных групп ихтиофауны, гораздо реже – остатки беспозвоночных – сколекодонт, фрагменты раковин беззамковых брахиопод, а также мелкие углефицированные растительные остатки. На основе палеоихтиологических данных, по вещественному составу пород и их положению в разрезе даны сведения о возрасте и корреляции дегтярёвской свиты желонского горизонта. Представленные материалы необходимо учесть при уточнении действующих в настоящее время стратиграфических схем девонских отложений Беларуси (2010 г.).

**Ключевые слова:** Беларусь, верхний девон, франский ярус, желонский горизонт, дегтярёвская свита, Латвийская седловина, ископаемая ихтиофауна

**Дз. П. Плакс<sup>1</sup>, Ю. У. Заіка<sup>2</sup>**<sup>1</sup>*Беларускі нацыянальны тэхнічны ўніверсітэт, Мінск, Беларусь,  
e-mail: agnatha@mail.ru*<sup>2</sup>*Унітарнае прадпрыемства «Геасэрвіс», Мінск, Беларусь,  
e-mail: yu\_z@tut.by*

**АБ ЖЭЛОНСКИХ АДКЛАДАХ (ФРАНСКИ ЯРУС, ВЕРХНИ ДЭВОН) ЛАТВИЙСКОЙ СЕДЛАВИНЫ  
Ў БАСЕЙНАХ РЭК САР'ЯНКА І РОСИЦА (БЕЛАРУСЬ)**

**Анотацыя.** Прыведзены дэталёвыя літалага-стратыграфічныя апісанні тыповых агаленняў жэлонскага гарызонту, якія выходзяць на дзённую паверхню ў басейнах рэк Сар'янка і Росіца. Вылучаецца новае мясцовае стратыграфічнае падраздзяленне – дзегцяроўская світа. Дадзены яе зводны разрез, складзены з серыі разрэзаў агаленняў, якія надбудоўваюць адно аднаго. У асобных агаленнях адклады дзегцяроўскай світы жэлонскага гарызонту добра

ахарактерызаваны выкапнёвымі рэшткамі. Яны ўтрымліваюць у асноўным шкілетныя элементы прадстаўнікоў розных груп іхтыяфаўны, радзей – рэшткі безхрыбетных (скалекаднты, фрагменты ракавін беззамковых брахіапод), а таксама дробныя вуглефікаваныя раслінныя фрагменты. На аснове палеаіхтыялагічных дадзеных, па рэчавіннаму складу парод і іх палажэнню ў разрэзе прыведзены звесткі аб узросце і карэляцыі дзегцяроўскай світы. Прадстаўленыя ў публікацыі матэрыялы неабходна ўлічыць пры ўдакладненні дзеючых стратыграфічных схем дэвонскіх адкладаў Беларусі (2010 г.).

**Ключавыя словы:** Беларусь, верхні дэвон, франскі ярус, жэлонскі гарызонт, дзегцяроўская світа, Латвійская седлавіна, выкапнёвая іхтыяфаўна

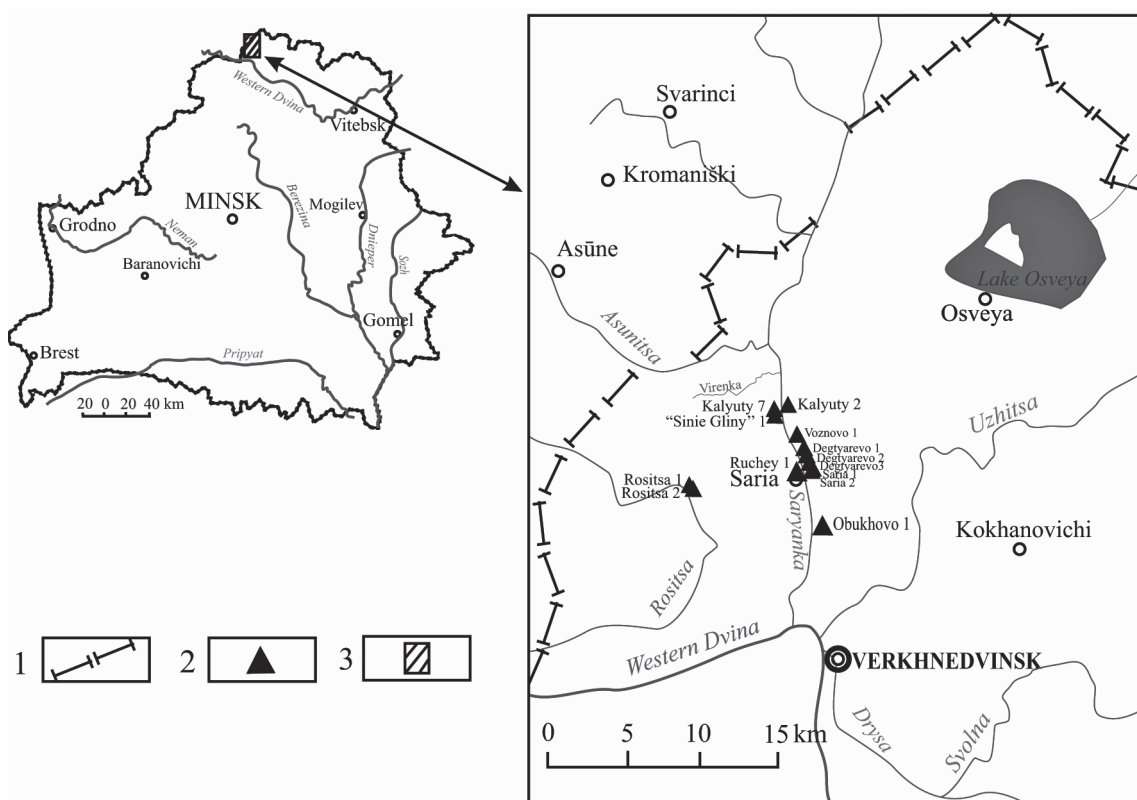
**Introduction.** The Zhelon (Frasnian, Upper Devonian) terrigenous deposits are widespread in northern Belarus within the Latvian Saddle [1]. They expose along the banks of the Saryanka and Rositsa Rivers. The first researcher who discovered Devonian clays and dolomites within the Saryanka River basin was L. F. Lungershausen [2]. Unfortunately, he revealed no organic remains in these deposits, and mistakenly considered them to be of the Middle Devonian age. Later A. A. Aleynikov [3] assigned these rocks to the Frasnian Stage of the Upper Devonian. Following researchers, Z. P. Vorobyeva [4] and L. S. Petrov [5, 6], studied mainly the carbonate part of this section, but they paid little attention to the terrigenous part. The first interpretation of the age of the terrigenous deposits was offered by P. P. Liepinš [7]. Based on lithological and mineralogical data he assigned these deposits (sandstones, siltstones and clays) to the Upper Gauja Subformation of the Gauja Formation of the Lower Frasnian Substage. In the same publication, P. P. Liepinš mentioned previously unknown outcrops of sandstones and clays along the Rositsa River, which he also assigned to the Upper Gauja Subformation. This author didn't mention any fossils from sandstones and clays of the Saryanka and Rositsa Rivers to support his conclusions regarding the geological age of these rocks. During the following forty years no one purposefully studied these deposits. In 2004, D. P. Plax for the first time discovered fossil ichthyofauna in sandy-clayey rocks (the «Sinie Gliny» 1 and Obukhovo 1 outcrops), which occur downstream the Saryanka River stratigraphically and hypsometrically below dolomites [8]. The finding of numerous macro-, meso- and micromeric ichthyofauna remains allowed him to palaeontologically prove the Zhelon (Early Frasnian) age of the enclosing strata and to suggest a correlation with the adjacent areas. In 2008, D. P. Plax discovered fossil ichthyofauna in the same part of the section in the Kalyuty 2 and Kalyuty 7 exposures, which helped him to clarify its taxonomic composition and to confirm the Zhelon age of the studied deposits [9, 10]. In 2018–2019, D. P. Plax and Yu. V. Zaika obtained new palaeontological and geological data regarding exposures of terrigenous strata along the Saryanka River, and, for the first time after P. P. Liepinš, in 2019 they located and described the Devonian outcrops along the Rositsa River.

The new data allowed the authors to distinguish in this part of the section a new local stratigraphic unit, i.e. the Degtyarevo Formation, which, according to the Stratigraphic Charts of the Devonian deposits of Belarus (2010) [1], is an age analogue to the Zhelon Regional Stage. This Formation is named after the Degtyarevo village of the Verkhnedvinsk district. As a stratotype for this new Formation, a composite section consisting of a series of exposures sequentially located downstream the Saryanka River, is proposed. Detailed descriptions of typical sections and a composite section of the Degtyarevo Formation are given below.

**Materials and methods.** This paper is based on lithological and palaeontological materials, collected and published by D. P. Plax and S. A. Kruchek [8–11], as well as on new collections obtained in 2018 and 2019 by D. P. Plax and Yu. V. Zaika during detailed survey of the Devonian outcrops occurring in the basin of the Saryanka River (Obukhovo 1, Ruchey 1, Saria 1, Saria 2, Degtyarevo 1, Degtyarevo 2, Degtyarevo 3, Voznovo 1, «Sinie Gliny» 1, Kalyuty 2 and Kalyuty 7 outcrops) and along the Rositsa River (Rositsa 1 and Rositsa 2 outcrops) (Text-Figure 1). Palaeontological materials collected from some of the above-listed outcrops, are represented mainly by skeletal elements of ichthyofauna. Fossil invertebrates and plants are rare and have little significance for stratigraphy.

Outcrops were described and lithologically subdivided in the field. In most cases, neighboring exposures were correlated in the field using lithological features. Some lithological members and intervals of deposits were sampled for laboratory study.

To draw up a composite section and to calculate the estimated total sediment thickness the authors used the following data: 1) the field measurements of the thickness of exposed Devonian rocks as well



Text-Fig. 1. Map of location of typical outcrops of the Degtyarevo Formation:  
 1 – state border, 2 – typical outcrops of the Degtyarevo Formation, 3 – the area of study

as of the Quaternary deposits that overlay them; 2) the hypsometrical data defined from topographic maps; 3) the absolute elevations obtained from the Google Earth service.

Field photographs were performed using a PowerShot SX130-IS. Geological sections were drawn up using the CoreIDRAW X3 software.

The identification of the collected scolecodonts and conodonts was made according to the external morphological features, while histological data were used to identify skeletal elements of agnathans and fishes, in addition to the external morphology.

Most of the studied palaeontological materials and rock samples are stored in a private collection of D.P. Plax. Part of the fossil skeletal material is located in the Republican Unitary Enterprise “Scientific and Production Center for Geology” and in palaeontological and lithological collections at the Department of Mining, Belarusian National Technical University.

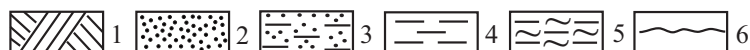
**Geological characteristics of the Degtyarevo Formation outcropping on the Saryanka and Rositsa Rivers.** The descriptions of the following outcrops: the «Sinie Gliny» 1, Kalyuty 2 and 7, Voznovo 1, Degtyarevo 1, 2 and 3, which were studied or first discovered by D.P. Plax in 2018, as well as the Obukhovo 1, Rositsa 1 and 2, Ruchey 1, Saria 1 and 2, which were additionally studied or first established by the authors in 2019, can be found below.

Bluish-grey, dense, fat, plastic Devonian clays expose in the riverbed (at the bottom and along the banks) of the Rositsa River (**Rositsa 1 outcrop**). They occur approximately 50 m from the bridge over the Rositsa River and continue for several tens of meters downstream.

**The Rositsa 2 outcrop** (Text-Figures 2 and 3) is located on the right bank of the Rositsa River near the village of Rositsa in the Verkhnedvinsk district approximately 200 m from the bridge over the river. The part of the section exposed by the pit includes the following rocks (from bottom to top):

(D<sub>3</sub> dgt) 1. Aleuritic clay, grey, ashen-grey, dense, plastic under wet conditions. The contact with the overlying bed is clearly defined. Exposed thickness . . . . .0.55 m

System	Series	Stage	Substage	Regional stage	Formation	Thickness, m	Bed №	Lithology
Quaternary system						0.3	6	
						0.05	5	
						0.25	4	
Devonian	Upper	Frasnian	Lower	Zhelon	Degtyarevo	0.35	3	
						0.15	2	
						0.55	1	



Text- Fig. 2. Geological section of the Rositsa 2 outcrop  
 Beds: 1 - vegetable soil, 2 – sand, 3 - clayey sand, 4 – clay, 5 - aleuritic clay. Other symbol: 6 - surface of discontinuity

(D<sub>3</sub> dgt) 2. Clayey quartz sand, light grey, with bluish tint, fine-grained, slightly micaceous, without clear layering. The contact with the overlying bed is quite clearly defined . . . . .0.15 m

(D<sub>3</sub> dgt) 3. Clay, bluish-grey, with brown, yellow and rusty spots, dense, fat, plastic under wet conditions, viscous. The contact with the overlying bed is clearly defined . . . . .0.35 m

(Q) 4. Feldspar-quartz sand, white-yellow, fine-grained, without clear layering . . . . .0.25 m

(Q) 5. Clayey feldspar-quartz sand, yellowish-brown, fine and small-grained . . . . .0.05 m

(Q) 6. Vegetable soil. . . . .0.3 m

The Devonian strata have an angle of dip of about 8–10° against the direction of the river.

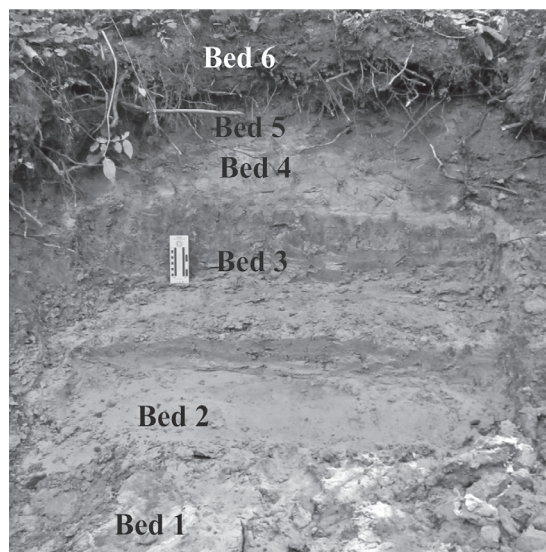
The organic remains have not been established in this exposure.

**The Obukhovo 1 outcrop** (Text-Figures 4 and 5)

is located approximately 2 km from the Obukhovo village, upstream of the Saryanka River, on its left bank. In this section the following strata are exposed (from bottom to top):

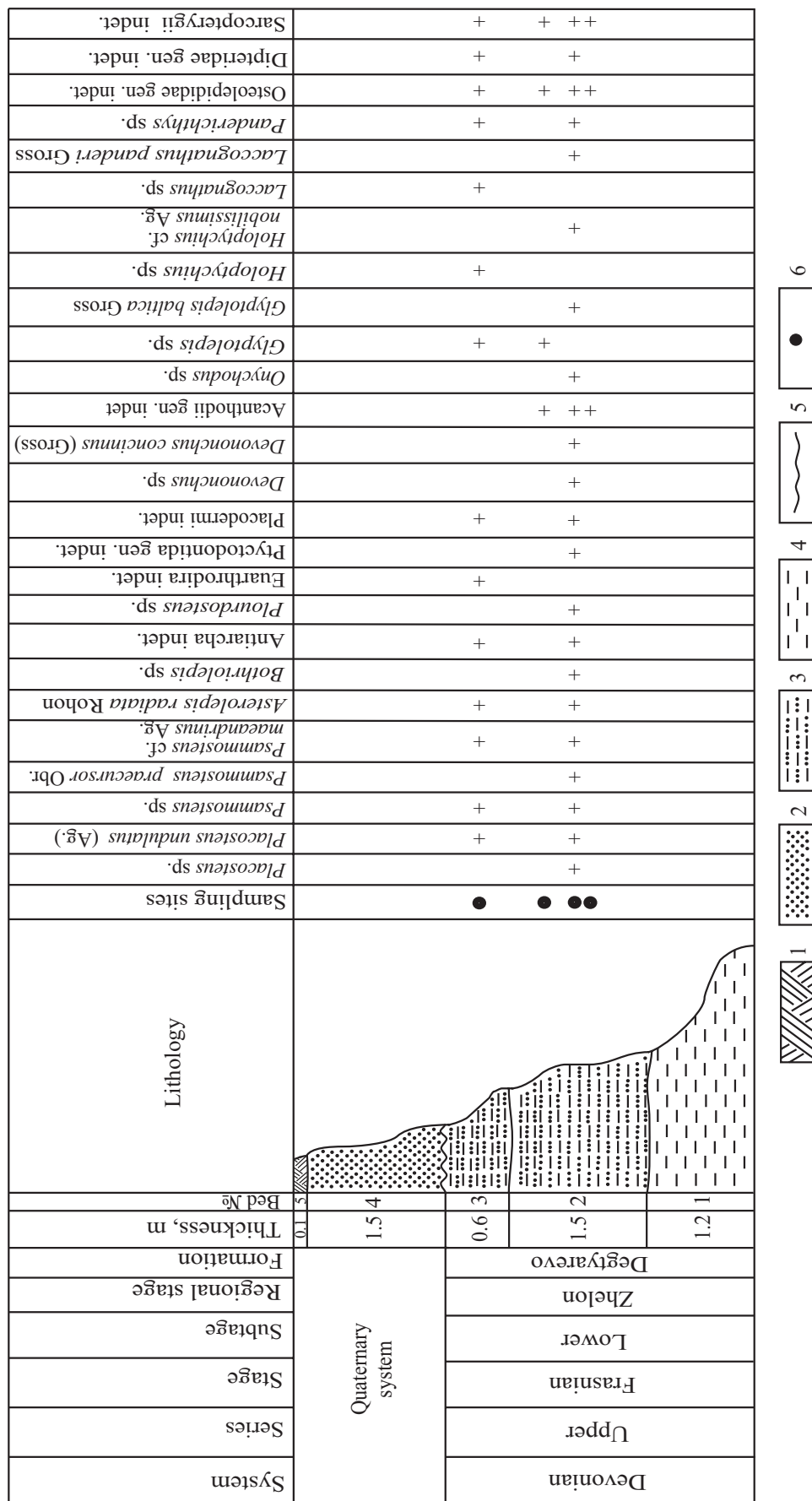
(D<sub>3</sub> dgt) 1. Clay, bluish-grey, with brown spots, homogeneous, fat, plastic under wet conditions and somewhat viscous. The contact with the overlying bed is clearly defined . . . . .1.8 m

(D<sub>3</sub> dgt) 2. Silty sandy clay, bluish-grey, dense, with the inclusion of rare small boulders (10–15 cm), and with numerous inclusions of rounded or slightly angled pebbles represented by feldspar, quartz, granite, quartzite, gneiss, sandstone, limestone, dolomite, etc. The clays also include large grains of sand represented mainly by feldspar and quartz. This bed is characterized by wavy layering. Many discrete fragments of the agnathan and fish skeletal elements (fragments of exoskeletal plates, fin spines, teeth, scales, tesseræ, dentine tubercles of the external layer of plates, etc.) belonging to the following taxa: *Placosteus* sp., *P. undulatus* (Ag.), *Psammosteus* sp., *P. praecursor* Obr., *P. cf. maeandrinus* Ag., *Psammosteioidei* indet., *Ptyctodontida* gen. indet., *Plourdosteus* sp., *Asterolepis radiata* Rohon,



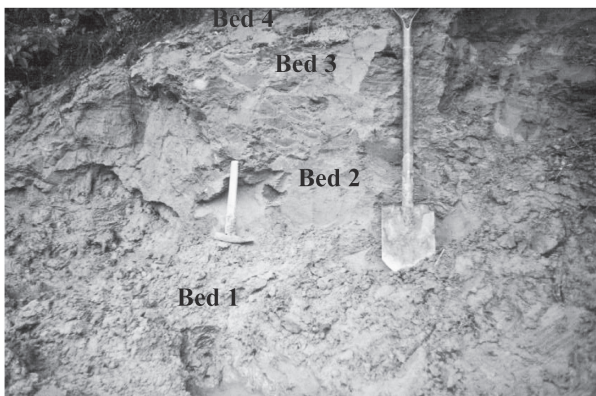
Text-Fig. 3. Rositsa 2 outcrop





Text-Fig. 4. Geological section of the Obukhovo 1 outcrop and distribution of the ichthyofauna (from [9] with some refinements and additions)  
 Beds: 1 – vegetable soil, 2 – sand, 3 – sandy clay, 4 – clay. Other symbols: 5 – discontinuity surface, 6 – sampling points

*Bothriolepis* sp., *Antiarcha* indet., *Placodermi* indet., *Devononchus* sp., *D. concinnus* (Gross), *Acanthodii* gen. indet., *Onychodus* sp., *Glyptolepis baltica* Gross, *Holoptychius* cf. *nobilissimus* Ag., *Laccognathus panderi* Gross, *Osteolepididae* gen. indet., *Panderichthys* sp., *Dipteridae* gen. indet. and *Sarcopterygii* indet. were found among organic remains. The skeletal elements of these taxa are mainly meso- and micro-sized. Numerous redeposited micromeric dacryoconarids (*Dacryoconarida*) of good preservation state were also found in this bed. The contact with the overlying bed is uneven, well expressed.....1.5 m



Text-Fig. 5. Obukhovo 1 outcrop

(D<sub>3</sub> dgt) 3. Sandy clay, light brown, cream-colored, with brown, orange and bluish-grey interlayers, dense, with a somewhat undulating layering.

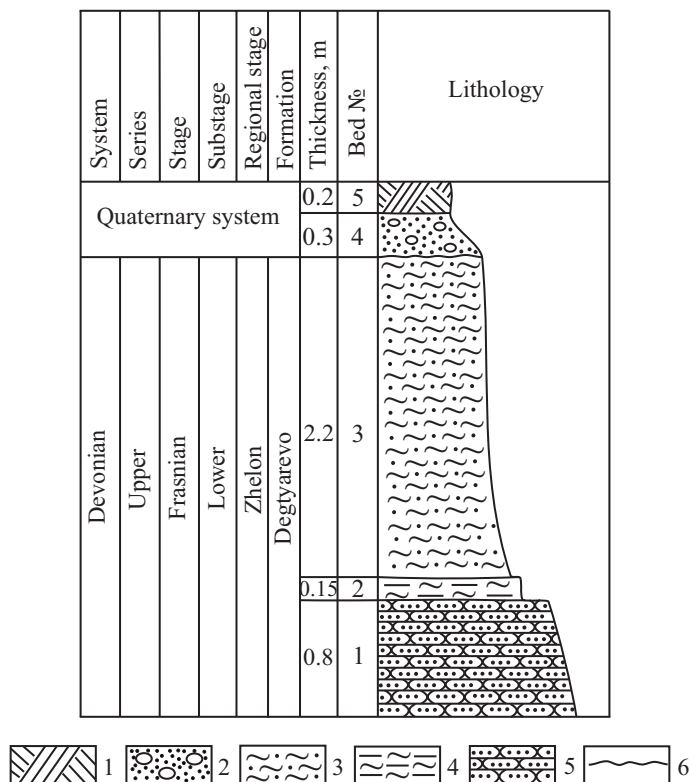
Skeletal fragments of the following agnathans and fishes were found: *Placosteus undulatus* (Ag.), *Psammosteus* sp., *P. cf. maeandrinus* Ag., *Asterolepis radiata* Rohon, *Euarthrodira* indet., *Placodermi* indet., *Glyptolepis* sp., *Holoptychius* sp., *Laccognathus* sp., *Osteolepididae* gen. indet., *Panderichthys* sp., *Dipteridae* gen. indet. and *Sarcopterygii* indet. The contact with the overlying bed is clearly defined . . . . . 0.6 m

(Q) 4. Feldspar-quartz sand, very fine-grained, greyish-yellow, with alternating thin horizontal layers of brown sand having a thickness of up to 1 cm . . . . . 1.5 m

All Devonian beds have a dip of about 20 - 30 ° in the direction of the river.

**The Ruchey 1 outcrop** (Text-Figure 6) is located near the spring in the village of Saria about 80 m from the Great Patriotic War monument. The following rocks are exposed from bottom to top:

(D<sub>3</sub> dgt) 1. Rusty-brown quartz sandstone, light brown, slightly clayey, fine-grained, micaceous, weakly cemented, dense, with subhorizontal thin intermittent lamination. The contact with the overlying bed is relatively clearly defined. Exposed thickness . . . . . 0.8 m



Text-Fig. 6. Geological section of the Ruchey 1 outcrop

Beds: 1 - vegetable soil, 2 – sand and gravel, 3 – silt, 4 – aleuritic clay, 5 – sandstone. Other symbol: 6 – surface of discontinuity

(D<sub>3</sub> dgt) 2. Aleuritic clay, bluish-grey, with a greenish tint, micaceous, dense. The contact with the overlying bed is clearly defined . . . . . 0.15 m

(D<sub>3</sub> dgt) 3. Quartz silt, light grey, with a bluish-greenish tint, without clear layering, fine-grained, slightly clayey, locally with numerous inclusions of large-grained sand and gravel of quartz feldspar, dolomite, granite, quartzite, etc. The rock contact with the overlying bed is sharp and clear.....2.2 m

(Q) 4. Sand and gravel, brown . . . . . 0.3 m

Vegetable soil, about 0.2 m thick occurs above the exposure.

The organic remains have not been established in this outcrop.

**The Saria 2 outcrop** (Text-Figures 7 and 8) is located on the left bank of the Saryanka River within the village of Saria, about 250-300 m downstream of the bridge over the river. The section is composed (from bottom to top) of the following strata:

(D<sub>3</sub> dgt) 1. Quartz sandstone, rusty-brown, light brown, fine-grained, micaceous, weakly cemented, dense. The contact with the overlying bed is smooth. Exposed thickness . . . . . 0.9 m

(D<sub>3</sub> dgt) 2. Quartz siltstone, grey, with a bluish tint, fine-grained, micaceous, slightly clayey, weakly cemented, dense, with subhorizontal thin intermittent lamination. The contact with the overlying bed is uneven. . 1.0 m

(D<sub>3</sub> dgt) 3. Clay, grey, with a bluish tint, in places with brown spots, plastic, viscous, dense. The contact with the overlying bed is very clearly defined . . . . . 0.1 m

(D<sub>3</sub> dgt) 4. Aleuritic clay, bluish-grey, micaceous, with subhorizontal thin layering. The contact with the overlying bed is uneven, clearly defined . . . . . 0.25 m

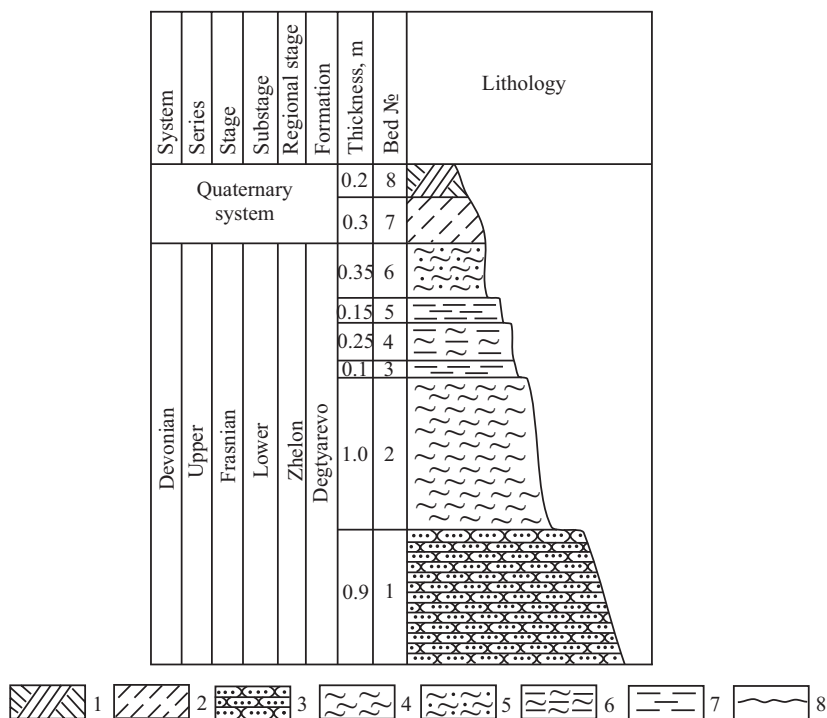
(D<sub>3</sub> dgt) 5. Clay, red-brown, in some areas bluish-grey, dense, plastic and viscous under wet conditions. The contact with the overlying bed is clearly defined . . . . . 0.15 m

(D<sub>3</sub> dgt) 6. Quartz silt, light grey, with bluish-greenish tint, fine-grained, micaceous, slightly clayey, without distinct layering, with inclusions of gravel represented by quartz, feldspar, granite, quartzite, etc. The contact with the overlying bed is sharp, uneven . . . . . 0.35 m

(Q) 7. Sandy loam, red-brown, clayey, dense, hidden by a landslide of vegetable soil . . . . . 0.3 m

The total dip of the above listed beds is about 5° in the direction of the river.

The organic remains have not been established in this exposure.

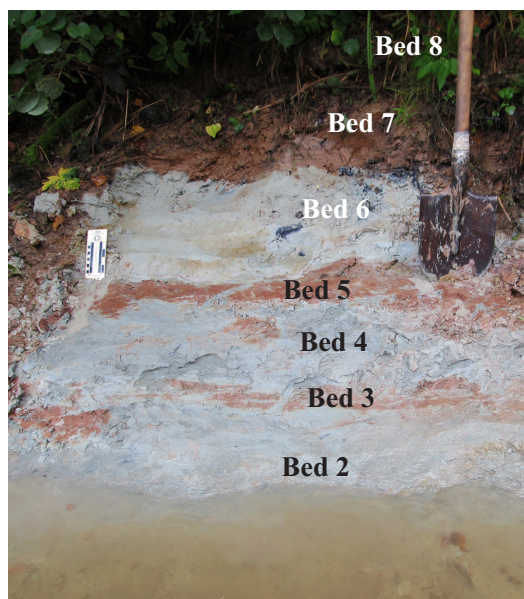


Text-Fig. 7. Geological section of the Saria 2 outcrop  
 Beds: 1 - vegetable soil, 2 – sandy loam, 3 – sandstone, 4 – siltstone, 5 – silt, 6 - aleuritic clay, 7 – clay. Other symbol:  
 8 – surface of discontinuity

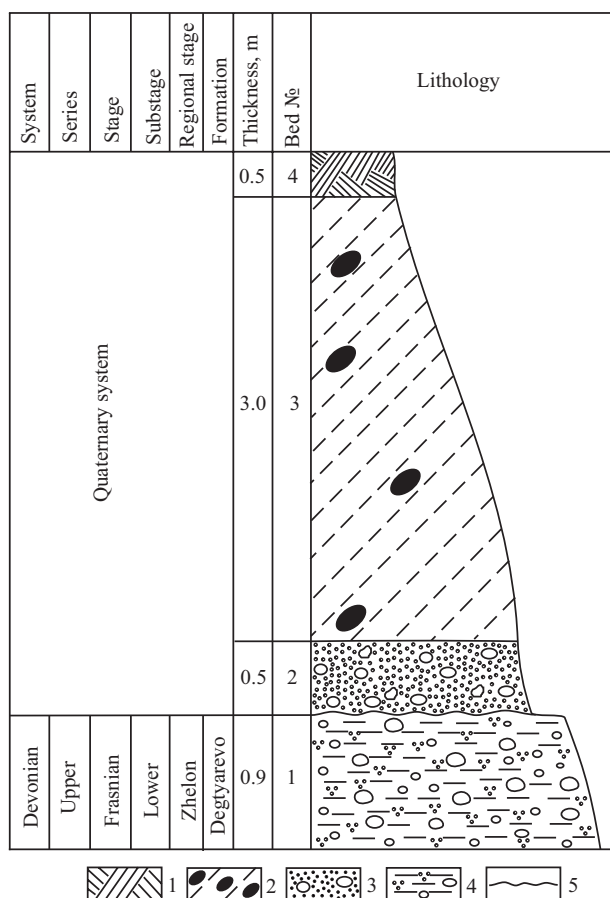
About 100 m upstream of the Saryanka River, on its left bank, the **Saria 1 outcrop** occurs with an almost identical lithological composition. It is also worth noting that there are at least 15 exposures of the Degtyarevo Formation along the Saryanka River within the Saria village (as of 2019). All of them are to some extent similar to the Saria 2 outcrop described above, and the visible variations in their composition are associated mainly with the variable thickness and different number of exposed beds of terrigenous rocks.

**The Degtyarevo 3 outcrop** is located in the left-bank terrace of the Saryanka River within the village of Degtyarevo, about 100 m upstream from the bridge over the river. At the time of description (2019), the outcrop was almost completely located below the water level, with the exception of its uppermost part. The observed thickness of the exposed Zhelon deposits was about 1.3 m. The rocks are represented by bluish-grey, dense, fat, viscous, plastic clay. The organic remains are not visually found.

**The Degtyarevo 2 outcrop** (Text-Figure 9) is located on the right bank of the Saryanka River in the village of Degtyarevo, about 250 m upstream of the bridge over the river. The following sediments are exposed in the section of this outcrop from bottom to top:



Text-Fig. 8. Saria 2 outcrop

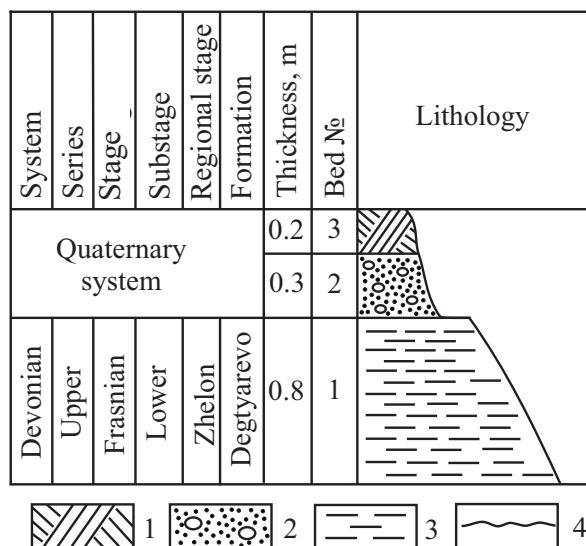


Text-Fig. 9. Geological section of the Degtyarevo 2 outcrop. Beds: 1 - vegetable soil, 2 – sandy loam with rare boulders, 3 – sand and gravel, 4 – clay with sand, gravel and pebbles. Other symbol: 5 – surface of discontinuity



(D<sub>3</sub> dgt) 1. Clay, bluish-grey, with bluish-greenish-grey spots, dense, fat, plastic and viscous under wet conditions, with very poorly expressed subhorizontal layering. Contains abundant sand, gravel and pebble material, mainly rounded, sometimes slightly angular. The clastic material is represented by quartz, feldspar, granite, gneiss, diorite, quartzite, limestone, dolomite, sandstone and other rocks and minerals; fragments of limestone and dolomite dominate. *In situ* organic remains have not been established, but redeposited organic remains are abundant and are represented by small brachiopods, bivalves, crinoids, etc. The contact with the overlying bed is clear, sharp. Exposed thickness.....0.9 m  
 (Q) 2. Sand and gravel of brown color .....0.5 m  
 (Q) 3. Sandy loam, brown, with rare inclusions of boulders, with local interbeds of red, yellow, fine- and medium sand. ....3.0 m  
 The sandy loam is covered by a talus of vegetable soil.

**The Degtyarevo 1 outcrop** (Text-Figure 10) is located on the left bank of the Saryanka River, about 350 m upstream of the bridge over the river. The outcrop is clearly visible in the river edge and is represented by bluish-grey, dense, fat, viscous, plastic clays. The total thickness of the exposed clays of the Zhelon age is about 0.8 m. Above are the Quaternary sands with gravel and pebbles (0.3 m thick), covered by a talus of vegetable soil.

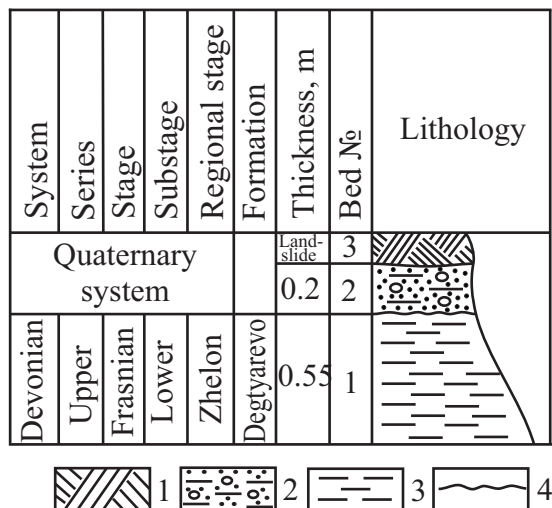


Text-Fig. 10. Geological section of the Degtyarevo 1 outcrop  
 Beds: 1 - vegetable soil, 2 – sand with gravel and pebbles, 3 – clay. Other symbol: 4 – surface of discontinuity

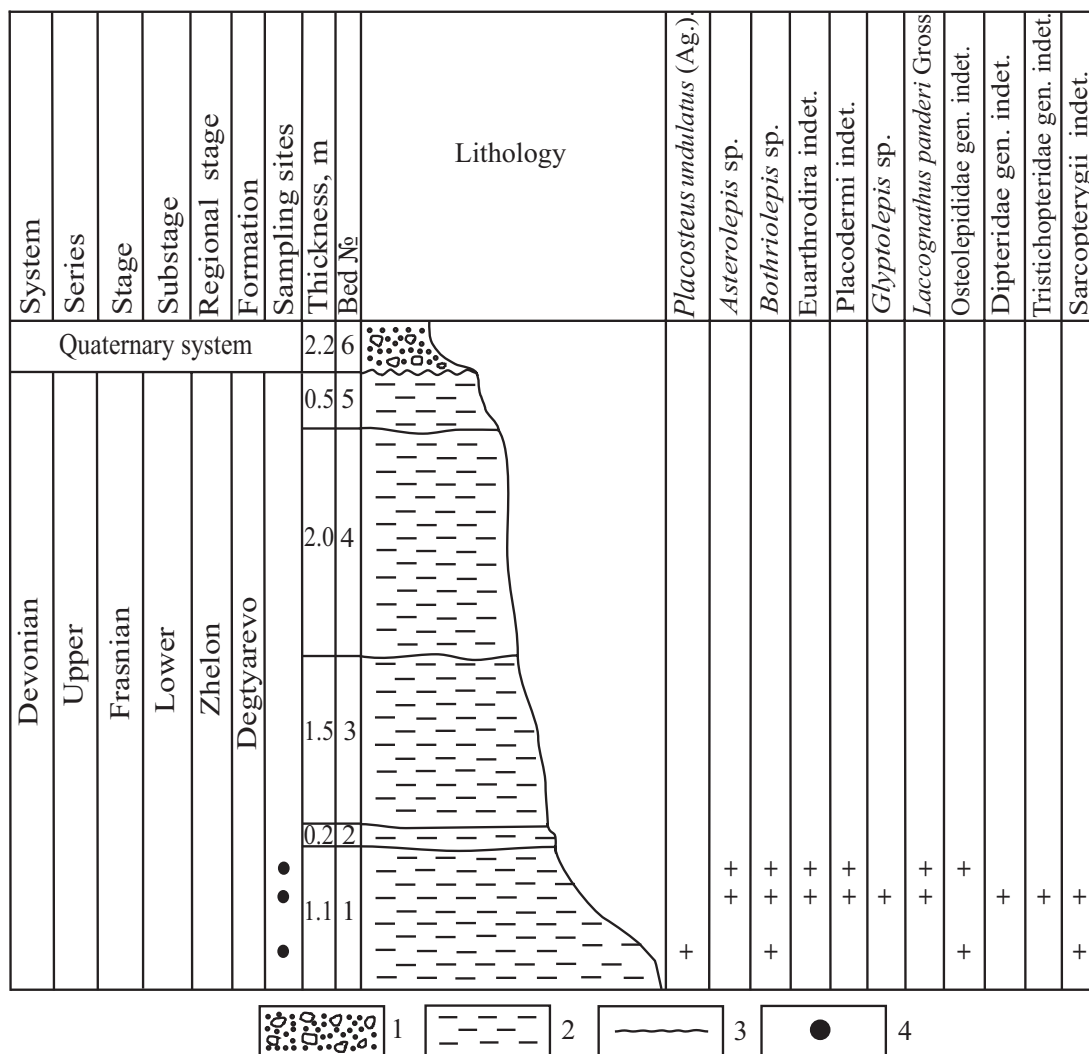
**The Voznovo 1 outcrop** (Text-Figure 11) is located on the right bank of the Saryanka River near the village of Voznovo, in the base of a large slope. At the time of the survey (2019), the outcrop almost completely occurs below the water level with only about 0.15 m of the Devonian rocks located above the water. The visible thickness of the flooded part of the outcrop is approximately 0.4 m. The section from bottom to top is as follows:

(D<sub>3</sub> dgt) 1. Clay, bluish-grey, fat, viscous and plastic under wet conditions. The organic remains were not found. The contact with the overlying bed is clear and uneven. Exposed thickness . . . . .0.55 m  
 (Q) 2. Clayey sand, light yellow, with numerous inclusions of pebbles and gravel of dolomite, quartz, quartzite, granite, gneiss, sandstone and other minerals and rocks. Visible thickness. . . . .0.2 m  
 A large landslide of vegetable soil occurs above the outcrop.

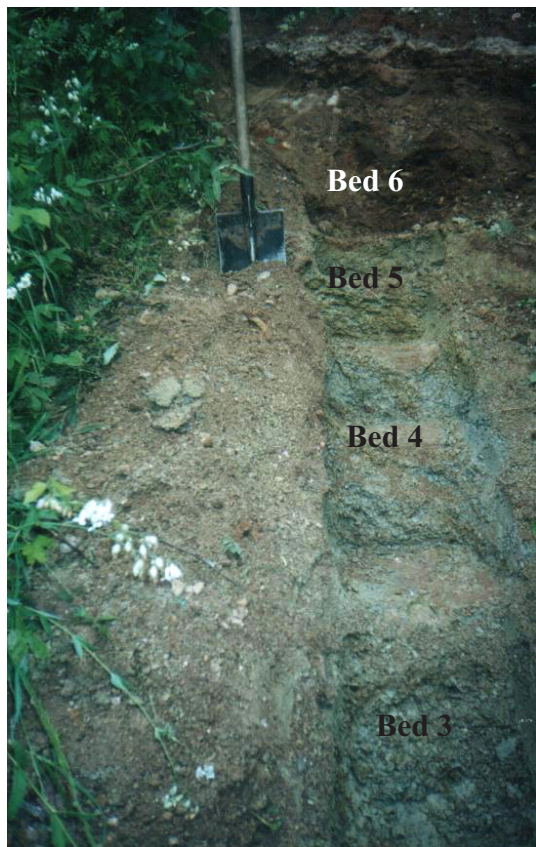
**The «Sinie Gliny» 1 outcrop** (Text-Figures 12 and 13) is located on the right bank of the Saryanka River, about 2 km downstream from the mouth of the Turia River. From bottom to top the following strata are exposed:



Text-Fig. 11. Geological section of the Voznovo 1 outcrop  
 Beds: 1 - vegetable soil, 2 – clayey sand with gravel and pebbles, 3 – clay. Other symbol: 4 – surface of discontinuity



Text-Fig. 12. Geological section of the «Sinie Gliny» 1 outcrop and distribution of the ichthyofauna (from [9] with some refinements and additions)  
 Beds: 1 – sand and gravel, 2 – clay. Other symbols: 3 – surface of discontinuity, 4 - sampling points



Text-fig. 13. «Sinie Gliny» 1 outcrop

(D<sub>3</sub> dgt) 1. Clay, blue, with rare brown spots, lumpy, indistinctly laminated, fat, dense, viscous and plastic under wet conditions, contains small (0.5–4.0 mm) fragments of minerals (quartz, feldspar) and rocks (sandstone, dolomite etc.), as well as abundant micro- and mesomeric fragments of the agnathan and fish skeletal elements (tubercles, teeth, vertebrae, bones, plates, etc.) represented by the following taxa: *Placosteus undulatus* (Ag.), *Asterolepis* sp., *Bothriolepis* sp., *Euarthrodira* indet., *Placodermi* indet., *Glyptolepis* sp., *Laccognathus panderi* Gross, *Dipteridae* gen. indet., *Osteolepididae* gen. indet., *Tristichopteridae* gen. indet. and *Sarcopterygii* indet. The contact with the overlying bed is clearly defined. Exposed thickness.....1.1 m

(D<sub>3</sub> dgt) 2. Clay, bluish-grey, with brown spots and stains on the surface, indistinctly laminated, fine-platy, fat, viscous and plastic under wet conditions. . . . .0.2 m

(D<sub>3</sub> dgt) 3. Clay, greyish, homogeneous, lumpy, indistinctly laminated, fat, viscous and plastic under wet conditions. The contacts with the underlying and overlying beds are clearly defined . . . . .1.5 m

(D<sub>3</sub> dgt) 4. Clay, grey, with frequent brown spots on the surface, homogeneous, indistinctly laminated, fine-platy, viscous and plastic under wet conditions . . .2.0 m

(D<sub>3</sub> dgt) 5. Clay, yellowish grey, homogeneous, platy, indistinctly laminated. The contacts with the underlying and overlying clay beds are clearly defined . . . . .0.5 m

(Q) 6. Feldspar-quartz sand, whitish-yellow, fine-grained, with weakly expressed lamination, with inclusions of granite and gneiss boulders and a rare content of pebbles represented by gneiss, quartzite, granite, sandstone, limestone, dolomite, etc . . . . .1.5 m

Vegetable soil, about 0.1 m thick, occurs above the outcrop.

All beds occur almost horizontally.

**The Kalyuty 2 outcrop** (Text-Figures 14 and 15) is located on the left bank of the Saryanka River; about 70 m upstream of the «Sinie Gliny» 1 outcrop. The section is composed of the following strata (from bottom to top):

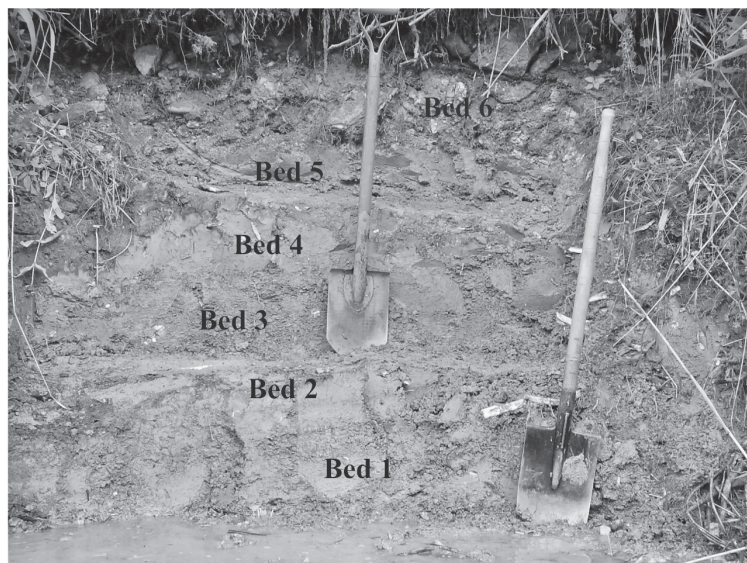
(D<sub>3</sub> dgt) 1. Clay, bluish and blue, wet, viscous, plastic, fat, lumpy, dense, indistinctly laminated, with small (0.5-5.0 mm) fragments of minerals and rocks: quartz, feldspar, sandstone, dolomite, etc. Approximately 33 to 35 cm from the bottom of the bed an interlayer of clay lumps with carbonate cement occurs, about 10 cm thick, containing a large number of small pebbles and gravel. Organic remains include rare carbonified plant fragments, two *Kettnerites* sp. scolecodont specimens, single fragments of lingulid shells, three specimens of "*Ligonodina*" sp. conodont, and a large number of micro- and mesomeric fragments of skeletal elements of the agnathans and fishes. The vertebrates are found throughout the entire bed 1, but they are most numerous in the above-mentioned interlayer. The agnathans and fishes are represented by the following taxa: *Placosteus undulatus* (Ag.), *Psammosteus* sp., *P. praecursor* Obr., *P. cf. praecursor* Obr., *P. cf. maeandrinus* Ag., *Psammosteidae* gen. indet., *Psammosteidae* gen. indet., *Ptyctodontida* gen. indet., "*Ptyctodus*" sp., *Holonema* sp., *Plourdosteus* sp., *Euarthrodira* indet., *Asterolepis* sp., *A. ?* sp., *A. radiata* Rohon, *Bothriolepis* sp., *B. obrutschewi* Gross, *Placodermi* indet., *Acanthodes ?* sp., *Devononchus* sp., *Strunius* sp., *Onychodontidae* gen. indet., *Glyptolepis* sp., *G. ?* sp., *Laccognathus* sp., *Porolepiformes* indet., *Osteolepididae* gen. indet., *Tristichopteridae* gen. indet., *Panderichthys* sp., *Dipteridae* gen. indet., *Dipteroidei* fam. gen. et sp. indet., *Dipterus* sp., *Grossipterus* sp., *Sarcopterygii* indet., *Cheirolepis* sp., *Moythomasia* sp. and *Actinopterygii* indet. Exposed thickness . . . . .0.6 m

System	Series	Stage	Regional stage	Formation	Sampling sites	Thickness, m	Bed №	Lithology
Devonian	Upper	Frasnian	Zhelon		●●	0.6	1	
						0.3	2	
						0.4	3	
						0.3	4	
						0.2	5	
						0.65	6	
						0.1	7	
						Lingulida indet. +		
						"Ligonodina" sp. +		
						Placosteus undulatus (Ag.) ++		
						Psammosteus praecursor Obr. ++		
						Psammosteus cf. praecursor Obr. +		
						Psammosteus cf. maecandrinus Ag. +		
						Psammosteus sp. ++		
						Psammosteidae indet. +		
						Psammosteidae indet. +		
						Psammosteoides indet. +		
						Plourdosteus sp. +		
						Holoneus sp. +		
						Pycnodonida gen. indet. +++		
						"Pycnodus" sp. +		
						Euarthrodira indet. +		
						Placodermi indet. +		
						Asterolepis sp. +		
						Asterolepis ? sp. +		
						Asterolepis radialis Rohon +		
						Bothriolepis sp. +++		
						Bothriolepis obrutschewi Gross +		
						Acanthodes ? sp. +		
						Devononchus sp. +		
						Onychodontidae gen. indet. ++		
						Strunius sp. +		
						Glyptolepis sp. +		
						Glyptolepis ? sp. +		
						Laccognathus sp. +		
						Porolepiformes indet. +		
						Osteolepidae gen. indet. +++		
						Tristichopteridae gen. indet. +		
						Panderichthys sp. ++		
						Dipterus sp. +		
						Grossipterus sp. +		
						Dipteridae gen. indet. +		
						Dipteroidei fam. gen. et sp. indet. ++		
						Stenopterygiid indet. ++		
						Chevroilepis sp. +		
						Moythomasia sp. +		
						Actinopterygii indet. +		



Text-Fig. 14. Geological section of the Kaliuty 2 outcrop and distribution of the ichthyofauna (from [9] with some refinements and additions)  
 Beds: 1 – vegetable soil, 2 – sand and gravel, 3 – clay, 4 – pebbles and gravel. Other symbols: 5 – surface of discontinuity, 6 - sampling points





Text-Fig. 15. Kalyuty 2 outcrop

(D<sub>3</sub> dgt) 2. Clay, grey, bluish, dense, homogeneous, platy, plastic under wet conditions; light brown weathering stains and spots are observed sometimes on the bed surface. The contact with the overlying bed is clearly defined by both the color and texture of the sediment. . . . .0.3 m

(D<sub>3</sub> dgt) 3. Clay, bluish-grey, dense, homogeneous, lumpy, indistinctly laminated, fat, viscous and plastic under wet conditions, in some places within the bed there are small clay fragments with light brown stains on their surfaces. The contact with underlying and overlying beds is clear . . . . .0.4 m

(D<sub>3</sub> dgt) 4. Clay, light grey, pale greenish (of mustard color), dense, plastic; light brown; buffy stains and spots are distinctly observed on the surface of the bed. The contact with the underlying bed is clearly defined by both the color and textural features. The contact with the overlying bed is clearly defined . . . . .0.3 m

(D<sub>3</sub> dgt) 5. Clay, light grey, yellowish-greenish, dense, plastic, indistinctly laminated, with yellow, brownish and buffy stains observed on the surface of the bed. The contact with the overlying bed is clearly defined . . . . .0.2 m

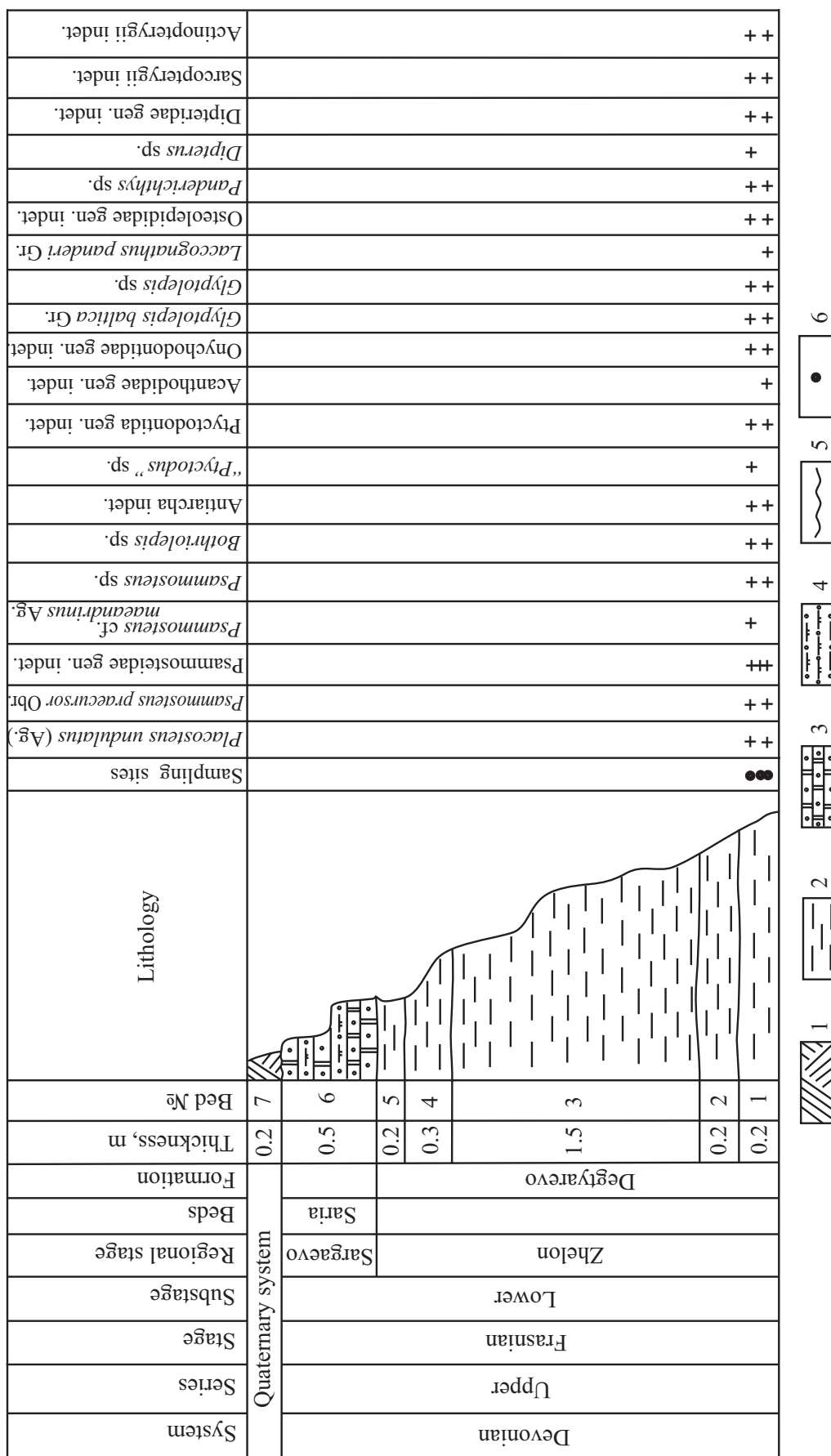
(Q) 6. Feldspar-quartz sand, light yellowish, fine-grained, with abundant pebbles and small boulders represented mainly by yellow, dense, slightly rounded dolomite; fragments of granite, gneiss, and silicified sandstone are occasionally found. Average diameter of the rock fragments is between 4–7 cm . . .0.65 m

Vegetable soil, about 0.1 m thick, occurs above the outcrop.

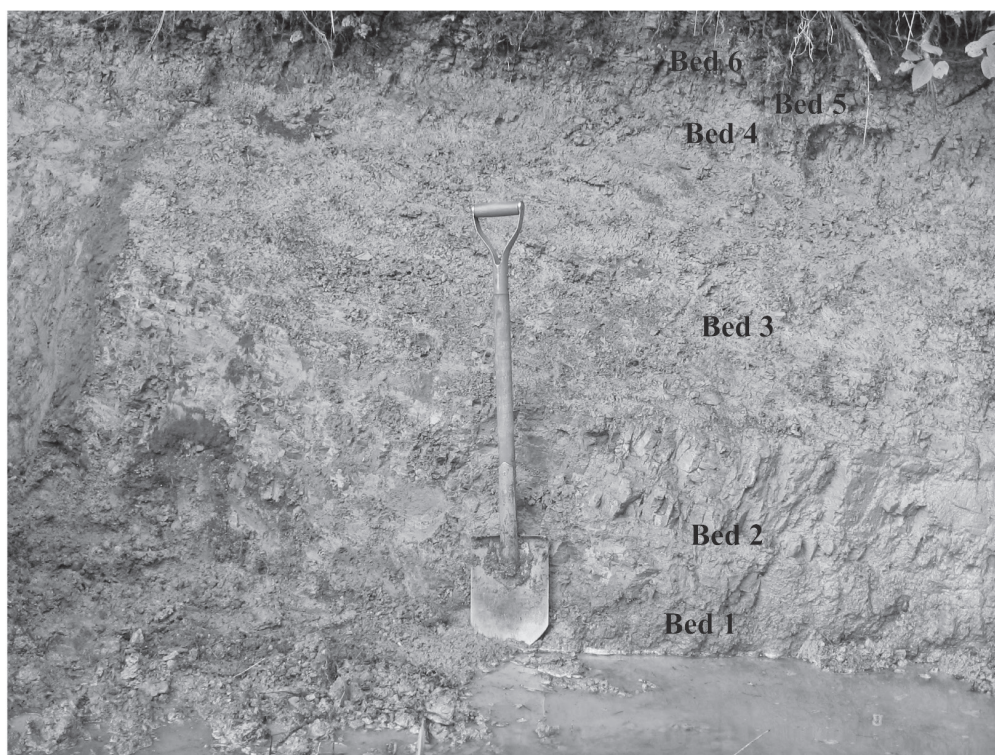
All the beds occur almost horizontally.

**The Kalyuty 7 outcrop** (Text-Figures 16 and 17) is located on the right bank of the Saryanka River, downstream of the Kalyuty 6 outcrop. The rocks of the Zhelon Regional Stage and the Saria Beds of the Sargaevo Regional Stage occur subhorizontally in the section. The following strata are exposed from bottom to top:

(D<sub>3</sub> dgt) 1. Clay, slightly sandy, bluish, dense, wet, viscous, plastic, indistinctly laminated, contains scarce small minerals particles (quartz, dolomite, feldspar, etc.) 0.3 to 7 mm in diameter, as well as fragments of magmatic, metamorphic and sedimentary rock debris (granite, gneiss, sandstone, dolomitic limestone, etc.). Clay encloses numerous isolated micro- and mesomeric, rarely, macromeric fragments of vertebrate skeletal elements that belong to the following taxa: *Placosteus undulatus* (Ag.), *Psammosteus* sp., *P. praecursor* Obr., *P. cf. maeandrinus* Ag., *Psammosteidae* gen. indet., *Ptyctodontida* gen. indet., «*Ptyctodus*» sp., *Bothriolepis* sp., *Antiarcha* indet., *Acanthodidae* gen. indet., *Onychodontidae* gen. indet., *Glyptolepis* sp., *G. baltica* Gross, *Laccognathus panderi* Gross, *Osteolepididae* gen. indet., *Panderichthys* sp., *Dipterus* sp., *Dipteridae* gen. indet., *Sarcopterygii* indet. and *Actinopterygii* indet. Rare carbonified plant remains are also found. The contact with the overlying bed is clearly defined by both the color and textural features. Exposed thickness . . . . .0.2 m



Text-Fig. 16. Geological section of the Kalyuty 7 outcrop and distribution of the ichthyofauna (from [9]) with some refinements and additions)  
 Beds: 1 – vegetable soil, 2 - clay, 3 – sucrosic dolomite, 4 – dolomite, 5 – surface of discontinuity, 6 - sampling points



Text-Fig. 17. Kalyuty 7 outcrop

(D<sub>3</sub> dgt) 2. Clay, bluish-grey, homogeneous, dense, lumpy, plastic under wet conditions, viscous. Scarce brown weather stains are observed on the bed surface . . . . .0.2 m

(D<sub>3</sub> dgt) 3. Clay, grey, heavy, homogeneous, fat, viscous and plastic under wet conditions, lumpy, indistinctly laminated. The contact with underlying and overlying beds is clearly defined. . . . . 1.5 m

(D<sub>3</sub> dgt) 4. Clay, grey, with numerous brown spots, thin-laminated, homogeneous, viscous and plastic under wet conditions . . . . .0.3 m

(D<sub>3</sub> dgt) 5. Clay, mustard-yellow, dense, laminated, homogeneous, viscous and plastic under wet conditions; rusty and brown weather stains and spots are sometimes observed on the bed surface. Numerous fragments of yellow and light yellow, dense, sucrosic dolomites are found in the upper part of the bed. The contact with underlying and overlying beds is clearly defined . . . . .0.2 m

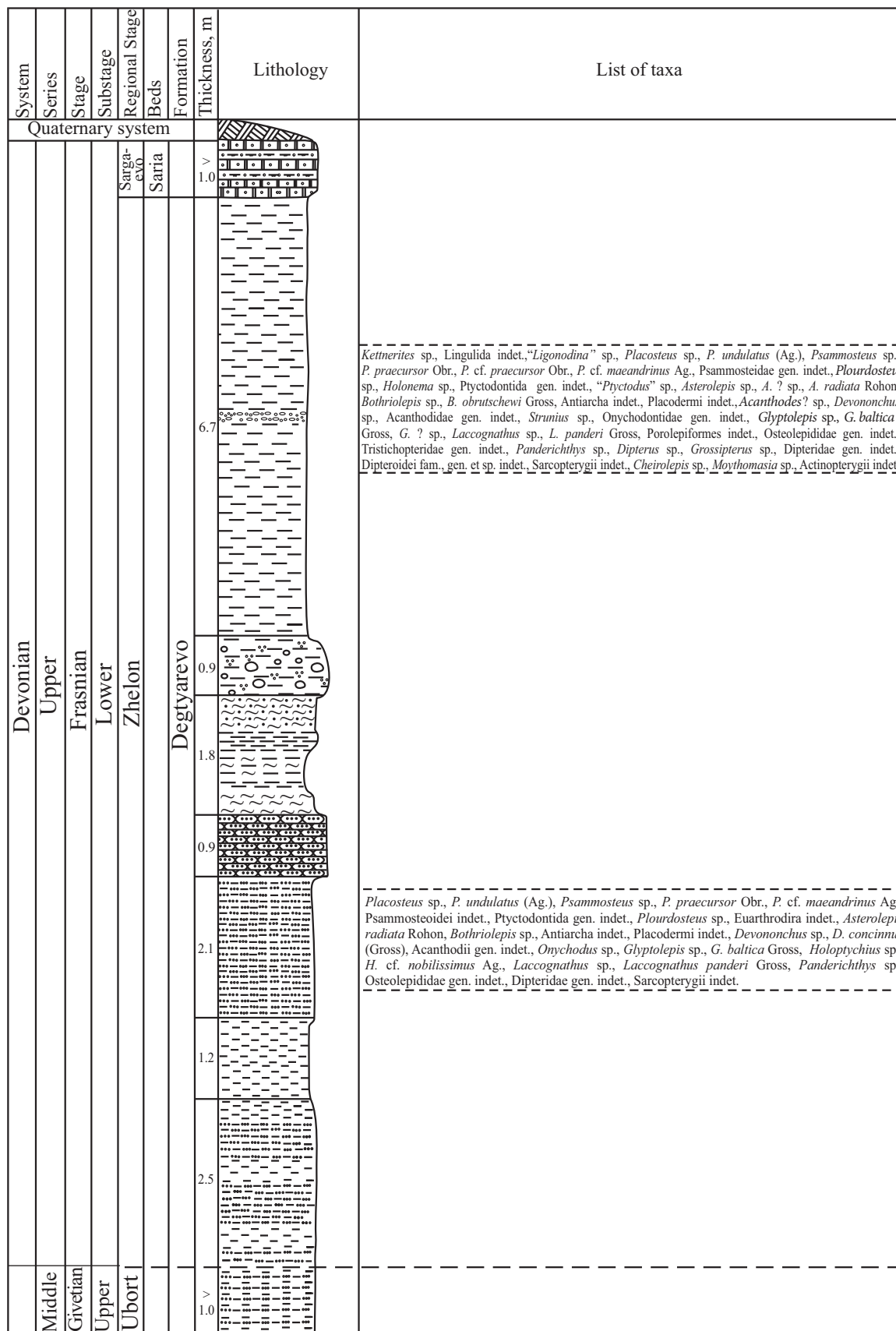
(D<sub>3</sub> srj) 6. Dolomite, fine-grained (sucrosic), dense, hard, indistinctly laminated, thick-bedded, fractured, with rare caverns up to 1 cm in diameter, slightly fissured, cracks are mainly seen along bedding surfaces; some amount of dolomite powder occurs as lenses or admixture. The dolomite and the dolomite powder are yellow and light yellow. Visually there are no organic remains . . . . .0.5 m

Vegetable soil, about 0.2 m thick, occurs, above the outcrop.

Based on the results of study of the above-described isolated outcrops, arranged in a stratigraphic sequence, a schematic composite section of the Degtyarevo Formation, which corresponds to the Zhelon Regional Stage, is given (Text-Figure 18). This composite section of the Degtyarevo Formation has a clear two-membered structure: clayey sediments dominate in the upper part, while silts and sandstones are often found in the lower part.

**Correlation of the Degtyarevo Formation.** Currently, exposures of terrigenous deposits of the Degtyarevo Formation have been reliably established in the Saryanka River basin in the area between the Obukhovo village and the former village of Kalyuty [8–10, 12]. Over this distance, eleven exposures have been studied in detail. The fossil remains were revealed in four of them: Obukhovo 1, «Sinie Gliny» 1, Kalyuty 2 and Kalyuty 7, and were represented mainly by skeletal elements of agnathans and fishes. In the remaining seven outcrops (Ruchey 1, Saria 1 and Saria 2, Degtyarevo 1, 2 and 3 and Voznovo 1) no organic remains were found. Despite this, it can be asserted with certainty that the age of the rocks





Text-fig. 18. Composite section of the Degtyarevo Formation (Lower Frasnian) and distribution of organic remains  
For explanations see previous figures



in these palaeontologically barren outcrops is identical. This conclusion is confirmed by the following data: general conditions of the occurrence of rocks in the section, the similarity of the composition of the rocks, the location of exposures with no fossils between palaeontologically well-studied outcrops, and the possibility of combining a conditional composite section from separated exposures that complementary to each other. The terrigenous deposits along the Rositsa River (Rositsa 1 and Rositsa 2 outcrops), taking into account similar lithological composition, are almost undoubtedly of the same age as deposits exposed along the Saryanka River at the localities of the Ruchey 1, Saria 1 and Saria 2. A direct correlation of exposed beds seems to be possible based on the lithological composition of the rocks, even without findings of organic remains.

The assemblage of agnathans and fishes revealed in the Degtyarevo Formation in the Obukhovo 1, «Sinie Gliny» 1, Kalyuty 2 and Kalyuty 7 outcrops denotes the heterostracan zone *Psammosteus praecursor*, which corresponds to the Amata Regional Stage of the Main Devonian Field [13]. In the territory of Belarus the deposits of the Amata Regional Stage correspond to the Zhelon Regional Stage [1, 14]. Consequently, according to the palaeontological data, the Degtyarevo Formation is an age analogue of the Zhelon Regional Stage in Belarus. In Russia, the Zhelon Regional Stage corresponds to the Timan Regional Stage [15]. In 2018, a very important finding was made in the clayey deposits of the Degtyarevo Formation in the Kalyuty 2 outcrop: among the numerous taxa of ichthyofauna, the species *Bothriolepis obrutschewi* Gross was found, which allows us to correlate this part of the section with the upper part of the Amata Regional Stage of the Main Devonian Field [16–19], and consequently denotes the upper part of the Zhelon Regional Stage of Belarus. The terrigenous deposits of the Degtyarevo Formation in the «Sinie Gliny» 1, Kalyuty 6 and Kalyuty 7 outcrops can also be correlated with the upper part of the Zhelon Regional Stage, despite the fact that the zonal species *Bothriolepis obrutschewi* Gross has not yet been found in them. These outcrops are located very close to each other (Text-Figure 1) and characterized by significant similarity of lithological composition.

In 2019 the Obukhovo 1 outcrop was further studied in order to clarify its relation to one or another part of the Zhelon Regional Stage. Unfortunately, so far it has not been possible to find a zonal species in this outcrop, which would allow us to define whether the lower or upper part of the Zhelon Regional Stage is represented here. At present, it can only be concluded that the rocks of the Degtyarevo Formation exposed on this area, as was already established earlier [8, 9, 10], undoubtedly belong to the Zhelon Regional Stage.

**Conclusions.** 1. The paper provides improved descriptions of the Obukhovo 1, Kalyuty 2, and Kalyuty 7 outcrops based on new results of the field works carried out in 2018-2019. In addition, detailed descriptions of the following outcrops of the Zhelon Regional Stage are given for the first time: Rositsa 2, Ruchey 1, Saria 2, Degtyarevo 1, Degtyarevo 2, Degtyarevo 3 and Voznovo 1.

2. On the basis of lithological and palaeontological data, a detailed subdivision of the above listed outcrops is performed and a new local stratigraphic unit, the Degtyarevo Formation, is distinguished.

3. A composite section is suggested as the stratotype section, consisting of a number of typical exposures of the Degtyarevo Formation occurring along the Saryanka River.

4. Information on the taxonomic composition of the ichthyofauna in the Obukhovo 1, «Sinie Gliny» 1 and Kalyuty 2 outcrops is supplemented. The largest number of taxa of agnathans and fishes is revealed in the last of the listed outcrops.

5. An important finding is made in the Kalyuty 2 outcrop, where zonal species *Bothriolepis obrutschewi* Gross is found, which makes it possible to attribute the deposits to the upper part of the Zhelon Regional Stage of Belarus and to correlate these strata with the upper part of the Amata Regional Stage of the Main Devonian Field.

6. Rare scolecodonts, sparse fragments of inarticulate brachiopods, single conodonts, as well as rare carbonified plant debris were for the first time found in the terrigenous rocks of the Degtyarevo Formation, in addition to the various remains of the ichthyofauna.

7. The Zhelon age of the Degtyarevo Formation is substantiated on the basis of palaeontological data. The Degtyarevo Formation is correlated with well-studied strata of the same age occurring within the Belarusian territory, as well as in the adjacent regions (Latvia and Russia).

8. The obtained new data should be used when performing large-scale geological surveys in the study area.

**Acknowledgements.** The authors are grateful to A. Yu. Machulsky, V. A. Sushkevich and A. S. Yakovlev for their help in carrying out field works and collecting the palaeontological material. Special gratitude is expressed to Dr. Sci. L. V. Shumlyansky for editing the English usage.

## References

1. *Obukhovskaya T. G., Kruchek S. A., Pushkin V. I., Nekryata N. S., Plax D. P., Sachenko T. Ph., Obukhovskaya V. Yu., Antipenko S. V.* The Devonian system / Stratigraphic Chart of the Precambrian and Phanerozoic deposits of Belarus: Explanatory Note. Minsk: State Enterprise "BelNIGRI", 2010, pp. 98–114 (with Stratigraphic Chart of the Devonian deposits of Belarus in 2 sheets) (in Russian).
2. *Lungershausen L. F.* Introduction into the geology of Belarus // Proc. of the Gory-Gorki Scientific Association / Belarusian Academy of Sciences, Branch of Nature and National Economy. – Gory-Gorki, 1930, vol. 7, pp. 181–213. + drawings (in Belarusian).
3. *Aleynikov A. A.* General Geological Map of the European part of the USSR, the western half and the northeastern quarter of the 28th sheet of the 10-verst map // Trudy GGU, 1933. (in Russian).
4. *Vorobyeva Z. P.* Fauna of the Devonian deposits of the Byelorussian SSR // Izvestiya Akademii Nauk BSSR, 1950, no. 6, pp. 99–103 (in Russian).
5. *Petrov L. S.* To the correlation of the sections of the Devonian deposits of the Byelorussian SSR and the Soviet Baltic States // Collection of Materials on the Exchange of Experience. Geology and Exploration. Moscow-Leningrad, 1951, pp. 7–8 (in Russian).
6. *Petrov L. S.* Devonian Deposits of the Northwest of the Russian platform. Leningrad, 1956, 174 p. (in Russian).
7. *Liepinš P. P.* Stratigraphy of the Frasnian deposits of the Latvian SSR / The Frasnian Deposits of the Latvian SSR. Riga, 1963, pp. 3–94 (in Russian).
8. *Plaksa D. P.* Preliminary results of palaeoichthyological study of the Devonian deposits of the Saryanka River basin (Vitebsk region) // Vestsi Natsyyanal'nai akademii navuk Belarusi. Seryya khimichnykh navuk = Proceedings of the National Academy of Science of Belarus. Chemical Series, 2005, no. 5, pp. 161–164 (in Russian).
9. *Plax D. P., Kruchek S. A.* Stratigraphy of Middle and Upper Devonian deposits of the Latvian Saddle (from ichthyofauna evidences derived from the Saryanka River outcrops, Belarus) // Lithosphere, 2010, no. 1 (32), pp. 43–59 (in Russian).
10. *Plax D. P.* Early Frasnian ichthyofauna of the north of Belarus // Lithosphere, 2010, no. 1 (32), pp. 60–81 (in Russian).
11. *Plax D. P., Kruchek S. A.* On the ichthyofauna of the Frasnian deposits of the Latvian Saddle of the Saryanka River basin (Belarus) // Palaeontology and the Improvement of the Stratigraphic Basis of Geological Mapping / Proc. of the LV Session of the Palaeontological Society of the Russian Academy of Sciences (St. Petersburg, April, 6–10, 2009). St. Petersburg, 2009, pp. 111–113 (in Russian).
12. *Plax D. P., Zaika Yu. V.* On the Sargaevo deposits (Frasnian, Upper Devonian) of the Latvian Saddle outcropping within Saryanka River basin (Belarus) // Lithosphere, 2018, no. 2 (49), pp. 54–82.
13. *Glin'skiy V. N.* The assemblages of Middle Devonian psammosteid agnathans from the eastern part of Main Devonian Field // Vestnik Saint-Petersburg University, Series 7, Geology, Geography, 4, pp. 62–71 (in Russian).
14. *Kruchek S. A., Makhnach A. S., Golubtsov V. K., Obukhovskaya T. G.* The Devonian system / Geology of Belarus // National Acad. Sci. Belarus, Institute of Geological Sciences; Ed. by A. S. Makhnach. Minsk, 2001, pp. 186–236 (in Russian).
15. *Rodionova G. D., Umnova V. T., Kononova L. I.* [et al.]. The Devonian of the Voronezh Anticline and the Moscow Syncline, Moscow, 1995, 265 p. (in Russian).
16. *Sorokin V. S., Lyarskaya L. A., Savvaitova A. S.* [et al.]. The Devonian and Carboniferous of the Baltic States, Riga, 1981, 502 p. (in Russian).
17. *Lyarskaya L. A., Lukševičs E. V.* Composition and distribution of agnathans and fishes in the Silurian and Devonian deposits of Latvia // Palaeontology and stratigraphy of the Phanerozoic of Latvia and the Baltic Sea, Riga, 1992, pp. 46–62 (in Russian).
18. *Mark-Kurik E.* The Middle Devonian fishes of the Baltic States (Estonia, Latvia) and Belarus // Courier Forschungsinstitut Senckenberg (Final Report of IGCP 328 project). 2000, vol. 223, pp. 309–324.
19. *Esin D., Ginter M., Ivanov A., Lukševičs E., Avkhimovich V., Golubtsov V., Petukhova L.* Vertebrate correlation of the Upper Devonian and Carboniferous on the East European Platform // Courier Forschungsinstitut Senckenberg (Final Report of IGCP 328 project). 2000, vol. 223, pp. 341–359.

Поступила 01.04.2020