

# New Data on the Middle Devonian Biostratigraphy of the Salair, Southwestern Siberia

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**Abstract**—The biostratigraphic data on the ammonoid, brachiopod, conodont, and ostracod assemblages of the Mamontovo and Zarechnoe horizons of the Salair were revised and analyzed. The stratigraphic succession of the Middle Devonian deposits of the Salair is clarified, and the new Zarechnoe Horizon, including the Akarachkino, Safonovo, and Kerlegesh beds, is proposed. The upper Eifelian ammonoid assemblage of the Agoniatites Zone, established in the upper part of the Akarachkino Beds, is the biostratigraphic level for global correlations. The upper Eifelian and lower Givetian brachiopod assemblage (*Indospirifer padaukpinensis* (= *I. pseudowilliamsi*)) characterizes the Safonovo Beds. Two middle Givetian brachiopod zones were recognized in the Kerlegesh Beds: Rhynchospirifer hians (= *Ilmenia subhians*) and *Subrensselandia? salairica* (= “*Chascothyris*” *salairica*). The conodont assemblage of the Akarachkino Beds characterizes the upper Eifelian. The middle Givetian conodont assemblage, including *Icriodus difficilis* Ziegler et Klapper, *Polygnathus linguiformis klapperi* Clausen, *Leuteritz* et Ziegler, *Po. parawebbi* Chatterton beta morphotype, *Po. ovatinodosus* Ziegler et Klapper, and *Po. pseudofoliatius* Wittekind, was found in the upper part of the Safonovo Beds. No conodont assemblage was found in the Kerlegesh Beds.

**Keywords:** Middle Devonian, Zarechnoe Horizon, brachiopods, ammonoids, conodonts, ostracods, Salair

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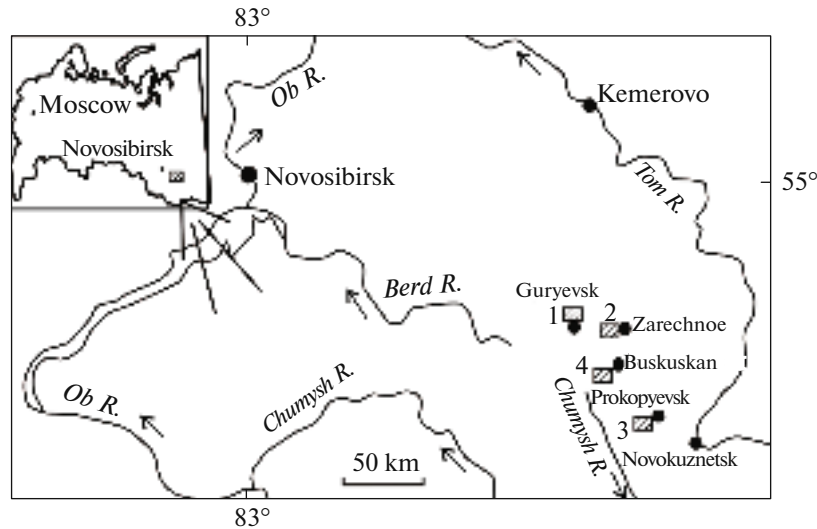
## INTRODUCTION

Lower and Middle Devonian deposits of the Salair play a key role in the structure of the Altai–Sayan fold belt. They are represented by different facies terrigenous-carbonate deposits bearing a rich faunal assemblage (*Resheniya...*, 1982). These deposits are exposed in full volume in quarries and roadside excavations along the eastern slope of the Salair (Fig. 1). In recent years, important results have been obtained in the course of biostratigraphic studies that made it possible to clarify the succession of these deposits. This paper presents a comprehensive justification of distinguishing a new Zarechnoe Horizon in the upper Eifelian and Givetian interval of the Salair based on a detailed study of the type localities of the Akarachkino, Safonovo, and Kerlegesh beds (Fig. 1). The new results obtained were presented at international and Russian conferences and the Devonian workshops of the Siberian Regional Interdepartmental Stratigraphic Commission and the Interdepartmental Stratigraphic Commission of Russia (Bakharev et al., 2012, 2013; Izokh and Yazikov, 2014; Yazikov and Izokh, 2014a, 2014b; Yazikov et al., 2014a, 2014b, 2015a, 2016; etc.).

## HISTORY OF STUDY

The study of Devonian deposits exposed at the margins of the Kuznetsk Basin has more than a century and a half of history and is inextricably connected with intensive evolution of the ideas about their biostratigraphic subdivision (Fomichev and Alekseeva, 1961; Kartseva and Tsyrlina, 1956; Lazutkin et al., 1936; Pets, 1901; Rzhonsnitskaya, 1959; Yavorsky, 1938; Yolkin, 1964, 1968; etc.). The actual material obtained upon conducting detailed geological survey works was summarized in the monograph *Stratigraphy of the USSR. Devonian System* (Rzhonsnitskaya, 1973). This material was the basis for developing the stratigraphic scheme of the Devonian of Siberia, which was presented at the Interdepartmental conference in 1979 (*Resheniya...*, 1982). This scheme is still officially valid (Table 1).

From the early 1980s until now, the geological study of the Salair and margins of the Kuznetsk Basin has been accompanied by a more detailed analysis of the Devonian deposits and different faunal assemblages. Special attention was paid to the study of conodonts; their zonal index species are markers of the lower boundaries of the Devonian stages (Gagiev et al., 1986, 1987; Rzhonsnitskaya et al., 1985; Yolkin



**Fig. 1.** Location scheme of the studied Middle Devonian sections. (1) Environs of the town of Guryevsk, Malaya Salairka Quarry (sections Ya-882, B-8418) and the right bank of the Maly Bachat River (section B-8410); (2) the western outskirts of the village of Zarechnoe, the right bank of the Bolshoi Bachat River (section B-8333); (3) Roadside quarries in the western outskirts of the town of Prokopyevsk (BS-091, BS-092, and BS-093 sections); (4) Buskuskan Quarry, southwest of the Buskuskan railway station (section B-8170).

et al., 1983; Yolkin and Izokh, 1986; etc.). In the early 2000s, A.Yu Yazikov clarified the brachiopod zonal scale of subdivision of the Middle Devonian fold frame of the Kuznetsk Basin (Yazikov, 2014c).

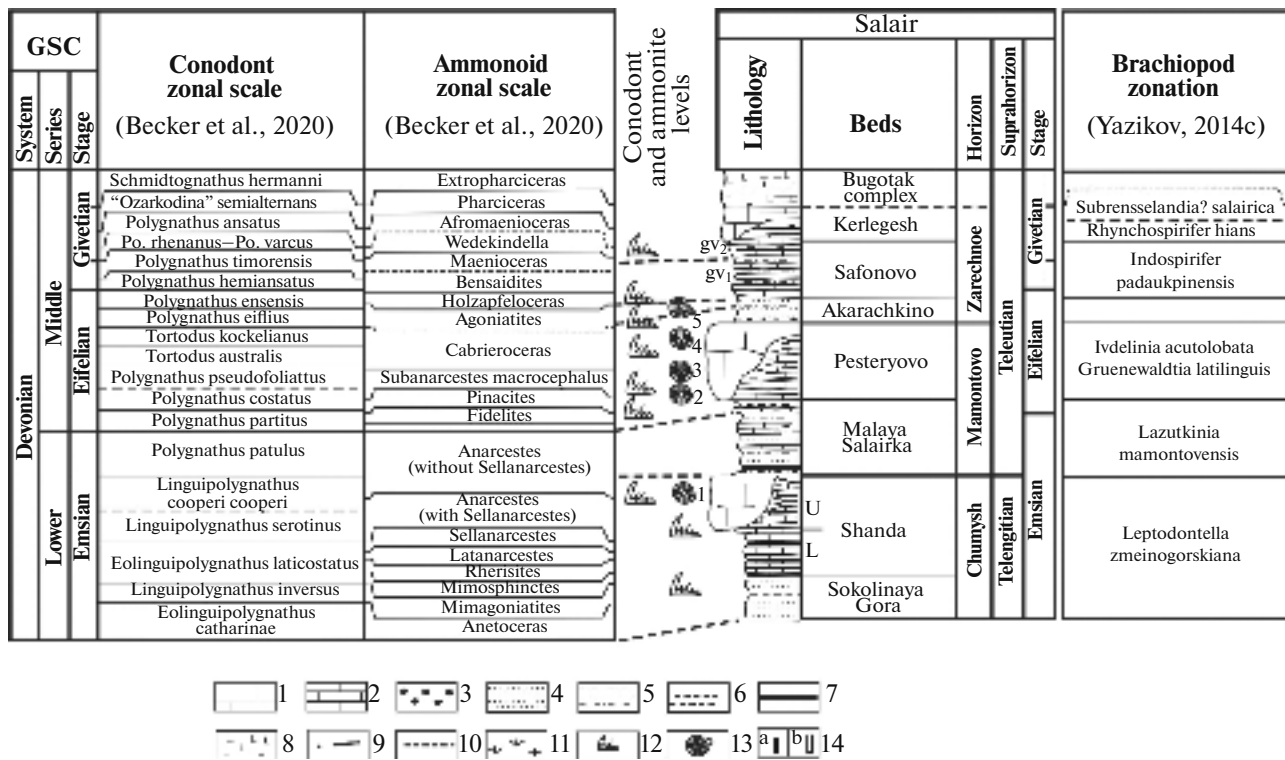
Researchers from different organizations have taken part in the study of Devonian deposits: E.A. Yolkin, R.T. Gratsianova, N.K. Bakharev, V.M. Zadorozhny, A.Yu. Yazikov, N.G. Izokh, B.M. Popov, E.S. Sobolev, and T.A. Shcherbanenko from the Institute of Geology and Geophysics of Siberian Branch of the USSR Academy of Sciences (now IPGG SB RAS), Novosibirsk; V.A. Zheltonogova, Ya.M. Gutak, and L.V. Galenko from AO West Siberian Geological Survey, Novokuznetsk; O.P. Mezentseva from the NPI, Novokuznetsk; M.A. Rzhonsnitskaya, N.M. Petrosyan, V.F. Kulikova, T.L. Modzalevskaya, Ya.N. Spassky, V.L. Klishevich, and O.B. Timofeeva from the Kar-

pinsky Russian Geological Research Institute, Leningrad; G.D. Isaev, V.I. Krasnov, N.P. Kulkov, and S.A. Stepanov from the Siberian Research Institute of Geology, Geophysics, and Mineral Raw Materials, Novosibirsk; M.Kh. Gagiev from the Shilo North-East Interdisciplinary Scientific Research Institute of the Far Eastern Branch of the Russian Academy of Sciences, Magadan; S.A. Rodygin from the Tomsk State University, Tomsk; N.M. Miretskaya from the Tomsk Branch of the Siberian Research Institute of Geology, Geophysics and Mineral Raw Materials, Tomsk; and others.

On the basis of the analysis of the previously published and new data on bio- and lithostratigraphy of the Devonian deposits of the Salair and western margins of the Kuznetsk Basin, the authors of the present paper have come to the conclusion that the strati-

**Table 1.** The development history of the regional stratigraphic scheme of the Middle Devonian deposits of the Salair (the western part of the Altai–Sayan region)

Lazutkin et al., 1936 Yavorsky, 1938	GSC	Resheniya..., 1982	Yolkin et al., 2000; Klyuchevye..., 2004	Kulkov and Peregoedov, 2010	Gutak et al., 2018	Yazikov et al., 2014 (with amendments)					
Beds	Division Stage	Horizon	Stage Suprahorizon, horizon, beds	Stage Brachiopod zones Beds	Stage Horizon	Stage Suprahorizon, horizon, beds					
Cheehiel Beds with <i>Spirifer cheehiel</i> , Indospirifer Beds with <i>Indospirifer pseudowilliamsi</i> , Chascothyris Beds with <i>Chascothyris</i> sp.	Middle Givetian	Alchedat	Givetian L M U	Givetian L M U	Givetian L M U	Givetian L M U	Suprahorizon				
		Safonovo					Mazalovo- Kitat	Euryspirifer pseudocheehiel	Izlyly Alchedat	Mazalovo- Kitat	Alchedat
		Kerlegesh					Safonovo	Stringocephalus burtini sibirica	Mazalovo- Kitat	Safonovo	Kerlegesh
		Akarachkino					Kerlegesh			Kerlegesh	Safonovo
Facies of the Eifelian Stage: (1) Agoniatid shales with Agoniatites  (2) with <i>Spirifer undiferus</i> and <i>Calceola sandalina</i>	Middle Eifelian	Mamontovo	Eifelian L M U	Eifelian L M U	Eifelian L M U	Eifelian L M U	Akarachkino				
							Pesteryovo	Indospirifer padaukpinensis	Safonovo	Mamontovo	
							Malaya Salairka	Chascothyris salairica	Kerlegesh		Akarachkino
		Shanda						Lazutkinia mamontovensis, Retzispirifer uriensis	Mamontovo		Mamontovo



**Fig. 2.** Regional stratigraphic scheme of the Lower and Middle Devonian in the Salair (after Yazikov et al., 2016, with amendments). (1) Massive limestones; (2) bedded limestones; (3) gravelites; (4) sandstones; (5) siltstones; (6) mudstones; (7) coal; (8) andesibasalts, trachybasalts, basalts; (9) faults; (10) correlation lines; (11) sodded interval; (12) conodonts; (13) ammonoids; (14a) brachiopods determined to the genus level; (14b) species of brachiopods determined with cf. Levels with ammonoids: (1) *Mimagoniatites bohemicus* (Barrande), Shanda Beds; (2) *Fidelites fidelis* (Barrande), *Fidelites occultus* (Barrande), *Fidelites* sp.; Pesteryovo Beds (lower part); (3) *Fidelites fidelis* (Barrande), *Fidelites bicanaliculatus* (Sandberger et Sandberger), *Fidelites* sp., *Subanarcestes* aff. *marhoumensis* Goddert; Pesteryovo Beds (lower part); (4) *Fidelites bicanaliculatus* (Sandberger et Sandberger), *Subanarcestes* ex gr. *marhoumensis* Goddert; Pesteryovo Beds (upper part); (5) *Agoniatites vanuxemi* (Hall), *Fidelites* sp., *Cabrierocheras salairicum* Nikolaeva; Akarachkino Beds (upper part) (Yazikov et al., 2015a, 2016).

graphic scheme of the Middle Devonian of the western part of the Altai–Sayan folded area should be corrected and revised. This conclusion is based on identifying inconsistencies between the existing ideas about the sequence of the Middle Devonian regional subdivisions of the Salair (*Resheniya...*, 1982) and the sequence that has been established recently in the type sections of the Safonovo and Kerlegesh beds.

The development of ideas about the stratigraphic subdivision of the Middle Devonian of the Salair is shown in Table 1. At the first stage, beds with faunal remains were identified and later were transferred to the rank of horizons (Lazutkin et al., 1936; *Resheniya...*, 1982; Rzhonsnitskaya, 1952; *Stratigraficheskii...*, 1975; Yavorsky, 1938; etc.). In recent years, different age estimates have been obtained for the Akarachkino, Kerlegesh, and Safonovo horizons (Gutak et al., 2018; Kulkov and Peregoedov, 2010; etc.), which differ from the dates of these units in the officially valid stratigraphic chart (Table 1). The ambiguity in understanding the age of these deposits makes it difficult to determine the actual stratigraphic sequence of the Middle Devonian in the Salair. According to the

results of a comprehensive analysis of the new and published data, we concluded that it is necessary to revise this sequence and consider the Kerlegesh Beds (*Chascothyris*) younger than the Safonovo Beds (*Indospirifer*). On the basis of considering the horizon as a specific transgressive-regressive cycle in the development of the paleobasin, we propose to distinguish a new Zarechnoe Horizon in the Middle Devonian of the Salair, which includes the Akarachkino, Safonovo, and Kerlegesh beds (Yazikov et al., 2014a) (Fig. 2).

The following data served as a justification for the revision of the stratigraphic scheme of the Middle Devonian:

(1) An ammonoid assemblage of the upper Eifelian *Agoniatites* Genozone, which can be considered as a regional and global biomarker has been identified. In four studied sections (B-8410, BS-091, BS-093, and B-8333), the distribution of these ammonoids was traced in the tuffaceous unit at the top of the Akarachkino Beds.

(2) The sequence of the distribution of brachiopods in the studied Middle Devonian sections of the Salair has been clarified. The Akarachkino Beds with

ammonoids of the upper Eifelian Agoniatites Zone are conformably overlain by the Safonovo Beds bearing the brachiopod assemblage of the *Indospirifer padaukpinensis* (= *I. pseudowilliamsi*) Zone (sections BS-091 and BS-093). Up section, the latter are overlain by deposits with brachiopods of the *Rhynchospirifer hians* (= *Ilmenia subhians*) and *Subrensselandia? salairica* (= *Chascothyris salairica*) zones, which are characteristic of the higher lying Kerlegesh Beds (sections BS-092 and B-8170).

(3) Finally, the conodont assemblages recognized in the upper part of the Safonovo Beds characterize the *Polygnathus rhenanus*/*Polygnathus varcus* (= *Icriodus difficilis*) Zone and the lower part of the middle Givetian *Polygnathus ansatus* Zone.

## MATERIAL

The studied sections are located in the type distribution area of the Akarachkino, Safonovo, and Kerlegesh beds in the environs of Guryevsk and Prokopyevsk, the village of Zarechnoe, and the Buskuskan railway station of Kemerovo oblast (Fig. 1). The main collections of macro- and microfaunal remains were made at the detailed description of the Middle Devonian reference sections from the 1980s to the early 2000s and then supplemented in subsequent years. The collection of ammonoids (about 300 specimens) was gathered in sections B-8410, E-837, BS-091, BS-093, and B-8333 by E.A. Yolkin, N.K. Bakharev, O.P. Mezentseva, and E.S. Sobolev in 1983, 1984, and 2005–2014. To study the microfauna (ostracods and conodonts), 201 samples weighing from 2 to 8 kg were selected: 10 samples from section B-8410, 61 samples from section BS-091, 70 samples from section BS-093, 20 samples from section B-8333, 20 samples from section BS-092, and 20 samples from section B-8170.

The brachiopod collection from the Zarechnoe Horizon includes a few thousand specimens and characterizes the assemblage of 73 taxa revised by A.Yu. Yazikov following the present-day classification. The significant changes in the nomenclature also concerned the species after which “*Indospirifer Beds*” and “*Chascothyris Beds*” were named. Thus, the zonal species *Indospirifer pseudowilliamsi* from the Safonovo Beds is included in the synonymy of *Indospirifer padaukpinensis*, and the index species *Ilmenia subhians* and “*Chascothyris salairica*” from the Kerlegesh Beds are assigned to the species *Rhynchospirifer hians* and *Subrensselandia salairica*, respectively (Yazikov, 2014c).

Microfaunal preparations were made using traditional chemical preparation methods of carbonate rocks with a weak solution of acetic acid (5–7%) and melting using sodium hyposulfite in the laboratories of the Trofimuk Institute of Petroleum Geology and Geophysics (IPGG SB RAS). Conodont elements of good and satisfactory preservation were found only in

23 out of 201 samples. However, it should be noted that no conodonts were found in two sections (B-8170 and BS-092). Complete ostracod shells and separate valves of good and satisfactory preservation were found in 55 samples from five sections, except for B-8410.

Conodonts were studied by N.G. Isokh; ostracods, by N.K. Bakharev and B.M. Popov; ammonoids, by N.K. Bakharev, S.V. Nikolaeva, E.S. Sobolev, T. Becker, and K. Klug; and brachiopods, by A.Yu. Yazikov and T.A. Shcherbanenko. The photographing of conodonts and ostracods was performed at the Shared Access Center of the Sobolev Institute of Geology and Mineralogy of the Siberian Branch of the Russian Academy of Sciences (IGM SB RAS) using a TESCAN MIRA3 scanning electron microscope. The collections were studied under a Stemi 2000 ZEISS binocular microscope.

The faunal collections are stored in the Laboratory of Paleozoic Paleontology and Stratigraphy, the Laboratory of Micropaleontology, and the Laboratory of Mesozoic Paleontology and Stratigraphy, as well as in the Shared Access Center Collection GEOCHRON of IPGG SB RAS (Novosibirsk).

## BIOSTRATIGRAPHIC STUDIES

### *Teleutian Suprahorizon*

E.A. Yolkin distinguished the Teleutian Suprahorizon in the Middle Devonian sequence in the western part of the Altai–Sayan folded area (Yolkin et al., 1983). This suprahorizon includes the Mamontovo, Kerlegesh, Safonovo, and Alchedat horizons. We propose to include the Mamontovo, Zarechnoe, and Alchedat horizons (horizons = Regional substages) in the structure of the Teleutian Suprahorizon and correlate it with the upper part of the Emsian, Eifelian, and Givetian stages of the General Stratigraphic Chart. The Mamontovo Horizon includes the Malaya Salairka and Pesteryovo beds, and the Zarechnoe Horizon includes Akarachkino, Safonovo, and Kerlegesh beds. The main biostratigraphic results were obtained by studying the typical outcrops of these regional divisions with a layer-by-layer selection of paleontological samples and their precise reference to sections.

### *Mamontovo Horizon*

This horizon was named by Rzhonsnitskaya (1952) after the village of Mamontovo, located on the southwestern outskirts of the Kuznetsk Basin. The Mamontovo Horizon stratotype was described on the right bank of the Maly Bachat River, northeast of the Akarachkino Quarry in the environs of the town of Guryevsk. The Mamontovo Horizon corresponds to the upper part of the Emsian Stage and the most of the Eifelian Stage or *Polygnathus patulus*, *Polygnathus partitus*, *Polygnathus costatus*, *Polygnathus pseudo-foliatus*, and *Tortodus australis* conodont zones and

the lower part of the *Tortodus kockelianus* Zone (*Klyuchevye...*, 2004; Yazikov et al., 2014a, 2014b, 2015a, 2016). The horizon includes the Malaya Salairka, and Pesteryovo beds (Fig. 2).

**Malaya Salairka Beds.** This name was first used by Rzhonsnitskaya (1968) to describe mainly clastic deposits overlying the Upper Shanda Beds with *Zdimir baschkiricus*. They were named after the village of Malaya Salairka, located near the town of Guryevsk. The section, exposed on “the first hill to the east of the village of Malaya Salairka”, was proposed as the stratotype (Rzhonsnitskaya, 1968, p. 87). At present, this section is likely located within the Malaya Salairka Quarry. The lower stratigraphic levels of the Malaya Salairka Beds and their contact with the Upper Shanda Beds crop out on the northeastern side of the Akarachkino Quarry, while the upper levels crop out in the southern and southwestern parts of the Malaya Salairka Quarry.

On the basis of brachiopods, the Malaya Salairka Beds correspond to the *Lazutkinia mamontovensis* Biozone. The typical species of these beds are *Lazutkinia mamontovensis* Rzhonsnitskaya, *Retzia salairica* Peetz, *Beckmannia* ex gr. *pentagona* (Kayser), *Tetratomia? yavorskii* Rzhonsnitskaya, *Urella asiatica* Rzhonsnitskaya, and *Eoreticularia aviceps* (Kayser) (Yazikov, 2014a, 2014c).

The Malaya Salairka Beds are poorly described using conodonts. Only *Caudicriodus* sp. A. was found. The joint occurrence of the first Eifelian zonal conodonts *Polygnathus partitus* Klapper, Ziegler et Mashkova, and *Po. costatus* Klapper was established in the lower part of the Pesteryovo limestones. Thus, the stratigraphic interval of the Malaya Salairka Beds corresponds to the *Polygnathus patulus* and *Polygnathus partitus* conodont zones, i.e., Emsian and Eifelian boundary deposits (Fig. 2). Considering the scale change of brachiopod assemblages in the upper part of the Malaya Salairka Beds, the authors of the present paper consider it appropriate to draw the Emsian–Eifelian conditional boundary at this level (Izokh and Yazikov, 2014; Yazikov and Izokh, 2014a, 2014b).

**Pesteryovo Beds.** The name was given by Pets (1901) after the village of Novopesteryovo of the Guryevsk district. The stratotype was determined by M.A. Rzhonsnitskaya and was considered as outcrops of light gray biomorphic limestones, “composing the hill in the central part of Novo-Pesteryovo on which the school is located” (Kharin, 1958; Rzhonsnitskaya, 1968, p. 88). Currently, the Pesteryovo Beds are fully exposed in the central, northern, and northeastern parts of the Malaya Salairka Quarry, where it is proposed to establish a neostatotype.

In the lower part of the Pesteryovo limestones, the first Eifelian zonal conodonts *Polygnathus partitus* Klapper, Ziegler et Mashkova and *Po. costatus* Klapper, together with *Icriodus regularicrescens* Bultynck and *Caudicriodus* sp. A, and ammonoids typical of the

lower Eifelian Pinacites Genozone were found (*Klyuchevye...*, 2004; *Middle-Upper...*, 2011).

In the upper part of the Pesteryovo Beds, conodonts belonging to the lower part of the *Tortodus kockelianus* Zone were found: *Polygnathus costatus* Klapper, *Po. linguiformis pinguis* Weddige, *Po. linguiformis klapperi* Clausen, Leuteritz et Ziegler, *Po. angusticostatus* Wittekindt, *Po. robusticostatus* Bischoff et Ziegler, *Icriodus regularicrescens* Bultynck, and *Tortodus* cf. *planus* (Bischoff et Ziegler) (*Klyuchevye...*, 2004; *Middle-Upper...*, 2011). The above-listed taxa are cosmopolite and widespread in different world regions (Klapper and Johnson, 1980; Weddige, 1977; etc.). *Polygnathus costatus* Klapper, *Po. linguiformis pinguis* Weddige, *Po. angusticostatus* Wittekindt, and *Po. robusticostatus* are typical species of the Eifelian Stage. Subspecies *Po. linguiformis klapperi* appears in the upper Eifelian *Tortodus kockelianus* Zone and passes to the Givetian Stage to the “Ozarkodina” semialternans conodont Zone (Clausen et al., 1979; Walliser and Bultynck, 2011).

Among the typical brachiopod species of the above beds are *Clorinda asinuata* Sapelnikov, *Gruenewaldtia latilinguis* (Schnur), *Corvinopugnax resupinata* (Kulkov), *Peratos pallax* L. Mizens, *Desquamatia (I.) zonata* (Schnur), *Isospinatrypa aspera subspinososa* (Lazutkin), and *Ivdelinia acutolobata* (Sandberger) (Yazikov, 2014a, 2014b, 2014c).

The Pesteryovo Beds in the type localities in the Malaya Salairka Quarry were characterized by conodonts of the *Po. costatus* Zone and the lower part of the *Tortodus kockelianus* Zone. On the basis of brachiopods, these beds correspond to the *Gruenewaldtia latilinguis* and *Ivdelinia acutolobata* biozones (Fig. 2).

The Mamontovo Horizon corresponds to the unified transgressive cycle. It is overlain by the Akarachkino Beds of the Zarechnoe Horizon. The boundary between the Mamontovo and Zarechnoe horizons crops out on the northeast side of the Malaya Salairka Quarry. Despite the fact that there is a sharp change in the composition of deposits (from limestones to fine-grained sediments), the boundary between them is conformable.

#### *Zarechnoe Horizon*

This horizon was named by A.Yu. Yazikov and N.G. Izokh (Yazikov et al., 2014) after the village of Zarechnoe (Belovo district, Kemerovo oblast), in environs of which outcrops of this horizon are widespread. The stratotype of the Zarechnoe Horizon is considered a composite one. It is represented by a set of the stratotypes of the following beds—Akarachkino, Safonovo, and Kerlegesh, which were previously considered in the rank of horizons (Fig. 2) (*Resheniya...*, 1982). This sequence is represented by a set of sections in the outskirts of Guryevsk (Ya-986, B-8410), Prokopyevsk (BS-091, BS-093, BS-092), Zarechnoe

(B-8333), and the Buskuskan Quarry (section B-8170) (Fig. 1). A reexamination of the BS-091, BS-093, BS-092, B-8333, and B-8170 sections allowed one to reveal that they were initially described in reverse order (Yazikov, 2014c).

The Zarechnoe Horizon corresponds to the upper Eifelian and lower and middle Givetian, to the interval of the following zones in the conodont zonal succession: *Tortodus kockelianus*, *Polygnathus eiflius*, *Polygnathus ensensis*, *Polygnathus hemiansatus*, *Polygnathus rhenanus*–*Polygnathus varcus*, *Polygnathus ansatus*, and *Ozarkodina semialternans* (Fig. 2).

**Akarachkino Beds.** The name was given by M.A. Rzhonsnitskaya after the settlement of Akarachkino, near the town of Guryevsk (Rzhonsnitskaya, 1952). The stratotype of the Akarachkino Beds (section B-8410) is located on the Maly Bachat River right bank, 0.5 km to the east of the outskirts of the settlement of Razdol'noe (Figs. 1, 3, 4). However, the contacts of these beds with the underlying Pesteryovo Beds and overlying Safonovo Beds are not exposed here. For this reason, the composite neostatotype is proposed for the Akarachkino Beds. The lower levels of these beds crop out on the northeastern side of the Malaya Salairka Quarry (Ya-896), while the higher levels crop out on the western outskirts of the town of Prokopyevsk (sections BS-091 and BS-093) and on the western outskirts of the village of Zarechnoe (section B-8333) (Figs. 1, 5–10). The thickness of the Akarachkino Beds is about 130 m. The authors of the present paper consider the Akarachkino Beds, previously included in the Mamontovo Horizon (*Klyuchevye...*, 2004, *Middle-Upper...*, 2011), in the rank of lower beds of the Zarechnoe Horizon (Yazikov, 2014c; Yazikov and Izokh, 2014b; Yazikov et al., 2014).

The lower part of Akarachkino Beds is faunistically poorly described. However, abundant brachiopods, ammonoids, and conodonts were found in the upper part (Figs. 3, 5, 7). Findings of tentaculites *Nowakia procera* (Maurer) are known from the lower part of the Akarachkino Beds in the Malaya Salairka Quarry; in the upper parts of beds, on the right bank of the Maly Bachat River, *Viriatellina afoniana* G. Ljaschenko was found (Klishevich and Miretskaya, 1986).

**Brachiopods.** The brachiopod assemblage includes 54 species from 40 genera (23 taxa were identified to the genus level). The species typical only of these beds are absent; all identified brachiopods occur in underlying and overlying younger deposits (Figs. 3, 5, 7, 9). However, the transition in the brachiopod assemblage to the new assemblage of the Zarechnoe Horizon and disappearance of most Mamontovo forms is observed in the Akarachkino Beds (Yazikov, 2014a, 2014b, 2014c; Yazikov et al., 2014).

**Ammonoids.** The regional and global biomarker of the Akarachkino Beds is the ammonoid assemblage, recognized at the top of four sections (Figs. 3, 5, 7, 9): B-8410 (in environs of the town of Guryevsk), BS-091

and BS-093 (environs of the town of Prokopyevsk), and B-8333 (the environs of the village of Zarechnoe, the right bank of the Bolshoi Bachat River) (Nikolaeva and Bakharev, 2010; Bakharev, Sobolev, 2011; Yazikov et al., 2014, 2015a). In calcareous siltstones of the upper part of the reference section of the Akarachkino Beds (section B-8410, Bed 7; Figs. 3, 4), *Agoniatites vanuxemi* (Hall) (Plate I: figs. 1–7), *Fidelites* sp. (Plate I: figs. 9, 10), and *Cabrieroceras salairicum* Nikolaeva (Plate I: figs. 11, 12) were found. The same ammonoids were found in two sections (BS-091, BS-093) in the tuffaceous terrigenous-carbonate unit in environs of the town of Prokopyevsk (Figs. 5, 7; Plate I: figs. 8, 13; Plate II), which was previously traditionally considered as part of the Safonovo Formation (Rzhonsnitskaya, 1968).

During the international field excursion in 2011, late Eifelian ammonoids *Agoniatites* cf. *vanuxemi* (Hall) and *Fidelites* sp. were first found in tuff sandstones at the “type” localities of Safonovo Beds (Zarechnoe Horizon section, B-8333, Bed 11; Fig. 9). According to the conclusion of leading experts on the Devonian ammonoids T. Becker, K. Klug, S.V. Nikolaeva, E.S. Sobolev, and N.K. Bakharev (participants of the field excursion), the country deposits of the above ammonoid localities (B-8410, BS-091, BS-093, and B-8333) should be attributed to the unified, rather narrow stratigraphic interval of the upper Eifelian *Agoniatites* Genozone. This interval corresponds to the upper part of the Akarachkino Beds.

As noted above, the identified ammonoid assemblage of the Akarachkino Beds includes about 300 specimens, regularly distributed in all four localities. The above assemblage characterizes a rather narrow biostratigraphic interval of the upper Eifelian *Agoniatites* Genozone of the standard ammonoid scale (MD I-F1), which is correlated with the *Polygnathus eiflius* conodont zone (Becker et al., 2020).

**Conodonts.** In the type locality of the Akarachkino Beds, below the level of findings of ammonoids, a late Eifelian conodont assemblage was found (Fig. 3, Plate III). This assemblage includes the following taxa: *Icriodus* aff. *obliquimarginatus* Bischoff et Ziegler, *Icriodus* sp. A, *Icriodus* sp., *Polygnathus costatus oblongus* Weddige, *Po. parawebbi* Chatterton, and *Neopanderodus aequabilis* Telford. The species *Po. costatus oblongus* was described from the upper Eifelian Ahrdorf Beds of the Eifel Mountains and characterizes a narrow stratigraphic interval—*Tortodus kockelianus* conodont zone (Klapper and Johnson, 1980; Weddige, 1977). The first occurrence of *Po. parawebbi* is noted in the *Tortodus kockelianus* Zone and traced to the lower *Polygnathus varcus* Subzone (Klapper and Johnson, 1980; etc.). Specimens attributed to *Icriodus* aff. *obliquimarginatus* Bischoff et Ziegler are most similar in the general structure of the platform to the type specimens of *Icriodus obliquimarginatus*, being different in opisthocline posterior edge of the platform



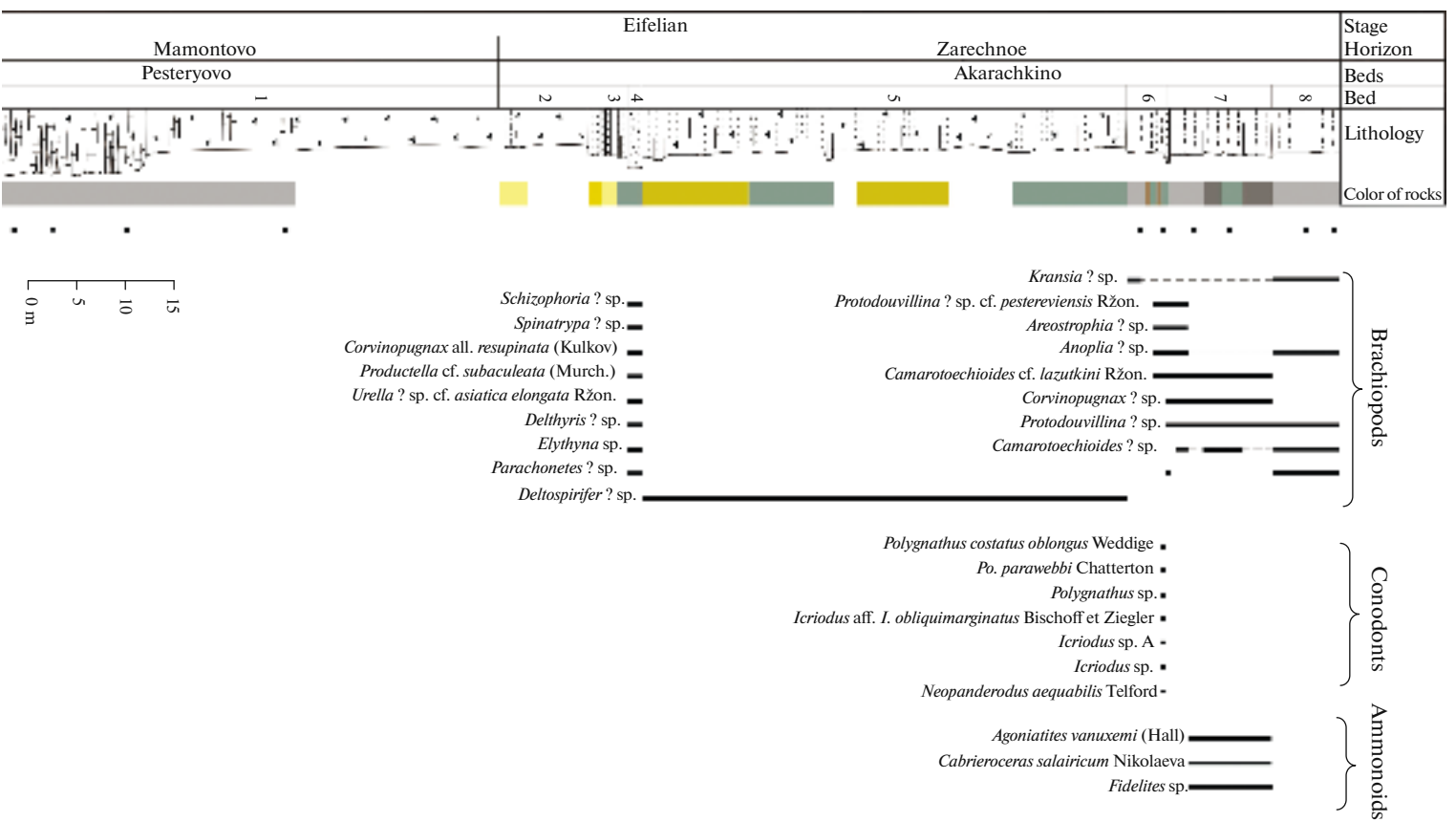


Fig. 3. Lithology and fauna distribution in the Akarachkino Beds (brachiopods, conodonts, ammonioids) in section B-8410, the right bank of the Malý Bacht River. See legend in Fig. 2.

(Plate III: fig. 1d). Additional material is needed to distinguish a new taxon. *Neopanderodus aequabilis* is known from the upper Emsian—middle Givetian of Australia (Anderson, 2003; Telford, 1975) and the lower and middle Givetian of Iran (Adhamian, 2003; Ghobadi Pour et al., 2013).



**Fig. 4.** Panoramic photo of the upper part of section B-8410, Bed 7 with findings of ammonoids, environs of the town of Guryevsk, the right bank of the Maly Bachat River.

M.Kh. Gagiev et al. (Gagiev et al., 1986, 1987; Rzhonsnitskaya et al., 1985, 1990) described the rich conodont assemblage, including *Polygnathus parawebbi* Chaterton beta morphotype and *Icriodus cymbiformis* Branson et Mehl from the same section.

Different assemblages of conodonts were found in sections of the Akarachkino Beds in roadside quarries (BS-091 and BS-093) in the environs of the town of Prokopyevsk (Figs. 5, 7; Tables 2, 3; Plates III, IV). In the upper part of the Akarachkino Beds (section BS-091), the following conodonts were found directly in the same bed with late Eifelian ammonoids: *Icriodus regularicrescens* Bultynck, *Icriodus* sp. B, *Icriodus* sp. C, *Icriodus* sp. D, *Icriodus* sp. E, *Polygnathus linguiformis klapperi* Clausen, Leuteritz et Ziegler, *Po.* aff. *Po. pseudofoliatum* Wittekindt, *Neopanderodus aequabilis* Telford, *Tortodus* cf. *T. obliquus* (Wittekindt), *Belodella* sp. A, etc. The representatives of the genus *Icriodus* dominate in the studied collection. Four groups are distinguished in this genus: *Icriodus* sp. B, *Icriodus* sp. C, *Icriodus* sp. D., and *Icriodus* sp. E. It is necessary to obtain additional material to attribute them to new species. Taxon *Tortodus obliquus* (Wittekindt) is within limits of the Eifelian Stage (Klapper and Johnson, 1980; etc.). The distribution interval of *Polygnathus linguiformis klapperi* Clausen and Leuteritz et

Ziegler covers the upper Eifelian and lower–middle Givetian, from the *Tortodus kockelianus* conodont zone to the *Ozarkodina semialternans* conodont zone (Clausen et al., 1979; Walliser and Bultynck, 2011). *Polygnathus pseudofoliatum* Wittekindt is characteristic of upper Eifelian and Givetian deposits (conodont zones from *Tortodus australis* to *Polygnathus L. varcus*) (Barskov et al., 1991; Klapper and Johnson, 1980; Weddige, 1977; Ziegler et al., 1976; etc.). The identified conodont assemblage of the Akarachkino Beds characterizes the upper part of the upper Eifelian *Tortodus kockelianus* conodont zone.

In the upper part of the Akarachkino Beds (section BS-093), below the findings of Late Eifelian ammonoids, conodonts *Caudicriodus* sp. A were found (Table 3; Plate III, Fig. 12).

In the Zarechnoe Horizon section, findings of conodonts of *Polygnathus linguiformis linguiformis* Hinde epsilon morphotype, *Po. linguiformis linguiformis* morphotype indet., and *Icriodus* ex gr. *expansus* Branson et Mehl are known from the conglomerate and tuff sandstone stratum currently attributed to the Akarachkino Beds (Gagiev et al., 1987). This assemblage characterizes the upper Eifelian (*Polygnathus ensensis* Zone) and Givetian (up to *Schmidtnathus hermanni* Zone) stages.



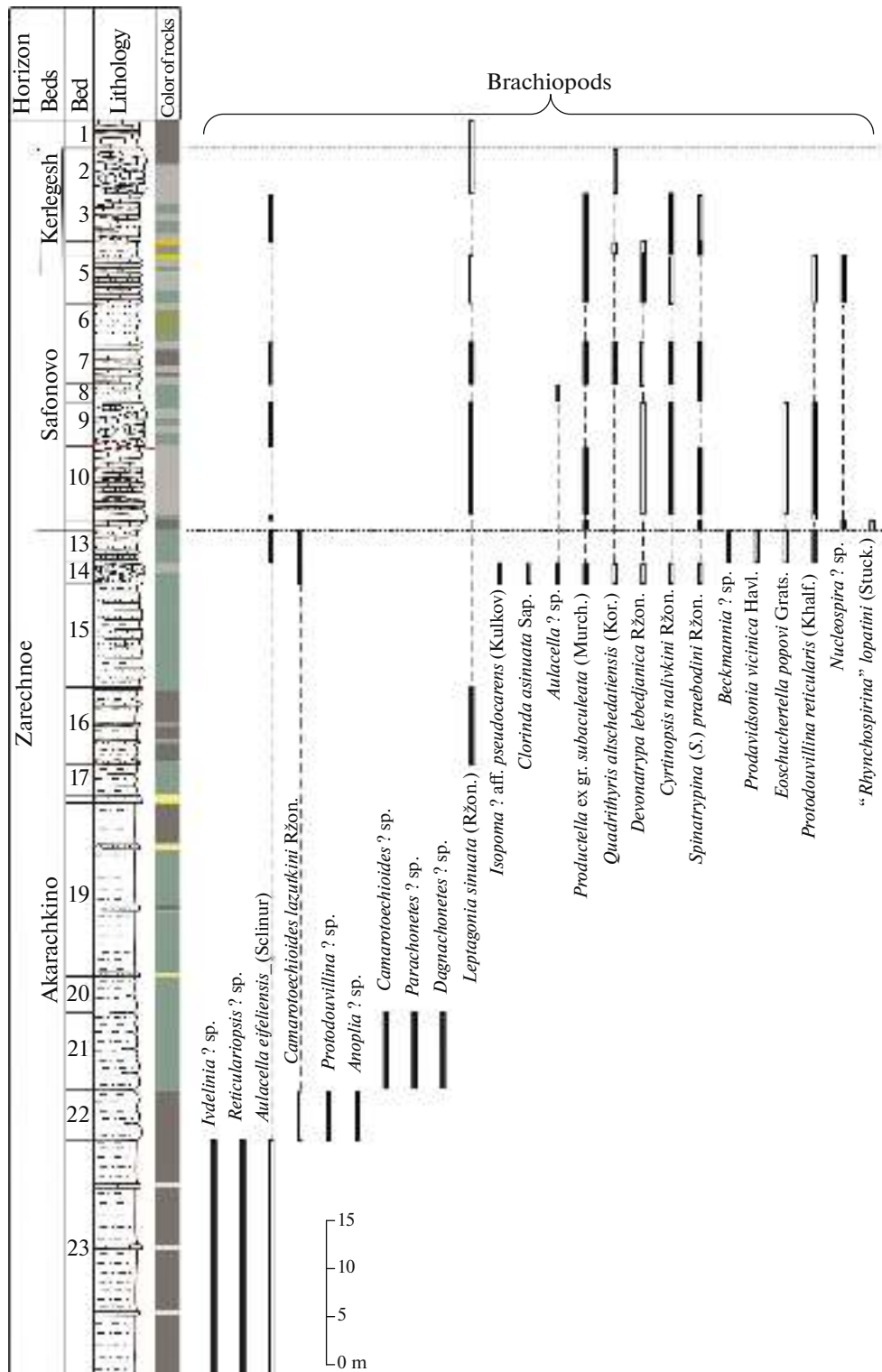


Fig. 5. Lithology and fauna distribution in the Akarachkino, Safonovo, and Kerlegesh beds (brachiopods, conodonts, ostracods, ammonoids) in section BS-091 in the roadside excavation along the left bank of an unnamed creek—a left tributary of Egos Creek, environs of the town of Prokopyevsk. See legend in Fig. 2.

**Ostracods.** Ostracods were not found in the strato-type section of the Akarachkino Beds (B-8410, outskirts of Guryevsk). The rich ostracod assemblage was described from the roadside quarry on the outskirts of

Prokopyevsk (section BS-091; Fig. 3, Plate V). The following taxa were described from the upper part of the Akarachkino Beds: *Amphissites* aff. *concentricus* Bakharev, *Hanaites mirabilis* (Polenova), *Parabolbi-*

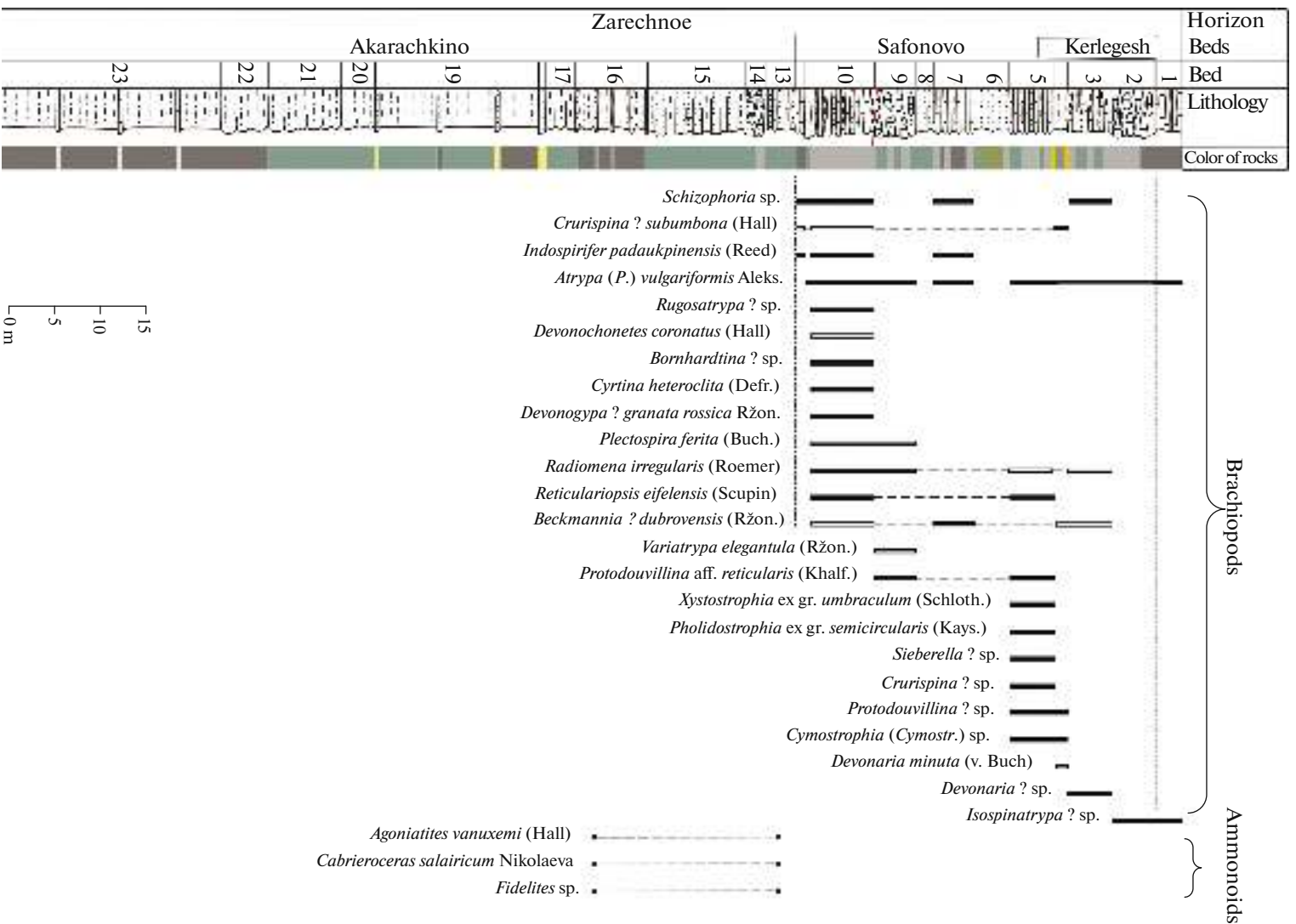


Fig. 5. (Contd.)

*nella* sp., *Amnuloides verrucosa* Polenova, *Microcheilinaella givetica* Rozhdestvenskaya, *Subligaculum* aff. *scrobiculatum* Kesling at McMillan, *Miraculum ornatus* Bakharev, and *Bairdia safonovskiensis* Polenova. Almost all identified species are characterized by a

wide vertical and lateral distribution. However, there are locally distributed species. Taxon *Amphissites concentricus* Bakharev is known from the upper Emsian Shanda Horizon of the Salair (Bakharev, 1987). *Miraculum ornatus* Bakharev was described in the

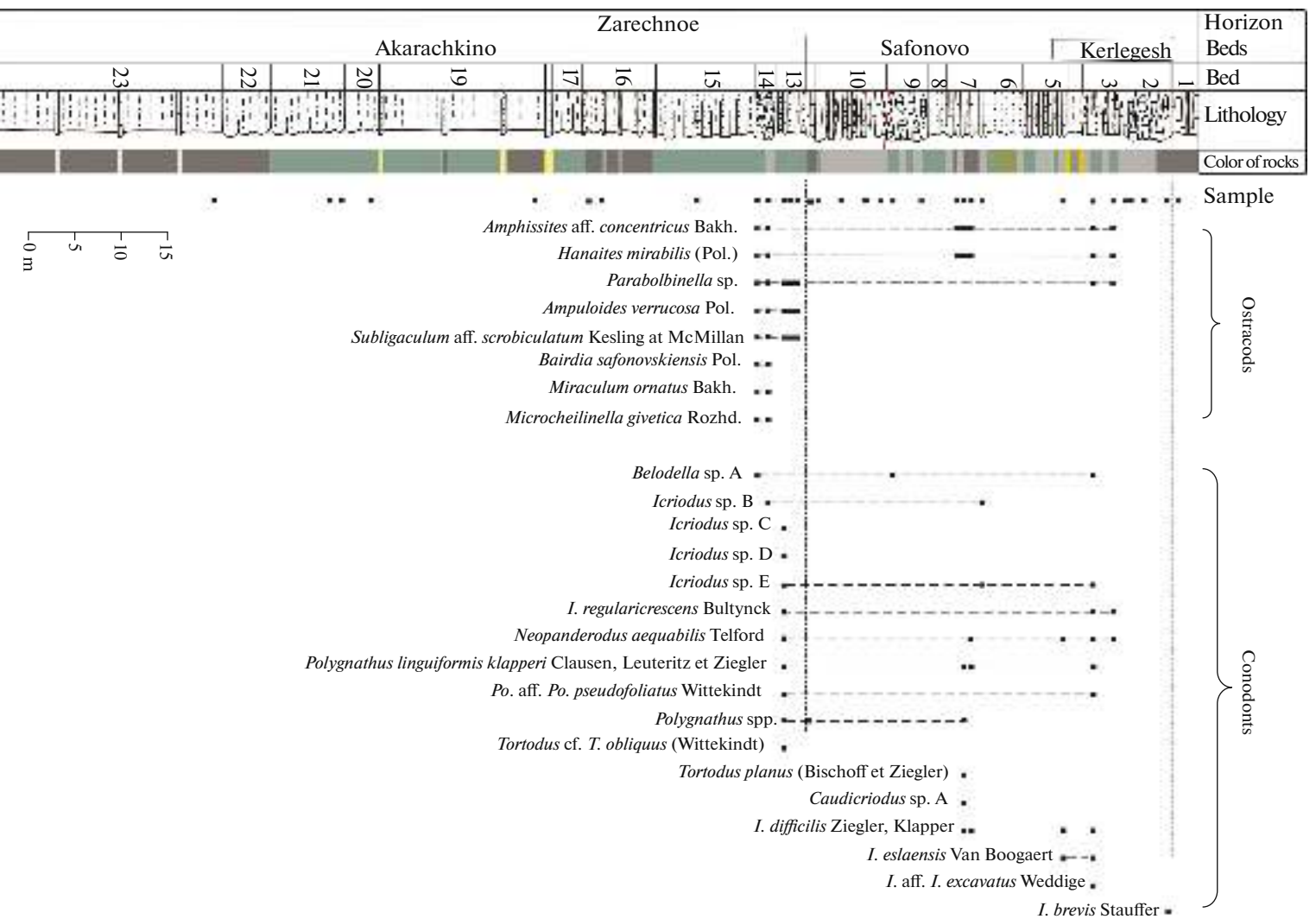


Fig. 5. (Contd.)

Middle Devonian Kerlegesh Beds of the Salair (Bakharev, 1986). *Bairdia safonovskiensis* Polenova and *Subligaculum* aff. *scrobiculatum* Kesling and McMillan occur in the Safonovo Beds of the Salair (Bakharev, 1985; Polenova, 1960). The holotype of *Subligaculum scrobiculatum* Kesling and McMillan was described from the Middle Devonian of the State of Michigan (USA) (Kesling and McMillan, 1951).



Fig. 6. Panoramic photo of section BS-091 in the roadside excavation along the left bank of an unnamed creek—a left tributary of Egos Creek, environs of the town of Prokopyevsk.

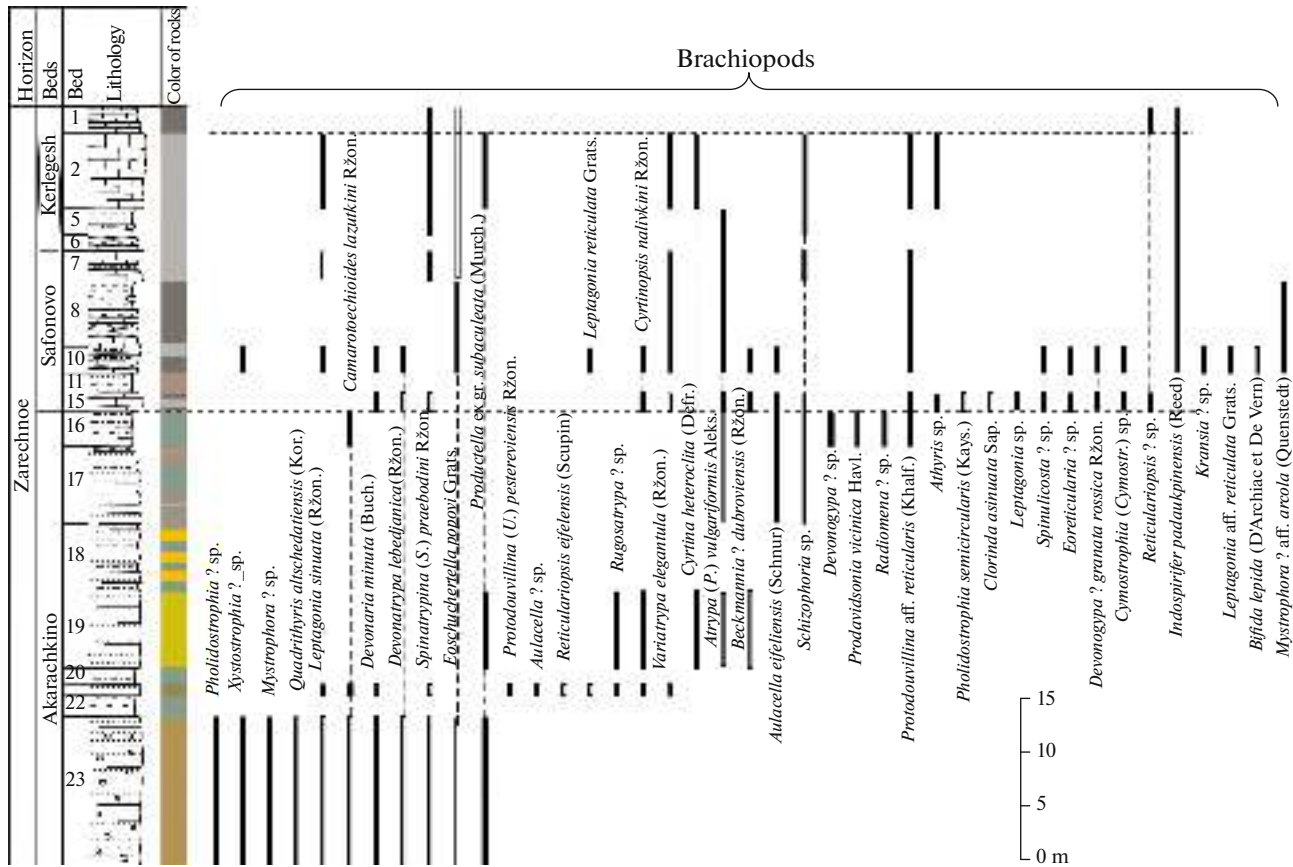


Fig. 7. Lithology and fauna distribution in the Akarachkino, Safonovo, and Kerlegesh beds (brachiopods, conodonts, ostracods, ammonoids) in section BS-093 in the roadside excavation (environs of the town of Prokopyevsk). See legend in Fig. 2.

The species *Hanaites mirabilis* (Polenova) was first found in the Stary Oskol Suprahorizon (Givetian) of the central part of the East European Platform (EEP) (Polenova, 1952), as well as in the Biisky (lower Eifelian) and Afonino (upper Eifelian) horizons of the Southern Urals (Rozhdestvenskaya, 1962). Within the

Timan–Pechora province, this species was reported from the Biisky (lower Eifelian) and Kedrovka and Omra (upper Eifelian) horizons, in the upper part of the Vozeishor Formation (upper Eifelian), in the upper Eifelian Kolva Formation of the Kolva megaswell, and in the Stary Oskol Suprahorizon (Givetian)



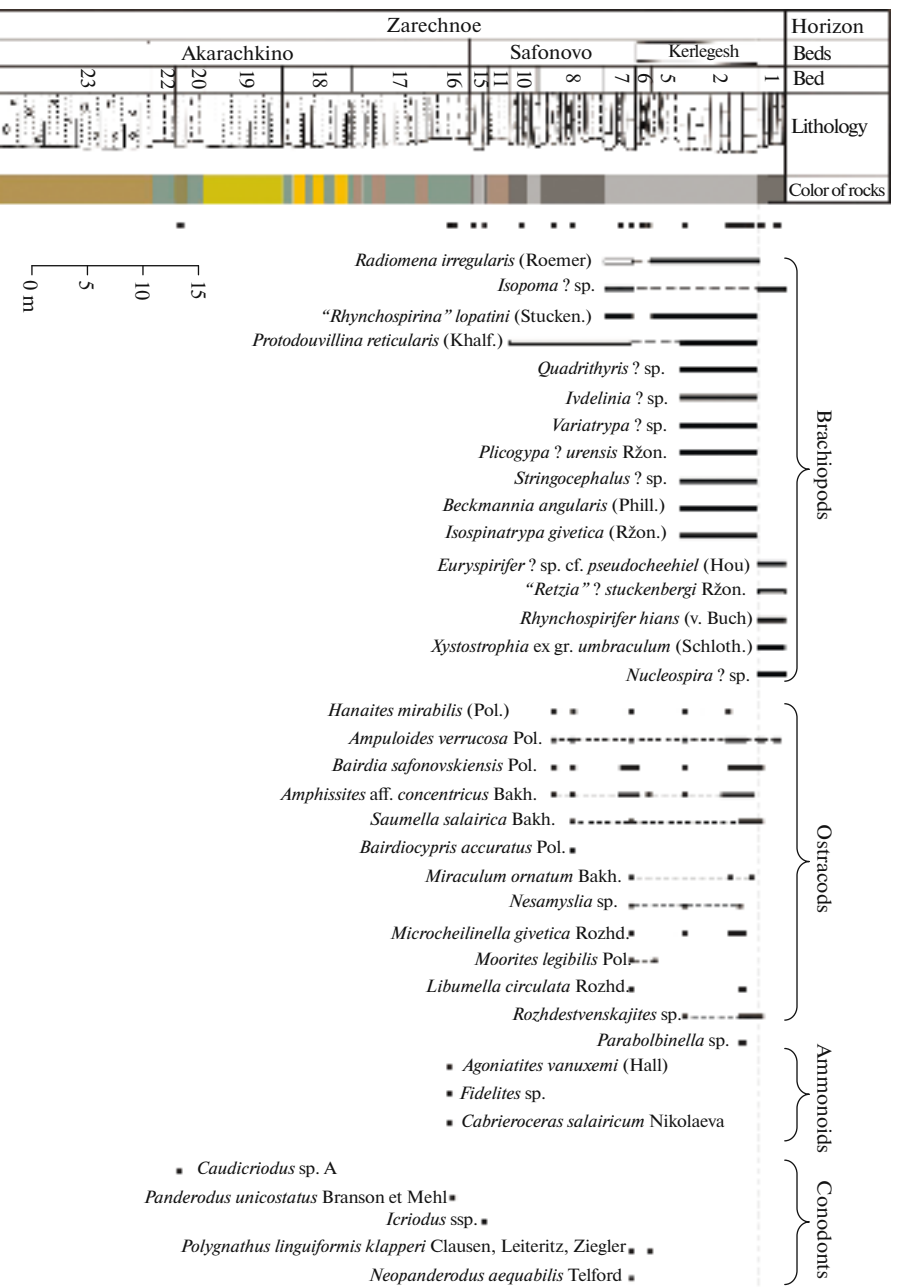


Fig. 7. (Contd.)

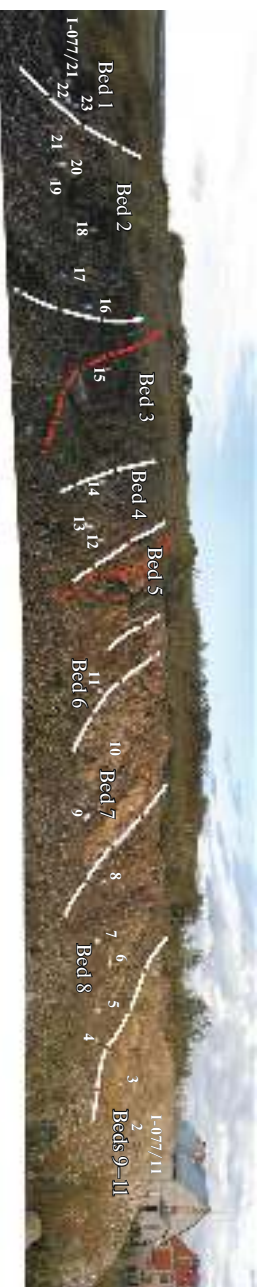


Fig. 8. Panoramic photo of section BS-093 in the roadside excavation (environs of the town of Prokopyevsk).



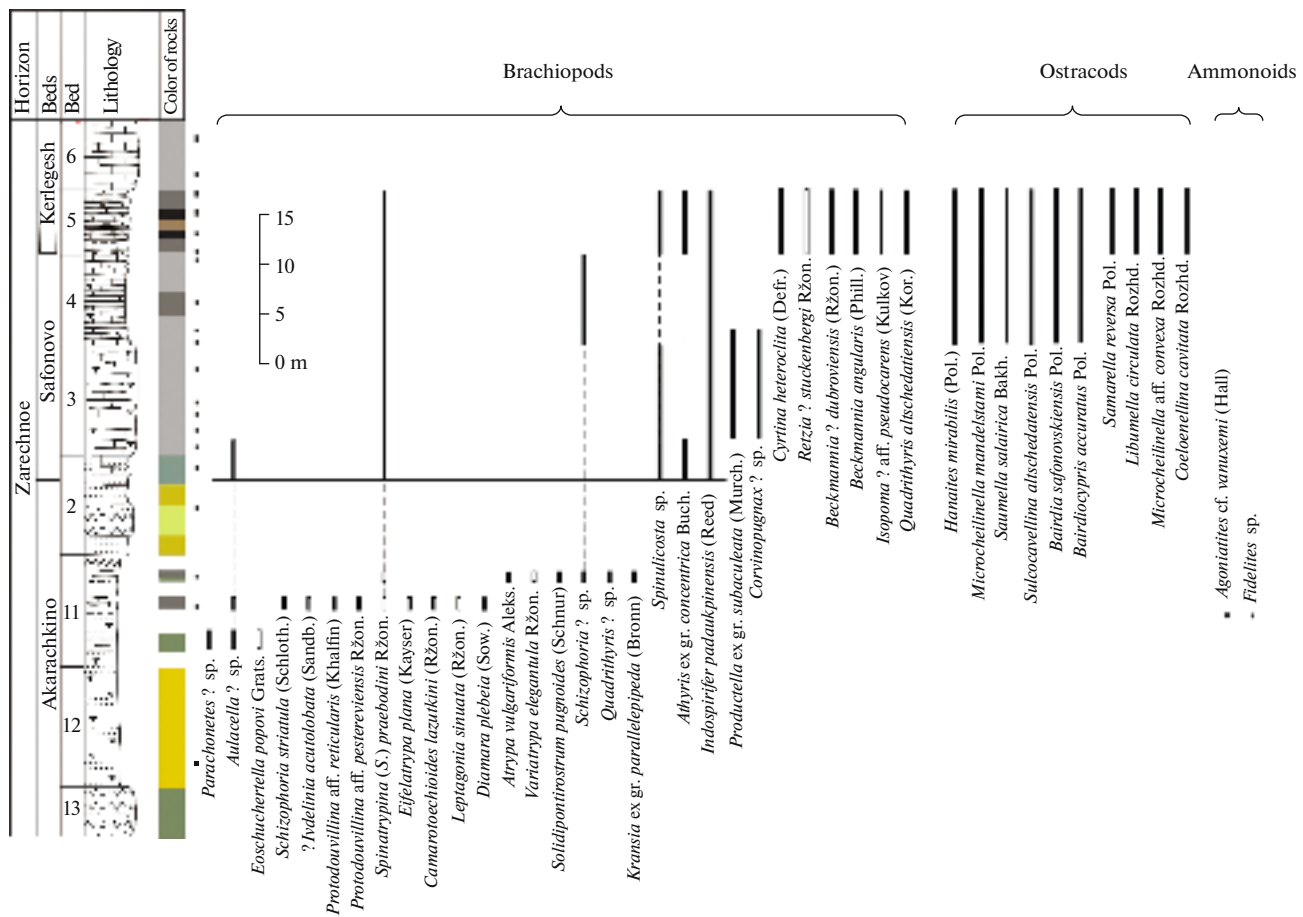


Fig. 9. Lithology and fauna distribution in the Akarachkino, Safonovo, and Kerlegesh beds (brachiopods, ammonoids, ostracods) in section B-8333 (western outskirts of the village of Zarechnoe). See legend in Fig. 2.

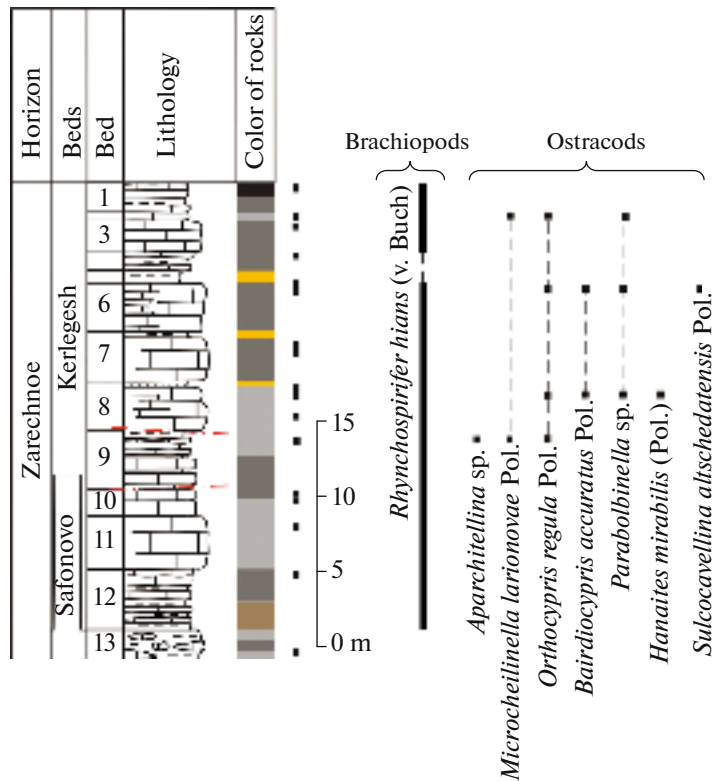


Fig. 10. Panoramic photo of the section B-8333 on the western outskirts of the village of Zarechnoe, the right bank of the Bolshoi Bachat River.

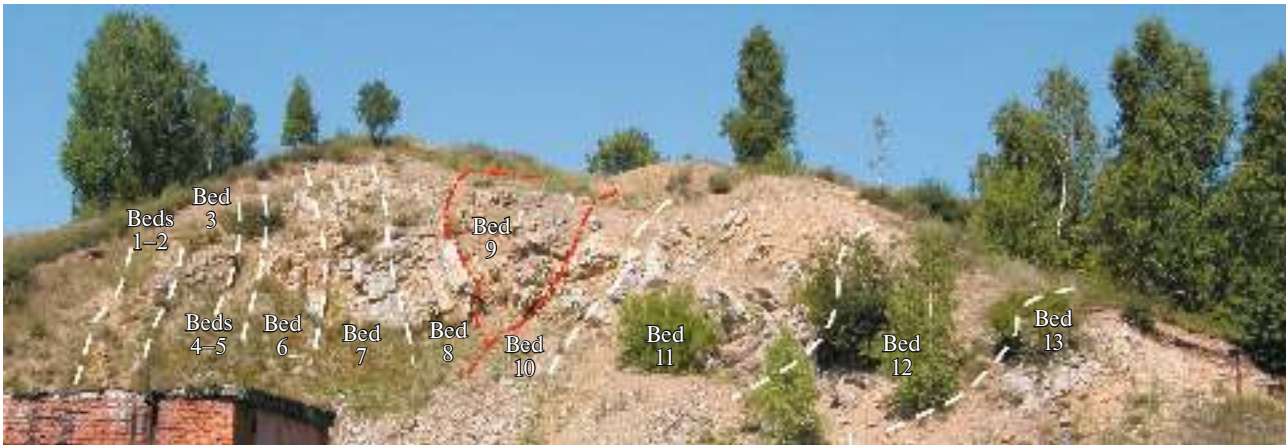
of the southern part of the Sorokin swell (Moskalenko, 2001). The given taxon was described in the upper Givetian of Western Pomerania of Poland (Zbikowska, 1983). In the Salair, it was previously found in the Kerlegesh Beds (Bakharev, 1985).

The species *Ampuloides verrucosa* Polenova was described from the Stary Oskol Suprahorizon (Givetian Stage) of the EEP (Polenova, 1952) and was found in the Iz'jol Formation (lower and middle Givetian) of

the Timan–Pechora province (Moskalenko, 2001) and the upper Givetian in Western Pomerania of Poland (Zbikowska, 1983). In the Salair, this species was previously described from the Safonovo Beds. However, the described specimens differ from the type species in the presence of a more distinct groove, limiting the shell's posterior part (Bakharev, 1985). The species *Microcheilinella givetica* Rozhdestvenskaya was found in the lower part of the Givetian Stary Oskol Supraho-



**Fig. 11.** Lithology and fauna distribution in the Kerlegesh Beds (brachiopods, ostracods) of section BS-092 in the roadside excavation along the right bank of an unnamed creek—a left tributary of Egos Creek, environs of the town of Prokopyevsk. See legend in Fig. 2.



**Fig. 12.** Panoramic photo of section BS-092 in the roadside excavation along the left bank of an unnamed creek—a left tributary of Egos Creek, environs of the town of Prokopyevsk.

rizon of Western Bashkiria (Rozhdestvenskaya, 1959), in the upper part of the Omra Horizon, and in the lower part of the Kolva Formation (upper Eifelian) of the Timan–Pechora province (Moskalenko, 2001).

The identified ostracod assemblage from the Akarackino Beds characterizes the upper Eifelian interval.

**Safonovo Beds.** This stratigraphic subdivision was named by Rzhonsnitskaya (1952) after the village of Safonovo (Kemerovo oblast). The stratotype of the Safonovo Horizon (beds, formation) is located in the southern watershed part of the chain of hills on the right bank of the Bolshoi Bachat River on the western

outskirts of the village of Zarechnoe (Belovo district, Kemerovo oblast) (Rzhonsnitskaya, 1952). According to the results of studying the type localities of the Safonovo Horizon on the eastern slope of the Salair near the village of Zarechnoe in 2009–2014, it was established that the stratum is exposed fragmentarily and is deformed by cataclasis zones and faults. Because of this, its reliable layer-by-layer description cannot be compiled (Yazikov et al., 2014). The interval of beds 12–2 in the section BS-091 on the western outskirts of the town of Prokopyevsk was proposed as the hypostratotype of the Safonovo Beds (Yazikov, 2014c; Yazikov et al., 2014). Here is the entire stratigraphic interval of the Safonovo Beds faunistically well characterized with normal lower and upper stratigraphic boundaries (Figs. 5, 6). The thickness of the Safonovo Beds is about 40 m. The direct contact zone between Akarachkino and Safonovo beds was also established in two other sections on the eastern slope of the Salair: in the section BS-093 on the outskirts of the town of Prokopyevsk (Figs. 7, 8) and in the section B-8333 near the village of Zarechnoe (*Middle-Upper...*, 2011) (Figs. 9, 10). The upper boundary with the Kerlegesh Beds is also exposed in the sections BS-093, BS-092, B-8333, and B-8170 (Figs. 11–14).

The Safonovo Beds were previously considered as overlying Kerlegesh Beds (*Resheniya...*, 1982; Rzhonsnitskaya, 1952, 1968; Yolkin et al., 2000; *Zonal'naya...*, 2006; etc.). However, the recent bio- and lithostratigraphic data (Yazikov, 2014a, 2014b, 2014c; Yazikov and Izokh, 2014a, 2014b; Yazikov et al., 2014, 2015a, 2016) showed the incorrectness of such ideas.

**Brachiopods.** On the basis of brachiopods, the Safonovo Beds correspond to the *Indospirifer padaukpinensis* Biozone (Figs. 5, 7, 9, 13). Along with *I. padaukpinensis* (Reed) (= *Indospirifer pseudowilliamsi* Ržonsnickaja) (Plate VI; figs. 1–3), the typical brachiopods of the Safonovo Beds are “*Rhynchospirina*” *lopatini* (Stuckenberg), *Radiomena irregularis* (Roemer), *Beckmannia angularis* (Phillips), and *Isospinatrypa givetica* (Ržonsnickaja) (Rzhonsnitskaya, 1952, 1968, 1975; Yazikov, 2014a, 2014b, 2014c).

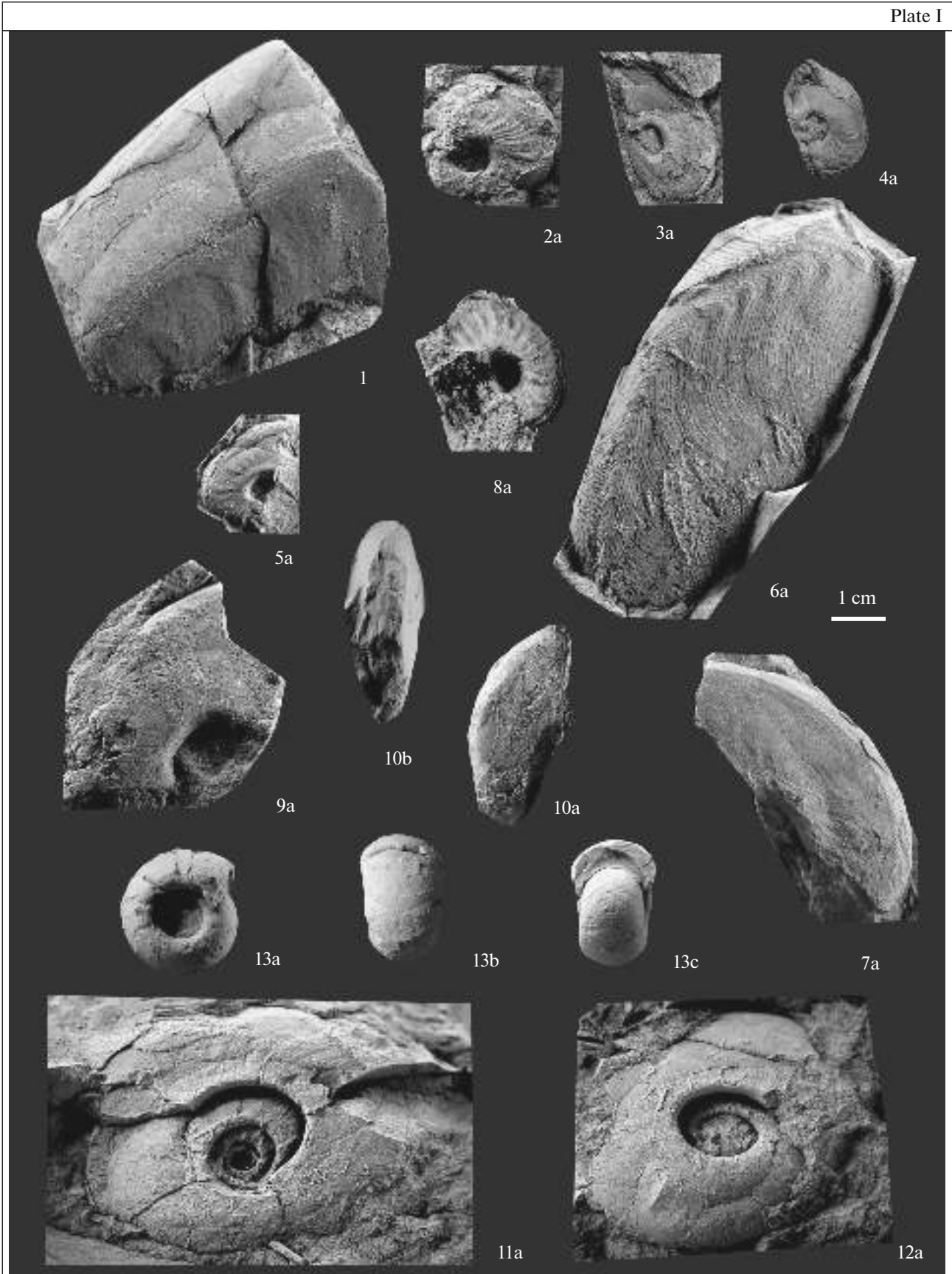
The Safonovo brachiopod assemblage is similar to that from the Padaukpin limestone of Myanmar (Burma), described in (Anderson et al., 1969). Common elements of brachiopod assemblages (*Aulacella*

*eifeliensis* (Verneuil), *Xystostrophia umbraculum* (Schlotheim), *Radiomena irregularis* (Roemer), *Devonaria minuta* (v. Buch), *Plectospira ferita* (v. Buch), *Reticulariopsis eifeliensis* (Scupin), *Indospirifer padaukpinensis* (Reed), *Bifida lepida* (D’Archiac et De Vern), *Cyrtina heteroclita* (Defrance)), as well as morphologically similar representatives of genera *Schizophoria*, *Mystrophora*, *Productella*, *Variatrypa*, *Atrypa*, *Isospinatrypa*, *Athyris*, etc., indicate the coevality of country deposits. A comprehensive analysis of the fauna of the Padaukpin limestone (Anderson et al., 1969) led the authors to the conclusion about the upper Eifelian age of country deposits, which is confirmed by conodonts (*Polygnathus linguiformis linguiformis* Hinde, *Po. sp. cf. Po. xylus sensu* Bischoff et Ziegler, and *Belodella triangularis* (Stauffer)) reported in the article. However, it was noted that *Indospirifer padaukpinensis* (Reed) was found in the Givetian deposits in association with *Stringocephalus* sp. in some localities of South China (Anderson et al., 1969, p. 119). Thus, we can draw a conclusion about the distribution of *Indospirifer padaukpinensis* (Reed) in the upper Eifelian and, apparently, lower Givetian of China, Myanmar (Burma), and India (Yazikov, 2014c). The similarity between the brachiopod assemblage of the Indospirifer Horizon of the Salair and Padaukpin (Birma) and Maoerhuang (South China) beds is also noted by Rzhonsnitskaya (1937) and Kulkov and Peregoedov (2010). This conclusion is in good agreement with the new stratigraphic position of the Safonovo Beds in the generalized sequence of the Salair (in this paper, they are assigned to the interval from the Eifelian–Givetian boundary beds to the middle of the middle Givetian) and the new data on conodonts (Yazikov and Izokh, 2014a, 2014b; Yazikov et al., 2014).

**Conodonts.** Conodonts of the genera *Polygnathus*, *Icriodus*, *Belodella*, and, probably, the last representatives of the genus *Caudicriodus* were identified only in the upper part of the Safonovo Beds (Figs. 5, 7; Tables 2, 3; Plates III, IV). The assemblage includes new taxa such as *Belodella* sp. A and *Caudicriodus* sp. A, as well as *Icriodus difficilis* Ziegler et Klapper, *I. eslaensis* van Adrichem Boogaert, *I. regularicrescens* Bultynck, *I. aff. excavatus* Weddige, *Icriodus* sp. B, *Icriodus* sp. E, *Neopanderodus aequabilis* Telford, *Panderodus unicostatus* Branson et Mehl, *Polygnathus linguiformis klapperi* Clausen, Leuteritz et

**Plate I.** Middle Devonian ammonoids of the Salair (upper Eifelian, Agoniatites Genozone, Zarechnoe Horizon, Akarachkino Beds; environs of the towns of Guryevsk and Prokopyevsk). All images are full-size. In all cases: (a) lateral view, (b) ventral view, (c) umbilical view. (1–8) *Agoniatites vanuxemi* (Hall, 1879): (1) specimen no. B-8410-7/113; ventral and lateral views; environs of the town of Guryevsk, section B-8410, Bed 7; (2) specimen no. B8410-7/100; environs of the town of Guryevsk, section B-8410, Bed 7; (3) specimen no. B-8410-7/109; environs of the town of Guryevsk, section B-8410, Bed 7; (4) specimen no. B-8410-7/116; environs of the town of Guryevsk, section B-8410, Bed 7; (5) specimen no. B-8410-7/115; environs of the town of Guryevsk, section B-8410, Bed 7; (6) specimen no. B-8410-7/117; environs of the town of Guryevsk, section B-8410, Bed 7; (7) specimen no. B-8410-7/120; environs of the town of Guryevsk, section B-8410, Bed 7; (8) specimen no. BS-09316/86; environs of the town of Prokopyevsk, section BS-093, Bed 16; (9, 10) *Fidelites* sp.: (9) specimen no. B-8410-7/95; environs of the town of Guryevsk, section B-8410, Bed 7; (10) specimen no. B-8410-7/123; environs of the town of Guryevsk, section B-8410, Bed 7; (11–13) *Cabrieroceras salairicum* Nikolaeva, 2010: (11) specimen no. B-8410-7/124; environs of the town of Guryevsk, section B-8410, Bed 7; (12) specimen no. B-8410-7/125; environs of the town of Guryevsk, section B-8410, Bed 7; (13) specimen no. BS-091-13/69; environs of the town of Prokopyevsk, section BS-091, Bed 13.





Ziegler, *Polygnathus* aff. *pseudofolius* Wittekindt, *Polygnathus* sp., *Tortodus planus* (Bischoff et Ziegler), and *Panderodus unicostatus* (Branson et Mehl). The taxa *Cauderiodus* sp. A, *Belodella* sp. A, *Icriodus* sp. E, *Neopanderodus aequabilis*, *Polygnathus* aff. *pseudofolius* Wittekindt, and *Polygnathus linguiformis klapperi* pass from the underlying Akarachkino Beds.

*Icriodus arkonensis* occurs in a wide interval from the upper Eifelian (*Tortodus kockelianus* Zone) to upper Givetian (*Schmidtognathus germanni* Zone) of Canada, Morocco, Europe, Russia, China, Tajikistan, and Australia (Bardashev and Ziegler, 1985; Bultynck, 2003; Kononova and Kim, 2005; Narkiewicz and Bultynck, 2007; etc.). *Icriodus eslaensis* van Adrichem Boogaert is known from the lower and middle Givetian (Lower *Polygnathus varcus* Zone) (Bultynck, 1987). P. Bultynck justified the validity of this taxon upon the study of *Icriodus brevis*, *I. lindensis*, and *I. eslaensis* from the Middle Devonian sections of Morocco and Ardennes (Bultynck, 1987).

*Tortodus planus* was found in the Givetian deposits of France, *Polygnathus hemiansatus* and *Polygnathus ansatus* conodont zones (Brice et al., 1979; Narkiewicz and Bultynck, 2010).

*Icriodus excavatus* characterizes Givetian (*Polygnathus varcus* Zone) and Frasnian deposits (*Ancyrog-nathus triangularis* Zone) (Weddige, 1984).

*Icriodus difficilis* Ziegler et Klapper is the index species of the same-named zone for shallow-water facies or *Polygnathus rhenanus*–*Polygnathus varcus* Zone, as well as for the lower boundary of the middle Givetian (Ziegler et al., 1976; Weddige, 1977; Bultynck, 2003; Bultynck and Gouwy, 2008). In the Salair, this species was found in the middle part of the Safonovo Beds (section BS-091, Bed 7). Correspondingly, the lower boundary of the *Polygnathus rhenanus*–*Polygnathus varcus* Zone should be drawn inside Bed 7 (sample BS-091-7/2.6 m).

According to the data of Gagiev et al. (1986, 1987; Rzhonsnitskaya et al., 1990), the carbonate unit of the Safonovo Beds in the Zarechnoe section bears cosmopolite conodont taxa *Polygnathus parawebbi* Chatterton beta morphotype, *Po. ovatinodosus* Ziegler et Klapper, *Po. pseudofolius* Wittekindt, *Icriodus expansus* Branson et Mehl, and *I. difficilis* Ziegler et Klapper. In general, this conodont assemblage characterizes the middle subzone of the varcus Zone. *Polygnathus pseudofolius* was reported from the interval of the upper Eifelian, the lower and middle Givetian, or the *kockelianus*, *ensensis*, and *hemiansatus* conodont zones, the lower subzone of the varcus Zone (Ziegler et al., 1976; Weddige, 1977;

Klapper and Johnson, 1980; Barskov et al., 1991; etc.). The species *Po. ovatinodosus* appears inside the middle subzone of the varcus (=ansatus) Zone and passes to the lower part of the Frasnian Stage (Ziegler et al., 1976; Klapper and Johnson, 1980; Aristov, 1988; Barskov et al., 1991; etc.). *Icriodus difficilis* Ziegler et Klapper is known in sections starting from the middle Givetian (*rhenanus*/*varcus* Zone) and traced to the lower Frasnian (Ziegler et al., 1976; Weddige, 1977; Klapper and Johnson, 1980; Bultynck, 2003). *Icriodus expansus* Branson et Mehl is more typical of the upper Givetian (Ziegler et al., 1976; Klapper and Johnson, 1980; Narkiewicz and Bultynck, 2007). However, findings of this species are noted in Central Canada beginning from the varcus Zone (Bultynck, 2003; Sparling, 1995, 1999).

After a detailed study of the tectonically complex section in the environs of the village of Zarechnoe (Fig. 10), we have come to the conclusion that this conodont-bearing carbonate unit corresponds to the upper part of the Safonovo Beds (Yazikov, 2014c; Yazikov et al., 2016).

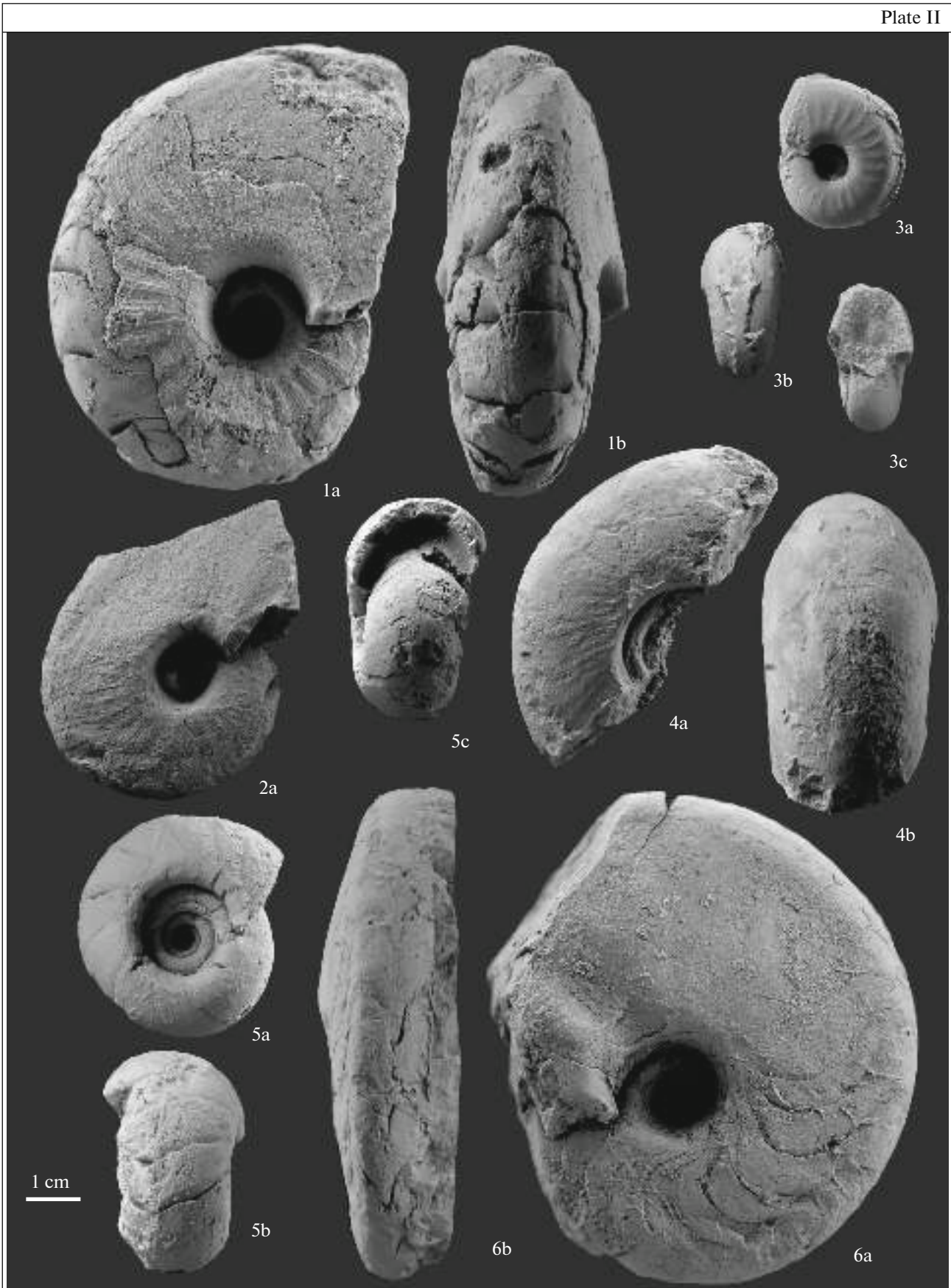
On the basis of the analysis of the data available on conodonts, the Safonovo Beds cover the interval from the Eifelian–Givetian boundary beds to the lower part of the middle Givetian. In the conodont biozonal standard, they correspond to the interval from the *ensensis* Zone to the middle varcus Zone (the lower part of the ansatus Zone).

**Ostracods.** The ostracod assemblage from the Safonovo Beds was studied on the basis of the analysis of the ostracod collections from the sections on the outskirts of the town of Prokopyevsk (sections BS-091, BS-09), in the Buskuskan Quarry (section B-8170), and on the outskirts of the village of Zarechnoe (section B-8333) (Figs. 5, 7, 9, 13, Plate V). In section BS-091 (Fig. 5), the ostracod assemblage is impoverished and is represented by three taxa *Amphisites* aff. *concentricus* Bakharev, *Parabolbinella* sp., and *Hanaites mirabilis* (Polenova), transitional from the underlying Akarachkino Beds. In other sections, ostracods occur only in the upper part of the Safonovo Beds.

The parallel section BS-093 (Beds 8–2; Fig. 7, Plate V) contains a richer ostracod assemblage: *Ampuloides verrucosa* Polenova, *Hanaites mirabilis* (Polenova), *Bairdia safonovskiensis* Polenova, *Amphisites* aff. *concentricus* Bakharev, *Saumella salairica* Bakharev, *Bairdiocypris accuratus* Polenova, *Miraculum ornatus* Bakharev, *Nesamyslia* sp., *Microcheilinella givetica* Rozhdestvenskaya, *Rozhdestvenskajites* sp., *Libumella circulata* Rozhdestvenskaya, *Parabolbinella* sp., and *Moorites legibilis* Polenova (Plate V, figs. 7, 8).

**Plate II.** Middle Devonian ammonoids of the Salair (upper Eifelian, Agoniatites Genozone, Zarechnoe Horizon, Akarachkino Beds; environs of the town of Prokopyevsk). All images are full-size. In all cases: (a) lateral view, (b) ventral view, (c) umbilical view. (1–3) *Agoniatites vanuxemi* (Hall, 1879): (1) specimen no. BS-091-13/54; section BS-091, Bed 13; (2) specimen no. BS-093-16/36; section BS-093, Bed 16; (3) specimen no. BS-091-13/74; section BS-091, Bed 13; (4, 5) *Cabrieroceras salairicum* Nikolaeva, 2010: (4) specimen no. BS-091-13/77; section BS-091, Bed 13; (5) specimen no. BS-093-16/85; section BS-093, Bed 16; (6) *Fidelites* sp., specimen no. BS-091-13/55; section BS-091, Bed 13.





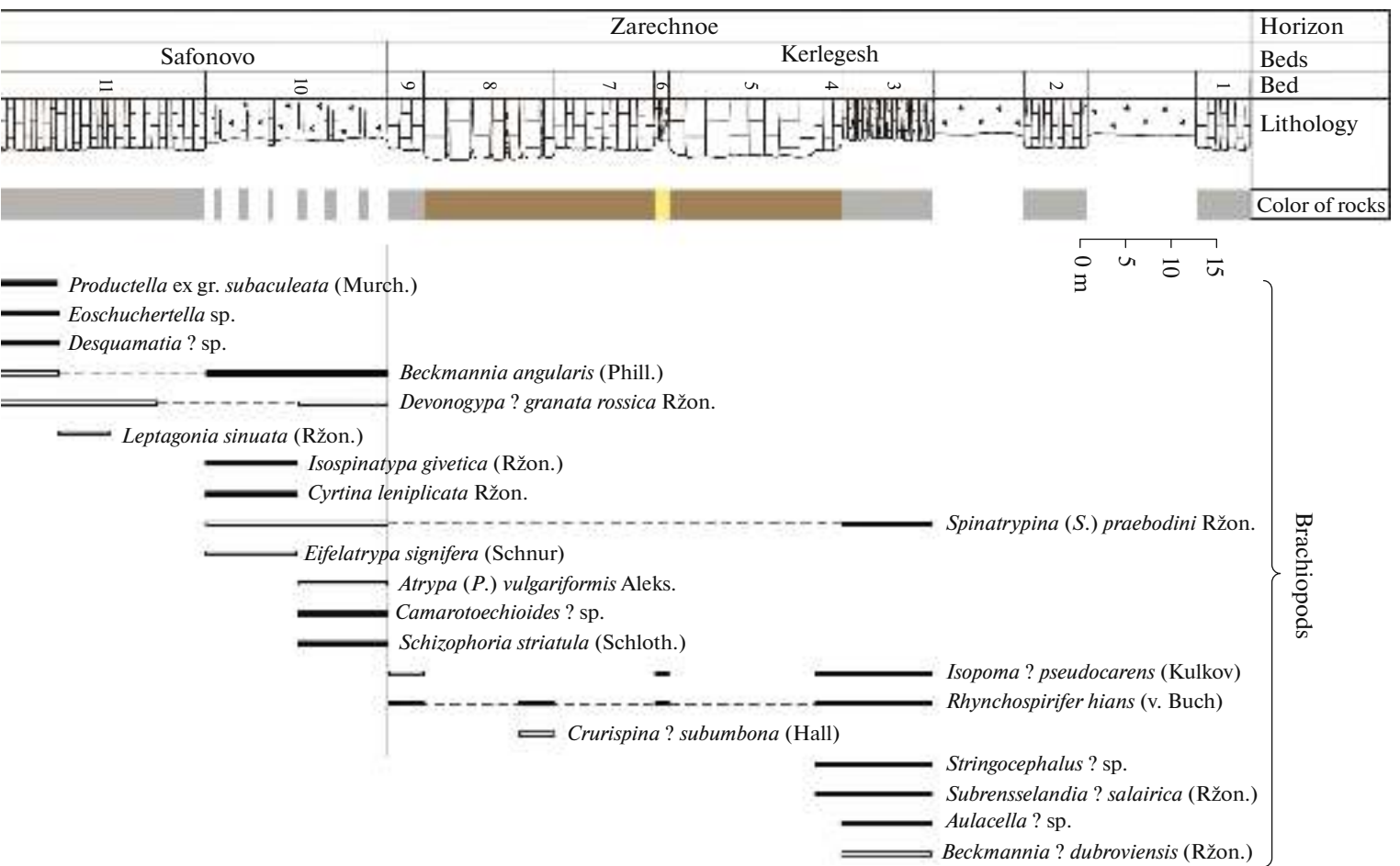


Fig. 13. Lithology and fauna distribution in the Safonovo and Kerlegesh beds (brachiopods, ostracods) in section B-8170 in the Buskuskán Quarry (after Bakhar'ev, 1985, with amendments). See legend in Fig. 2.

N.I. Savina described ostracods *Bairdia* aff. *safonovskiensis* Polenova from the upper part of the same section (Mezentseva et al., 2007).

It should be noted that the majority of species from section BS-093 are analogs of species recognized in the Akarachkino and Safonovo beds of section BS-091

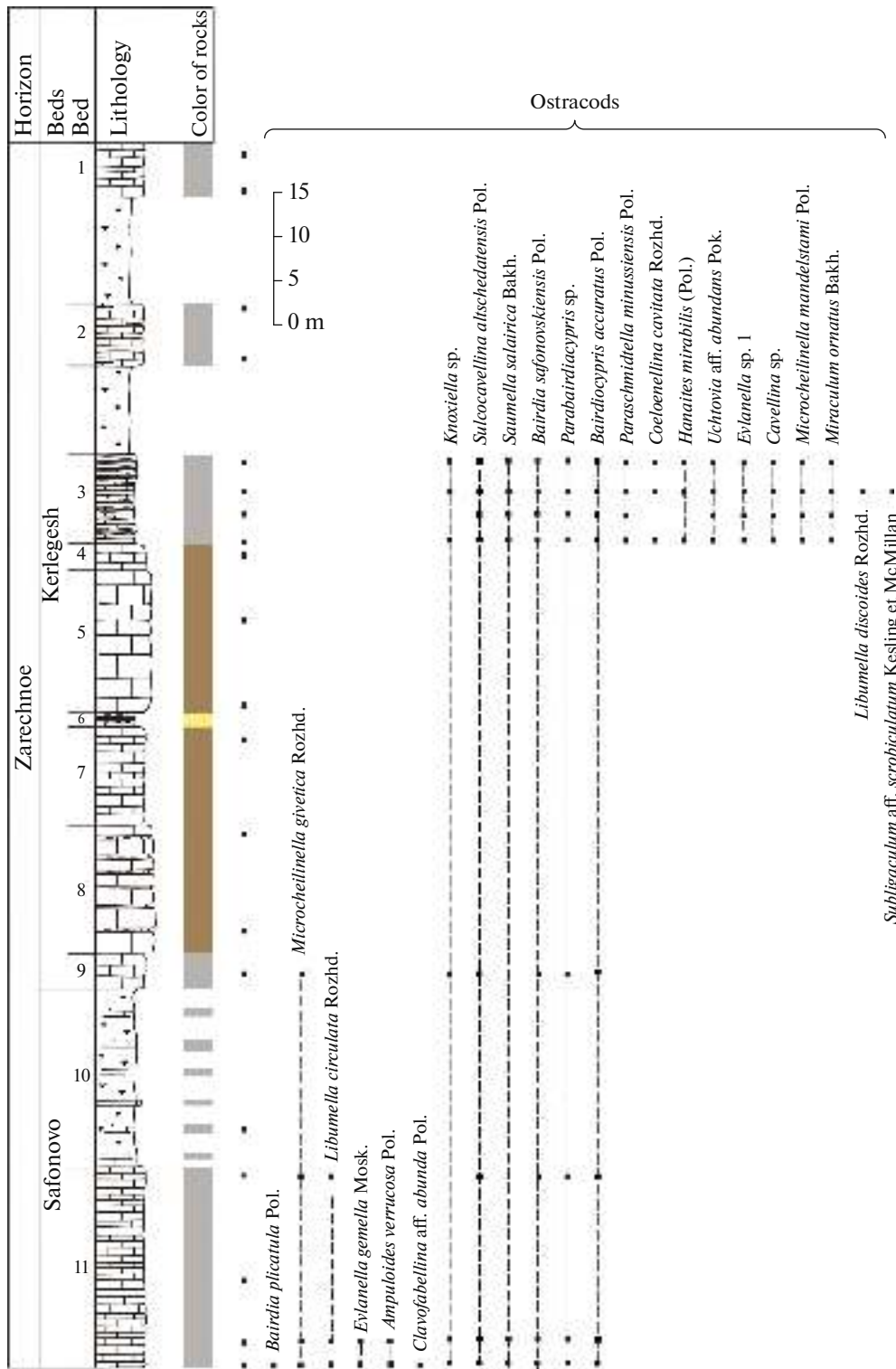


Fig. 13. (Contd.)

(Fig. 5, Plate V). However, there is a series of taxa found in the first section. For example, *Saumella salairica* Bakharev was previously described from the Safonovo and Kerlegesh Beds of the Salair (Bakharev, 1985). *Bairdiocypris accuratus* Polenova was found in

the upper Givetian Lebedyanka Beds, which crop out at the northeastern margin of the Kuznetsk Basin (Polenova, 1960). *Libumella circulata* Rozhdestvenskaya, known from the Afonino (upper Eifelian) Horizon of the Southern Urals (Rozhdestvenskaya,

1962), as well as from Kedrovka and Omra horizons (upper Eifelian) of the Timan–Pechora province (Moskalenko, 2001), has a wider lateral distribution. *Moorites legibilllis* Polenova was previously reported from the Kerlegesh and Safonovo beds of the Salair. In addition, this species was found in Lebedyanka Beds exposed at the northeastern margin of the Kuznetsk Basin and in deposits of the Beya Formation (upper Givetian) of the Minusinsk Depression (Polenova, 1960). *Coeloenellina cavitata* Rozhdestvenskaya was first described from the Biisky Horizon (lower Eifelian) of the Southern Urals (Rozhdestvenskaya, 1962). *Microcheilinella convexa* Rozhdestvenskaya was reported from the Afonino Horizon (upper Eifelian) of the Southern Urals. It also occurs in the Stary Oskol Suprahorizon of the EEP (Givetian) (Rozhdestvenskaya, 1962) and the upper Eifelian Kedrovka and Omra horizons of the Timan–Pechora province (upper Eifelian) (Moskalenko, 2001).

The following species were found in the upper part of the Safonovo Beds (Bed 11), which crop out in the Buskuskan Quarry (Fig. 13, Plate V): *Bairdia plicatula* Polenova, *Microcheilinella givetica* Rozhdestvenskaya, *Libumella circulata* Rozhdestvenskaya, *L. aff. L. discoides* Rozhdestvenskaya (Plate V, figs. 3, 4), *Evlanella gemella* Moskalenko, *Ampuloides verrucosa* Polenova (Plate V, figs. 1, 2), *Clavofabellina* aff. *abunda* Polenova, *Knoxella* sp., *Sulcocavellina altschedatensis* Polenova, *Saumella salairica* Bakharev, *Bairdia safonovskiensis* Polenova, *Bairdiocypris accuratus* Polenova, and *Parabairdiocypris* sp.

The species *Sulcocavellina altschedatensis* Polenova is known from the Safonovo and Kerlegesh Beds of the Salair and the Lebedyanka Beds exposed at the northeastern margin of the Kuznetsk Basin (Polenova, 1960). *Clavofabellina abunda* Polenova was described from the Vyazovsky Horizon (upper Emsian) of the Southern Urals (Polenova, 1955), as well as from the

Koiva (upper Emsian), Biisky (lower Eifelian), and Kedrovka and Omra (upper Eifelian) horizons (Moskalenko, 2001).

This assemblage includes two species typical of the Givetian Stage. The first species *Elvanella gemella* Moskalenko is known from the lower part of the Kolva Formation (lower Givetian) of the Timan–Pechora province (Moskalenko, 2001). The second species *Bairdia plicatula* Polenova, described in the Stary Oskol (Givetian) Suprahorizon of the East European Platform (Polenova, 1952), occurs in deposits of the Cheslav (lower and middle Givetian) Horizon (Middle Urals) (Rozhdestvenskaya, 1962) in the lower and middle Givetian Iz'yol Formation of the Timan–Pechora province (Moskalenko, 2001).

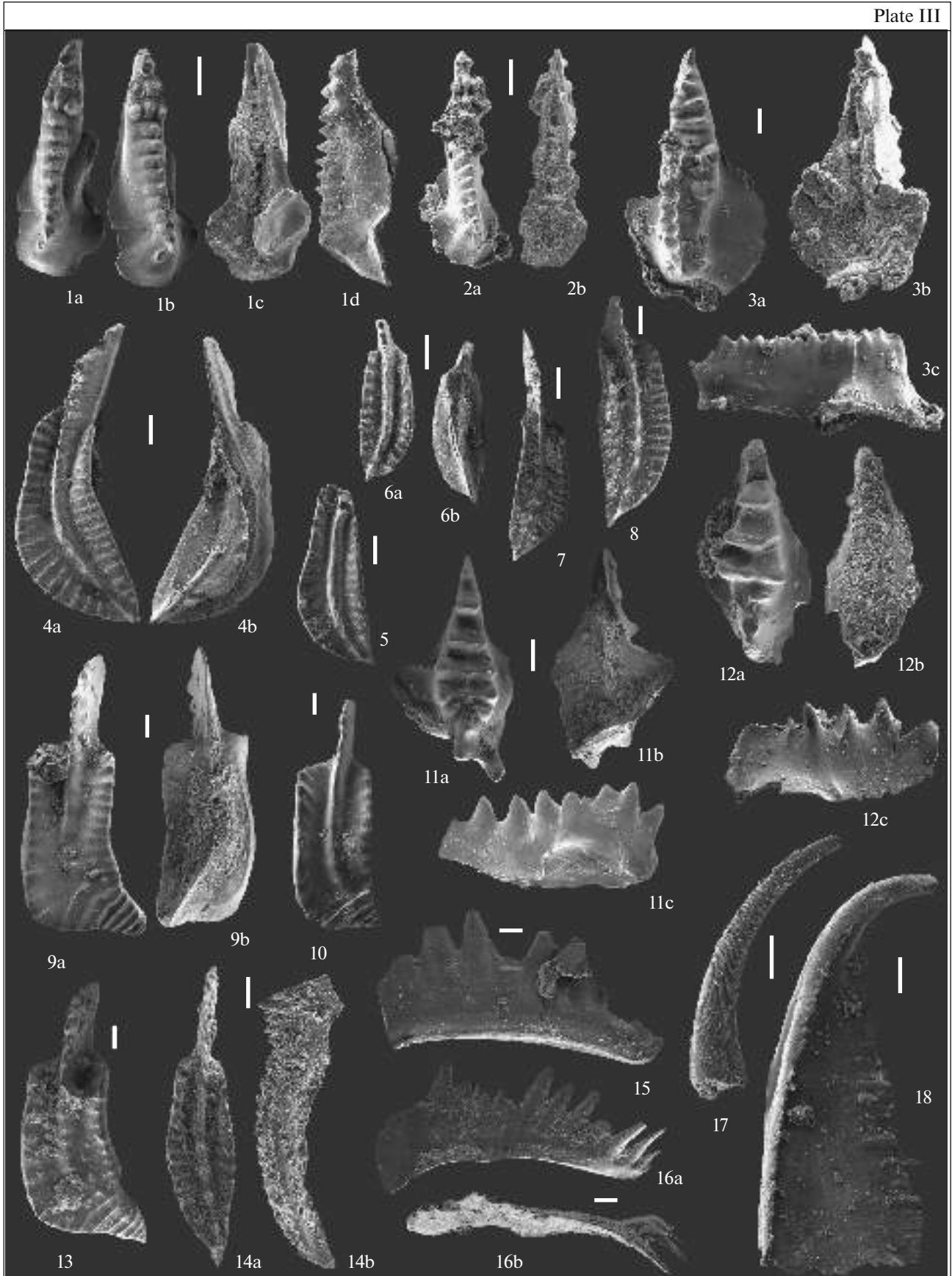
In the upper part of the Safonovo Formation (the outskirts of the village of Zarechnoe, section B-8333; Fig. 9), the following assemblage was recognized: *Saumella salairica* Bakharev and *Bairdiocypris accuratus* Polenova (Plate V, figs. 5, 6), *Libumella circulata* Rozhdestvenskaya, *Bairdia safonovskiensis* Polenova, *Sulcocavellina altschedatensis* Polenova, *Hanaites mirabilis* (Polenova), *Samarella reversa* Polenova, and *Coeloenellina cavitata* Rozhdestvenskaya (Plate V, figs. 19–23), *Microcheilinella mandelstami* Polenova, and *Microcheilinella* aff. *convexa* Rozhdestvenskaya. The first four species are common in three sections (BS-093, B-8170, B-8333), and the fifth species is typical of two sections (B-8170 and B-8333).

The type species *Microcheilinella mandelstami* Polenova was previously described from the Stary Oskol (Givetian Stage) Suprahorizon of the EEP (Polenova, 1952). In addition, it was found in the lower and middle Givetian Iz'yol Formation of the Timan–Pechora province (Moskalenko, 2001).

On the basis of the studied ostracod assemblage, the Safonovo Beds are attributed to the lower and middle Givetian.

**Plate III.** Conodonts from the Akarachkino and Safonovo beds of the Zarechnoe Horizon; upper Eifelian and Givetian stages, section B-8410 (eastern outskirts of the town of Guryevsk), sections BS-091 and BS-093 (northwestern and western outskirts of the town of Prokopyevsk). Scale bar, 100  $\mu$ m. (1, 2) *Icriodus* aff. *I. obliquimarginatus* Bischoff et Ziegler, 1957, Akarachkino Beds, section B-8410, Sample B-8410-6/edge: (1) specimen no. B-8410/1: (1a) upper view, (1b) lateral view, (1c) lower view, (1d) lateral view; (2) specimen no. B-8410/2: (2a) upper view, (2b) lower view; (3) *Icriodus* sp. A, specimen no. B-8410/4: (3a) upper view, (3b) lower view, (3c) lateral view; Akarachkino Beds, section B-8410, Sample B-8410-6/edge; (4, 5) *Polygnathus parawebbi* Chatterton, 1974, Akarachkino Beds, section B-8410, Sample B-8410-6/edge: (4) specimen no. B-8410/3: (4a) upper view, (4b) lower view; (5) specimen no. B-8410/5, upper view; (6) *Polygnathus* sp., juvenile specimen, specimen no. B-8410/6: (6a) upper view, (6b) lower view; Akarachkino Beds, section B-8410, Sample B-8410-6/edge; (7) *Polygnathus* sp., specimen no. BS-091/2, upper view, Akarachkino Beds, section BS-091, Sample BS-091-13/2.8; (8) *Polygnathus* sp., specimen no. BS-091/3, upper view, Akarachkino Beds, section BS-091, Sample Yo-8347/1 (=BS-091-13/2.8); (9, 10, 13) *Polygnathus linguiformis klapperi* Clausen, Leuteritz et Ziegler, 1979: (9) specimen no. BS-091/1: (9a) upper view, (9b) lower view; Safonovo Beds, section BS-091, Sample BS-091-7/2.6; (10) specimen no. BS-093/1, upper view, Safonovo Beds, section BS-093, Sample BS-093-7/0.05 m; (13) specimen no. BS-091/4, upper view, Akarachkino Beds, section BS-091, Sample E-834-7/1 (=BS-091-13/2.8); (11, 12) *Caudicriodus* sp.: (11) specimen no. BS-091/5: (11a) upper view, (11b) lower view, (11c) lateral view; Safonovo Beds, section BS-091, Sample BS-091-7/2.6; (12) specimen no. BS-093/2: (12a) upper view, (12b) lower view, (12c) lateral view; Akarachkino Beds, section BS-093, Sample BS-093-21/2.0 m; (14) *Polygnathus* aff. *pseudofoliatus* Wittekindt, 1966, specimen no. BS-091/11: (14a) upper view, (14b) lateral view, Akarachkino Beds, Sample Yo-834-7/1 (=BS-091-13/2.8); (15) *Tortodus* cf. *T. obliquus* (Wittekindt, 1966), specimen no. BS-091/12, lateral view, Akarachkino Beds, section BS-091, Sample BS-091-13/2.8; (16) *Tortodus planus* (Bischoff et Ziegler, 1957), specimen no. BS-091/13: (16a) lateral view, (16b) upper view; Safonovo Beds, section BS-091, Sample BS-091-7/2.6; (17) *Neopanderodus aequabilis* Telford, 1975, specimen no. BS-091/14, lateral view, Safonovo Beds, section BS-091, Sample BS-091-5/1.0; (18) *Belodella* sp. A, specimen no. BS-091/9, lateral view, Akarachkino Beds, section BS-091, Sample BS-091-14/2.0.







**Kerlegesh Beds.** They were named by Rzhonsnitskaya (1952) after the village of Bolshoi Kerlegesh, Prokopyevsk district, Kemerovo oblast. The stratotype was located near the village of Bolshoi Kerlegesh, probably, “on the sodded slope of the hill to the north of the village” (Mezentseva, 2009, p. 59). At present, this stratotype section is unavailable for study. The interval of Beds 1–9 in section B-8170, located in the old quarry, 2 km south of the Buskuskan railway station, is proposed as a neostratotype (Bakharev, 1985; Yazikov, 2014c) (Fig. 13). The thickness of Kerlegesh Beds is about 100 m. The Kerlegesh Beds are stratigraphically younger than the Safonovo Beds. They correspond to the upper half of the Givetian Stage, beginning from the middle varcus (=ansatus) Zone. The contact between the Safonovo and Kerlegesh beds was recorded in five sections: BS-091, BS-092, BS-093 (environs of the town of Prokopyevsk), B-8333 (the village of Zarechnoe), and B-8170 (an abandoned quarry, 2 km to the south of the Buskuskan railway station) (*Middle-Upper...*, 2011; Yazikov, 2014c; the present paper, Figs. 5, 7, 9, 11, 13, 14).

On the eastern slope of the Salair, the contact between the Kerlegesh Beds and younger deposits is not observed. The overlying interval is composed of effusive–terigenous deposits of the Bugotak–Mitrofanovo igneous complex. The Kerlegesh Beds are less characterized by fossil fauna compared to the Safonovo Beds. In addition to findings of brachiopods, ostracods, and corals (Rzhonsnitskaya, 1973; etc.), there are also findings of tentaculites *Heteroctenus* aff. *tagangaivi* G. Ljaschenko (Klishevich and Miretskaya, 1986).

**Brachiopods.** Two brachiopod zones have been established in the Kerlegesh Beds: Rhynchospiriferhians (=Ilmenia subhians) and stratigraphically higher lying Subrensselandia? salairica (= “Chascothyris” salairica) (Figs. 5, 7, 9, 11). In addition to index species (Plate VI, figs. 4, 5), a number of representatives of closely related stringocephalids belong to the characteristic brachiopod species according to published data: *Newberria* (= *Denckmannella*) *damesi* (Holzapfel), *N. circularis* (Holzapfel), and *Bornhardtina* sp.

(Rzhonsnitskaya, 1968). However, they are absent in the studied collection. The exact stratigraphic reference of these species is still unclear.

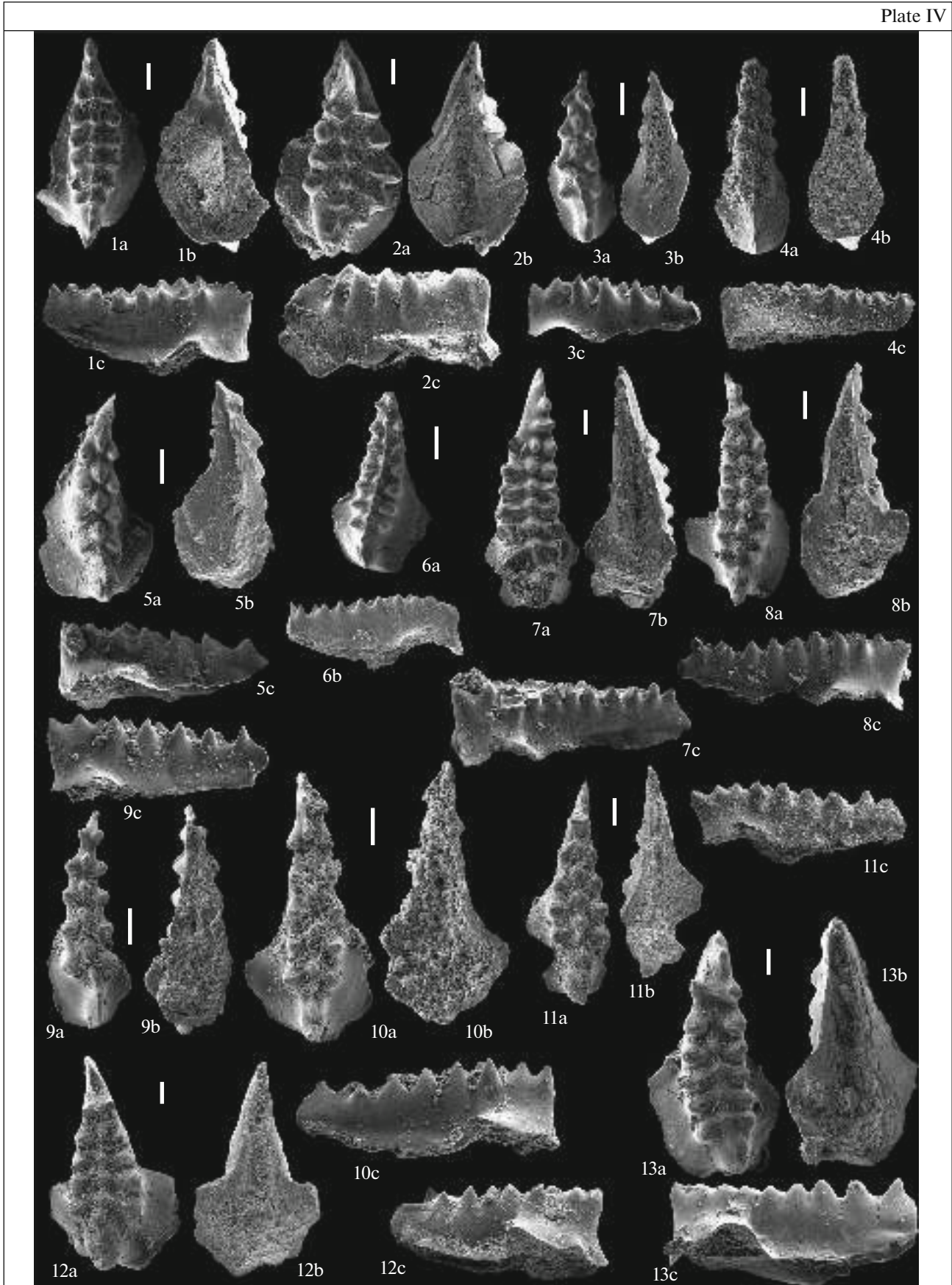
A characteristic feature of the brachiopod association from the Kerlegesh Beds is its extremely poor species composition due to facies reasons. It contains only reef-loving species forming bank-shell (stringocephalids) and pseudoplankton-superbenthic (Gratsianova, 1987) (rhynchospirifers) clusters scattered in sediments of various lithological composition. Throughout the Devonian, all these species indicate the Givetian Stage, except for representatives of *Bornhardtina*, which are also known in the Eifelian deposits.

**Ostracods.** Ostracods from the Kerlegesh Beds were found in the Buskuskan Quarry (Fig. 13, section B-8170) and in the roadside quarry on the outskirts of the town of Prokopyevsk, on the right side of an unnamed creek—a left tributary of Egos Creek (Fig. 11, section BS-092).

The following ostracod assemblage from the Buskuskan Quarry was identified: *Knoxella* sp., *Sulcocavellina altschedatensis* Polenova (Plate V, figs. 16–18), *Saumella salairica* Bakharev, *Bairdia safonovskiensis* Polenova (Plate V, figs. 9–12), *Bairdiocypris accuratus* Polenova, *Parabairdiocypris* sp., *Subligaculum* aff. *scrobiculatum* Kesling et McMillan (Plate V, figs. 24, 25), *Coeloenellina* sp., *Hanaites mirabilis* (Polenova) (Plate V, figs. 13–15), *Uchtovia abundans* (Pokorny), *Evanella* sp., *Cavellina* sp., *Paraschmidtella minussiensis* Polenova, *Microcheilinella mandelstami* Polenova, *M. givetica* Rozhdestvenskaya (Plate V, figs. 30, 31), *Miraculum ornatus* Bakharev (Plate V, figs. 26, 27), *Libumella* aff. *discoidea* Rozhdestvenskaya (Plate V, figs. 3, 4).

This assemblage includes species that are typical only of the Givetian Stage. The first seven species in this section were described from the underlying Safonovo Beds. *Uchtovia abundans* (Pokorny) was described from the Mulino (upper Givetian Stage) Horizon of Western Bashkiria (Rozhdestvenskaya, 1959). In addition, it occurs in Moravia (upper Givetian Stage), in the Czech Republic (Pokorný, 1950), in the Polish

**Plate IV.** Conodonts from the Akarachkino and Safonovo beds of the Zarechnoe Horizon of the Salair; upper Eifelian and Givetian stages, section BS-091 (western outskirts of the town of Prokopyevsk). Scale bar, 100 μm. (1) *Icriodus* sp. C, specimen no. BS-091/15: (1a) upper view, (1b) lower view, (1c) lateral view; Akarachkino Beds, Sample Yo-834-7/1 (=BS-091-13/2.8); (2) *Icriodus* sp. D, specimen no. BS-091/16: (2a) upper view, (2b) lower view, (2c) lateral view; Akarachkino Beds, Sample Yo-834-7/1 (=BS-09113/2.8); (3, 5, 9) *Icriodus* sp. E: (3) specimen no. BS-091/17: (3a) upper view, (3b) lower view, (3c) lateral view; Akarachkino Beds, Sample E-834-7/1 (=BS-091-13/2.8); (5) specimen no. BS-091/18: (5a) upper view, (5b) lower view, (5c) lateral view; Safonovo Beds, Sample BS-091-7/0.9; (9) specimen no. BS-091/19: (9a) upper view, (9b) lower view, (9c) lateral view; Safonovo Beds, Sample BS-091-3/3.7; (4) *Icriodus regularicrescens* Bultynck, 1970, specimen no. BS-091/20: (4a) upper view, (4b) lower view, (4c) lateral view; Akarachkino Beds, Sample Yo-834-7/1 (=BS-091-13/2.8); (6) *Icriodus* sp. B, specimen no. BS-091/21: (6a) upper view, (6b) lateral view; Akarachkino Beds, Sample BS-091-14/1.0; (7, 8, 13) *Icriodus difficilis* Ziegler, Klapper et Johnson, 1976: (7) specimen no. BS-091/8: (7a) upper view, (7b) lower view, (7c) lateral view; Safonovo Beds, Sample BS-091-7/2.0; (8) specimen no. BS-091/33: (8a) upper view, (8b) lower view, (8c) lateral view; Safonovo Beds, Sample BS-091-3/3.7; (13) specimen no. BS-091/22: (13a) upper view, (13b) lower view, (13c) lateral view; Safonovo Beds, Sample BS-091-3/3.7; (10) *Icriodus eslaensis* van Adrichem Boogaert, 1967, specimen no. BS-091/23: (10a) upper view, (10b) lower view, (10c) lateral view; Safonovo Beds, Sample BS-091-3/3.7; (11) *Icriodus brevis* Stauffer, 1940, specimen no. BS-091/24: (11a) upper view, (11b) lower view, (11c) lateral view; Safonovo Beds, Sample BS-091-2/0.8; (12) *Icriodus* aff. *excavatus* Weddige, 1984, specimen no. BS-091/25: (12a) upper view, (12b) lower view, (12c) lateral view; Safonovo Beds, Sample BS-0913/3.7.



**Table 2.** Taxonomic composition and the number of conodont elements in the Akarachkino and Safonovo beds (section BS-091)

Beds	Akarachkino										Safonovo														
	Samples from BS-091																								
Species	21/3.0	14/2.0	14/1.2	14/1.0	13/3.0	13/2.8	Yo-834-7/1 (=13/2.8)	13/2.0	12/0.85	10/5.2	9/4.0	7/3.4	7/2.6	Yo-834-7/4 (=7/2.6)	7/2.0	7/0.9	5/1.0	5/0.1	3/3.8	3/3.7	3/1.5	2/4.7	2/0.8	Total	
<i>Belodella</i> sp. A		1									3									1				5	
<i>Panderodus unicastatus</i>		2																	1					3	
<i>Icriodus regularicrescens</i>						1														1	2			4	
<i>Icriodus</i> sp. B				1												1								2	
<i>Neopanderodus aequabilis</i>							1					2					1			3	2			9	
<i>Po. aff. P. pseudofoliatius</i>						3														3				6	
<i>Tortodus</i> cf. <i>T. obliquus</i>						1																		1	
<i>Polygnathus</i> spp.						1	2		1			2												6	
<i>Icriodus</i> sp. D						2																		2	
<i>Icriodus</i> sp. C							2																	2	
<i>Icriodus</i> sp. E							1									1					1			3	
<i>Polygnathus linguiformis klapperi</i>							2					2		1						1				6	
<i>Tortodus planus</i>												1												1	
<i>Caudicriodus</i> sp. A												2	4											6	
<i>Icriodus difficilis</i>												4		1		1					2			8	
<i>Icriodus</i> sp.																	1	1			2		1	5	
<i>I. eslaensis</i>																				4	3			7	
<i>I. aff. excavatus</i>																				1				1	
<i>I. brevis</i>																						1		1	
Ramiform element														1			1			3				5	
<b>TOTAL</b>		3		1		8	7	1	1		3		13	4	3	2	2	2	2	2	18	11		2	83

**Table 3.** Taxonomic composition and a number of conodont elements in the Akarachkino and Safonovo beds (section BS-093)

Beds	Akarachkino		Safonovo										Total	
	Samples from BS-093													
Species	21/2.0	21/1.0	16/1.3	15/1.6	15/0.1	15/1.6	10/1/2	8/0.5	7/0.05	6/1.5	6/0.08	4/3.8	2/2.0	
<i>Caudicriodus</i> sp. A	1													1
<i>Panderodus unicastatus</i>			1											1
<i>Icriodus</i> sp.						1								1
<i>Neopanderodus aequabilis</i>									3					3
<i>Polygnathus linguiformis klapperi</i>									2		1			3
Ramiform element					1									1
Total	1		1		1	1			5		1			10

Pomerania (upper Givetian) (Zbikowska, 1983), and in the upper part of the Iz'yol Formation (middle Givetian) of the Timan–Pechora province (Moskalenko, 2001). *Paraschmidtella minussiensis* Polenova was previously reported from the Beya Formation (Givetian) of the South Minusinsk Basin (Polenova, 1960).

The specimens attributed to the species *Libumella* aff. *L. discoides* Rozhdestvenskaya are similar to the type species *Libumella discoides* Rozhdestvenskaya (Bakharev, 1985), which was previously described from the Biisky (lower Eifelian) Horizon in Western Bashkiria (Rozhdestvenskaya, 1959) and the Timan–Pechora province (Moskalenko, 2001).

In a roadside quarry on the right bank of Egos Creek (Fig. 11, section BS-092), the ostracod assemblage is somewhat different: *Aparchitellina* sp., *Microcheilinella larionovae* Polenova (Plate V, figs. 28, 29), *Orthocypris regula* Polenova, *Parabolbinella* sp., *Bairdiocypris accuratus* Polenova, *Hanaites mirabilis* (Polenova), and *Sulcocavellina altschedatensis* Polenova.

The given assemblage is characterized by ostracods locally distributed in the Salair (Polenova, 1960). *Orthocypris regula* Polenova has a wide vertical distribution within the basin. It was first described from the upper Emsian Shanda Beds and was also found in the Salairka, Mamontovo, Kerlegesh, and Safonovo beds (Polenova, 1960).

Of the common species, only two—*Hanaites mirabilis* (Polenova) and *Microcheilinella larionovae* Polenova—have been identified. The information about *Hanaites mirabilis* is given when describing the Akarachkino Beds, where it was found. The taxon *Microcheilinella larionovae* Pol. was first described in the eastern part of the EEP in the Biisky (lower Eifelian) Horizon (Polenova, 1955) and later found in the upper Emsian Koiva Horizon of Western Bashkiria (Rozhdestvenskaya, 1962). It was also reported in the Koiva (upper Emsian) and Biisky (lower Eifelian) horizons in the Timan–Pechora province (Moskalenko, 2001).

This taxon was previously reported in the Krekovo (upper Lockhovian), Salairka (lower Emsian), and Shanda (upper Emsian) beds of the Salair (Polenova, 1960).

On the basis of the biostratigraphic analysis of the identified ostracod assemblage, the conclusion follows about the middle Givetian age of the Kerlegesh Beds.

The late Givetian ostracod assemblage (Beds with *Bairdia carinata*) was previously established in the lower part of the Izyly Formation, the Izyly River basin near the village of Vassino (Popov, 2019). Three taxa (*Parabolbinella* sp., *Bairdiocypris accuratus* Pol., and *Coeloenellina cavitata* Rozh) pass to the Izyly ostracod assemblage from the underlying Kerlegesh Beds.

## DISCUSSION

The analysis conducted of the distribution of ammonoids, brachiopods, conodonts, and ostracods in the Middle Devonian sections of the Salair allowed us to make a number of changes to the existing stratigraphic sequence of local subdivisions. The relationships of the Akarachkino, Safonovo, and Kerlegesh beds are revised in a series of sections (Fig. 14). When restudying and preparing the Middle Devonian sections of the Salair for a demonstration to participants of the international field excursion in 2011, the Kerlegesh Horizon in the proposed stratigraphic scheme of the Devonian of the Salair was mistakenly correlated with the lower part of the Mamontovo Horizon, and the Safonovo Horizon was correlated with the upper part of this horizon, including the Akarachkino Beds (*Middle-Upper...*, 2011, fig. 5). The basis for this was the correlation of deposits based on coeval ammonoid assemblages given earlier in the lists of fauna from the Akarachkino and Safonovo horizons (Nikolaeva and Bakharev, 2010; Rzhonsnitskaya, 1973; etc.). Thus, *Agoniatites vanuxemi* (Hall), *Fidelites* sp., and *Cabrieroceras salairicum* Nikolaeva were reported



from calcareous siltstones of the upper part of the reference section of the Akarachkino Beds in environs of the town of Guryevsk (Bed 7, section B-8410) (*Middle-Upper...*, 2011; Bakharev et al., 2012). The same ammonoid assemblage was recognized in the sections previously attributed to the Safonovo Formation in environs of the town of Prokopyevsk: on the left bank of Egos Creek (Fig. 5, section BS-091, Beds 13, 16) and in a small quarry on the western outskirts of Prokopyevsk (Fig. 7, section BS-093, Bed 16) (*Middle-Upper...*, 2011; Nikolaev and Bakharev, 2010).

During the international geological excursion in 2011, *Agoniatites* cf. *vanuxemi* (Hall) and *Fidelites* sp. were first found in the tuffaceous, terrigenous-carbonate unit of the upper part of the section (Figs. 9, 10; section B-8333, unit 11), when examining “type localities” of the Safonovo Horizon near the village of Zarechnoe (Rzhonsnitskaya, 1968). This assemblage is similar to the known ammonoids from other localities of the Akarachkino Beds (sections B-8410, BS-091, and BS-093) and characterizes a rather narrow biostratigraphic interval of the upper Eifelian Agoniatites Genozone. The new finding of ammonoids made it possible to revise the structure of the given section, which includes both the Safonovo and Akarachkino beds (Figs. 9, 10).

The direct contact between the Akarachkino and Safonovo beds was established in three sections on the eastern slope of the Salair: BS-091 and BS-093 in the environs of the town of Prokopyevsk (Figs. 5–8) and B-8333 near the village of Zarechnoe (Figs. 9, 10) (*Middle-Upper...*, 2011).

Above the level of findings of ammonoids, the brachiopod assemblage corresponding to the Indospirifer padaukpinensis Zone and characterizing Safonovo Beds was found. It follows from this that the Safonovo Beds overlie the Akarachkino Beds. They are correlated with the interval from the Eifelian–Givetian transition beds to the lower part of the middle Givetian. Their stratigraphic volume corresponds to the

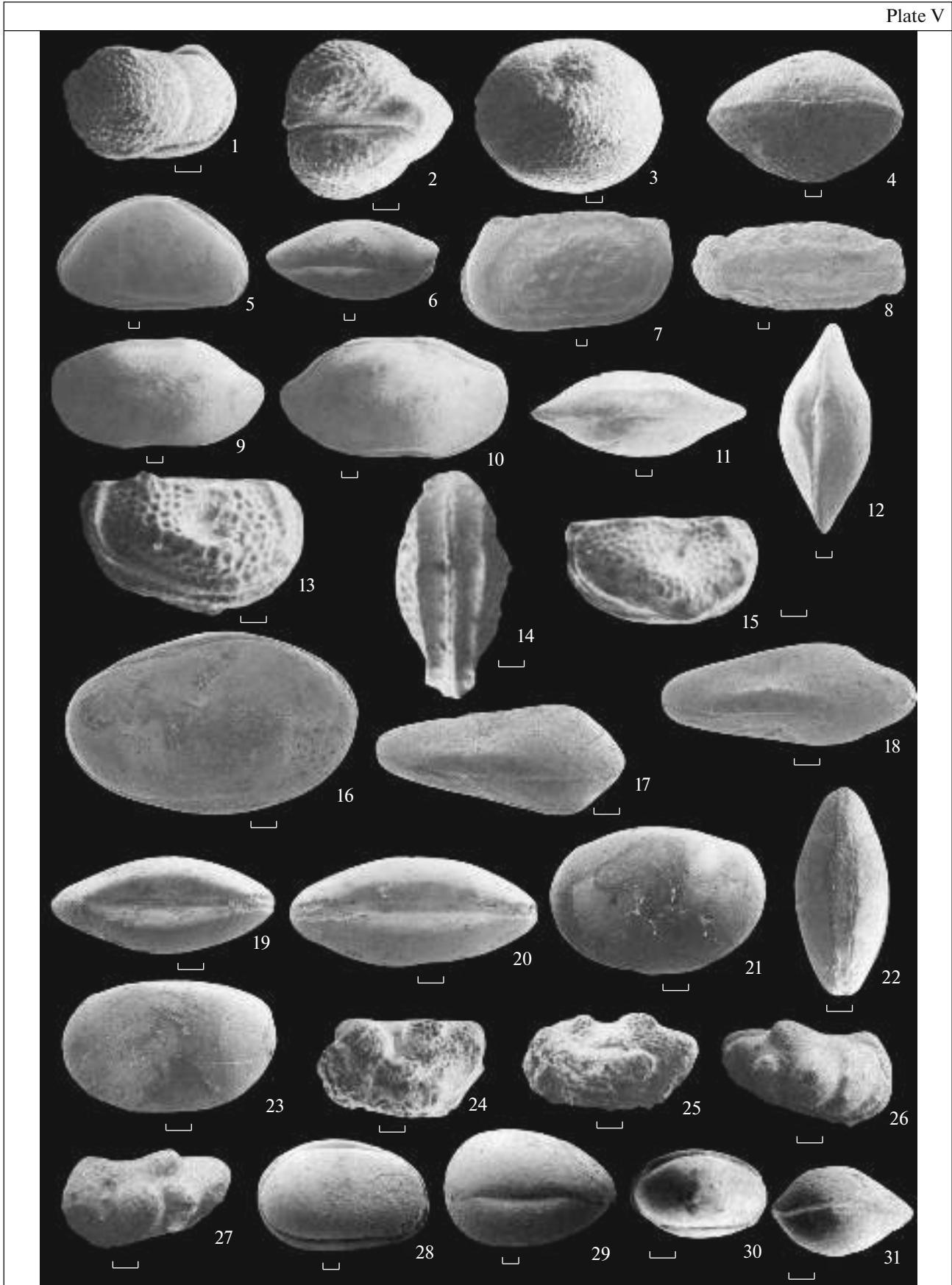
ensensis–Polygnathus rhenanus/Polygnathus varcus conodont zones and the lower part of the Polygnathus ansatus Zone.

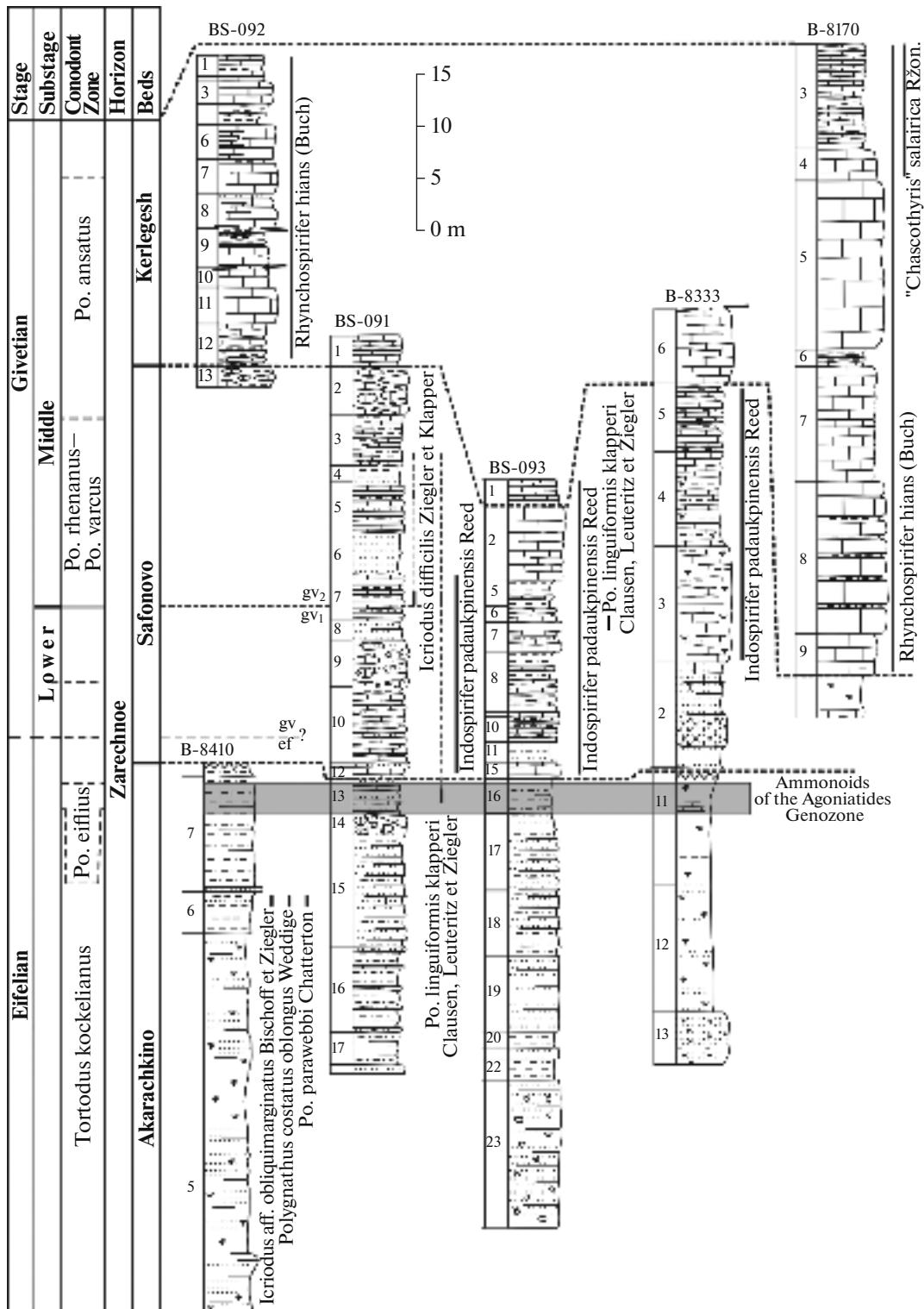
The contact between the Safonovo and Kerlegesh beds was established in sections BS-091, BS-092, and BS-093 in the environs of the town of Prokopyevsk (Figs. 5–8, 11, 12), in the central part of section B-8333 (Figs. 9, 10) near the village of Zarechnoe, and in section B-8170 (Fig. 13) located in the quarry 2 km south of the Buskuskan railway station (*Middle-Upper...*, 2011 (sections are given in reverse succession of beds); Yazikov, 2014c; Yazikov et al., 2014b). The Kerlegesh Beds are characterized by the mass appearance of brachiopods *Rhynchospirifer hians* (v. Buch) (= *Ilmenia subhians* Rzhonsnitskaja) and *Subrensselandia? salairica* (Rzhonsnitskaja) (= “*Chascothyris*” *salairica* Rzhonsnitskaja). The Kerlegesh Beds should be considered younger than the Safonovo Beds. They likely correspond to the upper part of the middle Givetian, beginning from the upper part of the Polygnathus ansatus Zone (Yazikov and Izokh, 2014b; Yazikov et al., 2014a).

In the modern sense, Teleutian Suprahorizon includes the Mamontovo and Zarechnoe horizons and analogs of the Bugotak complex. The Mamontovo Horizon is correlated with the upper Emsian and the greater part of the Eifelian Stage and corresponds to the Polygnathus patulus, Polygnathus partitus, Polygnathus costatus, and Tortodus kockelianus conodont zones. The Zarechnoe Horizon is correlated with the upper part of the Eifelian Stage and the lower and middle parts of the Givetian Stage or with the Tortodus kockelianus (upper part), Polygnathus eiflius, Polygnathus ensensis, Polygnathus hemiansatus, Polygnathus timorensis, Polygnathus rhenanus–Polygnathus varcus, and Ozarkodina semialternans conodont zones. On the basis of the conodont zonation, the position of the upper boundary of the Zarechnoe Horizon cannot be determined exactly because of the

**Plate V.** Ostracods from the Safonovo and Kerlegesh beds of the Zarechnoe Horizon of the Salair (sections BS-092, BS-093, B-8333, B-8170). Scale bar, 100 µm. (1, 2) *Ampuloides verrucosa* Polenova, 1952, Sample B-8170-11, Safonovo Beds, ×50: (1) specimen no. 1/71, right valve; (2) specimen no. 1/72, dorsal view; (3, 4) *Libumella* aff. *discooides* Rozhdestvenskaja, 1959, Sample B-8170-3/2, Kerlegesh Beds, ×30: (3) specimen no. 1/48, right valve; (4) specimen no. 1/49, dorsal view; (5, 6) *Bairdiocypris accuratus* Polenova, 1960, Sample B-8333-5/2, Safonovo Beds, ×20: (5) specimen no. 1/1, right valve; (6) specimen no. 1/2, dorsal view; (7, 8) *Moorites legibilis* Polenova, 1960, Sample BS-093-7/0.05 m, Safonovo Beds, ×20: (7) specimen no. 1/42, left valve; (8) specimen no. 1/43, ventral view; (9–12) *Bairdia safonovskiensis* Polenova, 1960, Sample B-8170-4/2, Kerlegesh Beds, ×30: (9) specimen no. 1/3, left valve; (10) specimen no. 1/4, right valve; (11) specimen no. 1/5, dorsal view; (12) specimen no. 1/6, ventral view; (13–15) *Hanaites mirabilis* Polenova, 1952, Sample B-8170-3/2, Kerlegesh Beds, ×50: (13) specimen no. 1/56, right valve; (14) specimen no. 1/57, ventral view; (15) specimen no. 1/58, right valve; (16–18) *Sulco-cavellina altschedatensis* Polenova, 1960, Sample B-8170-9, Kerlegesh Beds, ×50: (16) specimen no. 1/39, left valve; (17) specimen no. 1/41, dorsal view; (18) specimen no. 1/40, ventral view; (19–23) *Coeloenellina cavitata* Rozhdestvenskaja, 1962, Safonovo Beds, ×50: (19) specimen no. 1/36, Sample B-8333-7, dorsal view; (20) specimen no. 1/35, Sample B-8333-5/3, dorsal view; (21) specimen no. 1/34, Sample B-8333-5/3, left valve; (22) specimen no. 1/37, Sample B-8333-5/3, ventral view; (23) specimen no. 1/38, Sample B-8333-5, left valve; (24, 25) *Subligaculum* aff. *scrobiculatum* Kesling et Mc Millan, 1951, Sample B-8170-3/2, Kerlegesh Beds, ×50: (24) specimen no. 1/62, left valve; (25) specimen no. 1/63, ventral view; (26, 27) *Miraculum ornatus* Bakharev, 1985, Sample B-81703/2, Kerlegesh Beds, ×50: (26) specimen no. 1/16, right valve; (27) specimen no. 1/27, left valve; (28, 29) *Microcheilinella larionovae* Polenova, 1955, Sample BS-092-2, Kerlegesh Beds, ×30: (28) specimen no. 1/7, right valve; (29) specimen no. 1/8, dorsal view; (30, 31) *Microcheilinella givetica* Rozhdestvenskaja, 1959, Sample B-8170-9, Kerlegesh Beds, ×50: (30) specimen no. 1/11, right valve; (31) specimen no. 1/12, dorsal view.

Plate V



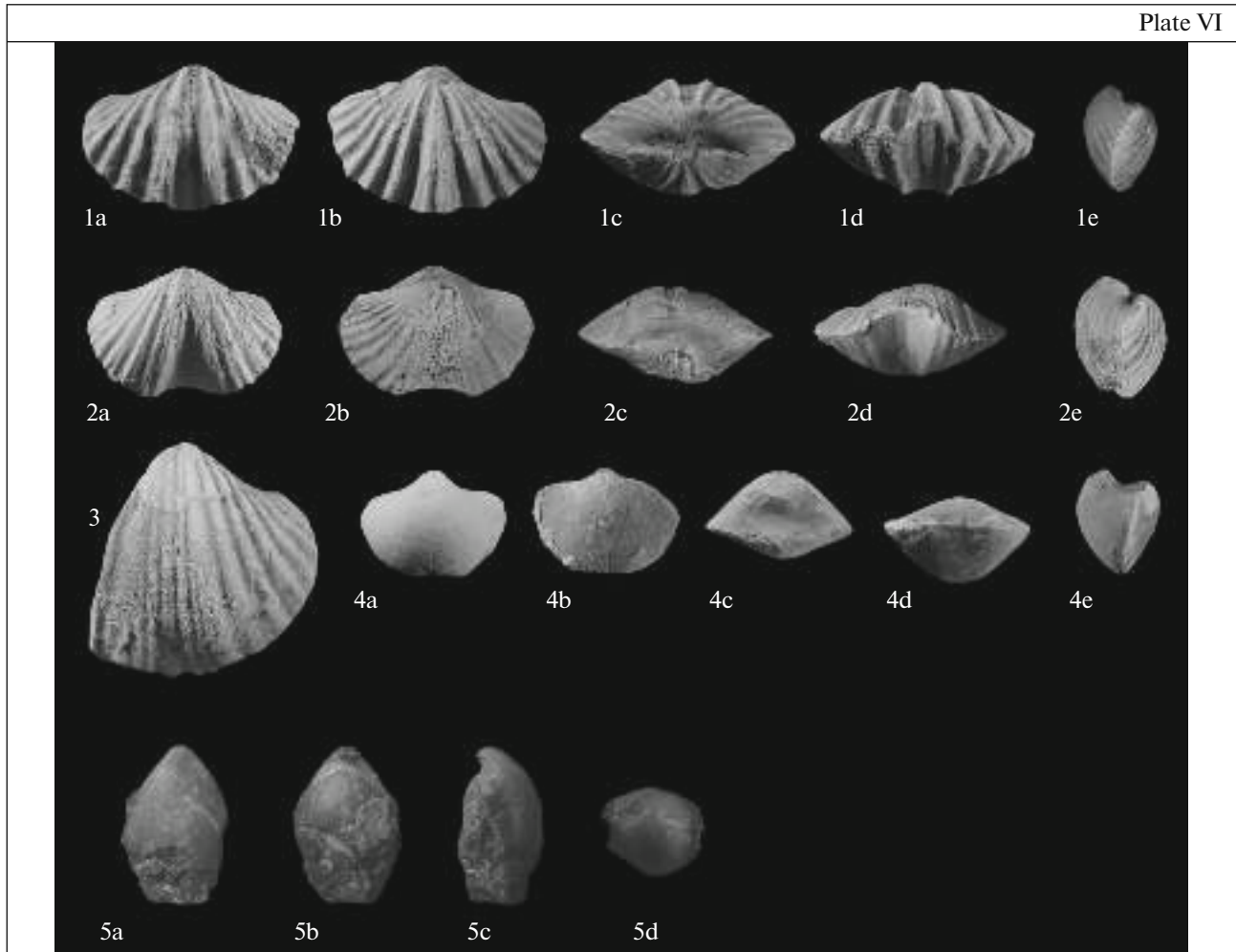


**Fig. 14.** Correlation scheme of reference sections of the Akarachkino, Safonovo, and Kerlegesh beds of the Middle Devonian Zarechnoe Horizon on the eastern slope of the Salair. See legend in Fig. 2.

absence of index species of zones, as well as taxa typical of this interval.

The contact of the Kerlegesh Beds with the stratigraphically younger deposits on the eastern slope of

the Salair is not observed. The overlying interval is composed of effusive-intrusive formations of the Bugotak igneous complex; the lower part encloses limestone interbeds. These limestone (the village of Ust'-



**Plate VI.** Brachiopods of the Safonovo and Kerlegesh beds of the Zarechnoe Horizon of the Salair. (1–3) *Indospirifer padaukpinensis* (Reed, 1908): (1) specimen no. Ya-132/11: (1a) ventral valve, (1b) dorsal valve, (1c) hinge edge, (1d) anterior edge, (1e) lateral view, all images  $\times 2.0$ ; the western margin of the Kuznetsk Basin, the village of Zarechnoe, Belovo district, Kemerovo oblast; lower Givetian, Safonovo Beds, Sample Ya-132; (2) specimen no. BS-093-2z/2: (2a) ventral valve, (2b) dorsal valve, (2c) hinge edge, (2d) anterior edge, (2e) lateral view, actual size; western outskirts of the town of Prokopyevsk, a small quarry near the cottage settlement; lower Givetian, Safonovo Beds, Sample BS-093-2z; (3) specimen no. Ya-133/4, a shell fragment with microsculpture, all images  $\times 2.0$ ; the western margin of the Kuznetsk Basin, the village of Zarechnoe, Belovo district, Kemerovo oblast; lower Givetian, Safonovo Beds, Sample Ya-133; (4) *Rhynchospirifer hians* (v. Buch, 1837), specimen no. B-8170-3/2: (4a) ventral valve, (4b) dorsal valve, (4c) hinge edge, (4d) anterior edge, (4e) lateral view, all images  $\times 3.0$ ; the western margin of the Kuznetsk Basin, a quarry 2 km south of the Buskuskan railway station, Givetian, Kerlegesh Beds, Sample B-8170-3; (5) *Subrensselandia ? salairica* (Ržonsnickaja, 1955), specimen no. B8170-3/5, complete shell (the anterior edge is destroyed): (5a) ventral valve, (5b) dorsal valve, (5c) lateral view, (5d) hinge edge, actual size; the western margin of the Kuznetsk Basin, a quarry 2 km south of the Buskuskan railway station, Givetian, Kerlegesh Beds, Sample B-8170-3.

Kamenka) bear conodonts *Icriodus cf. expansus* Branson et Mehl, characterizing the interval from the upper part of the Givetian Stage to the Frasnian Stage (hermanni Zone (upper Givetian)—the lower part of the punctata Zone (basal levels of the middle Frasnian)); (Yazikov et al., 2015b). Considering the data obtained, the stratigraphic volume of the Bugotak Formation corresponds to the upper Givetian—lower Frasnian interval (preliminarily the hermanni—guanwushanensis Zone) (villages of Ust-Kamenka and Vassino).

The study of the Middle Devonian sections of the Salair (environs of the village of Zarechnoe and the

town of Prokopyevsk) with a sampling of bryozoans, rugoses, and ammonoids was performed by O.P. Mezentseva and coauthors (Gumerova et al., 2015; Mezentseva, 2009; Mezentseva et al., 2007; etc.). On the basis of the biostratigraphic analysis of the faunal assemblages (bryozoans, rugoses), as well as the data on ammonoids (determinations by N.K. Bakharev and S.V. Nikolaeva), these authors concluded that the lower boundary of the Givetian Stage can be correlated with the base of the Safonovo Horizon, overlying the Akarackino Horizon (Gumerova et al., 2015).



For the period from 2005 to 2018, different variants of the regional stratigraphic schemes of the Devonian of the Altai–Sayan folded area of the new generation were proposed for discussion at the workshops of the Siberian Regional Interdepartmental Stratigraphic Commission. In one of these variants (Gutak et al., 2018), the Middle Devonian sequence of the Salair included the Mamontovo, Kerlegesh, and Safonovo horizons. On the basis of findings of the Givetian flora, the previously distinguished Akarachkino Horizon, the authors placed in the Kerlegesh Horizon as a “subaerial analog” (Gutak et al., 2018, p. 7). It is impossible to agree with this interpretation because the Akarachkino Beds in their type localities bear a reasonably substantiated late Eifelian faunal assemblage (ammonoids, conodonts, brachiopods) and occupy a particular position in the stratigraphic scheme of the Devonian of the Salair.

On the basis of the present-day biostratigraphic data, the interregional correlation of the Zarechnoe Horizon can provide the following variants. The Zarechnoe Horizon can be correlated with the upper part of the Mosolov Horizon, the Cherny Yar Horizon, and the Sary Oskol Suprahorizon of the Voronezh anteclise of the Russian Platform, the conodont zonation of which was clarified by Nazarova and Kononova (2015). Moreover, this horizon is correlated with the upper part of the Afonino Horizon, with the Chusovskoy and Cheslav horizons of the western slope of the Urals, with the upper part of the Langur Horizon and the Vysotinsky Horizon of the eastern slope of the Urals (*Stratigraficheskie...*, 1993; Sapelnikov et al., 2000), with the middle part of the Gerasimovo Horizon of the West Siberian geosyncline (*Stratigrafiya...*, 2001), and partially with the Yukta Horizon of the Siberian Platform (Matukhin, 1995).

## CONCLUSIONS

On the basis of the biostratigraphic analysis of the collection of macro- and microfauna from the type localities of Akarachkino, Safonovo, and Kerlegesh beds, the stratigraphic sequence of regional subdivisions of the Middle Devonian of the Salair has been clarified. The results of the studies indicate a younger age of the Kerlegesh Beds than previously considered. The results obtained are summarized as follows:

(1) The identified ammonoid assemblages in four studied sections (B-8410, environs of the town of Guryevsk; BS-091 and BS-093, environs of the town of Prokopyevsk; B-8333, the environs of the village of Zarechnoe) are coeval and correspond to the upper Eifelian Agoniatites Genozone. This assemblage is a regional and global biomarker confined to the upper part of the tuffaceous unit at the top of the Akarachkino Beds of the Salair.

(2) The succession of Middle Devonian conodonts of the Salair was established. Late Eifelian conodont

assemblages were found in the upper part of the Akarachkino Beds, below and together with the level of findings of ammonoids (sections B-8410, environs of the town of Guryevsk; BS-091, environs of the town of Prokopyevsk). In the middle part of the Safonovo Beds (section BS-091, environs of the town of Prokopyevsk), conodonts characterizing the middle Givetian interval, the *Polygnathus rhenanus*–*Polygnathus varcus* (= *Icriodus difficilis*) Zone, and the lower part of the *Polygnathus ansatus* Zone were identified. The Kerlegesh Beds should be considered younger than the Safonovo Beds, and they are correlated with the upper part of the middle Givetian and with the upper part of the *Polygnathus ansatus* Zone (section B-8333, environs of the village of Zarechnoe).

(3) The Akarachkino Beds with ammonoids of the Agoniatites Genozone and the conodont assemblage of the upper Eifelian *Polygnathus eiflius* Zone are overlain conformably by the Safonovo Beds bearing the brachiopod assemblage of the *Indospirifer padaukpinensis* Zone (sections BS-091 and BS-093). Upsection, the Safonovo Beds are followed by the Kerlegesh Beds, characterized by brachiopods of the *Rhynchospirifer hians* Zone and the stratigraphically younger than the *Subrensselandia? salairica* Zone (sections BS-092 and B-8170).

(4) The Zarechnoe Horizon includes the Akarachkino, Safonovo, and Kerlegesh beds belonging to the upper Eifelian and lower and middle Givetian. It corresponds to the interval of the following zones in the conodont zonal succession: *Polygnathus eiflius*, *Polygnathus ensensis*, *Polygnathus hemiansatus*, *Polygnathus rhenanus*–*Polygnathus varcus*, *Polygnathus ansatus*, and *Ozarkodina semialternans* (Fig. 2). The new biostratigraphic data show that the present-day stratigraphic scheme of the Middle Devonian (*Resh-eniya...*, 1982) should be revised.

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## CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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