XVIII INTERNATIONAL CONGRESS ON THE CARBONIFEROUS AND PERMIAN
August 11–15, 2015, Kazan, Russia

CARBONIFEROUS REFERENCE SECTIONS: POTENTIAL CANDIDATES FOR THE BASE OF THE SERPUKHOVIAN GSSP AND ORGANIC BUILDUPS SOUTH URALS

Post-Congress C3 Trip: August 16–19, 2015

Russian Academy of Sciences
Institute of Geology, Ufa Scientific Centre
Borissiak Paleontological Institute
Zavaritsky Institute of Geology and Geochemistry, Ural Branch

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The purpose of the field trip is to show the standard and reference Carboniferous sections of the eastern slope of the South Urals. The area of the excursion is on the border of the Chelyabinsk Region and the Republic of Bashkortostan. The guidebook includes a summary of geology and Carboniferous stratigraphy of the Urals. Eight geological objects of the excursions are described and illustrated. The Verkhnyaya Kardailovka section, a candidate for the base of the Serpukhovian GSSP, is described in detail. A Devonian-Carboniferous section near Verkhneuralsk, the stratotype of the Lower Viséan Ustgrekhovkian Horizon on the Ural River, and Bashkirian organic buildups on the Bolshoi Kizil and Khudolaz rivers are described.

Reviewer – Yu.A. Gatovsky

Опорные разрезы карбона: потенциальные кандидаты в GSSP нижней границы серпуховского яруса и органогенные постройки, Южный Урал. Пост-Конгрессная экскурсия С3: 16–19 августа, 2015. Путеводитель полевой экскурсии XVIII-го Международного конгресса по карбону и перми, 11–15 августа, Казань, Россия / Е.И. Кулагина, С.В. Николаева, Е.Н. Горожанина, Н.А. Кучева, Т.И. Степанова, А.С. Алексеев, Б.Ч. Ричардс, В.Н. Пучков, Н.Н. Кочетова, В.М. Горожанин, В.А. Коновалова. Под ред. Е.И. Кулагиной, С.В. Николаевой. СПб: «Свое издательство», 2015. 90 с.

Рецензент – Ю.А. Гатовский

Целью полевой экскурсии является демонстрация типовых и опорных разрезов карбона на территории восточного склона Южного Урала на границе республики Башкортостан и Челябинской области. Дано краткое описание геологического строения Урала и стратиграфии каменноугольных отложений. Наиболее детально охарактеризован разрез Верхняя Кардаиловка, претендент на стратотип нижней границы серпуховского яруса. Приведено описание разреза пограничных отложений девона и карбона района г. Верхнеуральск, стратотипа устьгреховского горизонта нижнего визе по р. Урал, органогенных построек башкирского яруса по рекам Большой Кизил и Худолаз.

ISBN 978-5-4386-0912-4

INTRODUCTION

The purpose of the field trip is to show the standard and reference Carboniferous sections of the eastern slope of the South Urals (Figs. 1, 2). The area of the excursion is on the border of the Chelyabinsk Region and the Republic of Bashkortostan, Russian Federation, known as Transuralia or the Trans-Urals. Transuralia is a mostly level, slightly mountainous territory adjacent to the eastern slope of the Ural Mountain Range, on the flood plains and terraces of the Ural and Tobol Rivers, bordering the western margin of the West Siberian Plain. The climate is profoundly continental with large range of temperatures from minus 34 to plus 38°C, with little precipitation. Large areas are covered by pastures and ploughed fields, and only 5% or less are forests. The region became part of the Russian Empire in the 1730s, as a result of a voluntary decision by the Bashkirian and Kasakh tribes, and soon after they were joined by migrants from central European Russia. The population includes Russians, Bashkirs, Tatars, Kasakhs, and Germans. Gold mining began in the 1830s in the upper reaches of the Khudolaz River. By 1923, 40% of all Uralian gold was produced in the Tanalyk-Baimak Mining Region. The Baimak District was established on 20 August 1930 as part of Bashkortostan. The Verkhneuralsk District was established on 4 November 1924 as part of the Chelyabinsk Region. There are many Stone Age archaeological sites. The Stone Age sites of Southern Transuralia (1500 Palaeolithic, Mesolithic and Neolithic sites and settlements) have been studied for more than 100 years.

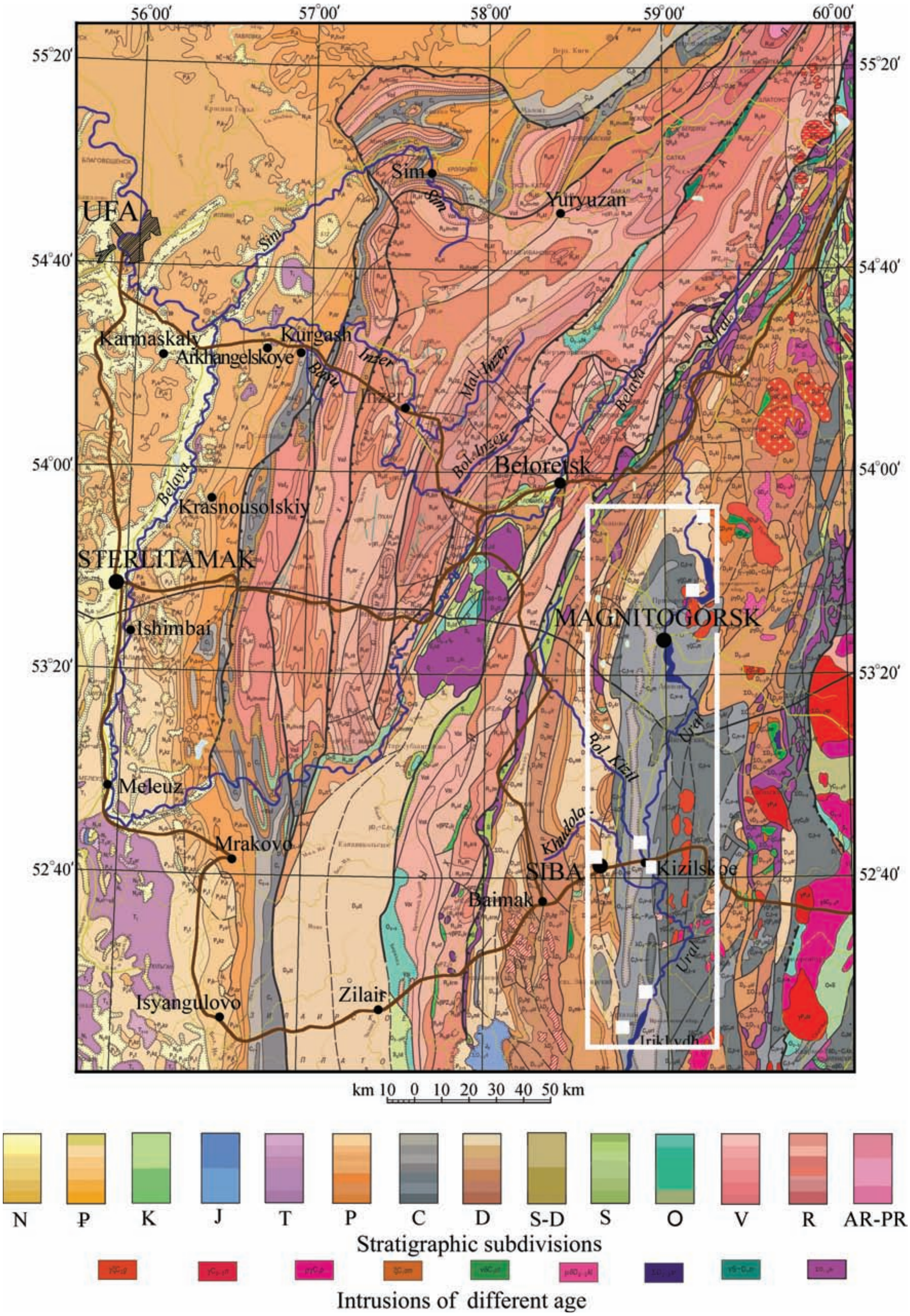


Fig. 1. The geological map of pre-Quaternary deposits of the South Urals (N-40 (41) Ufa) (Geological map..., 2002)

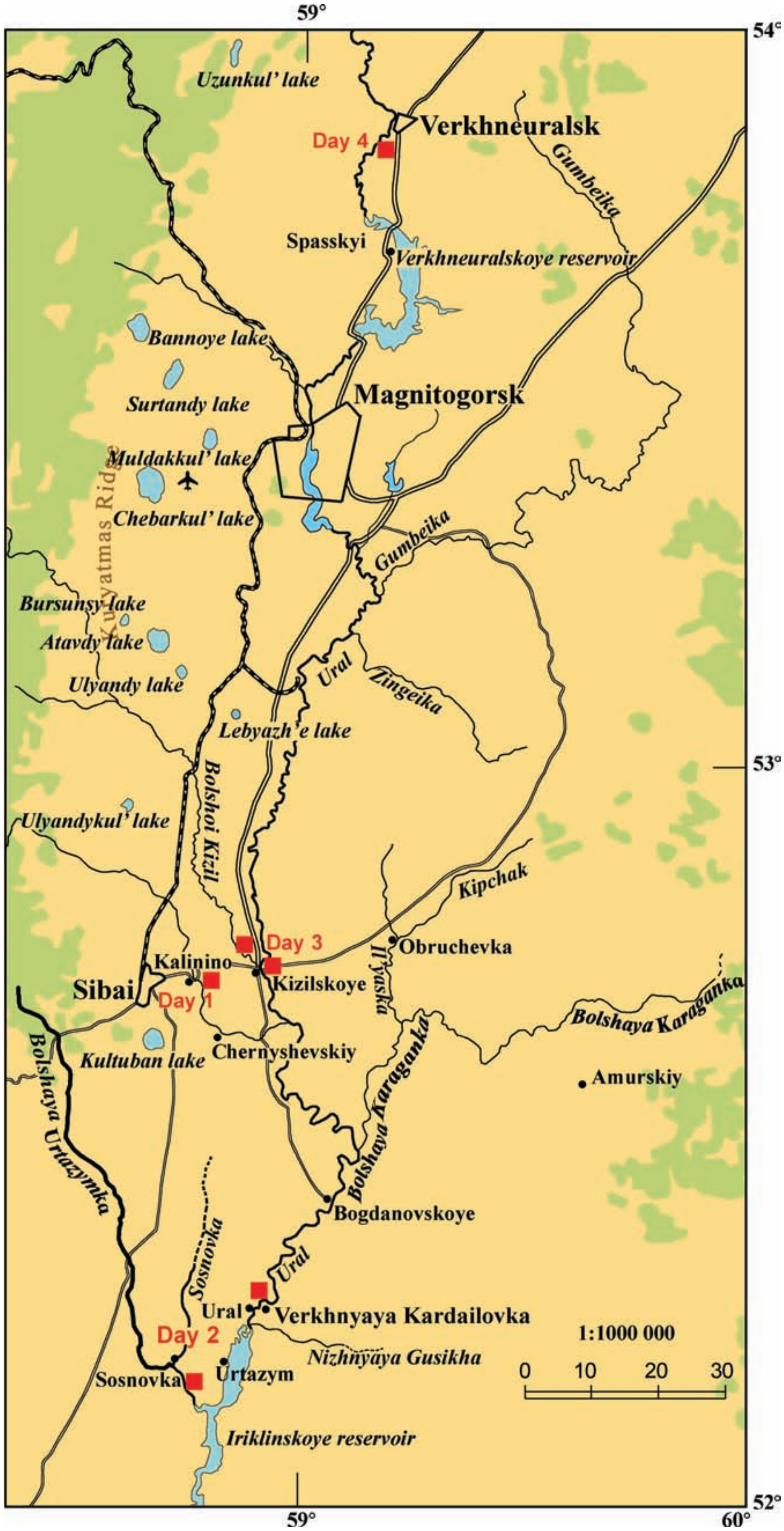


Fig. 2. Excursion sites

GEOLOGICAL BACKGROUND

The Urals are a Late Paleozoic orogenic belt, located at the western flank of a huge (more than 4000 km long) intracontinental Uralo-Mongolian mobile belt. The orogen developed mainly between the Late Devonian and the Late Permian, with a brief resumption of orogenic activity in the Early Jurassic and Pliocene-Quaternary time. Although its evolution is commonly related to the Variscides of Western Europe, its very distinctive features argue against a simple geodynamic connection. On first impressions, the evolution of Uralian orogen shows similarities with the "Wilson cycle", beginning with epicontinental rifting (Late Cambrian – Lower Ordovician) followed by passive margin (Middle Ordovician – Late Devonian and partly Early Carboniferous) development, onset of subduction and arc-related magmatism (Late Ordovician) followed by arc-continent collision (Late Devonian in the South and Early Carboniferous in the North) and continent – continent collision (beginning in the mid-Carboniferous) (Puchkov, 2009). The evolution of the Uralides is consistent with the development and destruction of a Uralian Paleoocean to form part of a giant Uralo-Mongolian Orogen, which involved an interaction of cratonic Baltica and Siberia with a young Kazakhstanian continent. The Uralides, in contrast to the Variscides, are characterized by recurrent and much more protracted orogeny, interrupted in the Early Triassic by tectonothermal activity associated with the Uralo-Siberian superplume.

The Uralian Foldbelt results from oblique collision between the East European (Laurussia) passive margin and the active margin on the Kazakhstanian continent. Collisions began in the south of the Urals and moved, wave-like, to the north. The eastern and northern parts of the Urals have also been affected by the Pre-Middle Jurassic Cimmerian intracontinental (intra-Pangaean) shortening. The Uralian-Cimmerian mountain belt (the Uralides) was eroded and partially inundated by seas in the Late Jurassic – Early Cretaceous times and has been reactivated since the Pliocene in response to a recent intracontinental shortening.

The Uralian Foldbelt is one of the oldest and richest mining regions of Russia. Therefore, it has attracted the attention of many geologists, among whom one should mention Murchison (the founder of the Permian system), Karpinsky (the proponent of the contractionist ideas who suggested that the changes in the Ural's strike were influenced by the outline of the rigid Russian plate), and Shatsky (who established the Riphean system in the Urals, discovered the remains of a Late Proterozoic foldbelt, and developed a theory of relationships between geosynclines and platforms). In the early 1970s, in light of the introduction of plate tectonics, Hamilton, Peyve and Ivanov proposed that the Urals represent a closed Paleozoic ocean.

The north-south-trending mountain range, approximately 2000 km long, is the geographic Europe – Asia boundary and is commonly divided into the Polar, Cis-Polar, Northern, Central and Southern Urals (Fig. 3). The characteristic feature of the fold belt is a distinct, though disturbed, linearity of tectonic zones. Thanks to Late Cenozoic tectonic movements the tectonic zones are all exposed in the Southern Urals. In the north, the Mesozoic and Cenozoic sediments of the West Siberian basin cover the easternmost zones. The Urals are divided into six sub-meridional zones that differ both in their structure and stratigraphy (see Fig. 1). From west to east they are (1) the Uralian Foredeep, (2) the West Uralian, (3) the Central Uralian, (4) the Tagil-Magnitogorsk (Magnitogorsk Zone in the South Urals), (5) the East Uralian and (6) the Transuralian zones. Zones 1, 2 and 3 represent the former passive margin of the Baltica continent (Puchkov, 1979). This margin formed from the Late Cambrian to Early Ordovician and was stable during the Ordovician, Silurian and Devonian times. In the Late Paleozoic, the platform was deformed to become part of the Uralian Foldbelt.

The Uralian Foredeep, 50–75 km wide, is filled with Permian flysch and molasse of eastern provenance, up to 6 km thick (Nalivkin, 1949; Chuvashov & Dyupina, 1973), underlain by 4–7 km thick Ordovician-Carboniferous shelf deposits, which, in turn, unconformably cover Precambrian sedimentary, metamorphic and magmatic complexes.

The West Uralian Zone comprises predominantly intensely folded and thrusted Lower and Middle Paleozoic sediments characterizing the former passive margin of the East European continent. There is no conspicuous facies change at the boundary between the Uralian Foredeep and the West Uralian Zone. Such a change, partially affected by later thrusts, occurs further to the east within the Zone, as an abrupt transition from shelf to bathyal sediments. Such sedimentary facies changes occur across the passive margin as well as along its 2000 km length.

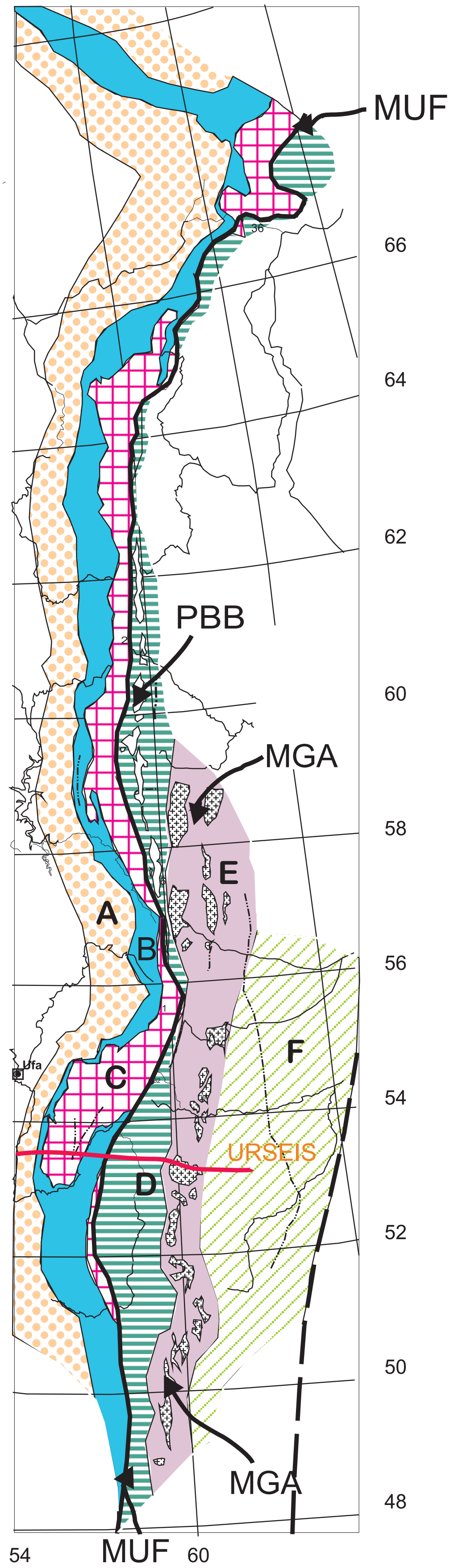


Fig. 3. Tectonic zoning of the Urals (Puchkov, 2009, fig. 1)

Zones: A – Uralian Foredeep, B – West Uralian Zone, C – Central Uralian Zone, D – Tagil-Magnitogorsk Zone, E – East Uralian Zone, F – Transuralian Zone. MUF – Main Uralian Fault, MGA – Main granitic axis of the Urals, PBB – Platinum-bearing belt, URSEIS – seismic line shown in Fig. 4

The Central Uralian Zone, up to 70–75 km wide, is characterized by well-exposed Precambrian sedimentary, metamorphic and magmatic rocks which are, in some places, thrust over the rocks of West Uralian Zone. The core of the Bashkirian anticlinorium, an exhumed Precambrian basement of the Paleozoic continental margin, includes crystalline complexes, produced by two or more stages of deformation and metamorphism, sedimentary sequences of Riphean aulacogens and Vendian molasse of the Late Precambrian Timanide orogen.

The Tagil-Magnitogorsk, East Uralian and Transuralian zones belonged to the active margin of the Kazakhstanian continent (Yazeva et al., 1989; Puchkov, 1996). They are less uniform compared the first three zones. They are united by a wide development of magmatic complexes, indicators of subduction. The Central Uralian and Tagil-Magnitogorsk zones are thought to be divided by an east-dipping major suture zone called the Main Uralian Fault. A considerable part of it is marked by serpentinitic mélanges.

The Magnitogorsk Zone is composed of Lower – Middle Paleozoic complexes of oceanic crust, island arcs, and flysch troughs covered by Carboniferous shallow-water sediments: limestones, coal-bearing terrigenous sequences and widespread rift and subductional volcanics. The development of subductional complexes finally ceased in the Bashkirian time. From this moment on, the subduction was changed by a collision, resulted in a Formation of the Uralian Orogen.

The East Uralian Zone is distinguished by the presence of sialic, microcontinental complexes, fragments of Precambrian continental crust. This is a collage of microcontinental blocks with relics of an autochthonous Paleozoic sedimentary and volcano-sedimentary cover and allochtonous Paleozoic ophiolite and island-arc formations. The distinct feature of the zone is also a chain of granite intrusions (Main Granitic Axis of the Urals), developed during the last stages of subduction (Tournaisian to Bashkirian) and later stages of collision (Moscovian to Permian). The relicts of collision-induced intermontane depressions, traced in the East Uralian Zone, were filled by Moscovian flysch-like deposits and a Gzhelian-Kasimovian molasse.

The Transuralian Zone. This, the easternmost, most poorly exposed and least studied Zone, has a rather controversial eastern boundary separating the Uralides from the Kazakstanides (Caledonides). The Zone has accretionary features, including Precambrian blocks, Ordovician rift complexes and ophiolites, Silurian and Devonian shallow and deep-water complexes. The most important are calc-alkaline volcano-plutonic subductional complexes of the Tournaisian to Bashkirian age.

The modern structure of the Uralian orogen. The complex geological and geo-physical studies at URSEIS-95 and SB-ESRU profiles demonstrated a well-preserved bivergent structure of the Uralian orogeny (Fig. 4).

The origin of the modern Ural mountains. The Late Paleozoic mountain belt rejuvenated by the Old Cimmerian dislocations existed only for a short time, due to rapid erosion. By the end of the Jurassic and during the Cretaceous the Urals were low hills and partially lowland ingressed and covered by seas (Papulov, 1974). Only since the Pliocene have Ural Mountains started to grow again. These processes are still active, proved by geodetic and horizontal stress measurements as well by weak to medium earthquakes. This orogeny probably results from an intracontinental process, a far-reached alpine deformation of a continental crust that followed favourable, weak directions in the lithosphere of Eurasia (Puchkov, 1988; Puchkov & Danukalova, 2009). The Shikhans (hills representing Lower Permian carbonate reefs) were uplifted and devoid of their evaporitic envelope during this late orogeny, in the Pliocene-Quaternary time.

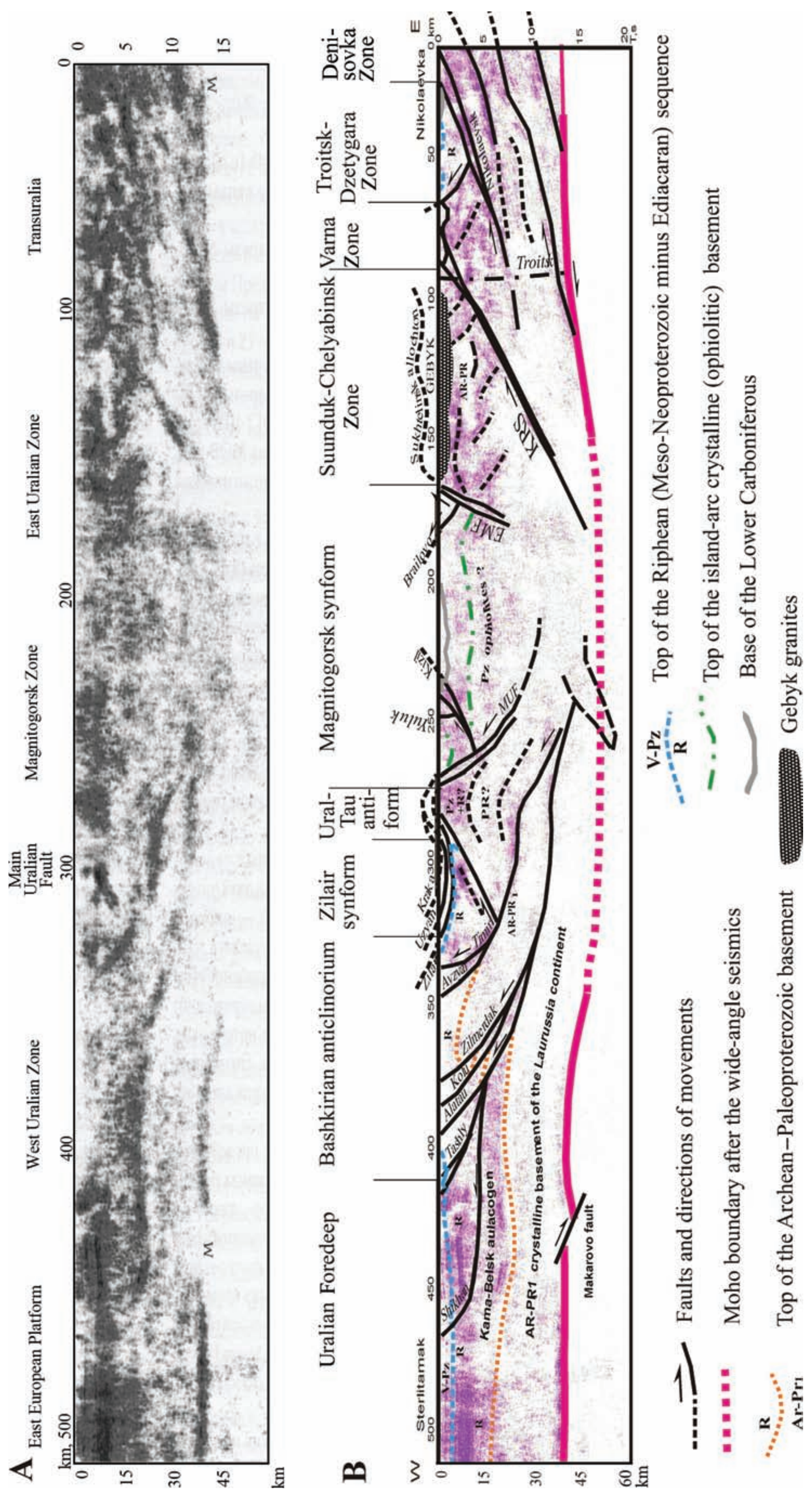


Fig. 4. Seismic profile (Puchkov, 2009, Fig. 3)

MAGNITOGORSK SYNCLINORIUM

Sections visited are located in the Magnitogorsk structural Zone (Magnitogorsk Synclinorium or Megasynclinorium).

The Lower and Early Upper Carboniferous carbonate beds crop out as a meridional belt 8–16 km wide and over 150 km long (Fig. 5). In the west they border the Kizil Fault, which separates them from the Devonian arc volcanics of the Western Magnitogorsk, and in the east – Magnitogorsk Fault (Znamensky, 2008), which separates the carbonates from the Devonian and Lower Carboniferous volcanic complexes. From north to south the carbonates are represented in a series of sections (Fig. 6).

In the northern regions of the Magnitogorsk Synclinorium, Famennian and Early Tournaisian volcanic rocks of the Shumilino Formation and its equivalent Gora Magnitnaya Formation crop out. They are studied in the Popovskiy (Dzerzhinka) (Kochetkova et al., 1980; Mizens et al., 2002), Spasskiy, Novoivanovskiy (Gorozhanina & Pazukhin, 2010), and near Magnitogorsk (Magnitnaya Gora Formation). In the Popovskiy (Dzerzhinka) section, the rock sequence indicates the transition from the carbonate shelf to the distant facies of a volcanic Zone beginning from the Lower Tournaisian. The Tournaisian sections of the Magnitogorsk Synclinorium are represented by volcanic bimodal complexes of the Berezovskiy Formation cropping out in the eastern regions of the area (eastern margin of the Magnitogorsk Trough). The Lower Viséan beds include volcanics and carbonates. Upper Viséan carbonate sections are widespread in the area (Salikhov & Yarkova, 1992).

The Lower Carboniferous volcanism was located near the graben structures. In the central part of the Magnitogorsk Zone there is a region of distribution of volcanic and volcanic-sedimentary complexes of the rift type – Magnitogorsk-Bogdanovskoe Graben, and the largest volcanic formations are developed here (Salikhov, 1997, 2009; Salikhov et al., 2014). The volcanic activity within the graben migrated from south to north during the Tournaisian and Viséan.

The distribution of different types of sediments within the graben depended on the proximity to the centres of volcanic activity. In the lateral zones of the graben, which were distant from volcanoes carbonates dominate the section (Fig. 7). In the Early Viséan, volcanic processes become localized. By the Late Viséan volcanism subsided.

The Upper Viséan and Serpukhovian beds are composed of various carbonate shelf facies, dominated by the shallow-water coral-brachiopod limestone (Kizil Formation) and relatively a really restricted cephalopod-deep-water carbonates (Formation not formally named). The exposures of the Kizil Formation are traced in the meridional direction from the latitude of Magnitogorsk southwards to Iriklinskoe Lake. The biogenic carbonate deposits of the Kizil Formation are widespread to the west of the graben.

The Kizil Formation is subdivided into regional substages ("Horizons") recognized in the coral-brachiopod facies.

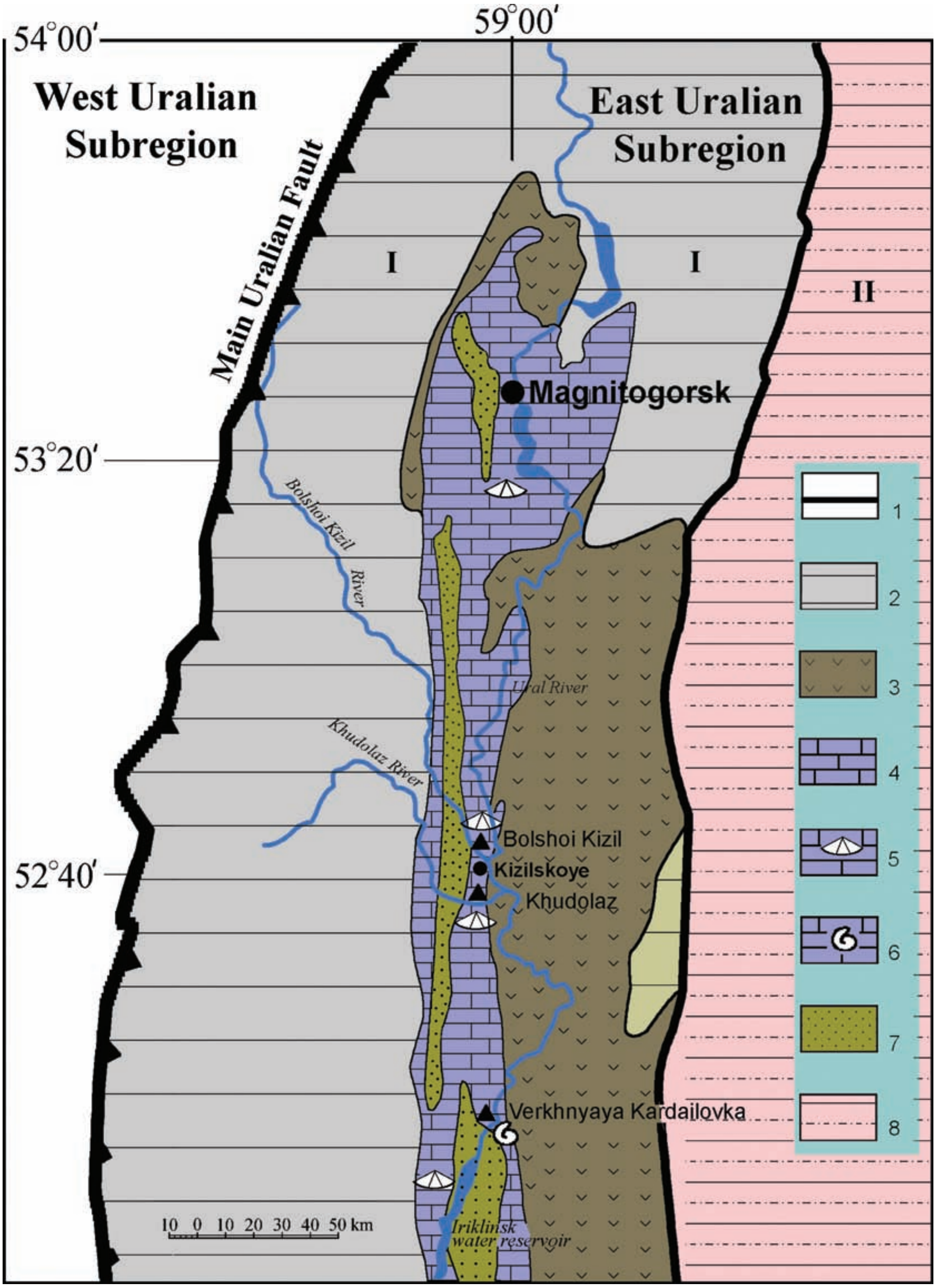


Fig. 5. Early Carboniferous formations and facies in the Magnitogorsk Zone (Stepanova & Kucheva, 2009a; Kulagina et al., 2011)

I – Magnitogorsk Zone; II – East Uralian Zone; 1 – borders of tectonic megazones; 2 – pre-Carboniferous deposits; 3 – area of volcanic rocks of the Upper Tournaisian: Zhukovian Substage of the lowermost upper Viséan with interrupted exposures of Viséan-Serpukhovian carbonates; 4–6 – Viséan-Serpukhovian and Bashkirian carbonates: 4 – carbonate rocks, 5 – shallow-water facies, 6 – deep-water facies; 7 – Moscovian siliciclastics and carbonates; 8 – area of mainly Tournaisian – Lower Viséan carbonates and siliciclastics.

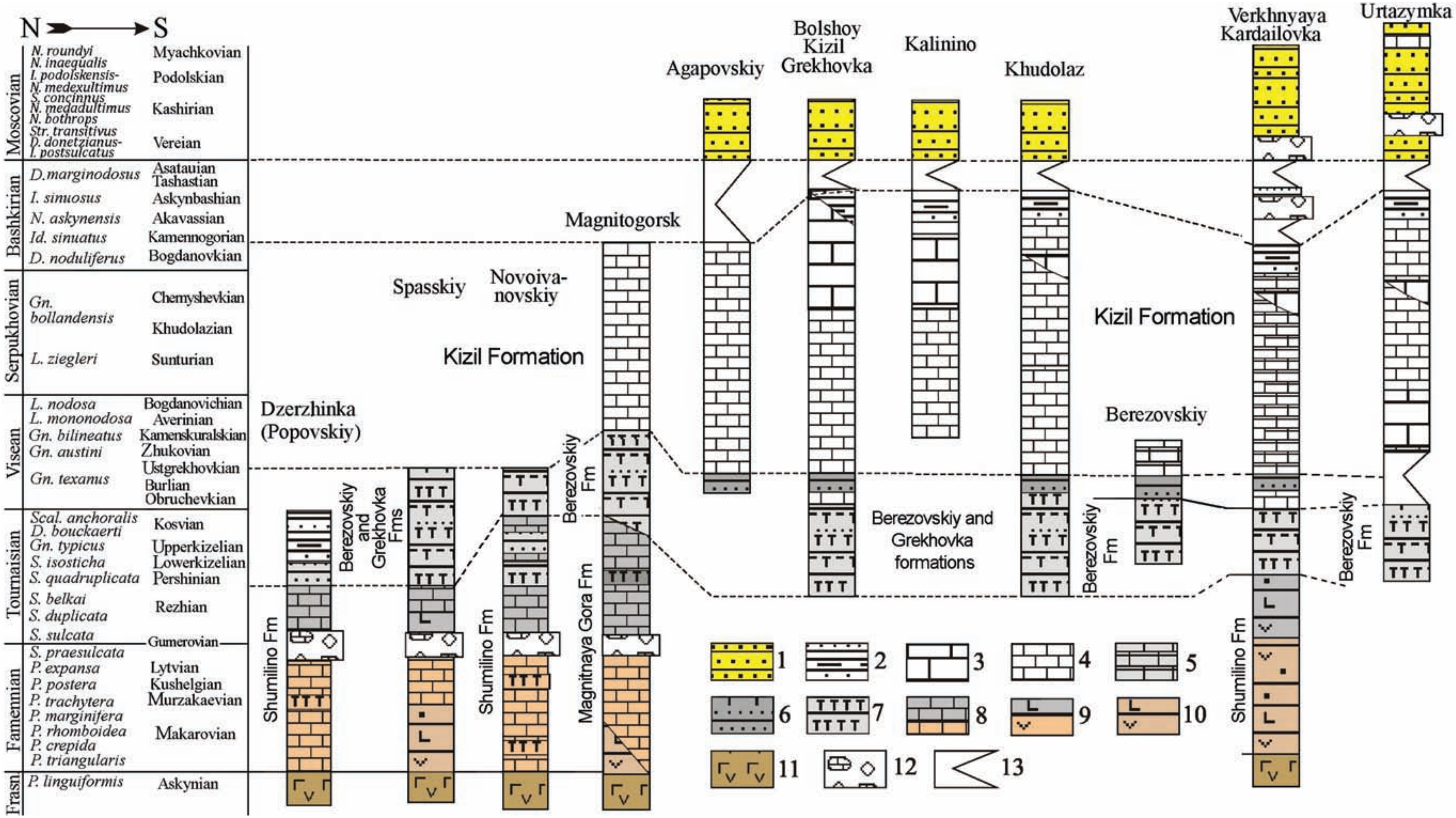


Fig. 6. Correlation scheme of selected Carboniferous sections in the Magnitogorsk Zone (compiled by E.N. Gorozhanina)

Legend: 1 – Urtazym flysch Formation C_2m: calcareous sandstones, conglomerates; 2 – clayey limestones and silica shales with sandstone interbeds C_2b_2; 3–6 – Kizil Formation C_1v–C_2b_1: 3 – biohermal, 4 – shelfal and 5 – deepwater shelf limestones, 6 – Zhukovian volcano-siliciclastic sediments C_1v_2; 7 – Berezovskiy and Grekhovka volcanic formations, C_1t–v; 8 – Magnitnaya Gora Formation, D_3fm–C_1t_1: shelf limestones; 9 – Shumilino Formation, D_3fm–C_1t_1: limestones and volcanics; 10 – Novoivanovskiy Formation, D_3fm: volcanics; 11 – Ablyazovo Formation, D_3f: volcanics; 12 – breccias and conglomerate horizons; 13 – hiatus.

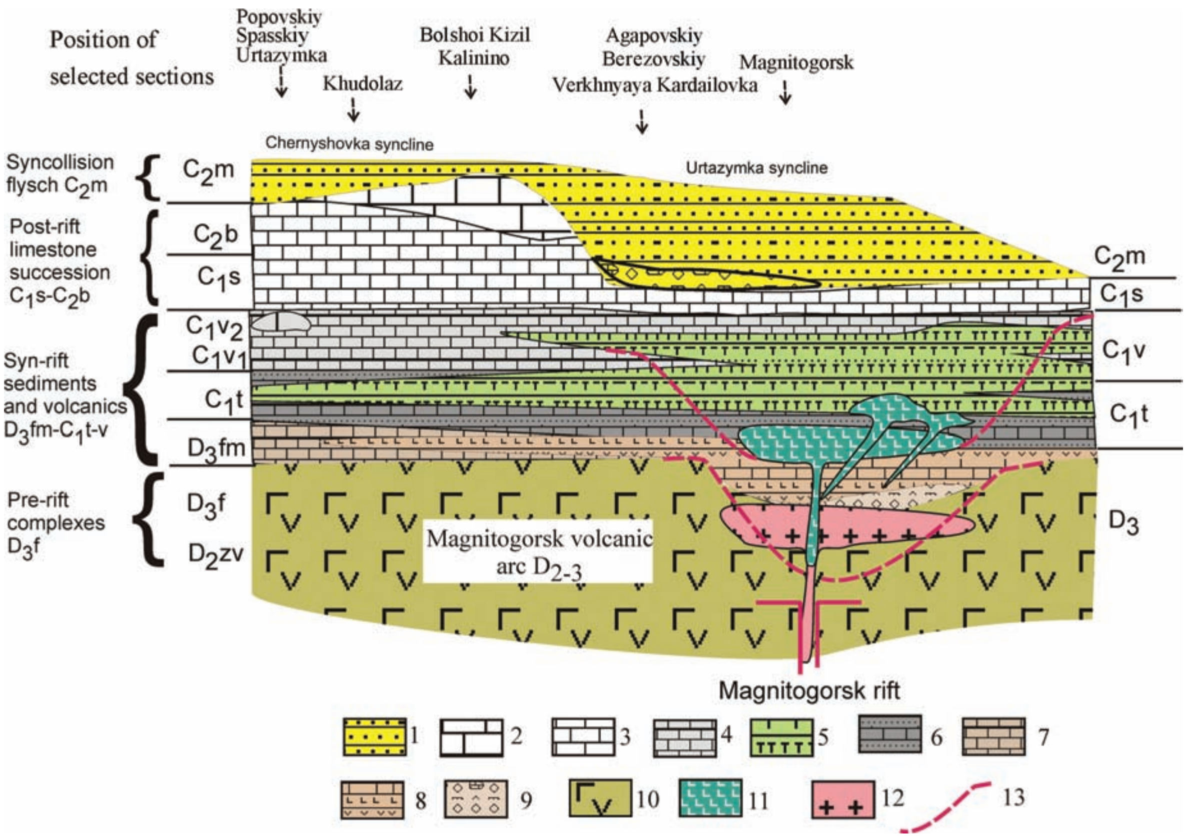


Fig. 7. Proposed model of Magnitogorsk-Bogdanovskoe graben evolution in the Carboniferous (compiled by E.N. Gorozhanina)

Legend: 1 – Urtazym flysch Formation, C_2m: calcareous sandstones, conglomerates; 2–4 – Kizil Formation, C_1v–C_2b_1: 2 – biohermal, and 3 – shelf limestones, 4 – shelf limestones, C_1v; 5 – Berezovskiy and Grekhovka volcanic formations, C_1t–v; 6–9 – Shumilino Formation, D_3fm–C_1t_1: 6 – limestones and polymictic sandstones, C_1t, 7 – limestones, D_3fm, 8 – volcanics, D_3fm, 9 – conglo-breccias; 10 – volcanic arc complexes, D_{2-3}; 11–12 – gabbro-granitic Magnitogorsk intrusive complex, C_1v; 13 – border faults.

Stratigraphy

The current stratigraphic scheme of the Lower Carboniferous that was adopted in 1990 includes two separate subregional stratigraphic schemes for the Western and Eastern Urals. Each of the subregions has own stratigraphic units. Units of the General Stratigraphic Scheme are accepted for the Pennsylvanian both in the Western and Eastern subregions. Two separate Subregional Stratigraphic schemes are used, because of active volcanism in the Tournaisian and Viséan in the Eastern Subregion (Fig. 8).

Tournaisian

Three main types of sections are recognized in the Magnitogorsk Zone:
1. Volcanic and volcanic-sedimentary type;
2. Carbonate type;
3. Siliciclastic type.

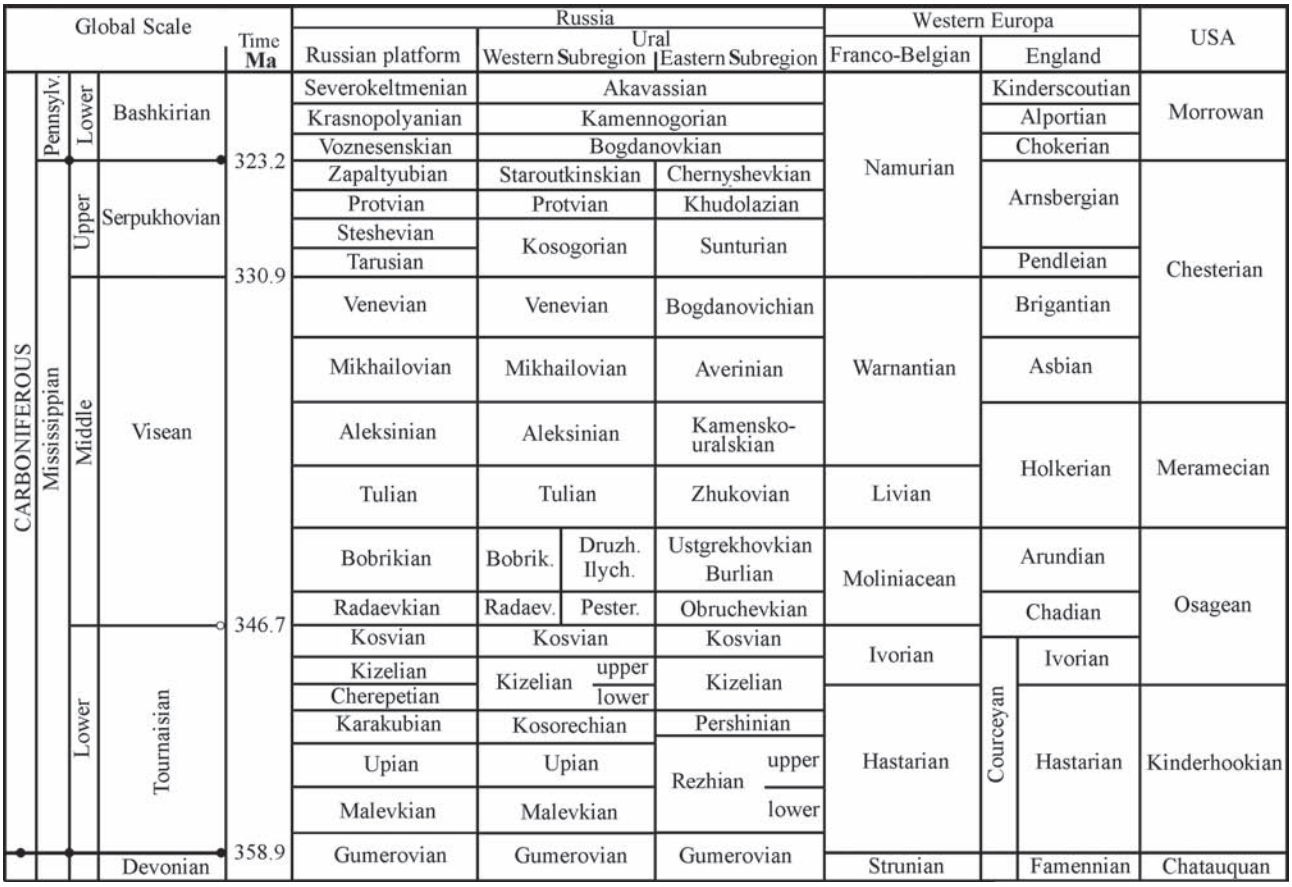


Fig. 8. Regional stratigraphic subdivisions and their correlation with the Belgian, British and North American scales

Volcanic and Volcanic-Sedimentary Type

The Tournaisian volcanic and volcanic-sedimentary rocks of the Shumilino Formation were formed in the central part of the Magnitogorsk-Bogdanovskoe graben of the Magnitogorsk Ore Field (Fig. 9).

Stage	Series	Horizons	Conodonts Zones	Rocks	Thickness, m
Tournaisian	Upper	Kosvian	*Sc. anchoralis*	Tuffs, tuffites, volcanimictic sandstones siltstones, spongolites, limestones	300–500
		Kizelian	*Gn. typicus* *S. isosticha*		
		Pershinian	*S. quadruplicata*		
	Lower	Rezhian Gumerovian	*Siphonodella sulcata*	Tuffs, tuffites layers of limestones	160

Fig. 9. Tournaisian rocks of the Magnitogorsk Ore Field (after Salikhov & Jarkova, 1992; conodonts Zones by Pazukhin)

The Berezovskiy Formation (C_1t_1p–t_2ks) is represented by basalts and their tuffs, tuffites, tuff-sandstones, tuff-siltstones, limestone layers with lower Tournaisian foraminifers and brachiopods. The thickness is 1500–4000 m.

Carbonate type

Tournaisian carbonate sections are represented by the Magnitnaya Mountain Formation (Famennian – Tournaisian), based on foraminifers (Simonova, 1972) and conodonts of the *S. sulcata*, *S. duplicata*, and *S. belkai* Zones.

Upper Tournaisian limestones are exposed in the quarry of the Magnitnaya Mountain. The beds contain foraminifers and brachiopods. The thickness of the Tournaisian stage varies from 100 to 150 m.

Siliciclastic type

Siliciclastic sections are represented by the coal-bearing Ilyasovo Formation (Late Tournaisian). They are composed of carbonaceous sandstones and siltstones with subdominant interbeds of tuffites of basic composition, 100–200 m thick.

Lower Viséan

Sections of two main types are recognized in the Magnitogorsk Zone in the Lower Viséan.

Volcanic and volcanic-sedimentary rocks belong to the Grekhovka Formation (C_1t_2ks–v_2bg).

The Lower Viséan carbonate deposits correspond to the Librovichian Superhorizon and are subdivided into the Obruchevkian, Burlian and Ustgrekhovkian Horizons.

Upper Viséan

At the beginning of the Late Viséan (Tulian) tectonic processes in older faults became more active. This led to the differentiation of carbonate facies into deeper facies deposited in inherited depressions (Verkhnyaya Kardailovka), and shallow facies (Kizilskoye, Khudolaz) deposited on the flanks of these depressions. Shelf carbonates were rested on the basement of the dormant island arc, and carbonate-siliciclastic turbidites accumulated in the inherited depressions.

The Late Viséan and Serpukhovian beds are represented by shelf carbonates of the Kizil Formation.

On the eastern slope of the South Urals, the upper Viséan and Serpukhovian beds are composed of various carbonate shelf facies, dominated by the shallow-water coral-brachiopod limestone (Kizil Formation) (Stepanova & Kucheva, 2009b) and relatively a really restricted cephalopod-deep-water carbonates (Formation not formally named). The exposures of the Kizil Formation are traced in the meridional direction from the latitude of Magnitogorsk southwards to Iriklinskoe Lake (Fig. 1). The Kizil Formation is subdivided into regional substages ("Horizons") of the unified scheme of the East Uralian Subregion, recognized in the coral-brachiopod facies (Stratigraficheskie..., 1993).

The Kizil Formation contains taxonomically diverse and rich (many specimens) assemblages of various groups of fossil organisms (algae, foraminifers, brachiopods, and corals).

The thickness of the shallow-water Viséan facies is up to 1500 m.

Serpukhovian

The shallow-water Serpukhovian deposits are exposed along the Bolshoi Kizil and Khudolaz Rivers are very similar in composition and fossils. The Viséan-Serpukhovian boundary is placed herein between the Bogdanovichian and Sunturian (substages accepted for the East Uralian Subregion). The total thickness of the Serpukhovian in the shallow-water facies is 300–500 m; in the deep-water facies the thickness of the Serpukhovian is about 40 m.

Bashkirian

The Bashkirian Stage is represented by carbonates of the upper part of the Kizil Formation (Syuranian, Akavassian and Askynbashian substages) and lower horizons of the Kordailovka Formation. The Kizil Formation crops out along the Western Kizil Fault. The total thickness of the Bashkirian Stage is around 370 m. The Late Bashkirian-Moscovian Kordailovka Formation is composed of siliciclastics with boulder horizons (Kochetkova et al., 1977). The total thickness is 450 m.

Paleozoic history of the Uralian Paleoocean

By the beginning of the Carboniferous, the subduction in the western margin of the Uralian Paleoocean ended with the Magnitogorsk Arc colliding with and accreting to the margin of Baltica (Puchkov, 2000; Brown et al., 2006). Arc volcanism ceased, and the syntectonic greywacke of the Famennian Zilair Formation filled the successor basins (Gorozhanina, 2000; Gorozhanina & Pazukhin, 2003; Gorozhanina et al., 2004). The accretion (soft collision) of the subduction accretionary complexes was accompanied by a shift of the subduction zone to the east, towards the closing ocean (Puchkov, 2000). The intra arc rift evolved to form the Magnitogorsk-Bogdanovskoe graben with sub-alkaline and bimodal volcanism, accompanied by gabbro-syenite intrusions. The thick arc basement, which was by then accreted to the continent of Baltica, was overlain by a carbonate shelf. Carbonate sedimentation was accompanied by deposition of volcanoclastics. The distribution of sediments of various kinds within the graben depended on the distance from active volcanoes. The margins of the graben, which were distant from the main volcanic sites, were dominated by carbonate sediments. The Magnitogorsk-Bogdanovskoe rift-graben developed in a transgressive sliding and rifting regime. The volcanism was active from the beginning of the Upper Tournaisian to the end of the Viséan, shifting in a northward direction (Salikhov, 1997, 2009; Salikhov et al., 2014). At the beginning of the Late Viséan (Tulian Time) volcanic and tectonic activity increased. By the end of the Viséan, the rift volcanism had slowed down and ceased. This was followed by the development of a carbonate platform (Chuvashov, 2000). By the Middle Carboniferous, subduction in the Uralian Paleoocean ended as a result of the convergence and subsequent collision of two continents (Baltica and Kazakhstania) (Puchkov, 2000). Syncollisional flysch deposits by the end of the Middle Carboniferous (Urtazym Formation) filled the superimposed depressions. In the convergence zone, shelf, reef, volcanic, magmatic, and microcontinental blocks were closely approximated.

OBJECTS OF EXCURSION

Day 1 August 16
Stop 1. Sibai Quarry

Location and brief information

Sibai Mine is the deepest open-dip mine in Russia and one of the largest pits in the world. The copper-zinc quarry is almost 2-kilometer (1.2 mi) wide and 500-meter (1.600 ft) deep (Fig. 10). The Sibai copper-sulphur deposit is located in the central region of the western wing of the Magnitogorsk Megasynclinorium. It is composed of three parts (from north to south): Staro-Sibai (discovered in 1913 based on the surface occurrence of ironstone), Novo-Sibai (discovered 1939) and Slepaya Deposit (discovered 1952). The deposit is tectonically located on the eastern wing of the volcanic horst anticlinal, composed of the Eifelian rhyolite-basaltic Formation of the Karamalytash Formation. It is delineated by steep faults, along which the ore-containing rocks border the overlying Middle – Upper Devonian volcanic-sedimentary Ulutau Formation. This locality is a typical example of the Uralian type of copper-sulphur deposit. Main ore minerals include: pyrite (65–90% of ore), chalcopyrite and sphalerite. The

Fig. 10. Sibai Copper Mine

http://virtualrb.ru/en/component/k2/item/71 deposit is a combined open pit and underground mining operation of the Sibai branch of the Uchaly mining-enrichment plant. The production in the Staro-Sibai field was also open pit, though now filled with the spoil from the Novo-Sibai field. The depth of the pit in 1995 was 444 m (expected depth 469 m). Exploration of this field revealed the new Nizhnyaya Field, which is currently mined at 600 m. A total output exceeding 100 million tons of ore was reached in 1973 (after Seravkin, 2009).

Stop 2. Left bank of the Khudolaz River. Bashkirian buildups near Sibai

Location and brief information

Several mound-shaped Bashkirian bioherms are exposed in a structurally complex fault sheet along the Khudolaz River southeast of Sibai and nearby village of Kalinino (Fig. 11). The mounds lie within the Syuranian regional substage and extend southward along the east bank of the Khudolaz River from the large quarry in upper Viséan to upper Serpukhovian limestone at Kalinino to the village of Novo-Pokrovka.

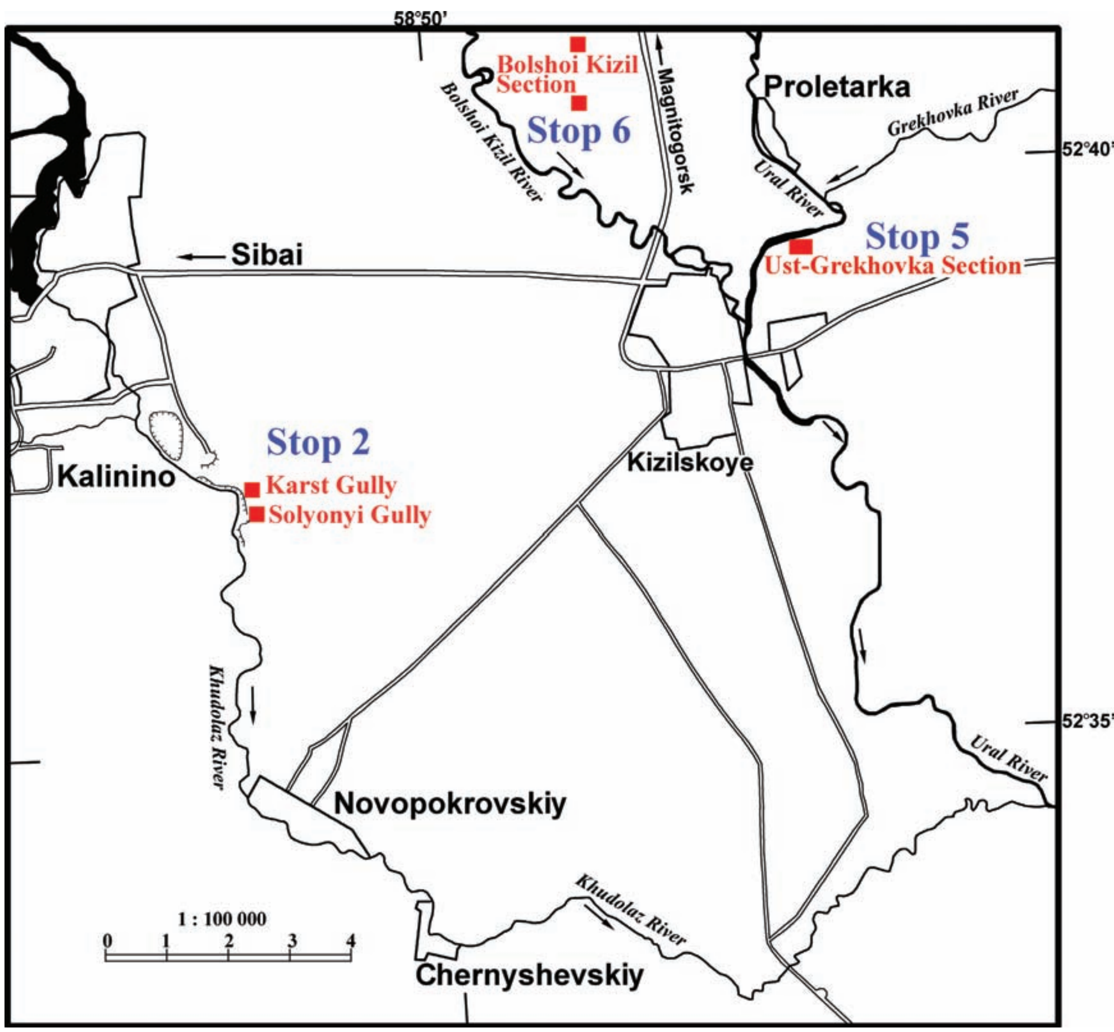


Fig. 11. Map showing the localities on the Khudolaz River

Historical Overview

A stretch of organic mounds was studied by Simonova in 1978. She described six cross-sections from the village of Novopokrovka to the village of Kalinino and studied a section of Borehole 9 near the limestone quarry. Simonova's foraminiferal assemblages date the host rocks as Syuranian (Lower Bashkirian). The region has a complex block structure. According to the data obtained by the Kalinino geological exploration expedition in 1953, the base of the Syuranian Regional Substage is cut off by a tectonic fault. A block of biohermal limestone lies within the Moscovian flysch (Fig. 12).

Characteristics of the section and fossils

Because of structural complications and characteristics of the present-day erosion surfaces, the bioherms are not exposed as three-dimensional convex-up buildups. Instead, only the core facies of most bioherms are well exposed across the undulatory two-dimensional low-relief

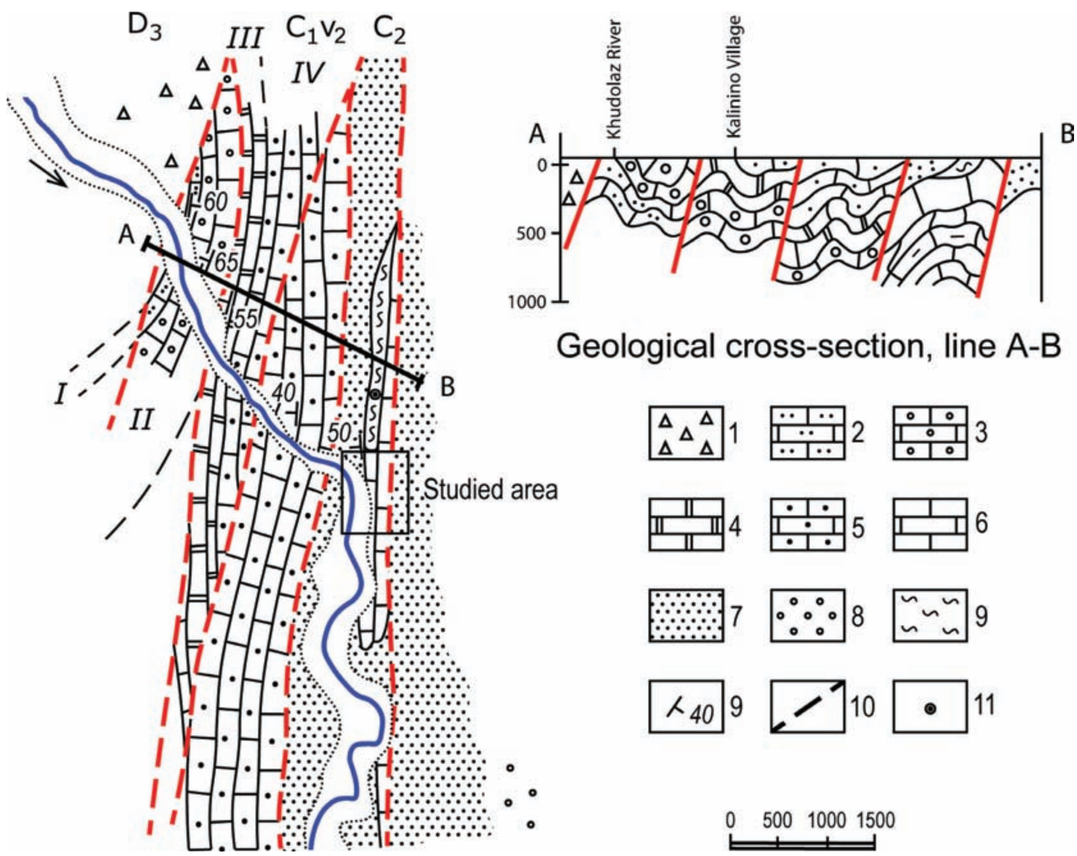


Fig. 12. Geological map of the lower reaches of the Khudolaz River (after Ivanova et al., 1972)

1 – Upper Devonian tuffs and tuff-breccia (Koltuban Formation); 2 – alternation of sandstone and limestone beds, Tulian (Zhukovian); 3 – crinoidal-bioclastic limestone, Kamenskouralskian (Aleksinian); 4 – dolomitic bioclastic limestone, Averinian (Mikhailovian); 5 – bioclastic grainstone, dolomitic, Bogdanovichian (Venevian); 6 – biohermal limestone (microbial limestone, boundstone), Bashkirian, Syuranian; 7 – polymictic calcareous sandstone with interbeds of shale and limestone, Lower Pennsylvanian; 8 – lime conglomerates, Moscovian; 9 – mudstone, cherty shale with ammonoids, with interbeds of polymictic sandstone and limestone, Upper Bashkirian; 9 – attitudes; 10 – faults; 11 – borehole 9. I–IV – lithological members.

erosion surfaces characteristic of the region but some gulley exposures show flanking facies and contacts with the foundation and capping deposits. The mounds are recognizable as bioherms by their very thick bedded thrombolytic internal fabric and by presence of syndepositional submarine cements.

Immediately south of the Kalinino quarry, the biohermal lithofacies are well displayed along the steep north side of the Karst Gully and Solyonyi Gully at its confluence with the Khudolaz River (Fig. 13).

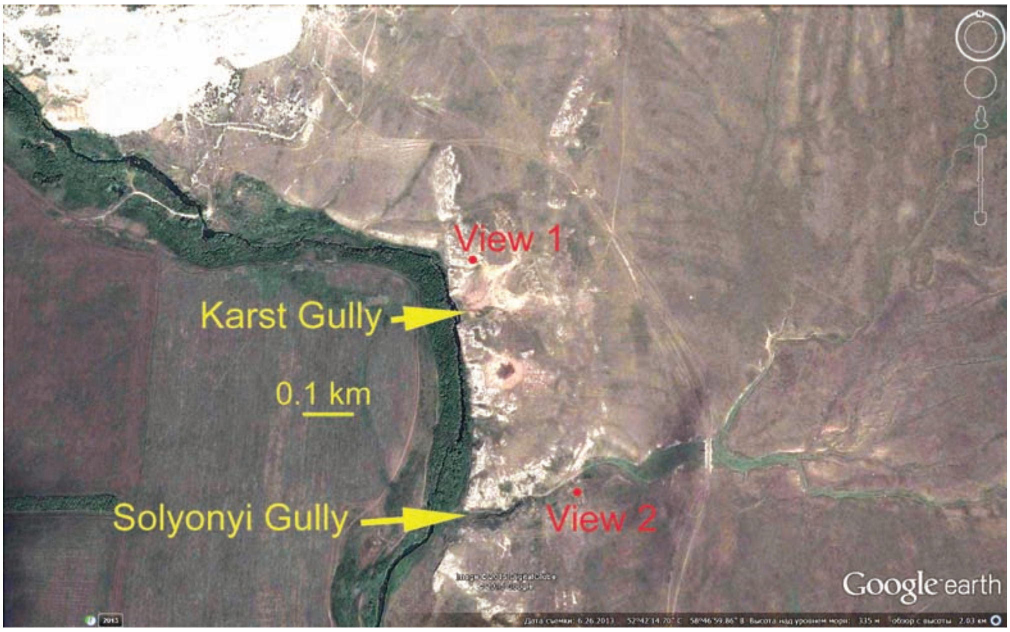


Fig. 13. Location of the Karst Gully and Solyonyi Gully

Along the Karst Gully the thrombolytic deposits locally display brachiopods, tabulate corals, and cephalopods. More than 10 brachiopod species occur but the genus *Phricodothyris* prevails with up to 50 shells collected at some localities (Fig. 14). Beds and lenses of lime grainstone are locally present in the bioherms and commonly contain the encrusting foraminifer

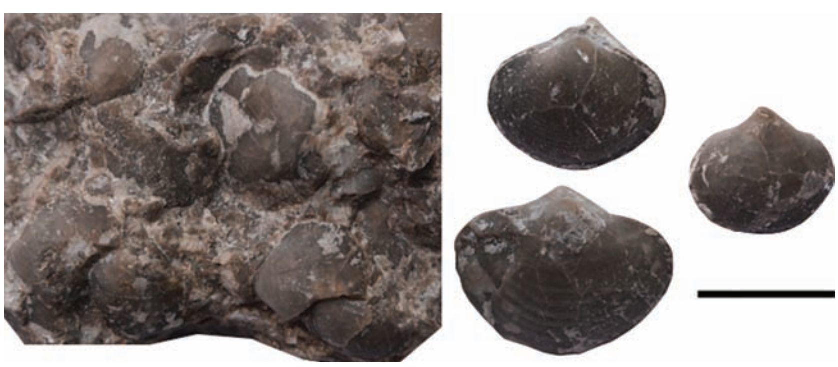


Fig. 14. Brachiopods *Phricodothyris subareata* Pol.

Karst Gully, Sample 7 (collection of Kucheva). Scale bar 1 cm.

Tolypammina sp., *Palaeonubecularia* sp. (Fig. 15), the eostaffellid genera *Eostaffella*, *Plectostaffella* (Fig. 16) and *Semistaffella*, and archaediscids. The foraminifers date the buildups to the Syuranian regional substage of the Bashkirian Stage. Bioherms resembling those along the Khudolaz occur to the northeast along the Bolshoi Kizil River but are of Akavassian (Bashkirian) age. Early Bashkirian reefs on the eastern slope of the South Urals record widespread reef development before the Uralian orogeny.

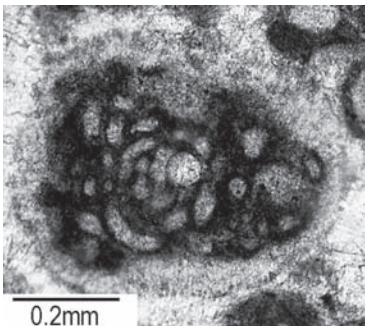


Fig. 15. ***Palaeonubecularia* sp.**
Karst Gully, Sample 7

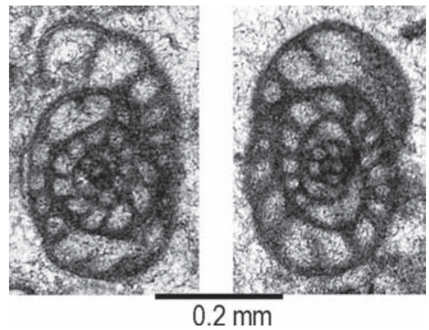


Fig. 16. ***Plectostaffella bogdanovkensis* Reitlinger.**
Karst Gully, Sample 7

(Fig. 15, 16 – collection of foraminifers by Stepanova).

A large mound is exposed along the Solyonyi Gully, which runs perpendicular to the depositional strike (Kulagina et al., 2015) (Fig. 17).

Fig. 17. A bioherm at the Solyonyi Gully (photograph by Kulagina)

Day 2 August 17
Stop 3. Verkhnyaya Kardailovka Section: a candidate for the base of the Serpukhovian GSSP

Location and geological summary

An almost uninterrupted succession of Lower Carboniferous beds from the Lower Viséan to the Moscovian inclusive crops out on the right bank of the Ural River opposite the village of Verkhnyaya Kardailovka from E.N.E. to W.S.W (Fig. 18). The base of the section is composed by Upper Tournaisian – Lower Viséan volcanic-siliciclastics. The overlying Viséan carbonate series continues as cliffs along the right bank of the Ural River above the floodplain with oxbow lakes.

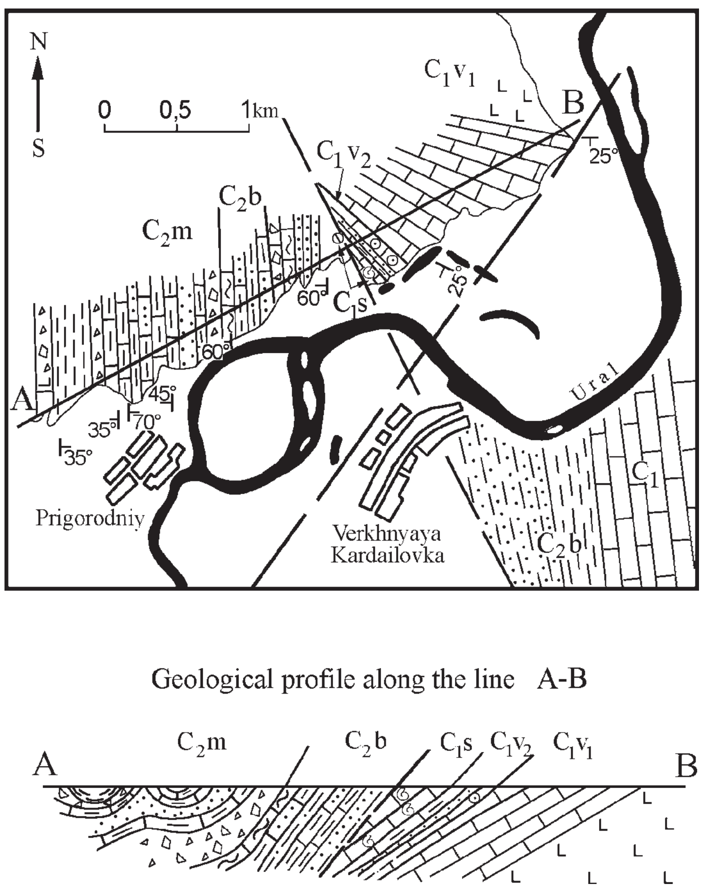


Fig. 18. Schematic geological map of the Verkhnyaya Kardailovka village region (from Pazukhin & Gorozhanina, 2002)

The succession, over 300 m thick, is composed of shallow-water Lower Viséan limestone with colonial corals and brachiopods, which in the upper part gradually become Upper Viséan crinoidal limestone. These are overlain by a previously covered interval followed by Upper Viséan – Serpukhovian carbonates 45 m thick. The Serpukhovian limestone forms a rock cliff over the western oxbow lake and contain numerous ammonoid shells (cephalopod facies). The outcrop of cephalopod limestone terminates with a tectonic dislocation striking northwest to southeast, to the west of which Bashkirian siliciclastic-carbonates, 250–300 m thick crop out. These are overlain by the Moscovian flysch (Kordailovka Formation) over 300 m thick.

Thus, the Upper Viséan – Serpukhovian beds constitute a small portion of the entire Carboniferous siliciclastic-carbonate succession (Fig. 19).

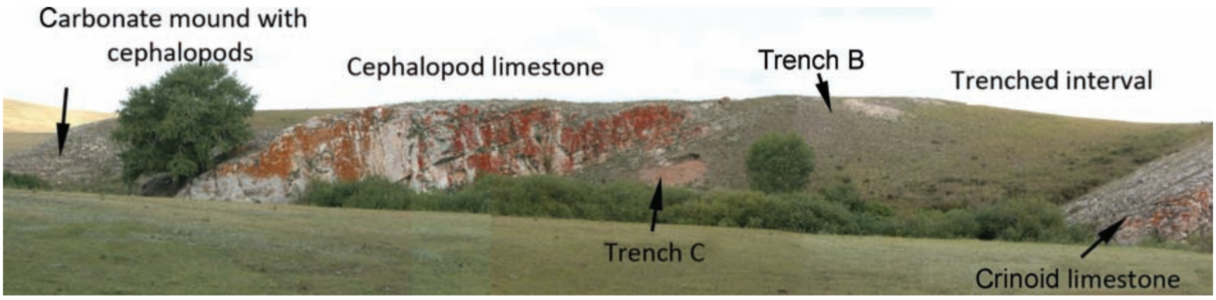


Fig. 19. A view of the Verkhnyaya Kardailovka section

Historical Overview

The first studies of the Verkhnyaya Kardailovka section (1936–1964)

Librovitch (1936) was the first to conduct in 1925–1939 1:200000 scale geological mapping of on the eastern slope of the South Urals of the sheets between 52° and 53° N and 58°30' and 59°15' E. Librovitch recognized several formations, including the Gusikha Formation, to which he assigned the carbonate series cropping out on both banks of the Nizhnyaya Gusikha River and along the Ural River to the east and opposite the village of Verkhnyaya Kardailovka (currently Verkhnekardailovka). The main part of the Gusikha Formation is composed of dark bituminous limestones, often with cherty concretions, containing in some beds numerous colonial corals *Syringopora* and solitary rugoses, and less commonly brachiopods *Productus ovatus* Hall. However the uppermost horizons of this Formation, according to Librovitch, have a "very distinct nature. These beds are represented by light grey, mainly fine-grained limestone, containing numerous goniatites and rare remains of other fauna". Of ammonoids, Librovitch identified numerous specimens of *Proshumardites*. In addition, cephalopod limestones contained trilobites, brachiopods, bivalves, gastropods and very small rugoses. Thin sections from these limestones contain rare foraminifers *Endothyra* sp. The thickness of this predominantly cephalopod facies was estimated as 40–50 m.

Early studies (1971–1992)

Ruzhencev & Bogoslovskaya (1971) published a bed by bed description of the Serpukhovian limestone, and gave it the name "Ural River, opposite the village of Verkhnyaya Kardailovka". They subdivided the deposits based on ammonoids into Genozones and levels in four lithological beds, and collected four samples of ammonoids. In each samples the identified from 9 to 20 species of ammonoids, and the number of individuals varies from 1 to 288, including new species.

In the 1970s the section was studied by researches from the Institute of Geology of Ufa Scientific Centre of the Russian Academy of Sciences who described the section "Prigorodnyi" from the volcanics of the Berezovskiy Formation (Lutfullin & Arkhipova, 1974; Kochetkova et al., 1977).

The thickness of the volcanic-sedimentary series represented by diabase, aglomeratic tuffs of diabase is over 350 m. The overlying Viséan carbonates extend for 2 km along the Ural River. These are followed by a covered interval up to 12 m thick, overlain by cephalopod limestone of 40 m thick (Serpukhovian). Some previous authors erroneously thought that the cephalopod limestone overlying the older rocks with a stratigraphic gap, with the large Viséan portion missing from the succession and that the covered interval includes a thin carbonate-siliciclastic series.

Malakhova (1971, 1973, 1975) emended the geochronology of the Viséan part of the section based on foraminifers. She subdivided the limestone series between the basal volcanics and cephalopod limestone into five members with five foraminiferal assemblages. The unexposed interval between the crinoidal and cephalopod limestone remained unstudied.

In 1976–1990 Pazukhin, Kulagina, and Kochetova studied Paleozoic biostratigraphy in this region. At that time two conodont experts, Starostina (Moscow University) and Pazukhin (Institute of Geology, Ufa) independently recovered conodont data from the Carboniferous rocks of Russia, although the results were published much later. Foraminifers from the Upper Serpukhovian *Delepinoceras bressoni* Zone (identifications by Bogoslovskaya) were described (Kulagina, 1985). Results of biostratigraphic and paleontological studies, of mainly the upper Serpukhovian interval were published (Kulagina et al., 1992) (Fig. 20).

GSSP Studies (2000–2009)

In 2000 a team from the mapping expedition of "Aerogeologiya" probed the covered interval between the crinoid and cephalopod limestone with a series of trial pits 200 m north of the main section. However 6 m of the section remained unexposed. In 2001 Pazukhin examined the Serpukhovian – Upper Viséan beds immediately below the cliff outcrop in a series of trial trenches, which he named Trenches 1 to 4. He was the first to find the Upper Viséan ammonoids and conodonts in Trench 2. Also, Bashkirian ammonoids ?*Cancelloceras* sp. were found 1 km north of the main section in a new quarry of mudstone-cherty succession. The study of the pits and trenches allowed a new lithological description of the Upper Viséan portion of the section, and volcanic ash was found in the covered interval.

Nikolaeva and Konovalova (Paleontological Institute, Moscow) studied the new ammonoid occurrences. The Viséan-Serpukhovian boundary was fixed by conodonts in Trench 4 immediately below the cliff, while the ammonoid- and conodont-based zonal subdivision was refined in a series of papers (Pazukhin & Gorozhanina, 2002; Pazukhin et al., 2002; Nikolaeva et al., 2002). These studies showed that the base of the Serpukhovian in the Urals can be clearly recognized based on the first appearance of the conodont *Lochriea ziegleri* approximately at the same level with the first appearance of *L. cruciformis*.

In 2002, an International Group was established within the SCCS to determine a new, universally recognizable level and establish the GSSP of the base of the Serpukhovian (Richards, 2003). In 2002–2009 paleontological and microfacies characterization of the section was amended, and the foraminiferal, ammonoid, conodont and ostracode Zones were recognized and correlated with zonations of Western Europe and North America (Kulagina & Gibshman, 2005; Nikolaeva et al., 2005, 2009; Pazukhin et al., 2009, 2010).

In 2009, the Verkhnyaya Kardailovka Section was shown to the participants of the SCCS geological field excursion in the Moscow Basin and in the Urals (11 August 2009). The section was resampled and some levels received additional study. However it was noted that only 1.5 m of the

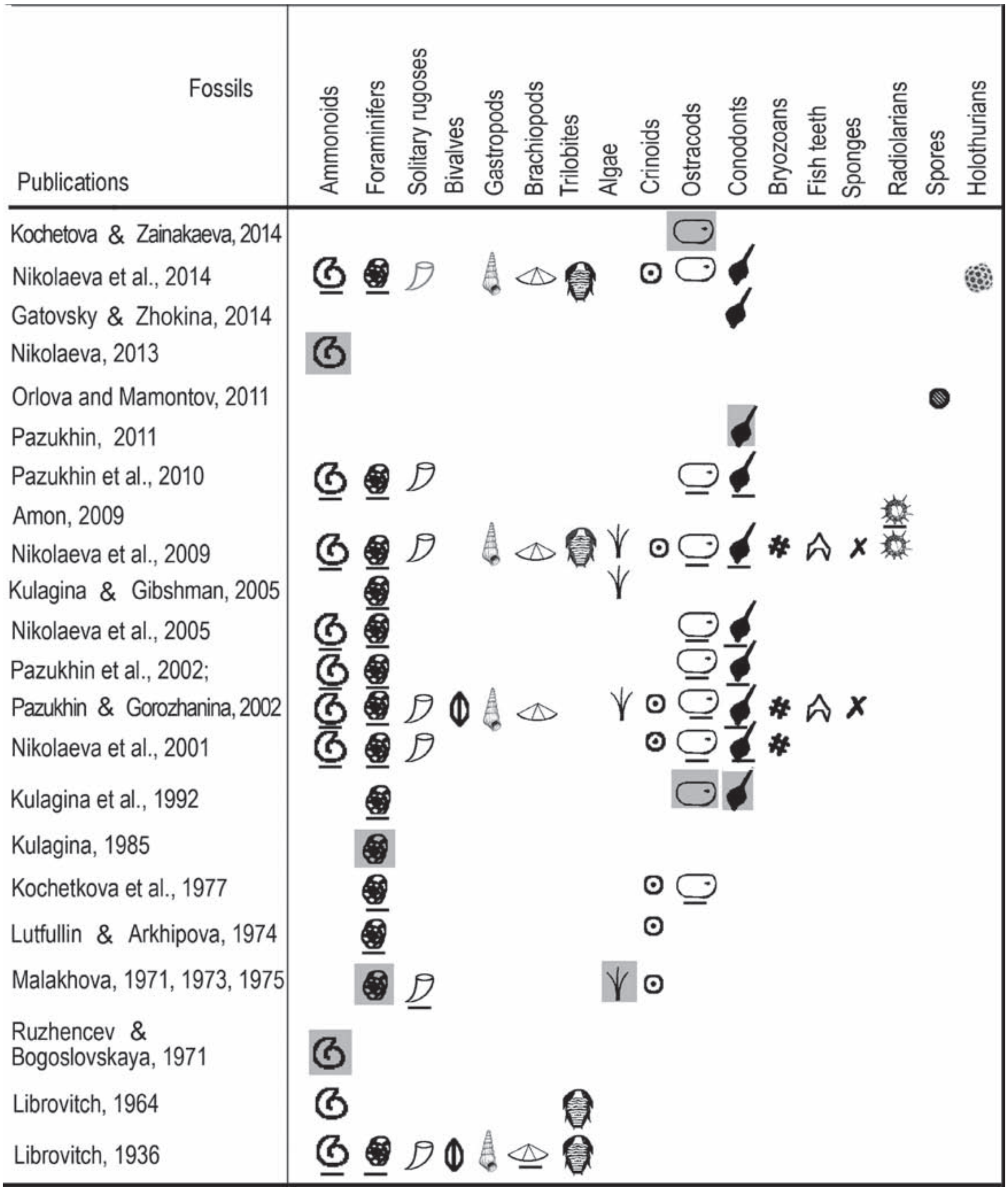


Fig. 20. The history of the paleontological and biostratigraphic studies of the Verkhnyaya Kardailovka section

The icons show fossil groups; shaded icons indicate papers with formal paleontological descriptions; underlined icons indicate papers with lists of fossils.

rock succession was exposed below the boundary (Fig. 21), which did not allow adequate placement of the entire succession in the local and regional geological context, which is expected from a GSSP section. Therefore it has become apparent that it was necessary to expose the previously covered interval in the upper part of the slope to connect two parts of the section. The International excursion of 2009 gave a new start to the examination of this well-known section.

Fig. 21. Trench C (formerly Trench 4) where Pazukhin first found *L. ziegleri*

Characteristics of the section and fossils

In 2010–2014, Institute of Geology (Ufa) organized and conducted expeditions attended by the Russian and International working groups for the base of the Serpukhovian GSSP search (participating organizations – Institute of Geology (Ufa), Moscow Paleontological Institute, and Institute of Geology and Geochemistry (Yekaterinburg), SCCS Chairman B. Richards and Chairman of the Carboniferous Commission of the Russian Interdepartmental Stratigraphic Committee Alekseev (Kulagina et al., 2010; Nikolaeva et al., 2011). A trench 30 m long was exposed using front-end loaders and tractors with hydraulic backhoes (this corresponded to 12 m of the thickness) (Fig. 22). The area of upper slope in places of Trenches 1 to 3 was open and renamed A–B. Trench 4 is renamed Trench C. All trenches are connected between each other and with the cliff exposure.

The results of the study of the previously covered interval between the crinoid and cephalopod limestones were sensational.

1. It was confirmed that the section has no stratigraphic hiatus, or tectonic fault near the proposed Viséan-Serpukhovian boundary.

2. The lithological succession of the Upper Viséan in the interval 12 m of thickness below the Serpukhovian base is open. The trench exposed fine-grained terrigenous clastics and volcanic ashes (Formation B) overlying the Zhukovian (middle Viséan) regional Substage (unnamed Formation A) (Figs. 22–25).

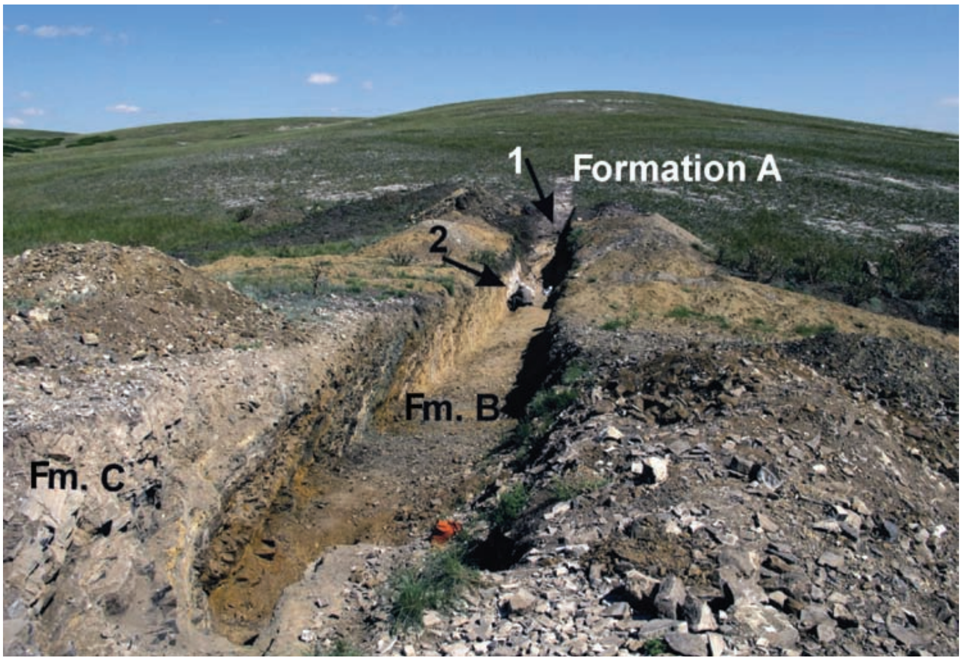


Fig. 22. General view of trench A looking toward the northeast

Most of the trench exposes Formation B comprising middle Viséan terrigenous clastics and volcanics. Arrow 1 indicates the position of pin 1 near the top of the underlying middle Viséan crinoidal limestone unit of Formation A (Figs. 22–25, photographs by Richards).

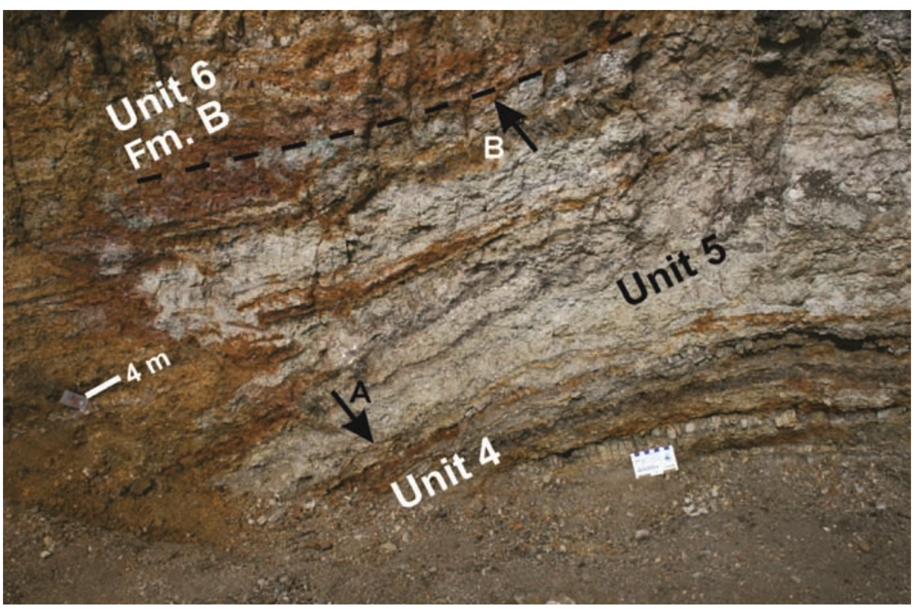


Fig. 23. Units 4 and 5 of the Verkhnyaya Kardailovka section

Thin- to medium-bedded, volcanic ash of unit 5 (3.11–4.7 m, arrow A indicates base, arrow B – top in Formation B and upper part of unit 4 (2.73–3.11 m) showing grey to brown, highly jointed and blocky, tuffaceous cherty siltstone beds intercalated with volcanic ash and tuffaceous mudstone. Quaternary weathering bleached unit 5 to a very light grey and on the right-hand side, it shows disruption by Holocene roots and burrows. Volcanic ash of unit 5 passes upward into fine-grained, moderate-brown weathering siltstone and mudstone. The 4 m label indicates dark mudstone containing a fragment of a calamite trunk; the palynomorph *Lycospora pusilla* (Ibrahim) was identified from the 3.21 m level (Orlova & Mamontov, 2011). Scale card is 8.5 cm across; blue divisions are 1 cm long.

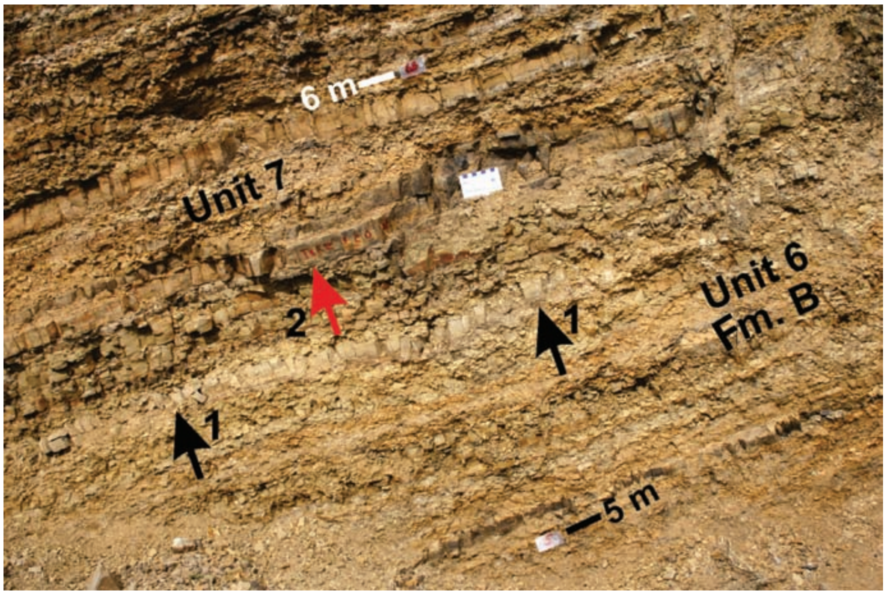


Fig. 24. Tuffaceous siliciclastic mudstone and sandy siltstone of upper unit 5 (4.7–5.46 m) and lower part unit 7 (5.46–9.98 m) in Formation B

Arrows indicate: 1 base unit 7, 2 level with remains of the calamite *Archaeocalamites radiatus* (Brongniart, 1828) (Orlova & Mamontov, 2011). Unit 7 contains numerous sharp-based beds and laminae that display subtle to distinct normal grading and appear to be thin turbidites (A–DE and B–DE Bouma sequences). The lithofacies indicate deposition well below storm wave base in a basin to distal toe-of-slope setting. Scale card is 8.5 cm across; blue divisions are 1 cm long.

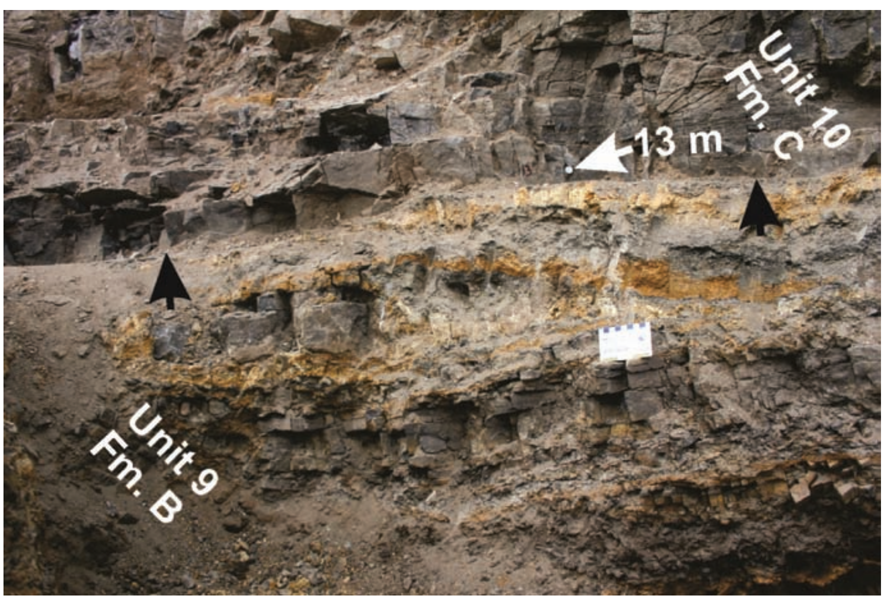


Fig. 25. Contact (arrows) between units 8 (11.87–12.98 m) and 9 (12.98–16.00 m) in trench A at junction with trench B

Upper unit 9, the lowermost unit in Formation C, shows a disrupted turbidite-like bed of pelmatozoan lime packstone sandwiched between two thin beds of light-brown volcanic ash; a band of thin-bedded chert underlies the lower ash. The lower deposits of unit 10 comprise planar-laminated, lime mudstone of hemipelagic aspect in lower Formation C. Unit 10 records the abrupt termination of the long episode of siliciclastic sedimentation that commenced with the deposition of unit 2; succession above is limestone dominant. Scale card is 8.5 cm across; blue divisions are 1 cm long.

3. New fossil groups previously unknown from this locality have been reported (spores, plant remains, holothurians, phyllocarids) and new data have been obtained on foraminifers, conodonts, ammonoids, and corals (Fig. 26).

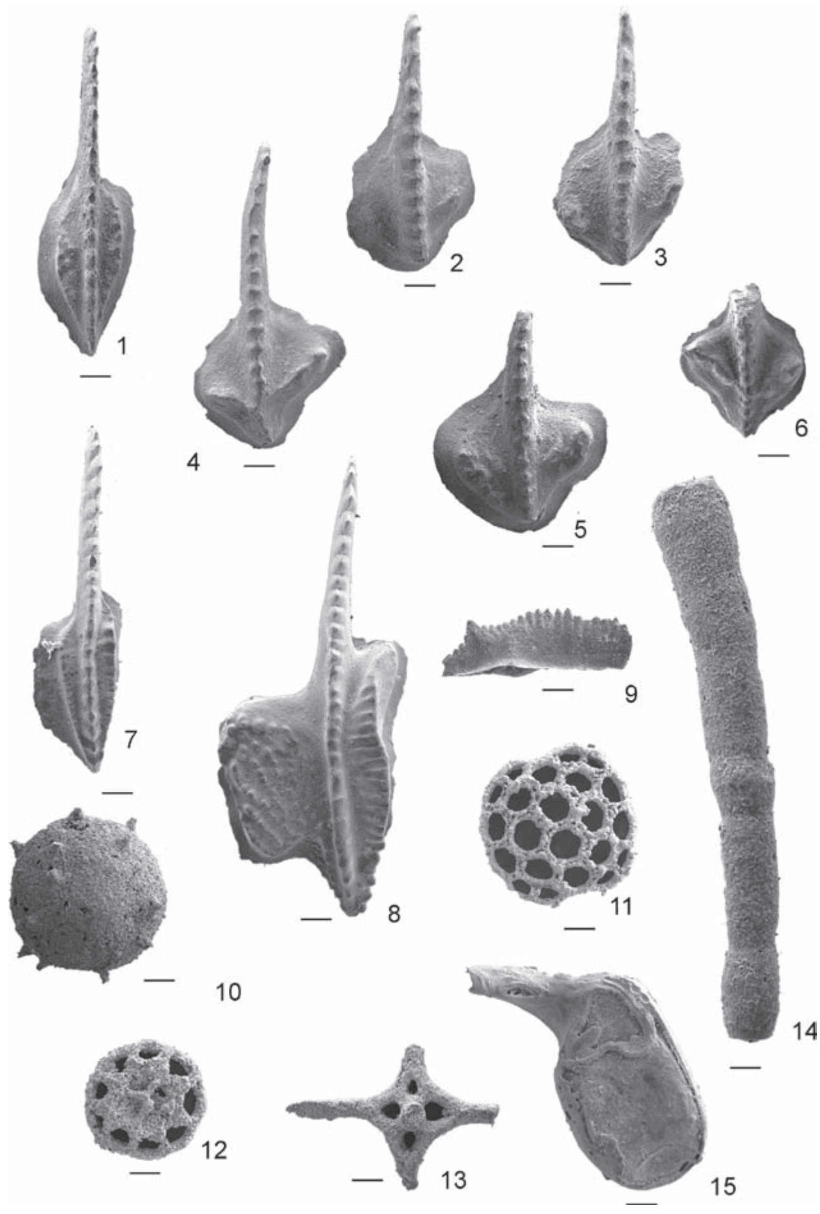


Fig. 26. Conodonts and other microfossils from the Viséan-Serpukhovian boundary beds in the Verkhnyaya Kardailovka section (from Nikolaeva et al., 2014a)

The specimen on photograph 6 is from Trench C, other specimens are from Trench B. In all cases magnification is ×60: 1 – *Pseudognathodus homopunctatus* (Ziegler), Trench B, Sample VK3/19.00–19.12; 2 – *Lochriea mononodosa* (Rh., Aust. et Dr.), Trench B, Sample VK3/19.00–19.12; 3 – *Lochriea nodosa* (Bischoff), Trench B, Sample VK3/19.12–19.20; 4 – *Lochriea cruciformis* (Clarke), Trench B, Sample VK3/19.72–19.83; 5 – *Lochriea ziegleri* Nem., Per. et Meisch., Trench B, Sample VK3/19.63–19.72; 6 – *Lochriea ziegleri* Nem., Per. et Meisch. Specimen 036, primitive morphotype with a few small-sized and low nodes. Trench C, Sample 012/1; 7 – *Gnathodus girtyi* Hass s.l., Trench B, Sample VK3/19.20–19.28; 8 – *Gnathodus bilineatus bilineatus* (Roundy), Trench B, Sample VK3/19.63–19.72; 9 – *Vogelgnathus postcampbelli* (Austin & Husri), Trench B, Sample VK3/19.63–19.72; 10 – *Thurammina papillata* Brady, Trench B, Sample VK3/19.12–19.20; 11–13 – Holothurian sclerites, Trench B, Sample VK3/19.72–19.83; 14 – Agglutinated foraminiferan, Trench B, Sample VK3/19.10–19.20; 15 – Phyllocarid mandible, Trench B, Sample VK3/19.63–19.

4. The section contains several thin beds and laminae of volcanic ash a few metres below the boundary interval that have provided material for radiometric dating (Schmitz & Davydov, 2012).

Trench B, which is now transformed into an exposure on the slope, is treated as the main outcrop to fix the Viséan-Serpukhovian boundary (Nikolaeva et al., 2014a, b) (Figs. 27, 28, 29).

Fig. 27. Horizontal trench connecting Trenches A and B
Ammonoids of the *Goniatites altus* Zone are found 36 cm below pin 17 on the right of the photograph.

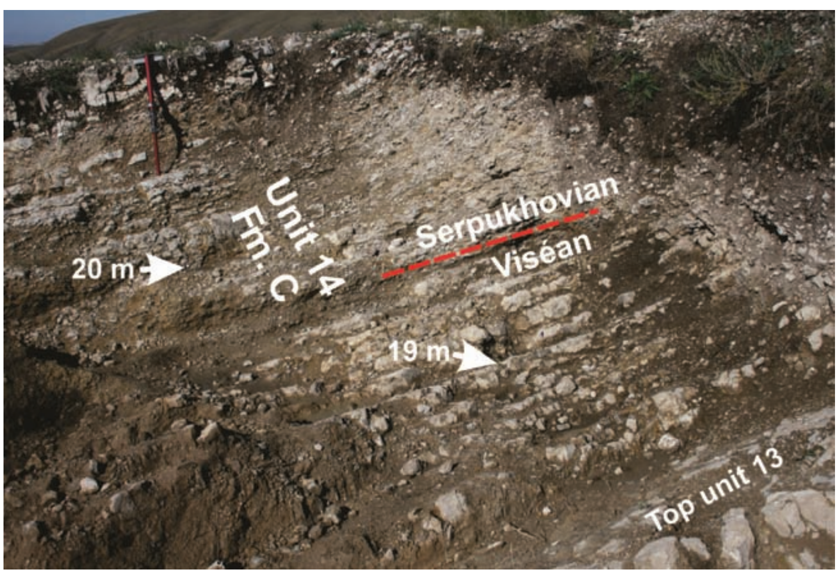


Fig. 28. The Viséan-Serpukhovian boundary level in unit 13 (18.50–21.76 m)
Arrows point to pins at 19.0 and 20.0 m. Interval comprises stylonodular skeletal lime mudstone and wackestone that is of deep-water (basin) origin and contains several ammonoid horizons. Sample 015 (from 18.50 m level, at top unit 13) has important corals, ammonoids, and conodonts. The Viséan-Serpukhovian boundary has not been precisely located in this trench but preliminary conodont data indicate the boundary, defined by the first occurrence of *Lochriea ziegleri*, lies at approximately 19.7 m. View is toward southwest in trench B; Jacob's staff near top is 1 m long.

The section was marked by pins 1–40 in traverse 1 (Figs. 30) and 1–16 in traverse 2. The samples collected before (Nikolaeva et al., 2001, 2002, 2005) are now correlated with the level marked by pins (Fig. 31, 32).

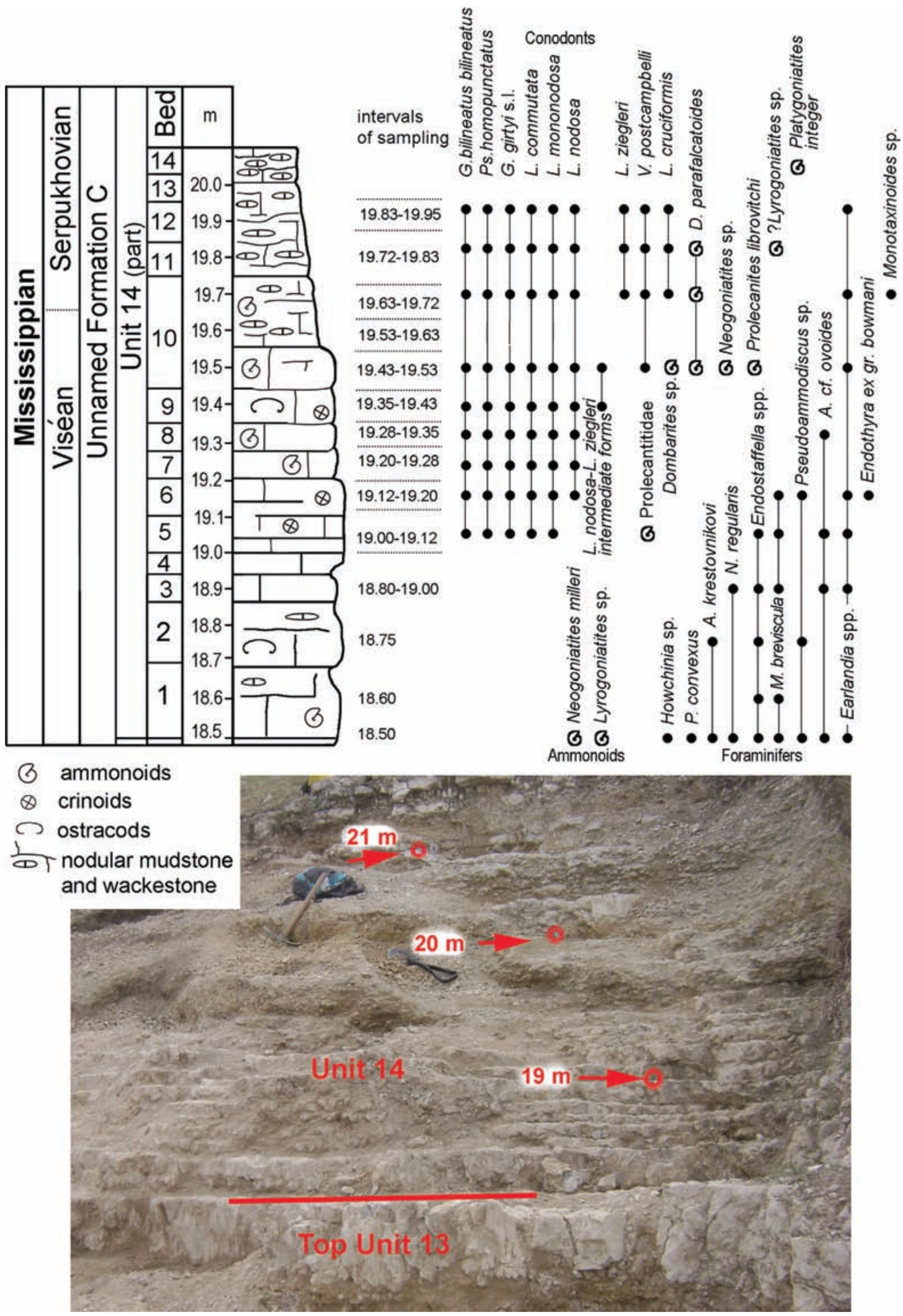


Fig. 29. Fossil records in the interval 19.00–19.95 m in Trench B in the Verkhnyaya Kardailovka Section

The photograph shows the boundary interval excavated in 2011–2012 and levels marked by the aluminium pins (19 m, 20 m, and 21 m) (from Nikolaeva et al., 2014a, 2014b).

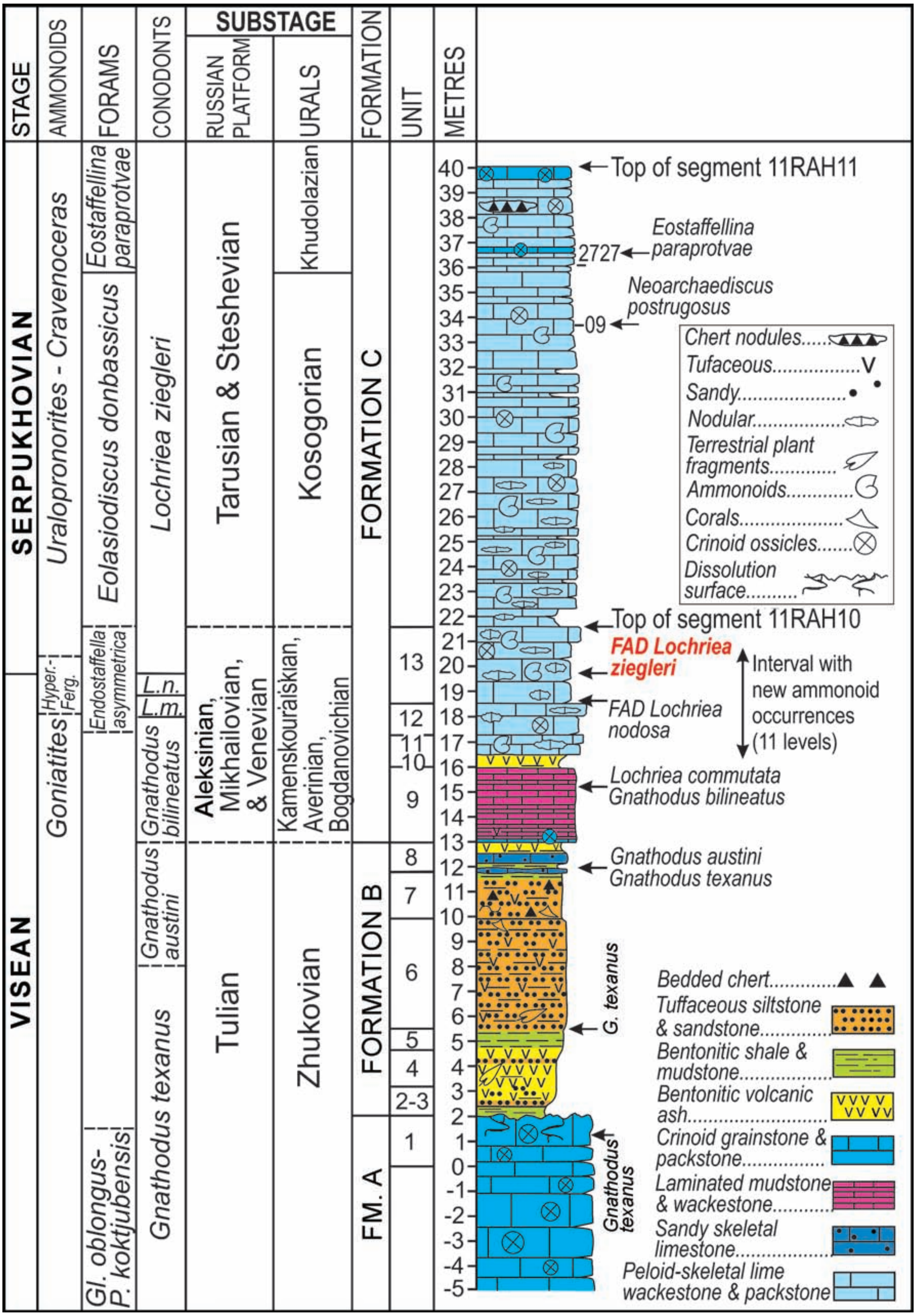


Fig. 30. A summary section of the Upper Viséan-Serpukhovian beds in the Verkhnyaya Kardailovka Section compiled based on natural outcrops and trenches

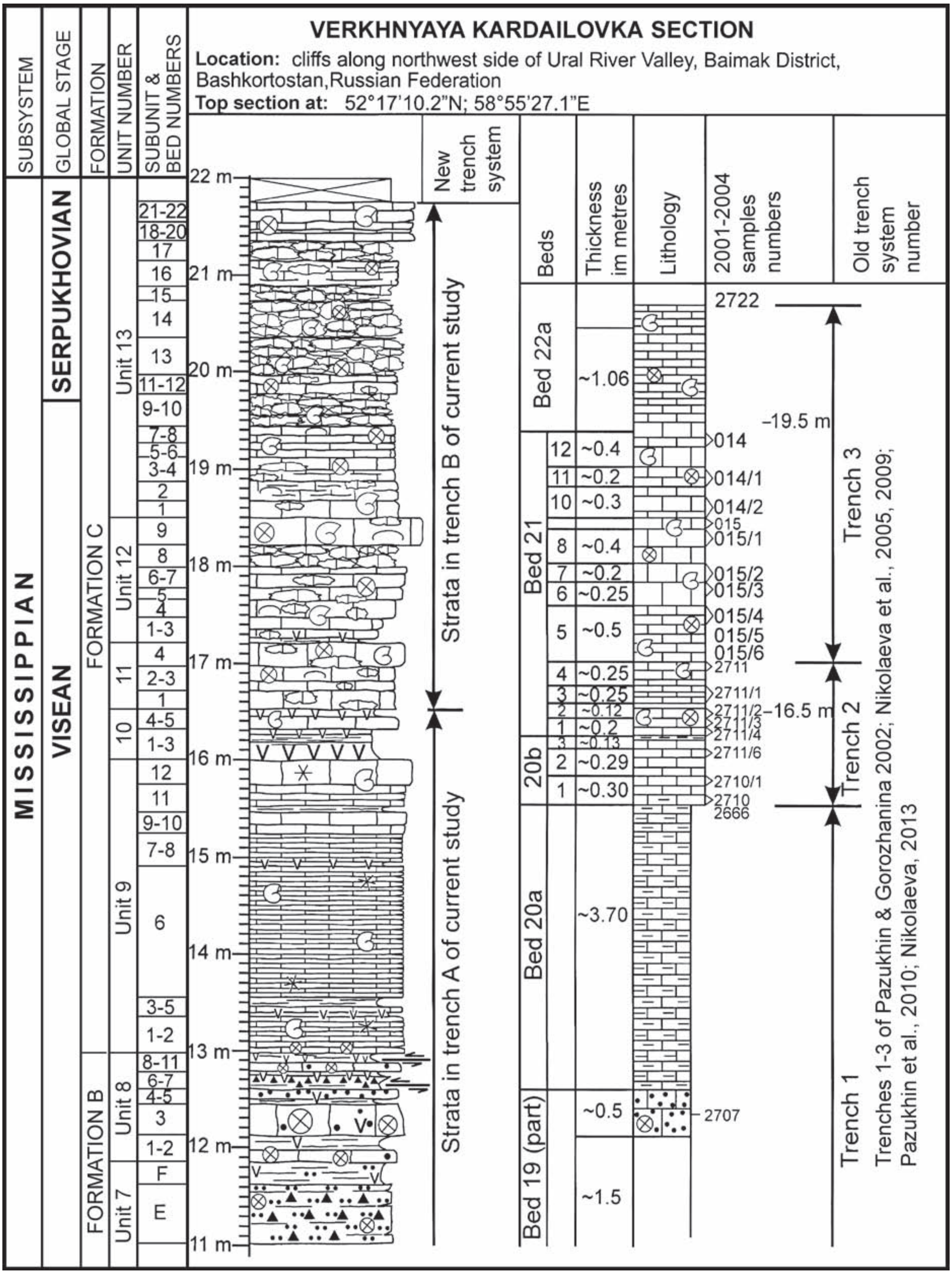


Fig. 31. Detailed stratigraphic log showing lithology, units, summarized unit descriptions, and beds in segment 11RAH10 of the Middle Viséan to Lower Serpukhovian succession in the Verkhnyaya Kardailovka Section

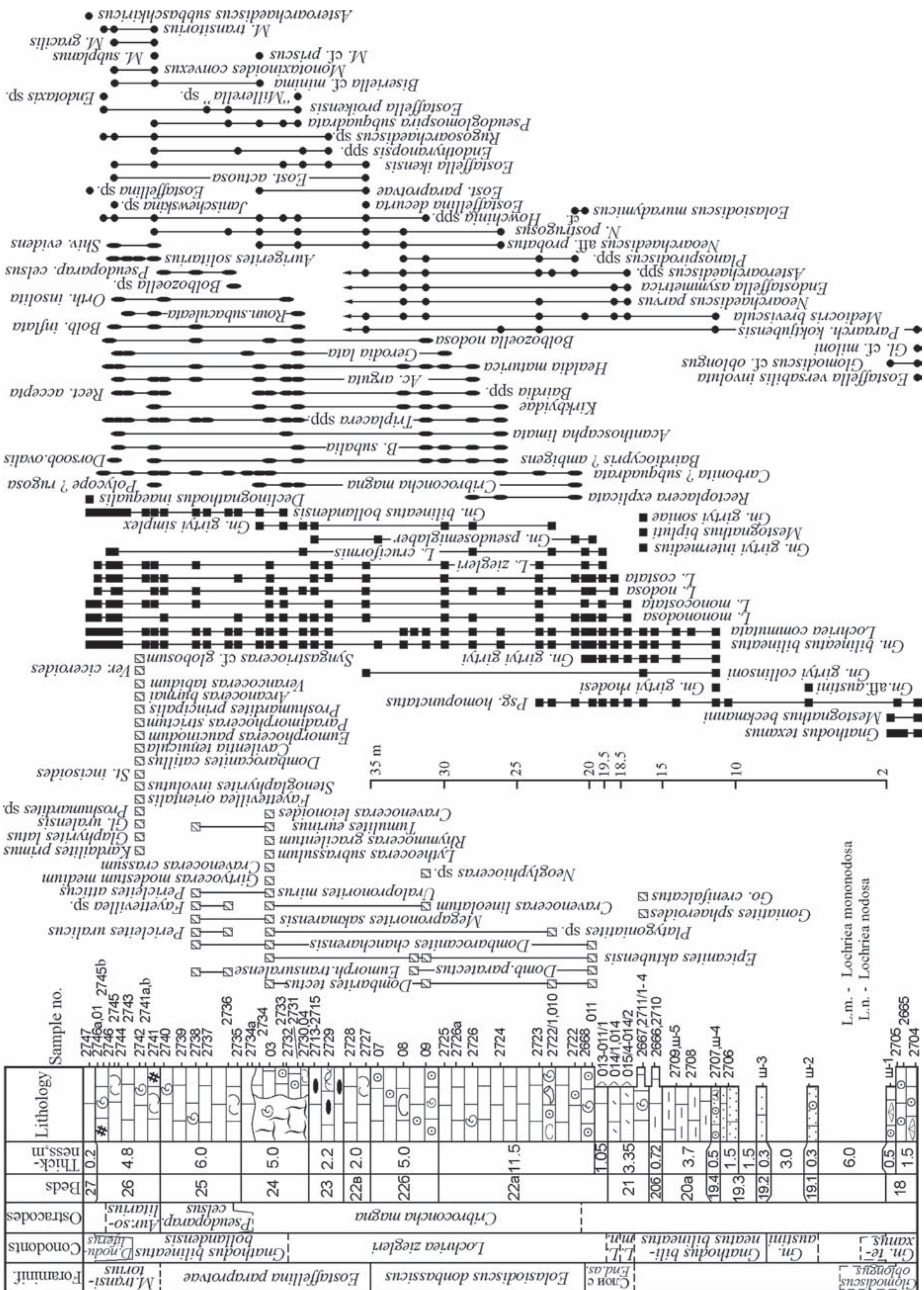


Fig. 32. Distribution of fossils in the Upper Viséan and Serpukhovian beds of the Verkhnyaya Kardailovka section (from Pazukhin et al., 2010)

Microfacies of the Viséan-Serpukhovian boundary beds of the Kardailovka Section are shown on Figs. 33–39 (compiled by Gorozhanina)

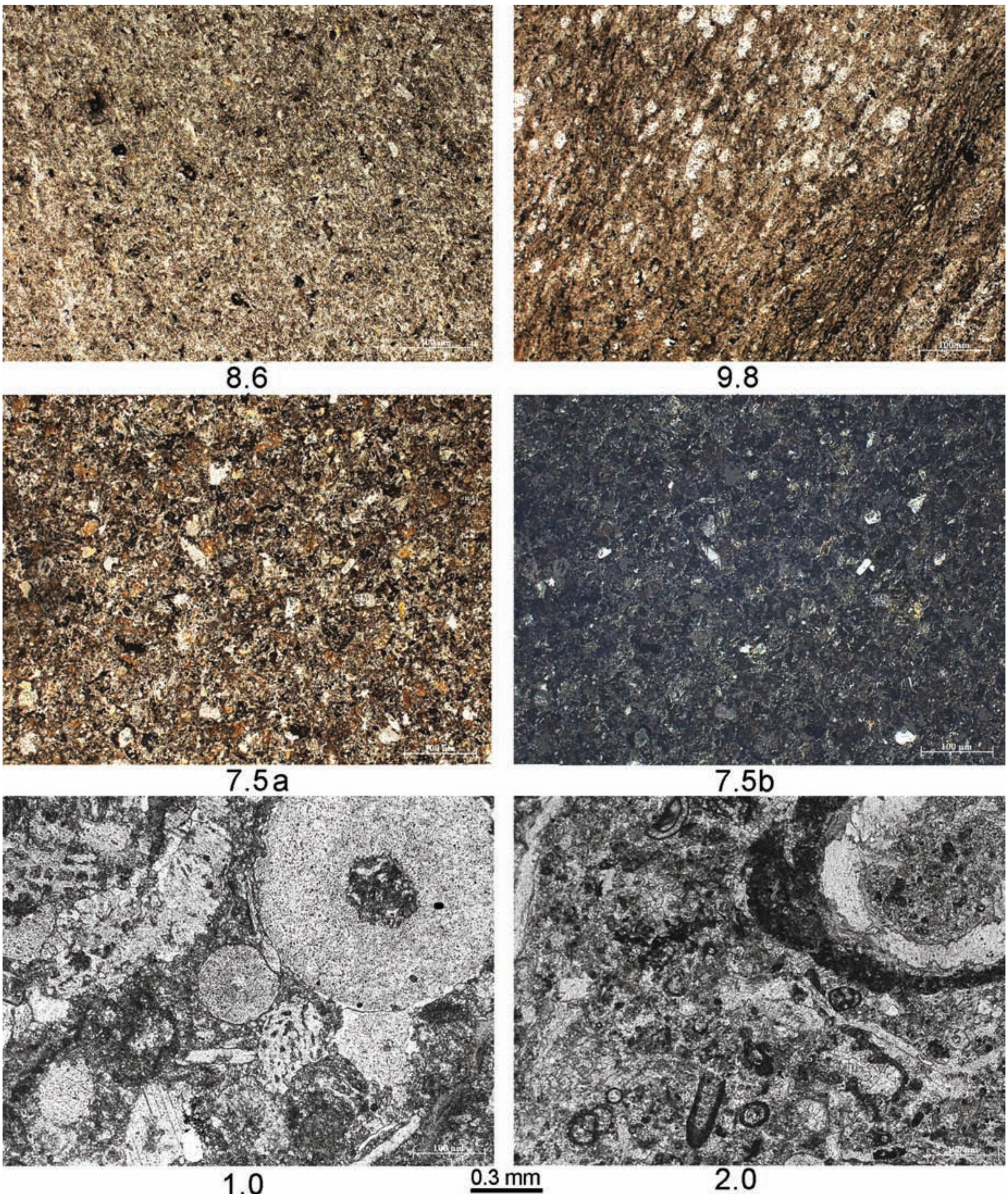


Fig. 33. Microfacies of Formations A and B

For Figs. 33–39 scale bar is 0.3 mm. Under the photos are metres from PIN 0.

Formation B, units 7: 8, 6 – siliciclastic claystone; 9, 8 – clayey silica shale with abundant chalcedonic spheres (radiolarian relicts); 7, 5 – siliciclastic claystone with fine quartz grains (white): (a) nicols parallel, (b) nicols crossed; **Formation A, unit 1:** 1.0 – coarse-grained bioclastic grainstone with crinoids (right); 2.0 – bioclastic packstone-grainstone.

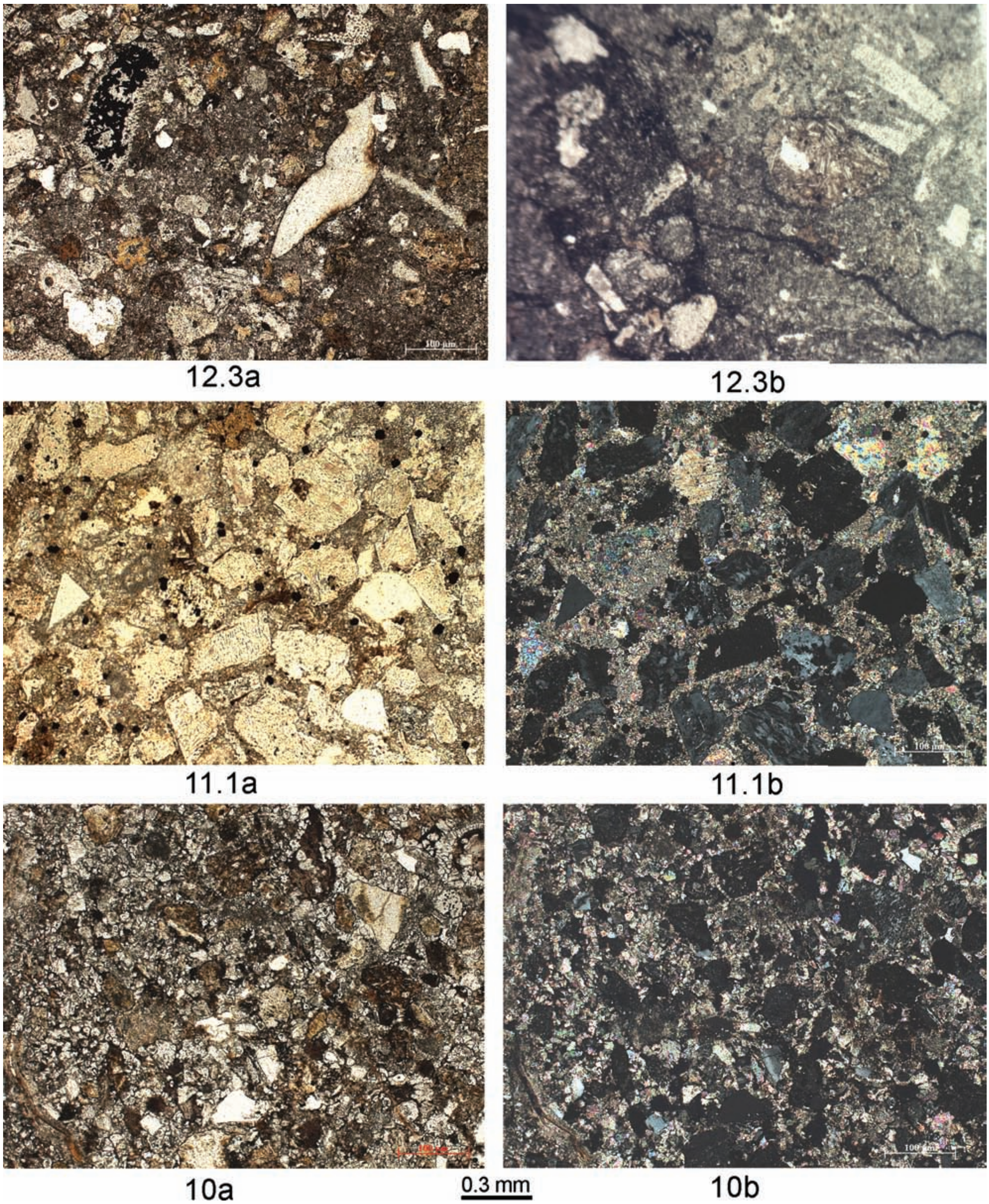


Fig. 34. Microfacies of Formation B and lowermost Formation C

Formation C, unit 9: 12.3 – bioclastic packstone with siliciclasts and: a – with conodont fragment (right), b – with crinoids and volcaniclasts (in the centre); **Formation B, unit 8:** 11.1 – calcareous sandstone with bioclasts, quartzes and plagioclase grains and volcaniclasts: (a) nicols parallel, (b) nicols crossed; 10 – calcareous sandstone with bioclasts, quartz and plagioclase grains and volcaniclasts: (a) nicols parallel, (b) nicols crossed.

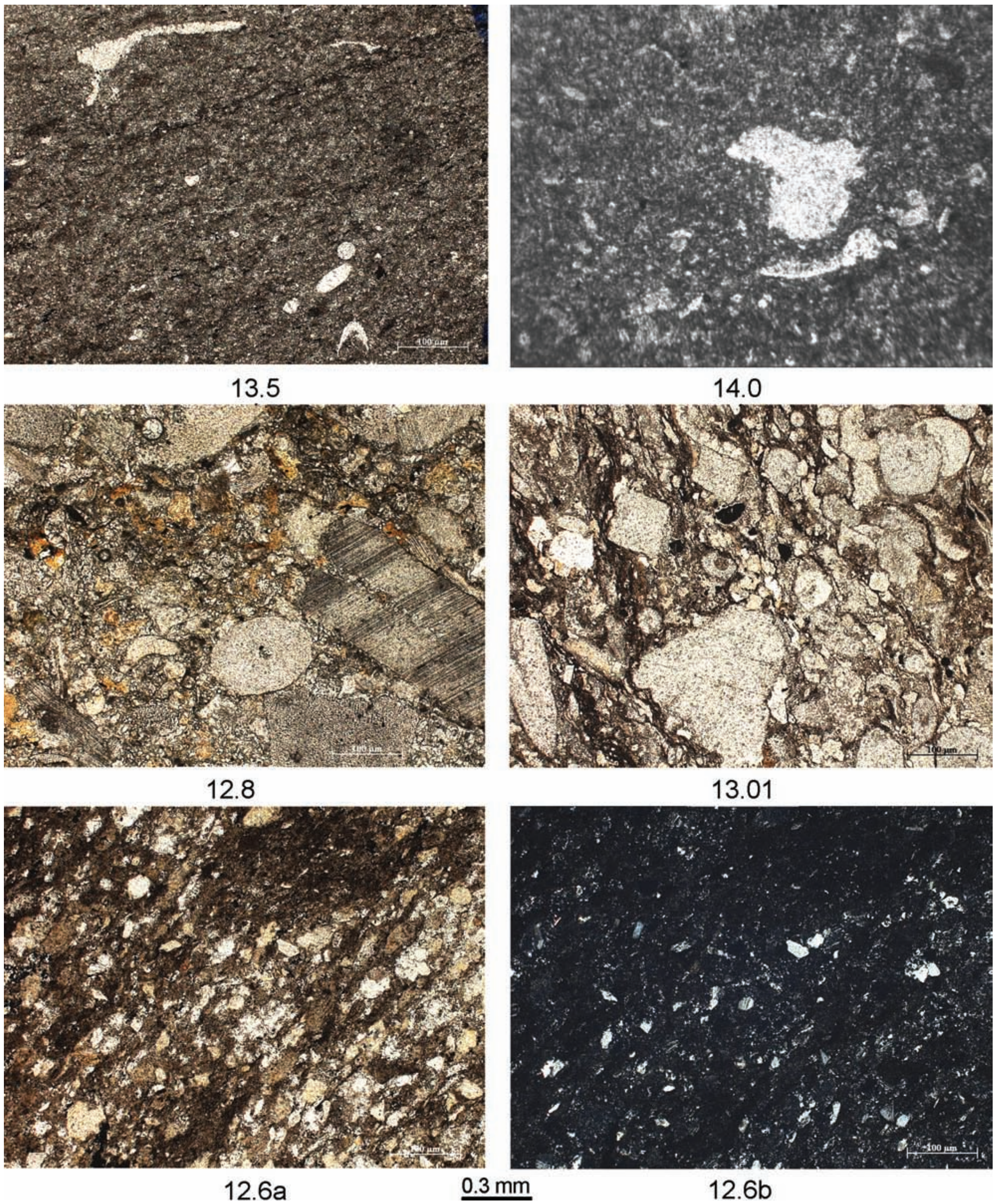


Fig. 35. Microfacies of Formation C, interval 12.6–14.0 m

Unit 9: 13.05 – bioclastic wackestone with crinoids; Unit 10: 14.0 – bioclastic wackestone with crinoids; Unit 9: 12.8 – crinoidal-bioclastic grainstone; Unit 10: 13.01 – crinoidal-bioclastic laminated grainstone; Unit 9: 12.6 – calcareous sandstone with bioclasts, quartz and plagioclase grains (white) and volcanoclasts: a – nicols parallel, b – nicols crossed.

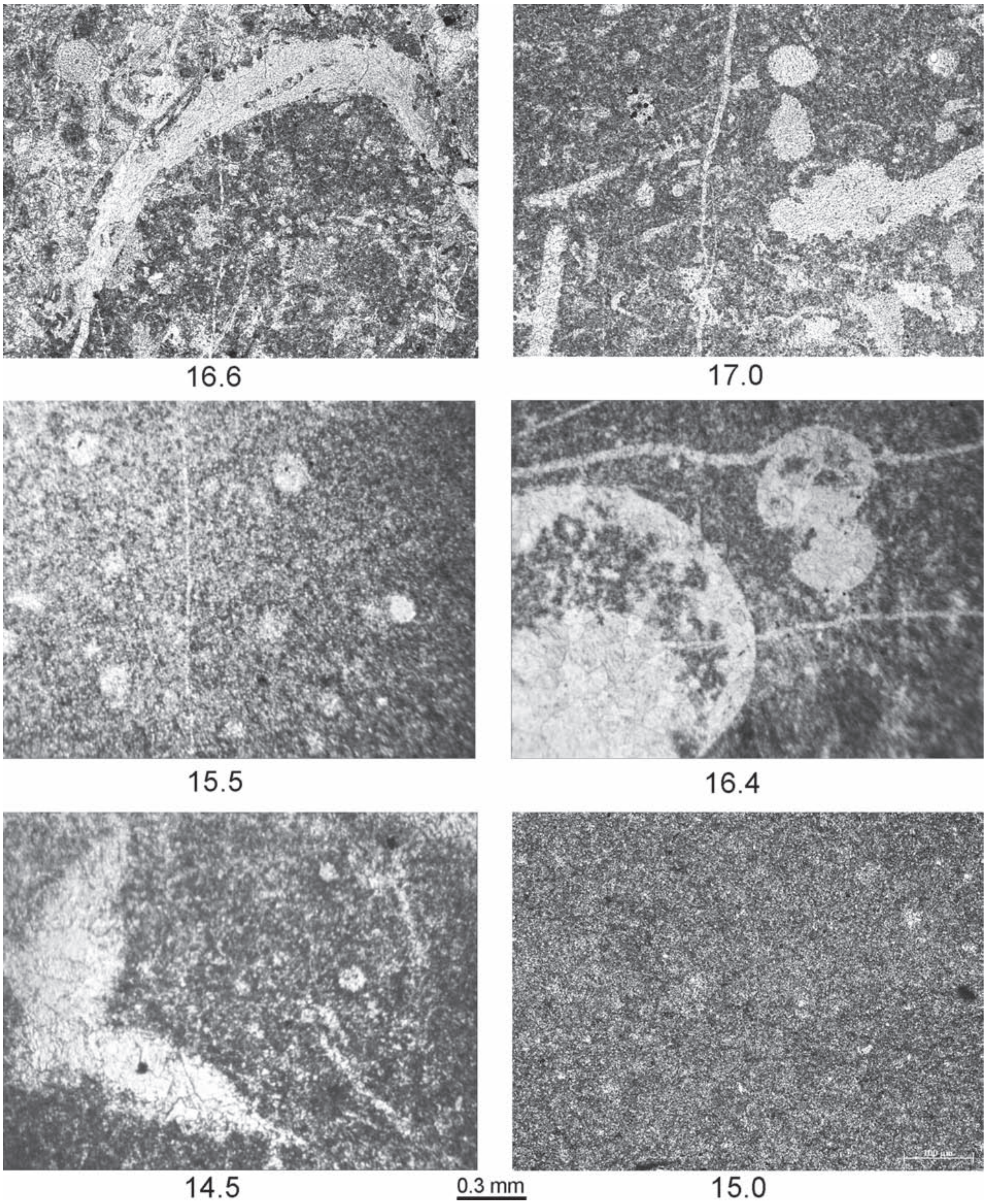


Fig. 36. Microfacies of Formation C, interval 14.5–17.0 m

Unit 11: 16.6 – bioclastic packstone with brachiopod shell;
Unit 12: 17.0 – bioclastic wack-packstone with abraded crinoids (right);
Unit 10: 15.5 – wackestone with spheres (carbonated radiolarian relicts);
Unit 11: 16.4 – wackestone with ammonoids;
Unit 10: 14.5 – bioclastic wackestone with *Parathuramminites* sp.;
Unit 10: 15.0 – mudstone.

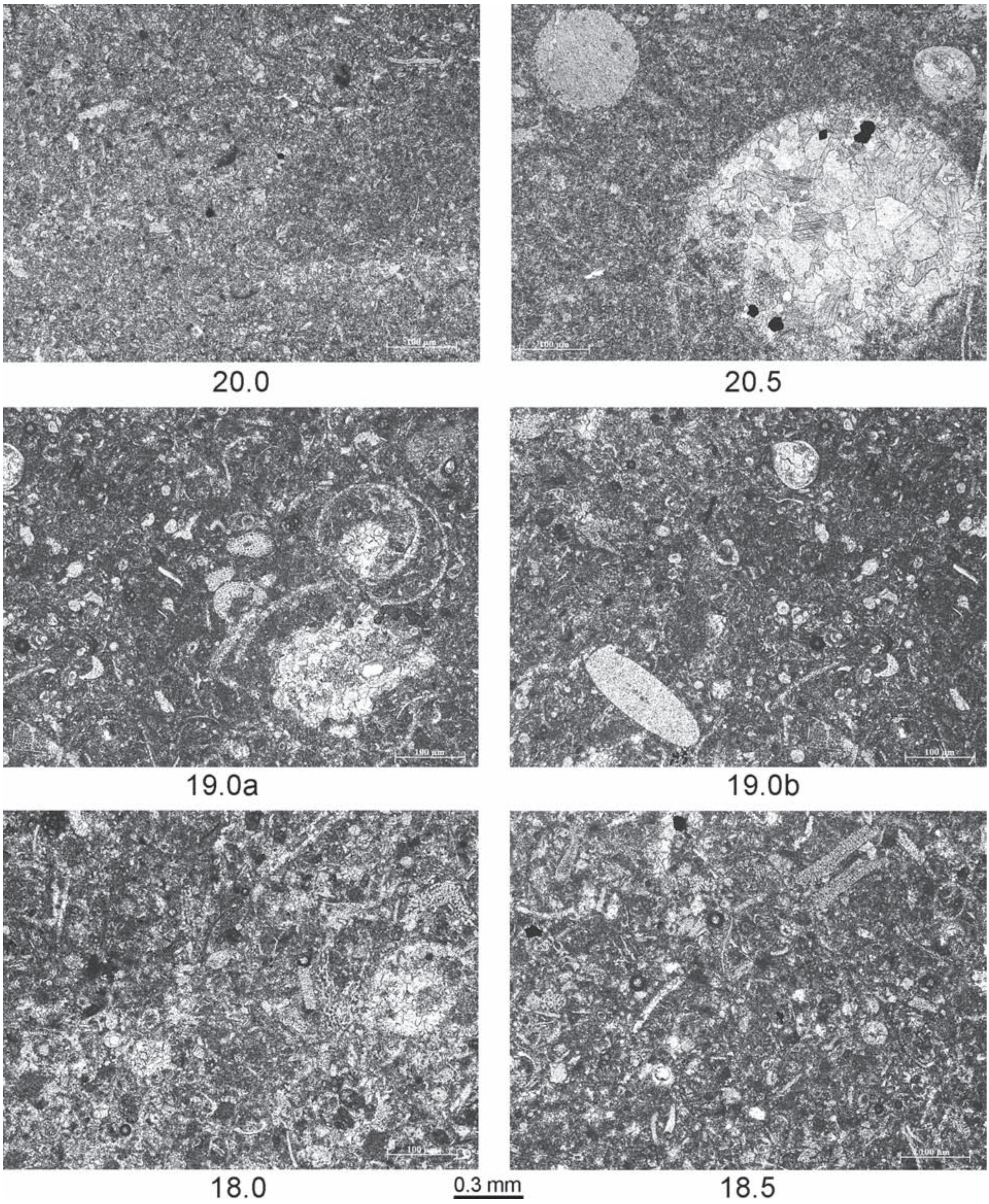


Fig. 37. Microfacies of Formation C, interval 18.0–21.0 m

Unit 14: 20.5 – bioclastic wackestone with ammonoids (left);
Unit 14: 21.0 – bioclastic wackestone;
Unit 14: 19.0 – bioclastic wack-packstone: a – with an ammonoid shell (right), b – with crinoid;
Unit 14: 20.0 – fine-grained mud-wackestone with small pachysphaerinas;
Unit 13: 18.0 – fine-grained bioclastic wack-packstone;
Unit 13: 18.5 – fine-grained bioclastic wack-packstone with *Pachysphaerina* sp. and crinoids.

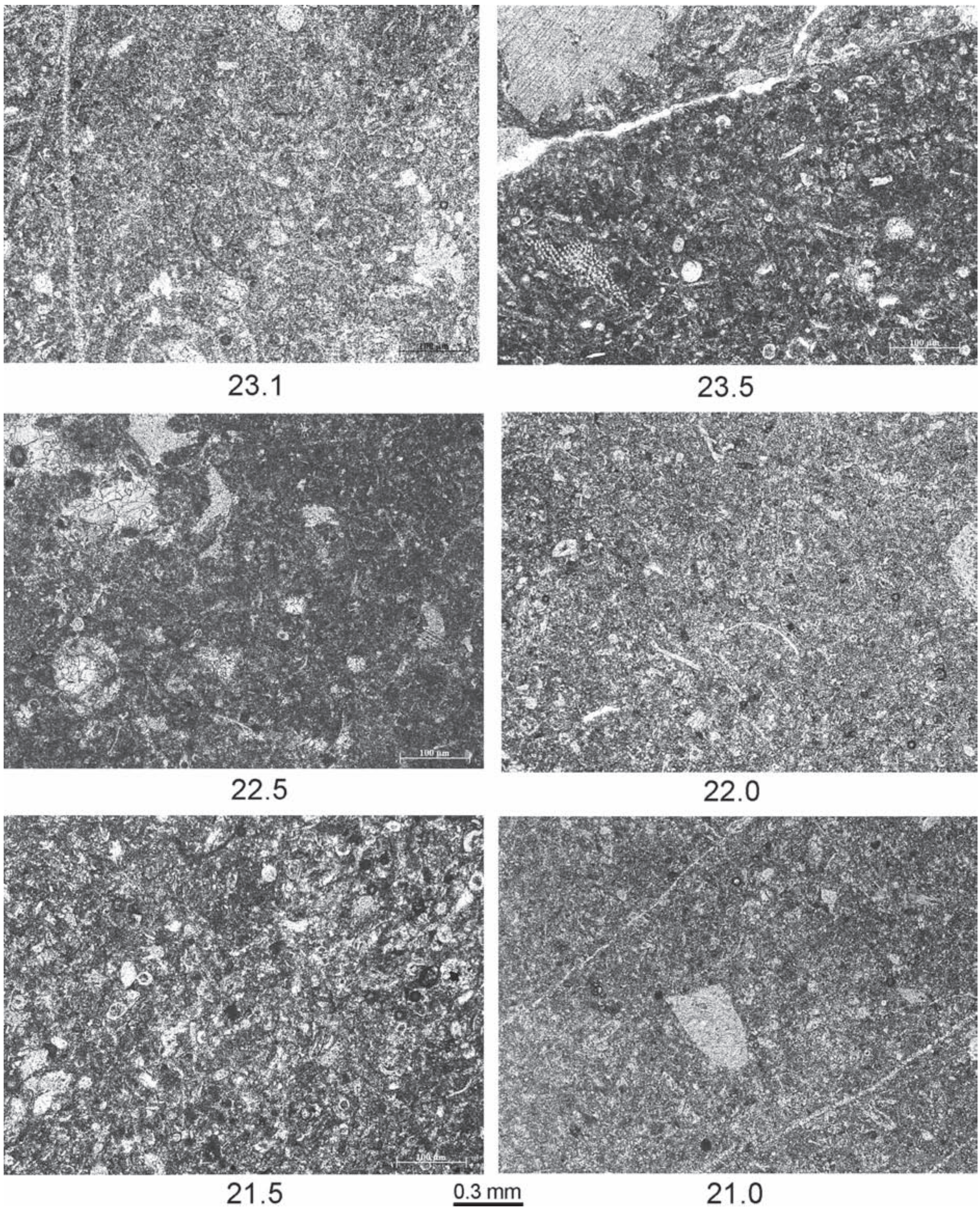


Fig. 38. Microfacies of Formation C, interval 21.0–24.0 m

23.1 – bioclastic wackestone with an ammonoid shell (below);
23.5 – bioclastic packstone with echinoderm clasts and spheres;
22.5 – clotted bioclastic wackestone with ammonoid (left);
22.0 – fine-grained bioclastic wackestone with a thin ostracod shell;
21.5 – fine-grained bioclastic wack-packstone;
21.0 – bioclastic wackestone with crinoids.

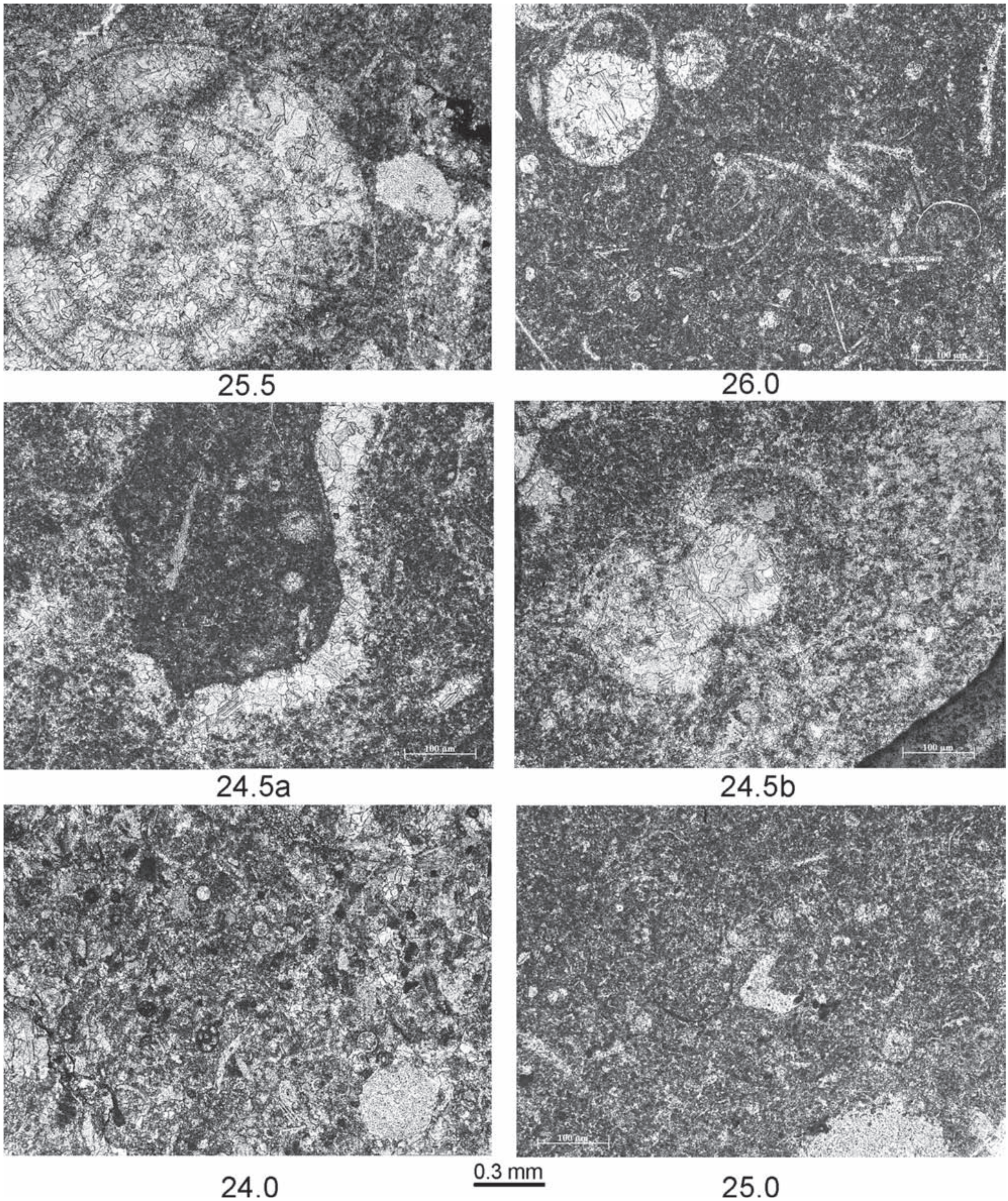


Fig. 39. Microfacies of Formation C, interval 24.0–26.0 m

25.5 – ammonoid shell in bioclastic wackestone;
26.0 – bioclastic wackestone with juvenile ammonoid (left);
24.5 – clotted wackestone with intraclast of wackestone (a) and ammonoid shell (b);
24.0 – fine-grained bioclastic packstone with small foraminiferas, pachysphaerinas, calcisphaeres, abraded crinoids;
25.0 – bioclastic wackestone with fine crinoids.

Stop 4. Bolshaya Urtazymka

On the banks of the Bolshaya Urtazymka River, the shallow shelf facies of the Kizil Formation show the Upper Viséan and Serpukhovian (Fig. 40). The thickness of the upper Viséan is more than 500 m. The area has a complex block structure. There is a repetition of sequences. Cliff outcrops of the Upper Viséan carbonates are observed on the steep slope of the Bolshaya Urtazymka River (Fig. 41).

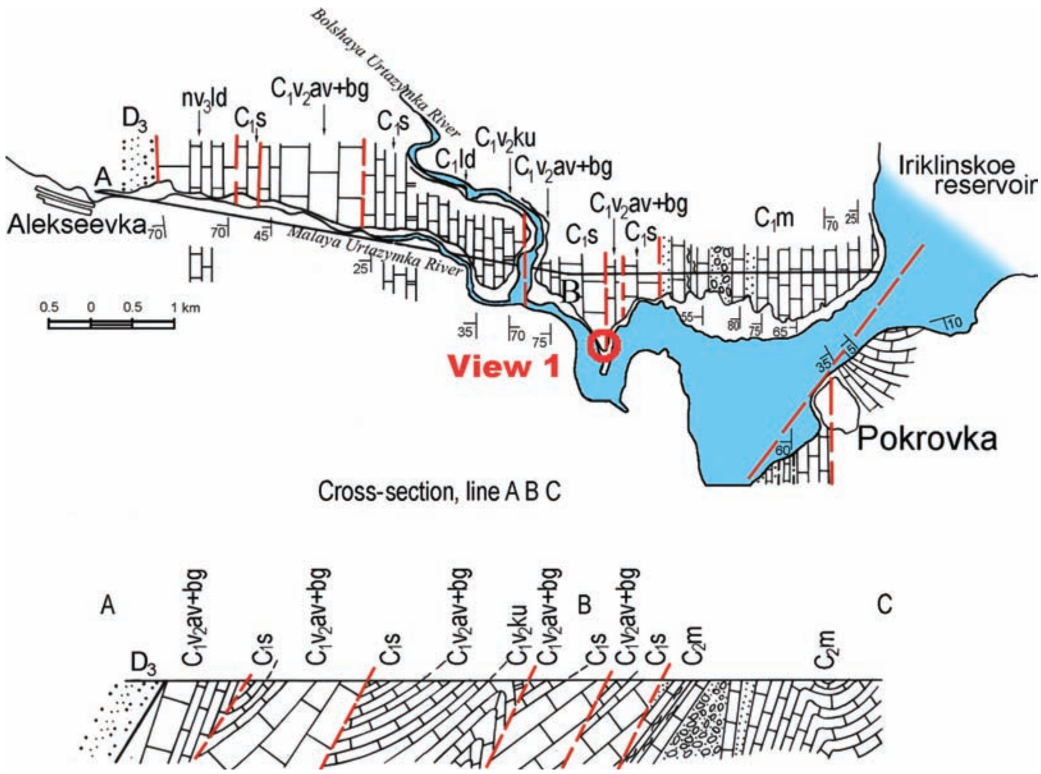


Fig. 40. Schematic geological map of the area between the Malaya Urtazymka River and the Bolshaya Urtazymka River (from Kochetkova & Lutfullin, 1976)

Fig. 41. View of the Iriklinskoe Reservoir near the mouth of the Bolshaya Urtazymka River

View 2. A karst sinkhole is observed on the left bank of the river 10 km upstream of the mouth, through a brachiopod bank. The bank is composed mainly of large productid shells (Fig. 42, 43). Thin sections made from samples of this limestone (bioclastic grainstone) contained the following foraminifers: *Endothyranopsis crassa* (Brady), *Omphalotis omphalota* (Raus. et Reitl.), *Eostaffella* cf. *mosquensis* Viss., *Tetrataxis* sp., Palaeotextulariidae, and also numerous bryozoan remains.

Fig. 42. *Gigantoproductus* sp. (s.l.)

Fig. 43. Brachiopod bank in the Upper Viséan beds of the Bolshaya Urtazymka River

Day 3. August 18
Stop 5. The Lower Viséan section near the mouth of Grekhovka Creek. Stratotype of the Ustgrekhovkian substage (Horizon)

Location and short information

The section is located on the left bank of the Ural River, 0.6 km downstream of the mouth of Grekhovka Creek, 2.5 km east of the eastern margin of the village of Kizilskoye (Fig. 44, see Fig. 11). This section is the stratotype section of the Ustgrekhovkian Regional Stage (Horizon),

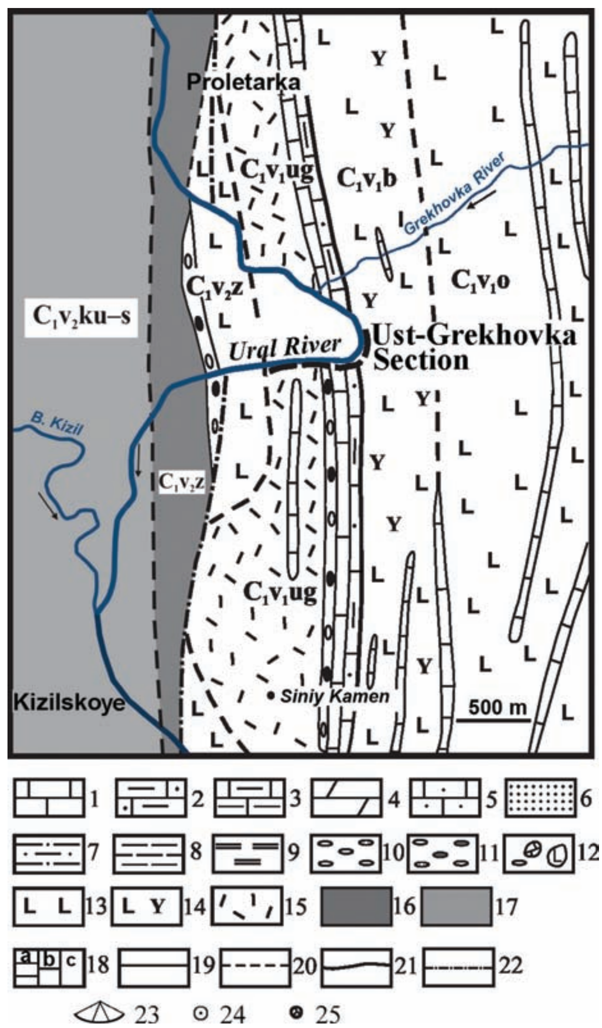


Fig. 44. Schematic geological map of the Ust-Grekhovka Section (compiled by Kucheva based on Plyusnina, 1972; Yarkova et al., 1972; Simonova, 1975)

Explanations to Figs. 44, 46: 1 – limestone, 2 – argillaceous limestone and calcareous sandstone, 3 – argillaceous limestone, 4 – marl, 5 – calcareous sandstone, 6 – polymictic sandstone, 7 – siltstone, 8 – shale, 9 – cherty shale, 10 – monomictic conglomerate, 11 – polymictic conglomerate, 12 – boulder and coarse pebble polymictic conglomerate, 13 – basic rock complex, 14 – alternation of basic and acid rocks, 15 – trachydacite, 16 – Zhukovian limestone, 17 – Kamenskouralskian limestone (Upper Viséan – Serpukhovian), 18 – rock textures: 18a – thinly laminated, 18b – medium-laminated, 18c – thickly-bedded; boundaries of stratigraphic units and beds: 19 – conformable, 20 – presumed, 21 – of local gaps, 22 – tectonic; fossils: 23 – brachiopods, 24 – crinoid stems, 25 – spores; Lower Viséan regional stages (“Horizons”): C_1v_1o – Obruchevkian, C_1v_1b – Burlian, C_1v_1ug – Ustgrekhovkian.

which terminates the Lower Viséan section. In the stratotype section, the regional stage is represented by carbonates and siliciclastics with dominating limestones. In the lower part, the section contains polymictic conglomerate, siltstone, and argillaceous shale, 250–300 m thick. Rocks of the Ustgrekhovkian Regional Stage overlie volcanic of the Burlian Regional Stage, which crop out on both banks of the Grekhovka River. The age of the volcanics is based on the foraminifers of the *Eoparastaffella subglobosa – Uralodiscus primaevus* Zone found in a limestone bed (Popova, 1970; Malakhova, 1973; Simonova, 1975). A carbonate member ca. 100 m thick contains numerous foraminifers and brachiopods.

Historical Overview

Librovitch (1936) was the first to describe the section. He assigned the limestone member to the upper part of the Berezovskiy Formation and subdivided it into four horizons (a, b, c, d) based on lithology and fossils. The beds with the Ustgrekhovkian assemblage of foraminifers were established by Simonova in 1965 (Donakova et al., 1968). Popova (1970) (the same person as Simonova) described the foraminiferal markers and indicated that the assemblage with *Uralodiscus* is a very distinct feature, and such a diverse *Uralodiscus* assemblage has not been found in the section, either below or above. Garan, Lutfullin, and Shokh established an abundant and diverse brachiopod assemblage of 30–35 species. Garan (1970) described two new species *Fusella* (*Unispirifer*) posttornacensis and *F.* (*U.*) *uralica*. Kochetkova studied ostracods from this section. Paleogeography was described by Yarkova (Yarkova et al., 1972).

Characteristics of the section and fossils

Beds of the Ustgrekhovkian Regional Stage are exposed for 500 m along a river bank, cropping out in steep cliffs (Fig. 45).

Fig. 45. Ust-Grekhovka Section along the left bank of the Ural River (photograph by Kucheva)

Based on rock lithology and fossils, the Ustgrekhovkian Regional Stage is subdivided into six members (Fig. 46). Carbonate member 2 (110 m thick) is divided into beds 1–7 (Fig. 47).

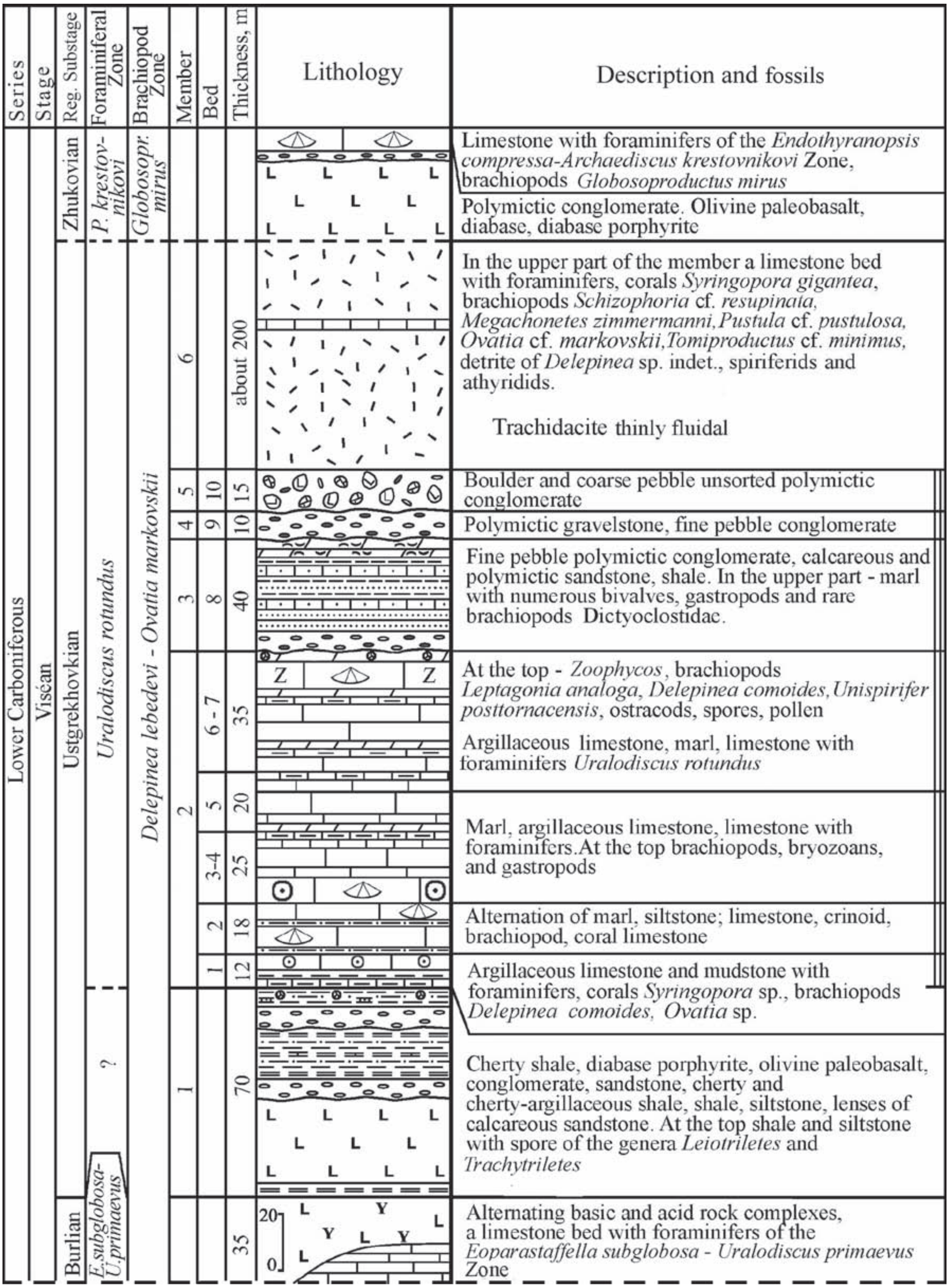


Fig. 46. Stratigraphic log of the Viséan strata of the Ust-Grekhovka Section (modified from Simonova, 1975)

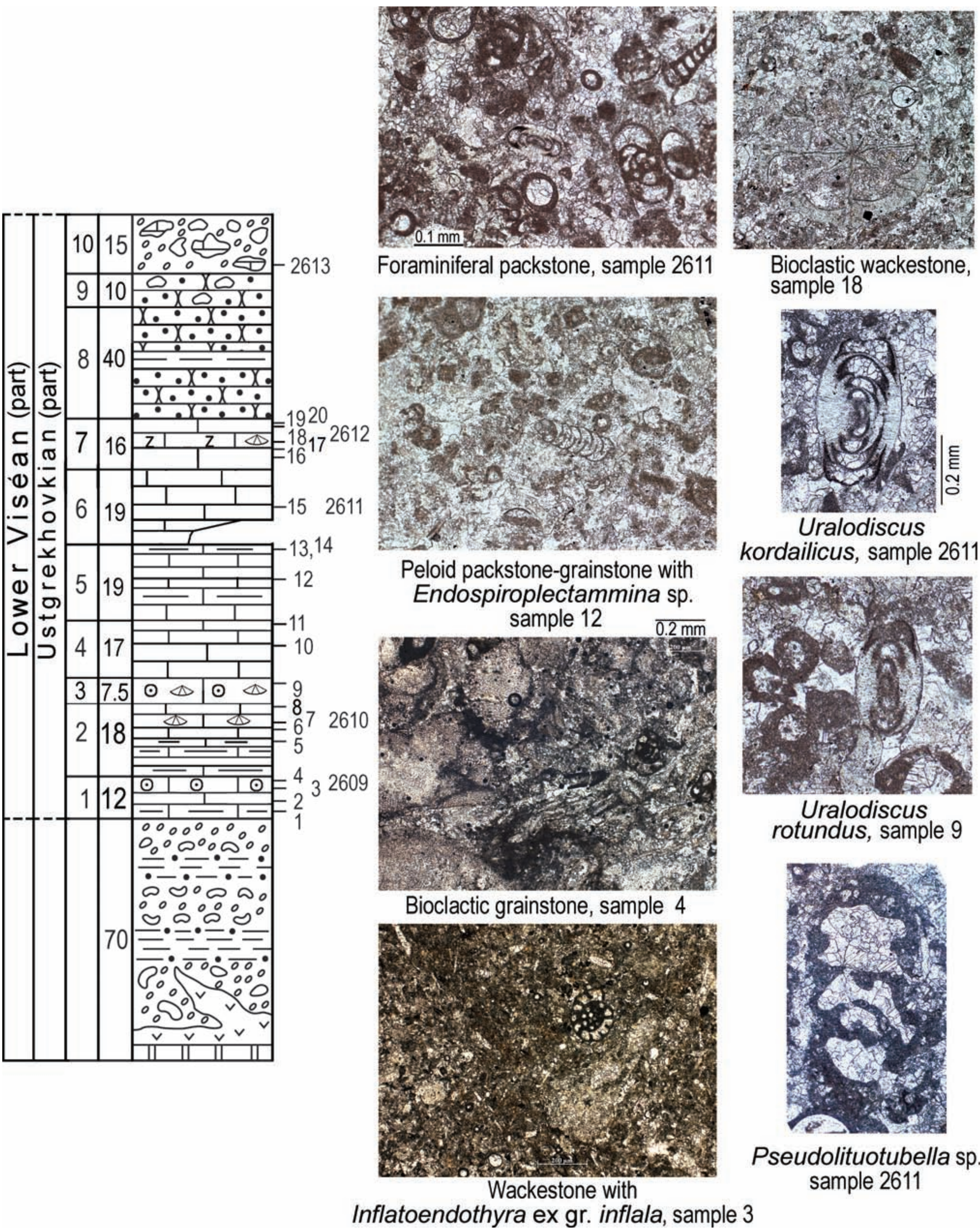


Fig. 47. Stratigraphic log of the Ust-Grekhovka Section, marked by a double black line in Fig. 46 (Beds 1–10), showing microfacies and foraminifers (compiled by Kulagina)

The entire succession contains alternations of medium- and thick-bedded bioclastic and thinly laminated limestones (Fig. 48).

Fig. 48. Alternation of limestone, shale, and siltstone, in the lower part of member 2 (photograph by Kucheva)

Fig. 49. Zoophycos trace fossils (photograph by Kucheva)

The beds with *Zoophycos* are frequent (Fig. 49). Some beds are overfilled with shells of brachiopods (Figs. 50, 51).

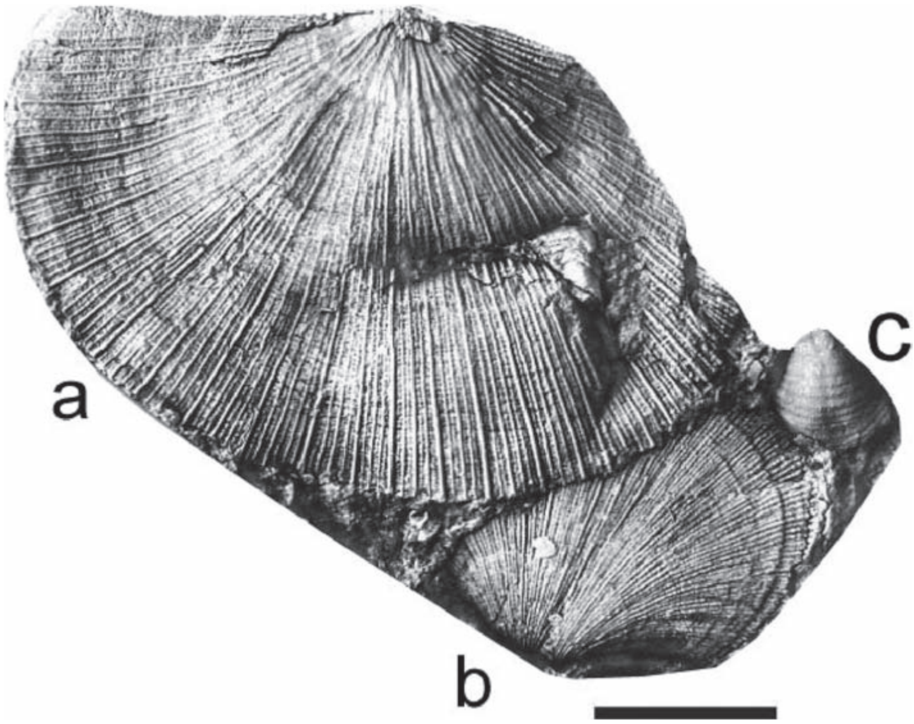
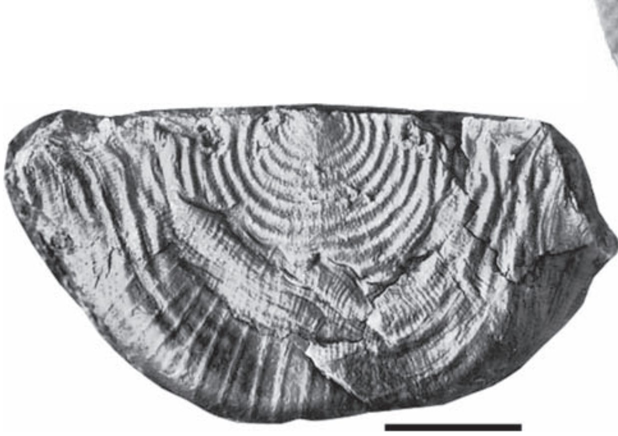
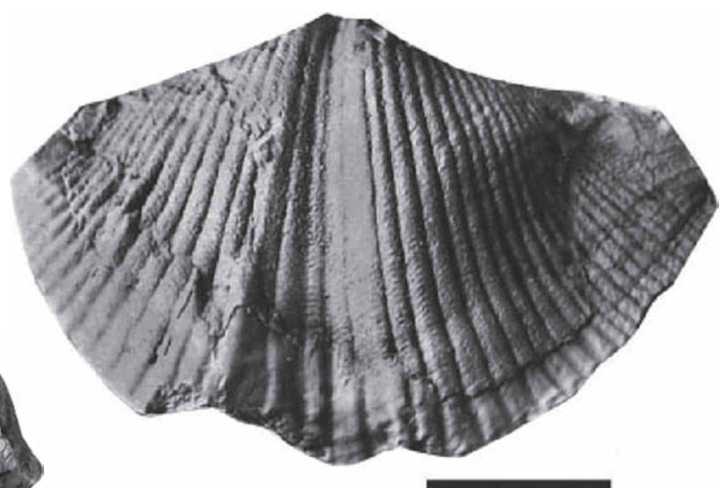


Fig. 50. Accumulation of brachiopod shells, bed 2

a – *Schuchertella portlockiana* (Sem.), b – *Schizophoria resupinata* (Mart.), c – *Pustula* sp. (Collection of Kucheva). Scale bar 1 cm.



Leptagonia analoga (Phill.)



Unispirifer posttornacensis (Gar.)

Fig. 51. Typical brachiopods of the Ust-Grekhovka section (Collection of Kucheva)

Scale bar 1 cm.

Stop 6. Bolshoi Kizil Section. Bashkirian organic buildups

Location and brief information

The section is located in the west of the Kizil District of the Chelyabinsk Region. It follows the Bolshoi Kizil River upstream for almost 7.5 km. The outcrops of carbonates along the Bolshoi Kizil River constitute the stratotype of the Kizil Formation. Sedimentation of the Kizil Formation occurred in a shallow-water shelf basin from the Late Viséan, throughout the Serpukhovian and most of the Bashkirian, and was terminated in the Askynbashian by the raising of a carbonate platform. The Kizil Formation extends along the Ural, Bolshoi Kizil, and Khudolaz Rivers. It overlies the volcanic rocks of the Berezovskiy Formation and is overlain with an unconformity by conglomerates of the Urtazym Formation of Moscovian age. It shows a faunal assemblage of the bioherm facies accumulated in an open shallow marine basin with many brachiopod shoals and banks, and with algal and coral bioherms. The Bolshoi Kizil section begins on the right bank of the Ural River 1.2 km south of the village of Proletarka (situated on the opposite bank) and continues along the left bank of the Bolshoi Kizil River (right tributary of the Ural River) (see Fig. 11).

Historical Overview

A thick series of carbonates, widespread on the eastern slope of the South Urals in the centre of the Magnitogorsk Megasynclinorium constitute the Kizil Formation established by Librovitch (1936). Much research has been done on the biostratigraphy and fossils of the Kizil Formation (Ivanova et al., 1972; Ivanova, 1973, 1975; Kochetkova et al., 1977; Kochetkova, 1983; Simonova, 1990; Stepanova & Kucheva, 2000, 2006; Kulagina et al., 2001; Kulagina & Gibshman, 2002; Kulagina, 2007). Due to the considerable thickness of the Formation and the abundance of small algal bioherms and biostromes, this sequence of rocks was described as a reefoid Formation (Korolyuk et al., 1983). The largest bioherms are found in the Bashkirian portion of the section (Shchekotova, 1978). Different researchers have estimated their thickness differently; the maximum estimate was 1500 m.

Characteristics of the section and fossils

Viséan Stage
Upper Viséan

The Upper Viséan strata are divided into regional units of substage rank (locally called horizons) including Zhukovian, Kamenskouralskian, Averinian and Bogdanovichian (Fig. 52). The Upper Viséan strata are exposed in outcrops separated by covered intervals Beds lie monoclinally (dipping at an azimuth 250–260°, at an angle 25–40°). The Zhukovian (upper part, Outcrop 8, thickness 190–210 m) correlates with the Tulian of the Russian Platform. These strata extend along the right bank of the Ural River. The outcrop begins 1.9 km upstream from the confluence of the Ural and Bolshoi Kizil rivers (Fig. 53).

Description of the Bolshoi Kizil section based on (Kulagina et al., 2009).

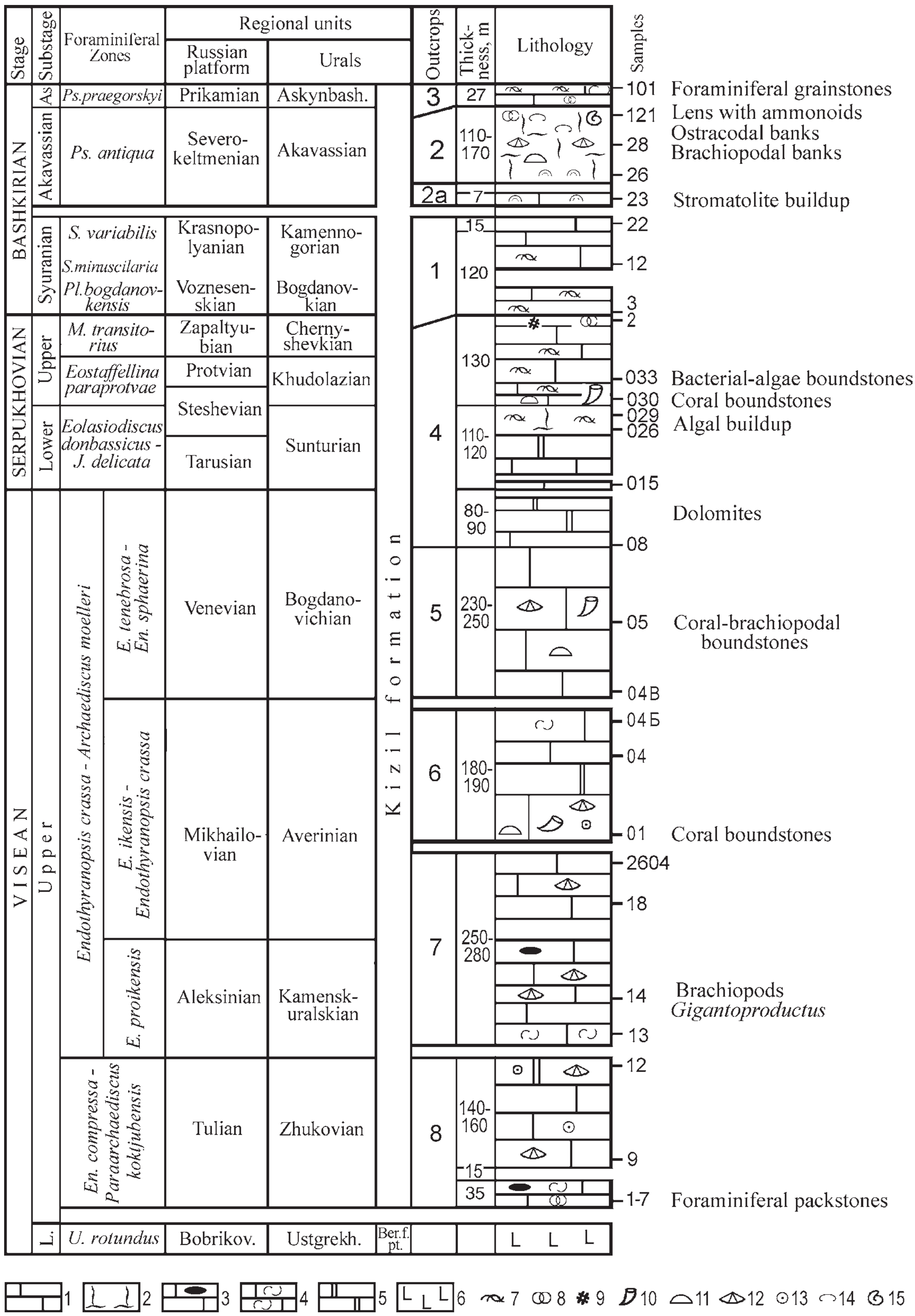


Fig. 52. Generalized scheme of the Kizil Formation in the Bolshoi Kizil Section (from Kulagina et al., 2009)

Legend: limestones: 1 — bedded (mudstones and wackestones); 2 — unbebbed; 3 — with cherty nodules; 4 — bioclastic packstones; 5 — dolomites; 6 — mafic effusives; 7 — algae; 8 — foraminifers; 9 — bryozoans; 10 — tetracorals; 11 — colonial corals; 12 — brachiopods; 13 — crinoids; 14 — ostracods; 15 — ammonoids.

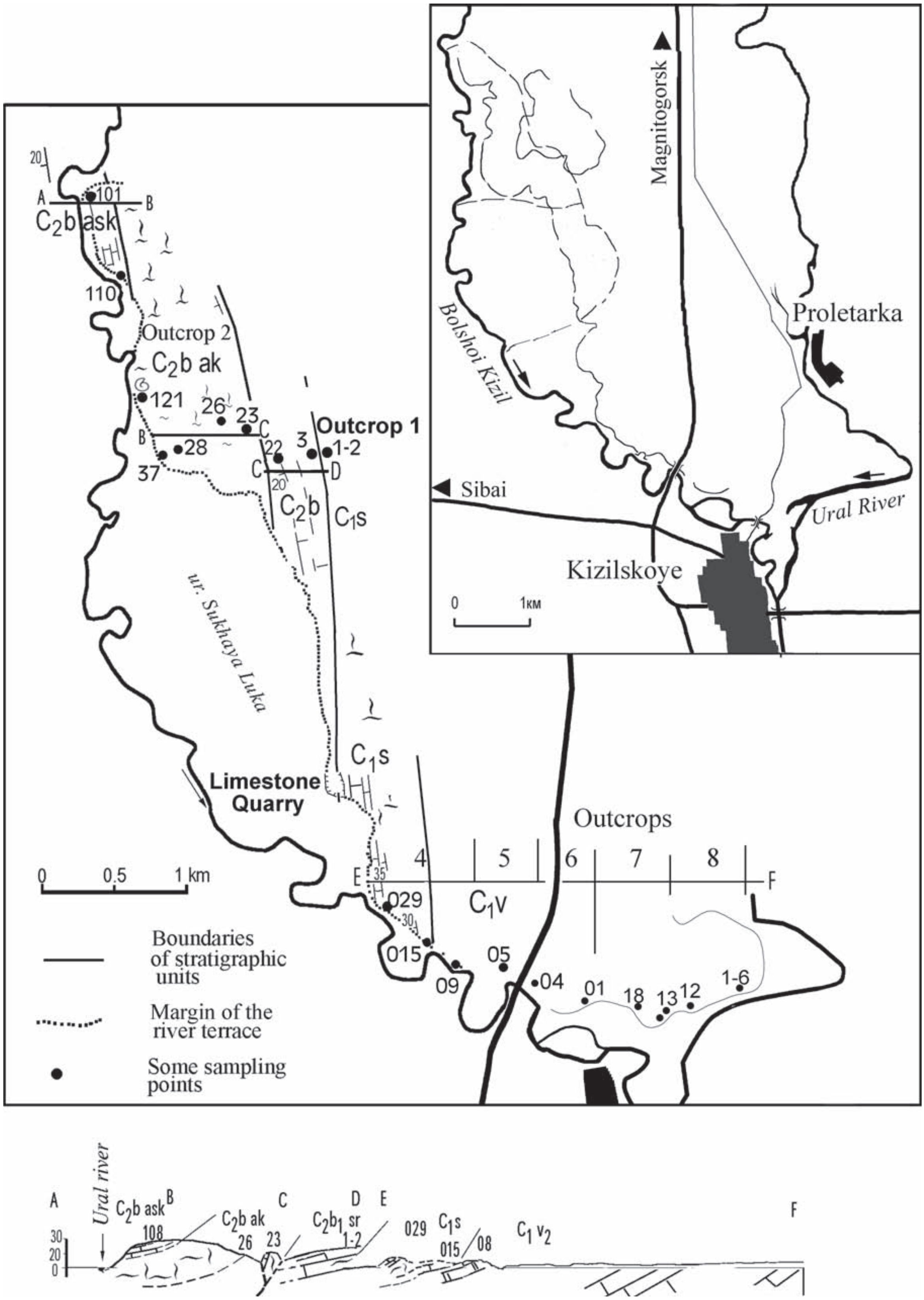


Fig. 53. Geological scheme of the outcrops along the Bolshoi Kizil River (from Kulagina et al., 2009, modified)

The Zhukovian is represented by medium and thick bedded bioclastic packstones and grainstones with inclusions and pellets. Bioclasts include foraminifers, crinoids, corals and brachiopods. They are partly rounded and micritized, sometimes slightly dolomitized. There are occasional nodules of flint at the base of the section. Fossils: alga *Koninckopora* sp., foraminifers *Lituotubella glomospiroides* Raus., *Endothyranopsis compressa* (Raus. et Reitl.), *Omphalotis omphalota* (Raus. et Reitl.), *Globoendothyra* spp., *Pojarkovella nibelis* (Durkina), *Parastaffella struvei* (Müller), *Paraarchaediscus koktjubensis* (Raus.), *P. cyrtus* (Conil et Lys).

The Kamenskouralskian (Outcrop 7, thickness 150 m) correlates with the Aleksinian of the Russian Platform. It is exposed 1.5 km north of the confluence of the Ural and Bolshoi Kizil rivers, consists of foraminiferal grainstones, foraminiferal-algal-bioclastic grainstones and packstones, sometimes dolomitized, with occasional nodules of light-coloured chert in the upper part, with the brachiopods *Gigantoproductus* and foraminifers of the *Eostaffella proikensis* Zone: *Lituotubella magna* Raus., *Haplophragmella* sp., *Omphalotis omphalota* (Raus. et Reitl.), *O. chariessa* (Conil et Lys), *Globoendothyra globulus* (Eichw.), *Eostaffella* cf. *parastruvei* (Raus.), *E.* cf. *proikensis* Raus., *Parastaffella concinna* (Schlyk.), Palaeotextulariidae.

The Averinian (Outcrops 7 and 6, thickness over 300 m) correlates with the Mikhailovian of the Russian Platform. It is exposed in the land between two rivers in outcrops 7 and 6, and consists of mostly organic limestones with diverse fossils. In Outcrop 7 (thickness 100–130 m), the horizon is composed of thick and indistinctly bedded limestones with accumulations of brachiopods. Algal-foraminiferal packstones and grainstones, algal boundstones, algal-brachiopod wackestones predominate. Algae include *Ungdarella uralica* Masl., and *Fasciella kizilia* R. Ivanova (= *Shartymophycus fusus* Kulik). Foraminifers generally continue from the underlying beds, while *Endothyranopsis crassa* (Brady), *Bradyina rotula* Eichw., *Janischewskina* sp., *Eostaffella ikensis* Viss., *E. ragushensis* Gan., *Archaediscus moelleri* Raus., *Asteroarchaediscus* cf. *rugosus* (Raus.) indicative of the *Eostaffella ikensis* Zone.

The Bogdanovichian (Outcrops 5, 4, thickness more than 330 m) correlates with the Venevian of the Russian Platform. It is exposed along the bend of the left bank of the Bolshoi Kizil River. The Bogdanovichian is composed of boundstone, bioclastic grainstone and dolomite. Crinoidal, foraminiferal, crinoid-brachiopod and oolite limestones are observed on the left bank of the Bolshoi Kizil River near the bridge across the river, on the Sibai – Magnitogorsk highway. Foraminifers included *Forschia mikhailovi* Dain, *Pseudoglomospira* spp., *Endostaffella parva* (Müller), *Endothyranopsis sphaerica* (Raus. et Reitl.), *Bradyina rotula* Eichw., *Biseriella parva* (N. Tchern.), *Palaeotextularia longiseptata crassa* Lip. of the *Eostaffella tenebrosa* Zone.

Outcrop 4 exposing the **Viséan-Serpukhovian boundary beds** (Kulagina & Gibshman, 2002, 2005; Kulagina et al., 2009) is on the Bolshoi Kizil River, 400 m northeast of the on the Sibai – Magnitogorsk highway. This outcrop shows a continuation of the succession described above. The description begins with the rocky exposures on the left bank of the Bolshoi Kizil River (43 m north-east of Point 09 on Fig. 53). The following sequence of thick bedded and indistinctly bedded limestones is observed (bottom to top):

1. At point 08 observed bioclastic packstones, with frequent fragments of coral, echinoids, crinoids and bryozoans, containing corals and brachiopods, matrix is dolomitized and re-crystallized.

2. Bioclastic and crinoidal packstones-rudstones with rare algae and foraminifers, in the upper part with corals. Thickness 7 m.

3. Dolomites (Point 09). Thickness 11 m.

4. Cavernous dolomites. There is a cave at this level. Thickness 9.5 m.

5. Limestones with calcite accumulations, numerous brachiopods *Striatifera*. At the bottom of the gully there is an outcrop of crinoid, algal-bioclastic packstones-rudstones, with rare foraminifers. The algae are mostly *Calcifolium okense* Schwet. et Bir., there also *Koninckopora* sp. and *Ungdarella* sp. Thickness 4.8 m.

Covered interval (bottom of the gully). 12 m.

6. Light limestones crop out in the mouth on the right slope of the gully, in thin section – algal packstone-boundstone with many foraminifers: *Pseudoglomospira* spp., *Haplophragmella tetraloculi* Raus., *Endothyranopsis sphaerica* (Raus. et Reitl.), *Janischewskina typica* Mikh. and other. Thickness 4 m.

Upstream of the river there is a covered interval 6.7 m thick.

Serpukhovian Stage

Sunturian

7. Algal boundstones, sometimes grainstones with remains of thin-shelled brachiopods. Algae *Calcifolium okense* Schwtz. et Bir. Foraminifers (Sample 015) include *Pseudoglomospira* sp., *Haplophragmina* cf. *beschewensis* (Brazhn.), *Endothyranopsis sphaerica*, *Globoendothyra globulus*, *Howchinia bradyana* (Howchin), *Bradyina* cf. *rotula*, *Janischewskina delicata* (Mal.), Palaeotextulariida, *Rugosoarchaediscus akchimensis* (Grozd. et Leb.), *Asteroarchaediscus baschkiricus* (Krest. et Theod.), *Neoarchaediscus postrugosus* (Reitl.), *Permodiscus vetustus* Dutk., *Eolasiodiscus donbassicus* Reitl. Thickness 1 m.

Covered interval 18 m.

8. Massive boundstones formed by *Calcifolium okense* Schwetz. et Bir. and *Fasciella kizilia* R. Ivanova, strongly dolomitized, containing brachiopods, crinoids and corals. 3 m.

9. Fine- and microbioclastic packstones with recrystallized matrix, containing algal, foraminifers, fragments of bryozoans, brachiopods, crinoids, spicules of sponges and chert. Fossils include algae *Calcifolium*, *Praedonezella*, *Fasciella*, and numerous foraminifers. 5 m.

Covered interval is 13 m.

10. Limestones, fissured and dolomite forming small flattened exposures. Thickness 6.5 m.

11. Relict-algal, algal and bioclastic packstones, strongly cavernous and dolomitized. Sometimes caverns are filled with oxidized bitumen; the matrix is represented by homogeneous, very compact, recrystallized micrite. Bioclasts include crinoids, bryozoans, and echinoids. Often areas with numerous algae may be observed. Presence of single-chambered *Eotuberitina* sp. (cementing the sediments) and bioencrustations (microspongiostromes) is very characteristic. Thickness 13 m.

12. Algal boundstones formed by the algae *Calcifolium okense* with bioencrustations, with foraminifers, frequent fragments of bryozoans, crinoids, a strong smell of bitumen, brachiopod banks in the lower part, in parts strongly dolomitized (Samples 026–029). Thickness 45–52 m.

The thickness of the Sunturian is up to 110 m.

Khudolazian

13. At its base, the Khudolazian is composed of boundstone, formed by colonial corals (coral bioherm) and algae (Sample 030, bed 1.3 m) with frequent encrustations, contains

bryozoans, spines of echinoids, numerous foraminifers and cysts formed by small *Mediocris* sp. and *Endostaffella* spp. Overlaying algal boundstone and packstone include algae of the genera *Calcifolium*, *Ungdarella* and *Fasciella*; foraminifers: *Turrispiroides multivolutus* (Reitl.), *Eostaffellina* cf. *paraprotvae* (Raus.), *Pseudoendothyra* cf. *kremenskensis* Ros., *Globivalvulina eogranulosa* Reitl., *Gl. bulloides* (Brady), *Bradyina* ex gr. *cribrostomata* (Raus. et Reitl.), *Br.* cf. *eonautiliformis* Reitl. Thickness 3.4 m.

14. The bed forms a vertical outcrop composed of distinctly laminar limestones. From bottom to top this bed shows a succession of boundstones formed by *Calcifolium* with bioclasts, bioclastic grainstone-packstone, wackestone with unidentified tubular remains (Figs. 54-4, 54-5), bioclastic wackestone-packstone with brachiopods, boundstones formed by structures produced by cyanobacteria in association with bacterial encrustations, and abundant fibrous cement with bacterial inclusions. At the top we observed a bed of “spotty” limestone, microscopically peloid-foraminiferal boundstone with prevailing palaeonubecularias (encrusting foraminifers), spheres and rhodophytes (Fig. 54-1, 54-2, 54-6), sometimes with numerous ostracods (Fig. 59-1). Thickness 11 m.

Limestone Quarry

15. In this interval in the separated outcrops before the quarry there are exposed medium-bedded brachiopods wackestones-packstones, followed by algal wackestones and bafflestones and peloid grainstones-packstones. In the wall of the quarry, there are exposed thickly bedded bioclastic wackestones-packstones with numerous brachiopods. Algae: *Praedonezella* sp., *Calcifolium okense*, *Ungdarella* sp., *Fasciella kizilia*. Foraminifers: *Earlandia vulgaris* (Raus. et Reitl.), *Endothyranopsis* spp., *Eostaffella* cf. *proikensis*, *E. ikensis*, *Asteroarchaediscus baschkiricus*, *A. parvus* (Raus.), *Biseriella parva*.

The thickness of the Khudolazian is nearly 67 m.

Chernyshevkian

Beds of the Chernyshevkian are exposed in a steep river bank excavated in a quarry. The upper part of the Chernyshevkian has been taken of by the quarry, and the description below is cited from Kochetkova (unpublished), who studied the outcrop before the quarry was excavated in 1975.

16. Bryozoan-algal packstones and wackestones containing corals, numerous brachiopods and foraminifers): *Endothyranopsis* sp., *Eostaffella* cf. *mirifica* Brazhn., *E. postmosquensis* Kir., *Neoarchaediscus probatus* (Reitl.), *N. postrugosus* (Reitl.), *Monotaxinoides* ex gr. *transitorius* Brazhn. et Jar. Thickness 11 m.

17. Fine-bioclastic packstones and wackestones with brachiopods in the some beds, with foraminifers: *Pseudoglomospira* spp., *Endothyra* ex gr. *bowmani* (Phillips), *Globivalvulina bulloides* Brady, *Asteroarchaediscus baschkiricus*. Thickness 24 m.

18–19. Mudstones and microbial-lumpy wackestones with numerous thin-walled *Glomospira*-like tubular organisms, possibly playing a role in cementation of the sediment. Thickness 24 m.

Covered interval is 5 m.

20. Bryozoan-crinoidal packstones with numerous foraminifers Archaediscidae. Thickness 2.5 m.

The presumed thickness of the Chernyshevkian is over 66 m, while the thickness of the entire Serpukhovian amounts to 250 m.

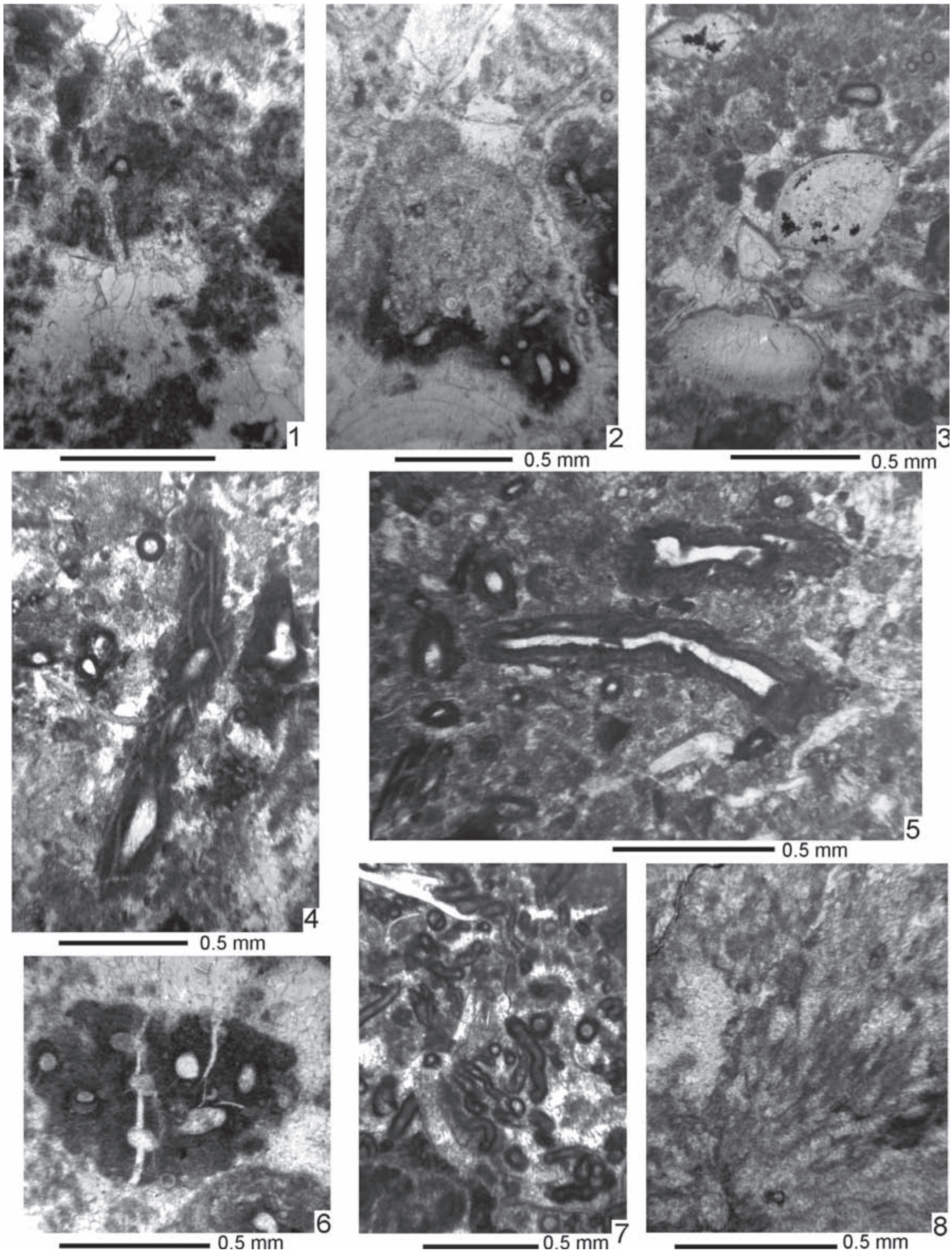


Fig. 54. Microfacies of Serpukhovian (Khudolazian) (Kulagina et al., 2009, Pl. 2).

1 – Microbial boundstone, Sample 2395(4); 2 – Alga-microbial boundstone with ostracods, Sample 32e; 3 – Peloidal wackestones with ostracods and cavity encrustations, Sample 032zh; 4, 5 – Wackestone including like-tubular encrusting organisms with microgranular porous wall: 4 – Sample 032b, 5 – Sample 032v; 6 – Microbial boundstone with fibrous cementation, Sample 2395(4); 7 – Boundstone formed by *Pseudoglomospira*-like encrusting unidentified organisms, Sample 032d; 8 – Microbial-algal boundstone formed by *Ortonella* sp. Sample 032z.

Mississippian-Pennsylvanian boundary

The Serpukhovian/Bashkirian boundary beds are exposed in unnamed gullies opening into the flood plain and cutting into the left bank of the Bolshoi Kizil River 4.5 km upstream of the village of Kizilskoye in Outcrop 1 (Kulagina et al., 2001) (Fig. 55, 56).

1. Pachysphaeral mudstones and wackestones, thickly bedded, with rare solitary corals, brachiopods, ostracods and single foraminifers (Sample 1). Thickness 4.5 m.

2. Bioclastic packstones and rudstones, in places with accumulations of small brachiopod shells, with bryozoans, crinoids, foraminifers and algae *Fasciella kizilia*, *Praedonezella cespeformis* Kulik, *Calcifolium okense* (Sample 2). This bed includes archaediscid biofacies and contains numerous *Paraarchaediscus*, *Neoarchaediscus*, *Asteroarchaediscus*, *Howchinia*, *Monotaxinoides*, rare *Planoendothyra* and *Eostaffella*. Thickness 1.5 m. This bed corresponds to Bed 20 of Outcrop 4.

Bashkirian Stage
Syuranian Substage
Bogdanovkian

The Bogdanovkian is composed of thick-bedded, indistinctly bedded and massive limestones.

3. Peloidal wackestone with rare brachiopods, pelmatozoan bioclasts, and ostracods and foraminifers (Sample 3): *Plectostaffella varvariensis* (Brazhn. et Pot.), *Plectomediocris* sp., *Rectoendothyra donbassica* Brazhn., conodonts *Declinognathodus noduliferus inaequalis* (Hig.). Thickness 1.5 m.

This bed is overlain by fine-crystallized dolomite with rare foraminifers and relicts of the micritic grains. Thickness 8.5 m.

4. Algal wackestones, in places recrystallized, with bryozoans, pelmatozoans, and brachiopods. Algae (Sample 5) include numerous *Ungdarella* sp., *Fasciella kizilia* R. Ivanova. The bed contains foraminifers and conodonts. Thickness 13 m.

5–6. Bafflestones formed mainly by *Ungdarella uralica* Masl. (Samples 74, 75). Thickness 15 m.

7–8. Boundstones formed by the algae *Fasciella kizilia* R. Ivanova with *Praedonezella cespeformis*, *Ungdarella parallela* Kulik, *Calcifolium okense* r. Bioclasts contains bryozoans, crinoids and rare foraminifers (Samples 6–10, 12a, 12b, 12v). Thickness 19 m.

Covered interval 5 m.

9. Foraminiferal-bioclastic-peloidal grainstones with fragments of brachiopods, crinoids, and corals (Sample 12). Thickness 6 m.

10. Boundstones intricately recrystallized in places with accumulations of thin-shelled ostracods, in thin sections with *Spongiostroma* structure and microbial (?) lumps, foraminifers, and brachiopods (Samples 13, 14). Thickness 20 m.

11–12. Bioclastic wackestones and packstones. Thickness 19 m.

Covered interval 7 m.

13. Bioclastic and foraminiferal-bioclastic wackestones with numerous calcisphaeres, ostracods, bryozoans, brachiopods. Thickness 4.5 m.

The thickness of the Bogdanovkian is 62 m.

The range of most characteristic microfauna is shown in Fig. 56.

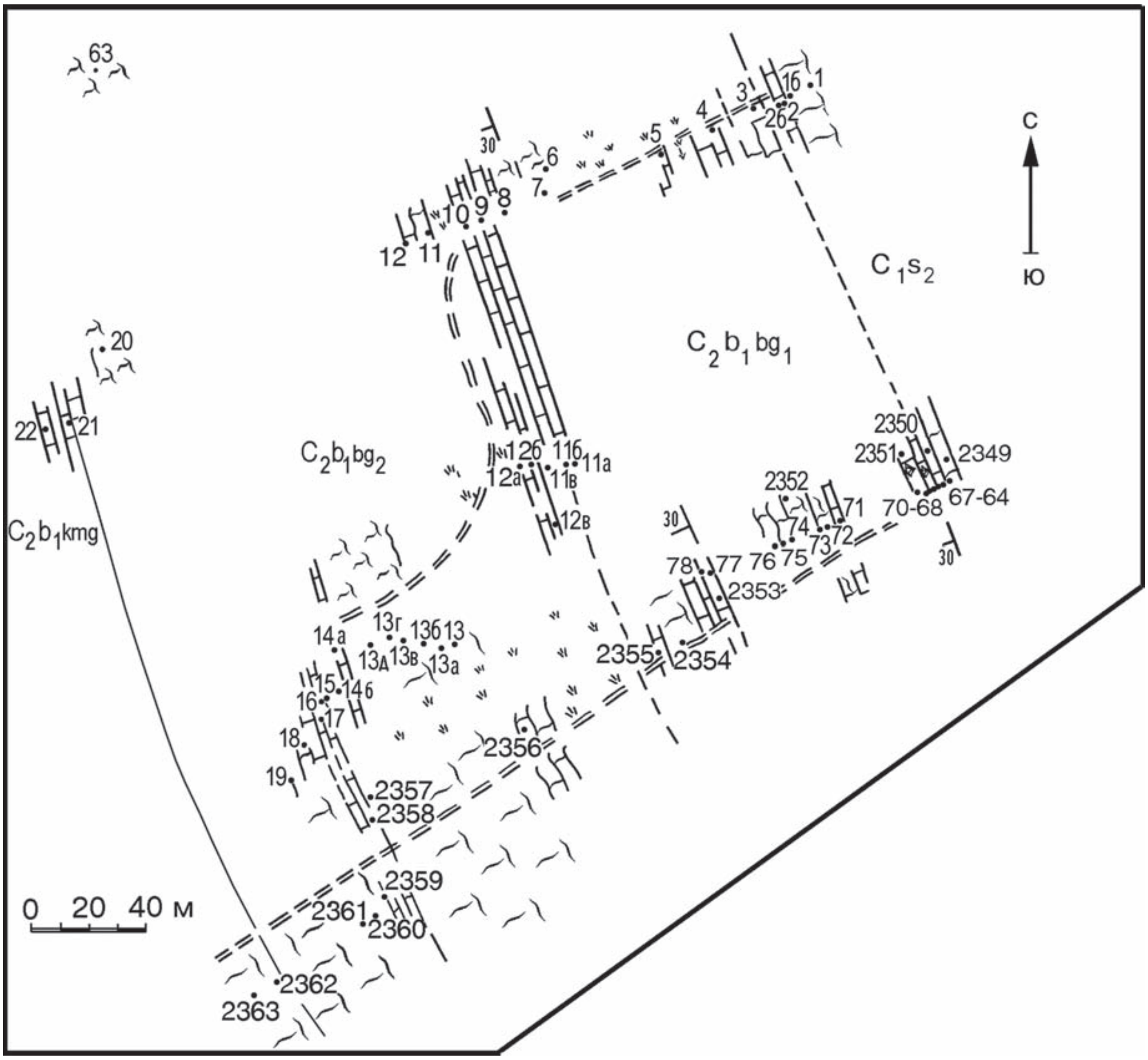


Fig. 55. Scheme of the Outcrop 1 (see Fig. 53) and samples of the Middle Carboniferous boundary beds on the left bank of the Bolshoi Kizil River (Kulagina et al., 2001, modified).

Legends see in Fig. 52.

14. Foraminiferal-fine-bioclastic grainstones and packstones with numerous encrusting foraminifers *Palaeonubecularia* sp., *Tolypammina* sp., *Ammovertella* sp. Thickness 7 m.

The apparent thickness of the entire Syuranian in this section is about 125 m.

Kamennogorian

The Kamennogorian is represented by medium-bedded wackestones and packstones with foraminifers, brachiopods, ostracods and echinoderms.

Outcrop 2

Akavassian substage

The Akavassian is represented by a bioherm massif formed by a series of bioherms (Fig. 57), which may be observed along the latitudinal direction of the steep riverbank almost right across the strike and further, after the turn to the north, almost along the strike.

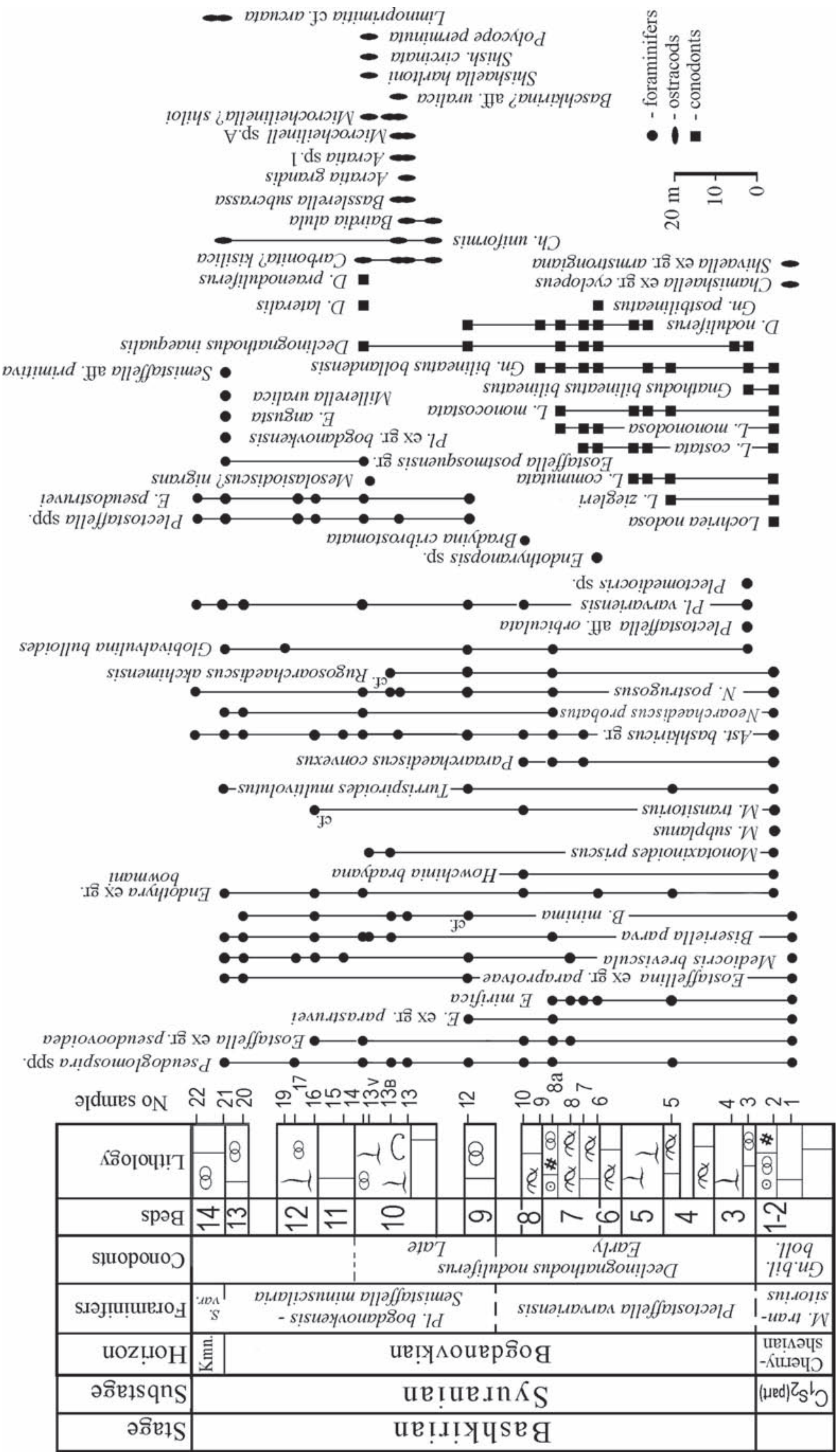


Fig. 56. Distribution of some foraminifers (Kulagina), conodonts (Pazukhin) and ostracods (Kochetova) in the Syuranian part of the section along the Bolshoi Kizil River (from Kulagina et al., 2001)

Fig. 57. Bashkirian (Akavassian) biohermal limestones on the left bank of the Bolshoi Kizil River

A small bioherm body can be observed in the mouths of the river channels upstream of the unexposed interval, at the right turn of the steep bank from the meridional to latitudinal direction. Outcrop 2 (marked points 23, Fig. 53).

1. Boundstones built by the algae *Donezella lutugini* Masl., *Beresella* sp., *Masloviporidium* sp. and stromatolites, often recrystallized with sparite cement and encrustations. Sometimes the rock is represented by carbonate breccia, with angular intraclasts of micrite and serpulid limestone, in places re-crystallized matrix produced by a decaying carbonate buildup. Fossils include crinoids, ostracods, gastropods, serpulids and assemblage of foraminifers of the *Pseudostaffella antiqua* Zone (Fig. 58). Thickness 6–7 m.

Further, the section is interrupted by a covered interval (thickness 40–50 m), probably including a tectonic dislocation.

2. At point 26 massive stromatolitic, in places strongly dolomitized, boundstones may be observed. Thin sections show stromatactis structures, in places bitumen. Thickness 4 m.

3. Along the steep bank in the latitudinal direction there are interrupted exposures of a similar massive limestone, in places strongly dolomitized, with accumulations of ostracods and serpulids. Thickness approximately 65 m.

4. Massive boundstones formed by the algae *Masloviporidium* sp. and *Donezella lutugini* Maslov in combination with radial-fibrous cement and microbial inclusions recrystallized in a lace-like pattern, with encrustations, contains banks of brachiopods, in places with numerous ostracods, rare foraminifers and ammonoids. (Samples 27, 27a). Thickness about 4 m.

5. A bioherm massif constructed by algal boundstones, ostracode, brachiopod and serpulid banks, and by stromatolite-building algae and structures such as *Spongiostroma*, in places

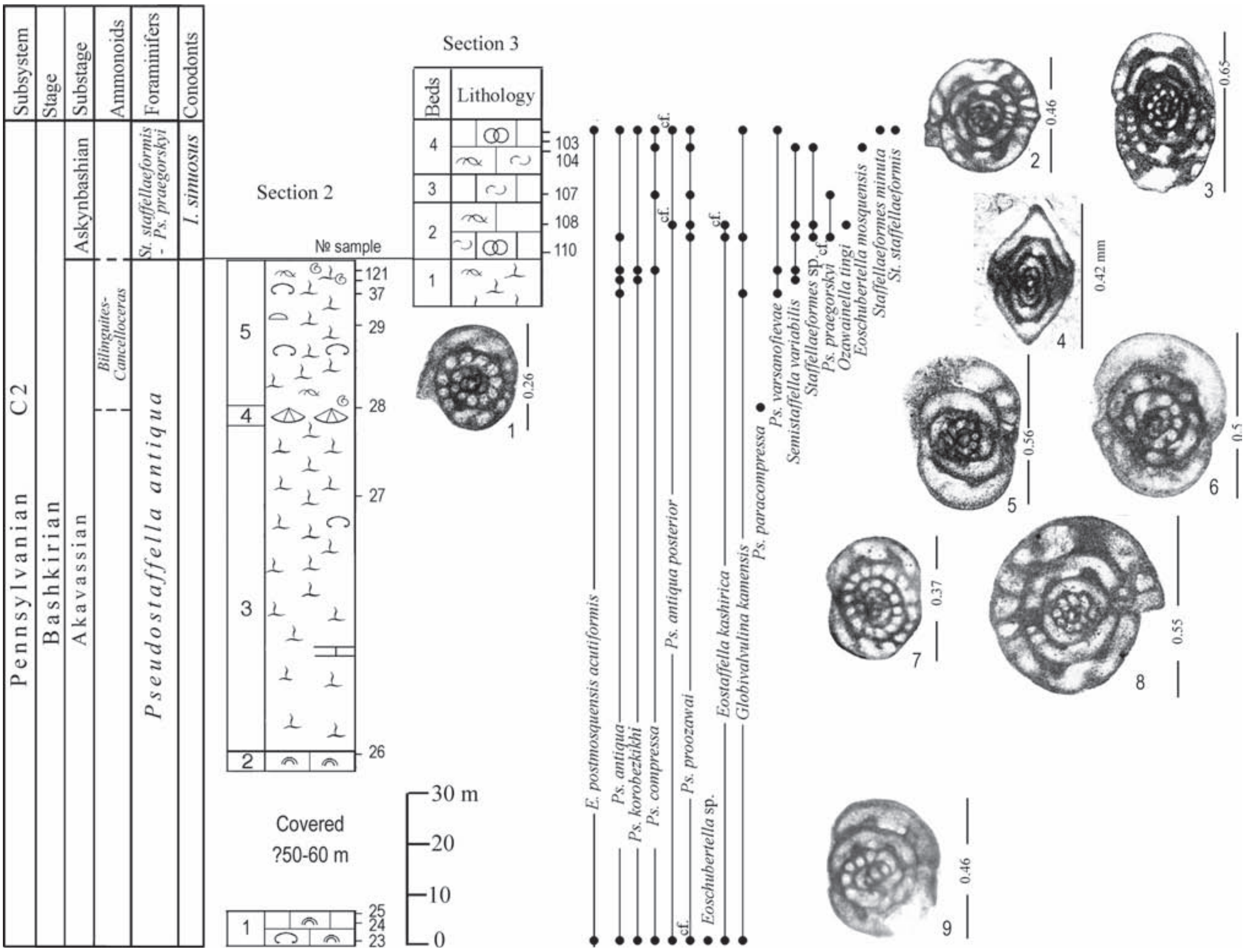


Fig. 58. Ranges of foraminifers in the Akavassian and Askynbashian strata, Bolshoi Kizil section (from Kulagina, 2007)

1 – *Semistaffella variabilis*, Sample 121; 2 – *Pseudostaffella praegorskyi*, Sample 108; 3 – *Ps. proozawai*, Sample 108; 4 – *Ozawainella tingi*, Sample 108; 5 – *Pseudostaffella compressa*, Sample 121; 6, 9 – *Ps. antiqua*: 6 – Sample 121, 9 – Sample 23; 7 – *Varistaffella varsanofievae*, Sample 37; 8 – *Ps. grandis*, Sample 37.

completely recrystallized and dolomitized, with encrustations (Samples 28, 33–37, 121, see Fig. 53). Boundstones with abundant radial-fibrous cement, embracing bioclasts (Fig. 59-2, 59-5). The foraminiferal wackestones and grainstones are occasionally present. The bioherm massif contains a limestone lens with numerous ammonoid shells. Fossils includes: algae of genera *Donezella*, *Ungdarella*, *Beresella*, *Girvanella*, and *Cuneiphycus*; foraminifers: *Pseudostaffella antiqua* (Dutk.), *Ps.* cf. *paracompressa* Saf., *Ps. compressa* (Raus.) (Fig. 59-3), *Varistaffella korobezkikh* (Raus. et Saf.), *V. varsanofievae* (Raus.); ammonoids: *Bilinguites superbilinguis* (Bisat) (Fig. 60), *Stenoglaphyrites* sp. nov., *Schartymites barbotanus* (Verneuil), and *Schartymites* sp. nov.; ostracods by the rich assemblage of the *Kirkbyella aperta* Zone (Kochetkova, 1983). Brachiopods were determined by Ya.L. Lutfullin and include *Enteletes mesolobus* (Jan), *Alphachoristites? baschkirikus* (Jan.), *Adventochoristites? moelleri* (Jan.) (Kochetkova et al., 1977). The thickness is approximately 30 m.

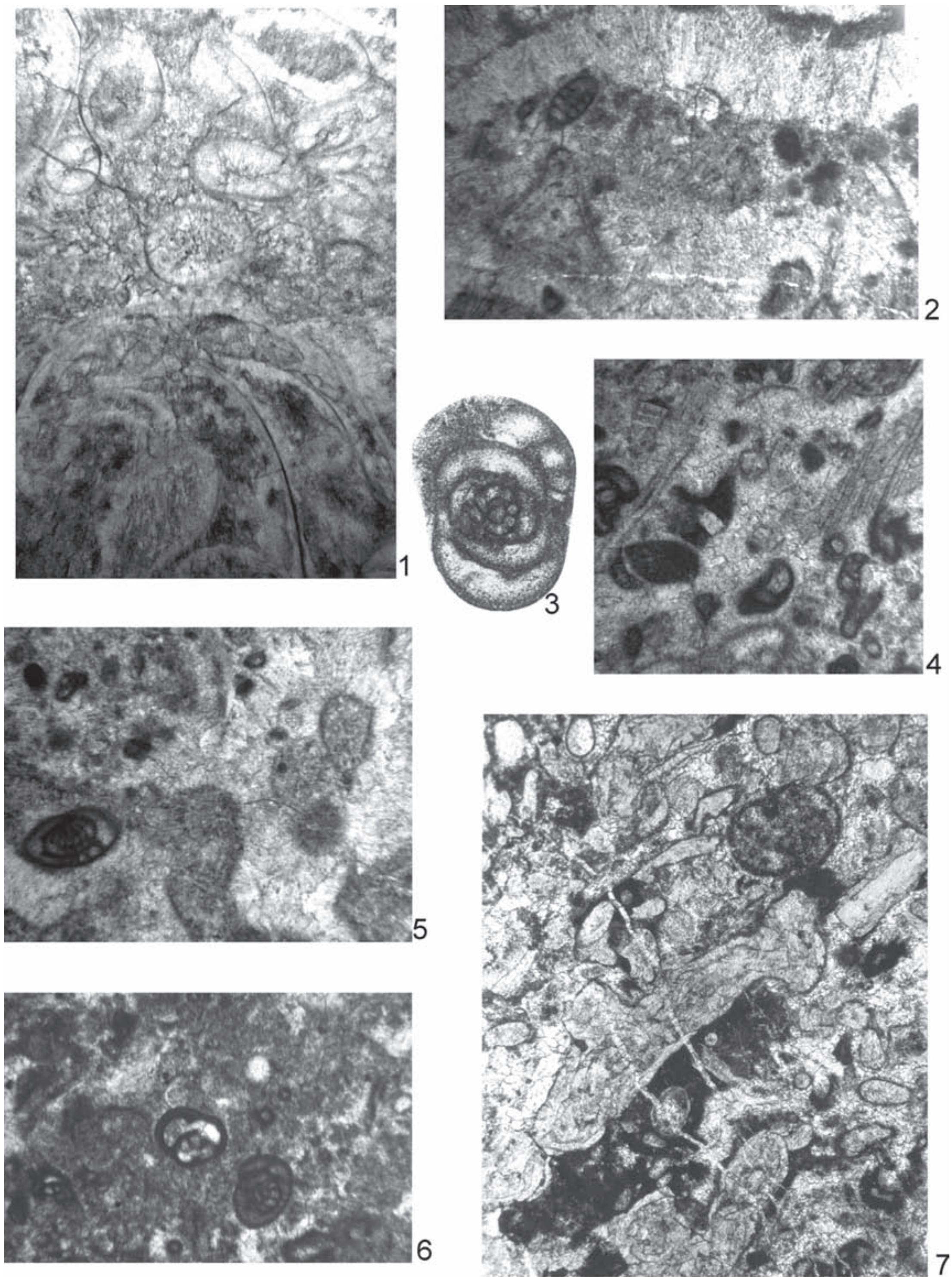


Fig. 59. Microfacies of the Serpukhovian (1) and Bashkirian (2–7) (Kulagina et al., 2009, pl. 3)

1 – Ostracod boundstone, Outcrop 2, Sample 33(2); 2, 5 – Algal boundstone formed by red alga *Cuneiphycus* in a fibrous cement; algal-microbial wackestone with small foraminifers filled up spaces between algal-fibrous inclusions, Sample 121a (4); 3 – *Pseudostaffella compressa*, ×60, specimen no. 121/1133, Sample 121v; 4 – Bioclastic-algal packstone-wackestone, partly recrystallized, filling spaces between skeletal remains that form a frame of the bioherm buildup, Sample 121A(5); 6 – Wackestones with *Tenebrozella* sp. and *Pseudostaffella* sp. Outcrop 2, Sample 37(1); 7 – Algal boundstone formed by *Fasciella kizilia*, ×25, Sample 7, Bogdanovkian.

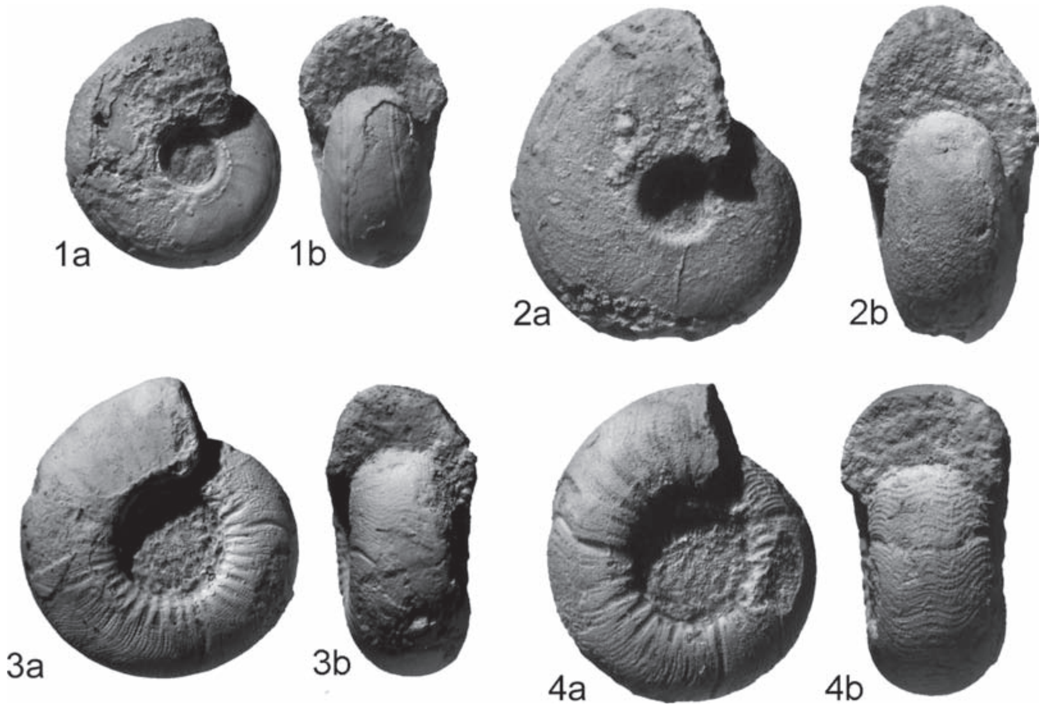


Fig. 60. Ammonoids from the Bolshoi Kizil Section. Bashkirian, Akavassian (from Kulagina et al., 2009).
1, 2 – *Bilinguites superbilinguis* (Bisat, 1924): 1 – specimen 4715/40 (×1.5), 2 – specimen 4715/39 (×2); 3, 4 – *Cancelloceras elegans* Ruzhencev et Bogoslovskaya, 1978: 3 – specimen 4715/30 (×1.5), 4 – specimen 4715/31 (×2).

The thickness of the bioherm limestones may only be estimated provisionally because the bedding is not obvious, while the thickness of the bioherm bodies constituting the massif varies. The bioherm massif extends almost along the strike to form rock exposures of the bank for ca. 2 km.

The apparent thickness of the Akavassian is 160–170 m.

Outcrop 3

This outcrop is 7 km upstream of the mouth of the Bolshoi Kizil River. In Outcrop 3, a contact of bioherm massive boundstones and overlying bedded limestones may be observed.

Askynbashian stage.

1. Algal boundstones formed by *Donezella lutugini* Masl., rare *Beresella* sp. *Cuneiphycus* sp., with rare bioclasts of crinoids, brachiopods, numerous foraminifers (Sample 111): *Pseudoglomospira* sp., *Climacammina* sp., *Globivalvulina* sp., *Asteroarchaediscus rugosus*, *Eostaffella* spp., *Pseudostaffella antiqua* (Dutk.), *Ps.* cf. *conspecta* (Raus.), *Staffellaeformes* sp. Thickness 2 m.

2. Crinoidal rudstones-grainstones with frequent foraminifers, bioclasts of pelmatozoans, bryozoans, brachiopods, and algae *Beresella* sp. Thickness 2 m.

3. Algal-foraminifers boundstones formed by *Donezella lutugini*, *Masloviporidium* sp., *Beresella* sp., *Dvinella* sp., *Pseudostacheoides* sp., *Stacheoides* sp., *Epistacheoides* sp. with bioclasts of crinoids, bryozoans, pelmatozoans, brachiopods, numerous foraminifers: *Pseudoglomospira* sp., *Globivalvulina* sp., *Eostaffella* spp., *Ozawainella* spp., *Pseudostaffella* spp., *Asteroarchaediscus* sp., and conodonts of the *Idiognathodus sinuosus* Zone. Thickness 13 m.

4. Foraminiferal bioclastic grainstones containing frequent foraminifers, bioclasts of algae, pelmatozoans, ostracods, algae *Ungdarella* sp., *Beresella* sp. (Samples 109–101). 10 m.

The thickness of the Askynbashian is 27 m.

Sedimentary settings

The carbonates of the Kizil Formation were deposited during the Late Tulian – Askynbashian. The Viséan beds were deposited on a shallow shelf, in a high wave energy environment. In the Serpukhovian and Bogdanovkian time, sedimentation occurred in the mid-shelf region near bioherm buildups and back-reef lagoons, and was characterized by low energy mudstone accumulation (facial bands 4 and 5 as in Wilson, 1975). In the Early Serpukhovian (Sunturian), small bioherms formed by the algae *Calcifolium okense*, *Ungdarella uralica* and *Praedonezella cespeformis* and brachiopod banks became widespread. In the Khudolazian time, bacterial-algal buildups with numerous encrusting foraminifers and ostracods and brachiopod banks were common.

In the Late Serpukhovian, among algae, the species *Fasciella kizilia* become dominant, and boundstones produced as a result of metabolism of cyanobacteria and bacterial encrustation, with abundant radial-fibrous cement are formed.

A similar environment was present at the beginning of the Bashkirian (Bogdanovkian). In the Late Bogdanovkian time, a low energy environment of a deepened lagoon prevailed, where micritic limestones with numerous thin-shelled ostracods and brachiopods accumulated. In the Kamennogorian, these were replaced by bedded foraminiferal packstones. In the Akavassian, bioherms reached their maximum development, with large bioherm bodies, which were possibly reef buildups formed by algae and hydroid organisms. The buildups are composed of various boundstones (stromatolitic, algal, ostracods, serpulid, or brachiopod). Of bioherm-forming algae – *Beresella*, *Donezella*, *Cuneiphycus*, *Coactilum*, *Ungdarella*, *Masloviporidium*, and *Ortonella* being widespread. There are also boundstones with an organogenic texture formed by stromatolites and frame-building algae *Spongiostroma*-like structures, bacterial inclusions. Limestones of organic origin (boundstones) of all types contain many bacterial inclusions and abundant radial-fibrous cement. Grainstones are subdominant.

In the Akavassian, we observed a limestone lens containing numerous ammonoid shells enclosed in bioherm rocks and connected by radial-fibrous cement. The lens is also in contact with grainstones and boundstones. No other fossils, apart from ostracods, are present. It is possible that algal bioherms were a suitable ammonoid habitat, while their shells were carried post-mortem by currents toward the base of the buildup and accumulated in local depressions, to subsequently become a substrate for a new buildup.

Day 4. August 19
Stop 7. Dzerzhinka (Popovskiy) Section. D–C boundary

Location and brief information

The most complete section of the D–C boundary beds on the eastern slope of the South Urals, 5 km south of the town Verkhneuralsk, near the village of Dzerzhinka (Popovskiy) (Fig. 61). The Upper Devonian (Famennian) beds are here represented by carbonates with cephalopods, and the Lower Carboniferous beds are carbonate-siliciclastics.

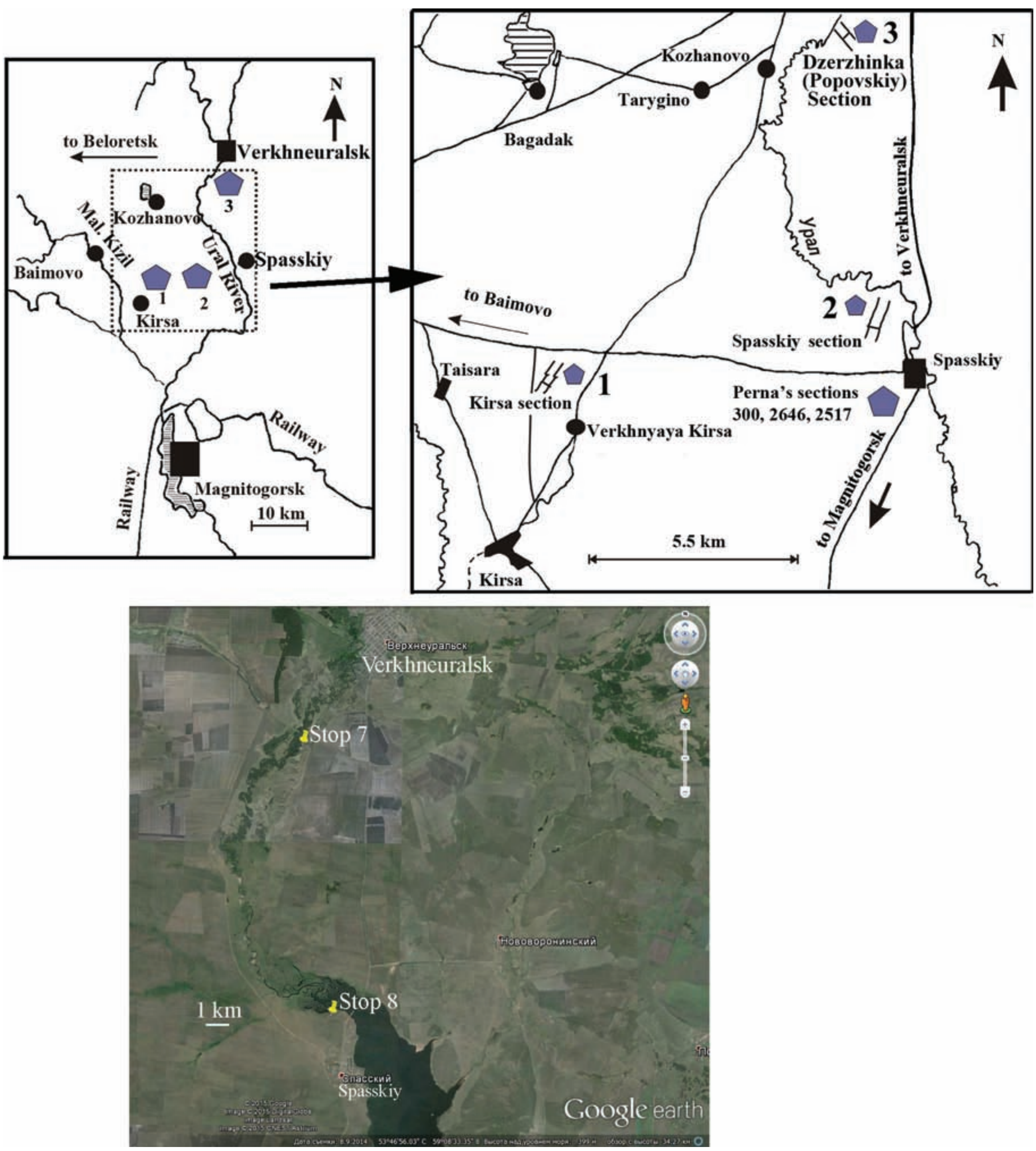


Fig. 61. Location of the D–C boundary sections

Historical Overview

Karpinsky (1885) was the first to describe limestone beds exposed near the village of Popovskiy and listed the Upper Devonian cephalopods and brachiopods. Tokarenko (1903) studied this fauna based on the collections of Stuckenberg and Janischewsky and considered it Upper Devonian. Perna (1912, 1914, 1915) also dated the collections Upper Devonian monographically described ammonoids and trilobites. Librovitch (1944) dated these beds as Famennian. Perna subdivided the limestones into several "horizons", of which the lower three (α, β, γ) he correlated with the *Cheiloceras*, *Prolobites* and *Laevigites* zones of Westphalia and Poland. Plyusnin & Plyusnina (1962) assigned the limestones with ammonoids, brachiopods, *Endothyra* ex gr. *communis* Raus. and overlying clastic limestones to the Lower Carboniferous Etroeungt Zone.

Later Plyusnina (1972–1974) raised the D–C boundary to the base of the horizon of fine-crystalline and crinoidal limestone forming a debris interval. Chuvashov et al. (1975) accepted the D–C boundary ate that level.

According to Malakhova (1963, 1965), limestones in this section contain a variety of Frasnian, Famennian and Tournaisian fossils and are of continental Post-Viséan origin. Differing view on the dating of beds and the position of the D–C boundary in this section is to a large extent connected with poorly studied geology of this region and understudied aps in the succession.

We biostratigraphically examined the section focusing on the rock lithology and attitudes, relationships of beds, comprehensive study of fossils. The lithological description was provided by Kochetkova and Arzhavitina, Lutfullin studied brachiopods, Kochetkova studied ostracods, Pazukhin and Kononova studied conodonts. Reitlinger and Arkhipova identified foraminifers and algae, and Bogoslovsky identified cephalopods.

Characteristics of the section and fossils

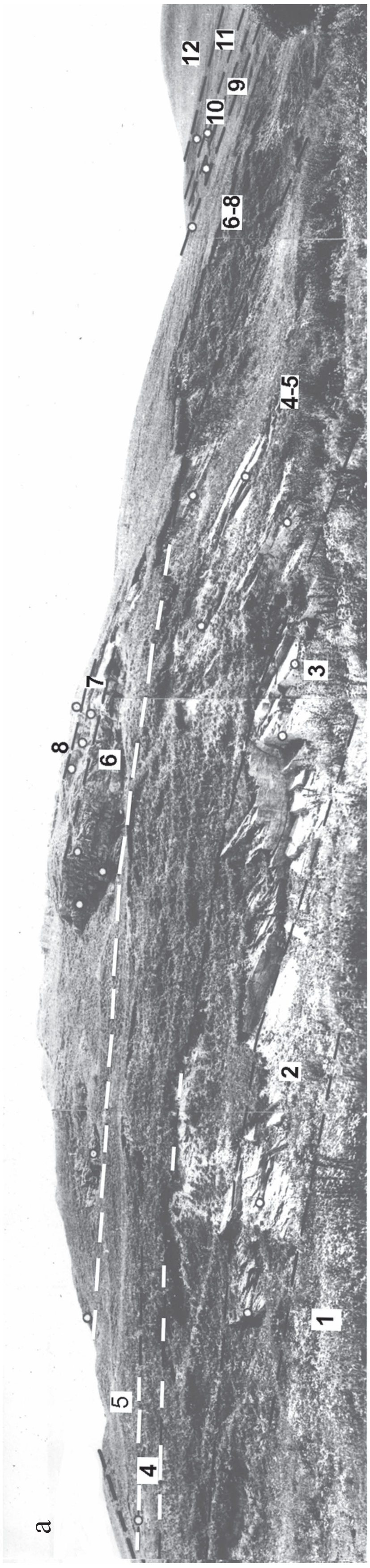
Limestones croup out in the sections and quarries on the left bank of the Ural River, 120–150 m southwest of the village of Dzerzhinka, while the top of the hill is composed of sandstones and spongolite shale. All rocks dip at 10 to 30° to the west (azimuth 260 to 240°). A very shallow synclinal fold is developed in the limestone beds at the base of the slope. In the northern side of the outcrop Plyusnina (1973) noted faults, which apparently caused the block structure of this region.

The section of the southern block is considered below. Along the left bank of the Urals River and up the slope, the following beds are exposed (Fig. 62, 63):

1–2. Loose debris (4 m) and bedrock exposures of grey thinly bedded, algal and bioclastic, in places re-crystallized limestone with *Shurygia flabelliformis* Antr., *Girvanella*, *Nodosinella*, foraminifers *Bisphaera irregularis* Bir., *B. elegans* Viss., and ostracods *Microcheilinella* aff. *sibirica* Busch., *Carbonia* aff. *inversa* Rome, *Bairdiacypris orientalis* Sam. et Smir., *B. aduncus* Netch., *B.* aff. *egorovae* Rozhd., and *Bairdiacypris* sp. In the middle part of the bed, limestones dip at 10° to the west (azimuth 240°), at the top dip at 30° to the west (of 250°). Visible thickness 11 m.

3. In a small quarry in the lower part of the slope – limestone grey, moderately thickly bedded, in places algal, with infrequent algae *Kamaena* sp. and foraminifers *Bisphaera elegans*

a



b

Fig. 62. Section of the Devonian-Carboniferous boundary beds near the village of Dzerzhinka

a – from Kochetkova et al., 1980, with beds numbers and sampling levels indicated; b – photograph by Kulagin, 2015.

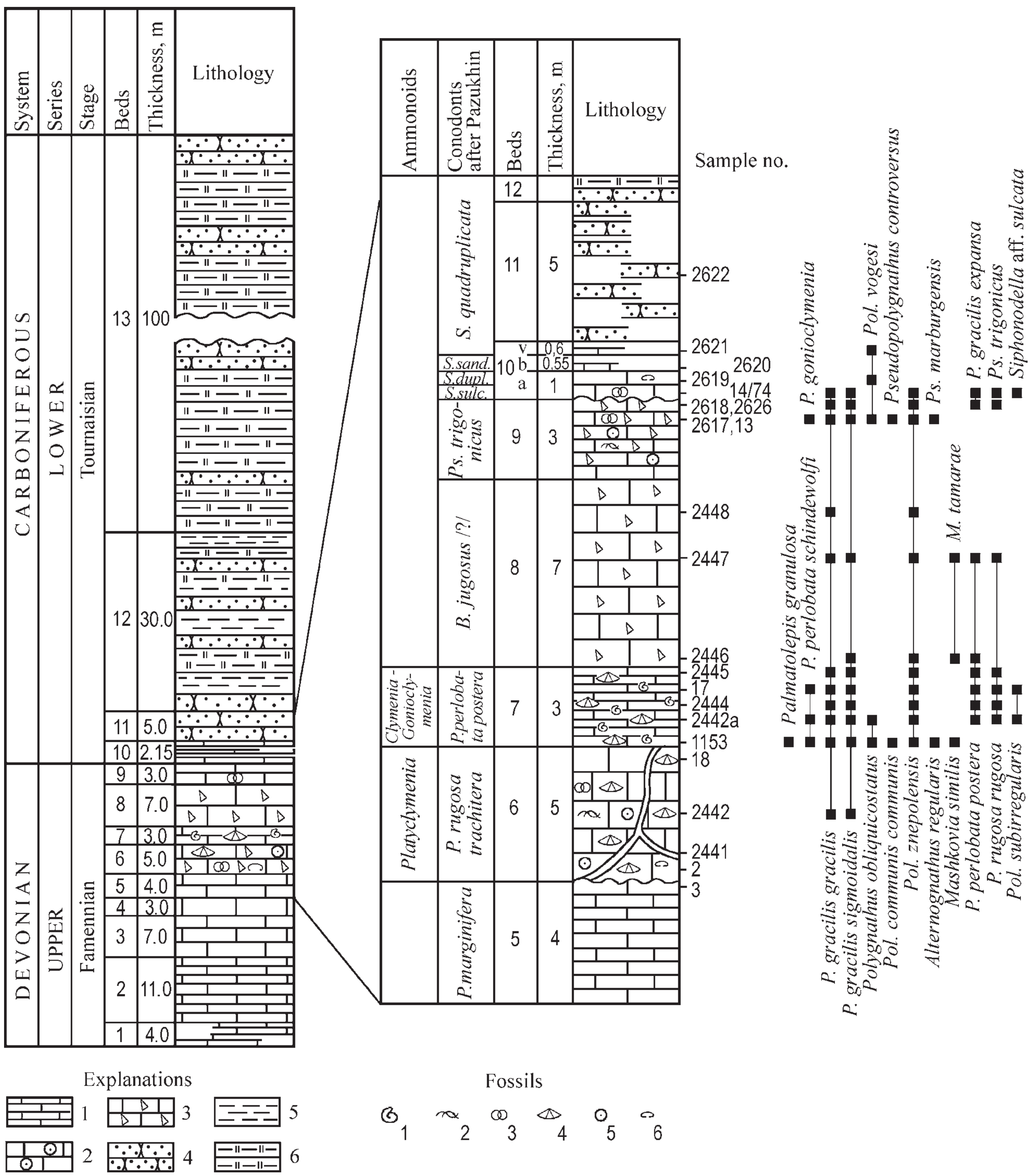


Fig. 63. Range of conodonts in the Popovskiy Section (according to Pazukhin in Kochetkova et al., 1980 and unpublished data)

Viss., *B. grandis* Lip. The limestones form a shallow syncline. At the top of the beds, the dip is 30 to the west (of 260). Thickness 7 m.

4. Limestone grey, algal, bioclastic (Fig. 64), with clay stains, with nodular bedding planes, in the upper part with foraminifers *Bisphaera irregularis* Bir., *B. elegans* Viss., ostracods

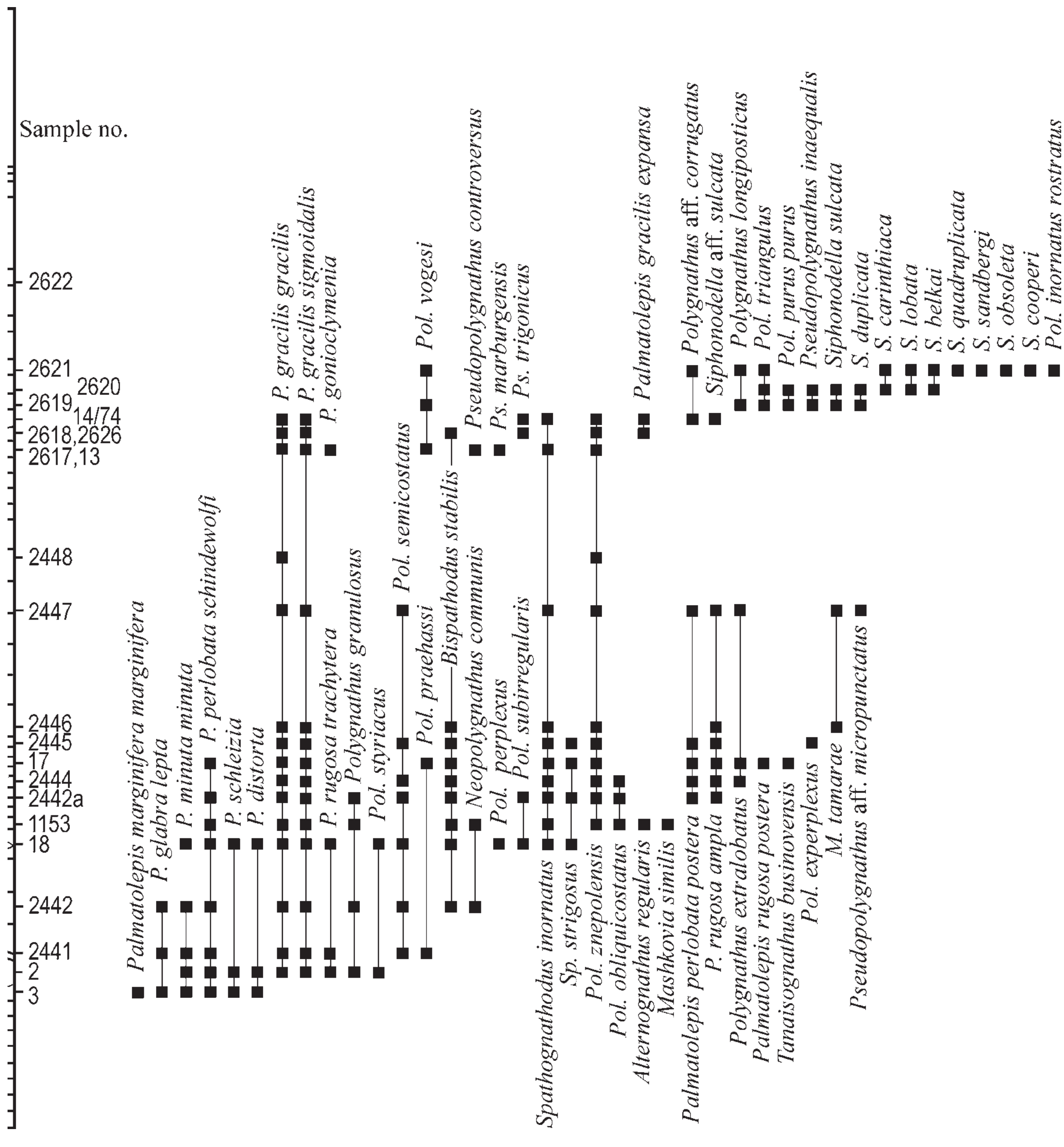


Fig. 63. Continuation

Microcheilinella aff. *sibirica* Busch., *Carbonita* aff. *inversa* Rome, *Bairdiacypris orientalis* Sam. et Smir., *B. aduncus* Netch., *Acratia siratchoica* Eg., *Bairdia referta* Rozhd. Dip is 30 to the west of 260. Thickness 3 m.

5. Covered slope, in the north with a small exposure of light grey bioclastic limestone with trilobites and ostracods *Famenella* sp., *Bairdia insolita* Kotsch., conodonts *Ozarkodina homoarcuata* Helms, *Palmatolepis distorta* Br. et M., *P. glabra lepta* Ziegl. et Hud., *P. glabra pectinata* Ziegl., *P. glabra prima* Ziegl. et Hud., *P. marginifera* Helms, *P. minuta minuta* Br. et M., *P. perlobata schindewolfi* Müller, *P. schleizia* Helms, *Polygnathus glaber bilobatus* Ziegl., the assemblage typical of the upper part of the *Palmatolepis marginifera* Zone, which in the South Urals is recognized in the upper Makarovian Horizon and lower Murzakae-

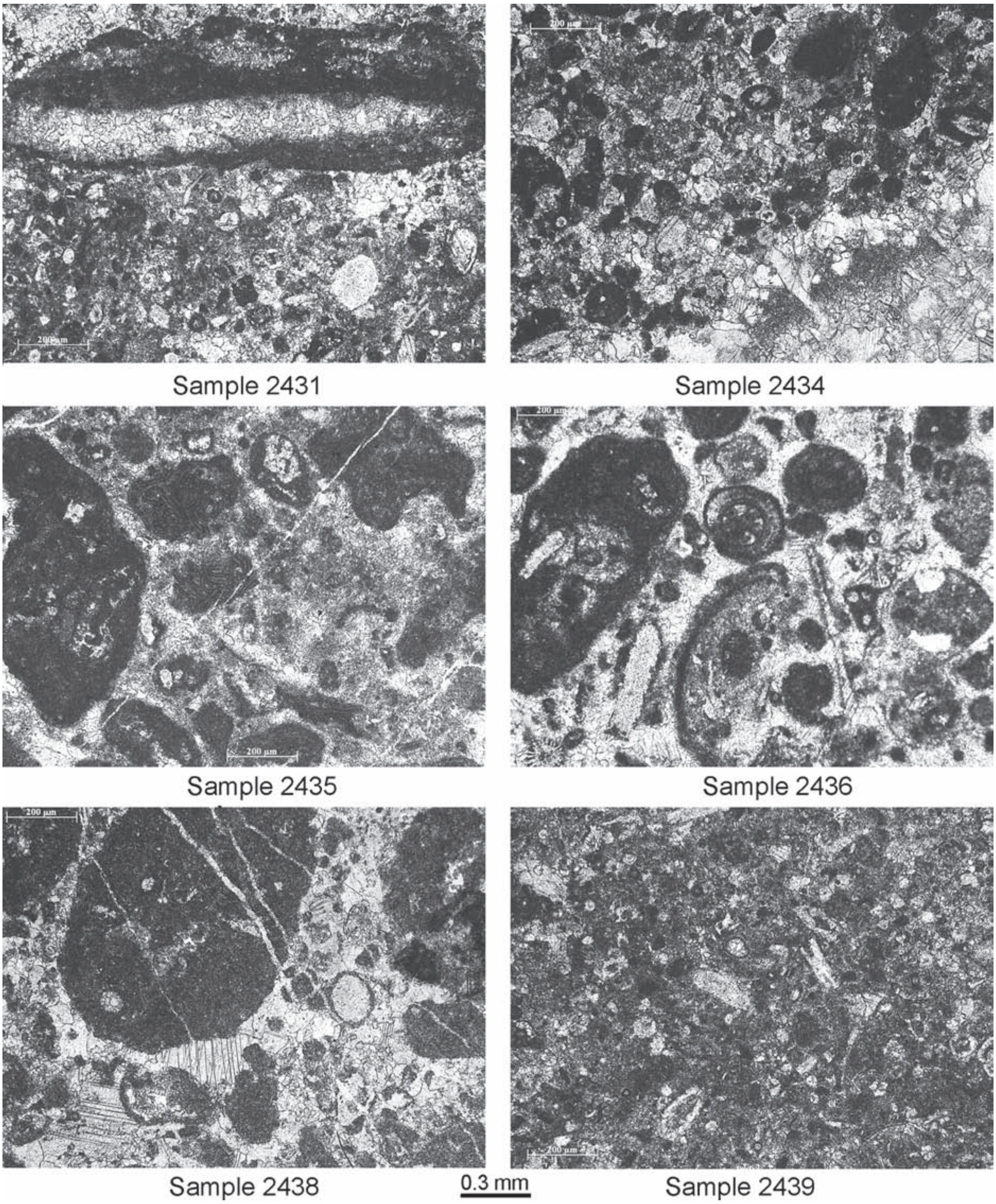


Fig. 64. Microfacies from the Dzerzhinka Section, Famennian, beds 1–4.

For Figs. 64–66 scale bar – 0.3 mm (compiled by Gorozhanina and Kulagina)
Sample 2431 – bioclastic packstone with intraclasts;
Sample 2434 – bioclastic packstone;
Sample 2435 – intraclastic pack-grainstone;
Sample 2436 – bioclastic grainstone with ooids and micritic intraclasts;
Sample 2438 – bioclastic packstone with micritic intraclasts with calcisphaeres;
Sample 2439 – algal-bioclastic pack-wackestone.

vian Horizon (Famennian) (Kononova, 1975). The limestones dip to the west (240°) at 20°. Thickness 4 m.

6. Limestones grey, light-grey, pinkish, in the upper part white, thickly and medium-bedded, crystalline, algal, bioclastic with numerous algae and crinoids, and brachiopod accumulations. The limestones crop out in the upper part of the slope as individual blocks, with varying attitudes. In the largest southern block the dip is 15, the azimuth is 180; in the middle the dip is 20, the azimuth is 220, and in the most northerly block the dip is 20, and the azimuth 40.

Limestones of all three blocks contain abundant fossils. The southern block yielded algae *Girvanella*, *Nodosinella*, *Dasycladacea*, foraminifers *Quasiendothyra communis* Raus., *Parathurammina suleimanovi* Lip., *Archaesphaera minima* Sul., brachiopods *Mesoplica popovskaensis* Lutf., *Plicatifera* cf. *kalmiussi* (Liss.), *Camarotoechia domgeri* (Tchern.), *Pugnax* sp., *Cyrtospirifer* aff. *ziganensis* (Krest. et Karp.), *Tenticospirifer* aff. *tychtensis* Besn., *Mucrospirifer* cf. *tylothyriformis* (Krest. et Karp.); ostracods, in the lower part *Selebratina* aff. *pauca* Shev., *Bairdiacypris orientalis* Sam. et Smirn., *Bairdia insolita* Kotsch., *Microcheilinella* aff. *sibirica* Bush., in the upper part, *Bairdia lipinae* Kotsch., *B.* aff. *referta* Rozhd; conodonts *Ozarkodina homoarcuata* Helms, *Palmatolepis glabra lepta* Ziegl. et Hud., *P. glabra prima* Ziegl. et Hud., *P. gracilis gracilis* Br. et M., *P. gracilis sigmoidalis* Ziegl., *P. minuta minuta* Br. et M., *P. perlobata schindewolfi* Müller, *P. rugosa trachytera* Ziegler, *P. schleizia* Helms, *Polygnathus granulosus* Br. et M., *Po. perplexus* (Thomas), and *Roundia aurita* Sann., typical of the conodont *Scaphignathus velifera* Zone, characterizing the Murzakaevian Horizon and characteristic of the ammonoid Platyclymenia Genozone. At the very top of this block, occasional *Polygnathus styriacus* Ziegl., are found along with the above listed conodonts. According to Ziegler (1962) this is indicative for the upper part of the *Scaphignathus velifera* Zone. Limestones of the middle and northern blocks contain conodonts, ostracods and brachiopods similar to those found in the southern block. The middle block contain the foraminiferans *Quasiendothyra communis* Raus., *Septaglomospiranella primaevae* Raus., *Parathurammina suleimanovi* Lip., and especially importantly *Maternella* cf. *hemisphaerica* (R. Richter), *M.* cf. *rotundata* Tschig. The latter in European Russian are usually present in the *Gonioclymenia* Genozone.

7. Limestones of the southern block are overlain by grey, laminated limestones, ferruginous in cracks and fissures, algal, bioclastic, in the middle part with abundant randomly oriented fossils (brachiopods, ammonoids, bivalves, trilobites, solitary rugosae, plants, fossilized wood, etc.) (Fig. 65). Thickness 3 m. Brachiopods: *Mesoplica popovskaensis* Lutf., *Cyrtospirifer* aff. *ziganensis* (Krest. et Karp.), *Tenticospirifer* aff. *tychtensis* Besn., ostracods *Ochescapha* aff. *leonidovkensis* (Tschig.), *Microcheilinella* aff. *sibirica* Bush., *Microcheilinella* sp. 1, *Barjatinella prosolida* Kotsch., ammonoids *Prionoceras divisum* (Munst.), *Cymaclymenia barbarae* (Loewinson-Lessing), *Platyclymenia ruedemanni* Wed., *Protoxyclymenia dubia* (Loewinson-Lessing), *Kosmoclymenia sedgwicki* (Munst.), which indicate the upper part of the *Platyclymenia* (IV) Genozone (*annulata*), and the lower part of the *Clymenia-Gonioclymenia* (V) Genozone. Conodonts *Bispathodus stabilis* (Br. et M.), *Ozarkodina homoarcuata* Helms, *Palmatolepis gracilis gracilis* Br. et M., *P. gracilis sigmoidalis* Ziegl., *P. perlobata schindewolfi* Müll., *P. rugosa ampla* Müll., *P. rugosa postera* Ziegl., *Polygnathus granulosus* Br. et M., *Po. hassi* Helms, *Po. irregularis* (Thomas), *Po. nodocostatus nodocostatus* Br. et M., *Po.* aff. *siphonellus* Druce, *Po. styriacus* Ziegl., *Po. znepolensis* Spas., *Spathognathus inornatus* (Br. et M.), *S. strigosus* (Br. et M.), indicating the *Polygnathus styriacus* Zone.

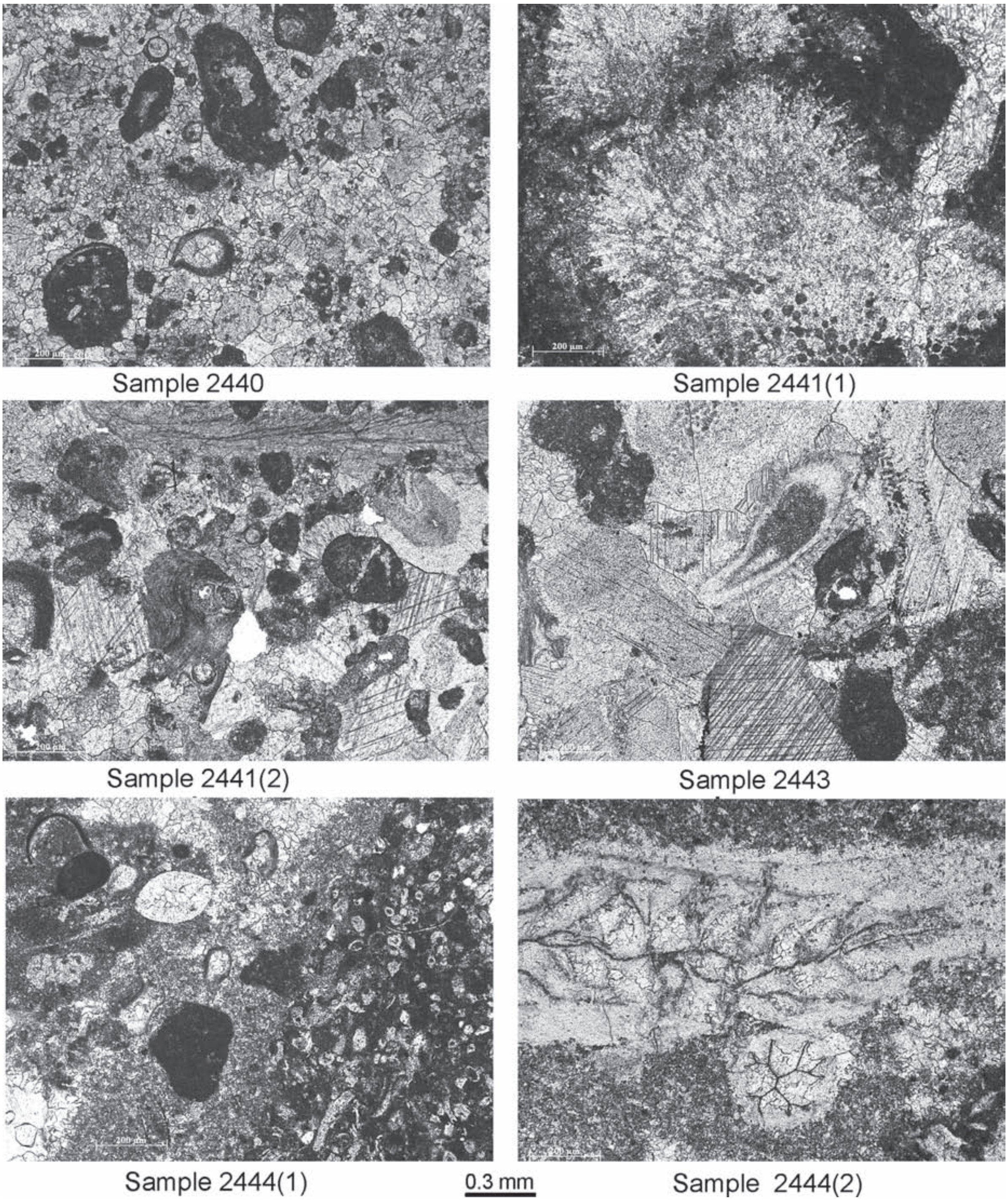


Fig. 65. Microfacies from the Dzerzhinka Section, Famennian, beds 5–7 (compiled by Gorozhanina and Kulagina)

Sample 2440 – bioclastic intraclastic grainstone;
Sample 2441(1) – alga *Solenopora* sp. in bioclastic-intraclastic grainstone;
Sample 2441(2) – recrystallized bioclastic intraclastic grainstone with brachiopod shells (top)
Sample 2443 – crinoidal grainstone with intraclasts;
Sample 2444(1) – limestone breccia with clasts of bioclastic wackestone with ostracode (left), algal packstone (right), and dark micritic intraclasts (centre) in sparitic cement;
Sample 2444(2) – coral fragment *Mariaephyllia* sp. in limestone breccia (determination by D. Weyer).

8. Up the slope and along the strike of Beds 6 and 7, there are limestones grey, medium- and coarse-clastic, thickly bedded. Variously rounded fragments are composed of grey and dark grey algal limestone, in places coarsely crystallized. The cement is crystallized dolomitized, argillaceous carbonate, which constitutes a small portion of the rock matrix. These limestone crop out at the very top, forming a flattened cap of the slope. Cement contains crinoidal and bryozoan fragments, and algal debris *Menselina clatrata* Antr. Fragments contain ostracods *Bairdiacypris orientalis* Sam. et Smir.; conodonts *Bispathodus stabilis* (Br. et M.), *Palmatolepis gracilis gracilis* Br. et M., *P. gracilis sigmoidalis* Ziegl., *P. rugosa ampla* Müll., *P. rugosa postera* Ziegl., *Polygnathus znepolensis* Spas., *Pseudopolygnathus* aff. *micropunctatus* Bish. et Ziegl., *Spathognathodus inornatus* (Br. et M.), characteristic of the *Polygnathus styriacus* conodont Zone. Thickness 7 m.

9. Up the section, there is an exposure in a shallow gully of a brownish-grey limestone, laminated, in places algal, in the middle part with a bed of 1-m thick finely-clastic limestone. Dip azimuth 250, angle 20. The thickness of the exposed part of the bed is not more than 3 m. Fossils include: algae *Shurygia* sp., *Rhabdoporella melekensis* Kul., foraminifers *Quasiendothyra communis* Raus., *Q. kobeitusana* Raus., *Q.* cf. *dentata* Durk., *Septaglomospiranella* sp., *Septabrunsia* sp. According to Reitlinger, the host rock is bioclastic sand. Fossil remains including foraminifers are rounded and partly granulated, but not redeposited. Conodonts include *Bispathodus stabilis* (Br. et M.), *Palmatolepis gracilis gracilis* Br. et M., *P. gracilis sigmoidalis* Ziegl., *Polygnathus znepolensis* Spas., *Po.* ex gr. *inornatus* Br. et Mehl, *Pseudopolygnathus trigonicus* Ziegl., characteristic of the Lytvian Horizon (*Bispathodus costatus* Zone).

10a. Ten metres along azimuth 150 (0.6 m thickness) from the previous limestone bed, grey limestone is exposed in small pits. The limestone is brownish-grey, detrital, bioclastic, micritic, algal; apparent thickness is up to 1 m. The basal layer contains the conodonts *Palmatolepis gracilis gracilis* Br. et M., *P. gracilis sigmoidalis* Ziegl., *Polygnathus znepolensis* Spas., *Pseudopolygnathus trigonicus* Ziegl., *Siphonodella* aff. *sulcata* (Hud.), a mixed assemblage of the *Bispathodus costatus* Zone (Lytvian Horizon) and *Siphonodella sulcata* Zone (Kynian Horizon). In a sample collected 0.1–0.5 m above, E.A. Reitlinger identified the foraminifers typical of the Upper Famennian. This is supported by the conodonts represented in the overlying bed 5 typical of the upper subzone of the *Palmatolepis marginifera* Zone or the ammonoid *Platyclymenia* Genozone (Kononova, 1975).

Limestones of Beds 6, 7, 8 form a “boulder horizon” of large am small chunky limestone pieces. Large limestone pieces with abundant, diverse brachiopods, ostracods, conodonts, and foraminifers are found at the base of the horizon (Bed 6). The foraminifers are typical of the *Quasiendothyra communis* Zone (Murzakaevian and Kushelgian Horizons) (Fig. 66, 67). Brachiopods in Beds 6 and 7 along with the species typical of the intermediate D–C boundary beds (“Etroeungt Zone”) as found e.g. on the Zigan River (*Cyrtospirifer* aff. *ziganensis*, *Mucrospirifer* cf. *subalatus*) include the Carboniferous species *Rhipidomella* cf. *michelini*, *Schuchertella* cf. *planiscula*, *Plicatifera* cf. *kalmiussi*, *Camarotoechia domgeri*. *Mucrospirifer* cf. *posterus* is a Famennian species, while ostracods are characteristic of the Lytvian Horizon (*Selebratina pauca*, *Ochescapha leonidovkensis*, *Bairdiacypris orientalis*, *Bairdia* aff. *referta*, *B. lipinae* etc. Bed 6 contains *Maternella* cf. *hemisphaerica*, *M.* cf. *rotundata*, characteristic of the *Gonioclymenia* ammonoid Genozone. The conodont assemblage from the same portion of the “boulder horizon” is typical of the *Scaphignathus velifera* Zone, which correlates with the upper part of the *Platyclymenia* Genozone and the Murzakaevian Horizon.

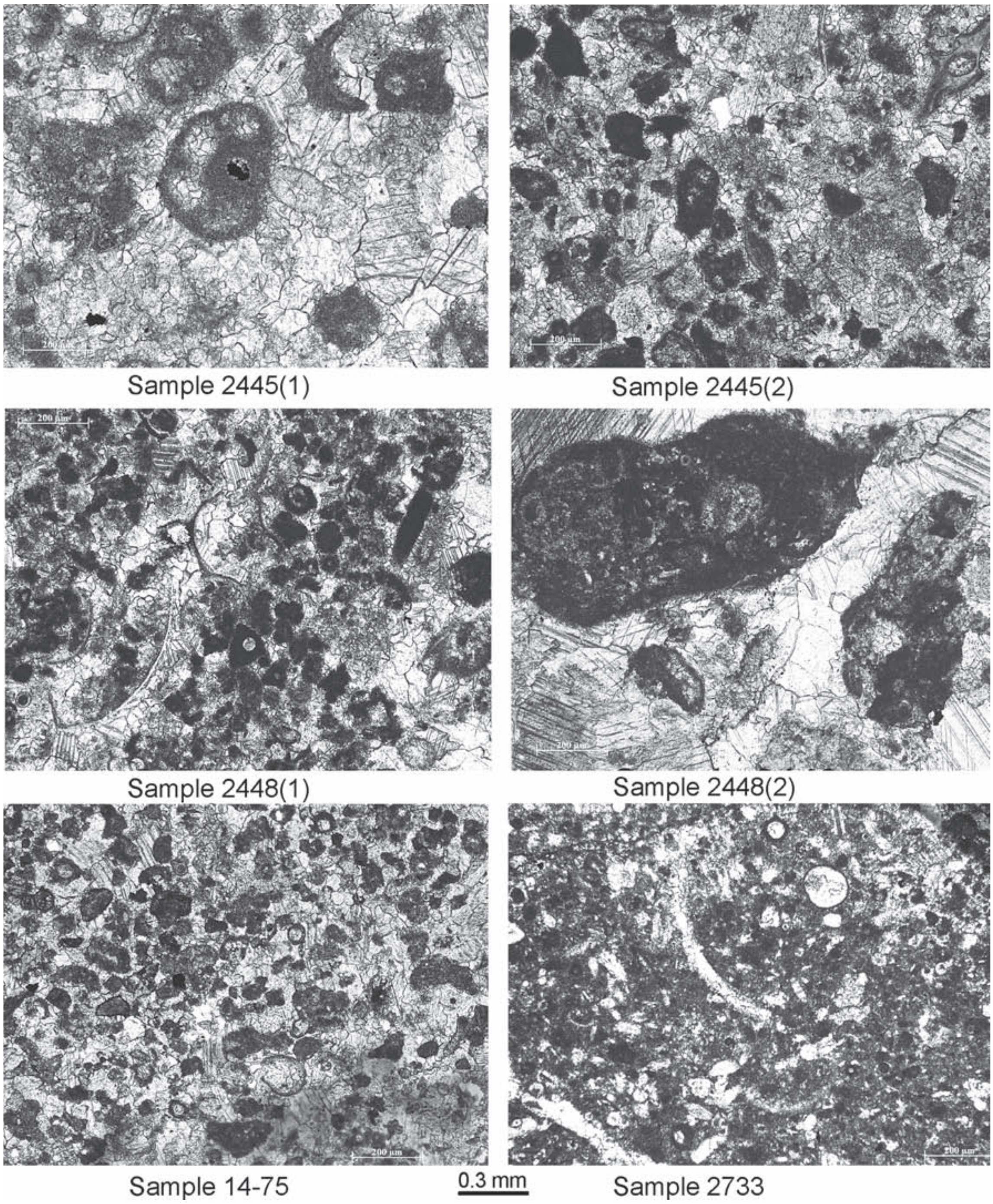


Fig. 66. Microfacies from the Dzerzhinka Section, Famennian and Tournaisian (compiled by Gorozhanina and Kulagina)

Sample 2445(1) – recrystallized bioclastic-intraclastic pack-grainstone with the foraminifera *Septaglomospiranella* sp. (centre), bed 7;
Sample 2445(2) – fine-grained intraclastic packstone with sparitic cement, bed 7;
Sample 2448(1) – fine-grained intraclastic packstone with *Vicinesphaera* sp., and thin-shell of ostracod (left) bed 8;
Sample 2448(2) – intraclasts of algal wackestone in recrystallized sparitic cement, bed 8;
Sample 14–75 – fine-grained bioclastic-intraclastic packstone with Parathuramminidae, and calcisphaeras, bed 10, Tournaisian;
Sample 2733 – bioclastic wack-packstone with *Parathurammina* sp., *Bisphaera* sp., and ostracod shell, Tournaisian.

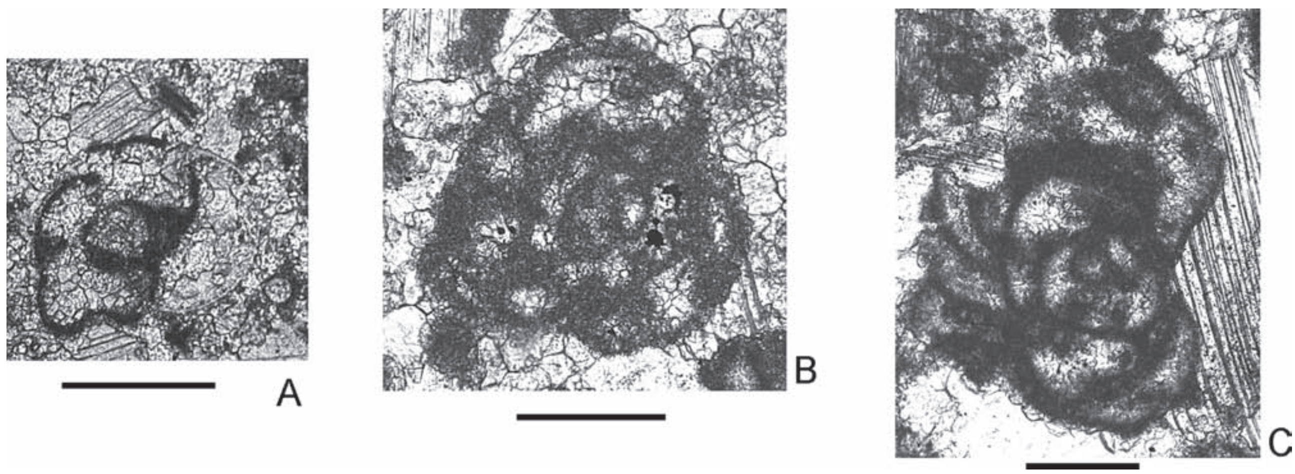


Fig. 67. Foraminifers from the Dzerzhinka Section, Famennian, scale bar 0.2 mm

A – *Tournayellina primitiva* Lip., Sample 2448(1), bed 8; B, C – *Quasiendothyra* ex gr. *communis* (Raus.); b – Sample 2445(1), bed 7, c – Sample 2448(2), bed 8.

Bed 7 shows accumulations of fragments and complete shells of ammonoids of the *Platyclymenia* and *Gonioclymenia* Genozones (Murzakaevian and Kushelgian Horizons), conodonts of the *Polygnathus styriacus* (Kushelgian Horizon).

The origin of the "boulder horizon" is not very clear, but it is most likely Lytvian. It lies below Bed 9 with foraminifers of the *Quasiendothyra kobeitusana* Zone and conodonts of the *Bispathodus costatus* Zone.

The upper part of the Lytvian and Kynian Horizons (*Siphonodella praesulcata* and *S. sulcata* zones) are probably eroded. This is suggested by the co-occurrence at the base of Bed 10 of the onodonts of the *Bispathodus costatus* and *Siphonodella sulcata* zones. Beds 10a, 10b contain ostracods, foraminifers and conodonts of the *S. duplicata* and *S. quadruplicata* zones characteristic of the middle (Upian) part of the Kynian Horizon. The siliciclastic series of the section (Beds 11, 12, 13) is probably Upper Tournaisian. In the Popovskiy section, a large portion of Upper Famennian deposits with the most abundant and diverse fossils are probably re-deposited, because of the presence of the "boulder horizon" of Lytvian age (see also Smirnov & Smirnova, 1967). On the eastern slope, the Lytvian "boulder horizon" is recorded in the Magnitogorsk Megasynclinorium – in the north (left bank of the Ural River, near the village of Kashirin), and in the south (Orsk District, Izvestkovyi Gully north of the town of Khabarnyi).

The conodont records suggest that the basal part (Malevkian) of the Kynian Horizon and upper part of the Lytvian Horizon are missing in the Popovskiy section.

Stop 8. Verkhneuralsk Reservoir near Spasskiy

Spasskiy Section. The section of Famennian limestones is approximately 2 km north of the village of Spasskiy (Perna, 1914, p. 10, no. 2528), where the light-grey limestone of the Murzakaevian Regional Stage contains *Sporadoceras muensteri* (Buch), *S. discoidale* Wedekind, *Maeneceras inflexum* (Wedekind), *Prolobites delphinus* (Sandberger), *P. atavus* Perna, *P. nanus*

Perna, *Armatites planidorsatus* (Münster), *Cyrtoclymenia involuta* (Wedekind), *C. frechi* (Tokarenko), *Pricella stuckenbergi* (Tokarenko), *P. pinnata* (Perna), *Hexaclymenia hexagona* (Wedekind), *Platyclymenia pompeckii* (Wedekind), *P. subnautilina* (Sandberger), *P. placida* (Perna), *Genuclymenia karpinskii* (Perna), *Rectoclymenia roemeri* Wedekind, *Rectoclymenia* sp., ?*Pricella orientalis* (Perna). Apart from this assemblage, Perna (1914) indicated *Pseudoclymenia drevermanni* (Born), but was not certain of the provenance of the latter specimen. If the last species is not taken into account, the above assemblage positively indicates the middle part of the *Prolobites-Platyclymenia* (*delphinus* Zone). Limestones with this assemblage were found by Perna also in the vicinity of the village of Spasskoe (nos. 300 (red limestone), 2646 and 2517). In 2517, Perna (1914) also listed *Protoxyclymenia dubia* (Loewinson-Lessing), possibly suggesting the *serpentina* Zone.

Other sections, studied by Perna

Kozhanovo. A section 3 km south of Verkhneuralsk, north of the town of Spasskoe, on the left bank of the Ural River, north of the village of Kozhanovo (loc. no. 2552 of Perna (1914, p. 2) and no. 15 of Bogoslovsky (1971). Fossils from this locality were also cited by Karpinsky (1884).

The light grey Famennian limestone rests on the Frasnian limestone and is overlain by sandstone and shale. The lower part of the Famennian beds contain abundant gastropods, trilobites, small corals, nautiloids, ammonoids *Sporadoceras muensteri* (Buch) and *Cheiloceras* sp.

This limestone corresponds to the upper part of the *Cheiloceras* Genozone from the *contiguum* to *mamilliferum* Zone inclusive and is overlain by lighter, more compact limestones with less abundant gastropods, but with numerous brachiopods, bivalves, and ammonoids. The assemblage contains: *Sporadoceras muensteri* (Buch), *S. discoidale* Wedekind, *S. clarkei* Wedekind, *Armatites planidorsatus* (Münster), *Prolobites delphinus* (Sandberger), *P. nanus* (Perna), *Cyrtoclymenia involuta* (Wedekind), *C.* ? *angustiseptata* (Münster), *Pricella stuckenbergi* (Tokarenko), ?*P. orientalis* (Perna), and *Genuclymenia karpinskii* (Perna). The above assemblage suggests the middle part of the *Prolobites-Platyclymenia* Genozone (*delphinus* Zone).

Two metres up the section, these limestones are overlain by grey and brownish-grey dense, crystalline limestone with remains of brachiopods, trilobites, bivalves and numerous ammonoids *Platyclymenia annulata* (Münster), *P. placida* (Perna) and *Protoxyclymenia dubia* (Loewinson-Lessing).

These limestones with this assemblage correspond to the middle-upper parts of the *Prolobites-Platyclymenia* Genozone (*annulata* and *dunkeri* zones).

These beds are overlain by a limestone series lacking ammonoid remains.

CONCLUSIONS

The post-congress field trip continued for four days from 16 to 19 August, 2015 and was attended by scientists from Russia, Kazakhstan, China, Germany, and Canada. The participants examined Carboniferous sections on the eastern slope of the South Urals, which span the geochronological interval from the D–C boundary (near the town of Verkhneuralsk) to the Akavassian Regional Stage of the Bashkirian Stage (Bolshoi Kizil River) inclusive. The excursion was successful, and included discussions of ongoing questions of Carboniferous biostratigraphy and lithology.

Field trip participants near Verkhneuralsk Lake

Front row, left to right: Qi Yuping (China), Nina Donova (Russia), Keyi Hu (China), Yurii Gatovsky (Russia); *back row, left to right:* Huang Xing (China), Dinara Miftakhutdinova (Russia), Elena Kulagina (Russia), Sezim Mustapayeva (Kazakhstan), Dieter Weyer (Germany), Guzel Sungatullina (Russia), Elena Gorozhanina (Russia), Vera Konovalova (Russia), Alexander Alekseev (Russia), Valeriy Gorozhanin (Russia), Barry Richards (Kanada), Svetlana Nikolaeva (Russia).

The guidebook contains new, previously unpublished data on a number of sections. The section of the Devonian-Carboniferous boundary beds near the village of Dzerzhinka was described by Kochetkova et al. (1980), but characteristic microfacies from this section are published for the first time in this volume. New original data on foraminifers and brachiopods are published for the first time from the section on the left bank of the Ural River, 600 m above the mouth of Grekhovka Creek. The Verkhnyaya Kardailovka section was a highlight of the excursion, being a candidate section for the base of the Serpukhovian GSSP. The guidebook includes a summary of the most recent research on this section by the working group on the Viséan-Serpukhovian boundary, and also a review of the history of its study. The original photographs of the microfacies in the interval 1–25 m, which includes the Viséan-Serpukhovian boundary, are published for the first time in this volume. The diverse carbonate buildups of Baskirian age cropping out on the banks of the Bolshoi Kizil and Khudolaz rivers were examined with great interest. The large exposures of various buildups show unique microbial structures and contain many fossils. The section on the Khudolaz River has long been known from unpublished geological reports, but bioherm facies from it have never previously been published. The excursion was very important for the development of the world's science, exchange of opinions and establishment of scientific connections. The re-examination of the standard and stratotype sections of the South Urals will help the global correlations, solving urgent problems of stratigraphy and development of the International Geochrolnological Scale.

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Contents

Appendix

Appendix 1

System	Series	Stage	Substage	Ammonoids Genozones	Foraminiferal Zones	Conodont Zones
CARBONIFEROUS	Upper	Gzhelian		*Shumardites-Vidrioceras*	*Daixina bosbytauensis-Globifusulina robusta*	*Streptognathodus wabaunsensis*
					Daixina sokensis	*Streptognathodus bellis*
					Jigulites jigulensis	*Streptognathodus virgilicus*
					Triticites rossicus-Rauserites stuckenbergi	*Streptognathodus vitali*
						Streptognathodus simulator
						Streptognathodus firmus
		Kasimovian		*Dunbarites-Parashumardites*	*Rauserites quasiarcticus*	*Streptognathodus toretzianus*
					Montiparus montiparus	*Streptognathodus cancellosus*
						Idiognathodus sagittalis
					Protriticites pseudomontiparus-Obsoletes obsoletus	*Streptognathodus makhlinae*
						Streptognathodus subexcelsus
	Middle	Moskovian	Myachkovian	*Pseudoparalegoceras-Wellerites*	*Fusulina cylindrica - Protriticites ovatus*	*Neognathodus roundui*
					Fusulinella bocki	*Neognathodus inaequalis*
			Podolskian		*Fusulinella colaniae - F. vozhgalensis Beedeina kamensis*	*I. podolkensis - N.medexultimus*
			Kashirian	*Paralegoceras-Eowellerites*	*Fusulinella subpulchra*	*S.concinnus - I.robustus*
					Priscoidella priscoidea	*Neognathodus medadultimus Neognathodus bothrops*
			Vereian	*Diaboloceras-Winslowoceras*	*Aljutovella aljutovica*	*Streptognathodus transitivus*
						Declinognathodus donetzianus - Idiognathoides postsulcatus
		Bashkirian	Upper	*Diaboloceras-Axinolobus*	*Verella spicata - A. tikhonovichi*	*Declinognathodus marginodosus*
				Branneroceras-Gastrioceras	*Profusulinella rhombiformis*	
					Profusulinella primitiva-Pseudostaffella gorskyi	
			Lower	*Bilinguites-Cancelloceras*	*Pseudostaffella praegorskyi-Staffelaeformes staffelaeformis*	*Idiognathodus sinuosus*
					Pseudostaffella antiqua	*Neognathodus askynensis*
				Reticuloceras-Bashkortoceras	*Semistaffella variabilis-S. minuscilaria*	*Idiognathodus sinuatus*
				Homoceras-Hudsonoceras	*Plectostaffella bogdanovkensis*	*Declinognathodus noduliferus*
	Lower	Serpukhovian	Upper	*Fayettevillea-Delepinoceras*	*Monotaxinoides transitorius*	*Gnathodus bilineatus bollandensis*
					Eostaffellina paraprotvae	?
			Lower	*Uralopronorites-Cravenoceras*	*Neoarchaediscus postrugosus*	*Lochriea cruciformuis*
		Visean	Upper	*Hypergoniatites-Ferganoceras*	*Endothyranopsis crassa-Archaediscus gigas*	*Lochriea nodosa*
				Beyrichoceras-Goniatites		*Gnathodus bilineatus bilineatus*
					Endothyranopsis compressa-Paraarchaediscus koktjubensis	*Gnathodus texanus*
			Lower		*Uralodiscus rotundus*	
					Eoparastaffella simplex-Eoendothyranopsis donica	
		Tournaisian	Upper	*Merocanites-Ammonellipsites*	*Endothyra elegia - Eotextularia diversa*	*Scaliognathus anchoralis*
						Dollymae bouckaerti
					Spinoendothyra costifera	*Gnathodus typicus*
				Protocanites-Pericyclus	*Palaeospiroplectammina tchernyshinensis*	*Siphonodella isosticha*
						Siphonodella quadruplicata
			Lower	*Protocanites-Gattendorfia*	*Chernyshinella disputabilis*	*Siphonodella belkai*
					Bisphaera malevkensis - Earlandia minima	*Siphonodella duplicata*
					Tournayellina pseudobeata-Septatournayella njumylga	*Siphonodella sulcata*

General Stratigraphic Scale of Russia (Postanovlenie…, 2003)

Appendix 2

General Stratigraphic Scale of Russia (Postanovleniya…, 2003, 2006)							Regional Subdivisions of the Urals
System	Series	Stage	Substage	Ammonoid Genozones	Foraminiferal Zone	Conodont Zone	Horizon (Regional Substage)
1	2	3	4	5	6	7	8
ARBONIFEROUS	LOWER	SERPUKHOVIAN	Upper	*Fayettevillea – Delepinoceras*	*Monotaxinoides transitorius*	*Gnathodus bollandensis*	**CHERNYSHEVKIAN** C_1s_2 *čh*
					Bradyina cribrostomata		**KHUDOLAZIAN** C_1s_2 *h*
			Lower	*Uralopronorites – Cravenoceras*	*Neoarchaediscus postrugosus*	*Lochriea ziegleri*	**SUNTURIAN** C_1s_1 *sn*
		VISÉAN	Upper	*Hypergoniatites – Ferganoceras*	*Endothyranopsis crassa – Archaediscus gigas*	*Lochriea nodosa*	**BOGDANOVICHIAN** C_1v_2 *bg*
				Beyrichoceras – Goniatites		*Lochriea mononodosa*	**AVERINIAN** C_1v_2 *a*
						Gnathodus bilineatus	**KAMENSKOURALSKIAN** C_1v_2 *ku*
					Endothyranopsis compressa – Paraarchaediscus koktjubensis		**ZHUKOVIAN** C_1v_2 *ž*
						Gnathodus austini	
						Gnathodus texanus (part)	

General Stratigraphic Scale of Russia and Stratigraphic subdivisions of the East Uralian Subregion, Lower Carboniferous

Continuation of the appendix 2

<table>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th colspan="2">8</th></tr>
<tr><td rowspan="14">CARBONIFEROUS</td><td rowspan="14">LOWER</td><td rowspan="4">VISÉAN</td><td rowspan="4">Lower</td><td rowspan="3">Ammonellipsites – Goniatites</td><td rowspan="2">Uralodiscus rotundus</td><td rowspan="4">Gnathodus texanus</td><td colspan="2">USTGREKHOVKIAN
C_1v_1 ug</td></tr>
<tr><td colspan="2">BURLIAN
C_1v_1 b</td></tr>
<tr><td rowspan="2">Eoparastaffella simplex – Eoendothyranopsis donica</td><td colspan="2" rowspan="2">OBRUCHEVKIAN
C_1v_1 o</td></tr>
<tr><td rowspan="4">Merocanites – Beyrichoceras</td></tr>
<tr><td rowspan="10">TOURNAISIAN</td><td rowspan="5">Upper</td><td>Eoparastaffella rotunda</td><td rowspan="2">Scaliognathus anchoralis</td><td colspan="2" rowspan="3">KOSVIAN
C_1t_2 ks</td></tr>
<tr><td rowspan="2">Endothyra elegia – Eotextularia diversa</td></tr>
<tr><td>Dollymae bouckaerti</td></tr>
<tr><td rowspan="3">Protocanites – Pericyclus</td><td>Spinoendothyra costifera</td><td>Gnathodus typicus</td><td rowspan="2">KIZELIAN
C_1t_2 kz</td><td>Upper</td></tr>
<tr><td rowspan="2">Palaeospiroplectammina tchernyshinensis</td><td>Siphonodella isosticha</td><td>Lower</td></tr>
<tr><td rowspan="5">Lower</td><td>Siphonodella quadruplicata</td><td colspan="2">PERSHINIAN
C_1t_2 p</td></tr>
<tr><td rowspan="3">Protocanites – Gattendorfia</td><td rowspan="2">Chernyshinella disputabilis</td><td>Siphonodella belkai</td><td rowspan="3">REZHIAN
C_1t_1r</td><td rowspan="2">Upper</td></tr>
<tr><td>Siphonodella duplicata</td></tr>
<tr><td>Bisphaera malevkensis – Earlandia minima</td><td rowspan="2">Siphonodella sulcata</td><td>Lower</td></tr>
<tr><td>Acutimitoceras</td><td>Tournayellina pseudobeata</td><td rowspan="2">GUMEROVIAN
C_1t_1 g</td><td>Upper</td></tr>
<tr><td>DEVON</td><td></td><td>D_3fm</td><td></td><td>Kalloclymenia</td><td>Quasiendothyra kobeitusana s.l.</td><td>Siphonodella praesulcata</td><td>Lower</td></tr>
</table>

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