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A CANDIDATE FOR THE GLOBAL STRATOTYPE SECTION AND POINT AT THE BASE OF THE SERPUKHOVIAN IN THE SOUTH URALS, RUSSIA

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Introduction

The Serpukhovian Stage, proposed by Nikitin [I], was re-established in the Russian stratigraphic scheme in 1974 by the Interdepartmental Stratigraphic Committee of the USSR and has become internationally recognized as the upper stage of the Mississippian Subsystem [II]. The base of the Serpukhovian has not been defined by a Global Stratotype Section and Point (GSSP) and it is one of the priorities of the Subcommission on Carboniferous Stratigraphy (SCCS) of the International Commission of Stratigraphy (ICS) to locate a suitable index for defining that boundary and establish a GSSP close to the existing Viséan–Serpukhovian boundary. In order to fulfil these goals, the Verkhnyaya Kardailovka section along the Ural River on the eastern slope of the South Urals (Baimak District, Bashkortostan, Russian Federation) and fossils within it are being intensively investigated. The Verkhnyaya Kardailovka section (figs. 1, 2) is one of the best candidates for the GSSP at the base of the Serpukhovian [III, IV, V].

Stratigraphy and sedimentology

For boundary definition, the first appearance of the conodont *Lochriea ziegleri* Nemirovskaya, Perret et Meischner, 1994 [VI] in the lineage *Lochriea nodosa* (Bischoff, 1957) [VII]– *L. ziegleri* is used at the Kardailovka section. *L. ziegleri* appears in the Venevian regional Substage of the Moscow Basin somewhat below the base of the Serpukhovian as defined by its lectostratotype by the city of Serpukhov [VIII]. In the Kardailovka section, the FAD of *L. ziegleri* lies within the *Hypergoniatites-Ferganoceras* ammonoid Genozone [IX] at 19.58 m above the section's base.

The boundary succession at Kardailovka comprises unnamed formations A to C, in ascending order, with the boundary lying in C. Upper formation A is grainstone (Plate 1, fig. 1), B is dominated by turbiditic volcanoclastics, and C comprises laminated to nodular deep-water limestone. Before 2010, the stylonodular limestone containing the boundary in formation C was well exposed but only 3 m of Viséan strata cropped out immediately below. Recent trenching exposed another 10 m of underlying Viséan carbonates in formation C and older Viséan volcanoclastics and tuffaceous shale to mudstone in formation B. The contact between formation B and underlying crinoidal lime grainstone in formation A, representing the middle Viséan Zhukovian (Tulian) regional Substage, was excavated. The boundary succession, situated in the Magnitogorsk

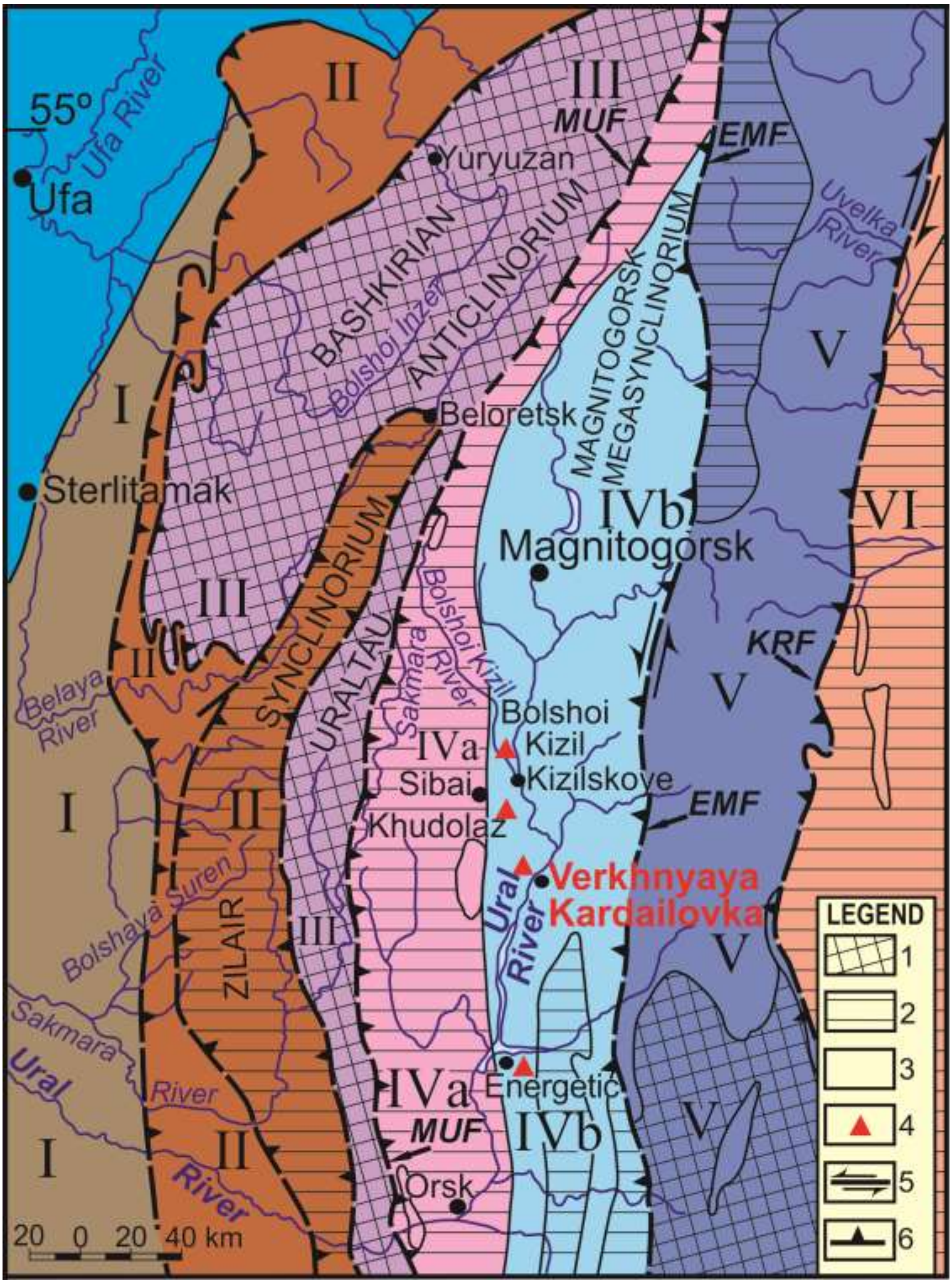

Figure 1 - Generalized map showing the geographic and tectonic setting of the Verkhnyaya Kardailovka section; base map simplified from *Stratigraficheskie*… (1993); tectonic zones and faults from Puchkov [X, XI]. Map legend: 1 – pre-Paleozoic and metamorphic rock complexes, 2 – pre-Carboniferous Paleozoic rocks, 3 – Carboniferous and younger strata and intrusives, 4 – localities, 5 – relative direction of movement, 6 – thrust fault; *MUF* – Main Uralian Fault, *EMF* – East Magnitogorsk Fault, *KRF* – Kartaly (Troitsk) Fault. I to VI are the main tectonic zones of the southern Urals: I – Cisuralia (Preuralian Foredeep); II –West Uralian Zone; III – Central Uralian Zone; IV – Magnitogorsk Zone (IVa – Western Subzone, IVb – Eastern Subzone); V – East Uralian zone and VI – Trans Uralian Zone.

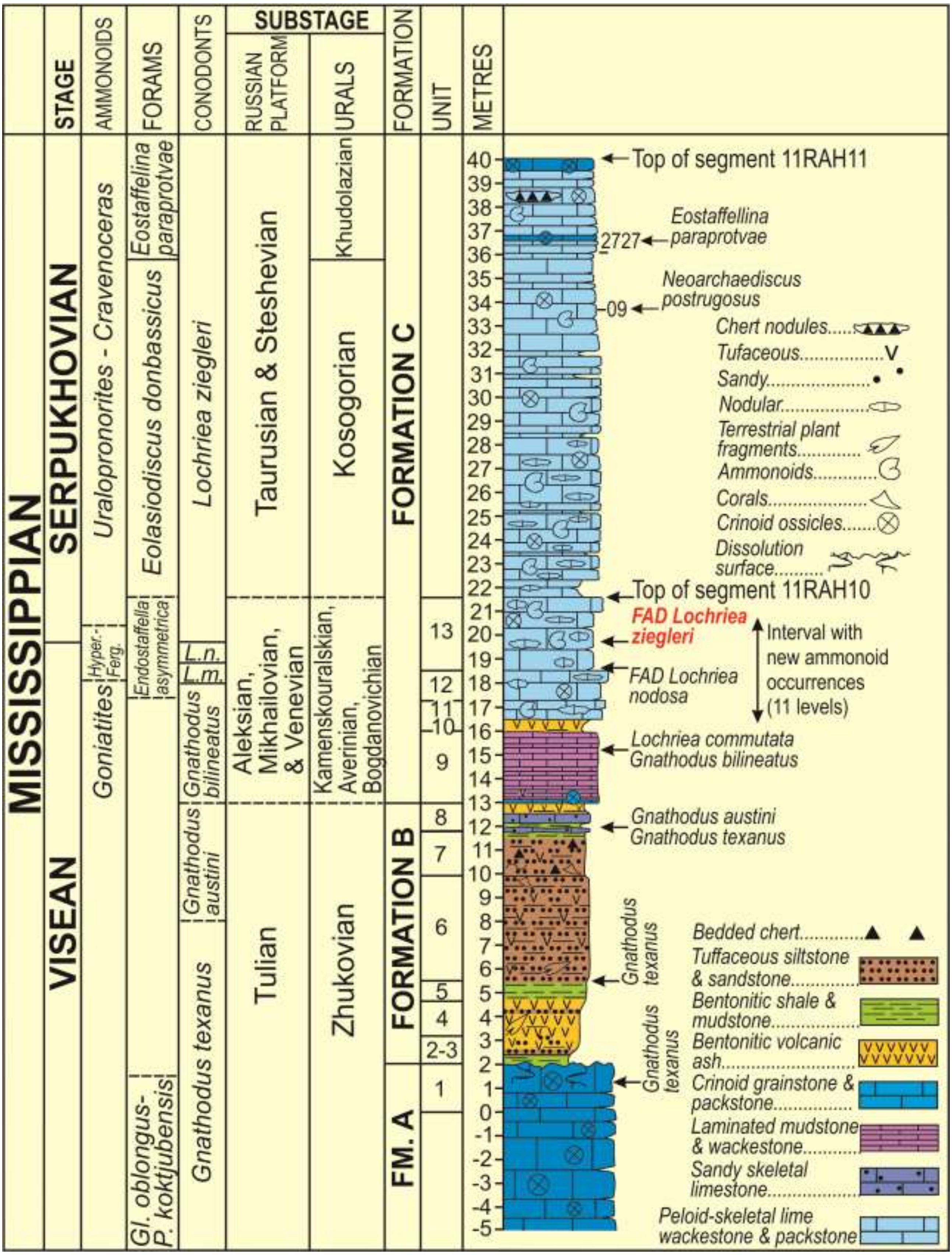

Figure 2 - Generalized stratigraphic log showing the middle Viséan to lower Serpukhovian succession in the lower and middle parts of the Verkhnyaya Kardailovka section and its relationship to the global Viséan and Serpukhovian stages, regional Russian substages and faunal zones. Abbreviations: (1) *Hyper.–Ferg.* = *Hypergoniatites–Ferganoceras*, (2) *L.n.* = *Lochriea nodosa*, (3) *L.m.* = *Lochriea mononodosa*, (4) *P.* = *Paraarchaediscus*, and (5) *Gl.* = *Glomodiscus.*

tectonic zone above the Devonian Magnitogorsk arc and Mississippian magmatic and sedimentary rift succession, was deposited in the Ural Ocean west of the Kazakhstanian continent.

In formation B, turbiditic, well-indurated, Viséan siltstone and sandstone tuff (feldspathic litharenite to arkose; Plate 1, figs. 2, 4) are interbedded with bentonitic volcanic ash and smectite- and illite-bearing shale and mudstone recording marked deepening after deposition of the neritic middle Viséan grainstone of formation A and subsequent subaerial exposure. Limestone beds, including sandy skeletal lime wackestone to packstone and pyroclast-bearing crystalline (diagenetic) limestone (Plate 1, fig. 3) occur in the unit and become more abundant upward. The lower 4.02 m of overlying upper Viséan and Serpukhovian formation C is dominated by hemipelagic, laminated lime wackestone to mudstone containing a pelagic grain association with radiolarians and cephalopods. The overlying 5.8 m of strata in lower formation C, including those in the boundary interval, are dominated by are deep-water stylonodular lime wackestone and packstone (Fig. 3) containing a pelagic radiolarian- and cephalopod-bearing grain association (Plate 1, fig. 5), elements of a heterozoan benthonic grain association dominated by crinoid debris, and a microfacies comprising intraclast lime rudstone to packstone (Plate 1, fig. 6). Lower formation C, deposited in a sediment-starved basin, contains several volcanic ash layers and one lying 1.5 m below the boundary gave a U-Pb date of $^{206}Pb/^{238}U$ of 333.87+/-0.08 Ma [XII]. Higher in the Serpukhovian, widely separated crinoidal turbidites occur and a carbonate mound shows: a massive ammonoid-rich core facies, flanking facies, and crinoidal capping facies.

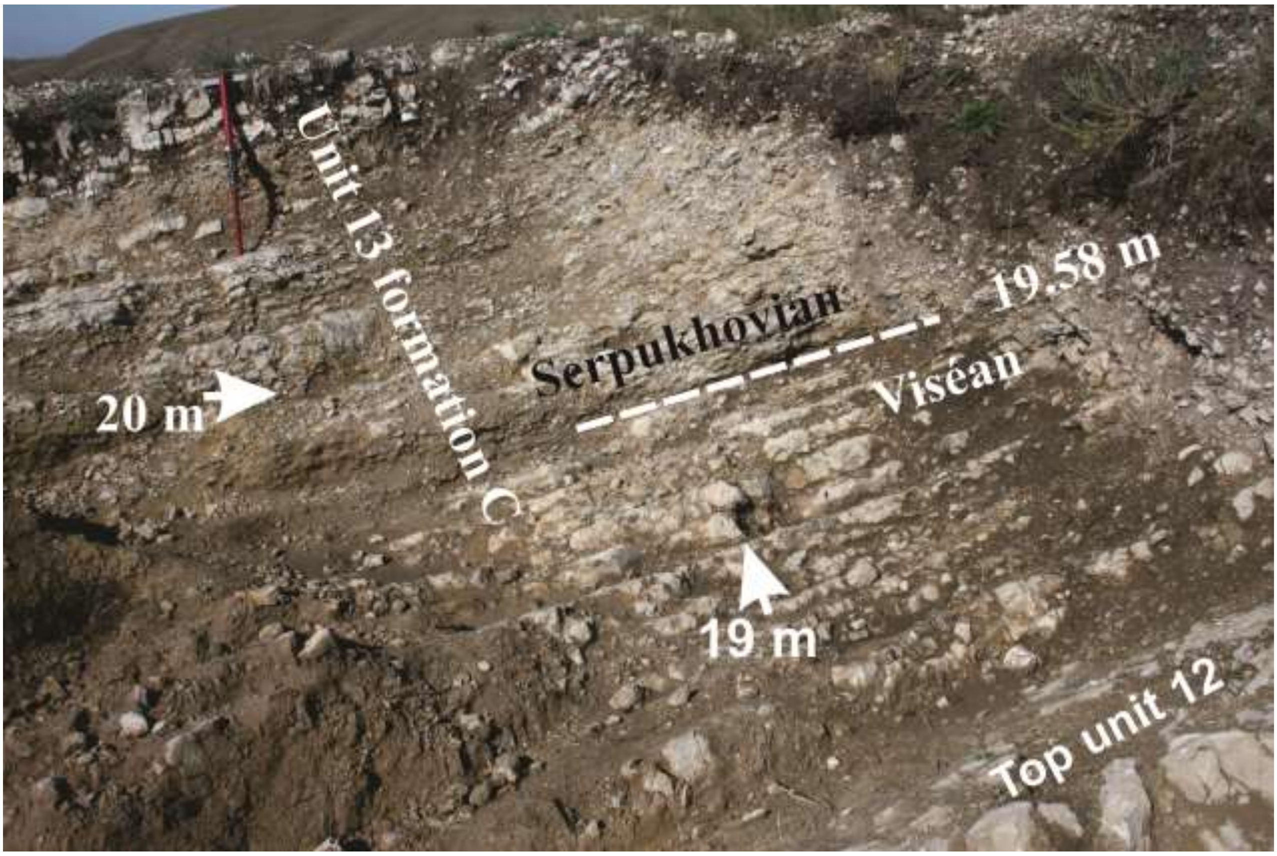

Figure 3 - The Viséan–Serpukhovian boundary level in unit 13 (18.50–21.76 m) of 11RAH10; arrows point to pins at 19.0 and 20.0 m. Interval comprises stylonodular, skeletal lime mudstone and wackestone that is of deep-water (basin) origin and contains several ammonoid horizons. Conodont data indicate the Viséan–Serpukhovian boundary, defined by the first occurrence of *Lochriea ziegleri*, lies at 19.58 m. View is toward west in trench B; Jacob's staff near top is 1 m long.

Geochemistry

The $\delta^{13}C_{carb}$ and $\delta^{18}O_{carb}$ plots lack significant excursions near the proposed boundary but show positive upward shifts in late Viséan. The $\delta^{13}C_{carb}$ plot shows a positive shift of 1‰ V-PDB (from +2 to +3‰) between 17.0 and 17.75 m (3.05 and 1.97 m below FAD L. ziegleri). On $\delta^{18}O_{carb}$ plot, a positive shift from -1.40 to -0.04‰ V-PDB occurs between 17.0 and 17.3 m and records global cooling in response to onset of main phase of late Paleozoic glaciations. The $\delta^{18}O_{apatite}$ graph displays a prominent upward shift from 19.9 to 21.1‰ V-SMOW (at 19.15 to 19.51 m) in the *nodosa* Zone immediately below the FAD of *Lochriea ziegleri* and could be a useful auxiliary boundary index.

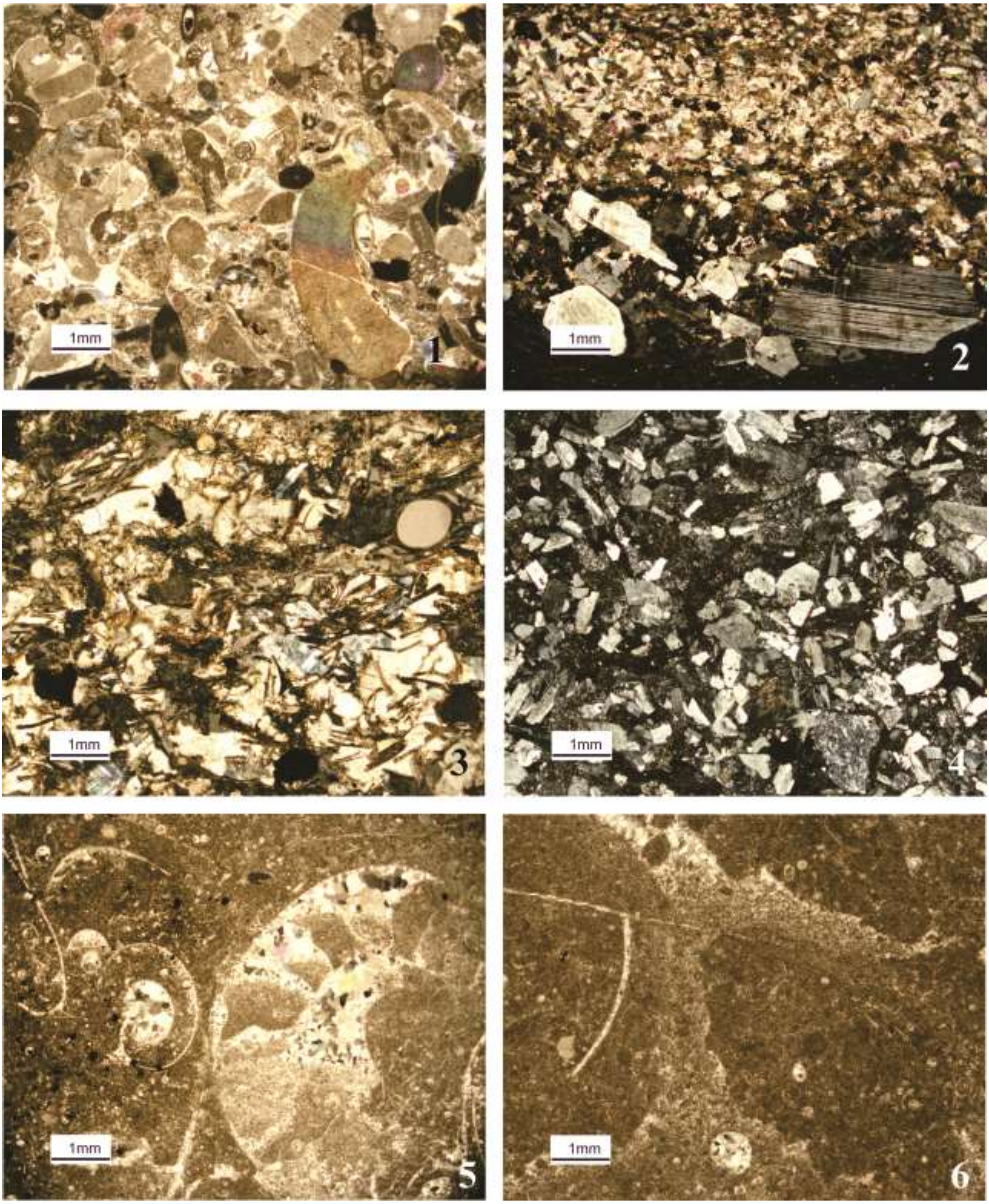

Plate 1, figs. 1-6. Photographs of thin sections showing representative microfacies from the Verkhnyaya Kardailovka section, South Urals, Russian Federation. Scale bars all 1mm; all photographs taken at crossed nicols. Sample positions are given in metres relative to level 0 in Figure 2 - Fig. 1) coarse-grained foraminifer-crinoid lime grainstone from formation A at 1.9 m; Fig. 2) very coarse to medium sandstone: calcareous plagioclase arkose (crystal tuff) showing large subhedral plagioclase crystals at base; the sandstone abruptly overlies dark, fine-grained, hemipelagic deposits and grades upward into sandy, pyroclast-bearing crystalline (diagenetic) limestone. Photo shows lower part of a tuffaceous, turbidite bed in formation B at 6.95 m. Fig. 3) sandy, pyroclast-bearing, crystalline (tuffaceous and diagenetic) limestone; sample consists of platy to cuspate, sand-size grains (shards derived from shattering of vitric, volcanic bubbles) and scattered calcite-filled vitric spheres encased in calcite cement; illustrates upper part of turbidite bed shown in Plate 1, fig. 2. Fig. 4) medium to coarse sandstone: siliceous, submature, lithic plagioclase arkose (crystal tuff); from formation B, at 12.6 m; shows plagioclase crystals and volcanic rock fragments. Fig. 5) peloid-skeletal lime wackestone to packstone showing fragmented to relatively complete ammonoids; from formation C at 19.74 m. Fig. 6) intraclast lime rudstone; intraclasts comprise peloid-skeletal lime wackestone; from formation C at 19.74 m.

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FAMENNIAN AND MISSISSIPPIAN REEFS AND MOUNDS IN EUROPE AND NORTH AFRICA

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Profound changes in the composition and abundance of reefs and mounds took place in the Frasnian, and the reef association of stromatoporid sponges and corals, which had dominated since the Silurian, collapsed gradually. Traditionally the Famennian and Mississippian are considered to represent the slow recovery of the reef environment characterised by low abundance of reefs and the dominance of mud-supported structures. However, this image has changed in the last two decades.

After the late Frasnian extinctions events wide-spread dominance of siliciclastic facies prevented the development of reefs and mounds in the Famennian of Europe. Hence, this suppressed reef development is more the expression of unfavourable facies than a delayed ecological-induced recovery phase after an extinction. Famennian reefs developed in place where carbonate facies predominated. Most often they were small and short-lived, but there are several examples of larger microbial mounds and reefs. Overall, the peak time for Famennian reef development in Europe is the latest Famennian (Strunian), when stromatoporid sponges and subordinately rugose corals formed biostromes, especially along the shelf of southern Laurussia. It is important to note that this Strunian reef association failed to construct build-ups, which maintained high relief and, which can be differentiated into core and flank facies.

This Strunian reef association collapsed with the final disappearance of the Palaeozoic stromatoporid sponges in the End-Devonian extinction event, and the Mississippian is characterised by its own reef history with particular reef associations. In general, the abundance of reefs and mounds during the Mississippian was lower compared to the Middle Palaeozoic peak, but there are spatially and temporally much more common than previously thought. Timing and duration of reef development and dimensions of the reefs varied considerably on a regional scale, but the reefs developed almost continuously throughout the entire Mississippian period. Reefs and mounds have been found in very different shallow and deeper-water facies and different organisms and communities contributed to their formation. Although microbial communities often played a crucial role in the formation of build-ups, the Mississippian mounds and reefs cannot be reduced to a post-disaster phase of mud-dominated build-ups after the late Devonian extinction events. The single reef and mound is directly bound to the local tectono-sedimentary history, but global governing factors as palaeoclimate and geodynamic evolution control the regional reef patterns.

Mississippian reefs and mounds are widely distributed in Europe from the Ivorian (upper Tournaisian) onward, their absence in the Hastarian (lower Tournaisian) is due to unsuitable facies conditions and the necessary reorganisation of the reef associations following the loss of the main Strunian bioconstructors. The deeper parts of ramp-dominated shelf systems are often occupied by mud-dominated build-ups. This is not restricted to the Waulsortian Facies of the Ivorian, but a more general phenomenon as evidenced by the late Viséan (Asbian and Brigantian) of Great Britain and Poland.

During Viséan times, very different bioconstructors formed reefs in various parts of the rimmed-shelf systems. The Belgian Dinantian gives a rare insight into reef formation in marginal marine settings, where small reefs were constructed by microbial communities and microconchids. On carbonate platforms, reef formation is often hampered by small-scaled sea-level oscillation, and reef dimensions stayed relatively low. This can be seen in the Molinacian and Livian (lower and middle Viséan) reefs in England and Belgium, when framework formation resulted from the interaction of microbial communities, bryozoans, tabulate corals and subordinated brachiopods. However, when accommodation space was available, reefs could attain thicknesses of several hundred meters. This is especially true along the edges of late Viséan shelf systems, where a reef association comprising microbes, sponges, corals, and bryozoans became abundant. In England these reefs are named Cracoan build-ups. but they also abundant in Ireland, Belgium, Spain and in North Africa (Morocco and Algeria). The African records are the first reefs described since the Frasnian. It is important to note that many late Viséan build-ups previously described as mounds or mud-mounds contain a well-defined framework, and thus represent true reefs. In southern Europe and in Morocco, these late Viséan reefs were cannibalized in the collapse of shelf systems during the Variscan Orogeny, and today are only documented in olistoliths in flysch basins.

Coral biostromes are another important reef type in the middle and late Viséan reefs of Europe. Compositions and dimensions can be very different, and their variations can be best described between the end-members “local, thin monospecific coral biostromes”, “regional, thick polyspecific coral biostrome complex” and “mixed coral-metazoan biostrome”. The best example of a biostrome complex is found in the 50 m thick *pauciradiale* beds in NW Ireland.

The youngest Mississippian reefs of Western and Central Europe are earliest Serpukhovian in age and found in southern France. Reef formation in the Serpukhovian is found in North Africa south of the mobile Variscan belt in the cratonal basins of the Sahara. The best examples are from the Béchar Basin, but compared to the Viséan, those reefs are less common, and smaller in sizes.

SERPUKHOVIAN AND BASHKIRIAN BIOHERM FACIES ON THE EASTERN SLOPE OF THE SOUTH URALS

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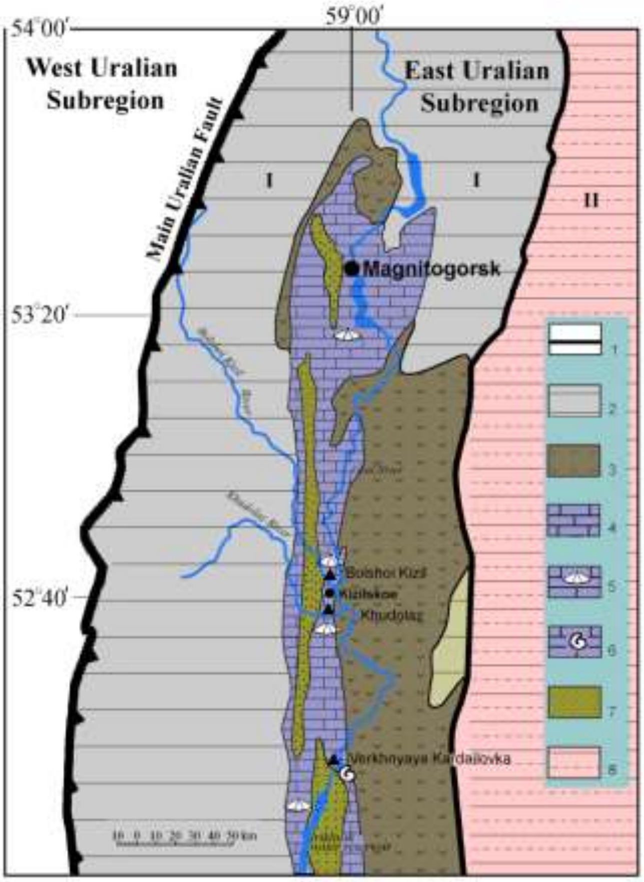
Bioherm facies are common on the eastern slope of the South Urals in the series of carbonate outcrops of the Kizil Formation. These outcrops stretch along the right bank of the Ural River from the Yangelka River in the north to the Iriklinsky Water Reservoir, and further south to Verkhnyaya Orlovka Creek [1; 2; 3]. The most representative outcrops of the bioherm buildups are of Serpukhovian (Upper Mississippian) and Bashkirian (Syuranian and Akavasian substages) (Pennsylvanian) [4; 5] (Fig. 1).



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 [5, fig. 5].

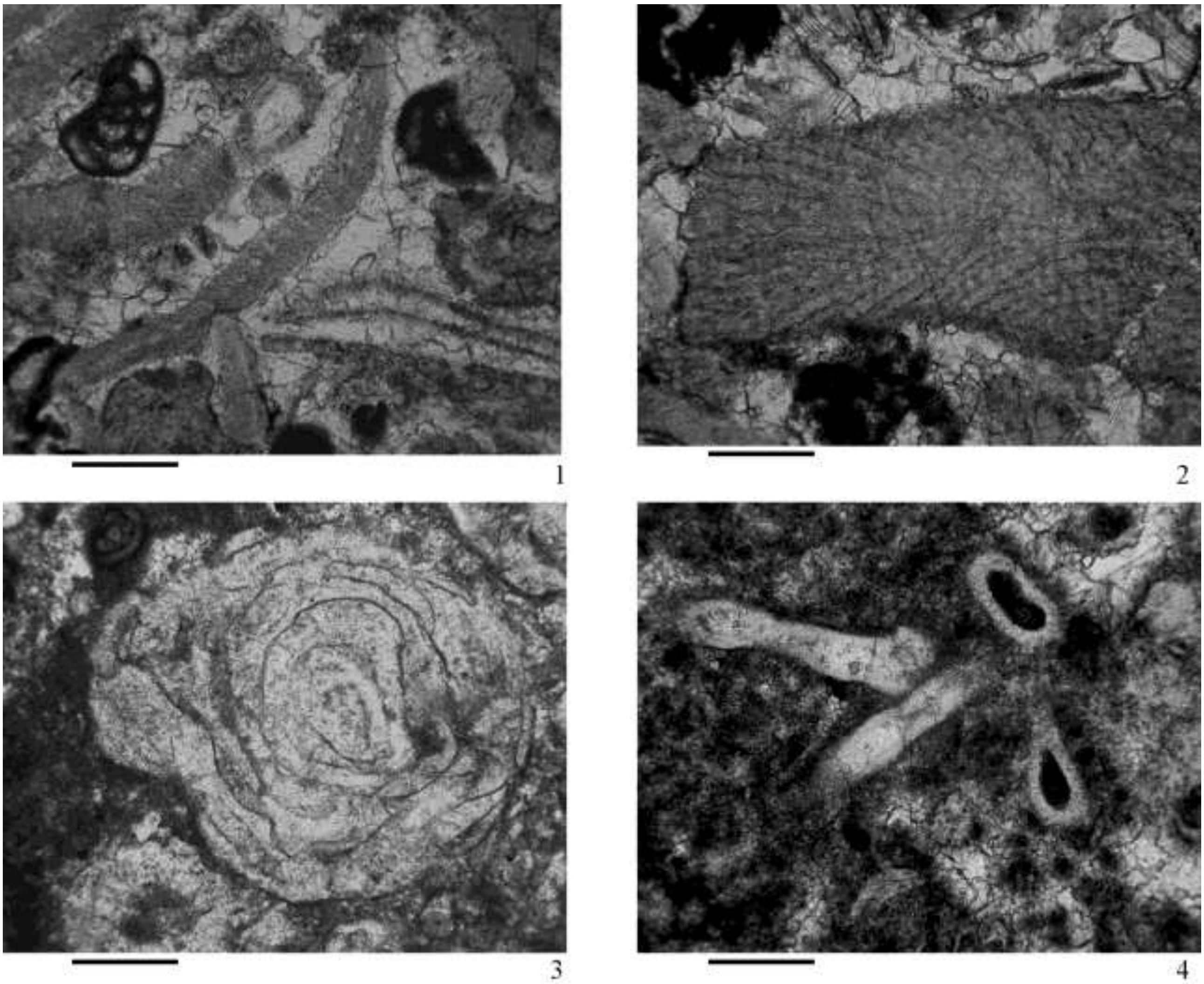
Fig. 1 - Early Carboniferous formations and facies in the East Uralian Subregion of the South Urals

In a section on the Bolshoi Kizil River (right tributary to the Ural River), small bioherms are observed in the Serpukhovian and Syuranian Substage (Bashkirian) and larger buildups are found in the Akavasian Substage (Bashkirian) [4]. The Khudolaz Substage (Serpukhovian) contains microbial biostromes.

Serpukhovian

The Serpukhovian Stage is represented by thick-bedded and indistinctly bedded limestones.

The Lower Serpukhovian Sunturian Substage contains mounds formed by massive algal boundstone with bioencrustations, in places becoming algal grainstone with remains of thin-shelled brachiopods, crinoids, corals, and fragments of bryozoans. Among the algae, *Calcifolium okense* Schwetzov et Birina, 1935 is dominant (Figs. 2-1, 3-14).



1. Boundstone formed by *Calcifolium okense* Schwetzov et Birina, 1935 with *Endothyra* sp. (left) and *Palaeonubecularia* sp. (right). Sample 025, Serpukhovian, Sunturian.
2. *Ungdarella uralica* Maslov, 1956. Sample 024, Serpukhovian, Sunturian.
3. *Fasciella kizilia* R. Ivanova, 1973. Sample 042a, Serpukhovian, Chernyshevkian.
4. *Praedonezella cespeformis* Kulik, 1973. Sample 041a, Serpukhovian, Chernyshevkian.

Figure 2 - Algae from the Bolshoi Kizil Section

This alga is characteristic of the Upper Visean and Serpukhovian [6]. The rock also contains *Ungdarella uralica* Maslov 1962 (Fig. 2-2), *Praedonezella cespeformis* Kulik, 1973, *Koninckopora* sp., and *Fasciella kizilia* R. Ivanova, 1973, and *Frustulata asiatica* Saltovskaja, 1985. Foraminifers include *Pseudoglomospira* spp., *Howchinia bradyana* (Howchin, 1888), *Rugosoarchaediscus akchimensis* (Grozdilova et Lebedeva, 1954), *Asteroarchaediscus baschkiricus* (Krestovnikov et Theodorovich, 1936), *Neoarchaediscus postrugosus* (Reitlinger, 1949), *Permodiscus vetustus* Dutkevitch, 1948, *Eolasiodiscus donbassicus* Reitlinger, 1956, *Haplophragmina* cf. *beschevensis* (Brazhnikova, 1967), *Endothyranopsis sphaerica* (Rauser-Chernousova et Reitlinger, 1936), *Globoendothyra globulus* (Eichwald 1860), *Bradyina* cf. *rotula* (Eichwald 1860), *Janischewskina delicata* (Malakhova 1956), and Palaeotextulariidae. The thickness of the Sunturian is up to 110 m.

The Khudolazian in the Bolshoi Kizil Section is composed of boundstone at its base, formed by colonial corals (coral bioherm) and algae, with frequent encrustations, contains bryozoans, spines of echinoids, numerous foraminifers and cysts formed by small *Mediocris* sp. and *Endostaffella* spp. The overlying medium- and thick-bedded limestones are represented by boundstone, bioclastic grainstone-packstone, wackestone-packstone, bafflestone, and peloid grainstones-packstones. The boundstones are formed by *Calcifolium okense*, rare *Ungdarella* and also structures produced by cyanobacteria in association with bacterial encrustations, and abundant fibrous cement with bacterial inclusions. The Khudolazian Substage contained an easily traceable bed of “spotty” limestone, microscopically peloid-foraminiferal boundstone with prevailing encrusting foraminifers *Palaeonubecularia* spp., and spheres; wackestones contain unidentified tubular remains [4]. The foraminifers include *Turrispiroides* sp., *Eostaffellina* cf. *paraprotvae* (Rauser-Chernousova, 1948), *Globivalvulina eogranulosa* Reitlinger, 1950, *Gl. bulloides* (Brady, 1876), *Bradyina* ex gr. *cribrostomata* (Rauser-Chernousova et Reitlinger, 1937), *Br.* cf. *eonautiliformis* Reitlinger, 1950.

The thickness of the Khudolazian Substage is nearly 67 m.

The Chernyshevkian Substage consists of bioclastic packstones, algal boundstone formed by *Fasciella kizilia* (Fig. 2-3), *Ungdarella uralica*, *Praedonezella cespeformis* (Fig. 2-4), bryozoan-algal, bryozoan-crinoidal packstones and wackestones with corals, numerous brachiopods and foraminifers: *Pseudoglomospira* spp., *Endothyra* ex gr. *bowmani* (Phillips,1846), *Globivalvulina bulloides*, *Endothyranopsis* sp., *Ikensieformis* cf. *mirifica* (Brazhnikova 1967), *Eostaffella postmosquensis* Kir., *Neoarchaediscus probatus* (Reitlinger, 1950), *N. postrugosus* (Reitlinger, 1949), *Monotaxinoides* ex gr. *transitorius* Brazhnikova et Jartzeva, 1956. The upper part of the substage is represented by mudstones and microbial-lumpy wackestones with numerous thin-walled *Glomospira*-like tubular organisms, possibly playing a role in the cementation of the sediment. The top of the substage contains a bed (2.5 m) of bryozoan-crinoidal packstones with numerous foraminifers Archaediscidae. The presumed thickness of the Chernyshevkian is over 66 m, while the thickness of the entire Serpukhovian amounts to 250 m.

A small bioherm of Khudolazian age is known on the right bank of the Ural River in the upper part of the Verkhnyaya Kardailovka section. The bioherm body is composed of massive limestones with abundant corals *Cladochonus* sp., crinoids, bryozoans, and ostracods. The flank facies surrounding the bioherm contain numerous ammonoids [7].

Bashkirian

Syuranian

The Syuranian Substage includes the Bogdanovkian and Kamennogorian infrasubstages. In the Bolshoi Kizil Section, the Bogdanovkian is composed of thick-bedded, indistinctly bedded and massive limestones with small biostromes up to 20 m thick. They consist of algal boundstones and bafflestones formed mainly by *Ungdarella* spp. and *Fasciella kizilia*. The boundstones are intricately recrystallized in places with accumulations of thin-shelled ostracods, in thin sections with *Spongiostroma* structure and microbial (?) lumps, foraminifers, and brachiopods. The Syuranian Substage also contains beds, formed by foraminiferal-fine-bioclastic grainstones and packstones with numerous encrusting foraminifers *Palaeonubecularia* spp., *Ammovertella* spp., *Pachysphaerina pachysphaerica* (Pronina 1963) (Fig. 3-9). The thickness of the Bogdanovkian is 62 m. The apparent thickness of the entire Syuranian in this section is about 125 m.

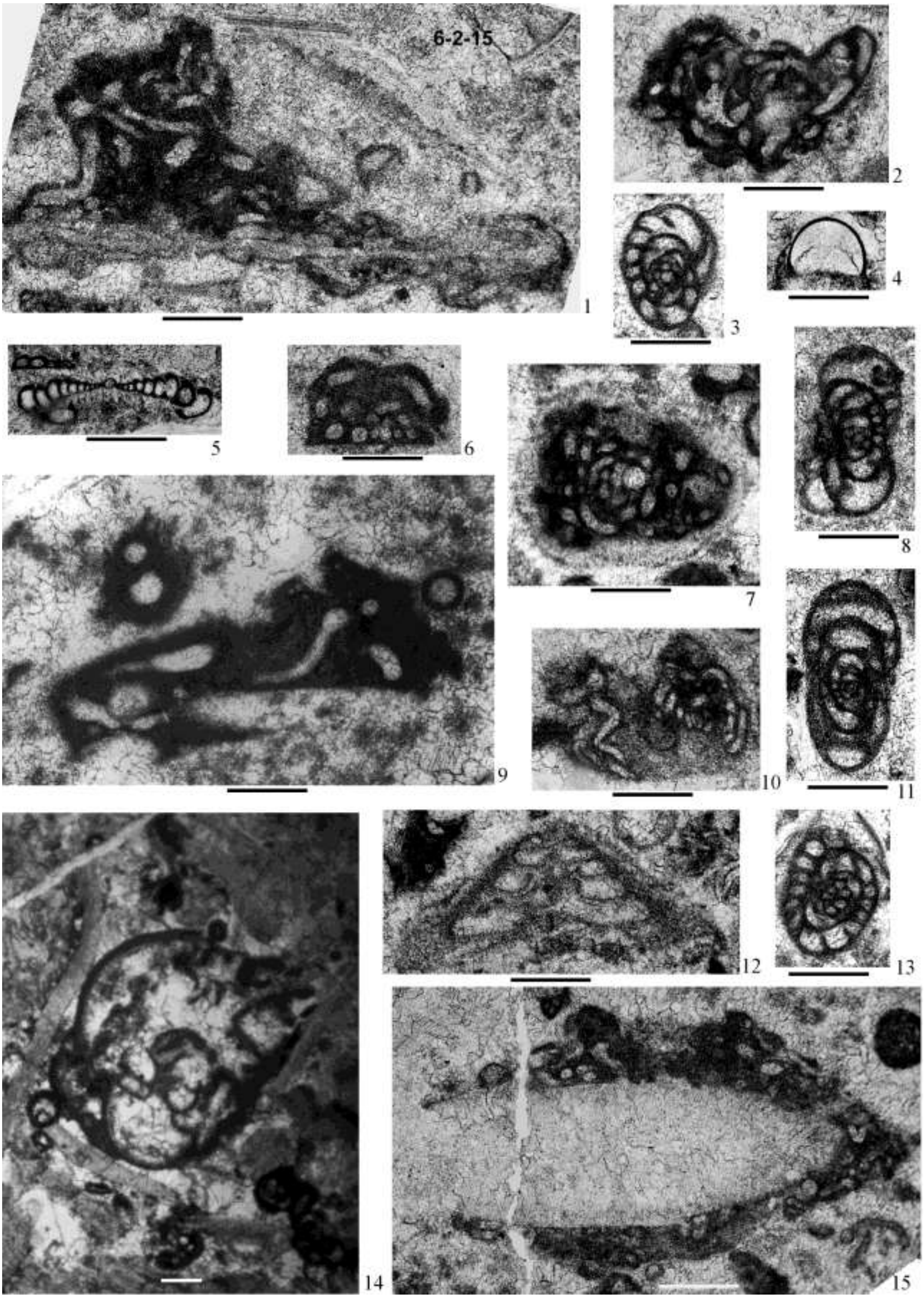


Figure 3 - Foraminifers from the Bolshoi Kizil and Khudolaz sections

1. *Tolypammina fortis* Reitlinger, 1950 (left) and *Palaeonubecularia* sp. (right) in boundstone. Kalinino, sample Ka-11/6, Syuranian.
2. *Tolypammina* sp. Kalinino, sample Ka-11/6, Bashkirian, Syuranian.
3. *Semistaffella primitiva* (Reitlinger, 1961). Kalinino, sample Ka-11/6, Bashkirian, Syuranian.
4. *Eotuberitina reitlingerae* A. Miklukho-Maclay, 1958. Kalinino, sample Ka-11/6, Bashkirian, Syuranian.
5. *Monotaxinoides transitorius* Brazhnikova et Jartzeva 1956. Kalinino, sample Ka-11/2, Bashkirian, Syuranian.
6, 7. *Palaeonubecularia fluxa* Reitlinger 1950: 5 – Kalinino, sample Ka-11/6, 7 – Kalinino, sample Ka-11/7, Bashkirian, Syuranian.
8. *Plectostaffella varvariensis* Brazhnikova et Potievskaya, 1948. Kalinino, sample Ka-11/6.
9. *Pseudolituotuba* sp. and *Pachysphaerina pachysphaerica* (Pronina) (right). Bolshoi Kizil, sample 11, Syuranian, Bogdanovkian.
10. Ammovertella sp., Kalinino, sample Ka-11/7, Syuranian.
11. *Eostaffella* ex gr. *pseudostruvei* (Rauser-Chernousova et Belyaev, 1936).
12. *Tetrataxis regularis* Brazhnikova, 1967. Kalinino, sample Ka-11/7, Bashkirian, Syuranian.
13. *Plectostaffella bogdanovkensis* Reitlinger, 1980. Kalinino, sample Ka-11/7, Bashkirian, Syuranian.
14. Boundstone formed by *Calcifolium okense* Schwetzov et Birina, 1935 with *Janischewskina delicata* (Malakhova, 1956). Bolshoi Kizil Section, sample 025, Serpukhovian, Sunturian,
15. *Palaeonubecularia* sp. in boundstone. Kalinino, sample Ka-11/6, Bashkirian, Syuranian.

The Khudolaz Section near the Kalinino village contains massive bioherm facies of Syuranian age [5, 8]. They are exposed as part of a tectonic block within the Moscovian flysch [9]. The facies 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. Along the Karst Gully, the thrombolytic deposits locally display brachiopods, tabulate corals, and cephalopods. Beds and lenses of lime grainstone are locally present in the bioherms and commonly contain the encrusting foraminifer *Tolypammina* sp., *Palaeonubecularia* spp. (Figs. 3-1, 3-2, 3-5, 3-7, 3-15), the eostaffellid genera *Eostaffella*, *Plectostaffella*, *Semistaffella* (Figs. 3-3, 3-8, 3-11, 3-13), *Monotaxinoides transitorius* Brazhnikova et Jarzeva, 1956 (Fig. 3-4), archaediscids and Tetrataxiidae (Fig. 3-12). The foraminifers date the buildups to the Syuranian regional substage of the Bashkirian Stage. Flank facies contained *Cancelloceras elegans* (Ruzhencev et Bogoslovskaya) suggesting the *Bilinguites-Cancelloceras* genozone and Lower Bashkirian conodonts.

The Akavassian bioherm mounds are located on the left bank of the Bolshoi Kizil River, 5.5 km upstream of the river mouth near the Kizilskoe Village (Chelyabinsk Region). Based on Shchekotova's data [3], the bioherms in the Bashkirian portion of the Kizil Formation formed dispersed bodies and have a small size of 10–15 mm in diameter and 3–5 m in height, whereas the largest bioherm body is 300 m in diameter and 3–30 m in height. The boundstones are built by the algae *Donezella lutugini* Maslov, *Beresella* sp., *Masloviporidium* sp. *Beresella* sp., *Girvanella* sp., *Cuneiphycus* sp. and stromatolites, contain banks of brachiopods, serpulids, crinoids, gastropods, in places with numerous ostracods, rare foraminifers and ammonoids. Massive algae boundstones often include encrustations, radial-fibrous cement and microbial inclusions recrystallized in a lace-like pattern. Sometimes the rock is represented by carbonate breccia, with angular intraclasts of micrite, in places re-crystallized matrix produced by a decaying carbonate buildup. Limestones include an assemblage of foraminifers of the *Pseudostaffella antiqua* Zone. The bioherm massif contains a limestone lens with numerous ammonoid shells: *Bilinguites superbilinguis* (Bisat), *Stenoglaphyrites deflexus* Nikolaeva et Konovalova, *Schartymites barbotanus* (Verneuil), and *Schartymites kizilensis* Nikolaeva et Konovalova. The apparent thickness of the Akavassian in the Bolshoi Kizil Section is 160–170 m.

In the Early Serpukhovian (Sunturian), small bioherms formed by the algae *Calcifolium okense,Ungdarella uralica, Praedonezella cespeformis,* and brachiopod banks became widespread. In the Khudolazian time, bacterial-algal buildups with numerous encrusting foraminifers and ostracodes and brachiopod banks were common. In the Late Serpukhovian, among algae, *Fasciella kizilia* become dominant. Similar algal-microbial buildups were formed in the Serpukhovian in the Peri-Caspian Region [10]. In the Bashkirian (Syuranian and Akavassian) bioherms reached their maximum development. Boundstones produced as a result of metabolism of cyanobacteria and bacterial encrustations, with abundant radial-fibrous cement, are formed.

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POTENTIAL BIOSTRATIGRAPHIC MARKERS FOR THE BASE OF THE GLOBAL SERPUKHOVIAN STAGE

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Determining the base of the Serpukhovian Stage is one of the most pressing tasks for Carboniferous biostratigraphy, since it has been shown that sections in the stratotype area in the Moscow region contain a gap at the base of the classical Serpukhovian (at the base of the Tarusian Regional Substage) and that the boundary level cannot be precisely correlated that in with other successions worldwide [1],[2], etc., although it seems apparent that the base of the Tarusian is close to the traditional Viséan–Namurian boundary [3], [4],[5]. The historical definition of the Viséan–Serpukhovian (formerly Viséan–Namurian) boundary by the level of the first appearance of the ammonoid genera *Cravenoceras* or *Eumorphoceras* (as adopted by Heerlen Congress in 1958, see [6] for references) can no longer be supported because of their scarcity [7]. The Task Group to establish a GSSP close to the existing Viséan–Serpukhovian boundary [8] focused on a search for a new boundary marker and agreed that the first evolutionary appearance of the conodont *Lochriea ziegleri* Nemirovskaya, Perret and Meischner, 1994 in the lineage *Lochriea nodosa* Bischoff, 1957 to *Lochriea ziegleri* is the best biostratigraphic event, since it has been recognized in many successions worldwide and is only slightly lower than the traditional base of the Serpukhovian in the Moscow Region and other areas ([1], [9], [10], [11], [12], [13], [14]).

The *L. nodosa— L. ziegleri* lineage is best developed in deep water successions and has been found in association with ammonoids in Western Europe and Russia ([1], [7]), and with foraminifers in Western Europe, Russia, and China ([11], [15], [16]). Here we summarize the major published data on the co-occurrences of conodonts, foraminifers, and ammonoids in several best known sections: Verkhnyaya Kardailovka (Russia, South Urals), Naqing (China), Novogurovsky (Russia, Moscow Basin), Vegas de Sotres (Spain), Ladeinyi Log section (Russia, Middle Urals), sections in Northern England, southern Scotland, UK, and Leitrim, Ireland.

Occurrences of ammonoids and foraminifers that are close to the FAD of *L. ziegleri* may also have correlative potential in areas where conodonts are scarce [17].

Main localities of the V–S boundary beds

Verkhnyaya Kardailovka section (Bashkortostan, South Urals, Russia) Deep-water slope and basin nodular carbonates with several thin beds and laminae of volcanic ash.

(1) Entry of the conodont *Lochriea ziegleri*: In a section near the village of Verkhnyaya Kardailovka, the *L. nodosa— L. ziegleri* lineage is found in the unnamed deep-water, limestone-dominated formation C of the Bogdanovichian Regional Substage, where the FAD of *L. ziegleri* is recorded in Unit 13 at 19.53–19.63 from the base of the section ([7], [13], [18], [19]) in association with ammonoids, foraminifers, solitary Rugosa corals, trilobites and ostracodes.

(2) Entry of the ammonoids *Dombarites, Hypergoniatites, Neogoniatites, Ferganoceras* and Cravenoceratidae: The ammonoids *Lyrogoniatites* sp., *Neogoniatites milleri* Ruzhencev and

Bogoslovskaya, 1970, *Dombarites parafalcatoides* Ruzhencev and Bogoslovskaya, 1971, and *Neogoniatites* sp. are found at 18.50 and 19.50 m from the base of the section, whereas *Platygoniatites integer* Nikolaeva, 2013 is found at 20.3 m, and *Ferganoceras constrictum* Nikolaeva and Konovalova, 2017 is found at 20.8 m from the base of the section [20]. *Dombarites, Hypergoniatites, Neogoniatites,* and *Ferganoceras* are typical of the *Hypergoniatites–Ferganoceras* Genozone of the Urals and Central Asia (Southwest Darvaz, South and Middle Tien Shan [21].

(3) Entry of the foraminifers *Neoarchaediscus regularis* and *Hemidiscopsis muradymica (= Eolasiodiscus muradymicus)*.In the Verkhnyaya Kardailovka section, *N. regularis* (Suleimanov, 1948) enters at 18.50 m, i.e., 1.03 m below the FAD of *L. ziegleri*, while *H. muradymica* is found 1.5 m above the FAD of *L. ziegleri* [15], just above the FAD of *Ferganoceras constrictum*.

(4) Entry of the foraminifers *Neoarchaediscus postrugosus* and *Howchinia gibba*: *N. postrugosus* (Reitlinger, 1949) and *Howchinia gibba* (Möller, 1879) enter at 34.15–34.40 m, i.e., between 14 and 15 m above the FAD of *L. ziegleri* ([7]), in the Serpukhovian (Kosogorian regional substage).

Ladeinyi Log section, the Middle Urals, Russia. Bioclastic lumpy limestone with fine-grained cement, bituminous, in places argillaceous and cherty.

(1) Entry of the conodont *Lochriea ziegleri*: Single specimens of *Lochriea ziegleri* are recorded in Bed 17, lower Serpukhovian, Kosogorian regional substage, approximately 1.5 above the entry of *Neoarchaediscus postrugosus* [22].

(2) Entry of the foraminifers *Neoarchaediscus postrugosus*: The FAD of *N. postrugosus* is recorded at the base of Bed 17 (lower Serpukhovian, Kosogorian regional substage, base of the *Neoarchaediscus postrugosus* Zone), more than 25 m above the earliest record of *Neoarchaediscus regularis.*

(3) Entry of the foraminifers *Eostaffella tenebrosa, Neoarchaediscus regularis, Biseriella parva, Janischewskina typica*: In the Ladeinyi Log section, *Biseriella parva* appears in Bed 13, *Eostaffella tenebrosa* appears in Bed 14, while the entry of *Neoarchaediscus regularis* and *Janischewskina typica* is recorded in Bed 15 (all in the upper Venevian, within the *E. tenebrosa* Zone) ([22], [23]).

Novogurovsky section (Moscow Basin, Russia). Shallow-water carbonates. The sequences VN1 and VN2 are composed of photozoan bioclastic packstones.

(1) Entry of the conodont *Lochriea ziegleri*: In the Novogurovsky section the FAD *L. ziegleri* is recorded in the shallow-water limestones of the upper half of the Venevian Regional Substage (middle of sequence VN2, Unit 23) ([2], [24]).

(2) Entry of the foraminifers *Janischewskina delicata* and *Plectomillerella tortula*: In the Novogurovsky section *Janischewskina delicata, Plectomillerella tortula, Planoendothyra* sp., and *Endothyra phrissa* enter ca. 6 m above the base of the Venev Formation (Venev FM, middle of sequence VN2, Unit 23) ([2], [24]). This is at virtually the same level as the entry of *L. ziegleri*.

(3) Entry of the foraminifer *Neoarchaediscus postrugosus*: The earliest *N. postrugosus* are recorded from Unit 29 (Lower Tarusian Regional Substage, Serpukhovian) [2].

Naqing section (Guizhou, South China). Deep water slope carbonates.

(1) Entry of the conodont *Lochriea ziegleri*: In the Nashui section, the *L. nodosa— L. ziegleri* lineage is recorded in the limestones, silicified limestones and bedded cherts ([10], [11], [18], [25]]). The lowest occurrence of *Lochriea ziegleri* is at 60.1 m above the base of the section ([26], [27]).

Vegas de Sotres section (Cantabrian Mountains, Spain). Bioclastic pale grey nodular and black limestones facies. This is a composite section consisting of several blocks somewhat affected by faulting [28].

(1) Entry of the conodont *Lochriea ziegleri*: The entry of *L. ziegleri* is recorded in the uppermost part of the Canalón Member of the Alba Formation (Section I, Unit 1; Sample VSC-1B3 = VSF 0) ([29], [28]) in nodular mudstone intercalated with occasional marl layers.

(2) Entry of the foraminifers *Hemidiscopsis muradymica, H. hemisphaerica* and *Howchinia gibba*: The FO of *H. muradymica* Kulagina in Kulagina et al., 1992 is recorded in the Canalón Member (Section IIa, Unit 1, VSF-113) approximately 3-4 m below the FO of *L. ziegleri*. The FO of *How. gibba* is recorded in the Canalón Member (Section I, Unit 2, VSF-104) approximately 1 m below the FO of *L. ziegleri*. *H. hemisphaerica* Cózar et al., 2015 enters in the Canalón Member (Section I, Unit 2, VSF-102) approximately 10 cm below the FO of *L. ziegleri*. Nine species of *Howchinia* enter approximately 1–2 m above the first occurrence of *L. ziegleri*, some of these still unnamed [28].

Lugasnaghta section, County L, Ireland. Predominantly dark grey, occasionally pyritic, commonly fossiliferous, calcareous shale with carbonate-rich members.

(1) Entry of the conodont *Lochriea ziegleri*: In the Lugasnaghta section (County Leitrim, Ireland), the FAD of *L. ziegleri* above the Ardvarney Limestone Member (CNLG14) approximately at the base of the P2a ammonoid zone [30] and the base of the Upper Cf6d (MFZ15) foraminiferal zone ([14]).

(2) Entry of the ammonoid *Cravenoceras leion*. The earliest occurrence of *C. leion* in this region is recorded in the lower two of three bands within the E1 zone, Pendleian of County Leitrim [31], and the lowermost bed also contained *E. pseudocoronula*.

Northern England and southern Scotland. This is a large area with several large blocks separated by actively subsiding basinal areas with cycles of transgressive and regressive facies. The transgressive phases are represented by bioclastic limestones or calcareous shale and the regressive phases by the presence of oolites or calcite mudstones [32].

(1) Entry of the conodont *Lochriea ziegleri*: The oldest record of *L. ziegleri* in northern England is documented in the lower levels of the Middle Limestone of the

Askrigg Block ([14], [33]) within the ammonoid zone P1d or possibly P1c. However, Cózar and Somerville [34] state that *L. ziegleri* could be recorded from a lower level than that, that is from the Single Post Limestone in the Stainmore Trough and Alston Block, and in slightly older levels than has been observed in Novogurovsky Quarry, Moscow Basin [2]. However, the letter conclusion is based on correlation and according to Cózar and Somerville [34] is not supported by actual biostratigraphic data.

(2) Entry of the foraminifer *Neoarchaediscus postrugosus* and *Plectomillerella tortula*. In northern England, the Single Post in the Late Brigantian (P2) Limestone contains few identifiable foraminifers, but somewhat above that, the Scar Limestone Member, contains abundant foraminiferal assemblages, which include *N. postrugosus* and *P. tortula*. In southern Scotland (Archerbeck Borehole, Solway Basin)**,** the earliest occurrence of *N. postrugosus* and *P. tortula* is even later as it has been recorded from the Brigantian (Buccleuch) Limestone and correlated with the level between the Three Yard Limestone and Five Yard Limestone in northern England ([34], [35]).

(3) Entry of the foraminifers of the genus *Monotaxinoides*. *Monotaxinoides* sp., *M. priscus*, *M.* cf. *subplana* have been recorded from the Four Fathom Limestone Member (uppermost late Brigantian) in Woodland Borehole, Alston Block; Great Limestone Member, Bollihope Quarry, North Pennines, northern England [35].

(4) Entry of the ammonoid *Cravenoceras leion*. This is a traditional base of the Pendleian in England [34]. The lowermost occurrence is possibly the type locality at the Wiswell farm (Light Clough, Lancashire), where the horizon with *C. leion* lies immediately above the shale of the Brigantian P2 Zone [36].

Potential markers for the V-S boundary

Lochriea ziegleri

The type locality section is Tantes, Gavarnie, Hautes-Pyrénées, France. ([9], [37]). This conodont species is currently considered as the best marker, as it is found in many sections in the Urals, Moscow Basin, China, and Western Europe. It has not been confirmed in the USA or North

Africa (see [18]). The FAD of *L. ziegleri* in Ireland is fixed in the early upper Cf6d (MFZ15) foraminiferal biozones and at the base of the P2a ammonoid biozones. In England *L. ziegleri* enters in the P1d ammonoid Zone. In the Moscow Basin *L. ziegleri* enters in the Venevian, at the level correlated with Cf6d (MFZ15) foraminiferal biozones at approximately the same level as the first *Janischewskina*. In Verkhnyaya Kardailovka section, no *Janischewskina* has been recorded, but *N. regularis* appears almost simultaneously with *L. ziegleri*, suggesting the Cf6d Zone. In the Rhenish Massif *L. ziegleri* is recorded at various levels from P1ab to E1a (see references in [13]).

***Dombarites, Hypergoniatites, Neogoniatites, Ferganoceras* and Cravenoceratidae**

Synchronous faunas are found in Novaya Zemlya [38], in the northern Verkhoyansk Region (Kharaulakh Ridge) [39], in Sud Oranais, Ksar El Azoudj (Algeria), and in Mondette, Ariège (western Pyrénées) [40], in Gara El Itima (Anti-Atlas, Morocco) (faunas G-4–G-6) [41], in the Cantabrian Mountains (Spain) [42], Xinjiang and Xizang (China) ([43], [44]), in North America: *Sulcogirtyoceras ornatissumum* Zone (Barnett Shale, Texas) ([45]), (*Lusitanoceras−Pachylyroceras* Genozone (North American Cordillera)) and the interval from the *Choctawites kentuckiensis* Zone to the *Lyrogoniatites georgiensis* Zone (American Mid-Continent) [46]. Ammonoids of this age have not been found in the Naqing section. The family Cravenoceratidae (*Cravenoceras, Pachylyroceras, Lyrogoniatites*) has the best correlative potential compared to other ammonoids, as it has been found throughout the northern hemisphere. The family Girtyoceratidae (*Edmooroceras, Sulcogirtyoceras, Eumorphoceras*) has limited value (it is extremely rare in the Urals and Central Asia), but works well for the Western European successions.

Neoarchaediscus regularis

This species is typical of the uppermost Viséan and lowermost Serpukhovian. It is found in the Bogdanovichian and Sunturian on the eastern slope of the Urals in the Khudolaz section [47], the Bolshoi Kizil section [48], Ladeinyi Log section [22], in the Donets Basin in the Mezhevian (Upper Viséan C1vg Zone) (Limestones B4–B6). In the Lviv-Volhynia Basin, it is scarcely found (Ustilug Formation of Mikhailovian age) but it is common in the Porits Formation of Venevian age and the Lower Serpukhovian Ivanichi Formation. Species of the *N. regularis* group occur in the Upper Viséan of the Pre-Dobrogean Trough [49]; in the Paltau Section (Middle Tien Shan) they are found beginning from the basal Serpukhovian [50]. *Neoarchaediscus regularis* was found in the Sikhote-Alin Range in the basin of the Tumanovka River, Zarod Mountain in the Lower Carboniferous (*Endothyranopsis crassa* Zone), i.e., in the Upper Viséan [51]. Importantly this level has also been recorded in the Chesterian Beech Creek Formation, USA [52].

Neoarchaediscus postrugosus

The first appearance of *N. postrugosus* is recorded in the late Brigantian in England, Scotland, Ireland, Morocco [17], [35],[53] and Spain [28]. In other areas *N. postrugosus* enters in the Serpukhovian (the Urals, see [54], [15], [22]; in the Moscow Basin, see [2]). The discrepancy of these records makes *N. postrugosus* currently unsuitable as a marker.

Janischewskina delicata

This species can be used for shallow-water facies. This species was proposed as a third marker for the base of the Serpukhovian [48]. It is recorded in the Khudolaz Section [47], Peri-Caspian Depression [55], and many other succession worldwide, including Morocco [17], China [18], [56], [57]), and Belgium (upper part of MFZ15). The disadvantage is the scarcity and absence of this species in the deep-water sections.

Hemidiscopsis muradymica (= Eolasiodiscus muradymicus)

In different sections, *H. muradymica* appears either slightly below or slightly above the FAD of *L. ziegleri*, and is likely to be facies-controlled, which impedes its use as a marker. However, this is a useful secondary indicator of the boundary interval.

Howchinia gibba

This species is known from the Urals, Kazakhstan, China and Spain, where it enters slightly below *L. ziegleri*. It can possibly be used as an alternative marker, but its range needs to be re-evaluated.

Summary

The FAD of the conodont *L. ziegleri* is currently the best supported candidate for the definition of the base of the Serpukhovian, as it is quite common, and in some places is found with foraminifers and ammonoids. The absence of *L. ziegleri* in some regions, e.g., in the North American successions, is a problem, that emphasizes the need for an additional marker. The level of the FAD of the conodont *L. ziegleri* level lies below the traditional base of the Serpukhovian based on the FADs of *Cravenoceras* and *Edmooroceras pseudocoronula*. It is also below the FAD of *N. postrugosus* in the Moscow Basin and in the Urals, except for the Ladeinaya Mountain. It is proposed that the FAD of *L. ziegleri* as a boundary definition should be put to a vote by the Viséan–Serpukhovian Task Group and the Subcommission on Carboniferous Stratigraphy.

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A POTENTIAL CONDONT-BASED VISÉAN-SERPUKHOVIAN BOUNDARY – DATA FROM THE RHENISH MOUNTAINS, GERMANY

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Introduction

The official ratification of the chronostratigraphic subdivision of the Carboniferous system by ICS and IUGS in early 2004 resulted in the recognition of the Tournaisian, Viséan and Serpukhovian stages for the Mississippian [1,2]. However, already two years earlier a task group for redefinition of the Viséan–Serpukhovian boundary was established [3], as the historical lectostratotype for the base of the Serpukhovian, the Zaborie Quarry close to the town of Serpukhov south of Moscow, contains a hiatus at the base of the Serpukhovian [4,5]. Therefore, neither section nor biostratigraphic index fossils from the type Serpukhovian are suitable to establish a GSSP.

In northwestern Europe, the Viséan-Namurian boundary is approximately correlative with the Viséan-Serpukhovian boundary in the type region [4,6]. According to the decision the Heerlen Congress 1958 that boundary is based on the FAD of the ammonoid "*Cravenoceras leion* Bisat, 1930" [= *Emstites leion* (Bisat, 1930) [7]. In the Rhenish Mountains (Germany) the FAD of *Edmooroceras pseudocoronula* (Bisat, 1950) was proposed to be a more suitable index ammonoid for the base of the Namurian, as *E. leion* apparently is restricted to northern England and only determinable in good preservation [6,8]. However, due to the rarity of ammonoids in many sections spanning the Viséan-Serpukhovian boundary [9,10] and expressed provinciality [6,11,12], the quest for a biostratigraphic marker of a GSSP at a revised Viséan–Serpukhovian boundary centred on the FAD of the conodont *Lochriea ziegleri* in the lineage *L. nodosa – L. ziegleri,* though the proposed index taxon is not yet not voted on by the task group and SCCS for final approval [13]. In consequence, it has to be stressed that the usage of the term "Serpukhovian" still has to rely on the classical definition of the Stage to maintain stability in nomenclature [14].

In fact, important problems remain that concern the isochronous FAD of the taxon, even within the relatively homogenous Subvariscan realm in northwestern Europe [15,16], and the absence of the lineage in Northern America [17]. Moreover, the entry of *Lochriea ziegleri* in the type region does not coincide with the base of the type Serpukhovian (the Tarussian substage), but is earlier within the middle part of the underlying Venevian substage [4,18] Still, smaller calcareous foraminifers might provide an alternative index fossil for the boundary. At least, they could aid to locate the boundary in carbonate platform settings that are unsuitable for conodonts, or in Northern America. Corresponding studies are numerous. Besides in the proposed GSSP candidate sections in S China (Nashui, now called Naqing) and other sections in South China [19], and in the S Urals (Verkhnaya Kardailovka) [20], data have been gathered e.g. from the Serpukhovian lectostratotype [21], in Morocco [22], Spain [23,24], and Britain [14,15].

Concerning conodonts, detailed studies have been conducted in Naqing [25] and Verkhnyaya Kardailovka [20,26], but detailed successions are also known e.g. from the Cantabrian Mountains (N Spain) [27] and the British Isles [16,28].

In the contrary, data from the Rhenish Mountains (Germany) is almost completely missing [4,29], and, moreover, contradictory. Herein, we present preliminary results from a section immediately north of the town Arnsberg [30], which help to clarify the entry of *Lochriea ziegleri* in Germany. In the meanwhile moderately overgrown, the section was completely exposed during construction of the motorway A46 in the early nineties of the last century [31] and sampled for microfacies purposes. Therefore, conodont samples relied on relatively small samples, weighing mostly 0.5-1.0 kg. Inspite of that shortcoming, results are comparable with still unpublished conodont data from the research well "Schälk" at Lethmathe, which is part of the town of Iserlohn, situated some 35 km further west (Fig. 1).

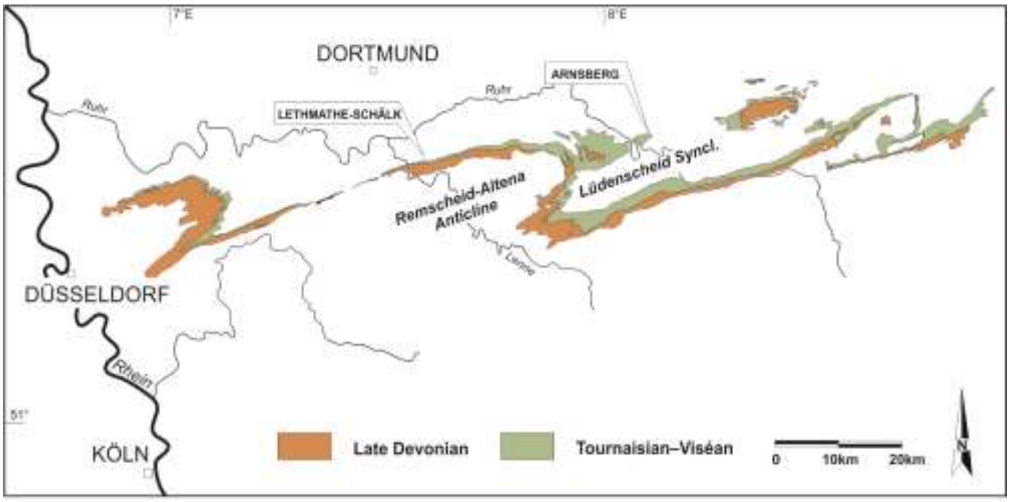

Figure 1 - Upper Devonian and Lower Carboniferous strata along the Northern margin of the Rhenish Massif and position of the Arnsberg section

Late Viséan–Serpukhovian conodonts from Germany with special reference to *Lochriea*

The knowledge of late Viséan–Serpukovian conodonts in Germany is scarce [32]. Besides early studies, which resulted in the recognition of "*Gnathodus commutatus nodosus*" [33] and introduction of the "*Paragnathodus nodosus Zone*" [34], it is restricted to the studies introducing *Lochriea ziegleri* and *L. senckenbergica [29]* and subsequent description of the conodont distribution across the Visean-Namurian transition [4].

A first problem concerns the taxonomic status of *L. senckenbergica*, that has no figured holotype. The holotype should be specimen GER-5, sample Schaelk-43 from the not any more existing Schälk section at Lethmathe, Rhenish Mountains, figured on pl 2, fig. 8. Instead of the holotype, specimen GER-11 from the same sample is figured. Specimen GER-5 is a *L. commutata* from the same sample, figured on pl. 2, fig. 1 [29]. Both specimens are figured in a subsequent publication (pl. 2, fig. 5, pl. 1, fig. 10) in better quality [4], thus ruling out an spelling error. Deriving from the same sample, specimen GER-11 is proposed herein as the lectotype.

Still more intriguing is the problem of the entry of *L. ziegleri* in the Rhenish Mountains (Fig. 2). In the original description [29], its FOD was placed in the "subzone of *Neoglyphioceras spirale* (cdIIIβ_{spi})". However, one year later and based on the same data, it was put into the "*Emstites schaelkensis* ammonoid zone", which was considered to be the uppermost Viséan subzone ("cdIIIγ_2") [4]. An "*Emstites schaelkensis* Zone" is not recognized in the Rhenish Mountains. The species is morphologically strikingly similar to *Emstites leion* and its entry almost exactly matches the entry of *Edmooroceras pseudocoronula [8,35]*. Therefore, the current stratigraphic usage in the Rhenish Mountains, correlates the entry of *L. ziegleri* with the base of the valid Serpukhovian, respectively with the base of the Namurian [36].

All figured specimens of *Lochriea* from Germany are from the Schaelk section [4,29] – it cannot be evaluated, if conodonts from other sections were taken into account at all. From that section also most specimens of *E. schaelkensis* have been derived. They were sampled from a single limestone bed, lumachelle-like enriched and mostly broken, and co-occurring with *E. novalis*, the guide of the uppermost Viséan ammonoid subzone. This caused also the placement of the FOD of *L. ziegleri* into the uppermost Viséan [4]. However, as stated above and exemplified in the near-by Edelburg section, *E. schaelkensis* enters later than *E. novalis [7,35]*. In the Schälk section, taphonomy indicates that the enigmatic co-occurrence of both *Emstites* species is related to reworking. It is apparently related to the base of sequence 12 in the Rhenish Kulm basin at the base of the Namurian [37].

A comparison between ammonoid zonation and the entry of *L. ziegleri* in northern England and Ireland also indicates minor discrepancies. In northern England, the entry is in either the P_{1c} or P_{1d} ammonoid Zone, in Ireland in the P_{2a} Zone [16,28] (Fig. 2).

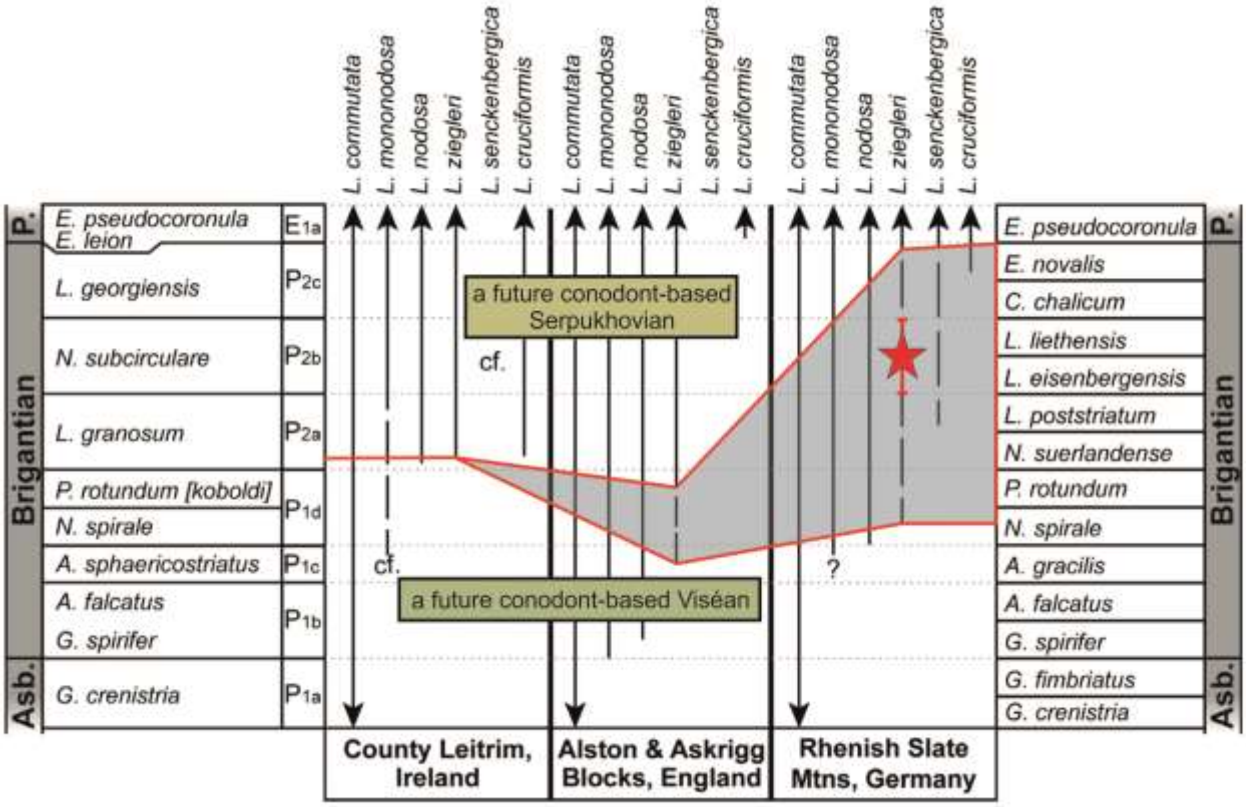

Figure 2- Entry of the proposed Viséan-Serpukhovian index conodont *Lochriea ziegleri* in the NW European Subvariscan realm and correlation with the ammmonoid zonation [16]. Note uncertainties in the FODs as documented in literature (grey shading). Red bar indicates the interval of its FOD in the Arnsberg section as discussed in the text.

Geological setting and local stratigraphy

The Arnsberg section is situated at the northern rim of the Rhenish Mountains, at the northeastern tip of the NE-plunging Remscheid-Altena Anticline [31] (Fig. 1). It exposed an about 215 m thick section from the middle Brigantian *Neoglyphioceras suerlandense* to the lower Arnsbergian *Cravenoceras edalensis* ammonoid zones. The upper part of the section exposed about 105 m of dark grey shale of the mostly Pendleian Seltersberg Fm [38] (ex Eisenberg Fm [36], resp. “Hangende Alaunschiefer”), overlain by 35 m of massive, coarse-grained greywacke and 25 m of blackish shale. The greywacke forms the base of the Arnsbergian Arnsberg Fm [38] (ex: Lüsenberg Fm [36]).

The about 38 m thick sampled lowermost part of the section mostly contains the calciturbidite succession from the uppermost Wicheln Mb and the Edelburg Mb of the Herdringen Fm (ex “Kulm-Plattenkalk”) [36]. The exposed part of the Wicheln Mb consists of thick calciturbidite packages separated by minor shale intercalations. The isochronous, 3.8 m thick black shale of the *Actinopteria* Shale interval [39] forms the base of the Edelburg Mb. It coincides with the base of *Neoglyphioceras suerlandense* Zone and the transgressive base of the Kulm sequence 11 commencing at the mid-Brigantian boundary [37]. Above the *Actinopteria* Shale interval, the Edelburg Mb consists of 12.8 m of medium-bedded calciturbidite beds and interbedded dark grey to blackish shale. The boundary to the overlying Seltersberg Fm is drawn above the first black shale bed. Above, calciturbidite beds abruptly become thin and scarce, and fade out about 17 m above the base of the Formation. A 3.7 m thick package of thin-bedded blackish chert and intercalated black shale 4 m above the base of the Formation is noteworthy.

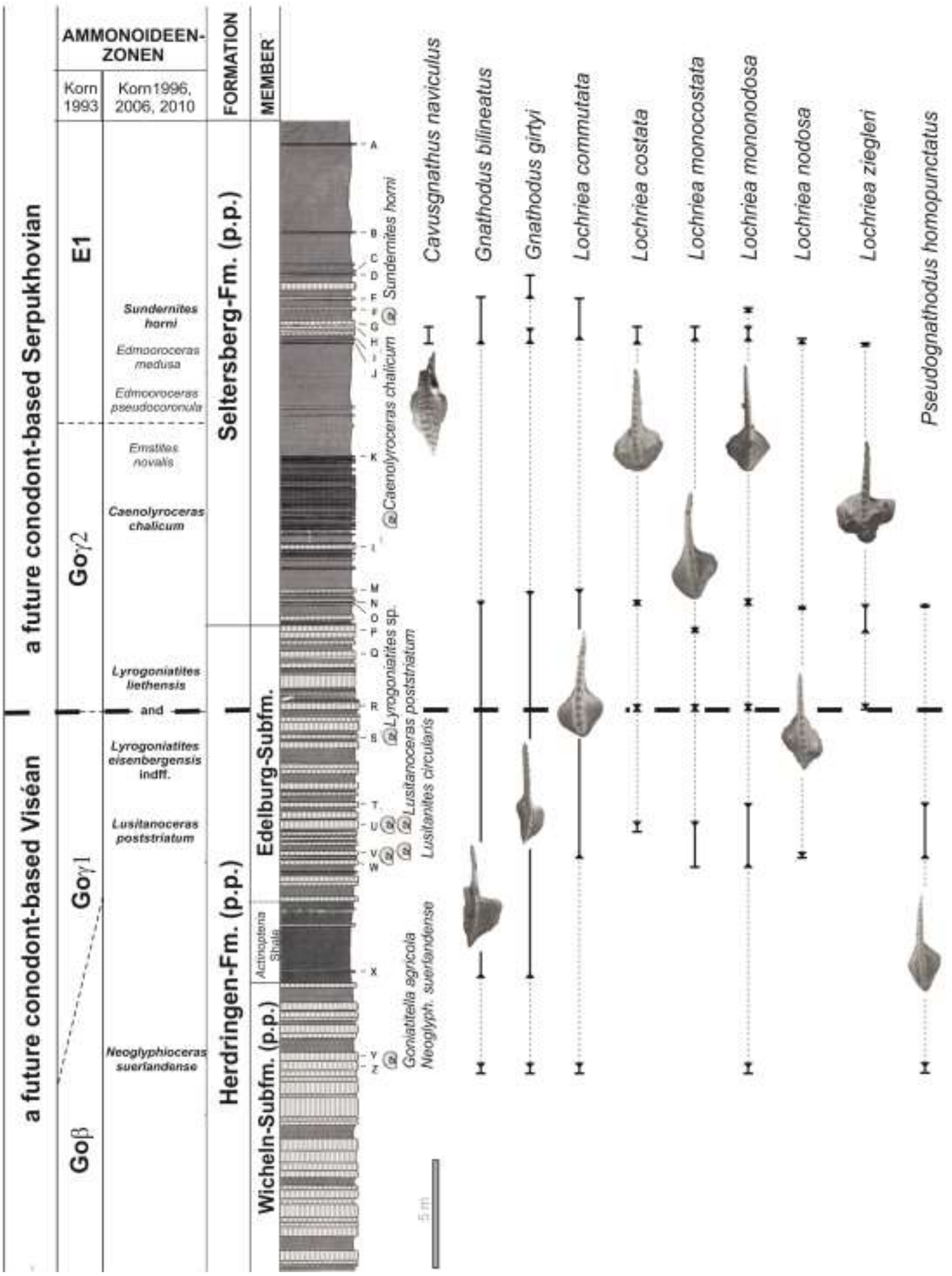

Figure 3 - Conodont distribution in the Arnsberg section and correlation with proven ammononoid zones (in bold); ammonoid bearing horizons [31] are shown, but zonal boundaries are unknown and not indicated. Position of a future Viséan-Namurian boundary based on L. ziegleri is within the undifferentatiated *Lyrogoniatites liethensis* and *L. eisenbergensis* zones. White vertically ruled: calciturbidites; grey: shales; dark grey: black shales; black: siliceous shales and bedded cherts.

The top of the Herdringen Fm is diachronous along the northern rim of the Rhenish Mountains. It becomes younger towards the west. In the Arnsberg section it is situated within the "lower Go2γ", i.e. within the *Caenolyroceras calicum* Zone; the index ammonoid is present 4.6 m above the top of the Formation. In the Schälk section, about 35 km further west it reaches into the lowermost Serpukhovian *Edmooroceras pseudocoronula* ammonoid Zone. Correspondingly the thickness of the calciturbidites of the Edelburg Mb increased from 12.8 m to 27.5 m [31].

Conodont biostratigraphy and correlation with ammonoid data

26 samples labelled Z to A were taken from the bottom to the top of the studied part of the section. Sample Y was strongly silicified and almost insoluble. Samples L and K were not processed due to the insufficient sample weight; K proved to be a tuffite. The uppermost samples D–A had been derived from the uppermost, only few centimeters thick calciturbidite beds exposed in the Seltersberg Fm. They were barren except for a single *Gnathodus girtyi* in sample D.

From the remaining 20 productive samples 1133 P_1-elements were extracted and correlated with published ammonoid data [31] (Fig. 3). The fauna is dominated by *Gnathodus bilineatus* and *G. girtyi* occurring throughout the studied interval. The less abundant genus *Lochriea* is represented by *L. commutata*, *L. costata*, *L. monocostata*, *L. mononodosa*, *L. nodosa* and *L. ziegleri*. *L. senckenbergica* and *L. cruciformis* were not found. *Pseudognathodus homopunctatus* remains rare. It fades out in the middle part of the Edelburg Mb, below the entry of *L ziegleri*. A single specimen from the lowermost Seltersberg Fm (sample N) is most probably reworked, as two specimens of *Siphonodella* were found immediately below in sample O. Few specimens of *Cavusgnathus naviculus* occur in samples J–H in the uppermost calciturbidite package of the lower Seltersberg Fm. This package is the stratum typicum of *Sunderites horni* Korn 1993 that occurs in the Pendleian above the occurrence of *Edmooroceras pseudocoronula* and below the entry of *Tumulites pseudobilinguis*.

The FOD of *L mononodosa* precedes the entry of *L. nodosa* - it is recorded already in our lowermost sample Z. The FOD of *L. nodosa* is recorded by a single specimen 6.0 m above the base of the Edelburg Mb (sample V, 0.9 kg, 50 P elements). An adjacent shale bed yielded *Lusitanites circularis* (*Lusitanoceras poststriatum* Zone). *L. monocostata* is first present in the underlying sample W (0.26 kg, 22 P elements), *L costata* in the overlying sample U (0.66 kg, 102 P elements).
L. ziegleri postdates the entry of the other stronger ornamented taxa that occur in the section. The first two specimens were recorded 12.8 m above the base of the Edelburg Mb (sample R, 0.7 kg, 20 P elements), 0.6 m above a horizon yielding *Lyrogoniatites* sp. This genus marks the *L. eisenbergensis* and *L. liethensis* ammonoid zones, which cannot be differentiated in the section. Thus, in Arnsberg a potential future conodont-based Viséan–Serpukhovian boundary would be located within these zones, but below the *C calicum* Zone. In lithostratigraphic terms, the boundary would be 12.8 m above the base of the Edelburg Mb within its upper part. Unpublished data from the research well Schälk (M. Piecha & M. Salamon, Geological Survey of Northrhine-Westphalia) places the entry of *L. ziegleri* also in the Edelburg Mb, about 11.5 m above the base of the Member, which is remarkably similar to Arnsberg.

Conclusions and perspectives

For the first time, the position of a future Viséan-Serpukhovian boundary based on the entry of *L. ziegleri* is more clarified in the Rhenish Mountains. According to the first data from Arnsberg and the research well Schälk, it is above the isochronous *Actinopteria* Shale interval. The base of the latter coincides with the base of the *Neoglyphioceras suerlandense* ammonoid Zone and the base of Kulm sequence 11. It is correlated with the base of the British P_{2a} ammonoid Zone. In the Arnsberg section the FOD of L. *ziegleri* is situated within the undifferentiated *Lyrogoniatites eisenbergensis* and *L. liethensis* ammonoid zones, an interval that is correlated with the P_{2b} Zone of the British ammonoid zonation in the middle part of the upper Brigantian. Thus, the present data indicate a younger FOD of *L. ziegleri* in the Rhenish Mountains than on the British Isles. Refined sampling might result in lowering of the boundary. However, the successive entry of *L. mononodosa*, *L. nodosa* and *L. ziegleri* is a striking feature, also observed in northern England [16] and in the southern Urals (Verkhnyaya Kardailovka) [26]. Also the entry of *L. ziegleri* above the *Actinopteria* Shale interval in two sections within a distance of 35 km underlines our results. Thus, a potential diachronous FOD in the Northwest European Subvariscan realm – as not yet excluded for the British Isles [16] – might be possible. Refinement of the studies in the Rhenish Mountains are in strong need to tackle this problem.

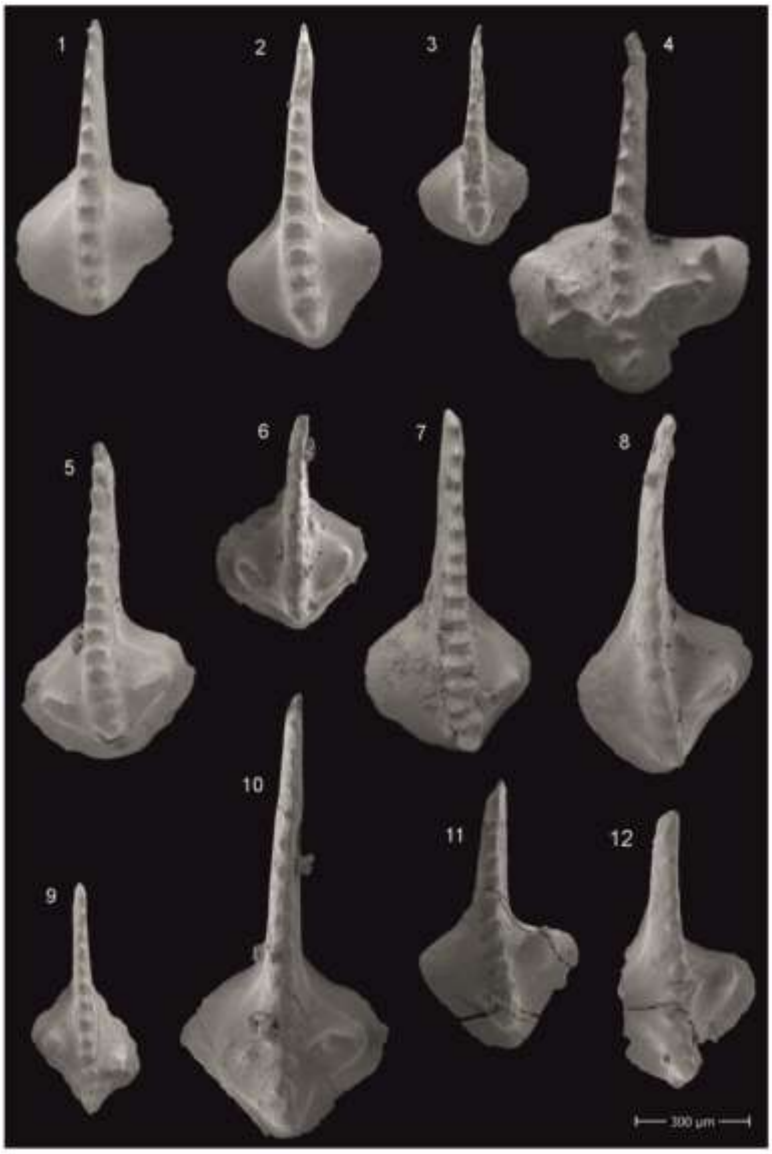

Figure 4 - Species of *Lochriea* SCOTT 1942 from Arnsberg. 1-3 *Lochriea commutata* (BRANSON & MEHL 1941). 1-sample Z, 2-sample U, 3-sample H. 4 *Lochriea ziegleri* NEMYROVSKA, PERRET & MEISCHNER 1994 → *Lochriea cruciformis* (CLARKE 1960). sample R. 5-6. *Lochriea costata* PAZUKHIN & NEMIROVSKA in KULAGINA et al. 1992. sample I. 7-8 *Lochriea monocostata* PAZUKHIN & NEMIROVSKA in KULAGINA et al. 19927 sample I,8-sample P. 9 *Lochriea nodosa* (BISCHOFF, 1957), sample J. 10-12 *Lochriea mononodosa* (RHODES, AUSTIN & DRUCE 1969). 10-sample R, 11-sample O, 12-sample N.

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КАСИМОВСКИЕ КОНОДОНТЫ РАЗРЕЗА УСОЛКА, ЮЖНЫЙ УРАЛ

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Конодонты являются эффективным инструментом расчленения и корреляции разрезов карбона морского генезиса. Их способность быстро эволюционировать позволяет строить детальные зональные шкалы и использовать отдельные виды в качестве биомаркеров границ Международной стратиграфической шкалы (МСШ). В настоящее время продолжаются работы по установлению лимитотипов (GSSP) ярусов верхнего карбона МСШ, на данный момент выбран вид-индекс нижней границы гжельского яруса – это *Streptognathodus simulator* Ellison [7, 8, 12]. Вид, определяющий нижнюю границу касимовского яруса, пока не установлен.

Рисунок 1 - Местоположение обнажения Усолка

Разрез Усолка (рис. 1) расположен на правом берегу одноименной реки (Республика Башкортостан). Он обладает уникальными свойствами, делающими его одним из лучших разрезов верхнего карбона в мире: здесь наблюдается непрерывная последовательность отложений от верхней части московского яруса карбона до сакмарского яруса перми, породы содержат большое количество конодонтов, имеются туфовые прослои с цирконами, по которым установлен абсолютный возраст отложений [9]. Кроме того, обнажение находится на территории санатория «Красноусольский» и доступно для изучения. Однако любое, даже самое лучшее обнажение, становится известным только благодаря людям, которые своим трудом открывают его для науки. Благоприятное сочетание уникального природного объекта и энергии его неутомимых исследователей Б.И.Чувашова, В.В.Черных и В.И.Давыдова [4-8] позволило обнажению Усолка приобрести мировую известность. Недостаточно изученными оставались только конодонты из касимовских отложений, это связано с тем, что данный интервал разреза продолжительное время был плохо обнажен. Для полевой геологической экскурсии в рамках XVIII Международного конгресса по карбону и перми касимовская часть разреза Усолка была расчищена (рис. 2), что и позволило провести здесь исследование конодонтов [11].

Рисунок 2 - Общий вид обнажения Усолка

В процессе изучения касимовских отложений данного разреза, пришлось столкнуться с некоторыми особенностями конодонтовых ассоциаций. Одна из них – эндемичность конодонтов в основании касимовского яруса, которая характерна для многих регионов и является одной из причин того, что до сих пор не выбран вид-индекс данной границы [1]. Остальные особенности конодонтов рассмотрены ниже при описании зональных комплексов

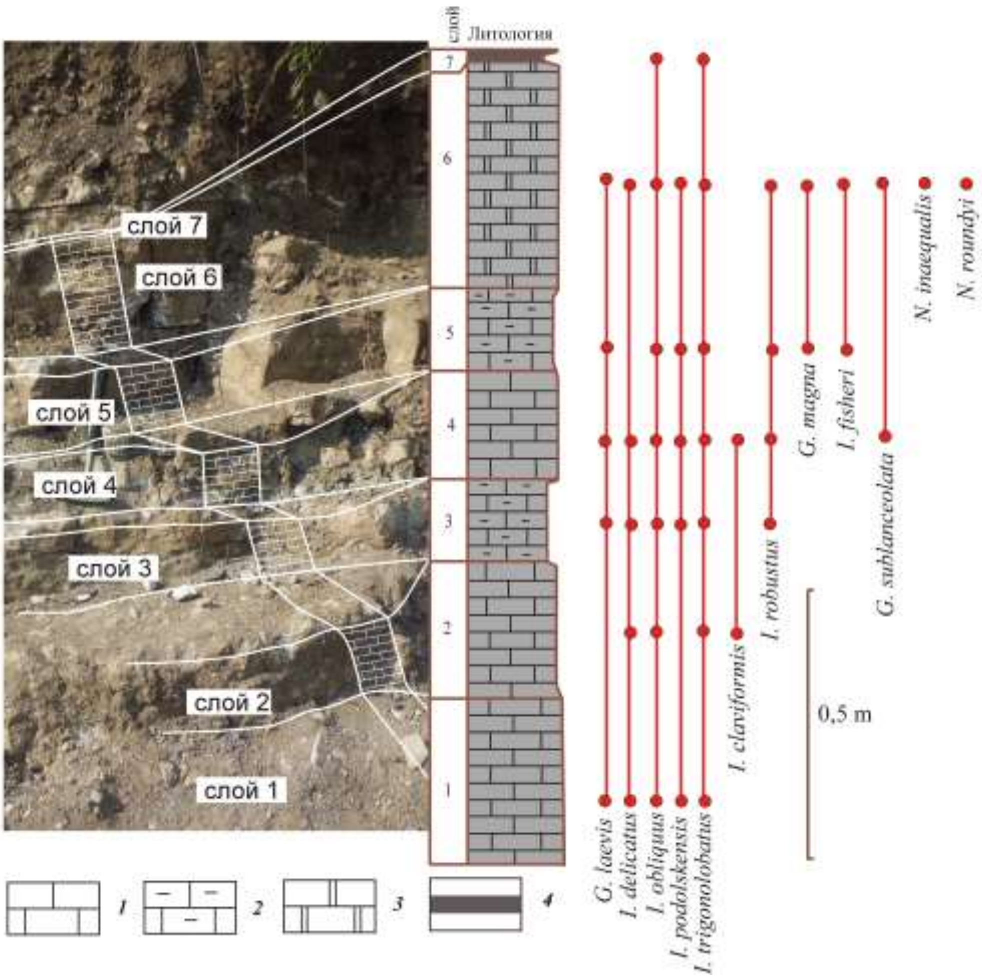

Рисунок 3- Распространение конодонтов в отложениях московского яруса разреза Усолка. Условные обозначения: 1 – известняк, 2– известняк глинистый, 3 – доломит, 4 – туф

каменноугольных отложений Усолки.

В терригенно-карбонатных отложениях касимовского яруса разреза Усолка мощностью около 13 м, конодонты встречаются неравномерно, но дают возможность провести зональное расчленение разреза.

Московский ярус, зона Neognathodus roundyi (слои 1-7) (рис. 3). Отложения сложены известняками светло-серыми, мелкозернистыми, массивными, с прослоями и линзами кремней, встречаются членики криноидей, брахиоподы. Конодонты интервала многочисленны, хорошей

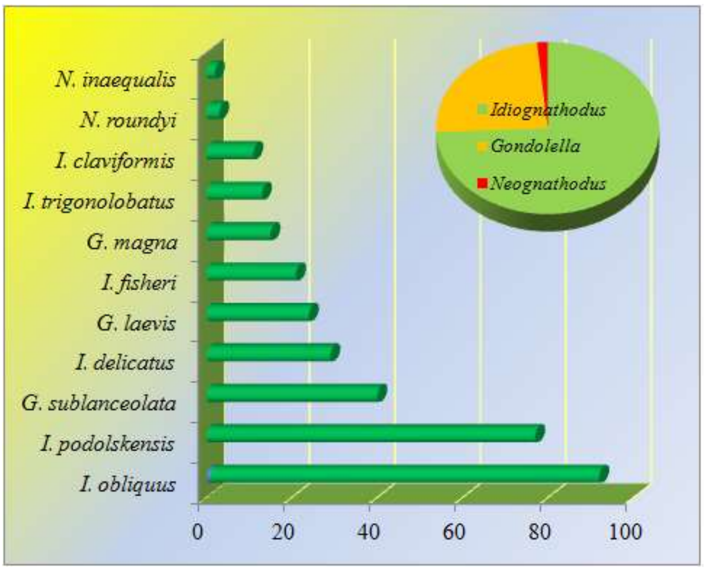

Рисунок 4 - Количество конодонтов в слое 6 сохранности, но не отличаются большим разнообразием, присутствует много ювенильных форм. Распределение видов по разрезу показывает, что в слоях 1-4 (рис. 3) доминантами комплекса являются *Idiognathodus obliquus* Kossenko et Kozitskaya и *I. podolskensis* Goreva. Конодонты *Gondolella laevis* Kossenko et Kozitskaya, *G. magna* Stauffer et Plummer, *G. sublanceolata* Gunnell, *Idiognathodus claviformis* Gunnell, *I. delicatus* Gunnell, *I.trigonolobatus* Barskov et Alekseev, *Neognathodus inaequalis* Kozitskaya et Kossenko, *N. roundyi* Gunnell представлены относительно небольшим количеством экземпляров. В верхней части разреза (особенно в слое 6), сосредоточено большое количество конодонтов. Здесь сохраняется доминирование *Idiognathodus obliquus* Kossenko et Kozitskaya и *I. podolskensis* Goreva (рис. 4),

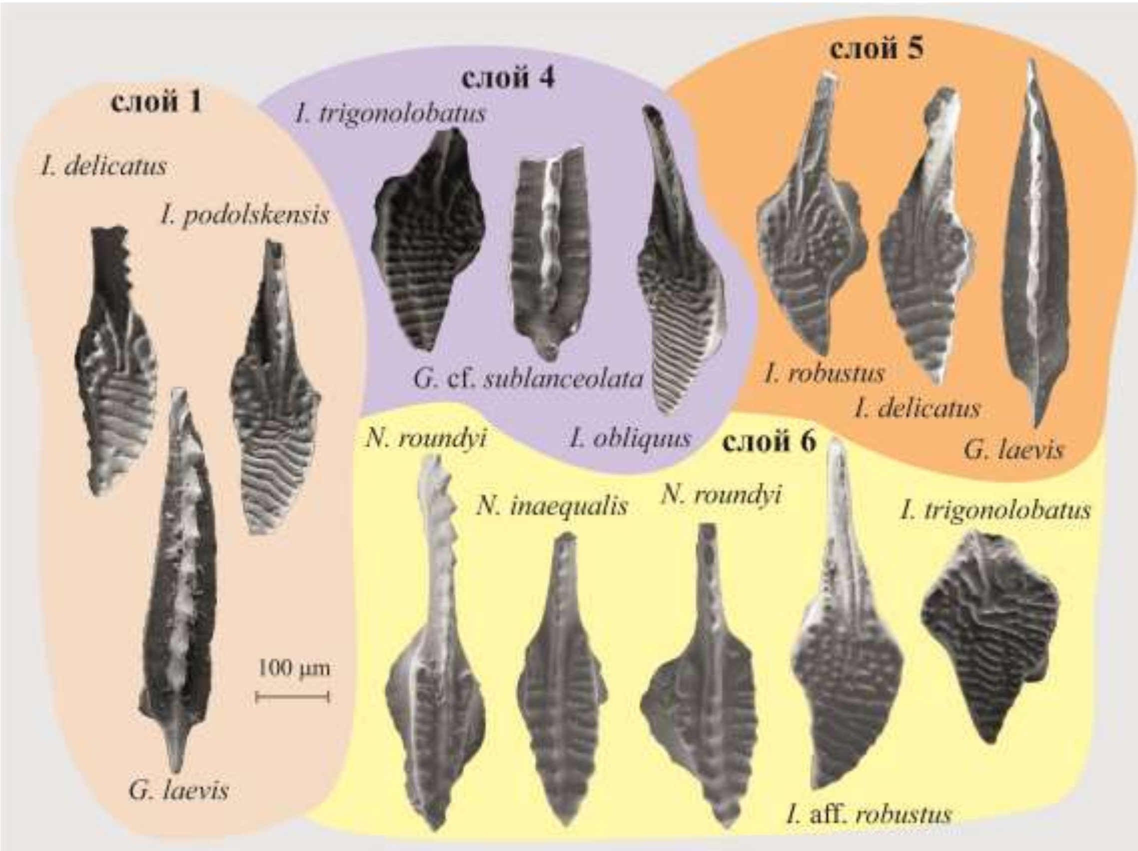

Рисунок 5 - Конодонты московского яруса разреза Усолка

наблюдается большое количество гондолелл (рис. 4) – индикаторов глубоководной морской остановки [1, 3]. Характерные виды конодонтов из отложений московского яруса приведены на рисунке 5.

Касимовский ярус, зона Streptognathodus subexcelsus (слои 8-14). Нижняя граница касимовского яруса отмечена появлением вида *Streptognathodus subexcelsus* Alekseev et Goreva, совместно с которым встречены многочисленные конодонты, подвергшиеся процессу «желобообразования» (рис. 6). Формирование различно выраженного и по-разному расположенного срединного желоба является наиболее значимой морфологической трансформацией, которой подверглись конодонты на московско-касимовском рубеже [10]. Поэтому из конодонтов-желобообладателей, вероятно, и нужно выбирать вид-маркер нижней границы касимовского яруса. Наиболее предпочтительным, на наш взгляд, является вид *Streptognathodus subexcelsus* Alekseev et Goreva, который, возможно, произошел от *Idiognathodus podolskensis* Goreva путем углубления центрального понижения и дальнейшего разрыва ребер в центральной части платформы с образованием срединного желоба (рис. 7).

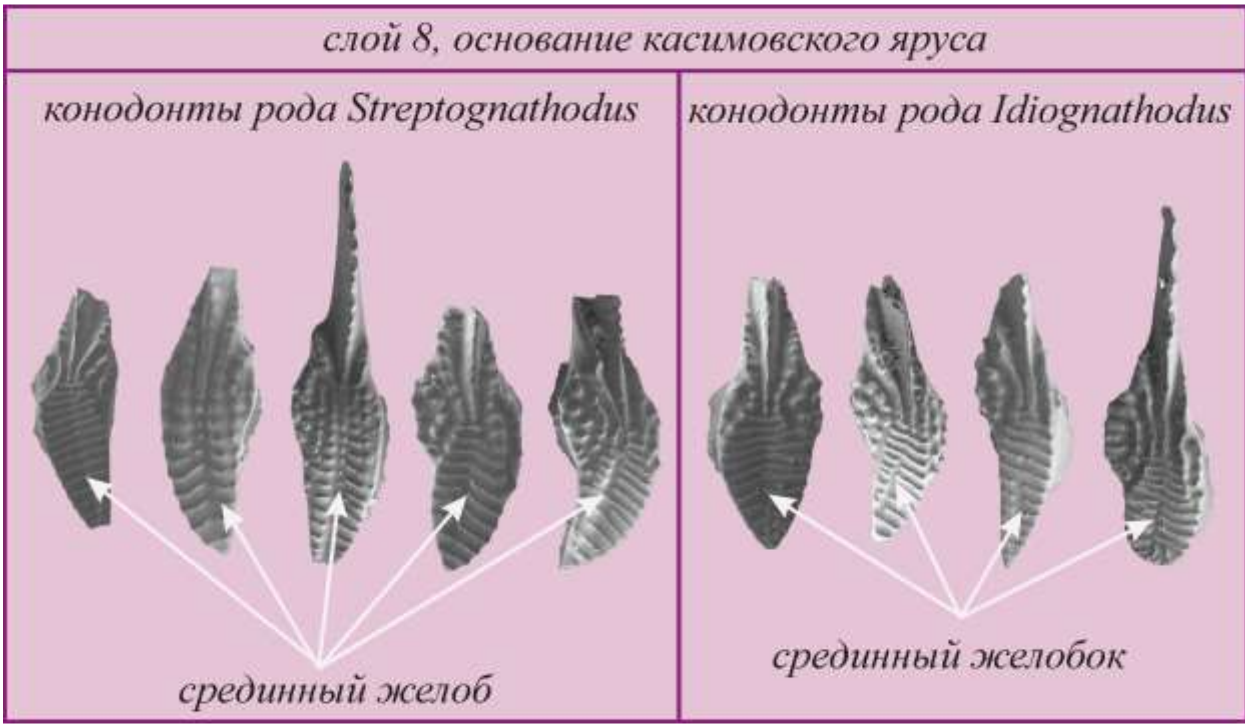

Рисунок 6 - Формирование желоба в начале касимовского века у различных конодонтов; слой 8, основание касимовского яруса

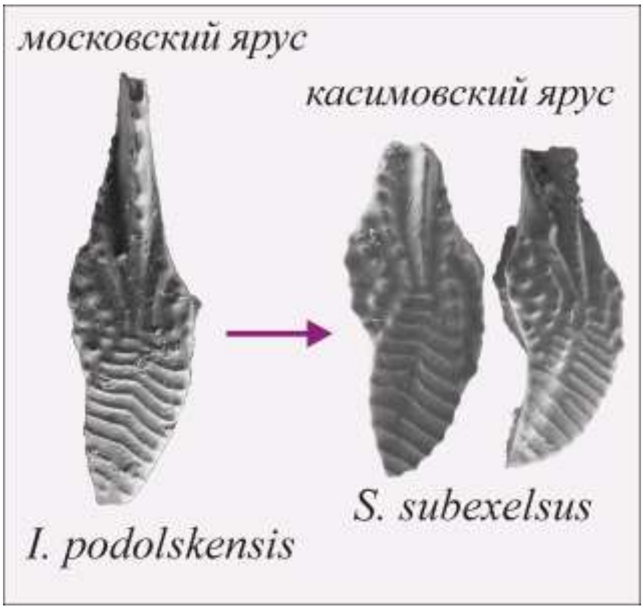

Рисунок 7 - Эволюционная линия *Idiognathodus podolskensis* Goreva – *Streptognathodus subexcelsus* Alekseev et Goreva

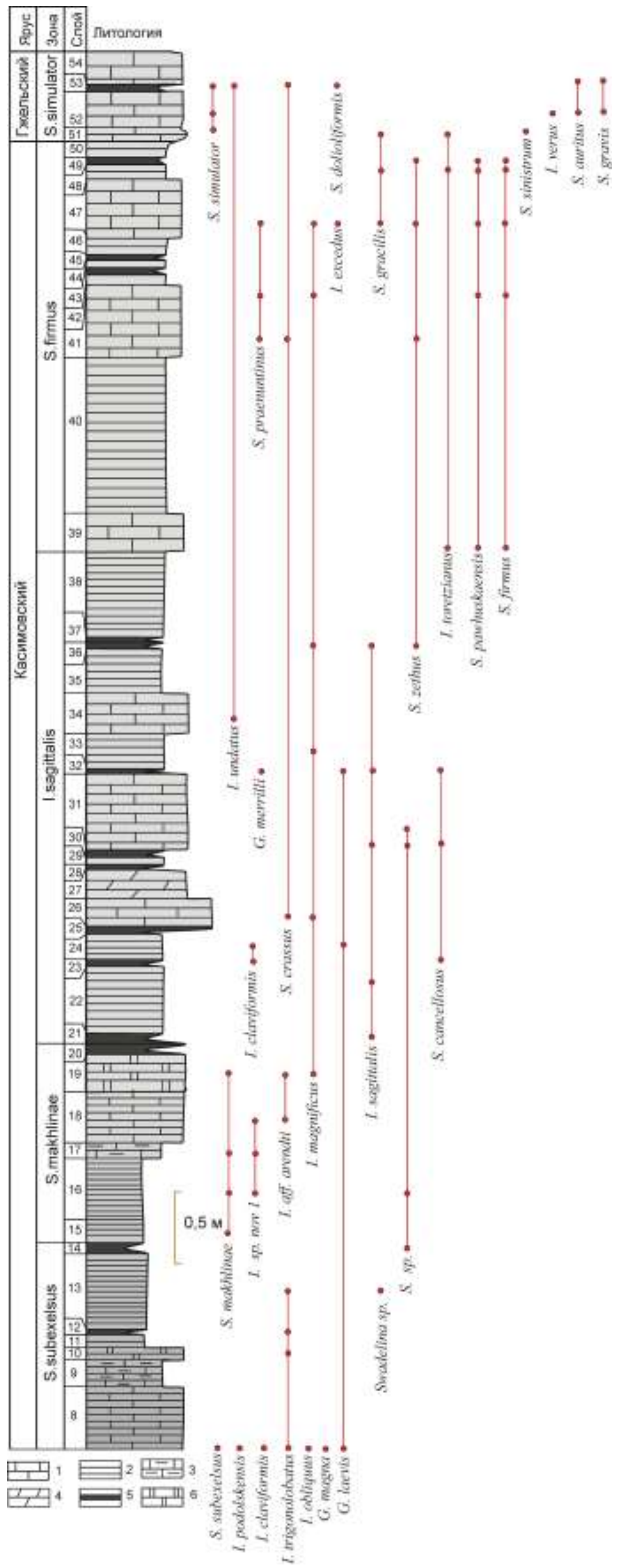

Рисунок 8 - Распространение конодонтов в отложениях касимовского яруса разреза Усолка Условные обозначения: 1 – известняк, 2 – глина, аргиллит, 3 – известняк глинистый, 4 – мергель, 5 – туф, 6 – доломит

Касимовский ярус, зона Streptognathodus makhlinae (слои 15-20). В отложениях зоны makhlinae, расположенной выше по разрезу, содержится специфический комплекс идиогнатодусов с сильно расширенной базальной полостью (рис. 7, слой 17, 18), также присутствуют *Idiognathodus arendti* Barskov et Alekseev, *I.trigonolobatus* Barskov et Alekseev и *Streptognathodus makhlinae* Alekseev et Goreva (рис. 8).

Касимовский ярус, зона Streptognathodus sagittalis (слои 21-38). В интервале разреза, отвечающего зоне sagittalis, конодонты встречаются редко, но они достаточно разнообразны. Кроме зонального вида, здесь присутствуют обладатели сильно выступающей внутренней лопасти: *Idiognathodus magnificus* Stauffer et Plummer и *I. undatus* Chernykh, редкие *Gondolella merrilli* Gunnell, разнообразные стрептогнатодусы (*Streptognathodus cancellosus* (Gunnell), *S. crassus, S. zethus* Chernykh et Reshetkova) (рис. 9).

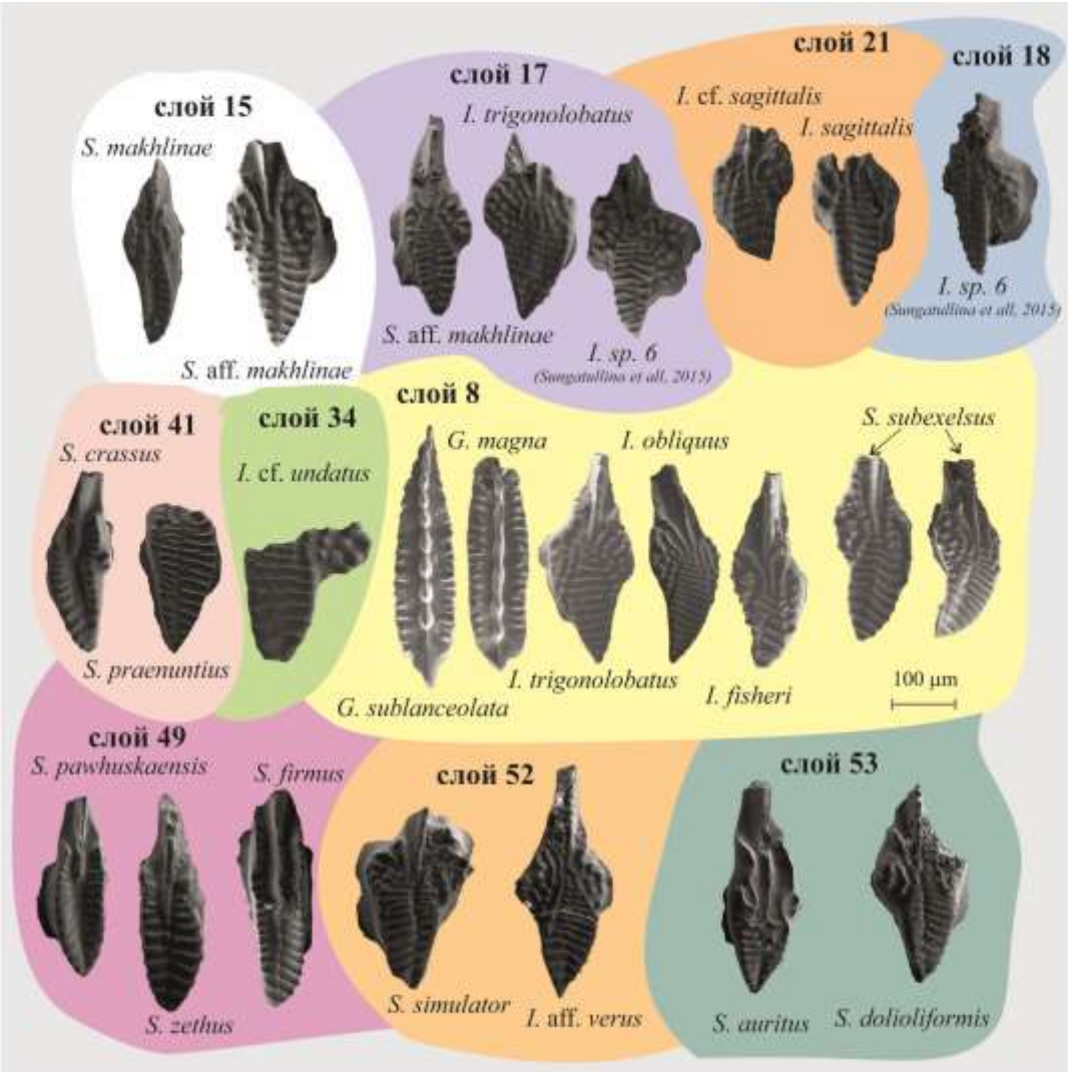

Рисунок 9 - Конодонты касимовского яруса разреза Усолка

Касимовский ярус, зона Streptognathodus firmus (слои 39-50). В конце касимовского века происходит обновление видового состава, впервые в касимовской истории конодонтов доминирует род *Streptognathodus*. По мере продвижения вверх по разрезу комплекс конодонтов становится богаче и разнообразнее. Здесь совместно с видом-индексом найдены *Idiognathodus excedus* Chernykh, *I. magnificus* Stauffer and Plummer, *I. toretzianus* Kozitskaya, *I. undatus* Chernykh, *Streptognathodus crassus* Chernykh, *S. gracilis* Stauffer and Plummer, *S. pawhuskaensis* Harris and Hollingsworth, *S. praenuntius* Chernykh, *S. zethus* Chernykh and Reshetkova.

Гжельский ярус, зона Streptognathodus simulator (слои 51-54). В начале гжельского века среди конодонтов снова начинается процесс образования срединного желоба, который затрагивает виды рода *Streptognathodus*, такие как *Streptognathodus auritus* Chernykh, *S. gravis* Chernykh, *S. simulator* Ellison, *S. sinistrum* Chernykh. Также присутствуют *Idiognathodus toretzianus* Kozitskaya, *I. verus* Chernykh, *I. undatus* Chernykh, *Streptognathodus crassus* Chernykh, *S. dolioliformis* Chernykh, *S. gracilis* Stauffer et Plummer.

Проведенное исследование показало, что массовое развитие и разнообразие конодонтов наблюдается только на пограничных рубежах: московско-касимовском и касимовско-гжельском. В течение касимовского века происходит постепенная смена комплексов конодонтов, позволившая установить последовательность конодонтовых зон (roundyi, subexcelsus, makhlinae, sagittalis, firmus, simulator), прослеживаемых на территории Восточно-Европейской платформы [2].

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STRATIGRAPHICAL SIGNIFICANCE OF THE FAMENNIAN-TOURNAISIAN BRYOZOANS FROM THE SOUTHERN AND CENTRAL REGIONS OF RUSSIA

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Among the aims of the International Subcommissions on Devonian and Carboniferous Stratigraphy is subdivision and correlation the Famennian-Tournaisian deposits. The correlation between the global stratotypes and other sections is difficult by some causes. There are differences between facies, interruptions in sedimentation at the Devonian-Carboniferous boundary, redeposition of sedimentary material, influence of local factors and etc.

With regards to these difficulties, the interdisciplinary study, including the palaeontological tools, is very important. The low degree of knowledge about parastratigraphical groups limits their practical using in biostratigraphy. We have a mistaken opinion about their uselessness. However, targeted research demonstrated the importance of such organisms for solution of stratigraphical problems. One of them is bryozoans.

Bryozoans are benthic organisms distributed chiefly to neritic facies, but occurring also in lagoons and open ocean. Some data have been accumulated about their Famennian-Tournaisian assemblages from different regions of Russia in the last decades. In the present paper I attempt to show the significance of bryozoans for regional and interregional biostratigraphical studies.

The present study is based on detailed studies of oriented sections in the collections of the author and in museums collected (Nekhoroshev V. P., CNIGR; Volkova K. N., IPGG SB RAS; Trizna V.B., VNIGRI; Morozova I. P., Popeco L.I., and Lavrent'eva V. D., PIN) that represent numerous localities in Russia (Fig. 1). The material was studied using a binocular microscopic. Additional data were obtained from the literature [2-4, 6-10, 15].

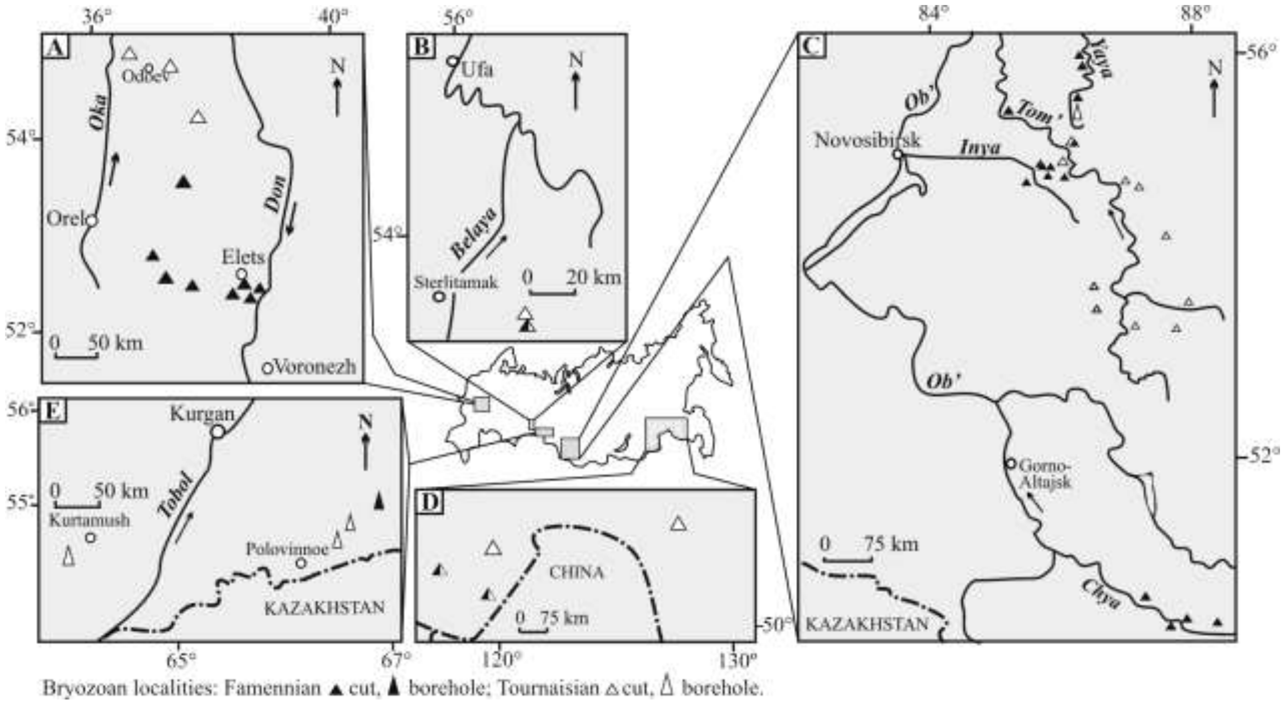
Taxonomically poor Famennian-Tournaisian bryozoan assemblages have been recorded from some localities in the basins of the Oka and Don rivers of the Russian plate [2, 3] (Fig. 1). The author identified the analogous generic composition in Lipovka village and Gornostaevka quarry (unpublished data). The stratigraphical distribution of bryozoans shows on Fig. 2. These are endemic species of cosmopolitan genera in dominant.

Rare bryozoans are recorded at the Devonian/Carboniferous of the Western Urals Zone from the Southern Urals [12] (Fig. 1, 3).

The Late Famennian bryozoan assemblage includes 11 species which are known from the south-western part of the West-Siberian plate (Fig. 1) [13]. The data about the Early Tournaisian bryozoans of this region are absent. The abundant assemblage (37 species of 28 genera) was described from the Upper Tournaisian [4, 14]. The stratigraphical distribution of bryozoans is demonstrated on Fig. 4.

In the deposits of the Kosoy Utyos and Mitikha horizons (Lower Famennian) of the western part of the Altai-Sayan Folded Area (ASFA, without the Rudny Altai) there are 34 species belonging to 20 genera [6] (Fig. 1). The Podonino bryozoan assemblage includes 12 species of 10 genera. It is characterized a large species endemism. Bryozoans from the Topki Horizon include 21 species of 15 genera [8, 15]. In the Early Tournaisian (Taidon Horizon) of ASFA 55 bryozoans are known. The Late Tournaisian bryozoan assemblage includes 93 species [5, 8, 15]. The stratigraphical distribution of the Famennian-Touranisian bryozoans from the western part of ASFA is demonstrated on Fig. 5.

Some Late Famennian and Tournaisian bryozoans were described in the Russian part of the Mongol-Ochotsk Orogen Belt also (MOOB) (Fig. 1). The Koticha assemblage of the uppermost Devonian (beds with brachiopod *Sphenospira julii*) consists of 14 species [9, 11]. Three bryozoan zones (39 species) were established in the Pavlovo Horizon of the Lower Tournaisian [10, 11] (Fig. 6). The Yamkunsk Horizon corresponds to the bryozoan zone *Polypora zvonkovae*, in which 29 species are present [8, 10, 11]. The stratigraphical distribution of the Famennain-Tournaisian bryozoans in the Russian part of MOOB is demonstrated on Fig. 6.



Legend: **A** – central part of the Russian plate, **B** – Southern Urals, **C** – western part of Altai-Sayan Folded Area, **D** – Mongolo-Ochotsk Orogen Belt, **E** – south-western of West-Siberian plate.

Figure 1 - Location map and bryozoan localities from central and southern regions of Russia

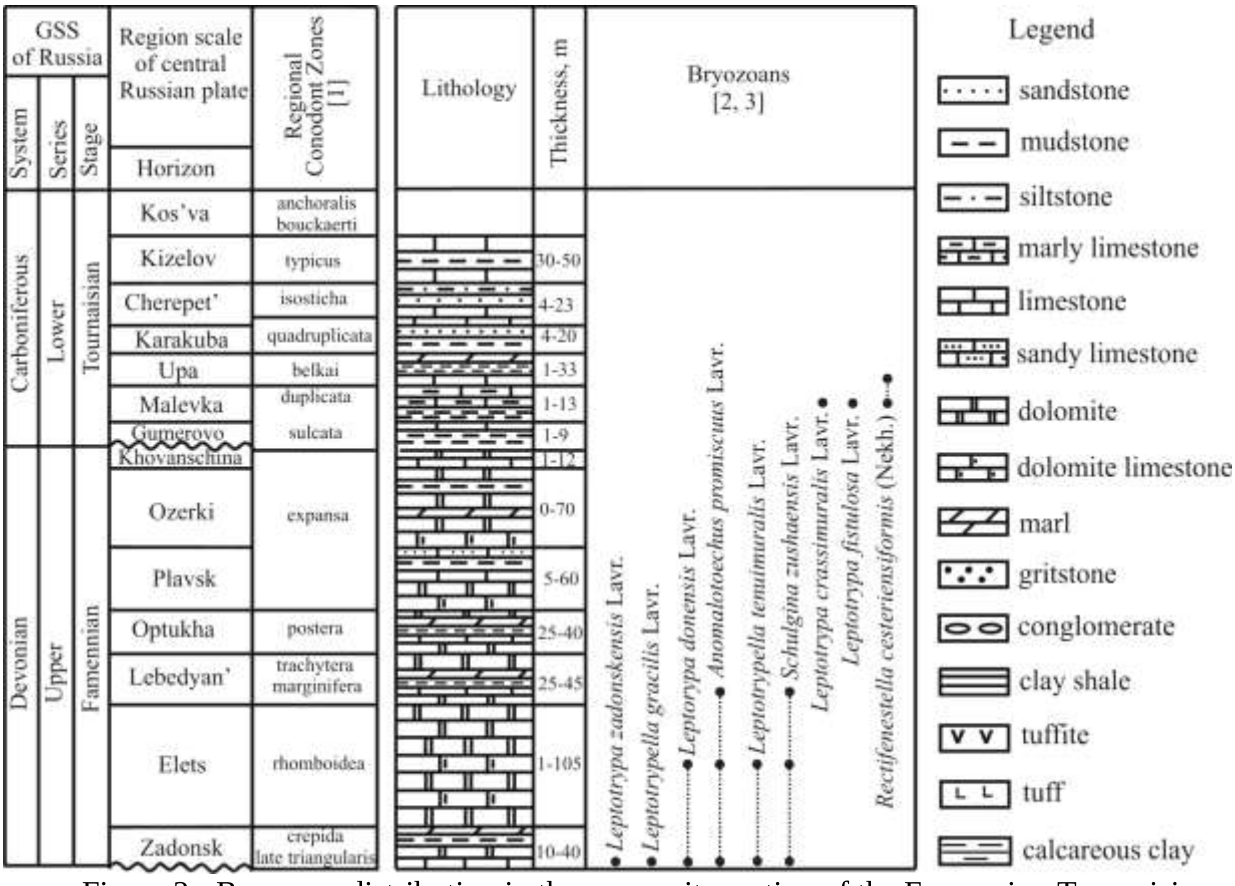


Figure 2 - Bryozoan distribution in the composite section of the Famennian-Tournaisian of the central part of the Russian plate

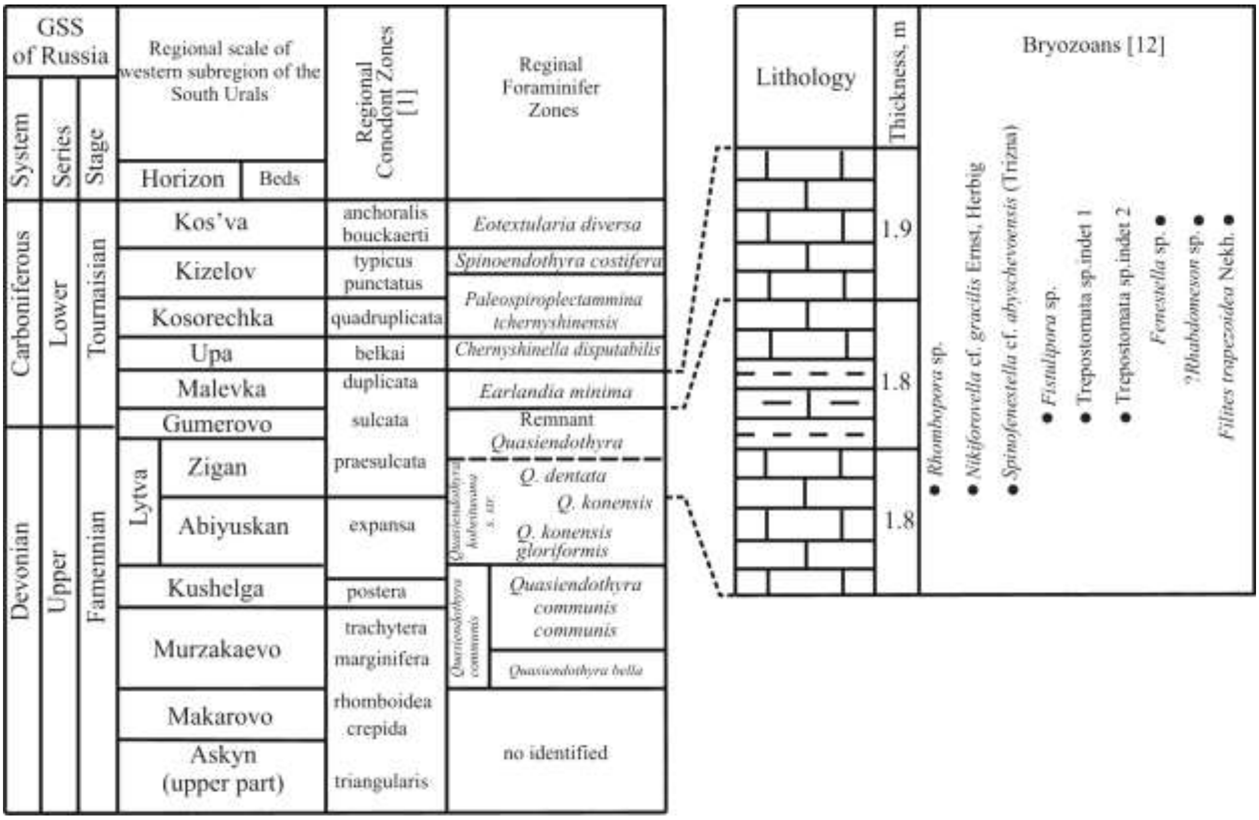


Figure 3 - Bryozoan distribution in the composite section of the Famennian-Tournaisian of the Southern Urals

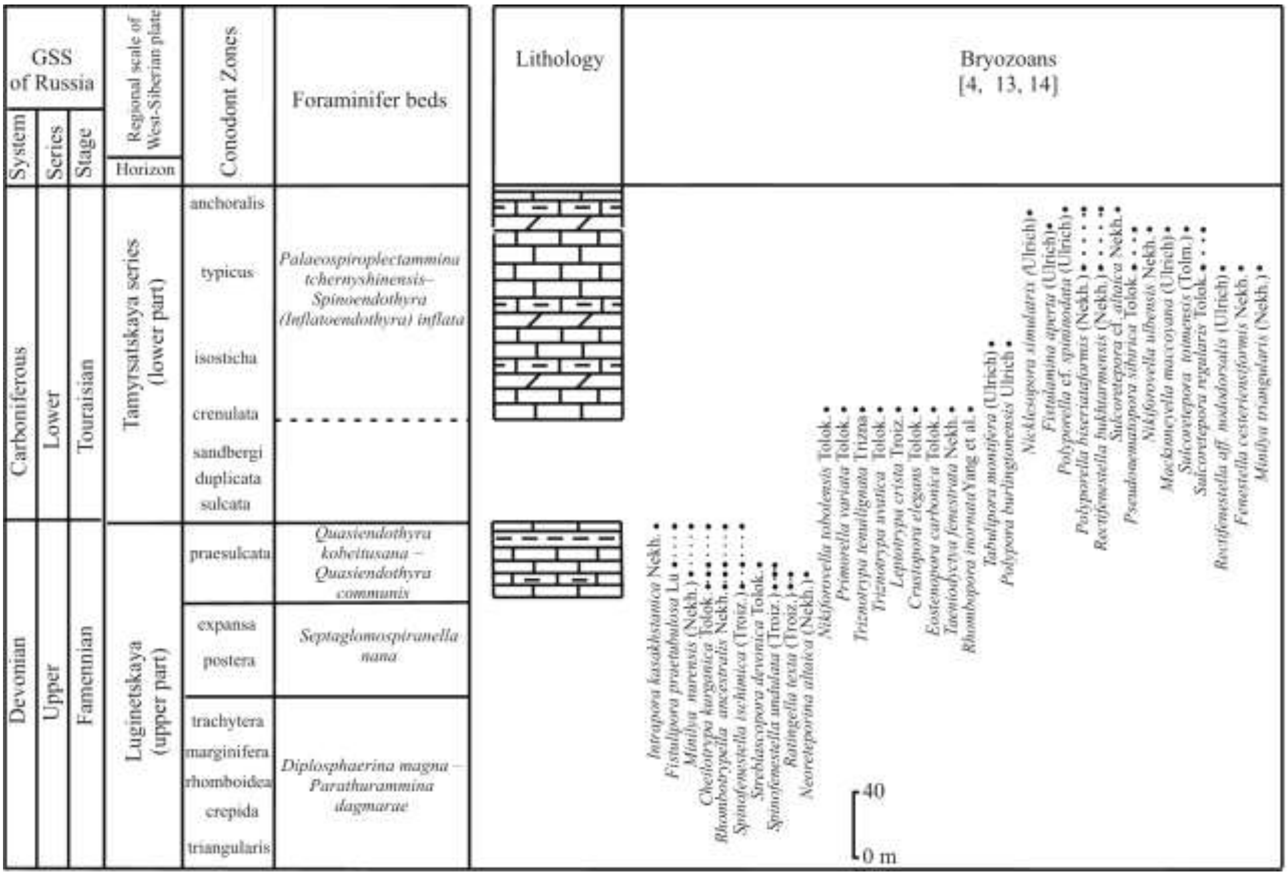


Figure 4 - Bryozoan distribution in the composite section of the Famennian-Tournaisian for the south-western part of the West-Siberian plate

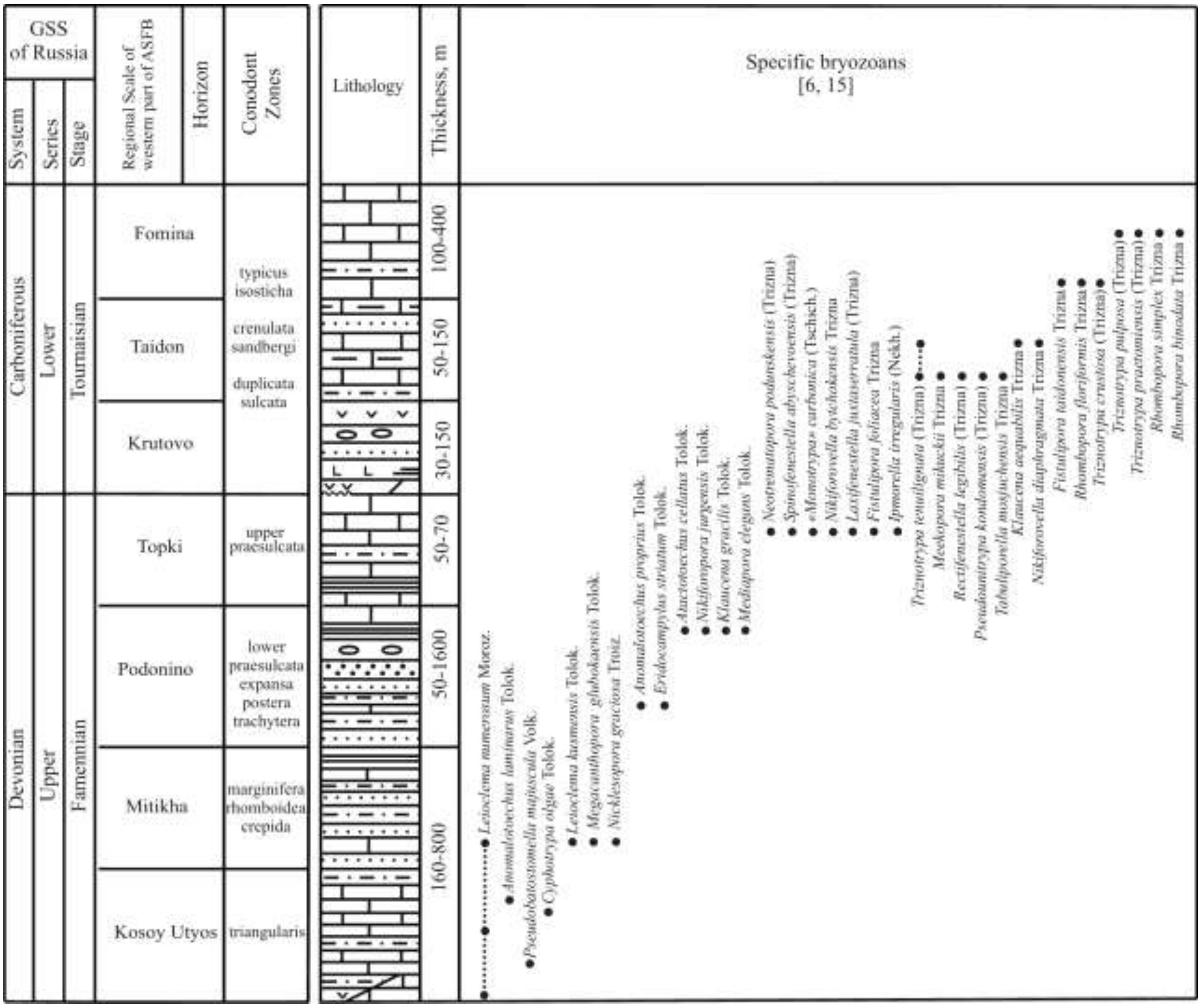


Figure 5 - Bryozoan distribution in the composite section of the Famennian-Tournaisian
for the western part of the Altai-Sayan Folded Area (without the Rudny Altai)

The current state of the knowledge of the Upper Devonian-Lower Carboniferous bryozoans does not allow operating with biostratones. However, the available data can be useful for the comparison of the bryozoan assemblages. Some species common for the different part of the Russia are noted. Two bryozoans from the Topki Horizon of ASFA (*Spinofenestella abyschevoensis*) and the Velbert formation of the Rhenish Massif (*Nikiforovella gracilis)* are identified as morphotypes (with cf. mark) from the Lytva Horizon of the Southern Urals.

Good correlation of the Famennian-Tournaisian deposits by bryozoans is possible for the western part of ASFA (without the Rudny Altai) and the Russian part of MOOB. The Topki and Koticha horizons (uppermost Famennian) share *«Monotrypa» carbonica, Neotrematopora podunskensis, Nikiforovella bytchokensis,* and *Laxifenestella juxtaserratula.* Bryozoan *Klaucena aculeus* is distributed in the Taidon (western part of ASFA) and Pavlovsk (Russian part of MOOB) horizons. The Upper Tournaisian deposits of the Russian part of MOOB, the western part of ASFA and the south-western part of the West-Siberian plate are contain some common species *Rhombopora floriformis, R. binodata, R. simplex,* and *Streblotrypa strabona.* One bryozoan *Sulcoretepora toimensis* unites Late Tournaisian assemblage from the south-western part of the West-Siberian plate and the western part of ASFA.

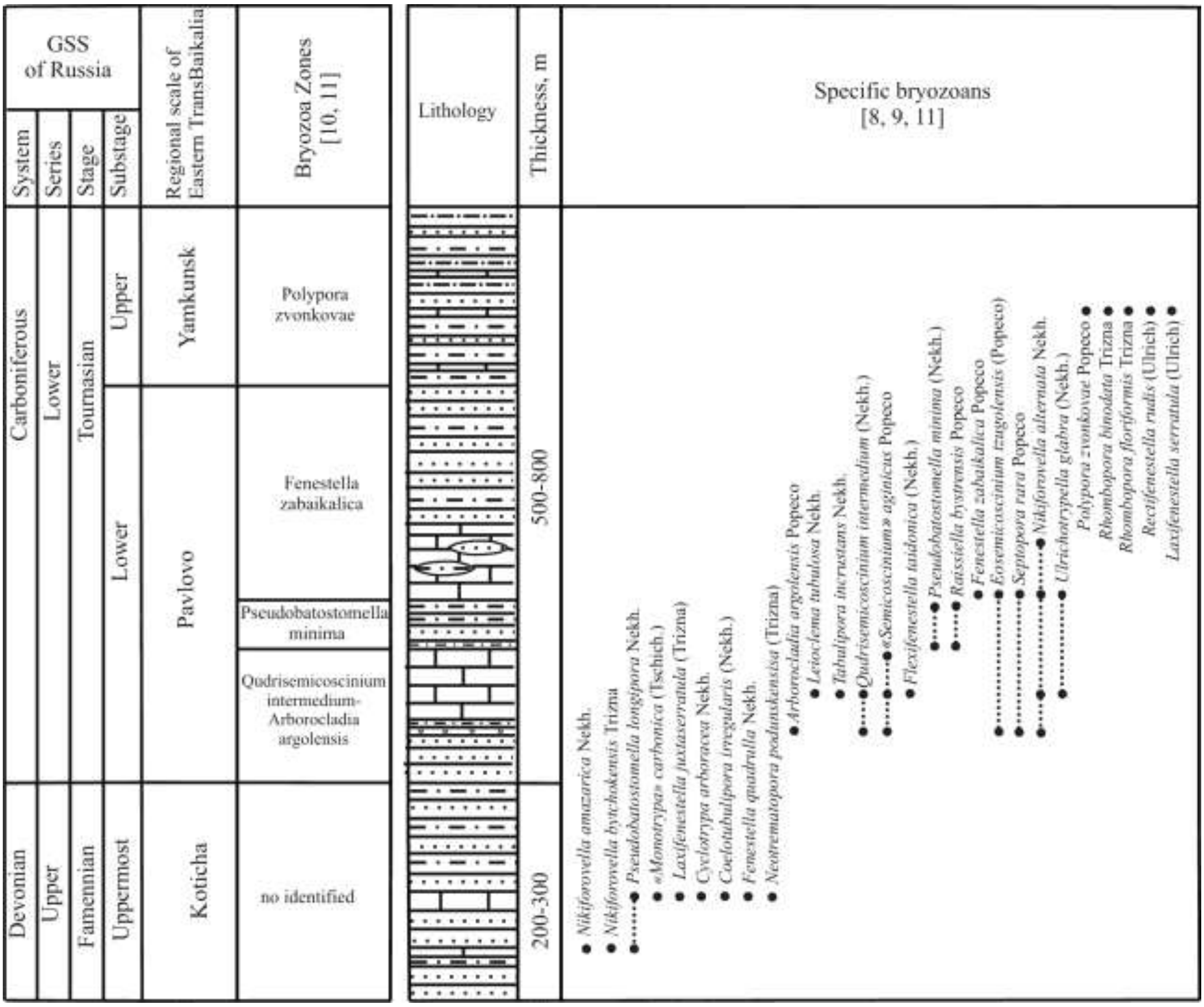


Figure 6 - Bryozoan distribution in the composite section of the Famennian-Tournaisian for the Mongolo-Ochotsk Orogen Belt (Russian part)

Notably, several species are common for the Famennain-Tournaisian assemblages of Russia, Kazakhstan, China, Mongolia, Azerbaijan and Armenia. Bryozoan *Leioclema numerosum* is known in the Meister Horizon of central Kazakhstan and the Kosoy Utyos-Mitikha horizons of the western part of ASFA. Two Chinese species *Coelotubulipora euspinusa* (Menggongao Formation of southern China) and *Fistulipora praetubulosa* (Hebukehe Formation of north-western China) are known from the Topki horizon (uppermost Famennian) of the western part of ASFA. Bryozoan *Spinofenestella abyschevoensis* unites the Topki horizon (ASFA) and the Arshaki-Akhbyur Formation of the Southern Transcaucasia; *Eodyscritella clatrata* occurs in the Topki Horizon and the Simorinsk Horizon of central Kazakhstan.

More bryozoans are common for the Lower Mississippian deposits of the Eurasian regions. Bryozoan *Rectifenestella cesteriensiformis* is known from the Malevka-Upa horizons (Lower Tournaisian) of central part of the Russian plate and the Tournaisian of the Rudny Altai (Kazakhstan). This species is characterized by the wide stratigraphical (Tournaisian-Lower Visean) and geographical distribution. The Early Tournaisian assemblages of the western part of ASFA (Taidon Horizon) and Kazakhstan (Kassinsk Horizon) contain *Nicklesopora taidonensis.* Some bryozoans *Raissiella tabulata, Pseudobatostomella minima, Ulrichotrypella glabra, Tabulipora incrustans, Hemitrypa altaica, Qudrisemicoscinium intermedium, Parafenestralia bukhtarmensis,* and *Anastomopora ovalifenestra* are common for the Lower Tournaisian of the Russian part of MOOB and the Rudny Altai (Kazakhstan). Species *Pseudobatostomella minima* is known from the Lower Tournaisian of Mongolia (*Pseudobatostomella minima* beds) and the Southern Transcaucasia (Geran-kalasi Formation). A few species are common for the Upper Tournaisian of the south-western part of the West-Siberian plate and Kazakhstan (*Rectifenestella simulans, R. bukhtarmensis*), Southern Transcaucasia (*R. bukhtarmensis*); the western part of ASFA and the Southern Transcaucasia (*Polyporella obscura*); the western part of ASFA and Mongolia (*Rhombopora floriformis, R. binodata, R. perpera, Streblotrypa strabona, Nicklesopora tersiensis*).

Conclusively, bryozoans can be employed successfully for the purpose of subdivision and correlation of the Famennian-Toursnaisian successions in the different regions of Russia and Eurasia. Further investigation of these organisms will expand their practical utility in biostratigraphy.

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EARLIEST CARBONIFEROUS STROMATOLITES FROM LOWER QIANHEISHAN FORMATION (TNB1), NORTHWESTERN CHINA: IMPLICATION FOR MICROBIAL CARBONATE PROLIFERATION AFTER THE END-DEVONIAN MASS EXTINCTION

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Microbial carbonates commonly flourished following mass extinction events. The end-Devonian (Hangenberg) mass extinction event is a first-order mass extinction on the scale of the 'Big Five' extinctions. However, to date, it is still unclear whether global microbial carbonate proliferation occurred after the Hangenberg event. In this study, early Tournaisian (Tnb1) stromatolites have been documented from the Qianheishan Formation at the Dashuigou section in Ciyao area, eastern Gansu Province, northwestern China. The stromatolites are exposed in a conglomerate and sandstone sequence of about 22.5 m thick, with lateral development more than 200 m in width. They mainly consist of micrites, peloids, oncoids, silt-sized quartz grains and sparry calcite with rare fine to coarse sand-sized detrital grains and bioclasts. The occurrences of marine fossils and fenestral structures in the stromatolites suggest that they developed in intertidal environments. Within the stromatolites, three laminae types are identified, including micritic laminae, grain-dominated mixed laminae and micrite-dominated mixed laminae which are separated by thin micritic crusts. The development of grain- and micrite-dominated laminae in the stromatolites indicates that they were formed by the combination of microbial baffling, binding, and calcification. Accretion of same or different laminae types leads to different lamination styles, containing repetitive lamination and alternating lamination. The growth and demise of the stromatolites were controlled by relative sea-level fluctuations. They grew during a gradually relative sea-level rise, indicated by the changes in their thickness and growth form from thin-bedded laminar form in the lower part, to medium-bedded laminar and wavy forms and thick-bedded domal form in the middle and upper parts respectively. The demise of the stromatolites was caused by dramatically relative sea-level fall, evidenced from their overlying siltstone to fine sandstone facies.

With other early Tournaisian microbe-dominated bioconstructions extensively distributed on shelves in Australia, South China, India, North America and Russia, the Qianheishan stromatolites support microbial carbonate proliferation after the Hangenberg extinction. Additional support comes from quantitative analysis of the abundance of microbe-dominated bioconstructions through the Famennian and early Tournaisian, which shows that they were globally distributed (between 40° latitude on both sides of the palaeoequator) and that their abundance increased distinctly in the early Tournaisian compared to the latest Devonian (Strunian). Comparison of variations in the relative abundance of skeleton- versus microbe-dominated bioconstructions across the Hangenberg and 'Big Five' extinctions suggests that changes in abundance of skeletal bioconstructors may play a first-order control on microbial carbonate proliferation during extinction transitions, but that microbial proliferation is not a general necessary feature after mass extinctions.

Ye. M. Fazylov, V.Ya. Zhaimina, E.S. Musina

LITHOLOGICAL CHARACTERISTICS OF CARBON-BEARING ROCK MASSES OF SOUTH KAZAKHSTAN AND THEIR ORE-BEARING AND OIL AND GAS CONTENT PROSPECTS

This review article is compilative and is based on the materials of various authors listed in the list of references.

A principal task of geological survey in Kazakhstan is replenishment of the Republic's mineral resource base. Unfortunately, no detailed exploration works have been conducted over the last 25 years regarding the detection of most types of commercial minerals, with the exceptions of oil, gas, gold and uranium. Now, however, the situation has cardinally changed and the task of replenishment of metallic minerals takes first place in Government plans for economic development. As the reserves of easily developed sub-surface deposits are depleted, the exploration works should be primarily focused on deep layers of the completed ore mining areas, which have an extensive infrastructure. In this context it is necessary to perform works on the scientific rationale of exploration directivity. First and foremost, this pertains to the development of standard patterns of various mineral resource deposits, which can be developed in each specific region. Among the prospective targets in this regard are carbon-bearing rock masses of the upper Palaeozoic era, represented in South Kazakhstan.

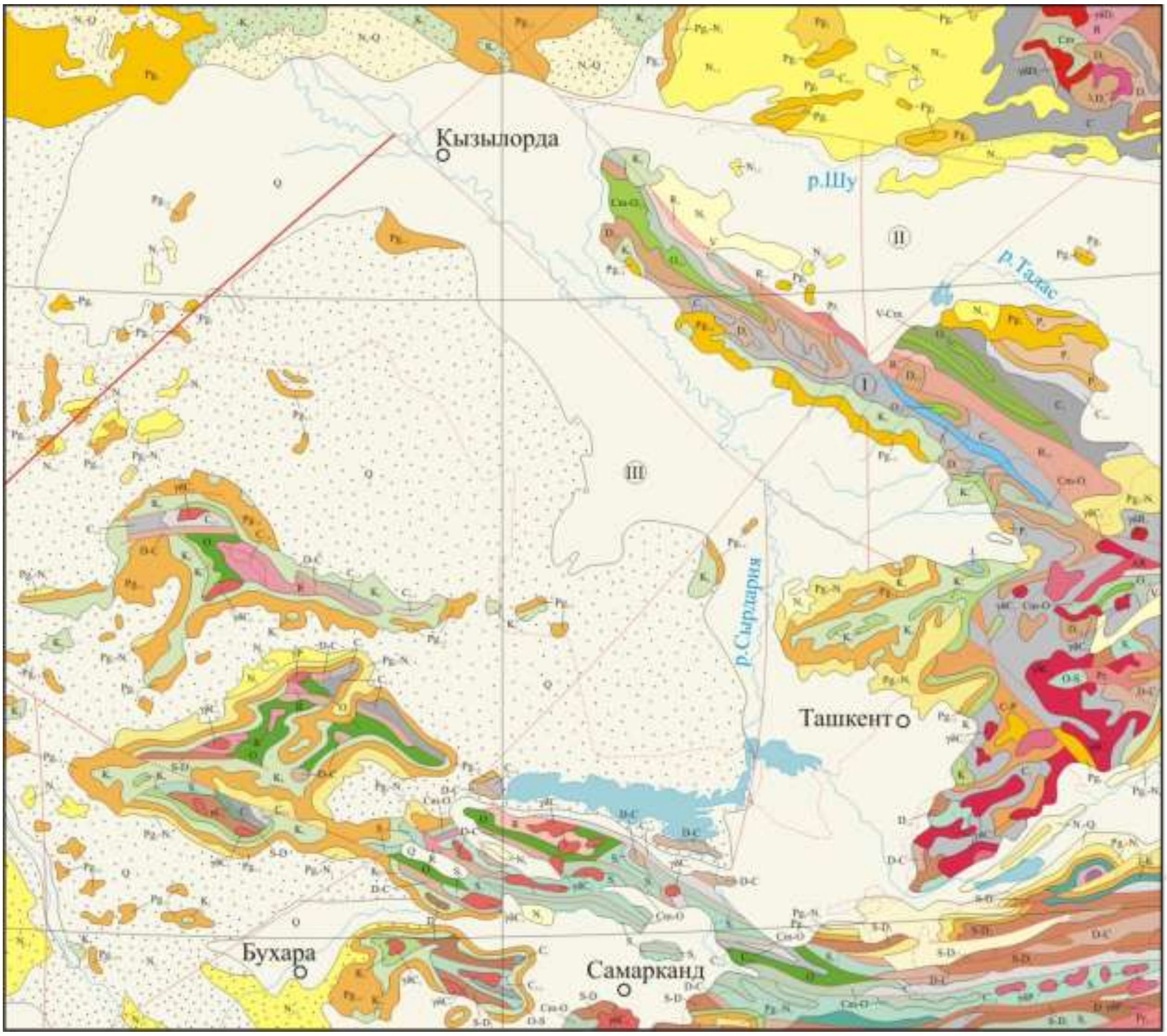
Carbonates of the Famennian-Mississippian period are well represented in the south of Kazakhstan: in the mountains of Great and Little Karatau, the Ugamskiy range of mountains, Syrdarinskiy, Shu-Sarysuskiy and East Aral sedimentary basins (fig. 1) [1]. In the Great Karatau mountains, lead and zinc deposits have been identified: Achisai, Mirgalimsai, Baizhansai, Shalkiya, Talap and others. Within the frame of the Shu-Sarysuiskiy sedimentary basin, the gas fields are associated with the rocks of that particular complex: Pridorozhnoe, Amangeldy, Airakty and others. At the surrounding grounds of the Uzbek part of the Syrdarinskiy sedimentary basin, gas fields have also been detected. However, the vast territory of Upper-Palaeozoic carbon-bearing complex has been marginally explored and has considerable prospects for detecting new deposits of lead, zinc and raw hydrocarbon deposits.

During the Famennian time, over a vast territory, covering the contemporary mountains of Great and Little Karatau, the Ugamskiy range of mountains, Syrdarinskiy, East Aral and Shu-Sarysuskiy, sedimentary basins formed a vast carbon-bearing platform, which existed through to the Bashkirian stage of Upper (Pennsylvanian) Carbon (fig. 2) [2]. At all the regions listed, the subsurface structure is generally identical and distinguished only by details (fig. 3). For the development of a geological model of a carbon-bearing platform, the Great Karatau region was chosen, where the Upper-Palaeozoic carbon-bearing rock masses are well exposed, are highly representative throughout all geological indicators (lithological composition, organic remains) and have significant thicknesses. Model results can be successfully and with considerable certainty applied at the surrounding areas.

The Karatau range of mountains is represented by the southern part of Kazakhstan Palaeozoic deposits. A folded structure of this mountainous area is observed north-westward by more than 400 km and is restricted by cavities of Syrdarinskaya and East Aral to the north-west and Shu-Sarysuskaya to the north-east (fig.1) [1]. Occupying the central position in relation to these structures, it can serve as a reference for modelling and forecasting in the delineation of new fields for commercial mining.

A detailed model of the ancient Famennian Lower Carboniferous basin of North-West Karatau was developed in our University. This is characterized by a carbonate rocks section that is unique in terms of its thickness, and here potential oil source facies and facies of reservoirs were identified, as well as sample lead and zinc deposits [3, 4, 5, 6, 7].

At Great Karatau, the carbonates, ranked from Upper Devonian (Frasnian-Fomennian) till Middle Carbon (Bashkirian) are well exposed, undisturbed, confined to solid sections and are located more or less in one solid line, reaching a thickness of 4,000 metres or more [3, 4, 5, 6, 7].



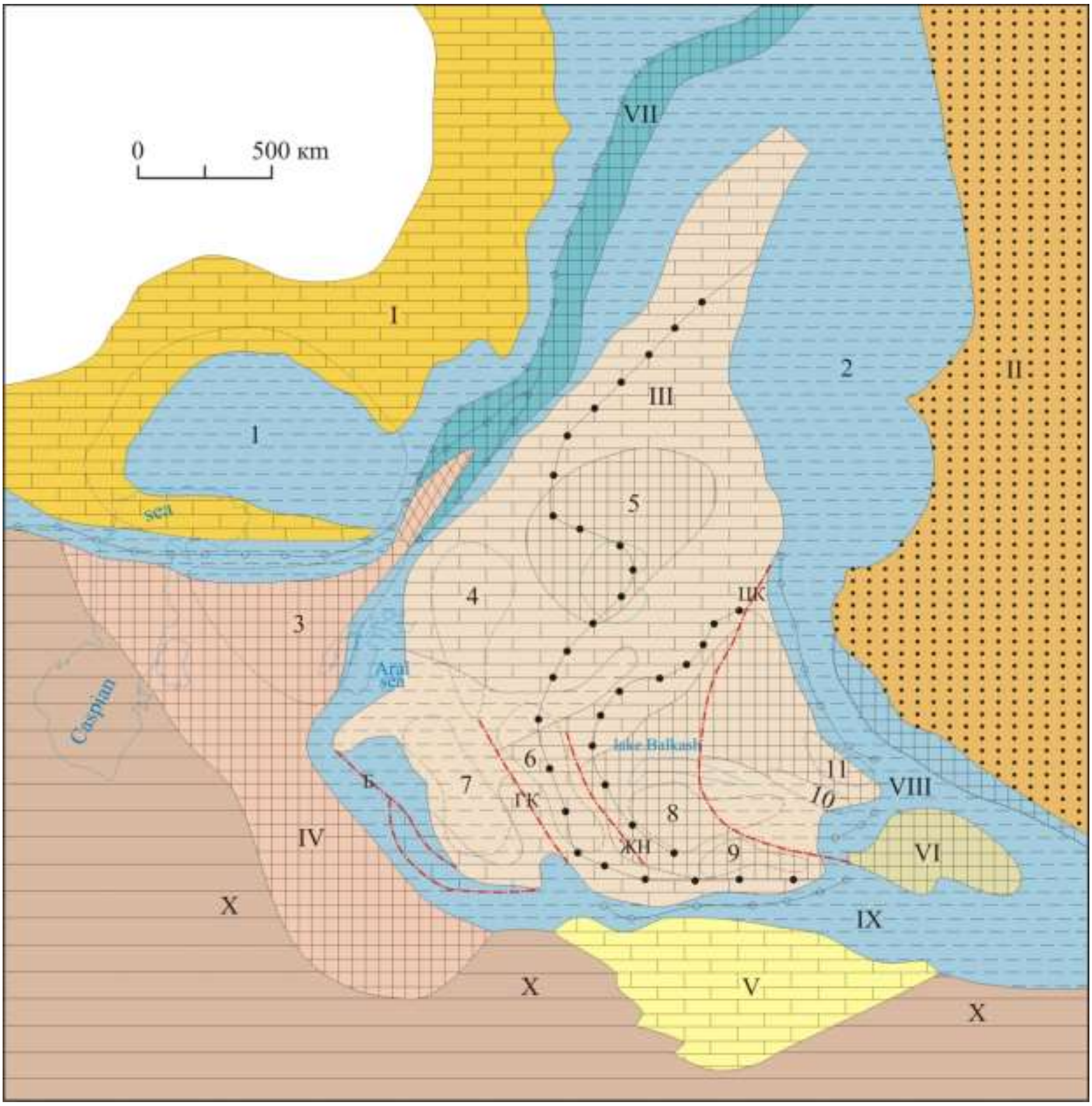
Regions (numbers in the circles): I – Bolshoy Karatau, II – Shu-Sarysu sedimentary basin,
III – Syrdarya sedimentary basin

Figure 1- Overviewed geological map of Southern Kazakhstan.

Upper Palaeozoic carbonates of Great Karatau were deformed during the Late Hercynian epoch, folding and forming mountains, due to a left lateral fault and partially contorted in horses of tiled faults [4, 8]. This early structural assembly was re-deformed in Jurassic time, and as a result of right shift, a transverse superimposed folded interference formed [4]. The Modern Karatau mountain structure formed after the Neogene.

Detailed lithofacies explorations of the Upper Palaeozoic sections of Great Karatau showed that they contain all elements of carbonate-bearing platform's facies belts: abyssal basin trough, slope of carbon-bearing platform, platform's margin, framed by reef and/or organogenic structures, carbonate ramp, platform's immature region (shelf border lake, tidal flat, halmeic basin and the zone of terrestrial carbonate formation in the ancient karst zones); currently here are explored the depositional breaks and blended nonconformities with developed karst and «Mottler surfaces», flood events in the carbonate and clastic-carbonate facial zones [5, 8, 9]. They are well characterized by various fauna: corals, brachiopods, crinoids, stromatoporoids, stakioids, sponges, algae and stromatolites. In sufficient quantity of foraminifers and conodonts.

At several levels in the Famennian and Tournaisian parts of the section there is a presence of orthoceratides and cephalopods.



Structures: 1 – Upper Palaeozoic, 2 – Lower Palaeozoic. Sedimentation Basins: 3 –carbonate, 4 – marine terrigenous, 5 – deepwater shale, 6 – boreal terrigenous. 7 –continent borders; 8 – regional faults: Б - Beltausky (right), MK – Major Karatau (right), ZN - Zhalair-Naymansky (left), CK – Central Kazakhstan (left). Regional tectonic structures: I – Russian platform, II – Siberian platform, III – Kazakhstan continent. Microcontinents: IV – Turan, V – Tarim, VI – Zhongar. Fold belts: VII – Ural, VIII – Yertis-Zhaysan, IX – Tyan-Shan, X – Tetisa. Sedimentation basins in Kazakhstan: 1 – Northern Pre-Caspian; 2 – Western Siberian, 3 – Ustyurt, 4 – South Torgay, 5 – Teniz, 6 – Shu Sarysusky, 7 – Middle Syrdarinskiy; 8 – South Balkash, 9 – Ileysky, 10 - Alakolsky, 11 - Zhaysansky.

Figure 2 - Paleogeographic Map of Famennian and Early Carboniferous Periods of Kazakhstan Continent [2]

Chronostratic and biostratigraphic breakdown and correlation of sections were conducted on the basis of foraminifers' and condonts' studies, wherein for the Devonian part of the section, the basis of stratigraphical developments was represented by conodontous complexes, while for

the carbon part of the section- foraminiferous complexes [10]. The litho-stratigraphic units were segregated [3], which characterize the standard facies belts of the carbon-bearing platform. They

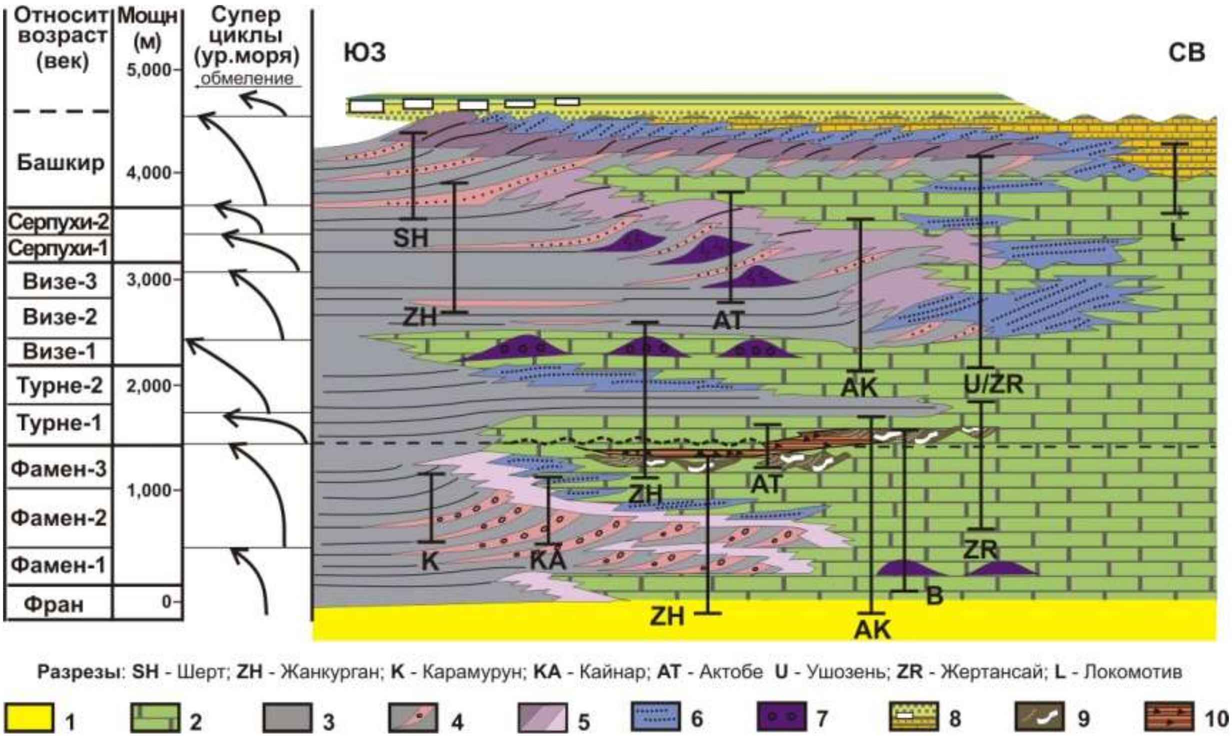


Figure 3- Sedimentary facies of Devonian-Carboniferous Carbonate Platform in North-Western Part of Great Karatau Range [9]

are considered in a rank of suites, and the previously known geological units are considered in a rank of sub suites or litho-stratigraphic members.

In solid sections significant flood events (transgressions and/or raising of sea level) and regressions (sharp drops of sea level) were recorded, connected with the change of facies composition of the section, which allowed, together with solid local biostratigraphic scale, to perform a litho-stratigraphic correlation of sediments with sufficient accuracy [3, 6].

The sea level oscillations analysis allowed development of a sequence of cyclical events, distinguishing of system tracts – transgressive systems tract (TST), regressive systems tract (LST) and highstand systems tract (HST) [6, 11, 12, 12]. A vivid example of a regressive systems tract is the Balaturlanskaya member, formed by karst and collapse breccias [13, 14], the distribution of this breccia across a vast territory and its thickness testify that the sea level could have been dropping lower than the platform's margin at the very end of Famennian time. A transgressive systems tract can be connected with the accumulation of Lower Visean Kazanbuzarskaya suite, and the highstand systems tract– with Shukurganatskaya suite of monotonous tidal carbonates of tidal flat, reaching the thickness up to 700 metres.

A unique high-order circularity is studied at the shoaly facies of Visean and Serpukhovskiy sections, as well as Lower Bashkirian beds along the rivers of Zhertansai and Ushozen, which is observed over the drain surfaces, emphasized by the development of a soil layer with root systems, enriched in organic materials, the so-called «Malter's crust» [12]. At the Ushozen section, this high-order circularity is also manifested by thin crusts of resorption and karsting, filled with red clay matter [13, 14].

Integration of detailed stratigraphical and lithofacies data allowed a sedimentological depositional profile of Famennian-Early Carbon carbonates accumulation to develop at Great Karatau [5, 6, 12].

The explored geological sequence of carbonate deposits and events, connected with their formation in the North-West part of Great Karatau is as follows [3, 5, 6, 9, 15, 16]:

1 The basement of the section is represented by the Ermaksuiskaya suite, associated with the very Upper Frasnian and entirely Lower Famennian, and in the shoaly sections with Middle Famennian. It has a gradational contact from the underlying green-coloured clay rocks of

Korpeshskaya member and is mainly represented by shoaly limestones and pierites of the littoral shelf Sea and tidal flat. Its thickness is variable, which testifies to initial Sea transgression for dissected relief. Underlying Tyulkubashskiy red beds have a marine shelf genesis, proved by hummocky ripple marks, while superincumbent marine carbonates of tidal flat and littoral shelf testify to the gradual slow nature of transgression due to the rising of Sea level.

Paleogeographic conditions of Early Famennian are characterized by tidally-influenced flat and a vast flat shelf; they prevailed over the entire territory. An easy-to-see small-shell fauna, mainly brachipod, shellfish and crinoids, testify to the fact that the water exchange with the World Ocean was limited. The marine environment had neither the normal degree of salinity, nor high oxygen saturation, the colour of rocks is notable for its shadow tone.

2 In the series of sections along South-West framing of mountains are observed the Zhankurganskaya suite (Kainarskaya series) abyssal deposits of the carbonate-bearing platform’s slope and basin’s flat - carbonate cleaving stones, turbidites and «basal» breccias, laid down by sediments of debris stream flows of carbonate slope. This stratigraphic datum is well dated by conodont complexes of the standard biostratigraphic scale. This thin condensed succession testifies to large Middle Famennian transgression over the carbonate platform. Platform flood was not entire and at the coeval levels of shoaly sections, a sharp increase of crinoids, cephalopods and shelf algal sponge bioherms is recorded, which is indicative of an open marine environment of the carbonate platform. Zhankurganskaya suite (Kainarskaya series) is dated by Middle Famennian.

Obviously, in Middle Famennian the abyssal environment of the carbonate platform’s framing came from South-West of Syrdarinskaya trough, for example the deposition marks in turbidites and debris breccias show the South-West direction. The margin of carbonate platform moved back (reverted) to the east and the area of shelf’s shoaly environment and tidal flat contracted. Conditions of marine carbonate accumulation became normal, open marine fauna of orthoceratides, cosmopolite conodonts and articulated branchiopods appeared, and hummocky algal bioherms formed.

The rocks in these environments at the shoaly part are characterized by grey tones of colour, and abyssal transgressive members- by dark grey and black colour.

3 The Upper Famennian stratigraphic datum is represented by the Shukurganatskaya suite of shoaly limestones and pierites, forming of monotonous cyclical sequences of carbonate tidal flat. The genesis of these formations is connected with multiphase diagenesis, which resulted in the replacement of primary limestone beds, pierites and further de-dolomitization with repeated limestone’s formation. The colour of rocks is very variable– light and grey limestones, while pierites are charcoal up to black.

The roof of this stratigraphic datum is associated with a horizon of karst breccias (Balaturlanskaya member), which are relatively dated by the Upper Famennian and which have areal extension along the entire South-West part of Great Karatau. This datum can respond to the global regression around the Devonian-Carbon border and it is well explored across many strata-typical sections of the World, being a good stratigraphical marker. The rocks of Balaturlanskaya breccia, generally of a limestone composition, have a mottled structure, with the prevailing light colours and it is very obvious in relief. These light chippings of limestone beds and more rarely pierite are blanketed with red lay groundmass.

Where the breccia is absent, the carbonate rocks are intensively dolomitized and de-dolomitized, with a large cavern porosity of a few centimetres in diameter. Caverns are filled with white spathic calcite.

In the Upper Famennian the paleogeographic conditions were characterized by a wide-spread occurrence of shelf shoal water and tidal flat, which existed in the beginning of turne, although in the Upper Famennian they were connected with the highstand systems tract, when the speed of carbonates accumulation was almost equal to the speed at which the Sea level was rising, and interdigitation of multi-facia beds, built up at the littoral shelf or tidal flat, occurred due to auto-circularity processes, which resulted in partial dolomitization. Carbonate platform partially progradated to West-South-West built up its thickness at the top. At the end of the Famennian period, a dramatic fall in sea level took place, exposing and drying most of the territory that had previously been at subsea level, which is indicative of a low amplitude of the fall in the sea level under the platform's margin, and the arched parts of the platform contained the subsurface systems of rivers. Shoaly-shelf and tidal environment of the beginning of turne were connected with the slow beginning of Upper Carbon transgression.

4 The entire complex of Famennian sediments is facially overlapped by heterogeneous sediments of the turne-vizo period -Bashkirian. Here, an Aksaiskaya suite of shoaly shelf and open maritime suites of abyssal shelf are observed: Orgailysaiskaya and Kazanbuzarskaya suites, Baktysaiskaya suite of abyssal carbonates (carbon-bearing cleaving stones, thick units of amalgamable carbon-bearing turbidites, debris breccias with large fragments of derived beds and shelly fauna). A shoaly age equivalent of this rock mass are carbonates of Maidantalskaya suite, laid down by sand bank's oolitic and lithoclustered grainstones of the carbonate platform's margin and organic carbonates of shelf cycles. Laterally, both abyssal carbonate Baktysaiskaya suite and shoaly carbonate Maidantalskaya suite are separated by the Akuyukskiy reef complex.

The rocks of this interval are very various and depend on the environments in which they formed. Abyssal Baktysaiskaya suite is coloured from charcoal to black, oolitic rock masses of Maidantalskaya suite are coloured from white to light grey, shelf rock masses are grey and light grey, rocks of Akuyukskiy reef complex are light grey and grey, and cavern space in the reef is filled with either white spathic cement, or brownish grey early-marine cement. Lateral areal distribution of this entire complex of sediments is very complicated, and thicknesses vary.

For example, in the Akuyuk section the sediments of the Late Famennian Balaturlanskaya karsted breccia are overlapped by abyssal slope sediments of Baktysaiskaya suite, which is dated here from the beginning of turne till middle vize. All these are evidence of diachronic boundaries of lithostratigraphic units and, most possibly, of the diastemas existence– concealed depositional breaks.

5 Paleogeographic conditions of the very beginning of carbonous time are characterized by transgression, as the most continuous monotonous botttomset beds of the Upper Fomennian are overlapped by various in terms of facial and litho stratigraphic composition beds of the Lower Carbon. Such correlation in occurrence can be explained not only by transgression, but also by possible transtension of the Earth's crust, as well as subsidence of individual blocks, which existed for a prolonged period of time.

They were characterized by open-maritime shelf and abyssal environments, availability of goniatidae, plenty of rugose simple corals and crinoids. Also several levels here contain silt uolsortskie bioherms.

6 By mid-Visean time at the margin of carbonate platform formed the environments of oolitic sand bank.

The Akuyukskiy reef complex at its basement is characterized by physiography of silt uolsortskie hills, and higher from the end of vize – by a cement and stone composition, when the rock's framework is laid down by dendrite moss life, slim crinoids and sponges, and the headroom between them is filled with maritime lathlike calcite. In eodiagenesis such calcite isomorphically substituted aragonite.

This reef complex has been formed within the environment behind the fold of carbonate platform, right under the basis of sea waves, was a barrier, forming the slope and shelf of carbonate platform.

Shoaly conditions back then were monotonous, which is indicative of their insignificant progradation, but generally they were building up at the top, almost without change in areal distribution.

Section's cyclic structure can be identified here only by using specialized methodologies and methods of lithofacies analysis.

7 Abyssal conditions occupied the major area of Nort-West part of Great Karatau to the mid-Baskririan time, when another transgression took place and the shoaly area contracted. Probably,

late in this period of time the shoaly conditions again progradated, as the slope complex of sediments shallows to the top.

8 Carbonate section of North-West of Great Karatau is disrupted by a member of red-coloured sandstones and siltstones with the horizons of gypsiferous sediments of Shertskaya suite of Late Bashkirian period. At that time at Great Karatau, as well as across the entire territory of Central Asia, a large reconstruction took place and the terrigenous rock masses began to form due to the growth of uplifts, which stopped the carbonate accumulation.

The problem of reef formation in Late Devonian carbonous oceans of Kazakhstan is very important and relevant due to the fact that giant oil and gas fields in Kazakhstan, as well as worldwide, are connected with the carbonate-bearing reef organic formations. Organic build ups (biostromes, bioherms, reefs, and reef systems) had been forming during the entire existence of Upper Palaeozoic carbon-bearing platform. At that, different periods of reef formation were characterized by the involvement of various organisms. Only certain small territories of Great Karatau were covered by specialized works, involving the exploration and time determination of organic build ups formation, rock types, building up the complexes, physiography of reefs, their location or arrangement at certain areas of maritime basins, factors of non-biological and biological evolution of reefs [15].

The carbonate platform contains several facies belts, which involve various types of bioherms and reefs [3, 5, 6, 9, 15, 16].

1. Polycyclic coral and algal bioherms with thickness of approximately 100 (hundred) m, built up in relatively abyssal environments of carbonate platform’s slope.

2. Algal reefs of the carbonate platform’s margin with thickness of 100-1000 m (hundred and thousand m.).

3. Crinoidal-bryozan-algal-silt uoltsortskie bioherms of platform’s immature region and deep shelf lagoon (thickness of 20-400 m).

Altogether, the carbonate deposits of Famennian-Lower Carbon and lower Pennsylvanian period at the Great Karatau contain eight types of bioherms and reefs, in size from scores to several thousand metres. They occupy the offshore facies belts and gradually migrated into a basin at a low stand of sea level to external zones of Syrdarinskaya cavity. Such displacement of reef complexes could reach dozens and for the first hundred kilometres, the direction of migration (progradation) was from North-East to South-West (columns and pictures of outcroppings).

The main organic structures built up at Late Devonian period. They are distributed across hundreds of kilometres as a wide broken line at Great Karatau, Ugam, Syrdarinskiy and East Aral sedimentary basins. Examples are– Besharykskiy large reef (Great Karatau), Seslavinskiy reef (Ugamskiy range of mountains).

Early carbonous reefs are also widely distributed: for example, Akuyukskiy reef complex with length of 70 km, and thickness of approximately 600 m.

The given above geologic model (the model of platform and reef) is considered as superficial analogue of Famennian-Early Carboniferous oil and gas condensate carbonate platform, building up the deposits of Tengiz-Kashagan group and Karashyganak fields [15, 16, 17].

Currently in Kazakhstan discovered and successfully being exploited oil and gas fields, located in carbonates of Upper Palaeozoic complex (Sections, columns of fields).

Kashagan – supergiant oil and gas field. Estimated mineral resources are 6.4 billion tons of oil, more than 1 trillion м^{3}of gas. Its exploitation has not yet started, but it is forecast that the annual oil yield will be up to 75 million tons, and Kazakhstan will become one of the TOP-5 oil producers (fig. 4).

Tengiz. Deposits – 3.1 billion tons of oil, the extractable reserves are estimated from 750 million to 1 billion 125 million tons. The associated gas reserves amount to 1.8 trillionm^3(fig. 5).

Karashyganak – oil and gas condensate field. Initial reserves – more than 1 billion tons of oil and gas condensate (fig.6).

Zhanazhol – gas condensate field. Mineral resources– 500 million tons. Gas – 133 billion m^3.

Analogous prospect locations in carbonates of Upper Palaeozoic period are detected within the area of Syrdarinskiy, East Aral (fig. 7), Shu-Sarysusskiy, South Torgaiskiy sedimentary basins. Certain areas are already involving the prospecting works (picture of East Aral Sedimentary Basin's seismic profile).

As mentioned above, within the limits of Karatau range of mountains deposits of lead and zinc are known, these are also associated with the rocks of carbonate complex of late Devonian-early Carbon (fig. 8) [18]. Here, deposits of three genetic are detected (Diagram by deposits):

Stratiform deposits: Shalkiya, Talap, Suleimansai, Baizhansai.

Stratiformbarytic-lead-zinc deposits: Mirgalimsai.

Karstic deposits: Achisai, Kantagi.

Shalkiya. Mineralization is associated with the sedimentation of Upper Famennian.

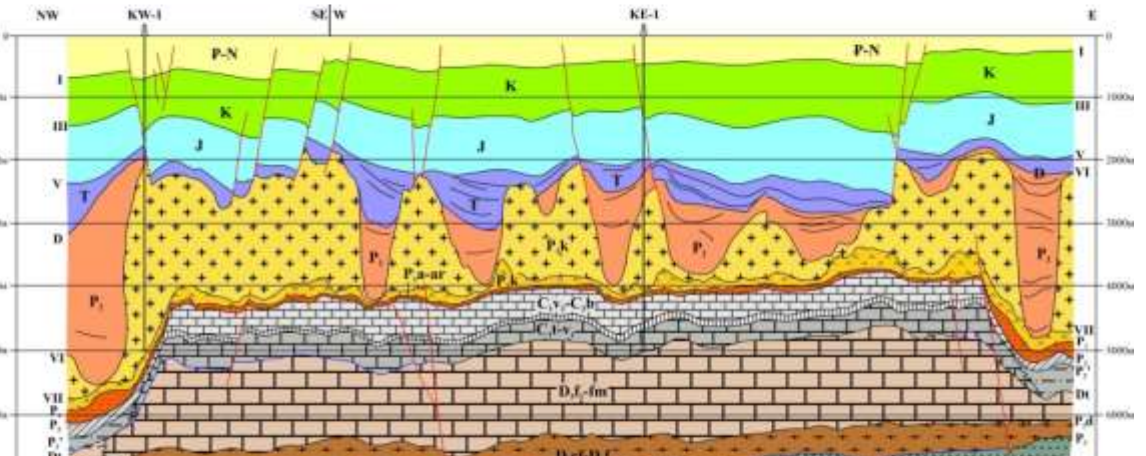
Commercial resources as at January 1, 2014 amounts to (thousand tons): per category $A+B+C_1$ – lead 1480.0, zinc 4829.50; per category C_2 – lead 154.4, zinc 615.6; non-commercial – lead 735.2, zinc 3258.6 (fig. 9).

Talap. Mineralization is associated with sedimentation of Upper Famennian. Commercial resources as at January 1, 2014 amount to (thousand tons): per category $A+B+C_1$ – lead 185.9, zinc 361.3; per category C_2 – lead 76.3, zinc 163.2; non-commercial – lead 48.6, zinc 112.9 (fig. 10).

Suleimansai. Mineralization is associated with sedimentation of Upper Famennian. The content of zinc in primary ores from 8 to 50%, zinc to 16%, silver to100 r/t. The deposit is exhausted.

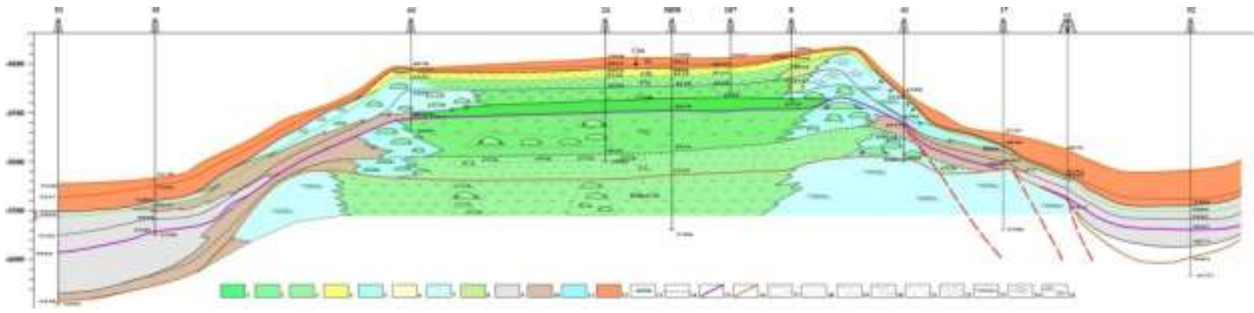
Baizhansai. Mineralization is associated with sedimentation of Upper Famennian. Content of zinc 4.97%, zinc – 0.78%. The deposit is exhausted. Lead commercial resources as at January 1, 2014: non-commercial – 4.5 thousand tons.

Mirgalimsai. Mineralization is associated with sedimentation of Upper Famennian. Reserves**:** lead commercial resources approved by the State Reserves Committee (SRC) in 2002. Lead commercial resources as at January 1, 2014 amount to (thousand tons): per category C_2 – 10.6, non-commercial – 795.5.



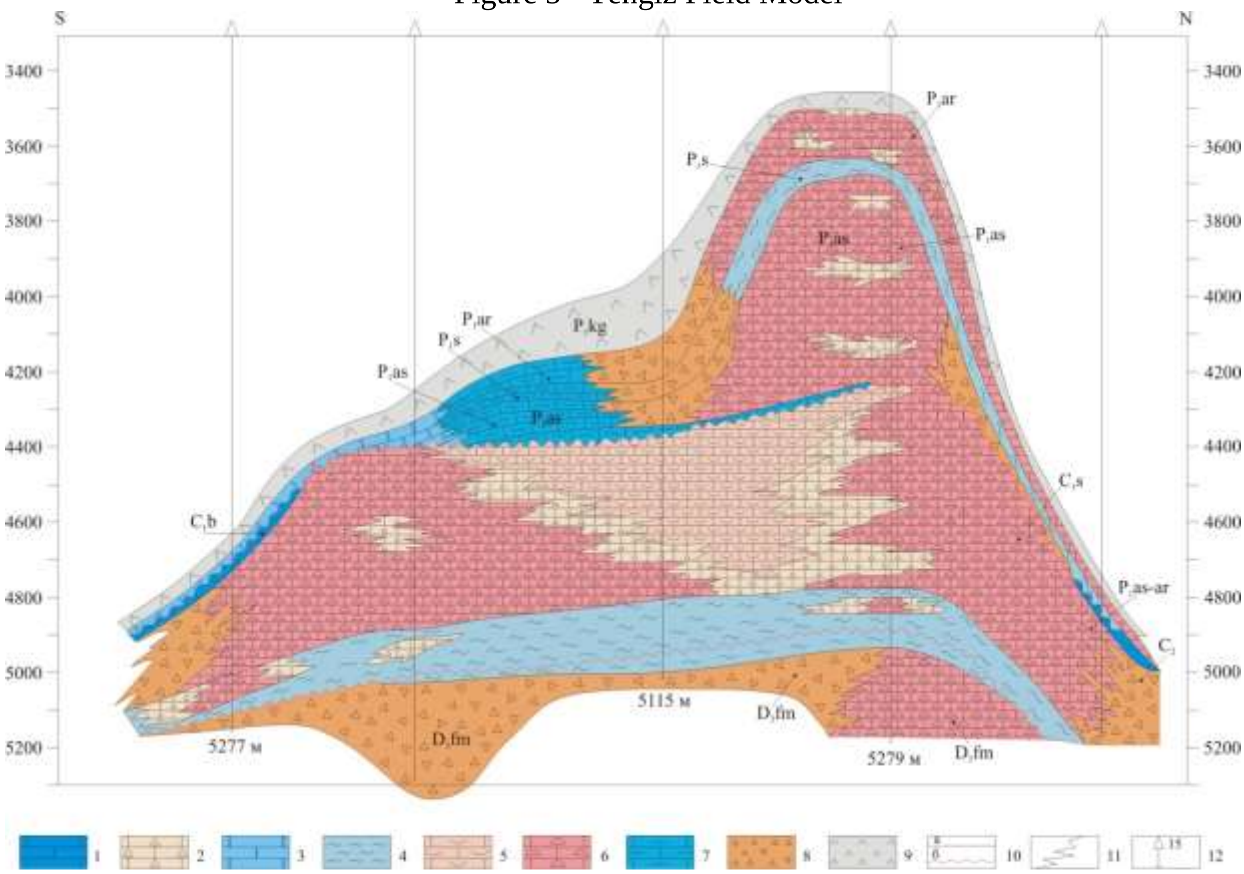
1 – Seismic reflecting horizons and their indexing. Major geological complexes: 2 – Lower Palaeozoic (Vend-Earky Devonian?) terrigenic; 3 – Eiffel-Early Franian carbonate-clayous external shelf (most likely oil and gas bearing rocks); 4 – Late Devonian – Bashkirian carbonate (without facial compartmentalisation); 5 – Late Devonian-Early Visean, predominantly terrigenic periphery of carbonate platform; 6 – Oksky-Baskhirian and Moscovian carbonate-clayous depression periphery of carbonate platform; 7 – Early Permian (Asselsky-Artian) terigenic, clayous and carbonate-clayous. Kungurian deposits. 8 – galite; 9 – anhydrate; 10- highly radioactive cluster on top of Tula deposits

Figure 4 - Kashagan Field Geological Model



Facies: carbonate platform: 1 - deepwater; 2 - submerged; 3 – shallow water; 4 – sand facies; 5 – biogerm structures of carbonate platform flanks and upper slope; 6 – shallow water zone of carbonate platform flanks; reef complex; 7 – reef massif; 8 – reef slope; 9 – lower slope and basin; 10 – slope (carbonate); 11 – biogerm structures within the limits of carbonate platform slope; 12 – non-compartmentalised deposits of Moskovian and Assel-Artian periods; 13 – small biogerm; 14 – stratigraphic borders; 15 – top of II suite (volcanic rocks); top of III suite; 17 – borders of proposed seismic facies. Lithological complexes: 18- pellet wackstone and packstone; 19 – lumpy and dense limestone; 20 – bioclastic packstone; 21 – lithoclastic greystone and packstone; 22 – overbedding of grainstone and algae limestone; 23 – boundstone; 24 – framestone; 25 – detrimental breccia.

Figure 5 - Tengiz Field Model



1- limestone, 2 – talus, 3 – normal marine, 4 – shallow marine, 5 – inner reef lagoon, 6 – reef core, 7 - relatively deep water, 8 – slope, 9 – anhydrite.

Figure 6 - Karashyganak Field Model

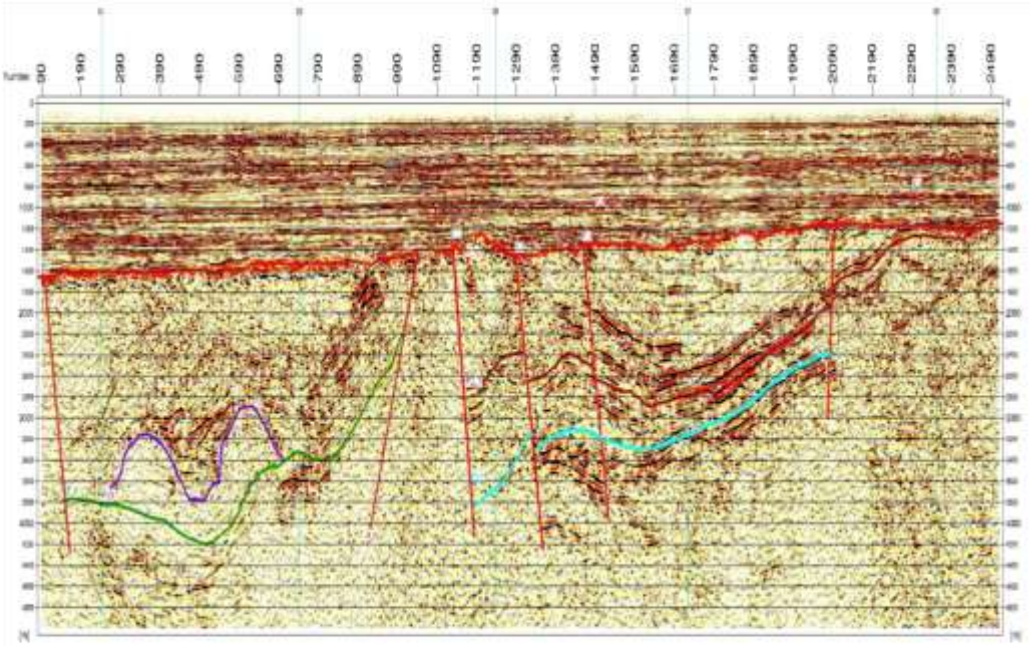


Figure 7 - Deep section of 12 Profile. Oral Munaygas LLP Licensed Area. East Aral Sedimentation Basin

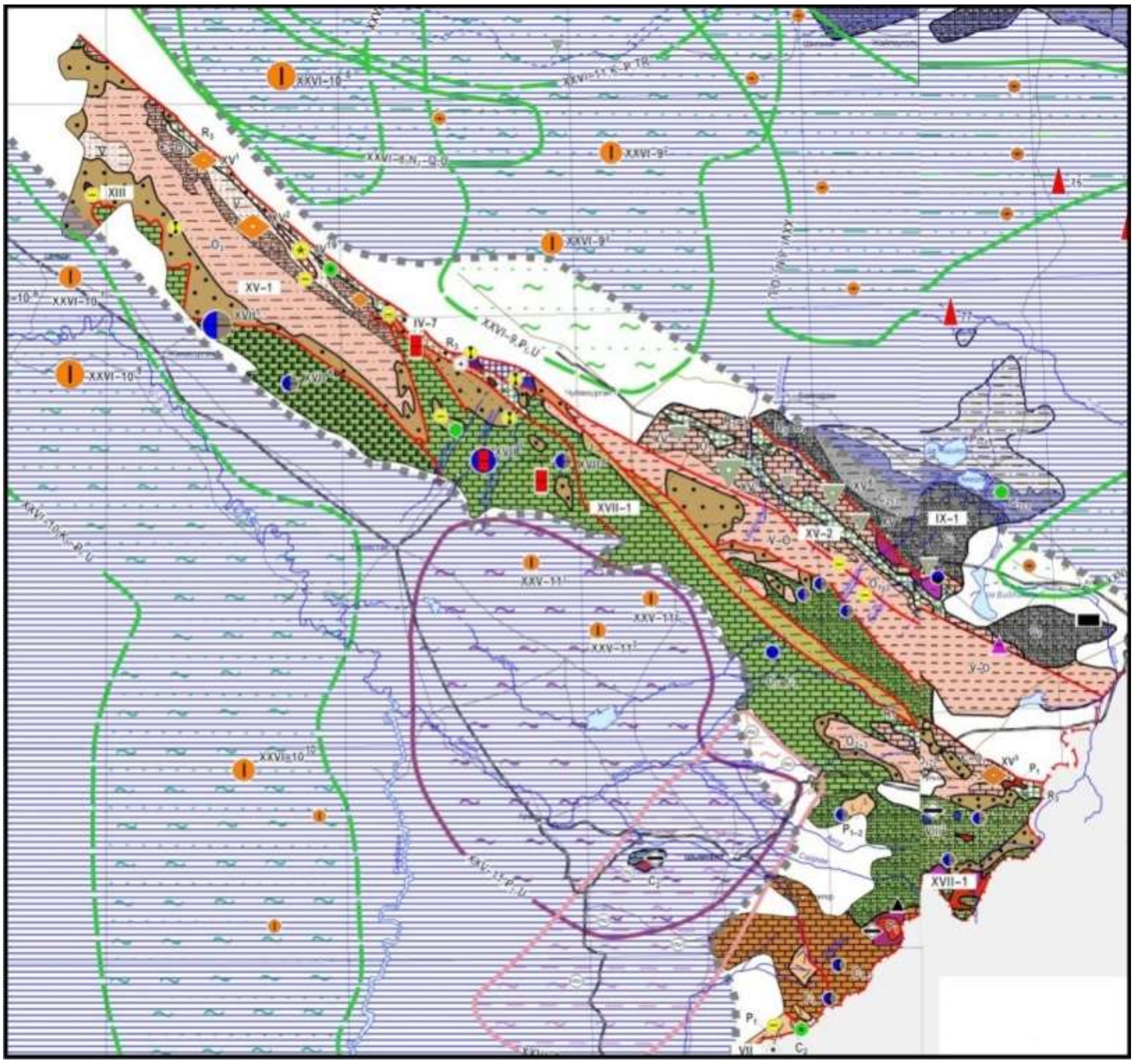
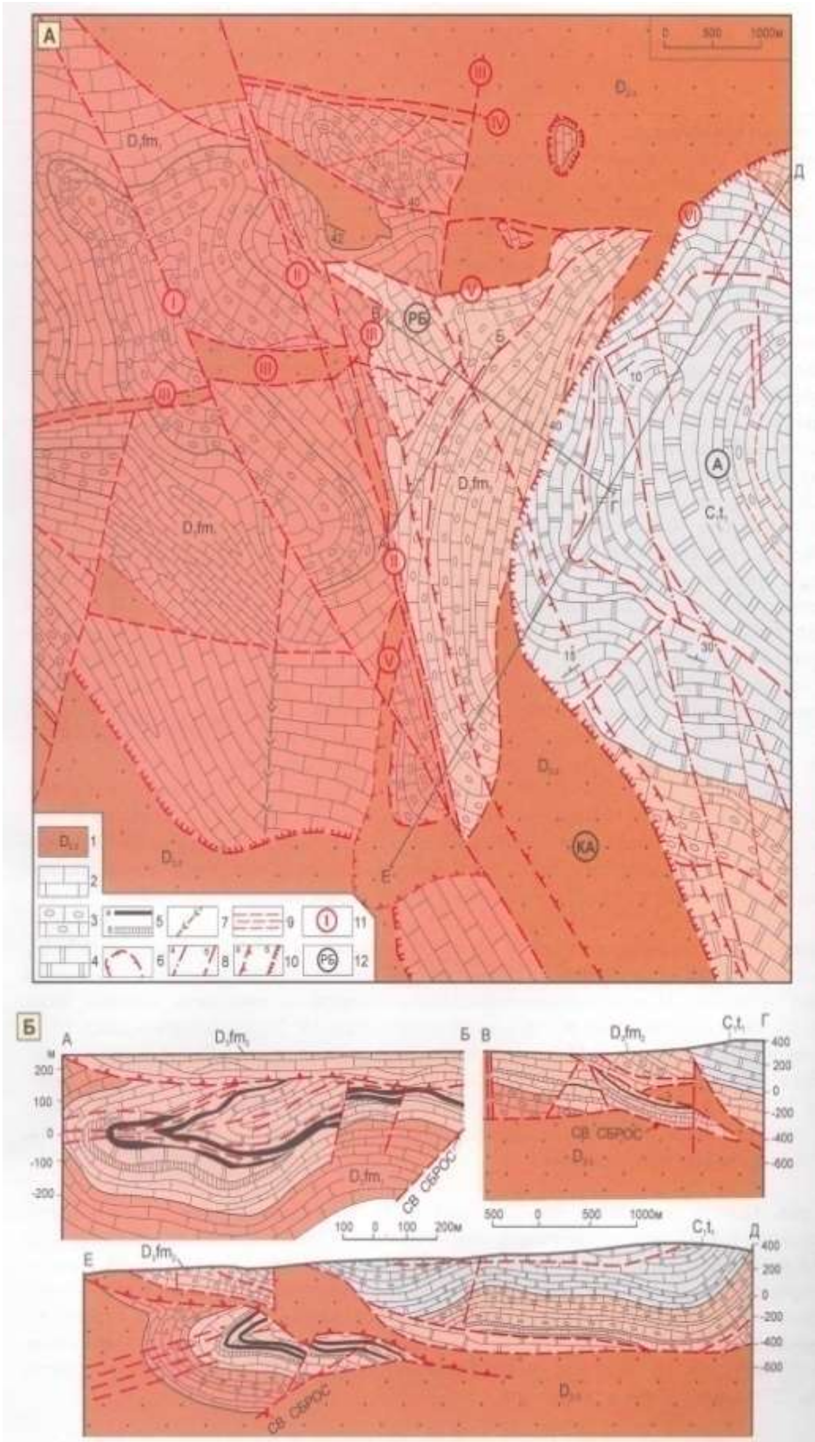
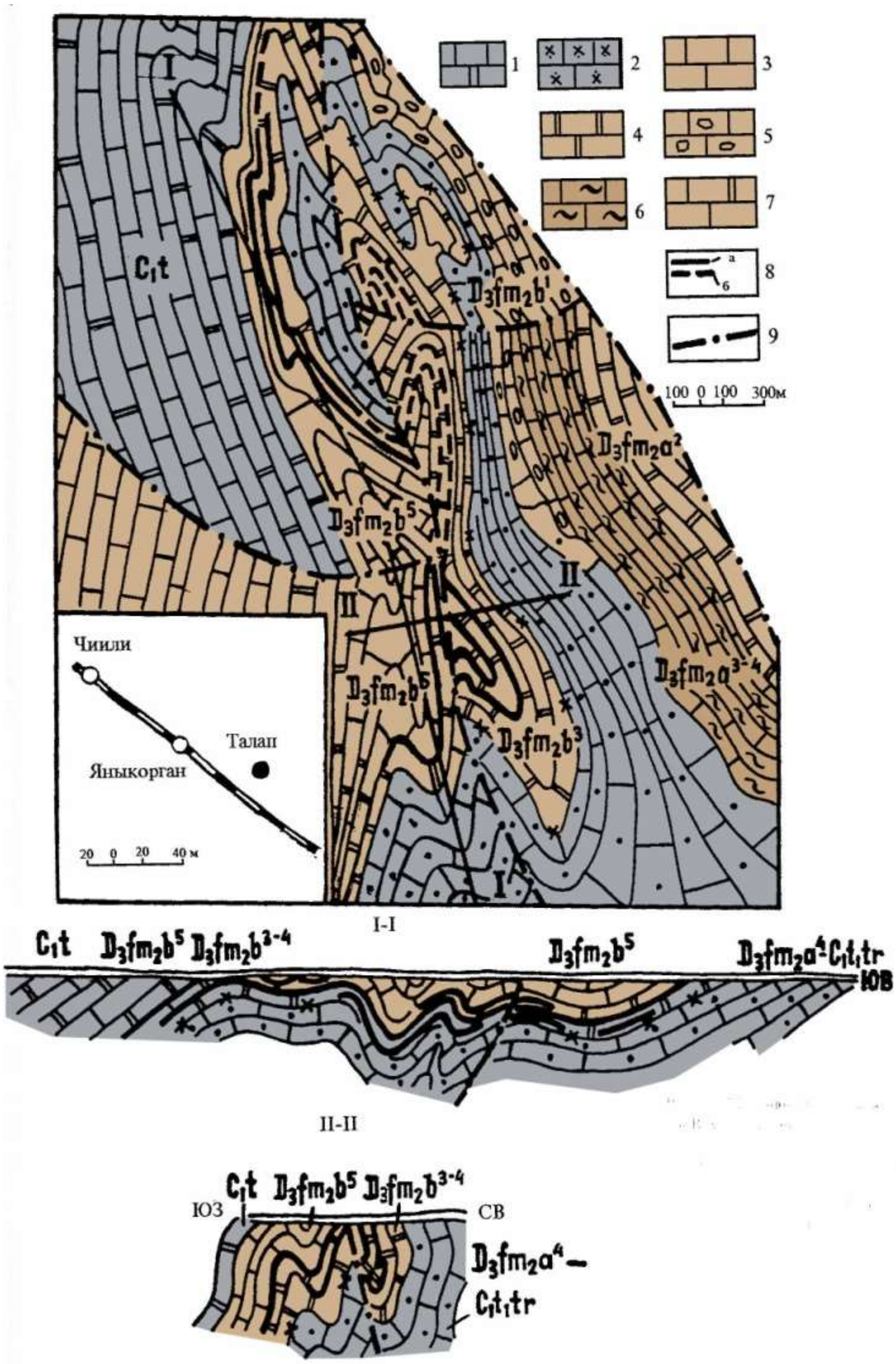


Figure 8 - Extract from Mineragenic Map of Kazakhstan [19]



1 – sandstone, siltstone and mudstone in Tyulkubash suite of Middle-Upper Devonian; 2-4 – Famennian-Turnean deposits; 2 – layered limestone, 3 – lumpy limestone; 4 – dolomites; 5 – ore bodies; a – industrial value; b – off spec; 6 – ore deposit outcrop on surface; 7 – alkili lamprophyr dykes; 8 – faults: a – identified; b – assumed; 9 – sub viscosity faults; 10 – thrusts: a – central thrust, b – other thrusts; 11 – faults; I, II - Main (both branches), III - Shalkinsky, IV - Northern, V – Central thrust, VI – Oguzmuyuksky; 12 – fold structures: A – Akuyuksky syncline, OB – ore block, KA – Kyzylsaysky anticline.

Figure 9 - Shalkiya Field [18]



1, 2 – Lower Carbon: 1 – limestones with silica, massive cavernous dolomites and limestones; 2 – organic carbonate reef structure; 3-7 Upper Famennian: 3 – post-ore cluster limestones; 4 – thin-layered dolomites with streaks of silica and dolomites, siliceous breccia of ore cluster; 5 – lumpy limestones; 6 – limestone with marl streaks; 7 – limestone and dolomite (massive); 8 – ore bodies: a – identified; b – assumed; 9 – faults.

Figure 10 - Talap Field [18]

Achisai. (Turlanskoe). Mineralization is associated with sedimentation of Upper Famennian and Lower Carbon. **Commercial resources of lead and zinc** approved by SRC in 1952, amounted to (thousand tons): per category A+B+C_1 – lead 102.0, zinc 376.2; per category C_2 – lead 12.6, zinc 15.4. Commercial resources as at January 1, 2014 amount to (thousand tones): per category A+B+C_1 – lead 2.0, zinc 102.1; per category C_2 – zinc 0.4.

Although Karatau range of mountains is is sufficiently well belted at the surface, there is a high possibility of detecting new beds of these mineral resources at a depth from several dozens to several hundreds of metres. Apart from that, exploration works should be conducted at Ugamskiy range of mountains and small thickness areas of Mezozoic-Cainozoic platform mantle in Syrdarinskiy and Shu-Sarysuskom sedimentary basins.

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A LATE DEVONIAN-CARBONIFEROUS FORMATION OF REEFS IN KAZAKHSTAN

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The purpose of this article is the reflect evolution Late Devonian-Carboniferous formation of reefs in Kazakhstan. That is represented very important and actual because oil and gas fields (Tengiz, etc.) are connected, first of all, with carbonates constructions in the World and in Kazakhstan. The basic methods were: studying foraminifers complexes for definition of age of formation carbonates constructions; studying of types of the breeds composing reefs complexes; morphology of reefs; their sites or an arrangement in certain sites of sea pools; factors of not biological and biological evolution of reefs. It is as a result established, that all versions carbonates constructions from bioherms and biostrom to reefs and reefs complexes of a difficult structure and of big thickness and length meet in sea sedirnments Late Devonian-Carboniferous formation Kazakhstan. Different associations of fossils participate in a structure uneven-age reefs constructions in quality builders of reefs. Thus, it is detailed Famennian - Early Bashkirian a cycle formation of reefs, evolution formation of reefs in Famennian- Carboniferous in Kazakhstan is presented, age levels are allocated some and the structure builders of reefs organisms is specified.

The problem formation of reefs is represented rather important and actual because with carbonates constructions as all over the world, and in Kazakhstan are connected, first of all, an oil field and gas (Tengiz, etc.)

Carbonates constructions (biostroms, bioherms, reefs and reefs systems) extend to Kazakhstan broad (Fig. 1). Late Devonian-Carboniferous formation of reefs in Kazakhstan are formed on all extent of existence carbonates platforms. Thus during the various periods formation of reefs in construction of reeves various organismus, including foraminifers took part.

In Kazakhstan, despite a wide circulation among sea adjournment late Devonian and Carboniferous carbonates constructions, not enough attention was given to their studying. Moreover, in the book «Reefs constructions in Paleozoic to Russia» (1997) it is said, that in Kazakhstan authentic reefs in Carboniferous it is noted [1]. At the same time, for example, V.Ya.Koshkin in 1982 was marked by some researchers reefs the nature of limestones tastykuduk formation Northern Pribalchachja which have been described subsequently by the author in more details [2].

Methods

Last decade, in connection with amplifying attention to oil fields and gas, are studied Famennian-Tournaisian reefs constructions in Caspian basin (Tengiz, etc.) [3], Famennian-Tournaisian and Visean-Bashkirian in Bolshoi Karatau Mountains and Talasso-Ugam Mountains [4,5,6]. So, Late Devonian (Famennian) and Carboniferous (Tournaisian) reefs region Talasso-Ugam constructions were studied by A.V.Zorin, etc., the author made studying foraminifers complexes in them and definition of age of their formation [7]. Also have been studied carbonates constructions of section Bajdzhansaj Bolshoi Karatau Mountains.

Especially big attention has been given studying and definition of time of formation carbonates constructions in Bolshoi Karatau Mountains at performance of program CRADa which results have been published later [5]. With 1987 for 1996 geologists of joint-stock company "Izdenis" and geological service of the USA carried out joint geological researches Paleozoic reefs in mountains Bolshoi Каратау. Were thus studied: types of the breeds composing reefs complexes, morphology of reefs, their site or an arrangement in certain sites of sea pools, factors of not biological and biological evolution of reefs. Thus, specialised works in which the author accepted direct participation, have been spent in separate areas of distribution reefs constructions. Data about distribution reefs constructions, their structure, with the detailed analysis of complexes foraminifers on which their age is established, are resulted in various publications [2,4,5,7].

Study to surface (1) and study to chink (2). Section: 1-Bolshoi Karatau Mountains, 2-Talasso-Ugam, 3-Zhezkazgan region, 4-Berchogur, 5-Aydaralashi, 6-Kiya, 7-Sholak-say, 8-Tengiz, 9-Zhanazhol, 10-Alibekmola, 11-M-Teresken, 12-the East Teresken, 13-Kostanai and Sherbakov profiles, 14-chink ARL, 15-Sholjadyr, 16-Semey polygon, 17-Sayak region, 18-Arganaty, 19-Borotala, 20-Betpakdala, 21-Malyi Karatau, 22-Chu depression, 23-Kirghiz Mountains, 24-Kungei Mountains, 25-Terskei Mountains, 26-Ketmen, 27-Zhamanbulak, 28-the Northern Zhongar Mountains, 29-chink Pavlovskaya II-3

Fig. 1 Localities formation of reefs in the Kazakhstan

In limits carbonate platforms Bolshoi Karatau Mountains different a little facies belts in which there are various types bioherms and reefs (V.G.Zhemchuzhnikov, etc., 1996):

1. Polycyclic coral and algae bioherms capacity about 100 (hundreds) the meters, generated in rather deep-water conditions of a slope of suburb carbonate platforms;

2. Algae suburb reefs carbonate platforms capacity 100-1000м (hundreds to thousand).

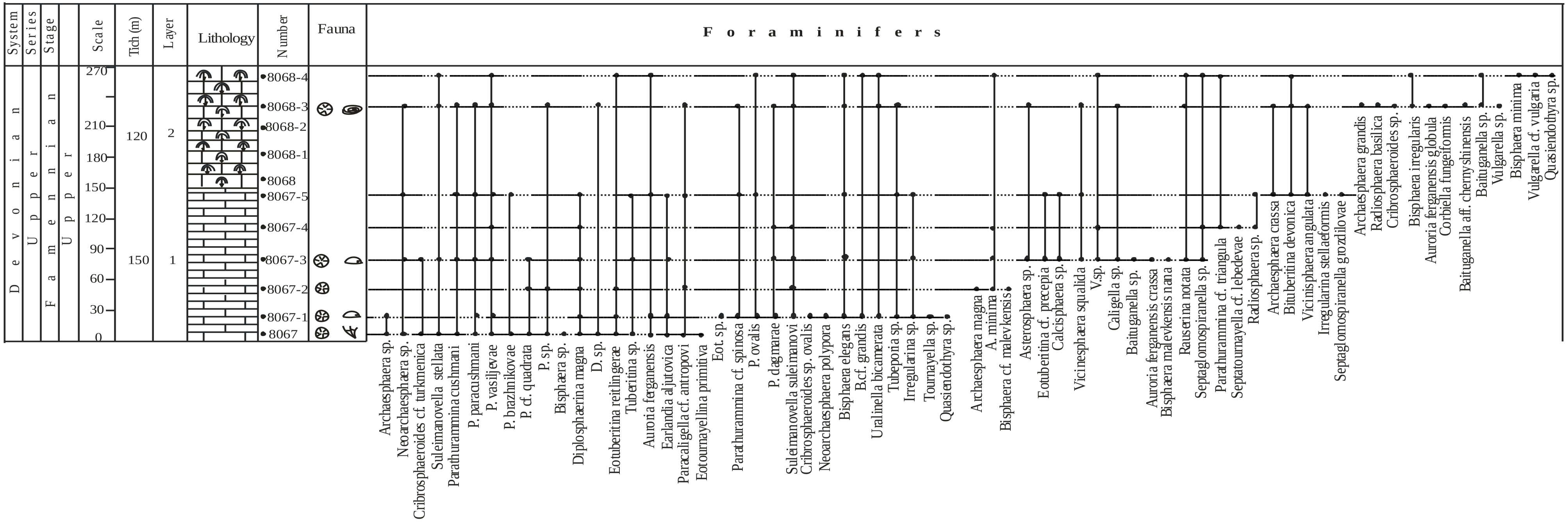
3. Crinoid-bryozoan-algal Waulsortian mud mounds an internal zone of a platform and a deep shelf lagoon (capacity 20-400м), etc.

In total carbonates of levels Famennian-Tournaisian and bottoms top Carboniferous, for example, in Bolshoi Karatau Mountains conclude eight types bioherms and reefs in the size from tens to several thousand meters. They occupy offshore facies belts and consistently migrated in pool at low standing of a sea level in external zones of the Sredne-Syr-Darya hollow. Such moving reefs complexes could reach tens and first hundreds kilometers, the direction migrations (progradation) has been focused from the northeast on the southwest.

Generalisation on a geological structure and structure Late Devonian-Carboniferous formation of reefs of Kazakhstan and the detailed description of a part from them have shown, that in sea adjournment top Devonian and Carboniferous Kazakhstan there are all versions carbonate constructions from bioherms and biostroms to reefs and reefs complexes of a difficult structure of considerable capacity and extent, as well as in other regions of the world [8-15]. They are studied rather non-uniformly. Different associations of fossils participate in a structure uneven-age reefs constructions in quality building reefs [16].

On the basis of these researches by the author it is revealed five basic levels building reefs which managed to be established on in details studied foraminifers to the complexes met or in reefs, or to reefs and over reefs sedyments.

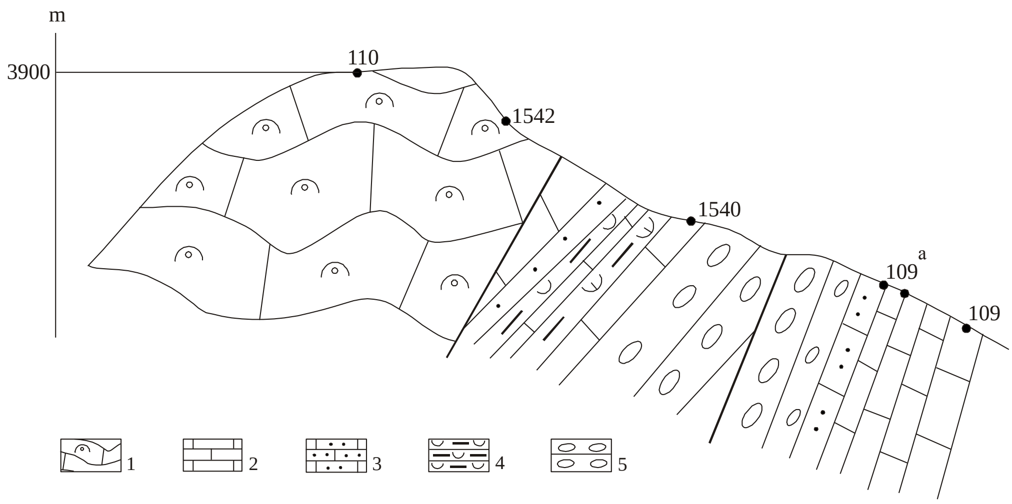
So, the first stage formation of reefs was showed in Late Famennian-Early Tournaisian time. Process building reefs in this stage is represented uniform and inseparable (an example: Upper Famennian, Kokterek Formation, Seslavian reefs, Talasso-Ugam Mountains - Fig. 2.; Upper Famennian Shukurganat Formation, Besharik section, Bolshoi Karatau Mountains, etc).



1 - limestones kokterek formation ; 2 -reefs facies (boundstones, ets) ; 3 -foraminifers 4 algae 5 ostracods 6 bryozoans

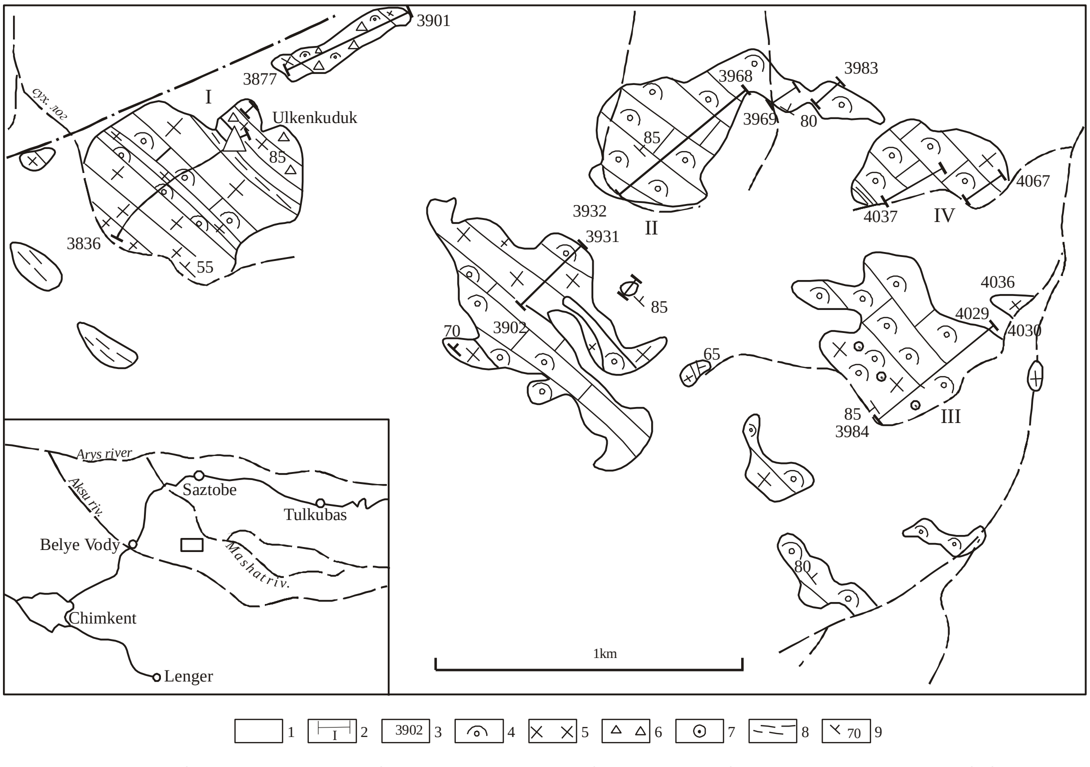
Fig. 2 Lithostratigraphy and foraminifers in Seslavinsk reefs and in Kokterek formation with Talasso-Ugam Mountains (Zorin A.V., Zhaimina V. Ja., 2002)

The following stage Early Visean time is characterised in the end by formation Mud Mounds hills and constructions Waulsortian type. Then in Late Visean- Serpukhovian-Early Bashkirian time occurred formation bioherms and large reefs systems (an example: Akujuk reefs a complex, Bolshoi Karatau Mountains; Tekes reef, Terskei Mountains - Figs. 3, Ulkenkuduk reef, Talasso-Ugam Mountains- Fig. 4).



1 - limestone lamination; 2 - limestone marble;
3 - sandstone limestones ; 4 - tuffs shale; 5 - conglomerates

Fig. 3 – Tekes reef in Terskei Mountains



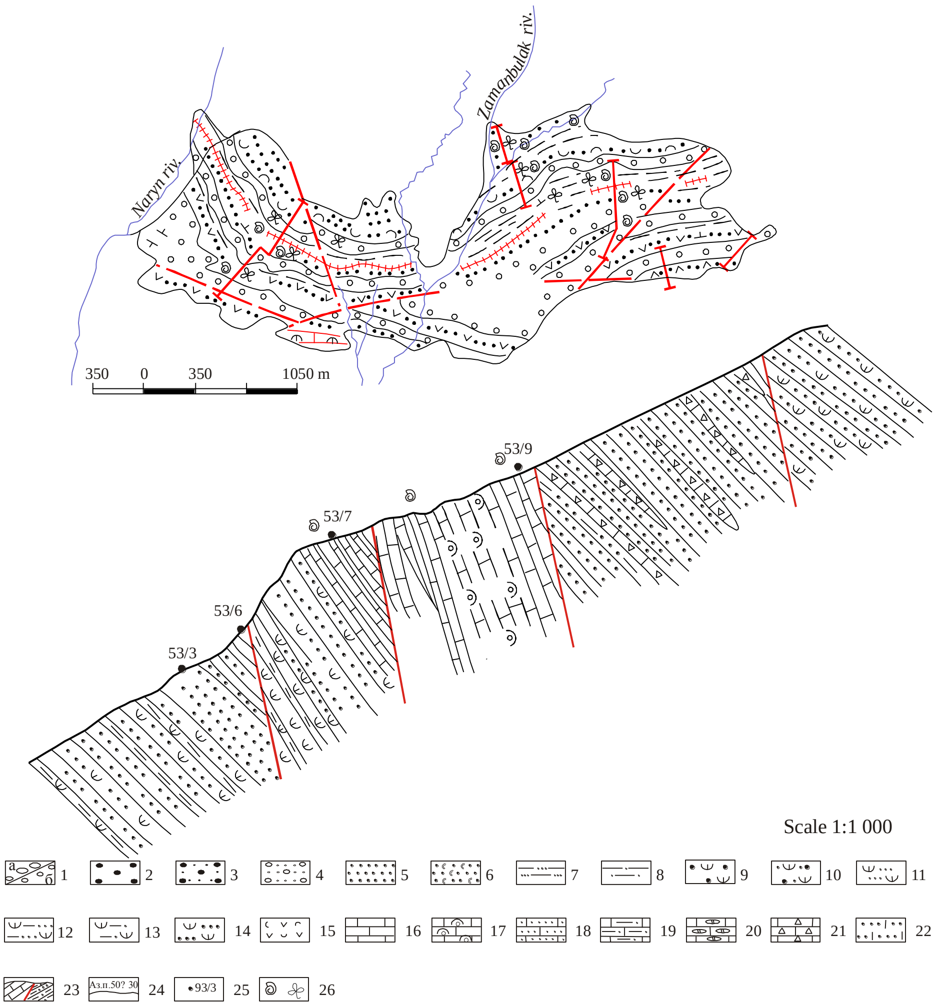
1 - place of study; 2 - number profils; 3 - place selections of sample; 4 - reefs limestone; 5 - between reefs facies;
6 - carbonate breccia; 7 - crinoid limestone; 8 - siliciclastics; 9 - bedding rocks

Fig. 4 - Bashkirian Ulkenkuduk Reef Formation, Ugam Mountains (Zorin A.V., Zhaimina V. Ja., 1998)

Late Bashkirian- Early Moskovian time large reefs, systems bioherms also were formed is Sandyktas (Zhongar Mountains) reefs a file, Sajak reefs a complex (Tastykuduk formation, Northern Pribalchachja- Fig. 5) and others.

Fig. 5 Bashkirian to Moskovian bioherms
(Tastykuduk formation, Tastykuduk section, Sajak reefs complex)
V.Ja. Zhaimina, 1989

In Late Carboniferous - Early Permian formation Karachaganak reefs a file in the Near-Caspian hollow which has begun stillin Tournaisian time [17] has come to the end. (an example: bioherm Upper Carboniferous in Zhaman-Bulak, Zhongar Mountains- Fig.6).

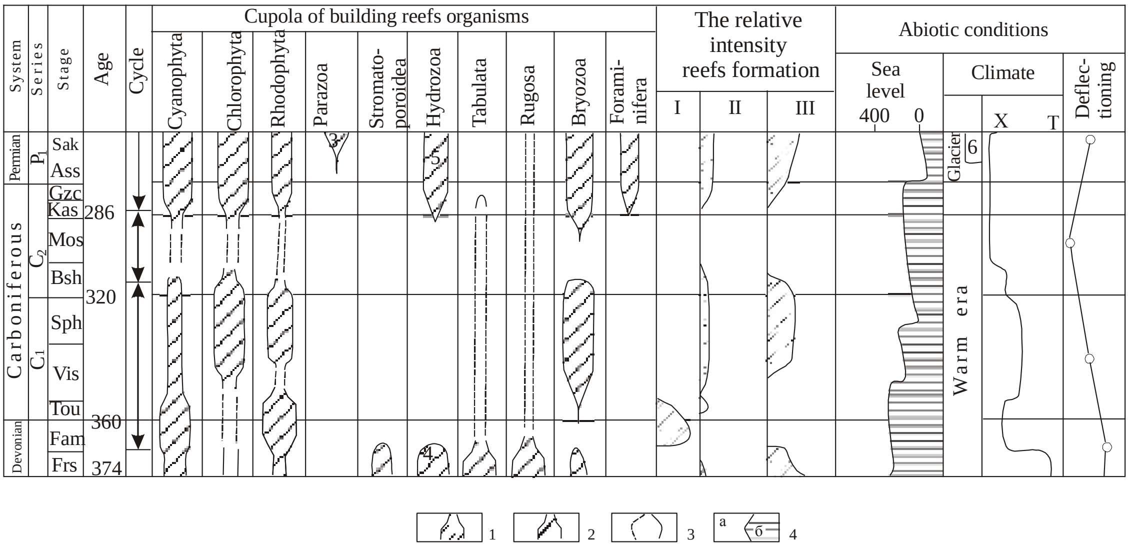


1 - conglomerates; 2 - gravelites; 3 - sandstone gravelites; 4 - sandstones with grained; 5 - sandstone; 6 - sandstones with shall separatens; 7 - shales sandstone; 8 - shales; 9 - tufs gravelites; 10 - gravelites tufs sandstone; 11 - tufs sandstone; 12 - tufs; 13 - tufs shales; 14 - tuffites; 15 - tufs dazit; 16 - limestone; 17 - bioherm; 18 - limestones sands; 19 - limestones shales; 20 -limestone with claysilica; 21 - limestone breccia; 22 -sandstones limestone; 23 -tectonic faults; 24 - bedding rocks; 25 - samples; 26 - faunas, flores.

Fig. 6 Upper Carboniferous bioherm in Zhamanbulak block

Evolution and recurrence Paleozoic reefs for Russia and the adjacent states is considered by

V.G.Kuznetsov [18]. Famennian-Early Bashkirian reefs he united in one cycle (Fig. 7).



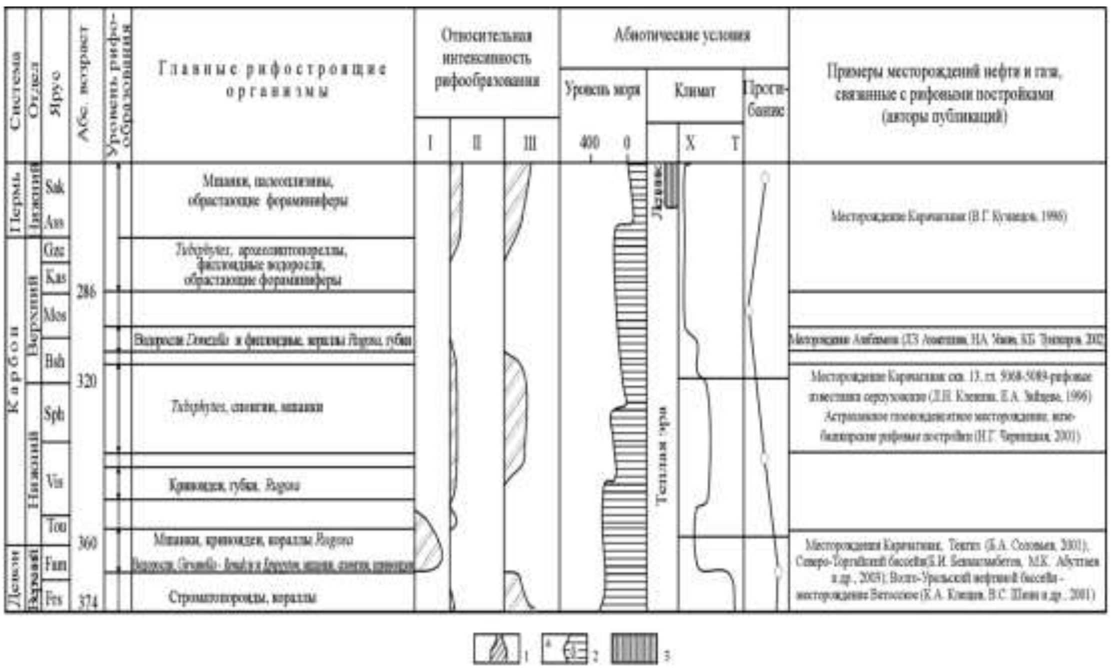
1 - a relative role of various organisms reef formations; 2 - relative intensity reef formations;
3 - the role of organisms and type of constructions are doubtful; 4 - a relative sea level (on Hartland et al.), 1982: a - a land, b - the sea

Figures in drawing: Sphynctozoa, 4 -Paleoplisina, 5-Fistulella, 6-soutern freezing

Fig. 7 Evolution Famennian - Carboniferous formation of reefs in Russia and the adjacent states (V.G. Kuznetsov, 1996)

Conclusions

By the author it is detailed Famennian- Early Bashkirian a cycle, evolution formation of reefs in Famennian - Carboniferous is considered, some levels are allocated and the structure building reefs organismus in Kazakhstan is specified (Fig.8).



1-mud mounds; 2-biostrom and bioherm; 3-reefs.

Fig.8 - Evolution Famennian-Carboniferous formation of reefs in Kazakhstan

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IN MEMORY OF SCIENTIST

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YESSENOV SHAKHMARDAN YESSENOVICH
BY THE 90TH ANNIVERSARY OF THE GREAT SCIENTIST

In 2017 the whole geological community of Kazakhstan celebrates the 90th anniversary of Sh. Ye. Yessenov. The geologist headed the Ministry of Geology of the Kazakh SSR when he was 33. He was the youngest minister in the Soviet Union and this is an indicator of his extraordinary thinking and intelligence.

The history of Yessenov's work began, as well as at all geologists after graduating from the Kazakh Mining and Metallurgical Institute. A young, gifted, efficient and talented geologist was one of the favorite students of the outstanding Kazakhstan geologist Kanysh Satpayev, who sent a young mining engineer to the Zhezkazgan complex exploration expedition in 1949, which laid the foundations of a modern mining complex in this region, one of the world's largest copper extracting and copper smelting.

Working as the Minister of Geology of the Kazakh SSR, Yessenov showed the exceptional versatility of his knowledge, delving deeply into the details of broad geological studies aimed at both regional generalization and solving issues of increasing efficiency and improving the economic performances of geological exploration.

During this time, Yessenov proved to be not only a talented organizer of production, but also as a great scientist. Despite the huge workload of current work, he wrote and brilliantly defended the thesis for the degree of candidate of geological and mineralogical sciences, on such a necessary and very important in Kazakhstan conditions, the method of searching and exploration of mineral deposits.

In 1967 he was elected as a president of the Academy of Sciences (A of S) of the KazSSR and simultaneously director of the Institute of Geological Sciences of the A of S of the KazSSR (1967-1974). During this period of time, Sh. Yessenov made a significant contribution to the development of an important section of geological science – metallogeny. This is evidenced by his monograph on geology, metallogeny and methods of searching and exploration of copper sandstone types (Zhezkazgan type), where the provisions on the genesis and industrial prospects of this type of deposits in Kazakhstan are comprehensively substantiated. The work was successfully defended in

Moscow for the degree of Doctor of Geological and Mineralogical Sciences. The monograph "Bowels of Kazakhstan" by Sh. Yessenov and co-authors is a great scientific, historical and cognitive value. It is devoted to the study of Kazakhstan's mineral wealth, ways and peculiarities of their national economic usage.

Shakhmardan Yessenov with colleagues-geologists in Zhezkazgan, 1950s.

Under Yessenov's leadership and with his direct participation was compiled and published the first geological map of Kazakhstan 1: 1 500 000 scale. At this time he headed a major work on geotectonic zoning of the entire territory of Kazakhstan.

In 1973 on the initiative of academicians Sh. Ye. Yessenov and A. K. Kayupov began a major work to generalize the geology and metallogeny of mineral deposits and compile medium-scale metallogenic and forecast maps of the entire territory of Kazakhstan and adjacent areas of neighboring republics. All the employees of the Satpayev Institute of Geological Sciences, geologists of production organizations of Kazakhstan, scientists from Moscow, who were considered and called like Kazakhstan geologists were involved. The result of these works was the publication of numerous predictive-metallogenic maps and eleven volumes of a series of monographs under the unified name "Metallogeny of Kazakhstan". This work was a further development in the field of metallogeny and methodology of the creating predicted-metallogenic maps, the foundations of which were laid in the 1950s by academician K. I. Satpayev at the federal level. A new predictive-metallogenic map covered the entire territory of Kazakhstan and was compiled on the basis of a new method of formational analysis – a unified principle of systematization of geological and ore formations forming in similar tectonic regimes, regardless of geological age.

In the office of K.I.Satpayev 1960

Shakhmardan Yessenov is considered to be one of the most outstanding Kazakhstani scientists along with K.I. Satpayev and Ye. Buketov. Due to the fruitful activity of Shakhmardan Yessenov and with his active participation were discovered and developed the largest deposits of natural resources (oil, gas, copper, etc.) for today - Zhezkazgan, Zhanaozen, Karazhanbas, Zhetybay, Kalamkas, Bozashi and others, and accordingly production complexes, which today form the basis of Kazakhstan's economy.

Shakhmardan Yessenov was not only a great scientist but also a man who made a great contribution to the history and development of the country. This was acknowledged by the well-known fact that thanks to Shakhmardan Yessenov the Mangystau oblast (Mangyshlak), and consequently all its resources, is still a part of the Republic of Kazakhstan. In 1962, after the discovery of large oil and gas reserves on the peninsula of Mangyshlak, Nikita Khrushchyov had an idea to transfer this region to Azerbaijan or Turkmenistan, citing greater experience in the development of oil fields. Dinmukhamed Kunayev instructs to Shakhmardan Yessenov not to allow the transfer of Mangyshlak to another republic.

Shakhmardan Yessenov with colleagues-geologists

Sh. Ye. Yessenov enjoyed great prestige and confidence with the allied leadership, scientific and state elite for talent, charisma, intelligence and the highest professionalism. This matter was discussed at a closed joint meeting of the Presidium of the Supreme Council and the Council of Ministers of the USSR. After the introductory speech of N. S. Khrushchyov, Shakhmardan Yessenov made a speech. He justified the need to leave the Mangyshlak region in the Kazakh SSR very clearly and reasonably, that Kazakhstan has enough scientific and industrial potential to develop and to master this region, that the resources of this region are equal to five Baku, etc. The then head of the Cabinet of Ministers of the USSR N. Kosygin supported Shakhmardan Yessenov, as well as the majority who was convinced by the Yessenov's presentation, voted for the preservation of the status quo of Mangyshlak. This decision was not just a historical one, preserving for Kazakhstan the most important part of it. In many respects this was a precedent for a democratic confrontation between the power vertical and its decisions.

In 1978 he was appointed as the head of the Department of Methods of Exploration of Mineral Deposits of the Kazakh National Technical University named after K.I. Satpayev – this flagship of engineering education in the country. The material and technical base of the Department of Methods of Exploration of Mineral Deposits was significantly strengthened by Yessenov, radically improved the main indicators of its activities. As he was an innovator and a creative person, the department he had headed for many years was equipped with the most advanced technologies and the teaching staff was assembled from the best geologists of not only the Republic but also of the large scientists of the Union Republics. He was the one who first introduced a comprehensive degree projecting, which allowed students to develop special sections of projects more detail. Under his leadership and with direct participation, more than 15 methodological instructions were drawn up for various types of training sessions. The department carried out research work, which took place both on contractual and state budget programs of the Ministry of Higher Education. All the staff of the department and laboratories was executors of these works. Students also took an active part in thematic works. All the studies carried out were completed by the introduction of the results obtained into the production process.

Shahmardan Yessenov with his colleagues-geologists near the building of the Institute of Geological Sciences K.I.Satpayev

Scientific researches and works of Yessenov were highly appreciated and widely recognized by the scientific community at various domestic and international conferences, forums and awarded with state and international awards: awarded with two Orders of Lenin, medals, Honorary Diplomas of the Supreme Council of the KazSSR, Lenin Prize Winner (1966) for the discovery of oil deposits in Mangyshlak, Laureate of the State Prize of the KazSSR (1972), Laureate of the Prize of the Academy of Sciences of the KazSSR named after Ch. Ch. Valikhanov (1971).

For his high creative and fruitful activity he enjoyed great authority and served for all as an example of scientific competence, integrity, selfless diligence.

In 2013 was established the Scientific and Educational Foundation named after academician Shakhmardan Yessenov. It is created in the best traditions of patronage with the aim of developing education, science and innovations in Kazakhstan and their introduction into production, and the system of higher education of the country. The foundation's mission is to develop the intellectual potential of Kazakhstan.

The Foundation is engaged in the realization of educational, scientific-research and grant programs, as well as programs for the commercialization and promotion of scientific developments, internships in laboratories in the United States, and others.

Sh. Yessenov is still contributing to the science of Kazakhstan with the work of his Foundation. There is very interesting fact that the International meeting and the field tour of the Upper Devonian-Carboniferous reef-building of the Bolshoy Karatau Mountains, which is being conducted under the auspices of the International Subcommission on Carboniferous Stratigraphy (SCCS), takes place on the days of the celebration of the 90th anniversary of Shakhmardan Yessenov in his home town where he spent his childhood and adolescence.

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СОДЕРЖАНИЕ

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