

Late Pennsylvanian conodont biostratigraphy and sedimentology of the Kriva Reka Fm. from the Jadar Block, Vardar Zone (NW Serbia)

By

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Abstract

In the Belovača section of the Jadar Block, Vardar Zone (NW Serbia), the Late Pennsylvanian Kasimovian and Gzhelian stages with several zones are documented on the basis of the conodonts. Reviewed the Late Carboniferous conodont fauna were found in the thick-bedded to massive mostly recrystallized limestone in the middle and upper parts of the Kriva Reka Fm. That marine formation consists of molasse-type sediments, is very specific characteristic for the Jadar Block's Late Variscan succession.

designated in previous investigations (FILIPOVIĆ 1995, p. 91). Also the sedimentological characteristics of the Kriva Reka Fm. could be recognized in the Belovača section. In this way, the paper represents the result of our intensive ongoing geological study of the conodonts and other characteristics of the Upper Paleozoic and Triassic rocks of the Jadar Block in NW Serbia. The paper includes more precise lithostratigraphic definition and documentation of all done paleontological and biostratigraphic data.

1. Introduction

Carboniferous sediments are widespread in the Jadar Block of NW Serbia in the regions of the Vlačić, Sokolska, Jagodnja and Medvednik Mts. They were also proved in a borehole further northward in southern Srem at 552 to 752 m depth below the Cenozoic sediments.

After the period of the geological investigations for the Basic Geological Map of SFR Yugoslavia (scale 1:100 000), the Carboniferous carbonate rocks were intensively studied during the work on thematic geological mapping in Serbia in the period between the 1980 and 1990 years. In both cases, the age determinations were mainly based on presented macrofauna and microfauna found in thin sections (fusulinaceans, some other characteristic foraminifera, etc.). Conodont analysis was very successful in the Mississippian and in the Early Bashkirian. On the other side, the investigations of the conodonts in the Pennsylvanian were sporadic and unsystematic, because the results were often incomplete. Subsequently, in later detailed lithostratigraphic studies (e.g. FILIPOVIĆ 1995, FILIPOVIĆ et al. 2003, etc.) it was obvious that there is serious shortage in defining properties of the formations of the Late Carboniferous age.

The aim of this research was to confirm presence of conodonts in the geological column of the Belovača section and study in detail their vertical distribution, as a part of the Late Variscan (the late Middle and the Late Pennsylvanian-Asselian) Kriva Reka Fm. Except of determination of precise age of conodonts we tried to solve the problem of upper boundary of the formation which was a open question

2. Geological setting

Geographically, the Jadar Block is located at the southern margin of the Pannonian Basin. It belongs to NW Serbia and to the westward spreads over the Drina River to eastern Bosnia (Fig. 1A).

The Jadar Block, as an exotic block terrane in which Dinaridic features predominate, was placed into the Vardar Zone before the Upper Cretaceous (KARAMATA et al. 2000, KARAMATA 2006, etc.). It is surrounded by the Vardar Zone Western Belt, except in the farthest southeastern part, where it is in the direct contact with the Kopaonik Block and Ridge Unit which is a part of the Vardar Zone, as well (Fig. 1A). The Jadar Block differs from the Vardar Zone Western Belt in lack of data on post-Liassic sediments, as well as in absence of ultramafites, ophiolitic mélange, and the Cretaceous flysch development (FILIPOVIĆ et al. 2003).

In that area, deposition took place during the Variscan and Early Alpine evolution with obvious similarities with coeval successions of the „Bükkium“ and Sana-Una terranes, even Carnic Alps (PROTIĆ et al. 2000, FILIPOVIĆ et al. 2003). The main characteristics of the Jadar Block during this time are: marine development of the Carboniferous and Permian, a sedimentation of shallow-water marine carbonates in the Upper Permian and in the lowermost Triassic, the specific features of the Triassic rocks with dolomite of Anisian age, „porphyrites“ and pyroclastics of Ladinian age, platform-reefal limestone of Middle and Upper Triassic age and their gradual transition into the Liassic limestone. Younger Jurassic formations are not known.

Carboniferous of the Jadar Block, comprises both autochthonous and allochthonous marine rocks. The former are

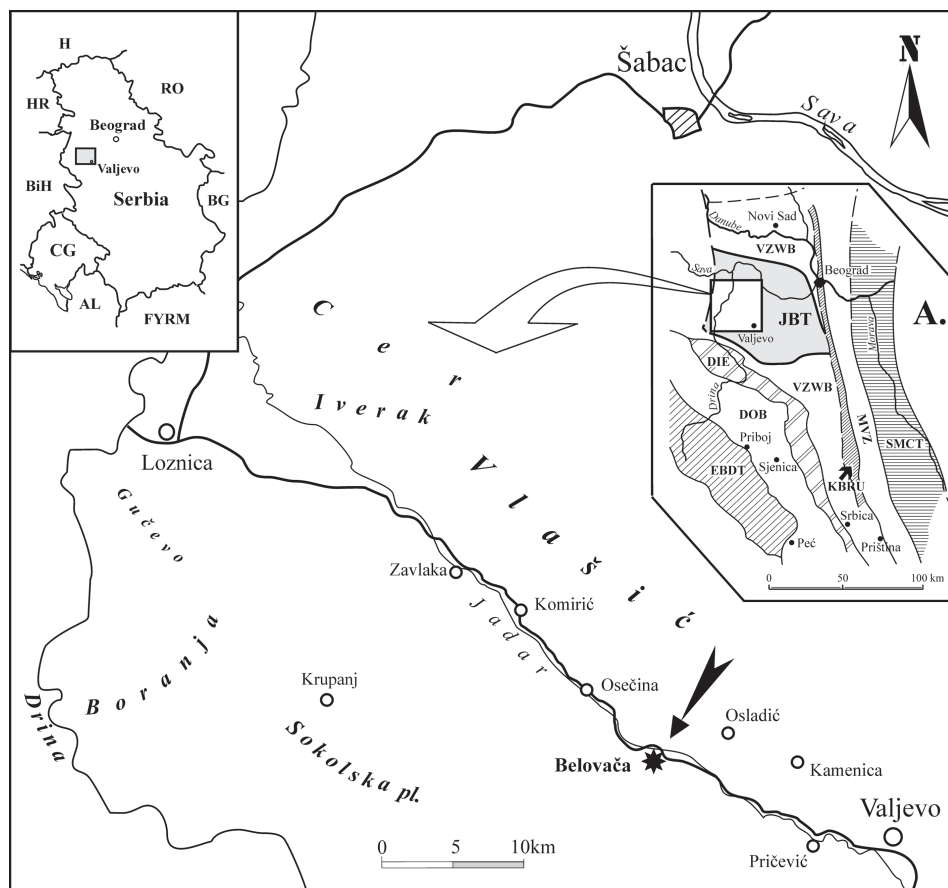


Fig. 1: Location of the Belovača section of the Jadar Block, Vardar Zone (NW Serbia).

A. Terranes of part of the Balkan Peninsula (KARAMATA et al. 2000, KARAMATA 2006): SMCT – Serbian–Macedonian Composite Terrane; MVZ – Main Vardar Zone; KBRU – Kopaonik Block and Ridge Unit; VZWB – Vardar Zone Western Belt; JBT – Jadar Block Terrane; DIE – Drina–Ivanjica Element; DOB – Dinaridic Ophiolite Belt; EBDT – East Bosnian–Durmitor Terrane.

products of the Variscan and Late Variscan sedimentary cycles, whereas allochthonous Carboniferous rocks of the Likodra Nappe are deposited only in the time of the Variscan evolution (Viséan–Early Moscovian).

Autochthonous Carboniferous deposits are divided on structural and facial criteria into clastic flysch (Variscan Flysch or Vlašić Fm.), pelagic carbonates (Družetić Fm.), and molasse sequences (Ivovik Fm., Kriva Reka Fm.). The rocks of the Likodra Allochthon are characterized by an apparently continuous succession of deep-water deposits (Variscan Flysch) followed by the transitional, basinal carbonates (Djulim Fm.) and shallow marine carbonate-terrigenous sediments mainly of biohermal characteristics (Rudine Fm., Stojkovići Fm. and Stolice Lst. Fm.).

2.1. Kriva Reka Formation

Late Variscan succession in the Jadar Block is characterized by molasse-type sediments deposited only in the Jadar Autochthon (FILIPOVIĆ 1995, FILIPOVIĆ et al. 2003). At first, the terrestrial debris flow-type sediments of the Ivovik Fm. (Krupanj–Valjevo, Vlašić and Ub regions), and later the marine offshore thick fusulinacean carbonates without siliciclastics of the Kriva Reka Fm. (Krupanj–Valjevo region on the Jadar Paleozoic southern margin) were formed. The Ivovik Fm. was deposited in the middle part of the Moscovian (Podolskian). The age of the Kriva Reka Fm. is from the Late Moscovian (Myachkovian) to the Asselian and it lies between the olistostrome formation (Ivovik Fm.),

and the transgressive Middle Permian clastics (Bobova Breccia and Cerova Fm.) (FILIPOVIĆ et al. 2003).

Kriva Reka Fm. was earlier named as the Fusulinid Limestone Fm. (FILIPOVIĆ 1974, JOVANOVIĆ 1995, etc.). It studied in detail at localities at Kriva Reka–Sklop (river Bogoštica in the village Šljivova near Krupanj) and on southern slopes of Vis, near the village of Bobova (JOVANOVIĆ 1995). The thickness of the formation is about 90 m. It consists of grey, light grey, even white limestone, massive or thick-bedded, rarely stratified. They contain abundant fusulinaceans, and occasionally small foraminifers, algae, brachiopods, conodonts, pelecypods, bryozoans, crinoids, etc. Sporadically are visible differently recrystallized rocks, cut with numerous secondary calcite veins. In the lowermost part of the formation occur rare chert lenses and intercalations. The presence of stratigraphically important fusulinaceans is characteristic for this formation. Fusulinacean assemblages usually have metric thickness (up to three metres), as at the road Kriva Reka–Sklop, where they occur in three levels. Three fusulinacean associations were found: the earliest, of the Myachkovian age with *Fusulinella bocki* and *F. eopulchra* (locality Tudjin), the middle of the Kasimovian age with the zone fossils *Protricitites pseudomontiparus*, *Tricitites irregularis* and different ozawainellids (localities: Belovača, Kriva Reka–Sklop, Ravno Brdo–Šljivova), and the third, of the closing Gzhelian and the Asselian age with *Rugofusulina alpina* and *Quasifusulina longissima* (Kriva Reka–Sklop, Ravno Brdo–Šljivova, Belovača) (FILIPOVIĆ 1995). The last fusulinacean association from the Belovača section was also cited in

PANTIĆ-PRODANOVIĆ (1980). Besides, according to PANTIĆ-PRODANOVIĆ (1980) and FILIPOVIĆ (1995) even the fourth association of fusulinaceans, which consists of *Parafusulina pseudojaponica*, *P. freganica*, *Rugofusulina complicata*, etc., corresponding to the Asselian, is present in the Kriva Reka Fm. (Kriva Reka-Sklop, Ravno Brdo-Šljivova). For these fusulinacean citations and the age determination in the study by FILIPOVIĆ (1995), the paper by PANTIĆ (1969) was used. In the mentioned paper, except one stratigraphic column where the presence of the Upper Carboniferous and Lower Permian on the Sokolska Mt. is indicated, there are no other data about the name of the locality where these fusulinacean associations were found. However, the presence of the Early Permian, in general a Sakmarian-Artinskian interval, in the Kriva Reka Fm. on the locality Kriva Reka-Sklop is confirmed first by F. KAHLER, and later by H. FORKE (unpublished data from 1992 and 2006) who determined *Cuniculinella* probably *fusiformis* (or *Chalartoschwagerina* sp.), *Eozellia* ? sp., and *Pseudo-schwagerina* ? sp.

Monotonous conodont faunas found in separate samples inside the limestone belonging to the Kriva Reka Fm. indicate the following ages: the Late Moscovian, the Myachkovian (Tudjin), upper part of the Kasimovian (Belovača), lower part of the Gzhelian (Belovača) and upper part of the Gzhelian (Belovača, Ravno Brdo-Šljivova). According to S. STOJANOVIĆ-KUZENKO and V. PAJIĆ (in FILIPOVIĆ 1995, p. 41, 91) most of the Gzhelian conodont species from the Belovača and Ravno Brdo-Šljivova continue into the Permian.

On the basis of sedimentological features, JOVANOVIĆ (1995) correlated the massive limestone of the Kriva Reka Fm. with Waulsortian mud mounds (WILSON 1974, 1975) deposited in flank and central parts on shelf edge bellow the wave base. They are mostly built of peloidal and bioclastic micrites (microsparites). Abundance of bryozoan and crinoid fragments are very characteristic. Fragments of pelecypods, brachiopods, different forams (e.g. *Tuberitina*, *Tetrataxis*, etc., some known as mud-catchers), incertae sedis *Tubiphytes obscurus* (known as a reef-builder) are very often, too. Typical reef, i.e. reef skeleton-building organisms are lacking; the role of reef-builders was taken by peloidal and bioclastic micrite. Significant is the occurrence of fusulinaceans, and they appear during transgressive phase of transgressive-regressive depositional cycle, when the climate became warmer and temperature of ocean higher (ROSS & ROSS 1985). The appearance of fusulinaceans usually is typical for clear shallow water of average energy and normal salinity, higher temperature, tropical and subtropical climate (ROSS & ROSS 1988).

3. Conodont biostratigraphy and sedimentology of the Kriva Reka Fm. in the Belovača section

3.1. Belovača section

Belovača section (old quarry) is located on the southern slopes of the Vlašić Mt. (i.e. on the NE hillside of Beljino Brdo) and on the left side of the Valjevo-Loznica road in the area of the village Osladić (Fig. 1).

In previous investigations, middle (Late Kasimovian) and upper parts (Gzhelian-Asselian) of the Kriva Reka Fm. were found on the locality Belovača. Corresponding fusulinacean and conodont microassociations were established (FILIPOVIĆ 1995).

Determined the Late Kasimovian fusulinacean fauna included numerous species of *Ozawainella* (*Oz. angulata*, *Oz. rhomboidalis*, *Oz. kurakhovensis*, etc.) and rugofusulinids, plectogyrids, bradyinids, and also stratigraphically significant, but rare triticitids. Besides alga *Anthracoporella spectabilis*, in the Gzhelian-Asselian micro-association two fusulinacean assemblages of different ages are presented. The older one is with *Quasifusulina longissima*, *Qu. nimia*, *Rugofusulina* ex gr. *prisca*, etc., while the younger is with *Rugofusulina* ex gr. *alpina*, *Pseudofusulina* sp., etc. (V. PAJIĆ and I. FILIPOVIĆ in FILIPOVIĆ 1995, p. 54, 55, 96, Pls. 42-44, 51).

On the basis of three poorly and scarce conodont associations taken randomly, presence of the Late Kasimovian and lower and upper parts of the Gzhelian are inferred, with possible presence of the Early Permian (Asselian) (S. STOJANOVIĆ-KUZENKO and V. PAJIĆ in FILIPOVIĆ 1995, p. 40, 89, 90, Pls. 23, 24).

Sediments of the Belovača section belong to middle-upper part of the Kriva Reka Fm. It is built of 28 m thick-bedded and bedded, almost massive black, grey, sometimes white colored or red-coated, unequally recrystallized limestone. Some parts show irregular dolomitization. The whole limestone section, divided into 6 units, is very monotonous from base to top. The last unit is separated by a fault (Figs. 2, 3). Recrystallized algae, fragmented crinoids and bryozoans, rarely fusulinaceans are visible on the surfaces. In Belovača section, as a part of the Kriva Reka Fm., the siliciclastics are not presented, just autigenic quartz appears randomly.

Sedimentological investigations embedded analysis of 19 thin sections. Studied limestone is mostly represented by recrystallized biomicrite-microsparite, intrabiomicrite, intrabiomicrite, intrapelbiomicrite, pelsparite (wackestone-packstone-grainstone). Abundant organic production represented by association of bryozoan and crinoid bioclasts joined with micrite lithoclasts, peloidal concentrations and tuberitinids (could be collectors of sediment grains, RICH 1970), usually typical in the Kriva Reka Fm., is very often on this section and characteristic for flank facies of mud mounds. Fragments of brachiopods, algae (*Anthracoporella*) and other small foraminifers are not so frequent. The presented fusulinaceans are rare, not bigger than 1.5 mm, coated by micrite or micritized, often fragmented. Obvious and visible interruption in sedimentation is not recorded on the Kasimovian-Gzhelian transition within the Kriva Reka Fm. in the Belovača section (Fig. 2).

3.2. Conodont fauna and dating

As part of a biostratigraphic study, on detailed observed geological column of the Belovača section, 28 limestone samples were collected for conodont analysis. These samples were prepared by standard conodont techniques, and 19 were productive. The Colour Alteration Index (CAI values) of the identified conodonts is 1.0-1.5 (sensu EPSTEIN

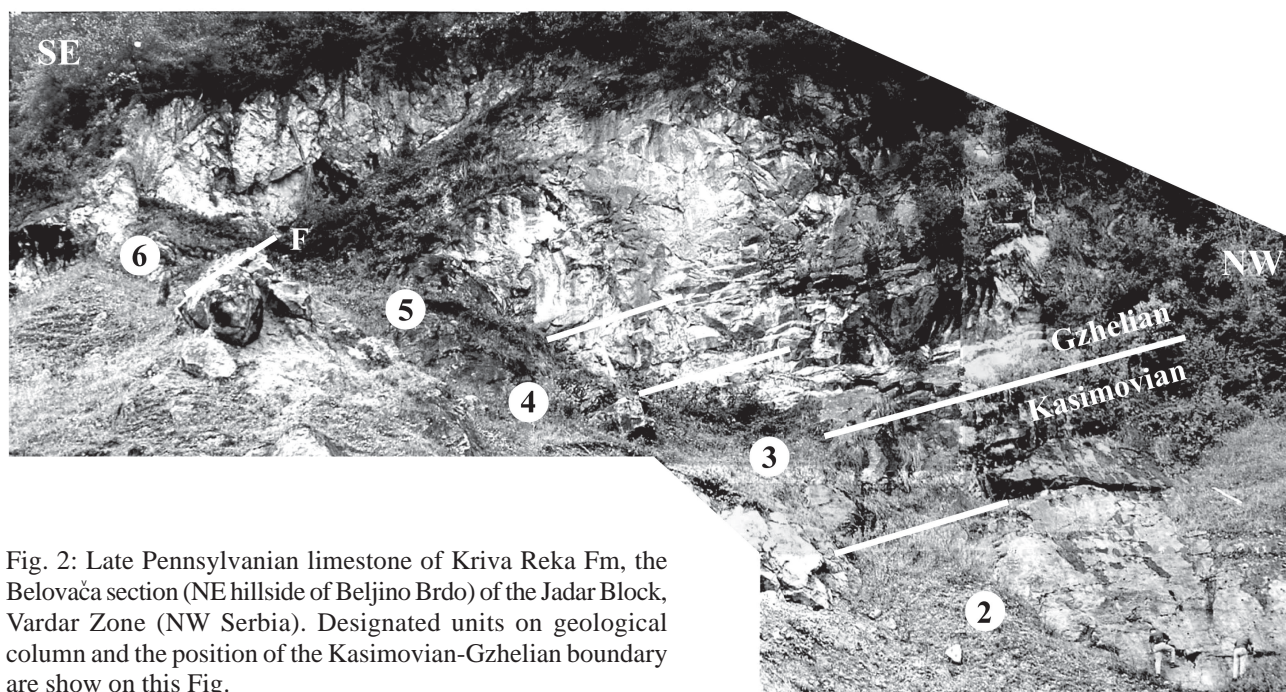


Fig. 2: Late Pennsylvanian limestone of Kriva Reka Fm, the Belovača section (NE hillside of Beljino Brdo) of the Jadar Block, Vardar Zone (NW Serbia). Designated units on geological column and the position of the Kasimovian-Gzhelian boundary are shown on this Fig.

et al. 1977).

Representative conodont specimens were photographed with a SEM at the Geological Institute of Hungary, Budapest, Hungary. All studied and illustrated specimens and thin sections have been catalogued and archived at the Department of Paleontology, Faculty of Mining and Geology, University of Belgrade, Belgrade, Serbia, under numbers MS 2050-2077.

As mentioned, in previous initial investigations on this locality, only in three samples, were found scarce and monotonous conodont associations. They indicate following ages: upper part of the Kasimovian (*Idiognathodus toretzianus*, *Id. sagittalis*), the lower part of the Gzhelian (*Id. lobulatus*, *Id. tersus*, *Anchignathodus minutus* and *Diplognathodus* sp.) and the upper part of the Gzhelian (*Streptognathodus simplex*, *St. alekseevi*, *St. elongatus*, *Streptognathodus* cf. *St. antiquus* and *St. elegantulus*) (S. STOJANOVIĆ-KUZENKO and V. PAJIĆ in FILIPOVIĆ 1995, p. 40, 89, 90, Pls. 23, 24). The authors concluded that in the last studied conodont fauna, found in this locality, all species except *St.* cf. *St. antiquus* continue into the Permian. This dual age determinations of later conodont fauna, according to M. SUDAR, even in that time, was not totally corresponded to the facts concerning vertical distribution of established conodonts and existence of some conodont zones around the Carboniferous-Permian boundary. Besides, what is very significant in relation to biostratigraphic importance of conodonts, this conclusion was not confirmed neither with detailed research of conodonts nor with their precise vertical ranges. How mentioned authors also were not totally convinced in that age conclusions they gave one statement more: „it is hoped that research in progress will establish the position of the boundary between the Carboniferous and Permian, if Permian is present“ (FILIPOVIĆ 1995, op. cit., p. 91).

Conodont fauna from the Belovača section, on the basis of

our investigations, contain two associations of the Palelements: older with *Streptognathodus elegantulus* (Pl. 1, Figs. 1-10), *Idiognathodus toretzianus* (Pl. 2, Figs. 1-5), *Idiognathodus* sp. A, *Idiognathodus* sp., and *Streptognathodus* sp., and younger, represented by *St. elegantulus* (Pl. 1, Figs. 11-15), *Id. lobulatus* (Pl. 2, Figs. 6-10), *Id. luganicus* (Pl. 3, Figs. 3-11), *St. pawhuskaensis* (Pl. 2, Figs. 11-15 and Pl. 3, Figs. 1, 2), *St. firmus* (Pl. 3, Fig. 12), *St.* cf. *gracilis* (Pl. 3, Fig. 15), *Idiognathodus* sp. B (Pl. 3, Fig. 13), *Idiognathodus* sp. C (Pl. 3, Fig. 14), *Idiognathodus* sp., and *Streptognathodus* sp. The vertical distribution, i.e. biostratigraphic characteristics of individual taxa in established conodont associations prove, that the first association determinates the Kasimovian (only their upper part with certain *toretzianus* and *firmus* Zones, and probably lower *cancellosus* Zone, too) (Fig. 3). The second association defines the Gzhelian, lower and middle parts with certain *simulator*, and possible next *vitali* and the lowermost part of *virgolicus* Zones (ALEKSEEV & GOREVA 2006) (Fig. 3). In separated conodont microfauna *Idiognathodus simulator* is not established, the conodont species has been proposed as the best index-fossil with its first appearance datum (FAD) as the event marker for the definition of the base of the global Gzhelian (VILLA and Task Group 2005, HECKEL et al. 2005, etc.). However, the boundary between the Kasimovian and the Gzhelian is surely identified in middle part of the unit No. 3 by the first occurrences of *Idiognathodus lobulatus*, *Id. luganicus*, and *St. pawhuskaensis*, the conodont species involved in the zonal assemblage of the *simulator* Zone in the base of the Gzhelian (ALEKSEEV & GOREVA 2006) (Figs. 2, 3). The presence of this zone in geological column between samples MS 2065 and 2070, confirmed mutual vertical ranges of quoted species, so as presence of *St. firmus*.

On the basis of FAD and vertical range of index species, the *toretzianus* Zone certainly established in the interval

between the samples MS 2059 and 2063. Next, the highest zone in the Kasimovian, *firmus* Zone is possible in column between samples MS 2063 and 2065, because in that range no *Id. toretzianus* and in the later sample for the first time appear species presented in *simulator* Zone of the earliest Gzhelian. In the lower part of column, below sample MS 2059, where first time appears *Id. toretzianus*, as mentioned, is possible presence of *cancellosus* Zone, and probably some other from that, lower, part of the Kasimovian (Fig. 3). Upper boundary of the *simulator* Zone is over sample MS 2070 and it is determined on the last appearance datum (LAD) of *Id. luganicus* and probably and *St. firmus*. Presence of the species *St. pawhuskaensis*, without *Id. luganicus* and *St. firmus*, in interval between samples MS 2070 and 2072, indicates next *vitali* and the lowermost part of the *virgilicus* Zones (Fig. 3).

In conodont fauna from the Belovača section, also are presented forms which we determined as *St. elegantulus* with relatively wide vertical range (Fig. 3). It is established in interval from the lowermost parts of the column in the Kasimovian (MS 2050) to the sample MS 2070 inside the Early Gzhelian. In this moment for that distribution we haven't confirmation from ALEKSEEV & GOREVA (2006), but in one earlier Russian biozonation (BARSKOV et al. 1987) range of this species was defined on two ways: in the text, on p. 87, inside of the Gzhelian, but on Table 3 (p. 140) there are from the latest Kasimovian to the earliest Asselian (if *wabaunsensis* Zone belongs to the Early Permian). In the region of Midcontinent North America it is settled exclusively in the *gracilis* Zone of the Missourian, i.e. in the Kasimovian (BARRICK & HECKEL 2000, BARRICK et al. 2004).

On the basis of all the facts, originated from comparison with the conodont zonal scheme established by ALEKSEEV & GOREVA (2006), in spite of reliable position of boundary between the Kasimovian and the Gzhelian, we could conclude that the following conodont zones are established this time with certainty: *toretzianus* and *firmus* in the uppermost parts of the Kasimovian, and *simulator* from the Early Gzhelian. Also is indicated presence of *cancellosus* Zone (middle parts of the Kasimovian), and *vitali* and the lowermost part of the *virgilicus* Zone in the Early and the Middle Gzhelian (Fig. 3).

Youngest conodont species (*St. pawhuskaensis*), in the determined conodont associations were found in the sample MS 2072 inside of the lower parts of the unit 5, and probably it determine the end of *vitali* and lowermost part of *virgilicus* Zones (middle part of the Gzhelian). Over are 8 m thick part of geological column (together with 4 m thick last unit separated by a fault) (Figs. 2, 3). The conodonts found in that part of the geological column are defined only on the level of genera *Streptognathodus* and *Idiognathodus*, what is not enough for their exact age. It permits possibility of existence of remaining conodont zones in the Late Gzhe-

lian (i.e. the upper part of *virgilicus*, as *bellus* and *wabaunsensis*), to some extent and question of the existence of the Early Permian, as is earlier established on the determinations of the fusulinacean and conodont associations (FILIPOVIĆ 1995).

However, without discussion about stratigraphic value of earlier established fusulinaceans and the age determinations based on their presence, after detailed investigations of conodonts, we could summarize:

- in conodont fauna belonging to Belovača section no any traces of the Early Permian taxa;
- vertical distribution of the determined conodonts and the geological relations in the Belovača quarry (small thickness of remaining undisturbed part of the geological column after the sample with last determined conodont species, presence of a fault after the fifth unit and a possibility of repetition in the section), does not exclude presence of the Early Permian;
- all exposed allows the conclusion that in the limestone of the Kriva Reka Fm. in the Belovača section are found only equivalents of the Late Pennsylvanian Kasimovian and Gzhelian stages.

3.3. Comparison of the Late Pennsylvanian lithostratigraphy and conodont faunas of adjacent areas

Regionally close areas which have more or less obvious similarities with coeval succession and particularly with the lithostratigraphic characteristics of geological development during the Late Variscan evolution of the Jadar Block are: the Carnic Alps, „Bükkium“ and Sana-Una terranes (PROTIĆ et al. 2000, FILIPOVIĆ et al. 2003). In all correlated areas, except in the Sana-Una, molasse-type sediments deposited in this second cycle (the Late Moscovian-Asselian). In the marine Kriva Reka Fm. (Jadar Block) offshore thick fusulinid limestone are present without siliciclastics, but the Mályinka Fm. („Bükkium“) with some quartz conglomerates represents a transitional setting towards the near-shore Auernig Group (Carnic Alps) characterized by abundant quartz-conglomerates. In the Jadar Block, below the Kriva Reka Fm., there is the terrestrial debris flow type Ivovik Fm., older than Auernig Group. In the Sana-Una terrane is established only the Blagaj Fm., which has olistostrome origin with clasts of limestone of the Devonian and Lower and Middle Carboniferous age, and the relations with underlain and overlain formations are not clear. As opposed to the S-vergent thrusting and folding during the Carnic phase in the Carnic Alps (VAI 1998), no evidence for such a tectonic and corresponding metamorphic event could be proven in the compared Jadar Block and „Bükkium“, e.g. between the Ivovik and Kriva Reka resp. the Szilvásvárad (flysch) and Mályinka Formations. Evidences for a Variscan metamorphism are lacking in the „Bükkium“. A Variscan

Fig. 3: Geological column of the Late Pennsylvanian limestone of the Kriva Reka Fm. in the Belovača section of the Jadar Block (Vardar Zone, NW Serbia). Legend. 1. massive to thick-bedded limestone with rare dolomitic parts; 2. fusulinaceans; 3. other foraminifers; 4. bioclasts; 5. quartz grains; 6. pellets; 7. intraclasts; 8. wackestone; 9. packstone; 10. determined conodont taxa on the level of the genus; 11. determined conodont species; 12. bryozoans; 13. brachiopods; 14. algae; 15. crinoids; 16. samples with thin section; 17. samples without thin section; F - fault.

unconformity between the Kriva Reka Fm. and the Middle Permian clastics (Cerova Fm.) can be clearly proven in the Jadar Block. In the „Bükkium“, at least a disconformity can be proven, the Szentlélek Fm. resting on different levels of the Mályinka Fm., indicating a post-Carboniferous uplift and erosion. Equivalents of the 800 m thick succession of the Rattendorf and Trogkofel Groups of the Carnic Alps are missing in the Jadar Block, „Bükkium“ and Sana-Una terranes.

Recently, the Late Pennsylvanian conodont zonation was published for Midcontinent region of North America (BARRICK & HECKEL 2000, BARRICK et al. 2004, etc), for Russia (ALEKSEEV & GOREVA 2006, etc.), and for South China (WANG & QI 2003), etc. DAVYDOV et al. (2004) proposed a conodont zonation for the Carboniferous System as a global standard with the eight zones (Pc12-Pc19) in the interval of the Late Pennsylvanian. Many conodont species from the Belovača section are presented in the mentioned zonal schemes with very similar vertical ranges. That on some way enabled comparison with their results, in spite of long distance and different developments of sediments of correlated areas and NW Serbia.

However, from all named conodont zonation, results presented by ALEKSEEV & GOREVA (2006) for the Kasimovian and Gzhelian sediments in the regions of the Russian Platform and the Urals, are most important for making correlation with conodont faunas from the Belovača section. It especially related on conodont biozonation adjusted in the Moscow Basin, where were established 12 interval-zones (in the Kasimovian 7 and in the Gzhelian 5) with the lower boundaries defined by the FAD of the index species. Besides certainly defined boundary between the Kasimovian and Gzhelian, with our investigations in the Belovača section, in the Kasimovian for sure are determined 2, and indicated presence of one zone, but in the Gzhelian is defined one zone, and insinuated presence of two zones. So, in comparison to all mentioned adjacent European areas with similar geological developments of the Late Pennsylvanian, in the Jadar Block the conodont fauna with numerous established zones is the best investigated.

In the Carnic Alps the conodonts of that interval are found only in the lowermost parts of the Auernig Group which belongs to the Kasimovian (FORKE & SAMANKASSOU 2000, FORKE et al. 2006). Three, i.e. four conodont associations were established and only in the youngest, between them, are presented *St. elegantulus* and *Id. toretzianus*, the same species found also in the Belovača section.

In the „Bükkium“ terrane (NE Hungary) the post-Variscan marine molasse stage is represented by the Mályinka Fm. of the Late Moscovian-Gzhelian age. It is divided into following members: Berenás and Csikorgó (S. KOVÁCS in HAAS 2001, p. 86, 87) or Kapubérc Lst., Tarófé Conglomerate and Csikorgó Lst. (PELIKÁN 2005, p. 185, 186). The formation is very rich in fossils and the main characteristic are: fusulinaceans, brachiopods, corals, algae, small foraminifers, conodonts, pelecypods, gastropods, etc. Fusulinaceans and conodonts biostratigraphically are the most important, but in the determined conodont fauna (especially in the lower parts of the formation) not the species found in the Belovača section (NW Serbia).

4. Conclusions

In the last ten years, in the regions of the Jadar Block (Vardar Zone, NW Serbia), we undertake the intensive geological study of the conodonts and other characteristics of the Upper Paleozoic and Triassic rocks. As the results of detailed sedimentological and biostratigraphic research of the Late Pennsylvanian deposits and conodonts from the Kriva Reka Fm. in the Belovača section some conclusions can be done.

1. In the presented middle and upper parts of the limestone of the Kriva Reka Fm. rich conodont fauna was found. It contains two assemblages: the older with *Streptognathodus elegantulus*, *Idiognathodus toretzianus*, *Idiognathodus* sp. A, *Idiognathodus* sp., and *Streptognathodus* sp., and the younger, represented by *St. elegantulus*, *Id. lobulatus*, *Id. luganicus*, *St. pawhuskaensis*, *St. firmus*, *St. cf. gracilis*, *Idiognathodus* sp. B, *Idiognathodus* sp. C, *Idiognathodus* sp., and *Streptognathodus* sp. Besides documentation of the reliable position of boundary between the Kasimovian and Gzhelian, the first association determinates the upper (? middle) part of the Kasimovian, and the second defines the lower and middle parts of the Gzhelian. In the stages are, on the basis of the precise established biostratigraphic ranges of the present conodont taxa, determined the following conodont zones: *toretzianus*, *firmus* and probably *cancellosus* (Kasimovian), as *simulator* and possible presence of *vitali* and lowermost part of *virgilicus* in the Gzhelian.
2. Mentioned numerous conodont taxa and all conodont zones was for the first time established in the area, as well as in Serbia and in central part of Balkan Peninsula. In comparison to the areas with similar geological developments of the Late Pennsylvanian („Bükkium“ and Sana-Una terranes, and the Carnic Alps), in this moment the Jadar Block has the best investigated conodont fauna, too. Besides, the presented studies gave new paleontological data from Serbia and that enable worldwide correlation (e.g. with Russia, USA, Canadian Arctic Islands, etc.).
3. In the limestone of the Kriva Fm. at the Belovača section are developed only the Late Pennsylvanian Kasimovian and Gzhelian stages, and there are not present the Early Permian. It is proved by presented results principally based on biostratigraphic characteristics of the conodonts.
4. According to the sedimentological investigations very monotonous massive to thick-bedded limestone of the Belovača section belongs to the middle and upper parts of the Kriva Reka Fm. They contain characteristic association of bryozoan and crinoid fragments typical for lateral concentrations of mud mounds deposited on shelf edge below the wave base. On the Kasimovian and Gzhelian boundary, determined with the conodonts, obvious sedimentological differences are not noticed.

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Plate 1

Late Pennsylvanian conodonts from the Belovača section of the Jadar Block (Vardar Zone, NW Serbia).

Figs. 1-15: *Streptognathodus elegantulus* STAUFFER & PLUMMER, 1932.

Figs. 1-10: Kasimovian. 1. 1/MS 2050, Figs. 2-9: *toretzianus* Zone. 2. 1/MS 2059, 3. 2/MS 2059, 4. 1/MS 2060, 5. 1/MS 2062, 6. 2/MS 2062, 7. 3/MS 2062, 8. 4/MS 2063, 9. 5/MS 2063, 10. *firmus* Zone, 1/MS 2064

Figs. 11-15: Gzhelian, *simulator* Zone. 11. 1/MS 2065, 12. 2/MS 2065, 13. 1/MS 2066, 14. 1/MS 2070, 15. 2/MS 2070.

Scale bar 100 µm. All Figs. are upper views.

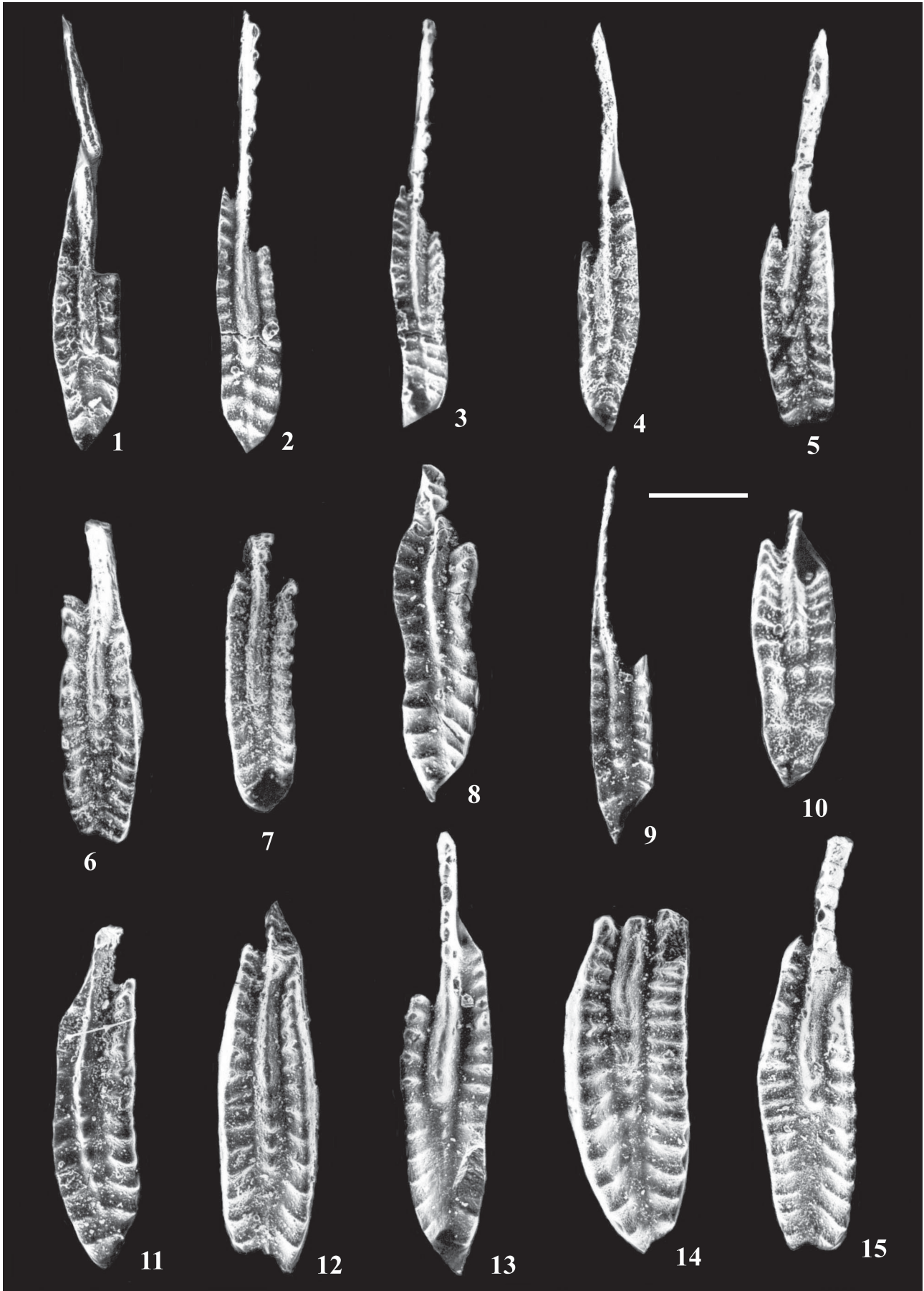


Plate 2

Late Pennsylvanian conodonts from the Belovača section of the Jadar Block (Vardar Zone, NW Serbia).

Figs. 1-5: *Idiognathodus toretzianus* KOZITSKAYA, 1978. Kasimovian, *toretzianus* Zone. 1. 2/MS 2060, 2. 3/MS 2059, 3. 4/MS 2059, 4. 6/MS 2063, 5. 2/MS 2062 (scale bar of 78 µm for this Fig. is shown below).

Figs. 6-10: *Idiognathodus lobulatus* KOZITSKAYA, 1978. Gzhelian, *simulator* Zone. 6. 3/MS2065, 7. 4/MS 2065, 8. 5/MS 2065, 9. 6/MS 2065, 10. 2/MS 2066.

Figs. 11-15: *Streptognathodus pawhuskaensis* (HARRIS & HOLLINGSWORTH, 1933). Gzhelian, *simulator* Zone. 11. 7/MS 2065, 12. 8/MS 2065 (scale bar of 75 µm for this Fig. is on its right side), 13. 9/MS 2065, 14. 3/MS 2066, 15. 3/MS 2070. Scale bar of 100 µm, between Figs. 7 and 8, refers to other Figs. All Figs. are upper views.

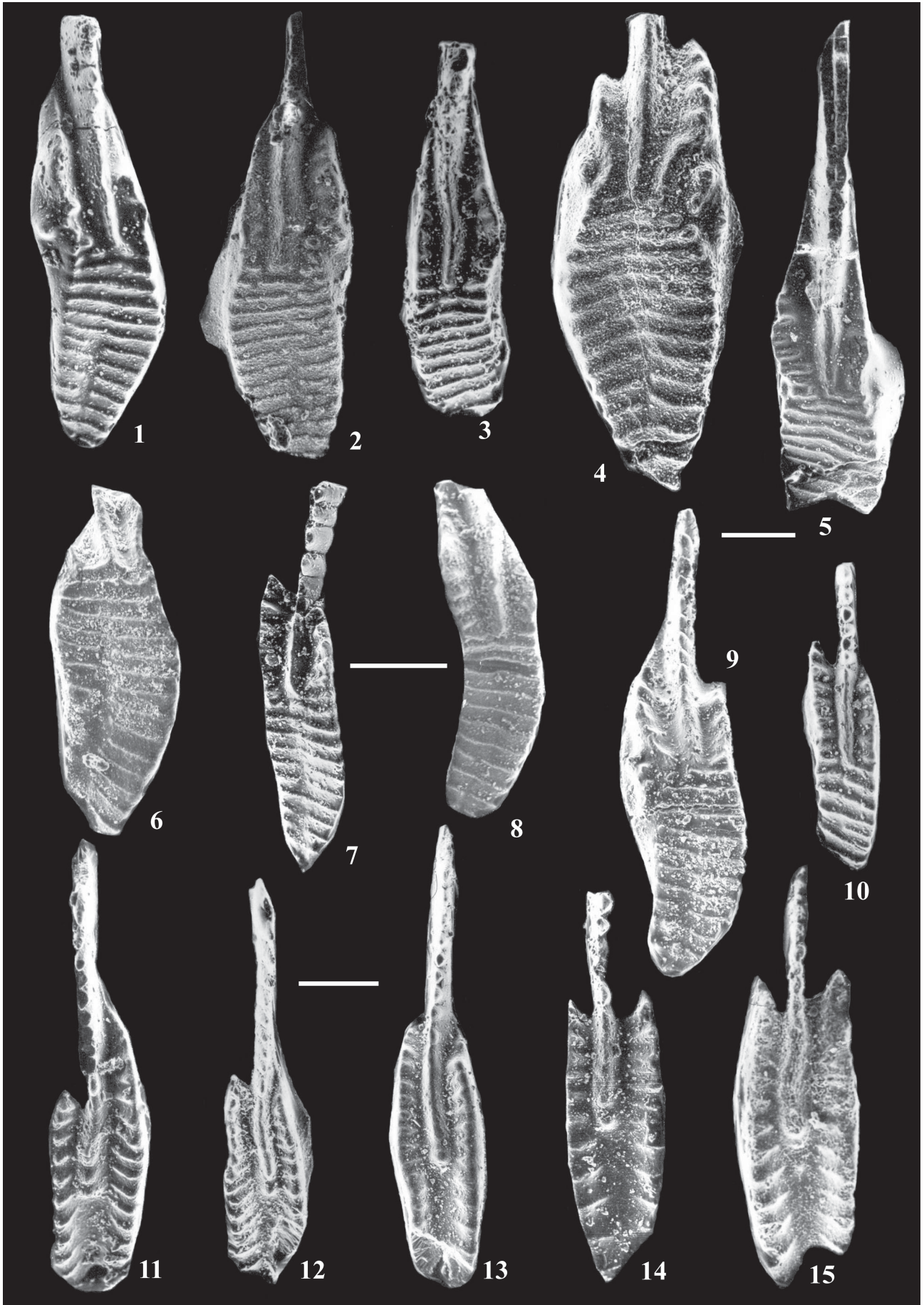


Plate 3

Late Pennsylvanian (Gzhelian, *simulator* Zone) conodonts from the Belovača section of the Jadar Block (Vardar Zone, NW Serbia).

Figs. 1, 2: *Streptognathodus pawhuskaensis* (HARRIS & HOLLINGSWORTH, 1933). 1. 10/MS 2065, 2. 4/MS 2070.

Figs. 3-11: *Idiognathodus luganicus* (KOZITSKAYA, 1978). 3. 11/MS 2065, 4. 12/MS 2065 (scale bar of 50 μ m for this Fig. is on its right side), 5. 13/MS 2065. 6. 14/MS 2065. 7. 15/MS 2065, 8. 16/MS 2065, 9. 4/MS 2066, 10. 5/MS 2070, 11. 6/MS 2070.

Fig. 12: *Streptognathodus firmus* KOZITSKAYA, 1978. 7/MS 2070.

Fig. 13: *Idiognathodus* sp. B. 17/MS 2065.

Fig. 14: *Idiognathodus* sp. C. 18/MS 2065.

Fig. 15: *Streptognathodus* cf. *gracilis* Stauffer & Plummer, 1932. 19/MS 2065.

Scale bar of 100 μ m, between Figs. 11 and 12, refers to other Figs. All Figs. are upper views.

