Correlation of Early Devonian (Lochkovian–early Pragian) conodont faunas of the South Urals (Russia)

TATYANA MAVRINSKAYA & LADISLAV SLAVÍK

Carbonate successions of the early Lower Devonian (Lochkovian–early Pragian) from the Mindigulovo section (West Zilair Zone, western slope of the South Urals) can be globally correlated using diverse conodont faunas. The number of documented widespread or cosmopolitan taxa of the Lochkovian and early Pragian age enables the definition of globally recognized conodont successions and the establishment of a refined regional conodont biozonal scale. The present three-fold global subdivision of the Lochkovian Stage can be applied as well to the studied area. The Lochkovian in the South Urals is represented by two Horizons (regional terminology) with different facies development: 1. The Siyak Horizon of the lower Lochkovian characterized by the dominance of shallow-water organogenic limestones of the hesperius-optima and optima-onoalpha Zones, and 2. The Sherlubai Horizon of the middle and upper Lochkovian age characterized by the dominance of carbonate-terrigenous successions. The middle and upper Lochkovian is subdivided into five biozones (using a binominal system): onoalpha-eeolaeanae, eeeolaeanae-eeleanorae, eleanorae-eeletrigonics, trigonicus-pandora beta and pandora beta-sulcatus etul/steinachensis. The Lochkovian-Pragian boundary and the early Pragian time are determined by the presence of eognathodontid and icriodontid stocks. The established regional conodont zonal scale in the South Urals provides a solid basis for refined correlation with the Lochkovian–early Pragian carbonate rocks of peri-Gondwana and Euramerica. • Key words: South Urals, West Zilair Zone, Lower Devonian, global conodont correlation, Lochkovian.


Tatyana Mavrinskaya, Institute of Geology, Ufa Scientific Centre, Russian Academy of Sciences, Karl Marx Str., 16/2, Ufa 450077, Russia; tspal@ufaras.ru • Ladislav Slavík (corresponding author), Institute of Geology AS CR, v.v.i., Rozvojova 269, CZ-165 00 Praha 6, Czech Republic; slavik@gli.cas.cz

Carbonate successions of Lochkovian age have a high potential with respect to global correlation based on conodont faunas. Regional Lochkovian conodont zonations have been established in many regions in the past decades (e.g., Nevada and Pyrenees, Valenzuela-Ríos & Murphy 1997; Sardinia and Carnic Alps, Corradini & Corriga 2012, Suttner 2007; Prague Synform, Slavík et al. 2012). The degree of provincialism during the Lochkovian time was rather low, and the evolution of cosmopolitan lineages enabled a good correlation, even across very distant areas. In spite of the favorable conditions for global correlation, conodont biostratigraphic data from many regions were only fragmentary or lacking for a long time. This paper presents for the first time data from conodont investigation of the interval from the latest Silurian to the early Pragian from the newly described section on the western slope of the South Urals. The stratigraphical framework of the Middle and the Upper Devonian deposits in the South Urals has been already developed. The functional subregional stratigraphic scheme of Devonian, and Lower Devonian especially, is based mostly on brachiopod and coral biostratigraphy (Antsigin et al. 1993, Tyazheva & Zhavoronkova 1972, Tyazheva et al. 1976). Until now a conodont zonation was established for the Upper Devonian and partly for the Middle Devonian (Abramova 1999, Baryshev & Abramova 1996, Yakupov et al. 2002, Abramova & Artyushkova 2004a, b, Artyushkova & Maslov 2008, Maslov & Artyushkova 2010). For a long time, the Lower Devonian conodont biostratigraphy in the South Urals remained undeveloped, as only scattered data have been published (Khalymbadzha et al. 1985, Maslov et al. 1983, Artyushkova 2009, Maslov & Artyushkova 2010). Accordingly, also the regional conodont zonal scale for the Lochkovian and Pragian was not established and the correlation with former “global” (i.e. Cordilleran-based conodont zonation, now obsolete) was performed only indirectly. The main purpose of this paper is to provide a correlation of the freshly presented conodont data from the Lower Devonian
(mostly Lochkovian) of the southern Urals and to test whether the stratigraphic successions of the documented cosmopolitan taxa match with those in other important regions of the Lower Devonian (i.e. regions of peri-Gondwana and Euramerica). The prospective applicability of conodont zones widely used in many regions to the area of the South Urals should be the basis for global correlation of the Lower Devonian strata in that part of the World.

A conodont-based subdivision of the Lochkovian Stage was first presented by Klapper (1977) and Klapper & Johnson (1980) on the basis of faunas of the North American Cordillera (see Fig. 2). This first four-fold zonation including the hesperius, eurekaensis, delta and pesavis Zones is, however, not globally applicable, as it has limitations that were pointed out by Valenzuela-Ríos (1994a) and Valenzuela-Ríos & Murphy (1997). This applies mostly to the limited regional distribution of the index taxa and poorly defined pesavis Zone whose index taxon remains actually unknown. The alternative zonal scheme proposed by Valenzuela-Ríos & Murphy (1997) that was later modified (Murphy & Valenzuela-Ríos 1999) concerns the middle and the upper part of the Lochkovian (cf. Fig. 2). In particular, the middle Lochkovian is well elaborated, being based on the successive appearances of taxa within the Lanea and Ancyrodelloides stocks. Therein, the newly established lineage of Lanea has a great importance for detailed subdivision. Slavík (2011) modified the concepts of the Lanea and Ancyrodelloides lineages by the integration of the taxon carlsi in the genus Lanea and supported its stratigraphic potential as a marker for the middle Lochkovian because the former taxon Lanea omoalpha has much earlier entry and its morphology is not easily distinguishable. Recently, the parts of the middle and upper Lochkovian zonation by Valenzuela-Ríos & Murphy (1997) have been applied with some modifications in Sar dinia and Carnic Alps (Corradini & Corriga 2012) and in the Prague Synform (Slavík et al. 2012, see Fig. 2).

The conodont investigation was focussed on the Lower Devonian sections located on the banks of the Irgizly, Siyak and Belaya Rivers (see Fig. 1). Studies were carried out on the known limestone exposures with samples taken from each lithological variety. Sampling for conodonts was done both from the bottom and roof of the beds. Homogenous, usually massive organogenic limestones were sampled at 1–3 m intervals. The weight of the rock samples reached 1 to 2 kg on the average. The total number of...
samples taken from the sections was 60 (including 10 samples from Irzigly and Siyak sections). Approximate number of obtained conodont elements was about 1100. The samples were processed using standard techniques with formic acid. The volume of insoluble residue was small and thus not subjected to separation in heavy liquids. The number of conodonts per sample varied from 10 to 15 specimens per 1 kg of rock (in massive organogenic limestones) and up to 80–150 specimens per 1 kg of rock (from packstones and micritic limestones). Preservation of conodont elements differed, but in general it was good or satisfactory. Some deformed conodont elements were found in layers owing to effect of tectonics.

The Lower Devonian of the South Urals

Recently, the overall characteristic of the Lower Devonian of the South Urals provided Artyushkova & Maslov (2008). Detailed investigations of the Lower Devonian strata in the western slope were carried out by Krauze & Maslov (1961). Later on, their biostratigraphical subdivision has been done based on monographic research of brachiopods and corals performed by Tyazheva et al. (1976). The development of the Early Devonian strata reflects the character of the main facies zones from the Late Silurian. The Lochkovian is underlain by the Ust-Irgizly beds of the Přídolí age. The transition from the underlying Přídolí is gradual and the Silurian-D Devonian boundary can be distinguished by the appearance of the typical Devonian brachiopods (genera Neomphyma and Ivelinia) and corals (genera Riphaeolites, Pachyfavosites and Acanthophyllum). The Lochkovian is subdivided into two regional Horizons (i.e. regional terminology followed herein). The Siyak Horizon characterizes the lower part of the Lochkovian with Cladopora actuosa, Neomphyma originata and Lanceomyonia borealiformis regional biozones (cf. Antsygin et al. 1993). It is represented by gray-beded limestones with interbeds of silstones. The conodonts previously reported from the Siyak Horizon are very poor, represented by early Devonian taxon Icriodus woschmidti Ziegler (Maslov et al. 1985). The thickness of the lower Lochkovian Siyak Horizon varies from 45 to 70 m. The upper part of the Lochkovian succession is represented by the Sherlubai Horizon, which is correlated by Favosites intricatus, Pseudoplexus subbrevis and Karpinskaia vagnensis regional biozones (cf. Antsygin et al. 1993; see Fig. 3). The late Lochkovian–early Pragian time is characterized by formation of reef complexes with up to 1000 m thickness of clear carbonate succession (Maslov et al. 1985, Artyushkova & Maslov 2008). The Lochkovian strata are overlain by shallow-water carbonates of the early Pragian Kulamat Horizon. The transition between Lochkovian and Pragian strata is also gradual. The Early Emsian time characterizes rapid change in sedimentation patterns with increased facies diversification both in near-shore and off-shore environments and complete transformation of faunal assemblages (for more information on the Emsian see Artyushkova & Maslov 2008).

As for the western slope of the South Urals, the most representative and uninterrupted successions of Lochkovian and Pragian carbonate rocks are located within the West Zilair structural Zone (see Fig. 1). These correspond to near-shore facies. This paper is focused on the Lochkovian strata because these enabled a detailed study due to relatively abundant and highly diversified conodont faunas.

The Lochkovian of the West Zilair Zone and conodont distribution

There are two main lithotypes in the Lochkovian deposits developed in the West Zilair Zone: The carbonate-dominated lithotype characterized by grey organogenic limestones with abundance of benthic faunas (mostly brachiopods and corals); it prevails in the south-western part of the Zone. The carbonate-terrigenous lithotype is represented by thin-layered mixed carbonate-terrigenous rocks containing abundant nektonic and planktonic faunal elements: conodonts, fish remains (thelodonts) and dacyroconarid tenaculites. The outcrops representing this lithotype can be found on the banks of the Belaya River (see Fig. 1C); these have been the subjects of the study presented in this paper.

For the conodont zonation is used herein the binomial system in the sense of Murphy (1977). This nomenclatorial system was originally used in the conodont zonation of the middle and upper Lochkovian by Valenzuela-Rios & Murphy (1997); please note it is not an ancestor-descendant sequence (see Figs 2 and 3).

The carbonate-dominated lithotype

The sections of this rock-type have been studied in detail along the Irgizly River and its tributaries. They are considered to be the type sections for the established regional horizons. Their basic biostratigraphical characteristics are adopted from Tyazheva et al. (1976) and Antsygin et al. (1993).

The Ust-Irgizly beds occur stratigraphically below the Siyak deposits of the Lochkovian age and correspond to the Přídolí (upper Silurian). They are represented by grey layered and selectively dolomitized organogenic limestones with scarce intercalations of silstones. The Přídolí strata are characterized by corals Entelophyllum losseiiformis (Zheltonogova), Microplasma gotlandica Dybowskii, Riphaeolites priscus Yanet and brachiopods: Uralotoechia kuschvensis (Tschernyschew), Tectatrypa

Tatyana Mavrinška & Ladislav Slavík • Correlation of Early Devonian conodont faunas of the South Urals

285
tectiformis (Tschernyschew), Atrypoidea (Atrypoidea) camelina (Buch), Atrypoidea (Lingatrypa) linguata (Buch), Lissatrypinella kuschvensis (Tschernyschew). The thickness of the horizon ranges from 20 to 40 m.

As in other parts of the South Urals, the Siyak Horizon is not characterized by a prominent change in lithology from the underlying Ust-Irgizly beds. The boundary between the two units is precisely determined by an abrupt change in the brachiopod and coral assemblages. In the Siyak Horizon, the typical coral species include Cladopora actuosa Yanet, Favosites clarus Yanet, Neomphyma originalata (Soshkina), Pachyfavosites kozlowskii (Sokolov) and Riphaeolites ramosus Yanet. The most important among brachiopods are Gipidula pelagica (Barrande), Lanceomyonia borealiformis (Siemiradzki), Protathyris praecursor Kozlowski, F. celsus Tjazheva and others. The thickness of the Siyak deposits ranges here from 55 to 70 m.

The Sherlubai Horizon includes grey and light-grey thick-layered, indistinctly bedded to massive limestones with diversified coral, brachiopod, bivalve and crinoid faunas. The macrofaunal assemblages that characterize the deposits are rich in taxa that are characteristic only for the Sherlubai Horizon. Among these are typical corals Favosites admirabilis Dubatolov, Favosites shiriktensis Chekhovich, Favosites intricatus Barrande, Pseudoplexus subbrevis Shurygina and Pseudoplexus quadriparti tus Soshkina. Brachiopod fauna is characterized by a significant renovation: Atrypinella losvensis Khodalevich, Karpiniska vagranensis Khodalevich appear and blossom out together with Atripopsis thetis (Barrande), Clorindina vijaica Khodalevich, Protathyris praecursor Kozlowski, P. celsus Tjazheva and others. The thickness of the Sherlubai Horizon in the West Zilair Zone ranges from 60 to 73 m.

The shallow-water clear carbonate facies that occur along the Irgiz River contain only scarce conodonts of the Přídolí and the Lochkovian age. They are represented mostly by elements of long-ranging taxa, e.g., Delotaxis Klapper & Philip (= Oulodus), Ozarkodina typica Branson & Mehl, Wurmiella excavata (Branson & Mehl) and W. wurmi (Bischoff & Sannemann). This faunal association does not allow a biozonal subdivision due to lack of diagnostically distinctive taxa.

The carbonate-terrigenous lithotype

The deposits of this type are developed on the banks of the Belaya River in the south-western part of the West Zilair
Zone. The sections are composed by medium to thin-layered fine-grained marlstones with interbeds and lenses of bioclastic limestones and siltstones. The best exposed Lochkovian rocks including lower and upper boundary strata of the Lochkovian have been studied in the vicinities of the village of Mindigulovo. The Paleozoic rocks are exposed in several cliff outcrops with Ordovician, Silurian and Lower Devonian rock units along the Belaya River. Three described outcrops form a composite section that provides almost complete succession of the Lochkovian including the upper Silurian and lower Pragian boundary intervals.

Outcrop 1 is located on the right bank of the Belaya River, 0.7 km upstream from the village of Mindigulovo (see Figs 1 and 4). It uncovers boundary strata of the upper Přídolí (Ust-Irgizly beds) and lower Lochkovian (Siyak Horizon). Three described outcrops form a composite section that provides almost complete succession of the Lochkovian including the upper Silurian and lower Pragian boundary intervals.

Outcrop 2 is located 2 km upstream from the Outcrop 1 and includes the strata of the Sherlubai Horizon (middle and upper Lochkovian) with abundance of stratigraphically significant conodonts (cf. Fig. 4). The basal

### Table

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>SUBDIVISION</th>
<th>Former standard conodont zonation (compiled)</th>
<th>Recent conodont zonation (Prague Synform)</th>
<th>South Urals, Western Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEVONIAN</td>
<td>Lower</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lochkovian</td>
<td>sulcat us</td>
<td>steinach. beta-brunsvicensis</td>
<td>Kulamat</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>gilberti-steinach. beta pandora beta-gilberti</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>lower</td>
<td>eurekaensis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SILLURIAN</td>
<td>Upper</td>
<td>eosteinhornensis</td>
<td>eosteinhornensis s.s.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>detorta</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>eosteinhornensis s.l.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Figure 3.** Stratigraphic scheme of the Lochkovian Stage with the lower and upper boundary intervals of the Western Slope of the South Urals matched with former and recent concepts of conodont zonation. Note the difference in conodont subdivision between the Prague Synform and the South Urals. The proposed regional conodont subdivision respects the absence of some stratigraphically significant taxa known from peri-Gondwana.

---

Scarce conodonts of mostly incomplete preservation represented by *W. eosteinhornensis* (Walliser) *sensu lato* were found 0.3 m above the base. The "*sensu lato*" designation is used in order to differentiate from the "ornamented" taxon *W. eosteinhornensis* according to emended diagnosis by Murphy *et al.* (2004). The overlying interval (14 m approximately) is characterized only by elements of *Wurmiella* (Murphy *et al.*) and *Panderodus* Ethington. Tentative age of the interval is the *eosteinhornensis* s.l. Zone. At the upper part of Outcrop 1, close to the top, enters a clear Devonian conodont indicator – *Icriodus cf. hesperius* (Klapper & Murphy). The specimen figured (Fig. 6T) is small and the main posterior process is long as in *I. hesperius*. The development of the posterior area is, however, not decisive for clear taxonomic classification due to immature stage of ontogeny. The typical early Lochkovian taxon *Zieglerodina remscheidensis* (Ziegler) co-enters with the early *Icriodus* mentioned above. The global origin of the genus *Icriodus* is at the base of the Devonian and *I. hesperius* represents one of the oldest icriodontids (*cf.* Carls *et al.* 2007). The age of the upper part of the Outcrop 1 can be correlated, e.g., with the *hesperius-optima* Zone of the Prague Synform (Slavik *et al.* 2012) and *C. hesperius* Zone of Podolia (Drygant & Szaniawski 2012). Outcrop 2 is located 2 km upstream from the Outcrop 1 and includes the strata of the Sherlubai Horizon (middle and upper Lochkovian) with abundance of stratigraphically significant conodonts (*cf.* Fig. 4).
interval (2 m thick) is characterized by dark grey medium to thin-layered marlstones inter-bedded with clayey shales. The thickness of these siltstone beds varies from 1 to 10–20 cm. Intercalated limestone beds contain abundant tentaculites, fish remains and conodonts. The conodont association includes *Z. remscheidensis* remscheidensis (Ziegler), *Z. r. repetitor* (Carls & Gandl), *Lanea omoalpha* Murphy & Valenzuela-Ríos and *Pandorinellina optima* optima (Moskalenko). The age of the interval is *omo-alpha-eoeleanorae* Zone that represents a transition between

**Figure 4.** Detailed distribution of the most relevant conodont taxa from the latest Silurian to the early Pragian in outcrops of the composite Mindigulovo section. Applied conodont zones on the left are those from the recent zonal schemes used in peri-Gondwana that can be directly or indirectly delimited in the Lower Devonian of the South Urals. The right column shows a percentage ratio of all determined conodont genera. Abbreviations: *Ancyrodell.* – *Ancyrodelloides*, *Masar.* – *Masaraella*, *Oz.* – *Ozarkodina*, *Pelekys.* – *Pelekysgnathus.*

the lower and the middle Lochkovian (cf. Valenzuela-Ríos & Murphy 1997, Slavík 2011). The above-mentioned taxa are mostly widespread. They are common not only in peri-Gondwana and Euramerica (Laurussia): a regional conodont zonal scale based on the spathognathodontids including Zieglerodina remscheidensis and species of Pandorinella has been established also in the South Tien-Shan (Bardashev & Ziegler 1992), or alternatively also in Podolia (Drygant & Szaniawski 2012).

Overlying 6 m thick interval forms alternation of yellowish-grey and grey micritic and nodular limestones. The uppermost part is formed by grey thin-layered calcilutites and calcisiltites with lenses of bioclastic limestones. The interval contains fish remains, algal fragments and rich and diverse conodont faunas: e.g., L. omoalpaha, L. eoelleanorae, Murphy & Valenzuela-Ríos, L. eleonorae (Lane & Ormiston), P. o. optima, Z. r. repetitor (Carls & Gandl), Flagella schulzei (Bardashev), F. stygia (Flajs), Kimognathus sp., Anycrodelloides cruzae Valenzuela-Ríos, A. transits (Bischoff & Sannemann) and transitional “slender” spathognathodontid morphologies – e.g., Masaraella aff. pandora (Murphy et al.). Especially, the presence of cosmopolitan phylogenetic lineage of Lanea and the entries of Flagella and Anycrodelloides indicate clearly the middle Lochkovian age with corresponding regional biozones (eoelleanorae-eleonorae and eleonorae-trigonics).

Approximately 8 m thick interval of interbedded clayey dark-grey marlstones, organodetrital limestones and calcisiltites follows. In this interval the conodont fauna contains stratigraphically important late middle Lochkovian marker – Anycrodelloides trigonicus (Bischoff & Sannemann) with entries of some associated specimens which are morphologically very close to cosmopolitan taxa: Lanea cf. telleri and Amydrotaxis aff. johnsoni (see Figs 4 and 5E, N–P). The sample M-36 in the middle part of the interval is exceptional as regards the faunal content. The age of this interval is not certain and is tentatively correlated with pandora beta–sulcatus eta/steinaechensis Zone. Outcrop 3 represents a transition from the Lochkovian Sherlubai Horizon and the Pragian Kulamat Horizon. It starts with 0.5 m thick interval of grey bituminous limestones. The basal bed contains only few but stratigraphically important conodonts including the transitional form Masaraella pandora (Murphy et al.) → Eogagnostodus sulcatus (Philip) (see Figs 4 and 6P, Q); it is in association with the last recorded M. pandora and with the entry of taxon morphologically close to Pandorinella miae (Bultynck). The latter is treated herein in open nomenclature because the P. miae displays very common spathognathodontid morphology, and, thus possible morphological convergence cannot be excluded. P. miae dominated in the Pragian and early Emsian in many paleogeographic areas (e.g., Bultynck 1971, Klapper & Johnson 1980, Slavík 2004); the entry of this morphology, together with appearance of transitional egognathodontid forms indicate proximity of the lower Pragian boundary. Following 1.0 m thick interval of grey

---

sample M12-279.  • M, N – Masaraella pandora morphotype alpha (Murphy et al., 1981); M – upper view, N – lateral view of Pa-element, sample M-34.  
organogenic limestones is overlain by dark-grey siltstones (1.35 m). The upper bedding surfaces resemble “hardgrounds” with remains of clay and bioclastic material (shell and crinoid fragments). The sample at the top of this bed (M-40a) contains characteristic early Pragian conodonts including egnathodontid faunas that are globally diagnostic for the lower Pragian boundary [i.e., Eognathodus sulcatus eta morphotype Murphy et al., 1981 = Eognathodus sulcatus eosulcatus (Murphy, 1989) and Eognatodus cf. irregularis Murphy, 2005]. The taxonomy and phylogenetic interpretation of the early Pragian egnathodontids is very complicated (cf. reconstructions and discussions in Murphy et al. 1981, Murphy 1989, Slavík & Hladil 2004, Murphy 2005 and Slavík et al. 2007). Irrespective of this, the biostratigraphic boundary of the Lochkovian/Pragian is placed to the level of the sample M-40a with content of the zonally diagnostic taxa. The lithostratigraphic boundary between Sherlubai and Kulamat is directly above and is marked by the onset of thick layered dolomitized limestones with relics of bioclasts. At the base of dolomitized limestones is a thin layer of black folded shale (0.05–0.5 m). The lower part of the Kulamat Horizon (here it is 15 m thick) contains only few I-elements of the typical Lochkovian/Pragian boundary taxon Latericriodus steinachensis (Al-Rawi) eta morphotype Klapper & Johnson, 1980 and a few elements of Wurmiella and Pandorinellina cf. miae.

Correlation of the conodont faunas of the South Urals

The number of conodont elements obtained from the section of Mindigulovo and the diversity of conodont faunas vary significantly at different stratigraphic levels. They largely depend on local facies development as well as on global diversity and abundance of Lower Devonian conodonts influenced by the degree of provincialism and global eustacy. In general, the highest diversity and abundance were found in thin-bedded fine-grained marlstones and condensed carbonate beds from pelagic environments. These are typical for the middle Lochkovian, containing off-shore conodont genera, such as Lanea, Ancyrodelloides and Kimognathus. As is the case elsewhere, conodont assemblages in the Devonian shallow-water clear organogenic (ref-efal) limestones are poor. In the Lower Devonian, shallow environments are characterized by a slightly elevated abundance and higher diversity of icriodontid faunas, which are very sensitive to fluctuations in water depth. Therefore, the inter-regional conodont correlation of Lower Devonian shallow-water environments is mostly based on icriodontids – genera Icriodus, Pelekysgnathus or Pedavis (cf. Slavík et al. 2007, Drygant & Sza- niawski 2012).

Shallow-water crinoidal debris of Ust-Irgizly and Siyak deposits are expectedly poor as regards conodont elements. The average number of specimens does not exceed 10–15 elements per 1 kg of rock. The correlation of the upper Přídolí is complicated due to only one stratigraphically important conodont (W. eosteinhornensis s.l.). The eosteinhornensis sensu lato Zone, however, covers almost the entire Přídolí Series (see discussion in Carls et al. 2007). The development of the conodont zonation of the Přídolí has been summarized in Corradini & Corriga (2012) and, in spite of some progress in the past years it still urgently needs a refinement.

The presence of early icriodontids indicates the proximity of the base of the Devonian. The specimen obtained from the Mindigulovo section (Fig. 6T) is very close to I. hesperius. Although the specimen is treated in open nomenclature, it can be correlated with the global hesperius Zone, originally established in Nevada by Klapper & Murphy (1974). The zone is also present in Sardinia and Carnic Alps (Corradini & Corriga 2012). The oldest Lochkovian zonal equivalent in the Prague Synform (Bar- randian area) is the “hesperius-optima Zone” (Slavík et al. 2012). The associated Z. r. remscheidensis is typically an early Lochkovian taxon (cf. Murphy et al. 2004, Carls et al. 2007) and provides a good correlation with peri-Gondwanan regions. The missing interval between Outcrops 1 and 2 is probably stratigraphically very short and is tentatively assigned to the optima-omoalpha Zone. Both nominal taxa are present above (in the Sherlubai Horizon): the succession of entries of the nominal taxa of the zone has been described, e.g., in the Prague Synform (Slavík et al. 2012).

The most important is the succession of the middle Lochkovian conodonts found in the South Urals. The base of the middle Lochkovian cannot be traced precisely because of the discontinuity between Outcrops 1 and 2. The middle Lochkovian marker – Lanea carlsi (Boersma) has not been found in the Mindigulovo section yet. According to the correlation with peri-Gondwanan regions, the base of the middle Lochkovian can be expected between the entries of Lanea omoalpha and L. eoeleanorae, because Lanea omoalpha can be, however, somewhat below the base of Outcrop 2. Accordingly, the base of the omoalpha-eleanorae Zone is herein delimited by the recorded entry of L. omoalpha but it may enter earlier – i.e., within the missing interval. The conodont association, however, indicates that the base of the middle Lochkovian should be very close to the base of Outcrop 2.

This is followed by the characteristic and globally dispersed middle Lochkovian conodont succession. The Lanea lineage including the taxa eoeleanorae and ele- norae together with associated cosmopolitan genera of middle Lochkovian origin (Flajssella, Kimognathus and
**Amydrotaxis** allow an excellent global correlation. The late middle Lochkovian (in the sense of Valenzuela-Ríos & Murphy 1997) is confirmed by occurrence of the late forms of the cosmopolitan genus *Ancyrodelloides* here. The *Ancyrodelloides* lineage completely disappears soon after the radiation toward the end of the middle Lochkovian. This radiation gave rise to several morphologies worldwide and took place in the short stratigraphic interval corresponding to the range of the short-lived taxon *A. kutcheri* (Bischoff & Sannemann, 1958).

In the studied section, the middle Lochkovian interval allows a very fine subdivision that can be correlated in detail in a global scale. Four small-scale chronostratigraphic units (*omalpha-eoleanorae, eoleanorae-eleanorae, eleanorae-trigonicus* and *trigonicus-pandora* beta) are characterized by the presence of widely distributed (actually cosmopolitan) taxa.

Although, the upper Lochkovian is documented here by the presence of the global biozonal marker *M. pandora* beta, the position of the upper Lochkovian boundary is only tentative due to tectonic disruption and resulting mixing of conodont elements. The assumed thickness of the upper Lochkovian interval is small (only few meters), much like in many other regions of the world. The end Lochkovian time is characterized by a sea-level drop that culminated around the Lochkovian-Pragian boundary. The sea-level change is pronounced in areas around peri-Gondwana. In the Prague Synform, the earliest Pragian time was interpreted as a "hot lowstand" (Hladil et al. 2008, Koptíková et al. 2010), with a very low accumulation rate (Slavík et al. 2012). The trend of a gradual increase in energy and shallowing at the base of the Pragian is known as the Basal Pragian Event (Chlupáč & Kukal 1986, 1988; House 2002) (also = the Lochkovian/Pragian Boundary Event, Walliser 1996). The general shallowing is accompanied by the subsequent occurrence of icriodontid taxa that tend to occur towards the late Lochkovian. In the Mindigulovo section, this trend starts with the single occurrence of *Pedavis*, followed by *Pelekysgnathus serratus* cf. *guadarramensis* Valenzuela-Ríos and *Icriodus* cf. *angustoides alcolae* Carls in the upper Lochkovian. The icriodontid lineage is then represented by the *Icriodus steinachensis* stock in the earliest Pragian, which serves as the alternative basal Pragian marker in shallow-water environments. *I. steinachensis* eta morphotype is older then beta morphotype; the latter is known to enter together with the earliest *E. sulcatus* (eta morph) in peri-Gondwana (Slavík et al. 2007). The ranges of both morphotypes, however, largely overlap. Some of the above listed taxa equally have a wide regional distribution. The upper Lochkovian time in the Mindigulovo section is represented by the *pandora* beta–*sulcatus* eta/*steinachensis* Zone.

As already mentioned above, the upper Lochkovian time (according to the present global subdivision) is globally represented by sedimentary intervals of small thickness due to low accumulation rate in shallow-water environments in carbonate successions. In contrast to other regions (*e.g.*, Pyrenees, Nevada, Carnic Alps and Prague Synform), the late Lochkovian *Pedavis* taxa are lacking in the South Urals. Therefore, the upper Lochkovian cannot be subdivided in more detail yet. Also, the presence of a tectonic disruption is a serious constraint for a refined subdivision in the Mindigulovo section. The concept of the global Lochkovian subdivision, however, needs a revision due to the proportional discrepancies between individual parts of the three-fold subdivision. According to the present global subdivision, the age of the Sherlubai Horizon is middle and upper Lochkovian. The early Pragian age of the Kulamat Horizon presented in Outcrop 3 is confirmed by the presence of parts of both cosmopolitan eognathodontid and *Icriodus steinachensis* stocks.

**Conclusions**

For the first time, the study presents conodont biostratigraphic data from the early part of the Lower Devonian from the western slope of the South Urals. The latest Přídolí to earliest Pragian sedimentary succession of the Mindigulovo section is almost complete with only insignificant interruptions. The section provides information on the ranges of many widely distributed or cosmopolitan taxa. Conodont data allowed a refined zonal subdivision that can be mostly directly correlated with global conodont biozones. The highest diversity of conodont faunas can be seen in deeper-water strata of the middle Lochkovian; it provides the best correlation on the basis of the *Lanea* and *Ancyrodelloides* lineages. The presence of many cosmopolitan taxa and the recorded single occurrences of representatives of widespread lineages (*e.g.*, *Pelekysgnathus* and *Pedavis*) are promising for a future detailed study and prospective refinement of the regional biozonation. The abundance of conodonts in shallow-water reefal carbonate rocks is very low but the correlation of the Lochkovian-Pragian boundary interval is relatively precise. The age of the studied upper Silurian strata (Ust Irgizly beds) is established only tentatively – *eosteinhornensis sensu lato* Zone of the Přidolí. According to the global subdivision of the Lochkovian, the age of the Siyak Horizon is lower Lochkovian, and the Sherlubai Horizon includes the middle and upper Lochkovian.

The character of sedimentation in the early Lower Devonian (Lochkovian–early Pragian) on the western slope of the South Urals corresponds with the general trends of eustatic sea-level fluctuations in other peri-Gondwanan regions (*e.g.*, the Prague Synform). The documented ranges of widespread conodont faunas point to a good paleo-oceanic communication of the Urals region with peri-Gondwana and Euramerica.
**Acknowledgements**

The authors would like to express thanks to Olga V. Artuyushkova and Victor A. Maslov for their critical comments and helpful advices in preparing the paper. The authors would also like to thank Larisa I. Mizens for information on modern brachiopod systematics. The review by Carlo Corradini significantly helped in improvement and correction of the early draft of the manuscript. Daniel Drygant kindly provided valuable review of the final version of the manuscript. The study was supported by the Russian Foundation for Basic Research through Grant No. 11-05-00737-a and by the AS CR, International Cooperation Project No. M100131201. The paper is a contribution to the project UNESCO/IGCP 596.

**References**

ABRAMOVA, A.N. 1999. Frasnian stage at the western slope of the South Urals. 54 pp. Institute of Geology, Ufa Scientific Center, Russian Academy of Sciences, Ufa. [in Russian]


KLAPPER, G. 1969. Lower Devonian conodont sequence, Royal
Creek, Yukon Territory and Devon Island. *Journal of Paleontology* 43, 1–27.


