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TRILOBITE BIOSTRATIGRAPHY OF THE KRÁLŮV DVŮR FORMATION (UPPER KATIAN, PRAGUE BASIN, CZECH REPUBLIC): GLOBAL FAUNAL CHANGES OR FACIES-RELATED DISTRIBUTION?

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Abstract

*Eight trilobite associations and sub-associations have been distinguished in the late Katian Králův Dvůr Formation. Spatial distribution of these associations reflects lithology but their succession was dictated also by global climatic changes and palaeogeographical positioning. Locally developed "Podolí Ore Horizon" trilobite association contains low-diversity but specific forms showing survivals from the underlying Bohdalec Formation combined with the late Katian taxa (*Chlustinia, Duftonia, Onnia, *etc.). The* Amphitryon – Kloucekia *Association is newly established for the lower two thirds of the formation. It is characterized by abundant benthic scavenger-predators accompanied by filter feeders and common pelagic/nektic predators. Within* Amphitryon –Kloucekia *Association can be distinguished four sub-Association 1) the newly established* Onnia ultima *sub-Association is characterized by a dominance of Onnia and Flexicalymene; it is developed at the lowermost levels of the formation, 2) the deeper-water* Nankinolithus granulatus *sub-Association (originally established as horizon), 3) rather shallow-water, brachiopod-dominated* Dedzetina-*Tretaspis sub-Association with rare trilobites and 4) the trilobite-dominated* Tretaspis anderssonni *sub-Association (originally horizon). Last three sub-associations are considered as rather facies-related, with limited stratigraphical applicability only. Impure bioclastic limestone below top of the formation contains a rich shallow- and temperate-water* Marekolithus kosoviensis *Association, which better corresponds with the original horizon concept. This association is dominated by small benthic scavenger-predator trilobites, which are associated by the filter feeder* Marekolithus. *The* Mucronaspis *Association of medium-sized scavenger-predators is characteristic for the uppermost portion of formation and persisted till the early onset of the glaciation at the base of Hirnantian. Minute detritus feeders are rare but present in all the above-discussed associations excluding the last one.*

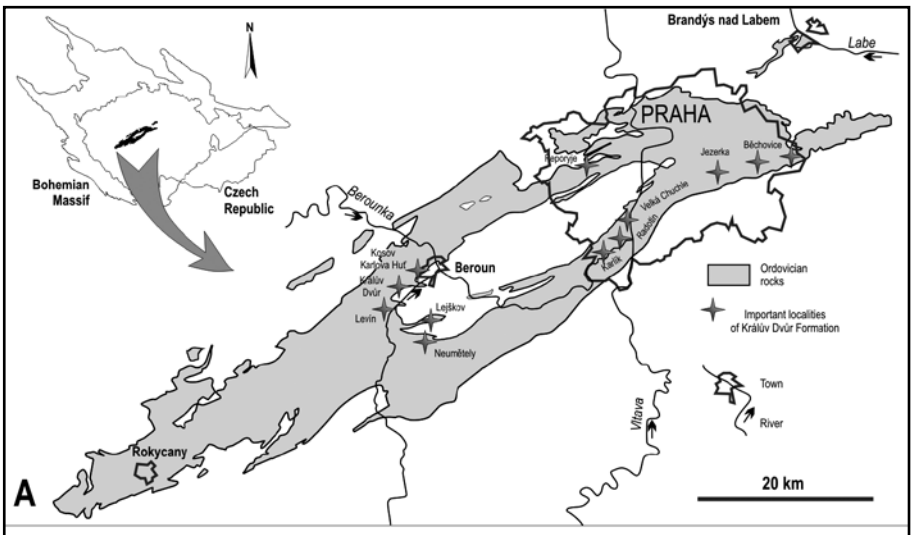
Introduction

Trilobites of the Králův Dvůr Formation (see fig. 1) belong to the most diversified within the Ordovician of the Prague Basin; they have been investigated since first half of the 19th century (see Barrande 1846, 1852, 1872, Hawle – Corda 1847, Novák 1883; for review of the older data see Havlíček – Vaněk 1966, Shaw 2000, Chlupáč 2002). They share many elements with the temperate-water trilobite assemblages of Baltica (see Kielan 1960, Bruton – Owen 1979, Owen 1981), Avalonia (Ingham 1970, Owen – Romano 2010), Kazakhstania (Apollonov 1974) and also with the European peri-Gondwana – nowadays Sardinia and Iberia (e. g. Hammann 1974, Hammann – Leone 1997). The spatial distribution of fauna of the Králův Dvůr Formation was studied by Havlíček – Vaněk (1966), they proposed the first zonation based mostly on trilobites and on brachiopods. This concept has been further developed by Havlíček – Vaněk (1990) and by Havlíček (1998). Shaw (2000) critically discussed their approach but he accepted the horizon concept in general. The upper part of the Králův Dvůr Formation was studied in detail by Štorch – Mergl (1989). The first occurrence of the Hirnantian fauna in the upper part of Králův Dvůr Formation recently discussed Mergl (2011) and the distribution of the agnostid *Arthrorhachis* is analyzed by Budil et al. (in press). Recently, Budil et al. (2009a-c, 2010) provided partially re-defined concept of Havlíček – Vaněk (their communities are considered to represent associations considering them as facies related). However, this revised approach was not properly published.

The association versus assemblage and horizon approach

The concept of trilobite associations of Budil et al. (2007a, b), Mergl et al. (2008) and Fatka – Mergl (2009) is followed here, instead of the traditional horizon and community concept of Havlíček (1998). One of important problems is the autochtonity of fossils. Similarly, the designation "trilobite horizon" as applied in the Králův Dvůr Formation by Havlíček – Vaněk (1966) is considered as inaccurate, especially for lower and middle levels of the unit. The occurrence of key species is rather facies related and/or or locality related (e. g. *Nankinolithus granulatus* occurs only sporadically outside the locality Lejškov). In addition, several tens to hundred meters thick sedimentary successions represent such trilobite horizons. The non-genetic, descriptive designation "Trilobite Association" is appropriate see Turvey – Zhou (2002, 2004).

Study of trilobite associations of the Králův Dvůr Formation is complicated by the absence of thick continuous sections, especially in lower and middle levels of the unit. The situation is comparatively better in upper part of the formation (see Štorch – Mergl 1989). The soft shale and claystones forming major part of the formation are often tectonically affected. This tectonics involves usually



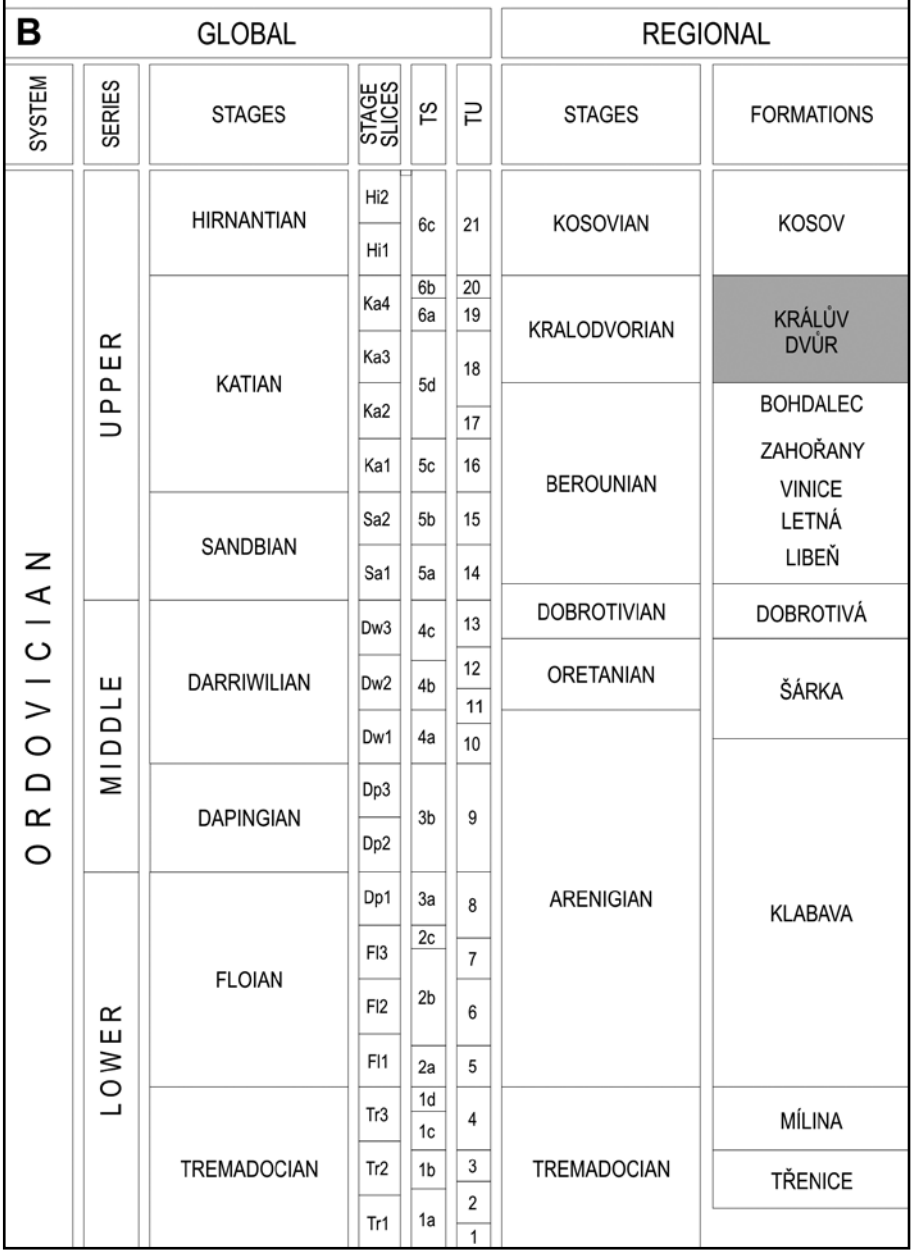


Fig. 1: A – A map of the distribution of the Ordovician rocks in the Barrandian area. The asterisks show the position of the major localities of the Králův Dvůr Formation. Modified after Manda (2008). B – The stratigraphical position of the Králův Dvůr Formation.

intensive folding. In addition, the belts of the Králův Dvůr Formation are commonly represented by tectonically limited blocks. There is also relative lack of exposures because of heavy weathering of the clayey shale (but great help sometimes represent the temporary exposures originated during diverse building activities). These all above-discussed aspects obscure the analysis.

Review of trilobite associations of the Králův Dvůr Formation

More than 60 trilobite species established from the Králův Dvůr Formation are grouped into eight trilobite associations and sub-associations (see tab. 1, fig. 2).

Their spatial distribution reflects rather lithology, especially in lower and middle levels of the formation, while the succession in upper part was directly influenced by the onset of global climatic changes induced by the Boda Event (see Fortey – Cocks 2005), and the subsequent onset of the Hirnantian glaciation in the uppermost portion of the sequence (see also Mergl 2011).

1. The "Podolí Ore Horizon" Trilobite Association (newly defined) locally present at the base of the formation is characterized by very scarce and poorly known trilobite fauna with apparent mixing of species known from the underlying Bohdalec and the Králův Dvůr formations: *Onnia* cf. *ultima*, *Chlustinia mikulasi* (= *keyserlingi fide* Vaněk – Valíček 2001), *Selenopeltis* sp., *Octillaenus*? sp., *Actinopeltis* cf. *gryphus*, *Duftonia juspa konika* (nomen nudum, MS Šnajdr) and *Kloucekia* sp.

2. The *Amphitryon-Kloucekia* Trilobite Associa-

species/(sub)associations	Podolí Ore Horizon	*Onnia ultima*	*Nankinolithus*	*Dedzetina -Tretaspis*	*Tretaspis*	*Marekolithus*	*Mucronaspis*
„Encrinurus“ sp.						R	
Actinopeltis barrandei					R		
Actinopeltis carolialexandri			C		R	R?	
Actinopeltis insocialis						C	
Actinopeltis cf. *gryphus*	R						
Alceste latissima					R	R	
Amphitryon radians		C	C		C		
Areia bohemica			R		R		
Arthrorachis tarda			R	R	R		
Birmanites kielanae			R		R		
Brongniatella platynota			R				
Bumastus sp.						R	
Carmon mutilus			C		R		
Cerampyx gratus			R				
Cyclopyge marginata			R		R		
Decoroproetus solus					R	R	
Degamella gigantea					R	R	
Dindymene fridericiaugusti			R		R	R	
Dionide speciosa			C		C	R	
Dreyfussina ? simaki					R		
Duftonia morrisiana					?	C	?
Duftonia juspa konika (MS)	R						
Dysplanus wahlenbergianus			R		C		
Eoleonaspis cf. *olini (=mirka)*						R	
Eoleonaspis koral					R	R	
Eoleonaspis musca					R		
Eoleonaspis peregrina			R		R	R	
Flexicalymene declinata		C	C		C		
Girvanopyge sp.					R		
Gravicalymene asperula					C	C	
Hadromeros fortis					R		
Harpidella cf. *kielanae*					R		

species/(sub)associations	Podolí Ore Horizon	*Onnia ultima*	*Nankinolithus*	*Dedzetina -Tretaspis*	*Tretaspis*	*Marekolithus*	*Mucronaspis*
Chlustinia keyserlingi	R		R		R		
Illaenus hospes					R		
Kloucekia ruderalis	?	R	C		C	?	
Lonchodomas portlocki			C	R	R		
Marekolithus kosoviensis						C	
Microparia speciosa		C	C		C	C	
Miraspis sp.						R	
Mucronaspis ganabina						C	
Mucronaspis grandis			?		?	C	C
Nankinolithus granulatus			C		?		
Octillaenus hisingeri	?				R	R	
Onnia ultima	?	C	R?		?		
Phillipsinella parabola			R		R	R	
Platylichas milosi					R		
Pseudosphaerexochus pectinifer			R				
Raphiophorus tenellus			C		R	R	
Selenopeltis vultuosa	?		C		R		
Sphaerexochus latens					R		
Staurocephalus cf. *clavifrons*						R	
Stenopareia oblita						C	
Stubblefieldia neglecta					R		
Symphysops armatus			R		?	R	
Telephina fracta			?		R		
Thorslundops? sp.						R	
Tretaspis anderssoni			?	R	C		
Trochurus sp.						R	
Trochurus toernquisti						R	
Xenocybe michle						R	
Zazvorkaspis neutra					R		
Zdicella (=Delgadoa) zeidlerí			C		R		
Zdicella? sola			R			R	

Tab. 1: The occurrence of the trilobites in the Králův Dvůr Formation. Modified after Shaw (2000).

tion (newly defined) is confined to the lower two thirds of the formation (see also fig. 4). It is characterized by the dominance of benthic scavenger-predatory forms associated with filter feeders and common pelagic/nektic predators. The association includes two previously defined trilobite "horizons" (*Tretaspis granulatus* and *Tretaspis seticornis sensu* Havlíček – Vaněk 1966) and one newly defined sub-association.

2.1. The *Onnia ultima* Trilobite sub-Association (newly defined) is known near the base of the formation at the locality Lejškov, Velká Chuchle and several other outcrops. It is poorly diversified, with dominant *Onnia ultima*, *Flexicalymene declinata*, *Amphitryon radians*, *Microparia speciosa* and only rare *Kloucekia ruderalis*.

2.2. The rather deeper-water *Nankinolithus granulatus* Trilobite sub-Association (horizon sensu Havlíček – Vaněk 1966) contains 29 trilobite species ranged to the following genera: *Nankinolithus*, *Onnia*, *Amphitryon*, *Kloucekia*, *Actinopeltis*, *Microparia*, *Flexicalymene*, *Octillaenus*, *Selenopeltis*, *Nobiliasaphus*, *Lonchodomas*, *Phillipsinella* etc. and the agnostoid *Arthrorhachis*.

2.3. Rather shallow-water *Dedzetina-Tretaspis* brachiopod-dominated sub-Association (= compact shales with *Foliomena* and *Dedzetina sensu* Havlíček and Vaněk 1966) locally occurs in middle levels of the formation. Three species of rare, minute trilobites are known from this sub-association: *Lonchodomas portlocki*, *Arthrorhachis tarda*, and *Tretaspis anderssoni*.

2.4. *Tretaspis anderssoni* Trilobite sub-Association (horizon *sensu* Havlíček – Vaněk 1966) is characteristic by highly diversified trilobites (44 species known); it shows proportional presence of the main feeding strategies (see fig. 3). It also shares many species with the older *Nankinolithus granulatus* sub-Association (see tab. 1, fig. 2). However, it is distinguished from the later sub-association by the presence of *Tretaspis anderssoni* as well as by somewhat higher position in the sequence. However, both index species are often mismatched in older collections. Both sub-associations characterized by dominance of benthic scavengers and planktonic or nektonic forms. The typical genera of the *T. anderssoni* sub-association are *Tretaspis*, *Amphitryon*, *Kloucekia*, *Microparia*, *Actionopeltis*, *Flexica-*

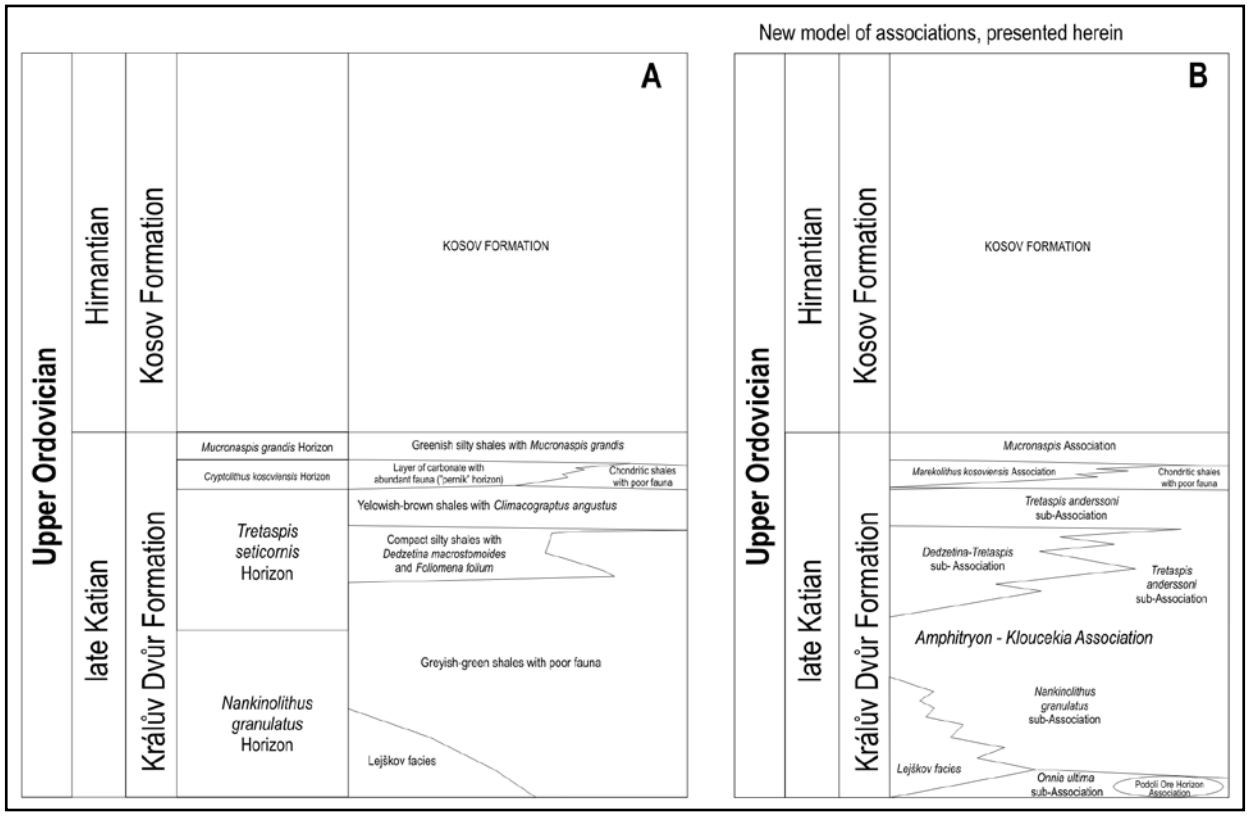


Fig. 2: A – The classical (Havlíček – Vaněk 1966 and Havlíček in Chlupáč et al. 1998) concept of trilobite horizons in the Králův Dvůr Formation. B – A new proposal of trilobite associations (see text).

lymene, *Octillaenus*, *Selenopeltis*, *Nobiliasaphus*, *Lonchodomas*; rare but typical are *Arthrorhachis*, *Phillipsinella* etc.

The richly fossiliferous, dark grey to almost black claystones are traditionally called the "Lejškov facies" of the Králův Dvůr Formation (Havlíček – Vaněk 1966, Havlíček 1998). It was supposed to be restricted to the lower part of the formation. However, the occurrence of index *Nankinolithus granulatus* together with *Normalograptus angustus* and *Dicellograptus* cf. *laticeps* (determination by P. Štorch; see Budil et al. in press) combined with the questionable co-occurrence of *N. granulatus* and *T. anderssonni* (see Vonka – Kolář 2006) approves the comparatively wider stratigraphical range of *N. granulatus*.

3. Diversified fauna of the *Marekolithus kosoviensis* Trilobite Association (horizon *sensu* Havlíček – Vaněk 1966) is confined to calcareous claystone in the uppermost levels of the formation. It contains the index filter feeder *Marekolithus* associated with shallow-water, small benthic scavenger-predators. Thirty trilobite species of the genera *Marekolithus*, *Mucronaspis*, *Duftonia*, *Actinopeltis*, *Stenopareia*, *Flexicalymene*, *Decoroproetus* and *Diacanthaspis* are known. The upper part of these claystone yielded slightly different association with *Staurocephalus* and rare but significant *Eoleonaspis* (= *Bojokoralaspis*). The association is supposed to be allochtonous, representing remains of rather shallow-water origin transported into the deeper part of basin (for different interpretation see Shaw 2000). In our opinion, this interval represents material transported by mudflows produced by the global sea level fall. It could reflect the onset of glaciations. In this association, Mergl (2011) recently described the first elements of the Hirnantian fauna, although this level is traditionally considered as of uppermost Katian in age.

4. The *Mucronaspis* Trilobite Association (horizon *sensu* Havlíček – Vaněk 1966) of medium-sized scavenger-predators is characteristic for the uppermost portion of the formation and persists to the appearance of the first dropstone level at the base of Hirnantian. Only two species of *Mucronaspis* – *M. grandis* and *M. ganabina* occur in the association, and very rare *Duftonia*? sp. The association clearly shows stress conditions and probably reflects a sudden deterioration of environment, when only a few species survived.

Supposed feeding modes of trilobites of the Králův Dvůr Formation

All supposed feeding strategies defined by Fortey – Owens (1999) were recognized within each of the eight trilobite associations and sub-associations (see also Budil et al. 2009 a, c, 2010) in the Králův Dvůr Formation. Their frequencies, however, strongly vary in separate association (see fig. 3). Numerous small benthic scavenger-predatory strategists (acastoids, calymenids, diversified illaenids, cheirurids, rare lichids) accompanied by rare large scavenger/predatory forms (e. g. *Birmanites*), common filter-feeders (*Nankinolithus*, *Cerampyx*, *Lonchodomas*, *Raphiophorus*), minute particle feeders (*Phillipsinella*, very rare *Harpidella*), and common pelagic/nectic? predator-scavengers (*Amphitryon*, cyclopygids, odontopleurids, rare *Telephina*) constitute the deeper-water trilobite-dominated *Nankinolithus granulatus* sub-Association in the gray and green claystones. Minute

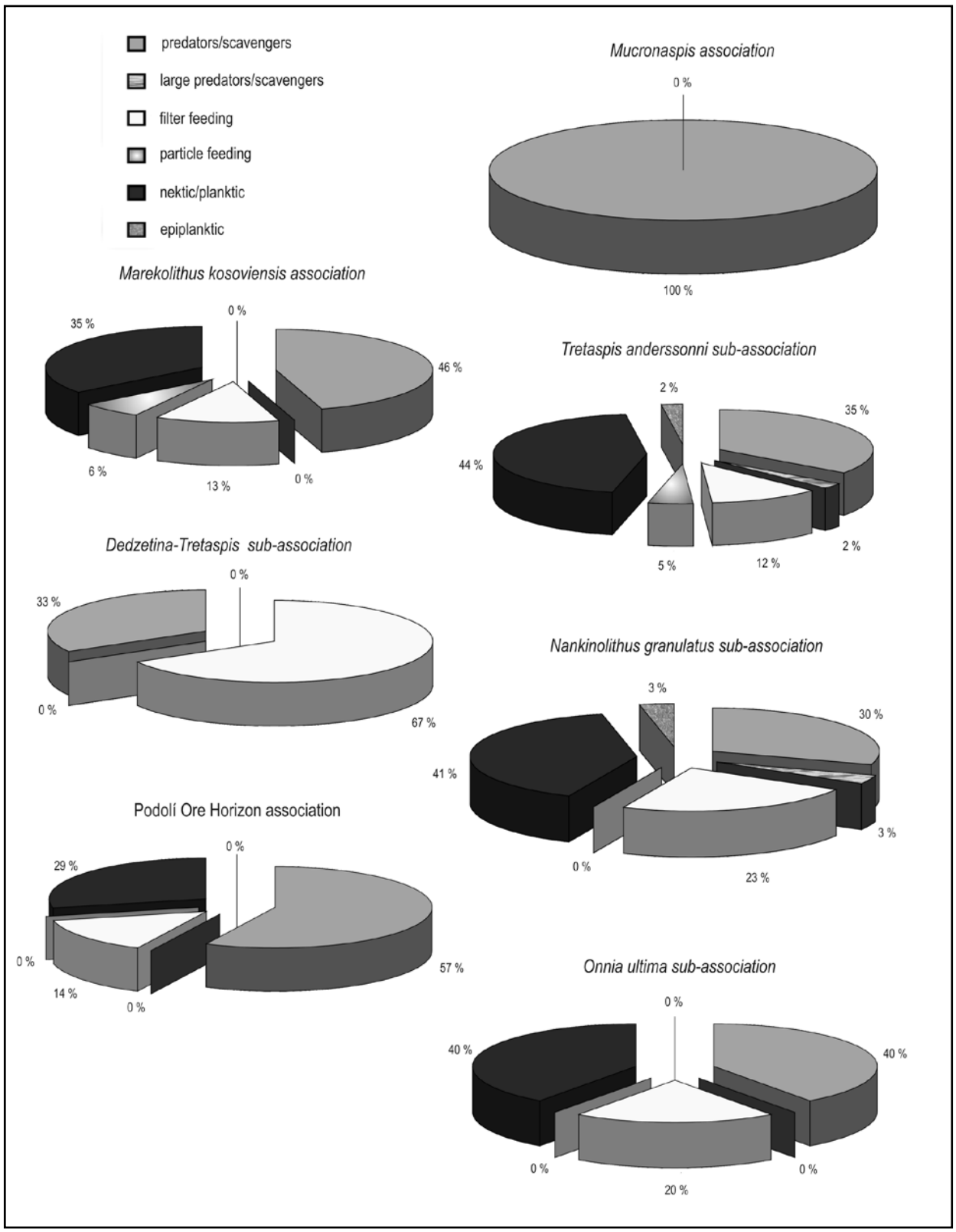


Fig. 3: The comparison of possible feeding modes in different associations of trilobites of the Králův Dvůr Formation.

filter feeders (*Tretaspis*, *Lonchodomas*) and benthic and/or epi-planctic agnostids (*Arthrorhachis*) prevail in the brachiopod-dominated *Dedzetina – Tretaspis* Association. Trilobite-dominated *Tretaspis anderssoni* sub-associations show a comparable composition with the *Nankinolithus granulatus* sub-Association. The *Marekolithus kosoviensis* Association is restricted to the bed of calcareous claystone to impure bioclastic limestones in the upper levels of the formation. Numerous small and medium-sized benthic scavenger-predatory strategists of this association probably used several different life strategies (dalmanitids, acastoids, calymenids, cheirurids, illaenids, very rare lichids and encrinurids). They are accompanied by filter feeders (common *Marekolithus*, very rare *Thorslundops*?)

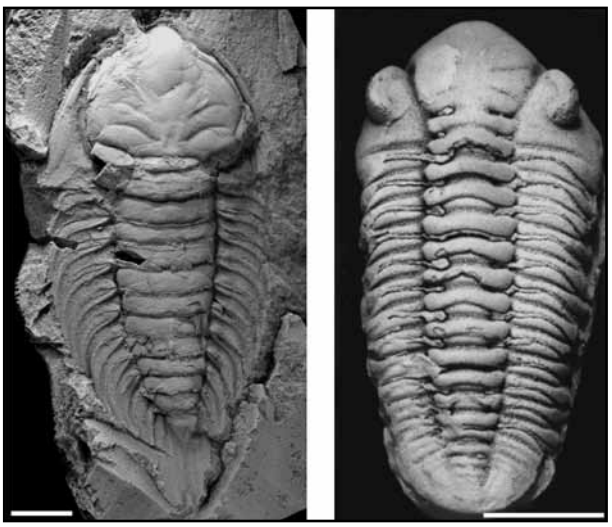


Fig. 4: *Amphitryon radians* (Barrande, 1846) and *Kloucekia* ? *ruderalis* (Hawle and Corda, 1847) (= *K. pachypa* Přibyl and Vaněk, 1980) – two typical elements of the newly defined *Amphitryon-Kloucekia* association confined to the lower and middle parts of the Králův Dvůr Formation. The scale bar represents 5 mm.

and rare, minute particle feeders (*Decoroproetus*). Active nectic/pelagic forms are represented by cyclopygids, rare odontopleurids and possibly also by some cheirurids. Only medium-sized scavenger-predatory strategists survived to the youngest, monotypic *Mucronaspis* Association.

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References

Apollonov, M. K. (1974): Ashgillskie trilobity Kazakhstana. [Ashgillian trilobites of Kazakhstan]. – Akadyemiya Nauk Kazakhskoi SSR, Institut Geologicheskikh Nauk, 1–136. Alma-Ata. (In Russian.)

Barrande, J. (1846): Notice préliminaire sur le Système Silurien et les trilobites de Bohême. Leipzig, 1–97.

Barrande, J. (1852): Système Silurien du centre de la Bohême. Vol. I, 1–935. Prague.

Barrande, J. (1872): Système silurien du centre de la Bohême. Vol. I, Suppl. I, 1–647. Prague.

Bruton, D. L. – Owen, A. W. (1979): Late Caradoc-early Ashgill trilobite distribution in the central Oslo Region, Norway. – Norsk Geologisk Tidsskrift, 59, 213–222. Oslo.

Budil, P. – Kraft, P. – Kraft, J. – Fatka, O. (2007 a): Faunal associations of the Šárka Formation (Middle Ordovician, Darriwilian, Prague Basin, Czech Republic). – Acta Palaeontologica Sinica, 46, Suppl., 64–70. Nanjing.

Budil, P. – Kraft, J. – Kraft, P. – Fatka, O. (2007 b): Arthropod associations of the Sarka Formation (Middle Ordovician, Darriwilian, Prague Basin, Czech Republic). – In: Zlínska, A. (ed.): 8. Paleontologická konferencia. Zborník abstraktov, 25–27. Štátny geologický ústav Dionýza Štůra Bratislava. Bratislava.

Budil, P. – Fatka, O. – Mergl, M. – Kraft, P. (2009a): Trilobite Associations of the Kralův Dvůr Formation (Czech Republic, Prague Basin, Upper Ordovician, Upper Katian). – In: Glen W. Storrs (ed.): 9th North American Paleontological Convention Abstracts, Cincinnati Museum Center Scientific Contributions, 174. Cincinnati Museum Center. Cincinnati.

Budil, P. – Fatka, O. – Mergl, M. (2009b): Feeding Strategies of Trilobites Occurring in the Kraluv Dvur Formation (Upper Ordovician, Prague Basin, Czech Republic). – In: Glenn W. Storrs (ed.): 9th North American Paleontological Convention Abstracts, 321–322. Cincinnati Museum Center. Cincinnati.

Budil, P. – Fatka, O. – Kraft, P. (2009c): Trilobitové asociace královdvorského souvrství (Barrandien, pražská pánev, svrchní ordovik, svrchní katian) a jejich vývoj v čase a prostoru. – In: Kohůt, M. – Šimon, L. (eds.): Spoločný kongres Slovenskej a Českej geologickej spoločnosti, Bratislava. Konferencie, sympózia, semináre 2009, 34–35. Štátny geologický ústav Dionýza Štura, Bratislava.

Budil, P. – David, M. – Fatka, O. – Mergl, M. (2010): Trilobite associations of the Králův Dvůr Formation (Czech Republic, Prague Basin). – In: Aldridge, R.A. (ed.): Programme and Abstracts of the 3rd International Palaeontological Congress, London June 28t – July 3, 106. Palaeontological Society. London.

Budil, P. – Fatka, O. – Kolář, P. – David, M. (in press): *Arthrorhachis* Hawle & Corda, 1847 (Agnostida) in the Prague Basin (Barrandian area, Czech Republic) revisited. – Bulletin of Geosciences. Praha.

Chlupáč, I. (2002): Explanatory remarks to reprinted Joachim Barrande: Système Silurien du centre de la Bohême. Vol. 1. Crustace´s: Trilobites, 1–47. Praha. Trilobit (published by Petr Materna).

Fatka, O. – Mergl, M. (2009): The "microcontinent" Perunica: status and story 15years after conception. – In: Bassett, M. G. (ed.): Early Palaeozoic Peri-Gondwanan Terranes: New Insights from Tectonics and Biogeography. The Geological Society, London, Special Publications, 325, 65–102. London.

Hammann, W. (1974): Phacopina und Cheirurina (Trilobita) aus dem Ordovicium von Spanien. – Senckenbergiana lethaea, 55, 1–5, 1–151. Frankfurt am Main.

Hammann, W. – Leone, F. (1997): Trilobites of the post-Sardic (Upper Ordovician) sequence of southern Sardinia. Part 1. – Beringeria, 20, 1–217. Würzburg.

Havlíček, V. (1998): Ordovician. – In: Chlupáč, I. – Havlíček, V. – Kříž, J. – Kukal, Z. – Štorch, P. (eds): Paleozoic of the Barrandian (Cambrian to Devonian), 149–164. Czech Geological Survey Prague.

Havlíček, V. – Vaněk, J. (1966): The biostratigraphy of the Ordovician of Bohemia. – Sborník geologických věd, Paleontologie, 8, 7–69. Praha.

Havlíček, V. – Vaněk, J. (1990): Ordovician invertebrate communities in black-shale lithofacies (Prague Basin, Czechoslovakia). – Věstník Ústředního ústavu geologického, 65, 4, 223–236. Praha.

Hawle, J. – Corda, A. J. C. (1847): Prodrom einer Monographie der bohmischen Trilobiten. 176 pp. J. G. Calve, Prague.

Fortey, R. A. – Owens, R. (1999): Feeding habits in trilobites. – Palaeontology, 42, 429–465.

Fortey, R. A. – Cocks, R. L. M. (2005): Late Ordovician global warming – The Boda event. –Geology, 33, 405–408.

Ingham, J. K. (1970): The Upper Ordovician trilobites from the Cautley and Dent districts of Westmorland and Yorkshire. 1. – Palaeontographical Society (Monograph), 124, 1–58.

Kielan, Z. (1960): Upper Ordovician trilobites from Poland and some related forms from Bohemia and Scandinavia. – Palaeontologica Polonica, 11, 1–198. Warszawa.

Manda, Š. (2008): *Trocholites* Conrad, 1838 (Nautiloidea, Tarphyceratida) in Middle Ordovician of the Prague Basin and its palaeobiogeographical significance. – Bulletin of Geosciences, 83, 3, 327–334. Praha.

Mergl, M. (2011): Earliest occurrence of the *Hirnantia* Fauna in the Prague Basin (Czech Republic). – Bulletin of Geosciences, 86, 1, 63–70. Praha.

Mergl, M. – Fatka, O. – Budil, P. (2008): Lower and Middle Ordovician trilobite associations of Perunica: From shoreface endemicity to offshore uniformity (Prague Basin, Czech Republic). – In: Rabano, I. – Gozalo, R. – Garcia-Bellindo, D. (eds.): Advances in trilobite research. Cuadernos del Museo Geominero 9, Instituto Geologico y Minero de España, 275–282. Madrid.

Novák, O. P. (1883): Zur Kenntniss der böhmischen Trilobiten. – In: Beiträge zur Palaeontologie Österreich-Ungarns und des Orients, 22–63. Wien.

Owen, A. W. (1981): The Ashgill trilobites of the Oslo Region, Norway. Palaeontographica, Abt. A175, 1–88. Stuttgart.

Owen, A. W. – Romano, M. (2010): Deep shelf trilobite biofacies from the upper Katian (Upper Ordovician) of the Grangegeeth Terrane, eastern Ireland. Geological Journal

Shaw, F. C. (2000): Trilobites of the Králův Dvůr Formation (Ordovician) of the Prague Basin, Czech Republic. – Bulletin of Geosciences, 75, 4, 371–404. Praha.

Štorch, P. – Mergl, M. (1989): Královdvor/Kosov Boundary and the late Ordovician environmental changes in the Prague Basin (Barrandian area, Bohemia). – Sborník geologických věd, Geologie, 44, 117–153. Praha.

Turvey, S. T. – Zhou, Z. (2002): Arenig trilobite associations of Daping, Yichang, Hubei, South China. – Acta Palaeontologica Sinica, 41, 10–18. Nanjing.

Turvey, S. T. – Zhou, Z. (2004) Arenig trilobite associations and faunal changes in southern Shaanxi, China. – Journal of Asian Earth Sciences, 23, 91–103.

Vaněk, J. – Valíček, J. (2001): New index of the genera, subgenera, and species of Barrandian trilobites. Part A-B (Cambrian and Ordovician). – Palaeontologia Bohemiae, 7, 1, 1–49. Praha.

Vonka, V. – Kolář, P. (2006): Sběry v královdvorských břidlicích v Praze – Radotíně (ordovik, Pražská pánev, Česká republika). – Zpravodaj České geologické společnosti, 2, 23. Praha.