



General palaeontology, systematics, evolution (Invertebrate palaeontology)

Deep-water brachiopod assemblage from the Middle Miocene of Kralice nad Oslavou, Moravia, southeastern Czech Republic

Un assemblage de brachiopodes d'eau profonde du Miocène moyen de Kralice nad Oslavou, Moravie, Sud-Est de la République tchèque

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ARTICLE INFO

Article history:

Received 26 November 2012

Accepted after revision 26 January 2013

Available online 11 March 2013

Presented by Philippe Taquet

Keywords:

Brachiopoda
Middle Miocene
Badenian
Central Paratethys
Moravia
Czech Republic

Mots clés :

Brachiopoda
Miocène moyen
Badénien
Paratéthys centrale
Moravie
République tchèque

ABSTRACT

Eight brachiopod species, i.e. *Novocrania* sp., *Cryptopora lovisati* (Dreger, 1911), “*Terebratula*” sp., *Megathiris detruncata* (Gmelin, 1791), *Argyrotheca cuneata* (Risso, 1826), *Joania cordata* (Risso, 1826), *Megerlia truncata* (Linnaeus, 1767), and *Platidia anomiooides* (Scacchi and Philippi, 1844), have been identified in the Middle Miocene deposits of Kralice nad Oslavou, Moravia, Czech Republic. The species *C. lovisati* and *P. anomiooides* dominate the studied assemblage, while others are very rare. *Novocrania*, *C. lovisati* and *M. truncata* are reported for the first time from the Moravian part of the Carpathian Foredeep. In species composition, the assemblage from Kralice resembles other Middle Miocene Paratethyan assemblages, interpreted as shallow water, but the dominance of *C. lovisati* and *P. anomiooides* makes it clearly different, indicating an environment deeper than 100 m.

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R É S U M É

Huit espèces de brachiopodes, *Novocrania* sp., *Cryptopora lovisati* (Dreger, 1911), “*Terebratula*” sp., *Megathiris detruncata* (Gmelin, 1791), *Argyrotheca cuneata* (Risso, 1826), *Joania cordata* (Risso, 1826), *Megerlia truncata* (Linnaeus, 1767) et *Platidia anomiooides* (Scacchi et Philippi, 1844) ont été identifiées dans les dépôts du Miocène moyen à Kralice nad Oslavou, Moravie, République tchèque. Les espèces *C. lovisati* et *P. anomiooides* dominent dans l'assemblage étudié, alors que les autres espèces sont très rares. C'est la première découverte de *Novocrania*, de *C. lovisati* et de *M. truncata* dans la partie morave de l'avant-fosse des Carpathes. En ce qui concerne sa composition taxonomique, l'assemblage de Kralice ressemble aux autres assemblages du Miocène moyen de la Paratéthys, interprétés comme représentant des milieux peu profonds ; toutefois, la domination numérique de *C. lovisati* et de *P. anomiooides* est un trait très différent, indiquant un milieu situé en dessous de l'isobathe 100 m.

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1. Introduction

Although brachiopods are common members of the Middle Miocene communities of the Central Paratethys, surprisingly little is known about Miocene brachiopods from the Czech part of the Central Paratethys. The first, and so far the only, record illustrates and briefly describes brachiopods from the boreholes of Přemyslovice, Moravia (Zágoršek et al., 2012) where four species were recognized, i.e. *Terebratula* sp., *Megathiris detruncata* (Gmelin, 1791), *Argyrotheca cuneata* (Risso, 1826), and *Joania cordata* (Risso, 1826), although brachiopods were quite often mentioned without illustrations and descriptions (e.g. Doláková et al., 2008; Hamršíd, 1984; Zágoršek et al., 2009). The same applies to the studied sections at Kralice nad Oslavou (Fig. 1), where brachiopods were reported in faunal lists by Procházka (1893), Toula (1893) and Hamršíd (1984), but were never described properly or illustrated. Therefore, the aim of this paper is to give taxonomic descriptions of the brachiopods newly collected from these outcrops.

2. Geological setting

The locality Kralice nad Oslavou is situated in one of the erosional relics of marine Neogene deposits located on the crystalline rocks of the southwestern margin of the Bohemian Massif (Hladilová et al., 1999). These relics document the actual extent of the Carpathian Foredeep and post-depositional uplift and erosion (Zágoršek et al., 2009). The surrounding terrestrial Neogene sediments occurring in the area of Kralice nad Oslavou were studied by Brzák et al. (2001) and Nehyba (2003).

Kralice nad Oslavou has long been known as a fossil-rich, Middle Miocene (Lower Badenian) locality (Brzobohatý, 1997, 2001; Hamršíd, 1984; Hladíková and Hamršíd,

1986; Hladilová et al., 1999; Janoschek, 1937; Koutek, 1971; Procházka, 1893; Redinger, 1992; Sváček, 1996; Toula, 1893; Zágoršek and Holcová, 2003), and was recently investigated in detail by Zágoršek et al. (2008, 2009). Three outcrops, situated on the left bank of the Rakovec creek have been distinguished (Fig. 1). The greyish claystone exposed in Kralice-I ($49^{\circ} 11.619' N$, $016^{\circ} 12.493' E$) has not yielded any fossils so far. In the second outcrop, (Kralice-II, $49^{\circ} 11.591' N$, $016^{\circ} 12.516' E$) the Miocene is represented by yellowish sandstone with foraminifers dominant (Zágoršek et al., 2008). The Miocene deposits of the third outcrop (Kralice-III, $49^{\circ} 11.584' N$, $016^{\circ} 12.538' E$) are represented by yellow marl and calcareous sandstone with a rich fauna of foraminifers, molluscs, bryozoans and echinoderms (Zágoršek et al., 2009). The age of these sections is interpreted as Early Badenian (Zágoršek et al., 2008, 2009) on the basis of planktonic foraminifers, calcareous nannoplankton, molluscs, bryozoans, and this conclusion is supported by co-occurrence of the Early Badenian forms *Bolboforma moravica* and *B. reticulata* (Redinger, 1992).

3. Material and methods

The investigated material was collected during fieldwork at Kralice-II and Kralice-III (Fig. 1) using samples taken as described by Zágoršek et al. (2008, 2009). Brachiopods were found in 31 samples, mostly from Kralice-III. The total number of specimens is 134; many damaged or fragmented, and most covered by epitaxial calcite cement. Specimens selected for scanning electron microscopy were mounted on stubs, coated with platinum and examined using a Philips XL-20 microscope at the Institute of Paleobiology, Warszawa. The specimens described here are deposited in the National Museum, Prague, under catalogue numbers P 1940–1968.

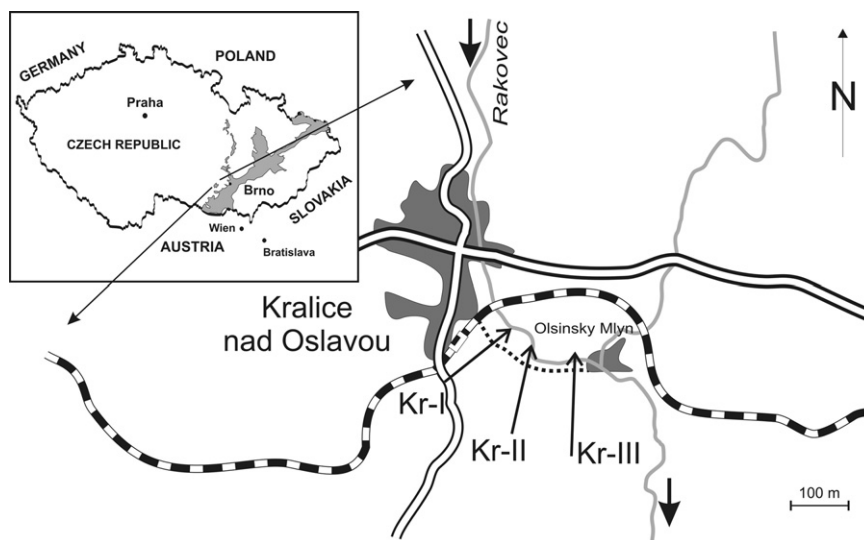


Fig. 1. Geographical sketch of the studied localities around Kralice nad Oslavou. (Kr-I: Kralice-I; Kr-II: Kralice-II; Kr-III: Kralice-III).

Fig. 1. Carte géographique des localités étudiées à Kralice nad Oslavou. (Kr-I: Kralice-I; Kr-II: Kralice-II; Kr-III: Kralice-III).

After Zágoršek et al., 2009.

4. Characteristics of the brachiopod fauna

The brachiopods identified in the Miocene deposits of Kralice nad Oslavou consist of eight species belonging to eight genera in six families (Craniidae, Cryptoporidae, Terebratulidae, Megathyrididae, Kraussinidae, Platidiidae), three orders (Craniida, Rhynchonellida, Terebratulida), and two subphyla (Craniiformea and Rhynchonelliformea) according to the classification adopted in the revised Treatise Kaesler (1997–2006).

4.1. Systematic part

Family: Craniidae Menke, 1828
Genus **Novocrania** Lee and Brunton, 2001
Type species: *Patella anomala* Müller, 1776.
Novocrania sp.

Fig. 2A

Material: one dorsal valve from Kralice-III, slightly broken.

Dimensions: length 1.5 mm, width 1.8 mm (specimen no. P 1940).

Remarks: the very limited material does not permit identification to species level. The valve is small, subcircular, wider than long with a rough surface and the beak situated postero-centrally. Muscle scars are indistinct. This is the first record of *Novocrania* from the Miocene of the Moravian Foredeep.

Family: Cryptoporidae Muir-Wood, 1955
Genus **Cryptopora** Jeffreys, 1869
Type species: *Cryptopora gnomon* Jeffreys, 1869.
Cryptopora lovisati (Dreger, 1911)

Fig. 2B–K

2004 *Cryptopora lovisati* – Bitner and Cahuzac, p. 4–5; figs. 3–6 (*cum syn.*).

2010 *Cryptopora lovisati* – Dulai, p. 24, pl. 1, figs 1–5.

Material: five complete specimens, seven ventral valves, and six dorsal valves from Kralice-II; 17 complete specimens, eight ventral valves, and three dorsal valves from Kralice-III. Many specimens are damaged and/or crushed.

Dimensions (in mm):

Locality	Specimen no.	Length	Width	Thickness
Kralice-II	P 1964	4.9	4.5	1.5
Kralice-II	P 1965	3.2	3.0	1.1
Kralice-III	P 1943	4.0	3.1	70.8
Kralice-III	P 1944	2.6	2.4	1.0

Remarks: *Cryptopora lovisati* is one of the two commonest species in the investigated assemblage. This small rhynchonellide is characterized by elaborate modifications of the deltidial plates forming a wing-like structure. Its shell is small, oval to subcircular, with a high, suberect beak and triangular, hypothyril foramen. The apical plate is long, and elevated above the valve floor. The teeth are small, hooked, and supported by short dental plates (Fig. 2C and

D). The dorsal median septum is very high, and is situated at mid-valve (Fig. 2G).

This is the first record of this species from the Miocene of the Czech Republic; however, the presence of the genus *Cryptopora* was already noted from Kralice by Hamršmíd (1984). In the Central Paratethys *C. lovisati* has so far been recorded only from the Pińczów area, Poland (Popiel-Barczyk and Barczyk, 1990). Originally described from the Middle Miocene of Sardinia (Dreger, 1911) it was also found in the Middle Miocene of northwestern Germany (Wienrich, 1999) and southwestern France (Bitner and Cahuzac, 2004). Recently Dulai (2010) described this species from the Late Miocene of northern Italy. *C. lovisati* seems to be restricted to the Miocene of Europe.

Family: Terebratulidae Gray, 1840
Genus **Terebratula** Müller, 1776
Type species: *Anomia terebratula* Linnaeus, 1758.
Terebratula sp.

Fig. 3A

Material: one complete specimen from Kralice-II; one ventral and one dorsal valve from Kralice-III.

Dimensions: length 2.4 mm, width 1.8 mm, thickness 0.9 mm (specimen no. P 1947).

Remarks: this small, smooth brachiopod with a large foramen is clearly a juvenile, perhaps of the short-looped genus *Terebratula*, already reported from Kralice (Toula, 1893). Various species of *Terebratula* are known from the Paratethys Miocene (e.g. Barczyk and Popiel-Barczyk, 1977; Bitner and Dulai, 2004; Bitner and Pisera, 2000; Bitner and Schneider, 2009; Dreger, 1889; Meznerics, 1944; Popiel-Barczyk and Barczyk, 1990).

Family: Megathyrididae Dall, 1870
Genus **Megathiris** d'Orbigny, 1847
Type species: *Anomia detruncata* Gmelin, 1791.
Megathiris detruncata (Gmelin, 1791)

Fig. 3J–L

1990 *Megathiris detruncata* – Bitner, p. 135–138; text-figs 3–4; pl. 3, figs -8; pl. 6, figs 1–7 (*cum syn.*).

2012 *Megathiris detruncata* – Zágoršek et al., p. 275; fig. 6D, E.

Material: six ventral valves, one dorsal valve and fragments from Kralice-III.

Dimensions: length 4.5 mm, width 5.6 mm (illustrated specimen no. P 1954).

Remarks: *Megathiris detruncata* is easily distinguishable externally by its transversely elongate outline and ornamentation of a few broad ribs, and internally by the presence of two lateral septa. Although rare in the investigated material, this species is one of the most common in the Middle Miocene of the Central Paratethys (see Bitner, 1990; Bitner and Dulai, 2004; Dulai, 2007; Kroh, 2003). Its presence at Kralice was already reported by Toula (1893) under the name *Argiope decollata*. Recently, *M. detruncata* was also noted from Přemyslovce, situated approximately 100 km north of Kralice (Zágoršek et al.,

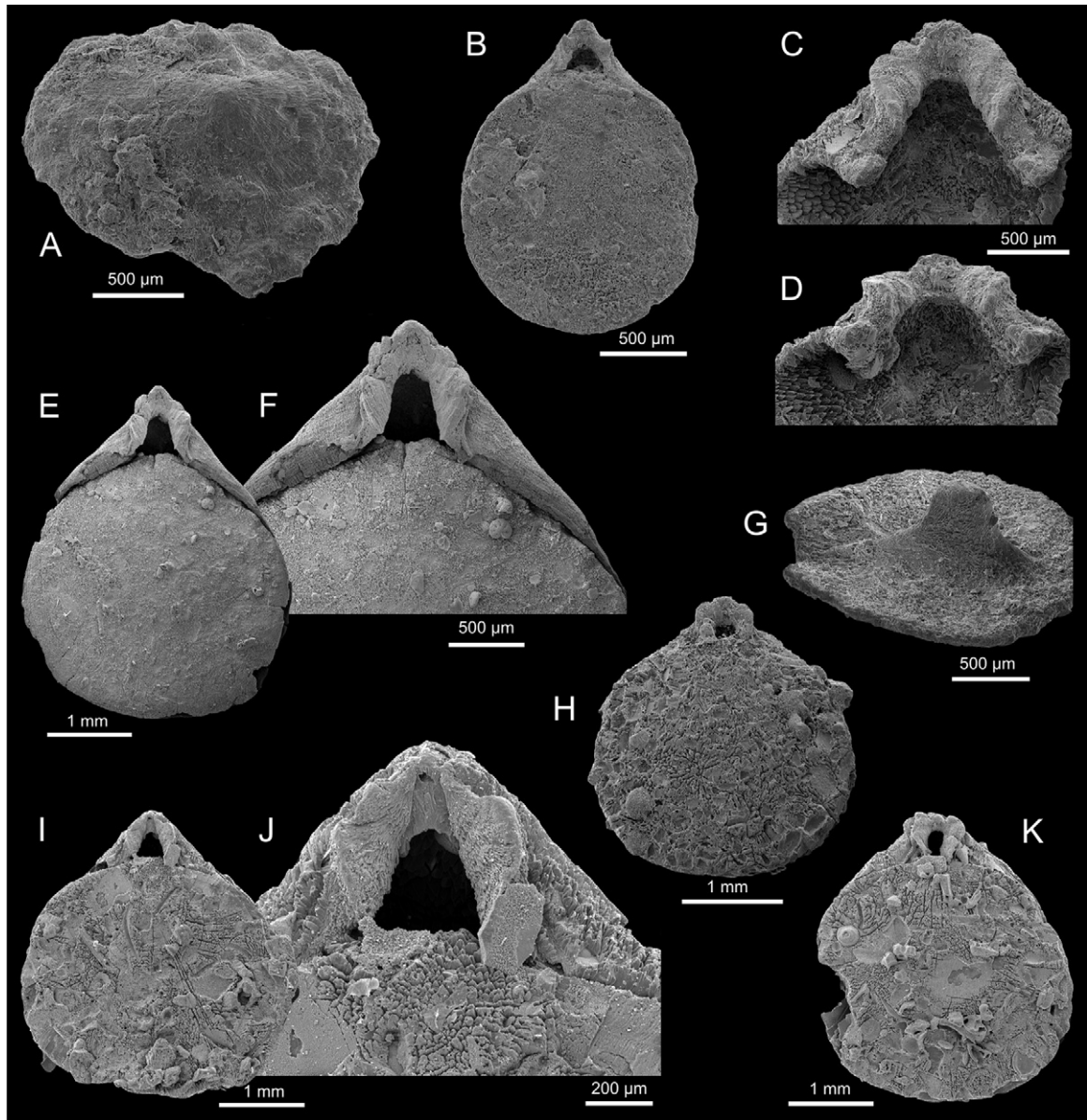


Fig. 2. A: *Novocrania* sp., outer view of dorsal valve, Kralice-III, P 1940. B–K: *Cryptopora lovisati* (Dreger, 1911), Kralice-III; B: dorsal view of young specimen, P 1941; C, D: inner and tilted views of the umbonal part of ventral valve to show teeth and dental plates, P 1942; E, F: dorsal view of complete specimen and enlargement of the umbonal part to show deltidial plates, P 1943; G: lateral view of dorsal valve showing a high median septum, P 1963; H: dorsal view of complete specimen, P 1944; I, J: dorsal view of complete specimen and enlargement of the umbonal part, visible apical plate and auriculate deltidial plates, P 1945; K: dorsal view of complete specimen, P 1946. All SEM.

Fig. 2. A : *Novocrania* sp., vue externe de la valve dorsale, Kralice-III, P 1940. B–K : *Cryptopora lovisati* (Dreger, 1911), Kralice-III ; B : vue dorsale d'un jeune spécimen, P 1941 ; C, D : valve dorsale, vues interne et inclinée de la partie postérieure montrant les dents et les plaques dentaires, P 1942 ; E, F : vue dorsale d'un spécimen complet et agrandissement de la partie postérieure pour montrer les plaques deltidiales, P 1943 ; G : vue latérale d'une valve dorsale montrant le septum médian élevé, P 1963 ; H : vue dorsale d'un spécimen complet, P 1944 ; I, J : vue dorsale d'un spécimen complet et agrandissement de la partie postérieure pour montrer la plaque apicale et les plaques deltidiales ailées, P 1945 ; K : vue dorsale d'un spécimen complet, P 1946. Photos MEB.

2012). The species is known since the Eocene and lives today in the Mediterranean Sea and the eastern North Atlantic. Its extant representatives occur at depths from 16 to 896 m (Álvarez and Emig, 2005; Brunton and Curry, 1979; Logan, 1979, 1993).

Genus *Argyrotheca* Dall, 1900

Type species: *Terebratula cuneata* Risso, 1826.
Argyrotheca cuneata (Risso, 1826)

Fig. 3D–I
1990 *Argyrotheca cuneata* – Bitner, pp. 138–140, text-figs 5–6, pl. 4 figs 1–9 (*cum syn.*).

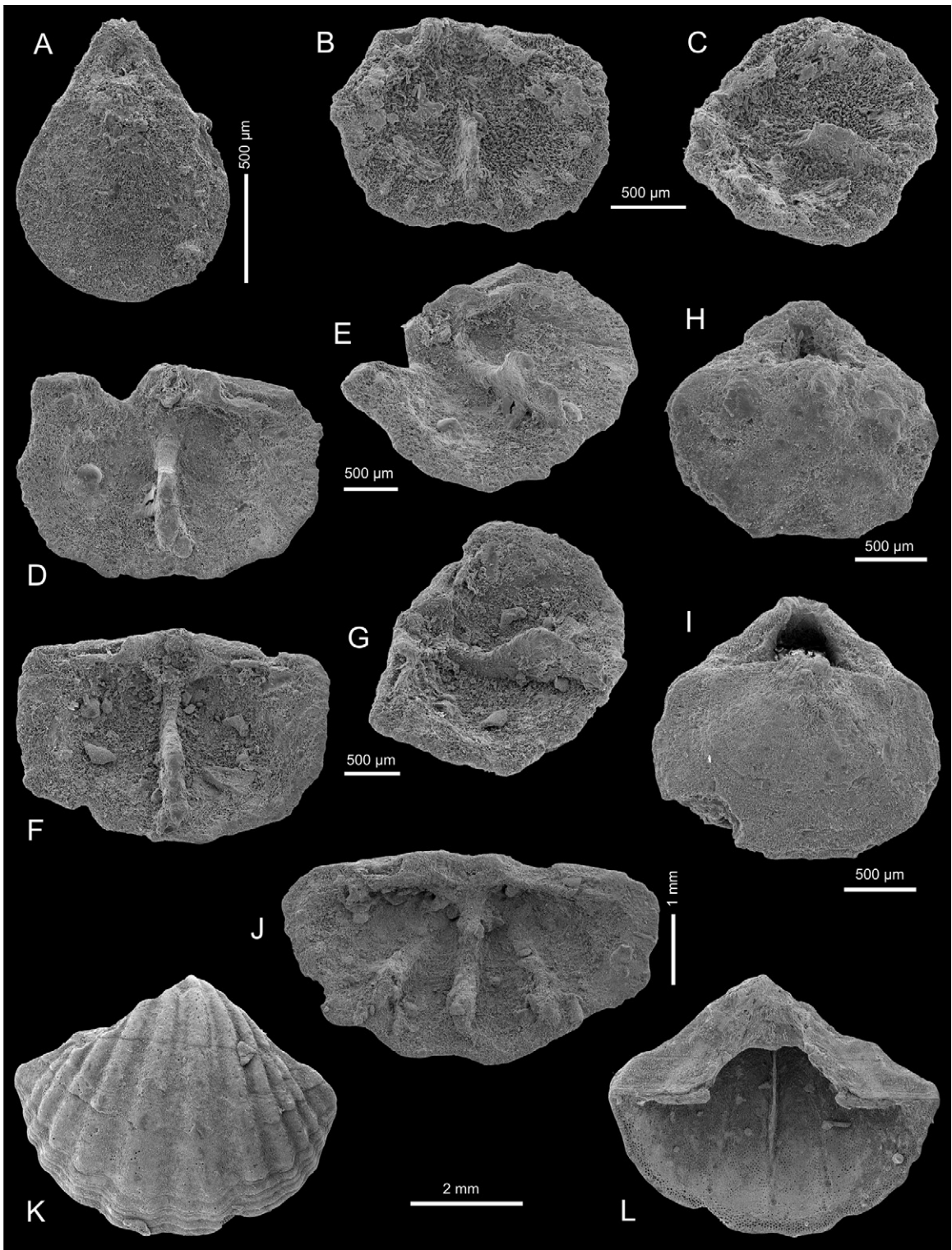


Fig. 3. A: "*Terebratulata*" sp., dorsal view of young specimen, Kralice-II, P 1947. B, C: *Joania cordata* (Risso, 1826), inner and oblique views of dorsal valve, Kralice-II, P 1948. D–I: *Argyrotheca cuneata* (Risso, 1826), Kralice-II; D–G: inner and oblique views of dorsal valves, P 1949–1950; H, I: dorsal views of complete specimens, P 1951–1952. J–L: *Megathiris detruncata* (Gmelin, 1791), Kralice-III; J: inner view of dorsal valve, P 1953; K, L: outer and inner views of ventral valve, P 1954. All SEM.

Fig. 3. A: "*Terebratulata*" sp., vue dorsale d'un jeune spécimen, Kralice-II, P 1947. B, C: *Joania cordata* (Risso, 1826), vues interne et oblique d'une valve dorsale, Kralice-II, P 1948. D–I: *Argyrotheca cuneata* (Risso, 1826), Kralice-II; D–G: vues internes et obliques de valves dorsales, P 1949–1950; H, I: vues dorsales des spécimens complets, P 1951–1952. J–L: *Megathiris detruncata* (Gmelin, 1791), Kralice-III; J: vue interne d'une valve dorsale, P 1953; K, L: vues externe et interne d'une valve ventrale, P 1954. Photos MEB.

2012 *Argyrotheca cuneata* – Zágoršek et al., p. 275; fig. 6A, B.

Material: two complete specimens and two ventral valves from Kralice-II; three complete specimens, two ventral valves, and six dorsal valves from Kralice-III.

Dimensions (in mm):

Locality	Specimen no.	Length	Width	Thickness
Kralice-II	P 1966	2.4	2.6	–
Kralice-II	P 1967	1.8	2.3	1.2
Kralice-II	P 1952	1.6	1.9	1.4

Remarks: these specimens correspond well to those hitherto described (Bitner, 1990, 1993; Bitner and Kaim, 2004; Bitner and Pisera, 2000; Dulai, 2007; Zágoršek et al., 2012). The shell is small, transversely subrectangular, with a long hinge line and large hypothyriform foramen. The shell surface is covered with low, rounded, single ribs; visible only on the better preserved specimens in the Kralice material.

A. cuneata is common in the Miocene of the Central Paratethys but in the investigated material it is rare. Most probably this species was already reported from Kralice under the name *Argiope squamata* (see Toulou, 1893), which is often considered to be a synonym of *A. cuneata* (see Bitner, 1990; Popiel-Barczyk and Barczyk, 1990). In modern waters, *A. cuneata* can be found in the Mediterranean Sea and eastern North Atlantic at depth from 5 to 645 m (Álvarez and Emig, 2005; Brunton and Curry, 1979; Logan, 1979, 1993).

Genus **Joania** Alvarez, Brunton and Long, 2008

Type species: *Terebratulula cordata* Risso, 1826.

Joania cordata (Risso, 1826)

Fig. 3B and C

1990 *Argyrotheca cordata* – Bitner, pp. 140–143, text-figs 7–8, pl. 5, fig. 1–14, pl. 7, fig. 1 (*cum syn.*).

2012 *Joania cordata* – Zágoršek et al., p. 275; fig. 6C, F.

Material: one dorsal valve from Kralice-II.

Remarks: *Joania cordata* is very rare, represented only by one dorsal valve. It is characterized by a smooth to weakly ribbed surface, prominent cardinal process and tubercles on the inner margin on both valves. Submarginal tubercles are the main feature on which this species was removed from *Argyrotheca* and transferred to *Joania* (Álvarez et al., 2008).

J. cordata is one of the most common species in the Central Paratethys (see Bitner, 1990, 1993; Bitner and Dulai, 2004; Bitner and Kaim, 2004; Bitner and Pisera, 2000; Dulai, 2007; Zágoršek et al., 2012). Today, it lives in the eastern North Atlantic, Mediterranean Sea and Red Sea at depths of 3 to 600 m (Álvarez and Emig, 2005; Logan, 1979, 1993; Logan et al., 2008).

Family: Kraussinidae Dall, 1870

Genus **Megerlia** King, 1850

Type species: *Anomia truncata* Linnaeus, 1767.

Megerlia truncata (Linnaeus, 1767)

Fig. 4H and I

1990 *Megerlia truncata* – Bitner, pp. 145–147, text-fig. 10, pl. 2, figs 6–9, pl. 7, figs 3–6, pl. 8, figs 1–7 (*cum syn.*).

2010 *Megerlia truncata* – Dulai, p. 28, pl. 3, figs. 4–5.

Material: one ventral valve and fragment of dorsal valve from Kralice-II; two ventral valves, two broken dorsal valves, and fragments from Kralice-III.

Dimensions: length 3.2 mm, width 3.9 mm (measurements taken from the best preserved specimen no. P 1961).

Remarks: although the material is limited and poorly preserved (no articulated specimen was found), this species is easily recognizable by its transversely oval outline, fine, slightly nodular, ribbed ornamentation, and large foramen. *M. truncata* is well known in the Central Paratethys where it can be locally abundant (Bitner, 1990; Bitner and Dulai, 2004; Popiel-Barczyk and Barczyk, 1990). From the Moravian Miocene it is reported for the first time. Today it is known from the Mediterranean Sea and the eastern North Atlantic (Brunton and Curry, 1979; Logan, 1979, 1993), as well from the Indian Ocean (Bitner et al., 2008). Its depth range is wide (Logan, 2007) but most common is from 60 to 600 meters.

Family: Platidiidae Thomson, 1927

Genus **Platidia** de Costa, 1852

Type species: *Orthis anomioides* Scacchi and Philippi, 1844.

Platidia anomioides (Scacchi and Philippi, 1844)

Fig. 4A–G

1990 *Platidia anomioides* – Popiel-Barczyk and Barczyk, 169–170, text-fig. 7; pl. 2, figs 1–3.

2004 *Platidia anomioides* – Bitner and Dulai, p. 76, pl. 4, figs 1–10.

Material: two complete specimens, 12 ventral valves, and four dorsal valves from Kralice-II; five complete specimens, 23 broken ventral valves, and nine dorsal valves from Kralice-III.

Dimensions (in mm):

Locality	Specimen no.	Length	Width	Thickness
Kralice-II	P 1968	4.3	4.0	1.6
Kralice-II	P 1958	3.6	3.1	1.7
Kralice-III	P 1960	4.7	4.3	1.5

Remarks: *Platidia anomioides*, already recorded from Kralice by Procházka (1893) and Toulou (1893), is the most common species in the studied assemblage. The specimens are entirely consistent with those already described from the Central Paratethys (Bitner, 1990; Bitner and Dulai, 2004; Popiel-Barczyk and Barczyk, 1990). The shell is small, smooth, oval to subcircular in outline with a short, straight hinge line and a large, amphithyriform foramen, flanked by narrow deltidial plates. The teeth are small, and supported by short, divergent dental plates. The inner socket ridges are massive, extending beyond the hinge margin. The dorsal median septum is short but high.

Today, *P. anomioides* is a cosmopolitan species widely distributed in all oceans and having a very wide depth range from shallow water to 2000 m (Logan, 2007).

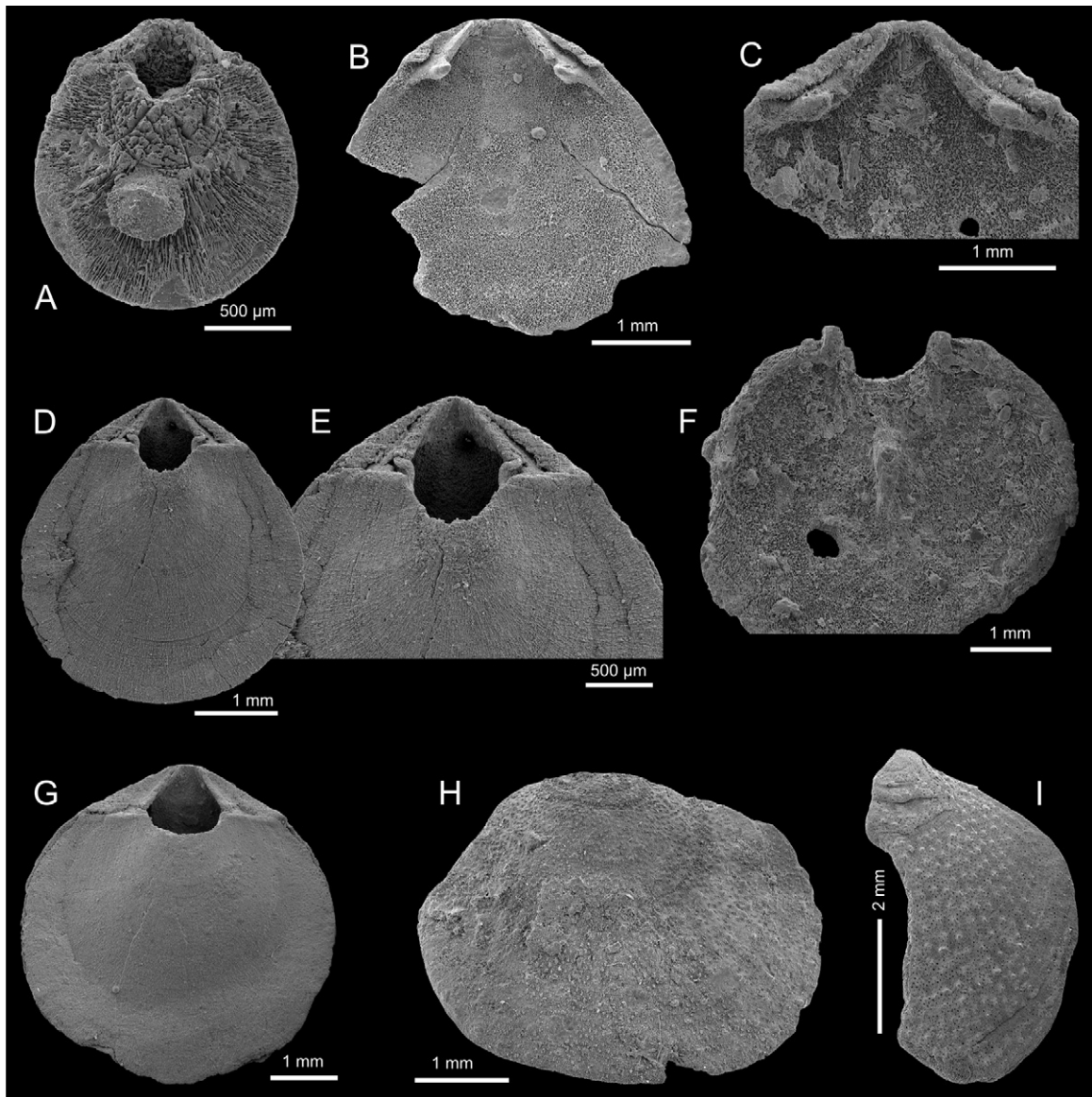


Fig. 4. A–G: *Platidia anomiooides* (Scacchi et Philippi, 1844); A: dorsal view of young specimen, Kralice-III, P 1955; B, C: inner views of ventral valves to show narrow deltidial plates and hooked teeth with weak dental plates, Kralice-III, P 1956–1957; D, E: dorsal view of complete specimen and enlargement of the umbonal part, Kralice-II, P 1958; F: inner view of dorsal valve showing high inner socket ridges and median septum, Kralice-III, P 1959; G: dorsal view of complete specimen, Kralice-III, P 1960. H, I: *Megerlia truncata* (Linnaeus, 1767), outer views of ventral valves, one broken; H: Kralice-II, P 1961; I: Kralice-III, P 1962. All SEM.

Fig. 4. A–G: *Platidia anomiooides* (Scacchi et Philippi, 1844); A : vue dorsale d'un jeune spécimen, Kralice-III, P 1955 ; B, C : vues internes des valves ventrales pour montrer les plaques deltidiales étroites et les dents associées à de fragiles plaques dentaires, Kralice-III, P 1956–1957 ; D, E : vue dorsale d'un spécimen complet et agrandissement de la partie postérieure, Kralice-II, P 1958 ; F : vue interne d'une valve dorsale montrant des cardinalia et le septum médian, Kralice-III, P 1959 ; G : vue dorsale d'un spécimen complet, Kralice-III, P 1960. H, I : *Megerlia truncata* (Linnaeus, 1767), vues externes de valves ventrales, l'une cassée ; H : Kralice-II, P 1961 ; I : Kralice-III, P 1962. Photos MEB.

5. Discussion

The brachiopod fauna, collected in the Middle Miocene deposits at two outcrops, Kralice-II and Kralice-III, in Kralice nad Oslavou, Moravia, Czech Republic (Fig. 1), contains eight species. The assemblages of the two localities display a great similarity, having five species in common, i.e. *Cryptopora lovisati* (Dreger, 1911), “*Terebratula*” sp.,

Argyrotheca cuneata (Risso, 1826), *Megerlia truncata* (Linnaeus, 1767) and *Platidia anomiooides* (Scacchi and Philippi, 1844). One species, *Joania cordata* (Risso, 1826) found in Kralice-II, is not present in Kralice-III, and in turn, *Novocrania* sp. and *Megathiris detruncata* (Gmelin, 1791) were not found in Kralice-II. In both assemblages, *C. lovisati* and *P. anomiooides* dominate, constituting more than 75% of the material; other species occur in negligible numbers.

Novocrania, *C. lovisati* and *M. truncata* are recorded for the first time in the Miocene deposits of the Moravian part of the Carpathian Foredeep.

All species recognized in Kralice are known from other Miocene Paratethyan localities; however, the dominance of *C. lovisati* and *P. anomioides* makes the investigated assemblage unusual. Typically, Megathyrididae is the dominant family among brachiopods of the Central Paratethys (cf. Bitner, 1990, 1993; Bitner and Pisera, 2000; Dulai, 2007; Dulai and Stachacz, 2011; Popiel-Barczyk and Barczyk, 1990). Extant representatives of Megathyrididae are mostly shallow water species, with a cryptic mode of life (Logan, 1979). On the other hand, *Cryptopora* and *Platidia* are deeper water brachiopods. The modern species *C. curiosa* from the Indian Ocean, which appears to be closely related to *C. lovisati*, is most common between 300–600 m (Logan et al., 2008). Extant *P. anomioides* is eurybathic, being most common in the Mediterranean Sea between 200–300 m (Logan, 1979) but in the Red Sea it occurs below 500–600 m (Logan et al., 2008). Thus, an environment deeper than 100 m is suggested for the Kralice deposits. These results strongly support previous estimation of a paleodepth of 100–200 m inferred from other fauna by Brzobohatý (2001) and Zágoršek et al. (2008, 2009).

Acknowledgements

The financial support of the Grant Agency of the Czech Republic (Project 205/09/0103) to SH and KZ is gratefully acknowledged. Dr B. L. Cohen (University of Glasgow, Glasgow) is thanked for reading an earlier version of the manuscript, making useful comments and improving English. Dr A. Halamski (Institute of Paleobiology, Warszawa) helped us with the French abstract. We wish to thank two anonymous reviewers for their useful comments.

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