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MIDDLE MIOCENE (BADENIAN) BRACHIOPODS FROM THE BORAČ AREA (CARPATHIAN FOREDEEP, MORAVIA, CZECH REPUBLIC)

Maria Aleksandra BITNER[1*], Šárka HLADILOVÁ[2], Jaroslav ŠAMÁNEK[2] & Tomáš TUREK[2, 3]

[1] *Institute of Paleobiology, Polish Academy of Sciences, Twarda 51/55, 00-818 Warszawa, Poland; e-mail: bitner@twarda.pan.pl*
[2] *Institute of Geological Sciences, Faculty of Science, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic; e-mails: sarka@sci.muni.cz, samanek.j@mail.muni.cz, 424007@mail.muni.cz*
[3] *Department of Geology and Paleontology, Moravian Museum, Zelný trh 6, 659 37 Brno, Czech Republic; e-mail: tturek@mzm.cz*
**Corresponding author*

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Abstract: Four brachiopod species, i.e., *Terebratula* cf. *styriaca* Dreger, *Terebratulina retusa* (Linnaeus), *Megathiris detruncata* (Gmelin) and *Megerlia truncata* (Linnaeus), have been recognised in the Middle Miocene (lower Badenian) deposits at the localities Borač and Borač-Podolí, Carpathian Foredeep, Moravia, Czech Republic. The species *M. truncata* predominates in the assemblage studied, while *M. detruncata* is very rare, found only at the locality Borač. *Terebratula* cf. *styriaca* and *Terebratulina retusa* are reported for the first time from the Moravian part of the Carpathian Foredeep. Two types of trace fossils have been observed on the brachiopod shells: drill holes penetrating the shell (ichnogenus *Oichnus* Bromley) and etching scars, produced by a brachiopod pedicle (ichnogenus *Podichnus* Bromley and Surlyk).

Key words: Brachiopoda, Middle Miocene, Langhian, Carpathian Foredeep, Central Paratethys, trace fossils.

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INTRODUCTION

Brachiopods are common fossils in the Middle Miocene deposits of the Central Paratethys. However, their abundance and diversity are very variable in different areas and localities. In the Moravian part of the Carpathian Foredeep (Czech Republic), they are rare, both in species and specimens. So far, brachiopods have been reported and taxonomically described from 11 Moravian localities (Reuss, 1860; Zágoršek *et al*., 2012; Bitner *et al*., 2013b, c, 2023; Pavézková *et al*., 2013; Hladilová *et al*., 2014; Kopecká *et al*., 2018) but only the assemblage from the locality Kralice nad Oslavou is rich and diverse, with eight species recognised (Bitner *et al*., 2013b).

The aim of this study is to describe a newly collected brachiopod fauna from two localities, Borač and Borač-Podolí in the Moravian part of the Carpathian Foredeep (Fig. 1). Although the investigated assemblage contains only four species, it provides new data on the Miocene brachiopods of Moravia. Its taxonomic composition differs from other Moravian assemblages, with two species reported for the first time from the Miocene of the Czech Republic.

GEOLOGICAL SETTING

The Miocene sediments in the study area occur only as isolated, erosional relics with areal extents that are poorly known because of the thick Quaternary cover. They are of marine origin and belong to the sedimentary infill of the Carpathian Foredeep, a peripheral foreland basin, formed on the loaded eastern margin of the Bohemian Massif, owing to tectonic emplacement of the Carpathian thrust wedge. Sedimentation in this sector of the basin started in the Egerian/early Eggenburgian and continued into the early Badenian (Brzobohatý and Cicha, 1993). In the early Middle Miocene (Badenian), the basin geometry of the Carpathian Foredeep was reorganized and thus the Badenian deposits represent a distinct period of basin evolution (Oszczypko, 1998; Kováč, 2000; Nehyba and Šikula, 2007).

In the wider surroundings of Borač and Borač-Podolí, the Miocene sediments lie on the pre-Neogene basement. It is composed mostly of metamorphic rocks of the Svratka Unit in the Moravian Zone. These are Precambrian under a Devonian cover – mainly gneisses, mica schists, phyllites, metabasites, granitoids, crystalline limestones

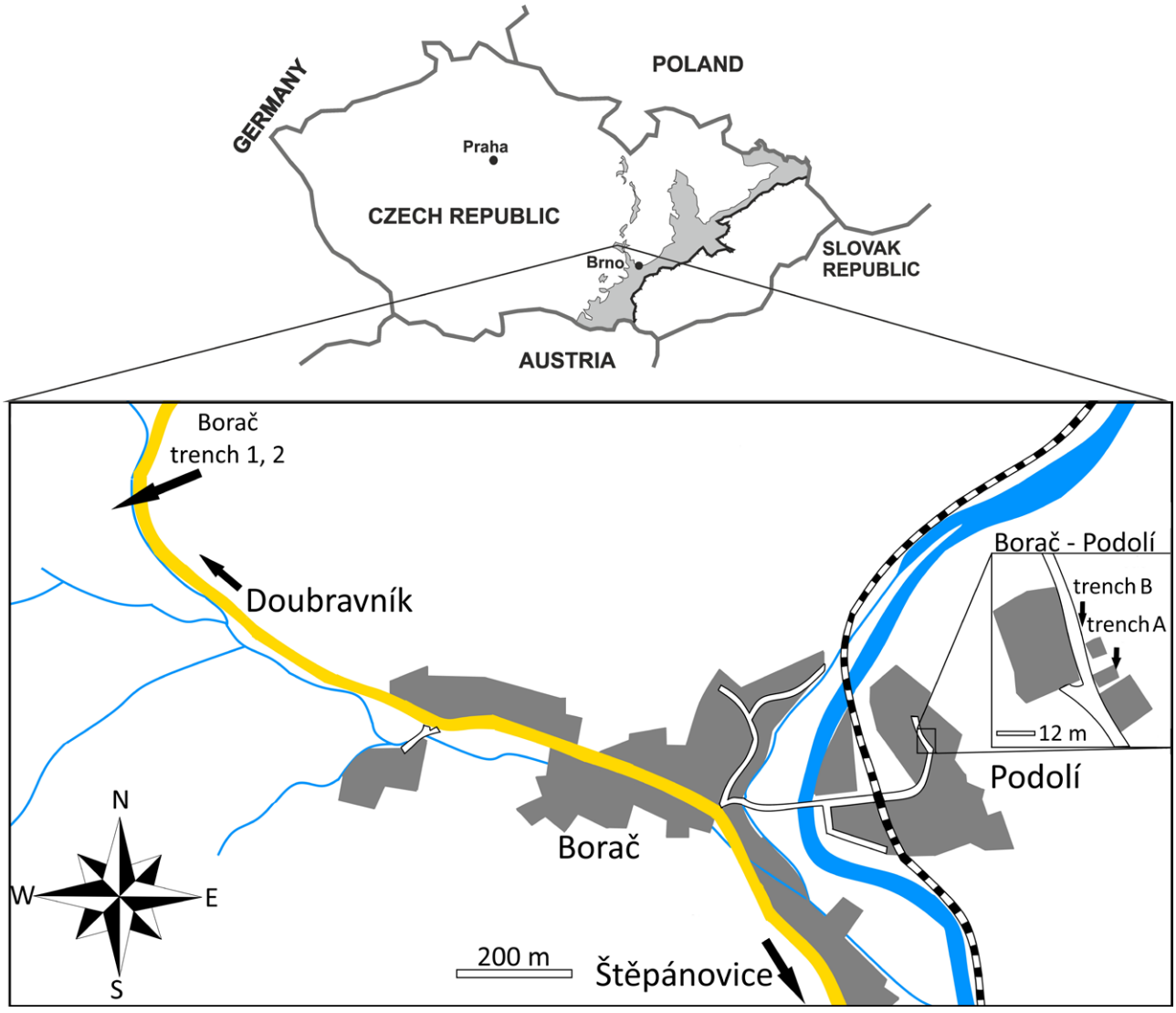

Fig. 1. Geographical location of the Neogene Carpathian Foredeep in the Czech Republic and a sketch of the studied localities in the Borač area.

and quartzites (Jaroš and Mísař, 1976; Mísař *et al*., 1983). Locally, Permo–Carboniferous sediments of the Boskovice Trough are developed, comprising conglomerates, claystones, siltstones, and argillaceous carbonates (Jaroš, 1963; Buriánková *et al*., 2001; Pešek *et al*., 2001; Ivanov, 2003, among others). Sporadically, Cretaceous sediments occur (Cicha and Dornič, 1958; Kettner, 1959).

At present, two localities exist in the area of Borač (Fig. 1).The famous Borač palaeontological locality is situated in the fields, about 800 m NW from the village, to the left of the Borač-Doubravník road. It comprises marine (euhaline) green-grey, grey-yellow or grey-blue, strongly calcareous clays (so-called tegels) of early Badenian age, transgressing directly on the metamorphic rocks of the Moravian Zone, without basal clastics. These sediments are not exposed in natural outcrops and can be studied only in excavations. The last two trenches were made in 2016 and 2017 by one of the authors (TT). Since the second half of the 19th century, this locality has attracted the attention of a number of researchers, owing to its exceptional richness in macro- and microfossils, mainly nannoplankton, foraminifers, radiolarians, sponge spicules, anthozoans, molluscs, ostracods, and fish otoliths (Procházka, 1892a, b, 1893, 1899; Rzehak, 1923; Cicha *et al*., 1957; Cicha and Dornič, 1959; Krystek and Tejkal, 1968; Weyer, 1974; Brzobohatý and Cicha, 1978; Seitl, 1981; Říha, 1983; Brzobohatý, 1997; Pekař and Lehotský, 2015, among others). The locality Borač was designated by Brzobohatý and Cicha in Papp *et al*. (1978) as a parastratotype of the lower Badenian (= the Moravian substage of the regional Badenian stage), corresponding to the lower part of the Langhian in the standard chronostratigraphy (Hohenegger *et al*., 2014).

The second locality, named Borač-Podolí, was documented in 2015 by Jaroslav Šamánek and Lucie Kleprlíková, students from the Department of Geological Sciences, Faculty of Science, Masaryk University, Brno. Two test trenches, about 2 m deep, were open on the property of Mr. Uher (house number 33). Trench A was situated behind the garage wall (49°24′6.031″N, 16°22′2.864″E) and it revealed no macrofossils. Trench B was situated 1.55 m to the N from

the high-voltage pole, parallel to the road (49°24′6.509″N, 16°22’2.434”E). In this trench, Badenian sediments can be described as alternating layers of green-greyish, calcareous clays (up to 25 cm thick) and yellow-brownish, fine-grained, quartz-rich sands (up to 10 cm thick). Sandy layers were rich in fossils (molluscs, corals, otoliths, echinoids, etc.). Finally, both trenches were covered up. Some fossils from this locality were studied in three MSc. theses so far (Kleprlíková, 2016 – corals, Šamánek, 2017 – trace fossils, and Turek, 2018 – molluscs), and the results already have been published in part (Kleprlíková and Doláková, 2016; Kleprlíková, 2018; Šamánek *et al*., 2018).

Although the Badenian clays near Borač are very rich in fossils, the brachiopods are only sporadically mentioned in the literature. Procházka (1892a) noted that brachiopods are very rare in the Borač clays. He reported one individual of *Cistella squamosa* (Eichwald, 1830) and three individuals of *Platidia anomioides* (Scacchi and Philippi *in* Philippi, 1844).

MATERIAL AND METHODS

The investigated material was collected by two of us (JŠ and TT) at two localities, Borač and Borač-Podolí (Fig. 1), during fieldwork, carried out between 2015 and 2018 (see above). At Borač, two test trenches (50 x 50 x 80 cm) were made by TT approximately 4 m NE from the high-voltage pole (N 49°24′19.271″ E 16°20′47.577″). The majority of brachiopods (samples 1a, 1b, 2a, 2b) come from the sediment bulk samples, washed using sieves with 5 mm, 2 mm and 0.5 mm mesh. Some specimens were collected by hand, while digging and doing fieldwork (including samples 6a, 6b). The studied material from the locality Borač-Podolí comes from field work (trench B – 207 cm thickness of the profile, in total 5 samples from various depths), carried out by JŠ and Lucie Kleprlíková during autumn 2015 (Šamánek *et al*., 2018). The total number of specimens is 141. For calculation also fragmented specimens were taken into consideration, if ventral or dorsal valves were recognisable. The brachiopods are poorly preserved and the majority of specimens are damaged, fragmented and/or crushed. The SEM micrographs were taken in the SEM laboratory of the Institute of Paleobiology using a Philips XL-20 scanning microscope. The material is housed at the Institute of Geological Sciences, Masaryk University, Brno, under the collection number UGV PAL Bp.03.

SYSTEMATIC PALAEONTOLOGY

Phylum Brachiopoda Duméril, 1805
Subphylum Rhynchonelliformea Williams, Carlson, Brunton, Holmer and Popov, 1996
Class Rhynchonellata Williams, Carlson, Brunton, Holmer and Popov, 1996
Order Terebratulida Waagen, 1883
Suborder Terebratulidina Waagen, 1883
Superfamily Terebratuloidea Gray, 1840
Family Terebratulidae Gray, 1840
Genus *Terebratula* Müller, 1776

Type species: *Anomia terebratula* Linnaeus, 1758, by subsequent designation of Lee and Brunton (1998).

Terebratula cf. *styriaca* Dreger, 1889
Fig. 2A–E

cf. 1889 *Terebratula Styriaca* n. sp. – Dreger, p. 187 (9), pl. 3, figs 1–6.

cf. 1977 *Terebratula styriaca* Dreger – Barczyk and Popiel-Barczyk, pp. 160–161, text-fig. 3, pl. 2, fig. 10.

cf. 1990 *Terebratula styriaca* Dreger – Popiel-Barczyk and Barczyk, pp. 165–167, text-fig. 6, pl. 3, figs 1–10.

cf. 2000 *“Terebratula” styriaca* Dreger – Bitner and Pisera, p. 9, pl. 1, figs 12–13.

cf. 2004 *Terebratula styriaca* Dreger – Bitner and Dulai, p. 72, pl. 2, figs 1–6.

Material: Two articulated specimens, 13 ventral valves and 10 dorsal valves from the locality Borač, and 11 ventral valves and five dorsal valves from Borač-Podolí; their state of preservation is very poor; most specimens are strongly fragmented, broken and/or crushed.

Description: Shell medium- to large-sized (maximum observed length 28.6 mm), subpentagonal to widely oval in outline. Shell surface smooth with weakly marked, numerous growth lines. Beak short, with large, circular foramen of permesothyrid type. Deltidial plates conjunct forming partially visible symphytium.

Ventral valve interior with wide but very short teeth and narrow pedicle collar. Dorsal valve interior with high inner socket ridges, prominent cardinal process, and U-shaped hinge plates. In adult specimens, low median ridge present in dorsal valve. Loop not preserved.

Remarks: With 41 specimens, *Terebratula* cf. *styriaca* is the second most common species in the material studied. However, it is very poorly preserved. Although all available characters point to the species *Terebratula styriaca*, known from the Middle Miocene of the Central Paratethys (Dreger, 1889; Barczyk and Popiel-Barczyk, 1977; Popiel-Barczyk and Barczyk, 1990; Bitner and Pisera, 2000; Bitner and Dulai, 2004), the lack of a preserved loop does not allow a precise identification.

Occurrence: Middle Miocene – lower Badenian, Borač and Borač-Podolí, Moravia, Czech Republic. It is worth mentioning that the genus *Terebratula*, represented by single valves of young individuals, was already mentioned from Moravia (Zágoršek *et al*., 2012; Bitner *et al*., 2013b, 2023). The species *Terebratula styriaca* is restricted to the northern part of the Central Paratethys (Dreger, 1889; Popiel-Barczyk and Barczyk, 1990; Bitner and Pisera, 2000; Bitner and Dulai, 2004).

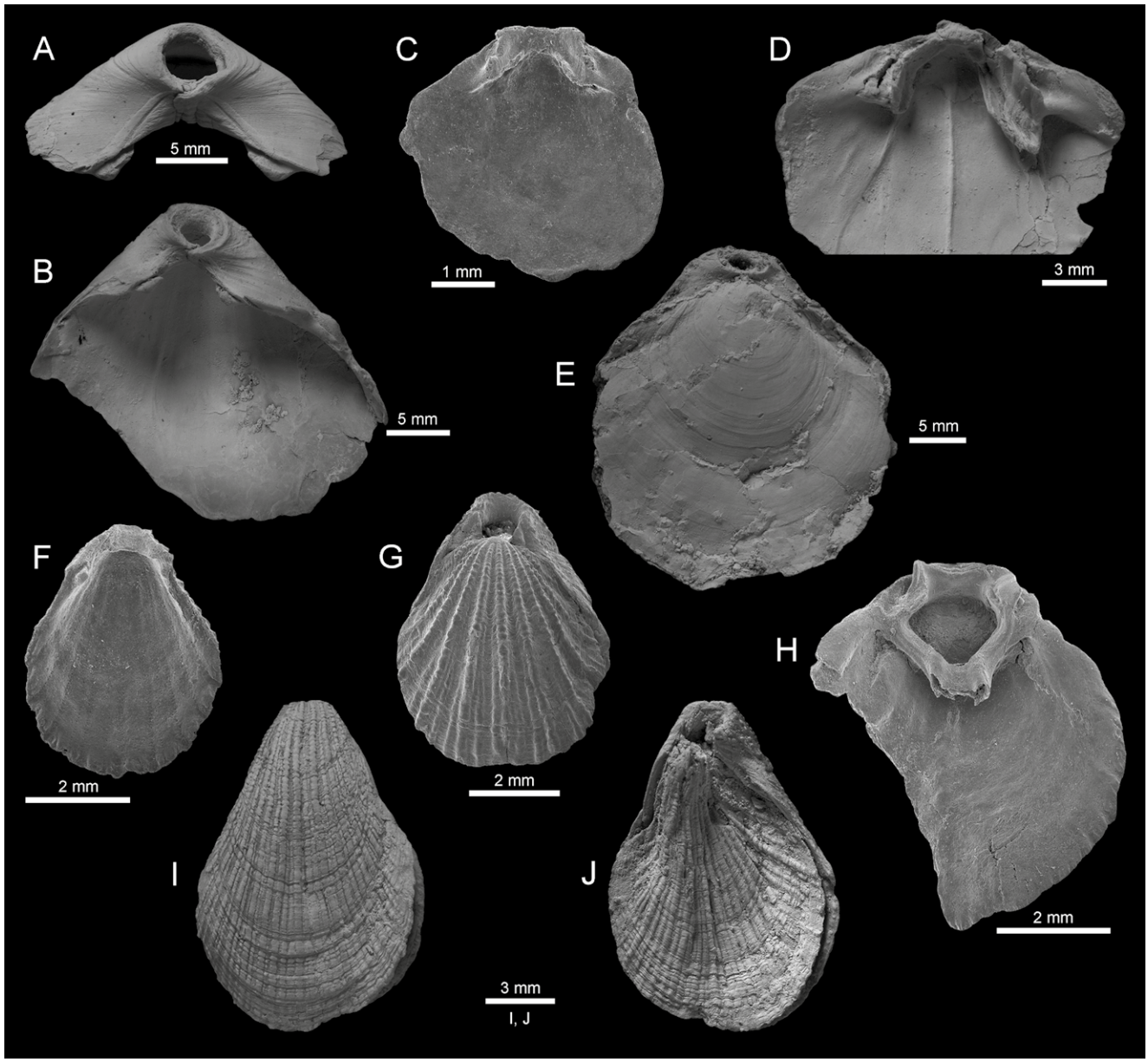

Fig. 2. Brachiopods from the Middle Miocene (Badenian), Carpathian Foredeep, Moravia, Czech Republic. **A–E.** *Terebratula* cf. *styriaca* Dreger, 1889; A – posterior part of ventral valve, Borač, trench 2, sample 2b (UGV PAL Bp.03/B/01); B – inner view of ventral valve, Borač-Podolí, trench B, sample 4 (UGV PAL Bp.03/BP/01); C, D – inner views of dorsal valves, visible high inner socket ridges, prominent cardinal process and low median ridge, Borač, sample 6a (UGV PAL Bp.03/B/02–03); E – dorsal view of articulated specimen, Borač-Podolí, trench B, sample 4 (UGV PAL Bp.03/BP/02). **F–J.** *Terebratulina retusa* (Linnaeus, 1758), Borač; F – inner view of ventral valve, trench 2, sample 2a (UGV PAL Bp.03/B/04); G – dorsal view of young articulated specimen, sample 6a (UGV PAL Bp.03/B/05); H – inner view of dorsal valve, visible the loop forming a ring-like structure typical of the genus, trench 1, sample 1b (UGV PAL Bp.03/B/06); I, J – ventral and dorsal views of articulated specimen, trench 1, sample 1a (UGV PAL Bp.03/B/07). C and F–H SEM images.

Superfamily Cancellothyridoidea Thomson, 1926
Family Cancellothyrididae Thomson, 1926
Subfamily Cancellothyridinae Thomson, 1926
Genus *Terebratulina* d'Orbigny, 1847

Type species: *Anomia retusa* Linnaeus, 1758, by subsequent designation (Brunton *et al.,* 1967).

Terebratulina retusa (Linnaeus, 1758)
Fig. 2F–J

2013a *Terebratulina retusa* (Linnaeus) – Bitner *et al*., pp. 584–586, fig. 2e–h (*cum syn*.).

2016 *Terebratulina retusa* (Linnaeus) – Álvarez, pp. 47–50, pls. 12E–DD, 13A–II, 14A–II, 15A–C (*cum syn*.).

2016 *Terebratulina retusa* (Linnaeus) – Dulai, pp. 87–89, figs 49–54 (*cum syn*.).

2018 *Terebratulina retusa* (Linné) – Emig, pp. 28–29, figs 5–6.

2019 *Terebratulina retusa* (Linnaeus) – Dulai, p. 129, pl. 1, figs 10–15.

2020 *Terebratulina retusa* (Linnaeus) – Hoffmann *et al*., p. 14, fig. 10H–K.

Material: Seven articulated specimens, nine ventral valves and 20 dorsal valves from Borač, and one articulated specimen from Borač-Podolí. There are also many fragments not attributable to any valves; most specimens are damaged and/or crushed.

Remarks: This is the first record of *Terebratulina retusa* from the Miocene of Moravia. The shell is small to medium-sized (maximum observed length 14.1 mm), elongate oval to subpentagonal in outline, longer than wide. Externally the shell is covered with numerous, fine ribs. The cardinalia are with prominent inner socket ridges. The crural processes are united, forming a short ring-like loop, peculiar to the genus (Fig. 2H).

Occurrence: The oldest fossil record of *Terebratulina retusa* is from the Upper Oligocene of the Aquitaine Basin (Bitner *et al*., 2013a). This species is well-known and common in the Neogene deposits of the Mediterranean province (Gaetani and Saccà, 1985; Taddei Ruggiero, 1985, 1994; Bitner and Moissette, 2003; Koskeridou, 2007; Dulai, 2016, 2019; Hoffmann *et al*., 2020) but very rare in the Miocene of the Central Paratethys. So far, it has been recorded from Austria (Dreger, 1889), Hungary (Bitner and Dulai, 2004) and the Czech Republic (this study). The genus *Terebratulina* also was mentioned from the Miocene of Poland (Popiel-Barczyk and Barczyk, 1990). In modern waters, *T. retusa* lives in the north-eastern North Atlantic and the Mediterranean Sea with a wide depth range from 9 to 3,614 m (Logan, 2007; Emig, 2018). However, its highest density is between 100 and 500 m (Curry, 1982).

Suborder Terebratellidina Muir-Wood, 1955
Superfamily Megathyridoidea Dall, 1870
Family Megathyrididae Dall, 1870
Genus *Megathiris* d'Orbigny, 1847

Type species: *Anomia detruncata* Gmelin, 1791, by subsequent designation of Dall (1920).

Megathiris detruncata (Gmelin, 1791)
Fig. 3A–F

1860 *Argiope decollata* Chemn. – Reuss, pp. 227–228.

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

2016 *Megathiris detruncata* (Gmelin) – Álvarez, pp. 69–72, pls. 29A, C–AA, 30A–X, 31A–S, 32A–V, 33A–MM, 34B–I, K–U (*cum syn*.).

2018 *Megathiris detruncata* (Gmelin) – Emig, p. 30, figs 5–7.

2022 *Megathiris detruncata* (Gmelin) – Bitner and Müller, pp. 93–95, fig. 5A–H (*cum syn.*).

2023 *Megathiris detruncata* (Gmelin) – Bitner *et al*., p. 40, fig. 2B–F.

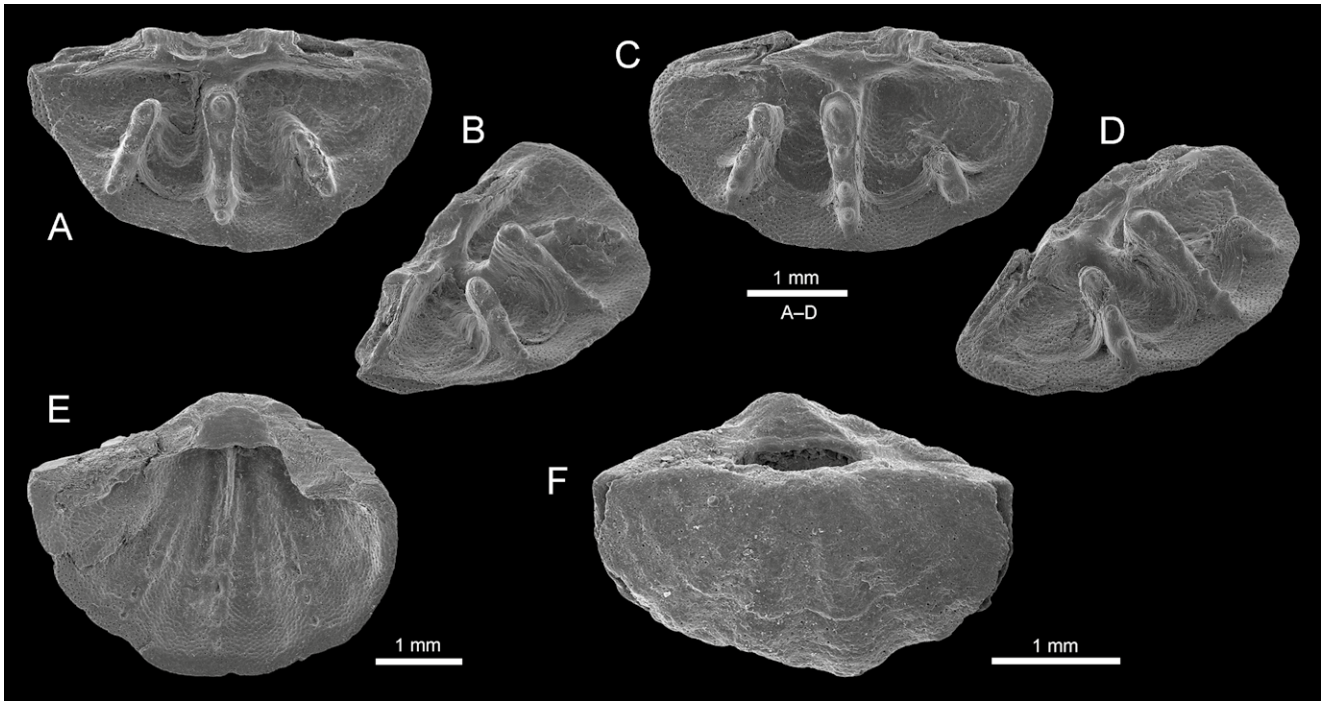

Fig. 3. *Megathiris detruncata* (Gmelin, 1791), Middle Miocene (Badenian), Borač, Moravia, Czech Republic. **A**–**D**. Inner and oblique (B, D) views of dorsal valves; A, B sample 6a (UGV PAL Bp.03/B/08); C, D trench 2, sample 2a (UGV PAL Bp.03/B/09). **E**. Inner view of ventral valve, trench 2, sample 2a (UGV PAL Bp.03/B/10). **F**. Dorsal view of articulated specimen, sample 6a (UGV PAL Bp.03/B/11). All SEM images.

Material: One articulated specimen, two ventral valves and four dorsal valves from Borač; two specimens are strongly damaged.

Remarks: *Megathiris detruncata* is very rare in the material studied, found only at the locality Borač. Its shell is very small (maximum observed length 3.4 mm), transversely elongate with a long, straight hinge line, ornamented by single, broad, rounded ribs. Internally, this species is characterised by the presence of three septa on the dorsal valve (Fig. 3A–D).

Occurrence: In the fossil record, this species is known since the Eocene (e.g., Bitner and Dieni, 2005; Bitner and Dulai, 2008, Dulai *et al*., 2010; Dulai, 2011; Bitner and Müller, 2017). In the Miocene of the Central Paratethys, it belongs to one of the most common species (e.g., Bitner, 1990; Popiel-Barczyk and Barczyk, 1990; Bitner and Dulai, 2004; Dulai, 2007; Bitner and Schneider, 2009; Bitner and Motchurova-Dekova, 2016). In Moravia, although not common, it already was reported from five localities (Reuss, 1860; Zágoršek *et al*., 2012; Bitner *et al*., 2013b, 2023; Pavézková *et al*., 2013). Extant *M. detruncata* lives in the Mediterranean Sea and the north-eastern Atlantic at the depth range 5–896 m (Logan, 2007; Emig, 2018).

Superfamily Kraussinoidea Dall, 1870
Family Kraussinidae Dall, 1870
Subfamily Megerliinae Hiller, MacKinnon and Nielsen, 2008
Genus *Megerlia* King, 1850

Type species: *Anomia truncata* Linnaeus, 1767, by the original designation of King (1850).

Megerlia truncata (Linnaeus, 1767)
Fig. 4A–F

1860 *Megerlea oblita* Micht. – Reuss, p. 227, pl. 6, fig. 2.
1990 *Megerlia truncata* (Linnaeus) – Bitner, pp. 145–147, pl. 2, figs 6–9, pl. 7, figs 3–6, pl. 8, figs 1–7 (*cum syn*.).
2016 *Megerlia truncata* (Linnaeus) – Álvarez, pp. 99–106, pls 59B–R, T–BB, 60A–E, G–O, R, T–AA, 61A, C–G, K–T, V–DD, 62A–AA, 63A–KK, 64A–V, 65A–Q, 66A–EE, 67A, C–BB, 68A–K (*cum syn*.).
2018 *Megerlia truncata* (Linné) – Emig, pp. 32–33, fig. 5-9, pl. 2A–D.
2022 *Megerlia truncata* (Linnaeus) – Bitner and Müller, pp. 101–102, fig. 11C–E (*cum syn*.).

Material: Seven ventral valves and 31 dorsal valves from Borač, and five articulated specimens, eight ventral valves and five dorsal valves from Borač-Podolí, and fragments; most specimens are damaged and fragmented.

Remarks: *Megerlia truncata* is the most common species in the material studied. The shell is small, hardly exceeding 10 mm, transversely oval to subcircular, ventribiconvex, with radial ornamentation of numerous, delicate ribs slightly nodulose. In larger specimens, the distinct growth lines can obscure the ribbed ornamentation (see Fig. 4F). The interior of both valves is radially tuberculate (Fig. 4A, C).

Occurrence: The oldest occurrence of *Megerlia truncata* is from the Lower Oligocene of Germany (Bitner and Müller, 2022). In the Neogene, this species is well known, both in the Mediterranean province and the Central Paratethys (e.g., Gaetani and Saccà, 1985; Taddei Ruggiero, 1985,

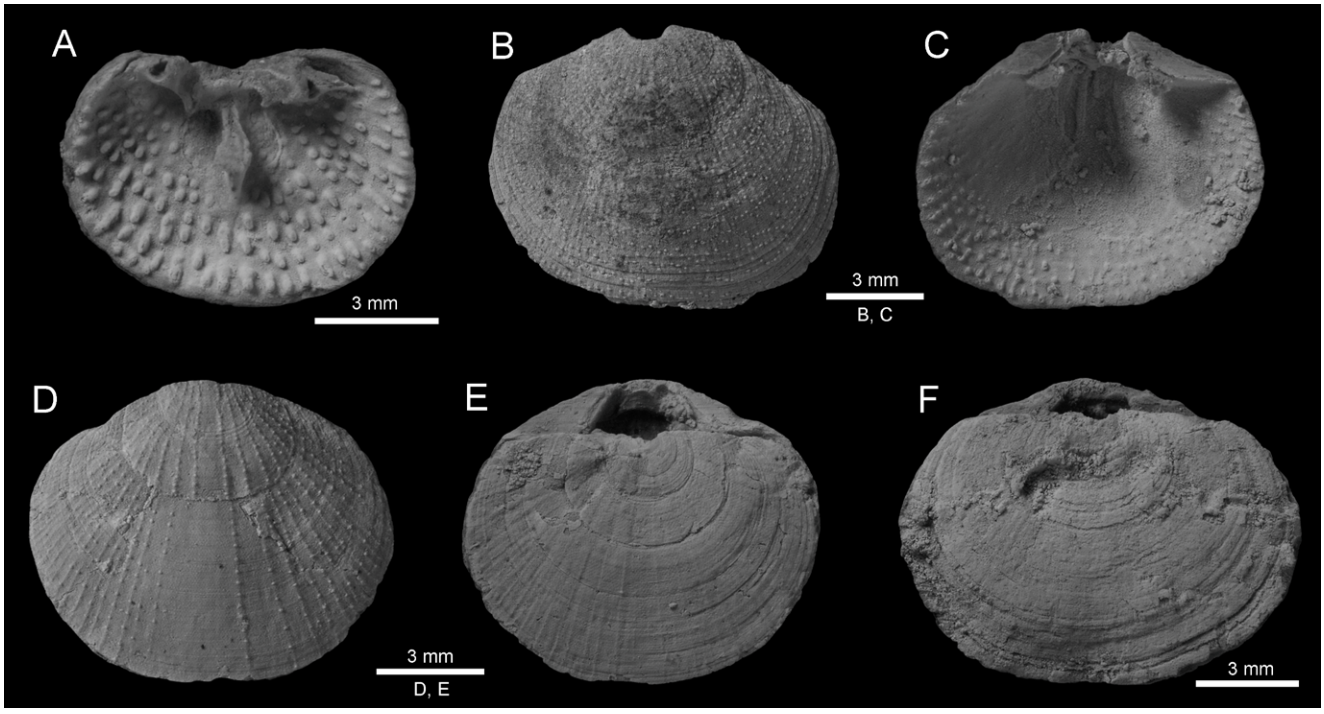

Fig. 4. *Megerlia truncata* (Linnaeus, 1767), Middle Miocene (Badenian), Moravia, Czech Republic. **A.** Inner view of dorsal valve, Borač, trench 2, sample 2a (UGV PAL Bp.03/B/12). **B, C.** Outer and inner views of ventral valve, Borač-Podolí, trench B, sample 4 (UGV PAL Bp.03/BP/03). **D, E.** Ventral and dorsal views of articulated specimen, Borač-Podolí, trench B, sample 4 (UGV PAL Bp.03/BP/04). **F.** Dorsal view of articulated specimen, Borač-Podolí, trench B, sample 2 (UGV PAL Bp.03/BP/05).

1994; Bitner, 1990; Bitner and Dulai, 2004; Dulai, 2010, 2019; Bitner and Motchurova-Dekova, 2016; Hoffmann *et al*., 2020). However, in the Moravian Miocene it is very rare, so far recorded from only two localities, Rudoltice and Kralice (Reuss, 1860; Bitner *et al.*, 2013b). Today, *M. truncata* is widely distributed, with representatives in the Mediterranean Sea and eastern North Atlantic (Logan, 2007; Álvarez, 2016; Emig, 2018), as well as in the western Indian Ocean (Bitner and Logan, 2016). Its depth range is very wide from 8 to 1,970 m (Logan, 2007; Emig, 2018).

BORINGS ON BRACHIOPOD SHELLS

Some studied brachiopod shells bear the presence of boring traces. Four shells of *Megerlia truncata* from the locality Borač display small rounded, fully penetrating drillings, ranging from 0.2 to 1.0 mm in diameter (Fig. 5A–D). They are cylindrical and straight-sided, occurring on both dorsal (three) and ventral (one) valves. They can be assigned to the ichnospecies *Oichnus simplex* Bromley, 1981. The ichnogenus *Oichnus* Bromley, 1981 is regarded as a predichnion (trace of predation; Wisshak *et al*., 2019). Although *Oichnus* is frequently associated with predatory gastropods of the families Muricidae and Naticidae, it may be also produced by other types of borers, such as nudibranchs or octopods (Young, 1969; Bromley, 2004 and references therein). The oldest examples of the ichnogenus *Oichnus* come from the late Precambrian of China (Bengtson and Zhao, 1992; Hua *et al*., 2003). Although it occurs throughout the Palaeozoic, *Oichnus* became more abundant during the Late Cretaceous with the appearance of two major boring families of gastropods, Muricidae and Naticidae (Bromley, 2004).

Three traces on fragments of *Terebratula* cf. *styriaca* shells from Borač are groups of circular pits ranging from 30 to 178 μm in diameter, covering roughly circular to oval-shaped areas, 2.2 to 3.5 mm in diameter (Fig. 5E, F). The diameter of the circular pits increases from the centre outwards and the orientation of the pits to the shell changes from a right angle to sharp angles of more peripheral penetrations. The inner side of the shell fragments bears signs of repair in the form of dome-shaped structures, ranging from 1.4 to 2.8 mm in diameter. The present authors attribute them to *Podichnus centrifugalis* Bromley and Surlyk, 1973. Ichnogenus *Podichnus* Bromley and Surlyk, 1973 is produced by pedunculate brachiopods of the orders Orthida, Rhynchonellida, and Terebratulida (Santos *et al*., 2014). *Podichnus* is regarded as a fixichnion (attachment trace; Gibert *et al*., 2004; Wisshak *et al*., 2019), occurring in calcareous and phosphatic substrates (Bromley and Surlyk, 1973; Robinson and Lee, 2008; Mergl, 2021). The oldest *Podichnus* is known from the Lower Ordovician of

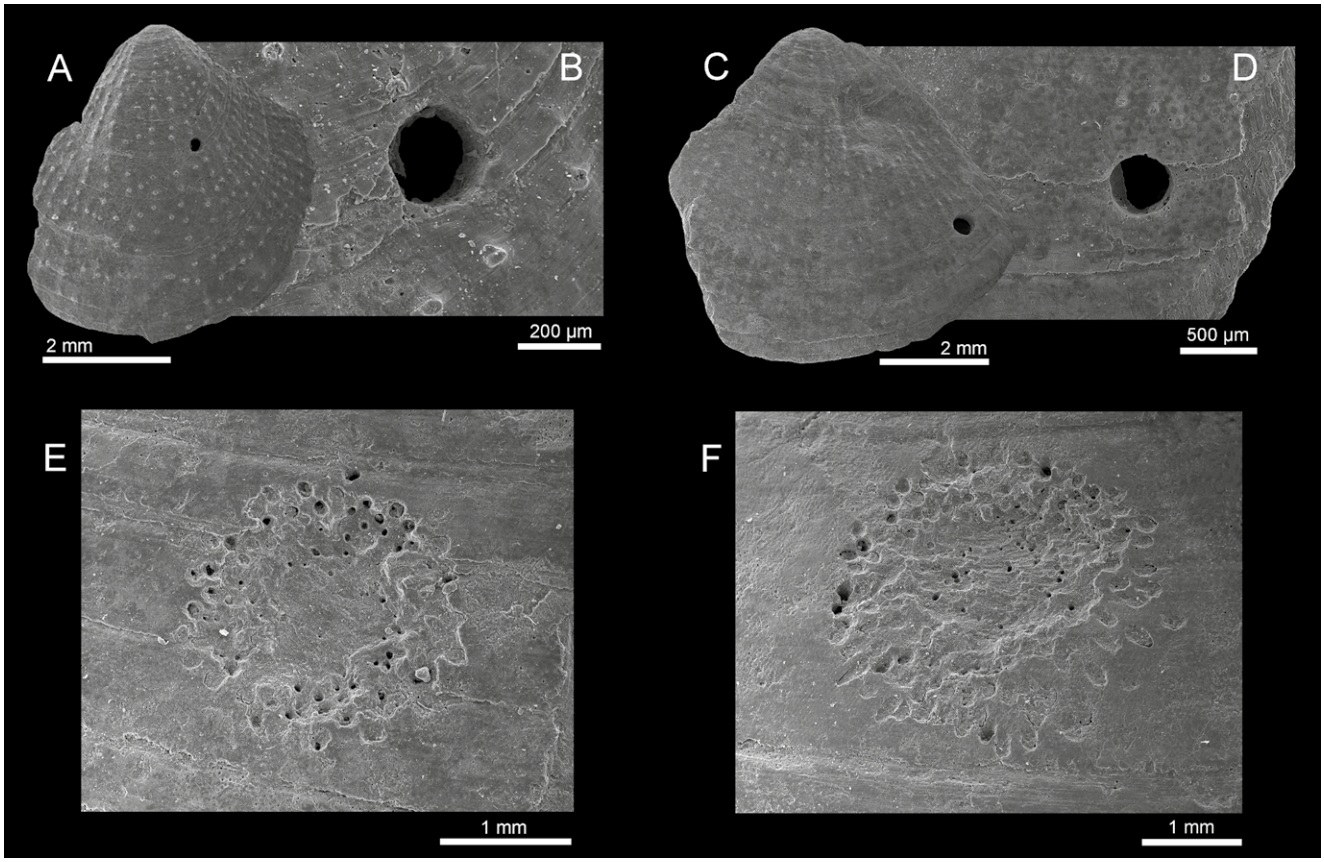

Fig. 5. Trace fossils, Middle Miocene (Badenian), Borač, Moravia, Czech Republic. **A–D.** Predatory boring *Oichnus simplex* Bromley, 1981 on *Megerlia truncata*, trench 1, sample 1b; A, B – outer view of ventral valve and enlargement (B), showing details of boring (UGV PAL Bp.03/B/13); C, D – outer view of dorsal valve and enlargement (D) of boring (UGV PAL Bp.03/B/14). **E, F.** Attachment scars *Podichnus centrifugalis* Bromley and Surlyk, 1973 on *Terebratula* cf. *styriaca* Dreger, 1889, sample 6b (UGV PAL Bp.03/B/15–16). All SEM images.

Argentina (Santos *et al*., 2014) and it occurs throughout the rest of the Phanerozoic (see Bromley, 2004; Taddei Ruggiero and Bitner, 2008).

DISCUSSION

The Middle Miocene brachiopods, collected at the localities Borač and Borač-Podolí, Moravia, Czech Republic, are of low diversity, containing four species, belonging to four genera. In species composition, however, the assemblage studied shows a considerable difference in comparison with other Moravian assemblages. All species recognised herein belong to the order Terebratulida. The large-sized, short-looped terebratulides have one representative, *Terebratula* cf. *styriaca*. Although the genus *Terebratula* was already mentioned from three Moravian localities (Zágoršek *et al*., 2012; Bitner *et al*., 2013b, 2023), for the first time the material was sufficient enough, including adult individuals, for assignment, even tentatively, to the species level. The cancellothyridid species *Terebratulina retusa* is recorded for the first time from the Miocene of Moravia. This species is relatively common in the material from the Borač locality but very rare, represented by one specimen only, at Borač-Podolí. In the Central Paratethys, *T. retusa* is rare, reported so far from Austria and Hungary (Dreger, 1889; Bitner and Dulai, 2004). Interesting is the predominance of *Megerlia truncata* in the material under study. Although one of the most common species in the Central Paratethys, *M. truncata* is rare in the Moravian part; this is its third occurrence. So far, it has been recorded only from two localities, Rudoltice and Kralice nad Oslavou (Reuss, 1860; Bitner *et al*., 2013b). The fourth species recognised in the investigated material is *Megathiris detruncata* (family Megathyrididae). This species is very rare in the material under study and was found only in the samples from the Borač locality. In Moravia, *M. detruncata* is relatively common, known from the localities Rudoltice, Přemyslovice, Kralice nad Oslavou, Židlochovice, and Oslavany (Reuss, 1860; Zágoršek *et al*., 2012; Bitner *et al*., 2013b, 2023; Pavézková *et al*., 2013). Surprising is the absence of other members of the family Megathyrididae, such as *Argyrotheca cuneata* (Risso, 1826) or *Joania cordata* (Risso, 1826), the species most frequent in Moravia, found at eight and nine localities, respectively (Reuss, 1860; Zágoršek *et al*., 2012; Bitner *et al*., 2013b, c, 2023; Pavézková *et al*., 2013; Hladilová *et al*., 2014; Kopecká *et al*., 2018). The rarity of megathyrid brachiopods might be caused by the absence of the shallow-water, cryptic habitats, preferred by this group.

Procházka (1892a) reported from Borač two brachiopod species, *Cistella squamosa* (Eichwald, 1830) and *Platidia anomioides* (Scacchi and Philippi *in* Philippi, 1844). The validity of the species *C. squamosa* is, however, uncertain. Its internal structures were neither described nor illustrated by Eichwald (1830, 1850, 1853). Nevertheless, he suggested a similarity to "*T. detruncata*", implying the attribution of this species to the genus *Megathiris* (see also discussion in Popiel-Barczyk and Barczyk, 1990). Thus, one can assume that the brachiopod recorded by Procházka (1892a) belongs to *Megathiris detruncata*, the species recognised by the authors in the material from Borač. The representatives of the species *P. anomioides* were not recognised in the material under study.

Although most living brachiopod species have very wide depth ranges (Logan, 2007) and are not considered to be good palaeobathymetric indicators, usually their optimum depth range is more restricted. Logan (1979) divided the Mediterranean brachiopods into two depth groups: shallow-water and eurybathic. Recent representatives of *Terebratulina retusa* and *Megerlia truncata* belong to a eurybathic group. In the Mediterranean Sea, *T. retusa* is most common between 200 to 300 m (Logan, 1979), while in the waters off Scotland this species is most commonly found at depths between 100 and 500 m (Curry, 1982). The species *M. truncata* is typical of bathyal zone. In turn, *Megathiris detruncata* belongs to a shallow-water group with its maximum occurrence from 60 to 160 m, preferring cryptic habitats (Logan, 1979). Little is known about palaeoecology of the extinct genus *Terebratula*. Recently, García-Ramos *et al*. (2020) investigated the palaeocommunity of *Terebratula* in the Águilas Basin, SE Spain, where this brachiopod forms shell beds in the Pliocene deposits. On the basis of the analysis of associated benthic and planktic foraminiferal and nannoplankton assemblages, they suggested that *Terebratula* thrived in relatively warm, well-oxygenated environments, at depths of 60–90 m on fine-grained sediments.

There are two types of borings observed on the studied brachiopod shells. The predichnion type is associated with muricid, naticid, and nudibranch gastropods as well as octopods (Young, 1969; Bromley, 1981, 2004). In the case under consideration, the most likely tracemakers are muricid and/or naticid gastropods, as they are common in the assemblage from Borač (Procházka, 1892a; Seitl, 1981; Pekař and Lehotský, 2015; Turek, 2018). On the other hand, tracemakers such as nudibranchs and octopods cannot be totally ruled out, as their preservation potential is very low, owing to the lack of shells and their soft-body anatomy. The etching traces *Podichnus* are a fixichnion type of bioerosion, produced by the pedicles of brachiopods. These traces are restricted to the shells of *Terebratula* cf. *styriaca*, and most probably are of conspecific origin. This is further supported by the occurrence of signs of repair on the inner sides of the shells, which means that the brachiopod host was alive during the boring activity.

CONCLUSIONS

The Middle Miocene brachiopods, described herein from two Moravian localities, Borač and Borač-Podolí comprise four species, belonging to four genera within the order Terebratulida. Among them, three species, i.e., *Terebratula* cf. *styriaca*, *Terebratulina retusa* and *Megerlia truncata*, were found at both localities, while the fourth species, *Megathiris detruncata* is absent from the material, collected at Borač-Podolí. The species *T*. cf. *styriaca* and *T. retusa* are reported for the first time from the Moravian part of the Central Paratethys. The brachiopods bear two types of trace fossils, predatory borings (*Oichnus*) and etching scars, produced by a brachiopod pedicle (*Podichnus*).

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