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The systematics and paleobiogeographic significance of Sub-Boreal and Boreal ammonites (Aulacostephanidae and Cardioceratidae) from the Upper Jurassic of the Bohemian Massif

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Abstract: Upper Jurassic marine deposits are either rarely preserved due to erosion or buried under younger sediments in the Bohemian Massif. However, fossil assemblages from a few successions exposed in northern Bohemia and Saxony and preserved in museum collections document the regional composition of macro-invertebrate assemblages and thus provide unique insights into broad-scale distribution and migration pathways of ammonites during the Late Jurassic. In this paper, we focus on the systematic revision of ammonites from the Upper Oxfordian and Lower Kimmeridgian deposits of northern Bohemia and Saxony. The ammonites belong to two families (Aulacostephanidae and Cardioceratidae) of high paleobiogeographic and stratigraphic significance. Six genera belong to the family Aulacostephanidae (*Prorasenia*, *Rasenia*, *Eurasenia*, *Rasenioides*, *Aulacostephanus*, *Aulacostephanoides*) and one genus belongs to the family Cardioceratidae (*Amoeboceras*). They show that the Upper Jurassic deposits of the northern Bohemian Massif belong to the Upper Oxfordian and Lower Kimmeridgian and paleobiogeographically correspond to the German-Polish ammonite branch with the geographical extent from the Polish Jura Chain to the Swabian and Franconian Alb. Therefore, the occurrences of ammonites described here imply that migration pathway connecting the Polish Jura Chain with habitats in southern Germany was located during the Late Oxfordian and Early Kimmeridgian in the Bohemian Massif.

Key words: Oxfordian, Kimmeridgian, Czech Republic, biostratigraphy, paleobiogeography, ammonites, Aulacostephanidae, Cardioceratidae.

Introduction

Post-sedimentional erosional processes and Cretaceous sedimentation removed or buried the Upper Jurassic deposits of the Bohemian Massif. The depositional conditions, ecosystem composition, and biogeographical affinity of this region thus remain weakly known. However, a few outcrops capturing the Upper Jurassic deposits are still exposed or fossil specimens from older outcrops are preserved in museum collections. Such findings allow us to fill the gap in distribution patterns of Upper Jurassic marine organisms. Although the first Upper Jurassic ammonites were found in the Bohemian Massif in the 1860s (Lenz 1870; Bruder 1881, 1882, 1885, 1886), the regional composition and temporal distribution of ammonite assemblages as well as their compositional relationships with adjacent geographical regions were poorly explored. In this paper, we focus on systematic revision of museum collections of two ammonite families of high biostratigraphic and paleobiogeographic significance (Aulacostephanidae and Cardioceratidae), and compare them with co-eval Tethyan and Boreal ammonite assemblages from other regions. We note that the majority of specimens in the ammonite assemblages in the Bohemian Massif, represented by Perisphinctidae, Ataxioceratidae, and Oppeliidae, will be described in a separate study.

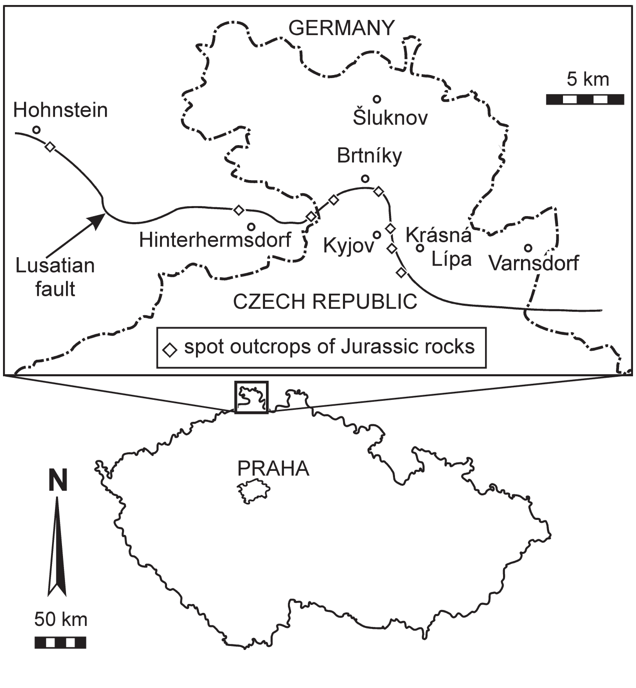

Fig. 1. Schematic map with surface outcrops of Jurassic rocks and Lusatian fault course in northern Bohemia (modified according to Kopecký et al. 1963).

In the Late Jurassic, the Sub-Mediterranean Realm was located along the northern margin of Tethys (namely the European part in the vicinity of the Mediterranean Sea — southern Spain, southern France, peri-Carpathian area and Balkan area in the east). The Sub-Boreal Realm ranged from Scotland, southern England, northern France, northern Germany, northern Poland up to the southern part of the Russian platform and Caspian area. The Boreal Realm was located north of the Sub-Boreal Realm. It was characterized by high-latitude, cold-water faunas occurring in the Canadian Arctic, Alaska, Greenland, Spitsbergen, the Barents Sea, and Siberian area (Callomon 2003).

Aulacostephanids are typical of the Sub-Boreal Realm and are used for zonal and subzonal subdivisions of the Sub-Boreal Upper Oxfordian and Kimmeridgian (Birkelund & Callomon 1985; Krymholts et al. 1988; Wright 2010). However, aulacostephanids also occur in the Sub-Mediterranean and Boreal regions. In contrast, Cardioceratids are typical of the Boreal Realm at high latitudes, and occur less frequently in Sub-Boreal and Sub-Mediterranean realms. The proposed global stratotype for the Oxfordian/Kimmeridgian (O/K) boundary, located at Staffin Bay, Isle of Skye in Scotland, is characterized by numerous aulacostephanid occurrences below and above this boundary (Matyja et al. 2006; Wierzbowski et al. 2006). This boundary is characterized by the replacement of the aulacostephanid *Ringsteadia* and *Microbiplices* by *Pictonia* and *Prorasenia*, which coincides with the first appearance of the Boreal species *Amoeboceras* (*Plasmatites*) (Wierzbowski et al. 2006; Glowniak et al. 2010; Wierzbowski 2010).

Materials and methods

This study is based on specimens known from the collections of the National Museum, Prague (NM-N), the Institute of Geology and Paleontology, Faculty of Science, Charles University, Prague (CIGP) and the State Museum of Geology and Paleontology, Dresden (SMGPD). This paper includes descriptions of 26 specimens belonging to Aulacostephanidae and Cardioceratidae, mostly coming from the Czech Republic, partly including specimens recorded in Germany. The ammonites described here were collected in the vicinity of Šluknov, Krásná Lípa, Doubice, Brtníky and Kyjov, in the former Šternberk quarry (northern Bohemia) and in Hohnstein, Saxony (Germany) (Fig. 1).

Ammonite preservation does not allow the determination of morphological characters in the majority of specimens. Sutures and other surface structures are not preserved, and determination of the body chamber and phragmocone part is hampered by poor preservation of internal moulds. Determination to a genus level is not possible in some specimens owing to strong shell deformation. However, the morphological characters of shells are sufficiently preserved in some specimens and allow comparison with aulacostephanids from Europe.

The following abbreviations are used in the 'Measurements' chapter:

D (max)	maximum diameter preserved
D (phg-ad)	diameter of fully grown individual
D (phg)	diameter of final whorl (incomplete conch)
Wh/D	ratio of height and diameter
Wt/D	ratio of thickness and diameter
U/D	ratio of umbilicus and diameter.

Geological settings

Jurassic outcrops in northern Bohemia are exposed only at several places as relicts of the epi-continental sea. These outcrops are associated with the Lusatian Fault that is responsible for overturning of successions and probably contributed to tectonic alteration and dolomitization (Eliáš 1981). Dur-

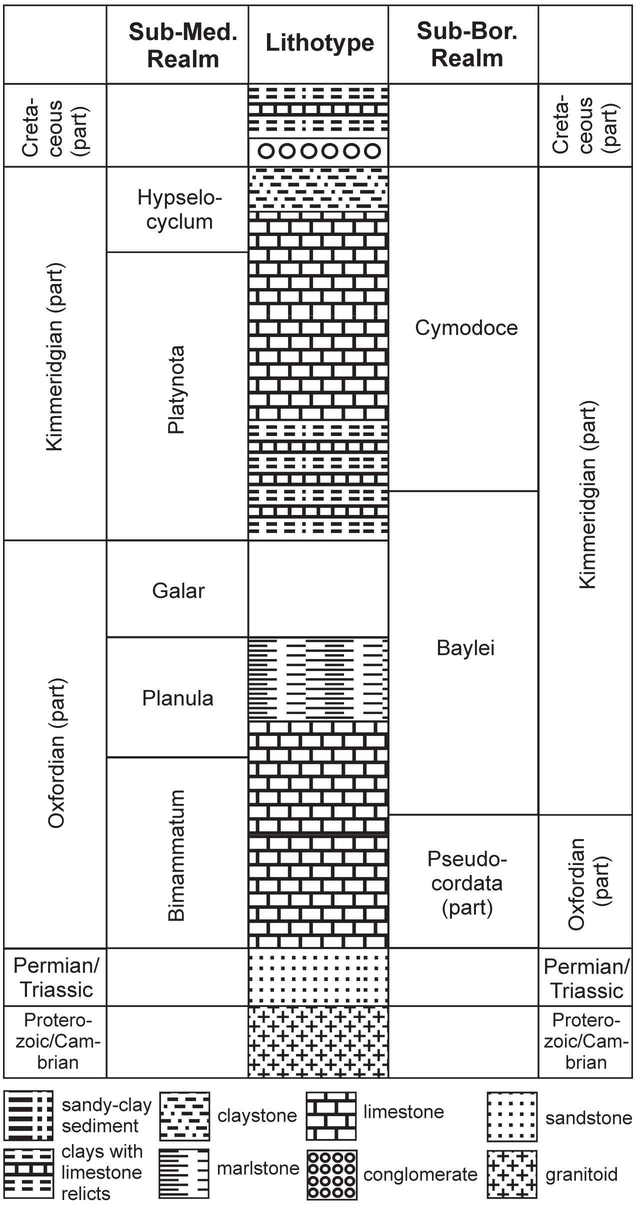

Fig. 2. The original lithostratigraphic scheme with lithotypes collected near Krásná Lípa town. Two massive limestone beds (Bimammatum and Platynota Zones) represent the most significant parts with high density of fauna (modified according to Bruder 1882, 1886).

ing the younger phase of the Saxonic tectonic event, the re-activation of the Lusatian tectonic zone pulled the Cadomian, Paleozoic and Jurassic sediments over the Cretaceous sediments.

Carboniferous and Permian sediments form the bedrock of the Middle Jurassic Brtníky Formation (Suk et al. 1984), which reaches up to 20 meters in thickness and is formed predominantly by sandy, fossil-poor clastics. The onset of sedimentation probably corresponds to the Callovian (Bruder 1881, 1882; Kopecký et al. 1963; Eliáš 1981; Chlupáč et al. 2002). The Doubice Formation overlies sandstones of the Brtníky Formation and exceeds 100 m in thickness (Kopecký et al. 1963; Eliáš 1981; Suk et al. 1984). It is predominantly formed by micritic limestones that were deposited in a deep-shelf marine environment. The lithological composition is variable, formed by interbeds of marly limestones, cherts, marls, and sandy rocks — see origin profile (Fig. 2). Carbonates are weakly to strongly dolomitized (due to influence of the Lusatian tectonic zone and the Tertiary volcanism). The Doubice Formation contains diverse fossil assemblages with ammonites, belemnites, brachiopods, bivalves, sponges, foraminifera, echinoderms, bryozoans, annelids and fish (Bruder 1881, 1882, 1885, 1886; Eliáš 1981). A relatively high abundance of sponges (also documented in limestone blocks preserved in the creek below the "Peškova stráň" locality) can imply that some assemblages correspond to sponge megafacies. However, a sedimentological analysis of Upper Jurassic facies from northern Bohemia is not possible at present due to the lack of surface outcrops.

Near Doubice, outcrops expose overturned successions that are located close to the Lusatian fault. Pešek's Hillside near Kyjov is a small-scale oucrop formed by sandy limestones, marly carbonates and micritic limestones. Sparitic limestones contain recrystallized bioclasts, mainly sponges and bivalves. Most bioclasts occur in micritic limestones (sponge spicules, brachiopods). Matrix and bioclasts (mainly bryozoans, sponges and bivalves) are characterized by extensive recrystallization. Some thin-sections show shear-like structures, possibly reflecting partial redeposition. Peloids and pellets-like structures are present (Fig. 3).

The location of coastal edge of this epicontinental sea is unknown; possibly extensive Jurassic sediments were eroded during the Early Cretaceous and at the beginning of the Late Cretaceous. However, the existence of a connection between

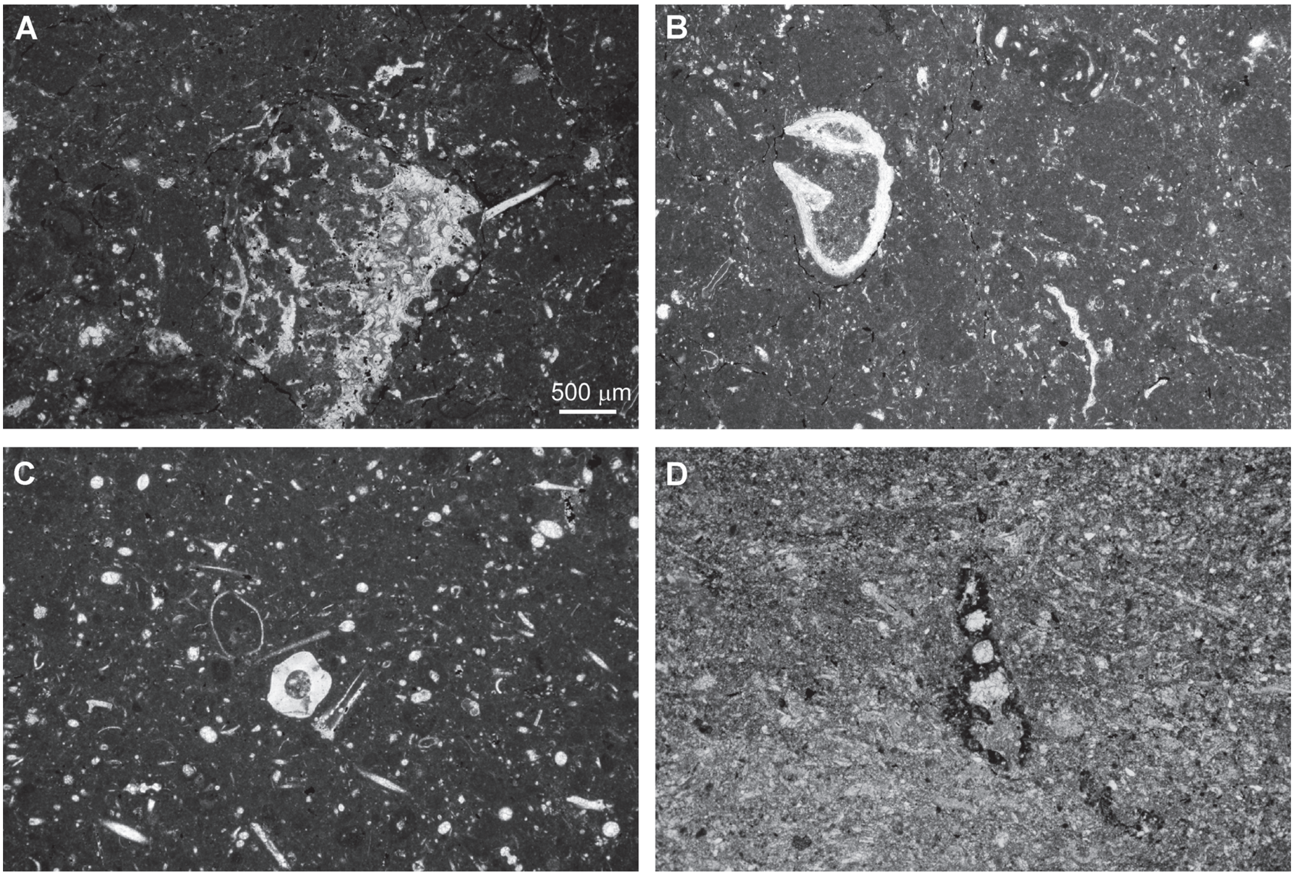

Fig. 3. Thin sections obtained from the Late Jurassic lithotypes collected from the Peškova stráň hillside near Kyjov. **A, B, C** — Micritic limestones: A, B — Predominantly almost oval-shaped peloid-like objects occur very abundantly with recrystallized organic relicts (sponges, brachiopods); C — Strongly recrystallized bioclasts in a homogeneous matrix. **D** — Calcareous-clayey siltstone. Sparitic siltstone with fragments of quartz suggests the possible contribution of terrestrial material. Recrystallized faunal relicts (bivalves, gastropods, corals, sponges) occur at a lower density in comparison with limestones. Jurassic lithotypes are characterized by similar development, but differ in degree of recrystallization.

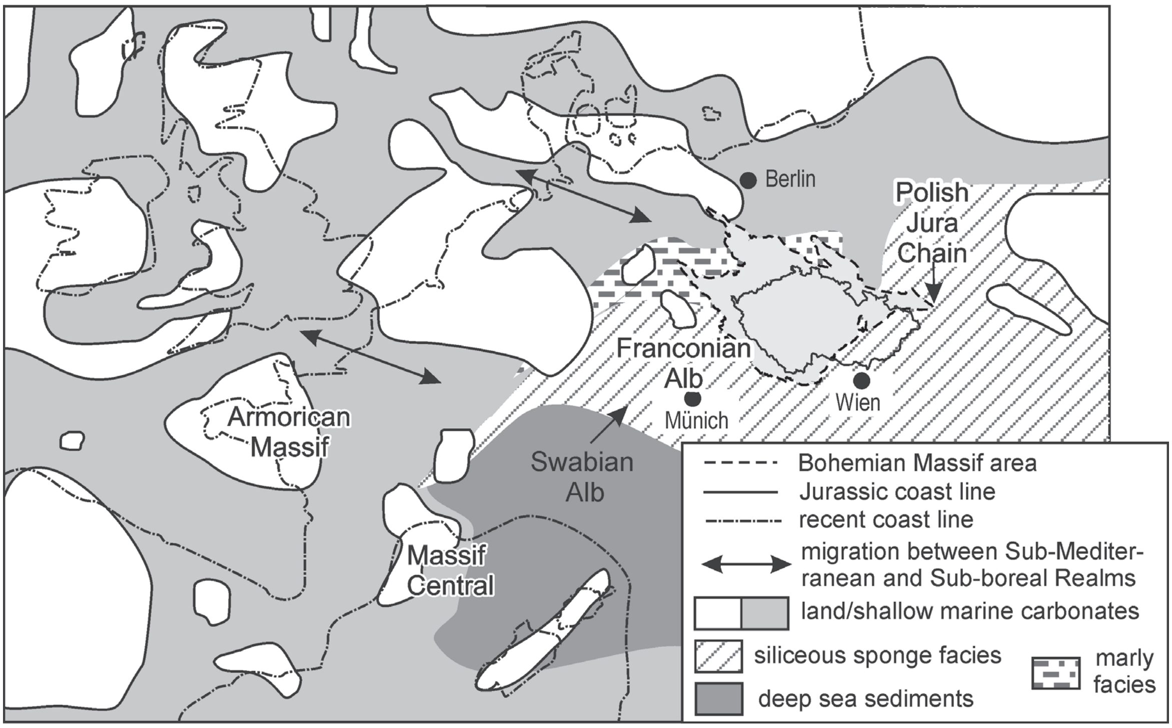

Fig. 4. Map showing paleogeographical situation in Central Europe during the Late Jurassic (modified according to Matyja & Wierzbowski 1995).

the northern Boreal Realm in the NW and the Tethyan Realm in the SE is suggested by the composition of ammonite assemblages. The marine ways, which led probably through the Paris Basin and Germany connecting the Tethyan Realm with the Boreal Realm (Fig. 4), were first opened during the Callovian (Page et al. 2009). During the Late Callovian, the Boreal sea penetrated into Bohemia from the north via the Labe zone and formed the Moravian (Saxonian) strait, which represents one of the most important migration routes in Europe during the Late Jurassic (Eliáš 1981).

Systematic paleontology

Order: **Ammonitida** Zittel, 1885
Superfamily: **Perisphinctoidea** Steinmann, 1890
Family: **Aulacostephanidae** Spath, 1924
Genus: *Microbiplices* Arkell, 1936

Microbiplices sp.
Fig. 5A

Material: NM-N55; from Šternberk quarry near Brtníky.

Measurements: NM-N55: D (phg): 28 mm; Wh/D: 0.30; Wt/D: 0.35; U/D: 0.40.

Description: Carbonate internal mould with preserved inner whorls. The umbilical part and lateral sides are not preserved. Evolute type of shell and regular rib bifurcation is typical. Umbilicus is wide. The whorl section is round to oval. Primaries have an almost radial direction. Secondary ribs cross the ventral margin fluently without fading.

Remarks: Carbonate internal mould, gently deformed. Character of ribbing and shell coiling suggests some affinity to *Microbiplices microbiplex* figured by Matyja et al. 2006, fig. 4a and *M. microbiplex* figured by Schairer 2003 (pl. 2, fig. 7, 8).

Genus: *Prorasenia* Schindewolf, 1925

Prorasenia sp.
Fig. 5B–E

Material: NM-N62/1, (fig. 5B); Šternberk near Brtníky. NM-N183 (fig. 5C); Kyjov near Krásná Lípa. NM-N56 (fig. 5D); Šternberk quarry near Krásná Lípa. NM-N62/2 (fig. 5E); Šternberk quarry near the Brtníky village.

Measurements: NM-N62/1 (No. 62): D (max): 22 mm. NM-N183; D (max): 36 mm. NM-N56; D (max): 27 mm; Wh/D: 0.23; Wt/D: 0.23, not measured. NM-N62/2; D (max): 12 mm.

Description: Evolute types of shell with low density of ribbing, only the specimen 5B shows a somewhat higher density of ribbing. Primaries regularly bifurcate, between them some ribs trifurcate, which is typical of this genus. It is visible in the specimens 5C and 5E. Ribs are typically sharp and they have almost radial direction.

Remarks: NM-N62/1: This specimen suggests a somewhat more prorsiradiate ribs than other figured specimens. It is similar to *Rasenia* cf. *hardyi* figured by Schweigert & Callomon, 1997, pl. 7, fig. 10 and *Rasenia* (*Prorasenia*) n. sp. figured by Geyer, 1961, pl. 1, fig. 8. NM-N183: Low density of ribbing suggests the similarity with the *Prorasenia* sp. fig-

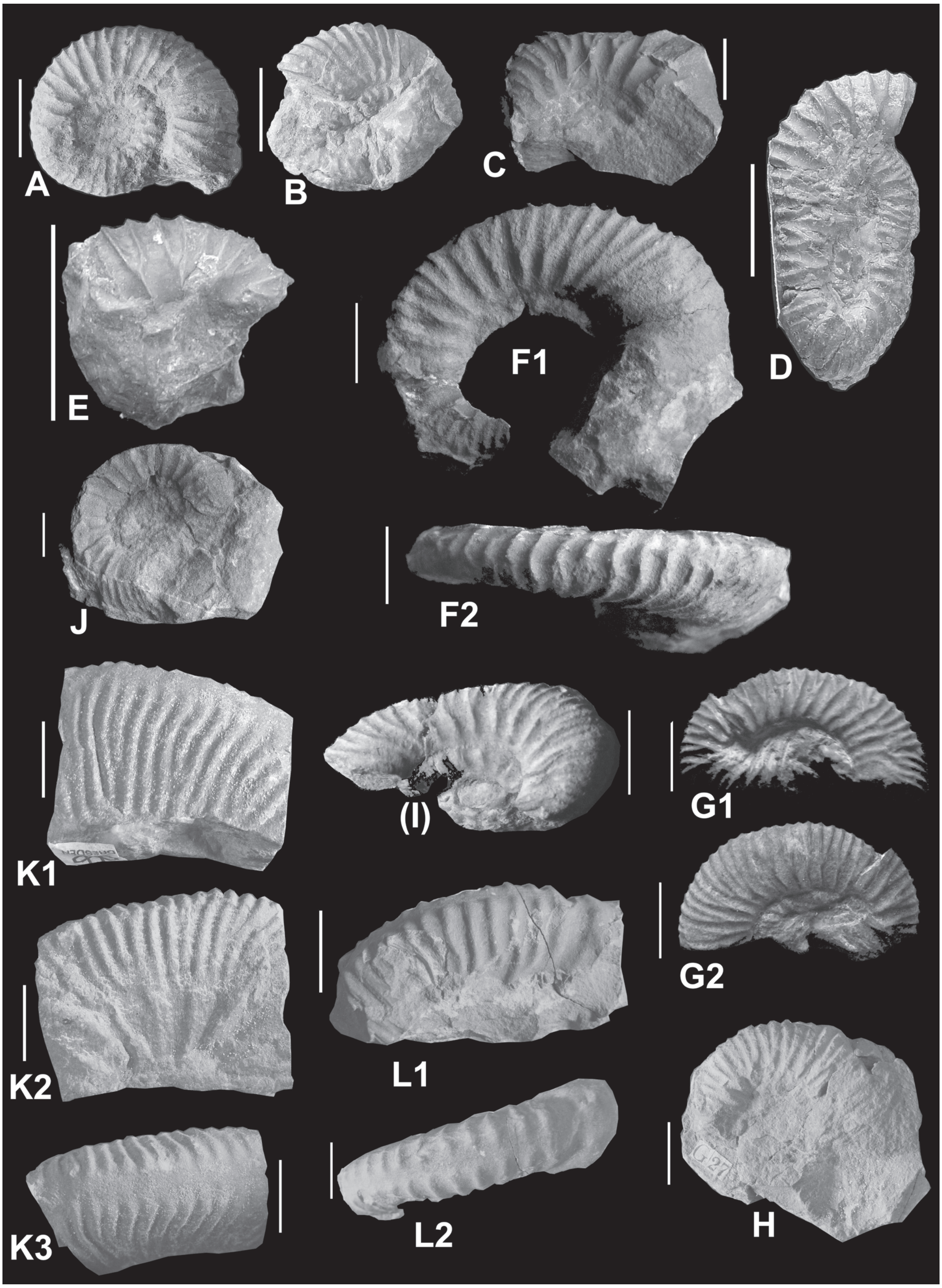

Fig. 5. Ammonites of the *Microbiplices*, *Prorasenia*, *Rasenia*, *Aulacostephanoides* and *Aulacostephanus* group. **A** — *Microbiplices* sp., NM-N55, Kyjov. **B–E** — *Prorasenia* sp.: B — NM-N62/1, Šternberk quarry; C — NM-N183, Kyjov; D — NM-N56; E — NM-N62/2, both from Šternberk quarry. **F–H** — *Prorasenia* cf. *bathyschista* Koerner: F — adult specimen; F1 — view from the right; F2 — ventral view, NM-N173, Kyjov; G1 — view from the right, G2 — view from the left, CIGP 12, Šternberk quarry; H — SMGPD CsJ 45, Doubice. **I** — *Prorasenia crenata* Quenstedt, CIGP 10506, Šternberk quarry. **J** — *Rasenia* sp. — NM-N179, Kyjov. **K** — *Aulacostephanoides* sp.: K1 — view from the left, K2 — view from the right, K3 — ventral view, SMGPD SaJ 3, Hohnstein quarry (Germany). **L** — *Aulacostephanus* sp.: L1 — view from the right, L2 — view from the left, SMGPD SaJ 15, Hohnstein quarry (Germany).

ured by Schairer, 2003 (pl. 2, fig. 12). Dichotomical and trichotomical branching of ribs is present. Both samples have similar shell size. NM-N56: Specimen is deformed and incomplete. It shows some similarity to *Prorasenia crenata* figured by Wierzbowski, 2010 (pl. 10, fig. 3, 4). NM-N62/2: One trichotomically branched rib suggests a similarity with genus *Prorasenia*. The density of ribs is not high. *Prorasenia* cf. *hardyi* figured by Schweigert & Callomon, 1997 (pl. 7, fig. 10) has somewhat stronger ribs than the specimen 5E.

Prorasenia cf. *bathyschista* Koerner, 1963
Fig. 5F–H

Material: NM-N173; (fig. 5F) Kyjov near Krásná Lípa. CIGP 12; (fig. 5G) former Šternberk quarry. SMGPD CsJ 45 (fig. 5H); Doubice village near Krásná Lípa.

Measurements: NM-N173; D (phg-ad): 47 mm; Wh/D: 0.35; Wt/D: 0.32; U/D: 0.45. CIGP 12; D (max): 33 mm; Wh/D: 0.30; Wt/D: 0.37, not measured. SMGPD CsJ 45; D (phg): 30 mm; Wh/D: 0.36; Wt/D: 0.37; U/D: 0.42.

Description: Evolute shells with a round whorl cross-section. Primary ribs are slightly prorsiradiate, secondaries bend gently backward and form S-shaped deflection.

Remarks: NM-N173: *Prorasenia* cf. *bathyschista* closely resembles the species figured by Matyja & Wierzbowski, 1998 (pl. 2, fig. 4, 5).

Prorasenia cf. *crenata* Quenstedt, 1887
Fig. 5I

Material: CIGP 10506, from Šternberk quarry.

Measurements: D (max): 35 mm; Wh/D: 0.26; Wt/D: 0.28; U/D: 0.37.

Description: Evolute coiling with the umbilical part and a round whorl cross-section. Primary ribs are gently prorsiradiate, sharp, and split into two secondaries, which have backward direction.

Remarks: The specimen is heavily deformed and the shell is incomplete. The ribbing suggests that it can belong to *Prorasenia*. The depicted specimen is of small size (less than 50 mm in diameter), similarly as *Prorasenia crenata* figured by Wierzbowski, 2010 (pl. 10, fig. 1–5). The character of ribbing is very similar in both specimens. Ribs are weaker then in *P. hardyi* figured by Schweigert & Callomon, 1997 (pl. 7, fig. 10), but the rib shape is similar in both specimens.

Occurrence: *Prorasenia crenata* occurs in the upper part of the Bimammatum Zone (the Bimammatum and the Hauffianum Subzones) and the lower part of the Planula Zone.

Genus: *Rasenia* Salfeld, 1913

Rasenia sp.
Fig. 5J

Material: NM-N179; Kyjov near Krásná Lípa.

Measurements: NM-N179; D (phg): 38 mm; Wh/D: 0.26; Wt/D: 0.26; U/D: 0.47.

Description: The character of inner whorls is reduced, ribbing is not apparent. The whorl cross-section is square-shaped up to oval with flat lateral sides. Umbilical wall is very low or absent. Primary ribs have radial direction. On the very flat ventral side, the secondaries appear with the same direction as primaries.

Remarks: Gently deformed, internal mould is cracked. Inner whorl is poorly preserved and does not allow detailed determination.

Genus: *Eurasenia* Geyer, 1961

Eurasenia sp.
Fig. 6A–C

Material: NM-N184, (fig. 6A) found in Šternberk quarry near Krásná Lípa. CIGP 16305, (fig. 6B) found in Hohnstein quarry (Germany). SMGPD SaJ 7, (fig. 6C) found in Hohnstein quarry, Germany.

Measurements: NM-N184; D (max): 175 mm. CIGP 16305; D (max): 54 mm. SMGPD SaJ 7; D (phg): 28 mm; Wh/D: 0.31; Wt/D: 0.30; U/D: 0.37.

Description: Very strong, massive and short primary ribs suggest some affinity to *Eurasenia*. Our specimens differ in the direction of ribbing. The specimen 2A has gently prorsiradiate ribs, 2B has almost radial ribs, and 2C shows slightly rursiradiate type of ribbing. Umbilicus is narrow with involute coiling of whorl. The whorl cross-section seems to be oval to square-shaped.

Remarks: NM-N184: The specimen is similar to *Rasenia* (*Eurasenia*) *pendula* figured by Geyer, 1961 (pl. 9, fig. 7). *R.* (*E.*) *frischlini* by Geyer, 1961 (pl. 18, fig. 2) is also similar to the specimen figured here. CIGP 16305: *Rasenia* (*Eurasenia*) *trimera* figured by Geyer, 1961 (pl. 9, fig. 6) seems to be very similar to the sample figured here, mainly by massive primary ribs and splitting into secondaries. SMGPD SaJ 7: Very short and massive primary ribs and their splitting is strikingly similar to *Rasenia* (*Eurasenia*) *balteata* figured by Geyer, 1961 (pl. 18, fig. 1), but differs by having more rursiradiate ribs than the specimen figured here.

Genus: *Rasenioides* Schindewolf, 1925

Rasenioides sp.
Fig. 6D–H

Material: SMGPD SaJ 12 (fig. 6D), found in Hohnstein quarry (Germany). SMGPD SaJ 24 (fig. 6E), found in Hohnstein quarry, (Germany). NM-N96 (fig. 6F), Šternberk quarry near Brtníky village. SMGPD SaJ 25 (fig. 6G), found in Hohnstein quarry, (Germany). NM-N60, (fig. 6H); Kyjov near Krásná Lípa town.

Measurements: SMGPD SaJ 12; D (phg): 29 mm; Wh/D: 0.35; Wt/D: 0.29; U/D: 0.42. SMGPD SaJ 24; D (phg): 22 mm, Wh/D: 0.35; Wt/D: 0.32; U/D: 0.28. NM-N96; D (phg): 41 mm; Wh/D: 0.32; Wt/D: 0.40 U/D: ?0.45. SMGPD SaJ 25; D (phg): 30 mm; Wh/D: 0.38; Wt/D: 0.20; U/D: 0.31. NM-N60: D (phg): 40 mm; Wh/D: 0.39; Wt/D: 0.28; U/D: 0.33.

Description: *Rasenioides* is characterized by involute type of shell with short and strong primary ribs and by high

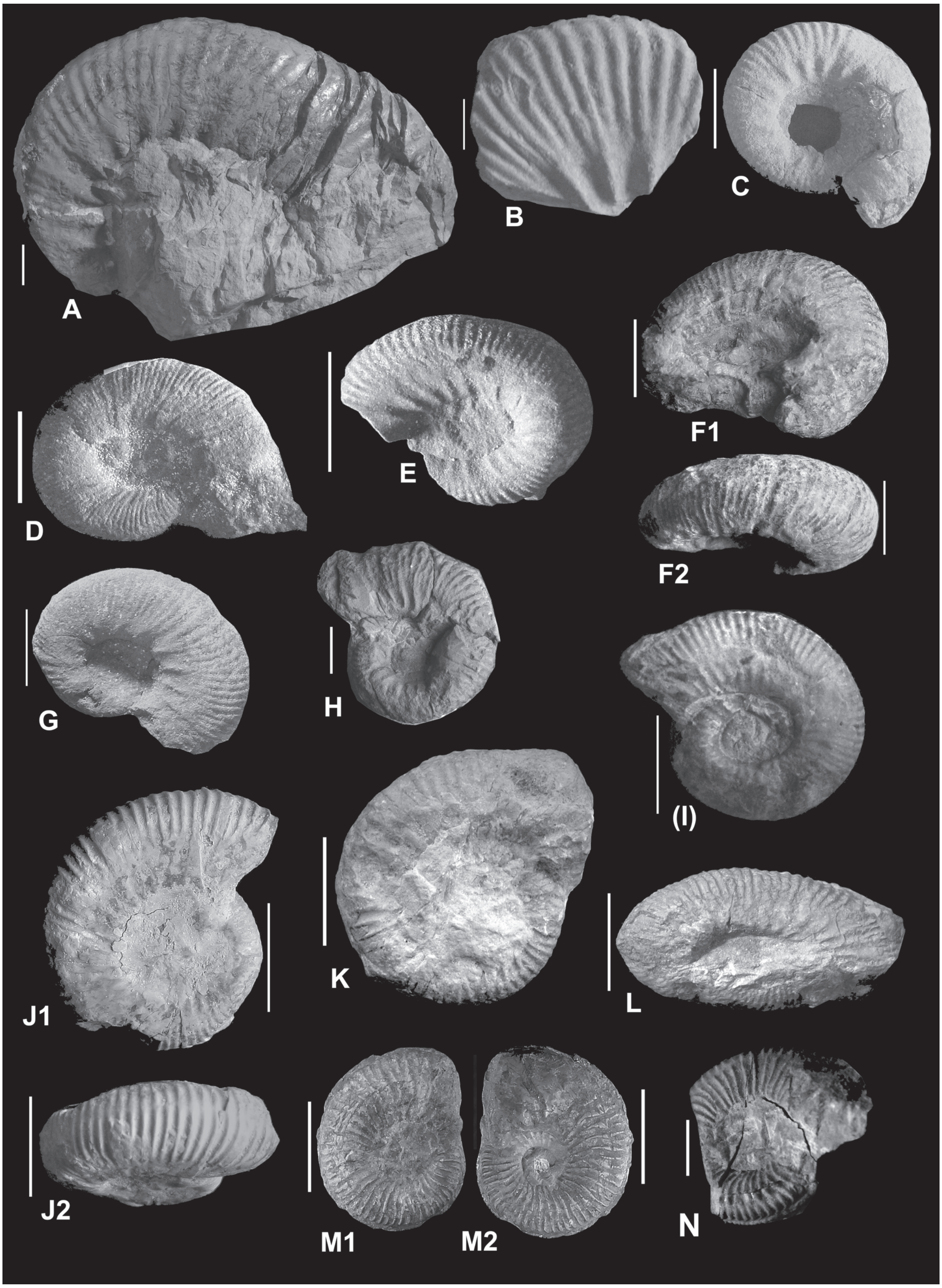

Fig. 6. Ammonites of the *Eurasenia*, *Rasenioides*, *Vielunia* and *Amoeboceras* group. **A–C** — *Eurasenia* sp.: A — NM-N184, view from the right, Šternberk quarry; B — CIGP 16305, fragment of the whorl; C — SMGPD SaJ 7, both from Hohnstein quarry (Germany). **D–H** — *Rasenioides* sp.: D — SMGPD SaJ 12, view from the right; E — SMGPD SaJ 24, view from the left, both from Hohnstein quarry (Germany); F — NM-N96, F1 — lateral view, F2 — ventral view, Šternberk quarry; G — SMGPD SaJ 25, view from the right, Hohnstein quarry (Germany); H — NM-N60, Kyjov. **I–L** — *Vielunia* sp.: I — CIGP 12651; J — NM-N172/1: J1 — view from the right, J2 — ventral view, Šternberk quarry; K — NM-N172/2; L — NM-N6, all from Šternberk quarry. **M** — *Amoeboceras ovale* Quenstedt, NM-N180: M1 — view from the right, M2 — view from the left, Šternberk quarry. **N** — *Amoeboceras* (*Plasmatites*) *praebauhini* Salfeld, CIGP 10524, Šternberk quarry.

density of secondaries. They have less prorsiradiate direction, sometimes almost radial, than primaries.

Remarks: SMGPD SaJ 12: *Rasenioides* sp. figured here resembles the *Rasenia* (*Rasenioides*) *lepidula* figured by Geyer, 1961 (pl. 8, fig. 5, 6), but the characteristics of primaries are worn away. SMGPD SaJ 24: *Rasenia* (*Rasenioides*) *paralepida* (pl. 5, fig. 10) and *R.* (*R.*) *transitoria* (pl. 1, fig. 6), both figured by Geyer, (1961) differ from this specimen figured by higher density of ribbing. A narrow umbilical part with massive last whorl is typical. NM-N96: Massive last whorl with poorly preserved umbilical part suggests the affinity to the *Rasenioides.* SMGPD SaJ 25: Poorly preserved mould similar to *Rasenia* (*Rasenioides*) *transitoria* figured by Geyer, 1961 (pl. 1, fig. 6). However, the figured specimen differs by having a more rursiradiate rib direction. NM-N60: Massive outer whorl suggests the affinity to *Rasenioides*.

Genus: *Vielunia* Wierzbowski & Glowniak, 2010

Vielunia sp.
Fig. 6I–L

Material: CIGP 12651: (fig. 6I), found in Šternberk quarry near Brtníky. NM-N172/1: (fig. 6J), collected on profile in Šternberk quarry near Krásná Lípa. NM-N172/2: (fig. 6K), collected on profile in Šternberk quarry near Krásná Lípa. NM-N6: (fig. 6L), found in Šternberk quarry near Krásná Lípa.

Measurements: CIGP 12651: D (phg): 27 mm; Wh/D: 0.32; Wt/D: 0.35; U/D: 0.33. NM-N172/1: D (phg): 26 mm; Wh/D: 0.37; Wt/D: 0.34; not measured. NM-N172/2: D (phg-ad): 25 mm; Wh/D: 0.35; Wt/D: 0.32; not measured. NM-N6: D (max): 29 mm.

Description: Involute shells with a round or oval whorl cross-section and a narrow umbilicus. Ribs have radial direction with a hint of falcoid rib type. Density of ribs is high and they are thick and blunt.

Remarks: NM-N172/1, 2: Only the last whorl shows measurable parameters. Both specimens show involute type of coiling with secondary filled umbilical area. The density of ribbing on the last whorl is high. The figured specimens resemble *Vielunia dzalosinensis* sp. nov. figured by Wierzbowski et al., 2010 (pl. 9). NM-N6: Strongly deformed mould.

Genus: *Aulacostephanoides*

Aulacostephanoides sp.
Fig. 5K

Material: SMGPD SaJ 3: found in Hohnstein quarry, Germany.

Measurements: D (max): 38 mm.

Description: A part of massive whorl with high-square whorl cross-section. Relatively short primary ribs show a low density. Secondaries have higher density and fade on the ventral margin, corresponding to the typical character of *Aulacostephanoides.*

Genus: *Aulacostephanus*

Aulacostephanus sp.
Fig. 5L

Material: SMGPD SaJ 15: found in Hohnstein quarry, (Germany).

Measurements: D (max): 70 mm.

Description: A part of whorl with typically fading ribs on the ventral margin, with a square-shaped whorl cross-section and flattened lateral sides.

Remarks: The weakening of the ribs suggests that this specimen belongs to *Aulacostephanus*.

Family: **Cardioceratidae** Siemiradski, 1891
Genus: *Amoeboceras* Hyatt, 1900

Amoeboceras ovale Quenstedt, 1849
Fig. 6M

Material: NM-N180: Šternberk quarry.

Measurements: D (phg): 18 mm.

Description: Involute type of shell. The figured specimen with partly filled umbilical part. The whorl cross-section has ellipsoid shape. The density of ribbing is high. A keel is developed on the ventral side, a typical character of *Amoeboceras*. Relicts of sutures are recognizable on the lateral side.

Remarks: The specimen figured here shows a similarity to *Amoeboceras ovale* figured by Gygi (2000), but the latter has more flattened lateral sides. This specimen also resembles *A. ovale* figured by Matyja & Wierzbowski, 1998 (pl. 1, fig. 5, 6).

Occurrence: *Amoeboceras ovale* occurs in the Regulare and Rosenkrantzi Zones in the Boreal Realm and in the upper part of the Bifurcatus Zone (Grossouvrei Subzone) up to the lower part of the Bimammatum Zone (Hypselum Subzone in the Sub-Mediterranean Realm).

Subgenus: ***Plasmatites*** Buckman, 1925

Amoeboceras (*Plasmatites*) *praebauhini* Salfeld, 1913
Fig. 6N

Material: CIGP 10524: Šternberk quarry.

Measurements: D (phg): 28 mm.

Description: Involute coiling of shell, with secondarily filled umbilical part. The specimen suggests an inversely egg-shaped whorl cross-section. A typical keel is partly well preserved.

Remarks: Gently deformed and cracked carbonate mould. Some ribs show variable direction caused by deformation. The specimen figured shows a similarity with *A. praebauhini* depicted by Atrops et al., 1993 (pl. 1, fig. 15–17). *A. bauhini* figured by Schweigert & Callomon, 1997 (pl. 1) suggests a similar deflection of ribs as the specimen figured here.

Occurrence: *Amoeboceras* (*Plasmatites*) *praebauhini* occurs in the uppermost part of the Bimammatum Zone (Hauffianum Subzone) and in the lower part of the Planula Zone in the Sub-Mediterranean Realm. In the Sub-Boreal Realm, taxon frequently occurs in the Baylei Zone (Densicostata and Normandiana Subzones) as well as in the Bauhini and Kitchini Zones (Boreal Realm).

Geographical distribution and stratigraphic ranges of Aulacostephanidae

Aulacostephanid ammonites appeared at the beginning of the Late Oxfordian and became extinct at the end of the Kimmeridgian (Page 2008). In addition to Sub-Boreal regions, Aulacostephanidae were found in some Sub-Mediterranean regions, such as southern Germany (Swabian Alb, Franconian Alb), Swiss Jura and Central Poland (Schneid 1940; Dabrowska 1984; Gygi 2000, 2003; Matyja & Wierzbowski 2002; Glowniak & Wierzbowski 2007; Hornung 2009; Moliner 2009; Glowniak et al. 2010). Species of this family were recorded also in the Boreal Realm, namely in East Greenland, Norwegian Sea shelf, Spitsbergen, Franz Josef Land, western and northern Siberia, British Columbia and Canadian Arctic Archipelago (Mesezhnikov & Shulgina 1982; Mesezhnikov 1984, 1988; Birkelund & Callomon 1985; Wierzbowski 1989). However, cardioceratids are dominant in the Boreal Realm and aulacostephanids are mostly restricted to a few stratigraphic intervals (Rogov 2012). Aulacostephanids are rare or entirely missing at most high-latitude sites, for example, in northern Siberia (Mesezhnikov 1984; Rogov & Wierzbowski 2009; Wierzbowski & Rogov 2013).

Eight aulacostephanid genera (*Microbiplices*, *Prorasenia*, *Rasenia*, *Eurasenia*, *Rasenioides*, *Vielunia*, *Aulacostephanoides* and *Aulacostephanus*) identified in the Lower Kimmeridgian associations of northern Bohemia represent new aulacostephanid occurrences in the Bohemian Massif. The replacement of *Microbiplices* by younger *Eurasenia*, *Prorasenia* or *Rasenioides* can correspond to the Oxfordian/Kimmeridgian boundary interval in the Sub-Boreal Realm (northern France, northern Germany and Great Britain — Wright 2010). In contrast, the existence of these aulacostephanid taxa indicates the Late Oxfordian in the Sub-Mediterranean Realm (German-Polish branch). Aulacostephanids appeared in Subpolar Urals during the latest Oxfordian (Mesezhnikov 1984), and during the Early Kimmeridgian became common in western and northern Siberia (Rogov & Wierzbowski 2009).

Vielunia, first described by Wierzbowski (2010), occurs in the upper part of the Bimammatum Zone and continues into the Planula Zone, corresponding to the lowermost Kimmeridgian in the Sub-Boreal and Boreal regions. The genus *Rasenia* and related genera (i.e. *Prorasenia*, *Eurasenia*, and *Rasenioides*) found in the Bohemian Massif belong to Sub-Boreal ammonites. *Rasenia* has a relatively broad geographical range, covering Greenland, Spitsbergen, the Norwegian Sea, Franz Josef Land, western Siberia, northern Siberia, Great Britain, France, Germany, Poland, Russian Platform, British Columbia and Arctic Canada (Tornquist 1896; Schneid 1940; Birkelund et al. 1978, 1983; Callomon & Birkelund 1980; Mesezhnikov 1984; Birkelund & Callomon 1985; Matyja et al. 2006; Wierzbowski et al. 2010). Therefore, aulacostephanids from northern Bohemia and Saxony thus seem to have a close relationship with ammonites representing the Sub-Mediterranean branch frequently occurring in southern Germany and Poland.

Aulacostephanoides and *Aulacostephanus* belong to the youngest genera of the family Aulacostephanidae described here. *Aulacostephanus* was recorded in Sub-Boreal and Boreal Realm as well as in some Sub-Mediterranean regions. It occurs in France, Great Britain, Switzerland, Germany, Norway, East Greenland, Russian Platform, western and northern Siberia (de Loriol 1874; Ziegler 1962; Birkelund et al. 1978, 1983; Mesezhnikov 1984; Callomon & Birkelund 1985).

Geographical distribution and stratigraphic ranges of Cardioceratidae

The Cardioceratid genus *Amoeboceras* was described from the Barents Sea, the Norwegian Sea shelf, Spitsbergen, western Siberia, northern Siberia, Russian Platform, and East Greenland, (Sykes & Callomon 1979; Birkelund & Callomon 1985; Wierzbowski & Smelror 1993; Wierzbowski et al. 2002; Meledina 2006; Rogov & Wierzbowski 2009; Glowniak et al. 2010; Rogov 2010), as well as from Scotland, northern and central Poland, southern Germany, and Switzerland (Matyja & Wierzbowski 1994, 2002; Schweigert & Callomon 1997; Gygi 2000; Matyja et al. 2006; Wierzbowski et al. 2010). The occurrence of *Amoeboceras* in northern Bohemia corresponds to the equatorward migration of Boreal ammonites close to the Oxfordian/Kimmeridgian boundary. In the Polish Jura Chain and in southern Germany, *Amoeboceras* (*Plasmatites*) *praebauhini* appears in the upper part of the Sub-Mediterranean Bimammatum Zone (Hauffianum Subzone) and continues into the Planula Zone. This stratigraphic range correlates with the Early Kimmeridgian Baylei and Bauhini Zones in Sub-Boreal and Boreal regions. *A. ovale* represents an older species occurring during the Late Oxfordian and stratigraphically precedes *Amoeboceras* (*Plasmatites*) *praebauhini*.

Discussion

Ammonite assemblages sharing many species in common occur in the Polish Jura Chain, Holy Cross Mountains, Swabian Alb and Franconian Alb (Wierzbowski 1978; Malinowska 1991; Schweigert & Callomon 1997; Matyja & Wierzbowski 2000, 2002; Wierzbowski et al. 2010). Ammonites occur in deep neritic sponge megafacies in the Polish Jura Chain as well as in southern Germany, and in more shallow deposits of the carbonate platform of the Holy Cross Mts. The connection between Poland and Germany that crossed the Bohemian Massif is assumed to have been active during the Late Jurassic (Matyja & Wierzbowski 1995, 2002; Schairer & Schlampp 2003). The connection between these two areas enabled a migration of Boreal and Sub-Boreal ammonites across the Bohemian Massif southward to the Tethyan Realm at the Oxfordian/Kimmeridgian transition (Atrops et al. 1993; Matyja & Wierzbowski 1994, 2000). Temporal proximity and lithological similarity of the Late Jurassic sediments in the North Bohemian and Moravian areas (i.e. Brno vicinity, Olomučany village, etc.) evokes the possibility of a paleogeographic connection between both regions. However, the direct evidence is still missing because no Jurassic sediments are preserved between these regions.

Conclusions

The Upper Jurassic marine deposits in northern Bohemian Massif are rarely preserved and limited to a few small outcrops, being mostly covered by Cretaceous and Tertiary deposits. The stretched fault system associated with the Lusatian Fault, reactivated multiple times, does not allow a discrimination of the original character of shelf and basinal deposits. However, ammonites recovered from a few outcrops and preserved in museum collections allow taxonomic determinations and have implications for paleobiogeographic pathways during the Late Jurassic. Aulacostephanid ammonites suggest that the Late Jurassic carbonates belong to the Upper Oxfordian and the Lower Kimmeridgian.

1. The appearance of typical Lower Kimmeridgian Boreal and Sub-Boreal assemblages in northern Bohemia, represented by *Prorasenia*, *Rasenioides* or *Eurasenia,* marks the Oxfordian/Kimmeridgian boundary.

2. With the exception of *Prorasenia bathyschista* Koerner figured by Bruder in 1882, ammonites of family Aulacostephanidae are described for the first time from the northern Bohemian Massif.

3. The presence of Boreal and Sub-Boreal taxa in the northern Bohemian Massif probably reflects the equatorward migration of cold-water ammonites close to the Oxfordian/Kimmeridgian boundary. Taxa occurring in northern Bohemia show affinity to those occurring in the Polish Jura Chain and southern Germany. This supports the presence of a marine connection between Poland and Germany across the Bohemian Massif (Matyja & Wierzbowski (1995).

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