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Early Cretaceous duvaliids (Belemnitida: Mollusca) of the Rarău Syncline (Eastern Carpathians, Romania)

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Abstract

The present paper focuses on the Early Cretaceous duvaliids of the Rarău Syncline, including the recently-sampled specimens from the grey marly matrix of the so-called "Gura Sadovei Breccia" and the previously-described ones from the "I. Turculeț" Collection (Museum of Paleontology, "Alexandru Ioan Cuza" University of Iași).
So far, the duvaliids of the Rarău Syncline indicate two main time span groups, namely latest Berriasian – earliest Valanginian (from the "Gura Sadovei Breccia"), and Hauterivian – Barremian (from the wildflysch deposits). The oldest include the following taxa: *Duvalia lata* morph div., *D.* aff. *haugi*, *D.* ex. gr. *miravetesensis*, *Duvalia* sp.1., and the younger *D. dilatata*, *D.* ex. gr. *dilatata*, *D. binervioides*, *Duvalia* sp. 2, and ?*Curtohibolites* sp. Several previous determinations have been updated.
The duvaliids include mainly mature specimens, with few juvenile ones occurring. There are both well-preserved and fragmented rostra, but few internal moulds were observed. The reworking of records in the "Gura Sadovei Breccia" can be advocated given the frequent fragmentation and small clasts intruded in the rostrum, or in the phragmocone/phragmocone filling. Sometimes, fine diaclases filled with calcite cross the specimens.
The various rocks of different ages and sizes, all randomly oriented, suggest a fissure-fill breccia along the fault which crosses the "*Aptychus* Beds" anticline in the outcrop.

Keywords: "*Aptychus* Beds," *Duvalia*, "Gura Sadovei Breccia," Berriasian-Valanginian, wild-flysch, Hauterivian-Barremian.

1. Introduction

Turculeț (1968, 1971) listed and figured the richest Cretaceous belemnite fauna from the Rarău Syncline, collected from two main outcrops: the marly matrix of the "Gura Sadovei Breccia" (between the Sadova and Pojorâta localities – outcrop 1,

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Fig. 1) and the Hauterivian wildflysch unearthed by the Izvorul Malului stream (Câmpulung Moldovenesc – outcrop 2, Fig. 1). Additionally, an incomplete specimen was collected from the wildflysch cropping out near Peciștea Hill, within the Pojorâta area (outcrop 3, Fig. 1).

The same year, Mutihac (1968: p. 50) quoted *Duvalia dilatata* from the anticline of the so-called "*Aptychus* Beds" (named Flyschoid Series by the author), placed in tectonic contact with the "Gura Sadovei Breccia" within the same geological section between the Sadova and Pojorâta localities. However, the author never described or illustrated the specimen.

Recent sampling of new specimens from the marly matrix of the "Gura Sadovei Breccia" has led to an overview of the duvaliids collected so far from the Early Cretaceous rocks of the Rarău Syncline.

2. Geological framework

The Rarău Syncline extends into the north-central part of the Eastern Carpathians, which represents a folded and faulted sector of the Romanian Carpathians (Fig. 1A). More specifically, the syncline belongs to the Mediane Dacides *sensu* Săndulescu (1984) or, informally

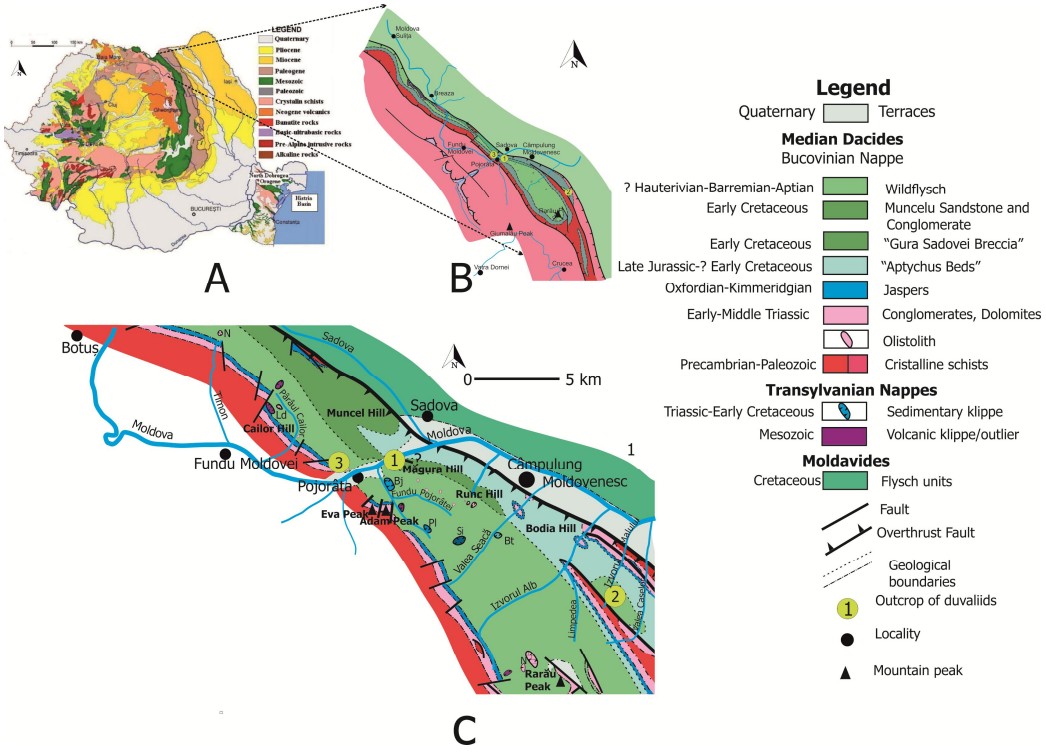

Fig. 1 Geological sketch of the central-southern part of the Rarău Syncline (A – after IGG; B – after Bercia et al., 1967; C – after Turculeț, 1971). 1 – outcrop of the "Gura Sadovei Breccia"; 2 – outcrop of the wildflysch on the Izvorul Malului stream; 3 – outcrop of the wildflysch within the Pojorâta locality (Moldova river Valley). Klippen ages: Ld – Ladinian; N – Norian; Bj – Bajocian; Bt – Bathonian; Pl – Pliensbachian; Si – Sinemurian.

the Crystalline Mesozoic Zone, being the northernmost tectono-structural unit with Mesozoic sedimentary rocks of the "Outer Marginal Syncline" *sensu* Uhlig (1907).

Two kinds of nappes built the syncline during the Alpine orogenesis (e.g. Săndulescu, 1984): the autochthonous or the Bucovinian nappes (the former "Bucovinische Decke" – Uhlig 1907) and the allochthonous or the Transylvanian nappes (the former "Siebenbürgische Decke" – Uhlig 1907). The Bucovinian nappes (from the bottom to top divided into Infrabucovinian, Subbucovinian and Bucovinian s. str.) have a metamorphic basement formed in the Variscan Orogeny and involved in the Alpine tectonics, overlain by a sedimentary cover of Early Triassic – Early Cretaceous age. The Transylvanian nappes of the same Early Triassic-Early Cretaceous ages (Perşani Nappe, Olt Nappe, and Hăghimaş Nappe *sensu* Săndulescu 1984) are documented by klippen and exotic blocks of sedimentary and volcanic rocks of various sizes, floating within the autochthonous Early Cretaceous wildflysch. The volcanic klippen/outliers are supposed to be fragments of the former seafloor of the Mureş-Vardar Ocean, and the sedimentary klippen were formed originally in the same ocean, during the Triassic-Early Cretaceous seafloor spreading.

More recently, Hoeck et al. (2009) proposed a different Alpine geodynamic evolution involving the presence of Meliata oceanic crust remnants in the Eastern Carpathians, but this model has not been completely accepted by Romanian geologists as of date.

The Early Cretaceous successions of the Rarău Syncline have been studied since the late 19th century by various researchers (for a detailed historical overview see Kräutner, 1930; Ilie, 1957; Popescu and Patrulius, 1964; Mutihac, 1968; Turculeţ, 1971), being assigned in the second half of the last century to both the autochthonous Bucovinian and the allochthonous Transylvanian nappes.

The autochthonous Cretaceous rocks were mapped only on the eastern syncline flank (e.g. Turculeţ, 1971). Generally, it should be noted that the lithostratigraphy of the Mesozoic sedimentary successions of the Mediane Dacides (Rarău, Hăghimaş/ Hăşmaş and Perşani areas) is not yet formalised due to various reasons that fall out of the scope of the present paper. Consequently, for the moment, we suggest the use of the following informal succession of terms for the autochthonous Cretaceous of the Rarău Syncline: "*Aptychus* Beds", "Gura Sadovei Breccia", and "Muncelu Sandstone and Conglomerate", followed by wildflysch.

As mentioned above, the age of the topmost part of the "*Aptychus* Beds," which is in contact with the breccia body between Sadova and Pojorâta (Gura Sadovei neighborhood), has long since been a matter of discussion. Mutihac (1968: p. 50) has assigned it to the Berriasian and in part to the Valanginian, but Turculeţ (1963, 1968: p. 84) acknowledged a Berriassian age only with a question mark.

The allochthonous Cretaceous rocks are only known as isolated klippen embedded within the Early Cretaceous wildflysch of the Bucovinian Nappe.

2.1 Historical overview of the "Gura Sadovei Breccia"

The first reference to the "Gura Sadovei Breccia" can probably be attributed to Mutihac (1966), who noted sev-

eral blocks of the Hallstatt facies-type within the "Muncelu Sandstone and Conglomerate." Later, Turculeț (1963, 1968) and Mutihac (1968, 1969) focused on the age of the breccia and the "Muncelu Sandstone and Conglomerate," as well as on their relationship with the subjacent "*Aptychus* Beds."

Turculeț (1963) described the Boreal ammonite *Polyptychites* cf. *quadrifidus* (von Koenen 1902), as well as two very small *Lamellaptychus* specimens from a sandstone bed near the old crusher of the Piatra Străjii-Pojorâta Quarry ("Muncelu Sandstone and Conglomerate"), advocating a Valanginian age for this informal unit.

Later, Turculeț (1968: pp. 80–81) noted the lithological variety of the breccias, which yield reworked Triassic-Jurassic taxa. From a level which "does not belong to any reworked rocks," the author listed a supposed Valanginian belemnite fauna including: "*Duvalia lata* (Blainv.), *Duvalia lata* (Blainv.) var. *constricta* Uhlig, *Duvalia urnula* (Duval), *Duvalia* sp., and *Pseudobelus bipartitus* (Blainv.)". Accordingly, the "Gura Sadovei Breccia" (Middle-Late Valanginian) and the "Muncelu Sandstone and Conglomerate" (Valanginian) are nearly comparable in age. Moreover, given the fact that within the breccia body lithological blocks of the "*Aptychus* Beds" have been found, Turculeț (1968) considered the breccia event as a result of the "Muncelu Sandstone and Conglomerate" transgression over the "*Aptychus* Beds." Consequently, between the late Jurassic of the "*Aptychus* Beds" (Late Oxfordian-Kimmeridgian-Tithonian) and the Valanginian of the "Gura Sadovei Breccia" – "Muncelu Sandstone and Conglomerate" there is a sedimentation gap corresponding at least to parts of the Berriasian (Turculeț, 1968).

In the same paper, "*Duvalia dilatata* Blainv., *Curtohibolites orbignyanus* (Duval.), *Mesohibolites* aff. *subfusiformis* (Rasp.)" were listed from the wildflysch cropping out on the slope of the Izvorul Malului stream, while *Duvalia binervia* (Raspail) and the ammonite *Holcophylloceras* cf. *calipso* (d'Orbigny) were listed from a wildflysch outcrop near Peciștea Hill, within the Pojorâta area (Moldova River Valley, Fig. 1).

Mutihac (1968) pointed out that *Polyptichites* cf. *quadrifidus*, signaled by Turculeț (1963) as index taxon for the age of the "Muncelu Sandstone and Conglomerate," was collected from the channel deposits of Moldova River, and there is no accurate host-level related to these rocks. Moreover, based on the calpionellid fauna from the Valea Seacă stream (Filipescu and Dragastan, 1963) and the aforementioned record of *Duvalia dilatata* sampled from the "*Aptychus* Beds" anticline of Gura Sadovei, Mutihac (1968) assigned the end of this informal unit to the Berriasian – early Valanginian. Regarding the breccia, Mutihac (1968: fig. 9, p. 49) delineated it by two faults within the "*Aptychus* Beds" succession, supposing a continuous sedimentation between the "*Aptychus* Beds" and the "Muncelu Sandstone and Conglomerate".

Subsequently, Avram et al. (1998) reassigned the ammonite specimen described by Turculeț (1963) to *Polyptichites* cf. *michalskii* (Bogoslowsky, 1902) in a paper dealing with the Boreal immigrants in the Valanginian of the Romanian Carpathians. The authors placed the breccia at the base of the "Muncelu Sandstone and Conglomerate" as "first level of this lithostratigraphic unit" (Avram et al., 1998: pp. 29–30).

The recent finding of a Tethyan ammonite specimen (*Olcostephanus (Olcosptephanus) guebhardi* Kilian, 1902) in the "Muncelu Sandstone and Conglomerate" has provided the opportunity to put several general observations on the Early Cretaceous rocks (Bucovinian Nappe) of the eastern syncline flank into a new perspective (Ţibuleac, 2012). It should be noted that the belemnite fauna was not studied in that paper, being used only for its biostratigraphical constraints, as the final conclusion concerning the "Gura Sadovei Breccia" was: "neither the accurate age..., nor its stratigraphic position in relation to the 'Muncelu Sandstone and Conglomerate' is clear".

2.2 Geological setting

The studied outcrop is situated in the central part of the Rarău Syncline, on the right bank of the Moldova River, between the Sadova and Pojorâta localities (Gura Sadovei neighborhood), within the natural reserve located near the Suceava-Vatra Dornei railway segment and the National Road DN17 (Fig. 1C).

The "Gura Sadovei Breccia" comprises various rocks of both the authochthonous and allochthonous nappes (Turculeţ, 1968; Ţibuleac, 2012), such as crystalline schists, Triassic dolomites and grey, dark-grey limestone with brachiopods, Early – Middle Jurasic limestone and coarse sandstones with belemnites, red japers (Callovian – Oxfordian), red clayey limestone and marls of the "*Aptychus* Beds," including *Aptychus* specimens (Late Jurassic – ?Early Cretaceous) etc. The size of the clasts varies largely from over one meter ("*Aptychus* Beds" block) to centimeters, while the marly and silty matrix prevails over cement.

It crops out along presumably 11–12 m steep cliffs, with tectonic contact with the recumbent anticline of the "*Aptychus* Beds" (Ţibuleac, 2012). Apparently, it passes laterally into the "Muncelu Sandstone and Conglomerate," but the contact cannot be examined in the field because of the absence of suitable outcrops.

This breccia yields small blocks of various limestones with belemnites, brachiopods, aptychi, and bivalves of various age. Rostra of belemnites can be encountered, generally, however, only as fragments, either in the cemented breccia or the matrix. In the debris found on the slope one can also collect fragments of belemnites and aptychi. Repeated field observations allowed the sampling of several well-preserved *Duvalia* rostra, as well as fragments of indet. rostra, and a few aptychi from the marly matrix from where the previous fauna has been collected (Turculeţ, 1968). A limited number of *Duvalia* specimens have been gathered from the cemented breccia up to the present day (e.g. Pl. II, Fig. 4a). Turculeţ (1968) also illustrated a specimen bound together with few lithoclasts by a recrystallized calcite (pl. III, fig. 1).

The second main outcrop (Izvorul Malului – Câmpulung Moldovenesc) mentioned by Turculeţ (1968) was not identified during our field trips because of the lack of detailed references as to its location and the scarcity of the outcrops. Also, the rare outcrops of the wildflysch along the Moldova River Valley within the Pojorâta locality did not yield any fossil specimens during these trips.

3. Material and methods

The specimens herein described have two sources: 1) the recently-collected re-

cords from the above-mentioned marly matrix, and 2) the fauna listed and illustrated by Turculeț (1968, 1971).

The "I. Turculeț" Collection is housed in the Museum of Paleontology (original collections) of the Department of Geology of the "Alexandru Ioan Cuza" University of Iași (= MP-UAIC) with the inventory numbers MR 114–116, 118, and MR 124–126. To be more precise, the previous labelling was detailed in relation to the plates (Turculeț, 1968): MR 114, 115... – number in the collection including several specimens of the same species; I, II, III – plate numbers; 1, 2... – figure on the plate; the recent records (MR 129–140) are stored within the collections of the Department of Geology at UAIC (see Appendix). The specimen "*Pseudobelus bipartitus* (Blainv.)" was not found in the MP-UAIC.

The terminology and taxonomy herein used follows: Jeletzky (1966), Doyle and Kelly (1988), Riegraf et al. (1998). The cross-sections were made only on the recently-collected and more complete rostra. On the *Duvalia* sp. described in the paper by Turculeț (1968: p. 81, Pl. II, Fig. 3), reassigned here as *D.* aff. *haugi* (see below), the cross-section was performed during the initial work.

Individual descriptions include size measurements of the more complete specimens. All measures are in millimetres. Estimated values for incomplete specimens are marked by an asterisk (*). The biometric parameters used (after Schwetzoff, 1913; Doyle and Kelly, 1988) are: Lm = maximum length of the specimen; Ddv = dorso-ventral diameter; Dl = diameter between lateral sides (Ddvmax, Dlmax = maximum values; Ddva, Dla = values measured on the alveolar cross-section); Ic = compression index = the ratio between Dvd and Dl (Icm = calculated at the level of Ddvmax; Ica = calculated at the alveolar cross-section); Dph = diameter of the phragmocone/phragmocone opening; lg = length of the alveolar groove; la = estimated length of the apical part. A compressed rostrum represents the lateral flattening assessed by Icd > 0, and a depressed rostrum means a dorso-ventral flattening (Icd < 0).

Generally, taking into account the incomplete rostra, the biometric data of the duvaliid fauna of the Rarău Syncline (see Appendix) are only indicative.

4. Paleontology

Two tendencies can be traced in the papers that deal with duvaliid taxa: 1) to consider all the subspecies of *D. lata* (*D. lata lata, D. lata constricta, D. lata zeugitana*) as morphological varieties (e.g. Combémorel, 1973; Janssen, 1997; Thomel and Picollier-Thomel, 2015), and 2) to preserve some of these morphs as distinctive subspecies (e.g. Vašíček et al., 1994; Janssen, 2003; Főzy et al., 2010). In our opinion, the first point of view would be more reasonable, since these taxa can be found in the same outcrop and they do not represent paleogeographic varieties, as already noted by Combémorel (1973), Doyle and Mariotti (1991), Janssen (1997, 2003). On the other hand, Doyle and Mariotti (1991) and Vašíček et al. (1994) maintain as distinctive morphs only *D. lata lata* and *D. lata constricta*, representing the so-called "end members" of the transitional morph series.

Herein, we will follow the first tendency by treating all the subspecies as morphological varieties of *Duvalia lata*.

Phylum Mollusca LINNÉ, 1758
Class Cephalopoda CUVIER, 1794/1797
Subclass Coleoidea BATHER, 1886/1888
Order Belemnitida MacGILLIVRAY, 1840
Suborder Belemnitina MacGILLIVRAY, 1840

Family Duvaliidae PAVLOW, 1914
Genus *Duvalia* BAYLE, 1878

Type-species: *Belemnites dilatatus* Blainville, 1827

Duvalia lata (Blainville, 1827) s.l. (= morph div.)
Pl. I, Fig. 1–9, Pl. II, Figs. 1–9.

1827 *Belemnites latus* de Blainville, p. 121, 136, pl. 5, figs. 10, 10a, 10b.
1840 *Belemnites latus* de Blainville. d'Orbigny, pp. 48–50, pl. 4, figs. 4–8.
1902 *Belemnites (Duvalia) lata* (de Blainville) var. *constricta* Uhlig, pp. 18-19, pl. I, fig.4.
1907 *Belemnites (Duvalia) latus* de Blainville. Lemoine, pp. 114–114a, figs. 10-b, H-Hb, T-Ta.
1964 *Duvalia lata* (de Blainville). Fülöp, pl. XII, fig. 10.
1965 *Duvalia lata* (de Blainville). Stoyanova-Vergilova, pp. 184–185, pl. I, figs. 1–3.
1965 *Duvalia lata constricta* (Uhlig). Stoyanova-Vergilova, pp. 185–186, pl. VIII, figs. 3–4.
1968 *Duvalia lata* (Blainv.). Turculeț, pl. I, figs. 2, 4. (= Turculeț, 1971: p. 119, pl. XXXVII, fig. 2, pl. XXXVIII, fig. 1)
1968 *Duvalia lata* (Blainv.). Turculeț, pl. I, figs. 1, 5; pl. III, fig. 1. (= Turculeț, 1971: p.119, pl. XXXVII, figs. 1, 3.
1968 *Duvalia lata constricta* (Uhlig). Turculeț, pl. II, fig. 2(= Turculeț, 1971: 119–120, pl. XXXIV, fig.10.
1970 *Duvalia lata lata* (de Blainville). Stoyanova-Vergilova, p. 51, pl. XXVI, figs. 1–3; pl. XXXII, fig. 19.
1970 *Duvalia lata constricta* (Uhlig). Stoyanova-Vergilova, p. 52, pl. XXVI, figs. 4–5.
1973 *Duvalia lata* var. *lata* (Blainville). Combémorel, pp. 137–139, pl. 1, figs. 1–8.
1991 *Duvalia lata* (de Blainville). Doyle and Mariotti, pp. 362–363, pl. 4, fig. 8.
1994 *Duvalia lata constricta* (Uhlig). Vašíček et al., p. 84, pl. 28, figs. 1–2.
1997 *Duvalia lata* (Blainville). Janssen, p. 21, pl 1, figs. 1, 4.
2003 *Duvalia lata constricta* Uhlig. Janssen, pp. 150–152, pl. 6, figs. 12–17.
2015 *Duvalia lata* (Blainville). Thomel and Picollier-Thomel, text and pls. 1–5.

Material: 12 specimens representing more complete rostra: MR 114-I-1, MR 114-I-2, MR 114-I-4, MR 114-I-5, MR 115-II-2, MR 115-III-1, MR 115-III-3, all from the "I. Turculeț" Collection (1968), and the recently-collected MR 129-133. Several apical parts and one intermediate fragment (MR 134-138) were also recently added. They were sampled from the "Gura Sadovei Breccia."

Description: Several remarks can be made on the specimens with respect to their general morphology. Five specimens would represent *D. lata* morph *lata*, (Pl. I, Figs. 1–5), namely MR 129-131, MR 114-I-2 and MR 114-I-4.

There are medium-sized rostra, with the oval shape of the cross-section more strongly compressed in comparison with all the specimens assigned to *D. lata* s.l. (Icm = 1.35–1.45, see Appendix). The dorsal side is less convex or almost straight as compared to the ventral one, which draws a large arch towards the blunt apex. The apical outline is asymmetric owing to the apex being placed dorsally. The mucron is not preserved. The specimen MR 114-I-4 with an almost cylindrical shape in lateral view (Pl. I, Fig. 4a) is an exception. Morphologically, it resembles *D. tornajoensis* Janssen 2003, but the dorsal side is rounded to flattened (Pl. I, Fig. 4b), and not slightly angled, as the former exhibits (Janssen, 2003: p. 153, pl. 6, figs. 1–2; 6–7).

In most specimens, the *rostrum solidum* is well-preserved, while the *rostrum cavum* is often damaged, or even missing. The alveolar groove is of variable length, generally broad and fading out near the maximum dorso-ventral diameter (MR 130-131, Pl. I, Figs. 1b, 2b), sometimes running on the apical area (MR 114-I-4, MR 114-I-2: Pl. I, Figs. 4b, 5b).

In the "I. Turculeț" Collection, there is an intermediate fragment of rostrum (MR 114-6) which can roughly be assigned to *Duvalia lata* morph *lata*, showing an oval-narrow cross-section of the rostrum.

The specimen MR 114-I-1 (Pl. I, Fig. 6) shares morphological features between *D. lata* morph *lata* and morph *constricta*: the rostrum is less bulged towards the apical part than usual for morph *constricta*, the cross section is more rounded than in previous specimens and a conspicuous constriction of the alveolus can be observed.

Four previous specimens (Pl. I, Fig. 9, Pl. II, Figs. 1–3: MR 114-I-5, MR 115-III-1, MR-115-II-2, MR 115-III-3) represent typical *constricta* morphs, having bulged rostra and an obvious constriction. MR 115-II-2 (Pl. II, Fig. 2) is comparable to *D. lata* morph *zeugitana* Pervinquière, 1907 through the general rostrum shape and less regular cross-section. It should be noted that both Combémorel (1973) and Janssen (2003) considered this taxon a junior synonym of *D. lata constricta*. The record MR 115-III-3 (Pl. II, Fig. 3) represents a juvenile specimen.

Two other recent records (MR 132-133) were assigned to *D. lata* ex. gr. morph *constricta*. The most complete rostrum (MR 132: Pl. I, Fig. 7) gets narrower approximately at the beginning of the *rostrum cavum* and displays a wide and long alveolar groove which becomes evanescent near the apex. The cross-section is almost rounded and the alveolus seems less profound, as compared to the morph *lata* (e.g. Vašíček et al., 1994), being placed approximately at 1/3 length of the rostrum.

The second one (MR 133: Pl. I, Fig. 8) is smaller and differs by the inflated rostrum, the more developed alveolus, and the narrowing beginning after the protoconch. It displays a similar deep and long alveolar groove. Caution was imposed by the incomplete rostrum.

In addition, several apical parts assigned to *Duvalia lata* s.l. (MR 134-137) show a moderate compression, with

the alveolar groove lacking near the apical region (Pl. II, Figs. 4–7 – *Duvalia lata* ex. gr. morph *constricta*). MR 138 (*Duvalia lata* ex. gr. morph *lata*) is an intermediate fragment of rostrum, which preserves an obvious alveolar groove on its entire length (Pl. II, Fig. 8). MR 139 represents an elongated alveolar part of rostrum, with almost flat ventral and dorsal sides, resulting in an oval to quadrangular cross-section (Pl. II, Fig. 9c). The alveolar groove is deep and bordered by two small edges (Pl. II, Fig. 9b). MR 139 could represent an immature specimen of *D. lata* ex. gr. *lata*.

The distinction of morph *constricta* is based on the constriction in the alveolar part, near the initiation of the *rostrum cavum*, the more rounded cross-sections (e.g. Pl. I, Figs. 7c, 8c), and the smaller Icm, as compared to *D. lata* morph *lata* (Icm = 1.002–1.24). The alveolar groove length is not a constant feature (see Appendix). Generally, herein the alveolar groove of morph *constricta* is longer, compared to the morph *lata* specimens, and frequently reach the apical part (e.g. Pl. I, Figs. 7b, 8b; Pl. II, Fig. 2b in comparison with Pl. I, Figs. 1b, 2a). There are also exceptions to this rule: MR 114-I-5 (Pl. I, Fig. 9b) displays a shorter alveolar groove than believed usual for the morph *constricta*, and MR 114-I-4 (Pl. I, Fig. 4b), assigned to *Duvalia lata* morph *lata*, develops a longer groove than believed usual for the specimens found within the breccia body. A similar development can be observed in the specimens of *D. lata lata* and *D. lata constricta* illustrated by Stoyanova-Vergilova (1970: pl. XXVI, figs. 1–2, 3–4).

Age: Thomel and Thomel-Picollier (2015) briefly summarized the historical framework of *D. lata* morph. div., outlining an abundance zone in France, within the *Tirnovella pertransiens* and *Busnardoites campylotoxus* Zones (Early Valanginian). In addition, they noted its presence since the Berriasian.

Observations: Sometimes, the rostrum can be crossed by fine diaclases filled with calcite (e.g. Pl. I, Figs. 6, 7, 9). More frequently, small quartz/lithic grains can be found inserted in the rostrum (Pl. I, Figs. 1b, 2b etc.) or adhered to its outer surface (Pl. I, Figs. 4, 5, 9 etc.). Even the phragmocone or the phragmocone filling is penetrated by quartz and other small grains (e.g. MR 130, MR 133: Pl. I, Figs. 2c, 8c). Signs of boring barnacles (Arthropoda: Cirripedia) were also found (e.g. MR 131: Pl. I, Fig. 2; MR 134: Pl. II, Fig. 4).

Duvalia aff. *haugi* (KILIAN, 1889)
Pl. II, Fig. 10

?1889 *Bélemnites* (*Duvalia*) *Haugi* n. sp. Kilian, p. 636, pl. XXVII, figs. 1a-c.
1968 *Duvalia* sp. Turculeț, p. 81, pl. II, fig. 6 (= Turculeț, 1971: pp. 120–121, pl. XXXVIII, fig. 3).
2003 *Duvalia* aff. *haugi* Kilian, 1889. Janssen, pp. 154–155, pl. 6, figs. 3–5 (cum syn.).

Material: 1 specimen: MR 124-II-6. "Gura Sadovei Breccia."

Description: The specimen was figured by Turculeț (1968) as *Duvalia* sp. The tapering appearance of the rostrum is conical, strongly compressed (Icm = 1.59)

and slender towards the apex. The cross-section of the *rostrum cavum* is more inflated towards the dorsum, narrowing to the ventral side. Unfortunately, the specimen is slightly damaged and the outline is not continuous. The alveolus is deep and a constriction seems to affect it. The alveolar groove is not as long as in the case of the holotype (Kilian, 1889: pl. XXVII, figs. 1a-c) or the specimen figured by Janssen (2003: RGM 345 920, pl. 6, figs. 3–5).

Age: *Duvalia* aff. *haugi* was recorded from the latest Berriasian to earliest Valanginian (*Thurmanniceras otopeta* – *Tirnovella pertransiensis* Subzones after Janssen, 2003).

Observations: Also, small clasts were observed intruded into the phragmocone.

Duvalia sp.1
Pl. II, Fig. 11

1968 *Duvalia urnula* (Duval-Jouve). Turculeț, p. 81, pl II, fig. 5 (= Turculeț, 1971: p. 120, pl. XVIII, fig. 2).

Material: 1 specimen: MR 126a-II-5, "I. Turculeț" Collection. "Gura Sadovei Breccia".

Description: The specimens has a compressed rostrum, with irregular trajectories of the dorsal/ventral borders (Pl. II, Fig. 11). The apex appears to be placed nearly centrally. The cross-section of the alveolus is more elliptical than rhomboidal-shaped, with a stronger narrowing towards the ventral side than the dorsal one. The beginning of the phragmocone is approximately round-shaped (Pl. II, Fig. 11d). The alveolar groove is narrow and relatively deep and it seems limited to the alveolar part (Pl. II, Fig. 11b).

Duvalia ex gr. *miravetesensis* Janssen, 2003
Pl. II, Fig. 12.

2003 *Duvalia miravetesensis* Janssen, p. 153, pl. 6, figs. 8–9, 18–20 (cum syn).

Material: 1 specimen: MR 140. "Gura Sadovei Breccia".

Description: MR 139 is an incomplete rostrum including the apical part and only the beginning of the phragmocone (Pl. II, Fig. 12). The general shape of MR 139 is similar to that of *Duvalia lata* morph *lata*, but slender and more compressed, like in *D. dilatata*. The cross-section is narrow-oval towards the dorsum (Pl. II, Fig. 12c), with the maximum dorso-ventral diameter near the apical region. An alveolar groove could not be observed. The apex is also orientated slightly towards the dorsal side.

Age: According to Janssen (2003), *Duvalia miravetesensis* occurs in the late Berriasian to earliest Valanginian (*Berriasella (Malbosiceras) paramimouna* – *Tirnovella pertransiensis* Subzones).

The Hauterivian-Barremian taxa:

Duvalia binervioides Stoyanova-Vergilova, 1965
Pl. II, Fig. 13

? 1915 *Belemintes dilatatus* Blainville (?). var. n. Jekelius, p. (93) 117, taf. X, fig. 4.
1965 *Duvalia dilatata binervioides* Stoyanova-Vergilova, p. 194, pl. VI, figs. 3–5.
1968 *Duvalia dilatata* (Blainville). Turculeț, p. 83, pl. II, fig. 3.(= Turculeț, 1971: p. 120, pl. XXXVIII, fig. 4).
1970 *Duvalia dilatata binervioides* Stoyanova-Vergilova p. 55, pl. XXX, figs. 3–5, pl. XXXIII, fig.7.
1973 *Duvalia dilatata binervioides* Stoyanova-Vergilova. Combémorel, p. 144, pl. 3, figs. 6,7.
1993 *Duvalia* cf. *Dilatata binervioides* Stoyanova-Vergilova. Avram and Grădinaru, pl. 7, figs. 6, 7.

Material: 1 specimen MR 125-II-3, "I. Turculeț" Collection. Wildflysch, Izvorul Malului stream, Câmpulung Moldovenesc.

Description: Among the *Duvalia dilatata* specimens collected by Turculeț (1968) from the wildflysch cropping out on the Izvorul Malului stream, there is a specimen which can be assigned to *D. binervioides*, given the constriction of the *rostrum cavum* and an eliptical-narrow cross-section (Pl. II, Figs. 13a, b, c). The alveolar groove was not observed and the mucron is only inferred. Also, the biometric data match with the previous values for this species: e.g. Icm = 2.11 fits between the 2 and 3 values, as estimated by Combémorel (1973: p. 145) for this species.

Age: *Duvalia dilatata binervioides* was recorded from Valanginian to Hauterivian beds (Stoyanova-Vergilova, 1965, 1970; Combémorel, 1973).

Duvalia dilatata (Blainville, 1827)
Pl. II, Fig. 16

1827 *Belemnites dilatatus* Blainville, pp. 99–100, pl. 5, fig. 18.
1840 *Belemnites dilatatus* Blainville. d'Orbigny, pp. 39–44, pl. 2, figs. 18, 21; pl. 3, figs. 4–5.
1841 *Belemnites dilatatus* Blainville. Duval-Jouve, p. 54, pl. 4, figs. 3–6.
1849 *Belemnites dilatatus* Bl., Quenstedt, p. 448, tab. 30, figs. 1, 3, 6, 7.
1888 *Belemnites dilatatus* Blainville. Herbich, p 196, taf. I, figs. 3–7.
pars1898 *Belemnites (Duvalia) dilatatus* Blainv. Simionescu, pp. 109–110(53–54), tab. I, fig. 1, non fig. 2.
1964 *Duvalia dilatata* (de Blainville). Fülöp, pl. XXIX, fig. 5.
1965 *Duvalia dilatata* (de Blainville). Stoyanova-Vergilova, pp. 191–194, text-figs. G-I, pl. V, fig. 10; pl. VII, figs.1–3; pl. VIII, figs. 1–2.
1970 *Duvalia dilatata dilatata* (de Blainville). Stoyanova-Vergilova, pp. 54–55, pl. XXVII,

fig. 9a,b, pl. XXIX, figs. 1–4, pl. XXXII, figs. 19 a, b, c.
1973 *Duvalia dilatata dilatata*(Blainville). Combémorel, pp. 142–144, pl. 2, fig. 10a-b, pl. 3, figs. 2–4 (*cum. syn*).
1994 *Duvalia dilatata dilatata* (de Blainville). Vašíček et al., pp. 84–85, pl. 29, figs. 1–2.
2011 *Duvalia dilatata* ((Blainville, 1827). Price et al., Fig. 2 (7 a, b).

Material: 1 specimen, "I. Turculeț" Collection (1968): MR 125a-4 (not figured by Turculeț). Wildflysch, Izvorul Malului stream, Câmpulung Moldovenesc.

Description: The specimen represents a ventral longitudinal-half rostrum, with the ventral side long and straight. It is highly compressed, the half-outline of the cross-section being elliptical-triangular.

Age: *D. dilatata dilatata* was recorded from the late Valanginian to the late Hauterivian or early Barremian (e.g. Avram and Grădinaru, 1993).

Duvalia ex. gr. *dilatata* (Blainville, 1827)
Pl. II, Figs. 14, 15

1968 *Duvalia dilatata* (Blainville). Turculeț, p. 83, pl. II, figs. 1(= Turculeț, 1971: p. 120, pl. XXXVIII, fig. 5)., pl. III, fig. 2. (= Turculeț, 1971: p. 120, pl. XXXVIII, fig. 3).

Material: 2 specimens, all included in the "I. Turculeț" Collection (1968) and updated herein as MR 125-II-1 and MR 125-III-2.

Description: One specimen preserved most of the rostrum and a partial phragmocone, and one only the rostrum, with a small cavity representing the beginning of the phragmocone (MR-125-III-2: Pl. II, Fig. 15c, ?protoconch). The rostra are generally elongated, apically-rounded, only the MR 125-II-1 specimen (Pl. II, Fig. 14a) displaying a small apex. The transversal shape is oval and strongly compressed (Icm = 1.81–1.99 – see Appendix), with the lateral sides slightly curved. The alveolar groove was not observed.

Observations: Turculeț (1968) collected all the specimens assigned to *D. dilatata* group from the wildflysch unearthed by the Izvorul Malului stream, without any other location indication. The author dated the host-bed as Hauterivian.

Duvalia sp. 2
Pl. II, Fig. 18

1968 *Duvalia binervia* (Raspail). Turculeț, p. 83, pl I, fig. 3 (= Turculeț, 1971: p. 120, pl. XXXIV, fig. 11).

Material: 1 specimen: MR 116-I-3, "I. Turculeț" Collection.

Description: Turculeț assigned to *D. binervia* (Raspail, 1829) a rostrum broken at both ends collected from the wildflysch cropping out on the left slope of Moldova River-Pojorâta. In the collection hosted at the "Alexandru Ioan Cuza" University of Iaşi, the

location is more accurate, namely Peciștea Hill, within the Pojorâta village area.

The rostrum is small, having a general sub-cylindrical tapering. The cross-section varies along the rostrum, from the quadrangular distal part to the oval apical part. Both dorsal and ventral sides are flattened, and two very shallow grooves can be observed extending on the most of the fragment.

Probably, Turculeț (1968) compared the fragment with the specimen figured by Schwetzoff (pl. II, figs. 10 i, j – cross-section on the lower part of the *D. binervia* rostrum), but the specimen of the Rarău Syncline is broken quite near to the apical part, and it cannot reach the compressed apical outline of this species.

Age: The host-rocks were dated as Hauterivian by Turculeț (1968).

?*Curtohibolites* sp.
Pl. II, Fig. 17

1968 *Curtohibolites orbignyanus* (Duval.). Turculeț, p. 83, pl. II, Fig. 4 (= Turculeț, 1971: p. 121, pl. XXXIV, fig. 8).

Material: 1 specimen: MR 118-II-4, "I. Turculeț" Collection. Wildflysch, Izvorul Malului stream, Câmpulung Moldovenesc.

Description: It is difficult to asses this juvenile subcylindrical specimen: the *rostrum solidum* exhibits an almost cylindrical shape, excepting the apical part, which is slightly narrow and rounded. The ventral side is nearly straight, while the dorsal one arches towards the ventrally-placed apex. The alveolar groove is straight, relatively deep and wide. The lateral sides are very sligthly flattened, marking an important difference from the "*orbignyanus*" species (Duval-Jouve, 1841: p. 65, pl. VIII, fig. 6)

Observations: Originally described as *"Belemnites" orbignyanus* by Duval-Jouve (1841), the species was assigned to *Curtohibolites* by Stoyanova-Vergilova (1963) and later placed in the genus *Castellanibelus* by Riegraf (1995). However, the latter morphologically-comparable genus belongs to the duvaliids (Combémorel, 1973), while *Curtohibolites* belong to the taxa related to hibolitoid belemnites (Janssen – personal communication). Moreover, they display different stratigraphical ranges. While *Castellanibelus* occurs in the late Berriasian to earliest-late Valanginian, *Curtohibolites* are only known from possible Hauterivian rocks in Bulgaria and well-dated early-late Barremian rocks in France and Hungary (Janssen – personal communication).

Age: *Curtohibolites* occur around the boundary of the early-late Barremian.

5. Discussion

The duvaliids include mainly mature specimens, with few juvenile ones occurring. There are both well-preserved rostra and fragmented ones. Quite frequently, the rostra include the alveolar/phragmocone part, but one also observed certain rostra representing only the internal moulds. The occurrence of small rock clasts onto the rostrum and as infill in the phragmocone/alveolar cavities would

indicate a tectonic reworking within the breccia body, as would the *in-situ* fragmentation of the rostrum. Generally, the biometric parameters are comparable to values known for the species quoted in the Tethyan areas (see Appendix).

The recent field trips have also allowed several tectonic observations. The western vergence of the recumbent anticline of the "*Aptychus* Beds" in the opposite direction of the general foldbelt development in the Eastern Carpathians suggests a back-thrust fault for the tectonic contact between the "*Aptychus* Beds" and the "Gura Sadovei Breccia." The obvious footwall in the outcrop (Țibuleac, 2012: pl. II, fig. 1) represented by the "*Aptychus* Beds" anticline and the random orientation of various rocks of different sizes and ages suggest a fissure-fill breccia. Few secondary faults and fissures at an angle to the main fault could be also observed within the breccia body.

6. Conclusions

The present paper is concerned with the Early Cretaceous duvaliids from the Rarău Syncline (Eastern Carpathians), both recent and old specimens (the latter from the "I. Turculeț" Collection-MP-UAIC).

The age of the host-beds divides the duvaliids from the Rarău Sycline into two main groups: latest Berriasian – earliest Valaginian records ("Gura Sadovei Breccia"), and Hauterivian-Barremian records (wildflysch). The described taxa include: *Duvalia lata,* morph div., *D.* aff. *haugi*, *D.* ex. gr. *miravetesensis*, *Duvalia* sp. 1 ("Gura Sadovei Breccia"), and *D. dilatata*, *D.* ex. gr. *dilatata*, *D. binervioides*, *Duvalia* sp. 2, and ?*Curtohibolites* sp. (wildflysch). Several previous determinations have been updated.

The specimens of the "Gura Sadovei Breccia" were sampled from the marly matrix of the breccia and only two from the cemented breccia. They represent both well-preserved and fragmentary rostra, including, in some cases, the phragmocone or phragmocone filling. Fine diaclases filled with calcite and small quartz/lithic grains intruded into the rostrum/phragmocone or only adhered on it suggest a tectonic reworking. Occasionally, signs of boring barnacles were also observed.

The specimens from the wildflysch were only updated, the outcrop of the Izvorul Malului stream was not found, and the wildflysch cropping out along the Moldova Valley (Pojorâta locality) did not furnish any fossil during the fieldtrips.

Regarding the "Gura Sadovei Breccia" genesis, the various-sized clasts from different rocks, all randomly oriented, suggest a fissure-fill breccia in connection with the back-thrust fault which crosses the "*Aptychus* Beds" in the outcrop.

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Appendix

Nr. crt.	Taxon		Inv. No.	Lmax	Ddv max	Dl max	Icm	Ddva	Dla	Ica	*lg	Dph	*lap
	species	morph											
1	*Duvalia lata*	*lata*	MR 129	46.81	17.96	12.52	1.43	-	-	-	-	-	17.25
2	*D. lata*	*lata*	MR 130	65.95	22.92	16.92	1.36	19.02	12.98	1.46	-	9.49	22.75
3	*D. lata*	*lata*	MR 131	57.48	20.30	14.77	1.37	-	-		19.80	*8.40	20.62
4	*D. lata*	*lata*	MR 114-I-4	52.25	*19.02	13.18	1.45	17.66	*12.89	1.37	43.37	7.56	11.08
5	*D. lata*	*lata*	MR 114-I-2	50.73	16.12	11.92	1.35	10.07	7.12	1.41	40.21	-	13.89
6	*D. lata*	*lata-constricta*	MR 114-I-1	66.20	21.96	16.18	1.35	*16.25	11.23	1.45	44.22	*8.94	18.97
7	*D. lata*	*constricta*	MR 114-I-5	56.29	19.07	15.64	1.22	14.84	11.17	1.32	26.63	*8.49	15.47
10	*D. lata*	*constricta*	MR III 115-3-1	59.23	-	-	-	*14.02	*12.84	1.10	-	-	-
11	*D. lata*	*zeugitana*	MR 115-II-2	77.53	24.64	24.58	1.002	16.48	16.17	1.02	53.65		23.66
12	*D. lata*	*constricta*	MR 115-III-3	23.26	6.24	5.02	1.24	*3.12	2.68	1.16	23.26	-	5.23
	D. lata	*ex. gr constricta*	MR 132	62.64	17.02	16.91	1.002	13.63	12.96	1.05	53.34	-	16.63
	D. lata	*ex. gr. constricta*	MR 133	54.77	19.45	17.54	1.11	14.15	13.82	1.02	40.73	9.92	15.32
	D. lata	*ex. gr. lata*	MR 139	-	-	-	-	*13.17	*88.71	*1.51	-	-	-
16	*Duvalia ex. gr. miravetesensis*	-	MR 140	32.66	12.27	7.53	1.63	12.27	7.53	1.63	-	-	-
17	*D. aff. haugi*	-	MR 124-II-6	43.83	15.38	9.70	1.59	15.38	9.70	1.59	31.29	7.20	-
18	*Duvalia* sp. 1	-	MR 126a-II-5	40.31	10.29	6.33	1.63	*9.80	6.27	1.56	22.51	3.78	
19	*Duvalia* sp. 2	-	MR 116-I-3	26.75	11.04	8.20	1.35	9.67					
	D. dilatata	-	MR 125a-4	61.59	-	-	-	½=10.6	-	-	-	-	12.10
20	*D. ex. gr. dilatata*	-	MR 125-II-1	59.43	20.29	10.18	1.99	17.28	8.15	2.09	-	12.39	17.37
22	*D. ex. gr. dilatata*	-	MR-125-III-2	46.62	18.36	10.14	1.81	14.54	8.20	1.77	-	-	13.50
21	*D. binervioides*	-	MR 125-II-3	55.74	19.2	9.09	2.11	*8.77	4.04	2.17	-	-	14.90
	?"Curtohibolites sp.		MR 118-II-4	25.46	7.75	7.18	1.79	-	-	-	23.71	-	7.98

PLATE CAPTIONS

Plate 1 (1-2, 4-9): a – lateral side, b – dorsal side; c – cross-section of the distal side; 3: a – the specimen embedded into the breccia clasts; b – lateral side, c – dorsal side; d – cross-section of the distal side.

Figs. 1-5 *Duvalia lata* (Blainville, 1827) morph *lata*. "Gura Sadovei Breccia", Rarău Syncline: 1, 2, 3= MR 130,131, 129; 4= MR 114-I-4, 5= MR 114-I-2.

Fig. 6 *Duvalia lata* (Blainville, 1827) transitions to morph *constricta* Uhlig, 1902. "Gura Sadovei Breccia", Rarău Syncline: MR 114-I-1.

Figs. 7-8 *Duvalia lata* (Blainville, 1827) ex. gr. morph *constricta* Uhlig, 1902. "Gura Sadovei Breccia", Rarău Syncline: MR 132-133.

Fig. 9 *Duvalia lata* (Blainville, 1827) morph *constricta* Uhlig, 1902. "Gura Sadovei Breccia", Rarău Syncline: MR 114-I-5.

Plate 2 (2-3, 8, 13-15, 17-18): a – lateral side, b – dorsal side; c – cross-section of the distal side; 4-7: lateral side; 9: a – lateral side, b – dorsal side, c – cross-section of the proximal side; 10-12: a – lateral side, b – dorsal side, c – cross-section of the distal side; 16: a – lateral side, b – ventral side, c – longitudinal cross-section.

Figs. 1, 2, 3 *Duvalia lata* (Blainville, 1827) morph *constricta* Uhlig, 1902. "Gura Sadovei Breccia", Rarău Syncline: 1= MR-115-III-1; 2= MR-115-II-2; 3= MR-115-III-3 (juvenile).

Figs. 4-7 *Duvalia* cf. *lata* morph div.? – apical parts and one intermediate fragment. "Gura Sadovei Breccia", Rarău Syncline: MR 134-137, 138.

Figs. 8, 9 *Duvalia* ex gr. *lata* (Blainville). "Gura Sadovei Breccia", Rarău Syncline: MR 138 and 139.

Fig. 10 *Duvalia* aff. *haugi* Kilian, 1889. "Gura Sadovei Breccia", Rarău Syncline: MR 124-II-6.

Fig. 11 *Duvalia* sp.1 "Gura Sadovei Breccia", Rarău Syncline: MR 124a-II-5.

Fig. 12 *Duvalia* ex. gr. *miravetesensis* Janssen, 2003. "Gura Sadovei Breccia", Rarău Syncline: MR 140.

Fig. 13 *Duvalia binervioides* Stoyanova-Vergilova, 1965. Wildflysch, Hauterivian, Izvorul Malului stream, Câmpulung Moldovenesc, Rarău Syncline: MR 125-II-3.

Figs. 14-15 *Duvalia* ex gr. *dilatata* (Blainville, 1827). Wildflysch, Hauterivian, Izvorul Malului stream, Câmpulung Moldovenesc, Rarău Syncline: MR 125-II-1, MR 125-III-2.

Figs. 16 *Duvalia dilatata* (Blainville, 1827). Wildflysch, Hauterivian, Izvorul Malului stream, Câmpulung Moldovenesc, Rarău Syncline: MR 125a-4.

Fig. 17 ?*Curtohibolites* sp. Wildflysch, Hauterivian, Izvorul Malului stream, Câmpulung Moldovenesc, Rarău Syncline: MR 118-II-4.

Fig. 18 *Duvalia* sp. 2. Wildflysch, Hauterivian, Peciştea Hill, Pojorâta, Rarău Syncline: MR 116-I-3.

Plate I

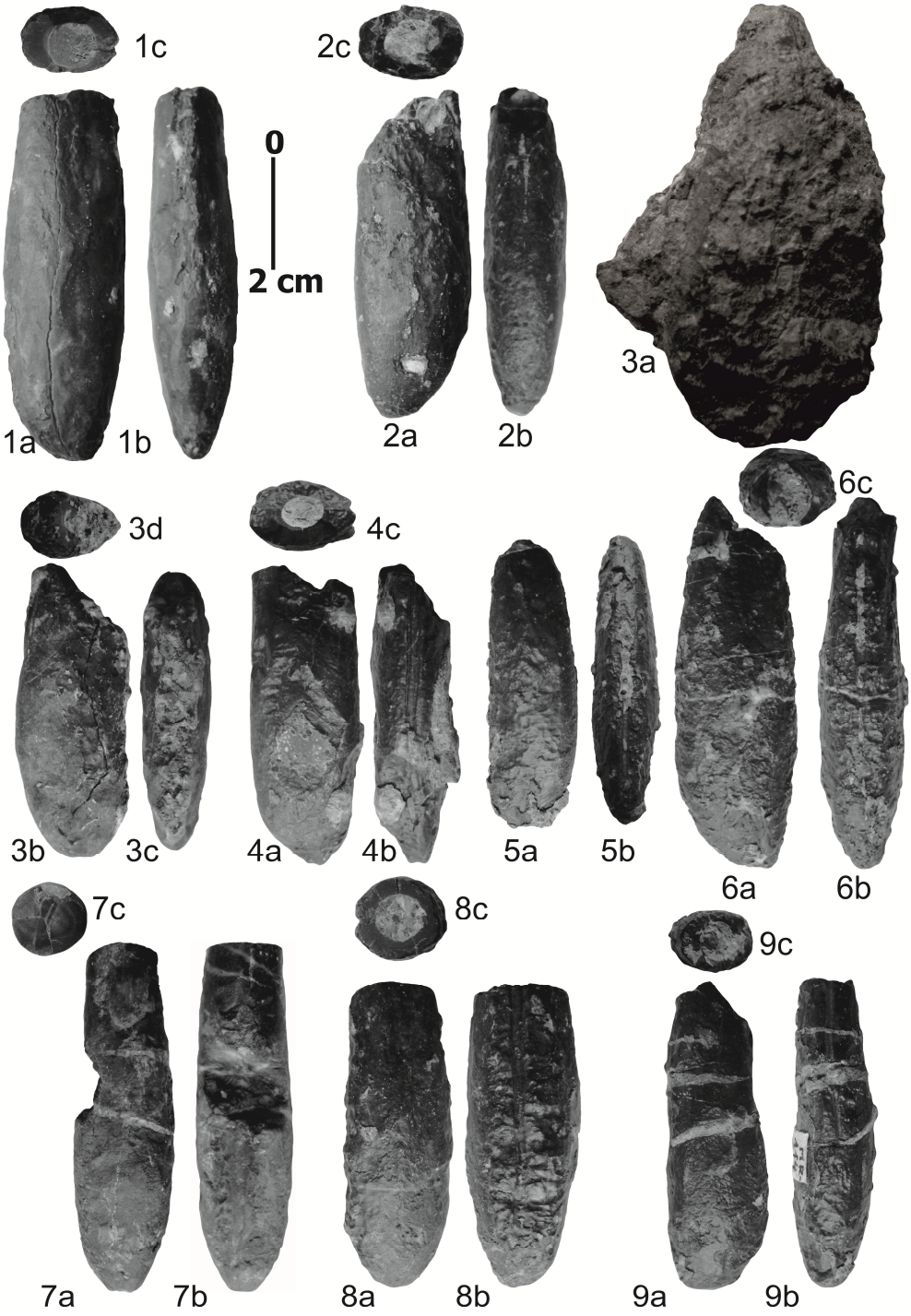
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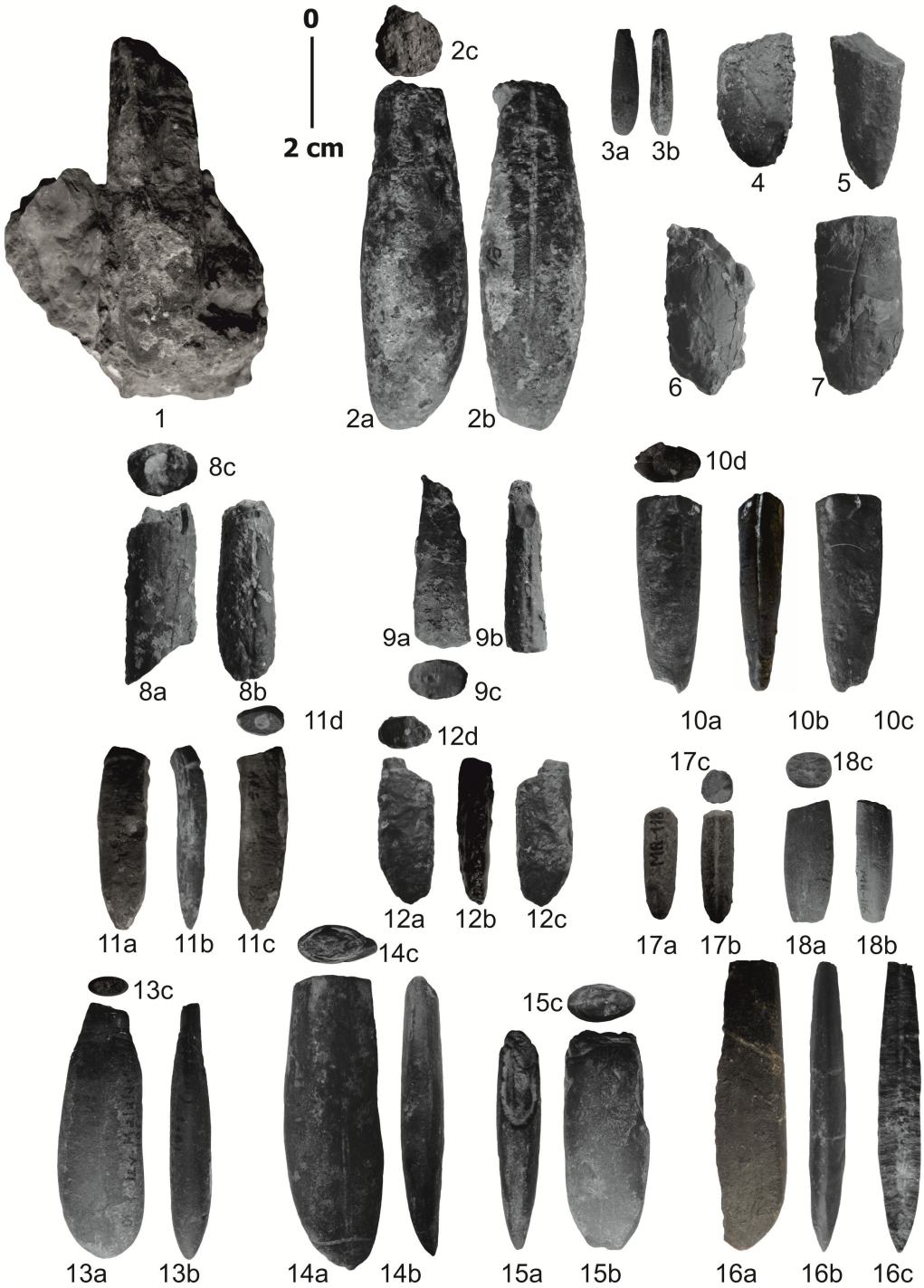
Plate II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