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Analele Stiintifice ale Universitatii "Al. I. Cuza" din Iasi
Seria Geologie 58 (2) (2012) 35–52

AUI GEOLOGIE

New data on the Early Cretaceous between Gura Sadovei and Pojorâta (Rarău Syncline, Eastern Carpathians, Romania)

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Abstract

The Early Cretaceous (Bucovinian Nappe) deposits have been mapped only on the external flank of the Rarău Syncline, where they form a coarse clastic succession (breccias, conglomerates and sandstones) with very poor fauna. New paleontological data are added through the present paper, the most important regarding the Tethyan ammonite *Olcostephanus* (*Olcostephanus*) *guebhardti* (KILIAN, 1902). This is the second species quoted in the "Muncelu Sandstone and Conglomerate" which can be used to confirm the age of the studied beds. Several observations concerning the breccias and their relation to the subjacent and suprajacent layers are also made.

Keywords: Bucovinian Nappe, "Muncelu Sandstone and Conglomerate", Tethyan ammonite, age specification, "Gura Sadovei Breccia".

Introduction

The Rarău Syncline is one of the most outstanding structural units with Mesozoic sedimentary succession in the Median Dacides of the Eastern Carpathians. The crystalline basement, the sedimentary infill, and the magmatic rocks of the syncline are ascribable to two kinds of nappes (Săndulescu, 1984), namely autochthonous (the Bucovinian Nappe) and allochthonous (the Transylvanian Nappes). The Mesozoic succession of the Bucovinian Nappe is Triassic–Early Cretaceous in age and it displays several sedimentary differences on its flanks. The Early Cretaceous rocks, more precisely the "Muncelu Sandstone and Conglomerate" (or the "Muncelu Conglomerate and Sandstone", as quoted in several papers), illustrate one of these differences, being mapped only on the external flank, from the surroundings of the Breaza locality (in the north) to Runcu Hill (the southernmost occurrence described by Turculeţ, 1971). These deposits seem to record a small-scale Mesozoic event of the

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Eastern Carpathians. Săndulescu (1976) suggested a different interpretation for these coarse clastic rocks which crop out south of Breaza (see below). In Moldova Valley (Fig. 1), more precisely in the Pojorâta Quarry, between the localities of Gura Sadovei and Pojorâta, the unit displays the maximum thickness recorded, around 200 m across a width of 1 km (Popescu and Patrulius, 1964; Turculeţ, 1971).

Near Gura Sadovei, at the contact with the so-called "*Aptychus* Beds" (Late Jurassic–?Early Cretaceous), a short event recorded as sub-conglomeratic breccias (Early Cretaceous in age according to Turculeţ, 1968, 1971) has a contradictory stratigraphic position. Thus, Turculeţ (1968, 1971) placed it at the top of the "Muncelu Sandstone and Conglomerate", while Avram *et al.* (1998) placed it at the base. The Cretaceous wildflysch has most likely overlain the Muncelu succession in a transgressive manner.

Historical framework

The age attributed to the so-called "Muncelu Sandstone and Conglomerate" was changed during different stages of the research dedicated to it. First af all, Paul (1876) correctly dated it as Early Cretaceous (together with the "*Aptychus* Beds"). The age then oscillated between Aptian and Paleogene (Uhlig, 1899, 1903; Kräutner, 1929; Ilie, 1957), until Băncilă, 1958 ("Neocomian") and Popescu and Patrulius (1960 *fide* Turculeţ, 1971; 1964), in particular, restored it to Paul's initial opinion.

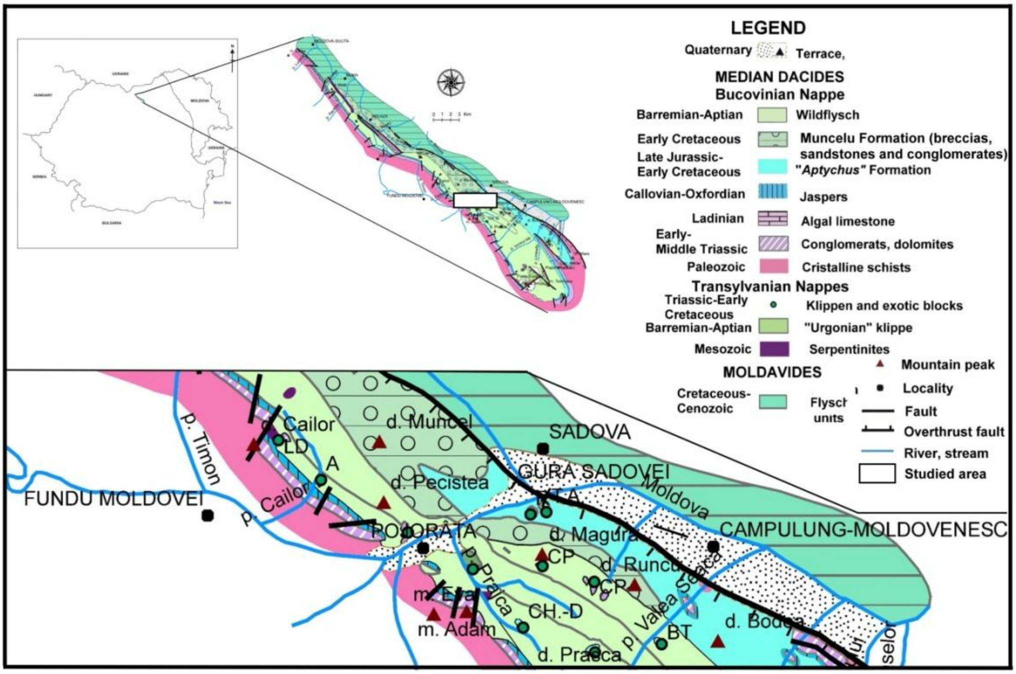

Fig. 1 General setting of the studied area and the geological sketch of the central part of the Rarău Syncline (after Turculeţ, 1971)

Based on the paleontological arguments, Turculeţ (1963, 1968 and 1971) confirmed the presence of the Early Cretaceous, more precisely of the Valanginian age. In the first paper, the author described the ammonite taxon *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.

In a paper dealing with the Boreal immigrants into the Valanginian of the Romanian Carpathians, Avram et al. (1998) revised the specimen above as being *Polyptychites cf. michalskii* (BOGOSLOWSKY, 1902). The host rock of the ammonite also contain several nannofossil taxa, namely *Micrantholithus speetonensis* PERCH-NIELSEN 1979, *Crucibiscutum salebrosum* (BLACK 1971), *Tegumentum striatum* (BLACK, 1971), and *Sollasites horticus* (STRADNER) CEPEK and HAY 1969, considered "partly Tethyan or cosmopolitan, and partly Boreal". *Micrantholithus speetonensis* and *Sollasites horticus* are Boreal taxa (Mutterlose, 1996; Briceag et al., 2008), *Crucibiscutum salebrosum* would reflect the "meridional thermal gradient" (Mutterlose et al., 2003), being very rare at low latitudes and abundant at high latitudes, while *Tegumentum striatum* is the cosmopolitan species (Mutterlose, 1992), having significant biostratigraphic value. For the Tethyan Realm, the first occurrence is recorded in the Early Hauterivian (according to Applegate et al., 1989 *fide* Mutterlose, 1992), while for the Boreal Realm it is documented within the ?Early–Late Valanginian range (Mutterlose, 1992).

In the second paper having the Early Cretaceous as topic, Turculeţ (1968) described the sub-conglomeratic breccias at the contact with the "*Aptychus* Beds". Among the clasts of the breccias, the author signalled fauna and rock-types of different pre-Cretaceous ages, as follows: Middle Triassic white-grey limestone (of the "Guttenstein" facies), grey limestone of Rhetian age (with *Rhaetina gregaria* (SUESS, 1854), *R. pyriformis* (SUESS, 1854), *Austrirhynchia cornigera* (SCHAFHAUTL, 1851) etc.), sandy-limestone of Toarcian–Aalenian age (with *Phymatoceras comensis* (de BUCH) = *Phymatoceras crassicosta* MERLA, 1933), *Belemnopsis subblainvillei* (DESLONG.) = *Holcobelus subblainvillei* (EUDES-DESLONGCHAMPS, 1878), *Rhabdobelus exilis* (d'ORBIGNY) = ?*Pseudobelus exilis* (d'ORBIGNY, 1842), Middle Jurassic coarse sandstones with belemnites (*Megateuthis* sp.), red japers (Callovian–Oxfordian), and the red clayey limestone and marls of the "*Aptychus* Beds" (Oxfordian–Tithonian–?Early Cretaceous). The breccias are poorly cemented and the several rounded clasts would indicate a short transport.

Within the breccia unit, Turculeţ (1968) also noted the presence of the *Punctaptychus*, *Lamellaptychus* and *Laevaptychus* paragenera, through specimens considered reworked from the "*Aptychus* Beds". Up to the present moment, *Laevaptychus* has not been encountered in other sedimentary rocks of the Rarău Syncline. It is considered a primitive parataxon, whose evolution was recorded between the Oxfordian and the Early Tithonian (Turculeţ, 2000).

Further on, Turculeţ (1968) described several peculiar belemnite specimens, which "do not belong to any reworked rocks" (Turculeţ, 1968: p. 81) or "*in situ*" rocks (Turculeţ, 1971: p. 43), namely: *Duvalia lata* (BLAINVILLE, 1825), *D. lata constricta* (UHLIG, 1902) = ?*Duvalia lata*, *D. urnula* (DUVAL-JOUVE, 1841) = *Pseudoduvalia polygonalis* (BLAINVILLE, 1827), *Duvalia* sp., and *Pseudobelus bipartitus* (BLAINVILLE, 1827). These taxa would indicate a Valangi-nian age, with the exception of *Pseudoduvalia polygonalis*, which has survived until the Hauterivian. The author pointed out the taxon-index value of *Pseudobelus bipartitus*, regarded by Kilian (1910) as a marker for the Valanginian until the *Saynoceras verrucosum* Taxon-range zone.

Popescu and Patrulius (1964) accurately described several geological sections exposing Early Cretaceous rocks of the Rarău Syncline and dated the "*Aptychus* Beds" (considered a lateral facies of the "Sinaia Beds") as Neocomian (Berriasian–Valanginian–?Hauterivian), despite admitting that Uhlig's hypothesis (supported by Băncilă, 1937 and Turculeţ, 1963), which refers to a Late Jurassic–Early Cretaceous/Tithonian–Berriasian age, is supported by paleontological arguments. The "Muncelu Sandstone and Conglomerate" corresponds to the same interval, and the Barremian–Aptian wildflysch (with a possible discontinuity between it and the underlying strata) ends the Early Cretaceous sequence.

Mutihac (1966) noted several blocks of the Hallstatt facies-type within the "Muncelu Sandstone and Conglomerate", based on which he considered that the Transylvanian Nappes were overthrusted onto the Bucovinian Realm before or during the sedimentation of the wildflysch. In 1968, the same author dated the "*Aptychus* Beds" ("Flyschoid Series") as belonging to the Berriasian–Valanginian interval based on previous calpionellid fauna (peculiar for the Tithonian–Berriasian transition) and, in particular, on a specimen of *Duvalia dilatata* (de BLAINVILLE, 1825) collected from an anticline at Gura Sadovei. The "Muncelu Sandstone and Conglomerate" was considered a lateral facies of the "*Aptychus* Beds", the wildflysch (Hauterivian-Albian) ending the Early Cretaceous succession. Mutihac (1968, p. 50) also suggested that the specimen of *Polyptychites* mentioned by Turculeţ (1963) was collected from the deposits in the channel of the Moldova River, therefore a Valanginian age for the supposed host beds of the "Muncelu Sandstone and Conglomerate" cannot be justified.

Turculeţ (1971) reviewed all the previous data on Early Cretaceous deposits, namely the "Muncelu Sandstone and Conglomerate", the sub-conglomeratic breccias and the overlying wildflysch. At the base of the wildflysch, the author documented the Hauterivian stage through a fossil assemblage with *Duvalia dilatata* (de BLAINVILLE, 1825), *Curtohibolites* (=*Castellanibelus*) *orbignyanus* (DUVAL-JOUVE, 1841), *Mesohibolites* (= *Hibolites*) *subfusiformis* (RASPAIL, 1829) identified in the Izvorul Malului stream, and *Duvalia binervia* (RASPAIL, 1829), identified in Moldova Valley (Pojorâta). Nowadays, only *Hibolites subfusiformis* argues the Late Hauterivian-Early Barremian interval, the others species arising from Valanginian.

Săndulescu (1975) suggested a similarity between the "Muncelu Sandstone and Conglomerate" and the "Chicera Conglomerates" of the Hăşmaş (= Hăghimaş) Syncline, based on arguments such as the same intermediate position between the "Lunca Beds" (= "*Aptychus* Beds") and the wildflysch, the reduced areal development, the presence of several klippen within the conglomerate unit etc. The author also mentioned several differences, such as the petrographic composition of the clasts of the "Chicera Conglomerate", mainly dolomites and crystalline schists with some clasts of the "*Aptychus* Beds" – type limestone and marl, as well as their younger age (?Hauterivian).

In 1976, Săndulescu suggested a different approach to the Early Cretaceous succession characterizing the autochthonous Bucovinian Nappe from the external flank of the Rarău Syncline. The author divided the "*Aptychus* Beds" *s.l.* (*sensu* Turculeţ, 1971, and several previous authors) into two "lithofacies", namely an external one, called Pojorâta (Tithonian–Berriasian), and an internal one *s.str.* (Tithonian–Valanginian). The reason for this separation seems to be the delineation of the Sadova tectonic Outlier (arguments against this point of view can be read in Turculeţ, 1977). In the upper part of the sequence, a Valangianian unit of oncolytic calcarenites was mapped north of Moldova Valley, and, consequently, the "Muncelu Sandstone and Conglomerate" was dated, based on its geometric position, as ?Valanginian–Hauterivian–?Barremian. The lowermost wildflysch deposits were considered of Barremian age. According to this reasoning, the coarse clastic succession south of the Breaza locality (the Lefele, Floarea and Măcieş peaks) are not part of the "Muncelu Sandstone and Conglomerate", but the rabotage outlier of the Sub-Bucovinian (or Infra-Bucovinian) Nappe, Early Cretaceous as well. Săndulescu (1976, p. 166) also pointed out two pre-paroxysmal tectogeneses (before the Austrian Tectogenesis of the Albian), namely the intra-Triassic one and the Hauterivian–Barremian/Early Barremian one, the latter being proven by the tectonic contact between the "Pojorâta Beds" and the "*Aptychus* Beds" *s.str.* (*sensu* Săndulescu, 1976), which occurs south of Moldova Valley.

From a petrographic point of view, Grasu et al. (1995) described the Muncelu "Sandstone and Conglomerate" as an alternation of sandstones (calcareous litharenite) with sandy pelsparites and microconglomerates-conglomerates; several sand interlayers were observed subordinately. The authors also noted that the litharenites and pelsparites display the same epiclastic material, the differences consisting in the predominance of sparitic cement and the presence of pellets and glauconite in the second petrographic type. It is also noteworthy that the conglomerate clasts consist of epimetamorphics, dolomites, white and red Triassic limestone, Middle Jurassic limestone, jaspers and marls of the "*Aptychus* Beds". The main source for these clasts was considered the autochthonous Bucovinian Realm.

Paleontological records for the Early Cretaceous

The following observations start from the breccias described by Turculeţ (1968). Taking into account that the geological data are not sufficient so as to characterize these deposits, we suggest the use of the following informal terms: "*Aptychus* Beds", "Gura Sadovei Breccia" and "Muncelu Sandstone and Conglomerate".

The "*Gura Sadovei Breccia*" occurs near the "*Aptychus* Beds", along an obvious fault which can be observed in the outcrop found in the vicinity of the railroad crossing of Gura Sadovei. The outcrop has a width of more than 11–12 m. The contact point between the breccias and the "Muncelu Sandstone and Conglomerate" cannot be examined in the field because of the absence of outcrops. Near the tectonic contact (Pl. II, Fig. 1), blocks of several decimeters in diameter, containing Rhetian brachiopods, were signalled, together with an important olistolith of "*Aptychus* Beds" – type rocks (1 m^3). A small number of clasts of red clayey limestone were also observed in these polymictic breccias, to which crystalline schists and dolomites could be added.

The fossil record is poor, belemnite rostra being the most common. As Turculeţ (1968) pointed out, belemnites occur in the breccia matrix as fragments of different sizes, but they were also observed within the rock bulks (Pl. I, Figs. 9 and 10). A large number of fragmented rostra can also be collected from the talus deposits at the base or between several steep cliffs, most of them without the apical part. It was from such materials that we collected several of the species described, the most important being *Duvalia lata, Duvalia sp.*, *Pseudobelus bipartitus* and, for the first time, a specimen of *Hibolites sp.* (Pl. I, Fig. 9) with the phragmocone partly preserved. Several incomplete and indeterminable casts of bivalves (a more important one being an *Exogyra*-like bivalve, which can point to a specific environment) were also gathered (Pl. I, Fig. 11). Finally, several aptychi specimens were collected during the field work, the most important being *Beyrichilamellaptychus cf. beyrichi beyrichi* and *Punctaptychus monsalvensis monsalvensis*.

The "*Muncelu Sandstone and Conglomerate*" consists of deposits generally devoid of macrofossils, only a small number of strata yielding fossil fauna. As mentioned above, the only specimen currently known is the *Polyptychites* quoted by Turculeţ (1963). A new ammonite species, *Olcostephanus (Olcostephanus) guebhardti* (KILIAN 1902) (Pl. I, Fig. 1), as well as an indeterminable specimen (Pl. I, Fig. 3), were added by means of the present paper. The ammonites were collected near the eastern extremity of the Pojorâta Quarry, from a greenish limestone located very close to the inner part of the small eastern anticline, several hundred meters away from the supposed location of the first record. The olcostephanid specimen has been preserved satisfactorily, despite the deformation and the absence of the apertural part. The best preserved portion, however, is its inner part, which was detached from the rock in the laboratory.

Table 1 Berriasian and Valanginian ammonite and belemnite zones

Stages		Standard ammonite zones (Reboulet et al., 2009)		Belemite Zonation Janssen (1997)		NW European ammonite zones (Rawson, 1995 fide Rawson, 1999); Rawson et al., 1999, Hoedemaeker (in Rawson et al., 1999)
VALANGINIAN	Late	*Criosarcinella furcillata*	*Teschenites callidiscus*	*Duvalia dilatata dilatata*	*Pseudobelus brevis*	*? Olcostephanus densicostatus*
			Criosarcinella furcillata			*Stoicoceras tuberculata* *Dichotomites bidichotomoides*
		Neocomites peregrinus	*Olcostephanus (Olcostephanus) nicklesi*			*Dichotomites triptychoides*
			Neocomites peregrinus			*Dichotomites crassus*
		Saynoceras verrucosum	*Karakaschiceras pronecostatum*			*Prodichotomiets polytomus*
			Saynoceras verrucosum		*Duvalia emericii*	
	Early	*Busnardoites campylotoxus*	*Karakaschiceras biassalense*			*Prodichotomites hollwedensis*
			Busnardoites campylotoxus			*Polyptychites hapkei* *Polyptychites clarkei* *Polyptychites multicostatus*
		Tirnovella pertransiensis				*Polyptychites pavlowi*
						Platylenticeras involutum
				Duvalia lata	*Pseudobelus bipartitus*	*Platylenticeras heteropleurum*
BERRIASIAN	Late	*Subthurmania boissieri*	*Thurmaniceras otopeta*			*Platylenticeras robustus* *Peregrinoceras albidum*
			Tirnovella alpillensis			*Surites stenomphalus* *Surites icenii*
			Berriasella picteti			Hiatus
			Malbosiceras paramimounum		*Rhabdobelus strangulatus*	*Heterococeras kochi*
	Middle	*Subthurmania occitanica*	*Dalmasiceras dalmasi*			Hiatus
			Berriasella privasensis			
			Subthurm ania subalpina			*Runctonia runctoni*
	Early	*Berriasella jacobi*	*Berriassela grandis*		*Duvalia tithonica*	*Subcraspidites lamplughi*
			Berriasella jacobi			*Subcraspedites prelicomphalus* *Subcraspedites primitivus*

Discussion

The first observation which should be made is that, in the upper part of the "*Aptychus* Beds", what is identifiable is the Jurassic–Cretaceous boundary, the point of view belonging to Turculeţ (up to Berriasian) being the most plausible in this respect. The *Duvalia dilatata* quoted by Mutihac (1968) and subsequent researchers (Săndulescu, 1976; Avram et al., 1998) could have its first occurrence since the Berriasian (Tab. 1, base to middle *Tirnovella alpilensis* T.-r. Subzone, after Janssen, 1977, p. 18). Further studies on the calpionellid fauna present in the limestone of the upper part of the "*Aptychus* Beds" in the Gura Sadovei anticline could be used for more accurate dating.

As mentioned above, Săndulescu (1976) divided the "*Aptychus* Beds" *s.l.* into two units: the "Pojorâta Beds" (Tithonian–Berriasian), belonging to the Sadova Outlier, and the "*Aptychus* Beds" *s.s.* (Tithonian–Valanginian). In order to prove the age of the latter, Săndulescu (1976, p. 153–154) quoted general fauna, based on several previous papers (Ilie, 1957; Popescu and Patrulius, 1964; Mutihac, 1968; Turculeţ, 1971; Săndulescu, 1973; Săndulescu *et al.*, 1976), namely: *Lamellaptychus beyrichi*, *L. lithographus*, *L. lamellosus* var. *gracilicostata*, *Punctaptychus punctatus*, *P. punctatus* var. *aff. longa*, *Crassicolaria massutiniana*, *Cr. parvula*, *Calpionella alpina*, *Tintinopsella carpathica*, *Calpionellites* (=*Calpionellopsis*) *darderi*, *C. simplex*, *Duvalia dilatata*. Although the taxa *Calpionellopsis darderi* – *Calpionellites simplex* could act as paleontological arguments for the Late Berriasian–Valanginian, Săndulescu et al. (1976) did not mention them in the paper, where they concluded that "what crops out in the Valea Seacă (Brook) and, possibly, the Izvorul Alb as well, is only the Tithonian sequence of the Pojorâta Beds, the Berriasian sequence identified north of Moldova Valley (Săndulescu, 1974) having been, most likely, eroded" (p. 170). It is also worth noting that the Valea Seacă Brook seems to host the most complete succession of the "*Aptychus* Beds" *s.l.* (e.g. Popescu and Patrulius, 1964; Turculeţ, 1971). Among the aptychi fauna, only the *Lamellaptychus* (*Didaylamellaptychus*) *didayi* (COQUAND, 1841) quoted by Paul (1876) and Ilie (1957) could indicate the Berriassian–Early Hauterivian (even Kamenov, 1936 *fide* Turculeţ, 2000 described it as belonging to the Tithonian). No other records were mentioned later.

It is also important to discuss the stratigraphic position and the age of the "Gura Sadovei Breccia". In order to do so, we have to mention the study conducted by Janssen (1997, p. 35), who suggested a provisional attempt at belemnite zonation for the Tethyan Realm, since "most of the papers did not deal with a bed-by-bed collection of the belemnite species in the ammonite controlled sections" (idem, p. 33). In the Tethyan Realm, the coexistence of *Duvalia lata* and *Pseudobelus bipartitus* requires an interval between the bases of the *Berriasella picteti* Taxon-range Zone (T.-r. Z.) and the *Tirnovella pertransiens* T.-r. Z., possibly up to the base of the *Saynoceras verrucosum* T.-r. Z,. as the author stated (Tab. 1). The last occurrences of both taxa (*Duvalia lata* ssp. and *Pseudobelus bipartitus*) are not very precise (Janssen, 1997, Fig. 5, p. 11). It is also noteworthy that the age of the breccias should be considered younger in comparison to all their fauna, and that these rocks should be viewed as a subsequent event, as (at least) the end of the *Berriasella picteti* T-r. Subzone (Late Berriasian) (Tab. 1).

Another paleontological observation is that the aptychi seem to belong to two groups: specimens reworked from the upper part of the "*Aptychus* Beds", and specimens from the breccias themselves, several aptychi being distinguished within the bodies of the breccias (Pl. I, Figs. 7 and 8). The same observation was made in passing by Mutihac (1969: p. 219), who stated that breccias belong to the so-called "Clayey Formation" (= "*Aptychus* Beds"). The *Laevaptychus* specimen quoted by Turculeţ (1968) most likely belongs to the second group (as mentioned above, no other

Laevaptychus specimen has been recorded in the Rarău Syncline).

So far, only two ammonite species have been mentioned from specific "Muncelu Sandstone and Conglomerate" beds: one Boreal immigrant – *Polyptychites cf. michaslkii* (according to Avram et al., 1998), and one of Tethyan origin – *Olcostephanus (Olcostephanus) guebhardti s.s*.

Polyptychites michalskii (BOGOSLOVSKY 1902) is a primitive species belonging to the first polyptychinid group of Jeletzky and Kemper (1988), namely *P. michalskii – P. oerlinghusanus* (VEERTH, 1884). Its first occurrence seems to be in the Lower Saxony Basin ("Lower Lower Valanginian", according to Jeletzky and Kemper, 1988: p. 44), from which it migrated to the Eastern Basin of Europe and Asia, where it reached its main phase of evolution. In Central and Western Europe, *P. michalskii* must have been rapidly replaced by the second polyptychitinid group, *Polyptychites keyserlingi* (NEUMAYR and UHLIG, 1881), represented by *Polyptychites pavlowi* KOENEN 1902 – *P. lamplughi* PAVLOW 1892 subgroup 2a (Jeletzky and Kemper, 1988). However, in North Siberia, *P. michalskii* seems to coexist with *P. keyserlingi* (Shulgina, 1996), acting as a marker for the second part of the Early Valanginian, even it was removed from the denomination of the *Polyptychites keyserlingi – Temnoptychites hoplitoides* Zone. A possible diachronism of this species should be taken into account, since *P. michalskii* was initially thought to represent the Middle Valanginian (Shulgina, 1996: p. 89). *P. michalskii* was also described in several extreme basins of the Boreal Realm. Based on the discussion above, one can assume the age of the beds from where *Polyptychites cf. michaslkii* was collected to be Early Valanginian, more precisely the *Tirnovella pertransiensis*T.-r. Z. (before the appeareance of *Polyptychites pavlowi* species – Tab. 1).

The first occurrence of *Olcostephanus (Olcostephanus) guebhardti* was recorded from the middle of the *Busnardoites campylotoxus* T.-r. Z., before the occurrence of the *Karakasiceras* genus (Bulot, 1992), being also documented in the *Saynoceras verrucosum* T.-r. Z by Vašiček (2010). Its biostratigraphic value was discussed by Bulot (1992) in a paper about the Valanginian and Hauterivian Olcostephaninae of the French and Swiss Jura. According to his observations, during the first stage of its development, the species was characterized by a sphaerocone shell with nearly straight primary ribbing and well-developed secondary ribs. During its evolution in the following *Saynoceras verrucosum* T.-r. Z., the species acquired denser ribbing and reached a larger size. These changes determined Bulot (1992) to propose a new morphotype restricted to this level, namely the *Olcostephanus* (*Olcostephanus*) *guebhardti* morph. type *querolensis*. Lukeneder (2004) confirmed this new morphotype based on an Early Cretaceous section from the deposits of the Ternberg Nappe (Northern Calcareous Alps, Austria), even if several of the specimens illustrated (text-Fig. 6, Figs. 3 and ?4) seem to be of *O.* (*O.*) *guebhardti s.s.* Lukeneder (2004) also confirmed the preference of the *O.* (*O.*) *guebhardti* lineage for the outer shelf facies, despite the *O.* (*O.*) *tenuituberculatus* group restricted to the basin facies. What was also documented was a sexual dimorphism for *O.* (*O.*) *guebhardti s.s*, represented by microconchs (females) and macroconchs (males), based on the differences in size and sculptural details.

This kind of Boreal–Tethyan mixture is quite common in the Early Cretaceous basins of Northwestern Europe, where the repeated northward and southward migrations of ammonite fauna by means of several seaways allow the correlation between the two realms. Generally, ammonites are predominantly of Boreal origin, but several strong Tethyan influences have been documented as well. In this respect, Kemper et al. (1981) noted the spectacular expansion of the long-ranged *Olcostephanus* genus in both the Boreal and the Tethyan Realms at the end of the Early and during the Late Valanginian, respectively. The distributional pattern of these two mass-occurrences was mainly related to the transgressions.

Consequently, for the specific beds of "Muncelu Sandstone and Conglomerate" from which both ammonite taxa were collected one can assume an Early Valanginian age, extending between the *Tirnovella pertransiensis* T.-r. Z. (documented through the *Polyptichites* taxon) and the *Busnardoites campylotoxus* T.-r. Z. (documented through the *Olcostephanus* taxon). The beginning of the Late Valanginian can also be registered if one accepts the existence of *Olcostephanus guebhardti* within the *Saynoceras verrucosum* Zone (Vašiček, 2010). However, both the Late Valanginian and the Hauterivian could also be present, but the paleontological arguments necessary to prove their presence still need to be found.

As a final conclusion for the discussion above, neither the age of the breccias, nor their stratigraphic position in relation to the "Muncelu Sandstone and Conglomerate" (at least the specific beds from which the ammonites were collected), are yet clarified. Two hypotheses should be taken into account: an Early Cretaceous age, according to Turculeţ's point of view (1968, 1971), or a post-paroxysmal (post-Albian) age.

If one assume an Early Cretaceous age, it is difficult to explain the mixture of rocks which form the clasts of the breccias. The polymictic "Gura Sadovei Breccia" is unusual, given the fact that it consists of clasts from both autochthonous and allochthonous sedimentary successions (according to the classic model of the evolution of the Romanian territory suggested by Săndulescu, 1984). The clasts of crystalline schists, dolomites, Middle Triassic white-grey limestone, red jaspers, red clayey limestone and marls of the "*Aptychus* Beds" belong to the autochthonous Bucovinian Nappe. On the other hand, the clasts of Middle Triassic white-grey limestone, grey limestone of Rhetian age, sandy-limestone of Toarcian–Aalenian age, coarse sandstones with belemnites (Middle Jurassic) were supplied by the allochthonous Transylvanian Nappes. Several small klippen of the Transylvanian Nappes were also signaled over the "*Aptychus* Beds". In the studied area, such klippen (the Rhetian limestone with brachiopods (Merhart, 1910 and subsequent researchers), the small Toarcian–Aalenian klippen with ammonites, brachiopods, and bivalves (Turculeţ, 1966; Stănoiu, 1967) are usually mentioned in relation with the wildflysch. Small (decimeters in size) exotic blocks of Rhetian age with similar fauna were also signalled in the breccias by Turculeţ (1968) and by recent field observations.

Consequently, if one assumes an Early Cretaceous age, it is difficult to explain the presence within the Bucovinian succession of the allochthonous Transylvanian rock-types, which were later overthrust onto the autochthonous Bucovinian Realm during the Albian. Only a tectonic event (recorded as a fault between the "*Aptychus* Beds" and several intra-breccia faults) could be invoked to explain the mixture, but further sedimentological and petrographic studies are needed in order to confirm this hypothesis.

If one assumes the breccias as a post-paroxysmal event (like the "Bârnadu Conglomerate" in the Hăşmaş/Hăghimaş Syncline), the rock mixture is normal, but there is no paleontological evidence for such a younger age. The age of the fault between the "*Aptychus* "Beds" and the breccias, as well as that of the intra-breccia faults, still have to be documented. During the pre-paroxismal phase of the Austrian Tectogenesis, the "*Aptychus* Beds" and the "Muncelu Sandstone and Conglomerate" were probably folded, the folds having a westward vergence in opposition with the general eastward vergence of the main structural units of the Eastern Carpathians. Săndulescu (1976) placed this phase at the boundary between the Hauterivian and the Barremian or in the Early Barremian, but, given the presence of the Late Hauterivian–Early Barremian interval in the wildflysch (Turculeţ, 1971, see above), one can limit the age to the Hauterivian.

Conclusions

The Early Cretaceous deposits of the eastern flank of the Rarău Syncline consists of the ?"*Aptychus* Beds", the "Gura Sadovei Breccia", the "Muncelu Sandstone and Conglomerate", as well as wildflysch deposits. Until now, between Gura Sadovei and Pojorâta, the fossil assemblage described in the sedimentary succession has been poor: belemnites, aptychi and brachiopods in the "Gura Sadovei Breccia", and only one Boreal ammonite specimen in the "Muncelu Sandstone and Conglomerate". The present paper points out several paleontological observa-tions on the fauna of the "Gura Sadovei Breccia" and the "Muncelu Sandstone and Conglomerate", the most important being the Tethyan ammonite *Olcostephanus* (*Olcostephanus*) *guebhardti*, recorded from the latter informal unit. Several observations based on the premise of the coexistence of Tethyan–Boreal ammonites within the "Muncelu Sandstone and Conglomerate", as well as the age range for the host-beds of the ammonite specimens (the *Tirnovella pertransiensis* – *Busnardoites campylotoxus* T.-r. Zones, possibly the beginning of the *Saynoceras verrucosum* T.-r. Z.), were also made. *Olcostephanus* (*Olcostephanus*) *guebhardti* confirms the Valanginian age within the "Muncelu Sandstone and Conglomerate" (Turculeţ, 1963), an age previously questioned by several authors (e.g. Mutihac, 1968).

So far, neither the accurate age of the "Gura Sadovei Breccia", nor its stratigraphic position in relation to the "Muncelu Sandstone and Conglomerate", is clear. However, it should be noted that the fauna of the "Gura Sadovei Breccia" is reworked, consisting of a mixture of Bucovinian autochthonous and Transylvanian allochthonous sources, and the oldest zone argued by fossil records until now is *Berriasella picteti* T-r. Subzone (Late Berriasian). Two hypotheses could be taken into account: 1) a Berriasian–Valanginian age, as suggested by Turculeţ (1968, 1971) based on the age biostratigraphically proven, remaining to justify the double source areas of the clasts or 2) a post-Albian age, which explains the mixture of clasts, but for which no paleontological data to prove a younger than Valanginian age is currently available.

Palaeontology

Phylum Mollusca LINNÉ, 1758
Class Cephalopoda CUVIER, 1795
Subclass Ammonoidea ZITTEL, 1884
Order Ammonitida HYATT, 1889
Superfamily Perisphinctaceae STEINMANN, 1890
Family Olcostephanidae HAUG, 1910
Subfamily Olcostephaninae HAUG, 1910

Genus *Olcostephanus* NEUMAYR, 1875
Subgenus *Olcostephanus* NEUMAYR, 1875
Type-species: *Ammonites astierianus* d'ORBIGNY, 1840.

Olcostephanus (Olcostephanus) guebhardti (KILIAN, 1902)
Pl. I, Figs. 1a-d

1902 *Holcostephanus (Astieria) Guebhardti* n. sp.; Kilian, p. 866, Pl. 57, Figs. 2 a, b.
1992 *Olcostephanus (Olcostephanus) guebhardi* KILIAN; BULOT, p. 151–152, Pl. 1, Figs. 2a, 2b.
2005 *Olcostephanus guebhardti* Kilian. Klein, p. 88–89 (*cum syn.*)
2010 *Olcostephanus guebhardi* (KILIAN 1902).Vašiček, p. 398, Pl. I, Fig. 1, Pl. 2, Fig. 2.

Material: 1 specimen – PCr 1.

Description: The specimen was collected from a sandy pelsparite level in the lower part of the former "Muncelu Sandstone and Conglomerate," within the succession exposed in the

Pojorâta Quarry. The shell mould is compressed, with the exception of the terminal part, detached during the preparation process. It is a convolute shell, without the apertural part. The primary ribs are obviously rursiradiate, sometimes becoming concave (in the deformed part). In the lower approximate third of the flank, the primaries acquire refined bullae, from which fascicles of 3 or (very rarely) 4 secondary ribs reach everyone. The fasciculate secondary ribs run straight to the prorsiradiate, sometimes with a slight flexuosity. They display no bifurcations and pass continuously over the venter. The bundles of ribs are very rarely intercalated with one inserted rib. The round whorl section of the species can be observed on the last fragment of the conch, which is detached from the main part of the shell mould; on it, the whorl section seems to be deformed. No peristomal details and no suture line are noticeable.

Dimensions: D = 62.8 mm; U = 17 mm; H = 24.6; app. W = 22 mm; U/D = 0.26; W/H = 0.89.

Age: In the Tethyan Realm, *Olcostephanus guebhardti s.s* is documented from the middle/end of the *Busnardoites campylotoxus* T.-r. Zone until the *Saynoceras verrucosum* T.-r. Zone (Bulot, 1992; Vašiček, 2010, respectively). Bulot and Thielouy (1995 - *fide* Rawson, 1999) placed its "abundance zone" in the *Busnardoites campylotoxus* T.-r. Z. (median part of the *Olcostephanus stephanophorus* T.-r. Zone after Rawson, 1999).

Occurrences in Romania: The genus *Olcostephanus* was documented through *Olcostephanus sayni* (KILIAN), *O. cf. psilostomus* (NEUMAYR and UHLIG) and *O. atherstoni* (SHARPE) by Jekelius (1915) in the Dâmbovicioara Formation, Southern Carpathians (the fauna was revised by Patrulius and Avram, 1976), through *O. aff. psilostomus* (NEUMAYR and UHLIG, 1881) in the sandstone sequences of the Sinaia Formation, Baraolt Mountains, Eastern Carpathians (Avram and Kusko, 1984), *O. (O.) sublaevis* SPATH 1939 in the "Crivina marls" (Reşiţa region, Southern Carpatians) by Avram (1990), *O. cattuloi* (RODIGHIERO, 1919) in the Braşov Formation by Avram and Grădinaru (1993) etc.

Order Ammonitida HYATT, 1889
Aptychi

Paragenus *Beyrichilamellaptychus* TURCULEŢ, 1994

Type-paraspecies: *Aptychus beyrichi* OPPEL, 1865

Beyrichilamellaptychus cf. beyrichi beyrichi (OPPEL, 1865)
Pl. I, Fig. 4

1943 *Lamellaptychus beyrichi* (Opp.) em. Trauth. Anton, p. 633, Fig. 2a.
1956 *Lamellaptychus beyrichi* (Opp.). Răileanu et al., p. 225, Fig. 7.
1958 *Lamellaptychus beyrichi* (Opp.) em. Trauth. Marinescu, p. 138, Pl. 11.
1960 *Lamellaptychus inflexicosta* (Park.) var. *cincta* Trauth. Răileanu et al., p. 28, Pl. X, Fig 34.
1965 *Lamellaptychus*, grupa A, *beyrichi* (Opp.) em. Trauth *f. typ. Trauth.* Turculeţ and Grasu, Pl. I, Fig. 11, Pl. II, Figs. 3 and 6.
1968a *Lamellaptychus*, grupa A, *beyrichi* (Opp.) em. Trauth *f. typ. Trauth.* Turculeţ and Grasu, p. 28, Pl. II, Figs. 7–8.
1968b *Lamellaptychus*, grupa A, *beyrichi* (Opp.) em. Trauth *f. typ. Trauth.* Turculeţ and Grasu, p. 89, Pl. II, Fig. 6.
2000 *Lamellaptychus (Beyrichilamellaptychus) beyrichi beyrichi* (Oppel, 1865) em. Trauth, *f. typ.* Trauth 1938. Turculeţ, p. 85, Pl. I, Figs. 2–15, Pl. II, figs. 1–4, Pl. XXIV, Fig. 9 (*cum syn.*).

Material: 1 specimen – PCr.2.

Description: Medium-sized specimen, not very well preserved, representing a mould; the sculpture is simple, with ribs whose trajectories end on the symphysal, outer and lateral margins; the ribs are negligibly inflected.

Dimensions: Length (L) = aprox. 4.76 cm, Width (W) = aprox. 2.13 cm; W/L = 0.45.

Age: Oxfordian–Berriasian, with a maximum of frequency in the Kimmeridgian–Tithonian (Turculeţ, 2000).

Occurrences in Romania: The Eastern Carpathians and the Apuseni Mountains (Turculeţ, 2000).

Paragenus *Punctaptychus* TRAUTH, 1927

Type-paraspecies: *Aptychus punctatus* VOLTZ, 1837 emend. ZITTEL, 1886

Punctaptychus monsalvensis monsalvensis TRAUTH, 1935
Pl I, Fig. 5

1960 *Punctaptychus monsalvensis* Trauth. Răileanu et al., p. 34, Pl. 10, Fig. 36.
1962 *Punctaptychus monsalvensis* Trauth (partim). Gasiorowski, p. 261, Fig. 17/9.
1962 *Punctaptychus* group A *monsalvensis* Trauth (partim). Gasiorowski, p. 106, Pl. VI, Fig. 2.
1964 *Punctaptychus* grupa A *monsalvensis* Trauth. Turculeţ, p. 63, Pl. V, Figs. 3–6.

Material: 1 specimen – PCr 3.

Description: An incomplete specimen which preserved its ventral part and nearly all the external facet clearly. The sculpture is simple: the ribs run subparallel with the symphysal margin, with a slightly lateral inflexion; on the ventral part, the ribs finish on the outer margin, but there is a tendency of their endings to reach the terminal point. The punctate layer is very well developed, reaching the outer margin.

Age: The parataxon is a marker for the Kimmeridgian–Tithonian interval. It was collected *ex situ* near the contact point between the "*Apytychus* Beds" and the "Gura Sadovei Breccias".

Occurrences in Romania: It was quoted in the Rarău Synclyne in the "*Apytychus* Beds" and the Valea Seacă Brook by Turculeţ (1968, 2000), at Tulgheş (Hăşmaş Syncline) and in the Apuseni Mountains (Turculeţ and Grasu, 1971) etc.

Punctaptychus sp.
Pl. I, Fig. 6

Material: 1 specimen – PCr 4.

Description: It is also an incomplete specimen, without the ventral part. On the terminal margin, the ribs run in a subparallel manner, having a slightly lateral inflexion and a tendency to close one other towards the symphysal margin. On the missing part of mould, the last ribs seem to follow the outline of the "valve" as in the case of *P. cinctus* TRAUTH, 1935, but the disharmonic contact between the bundles of ribs cannot be observed.

Dimensions Length (L) = 1.96 cm, Width (W) = 1.09 cm; W/L = 0.57.

Age: Late Tithonian–Late Berriasian.

Occurrences in Romania: Most probably, a juvenile specimen (after Mechova et al., 2010) is quoted by Patrulius and Avram (1976) within the Carhaga Formation (Perşani Mountains).

Acknowledgements

The author would like to express his gratitude toward Associate Professor Viorel Ionesi, for his help regarding the ammonite specimen, toward Professor Ilie Turculeţ for the careful revision of manuscript, and toward Associate Professor Crina Miclăuş, who improved the present paper through her discussions and thorough observations.

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Received October, 2012
Revised: November, 2012
Accepted: December, 2012

CAPTION OF PLATE

Plate I

Scale I, Figs. 1, 2, 3, 4, 7, 8, 9, 10, 11
Scale II, Figs. 5 and 6

Fig.1 *Olcostephanus (Olcostephanus) guebhardti* (KILIAN, 1902). “Muncelu Sandstone and Conglomerate”, Valanginian.
Fig. 2 *Olcostephanus (Olcostephanus) guebhardti* (KILIAN, 1902). Partial cast of specimen from Fig. 1.
Fig. 3 Indeterminable ammonite cast. “Muncelu Sandstone and Conglomerate”, Valanginian.
Fig. 4 *Beyrichilamellaptychus cf. beyrichi beyrichi* (OPPEL, 1865), “Gura Sadovei Breccia”, specimen reworked from the “*Aptychus* Beds”.
Fig. 5 *Punctaptychus (Beyrichipunctaptychus) monsalvensis monsalvensis*, “Gura Sadovei Breccia”, specimen assumed to originate from the body of the breccias.
Fig. 6 *Punctaptychus sp.* “Gura Sadovei Breccia”, specimen reworked from the “*Aptychus* Beds”.
Figs. 7, 8 Aptychi fragments from the breccias; “Gura Sadovei Breccia”.
Fig. 9 *Hibolites sp.*, “Gura Sadovei Breccia”.
Fig. 10 Rostrum fragment from the breccias, “Gura Sadovei Breccia”.
Fig. 11 *Exogyra*-like bivalve, “Gura Sadovei Breccia”.

Plate II

Fig. 1 Fault scarp/plane between the “*Aptychus* Beds” and the “Gura Sadovei Breccia”, Gura Sadovei-Pojorâta.
Fig. 2 Fault scarp/plane within the “Gura Sadovei Breccia”, Gura Sadovei-Pojorâta.

Plate I

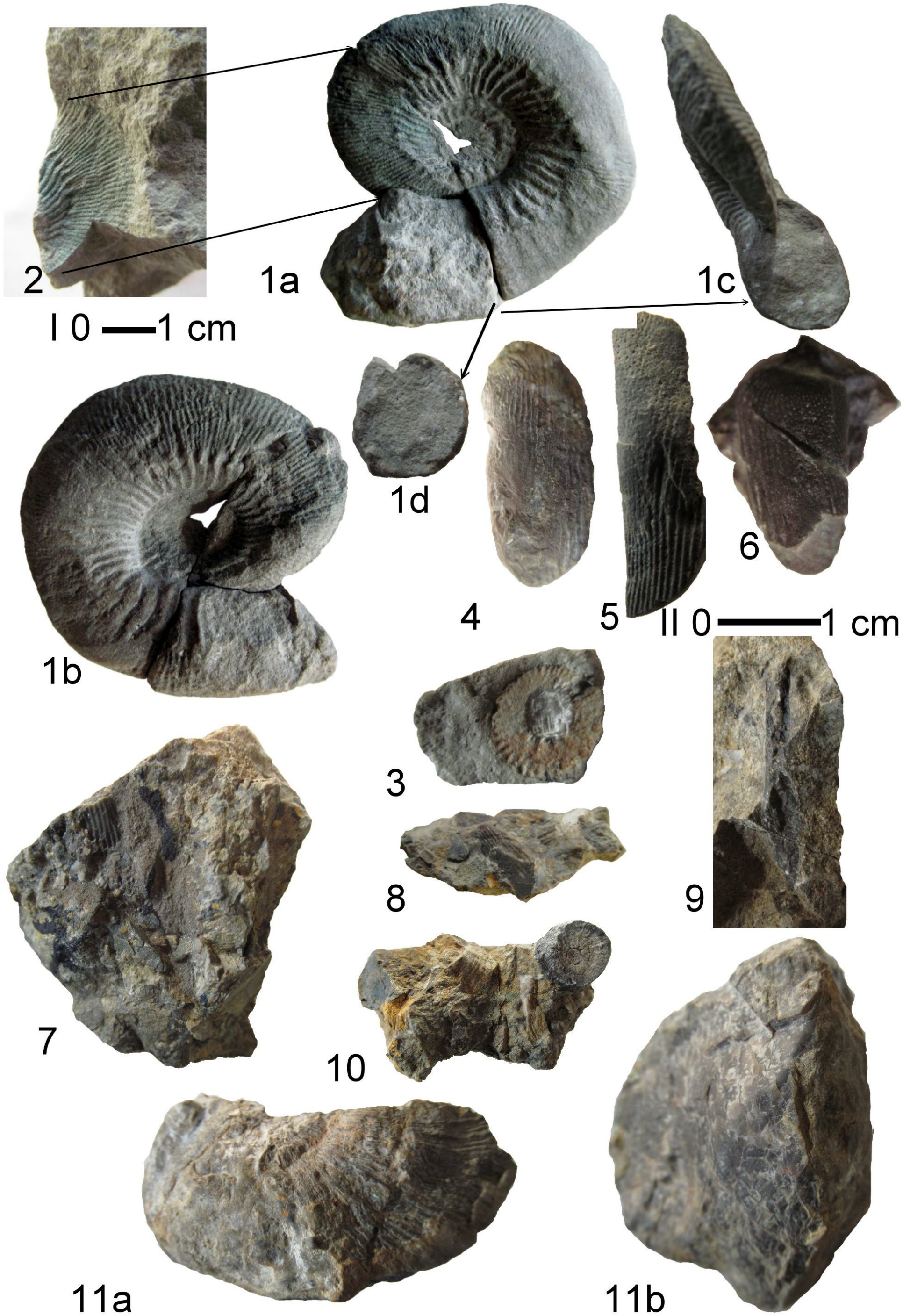

Plate II

Fig. 1

Fig. 2