



BABEŞ-BOLYAI UNIVERSITY
FACULTY OF BIOLOGY AND GEOLOGY



The study of the multituberculates and of some associated Maastrichtian vertebrates from the “Hațeg Island”: systematics, paleobiogeography, paleoenvironments

SUMMARY

by

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Key words: Hațeg Island, Transylvanian Basin, Hațeg Basin, Rusca Montană Basin, Maastrichtian, multituberculates, Kogaionidae, terrestrial deposits, vertebrates, systematics, paleobiogeography, paleoenvironments, intraspecific variability, Anura, taphonomy, Romania, Europe.

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1. Introduction

1.1. Introduction

This PhD thesis is focused on the uppermost Cretaceous “Hațeg Island”¹.

In Earth’s history, several catastrophic bio-events (extinctions) took place. Probably, the best known and documented extinction is the one happened at the Cretaceous/Paleogene boundary (65.5 +/- 0.3 Ma), well known as the K/T extinction (for a review see **Prothero, 2006**, and references therein). At that time a turnover in the animal and plant communities occurred, which is marked in the continental record by the extinction of dinosaurs, explained through various scenarios. The most popular one is the impact between an asteroid and the Earth (**Alvarez, 1983; Alvarez et al., 1980**).

At the end of the Cretaceous, a reconfiguration of the Tethys realm occurred (**Csontos and Vörös, 2004**). As a consequence, southern Europe consisted of an archipelago of islands (**Dercourt et al., 2000; Csontos and Vörös, 2004; detailed review in Csiki et al., 2015; Fig. 1**).

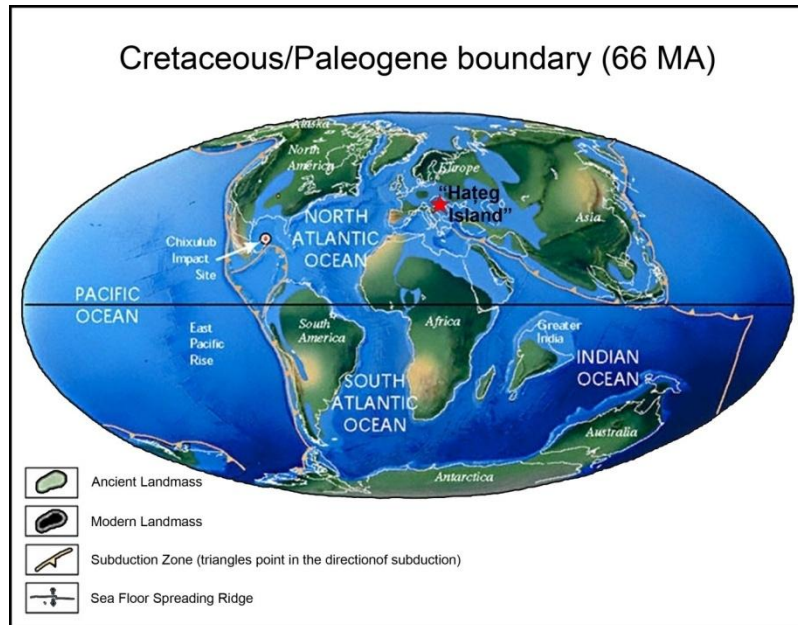


Fig. 1 – Earth’s paleogeography at the K/T boundary (~66 MA). The star approximates the position of “Hațeg Island” within the southern European archipelago. Map modified after **Scotese (2006)**.

¹ For details related to the geology of the “Hațeg Island” see **Chapter 2**.

Between these islands the “Hațeg Island” (Nopcsa, 1914; Fig. 1) is worldwide famous due to the rich and peculiar vertebrate assemblages including mainly dwarf dinosaurs, firstly reported at the end of the 19th century (Nopcsa, 1897; Halaváts, 1897; Grigorescu, 2010), but also other inhabitants, such as the endemic multituberculate mammals, were important members in the paleoecosystems.

1.2. Aim and general content of the thesis

This thesis consists of 11 chapters. Chapters 4 to 10 rely on seven articles I have authored or co-authored during my PhD studies.

Part 1 consists of Chapters 2 and 3.

Chapter 2 presents a summarized geological setting of the “Hațeg Island”, being the result of the combined geological settings of some of the articles in which I was one of the authors.

In **Chapter 3** an overview of the materials used in this study is made (for details related to materials see subsequent chapters). Also the methodology involved in the study and investigation of fossils vertebrates is presented. These are the results of the experience which I have gained since I work under the coordination of prof. univ. dr. Vlad CODREA.

Part 2 comprises Chapters 4 to 7 and is related to the study of multituberculate mammals, the main goal of the thesis.

Part 3 comprises Chapters 8 to 10 and is related to some associated vertebrates and to some taphonomical processes.

Chapter 11 consist of the general conclusion of this PhD thesis.

2. The Uppermost Cretaceous “Hațeg Island” - brief geological characterization

2.1. Introduction

The main focus of the PhD thesis is on solving some issues related to the uppermost Cretaceous multituberculates from Romania which are curate at Babeș-Bolyai University of Cluj-Napoca.

Due to this and to the fact that the geology of the “Hațeg Island” was largely discussed in the last decades I will summarize in this chapter the geological aspects related to the uppermost Cretaceous evolution of this emerged area. However, a short geological/lithological characterization for each locality/outcrop which yielded the material used in this thesis is given in the subsequent chapters.

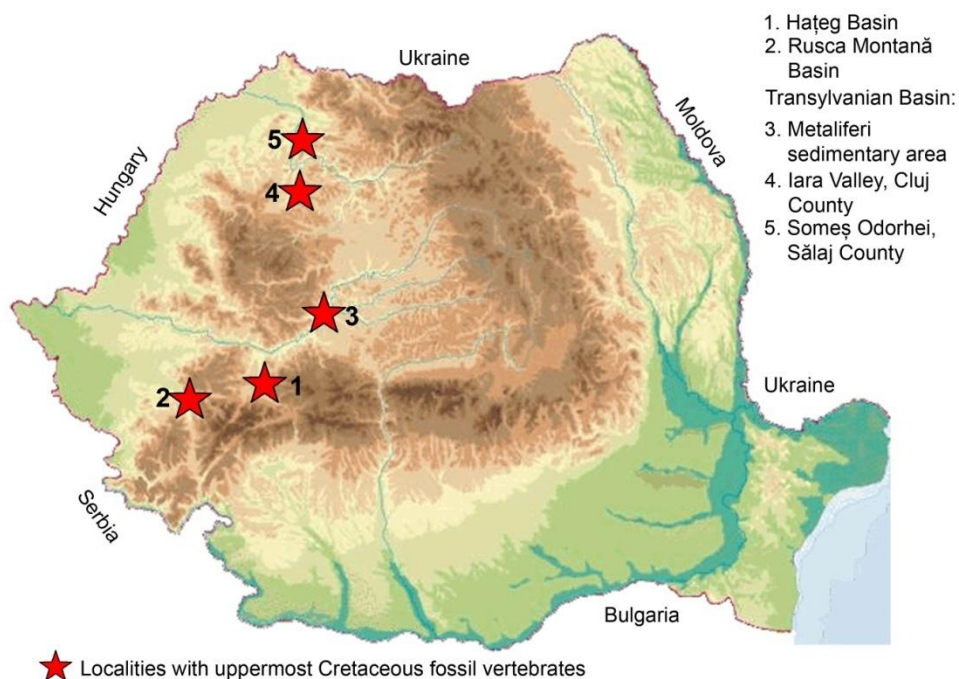


Fig. 2– The distribution of the areas where continental uppermost Cretaceous vertebrates were found in Romania indicated by a star: 1. Hațeg Basin; 2. Rusca Montană Basin; 3. Metaliferi sedimentary area, Alba County; 4. Iarii Valley, Cluj County; 5. Someș Odorhei, Sălaj County.

In Romania, the latest Cretaceous/Paleogene terrestrial formations are located within the Carpathian regions (**Fig. 2**). The compressive regime leading to the rise of the South Carpathians orogene ended in the Early Maastrichtian (latest Cretaceous tectogenesis, “Laramian”; **Săndulescu, 1984**). It was followed by the collapse of several parts of the new erected nappes, with the formation of several extensional basins (**Willingshofer, 2000; Willingshofer et al., 2001**), filled by terrestrial deposits. Such uppermost Cretaceous (mainly Maastrichtian) continental deposits are exposed in our country in the Hațeg and Rusca Montană basins, and in the several areas in the Transylvanian basin (**Fig. 2**). In this manner, a whole alignment of exposures allows to reconstruct at least a margin of the “Hațeg Island”.

2.2. Hațeg Basin

Located at the limit between Occidental and Southern Carpathians (**1** in **Fig. 2**), the Hațeg Basin is famous due to its terrestrial uppermost Cretaceous (Maastrichtian) deposits bearing peculiar vertebrate assemblages dominated by dwarf dinosaurs, firstly described since the end of the 19th century (**Halaváts, 1897; Nopcsa, 1897**).

The basin basement concerns metamorphic, magmatic and sedimentary parts of the Getic Nappe (Median Dacides) and possibly, the Inner Danubian Unit (Marginal Dacides; **Săndulescu, 1984**). In the Getic Nappe, the metamorphic rocks (Drăgșani and Zeicani series) are directly covered by Permian and Lower Jurassic clastics, followed by Middle Jurassic marine limestone and marl, Upper Jurassic-Lower Cretaceous reef and fore-reef limestones (**Codarcea et al., 1967; Dessila-Codarcea et al., 1968; Stilla, 1985; Pop, 1990; Bojar et al., 2010**). Around the Aptian/Albian boundary (“the Austrian phase”; **Săndulescu, 1984**), the collision of the Apulia, Rhodope, and Moesia microplates lead to the exhumation of the Hațeg area followed by erosion (**Willingshofer et al., 2001; Csontos and Vörös, 2004; Therrien, 2005**).

In the first stages of the latest Cretaceous history, the sedimentation was mainly marine and dominated by flysh sequences (**Melinte, 2010; Melinte and Bojar, 2010**), but after all the basin area became emerged and molasse sediments were accumulated during Maastrichtian-?Early Paleocene. The molasse consists mainly of conglomerates, sandstones and clays (**Grigorescu and Anastasiu, 1990**). This uppermost Cretaceous continental history is documented by at least two Maastrichtian terrestrial formations (**Grigorescu and Anastasiu 1990**): Densuș-Ciula and Sânpetru formations.

The Densuș-Ciula Formation, is exposed in the northern sectors of the basin (e.g. Densuș, Vălioara, Tuștea, General Berthelot, Crăguiș; **Anastasiu and Csobuka, 1989; Grigorescu et al., 1990; Bojar et al., 2005**), whereas Sânpetru Formation in the southern basin areas, as the Sibișel, Râul Mare and Bărbat Rivers (e.g. Sânpetru, Totești, Nălaț-Vad, Pui; **Nopcsa, 1905; Grigorescu et al., 1985, 1999; Codrea et al., 2002; Smith et al., 2002; Van Itterbeeck et al., 2004, 2005; Bojar et al., 2005; Therrien, 2005, 2006; Therrien et al., 2009**).

Both formations are of same fluvial origin (**Grigorescu and Anastasiu 1990; Grigorescu, 1992; Van Itterbeeck et al., 2004, 2005; Therrien, 2005, 2006; Therrien et al., 2009; Panaiotu and**

Panaiotu, 2010). **Van Itterbeeck et al. (2004, 2005)** and **Therrien (2005, 2006)** considered that these sediments accumulated in well drained floodplain environments.

The paleomagnetic data (beginning of the Chron C32n.1n - end of the Chron 31n; **Panaiotu and Panaiotu, 2010**), as well as the microvertebrates (e.g. **Grigorescu et al., 1999; Smith et al., 2002**), pollen (**Antonescu, 1983; Van Itterbeeck et al., 2005**) or freshwater gastropods (**Pană et al., 2001**) are indicative for an early-late Maastrichtian age for these rocks (for a review about the age constrains see **Csiki-Sava et al., 2016**).

2.3. Rusca Montană Basin

The Rusca Montană (2 in **Fig. 2**) is an intra-mountain basin located in southwestern Romania, in the Western Carpathians, south of Mureş River. It lies over the rocks of Valea lui Stan and Uria thrusting nappes, both belonging to the Supragetic Nappes erected in the latest Cretaceous tectogenesis (**Balintoni, 1997**). Therefore, the sole of this basin concerns various metamorphic rocks, covered by Mesozoic sedimentary deposits (Lower Jurassic–uppermost Cretaceous; **Codrea et al., 2012a**, and references therein).

The latest Cretaceous evolution of this basin concerns a rather long lasting marine realm (Coniacian-Late Campanian; **Mamulea, 1955; Dincă, 1977**), ended by emersion. After that, only continental environments (?Late Campanian-Maastrichtian-?Paleogene; **Pop et al., 1972**) have developed, resulted from the evolution of a fluvial system. This marine/continental transition shares similitude with the Haţeg and Transylvanian basins (**Grigorescu and Melinte, 2002; Codrea and Dica, 2005, Codrea et al., 2010c; Melinte-Dobrinescu, 2010**) and even the tectonic evolution of the Rusca Montană Basin is very similar to that of the Haţeg Basin (**Willingshofer et al., 2001**).

The age of all these deposits is considered uppermost Cretaceous (Maastrichtian), based on the pollen and spores (**Antonescu et al., 1983**), macroflora (**Popa et al., 2014, 2016**, and references therein) and vertebrates (**Codrea et al., 2009, 2012a; Vasile and Csiki, 2011; Csiki-Sava et al., 2016**).

For long time, Maastrichtian vertebrates were not mentioned at all in Rusca Montană Basin. Even the Baron Fr. Nopcsa, a fine viewer of these faunas couldn't find evidence on terrestrial

vertebrates in this basin. However, in the last decade, evidence of the presence of Maastrichtian vertebrates occurred in the eastern half of the basin, mainly near Lunca Cernii de Sus area (**Codrea et al., 2009, 2012a**). The main outcrops of interest for vertebrates are exposed at Negoiu village, on Fărcădeana Creek, which we name Ng1 and Ng2.

2.4. Transylvanian Basin

2.4.1. Southwestern border of the Transylvanian Basin (=“Metaliferi sedimentary area”)

The uppermost Cretaceous-Lower Moicene deposits are of peculiar interest in the Transylvanian Basin. These deposits are well exposed in Alba County and here the Cretaceous/Paleogene transition is well documented together with the evolution of the sedimentary environments during the early Cenozoic.

Nopcsa later extended his research outside the Hațeg Basin to other areas (**Nopcsa, 1905**), reporting new Late Cretaceous exposures and Maastrichtian dinosaur localities in the SW Transylvanian Basin. One of these regions is located in Alba County, and named the Metaliferi sedimentary area (**Codrea and Dica, 2005; 3 in Fig. 2**). Located in the Southwest Transylvanian Basin, these Late Cretaceous continental deposits are sandwiched between marine sequences (**Codrea and Dica, 2005**). Such rocks crop out between Alba Iulia, Șard, Vurpăr, Pianu de Jos, Petrești, Sebeș, Berghin and Teleac (**Codrea et al., 2010a, b, c; Vremir, 2010; Vremir et al., 2015b**).

The lithostratigraphic units (cf. **Codrea and Dica, 2005²**) from the area are: Bozeș Formation (Santonian–Early Maastrichtian), Vurpăr Formation (Early Maastrichtian), Șard Formation (Maastrichtian), Ighiu Formation (Early Priabonian–Early Rupelian), Bărbant Formation (Rupelian–Chattian) and Sântimbru Formation (Aquitanian).

The Vurpăr Formation includes deltaic sequences interleaved with several short marine episodes, whereas the Șard Formation accumulated in fluvial environments, represented by floodplain overbank red silty mudstones, interleaving with clastic channel fills (e.g. **Codrea et al., 2001, 2010c; Codrea and Dica, 2005; Therrien, 2005**). The Șard Formation is dominated by red beds

² For other proposed stratigraphy see **Vremir et al., 2015b**.

accumulated in a meandering fluvial environment with numerous inner bars and channel lags (sandstone and coarse conglomerate).

Accordingly to **Codrea et al. (2001)**, in this area of the Transylvanian Basin, two sectors with uppermost Cretaceous terrestrial deposits can be outlined: Vințu de Jos-Vurpăr-Pâclișa-Șard and Oarda de Jos-Lancrăm-Sebeș, respectively. The same authors remarked that the fossils which can be found in this area sustain Nopcsa's idea who suggested that these deposits can be compared with the ones of the Sânpetru Formation (Hațeg Basin).

2.4.2. Cluj County – Iara Valley

Upper Cretaceous terrestrial vertebrates were also mentioned from Cluj County (4 in **Fig. 2**), on Iara Valley.

From a geographical point of view, Iara is located on the SW border of the Iara Basin. **Săndulescu (1984)** and **Codrea et al. (2010c)** remarked the fact that the Iara Basin represents nothing else than a part of the larger Transylvanian Basin, more precisely just an embayment of this basin which accordingly to these authors is bounded by the Inner Dacidian and Transylvanide segments of the Carpathian orogenic belt. **Rusu (1987)** considers the Paleogene deposits from the area as being a part of the “Gilău sedimentary area” (**Codrea et al., 2010c**).

2.4.3. Sălaj County – Someș Odorhei

Last but not least, uppermost Cretaceous terrestrial deposits are cropping out in Sălaj County (5 in **Fig. 2**) at Someș Odorhei, near Jibou City.

This region is the northernmost area where uppermost Cretaceous terrestrial deposits crop out in Romania. Although, uppermost Cretaceous continental deposits are exposed, the area near Jibou is well-known due to the Paleogene deposits, the outcrops from here being among the most representative for such deposits in northwestern side of the Transylvanian Basin (=“Meseș sedimentary area”; **Rusu, 1987; Codrea et al., 2010c**).

The first uppermost Cretaceous terrestrial vertebrates from Sălaj County were reported by **Baron F. Nopcsa (1905)** from Bârsa Valley. His find consists of a rib fragment which documented an ornithomimid dinosaur, namely “*Mochlodon seussi*”, a crocodylian tooth and some turtle remains.

More than 100 years, no other Maastrichtian terrestrial vertebrates were reported from the area, until the discovery of **Codrea and Godefroit (2008)**.

Based on these osteological remains **Codrea and Godefroit (2008)** proved that at least the base of Jibou Formation is of Maastrichtian age, being coeval with the Sânpetru and Densuș-Ciula formations of the Hațeg Basin, extending the “Hațeg Island” several hundreds of kilometers from Hațeg to the northeast (**Codrea and Godefroit, 2008**).

2.5. Remarks

In such a context, where the terrestrial uppermost Cretaceous deposits are affected either by natural changes of the heritage (e.g. Sânpetru, Totești, Nălaț-Vad) or by human activity (e.g. Pui, Tuștea, Someș-Odorhei, but also the ones from Alba County which are more and more dirtier due to the people who throw the thrash directly in the river or on the paleontological/geological site), in order to let to the following generations of paleontologists and geologists images of the most representative such outcrops as they were nowadays, some actions must be taken. Such an action was already taken by **Codrea et al. (2015)** who proposed a 3D database of the uppermost Cretaceous outcrops from the “Hațeg Island”.

3. Materials and Methods

3.1. Introduction

The study of terrestrial fossil vertebrates is used in order to obtain a high-resolution stratigraphy for the terrestrial ecosystems. In contrast to marine sediments, where invertebrates are usually the index fossils (*marker species*), in the continental deposits the vertebrate remains represent such markers. Therefore, in the continental paleoenvironments, these vertebrate fossils can be used for establishing the geological age of various formations and for reconstruction of the paleobiogeography.

3.2. Materials

All the materials used in this thesis were recovered from the terrestrial latest Cretaceous deposits of the “Hațeg Island” (**Nopcsa, 1914**) and are curate in the paleontological collections of the

Paleontology-Stratigraphy Museum and of the Laboratory of Paleotheriology and Quaternary Geology from the Babeş-Bolyai University of Cluj-Napoca.

3.3. Methods

Firstly, we have to do periodic monitoring of the known sites, and also must try to identify new fossiliferous localities by prospecting various areas. In the known/new fossil-bearing sites/localities it is necessarily to identify levels of interest (concentration levels). The fossilization process involves specific taphonomical conditions. Some of these conditions will be presented in subsequent chapters.

3.3.1. Methodology in the study of macrovertebrates

This involves the following:

- Prospecting the area of interest.
- Finding and extracting the fossil remains.
- Draw a grid plan.
- The digging direction is vertical.
- Drawing and photographing the *in situ* fossil.
- The remains are excavated one by one.
- The “plaster-jacket” technique involves the following: the fossil is outlined, than it is covered by moisten paper; on the moisten paper you have to put textile stripes which are covered by a plaster layer; after the plaster jacket is consolidated, you must dig on vertical and after you must carefully overturn the fossil in order to do the previous steps for its base; after that, you have a “cocoon” which is taken to the laboratory for extracting the fossil, conservation and study.

3.3.2. Methodology in the study of microvertebrates

In paleontology, the term “micro-preparation” concerns of the methods of preparation and conservation of the fossils using techniques under a binocular microscope.

This thesis is mainly focused on the Maastrichtian multituberculate mammals which populated the “Hațeg Island”. Some of the multituberculate fossils were recovered in field and extracted directly from the layers in which they occurred, but others were recovered by **screen-washing**.

This method involves:

- Prospecting the area of interest in order to identify the possible facies where micro remains may have been conserved.
- The best sediments for the preservation of microvertebrate remains are the marls and clays.
- Collecting about 40-80 kg of sediments for sampling; drying the sediment; processing the sediment; searching for diagnostic elements for distinct groups of microvertebrates; collecting massive amounts of sediment; processing the final amount of sediment;
- The recovered material should be cleaned in order to study it.
- Preserving the remains.
- Registering the remains in a collection (inventory).

3.4. Several techniques for preparing and preserving the fossil vertebrates in the laboratory

Preparing and preserving the fossil remains can be done by using chemical or mechanical methods, or by combining the previous two methods. For each fossil remain you have to decide which technique (method) you will use.

The **chemical methods** refer to the removal of the sediment by sinking the sample, which contains the osteological remains in various diluted chemicals such as acetic acid or peroxide.

The **mechanical methods** involves the removal of the sediment in order to extract the fossil by using small hammers and different chisels („**classical method**”), but also using different **percussive and pneumatic tools**.

During the preparation and preservation processes **the fossil remains are impregnated with special polymers** such as paraloid, rodopast or mowillite in order to strengthen it.

The identification and description of the materials used in this thesis was made by direct observations on the fossils.

Remarks. Due the fact that various methods were used in the preparation and conservation of the remains used in this thesis, for each of them the detailed methods are given in the subsequent chapters.

3.5. Terminology used in the description of multituberculate mammals teeth

The PhD thesis is focused on solving several issues related to the uppermost Cretaceous multituberculates unearthed in our country.

The specific morphologic elements and the direction of observation for multituberculate mammals' cheek teeth are exemplified in **Fig. 3**.

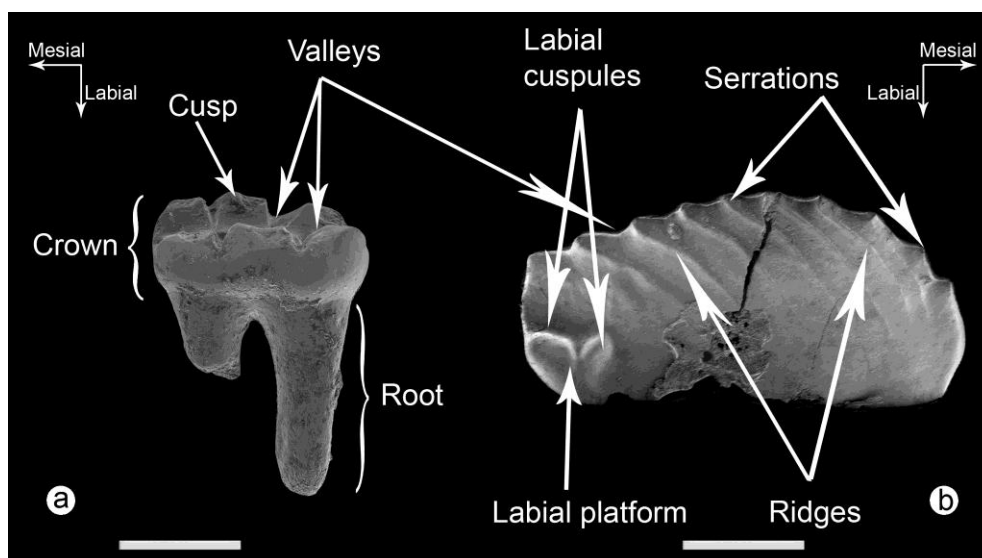


Fig. 3 – Main morphologic elements of kogaionid multituberculate cheek teeth **a**. A lower molar (m1); **b**. A kogaionid multituberculate p4. Note that the p4's root is broken. Scale bars equal 1 mm.

4. Generalities about multituberculate mammals and an overview of Mesozoic multituberculates from Europe

This chapter aims to highlight the most important discoveries of Mesozoic multituberculate mammals from Europe, with a special focus on the ones originating from Romania.

Multituberculates were clearly present in the European vertebrate faunas from the Middle Jurassic, reaching their maximum systematic diversity on the continent, in the Early Cretaceous. In the Late Cretaceous, multituberculates continually inhabited the European archipelago, being

present on the landmasses of the “Hațeg Island”, where the endemic Kogaionidae family had diversified along a totally different evolutionary direction compared to the lineages present in the Upper Cretaceous of Asia, or North America. Kogaionids continued to populate the European landmasses during the Paleocene, their remains being found in Romania, France, Spain and Belgium.

5. New data about the multituberculate mammal *Barbatodon transylvanicus* from the Upper Cretaceous of the Hațeg Basin (Romania)

5.1. Introduction

In Europe, there is a considerable disparity between the knowledge of the western versus eastern latest Cretaceous mammalian faunas. While in Western Europe only therians—mainly laiodontine “zhelestids”—are reported (**Gheerbrant and Astibia, 2012; Tabuce et al., 2013**, and references therein), in Eastern Europe mammals are documented exclusively by representatives of the family Kogaionidae (**Rădulescu and Samson, 1996**), an endemic group of multituberculates that seem to have evolved in insular environments (**Codrea et al., 2014; this thesis-Chapter 6**).

The intraspecific variability of *Barbatodon transylvanicus* is described in this chapter based on new discovered materials.

5.2. The Geology of the Pui Locality

Within the Hațeg Basin, Pui is the southeasternmost locality where Maastrichtian continental exposures, dominated by red beds, crop out. Nopcsa’s first studies already pointed out their fluvial origin, including the ones from Pui (**Nopcsa, 1905**). The Pui township is located about 20 km southeast from the town of Hațeg, crossed by the Bărbat River. In the riverbed, the red beds can be observed due to the river stream erosion. The best time when the exposures can be studied is in the dry seasons, when the water level is low.

5.3. Materials and methods

The multituberculate material available for the present study was collected from the red beds in the Maastrichtian locality of Pui from the same area as UBB P-Mt1 (see **Smith and Codrea,**

2015 for more details about the site). This new material has derived from two individuals labeled UBB P-Mt2 and UBB P-Mt3.

The photographs were taken with a Nikon D7000 DSLR camera and a Nikon AF 60 mm f2.8 G ED Micro lens mounted on a tripod. The specimens were whitened with a light coating of ammonium chloride (NH₄Cl) in order to prevent any specular glare from the shiny enamel surface.

5.4. Systematic paleontology

Mammalia Linnaeus, 1758

Allotheria Marsh, 1880

Multituberculata Cope, 1884

Cimolodonta McKenna, 1975

Kogaionidae Rădulescu and Samson, 1996

Barbatodon Rădulescu and Samson, 1986

Type species: Barbatodon transylvanicus Rădulescu and Samson, 1986.

Holotype: ISB IS.001, isolated left m1.

Type locality: Pui, Hunedoara District, Transylvania, Romania.

Type Horizon: Sânpetru Formation, Maastrichtian, Late Cretaceous.

New available referred specimens: UBB P-Mt2 (material originating from the same individual): UBB P-Mt2-1, left dentary with i1-m2; UBB P-Mt2-2, right dentary with i1 (broken)-m1; UBB P-Mt2-3, left I2; UBB P-Mt2-4, left P2; UBB P-Mt2-5, right P2; UBB P-Mt2-6, left P4; UBB P-Mt2-7, left M1; UBB P-Mt2-8, left M2; UBB P-Mt3 (material originating from the same individual): UBB P-Mt3-1, left dentary with i1 (broken)-m2; UBB P-Mt3-2, left P1-P2; UBB P-Mt 3-3, left P4; UBB P-Mt3-4, right M1; UBB P-Mt3-5, left M2.

Other species: Barbatodon oardaensis Codrea, Solomon, Venczel and Smith, 2014.

5.4.1. Description of the New Remains from the Pui Locality

5.4.1.1. Upper Dentition

The only available I2 (UBB P-Mt2-3) is a left incisor. It bears two cusps.

P1 - The single specimen (UBB P-Mt3-2) is a P1, in connection with a P2. The crown outline is sub-rounded. It is tricuspid, the mesial cusp being the largest.

P2 - Three specimens are available for study (UBB P-Mt2-4, left P2; UBB P-Mt2-5, right P2; UBB PMt3-2, left P2 in connection with the P1 described above). UBB P-Mt2-4 and UBB P-Mt2-5 are the left and right P2 of the same specimen. Both P2s have an oval outline with a cusp formula of 2:2. The cusps are distinct and separated by longitudinal and transverse valleys. All cusps are roughly similar in size.

Both specimens (UBB P-Mt2 and UBB P-Mt3) lack the upper third premolars.

P4 - Two left upper P4s are available for study (UBB PMt2-6, and UBB P-Mt3-3). The size of these P4s is comparable (3.82×2.10 mm, and 3.79×2.10 mm, respectively). The cusp formula is 4:2-3. The cusps are set in two mesially convergent crests. The labial crest is higher than the lingual one. The teeth are biradicate.

M1 - Two upper first molars are available for this study, one left (UBB P-Mt2-7; 4.12×2.94 mm; the actual length of the specimen may be slightly smaller due to the fact that the specimen was broken and the two pieces were subsequently glued together), and one right (UBB P-Mt3-4, 3.94×3.08 mm). The teeth are biradicate and have a subrectangular outline in occlusal view. The cusp formula is 4:4:2.

M2 - Two left second upper molars are available in the sample (UBB P-Mt2-8; 2.63×2.52 mm, and UBB PMt3-5; 2.85×2.59 mm). This molar has a triangular to square outline, with a variable cusp formula of ridge:2:3-4.

5.4.1.2. Dentary and Lower Dentition

UBB P-Mt2 is represented by two incomplete dentaries. The left dentary (UBB P-Mt2-1) is better preserved than the right one (UBB P-Mt2-2). UBB P-Mt2-1 preserves all the teeth, whereas the right dentary, UBB P-Mt2-2, is damaged. It preserves a broken i1 and the p4-m1.

The specimen UBB P-Mt3-1 represents the best preserved dentary of *Barbatodon* known to date, with in situ p4-m2. The total length, measured in occlusal view, from the base of the incisor to the distal part of the articular condyle is 32.85 mm. The diastema is 5.24 mm.

Lower Teeth of UBB P-Mt2. The left i1 is elongated and relatively gracile. The right i1 has a similar morphology to its counterpart, but the tip is broken off.

The p4s are blade-like, biradicate teeth. The length of the crown of the left p4 is 7.99 mm, while the length of the crown of its counterpart is 8.60 mm, but this value is altered by the cracks present on the crown surface. The crown is asymmetrically rounded in lateral view, with 11 small conical serrations along its edge, and two cuspules on the labio-distal platform.

The m1s have a nearly rectangular outline in occlusal view with two rows of three cusps distributed mesio-distally. The cusps are pyramidal and separated by V-shaped valleys. The disto-labial cusp is surrounded by a long cingulid. The length of the left m1 is 3.37 mm and the width is 2.39 mm.

The left m2 has a sub-rounded outline (2.49×2.48 mm) and a cusp formula of 3:2. All cusps are distinct, pyramidal shaped, and separated by longitudinal and transverse valleys.

Lower Teeth of UBB P-Mt3. The p4 is blade-like and bears 11 serrations on the edge and two cuspules on the labio-distal platform. Six ridges are present under the serrations three to eight on both labial and lingual sides. The length of the crown is 8.60mm. The highest point is situated at the level of serrations four to five.

The m1 has the same sub-rectangular outline characteristic for *Barbatodon*, with two short rows of cusps distributed mesio-distally. The length is 3.80 mm and the width is 2.57 mm, this specimen being the largest *B. transylvanicus* m1 known to date.

The m2 has a sub-rounded outline (2.85×2.56 mm) and a cusp formula of 3:2. All cusps are distinct, pyramidal shaped, and separated by longitudinal and transverse valleys.

5.4.2. Intraspecific Variability of *Barbatodon transylvanicus*

Intraspecific variability was already reported and discussed in multituberculate teeth from the latest Cretaceous Lance Formation of the Western interior, Wyoming (**Donohue et al., 2013**). Similarly, the new specimens from Pui reveal new data on the dental morphology and size differences, as well as on the variations of dentary morphology in *B. transylvanicus*.

The new incisor's main cusp presents a reddish pigmentation, a feature first reported in *B. transylvanicus* by **Smith and Codrea (2015)**, and observed now in all the I2s belonging to this taxon.

Only two I3s of *B. transylvanicus* were reported to date (**Smith and Codrea, 2015**). The I3 of these specimens (UBB P-Mt1 and UBB P-Mt4-2) is single cusped, and presents red iron pigmented enamel on its tip (**Smith and Codrea, 2015**).

All P1s known to date and belonging to *B. transylvanicus* are tricuspid. For the mean size of the P1 of this taxon see **Table 1**.

The crown of the P2 of *B. transylvanicus* shows in occlusal view a slope starting from the distal cusps of each row towards the distal margin of the tooth.

The size of these three P2s is larger than the ones of UBB P-Mt1 (**Smith and Codrea, 2015**; for the mean size of the P2 of this taxon see **Table 1**), but share with these the same morphological patterns. We interpret these size differences as intraspecific variation.

To date, only one P3 (UBB P-Mt1) belonging to *B. transylvanicus* is reported (**Smith and Codrea, 2015**). Based on this, we may remark only that the P3 is the longest cheek tooth of this taxon and respects the diagnosis of kogaionids (**Csiki et al., 2005**).

The new premolars are larger than the P4 present in UBB P-Mt1 (**Smith and Codrea, 2015**; for the mean size of the P4 of this taxon see **Table 1**), but share the same morphology, and thus, the size variation represents an intraspecific variation in this species. The crown outline of the P4s of *B. transylvanicus* is sub-rectangular, with a quasi-constant width along the entire crown. One of the new P4s (UBB PMt2-6) has three lingual cusps, whereas the other P4 (UBB PMt3-3) has only two lingual cusps. We interpret this feature as intraspecific variation.

The M1 of *B. transylvanicus* is biradicate and has a sub-rectangular outline in occlusal view. It has a cusp formula of 3-4:4:2, the lingual row of cusps being the shortest. The new available M1s cusp formula is 4:4:2, differing in this aspect from UBB P-Mt1 (**Smith and Codrea, 2015**), where the M1 bears only three labial cusps. Also the new specimens are larger than the M1 of UBB P-Mt1 (for the mean size of the M1 of this taxon see **Table 1**). We interpret these morphological and size differences as intraspecific variability.

Table 1 - Measurements (in mm) of all *Barbatodon transylvanicus* teeth known to date.

Position in tooth row	n	Lmin	Lmax	Lmean	Wmin	Wmax	Wmean
P1	3	2.60	3.05	2.78	2.10	2.49	2.23
P2	5	3.20	4.09	3.71	2.10	2.46	2.25
P3	1						
P4	3	3.30	3.82	3.63	1.90	2.10	2.03
M1*	2	3.20	3.94	3.57	2.50	3.08	2.79
M2	5	2.30	2.85	2.52	2.20	2.59	2.38
p4* [#]	4	7.60	8.60	7.94	2.20	2.40	2.30
m1*	7	3.00	3.80	3.33	2.15	2.70	2.28
m2 [^]	4	2.00	2.85	2.33	2.10	2.56	2.31

* The measurements of some known teeth are problematic due to the preservation and were not used in this table;

[#] Csiki et al. (2005) don't give dimensions for their p4[#];

[^] Grigorescu and Hahn (1987) is measured after a moulage and is not used in this table.

The M2 of *B. transylvanicus* has a triangular to square outline, with a variable cusp formula of ridge:2:3-4. In the lingual row of UBB P-Mt3-5, four distinct cusps are present, differing from UBB P-Mt2-8, and UBB P-Mt1 (Smith and Codrea, 2015), which have only three lingual cusps. We interpret this feature as intraspecific variability, not as a species defining character. The new M2s (UBB PMt3-5 and UBB P-Mt2-8) are larger than the ones present in UBB P-Mt1. The M2 (FGGUB M.1635; 2.45×2.20 mm) described by Csiki et al. (2005) is smaller than the new M2s, but shows the same morphology. These size differences (for the mean size of the M2 of this taxon see **Table 1**) support the size variability of this species. In this respect, we consider these specimens as well as the one described by Csiki et al. (2005) as belonging to the same species, *B. transylvanicus*.

The angle of the mesial margin of the coronoid process with the occlusal surface of the molar (α) is about 45° in UBB P-Mt3-1, the only new specimen that allows such measurement. Due to the fact that the newly described specimen preserves only the base of this process, the measurement

is only estimated, because the inclination of the process is possibly not correctly approximated. The coronoid process is often somewhat straighter than the dorso-mesial border of the masseteric fossa. This could explain why this angle is lower in UBB P-Mt3-1 than in FGGUB M.1635 (57°; **Csiki et al., 2005**), but in this specimen the coronoid process is by far better preserved. But if our measurements and interpretation of this angle are correct, we can consider this difference in angle measurements in the two specimens as another feature related to intraspecific variability. Based on the new specimens and on FGGUB M.1635 the length differences between the dentaries of *B. transylvanicus* are remarked.

The i1 in this species is elongated, relatively gracile (but less so than in ptilodontoids, as **Csiki et al., 2005** already reported), and slightly curved.

The p4 of *B. transylvanicus* is double-rooted, has ten or eleven serrations on its edge, and an arcuate crown outline. All of the new p4 specimens have 11 serrations on the edge, differing from UBB P-Mt1, which bear only ten, and FGGUB M.1635, where only nine serrations were recognized (called cusps by **Csiki et al., 2005**). The left p4 of UBB P-Mt2 is the first p4 of *Barbatodon* where cuspules are observed on the labio-distal platform. All the new p4s are larger than the previously known p4s of *B. transylvanicus* (**Csiki et al., 2005**; **Smith and Codrea, 2015**; for the mean size of the p4 of this taxon see **Table 1**).

The m1 of *B. transylvanicus* has a nearly rectangular outline, with two rows of cusps distributed mesio-distally. However, there are four labial cusps and three in the lingual row of the m1 of UBB P-Mt3-1, similar to the holotype of *B. transylvanicus* (**Rădulescu and Samson, 1986**), being different in respect from the m1s present in UBB P-Mt1 (**Smith and Codrea, 2015**), UBB P-Mt2, and FGGUB M.1635 (**Csiki et al., 2005**), which bear only three labial cusps.

The left m1 of UBB P-Mt2 is similar in size to the holotype of *B. transylvanicus* (ISB IS.001; **Rădulescu and Samson, 1986**), and to the m1 described by **Csiki et al. (2005)**, while the m1 of UBB P-Mt3 is the largest m1 of *B. transylvanicus* (for the mean size of the m1 of this taxon see **Table 1**).

The m2 of *B. transylvanicus* has a sub-rounded outline with a cusp formula of 3:2. The new teeth have twice the size, but have a similar morphology to that described by **Grigorescu and Hahn (1987; 1.25×1.25)** as *Paracimexomys? dacicus* (a junior synonym of *B. transylvanicus*). The new

m2s are larger (20–30% longer and 15–19% wider) than the ones of UBB P-Mt1. The m2 is the least worn tooth from the lower dentition.

5.4.3. Comparisons of the new remains of *Barbatodon transylvanicus* with other kogaionid multituberculates

The preserved part of the crown of the new I2 of *B. transylvanicus* is covered by enamel differing to the restricted enamel band of I2 of *Kogaionon unguoreanui* (Rădulescu and Samson, 1996).

The dimension of the available P1 (UBB P-Mt3-2) are shorter and wider than the P1 of *Kogaionon unguoreanui* (Rădulescu and Samson, 1996), but much larger than that of *B. oardaensis* (Codrea et al., 2014; this thesis-Chapter 6) and of *Hainina pyrenaica* (Peláez-Campomanes et al., 2000). Its tricuspid morphology is reminiscent of *K. unguoreanui* (Rădulescu and Samson, 1996) and *H. belgica* (Vianey-Liaud, 1979).

The size of new three P2s is comparable with the ones of *K. unguoreanui* (4.20×2.20 mm), being around twice the size of *B. oardaensis*. In occlusal view, the crown shows a slope starting from the distal cusps of each row towards the distal margin of the tooth, as in *B. oardaensis* (Codrea et al., 2014; this thesis-Chapter 6). The enamel is wrinkled as in *B. oardaensis*, in contrast to the condition known in *K. unguoreanui*.

The size of the new P4s is almost the same as in *K. unguoreanui* (3.70×2.15 mm). It is almost twice as large as the corresponding tooth of *B. oardaensis* and more than twice as large as the P4 of *H. pyrenaica*. The cusps are conical as in *K. unguoreanui*, *H. belgica*, and *H. pyrenaica*. The crown outline is similar to that of *Kogaionon*, but differs from *H. belgica* and *H. pyrenaica*, which have a narrower distal margin. Analyzing the three known species of latest Cretaceous kogaionids, we may conclude that the crown outline of the kogaionid P4s is sub-rectangular with a quasi-constant width along the entire crown. This is a pattern also observed in the Paleocene genus *Hainina* (Vianey-Liaud, 1979, 1986; Peláez-Campomanes et al., 2000).

The new M1s have one lingual cusp less than in the nominative species of the family, *K. unguoreanui* (Rădulescu and Samson, 1996), and two cusps less than in *H. pyrenaica* (Peláez-Campomanes et al., 2000), and furthermore its outline is more sub-rectangular than in these two

latter species. It has four internal cusps as in other Late Cretaceous kogaionids and as in *H. pyrenaica*. These teeth are similar in size to those of *K. unguereanui* (3.90×3.20 mm), and larger than in *B. oardaensis* and *H. pyrenaica*.

Two new M2s of *B. transylvanicus* are reported (UBB PMt2-8, and UBB PMt3-5). In one of the new M2s (UBB PMt3-5), four distinct cusps are present in the lingual row, differing from the condition of three lingual cusps present in *K. unguereanui* and *B. oardaensis*. The size of these teeth is quite similar to the M2 of *K. unguereanui* (2.90×2.70mm), but the outline of the M2 of *Kogaionon* is more triangular than in *Barbatodon*. The specimens are larger than all the M2s described for *B. oardaensis* (Codrea et al., 2014; this thesis-Chapter 6).

No other kogaionid dentaries were described than those known from *B. transylvanicus*.

The i1s of *B. transylvanicus* are elongated, relatively gracile, and slightly curved. The enamel, which covers the whole crown surface, is similar to those described previously by Rădulescu and Samson (1997), Csiki and Grigorescu (2000), and Csiki et al. (2005).

From a morphometrical point of view, the p4 of *B. transylvanicus* is at least twice as large as the p4s of *B. oardaensis* (Codrea et al., 2014, 2016; this thesis-Chapter 6 and 7) and *H. belgica* (Vianey-Liaud, 1979). All of the new p4 specimens of *B. transylvanicus* have 11 serrations on the edge, similar to the p4 UBB ODAN-Mt-1 of *B. oardaensis* from Oarda de Jos (Codrea et al., 2014; this thesis-Chapter 6), being different in this respect to the p4 UBB Ng2-01 of *B. oardaensis* described from Rusca Montană Basin (Codrea et al., 2016; this thesis-Chapter 7) and of *H. belgica* (Vianey-Liaud, 1979).

All the new m1s have a nearly rectangular outline as seen in other kogaionids (Vianey-Liaud, 1979, 1986; Codrea et al., 2014), with two rows of cusps distributed mesio-distally. The left m1 of UBB P-Mt2 is 1.5 times larger than the largest m1 described in *B. oardaensis* (Codrea et al., 2014) and also considerably larger than the m1 in *H. pyrenaica* (Peláez-Campomanes et al., 2000).

The new m2s have a similar sub-rounded outline to that of *B. oardaensis*. The teeth are twice as large as the m2 of *B. oardaensis* (Codrea et al., 2014; this thesis-Chapter 6) and also larger than the m2 of *H. pyrenaica* (Peláez-Campomanes et al., 2000).

5.5.1. Dental Variability

The cheek teeth of North American Early to Late Cretaceous multituberculate mammals are usually based on samples with statistically adequate number of specimens for each tooth of the dental rows.

The occurrence of intraspecific variability in *B. transylvanicus* from Pui is suggested by different cusp formulae observed on the same dental position such as in P4 (4:2-3), M1 (3-4:4:2), M2 (ridge:2:3-4), p4 (10-11 serrations), and m1 (3-4:3), and also by size differences in each tooth position (**Table 1**). These differences are comparable with the ones seen in the North American multituberculates from the Early-Late Cretaceous boundary, latest Cretaceous and even Paleocene (e.g. **Eaton and Cifelli, 2001; Scott, 2003; Eaton, 2006a, b; Hunter et al., 2010; Donohue et al., 2013**).

5.5.2. General pattern of wear of the new cheek teeth

The patterns of wear are similar with the ones seen on UBB P-Mt-1 being related to a hard diet specialized dentition as (**Smith and Codrea, 2015**).

5.6. Conclusions

The new *B. transylvanicus* sample described from Pui provides new data about the dental morphology of this genus, as well as new opportunities for comparisons with *Kogaionon*. Based on this new material and on the material of *B. oardaensis* (**Codrea et al., 2014; this thesis-Chapter 6**), an emended diagnosis of the genus *Barbatodon* is proposed. The upper dentition of *Barbatodon* was compared to *K. ungureanui* and several similarities were noticed. The new material is important because it augments our knowledge on the dentition and dentary morphology of *B. transylvanicus*, pointing out the presence of intraspecific variations.

6. A new kogaionid multituberculate mammal from the Maastrichtian of the Transylvanian Basin, Romania

6.1. Introduction

Late Cretaceous mammals are poorly known from Europe. Whereas in western Europe only therians have been recorded, including mainly “Zhelestidae” (**Gheerbrant and Astibia, 2012**), and one herpetotheriid marsupial (**Martin et al., 2005**), in eastern Europe only multituberculate mammals have been recorded, all belonging to the endemic family Kogaionidae. These mammals were widespread on the landmass of the so-called “Hațeg Island” (**Grigorescu et al., 1985; Rădulescu and Samson, 1986, 1996; Csiki and Grigorescu, 2000; Codrea et al., 2002, 2009, 2012a, b; Smith et al., 2002; Csiki et al., 2005**). After the Cretaceous–Paleogene boundary, kogaionids survived in Paleocene, aside from Romania, in France, Spain, and Belgium (**Vianey-Liaud, 1979, 1986; Gheerbrant et al., 1999; Peláez-Campomanes et al., 2000**). This study is focused on a new species of kogaionid from the Late Cretaceous of Romania, the first Cretaceous kogaionid discovered outside the Hațeg Basin.

6.2. The Geology of Oarda de Jos Locality

The Maastrichtian deposits at Oarda de Jos are exposed at two outcrops, designated as ODA and ODB, located about 3 km south of Alba Iulia, on Sebeș River. We focus here only on the outcrop ODA (**Codrea et al., 2010a, b, c**), a steep slope of about 50 m in length and of 17–19 m in height. In the top of ODA, a lens-like accumulation of grey silt documenting a fluvial abandoned channel floodplain environment, yielded an extremely rich vertebrate concentration, including fishes, albanerpetontids, frogs, lizards, turtles, crocodylians, dinosaurs, birds and mammals (**Codrea et al., 2010a, 2012b**).

In summary, the Oarda de Jos accumulation is here interpreted as a fluvial, pond environment, with high variations of flow energy.

6.3. Materials and methods

The material available consists of more than 70 isolated teeth of multituberculate mammals, recovered by screen-washing and processing of about 2800 kg of sediments. Photographs of the

studied specimens were taken with scanning electron microscope (ESEM Quanta 200) at the Royal Belgian Institute of Natural Sciences, Brussels.

The cusp formula is counted from the labial to the lingual side. Upper premolars position is following **Kielan-Jaworowska and Hurum (2001)**, see addendum p. 426 for more details).

For this chapter, only the cheek teeth from **Codrea et al. (2014)** together with some unpublished incisors will be used.

6.4. Systematic paleontology

Barbatodon Rădulescu and Samson, 1986

Type species: Barbatodon transylvanicus Rădulescu and Samson, 1986.

Barbatodon oardaensis new species (Codrea, Solomon, Venczel and Smith, 2014).

Derivation of name: ‘oardaensis’ refers to Oarda de Jos locality, where the specimens were collected.

Holotype: UBB ODAN-Mt-13, isolated M1 (**Fig. 4**).

Referred specimens: UBB ODAN-Mt-44: ?left I2; UBB ODAN-Mt-45: left I3; UBB ODAN-Mt-38: right P1; UBB ODAN-Mt-70, 71: right P2; UBB ODAN-Mt-24, 29, 69: right P3; UBB ODAN-Mt-35: left P3; UBB ODAN-Mt-22, 23, 25,27, 28: right P4; UBB ODAN-Mt-21, 26, 33: left P4; UBB ODAN-Mt-10, 11, 12, 13: right M1; UBB ODAN-Mt-6, 7, 8, 9, 65: left M; UBB ODAN-Mt-66, 67: right M2; UBB ODAN-Mt-16, 31, 36, 37: left M2; UBB ODAN-Mt-50: right i1; UBB ODAN-Mt-49, 51: left i1; UBB ODAN-Mt-1: right p4; UBB ODAN-Mt-18, 19: right m1; UBB ODAN-Mt-14, 15, 17, 20: left m1; UBB ODAN-Mt-68: right m2; UBB ODAN-Mt-32, 34: left m2.

Diagnosis: Small species of *Barbatodon* with the following cusp formula: P1 1:2; P2 2:2; P3 3:3; P4 4:2-3; M1 3:4:2; M2 2:3; p4 with 11 serrations and seven ridges; m1 3:3; m2 2-3:2. It differs from *B. transylvanicus* in being approximately 35% smaller. Differs from *Kogaionon unguoreanui* in being approximately 45% smaller, in having an additional cusp in P3, and in having only two cusps on the lingual row of M1 instead of three.

Type locality: Oarda de Jos (ODA section), Alba County, Transylvania, Romania; Uppermost Cretaceous (Maastrichtian), Șard Formation.

6.4.1. Description

6.4.1.1. Upper Dentition

I2 - the first upper incisor UBB ODAN-Mt-44 is probably a left incisor. It bears a main cusp forming the major part of the crown, and an additional cusp.

I3 - the second upper incisor UBB ODAN-Mt-45 is a right incisor. It is single-cusped and preserves both the crown and the root.

P1 - is extensively worn and the mesial part of the crown is broken. It bears three conical cusps.

P2- has two roots and a nearly oval crown outline with four conical cusps (cusp formula 2:2). The cusps are distinct and separated by longitudinal and transverse valleys.

P3 - has two roots, an oval crown outline, and two parallel longitudinal cusp rows (cusp formula 3:3). The cusps are conical, large, except for the third labial one which is small, but distinct.

P4 - has two roots, a sub-rectangular crown outline, and a cusp formula of 4:2-3. The cusps are aligned on two mesially convergent crests.

M1 - has two roots and a sub-rectangular outline. UBB ODAN-Mt-13, the holotype, is the best preserved M1. The mesial and distal margins of the crown are nearly parallel. The cusp formula is 3:4:2. The wear stage is different in each specimen.

M2 - has two roots and a triangular to square crown outline (cusp formula 2:3). The crown supports two short longitudinal cusp rows separated by a deep longitudinal valley.

6.4.1.2. Lower Dentition

i1 - two mesial extremities of lower first incisor (UBB ODAN-Mt-50: right i1; UBB ODAN-Mt-51: left i1), and a more complete left lower incisor (UBB ODAN-Mt-49) are available for this study. The incisors have a slightly curved elongated crown.

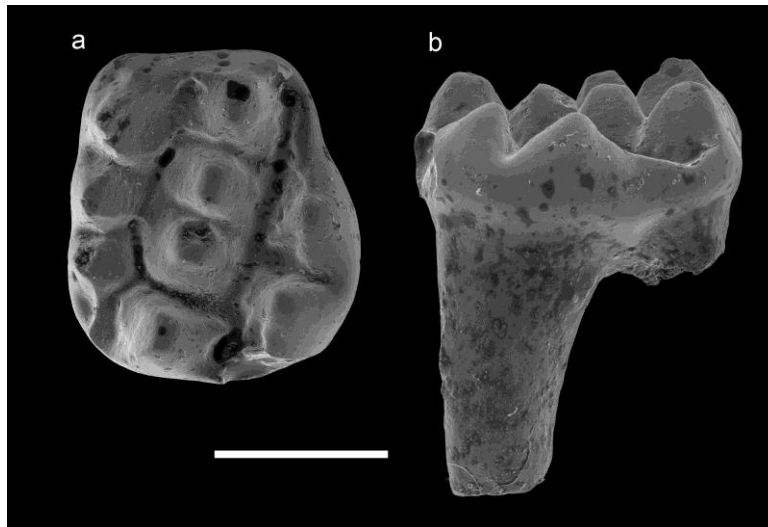


Fig. 4 - *Barbatodon oardaensis* - holotype, right M1: **a.** occlusal view; **b.** lingual view; Scale bar equals 1 mm.

The p4 is two-rooted, blade-like and arcuate with oblique ridges as in other cimolodontans (**Kielan-Jaworowska and Hurum, 2001**). The crown is asymmetrically rounded in lingual and labial views, with eleven small serrations, the first two projecting mesially, the others dorsally and distally, with the highest point situated at the level of serrations four and five.

m1 - the first lower molar is two-rooted and nearly rectangular in occlusal view with two rows of three cusps aligned mesio-distally. The cusps are pyramidal and separated by “V”-shaped transverse valleys. Two diverging ridges are present extending from the distalo-lingual part of the median labial cusps to the second and third lingual cusps. There is variability in the shape of the distalo-labial cusp, which can occur as a single large cusp or a small cusp surrounded by a long distalo-labial cingulum.

m2 - the second lower molar has a cusp formula of 2-3:2 and the crown outline is sub-circular. All cusps are well individualized, pyramidal, and separated by longitudinal and transverse valleys.

6.4.2. Comparisons with other kogaionids

The I2 is bicuspid as seen in the I2 of *B. oardaensis* from Rusca Montană Basin (**Codrea et al., 2016; this thesis-Chapter 7**) and as in *B. transylvanicus* (see **Smith and Codrea, 2015**, fig. 5).

The I3 of *B. oardaensis* is single cusped as in the large *B. transylvanicus* (UBB P-Mt1 and UBB P-Mt4–2; **Smith and Codrea, 2015**) having a similar general pattern as seen in the larger species, but showing no red iron pigmented enamel on its tip as in the species from Pui (**Smith and Codrea, 2015**).

The P1 (=P2 cf. **Peláez-Campomanes et al., 2000**) of *Barbatodon oardaensis* is less than half of that of *Kogaionon unguoreanui* (**Fig. 5**). This P1 has a similar crown outline to the P1 of *Hainina belgica* (**Vianey-Liaud, 1979**).

The P2 (=P3 cf. **Peláez-Campomanes et al., 2000**) of *K. unguoreanui* is twice larger than in *B. oardaensis* (**Fig. 5**). The enamel noticed in the P2 of *B. oardaensis* is wrinkled, in contrast with the smooth enamel seen in *Kogaionon*.

The P3 has six rather than five cusps as in the case of *K. unguoreanui*, whose P3 (=P4 cf. **Peláez-Campomanes et al., 2000**) is more than twice larger than in *B. oardaensis* (**Fig. 5**). The presence of six cusps on the P3 is similar to *H. belgica*, and different to *H. pyrenaica* which bears five lingual cusps, and three on the labial row (**Peláez-Campomanes et al., 2000**).

The P4 (=P5 cf. **Peláez-Campomanes et al., 2000**) is almost half-sized than that of *K. unguoreanui* (**Fig. 5**) and in some cases has three cusps on the lingual row (e.g., UBB ODAN-Mt-69) differing from *K. unguoreanui*, which has only two lingual cusps. The shape of the cusps is conical as in *K. unguoreanui*, *H. belgica* and *H. pyrenaica*.

The M1 has a more acute subrectangular outline than in *K. unguoreanui* and *H. pyrenaica*, due to the fact that it has only two lingual cusps, not three as in *K. unguoreanui*, or four as in *H. pyrenaica*. The size of the M1 of *K. unguoreanui* is considerably larger than in *B. oardaensis* (**Fig. 5**). The lingual longitudinal valleys are deeper and more intensively affected by wear than the shallower labial valley, as in *H. pyrenaica*. The lingual row of the M1 of *B. oardaensis* is the shortest, other than in *Kogaionon* and all *Hainina* species, where the lingual row is the longest (**Peláez-Campomanes et al., 2000**).

The M2 of *B. oardaensis* has the cusp formula 2:3, as *B. transylvanicus* (**Csiki et al., 2005**), while in *K. unguoreanui* the cusp formula is 1:2:3. The M2 of *K. unguoreanui* is also larger (**Fig. 5**). The cusps are conical, as in other kogaionids.

The i1 from Oarda de Jos shares the same morphology of the crown with the incisors of *B. oardaensis* from Negoiu-Fărcădeana (Codrea et al., 2016; this thesis-Chapter 7) and with FGGUB M.1612 from Vălioara (Csiki and Grigorescu, 2000, fig. 3), described as an indeterminate multituberculate.

The p4 of *B. oardaensis* is similar in shape with *B. transylvanicus* (Csiki et al., 2005; Solomon et al., 2016; this thesis-Chapter 7), but is much smaller (Fig. 6). The p4 mentioned by Codrea et al. (2012a) from Rusca Montană and subsequently assigned to *B. oardaensis* (Codrea et al., 2016; this thesis-Chapter 7) has similar blade-like shape as in *B. oardaensis* from Oarda de Jos, but bears only ten serrations, whereas in the specimen from Oarda de Jos, there are eleven serrations. This difference is related to intraspecific variability (see this thesis-Chapter 7).

The m1 of *B. oardaensis* has a similar shape to *B. transylvanicus* (Rădulescu and Samson, 1986; Csiki et al., 2005; Solomon et al., 2016; this thesis-Chapter 5) and it is also much smaller (Fig. 5), but it differs, according to the available data at the moment, from *B. transylvanicus* by having a constant cusps formula of 3:3 instead of a variable cusp formula of 3-4:3 (see Solomon et al., 2016 and this thesis-Chapter 5 for details). As such, *B. oardaensis* has one less cusp on the labial row. The two species from Hainin described by Vianey-Liaud (1979) bear similar patterns to *B. oardaensis*, such as the similar outline, the pyramidal shape of the cusps, and the number of cusps on each row.

The m2 is the least worn tooth from the lower dentition, as in *B. transylvanicus* (Solomon et al., 2016; this thesis-Chapter 5).

6.5. Discussion and Conclusions

The multituberculate sample from Oarda de Jos is the richest discovered from the Late Cretaceous of Europe to date. The sample documents at least one tooth from each locus, with most positions represented by three to four specimens, thus allowing an estimate of the morphological (described above), and size (Fig. 5) variability of the new species from this locality.

Analyzing the size variability (Fig. 5) one can observe that most of the teeth of *B. oardaensis* represented by more than five specimens (i.e., m1, P4, M1) show size differences which could not be valid as diagnostic criteria for two different species.

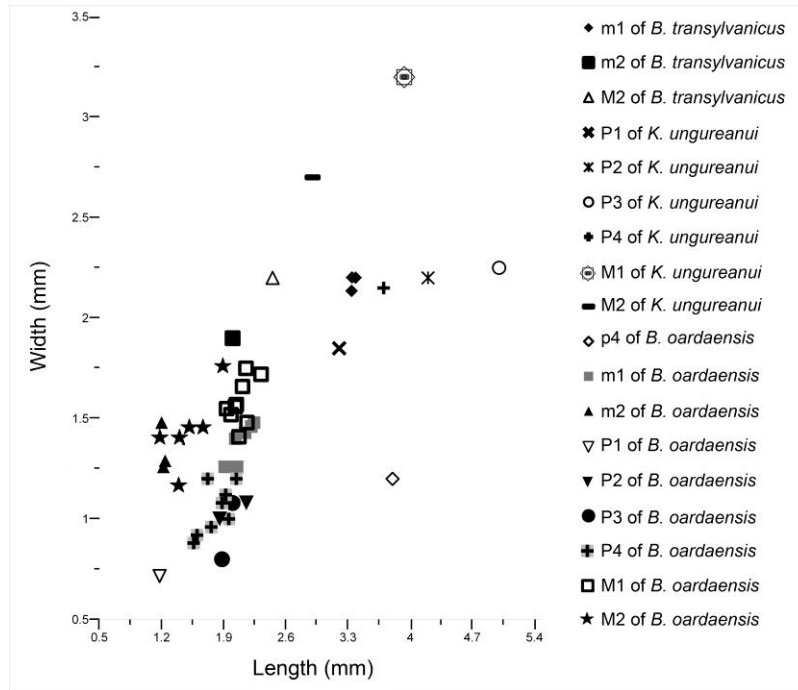


Fig. 5 – Size variations of teeth of *B. oardaensis* and dimensions of teeth of the other two known Late Cretaceous kogaionids, *B. transylvanicus* and *K. ungureanui*.

The origin of Kogaionidae remains uncertain. The family is restricted to the Maastrichtian-Paleocene, and is known exclusively from Europe.

The association of this kogaionid species with other vertebrates such as ornithopod dinosaurs (*Zalmoxes robustus*, *Z. shqiperorum*, *Telmatosaurus transylvanicus*), ankylosaurs (Nodosauridae indet.), sauropods, indeterminate theropods, crocodylians (*Allodaposuchus precedens*), and turtles (*Kallokibotion bajazidi*) resembles the vertebrate faunas from Hațeg Basin, Rusca Montană or Someș-Odorhei (Codrea and Godefroit, 2008; Codrea et al., 2010a, b, c, 2012a, 2016; this thesis-Chapter 7), and suggests that an unusual continental vertebrate fauna existed during the Late Cretaceous in Romania.

7. First mammal species identified from the Upper Cretaceous of the Rusca Montană Basin (Transylvania, Romania)

7.1. Introduction

The kogaionids survived the Cretaceous/Cenozoic boundary events, being found in the Paleocene at Jibou (Romania; **Gheerbrant et al., 1999**), but also in France, Spain, and Belgium (**Vianey-Liaud, 1979, 1986; Peláez-Campomanes et al., 2000; De Bast and Smith, 2016**). However, they were replaced around the Late Paleocene by the world-widely distributed North American Neoplagiaulidae (**Vianey-Liaud, 1986**), the latter being the last family occurring in Europe before the extinction of the multituberculates from the old continent during the Eocene.

This chapter focuses on the description and identification of some previously reported specimens (P1 and p4; **Codrea et al., 2012a**) and of new dental specimens (P4, I2 and i1). The P1 (UBB Ng1-02) and p4 (UBB Ng2-01) were briefly described by **Codrea et al. (2012a)** and assigned to Kogaionidae indet. All this material is assigned to *Barbatodon oardaensis* (**Codrea et al., 2014; this thesis-Chapter 6**), reported here for the first time in the Upper Cretaceous fluvial deposits of the Rusca Montană Basin (abbreviated now on RMB), Romania .

7.2. Negoiu locality

The multituberculate teeth here described were discovered in the easternmost side of the RMB, near Lunca Cernii de Jos at Negoiu, along the Fărcădeana Creek.

Two levels bearing Maastrichtian vertebrates crop out along this creek. The lower one, located on the left side of the creek, consists of black clay and sand, not exceeding few centimeters in thickness, while the second one crops out on the right side of the creek, consisting of red and yellowish-greyish siltstones. We name them here Negoiu-Fărcădeana 1 and 2, respectively (abbreviated Ng as in **Codrea et al., 2012a**).

7.3. Materials and methods

The available material consists of six isolated teeth of multituberculate mammals, recovered by screen-washing and processing of about 750 kg of sediment. The images were processed using Adobe Photoshop CS2. The cusp formula is counted from the labial towards the lingual side.

7.4. Systematic paleontology

Barbatodon oardaensis Codrea, Solomon, Venczel and Smith, 2014.

Holotype: UBB ODAN-Mt-13, isolated M1 (Codrea et al., 2014, fig. 2J1 and J2).

Referred specimens: The material described by Codrea et al., 2014; new available referred specimens: UBB Ng1-01: right I2; UBB Ng1-02: left P1; UBB Ng2-04: right P4; UBB Ng2-02: left i1; UBB Ng2-03: right i1; UBB Ng2-01: right p4.

Emended diagnosis - based on Codrea et al. (2014). Small species of *Barbatodon* with the following cusp formula: I2 bicuspid; P1 1:1-2; P2 2:2; P3 3:3; P4 (1):4:2-3; M1 3:4:2; M2 2:3; p4 with ten to eleven serrations and six to seven ridges; m1 3:3; m2 2-3:2. It differs from *B. transylvanicus* in being approximately 35% smaller. Differs from *Kogaionon unguereanui* in being approximately 45% smaller, with an additional cusp in P3, and with only two cusps on the lingual row of M1 instead of three. Differs from all *Hainina* species in having a short lingual row in M1, while in *Hainina* the lingual row is as long as the labial row.

Occurrences: Oarda de Jos (ODA section), Alba District, Transylvanian Basin, Romania; Uppermost Cretaceous (Maastrichtian), Șard Formation (Type locality); Lunca Cernii de Jos, Negoiu, Fărcădeana Creek (Negoiu-Fărcădeana layers 1 and 2), Hunedoara District, Rusca Montană Basin, Romania; Uppermost Cretaceous (Maastrichtian), unnamed formation.

7.4.1. Description

7.4.1.1. Upper Dentition

I2 – a single right bicuspid first upper incisor (UBB Ng1-01) is broken on the lingual side.

P1 – the first upper left premolar has an oval-shaped outline in occlusal view, with a simple morphology (UBB Ng1-02).

P4 – a right P4 is perfectly preserved (UBB Ng2-04). It has a sub-rectangular outline in occlusal view. The cusp formula is (1):4:3. The cusps are aligned on two mesially convergent crests.

7.4.1.2. Lower Dentition

i1 – two mesial extremities of lower first incisor are available for study (UBB Ng2-02: left i1; UBB Ng2-03: right i1). Both incisors have a slightly curved elongated crown.

p4 – a single blade-like p4 is available for study (UBB Ng2-01). The edge bears ten conical serrations, the last one being the largest. Seven ridges are present on the labial side under serrations three-nine, while on the lingual side only six ridges can be noticed, under serrations three-eight. Two well-distinct serrations (=labial cuspules; e.g., in **Vianey-Liaud, 1986; Yuan et al., 2013**), separated by a “V”-shaped valley, are present on the labio-distal platform of the edge.

7.4.2. Comparisons of the *Barbatodon oardaensis* specimens from RMB with other known kogaionid multituberculates

The I2 is bicuspid as in *B. transylvanicus* (see **Smith and Codrea, 2015**, fig. 5), having a main mesial cusp and one accessory much smaller distal cusp, resembling in this aspect the small incisor FGGUB M.1609 described from Tuștea (**Csiki and Grigorescu, 2000**). Other similarity with the incisor from Tuștea is the same stage of the wear on the tips of the cusps.

The P1 (=P2 of **Peláez-Campomanes et al., 2000**) of *B. oardaensis* from RMB is much smaller than those of *K. unguoreanui* and *B. transylvanicus*. It bears two conical cusps as seen in *H. pyrenaica*, *H. godfriauxi* and the P1s FGGUB M.1610 and M.1611 from Vălioara (**Csiki and Grigorescu, 2000**), but differs from *H. belgica*, *K. unguoreanui*, *B. transylvanicus* and the P1 of *B. oardaensis* from Oarda de Jos (**Codrea et al., 2014; this thesis-Chapter 6**), which have three cusps. This P1 is somewhat larger (**Fig. 6**) than the P1s from Vălioara (**Csiki and Grigorescu, 2000**) and also less wrinkled.

The new P4 (=P5 of **Peláez-Campomanes et al., 2000**) has a sub-rectangular outline and possesses conical cusps as in *K. unguoreanui*, *H. belgica*, *H. godfriauxi*, *H. pyrenaica* and *B. oardaensis* from Oarda de Jos. It resembles “type e” of kogaionid premolars (**Peláez-Campomanes et al., 2000**). It differs from *H. belgica* in having one less cusp on the labial row and two more on the lingual row. The number of cusps on each row is similar to the specimens from Oarda de Jos, the small vestigial mesio-labial cusp of UBB Ng2-04 being interpreted as an intraspecific variability. It is similar in size with the mean dimensions of the P4s from Oarda de Jos, having also nearly the same size as that of *H. belgica* and being smaller than that of *H. godfriauxi* (**Fig. 6**).

The i1 of *B. oardaensis* shares the same morphology of the crown with the incisor FGGUB M.1612 from Vălioara (Csiki and Grigorescu, 2000, fig. 3), described as an indeterminate multituberculate. Also, the reduced lingual enamel is the same in these specimens.

The p4 is blade-like and has an arcuate crown outline, with oblique ridges resembling other cimolodontan p4s (Kielan-Jaworowska and Hurum, 2001). Few kogaionid p4s are known to date. The p4 (UBB Ng2-01) is smaller than the one of *B. transylvanicus* (Csiki et al., 2005; Smith and Codrea 2015; Solomon et al., 2016; this thesis-Chapter 5), but has a similar general shape. UBB Ng2-01 differs from UBB ODAN-Mt-1 in having one less serration on the edge (ten vs. eleven), resembling *H. belgica* in this aspect. UBB Ng2-01 also bears two well-individualized labial cuspules on the labio-distal platform. From a morphometrical point of view (Fig. 6), compared to UBB ODAN-Mt-1 (3.85x1.20 mm), UBB Ng2-01 is somewhat smaller (3.36x1.00 mm), but the size differences, as well as the morphological ones, may be attributed to intraspecific variations.

7.5. Discussion and Conclusions

Although the multituberculate sample from RMB is not very rich, its importance is high. This material documents the first Mesozoic multituberculate species identified from the RMB and extends the distribution of *B. oardaensis* (Codrea et al., 2014; this thesis-Chapter 6) westward in Romania, outside the Transylvanian Basin.

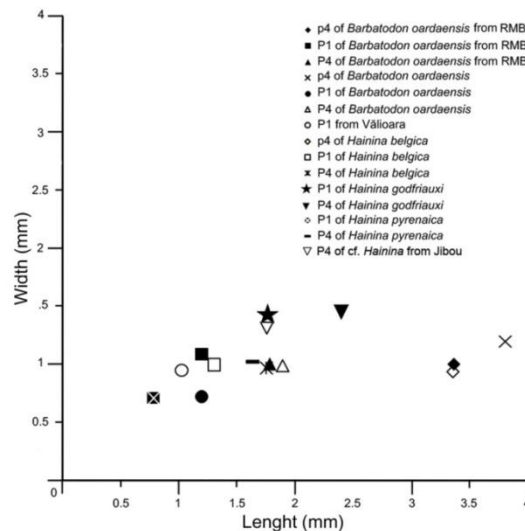


Fig. 6 – Plot diagram with teeth sizes of *Barbatodon oardaensis* vs. *Hainina*.

Barbatodon oardaensis is by far smaller than *Kogaionon unguoreanui* and *B. transylvanicus*, but comparable in size with *Hainina belgica* (**Fig. 6**). We describe herein the first upper and lower incisors belonging to *B. oardaensis*.

The presence of *Barbatodon oardaensis* in association with other Maastrichtian vertebrates underlines once again the similarities of the faunal assemblages from the RMB with those known from the Hațeg and Transylvanian basins, demonstrating that in these peculiar and complex Maastrichtian ecosystems, dominated by dinosaurs, the endemic multituberculate mammals were also important components of the terrestrial communities.

8. New insights into Europe's most diverse Late Cretaceous anuran assemblage from the Maastrichtian of western Romania

8.1. Introduction

Lissamphibians are a characteristic component of nonmarine vertebrate microfossil assemblages in the Maastrichtian of western Romania. Both anurans (frogs) and albanerpetontids are known, but urodeles (salamanders) are not (e.g. **Grigorescu et al., 1999; Folie and Codrea, 2005; Csiki-Sava et al., 2015, 2016**).

Here, an updated and comprehensive account for the anurans from the Maastrichtian of western Romania is presented, on the basis of previously published (for details see **Venczel et al., 2016**) and new fossils from all three sedimentary basins.

8.2. Materials and methods

All the anuran fossils from the Maastrichtian of western Romania included in **Venczel et al. (2016)**, the paper on which this chapter is based on, are isolated, incomplete skull and postcranial bones recovered by screen-washing of vertebrate microfossil localities.

For this chapter, only the materials curate at the Paleontology-Stratigraphy Museum, Babeş-Bolyai University [PSMUBB], Cluj-Napoca, Romania, are used and figured, but some remarks and comparisons are also made on the materials from Bucharest.

8.3. Localities

Uppermost Cretaceous continental deposits in western Romania crop out discontinuously over an extensive area: along the southwestern margin of the larger Transylvanian Basin in the north and, to the southwest, within the smaller, intermountain Hațeg and Rusca Montană basins. Within these uppermost Cretaceous deposits, vertebrate microfossil localities are found in exposures along the walls of valleys and river banks. Some of the localities are submerged for most of the year, and are only accessible when water levels drop in late summer and early autumn.

8.4. Systematic paleontology

Anura Fischer von Waldheim, 1813

Remarks: Isolated skull and postcranial bones of anurans (i.e. crown clade frogs) from the Maastrichtian of Romania are assignable to Alytidae and Bombinatoridae, possibly to Pelobatidae, and to Anura indet.

Paralatonia transylvanica Venczel and Csiki, 2003

Holotype: LPB(FGGUB) v. 455, incomplete left ilium preserving about anterior two-thirds of acetabular region and posteriormost part of iliac shaft (**Venczel and Csiki, 2003**, figs. 1B, 3A).

Holotype locality: Vălioara-Budurone, Hațeg Basin; middle subunit of Densuș-Ciula Formation; lower Maastrichtian.

Newly referred specimens³:

1. Pui Islaz ($n=6$): PSMUBB v. 353, urostyle, originally reported as “Discoglossidae indet.” (**Folie and Codrea, 2005**, p. 62, fig. 3D); PSMUBB v. 354, urostyle, originally reported as “Discoglossidae indet.” (**Folie and Codrea, 2005**, p. 62); PSMUBB v. 357, ilium, originally reported as “cf. *Paradiscoglossus* sp.” (**Folie and Codrea, 2005**, p. 62, fig. 3B); PSMUBB v. 358, ilium, originally reported as “cf. *Paradiscoglossus* sp.” (**Folie and Codrea 2005**, p. 62, fig. 3C); PSMUBB v. 359, ilium, originally reported as “cf. *Paradiscoglossus* sp.” (**Folie and Codrea, 2005**, p. 62); PSMUBB v. 360, ilium, originally reported as “cf. *Paradiscoglossus* sp.” (**Folie and Codrea, 2005**, p. 62).
2. Pui Depozit ($n=2$): PSMUBB.PUI-A-1, maxillae; PSMUBB.PUI-A-2, angulosplenial.

³ Only the new materials from PSMUBB are referred (excluding the materials from LBP(FGGUB) from **Venczel et al., 2016**)

3. Oarda de Jos A ($n=6$): PSMUBB.ODAN-A-6, urostyle; PSMUBB.ODAN-A-7, scapula; PSMUBB.ODAN-A-8, scapula; PSMUBB.ODAN-A-3, ilium; PSMUBB.ODAN-A-4, ilium; PSMUBB.ODAN-A-5, ilium.

Eodiscoglossus Villalta, 1954

Remarks: *Eodiscoglossus* is a Middle Jurassic-Late Cretaceous and exclusively Eurasian alytid genus (**Sanchiz, 1998; Roček, 2013**). Two named species are recognized: the Middle Jurassic (late Bathonian) *E. oxoniensis* Evans et al., 1990, known by isolated bones from England (**Evans et al., 1990; Evans and Milner, 1994**); and the Early Cretaceous *E. santonjae* Villalta, 1954 (type species), known by twodimensionally preserved skeletons from the upper Berriasian or lower Valanginian of Spain (**Villalta, 1954; Hecht, 1970; Estes and Reig, 1973; Vergnaud-Grazzini and Wenz, 1975**) and, possibly, by isolated bones from the Barremian of Spain (**Estes and Sanchiz, 1982b**; but see **Sanchiz's, 1998** identification as cf. *E. santonjae*). Isolated bones from the Bathonian of Siberia (**Skutschas et al. in press**), the Aptian–Albian of Mongolia (**Gubin, 1993**), and the Maastrichtian of Romania (**Grigorescu et al., 1999; Folie and Codrea 2005; this chapter** based on **Venczel et al., 2016**) have also been attributed to *Eodiscoglossus* sp. **Martín et al. (2012)** provided a helpful summary of the convoluted taxonomic and publication history for the genus and its type species.

Bombinatoridae Gray, 1825

Remarks: Bombinatoridae sensu **Ford and Cannatella (1993)** is equivalent in content to the subfamily Bominatorinae (e.g. **Sanchiz, 1998**) or tribe Bombinatorini (e.g. **Clarke, 2007**). The family is well supported by morphological and molecular evidence, and it minimally contains the Miocene-Recent *Bombina* (1 extinct and 5-8 extant species, Eurasia) and the extant *Barbourula* (2 species, Southeast Asia).

Besides *Eobarbourula*, the only other fossil taxon that we include within Bombinatoridae is the Romanian Maastrichtian species *Hatzegobatrachus grigorescui* (see below).

Hatzegobatrachus Venczel and Csiki, 2003

Remarks: Monotypic genus, known only by the type species *Hatzegobatrachus grigorescui* Venczel and Csiki, 2003. *Hatzegobatrachus* was described on the basis of three isolated and

incomplete bones (holotype ilium and two referred angulosplenials) from one locality in the Hațeg Basin (**Venczel and Csiki, 2003**). Until now, it has been regarded as an incertae sedis anuran (**Venczel and Csiki, 2003**; **Blackburn and Wake, 2011**, footnote 6; **Roček, 2013**; **Marjanović and Laurin, 2014**, fig. 3; **Csiki-Sava et al., 2015**). Six additional bones were reported in **Venczel et al. (2016)** which extend the geographic and stratigraphic distribution of the taxon in western Romania, allow for an expanded diagnosis that further reinforces the distinctiveness of the taxon, and support assigning the taxon to Bombinatoridae.

Hatzegobatrachus grigorescui Venczel and Csiki, 2003

Holotype: LPB(FGGUB) v. 433, incomplete left ilium preserving the posterior portion of the iliac shaft and much of the acetabular region, except for the posterior margin of the supraacetabular area and the posteroventral portion (especially medially) of the subacetabular area (**Venczel and Csiki, 2003**, figs. 1A, 2A).

Holotype locality: Vălioara-Fântânele 1, Hațeg Basin; middle subunit of Densuș-Ciula Formation; lower Maastrichtian.

Newly referred specimens (all incomplete)⁴:

Oarda de Jos A locality ($n=3$): PSMUBB.ODAN-A-9, incomplete urostyle; PSMUBB.ODAN-A-10, left ilium; and PSMUBB.ODAN-A-11, left ilium.

Previously referred specimens (both incomplete): Holotype locality (i.e. Vălioara-Fântânele 1; $n=2$): LPB(FGGUB) v. 437, left angulosplenic (**Venczel and Csiki, 2003**, p. 610, fig. 4B); LPB(FGGUB) v. 451, right angulosplenic (**Venczel and Csiki, 2003**, p. 610, fig. 4A).

Previously reported, but now excluded specimens:

1. Crăguș: LPB(FGGUB) v. 808, angulosplenic, identified as *?Hatzegobatrachus grigorescui* by **Zaharia (2011, p. 35, fig. 8d, e)**, but here regarded as non-diagnostic and transferred to Anura indet.

Oarda de Jos A: unspecified radioulnae, tibiofibulae or both, identified as *Hatzegobatrachus* by **Jipa et al. (2010, p. 42)**, but here regarded as non-diagnostic and transferred to Anura indet.

⁴ Only the new materials from PSMUBB are referred (excluding the materials from LBP(FGGUB) from **Venczel et al., 2016**)

Distribution: Late Cretaceous (Maastrichtian) of western Romania: middle subunit of Densuș-Ciula Formation, Vălioara-Fântânele 1 locality, Hațeg Basin; and lower-middle part of Șard Formation, Oarda de Jos A locality, Transylvanian Basin.

Pelobatidae Bonaparte, 1850

Remarks: In **this chapter**, as in **Venczel et al., (2016)**, the restricting of Pelobatidae to two genera: *Pelobates* (eight species: Oligocene–Recent of Europe east to the Ural Mountains and Ural River, and Quaternary–Recent of the Middle East and North Africa) and *Eopelobates* (six species: Eocene of North America and Eocene–Pliocene of Europe), is following **Frost et al. (2006)**; see also **Roček, 2013**; **Roček et al., 2014**; **Frost, 2015**).

8.5. Discussion

The Maastrichtian lissamphibian assemblage of Romania consists exclusively of anurans (multiple genera and species) and albanerpetontids (at least one species of *Albanerpeton*), with both groups co-occurring at most localities in all three of the sedimentary basins in the western part of the country.

By Late Cretaceous standards and certainly compared to other European occurrences, the Maastrichtian anuran assemblage from western Romania is relatively diverse.

From a paleoecological perspective, the Maastrichtian anuran assemblage in present-day western Romania consisted of a moderate number of smaller-bodied and relatively generalist taxa. Available specimens suggest maximum snout-vent lengths in the 30–50 mm range, which places individuals in the small (but not smallest) end of the size range for anurans (e.g. **Mattison, 2011**) and is broadly consistent with body sizes that can be inferred from similarly incomplete fossils reported for many other Late Cretaceous anurans from Laurasia (e.g. **Roček et al., 2010**).

8.6. Conclusions

The existence of latest Cretaceous (Maastrichtian) lissamphibians in western Romania was first reported by **Grigorescu et al. (1985)** on the basis of a collection from a now-lost locality in the Hațeg Basin. Since then, prospecting and screen-washing programs in the Maastrichtian of western Romania have recovered larger samples of isolated lissamphibian bones from at least 14

localities in the Hațeg Basin and from one locality each in the Rusca Montană and Transylvanian basins.

Within the assemblage, the presence of Alytidae is affirmed (formerly recorded as Discoglossidae sensu lato): *Paralatonia transylvanica*, cf. *Eodiscoglossus*, and cf. *Bakonybatrachus*, identified on the basis of an ilium originally referred to *Paralatonia* from the Hațeg Basin. Alytid ilia from the Hațeg Basin originally identified as cf. *Paradiscoglossus* by **Folie and Codrea (2005)** are here transferred to *Paralatonia* (based on **Venczel et al., 2016**). Newly recognized specimens of *Hatzegobatrachus*, three examples each from the holotype locality (details in **Venczel et al., 2016**) and from Oarda de Jos in the Transylvanian Basin (**this chapter** and **Venczel et al., 2016**), now allow to be recognized as the geologically oldest member of Bombinatoridae. Also, the possible presence of Pelobatidae and two potentially distinctive, but indeterminate anurans was reported from the Hațeg Basin. No other anurans—including paleobatrachids, which are present in some Western European localities during the Campanian-Maastrichtian, or the neobatrachian *Hungarobatrachus*, which is present at the Santonian locality of Iharkút in Hungary—have been recognized at any of the Romanian localities.

9. Some local restricted Maastrichtian environments of the “Hațeg Island” (Transylvania, Romania) observed at Oarda de Jos (Alba District) and Pui (Hunedoara District)

9.1. Introduction

Transylvania is famous mainly for the dwarf dinosaur fauna. Although the first reported findings in southwestern Transylvanian Basin were discovered in 1866 (**Téglas, 1886**), the first who recognized their dinosaur origin was the Transylvanian palaeontologist baron **Nopcsa (1897)** based on some bones and teeth collected in the Hațeg Basin (South Carpathians).

This chapter is focused on some peculiar, although rare continental restricted environments preserving fossils that have been recorded in the southwestern Transylvanian and Hațeg sedimentary basins in specific manner.

9.2. Peculiar restricted Maastrichtian environments in Transylvania

The lithostratigraphy of the Maastrichtian localities of interest for this work concerns the following rock formations:

- in southwestern Transylvanian Basin the main formation bearing Maastrichtian land fossils is the fluvial Șard Formation (**Codrea and Dica, 2005; Codrea et al., 2010 a,b,c**) with Oarda de Jos as the most interesting locality;
- in Hațeg Basin, the fluvial Sânpetru Formation (**Grigorescu and Anastasiu, 1990**) with the exposures on the Bărbat River, at Pui (**Codrea and Solomon, 2012**) stands out.

9.2.1. Oarda de Jos

This locality belongs to the Metaliferi sedimentary area (**Codrea and Dica, 2005**).

Red mudstones are interfingering with extensive channels filled by microconglomerate and various sized sands.

All these deposits yielded various fossils like tree trunks (*Mastixia amygdalaeformis* was reported by **Givulescu et al., 1995**), but the vertebrates are prevailing.

In contrast with this kind of deposits there is a lens-like channel filled by light colored fine grained sediments, recorded at the top of the Oarda A succession. The lateral extension of the lens-like deposits is ranging close to four meters, while the maximum thickness is nearly one meter.

Being different from the other deposits, this one is extremely rich in vertebrate remains, mainly microvertebrates, but also in medium and even large vertebrates, as well as in plants (charophytes) and some invertebrates.

9.2.2. Pui

This locality is a classical one for the Hațeg Basin, being the southeasternmost one in this basin. The fluvial deposits from Pui have been reported since the beginning of the 20th century by **Nopcsa (1905)**. These Uppermost Cretaceous fluvial deposits have been related since a rather long time ago to the Sânpetru Formation (**Nopcsa, 1905; Grigorescu et al., 1985; Grigorescu**

and Anastasiu, 1990; Grigorescu, 1992). Later, **Therrien (2005)** called the exposures from Bărbat River as “Pui beds”, but suggested also a distinct name for this continental sequence i.e. “Bărbat Formation”, underlining the difficulties in correlating the terrestrial Uppermost Cretaceous sequences exposed in different areas of the basin.

Inside these *red beds* there are three levels of black silt rich in white mica, bearing also pyrite concretions, sharply contrasting with the dominant red beds usually exposed in the riverbed. These three successive levels have been recently named from base to top, “Pui Gater” (=“Pui Mlaștină” in **Vasile and Panaitescu, 2012**, “Pui Swamp” in **Csiki-Sava et al., 2016**; all junior synonyms of Codrea and Solomon’s name), “Pui Depozit”, and “Pui Islaz” (**Codrea and Solomon, 2012**).

Different from Oarda, is the color of the teeth and bones. Commonly, the bones preserved in the red beds at Pui are white, with cracked surfaces filled by red clay. On the contrary, in these dark colored mudstones, the bones are fossilized in a very different manner, being black or gray, sometimes covered by pyrite.

9.3. Maastrichtian environments at Oarda de Jos and Pui

Fluvial Maastrichtian deposits at Oarda de Jos should be considered as documenting a poorly drained floodplain. In spite of such an evolution, the water probably never had low oxygen tendencies. Some of the fossils were autochthonous (fish, frogs, crocodiles, turtles) or had been transported from minor distances (hadrosaur or sauropod remains). On the opposite, some others originated from a longer distance, like theropods or mammals. The majority of vertebrate fossils belong to micro- or medium-sized vertebrates, the large ones being almost rare. Some taxa, such as the multituberculate mammals are well represented in the faunal record at Oarda, while, until now, they are completely missing from Pui Depozit.

The Maastrichtian terrestrial deposits of Pui are related to a braided fluvial system (**Therrien, 2005**). The black mudstone here reported at Pui Depozit, now rich in diagenetic pyrite indicates that the environment was poorly oxygenated, with clear tendency to anoxic stagnant pond-like waters.

9.4. Conclusions

The case study at Oarda de Jos on Sebeş River allows distinguishing local restricted environments, related to abandoned channels, while at Pui, on Bărbat River, the dark silts which appear in a repetitive manner are related to abandoned channels or to true ox-bow lakes. The main difference between these two cases concern the highest tendency to low oxygen water at Pui compared to Oarda de Jos. As a consequence, the lithology is specific for each deposit. The sediments of Oarda de Jos are light colored, reflecting differences with Pui, where the sediments are dark. Same colors are recorded for the fossil teeth and bones collected in these localities.

10. Some Maastrichtian vertebrates from fluvial channel fill deposits at Pui (Hațeg Basin)

10.1. Introduction

Within the “Hațeg Island”, the Hațeg Basin is the most studied, due to the peculiar sedimentary Maastrichtian deposits (Nopcsa, 1905; Grigorescu et al., 1985; Grigorescu and Anastasiu, 1990; Grigorescu, 1992; Therrien, 2005, 2006; Van Itterbeeck et al., 2005; Therrien et al, 2009; Panaiotu and Panaiotu, 2010) bearing rich fossil assemblages - mainly vertebrates - and among these ones, peculiar endemic dwarf dinosaurs, reported both by baron Francisc Nopcsa and Gyula Halaváts since the end of the 19th (Halaváts, 1897; Nopcsa, 1897; for more details see Grigorescu, 2010). Apart their systematic, biodiversity and ecology, very important data refer to their taphonomy and fossilization processes (Csiki et al., 2010a).

10.2. Pui locality – short characterization

Therrien’s work (2005) points out that at Pui the red mudstones are in prevalence. Another kind of deposits can be also noticed, interpreted as oxbow ponds. Such deposits are in sharp contrast with the red beds, dominated by dark color mudstones with white mica flakes and pyrite nodules (Codrea and Solomon, 2012; Vasile and Panaitescu, 2012; a.o).

Inside the red beds, the channel filling rocks were a specific fossilization environment.

10.3. Materials and methods

This work is focused on the vertebrate fossils recovered from a channel fill block collected at Pui, on the Bărbat River. The block was found *ex situ* in the river alluvia, at Pui Gater. The rock has a gray-faint greenish color. The full rock block, estimated at 250-300 kg was extracted from the alluvia. The block was turned into small pieces using classical tools as chisels and hammers, but also electric borehammer (Borehammer Z1C-DI05-26) and microengraver (Dremel engraver 290). The vertebrate fossils from the smaller pieces of rocks were extracted from their matrix by classical methods, using chisels, hammer and microengraver. Professional polymers such as paraloid and mowillite consolidated the bones, when necessary. The cleaned bones were measured with professional calipers, than photographed with Nikon Coolpix P520 (18.1 megapixels). The photographs were processed in Adobe Photoshop CS2.

10.4. Systematic paleontology

Inside the block matrix several bones - most broken - and teeth belonging to various reptiles were recovered. The majority of these remains belong to crocodylians, especially to *Allodaposuchus precedens* Nopcsa, 1928 (**Nopcsa, 1928**). Other remains by far less numerous, are documenting the crocodylian *Acynodon*. Various dinosaur remains are present in this block too. This study is focused on the description of the faunal material recovered from the block, and on some taphonomic processes, which took place before the final burial of the vertebrate remains.

10.5. Taphonomy

The remains are isolated, broken and some of them rounded, indicating a pre-burial transport. Usually, the vertebrate fossils found at Pui in the red beds, are white colored. No microvertebrate remains were found in the block because the channel fill consists of coarse clasts which do not represent a proper environment for the fossilization of micro remains.

Following **Csiki et al. (2010a)**, the sedimentary facies of the block is in concordance with “massive, structureless conglomerates and coarse conglomeratic sandstones, cross-bedded coarse and medium grained sandstones”, a near-channel facies, coded “CH”, and interpreted as a channel fill. Also following their hierarchical classification of the taphonomic modes, in the block are present two groups of fossils: complete isolated bones, coded “A1” (e.g. teeth and one

of the vertebrae), and incomplete isolated bones, coded “A2” (in dominance). The remains from the block bear marking features for these two taphonomic modes, such as: for A1 - low degrees of weathering, abrasion, breakage; for A2 - advanced weathering, breakage, rarely identifiable taxonomically. However, a difference between the fossil assemblages from this block and the above mentioned taphonomic modes consist in the mix of taxa in the block, while in the coined modes there is only a mono-taxon.

10.6. Conclusions

The block extracted near the location called “Pui Gater” (**Codrea and Solomon, 2012**) contained at least eight reptiles taxa with the majority of the remains belong to crocodylians. The vertebrate remains include also turtles (*Chelonia* indet.), pterosaurs (*Pterosauria* indet.) and various dinosaurs. The dinosaur remains include indeterminate theropods and sauropods, but also ornithomimid dinosaurs such as the basal hadrosaur *Telmatosaurus transylvanicus* Nopcsa, 1900 and the euornithomimid *Zalmoxes* Weishampel, Jianu, Csiki and Norman, 2003. No small vertebrates were found inside the block. Therefore, this channel fill may be interpreted as a high-energy deposit (storm deposit). It is possible that a flood took place bringing together teeth and bones originating from several skeletons. This taphonomic context could have been possible due the fact that the climate in “Hațeg Island” was subtropical, characterized by alternation of dry and rainy seasons (**Van Itterbeeck et al., 2004; Therrien, 2005**).

11. Conclusions

As a general conclusion, this thesis provided new important information related to the terrestrial uppermost Cretaceous vertebrate fauna and fossilization environments from the “Hațeg Island” such as a new kogaionid multituberculate species, its distribution on the landmass of this island and its intraspecific variation; the first report of intraspecific variation of the species *B. transylvanicus* from Pui locality (Hațeg Basin) based on the most complete dentaries of this species found to date; new data related to some associated vertebrates as the anurans including descriptions of new specimens and their contribution to our understanding of the palaeoecology, palaeobiogeography, and evolutionary history of anurans; some data about specific fossilization environments and their related taphonomical processes; and the first vertebrates originating from a channel fill block recovered from Pui together with their taphonomy were presented here.

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