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



Un nouveau mammifère multituberculé kogaionidé du Maastrichtien du bassin de Transylvanie, Roumanie

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ABSTRACT

The Latest Cretaceous (Maastrichtian) terrestrial sedimentary sequences of the Hațeg Basin in Transylvania are well known for the so-called “Hațeg Island” vertebrate faunas, which evolved in endemic (insular?) conditions. In addition to frogs, lizards, turtles, crocodylians, birds and dinosaurs, peculiar multituberculate mammals have been recorded, all belonging to the family Kogaionidae. Here, a new species of the genus *Barbatodon* is reported from the Maastrichtian Șard Formation in the Transylvanian Basin (Alba County, Romania). *Barbatodon oardaensis* n. sp. is characterized by M1 cusp formula 3:4:2 and is much smaller than the two other Maastrichtian kogaionids from Transylvania, *Barbatodon transylvanicus* and *Kogaionon unguoreanui*. The origin and paleobiogeography of kogaionids are discussed.

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R É S U M É

Les séquences continentales du Crétacé terminal (Maastrichtien) du bassin de Hațeg en Transylvanie sont réputées pour leurs faunes de vertébrés originaires de « l'île de Hațeg », qui ont évolué dans des conditions endémiques (insulaires ?). Hormis des grenouilles, lézards, tortues, crocodiles, oiseaux et dinosaures, des mammifères multituberculés particuliers ont également été mentionnés, tous appartenant à la famille des Kogaionidae. Une nouvelle espèce du genre *Barbatodon* est décrite dans le Maastrichtien de la Formation de Șard, dans le bassin de Transylvanie (district d'Alba, Roumanie). *Barbatodon oardaensis* n. sp. est caractérisée par une formule dentaire de M1 3:4:2 et est plus petite que les deux autres kogaionidés de Transylvanie, *Barbatodon transylvanicus* et *Kogaionon unguoreanui*. L'origine et la paléobiogéographie des kogaionidés sont discutées.

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1. Introduction

Late Cretaceous mammals are poorly known from Europe. To date, they have only been reported from Portugal: Taveiro (Antunes et al., 1986), France: Champ-Garimond (Ledoux et al., 1966; Sigé et al., 1997), Vitrolles (Tabuce et al., 2004, 2013), Cruzy (Buffetaut, 2005), Font de Benon quarry (Vullo et al., 2009), Spain: Laño (Gheerbrant and Astibia, 1999, 2012), Quintanilla del Coco (Pol et al., 1992), Belgium: ENCI-Maastricht B.V. quarry, Valkenburg Member (Martin et al., 2005) and Romania (see below for references). 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 (Codrea et al., 2002, 2009, 2012a, 2012b; Csiki and Grigorescu, 2000; Csiki et al., 2005; Grigorescu et al., 1985; Rădulescu and Samson, 1986, 1996, 1997; Smith et al., 2002). After the Cretaceous–Paleogene boundary, kogaionids survived in Paleocene, aside from Romania, in France, Spain, and Belgium (Gheerbrant and Astibia, 1999; Peláez-Campomanes et al., 2000; Vianey-Liaud, 1979, 1986) (Table 1). This paper is focused on a new species of kogaionid from the Late Cretaceous of Romania, the first Cretaceous kogaionid discovered outside the Hațeg Basin.

2. Geological setting

The Late Cretaceous terrestrial vertebrates from Romania were first reported in 1897 from the Maastrichtian deposits of the Hațeg Basin in southern Carpathians, by Gyula Halárvats and Francisc Nopcsa (Grigorescu, 2010 and references herein). Looking for such fossils, 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 Transylvanian Basin. One of these regions is the Metaliferi sedimentary area (Codrea and Dica, 2005). Located in the Southwest Transylvanian Basin, these Late Cretaceous continental deposits are sandwiched between marine sequences (Codrea and Dica, 2005). In Alba County (Fig. 1A), such rocks crop out between Alba Iulia, Șard, Vurpăr, Pianu de Jos, Petrești, Sebeș, Berghin and Teleac (Codrea et al., 2010a, 2010b, 2010c). This continental megasequence may be considered the basalmost unit of the post-tectonic cover of the folded nappes of the southern Apuseni Transilvanides (Balintoni, 2003). In the area of these localities, the Late Cretaceous terrestrial sediments are represented by the Vurpăr Formation (Early Maastrichtian), and the Șard Formation (Maastrichtian) (Fig. 1A).

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 (Codrea and Dica, 2005; Codrea et al., 2001, 2010b; Therrien et al., 2002; Therrien, 2005). The Șard Formation is dominated by red

beds accumulated in a meandering fluvial environment with numerous inner bars and channel lags (sandstone and coarse conglomerate). The red silts contain pedogenic levels with root traces, although at Oarda de Jos pond-like conditions have been inferred (Fig. 1B and C), documented by green-grey silty clay (Codrea et al., 2001, 2010a, 2010b, 2010c).

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, 2010b, 2010c), a steep slope of about 50 m in length and of 17–19 m in height, representing exclusively the source of mammalian fossils (Fig. 1B). Its deposits are exposed both in the riverbed and along the riverbanks. The location ODB is a larger exposure, cropping out about 300 m south of ODA. The lithology is rather similar to that of ODA, but these deposits are devoid of microvertebrates.

From the different levels in ODA, an important vertebrate fauna was reported, including mainly dinosaurs, crocodylians and birds (Codrea et al., 2010a, 2010b, 2010c, 2012b; Delfino et al., 2008; Dyke et al., 2012). In addition to vertebrate fossils, those of invertebrates and plants are also recorded (Codrea et al., 2010a, 2010b, 2010c, 2012b; Givulescu et al., 1995; Iamandei et al., 2005).

In the top of ODA, a lens-like accumulation of grey silt (Fig. 1B and C) 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). Among these vertebrates, mammals are represented by numerous isolated teeth of multituberculates, described later in the text. Presently, this is the richest sample ever recorded in Romania or in Europe documenting this group. The simplified cheek teeth morphology is characteristic of the Kogaionidae, a peculiar multituberculate family first described from the Maastrichtian of Transylvania, in the Hațeg Basin (Rădulescu and Samson, 1996). In summary, the Oarda de Jos accumulation is here interpreted as a fluvial, pond environment, with high variations of flow energy.

3. Material and methods

The material available for this study was collected from the uppermost part of ODA section, along the right riverbank of Sebeș (Codrea et al., 2010a, 2010b, 2010c). It consists of 40 isolated teeth of multituberculate mammals, recovered by screen-washing and processing of about 2500 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).

Institutional abbreviations.– UBB ODAN-Mt-X; UBB: Babeș-Bolyai University of Cluj-Napoca, Vertebrate Laboratory collection, Romania; ODAN: the name given for all the fossil material originating from the lens-like accumulation

Table 1

Kogaionids distribution in the Late Cretaceous and the Paleocene.

Tableau 1

Distribution des Kogaionidés pendant le Crétacé supérieur et le Paléocène.

Area	Species	Locality	Age	References
Romania	<i>K. ungureanui</i>	Sânpetru	Maastrichtian	Rădulescu and Samson, 1996
Romania	<i>B. transylvanicus</i>	Pui	Maastrichtian	Csiki et al., 2005; Rădulescu and Samson, 1986
Belgium	<i>H. belgica</i>	Hainin	Montian	Vianey-Liaud, 1979
Belgium, France	<i>H. godfriauxi</i>	Hainin, Cernay	Montian, Thanetian	Vianey-Liaud, 1979; Vianey-Liaud, 1986
Romania	<i>Hainina</i> sp.	Jibou	Thanetian	Gheerbrant et al., 1999
France	<i>H. vianeyae</i>	Cernay	Thanetian	Peláez-Campomanes et al., 2000
Spain	<i>H. pyrenaica</i>	Fontllonga-3	Early Danian	Peláez-Campomanes et al., 2000
Romania	Kogaionidae indet.	Totetși-Baraj, Tuștea, Fântânele, Lunca Cernii de Sus, Oarda de Jos (<i>B. oardaensis</i> in this paper), General Berthelot 1 or 2, Petrești	Maastrichtian	Codrea et al., 2002, 2009, 2010a, 2012a; 2012b; Csiki and Grigorescu, 2000; Csiki-Sava et al., 2012; Vasile et al., 2011
Romania	<i>Barbatodon</i> sp.	Nălaț-Vad	Maastrichtian	Smith et al., 2002
Romania	<i>Hainina</i> sp. A ^a , <i>Hainina</i> sp. B ^a	Fântânele	Maastrichtian	Csiki and Grigorescu, 2000
Romania	<i>B. oardaensis</i>	Oarda de Jos	Maastrichtian	This paper

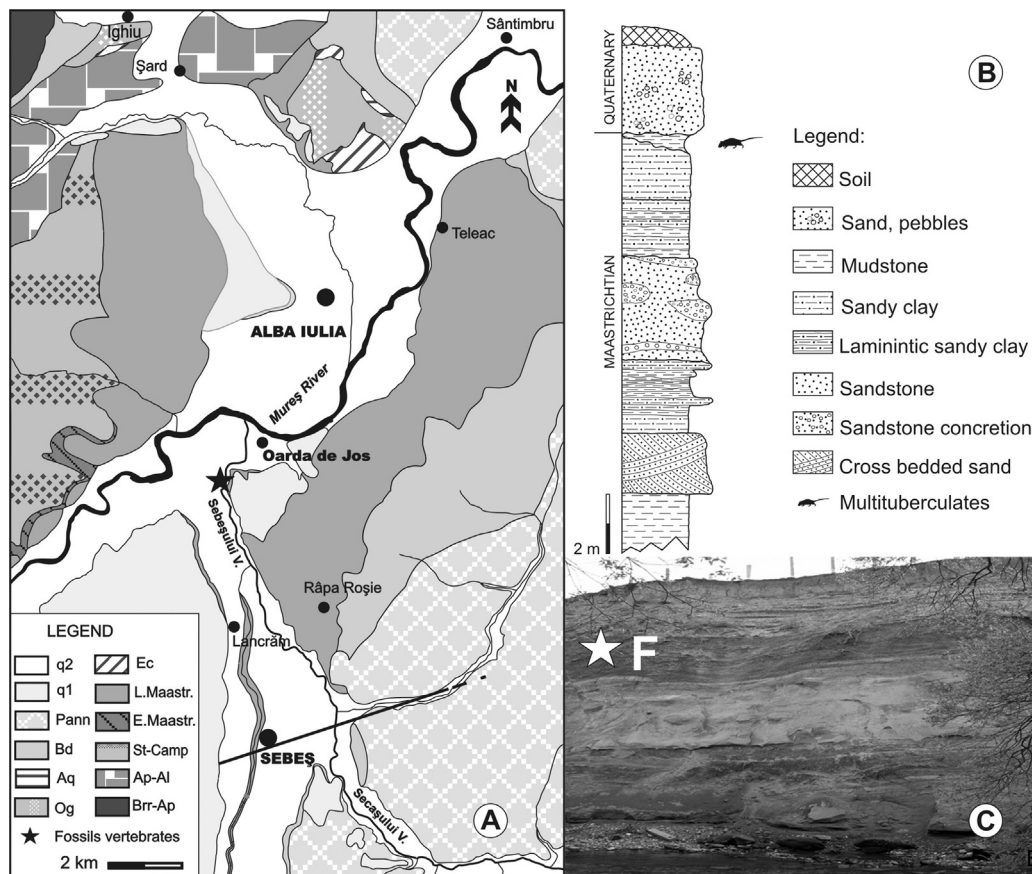
^a These “*Hainina*” species are uncertain.

Fig. 1. A. Location of the Metaliferi sedimentary area on geological map; the black star indicates Oarda de Jos locality. B. Stratigraphic column of ODA section. C. Image of ODA section; the white star and the “F” symbols indicate the lens-like accumulation of vertebrate fossils.

Fig. 1. A. Localisation de l'aire sédimentaire Metaliferi sur la carte géologique; l'étoile noire indique la localité Oarda de Jos. B. Colonne stratigraphique de la coupe ODA. C. Image de la coupe ODA; l'étoile blanche et le symbole «F» indiquent l'accumulation en lentille des vertébrés fossiles.

Table 2Measurements (in mm) of *Barbatodon oardaensis* n. sp. teeth.**Tableau 2**Mesures (en millimètres) des dents de *Barbatodon oardaensis* n. sp.

Position in tooth row	n ^a	L _{min}	L _{max}	L _{mean}	W _{min}	W _{max}	W _{mean}
P1	1						
P2	2	1.88	2.16	2.02	1.00	1.08	1.04
P3	4	1.80	2.00	1.89	0.80	1.20	0.99
P4	8	1.56	2.04	1.80	0.88	1.20	1.04
M1	9	1.93	2.32	2.09	1.41	1.75	1.58
M2	6	1.18	1.91	1.51	1.16	1.76	1.43
p4	1						
m1	6	1.91	2.24	2.09	1.26	1.48	1.38
m2	3	1.20	1.24	1.22	1.26	1.48	1.34

^a Some specimens bear different stages of wear, and some are damaged, but the dimensions were measurable.

from Oarda de Jos, Mt: multituberculata, X: number for each specimen; FGGUB: Faculty of Geology and Geophysics, University of Bucharest, Romania; ISB: Institute of Speleology “Emil Racoviță”, Bucharest, Romania.

4. Systematic paleontology

Class MAMMALIA Linnaeus, 1758

Subclass ALLOThERIA Marsh, 1880

Order MULTITUBERULATA Cope, 1884

Suborder CIMOLODONTA McKenna, 1975

Family KOGAIONIDAE Rădulescu and Samson, 1996

GENUS BARBATODON Rădulescu and Samson, 1986

Type species. *Barbatodon transylvanicus*, Rădulescu and Samson, 1996.

Barbatodon oardaensis new species.

Fig. 2, Table 2.

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

Holotype. UBB ODAN-Mt-13, isolated M1 (Fig. 2J1 and J2).

Referred specimens. 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 M1; UBB ODAN-Mt-66, 67: right M2; UBB ODAN-Mt-16, 31, 36, 37: left M2; 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 (Fig. 3). Differs from *Kogaionon unguoreanui* Rădulescu and Samson (1996) 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 (Maastriichtian), Șard Formation.

5. Description

P1 is extensively worn and the mesial part of the crown is broken. It bears three conical cusps, one labial and two forming a lingual row. All cusps are distinct, similar in size, and with smooth enamel.

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. All cusps are similar in size. In labial and lingual views, the crown shows a slope extending from the distal cusps of each row toward the distal margin of the tooth. In UBB ODAN-Mt-71 (Fig. 2B), radial enamel wrinkles diverge as very fine crests from the top of each cusp toward the crown base. In UBB ODAN-Mt-70 (Fig. 2C), the slope protrudes more distally than in UBB ODAN-Mt-71 (Fig. 2B). In UBB ODAN-Mt-71 (Fig. 2B), the enamel wrinkles are less marked than in the other P2, being limited to the mesial and distal labial cusps. Very fine enamel crests occur also on the mesial side of the mesio-lingual cusp. The enamel wrinkles are best noticeable in the mesio-labial cusp.

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. The cusp rows are separated by a longitudinal valley, which is closed at the level of the distal cusps of the labial row. In lateral view (Fig. 2D2), “V” shaped valleys that are separating the cusps can be observed. The height of the tooth crowns slowly increases towards the mesial side. Radial enamel wrinkles diverge as very fine crests from the top of each cusp toward the crown base (Fig. 2D1, D2 and E). The enamel is best developed in the distal-lingual cusp (Fig. 2D1 and D2). In UBB ODAN-Mt-69 (Fig. 2D), a wear facet is noticeable on the top of the mesio-lingual cusp.

P4 has two roots, a subrectangular crown outline, and a cusp formula of 4:2-3. The cusps are aligned on two mesially convergent crests. The labial crest bears four cusps and is higher than the lingual one, its height decreasing, the lingual crest bears two or three cusps and decreases in height mesially. The cusps are conical. The labial row cusps are connected by a mesio-distal ridge nearly as high as the cusps (Fig. 2F1, F2, G and I). This ridge is lost in the case of UBB ODAN-Mt-23 (Fig. 2H) due to advanced wear. The enamel surface is variable in P4, being either relatively smooth (Fig. 2H), or appearing as two to three lingual wrinkled ridges (Fig. 2F1, G and I). The wrinkles are best preserved in the case of the second labial cusp (Fig. 2F1 and G). A wear facet is present on the labial side of the mesio-labial cusp, nearly reaching the crown base (Fig. 2F1, G, H and I). This wear facet abraded also the lingual side of the tooth, therefore in some specimens (e.g., UBB ODAN-Mt-23: Fig. 2H), the lingual cusps are almost lost. In some specimens, wear facets appear also on the lingual side of the labio-distal cusp (Fig. 2I).

M1 has two roots and a subrectangular outline. UBB ODAN-Mt-13 (Fig. 2J1 and J2), 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. Longitudinal valleys separate the three cusp rows, the lingual being the deepest, and more worn. The crown narrows mesially, due to the shorter lingual cusp row. The cusps of the middle

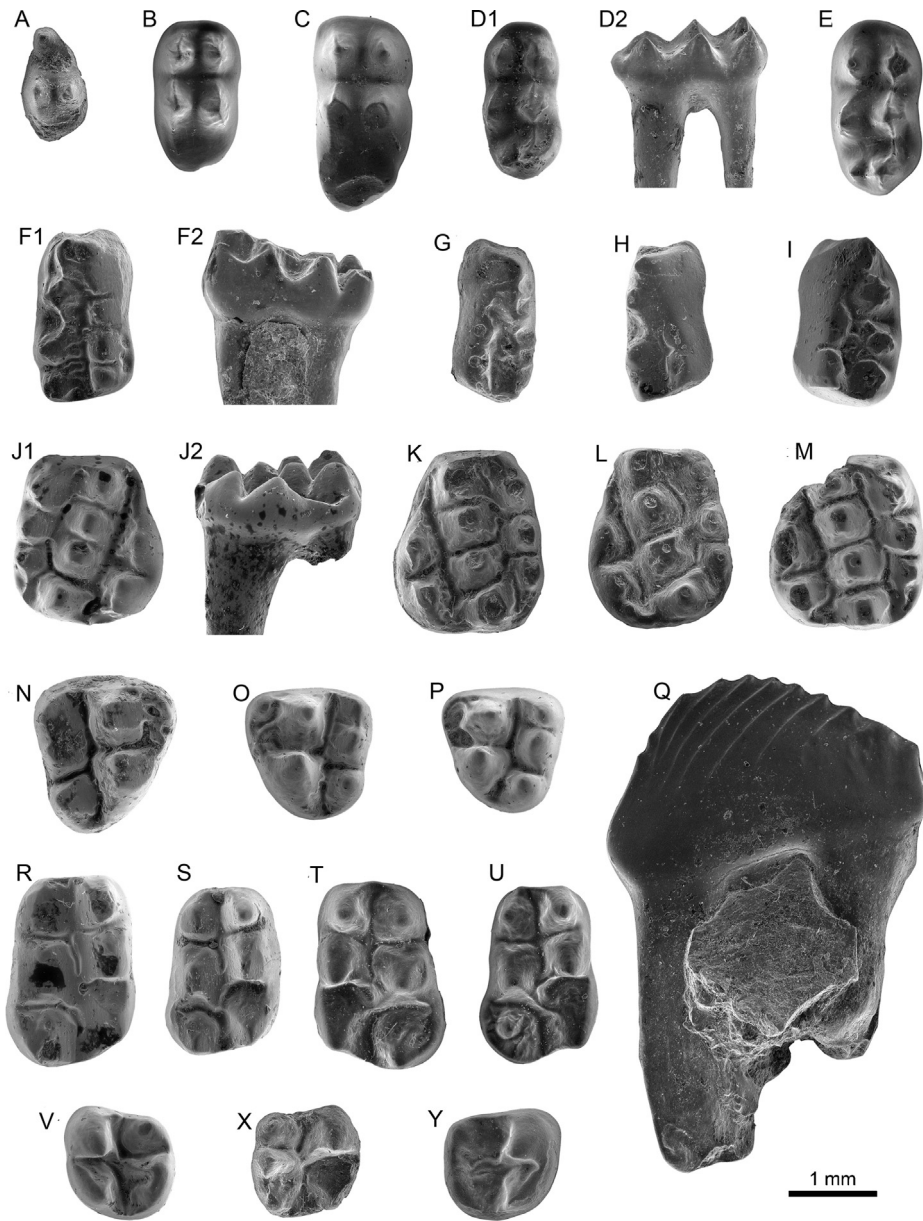


Fig. 2. *Barbatodon oardaensis* n. sp., isolated teeth; A. UBB ODAN-Mt-38, right P1 in occlusal view; B. UBB ODAN-Mt-71, right P2 in occlusal view; C. UBB ODAN-Mt-70, right P2 in occlusal view; D1. UBB ODAN-Mt-24, right P3 in occlusal view; D2. UBB ODAN-Mt-24, right P3 in labial view; E. UBB ODAN-Mt-69, right P3 in occlusal view; F1. UBB ODAN-Mt-25, right P4 in occlusal view; F2. UBB ODAN-Mt-25, right P4 in lingual view; G. UBB ODAN-Mt-21, left P4 in occlusal view; H. UBB ODAN-Mt-23, right P4 in occlusal view; I. UBB ODAN-Mt-26, left P4 in occlusal view; J1. UBB ODAN-Mt-13, the holotype, right M1 in occlusal view; J2. UBB ODAN-Mt-13, the holotype, right M1 in lingual view; K. UBB ODAN-Mt-6, left M1 in occlusal view; L. UBB ODAN-Mt-7, left M1 in occlusal view; M. UBB ODAN-Mt-65, left M1 in occlusal view; N. UBB ODAN-Mt-16, left M2 in occlusal view; O. UBB ODAN-Mt-66, right M2 in occlusal view; P. UBB ODAN-Mt-67, right M2 in occlusal view; Q. UBB ODAN-Mt-1, right p4 in lingual view; R. UBB ODAN-Mt-14, left m1 in occlusal view; S. UBB ODAN-Mt-15, left m1 in occlusal view; T. UBB ODAN-Mt-19, right m1 in occlusal view; U. UBB ODAN-Mt-20, left m1 in occlusal view; V. UBB ODAN-Mt-68, right m2 in occlusal view; X. UBB ODAN-Mt-32, left m2 in occlusal view; Y. UBB ODAN-Mt-34, left m2 in occlusal view; scale bar equals 1 mm.

Fig. 2. *Barbatodon oardaensis* n. sp., dents isolées; A. UBB ODAN-Mt-38, P1 en vue occlusale; B. UBB ODAN-Mt-71, P2 droite en vue occlusale; C. UBB ODAN-Mt-70, P2 droite en vue occlusale; D1. UBB ODAN-Mt-24, P3 droite en vue occlusale; D2. UBB ODAN-Mt-24, P3 droite en vue labiale; E. UBB ODAN-Mt-69, P3 droite en vue occlusale; F1. UBB ODAN-Mt-25, P4 droite en vue occlusale; F2. UBB ODAN-Mt-25, P4 droite en vue linguale; G. UBB ODAN-Mt-21, P4 droite en vue occlusale; H. UBB ODAN-Mt-23, P4 droite en vue occlusale; I. UBB ODAN-Mt-26, P4 gauche en vue occlusale; J1. UBB ODAN-Mt-13, holotype, M1 droite en vue occlusale; J2. UBB ODAN-Mt-13, holotype, M1 droite en vue linguale; K. UBB ODAN-Mt-6, M1 gauche en vue occlusale; L. UBB ODAN-Mt-7, M1 gauche en vue occlusale; M. UBB ODAN-Mt-65, M1 gauche en vue occlusale; N. UBB ODAN-Mt-16, M2 gauche en vue occlusale; O. UBB ODAN-Mt-66, M2 droite en vue occlusale; P. UBB ODAN-Mt-67, M2 droite en vue occlusale; Q. UBB ODAN-Mt-1, p4 droite en vue linguale; R. UBB ODAN-Mt-14, m1 gauche en vue occlusale; S. UBB ODAN-Mt-15, m1 gauche en vue occlusale; T. UBB ODAN-Mt-19, right m1 droite en vue occlusale; U. UBB ODAN-Mt-20, m1 gauche en vue occlusale; V. UBB ODAN-Mt-68, m2 droite en vue occlusale; X. UBB ODAN-Mt-32, m2 gauche en vue occlusale; Y. UBB ODAN-Mt-34, m2 gauche en vue occlusale; barre d'échelle: 1 mm.

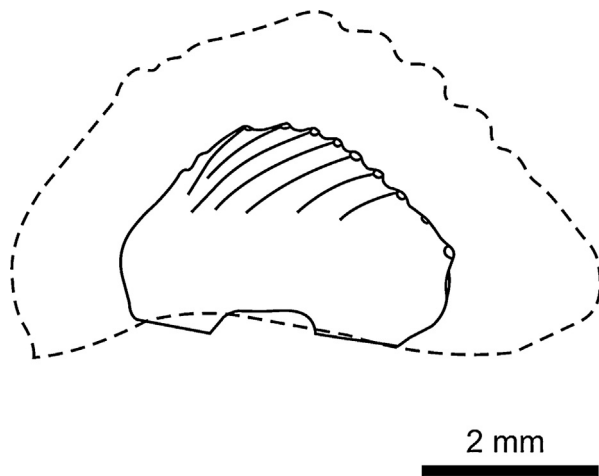


Fig. 3. Comparison between p4 lateral outlines of *B. transylvanicus* (dotted lines) and *B. oardaensis*; scale bar equals 2 mm.

Fig. 3. Comparaison entre les profils latéraux des p4 de *B. transylvanicus* (pointillé) et *B. oardaensis*; échelle graphique 2 mm.

row are pyramidal and clearly distinct. On the labial row, the cusps are rounded pyramidal (this pattern may be lost in some cases due to the advanced stage of the wear, e.g., Fig. 2K) and also clearly distinct. The labial cusps decrease in height distally, whereas the medial cusps increase in height distally. The lingual row supports two pyramidal cusps. The enamel is relatively smooth, but, supports some divergent ridges. In some specimens (UBB ODAN-Mt-7: Fig. 2L, 9, 11, 13, 65: Fig. 2M) a small additional crest is present mesially and distally. The labial cusps and the internal ones are connected by small ridges (Fig. 2J1, K, M and L). Wear facets are present in different areas of the tooth crown, both in the longitudinal valleys separating the cusp rows and on the cusps. The wear stage is different in each specimen. In some specimens, wear facets occur on both sides of the labial valley, wearing also the cusp apices (e.g., UBB ODAN-Mt-65: Fig. 2M). In other cases, the wear is restricted to the cusp apices (e.g., UBB ODAN-Mt-7: Fig. 2L).

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. The labial row has only two cusps; the lingual row has three, and an additional crest occurs on the mesio-labial extremity, lateral to the labial row. The cusps are conical and separated by transverse valleys. The valley that separates the first two lingual cusps is shallow; therefore the cusps appear almost connected. The enamel is smooth. In UBB ODAN-Mt-16 (Fig. 2N) the distal cusp on the lingual row protrudes distally, as a diverging ridge, giving a triangular shape to the tooth, whereas, UBB ODAN-Mt-66 (Fig. 2O) and UBB ODAN-Mt-67 (Fig. 2P) are squarer in occlusal view. In the case of UBB ODAN-Mt-66, a diverging ridge is developed from the labial side of the mesio-labial cusp towards the labial edge of the crown. But in UBB ODAN-Mt-67, this divergent ridge is less developed, and a groove is present in the labial side of the crown. UBB ODAN-Mt-36 and UBB ODAN-Mt-37 bear rolling marks, probably due the pre-burial transport. Wear facets are present on M2. In two of the three best-preserved specimens, the wear

is almost insignificant. The most worn is the lingual side of the labial cusp row, but wear facets may occur also on the lingual side of the lingual cusps (Fig. 2N).

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. In labial and lingual views, the tooth presents seven parallel ridges, below serrations three to nine. On the labial side a small platform is developed, but due to wear it is unclear whether a cusp was present there or not. The shape of the serrations is conical. The first two serrations are smaller than the other ones, which have nearly same sizes. The fourth serration is the sharpest one. The serrations' wear stage increases to the distal part of the tooth, so that in lingual and labial views serration ten is almost unperceivable. "U" shaped gentle slopes separate the serrations, the distance between serrations being almost equal, except the ones located between serrations two/three and three/four.

The m1 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. Wear facets affect more or less the m1. They appear in some specimens on both lingual and labial sides of the crown, wearing both the labial and lingual sides of the longitudinal valley (i.e. UBB ODAN-Mt-14: Fig. 2R and UBB ODAN-Mt-15: Fig. 2S).

The m2 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. The mesio-labial cusp and the distal-lingual one are connected by divergent ridges (Fig. 2V and Y). In the case of UBB ODAN-Mt-32 (Fig. 2X) the divergent ridge connects the mesio-lingual cusp with the second labial one. The enamel is relatively smooth. The m2 is the least worn tooth in the lower tooth row.

6. Comparisons

Barbatodon was originally described based on a single tooth (ISB IS001), a left m1 from the Maastrichtian locality of Pui, Romania and the genus was tentatively assigned to the *Paracimexomys* group (Kielan-Jaworowska and Hurum, 2001; Kielan-Jaworowska et al., 2004). Two associated incomplete dentaries, an isolated left I2 and a right M2 belonging to the same individual (FGGUB M1635) from the same locality recently allowed Csiki et al. (2005) to definitely refer *Barbatodon* to the European family Kogaionidae. Csiki et al. (2005) largely debated the controversial systematic status of *Barbatodon* including the confusion of the position of the holotype in the tooth row: the presumed M1 is in fact an m1. The genus that until now included the single species *B. transylvanicus*, was assigned to the family

Kogaionidae based on dental characters shared with the genera *Kogaionon* and *Hainina*. These characters are the elongated i1 with limited enamel band, differing in this respect from Ptilodontoidea; the p4 arched, slightly raised above the level of molar occlusal plane, but to a lesser extent than in Ptilodontoidea, with small number of serrations (nine-ten); the m1 short, rectangular, with a low cusp formula (3-4:3), lower than in most other cimolodontans and reminiscent of certain plagiaulacids; the molar enamel smooth in *Kogaionon* and *Barbatodon*, but ornamented with grooves in some species of the genus *Hainina*. Next to the morphology, paleogeographic arguments also allowed Csiki et al. (2005) to consider all the Maastrichtian multituberculates from Transylvania as kogaionids. Their arguments are credible, as long as in the Paleocene of Transylvania there are also present exclusively kogaionids of the genus *Hainina* (Gheerbrant et al., 1999).

Comparisons with other kogaionid species based on the new specimens here described can be extended as follows.

The P1 (=P2 cf. Peláez-Campomanes et al., 2000) of *Barbatodon oardaensis* is less than half of that of *Kogaionon unguereanui* (Fig. 4). This P1 has a similar crown outline to the P1 of *Hainina belgica* (Vianey-Liaud, 1979). It bears three conical cusps as *K. unguereanui* and *H. belgica*, differing in this aspect from *H. pyrenaica* (Peláez-Campomanes et al., 2000), which bears only two cusps. The enamel is smooth, in contrast to the wrinkled enamel seen in *H. belgica*.

The P2 (=P3 cf. Peláez-Campomanes et al., 2000) of *K. unguereanui* is twice larger than in *B. oardaensis* (Fig. 4). The P2 bears the same outline and conical cusp shapes as in *K. unguereanui*, but 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. unguereanui*, whose P3 (=P4 cf. Peláez-Campomanes et al., 2000) is more than twice larger than in *B. oardaensis* (Fig. 4). 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 cusps are conical as in *K. unguereanui* and *H. belgica*. It bears the same oval elongated outline as *Kogaionon*, differing in this aspect by *H. belgica*, which has a shorter crown. The enamel is wrinkled as in *H. belgica* and *H. pyrenaica*. One P3 (UBB ODAN-Mt-69, Fig. 2D) bears a wear facet on the top of the mesio-lingual cusp. The wear facet dips at about 45 degrees towards the lingual side, as in *H. pyrenaica* (Peláez-Campomanes et al., 2000). The position of the wear facet of P3 of *B. oardaensis*, on the mesio-lingual cusp, is different from the one seen in *H. pyrenaica*, on the penultimate, largest cusp.

The P4 (=P5 cf. Peláez-Campomanes et al., 2000) is almost half-sized that of *K. unguereanui* (Fig. 4) and in some cases has three cusps on the lingual row (e.g., UBB ODAN-Mt-69) differing from *K. unguereanui*, which has only two lingual cusps. The shape of the cusps is conical as in *K. unguereanui*, *H. belgica* and *H. pyrenaica*. The outline is similar as in *Kogaionon*, and differs to *H. belgica* and *H. pyrenaica*, which have a narrower distal margin. The enamel surface is variable in the case of the P4 of *B. oardaensis*, being relatively smooth (Fig. 2H), and similar with the enamel present in the P4 of *Kogaionon*, or

appearing as lingual wrinkled ridges (Fig. 2F1, G and I), as in *H. belgica*. A central situated ridge is present as in *H. pyrenaica* (Peláez-Campomanes et al., 2000), but in *B. oardaensis* this ridge is complete.

The M1 has a more acute subrectangular outline than in *K. unguereanui* and *H. pyrenaica*, due to the fact that it has only two lingual cusps, not three as in *K. unguereanui*, or four as in *H. pyrenaica*. The size of the M1 of *K. unguereanui* is considerably larger than in *B. oardaensis* (Fig. 4). 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 M1 enamel is relatively smooth, but supports some divergent ridges as *H. belgica*, being different to the more decorated enamel of *H. godfriauxi* (Vianey-Liaud, 1979, 1986). Wear facets are more or less present on the surface of different specimens. Some affect both the lingual and labial valleys, with a higher advanced stage on the labial one, which is worn on both sides. Others appear as horizontal planes, and affect just the apices of cusps. Similar wear facets were described by Peláez-Campomanes et al. (2000) on the surface of M1 of *H. pyrenaica*.

The M2 of *B. oardaensis* has the cusp formula 2:3, as *B. transylvanicus* (Csiki et al., 2005), while in *K. unguereanui* the cusp formula is 1:2:3. The M2 of *K. unguereanui* is also larger (Fig. 4). The cusps are conical, as in other kogaionids (*B. transylvanicus*, *K. unguereanui* and *H. godfriauxi*). The M2 of *B. oardaensis* has a square to triangular crown outline. This variability occurred in the sample means that this character is not enough diagnostic to distinguish *Kogaionon* from *Barbatodon*, as suggested in Csiki et al. (2005). It is rather a matter of intraspecific variability. The enamel is less decorated than in *H. godfriauxi*.

The p4 of *B. oardaensis* is similar in shape with *B. transylvanicus* (Csiki et al., 2005), but is much smaller (Fig. 3). The p4 mentioned by Codrea et al. (2012a) from Rusca Montană has similar blade-like shape as in *B. oardaensis*, but bears only ten serrations, whereas in the taxon from Oarda de Jos, there are eleven serrations. The *B. oardaensis* p4 has seven parallel ridges both on lingual and labial sides under serrations three to nine. In the p4 from Rusca Montană, seven labial ridges are present under serrations three to nine and only six lingual ridges under serrations three to eight. The p4 from Rusca Montană develops a small labial platform bearing two well distinct cusps, while in Oarda this character is indistinct, probably due to the wear. From a morphometrical point of view, compared to the p4 (3.35 × 0.94 mm) of *H. belgica* (Vianey-Liaud, 1979), the p4 (3.20 × 1.85) of *B. oardaensis* is shorter, but wider. Also the blade of p4 of *B. oardaensis* is higher than in *H. belgica*, being similar in this aspect with the p4 of *B. transylvanicus* (Csiki et al., 2005) (Fig. 3). In the case of *H. belgica*, all serrations are trended dorsally and distally, while in *B. oardaensis* the first two serrations are trended mesially. The p4 of *B. oardaensis* bears one extra serration compared with *H. belgica*.

The m1 of *B. oardaensis* has a similar shape to *B. transylvanicus* (Csiki et al., 2005; Rădulescu and Samson, 1986) and it is also much smaller (Fig. 4), but it differs from

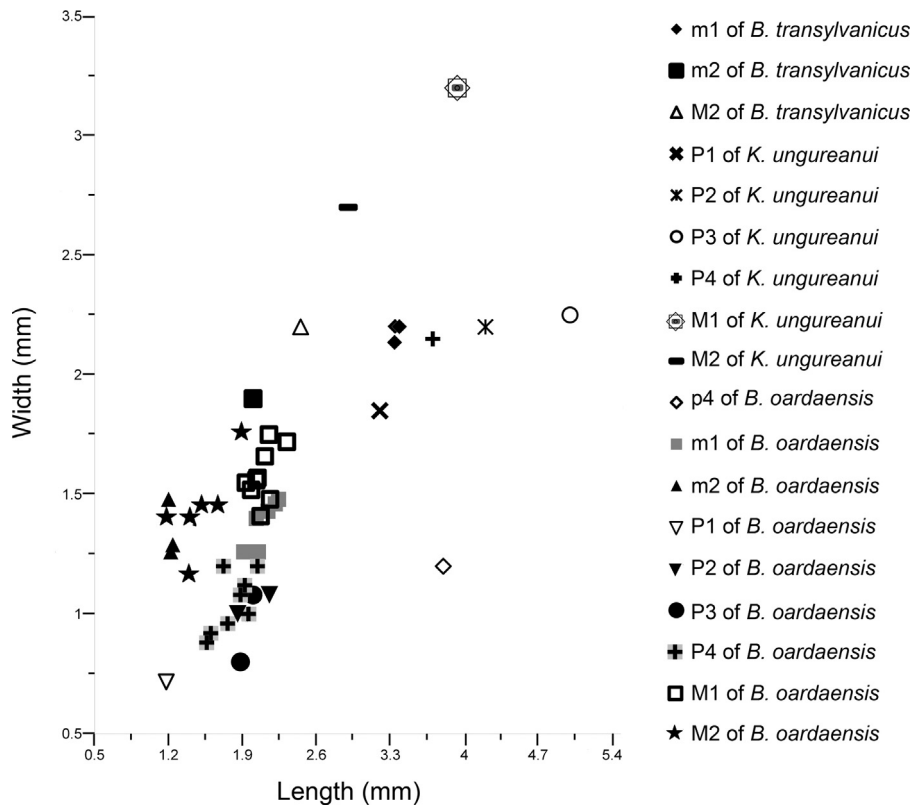


Fig. 4. Size variations of teeth of *B. oardaensis* and dimensions of teeth of the other two known Late Cretaceous kogaionids, *B. transylvanicus* and *K. ungureanui*. **Fig. 4.** Variation dimensionnelle des dents de *B. oardaensis* et dimensions des dents des deux autres espèces de kogaionidés du Crétacé récent, *B. transylvanicus* et *K. ungureanui*.

B. transylvanicus by having one less cusp on the labial row. The two species from Hainin (Table 1) 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 enamel is similar with the one of *H. belgica*, with small divergent ridges, differing by the wrinkled enamel of *H. godfriauxi*.

UBB ODAN-Mt-32 (Fig. 2X) is similar in size and morphology to the m2 described by Grigorescu and Hahn (1987) as “*Paracimexomys? dacicus*” (in fact, this name is a junior synonym of *B. transylvanicus*). The other two m2s have only two cusps on the labial row. The enamel is smooth as in *B. transylvanicus*, differing by the decorated enamel of *H. godfriauxi*.

7. Discussion

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. 4 and Table 2) variability of the new species from this locality. We consider all the specimens from Oarda de Jos referable to a single species, based on the fact that all M1s have similar pattern with only two cusps on the lingual row, and that all m2s have a similar size. We interpret the morphological and size differences

in P4, M2, m1 and m2 as the result of intraspecific variability. Some of the size differences may be related to different wear stages of the teeth, or issued from the teeth transport before burial (especially M2 and P4).

The variability in teeth morphology (i.e., variable cusps formula, and presence of accessory crest) can be very high. For example, Donohue et al. (2013) pointed out intraspecific variability for several teeth originating from the same localities. The sample from Oarda de Jos, which is richer than usual for Mesozoic mammals, can provide some data about size interspecific variability (Fig. 4) in the case of this new taxon. Analyzing the size variability (Fig. 4), 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.

All dental positions are important in the identification of multituberculates (Kielan-Jaworowska and Hurum, 2001; Kielan-Jaworowska et al., 2004). The M1s in the current sample bear important diagnostic features such as a sub-rectangular occlusal outline with a reduced cusp formula, a feature characteristic for the family Kogaionidae. The teeth have variable enamel. Some of them show similar enamel to those of the kogaionids *Kogaionon* and *Barbatodon* (Csiki et al., 2005; Fosse et al., 2001), differing in this respect from the coarse enamel reported in the Paleocene *H. godfriauxi* and *H. pyrenaica* (Peláez-Campomanes et al., 2000; Vianey-Liaud, 1979). Others have wrinkled

enamel. The upper premolars have a similar overall morphology to the type species of the family Kogaionidae (*K. unguereanui*), with the exception of P3, which has six rather than five cusps. Indeed, the labial row of P3 (=P4 cf. Peláez-Campomanes et al., 2000) has only two cusps in *K. unguereanui* (Rădulescu and Samson, 1996), whereas there is a third distalo-labial cusp in *B. oardaensis*. Moreover, P3 is significantly shorter than that of *K. unguereanui*. *B. oardaensis* has only two lingual cusps on M1, this pattern also differing from *K. unguereanui* which has three distinct lingual cusps, giving the M1 a more rounded occlusal outline. In the known kogaionids (*Kogaionon* and *Hainina*), the lingual row is the longest (Peláez-Campomanes et al., 2000), but in *B. oardaensis* this row is the shortest. By comparison, the Paleocene kogaionid *Hainina* has a fourth cusp in the lingual row of M1 (Peláez-Campomanes et al., 2000; Vianey-Liaud, 1979). If the length and number of cusps in M1 lingual row is proportional with the age of the species, this would suggest that *B. oardaensis* may be more plesiomorphic than either *Kogaionon* or *Hainina*. However, the polarity of the characters has not yet been studied in kogaionids and this has to be confirmed. The number of cusps in M2 is similar to that of *K. unguereanui*, but two (UBB ODAN-Mt-66: Fig. 3O, and UBB ODAN-Mt-67: Fig. 3P) of the three best preserved specimens available have a less protruding distal cusp on the lingual row, giving to the teeth a more square shape in occlusal view than in *K. unguereanui*.

The p4 of *B. oardaensis* is blade-like, being similar to the p4 known in *B. transylvanicus* with the highest point situated at the level of serrations four and five (Csiki et al., 2005), but also being much smaller (Figs. 3 and 4). The m1 has two rows of three cusps mesio-distally distributed, such as in *B. transylvanicus*, but the latter has four labial cusps. This feature is not typical for Late Cretaceous cimolodontans, which generally have a cusp formula 5:4 or even higher, with the exception of the North American *Paracimexomys* group (Eaton, 1995) and Asian djadochtatherians (Kielan-Jaworowska and Hurum, 1997). The more or less rounded outline of the m2 is similar to that of *B. transylvanicus*.

Wear facets affect all the distal upper teeth (P3-M2). The facets appear as longitudinal or oblique wear striations and as in *H. pyrenaica*. The character of the wear facets was already deeply discussed by Peláez-Campomanes et al. (2000). They showed that the last upper premolar and the first upper molar had a composite functional structure (more details in Peláez-Campomanes et al., 2000, and references therein). This similar composite structure can be recognized also in *B. oardaensis*, and is sustained by the fact that the P4 and M1 of this new species bear the most advanced stages in the sample from Oarda de Jos. The facets appear as longitudinal wear striations.

The origin of Kogaionidae remains uncertain. The family is restricted to the Maastrichtian-Paleocene, and is known exclusively from Europe. The cheek teeth have a morphology with a reduced number of cusps compared to other Maastrichtian and Paleocene derived multituberculate families belonging to ptilodontoids, taeniolabidoids and djadochtatheroids.

Cretaceous multituberculates were present in Europe since Early Cretaceous to Latest Cretaceous. In Early

Cretaceous they were reported in Britain and the Iberian Peninsula. In Britain, Albionbaataridae (Berriasian, Kielan-Jaworowska and Ensom, 1994), Eobaataridae (Valanginian, Simpson, 1928), Paulchoffatiidae (Berriasian, Kielan-Jaworowska and Ensom, 1992), Pinheirodontiidae (Berriasian, Kielan-Jaworowska and Ensom, 1992), and Plagiaulacidae (Berriasian, Cope, 1884; Falconer, 1857; Kielan-Jaworowska and Hurum, 2001; Owen, 1871; Simpson, 1928) are mentioned. In the Iberian Peninsula the families Eobaataridae (Early Berriasian, Crusafont Pairo and Adrover, 1966; Hahn and Hahn, 1992, 2001), Paulchoffatiidae (Early Berriasian, Hahn and Hahn, 1992, and Late Berriasian, Kielan-Jaworowska et al., 2004), Pinheirodontiidae (Early Berriasian, Canudo and Cuenca-Bescós, 1996, and? Berriasian, Hahn and Hahn, 1999) and a family *incertae sedis* (Late Berriasian, Kielan-Jaworowska et al., 2004) were present. Badiola et al. (2011) reported *Iberica hahni* from the Early Berriasian of La Cantalera and Galve, a species with uncertain family status, belonging probably either to Plagiaulacidae, or to Eobaataridae.

Surprisingly, after the luxuriant Lower Cretaceous systematic diversity in Europe, in the Late Cretaceous only the kogaionids from Romania are known. Their teeth structure is totally different from the Lower Cretaceous European representatives. This evidence is a challenge for the paleogeographical interpretations, allowing various scenarios. It is strange that multituberculates as any other mammals are completely missing from the fossil record in Iarkút (Santonian, Ősi et al., 2012 and references therein) or the Gosau Basin (Bunzel, 1871; Pereda-Suberbiola, 2009). In this situation, their origin remains unclear. Either the kogaionids are descendants of a group that evolved somewhere in the Tethys or peri-Tethys regions, or they migrated into Transylvania probably from Asia, similarly to several dinosaurs from the Hațeg Island (Grellet-Tinner et al., 2012; Weishampel and Jianu, 2011; Weishampel et al., 1993, 2003).

The association of this kogaionid species with other vertebrates such as ornithomimid 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., 2009, 2010a, 2010b, 2010c, 2012a), and suggests that an unusual continental vertebrate fauna existed during the Late Cretaceous in Romania.

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