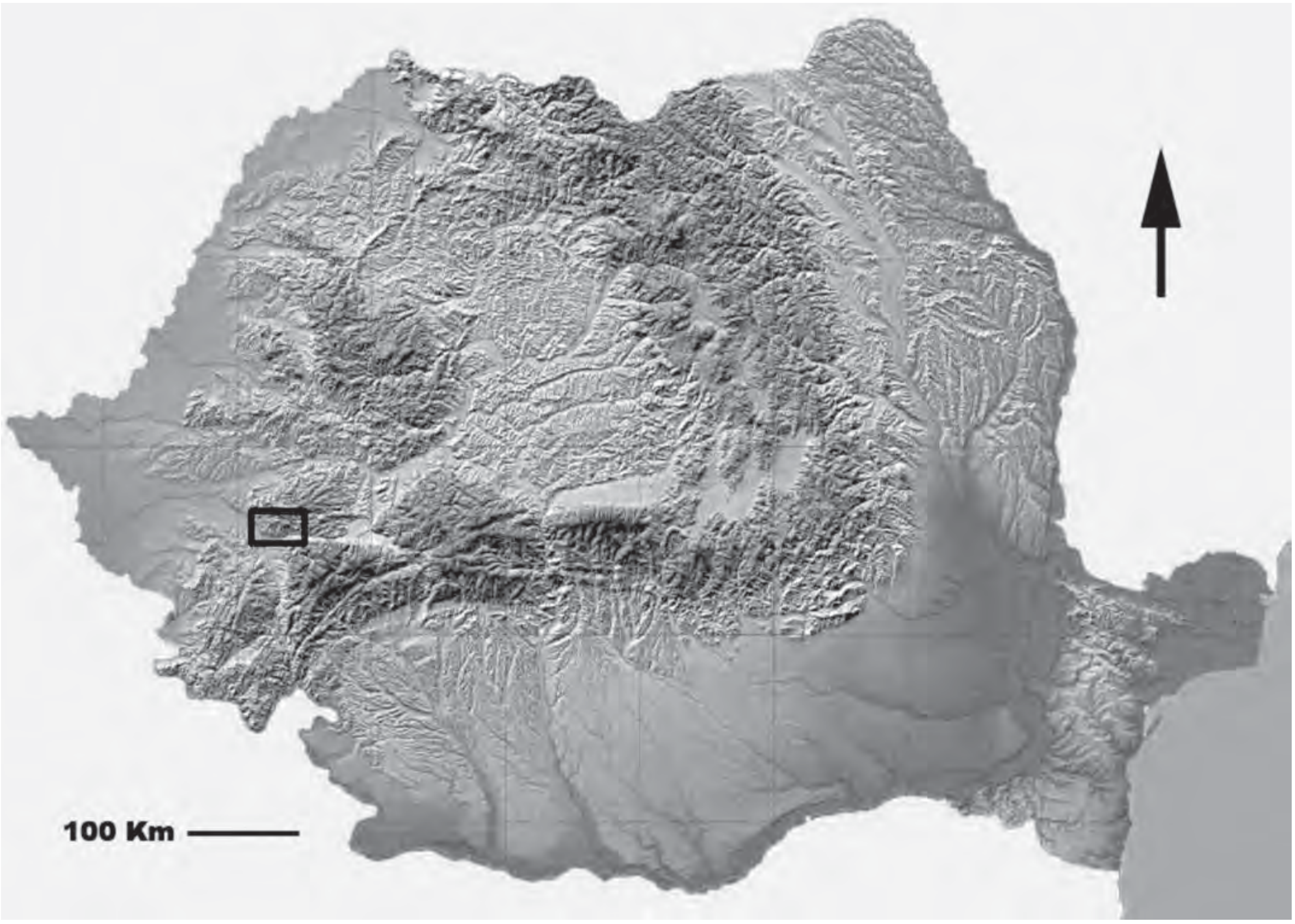


31.1. Location of the Rusca Montană Basin in Romania.

First Discovery of Maastrichtian (Latest Cretaceous) Terrestrial Vertebrates in Rusca Montană Basin (Romania)

31

Vlad A. Codrea*, Pascal Godefroit, and Thierry Smith

First mentioned by F. Nopcsa, Haţeg Island was a paleogeographical concept sketched by this famous paleontologist in order to explain the presence of small-sized dinosaurs in uppermost Cretaceous localities from Transylvania (western Romania), and particularly from the Haţeg Basin. However, this insularity is still debated, even after more than a century of research. In order to reconstruct the precise paleogeography of this area by Maastrichtian time, it is important to study all the coeval uppermost Cretaceous continental deposits from Transylvania. The westernmost region where these formations are exposed is the Rusca Montană Basin (western Romanian Carpathians). The geological history of this sedimentary basin appears similar to that of the Haţeg Basin. We report the first Maastrichtian vertebrates from the Rusca Montană Basin. These fossils include dinosaurs (ornithopod, sauropod, theropods), turtles (*?Kallokibotion*), indeterminate crocodiles, and multituberculate mammals (Kogaionidae). This fauna closely resembles that from the Haţeg Basin and is the first evidence of their presence to the west of Haţeg.

Introduction

More than a century ago, the paleontologist Baron Francise von Nopcsa (1897) reported the first latest Cretaceous small-sized dinosaurs from Transylvania (western Romania) in the Haţeg Basin in the southern Carpathians. Soon, he also reported similar taxa in other areas from Transylvania, including Alba and Sălaj counties (Nopcsa, 1905), where Maastrichtian continental formations are widely exposed (Codrea and Dica, 2005; Codrea and Godefroit, 2008; Codrea et al., 2010).

Nopcsa (1914) was impressed by the remarkably small size of the dinosaurs in Transylvania and regarded it as an example of dwarfism on an island later called by Weishampel "Haţeg Island" (Weishampel et al., 1991). According with this idea, the island had a surface area of about 7,500 km^2 and was located 200 to 300 km from the rest of Europe. This topic remains controversial; some authors have supported Nopcsa's original hypothesis (Lapparent, 1947; Weishampel et al., 1991, 1993, 2003; Jianu and Weishampel, 1999; Dalla Vecchia, 2006, 2009), whereas others have challenged it (Jianu and Boekschoten, 1999; LeLoeuff, 2005; Pereda Suberbiola and Galton, 2009). In our opinion, the geological data at hand suggest that Europe was an archipelago during the Maastrichtian (see, e.g., Smith et al., 1994) rather than a wide land, so we are inclined to agree with Nopcsa's hypothesis. However, episodic connections between Haţeg Island and wider

European emerged areas cannot be excluded (Folie and Codrea, 2005; Benton et al., 2010; Weishampel et al., 2010).

In order to reconstruct the paleogeography of the Transylvania area during the Maastrichtian, it is important to take all exploitable exposures into consideration (Codrea et al., 2010). The presence of the rhabdodontid *Zalmoxes* at Someş-Odorhei, a site located in the basin of Transylvania, confirms the northeastern extension for Haţeg Island in Transylvania (Nopcsa, 1905; Codrea and Godefroit, 2008). The Rusca Montană Basin is the westernmost region where continental Maastrichtian deposits can be observed in Romania. This sedimentary basin is located in the western Romanian Carpathians, on the southwestern side of the Poiana Ruscă Mountains (Fig. 31.1).

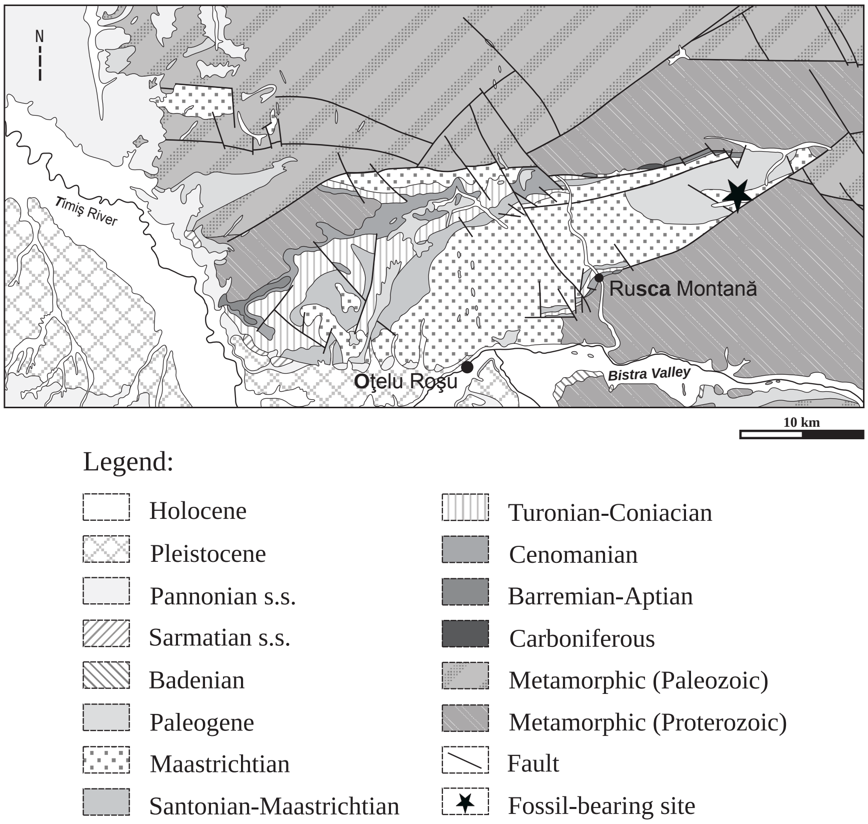
Although Romanian geologists have long observed that the geological history of Rusca Montană Basin appears similar to that of Haţeg Basin, vertebrate remains have not been found in the Rusca Montană Basin. Here, we briefly describe the first Maastrichtian terrestrial vertebrates ever found in the Rusca Montană Basin.

Institutional abbreviation. UBB, University Babeş-Bolyai, Cluj-Napoca, Romania.

Geological Setting

Rusca Montană Basin is one of the Late Cretaceous ("Senonian") synorogenic sedimentary basins located south of Mureş River, which were formed as a consequence of the Late Cretaceous tectogenesis that erected the Getic and Supragetic nappes in the Median Dacides (Săndulescu, 1984). Rusca Montană Basin and Haţeg Basin probably share the same geological evolution, from piggyback to collapse type (Willingshofer et al., 2001). The basement of Rusca Montană Basin is formed by metamorphic rocks covered by Jurassic (Lias, Malm), Lower Cretceous (?Albian; terrestrial environments with bauxite) and Upper Cretaceous (Cenomanian, Turonian) marine deposits (Dincă et al., 1972; Dincă, 1977; Bucur et al., 1985), all related to the Getic Nappe realm. A disconformity is present in the Middle–Late Turonian or within the Late Turonian (Strutinski, 1986; Strutinski and Hann, 1986). Therefore, "Senonian" evolution started with transgressing Coniacian deposits (calcarenites, marls) over older rocks (Mamulea, 1955). Santonian and Campanian deposits are represented by deep-water turbidites (marlstones and claystones, distal flysh deposits; Dincă, 1977) (Fig. 31.2).

A sedimentary turnover occurred when marine environments (Pop et al., 1972) were replaced by continental ones. As in Haţeg Basin (Melinte-Dobrinescu, 2010), continental sedimentation probably began during the Late Campanian and lasted through the Maastrichtian. The continental succession begins with siliciclastic rocks bearing coal beds (?Early Maastrichtian) and follows with siliciclastic beds interleaving Banatitic volcanoclastic strata (Kräutner et al., 1986; Grigorescu, 1992). In fact, volcanic activity in Rusca Montană Basin started even earlier in the Turonian–Coniacian, when basic tuffs associated with radiolarian rocks accumulated as a result of marine eruptions related to an east–west fracture bounding the northern basin margin (Strutinski and Bucur, 1985; Strutinski and Hann, 1986).



31.2. Geology of the Rusca Montană Basin in Romania.

The Upper Cretaceous deposits form an asymmetric syncline: the strata on the northern sector are more abruptly inclined than those on the southern side. The faults are not very numerous, and two main fault directions—southwest–northeast and southeast–northwest—can be observed.

The Terrestrial Maastrichtian in the Rusca Montană Basin

The Maastrichtian continental deposits are particularly well documented in Rusca Montană Basin, mainly because of coal mining works, including rich drilling data (Papp, 1915; Duşa, 1987). However, despite of the numerous boreholes and mining excavations, which stopped immediately under Coal Bed 1, the basin basement was never reached. Therefore, the base of the Maastricthian continental sequence remains poorly known and is based on data restricted to only a few scarce outcrops.

Coal exploitation started at the beginning of the twentieth century and stopped around 1930. The geological survey continued until 1970, but the results were disappointing for profitable mining exploitation; although the quality of the coal is good, the coal beds are rather thin (Duşa, in Petrescu et al., 1987).

Grigorescu (1990, 22–23) briefly described the molass deposits from Rusca Montană Basin and correlated them with the "lower and median members of the Densuş-Ciula Formation" in the Haţeg Basin. Later, Therrien et al. (2002) mentioned the so-called Rusca Formation, a name devoid of formal lithostratigraphy. On the basis of drilling data, Duşa (1974, 1987) reported two Maastrichtian complexes, a lower clastic, coaly complex and an upper clastic, volcanic complex. The former is 320 m thick, with conglomerates, microconglomerates, sandstones, clay shale with few acid lava flows, tuffs, and volcanic agglomerate interbeds, bearing toward its base up to 20 bituminous coal beds and coaly intercalations, 1.4 m the thickest; the coal beds are of different lateral extent, some of them completely vanishing toward the basin central areas. The latter is 370 m thick, with coarser clastic rocks such as conglomerates, microconglomerates, and sandstones alternating with volcanic agglomerates and tuffs, but rarer lava flows; thermal metamorphism of coals at the contact with volcanic dikes was reported by Duşa and Bărilă (1973).

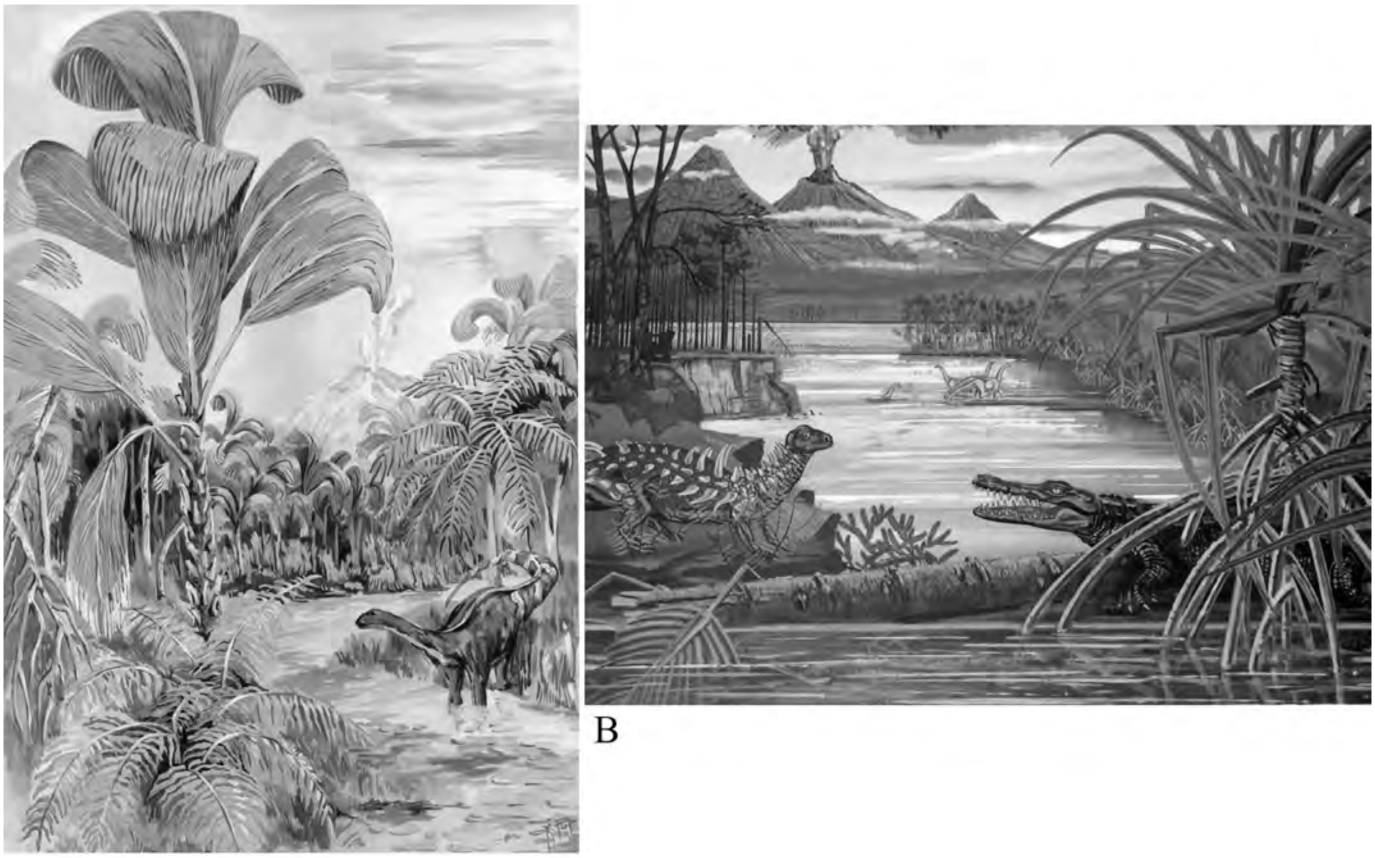
It is clear that an additional survey is necessary for a refined stratigraphy in Rusca Montană Basin. If the Maastrichtian flora is particularly poor in Haţeg Basin, the latest Cretaceous flora in Rusca Montană Basin is the richest in Romania. Several fossil macroflora were collected from the coal deposits, and 34 species have been described so far (Schafarzik, 1907; Tuzson, 1913; Cantuniari, 1937; Givulescu, 1966, 1968; Balteş, 1966; Petrescu and Duşa, 1970, 1980, 1984; Pop and Petrescu, 1983). However, Kvaček and Herman (2004), in a revision of the *Pandanites*, rejected some of the new species proposed by Petrescu and Duşa (1980). The plant assemblage includes ferns, monocotyledonous (palm trees), and dicotyledonous angiosperms.

The Late Cretaceous palaeoenvironment in Rusca Montană Basin was tentatively reconstructed by several authors. Tuzson (1913) illustrated a floodplain-dense forest, rich in *Pandanus* trees (Fig. 31.3A). Duşa (1974) also suggested a mangrovelike paleoenvironment, as figured in a picture from the collection of the Babeş-Bolyai University, Cluj-Napoca (Fig. 31.3B).

The continental deposits from Rusca Montană Basin are usually regarded as Maastrichtian (="Danian" in older contributions) in age. This age is based on similarities with the Maastrichtian formations in Haţeg Basin of the macroflora and especially of the pollen and spore assemblage, with *Pseudopapilopollis praesubhercynicus* (Antonescu et al., 1983). According to Antonescu et al. (1983), this latter marker indicates a Late Maastrichtian age for the latest Cretaceous continental formations in Haţeg Basin. As mentioned by Dalla Vecchia (2006, 2009), the dinosaur-bearing deposits from Transylvania were usually regarded as Late Maastrichtian during the 1970s and 1980s. However, more recent data instead suggest an Early Maastricthian age for the dinosaur localities in Haţeg Basin (López-Martínez et al., 2001; Panaiotu and Panaiotu, 2002, 2010; Bojar et al., 2005; Van Itterbeeck et al., 2005; Therrien, 2005). Therefore, it is not clear whether the continental formations in Rusca Montană Basin are Early rather than Late Maastrichtian in age, or both.

Maastricthian Land Vertebrates from the Rusca Montană Basin

We found the first Maastrichtian vertebrates from Rusca Montană Basin in the eastern part of the basin, near Lunca Cernii de Sus. The fossils formed a vertebrate microfossil assemblage (sensu Eberth and Currie, 2005) concentrated in red beds of fluvial origin both in the overbank silty clay and in the sandy channel fills. About a ton of sediments were screen washed. The red clay is rich in plant remains, including small pieces of yellowish amberlike resin. All the vertebrate remains are dark colored. Aquatic taxa (crocodiles, turtles) are typically most abundant, but dinosaur bone fragments and teeth are also well represented. Multituberculate mammals are also present. The bones and teeth of large reptiles are rare.



A

B

31.3. Paleoenvironmental reconstructions of the Rusca Montană Basin (Romania) during the Maastrichtian.

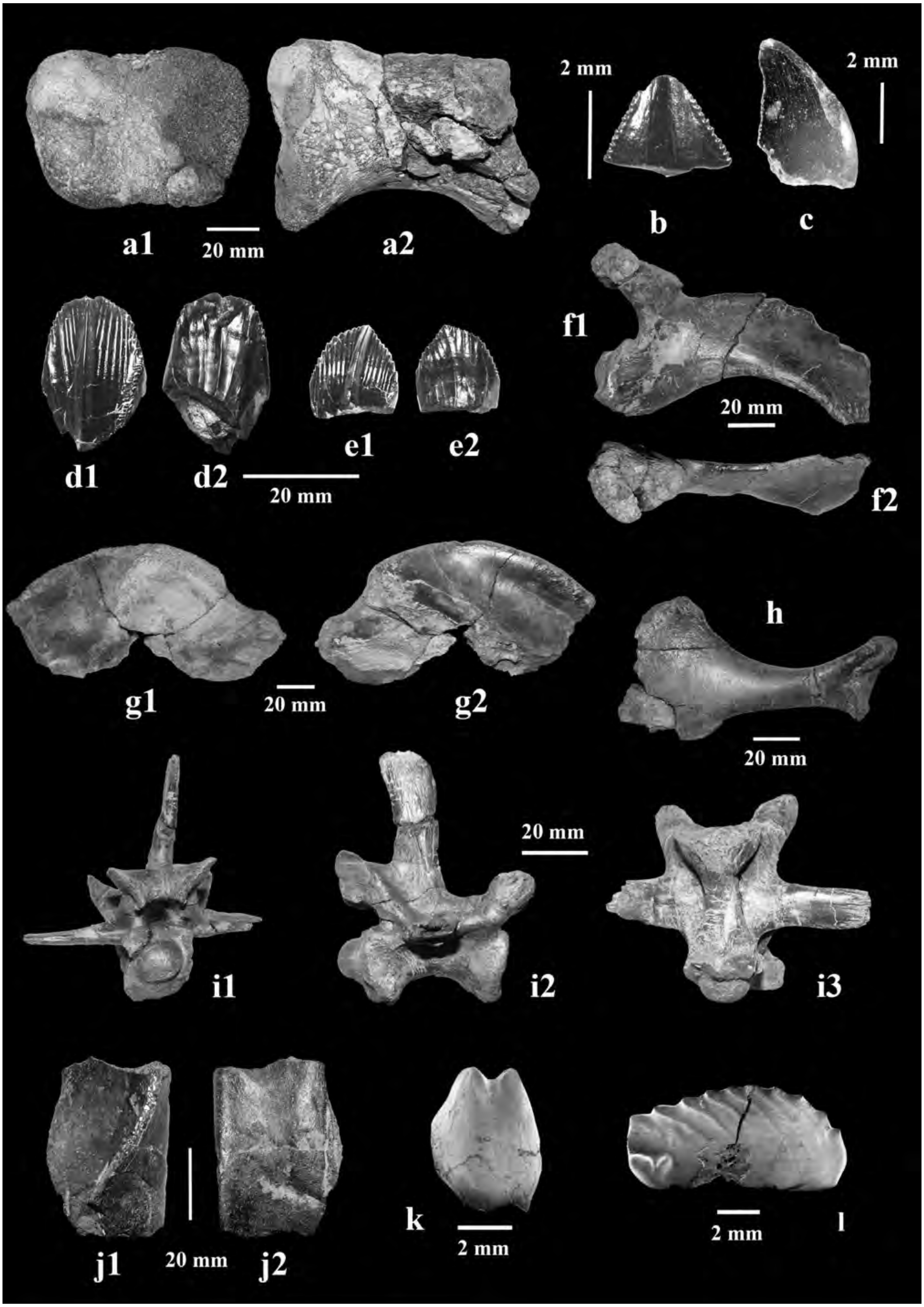
A, After Tuzson (1913), modified. B, Oil on canvas by V. Svinţiu in the collection of Babeş-Bolyai University, Cluj-Napoca (Romania).

Sauropoda

Sauropods are represented by a single distal caudal vertebra (UBB NgS1; Fig. 31.4A) with a maximum preserved length of 105 mm. The centrum is eroded and broken, marked by intensive postmortem reworking. It is dorsoventrally compressed, with both articulation facets poorly preserved. Although the general aspect of the centrum evokes some Titanosauriformes, this centrum is too poorly preserved to warrant precise identification, and we regard it as an indeterminate sauropod.

Ornithopoda

Two isolated dental crowns (UBB NgO2 and NgO3; Fig. 31.4D,E) resemble the dentary teeth of the rhabdodontid *Zalmoxes*, abundantly represented in the Sânpetru Formation in the Haţeg Basin (Weishampel et al., 2003; Godefroit et al., 2009). The enamel is much thicker on the lingual side than on the labial side of the crown. The lingual side of the crown is asymmetrically divided by a strong primary ridge. High, slightly divergent vertical subsidiary ridges cover either side of the median ridge. Tiny crenulations are present along both edges of the crown. There is no real cingulum, but a thin enameled lip marks the base of the distal part of the crown. Contrary to typical *Zalmoxes* teeth, the basal lip bears tiny mammillations (Fig. 31.4, D1). Subsidiary ridges extend on the apical part of the labial side in UBB NgO3 (Fig. 31.4, E2), a character not described in *Zalmoxes* dentary teeth


a1
20 mm
a2
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e1
e2
f1
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g1
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g2
h
20 mm
20 mm
i1
i2
i3
j1
20 mm
j2
k
2 mm
2 mm
l

so far. The whole labial side of UBB NgO2 and the basal part the labial side of UBB Ng03 are heavily worn. Therefore, because of small differences in the morphology of the dental crowns, it cannot be ascertained that these teeth really belong to *Zalmoxes*. One caudal vertebral centrum (UBB NgO1) may also tentatively be referred to an ornithopod dinosaur. Hadrosaurids are not represented in the Rusca Montană Basin fossil record; however, the collected sample is quite small, so this absence is not significant.

31.4. Late Cretaceous vertebrates from the Rusca Montană Basin. A, Caudal vertebra of Sauropoda indet. (UBB NgS1) in anterior (A1) and lateral (A2) views. B, Troodontid-like theropod tooth (UBB NgTh 1) in lingual or labial view. C, Velociraptorine-like theropod tooth (UBB NgTh 2) in lingual or labial view. D, E, Dentary teeth of rhabdodontid indet. (UBB NgO2, NgO3) in lingual (D1, E1) and labial (D2, E2). F, Left ischium of Crocodylia indet. (UBB NgC2) in lateral (F1) and ventral (F2) views. G, Left ilium of Crocodylia indet. (UBB NgC1) in medial (G1) and lateral (G2). H, Left pubis of Crocodylia indet. (UBB NgC3) in lateral view. I, Caudal vertebra (UBB NgC4) of Crocodylia indet. in anterior (I1), lateral (I2), and ventral (I3) views. J, Peripheral fragment of the carapace of a Chelonia indet. in ventral (J1) and dorsal (J2) views. K, P1 (UBB Ng-1-02) of Kogaionidae indet. in posterior view. L, p4 (UBB Ng-2-01) of Kogaionidae indet. in lateral view.

Theropoda

Theropods are represented by several isolated teeth. Three of them may be assigned to the velociraptorine morphotype (Currie et al., 1990; Sankey et al., 2002) because of the great disparity in size and distribution of the denticles along the mesial and distal carinae. In UBB NgTh2 (Fig. 3C), the upper third of the distal carina bears 10 denticles per millimeter, whereas denticles are nearly completely missing on the mesial carina, with the exception of few denticles along its basal portion. The tooth crown is strongly compressed laterally, pointed, and sharply recurved.

UBB NgTh1 (Fig. 31.4B) is the apical part of a theropod tooth. It may be tentatively attributed to a troodontid-like theropod because it displays the following characters (Currie et al., 1990): the crown is less recurved than in teeth ascribed to velociraptorines, and both the mesial and distal denticles are well developed (six denticles per millimeter) and hooklike.

Both velociraptorine and troodontid dental morphotypes have already been described from the Sânpetru Formation of the Haţeg Basin (Csiki and Grigorescu, 1998; Codrea et al., 2002).

Crocodylia

Pelvic elements and vertebrae of crocodilians are rather abundant in the bonebed. UBB NGC1 (Fig. 31.4G) is a well-preserved iliac blade characterized by a reduced anterior process. UBB NGC1 (Fig. 31.4F) is a partial ischium; its posterior part is incomplete, but the iliac and pubic processes are preserved on the anterior portion of the bone. The pubis (UBB NgC3; Fig. 31.4H) is gracile and the articulation facet for the ischium is preserved. The anterior portion of pubis expands and becomes thin. Two crocodilian caudal vertebrae, probably from the middle part of the tail, have been discovered in the bonebed. UBB NgC4 (Fig. 31.4I) is procoelous, with an elongated centrum. The neural arch is much higher than the centrum, with well-developed prezygapophyses and postzygapophyses, and a robust neural spine. UBB NgC5 is less complete.

These fossils are too scarce to warrant a precise identification, and pending further information, we regard them as belonging to indeterminate crocodilians. Their size corresponds to similar fossils discovered in Haţeg Basin and attributed to the eusuchian *Allodaposuchus*, with a body longer than 3 m (Delfino et al., 2008)

The crocodilian bones are the most abundant fossils collected in this bonebed. However, they are less abundant than in the Maastrichtian locality of Oarda de Jos, in the southwestern part of the Transylvania Basin to the north (Codrea et al., 2010). There, crocodile teeth and bones can be found at nearly all levels, with some of the collected bones even displaying bite marks.

Chelonia

Cryptodiran turtles are represented in the Maastrichtian assemblage from Rusca Montană Basin by scarce carapace fragments, including one peripheral fragment (UBB NgCh1; Fig. 31.4J), one costal plate fragment (UBB NgCh2), and three indeterminate other fragments. Bone thickness and ornamentation suggest the presence of the genus *Kallokibotion*, widespread in Maastrichtian localities from Transylvania (Codrea and Vremir, 1997; Vremir, 2004; Lapparent et al., 2009; Vremir and Codrea, 2009), but this identification needs to be confirmed by more complete material.

Mammalia

Multituberculate mammals are represented by isolated teeth. The simple tooth pattern and the reduced number of cusps in premolar and molar series are indicative for Kogaionidae. P2 (UBB NgCh1; Fig. 31.4K) has only two simple cusps, one on the labial side and the other on the lingual side. The damaged right p4 (NgCh1; Fig. 31.4L) has a bladelike crown with 10 cusps. Parallel labial ridges exist only under cusps 3–9, whereas sharp lingual ridges are present only under cusps 3–8. Under cusp 9, only an interrupted trace could mark the presence of a faint lingual ridge.

Two multituberculate taxa have been described from the Haţeg Basin, *Barbatodon transylvanicus* Rădulescu and Samson, 1986, and *Kogaionon ungureanui* Rădulescu and Samson, 1996; the second species is the type species for the family Kogaionidae. Csiki et al. (2005) recently discussed *B. transylvanicus* and other Kogaionidae from Haţeg Basin.

The Rusca Montană Basin multituberculate sample is too limited for precise identification. However, the discovery of kogaionid teeth in Rusca Montană Basin confirms that these multituberculates were widespread and probably diversified in Transylvania during the Maastrichtian. Indeed, Kogaionidae are rather abundant in Haţeg Basin, but also in the Basin of Transylvania (Codrea et al., 2010). Late Cretaceous kogaionids from Transylvania are apparently closely related to the later *Hainina*—for example, those reported from the Thanetian (Late Paleocene) of Jibou in the northwestern part of the Transylvania Basin (Gheerbrant et al., 1999). As in the other Maastrichtian localities from Transylvania, eutherians are apparently missing from the Rusca Montană Basin record.

Conclusion

The westernmost occurrences of continental Maastricthian formations in Romania can be observed in the Rusca Montană Basin. Westward, observation of these formations is particularly problematic because late Mesozoic rocks are hidden under molasse deposits in the Lugoj and Faget Cenozoic sedimentary basins.

Besides a rich Maastrichtian plant assemblage, vertebrate fossils are now reported from the Rusca Montană Basin. Preliminary observations suggest that the Maastrichtian vertebrate assemblage from Rusca Montană

Basin closely resembles assemblages described in other sedimentary basins (Haţeg Basin, Transylvania Basin) from western Romania (Codrea et al., 2001, 2010; Codrea and Godefroit, 2008). The Maastrichtian fauna appears globally similar in these different basins, reflecting a homogeneous paleoenvironment. The Rusca Montană Basin Maastrichtian assemblage demonstrates the extent of Haţeg Island toward the west. In spite of over a century's worth of research, this island still cannot be completely defined only on the basis of paleontological and sedimentological data as a result of the lack of information outside the Haţeg Basin. As already pointed out by Rage (2002) and Codrea et al. (2010), every piece of new data on the Upper Cretaceous continental deposits located outside Haţeg greatly aids our understanding of the paleobiology and paleogeography of the latest Cretaceous in this part of the continent. In this chapter, we show that the Rusca Montană Basin has great potential for future research.

Acknowledgments

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