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Diplocynodon: a salt water eocene crocodile from Transylvania?

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Abstract. Crocodiles are a conservative group of reptiles regarding their morphology and behaviour. Fossil representatives are hence important to be studied. In the Paleogene sedimentary area of Gilău, from the former Mănăştur limestone quarry in Cluj-Napoca, a fossil fragmentary crocodile skull was found in Priabonian rocks. This 19th century discovery documents a new species of *Diplocynodon.* From the Leghia-Tabără limestone quarry, another crocodile fossil was unearthed a decade ago. The latter specimen, representing a crocodile mandible, may be associated to the same new species. The new discovery provides new characters enhancing our knowledge on that species and on the whole group. Unusual is the Eocene marine environment where the crocodile fossil originated from. As a consequence, the following questions are raising: had it been a marine taxon or a terrestrial representative that managed to get in marine environments during incursions for food, or had it been transported postmortem in the marine basin by fluvial streams? The mentioned genus probably had limited osmoregulatory capabilities, in a similar way to recent alligators, which do not possess osmoregulatory salt glands, which would keep their homeostatic equilibrium under control.

Key words: alligatoroid crocodile, marine Eocene, Viştea Limestone, Transylvania, Romania.

Introduction

Crocodiles are a group of emblematic reptiles in terms of conservative tendencies of their physiognomy, which conveys a high-level adaptation to a specific style of food access. They hunt using the ambush technique, their prey being diverse. Crocodiles gained certain adaptations in the far geological past, the refinement of these ones assuring a remarkable continuity of the group's geological existence (they appeared first in the Triassic, at 228.7 Ma.). Apart from a single exception all actual representatives are associated to terrestrial freshwater environments. The single marine representative is *Crocodylus porosus* spread in SE Asia, Australia and Micronesia (Webb et al. 2010). From the more recently known and most frequently met crocodilian fossils, Alligatoroidea (caimans and alligators) are accommodated to freshwater environments, resisting only for short episodes in marine waters. The ancestral group is supposed to have had the ability to eliminate the excess amount of salt from their organism through osmosis (due to the presence of saline glands located on the dorso-posterior side of the tongue), an ability that actually only Crocodylidae have. Regarding Diplocynodontidae, it is not documented if they had or not the ability to eliminate the salt in excess (Brochu, 2001). Crocodiles are among the reptiles that survived the major geological events, followed by extinctions at the Cretaceous/Cenozoic boundary.

Locality, geological setting and age

The area of interest for this study is situated in the northwestern side of the Transylvanian Depression, a geomorphological unit in the central part of Romania. The sedimentary area of Transylvania throughout geological times has been influenced by the evolution of the overlapping and successor sedimentary basins (Balintoni et al., 1998). The development of the Paleogene sedimentary basin started after the Laramic tectogenesis, contemporaneously with the first sedimentary megacycle that took place in the Upper Cretaceous – Lower Miocene time span. Strictly, its beginning is marked by the continental deposits of the Jibou Formation (crocodile fossils were collected from it as well), which started in the latest Cretaceous (Maastrichtian).

The sedimentation in the studied area exposes the characteristics of a *foreland* area, with marine and continental interleaving (Hos, 1999, Codrea & Hosu 2001). An example of this kind can be mentioned from the Gilău sedimentary area (Rusu 1970, 1987, Popescu 1976) where in the lowermost Priabonian a marine carbonate platform overlapped the underlying deeper marine rocks of the Mortănuşa Formation (Codrea et al. 2010). This platform is illustrated by the Viştea Limestone Formation (Răileanu & Saulea 1956). The marine environment ceased afterwards, when a continental sedimentation began in the area, corresponding to the Valea Nadăşului and the Turbuţa formations, associated to the pre-Pyrenean and Balkan tectonic pulses (Dudich & Mészáros 1963). This marine sequence means the first cycle of the Paleogene evolution (Krézsek & Bally 2006).

We focus on the geological formation the crocodile fossil originates from, this fossil representing the main subject of this study. The sample was found in the Upper Eocene calcareous rocks, more exactly of Priabonian age referred to the Viştea Limestone Formation (lowermost Priabonian), named by Koch (1894) "Lower coarse limestone", due to the limestone's coarse granulometry. It is composed of compact packstone, bioclastic calcarenite with crushed bioclasts (calcareous algae, echinoderms, foraminifers as alveolinides - *Alveolina elongata* or nummulites – *Nummulites fabianii*; Popescu et al., 1978), biomicrite with sometimes consistent terrigenous inputs (quartz, feldspar, muscovite, biotite, clay minerals, limonite) that prove an influence of the sedimentary terrestrial inputs coming from nearby land areas, and even dolomitic tendencies, with dolomicrites (Ghergari et. al. 1987). Koch mentioned similarities between these rocks and the so called ″calcaire grossier″ type from the Paris Basin.

The shoals of the described formation from Leghia have an ashy-yellowish color, with rusty nuances. In this sequence there can be separated: in the basal portion a sequence of sandy limestone (3 m thick), followed by grey ashy marls (4 m), organogenic limestones (2 m) and ashy sandy marls (1.5 m), followed by variegated continental fine clays, and a last sequence of sandy marls (Mészáros et al. 1987). According to these authors the fossil content of this locality refers to molluscs (*Panopea oppenhaimi, Thracia stenochora, Tellina* sp., *Cardiopsis* sp., *Corbulla sp., C. gallica, Lucina* sp., *L. mutabilis, Chlamys subimbricatus, Ostrea cymbula, Terebellum* sp.), to which *Sismondia occitana* sea urchin can be added. Regarding vertebrates, this limestone is extremely scarce in fossils. Koch (1894, 1900) mentioned only shark teeth (”*Lamna elegans*, *L. cuspidata*, *Lamna* sp., *Oxyrhina quadrans*, and undetermined shark's teeth”). In this way, this formation is by far scarcer in comparison to the Cluj Limestone Formation (late Priabonian). Besides fish remains, there had been reported turtles (*Eochelone, Trionyx, Trachyaspis*), reptile's teeth (crocodilians: *Crocodylus, Diplocynodon,* cf. *Asiatosuchus*), together with ?dolphins (*Delphinus*), or sea-cows (*Sirenavus, Halitherium*) etc. (Koch 1894, Codrea et al. 1997). The limestone's estimated thickness at Leghia is ca. 5 m (Popescu et al. 1978).

The fossiliferous outcrop of interest refers to Leghia locality (Cluj County), situated to W-NW from Cluj-Napoca (Fig. 1). At the South-Western neighborhood of this locality there was an active quarry (Leghia-Tabără; closed today) in which the limestone was mined, extracted as block-shaped pieces. After extraction, these blocks were transported to Baciu locality, near Cluj-Napoca, where they were cut into slices, which were shaped as plates for interior and exterior decorations for buildings, by the RESIDO TRADE Company. Thus, we cannot refer to a natural outcrop that would expose these rocks, but rather to a project which starting from natural exposures of rock, extracted the limestone reserve to a certain point. The mining stopped when the monocline slope of these strata implied a much too large volume of stripping in comparison to the economic viability. From the sliced limestone plates, before grinding, one of the former workers, Mr. Adrian Oltean collected a limestone slab which contains fragments of a crocodile mandible. The present study refers to this extremely rare fossil not only for Romania, but for the whole Europe, bringing new data for the systematic knowledge of the group.

Material and Methods

The material refers to a bioclastic limestone tile, shaped through cutting. The counterpart of the limestone plate which most likely contained the dorsal continuation of the specimen was never recovered from the scraps. The limestone slab which contains the fossil remains was slightly processed in the laboratories of the ”Ţării Crişurilor” Museum from Oradea, through clearance of the sediment from some parts of the mandible bone, with the goal of revealing certain anatomical contacts. Taking into consideration the bone's fragility, no air-scribe devices were used, but only specially manufactured small hammers and chisels.

Photographs were captured at the ”Ţării Crişurilor” Museum from Oradea, using a digital Canon EOS 5D Mark III camera with a macro Carl Zeiss 100 mm f/2 objective. The anatomical nomenclature follows Turner (2015).

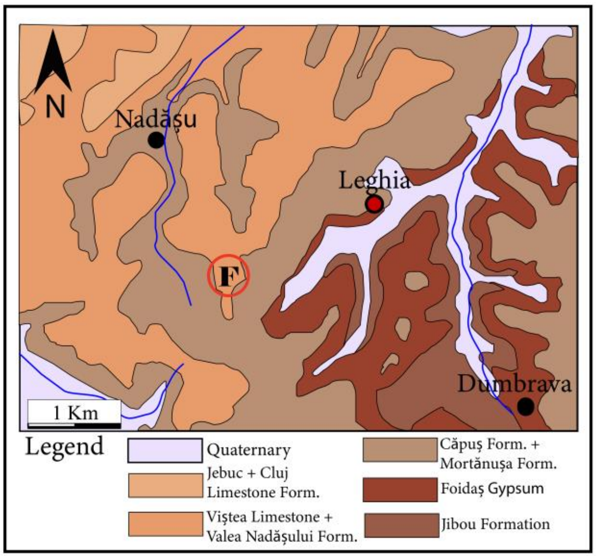

Figure 1. Geological map of the studied area, after Popescu et al. 1978.

Results

Systematic paleontology

Class Reptilia LAURENTI, 1768

Order Crocodylia GMELIN, 1789 (sensu Martin & Benton, 2008)

Suborder Eusuchia HUXLEY, 1875

Superfamily Alligatoroidea GRAY, 1844 (sensu Brochu, 2003)

Family Diplocynodontidae HUA, 2004

Genus *Diplocynodon* POMEL, 1847

***Diplocynodon* sp.**

Referred material: one pair of fused dentaries and one partial fragment of the right mandible detached from the fused dentary pair, both of which are being preserved in a limestone slab (Fig. 2). The slab which presents the exposed mandible remains was cut about 12 years ago. Collected by one of the quarry workers, it was donated to the Paleontology-Stratigraphy Museum of the Babeş-Bolyai University from Cluj-Napoca (UBB V 1004).

The cut plane crossing the dentary remains is quite horizontal. The section plan cut across the dentary remains right below the base of the tooth crowns, in such a manner, that only alveoli and replacement teeth crowns are exposed (Fig. 3). The fused pair of dentaries exposes 19 alveoli on both sides. The first pair of alveoli have an oval contour and are slightly wider in comparison to the pair of third and fourth enlarged alveoli. The contour shape of the alveolar margins indicates an antero-dorsal, slightly lateral orientation of the first teeth. The second alveoli are situated in the near vicinity of the first pair, in a nearly confluent position, having a similar orientation. The fourth and fifth alveoli are enlarged, are almost equal in size and are oriented dorso-laterally. The next largest alveoli are the 11th and the 12th, whereas the last six alveoli are smaller in size and are compressed medio-laterally. The dentary curves slightly between the fourth and tenth alveoli. The symphysis extends backwards to the level

Figure 2. Cut surface of the mandible in the limestone slab. Scale bar: 50 mm.

Figure 3. Detail of the fused dentary pair. Scale bar: 50 mm.

of the fourth alveoli and is reinforced by a bony ridge that extends transversally on the medial side of the dentary, below the Meckel's groove anterior opening. The dentaries share a fusion angle of about 30°. The splenial is damaged, but its anteriormost remains and the impression present on the dentary indicates that it reached as far as the fifth alveoli, and as a consequence it was not involved in the dentary symphysis. The rostral portion of the splenial is cleft by the Meckel's groove anterior opening, the groove extending below the anterior extremity of the bone tip. The bony limit that separates the splenial and the dentary is extremely hard to distinguish at the level of the 9th-14th alveoli, meanwhile it is better exposed posteriorly to the level of the 15th alveoli, where the splenial reinforces the medial alveolar wall, just like in other representatives of *Diplocynodon* (Martin et al. 2014).

A posterior fragment of the mandible, detached from the right dentary is positioned on the same limestone slab, at a small distance from the fused dentary pair. In comparison to

Figure 4. Detached posterior part of the mandible. Scale bar: 50 mm.

the position of the fused dentary pair, the posterior mandible fragment lays on its medial side, exposing the splenial, angular, articular and retroarticular process (Fig. 4). The cutting plane formed an angle with the postdentary bones in such a manner, that important details of mandibular morphology were revealed.

The external mandibular window was present, but only the trace of its ventral side is still preserved (i.e., the cutting plane sectioned the piece below the external mandibular window), while the coronoid is missing as well. The extreme ventral side of the supraangular is visible on the posterior-medial side of the external mandibular window, contacting the angular laterally and the articular medially, meanwhile their suture is trending in an antero-posterior direction. The imprint of the retroarticular process suggests that it was oriented slightly dorsally. The angular reached the tip of the retroarticular process apparently, while anteriorly it did reach the level of the four posteriormost teeth.

Discussion

The described material documents an extremely rare case: it refers to specimens discovered in marine environments, with normal salinity. There is only one more Eocene crocodile skull in Romania known to day, assigned to a new species of the genus *Diplocynodon* (Codrea & Venczel 2020), discovered in the Cluj Limestone Formation (Upper Priabonian), in the former Cluj Mănăştur limestone quarry. The fossil was reported by Koch (1884), who on one hand did not prepare it, neither did he accord special attention to it in the means of scientific detailing.

The discovery of complementary material was considered to be extremely unlikely, if considering the rarity of these fossils. The exceptional discovery from Leghia-Tabără of the fossil that we consider to belong to the same taxa, completes the knowledge on this reptile. The size of this crocodile could be estimated to a length of about 180 cm, based on the cranial bones.

The fundamental question that persists is how these remains got in that abnormal environment, at the specified stratigraphic level. Regarding this matter we can illustrate three scenarios. In the first one we can think of a crocodile carcass brought in the marine basin by nearby fluvial streams, whose influence cannot be denied. In this situation, the carcass decomposed gradually and its pieces sank separately to the bottom, where they were buried into the calcareous mud formed mainly from bioclasts of invertebrates and algae. In any case, obviously, at the bottom of the basin hydrodynamics were very low (this is the reason why the broken off piece of the mandibula is situated at such a small distance from its original anatomical position).

In a second scenario, despite its occurrence in a typical marine sedimentary environment, we could be thinking of the rather limited osmoregulatory abilities of the genus *Diplocynodon*, in a comparable manner to those of recent alligators, who lack the presence of salt glands responsible for the homeostatic balance in marine water (Grigg & Kirschner 2015: 416). In contrast, recent crocodiles (e.g., *Crocodylus porosus*), who possess these glands (Taplin 1988) are able to survive in marine waters, as they are able to tolerate hypersaline environments (Taplin 1984). It is known that tolerance of salty water is a plesiomorphic character of Eusuchia, thus the ancestors of recent alligatoroids could have lost their marine abilities throughout the Mesozoic (Wheatley 2010, Wheatley et al. 2012). According to Brochu (2001), it is not known if *Diplocynodon* was able to tolerate saline water or not. Either way, an indirect proof of a low tolerance of saline waters regarding diplocynodontidae and other alligators would permit the support of the documented limited capabilities of transoceanic colonization (Delfino et al. 2007). Nevertheless, large sized individuals of *Alligator mississippiensis* were observed in saline ambiances in the vicinity of freshwater swamps and occasionally in the sea, at a considerable distance from the coastline (more than 60 km; Grigg & Kirschner, 2015). A scenario of this kind could have been possible for large, adult individuals of the genus *Diplocynodon*, during incursions for food in seaside areas, not very far from the coastline.

There could also be mentioned a third scenario, which at the same time would seem quite unlikely, as for now. This specific scenario illustrates an exquisite marine *Diplocynodon*, which inherited the plesiomorphic character of the ancestral group and was capable of osmoregulation, in which case its presence in marine sediments would not be a surprise. At the same time, this possibility would contradict previous knowledge and the assigning of *Diplocynodon* as a freshwater crocodile. Still, this possibility needs further proof.

Conclusions

The present study refers to an extremely rare fossil, recovered from a non-typical sedimentary environment for the referred crocodile, typical for freshwater. From a systematic point of view, it is a new species (the diagnosis will be published elsewhere) for the vertebrate paleontology of Romania, completing the list of known taxa reported from the late Eocene (Priabonian) of Transylvania. This kind of a piece is extremely important for the reconstruction of the Eocene trophic chains, as the crocodile is occupying the highest rank of the trophic pyramid, as a top predator.

To what extent was this crocodile a freshwater representative that realized incursions for food in marine environments, or it was completely adapted to this specific ambiance needs more proof in the future. Certain thing is that both discoveries – from Cluj-Napoca and from Leghia – are in typical marine environments.

Would it be possible that our crocodile fell in love with the sea? We do not know for sure yet, but a certain type of relationship still existed…

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