SHARK REMAINS FROM THE CENOMANIAN OUTCROPS FROM THE PEȘTERA FORMATION (SOUTH DOBROGEA, ROMANIA)

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Abstract. The Cenomanian outcrops belonging to the Peștera Formation yielded numerous fossil remains of Mesozoic sharks, however due to the taphonomic conditions of the environment in which they were deposited, most of the material is fragmented and indeterminable at the species level. Here we report two fossil shark teeth from this formation belonging to *Ptychodus mammillaris* and *Cretalamna* sp., based on comparisons with descriptions of similar specimens in published literature. We provide descriptions and discussions based on this material. The aim of this work is to bring to attention new specimens related to Mesozoic sharks.

Keywords: Sharks, Cenomanian, Peștera Formation, South Dobrogea, Romania.

Rezumat. Resturile ichtiofaunei din aflorimentele cenomaniene ale Formațiunii Peștera (Dobrogea de Sud, România). Aflorimentele de vârstă Cenomanian ce aparțin Formațiunii de Peștera au furnizat numeroase resturi fosile ale rechinilor mesozoici, însă datorită condițiilor tafonomice ale mediului în care aceastea au fost depuse, majoritatea materialului este fragmentată și indeterminabilă. În această lucrare menționăm doi dinți de rechini fosili descoperiți în această formațiune, aparținând taxonilor *Ptychodus mammillaris* și *Cretalamna* sp., atribuire bazată pe comparațiile cu specimene similare din literatura de specialitate. Furnizăm descrieri și discuții pe baza acestui material. Scopul acestei lucrări este de a aduce în atenție specimene noi ce au legătură cu rechinii mezozoici.

Cuvinte cheie: Rechini, Cenomanian, Formațiunea de Peștera, Dobrogea de Sud, România.

INTRODUCTION

Although remains of Mesozoic ichthyofauna are rare, several papers have had the objective of studying the few remains found in the Romanian territory, and, as such, several important localities have been brought to attention by different authors: Ghilcoș and Moneasa (KOCH, 1900), Cernavodă and Tureni (SIMIONESCU & BARBU, 1943), Ormeniș (ȘURARU, 1984), the Hațeg Basin (GRIGORESCU & CSIKI, 2002), Ponor, near Anina (Caraș-Severin county) (DICĂ & CODREA, 2006), to name a few. More recently, Mesozoic shark fossils have been brought to attention from sites such as Peștera (GALLEMI et al., 2011; TRIF & CODREA, 2017), Lugașu de Sus (POSMOȘANU, 2015), and the Bucegi Mountains (TORCĂRESCU et al., 2019). Another important fact to note is that the knowledge about this period of shark evolution is limited in Romania due to different subjective and objective factors. One such subjective factor would be the mismanagement of the collections that housed the specimens meant for study (TRIF & CODREA, 2018a), while the objective factor is the disparity in the occurrences and geographical distribution. The purpose of this work is to provide a preliminary report on the ichthyofaunal remains from the Cenomanian outcrops belonging to the Peștera Formation, to provide descriptions and to, hopefully, contribute to the knowledge of Mesozoic sharks in Romania.

GEOLOGICAL SETTING

The Peștera village is located in the southeast of Romania in Constanța county, about 40 km east of Constanța and 14 km southwest of Medgidia. From a geological point of view, this region belongs to the Dobrogea Sector of the Moesian Platform (Fig. 1) (SĂNDULESCU, 1984). The samples were collected from a quarry located near the Peștera village from Cenomanian deposits belonging to the Peștera Formation. The Peștera Formation (Fig. 2) consists of five distinct lithological units, from base to top: a basal conglomerate (20 – 100 cm), a gritty – sandy unit with microconglomerate lenses (up to 25 m), a transitional unit of quartzose-glauconitic chalky sandstone (1 – 3 m), a quartzose-glauconitic chalk unit (up to 15 m) and a chalky quartzose-glauconitic sandstone unit (5 – 10 m). Only the first two units outcrop in the Peștera quarry but all of them can be seen in the Mircea Vodă – Remus Opreanu Sector from the Carasu Valley. The basal conglomerate unit, from where our samples originate, is composed of quartzite or detrital quartz, phosphate grains and a fragmented fauna that are partly or totally phosphatized, all this enclosed in a gritty – chalky glauconitic matrix. In this unit there are two types of fossil faunas, an autochthonous one, composed of ammonites such as *Marriela cenomanense* Schlüter, *Mantelliceras mantelli* Sowerby, *M. cantianum* Spath, *Neostlingoceras carcitanense* Matheron, *Hypoturrilites tuberculatus* Bose and pelecypods such as *Inoceramus crippsi* Mantell that point out an Early Cenomanian age (AVRAM et al., 1993).

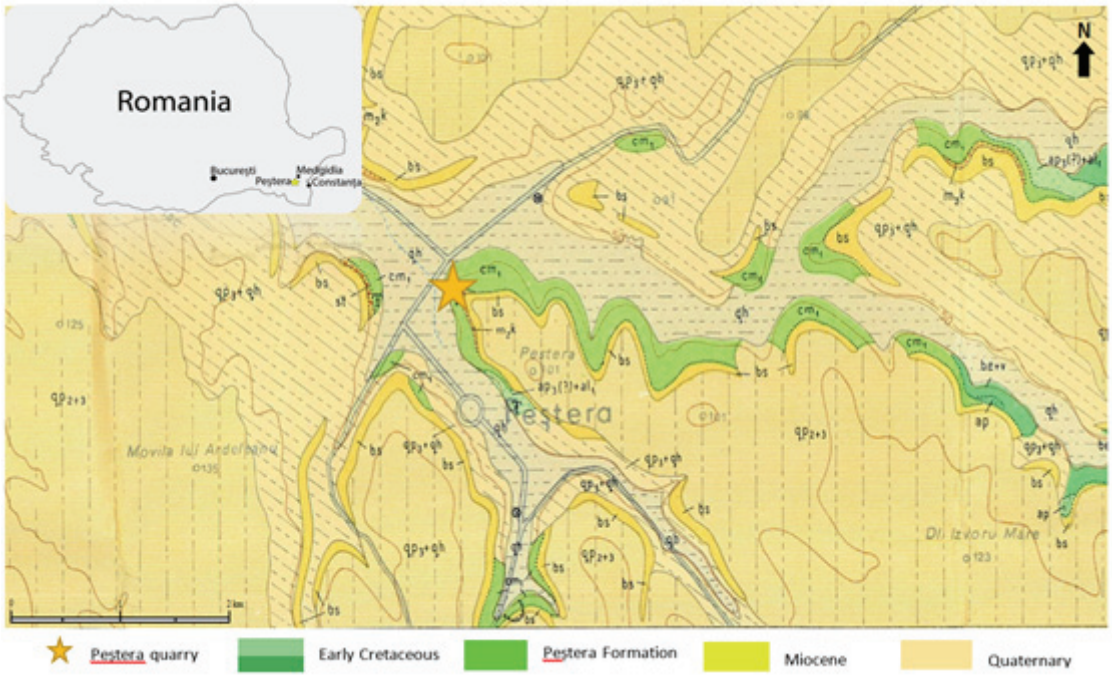

Figure 1. Geological location of the Peștera Formation with the point of origin of shark teeth (after AVRAM et al., 1993 and IGR, Peștera folio, 1:50.000).

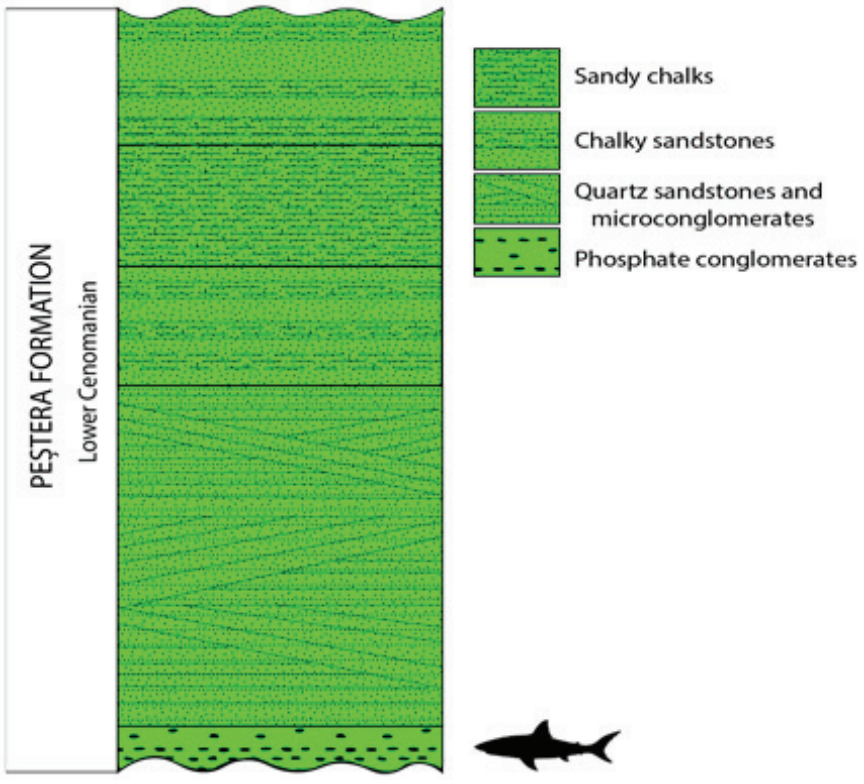

Figure 2. Synthetic lithological column of the Peștera Formation with the point of origin of shark teeth (after AVRAM et al., 1993 and IGR, Peștera folio, 1:50.000).

The other type of fossil fauna is reworked mainly from the latest Albian. Most of the reworked fauna belongs to *Stoliczkaia dispar* Zone, a great number of specimens is represented by *Anisoceras perarmatum* Pictet and Campiche, *Ostlingoceras puzosianum* d'Orbigny, *Mariella bergeri* Brongniart, *M. miliaris* Pictet & Campiche, *Hyphoplites campichei* Spath, *Mortoniceras perinflatum* Spath and *Stoliczkaia* spp. (AVRAM et al., 1988; AVRAM et al., 1993). According to Dragănescu in Avram et al. (1988), these deposits represent a Cenomanian transgressive lag.

The gritty-sandy unit consists of sandstones and sands with lenses of quartz- or quartzose-glauconitic microconglomerates, deposited in coastal marine conditions. The palaeontological content from this unit is very poor and without biostratigraphic value. The quartzose-glauconitic chalky sandstone unit is the most abundant in fossiliferous content from the Peștera Formation and represents a transition facies from the basal conglomerate or the sandstones unit to the overlying chalky unit. The fossil fauna is composed of abundant *Neohibolites*, echinoids, inoceramids such as *Inoceramus crippsi* Mantell and ammonites such as *Mantelliceras cantianum* Spath, *M. mantelli* Sowerby, *M. couloni* d'Orbigny, *M. saxbii* Sharpe, *M*. aff. *dixoni* Spath, *M. picteti* Hyatt, *Hypoturrilites gravesianus* d'Orbigny, *H. mantelli* Sharpe, *Neostlingoceras carcitanense* Matheron, *Mariela cenomanense* Schlüter, *Stoliczkaia* (*Lamnayella*) *sanctaecatherinae* Wright & Kennedy and *Hyphoplites* sp. (SZASZ in AVRAM et al., 1988). These deposits reveal plentiful mottled bioturbation occasionally with parallel lamination that suggest a sublittoral shoreface sedimentation (DRĂGĂNESCU in AVRAM et al., 1988). The chalky unit is composed of a rather glauconitic, gritty, and occasionally argillaceous chalk. The fossil fauna is much the same to that of the previous unit. The microfauna is rich, with both planktonic and benthonic foraminifers. This unit is strongly bioturbated, which suggests offshore depositional conditions. The chalky quartzose-glauconitic sandstone is the uppermost unit from the Peștera Formation. This unit lacks macrofauna fossils but is abundant in benthonic foraminifers that indicate an offshore deposition. (DRĂGĂNESCU in AVRAM et al., 1988). The age of the Peștera Formation was confined to Early Cenomanian based on the macro- and microfauna fossil remains (MACOVEI & ATHANASIU, 1934; CHIRIAC, 1988; SZASZ, 1983; AVRAM et al., 1988; AVRAM et al., 1993).

MATERIALS AND METHODS

The studied material was collected from the Cenomanian conglomerate deposits during fieldwork at the quarry located near Peștera village, and is now housed in the collection of the National Museum of Geology. Most of the material is in a very poor state of preservation, and, as such, could not be taxonomically evaluated. The material that was complete enough to warrant a taxonomical assignment, was ascribed based on comparisons with similar specimens cited in the specific literature. The terminology used for the *Ptychodus* specimen follows Hamm (2008). For *Cretalamna*, the used terminology follows Siversson et al. (2015). The macrophotographs were taken using a Canon EOS 60D digital camera with a Canon EF-S 18-55mm lens.

SYSTEMATIC PALAEONTOLOGY

Class Chondrichthyes Huxley, 1880
Subcalss Elasmobranchii Bonaparte, 1838
Cohort Euselachii, Hay, 1902
Subcohort Neoselachii Compagno, 1977
Order *incertae sedis*
Family Ptychodontidae Jaekel, 1898
Genus *Ptychodus* Agassiz, 1835
Ptychodus mammillaris Agassiz, 1835

Description: the described material is represented by a tooth (Fig. 3, A-B) that presents itself in a good state of preservation. The specimen retains a complete crown, and a fragment of the marginal surface. The root is missing entirely, and the internal structure of the tooth can be observed. The overall shape of the specimen is rectangular. The crown is composed of nine transversal ridges, that are elevated, and clearly delineated from one another. The ridges extend across the apex of the specimen. The marginal area is covered in coarse and concentric ornamentation. Hamm (2008) presents a number of 12 valid species for the genus *Ptychodus*, three of which (*P. occidentalis*, *P. whipplei* and *P. martini*) are endemic to the Western Interior Seaway. Everheart & Caggiano (2004) mention that the species *P. anonymus* is also restricted to the Western Interior Sea of North America. *P. atocensis* has only been recovered from the Atco Formation of the Austin Group, in Texas (Hamm, 2008). As such, comparisons of our specimen will only be made with the species that have a European distribution. The criteria used to distinguish between the different species include crown height, the number and configuration of ridges on the crown and the ornamentation present on the marginal surface (Hamm & Shimada, 2004). Our specimen differs from *P. mortoni* due to the fact that this species is characterized by coronal ridges that radiate from a central point located at the apex of the cusp. Our specimen differs from *P. rugosus* due to the fact that the cusp of this species presents a number of no more than six transverse, slightly wavey ridges, that are discontinuous, while our specimen has a number of nine continuous and straight ridges. It differs from *P. decurrens* in the fact that this species has ridges that bifurcate towards the marginal surface. It differs from *P. marginalis* due to the fact that this species presents ridges that are slightly wavey across the apex and loop anteriorly towards the tooth margin. It differs from *P. polygyrus* given the fact that this species presents thick, widely spaced transverse ridges that loop and connect with one-another at the tooth margin. It differs from *P. latissimus* due to the thinner and more numerous ridges present on our specimen. *P. latissimus* is characterized by fewer, but thick ridges,

that curve at the tooth margin. Given this information, we conclude that the morphological characteristics of out specimen more closely resemble those of the species *P. mammillaris* and therefore, we assign this tooth to this taxon.

Discussions: *Ptychodus* represents a Cretaceous shark genus that occurs in the Albian to early Campanian marine deposits in Europe, North America, South America, Asia and Africa, and is primarily know from teeth fossils, characterized by an extensive crown that is used for crushing shelled invertebrates (Hamm & Shimada, 2004). Teeth are usually arranged in parallel rows forming a pavement-like dentition (Brignon, 2015). There is some debate regarding the systematic position of this genus, given the fact that its position within Condrichthyes remains uncertain (Brignon, 2015). The primitive structure of the teeth often results in the assignment to Hybodontoidaea class, while the occurrence of calcified centra present in very well-preserved teeth results in the assignment to Neoselachii (Stewart, 1980; Hamm, 2008). Species of this genera always occur together with Inoceramid genera such as *Mytiloides* and *Inoceramus* and a possible predation by *Ptychodus* was described by Kauffmann (1972). Inoceramid genera were also reported by Avram et al. (1993) to occur in the basal conglomerate of the Peștera Formation, therefore a possible predator-prey relationship could have occurred in the studied area based on knowledge from similar interactions cited in published literature. Tooth taphonomy indicates that *Ptychodus mammillaris* is a hemibenthic selachian, persisting in temperate, boreal, shallow marine areas (Diedrich, 2013).

Occurence: The genus *Ptychodus* has a worldwide distribution, being found in North America: Kansas (Everhart & Darnell, 2004), Black Mesa Arizona (Williamson et al., 1993), Wyoming (Evetts, 1979), South Dakota (Cicimurri, 1998) to name a few, Europe: north-western France and Belgium (Agassiz, 1833-1843), Germany (Reuss, 1845) and Italy (D'Erasmo, 1922). Specimens have also been reported from Japan (Itoigawa et al., 1977) and Angola (Antunes & Cappetta, 2002).

Class Condrichthyes Huxley, 1880
Subclass Elasmobranchii Bonaparte, 1838
Cohort Euselachii Hay, 1902
Subcohort Neoselachii Compagno, 1977
Superorder Galeoporphii Compagno 1973
Order Lamniformes Berg, 1958
Family Cretoxyrhinidae Glickman, 1958
Genus *Cretalamna* Glickman, 1958

Description: one tooth (Fig. 3, C-E), that is in a good state of preservation, however part of the root and of a cusp are missing. The main cusp has a triangular shape, with a well-developed base. Two additional cusplets can be observed on either side of the main cusp, but one is fragmented. The one complete cusp appears well-developed, broad, with an overall triangular shape. A slight divergence from the main cusp can be observed in both cusplets. The cutting edge is continuous, smooth, and extends on the two cusplets. The surface of the crown is smooth, lacking any ornamentation or email folds. The root appears bi-lobate, with at least one triangular lobe, while the other is missing. No nutrient groove is present. For an exact taxonomic determination Siversson et al. (2015) mention the importance of a complete root, which our specimen is lacking. Therefore, seeing as the tooth is thus indeterminable at the species level, we will attribute our studied specimen to *Cretalamna* sp.

Discussion: tooth morphology has been used as the basis for the classification into the order Lamniformes, given the large bilobed root and the triangular principal cusp, the taxonomic attribution is further strengthened by the presence of well-calcified, radial, cartilage lamellae (Shimada, 2007). Cappetta (1987) mentions that the genus *Cretalamna* is represented only by the species *Cretalamna appendiculata* that ranges from the latest Albian to Ypresian, for a time period that amounts to 50 Ma. This vast range was attributed to the fact that *C. appendiculata* was thought to be an ecological generalist (Shimada, 2007). Siversson et al. (2015) disagrees with this view, having described eight species of *Cretalamna appendiculata* type, with *C. borealis* being the one with the biggest range (Santonian-Campanian). Seven of the species from the Cretaceous of the Northern Hemisphere were included in three distinct groups: *C. appendiculata* group, *C. borealis* group and *C. hattini* group. Size and tooth morphology suggests a diet composed of small to medium sized bony fishes, similar to *Lamna* spp. (Shimada, 2007).

Occurence: in terms of the geographic range, the genus *Cretalamna* can be found on all continents except Antarctica. Several sites include: Japan (Itoigawa et al., 1977), Lithuania (Dalinkevicius, 1935), Morocco (Arambourg, 1952).

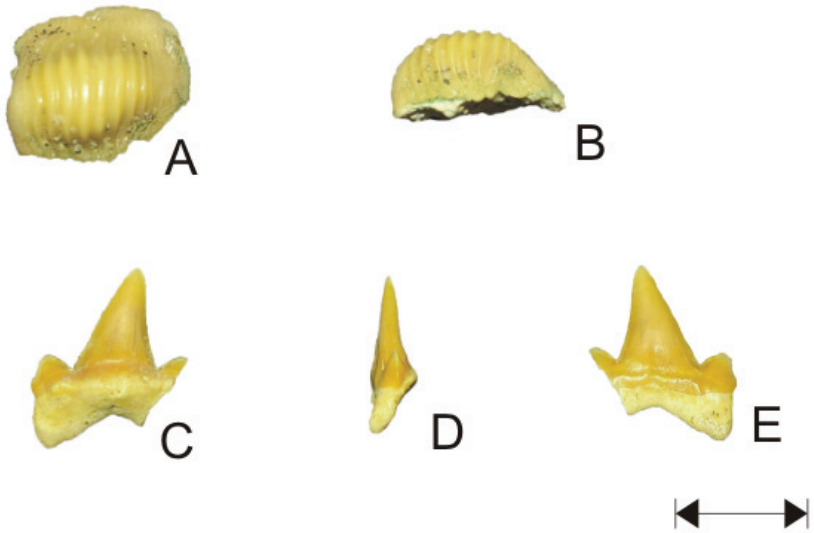

Figure 3. Studied Cenomanian shark teeth: *Ptychodus mammillaris*: A – occlusal view; B – lateral view. *Cretalamna* sp.: C – lingual view; D – lateral view; E – labial view. Scale bar: 5 mm.

CONCLUSIONS

The Cenomanian outcrops belonging to the Peștera Formation provide abundant fossil material for the ichthyofauna of the area, material such as the one presented in this work provides an important window into the faunal association of the Peștera Formation. Furthermore, the list of taxa from the Peștera Formation includes species such as: *Scapanorhynchus* sp., *Paranomotodon* sp., *Squalicorax* sp., *Protoscyliorhinus* cf. *bettrechiensis*, *Hexanchus* sp., *Cretoxyrhina* sp., just to name a few (GALLEMI et al., 2011; TRIF & CODREA, 2018b). The vertebrate remains are completed by a rich invertebrate fauna. This fauna points to a Cenomanian age, however given the fact that both CHIRIAC (1981) and AVRAM et al. (1993) mention invertebrate remains that have been reworked, the same could be possible for the shark remains (TRIF & CODREA, 2018b). The fossil material is in a poor state of preservation due to their transport in a highly dynamic environment before burial (TRIF & Codrea, 2018b), and, as such, complete or better-preserved specimens are very rare, most of the material found being fragmentary and indeterminable. Also, AVRAM et al. (1993) mention that the Peștera Formation reflects transgressive coastal conditions, replaced by offshore environments, as suggested by chalk deposits. In sum, we present in this paper two fossil teeth belonging to the Mesozoic sharks *Ptychodus mammillaris* and *Cretalamna* sp., that were present in the studied area in the Upper Cretaceous.

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