SOME BADENIAN FISH TEETH FROM WESTERN TRANSYLVANIA (ROMANIA)

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Abstract. The work herein reports some Badenian (Middle Miocene) fish of western Transylvanian Basin documented by teeth. So far, the Middle Miocene fish teeth from Transylvania were very rarely reported and hardly ever illustrated. Teeth from recent fieldwork and from several collections were analyzed. They originate from the localities Gârbova de Sus, Cetea, Lopadea Veche and Rachiș, all in Alba County. The present article describes and illustrates nine fish teeth that belong to *Otodus (Megaselachus) megalodon* Agassiz 1835, *Hemipristis serra*, Agassiz 1835, *Carcharodon hastalis* Agassiz 1838, *Carcharias* sp., *Diplodus jomnitanus* and Sparidae indet. These representatives refine the knowledge of the upper trophic links in the Badenian Paratethys Sea ecosystems in the Inner Carpathian region of Romania.

Keywords: Middle Miocene, fish, ecosystem**,** Transylvania, Romania.

Rezumat. Dinți de pești badenieni din Transilvania de Vest (România). Acest articol semnalează câțiva dinți de pești de vârstă badeniană din vestul Bazinului Transilvaniei. Până acum dinții de pești din Miocenul mediu al Transilvaniei au fost foarte rar semnalați și nu au fost aproape niciodată ilustrați. Am analizat dinți rezultați din activitatea recentă pe teren precum și dinți care aparțin mai multor colecții. Acești dinți provin din localitățile Gârbova de Sus, Cetea, Lopadea Veche și Rachiș, toate din județul Alba. Articolul de față descrie și ilustrează nouă dinți de pești care aparțin speciilor *Otodus (Megaselachus) megalodon, Hemipristis serra, Carcharodon hastalis, Carcharias* sp.*, Diplodus jomnitanus* și Sparidae indet. Acești reprezentanți se adaugă la cunoașterea rețelei trofice superioare a mării Parathetys din Badenianul regiunii intra-carpatice a României.

Cuvinte cheie: Miocen mediu, pești, ecosistem, Transilvania, România.

INTRODUCTION

Both bony fish and shark teeth in the Badenian deposits from Romania are poorly known. The scarce data already published so far is based on scattered finds, mostly at the end of the 19th and the beginning of the 20th centuries. Thus, HEREPEY (1896) listed a few shark species he found in the Leitha deposits, nearby Aiud (western margin of the Transylvanian Basin). From the conglomerates in Valea Lupului (Cetea village), he mentioned the species *Lamna rhaphiodon* Agassiz 1843 and *Carcharodon megalodon* and from Pârâul Pietrii (Gârbova de Sus), the species *Lamna elegans* Agassiz 1843. On his turn, when referring to the Leitha limestone from western Transylvania, NOSZKY (1925) listed the species *Lamna subulata* Agassiz 1843, *L. gracilis* Agassiz 1843, *L. cuspidata* Agassiz 1843, *Oxyrhina hastalis* Agassiz, 1838, *O. xyphodon* Agassiz 1843, *Carcharodon megalodon* and *Sparoides robustus* Probst 1874. This sample originates from Gârbova de Sus and is currently hosted by the Hungarian Natural History Museum in Budapest. None of these couple of authors described or illustrated the species they mentioned. Recently, SZABO & KOCSIS (2016) reassigned the species mentioned by NOSZKY (1925). This new list includes the following taxa: *Carcharias* sp., *C. acutissima* Agassiz 1843, *Araloselachus cuspidatus* Agassiz 1843, *Carcharoides* cf. *catticus* Philippi, 1846, *Cosmopolitus hastalis*, *Isurus desori* Agassiz 1843, *Isurus* sp. and *Otodus megalodon*. One tooth *Otodus (Megaselachus) megalodon* was illustrated, described and discussed for the first time from the Badenian of Transylvania in TRIF et. al., (2016).

This study aims to complete the knowledge we already have on the taxonomy of the bony fish and sharks in the Badenian from Transylvania, describing and illustrating an unpublished material coming from the Natural History Museum in Aiud, Babeș-Bolyai University Palaeontology-Stratigraphy Museum in Cluj Napoca, and recently collected by ourselves.

GEOLOGICAL SETTING

Much of the sedimentary deposits from the western border of the Transylvanian Basin are Middle Miocene, especially Lower Badenian, part of the Dej Formation (CHIRA et al., 2000). These marine sediments document the *Orbulina suturalis* biozone and are dominated by siliciclastic rocks, algal and bioclastic limestones (HOSU & FILIPESCU, 1995). Part of the Central Paratethys, the Transylvanian Basin was in the Badenian an area of a larger tropical sea formed in a global warming episode (CHIRA et al., 2000). This marginal depositional area functioned when the Transylvanian Basin was a back arc basin (KREZSEK & FILIPESCU, 2005) occurred behind the Carpathians. Alongside other land masses, the emerged areas of the Carpathians acted as an archipelago in the Central Paratethys (RÖGL, 1998).

The richness of fossils draws the attention of paleontologists since the 19th century. The Badenian sediments bear rich fauna of gastropods, shells, sea-urchins, bryozoans, algae and foraminifers (HEREPEY, 1896; VADASZ, 1915; NOSZKY, 1925; GÁBOS & GHIURCĂ, 1969; ȘURARU, 1992; CHIRA, 2000; ZÁGORŠEK et al., 2010).

At **Lopadea Veche**, several Neogene formations are cropping out. Starting from the west to the east, one encounter: Gârbova Formation (Early-Middle Badenian), Cheia Formation (Middle Badenian), Lopadea Formation (Pannonian *s.s.*) and Măhăceni Formation (Sarmatian s.s.; BUCUR & FILIPESCU, 2011). Gârbova Formation is the only marine formation and

we allocate to this stratigraphic unit the specimens NHMA no. 1327A, 1327B and 1327C. Gârbova de Sus Formation is exposed at Lopadea Veche on Buchii and Șesuri Creeks. It includes conglomerates, shales, nodular and bioclastic limestones, sandy-limestones and rhodolith limestones (ȘURARU, 1992; BUCUR & FILIPESCU, 2011).

Rachiș has a similar geology as in Lopadea Veche with a facies mostly carbonatic (FILIPESCU, 1996).

Gârbova de Sus is another well-known locality for its fossil-bearing Badenian sediments. A similar succession to Lopadea Veche can be observed on Pietrii and Bobii creeks. The sediments here form two sequences: one siliciclastic in dominance and a second one, limy, both once included in same coastal platform (HOSU & FILIPESCU, 1995). The new materials (*Diplodus* sp. and Sparidae indet.) originate from the upper sequence, from a yellow conglomerate layer rich in clam fragments, situated on Bobii Creek, on the western side of the locality.

At **Cetea**, a less known locality, the Badenian deposits are although well exposed. There, on the western side of the village, on Lupilor (Lupi) Creek, one can observe a sedimentary sequence with blue marls, sandy marls with thin rhodoid levels and conglomerates bounded by a depositional unconformity, overlying a flysch formation. Our recent field survey did not reveal any new vertebrate materials.

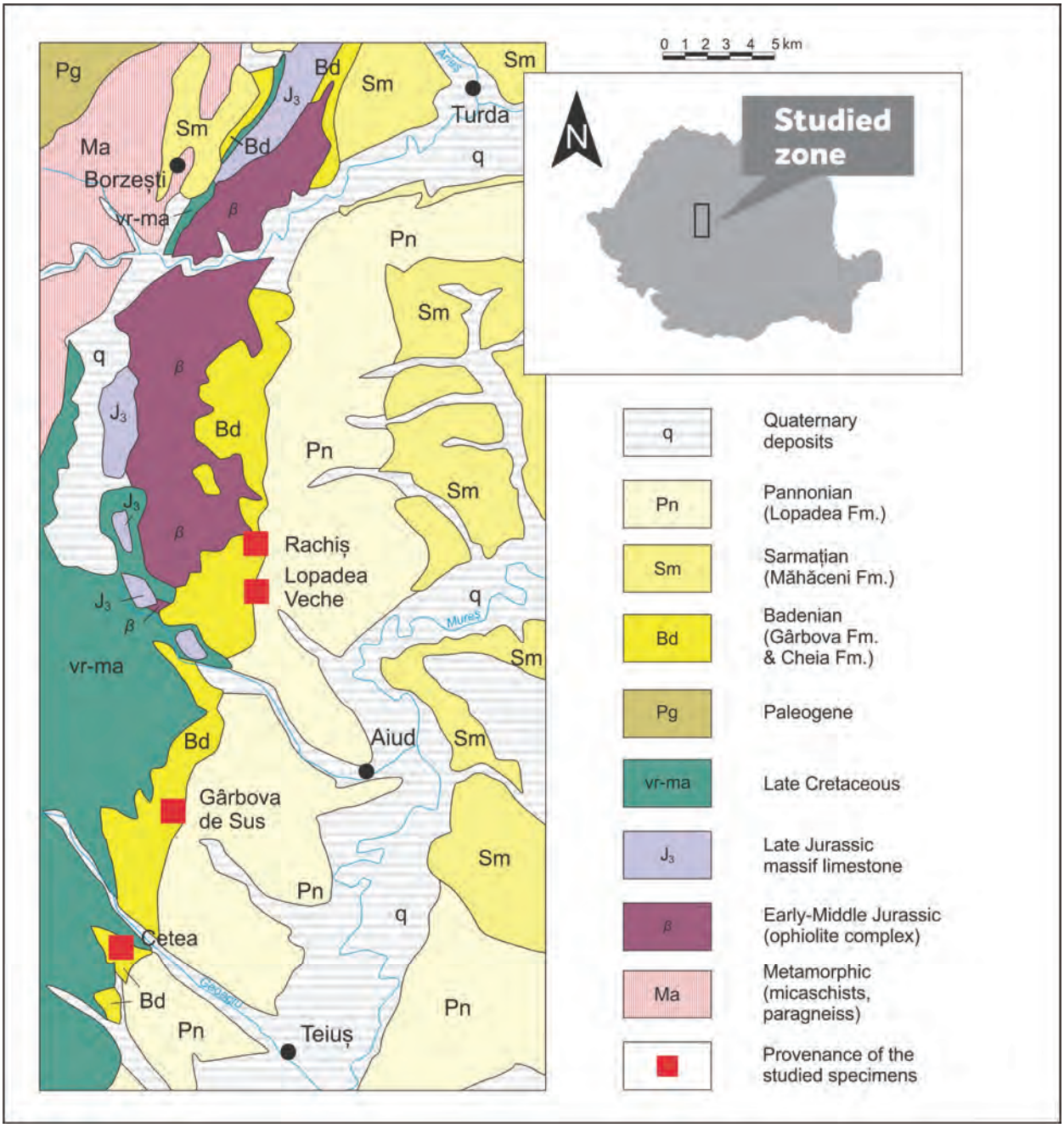

Figure 1. Geological map of the area where the studied specimens were collected from (after the Geological Map of Romania, 1:200.000 *folio* Turda, simplified and modified).

MATERIAL AND METHODS

Herein, we evaluate nine teeth hosted either in museums from Romania, or collected by one of us (TN). The abbreviations for the collection names where the specimens are hosted are: NHMA for the Natural History Museum in Aiud, BBUPSM for Babeş-Bolyai University Palaeontology-Stratigraphy Museum in Cluj Napoca. Recently collected fossils by TN are labeled as NTC (Nicolae Trif Collection). When several specimens were found under the same registration number, a letter was added for each specimen in order to distinguish them.

The fossils were measured on digital images, using a standard scale reference of 1 cm. The images were captured either with Nikon D700, or Nikon D5300 cameras mounted on a professional tripod, using Sigma lens of 105 mm.

It is also interesting to note that the material has also historical significance. The specimens BBUPSM 1939A and BBUPSM of *Hemipristis serra* were collected by, or at least belong to the collections of Herepey Károly and respectively, Lőrenthey Imre. Both of them are well known geologists from the end of the 19th century, with important works on the geology of Transylvania.

Systematic palaeontology
Superorder: Galeomorphii COMPAGNO 1973
Order: Lamniformes BERG 1958
Family: Otodontidae GLICKMAN 1964
Genus: *Otodus* AGASSIZ 1843 (*sensu* Cappetta, 2012)

Otodus (*Megaselachus*) *megalodon* AGASSIZ 1835

Material: Four teeth in NHMA Collection (no. 697 from Cetea, Lupului (Lupi) Creek - Fig 4a; no. 1327A from Lopadea Veche - Figs. 3a-c; no. 1339 from Gârbova de Sus) - Figs. 3d-f; all localities in Alba County.

The Gârbova de Sus tooth (Fig. 3d-f) is the most complete specimen. It has a total height of 5.75 cm and a width of 4.67 cm. The crown outline is triangular. Both cutting edges are finely and regular serrated on the entire length to the apex. The distal cutting edge is convex, while the mesial one is mainly straight with a faint convexity in the upper third part of the crown. Lateral cusplets are not present. The neck is well developed on the lingual side. The root is slightly chipped on its mesial side.

The Cetea tooth (Fig. 4a) is only a fragment, but it seems that it was the biggest specimen from the NHMA Collection, with a total width of 6.97 cm. The largest part of the crown is missing, as well as an important portion of the root. The cutting edges are also chipped, but on the distal side the regular, fine serration is fairly preserved.

The Lopadea de Sus specimen (Fig. 3a-c) has also an impressive size, with a total height of 7.10 cm. Unfortunately, both lateral sides are chipped and the width cannot be measured. The root is fragmented but the central part is still present. The neck is well developed as in the other specimens. The cutting edge is preserved only on one side. The serration is sharp and regular.

Discussions: Although not complete, all the teeth can be assigned with confidence to *Otodus* (*Megaselachus*) *megalodon* (CAPPETTA, 2012, Fig. 210). The phylogeny of the genus *Otodus* has been long debated (GLIKMAN, 1964; CAPPETTA, 1987; WARD & BONAVIA, 2001; PURDY et al., 2001). This debate has reached now a conclusion, with the help of high resolution stratigraphy correlated with the find of successive *Otodus* species (KING et al., 2013) that the genus *Otodus* is actually a single chronospecies that culminates with the Mio-Pliocene *O.* (*Megaselachus*) *megalodon*. Although sometimes the limit between the species is uncertain (e.g. *O. sokolovi* - *O. angustidens* or *O. chubutensis* - *O. megalodon*) in the Middle Miocene, it is obvious that we deal with a well definite *O. megalodon* species. This shark of circumglobal distribution is well known, with records from Slovenia (MIKUŽ et al., 2015), Spain (REOLID & MOLINA, 2015), Denmark (BENDIX-ALMGREEN, 1983), Southern France (CAPPETTA, 1970), Malta (WARD & BONAVIA, 2001), Austria (SCHULTZ & PILLER, 2013) Italy (MARSILI, 2006), New Zealand (KEYES, 1972), Japan (YABE et al., 2004), USA (PURDY et al., 2001) and from the bottom of the Pacific Ocean (BELYAEV & GLIKMAN, 1970), etc.

Order: Carchariniformes COMPAGNO 1973
Family: Hemigaleidae HASSE 1879
Genus: *Hemipristis* AGASSIZ 1843

Hemipristis serra (AGASSIZ 1835)

Material: One tooth in BBUPSM Collection (7049, from Rachiş, Alba County), Figs. 2i-l;

The tooth is a lower anterior with a central position. The crown is bent lingualy and has a slight sigmoidal profile (Fig. 2k). Both labial and lingual faces are convex, the labial side being clearly more bulged. The cutting edge is poorly developed and it is restricted to the upper third of the crown (Figs. 2k & k'). No lateral cusplets are present. The root is

bilobate with a strong lingual protuberance. The central foramen is oval and reduced to a small depression. In basal view, this protuberance forms an almost equilateral triangle (Fig. 2l). The extremities of the root lobes are rounded.

Discussions: Only a few species belong to this genus. In Eocene, there are known *H. curvatus* Dames 1883, and *H. wyattdurhami* White 1956, although this last species might be only a junior synonym of *H. curvatus* (KENT, 1994). Only one tooth of *H. curvatus* is known from Romania, originating from the Eocene deposits of Southern Transylvania, at Turnu Roșu (CIOBANU, 2002, p.118). A Lower Oligocene *Hemipristis* cf. *serra* from Pakistan is reported as having transitional characters between *H. curvatus* and *H. serra* with weaker and less vertically developed serrations (ADNET et al., 2007; CICIMURRI & KNIGHT, 2009). The Late Oligocene to Neogene species *H.* serra has some morphological similarities with the Recent *H. elongatus* Klunzinger 1871. Histological differences in the structure of the teeth demonstrate that there are nonetheless two distinct species (COMPAGNO, 1988).

H. serra was an important predator of the Badenian sea. With a total length of 5 to 6 m (KENT, 1994, p.78) and serrated teeth it probably predated on marine mammals like sea-cows (Sirenidae). The Recent species *H. elongatus* can be encountered in warm and tropical waters near continental or insular shelves at depths of 1 to 30 m (COMPAGNO, 1984, p. 440). A similar habitat was observed to the *H. serra* that is abundant in sublittoral deposits of warm water faunas (CAPPETTA, 1987, p.120).

H. serra can be encountered worldwide, with circumglobal distribution. This species was found in the Late Oligocene of South Carolina, USA (CICIMURRI & KNIGHT, 2009), Miocene of North Carolina (PURDY et al., 2001), Malta (WARD and BONAVIA, 2001), Hungary (KOCSIS, 2007), Italy (MARSILI et al., 2007), Costa Rica (LAURITO & VALERIO, 2008), Madagascar (ANDRIANAVALONA et al., 2015) and the Miocene and Pliocene of Chesapeake Bay region (KENT, 1994).

Order: Lamniformes BERG 1958
Family: Lamnidae MÜLLER AND HENLE 1838
Genus: *Carcharodon* SMITH 1838

Carcharodon hastalis (AGASSIZ 1838)

Material: two teeth in NHMA Collection (no. 1327B - Figs. 2c-e; and 1327C - Figs. 2f-h; from Lopadea Veche)

Both teeth from Lopadea are triangular with a smooth crown and straight cutting edges. In lateral view, we can see that the crown is very compressed labio-lingualy and the apex of the crown is reversed in lingual direction (Figs. 2f & h). No lateral cusplets are present. The root is small with the end of the lobes rounded. The angle of the root branches is obtuse, slightly surpassing 150º.

Discussions: Teeth of the shark *Carcharodon hastalis* have been found in most of the Miocene deposits around the world. This species can usually be found alongside *Otodus megalodon*, *Hemipristis serra* and *Carcharias* spp. and is one of the largest predators of its time.

The taxonomy of this species was for a long time disputed. An important step forward in its research was made when irrefutable fossil evidence became available to prove the phylogenetic connection with the Recent *Carcharodon carcharias*, the great white shark (NYBERG et al., 2006; EHRET et al., 2012). The species *C. hastalis* and a newly described, intermediary species, *C. hubelli* Ehret, Macfadden, Jones, Devries, Foster & Salas-Gismondi, 2012, were subsequently assigned to *Carcharodon* genus (EHRET et al., 2012).

Family Odontaspididae MÜLLER & HENLE 1839
Genus: Carcharias RAFINESQUE 1810

Carcharias sp.

Material: one tooth in BBUPSM Collection (no. 1939A from Gârbova de Sus) - Figs. 2 a-b'.

The figured specimen is a medium to large size tooth (4.7 cm) with a slender crown that widens towards the base and it is slightly curved in distal direction. The surface of the crown is smooth. The labial side is flat, while the lingual side is moderately convex. One pair of small cusplets is present next to the principal cusp. The root has a strong central protuberance with a clearly marked but narrow nutrient groove and lobes well separated. The root angle is of 82º. The extremities of the root lobes are broken. The shape of the lateral profile is hard to evaluate because of the imperfect contact of the two fragments.

Discussions: Although the tooth is fragmented in two pieces, it preserves enough characters to be assigned at least to genus level. It presents similarities with the genus *Carcharias*, with robust teeth with a smooth crown, sharp apex, convex lingual side and small and sharp lateral cusplets (CIOBANU, 2002, p.87).

We consider that the tooth differs from the similar genus *Araloselachus* (GLIKMAN, 1964). In contrast with this genus, the cutting edge reaches the base of the crown (as defined in CAPPETTA, 2012, p. 191).

Class: Actinopterygii KLEIN 1885
Infraclass: Teleostei MÜLLER 1846
Order: Perciformes BLEEKER 1859
Family: Sparidae BONAPARTE 1831
Genus: *Diplodus* RAFINESQUE 1810

Diplodus jomnitanus (VALENCIENNES 1844).

Material: one incomplete tooth in NTC (Bobii Creek, Gârbova de Sus) - Figs. 4e-h.

The straight shape of the tooth indicates a frontal position (incisor). On the labial side, the tooth is slightly convex (Fig. 4e), while on the lingual side is concave (Fig. 4f). The apical portion exposes strong traces of functional wear, with parts of the enamel missing. The root is as high as the crown being preserved on the same side as the crown.

Discussions: the shape of the tooth is very similar with the other teeth described and figured as *Diplodus jomnitanus* from the Badenian sediments of Austria (SCHULTZ & PILLER, 2013, p. 300 & pl. 67 Figs. 1a-b). Other similar teeth are described and figured in JONET (1975, p. 148 & pl. I Fig. 22), MIKUZ et al., (2013, pl. 1 fig. 3a-c) and ANTUNES et al., (1981, pl. 5, Fig. 7). *Diplodus* is a genus that still has 23 extant species and subspecies (PAZ, 1975; FRICKE et al., 2016). Its dentition is characterized by a frontal row of teeth (incisors) and back and lateral teeth of low oval or round shape disposed in two or three rows (BAUZA & PLANS, 1973) and sometimes more, as for example in *Diplodus capensis* Smith, 1844 (FRICKE et al., 2016).

The extant *Diplodus sargus* (LINNAEUS, 1758) and Sparidae in general are alongside Labridae the main sea-urchins predators (FIGUEIREDO et al., 2005) and have a general durophagous diet (SANTINI et al., 2014). Since Gârbova de Sus has one of the most abundant Badenian sea urchins fauna in Transylvania (VADASZ, 1915; GABOȘ & GHIURCA, 1969), then the presence of *Diplodus* indicates one of the superior trophic links of this ecosystem.

A large number of *Diplodus* species (teeth and otoliths) were reported from the Badenian of Austria as *Diplodus jomnitanus* Valenciennes 1844, *D. karrerae* Nolf & Steurbaut 1979, *D.* cf. *puntazzo* Cetti 1777, *D. sitifensis* Valenciennes 1844 (see SCHULTZ & PILLER, 2013), this diversity being an indicator of the success of this genus in the Middle Miocene.

Sparidae indet.

Material: *Material*: one tooth in NTC (Bobii Creek, Gârbova de Sus) - Figs. 4b-d.

The tooth has a general oval shape, with a very shallow central depression on its apical side, while the basal side shows a low and rounded root. The general shape corresponds with a molariform Sparidae tooth.

CONCLUSIONS

The described and illustrated fauna from this article and the taxa reported by the previous 19th century authors constitute a classical fish fauna for the Badenian of Europe. Similar fossil fish assemblages were reported from nearby countries like Hungary (SZABO & KOCSIS, 2016) or Austria (SCHULTZ & PILLER, 2013). Our work adds to the distribution of these genera and species of fish in Paratethys of the Badenian.

It is interesting to note the presence of the big predators like *O. megalodon* and *H. serra* in these deposits, but the almost total absence, at least until now, of the bones of marine mammals. Possibly these large predators were only stray visitors in this area. Regarding the species of *Isurus*, *Carcharoides*, *Araloselachus* and *Carharias*, these are fish eaters that are common in all Neogene warm waters. The occurrence of the genus *Diplodus* is interpreted in relation with the sea-urchin fauna, as their predator.

The material described by us comes from fortuitous (and lucky) finds and it is obviously small both in number of specimens and in diversity of species. A systematic survey of the above mentioned localities is not often possible since the rocks are compact and develop non-extensive outcrops, usually restricted to the small creeks banks.

The presence of the genera *Hemipristis* and *Diplodus* is the first report of these taxa for the Badenian of Romania. New field works should be continued, to complete the Badenian fish fauna repertory of Romania.

ACKNOWLEDGMENTS

The authors thank the reviewers Mr. Ortwin Schultz, from the Natural History Museum Vienna (retired) and Ms. Rodica Ciobanu from the Natural History Museum Sibiu for the useful comments and corrections, which improved the manuscript. We thank also the curators Iulia Ștefănescu and Ramona Mărginean for allowing our access to the specimens from the Natural History Museum in Aiud.

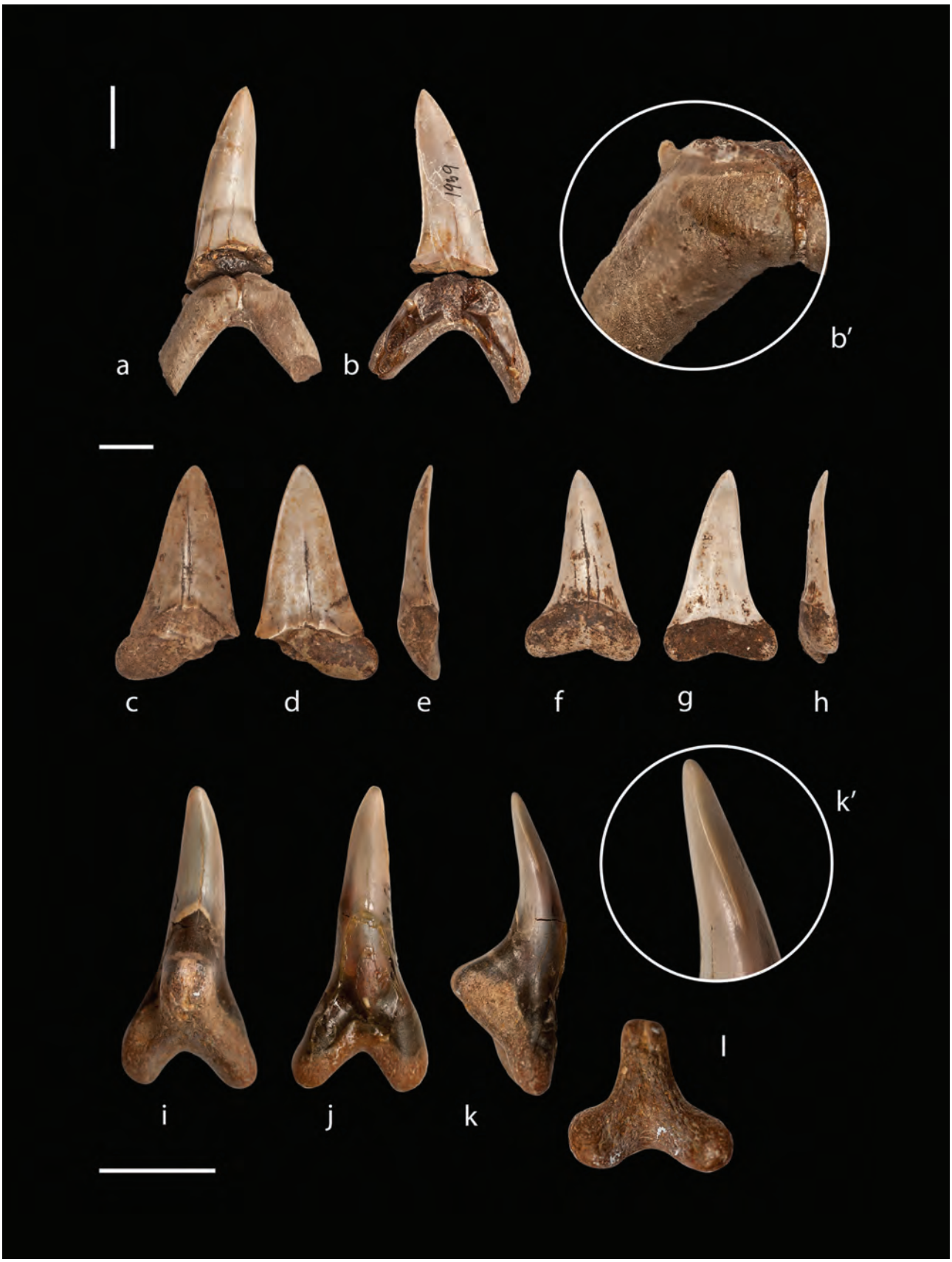

Figure 2. *Carcharias* sp. BBUPSM 1939A (a-b): a - lingual view; b - labial view; b' -detail of the cuplets; *Carcharodon hastalis* NHMA 1327B (left) and 1327C (right) (c-h): c,f - lingual view; d,g - labial view; e,h - lateral view; *Hemipristis serra* BBUPSM 7049 (i-l): i - lingual view; j - labial view; k - lateral view; k' - detail of the cutting edge; l - basal view; Scale bar - 1 cm (original).

Figure 3. *Otodus (Megaselachus) megalodon* NHMA 1327A (a-c): a - lingual view; b - labial view; c - lateral view; *Otodus (Megaselachus) megalodon* NHMA 1339 (d-f): d - lingual view; e - labial view; f - lateral view; Scale bar - 1 cm (original).

Figure 4. *Otodus (Megaselachus) megalodon* NHMA 697 (a): a - lingual view; Sparidae indet TNC (b-d): d - apical view; e - basal view; f - lateral view; *Diplodus jomnitanus* TNC (e-h): e - labial view; f - lateral view; g - mesial view; h - distal view; Scale bar - 1 cm (original).

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Received: March 22, 2017
Accepted: August 23, 2017