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PhD Thesis Summary

CENOZOIC AND MESOZOIC FISHES FROM ROMANIA

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NOTE: The numbering of the figures and tables was kept according to the one from the text *in extenso*.

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INTRODUCTION

The systematic analysis of Mesozoic and Cenozoic fish faunas from Romania brings new data regarding the diversity of this taxonomic group that is still insufficiently known from in this country.

Comparing the Romanian paleontological literature with the foreign one, especially from western Europe or the United States, but also from the east, especially from Russia, it becomes evident that the research on fossil fish at national level had rather a modest weight in relation to the advances of paleontological knowledge overall.

Even the fundamental works of historical geology or the syntheses that address the reconstructions of paleomedia or the biostratigraphy of sedimentary basins frequently omit the fish. The small exception to this rule concerns the skeletons of oligocene fish in the Eastern and Southern Carpathians. Additionally, significant mistakes in the collections management have often led to the definitive loss of the described and illustrated materials, which can no longer be re-examined and re-evaluated.

The analysis of the bibliographical references regarding the territory of Romania indicates the existence of important gaps in the knowledge of the fossil fish teeth, both for the cartilaginous and the bony fish groups. Because of this fact we are even in the present moment, still in the phase of completing the data regarding the taxonomic diversity and to a lesser extent in the one of the synthetic approaches regarding the temporal evolution of the fauna, for sedimentary basins or for certain geological time intervals.

Much of the material published before 1980 is considered to be permanently lost or in any case cannot be found for the moment, as it was rarely recorded in any public collection by authors.

It is noteworthy, with few exceptions, that from the fauna collected so far, teeth from small fish taxa are missing. It is possible that they were completely ignored by the researchers who did not have the logistics needed to find them or who focused on other fossils, such as foraminifers or molluscs found in the same dimensional fraction of the analysed sediments.

It is also disappointing to note that in a multitude of published works, the phrase "*Pisces indet*." appears repetitive in faunal lists.

All these facts were the arguments for the continuation of the taxonomic study of the fossil fish in Romania, a study based mainly on dental elements: oral teeth, pharyngeal teeth, to which we added rostral spines and some other isolated fragments.

As an exception, we will mention a few other fossil remains associated with fish fauna and that complete the information on the faunal diversity such as the dermal spines of the Rajids or the caudal spines and the gill rakers of the sharks. The gill rakers, although not *stricto sensu* dental pieces, nevertheless represent hard elements of the buccal apparatus, made of keratin (Paig-Tran & Summers, 2014) used for feeding by sharks in the Cetorhinidae family.

The research project of the doctoral thesis is motivated, in particular, by the incipient stage of the study of fish and fossil shark species at national level, a field of paleontology rarely approached by specialists in Romania.

The completion of the trophic food chains in the Mesozoic and Cenozoic paleo environements appeared as another motivation. The continuation and development of the research directions outlined by the few predecessors of the Romanian field was another goal of the project, to add new study perspectives.

We also considered it absolutely necessary to update the taxonomy of the specimens from the museum and university collections that were previously understudied. Incorrect or absent labeling of museum specimens has been the source of errors for curators or visitors.

The objectives I have proposed for this work are:

- completion of the paleoichthyologic taxonomic list at national level;
- the reconstruction of the paleo environments in which these fish were identified;
- the integration of fauna or faunal communities encountered in the regional or national context;
- the reevaluation of the materials from the most representative paleontological collections in Romania and the correlation of the new data obtained during this research with the already published data;
- reporting and publishing paleontological pieces of special value for the science or for the history of paleontology

- the creation of new directions in research of fossil fish in Romania, based on dentitions or other isolated skeletal elements in order to give a new impulse to the research in the field of paleoichthyology

In order to achieve the proposed objectives, the work was structured as follows:

Chapter 1, Methodology, records the 12 main museum and university collections consulted personally in Romania and Hungary. Along with these collections we have consulted digitally holotypes and syntypes of some species of interest from Italy, USA, UK and Russia. Also in this chapter, we listed the 27 localities from which the studied material comes. We also briefly described the instrumentation and the laboratory methods used to carry out this study.

Chapter 2, History of research, contains the results of consulting a total of 124 bibliographic sources. Based on them, we have made a history of reaserch, highlighting the incipient stage in which the field of paleoichthyology is in Romania. This chapter also brings an important contribution, namely the rediscovery of a valuable scientific collection whose traces were no longer known to us in the country - the Johann Ludwig Neugeboren Collection. This collection is currently housed in two museums, the Hungarian Museum of Natural History in Budapest and the Museum of Natural History in Sibiu.

Chapter 3, The geological settings of the provenance areas of the studied material, briefly describes the geological situation of the origin localities of the studied material.

Chapter 4, Systematic Paleontology, describes and analyses in detail the **58 taxons identified**

Chapter 5, Paleoecological considerations on some of the faunal associations and communities discovered, refers to the local paleoecological reconstructions inferred by the ecological preferences of the determined taxa. The taxa were compared with the equivalent ichthyofaunas from Europe and northern Africa.

Alongside these chapters we added parts dedicated to the conclusions, the list of published works, the references (644 titles) and 35 plates.

The present study adds new localities to the fossil fish tooth occurrence map, describes new faunal associations and taxonomically re-evaluates materials from national, local and university museum collections.

CHAPTER 1
MATERIALS AND METHODS

1.1. Consulted collections

In order to carry out this study, in addition to the field activity, a number of 12 museum collections and university collections from Romania and Hungary were examined, with the following institutional abbreviations specified: Museum of Paleontology-Stratigraphy of Babes-Bolyai University (MSPUBB); The Collection of the Faculty of Environmental Science and Engineering of Babeș-Bolyai University (CFSMUBB), The Collection of Paleontology of the University of Bucharest (CPUB), The Collection of the Museum of Natural History of Sibiu (which includes the Brekner Collection - MINSBK and the Transylvanian Society of Natural Sciences Collection - MINSCS), Mureș County Museum (MSNTM), Argeș County Museum, Pitești (MSNP), Aiud Museum of Natural Sciences (MSNA), Câmpulung Municipal Museum (CMMC), National Museum of Geology (MNG), Paleotheriology and Quaternary Geology Laboratory of Babes-Bolyai (LPGCUBB) as well as the Hungarian Museum of Natural History in Budapest (MUSNB).

With the help of colleagues from abroad, holotypes belonging to the Natural History Museum of London (MINL), the Darwin Museum of Moscow (MDM) and the "Sapienza" Museum of the University of Rome (MSUR) were examined in digital format as well as comparative material hosted at the Smithsonian Institute Zoological Museum, Washington DC.

Several trips in the field to collect new materials were done to the following localities: Turnu Roșu (= Porcești; Sibiu County), Cetea, Gârbova de Sus (Alba County), Luna de Sus, Cluj-Napoca, Coasta Mare (jud. Cluj), Petroșnița (Caraș Severin County), Peștera (Constanța County), Lăpugiu de Sus, Vălioara (Hunedoara County). In addition, we processed material from: Racoșu de Sus, Ormeniș (Brașov County), Albesti, Bogătești (Argeș County), Vârciorog (Bihor County), Gârbova de Sus, Lopadea Veche, Rachiș, Borzești (Alba County), Huedin, Leghia, Suceag (Cluj County), Turnu Severin (Mehedinți County), Turbuța (Piscul Ronei; Sălaj County) and Coza (Vrancea County).

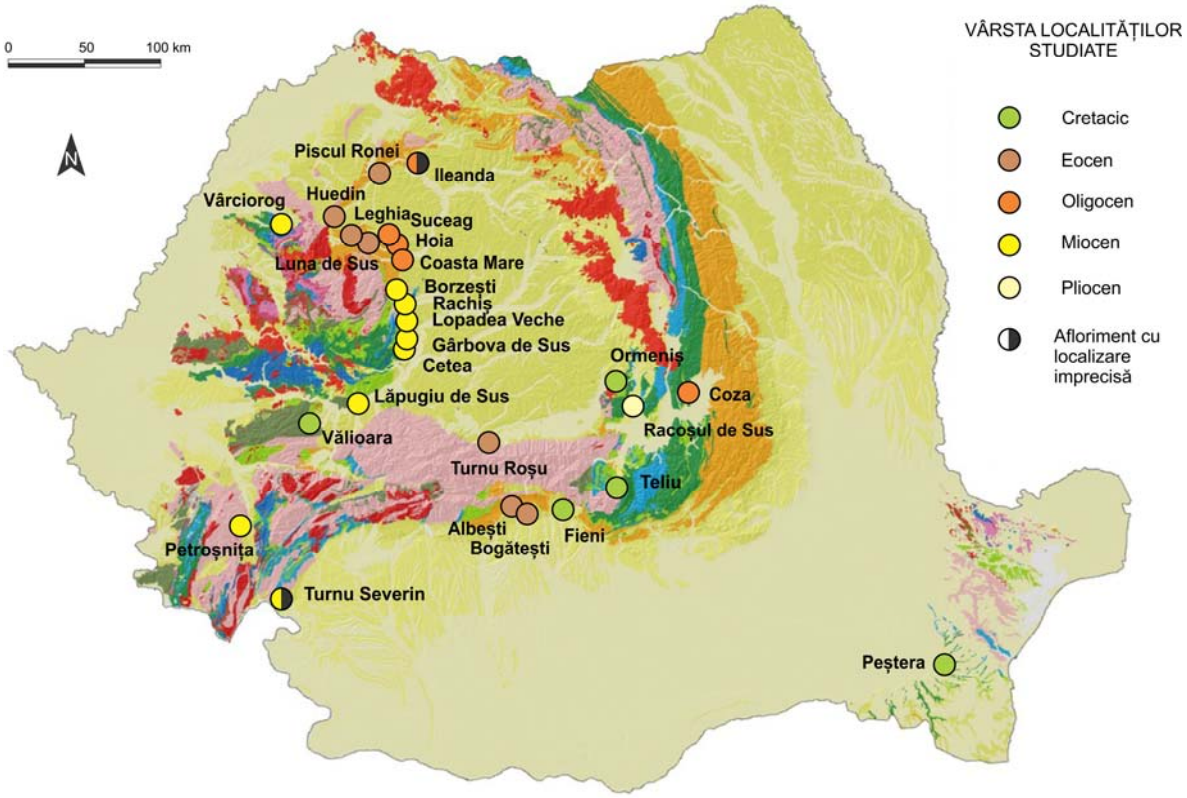

Fig. 1. Map of the localities from which the studied material originates

The gathering of specimens was performed directly on the field and through the processing of sedimentary rock samples in the laboratory. We collected especialy disaggregated or weakly consolidated sedimentary rocks. When this was not possible, the sediment blocks were submerged in a hot solution of acetic acid with a concentration of 9%, in order to solubilize the carbonates and to disintegrate the rock. From the material collected for this work we formed the Trif Collection (CT). Depending on the possibilities, we used current comparative material recently prepared, or already existing in the collections. There have also been situations where even the comparative material had to be taxonomically revised (Trif & Vonica, 2018).

1.3. Instrumentation and laboratory methods

The studied material was photographed using Nikon D700, D7000, D90 and D5300 cameras with a 105 mm Sigma lens. The very small teeth were photographed using a Nikon SZM 1000 binocular microscope in combination with one of the cameras mentioned above. As an exception in the absence of our own equipment, for the Teliu

specimen, a Zeiss Stemi 2000-C binocular equipped with a Canon DS 126191 camera was used for photography.

In order to obtain a maximum resolution of the images, a photographic technique derived from entomological imaging was used, namely the photo stacking.

The photo stacking involves combining a group of images with the same specimen taken from the same angle, but with a different depth of field. It is well known that images obtained with ordinary optical equipment do not have the same depth field such as images obtained under the electron microscope. The depth field decreases with the focal length of the lens or lens assembly reaching sub-millimeter depths at magnifications of 20-80x. The images are digitally superimposed in the layers, aligned using a specialized function and the result is a high resolution composite that combines the clearest regions of each image.

More than 31,400 photos were needed in order to complete the plates for this work.

1.4. Terminology

We consider it necessary to briefly describe the terminology used to describe the morphology of Chondrichthyes teeth given its high complexity and diversity.

1.4.1. Terminology of the lamnid teeth (Order Lamniformes)

The terminology of the lamnid teeth is that used by Cappetta (1987), which is the one that has largely standardized the language used to describe the teeth of this order.

1.4.2. Terminology of the gill rakers (Family Cetorhinidae, Order l Lamniformes)

The terminology that I followed in the description is that used by Welton (2013, pp. 19-20). It is important to note that Welton's terminology is slightly different from that previously proposed by Hovestadt & Hovestadt-Euler (2012, p. 74) regarding the use of the mesial and distal directions.

1.4.3. Hexanchid teeth type terminology (Order Hexanchiformes)

For the hexanchid type teeth, the terminology based on Ward (1979) was used, which summarizes the previous terminologies, respectively Applegate, 1965; Compagno, 1970; Kemp, 1978). Hexanchid type teeth have a high degree of variability (teeth differ morphologically depending on the position occupied on the upper (palatoquadrate) or lower jaw (Mekel cartilage). Only the lower teeth are considered diagnostic (Cappetta, 2012).

1.4.4. Dasytoid teeth type terminology (Family Dasyatidae, Order Myliobatiformes)

For a long time, the teeth of batoids with a triangular morphology, sharpened or showing well-marked ridges were considered as belonging to males and the teeth more rounded or flattened as belonging to females. However, it has been shown that there is a seasonal variability of the teeth in males, induced by the mating season (Kajiura & Tricas, 1996).

With the entry into the mating season the male teeth become sharper. This transformation probably has two functions: a. Increasing the feeding efficiency for sustaining a sudden growth impulse; b. The enhancement of cooperation by the female through attachment bites, during mating. After the end of the mating season, the dentition returns, through the mechanism of replacement to the initial form, similar to that of the females. This periodic replacement character is defined as periodic dental dimorphism.

1.4.5. Terminology of the ptychodontid teeth (Order Incertae sedis)

For the *Ptychodus* genus, the specific descriptive terminology is translated into Romanian after Hamm (2008), with some changes. For the terms labial and lingual, we used other terms, respectivly mesial and distal in order to avoid the confusion with the lamnid type teeth, where labial and lingual have another meaning.

CHAPTER 2
HISTORY OF RESEARCH

This chapter provides a critical overview of the last 168 years of research on fossil fish teeth found in the Mesozoic and Cenozoic deposits in Romania, analysing the challenges faced by the predecessor authors, but also the progress made by them.

By comparing paleontological literature in Romania with the foreign one, it is obvious that the research on fossil fish had a modest weight compared to the progress of paleontological knowledge as a whole. Even the fundamental works of historical geology or the syntheses that address the reconstructions of paleomedia or the biostratigraphy of sedimentary basins frequently omit the fish most of the times.

Access to comparative, current or fossil materials was extremely limited, often leading to controversial results, especially concerning the systematics To all this was added the acute shortage of specialized literature, especially in the years of communism, but also in the years immediately following the change of political regime (the 90s of the last century), which led to extremely pale and confusing advances in fossil fish research in Romania. The effects of that context are still clearly visible today in the great university libraries or museums in our country, even after almost three decades of the major changes in the political regime.

While describing the occurrences of fish teeth in this chapter we used the original (old) nomenclature of ages, lithostratigraphic units as well as the original spelling of the names of genera and species used by the different authors. The ages whose names have become obsolete internationally are written between quotation marks. The names of the localities are those commonly used, but in brackets are also mentioned the Hungarian or German place names where they were used in the old original text.

The comments related to the taxonomy were not intended to be redeterminations, but more like an opportunity to discuss the issues related to the incorrect description, illustration or determination of some specimens. Only the research conducted on fish teeth were considered in this study. The works that describe skeletons are not the subject of this work. As an exception to this rule, we will also mention the works that deal with shark gill rakers, dermal thorns and caudal spines. A number of 124 bibliographic sources regarding systematic works, monographs of geological units,

various articles and doctoral theses were consulted. Holocene remains from outcrops or archaeological excavations have not been analysed.

2.1. The history of Mesozoic fish research in Romania.

Mesozoic fish teeth have generally not received too much attention from geologists and paleontologists. Considering the bibliographic sources, they appear to be quite rare in formations having this age in Romania. In most cases, Mesozoic teeth are isolated and so far, with the exception of the Bihor Triassic deposits, no faunal assemblage has been reconstructed.

2.2. History of Cenozoic fish research in Romania.

In the history of Cenozoic fish research in Romania it is noted the paleontologists' concern for some special areas with rich fauna, which have attracted the attention of researchers since the 19th century. In this category is the northwest region of the Transylvanian Depression, especially in the Cluj area, where both Paleogene and Neogene deposits outcrop with very interesting fauna content. It is worth mentioning here also the south of the aforementioned depression, in particular the village of Turnu Roșu (= Porcești), where Paleogene deposits emerge only in the form of small areas left from the erosion, but with a rich fish fauna. Next to these areas there are others with great potential such as the Borzești-Cetea zone in western Transylvania where Badenian rocks in marine facies appear on large surfaces (Gârbova Formation).

CHAPTER 3.
GEOLOGICAL FRAMEWORK OF THE AREAS OF PROVENANCE OF THE STUDIED MATERIAL

Fieni (Dâmbovița County)

The Fieni area is located at the contact between the geographical units of the Carpathians and Subcarpathians (Fig. 7). From a structural point of view, there is a tectonic complex of thrusting nappes (Ștefănescu et al., 1988). The outcrop belongs more precisely to the Teleajen Nappe (Moldavide, *sensu* Săndulescu, 1984), in the so-called "Seria de Fieni" (Ștefănescu, 1995).

The geological age of the rocks in this series is included in the Albian terminal-Turonian range Ștefănescu et al. (1965).

Teliu (Brașov County)

The geological formations in the region of Teliu locality (Fig. 8) are part of the Ceahlău Nappe (External Dacids) and belong to the so-called Teliu Formation (Băncilă, 1958). This formation has been described from the Teleajen Unit, but it probably has a somewhat distinct lithological composition compared to the Teliu stratigraphy. The age of these deposits was considered to be "Vraconian" - Cenomanian by Băncilă, (1958). Săndulescu (1984) describes these formations as "layers with auceline" and also assigns them a "Vraconian" - Cenomanian age. However, Mutihac & Ionesi (1974) consider that two distinct levels can be separated, namely "Strata with auceline", of age "Vraconian" and "Teliu Strata", restricted exclusively to Cenomanian.

Peștera (Constanța County)

Structurally, the locality of the Peștera is located in the Moesic Platform (*sensu* Băncilă, 1958; Dumitrescu et al., 1962; Săndulescu, 1984) (Fig. 9). Based on the differences in structure, the Moesic Platform is divided into three sectors: Central Dobrogea, South Dobrogea and Valachian Platform. A different interpretation belongs to Ionesi (1994) who considers the Valachian Platform and South Dobrogea as integral parts of the Moesian Platform (in fact resuming a structural model designated

by Paraschiv, 1975) and Central Dobrogea as a distinct massif. The locality of the Peștera is located in the southern Dobrogea sector framed by the Capidava-Ovidiu fault and the Intra-Moesian fault (Săndulescu, 1984).

At Peștera are exposed the deposits of the Cochirleni Formation, of ?Upper Aptian-Albian - Lower Cenomanian age, covered by the Cenomanian transgression of the Peștera Formation (Avram et al., 1988).

Ormeniș (Brașov County)

Located in the northwestern part of Brașov County (Fig. 11), the Ormeniș site has been known since the 19th century for the Upper Cretaceous age fauna (Hauer, 1872; Herbich, 1886; Simionescu, 1899). Structurally, the deposits containing this fauna belong to the post-tectogenetic cover of the Baraolt Nappe (Sandulescu, 1984), a component of the External Dacids in the Eastern Carpathians. For this area there are relatively few geological studies that bring these deposits into question. However, the age proposed by Simionescu (1899), Turonian- "Senonian" is confirmed by the re-evaluation of its determinations, which indicates an Upper Turonian-Lower Coniacian age (Pauliuc, 1968; Walaszczyk and Szasz, 1997).

Vălioara (Hunedoara County)

Vălioara locality is located in the northwest part of the Hațeg Basin (Fig. 12) and has been known for its continental deposits since the beginning of the 20th century when the first fossil vertebrates were reported (Nopcsa, 1905; Kadic, 1916). Today the biodiversity of continental deposits in the Upper Cretaceous of the region is well known. Amphibians, mammals, crocodilians, theropods, pterosaurs and fish along with invertebrates and plants have been found in Vălioara (Grigorescu, 1992, 1999; Csiki et al., 2008; Vremir et al., 2018). The continental deposits from Văliora are part of the Maastrichtian Densuș-Ciula (Grigorescu, 1992) formation.

Turnu Roșu (Sibiu County)

This locality is located in the south of the Paleogene basin of Transylvania (Fig. 13) and is known in the older bibliographical references under the name Porcești, = Portsest (in Hauer, 1846) or = Portsesd (in Neugeboren, 1850, 1851). While Hauer (1846) considered in his early studies that fossils from Turnu Rosu are a mixture of Eocene and Miocene taxa, from the second half of the 19th century the age of

sedimentary deposits in this locality began to be considered to be exclusively Eocene. (Hauer & Stache, 1863; Koch, 1894).

In the twentieth century geologists established an age in the Ypresian-Luteţian interval (Mészáros, 1960; Bombiţă, 1963) or "Cuisian" -Priabonian (Tătărâm, 1967). Later, the presence of the Oligocene was also discussed (Mészáros & Ianoliu, 1971). The stratigraphy of the region was completed by the description of three geological formations by Mészáros (1996), namely: the Valea Satului Formation (Ypresian), the Strada Muntelui Formation (Luteţian-Priabonian) and the Valea Nişului Formation (Priabonian-Lower Oligocene). Unfortunately, the lithological limits of these formations were not established and a synthetic stratigraphic column was not included by the author The observations from the field led us to the conclusion that the stratigraphic situation is somewhat more complicated than previously thought, mainly because of the local tectonics.

Albeşti şi Bogăteşti (Argeş County)

Albesti village is located a few kilometers northwest of the city of Câmpulung (Argeş County). The Eocene deposits from this locality are well known to geologists as early as the second half of the 19th century. The main interest was the Albesti Limestone, also known as "Piatra de Albeşti" or "Piatra de Câmpulung" (Bleahu et al., 1976). Popovici-Hatzeg (1896, 1898) considered these deposits as belonging to Luteţian, but later (Popescu-Voiteşti, 1910) established an age between lower Luteţian and upper Eocene. Based on the study of nummulites, Bombiţă (1963) considered the limestone as Ypresian-Lower Lutetian. Half a century later studying fragments of Sirenidae from this location Grigorescu (1967) admitted this age, but indicated that the age of the sands covering these limestones is probably Priabonian.

The geology of Bogăteşti locality (= Bogăteşti-Bilceşti) is relatively little known. Bombiţă et al., (1980) make some remarks on the Paleogene deposits from here represented by the Albeşty type limestone outcroping in the Oleia quarry in the east of the locality. Here, transgressive over Cenomanian, an eocene numulitic limestone lens supports sands and sandstons of probable Neogene age. Oligocene deposits are present in the area, but their relationship with the Eocene is unclear, being indicated as transgressive only over the Cenomanian (Bombiţă, et al., 1980, fig. 3).

The limestone horizon from Bogăteşti is synchronous with the middle horizon from the Albesti quarry (Bombiță et al., 1980, p. 82), so probably has a Lower to Middle Eocene age.

Luna de Sus (Cluj County)

Recent surveys of the deposits of the Middle Eocene in the village of Luna de Sus led to the discovery of a rich fish fauna, represented by teeth, but also rostral, dermal and caudal spines. The Luna de Sus is located in the northwestern part of the paleogene basin of Transylvania, in the central part of Romania, approximately 10 km west of Cuj-Napoca (Fig. 15). This locality is new for the fossil fish fauna of Romania.

The outcrop from which the fish remains were collected belongs to the Căpuș Formation. The formation of Căpuș (Popescu, 1978) is located in the northwest of the Transylvanian Basin (Gilău sedimentary area; Rusu, 1987). The sedimentology of this formation reflects a paleoenvironment belonging to a continental shelf from an open sea with a tidal regime (Rusu et al., 2004).

Leghia Quarry (Cluj County)

Leghia is located at approx. 45 km northwest of Cluj Napoca. In the south of this locality is the quarry of Valea Fânului where the specimen analysed by us comes from. The deposits from the Leghia belong to the Călata group that includes here the Căpuș Formation, the Inucu Formation, the Văleni Limestone and the Ciuleni Formation (Rusu, 1995). These deposits are part of the Gilău sedimentary area (Popescu, 1984). The Vișstea Limestone (Rusu, 1987) also known as the "Calcarul Grosier Inferior" is the level where one of the specimens of *Anoxypristis* studied by us (MSPUBB 24019) was collected. The age of this lithostratigraphic unit is Bartonian fact indicated by the NP 16 nanoplankton area (Rusu et al., 2004). The limestone of Vișstea is considered to be deposited in very shallow waters, in the inter-tidal area with large variations of salinity (Rusu et al., 2004).

Rona Peak from Turbuța

Turbuța area is located in the northwestern part of the Transylvanian Basin and is part of the Meseș depositional area. In the north-western part of the village Turbuța rises a peak with a height of 919 m known as Piscul Ronei, (Fig. 17) carved by erosion

against on a Paleogene monoclin structure. This height is emblematic for the Jibou's surroundings. In the area, formations from the Upper Cretaceous - Paleogene range and reduced patches of Pleistocene deposits are encountered.

The succession of the deposits from Piscul Ronei is composed of: Jibou Formation (Rona Member -Thanetian-? Sparnacian; "upper red member" - Paleocene-Luteţian), Foidaş Formation (anhydrites-Luteţian), Călata Group (Căpuş Formation) - Luteţian-Bartonian Inferior; Racoţi Sandstone - Lower Priabonian) and Turbuţa Formation (Middle Priabonian) (Petrescu et al., 1975; Mészáros, 2000; Codrea & Săsăran, 2002). In the southern part of Rona's can be observed also the Turea Group (Cluj Limestone - Priabonian Superior). From the Racoţi Sandstone it was colected a rostral spine of *Anoxypristis* sp. (MSPUBB 24018).

Hoia Hill (Cluj County)

Hoia Hill is located in the northwest part of the municipality of Cluj-Napoca, on the left bank of Someşului Mic (Fig. 18). The interpretation of the age of "Hoia Strata" has changed over time. Initially they were considered a complete equivalent of the Mera Formation (Koch, 1874). Later interpretations changed (see research history in Moisescu, 1975) and it was suggested that "Hoia Strata" comprise only the basal part of the Oligocene, being located above the Marnele de Brebi which ends the Eocene sedimentary succession in the Cluj area (Moisescu, 1975). Later, Rusu (1979) establishes the Eocene-Oligocene boundary within the Marni de Brebi, as confirmed later in the Brebi stratotype, in the Meseş sedimentary area (Rusu, 1993).

Suceag (Cluj County)

Suceag locality (Fig. 18), is located at approx. 15 km northwest of Cluj Napoca. Near the village, outcrops the upper part of the Dâncu Formation (Rusu, 1972). The Dâncu Formation is a lacustrine fluvial formation with marsh areas. Lithologicaly it is formed of an alternation of clays, marls, sands and levels of coals. The formation is rich in invertebrates and vertebrates. Its age is Oligocene (Rupelian), a fact indicated by the mammalian zones MP 23 and MP 24 (Reichenbacher & Codrea, 1999; Codrea & Fărcaş, 2002; Fărcaş & Codrea, 2008).

Coza (Vrancea County)

The studied specimen originates from near the village of Coza, Vrancea County. From the limits of the village towards the outcrop, a succession of Miocene and Oligocene age deposits is visible (Bordeianu et al., 2018). Although affected by a complex of faults, the Oligocene sediments can be easily separated due to their lithological appearance and composition. These are part of the Bituminous Marls Formation. From a tectonic point of view, the Formation of Bituminous Marls belongs to the Moldavids, respectively the Marginal Folds Nappe visible in the Vrancea semi-window (Săndulescu, 1984).

Coasta Mare (Cluj County)

The topoym Coasta Mare designates a part of the northern slope of Feleac Hill in the southern part of Cluj-Napoca (Fig. 20). On this side there is a sand quarry which represents one of the classic outcrops for the Neogene of Transylvania. Miocene deposits in this outcrop are positioned discordantly and transgressively over the Oligocene ones (Nicorici et al., 1979). The succession of the Miocene deposits is formed from volcanic sands, clays and tuffs belonging to the Coruș Formation (Lower Eggenburgian), the Chechis Formation (Upper Eggenburgian) and the Dej Formation (Badenian). The Coruș formation contains a rich fauna of molluscs and fish (Nițulescu, 1937; Nicorici et al., 1979; Șuraru et al., 1978).

Petroșnița (Caraș-Severin County)

Petroșnița locality is located in the Caransebeș Basin, on its western border (Fig. 21). The formations present in the area belong to the mountain edge and to the post-Neogene basin (Breban et al., 1993). The frame and foundation formations are represented by crystalline, Mesozoic and secondary eruptive rocks (banatite) (Breban et al., 1993; Lubenescu et al. 1993). The Neogene sedimentary in the southern area of Caransebeș is composed of several formations with ages ranging from Badenian to Lower Pontian. Marinescu & Popescu (1987) and then Lubenescu et al., (1993) propose a series of five formations, namely the Rugi Formation (Langhian), the Delinești Formation (Langhian - Kosovian), the Sadova-Armeniș Formation (Sarmațian), the Timiș Valley Formation (Pannonian) and Turnu Ruieni Formation (Upper Pannonian *stricto senso* - Lower Pontian).

A year later, Mărunțeanu et al., (1994) propose another series of formations with reference this time to the entire Caransebeș-Mehadia Basin: Calva Formation (Upper Badenian), Belcovăț Formation, the Globul Craiovei Formation (Volhinian), the Petnic Formation (of lower Sarmatian age for the Cuptoare Member and Bessarabian for the Crușovăț Member), the Timis Valley Formation (Pannonian) and the Turnu Ruieni Formation (Pannonian). Unfortunately Mărunțeanu et al. (1994) does not comment on the potential synonymy with the formations previously proposed by Lubenescu et al. (1993). However, the maps of both authors indicate, in the Petroșnița area exclusively Badenian deposits (with the exception of quaternary terrace deposits).

Lăpugiu de Sus (Hundeoara County)

In the Miocene the water of the Badenian sea made a connection between the Pannonic Basin and that of Transylvania, including the small connected basins, of Făgetului and Streiului through the so-called Mureş corridor located between the southern Apuseni Mountains and the Poiana Ruscă Mountains. The exact paleogeography is difficult to reconstruct because it is assumed that at least some of the sedimentary deposits have been eroded.

In this marine corridor are deposited Lower Badenian (Moravian) deposits with a rich fauna of molluscs. The most known are those from Lăpugiu de Sus and Coştei. Along with molluscs these deposits contain rare vertebrates and plants (Givulescu & Codrea, 1997), the latter indicating proximal continental influences in this marine basin.

The most representative outcrops from Lăpugiu de Sus are found on the Coșului and Lăpugiului creeks (Fig. 22).

Cetea, Rachiș, Lopadea Veche, Gârbova de Sus (Alba County)

The most part of the sedimentary deposits of the western edge of the Transylvanian Basin belong to the middle Miocene (Fig. 23). These marine sediments belong to the biozone with *Orbulina suturalis* and are dominated by siliciclastic rocks, algal and bioclastic limestones (Hosu & Filipescu, 1995). A part of Central Parathetys, the Transylvanian Basin was in Badenian an area of a larger tropical sea formed in an episode of global warming (Chira et al., 2000). Together with other land territories the

emerging portions of the Carpathians formed an archipelago in the Central Parathetys (Rögl, 1998).

Vârciorog (Bihor County)

The studied fossils come from the locality of Vârciorog, Bihor County (Fig. 24). The outcrop is located on the Vișinilor Creek, in the south west of Varului Hill. The sedimentary succession here is formed by clays and sands belongs to the Sarmatian Cornițel Formation (Istocescu & Istocescu 1974; Popa 2000; Filipescu et al. 2014). This formation is part of the eastern edge of the Pannonic Basin. The microfauna indicate the *Elphidium reginum* zone and therefore the Lower Sarmatian (Filipescu et al., 2014). Next to the foraminifera it was discovered a mollusc fauna, but more remarkable, a rich fauna of vertebrates, represented mainly by micromammals (Hir et al., 2019 - in press) and fish. Although the fish fauna was recently evaluated, this analysis was performed exclusively on otoliths, the existence of fish teeth being transient and vaguely remembered (Reichenbacher et al., 2018).

Racoșul de Sus (Brașov County)

Racoșul de Sus locality is located in the Brașov sedimentary basin, the largest intra-mountain basin at the boundary between the Eastern and Southern Carpathians (Fig. 25). This basin includes three sub-basins, Bârsa-Baraolt, Sf. Gheorghe and Bretcu (Săndulescu, 1984). The first of these is the one of interest to us being the place of collecting of the specimens described. The Bârsa-Baraolt sub-basin is bounded by the Perșani and Baraolt Mountains and is crossed by the Baraolt and Cormoș rivers. The foundation of the Barsa-Baraolt Basin is made up of the Mesozoic deposits (Lower Cretaceous, "Neocomian") that make up the Baraolt Nappe and the Ceahlău Nappe. Both thrust sheets are part of the External Dacids (Săndulescu, 1984). Partially these rocks are covered by volcanic and volcanic-sedimentary deposits of the Harghita Mountains (Fielitz & Seghedi, 2005; Lexa et al., 2010). Based on molluscs and plant remains, it was assumed that sedimentation began in the Upper Miocene but the magnetostratigraphy (Andreescu et al., 1987) and the fossil vertebrates (Rădulescu & Samson, 1985) indicate that the sedimentation began in the Pliocene (Andreescu et al., 1987).

CHAPTER 4
SYSTEMATIC PALEONTOLOGY

The systematics follows mainly Cappetta (2012), Last *et al.*, (2016) and Nelson *et al.*, (2016).

Class Chondrichthyes HUXLEY, 1880
Subclass Elasmobranchii BONAPARTE, 1838
Cohort Euselachii HAY, 1902
Order Hybodontiformes MAISEY, 1975
Superfamily Hybodontoidea OWEN, 1846
Family Polyacrodontidae GLUCKMAN, 1964
Polyacrodontidae indet.
Material: 1 tooth (MSPUBB V697), plate I, fig. a-d'
Origin: Vălioara, Hunedoara County
Age: Upper Cretaceous, Maastrichtian

Order Squaliformes GOODRICH, 1909
Family Echinorhinidae GILL, 1862
Echinorhinus BLAINVILLE, 1816
Echinorhinus sp.
Material: 1 tooth, (CPUB 3152), pl. II, fig. a-d
Origin: Teliu, Brașov County
Age: Upper Cretaceous, Cenomanian

Order *incertae sedis*
Family Ptychodontidae JAEKEL, 1898
Genus *Ptychodus* AGASSIZ, 1835

Ptychodus altior Agassiz, 1835
Material: 1 tooth (MSPUBB 21681), pl. III, fig. a-d

Origin: ”Marnele cu inocerami” from the right bank of the Satului Valley, Ormeniș, Brașov County;
Age: Upper Cretaceous, Upper Turonian – Lower Coniacian

Ptychodus sp.
Material: 2 teeth (CT 103; 154), pl. III, fig. e-g
Origin: basal microconglomerates from Peștera Quarry, Constanța County (Peștera Fm.)
Age: Upper Cretaceous, Cenomanian

Order Heterodontiformes BERG, 1937
Family Heterodontidae GRAY, 1851
Genus *Heterodontus* BLAINVILLE, 1816
Heterodontus sp. 1
Material: 1 tooth (CT 101), pl. IV, fig. a-b
Origin: basal microconglomerates from Peștera Quarry, Constanța County (Peștera Fm.)
Age: Upper Cretaceous, Cenomanian

Heterodontus sp. 2
Material: 2 teeth (CFSMUBB 045; 098), pl. IV, fig. c-i
Origin: Luna de Sus, Cluj County
Age: Lower Bartonian

Order Lamniformes BERG, 1958
Family Odontaspididae MÜLLER & HENLE, 1839
Genus *Hypotodus* JAEKEL, 1895
Hypotodus verticalis Agassiz, 1843
Material: 1 tooth (CFSMUBB 061), pl. V, fig. a-c
Origin: Luna de Sus, Cluj County;
Age: Lower Bartonian

Genus *Jaekelotodus* MENNER, 1928
Jaekelotodus robustus (LERICHE, 1921)

Material: 3 anterior teeth (CFSMUBB 062, 063, 064) and 2 lateral teeth (CFSMUBB 060, 093), pl. V, fig. d-i
Origin: Luna de Sus, Cluj County
Age: Lower Bartonian

Genus: *Carcharias* RAFINESQUE 1810
Carcharias sp.
Material: 1 fragmented tooth (MSPUBB no. 1939A), pl. VI, fig. d-f
Origin: Gârbova de Sus, Alba County (Gârbova Fm.)
Age: Badenian

cf. *Carcharias* sp.
Material: 1 tooth (CT no. 232); pl. V, fig. g-i
Origin: Petroșnița, Caraș-Severin County
Age: Badenian

aff. *Carcharias* sp.
Material: 1 tooth (CT no. 141); pl. V, fig. a-c
Origin: Peștera, Constanța County
Age: Cenomanian

Family Cetorhinidae GILL, 1862
Genus *Keasius* WELTON, 2013
Keasius parvus (LERICHE, 1908)
Material: 1 gill raker (MSPUBB V547), pl. VII, fig. a-a'
Origin: Coza Valley, Vrancea County
Age: Oligocene

Family Lamnidae MÜLLER & HENLE, 1838
Genus *Macrorhizodus* GLIKMAN, 1964
Macrorhizodus praecursor Leriche, 1905
Material: 2 teeth (CFSMUBB 041, 042), pl. VII, fig. b-e
Origin: Luna de Sus, Cluj County
Age: Lower Bartonian

Genus: *Carcharodon* MÜLLER & HENLE, 1838

Carcharodon hastalis (AGASSIZ 1838)

Material: 2 teeth, (MSNA no. 1327B and 1327C), pl. VII, fig. f-k

Origin: Lopadea Veche, Alba County (Gârbova Fm.)

Age: Badenian

Family Otodontidae GLICKMAN 1964

Genus *Otodus* AGASSIZ 1843 (*sensu* Cappetta, 2012)

Otodus (Otodus) obliquus AGASSIZ 1843

Material: 6 teeth, pl. VIII, fig. a-i

Origin: Turnu Roșu (MINSBK 35631, 35632); Albești (MSNP 155, 173; MNG 1046B; 10560)

Age: Eocene

Otodus (Carcharocles) aksuaticus MENNER 1928

Material: 11 teeth, pl. IX, fig. a-i

Origin: Turnu Roșu (MINSBK 35575, 35615, 35620, 35672, 35673); Albești (MSPUBB 1365A; MSNP 400; CMMC 102, 106; MNG 1045A, 1046A)

Age: Eocene

Otodus (Carcharocles) auriculatus BLAINVILLE 1818

According to Applegate & Espinosa-Arrubarrena (1996) the species *Carcharodon disauris* Agassiz, 1843; *Carcharodon debrayi* Leriche, 1906; and *Carcharodon nodai* Yabumoto, 1987 are the synonyms of *Otodus (Carcharocles) auriculatus*

Material: 26 teeth, pl. X, fig (a-i)

Origin: Turnu Roșu (MINSBK nr. 35571, 35576, 35577, 35593, 35600, 35603, 35604; MSPUBB 1358B, 1359A 1359B; 1360A, 1360B, 1360C; 795); Albești (MSPUBB . 1365D, 1365F; CPUB 2, 87, 1303A, 1303B; MSNP 129, 154, CMMC 688A and 732; MNG 1045B); Bogătești, Argeș County (CPUB a specimen without registration no.), Huedin area (MSNTM 251)

Age: Eocene

Otodus (*Carcharocles*) *sokolovi* (JAEKEL 1895)

Material: 1 tooth (MSPUBB 225A, pl. XI, fig. 4a-b'

Origin: Mănăștur, „Marnele cu briozoare" Fm., Cluj County

Age: Eocene, Priabonian

Otodus (Carcharocles) angustidens AGASSIZ, 1843

Material: 1 tooth (MSPUBB 1363), pl. XI, fig. c-d'

Origin: ?Poiana Sărată, Ileanda, Sălaj County

Age: ?Oligocene

Otodus (*Megaselachus*) *megalodon* AGASSIZ 1835

Material: 8 teeth, pl. XI, fig. e-g și pl. XII, fig. a-h, pl. XIII, fig. a-f

Origin: Cetea, Pârâul Lupului (MSNA 697); Lopadea Veche (MSNA 1327A); Gârbova de Sus (MSNA 1339); Lăpugiu de Sus (CT 231); Cheile Turzii (MSPUBB 1352); Borzești (MSPUBB 22375); NV de Turnu Severin (MNG 14267); Cluj area (MSNTM 250)

Age: Badenian (MSNA 697; MSNA 1327A; MSNA 1339; CT 231; MSPUBB 1352, MSPUBB 22375; MNG 14267) and Burdigalian (MSNTM 250)

Otodus (Carcharocles) sp.

Material: 146 teeth

Origin: MINSBK 35003, 35004, 35005, 35006, 35007, 35008, 35391, 35408, 35421, 35469, 35478, 35492, 35495, 35565, 35566, 35567, 35568, 35569, 35570, 35573, 35574, 35578, 35579, 35580, 35581, 35582, 35583, 35584, 35585, 35586, 35587, 35588, 35589, 35590, 35591, 35592, 35594, 35595, 35596, 35597, 35598, 35599, 35601, 35602, 35605, 35606, 35607, 35608, 35608, 35610, 35611, 35612, 35613, 35614, 35616, 35617, 35618, 35619, 35621, 35622, 35623, 35659, 35660, 35661, 35662, 35663, 35664, 35665, 35666, 35667, 35668, 35669, 35670, 35671, 35672, 35672, 35673, 35674, 35675, 35676, 35677, 35678, 35679, 35680, 35681, 35777 from Turnu Roșu; MINSCS 9346, 9348, 9349, 9350, 9351, 9352, 9356, 9360, 9378, 9300, 9301, 9303, 9304, 9305, 9330, 9281, 9233, 9234, 9241, 8177, 7620, 7627, 8483, 7634, 7635, 7636, 8179, 8176, 8434 from Turnu Roșu; MSPUBB 771A, 771B, 1354A, 1354B, 1354C, 1355, 1357A, 1357B, 1358A, 1358C, 1359C, 770 from Turnu Roșu, 1409, 1417 without specified collection place, 21838 from Mănăștur, 151 from

Baciu, 1362 from Căpâlna pe Someș, 1365B, 1365C, 1365D, 1365E, 225B, 1915 from Turnu Roșu; CPUB 1303A, 2, 87 from Albești, specimen without no. A, specimen without no. B, from Bogătești; MUSNB V.69.959A, V.69.959B from Turnu Roșu; CFSMUBB 071 from Luna de Sus.
Age: Eocene

Genus *Cretalamna* GLIKMAN, 1958
Cretalamna sp. (AGASSIZ, 1843)
Material: 1 lateral tooth (CT 105) and 1 symphysis tooth (CT 109); (pl. XIV, fig. a-e)
Origin: Peștera, Constanța County
Age: Cenomanian

Genus *Striatolamia* GLIKMAN, 1964
Striatolamia macrota (Agassiz, 1843)
Material: 3 anterior teeth (CFSMUBB 068, 069, 070) and 5 lateral teeth (CFSMUBB 058, 059, 067, 091, 103); pl. XIV, fig. i-o'
Origin: Luna de Sus, Cluj County
Age: Lower Bartonian

Genus *Scapanorhynchus* WOODWARD, 1889
Scapanorhynchus cf. *minimus* LANDEMAINE, 1991
Material: 1 tooth (CT 142); pl. XIV, fig. f-h
Origin: Peștera, Constanța County
Age: Cenomanian

Family Truyolsodontidae BERNÁRDEZ, 2018
Genus *Truyolsodontos* BERNÁRDEZ, 2018
Truyolsodontos sp.
Material: 1 antero-lateral tooth (CT 121); pl. XV, fig. a-c
Origin: Peștera, Constanța County
Age: Cenomanian

Family Anacoracidae CASIER, 1947
Genus *Squalicorax* WHITLEY, 1939

Squalicorax aff. *primaevus* Dalinkevicius, 1935

Material: 1 tooth (CT 102); pl. XV, fig. d-e

Origin: Peștera, Constanța County

Age: Cenomanian

Squalicorax sp. 1

Material: 4 teeth (CT 130, 131, 132, 152); pl. XV, fig. f-n

Origin: Peștera, Constanța County

Age: Cenomanian

Squalicorax sp. 2

Material: 1 tooth (CT 153); pl. XV, fig. o-p

Origin: Peștera, Constanța County

Age: Cenomanian

Family Pseudoscapanorhynchidae HERMAN, 1979

Genus *Protolamna* CAPPETTA, 1980b

Protolamna sp.

Material: 1 tooth (CT 112); pl. XVI, fig. a-c

Origin: Peștera, Constanța County

Age: Cenomanian

Incertae familiae

Genus *Paranomotodon* HERMAN 1977

Paranomotodon sp.

Material: 3 teeth (CT 116, 117, 118); pl. XVI, fig. d-j

Origin: Peștera, Constanța County

Age: Cenomanian

Order Carcharhiniformes COMPAGNO, 1977

Family Carcharhinidae JORDAN & EVERMANN, 1896

Genus *Rhizoprionodon* WHITLEY, 1929

Rhizoprionodon ganntourensis Arambourg, 1952

Material: 2 teeth (CFSMUBB 076, 082), pl. XVII, fig. a-d

Origin: Luna de Sus, Cluj County

Age: Lower Bartonian

Genus *Galeocerdo* MÜLLER & HENLE, 1838
Galeocerdo eaglesomei WHITE, 1955
Material: 2 lateral teeth (CFSMUBB 043, 044); pl. XVII, fig. e-h
Origin: Luna de Sus, Cluj County
Age: Lower Bartonian

Genus *Physogaleus* CAPPETTA, 1980a
Physogaleus secundus WINKLER, 1876
Material: 3 lateral teeth (CFSMUBB 050, 051, 052) and 1 antero-lateral tooth (CFSMUBB 053); pl. XVII, fig. i-k
Origin: Luna de Sus, Cluj County
Age: Lower Bartonian

Genus *Abdounia* CAPPETTA, 1980a
Abdounia sp.
Material: 1 anterior tooth (CFSMUBB 055) și 1 lateral tooth (CFSMUBB 056); pl. XVIII, fig. a-d
Origin: Luna de Sus, Cluj County
Age: Lower Bartonian

Family Hemigaleidae HASSE 1879
Genus *Hemipristis* AGASSIZ, 1843
Hemipristis serra (Agassiz, 1835)
Material: 1 incomplete tooth (MSPUBB 7049); pl. XVIII, fig. e-h;
Origin: Rachiș, Alba County (Gârbova Fm.)
Age: Badenian

Family Scyliorhinidae GILL, 1862
Scyliorhinidae *incertae subfamiliae*
Genus *Protoscyliorhinus* HERMAN 1977
Protoscyliorhinus bettrechiensis (HERMAN, 1977)

Material: 2 teeth (CT 122, 123); pl. XVIII, fig. i-n
Origin: Peștera, Constanța County
Age: Cenomanian

Order Squatiniformes BUEN, 1926
Family Squatinidae BONAPARTE, 1838
Genus *Squatina* DUMERIL, 1806
S*quatina* sp.
Material: 1 tooth (CT 108); pl. XVIII, fig. a-e
Origin: Peștera, Constanța County
Age: Cenomanian

Order Hexanchiformes BUEN, 1926
Suborder Hexanchoidei GARMAN, 1913
Family Hexanchidae GRAY, 1851
Genus *Notidanodon* CAPPETTA, 1975

Notidanodon sp. (WOODWARD, 1886)
Material: 1 tooth (MNG Collection, nr. 2087); pl. XIX, fig. l-m
Origin: Right bank of Ialomița river at Fieni, Dâmbovița County
Age: Lower Cretaceous (Albian)

Genus *Hexanchus* RAFINESQUE, 1810
Hexanchus sp.
Material: 3 fragmented teeth (CT 113, 114, 115); pl. XIX, fig. f-k
Origin: Peștera, Constanța County
Age: Cenomanian

Superorder Batomorphii CAPPETTA, 1980a
Order Rajiformes BERG, 1940
Suborder Pristoidei CAPPETTA, 1980a
Family Pristidae BONAPARTE, 1838
Genus *Anoxypristis* WHITE & MOY-THOMAS 1941
Anoxypristys sp.

Material: 2 rostral spines MSPUBB, nr. 24018 and 24019 (pl. XX, fig. a-h).
Origin: Turbuța (Racoți Sandstone) (MSPUBB 24018) Leghia Quarry (Vișstea Limestone) (MSPUBB 24019)
Age: Lower Priabonian (MSPUBB 24018); Bartonian-Priabonian (MSPUBB 24019)

Genus *Pristis* LINCK 1790
Pristis sp.
Material: 7 rostral spines: (pl. XXI, fig. a-o; pl. XXII, fig. a-i);
Origin: CFSMUBB 003, 004, 005, 006, 007, 008 from Luna de Sus and CLPVUBB, without no., Someș-Dig, Cluj-Napoca
Age: Lower Bartonian (CFSMUBB 003, 004, 005, 006, 007, 008), Căpuș Fm.; Priabonian (CLPVUBB, without no.) from Calcarul de Cluj.

Suborder Rhinobatoidei FOWLER, 1941
Family Rhinobatidae MÜLLER & HENLE, 1838
Genus *Rhinobatos* LINCK, 1790
Rhinobatos cf. *steurbauti* CAPPETTA & NOLF, 1981
Material: 2 teeth (CFSMUBB 096, 097), pl. XXIII, fig. a-d
Origin: Luna de Sus, Cluj County
Age: Lower Bartonian

Incertae subordinae
Incertae familiae
Genus *Turoniabatis* LANDEMAINE, 1991
Turoniabatis cappettai LANDEMAINE, 1991
Material: 1 tooth (CT 150); pl. XXIII, fig. e-h
Origin: Peștera, Constanța County
Age: Cenomanian

Order Myliobatiformes COMPAGNO, 1973
Superfamily Miliobatoidea COMPAGNO, 1973
Family Myliobatidae BONAPARTE, 1838
Subfamily Myliobatinae BONAPARTE, 1835
Genus *Myliobatis* CUVIER, 1816

cf. *Myliobatis* sp.

Material: 1 almost complete dental plate (CFSMUBB 074); pl. XXIII, fig. i-j

Origin: Luna de Sus, Cluj County

Age: Lower Bartonian

Family Aetobatidae WHITE & NAYLOR, 2016

Genus *Aetobatus* BLAINVILLE, 1816

cf. *Aetobatus* sp.

Material: 2 fragmented upper teeth (CFSMUBB 072, 073); pl. XXIII, fig. k-n

Origin: Luna de Sus, Cluj County

Age: Lower Bartonian

Myliobatinae indet. 1

Material: 1 incomplete dental plate composed from 3 teeth (MSPUBB VT459); pl. XXIV, fig. a-e

Origin: Luna de Sus, Cluj County

Age: Lower Bartonian

Myliobatinae indet. 2

Material: 1 caudal spine (CFSMUBB 048); pl. XIV, fig. f-h

Origin: Luna de Sus, Cluj County

Age: Lower Bartonian

Myliobatinae indet. 3

Material: 1 lateral tooth of a dental plate (CT 203); pl. XIV, fig. i-l

Origin: Suceag

Age: Oligocen (Rupelian)

Superfamily Dasyatoidea WHITLEY, 1940

Family Dasyatidae * JORDAN, 1888

Genus *Dasyatis* RAFINESQUE, 1810

* Dasybatidae in Jordan & Gilbert, 1879, p. 386, then corrected as Dasyatidae in Jordan, 1888, p. 22 (Last, 2016c)

Dasyatis cf. *jaekeli* (LERICHE, 1905)

Material: 1 tooth (CFSMUBB 095); pl. XXV, fig. a-d
Origin: Luna de Sus, Cluj County
Age: Lower Bartonian

Dasyatis cf. *rugosa* (PROBST, 1877)
Material: 19 teeth of female or male outside the mating season (CT 197-199, 203, 208-220, 225, 228; pl. XXV, fig. e-i) and 1 male teeth (CT 200; pl. XXV, fig. j-n
Origin: Suceag, Cluj County
Age: Oligocen (Rupelian)

Dasyatis aff. *strangulata* (PROBST, 1877)
Material: 1 tooth of female or male outside the mating season (CT 201; pl. XXV, fig. o-s)
Origin: Suceag, Cluj County
Age: Oligocen (Rupelian)

Genus *Taeniurops* GARMAN, 1913
Taeniurops cavernosus
Material: 1 tooth of female or male outside the mating season (CT 202); pl. XXV, fig. t-x)
Origin: Suceag, Cluj County
Age: Oligocen (Rupelian)

Batomorphii indet.
Material: 2 bases of dermal spines (CFSMUBB 086, 087); pl. XXVI, fig. a-f
Class Actinopterygii, KLEIN, 1885
Order Pycnodontiformes BERG, 1940
Family *incertae sedis*
Genus *Phacodus* DIXON, 1850
Phacodus cf. *punctatus* DIXON, 1850
Material: 30 teeth (CFSMUBB 012 - 040) and LPGCUBB (without inv. no.); pl. XXVI, fig. g-m
Origin: Luna de Sus, Cluj County and Căpușul Mic, (Căpuș Fm.)
Age: Lower Bartonian

Pycnodontiformes indet.

Material: 2 oral teeth (CT 144, 146) and 2 teeth from vomer (CT 145, 151); pl. XXVI, fig. n-t

Origin: Peștera, Constanța County

Age: Cenomanian

Order Perciformes BLEEKER, 1859

Suborder Labroidei BLEEKER, 1859

Family Labridae CUVIER, 1816

Labridae indet.

Material: 1 upper pharyngeal dental plate (CFSMUBB 057); pl. XXVII, fig. a-c

Origin: Luna de Sus, Cluj County

Age: Lower Bartonian

Family Sparidae RAFINESQUE, 1810

Genus *Diplodus* RAFINESQUE, 1810

Diplodus jomnitanus (VALENCIENNES, 1844)

Material: 1 fragmented tooth (CT 174) - pl. XXVII, fig. d-g

Origin: Bobii Creek, Gârbova de Sus, Alba County

Age: Badenian

Diplodus sp.

Material: 3 incisor-like teeth (Collection CT 160, 162, 168); pl. XXVII, fig. h-j

Origin: Vârciorog, Bihor County

Age: Lower Sarmatian

Genus *Sparus* LINNAEUS, 1758

Sparus sp.

Material: 2 incisor-like teeth (CT 161, 172), pl. XXVIII, fig. a-c

Proveniență: Vârciorog, județul Bihor

Vârstă: Lower Sarmatian

Genus *Pagellus* VALENCIENNES, 1830

cf. *Pagellus* sp.

Material: 4 incisor-like teeth (CT 176-178); pl. XXVIII, fig. d-g
Origin: Vârciorog, județul Bihor
Age: Lower Sarmatian

Sparidae indet. 1
Material: 1 incisor-like tooth (CT 192); pl. XXX, fig. a-d; 3 molariform teeth, (CT 193, 194, 195), pl. XXX, fig. e-j
Origin: Turnu Roșu, Sibiu County
Age: Eocen (Lutetian-Priabonian)

Sparidae indet. 2
Material: 1 molariform tooth (CT 196), pl. XXVIII, fig. h-j
Origin: Hoia Hill, Cluj-Napoca, Cluj County
Age: Oligocen

Sparidae indet. 3
Material: 1 molariform tooth (CT 233), pl. XXVIII, fig. k-l
Origin: Râpei Valley, Petroșnița, Caraș-Severin County
Age: Badenian

Sparidae indet. 4
Material: associated molariform teeth (CT 223), pl. XXIX, fig. e-f; isolated teeth (CT 206), pl. XXIX, fig. g-i; 1 caniniform (CT 207); pl. XXIX, fig. a-d
Origin: Suceag, Cluj County(Dâncu Fm.)
Age: Oligocen (Rupelian)

Family Latidae JORDAN, 1923
Genus *Lates* CUVIER, 1828
Lates sp.
Material: 2 incomplete dentary, (CT 166, 170), pl. XXXI, fig. a-c; pl. XXXII, fig. a-d
Origin: Vârciorog, Bihor County
Age: Lower Sarmatian

Order Esociformes NELSON, 1994

Family Esocidae CUVIER, 1816

Genus *Esox* LINNAEUS, 1758

Esox sp.

Material: 2 dentary and 1 isolated tooth on the rock from Collection MSPUBB (531A and531B) from Racoș, Brașov County; pl. XXXIII, fig. a-d; pl. XXXIV, fig. a-c

Age: Lower Pliocene, Dacian.

Order Aulopiformes ROSEN, 1973

Family Enchodontidae WOODWARD, 1901

Enchodontidae indet.

Material: 1 tooth (CT nr. 136); pl. XXXV, fig. a-b

Origin: Peștera, Constanța County

Age: Cenomanian

Actinopterygii indet.

Material: 2 pharyngeal teeth

(CT no. 147, 148); pl. XXXV, fig. c-d

Origin: Peștera, Constanța County

Age: Cenomanian

CHAPTER 5
PALEOECOLOGICAL CONSIDERATIONS ON SOME OF THE ANALYSED FAUNAL ASSOCIATIONS AND COMMUNITIES

5.1. The Cenomanian fauna from Peștera

Unlike the Cenozoic fish fauna, the Cretaceous taxa are much less represented by correspondents in recent fauna and the principle of actualism is much more limited here. The attempt to reconstruct the living environment for the fauna from Peștera is alo made difficult due to the low degree of conservation of the material.

From the analysis of the faunal structure, we observe a stronger similarity of the fauna from Peștera with the Cenomanian occurrences in France (Charentes region) and Germany (Ascheloh) with ten and nine common genera and a strong difference from the Cenomanian in the Baharyia Formation (Egypt), with one common genus.

We also notice the complete or almost complete absence in the fauna from Peștera of the orders Myliobatiformes, Rhinopristiformes, Orectolobiformes and Rajiformes (which is nonetheless represented by one genus). This indicates the absence of the characteristic fauna of the coastal areas and the of waters with very shallow depths. The microconglomeratic sediment indicates that the local depositional environment was probably active corresponding to an underwater channel. Regional paleogeographic reconstructions (Dercourt et al., 2000) indicate in Dobrogea for Cenomanian deeper carbonate platforms with hemipelagic or pelagic waters, but also narrow coastal areas with terrestrial sedimentation.

5.2. The eocene fauna from Luna de Sus

The environment of sharks, bats and bone fish from Luna de Sus can be reconstructed taking into account the habitat preferences of their current representatives.

The paleoecology of modern fish correspondents indicates a water with a moderate depth of less than 200 m (but probably less than 100 m as indicated by the preferred depth) in a warm sea.

At the regional level of Eastern Europe we can notice that there is little information on Eocene fish (represented by teeth). We compared the taxa from Luna de Sus with those from the region and with a few occurrences from the classical basins of Europe and Africa (Tab. 5). We analysed the faunal diversity of 12 sites from the European part of Russia, Hungary, Ukraine, Denmark, Germany, Belgium, France, Egypt and Morocco (Fig. 34). Data included a Lower Luteţian - Upper Bartonian range. Only genera were taken into consideration, many specimens lacking species-level determination.

Analysing the available data we can notice some genera common to both the Tethysian and to the boreal domain, probably more adaptable and migratory. So are *Striatolamia*, *Macrorhizodus* and the small-sized Carcharhiniforms *Abdounia* and *Physogaleus*. The absence of the *Otodus* genus from many sites of the nearby region is surprising given that this top predator is present in many of the Western European and North African localities. We can notice that the diversity of genera in the North Sea Basin, the Paris Basin and in the southern part of the Tethys is significantly greater than in Eastern Europe. The presence of pristidae and small carcharinids in southwestern Morocco and the Midawara Formation in Egypt (Adnet et al., 2010), where tropical conditions are well documented, indicates a warm climate also for Luna de Sus. Another evidence that supports this hypothesis is the absence of the genera that prefer cold waters such as *Centrophorus, Chlamydoselachus, Coupatezia, Echinorhinus* as well as the absence of hexanchiformes.

Alongside with the comparisons with the current fauna the palinological analyses indicate the existence of a warm climate (Petrescu & Balintoni, 2003). This is also confirmed by climate reconstructions based on oxygen and carbon isotopes. The measurements of these isotopes were carried out on specimens of *Nummulites perforatus* collected in the same locality, Luna de Sus, on Pavel Creek. For the interval that includes the fish fauna presented by us, an average annual temperature of 26° C was established, and for the next part a slight cooling tendency was recorded with an average temperature of 23-24° C (Bartholdy et al., 2000).

5.3. The faunistic community of Oligocene batoids from Suceag

The Suceag site was already known for a fish fauna but only based on otoliths (Reichenbacher & Codrea, 1999). This fauna consists of eight species of bony fish, the *Dapalis* genus being the dominant genus with three species of which *D. transylvanicus* represents more than 95% of the collected specimens. Fish teeth were reported only later, by Dica (2006) under the name? Sparidae indet.

The most recent collected material allowed the identification of two new cartilaginous fish families (Milyobatidae and Aetobatidae) that include two genera (*Dasyatis* and *Taeniurops*) with three species (*D. rugosa*, *D.* aff. *strangulata* and *T. cavernosus*) as well as confirming the existence of the Sparidae. It is important to note that this cartilaginous fish association is widespread in Western Europe and is present in Germany, Poland and the Netherlands. (Reinecke et al., 2011, 2014; Bor et al., 2012; Reinecke & Radwanski, 2015) but only in the Upper Oligocene or the Lower Miocene. This is the first time that this association is reported from the Lower Oligocene.

The previous reconstruction of the paleo environment (Reichenbacher & Codrea, 1999) for the Suceag outcrop (Chipcheș Valley) indicates a reduced salinity of the water with a probable lower freshwater supply than in the rest of the formation. We can confirm this conclusion, based on the comparison with the salinity preferences of the present species of *Dasyatis* (see previous comments and references from the Eocene fauna from the Luna de Sus). The trophic chain for these species is quite unclear yet. Within the formation crocodiles were encountered, but also a small shark identified only as belonging to the Superorder Galeomorphii which could constitute the peaks of the trophic chain in these waters.

5.4. The Badenian fauna from Romania

Unlike the Cenomanian fauna from Peștera or the Eocene one from the Luna de Sus, the Badenian fauna is found scattered in a rather large number of localities, especially on the western border of the Middle-Upper Miocene Basin of Transylvania, but also in a few marginal basins of the same age, such as Făget, Caransebeș and Mehadia. The specimens and taxa encountered are in small numbers in all occurrences, but this does not certainly reflect the faunal structure but probably the lack of representativeness of the fauna within the collections. This bias is due to both the modest outcrops and the prevalence of tougher rocks in some occurrences, rocks that

do not facilitate the collection of fish teeth. The illustrated and described taxa are common and reported from the entire Central Parathetys (Tab. 6).

We note the small number of genera from the Badenian of Romania, only the Sava basin (Slovenia) having a similar paucity of taxa, but in this case we also assume an incomplete collection of the existing taxa.

It is interesting to note in Romania the presence of large predators such as O. megalodon and H. serra, but also the absence, so far, of the bones of marine mammals. In the rest of Central Paratethys, however, this dual presence is confirmed by numerous occurrences (Fig. 35).

The palynological analyses indicate a warm, subtropical climate with average annual temperatures of 15-18° C and 1200 (Ţabără, Chirilă 2012, p. 200) or 1800 mm (Chira et al. 2000, p. 6; Petrescu 2003, p. 168) annual rainfall. The invertebrate fauna indicates a coastal and sublittoral habitat with normal salinity (Chira et al., 2000).

5.5. The Sarmatian (*s.s.*) faunal community of Sparidae and Latidae from Vârciorog

The fish fauna from Vârciorog was also analysed by other authors (Reichenbacher et al., 2018), but the taxonomic information and trophic relations data were limited by the exclusive analysis of otoliths. Otoliths revealed a fauna dominated by the Gobioidei, along with representatives of the families Atherinidae, Valenciidae, Aphaniidae and Blenniidae (Reichenbacher et al., 2018). Alongside these were mentioned teeth belonging to the Sparidae. Detailed analysis of fish teeth from this occurrence as well as isolated dentary fragments allowed us to add to the already known fauna four genera included in two families: Sparidae (*Diplodus* sp., *Sparus* sp., cf. *Pagellus* sp.) and Latidae (*Lates* sp.). This shows that an integrated approach can more accurately determine the taxonomic content of some deposits.

CONCLUSIONS

The present work brings new data to the field of Romanian paleoichthyology, through the material that we collected and prepared over the last 10 years. In brief, the thesis reports six families, ten genera and ten species that are all new for Romania. It also extends the geographical dispersion of eight species and the stratigraphic range of six species. Along with the new data, the study confirms the presence of some previously reported species and of some paleomedia determined on the basis of other vertebrate or invertebrate associations.

Given that the state of knowledge of fossil species in our country is still in an early stage, we have fulfilled the general objectives we had established:

- to enrich the taxonomic list at a national level;
- to systematicly reassess the already existing material from the Romanian collections;
- to make paleoecological interpretations based on faunal associations we discovered;
- to integrate the ichthyological associations that we discovered in the regional and continental context;
- to report and publish paleontological pieces of special value for the history of paleontology
- to create new research directions regarding the fossil fishes from Romania, based on dentition or other isolated skeletal elements that are to give a new impulse to the research in the field of paleoichthyology;

The identification of these taxa brings an important contribution to the paleontological knowledge on both national and regional levels. A large part of the taxa described herein are new for Romania and their record has two possible consequences: the expansion of the geographical area of occurrence of the species and/or the extension of the stratigraphic range of the species in question:

- The specimen from the Haţeg Basin that has been attributed to the Polyacrodontidae family, although incomplete and identified only at the family level, is the first elasmobranch discovered in the Maastrictian of Romania and the second known representative of the family in Romania.

- The specimen of *Echinorhinus* sp. from the Upper Cretaceous of Teliu represents the first report of the Echinorhinidae family and of the Echinorhinus genus in Romania and the Eastern Europe.
- The species of *Ptychodus altior* from Ormeniș represents the first mention of this species in Romania.
- **The Heterodontidae family**, with the two reports of the *Heterodontus* genus from the Eocene of Luna de Sus and from the Upper Cretaceous of the Peștera **represents a new taxonomic premiere for Romania**.
- **The *Hypotodus* genus (with the H. verticalis species)** in the Lower Bartonian from the Luna de Sus **is reported in Romania for the first time**
- The ***Jaekelotodus robustus*** species **is also reported in Romania for the first time**. The *Jaekelotodus* genus was already known, but the degree of preservation of the previously reported material did not allow the determination at the species level.
- The *Keasius parvus* report from the Oligocene of Cozla **completes the information about the dispersion area of the species** which was previously reported in several other localities of Romania.
- T**he *Macrorhizodus praecursor* species is reported for the first time in the northwest of the Transylvanian Basin,** having been known so far in Turnu Rosu only.
- The *Otodus* genus is widely discussed and **some of its species are described in Romania for the first time: *Otodus (Carcharocles) aksuaticus*,** identified in two occurrences, Turnu Roșu and Albești, **and *Otodus (Carcharocles) sokolovi***, from Cluj-Mănăștur, (Brebi Formation). Alongside these species, *Otodus (Carcharocles) angustidens, Otodus (Carcharocles) auriculatus, Otodus (Otodus) obliquus and Otodus (Megaselachus) megalodon* are discussed in detail. In the case of these species, both the geographical area of their signaling and their stratigraphic range have been extended. *Otodus* (*O.*) *obliquus* was reported for the first time south of the Carpathians, in Albesti, this being the second locality of provenance next to the previously known one, Turnu Roșu. ***Otodus* (*C.*) *auriculatus* was firstly reported in the northwest of the Transylvanian Basin (Huedin area), extending its dispersion area within the basin**, previously known only from Turnu Rosu. We have also

made a geographical extension for the *O. (M.) megalodon* species, previously known only from the Transylvanian Basin. The geographic area of this species has been widely extended, including now the Făget and Caransebeș-Mehadia Basins. Analysing the structure of the collections it became obvious that we deal with a bias concerning the taxa of fish teeth fossils present in the Romanian museums. *Otodus* comprises the largest number of specimens (197), a number that is eight to nine times more than any other genera of fossil fish identified in the country. It is obvious that *Otodus* was collected in a greater number due to its exceptional size, while the other smaller genera were much less noticed. Another conclusion in the study of *Otodus* was that the vast majority of specimens can only be attributed to the genus level because of a poor conservation status (lack of distinctive species' characteristics). Based on the taffonomic aspects, we consider that the teeth fossilised in an active environment located in high energy shore regions.

- *Cretalamna* sp. from Peștera (Cenomanian) represents the first report of the genus in the Mesozoic of Romania, previously being documented only in the Cenozoic (the Eocene of Turnu Roșu).
- *Truyolsodontos* sp. represents a recently described genus (Bernárdez, 2018); prior to this study it had been reported in three locations from the western and northern Europe only. **We report the Truyolsodontidae genus and family in Romania for the first time.**
- **The two morpho-species of *Squalicorax* from Peștera** confirm the presence of this genus in this locality, **but they also indicate a greater taxonomical diversity diversity than previously noted**.
- **The *Abdounia* genus is reported in northwestern Transylvania for the first time**, having previously been restricted to the Eocene of Turnu Rosu.
- **The *Protolamna* genus and the Pseudoscapanorhynchidae family represent another new report for Romania.** *Protolamna* sp. is part of the Cenomanian faunal association of Peștera.
- The *Rhizoprionodon ganntourensis* species, although previously reported in Romania (Dica, 2006; Ciobanu, 2002), is present in the fauna association of Luna de Sus and it represents **the oldest reported record from Romania; it's**

extending its known stratigraphic range from the Priabonian to the Lower Bartonian.

- **The *Galeocerdo eaglesomei* species is reported in Romania for the first time.** It is interesting to note the connection that this species makes with the tropical and subtropical fauna from the Eocene of North and Central Africa, as well as with the fauna of the northern Gulf of Mexico.
- **The stratigraphic range has also been significantly extended for the *Physogaleus secundus* species**. In this study, the species is reported in the Bartonian for the first time, extending its stratigraphic range (on the territory of our country) from the Priabonian to the Bartonian.
- **The *Hemipristis serra* species** is documented in the Badenian of Rachiș, and although it represents a common presence in the Miocene worldwide, it **is another first new report for Romani**a.
- **The Squatinidae family and the *Squatina* genus are new presence in the fossil fauna of Romania**. The genus is represented, for the moment, by a single specimen, identified in the Cenomanian of Peștera.
- ***Notidanodon* sp. is the oldest taxon illustrated and described in this work.** The specimen comes from an accidental discovery made in the Lower Cretaceous (Albian) of Fieni. Although isolated, the taxon is very important representing one of the few taxa found in the Lower Cretaceous of Romania. **Also, the current study represents the first report of the *Notidanodon* genus in Romania.**
- ***Hexanchus* sp.** discovered in the fauna from Peștera documents the first representative of the genus from the Mesozoic of Romania. The genus was previously reported only from the Eocene (Ciobanu, 2002), so **this discovery extends significantly its stratigraphic range in Romania.**
- After an extended discussion on the Pristidae family, multiple specimens belonging to the *Pristis* genus from the Lower Bartonian of the Luna de Sus and a specimen described previously from the fossiliferous point Someș-Dig (Priabonian) are analysed. Based on comparisons with the current specimens of *Pristis*, but also by comparison with the 42 fossil species described in the literature, we conclude that Pristis cannot be identified at the species level, the distinctive specific characters being difficult to highlight. The presence of

Pristis sp. in the Lower Bartonian from the Upper Moon extends the stratigraphic range of the genus in Romania from Priabonian to Bartonian.

- The *Anoxypristis* genus (Family Pristidae) is for the first time reported in Romania from the outcrops of Leghia and Turbuța.
- ***Rhinobatos* cf. *steurbauti* is another new species for Romania** and, at the same time, the oldest representative of the Rhinobatidae family. Undoubtedly, the extremely small dimensions (about 1 mm) have so far not allowed the paleontologysts to observe this representative of the *Rhinobatos* genus. The microscopic sorting of the disaggregated sediment from the Căpuș Formation will probably reveal new specimens or other small taxa.
- ***Turoniabatis cappettai*** from Peștera is another very small batoid, being **reported for the first time in Romania, as well as in southeastern Europe.** Currently, with an uncertain upper taxonomy (*Incertae subordinae* and *Incertae familiae*), the *T. cappettai* species is still only known from the Cenomanian of France and Spain and from the basal Turonian of Russia.
- ***Dasyatis cf jaekeli*** from Luna de Sus (Cluj County) **extends the stratigraphic range of the species in Romania** from Priabonian to the Lower Bartonian.
- ***Dasyatis* cf. *rugosa*,** discovered in lower Oligocene deposits that are located in **Suceag** (Cluj County) represents the first report of this species from the Rupelian in Romania and the oldest report of the species at European level **extending the entire stratigraphic range of the species in question**.
- ***Phacodus* cf. *punctatus* from the Lower Bartonian of the Luna de Sus represents a remarkable new discovery, being until now the only pycnodont fish found in northwestern Transylvania.** The species was also found in Romania in the Eocene of Turnu Roșu. T**he two localities represent the only known occurrences in Cezonoic of this species**. The *Phacodus* genus is one of the few genera of fish that survived the Cretaceous/Tertiary (K/T) limit documented in Romania.
- The Sparidae, although previously reported in Romania based on dental material, were identified only at family level. The only exception was the otolith from Coștei that allowed the identification of a genus. The present study significantly extends the knowledge of this family by identifying new occurrences and new genera/species for Romania. ***Diplodus jomnitanus* from**

Badenian from Gârbova de Sus (Alba county) is a species of the Sparidae family that is for the first time described from Romania. Genus *Pagellus* sp. from the Sarmatian *s.s.* of Vârciorog represents the f**irst report of the genus based on elements of the dentition, the first report from Sarmatian in Romania** and the **first report from this locality**. **The Sparidae from Turnu Roșu,** currently unidentifiable at species or genus level, **are the first report of this family from this locality.**

- *Lates* sp. from the Sarmatian (*s.s.*) of Vârciorog, documented by two dentary fragments, is the first report of this kind of fossil perch from Romania.
- *Esox* sp. from the Pliocene of Racoș (Brașov County) is the **first report of a fossil pike in Transylvania.**
- **The family Enchodontidae is reported in Romania for the first time in the Cenomanian of Peștera**. Although the presence of the family is argued on the basis of a single small tooth, we consider that the posterior border with double edges and the sigmoidal profile constitute sufficient morphological arguments for the family level of the tooth in question.

From the point of view of future research directions, we can consider two broad horizons of action, namely:

- a further exploration of the Transylvanian Basin formations for the outlining of the evolution of the Paleogene and Neogene fish fauna;

- a further exploration of the Cretaceous formations of Dobrogea in order to discover new fossiliferous points in this geographical area.

This work represents only one stage in the development of paleoichthyologic research, taking our study forward being a strong personal aspiration.

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