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CYLINDRACANTHUS (LEIDY, 1856) IN THE COLLECTIONS OF THE NATURAL HISTORY MUSEUM, SIBIU

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Abstract In this contribution, we describe a fossil specimen that is part of the Richard Breckner Collection of the Natural History Museum in Sibiu. The fossil was collected from the Eocene limestone of Turnu Roşu, Sibiu County. The systematic and anatomical position of this fossil represented the topic of numerous debates between palaeontologists. However, our study clearly demonstrates that the described specimen can be referred without doubt to the genus *Cylindracanthus* (Leidy, 1856a).

Keywords: *Cylindracanthus*, Eocene, rostrum

INTRODUCTION

This paper continues the task of revising the specimens of the "Richard Breckner" fossil collection (Ciobanu, 1998b, 2006, 2011a, 2011b, 2013; Ciobanu & Trif, 2012, 2014), hosted by the Natural History Museum in Sibiu, and which is likely the most valuable of its kind in Romania (Ciobanu, 1998a). It consists of a few thousand teeth of sharks and bony fish that document a very complex marine vertebrate association from the Eocene epoch. All these teeth (Fig. 1) have been collected near the village of Turnu Roşu, in Sibiu County. Unfortunately, since no detailed locality information is available for any of the specimens, only a general stratigraphic assignment can be made. However, as only Eocene limestone can be found outcropping near Turnu Roşu, all the fossils from the studied collection are considered as coming from these deposits.

Presently, the Eocene limestones from Turnu Roşu (Porceşti) are is part of a paleontological protected area. Situated to the south-east of Turnu Roşu, these limestone deposits represent an isolated patch of the sedimentary cover of the Transylvanian Basin. A large number of fossils have been collected here by members of the Transylvanian Society of Natural Science, an amateur association that subsequently founded the Natural History Museum of Sibiu. Richard Breckner was one of its members; he was also a curator of the Society's paleontological collection, who amassed a valuable collection of fish teeth throughout his years of activity (Ciobanu, 1998b).

Today, the Richard Breckner Collection is composed mainly of shark teeth, but next to them, there are also an important number of other vertebrate remains, such as crocodilian and bony fish teeth. One of these vertebrate remains has captured our attention and is described below.

MATERIAL AND METHODS

In this contribution, we describe an isolated fossil specimen from the paleontological reservation "Calcarele eocene de la Turnu Roşu (Porceşti)" ['The Eocene limestones from Turnu Roşu (Porceşti)']. The richness of the Eocene fauna recovered from these deposits has attracted the attention of scientists as early as the beginning of the 19th century, when several valuable systematic research activities were conducted in this area. The majority of the early paleontological studies referring to this particular area belong to members of the above-mentioned society.

Fig. 1 A small part of Richard Breckner Collection, Natural History Museum Sibiu

Eocene epicontinental deposits are outcropping north of the Făgăraş Mountains, on the southern edge of the Transylvanian Basin. Around the Turnu Roşu area, these Eocene formations appear like a klippe area on the north-western edge of the Făgăraş Crystalline. The latest concept regarding the age of the limestone levels at Turnu Roşu is developed by Mészáros (1996). He defined the Turnu Roşu Group, together with the included Valea Nişului, Strada Muntelui and Valea Satului formations, all of which contain fish teeth. The analysis of the fossils from these deposits reveals the existence of a rich Eocene marine fauna at Turnu Roşu (Ciobanu, 2004). The reservation areas where teeth and other fish fossils were recently collected are situated in the middle and lower parts of the Piscurilor Hill (Fig. 2), on the right side of the

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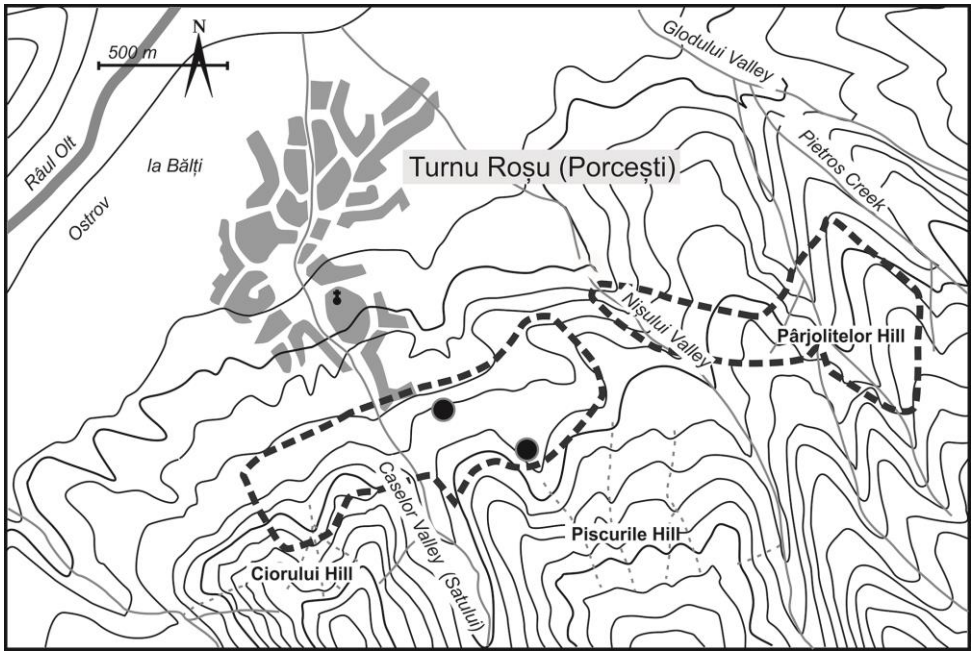

Fig. 2 Turnu Roşu (Sibiu) paleontological reserve (recent collecting points are marked)

Caselor (Satului) Valley, in Strada Muntelui Formation (Mészáros, 1996, p.43).
The studied material was observed under an Optika stereomicroscope and measured using a Unior electronic caliper with a measurement error of 0.02 mm.

SYSTEMATIC TAXONOMY

We follow here the systematic palaeontology scheme proposed by Parris et al. (2007, p.100)

Class Osteichthyes (Huxley, 1880)
Order Acipenseriformes *?* (Berg, 1940)
Family incertae sedis
Genus *Cylindracanthus* (Leidy 1856a)
Cylindracanthus sp.
(Fig. 3 a-h)

Type Species *Cylindracanthus rectus* (Agassiz 1843); type species according to Schultz (1987) and Parris et al. (2001); note that Parris et al. (2007) acknowledges *Cylindracanthus ornatus* (Leidy 1856a) as type of this genus.
Material: 1 isolated fossil (inv. no: 34317) from the Breckner Collection, Natural History Museum of Sibiu.
Origin: Eocene limestone from Turnu Roşu (Porceşti)

Diagnosis:
The below diagnosis is based on *Cylindracanthus rectus* (Agassiz 1843); in the original study, this fossil is described (under the name *Coelorhynchus rectus*) as having a circular section and a straight, very slightly conical rod-like morphology. There is an inner channel extending almost throughout the entire length of the element. In the amended diagnosis, Arambourg (1952) emphasizes the presence of deeply fluted longitudinal grooves with 40 to 55 ridges, as main characteristic feature of the taxon. He also states that no obvious bilateral symmetry or tooth base development is present. Parris et al. (2001) amended the description of this taxon again, and showed that the bilateral symmetry is, in fact, present. This is demonstrated by the shape and disposition of the internal canal(s), and by the paired grooves that might represent teeth bases. The number of ridges between the two grooves/tooth alveoli varies considerably. Arambourg (1952, p.272) and Weems (1999, p.61) both considered *C. rectus* as a typical member of the genus for the Eocene, while the range of the genus itself extends from the Cretaceous to the Eocene.
At least ten more species of the genus *Cylindracanthus* are described in the literature (e.g., Schultz, 1987), but their status seems more or less uncertain.

Remarks:
One can easily note that the descriptions of the different species attributed to *Cylindracanthus* are more or less sketchy. In general, it is stated that these remains are cylindrical, slightly conical, with external ridges running along the entire length of the element. The total number of ridges seems to be, for the moment, the only characteristic that differentiates between the species. However, beside this reliable character, two opinions of different authorities, together with their specific nuances, must be noted:
- one important note to consider is in Leriche's descriptions (1905, 1906) of *C. rectus*. Leriche makes a few notes relying on complete specimens. Like others before him, he remarks the cylindrical transversal section for the most part of the length, but, at the wider end of the element (i.e., the part that is supposed to join with the rest of the skull), he notes the existence of an important sulcus, a groove (*sillon* - in French) that deepens and widens rapidly towards the end. This groove, located on the presumed upper (dorsal) side, has a narrower equivalent on the inferior (ventral) side.
- a more "mainstream" description belongs to Fowler (1911, p.141) who writes about the genus: "...spine very

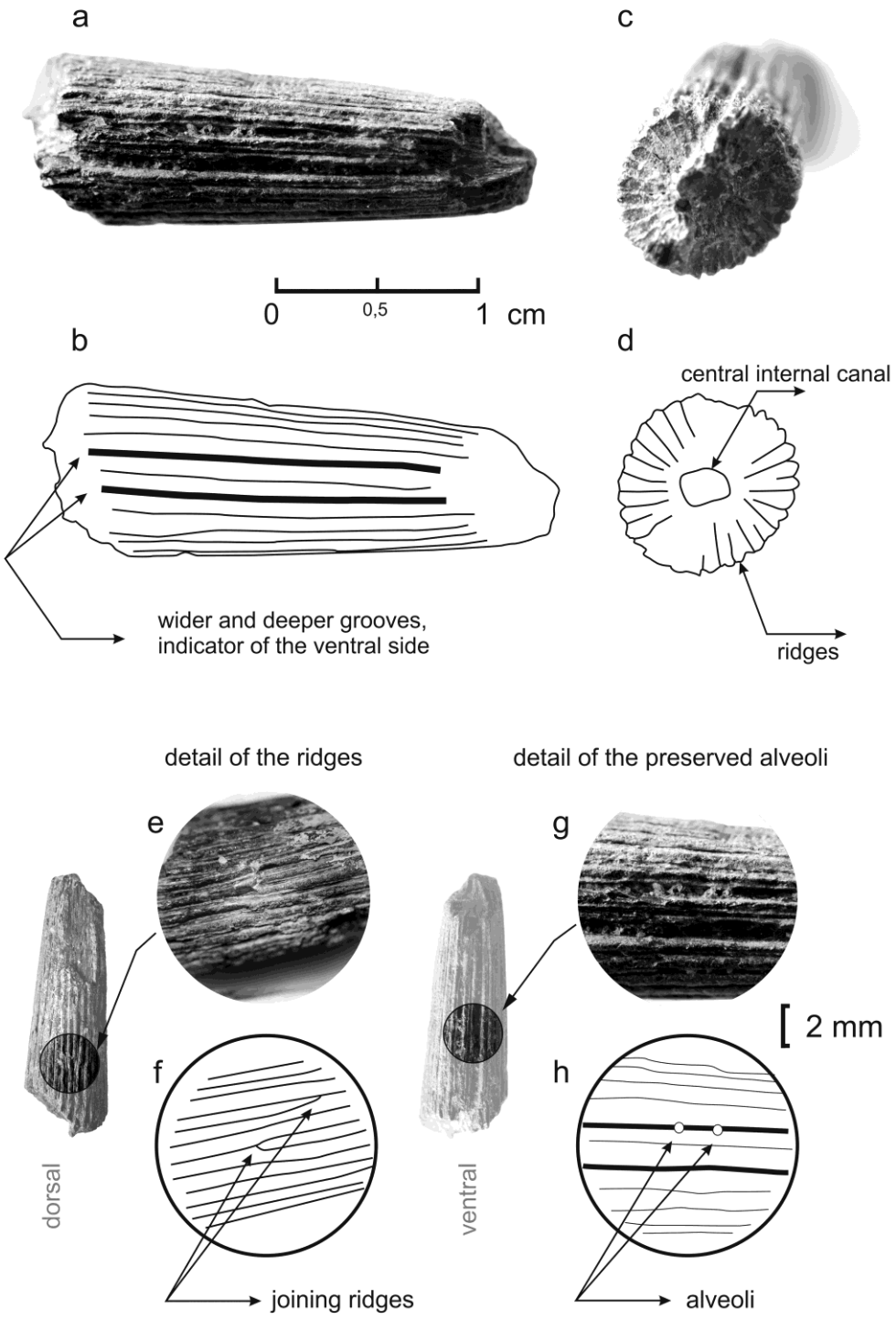

Fig. 3 The fossil specimen referred to *Cylindracanthus* sp. (inv. no: 34317): **a** lateral view of the specimen, and **b**, interpretative drawing; **c** natural transverse section of the specimen, and **d**, interpretative drawing; **e** details of joining longitudinal ridges, and f, interpretative drawing; **g** details of the alveoli, with **h** interpretative drawing.

long, slender, external face longitudinally ridged and grooved, each ridge corresponding to a wedge-shaped plate which forms small sector of spine. Central cavity relatively small, sometimes in part simple, but usually divided by median partition. Division plane passing through middle of partition, thus allowing spine to be readily split into two symmetrical halves". Fowler (1911, p.141, 142) described his *ornatus* specimens, and for the *acus* species he used the description from Cope (1870, p.294). The differences between species are minor, linked to size, the central canal, and the number of ridges. In regard to size, Cope (1870, p.294) indicates that *C. acus*

is smaller than *C. rectus* Agassiz and *C. ornatus* Leidy. It is important to note that Fowler recognizes the bilateral symmetry.

Description:
The specimen we report here is obviously only a fragment, most likely originating from the anterior part of the rostrum. The length of the fragment is of 25.7 mm; at its wider end, it has a diameter of 8.5 mm, while on the smaller end, this reduces to only 6.05 mm (Fig. 3a-b). The cross-section is circular and shows a central canal (Fig. 3c-d). The external surface seems to be a thick, deeply fluted enamel-like layer that shows 32 ridges. We observed a feature also described by Leidy (1856a, p.12), i.e., that some ridge pairs unite into single ones (Fig. 3e-f). Also, it is important to note the presence of two deeper grooves, slightly wider than the rest, which could represent the insertion place of blunted teeth as discussed by Parris et al. (2001). The two grooves are bilateral and symmetric, separated by only one pair of ridges. No actual teeth have been observed, but insertion places (the alveoli) appear to present (Fig. 3g-h).

DISCUSSIONS

In a regular fashion, all studies dealing with *Cylindracanthus* begin with observations such as "a perplexing taxon" (Stevens et al., 2011, p. 294) or "taxonomic problem" (Parris et al., 2001, p.161). Friedman (2012, p.116) states that *Cylindracanthus* has a tumultuous taxonomic history, being variously associated with chimaeroids (chondrichthyans related to sharks and rays), tetraodontiforms, billfishes (Schultz, 1987), and most recently, sturgeons (Parris et al., 2001).
The main issues that have made the subject of a vast majority of studies concerning *Cylindracanthus*-type fossils are related to their anatomical functionality, the position of these skeletal elements within the body, their systematic affinities, and their stratigraphic position.

Anatomical functionality and position:
The anatomical functionality position of this fossil is a long disputed subject. In more than 150 years since the genus was described by Leidy, generations of palaeontologists were puzzled by its anatomical functionality and position. In his first note, Leidy (1856a, p.12), while expressing his doubts, describes *Cylindracanthus* as "portions of ichthyodorulites" (dorsal spines). However, later the same year (Leidy 1856b, p. 302), he makes a new remark concerning *Cylindracanthus*: "The fossil fragments of long, conical bones, which I supposed to be portions of the dorsal spine of a fish, Prof. Agassiz informs me he considers to be the snout of a peculiar genus of sword fishes, which he has incidentally mentioned in the Poisson Fossiles, (t. v. p. 92,) under the name of *Coelorhynchus*. The correctness of this view I do not hesitate to admit..."
The position and function of the *Cylindracanthus* remains within the body of the fish is still debated. Already in the first years following its description two main opinions arose, and were sustained subsequently by various paleontologists: the first opinion held that *Cylindracanthus* was a portion of a dorsal spine, whereas the second one claimed that *Cylindracanthus* was in fact the snout of a billfish (a group composed by marlins and swordfishes).
The anatomical identity of the *Cylindracanthus* fossils was thus interpreted divergently by different authors. An analysis of more than 60 studies published until 1974, done by Shultz (1987), reveals that most studies referred this fossil to the swordfishes (rostrum) and placed it within different families of the suborder Xiphioidei. In other studies, it was allocated to Chimaeroids (as dorsal spine; e.g., Woodward, 1888, 1891; Jordan, 1917, 1923), to Tetraodontiformes (dorsal fin spine; Williamson, 1849), or it was considered more generally as an ichthyodorulit. The ichthyodorulites are an artificially created group that includes a great variety of spines, dermal armature elements, tubercles and other fish-related fossil remains; they belong to different genera, but they sometimes have similar morphologies.
An overlooked piece of information originating from Leriche (1905, 1906) states that complete specimens of *Cylindracanthus* have a size of near one meter in length, and this fact alone should obviously exclude the previously circulated opinions that *Cylindracanthus* might be a spine of a member of Tetraodontiformes or Chimaeriformes. Due to this argument, Leriche (1905, 1906) had firmly expressed the opinion that *Cylindracanthus* is the skeletal part representing Xiphiidae, more precisely it is a xiphiid rostrum. His affirmation might be now outdated since giant Chimaeriformes were recently uncovered and described (Gouiric-Cavalli et al., 2015). The size of this giant chimaera implies that its dorsal spine could have reached dimensions similar to that of the specimen Leriche described. However, no spine remains were found associated with mandibular tooth plates in the material reported by Gouiric-Cavalli et al. (2015).
Unfortunately, this type of fossil has not been associated with any other skeletal material, with one remarkable exception. Leriche (1908, 1910) stated that *Cylindracanthus* remains were associated with a vertebra that presented characteristics specific to the Xiphiidae. However, this association was later considered by Fierstine (1974, p. 36) to be circumstantial, and Parris et al. (2001, p. 162) stated: "the anatomical position of *Cylindracanthus* specimens remained unresolved".
Fierstine (1974, p. 43) attempted to resolve the anatomical identity of *Cylindracanthus* and to answer the question: bills or spines? It has been shown, however, that not even microscopic studies can shed light regarding the structure and nature of the fossil. It is not clear whether the internal structure of *Cylindracanthus* is composed of dentine (Carter, 1927) or of a cellular bone, as expected in a bill (Fierstine, 1974, p. 43; Habegger, 2014).
Friedman (2012, p. 116), in his study of *Cylindracanthus* fossils, considers that it is difficult to appreciate what their actual anatomical position was: fin spine or rostrum. In this regard, the confusion is linked mainly to the fact that no associated skeletal remains were ever found together with *Cylindracanthus*, allowing to establish a clear anatomical identity.
Lately, a new hypothesis emerged: *Cylindracanthus* could be a partial snout of an Acipenseriformes, an order

that includes sturgeons and paddlefishes, which leads to the conclusion that *Cylindracanthus* may represent a sturgeon-like rostrum (Parris et al., 2001). Finally, in opposition to the opinions of all the authors cited above, Stevens et al. (2011) stated that *Cylindracanthus* cannot be assigned to any fish order. A reassessment of the anatomical position of this genus, and consequently its affiliation to the cartilaginous or bony fishes, will likely be solved only by future studies.

Systematic affinities and stratigraphic position

It is not the purpose of our study to present a detailed taxonomic history, or even a taxonomic reassessment, of *Cylindracanthus*. However, we mention here briefly the main stages in its problematic taxonomic history, firstly, because this genus is mentioned now for the first time in Romania, and secondly, in order to highlight its synonymy with several other names in the old research literature that are, in fact, referring to the same type of fossil.

Agassiz (1833-1843, p. 92) described two species, *Coelorhynchus rectus* and *C. sinuatus*, from the London Clay of Sheppey. He considered these very elongated remains "becs" (in French, beaks), placing them into the Xiphiidae family.

Without reading Leidy's (1856 a) paper, and realizing that Agassiz was not aware that his suggested name, *Coelorhynchus*, was preoccupied, being used previously by another naturalist (Giorna, 1805), Leriche (1906, p.255) later revises the name, replacing it with *Glyptorhynchus* (with *G. rectus* as type species), to which he assigns a fossil from the Belgian Eocene. Fortunately, a few years later Leriche (1908, p. 382) amends his opinion and gives Leidy's name *Cylindracanthus* the necessary priority, but he also keeps the name *Glyptorhynchus* as valid, for a sub-genus of *Cylindracanthus* (Leriche 1910, p. 338). Leriche changes his mind again and, arguing that new characters were observed, erects *Glyptorhynchus* to the genus level (Leriche, 1925, p. 122). In 1966, Casier erects a new genus, *Aglyptorhynchus*, in order to replace some of the species of the genus *Glyptorhynchus* (Casier 1966, p. 303), suggesting this change because he considered the species that Leriche includes in this genus to be very different from one another. Casier (1966, p. 304) states that the forms that have a woody appearance (*ligneuse* – in French) and the ventral side covered by denticles are part of the new genus *Aglyptorhynchus* with type species *G. denticulatus* while the forms completely or partially crenulated are part of "*Cylindracanthus*" (with the type species *G. rectus*).

Summing up the above-mentioned opinions, Fierstine (1974, p. 43) states: "The "*Cylindracanthus* group" is a taxonomic chaos". He shows that Casier (1966) divided the group into two parts: the families Blochiide (Ord. heteromi) and Xiphiidae (Ord. Scombroidei). In order to clarify billfish classification, Fierstine (1974, p. 40) created a new taxonomic group, Xiphioidei *incertae sedis*, within Order Perciformes, without giving it a precise taxonomic hierarchy level. In the Xiphioidei *incertae sedis* he included two families, Paleorhynchidae and Blochiidae, with the latter one comprising the ?"*Cylindracanthus* group". Somehow reluctantly accepted as a member of Xiphioidei, with an uncertain position within Blochiidae (Fierstine, 1974; Schultz, 1987), it was argued that *Cylindracanthus* cannot represent a fish bill, since no teeth were ever found in the alveoli of the two grooves running along the (presumed) ventral part of the fossil (Fierstine, 1974).

More recently, Parris et al. (2001) made a reassessment of the genus based on the study of new specimens from Campanian deposits of South Dakota and Alabama. Several interesting remarks were made by these authors: the observed specimens actually presented teeth in the already well known, thoroughly described bilateral grooves, and, a "sulcate groove" is reported on the side opposite of the bilateral grooves that are now interpreted as marking the dorsal side. This description is thus very important, because it documents for the first time a clear, bilateral symmetry of the fossil, with the identification of the ventral and dorsal sides, as well as that of the actual teeth, whose presence has only been conjectured so far.

Taking into account the position of the teeth and the way the rostrum is inserted, Parris et al. (2001, p. 169–170) suggested a possible relationship of *Cylindracanthus* with Acipenseriformes, more specifically with sturgeons (with a closer resemblance to juveniles). They also emphasized that the fossil record of this group is substantial in the sediments of about the same age as those yielding *Cylindracanthus*. From all known actinopterygians, the Acipenseriformes seems to be the only group of fishes that have a rostrum with no evidence of an occluding lower jaw. Finally, Parris et al. (2001) argued that the inclusion of *Cylindracanthus* within xiphioidei would make it the oldest record of this group, but in such a case the hypothesized cartilaginous nature of *Cylindracanthus* (as suggested by the lack of additional skeletal remains) stands in contrast with the bony skeleton of present-day xiphioids. To support their idea about the relationship between *Cylindracanthus* and Acipenseriformes, Parris et al. (2001) noted that, just like *Cylindracanthus*, the Acipenseriformes also had a good fossil record during the Cretaceous, crossing with success the Cretaceous/Paleogene Boundary, but fading during the next period once perciforms evolved. Although acipenseriforms themselves are extant, *Cylindracanthus* did not survive, becoming extinct at the end of the Eocene (Parris et al., 2001, p. 169–170).

In the framework of a recent re-description of the members of Blochiidae from the middle Eocene of Monte Bolca in Italy, Fierstine & Monsch (2002) also discussed *Cylindracanthus*. A wider cladistic analysis of Blochiidae has been attempted in order to reveal the phylogenetic position of *Blochius* among related genera; during this cladistic analysis, *Cylindracanthus* had to be excluded because of its ambiguity (Fierstine & Monsch, 2002, p. 146). Their conclusion was that the phylogenetic position of *Cylindracanthus*, and also that of other members of the "*Cylindracanthus* group," remains unresolved.

Another interesting position is expressed by Monsch (2005, p. 466-467, 484) who, while revising the scombroid fishes from the Cenozoic of England, also manifested serious scepticism regarding the referral of *Cylindracanthus* within billfishes by Casier (1966) and Schultz (1987). He placed the *Cylindracanthus* fossil remains "known from rostra only, which bear two

dentigerous zones which are separated by a narrow median edentulous zone", with nutrient canals variable, into the suborder Scombroidei (Bleeker, 1859), Incerti Tribus as the new genus *Aglypthothynchus* (Monsch, 2005, p.466). The fossil remains whose diagnosis is "rostra with almost circular cross-section, whole outer surface with parallel lengthwise grooves, two large and two small canals (sometimes the small canals are missing) and two narrow, widely separated tooth rows" belong to the genus *Cylindracanthus* Leidy, placed as a non-Xiphiinae incertae sedis subfamily (Monsch, 2005, p.484)

In a later paper, Parris et al. (2007, p. 100–101) synthesized and compared the major characteristics of the Acipenseiformes, of billfishes, and of *Cylindracanthus*. as far as the latter is concerned, the authors considered that its fossil record starts with the Cretaceous. Its main characteristics are its cylindrical bony rostrum with bilateral symmetry, and a most likely cartilaginous skeleton.

Parris et al. (2001, 2007) also made several comments regarding the evolution of the genus. Examining a large number of specimens, they observed that the teeth of the Eocene specimens are much smaller than those of the Cretaceous ones, hence they hypothesized a gradual reduction of the already vestigial dentition. They even go as far as to consider these changes in the development of the teeth to represent a biostratigraphic indicator. Finally, Parris et al. (2001) proposed that *Cylindracanthus rectus* was a descendant of *C. ornatus*, with a separate lineage leading to *C. acus*.

As a result of extensive research in the literature, and after a long consideration of various authors' opinions, it is now obvious that many questions remain yet unsolved. One of these refers to the functionality of the very small teeth observed on the bilateral ventral grooves. If the assessments of Parris et al. (2001) concerning the lack of functionality and the vestigial character of the *Cylindracanthus* teeth are correct, then we might rightly wonder: who was the ancestor of *Cylindracanthus* that developed these teeth and used them as functional ones?

Another question might also arise: Is it possible that a certain number of the fossil taxa is represented only by different sections of the same skeletal part, e.g., the rostrum?

CONCLUSIONS

The fossil specimen described in this paper as pertaining to the genus *Cylindracanthus* (Leidy, 1856) is the first report of this controversial taxon in the Eocene deposits of Romania, and in the "Turnu Roşu (Sibiu) Eocene limestones" paleontological protected area. Although it does not add to our knowledge concerning the skeletal identity, function and systematic affinity of *Cylindracanthus*, the Turnu Roşu occurrence represents a new important data point for the stratigraphic and geographic distribution of this enigmatic fossil fish.

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