A review of otoliths collected by W. Weiler from the Badenian of Romania and by B. Strashimirov from Badenian equivalents of Bulgaria

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The early Badenian represents the last period of unrestricted marine connectivity with adjacent oceans in the history of the Paratethys. A comprehensive capture of the fish fauna roaming the early Badenian seas of the Paratethys is necessary to fully comprehend the endemic evolution that took the stage following its isolation during the Serravallian (late Badenian in the Central Paratethys and Karaganian and Konkian in the Eastern Paratethys). Many publications have dealt with early Badenian otolith-based fish assemblages in the northern and western parts of the Central Paratethys, but coeval faunas from the southeastern Central Paratethys and the Eastern Paratethys are scarce and in dire need of revision.

Here I present a review of the rich otolith assemblage described by Weiler in 1950 from the early Badenian of Coşteiu de Sus and Lăpugiu de Sus in Romania and update their identifications. The review results in the recognition of a number of new species, i.e. *Aulopus costeiensis* n. sp., *Bathypterois solidus* n. sp., *Myripristis lobata* n. sp., *Lesueurigobius magniiugis* n. sp., *Weilerigobius lapugiensis* n. gen., n. sp., *Callanthias transylvanicus* n. sp. and *Pagellus schuberti* n. sp. A comparison with the well known otolith-based fish faunas from the northern and western Central Paratethys reveals good correlation, but nearly one quarter of all fish species are not recorded from there. The most likely explanation of this phenomenon is a latitudinal / climatic difference and probably a greater influence of Eastern Paratethyan elements in Romania. A much smaller collection from Badenian equivalent strata of wells in Bulgaria, inherited from B. Strashimirov, was also studied. It contained the first fossil record of the gobioid family Microdesmidae - *Microdesmus paratethycus* n. sp. This collection is dominated by very small otoliths that appear to have been collected in the course of search for microfossils and hence shows many small fish representatives missing from the Romanian locations. The role of collecting bias versus potential faunal differences is discussed with this example.

It is concluded that the knowledge of the early Badenian otolith-based fish fauna of the Central Paratethys is much improved, albeit far from being completely assessed. Important additional data, however, are more likely to be expected from coeval Eastern Paratethyan strata when comprehensively collected and older material being reviewed, if still available.

Key words: Central Paratethys, Eastern Paratethys, Teleostei, Aulopiformes, Gobioidei.

Introduction

The rich early Badenian faunas from Coşteiu de Sus (= Kostej) and Lăpugiu de Sus (= Lapugy) have been known since the late 19th century (Hoernes &Auinger, 1884 and Boettger, 1902; see Gaal, 1912 and Landau *et al*., 2009). The molluscs particularly are known for their exceptional preservation and have also been the subject of many publications in recent times (Caze *et al*., 2010; Kronenberg & Harzhauser, 2011; Harzhauser & Kronenberg, 2013; Tămaş *et al*., 2013).

The chronostratigraphic correlation of the middle to late Miocene sequences of the various Paratethyan subbasins is chronically complex and currently under review and re-evaluation. Recently, the basal Badenian flooding event has been identified as a diachronous event across the Pannonian Basin (Sant *et al*., 2017). The southern and eastern regions of the Pannonian Basin were flooded later than the northern and western regions during the early Badenian, transgressing over a non-marine sediment sequence of early to middle Miocene age (Mandic *et al*., 2012). The early Badenian strata of Coşteiu de Sus and Lăpugiu de Sus thus would have been deposited during a time interval belonging to the upper Lagenidae Zone as shown in Pezelj *et al*. (2013) and be more or less time equivalent to the Tshokrakian (Ćorić *et al*., 2009) between about 14.5-14.0 Ma.

First finds of otoliths have been mentioned occasionally, for instance by Prochazka (1893) and Schubert (1906). The first figured otoliths from Lăpugiu de Sus are found in Schubert (1912), but it is in the monograph of Weiler (1950) based on Boettger's collection that a comprehensive description of otoliths of both locations has been achieved. Later Rado (1981) published a summary review of otoliths of both locations and other Langhian localities in southern Romania (in Romanian), but she did not add new taxonomic records. Nolf (1981) revised the material of Schubert, but could not find all specimens recorded by him and therefore left several as of doubtful nature. Nolf also reviewed Weiler's types from 1950 and offered revisions for the taxa in his handbooks on otoliths in 1985 and 2013. A comprehensive review of the material of Weiler's monograph, however, was never performed or published. The purpose of this study is to update the interpretation of the otolith collections from Coşteiu de Sus and Lăpugiu de Sus described by Weiler, since it represents one of the largest and most diverse otolith assemblages from the Badenian of the southern Pannonian Basin. I soon realized that it would contain fishes not present in the well known otolith associations of the Vienna Basin and the northern Pannonian Basin, possibly because of latitudinal differences. Also, it is of importance to achieve a good understanding of the Langhian otolith assemblages of the Paratethys because they represent the last truly marine fish fauna spread across the basin without geographic obstacles prior to the final separation of the Paratethys and the onset of its endemic evolution.

Also included in this study are some otoliths collected from wells in the Eastern Paratethys in Bulgaria by the late B. Strashimirov and covering a similar time interval from Tarchanian to Konkian. The result of the revision of Weiler's specimens is summarized in Table 1. The following systematic part only contains descriptions of new species and species for which a revision of the taxonomic allocation is proposed (see also Table 1). Specimens mentioned by Schubert (1912) from Lăpugiu de Sus are also listed in Table 1, but have not been subject of this review. The result of the specimens collected by Strashimirov is summarized in Table 2. These otoliths originated from wells and apparently have been obtained while searching for microfossils in a very fine fraction. For the most part it comprises unpublished material.

Material and methods

Weiler's otoliths are stored at the Natur-Museum und Forschungsinstitut Senckenberg in Frankfurt/Main, Germany (SMF) under the registry P. (Pisces) and the newly catalogued ones under the registry PO. (Pisces, otoliths). Strashimirov's otoliths are housed at the Museum of Geology and Paleontology, University of Mining

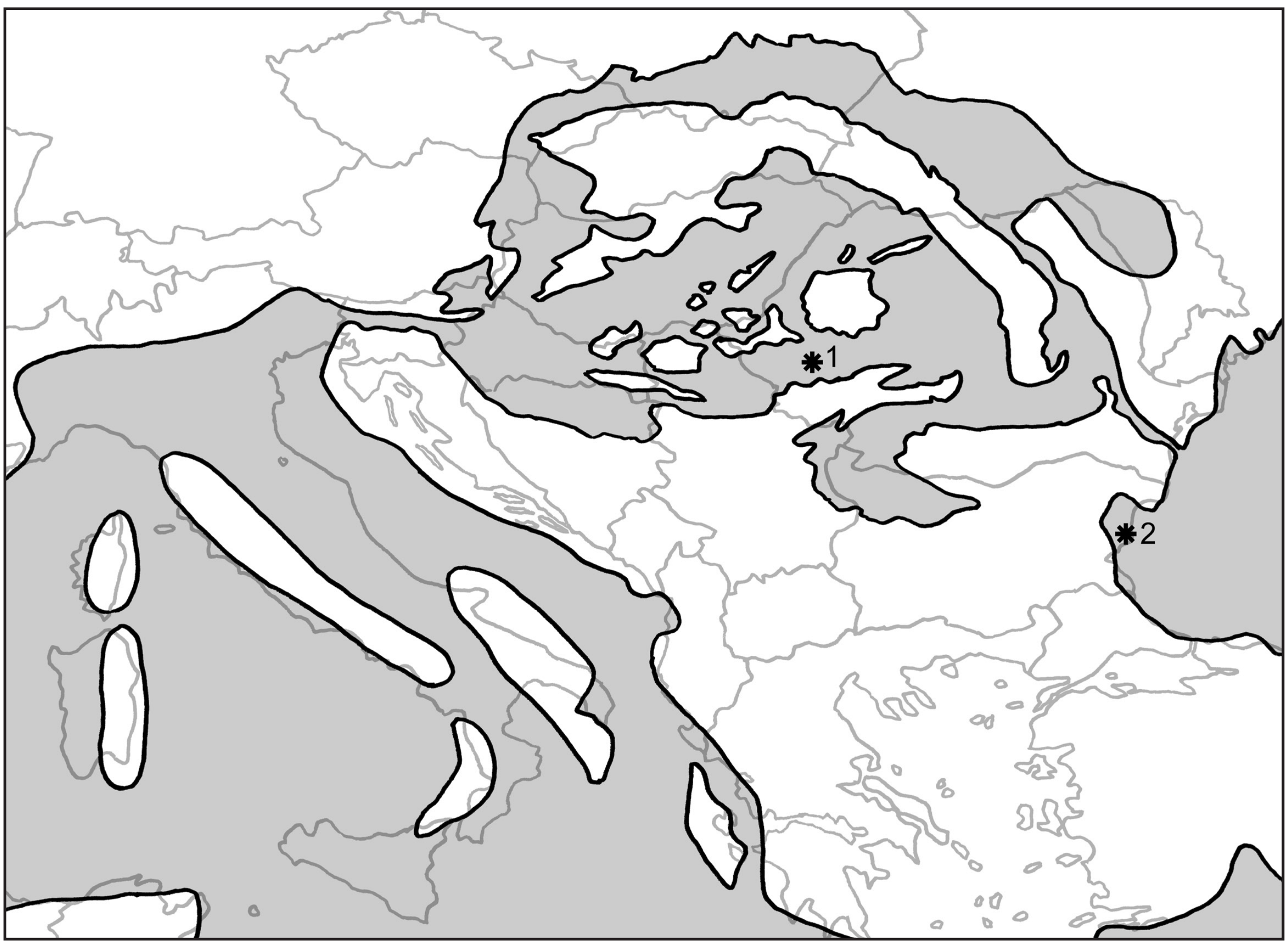


Figure 1. Paleogeographic map of the Central Paratethys and adjacent seas during the early Badenian (after Sant *et al*., 2017); marine terrain shaded. Locations are marked with an asterisk: 1) Coşteiu de Sus and Lăpugiu de Sus in Romania, 2) wells in Bulgaria. Northing is vertical up.

and Geology 'St. Ivan Rilski', Sofia, Bulgaria (UMG) under the registry -X. Otoliths were photographed with a Canon EOS camera mounted on a Wild M400 photomacroscope and remotely controlled from a computer. Individual photographs were stacked using the Helicon-Focus software. Small inconsistencies were retouched and contrast enhancement was occasionally performed with Adobe Photoshop. Several otoliths from Coşteiu de Sus have small, black, oily speckles on the surface which can not be removed without inflicting damage to the specimens. These speckles do not obliterate morphological features, but negatively affect the clarity of photographs. To achieve better clarity of the pictures, these pigmentations have been selectively brightened during the digital retouching process. All otoliths are depicted from the right side and show inner faces if not annotated otherwise in the captions. Left side otoliths are reversed for a better comparison and are annotated in the captions with (r).

The morphological terminology of otoliths was established by Koken (1891) with amendments by Weiler (1942), Schwarzhans (1978) and for gobiids Schwarzhans (2014). The morphometric measurements of otoliths follows Schwarzhans (2013a).
The following abbreviations are used in the descriptions:

OL otolith length
OH otolith height
OT otolith thickness
OsL ostium length
CaL cauda length

The rostrum length is measured from the tip of the rostrum to the level of the deepest point of incision of the excisura and calculated as percentage of OL.

Other abbreviations used in the text:

NSMT National Science Museum, Department of Zoology, Tokyo, Japan.
SMF Natur-Museum und Forschungsinstitut Senckenberg in Frankfurt/Main, Germany.
UMG Museum of Geology and Paleontology, University of Mining and Geology 'St. Ivan Rilski', Sofia, Bulgaria.
WAM Western Australian Museum, Perth, Western Australia, Australia.

Systematic part

The systematic scheme follows Nelson *et al.* (2016) except Apogonidae included in Gobiiformes following Thacker & Roje (2009) and Sciaenidae included in Perciformes.

Order Anguilliformes Regan, 1909
Family Congridae Kaup, 1856
Genus *Pseudophichthys* Roule, 1915

***Pseudophichthys* sp.**
Plate 1, fig. 1

1950 Otolithus [Congridarum] sp. – Weiler, pl. 5, fig. 29; ? pl. 12, fig. 93.
1992 *Pseudophichthys* sp. – Radwanska, text-fig. 15, pl. 3, figs 10-12.
2014 *Pseudophichthys* sp. – Schwarzhans, pl. 1, fig. 3.

Material examined – One specimen, SMF P.2791, Coşteiu de Sus.

Description – Single otolith about 2.8 mm long with somewhat eroded and leached surface. Elongate shape, OL:OH = 1.95 and OH:OT = 2.1. Anterior tip distinctly sharper than broadly rounded posterior tip including the pronounced and broadly rounded postdorsal angle. Sulcus positioned on center of inner face and inclined at an angle of about 8°. Sulcus closed anteriorly and showing a distinct, uniform and oval colliculum terminating far from anterior rim of otolith.

Discussion – Otoliths of *Pseudophichthys* have been occasionally recorded from the early Badenian of Poland (Radwanska, 1992), Moravia (Brzobohaty pers. com.) Romania (Weiler, 1950) and the Serravallian of SE-Turkey (Schwarzhans, 2014). All specimens are likely represent the same, as yet undescribed species, but none of the material identified so far is well enough preserved for an adequate definition. Characters distinguishing otoliths of the genus *Pseudophichthys* and related genera are few and delicate requiring particularly good preservation and understanding of variability.

Order Stomiiformes Regan, 1909
Family Sternoptychidae Dumeril, 1806
Genus *Valenciennellus* Jordan & Evermann, 1896

***Valenciennellus* sp.**
Plate 1, fig. 3

1950 Otolithus inc. sed. sp. 5 – Weiler, pl. 8, fig. 61

Material examined – One specimen, SMF P.2832, Lăpugiu de Sus.

Discussion – The single, very small otolith of less than 1 mm length is slightly eroded particularly along the rostrum, which is incomplete. Two nominal species of the genus *Valenciennellus* have been described from the middle Miocene: *V. weinfurteri* (Brzobohaty & Schultz, 1978) (as *Argyropelecus weinfurteri*) from the Badenian of Borać in the Czech Republic and *V. kotthausi* Steurbaut, 1979 from the Langhian of the Aquitaine Basin. Brzobohaty & Schultz synonymized Weiler's record from Lăpugiu de Sus with *V. weinfurteri*, but later Brzobohaty & Nolf (2002) found arguments to synonymize *V. weinfurteri* with the extant *V. tripunctulatus* (Esmark, 1871).

The Recent specimens, however, are generally slightly more compressed and with a shorter rostrum as the ones from the Badenian (see Rivaton & Bourret, 1999 and Brzobohaty & Nolf, 2002 for extant otoliths) and therefore the synonymization of *V. weinfurteri* may require review. The singular specimen from Lăpugiu de Sus is too poorly preserved to warrant further discussion and is therefore left here in open nomenclature. Otoliths of *V. kotthausi* are well distinguished by the less compressed outline.

Family Gonostomatidae Gill, 1893
Genus *Gonostoma* Rafinesque, 1810

***Gonostoma*? *cyclomorphum* (Weiler, 1950)**
Plate 1, figs 4-7

1950 *Argentina cyclomorpha* Weiler, pl. 7, fig. 53.
2002 *Bonapartia* sp. – Brzobohaty & Nolf, pl. 1, figs 3-5.
?2002 *'genus Gonostomatidarum'* aff. *hoffmani* Nolf & Brzobohaty, 2001 – Brzobohaty & Nolf, pl. 2, fig. 5
2013 *'Gonostomatida' cyclomorpha* (Weiler, 1950) – Nolf, pl. 48.

Material examined – Thirteen specimens: one specimen, SMF P.2828 (Weiler's holotype), Lăpugiu de Sus; three specimens, UMG-X 8547, Tarchanian, well Goren Blisnak C-2, 143.4-145.5 m; three specimens, UMG-X 8558, Tarchanian, well Goren Blisnak C-55, 180.3 m; five specimens, UMG-X 8561, Tarchanian, well Goren Blisnak C-55, 176.5 m; one specimen, probably Tarchanian, UMG-X 8603, well Dolen Blisnak C-5, 40 m.

Discussion – These otoliths rarely exceed 1 mm length. They are characterized as gonostomatids by the cauda being somewhat widened at its central portion and in fact being wider than the short ostium. The otolith outline is moderately rounded, but somewhat variable, often with a pronounced postdorsal angle and with a short, thin, pointed rostrum, which is rarely completely preserved. The short rostrum is the main difference from otoliths of the genus *Gonostoma*. It is quite possible that these otoliths represent an extinct gonostomatid genus, but such a conclusion would be premature at a time when extant gonostomatid otoliths are still insufficiently known. Nolf (1985, 2013) also considered these otoliths as gonostomatids of uncertain relationship while Brzobohaty & Nolf (2002) placed them with the genus *Bonapartia*. *Gonostoma*? *cyclomorphum* appears to be a widespread bathypelagic fish in the early Badenian and particularly in the Tarchanian of the Eastern Paratethys.

Family Phosichthyidae Weitzman, 1974
Genus *Woodsia* Grey, 1959

***Woodsia emi* Brzobohaty & Nolf, 2002**
Plate 1, fig. 8

2002 *Woodsia emi* Brzobohaty & Nolf, pl. 2, figs 16-17.

Material examined – One specimen, UMG-8598, Tarchanian, well Goren Blisnak C-2, 143.4-145.3 m.

Discussion – *Woodsia emi* is a rare bathypelagic species of the early Badenian first described from the Czech Republic and now also recorded from the Tarchanian of Bulgaria (Eastern Paratethys). It differs from *Gonostoma*? *cyclomorphum* in the shape of the posterior rim, which is inclined downward/backward, characterized by a strongly protruding postventral lobe, and the less well structured sulcus.

Order Myctophiformes Regan, 1911
Family Myctophidae Gill, 1893
Genus *Diaphus* Eigenmann & Eigenmann, 1890

***Diaphus* aff. *obliquus* (Weiler, 1943)**
Plate 1, fig. 11

1943 *Scopelus obliquus* Weiler, pl. 1, figs 20-21.
1950 *Scopelus obliquus* Weiler, 1943 – Weiler, pl. 7, figs 48-50, 64.
2013 *Diaphus obliquus* (Weiler, 1943) – Schwarzhans & Aguilera, pl. 9, figs 16-17.

Material examined – One specimen, SMF P.2864 (identified as *Scopelus debilis* by Weiler, 1950), Lăpugiu de Sus.

Discussion – *Diaphus obliquus* was redefined by Schwarzhans & Aguilera (2013, p. 123), while Nolf (2013) held it as doubtful species. It is characterized by a compressed outline (OL:OH = 1.0-1.05) with a rounded predorsal rim, a completely flat inner face combined with a rather strongly convex outer face, a distinct rostrum and 4 to 5 strong denticles on the ventral rim. It is probably an endemic species of the late Badenian of the Paratethys found in deep water environments of that time. The majority of the specimens identified by Weiler (1950) as *Scopelus debilis* (Koken, 1891) (SMF P.2821, 2822/2-3, 2856, 2862, 2863) belong to *Diaphus austriacus* (Koken, 1891) (Pl. 1, fig. 9), which is characterized by its slightly more elongate shape (OL:OH = 1.1-1.25), a convex inner face, an anteriorly pronounced dorsal rim, a short rostrum not longer than the antirostrum and 6 to 8 small denticles on the ventral rim. One specimen also identified by Weiler as *Scoeplus debilis* (SMF P.2822/1) (Pl. 1, fig. 10) represents *Diaphus kokeni* (Prochazka, 1893) and is characterized by a nearly flat inner face and convex outer face, a relatively short rostrum, a marked and sharp postdorsal angle and 6 to 8 denticles on the ventral rim. Finally, still another specimen identified by Weiler as *Scopelus debilis* is here regarded as tentatively associated with *Diaphus obliquus* (Pl. 1, fig. 11). The flat inner face,

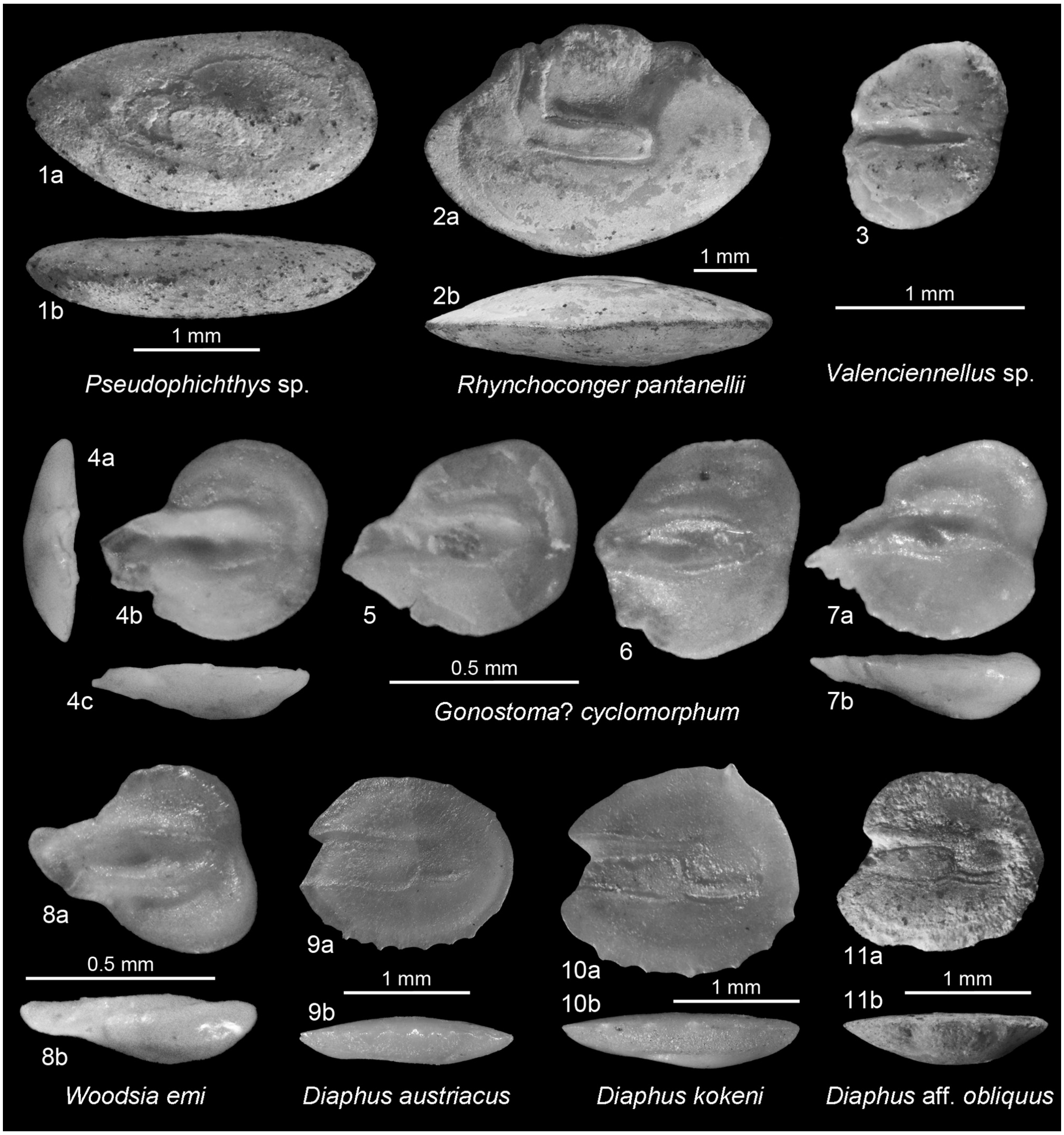


Plate 1

1. *Pseudophichthys* sp., SMF P.2791, Coşteiu de Sus.
2. *Rhynchoconger pantanellii* (Bassoli, 1906), SMF P.2789, Coşteiu de Sus.
3. *Valenciennellus* sp. (r), SMF P.2832, Lăpugiu de Sus.

4-7. *Gonostoma*? *cyclomorphum* (Weiler, 1950), Tarchanian, Bulgaria, 4: UMG-X 8603, well Dolen Bliznak C-5, 40 m; 5 (r): UMG-X 8547, well Goren Bliznak C-2, 143-145 m; 6 (r): UMG-X 8558, well Goren Bliznak C-55, 180 m; 7: UMG-X 8561, well Goren Bliznak C-55, 176 m.

8. *Woodsia emi* Brzobohaty & Nolf, 2002, (r), UMG-X 8598, Tarchanian, Bulgaria, well Goren Bliznak C-2, 143-145 m.
9. *Diaphus austriacus* (Koken, 1891), SMF P.2822/2, Coşteiu de Sus.
10. *Diaphus kokeni* (Prochazka, 1893), SMF P.2822/1, Coşteiu de Sus.
11. *Diaphus* aff. *obliquus* (Weiler, 1943), (r), SMF P.2864, Lăpugiu de Sus.

strongly convex outer face and general appearance are closely similar, but the rostrum is longer than in the late Badenian specimens (see Schwarzhans & Aguilera, 2013 for figures) and consequently the index OL:OH is larger (1.15 vs 1.0-1.05). Unfortunately, the single specimen is not very well preserved and in particular its denticles on the ventral rim are eroded. It is possible that it represents an as yet undescribed species related to but older than *D. obliquus*.

Order Aulopiformes Rosen, 1973
Family Aulopidae Bonaparte, 1831
Genus *Aulopus* Cloquet, 1816

Aulopus costeiensis **n. sp.**
Plate 2, fig. 1

1950 Otolithus inc. sed. sp. 1 – Weiler, pl. 6, fig. 39.

Holotype – Pl. 2, fig. 1, SMF P.2819, Romania, Banat, Coşteiu de Sus, middle Miocene, early Badenian, during deposition of the upper Lagenidae Zone.

Etymology – Named after the type-locality Coşteiu de Sus.

Diagnosis – OL:OH = 1.8. Rostrum short. Projection of postdorsal portion of posterior rim distinct, but not expanded vertically. Inner face slightly twisted along long axis. Ostium very short. CaL:OsL = 2.4. Cauda slightly curved downward towards posterior and slightly widened.

Description – A moderately large, elongate otolith of 4.5 mm length. OH:OT = 2.0. Rostrum short, blunt, but with pointed tip; excisura and antirostrum minute. Ventral rim regularly curved, shifted towards anterior. Dorsal rim slightly shallower curved than ventral rim, shifted towards posterior. Posterior rim almost parallel to anterior rim with pronounced, broad and rounded postdorsal projection. All rims smooth.
Inner face very slightly convex, somewhat twisted along long axis. Sulcus moderately deep, slightly inclined, with very short and narrow, anteriorly opened ostium and slightly, regularly bent, long cauda terminating close to posterior-ventral rim of otolith. Posterior half of cauda slightly widened dorsally. Distinct but narrow dorsal depression; ventral field smooth without ventral furrow. Outer face slightly more convex than inner face, smooth.

Discussion – Aulopid otoliths have occasionally been described from Paleogene strata (Nolf, 2013), but this is the first record in the Neogene. The family Aulopidae is a small family with four extant genera and 12 species (Froese & Pauly, 2017) and otoliths are available to me from three of these genera and five species. They are all characterized by the sulcus shape and proportions, the massive posterior-dorsal projection and the slight twist of the inner face along the long axis. Two species of the genus *Aulopus* occur in the Atlantic and Mediterranean, *A. filamentosus* (Bloch, 1792) (see Lombarte *et al*., 2006 for figures of Recent otoliths), and restricted to the tropical eastern Atlantic *A. cadenati* Poll, 1953. *Aulopus costeiensis* differs from both species in the slightly convex dorsal rim with the postdorsal projection not being expanded vertically (vs depressed at its middle section and the postdorsal projection also being vertically expanded) and the widened posterior half of the cauda. It differs from otoliths of *A. cadenati* additionally in being more compressed (OL:OH = 1.8 vs 2.2).

Family Ipnopidae Gill, 1885
Genus *Bathypterois* Günther, 1878

Bathypterois solidus **n. sp.**
Plate 2, fig. 2

Holotype – Pl. 2, fig. 2, SMF P.2851, Romania, Banat, Coşteiu de Sus, middle Miocene, early Badenian, during deposition of the upper Lagenidae Zone.

Etymology – From *solidus* (Latin) = stable, compact, referring to the massive appearance of the otolith.

Diagnosis – OL:OH = 1.7. OH:OT = 1.9. Rostrum short, massive. Dorsal rim high, rounded, anteriorly depressed, concave. Inner face nearly flat; outer face distinctly convex. Ostium short, ventrally widened. CaL:OsL = 2.3. Cauda narrow, straight.

Description – A relatively large, thick, robust, moderately elongate otolith of 5.6 mm length. Rostrum short, massive, with pointed tip; no excisura or antirostrum. Ventral rim moderately deep and regularly curved, deepest slightly anterior of its middle. Dorsal rim high posteriorly, its anterior third depressed, slightly concave, without distinct angles. Posterior rim broadly rounded, slightly dorsally pronounced. All rims smooth.
Inner face nearly flat. Sulcus moderately deep, slightly inclined, with very short and widened, anteriorly opened ostium, positioned entirely on rostrum and narrow, straight, long cauda terminating at some distance from posterior rim of otolith. Dorsal field without distinct dorsal depression, anterior region of dorsal field along depressed anterior-dorsal rim strongly bent outwards (best seen in dorsal view; pl. 1, fig. 13c); ventral field smooth without ventral furrow. Outer face strongly convex, smooth.

Discussion – Ipnopid otoliths show a relatively high degree of morphological diversity, with those of the genera *Bathymicrops, Bathythyphlops* and *Ipnops* being small, compressed and with a reduced sulcus morphology, while those of the two remaining genera *Bathypterois* and *Bathysauropsis* are larger and show a sulcus morphology similar to the fossil *B. solidus*. The massive appearance,

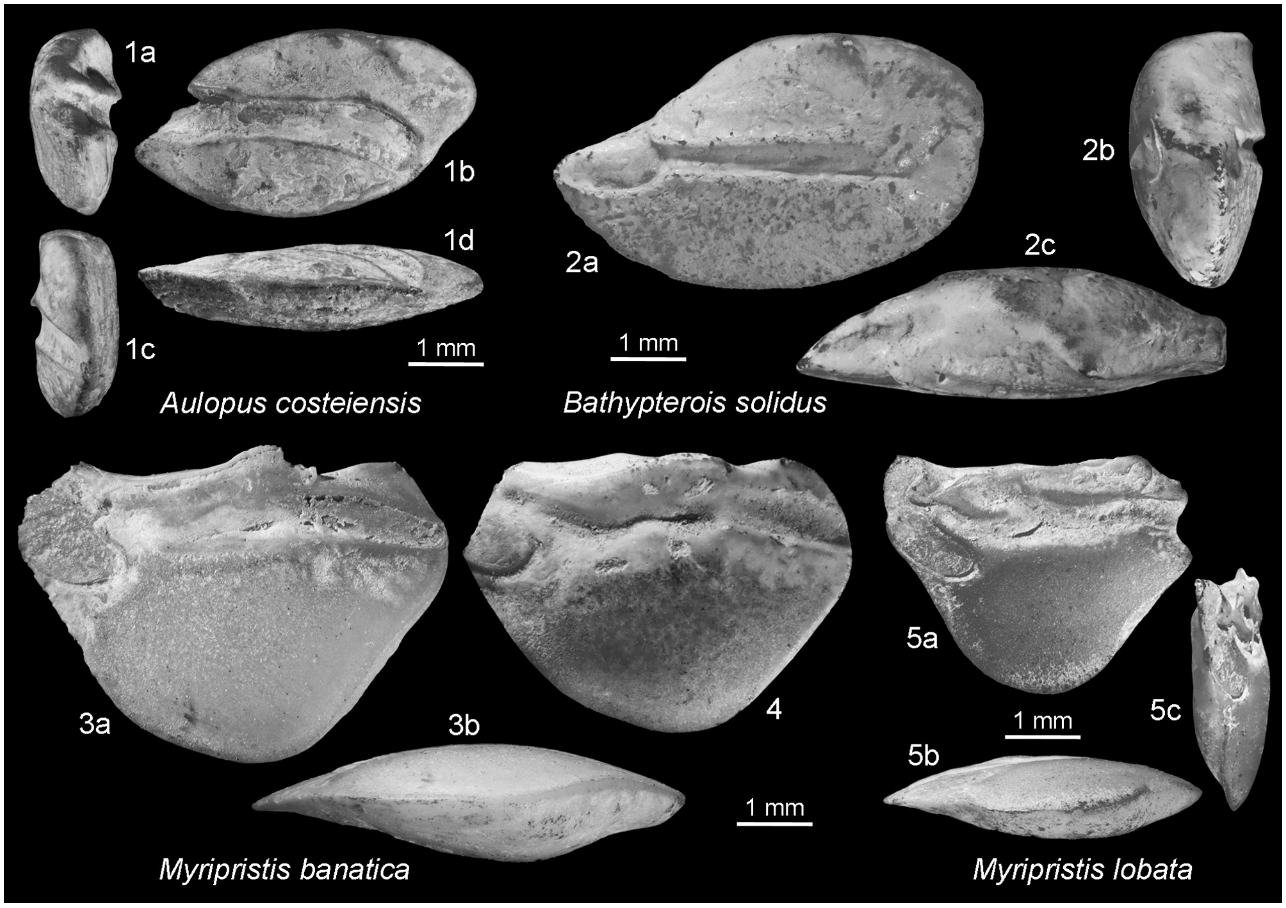


Plate 2
1. *Aulopus costeiensis* n. sp., **holotype**, SMF P.2819, Coşteiu de Sus.
2. *Bathypterois solidus* n. sp., **holotype**, SMF P.2851, Coşteiu de Sus.
3-4. *Myripristis banatica* Weiler, 1950, Coşteiu de Sus, 3: **holotype**, SMF P.2774; 4: **paratype**, SMF P.2776.
5. *Myripristis lobata* n. sp., **holotype**, SMF P.2775 (**paratype** of *M. banatica* as designated by Weiler, 1950), Coşteiu de Sus.

the relatively wide ostium and the depressed predorsal rim clearly distinguish *B. solidus* from all known extant species of the genus *Bathypterois*. For Recent otoliths of *Bathysauropsis* see Smale *et al*. (1995) and Rivaton & Bourret (1999) and for *Bathypterois* see Campana (2004), Lombarte *et al*. (2006) and Nolf (2013).

Order Holocentriformes Patterson, 1993
Family Myripristidae Nelson, 1955
Genus *Myripristis* Cuvier, 1829

***Myripristis lobata* n. sp.**
Plate 2, fig. 5

1950 *Myripristis banatica* Weiler, pl. 1, fig. 5 (*partim, non* fig. 6).
?1992 *Myripristis verus* Steurbaut, 1979 – Radwanska, text-fig. 74, pl. 15, figs 3-4 (*partim, non* figs 1-2).

Holotype – Pl. 2, fig. 5, SMF P.2775 (one of two paratypes of *M. banatica* Weiler, 1950), Romania, Banat, Coşteiu de Sus, middle Miocene, early Badenian, during deposition of the upper Lagenidae Zone.

Etymology – From lobatus (Latin) = lobed, referring to the deep ostial lobe.

Diagnosis – OL:OH about 1.35 (rear tip of holotype slightly damaged). Dorsal rim flat, without middorsal expansion. Ostium very short, but with deep lobe; ratio total ostium height to ostium length at joint with cauda = 2.65. Caudal keel positioned right behind ostial joint.

Description – Compressed, moderately thick otolith of 4 mm length. OH:OT = 2.7. Dorsal rim flat, even slightly depressed along most of its length, slightly expanded above ostium, without middorsal expansion, and with moderate postdorsal angle. Ventral rim deep, broadly rounded at mid-section, Anterior rim rounded dorsally, straight and inclined below ostium: Posterior rim damaged at level of caudal tip, straight and inclined below. Dorsal rim slightly undulating, other rims smooth.
Inner face moderately convex with a distinctly supramedian sulcus. Ostium short but strongly widened, shallow.

Dorsal ostial lobe slightly curving backwards; ventral ostial lobe very deep and backward inclined. Ostial / caudal joint inclined. Cauda long, straight but somewhat oscillating, caudal keel (terminology of Frizzell & Lamber, 1961) positioned right behind ostial / caudal joint before middle of sulcus. CaL:OsL about 5.5. Dorsal field extremely narrow and indistinctly structured; ventral field very deep and smooth, without ventral furrow. Outer face as convex as inner face, smooth.

Discussion – Myripristid otoliths are characterized by a highly specialized set of morphological features including the outline of the otolith, the wide and smooth ventral field, the strongly supramedian position of the sulcus, the short and strongly widened ostium usually with prominent dorsal and ventral lobes and the development of the caudal keel above part of the cauda and connected with it. The caudal keel was first established as a term by Frizzell & Lamber (1961). Myripristids are known *'*for a direct connection between the posterior portion of the auditory bulla enclosing each sacculus and two antero-lateral projections of the swim bladder*'* (Coombs & Popper, 1979). Studies performed by Coombs & Popper (1979) of the auditory system of myripristids have shown low thresholds and wide frequency ranges resulting in some of the most sensitive hearing known for fishes. The maccula sacculi of myripristids, corresponding to the sulcus of the otolith, shows a complex and highly specialized orientation pattern of the ciliary bundles (Popper, 1977; Schulz-Mirbach & Ladich, 2016). Also, the caudal keel determined by Frizzell & Lamber (1961) corresponds to a special field of supporting cells of the maccula sacculi (Popper, 1977; Schulz-Mirbach & Ladich, 2016). Clearly, the unusual otolith pattern unique to myripristids is a functional morphological response to a specialized auditory system that has evolved in these fishes.
Important characters for distinction of *Myripristis* otoliths are the shape of the ostium, the shape and position of the caudal keel and characters of the otolith outline and its proportions. *Myripristis lobata* differs from the coeval *M. banatica* (Pl. 2, figs 3-4) in the much shorter and wider ostium with a very deep ventral ostial lobe (ratio total ostium height to ostium length at joint with cauda = 2.65 vs 1.5), the caudal keel being positioned forward of the middle of the sulcus just behind the ostial/caudal joint (vs positioned at the middle of the cauda) and the lack of a middorsal expansion of the dorsal rim. Much more similar in this respect is *M. vera* Steurbaut, 1979 from the Langhian of the Aquitaine Basin in France, which also has the forward positioned caudal keel and the flat dorsal rim. *Myripristis lobata* differs from *M. vera* in being more compressed (OL:OH = 1.35 vs 1.5-1.7) with a much deeper and broader ventral rim, and in the very deeply curved and narrow ventral ostial lobe. Steurbaut (1984) figured another specimen of *M. vera* from the Burdigalian, which differs in the broader ostium and a distinct postdorsal expansion of the dorsal rim and probably represents yet another species of the genus. Radwanska (1992) figured four otoliths as *M. vera* from the early Badenian of Poland of which two (her pl. 15, figs 3-4) show the same proportions as *M. lobata*, but are too eroded for a reliable identification, particularly because of the damaged anterior part of the otoliths bearing the ostium. The other two specimens identified by her as *M. vera* (her pl.15, figs 1-2) are very slender otoliths with a rather shallow and regularly curved ventral rim and a weak ventral ostial lobe. They represent a completely different morphology, probably that of *Ostichthys radiatus* (Weiler, 1959) described from the late Oligocene to early Miocene of the North Sea Basin (see Schwarzhans 2010 for figures and further synonymies).

Order Gobiiformes Thacker, 2009
Family Apogonidae Günther, 1859
Genus *Apogon* Lacepède, 1801

***Apogon banaticus* Weiler, 1950**
Plate 3, figs. 1-2

1950 *Apogon banaticus* Weiler, pl. 2, fig. 9.
1952 *Apogon imberboides* Weinfurter, pl. 2, fig. 3.
1979 *Apogon banaticus* Weiler, 1950 – Steurbaut, pl. 21, figs 1-2.
2009 *Apogon* aff. *imberbis* Linnaeus, 1758 – Nolf & Brzobohaty, pl. 3, fig. (refigured holotype of *A. imberboides*).

Material – Two specimens, SMF P.2779 (holotype) and SMF P.2780 (paratype), Coșteiu de Sus.

Discussion – Weiler's description of *A. banaticus* was based on two relatively large and well preserved otoliths of about 4 mm length (newly photographed here) that differ from the extant *A. imberbis* (see Lombarte *et al*., 2006 for figures) in the presence of a postcaudal depression connecting the caudal tip with the posterior-dorsal rim and a relatively long cauda resulting in a ratio OsL:CaL of 1.3-1.5 (vs 1.8-2.2).
In 1912, Schubert described *Apogon*? *ribicensis* from Ribița (= Ribice) not far from Weiler's location based on a small specimen of 1.8 mm length, which according to his drawing is also somewhat eroded and therefore not very suitable as holotype. Weiler noted as main difference from Schubert's drawing that the cauda of *A. ribicensis* was longer than the ostium, while in *A. banaticus* it is the other way round. Schubert mentioned a second, slightly larger specimen of 2.2 mm length from Lăpugiu de Sus, however without figuring it. In his review of Schubert's material Nolf (1981) could not locate the specimens, but also came to the conclusion that *A. ribicensis* was probably based on an eroded juvenile otolith and regarded it as a doubtful species.
Weinfurter (1952) described *A. imberboides* from the early Badenian of Austria based on a unique specimen of 2.8 mm length. He mentioned differences from *A. banaticus* as pertaining to lesser ornamentation of the otolith rims, which I consider to be a result of ontogenetic changes or slight erosion or a combination of both, and differences

in the outline of the otolith, which I cannot verify. Later, Nolf & Brzobohaty (2009) refigured Weinfurter's holotype as *Apogon* aff. *imberbis* without further explanation. The ratio OsL:CaL measured from Nolf & Brzobohaty's drawing is about 1.2 and thus within the expected range of variability of *A. banaticus*. Therefore, I consider *A. imberboides* as junior synonym of *A. banaticus*.
Steurbaut (1984) described otoliths of *A. banaticus* of about 2.5 mm length from the late Burdigalian of the Aquitaine Basin with similar sulcus proportions. In conclusion, *Apogon banaticus* appears to be a widely distributed species during the late Burdigalian and Langhian in the warm European seas just like the extant *Apogon imberbis*. *Apogon*? *ribicensis* is regarded as a doubtful species for the time being.

Family Gobiidae Cuvier, 1816
Genus *Buenia* Iljin, 1930

***Buenia elegans* (Prochazka, 1900)**
Plate 3, figs 3-4

1900 *Otolithus* (*Gobius*) *elegans* Prochazka, fig. 4.
1992 Genus Gobiidarum sp. 5 – Radwanska, text-fig. 150, pl. 35, figs 3-4

Material – Two specimens: one specimen UMG-X 8606, Tshokrakian, Bulgaria, well Balchik 103a, 224 m; one specimen SMF PO.91849, early Badenian, during deposition of the upper Lagenidae Zone (*'Amphisteginenmergel'*), Austria, Wien-Nußdorf, Grünes Kreuz.

Diagnosis (new) – OL:OH = 0.9-0.95. Pre- and postdorsal, pre- and postventral projections all equally developed, not much projecting. Dorsal rim regularly curved. Anterior and posterior rims nearly vertical, with broad concavities at level of ostial and caudal tips respectively. Inner face nearly flat, outer face convex. Sulcus narrow, inclined at about 15°, with low ostial lobe; no subcaudal iugum.

Description - Small, compressed, thick otoliths up to about 1.5 mm length. OH:OT = 2.5. Outline of otolith nearly rectangular with flat ventral rim, nearly vertical anterior and posterior rims and slightly curved dorsal rim. Anterior and posterior rims with broad concavities at level of ostial and caudal tips respectively. All rims smooth.
Inner face nearly flat, with small, narrow, shallow sulcus at its center. Sulcus inclined at about 15°, slender sole-shaped with low ostial lobe and without subcaudal iugum. Dorsal depression weak; ventral furrow distinct surrounding entire ventral field close to ventral rim of otolith. Outer face distinctly convex, smooth.

Discussion – The two specimens described here allow a proper redefinition of this enigmatic species of Prochazka, of which the type specimens have to be considered lost. The characteristic outline and the narrow and strongly inclined sulcus correlate well with Prochazka's somewhat schematic drawing. Schwarzhans (2010) indicated that certain specimens figured by Radwanska (1992) might belong to *Buenia elegans* (then regarded as a species of *Pomatoschistus*), namely her genus Gobiidarum sp. 1 and sp. 5. With these new finds it has now become clear that both morphologies recognized by Radwanska indeed represent separate species, her genus Gobiidarum sp. 1 belongs to *Pomatoschistus bunyatovi* Bratishko, Schwarzhans & Reichenbacher, 2015 (see Schwarzhans *et al*. 2015) and her genus Gobiidarum sp. 5 to *Buenia elegans*. There appears to be some variation of the curvature or flatness respectively of the ventral rim in *B. elegans*. *Buenia elegans* differs from otoliths of the extant *Buenia affinis* Kolombatovic, 1891 (see Lombarte *et al*., 2006 for figures) in being slightly compressed (OL:OH = 0.9-0.95 vs 1.0-1.05) and the more regularly curved dorsal rim (vs postdorsally pronounced). *Buenia elegans* differs from the coeval *Pomatoschistus bunyatovi* in the vertical anterior and posterior rims (vs pre- and postdorsally expanded, the flat inner face (vs slightly convex) and the very narrow sulcus.

Genus *Gobius* Linnaeus, 1758

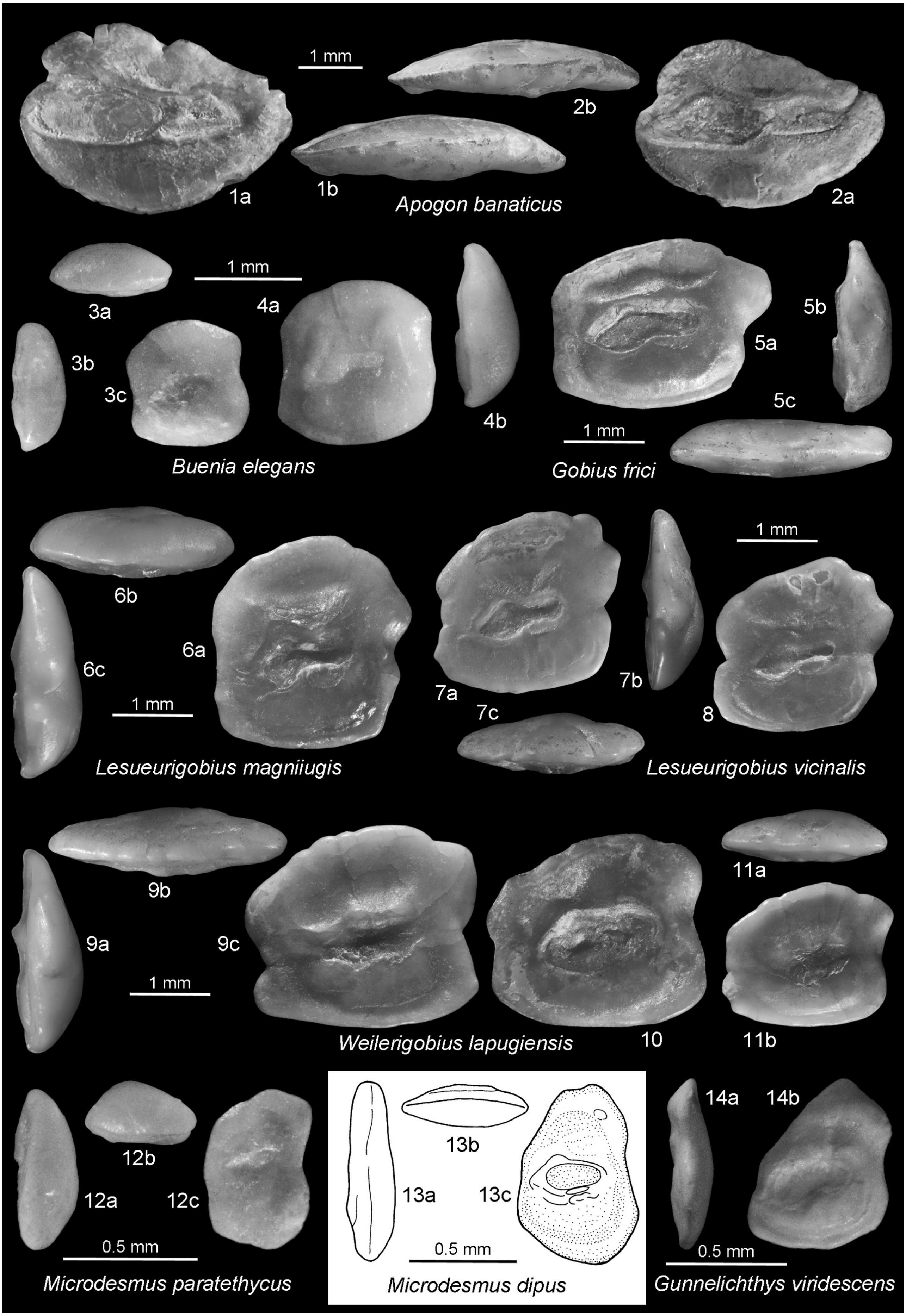
***Gobius frici* Prochazka, 1900**
Plate 3, fig. 5

1900 *Otolithus* (*Gobius*) *frici* Prochazka, fig. 1.
1950 *Gobius pretiosus* Prochazka, 1893 – Weiler, pl. 4, fig. 25 (*non* pl. 4, fig. 27, pl. 8, fig. 62).
1992 *Gobius* aff. *geniporus* Valenciennes, 1837 – Radwanska, text-fig.141, pl. 34, figs 1-2.

Material – One specimen, SMF P.2801, Coşteiu de Sus.

Diagnosis (new) – OL:OH = 1.3. Anterior rim vertical, without indentation and without preventral projection. Postdorsal projection distinct, but not bent outwards. Dorsal rim smooth, anteriorly slightly depressed, with broad postdorsal angle. Sulcus narrow, relatively small, inclined at about 10°, with moderate ostial lobe, and distinct long and wide subcaudal iugum.

Description – Relatively large, elongate, moderately thick otoliths up to at least 2.7 mm length (Prochazka, 1900 mentioned 9 mm length). OH:OT = 3.0. Outline of otolith typical for many *Gobius* species, but without preventral projection and vertical, straight anterior rim. Postdorsal projection broad and moderately strong, not bent outwards. Ventral rim slightly and regularly curved; dorsal rim anteriorly depressed posteriorly expanded at broad postdorsal angle. All rims smooth.
Inner face slightly convex, with relatively small, moderately shallow and narrow sulcus. Sulcus inclined at about 10°, slender sole-shaped with moderate ostial lobe. Subcaudal iugum long, wide, below entire caudal section.


1 mm
2b
1a
1b
Apogon banaticus
2a
1 mm
3a
4a
3b
3c
4b
5b
5a
5c
1 mm
Buenia elegans
Gobius frici
1 mm
6b
6a
6c
1 mm
7a
7b
7c
8
Lesueurigobius magniiugis
Lesueurigobius vicinalis
9b
11a
9a
9c
1 mm
Weilerigobius lapugiensis
10
11b
14a
14b
12b
13b
12a
12c
13a
13c
0.5 mm
0.5 mm
0.5 mm
Microdesmus paratethycus
Microdesmus dipus
Gunnelichthys viridescens

Dorsal depression narrow, distinct with sharp ventral margin; ventral furrow distinct surrounding entire ventral field close to ventral rim of otolith. Outer face nearly flat, smooth.

Discussion – The very well preserved specimen from Coşteiu de Sus allows for a redefinition of another of the enigmatic species of Prochazka. Considering Prochazka's description it may grow to considerable size. In fact there are very few gobiid species with otoliths of that size. The whereabouts of Prochazka's types are unresolved and in our current understanding they are most likely lost. The specimen used here for redefinition of the species resembles Prochazka's holotype in all aspects except that Prochazka did not show a subcaudal iugum in his drawing. However, this feature was not recognized in most early drawings of gobiid otoliths and it is also easily affected by even slight erosion. I therefore interpret its lacking in Prochazka's figure as an artifact rather than a trait of diagnostic value.
The outline with the distinct postdorsal projection in combination with the sulcus with its distinct subcaudal iugum is typical for otoliths of the genus *Gobius*. *Gobius frici* differs from the otoliths of the extant *Gobius geniporus* Valenciennes, 1837 (see Lombarte *et al*., 2006 for figures), with which it has been compared, in the less depressed predorsal rim and the moderately developed ostial lobe (vs low ostial lobe and bent dorsal sulcus margin). In the fossil record *Gobius mustus* Schwarzhans, 2014 from the Serravallian of the Karaman Basin in Turkey is closest, but *G. frici* differs in the comparatively larger subcaudal iugum and smaller sulcus. Also *G. mustus* is more compact than *G. frici* and usually shows an indentation of the anterior rim.

Genus *Lesueurigobius* Whitley, 1950

***Lesueurigobius magniiugis* n. sp.**
Plate 3, fig. 6

Holotype – Pl. 3, fig. 6, SMF P.2916a (identified as *Gobius vicinalis* by Weiler, 1950), Romania, Banat, Lăpugiu de Sus, middle Miocene, early Badenian, during deposition of the upper Lagenidae Zone.

Etymology – Combined from *magnus* (Latin) = large and *iugum* (Latin) = ridge also technical term for a bulging feature below the cauda in gobiids, referring to extremely large subcaudal iugum found in this species.

Diagnosis – OL:OH = 0.95. Dorsal rim broadly and regularly curved, predorsal region not depressed. Sulcus wide, deep, inclined at about 7°, with strong ostial lobe. Subcaudal iugum very large, nearly as wide as long.

Description – Moderately large, compressed, moderately thick otoliths of 2.5 mm length. OH:OT = 3.0. Outline of otolith high bodied with near vertically cut anterior rim, regularly rounded dorsal rim without postdorsal angle, posterior rim with slightly projecting, broad postdorsal projection and small notch at level of caudal tip and rather flat ventral rim. All rims smooth, dorsal rim slightly undulating.
Inner face flat along vertical axis and slightly convex in horizontal direction. Sulcus relatively large, moderately deep and wide. Sulcus inclined at about 7° with cauda nearly horizontal. Sulcus sole-shaped, anteriorly much widened with strong ostial lobe and blunt anterior tip. Subcaudal iugum very large, about as wide as long, below most of caudal section. Dorsal depression wide, short, moderately distinct towards ventral margin; ventral furrow distinct surrounding entire ventral field close to ventral rim of otolith. Outer face convex, smooth.

Discussion – *Lesueurigobius magniiugis* is readily distinguished from the coeval and common *L. vicinalis* (Koken, 1891) (Pl. 3, figs. 7-8) (see also refigured holotype in Nolf, 2013) and other fossil *Lesueurigobius* species by the extremely wide subcaudal iugum, the high and regularly rounded dorsal rim (vs anteriorly inclined and with distinct postdorsal projection) and the very wide ostium with its blunt tip.

Genus *Weilerigobius* n. gen.

Type species – *Weilerigobius lapugiensis* n. sp.

Etymology – Named in memoriam of Wilhelm Weiler for his great contributions to the knowledge of fossil otoliths. Gender masculine.

Plate 3

1-2. *Apogon banaticus* Weiler, 1950, Coşteiu de Sus, 1: **holotype** (r), SMF P.2779; 2: **paratype**, SMF P.2780.
3-4. *Buenia elegans* (Prochazka, 1900), 3 (r): UMG-X 8606, Tshokrakian, Bulgaria, well Balchik 103a, 224m; 4: SMF PO.91849, early Badenian, upper Lagenidae Zone (*'Amphisteginenmergel'*), Austria, Wien-Nußdorf, Grünes Kreuz.
5. *Gobius frici* Prochazka, 1900, SMF P.2801, Coşteiu de Sus.
6. *Lesueurigobius magniiugis* n. sp., **holotype**, SMF P.2916a, Lăpugiu de Sus.
7-8. *Lesueurigobius vicinalis* (Koken, 1891), SMF P.2806, Coşteiu de Sus.
9-11. *Weilerigobius lapugiensis* n. sp., 9: **holotype**, SMF P.2916b, Lăpugiu de Sus; 10-11: **paratypes**, Coşteiu de Sus, 10 (r): SMF P.2802, 11 (r): SMF P.2803.
12. *Microdesmus paratethycus* n. sp., **holotype**, UMG-X 8616, Konkian, Bulgaria, well Balchik 105a, 197m.
13. *Microdesmus dipus* Günther, 1864, Recent, Baja California, refigured from Nolf (2013).
14. *Gunnelichthys viridescens* Dawson, 1968, WAM 32796-001, Recent, 03°50'S - 134°04'E.

Diagnosis – An otolith-based fossil genus of the family Gobiidae with moderately large otoliths up to about 3 mm length and with an OL:OH of 1.1-1.15. Ventral rim flat, dorsal rim inclined. Preventral projection about as long as anterior-dorsal angle. Postdorsal projection blunt, not bent outwards, not extending further than postventral angle. Inner face flat except for raised crista superior. Sulcus deepened, moderately large, inclined at about 10°, with low ostial lobe and poor distinction between ostium and cauda. No subcaudal iugum. Dorsal depression very large.

Discussion – *Weilerigobius* is monospecific. The combination of the poorly structured sulcus, the absence of a subcaudal iugum, the flat inner face and the shape of the dorsal and anterior rims distinguish this otolith morphology from those of all known extant or fossil genera in Europe. Similarly poorly structured sulci are found in *Benthophilus* and *Protobenthophilus* (see Schwarzhans *et al*., 2017), but these tend to be smaller, entirely without ostial lobe and more shallow. Otoliths of *Thorogobius iucundus* Schwarzhans 2014, a widespread species in the Badenian of the Paratethys and the Serravallian of the Karaman Basin is also similar in general appearance, but *Weilerigobius* differs in the presence of a preventral projection, albeit short, and the postdorsal projection not extending further than the postventral projection (vs distinctly longer) and a deepened sulcus (vs rather shallow). Therefore, these observed morphological similarities in my view most likely represent homologies of probably unrelated gobiid genera that may have adapted to similar benthic live styles.

***Weilerigobius lapugiensis* n. sp.**
Plate 3, figs 9-11

1950 *Gobius vicinalis* Koken, 1891 Weiler, partim (not figured specimen)
1950 *Gobius pretiosus* Prochazka, 1893 – Weiler, pl. 4, fig. 27 (*non* pl. 4, fig. 25, pl. 8, fig. 62).

Holotype – Pl. 3, fig. 9, SMF P.2916b (identified as *Gobius vicinalis* by Weiler, 1950), Romania, Banat, Lăpugiu de Sus, middle Miocene, early Badenian, during deposition of the upper Lagenidae Zone.

Paratypes – Three specimens, SMF P.2802 and 2803 (identified as *Gobius pretiosus* by Weiler, 1950) (Pl. 3, figs 10-11), Romania, Banat, Coşteiu de Sus, middle Miocene, early Badenian, during deposition of the upper Lagenidae Zone.

Etymology – Named after the type locality Lăpugiu de Sus.

Diagnosis – Same as for genus.

Description – Moderately large, moderately compressed, and moderately thick otoliths up to 3.0 mm length (holotype 2,9 mm). OH:OT = 2.8-3.0. Dorsal rim anteriorly inclined, depressed, posteriorly with broad postdorsal angle. Ventral rim almost flat. Anterior rim vertical with distinct preventral projection and predorsal angel of about equal length and variable notch in between. Posterior rim much higher than anterior rim, nearly vertical, with postdorsal projection not extending beyond postventral angle, with broad indention at level of caudal tip. Ventral rim smooth, dorsal rim slightly undulating.
Inner face flat except for slightly elevated crista superior. Sulcus somewhat variable in size, rather deep and wide. Sulcus inclined at about 10° and rounded tips. Sulcus poorly structured, with weak ostial lobe and often with slight central concavity of ventral sulcus margin. No subcaudal iugum. Dorsal depression moderately wide and distinct with prominent crista superior along ventral margin; ventral furrow distinct surrounding entire ventral field at some distance from ventral rim of otolith. Outer face convex, smooth or with few faint radial furrows dorsally.

Discussion – See discussion of monospecific genus above.

Family Microdesmidae Regan, 1912
Genus *Microdesmus* Günther, 1864

***Microdesmus paratethycus* n. sp.**
Plate 3, fig. 12

Holotype – Pl. 3, fig. 12, UMG-X 8616, Konkian, Bulgaria, well Balchik 105a, 197 m.

Etymology – Referring to the occurrence of this species in the Paratethys.

Diagnosis – OL:OH = 0.65. Otolith extremely high bodied and thick. Dorsal and ventral rims posteriorly expanded; anterior and posterior rims nearly vertical, posterior rim with broad indentation. Sulcus supramedian, small, narrow, inclined at about 15°, without ostial lobe. No subcaudal iugum.

Description – A small otolith with 0.6 mm length along the longest (vertical) axis and one of the most compressed teleost otoliths known to date. OH:OT = 2.5. Anterior rim nearly vertical, slightly curved, without indentation; posterior rim with broad, short postdorsal expansion about as much projecting as bulge along ventral part of posterior rim, with broad indentation in between. Dorsal and ventral rims high, both posteriorly pronounced. All rims smooth.
Inner face flat except for slightly convex anterior most and posterior most regions. Sulcus distinctly supramedian positioned, very small, somewhat deepened, narrow, without ostial lobe and therefore with tapering terminations on both ends. Sulcus inclined at about 15°. No subcaudal iugum. Dorsal depression indistinct; ventral fur-

row feeble, running at some distance from ventral rim of otolith. Outer face distinctly convex, smooth.

Discussion – Microdesmid otoliths are small and high bodied, but the one of *M. paratethycus* represents one of the most compressed and high bodied otoliths ever recorded from a teleost. It differs from otoliths of the related genus *Gunnelichthys,* for instance *G. viridescens* Dawson, 1968 (Pl. 3, fig. 14), in the small sulcus and its supramedian position (vs inframedian). Otoliths of *Microdesmus*, for instance *M. dipus* Günther, 1864 (Pl. 3, fig. 13, reproduced from Nolf, 2013), correlate better with the small and supramedian positioned sulcus. *Microdesmus paratethycus* is the first fossil record of the family and the only record from Europe.

Order Istiophoriformes Betancur-R. *et al*., 2013
Family Sphyraenidae Rafinesque, 1815
Genus *Sphyraena* Artedi, 1793

***Sphyraena* sp.**
Plate 4, fig. 1

1950 Otolithus inc. sed. sp. 4 – Weiler, pl. 6, fig. 41.

Material – Two specimens, SMF P.2792, 2793, Coşteiu de Sus.

Discussion – A number of *Sphyraena* species have been described from the Badenian of the Central Paratethys: *Sphyraena hansfuchsi* Schubert, 1906 (figures in Schubert, 1906 and Schultz, 2013), which was regarded as a doubtful species following the review of Schubert's specimens by Nolf (1981) because of having been based on small, probably juvenile specimens; *Sphyraena dentata* Radwanska, 1984, later revised as representing the extant *Sphyraena* aff. *afra* Peters, 1884 (in Radwanska, 1992, see also figure in Schultz, 2013); and another extant species *Sphyraena* aff. *sphyraena* (Linnaeus, 1758) in Brzobohaty, Nolf & Kroupa (2007), apparently a well preserved large and adult specimen. This situation is confusing and unsatisfactory. Most likely, all these specimens represent a single species, which needs to be properly defined. However, the specimens from Coşteiu de Sus clearly represent a different species, characterized by a relatively thick appearance, a flat or even slightly convex outer face (vs concave) and the pointed posterior tip which extends well beyond the postdorsal angle (vs blunt posterior tip). The only available specimens, however, are somewhat eroded and relatively small and therefore not suitable for a species definition.

Order Labriformes Bleeker, 1859
Family Scaridae Rafinesque, 1810
Genus *Scarus* Forsskål, 1775

***Scarus* sp.**
Plate 4, fig. 2

Material – One incomplete otolith, SMF P.2883a, Coşteiu de Sus.

Discussion – A thin, slightly eroded and anteriorly damaged otolith with incomplete rostrum of about 3.1 mm length. The outline is characterized by a broad midventral angle, a prominent angle at the posterior tip and a distinct postdorsal angle. The distinctly deepened and supramedian sulcus on the slightly convex inner face shows a widened, but incomplete ostium and a posteriorly strongly widened caudal tip whereas the anterior half of the cauda is narrow and slightly inclined. Sulcus and otolith outline are typical for scarid otoliths, particularly of the genus *Scarus* (see Lombarte *et al*., 2006 for figures of Recent otoliths). Radwanska (1992) figured another, more slender scarid as *'genus Scaridarum'* sp. from the early Badenian of Poland.

Order Perciformes Bleeker, 1859
Family Lactariidae Fowler, 1904
Genus *Lactarius* Valenciennes, 1833

***Lactarius* cf. *sigmoidalis* (Frost, 1933)**
Plate 4, fig. 7

1933 Ot. (Sparidarum) *sigmoidalis* Frost, figs 41-42.
1980 *Lactarius sigmoidalis* (Frost, 1933) – Schwarzhans, figs 519-526.

Material – One very slightly eroded specimen, SMF P.2860, Lăpugiu de Sus.

Discussion – *Lactarius* otoliths are relatively common and widespread in the Eocene to early Miocene of Europe (Steurbaut, 1984; Nolf, 2013) and New Zealand (Schwarzhans, 1980). The single specimen recorded here from Lăpugiu de Sus represents the youngest record in Europe. It clearly differs from the late Burdigalian *L. atlanticus* Steurbaut & Jonet, 1982 from Portugal and the Aquitaine Basin in the smoothness of the otolith rims (vs intensely crenulated), the more compressed shape (OL:OH = 1.2 vs 1.3-1.4) and the wider ostium. Much more similar is *Lactarius sigmoidalis* (Frost, 1933) (see Schwarzhans, 1980 for figures), a common species in the Oligocene to middle Miocene of New Zealand. In fact I am unable to identify any significant differences, with the caveat, however, that the only available specimen from the Paratethys is somewhat eroded. Therefore, this singular specimen is only tentatively referred to that species. In case any new finds in the Paratethys should confirm the identity of *L. sigmoidalis* it would indeed represent the first record in the middle Miocene fish fauna of the Paratethys pointing to a direct influence from the Indo-West Pacific.

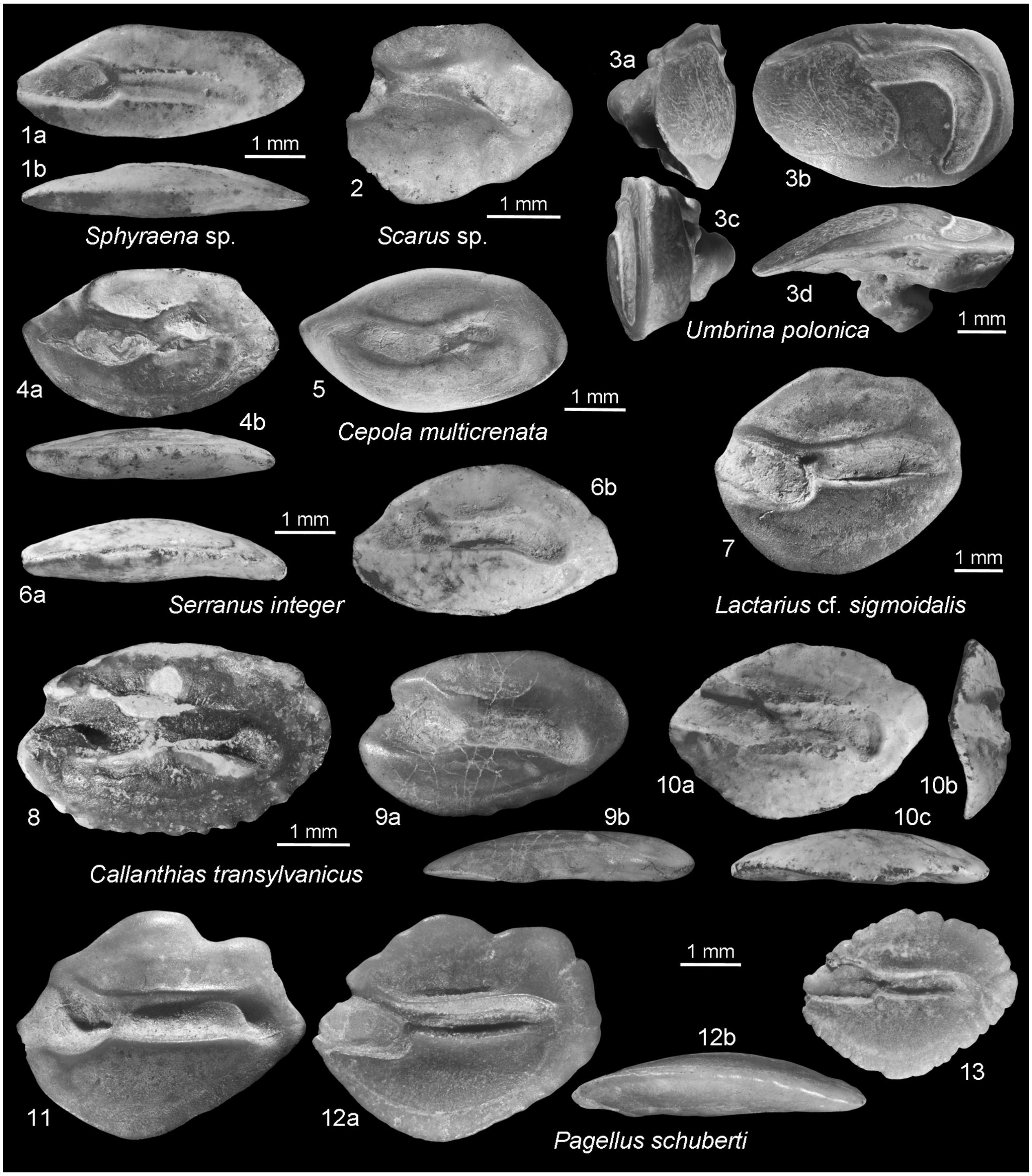


Plate 4

1. *Sphyraena* sp., SMF P.2793, Coşteiu de Sus.
2. *Scarus* sp., SMF P.2883a, Coşteiu de Sus.
3. *Umbrina polonica* (Radwanska, 1984), (r), SMF P.2849, Coşteiu de Sus.

4-5. *Cepola multicrenata* Radwanska, 1984, Coşteiu de Sus, 4 (r): SMF P.2781; 5 (r): SMF P.2782.

6. *Serranus integer* (Schubert, 1906), SMF P.2813, Coşteiu de Sus.
7. *Lactarius* cf. *sigmoidalis* (Frost, 1933), SMF P.2860, Lăpugiu de Sus.

8-10. *Callanthias transylvanicus* n. sp., Coşteiu de Sus, 9 (r): **holotype**, SMF P.2883b; 8 (r): **paratype**, SMF P.2820; 10: tentatively assigned specimen, SMF P.2824.

11-13. *Pagellus schuberti* n. sp., Coşteiu de Sus, 12: **holotype**, SMF P.2868b; 11 (r): **paratype**, SMF P.2815; 13: **paratype**, SMF P.2868c.

Family Sciaenidae Cuvier, 1828
Genus *Umbrina* Cuvier, 1816

***Umbrina polonica* (Radwanska, 1984)**
Plate 4, fig. 3

1950 *Sciaena pecchioli* Lawley, 1876 – Weiler, pl. 3, fig. 13.
1979 *Sciaena pecchioli* Lawley, 1876 – Smigielska, text-fig. 21, pl. 7, fig. 2.
1984 *Argyrosomus polonicus* Radwanska, text-figs 13-14, pl. 4, figs 1-3.
1992 *Sciaena polonica* (Radwanska, 1984) – Radwanska, text-fig. 115, pl. 28, figs 1-2.

Material – One specimen, SMF P.2849, Coşteiu de Sus.

Discussion – A beautifully preserved specimen of *Umbrina polonica*, probably the best known so far and therefore refigured here in detail.

Family Cepolidae Rafinesque, 1810
Genus *Cepola* Linnaeus, 1766

***Cepola multicrenata* Radwanska, 1984**
Plate 4, figs 4-5

1950 *Cepola praerubescens* Bassoli & Schubert, 1906 – Weiler, pl. 4, fig. 23.
1984 *Cepola multicrenata* Radwanska, text-fig. 17, pl. 5, figs 8-10.
1992 *Cepola rubescens* Linnaeus, 1766 – Radwanska, pl. 30, figs 5-6 (*non* figs 1-4, 7).

Material – Three specimens, SMF P.2781-2782, Coşteiu de Sus.

Discussion – Two fossil otolith-based *Cepola* species have been described from the Badenian - *C. voeslauensis* Schubert, 1907 and *C. multicrenata* Radwanska, 1984 - and one from the Tortonian - *C. prerubescens* Bassoli, 1906. In recent literature, they have all been referred to the extant *C. macrophthalma* (Linnaeus, 1758) (see Nolf, 2013), a senior synonym of *C. rubescens* Linnaeus, 1764. Schwarzhans (2014), pointed out that actually two different species are reported under this name: one with the ostial colliculum reaching or almost reaching the anterior rim of the otolith, the outer face being flat to concave and the anterior and posterior tips of the otolith being equally pointed and the other with the ostial colliculum terminating far from the anterior rim of the otolith, the outer face being convex and the posterior tip being rounded and less pointed than the anterior tip of the otolith. The first pattern relates to *C. macrophthalma, C. prerubescens* and *C. voeslauensis* and I consider it subject to detailed investigations and review whether they all really represent a single species, *i.e. C. macrophthalma*. The second pattern is related to *C. multicrenata* and is here regarded as valid. The specimens from Coşteiu de Sus are well preserved and large and thus verify Radwanska's definition (1984), but the situation is still unresolved for many other records in literature and hence the synonymy list is reduced to few verified records from the Badenian of the Paratethys only.

Order Spariformes Bleeker, 1876
Family Callanthiidae Fowler, 1907
Genus *Callanthias* Lowe, 1839

***Callanthias transylvanicus* n. sp.**
Plate 4, figs 8-10

1950 Otolithus inc. sed. sp. 2 – Weiler, pl. 6, fig. 38.
1950 Otolithus inc. sed. sp. 3 – Weiler, pl. 6, fig. 40.

Holotype – Pl. 4, fig. 9, SMF P.2883b, Romania, Banat, Coşteiu de Sus, middle Miocene, early Badenian, during deposition of the upper Lagenidae Zone.

Paratype – One specimen, SMF P.2820, same data as holotype.

Tentatively assigned specimen - SMF P. 2824, same data as holotype.

Etymology – Named after the Romanian region Transylvania.

Diagnosis – Moderately elongate, oval otoliths. OL:OH = 1.5-1.65. Dorsal rim regularly curved without angles. Sulcus moderately deep with moderately widened ostium and posteriorly widened and slightly curved cauda terminating close to postventral rim. Ventral furrow distinct, running at some distance from ventral rim of otolith.

Description – Elongate, moderately thin and moderately large otoliths reaching at least 4.3 mm length (holotype 3.65 mm). OH:OT = 3.3. Dorsal rim shallow, regularly curved, slightly undulating and without prominent angles. Ventral rim slightly deeper, regularly curved, deepest anterior of its middle, slightly undulating to gently and widely crenulated (pl. 4, fig. 8). Anterior rim with short, broad, rounded rostrum and small excisura and antirostrum. Posterior rim rounded, its tip distinctly supramedian.

Inner face distinctly convex both in longitudinal as well as vertical direction. Sulcus slightly supramedian, deep, with slightly shorter and moderately widened ostium and longer, slightly inclined cauda. Cauda posteriorly slightly widened and slightly curved downwards. CaL:OsL = 1.15-1.3. Dorsal depression small, narrow, only above central portion of sulcus, ventrally well marked by crista superior; ventral furrow mostly distinct, running at some distance from ventral rim of otolith. Outer face flat to slightly concave; smooth or with few faint radial furrows.

Discussion – The otoliths of *Callanthias transylvanicus* resemble those of the extant *C. ruber* (Rafinesque, 1810) from the Mediterranean (see Lombarte *et al*., 2006 for figure). They differ from the extant species in the shorter ostium and the widened caudal tip. One specimen (Pl. 4, fig. 10) was considered by Weiler (1950) to represent another species. It does indeed differ from the holotype and the paratype (Pl. 4, figs 8-9) in the deeper ventral rim and the narrower ostium. It is therefore only tentatively placed in the same species.

Family Sparidae Rafinesque, 1810
Genus *Pagellus* Valenciennes, 1830

Pagellus schuberti **n. sp.**
Plate 4, figs 11-13

Holotype – Pl. 4, fig. 12, SMF P.2868b, Romania, Banat, Coşteiu de Sus, middle Miocene, early Badenian, during deposition of the upper Lagenidae Zone.

Paratypes – Three specimens, SMF P.2815, 2852, 2868c, (Pl. 4, figs 11, 13) same data as holotype.

Etymology – Named in memoriam of Richard Schubert for his important contributions to the knowledge of fossil otoliths in the Paratethys.

Diagnosis – OL:OH = 1.25-1.3. Dorsal rim with broad predorsal angle usually followed by distinct concavity. Sulcus with short, ventrally widened ostium and almost straight cauda, only oscillating at its tip and terminating at some distance from posterior rim of otolith. Ventral furrow distinct, running at some distance from ventral rim of otolith.

Description – Moderately compressed and moderately robust otoliths reaching at least 4.7 mm length (holotype). OH:OT = 3.5. Dorsal rim somewhat irregularly curving, with prominent, broad predorsal angle, much weaker postdorsal angle and distinct concavity in between in otoliths larger than 4 mm length. Smaller otoliths (pl. 4, fig. 13) not showing mediodorsal concavity, but instead intensely crenulated dorsal and posterior rims. Ventral rim moderately deep, regularly curved, deepest anterior of its middle, slightly crenulated in specimens smaller than 4 mm length (pl. 4, fig. 13). Rostrum short, broad, with rounded tip; antirostrum and excisura minute. Posterior rim blunt, its tip positioned at or below caudal tip.
Inner face moderately convex. Sulcus slightly supramedian, moderately deep, with short and ventrally widened ostium and longer, nearly straight cauda, slightly oscillating towards tip. Caudal tip tapering, terminating at some distance from posterior rim of otolith. CaL:OsL = 1.4-1.5. Dorsal depression narrow, above rear part of ostium and straight section of cauda, ventrally well marked by crista superior; ventral furrow usually distinct, running at some distance from ventral rim of otolith. Outer face flat; smooth or with many radial furrows in small specimens.

Discussion – *Pagellus schuberti* appears to represent the allopatric counterpart to *Pagellus weitzmani* Nolf, 1977 from the early and middle Miocene of the North Sea Basin (see Schwarzhans, 2010 for figures), differing in the more compressed shape (OL:OH = 1.25-1.3 vs 1.5-1.6), deeper curved ventral rim and the specific outline of the dorsal rim with its mediodorsal concavity and raised predorsal angle (vs postdorsal angle as strong as predorsal angle and dorsal rim flat or irregularly crenate in large specimens). In the Miocene of the Aquitaine Basin and Portugal (Steurbaut, 1984) and the northern Central Paratethys (Radwanska, 1992) the genus *Pagellus* is represented by *P. albuquerquae* Steurbaut & Jonet, 1982, which is a more slender form with a regular dorsal rim with clear-cut pre- and postdorsal angles. Presumably, *Pagellus schuberti* is one of those fishes in the early Badenian of the southern Central Paratethys that reflect a warmer temperature and possibly a link to the Eastern Paratethys of the time.

Order Scorpaeniformes Garman, 1899
Family Gasterosteidae Bonaparte, 1831
Genus *Pungitius* Coste, 1848

Pungitius kornyensis **Schubert, 1912**
Plate 5, figs 2-4

1912 *Otolithus* (*Mugil*?) *kornyensis* Schubert, fig. 9.
1954 *Clupea suzini* Pobedina, pl. 3, fig. 5.

Material – Three specimen: one specimen UMG-X 8571, Tarchanian, Bulgaria, well Tsarichino C-26, 250.7 m; two specimens UMG-X 8532, Karaganian, Bulgaria, well Balchik 103a, 212 m.

Diagnosis (new, based on specimen of plate 5, fig. 2) – OL:OH = 1.6. Ventral rim shallow, nearly flat; dorsal rim with broad mediodorsal angle. Posterior rim blunt; anterior rim with projecting, robust rostrum. Sulcus very narrow, somewhat oscillating at its rear part, moderately deep. Ostium narrow, deep tapering into cauda.

Description – Small, delicate otoliths reaching at least 1 mm length (pl. 5, fig. 2) (Pobedina's type specimen of *Clupea suzini* was 1.5 mm long, and Schubert's type specimen of *Ot.* (*Mugil?*) *kornyensis* 0.7 mm). OH:OT = 2.6. Ventral rim shallow, nearly flat and horizontal in specimens of 1 to 1.5 mm length, slightly convex in smaller specimens between 0.6 and 0.75 mm length (pl. 5, figs 3-4). Dorsal rim regularly curved with broad, obtuse mediodorsal angle. Posterior rim blunt, vertically cut in larger specimens and rounded in smaller ones. Rostrum prominent, robust, with rounded tip; rostrum length 15-20% of OL, increasing with size. Antirostrum and excisura moderate in small specimens, more pronounced with sharp excisura in larger ones. All rims smooth.

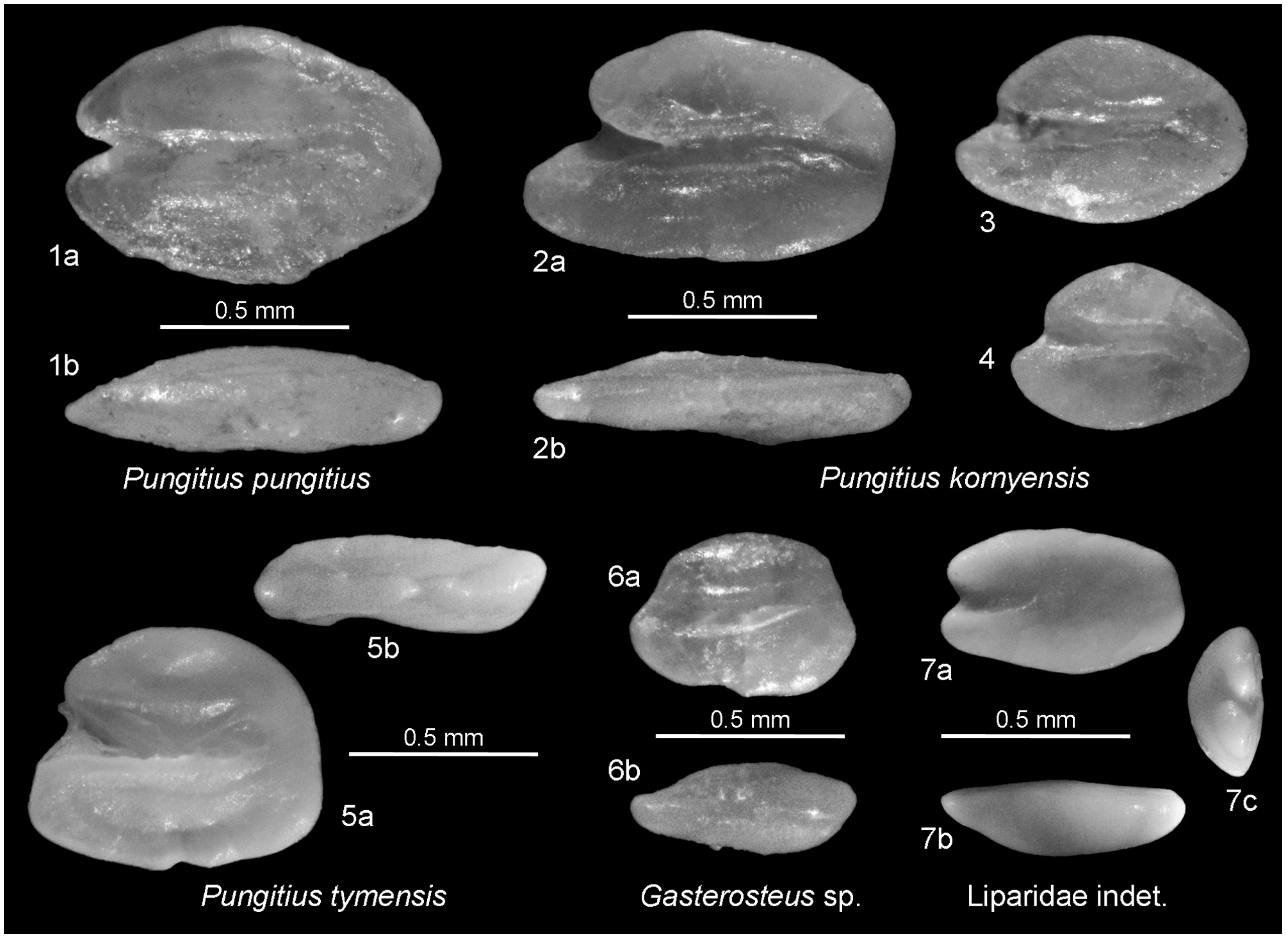


Plate 5

1. *Pungitius pungitius* (Linnaeus, 1758), Recent, Portugal.

2-4. *Pungitius kornyensis* (Schubert, 1912), 2 (r), 4: UMG-X 8532, Karaganian, Bulgaria, well Balchik 103a, 212m; 3 (r): UMG-X 8571, Tarchanian, Bulgaria, well Tsarichino C-26, 250.7m.

5. *Pungitius tymensis* (Nikolskii, 1889), NSMT 104767, Recent, Hokkaido, Japan.

6. *Gasterosteus* sp., (r), UMG-X 8615, Konkian, Bulgaria, well Balchik 105a, 197m.

7. Liparidae indet., UMG-X 8613, Tarchanian, Bulgaria, well Goren Bliznak C-2, 143-145m.

Inner face slightly convex with long, narrow, slightly supramedian sulcus. Ostium much shorter than cauda and only slightly wider, i.e. slightly widening towards antirostrum. CaL:OsL (measured at rear tip of deepened ostium) = 1.65-1.75. Cauda slightly oscillating, terminating relatively close to posterior tip of otolith. Dorsal depression small, indistinct; ventral furrow weak. Outer face flat to slightly convex, smooth.

Discussion – The largest specimen of Plate 5, fig. 2 compares very well with *Clupea suzini* as figured by Pobedina (1954) from the Karaganian of Azerbaijan. There appears to be some ontogenetic shift taking place between 0.75 and 1 mm length (Pl. 5, figs 2 and 3) and Schubert's type from the lower Sarmatian of Cornea (= Kornya) in NW Romania belongs to the same category of size. The smaller specimens have a rounded ventral rim (vs flat) and a rounded posterior rim (vs blunt and vertically cut) and also differs slightly in the expression of the rostrum and excisura. I regard all these changes as consequences of ontogeny.

Similar otoliths are found in certain gasterosteids, *i.e.* in *Pungitius pungitius* (Linnaeus, 1758) (Pl. 5, fig. 1) and *Spinachia spinachia* (Linnaeus, 1758) (see Härkönen, 1986), which share the moderately elongate otolith shape and the narrow sulcus with the slightly oscillating cauda and deepened and short ostium. Both species, however, clearly differ in the short rostrum. Most gasterosteids are anadromous freshwater and brackish water fishes of the higher northern latitudes. The occurrence of *P. kornyensis* is thus more warmth-loving than extant species of the group. Its occurrence during the Karaganian crisis (see Baykina & Schwarzhans, 2017) and the early Sarmatian matches its ecological profile in the Recent, but the singular record in the Tarchanian is somewhat contradictory. *Pungitius kornyensis* is the first fossil gasterosteid otolith recognized although time equivalent records of articulated skeletons have been described from California and Siberia (Patterson, 1993), the latter also placed in the genus *Pungitius* (*P. hexacanthus* Schtylko, 1934).

Genus *Gasterosteus* Linnaeus, 1758

***Gasterosteus* sp.**
Plate 5, fig. 6

Material – One specimen UMG-X 8615, Konkian, Bulgaria, well Balchik 105a, 197 m.

Description – A single small, robust otolith of about 0.6 mm length; OL:OH = 1.4; OH:OT = 1.8. Ventral rim irregularly curved, deepest posteriorly; dorsal rim shallow, regularly curved. Posterior rim oblique, ventrally pronounced; anterior rim with short, massive rostrum and indistinct excisura and antirostrum; rostrum length about 12% of OL.
Inner face convex, with a narrow, tapering slightly upward directed sulcus, not clearly distinguished into ostium and cauda. Dorsal depression narrow, indistinct; ventral furrow feeble. Outer face convex and smooth.

Discussion – The small compact otolith with its narrow, undivided sulcus resembles the character status of figured *Gasterosteus* species (see Härkönen, 1986 and Campana, 2004), but is also found in some *Pungitius* species, like *P. tymensis* (Nikolskii, 1889) (pl. 5, fig. 5).

Family Liparidae Scopeli, 1777
genus indet.

Liparidae indet.
Plate 5, fig. 7

Material – One specimen UMG-X 8613, Tarchanian, Bulgaria, well Goren Bliznak C-2, 143-145 m.

Discussion – The single, small, elongate oval otolith of 0.64 mm length is characterized by a completely flat inner face with a short deepened visible sulcus probably representing the ostium while a cauda is not discernable, and a nearly symmetrical, moderately long rostrum and antirostrum with a moderately deep excisura in between. The unusual sulcus morphology best matches extant otoliths of Cyclopteridae and Liparidae (see Campana, 2004), and I therefore tentatively associate this otolith with liparids.

Faunal evaluation

The otoliths from the early Badenian of Coşteiu de Sus and Lăpugiu de Sus represent the most south-easterly neritic fish fauna known from the Pannonian Basin at the time. It is a rich faunal composition, particularly the one from Coşteiu de Sus, with a diverse assemblage of neritic fishes and some admixture of deep water fishes, primarily myctophids, which is typical for outer and deeper shelf assemblages (Schwarzhans, 2013b). The composition correlates well with the much better known assemblages from the northern Pannonian Basin and the Vienna Basin (Schubert, 1902, 1905, 1906, reviewed in Nolf, 1981; Brzobohaty, 1978, 1994; Radwanska, 1984, 1992; Brzobohaty, Nolf & Kroupa, 2007; Nolf & Brzobohaty, 2009). Of 42 identifiable species recorded here from Coşteiu de Sus and Lăpugiu de Sus, 32 are also known from the more north-westerly locations, but nearly a quarter of all species (10) are not known from there. Most of these species are rare, but nevertheless this surprisingly high count warrants some contemplation.
The first to consider are two deep water aulopiforms (*Aulopus costeiensis* and *Bathypterois solidus*) the latter representing the first record of the family Ipnopidae in the Miocene. *Aulopus* is bathybenthic on the lower shelf and the continental slope, *Bathypterois* bathydemersal on the continental slope down to the abyssal plains. They are both singular finds, but in as much interesting as they represent the only bathybenthic fishes together with *Hoplobrotula gibba* (Bassoli, 1906) and *Pseudophichthys* sp. in this community. Macrourids, usually the most common bathybenthic fish in Neogene sediments, are completely absent.
All other species not recorded north of these two locations represent neritic fishes with the possible exception of *Ambassis*? *lapugyensis* as transitional marine, but which was not available for study (see Nolf, 1981). In this assemblage of fishes one may distinguish three groups: one that has no relation to north-westerly species, a second which appears to have possibly allopatric counterparts in the north and thirdly an exotic surprise.
The first group containing no counterparts in the north comprises *Scarus* sp., *Callanthias transylvanicus* and the gobiid *Weilerigobius lapugiensis*. *Scarus* and *Callanthias* are both genera which occur in the Mediterranean today, although the majority of their species are living in warmer seas (Froese & Pauly, 2017). *Weilerigobius* is a fossil otolith-based genus of uncertain relationships. It bears a resemblance to *Thorogobius* of the *Gobius*-group as well as to *Benthophilus* of the Ponto-Caspian gobies, but may not be related to either.
Of more interest are those species which appear to have an allopatric counterpart in more north-westerly regions. *Pagellus schuberti* for instance appears to be the warm habitat allopatric counterpart to *Pagellus weitzmani* of the North Sea Basin (Schwarzhans, 2010). Another species, *Pagellus albuquerquae* is known from the North Sea Basin (rare) southwards to the Aquitaine Basin, Portugal and the northern part of the Central Paratethys (Steurbaut, 1984; Radwanska, 1992). It belongs, however, to a different lineage within *Pagellus*. Thus, the distribution of the species of the genus *Pagellus* represents one of the most conclusive examples of latitudinal diversification affecting the Romanian localities. *Sphyraena* sp. is based on two small specimens much too eroded to warrant description, but nevertheless it is clear that it represents a different species from *Sphyraena hansfuchsi* in the northern Paratethys (see also discussion in the systematic part). The distribution of the involved species might reflect another case of latitudinal diversification,

but subject to more data and a detailed review. *Lesueurigobius magniiugis* finally represents a very distinctive otolith morphology that is easy to distinguish from the ubiquitous Mediterranean and Paratethyan *L. vicinalis* of the time. In fact, *Lesueurigobius vicinalis* also is the most common gobiid in Coşteiu de Sus and Lăpugiu de Sus, while *L. magniiugis* is a singular record, which indicates that its primary distribution might be expected further to the south.

A record of special interest is *Lactarius* cf. *sigmoidalis*, an abundant species from coeval strata of New Zealand (Schwarzhans 1980). Due to the absence of any comparative coeval data from the Indian Ocean we can only speculate about the former distribution of *Lactarius sigmoidalis*. However, we do know that a (allopatric) species existed at the same time in the NW Atlantic, namely *Lactarius atlanticus* Steurbaut & Jonet, 1982. If verified by further specimens, the occurrence of *Lactarius sigmoidalis* in the Paratethys would represent a prime example of its connectivity to the Indian Ocean sometime during the early to middle Miocene interval.

Why did these fishes occur in the southern Pannonian Basin, *i.e.* in Coşteiu de Sus and Lăpugiu de Sus, and not in the well studied more north-westerly locations of Hungary, Austria, Czech Republic or Slovakia, and where did they come from? The first part of the question is probably best answered by latitudinal / climatological differences. The seas at Coşteiu de Sus and Lăpugiu de Sus were just a bit warmer than at those other locations. The presence of three potential allopatric species pairs is the best argument in my view for such an explanation. A climatic-controlled gradient along the Central Paratethys was also discussed by Harzhauser et al. (2003, molluscs) and Brzobohatý et al. (2007, otoliths).

More difficult to answer is the question of regional provenance of the faunal elements unrecorded further north. That is mainly because our knowledge of coeval neritic fish faunas to compare with them is very limited from the Mediterranean and non-existent from the Indian Ocean. Even the records of otoliths from the Tarchanian and Tshokrakian of the Eastern Paratethys are meagre and in dire need of review. Also, they seem to primarily represent deep water environments. A small faunule found in the collection of Strashimirov from wells in Bulgaria from the Dacian Basin shows limited correlation, restricted to few bathypelagic fishes and gobies. However, it shows additional elements not known from the Central Paratethys such as *Gobiusculus rotundus* (Pobedina, 1954), *Mullus bifurcus* (Strashimirov, 1972), *Pontinus*? *obrotchishtensis* (Strashimirov, 1981) and the first record of a microdesmid - *Microdesmus paratethycus* - in the Konkian. Except for apparent palecological differences these relatively few otoliths also reflect a different sampling attitude. While otoliths in Coşteiu de Sus and Lăpugiu de Sus primarily stem from large scale collection for molluscs and hence may be biased towards large otoliths, those from the Bulgarian wells were picked from residue for microfossils and thus are biased towards small specimens. It therefore rather documents what might be missing in each location rather than representing true faunistic differences. In conclusion, it appears likely that those unrecorded new species in Coşteiu de Sus and Lăpugiu de Sus could be of Eastern Paratethyan origin, but this hypothesis is out to be tested. Paleogeographic considerations would be in favour of an Eastern Paratethyan origin. Both Coşteiu de Sus and Lăpugiu de Sus are locations with sediments dating to, or shortly after the Tarchanian sea connection between the Eastern and the Central Paratethys (Sant *et al*., 2017).

Conclusions and Outlook

Otoliths reviewed from the localities Coşteiu de Sus and Lăpugiu de Sus in Romania in the south-eastern part of the Pannonian Basin and from wells in Bulgaria in the Euxinic Basin have revealed generally good correlation with the well known otolith associations of Austria, Czech Republic, Hungary and Slovakia, but at the same time show a number of indigenous faunal elements (about 25%) not recorded from those other regions. It is assumed that the cause of these differences is latitudinal in nature with the fauna studied here representing a relatively warmer climate and possibly indicating connectivity to the Eastern Paratethys at this time or shortly before.

Future studies are necessary to resolve the conundrum by addressing time equivalent strata in the Eastern Paratethys and the Indian Ocean. The Eastern Paratethys particularly appears to offer many locations suitable for such purposes. A good knowledge of the early Badenian as well as Tarchanian and Tshokrakian otolith assemblages is essential for understanding the genesis of the highly endemic Paratethyan fish fauna that evolved subsequently during and after the Karaganian Crisis. Investigations from the realms of the Indian Ocean are necessary to reveal if there were still any faunistic interchanges of fishes with the Paratethys as late as Middle Miocene.

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Order Fam. Species	SMF P.#	Lapugiu	Costeiu	Fig.	Weiler 1950 ident.	Reference of revision
Anguilliformes						
Congridae						
***Pseudophichthys* sp.**	2791		X	Pl. 1: Fig. 1	Otolithus (Congridarum) sp.	
Rhynchoconger pantanellii (Bassoli, 1906)	2789, 2790		X	Pl. 1: Fig. 2	*Congermuraena pantanellii*	
Siluriformes						
Ariidae						
Arius germanicus Koken, 1891	2784, 2785		X		*Arius germanicus*	
Stomiiformes						
Sternoptychidae						
***Valenciennellus* sp.**	2832	X		Pl. 1: Fig. 3	Otolithus inc. sed. sp. 5	
Gonostomatidae						
***Gonostoma*? *cyclomorphum* (Weiler, 1950)**	2828	X			*Argentina cyclomorpha*	Nolf, 2013
Myctophiformes						
Myctophidae						
Myctophum murbani (Weinfurter, 1952)	2822/4		X		*Scopelus debilis*	Schwarzhans & Aguilera, 2013
Lampadena speculigeroides Brzobohaty & Nolf, 1996	2829, 2830, 2857	X			*Scopelus splendidus*	Brzobohaty & Nolf, 1996
Diaphus austriacus (Koken, 1891)	2821, 2822/2-3, 2856, 2862, 2863	X	X	Pl. 1: Fig. 9	*Scopelus debilis*	Schwarzhans & Aguilera, 2013
Diaphus kokeni (Prochazka, 1893)	2822/1	#	X	Pl. 1: Fig. 10	*Scopelus debilis*	Schwarzhans, 2010
***Diaphus* aff. *obliquus* (Weiler, 1943)**	2864	X		Pl. !: Fig. 11	*Scopelus debilis*	Schwarzhans & Aguilera, 2013
Diaphus sp. juv.	2833, 2834	X			*Scopelus pulcher*	
Notoscopelus mediterraneus (Koken, 1891)	2794-96		X		*Scopelus mediterraneus*	Brzobohaty & Nolf, 1996
Aulopiformes						
Aulopidae						
***Aulopus costeiensis* n.sp.**	2819		X	Pl. 2: Fig. 1	Otolithus inc. sed. sp. 1	
Ipnopidae						
***Bathypterois solidus* n.sp.**	2851		X	Pl. 2: Fig. 2	Otolithus inc. sed. sp.	
Gadiformes						
Gadidae						
Gadiculus argenteus (Guichenot, 1850)	2786-88, 2854, 2918		X		*Macrurus ellipticus*	Nolf, 1985
Paratrisopterus rumanus (Weiler, 1943)	2831, 2835	X			*Macrurus rumanus*	Schwarzhans et al., 2017
Phycidae						
Phycis musicki Cohen & Lavenberg, 1984	2799a,b, 2800, 2858	X	X		*Phycis tenuis*	Cohen & Lavenberg, 1984
Ophidiiformes						
Ophidiidae						
Hoplobrotula gibba (Bassoli, 1906)	2783, 2850		X		Otolithus (Ophidiidarum) *joachimicus* + *difformis*	Schwarzhans, 2010
Holocentriformes						
Myrirpristiidae						
Myripristis banatica Weiler, 1950	2774, 2776		X	Pl. 2: Figs. 1-2	*Myripristis banatica*	
***Myripristis lobata* n.sp.**	2775		X	Pl. 2: Fig. 3	*Myripristis banatica*	
Zeiformes						
Antigoniidae						
Antigonia alta (Weiler, 1950)	2778		X		Otolithus (Monocentridarum) *altus*	Nolf, 1985
Antigonia sp.	2853		X		Otolithus (Monocentridarum) *altus*	Schwarzhans, 2010

Gobiiformes						
Apogonidae						
***Apogon banaticus* Weiler, 1950**	2779, 2780	#	X	Pl. 3: Figs. 1-2	*Apogon banaticus*	
Gobiidae						
Deltentosteus telleri (Schubert, 1906)		#				
***Gobius frici* Prochazka, 1900**	2801		X	Pl. 3: Fig. 5	*Gobius pretiosus*	
***Lesueurigobius magniiugis* n.sp.**	2916a	X		Pl. 3: Fig. 6	*Gobius vicinalis*	
Lesueurigobius vicinalis (Koken, 1891)	2804-06, 2870	X	X	Pl. 3; Figs. 7-8	*Gobius vicinalis*	Nolf, 1985
***Weilerigobius lapugiensis* n.gen. n.sp.**	2802, 2803, 2916b	X	X	Pl. 3: Figs. 9-11	*Gobius pretiosus* + *G. vicinalis*	
gobiid indet.	2859	X			*Gobius pretiosus*	
Istiophoriformes						
Sphyraenidae						
***Sphyraena* sp.**	2792, 2793		X	Pl. 4: Fig. 1	Otolithus inc. sed. sp. 4	
Labriformes						
Scaridae						
***Scarus* sp.**	2883a		X	Pl. 4: Fig. 2	Otolithus inc. sed. sp.	
Perciformes						
Ambassidae						
Ambassis? *lapugyensis* (Schubert, 1912)		#				
Acropomatidae						
Verilus mutinensis (Bassoli, 1906)	2797, 2798		X		Otolithus (Percidarum) *opinatus*	Schwarzhans & Prokofiev, 2017
Serranidae						
Serranus integer (Schubert, 1906)	2812, 2813		X	Pl. 4: Fig. 6	Otolithus (Serranidarum) sp.	Nolf, 1981
Lactariidae						
***Lactarius* cf. *sigmoidalis* (Frost, 1933)**	2860	X		Pl. 2: Fig. 8	Otolithus indet.	
Haemulidae						
Brachydeuterus latior (Schubert, 1906)	2816-18, 2825, 2861, 2917	X			*Dentex nobilis miocenica* + *Dentex latior*	
Brachydeuterus speronatus (Bassoli, 1906)	2814		X		*Cantharus*? *sp.*	
Sciaenidae						
***Umbrina polonica* (Radwanska, 1984)**	2849		X	Pl. 4: Fig. 3	*Sciaena pecchioli*	
Cepolidae						
***Cepola multicrenata* Radwanska, 1984**	2781, 2782		X	Pl. 4: Figs. 4-5	*Cepola praerubescens*	
Spariformes						
Callanthiidae						
***Callanthias transylvanicus* n.sp.**	2820, 2824, 2883b		X	Pl. 4: Figs. 8-10	Otolithus inc. sed. sp.2 + 3, sp.	
Sparidae						
Dentex doederleini (Bassoli & Schubert, 1906)	2807		X		*Chrysophrys doederleini*	Schwarzhans, 2010
Dentex gregarius (Koken, 1891)	2809-2811, 2868a		X		*Pagellus gregarius*	Nolf, 1985
Diplodus sp.	2808, 2823		X		*Chrysophrys doederleini* + *Paracentropristis* sp.	
***Pagellus schuberti* n.sp.**	2815, 2852, 2868b-c		X	Pl. 4: Figs. 11-13	*Cantharus*? sp., *Pagellus gregarius*	
Scorpaeniformes						
Agonidae						
Agonus elongatus Weiler, 1950	2855		X		*Agonus elongatus*	

Table 1. Revised species list of Weiler's specimens at SMF with catalog details from Coşteiu de Sus and Lăpugiu de Sus, Romania. Species printed in bold are described or discussed in the systematic part. In column Lapugiu: # indicates records by Schubert (1912).

Order Fam. Species	UMG-X #	Fig.	Tarchanian	Chokrakian	Karaganian	Konkian
Stomiiformes						
Gonostomatidae						
***Gonostoma*? *cyclomorphum* (Weiler, 1950)**	8547, 8558, 8561, 8603	Pl. 1: Figs. 4-7	X			
Phosichthyidae						
***Woodsia emi* Brzobohaty & Nolf, 2002**	8598	Pl. 1: Fig. 8	X			
Gobiiformes						
Gobiidae						
***Buenia elegans* (Prochazka, 1900)**	8606	Pl. 3: Fig. 4		X		
Economidichthys triangularis (Weiler, 1943)	8528			X?		
Gobiusculus rotundus (Pobedina, 1954)	8522, 8527, 8533, 8546, 8549-51, 8554-56, 8565, 8569-70, 8593		X	X		
Gobius sp.	8614					X
Pomatoschistus bunyatovi Bratishko, Schwarzhans & Reichenbacher, 2015	8605			X		
Microdesmidae						
***Microdesmus paratethycus* n. sp.**	8616					X
Perciformes						
Mullidae						
Mullus bifurcus (Strashimirov, 1972)	8563		X			
Scorpaeniformes						
Scorpaenidae						
Pontinus? *obrotchishtensis* (Strashimirov, 1981)	8548		X			
Gasterosteidae						
***Pungitius kornyensis* (Schubert, 1912)**	8532, 8571		X		X	
***Gasterosteus* sp.**	8615					X
Liparidae						
Liparidae indet.	8613		X			

Table 2. Species list of specimens from the inheritance of B. Strashimirov at UMG with catalog details from wells in Bulgaria. Species printed in bold are described or discussed in the systematic part.

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