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Late Miocene (Pannonian) sciaenid fish otoliths from Hungary – preliminary studies

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(with 3 figures and 3 plates)

Fossil sciaenid fish otoliths are reported here from Pannonian (Upper Miocene) deposits of 11 Hungarian localities. 41 specimens belonging to four species are described in this paper: *Umbrina cirrhosoides* (SCHUBERT, 1902), *Umbrina subcirrhosa* SCHUBERT, 1902, *Trewasciaena kokeni* (SCHUBERT, 1902), and *Sciaena* sp. This material is a great example for present intraspecific variation of sciaenid otoliths.

Introduction

Otoliths in Pannonian deposits are rarer than in Badenian ones but the most common otoliths in Pannonian deposits are sciaenid fish otoliths. Their conspicuous large size attracted the attention of researchers since the early twentieth century. Detailed taxonomic work on Pannonian otoliths has been published last in 1912 by SCHUBERT, who has summarized the data of Imre LŐRENTHEY.

More than a hundred years ago, LŐRENTHEY, who was the head of the Department of Paleontology at Budapest University, studied fish otoliths at first time from Pannonian beds of Hungarian localities. He described three new species in the so-called Balaton monography (1905). His type specimens have been lost, just a few samples are preserved in the collection of the Department of Paleontology, Eötvös University in Budapest.

This study is based on this poor material complemented with new collections. My aim is to revise LŐRENTHEY's specimens and to broaden our knowledge about the morphological variation of sciaenid otoliths. This work constitutes elemental part of the reconstruction of the Pannonian fish fauna.

Importance of the otoliths

Otoliths or earstones are the part of the inner ear (membranous labyrinth) of teleost fishes in the acustico-lateralis system. This system is a sensory organ which detects both the position of the fish and sound. The membranous labyrinth is filled with endolymphatic fluid and divided into a pars superior and a pars inferior. Pars superior is composed of three major canals and one sac-like structure, the utriculus, pars inferior is composed of two additional sac-like structures, the sacculus and the lagena (ZBORAY 1997). The sacculus is generally the largest part of the lower labyrinth and contains the largest otolith known as sagitta, the structure commonly used in fish determination or age estimation. The utriculus contains the lapillus otolith and the lagena contains the asteriscus otolith (NOLF 1985). Morphologically the less variable is the lapillus. In the present discussion the term 'otolith' always refers to sagitta.

All three sac-like otolithic end organs of the inner ear have sensory epithelium, known as maculae. The macula contains sensory hair cells and is associated with branches of the eighth cranial (auditory) nerve. The apical surface of the macula is covered by an otolithic membrane, which becomes thickened by mineral depositions, forming a single mass, the otolith. The otolithic membrane holds the otolith in its place next to the epithelium and is connected to it by ciliary bundles (POPPER et al. 2005).

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Otoliths are composed of calcium carbonate, primarily aragonite (DEGENS et al. 1969). The aragonite crystals are oriented with their long axes radiating from a central nucleus in three dimensions. The new crystals deposit on the outer surface. The calcification depends on the composition of endolymphatic fluid sorrounding the otolith, which is under endocrinological control (CAMPANA 1999). Otoliths also contain 0.2 to 10% organic matter in the form of a fibrous protein called otolin (DEGENS et al. 1969). Otolin is a kind of acidic amino acid with rather uniform chemical composition trough various taxa (NOLF 1985). Otoliths are three times denser than the fish body (POPPER & LU 2000, POPPER et al. 2005). During the fossilization otolith aragonite has recrystallized into calcite and became more compact and abrasion-resistant. Therefore, otoliths are more frequent in the sediments and more usable for paleontological studies than the other part of the fish skeleton.

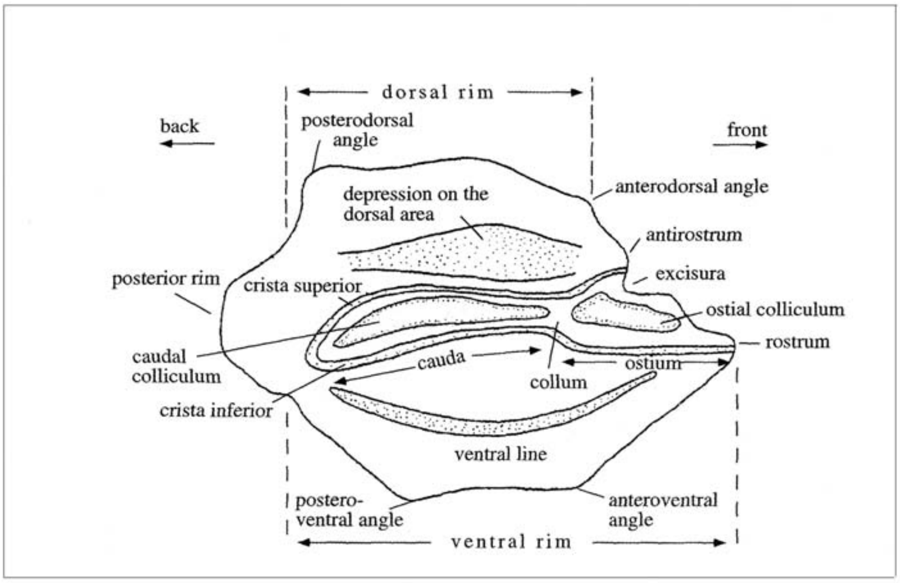

Fig. 1. General morphological terminology of the fish otoliths (REICHENBACHER & CAPPETTA 1999).

Morphologically, sagittae are typically oval and laterally flattened in shape with smooth or crenulated rims. Many sagittae have long, well-developed processes or highly irregular rims. The so-called inner face (or ventral face) of the otolith is very diverse. Generally it has a deep furrow through its surface mid-line from the anterior to the posterior rim, known as sulcus. The sulcus can be divided into two regions, the anterior region is called the ostium and the posterior is the cauda. Both of them have their own small pulp called colliculum. In many cases a fissura runs below the sulcus in line with the ventral rim. Above the sulcus there is a shallow dent called area. The dorsal face of the sagitta is usually irregular, with secondary importance in the determination. In the work Otolithi Piscium a summary of terms is presented to describe the inner face (NOLF, 1985). The general terminology of the inner face is shown in Fig. 1. The morphology of sciaenid fish otoliths differs from general otolith appearance (see Fig. 2). Sciaenid otoliths have wide, rounded ostium with flat and smooth colliculum, which completely filled the ostium. The cauda is diverse, generally curved, and the relative length of its downturned portion is an important character. The curvature of the inner face is an other important feature in the determination.

The primary function of otolithic organs is sound detection but in many taxa they have both auditory and vestibular roles (POPPER & LU 2000). Sensory hair cells of the maculae react to sound, gravity and to linear accelerations of the fish. They not only detect sounds but also can discriminate different frequencies and intensities (FAY & POPPER 2000), and can determine the location of the sound in three dimension. This capability varies in different fish groups. Most of the species can detect sounds from 50 Hz to perhaps 1000 or 1500 Hz, but there are some species, which can detect sounds to over 3000 Hz (POPPER & LU 2000, POPPER et al. 2005).

Material and methods

The material described here is housed in the collection of the Department of Paleontology at Eötvös Loránd University. The basis of the material was collected by Imre LŐRENTHEY from Budapest–Kőbánya, Tihany–Fehérpart and Zalaapáti at the beginning of the twentieth century. Samples are eroded, the determination is impossible in some cases. The other part is from the private collections of Imre MAGYAR, Pál MÜLLER and Janina HORVÁTH. These latter materials are well-preserved.

The altogether 79 specimens were collected from the following localities, both sandy and argillaceous sediments: Balatonalmádi, Bátaszék, Budapest–Kőbánya, Kötcse, Kurd, Mohács, Korsós-bánya, Tab, Tata, Tihany–Fehérpart, Tihany–Gödrös, Vázsnok (Fig. 3). These samples are sporadic, not an upshot of systematical collecting. All of them is without the designation of the exact stratigraphical position except the samples of Tihany–Fehérpart of MÜLLER's collection (MÜLLER & SZÓNOKY 2007).

Forty-one otoliths were identified using binocular microscope. The terminology used below follows that of SCHWARZHANS (1993). The photos were made by Nikon Coolpix 4500 digital camera.

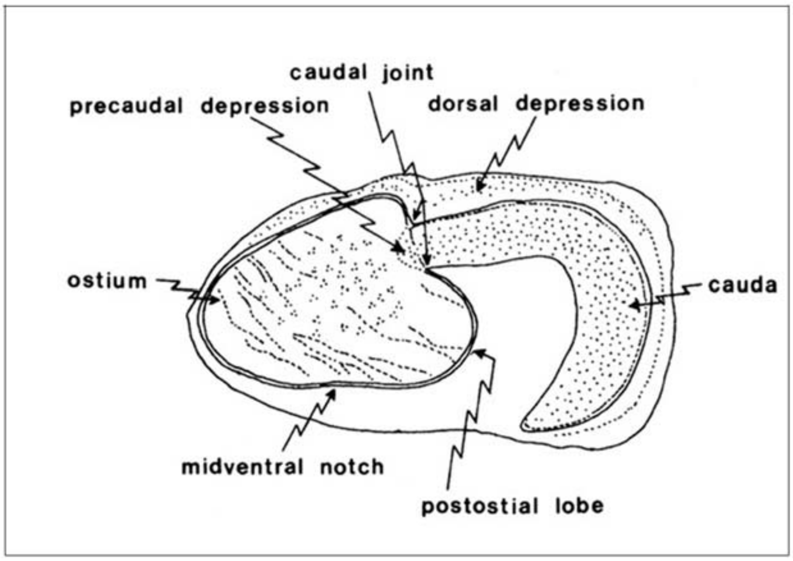

Fig. 2. Morphological terminology of sciaenid otoliths (SCHWARZHANS 1993).

Brief historical survey of Pannonian otolith studies

In 1906 LŐRENTHEY published his monograph in German on the Pannonian beds ('Congerien Schichten') around Lake Balaton. In this contribution he presented a few otolith taxa with figures and descriptions and described three new species: *Otolithus (Sciaenidarum) loczyi*, *Otolithus (Sciaenidarum) pannonicus* and *Otolithus (Sciaenidarum) schuberti*. His work was based on the paper of SCHUBERT (1902). The type specimens after all has been considered to be lost and the revision has been done by NOLF (1985) based on the illustrations. NOLF regarded these otoliths as coming from very juvenile fishes.

Also in 1906, SCHUBERT summarized otolith records from the Tertiary of eastern Austria and Hungary in the third part of his contribution. He mentioned the Pannonian samples collected by LŐRENTHEY from the localities of Tihany, Fonyód, Tab, Zalaapáti and Budapest-Kőbánya and cited the monograph. In 1912, SCHUBERT's paper on the Tertiary otoliths was published, repeating the list of 1906 and describing a new species.

The species described by SCHUBERT have been revised by NOLF in 1981. He rejected many doubtful taxa because the erosion of the type specimens or the assigned holotypes being juvenile material in many cases. Studies by WEINFURTER (1954) on otoliths from the Pannonian of Vösendorf, Vienna Basin, presented new taxa. In 1985 BRZOBOHATY & PANA gave a short review about Pannonian fish faunas, which utilized previous works without revision. In 1992, BRZOBOHATY published a few fish otolith taxa from the deposits of the famous mammal locality of Götzendorf, Lower Austria.

In 1993, a serious contribution was published by SCHWARZHANS on comparative morphological research of recent and fossil sciaenids. He also revised Schubert's type specimens and discussed Pannonian otoliths probably not only from the Vienna Basin, but "much wider distributed in the Neogene of Paratethys" (SCHWARZHANS 1993).

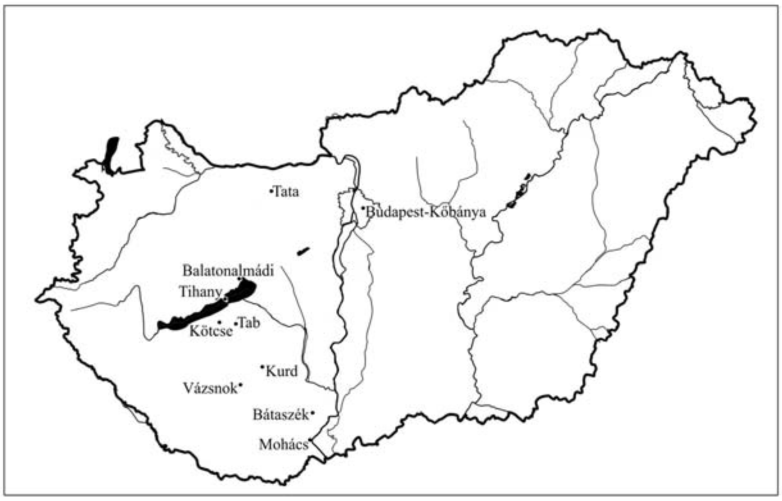

Fig. 3. Sketch map of the localities.

Otoliths of Sciaenidae

All otoliths studied here belong to the family Sciaenidae (Perciformes), commonly called drums or croakers, found in the Atlantic, Indian and Pacific Oceans. About 270 recent species are known but only a few occur in fresh waters, four of them are endemic genera in South America (LOVEJOY et al. 2006). The members of Sciaenidae produce croaking or drumming sounds by their specialized musculature near the swim-bladder, hence their public name. The sensory system of their head is characteristically cavernous.

The sciaenids have large otoliths and are known for their specific differences in sound production. Because of their function as sound transducers, sciaenid otolith shape variation should influence the frequency sensitivities and directional hearing in fish (NOLF, 1985, SCHWARZHANS 1993, BÖHME 2002, MONTEIRO et al. 2005).

They are neritic fishes living in the temperate and warm shallow seas and estuaries. Only a few genera are known from deeper shelf environments. Sciaenids are generally bottom-dwelling species feeding on invertebrates and smaller fishes with a key role in estuarine ecosystems (CARNEVALE et al. 2006).

About 100 fossil otolith-based sciaenids have been described from the 1870's, many of them by KOKEN (1884, 1888, 1891) and SCHUBERT (1902). No endemic sciaenid species are known from the Late Miocene Paratethys (SCHWARZHANS 1993).

The intraspecific variation is the consequence of the ontogenetic changes and the sound producing and detecting function of the otoliths. The situation is easier on the case of recent sciaenid otoliths, but it is chaotic on fossil specimens. In many cases, new species had been described on the basis of juvenile specimens making the determination more difficult. In 1993 SCHWARZHANS essayed to revise the fossil sciaenid literature and gave a useful handbook to the taxonomic work.

Summary

41 specimens belonging to four sciaenid species are described here from 11 Pannonian localities of Hungary: *Umbrina cirrhosoides* (SCHUBERT, 1902), *Umbrina subcirrhosa* SCHUBERT, 1902, *Trewasciaena kokeni* (SCHUBERT, 1902), *Sciaena* sp. The specimens collected by LŐRENTHEY are fairly eroded, only ones come from Budapest–Kőbánya were identified.

This material is an example to demonstrate ontogenetic changes of sciaenid otoliths, which is a well-known phenomenon and makes the determination more difficult. The characteristics are

very similar in the juvenile stages of each species of *Sciaena* and *Pogonias*. The lenght:height and height:thickness ratios may also change during ontogeny, therefore it is very difficult to distinguish between ontogenetic variability and variation above species level.

This study became necessary in the light of new investigation: the newest intetion of the otolith workers is to reduce the number of species based on fossil otoliths of uncertain systematic position. SCHWARZHANS and NOLF attempted to unite or reject many doubtful species.

The low quantity of the Pannonian record does not provide possibilities to wide conclusions. From palaeoecological aspects, based on the comparison with extant related taxa, the fish fauna represents brackish estuaries with developed ecosystem. Sciaenid predators feed on smaller fishes, for example gobiids, whose otoliths also occur in the investigated sediments.

Further investigation is needed with much more record for the statistical analysis from each localities to establish the stratigraphic distributions of the species and the faunal relationship.

Systematic Paleontology

Superclass Osteichthyes HUXLEY, 1880
Class Actinopterygii COPE, 1887
Order Perciformes BLEEKER, 1859
Family Sciaenidae GILL, 1861
Sciaena Group
Genus *Umbrina* CUVIER, 1817

Umbrina cirrhosoides (SCHUBERT, 1902)
Pl. I, Fig. 1-7

1902 *Otolithus* (*Corvina*?) *cirrhosoides* n. sp. – SCHUBERT, p. 304, pl. X, fig. 4 a, b.
1902 *Otolithus* (*Umbrina*?) *plenus* n. sp. – SCHUBERT, p. 304, pl. X, fig. 6 a, b, c.
1993 *Umbrina cirrhosoides* (SCHUBERT, 1902) – SCHWARZHANS, p. 77, figs 124-125.

Material. 7 samples, Balatonalmádi: 1, Kötcse-120: 1, Tihany, Fehérpart 2b: 1, Vázsnok: 1, Budapest –Kőbánya: 3.

Measurements. L/H= 1,3-1,6; H/T= 1,8-2,8; CL/OL= 0,9-1,3; OL/OH= 0,8-1,2;

Description. Large specimens. Sagittae having a rounded rectangular shape. Dorsal rim nearly horizontal, characterized by a tip above the gap of the ostium and the cauda. Dorsal rim terminates in the pronounced posterodorsal angle.

The inner face is rather convex, the outer face is concave and strongly thickened in the posterior part. The ventral rim is undulate.

The ostium is large and rounded, characterized by the curved postostial lobe. Cauda is wide, shallow, first straight and then drops down vertically, terminates slightly bending to the front. The curved cauda encompasses a hump.

Remarks. Adult and subadult specimens.

Umbrina subcirrhosa SCHUBERT, 1902
Pl. II, Fig. 1-11

1902 *Otolithus (Umbrina) subcirrhosus* n. sp. – SCHUBERT, p. 304, pl. X, fig. 3 a, b.
1902 *Otolithus (Sciaenidarum) subsimilis* n. sp. – SCHUBERT, p. 309, pl. X, fig. 12 a, b.
1902 *Otolithus (Sciaenidarum)* aff. *claybornensis* KOKEN – SCHUBERT, p. 310, pl. X, fig.13 a, b, non Textfig. 2.
1989 *Umbrina* sp. – NOLF & CAPPETTA, pl. XVI, fig. 7 a, b.
1993 *Umbrina subcirrhosa* SCHUBERT, 1902 – SCHWARZHANS, p. 71, figs 103-107.

Material. 23 samples, Vázsnok: 2, Tihany, Fehérpart 8: 3, Tihany, Gödrös: 2, Bátaszék-25: 1, Bátaszék-46: 1, Balatonalmádi: 1, Kötcse-120: 7, Tab: 3, Budapest–Kőbánya: 3.

Measurements. L/H= 1,2-1,7; H/T= 2,4-3,4; CL/OL= 0,9-1,3; OL/OH= 1,0-1,6;

Description. Sagittae have a rounded rectangular, elongated shape, the smaller specimens have crenulated rim. Inner face is slightly convex, outer face is flat.

The sulcus is divided to a large and rounded ostium and a wide, curved cauda; the former is thinner in the middle, the latter drops down vertically along the posterior rim and terminates on the ventral rim with a shallow groove.

Remarks. Juvenile and subadult specimens become more elongated during the ontogeny and the subadult specimens show a less curved cauda.

Genus *Sciaena* LINNAEUS, 1758

Sciaena sp.
Pl. I, Fig. 8-10

?1993 *Sciaena umbra* LINNAEUS, 1758 – SCHWARZHANS, p. 80, fig. 129.

Material. 3 samples, Tata, Szomódi road:1, Kötcse-120: 2.

Measurements. L/H= 1,3-1,5; H/T= 1,9-3,2; CL/OL= 0,9-1,3; OL/OH= 0,9-1,0;

Description.The shape of *Sciaena* sp. is more rounded and its posterior part is narrower than those of *U. cirrhosoides*.

Remarks. The illustrated inner face is very similar to the recent species *Sciaena umbra* LINNAEUS, 1758 in Fig. 129 in SCHWARZHANS 1993, but the outer side features are more flatter.

Sciaena umbra LINNAEUS, 1758 prefers coastal water and is known from 20-180 m water depth (REICHENBACHER & CAPPETTA 1999).

Pogonias Group

Genus *Trewasciaena* SCHWARZHANS, 1993

Trewasciaena kokeni (SCHUBERT, 1902)
Pl. III. Fig. 1-8

1902 *Otolithus (Sciaenidarum) Kokeni* n. sp. – SCHUBERT, p. 305, pl. X, fig. 18 a, b.
1902 *Otolithus (Sciaena) irregularis var. angulata* m. – SCHUBERT, p. 306, pl. X, fig. 8 a, b.
1902 *Otolithus (Sciaena?) levis* n. sp. – SCHUBERT, p. 306, pl. X, fig. 9 a, b.
1902 *Otolithus (Sciaenidarum) Telleri* n. sp. – SCHUBERT, p. 307, pl. X, fig. 16 a, b.
1902 *Otolithus (Sciaenidarum) excissus* n. sp. – SCHUBERT, p. 307, pl. X, fig. 17 a, b.
1993 *Trewasciaena kokeni* (SCHUBERT, 1902) – SCHWARZHANS, p. 98, figs 171-177.

Material. 8 samples, Tihany, Fehérpart: 2, Tihany, Fehérpart 8: 1, Tihany, Fehérpart 23: 1, Mohács, Korsós-bánya: 2, Budapest – Kőbánya: 2.

Measurements. L/H= 1,3-1,5; H/T= 2,2-3,0; CL/OL= 1,1-1,4; OL/OH= 0,9-1,3;

Description. Sagittae are robust, elongated and rectangular, the dorsal rim is strongly sinous, slightly concave. Inner face is convex, outer face is slightly convex and wrinkled.

Ostium is rounded. Cauda is slightly bent at the posterior rim, terminates in tip.

Remarks. Juvenile and subadult specimens. *Trewasciaena* is a genus based on fossil otoliths.

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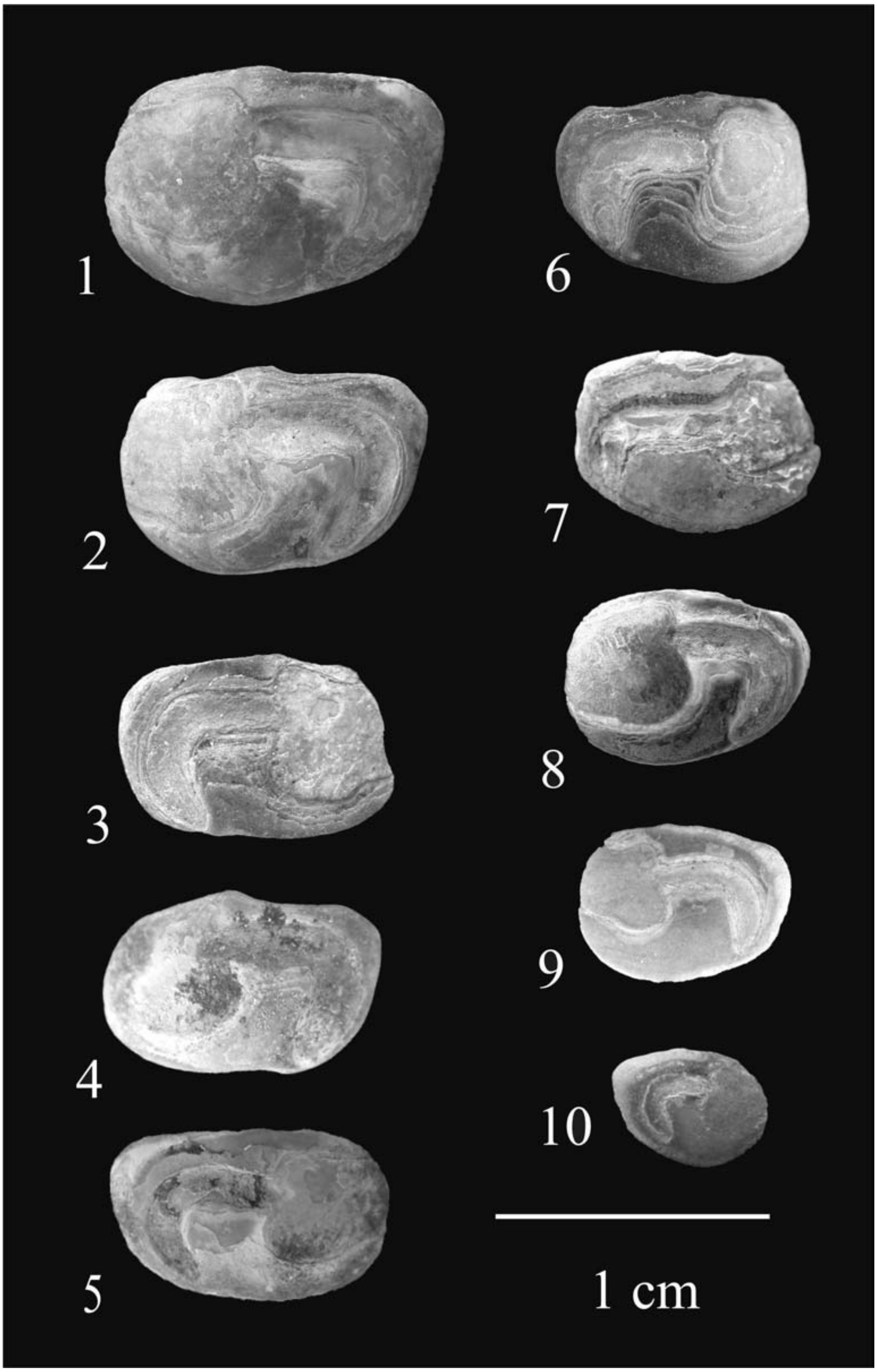
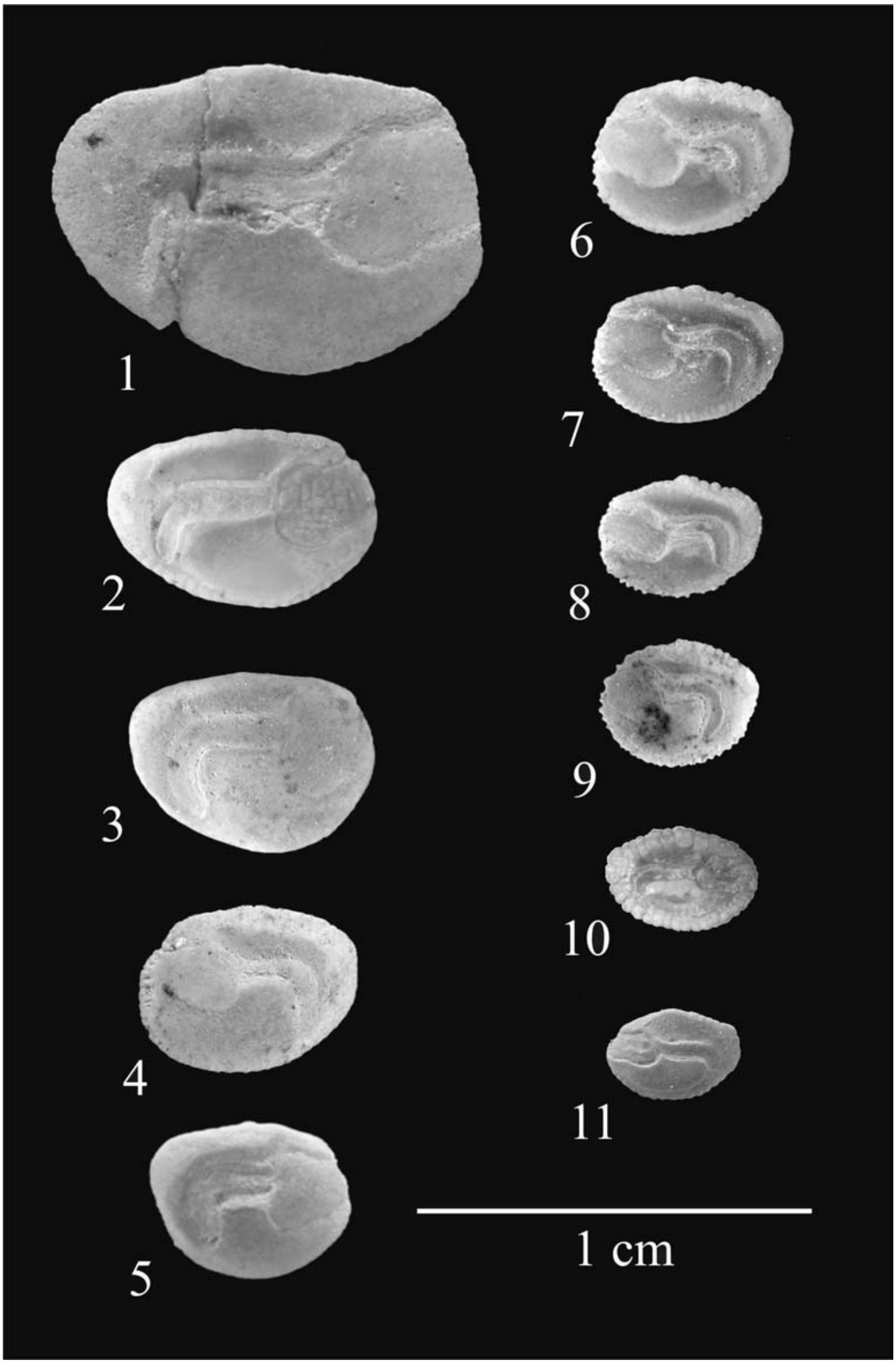
Plate I



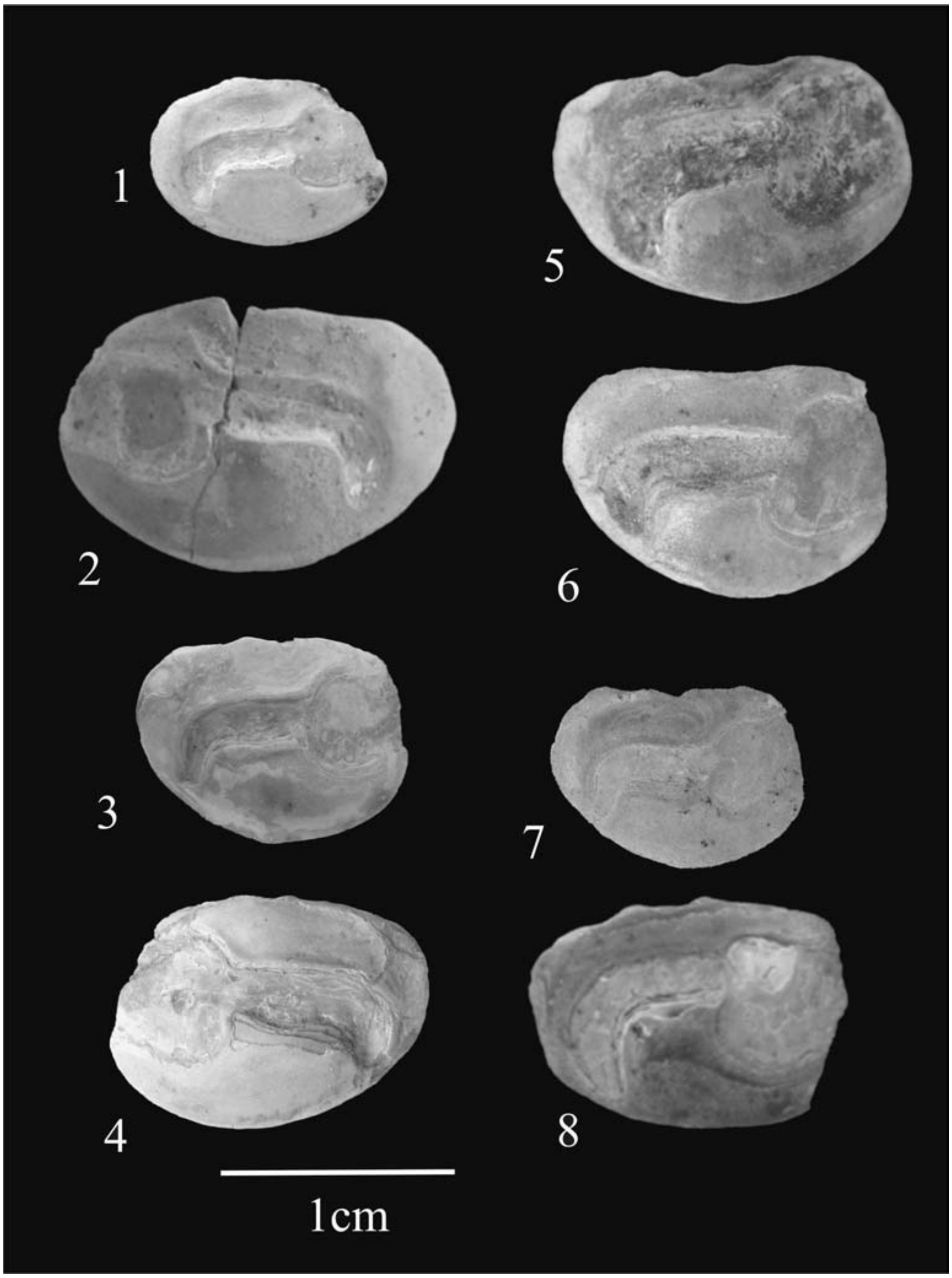
1: *Umbrina cirrhosoides* (SCHUBERT, 1902); Vázsnok.
2: *Umbrina cirrhosoides* (SCHUBERT, 1902); Balatonalmádi.
3: *Umbrina cirrhosoides* (SCHUBERT, 1902); Tihany, Fehérpart, 2b.
4-5, 7: *Umbrina cirrhosoides* (SCHUBERT, 1902); Budapest–Kőbánya (coll. Lőrenthey).
6: *Umbrina cirrhosoides* (SCHUBERT, 1902); Kötcse-120.
8: *Sciaena* sp.; Tata, Szomódi út.
9-10: *Sciaena* sp.; Kötcse-120.

Plate II



1: *Umbrina subcirrhosa* SCHUBERT, 1902; Tihany, Fehérpart 8.
2: *Umbrina subcirrhosa* SCHUBERT, 1902; Bátaszék–46.
3-4: *Umbrina subcirrhosa* SCHUBERT, 1902; Tihany, Fehérpart 8.
5: *Umbrina subcirrhosa* SCHUBERT, 1902; Kurd.
6-8: *Umbrina subcirrhosa* SCHUBERT, 1902; Kötcse–120.
9: *Umbrina subcirrhosa* SCHUBERT, 1902; Budapest–Kőbánya (coll. Lőrenthey).
10: *Umbrina subcirrhosa* SCHUBERT, 1902; Vázsnok.
11: *Umbrina subcirrhosa* SCHUBERT, 1902; Bátaszék–25.

Plate III



1: *Trewasciaena kokeni* (SCHUBERT, 1902); Tihany, Fehérpart 8.
2: *Trewasciaena kokeni* (SCHUBERT, 1902); Tihany, Fehérpart 23.
3-4: *Trewasciaena kokeni* (SCHUBERT, 1902); Mohács, Korsós-bánya.
5-6: *Trewasciaena kokeni* (SCHUBERT, 1902); Budapest–Kőbánya (coll. Lőrenthey).
7: *Trewasciaena kokeni* (SCHUBERT, 1902); Tihany, Fehérpart.
8: *Trewasciaena kokeni* (SCHUBERT, 1902); Tihany, Gödrös.