Otoliths from the middle Miocene (Serravallian) of the Karaman Basin, Turkey

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Received 26 February 2014, revised version accepted 26 April 2014

Otoliths are described from middle Miocene, Serravallian rocks of the Karaman Basin of southeastern Turkey. Nearly 1100 specimens were identified representing a total of 47 species, thereof 27 fossil species, 6 extant species and 14 species left in open nomenclature. 11 species are new: *Mascarenichthys exilis* n. sp., *Scorpaena*? *landaui* n. sp., *Serranus*? *ariejansseni* n. sp., *Lethrinus anatolicus* n. sp., *Spicara pamphyliensis* n. sp., *Gobius mustus* n. sp., *Gobius reichenbacherae* n. sp., *Gobius vandervoorti* n. sp., *Knipowitschia suavis* n. sp., *Pomatoschistus rueckertae* n. sp. and *Thorogobius iucundus* n. sp. The predominant group represented by otoliths are the Gobiidae, a family typical for shallow marine to brackish environments, followed by Sparidae and Lethrinidae. The teleost association is typical for warm, shallow, sheltered seas without any significant open marine influence, which is corroborated by other fossil groups previously studied from the area.

The faunal correlation of the Serravallian otoliths from the Karaman Basin shows the nearest relationship to the fish fauna of the slightly older Badenian (Langhian to early Serravallian) of the Vienna Basin of the Central Paratethys, which is similar to the conclusions recently also reached for molluscs. Twelve of the 16 previously known fossil species have also been recorded from the Badenian of the Paratethys and four exclusively so, while two species are of NE Atlantic affinities. However, comparative and time equivalent shallow marine otolith data from the Mediterranean are still poorly known. A few species indicate relation to the present-day Indo West-Pacific fish fauna, namely of the genera *Mascarenichthys, Sillago* and *Lethrinus*, and are indicative of an earlier faunal interchange between the two areas, which terminated only during the Langhian to Serravallian interface.

Certain species of the Gobiidae are interpreted to represent derived forms from earlier, Badenian and older gobiid species from the Paratethys and thus indicate potential for a local biostratigraphic application.

KEY WORDS: Otoliths, middle Miocene, Serravallian, Karaman Basin, Turkey, Teleostei, Gobiidae, systematics, paleobiogeography.

Introduction

The otoliths described in the following were obtained from predominantly marls and clays of middle Miocene, Serravallian age along a number of surface outcrops in the Karaman Basin of SE Turkey. A total of about 1100 otolith specimens were collected in the course of sampling primarily for molluscs during several field trips undertaken by J. van der Voort and A.W. Janssen.

Previous studies of fossil otoliths from marine strata in Turkey have been published by Rückert-Ülkümen (1992, 1996) and Rückert-Ülkümen *et al*. (1993). They mainly deal with faunas from western Turkey and appear to be all from younger sediments (late Miocene). Thus, this fossil otolith assemblage now represents the first one from southern Turkey. A total of 47 teleost species are identified from the Serravallian of the Karaman Basin, thereof 16 previously described from other southern European locations ranging from the Aquitaine Basin in southern France to the basins of the former Paratethys. Six species represent species still extant in the Mediterranean and/or eastern Atlantic, 11 species are new and further 14 species are left in open nomenclature, indicating that many more elements of this ancient fish fauna are still to be recovered.

Localities and geology

The otoliths described in the following have been obtained from 8 localities in the Karaman Basin, S-Turkey. For detailed descriptions of the localities reference is made to Landau *et al*. (2013). The localities sampled for otoliths are (Fig. 1): localities 2 and 3 at road cuts near Lale, locality 6 on hill slopes NW of Lale, locality 7 Akbogazi on slopes along Lale river, locality 11 on southwest bank of Gödet Creek across from Tilkikaya, locality 13 south of Akpinar - Pinarlar Yaylasi, locality 17 fields south of Seyithasan and locality 19 on road to Mut about 27 km S of Karaman. The numbering and naming of the

localities follows Landau *et al*. (2013).
The Karaman Basin represents a relatively small intramontaneous Neogene basin located between the high plain of central Anatolia and the Taurus Mountains to the south. Since the deposition of the sediments of the Karaman Basin in the Miocene it has been uplifted to 1100 to 1300 m above sea level. The stratigraphic position of the sampled intervals is considered to be of middle to late Serravallian according to the holoplanktonic-mollusc-based biostratigraphy of Janssen (1999, 2012) and as discussed in Landau *et al*. (2013). It is therewith slightly younger than the rich Badenian (Langhian to early Serravallian) fauna of the well-known Vienna and Carpathian Foredeep basins.

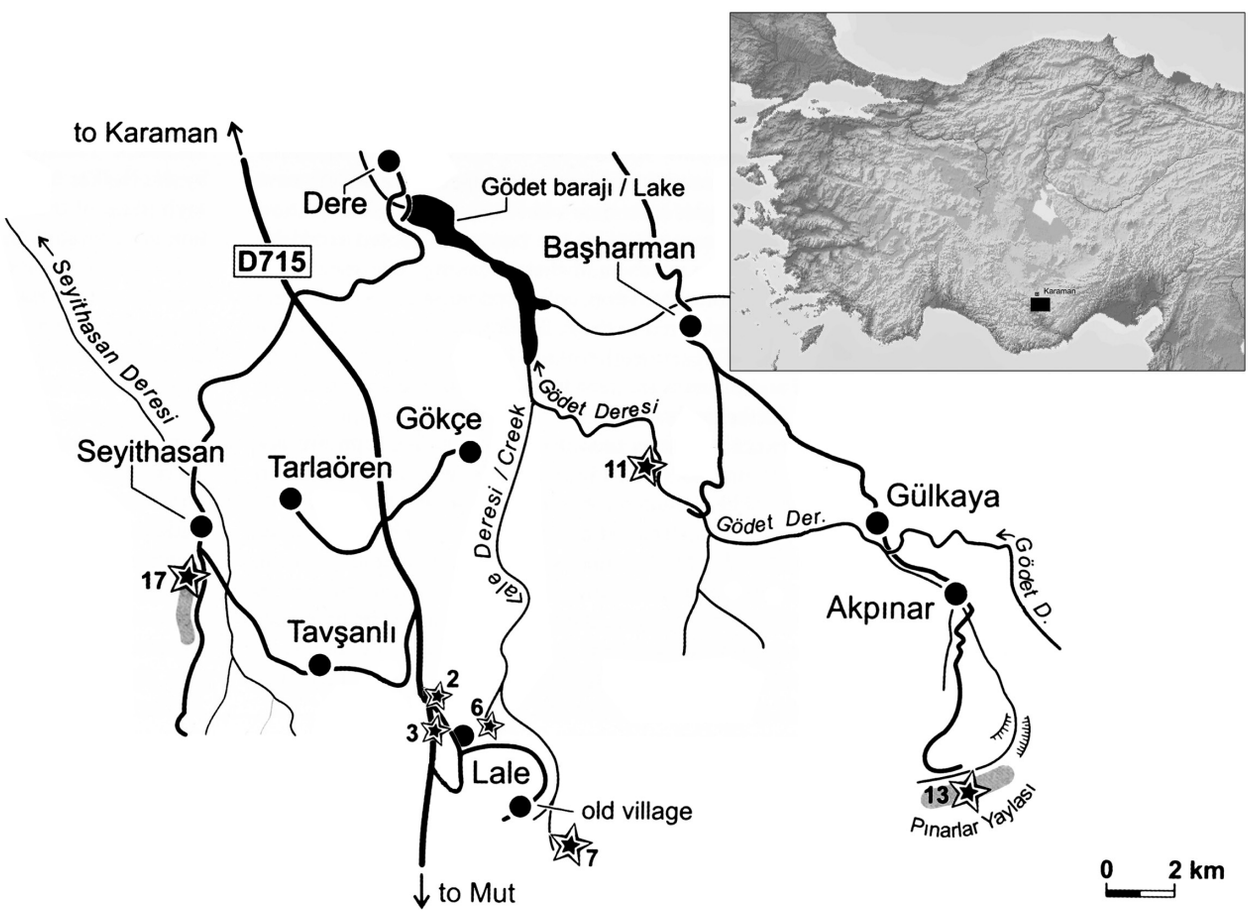

Figure 1. Location map depicting localities in the Karaman Basin from which otolith were obtained (locality 19, road to Mut, south of map, not shown). Map compiled after Landau *et al*., 2013; insert map created from Microsoft Encarta 2006.

Depository and methods

For optimal comparison purposes, all figures show otoliths of the right side. Drawings of left otoliths have been mirror imaged and are marked with an (r) for reversed.
The following abbreviations are used in the descriptions: otolith length = OL, otolith height = OH, otolith thickness = OT, ostium length = OsL, cauda length = CaL, ostial colliculum length = OCL, caudal colliculum length = CCL, total colliculum length = CoL, ostial colliculum height = OCH, caudal colliculum height = CCH, total colliculum height = CoH, sulcus length = SuL, sulcus height = SuH. Other abbreviations used in the text: FM = formation. The curvature index of the inner face is calculated as percentage of OL. 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.
All specimens including holotypes and paratypes are deposited at the Naturalis Biodiversity Center, Paleontology Department, Leiden, The Netherlands, formerly Rijksmuseum van Geologie en Mineralogie (RGM registration numbers).
The morphological terminology of otoliths was established by Koken (1891) with amendments by Weiler (1942) and Schwarzhans (1978) (Fig. 2 upper left). The morphometric measurements of otoliths follows Schwarzhans (2013b) (Fig. 2 upper right).

Gobiid otoliths are particularly common in the Karaman Basin and therefore I have considered it useful to provide certain specific measurements to support a better

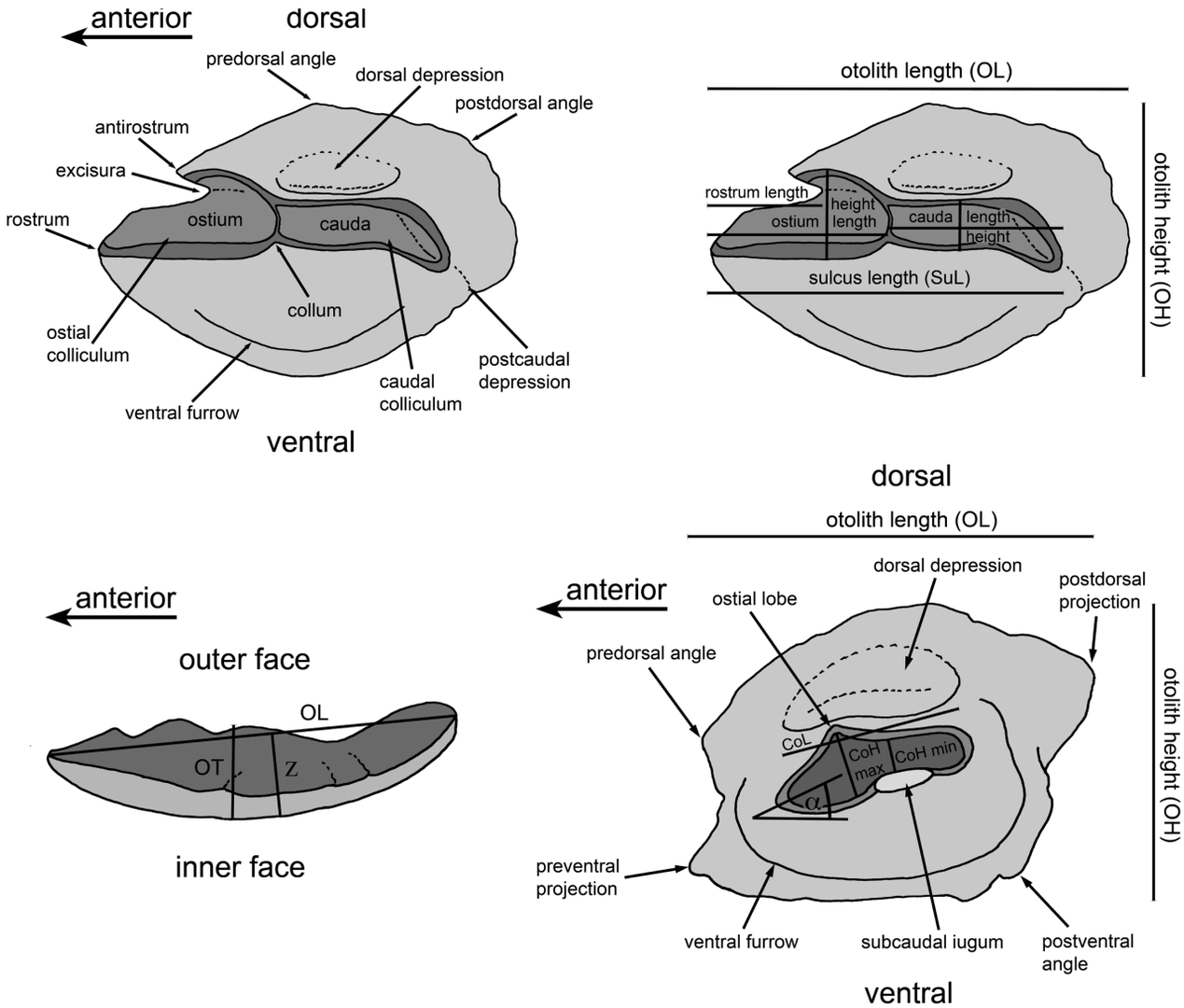

Figure 2. Otolith terminology and explanation of morphometric measurements. The upper row shows a typical heterosulcoid percoid otolith. The lower row shows a gobioid otolith and explains newly established specific characters used in goby otoliths such as the subcaudal iugum, angles and projections of the otolith rim and specific morphometric measurements including the inclination angle; α referring to the sulcus inclination.

description of their morphological characters and allow a more detailed analysis and comparison, as explained on the lower row of Fig. 2. Gobiid otoliths exhibit some very specific and rather unique characters, such as the sole-shaped median sulcus with its ostial lobe of varying shape and intensity and the inclination of the sulcus. Ostial and caudal colliculi are always fused. A unique character of many, but not all gobiid otoliths is a broad patch (Latin = *iugum*) of varying size, usually only below the cauda and then termed the 'subcaudal iugum'. It appears to be a widening of the crista inferior and not homologous to the caudal pseudocolliculum found in myctophids and certain batrachoidids, although sometimes the iugum appears to be separated from the proper rim of the sulcus by a feeble furrow. Recognition of the subcaudal iugum requires good preservation of the otolith and cannot be seen in every specimen. Other characters of specific importance in gobiid otoliths include shape and intensity of the preventral and postdorsal projections and predorsal and postventral angles. The curvature of inner and outer face including the curvature index (Z as percentage of OL) is best seen from the dorsal view since it depends to a large extend on the curvature of the postdorsal projection. Finally, gobiid otoliths exhibit another rather specialized feature: a long ventral furrow curving around the anterior and posterior tips of the sulcus and sometimes joining up to a small but mostly well developed dorsal depression.

Acknowledgements

First and foremost, I wish to thank Arie W. Janssen (Naturalis Biodiversity Center, Leiden, The Netherlands) and Jaap van der Voort (Ostercappeln-Venne, Germany) for having put together this interesting collection of fossil

otoliths and having made it available to me. Further, I wish to thank Irene Zorn (Vienna, Austria) for information concerning location of some of Prochazka's original otolith material, Rostislav Brzobohaty (Brno, Czech Republic) for his advice to the nature of *Gobius intimus* and *Cepola voeslauensis* and Bettina Reichenbacher (Munich, Germany) for information concerning her ongoing studies of *Gobius multipinnatus*.
In respect to Recent comparative material used for this study, I would like to cordially thank for their support and advice: G. Allen (WAM, Perth, Australia), P. Bearez (MNHN, Paris, France), D. Catania (CAS, San Francisco, U.S.A.), O. Crimmen (BMNH, London, Great Britain), G. Duhamel (MNHN, Paris, France), R. Feeney (LACM, Los Angeles, U.S.A.), R. Fricke (SMNH, Stuttgart, Germany), K. Hartel (MCZ, Cambridge, U.S.A.), J. Maclaine (BMNH, London, Great Britain), P. Møller (ZMUC, Copenhagen, Denmark), S. Morrison (WAM, Perth, Australia), J. Nielsen (ZMUC, Copenhagen, Denmark), F. Ohe (Seto City, Japan), J. Paxton (AMS, Sydney, Australia), S. Raredon (USNM, Washington D.C., U.S.A.), J. Williams (USNM, Washington D.C., U.S.A.), A. Williston (MCZ, Cambridge, U.S.A.). Institutional abbreviations follow Fricke & Eschmeyer (2011).
Rostislav Brzobohaty and a second, anonymous reviewer are thanked for their constructive review of an earlier version of the manuscript.

Systematic part

Order Anguilliformes Regan, 1909
Family Congridae Kaup, 1856
Genus *Ariosoma* Swainson, 1838

***Ariosoma balearicum* (Delaroche, 1809)**
Plate 1, figs 1-2

1932 *Congermuraena moravica* Sulc, fig. 2.
1966 *Congermuraena balearica* (Delaroche, 1809) – Smigielska, pl. 14, fig. 3.
1984 *Ariosoma* aff. *balearica* (Delaroche, 1809) – Steurbaut, pl. 1, figs 15-16 (with further synonymies).
1984 *Ariosoma* aff. *moravica* (Sulc, 1932) – Steurbaut, pl. 2, figs 1-2 (with further synonymies).
1984 *Ariosoma longicaudatum* Radwanska, text-figs 2-3, pl. 1, figs 1-3.
1992 *Ariosoma balearica* (Delaroche, 1809) – Radwanska, text-fig. 11, pl. 11, figs 5-8 (with further synonymies).

Material examined – Three specimens; 1 specimen RGM 816 400, Lale (locality 2), 2 specimens RGM 816 401, Seyithasan (locality 17).

Discussion and distribution – A typical *Ariosoma*-type high bodied otolith with a convex, smooth inner face and a centrally positioned, anteriorly closed, and s-shaped undivided sulcus, connected to the anterior-dorsal rim with a thin ostial channel. Otoliths of the extant *A. balearicum* have been identified in the Atlantic basins of Europe and in the Mediterranean and the Paratethys since Langhian (Badenian) times. In the Recent the species is known from the subtropics and tropics from both sides of the Atlantic.

Genus *Rhynchoconger* Jordan & Hubbs, 1925

***Rhynchoconger pantanellii* (Bassoli, 1906)**

1906 *Ophidium pantanellii* Bassoli, pl. 1, figs 41-42.
1992 *Hildebrandia pantanellii* (Bassoli & Schubert, 1906) – Radwanska, text-fig. 14, pl. 2, figs 2-4 (with further synonymies).
2013a *Rhynchoconger pantanellii* (Bassoli, 1906) – Schwarzhans, pl. 1, fig. 14.

Material examined – 1 specimen RGM 816 402 from Akpinar (locality 13).

Discussion – A common and widespread species in the Miocene and Pliocene of the Mediterranean, the Miocene of the Paratethys and the European Atlantic basins and the Pliocene of Morocco (Brzobohaty *et al*., 2007, Radwanska, 1992, Schwarzhans, 2013a, Steurbaut, 1984, Steurbaut & Jonet, 1982). In the Recent, only a few *Rhynchoconger* larvae had been identified from the East Atlantic while several species are recorded from the tropical West Atlantic (Froese & Pauly, 2014). However, identification of some large sub-recent *Rhynchoconger* otoliths from dredges off the Gulf of Guinea (Schwarzhans 2013a), which are very similar to the fossil *R. pantanellii*, have shown a consistent record of the genus in the East Atlantic as well.

Genus *Pseudophichthys* Roule, 1915

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

1992 *Pseudophichthys* sp. – Radwanska, text-fig. 15, pl. 3, figs 10-12.

Material examined – One specimen RGM 816 403 from a road cut on the road to Mut, *c*. 27 km south of Karaman (locality 19).

Discussion – This is a typical otolith of the genus *Pseuophichthys* characterized by an anteriorly reduced sulcus with the colliculum terminating far away from the anterior rim of the otolith, no ostial channel and a distinct, deep dorsal depression. The same species has been recorded in open nomenclature from the Badenian of Poland. I have chosen to refrain from a specific identification as well until sufficiently large and diagnostically valid specimens have been retrieved.

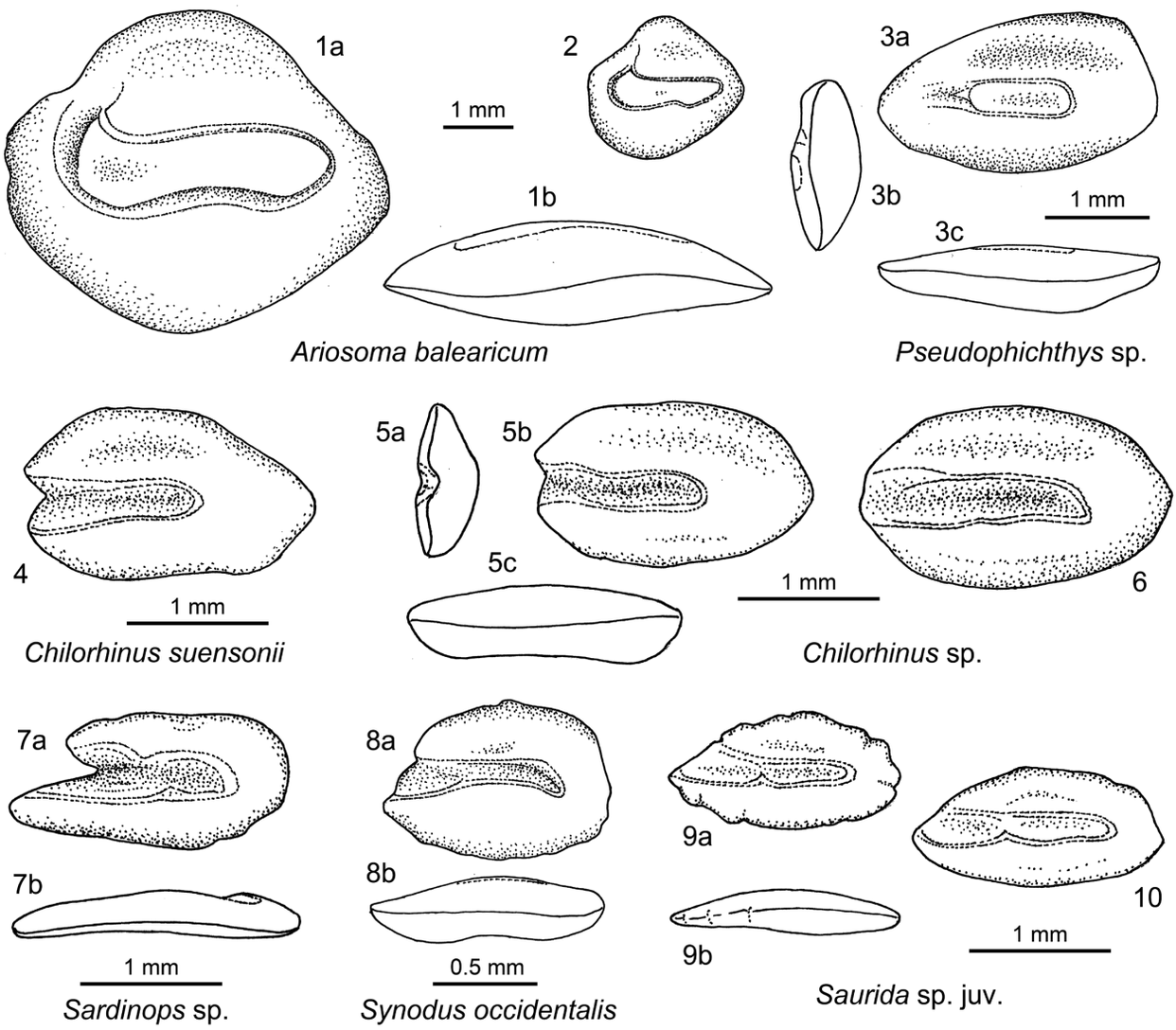

Plate 1

1-2. *Ariosoma balearicum* (Delaroche, 1809); 1: (r) Seyithasan, RGM 816401; 2: (r) Lale, RGM 816 400.
3. *Pseudophichthys* sp. (r) ; road to Mut, RGM 816 403.
4. *Chilorhinus suensonii* Lütken, 1852; Recent from the former Danish West Indies, ZMUC unregistered (21.9.1916.17-20), SL 92 mm.
5-6. *Chilorhinus* sp.; 5: Akpinar, RGM 816 404; 6: (r) Akbogazi, RGM 816 405.
7. *Sardinops* sp.; Seythasan, RGM 816 406.
8. *Synodus occidentalis* Steurbaut, 1984; Seyithasan, RGM 816 411.
9-10. *Saurida* sp. (r) ; Seyithasan, RGM 816 409-410.

Family Chlopsidae Rafinesque, 1815
Genus *Chilorhinus* Lütken, 1852

***Chilorhinus* sp.**
Plate 1, figs 5-6

Material examined – Two specimens, RGM 816 404 from Akpinar Pinarlar Yaylasi (locality 13), RGM 816 405, Akbogazi (locality 7).

Description – Small, elongate, oval otoliths to about 2.2 mm length. OL:OH = 1.7. OH:OT about 2.5. Dorsal and ventral rims regularly curved without marked angles; posterior tip an obtuse median angle; anterior rim blunt, vertically cut, with broad, moderately deep excisura and short, equally developed rostrum and antirostrum.
Inner face bent along horizontal axis and only slightly bent in vertical direction. Sulcus narrow, deep, undivided, straight but slightly oscillating, anteriorly open, posteriorly tapering, terminating at considerable distance from posterior tip of otolith. Single undivided colliculum poorly marked, anteriorly reduced. OL: SuL = 1.35-1.65. Dorsal depression narrow, indistinct; ventral furrow very indistinct.

Outer face nearly flat along horizontal direction, convex in vertical direction, smooth. Rims thickened.

Discussion – These otoliths are rather inconspicuous at first sight, but show the characteristic short, anteriorly open and slightly oscillating but otherwise straight cauda typical for chlopsid otoliths. An otolith of the Recent West Atlantic *Chilorhinus suensonii* Lütken, 1852 is figured for comparison (Pl. 1, fig. 4). It resembles the fossil specimens in all characters except for the flat ventral rim and the ventrally shifted posterior tip. More specimens should be awaited before a specific identification can be achieved. In the Recent, *Chilorhinus* is not known from the East Atlantic.

Order Clupeiformes Bleeker, 1859
Family Clupeidae Rafinesque, 1810
Genus *Sardinops* Hubbs, 1929

***Sardinops* sp.**
Plate 1, fig. 7

Material examined – One specimen RGM 816 406, Seyithasan (locality 17).

Discussion – A single, reasonably well preserved juvenile otolith resembling *Sardinops pulcher* (Smigielska, 1966) known from the middle Miocene of the North Sea Basin and the Paratethys (see Schwarzhans, 2010).

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

***Diaphus* sp.**

Material examined – Two specimens: RGM 816 407, from Akpinar (locality 13) and RGM 816 408, from Seyithasan (locality 17).

Discussion – Two poorly preserved specimens which cannot be specifically identified. Myctophids are amongst the most common open marine, mesopelagic or pseudoceanic fishes and as such represent rare finds in the shallow marine inshore environment of the Karaman Basin.

Order Aulopiformes Rosen, 1973
Family Synodontidae Gill, 1861
Genus *Saurida* Cuvier & Valenciennes, 1849

***Saurida* sp.**
Plate 1, figs 9-10

Material examined – Two specimens RGM 816 409-410, Seyithasan (locality 17).

Discussion – Two juvenile specimens which cannot be identified to species level. However, there is only one species recorded from the European Miocene – *Saurida germanica* (Weiler, 1942) and it is therefore likely that these otoliths represent the same species.

Genus *Synodus* Scopoli, 1777

***Synodus occidentalis* Steurbaut, 1984**
Plate 1, fig. 8

1984 *Synodus occidentalis* Steurbaut, pl. 7, figs 19-21

Material examined – One specimen RGM 816 411, Seyithasan (locality 17).

Description – A small specimen of about 1 mm length. OL:OH = 1.4; OH:OT = 2.5. Dorsal and ventral rims regularly curved, dorsal rim with indistinct mediodorsal angle; posterior rim blunt; anterior rim with short, massive rostrum and indistinct antirostrum and excisura. All rims slightly undulating.
Inner face slightly bent. Sulcus very narrow, moderately deep, indistinctly divided into a slightly wider and much shorter ostium and a narrower, longer cauda, terminating with a slight bent at moderate distance from posterior tip of otolith. Colliculi poorly marked. No dorsal depression or ventral furrow.
Outer face flat to slightly concave, smooth.

Discussion – This is the second record of the species hitherto only reported from the Burdigalian of SW-France.

Order Gadiformes Goodrich, 1909
Family Bregmacerotidae Gill, 1872
Genus *Bregmaceros* Thompson, 1840

***Bregmaceros hybridus* Schwarzhans, 2013**
Plate 2, figs 1-2

2013d *Bregmaceros hybridus* Schwarzhans, pl. 5, figs 11-18 (with further synonymies)

Material examined – Two specimens; RGM 816 412 (ex coll. van der Voort), Akbogazi (locality 7) and RGM 816 413, Akpinar (locality 13).

Discussion – Two small specimens of less than 1 mm length, which based on their moderately compressed proportions are placed in *B. hybridus*, a species recently described from the Serravallian of West Africa and likewise known from the Burdigalian to Langhian of the Mediterranean (Schwarzhans, 2013d).

Family Phycidae Swainson, 1838
Genus *Phycis* Artedi, 1792

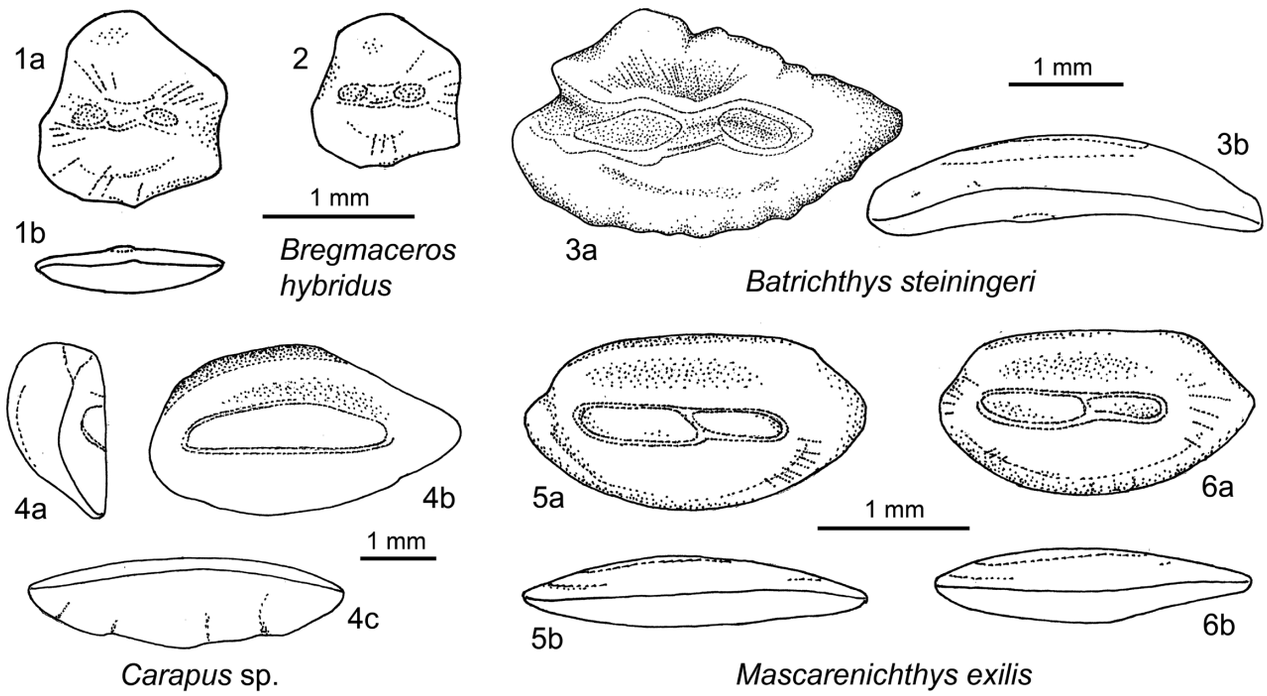

Plate 2

1-2. *Bregmaceros hybridus* Schwarzhans, 2013; 1: Akbogazi, RGM 816 412; 2: (r) Akpinar, RGM 816 413.
3. *Batrichthys steiningeri* Reichenbacher, 1998 (r) ; Seyithasan, RGM 816 414.
4. *Carapus* sp.; Akpinar, RGM 816 415.
5-6. *Mascarenichthys exilis* n. sp. (r) ; Seyithasan, 5: **holotype**, RGM 816 416; 6: **paratype**, RGM 816 417.

***Phycis musicki* Cohen & Lavenberg, 1984**

1891 *Gadus tenuis* Koken, pl. 4, fig. 6.
1984 *Phycis musicki* Cohen & Lavenberg, pp.1008-1009 [replacement name for *P. tenuis* (Koken, 1891), preoccupied by *P. tenuis* Mitchill, 1815].
2010 *Phycis musicki* Cohen & Lavenberg, 1984 – Schwarzhans, pl. 27, figs 10-11 (with further synonymies).

Material examined – One specimen coll. van der Voort, Lale (locality 2).

Order Batrachoidiformes Goodrich, 1909
Family Batrachoididae Bonaparte, 1832
Genus *Batrichthys* Smith, 1934

***Batrichthys steiningeri* Reichenbacher, 1998**
Plate 2, fig. 3

1998 *Batrichthys steiningeri* Reichenbacher, pl. 1, figs 4-7.

Material examined – One specimen RGM 816 414, Seyithasan (locality 17).

Description – A moderately large and well preserved otolith of about 3.5 mm length. OL:OH = 1.7; OH:OT = 2.5. Dorsal rim with pronounced predorsal angle, postdorsal portion straight, declining, irregularly ornamented; ventral rim regularly curved, deepest at its middle, slightly undulating; posterior tip pointed slightly above tip of cauda; anterior rim with obtuse, short, massive rostrum and small antirostrum and excisura.
Inner face distinctly bent along horizontal axis. Sulcus narrow, slightly supramedian, moderately deep, with well defined, widely separated colliculi and pseudocolliculum along ventral margin of collum. Ostium anteriorly open, but ostial colliculum terminating at some distance from anterior rim of otolith, slightly wider than cauda. OsL:CaL measured to centre of collum about 1.5. Cauda slightly inclined, terminating at considerable distance from posterior rim of otolith. Dorsal depression deep, well separated from sulcus by distinct crista superior; ventral furrow distinct, distant from ventral rim of otolith.
Outer face slightly concave, slightly ornamented.

Discussion – This well preserved otolith closely resembles the type specimens described by Reichenbacher (1998) from the Karpatian (late Burdigalian) of the Central Paratethys. The only notable variance is a slightly more convex ventral rim, which, however, is considered to represent intraspecific variation. *Chatrabus weileri* Schwarzhans, 2013d from the Serravallian to early Tortonian of Gabon, West Africa, differs in the smaller sulcus, which is anteriorly closed and the less pronounced pre-

dorsal angle. *Halobatrachus korytnicensis* (Smigielska, 1979) from the early Badenian (Langhian) of Poland is more compressed, shows a rounded, shallower dorsal rim, an inferior posterior tip and a larger sulcus with almost equally long ostium and cauda.

Order Ophidiiformes Berg, 1937
Family Carapidae Jordan & Fowler, 1902
Genus *Carapus* Rafinesque, 1810

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

Material examined – One specimen RGM 816 415, Akpinar (locality 13).

Discussion – A moderately large and reasonably well preserved otolith of about 4 mm length. It is characterized as a member of the genus *Carapus* by its relatively narrow and short sulcus. Otoliths recorded by Radwanska (1992) as representing the extant species *C.* aff. *acus* (Brünnich, 1768) from the early Badenian (Langhian) of Poland differ in the longer sulcus and it being inclined versus the long axis of the otolith.

Family Bythitidae Gill, 1861
Genus *Mascarenichthys* Schwarzhans & Møller, 2007

***Mascarenichthys exilis* n. sp.**
Plate 2, figs 5-6

Holotype – Pl. 2, fig. 5, RGM 816 416, Turkey, Karaman Basin, Seyithasan (locality 17), middle Miocene, Serravallian.

Paratype – One specimens, RGM 816 417, same locality as holotype.

Etymology – From *exilis* (Latin) = slender, referring to the narrow, straight sulcus.

Diagnosis – OL:OH = 1.9-2.0. OL: SuL = 1.6. OCL:CCL = 1.3-1.5. SuL:SuH about 5. Sulcus narrow, with straight dorsal margin. Dorsal rim straight, slightly elevated towards broadly rounded postdorsal angle. Anterior and posterior rims with obtuse, symmetrical tips.

Description – Small, elongate otoliths to about 2.3 mm length. OH:OT = 2.2-2.5. Dorsal rim straight, somewhat ascending towards broadly rounded postdorsal angle; rounded predorsal angle located above tip of ostium, postdorsal angle distinctly behind termination of cauda; ventral rim gently curved, deepest at its middle; posterior tip an obtuse slightly dorsally shifted angle with curved lower and straight upper rims; anterior tip similarly developed, slightly more rounded.
Inner face moderately convex. Sulcus very narrow, shallow, with straight dorsal rim and clearly distinct ostium and cauda with separate colliculi. Ostium only slightly longer and wider than cauda, far from reaching anterior rim of otolith, but not as far as caudal tip from posterior rim of otolith. Sulcus very slightly inclined compared to otolith axis. Dorsal depression narrow, indistinct; ventral furrow moderately well developed, running close but not entirely parallel to ventral rim of otolith. Outer face flat to slightly convex, smooth.

Discussion – Dinematichthyin otoliths with clearly separate colliculi are comparatively few in the Recent record and have been recorded from the American genera *Ogilbia* and some species of the related genus *Ogilbichthys* and in the Indo West-Pacific from *Alionematichthys, Dinematichthys, Mascarenichthys* and *Porocephalichthys* (the latter remarkable for its large sulcus and nearly equally sized ostium and cauda) (Møller *et al*. 2004, 2005, Møller & Schwarzhans, 2006, 2008, Schwarzhans & Møller, 2007). Except *Porocephalichthys* they all show reduced sulcus lengths and particularly short caudas. *Mascarenichthys exilis* differs from all of them in the low index OcL:CcL at 1.3-1.5, well below the 2.0 + observed in the extant genera. The fossil species from Karaman is placed with *Mascarenichthys*, Recent in the Indian Ocean because of its close resemblance with the short and narrow sulcus and the straight dorsal rim (Schwarzhans & Møller, 2007), but it might as well represent an extinct genus.
Dinematichthyins are viviparous fishes, specialized in living on reefs or reef associated environments of the tropics at water depths less than 40-50 m. A few genera (*Dermatopsis, Dermatopsoides* and certain species of the genus *Dipulus*) are endemic to southern hemisphere subtropical shores just south of the reef belt (Møller & Schwarzhans, 2006). Dinematichthyin otoliths have been reported from Tertiary formations in Europe since Paleocene (Schwarzhans, 2003, Schwarzhans & Bratishko, 2011) and well into Miocene times while there are no extant records from the area or even from tropical West Africa. As stated above, the presence of Dinematichyini can be taken as an ecological indicator in fishes for reef associations, which agrees well with the presence of a tropical Tethyan ecosystem that became extinct in the Mediterranean only during the terminal Miocene. Fossil records of dinematichthyin otoliths from the European Oligo-Miocene included so far species of the genera *Ogilbia* - *O. dispar* (Koken, 1891) from the Rupelian of the Mainz Basin, *O. mediterraneus* (Nolf & Cappetta, 1980), originally placed in the genus *Dipulus*, from the Burdigalian of SW-France and *O. sovisi* Reichenbacher, 1998 from the Karpatian of Austria - and *Ogilbichthys* - *O. chalossiana* (Nolf & Steurbaut, 2002) from the Rupelian of SW-France - all of which demonstrate relationship to the neotropics. Now *Mascarenichthys exilis* represents the youngest dinematichthyin record in the Mediterranean and Europe (*Ogilbia heinzelini* Lanckneus & Nolf, 1979 from the Pliocene of NW-France represents a species of the brosmophycin genus *Melodichthys*; for otolith figures of the Recent *M. hadrocephalus* Nielsen & Cohen, see

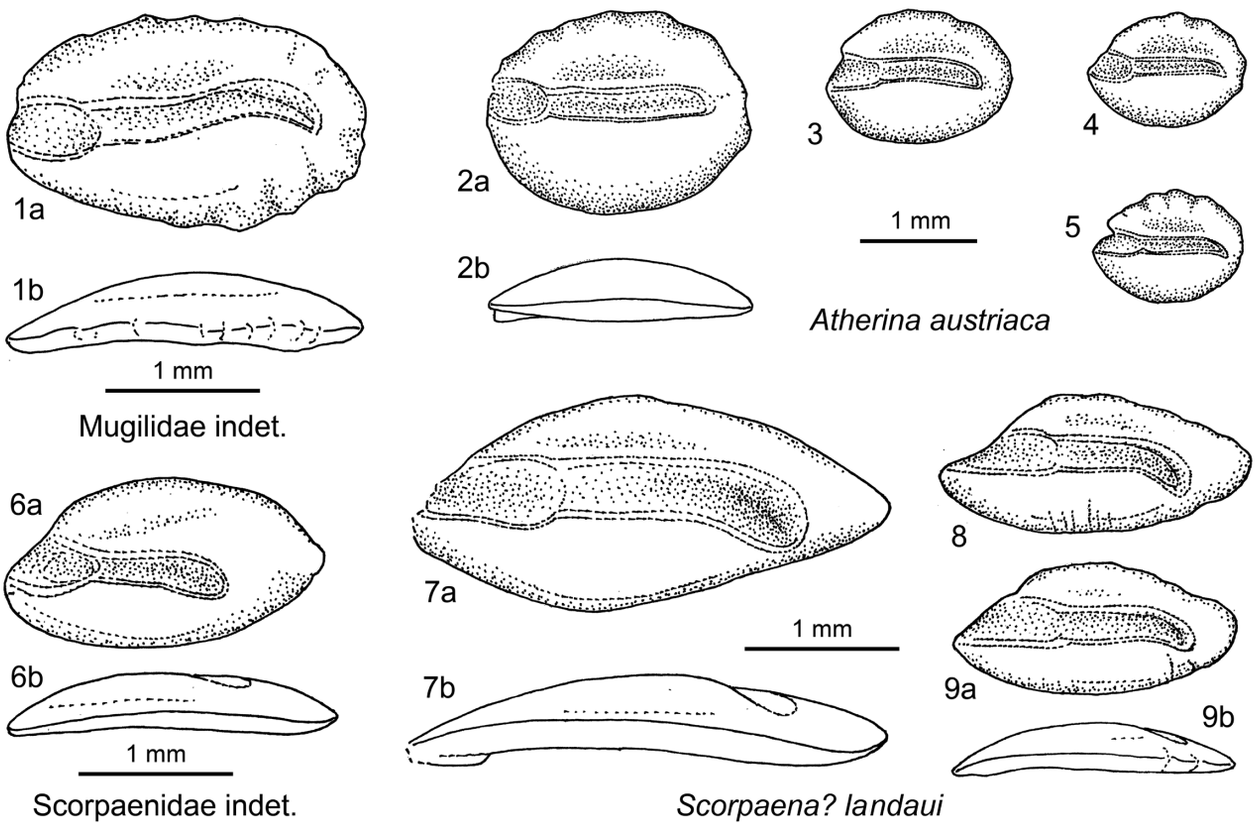

Plate 3

1. Mugilidae indet.; Seyithasan, RGM 816 418.

2-5. *Atherina austriaca* Schubert, 1906; Seyithasan; 1: RGM 816 419, 3-5: (r), RGM 816 420-422.

6. Scorpaenidae indet.; Seyithasan, RGM 816 427.

7-9. *Scorpaena*? *landaui* n. sp.; Seyithasan; 7: **holotype**, RGM 816 423; 8-9: (r) **paratypes**, RGM 816 424-425.

Nielsen & Cohen, 1986) and also the only one so far with a clear Indo-Pacific relationship.

Order Mugiliformes Regan, 1909
Family Mugilidae Risso, 1827
Genus indet.

Mugilidae indet.
Plate 3, fig. 1

Material examined – One specimen RGM 816 418, Seyithasan (locality 17).

Discussion – Several otolith-based mugilid species have been recorded from the Miocene of Europe (four of them in the Central Paratethys). The single, subadult specimen does not warrant a specific identification.

Order Atheriniformes Rosen, 1964
Family Atherinidae Risso, 1827
Genus *Atherina* Linnaeus, 1758

***Atherina austriaca* Schubert, 1906**

Plate 3, figs 2-5

1906 *Atherina austriaca* Schubert: pl. 4, fig. 45.
1994 *Atherina austriaca* Schubert, 1906 - Brzobohaty, pl. 3, figs 15-18 (with further synonymies).
2007 *Atherina austriaca* Schubert, 1906 - Brzobohaty *et al*., pl. 3, figs 16-17.

Material examined – Nine specimens, 6 in RGM 816 419-422 and 3 in coll. Van der Voort, Seyithasan (locality 17).

Discussion – A characteristic otolith of shallow near shore environments of the Langhian and Serravallian of the Paratethys.

Order Scorpaeniformes Garman, 1899
Family Scorpaenidae Risso, 1827
Genus *Scorpaena* Linnaeus, 1758

***Scorpaena*? *landaui* n. sp.**
Plate 3, figs 7-9

Holotype – Pl. 3, fig. 7, RGM 816 423, Turkey, Karaman Basin, Seyithasan (locality 17), middle Miocene, Serravallian.

Paratypes – Three specimens, RGM 816 424-426, same locality as holotype.

Etymology – In honor of Bernard M. Landau (Albufeira, Portugal) in recognition of his contribution to the knowledge of the mollusc fauna from the Miocene of the Karaman Basin.

Diagnosis – OL:OH = 2.1-2.3, increasing with size. Fusiform outline; anterior and posterior tips pointed; dorsal and ventral rims with broad, obtuse median angles. Sulcus wide; ostium short, only slightly wider than cauda; cauda slightly bent and widened and deepened at tip.

Description – Small, rather thin, elongate otoliths to about 3.2 mm length. OH:OT about 3.0. Dorsal rim with broad, obtuse, smoothened mediodorsal angle; ventral rim with similarly developed medioventral angle slightly in front of mediodorsal angle; anterior tip with pointed rostrum; no antirostrum or excisura; posterior tip sharply pointed, symmetrical to anterior tip. All rims smooth, slightly undulating in juveniles.
Inner face slightly convex. Sulcus large, wide, long, slightly supramedian. Ostium short, only slightly wider than cauda; cauda slightly bent downward towards tip and widened and deepened, terminating close to postventral rim. Dorsal depression very narrow, indistinct; ventral furrow feeble, very close to ventral rim of otolith. Outer face flat to slightly concave, smooth.

Discussion – A small scorpaenid otolith which appears to becoming morphologically mature at about 2.5 to 3 mm length. Despite the rather characteristic outline and sulcus, the generic assignment remains tentative since otoliths are still unknown from many Recent Indo-Pacific genera of the Scorpaenidae. Rückert-Ülkümen (1996) described an otolith with a similar outline from the late Miocene near Istanbul as *Serranus acuterostratus* Rückert-Ülkümen. These otoliths, however, show a wide and long, shallow ostium and a more distinctly curved caudal tip and are likely to represent a sciaenid genus near *Genyonemus* or *Isopisthus* or similar extant genera from tropical America (Schwarzhans, 1993).

Scorpaenidae indet.
Plate 3, fig. 6

Material examined – One specimen RGM 816 427, Seyithasan (locality 17).

Discussion – A single subadult and somewhat eroded scorpaenid otolith characterized by a short, somewhat inclined but not bent cauda.

Order Perciformes Bleeker, 1859
Family Sillaginidae Richardson, 1846
Genus *Sillago* Cuvier, 1816

***Sillago schwarzhansi* Steurbaut, 1984**
Plate 4, fig. 1

1979 *Sillago hassovica* (Koken, 1891) – Smigielska, pl. 4, fig. 8.
1984 *Sillago schwarzhansi* Steurbaut, pl. 22, figs 1-4.
1992 *Sillago* aff. *schwarzhansi* Steurbaut, 1984 – Rückert-Ülkümen, pl. 2, figs 11-12.
2002 *Sillago schwarzhansi* Steurbaut, 1984 – Nolf & Brzobohaty, pl. 10, fig. 3.
2009 *Sillago schwarzhansi* Steurbaut, 1984 – Nolf & Brzobohaty, pl. 4, figs 8-9.

Material examined – One specimen RGM 816 428, Seyithasan (locality 17).

Discussion – Sillaginid otoliths are easily recognized by their characteristic sulcus shape filled by a flat and undivided colliculum. In the Recent, Sillaginidae are restricted to the Indo West-Pacific, but during Oligocene and Miocene times they were also represented by several species in European basins, the youngest being *S. schwarzhansi* known from the Burdigalian to Serravallian of SW-France, Turkey and the Paratethys.

Family Carangidae Rafinesque, 1815
Genus *Trachurus* Gronow, 1854

***Trachurus* sp.**
Plate 4, fig. 3

Material examined – Three specimens RGM 816429-30, Seyithasan (locality 17).

Discussion – The largest specimen is reasonably well preserved and 5 mm long (Pl. 4, fig. 3), but nevertheless does not exhibit sufficient diagnostic valuable characters for a specific identification.

Family Serranidae Swainson, 1839
Genus *Serranus* Cuvier, 1816

***Serranus*? *ariejansseni* n. sp.**
Plate 4, fig. 2

Holotype – Pl. 4, fig. 2, RGM 816 431, Turkey, Karaman Basin, Seyithasan (locality 17), middle Miocene, Serravallian.

Paratypes – Four identifiable but incomplete specimens, RGM 816 432-435, same locality as holotype.

Etymology – In honor of Arie W. Janssen (Leiden, The Netherlands) in recognition of his contribution to the knowledge of the fossil fauna from the Miocene of the Karaman Basin.

Diagnosis – OL:OH = 2.1. Dorsal rim shallow, postdor-

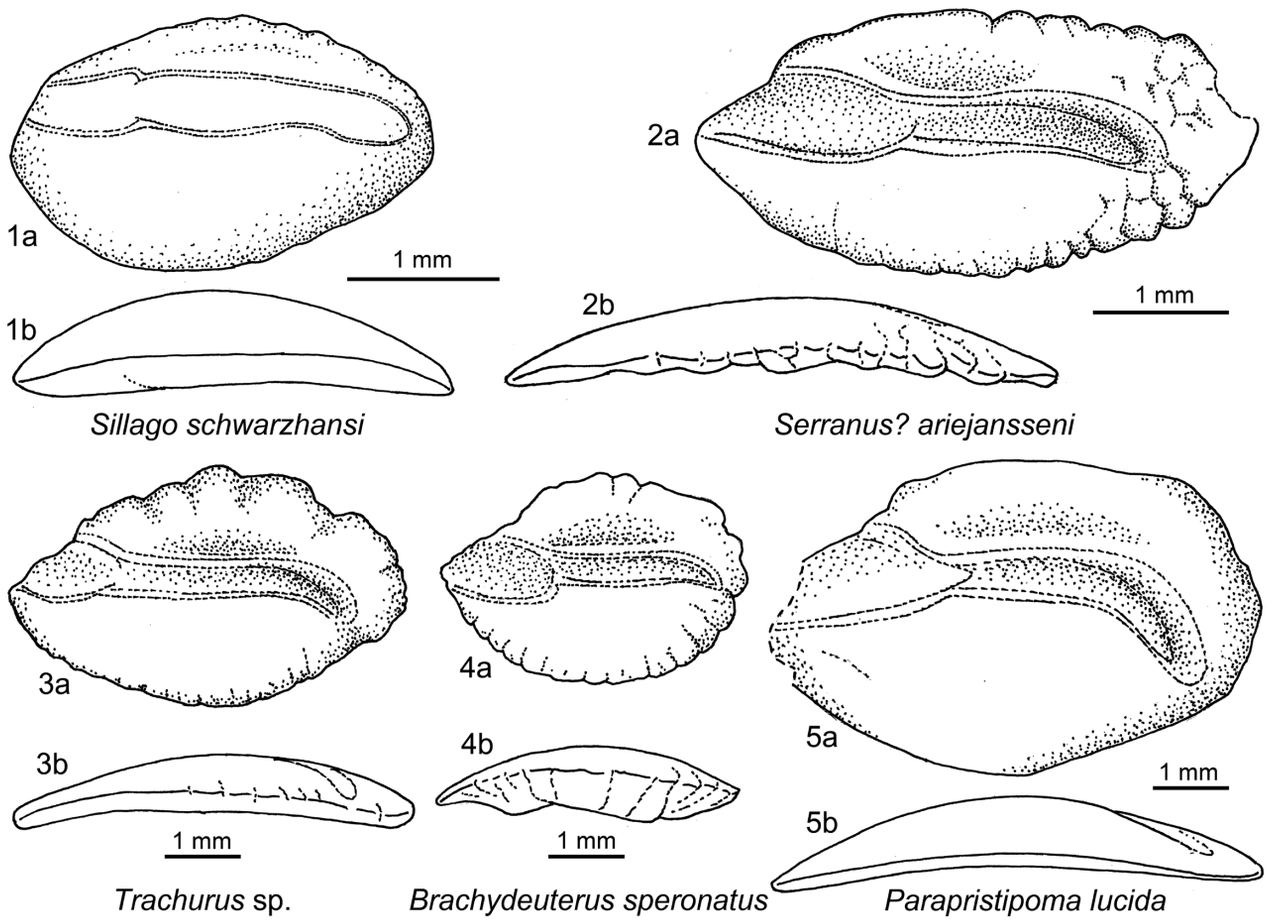

Plate 4

1. *Sillago schwarzhansi* Steurbaut, 1984 (r); Seyithasan, RGM 816 428.
2. *Serranus*? *ariejansseni* n. sp.; **holotype**, Seyithasan, RGM 816 431.
3. *Trachurus* sp.; Seyithasan, RGM 816 429.
4. *Brachydeuterus speronatus* (Bassoli, 1906); Seyithasan, RGM 816 436.
5. *Parapristipoma lucida* (Bassoli, 1906); Lale, coll. van der Voort.

sally expanded. Rear part of otolith intensely crenulated. CaL:OsL = 1.15. Cauda only slightly bent.

Description (morphometrics based on holotype) – Delicate, thin, elongate otoliths to at least 4.3 mm length. OH:OT about 4.0. Dorsal rim shallow, without angles, but expanded postdorsal region; ventral rim also rather shallow, very regularly curved; anterior tip with pointed rostrum; no antirostrum or excisura; posterior tip broad, dorsally sifted, slightly damaged in the holotype. Rims anteriorly rather smooth, posteriorly intensely crenulated.

Inner face slightly convex. Sulcus supramedian, narrow, moderately long and deep. Ostium not much wider than cauda; cauda slightly longer than ostium and only very slightly bent downward towards tip, terminating at some distance from posterior tip of otolith. Dorsal depression small; no ventral furrow. Outer face concave, ornamented.

Note – Three of the paratypes lack the anterior portion of the otolith, but are easily recognized by their much expanded postdorsal region resulting in a dorsal projection of the posterior rim, which is slightly damaged in the holotype.

Discussion – *Serranus*? *ariejansseni* resembles *S. aquitaniensis* Steurbaut, 1984, but differs in the shallower dorsal rim, the dorsally pronounced posterior tip, the less downward bent, short cauda and the intensely crenulated posterior part of the otolith. Recent serranid otoliths are still insufficiently known and a more precise allocation therefore is not possible. Otoliths similar in sulcus outline and proportions are known from the genera *Chelidoperca, Plectranthias* and *Pseudanthias* (see Smale *et al*., 1995, Rivaton & Bourret, 1999, Lin & Chang, 2012), but none of them shows the peculiar dorsally projecting posterior rim.

Family Haemulidae Gill, 1885
Genus *Parapristipoma* Bleeker, 1873

***Parapristipoma lucida* (Bassoli, 1906)**
Plate 4, fig. 5

1906 *Labrax lucidus* Bassoli, pl. 2, fig. 28.
1979 genus Pomadasyidarum *lucidus* – Nolf & Steurbaut, pl. 3, figs 1-5.
1983 genus Pomadasyidarum *lucidus* – Nolf & Steurbaut, pl. 7, figs 8-9.
1984 genus Pomadasyidarum *lucidus* – Steurbaut, pl. 25, figs 5-8.
2002 genus Haemulidarum *lucidus* (Bassoli, 1906) – Nolf & Brzobohaty, pl. 10, fig. 1.
2009 genus Haemulidarum *lucidus* (Bassoli, 1906) – Nolf & Brzobohaty, pl. 5, fig.

Material examined – Three specimens coll. van der Voort, Lale (localities 2 and 3).

Discussion – The relatively large specimens from Lale of up to about 8 mm length show the elongate shape typical for *Parapristipoma* and thus allow generic allocation.

Genus *Brachydeuterus* Gill, 1862

***Brachydeuterus speronatus* (Bassoli, 1906)**
Plate 4, fig. 4

1906 *Dentex speronatus* Bassoli, pl. 2, figs 37-38.
1983 *Brachydeuterus speronatus* (Bassoli, 1906) – Nolf & Steurbaut, pl. 7, figs 10-12.
1984 *Brachydeuterus speronatus* (Bassoli, 1906) – Steurbaut, pl. 24, figs 19-20.
1992 *Brachydeuterus speronatus* (Bassoli, 1906) – Radwanska, text-fig. 98, pl. 21, figs 9-11.
2007 *Brachydeuterus speronatus* (Bassoli, 1906) – Brzobohaty *et al*., pl. 5, figs 1-6 [*non* figs 7-10 = *Brachydeuterus latior* (Schubert, 1906)].

Material examined – Three specimens RGM 816 436-437, Seyithasan (locality 17).

Discussion – *Brachydeuterus speronatus* (Bassoli, 1906) is distinguished from *B. latior* (Schubert, 1906) by the more compressed shape and the dent-like development of the postdorsal process in large specimens. Radwanska (1992) found both species contemporaneously in the Badenian of Poland and discussed the differences of the two species and established their distinction. The juvenile specimens from the Karaman Basin are placed in *B. speronatus* primarily because of their compressed shape resembling the juveniles figured by Brzobohaty *et al*. (2007) as part of a complete ontogenetic sequence of otoliths obtained from the Serravallian of SW-France (see their pl. 5, figs 1-6). The specimens figured by them on pl. 5, figs 7-10 from the Badenian of Kienberg, Czech Republic, are more elongate and according to Radwanska would represent *B. latior*. However, Brzobohaty *et al*. consider both species synonymous. I follow Radwanska's view in recognizing two separate species, *B. latior* ranging stratigraphically from Aquitanian to Langhian and *B. speronatus* from late Langhian or Serravallian to Tortonian.

Family Lethrinidae Bonaparte, 1831
Genus *Lethrinus* Cuvier, 1829

***Lethrinus anatolicus* n. sp.**
Plate 5, figs 7-8

Holotype – Pl. 5, fig. 7, RGM 816 438, Turkey, Karaman Basin, Seyithasan (locality 17), middle Miocene, Serravallian.

Paratype – One specimen, RGM 816 439, same locality as holotype.

Etymology – Referring to Anatolia, the Asian part of Turkey.

Diagnosis – OL:OH = 1.5. OH:OT about 4.0. Dorsal rim with sharp postdorsal angle and low mediodorsal portion. Rostrum length about 20-25% of OL. Inner face moderately bend; curvature index of inner face = 17-20% of OL.

Description – Moderately thin and elongate otoliths reaching at least 4.6 mm length. Dorsal rim shallow, sometimes almost horizontal, with shallow mediodorsal and sharp postdorsal angles; ventral rim deep, deepest slightly anterior of its middle, regularly curved; anterior tip with long, massive rostrum; no or very feeble antirostrum or excisura; posterior tip broad, blunt or with obtuse inferior angle. Rims slightly undulating or crenulated, getting smoother with size.
Inner face moderately convex. Sulcus supramedian, moderately deep, distinctly heterosulcoid. CaL:OsL = 1.1-1.2. Ostium distinctly wider than cauda; cauda slightly longer than ostium, narrower, deeper, slightly downward inclined and its rear part bent downward at an angle of about 45°, its tip terminating close to postventral rim of otolith. Dorsal depression small; ventral furrow indistinct. Outer face concave, slightly ornamented.

Discussion – The overall proportions of the otolith and the sulcus with its slightly inclined cauda and its moderately curved tip are typical for the genus *Lethrinus* of the Indo West-Pacific family Lethrinidae (see Lin & Chang, 2012 for figures of Recent otoliths). *Lethrinus anatolicus* is readily distinguished from the contemporaneous *L. styriacus* Nolf & Brzobohaty, 2009 by the different shape of the dorsal rim, the thinner appearance (OH:OT = 4.0 vs 3.0), the longer rostrum (20-25% of OL vs 15-20% of OL) and the less strongly bent inner face expressed in the difference of the curvature index on the inner face (17-20% of OL vs 25-27% of OL).

***Lethrinus styriacus* Nolf & Brzobohaty, 2009**
Plate 5, figs 1-6

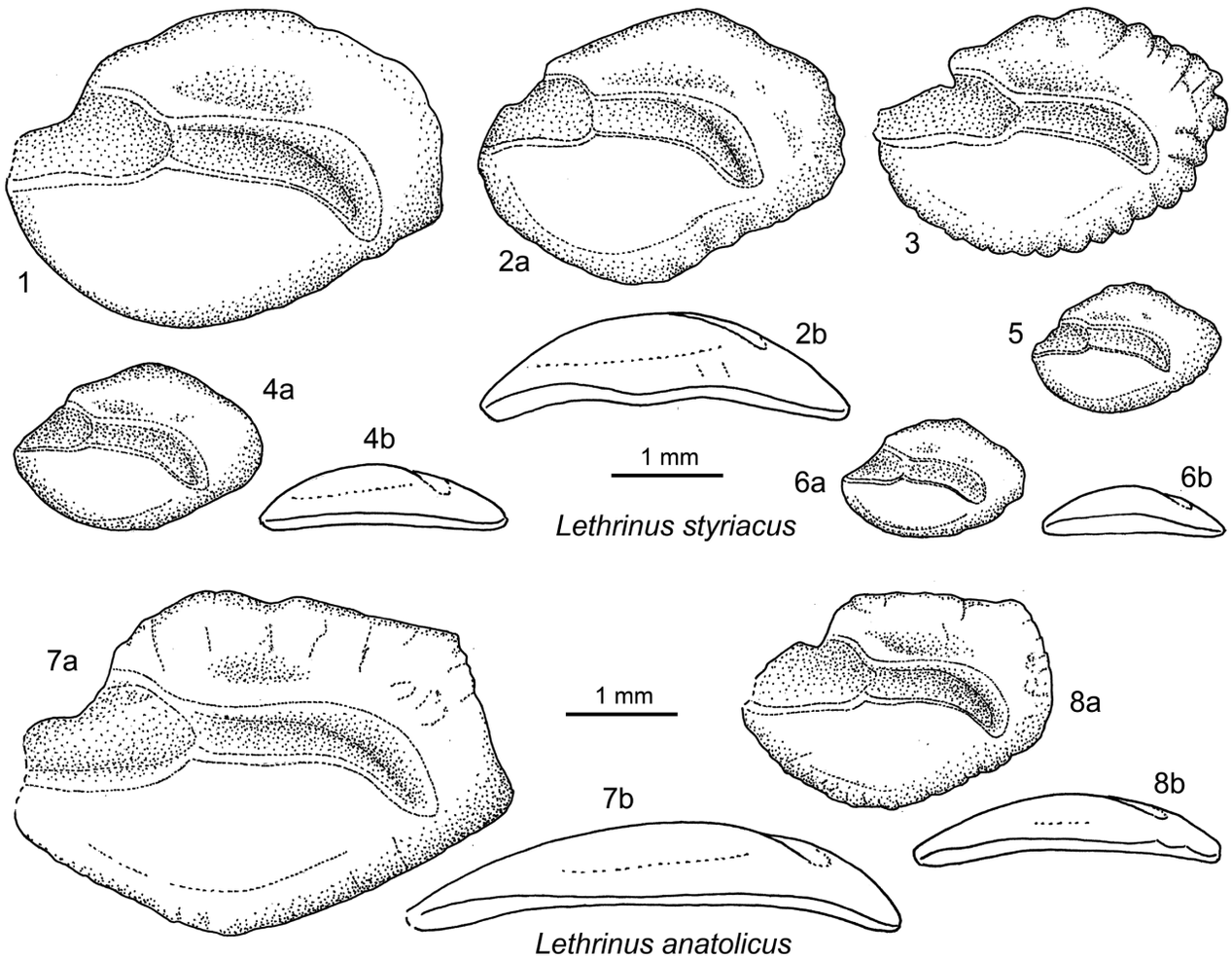

Plate 5
1-6. *Lethrinus styriacus* Nolf & Brzobohaty, 2009; 1 (r), 2, 4-6: Seyithasan, RGM 816 440-444; 3: (r) Lale, coll. van der Voort.
7-8. *Lethrinus anatolicus* n. sp.; Seyithasan; 7: **holotype**, RGM 816 438; 8: (r) **paratype**, RGM 816 439.

2009 *Lethrinus styriacus* Nolf & Brzobohaty, pl. 7, figs 7-9.

Material examined – Thirteen specimens; 2 specimens coll. van der Voort, Lale (locality 2); 9 specimens RGM 816 440-445 and 2 specimens coll. van der Voort, Seythasan (locality 17).

Description (based on 5 specimens; 1.7-4.0 mm) – Massive, thick and rather compressed otoliths reaching at least 5 mm length. OL:OH = 1.3-1.5, decreasing with size; OH:OT about 3.0. Dorsal rim with broad, distinct mediodorsal angle and depressed, rounded postdorsal angle; ventral rim deep, deepest slightly anterior of its middle and anterior of mediodorsal angle, usually anteriorly more strongly curved than posteriorly; anterior tip with moderately long, massive rostrum; no or very feeble antirostrum or excisura; rostrum length 15-20% of OL; posterior tip inferior, broadly rounded. Rims slightly undulating to intensely crenulated at times, getting smoother with size.
Inner face strongly convex, curvature index of inner face 25-27% of OL. Sulcus supramedian, moderately deep, distinctly heterosulcoid. CaL:OsL = 1.25-1.5. Ostium wider than cauda; cauda longer than ostium, narrower, deeper, slightly downward inclined and its rear part bent downward in a gently curved bent, its tip terminating close to postventral rim of otolith. Dorsal depression small; ventral furrow mostly indistinct. Outer face flat to concave, smooth to slightly ornamented.

Discussion – For comparison with *L. anatolicus* see above. *Lethrinus styriacus* represents the most common non-gobiid otolith-based species in the Karaman Basin.

Family Centracanthidae Gill, 1891
Genus *Spicara* Rafinesque, 1810

***Spicara pamphyliensis* n. sp.**
Plate 6, figs 1-3

Holotype – Pl. 6, fig. 1, RGM 816 446, Turkey, Karaman Basin, Seyithasan (locality 17), middle Miocene, Serravallian.

Paratypes – Two specimens, RGM 816 447-448, same locality as holotype.

Etymology – Referring to Παμφυλία = Pamphylia (Greek), the name of an ancient geographic region covering the Karaman Basin.

Diagnosis – OL:OH = 1.6-1.8. OH:OT about 4.0. Dorsal rim with distinct mediodorsal and low postdorsal angle. Rostrum length about 20% of OL. Posterior tip inferior. Cauda anteriorly horizontal, posteriorly bent downward in distinct angle. Curvature index of inner face = 20-23% of OL. Outer face markedly concave.

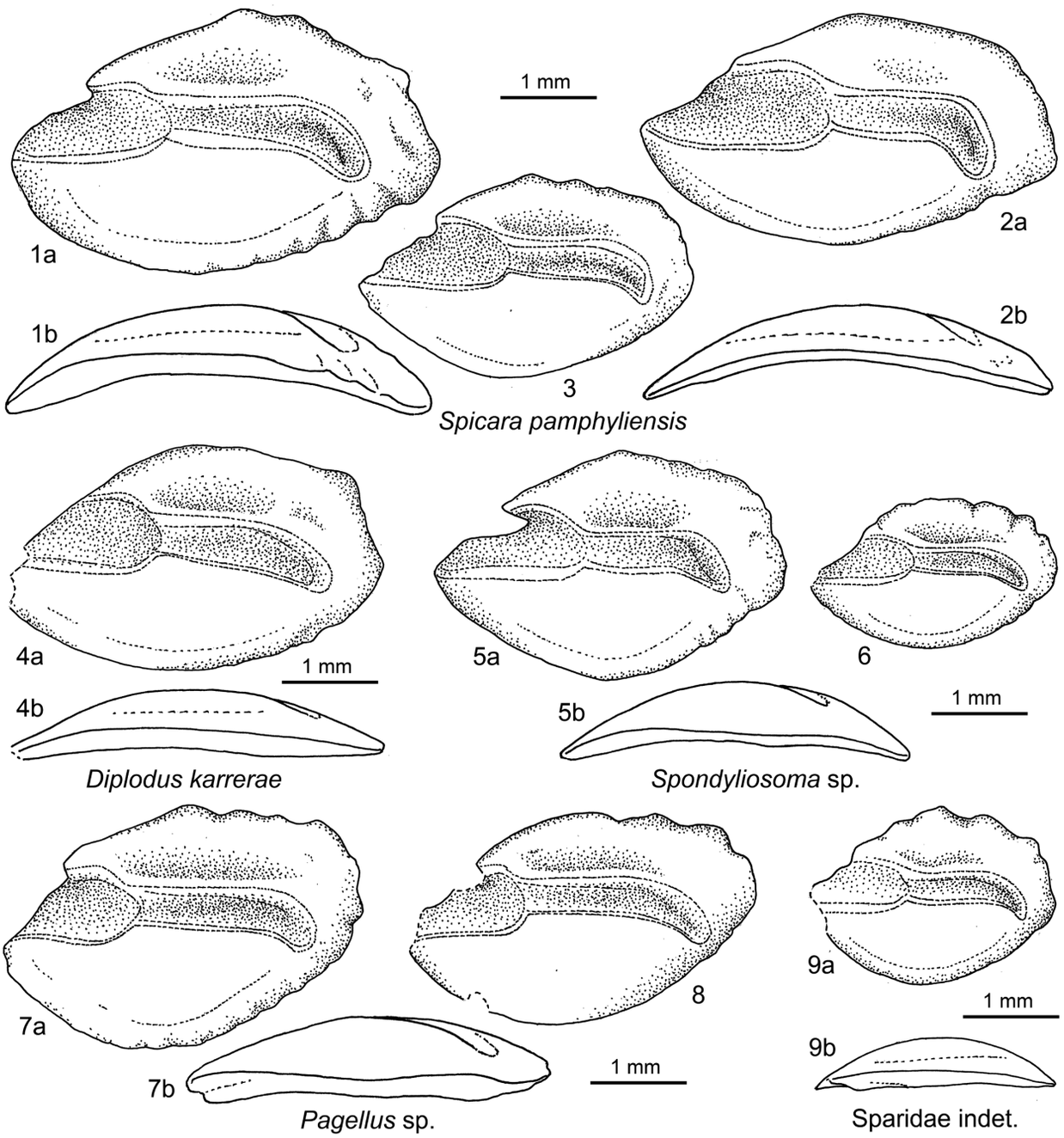

Plate 6

1-3. *Spicara pamphyliensis* n. sp.; Seyithasan; 1: **holotype**, RGM 816 446; 2-3: (r) **paratypes**, RGM 816 447-448.
4. *Diplodus karrerae* Nolf & Steurbaut, 1979 (r); Seyithasan, RGM 816 452.
5-6. *Spondyliosoma* sp. (r); Seyithasan, RGM 816 456-457.
7-8. *Pagellus* sp.; Seyithasan, RGM 816 453-454.
9. Sparidae indet. (r); Seyithasan, RGM 816 459.

Description – Thin, elongate otoliths up to about 4.5 mm length. Dorsal rim moderately high, with well developed, obtuse mediodorsal angle and weakly developed, depressed postdorsal angle; ventral rim rather shallow, regularly curved; anterior tip with long, massive rostrum; no or very feeble antirostrum or excisura; posterior tip more compact than anterior tip, usually with well developed inferior angle. Rims mostly smooth; postdorsal rim sometimes irregularly undulating and postventral rim sometimes crenulated.
Inner face markedly convex. Sulcus supramedian, moderately deep, distinctly heterosulcoid. CaL:OsL = 1.0-1.2. Ostium distinctly wider than cauda; cauda as long as ostium or slightly longer, narrower, deeper, anteriorly horizontal, posteriorly bent downward at distinct angle, terminating moderately close to postventral rim of otolith, sometimes with postcaudal depression. Dorsal depression small; ventral furrow thin, mostly well developed and moderately close to ventral rim of otolith. Outer face distinctly concave, smooth to slightly ornamented.

Discussion – *Spicara pamphyliensis* differs from the Recent *S. maena* (Linnaeus, 1758) from the Mediterranean (see Nolf *et al*., 2009 for otolith figures) in being more elongate and showing a more regular dorsal rim. The other Recent Mediterranean *Spicara* species, *S. smaris* (Linnaeus, 1758) shows similarly elongate otoliths, but with a shallower mediodorsal and more pronounced postdorsal region, a shorter ostium and a lower curvature index of the inner face (15-18% of OL vs 20-23% of SL) (see Nolf *et al*., 2009). Otoliths of the West African *S. alta* (Osorio, 1917) and the South African *S. australis* (Regan, 1921) are both considerably more compressed. The most similar Recent species in terms of otolith and sulcus proportions are found in *S. axillaris* (Boulanger, 1900) from South Africa (see Smale *et al*., 1995). Again, the main differences are the low mediodorsal and the more pronounced postdorsal angles. Otoliths of the extant *S. smaris* were described by Steurbaut (1984) from the Serravallian of SW France and by Radwanska (1992) from the Badenian of Poland. They both differ from *S. pamphyliensis* in being more compressed. The same is true for *S. gossei* Steurbaut, 1984 from the Burdigalian of SW France. Of all recorded fossil *Spicara* otoliths those figured by Steurbaut (1984) as *Spicara* sp. 1 from the Aquitanian of SW France resemble *S. pamphyliensis* most in respect to all relevant aspects of outline and otolith and sulcus proportions, and it is only the stratigraphic difference between the two records that has led me to not formally place them in the same species now.

Family Sparidae Rafinesque, 1810
Genus *Dentex* Cuvier, 1814

***Dentex gregarius* (Koken, 1891)**
Plate 7, figs 1-4

1891 Ot. (Sparidarum) *gregarius* Koken, text-figs 18-20.
1906 *Smaris? elegans* – Schubert, pl. 10, figs 36, 38.
2010 *Dentex gregarius* (Koken, 1891) – Schwarzhans, pl. 89, figs 1-9 (with further synonymies).

Material examined – Eight specimens; 5 specimens coll. van der Voort, Lale (locality 2), 2 specimens RGM 816 449-450, Akpinar (locality 13), 1 specimen RGM 816 451, road cut on the road to Mut, *c*. 27 km south of Karaman (locality 19).

Discussion – See Schwarzhans (2010) for a detailed discussion about recognition of *D. gregarius* and its distinction from the poorly differentiated Recent species of the genus.

Genus *Diplodus* Rafinesque, 1810

***Diplodus karrerae* Nolf & Steurbaut, 1979**
Plate 6, fig. 4

1979 *Diplodus karrerae* Nolf & Steurbaut, pl. 3, figs 19-21, text-fig. 2.
1984 *Diplodus karrerae* Nolf & Steurbaut, 1979 – Steurbaut, pl. 25, figs 16-18.
1992 *Diplodus karrerae* Nolf & Steurbaut, 1979 – Radwanska, text-fig. 100, pl. 23, figs 5-7.
2010 *Diplodus karrerae* Nolf & Steurbaut, 1979 – Schwarzhans, pl. 90, figs 3-4.

Material examined – One specimen RGM 816 452, Seyithasan (locality 17).

Discussion – Otoliths of *D. karrerae* are recognized by their elongate shape and the inclined cauda with its only slightly bent tip.

Genus *Pagellus* Valenciennes, 1830

***Pagellus* sp.**
Plate 6, figs 7-8

2007 *Pagellus* aff. *acarne* (Risso, 1806) – Brzobohaty *et al*., pl. 6, figs 2-3.

Material examined – Three specimens RGM 816 453-455, Seyithasan (locality 17).

Discussion – Relatively small otoliths of about 3.5 to 3.7 mm length, which likely represent small specimens of an unidentifiable species of the genus *Pagellus*. Potentially diagnostic characters are the shallow, almost flat dorsal rim terminating in a dorsally shifted posterior tip well above the tip of the cauda and the gently and only slightly bent cauda. Very similar otoliths have been described from the late Langhian of the Czech Republic by Brzobohaty *et al*. (2007) as *P.* aff. *acarne*. Otoliths of the Recent *P. acarne*, however, are much more elongate and do not exhibit this kind of flat dorsal rim nor the dorsally shifted posterior tip (see .Nolf *et al*., 2009 for figures).

Genus *Spondyliosoma* Cantor, 1849

***Spondyliosoma* sp.**
Plate 6, figs 5-6

?1984 *Pagrus* sp. – Steurbaut, pl. 26, figs 15-17.
1992 *Diplodus* sp. 2 – Radwanska, text-fig. 102, pl. 23, figs 8-10.
?2007 *Spondyliosoma cantharus* (Linnaeus, 1758) – Brzobohaty *et al*., pl. 6, figs 10-12.
2009 *Boops boops* (Linnaeus, 1758) – Nolf & Brzobohaty, pl. 5, fig. 8.
2010 *Centracanthus* sp. – Schwarzhans, pl. 93, figs 7-8.

Material examined – Five specimens RGM 816 456-458 Seyithasan (locality 17).

Discussion – These inconspicuous otoliths have been described under several different systematic allocations. Brzobohaty *et al*.'s association with the genus *Spondyliosoma* may represent the most likely of those varying allocations, but assignment to the Recent species *S. cantharus* would require larger specimens than those currently available. The largest specimen from the Karaman Basin is 3.7 mm long. A specimen from the North Sea Basin figured by Schwarzhans (2010) of nearly 5 mm length represents the largest, but still ranks at subadult size, while otoliths of truly adult Recent specimens of *S. cantharus* are in the range of 10 mm plus. The otoliths of the Recent *S. cantharus* are more elongate than those from the Miocene and from a certain size onwards are characterized by a projecting postdorsal angle resembling a backward oriented denticle. This is also the case in specimens up to 6 mm length figured by Brzobohaty *et al.* (2007) from the Badenian of the Czech Republic. These otoliths are also somewhat more elongate than the other ones mentioned above in the synonymy listing and thus could indeed indicate an extended stratigraphic range of *S. cantharus* back into middle Miocene times.

Genus indet.

Sparidae indet.
Plate 6, fig. 9

Material examined – One specimen RGM 816 459, Seyithasan (locality 17).

Discussion – This is an inconspicuous single, juvenile specimen of about 2.6 mm length, with broadly undulating regularly curved dorsal rim of unknown affinities.

Family Mullidae Rafinesque, 1815
Genus *Mullus* Linnaeus, 1758

***Mullus* sp.**
Plate 7, fig. 7

Material examined – One specimen RGM 816 460, Seyithasan (locality 17).

Discussion – A well preserved, very small juvenile otolith of about 1.2 mm length, which shows the typical outline and sulcus of otoliths of the genus *Mullus*.

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

***Cepola macrophthalma* (Linnaeus, 1758)**
Plate 7, figs 5, 6

1906 *Cepola praerubescens* Bassoli, pl. 2, fig. 43.
1906 *Cepola vöslauensis* Schubert, pl. 5, figs 6-7.
1984 *Cepola multicrenata* Radwanska, text-fig. 18, pl. 5, figs 8-10
1992 *Cepola rubescens* Linnaeus 1766 – Radwanska, text-figs 124-125, pl. 30, figs 1-7 (with further synonymies).
2010 *Cepola macrophthalma* (Linnaeus, 1758) – Schwarzhans, pl. 95, figs 4-7.

Material examined – Four specimens; 2 in coll. van der Voort, Lale (locality 2), 2 in RGM 816 461-462 Seyithasan (locality 17).

Discussion – *Cepola macrophthalma* is a persistent species in European basins recorded since Burdigalian times in the fossil record (Radwanska, 1992, Schwarzhans, 2010). It appears, however, that two different morphotypes of *Cepola* otoliths are represented at least during the early to middle Miocene times: One with anterior and posterior tips equally pointed, a depressed postdorsal angle, an ostial colliculum reaching the anterior rim of the otolith and a bent shape in lateral view with a clearly convex inner face and a concave or flat outer face (specimens figured by Bassoli, 1906 and as *C. vöslauensis* by Schubert, 1906), the other with the posterior tip more blunt than the pointed anterior tip, an expanded postdorsal angle, the ostial colliculum terminating at considerable distance from the anterior rim of the otolith and a planar shape in lateral view with both inner and outer faces being slightly convex (specimens figured as *C. praerubescens* by Schubert, 1906, as *C. multicrenata* by Radwanska, 1984, *C. rubescens* by Radwanska, 1992 and *C.macrophthalma* by Schwarzhans, 2010). Both morphotypes are present at Karaman, the first shown in Fig. 6, the second in Fig. 5. It is quite probable that these two morphotypes represent distinct species, but in the light of the many fossil citations and the high degree of variability recorded the limited material available to me certainly is not adequate to arrive at a conclusive judgement.

Family Sphyraenidae Rafinesque, 1815
Genus *Sphyraena* Röse, 1793

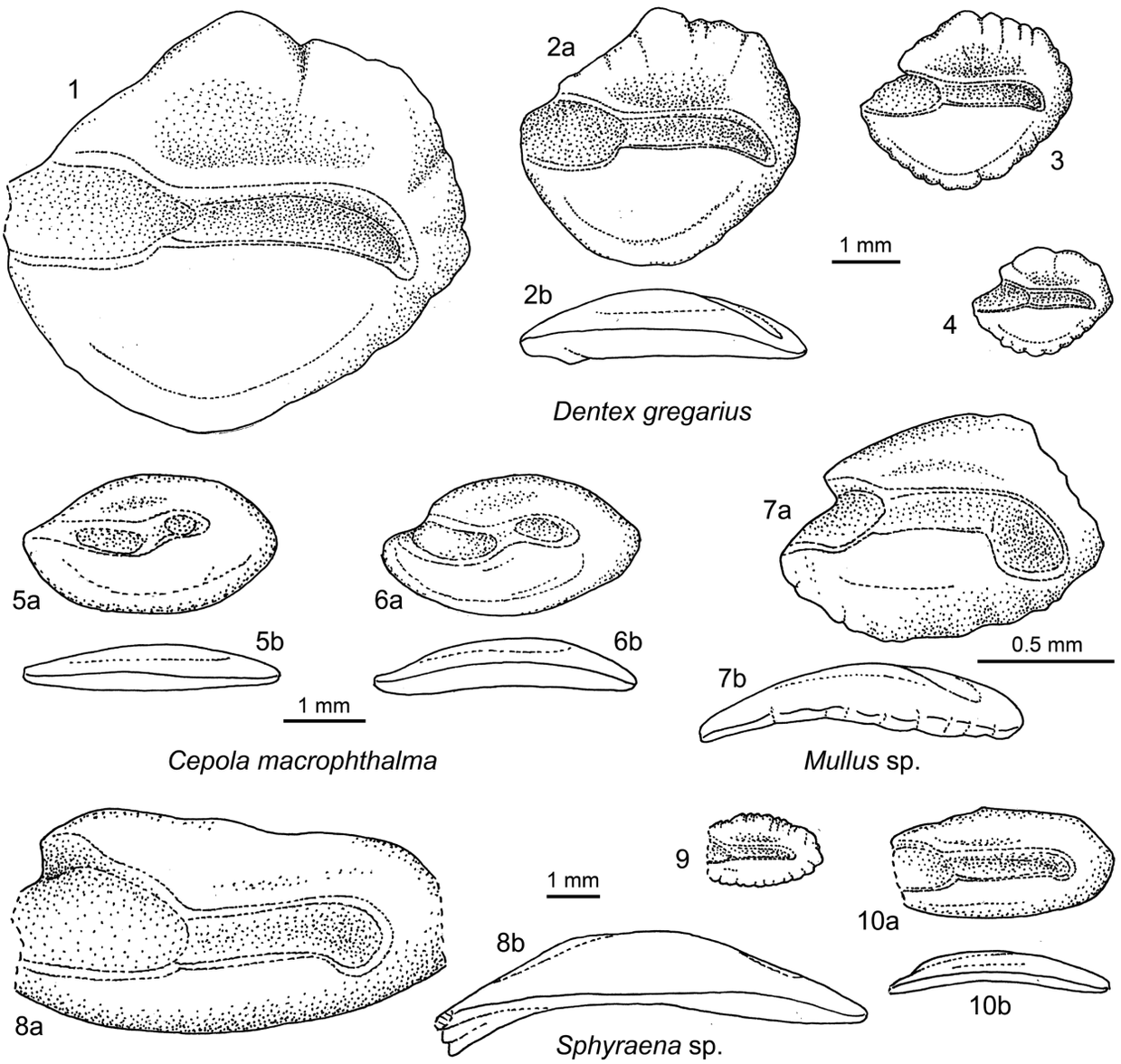

Plate 7

1-4. *Dentex gregarius* (Koken, 1891); 1-2: (r) Lale, coll. van der Voort; 3: (r), road to Mut, RGM 816 451; 4: (r) Akpinar, RGM 816 449.

5-6. *Cepola macrophthalma* (Linnaeus, 1758); 5: Lale, coll. van der Voort; 6: Seyithasan, RGM 816 462.

7. *Mullus* sp.; Seyithasan, RGM 816 460.

8-10. *Sphyraena* sp.; Seyithasan; 8-9 (r): RGM 816 463-464; 10: RGM 816 465.

***Sphyraena* sp.**

Plate 7, figs 8-10

Material examined – Three specimens RGM 816 463-465, Seyithasan (locality 17).

Discussion – Diagnostically useful and identifiable large *Sphyraena* otoliths have been rarely recorded in the fossil record. Schubert (1906) described *S. hansfuchsi* from the Badenian of Austria mentioning sizes up to 8 mm length, which would qualify as representing an adult fish. In his review of Schubert's specimens, Nolf (1981) mentioned all otoliths to represent juvenile specimens because of their small size, but does not mention actual measurements. The specimens from Karaman include one large but somewhat eroded and incompletely preserved specimen of about 8 mm length (Pl. 7, fig. 8; probably more than 9 mm when reconstructed), which shows an intensely bent otolith in lateral view. Particularly the expanded predorsal region with the short, massive antirostrum is strongly bent outwards. It may represent a species different from *S. hansfuchsi*, but better preserved specimens have to be awaited for a proper judgement.

Family Gobiidae Cuvier, 1816

Notes – The Gobiidae are by far the largest and speciose group of fishes represented by otoliths in the Karaman Basin. In the Recent, the family Gobiidae are the most speciose of all marine teleost families. In fact in the fossil record too, gobiid otoliths represent a dominant faunal element in many shallow water sediments on a worldwide basis, particularly since the Miocene. Gobiid otoliths are easily recognized as such by the characteristic outline and the sole-shaped sulcus, but the still limited knowledge of otoliths from the many Recent genera and species and the lack of a comprehensive comparative study has resulted in a confusing and often erroneous and inaccurate state of knowledge when it comes to fossil otolith-based gobiid taxa. Due to their importance in the fossil record I have attempted to formalize the pertinent characters in a form (see Fig. 2 above under 'methods') that I hope allows for a more precise definition and comparison, and which is utilised in the following descriptions.

Genus *Gobius* Linnaeus, 1758

***Gobius* aff. *dorsorostralis* Weinfurter, 1954**
Plate 8, fig. 3

1954 *Gobius dorsorostralis* Weinfurter, pl. 6, figs 49-50.
1954 *Gobius dorsorostralis sculpta* Weinfurter, pl. 6, figs 51-52.
1992 *Gobius* sp., aff. *G. dorsorostralis* Weinfurter, 1954 – Brzobohaty pl. 1, fig. 2.
2010 *Gobius dorsorostralis* Weinfurter, 1954 – Schwarzhans, pl. 103, figs 2-4.

Material examined – Four specimens coll. van der Voort, Gödet creek (locality 11).

Description – Otoliths of *G. dorsorostralis* are characterized by well developed and sharp preventral and postdorsal projections, the latter of which is strongly bent outwards resulting in a curvature index of the inner face of about 20% of OL in adults, orthogonal postventral and predorsal angles and rather straight horizontal dorsal and ventral and vertical anterior and posterior rims. The sulcus shows a feeble ostial lobe and an indistinct and small subcaudal iugum. The otoliths are rather compressed at small sizes of less than 1.2 mm length (OL:OH = 1.05-1.2) and smooth, but become more elongate with growth (OL:OH reaching up to 1.4) with an increasing ornamentation of the dorsal rim and a pronunciation of the preventral and postdorsal projections, all typical ontogenetic changes observed in many gobiid otoliths.

Discussion – The otoliths from the Karaman Basin are all smaller than any of the others known to date from Austria and therefore are only tentatively placed in the species.
The otoliths of *G. dorsorostralis* were originally described by Weinfurter from the brackish-marine Pannonian (Tortonian) of the Vienna Basin. In 2010, Schwarzhans figured specimens from the likewise brackish-marine Sarmatian (Serravallian) of Wiesen in Austria. These otoliths are here refigured for comparison reasons (Pl. 8, figs 1-2). The four small specimens found in the Serravallian rocks of the Karaman Basin likewise were obtained from the brackish-marine environment of locality 11 at the Gödet creek. No such otoliths were identified amongst the many gobiid specimens obtained from the other sampled, fully marine sediments in the area, indicating that *G. dorsorostralis* probably represented a non-marine species.

***Gobius mustus* n. sp.**
Plate 8, figs 4-16

Holotype – Pl. 8, fig. 4, RGM 816 466, Turkey, Karaman Basin, Akpinar Pinarlar Yaylasi (locality 13), middle Miocene, Serravallian.

Paratypes – Eighteen specimens; 1 in RGM 816 467, from the type locality; 17 specimens RGM 816 468-484, Seyithasan (locality 17).

Additional specimens – Ninety-seven specimens; 1 in RGM 816 485, Akbogazi (locality 7); 68 in RGM 816 486 and 28 in coll. van der Voort, Seythasan (locality 17).

Etymology – From *mustus* (Latin) = young, fresh, referring to the unspectacular morphology of these otoliths.

Diagnosis – OL:OH = 1.1-1.25; OH:OT about 3.0. Curvature index of inner face < 10% of OL. Preventral projection very weak or absent; postdorsal projection short, broad, not or very little bent outwards. Predorsal angle mostly well developed; postventral angle broadly rounded. Dorsal rim highest at obtuse angle behind middle of rim. Sulcus inclination 15-20°. Ostial lobe low; subcaudal iugum small, only below anterior half of cauda.

Description (based on holotype and 18 paratypes) – Moderately compressed and massive otoliths up to about 3.3 mm length. Outline showing weak or absent preventral projection, well developed predorsal angle, high, obtusely angled postdorsal region, broad, short postdorsal projection and rounded postventral angle. Ventral rim flat, smooth; dorsal rim posteriorly elevated, smooth to slightly undulating; anterior and posterior rims vertical with slight indentation at level of sulcus.
Inner face only very slightly bent, including the postdorsal projection. Sulcus centrally positioned, anteriorly inclined at 15-20°, rather shallow and with typical sole-shape although weakly developed ostial lobe. Subcaudal iugum mostly small, short, only below anterior portion of cauda. Dorsal depression wide and prominent; ventral furrow distinct, close to ventral rim, anteriorly curving upward to ostium, posteriorly upward behind caudal tip. Outer face slightly convex, smooth.

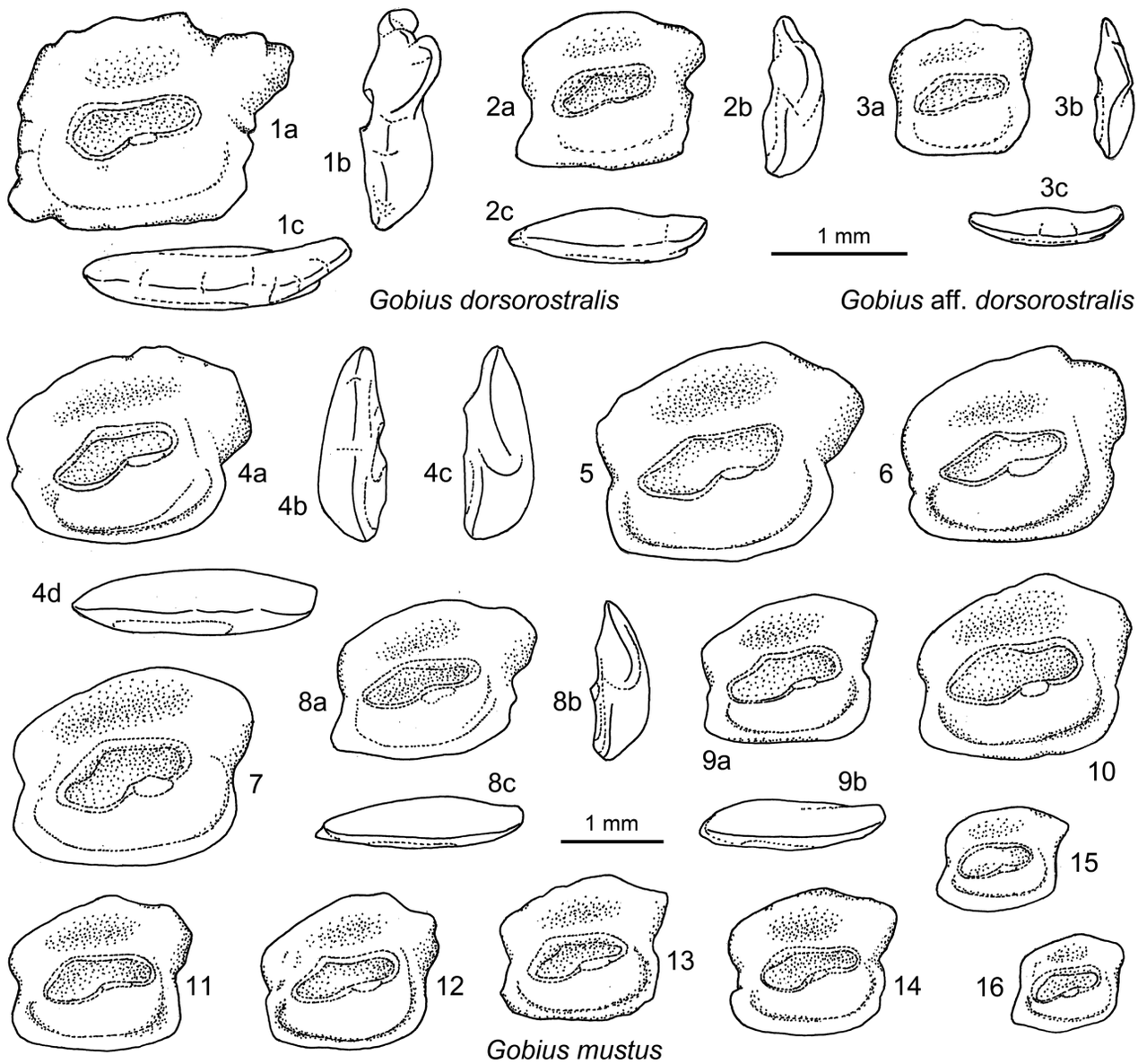

Plate 8

1-2. *Gobius dorsorostralis* Weinfurter, 1954; Wiesen, Austria, Sarmatian, coll. Schwarzhans (fig. 2 r).

3. *Gobius* aff. *dorsorostralis* Weinfurter, 1954; Gödet creek, coll. van der Voort.

4-16. *Gobius mustus* n. sp.; 4: **holotype**, Akpinar, RGM 816 466; 5, 6, 7 (r), 8, 9 (r), 10-16 (r): **paratypes**, Seyithasan, RGM 816 468-479.

Discussion – *Gobius mustus* resembles the otoliths of the Recent *G. auratus* Risso, 1810 (see Lombarte *et al*., 2006 for figures) and *G. fallax* Sarato, 1889 in outline and the postdorsal projection not being bent outwards, but both differ in the presence of a preventral projection and *G. fallax* additionally in being slightly more elongate. In the fossil record few species resemble *G. mustus* despite its rather unspectacular morphology.

The ubiquitous *G. multipinnatus* (H.von Meyer, 1852) (see below for further discussion) has a sharp preventral and a sharp, strongly outward bent postdorsal projection. Reichenbacher (1993) and Reichenbacher & Weidmann (1992) described several otoliths from early Miocene freshwater to brackish-marine environment from the northern Alpine molasse basins of which *G. brzobohatyi* Reichenbacher, 1993 resembles in the short preventral projection but differs in the more compressed overall shape and the longer postdorsal projection. Another species from the same region and age is *G. brevis* (Agassiz, 1839), of which otoliths *in situ* have been described by Reichenbacher *et al.* (2007) and Brzobohaty & Gaudant (2009) (*G. latiformis* Reichenbacher, 1992 is a junior otolith-based synonym). These otoliths appear more compressed than *G. mustus* and with short preventral and postdorsal projections. Rückert-Ülkümen *et al*. (1993) described *Neogobius rhachis* from the Sarmatian

to Pannonian of a freshwater to brackish environment of Thrace, Turkey. These otoliths resemble in outline, but show a wider sulcus and a vertical edge or kink on the inner face separating the posterior portion behind the sulcus from the main part of the inner face.

***Gobius reichenbacherae* n. sp.**
Plate 9, figs 2-9

Holotype – Pl. 9, fig. 4, RGM 816 487, Turkey, Karaman Basin, Seyithasan (locality 17), middle Miocene, Serravallian.

Paratypes – Seven specimens RGM 816 488-494, same locality as holotype.

Additional specimens – Twenty five specimens: 16 in RGM 816 495 and 6 in coll. van der Voort, same locality as holotype; from Akbogazi (locality 7), 2 specimens coll. van der Voort, Lale (localities 2 and 3); 1 specimen coll. van der Voort, Gödet creek (locality 11).

Etymology – In honor of Bettina Reichenbacher (München) for her many contributions to the knowledge of fossil gobiid fishes.

Diagnosis – OL:OH = 1.25-1.35; OH:OT about 3.0. Curvature index of inner face 12-15% of OL. Preventral projection weak, angular; postdorsal projection short, broad, moderately bent outwards. Predorsal angle depressed; postventral angle moderately rounded. Dorsal rim highest behind middle of rim. Sulcus inclination 15-20°. Ostial lobe low; subcaudal iugum very small, only below anterior half of cauda.

Description (based on holotype and 7 paratypes) – Moderately elongate and moderately thick otoliths up to about 3.0 mm length. Outline showing weak, angular preventral projection, somewhat depressed predorsal angle, high, rounded postdorsal region, broad, moderately long postdorsal projection and slightly rounded postventral angle. Ventral rim flat, smooth; dorsal rim posteriorly elevated, smooth; anterior rim inclined, posterior rim vertical with slight indentation at level of cauda.
Inner face slightly convex, with postdorsal projection slightly bent outward. Sulcus centrally positioned, anteriorly inclined at 15-20°, moderately deep and with typical sole-shape although weakly developed ostial lobe. Subcaudal iugum small, short, only below anterior portion of cauda. Dorsal depression wide and prominent; ventral furrow distinct, close to ventral rim, anteriorly curving upward to ostium, posteriorly upward behind caudal tip. Outer face flat to slightly convex, smooth.

Discussion – *Gobius reichenbacherae* differs from the contemporaneous *G. mustus* n. sp. in being more elongate, the often low position of the depressed predorsal angle and the more convex inner face with the postdorsal projection being bent outward to a moderate degree. More similar is *G. multipinnatus* (H. von Meyer, 1952) known from the Ottnangian to Badenian of the Paratethys and with otoliths *in situ* (Weiler, 1955; Reichenbacher, 1993). That species, however, differs in the sharper preventral and postdorsal projections and the stronger curvature index of the inner face (20-23% of OL vs 12-15% of OL). For comparison a specimen is figured (Pl. 9, fig. 1) of *G. multipinnatus* from the Badenian of the Czech Republic. The fishes and otoliths referred to *G. multipinnatus* are currently under review by B. Reichenbacher (pers. com.).

***Gobius vandervoorti* n. sp.**
Plate 9, figs 10-15

Holotype – Pl. 9, fig. 10, RGM 816 496, Turkey, Karaman Basin, Lale (locality 2), middle Miocene, Serravallian.

Paratypes – Seven specimens; 1 in RGM 816 497, same locality as holotype; 5 specimens RGM 816 498-502, Seyithasan (locality 17); 1 specimen RGM 816 503, road cut on the road to Mut, ca. 27 km south of Karaman (locality 19).

Etymology – In honor of Jaap van der Voort (Venne, Germany) who has obtained and made available so many otoliths from the Karaman Basin.

Diagnosis – OL:OH = 1.05-1.15; OH:OT about 2.5. Curvature index of inner face 10-13% of OL. Preventral projection rounded; postdorsal projection short, very broad, not bent outwards. Predorsal angle low; postventral angle moderately rounded. Dorsal rim highest behind middle of rim, crenulated. Sulcus inclination about 15°. Ostial lobe low; subcaudal iugum long, extending along 2/3 of cauda.

Description (based on holotype and 7 paratypes) – Compressed, compact and thick otoliths up to about 3.0 mm length. Outline showing weak preventral angle, low and mostly rounded predorsal angle, high, rounded postdorsal region, broad, short postdorsal projection and slightly rounded postventral angle. Ventral rim flat, smooth; dorsal rim posteriorly elevated, broadly crenulated; anterior rim short, posterior rim vertical with slight indentation at level of cauda.
Inner face very slightly convex, with postdorsal projection not bent outward. Sulcus slightly inframedian, anteriorly inclined at about 15°, moderately shallow and with typical sole-shape, shallow ostial lobe. Subcaudal iugum long, well defined, extending below two-thirds of cauda. Dorsal depression very large and prominent; ventral furrow distinct, close to ventral rim, anteriorly and posteriorly curving upward to level of ostium.
Outer face more strongly convex than inner face, with few long radial furrows on dorsal field originating from marginal crenulation.

Discussion – *Gobius vandervoorti* n. sp. is easily distinguished from other fossil gobiid otoliths from Europe by its compact and thick appearance, the flat inner face

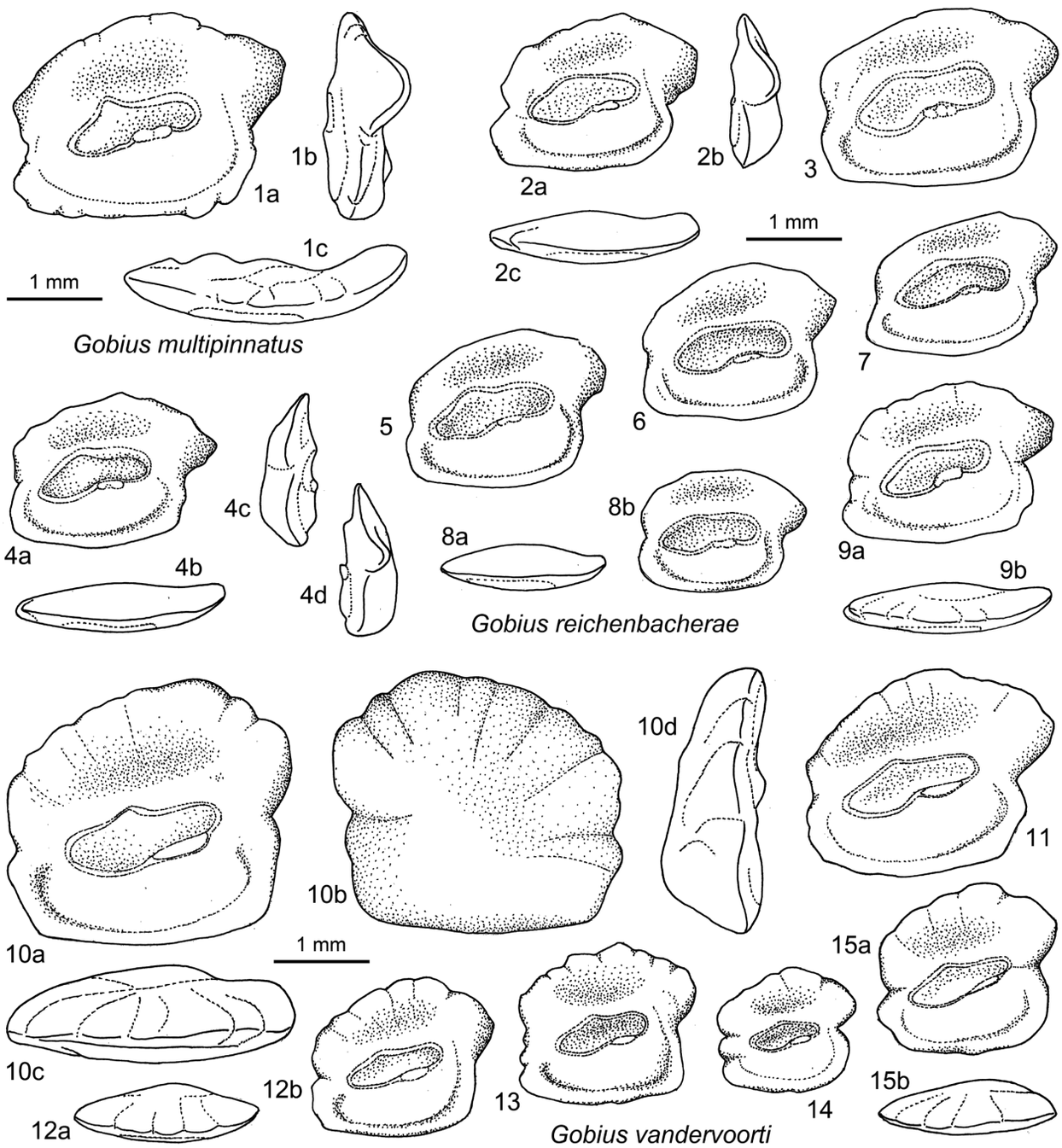

Plate 9

1. *Gobius multipinnatus* (H. von Meyer, 1852) (r); Borsky Sväty Mikulás, Slovakia, Badenian, coll. Schwarzhans, leg. Holec.
2-9. *Gobius reichenbacherae* n. sp.; Seyithasan; 4: **holotype**, RGM 816 487; 2, 3, 5, 6 (r), 7 (r), 8, 9: **paratypes**, RGM 816 488-494.
10-15. *Gobius vandervoorti* n. sp.; 10: **holotype**, Lale, RGM 816 496; 11, 12-14 (r): **paratypes**, Seyithasan, RGM 816 498-501; 15: **paratype**, road to Mut, RGM 816 503.

and the sulcus with its very low ostial lobe and the long subcaudal iugum. Amongst the Recent otoliths of *Gobius* species those of *G. geniporus* Valenciennes, 1837 and *G. roulei* de Buen, 1928 (see Lombarte *et al*., 2006 for figures) are the most similar. *Gobius vandervoorti* differs from *G. geniporus* in the more compressed shape (OL:OH = 1.05-1.15 vs 1.3-1.5), the lack of an angular predorsal process and the less depressed predorsal rim. Otoliths of *G. roulei* are also somewhat more elongate than those of *G. vandervoorti* (OL:OH = 1.15-1.3 vs 1.05-1.15) and exhibit a more pronounced preventral angle. Both Recent species exhibit a slightly bent sulcus while in *G. vandervoorti* it is perfectly straight.

Genus *Knipowitschia* Iljin, 1927

***Knipowitschia suavis* n. sp.**
Plate 10, figs 7-14

Holotype – Pl. 10, fig. 7, RGM 816 504, Turkey, Karaman Basin, Seyithasan (locality 17), middle Miocene, Serravallian.

Paratypes – Seven specimens; 6 in RGM 816 505-510, same locality as holotype; 1 specimen RGM 816 511, Gödet Creek, Tilkikaya (locality 11).

Additional specimens – A total of 179 specimens, 119 in RGM 816 512 and 60 in coll. van der Voort, same locality as holotype.

Etymology – From *suavis* (Latin) = sweet, agreeable, delightful, referring to the exceptionally long subcaudal iugum representing a character of high diagnostic value.

Diagnosis – OL:OH = 0.85-0.9; OH:OT =3.0-3.5. Curvature index of inner face 10-13% of OL. Outline roughly triangular with flat ventral rim, marked pre- and postventral angles, high mediodorsal angle and postdorsal projection almost absent. Sulcus inclination <10°. Ostial lobe low; subcaudal iugum very long, extending below entire cauda and beyond, at times.

Description (based on 10 specimens including the holotype and 7 paratypes) – Small, compressed, compact and moderately thick otoliths up to about 1.2 mm length. Outline almost triangular with distinct pre- and postventral and mediodorsal angles. Ventral rim straight to slightly bent, sometimes concave at its middle. Anterior rim steep, gently bending backwards over predorsal portion towards pronounced mediodorsal angle. Postdorsal rim steeply inclined to week, broadly rounded; postdorsal angle not projecting. Posterior rim nearly vertical with shallow indentation at level of cauda.
Inner face very slightly convex in horizontal direction but not bent in vertical direction. Sulcus slightly inframedian, slightly inclined at less than 10°, somewhat deepened, with typical sole-shape and shallow ostial lobe. Subcaudal iugum exceptionally large and long, well defined, extending below entire cauda and often reaching beyond tip of cauda and then turning upwards. Dorsal depression rather small but prominent; ventral furrow distinct, close to ventral rim, anteriorly and posteriorly curving upward only to lower margin of sulcus. Outer face more strongly convex than inner face, smooth.

Discussion – These small otoliths resemble juveniles of the contemporaneously occurring *Lesueurigobius suerii* (see below) and may not always be distinguishable, when poorly preserved. The majority of specimens, however, is well preserved and then both species are easily distinguished by *K. suavis* exhibiting the highly diagnostic long subcaudal iugum, the high mediodorsal angle (*vs* moderately high postdorsal angle) and the postdorsal region projecting less than the postventral angle (*vs* moderately developed postdorsal projection).

The genus *Knipowitschia*, and the related genus *Economidichthys*, are commonly found in the Recent in freshwaters and brackish to marginal marine waters of the eastern Mediterranean and the terrain of the former Paratethys. Many of the Recent species are highly endemic freshwater fishes while the few more brackish to marginal marine species are geographically more widespread (Miller, 2004). Otoliths are primarily known from the latter, which are for this purpose the more relevant, and which I have figured for comparison – *Economidichthys pygmaeus* (Holly, 1929) (Pl. 10, figs 1-2), *Knipowitschia caucasica* (Berg, 1916) (Pl. 10, figs 4-6), *Knipowitschia thessala* (Vinciguerra, 1921) (Pl. 10, fig. 3). Outline and general appearance of *K. suavis* relates well with the Recent species, particularly with *K. thessala*. The Recent species likewise have a long subcaudal iugum, however never as large and extending as in *K. suavis*. *Knipowitschia suavis* is one of only three species found in the brackish water environment of the Gödet Creek (locality 11).

Genus *Lesueurigobius* Whitley, 1950

***Lesueurigobius suerii* (Risso, 1810)**
Plate 11, figs 1-13

1983 *Pomatoschistus vicinalis* (Koken, 1891) – Brzobohaty, pl. 7, fig. 1.

Material examined – A total of 563 specimens: 50 in coll. van der Voort, Lale (locality 2); 29 coll. van der Voort, Lale (locality 3); 3 specimens RGM 816 513, NW-Lale (locality 6); 4 specimens RGM 816 514 and 14 specimens coll. van der Voort, Akbogazi (locality 7); 30 specimens RGM 816 515, Akpinar (locality 13); 369 specimens RGM 816 516-528 and 56 specimens coll. van der Voort, Seyithasan (locality 17); 8 specimens RGM 816 529, road to Mut, 27 km S of Karaman (locality 19).

Diagnosis – OL:OH = 0.95-1.05; OH:OT =2.7-3.5. Curvature index of inner face 12-15% of OL. Outline subrectangular with rather low dorsal rim and postdorsal angle and weak postdorsal projection. Sulcus inclination 10-15°. Ostial lobe moderately low; subcaudal iugum broad, extending below anterior 2/3rd of cauda.

Description (based on 17 specimens) – Moderately large, compressed, compact and moderately thick otoliths up to nearly 3.0 mm length. Outline subrectangular. Dorsal rim low, with broadly rounded predorsal and moderately elevated postdorsal angles. Ventral rim straight to slightly bent, shorter than dorsal rim, with well developed pre- and postventral angles. Anterior rim near vertical with minor indentation at level of ostium. Posterior rim nearly vertical, with weak postdorsal projection and with shallow indentation at level of cauda.
Inner face slightly convex in horizontal direction but not bent in vertical direction. Sulcus slightly inframedian, inclined at 10-15°, slightly deepened, with typical sole-shape and shallow ostial lobe. Subcaudal iugum well

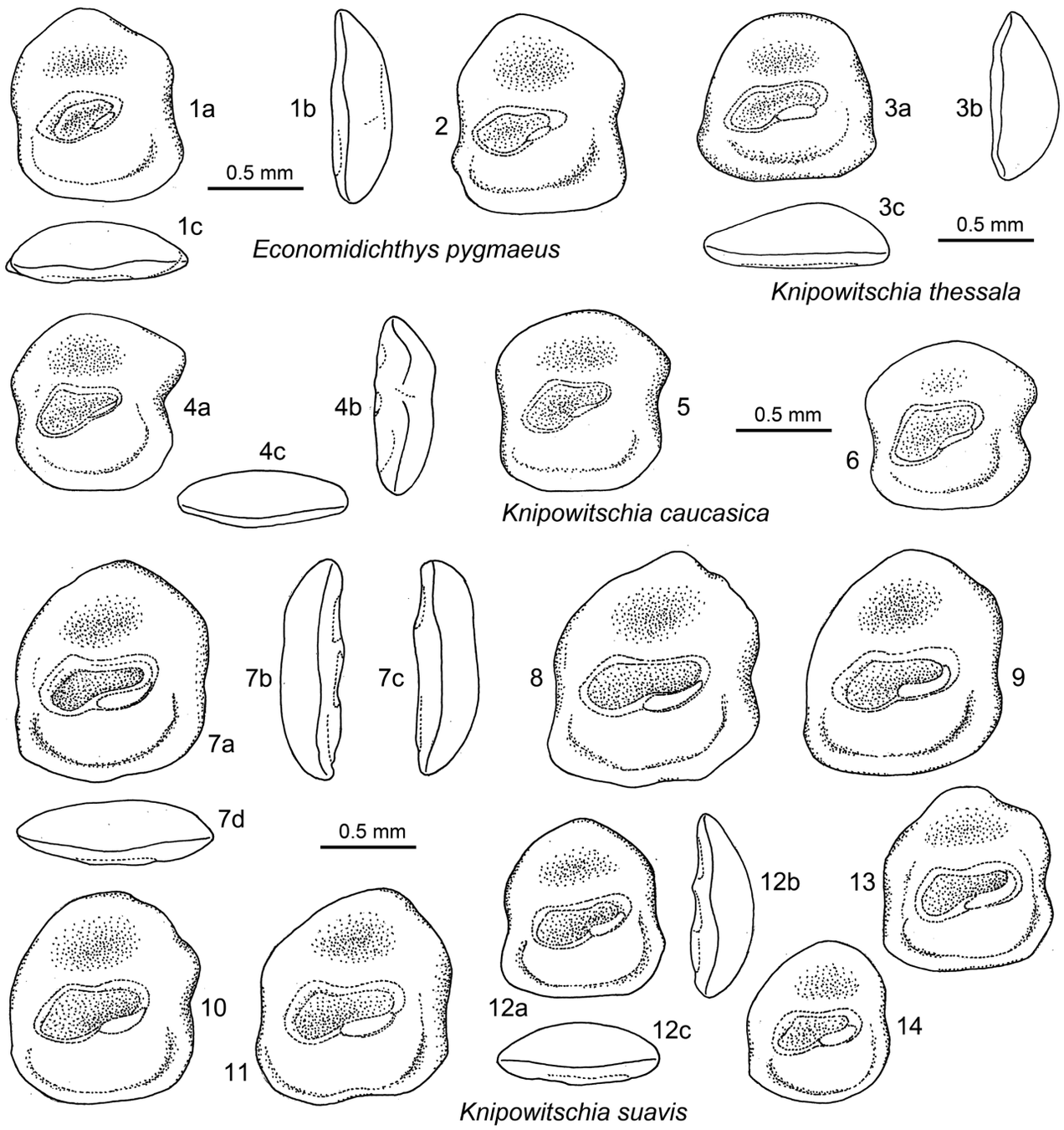

Plate 10

1-2. *Economidichthys pygmaeus* (Holly, 1929); Recent, Lake Trichonis, Greece, BMNH 1999.4.23.231-290.

3. *Knipowitschia thessala* (Vinciguerra, 1921); Recent, Mati Tyrnavo, Greece, BMNH 1989.3.15.33-58.

5-6. *Knipowitschia caucasica* (Berg, 1916); Recent, Lake Votvi, Macedonia, BMNH 1989.3.15.59-124.

7-14. *Knipowitschia suavis* n. sp.; 7: **holotype**, Seyithasan, RGM 816 505; 8-11, 13-14 (r): **paratypes**, Seyithasan, RGM 816 505-510; 12 (r): **paratype**, Gödet creek, RGM 816 511.

developed, wide and moderately long, extending below anterior 2/3rd of cauda. Dorsal depression rather small but prominent; ventral furrow distinct, close to ventral rim, anteriorly and posteriorly curving upward only to lower margin of sulcus. Outer face more strongly convex than inner face, smooth or with few faint radial furrows dorsally.

Discussion – Otoliths of *L. suerii* represent the most common otolith-based species in Karaman. Three Recent specimens are figured for comparison (Pl. 11, figs 1-3) documenting that this species has been present in the Mediterranean since Serravallian times. The earliest attributable record appears to be the one documented by Brzobohaty (1983) from the late Badenian (early Serravallian).

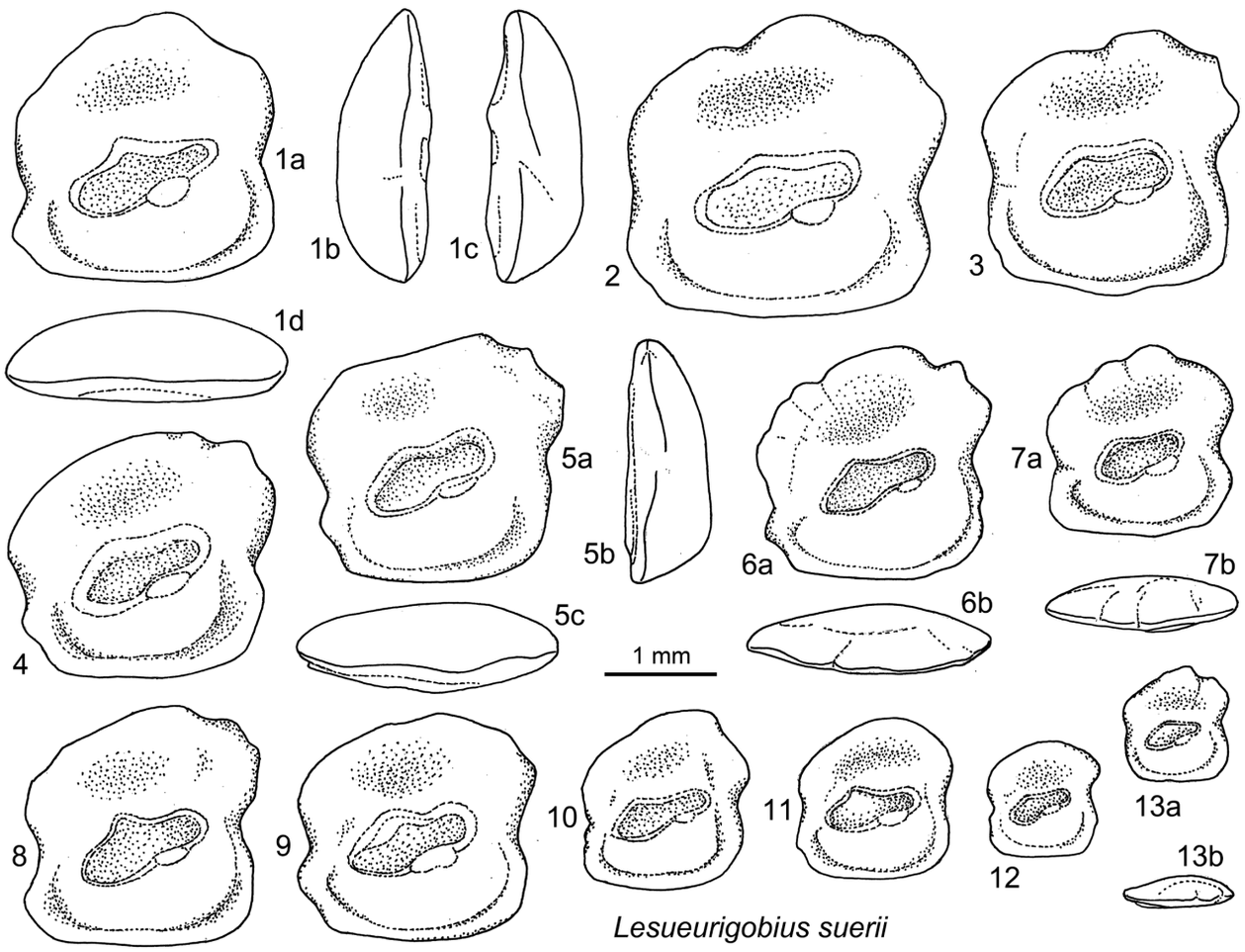

Plate 11

1-3. *Lesueurigobius suerii* (Risso, 1810); Recent, off Neapel, Italy, ZMUC unregistered, leg. Bellotti 26.11.1888.

4-13. *Lesueurigobius suerii* (Risso, 1810); 4, 6-8 (r), 10, 11 (r), 12, 13: Seyithasan, RGM 816 516-523; 5: Lale, coll. van der Voort; 9: (r) Akbogazi, RGM 816 514.

The common, earlier Burdigalian to Langhian *L. vicinalis* (Koken, 1891) is characterized by a higher postdorsal portion, a crenulated dorsal rim and ornamented dorsal field on the outer face and a smaller sulcus. A similar, even more intensely ornamented undescribed species has been recorded from the Serravallian of SW France as *Acentrogobius* sp. by Steurbaut (1984) and as *Lesueurigobius* sp. from the late Serravallian of the North Sea Basin by Schwarzhans (2010). A further undescribed, less high-bodied species with no marginal crenulation or ornamentation but occasionally depressed middorsal rim has been described from the Burdigalian to Langhian of Mallorca as *Lesueurigobius* sp. and genus Gobiidarum sp.3 by Hoedemakers & Batllori (2005). A more compressed species (OL:OH = 0.85-0.95) with expanded, rounded postdorsal region and some marginal crenulation has been described by Schwarzhans (2013d) as *L. ewonguensis* from the Serravallian to early Tortonian of Gabon.

Genus *Pomatoschistus* Gill, 1863

***Pomatoschistus quagga* (Heckel, 1837)**
Plate 12, figs 7-8

Material examined – Two specimens RGM 816 530-531, Seythasan (locality 17).

Diagnosis – OL:OH = 0.9-0.95; OH:OT about 3.3. Curvature index of inner face about 15% of OL. Outline high-bodied with rounded angles. Rims smooth; inner face convex, smooth, with shallow sulcus. Sulcus inclination about 20°. Ostial lobe pronounced, but small; subcaudal iugum indistinct, narrow or absent.

Description – Small, high-bodied, compact and moderately thick otoliths up to about 1.0 mm length. All rims gently curving, smooth. Dorsal rim high, highest at its middle, without prominent angles. Ventral rim straight or gently curving, with broadly rounded pre- and postventral angles. Anterior rim near vertical without indenta-

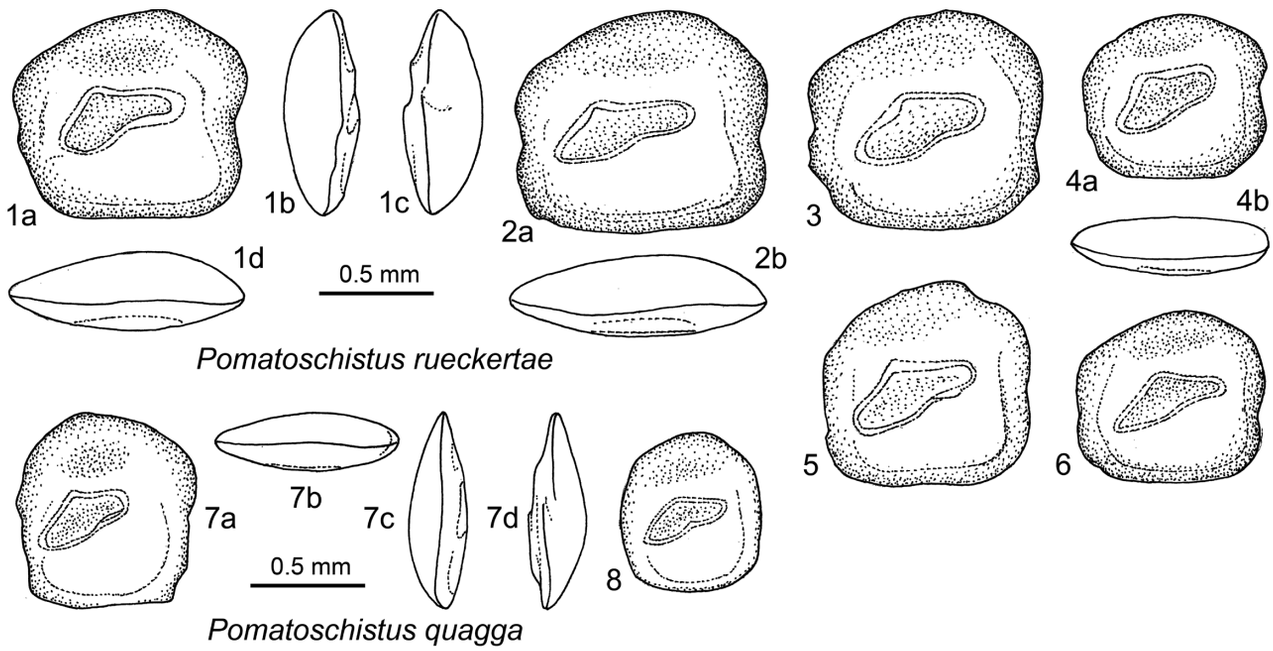

Plate 12

1-6. *Pomatoschistus rueckertae* n. sp.; 1: **holotype**, Seyithasan, RGM 816 532; 2, 3 (r), 4 (r), 5, 6 (r): **paratypes**, Seyithasan, RGM 816 533-537.

7-8. *Pomatischistus quagga* (Heckel, 1837); Seyithsan, RGM 816 530-531.

tion. Posterior rim nearly vertical, without postdorsal projection and with very weak indentation at level of cauda.

Inner face markedly convex and smooth. Sulcus median, rather steeply inclined at about 20°, shallow, with typical sole-shape and marked but small ostial lobe. Subcaudal iugum small, narrow and indistinct or entirely absent. Dorsal depression rather small, shallow; ventral furrow distinct, but narrow, close to ventral rim, anteriorly and posteriorly curving upward above sulcus level. Outer face moderately convex, smooth.

Discussion – Otoliths of *P. quagga* differ from other species of the genus in the high-bodied appearance with an OL:OH index well below 1.0 (for comparison see Lombarte *et al*., 2006). In the Recent, *P. quagga* is known from the western Mediterranean basin and the Adriatic Sea, but its distribution does not reach as far as Turkey.

***Pomatoschistus rueckertae* n. sp.**

Plate 12, figs 1-6

Holotype – Pl. 12, fig. 1, RGM 816 532, Turkey, Karaman Basin, Seyithasan (locality 17), middle Miocene, Serravallian.

Paratypes – Five specimens RGM 816 533-537, same locality as holotype.

Additional specimens – Fourty four specimens, 31 in RGM 816 538 and 13 in coll. van der Voort, same locality as holotype.

Etymology – In honor of Ms Neriman Rückert-Ülkümen (München) and her many contributions to the knowledge of fossil fishes from Turkey.

Diagnosis – OL:OH = 1.05-1.15; OH:OT = 2.5-3.0. Curvature index of inner face about 15% of OL. Outline moderately elongate rectangular with rounded angles. Rims smooth; inner face convex, smooth, with shallow sulcus. Sulcus inclination about 15°. Ostial lobe pronounced; no subcaudal iugum.

Description (based on 8 specimens including the 6 type specimens) – Small, thick otoliths with rounded rectangular outline up to about 1.2 mm length. All rims smooth. Dorsal rim gently curving without prominent angles, highest posterior of its middle. Ventral rim straight or gently curving, with broadly rounded pre- and postventral angles. Anterior rim near vertical with very weak indentation. Posterior rim nearly vertical, with minute or without postdorsal projection and with very weak, broad, shallow indentation at level of cauda.

Inner face markedly convex and smooth. Sulcus median to slightly supramedian, moderately inclined at about 15°, shallow, with typical sole-shape and marked ostial lobe. No subcaudal iugum. Dorsal depression rather small, shallow; ventral furrow distinct, but narrow, close to ventral rim, anteriorly and posteriorly curving upward above sulcus level. Outer face markedly convex, smooth.

Discussion – Otoliths of *P. rueckertae* resemble *P. quagga*

in the biconvex appearance and the smooth inner face, but are considerably more elongate (OL:OH = 1.05-1.15 vs 0.9-0.95). Otoliths of *P. marmoratus* (Risso, 1810), a widespread Recent species in the Mediterranean, resembles well, but shows less elongate otoliths and a more expanded dorsal region. Another, again more compressed species of the genus *Pomatoschistus* has been recorded from the Badenian of Poland as genus Gobiidarum sp. 1 by Radwanska (1992).
Like *P. quagga, P. rueckertae* is distinguished by the smooth and convex inner face and the only moderately developed ostial lobe.

Genus *Thorogobius* Miller, 1969

***Thorogobius iucundus* n. sp.**
Plate 13, figs 3-13

1906	*Gobius intimus* Prochazka, 1893 – Schubert, pl. 20, figs 35, 37 (*non* fig. 36).
1992	*Gobius* sp. – Radwanska, text-fig. 144, pl. 34, figs 7-9.
1994	*Gobius* sp.6 – Brzobohaty, pl. 6, figs 17-20.
2007	*Priolepis* sp. – Brzobohaty *et al*., pl. 8, figs 9-10.
?2009	genus Gobiidarum sp.2 – Nolf & Brzobohaty, pl. 7, fig. 10.
2010	*Thorogobius intimus* (Prochazka, 1893) – Schwarzhans, pl. 106, figs 11-13.

Notes – Similar looking otoliths have been recorded as *Gobius intimus* Prochazka, 1893 by Schubert (1906) and *Thorogobius intimus* respectively by Schwarzhans (2010). In Schwarzhans (2010) it was argued that the notch in the dorsal rim might be misleading. Brzobohaty kindly informed (pers. com.) that specimens he had collected from Prochazka's type strata exhibit a similar morphology than that depicted in Prochazka's schematic drawing and hence are different from the morphology shown in Schwarzhans (2010). A few otoliths described by Prochazka (1893) and other specimens originally identified by Prochazka have recently been located in the paleontological collection of the Geological Survey of Austria (pers. com. I. Zorn) but others might have to be considered lost. In a review of ostracodal type specimens stored at the Geological Survey of Austria four out of seven species of ostracods described by Prochazka in the same study in 1893 were recovered and listed by Zorn (2010). A decision about re-description and allocation of *'Gobius' intimus* or establishing of a neotype therefore is postponed until all available specimens originally identified by Prochazka have been reviewed.

Holotype – Pl. 13, fig. 3, RGM 816 539, Turkey, Karaman Basin, NW Lale (locality 6), middle Miocene, Serravallian.

Paratypes – Ten specimens: 2 in RGM 794 407-408, Akbogazi (locality 7); 3 in RGM 816 544, 794 409-410, Seyithasan (locality 17); 1 in RGM 794 411, Lale (locality 2); 3 in RGM 816 540-542, Akpinar (locality 13); 1 in RGM 816 545, road to Mut, 27 km S of Karaman (locality 19).

Additional specimens – Fourty four specimens:10 in coll. van der Voort, Lale (locality 2); 1 specimen coll. van der Voort, Akbogazi (locality 7); 4 specimens RGM 816 543, Akpinar (locality 13); 6 specimens RGM 794 412, Seyithasan (locality 17); 1 in RGM 794 413, road to Mut, 27 km S of Karaman (locality 19).

Etymology – From *iucundus* (Latin) = acceptable, satisfactory, referring to its distinct morphology typical for the genus *Thorogobius*.

Diagnosis – OL:OH = 1.15-1.3; OH:OT = 2.5-2.8. Curvature index of inner face <10% of OL. Dorsal rim anteriorly depressed, highest behind middle of rim; postdorsal projection short, very broad, not bent outwards. Anterior rim vertical. Sulcus inclination about 10°. Ostial lobe weak, ostium not much wider than cauda; no subcaudal iugum.

Description (based on 12 specimens, including the 11 type specimens) – Moderately elongate, massive otoliths up to about 3.0 mm length. Dorsal rim anteriorly depressed with moderately developed predorsal angle and high, obtuse postdorsal region, smooth or coarsely undulating; broad, short postdorsal projection. Ventral rim slightly curved, smooth; preventral angle weak, often weaker than predorsal angle; postventral angle well developed; anterior rim short, vertical, with small notch at level of ostium; posterior rim with slight, broad indentation at level of cauda.
Inner face almost perfectly flat, with postdorsal projection not bent outward. Sulcus median, anteriorly inclined at about 10°, rather shallow and wide and with a more gently curving outline than the typical sole-shape; ostial lobe very shallow and rounded. No subcaudal iugum. Dorsal depression very large and prominent; ventral furrow distinct, close to ventral rim, anteriorly and posteriorly curving upward to level slightly above sulcus. Outer face markedly convex usually smooth or with few indistinct short radial furrows on dorsal field.

Discussion – These otoliths are readily recognized by their almost flat inner face, the large sulcus with its gently curving outline and the lack of a subcaudal iugum. Radwanska (1992) was the first to recognize the relation of this morphology to the Recent *Thorogobius angolensis* (Norman, 1935) (then regarded as a species of the genus *Gobius*). Otoliths are known from three of the four Recent species placed in *Thorogobius* and they all share the same sulcus pattern, but *T. ephippiatus* (Lowe, 1839) and *T. macrolepis* (Kolombatovic, 1891) may show an indistinct narrow subcaudal iugum. I have figured two specimens of *T. angolensis* (Pl. 13, figs 1-2) as the ones most closely resembling the fossil *T. iucundus* and differing mainly in being more slender (OL:OH = 1.35-1.45 vs 1.15-1.3).

Thorogobius iucundus is known from the Langhian (Badenian) to Serravallian of the Paratethys and the eastern Mediterranean. A specimen figured by Nolf & Brzobohaty (2009) depicts a narrow subcaudal iugum and is therefore only tentatively placed in synonymy.

Order Pleuronectiformes Bleeker, 1859
Family Psettodidae Regan, 1910
Genus *Psettodes* Bennett, 1831

***Psettodes belcheri* Bennett, 1831**
Plate 14, fig. 1

Material examined – One specimen RGM 816 546, Seyithasan (locality 17).

Discussion – This otolith of 3.5 mm length probably stems from a subadult specimen and is not morphologically mature as would be expected from specimens of sizes larger than 5 mm. Such larger specimens for instance exhibit intensely notched otolith rims and also there is a trend for higher OL:OH ratios with size. However, otoliths of *P. belcheri* differ from those of the other Recent species of the genus, *P. erumei* (Bloch & Schneider, 1801) in being more elongate at all comparable sizes (Schwarzhans, 1999). *Psettodes belcheri* is known from

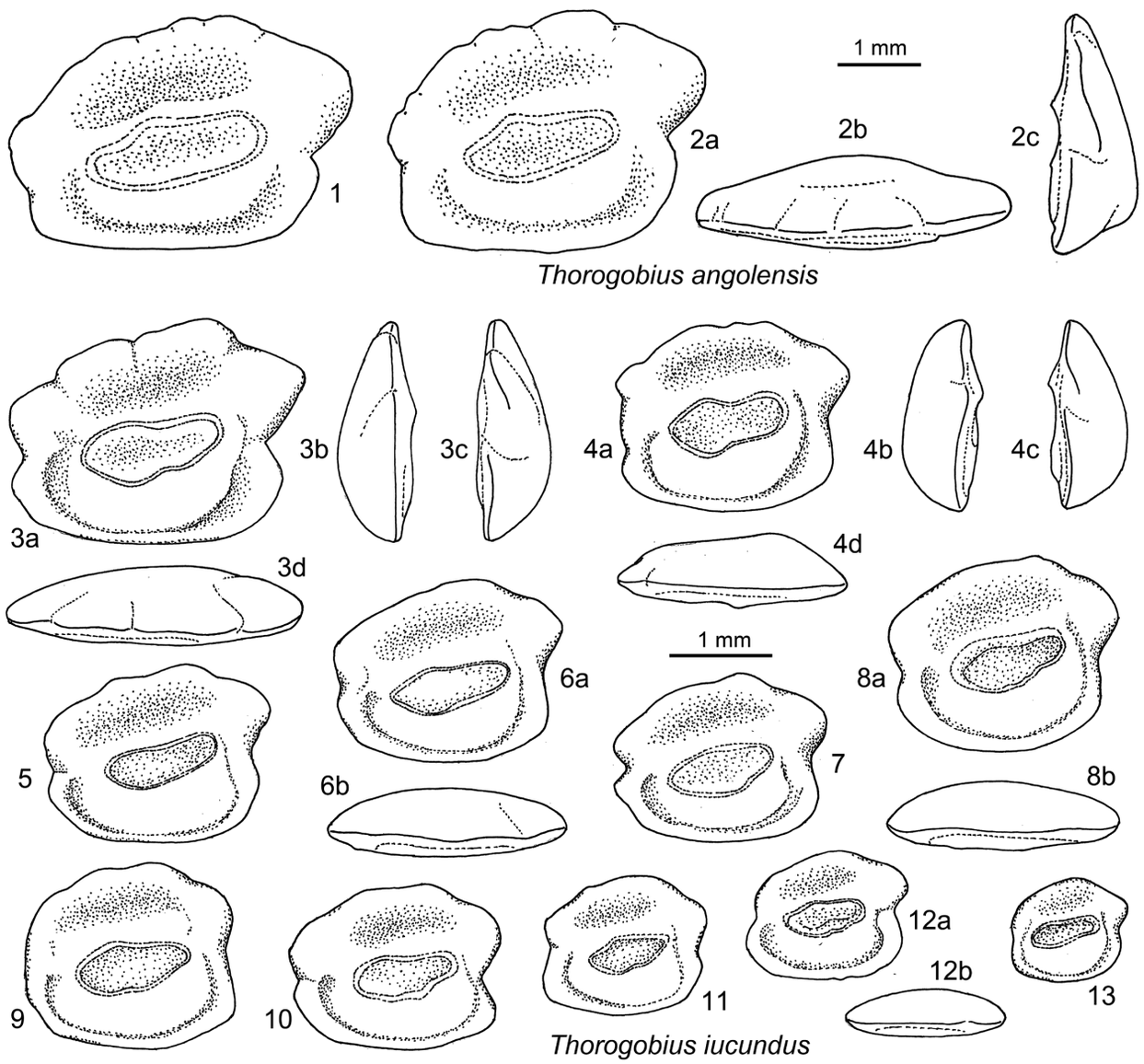

Plate 13

1-2. *Thorogobius angolensis* (Norman, 1935); Recent, Discovery st. off Angola, BMNH 1935.5.11.136-155, syntypes.

3-13. *Thorogobius iucundus* n. sp.; 3: **holotype**; NW Lale, RGM 816 539; 4, 11: **paratypes**, Akbogazi, RGM 794 407-408; 5 (r), 7, 12: **paratypes**, Seyithasan, RGM 816 544, 794 409-410; 6: **paratype**, Lale, RGM 794 411; 8 (r), 10 (r), 13: Akpinar, RGM 816 540-542; 9: road to Mut, RGM 816 545.

West Africa in the Recent, while *P. erumei* is a species of the Indo West-Pacific.

Family Citharidae Hubbs & Hubbs, 1945
Genus *Citharus* Röse, 1793

***Citharus lusitanicus* Jonet, 1972**
Plate 14, fig. 2

1972 *Eucitharus lusitanicus* Jonet, text-fig. 12, pl. 4, figs 131-133.
1999 *Citharus lusitanicus* Jonet, 1972 – Schwarzhans, figs 65-73 (with further synonymies).
2002 *Citharus lusitanicus* Jonet, 1972 – Nolf & Brzobohaty, pl. 12, figs 6-7.
2007 *Citharus lusitanicus* Jonet, 1972 – Brzobohaty *et al*., pl. 9, figs 8-9.
2009 *Citharus linguatula* (Linnaeus, 1758) – Nolf & Brzobohaty, pl. 8, fig. 3.

Material examined – One specimen RGM 816 547, Seyithasan (locality 17).

Discussion – Otoliths of *Citharus lusitanicus* closely resemble those of the Recent *C. linguatula*, which probably has led Nolf & Brzobohaty (2009) to record the Recent species from the Badenian of Austria in stead of the nominal fossil *C. lusitanicus*. In the review of pleuronectiform otoliths (Schwarzhans, 1999) I noted as a possibly diagnostic character for distinction the shallow dorsal rim in *C. linguatula* as compared to the presence of a distinct though obtuse mediodorsal angle in *C. lusitanicus*. I have tentatively maintained the distinction of both species, but it is noted that small specimens such as of the size found in Karaman may not always be clearly distinct. A second fossil species is known from the middle Miocene of the North Sea Basin and the early Pliocene of the NE Atlantic: *C. miocenicus* Weiler, 1942 (see Schwarzhans, 2010 for figures), which is more compressed, and a third with a pronounced postdorsal angle and a depressed medio- and predorsal rim from the deep water environment of the late Miocene of the Mediterranean: *C. schuberti* Bassoli, 1906.

Family Bothidae Regan, 1910
Genus *Arnoglossus* Bleeker, 1862

***Arnoglossus taureri* (Weinfurter, 1952)**
Plate 14, figs 5-9

1952 *Solea taureri* Weinfurter, pl. 2, figs 12-13.
1999 *Arnoglossus taureri* (Weinfurter, 1952) – Schwarzhans, figs 353-359 (with further synonymies).
2009 *Arnoglossus taureri* (Weinfurter, 1952) – Nolf & Brzobohaty, pl. 8, figs 8, 10 (*non* fig. 9).

Material examined – Eight specimens: 2 in coll. van der Voort, Lale (locality 3); 4 in RGM 816 548 and 1 in coll. van der Voort, Seythasan (locality 17); 1 specimen RGM 816 549, road to Mut, 27 km S of Karaman (locality 19).

Discussion – Otoliths of *Arnoglossus taureri* are recognized by the well developed pre- and postdorsal and postventral angles, whereas the contemporaneously occurring *A. holleri* Weinfurter, 1952 shows a much more rounded outline (Schwarzhans, 1999). Recently, Nolf & Brzobohaty (2009) synonymized both species, but their figures of the type specimens confirm the likelihood of the presence of two distinct species. *Arnoglossus taureri* shows a more southernly distribution and is known from the early to middle Miocene of the Paratethys and Portugal, and now Turkey. Its distribution overlaps with *A. holleri* in at least part of the Paratethys and Portugal, but *A. holleri* extends further north into the North Sea Basin and is missing from Turkey.

Family Soleidae Bonaparte, 1835
Genus *Buglossidium* Chabanaud, 1930

***Buglossidium frequens* Steurbaut, 1984**
Plate 14, fig. 4

1984 *Buglossidium frequens* Steurbaut, pl. 35, figs 9-18.
1999 *Microchirus frequens* (Steurbaut, 1984) – Schwarzhans, figs 718-724 (with further synonymies).
2007 *Dicologlossa hexophthalma* (Bennett, 1831) – Brzobohaty *et al*., pl. 9, fig. 10.
2010 *Buglossidium frequens* Steurbaut, 1984 – Schwarzhans, pl. 117, figs 2-5 (with further synonymies).

Material examined – One specimen RGM 816 550, Seyithasan (locality 17).

Genus *Dicologlossa* Chabanaud, 1927

***Dicologlossa hexophthalma* (Bennett, 1831)**
Plate 14, fig. 3

2010 *Dicologlossa hexophthalma* (Bennett, 1831) – Schwarzhans, pl. 117, figs 6-8 (with further synonymies).

Material examined – Two specimens RGM 816 551-552, Seyithasan (locality 17).

Discussion – Otoliths of *Dicologlossa hexophthalma* are recognized by the narrow sulcus and the thin appearance caused by the flat outer face.

Faunal reconstruction

Composition and environmental evaluation

About 1100 otolith specimens have been collected from eight localities in the Karaman Basin, all of which except

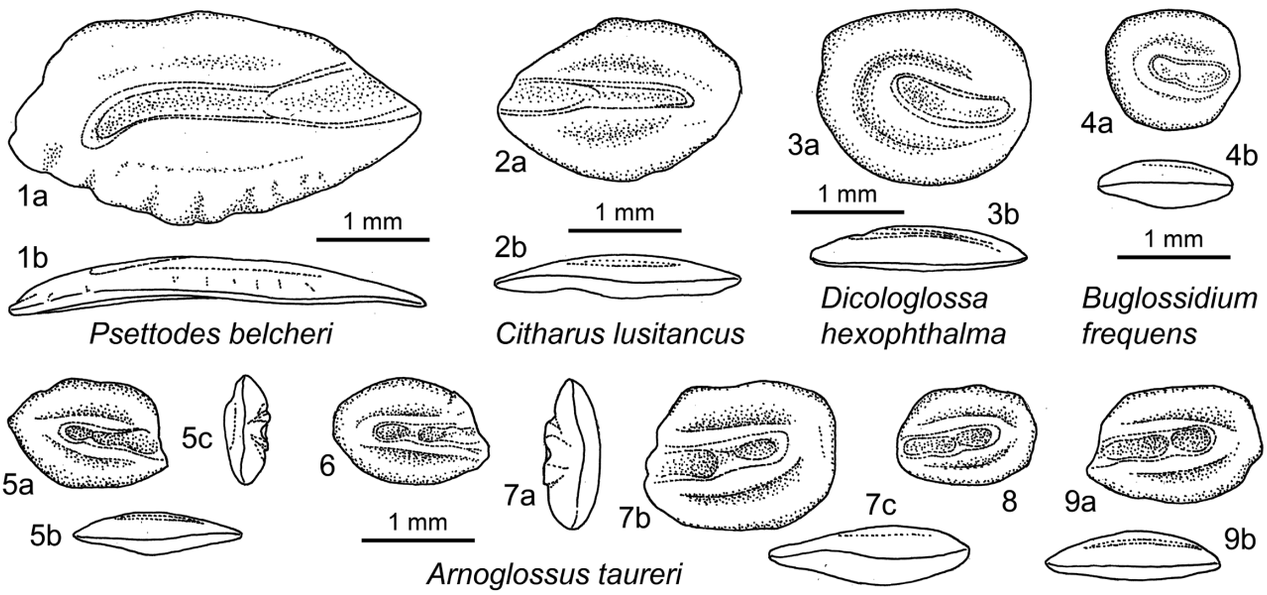

Plate 14

1. *Psettodes belcheri* Bennett, 1831; Seyithasan, RGM 816 546.
2. *Citharus lusitanicus* Jonet, 1972; Seyithasan, RGM 816 547.
3. *Dicologlossa hexophthalma* (Bennett, 1831); Seyithasan, RGM 816 551.
4. *Buglossidium frequens* Steurbaut, 1984; Seyithasan, RGM 816 550.

5-9. *Arnoglossus taureri* (Weinfurter, 1952); 5, 6, 9: Seyithasan, coll. van der Voort; 7: Seyithasan, RGM 816 548; 8: Lale, coll. van der Voort.

one representing shallow marine, soft-bottom inshore habitats with some solitary coral growth, but no reef bodies, and sea-grass meadows (Landau *et al*., 2013, p.347). The only exception is locality 11 at the Gödet Creek, which stems from a brackish environment and yielded only six otolith specimens, four of which represent a species (*Gobius* aff. *dorsorostralis*) not found in any of the other, shallow marine localities. Of the seven shallow marine localities, one, Seyithasan (locality 17), sticks out as the richest by far in terms of otolith abundance with nearly 900 specimens.

The otolith-based teleost fauna is dominated by the family Gobiidae in all localities, which reflects the sheltered near shore environment and is in line with the occurrence of gobiids in the Recent. The single most common species is the extant *Lesueurigobius suerii*, which accounts for half of all specimens identified. *Lesueurigobius suerii* makes up between 65 to 90% in most localities such as Lale (localities 2 and 3), Akbogazi (locality 7) or Akpinar (locality 13) and 46% in the rich locality of Seyithasan. In Seyithasan, other common species are *Knipowitschia suavis* (20.5%), *Gobius mustus* (12.5%), *Pomatoschistus rueckertae* (5.5%) and *Gobius reichenbacherae* (3.5%). Apart from some 30 unidentifiable fragmentary, eroded or juvenile percoid otoliths of some sort at Seyithasan (3.5%) the next common species, *Lethrinus styriacus* with 1.2%, is the most common non-gobiid, followed by *Atherina austriaca* and again a gobiid, *Thorogobius iucundus*, each with 1%. The Atherinidae is another family typical for near shore to estuarine environments whereas the Lethrinidae are commonly reef-associated fishes. Together with the rare representative of the Brotulidae, tribe Dinematichthyini (*Mascarenichthys exilis*), they represent the only indications of some reef-association in the fauna from the Karaman Basin. The only open marine fishes represented in the collection are two eroded unidentifiable otoliths of the myctophid genus *Diaphus* and two specimens of *Bregmaceros hybridus*. The mesopelagic myctophids are very abundant in the oceans below 100 m water depth and are also known for regular vertical migrations to near the sea surface at night so that these two singular occurrences must be explained by some taphogenic effect.

The faunal diversification index [defined as the number of the most common species up to a percentage of 90% of the total faunal association, see Schwarzhans (2010, p. 302)] is low, with only 6 species making up 90% of the faunal assemblage at Seyithasan. Again, a low diversification is to be expected for a fish fauna in such shallow marine soft-bottom and sea-grass dominated near shore environment, unlike the mollusc faunal composition described by Landau *et al*. (2013).

Biogeographic evaluation

The Karaman Basin was located near the junction of the eastern Mediterranean with the southeastern Paratethys, which during Serravallian times had already transformed into a landlocked inland sea basin except for a strait lead-

	2 - Lale	3 - Lale	6 - NW Lale	7 - Akbogazi	11 - Gödet creek	13 - Akpinar	17 - Seyithasan	19 - Road to Mut	Sum
Anguilliformes									
Congridae									
Ariosoma balearicum (DelaRoche, 1809)	1						2		**3**
Rhynchoconger pantanellii (Bassoli, 1906)						1			**1**
Pseudophichthys sp.								1	**1**
Chlopsidae									
Chilorhinus sp.				1		1			**2**
Clupeiformes									
Clupeidae									
Sardinops sp.							1		**1**
Myctophiformes									
Myctophidae									
Diaphus sp.						1	1		**2**
Aulopiformes									
Synodontidae									
Saurida sp. juv.							2		**2**
Synodus occidentalis Steurbaut, 1984							1		**1**
Gadiformes									
Bregmacerotidae									
Bregmaceros hybridus Schwarzhans, 2013				1		1			**2**
Phycidae									
Phycis musicki Cohen & Lavenberg, 1984	1								**1**
Batrachoidiformes									
Batrachoididae									
Batrichthys steiningeri Reichenbacher, 1998							1		**1**
Ophidiiformes									
Carapidae									
Carapus sp.						1			**1**
Bythitidae									
Mascarenichthys exilis n.sp.							2		**2**
Mugiliformes									
Mugilidae									
Mugilidae indet.							1		**1**
Atheriniformes									
Atherinidae									
Atherina austriaca Schubert, 1906							9		**9**
Scorpaeniformes									
Scorpaenidae									
Scorpaena? *landaui* n.sp.							4		**4**
Scorpaenidae indet.							1		**1**
Perciformes									
Sillaginidae									
Sillago schwarzhansi Steurbaut, 1984							1		**1**
Carangidae									
Trachurus sp.							3		**3**
Serranidae									
Serranus? *ariejansseni* n.sp.							5		**5**
Haemulidae									
Parapristipoma lucida (Bassoli, 1906)	2	1							**3**
Brachydeuterus speronatus (Bassoli, 1906)							3		**3**

continued on next page

	2 - Lale	3 - Lale	6 - NW Lale	7 - Akbogazi	11 - Gödet creek	13 - Akpinar	17 - Seyithasan	19 - Road to Mut	Sum
Lethrinidae									
Lethrinus anatolicus n.sp.							2		**2**
Lethrinus styriacus Nolf & Brzobohaty, 2009	2						11		**13**
Centracanthidae									
Spicara pamphyliensis n.sp.							3		**3**
Sparidae									
Dentex gregarius (Koken, 1891)	5					2		1	**8**
Diplodus karrerae Nolf & Steurbaut, 1979							1		**1**
Pagellus sp. juv.							3		**3**
Spondyliosoma sp. juv.							5		**5**
Sparidae indet.							1		**1**
Mullidae									
Mullus sp.							1		**1**
Cepolidae									
Cepola macrophthalma (Linnaeus, 1758)	2						2		**4**
Sphyraenidae									
Sphyraena sp.							3		**3**
Gobiidae									
Gobius aff. *dorsorostralis* Weinfurter, 1954					4				**4**
Gobius mustus n.sp.				1		3	112		**116**
Gobius reichenbacherae n.sp.	1	1			1		30		**33**
Gobius vandervoorti n.sp.	2						5	1	**8**
Knipowitschia suavis n. sp.					1		186		**187**
Lesueurigobius suerii (Risso, 1810)	50	29	3	18		30	425	8	**563**
Pomatoschistus quagga (Heckel, 1840)							2		**2**
Pomatoschistus rueckertae n.sp.							50		**50**
Thorogobius iucundus n.sp.	11		1	3		7	9	2	**33**
Pleuronectiformes									
Psettodidae									
Psettodes belcheri Bennett, 1831							1		**1**
Citharidae									
Citharus lusitanicus Jonet, 1972							1		**1**
Bothidae									
Arnoglossus taureri (Weinfurter, 1952)		2					5	1	**8**
Soleidae									
Buglossidium frequens Steurbaut, 1984							1		**1**
Dicologlossa hexophthalma (Bennett, 1831)							2		**2**
Totals specimens	**77**	**33**	**4**	**24**	**6**	**47**	**898**	**14**	**1101**
Totals species	**10**	**4**	**2**	**5**	**3**	**9**	**38**	**6**	**47**

Table 1. Otolith-based teleost species and number of specimens from the Miocene of the Karaman Basin.

ing nearby the Karaman Basin (Rögl, 1998; Landau *et al*., 2013), which, however, became abandoned shortly thereafter during the late Miocene. The last connection to the Indo West-Pacific through the Persian Gulf was also nearby and had been aborted at the turn of the Langhian to Serravallian during the uplift of the Palmyrids of the Levant. Thus, considering the overall time interval, the Karaman Basin fauna represents a unique insight into a fauna located at the crossroads of three major oceans during its terminal phase.

Unfortunately, the otolith-based fish fauna can only be correlated to other European faunas in the total absence of any knowledge of fossil otoliths from the Persian Gulf or other Neogene strata of the Indian Ocean. Relevant European otolith associations of shallow water environments to compare with are mostly somewhat older, for instance Burdigalian or Langhian in age. The most complete knowledge base is from the Badenian of the Central Paratethys (Radwanska, 1992; Brzobohaty *et al*., 2007; Nolf & Brzobohaty, 2009), the Burdigalian of Portugal (Steurbaut & Jonet, 1982), the Burdigalian to Serravallian of SW-France (Steurbaut, 1984) and the Langhian to Serravallian of the North Sea Basin (Schwarzhans, 2010). No shallow water otolith association is known from the middle Miocene of the Mediterranean, nor from the eastern Paratethys. The comparison stick-graph of Fig. 3 shows the highest degree of relation on the species level with the Central Paratethys amounting to 17 of 33 identifiable species in Karaman, *i.e*. 52%. The correlation would raise to 61%, when considering three further species representing species closely related to species of the Badenian of the Central Paratethys and possibly in fact part of individual evolutionary lineages (*Brachydeuterus speronatus, Gobius reichenbacherae* and *Lesueurigobius suerii*). To the Atlantic basins in Portugal and SW France the correlation is at an only slightly lower level – 15 species corresponding to 45% – including only one species not shared with the Central Paratethys (*Synodus occidentalis*). The correlation to the North Sea Basin is low with only 5 species (15%) indicating significant temperature difference and/or restricted faunal exchange (Schwarzhans, 2010).

The position of the Karaman Basin close to one of the most important faunal cross roads of the Miocene, which had just been abandoned shortly before, geologically speaking, suggests to also compare the otolith-based fish fauna on a higher systematic level with the Recent faunas of the tropical Atlantic, the Mediterranean and the Indian Ocean (Fig. 4). Expectedly, the highest degree of relationship on the genus level is found with the current Mediterranean and northern temperate Atlantic: 24 of a total of 37 recognized genera (65%) recognized in the Serravallian of Karaman are still extant in the Mediterranean or the adjacent NE Atlantic (Whitehead *et al*., 1984). Another eight genera require widening of the correlation matrix to the tropical Atlantic (22%), thereof two (*Chilorhinus* and *Rhynchoconger*) from the West Atlantic (Froese & Pauly, 2014). Only one genus (*Brachydeuterus*) is exclusively Atlantic, but at least five more genera relate to tropical West African species and a sixth (*Rhynchoconger*) may as well, subject to confirmation in the Recent (Quero *et al*., 1990, Schwarzhans 2013a for comments to *R. pantanelli*). Eleven genera (30%) of those not present any more in the Mediterranean or NE Atlantic are known from the Indo West-Pacific in the Recent, thereof five (13,5%) exclusively, *i.e. Sardinops, Batrichthys, Mascarenichthys, Sillago* and *Lethrinus* (Froese & Pauly, 2014), the latter with a single species also off West Africa.

In conclusion, the Karaman Basin fish fauna expectedly reflects close affinities on the genus level to the present day Mediterranean and NE Atlantic fauna (65%). Of the remainder, eight genera (22%) are known in the Recent from the tropical Atlantic and ten (32%) from the Indo West-Pacific, thereof five chiefly or exclusively so. This correlation supports the concept that some faunal elements of a former tropical Tethyan fauna of the Mediterranean were still present during the middle Miocene of the Karaman Basin.

Biostratigraphic evaluation

The close relation of the Serravallian otolith association in the Karaman Basin with that of the late Langhian of the Central Paratethys as discussed above clearly is also an expression of close stratigraphic position. Certain groups of otoliths have been used for biostratigraphic purposes, but none of those which are dominating the Karaman association. Nevertheless, a few species changes observed within perceived evolutionary lineages may be indicative of a stratigraphic differentiation. These are (first Langhian then Serravallian species): *Brachydeuterus latior* and *B. speronatus*, *Gobius multipinnatus* and *G. reichenbacherae*, *Lesueurigobius vicinalis* and *L. suerii*. Gobiid otoliths specifically may provide means for stratigraphic usage in shallow marine to brackish environments in the future, but due to the narrow geographical distribution of most gobies it will naturally face some areal restrictions.

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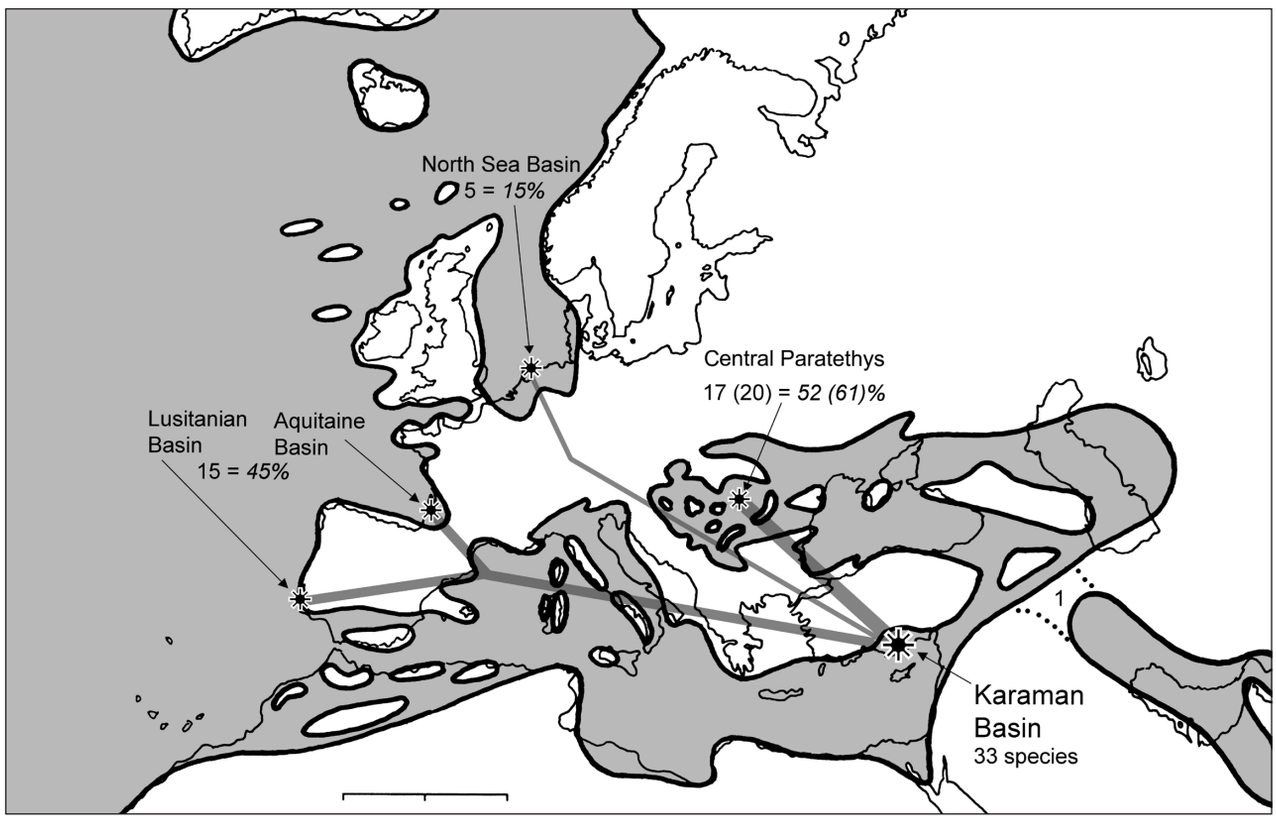

Figure 3. Comparison stick-graph of European Langhian/Serravallian otolith based faunas with the one from Karaman. The late Serravallian paleogeographic map is based on Rögl (1998) as altered and depicted in Landau *et al*. (2013). Bold numbers refer to number of co-occurring species, italic numbers refer to percentage of Karaman Basin taxa co-occurring in other basins. Legend: stars denote major otolith-based teleost faunas recorded, 1 denotes sea-way connecting the Indian Ocean with the Paratethys/Mediterranean, which has become permanently abandoned only at the turn of Langhian to Serravallian.

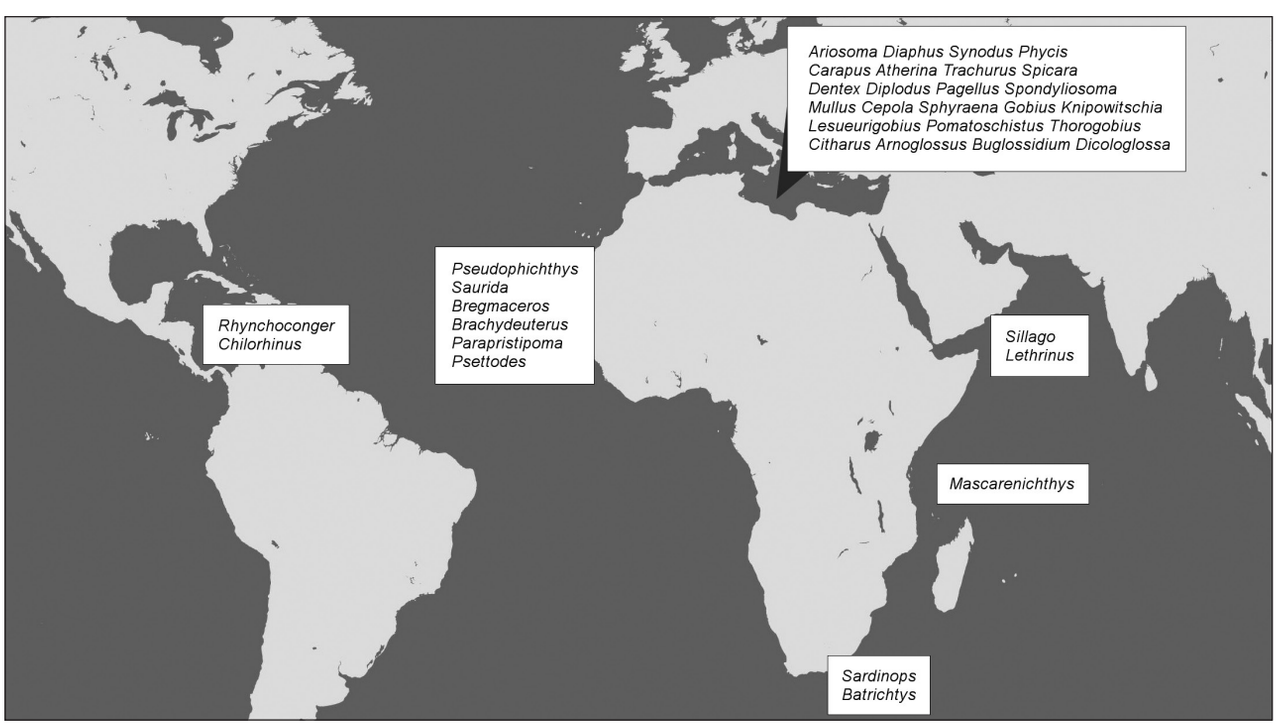

Figure 4. Geographic correlation map showing the nearest Recent reference locations (Froese & Pauly, 2014, Quero *et al*., 1990, Whitehead *et al.* 1984, 1986) on the genus level for the otolith-based fishes identified in the Serravallian of the Karaman Basin.

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