

FISH OTOLITHS FROM EURYHALINE OLIGOCENE DEPOSITS IN BELGIUM (ATUATUCA FORMATION) AND THE NETHERLANDS (GOUDSBERG DEPOSITS) AND THEIR PALEOECOLOGICAL IMPORTANCE

by

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Paleontological evaluation of 34 samples of Oligocene euryhaline sediments from the Belgian Tongeren area (32 samples) and the Dutch Valkenburg area (2 samples) yielded over a thousand specimens of fish otoliths. The genera *Thaumaturus*, genus aff. *Hemiramphidarum*, *Gazza*, *Dapalis* and genus *Gobiidarum* are new for the Oligocene of Belgium and the Netherlands. Sixteen species were recognized, eleven of which were not yet known from these deposits. Three new species are introduced, viz. genus *Clupeidarum atuatucae* n. sp., genus *Leiognathidarum nolfi* n. sp. and genus *Pomadasyidarum pouwi* n. sp.

The faunal composition allowed the distinction of several fish associations. Related to lithostratigraphical and geographical data they supply information on the paleoenvironment, mainly about the salinity.

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INTRODUCTION

In the Belgian provinces of Brabant and Limburg and in the adjacent Dutch province of Limburg euryhaline deposits of Oligocene age are present (Glibert & de Heinzelin, 1954; Buurman & Langeraar, 1975). For nine years these deposits have been the subject of a research-project executed in close cooperation by members of the Werkgroep voor Tertiaire en Kwartaire Geologie and the Rijksmuseum van Geologie en Mineralogie, Leiden (cf. Janssen et al., 1976). Several of these deposits contain abundant mollusc material, indicating that their sediments were deposited in an ecosystem, generally indicated as 'brackish water', but ranging from almost completely freshwater to environments strongly influenced by marine circumstances. All these deposits are supposed to be laid down within different parts of a lagoon or coastal lake (Janssen et al., 1976). In Belgium they are indicated as 'Tongrien supérieur' (Glibert & de Heinzelin, 1954), 'Upper Tongeren Beds' (Nolf, 1976) or 'Atuatuca Formation' (Janssen et al., 1976). In the Netherlands their lithostratigraphical indication is Goudsberg Deposits (Buurman & Langeraar, 1975). They overlie the Grimmeringen Formation (in Belgium) and the Klimmen Deposits (in the Netherlands). In the Netherlands and in the area around Tongeren in Belgium these lagoonal deposits are subdivided in Henis Clay and Sands and Marls of Oude Biesen (Glibert & de Heinzelin, 1954; Janssen et al., 1976). More to the West, in the Leuven-Sint Truiden area, several other members are distinguished (Glibert & de Heinzelin, 1954). In this paper the deposits concerned will be indicated as Atuatuca Formation and Goudsberg Deposits, respectively.

Contrarily to the sometimes extremely high numbers of mollusc specimens, fish-remains are encountered only rarely. Bor (1980) reported several elasmobranch species. Nolf (1976) mentioned the otoliths of nine species of Teleostei, of which six were collected from the Atuatuca Formation in the Tongeren area. These are all small species of a brackish water environment with more or less marine influences.

During the last seven years many samples were collected from the Atuatuca Formation and the Goudsberg Deposits in the Tongeren and Valkenburg areas. They were collected from outcrops and auger borings for paleontological investigation (mainly molluscs). Their residues yielded many, mainly very small otoliths. In the present report these otoliths are described. The existence of several associations of teleost fishes could be established within the lithological sequence of the Atuatuca Formation.

ACKNOWLEDGEMENTS

The greater part of the otoliths described in this paper is kept in the collections of the Rijksmuseum van Geologie en Mineralogie at Leiden. RGM-registration numbers are added to the individual samples.

I am grateful to Mr A.W. Janssen (RGM), who made extensive efforts to collect most of this material, and to Mr W. Pouw (RGM), who very carefully picked out most of the residues. I am also indebted to Mr T. Bor (Maartensdijk), Mr M.C. Cadée (Leiden), Dr P.A.M. Gaemers (Leiden) and Mr F. Maatman (Geldrop), who placed otoliths at my disposal for this study. Furthermore I thank Dr Gaemers for his interest and suggestions. I am much indebted to Dr D. Nolf (Ghent, Belgium), who kindly advised me in several identifications and systematical problems and whose collection of Recent otoliths was indispensable for a proper identification of many species.

MATERIAL AND LOCALITIES

Alltogether 1142 otoliths were available of which 1025 were collected in the Tongeren area and 117 in the Valkenburg area. They represent 16 species. The material is kept in several collections, indicated in the captions of illustrations and in the text with the following abbreviations:

- RGM Collection Rijksmuseum van Geologie en Mineralogie, Leiden, The Netherlands.
- TBM Collection T.J. Bor, Maartensdijk, The Netherlands.
- PGL Collection Dr P.A.M. Gaemers, Leiden, The Netherlands.
- FMG Collection F. Maatman, Geldrop, The Netherlands.
- VHL Collection V.W.M. van Hinsbergh, Leiden, The Netherlands.

All otoliths were collected from sediment sample residues, that always for the greater part consist of molluscs. Residues were obtained from sandy sediments by washing without previous treatment. Clay samples were dried for several days (at some 60° C), subsequently desintegrated in hot water and washed. In rare cases this treatment had to be repeated to achieve complete desintegration of the clay.

In columns 1-34 of Table 1 the various faunas are summarized. The samples, to which these figures refer, are listed below, together with the localities from which the material was collected. Moreover, the geographical position of the localities is shown in text-figs. 1 and 2.

Belgium

Borgloon. Northern side of the road-cut Tongeren-Sint Truiden, 2.45-3.15 m.

Map-sheet: 33/7-8. Lambert coordinates X = 218.94 Y = 165.86.

File nr. G.S.B.: 106E 774(V)(Ic).

Literature: Kruissink et al. (1978).

Stratigraphy: Atuatuca Formation, Sands and Marls of Oude Biesen, crag in the upper part of the alternating sandy and clayey deposits.

Several samples were obtained: RGM, leg. A.W. Janssen (Table 1, column 30), TBM (column 31), PGL (column 32).

Kleine Spouwen (municipality of Bilsen), Nachtegaalstraat, roadside exposure.

Map-sheet: 34/1-2. Lambert coordinates X = 233.175 Y = 170.275.

File nr. G.S.B.: 93W 301(1).

Literature: Glibert & de Heinzelin (1954); van Hinsbergh et al. (1973).

Stratigraphy: Atuatuca Formation, Sands and Marls of Oude Biesen, crag in the upper part of the alternating sandy and clayey deposits.

Thirty kg of sediment were washed on a 0.3 mesh, RGM, leg. A.W. Janssen (column 21). Several other samples were obtained: TBM (columns 23); VHL, leg. M.C. Cadée (column 22); PGL, leg. T. Meijer and J.G.M. Raven (column 24).

Kleine Spouwen (municipality of Bilsen), Dorpsstraat, former roadside exposure.

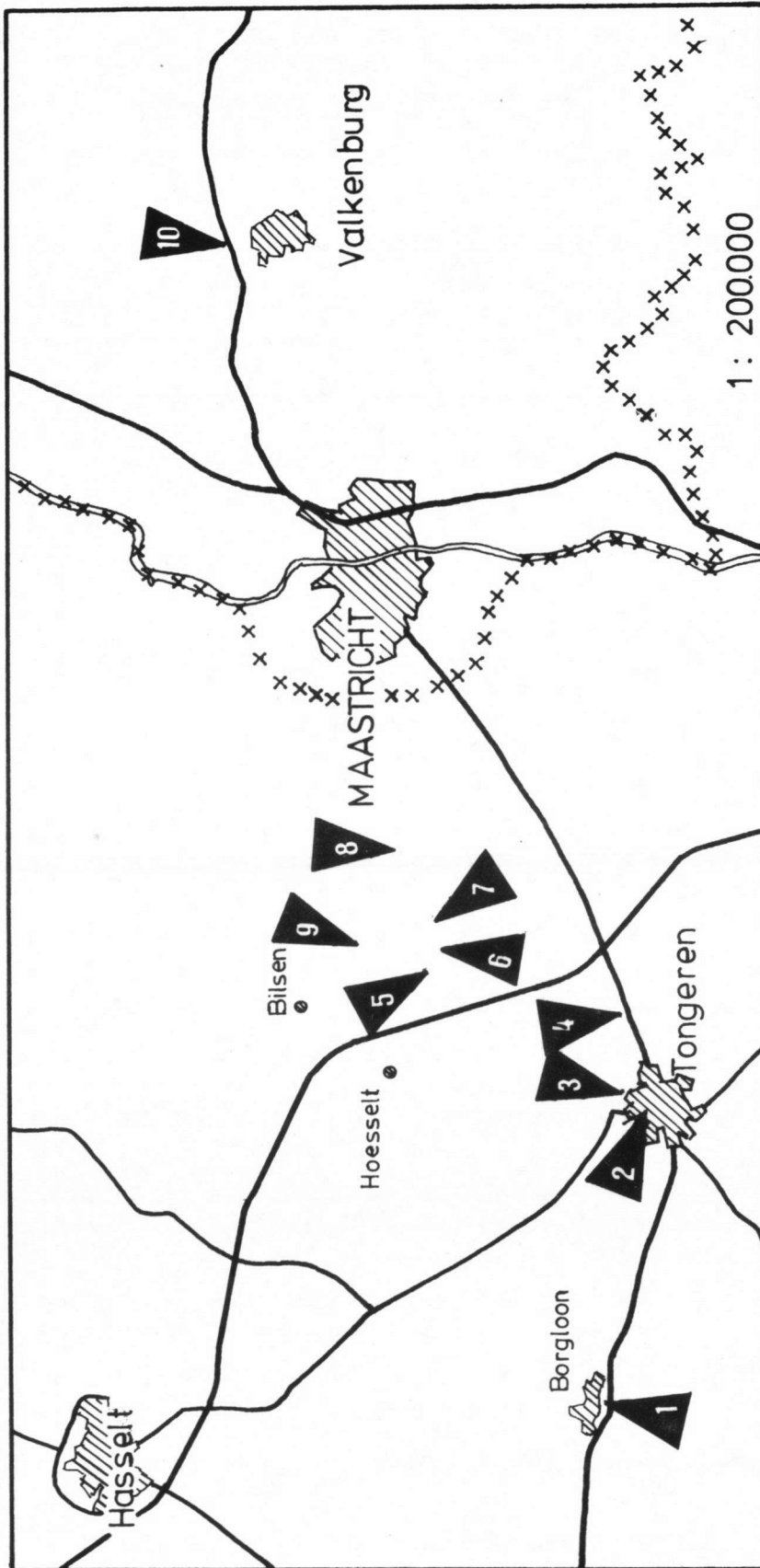
Map-sheet: 34/1-2. Lambert coordinates X = 232.925 Y = 170.275.

File nr. G.S.B.: 93W 9(1).

Literature: Glibert & de Heinzelin (1954); van Hinsbergh et al. (1973).

Stratigraphy: Atuatuca Formation, Sands and Marls of Oude Biesen, crag in the upper part of the alternating sandy and clayey deposits.

One small sample was obtained: PGL, leg. T. Meijer (column 25).



Text-figs 1 and 2. Geographical position of the localities.

Exposures and auger borings are indicated with black arrows: (1) Borgloon, roadside exposure; (2) Tongeren, T1 exposure; (3) Tongeren, Francart clay-pit; (4) Tongeren, Galgeberg exposure; (5) Rijkhoven, Alde Biesen; (6) Rijkhoven, R1 boring; (7) Kleine Spouwen, Nachtegaalstraat and Dorpsstraat; (8) Rosmeer, Diepenstraat; (9) Waltwilder, M5 boring; (10) Valkenburg, roadside exposure. Further data are given in the text.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
genus <i>Clupeidarum atuatucae</i>	-	-	1	-	10	11	16	1	29	-	-	30	-	-	-	-	-	-	90	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	
<i>Pterothrissus umbonatus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	
<i>Notogoneus longiceps</i>	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Thaumaturus rhenanus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17	6	1	6	-	-	-	-	-	-	-	-	-	-	3	-
genus aff. <i>Hemiramphidarum</i> sp.	-	-	7	2	3	1	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	
<i>Dapalis rhenanus</i>	-	-	-	-	-	-	-	-	-	-	-	10	21	10	-	-	-	-	-	-	-	-	-	-	-	-	3	1	1	-	5	-	-	-	
<i>Dapalis</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	1*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Gazza</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	1*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
genus <i>Leiognathidarum nolli</i>	-	1	1	2	-	-	-	-	1	-	-	3*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Leiognathidae sp. indet.	1	-	-	-	1	1	2	2	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Spicara kugleri</i>	-	-	-	-	-	-	-	-	-	-	-	5	7	5	6	-	136	2	87	14	27	6	1	108	5	12	3	3	82	4	4	11	-	-	-
genus <i>Spanidarum whiteheadi</i>	-	5	2	9	3	3	1	3	3	4	21	3	1	-	1	34	1	1	2	1	1	9	-	1	9	-	1	6	1	5	40	-	-	-	
genus <i>Spanidarum</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
? <i>Chanda</i> sp.	-	-	-	-	1	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
genus <i>Pomadasyidarum pouwi</i>	-	-	-	-	-	-	-	-	-	-	-	5	1	3	-	-	-	-	-	1	-	-	-	-	-	-	9	1	-	-	-	-	8	48	
genus <i>Gobiidarum</i> sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	2	3	-	-	-	-	-	-	-	-	-	-	-	-	
genus <i>Percoideorum</i> sp.	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
<i>Percoidea</i> juv. indet.	-	-	1	2	2	-	-	-	-	-	1	1	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
<i>lapilli</i> indet.	-	-	4	6	2	3	1	-	1	-	1	-	1	-	1	-	-	-	-	9	-	-	1	-	-	-	1	-	-	-	-	-	-	-	

gully level (base of) alternating sandy and clayey deposits

Table 1. Fish otoliths collected from the Atuatuca Formation near Tongeren (Belgium) and from the Goudsberg Deposits at Valkenburg (The Netherlands).

Thirty-four samples (columns 1-34) were inspected. These samples were obtained from Atuatuca Formation deposits at Rijkhoven, boring R1 (1), Waltwilder, boring M5 (2), Rosmeer (3), Tongeren, Francart clay-pit (4-17), Tongeren, T1 exposure (18), Tongeren, Galgeberg exposure (19-20), Kleine Spouwen, Nachtegaalstraat (21-24), Kleine Spouwen, Dorpsstraat (25), Rijkhoven, Alde Biesen (26-29), Borgloon (30-32) and from the Goudsberg Deposits (Sands and Marls of Oude Biesen) at Valkenburg (33-34). Further data on the localities and the stratigraphy are given in the chapter "material and localities".

Columns 1-12 and 13 (partly) represent samples from the gully level in the Sands and Marls of Oude Biesen. Columns 14-32, and 13 (partly) represent samples from the alternating sandy and clayey deposits in the Sands and Marls of Oude Biesen. Columns 14, 15 and 13 (partly) belong to the basal part of these alternating sandy and clayey deposits.

* placed in the RGM collections.

Rosmeer (municipality of Bilsen), Diepenstraat, temporary excavation on roadside.

Map-sheet: 34/1-2. Lambert coordinates X = 235.85 Y = 171.62.

Literature: Janssen (1977).

Stratigraphy: Atuatuca Formation, Sands and Marls of Oude Biesen, gully level.

The residue of 0.3 kg of clay, washed on a 0.3 mm mesh, was inspected, RGM, leg. A.W. Janssen (column 3).

Rijkhoven (municipality of Bilsen), auger boring R1, 2.65-3.15 m.

Map-sheet: 34/1-2. Lambert coordinates X = 231.840 Y = 170.160.

File nr. G.S.B.: 93W 360 (2).

Literature: Cadée et al. (1976).

Stratigraphy: Atuatuca Formation, Sands and Marls of Oude Biesen, gully level.

The residue of 0.2 kg of sediment, washed on a 0.5 mm mesh, was inspected, VHL, leg. M.C. Cadée (column 1).

Rijkhoven (municipality of Bilsen), exposure East of Alde Biesen castle, 0.30-1.20 m.

Map-sheet: 34/1-2. Lambert coordinates X = 231.60 Y = 170.72.

File nr. G.S.B.: 93W 567IXa.

Literature: van Hinsbergh et al. (1973).

Stratigraphy: Atuatuca Formation, Sands and Marls of Oude Biesen, crag in the upper part of the alternating sandy and clayey deposits.

Several hundredweights of sand were washed on a 0.5 mm mesh, partly on a 0.3 mm mesh, RGM, leg. A.W. Janssen (column 26). Several other samples were obtained: VHL, leg. M.C. Cadée and V.W.M. van Hinsbergh (column 27); PGL, leg. J. Vermeulen, T. Meijer and J.G.M. Raven (column 28), FMG (column 29).

Tongeren, Berg, Galgeberg exposure, 1.20-1.30 m.

Map-sheet: 34/5-6. Lambert coordinates X = 230.1 Y = 164.9.

File nr. G.S.B.: 107W 92(1) and (2).

Literature: Cadée et al. (1976).

Stratigraphy: Atuatuca Formation, Sands and Marls of Oude Biesen, clay level in the upper part of the alternating sandy and clayey deposits.

The residue of 50 kg of sediment, washed on a 0.3 mesh, was inspected; fractions below 0.85 mm were only partly inspected, RGM, leg. A.W. Janssen (column 19). Another small sample was obtained: PGL, leg. J.G.M. Raven (column 20).

Tongeren, Bilzer Steenweg, T1 exposure, 1.55-2.25 m.

Map-sheet: 34/5-6. Lambert coordinates X = 227.190 Y = 164.700.

File nr. G.S.B.: 107W 116(1)(IVa).

Literature: Janssen et al. (1976).

Stratigraphy: Atuatuca Formation (stratotype), Sands and Marls of Oude Biesen, clay level in the upper part of the alternating sandy and clayey deposits.

A sample of 0.5 kg of sediment was washed on a 0.6 mm mesh, VHL (column 33).

Tongeren, Francart clay-pit.

Map-sheet: 34/5-6. Lambert coordinates X = 227.75 Y = 165.17.

File nr. G.S.B.: 107W 196(1) and (2).

Literature: Felder (1963), Janssen et al. (1976), Janssen (1977a).

Stratigraphy: Atuatuca Formation, Sands and Marls of Oude Biesen, gully level and basal part of the alternating sandy and clayey deposits (no samples were inspected from the Henis Clay, underlying the gully level; this sediment seems to be barren). The uppermost samples of the section sampled by A.W. Janssen (see below) probably were taken from the basal part of the clay deposit overlying the gully level, but no otoliths were present in the residues.

Various samples from several levels were taken. In 1963 Mr F. Maatman collected several otoliths (columns 15-16) from sand layers containing many molluscs at the top of the hill. These deposits probably belong to the highest part of the alternating sandy and clayey deposits of the Sands and Marls of Oude Biesen (cf. Felder, 1963). They are completely excavated now.

Mr T.J. Bor and I collected samples (together about 50 kg) from two levels. One (column 12) was taken at the West wall of the clay-pit from the level 1.40-2.35 in the section measured by Janssen et al. (1976), which represents the gully level. The other sample (column 14) was taken from a dark brown clay, exposed in the North wall of the clay-pit, and situated just on top of the section given by Janssen et al. (1976, p. 99-103). Unfortunately, the residues of the two samples collected by Mr Bor (column 13) were put together.

Mr A.W. Janssen (RGM) collected many samples from the upper part of the Southern wall in 1977. This is a lateral equivalent of the section measured by Janssen et al. [1976, p. 99-103; file nr G.S.B. 107W 195(1) and (2)], and is described in detail by Janssen (1977a). The following samples were washed on a 0.3 mm mesh:

0.00-0.86 m : 8 samples of clay and sand, together 107.5 kg: no otoliths

0.86-0.88 m : 1.4 kg of clayey sand (column 11)

0.88-0.91 m : 0.5 kg of clayey sand: no otoliths

0.91-0.96 m : 49.5 kg of clay (column 10)

0.96-1.23 m : 53 kg of clayey sand (column 9)

1.23-1.49 m : 57.5 kg of clayey sand (column 8)

1.49-1.55 m : 19 kg of sandy clay (column 7)

1.55-1.60 m : 21 kg of clayey sand (column 6)

1.60-1.82 m : 3 samples of clayey sand, together 72.5 kg: no otoliths

1.82-1.88 m : 35.5 kg of sand (column 5)

1.88-2.05 m : 13.5 kg of sand (column 4)

2.05-2.25 m : 16.5 kg of sandy clay: no otoliths.

Waltwilder (municipality of Bilsen), auger boring M5, 6.10-7.25 m.

Map-sheet: 34/1-2. Lambert coordinates X = 233.670 Y = 172.760.

File nr. G.S.B.: 93W 578(2).

Literature: Cadée et al. (1976).

Stratigraphy: Atuatuca Formation, Sands and Marls of Oude Biesen, gully level.

A small sample was washed on a 0.5 mm mesh: RGM, leg. M.C. Cadée (column 2).

The Netherlands

Valkenburg, road-cut of motorway near Stoepert, 0.00-0.90 m.

Map-sheet: 62W, R.D. coordinates X = + 31.090 Y = - 142.050.

Literature: Cadée & Vaessen (1975).

Stratigraphy: Goudsberg Deposits, Sands and Marls of Oude Biesen.

Two samples were taken here by A.W. Janssen (RGM). The largest of these (70 kg) was taken from the upper part of the Sands and Marls of Oude Biesen (column 34), whereas the smaller one was collected from a more extensive interval. They were both washed on a 0.85 mm mesh.

SYSTEMATICAL PART

Classis: PISCES
Sub-classis: TELEOSTEI
Ordo: CLUPEIFORMES
Familia: CLUPEIDAE

Genus Clupeidarum atuatucae n. sp.

Pl. 1, Fig. 1-5.

Holotype: Tongeren, Galgeberg exposure, 1.20-1.30 m. RGM 176 550, pl. 1, fig. 1. Dimensions: L : 1.89 mm, H : 1.04 mm, T : 0.30 mm.

Other material: 190 sagittae: 98 specimens Tongeren, Francart clay-pit (30 specimens TBM, 68 specimens RGM 176 508-176 513); 89 specimens Tongeren, Galgeberg, RGM 176 551-176 555; 2 specimens Kleine Spouwen, Nachtegaalstraat (1 specimen TBM, 1 specimen RGM 176 568); 1 specimen Rosmeer, RGM 176 505.

Stratum typicum: Atuatuca Formation, Sands and Marls of Oude Biesen, alternating sandy and clayey deposits.

Derivatio nominis: named after the Atuatuca Formation (see Janssen et al., 1976).

Diagnosis: small clupeiform otolith with a solid but not elongated rostrum and a smaller but distinct antirostrum. It has a distinctly rounded postdorsal angle. The dorsal rim and the coarsely knobbed ventral rim are nearly parallel. The shape of the sulcus resembles that of the genus *Sardinops*.

Description of the holotype: small and roughly rectangular otolith. Its smooth dorsal rim has a rounded postdorsal angle. The ventral rim has coarse irregular lobes. The strong rostrum and the antirostrum have both a rounded point. Sharp excisura ostii.

The inner surface is flat and somewhat convex along the rims. The broad, medially situated sulcus is divided in a large ostium and a somewhat shorter cauda. The dorsal margin of the ostium is bent, it reaches the antirostral point. The ventral margin of the sulcus is straight and does not entirely reach the rostral point. At the transition between cauda and ostium the sulcus is constricted by a bend in its dorsal margin, accompanied by an elevation in the dorsal part of the sulcus. A distinct furrow runs from the excisura ostii somewhat obliquely through the entire sulcus, but it is interrupted at the ostium-cauda transition. A very faint irregular line runs from this furrow towards the caudal end. A distinct crista superior is present along the middle part of the sulcus, bordering an elongated area. The crista inferior runs along the entire sulcus, but fades away near the caudal end.

The outer surface is smooth and slightly concave in length direction. It has faint concentric growth lines, that follow the pattern of rim lobes. In the centre a very small and indistinct knob is visible.

Variability: although most characteristics of *genus Clupeidarum atuatucae* are rather constant,

there is a wide range of variability in the length of the rostrum and the pattern of rim lobes. Usually the area is less elongated than in the holotype. In small specimens the faint line posterior of the cauda is often missing. Very small otoliths sometimes have a more rounded ventral rim, resulting in a less rectangular outline. The dorsal margin of the posterior part of the cauda sometimes has an inward inflexion.

Discussion: the shape of the sulcus is in good agreement with those of the Recent genera *Sardinops* and *Sardinella* Valenciennes, 1847. However, the outline of the species here described differs from the Recent ones in particular by the shape of the rostrum. From the Early Miocene genus *Clupeidarum alzeyensis*, which was described by Weiler (1963) from a similar environment in Germany, the present species can be distinguished by the shape of the rostrum and by its different outline.

Ordo: ELOPIFORMES

Familia: ALBULIDAE

Pterothrissus umbonatus (Koken, 1884)

Pl. 1, Fig. 6.

1884 *Otolithus (incertae sedis) umbonatus* Koken, p. 557, pl. 12, fig. 12.

1884 *Otolithus (incertae sedis) minor* Koken, p. 558, pl. 11, fig. 14.

1976 *Pterithrissus umbonatus* - Nolf, p. 14.

1978 *Pterothrissus umbonatus* - Gaemers & van Hinsbergh, p. 7, pl. 1, figs. 1-4.

Material: 1 sagitta Kleine Spouwen, Nachtegaalstraat. Coll. PGL, leg. J. Raven.

Discussion: one juvenile specimen was found. Juvenile specimens, formerly incorrectly indicated as *Pterothrissus minor*, are found in a more shallow marine environment, whereas the adults usually are found in deeper seas.

Ordo: GONORHYNCHIFORMES

Familia: GONORHYNCHIDAE

Notogoneus longiceps (H. v. Meyer, 1851)

Pl. 1, Fig. 9.

1942 *Ot. (? Coregoni) alsheimensis* - Weiler, p. 15-16, pl. 1, figs. 14-19.

1963 *Notogoneus longiceps* - Weiler, p. 19-23, figs. 48-58.

1978 *Notogoneus longiceps* - Malz, p. 467, pl. 1, figs. 16-20.

Material: 1 sagitta Tongeren, Francart clay-pit, VHL.

Description and discussion: the only available specimen is a relatively large and thickset otolith. The tip of the rostrum is broken off. It agrees very well with the description given by Weiler (1963).

Notogoneus sp., described by Nolf (1976) from the Boutersem Sands probably belongs to the same species. The genus *Notogoneus* occurred from Eocene till Early Miocene, but only in brackish-lagoonal or fresh-water deposits (Weiler, 1963).

Ordo: SALMONIFORMES
Familia: THAUMATURIDAE

Thaumaturus rhenanus Weiler, 1963
Pl. 1, Fig. 7,8.

1963 *Thaumaturus rhenanus* Weiler, p. 17-18, figs. 35-42.

1978 *Thaumaturus rhenanus* - Malz, p. 468, pl. 1, fig. 21-23.

Material: 33 sagittae: 13 specimens Kleine Spouwen, Nachtegaalstraat (6 specimens RGM 176 569-176 570; 1 specimen VHL, leg. M.C. Cadée; 6 specimens TBM); 17 specimens Tongeren, Galgeberg, RGM 176 556-176 557; 3 specimens Borgloon, TBM.

Discussion: the specimens agree very well with those described by Weiler (1963) from the Early Miocene in Germany. The outer surface and the rims, however, are less sculptured in our specimens. In several specimens the dorsal and especially the ventral rim have many very small furrows and lobes. In one juvenile specimen the caudal end of the sulcus is not closed, which was also observed in one of the Early Miocene specimens (Weiler, 1963, fig. 39).

Ordo: BELONIFORMES
Familia: HEMIRHAMPHIDAE

Genus aff. *Hemiramphidarum* sp.
Pl. 1, Figs. 10, 11.

Material: 15 sagittae: 14 specimens Tongeren, Francart clay-pit (13 specimens RGM 176 514-176 518; 1 specimen TBM); 1 specimen Tongeren, Galgeberg, RGM 176 558.

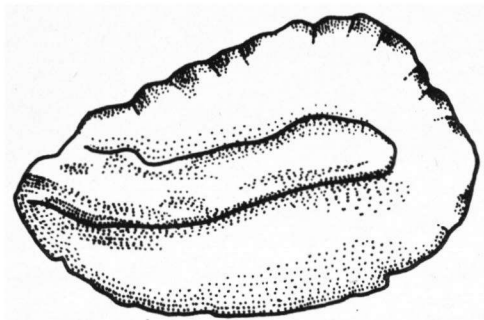
Description: the specimen illustrated on pl. 1, fig. 10 is the best preserved one. It is a small and rather thin otolith. Its outline is oval with a broad, indistinct mid- till postdorsal angle. Both rostrum and antirostrum are very blunt. No excisura ostii is present.

The inner surface is highly convex. The shallow sulcus is divided in a short, slightly sigmoidal ostium and a long, narrow and sigmoidally bent cauda, which nearly runs all over the otolith. Its caudal end bends in ventral direction. A small area is present, separated from the cauda by an indistinct crista superior.

The outer surface is smooth. It is almost flat transversely and somewhat concave in length direction. The central part of the outer surface is depressed.

Variability: frequently the mid- till postdorsal angle is less developed, as a result of which especially the very small specimens are more rounded. These very small specimens have an excisura ostii. In several otoliths the dorsal part of the ventral side has a few indistinct folds, resulting in knobs along the dorsal rim. Most specimens have a depression on the outer surface, which in very small otoliths is visible as a pit.

Discussion: the specimens found in the Tongeren area look very much like those of the family Hemiramphidae. There is a rather good resemblance in outline and shape of the sulcus with the Recent species *Hemiramphus sajori* Schlegel, 1846 (text-fig. 3). Hemiramphidae are often found in a lagoonal environment.



Text-fig. 3. Sagitta of the Recent species *Hemiramphus sajori* Schlegel, 1846 (coll. Dr D. Nolf, Ghent, Belgium). This species lives near-shore off Japan. The otolith is illustrated at a 25x magnification.

Ordo: PERCIFORMES
Familia: CENTROPOMIDAE

? *Chanda* sp.
Pl. 1, Fig. 12.

Material: 3 sagittae, Tongeren, Francart clay-pit, RGM 176 535-176 537.

Discussion: three very small, thickset and rather eroded otoliths resemble sagittae of the genus *Chanda* Hamilton, 1822 in their outline and the shape of the sulcus. They are, however, very juvenile specimens in which the specific characteristics were not yet developed.

Familia: SERRANIDAE

Dapalis rhenanus (Koken, 1891)
Pl. 2, Fig. 1, 2.

1891 *Ot. (Berycidarum) rhenanus* Koken, p. 120, pl. 6, fig. 10, 10a.

1942 *Smerdis rhenanus* - Weiler, p. 33, pl. 1, fig. 57, 58, non fig. 59, 60.

1978 *Dapalis rhenanus* - Malz, p. 464-466, fig. 5.

Material: 51 sagittae: 41 specimens Tongeren, Francart clay-pit (21 specimens VHL; 10 specimens TBM; 10 specimens FMG); 5 specimens Rijkhoven, Alde Biesen (3 specimens RGM 176 578; 1 specimen PGL; 1 specimen FMG); 5 specimens Borgloon, TBM.

Discussion: the adult specimens agree very well with the description of Koken (1891) and with the Middle Oligocene specimen represented by Weiler (1942, fig. 58). The juvenile specimens are spindle-shaped and much more elongate than those from the Hydrobien Schichten, indicated by Weiler (1942) as *Smerdis rhenanus*. These latter specimens may belong to another *Dapalis* species.

Dapalis sp.

Material: 1 sagitta Tongeren, Francart clay-pit, RGM 176 598, leg. VHL.

Description: the only available specimen is a small, oval otolith with a distinct rostral point. The dorsal rim has a few indistinct lobes and a faint predorsal angle. The part behind the more pronounced but rounded postdorsal angle declines rather steeply to the caudal end. The ventral rim is

regularly rounded. A distinct but shallow excisura ostii and a blunt antirostrum are present.

The inner surface is slightly convex. The sulcus acusticus is nearly straight, medially situated and, except for the rostral point, covered with colliculi. Ostium and cauda are almost equal in length, but the ostium is broader than the cauda. The dorsal margin of the ostium widens towards the dorsal rim; its ventral margin proceeds nearly straight forward, but suddenly bends upwards near the rostral point. The cauda is almost straight, but its posterior end slightly bends in ventral direction, mainly because of inflexion of its dorsal margin. The dorsal part of the cauda is deeper than its ventral part. A thin furrow runs along the deepest and most dorsal part of the cauda, but is no longer visible at the caudal end. A distinct crista superior is present, but it fades away near the caudal end. It visualizes an indistinct area. No crista inferior is present. A ventral furrow is clearly visible below the cauda.

The outer surface is slightly concave in length direction. An elevation protrudes from the rostrum and covers the central part. Particularly at the caudal side, a shallow circular groove separates the central part from irregular knobs surrounding it.

Discussion: the only available specimen is a juvenile otolith. It resembles *Dapalis formosus* (H. v. Meyer, 1852), which is known from Early Miocene brackish water deposits in Czechoslovakia (Weiler, 1966; Brzobohatý, 1969). The present specimen differs by its more elongated shape and its less developed postdorsal angle. It is uncertain, whether these differences represent specific characteristics. They merely may be due to the juvenile age of the specimen.

Familia: LEIOGNATHIDAE

Gazza sp.

Pl. 1, Fig. 13.

Material: 1 sagitta Tongeren, Francart clay-pit, RGM 176 519, leg. TBM.

Description and discussion: the only available specimen is a small, well-preserved, pentagonal otolith. The dorsal rim is irregularly shaped and has a predorsal and a distinct postdorsal angle. The ventral rim is more regularly curved. The specimen has a short, pointed rostrum and a deep excisura ostii, which runs from the rostrum to the antirostrum.

The inner surface is convex, the outer surface slightly concave. The shape of the sulcus is almost identical to that of the Recent species *Gazza minuta* (Bloch, 1797), which was represented by Nolf & Lapierre (1979). The sagittae of *Gazza minuta* are somewhat longer than the present specimen, but this may be due to the juvenile age of the fossil specimen. A closer identification, based on this juvenile otolith, is not possible.

Genus *Leiognathidarum nolfi* n. sp.

Pl. 1, Fig. 14-16.

1976 *Leiognathus* sp. – Nolf, p. 49, pl. 14, fig. 18.

Holotype: Tongeren, Francart clay-pit. RGM 176 520, leg. TBM, pl. 1, fig. 14. Dimensions: L : 1.54 mm, H : 1.17 mm; T : 0.31 mm.

Other material: 7 sagittae: 5 specimens Tongeren, Francart clay-pit (4 specimens RGM 176 521-

176 524; 1 specimen TBM); 1 specimen Rosmeer, RGM 176 506; 1 specimen Waltwilder, boring M5, RGM 176 504, leg. M.C. Cadée.

Stratum typicum: Atuatuca Formation, Sands and Marls of Oude Biesen, gully level, Francart clay-pit Tongeren.

Derivatio nominis: this species is dedicated to Dr D. Nolf, who earlier reported the present species as *Leiognathus* sp.

Diagnosis: small, rather thin, oval otolith without or with only a small excisura ostii. The ostium and the posterior part of the cauda are remarkably deepened.

Description of the holotype: small otolith with a convex inner surface. It has a blunt rostrum and no excisura ostii. The dorsal rim is irregularly knobbed, it reaches its highest point in the middle of the otolith. The ventral rim is regularly curved.

The medial sulcus is divided in an ostium and a cauda of equal length. The ostium widens slightly towards the rostral side. The ostium is distinctly deeper and somewhat wider than the cauda. The posterior end of the cauda is markedly deepened, it bends slightly in ventral direction. The crista superior, which is present along the ostium and the rostral part of the cauda, borders an indistinct area. No crista inferior or ventral furrow is visible.

The outer surface is concave, especially in length direction. It is slightly thickened in the middle part of the otolith and almost smooth.

Variability: the outline of the otoliths of *genus Leiognathidarum nolfi* is very variable. The highest point of the dorsal rim may be situated more rostrally of the middle of the dorsal rim. In two specimens a small excisura ostii exists in the dorsal part of the ostium.

Discussion: *Leiognathus* sp., described by Nolf (1976) from similar deposits, belongs to the same species. The shape of the sulcus resembles fairly well those of the Recent species *L. insidiator* (Bloch, 1787), represented by Nolf (1976) and of *L. splendens* (Cuvier, 1829), *L. rivulatus* (Temminck & Schlegel, 1895) and *Gazza minuta* (Bloch, 1797), which were illustrated by Nolf & Lapierre (1979). The excisura ostii is less distinctly developed than in these Recent species. *Leiognathidae* are found in coastal waters. They occur in open sea and brackish water, and also in fresh-water environments.

Leiognathidae indet.

Material: 9 sagittae: 1 specimen Rijkhoven, boring R1, VHL, leg. M.C. Cadée; 8 specimens Tongeren, Francart clay-pit (6 specimens RGM 176 525-176 528; 1 specimen TBM; 1 specimen VHL).

Discussion: several rounded otoliths were collected, that have a similar shape of the sulcus as the other *Leiognathidae* here described. They have a distinct excisura ostii, running from the blunt rostrum to the antirostrum. Since they are all rather eroded, it is impossible to decide whether these specimens belong to *genus Leiognathidarum nolfi*, *Gazza* sp., or to another species of *Leiognathidae*.

Familia: EMMELICHTHYIDAE

Spicara kugleri Nolf, 1976

Pl. 2, Fig. 3-5.

Material: 535 sagittae: 30 specimens Tongeren, Francart clay-pit (5 specimens TBM; 7 specimens VHL, 12 specimens FMG, 6 specimens PGL); 138 specimens Tongeren, Galgeberg (136 specimens RGM 176 559; 2 specimens PGL); 135 specimens Kleine Spouwen, Nachtegaalstraat (87 specimens RGM 176 571-176 573; 27 specimens TBM; 14 specimens VHL; 7 specimens PGL); 128 specimens Rijkhoven, Alde Biesen (108 specimens RGM 176 579-176 581; 5 specimens VHL; 12 specimens PGL; 3 specimens FMG); 89 ex. Borgloon (3 specimens RGM 176 585; 82 specimens TBM; 4 specimens PGL; 15 specimens Valkenburg RGM 176 586-176 587).

Description: the otoliths have a solid, blunt rostrum and a distinct postdorsal angle, from which the dorsal rim runs rather steeply to the caudal end. The dorsal rim is rather variable in shape, it has an indistinct predorsal angle in some specimens. The ventral rim is regularly curved and shows fine knobs in some specimens, especially on the caudal half. Both antirostrum and excisura ostii are absent.

The spatula-shaped ostium is broader and deeper than the cauda. The rim of the ostium usually shows a distinct inflation, as a result of which the rostral part of the dorsal rim sometimes is very steep. The cauda is 1.6-1.8 times longer than the ostium. Its ventral margin bends in ventral direction only slightly, whereas its dorsal margin is strongly and abruptly bent. So in adult specimens the cauda ends with a point, which is directed slightly in ventral direction. An obvious crista superior runs between the sulcus and the elongate area; it fades away towards the caudal end. There is no crista inferior. Some specimens a faint ventral furrow.

The outer surface is concave in length direction. It has many weak folds and furrows running from the rim towards the centre of the otolith. In most specimens a medial ridge runs over the outer surface.

Variability: the outline of the otoliths of this species is rather variable, in particular the height-length ratio. In relatively slender specimens the inflation of the ostial rim is absent.

Among the specimens there are two very thin otoliths, which possess a deep excisura ostii. The most aberrant specimen (pl. 2, fig.5) is ornamented with many folds and furrows perpendicular to the dorsal and ventral rims.

Seven specimens have a more elongated and more rounded, elliptic shape. It is not certain whether they still belong within the range of variability of the present species or should be considered to be specifically different.

Familia: SPARIDAE

Genus Sparidarum whiteheadi Nolf, 1976

Pl. 2, Figs. 12, 13.

1976 *genus Sparidarum whiteheadi* Nolf, p. 52-53, pl. 15, figs 10-13.

Material: 158 sagittae: 5 specimens Rosmeer, RMG 176 507; 50 specimens Tongeren, Francart clay-pit (21 specimens RGM 176 529-176 534; 21 specimens TBM; 7 specimens VHL; 1 specimen FMG); 1 specimen Tongeren, T1 exposure, VHL; 35 specimens Tongeren, Galgeberg (34 specimens RMG 176 560; 1 specimen PGL); 4 specimens Kleine Spouwen, Nachtegaalstraat (1 specimen RGM 176 754; 2 specimens TBM; 1 specimen PGL); 1 specimen Kleine Spouwen, Dorpsstraat, PGL; 10 specimens Rijkhoven, Alde Biesen (9 specimens RGM 176 582; 1 specimen FMG); 7 specimens

Borgloon (6 specimens TBM; 1 specimen PGL); 45 specimens Valkenburg, RGM 176 588-176 589. Description: the otoliths are medium-sized and have a moderate thickness. The dorsal rim has rounded mid-dorsal and postdorsal angles and a few coarse and indistinct knobs. The ventral rim is rather smooth and regularly curved, but it has a rounded angle, situated slightly anteriorly of the middorsal angle. The otoliths have a blunt rostrum; both excisura ostii and antisostrum are absent. Juvenile specimens are relatively thickset and spindle-shaped.

The inner surface is convex in both length and height direction. The sulcus acusticus lies in the middle, it is divided in a small, spatula-shaped ostium and a narrower cauda, which is 1.6-1.8 times longer than the ostium. The caudal end bends to the ventral side. A distinct crista superior borders the area. No crista inferior is present. The ventral part of the inner surface is almost smooth. Near the dorsal rim a few superficial folds are present in some specimens. A ventral furrow is absent.

The outer surface is concave in length direction, except for the largest specimen. In height direction most otoliths are slightly concave in the centre and convex towards the dorsal and ventral rims. The ventral part of the outer side is relatively smooth. The dorsal part has a few irregular folds.

Genus Sparidarum sp.

Pl. 2, Fig. 14.

Material: 1 sagitta Tongeren, Galgeberg, RGM 176 561.

Description: a thin, oval otolith with a pointed rostrum and caudal end. The dorsal and ventral rims are regularly curved and crenulated. The lowermost part of the ventral rim lies somewhat rostrally from the middle of the otolith. A small excisura ostii exists.

The inner surface is slightly convex in length direction. The medial sulcus is divided in a spatula-shaped ostium and a cauda, which is 1.8 times longer. The caudal end curves slightly in ventral direction. There is no depression behind the cauda. A crista superior is present. Perpendicular to the dorsal rim many furrows run into the direction of the crista superior.

The outer surface is concave in length direction and flat in height direction. The middle part of the otolith has indistinct irregular folds. Outside this part the outer surface is ornamented with regular folds and furrows running perpendicularly to the dorsal and ventral rims.

Discussion: the otolith of this species is thinner than those of *Serranus krefeldensis* Schwarzhans, 1974 and *genus Sparidarum* sp. Nolf, 1976. Furthermore, it is characterized by its more rounded outline and by its more pronounced ornamentation on the outer surface. Several sagittae of the here described species were also found in the Berg Sands (Middle Oligocene marine deposits overlaying the Atuatuca Formation, coll. VHL).

Familia: POMADASYIDAE

Genus Pomadasyidarum pouwi n. sp.

Pl. 2, Figs. 6-9.

1976 *genus Pomadasyidarum* sp. - Nolf, p. 50-51, pl. 14, fig. 20.

Holotype: Valkenburg, roadside of motorway near Stoepert, 0,00-0,90 m. RGM 176 590, pl. 2, fig. 6. Dimensions: L : 2,23 mm, H : 1,19 mm, T : 0,50 mm.

Other material: 75 sagittae: 55 specimens Valkenburg, RGM 176 591-176 595; 9 specimens Tongeren, Francart clay-pit (5 specimens TBM; 3 specimens VHL; 1 specimen FMG); 1 specimen Tongeren, Galgeberg, RGM 176 562); 10 specimens Rijkhoven, Alde Biesen (9 specimens RGM 176 583; 1 specimen PGL).

Stratum typicum: Goudsberg Deposits, Sands and Marls of Oude Biesen, Valkenburg (province of Limburg), the Netherlands.

Derivatio nominis: named in honour of Mr W. Pouw (RGM), for his dedication in picking out these small otoliths from the residues.

Diagnosis: small and rather thick, elongate otoliths with smooth rims and a sulcus, which is characteristic for Pomadasyidae.

Description of the holotype: small and rather thickset, spindle-shaped otolith. The caudal end is somewhat elongated. The rostral half of the ventral rim is strongly curved, whereas its caudal part is nearly straight. The otolith has a blunt rostrum; both excisura ostii and antirostrum are absent.

The inner surface is convex and smooth. The sulcus lies supramedially. The spatula-shaped ostium is broader and somewhat deeper than the cauda. At the transition of ostium and cauda the sulcus is somewhat constricted by angles in the cristae. The angle in the crista superior lies somewhat more rostrally than that of the crista inferior. The cauda is 1.5 times longer than the ostium and is covered by a colliculum, which becomes narrower to the caudal end. The caudal end is firmly bent towards the ventral side. An indistinct crista superior runs along the sulcus to halfway the cauda. A thin and long area is present along the sulcus, but fades away near the caudal end. The ventral furrow lies close to the ventral rim.

The outer surface is nearly flat and smooth. The ventral part is somewhat thicker than the dorsal part, which has a few very indistinct folds.

Variability: most specimens are of equal size and to a high degree similar in shape. The dorsal rim is usually more rounded than in the holotype. The caudal end is usually elongated, but sometimes more pointed. The ostium may be deeper than the cauda, or equally deep. Only in one specimen (pl. 2, fig. 8) the dorsal and ventral rims are ornamented with fine knobs and furrows.

Discussion: *genus Pomadasyidarum* sp. described by Nolf (1976) belongs to the same species. Nolf (1976) indicated that the elongated shape of the otoliths resembles that of otoliths of the genus *Isacia* Jordan & Fesler, 1893.

Familia: GOBIIDAE

Genus Gobiidarum sp.

Material: 16 sagittae: 11 specimens Tongeren, Galgeberg, RGM 176 563-176 564; 5 specimens Kleine Spouwen, Nachtegaalstraat (3 specimens TBM; 2 specimens RGM 176 575-176 576).

Description: The material consists of 1 adult, 2 medium-sized and 12 very juvenile specimens, all belonging to the same species. All specimens are rather thickset. The adult and medium-sized otoliths have a more or less squarish outline. The very juvenile ones have a relatively long ventral rim, giving them a more triangular shape. The anterior rim is perpendicular to the ventral side, it has a slight inflation. The anterior ventral edge is rounded. The posterior ventral edge is rounded and elongated, as a result of which the posterior side runs obliquely in antero-dorsal direction. The posterior side has a distinct inflation. The dorsal rim is rounded and has its highest point posteriorly of the middle of the otolith. At the inner side the ventral area is thickened below the typical gobioid sulcus. A

shallow dorsal area is present. The outer surface is smooth and convex.

Discussion: The characteristic outline of the otoliths suggests that they belong to an undescribed species. As most of the otoliths belong to juvenile fishes, they do not allow a sufficiently diagnostic description of the characteristics and variability of this species.

Genus Percoideorum sp.

Pl. 2, Fig. 15.

Material: 2 sagittae Tongeren, Francart clay-pit, RGM 176 538-176 539.

Description: The specimens are badly preserved. In the better one height equals length. The dorsal rim has a middorsal and a postdorsal angle, behind which the dorsal rim turns abruptly in ventral direction. The ventral rim is regularly curved. The rostrum is eroded.

The inner surface is convex. The medial sulcus has a broad ostium and a much narrower cauda, which obviously bends in ventral direction. An indistinct crista superior is present along the cauda. The area and the part posterior of the cauda are eroded.

The outer surface is nearly flat, but convex along the ventral rim. It has a large depression in the middle of the otolith. The rostrum and rostral part of the dorsal rim show several folds.

The smaller, very eroded specimen has a somewhat less angular outline and is consequently more oval in form.

Percoidea juv. indet.

Several juvenile perciform otoliths (RGM 176 540-176 544; 176 565; 176 596) could not be identified, since their specific characteristics are not yet developed.

Incertae sedis

Lapilli non det.

Material: 27 lapilli: 9 specimens Tongeren, Galgeberg, RMG 176 566; 16 specimens Tongeren, Francart clay-pit (15 specimens RGM 176 545-176 549; 1 specimen TBM); 1 specimen Kleine Spouwen Nachtegaalstraat, TBM; 1 specimen Rijkhoven, Alde Biesen, VHL.

GENERAL DISCUSSION

All otoliths described in the present report belonged to juvenile fishes, presumably smaller than 10 cm. This hinders sometimes a proper identification, since the characteristics of juvenile otoliths are usually less specific. Therefore several juvenile Percoid otoliths could not be identified.

In his treatise on the Oligo-Miocene fish otoliths of Belgium Nolf (1976) reported six species from the 'Upper Tongeren Beds' (= Atuatuca Formation) in the Tongeren area: Clupeidae indet., *Leiognathus* sp., genus *Sparidarum* *whiteheadi*, *Spicara kugleri*, genus *Pomadasyidarum* sp. and genus *Euteleosteorum* aff. *crassus*. The latter species belongs to the Umbridae family (Dr Nolf, pers.

comm.). All species, except *genus Euteleosteorum* aff. *crassus* could be demonstrated in the present material. The preservation of this material allowed closer identification of *genus Clupeidarum atuatucae*, *genus Leiognathidarum nolfi* and *genus Pomadasyidarum pouwi*. They were introduced as new species.

Except for these already known species ten further species were found, eight of which are new for the Atuatuca Formation and/or Goudsberg Deposits: *Pterothrissus umbonatus*, *Thaumaturus rhenanus*, *Gazza* sp. *Dapalis rhenanus*, *Dapalis* sp., ? *Chanda* sp., *genus Gobiidarum* sp. and *genus Percoideorum* sp. Furthermore *Notogoneus longiceps* and *genus* aff. *Hemiramphidarum* sp. were found, mentioned sub nomina *Notogoneus* sp. and *genus Cyprinodontoideorum* sp. by Nolf (1976) from the 'Horizon de Boutersem', which also belongs to the Atuatuca Formation. A further *genus Sparidarum* sp. reported by Nolf from the Horizon de Boutersem (Hoeleden locality), was not found in the Tongeren area.

Only five of the species found in the Atuatuca Formation and Goudsberg Deposits are known from other deposits. *Pterothrissus umbonatus* is found in marine sediments of NW Europe, ranging from Eocene to Late Oligocene. *Thaumaturus rhenanus*, *Notogoneus longiceps* and *Dapalis rhenanus* are reported from euryhaline Early Miocene deposits from the areas around Mainz and Frankfurt in Germany (Weiler, 1963; Malz, 1978). *Dapalis rhenanus* is also reported from littoral marine Middle Oligocene deposits of the Mainz Basin (Koken, 1891; Weiler, 1942). *Genus Sparidarum* sp. was found by us in the Middle Oligocene Berg Sands in Belgium, which are laid down in a littoral near-shore environment.

Fish associations in the Atuatuca Formation and Goudsberg Deposits

The large number of fish otoliths, which was at my disposal, makes it possible to distinguish several fish associations in the Atuatuca Formation and Goudsberg Deposits.

Group 1 (columns 1-11 in Table 3, column 13 partly).

Genus Sparidarum whiteheadi, Leiognathidae species and *genus Clupeidarum atuatucae* are the most common species, whereas *Spicara kugleri*, *genus Pomadasyidarum pouwi* and *Thaumaturus rhenanus* are absent. *Genus* aff. *Hemiramphidarum* sp. and lapilli indet. are frequently found.

Group 2 (columns 14 and 15 in Table 1, column 13 partly).

The dominant species is *Dapalis rhenanus*. This population contains the single specimens of *Dapalis* sp. and *Notogoneus longiceps*. *Spicara kugleri* and, less frequently, *genus Sparidarum whiteheadi* and *genus Pomadasyidarum pouwi* are found. Small species may be underestimated, since no residues below 0.6 mm were inspected.

Group 3 (columns 16-32 in Table 1).

The dominant species is *Spicara kugleri*. *Genus Sparidarum whiteheadi* is distinctly less frequent. *Thaumaturus rhenanus*, *genus Gobiidarum* sp. and *genus Pomadasyidarum pouwi* are regularly found. *Genus Clupeidarum atuatucae* was only abundant in the Galgeberg exposure (Tongeren). In this exposure also the only specimen of *genus* aff. *Hemiramphidarum* sp. was found. Leiognathidae are absent.

Group 4 (columns 33-34 in Table 1).

In the Valkenburg area *genus Pomadasydarum pouwi* is remarkably abundant and dominant together with *genus Sparidarum whiteheadi*. Less frequently *Spicara kugleri* is encountered. Small species may be underestimated, since only a restricted quantity of the residue below 0.85 mm was inspected.

The existence of these associations is acknowledged if we compare the data on Nolf (1976). Nolf washed 500 kg of sediment from the Francart clay-pit, Tongeren, on a 1 mm mesh to obtain 38 fish otoliths. His sample was taken from the 'upper part of the Henis Clay' (Dr Nolf, pers. comm.), which represents the gully level of the Sands and Marls of Oude Biesen, as described by Janssen et al. (1976). The fauna described by Nolf belongs to the group 1 association, whereas the faunas from the higher parts of the Sands and Marls of Oude Biesen at Borgloon and Tongeren represent the group 3 population.

Comparison with lithostratigraphical data.

Janssen et al. (1976) redefined the boundary between Henis Clay and the Sands and Marls of Oude Biesen. Only the lower clay deposit of the Henis-Oude Biesen is regarded as Henis Clay by them. From this sediment no otoliths are known. The Sands and Marls of Oude Biesen consist of a sequence of deposits indicated as (from bottom to top) the gully level, the upper clay deposit and the alternating sandy and clayey deposits. The fish association of the gully level (group 1) differs clearly from that of the alternating sandy and clayey deposits (group 3). This difference is of biostratigraphical interest. The transition might coincide with the appearance of pollen in the upper clay deposit (Bremer, 1975). Unfortunately, the exact situation of the boundary between these fish associations could not be established, since no otoliths were obtained from the upper clay deposit. The group 2 association, which was found in the basal part of the alternating sandy and clayey deposits, reflects ecological circumstances more or less intermediate between those of the group 1 and group 3 associations. Its relationship to the group 3 association is indicated by the appearance of *Spicara kugleri* and *genus Pomadasydarum pouwi*.

Ecological considerations.

Table 2 shows the ecological range of the genera found in the teleost fish associations of the Atuatuca and Goudsberg Deposits. The group 1 association lived in a lagoonal environment. Leiognathidae, Hemiramphidae and *Chanda* species are pelagic fishes, commonly living in lagoonal environments. All Clupeidae otoliths described here belonged to very juvenile specimens. Large numbers of such Clupeidae are often present on coastal breeding grounds, that are more or less sheltered from open sea.

The genera of the group 2 association indicate a marine or brackish water environment. The group 3 population shows both marine and freshwater influences, and probably represents an euryhaline environment with many fluctuations in salinity. The occasional presence of marine and freshwater molluscs gives a similar indication. The rare occurrence of sharks and rays together with the group 1 and 3 associations (Bor, 1980) also points to marine influences.

The group 4 association, which lived about 20 km more to the East, is rather similar to the group 3 association.

Table 2. Ecological range of the genera and/or families found in the teleost fish associations of the Atuatuca Formation and Goudsberg Deposits.

genus/family	environment			association group			
	marine	brackish	freshwater	1	2	3	4
<i>Clupeidae</i>	+	-	-	++	-	++	-
<i>Thaumaturus</i>	-	-	+	-	-	+	-
<i>Pterothrissus</i>	+	-	-	-	-	1	-
<i>Notogoneus</i>	-	+	+	-	1	-	-
Hemiramphidae	+	+	-	+	-	1	-
<i>Dapalis</i>	+	+	-	-	++	+	-
Leiognathidae	+	+	-	++	-	-	-
<i>Spicara</i>	+	-	-	-	+	++	+
Sparidae	+	-	-	++	+	+	++
<i>Chanda</i>	+	+	(+)	+	-	-	-
Pomadasyidae	+	-	-	-	+	+	++
Gobiidae	+	+	+	-	-	+	-

The frequency is indicated by symbols: - = absent, 1 = only one specimen found, + = present, ++ = frequently found.

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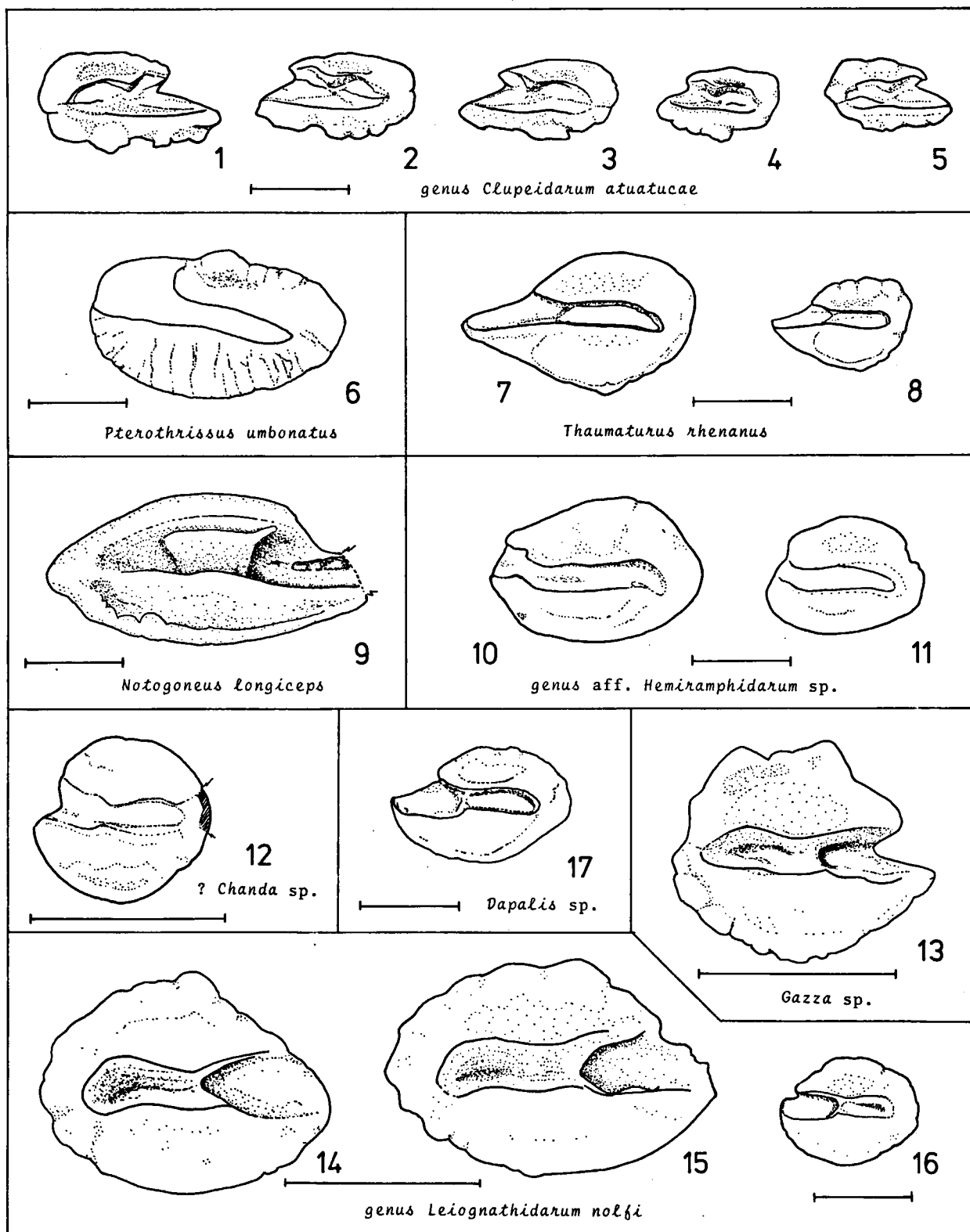
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EXPLANATION OF PLATE 1

- Fig. 1 - 5 *Genus Clupeidarum atuatucae* n. sp.
Atuatuca Formation, Sands and Marls of Oudé Biesen, clay level in the upper part of the alternating sandy and clayey deposits. Tongeren, Galgeberg exposure, 1.20-1.30 m.
Fig. 1 Holotype. RGM 176 550, leg. A. W. Janssen.
Fig. 2 - 5 RGM 176 551-4, leg. A. W. Janssen.
- Fig. 6 *Pterothrissus umbonatus* (Koken, 1884)
Atuatuca Formation, Sands and Marls of Oude Biesen, crag in the upper part of the alternating sandy and clayey deposits. Kleine Spouwen, Nachtegaalstraat. Coll. PGL, leg. J. G. M. Raven.
- Fig. 7 - 8 *Thaumaturus rhenanus* Weiler, 1963
Atuatuca Formation, Sands and Marls of Oude Biesen, alternating sandy and clayey deposits.
Fig. 7 Crag in the upper part. Kleine Spouwen, Nachtegaalstraat. RGM 176 569, leg. A. W. Janssen.
Fig. 8 Clay level in upper part. Tongeren, Galgeberg exposure. 1.20-1.30 m. RGM 176 556, leg. A. W. Janssen.
- Fig. 9 *Notogoneus longiceps* (H. v. Meyer, 1851)
Atuatuca Formation, Sands and Marls of Oude Biesen, basal part of the alternating sandy and clayey deposits. Tongeren, Francart clay-pit. Coll. VHL.
- Fig. 10 - 11 *Genus aff. Hemiramphidarum* sp.
Atuatuca Formation, Sands and Marls of Oude Biesen, gully level. Tongeren, Francart clay-pit. RGM 176 514 and 176 518, leg. A. W. Janssen.
- Fig. 12 ? *Chanda* sp.
Atuatuca Formation, Sands and Marls of Oude Biesen, gully level. Tongeren, Francart clay-pit. RGM 176 535, leg. A. W. Janssen.
- Fig. 13 *Gazza* sp.
Atuatuca Formation, Sands and Marls of Oude Biesen, gully level. Tongeren, Francart clay-pit. RGM 176 519, leg. T. J. Bor.
- Fig. 14 - 16 *Genus Leiognathidarum nolfi* n. sp.
Atuatuca Formation, Sands and Marls of Oude Biesen, gully level.
Fig. 14 Holotype. Tongeren, Francart clay-pit. RGM 176 520, leg. T. J. Bor.
Fig. 15 Tongeren, Francart clay-pit. RGM 176 521, leg. T. J. Bor.
Fig. 16 Waltwilder, auger boring M5. RGM 176 504, leg. M. C. Cadée.
- Fig. 17 *Dapalis* sp.
Atuatuca Formation, Sands and Marls of Oude Biesen, basal part of the alternating sandy and clayey deposits. Tongeren, Francart clay-pit. RGM 176 598, leg. V. W. M. van Hinsbergh.

bar length represents 1 mm

drawings made by the author, with a Wild M5 binocular with *camera lucida* device

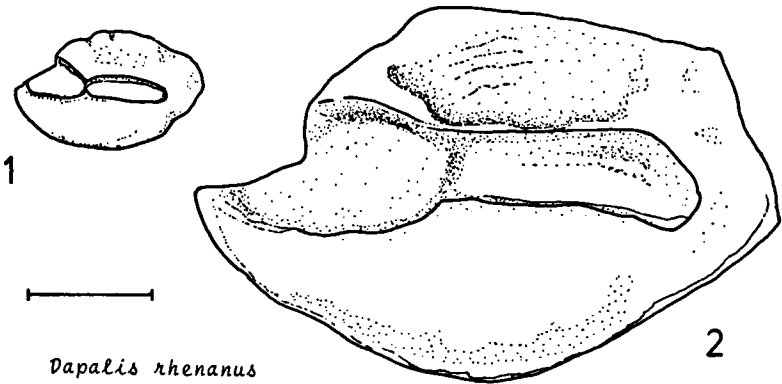


EXPLANATION OF PLATE 2

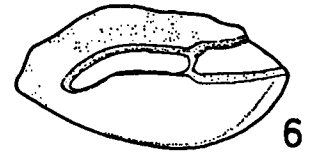
- Fig. 1 - 2 *Dapalis rhenanus* (Koken, 1891)
Atuatuca Formation, Sands and Marls of Oude Biesen, basal part of the alternating sandy and clayey deposits. Tongeren, Francart clay-pit. Coll. VHL.
- Fig. 3 - 5 *Spicara kugleri* Nolf, 1976
Atuatuca Formation, Sands and Marls of Oude Biesen.
Fig. 3 Gully level. Rijkhoven, exposure East of Alde Biesen castle. RGM 176 579.
Fig. 4 - 5 Crag in the alternating sandy and clayey deposits. Kleine Spouwen, Nachtegaalstraat. RGM 176 571-2, leg. A. W. Janssen.
- Fig. 6 - 9 *Genus Pomadasyidarum pouwi* n. sp.
Goudsberg Deposits, Sands and Marls of Oude Biesen. Valkenburg, the Netherlands.
Fig. 6 Holotype, RGM 176 590, leg. A. W. Janssen.
Fig. 7 - 9 RGM 176 591-3, leg. A. W. Janssen.
- Fig. 10 - 11 *Genus Gobiidarum* sp.
Atuatuca Formation, Sands and Marls of Oude Biesen, alternating sandy and clayey deposits.
Fig. 10 Clay level in upper part. Tongeren, Galgeberg exposure, 1.20-1.30 m. RGM 176 563, leg. A. W. Janssen.
Fig. 11 Crag in upper part. Kleine Spouwen, Nachtegaalstraat. RGM 176 575, leg. A. W. Janssen.
- Fig. 12 - 13 *Genus Sparidarum whiteheadi* Nolf, 1976
Atuatuca Formation, Sands and Marls of Oude Biesen, alternating sandy and clayey deposits.
Fig. 12 Crag in upper part. Borgloon. Coll. PGL, leg. T. Meijer.
Fig. 13 Basal part. Tongeren, Francart clay-pit. Coll. VHL.
- Fig. 14 *Genus Sparidarum* sp.
Atuatuca Formation, Sands and Marls of Oude Biesen, crag in the upper part of the alternating sandy and clayey deposits. Kleine Spouwen, Nachtegaalstraat. RGM 176 561, leg. A. W. Janssen.
- Fig. 15 *Genus Percoideorum* sp.
Atuatuca Formation, Sands and Marls of Oude Biesen, gully level. Tongeren, Francart clay-pit. RGM 176 538, leg. A. W. Janssen.

bar length represents 1 mm

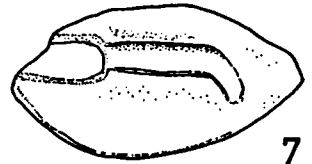
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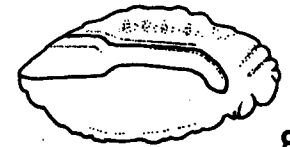
Dapalis rhenanus



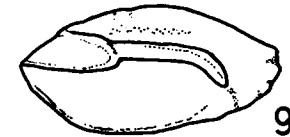
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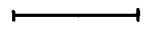
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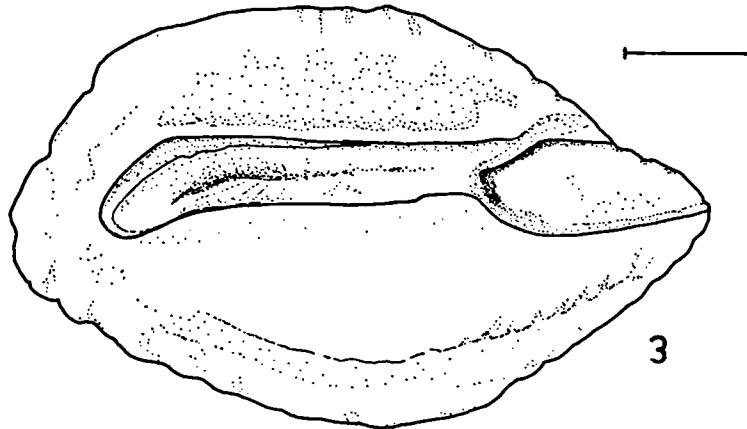
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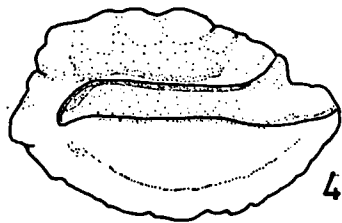
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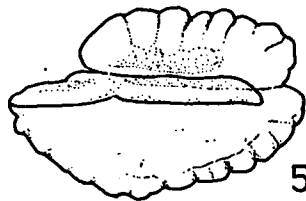
genus *Pomadasyidarum* powi



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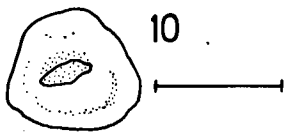
Spicara kugleri



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genus *Sparidarum* sp.

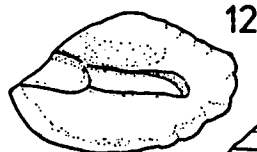


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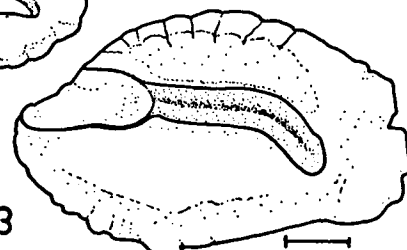


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genus *Gobiidarum* sp.



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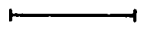


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genus *Sparidarum* whiteheadi



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genus *Percoideorum* sp.