Rupelian (Middle Oligocene) fish otoliths from the clay pit 'De Vlijt' near Winterswijk, The Netherlands

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A large, interesting otolith fauna from the Middle Oligocene was found in the clay pit 'De Vlijt' near Winterswijk by sifting large quantities of clay and by collecting large loose specimens in the clay pit. Thirty-five species and one subspecies were indentified; nine species are new, viz. Clupeiformorum *planus*, Congridarum *trapezioides, Gadichthys altus, Palaeogadus compactus*, Brotulidarum *phaseoloides, Paralabrax splendens, Dentex kokeni*, Carangidarum *robustus*, and Acropomidarum *martini*. The study of part of Koken's type material was very helpful for the identification of many species. Photographs have been included of important specimens in Koken's collection.

The fauna, in which Argentinidae, Gadidae, Brotulidae, and Ophidiidae dominate, is indicative of a moderately warm to temperate sea with a probable depth of 100-200 m. The Middle Oligocene North Sea surely must have been in open communication with the Tethys Ocean.

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Introduction

STRATIGRAPHY

The Middle Oligocene deposits in the eastern part of The Netherlands consist of three members: the Ratum Member, the Brinkheurne Member, and the Winterswijk Member.

The lithostratigraphy of these members has been described in detail by van den Bosch, Cadée & Janssen (1975), to which the reader is referred. The Winterswijk Member consists of a somewhat sandy clay and can be related lithostratigraphically to the Lintorf Beds in western Germany. The Brinkheurne Member consists of a heavy clay and it can be correlated with the Boom Clay in Belgium and with the 'Septarienton' in western Germany. The otoliths described in the following sections were collected from the Brinkheurne and Winterswijk Members.

On the basis of the presence of mollusc faunas, van den Bosch et al. (1975) introduced two biozones in the Brinkheurne Member: the *Serpula septaria-Ancistrosyrinx volgeri* Assemblage Zone and the *Cyclocardia kickxi-Astarte kickxi* Assemblage Zone. The former biozone is found at the top of the Brinkheurne Member, the latter at its base. The basal part of the Brinkheurne Member was not exposed when the otoliths were collected.

The boundary between the Brinkheurne Member and the Winterswijk Member is locally abrupt because of a short interruption of sedimentation (van Hinsbergh, 1972). At such places the top of the Brinkheurne Member is somewhat eroded. Therefore a slight concentration of reworked fossils can be found in the basal layer of the Winterswijk Member.

LOCALITIES

The material described here was collected from the clay pit complex of the brickyards 'De Vlijt' and 'Te Siepe', about 1.5 km southwest of Winterswijk (Fig. 1). Since the clay pits of both brickyards were scattered throughout the same area and the brickyard 'Te Siepe' was closed some ten years ago, we will refer to them collectively as the clay pits 'De Vlijt'.

The Brinkheurne Member is encountered throughout the clay pits 'De Vlijt'; the Winterswijk Member occurs only in the southwesternmost part of the complex. This part is in fact the type locality of the Winterswijk Member (section 41 E. 3-143 in van den Bosch et al., 1975). Here the base of the Winterswijk Member contains

much reworked material from the Brinkheurne Member. The apparent top of the Brinkheurne Member is rather fossiliferous and contains a mollusc fauna of the *Serpula septaria-Ancistrosyrinx volgeri* Assemblage Zone. Although the *Serpula septaria-Ancistrosyrinx volgeri* Assemblage Zone is represented throughout the entire clay pit complex, it is not impossible that another assemblage zone present in lower parts of the Boom Clay has formerly been excavated.

A few otoliths from the Boom Clay of Belgium were used for comparison. They were obtained from clay pits at Kruibeke (near Antwerp) and Herselt (near Oudenaerde, prov. Antwerp). The clay pit at Kruibeke is situated 1500 m S and 1800 m W of the church of Burght (prov. Antwerp); the exposed clay represents

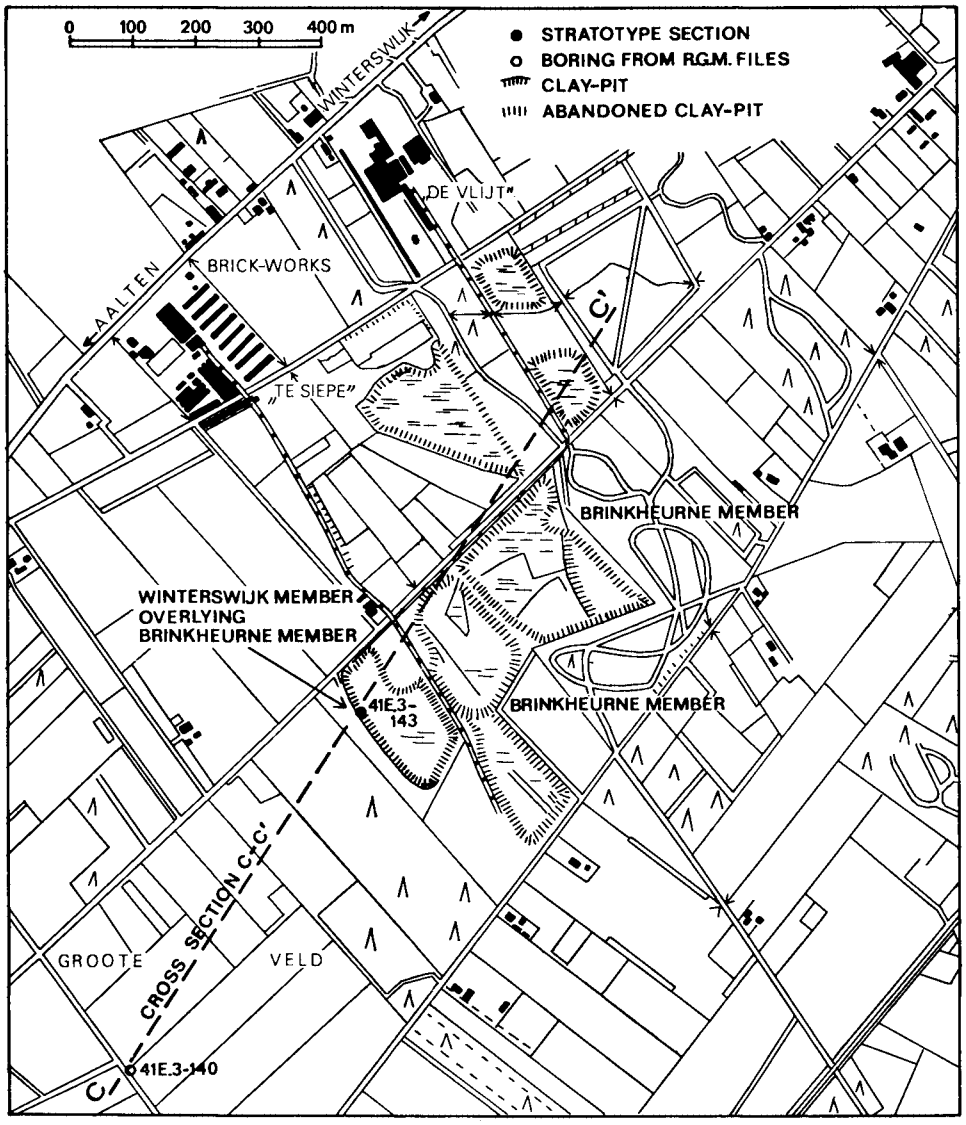


Fig. 1. Map of the surroundings of the clay pit 'De Vlijt' (from van den Bosch et al., 1975, Fig. 5, p. 16).

the middle part of the Boom Clay. The clay pit at Herselt is situated 400 m N of the church of Ramsel (prov. Antwerp). This clay pit is situated in the eastern part of the area where the Boom Clay has been found in Belgium. Its mollusc fauna belongs to the *Serpula septaria-Ancistrosyrinx volgeri* Assemblage Zone.

MATERIAL

Otoliths were studied from the Winterswijk and Brinkheurne Members from the clay pits 'De Vlijt'. The material was obtained from several collections. In the figures and text the following abbreviations will be used:
RGM: Rijksmuseum van Geologie en Mineralogie, Leiden, The Netherlands;
PBB : Dr P. Buurman, Bennekom, The Netherlands;
PGL : P. A. M. Gaemers, Leiden, The Netherlands;
VHN : V. W. M. van Hinsbergh, Nijmegen, The Netherlands;
MCL : M. C. Cadée, Leiden, The Netherlands;
HMH: H. van der Made, The Hague, The Netherlands.
The otoliths are summarized in Table 1. Several collecting methods were used, since they greatly influence which species are found, they will be described briefly.

Picking up the otoliths at random throughout the clay — This method is commonly used in heavy clays. Most of the former publications dealing with otoliths from Middle Oligocene heavy clays (e.g. Koken, 1884, 1891; Leriche, 1910) have been based on otoliths collected in this way. However, otoliths which are picked up tend to be the larger otoliths, and this collecting method will not provide a reliable impression of the fauna. Of the 2167 otoliths studied 331 were collected in this way (Table 1, columns 1-4, 11).

Breaking the clay into little pieces — Because otoliths exhibit a striking orange-brown color in fresh clay, they are easily recognized. Although this method is more reliable than the first, it is very laborious and time-consuming. In this manner 198 otoliths were collected (Table 1, column 5).

Sifting the clay — For this purpose the clay was first dried thoroughly at 60°C, and then placed in hot water for 24 hours. During that time the clay fell apart into pieces. The pH was kept above 7 with the aid of soda. No peroxide was used as the clay contains much pyrite. After sifting the clay with a sieve (0.4 mm mesh), the residue was dried again. This procedure was repeated several times until all of the clay lumps had fallen apart. Glauconite was removed from the residue by means of a magnetic separator. In the final residue the otoliths were picked out using a

Table 1. Numbers of sagittas collected from the different stratigraphic horizons, divided according to collections and mode of collecting.
I. Collected by picking up the otoliths in the field. II. Collected by breaking the clay into little pieces. III. Collected by sifting the clay using a 0.6 mm sieve.
1. Coll. RGM, don. van den Bosch, Janssen, Freudenthal, de Groot, G. C. & M. C. Cadée, van Hinsbergh, Stiva. 2. Coll. Buurman. 3. Coll. van Hinsbergh, don. G. C. & M. C. Cadée, Janse, van Hinsbergh. 4. Coll. Gaemers, don. Stiva. 5. Coll. van Hinsbergh, don. M. C. Cadée, van Hinsbergh. 6. Coll. RGM, don. van den Bosch, Janssen. 7. Coll. RGM, don. van den Bosch, Janssen, van der Made. 8. Coll. van Hinsbergh, don. M. C. Cadée, van Hinsbergh. 9. Coll. Gaemers, don. van der Made, M. C. Cadée, Gaemers. 10, 11. Coll. van Hinsbergh.

Species	Stratigraphic horizon	Brinkheurne Member				Top of Brinkheurne Member		Base of Winterswijk Member			Winterswijk Member	Member unknown
	Mode of collecting	I	I	I	I	II	III	III	III	III	III	I
	Collection	1	2	3	4	5	6	7	8	9	10	11
Pterothrissus umbonatus (Koken, 1884)		3	—	5	—	—	1	—	—	1	—	—
?*Anguilla rouxi* Nolf, 1977		—	—	—	—	—	—	1	—	—	—	—
Congridarum *trapezioides* sp. n.		1	—	—	—	—	1	1	—	—	—	—
Clupeiformorum *planus* sp. n.		—	—	—	—	—	2	2	—	1	—	—
? *Alosa* sp.		—	—	—	—	—	1	—	—	—	—	—
Argentina parvula (Koken, 1891)		1	—	7	—	41	348	57	25	23	4	—
Zaphotias cyclomorphus (Weiler, 1950)		—	—	—	—	—	—	1	—	—	—	—
Colliolus parvus Gaemers, 1976		29	—	54	1	120	638	119	43	120	1	—
Gadichthys altus sp. n.		—	—	—	—	—	5	1	2	1	1	—
Palaeogadus emarginatus (Koken, 1884)		—	—	3	—	—	2	—	—	—	—	—
Palaeogadus compactus sp. n.		8	—	8	—	7	7	2	6	7	—	—
Palaeogadus sp. indet.		—	—	1	—	—	4	2	—	—	—	—
Palaeoraniceps tuberculosus (Koken, 1884)		—	—	—	—	—	—	—	1	—	—	1
Brotulidarum *occultus* (Koken, 1891)		3	1	7	1	3	11	3	—	—	—	—
Brotulidarum *marchicus* (Koken, 1891)		8	—	28	1	5	12	3	1	—	—	—
Brotulidarum *phaseoloides* sp. n.		2	—	—	—	—	7	—	—	1	—	—
Diplacanthopoma tortonesei Nolf, 1977		—	—	—	—	7	11	5	2	2	—	—
Palaeomorrhua faba (Koken, 1884)		1	—	—	—	—	—	—	—	—	—	—
Hoplobrotula difformis (Koken, 1884)		39	7	50	4	2	13	1	6	3	2	—
H. acuntangula acutangula (Koken, 1884)		9	2	30	1	—	—	—	—	—	—	—
H. acutangula hermsdorfensis (Koken, 1891)		—	—	3	—	—	—	—	—	—	—	—
Hoplobrutula sp. juv.		—	—	—	—	12	23	5	1	4	—	—
Hoplostethus sp.		—	—	—	—	—	—	1	—	—	—	—
Paralabrax splendens sp. n.		2	—	—	—	—	3	1	—	—	—	—
Dentex kokeni sp. n.		—	—	—	—	—	—	—	—	—	1	—
? *Polysteganus* sp.		1	—	—	—	—	—	—	—	—	—	—
Sparidarum sp. 1		—	—	—	—	—	—	—	1	—	—	—
Sparidarum sp. 2		—	—	—	1	—	—	—	—	—	—	—
Carangidarum *robustus* sp. n.		1	—	—	—	—	—	—	—	—	—	—
Pempheridarum sp.		—	—	—	—	—	1	1	—	—	—	—
Acropomidarum *martini* sp. n.		—	—	—	—	—	—	1	—	—	—	—
Mupus neumanni Schwarzhans, 1974		1	—	—	2	—	14	—	1	3	—	—
Trichiuridarum *wongratanai* Nolf, 1977		—	—	—	—	—	1	—	—	—	—	—
Blenniidarum *minisculus* (Nolf, 1977)		—	—	—	—	—	38	4	1	2	—	—
? *Pontinus foreyi* Nolf, 1977		—	—	—	—	—	—	1	—	—	—	—
? *Trigloporus* sp.		—	—	—	—	—	4	—	—	—	—	—
Scorpaeniformorum *ellipticus* (Koken, 1884)		4	—	—	—	1	10	1	—	—	—	—
Gen. et sp. indet.		—	—	—	—	—	1	—	—	1	—	—
Total		113	10	196	11	198	1157	213	90	169	9	1

stereomicroscope with a magnification of 12 x. Members of the RGM staff collected 1370 otoliths from the basal layer of the Winterswijk Member and the uppermost part of the Brinkheurne Member in this way (Table 1, columns 6, 7); 268 otoliths from the Winterswijk Member, mainly from its basal layer, were collected in a similar way using a 0.6 mm sieve (Table 1, columns 8-10).

Acknowledgements

We would like to thank all those who placed otoliths at our disposal for this study. Most of the material comes from the Rijksmuseum van Geologie en Mineralogie (Netherlands National Museum of Geology and Mineralogy: RGM), and was collected mainly by Messrs. M. van den Bosch and A. W. Janssen. Dr P. Buurman (Bennekom), Dr G. C. Cadée (Den Burg, Texel) and Messrs. M. C. Cadée (Leiden), H. van der Made (The Hague) and A. Stiva (Amsterdam) donated their collections to us and we also sampled some material ourselves.

Important supplementary material from Belgian localities was supplied by Messrs. M. Vervoenen (Aalst, Belgium), and M. van den Bosch and A. W. Janssen (both of the RGM). We highly appreciated the kind co-operation of Dr W.-D. Heinrich (Paläontologisches Museum der Humboldt Universität, Berlin, German Democratic Republic) who sent the first author the type material of otoliths collected and described by Prof. E. Koken for examination.

Dr J. E. Fitch (Department of Fish and Game, Marine Resources Region, Long Beach, California, U.S.A.) was helpful in providing recent material for comparison.

We wish to thank Messrs. W. C. Laurijssen and W. A. M. Devilée (Geologisch en Mineralogisch Instituut der Rijksuniversiteit: GMI, Leiden), who made the photographs, and Mr B. G. Henning (GMI), who drew Figures 2 and 3. The permission of Mr M. van den Bosch to use text-figure 5 of van den Bosch et al. (1975) as our Figure 1 is gratefully acknowledged.

Systematic descriptions

We use the special systematic nomenclature which has become established in otolith literature, although we are fully aware that is is not quite in agreement with the International Code of Zoological Nomenclature (Stoll et al., 1961). Strict adherence to the code would however make the systematic descriptions unduly complicated by the excessive use of open nomenclature or by the creation of special genera for otoliths. At the present state of our knowledge it is often impossible to tell to which fish genus an otolith belongs, because the otoliths of related genera which could be considered are often unknown.

The best procedure would be that otolith specialists would hand in a proposal with the International Commission on Zoological Nomenclature to ask the next International Congress of Zoology to amend the Code (especially articles 5, 11gii) in such a way that the established practise in otolith systematics becomes legitimate.

Concerning the categories higher than families we have followed the classification of Greenwood et al. (1966).

ORDO ELOPIFORMES

Familia Pterothrissidae Gill, 1892
Genus *Pterothrissus* Hilgendorf, 1877

Pterothrissus umbonatus (Koken, 1884)
Pl. 1, figs. 1-4.

1972 *Pterothrissus minor* (Koken) — Anfossi & Mosna, p. 94, pl. 15 (I), fig. 1a, b.
1974 *Pterothrissus* cf. *umbonatus* (Koken) — Nolf, p. 3, pl. 1, fig. 1.
1974 *Pterothrissus minor* (Koken) — Schwarzhans, p. 93, fig. 1.
1974 *Pterothrissus umbonatus* (Koken) — Schwarzhans, p. 94.
1977 *Pterothrissus umbonatus* (Koken) — Nolf, p. 14.

Material — Brinkheurne Member: 8 sagittas (3 specimens RGM 85 513, 127 064, 175 959); upper part of Brinkheurne Member: 1 sagitta, RGM 175 960, don. M. van den Bosch; basal layer of Winterswijk Member: 1 sagitta.

Range — Lower Eocene ?, Middle Eocene – Middle Miocene.

Discussion — Nolf (1974) gives a long list of synonyms for *P. umbonatus,* which we have therefore not repeated here. Koken (1884) gives an adequate description. All specimens found in the Brinkheurne Member in 'De Vlijt' are eroded adult otholiths. This is often the case with adult specimens, also from other localities. A very young, eroded otolith was only found in the basal layer of the Winterswijk Member.

ORDO ANGUILLIFORMES

Familia Anguillidae Rafinesque, 1810
Genus *Anguilla* Shaw, 1803

? *Anguilla rouxi* Nolf, 1977
Pl. 2, fig. 4.

1977 *Anquilla rouxi* — Nolf, p. 14., pl. 1, fig. 6.

Description — One strong, thick but eroded specimen has been found in 'De Vlijt'. An otolith of the same species in a much better state of preservation comes from Herselt, Belgium. Only this specimen is shown here. The description is based mainly on the Belgian otolith.

The outline is more or less oval, approximating a circle. Rims are smooth except for a few typical arches. Rostrum blunt and massive. Antirostrum blunt and unimportant. Excisura shallow. Caudal end with a small but obvious point. Highest part of the otolith shifted somewhat to the front.

Inner surface convex. Median sulcus with a short, wide ostium and a long, deep and rather narrow cauda. Caudal end clearly curves towards ventral side. Area large. No ventral furrow.

Outer surface convex, not sculptured. Some growth rings are visible, especially on the eroded specimen.

Material — Basal layer of Winterswijk Member: 1 eroded sagitta, RGM 175 996; *Serpula septaria – Ancistrosyrinx volgeri* Assemblage Zone, Boom Clay, Herselt, clay pit 400 m N of the church of Ramsel, province of Antwerp, Belgium: 1 sagitta, RGM 175 964.
L: 4.07 mm H: 2.51 mm T: 1.19 mm (Herselt)

Range — Middle Oligocene, basal layer of Winterswijk Member.

Discussion — In many respects the fossil otoliths resemble the sagittas of the Recent *Anguilla anguilla* (Linnaeus). Some important differences however exist. The cauda of *A. anguilla* is mainly straight or only slightly bent towards the ventral side. Moreover the cauda of this species is wider, less sharply defined and for the most part less regular. It is therefore with hesitation that we classify the fossil otoliths in the Recent genus for the time being.

Familia Congridae Kaup, 1856

Congridarum *trapezioides* sp. n.
Pl. 2, fig. 3.

Type — Holotype: Pl. 2, fig. 3, RGM 175 967, don. M. C. Cadée.
Locus typicus — Clay pit 'De Vlijt' near Winterswijk, The Netherlands.
Stratum typicum — Middle Oligocene, Rupelian, Brinkheurne Member.
Derivatio nominis — trapezion (Greek) = trapezium; eidòmai (Greek) = be like, resemble; named for the trapezium-shaped outline of the otolith.

Diagnosis — A strong, thickset, oval otolith of the Congridae with a bilateral symmetry. Sulcus deep, clearly divided into an ostium and a cauda of equal lengths, and without colliculi.

Description of holotype — A strong, thickset, oval otolith of medium size with a bilateral symmetry. All rims smooth. Dorsal rim rounded with small indistinct angles. Ventral rim regularly rounded, less curved than dorsal rim. Slightly eroded rostrum massive and blunt. Very weak concavity at the location of excisura ostii. Antirostrum insignificant. Caudal end somewhat more pointed than rostrum.

Inner surface convex. Deep inframedial sulcus, clearly divided into an ostium and a cauda of equal lengths. Ostium a little wider than cauda. Crista superior sharp, especially above middle part of sulcus. Crista inferior insignificant. Area well-developed extending to the dorsal rim and laterally limited by two radial elevations. Ventral part somewhat eroded.

Outer surface concave. The sculpture consists only of a few large, weak folds.

Material — Brinkheurne Member: 1 sagitta, RGM 175 967, don. M. C. Cadée (holotype); upper part of Brinkheurne Member: 1 sagitta, RGM 175 968; basal layer of Winterswijk Member: 1 sagitta, RGM 175 969.
L: 5.67 mm H: 3.38 mm T: 1.06 mm (holotype)

Range — Middle Oligocene, Brinkheurne Member – basal layer of Winterswijk Member.

Discussion — The straight sulcus with its well-defined ostium and cauda is highly characteristic. No other described fossil otolith of the Congridae has these characteristics (see for instance Stinton, 1975). The Recent *Conger conger* (Linnaeus) shows rather close similarity to our specimen. The main differences are the more compact shape, the convex outer surface and the absence of colliculi of the fossil species in contrast to the elongated outline, the convex outer surface and the presence of colliculi of the living species.

Variation — The dorsal rim seems to be the most variable part of the otolith. It can be concluded from a second, somewhat eroded, specimen that the dorsal rim can be more angular than that of the holotype. In combination with this feature the postdorsal angle is more pronounced and the caudal part is more blunt.

ORDO CLUPEIFORMES

Clupeiformorum *planus* sp. n.
Pl. 1, figs. 5, 6, 8.

Type — Holotype: Pl. 1, fig. 5, RGM 175 953, don H. van der Made.
Locus typicus — Clay pit 'De Vlijt', near Winterswijk, The Netherlands.
Stratum typicum — Middle Oligocene, Rupelian, basal layer of Winterswijk Member.
Derivatio nominis — planus (Latin) = flat.

Diagnosis — Small, thin, flat otoliths with a straight shallow sulcus the width of which is one-third of the total height. Rounded cristae along the cauda clearly visible.

Description of holotype — A small, thin, flat otolith with an elongated oval outline. Dorsal rim for the most part straight with irregularly spaced small, round knobs. A distinct postdorsal angle is situated close to the caudal end. The posterior part of the otolith therefore is truncated. Ventral rim irregularly curved and dotted with many small, round knobs. Caudal end straight. Rostrum broken. Excisura ostii insignificant, antirostrum low and rounded.

Inner surface flat. Sulcus acusticus straight and very shallow, slightly supramedial. Width of sulcus one-third of the total height. Cauda only slightly narrower than ostium. Cristae rounded but distinct along cauda. Postcaudal depression not well-developed. Area clearly visible above entire sulcus. Short small furrows in dorsal part; in ventral and caudal parts these furrows are longer, sometimes extending up to the cristae.

Outer surface concave in length and height directions. Small furrows are sharp at the rims, becoming more vague toward the centre. An irregular, medial groove is elearly visible. Ventral part more regularly and more finely sculptured than dorsal part.

Material — Upper part of Brinkheurne Member: 2 sagittas, RGM 175 954, 175 955, don. M. van den Bosch; basal layer of Winterswijk Member: 1 sagitta, RGM 175 953, don. H. van der Made, 2 sagittas, RGM 175 956, 175 957.
(L: 2.28 mm) H: 1.55 mm T: 022 mm (holotype)
(L: 1.39 mm) H: 0.93 mm T: 0.18 mm

Range — Middle Oligocene, upper part of Brinkheurne Member – basal layer of Winterswijk Member.

Variation — The dorsal rim is usually more irregularly curved. There is a wide variation in the number of knobs along the rims. Juvenile specimens have relatively few large knobs; adult specimens have more numerous but much smaller knobs. The postcaudal depression and the incision are more pronounced in juvenile than in the older specimens. The sulcus is medial in juvenile and somewhat supramedial in adult otoliths. The caudal end is steeper and more straight in the adult specimens than in juveniles.

Discussion — The concavity of the outer surface, the flatness of the otoliths and the shallowness of the sulcus are unknown to us from the few extant species of Clupeiformes that we could study. The outline of the otoliths and the shape of the sulcus in any case indicate a close relationship with the family of Clupeidae.

Familia Clupeidae Bonaparte, 1831
Genus *Alosa* Linck, 1790

? *Alosa* sp.
Pl. 1, fig. 7.

Description — Only one fragment of a fragile otolith is available, the rostral part of which is broken. Outline of caudal part well-rounded and regularly formed. Ventral rim with several small regular knobs. Dorsal rim nearly smooth.

Ventral part of inner surface convex, dorsal part flat. Of the sulcus only part of the cauda is preserved; it is straight, wide and very deep with an asymmetrical v-shaped profile. Cristae sharp; crista inferior absent from the posterior end of cauda. Area flat and large, extending up to the dorsal rim. Many parallel shallow furrows extend over the entire area at regular distances and perpendicular to the dorsal rim.

Eroded outer surface convex in height direction. A regular pattern of shallow furrows and low knobs decorates the parts near the dorsal and ventral rims.

Material — Upper part of Brinkheure Member: 1 broken sagitta, RGM 175 958, don. M. van den Bosch.

Range — Middle Oligocene, upper part of Brinkheurne Member.

Discussion — The fossil specimen is too poorly preserved to be specifically identified. It resembles the extant species *Alosa alosa* Linnaeus the most, after comparison with *Clupea harengus, C. pallasi, Sprattus sprattus, Opisthonema oglinum, Dorosoma petense, Sardinops caeruleus, Alosa fallax* and *Sardinia pilchardus* as well as some other species from the literature (Fitch, 1969). The resemblance to *A. alosa* is reflected in the rounded posterior end of the otolith and the shape and position of the cauda.

ORDO SALMONIFORMES

Familia Argentinidae Bonaparte, 1846
Genus *Argentina* Linnaeus, 1758

Argentina parvula (Koken, 1891)
Pl. 1, figs. 9-15; Pl. 2, fig. 1.

1891 *Otolithus* (Berycidarum) *parvulus* — Koken, p. 121, pl. 10, figs. 4, 5.
1923 *Otolithus* (? Gonostoma) *parvulus* (Koken) — Posthumus, p. 128, figs. 58, 59.
1929 *Otolithus* (Beŕycidarum) *parvulus* (Koken) — Weiler, p. 107, pl. 6, figs. 9, 10.
1942 *Argentina parvula* (Koken) — Weiler, p. 19, pl. 1, figs. 20-25, 27-29.
1957 *Argentina parvula* (Koken) — Weiler, p. 136.
1958 *Argentina parvula* (Koken) — Weiler, p. 327, pl. 1, figs. 6-8.
1959 *Argentina parvula* (Koken) — Weiler, p. 96.
1964a *Argentina parvula* (Koken) — Brzobohatý, p. 236.
1964b *Argentina parvula* (Koken) — Brzobohatý, p. 275.
1968 *Argentina parvula* (Koken) — Martini, p. 67, pl. 1, fig. 15.
1974 Argentinidarum *parvula* (Koken) — Schwarzhans, p. 95, fig. 2.
1977 *Argentina parvula* (Koken) — Nolf, p. 17, pl. 1, figs. 14-19.

Material — Brinkheurne Member: 8 sagittas (1 specimen RGM 175 964, don. de Groot); upper part of Brinkheurne Member: 389 sagittas (348 specimens RGM 175 961, 175 963); basal layer of Winterswijk Member: 104 sagittas (57 specimens RGM 175 962, 175 963); Winterswijk Member: 4 sagittas.

Range — Middle Oligocene – Middle Miocene.

Discussion — The Middle Oligocene *A. parvula* is well described by Koken (1891). It resembles the Recent species *A. sphyraena* Linnaeus, 1758 from which it is easily distinguished by its smaller size. *A. sialis* (Gilbert) has a more supramedial sulcus than the other two species. *A. silus* (Ascanius, 1775) is distinguished by the fact that the dorsal part is not as well-developed as in other species.

Familia Gonostomidae Gill, 1892
Genus *Zaphotias* Goode & Bean, 1898

Zaphotias cyclomorphus (Weiler, 1950)
Pl. 2, fig. 2.

1950 *Argentina cyclomorpha* — Weiler, p. 216, pl. 7, fig. 53.
1968 *Bonapartia subdenudata* (Schubert) — Weiler, p. 17.

Material — Basal layer of Winterswijk Member: 1 sagitta, RGM 175 965, don. M. C. Cadée.
L. 1.66 mm H: 1.26 mm T: 0.44 mm

Range — Middle Oligocene – Upper Miocene (Tortonian).

Discussion — This specimen of *Z. cyclomorphus* resembles that of Weiler (1950) very closely. As a result of erosion the holotype has a more rounded outline. The dorsal rim of our specimen is less rounded and has a distinct but small postdorsal angle; the ventral rim has a straight anterior part and a rounded posterior part

separated by a blunt midventral angle. The ventral furrow, which is not present in Weiler's specimen because of erosion, is situated close to the ventral rim and is absent in the posterior part. ? *Gonostoma subdenudatum* Schubert, 1908 undoubtedly belongs to another species and genus of the Gonostomidae than *Z. cyclomorphus*.

Comparison with the photographs of the gonostomid otoliths in Kotthaus (1967, 1972) indicates that our otolith resembles that of *Bonapartia pedaliota* Goode & Bean, 1896 the most. The otolith of *Vinciguerria poweriae* (Cocco, 1838) is quite similar but its sulcus is supramedial and its dorsal rim differs from that of *Z. cyclomorphus* in the posterior part. The other *Vinciguerria* species in Kotthaus (1972) also have quite different dorsal rims. According to Golvan (1965) the genus *Bonapartia* Goode & Bean, 1895 was already used earlier in zoological nomenclature and is a synonym of *Zaphotias*.

ORDO GADIFORMES

Familia Gadidae Rafinesque, 1810
Subfamilia Gadinae Rafinesque, 1810
Genus *Colliolus* Gaemers & Schwarzhans, 1973

Colliolus parvus Gaemers, 1976
Pl. 2, figs. 5-14.

1910 *Gadus elegans* Koken — Leriche, p. 349, fig. 150A.
1976a *Colliolus parvus* Gaemers — Gaemers, p. 514, pl. 6, figs. 1a, b-8a, b.
1977 «genus Gadidarum» *parvus* (Gaemers) — Nolf, p. 31, pl. 8, figs. 10-16.

Material — Brinkheurne Member: 84 sagittas; upper part of Brinkheurne Member: 758 sagittas (638 specimens RGM 175 971, 176 060, 176 061); basal layer of Winterswijk Member: 282 sagittas (119 specimens RGM 175 970, 175 971); Winterswijk Member: 1 sagitta.

Range — Middle Oligocene, Brinkheurne Member – Winterswijk Member.

Variation — On the average the juvenile otoliths of this species appear to be more compact than the adults. The cauda is relatively shorter than the ostium in juvenile specimens, so that the ratio of the length of the cauda to that of the ostium is approximately 1.

Discussion — For a description of *C. parvus* see Gaemers (1976a). The genus *Colliolus* distinguishes itself from *Trisopterus* by its distinctly flatter otoliths; this characteristic also provides an easy means of distinction between *Colliolus parvus* and *Trisopterus elegans*. A postdorsal angle which is always present in *Colliolus parvus* is absent in *T. elegans*. In juvenile specimens of *C. parvus* the postdorsal angle is less pronounced.

We have studied the six otoliths which Koken (1891, p. 93) describes as *Otolithus (Gadus) elegans* from the Middle Oligocene of Hermsdorf. It was important to see these specimens because the possibility existed that they belonged to *Colliolus parvus*. To our astonishment it soon became evident that five otoliths were specimens of *Colliolus friedbergi* and one otolith was a representative of

Trisopterus concavus. Both species only lived in the Miocene and thus it is impossible for them to have come from Hermsdorf, where only Middle Oligocene Septaria Clay crops out. Moreover the state of preservation of the otoliths, which is not like that of any other otoliths found in the Septaria Clay but resembles that of many Miocene specimens, proves that the otoliths have been incorrectly labeled.

The 80 best-preserved specimens from a sample of 541 otoliths of *Colliolus parvus* from the apparent top of the Brinkheurne Member were measured for use in length versus height or thickness diagrams (Figs. 2a, b). These otoliths have been stored separately from the rest of the sample (RGM 176 060). Unfortunately

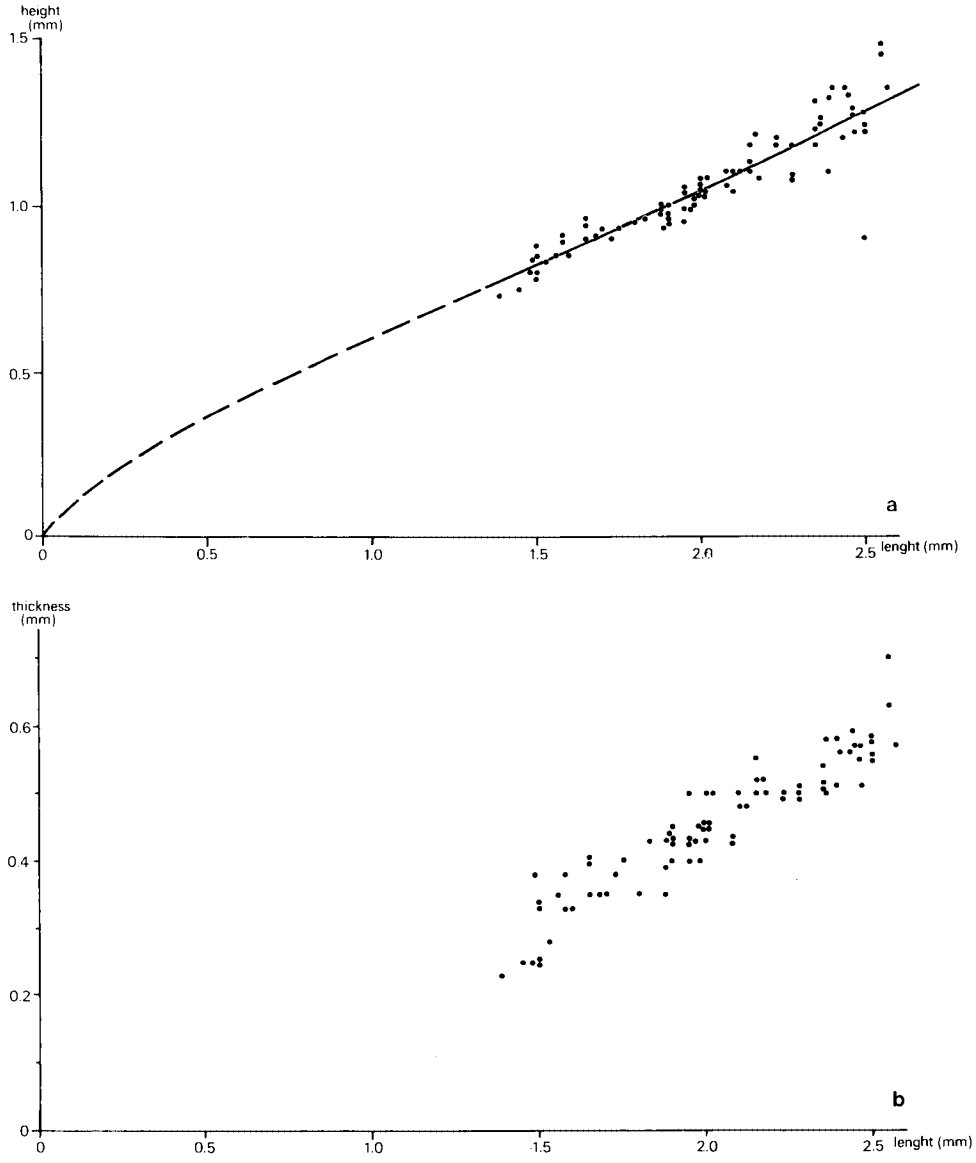


Fig. 2. Sagittas of *Colliolus parvus* Gaemers, 1976, clay pit 'De Vlijt' near Winterswijk, top of Brinkheurne Member; 2a: relation between length and height; 2b: relation between length and thickness.

no otoliths with a height of less than c. 0.7 mm were available. This is probably due to the fact that the clay was sifted with a sieve of 0.4 mm mesh, thus the diagonal was $0.4\sqrt{2} = 0.58$ mm. It is to be regretted that measurements of young specimens are totally lacking.

If we take the zero point as the beginning of an ontogenic curve (see Gaemers, 1976b), then the line which connects the mean values in the length-height diagram cannot be a straight line. It can only be a convex line, whereby the beginning is obviously convex and the continuation increasingly approaches a straight line. No conclusion can be reached on the basis of the diagram for length versus thickness because of the much greater spread of the measurements. This is probably caused by measurement errors which can influence the values of the small thicknesses considerably. The convex curve in the length-height diagram agrees completely with the evolution hypothesis of Gaemers (1976b).

Genus *Gadichthys* Gaemers & Schwarzhans, 1973

Gadichthys altus sp. n.
Pl. 2, figs. 15, 16; Pl. 3, figs. 1-3.

Type — Holotype: Pl. 2, fig. 15, RGM 176 065, don. A. W. Janssen, 1976.
Locus typicus — Herselt (Belgium, province of Antwerp), clay pit 400 m N of the church of Ramsel.
Stratum typicum — Middle Oligocene, Rupelian, *Serpula septaria* — *Ancistrosyrinx volgeri* Assemblage Zone.
Derivatio nominis — altus (Latin) = high; named for the relatively large height of the otoliths for the genus *Gadichthys*.

Diagnosis — A high, pear-shaped *Gadichthys* species; rostral part of ventral rim pronounced.

Description of holotype — Unfortunately only well-preserved otoliths of juvenile fishes have been found so far and therefore we were forced to choose the holotype from these juvenile otoliths.

It is a small, compact otolith with a pear-shaped outline. Ventral rim regularly curved. Rostral part of ventral rim pronounced, rounded and rather massive; it curves more sharply than the caudal part of this rim. Middle part of ventral rim clearly sculptured. Dorsal rim entirely but not heavily sculptured. Predorsal and postdorsal angles both distinct. Dorsal rim straight between the angles and between postdorsal angle and caudal end. A shallow but nevertheless obvious exisura ostii separates the rounded rostrum and antirostrum. Caudal end bluntly pointed.

Inner surface slightly convex. Sulcus acusticus wide and shallow, slightly supramedial. Cauda somewhat longer than ostium. The same holds for the caudal colliculum when compared with the ostial colliculum. Collum wide, with the characteristic sharp, small furrow on the ventral part of it; this furrow is slightly convex toward the ventral side. Crista superior broad and rounded, crista inferior narrow and sharp. Area not yet formed. Small furrows from dorsal rim often extend to the crista inferior, sometimes even entering the sulcus. Small furrows from ventral rim usually extend up to the distinct ventral furrow.

Outer surface very slightly concave lengthwise and slightly convex in the direction of the height. Sharp furrows radiate from the centre to the rims; these furrows are longer and more numerous on the dorsal side than on the ventral side.

Material— Upper part of Brinkheurne Member: 5 sagittas, RGM 175 972, 175 973, 175 975; basal layer of Winterswijk Member: 4 sagittas, RGM 175 974; *Serpula septaria – Ancistrosyrinx volgeri* Assemblage Zone, Boom Clay, Herselt, clay pit 400 m N of the church of Ramsel, province of Antwerp, Belgium: 10 juvenile sagittas, RGM 176 065 - 176 069.
L: 2.23 mm H: 1.32 mm T: 054 mm (holotype)
L: 1.82 mm H: 1.19 mm T: 0.45 mm
L: 1.81 mm H: 1.21 mm T: 0.41 mm

Range — Middle Oligocene, upper part of Brinkheurne Member – basal layer of Winterswijk Member.

Variation — The other four juvenile otoliths from Herselt have a less distinct postdorsal angle; also the excisura ostii of these specimens is not as pronounced and sometimes even completely absent. The sulcus is medial. The length-height ratio of one specimen is smaller. The postdorsal angle of two otoliths is shifted toward the back.

A comparison with the outline of the bigger, more adult otoliths from 'De Vlijt' is not yet possible because the rims of the latter are markedly eroded. The sulcus is in any case relatively narrower and seems to be slightly inframedial but perhaps this is caused by erosion. Inner and outer surfaces of the bigger specimens tend to be flatter than those of the juveniles.

Discussion — The new species is at present the oldest known species of the genus *Gadichthys*. It cannot be confused with other members of this genus because of its regular and thickset shape.

Undoubtedly this species is the ancestor of all other known *Gadichthys* species; with the discovery of *G. altus* the *Gadichthys* lineage is more complete.

The shape of *G. altus* agrees entirely with that which could be expected on the basis of the theory of the evolution of the Gadidae (Gaemers, 1976b). A small thickset ancestor of the whole lineage can now be expected in the Early Oligocene, which should complete the *Gadichthys* lineage.

In the first instance the juvenile *Gadichthys* otoliths resemble the sagittas of *Colliolus parvus,* which however are generally more elongated. The best characteristics for distinguishing between the species are the rostral part and the caudal colliculum. The rostral part of *Gadichthys* is always rounded, whereas that of *C. parvus* is pointed at the rostrum. The caudal colliculum of *Gadichthys altus* is only slightly longer than the ostial colliculum. In adult specimens of *C. parvus* the colliculi obviously differ in length, whereby the caudal colliculum is much longer.

Subfamilia Lotinae
Genus *Palaeogadus* von Rath, 1859

Palaeogadus emarginatus (Koken, 1884)
Pl. 3, figs. 4, 5, 7; Pl. 4, fig. 1.

1884 *Otolithus (Merluccii) emarginatus* — Koken, p. 547, pl. 11, fig. 6.
1891 *Otolithus (Merluccius) emarginatus* Koken — Koken, p. 84, pl. 2, figs. 8, 9.
1928 *Merluccius emarginatus* Koken — Weiler, p. 50, pl. 1, figs. 3, 4, 5, 9.
1942 *Nemopteryx emarginatus* (Koken) — Weiler, p. 86, pl. 6, figs. 2, 3; pl. 10, figs. 7-12; non pl. 6, figs. 1, 4.

1958 *Palaeogadus (Palaeogadus) emarginatus* (Koken) — Weiler, p. 332, pl. 1, figs. 20, ? 21.
1968 *Palaeogadus emarginatus* (Koken) — Martini, p. 66, pl. 1, fig. 6; non pl. 2, fig. 3.
1977 *Palaeogadus emarginatus* (Koken) — Nolf, p. 22, pl. 3, figs. 4, ? 5.

Material — Brinkheurne Member: 3 sagittas, RGM 175 978; upper part of Brinkheurne Member: 2 sagittas, RGM 175 976, 175 977.

Range — Middle Oligocene – Upper Oligocene; ? Middle Miocene.

Discussion — For the description of this species, see Koken (1884, 1891) and Weiler (1942). Our specimens closely resemble the otoliths of *P. emarginatus* from the Middle Oligocene of Söllingen (Germany) in Koken's collection. We have had the opportunity to study these otoliths which are the type specimens for this species. One of the best-preserved otoliths has been choosen as lectotype, as it was impossible to say with certainty which one was drawn by Koken (1884). Photographs of the lectotype can be seen in Plate 3, fig. 5a, b, c, d. Also two of the better preserved paralectotypes from the same locality are shown (Pl. 3, fig. 7; Pl. 4, fig. 1).

The Upper Oligocene otoliths of this species from Doberg near Bünde (Germany) and from Glimmerode near Kassel (Germany), which are part of the collections of the authors, are also quite similar to the otoliths of this species from Winterswijk.

For a comparison with *P. compactus,* see the discussion of this latter species.

Palaeogadus compactus sp. n.
Pl. 3, fig. 6; Pl. 4, figs. 2-4; Pl. 5, figs. 2-6.

1942 ? *Nemopteryx emarginatus* (Koken) — Weiler, p. 86, pl. 6, fig. 4a, b; non pl. 6, figs. 1, 2, 11, 15, pl. 10, figs. 7-12.
1964 *Palaeogadus emarginatus* (Koken) — Martini, p. 54, pl. 1, fig. 3.
1968 *Palaeogadus emarginatus* (Koken) — Martini, pl. 2, fig. 3; non pl. 1, fig. 6.

Type — Holotype: Pl. 4, fig. 4, RGM 175 979, leg. M. Vervoenen.
Locus typicus — Schelle, clay pit near Niel, Belgium.
Stratum typicum — Middle Oligocene, Rupelian, Boom Clay, *Ancilla karsteni — Niso* sp. Assemblage Zone *(Corbula* horizon).
Derivatio nominis — compactus (Latin) = compact; named for the compact shape of the otoliths.

Diagnosis — Big, compact, oval to triangular *Palaeogadus* species with rounded and massive predorsal angle.

Description of holotype — A big, strong and compact otolith with an oval to triangular shape. Rims are eroded, especially the dorsal rim which is regularly bent with a rounded and massive predorsal angle near the middle. Ventral rim slightly and evenly rounded. Rostral end bluntly pointed, dorsal rim near the rostral end slightly concave. Caudal end also bluntly pointed but more massive because of the convex posterior part of the dorsal rim. Dorsal rim with regular and rather coarse knobs, ventral rim with small regular knobs.

Inner surface clearly convex along the length and height axes. Sulcus acusticus wide and shallow with distinct colliculi. Cauda about 1.5 times as long

as ostium. Ostial colliculum covers most of the oval ostium with the exception of the anterior part. Triangular caudal colliculum covers most of the triangular cauda with the exception of the posterior part. Collum wide and high. Crista superior well-developed, caudal part of it sharply curved toward the dorsal rim. Crista inferior insignificant. Distinct and large area up to the dorsal rim. The ventral region joining the crista inferior is elevated with respect to the region directly along the ventral rim. Along the rims there are small, shallow but distinct furrows.

Outer surface concave lengthwise and nearly flat in the direction of the height. Well-developed medial rib with a round wart in the middle. Entire outer surface with distinct, deep furrows and ridges. Furrows on the dorsal part radiate from the centre, furrows on the ventral part perpendicular to the ventral rim.

Material — Brinkheurne Member: 16 sagittas (8 specimens RGM 175 985, 175 986); upper part of Brinkheurne Member: 14 sagittas (7 specimens RGM 175 982, 175 983); basal layer of Winterswijk Member: 9 sagittas (2 specimens RGM 175 984). Moreover 6 indeterminable *Palaeogadus* sagittas and 1 *Palaeogadus* sp. sagitta.
L: 12.45 mm H: 5.60 mm T: 1.53 mm (holotype)
L: 7.93 mm H: 3.52 mm T: 1.19 mm

Range — Middle Oligocene, Brinkheurne Member – basal layer of Winterswijk Member.

Variation — The predorsal angle of juvenile specimens is situated closer to the rostral point. The knobbing of the dorsal rim is generally not very pronounced except around the predorsal angle. This part of the dorsal rim can be somewhat irregular due to several peculiar knobs. In some specimens an indistinct excisura ostii occurs. The more juvenile specimens have an outer surface which is convex in the direction of the height and flat in the direction of the length; because of these features the juvenile otoliths are stronger and more massive. All specimens are less sculptured on the outer surface than the holotype.

Discussion — *Palaeogadus compactus* is distinguished from *P. emarginatus* by its more compact and more rounded shape. Especially the more adult specimens of *P. compactus* have blunter rostral and caudal points and a rounded predorsal angle that is situated closer to the middle of the dorsal rim. *P. emarginatus* on the other hand has a sharp predorsal angle closer to the rostral point; behind this predorsal angle a clearly concave part of the dorsal rim is often seen; this is never found in *P. compactus*. The juveniles of *P. compactus* are always thicker at the rims than those of *P. emarginatus*.

According to Weiler's drawing (1935, fig. 7a, b) of *Nemopterus (= Palaeogadus) moravicus* the cauda of this species is distinctly narrower than that of *P. compactus*. The dorsal rim of *N. moravicus* shows a closer resemblance to that of *P. emarginatus* because of its less regular outline.

Novitskaja (1961, fig. 3a, b) shows pictures of a *Palaeogadus* species, viz. *P. rarus,* which resembles *P. compactus*. It is not possible to conclude from her pictures that our otoliths belong to *P. rarus* because of the fact that at least some of the pictures do not seem to reflect the true shape. Moreover the dimensions of the otoliths are not given by Novitskaja.

Subfamilia Ranicepsinae
Genus *Palaeoraniceps* Gaemers, 1976

Palaeoraniceps tuberculosus (Koken, 1884)
Pl. 6, figs. 2, 3.

1976 *Palaeoraniceps tuberculosus* (Koken) — Gaemers, 1976a, p. 517, pl. 4, figs. 5a, b.
1977 *Raniceps tuberculosus* (Koken) — Nolf, p. 28, pl. 8, fig. 8.

Material — Basal layer of Winterswijk Member: 1 sagitta; one sagitta, with no exact stratigraphic position (found loose in the southwesternmost clay pit of 'De Vlijt').

Range — Lower Oligocene – Upper Oligocene.

Discussion — For a description see Koken (1884, 1891) and Weiler (1942). An extensive list of synonyms can be found in Gaemers (1976a). The other *Raniceps* species described by Koken, viz. *R. planus* and *R. latisulcatus,* cannot be distinguished from *P. tuberculosus,* as indicated by Gaemers (1976a).

Both specimens from 'De Vlijt' are regularly shaped. The more adult one has a relatively wide sulcus which is a common feature for large individuals of the Gadidae. The outer surface of the younger specimen is heavily knobbed (which actually gave this species its name); the more adult specimen has a more irregularly structured outer surface and is relatively thinner than the younger otolith.

Familia Brotulidae

Brotulidarum *occultus* (Koken, 1891)
Pl. 7, figs. 1, 3, 4, 8.

1891 *Otolithus* (Ophidiidarum) *occultus* — Koken, p. 104, pl. 6, fig. 1.
1942 *Otolithus* (Ophidiidarum) *occultus* Koken — Weiler, p. 105, pl. 5, figs. 49, 52, pl. 6, figs. 21, ? 22, pl. 11, fig. 8.
1965 *Otolithus* (Ophidiidarum) *occultus* Koken — Zilch, p. 471, pl. 37, fig. 17.

Description — Rather large, oval otoliths with a fairly thickset outline, which is regular; nearly symmetrical along the height axis. Dorsal rim coarsely lobed; predorsal and postdorsal angles are not always clearly developed, they are usually rounded. Predorsal angle more pronounced than postdorsal angle. Part of dorsal rim between dorsal angles straight to slightly convex. The more rostral and caudal parts of the dorsal rim are generally nearly straight. Ventral rim regularly bent and less sculptured than dorsal rim. Rostral point somewhat sharper than caudal point, but both are rather blunt.

Inner surface only slightly convex. Sulcus acusticus wide and large; dorsal part of sulcus straight, ventral part clearly bent toward ventral rim. Ostium 3 to 5 times as long as cauda. Ostium can be distinguished from cauda by a small constriction of the sulcus at the ventral boundary. Entire sulcus filled with one big colliculum. Crista superior distinct and narrow, crista inferior massive but less pronounced. Area large and subsided. Dorsal field up to the sulcus incised with several furrows, most of which have faded away due to erosion.

Outer surface slightly convex. Lengthwise a low inframedial ridge; from the dorsal rim several incisions cross the dorsal part of the outer surface forming coarse

knobs. This sculpturing fades away towards the inframedial ridge. In adult specimens the centre of the dorsal field tends to be somewhat concave. The ventral field shows a vague coarse folding.

Material — Brinkheurne Member: 12 sagittas (3 specimens RGM 175 987, 175 988); upper part of Brinkheurne Member: 14 sagittas (11 specimens RGM 175 989); basal layer of Winterswijk Member: 3 sagittas, RGM 175 990.
L: 6.52 mm H: 3.39 mm T: 1.24 mm
L: 4.68 mm H: 2.16 mm T: 0.91 mm

Range — Lower Oligocene – Middle Oligocene.

Variation — The very juvenile otoliths (length up to 2 mm) are regularly oval without angles; furrows and knobs have developed along dorsal and ventral rims. These otoliths are relatively thick. At the transition between ostium and cauda a dimple is present on the ventral side of the sulcus. Inner surface only slightly convex; outer surface convex, with an irregular pattern of distinct furrows and knobs.

The biggest otoliths are relatively higher than the younger ones. Thus, allometrical growth seems to be fairly well-developed.

Discussion — The Recent brotulid species *Oligopus diagrammus* Heller & Snodgrass from the Californian Pacific has otoliths with an outline which closely resembles that of our species. The sulcus however consists of only one compartment, so that ostium and cauda cannot be separated. Therefore it is impossible for both species to belong to the same genus. Other known Recent Brotulidae or Ophidiidae (see for instance Nolf, 1974) differ even more from *B. occultus*.

Brotulidarum *marchicus* (Koken, 1891)
Pl. 5, fig. 1; Pl. 6, figs. 7, 8; Pl. 7, figs. 2, 5-7.

1891 *Otolithus* (Ophidiidarum) *marchicus* — Koken, p. 104, pl. 10, fig. 18.
1891 ? *Otolithus* (Pleuronectidarum) *acuminatus* — Koken, p. 107, pl. 5, fig. 12.
1965 ? *Otolithus* (Ophidiidarum) *occultus* Koken — Zilch, p. 473, pl. 37, fig. 18, non fig. 17.
1967 *Ammodytes* sp. — Brzobohatý, p. 144, pl. 3, fig. 10.
1968 *Ammodytes acuminatus* (Koken) — Weiler, p. 74.
1977 *Brosmophycis marchicus* (Koken) — Nolf, p. 32, pl. 9, figs. 2-5.

Description — Strong, rather large, fusiform otoliths with pointed rostral and caudal ends. Outline elongated. Dorsal rim with rounded predorsal and postdorsal angles. Predorsal angle usually more pronounced than postdorsal angle. A low swelling can be present between predorsal and postdorsal angles. Ventral rim regularly bent. The curvature of this rim is sharpest near the rostral part, so that the maximum height of the otolith is reached at one-third of the total length. Ventral rim of adult otoliths sometimes has weak undulations.

Inner surface somewhat convex in the direction of the length, clearly convex in the direction of the height. Sulcus acusticus straight, wide and rather short; not divided into ostium and cauda. In the largest specimens (length more than 5 mm) the sulcus extends in parallel with the long axis. In smaller otoliths the sulcus forms

a small angle with the long axis. Entire sulcus filled with one colliculum. Cristae weakly developed. Large, rather deep area. From the rostral point to the sulcus there is a straight, sharp, little crest. Caudal to the sulcus an irregular depression is sometimes observed. No ventral furrow.

Outer surface convex in both directions. Dorsal field weakly folded so that the rostral part is somewhat concave. Ventral field almost without sculpturing.

Material — Brinkheurne Member: 37 sagittas (8 specimens RGM 175 991, 175 992); upper part of Brinkheurne Member: 17 sagittas (12 specimens RGM 175 993); basal layer of Winterswijk Member: 4 sagittas (3 specimens RGM 175 994, 175 995).

L: 7.96 mm H: 3.33 mm T: 1.27 mm
L: 6.79 mm H: 3.05 mm T: 1.21 mm
L: 7.83 mm H: 3.38 mm T: 1.37 mm (holotype)

Range — Middle Oligocene.

Variation — The width and length of the sulcus vary somewhat. Furthermore the dorsal part of the otoliths can be more or less developed.

Discussion — So far no really juvenile otoliths have been found, in contrast to B. *occultus*.

There is good agreement with the outline of *Brosmophycis marginata* (Ayres). The sulcus of this species however is much longer than that of B. *marchicus*. A rather close relationship between the two species surely exists. It is remarkable that Fitch (1967, fig. 6) identifies an otolith as *Brosmophycis marginata* which has a sulcus comparable with that of B. *marchicus*.

Judging from Koken's holotype (1891, pl. 5, fig. 12) and Zilch's photograph (1965, pl. 37, fig. 18) of the same specimen of Ophidiidarum *acuminatus* it seems highly probable that this eroded otolith belongs to B. *marchicus* because of the shape of the sulcus and the outline.

The holotype of Brotulidarum *marchicus* is in a fair state of preservation; it shows no signs of erosion of any importance. Dr W.-D. Heinrich kindly sent this specimen from the Middle Oligocene of Hermsdorf. Photographs of this holotype can be seen in Pl. 5, figs. 1a-d.

Brotulidarum *phaseoloides* sp. n.
Pl. 6, figs. 9, 10; Pl. 8, fig. 2.

Type — Holotype: Pl. 6, fig. 10, RGM 176 001.
Locus typicus — Clay pit 'De Vlijt' near Winterswijk, The Netherlands.
Stratum typicum — Middle Oligocene, Rupelian, upper part of Brinkheurne Member.
Derivatio nominis — Named for *Phaseolus* Linnaeus, the genus name of the bean, because for its bean shape.

Diagnosis — A small, robust otolith with a markedly convex outer surface and a blunt rostral point. Sulcus straight and narrow. Length of sulcus nearly two-third the total length of the otolith. The colliculum does not cover the most rostral part of the sulcus.

Description of holotype — A small, robust otolith with a bean-shaped outline. Blunt rostral point and a truncated caudal end. Dorsal rim with few big but low undulations. Ventral rim regularly bent.

Inner surface slightly convex. Sulcus straight and narrow. Length of sulcus nearly two-third the total length of the otolith. The colliculum does not cover the most rostral part of the sulcus which is sharply pointed. Sulcus slightly supramedial. Cristae rounded and well-developed; they fuse together near the rostral point. From there a small ridge runs to the rostrum. Area large and clearly depressed.

Outer surface markedly convex in the direction of the height, convex in the lengthwise direction; entirely smooth.

Material — Brinkheurne Member: 2 sagittas, RGM 176 002, 176 003; upper part of Brinkheurne Member: 7 sagittas, RGM 176 001, 176 004; basal layer of Winterswijk Member: 1 sagitta.
L: 2.50 mm H: 1.54 mm T: 0.88 mm
L: 4.04 mm H: 2.49 mm T: 1.15 mm

Range — Middle Oligocene.

Variation — Most specimens have a somewhat more irregular outline than the holotype; generally the blunt rostrum is more pointed and the dorsal rim near the rostrum is somewhat dented. In some examples the sulcus is slightly oblique with its caudal part closer to the ventral side.

Discussion — Recent species which resemble B. *phaseoloides* are unknown to us. Otolithus (Ophidiidarum-Brotulidarum) sp. 2 (Anfossi & Mosna, 1972, pl. 21, fig. 2) from the Lower Pliocene of Italy resembles our species the best, although its sulcus is clearly inframedial.

Genus *Diplacanthopoma* Günther, 1887

Diplacanthopoma tortonesei Nolf, 1977.
Pl. 6, figs. 1, 4-6.

1977 *Diplacanthopoma tortonesei* — Nolf, p. 33, pl. 9, figs. 7-9.

Description — Small, thick otoliths with ovoid outline. Rostral part narrower than caudal part, whereby rostral point is sharper than caudal point. Dorsal rim blunt with a few irregular lobes. Postdorsal angle only developed in the larger specimens. Blunt ventral rim more regularly curved than dorsal rim. Ventral rim weakly sculptured.

Inner surface flat to slightly convex. Sulcus acusticus undivided, slightly convex toward ventral side or straight; medial in juvenile and inframedial in larger otoliths; caudal part of sulcus closer to ventral than rostral part; thus sulcus oblique. Total length of otolith is 2.5 to 3 times the length of sulcus. One big colliculum covers entire sulcus. Crista superior insignificant; no crista inferior. Area large. A small, straight and sharp crest runs from the sulcus (crista superior) to the rostral point; in juvenile specimens this characteristic is less distinct. Behind sulcus a flattened part. An indistinct ventral furrow is present only below the sulcus.

Outer surface highly convex. Only a few irregular knobs, separated by deep irregular furrows which are almost perpendicular to the rims. Dorsal sculpturing is more pronounced than ventral. Thickest part of otoliths inframedial.

Material — Upper part of Brinkheurne Member: 18 sagittas (11 specimens RGM 175 996, 175 997); basal layer of Winterswijk Member: 9 sagittas (5 specimens RGM 175 998, 175 999).
L: 2.91 mm H: 1.64 mm T: 0.83 mm
L: 1.95 mm H: 1.07 mm T: 0.49 mm

Range — Middle Oligocene.

Discussion — This species shows the closest resemblance to Ophidiidarum *obliquus* Weiler (1942, pl. 5, figs. 36, 37, non fig. 35), which is incorrectly placed by Weiler (1958, 1968) in the genus *Ammodytes*. All Ammodytidae have a sulcus which opens on the rostral side. The most obvious difference between O. *obliquus* and our species can be found in the ornamentation. O. *obliquus* has entirely smooth rims, whereas *Diplacanthopoma tortonesei* is always coarsely knobbed.

Genus *Palaeomorrhua* Gaemers & Schwarzhans, 1973

Palaeomorrhua faba (Koken, 1884)
Pl. 8, fig. 1.

1884 *Otolithus* (Gadi) *faba* — Koken, p. 541, pl. 11, fig. 8.
1891 *Otolithus (Morrhua) faba* (Koken) — Koken, p. 95.
1891 *Otolithus (Morrhua) söllingenensis* — Koken, p. 94, pl. 3, fig. 1, 1a.
1910 *Gadus* cf. *faba* (Koken) — Leriche, p. 351, figs. 151, 151a, 151b.
1977 «Genus Gadidarum» *lerichei* — Nolf, p. 31, pl. 8, fig. 9.

Description — Only one sagitta has been found of this species. The otolith is perfectly oval and nearly symmetrical with respect to the length and height axes. Also because of the nearly symmetrical sulcus it is difficult to ascertain which are the dorsal and ventral rims and the rostral and caudal ends, respectively. Dorsal rim regularly rounded with small, flattened knobs of nearly equal size. Smooth ventral rim regularly rounded, but somewhat more sharply curved than dorsal rim. Caudal and rostral ends are missing a small piece.

Inner surface extremely convex in both directions. The medial sulcus has been divided into an ostium and a cauda, the ostium being somewhat longer than the cauda (about 4 to 3). Ostium and cauda completely filled with colliculi and therefore very shallow. The ventral boundary of the ostium bends upwards towards the rostral end, so that the ostium becomes narrower there. The ventral boundary of the cauda also bends upwards towards the caudal end but this is less pronounced than in the ostium. At the partition between ostium and cauda, the boundary between the sulcus and the ventral part bends sharply covering up to half of the width of the sulcus. Above this the collum is present as a narrow furrow. No cristae and no area. The uppermost section of the dorsal part is trimmed with peculiar small furrows, which cut deeper into the dorsal region as they approach the dorsal rim. Ventral part smooth.

Outer surface concave in both directions and completely ornamented with

very pronounced knobs. In the lengthwise direction is a clear and deep medial furrow which fades towards the rostral and caudal ends. On the dorsal part the knobs have merged into ridges, on the ventral part separate knobs occur.

Material — Brinkheurne Member: 1 sagitta, RGM 176 000, don. A. Stiva.
(L: 8.07 mm) H: 4.78 mm T: 1.86 mm

Range — Middle Oligocene.

Discussion — In contrast to earlier publications (Koken, 1884, 1891; Weiler, 1968; Gaemers & Schwarzhans, 1973) in which *P. faba* was considered a member of the Gadidae, it is most likely that this species belongs to the Brotulidae-Ophidiidae complex. Certain affinities exist with *Sirembo* species, especially with respect to the inner surface. The concavity of the outer surface of *P. faba* however is a characteristic that is fairly rare for the group as a whole. Furthermore the knobbing on the outer surface is seen in only a few species of this group (for instance in Ophidiidarum *ornatissimus* Nolf, 1974).

The orientation of *P. faba* is difficult to determine at first glance. The narrowing of the sulcus below the collum is ventral in Brotulidae-Ophidiidae and points toward the ostium. In these families the ostium is never smaller than the cauda. Because of these arguments we believe that the orientation of the otolith of *P. faba* should be reversed with respect to Koken's drawings (Koken, 1884, 1891).

Koken describes *Otolithus (Morrhua) soellingenensis* as a separate species which is somewhat more slender than *P. faba*. We consider this difference to be due to allometric growth of the species, for *M. soellingenensis* is in a more juvenile stage than *P. faba*.

The genus *Palaeomorrhua* is probably closely related to *Signata* Frizzell & Dante, 1965. Unfortunately the shape of the sulcus is barely visible on the photographs of *Signata stenzeli* and only partly visible on *S. nicoli*.

The specimen shown by Nolf (1977) and described as a new species undoubtedly is a highly eroded sagitta of *P. faba*. The species identification of this otolith made by Leriche was therefore correct.

Familia Ophidiidae Rafinesque, 1810
Genus *Hoplobrotula* Gill, 1863

Hoplobrotula difformis (Koken, 1884)
Pl. 8, figs. 3, 4; Pl. 9, figs. 1-5; Pl. 10, figs. 1, 2.

1884 *Otolithus* (Gadidarum) *difformis* — Koken, p. 547, pl. 11, fig. 13.
1891 *Otolithus* (Ophidiidarum) *difformis (typus)* — Koken, p. 101, pl. 5, figs. 7, 8.
1891 *Otolithus* (Ophidiidarum) *difformis* var. *vetusta* — Koken, p. 103.
1891 *Otolithus* (Ophidiidarum) *difformis* var. *joachimica* — Koken, p. 103, pl. 1, fig. 7.
1910 Ophidiidarum *acutangulum* (Koken) — Leriche, p. 348, figs. 148, 149.
1942 *Otolithus* (Ophidiidarum) *difformis* (Koken) — Weiler, p. 101, pl. 12, figs. 1, 2, 3.
1942 *Otolithus* (Ophidiidarum) *joachimicus* Koken — Weiler, p. 102, pl. 12, figs. 6, 7, 8, 12, pl. 13, fig. 4.
1962 *Ophidion joachimicum* (Koken) — Weiler, p. 287, fig. 3.
1965 *Otolithus* (Ophidiidarum) *difformis* (Koken) — Brzobohatý, p. 279.
1965 *Otolithus* (Ophidiidarum) *joachimicus* Koken — Zilch, p. 470, pl. 35, fig. 16.
1967 *? Otolithus* (Ophidiidarum) *difformis* (Koken) — Brzobohatý p. 144, pl. 5. figs. 3, 4.
1977 *Hoplobrotula difformis* (Koken) — Nolf, p. 33, pl. 9, figs. 14-15.

Material — Brinkheurne Member: 101 sagittas (39 specimens RGM 176 009-176 013, 108 754); upper part of Brinkheurne Member: 15 sagittas (13 specimens RGM 176 007, 176 008); basal layer of Winterswijk Member: 9 sagittas (1 specimen RGM 176 006); Winterswijk Member: 2 sagittas.

L: 10.50 mm H: 6.45 mm T: 4.10 mm
L: 9.24 mm H: 5.43 mm T: 2.54 mm
L: 7.34 mm H: 4.06 mm T: 2.27 mm (Kruibeke)
L: 6.08 mm H: 3.24 mm T: 1.61 mm
L: 2.00 mm H: 1.35 mm T: 0.60 mm

Range — Lower Oligocene – Middle Oligocene; ? Middle Miocene.

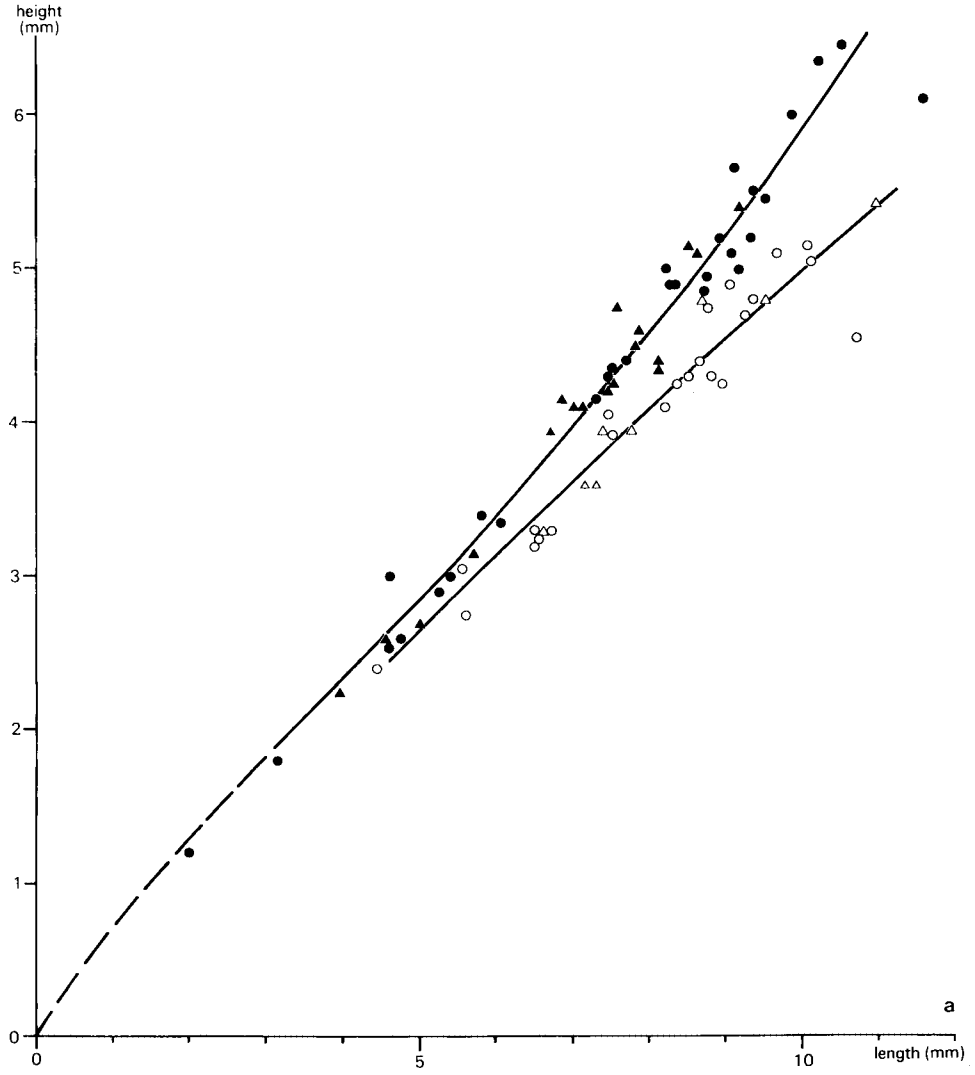
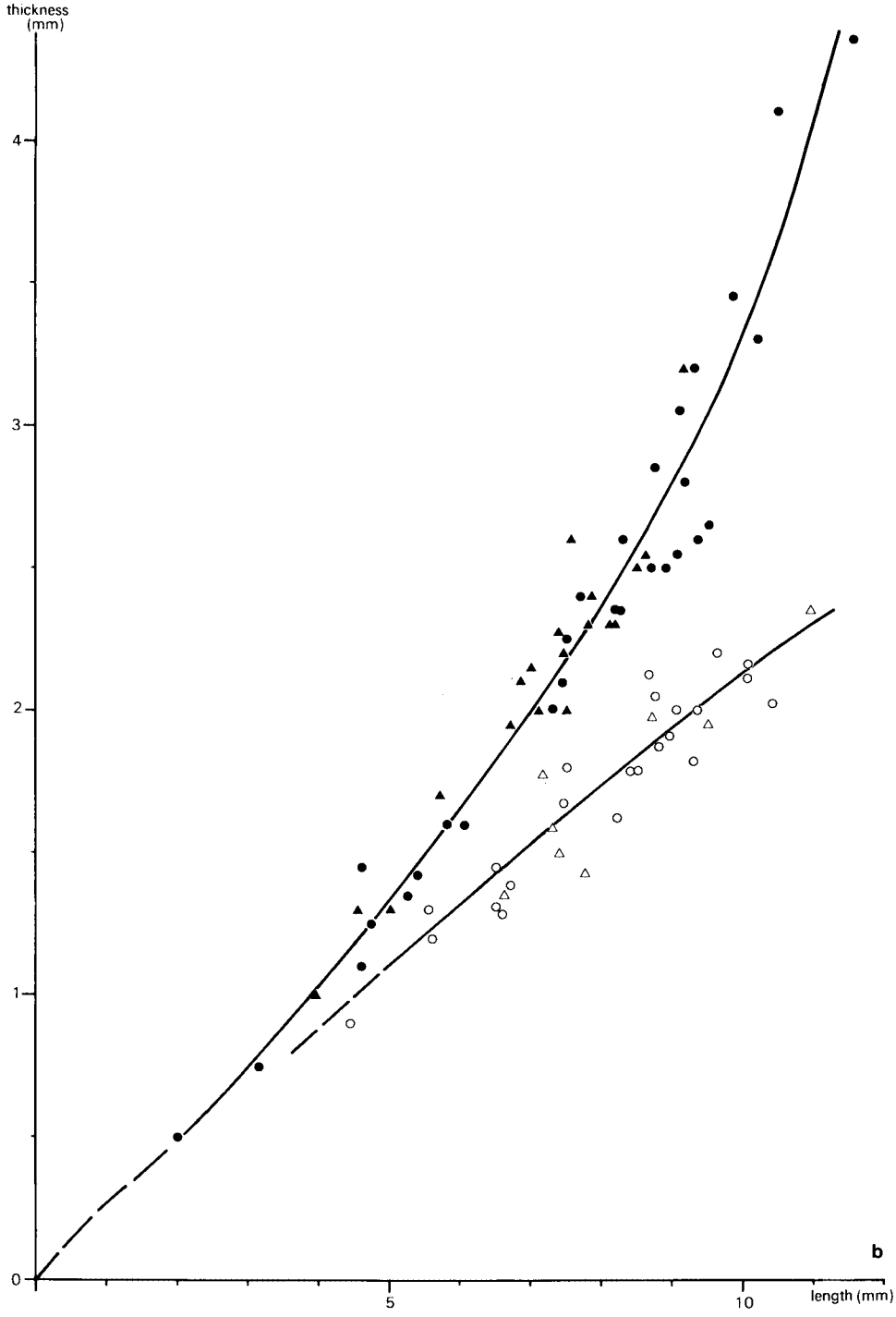


Fig. 3. Sagittas of *Hoplobrotula difformis* (Koken, 1884) (solid symbols) and *Hoplobrotula acutangula* (Koken, 1884) (open symbols); triangles: specimens from a clay pit at Kruibeke (1500 m S, 1800 m W of the church of Burcht), Belgium, *Ancilla karsteni-Nisso* sp. Assemblage Zone; circles: specimens from clay pit 'De Vlijt' near Winterswijk, Brinkheurne Member, *Serpula septaria-Ancistrosyrinx volgeri* Assemblage Zone; 3a: relation between length and height; 3b: relation between length and thickness.



Discussion — An obvious allometric growth can be seen in this species. The juvenile specimens are relatively slender and thin, whereas the adults are quite thickset. Since we have numerous otoliths at our disposal, many transitional forms between juveniles and seniles have been found. Thus, it can be demonstrated that the otoliths of Ophidiidarum *joachimicus* and O. *difformis* belong to only one species (Fig. 3a, b). Up to now the large adult otoliths were considered to be O. *difformis* and the medium-sized otoliths O. *joachimicus* (see for instance Weiler, 1942, p. 102, 103).

Leriche (1910) shows two otoliths which he describes as O. *acutangulum*. Because of the good quality of the photographs it can easily be ascertained that both belong to *H. difformis*.

The Miocene otoliths described as O. *difformis* by Weiler (1942, pl. 12, fig. 4; 1950, pl. 6, fig. 36) probably belong to a more highly evolved descendant because their thickset shape is even more pronounced. They resemble the very high and thick species *Bauzaia ornatissima* Robba, 1970, which is probably synonymous with *Otolithus* (Ophidiidarum) *gibbus* Bassoli, 1906.

Hoplobrotula acutangula acutangula (Koken, 1884)
Pl. 10, figs. 3, 4; Pl. 11, figs. 1-3.

1884 *Otolithus* (Gadidarum) *acutangulus* — Koken, p. 546, pl. 11, fig. 13, non 11 (Lattorf).
1891 *Otolithus* (Ophidiidarum) *difformis* var. *acutangula* — Koken, p. 103, pl. 5, fig. 9.
1891 *Otolithus* (Marcruridarum) *singularis* — Koken, p. 98, pl. 6, fig. 9 (Lattorf).
1942 *Otolithus* (Ophidiidarum) aff. *hilgendorfi* Koken — Weiler, p. 103, pl. 13, fig. 3.
1962 *Otolithus* (Ophidiidarum) *acutangulus* (Koken) — Weiler, p. 286, fig. 1.
1967 *Otolithus* (Ophidiidarum) *acutangulus* (Koken) — Brzobohatý, p. 144, pl. 5, figs. 1, 2.
1977 *Hoplobrotula joachimica* (Koken) — Nolf, p. 34, pl. 9, figs. 12, 13.

Material — Brinkheurne Member: 42 sagittas (9 specimens RGM 176 014-176 016).
L: 10.05 mm H: 5.15 mm T: 2.11 mm C: 2.15 mm
L: 9.30 mm H: 4.52 mm T: 1.82 mm C: 1.91 mm
L: 6.48 mm H: 3.19 mm T: 1.31 mm C: 1.33 mm

Range — Lower Oligocene – Middle Oligocene.

Discussion — A slight allometric growth has been observed in this species. In contrast to O. *difformis* the otoliths of this species become more slender during their individual lifes. The juvenile specimens of both species resemble each other strikingly, because the otoliths which are less than 5 mm long have nearly equal L/H and L/T ratios (Fig. 3a, b).

Adult otoliths become relatively thinner and longer. The outer surface of the adult otoliths has a distinct part which is longitudinally concave.

The ornamentation of the outer surface is not pronounced and consists mainly of some indistinct folds. The outer surface of O. *difformis* in contrast is highly sculptured, the pattern of which changes with age.

The medium-sized otoliths have a distinct pattern which has been described as characteristic for var. *joachimica* by Koken (1891, p. 101). This pattern changes rather abruptly into coarser knobs which are typical of O. *difformis typus* (Koken,

1891). The general description of O. *hilgendorfi* as given by Weiler (1942, p. 103) agrees with the otoliths of *H. acutangula,* but only one otolith (Weiler, 1942, pl. 13, fig. 3) can be assigned to this species. All other otoliths possess a different dorsal rim with a coarse undulation, also to observe in Koken's specimen (1891, pl. 5, fig. 14), which unfortunately seems to be eroded.

Hoplobrotula acutangula hermsdorfensis (Koken, 1891)
Pl. 11, fig. 5.

1891 *Otolithus* (Ophidiidarum) *difformis* var. *hermsdorfensis* — Koken, p. 103, pl. 6, fig. 5.
1965 *Otolithus* (Ophidiidarum) aff. *hilgendorfi* Koken, 1891 — Zilch p. 470, pl. 35, fig. 15 (= holotype of *O.* (O.) *difformis* var. *hermsdorfensis* Koken, 1891).

Material — Brinkheurne Member: 3 sagittas (two are highly eroded).
L: 10.60 mm H: 4.55 mm T: 1.95 mm C: 2.05 mm

Range — Middle Oligocene.

Discussion — For a description see Koken (1891). Only three otoliths are available and they differ markedly in L/H ratio from *H. acutangula,* being much more slender. Although this feature is highly characteristic it is not justifiable to introduce another species because no further differences can be detected and there is not enough material. Koken's specimen of var. *hermsdorfensis* is eroded but in spite of that our otoliths resemble the type specimen closely.

ORDO BERYCIFORMES

Familia Trachichthyidae Bleeker, 1859
Genus *Hoplostethus* Cuvier & Valenciennes, 1829

? *Hoplostethus* sp.
Pl. 13, fig. 8.

Description — Small and compact otolith. Outline oval with sharp preventral angle. Blunt rostrum, eroded; excisura ostii small but clear-cut; antirostrum indistinct and rounded. Dorsal rim rounded with insignificant postdorsal angle. Rims without knobs.

Inner surface flat. Sulcus acusticus wide and relatively long. Ostium deep, cauda shallower; dorsal part of cauda distinctly deeper than ventral part. Posterior end of cauda clearly but slightly curved toward dorsal rim. Partly eroded area large and vaguely defined. Ventral furrow almost totally eroded.

Outer surface convex; in the middle an umbilical subsidence; some furrows and big knobs radiate roughly from the centre.

Material — Basal layer of Winterswijk Member: 1 sagitta, RGM 176 033.
L: 2.12 mm H: 2.13 mm T: 0.51 mm

Discussion — The otolith described is a juvenile one, which cannot be identified with other known fossil species of *Hoplostethus* (e.g. Koken, 1891) because allometric growth may influence the shape of the rims. Although this species most probably belongs to *Hoplostethus,* it can not be excluded that it belongs to the related genus *Gephyroberyx.*

ORDO PERCIFORMES

Familia Serranidae Richardson, 1817
Genus *Paralabrax* Girard, 1856

Paralabrax splendens sp. n.
Pl. 13, figs. 2, 3, 5, 7.

Type — Holotype: Pl. 13, fig. 5, RGM 176 018.
Locus typicus — Clay pit 'De Vlijt' near Winterswijk, The Netherlands.
Stratum typicum — Middle Oligocene, Rupelian, upper part of Brinkheurne Member.
Derivatio nominis — splendens (Latin) = brilliant, because of its beautiful appearance.

Diagnosis — *Paralabrax* species with slender otoliths, having a well-developed postdorsal angle close to the caudal end. Cauda narrow, straight; posterior end curves sharply toward ventral side.

Description of holotype — Otoliths fragile and of medium size. Outline elongated oval. All rims thin. Anterior part of dorsal rim rounded, fading into a straight part up to the distinct postdorsal angle. Dorsal rim behind this angle steeply inclined toward ventral rim. Entire dorsal rim irregularly knobbed. Ventral rim regularly and weakly rounded; posterior part eroded. Rostrum sharp and pronounced. No excisura ostii.

Inner surface convex and curved along long axis. Sulcus acusticus long and situated in the middle. Ostium somewhat shorter than cauda, widening toward the rim. Cauda straight and narrow; posterior part wider and abruptly bent toward ventral side. Crista superior distinct along entire sulcus, crista inferior only along cauda and less distinct. Area rather small but clearly bounded by four large knobs on dorsal inner face. No ventral furrow.

Outer surface concave and curved along long axis. Furrows radiate from the centre to the rims; they are most pronounced on the posterior part of the dorsal side and become deeper towards the rims. Rostral part thickened.

Material — Brinkheurne Member: 2 sagittas (1 juvenile), RGM 176 021, 176 022; upper part of Brinkheurne Member: 3 sagittas (2 juvenile ones) RGM 176 018-176 020; basal layer of Winterswijk Member: 1 juvenile sagitta, RGM 176 023.
L: 7.39 mm H: 2.98 mm T: 0.68 mm C: 1.45 mm (holotype)
L: 2.11 mm H: 1.07 mm T: 0.38 mm

Range — Middle Oligocene, Brinkheurne Member – basal layer of Winterswijk Member.

Variation — The adult paratype can be distinguished from the holotype mainly because the dorsal rim is more rounded and the postdorsal angle is less distinct.

The dorsal rim contains more and finer knobs. Furthermore three juvenile otoliths have been found which are relatively shorter than the adults. Other differences with respect to the large specimens are the undeveloped sculpturing and the presence of an excisura ostii, which is a common feature within many families of Perciformes.

Discussion — As reference material we used three extant species of *Paralabrax,* viz. *P. nebulifer* (Girard), *P. clathratus* (Girard), and *P. maculatofasciatus* (Steindachner), all from California, U.S.A. The most obvious fact is that the sulcus of all extant species is wider than that of the fossil. Furthermore the sulcus of the extant species is situated closer to the dorsal side, and the posterior part of the cauda bends more gradually towards the ventral side.

In both *Paralabrax* sp. (Herman, 1972) and *P. tenuicauda* Stinton, 1966, the posterior end of the cauda is very close to the ventral rim. This is not the case in the extant species nor in our *Paralabrax*. Moreover the outline of the two other fossil *Paralabrax* species is clearly different from that of *P. splendens* as well as the recent species. Therefore it is highly improbable that the species described as *Paralabrax* by Herman and by Stinton belong to this genus.

Familia Sparidae Bonaparte, 1831
Genus *Dentex* Cuvier, 1815

Dentex kokeni sp. n.
Pl. 11, fig. 4; Pl. 12, figs. 1-3.

1891 *Otolithus* (Sparidarum) *gregarius* Koken — Koken, p. 128, 129, figs. 18, 20; non fig. 19, nec pl. 7, figs. 7, 7a, 8, 8a.
1932 *Pagellus gregarius* (Koken) — Weiler, p. 338, fig. 30.

Type — Holotype: Pl. 12, fig. 1, Coll. PMHU Ot. 157 (Coll. Koken).
Locus typicus — Waldböckelheim, Mainz Basin, Federal Republic of Germany.
Stratum typicum — Middle Oligocene.
Derivatio nominis – named after Professor Ernst von Koken, the pioneer of otolithology, who found the first specimens of the new species.

Diagnosis — Rather large otoliths; the height is not much less than the length. In comparison with height and length the otoliths are thin. Sulcus clearly supramedial. Small and medium-sized specimens have a distinct excisura ostii.

Description of the holotype — A medium-sized, thin otolith with a compact pentagonal outline. Dorsal rim is composed of three straight parts, interrupted by sharp predorsal and postdorsal angles. The somewhat irregular knobs on the dorsal rim are usually rather big. Postdorsal angle far to the back. Rostrum and caudal point are partly broken. Ventral rim markedly and regularly rounded and ornamented with knobs which are more regular but smaller than those on the dorsal rim. Distinct excisura ostii. Small, rounded antirostrum. Highest part of otolith closer to rostrum than to caudal end.

Inner surface highly convex along the long axis, slightly convex along the height axis. Sulcus acusticus deep and clearly supramedial. Ostium somewhat deeper than cauda. End of cauda gradually but distinctly curves toward ventral side. Crista superior well-developed, crista inferior insignificant. Area large and deep. Some short and irregular furrows invade the area.

Outer surface longitudinally concave. Entire surface sculptured. Ventral part with smallest knobs which are regularly formed. Dorsal part with shallow and deep furrows and with irregular knobs. In the central part the ornamentation tends to be folds that are parallel to the height axis.

Material — Winterswijk Member: 1 juvenile sagitta; Middle Oligocene, Waldböckelheim: 3 sagittas, Coll. PMHU Ot. 157 (Coll. Koken); Middle Oligocene, Söllingen: 1 juvenile sagitta, Coll. PMHU Ot. 158 (Coll. Koken).
(L: 5.80 mm) H: 5.10 mm T: 1.02 mm (holotype)
(L: 6.92 mm) H: 5.69 mm T: 1.22 mm (paratype)
(L: 4.78 mm) H: 3.72 mm T: 0.85 mm (paratype)
(All specimens from Waldböckelheim)

Range — Middle Oligocene.

Variation — The juvenile otolith of Waldböckelheim is more highly and more regularly sculptured along the dorsal rim, has a deeper and sharper excisura and is more elongated in comparison with the holotype. The largest otolith has the coarsest and most irregular knobs of all specimens. The juvenile otolith of Winterswijk is the smallest of all specimens. It has the deepest excisura and the straightest cauda. These phenomena can also be seen in other species and genera of the Sparidae family.

Discussion — The type material of Sparidarum *gregarius* Koken belongs to more than one species. This mistake by Koken is understandable when we know that many species and even genera of the Sparidae have otoliths that resemble each other very closely. The new species certainly is an ancestor of one or more of the living *Dentex* species. Most likely Sparidarum *gregarius* belongs to another genus. Three of the six specimens of Coll. PMHU Ot. 157 are representatives of S. *gregarius*. Weiler has choosen a specimen of Koken's type material that is stored at Senckenberg, Frankfurt am Main, as lectotype for S. *gregarius* (see also Zilch, 1965, pl. 37, fig. 10) and there is no doubt that these three East Berlin specimens belong to this species.

The sample Ot. 158 (Coll. PMHU) contains one eroded juvenile sagitta of the new species. The two other specimens are in different states of preservation and belong to *'Trigla' rhombica* Schubert or a related form. The species and the state of preservation of the otoliths make it impossible for these otoliths to come from Middle Oligocene deposits. They certainly must be younger: Miocene or Late Oligocene most probably.

Genus *Polysteganus* Klunzinger, 1870

? *Polysteganus* sp.
Pl. 13, fig. 1.

Description — A large pentagonal otolith, the rostral part of which has been broken. Dorsal rim with irregular undulations and a distinct postdorsal angle. Ventral rim smooth with a pronounced midventral angle. Caudal end sharply pointed.

Inner surface clearly convex in both directions and smooth. Long medial sulcus with a wide ostium and a long, rather narrow cauda. Posterior part of cauda sharply bent towards ventral rim; this part is short. No cristae. The small area is limited to the part above the anterior half of the cauda. No ventral furrow.

Outer surface clearly concave in both directions. From the caudal point to nearly the centre of the outer surface is a rectilinear ridge. Above this ridge there is a triangular depression with a more or less fan-shaped pattern of shallow furrows. At the middorsal part coarse undulations run from the dorsal rim to the centre. Ventral part is rather smooth.

Material — Brinkheurne Member: 1 sagitta, RGM 176 024, don. M. C. Cadée. (L: 7.68 mm) H: 4.55 mm T: 0.94 mm

Range — Middle Oligocene, Brinkheurne Member.

Discussion — The outline of the otolith resembles that of the extant *Polysteganus undulosus* the most. The sulcus however shows more similarities with that of the extant *P. praeorbitalis,* especially the posterior part of the cauda. In other Sparidae this part often bends less abruptly towards the ventral side. Differences with respect to extant species are the more elongated shape and the more simple outline of our specimen.

Sparidarum sp. 1
Pl. 11, fig. 7.

Material — Basal layer of Winterswijk Member: 1 juvenile sagitta.
(L: 1.84 mm) H: 1.32 mm T: 0.29 mm

Range — Middle Oligocene, basal layer of Winterswijk Member.

Discussion — According to the shape of the sulcus and the outline of the otolith the specimen belongs to the Sparidae. The cauda of the sulcus is rather straight, the posterior part is slightly bent toward the ventral side. The rostral part is a bit broken but in spite of this the rostrum, antirostrum and excisura ostii are clearly visible. The outline is oval with regularly undulating rims. The dorsal rim has an indistinct postdorsal to middorsal angle.

Recent representatives of this family always have an outline with more pronounced features than our fossil specimen. Unfortunately no juvenile otoliths of extant species are available to us. Nevertheless it is quite probable that juvenile sagittas always have less pronounced characteristics than adult sagittas of the same species.

It may be possible that our specimen is a juvenile of *Pagrus distinctus* (Koken, 1891), which is known from the Middle Oligocene of Germany. They have the middorsal angle in common. Also the position of the sulcus is about the same, judging from the photograph of the lectotype of *P. distinctus* in Zilch (1965, pl. 37, fig. 11).

Sparidarum sp. 2
Pl. 11, fig. 6.

Material — Brinkheurne Member: 1 strongly eroded juvenile sagitta.

Range — Middle Oligocene, Brinkheurne Member.

Discussion — Although this specimen is highly eroded, it clearly differs from Sparidarum sp. 1 because of the rounded predorsal angle, a more pronounced postdorsal angle which is situated nearer to the caudal end and the curvature of the posterior part of the cauda towards the ventral side. A more precise identification of this otolith is impossible because it is so poorly preserved.

Familia Carangidae Rafinesque, 1815

Carangidarum *robustus* sp. n.
Pl. 14, fig. 4.

Type – Holotype: Pl. 14, fig. 4, RGM 176 025, don. V. W. M. van Hinsbergh.
Locus typicus — Clay pit 'De Vlijt' near Winterswijk, The Netherlands.
Stratum typicum — Middle Oligocene, Rupelian, Brinkheurne Member.
Derivatio nominis — Robustus (Latin) = robust, vigorous, because of its shape.

Diagnosis — A compact otolith of the Carangidae with a very pronounced rectangular postdorsal angle. Dorsal rim between predorsal and postdorsal angles slightly concave. Rostrum blunt, ostium short, no excisura ostii.

Description of holotype — A compact otolith of medium size. Outline irregularly pentagonal. Dorsal rim with a blunt predorsal angle, a very pronounced rectangular postdorsal angle and irregular large knobs. Dorsal rim before predorsal angle convex, between predorsal and postdorsal angles slightly concave and behind postdorsal angle rather straight. Ventral rim sharply and regularly rounded; only the more convex posterior end irregularly knobbed. Rostrum blunt, no excisura ostii.

Inner surface highly convex along the length and height axes; even more convex in the posterior part. Deep sulcus acusticus supramedial but end of cauda medial. Ostium wide, opening upwards at the dorsal rim. Cauda about 2.5 times as long as ostium. Posterior end of cauda sharply bent towards ventral side. Dorsal boundary of cauda straight up to the curvature. Ventral boundary of cauda sigmoidal. Cristae equally obvious. Area large. No ventral furrow.

Outer surface highly concave lengthwise, slightly concave in the direction of the height, although only at the posterior end. Dorsal part with pronounced furrows and knobs perpendicular to the rim and parallel to each other. Near the caudal end a deep and obviously incised furrow and some shallow ones. Beginning from the rostrum a sharp fold runs in parallel with the ventral boundary of the ostium. Central part softly and irregularly curved.

Material — Brinkheurne Member: 1 sagitta, RGM 176 025.
L: 6.35 mm H: 4.16 mm T: 0.88 mm C: 1.36 mm

Range — Middle Oligocene, Brinkheurne Member.

Discussion — The shape of the sulcus is typical of the Carangidae family. However no otoliths of extant members of this family are known to us which have an outline that resembles that of the fossil species.

Familia Pempheridae

Pempheridarum sp.
Pl. 13, fig. 6.

Description — Tiny, nearly circular otoliths. Dorsal and ventral rims regularly rounded. Many small knobs on ventral rim, a few large knobs on dorsal rim. Excisura ostii deep and sharp. Rostrum and antirostrum rounded.

Inner surface slightly convex. Sulcus acusticus supramedial. Ostium and cauda nearly of the same length, but ostium almost twice as wide as cauda. Posterior part of cauda slightly bent towards ventral side. Rostral part of ventral boundary of ostium clearly bent toward dorsal side. A rounded rather massive crista superior is present along part of the cauda. Area relatively large. Ventral furrow vague and rather far from ventral rim. Part of inner surface between ventral furrow and sulcus elevated. The small furrows are longer in the dorsal part than in the ventral part.

Outer surface concave and ornamented with pronounced knobs and sharp and deep furrows perpendicular to the rims. The depressed centre is full of tiny knoblets; the deep furrows do not traverse this field.

Material — Upper part of Brinkheurne Member: 1 sagitta, RGM 176 026; basal layer of Winterswijk Member: 1 sagitta, partly eroded, RGM 176 027.
L: 0.81 mm H. 0.74 mm T: 0.19 mm

Range — Middle Oligocene, upper part of Brinkheurne Member – basal layer of Winterswijk Member.

Discussion — The outline of the otoliths and the shape of the sulcus indicate that the specimens most probably belong to the Gerridae or Pempheridae. The ventral boundary of the ostium with its rostral part bent toward the dorsal side is typical of the Pempheridae, and therefore we have incorporated these otoliths in this family.

Familia Acropomidae

Acropomidarum *martini* sp. n.
Pl. 13, fig. 4.

Type — Holotype: Pl. 13, fig. 4, RGM 176 034, leg. M. C. Cadée.
Locus typicus — Clay pit 'De Vlijt' near Winterswijk, The Netherlands.
Stratum typicum — Middle Oligocene, Rupelian, basal layer of Winterswijk Member.
Derivatio nominis — Named after Mr Martin C. Cadée, because of his investigations into the Middle Oligocene and his donation of an important part of the otolith material for this publication.

Diagnosis — A pentagonal otolith of medium size. Postdorsal angle rather rounded. Ostium wide with ventral boundary parallel to long axis.

Description of holotype — A pentagonal otolith of medium size. Rims smooth with very weak knobs. Predorsal angle weak, postdorsal angle rounded. All parts of dorsal rim before and behind the angles are straight. Posterior part of dorsal rim makes an angle of c. 70° with the long axis. Ventral rim asymmetrically and rather markedly rounded. Pointed rostrum slightly broken on ventral side. Sharp, small excisura ostii. Antirostrum rather sharp.

Inner surface slightly convex along the long axis, flat along the height axis. Straight sulcus acusticus medial. Triangular ostium distinctly deeper than cauda. Anterior part of ventral boundary of ostium straight and parallel to the long axis. Dorsal boundary of ostium straight; it runs upwards to the dorsal rim. Cauda narrower and a little bit longer than ostium. Dorsal boundary of cauda somewhat sigmoidally bent. Posterior part of cauda slightly curved towards ventral side. Behind cauda a postcaudal depression. Long crista superior sharp and distinct. No crista inferior. Large area along entire sulcus, extending to halfway between the sulcus and the dorsal rim. Ventral furrow close to the ventral rim.

Outer surface slightly concave lengthwise and convex in the direction of the height. A low, large central knob is surrounded by a shallow ring-shaped depression. An irregular coarse pattern of folds parallel to the height axis is characteristic. A clear-cut furrow extends from the excisura ostii.

Material — Basal layer of Winterswijk Member: 1 sagitta, RGM 176 034.
(L: 4.38 mm) H: 2.88 mm T: 0.79 mm

Range — Middle Oligocene, basal layer of Winterswijk Member.

Discussion — Kotthaus (1974) showed an otolith of the extant *Acropoma japonicum* Günther from the Indian Ocean. Although the otolith was corroded by formalin and is therefore not very well-preserved, the shape of the sulcus (especially its ventral boundary) resembles the fossil species described above. The recent species however has a more oval outline.

The fossil species described as Percidarum *opinatus* Procházka (see Schubert, 1906; Weiler, 1950; Brzobohatý, 1967; Dieni, 1968; Robba, 1970) shows many similarities with Acropomidarum *martini*. The main differences are the upwards curve of the ventral boundary of the ostium, the steeper posterior part of the dorsal rim and the more pronounced postdorsal angle. Certainly Percidarum *opinatus* does not belong to the family of Percidae.

Familia Centrolophidae
Genus *Mupus* Cocco, 1833

Mupus neumanni Schwarzhans, 1974
Pl. 14, figs. 1-3.

1974 *Mupus neumanni* — Schwarzhans, p. 111, figs. 71-73, pl. 2, fig. 9.

Description — Small, flat and thin otoliths with an elongated oval shape. Nearly all specimens have lost their rostral parts. Dorsal rim slightly rounded with a clear but blunt postdorsal angle, which is situated not far from the distinctly pointed caudal end. Rim between postdorsal angle and caudal end is straight, forming an angle of c. 60° with the long axis of the otolith. Ventral rim rounded and running

beyond the cauda. Both rims are clearly and rather finely knobbed. Dorsal rim is somewhat more coarsely knobbed than ventral rim.

Inner surface flat. Cauda straight, supramedial; caudal end bent towards ventral side. Crista superior low and rather sharp; no crista inferior. Area long, narrow and shallow.

Outer surface flat with a central depression. Furrows and knobs more or less perpendicular to the rims, irregularly formed and most pronounced near the rims. Ventral side more highly sculptured than dorsal side.

Material — Brinkheurne Member: 3 sagittas: RGM 176 031; upper part of Brinkheurne Member: 14 sagittas, RGM 176 028-176 030; basal layer of Winterswijk Member: 4 sagittas (1 specimen RGM 176 032).

Range — Middle Oligocene – Upper Oligocene.

Discussion — Our specimens of *M. neumanni* differ from the extant *M. ovalis* (Valenciennes) because they have coarser knobs and a more supramedial sulcus. The Eocene *M. confinis* Nolf has a postdorsal angle which is situated farther from the caudal end, and the most caudal part of the dorsal rim forms a more obtuse angle with the long axis of the otolith than in our specimens.

Familia Trichiuridae Rafinesque, 1810

Trichiuridarum *wongratanai* Nolf, 1977
Pl. 14, figs. 10-11.

1977 «genus Trichiuridarum» *wongratanai* — Nolf, p. 59, pl. 17, fig. 7.

Description — One small, badly preserved otolith with an elongated outline; the rostral part is broken off. Dorsal and ventral rims irregularly knobbed.

Inner and outer surfaces both considerably eroded. Only a part of the big crista superior is visible. Sulcus seems to be straight. Area long and narrow. On the outer surface the original sculpturing is only present along the rims; it consists of clearly defined knobs and furrows perpendicular to the outline.

A much better specimen has been found in the clay pit at Herselt, 400 m N of the church of Ramsel, province of Antwerp, Belgium, from the *Serpula septaria* - *Ancistrosyrinx volgeri* Assemblage Zone (see Pl. 14, fig. 11).

Material — Upper part of Brinkheurne Member: 1 eroded sagitta, RGM 176 040.
(L: 1.69 mm) H: 0.92 mm (T: 0.25 mm)
L: 2.26 mm H: 0.86 mm T: 0.37 mm

Range — Middle Oligocene, upper part of Brinkheurne Member.

Discussion: The outline and the sulcus of the otolith closely resemble those of the otoliths of the extant genus *Trichiurus*. Therefore a close relationship with this genus must exist.

Familia Blenniidae Rafinesque, 1810

Blenniidarum *minisculus* (Nolf, 1977)
Pl. 15, figs. 8-15.

1977 «genus aff. *Liparis*» *minisculus* — Nolf, p. 45, pl. 13, figs. 14-16.

Description — Very small, compact otoliths. Outline rounded triangular and smooth. Dorsal rim with obvious mediodorsal angle. Ventral rim regularly rounded. Rostrum large and massive. Excisura ostii small and sharp. Antirostrum small.

Inner surface flat to slightly convex. Clear straight medial sulcus acusticus with a big triangular ostium and a much smaller and shorter cauda. Ostium and cauda are separated by a high collum. Ostium widens towards the dorsal rim. Big and indistinct area above sulcus, intersected by two shallow furrows which are perpendicular to the dorsal rim. Clear ventral furrow, relatively far from ventral rim and covering about half the length of ventral side. Between cauda and ventral furrow is a pronounced thickening. Between ventral furrow and ventral rim indistinct small furrows extend perpendicular to the rim.

Outer surface clearly convex. Some shallow furrows radiate to the rims; they do not exist in the centre which is slightly depressed.

Material — Upper part of Brinkheurne Member: 38 sagittas, RGM 176 042 - 176 049; basal layer of Winterswijk Member: 7 sagittas (4 specimens RGM 176 050).

L: 1.17 mm	H: 0.67 mm	T: 0.29 mm	(Pl. 15, fig. 14)
L: 1.25 mm	H: 0.82 mm	T: 0.35 mm	(Pl. 15, fig. 13)
L: 1.33 mm	H: 0.81 mm	T: 0.40 mm	(Pl. 15, fig. 12)
L: 1.35 mm	H: 0.84 mm	T: 0.43 mm	(Pl. 15, fig. 11)
L: 1.21 mm	H: 0.77 mm	T: 0.34 mm	(Pl. 15, fig. 10)
L: 1.03 mm	H: 0.58 mm	T: 0.25 mm	(Pl. 15, fig. 8)

Range — Middle Oligocene, upper part of Brinkheurne Member – basal layer of Winterswijk Member.

Variation — This species shows considerable variability. The outline can be smooth to somewhat knobbed. The curvature of the ventral rim can be pronounced to slight so that the rostrum and caudal end also vary in shape. Sometimes the sulcus is somewhat inframedial. Frequently the sulcus forms a small angle with the long axis of the otolith, whereby the cauda points towards the ventral side. Although the convexity and shallow central depression have been found on the outer surfaces of all specimens, the number and nature of the foldlike furrows are variable.

Discussion — The outline of the otoliths and the shape of the sulcus are characteristic of the Blenniidae. Unfortunately we did not have enough recent material to identify the genus of our fossil specimens in this family which is very rich in species and genera.

ORDO SCORPAENIFORMES

Familia Scorpaenidae Risso, 1826
Genus *Pontinus* Poey, 1860

? *Pontinus foreyi* Nolf, 1977
Pl. 14, fig. 5.

1977 «genus aff. *Pontinus*» *foreyi* — Nolf, p. 40, pl. 12, fig. 5.

Description — A small otolith with an outline of a rounded isosceles triangle. Dorsal and ventral rims have been built up from a few big lobes. Dorsal rim with a rounded middorsal angle. Rostrum and caudal end rather pointed. No antirostrum and excisura.

Inner surface slightly convex. Sulcus divided into a short ostium and a long cauda (cauda nearly twice as long as ostium). Cauda straight, only posterior part somewhat bent towards ventral side. Clearly triangular ostium with a wide opening at the rim. Crista superior only distinct along anterior part of cauda. A few small furrows are perpendicular to the rims.

Outer surface slightly concave lengthwise, flat in the direction of the height. Some coarse knobs are separated by distinct furrows perpendicular to the rims.

Material — Basal layer of Winterswijk Member: 1 sagitta, RGM 176 035, don. H. van der Made.
L: 1.08 mm H: 0.70 mm T: 0.25 mm

Range — Middle Oligocene, basal layer of Winterswijk Member.

Discussion — Since our specimen is a small, juvenile otolith with the general appearance of scorpaenid otoliths, identification of the genus is difficult.

Familia Triglidae Risso, 1826
Genus *Trigloporus* J. L. B. Smith, 1934

? *Trigloporus* sp.
Pl. 14, figs. 6-9.

Description — Only two eroded adult specimens have been found. Both are clearly triangular, whereby the caudal part in particular is pronounced but not massive, and more or less pointed.

One otolith is medium-sized, with a more rounded, compact shape. Dorsal rim with a rounded middorsal angle. Posterior part of dorsal rim straight, anterior part regularly rounded. Ventral rim regularly and rather sharply curved; some indistinct knobs occur on the posterior part of this rim. Rostrum small and pointed, antirostrum insignificant, no excisura ostii. Caudal end bluntly pointed.

Inner surface convex. Small furrows from dorsal rim invade the area; from ventral rim they extend to the ventral furrow. Sulcus acusticus dumbbell-shaped. Anterior part of cauda narrow, posterior part somewhat smaller than ostium. Indistinct cristae only visible along the anterior part of cauda. Deep oval area. Ventral furrow for the most part missing due to erosion.

Outer surface slightly concave. From the slightly elevated centre some small furrows radiate to the dorsal rim.

Material — Upper part of Brinkheurne Member: 4 sagittas (one juvenile; 3 specimens clearly eroded), RGM 176 036 - 176 039.
L: 2.53 mm H: 1.69 mm (T: 0.45 mm)
(L: 2.10 mm) H: 1.68 mm T: 0.50 mm
L: 2.02 mm H: 1.42 mm (T: 0.47 mm)

Range — Middle Oligocene, upper part of Brinkheurne Member.

Discussion — Koken (1891) has described the species *Trigla adjuncta* from the Middle Oligocene of Germany. We could study the holotype of this species and it was clear that it is not a triglid species but a callionymid one. Thus no triglid species was known from the Middle Oligocene of western Europe. Most probably therefore our specimens represent a new species, but because of the lack of a well-preserved specimen a new species has not yet been described.

The variation among the otoliths of the many species belonging to the Triglidae is considerable, as can be concluded from the many excellent photographs of recent triglid otoliths published by Chaine & Duvergier (1934); rounded specimens occur together with more angular ones within all species. For the present therefore we cannot find any reason to expect more than one fossil species in our poor triglid material, in spite of the considerable variation among the otoliths. The agreement with the otoliths of *Trigloporus lastoviza* (Brünnich, 1768) (synonyms: *Cuculus lineatus* Pennant, 1769 and *Trigla lineata* Gmelin, 1789) is the greatest. The development of the dorsal rim, the caudal end and the excisura ostii is similar for the two species. Also the thicknesses of the otoliths are about the same. It is however very difficult to identify the genus within the Triglidae with the help of otoliths because of the great similarity among the otoliths belonging to different genera of this family and because of the great variability within the species. Moreover, it is also possible that our species belongs to an extinct genus. In this respect nothing more can be said until additional information is available about the Triglidae, although so far only incidental finds have been made.

Scorpaeniformorum *ellipticus* (Koken, 1884)
Pl. 15, figs. 1-7.

1884 *Otolithus (Triglae) ellipticus* — Koken, p. 555, pl. 12, figs. 9, ?10.
1891 *Otolithus (Triglae) ellipticus* Koken — Koken, p. 130, fig. 21 (p. 131).
1942 *Peristedion ellipticum* (Koken) — Weiler, p. 63, pl. 4, figs. 11-13, ?15, non pl. 12, fig. 9.
1967 *Peristedion ellipticum* (Koken) — Brzobohatý, p. 145, pl. 4, figs. 6, 7.

Description — Strong otoliths of medium size; outline oval. Caudal part truncated in adult specimens and bluntly pointed in juveniles because of presence of a post-dorsal angle in adult specimens. Dorsal rim irregularly curved with big lobes with different shapes in various specimens. The highest point of the dorsal rim is situated in the middle; this is more pronounced as the specimens increase in size. The excisura ostii is bigger and deeper in juvenile than in adult otoliths; in some adults it is missing completely. Rostrum pointed; antirostrum more rounded, in juvenile

specimens pointed. Ventral rim regularly rounded with indistinct coarse knobs. The older the animals become, the closer the caudal end approaches the ventral side.

Inner surface convex in both directions. Sulcus acusticus dumbbell-shaped and deep, especially the ostium and the caudal end. Cauda is about 1.5 times the length of the ostium. Ostium wider than cauda; the ventral boundary of the posterior part of the cauda curves towards the ventral side so that the posterior part of the cauda becomes as wide as the ostium. Crista superior distinct, crista inferior hardly developed. Area large and deep in adult specimens, weakly developed in juveniles. Ventral furrow vague and close to the ventral rim.

Outer surface somewhat concave in adult and almost flat in juvenile specimens. A furrow coming from the excisura ostii and another furrow coming from the anterior part of the ventral rim separate the rostral part from the rest of the outer surface. Directly behind the rostral part the outer surface is elevated and then depressed. Juvenile otoliths are sculptured with coarse knobs. The more adult specimens have only a few furrows which radiate from the centre and occur predominantly on the dorsal part.

Material — Brinkheurne Member: 8 sagittas (4 specimens RGM 176 052, 176 058); upper part of Brinkheurne Member: 11 sagittas (10 specimens RGM 176 053 - 176 057); basal layer of Winterswijk Member: 1 sagitta, RGM 176 051.

Range — Middle Oligocene – Upper Oligocene.

Discussion — The Miocene otolith shown by Weiler (1942, pl. 12, fig. 9) certainly belongs to a different genus since its outline differs in many respects, especially the posterior part of the otolith. The juvenile otolith from the Miocene shown by Weiler (1942, pl. 4, fig. 15) has a remarkable predorsal angle, no clear antirostrum and no excisura. Therefore it is unlikely that this specimen belongs tot *S. ellipticus*. Thus the occurrence of S. *ellipticus* in the Miocene is not yet proven.

ORDO INCERTA

Gen. et sp. indet.
Pl. 15, fig. 16.

Description — A medium-sized, rather thick, elongated pear-shaped otolith. Dorsal rim regularly knobbed with large, low knobs. Anterior part of dorsal rim slightly concave, middle part weakly rounded, posterior part descends relatively steeply to the rounded caudal end. Ventral rim regularly curved, nearly smooth. Rostrum massive.

Inner surface flat along long axis, convex along height axis. Posterior part rather damaged. A long and wide sulcus lies somewhat obliquely whereby the posterior part is closer to the ventral side than the anterior part. No clear distinction between cauda and ostium is visible. Caudal end of sulcus slightly broken. Sulcus is entirely closed. No colliculi. Cristae both well-developed, broad, but not sharp. Crista inferior gradually rises from the sulcus and terminates abruptly at the ventral part. Crista superior less massive, along the ostial part of the sulcus steeply elevated, along the caudal part rising gradually. Area small, situated mainly before the middle of the dorsal part.

Outer surface slightly concave, somewhat twisted along the long axis. The rostral part, one third of the outer surface, is nearly smooth. The outer surface has a large, blunt elevation at both the dorsal and caudal ends. The remaining part is covered with small irregularly spaced knobs.

Material — Upper part of Brinkheurne Member: 1 sagitta, RGM 176 059. Basal layer of Winterswijk Member: 1 sagitta.

Range — Middle Oligocene, upper part of Brinkheurne Member – basal layer of Winterswijk Member.

Palaeoecological remarks on the fish fauna

It is always a difficult task to determine the life habits of fossil species and such an enterprise becomes more precarious as they date from older periods. Therefore uncertainties with regard to the ecological niches will surely exist in many cases when we consider the individual species separately.

The most important goal of a survey of this kind however is to discover the general conditions in which the fauna of bony fishes lived. For this purpose a rather rough general impression will be sufficient.

We start from the supposition that most fishes will not have changed their life habits essentially during their evolutionary history. For the majority of the Middle Oligocene otoliths the genus names are not known or are uncertain and so we have to rely mostly on the general trends within each family. The mode of life of the recent representatives is taken as the starting point. If different results are obtained, they are weighed against one another.

We have consulted the following literature for the mode of life of recent fishes: Hureau & Monod (1973), Lindberg (1974), Lythgoe & Lythgoe (1974), Muus (1966), and Svetovidov (1962).

DEPTH INDICATIONS

Various data can be used to determine the depth of the sea. In the first place pure bathymetric data for recent relatives of the fossil species are available in biological literature. Another important source of information is the mode of life with respect to the sea bottom: the benthic way of life versus the pelagic. There is a simple rule which tells us that the more pelagic elements found in a fauna the deeper the sea has been. In deeper water the number of benthic animals diminishes markedly, whereas that of pelagic animals generally increases or remains the same. This refers to the number of individuals as well as the number of species. Finally the trophic processes of the benthic species can provide us with some information about the depth. Herbivorous species self-evidently are limited to those depths which can be penetrated by light, whereas fishes of prey and omnivorous species are not restricted to these shallower waters.

The two most abundant species are *Colliolus parvus* and *Argentina parvula,* both of which must have been small fishes. Many species of the family of Argentinidae are pelagic, although some live on or close to the bottom. They seem to

prefer however to live along the lower part of the shelf or the (upper part of the) continental slope. Most probably the fossil species also had a pelagic mode of life and lived in moderately deep water.

The fishes of the species *Colliolus parvus* rarely exceeded a length of 7 cm, if the ratio between the length of the fish and the length of the otoliths has not changed markedly during the evolution from the Middle Oligocene species up to the extant species *Neocolliolus esmarki*. The latter species lives close to the sea bottom, preferably at depths of 80 to 200 m. The young specimens of up tot 5 - 6 cm however are pelagic, as is common for many codfish species. Therefore it is probable that *C. parvus* was pelagic during its entire life.

The families of Brotulidae and Ophidiidae are well-represented, both in the number of species and the number of specimens. Those Ophidiidae which are known from present day European seas are benthic animals which live on the shelf and are seldom encountered. Most of the 14 living European species of the Brotulidae are benthic, only three are pelagic. Without a doubt most of the species live at depths ranging from several hundreds of metres to even more than 1000 m; only one species is known to prefer water 30 m deep.

Of the Gadidae family the species *Gadichthys altus, Palaeogadus emarginatus,* and *P. compactus* probably lived in deep waters. *G. altus* is closely related to the recent species *G. thori,* which is bathypelagic and lives at depths of 200-1000 m. The *Palaeogadus* species are related to the recent *Molva* species, which also prefer deep waters. It is known that *Molva molva* and *M. dypterygia* are benthic. The former lives mainly at depths of 200 - 400 m, preferably on rocky bottoms; the latter prefers sandy bottoms at depths of 200 - 1000 m. Both species can live easily in deeper waters.

A pelagic mode of life is very probable for the following species: Clupeiformorum *planus, Alosa* sp., *Pterothrissus umbonatus, Zaphotias cyclomorphus* (100-600 m), Carangidarum *robustus, Mupus neumanni,* and *Hoplostethus* sp. (180-500 m). The depths listed in parentheses are the data for living European relatives. Trichiuridarum *wongratanai* belongs to the family of Trichiuridae all of which are benthopelagic, living mostly above the continental slope.

It is fairly certain that the following species led a benthic life: *Anguilla rouxi,* Congridarum *trapezioides, Palaeoraniceps tuberculosus, Paralabrax splendens,* all members of the Sparidae family, Acropomidarum *martini, Pontinus foreyi,* ? *Trigloporus* sp., and Blenniidarum *minisculus. Acropoma japonicum* lives nowadays along the deeper parts of the shelf and the edge of the continental slope at depths of c. 200 m in the Indian Ocean and the Western Pacific (Kotthaus, 1974). The living relative of *Pontinus foreyi, P. kuhlii,* lives on hard bottoms at the limit of the continental slope at dephs of 100-460 m.

Although most species are indicative of a rather deep sea, some in fact do not follow this pattern. Adult as well as juvenile otoliths of *Paralabrax splendens* have been found in the Middle Oligocene clay of Winterswijk. Therefore it is very likely that this species is autochthonous here. Nowadays *Paralabrax* species are abundant in shallow waters, for example along the southern Californian coast (Fitch, 1966). They are typical shelf dwellers.

Blenniidarum *minisculus* is a common species; most of the recent relatives live on the shelf. Many of them even inhabit very shallow waters close to the coast.

There are also some rare species which would be expected to inhabit shallow seas. *Raniceps raninus* lives today in shallow marine waters up to 20 m deep and even penetrates estuaries. It is rare for this species to be found at depths of 100 m.

Only two adult and no juvenile otoliths of the fossil *Palaeoraniceps tuberculosus* were found. Juvenile specimens of this species commonly occur in the Sands of Berg (Belgium) which were deposited under shallow marine conditions during the Middle Oligocene. It is feasible to suppose that adult specimens may sometimes have swum to depths greater than those of their normal mode of life.

In the Sparidae family many species are herbivorous, although most of these also feed on small invertebrates such as molluscs, crabs, and ophiuroids. This group also includes pure predators. Nearly all members of this family are restricted to the shelf. The occurrence of three juvenile specimens in the otolith fauna can be explained by assuming that these small fishes were eaten by larger animals that lived in shallow as well as deep waters.

Summarizing all data, 11 out of a total of 35 species were probably pelagic, including the two most common species, whereas at the most 22 species can be considered benthic. The remaining species cannot be identified sufficiently or the mode of life of their living relatives is not known to us.

The majority of the fossil species seem to have lived in rather deep water, judging from the mode of life of their recent relatives. The mollusc and foraminifera faunas also indicate a deep sea. Boekschoten (1963) concluded, with the help of palaeoecologic interpretations of the mollusc fauna, that the Middle Oligocene sea near Winterswijk was at least 200 and at most 500 m deep. The benthonic foraminifera fauna from a boring in the Middle Oligocene clay in the Peel region, about 100 km SW of Winterswijk, was studied by Brouwer (1977). Bathymetric data of recent relatives of these foraminifera suggest a sea depth of more than 300-500 m.

Judging from the bony fish fauna as a whole the most likely theory is that the depth of the sea near Winterswijk is consistent with the lower part of the shelf (100-200 m deep). Quite a number of species could have lived in a deeper sea, only a few in a possibly shallower sea.

If the sea was as deep as 300-500 m, or even deeper as Brouwer (1977) suggests, it becomes difficult to explain the general geological setting of the Middle Oligocene North Sea. In that case one would have to accept a fairly rapidly sloping sea bottom, so that the shelf would become only a narrow belt less than 80 km wide along the continent, for the shore at that time was situated not far from the southern border of Southern Limburg.

Moreover it is probable that the older deposits below the Septaria Clay were formed in a shallow marine environment. If one assumes that the sea depth was many hundreds of metres, involved tectonic events have to be accepted. In such a case the continental crust would have had to sink considerably in the Netherlands. This would probably have caused important faults, which are however unknown. Moreover other evidence of tectonic instability is lacking.

CLIMATIC INDICATIONS

Since the Middle Oligocene sea near Winterswijk was fairly deep, surely considerable temperature differences must have existed between the surface layers and the water near the bottom. Therefore we have to remember whether we are dealing with pelagic or benthic fishes when we consider the individual species.

We can start from the supposition that most families and genera will not have changed their temperature range essentially during their existence, although exceptions are possible. Of course a temperature indication for a fossil species

will be much more precise when the genus can be identified, and it usually will be less precise when only the family name is known. Unfortunately the genus name of many species could not be identified as a result of the lack of sufficient recent material for comparison. For the present these fishes cannot help us much.

Probably the water on the surface as well as at the bottom was not very warm. The presence of many members of the codfish family (Gadidae), which nowadays preferably inhabit temperate and cold seas, is an important indication of this. *Colliolus parvus,* the most common species of all, presumably was pelagic, as stated above. *Gadichthys altus* most probably was also a pelagic fish, although it will have lived in deeper waters than *C. parvus*. The presence of two *Palaeogadus* species with a presumable benthic mode of life indicates rather low temperatures for the bottom waters.

The best argument for rather cool conditions in the Middle Oligocene sea however can be furnished by a codfish that lived simultaneously along the coast of this sea. In the shallow marine deposits of the Sands of Berg, in the NE part of Belgium, *Trisopterus elegans* was by far the most common species. This species is markedly predominant in the otolith fauna of these sands (see Gaemers, 1972). Another member of the Gadidae, *Palaeoraniceps tuberculosus,* appears to be much more numerous in some parts of the Sands of Berg than is evident from previously published data (Gaemers, 1972). Recent relatives of both species live in the temperate North Sea.

On the other hand there are some species which are fairly reliable indicators that point to temperatures above the temperate range; they include the following species: *Paralabrax splendens, Pterothrissus umbonatus, Mupus neumanni,* and Acropomidarum *martini.*

The conclusion that can be drawn from the above discussion is that the temperature must have been subtropical to temperate. Certainly the Middle Oligocene North Sea was warmer than it is at present.

Palaeogeographical remarks on the fish fauna

Four families dominate the bony fish fauna of the Middle Oligocene of Winterswijk with respect to the number of individuals and/or the number of species. These families are the Argentinidae, Gadidae, Brotulidae, and Ophidiidae.

Of these families the first does not provide us with any interesting information, because this group of fishes has a worldwide distribution. The Gadidae is a typical European family and many representatives can be found in Europe from the Palaeocene up to the present.

The Ophidiidae and Brotulidae on the other hand are found nowadays predominantly in Indo-Pacific waters, although they are not absent in the Atlantic Ocean. The general trend of the occurrence of these families in the Tertiary of the North Sea Basin explains this phenomenon. During Eocene times the number of species and individuals of these families was at a maximum. During the Early and Middle Oligocene their numbers decreased markedly but both families were still important. Since Late Oligocene times they no longer play an important role, quantitatively. These facts can be explained by the general shrinkage of the Tethys in the course of the Tertiary.

The occurrence of members of the families of Acropomidae and Pempheridae also suggests that a good-sized open communication must still have existed between the Middle Oligocene North Sea and the Tethys Ocean. Both families at present have an Indo-Pacific distribution.

Paralabrax splendens occupies a peculiar place in this discussion. Three recent species of the *Paralabrax* genus live along the Pacific coast of California; one species, *P. dewegeri,* inhabits the sea outside the Venezuelan coast and thus lives in the Atlantic realm (personal communication of Dr M. Boeseman). The present day distribution of *Paralabrax* makes it difficult to conclude whether a Tethyan or an Atlantic origin is more probable.

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Manuscript received 31 January 1978.

Plates 1-15

Plate 1

Figs. 1-4. *Pterothrissus umbonatus* (Koken, 1884)
1. Brinkheurne Member, coll. V.W.M. van Hinsbergh, don. M. C. Cadée, x 7.5.
2. Brinkheurne Member, coll. V.W.W. van Hinsbergh, don. M. C. Cadée, x 5.
3. Brinkheurne Member, coll. P. F. L. de Groot, RGM 85 513, x 7.5.
4. Brinkheurne Member, coll. M. Freudenthal, RGM 127 064, x 7.5.

Figs. 5-6, 8. Clupeiformorum *planus* sp. n.
5. Holotype, basal layer of Winterswijk Member, coll. H. van der Made, RGM 175 953, x 15.
6. Paratype, basal layer of Winterswijk Member, coll. A. W. Janssen, RGM 175 956, x 15.
8. Paratype, upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 175 954, x 15.

Fig. 7. ? *Alosa* sp. Upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 175 958, x 15.

Figs. 9-15. *Argentina parvula* (Koken, 1891)
9. Upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 175 961, x 10.
10. Winterswijk Member, coll. V. W. M. van Hinsbergh, x 10.
11. Upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 175 961, x 10.
12. Basal layer of Winterswijk Member, coll. V. W. M. van Hinsbergh, x 10.
13, 14. Brinkheurne Member, coll. V. W. M. van Hinsbergh, x 10.
15. Basal layer of Winterswijk Member, coll. V. W. M. van Hinsbergh, x 10.

Plate 1

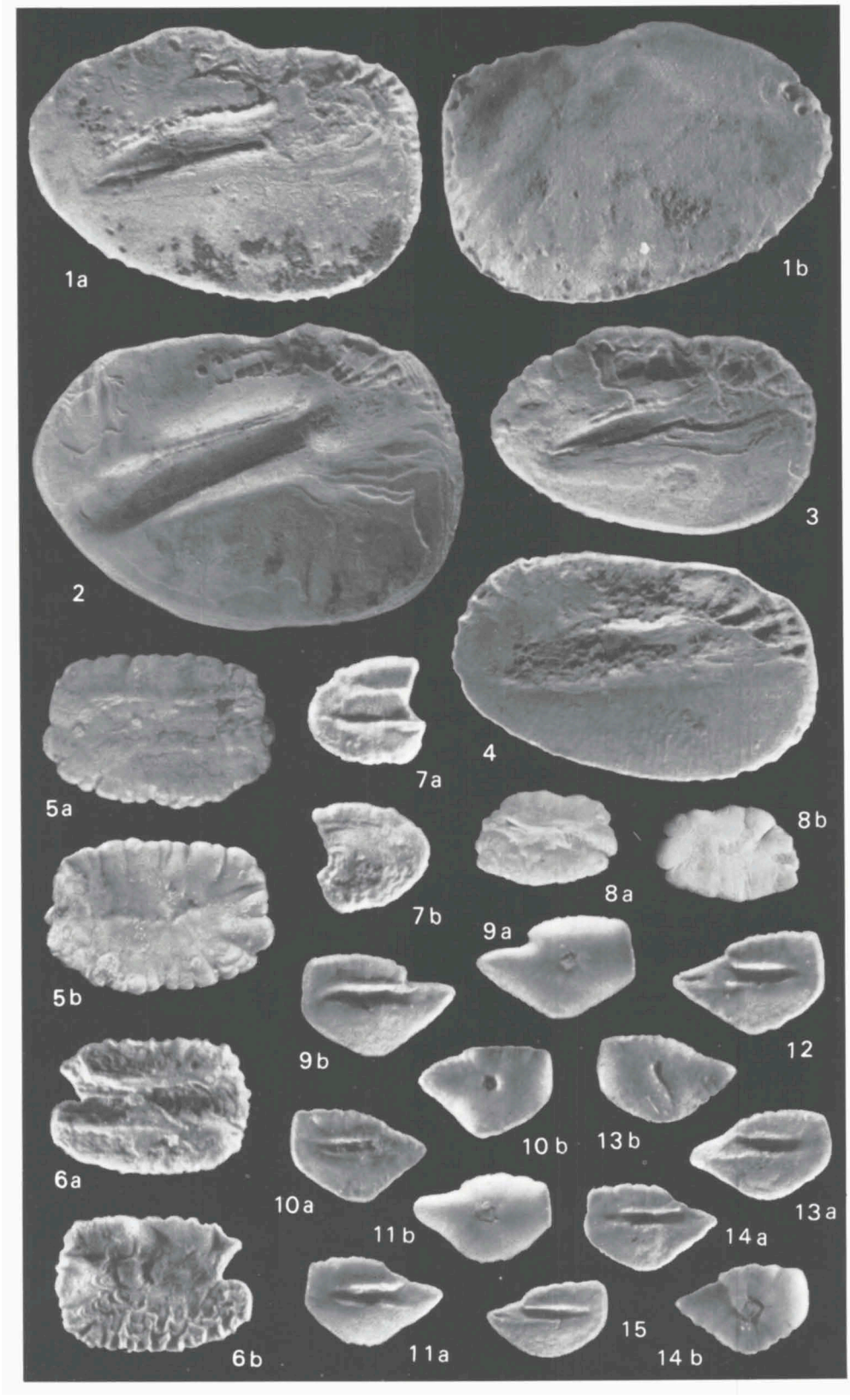
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Plate 2

Fig. 1. *Argentina parvula* (Koken, 1891). Winterswijk Member, coll. V. W. M. van Hinsbergh, x 10.

Fig. 2. *Zaphotias cyclomorphus* (Weiler, 1950). Basal layer of Winterswijk Member, coll. M. C. Cadée, RGM 175 965, x 15.

Fig. 3. Congridarum *trapezioides* sp. n. Holotype, Brinkheurne Member, coll. M. C. Cadée, RGM 175 967, x 10.

Fig. 4. *?Anguilla rouxi* Nolf, 1977, *Serpula septaria – Ancistrosyrinx volgeri* Assemblage Zone, Boom Clay, Herselt, clay pit 400 m N of the church of Ramsel, province of Antwerp, Belgium, coll. A. W. Janssen, RGM 176 064, x 15.

Figs. 5-14. *Colliolus parvus* Gaemers, 1976
5. Basal layer of Winterswijk Member, coll. V. W. M. van Hinsbergh, x 10.
6. Brinkheurne Member, coll. V. W. M. van Hinsbergh, don. M. C. Cadée, x 10.
7. Basal layer of Winterswijk Member, coll. V. W. M. van Hinsbergh, x 10.
8. Basal layer of Winterswijk Member, RGM 175 822, x 10.
9-11. Basal layer of Winterswijk Member, coll. V. W. M. van Hinsbergh, x 10.
12. Winterswijk Member, coll. V. W. M. van Hinsbergh, x 10.
13. Brinkheurne Member, coll. V. W. M. van Hinsbergh, don. M. C. Cadée, x 10.
14. Basal layer of Winterswijk Member, coll. V. W. M. van Hinsbergh, x 10.

Figs. 15-16. *Gadichthys altus* sp. n.
15. Holotype, *Serpula septaria – Ancistrosyrinx volgeri* Assemblage Zone, Boom Clay, Herselt, clay pit 400 m N of the church of Ramsel, province of Antwerp, Belgium, coll. A. W. Janssen, RGM 176 065, x 15.
16. Paratype, same locality and horizon as above, coll. A. W. Janssen, RGM 176 066, x 15.

Plate 2

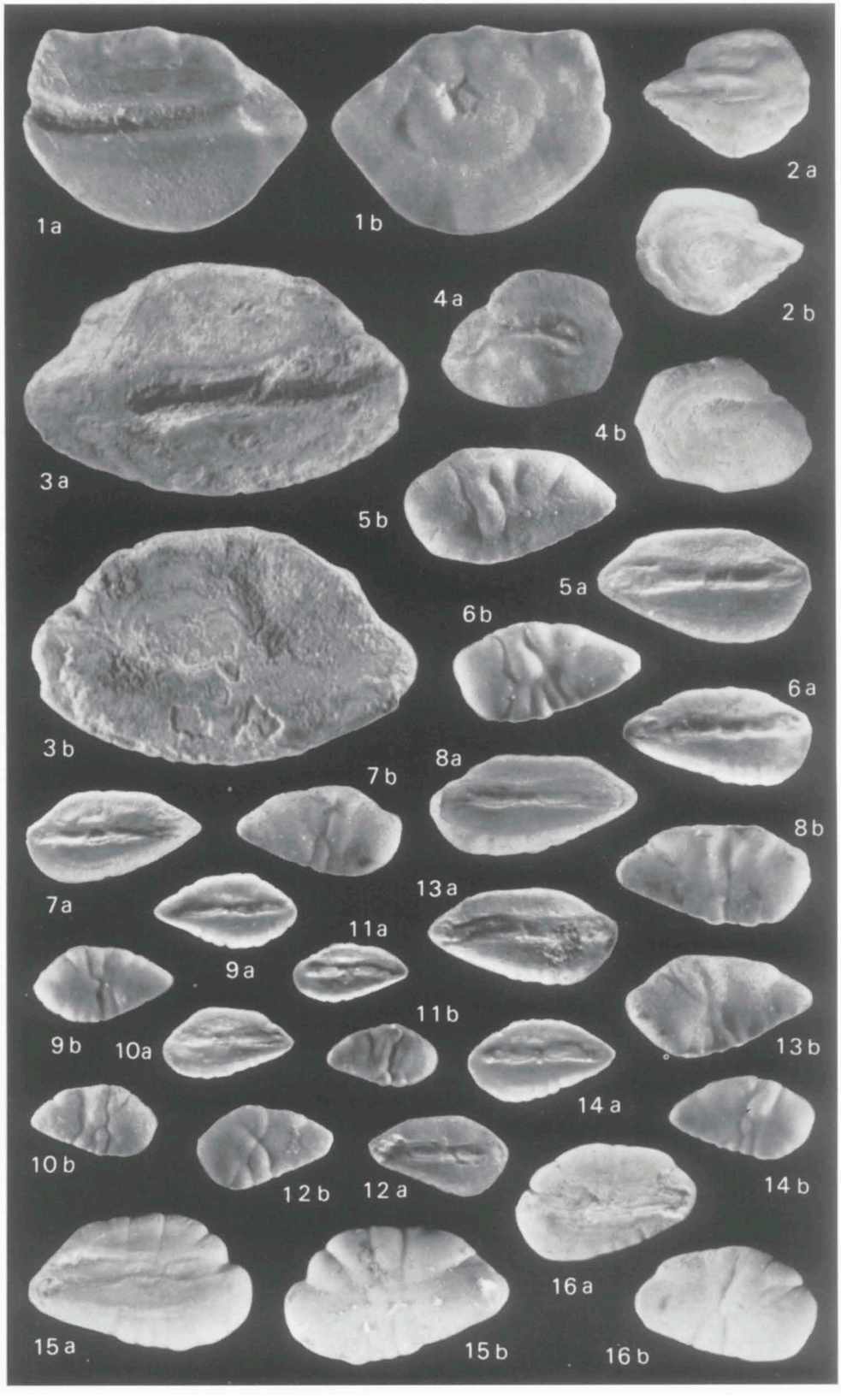
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Plate 3

Figs. 1-3. *Gadichthys altus* sp. n.

1. Paratype, upper part of Brinkheurne Member, RGM 175 972, x 15.
2. Paratype, upper part of Brinkheurne Member, RGM 175 973, x 15.
3. Paratype, *Serpula septaria – Ancistrosyrinx volgeri* Assemblage Zone, Boom Clay, Herselt, clay pit 400 m N of the church of Ramsel, province of Antwerp, Belgium, coll. A. W. Janssen, RGM 176 067, x 15.

Figs. 4-5, 7. *Palaeogadus emarginatus* (Koken, 1884)

4. Upper part of Brinkheurne Member, RGM 175 977, x 10.
5. Lectotype, Middle Oligocene, Söllingen, Federal Republic of Germany, coll. Koken, PMHU Ot. 61, x 7.5.
7. Middle Oligocene, Söllingen, Federal Republic of Germany, coll. Koken, PMHU Ot. 36, x 10.

Fig. 6. *Palaeogadus compactus* sp. n. Paratype, Brinkheurne Member, coll. V. W. M. van Hinsbergh, don. M. C. Cadée, x 10.

Plate 3

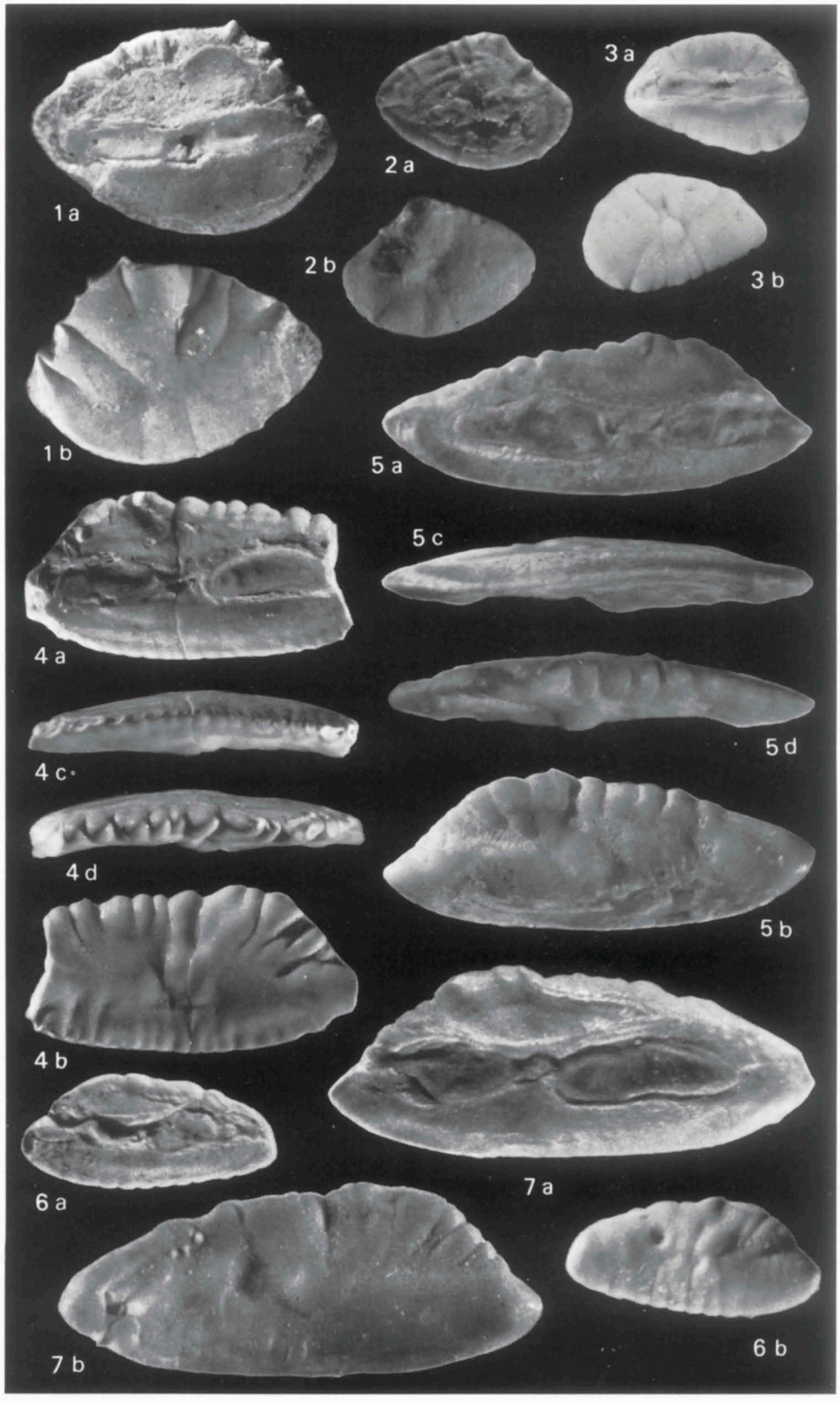


Plate 4

Fig. 1. *Palaeogadus emarginatus* (Koken, 1884). Middle Oligocene, Söllingen, Federal Republic of Germany, coll. Koken, PMHU Ot. 36, x 7.5.

Figs. 2-4. *Palaeogadus compactus* sp. n.

2. Paratype, basal layer of Winterswijk Member, coll. V. W. M. Hinsbergh, x 15.
3. Paratype, Brinkheurne Member, coll. V. W. M. van Hinsbergh, don. M. C. Cadée, x 10.
4. Holotype, *Ancilla karsteni – Niso* sp. Assemblage Zone *(Corbula* horizon), Boom Clay, Schelle (near Niel), province of Antwerp, Belgium, coll. M. Vervoenen, RGM 175 979, x 5.

Plate 4

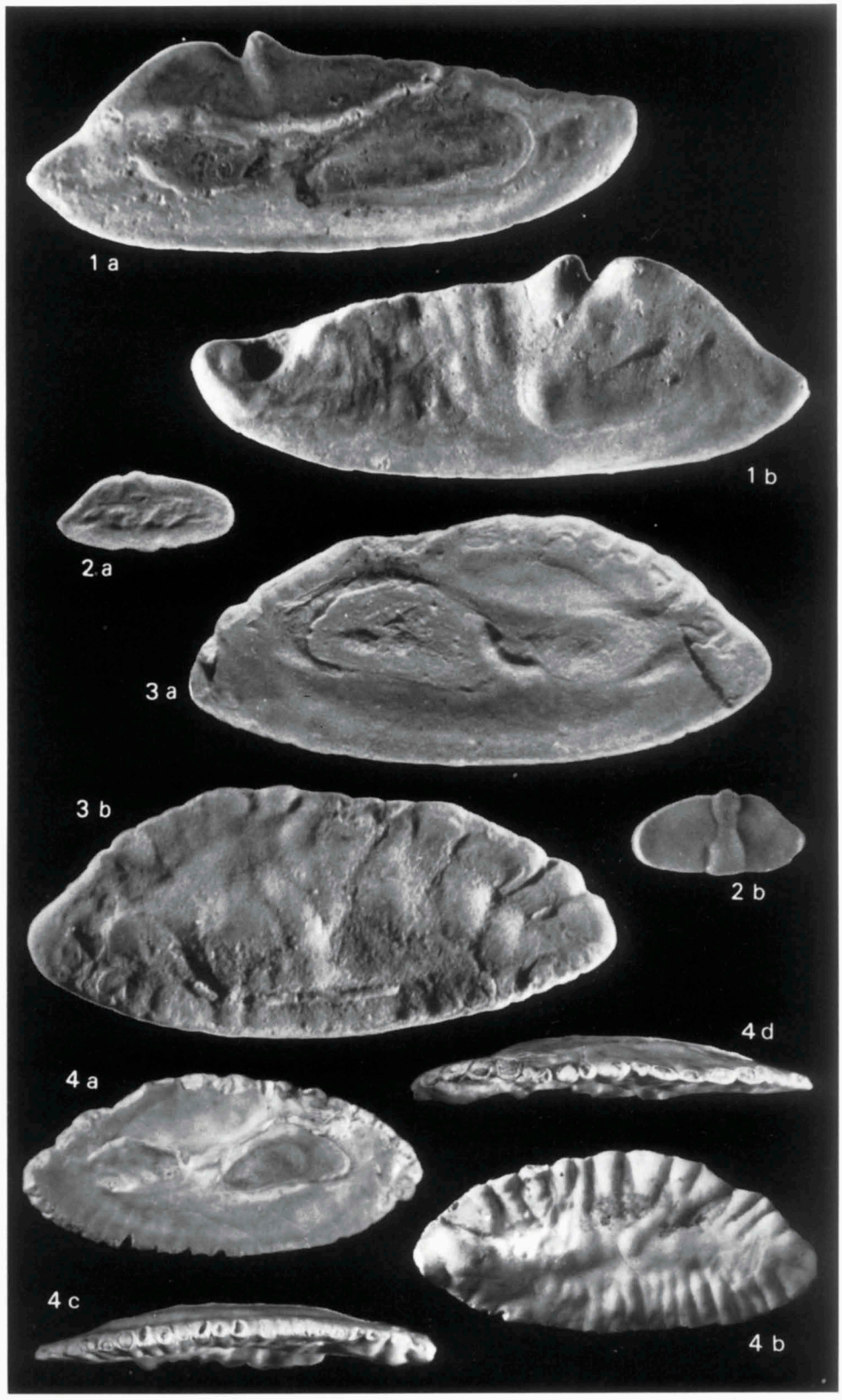


Plate 5

Fig. 1. Brotulidarum *marchicus* (Koken, 1891). Holotype, Middle Oligocene, Hermsdorf, German Democratic Republic, coll. Koken, PMHU Ot. 172, x 10.

Figs. 2-6. *Palaeogadus compactus* sp. n.

2. Paratype, *Serpula septaria – Ancistrosyrinx volgeri* Assemblage Zone, Boom Clay, Herselt, clay pit 400 m N of the church of Ramsel, province of Antwerp, Belgium, coll. A. W. Janssen, RGM 175 980, x 7.5.
3. Paratype, basal layer of Winterswijk Member, coll. V. W. M. van Hinsbergh, x 10.
4. Paratype, upper part of Brinkheurne Member, RGM 175 982, x 10.
5. Paratype, *Serpula septaria – Ancistrosyrinx volgeri* Assemblage Zone, Boom Clay, Herselt, clay pit 400 N of the church of Ramsel, province of Antwerp, Belgium, coll. A. W. Janssen, RGM 175 981, x 7.5.
6. Paratype, Brinkheurne Member, coll. V. W. M. van Hinsbergh, don. M. C. Cadée, x 10.

Plate 5

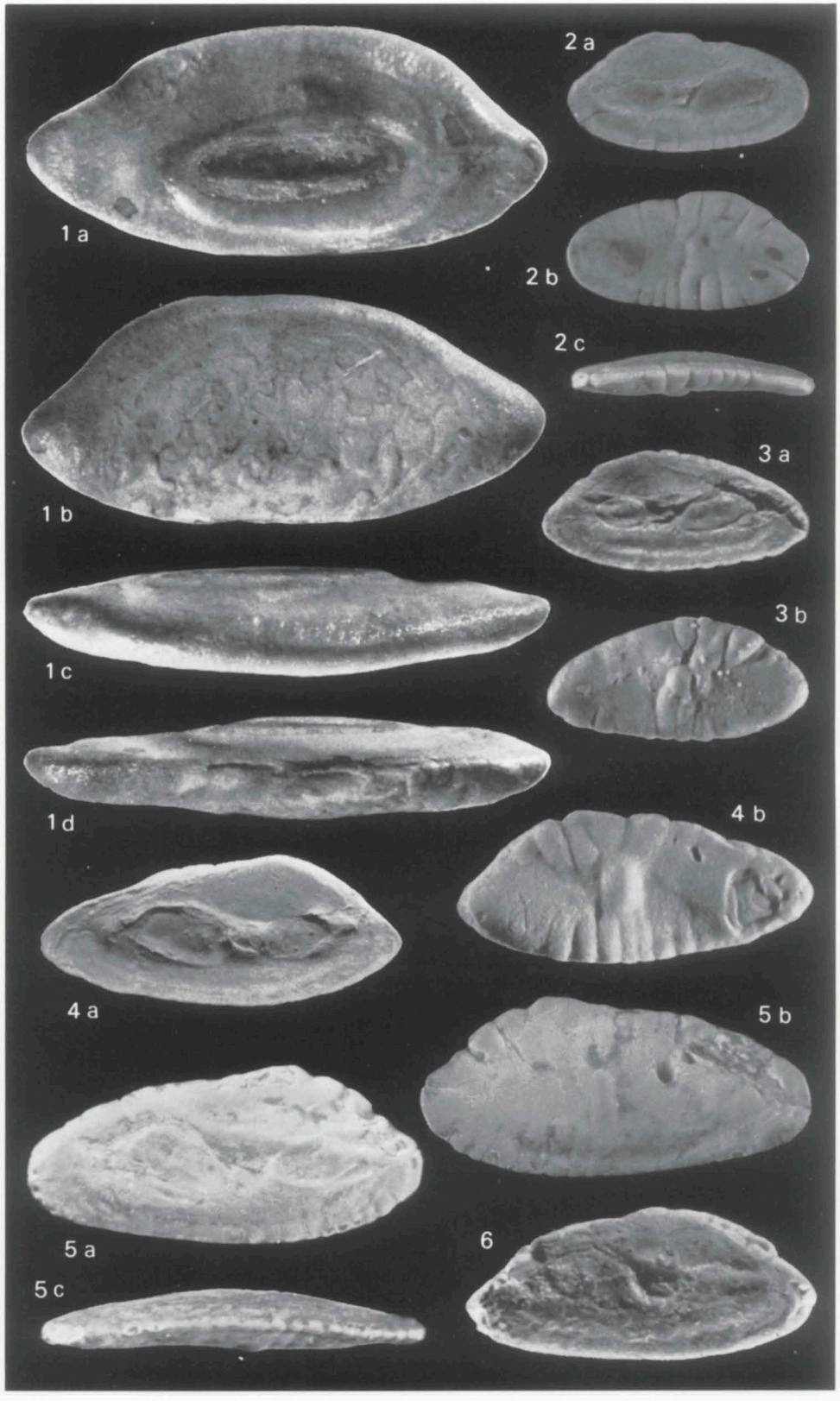


Plate 6

Figs. 1, 4-6. *Diplacanthopoma tortonesei* Nolf, 1977
1. Upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 175 997, x 15.
4. Basal layer of Winterswijk Member, coll. V. W. M. van Hinsbergh, x 15.
5. Basal layer of Winterswijk Member, coll. A. W. Janssen, RGM 175 999, x 15.
6. Brinkheurne Member, coll. V. W. M. van Hinsbergh, x 15.

Figs. 2-3. *Palaeoraniceps tuberculosus* (Koken, 1884)
2. Exact stratigraphic horizon unknown, coll. V. W. M. van Hinsbergh, x 4.5.
3. Basal layer of Winterswijk Member, coll. V. W. M. van Hinsbergh, don. M. C. Cadée, x 10.

Figs. 7-8. Brotulidarum *marchicus* (Koken, 1891)
7. Brinkheurne Member, coll. V. W. M. van Hinsbergh, don. M. C. Cadée, x 7.5.
8. Brinkheurne Member, coll. V. W. M. van Hinsbergh, don. M. C. Cadée, x 10.

Figs. 9-10. Brotulidarum *phaseoloides* sp. n.
9. Paratype, Brinkheurne Member, coll. M. C. Cadée, RGM 176 002, x 15.
10. Holotype, upper part of Brinkheurne Member, RGM 176 001, x 15.

Plate 6

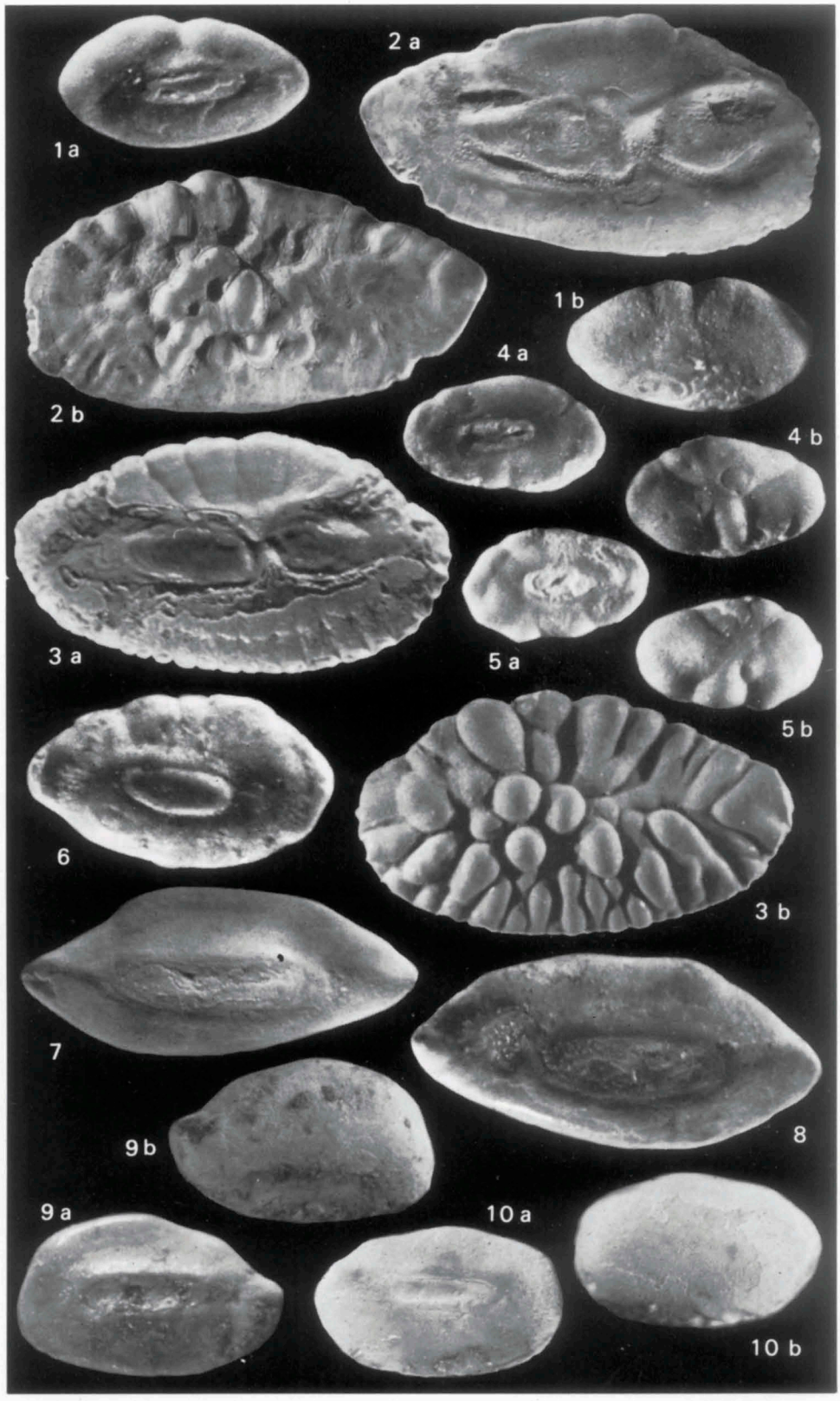


Plate 7

Figs. 1, 3, 4, 8. Brotulidarum *occultus* (Koken, 1891)
1, 3, 4. Brinkheurne Member, coll. V. W. M. van Hinsbergh, don. M. C. Cadée, x 10.
8. Juvenile specimen, Brinkheurne Member, coll. V. W. M. van Hinsbergh, x 15.

Figs. 2, 5-7. Brotulidarum *marchicus* (Koken, 1891). Brinkheurne Member, coll. V. W. M. van Hinsbergh, don. M. C. Cadée, x 10.

Plate 7

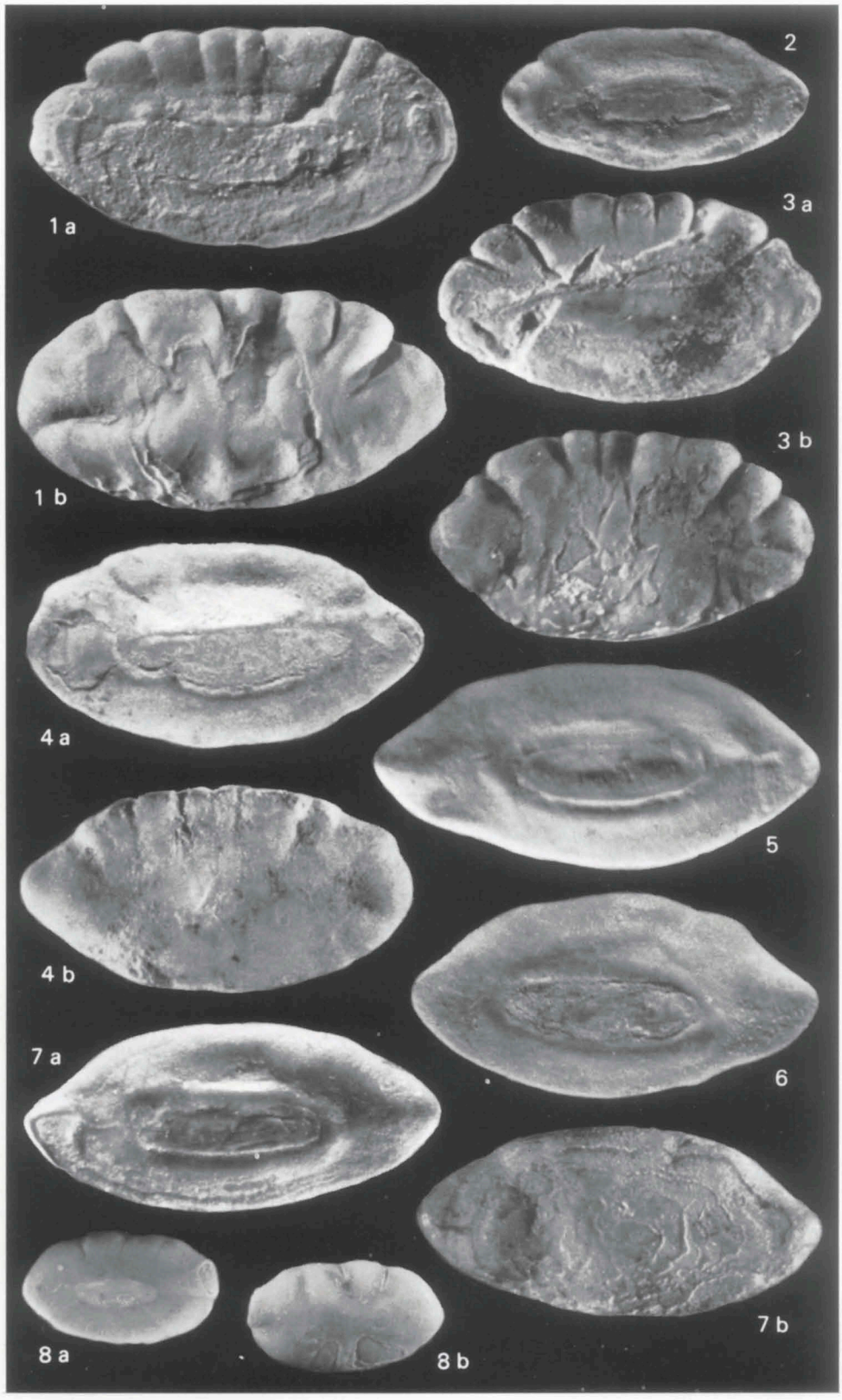


Plate 8

Fig. 1. *Palaeomorrhua faba* (Koken, 1884). Brinkheurne Member, coll. A. Stiva, don. P. A. M. Gaemers, RGM 176 000, x 7.5.

Fig. 2. Brotulidarum *phaseoloides* sp. n. Paratype, Brinkheurne Member, coll. M. C. Cadée, RGM 176 003, x 15.

Figs. 3-4. *Hoplobrutula difformis* (Koken, 1884)
3. Winterswijk Member, coll. V. W. M. van Hinsbergh, x 7.5.
4. Brinkheurne Member, coll. V. W. M. van Hinsbergh, don. J. Buurman, x 7.5.

Plate 8

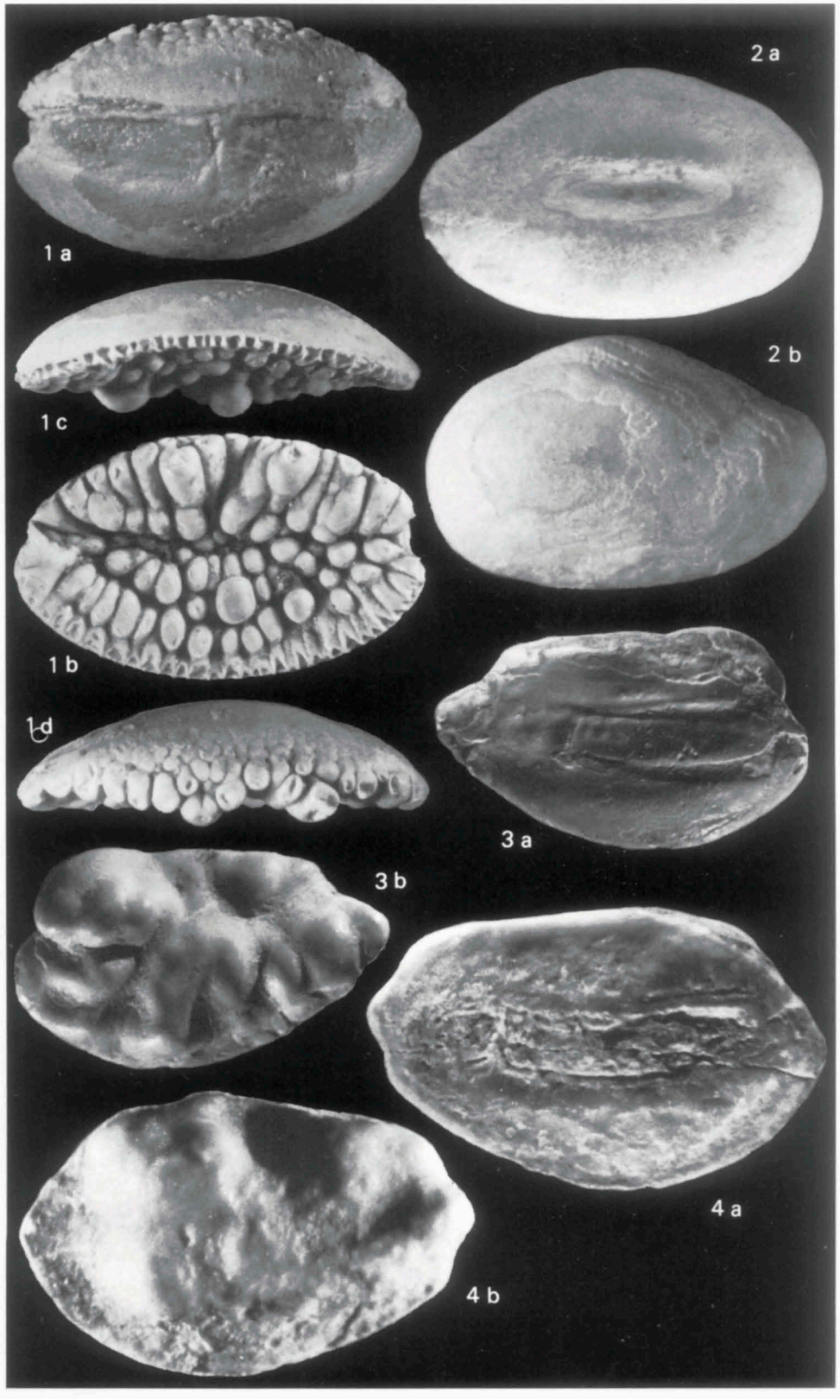


Plate 9

Figs. 1-5. *Hoplobrotula difformis* (Koken, 1884)

1. Winterswijk Member, coll. V. W. M. van Hinsbergh, x 7.5.
2. Juvenile specimen, basal layer of Winterswijk Member, coll. A. W. Janssen, RGM 176 005, x 15.
3. Brinkheurne Member, coll. V. W. M. van Hinsbergh, x 7.5.
4. Upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 176 007, x 10.
5. Brinkheurne Member, coll. P. F. L. de Groot, RGM 176 010, x 7.5.

Plate 9

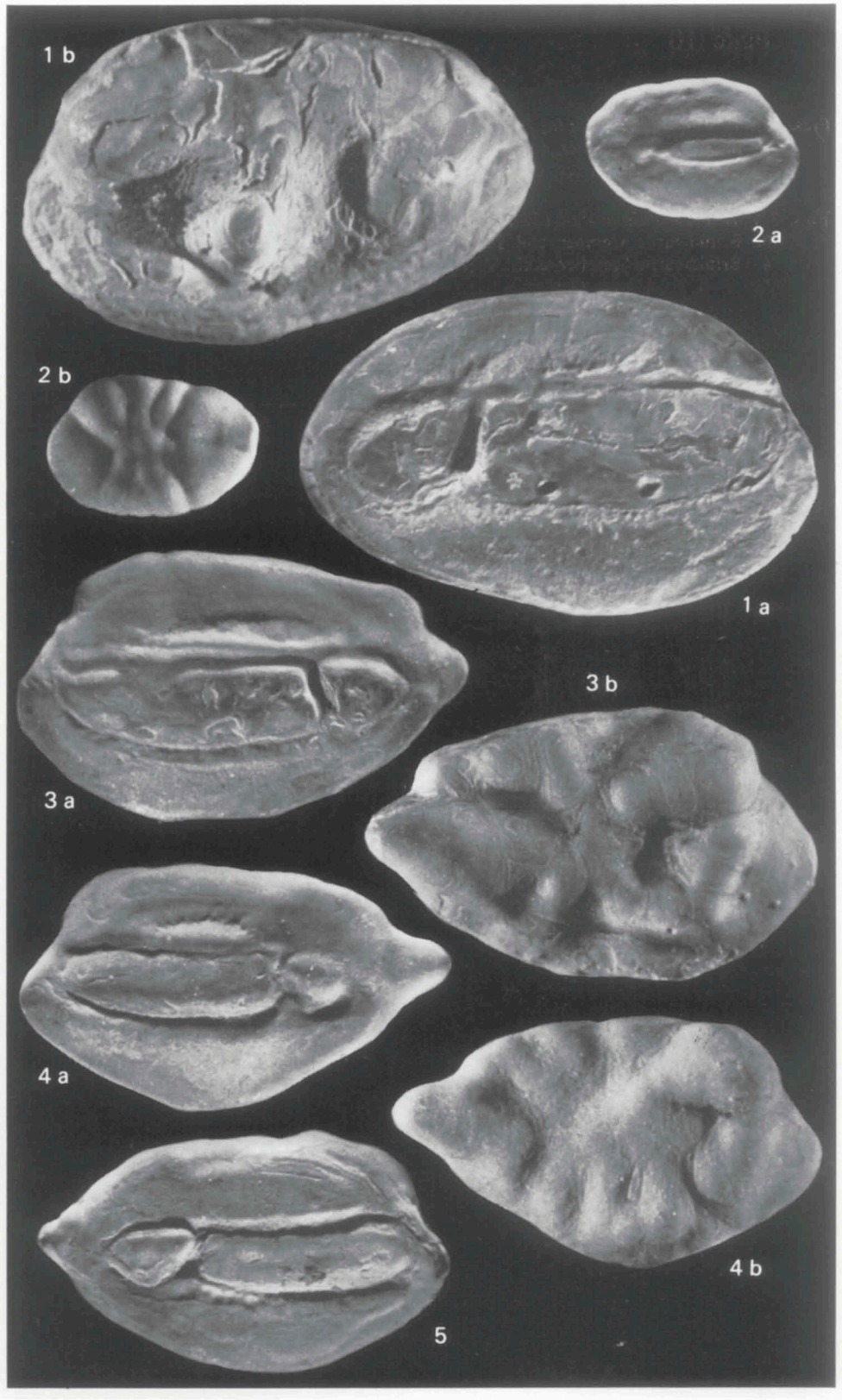


Plate 10

Figs. 1-2. *Hoplobrotula difformis* (Koken, 1884)
1. Brinkheurne Member, coll. V. W. M. van Hinsbergh, don. P. Buurman, x 7.5.
2. Brinkheurne Member, coll. P. F. L. de Groot, RGM 176 011, x 10.

Figs. 3-4. *Hoplobrotula acutangula acutangula* (Koken, 1884)
3. Brinkheurne Member, coll. P. A. M. Gaemers, don. D. Mol, x 7.5.
4. Brinkheurne Member, coll. V. W. M. van Hinsbergh, don. M. C. Cadée, x 7.5.

Plate 10

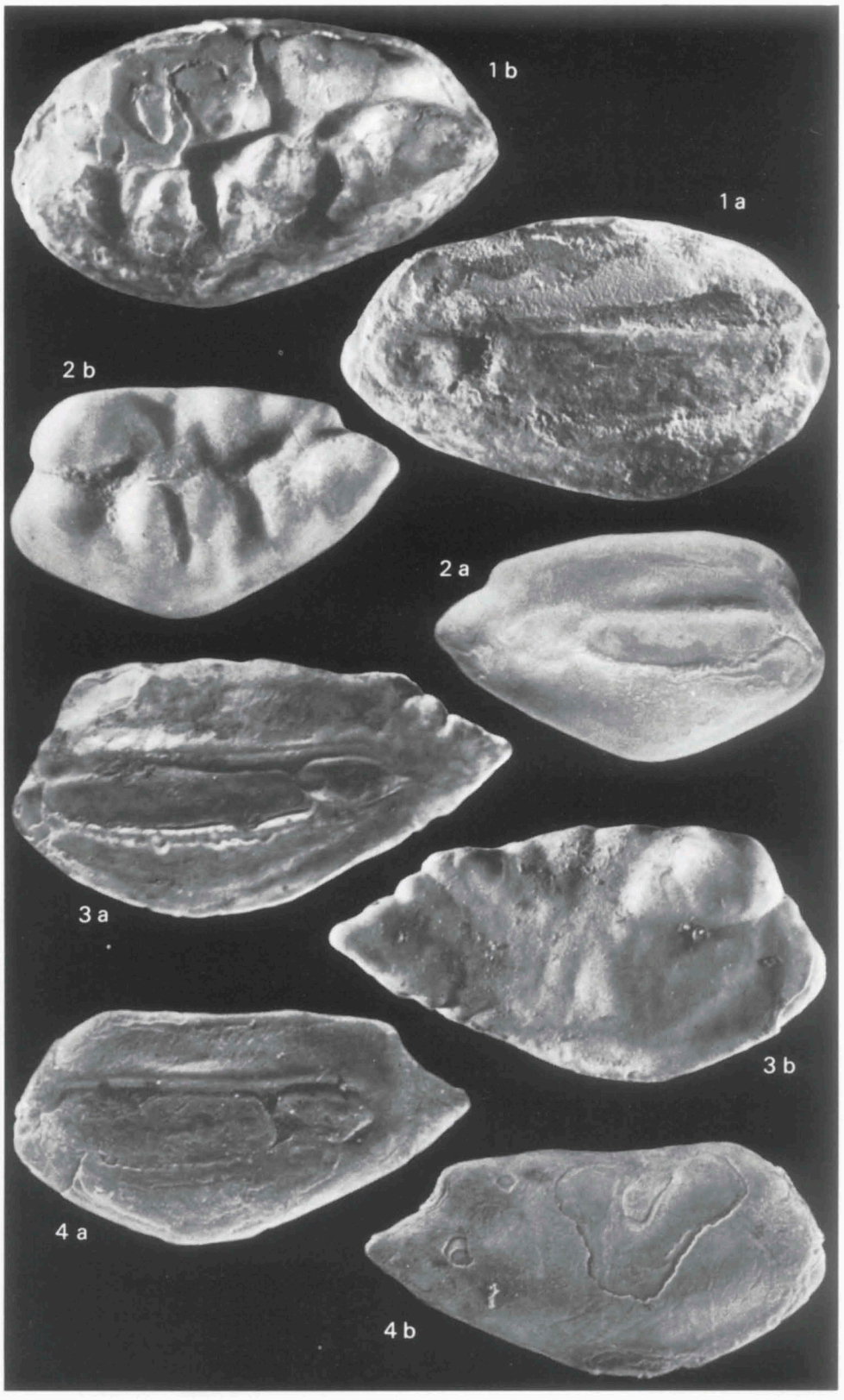


Plate 11

Figs. 1-3. *Hoplobrotula acutangula acutangula* (Koken, 1884)
1. Brinkheurne Member, coll. V. W. M. van Hinsbergh, don. M. C. Cadée, x 10.
2. Brinkheurne Member, coll. V. W. M. van Hinsbergh, don. M. C. Cadée, x 7.5.
3. Brinkheurne Member, coll. P. F. L. de Groot, RGM 176 014, x 10.

Fig. 4. *Dentex kokeni* sp. n. Paratype, Winterswijk Member, coll. V. W. M. van Hinsbergh, x 15.

Fig. 5. *Hoplobrutula acutangula hermsdorfensis* (Koken, 1891). Brinkheurne Member, coll. V. W. M. van Hinsbergh, don. M. C. Cadée, x 7.5.

Fig. 6. Sparidarum sp. 2. Brinkheurne Member, coll. V. W. M. van Hinsbergh, x 15.

Fig. 7. Sparidarum sp. 1 Basal layer of Winterswijk Member, coll. V. W. M. van Hinsbergh, don. M. C. Cadée, x 15.

Plate 11

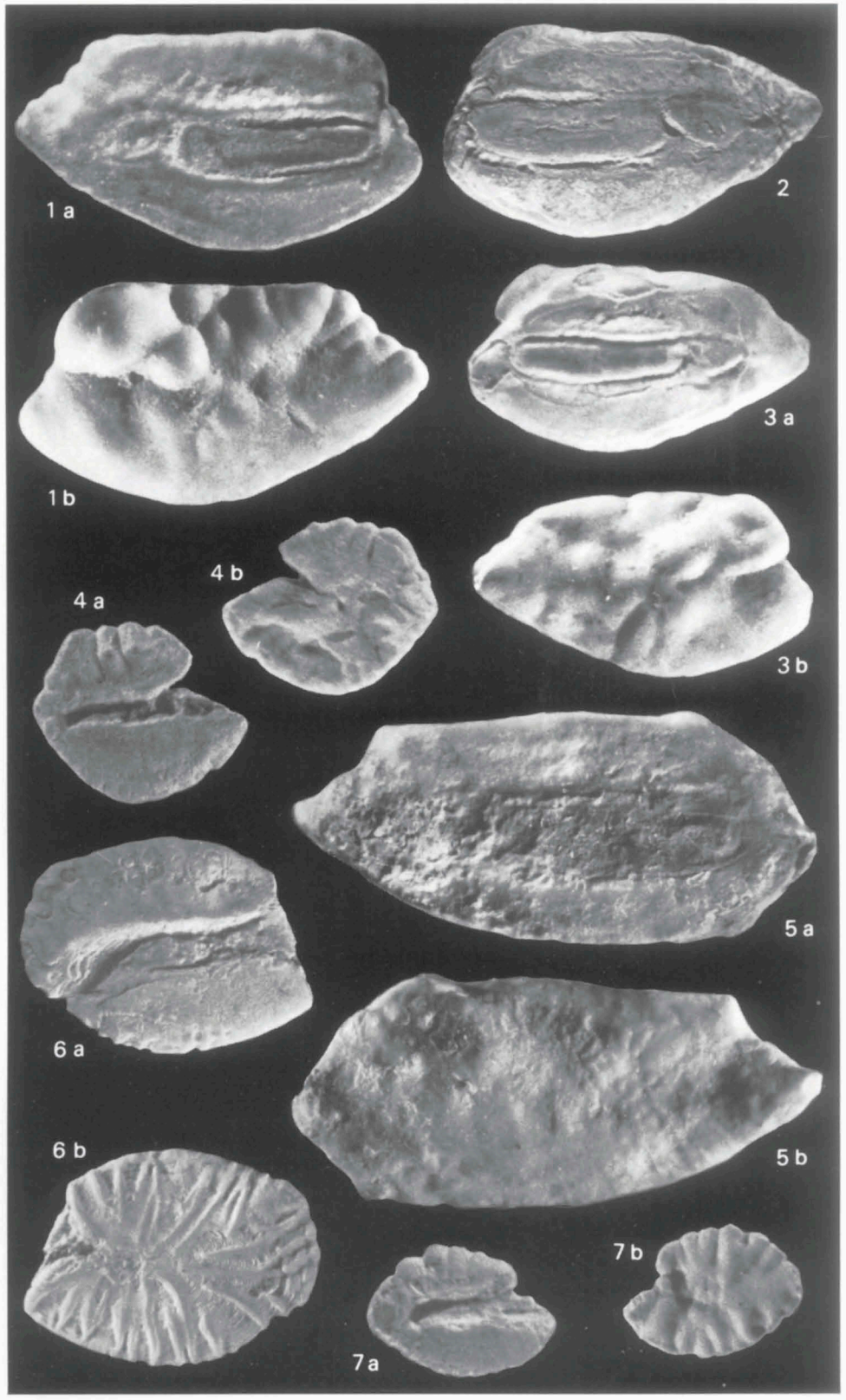


Plate 12

Figs. 1-3. *Dentex kokeni sp. n.*
1. Holotype, Middle Oligocene, Waldböckelheim, Federal Republic of Germany, coll. Koken, PMHU Ot. 157, x 10.
2, 3. Paratypes, same locality and horizon as above, coll. Koken, PMHU Ot. 157, x 10.

Plate 12

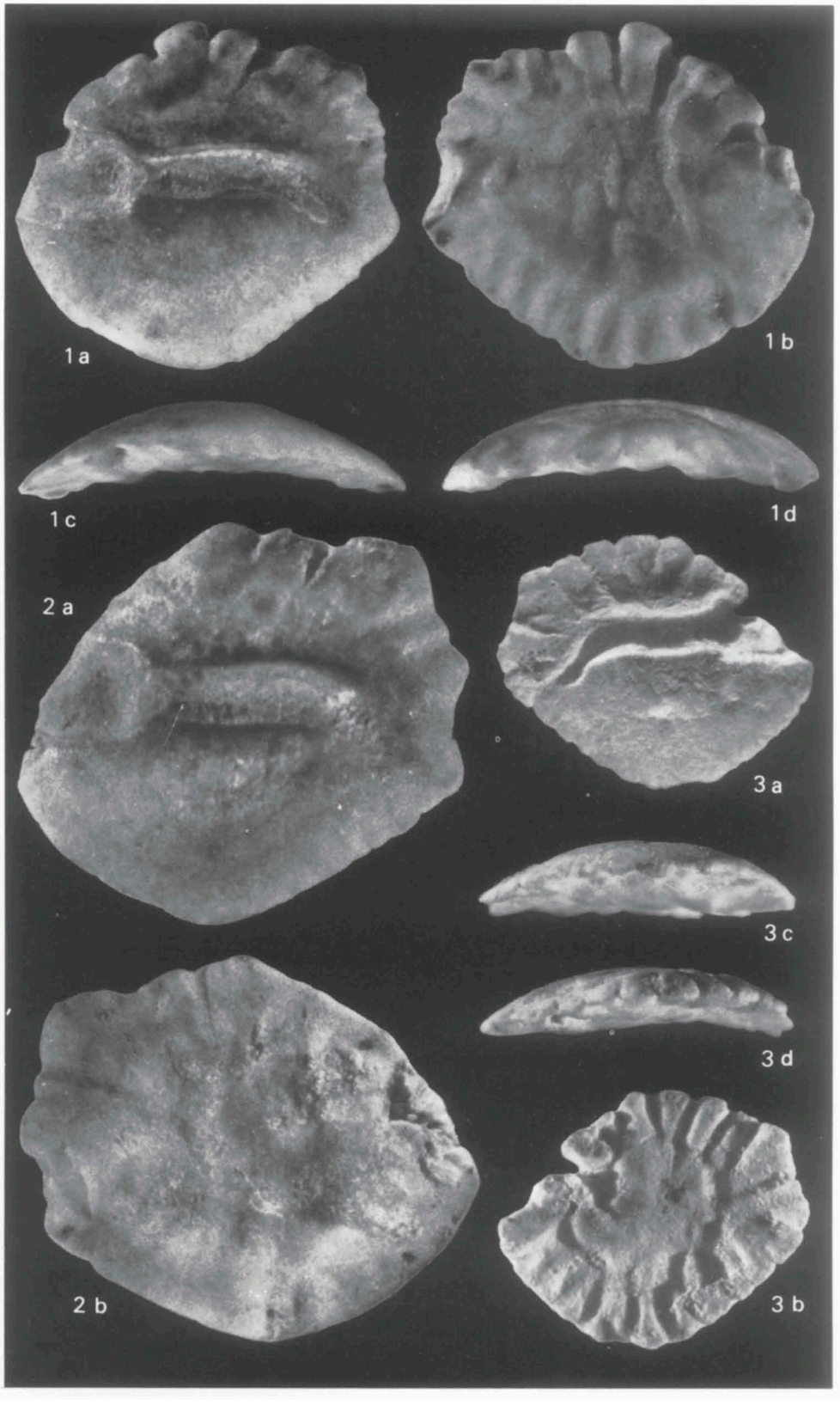


Plate 13

Fig. 1. *?Polysteganus* sp. Brinkheurne Member, coll. M. C. Cadée, RGM 176 024, x 10.

Figs. 2, 3, 5, 7. *Paralabrax splendens* sp. n.
2. Paratype, juvenile specimen, upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 176 020, x 15.
3. Paratype, juvenile specimen, upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 176 020, x 10.
5. Holotype, upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 176 018, x 10.
7. Paratype, Brinkheurne Member, coll. V. W. M. van Hinsbergh, RGM 176 021, x 10.

Fig. 4. Acropomidarum *martini* sp. n. Holotype, basal layer of Winterswijk Member, coll. M. C. Cadée, RGM 176 034, x 10.

Fig. 6. Pempheridarum sp. Upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 176 026, x 15.5.

Fig. 8. *Hoplostethus* sp. Basal layer of Winterswijk Member, RGM 176 033, x 15.

Plate 13

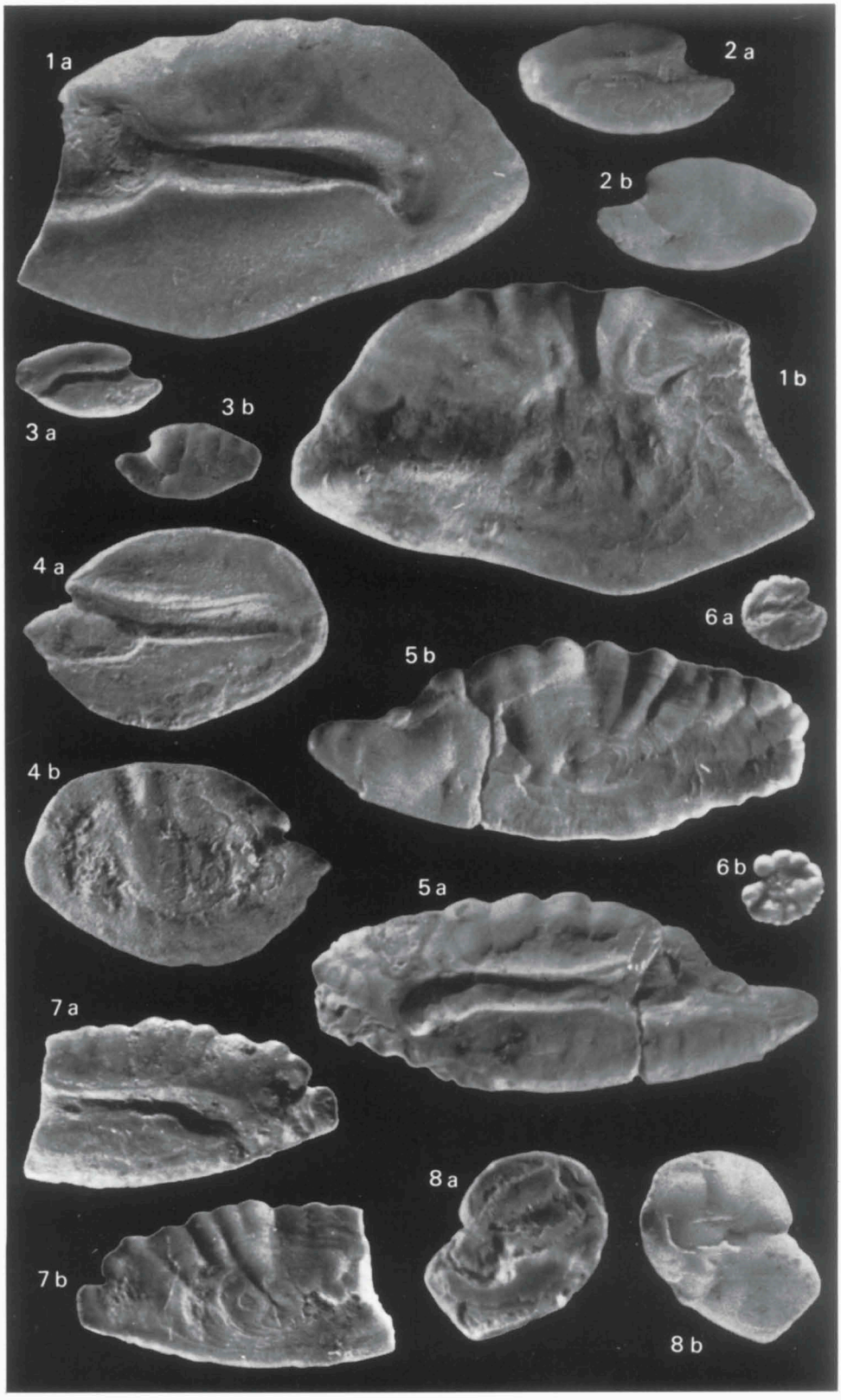


Plate 14

Figs. 1-3. *Mupus neumanni* Schwarzhans, 1974.
1. Brinkheurne Member, coll. V. W. M. van Hinsbergh, don. M. C. Cadée, x 10.
2. Upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 176 028, x 15.
3. Upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 176 029, x 10.

Fig. 4. Carangidarum *robustus* sp. n. Holotype, Brinkheurne Member, coll. V. W. M. van Hinsbergh, RGM 176 025, x 10.

Fig. 5. ? *Pontinus foreyi* Nolf, 1977. Basal layer of Winterswijk Member, coll. H. van der Made, RGM 176 035, x 15.

Figs. 6-9. ? *Trigloporus* sp.
6. *Serpula septaria* – *Ancistrosyrinx volgeri* Assemblage Zone, Boom Clay, Herselt, clay pit 400 m N of the church of Ramsel, province of Antwerp, Belgium, coll. A. W. Janssen, RGM 176 070, x 15.
7. Upper part of Brinkheurne Member, RGM 176 036, x 15.
8. Upper part of Brinkheurne Member, RGM 176 037, x 15.
9. Upper part of Brinkheurne Member, RGM 176 038, x 15.

Figs. 10-11. Trichiuridarum *wongratanai* Nolf, 1977.
10. Upper part of Brinkheurne Member, RGM 176 040, x 15.
11. *Serpula septaria* – *Ancistrosyrinx volgeri* Assemblage Zone, Boom Clay, Herselt, clay pit 400 m N of the church of Ramsel, province of Antwerp, Belgium, coll. A. W. Janssen, RGM 176 041, x 15.

Plate 14

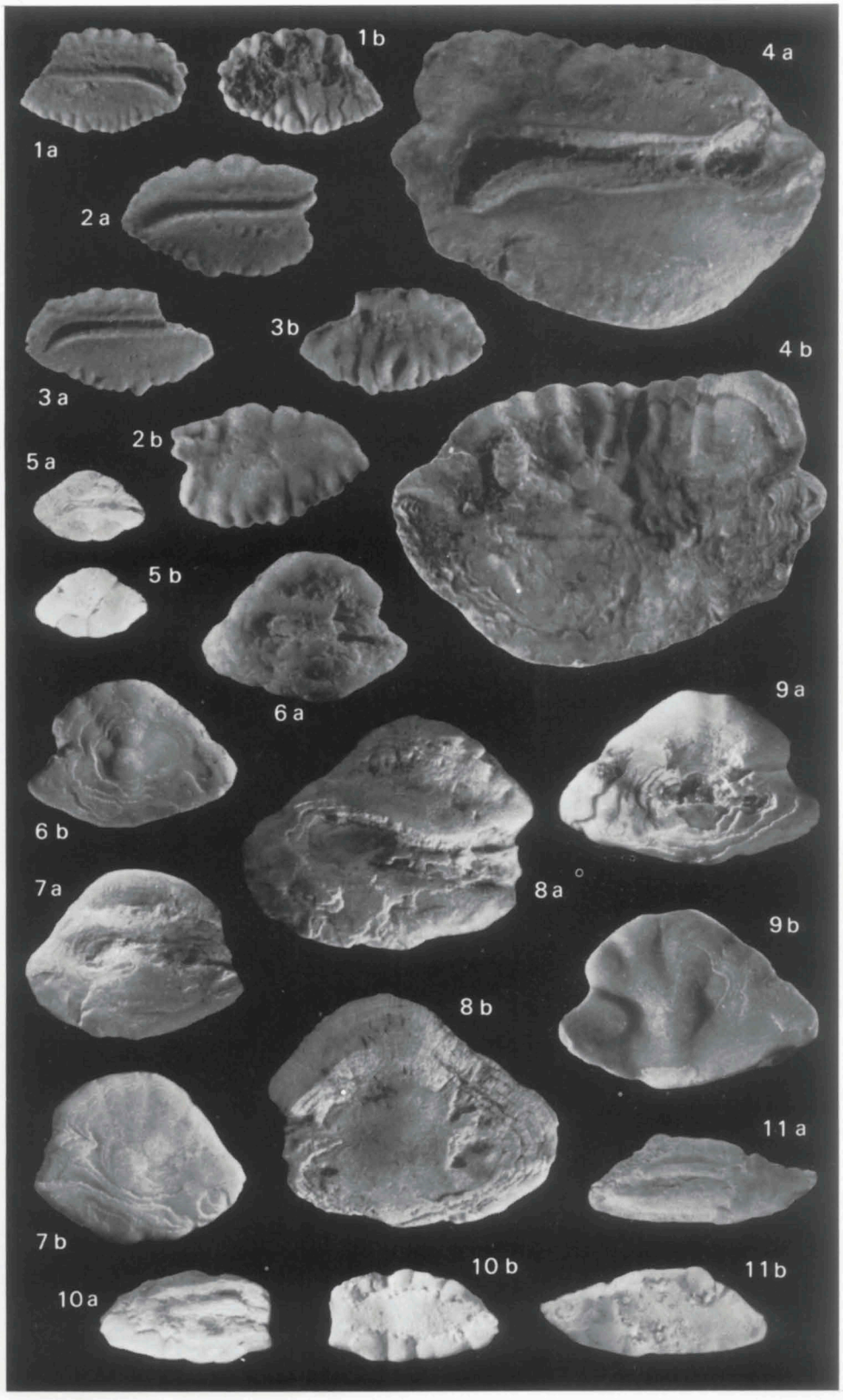


Plate 15

Figs. 1-7. Scorpaeniformorum *ellipticus* (Koken, 1884)

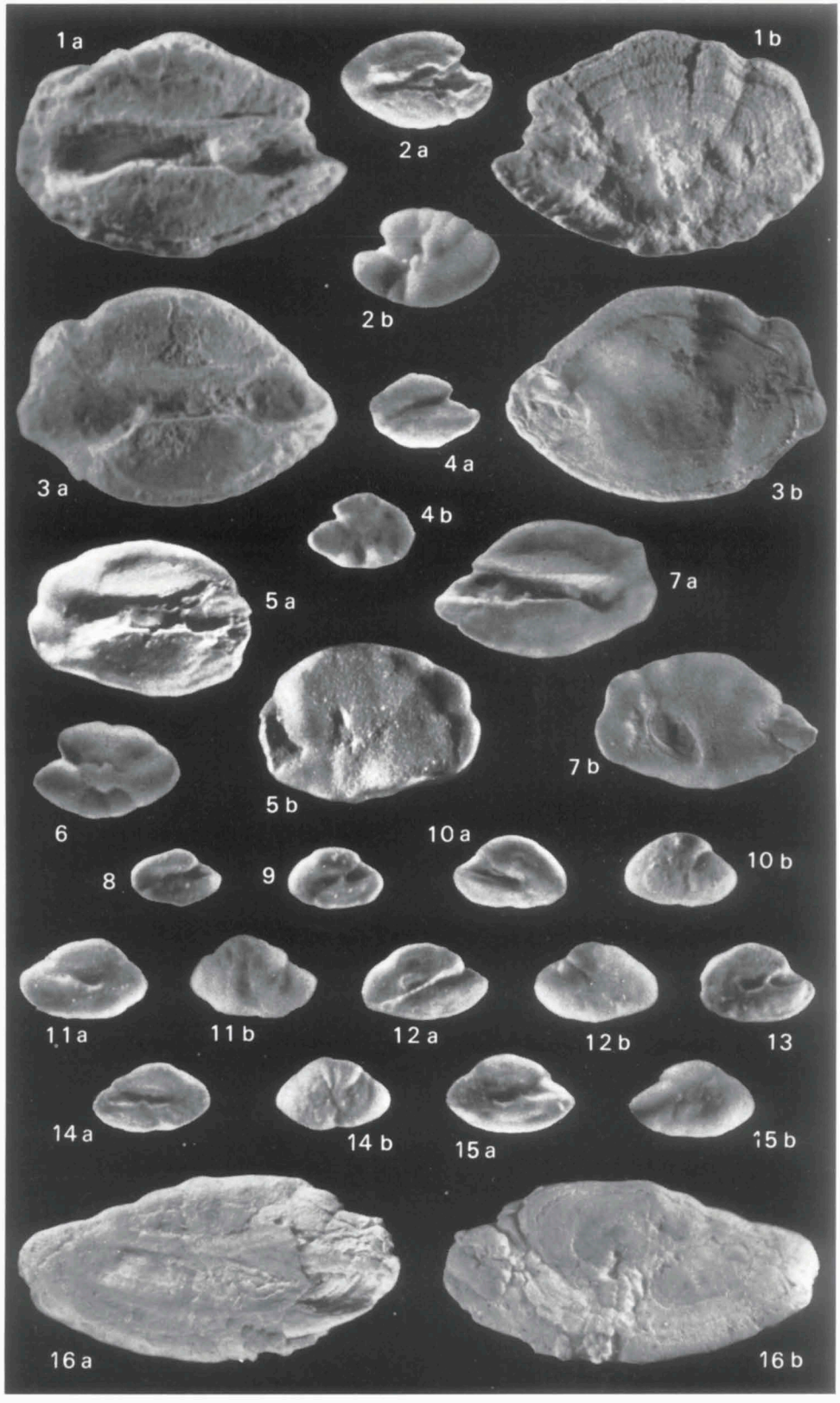
1. Brinkheurne Member, coll. V. W. M. van Hinsbergh, don. M. C. Cadée, x 10.
2. Juvenile specimen, basal layer of Winterswijk Member, RGM 176 051, x 15.
3. Brinkheurne Member, coll. P. F. L. de Groot, RGM 176 052, x 10.
4. Juvenille specimen, upper part of the Brinkheurne Member, coll. M. van den Bosch, RGM 176 053, x 16.5.
5. Upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 176 054, x 15.
6. Upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 176 055, x 15.
7. Upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 176 056, x 10.

Figs. 8-15. Blenniidarum *minisculus* (Nolf, 1977).

8. Upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 176 042, x 15.
9. Upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 176 043, x 15.
10. Upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 176 044, x 15.
11. Upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 176 045, x 15.
12. Upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 176 046, x 15.
13. Upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 176 047, x 15.
14. Basal layer of Winterswijk Member, coll. V. W. M. van Hinsbergh, x 15.
15. Upper part of Brinkheurne Member, coll. M. van den Bosch, RGM 176 048, x 15.

Fig. 16. Gen. et sp. indet. Upper part of Brinkheurne Member, RGM 176 059, x 15.

Plate 15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