

# Fish otoliths from the Ypresian (early Eocene) of Vastan, Gujarat, India

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NOLF, D., RANA, R.J. & SINGH, H. 2006 — Fish otoliths from the Ypresian (Early Eocene) of Vastan, Gujarat, India. *Bulletin de l'Institut royal des Sciences naturelles de Belgique, Sciences de la Terre*, 76: 105-118, 4 pls., 1 fig., 1 table, Brussels, April 15, 2006 – ISSN 0374-6291.

## Abstract

Sampling of about 1000 kg of sediment at the Vastan Lignite Mine provided otoliths of 20 teleost taxa of which nine could be described as new species: “genus Atherinidarum” *rhomboides*, “genus Atherinidarum” *spinifer*, “genus Percoideorum” *thierrysmithi*, “genus Centropomidarum” *obesum*, *Acropoma massiva*, “genus Acropomidarum” *angulosum*, “genus Ambassidarum” *dominans*, “genus Ambassidarum” *celatum* and “genus Menidarum” *inflatum*. All present-day relatives of the represented taxa occur in the marine realm. However, several of those fishes may have been able to penetrate into fresh water, e.g. the pristigasterids, atherinids, centropomids and ambassids. Primary freshwater fishes however, are lacking completely. All represented taxa are mainly confined to tropical, very shallow near shore habitats, and the association is completely devoid of oceanic fishes (mesopelagic and deep water bottom fishes). All these data suggest a protected shallow marine environment, not widely exposed to the oceanic realm, and probably with a regular influx of freshwater, maybe an estuary or a protected bay, with mangrove vegetation. It is probable that some of the represented taxa were able to intrude into fresh water.

**Key words:** Otoliths, teleosts, Ypresian, Early Eocene, India.

## Résumé

Le tamisage d'environ 1000 kg de sédiment provenant de la carrière à lignite de Vastan a livré des otolithes de 20 taxa de téléostéens dont neuf constituent des espèces nouvelles: “genus Atherinidarum” *rhomboides*, “genus Atherinidarum” *spinifer*, “genus Percoideorum” *thierrysmithi*, “genus Centropomidarum” *obesum*, *Acropoma massiva*, “genus Acropomidarum” *angulosum*, “genus Ambassidarum” *dominans*, “genus Ambassidarum” *celatum* et “genus Menidarum” *inflatum*. Tous les taxa recensés sont apparentés à des espèces actuelles du domaine marin. Plusieurs de ces poissons, cependant, peuvent également pénétrer en eau douce, par exemple, les pristigasteridés, atherinidés, centropomidés et ambassidés. Par contre, des poissons vivant exclusivement en eau douce manquent. Tous les taxa représentés sont typiques du milieu marin très côtier et l'association est complètement dépourvue de poissons océaniques (des domaines mésopélagique et benthique profond). Toutes ces données suggèrent un environnement marin peu profond et abrité, peu exposé au domaine océanique, et probablement sujet à des apports réguliers d'eau douce, tels qu'un estuaire ou une baie abritée bordée de mangroves. Il est probable que plusieurs des taxa représentés avaient la faculté de pénétrer en eau douce.

**Mots-clés:** Otolithes, téléostéens, Yprésien, Eocène inférieur, Inde.

## Introduction

Studies on Cenozoic fish otoliths from the Indian and South Asiatic realm only started in 1982 (SAHNI & SAKSENA, 1982). NOLF (1991) described a small fauna from the middle to late Eocene from eastern Pakistan, followed by a more substantial paper on middle Eocene otoliths from India and Java (NOLF & BAJPAI, 1992). The first Ypresian otoliths from India were mentioned by SAMANT & BAJPAI (2001), who figured six taxa, with tentative identifications at the familial or sub-ordinal level. Finally, BAJPAI & KAPUR (2004) described two species of gobioids, collected at the Vastan Lignite Mine (Ypresian), which is the same locality that provided the otoliths studied herein.

The Vastan Lignite Mine is located on the east side of the Gulf of Cambay, NW Indian Peninsula (Fig. 1). In the Cambay Basin, Deccan trap and extrusive rocks formed the platform for the sedimentation of Paleogene and Neogene sediments, in most of the basin covered by a thick deposit of Recent alluvium (Gujarat Alluvium). In the Cambay Basin, Paleogene beds are exposed as thin strips, on the west coast near Gogha and on the east side of the gulf, at about 40 km from the coast. The Vagadkhol/Olpad Fm., deposited over the Deccan Traps, comprises the oldest sediments (Paleocene – lower Eocene) in the Basin. It is overlain by the 75-1500 m thick Cambay Fm., comprising greenish, whitish-gray and black clays and shales with lignite seams (RANA et al., 2004).

## Locality data

The Vastan locality is an open pit mine, located at 21°25'47''N, 73°07'30''E, about 3 km NE of the village Nani Naroli, and is managed by the Gujarat Industrial Power Corporation Limited (GIPCL). The Cambay Fm. is 20-145 m thick here, with a fossiliferous horizon of 31.4 m (Fig. 1). This horizon is concealed between an upper coal seam (“main coal seam 1”) and a lower coal seam (“main coal seam 2”). Our main sample (sample 1, ± 500 kg of sediment) is from about 3 m above the lower coal seam, and a less productive sample (sample 2, ± 500 kg of sediment) comes from about 5.5 m above the lower coal seam, but also several other layers are fossiliferous. The go-

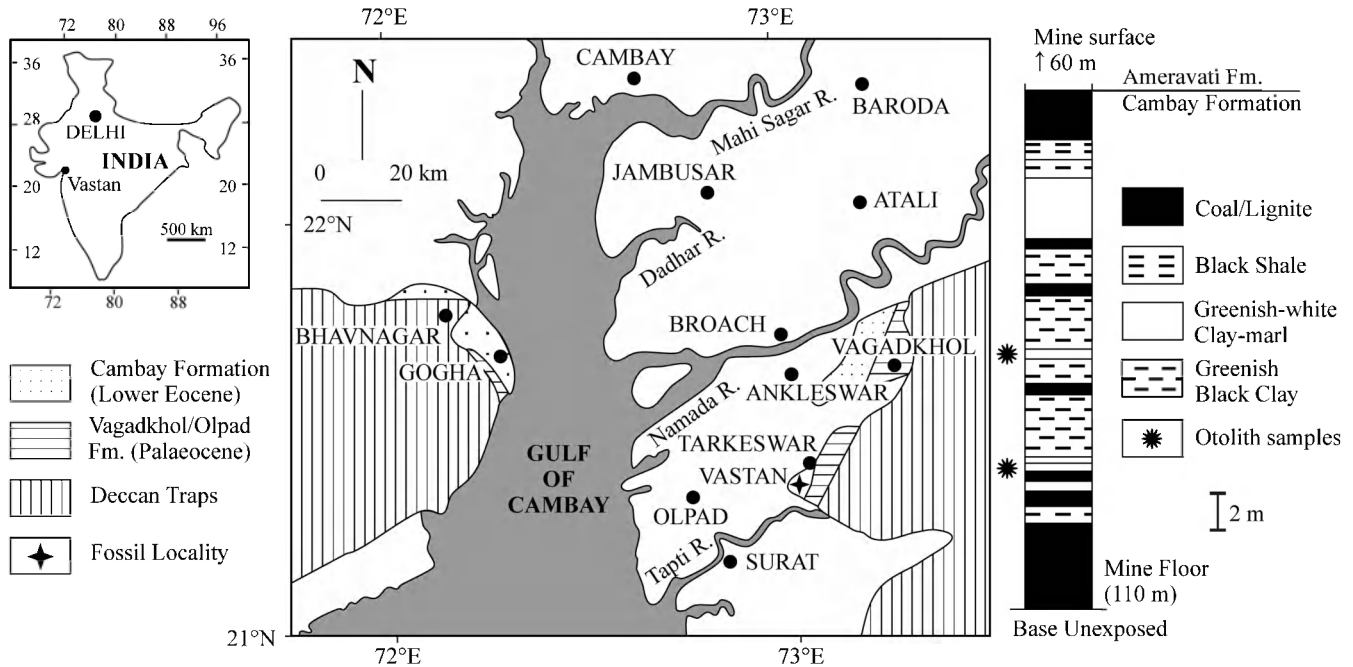


Fig. 1 — Geological map of the area around Vastan and measured log of the fossiliferous section at the Vastan Lignite Mine (from RANA *et al.*, 2004).

bioid otoliths described by BAJPAI & KAPUR (2004), e.g. come from about 3 m below the upper coal seam. Our sample 1 is also from the same layer that provided the bulk of other vertebrate remains, including mammal teeth recently collected by Rana, Smith, and Missiaen. RANA *et al.* (2004) mentioned the age diagnostic species *Nummulites burdigaliensis* from the Vastan sediments, which allows placing the fossiliferous level in the Middle Ypresian.

## Taxonomy

### Family PRISTIGASTERIDAE

#### ? *Pellona* sp.

Pl. 1, Fig. 3

**Material:** Four otoliths from the Vastan Lignite Mine, sample at 3 m above main coal seam 2.

**Comments:** These very small herring otoliths show most affinities to those of pristigasterids, e.g. the Recent *Pellona ditchela* VALENCIENNES, 1847, but the material is too restricted and too small for allowing a more formal designation. The genus *Pellona* is widely distributed in present-day south Asian coastal waters.

#### *Pristigasteridae* ind.

Pl. 1, Fig. 1

**Material:** Sixteen otoliths from the Vastan Lignite Mine, sample at 3 m above main coal seam 2.

**Comments:** These relatively thick otoliths with an inner face showing a rather strong convexity in the dorso-ventral direction and a rounded posterior end fit best within pristigasterids like *Dussumieria acuta* VALEN-

CIENNES, 1847 (Pl. 1, Fig. 2). Most specimens are rather eroded, which excludes a more rigorous identification.

### Family ATHERINIDAE

#### “genus *Atherinidarum*” *rhomboides* n. sp.

Pl. 1, Figs. 8-10

**Type material:** Holotype: a left otolith (Pl. 1, Fig. 8) (IRSNB P 8072); two figured paratypes (Pl. 1, Figs. 9-10) (IRSNB P 8073) and 16 unfigured paratypes from the Vastan Lignite Mine, 14 from sample at 3 m above main coal seam 2 (GU/RSR/VAS/O – 1) and two from sample at 5.5 m above main coal seam 2 (GU/RSR/VAS/O – 2). **Dimensions of the holotype:** Length: 2.4 mm; height: 1.7 mm; thickness: 0.5 mm.

**Stratum typicum:** Cambay Shale Fm., Ypresian, at the Vastan Lignite Mine, Gujarat, India, sample at 3 m above lower coal seam.

**Derivatio nominis:** *rhomboides* (Latin) = rhomb-like, lozenge-like; alludes to the outline of the otoliths.

**Diagnosis:** This species is characterized by rather high otoliths, which outline narrows towards the anterior and posterior end, providing them a typical lozenge-like shape. The outer face has an almost smooth surface with some vague irregular undulations and is slightly concave in the antero-posterior direction, but nearly flat in the dorso-ventral direction. The ostium is rather well opened, with a rather wide ventral expansion. The cauda is clearly incised and almost straight along most of its length; only the extreme posterior end is bent in the ventral direction.

**Affinities:** Otoliths of this species are easily distinguished from those of “genus *Atherinidarum*” *spinifer* n. sp. from the same beds by their lozenge-like shape, the lack of a clear posteroventral spur, a wider ostium and an

almost straight cauda. Both species from the Vastan Ypresian are more closely related to the extinct “genus *Atherinidarum*” *debilis* (KOKEN, 1888) from the upper Eocene of the U.S. Gulf Coast than to any living atherinid taxon. However, the American species has an almost hook-like caudal end that is strongly bent in ventral direction; see NOLF, 2003, pl. 1, fig. 10.

**“genus *Atherinidarum*” *spinifer* n. sp.**

Pl. 1, Figs. 5-7

*Type material*: Holotype: a left otolith (Pl. 1, Fig. 5) (IRSNB P8069); two figured paratypes (Pl. 1, Figs. 6-7) (IRSNB P 8070, P 8071) and 12 unfigured paratypes from the Vastan Lignite Mine; ten from sample at 3 m above main coal seam 2 (GU/RSR/VAS/O – 3) and two from sample at 5.5 m above main coal seam 2 (GU/RSR/VAS/O – 4).

*Dimensions of the holotype*: Length: 2.3 mm; height: 1.6 mm; thickness: 0.5 mm.

*Stratum typicum*: Cambay Shale Fm., Ypresian, at the Vastan Lignite Mine, Gujarat, India, sample at 3 m above lower coal seam.

*Derivatio nominis*: *spinifer* (latin) = bearing a spine; alludes to the small, but very characteristic spur at the junction of the posterior and ventral rims.

*Diagnosis*: This species is provided with rather robust otoliths showing a very characteristic spine-like spur at the junction of the posterior and the ventral rim. The outer face is nearly flat and shows a smooth surface. The inner face is manifestly convex in all directions and has a rather expanded posteroventral area. The ventral furrow is visible on most specimens, but tends to become obsolete in some. The sulcus is constituted by a small, very short ostium and a long narrow cauda, whose posterior end is slightly bent in ventral direction. The cauda is well incised, and the incision shows a U-like transverse section. In larger specimens, the posterior half of the cauda tends to approach somewhat towards the dorsal rim. On the dorsal area, an elongate but very shallow depression is visible.

*Affinities*: see under “genus *Atherinidarum*” *rhomboides*.

Suborder: PERCOIDEI

Percoidei inc. sed.

**“genus *Percoideorum*” *thierrysmithi* n. sp.**

Pl. 3, Figs. 7-9

*Type material*: Holotype: a left otolith (Pl. 3, Fig. 7) (IRSNB P 8100); two figured paratypes (Pl. 3, Figs. 8-9) (IRSNB P 8101, P 8102) and nine unfigured paratypes from the Vastan Lignite Mine; eight from sample at 3 m above main coal seam 2 (GU/RSR/VAS/O – 5) and one from sample at 5.5 m above main coal seam 2 (GU/RSR/VAS/O – 6).

*Dimensions of the holotype*: Length: 3.0 mm; height: 1.9 mm; thickness: 0.6 mm.

*Stratum typicum*: Cambay Fm., Ypresian, at the Vastan Lignite Mine, Gujarat, India, sample at 3 m above lower coal seam.

*Derivatio nominis*: This species is named after Thierry Smith, who organized the Belgian-Indian cooperation for the study of the Vastan Lignite Mine.

*Diagnosis*: This species is characterized by oval, rather elongate otoliths with an expanded anterodorsal area, a clear posterodorsal angle, and a straight, well incised sulcus with ostial and caudal portions of about equal length. The outer face has a very smooth surface and is nearly flat in the antero-posterior direction; slightly convex in the dorso-ventral direction. The inner face is convex in all directions. The ostium is about twice as wide as the cauda. The crista superior is very salient because of the strong incision of the sulcus and the rather strong depression in the area just above the sulcus. Most specimens show a clear ventral furrow very near to the ventral rim.

*Affinities*: These otoliths show a mixture of apogonid and ambassid features and may either belong to one of those families or to an extinct plesiomorph percoid group.

Family: CENTROPOMIDAE

**“genus *Centropomidarum*” *obesum* n. sp.**

Pl. 3, Figs. 13-16

*Type material*: Holotype: a left otolith (Pl. 3, Fig. 13) (IRSNB P 8106); three figured paratypes (Pl. 3, Figs. 14-16) (IRSNB P 8017 - P 8019) and 19 unfigured paratypes from the Vastan Lignite Mine; 18 from sample at 3 m above main coal seam 2 (GU/RSR/VAS/O – 7) and one from sample at 5.5 m above main coal seam 2 (GU/RSR/VAS/O – 8).

*Dimensions of the holotype*: Length: 5.2 mm; height: 3.0 mm; thickness: 0.6 mm.

*Stratum typicum*: Cambay Shale Fm., Ypresian, at the Vastan Lignite Mine, Gujarat, India, sample at 3 m above lower coal seam.

*Derivatio nominis*: *obesus, a, um*, (Latin) = very thick, alludes to the very thick, massive otoliths.

*Diagnosis*: This species is characterized by robust, massive otoliths with a well incised sulcus of generalized percoid type. The ostium and the cauda are about equal in length; the cauda is rather large and well incised. The outer face is very smooth and is convex in the dorso-ventral direction; flat to slightly concave in the antero-posterior direction. The inner face is strongly convex in all directions. The posterior end of the cauda is slightly bent downwards, which feature is much more strongly expressed in the crista superior than in the crista inferior. All available specimens have a slightly eroded surface, but some of them show traces of a weak ventral furrow. *Affinities*: Otoliths of “genus *Centropomidarum*” *obesum* look most like those of the genus *Centropomus* (see NOLF, 1993, pl. 2, fig. 5) (subfamily Centropominae) but differ from them by their broader sulcus and greater thickness. They match less well with those of the subfamily Latinae. Because of the exclusive American

present-day distribution of the Centropominae and the noticed differences with *Centropomus*, we prefer not to allocate the species to one of the subfamilies.

Family: ACROPOMATIDAE

*Acropoma massiva* n. sp.

Pl. 1, Figs. 11-15

*Type material*: Holotype: a left otolith (Pl. 1, Fig. 11) (IRSNB P 8075); four figured paratypes (Pl. 1, Figs. 12-15) (IRSNB P 8076 - P 8079) and 29 unfigured paratypes from the Vastan Lignite Mine; 13 from sample at 3 m above main coal seam 2 (GU/RSR/VAS/O - 9) and 16 from sample at 5.5 m above main coal seam 2 (GU/RSR/VAS/O - 10).

*Dimensions of the holotype*: Length: 4.5 mm; height: 3.3 mm; thickness: 1.0 mm.

*Stratum typicum*: Cambay Fm., Ypresian, at the Vastan Lignite Mine, Gujarat, India, sample at 3 m above lower coal seam.

*Derivatio nominis*: *massivus*, *a*, *um* (Latin) = massive; alludes to the very thick, robust otoliths.

*Diagnosis*: This species is characterized by rather thick otoliths with an elliptical outline, but showing a well marked posterodorsal angle and a somewhat expanded anterodorsal portion. The outer face is smooth, nearly flat in the antero-posterior direction and slightly convex in the dorsoventral direction. The inner face is globally convex in all directions, but shows a weak depression in the dorsal area just above the crista superior. Most specimens are somewhat eroded and show no ventral furrow. In the holotype however, a very superficial ventral furrow is visible, especially in the anterior portion very near to the ventral rim. The sulcus is constituted of ostial and caudal portions of about equal length. The cauda is nearly straight and rather wide for an acropomatid.

*Affinities*: The otoliths of *A. massiva* show much resemblance to those of the Recent *A. japonica* GÜNTHER, 1859 (see NOLF, 1993, fig. 8M), but the Recent species has a longer and narrower cauda.

“genus *Acropomatidarum*” *angulosum* n. sp.

Pl. 3, Figs. 10-12

*Type material*: Holotype: a left otolith (Pl. 3, Fig. 10) (IRSNB P 8103); two figured paratypes (Pl. 3, Fig. 11-12) (IRSNB P 8104, P 8105) and 3 unfigured paratypes from the Vastan Lignite Mine at 3 m above main coal seam 2 (GU/RSR/VAS/O - 11).

*Dimensions of the holotype*: Length (incomplete): 4.6 mm; height: 3.0 mm; thickness: 0.9 mm.

*Stratum typicum*: Cambay Fm., Ypresian, at the Vastan Lignite Mine, Gujarat, India, sample at 3 m above lower coal seam.

*Derivatio nominis*: *angulosus*, *a*, *um* (Latin) = angular; alludes to the angular outline of the otoliths.

*Diagnosis*: This species is characterized by robust otoliths with an angular outline especially in the upper and posterior part. The most salient angle is the posterior one, but

also the anterodorsal and posterodorsal angles are well marked. All specimens show at least some lobes at some parts of their margins. The outer face is smooth, but near to the marginal zone, some very small grooves separating the lobes are visible. This face is nearly flat in the antero-posterior direction, but in the dorso-ventral direction, a rather strong convexity is visible very near to the ventral rim. The sulcus is straight and broad; the ostial and caudal portions are about equal in length. Collicular formations are only very weakly developed. Near the caudal crista inferior, a very delicate collicular crest is visible. Only some specimens show a trace of a ventral furrow, very near the ventral rim.

*Affinities*: Otoliths of this species can easily be distinguished from those of *Acropoma massiva*, described here above, by their more angular outline, their narrower ostium, and their broader cauda.

Family AMBASSIDAE

The ambassids or glass perches are common in the Vastan association. There are probably at least three taxa represented, of which the variability overlaps in a more or less considerable way. In fact it is possible to select transitional series between the three most clearly expressed morphologies, and to suggest lumping of the taxa. There are nearly 50 Recent ambassids of which the otolith morphologies overlap partly in the same way, and this clearly indicates that lumping together all our fossil ambassids is not the right approach. Here below, selected specimens of the three most characteristic forms are described and figured on Pl. 2, but many specimens had to be discarded just as unidentified ambassids.

“genus *Ambassidarum*” *dominans* n. sp.

Pl. 2, Figs. 5-11

*Type material*: Holotype: a left otolith (Pl. 2, Fig. 5) (IRSNB P 8084); six figured paratypes (Pl. 2, Fig. 6-11) (IRSNB P 8085 - P 8090) and 424 unfigured paratypes from the Vastan Lignite Mine; 301 from sample at 3 m above main coal seam 2 (GU/RSR/VAS/O - 14) and 123 from sample at 5.5 m above main coal seam 2 (GU/RSR/VAS/O - 15).

*Dimensions of the holotype*: Length: 2.7 mm; height: 2.1 mm; thickness: 0.7 mm.

*Stratum typicum*: Cambay Fm., Ypresian, at the Vastan Lignite Mine, Gujarat, India, sample at 3 m above lower coal seam.

*Derivatio nominis*: *dominans* (Latin) = dominating; alludes to the very common occurrence of this species, dominating among the ambassids of the Vastan association.

*Diagnosis*: This species is characterized by rather robust, high bodied otoliths with a clearly prominent rostrum and a strongly salient anterodorsal angle. However, the most recognizable feature of these otoliths is probably the “angular” disposition of the ostial and caudal part of the sulcus. With this, we mean that the line going straight from the rostrum to the centre of the junction of the ostium and cauda always forms an obtuse angle with

the main direction of the cauda. The outer face is smooth, nearly flat in the antero-posterior direction and slightly convex in the dorso-ventral direction. The inner face is globally convex, with a well incised sulcus and a slight depression just above the crista superior. Some specimens show a vague trace of a ventral furrow.

*Affinities:* See general remarks under “family Ambassidae”.

**“genus Ambassidarum” *celatum* n. sp.**

Pl. 2, Figs. 12-14

*Type material:* Holotype: a left otolith (Pl. 2, Fig. 12) (IRSNB P 9091); two figured paratypes (Pl. 2, Fig. 13-14) (IRSNB P 8092, P 8093) and 43 unfigured paratypes from the Vastan Lignite Mine, 38 from sample at 3 m above main coal seam 2 (GU/RSR/VAS/O – 16) and five from sample at 5.5 m above main coal seam 2 (GU/RSR/VAS/O – 17).

*Dimensions of the holotype:* Length: 4.0 mm; height: 2.6 mm; thickness: 0.7 mm.

*Stratum typicum:* Cambay Fm., Ypresian, at the Vastan Lignite Mine, Gujarat, India, sample at 3 m above lower coal seam.

*Derivatio nominis:* *celatus, a, um* (Latin) = hidden; alludes to the fact that otoliths of this species are, to some extent, hidden in the variability of other ones.

*Diagnosis:* This species is characterized by relatively thin, rather elongate otoliths with a salient anterodorsal portion and a clear antirostrum. The outer face is smooth, slightly concave in the antero-dorsal direction, and somewhat convex in the dorso-ventral direction. The inner face is slightly convex. The sulcus consists of an ostium with a rather widely extended ventral portion. On the dorsal side, only the anterior part of the ostium shows some widening. The cauda traces a general anterodorsal-posteroventral tract. There is a shallow depression in the dorsal area, accentuating the caudal crista superior.

*Affinities:* See general remarks under “family Ambassidae”.

***Ambassis* sp.**

Pl. 2, Figs. 1-4

*Material:* Ninety-nine otoliths from sample at 3 m above main coal seam 2 and three from sample at 5.5 m above main coal seam 2, at the Vastan Lignite Mine.

*Comments:* Some ambassid otoliths in the association seem to be rather round with a straight sulcus. Among the Vastan otoliths, this morphotype is the closest to otoliths of the Recent genus *Ambassis*, see e.g. *Ambassis nalua* (HAMILTON, 1822) in NOLF, 1993, pl. 1, fig. 3.

Family APOGONIDAE

***Apogon* sp.**

Pl. 3, Fig. 6

*Material:* Five otoliths from sample at 3 m above main coal seam 2, and 11 from sample at 5.5 m above main coal seam 2, at the Vastan Lignite Mine.

*Comments:* Although the material is too restricted and too poorly preserved for a more rigorous identification, these otoliths are clearly related to the Recent genus *Apogon*, while the much more common “genus *Apogonidarum*” *robertwesti* is more tentatively included in the apogonids.

**“genus Apogonidarum” *robertwesti* NOLF, 1991**

Pl. 3, Figs. 1-5

*Material:* Four hundred sixty-three otoliths from sample at 3 m above main coal seam 2 and one from sample at 5.5 m above main coal seam 2, at the Vastan Lignite Mine

*Comments:* This species is also known from the middle Eocene of Pakistan and from Kachchh, northwest India.

Family MENIDAE

**“genus Menidarum” *inflatum* n. sp.**

Pl. 4, Fig. 1

*Type material:* Holotype: a left otolith (Pl. 4, Fig. 1) (IRSNB P 8110) and 23 unfigured paratypes from the Vastan Lignite Mine, 22 from sample at 3 m above main coal seam 2 (GU/RSR/VAS/O – 16) and one from sample at 5.5 m above main coal seam 2 (GU/RSR/VAS/O – 17).

*Dimensions of the holotype:* Length: 1.7 mm; height: 1.8 mm; thickness: 0.7 mm.

*Stratum typicum:* Cambay Fm., Ypresian, at the Vastan Lignite Mine, Gujarat, India, sample at 3 m above lower coal seam.

*Derivatio nominis:* *inflatus, a, um* (Latin) = blown up; alludes to the extreme thickness of the otoliths, which makes them look like an inflated pillow.

*Diagnosis:* This species is characterized by small, very thick, short otoliths with a wide and deeply incised sulcus. The height is greater than the length. The outer face has a smooth surface and is globally convex in the antero-posterior direction. The strongest hollowing is located just behind the rostrum, which curves the rostrum outwards, and gives it a hook-like aspect in some specimens. In the dorso-ventral direction, the outer face is flat in its centre, but clearly convex towards the margins. The inner face is strongly convex, especially in the antero-posterior direction. There is a deep hollowing in the dorsal area, and the ventral area is strongly incised by an extended ventral furrow.

*Affinities:* Otoliths of “genus *Menidarum*” *inflatum* differ from those of the Recent *Mene maculata* (BLOCH, 1801) by their extremely shortened rostrum and great thickness. Among fossil menids (see list in NOLF & BAJPAI, 1992, p. 202; the “undescribed menid from the Priabonian of Louisiana” is figured by NOLF & STRINGER, 2003, pl. 4, fig. 16) they seem to be closest to “genus *Menidarum occultus* NOLF & BAJPAI, 1992 from India and Java, and to *Mene* sp. from the Priabonian of Louisiana, U.S.A., but are readily distinguished from these species by their greater thickness.

## Family CEPOLIDAE

**“genus Cepolidarum”** sp.

Pl. 4, Fig. 3

*Material:* Three otoliths from sample at 3 m above main coal seam 2 and from sample at 5.5 m above main coal seam 2, at the Vastan Lignite Mine.

*Comments:* Some imperfectly preserved specimens can be considered as plesiomorph cepolid otoliths, which have not developed the modification (formation of a longitudinal deepening, just below the crista) of the anterior ostial crista inferior.

## Family PERCOPHIDAE

**? Bembrops** sp.

Pl. 4, Fig. 8

*Material:* A single otolith from sample at 3 m above main coal seam 2 at the Vastan Lignite Mine.

*Comments:* a very small otolith (about 1 mm) may belong to the genus *Bembrops* [compare with the Recent *Bembrops platyrhynchus* (ALCOCK, 1894) in NOLF, 1993, fig.10 J].

## Suborder GOBIOIDEI

BAJPAI & KAPUR (2004) described the otoliths of two presumed gobiid species from the Ypresian of Vastan and stated them as the oldest fossil record of the family. Their “genus Gobiidarum” *vastani* is probably a true gobiid, but their “genus Gobiidarum” *nolfi* can only tentatively be interpreted as a plesiomorph sister taxon of the other known gobiid taxa. Both species were also recorded in our samples.

**“genus? Gobiodeorum”** *nolfi* (BAJPAI & KAPUR, 2004)  
Pl. 4, Figs. 4-5

2004 — Genus *Gobiidarum nolfi* – BAJPAI & KAPUR, p. 434, fig. 2, a-f.

*Material:* Ten otoliths from the Vastan Lignite Mine, sample at 3 m above main coal seam 2.

*Comments:* Although the outline of the sulcus of these otoliths shows some general resemblance to what is observed in gobiids, several features are not suggestive for such an attribution, e.g. the very salient rostrum and the deep ostium, opening completely on the ostial rim. In eleotrids, the ostium opens on the ostial rim, but this is always by means of some channel-like structure. There is also no clear evidence of a swollen collicular crest near to the caudal crista inferior, another feature seen in most gobioids. Interpreting these otoliths as belonging to a plesiomorph sister group of modern gobioids is an acceptable hypothesis, but other alternatives, such as considering them as an apomorph perciform group of uncertain relationships are just as valuable. Anyhow, such fossils should not be given much consideration in a discussion of the ancestry of gobioids.

**? Gobioides**

Pl. 4, Figs. 6-7

*Material:* Two otoliths from the Vastan Lignite Mine, sample at 3 m above main coal seam 2

*Comments:* These otoliths have a somewhat similar outline as those of “genus? Gobiodeorum” *nolfi*, but they exhibit a very different sulcus pattern, which excludes consideration as more advanced ontogenetic stages of the former. As in “genus Gobiodeorum” *nolfi*, considering these otoliths as belonging to a plesiomorph sister group of modern gobioids is an acceptable interpretation, but the very wide opening of the sulcus on the ostial rim is not a feature of modern gobioids.

## Family GOBIIDAE

**“genus Gobiidarum”** *vastani* BAJPAI & KAPUR, 2004

Pl. 4, Fig. 2

2004 — Genus *Gobiidarum vastani* – BAJPAI & KAPUR, p. 435, fig. 2, g-o.

*Material:* Eleven otoliths from Vastan Lignite Mine, sample at 3 m above main coal seam 2.

*Comments:* These otoliths show some features, such as the appearance of a swollen collicular crest above the caudal crista inferior and the anterior closing of the ostium that can be considered as gobioid. Therefore, they are probably more valuable candidates for inclusion in gobiids than the two previously discussed taxa. Other features, like the narrow ostium and the separate ostial and caudal collicula, are not seen in modern gobiids.

## Family BRACHYPLEURIDAE

***Brachypleura*** sp.

Pl. 4, Figs. 9-10

*Material:* Sixteen otoliths from the Vastan Lignite Mine, sample at 3 m above main coal seam 2.

*Comments:* The available material constitutes a highly variable series of flatfish otoliths, and several among them are more or less affected by erosion. The two figured specimens show a reasonable similarity to those of Recent flatfishes of the genus *Brachypleura* (see SCHWARZHANS, 1999, fig. 105-110, p. 59), but more and better preserved material is required to decide if the series is homogeneous.

**Conclusions**

Sampling of about 1000 kg of sediment at the Vastan Lignite Mine provided otoliths of 20 teleost taxa of which nine could be described as new species. Most otoliths are from very small fishes, hardly exceeding 5 cm in length. An overview of the identified taxa is provided in Table 1. All Recent relatives of the represented taxa occur in the marine realm. It is true that the association contains a considerable amount of otoliths of fishes penetrating also

Table 1 — Overview of the otolith-based fish taxa from the Cambay Fm. (Ypresian) at the Vastan Lignite Mine, Gujarat, India.

FAMILY	TAXA	Sample + 3 m	Sample + 5.5 m	ICONOGRAPHY
PRISTIGASTERIDAE	? <i>Pellona</i> sp.	+	–	Pl. 1, Fig. 3
	Pristigasteridae ind.	+	–	Pl. 1, Fig. 1
ATHERINIDAE	“genus Atherinidarum” <i>rhomboides</i> n. sp.	+	+	Pl. 1, Figs. 8-10
	“genus Atherinidarum” <i>spinifer</i> n. sp.	+	–	Pl. 1, Figs. 5-7
PERCOIDEI inc. sed.	“genus Percoideorum” <i>thierrysmithi</i> n. sp.	+	+	Pl. 3, Figs. 7-9
CENTROPOMIDAE	“genus Centropomidarum” <i>obesum</i> n. sp.	+	+	Pl. 3, Figs. 13-16
ACROPOMATIDAE	<i>Acropoma</i> <i>massiva</i> n. sp.	+	+	Pl. 1, Figs. 11-15
	“genus Acropomatidarum” <i>angulosum</i> n. sp.	+	–	Pl. 3, Figs. 10-12
AMBASSIDAE	“genus Ambassidarum” <i>dominans</i> n. sp.	+	+	Pl. 2, Figs. 5-11
	“genus Ambassidarum” <i>celatum</i> n. sp.	+	+	Pl. 2, Figs. 12-14
	<i>Ambassis</i> sp.	+	+	Pl. 2, Figs. 1-4
APOGONIDAE	<i>Apogon</i> sp.	+	+	Pl. 3, Fig. 6
	“genus Apogonidarum” <i>robertwesti</i> NOLF, 1991	+	+	Pl. 3, Figs. 1-5
MENIDAE	“genus Menidarum” <i>inflatum</i> n. sp.	+	+	Pl. 4, Fig. 1
CEPOLIDAE	“genus Cepolidarum” sp.	+	+	Pl. 4, Fig. 3
PERCOPHIDAE	? <i>Bembrops</i> sp.	+	–	Pl. 4, Fig. 8
GOBIOIDEI inc. sed.	“genus” <i>Gobioideorum</i> ” <i>nolfi</i> (BAJPAI & KAPUR, 2004)	+	–	Pl. 4, Figs. 4-5
	? <i>Gobioidei</i>	+	–	Pl. 4, Figs. 6-7
GOBIIDAE	“genus Gobiidarum” <i>vastani</i> BAJPAI & KAPUR, 2004	+	–	Pl. 4, Fig. 2
BRACHYPLEURIDAE	<i>Brachypleura</i> sp.	+	–	Pl. 4, Figs. 9-10

in fresh water, such as the atherinids, centropomids, and ambassids, but primary freshwater fishes (= occurring in fresh water only) are lacking completely. The association is quantitatively dominated by ambassids and “genus Apogonidarum” *robertwesti*, a plesiomorph percoid that we tentatively attribute to the apogonids. All represented taxa are mainly confined to tropical, very shallow near shore habitats, and the association is completely devoid of oceanic fishes (i.e. mesopelagic and deep water bottom fishes). In order to provide a more detailed overview, the ecology and biogeography of each represented family is treated separately. Data on the present-day freshwater distribution are mainly from BERRA (2001) or from NELSON (1994).

PRISTIGASTERIDAE. – Pristigasterid herrings are coastal marine fishes occurring in tropical and subtropical waters on both sides of the Atlantic and Pacific Oceans and throughout the Indian Ocean. Only four South American species have an extensive distribution in fresh water, and one occurs in the rivers of Myanmar (Burma).

ATHERINIDAE. – Most of the about 160 Recent atherinid species are marine fishes, but there are about 50 species confined to freshwater, and others enter freshwater. The otolith morphology of the two atherinid species recorded at Vastan does not match exactly with those of any precise Recent genus. Their closest relationships are apparently with the middle and late Eocene “genus Atherinidarum” *debilis* (KOKEN, 1888) from the Bartonian and Priabonian of the U.S. Gulf Coast. Those three Eocene atherinid taxa apparently constitute a plesiomorph clade that may be considered as the sister group of all other Recent atherinid subgroups.

CENTROPOMIDAE. – The family Centropomidae includes two subfamilies. The Centropominae have an exclusive American distribution in tropical and subtropical waters of the Atlantic and eastern Pacific realm, but enter seasonally in to fresh water. The Latinae, include eight African freshwater species and one marine species of the genus *Lates* and two other marine genera, *Hypopterus* and *Psammoperca*. The marine Latinae are distributed from Pakistan till the north Australian coast.

ACROPOMATIDAE. – Although many acropomatids are confined to rather deep water, *Acropoma japonica* is a regular inhabitant of shallow mangrove shore areas of Gazi Bay (DE TROCH *et al.*, 1996; KIMANI *et al.*, 1996).

AMBASSIDAE. – The present-day distribution of ambassids reaches from southern Africa through India to New Guinea and Australia, but otoliths of their fossil relatives are known from many European euryhaline deposits, from the lower Eocene till the middle Miocene. They are unknown in American Tertiary deposits. Ambassids are especially well represented in the Oligocene and Lower Miocene deposits of the Paratethys. The Recent ambassids have greater diversity in freshwater than in the sea. Of the 41 species, 21 are confined to fresh water, and a few additional species can occur in fresh water. Some species are even mainly staying in fresh water. Most ambassids are small, less than 10 cm, and many are transparent, with the vertebral column and swim bladder visible.

APOGONIDAE. – Members of this family are essentially reef-associated, but apogonids may also constitute a quantitatively important portion of the fish communities

in tropical bays with mangrove vegetation, e. g. Gazi Bay, Kenya (DE TROCH *et al.*, 1996; KIMANI *et al.*, 1996) and the Sikao Creek estuary, Trang Province, Thailand (IKEJIMA *et al.*, 2003).

**MENIDAE.** – In the Recent fauna, the menids are represented by a single genus and one species, *Mene maculata* BLOCH & SCHNEIDER, 1801, inhabiting coastal waters of southeast Asia and Australia, sometimes entering estuaries. Fossil menids seem to have a worldwide circumtropical distribution during the Eocene. They are known from the Ypresian of Aquitaine, the Lutetian of Monte Bolca in northern Italy, the Paris Basin, southern England, western India, the Bartonian of northern Spain and Java, and the Priabonian of Louisiana (see list in NOLF & BAJPAL, 1992, p. 2002).

**CEPOLIDAE.** – This family occurs in the eastern Atlantic, the Mediterranean, and Indo-West Pacific including New Zealand. The genus *Cepola*, exclusively marine, occurs from very shallow depths till about 200 m, but *Owstonia* is merely confined to greater depths.

**PERCOPHIDAE.** – One very small otolith is tentatively referred to the genus *Bembrops*, subfamily Bembropinae. Recent Bembropinae are marine bottom fishes, living mainly in the deep neritic zones and upper slope of tropical seas. Their otoliths are quite distinct from those of the two other subfamilies (Percophinae and Heterocoetinae) included in the family (see NOLF, 1993, fig. 10 i-k).

**GOBIOIDEI.** – This suborder is a very large, essentially marine group, with more than 2100 species. About 10% of these fishes occur in fresh water. PATTERSON (1993) recognizes nine families; other arrangements (MILLER in HUREAU & MONOD, 1973) consider only two families, Rhyacichthyidae (freshwater streams of various Indo-pacific islands) and Gobiidae. Among gobiids *sensu lato*, the Gobiidae, essentially marine, are the most important

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group with about 1875 species. Eleotrids constitute the second important group (about 150 species) and are found mainly in tropical and subtropical marine, brackish and fresh waters, throughout the world. They form an important component of the freshwater fauna of Australia, New Guinea, New Zealand, Hawaii, and islands of the Indo-Pacific.

**BRACHYPLEURINAE.** – The citharid subfamily Brachypleurinae consists of neritic marine flatfishes whose Recent distribution is restricted to the Indo-West Pacific realm. In the Eocene, however, the family seems to have been distributed over a much larger geographic area: “genus aff. *Brachypleura*” *nanus* (MÜLLER, 1999) occurs in the middle Eocene Piney Point Fm., Virginia, U.S.A. (originally described as “genus *Bothidarum*”); *Brachypleura pentagonalis* (STEURBAUT, 1984) in the lower Oligocene Yrieu Sands, Aquitaine (originally described as “genus *Pleuronectidarum*”) and “genus aff. *Brachypleura*” *xenosulcus* SCHWARZHANS, 1999, from the Bartonian Nanggulan Fm., Java. This pattern indicates that the taxon had an ancient circumglobal distribution.

All these data suggest a protected shallow marine environment, not widely exposed to the oceanic realm, probably with a regular influx of fresh water, possibly an estuary or a protected bay, possibly with mangrove vegetation. It is probable that some of the represented taxa were able to intrude into fresh water.

## Acknowledgments

It is a pleasure for us to express our sincere gratitude to Anne Wauters, Hugo De Potter and Angela Girone, who helped in preparing the iconography of the present paper and to Rostislav Brzobohaty and Gary Stringer for reviewing the manuscript.

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### Explanation of Plates

All figured specimens are deposited in the collections of the Institut Royal des Sciences Naturelles de Belgique (IRSNB) and are from sample 1, at about 3 m above the lower coal seam. The fossil otoliths bear numbers of the collection of types and figured fossil fish specimens of the IRSNB. The Recent otoliths are part of the reference collection of Recent otoliths, at the same Institution. The latter collection is arranged in systematic order without numbering; therefore, such specimens, when figured, bear only the notation "coll. IRSNB". All unfigured otoliths are deposited in the collections of the Garghwal University under the labels GU/RSR/VAS/O (Garhwal University/R.S.Rana/Vastan/Otoliths)

The abbreviations F and R in the upper right corner of each compartment of the plates indicate if the figured specimens in that compartment are fossils (F) or Recent (R). In the text of the explanations, L stands for left otolith and R for right otolith. The annotations Fig. a, b and c are used to indicate respectively ventral, inner (= mesial) and posterior views. Figures without letter show inner views.

#### PLATE 1

- Fig. 1 — *Pristigasteridae* ind., L, Vastan Lignite Mine (IRSNB P 8067).  
 Fig. 2 — *Dussumieria acuta* VALENCIENNES, 1847, Indonesia, Siboga station 71 (coll. IRSNB).  
 Fig. 3 — ? *Pellona* sp., Vastan Lignite Mine (IRSNB P 8068).  
 Fig. 4 — *Pellona ditchela* VALENCIENNES, 1847, L, Recent, off South Africa (coll. IRSNB).  
 Figs. 5-7 — "genus *Atherinidarum*" *spinifer* n. sp., L, Vastan Lignite Mine, 5 = holotype (IRSNB P 8069), 6-7 = paratypes (IRSNB P 8070, P 8071).  
 Figs. 8-10 — "genus *Atherinidarum*" *rhomboides* n. sp., L, Vastan Lignite Mine, 8 = holotype (IRSNB P 8072), 9-10 = paratypes (IRSNB P 8073, P 8074).  
 Figs. 11-15 — *Acropoma massiva* n. sp., L, Vastan Lignite Mine, 11 = holotype (IRSNB P 8075), 12-15 = paratypes (IRSNB P 8076 - P 8079).

#### PLATE 2

- Figs. 1-4 — *Ambassis* sp., L, Vastan Lignite Mine, (IRSNB P 8080 - P 8083).  
 Figs. 5-11 — "genus *Ambassidarum*" *dominans* n. sp., 5-8 = L, 9-11 = R, Vastan Lignite Mine, 5 = holotype (IRSNB P 8084), 6-11 = paratypes (IRSNB P 8085 - P 8090).  
 Figs. 12-14 — "genus *Ambassidarum*" *celatum* n. sp., 12-13 = L, 14 = R, Vastan Lignite Mine, 12 = holotype (IRSNB P 9091), 13-14 = paratypes (IRSNB P 8092, P 8093).

#### PLATE 3

- Figs. 1-5 — "genus *Apogonidarum*" *robertwesti* NOLF, 1991, L, Vastan Lignite Mine (IRSNB P 8094 - P 8098).  
 Fig. 6 — *Apogon* sp., L, Vastan Lignite Mine (IRSNB P 8099).  
 Figs. 7-9 — "genus *Percoideorum*" *thierrysmithi* n. sp., 7 = L, 8-9 = R, Vastan Lignite Mine, 7 = holotype (IRSNB P 8100), 8-9 = paratypes (IRSNB P 8101, P 8102).  
 Figs. 10-12 — "genus *Acropomatidarum*" *angulosum* n. sp., 10-11 = L, 12 = R, Vastan Lignite Mine, 10 = holotype (IRSNB P 8103, 11-12 = paratypes (IRSNB P 8104, P 8105).  
 Figs. 13-16 — "genus *Centropomidarum*" *obesum* n. sp., 13-14 = L, 15-16 = R, Vastan Lignite Mine, 13 = holotype (IRSNB P 8106), 14-16 = paratypes (IRSNB P 8107 - P 8109).

#### PLATE 4

- Fig. 1 — "genus *Menidarum*" *inflatum* n. sp., L, Vastan Lignite Mine, 13 = holotype (IRSNB P 8110).  
 Fig. 2 — "genus *Gobiidarum*" *vastani* BAJPAI & KAPUR, 2004, R, Vastan Lignite Mine (IRSNB P 8111).  
 Fig. 3 — "genus *Cepolidarum*" sp., R, Vastan Lignite Mine (IRSNB P 8112).  
 Fig. 4-5 — "genus ? *Gobioideorum*" *nolfi* (BAJPAI & KAPUR, 2004), 4 = L, 5 = R, Vastan Lignite Mine (IRSNB P 8113, P 8114).  
 Figs. 6-7 — ? *Gobioidei*, 6 = L, 7 = R, Vastan Lignite Mine (IRSNB P 8115, P 8116).  
 Fig. 8 — ? *Bembrops* sp. L, Vastan Lignite Mine (IRSNB P 8117).  
 Figs. 9-10 — *Brachypleura* sp., 9 = L, 10 = R, Vastan Lignite Mine (IRSNB P 8118, P 8119).

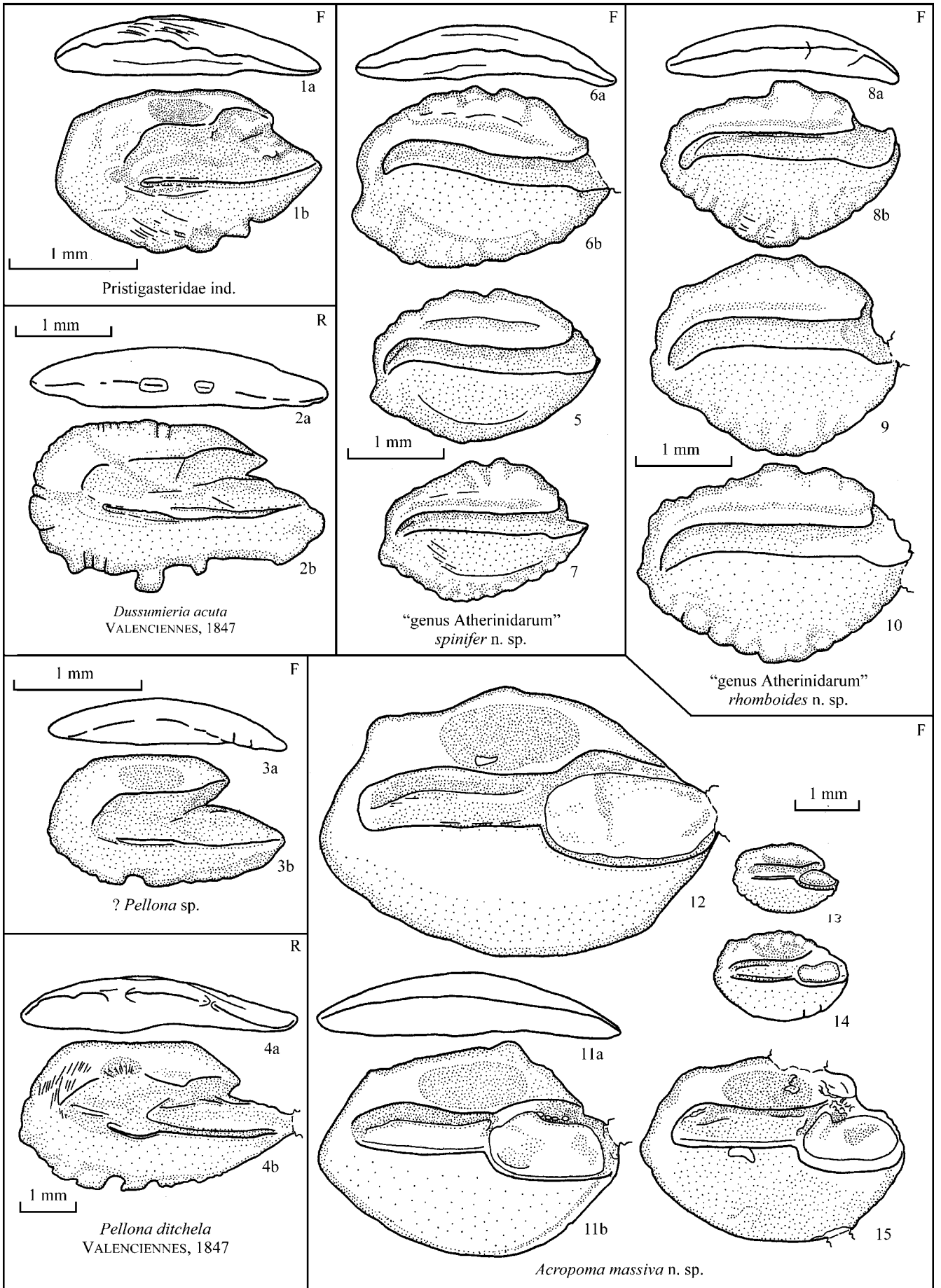
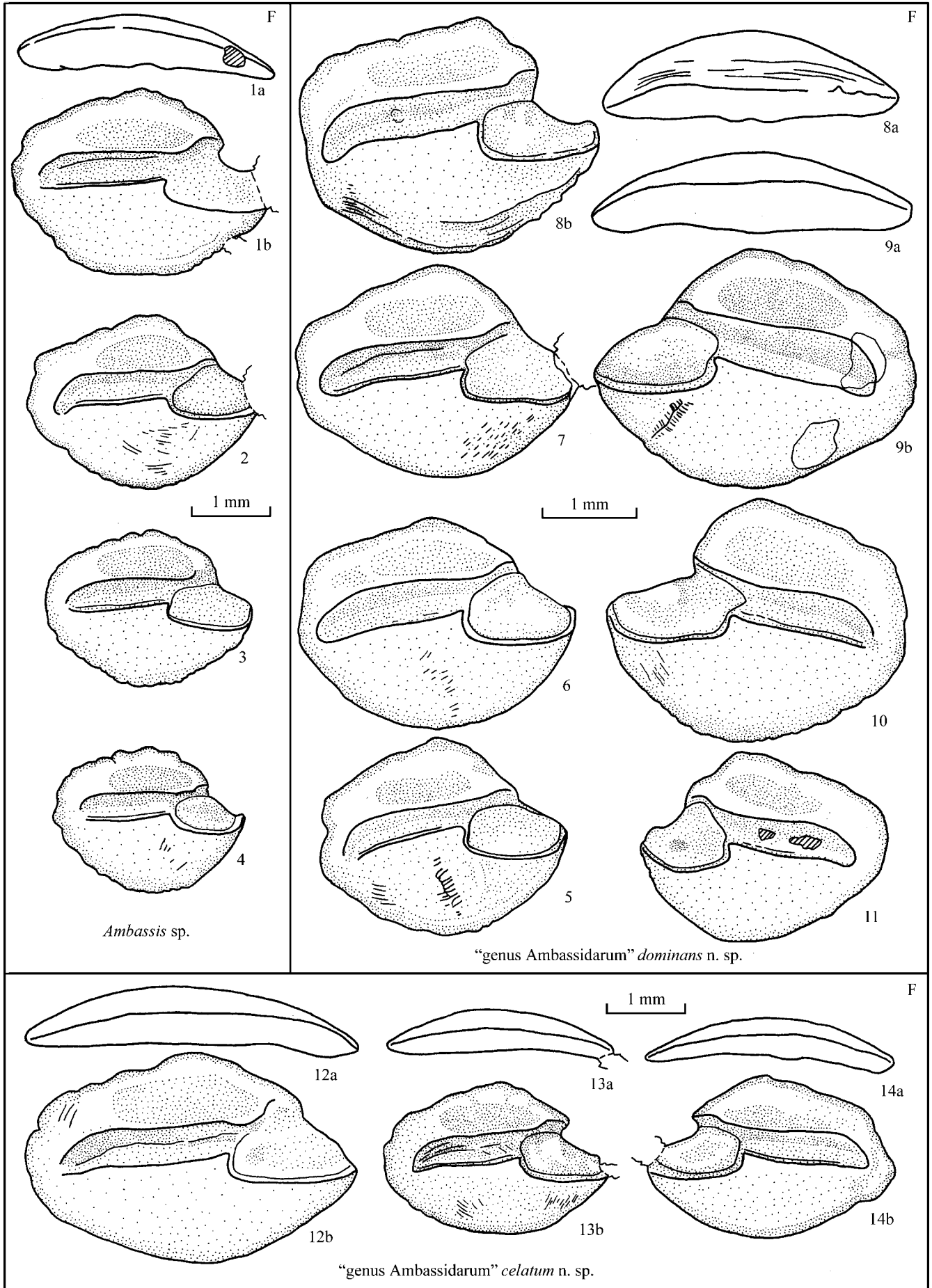
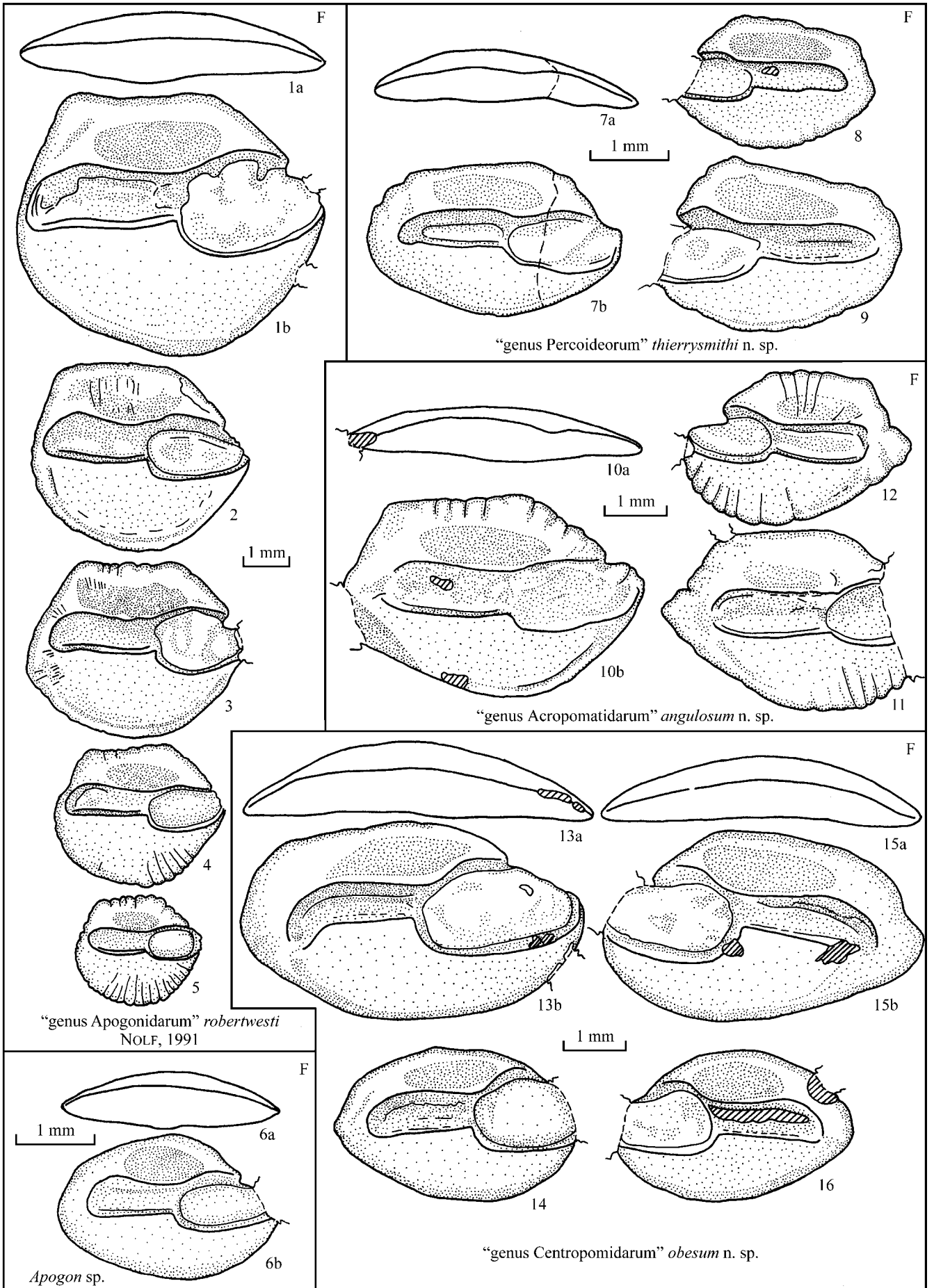


PLATE I





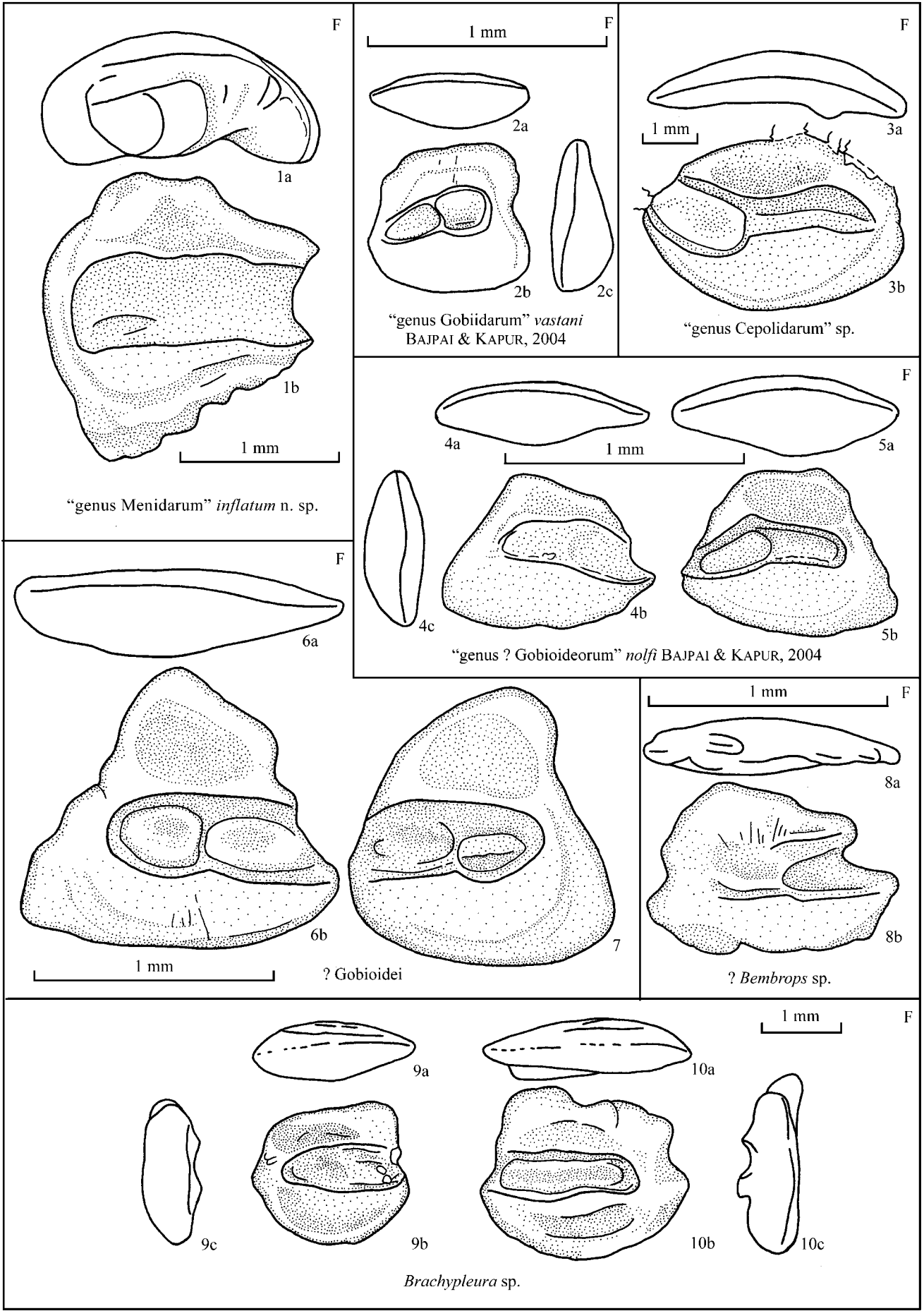


PLATE 4