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FISH OTOLITHS FROM THE COFFEE SAND (CAMPANIAN) OF NORTHEASTERN MISSISSIPPI

Dirk Nolf
Royal Belgian Institute of Natural Sciences
29, Vautierstraat, 1040-Brussel, Belgium

and

David T. Dockery III
Mississippi Bureau of Geology

ABSTRACT

Otoliths collected from the Coffee Sand (Campanian) in Mississippi revealed the presence of 20 teleost taxa. Six new species are introduced: "genus ? Albulidarum" *ensis*, "genus Pterothrissidarum" *griffini*, "genus Synodontidarum" *pseudoperca*, "genus Trachichthyidarum" *coffeesandensis*, "genus Percoideorum" *pseudochanda*, and "genus Perciformorum" *cepoloides*. Otolith-based faunal reconstructions reveal different spectra than skeleton-based ones; as a result, the present study traces several groups (congrids, ariids, synodontids, *Bathyclupea*, apogonids) much further back in time than previously recorded. Also, the record of five additional species of perciform fishes strongly contrasts with the scarcity of this group in the osteological record. From a paleoecological point of view, the reconstructed fauna suggests a rather shallow neritic environment in a tropical or subtropical area.

INTRODUCTION

Otolith records from Cretaceous strata are very scarce. This strongly contrasts with the many otolith-based reconstructions of fish faunas from various Tertiary deposits. Nolf (1985, p. 27) records less than 20 valid species for the whole Cretaceous, while this number is on the order of 1000 for the Tertiary. A critical analysis of otolith taphonomy reveals that the sudden appearance of these fossils in a great variety of Tertiary sediments has no evolutionary significance but is essentially due to preservation conditions and collecting techniques.

A primary condition for otolith collecting is an unconsolidated sediment that can be sieved (sand, silt, clay, or marl). This means that no otoliths from indurated rocks are represented in our record. Another aspect concerns the mineral composition of otoliths; they consist of aragonite, a metastable polymorph of calcium carbonate. Decalcification often affects sediments to the extent that aragonite is dissolved, while the stable polymorph calcite remains (e.g., oysters, pectinids, brachiopods, and echinoderms are preserved). This is the case in the majority of the Cretaceous deposits in Europe, the continent where fossil otoliths have been studied most intensively. Recrystallization of otoliths into calcite is rare,

which explains their absence in the fossil record of this period.

Among potential otolith-bearing Cretaceous strata, Nolf and Steurbaut (1989b, p. 48) cite the U. S. Upper Cretaceous Coffee Sand and Ripley formations as candidates, a statement that was based on the excellent preservation of aragonitic shelled gastropods from these strata, as figured by Sohl (1960, 1964a, 1964b). In several areas of the Cretaceous in the southern and eastern United States, the prevailing chalk facies laterally grade into unconsolidated glauconitic sands or sandy clays with well preserved molluscan faunas. These greensands represent more shallow and nearshore neritic environments than their lateral carbonate equivalents. Maastrichtian otoliths from such facies have already been cited by Huddleston and Savoie (1983) in the area of Washington, D. C.

The present study deals with an otolith assemblage of Campanian age from northeastern Mississippi. All the material comes from a sandpit located on the Griffin property (also called "Friendship Locality"), east of Chapelville, Lee County (Ratliff quadrangle, UTM point x=355,000m E., y=3,812,850m N.). At this location is exposed a fossiliferous greensand horizon, informally called the "Chapelville fossiliferous horizon" of the Tupelo Tongue of the Coffee Sand (Figure 1).

The precise stratigraphic position of this approximately 3 meter thick fossiliferous horizon has been discussed by Dockery and Jennings (1988) on the basis of test holes drilled in the Griffin sandpit and at two other nearby localities. These data indicate that the Coffee Sand reaches a total thickness of 72 m in the area concerned; it lies on the Mooreville Chalk and is overlain by the Demopolis Chalk. The top of the Chapelville fossiliferous horizon lies about 17 m above the base of the formation. The present study is based on otoliths obtained by screen washing of about 1500 kg of sediment from bed E and about the same weight from bed B. Preservation is usually better in bed E. In total, only 117 otoliths have been collected. This means that the sampled greensand coquina is rather poor in otoliths when compared with similar facies in the Tertiary (e.g. about 1 otolith per kg of sediment in the Edegem Sands, Lower Miocene of Belgium, Nolf and Smith, 1983). In the Paleogene of the Washington, D.C., area however, both otolith-rich and otolith-poor greensand coquinas occur.

SYSTEMATICS

For general information about otoliths (morphological nomenclature, composition, diagnostic value, ontogenetic changes, variability, etc.), the reader is referred to the otolith volume of the *Handbook of Paleoichthyology* (Nolf, 1985). A few words can be said, however, about collective (or open) generic nomenclature, a procedure that is currently used in numerous papers on otolith taxonomy and that is applied in the present paper. For species of uncertain generic position (i.e., of which the systematic position can be identified only at familial, subordinal or ordinal level), we use the word "genus", followed by the species name (e.g. "genus Synodontidarum" *pseudoperca*); see Nolf, 1985, p. 30 for a full explanation. To keep nomenclature as simple as possible, taxa that could not be identified at species level (badly preserved or insufficiently documented material; undiagnostic juvenile otoliths) are cited with just the name of the family or higher category at which identification was possible.

As discoveries of fossil skeletons with otoliths in situ are extremely rare, in nearly all cases the relations of a fossil otolith are evaluated by comparison with Recent forms. Therefore, the precision of the identification largely depends upon the extent of the Recent reference collection. It is evident, in the context of general paleontology, that fossil teleost faunas from various strata, from Jurassic to Quaternary, may contain both extinct and living genera. But the proportion of the two categories is not directly evident, especially in Tertiary strata, which contain the most abundant otolith faunas. Thus, an otolith of uncertain systematic position may belong either to an extinct genus or to a Recent genus of which the otoliths are unknown. Use of a fossil genus name therefore implies deciding arbitrarily in favor of the first hypothesis (and refuting the second). Even in those rare cases where knowledge of the Recent otoliths of a group is very extensive, it is a wise rule not to use exclusively otolith-based fossil genera.

One could object that, as far back as the Cretaceous, the majority of species belong to extinct genera and families that can be given a name with confidence. Ignorance of otoliths in situ for nearly all Cretaceous skeleton-based taxa, however, precludes this practice. For instance, no one knows how the otoliths of ichthyotringids, apateopholids, cimolichthyids, enchodontids, eurypholids, halecids, sardinoidids, or aulolepidids look, to cite but a few primitive euteleostean families; see also Goody (1969). It is evident that in such a situation, introduction of purely otolith-based genera and higher taxa would build but a pedantic system of pseudotaxonomy, full of hidden synonyms. Although collective generic nomenclature does not conform to usual taxonomic practice, it exactly and objectively reflects the state of knowledge about the position of the given species, while using fossil genera suggests a precision that does not exist, and merely hints that the species are incertae sedis.

Subdivision: TELEOSTEI Muller, 1846
Supercohort: ELOPOCEPHALA Patterson and Rosen, 1970
Cohort: ELOPOMORPHA Greenwood et al., 1966

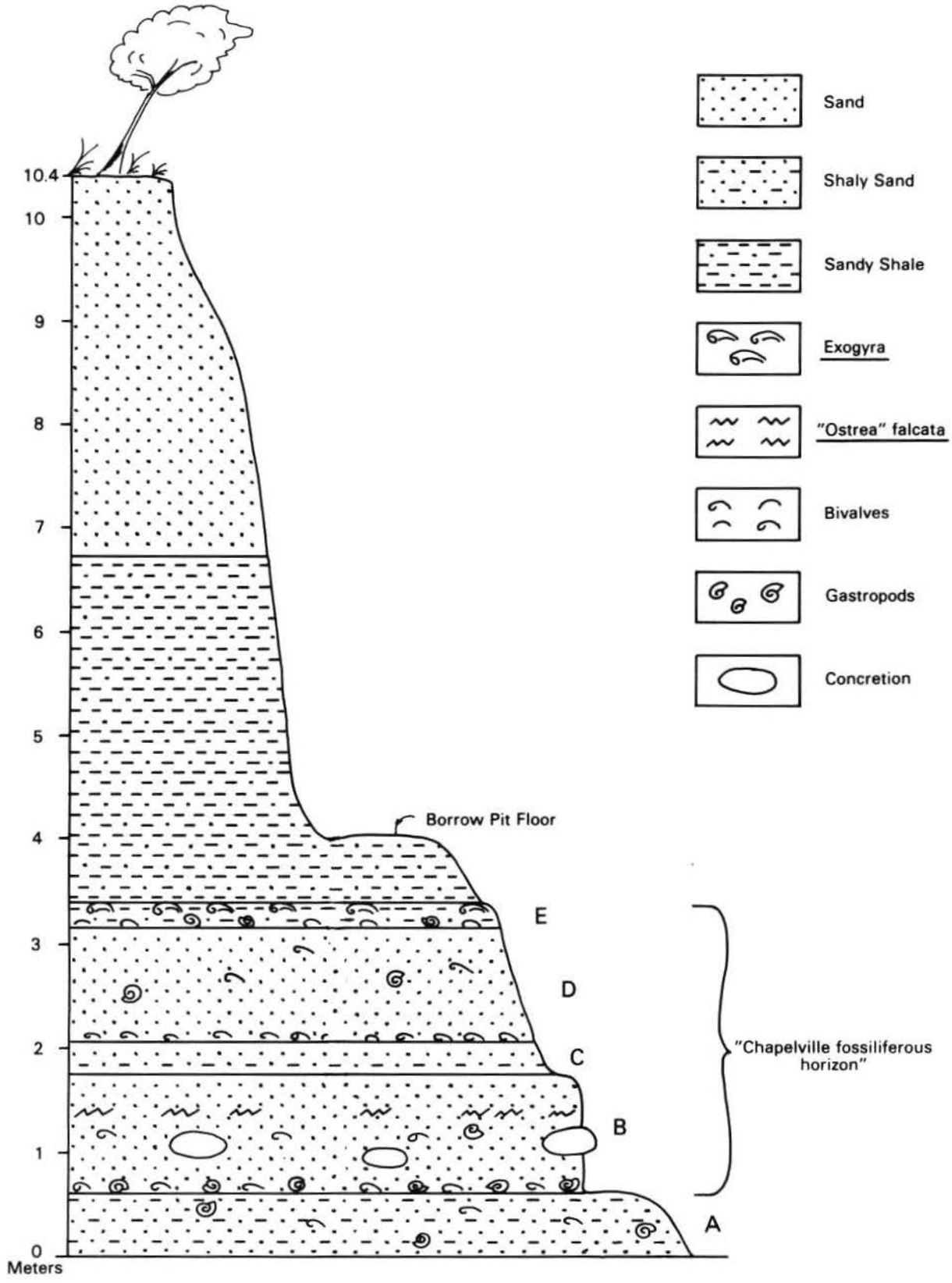

Figure 1. Measured section of the Tupelo Tongue of the Coffee Sand at the Griffin borrow pit, east of Chapelville, Lee County, Mississippi. Fossiliferous beds of the lower sequence are labeled in ascending order from A to E with the highly fossiliferous units B-E informally designated as the "Chapelville fossiliferous horizon." The borrow pit floor is on a nonfossiliferous shale unit of Tupelo Tongue. This unit can be correlated in the subsurface on electric logs over a several mile area (Dockery and Jennings, 1988). It is conformably overlain by a weathered, nonfossiliferous sand in the Tupelo Tongue, which may have lost its fossil shell content due to leaching.

Order: MEGALOPIFORMES Patterson and Rosen, 1977

? Megalopidae
Plate 1, figure 1

Material. - Two otoliths, one from bed E and another without precise location in the section, but probably also from bed E according to its preservation state.

Remarks. - Two very small otoliths, with relatively large caudae and strongly sculptured inner and outer faces, belong to juvenile fishes. Among Recent fishes, they seem to be most closely related to megalopids; otoliths of the Recent *Megalops atlanticus* Valenciennes (1846) (Plate 1, figure 2) are figured here for comparative purposes, but we do not have comparable Recent juvenile material to make a more pertinent comparison and identification.

Order: ANGUILLIFORMES Regan, 1909
Suborder: ALBULOIDEI Jordan, 1923
Superfamily: ALBULOIDEA Bleeker, 1859
Family: ALBULIDAE Bleeker, 1859

Recent albulids are represented by two genera: *Albula* Bleeker, 1859, and *Dixonia* Fowler, 1911. Most authors have hitherto recognized only a single worldwide (circumtropical in warm coastal waters; sometimes deeper) species of *Albula, A. vulpes* (Linnaeus, 1758), but recently it has been shown by biochemical techniques (Shaklee and Tamaru, 1981) that there are at least two species of bonefishes in Hawaiian waters. These species can also be recognized by differences in the outline of the postero-dorsal portions of their otoliths; otoliths of one of them, *A. glossodonta* Forsskal, 1775, are figured here for comparative purposes (Plate 2, figures 1-2). The monospecific genus *Dixonia* Fowler (otoliths figured in Plate 2, figure 6) is considered to be different from *Albula* by most authors, but has been included in that genus by Robins et al. (1986).

"genus aff. *Albula*" sp.
Plate 2, figure 8

Material. - Three otoliths, two from bed E, and one without precise location in the section.

Remarks. - Although slightly eroded, these otoliths are very similar to Recent *Albula* otoliths (Plate 2, figures 1-2) and may be assigned to that genus. Identification at species level is excluded because, as already pointed out, the main diagnostic features of *Albula* concern details of the outline, which are abraded on the fossil specimens. The presently described specimens constitute the oldest record of the genus, which is also represented by at least six fossil species from various Tertiary strata.

"genus? Albulidarum" *ensis* n. sp.
Plate 2, figure 7

Type material. - Holotype: a left otolith (Plate 2, figure 7) (IRSNB P5681), one unfigured paratype.

Dimensions of the holotype. - Length: 4.5 mm; height: 1.9 mm; thickness: 0.5 mm.

Stratum typicum. - Tupelo Tongue of the Coffee Sand, Chapelville fossiliferous horizon, bed B at Griffin sandpit, Chapelville, Lee County, Mississippi.

Derivatio nominis. - *Ensis* (Latin) = sword; refers to the elongate, thin otoliths with a very cutting ventral rim profile.

Diagnosis. - Thin, elongate otoliths with a general elliptical outline, showing, however, a slightly pointed rostrum and a well marked postero-dorsal angle. The outer face is moderately concave. There is a short groove-like antero-posterior depression just below the anterior part of the ostial and dorsal rim, and a short groove-like vertical depression just below the notch in front of the postero-dorsal angle. The ventral rim is cutting, but the posterior rim is blunt, with a little thickening on the outer face. The inner face is markedly convex in dorso-ventral direction, more moderately convex in antero-posterior direction. The very large sulcus covers about the upper two-thirds of the inner surface of the otolith. It opens very wide; the ostial rim reaches from the rostrum almost to the postero-dorsal angle. There is no clear division into ostial and caudal portions. The incision of the sulcus is minimal, except in the most caudal part, where it is deeply incised just in front of the dorso-posterior sulcus end. Only the holotype shows a little collicular formation in this area, which is not observed in the paratype; the latter, however, is a more juvenile and slightly eroded specimen.

Affinities. - These otoliths are tentatively referred to the albulids on the basis of their great similarity with Recent albulids in the ventral rim profile, the convexity of the inner and outer faces, and the incised posterior sulcus end. It should, however, be noted that otoliths of the extinct family Osmeroididae are unknown to us (see Forey, 1973, for the content of skeleton-based albulid taxa).

"genus Albulidarum" aff. *sohli* (Frizzell, 1965)
Plate 2, figure 3

1965 *Protalbula sohli* n. sp. - Frizzell, p. 100, pl. 4, fig. 2.

Material. - Three otoliths, one from the middle of bed B and two without precise location in the section.

Remarks. - The holotype of this species comes from the Blufftown Formation, Early Campanian of Stewart County, Georgia. According to the figure in Frizzell (*loc. cit.*), this type agrees fairly well in outline, convexity and sulcus pattern with our specimen. The latter is probably conspecific with it, but more and

better preserved material is needed to make a definitive attribution.

Family: PTEROTHRISSIDAE Gill, 1893

***Pterothrissus* sp.**
Plate 1, figures 10-12

Material. - 30 otoliths; 17 from bed E, 9 from bed B, and 4 without precise location in the section.

Remarks. - Most specimens are juveniles that are too small to be diagnostic. The largest specimen (Plate 1, figure 10) is imperfectly preserved but shows clear affinities with Recent otoliths of the genus *Pterothrissus;* see Plate 1, figures 4-7: *P. belloci* Cadenat, 1937 and Plate 1, figures 8-9: *P. gissu* Hilgendorf, 1877. The fossil species differs from both Recent species by the more convex dorso-ventral profile of the inner face, the shorter ostium, and the appreciable extension of the postero-dorsal area.

The figured comparative material represents the only two Recent species of the genus. *P. gissu* is an inhabitant of the continental slope of South Asia and Japan, below 200 m. *P. belloci* lives on the continental slope of West Africa, down to depths of 500 m. It is most abundant in the deep neritic zone between 150 and 200 m but occurs as shallowly as 50 m. However, the frequent presence of extinct *Pterothrissus* species in very shallow Paleocene and Eocene facies of the Paris Basin suggests that at least some fossil species had a much shallower habitat than their Recent relatives.

"genus Pterothrissidarum" *griffini* n. sp.
Plate 2, figure 9

Type material. - The unique holotype (Plate 2, figure 9) (IRSNB P5683), a well preserved, large-sized right otolith.

Dimensions of the holotype. - Length: 10.8 mm; height: 8.2 mm; thickness: 2.4 mm.

Stratum typicum. - Tupelo Tongue of the Coffee Sand, Chapelville fossiliferous horizon, bed E at Griffin sandpit, Chapelville, Lee County, Mississippi.

Derivatio nominis. - This species is named after the owner of the sandpit where it was discovered.

Diagnosis. - The holotype is a robust, thick otolith, with approximately a circular outline. The outer face is smooth, slightly concave in the antero-posterior direction but convex in the dorso-ventral direction. The ventral rim has a cutting profile. The inner face is clearly convex in both directions, and is rather strongly incised by the sulcus. The ostium opens largely on the anterior and antero-dorsal rim. It lies somewhat deeper than the ostium and is filled with a very smooth colliculum. The cauda is less incised than the ostium, has a very thin colliculum in its central part, and is regularly curved in the ventral direction, but without showing a deep incised and nearly vertically oriented posterior end as in albulids. The crista superior is salient and accentuated by a shallow depression in the area just above its anterior part.

Pterothrissidae
Plate 2, figure 4

Material. - Six otoliths, five from bed B and one without precise location in the section.

Remarks. - The family Pterothrissidae seems to be represented by a third species which is related to "genus Pterothrissidarum" *griffini,* but the specimens have a more elongate outline and a much narrower cauda. Unfortunately, these specimens are imperfectly preserved and juveniles; as such, they do not provide a solid basis for the diagnosis of a new species.

Suborder: ANGUILLOIDEI Regan, 1909
Family: CONGRIDAE Kaup, 1856

Congridae
Plate 1, figure 3

Material. - Two otoliths from bed E.

Remarks. - These juvenile otoliths certainly belong to congrid eels, as shown by their sulcus, which opens to the dorsal rim by a narrow, vertically oriented ostial channel, but are too small for a more precise identification. Congrids are benthic fishes on the continental shelf or slope. Some species burrow, but many that live in deep water and the large species do not.

Cohort: CLUPEOCEPHALA Patterson and Rosen, 1977
Subcohort: EUTELEOSTEI Greenwood et al., 1967
Infracohort: OSTARIOPHYSI Sagemehl, 1885
Series: OTOPHYSI Garstang, 1931
Order: SILURFORMES Cuvier, 1817
Family: ARIIDAE Guenther, 1864

Ariidae

Material. - One utricular otolith from bed B.

Remarks. - The available specimen is very worn, incomplete, and probably derived from a juvenile fish. In comparison with most of the Recent ariids, it is rather thin and has a very flat inner face. Ariid otoliths have been previously noted from the Maastrichtian of Maryland (Huddleston and Savoie, 1983, p. 660, fig. 2D and E).

Recent ariids are a family of marine catfishes, living essentially in tropical and subtropical coastal waters, especially in waterways, bays and harbors and in the muddy areas near river mouths.

Infracohort: NEOGNATHI Rosen, 1973

Supersection: PROTACANTHOPTERYGII
Greenwood et al., 1966
Order: SALMONIFORMES Bleeker, 1859

Salmoniformes
Plate 2, figures 10-11

Material. - Seven otoliths, two from bed B and five from bed E.

Remarks. - The available material consists of six juvenile otoliths and only one larger but incomplete specimen (Plate 2, figure 10). They apparently belong to an extinct salmoniform family, the closest Recent relatives of which seem to be the osmerids and argentinids, according to their outline and sulcus pattern (see Nolf, 1985, fig. 41 and 42 for figures of comparative Recent material). The juveniles have a regularly rounded ventral rim and a lobate outer face, while the larger (?adult) specimen shows a flat and smooth outer face and has a ventral rim with large irregularly shaped lobes.

Although the figured otoliths apparently belong to a new species, we do not want to give them a formal name because none of the available specimens are sufficiently well preserved to serve as type material.

Recent salmoniform taxa inhabit a great variety of environments, from fresh water (e.g. pikes and salmons) to deep water, often below 1000 m (e.g. alepocephalids and searsiids). Among the two Recent families cited above as possible relatives, the osmerids include shallow marine, anadromous, and purely freshwater species and populations; argentinids *(sensu stricto)* are essentially continental shelf and upper slope fishes.

Supersection: NEOTELEOSTEI Nelson, 1969
Section: EURYPTERYGII Rosen, 1973
Subsection: CYCLOSQUAMATA Rosen, 1973
Order: AULOPIFORMES Rosen, 1973
Suborder: ALEPISAUROIDEI Regan, 1911
Family: SYNODONTIDAE Gill, 1872

"genus Synodontidarum" *pseudoperca* n. sp.
Plate 2, figures 12-16

Type material. - Holotype: a left otolith (Plate 2, figure 12) (IRSNB P5686); 31 paratypes, of which four are figured (IRSNB P5687-P5690).

Dimensions of the holotype. - Length: 2.9 mm; height: 1.5 mm; thickness: 0.6 mm.

Stratum typicum. - Tupelo Tongue of the Coffee Sand, Chapelville fossiliferous horizon, bed E at Griffin sandpit, Chapelville, Lee County, Mississippi.

Derivatio nominis. - Alludes to the superficial resemblance to the otoliths of perch-like fishes.

Diagnosis. - This species is characterized by relatively thick, elongate otoliths with a sharp rostrum. The outer face is smooth, markedly convex in the dorso-ventral direction, and nearly flat in the anteroposterior direction. The inner face is clearly convex

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Explanation of the plates

All specimens are deposited in the collections of the Institut Royal des Sciences Naturelles de Belgique (IRSNB). 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, kept at the same institution. The latter collection is arranged in a systematic order without numbering; therefore, such specimens, when figured, bear only the mention "coll. IRSNB."

The abbreviations F and R in the right corner of each compartment of the plates indicate if the figured specimens in that compartment are fossils (F) or belong to Recent (R) species. In the text of the explanations, L stands for left otolith and R for right otolith.

Plate 1

Fig. 1 ? Megalopidae
L; Griffin sandpit, bed E (IRSNB P5673).

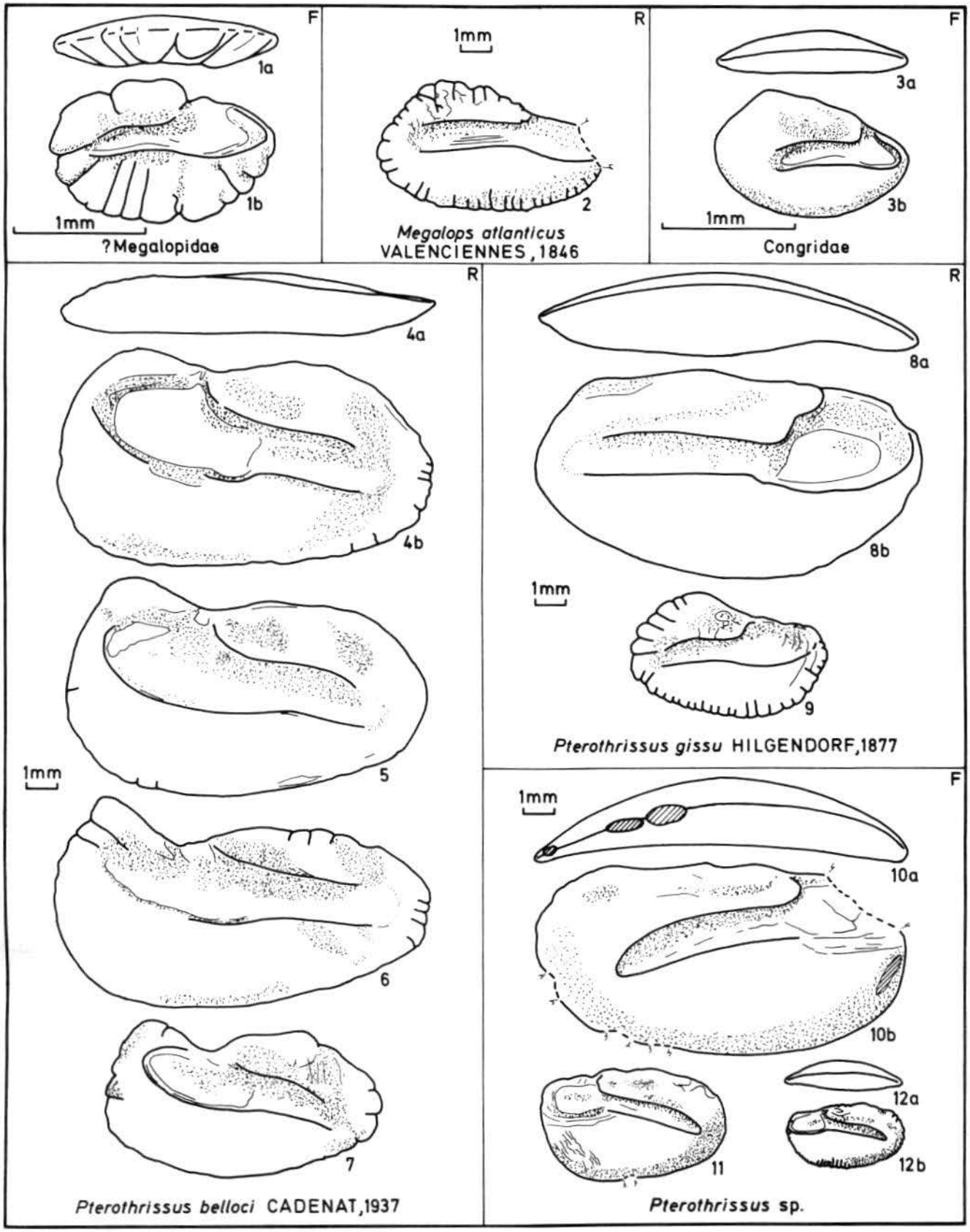
Fig. 2 *Megalops atlanticus* Valenciennes, 1846
L; Recent, off West Africa (coll. IRSNB).

Fig. 3 Congridae
L; Griffin sandpit, bed E (IRSNB P5674).

Fig. 4-7 *Pterothrissus belloci* Cadenat, 1937
R; Recent, off Zaire (coll. IRSNB).

Fig. 8-9 *Pterothrissus gissu* Hilgendorf, 1877
L; Recent, off Japan (coll. IRSNB).

Fig. 10-12 *Pterothrissus* sp.
10 = L, 11-12 = R; Griffin sandpit, 11 and 12 are from bed E; no precise location for 10 (IRSNB P5675-P5677).


F
1a
1b
1mm
?Megalopidae
R
1mm
2
Megalops atlanticus
VALENCIENNES, 1846
F
3a
3b
1mm
Congridae
R
4a
4b
5
1mm
6
7
Pterothrissus belloci CADENAT, 1937
R
8a
8b
1mm
9
Pterothrissus gissu HILGENDORF, 1877
F
1mm
10a
10b
11
12a
12b
Pterothrissus sp.

in both directions. The dorsal rim is blunt, but the ventral rim has a slightly cutting profile. In most of the well preserved specimens, the ventral rim shows at least some zones of very fine serration. This is most clear in the paratype figured in figure 15 of Plate 2. The sulcus is not deeply incised but has clear cristae. The collicula, if clearly discernible, are very flat and smooth. The area above the crista superior shows a hollow depression. The sulcus is clearly divided into a broad ostium and a narrow cauda, with nearly parallel cristae; the cauda is regularly bent in a ventral direction. In the crista inferior, the limit between the ostial and caudal portion is clear, but less angular than in most perciform fishes.

Affinities. - In Recent synodontids, one observes a similar type of sulcus configuration in the genus *Saurida* Valenciennes, 1849. A similar convexity of the inner and outer faces is seen in the genus *Trachinocephalus* Gill, 1861, but there is no Recent genus with a general otolith configuration similar to that of our fossil species.

Subsection: CTENOSQUAMATA Rosen, 1973
Sept: ACANTHOMORPHA Rosen, 1973
Superorder: ACANTHOPTERYGII Gouan, 1770
Series: PERCOMORPHA Rosen, 1973
Order: BERYCIFORMES Regan, 1909
Family: TRACHICHTHYIDAE Bleeker, 1859

"genus Trachichthyidarum" *coffeesandensis* n. sp.
Plate 3, figures 1-4

Type material. - Holotype: a left otolith (Plate 3, figure 1) (IRSNB P5691); 21 paratypes of which three have been figured (Plate 3, figures 2-4) (IRSNB P5692-P5694).

Dimensions of the holotype. - Length: 5.0 mm; height: 5.1 mm; thickness: 1.3 mm.

Stratum typicum. - Tupelo Tongue of the Coffee Sand, Chapelville fossiliferous horizon, bed B at Griffin sandpit, Chapelville, Lee County, Mississippi.

Derivatio nominis. - This species is named after the formation from which it was collected.

Diagnosis. - This species is characterized by subpentagonal otoliths which show a slight elongation along the postero-dorsal/antero-ventral axis. The outer face is convex in adult specimens (Plate 3, figures 1 and 4), but in juveniles (Plate 3, figures 2-3) marginal lobes exist, separated by radial grooves. The inner face is slightly convex, nearly flat. The sulcus is large and shows a clear division into ostium and cauda. Ostial collicular formations are not clear in juveniles but larger specimens (e.g. Plate 3, figure 1) show a flat and smooth ostial colliculum. A caudal colliculum is present in all specimens, and there is a well marked collicular crest just above the caudal crista inferior. The crista superior is accentuated by a depression in the dorsal area just above the sulcus.

Affinities. - The otoliths of this species show a close relationship with those of Recent trachichthyids, but do not exactly correspond in morphology with any of the Recent genera (see Schwarzhans, 1980, p. 108, for figures of some Recent trachichthyid otoliths); they apparently belong to an extinct taxon with a ple-

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Plate 2

Fig. 1-2 *Albula glossodonta* Forsskal, 1775
L; Recent, off Hawaii (coll. IRSNB).

Fig. 3 "genus Albulidarum" aff. *sohli* (Frizzell, 1965)
L; Griffin sandpit, no precise location (IRSNB P5678).

Fig. 4 Pterothrissidae
L; Griffin sandpit, bed B (IRSNB P5679).

Fig. 5 Acanthomorpha
L; Griffin sandpit, bed E (IRSNB P5680).

Fig. 6 *Dixonia nemoptera* Fowler, 1911
R; Recent, Caribbean, off Colombia (coll. IRSNB).

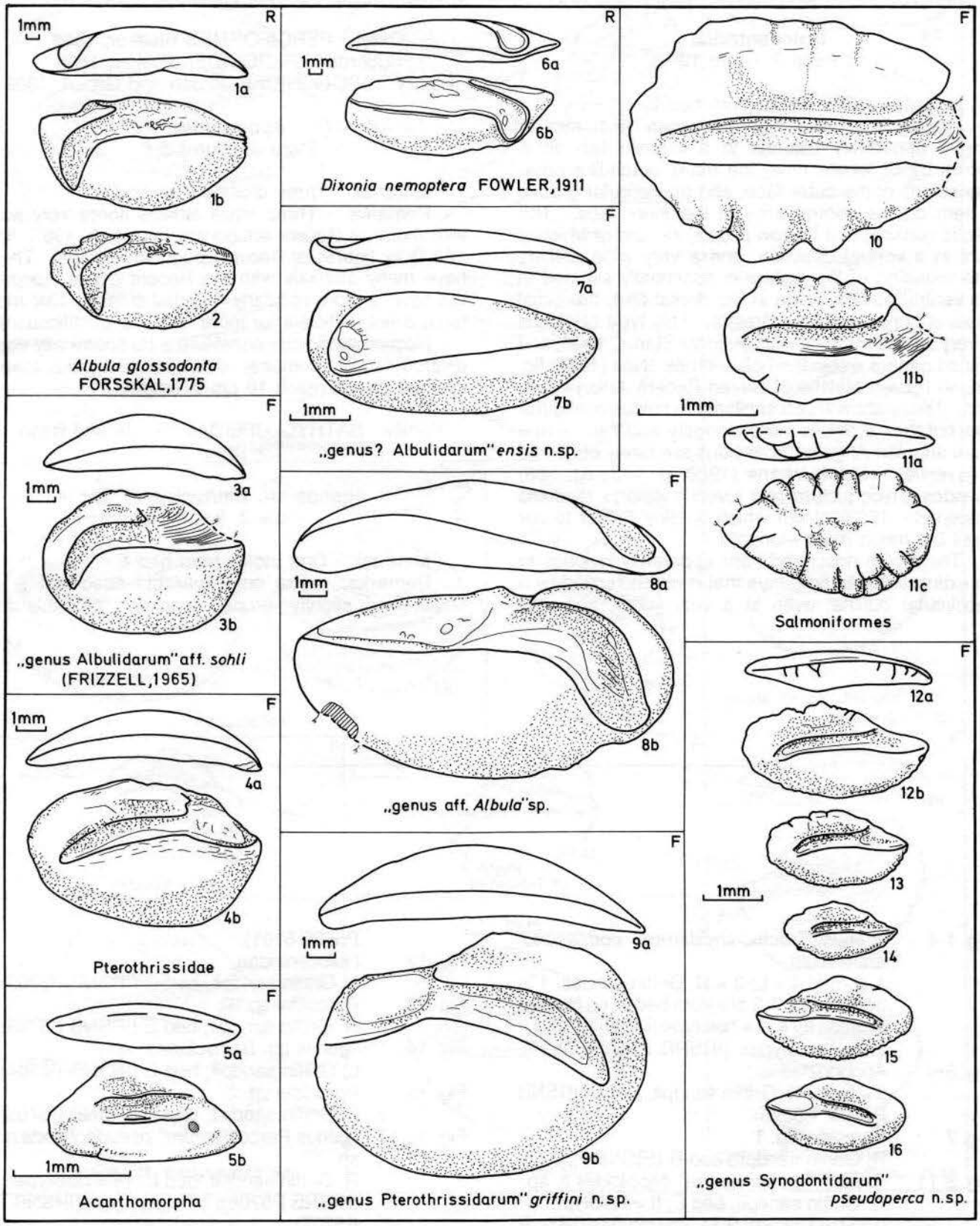
Fig. 7 "genus Albulidarum" *ensis* n. sp.
L; Griffin sandpit, bed B; holotype (IRSNB P5681).

Fig. 8 "genus aff. *Albula*" sp.
R; Griffin sandpit, no precise location (IRSNB P5682).

Fig. 9 "genus Pterothrissidarum" *griffini* n. sp.
R; Griffin sandpit, bed E; holotype (IRSNB P5683).

Fig. 10-11 Salmoniformes
L; 10 is from bed B, 11 from bed E (IRSNB P5684, P5685).

Fig. 12-16 "genus Synodontidarum" *pseudoperca* n. sp.
12-14 = L, 15-16 = R; Griffin sandpit, bed E. 12 = holotype (IRSNB P5686). 13-16 = paratypes (IRSNB P5687-P5690).


R
1mm
1a
1b
2
Albula glossodonta
FORSSKAL,1775
F
1mm
3a
3b
„genus Albulidarum" aff. sohli
(FRIZZELL,1965)
F
1mm
4a
4b
Pterothrissidae
F
5a
5b
1mm
Acanthomorpha
R
1mm
6a
6b
Dixonia nemoptera FOWLER,1911
F
7a
1mm
7b
„genus? Albulidarum" ensis n.sp.
F
1mm
8a
8b
„genus aff. Albula" sp.
F
1mm
9a
9b
„genus Pterothrissidarum" griffini n.sp.
F
10
1mm
11b
11a
11c
Salmoniformes
F
12a
12b
13
1mm
14
15
16
„genus Synodontidarum"
pseudoperca n.sp.

siomorphic otolith morphology.

Family: HOLOCENTRIDAE Richardson, 1864

Holocentridae
Plate 3, figure 12

Material. - One otolith from bed E.

Remarks. - This little specimen (2.1 mm in length) apparently belongs to a juvenile fish as is shown by its lobate rims, the many notch-like ornamentations of the outer face, and the reticular groove pattern on the ventral area of the inner face. The sulcus consists of a narrow cauda, the end of which is bent in a ventral direction, and a very wide ostium. The widening of the ostium is essentially situated in the ventral portion, while in the dorsal part, the ostial crista superior is nearly straight. This type of sulcus is very typical for the genus *Adioryx* Starks, 1908, and related genera within the holocentrids. Nolf (1985, fig. 13L-V) figured otoliths of eleven Recent *Adioryx* species. These show much similarity in sulcus configuration, but their shape is more elongate and their outline more angular. Angular projections are rarely observed in juveniles. Schwarzhans (1980, p. 113, fig. 368) provides a nice picture of a juvenile *Adioryx diadema* (Lacepede, 1803) otolith which is fairly similar to our fossil but much more elongate.

The otolith described here apparently belongs to an extinct holocentrid genus that is characterized by a subcircular outline, even at a very young age; this feature is not observed in any Recent holocentrid taxon. Patterson (1964) cites two Cretaceous genera of holocentrids, but their otoliths are unknown.

Order: PERCIFORMES Bleeker, 1859
Suborder: PERCOIDEI Bleeker, 1859
Family: APOGONIDAE Jordan and Gilbert, 1882

Apogonidae
Plate 3, figures 5-6

Material. - Three otoliths from bed E.

Remarks. - Three small otoliths agree very well with those of Recent apogonids (see Nolf, 1985, fig. 12A-D for figures of Recent apogonid otoliths). They have many affinities with the Recent genus *Apogon* but have a more regularly rounded outline. Our material is not sufficient for more precise identifications.

Recent apogonids constitute a taxonomically very diverse family of mainly small neritic fishes; many species do not reach 10 cm in length.

Family: BATHYCLUPEIDAE Goode and Bean, 1896

"genus aff. *Bathyclupea*" sp.
Plate 3, figure 14

Material. - One otolith from bed E.

Remarks. - The only available specimen is a small sized, slightly eroded specimen, probably de-

---

Plate 3

Fig. 1-4 "genus Trachichthyidarum" *coffeesandensis* n. sp.
1, 2, and 4 = L; 3 = R; Griffin sandpit, 1 is from bed B, 2-3 are from bed E; no precise location for 4. 1 = holotype (IRSNB P5691); 2-4 = paratypes (IRSNB P5692-P5694).

Fig. 5-6 Apogonidae
5 = L, 6 = R; Griffin sandpit, bed E (IRSNB P5695, P5696).

Fig. 7 Percoidei sp. 1
R; Griffin sandpit, bed B (IRSNB P5697).

Fig. 8-11 "genus Perciformorum" *cepoloides* n. sp.
R; Griffin sandpit, bed E; 8 = holotype (IRSNB P5698); 9-11 = paratypes (IRSNB P5699-5701).

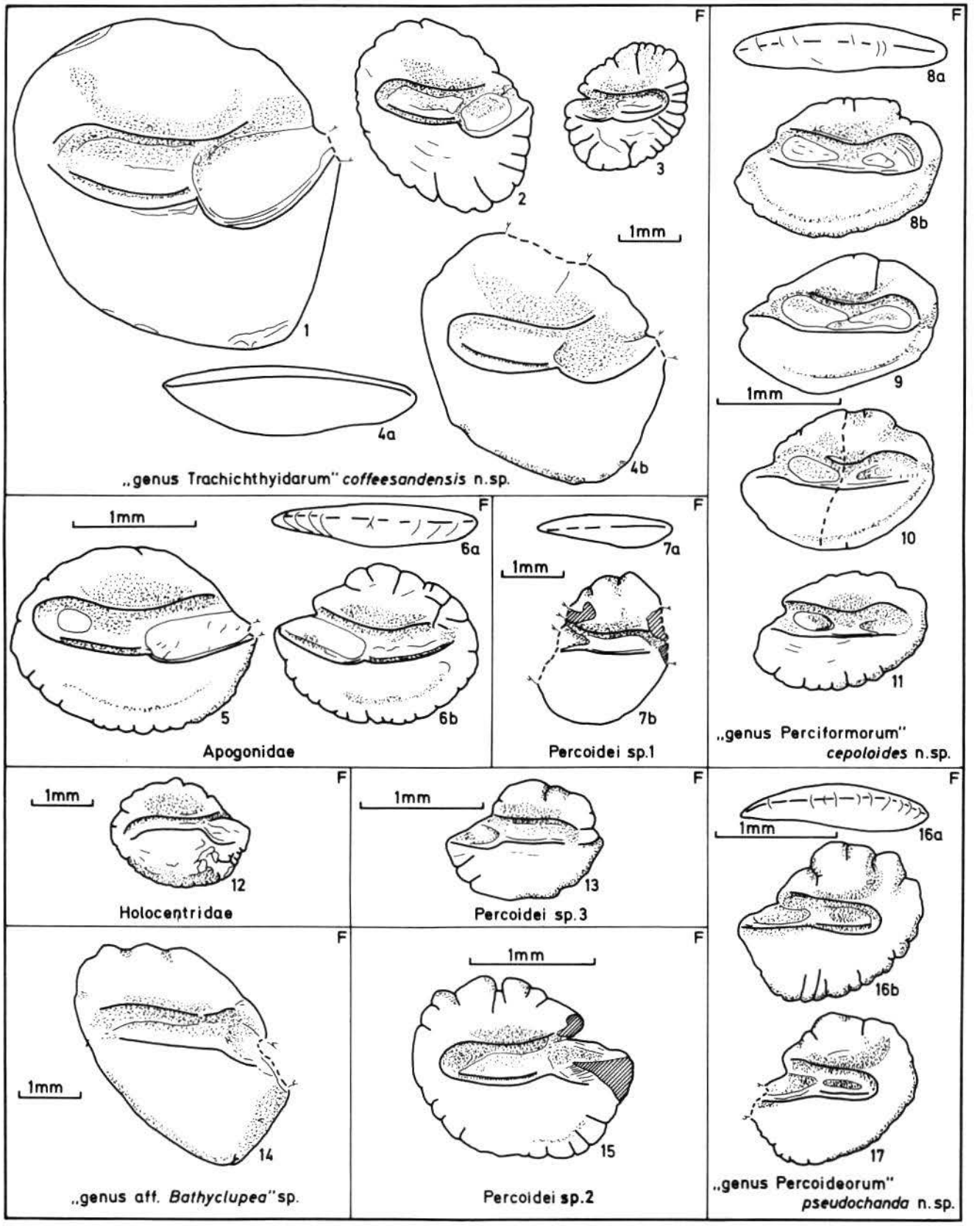
Fig. 12 Holocentridae
L; Griffin sandpit, bed E (IRSNB P5702).

Fig. 13 Percoidei sp. 3
R; Griffin sandpit, bed E (IRSNB P5703).

Fig. 14 "genus aff. *Bathyclupea*" sp.
L; Griffin sandpit, bed E (IRSNB P5704).

Fig. 15 Percoidei sp. 2
L; Griffin sandpit, bed E (IRSNB P5705).

Fig. 16-17 "genus Percoideorum" *pseudochanda* n. sp.
R; Griffin sandpit, bed E; 16 = holotype (IRSNB P5706); 17 = paratype (IRSNB P5707).


F
1
2
3
1mm
4a
4b
„genus Trachichthyidarum" coffeesandensis n.sp.
F
8a
8b
9
1mm
10
11
„genus Perciformorum" cepoloides n.sp.
1mm
F
6a
5
6b
Apogonidae
F
7a
1mm
7b
Percoidei sp.1
F
1mm
12
Holocentridae
F
1mm
13
Percoidei sp.3
F
1mm
16a
16b
17
„genus Percoideorum" pseudochanda n.sp.
F
1mm
14
„genus aff. Bathyclupea" sp.
F
1mm
15
Percoidei sp.2

rived from a juvenile fish. The very typical shape of the otolith, presenting an oblique elongation along an antero-ventral/dorso-posterior axis, leaves no doubt that this fossil belongs to the bathyclupeids, but better preserved material is needed to decide if it is identical or not with *Bathyclupea,* the only Recent genus known in the family, with six species. They all are deep sea fishes, mainly below 400 m, and none of them have ever been caught in large numbers (Dick, 1972). In the Upper Eocene of Aquitaine (SW France), a fossil *Bathyclupea* species is recorded from deep neritic facies (Nolf, 1988). The present find constitutes the first Cretaceous record of bathyclupeids. The statement of Dick (1972, p. 540) that "Fossil records indicate that the group was well established by the late Cretaceous" is apparently based on Bertin and Arambourg's (1958, p. 2335) "order Bathyclupeiformes" which includes the family Ctenothrissidae.

Family: incertae sedis

"genus Percoideorum" *pseudochanda* n. sp.
Plate 3, figures 16-17

Type material. - Holotype: a right otolith (Plate 3, figure 16) (IRSNB P5706); one paratype (Plate 3, figure 17) (IRSNB P5707).

Dimensions of the holotype. - Length: 1.8 mm; height: 1.2 mm; thickness: 0.3 mm.

Stratum typicum. - Tupelo Tongue of the Coffee Sand, Chapelville fossiliferous horizon, bed E at Griffin sandpit, Chapelville, Lee County, Mississippi.

Derivatio nominis. - Alludes to a superficial resemblance with otoliths of the percoid genus *Chanda* Hamilton, 1822.

Diagnosis. - This species is characterized by high otoliths with a salient rostrum. The outer face is flat in the antero-posterior direction and convex in the dorso-ventral direction. Its surface is almost entirely smooth, except for some radial grooves separating the lobes of the rims in the marginal zone. The inner face is very slightly convex, nearly flat. The sulcus is quite short and shows a clear division into ostial and caudal portions of about equal length. The collicular formations of the ostium are restricted to a somewhat deeper antero-central area with a more rugged surface. The central area of the cauda is also somewhat hollow, but, just above the caudal crista inferior, a very clear collicular crest exists. The cauda is very short with respect to its width and shows no ventral deflection of the posterior part. The crista superior is very salient, due to a considerable depression in the area just above.

Affinities. - Although it is premature to postulate a phylogenetic relation with any well defined percoid taxon, the fossils described here show some overall resemblance with Recent chandid otoliths (see Nolf and Cappetta, 1980, pl. 2, fig. 6-8, for figures of Recent species) and with plesiomorph gerreid otoliths as in *Parequula* Steindachner, 1879 (see Nolf, 1988, pl. 11, fig. 21). It is difficult however to find any true synapomorphy that unites them with one of the taxa cited. Our finds probably belong to an extinct family of small sized plesiomorph percoid fishes.

Percoidei sp. 1
Plate 3, figure 7

Material. - Two otoliths from bed B.

Remarks. - Both specimens are very worn. Their outline is somewhat similar to that of "genus Percoideorum" *pseudochanda* (Plate 3, figures 16-17), but the cauda is markedly narrower, reaches as far as the posterior rim, and has a very slight ventral inflation of the posterior end.

Percoidei sp. 2
Plate 3, figure 15

Material. - One otolith from bed E.

Remarks. - The only available specimen is a juvenile, somewhat eroded otolith; more material is needed to evaluate its affinities and variability.

Percoidei sp. 3
Plate 3, figure 13

Material. - One otolith from bed E.

Remarks. - This unique juvenile specimen constitutes a third morphotype of unidentified percoid otoliths, but as in the foregoing case, the available material is insufficient for adequate description and comparison.

Suborder: incertae sedis

"genus Perciformorum" *cepoloides* n. sp.
Plate 3, figures 8-11

Type material. - Holotype: a right otolith (Plate 3, figure 8) (IRSNB P5698); three paratypes (Plate 3, figures 9-11) (IRSNB P5699-P5701).

Dimensions of the holotype. - Length: 1.6 mm; height: 1.0 mm; thickness: 0.4 mm.

Stratum typicum. - Tupelo Tongue of the Coffee Sand, Chapelville fossiliferous horizon, bed E at Griffin sandpit, Chapelville, Lee County, Mississippi.

Derivatio nominis. - Alludes to a superficial resemblance with otoliths of the percoid genus *Cepola* Linnaeus, 1764.

Diagnosis. - Massive otoliths with a general elliptical outline, but somewhat distorted along the antero-ventral/postero-dorsal axis. All specimens have a blunt rostrum, a shallow excissura and a little antirostrum. The holotype shows a well marked postero-

dorsal angle and rudiments of such a projection seem to be present also in two of the paratypes. The outer face is nearly flat in the antero-posterior direction and convex in the dorso-ventral direction. The surface is smooth in the three largest specimens, but bears radial grooves separating the marginal lobes in the smallest one.

The inner face is moderately convex and the incision of the sulcus is rather strong. The ostium is slightly larger than the cauda, and the anterior part of the ostial crista inferior is marked by an upward curving in the direction of the ostial rim. The posterior part of the cauda is expanded in the dorsal direction. Both ostium and cauda have flat collicula. In the anterior part of the cauda, there exists a very thin collicular crest near the crista inferior.

Affinities. - These otoliths do not closely resemble those of any Recent fish taxon. They bear a superficial resemblance with those of the percoid family of the cepolids, but it is very difficult to find acceptable synapomorphies. Another perhaps more realistic alternative considers them to be derived from an extinct taxon (subordinal level) somewhere near the labroids.

Superorder: incertae sedis

Acanthomorpha
Plate 2, figure 5

Material. - One otolith from bed E.

Remarks. - The only available specimen is a small otolith (1.5 mm in length), but its preservation is rather good. It is a quite robust, thick otolith with a smooth outer face, which is convex in dorso-ventral direction and nearly flat in antero-posterior direction. Its outline is marked by a very salient postero-dorsal angle. The inner face is convex. The sulcus is well incised, does not open directly on the ostial rim, and is well divided into an ostial and a caudal part, both of which form shallow depressions. In the central and antero-caudal part of the sulcus, there is a collicular formation that tends to form a little crest near the crista inferior. The only Recent fishes where one observes such a collicular formation are the freshwater cave, spring, and swamp dwelling family Aphredoderidae (see Nolf and Steurbaut, 1989a, fig. 6D), but the general outline of their otoliths and their ecology do not support a close relationship with our fossil. The hollowing out of the central ostial and caudal areas and the very strong postero-dorsal angle are features observed in several batrachoidid fishes. Therefore, we think that this fossil otolith belongs to an extinct family with affinities with plesiomorph acanthomorph fishes, maybe paracanthopterygians.

CONCLUSIONS

Otolith study reveals the presence of twenty taxa of teleosteans in the Coffee Sand of Mississippi. They constitute the first otolith record of Campanian age. Their degree of affinity with Recent forms can be deduced from the taxonomic level at which the species have been named. Three could be tentatively assigned to Recent genera (*Albula, Pterothrissus* and *Bathyclupea)*, ten have been identified at family rank, four at subordinal rank, two at ordinal and one at supra-ordinal rank. In the last three groups, much uncertainty exists about their true nature because we know of many extinct Cretaceous taxa based on skeletal material but not on otoliths; these unknown otoliths constitute an annoying problem of "imperfect ignorance."

It should be remembered that in strata where both otoliths and osteological material are known (e.g. the London Clay, the Belgian Eocene, the Middle Oligocene septaria clay of the North Sea and Mainz Basin), the faunal reconstructions by means of these different types of fossils cover each other only to a limited extent; in fact they are rather complementary (see Nolf, 1985, p. 19, and Patterson, 1987, for discussion and explanation).

The present otolith approach to faunal reconstruction constitutes a method that, except for some few isolated cases, has never been applied to Cretaceous deposits. The result is that several groups of small sized fishes could be traced back much earlier (Campanian) in the fossil record. These are:

- Congridae, previously unknown before the Early Eocene (Andrews et al., 1967);
- Ariidae, previously unknown before the Maastrichtian (Huddleston and Savoie, 1983);
- Synodontidae, previously unknown before the Early Eocene (Nolf, 1985);
- *Bathyclupea*, previously unknown before the Late Eocene (Nolf, 1988);
- Apogonidae, previously unknown before the Maastrichtian (Huddleston and Savoie, 1983).

Also, the record of five additional species of perciform fishes strongly contrasts with the scarcity of this group in the osteological record (see Andrews et al., 1967, p. 663).

In contrast with studies on Tertiary faunas, especially Late Tertiary, where otolith associations can provide very precise paleoecological and bathymetrical conclusions (see e.g. Nolf and Cappetta, 1989), such deductions have to remain rather vague after the present analysis due to the lack of close affinities of our finds with Recent taxa. Nevertheless, where possible, we have included ecological data in the discussion following each species in the systematic section. The overall emerging picture suggests a rather shallow neritic fish fauna in a tropical or subtropical area.

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CLEAR CREEK FIELD AFTER TWO YEARS OF PRODUCTION

Jack Moody
Mississippi Bureau of Geology

Do you remember that eventful morning of May 23, 1988, when with a cup of coffee by your side you stretched out the *Southeastern Oil Review* in order to feast upon the successes of the week? There before your eyes, in the big, black, bold print, you read "Weeks Completes Smackover Discovery Flowing 888 Barrels Daily in Wayne." For a moment you think of what it would be like if that were your well. You'd enjoy the limelight, you'd relish in the inward satisfaction of the success. And of course there is the small matter of the financial possibilities. Who is there that wouldn't love to find himself or herself in that position? Yet this is only the beginning of the story and the real results are displayed in time. In the beginning we have finding success, in time we'll see if we have business success.

This article is the first of a series that will review the headline wells of the past in order to help the reader appreciate the true results from the business perspective. We commend those behind the drilling and exploration efforts. We'll see through time that discoveries are like so many things: some are great, some are horrible, and there are all gradations in between. This has been, is, and will continue to be the reality of the business. One in the business can appreciate the proverb, "in the day of prosperity rejoice (a good well) but know that one day is set against another (the failures)."

Whatever happened to Weeks' 15,000 foot Smackover discovery of Clear Creek Field in Section 20-10N-7W, Wayne County, Mississippi? The discovery well is by far the best well of the three. This well flowed 218,908 BO and 201,260 MCFG from May 1988 through December 1989. The well produced for 496 days in that period, which yields an average daily producing rate of 441 BOPD and 406 MCFGPD. In January of 1990 the well flowed 8969 BO and was placed on pump in February 1990. March was the first full month on pump and the well averaged 341 BOPD, 15 BWPD, and 165 MCFGPD.

The first offset was the #2 McCoy and it began producing in December 1988. The well flowed 50,382 BO and 46,106 MCFG from December 1988 through July 1989. That yields an average daily flow of 338 BOPD and 355 MCFGPD. The well began pumping in August 1989. From August 1989 through March 1990 the well pumped 49,117 BO and 37, 307 MCFG. In March 1990 the daily average production was 210 BO, 4 BW, and 237 MCFG.

The third well in the field has been a poor well. It began producing on the pump in September 1989. It produced 1002 BO, 258 BW, and 1400 MCFG in the initial month. The following month it pumped for 14 days and produced 510 BO, 84 BW, and 700 MCFG. In November it pumped for 7 days and produced only 191 BO, 42 BW, and 350 MCFG. This well was shut-in from December 1989 through February 1990. In March the well was pumped for 7 days and produced 1513 BO, 471 BW, and no gas.

From May 1988 through March 1990 this headline discovery has produced as shown in Table 1. Table 2 gives the daily average production for the days produced over the life of the wells.

This field discovery looks like the finding success has become a business success. Our brief history has shown the payout should have occurred and Weeks and its partners can enjoy a nice cash flow from Clear Creek Field.

Table 1

Well Name	Cumulative Oil(BO)	Cumulative Water (BW)	Cumulative Gas (MCF)	March 1990 Daily Average Oil(BO)	March 1990 Daily Average Water (BW)	March 1990 Daily Average Gas (MCF)
McCoy #1	243,155	465	215,836	341	15	165
McCoy #2	99,499	250	83,413	210	4	237
McCoy #3	3,216	855	2,450	216	67	0

Table 2

McCoy #1	576 days	422 BOPD	<1BW	375 MCFGPD
McCoy #2	347 days	287 BOPD	<1BW	240 MCFGPD
McCoy #3	56 days	57 BOPD	15BW	44 MCFGPD

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Editors: Michael B. E. Bograd and David Dockery