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SELACHIANS (SHARKS) FROM THE TUPELO TONGUE OF THE COFFEE SAND (CAMPANIAN, UPPER CRETACEOUS) IN NORTHERN LEE COUNTY, MISSISSIPPI

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ABSTRACT

Seventeen figured chondrichthyan specimens (14 teeth and 3 rostral denticles) are here described from the Tupelo Tongue of the Coffee Sand (Campanian) of the Upper Cretaceous of Lee County, northeastern Mississippi. Numerous additional specimens, which were not figured, were present in the collection examined. None of the species described here are new, with the possible exception of ?*Carcharias* sp. 1 and *Carcharias* sp. 2. ?*Carcharias* sp. 1 may be a juvenile tooth of *Scapanorhynchus*, while *Carcharias* sp. 2 may be a new species. As the presently known material is inadequate, it is best not to describe the latter species as new at the present time.

The fauna represents eleven taxa: a bamboo shark, *Hemiscyllium*; a nurse shark, *Ginglymostoma*; two possible sand sharks, ?*Carcharias* sp. 1 and *Carcharias* sp. 2; a goblin shark, *Scapanorhynchus*; a primitive mackerel shark, *Cretolamna*; a false "crowshark", *Pseudocorax*; a "crowshark", *Squalicorax*; two sawfishes, *Ischyrhiza* and *Sclerorhynchus*; and a batoid fish related to either the skates or sawfishes, *Ptychotrygon*.

INTRODUCTION

The selachian specimens of this report were collected by David T. Dockery III and his associates at the Mississippi Office of Geology from the Chapelville fossiliferous horizon, an informal unit in the Tupelo Tongue of the Coffee Sand, at a borrow pit near the community of Chapelville in Lee County, Mississippi. According to calcareous nannofossil and ammonite correlations, the Chapelville horizon is near the lower-middle Campanian boundary (Dockery, 1990). The Mississippi Office of Geology was primarily concerned with a study of invertebrate specimens (i.e., gastropods and other mollusks) at this site as well as from test holes in the same horizon in northern Lee County (Dockery and Jennings, 1988). The recovery of vertebrate specimens in the shell debris was most fortunate, and enables the writer to present here distinct selachian species types from Mississippi's Coffee Sand. These specimens were recovered from a large quantity of sieved material from the Chapelville horizon with the finest fraction collected in a no. 35 (0.5 mm opening) sieve and picked under a microscope.

Nolf and Dockery (1990) described the fish otoliths (ear bones) from the Coffee Sand at the "Friendship locality" (Griffin property) near Chapelville, the locality of the present study. According to their placement of this site, it is to be found in the Ratliff Quadrangle, UTM point X-355,000 m E., Y-3,812,850 m N. This locality is designated as Mississippi Office of Geology (formerly the Mississippi Geological Survey) locality MGS-129.

GEOLOGY

The Tupelo Tongue of the Coffee Sand overlies the Mooreville Chalk and is in turn overlain by the Demopolis Chalk. The top of the Chapelville horizon is about 17 m above the base of the Tupelo Tongue's 73 m sequence in the vicinity of Guntown in northern Lee County, Mississippi (Nolf and Dockery, 1990).

According to Dockery and Jennings (1988), the Coffee Sand is an updip terrigenous facies of the Selma Chalk sequence, which is of Campanian to Maastrichtian age. It crops out in a belt extending from the Alcorn-Tishomingo County area of northeastern Mississippi southward to central Lee County, where the sand facies changes to argillaceous chalk. They further stated that the Coffee Sand forms the basal unit of the Selma Group in northernmost Mississippi where the Mooreville Chalk is absent and the Coffee Sand rests directly upon the Tombigbee Sand Member of the Eutaw Group. There the Coffee Sand is predominantly a cross-bedded sand with occasional thin clay beds and some burrowed sand intervals. Dockery and Jennings (1988) noted that the clay component of the Coffee Sand increases in a south and westward direction and the formation becomes more fossiliferous, especially in the lower part.

SYSTEMATICS

The classification here follows that of Cappetta (1987). All specimens described are deposited in the Mississippi Office of Geology collections and are from the Chapelville horizon of the Tupelo Tongue of the Coffee Sand at MGS locality 129 near Chapelville in Lee County, Mississippi. The age of this horizon is near the lower-middle Campanian boundary as determined by calcareous nannofossils and ammonites. MGS before the specimen number is an abbreviation for the Office's former name, Mississippi Geological Survey.

Class CHONDRICHTHYES Huxley, 1880

Subclass ELASMOBRANCHII Bonaparte, 1838
Cohort EUSELACHII Hay, 1902
Subcohort NEOSELACHII Compagno, 1977
Superorder GALEOMORPHII Compagno, 1973
Order ORECTOLOBIFORMES Applegate, 1972
Family HEMISCYLLIDAE Gill, 1862
Genus *HEMISCYLLIUM* Smith, 1837

Hemiscyllium sp.
Plate 1, figure 2

Material: One antero-lateral tooth.
Figured specimen: MGS 1720.

Description: A single tooth from the antero-lateral file of a small bamboo shark. The tooth measures approximately 1 mm in height. Only the back face (labial view) of the tooth crown is preserved. There is no root, nor lingual face containing a root boss, or lateral facette foramen.

Discussion: Cappetta (1987, p. 74) gave a range for *Hemiscyllium* from the Late Paleocene to the Recent (existing today in the Indo-Pacific area). This specimen may be closer to *Chiloscyllium*, another orectolobid shark, which has an even older ancestry dating back to the Late Cretaceous. Case (1979a) described *Chiloscyllium missouriense* in the late Campanian of Montana. At present, the writer has come to the conclusion that the specimen described here is probably the oldest example in the fossil record of *Hemiscyllium*, and is *not* related to any of the following: *Chiloscyllium*, *Acanthoscyllium*, *Eostegostoma*, or *Stegostoma*.

Family GINGLYMOSTOMATIDAE Gill, 1862
Genus *GINGLYMOSTOMA* Muller and Henle, 1837

Ginglymostoma globidens Cappetta and Case, 1975
Plate 1, figure 1

Material: One anterior tooth.
Figured specimen: MGS 1721.
Description: An incomplete anterior tooth missing part

PLATE 1

Figure 1. *Ginglymostoma globidens* Cappetta and Case. Partial anterior tooth (missing left side), labial view, height 2 mm, MGS specimen 1721.

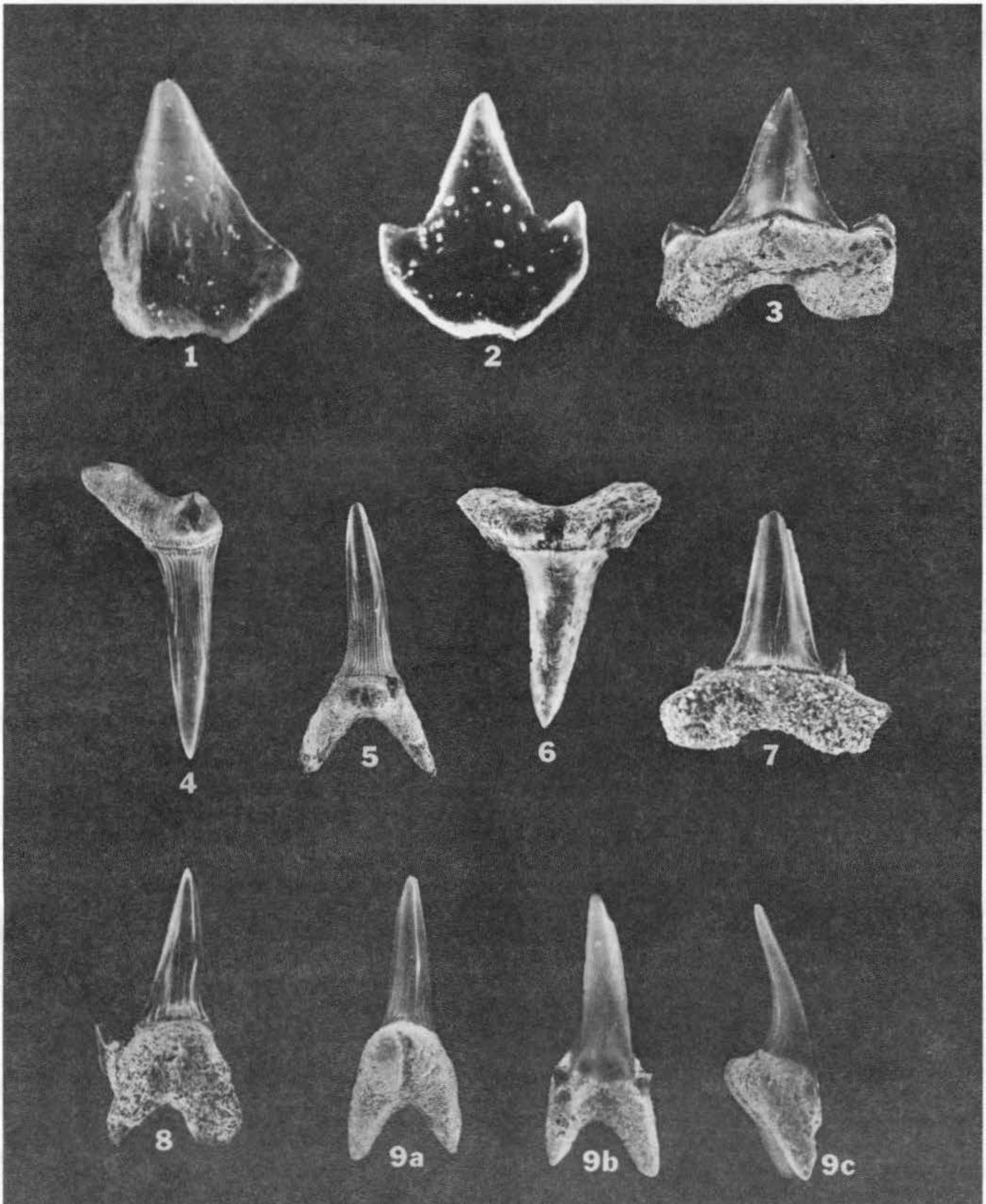
Figure 2. *Hemiscyllium* sp. Antero-lateral tooth, labial view, height 1 mm, MGS specimen 1720.

Figure 3. *Cretolamna appendiculata* (Agassiz). Lateral tooth, lingual view, height 15 mm, MGS specimen 1728.

Figures 4-7. *Scapanorhynchus texanus* (Roemer)
4. Anterior tooth (probably upper jaw), lingual view, height 35 mm, MGS specimen 1724.
5. Anterior tooth (lower jaw), lingual view, height 28 mm, MGS specimen 1725.
6. Antero-lateral tooth, lingual view, height 20 mm, MGS specimen 1726.
7. Lateral tooth (lower jaw?), lingual view, height 20 mm, MGS specimen 1727.

Figure 8. ?*Carcharias* sp. 1. ?Antero-lateral tooth, lingual view, height 10 mm, MGS specimen 1722.

Figure 9. *Carcharias* sp. 2. Anterior tooth, height 8 mm, MGS specimen 1723; a, lingual view; b, labial view; c, profile view.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of the crown on its left side, with a partially preserved lingual face (not shown in Plate 1). The tooth measures 2 mm in height, with several rugose striae (plications) running parallel to the vertical direction on the labial face of the tooth crown (see Plate 1, figure 1). The missing heel (shoulder) of the tooth crown was a symmetrical replica of the right side of the tooth.

Discussion: Cappetta and Case (1975b) first described *Ginglymostoma globidens* from the late Campanian-early Maastrichtian (now updated to the early-middle Maastrichtian) of New Jersey and Delaware. Most of the teeth found in New Jersey's Cretaceous were of the lateral file; none were found of the anterior files. The Mississippi specimen reported here is the first anterior tooth found of *G. globidens*.

Order LAMNIFORMES Berg, 1958
Family ODONTASPIDIDAE Muller and Henle, 1839
Genus *CARCHARIAS* Rafinesque, 1810

? *Carcharias* sp. 1
Plate 1, figure 8

Material: One tooth specimen.

Figured specimen: MGS 1722.

Description: An isolated (probable) antero-lateral tooth, missing the lateral cusp on the left side (the opposite in the photo on Plate 1, figure 8, as the tooth is turned to its lingual position). The height of the tooth is exactly 10 mm and the tooth has plications or the start of striae (rugose) starting at the base of the lingual side of the tooth crown (see Plate 1, figure 8). This indicates that it may be a juvenile of *Scapanorhynchus texanus*; however, juvenile teeth of that species are not common in Upper Cretaceous deposits, as only the adult teeth are usually found. As this specimen may not be a juvenile, it is tentatively identified here as *Carcharias*.

Discussion: As stated above, ?*Carcharias* sp. 1 may be a juvenile *Scapanorhynchus texanus*. If so, it will be the first record of such a juvenile tooth specimen in a scientific report.

Carcharias sp. 2
Plate 1, figures 9a-c

Material: One tooth.

Figured specimen: MGS 1723.

Description: A single (probable) anterior tooth, with a slight chip off the tip of the central blade. The tooth has small and divergent lateral denticles (Plate 1, figure 9b) that are slightly spade-like in structure and are approximately 1/8th the size of the entire central cusp. In lingual and profile views (cf. Plate 1, figures 9a and 9c) striae are visible on the lingual face of the tooth blade, running anteriorly from the enamel margin, about halfway up the central cusp. These striae are not rugose as are those of ?*Carcharias* sp. 1, but are less pronounced, probably due to the fact that this may be a juvenile, as the tooth is only 8 mm in height.

Discussion: Having only one tooth of this species, the material is insufficient to describe it as a new species, or refer it to a known species. It may be also a juvenile tooth of *Scapanorhynchus texanus*, but, as discussed previously, juvenile teeth of *Scapanorhynchus* are rare. Schwimmer (*in* Case and Schwimmer, 1988, p. 295) considered *Carcharias holmdelensis* (Cappetta and Case, 1975b) to be a juvenile tooth of *Scapanorhynchus texanus*.

Family MITSUKURINIDAE Jordan, 1898
Genus *SCAPANORHYNCHUS* Woodward, 1889

Scapanorhynchus texanus (Roemer, 1845)
Plate 1, figures 4-7

Material: Several teeth, upper and lower jaw anteriors, antero-laterals, and laterals.

Figured specimens: MGS 1724, MGS 1725, MGS 1726, and MGS 1727.

Description: Four teeth are described herein from various parts of the jaws of the goblin shark *Scapanorhynchus*. The largest of the four teeth is an upper jaw anterior tooth, MGS 1724 (Plate 1, figure 4). The tooth is approximately 35

PLATE 2

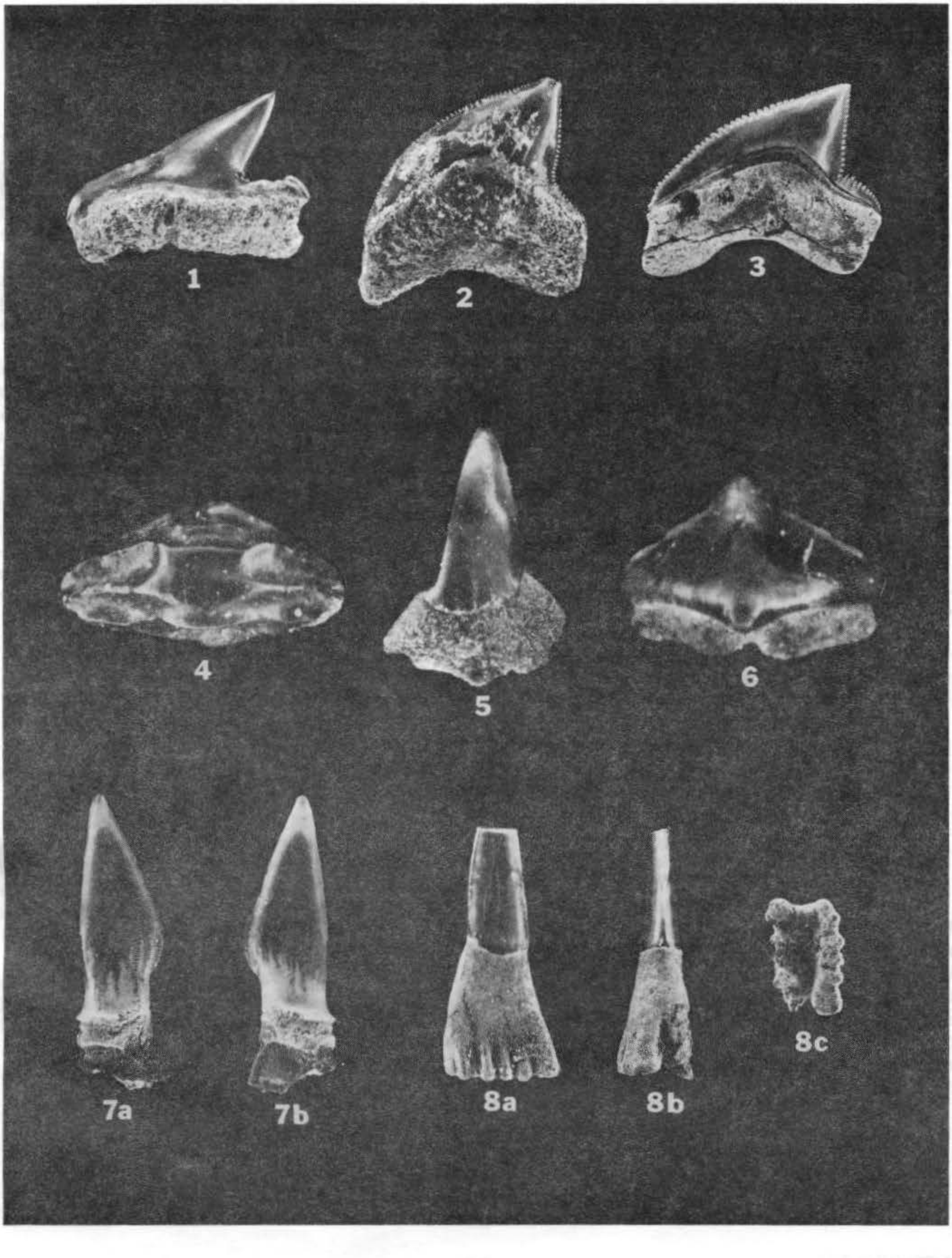
Figure 1. *Pseudocorax granti* Cappetta and Case. Lateral tooth, lingual view, width 6 mm, height 4.5 mm, MGS specimen 1729.

Figures 2-3. *Squalicorax kaupi* (Agassiz)
2. Antero-lateral tooth, lingual view, width 14.5 mm, height 14 mm, MGS specimen 1730.
3. Lateral tooth, lingual view, width 16 mm, height 13 mm, MGS specimen 1731.

Figures 4-5. *Ptychotrygon vermiculata* Cappetta
4. Tooth, occlusal view, greatest width 2 mm, MGS specimen 1735.
5. Rostral denticle, posterior view, height 4 mm, MGS specimen 1736.

Figures 6-7. *Sclerorhynchus* sp.
6. Tooth, labial view, width 1 mm, MGS specimen 1733.
7. Rostral denticle (spine) (incomplete, missing root of spine), height 7 mm, MGS specimen 1734; a, right profile; b, left profile.

Figure 8. *Ischyrhiza mira* Leidy. Rostral denticle (spine) (incomplete, missing tip of spine), height 18 mm, MGS specimen 1732; a, left profile; b, anterior (border) view; c, basal view to show notch for attachment to rostrum.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mm in height, with full rugose striae on its lingual face, and lacks lateral denticles, which were probably worn away. Plate 1, figure 5, shows a lower jaw anterior tooth, MGS 1725, which is also striated on its labial face, but is sigmoidal in its tooth structure, indicating a lower jaw grasping anterior tooth. This tooth is a little bit smaller than the upper anterior one, and may be from a younger shark. Plate 1, figure 6, shows an abraded (lacking lateral cusps and without full striae on its lingual face) antero-lateral tooth, which has only the traces of striae at its enamel margin at the root area. The specimen (MGS 1726) is badly abraded, and the lateral denticles (side cusps) are broken away from the specimen. The final tooth is MGS 1727, a lower? lateral tooth (Plate 1, figure 7) with part of the tip of its central blade missing, and fairly good lateral cusps (at least on its right side). The tooth shows the vestigial striae at the base of the enamel of the central cusp (this is diagnostic for lateral teeth, while the anterior teeth seem to all have 3/4 length striae, flaring out at their termination on the tooth blade as shown in Plate 1, figure 7).

Discussion: *Scapanorhynchus texanus* is an ubiquitous shark found worldwide in formations of Late Cretaceous age from the Santonian up into the middle Maastrichtian. It seems to have been most abundant in the Campanian-Maastrichtian and disappeared in the late Maastrichtian.

There is a slight variability among the specimens of *Scapanorhynchus* found in the late Santonian. The lateral denticles on the lateral teeth (for example, see Plate 1, figure 7) seem to be more pointed and longer than those of the Campanian-Maastrichtian. This variation is not enough to separate the teeth in differing species.

Family CRETOXYRHINIDAE Gluckman, 1958
Genus *CRETOLAMNA* Gluckman, 1958

Cretolamna appendiculata (Agassiz, 1843)
Plate 1, figure 3

Material: Several teeth, mostly laterals.

Figured specimen: MGS 1728.

Description: The tooth illustrated in Plate 1, figure 3, MGS specimen 1728, is a typical lateral tooth, probably from the lower jaw, as the root seems to be slightly constricted (an indication of lower jaw teeth) as opposed to the laterally flaring roots of the upper jaw, with wide, slightly divergent side cusps. The wide side cusps of this species are quite diagnostic (Plate 1, figure 3). The tooth illustrated is approximately 15 mm in height, and about that in width. The central cusp is large and spade-like and contains no striae.

Discussion: *Cretolamna* is one of the longest surviving neoselachian genera, ranging from the earliest part of the Late Cretaceous (the Cenomanian) to the Eocene. *Cretolamna appendiculata* has been reported by Case (1989) from the Cenomanian of New Jersey. This species is common throughout the Campanian-Maastrichtian worldwide.

Family ANACORACIDAE Casier, 1947
Genus *PSEUDOCORAX* Priem, 1897

Pseudocorax granti Cappetta and Case, 1975
Plate 2, figure 1

Material: One lateral tooth.

Figured specimen: MGS 1729.

Description: A small lateral tooth, measuring 6 mm in its greatest width, devoid of striae and serrations on its blade and margin, and with one foramen situated on its root boss. The tooth has a sloping blade on its left side (approximately at a 45 degree angle), and the other side has a notch and a low and wide (though damaged) heel.

Discussion: Cappetta and Case (1975a) described *Pseudocorax granti* from the Campanian Ozona Member of the Sprinkle Formation of the Taylor Group in northeastern Texas (North Sulphur River site, near Ladonia, Texas). The tooth blade margin is without serrations in contrast with *Squalicorax*, which has serrations.

In contrast to *Pseudocorax granti*, *P. affinis* (Agassiz) of the late Campanian of Europe (particularly Belgium) has serrations. Case and Schwimmer (1988) described a specimen of *Pseudocorax* from the Campanian of Georgia (Blufftown Formation) as *P. affinis*, which is now thought to be *P. granti*.

Genus *SQUALICORAX* Whitley, 1939

Squalicorax kaupi (Agassiz, 1843)
Plate 2, figures 2-3

Material: Several teeth, antero-laterals and laterals.

Figured specimens: MGS 1730 and MGS 1731.

Description: An antero-lateral tooth (MGS 1730, Plate 2, figure 2), missing a bit of the tip of the blade. It is fully serrated along the entire enamel margin, with a large root face in lingual view. The second tooth, a lateral (MGS 1731, Plate 2, figure 3), is fully serrated on the entire enamel margin, with a large root face in lingual view, and shoulder notch as in *Pseudocorax*.

Discussion: This is another ubiquitous Late Cretaceous shark species. *Squalicorax kaupi* follows the Santonian *S. falcatus*, and survives until the late Maastrichtian. The notch or "hump" in the mid-anterior edge of the tooth blade of *S. kaupi* differentiates it from the teeth of *S. falcatus* (Cenomanian to early Santonian)(Case and Schwimmer, 1988, p. 294).

Superorder BATOMORPHII Cappetta, 1980
Order RAJIFORMES Berg, 1940
Suborder SCLERORHYNCHOIDEI Cappetta, 1980
Family SCLERORHYNCHIDAE Cappetta, 1974

Genus *ISCHYRHIZA* Leidy, 1856

Ischyrhiza mira Leidy, 1856
Plate 2, figures 8a-c

Material: Several rostral denticles.

Figured specimen: MGS 1732 (rostral denticle).

Description: A rostral denticle, missing the tip of its enameled blade, approximately 18 mm in height, but which probably would have measured over 20 mm if the blade were complete. The rostral denticle is approximately half and half, enamel and root. The basal view (Plate 2, figure 8c) shows a hollowed-out "notch" which would have been an attachment area to the sawfish rostrum, which held the denticle securely in place.

Discussion: *Ischyrhiza* seems to be restricted to North American fossil deposits of Late Cretaceous age, and has a range from the Santonian to the late Maastrichtian, where it is joined by a larger subspecies: *I. mira mira*. *Ischyrhiza mira* is common in Upper Cretaceous sediments (Santonian to Maastrichtian) in Canada and the United States (Case, 1978, 1979a, 1979b, 1987, and Cappetta and Case, 1975b).

Genus *SCLERORHYNCHUS* Woodward, 1889

Sclerorhynchus sp.
Plate 2, figures 6-7

Material: Several rostral denticles and teeth.

Figured specimens: MGS 1733 (tooth) and MGS 1734 (rostral denticle).

Description: A minute tooth, measuring 1 mm in greatest width, with a small root and larger enamel tooth cap, which is radially (not shown in illustration) and rugosly striated (Plate 2, figure 6), and having a slightly declining apron on its labial face. The rostral denticle (Plate 2, figures 7a-b) is missing a portion of the lower root area (attachment area to the rostrum of the sawfish) and has a pronounced recurved area medial on its posterior edge. In a species yet to be described from the late Maastrichtian, this curved area becomes a recurved "barb-like" appendage (Case and Cappetta, in preparation).

Discussion: Rostral denticles of *Sclerorhynchus* are contemporaneous with *Ischyrhiza*, being found in marine sediments of Santonian to Maastrichtian age worldwide. Similar denticles found in Europe and North Africa are called *Sclerorhynchus atavus*. More comparative studies of European/North African species to the present specimens need to be done before assigning a species. This is also true for the teeth, which are hard to identify as to species.

Family INCERTAE SEDIS (Rhinobatoidei or Sclerorhynchoidei)
Genus *PTYCHOTRYGON* Jaekel, 1894

Ptychotrygon vermiculata Cappetta, 1975
Plate 2, figures 4-5

Material: One tooth and one rostral denticle.

Figured specimens: MGS 1735 (tooth) and MGS 1736 (rostral denticle).

Description: The tooth of *Ptychotrygon vermiculata* (MGS 1735, Plate 2, figure 4) shows a wrinkled occlusal surface with ridges, the crests of which in turn have complex convolutions and striae. These are minute crushing (pavement) teeth averaging about 2 mm in their greatest width, and are used for crushing mollusks. The rostral denticle is very minute (less than 4 mm in its greatest height) and has a rounded base (probably to fit on a "rasp" or "file"-like rostrum).

Discussion: Cappetta and Case (1975b) described specimens like those of the present material as *Ptychotrygon triangularis* (Reuss) in their report on the Upper Cretaceous neoselachians of New Jersey and Delaware. Cappetta (1975) shortly thereafter redescribed these specimens as *P. vermiculata* nov. sp. *Ptychotrygon triangularis* (Reuss), described from Europe, is known only from Texas in North America (Cappetta, 1975).

Ptychotrygon is widespread in North American fossil deposits, and *P. vermiculata*, in particular, has been recovered in New Jersey, Delaware, Texas, Georgia, and now Mississippi. Its geological range is from Campanian to late Maastrichtian.

RESULTS AND CONCLUSIONS

The presently described fauna including 17 figured chondrichthyan fish specimens cannot be considered a complete fauna from this site in Mississippi. Missing from this fauna are the following: *Hybodus*, *Lissodus*, *Squatina* and/or *Cretorectolobus*, *Brachaelurus*, *Rhinobatos* and several others. However, the 11 species described here add to our knowledge of the geographical and geological distribution of sharks and rays in the Upper Cretaceous of North America.

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UPPER CRETACEOUS (MAASTRICHTIAN) TELEOSTEAN OTOLITHS FROM THE RIPLEY FORMATION, UNION COUNTY, MISSISSIPPI

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ABSTRACT

Upper Cretaceous teleostean otoliths (fish ear bones) from the basal Ripley Formation (Early Maastrichtian) from near Blue Springs, Union County, Mississippi, represent only the third Cretaceous otolith assemblage to be formally studied in North America. The sample from the Ripley Formation was fairly prolific, yielding 6.12 otoliths per kilogram of sample and a total of 257 otoliths. The 257 otoliths represent at least 21 taxa of teleosts. Two taxa, "genus Trachichthyidarum" *coffeesandensis* and "genus Synodontidarum" *pseudoperca*, comprise 58.8% of the Ripley Formation assemblage. The Ripley Formation otolith assemblage has much in common with that from the late Campanian Coffee Sand in Lee County, Mississippi. Otolith paleoecological evidence, supported by that from Foraminifera and ostracodes, points to a marine shelf environment, possibly middle to outer shelf, with tropical to subtropical conditions.

INTRODUCTION

Previous Studies

Research concerning Cretaceous otoliths in North America is limited to only a few studies, and descriptions of Cretaceous otolith assemblages are even more limited. Only two descriptions of Cretaceous otolith assemblages in North America have been published. In 1983, Huddleston and Savoie described an assemblage of otoliths from the Severn Formation (early-middle Maastrichtian) of Maryland. The authors described at least 14 kinds of fishes based on otoliths. Nolf and Dockery (1990) described otoliths from the Coffee Sand (Campanian) in Lee County, Mississippi. Their study revealed the presence of 20 different teleosts.

Other studies of North American Cretaceous otoliths have been based on isolated sagittae. Tychsen and Vorhis (1955) reported otoliths from the Fox Hills Sandstone (Maastrichtian) of South Dakota, but they did not describe them. Frizzell (1965a) described one Cretaceous albulid from the Eutaw Formation (probably late Santonian) and another Cretaceous otolith from the Blufftown Formation (early Campanian). Frizzell (1965b) also described a Cretaceous ariid, *Vorhisia vulpes*, from the Fox Hills Sandstone (Maastrichtian) of South Dakota. The identification was based on lapilli. Waage (1968) utilized otoliths (lapilli) of *Vorhisia vulpes* in stratigraphic and paleoenvironmental studies of the Fox Hills Sandstone. Frizzell and Koenig (1973) later described asterisci from the same formation as belonging to *Vorhisia vulpes*. However, Huddleston and Savoie (1983) noted that the asterisci did not belong to *Vorhisia vulpes*.

Huddleston (1981) reported the occurrence of a single, well-preserved teleost otolith (designated as *Bernardichthys zorraquinosi* from the Bernard Formation (early Cenomanian) of Oregon. This otolith represents the earliest reported occurrence of a teleostean otolith in North America (Huddleston, 1981).

Location of Collection Site

The collection site for this study is the Blue Springs locality, which is well known for containing fossil crabs in phosphatic nodules. Bishop (1983) collected over 1300 decapod specimens from this locality consisting of 11 species. The site is located in northeastern Mississippi in Union County, 22 kilometers northwest of Tupelo, Mississippi, (Figure 1) and approximately 0.3 km from the intersection of U.S. Highway 78 (Blue Springs Exit) and Mississippi Highway 9. The exposure is a partially vegetated roadcut on the southeastern side of Mississippi Highway 9 (NW 1/4, Sec. 16, T8S, R4E).

Collection Methods

Approximately 42 kilograms of blue-gray sandy clay were collected from the roadcut by the author. In order to obtain fresh sediment, samples were collected approximately 0.3 meter below the surface. A few otolith specimens were collected from the surface. The samples were processed for standard micropaleontologic examination (wet-screened). In order to disaggregate the clay, the samples had to be air-dried and wet-screened several times. The wet-screening process resulted in approximately 0.6 kilogram of residue. A 40-mesh sieve was utilized for the screening, and the majority of the residue was between 10 mesh and 30 mesh in size.

Stratigraphy

The collection locality is late Cretaceous in age and is placed stratigraphically in the basal portion of the Ripley

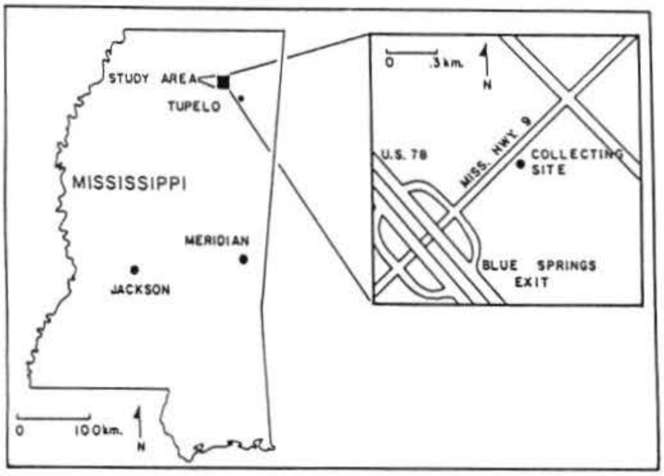


Figure 1. Location of collection site.

Formation (Russell et al., 1983). The formation has been assigned to the Maastrichtian. Russell (personal communication) noted that the outcrop is above the *Exogyra cancellata* Subzone and, therefore, is certainly no older than early Maastrichtian. Russell also noted that planktonic foraminifers in equivalent beds are assigned an early Maastrichtian age.

The Ripley Formation was first named by Hilgard (1860) and included all strata between the top of the "rotten limestone" (Demopolis Formation) and the base of the Tertiary in the Ripley, Mississippi, area. Hilgard included the Owl Creek marl as part of the Ripley Formation. However, due to an unconformity at the base of the Owl Creek, Stephenson and Monroe removed the Owl Creek from the Ripley Formation (Russell et al., 1983).

The Ripley Formation is characterized by several lithologies ranging from clays to marls to sands. The sample collected for this study at the Blue Springs outcrop consisted of a highly micaceous (muscovite) and glauconitic, very fossiliferous (marine), blue-gray, silty, sand and clay mixture. Thin shell stringers (less than 1 cm) were also present. This outcrop is part of a sequence of beds resulting from the regression of the Ripley as the McNairy delta prograded onto the Demopolis Shelf. The lower part of the Ripley Formation at the Blue Springs locality and throughout Mississippi is laterally equivalent to the Coon Creek Formation of western Tennessee (Russell et al., 1983). This has caused confusion in the Blue Springs area as several studies have referred to the fossiliferous marine sands and clays as the Coon Creek Formation (e.g., Bishop, 1983).

DESCRIPTION OF OTOLITH MATERIAL

The basal Ripley Formation sample collected for this study produced 257 otoliths. This is an average of 6.12 otoliths per kilogram of sample, which is much more prolific than the Campanian Coffee Sand of Lee County, Mississippi, studied by Nolf and Dockery (1990); it yielded only 117 otoliths in 3000 kilograms of sample (0.04 otoliths per kilogram). However, the Ripley Formation sample is not quite as prolific as the Maastrichtian Severn Formation of Maryland, which yielded 10.8 otoliths per kilogram (Huddleston and Savoie, 1983). In comparison to the Cretaceous sediment, Nolf and Dockery (1990) noted that Tertiary greensand coquinas in Europe produced 1.0 otolith per kilogram of sediment. Many Tertiary clays are known to be much more prolific in terms of otoliths. For example, a middle Eocene formation in Louisiana produced 62.3 otoliths per kilogram of sediment (Stringer, unpublished data), and a lower Miocene formation in Czechoslovakia produced 510 otoliths in one kilogram of sample (Brzobohaty, personal communication). The most phenomenal sample in terms of otoliths known to this author is a one kilogram sample of the Pliocene Yorktown Formation from North Carolina that yielded approximately 2250 otoliths.

The otoliths from the Ripley Formation are generally well-preserved, especially for Cretaceous-age material. Many have crenulate and lobate margins preserved. The color tends to be beige and light brown. This is the same color typical of many Tertiary otoliths. The otoliths ranged in size from 8 mm (a specimen of "genus Trachichthyidarum" *coffeesandensis)* to less than 2 mm (a specimen of "genus Synodontidarum" *pseudoperca*). The vast majority of the otoliths range from 3-5 mm in length. Sagittae comprise 97% of the total otoliths (250 sagittae) with lapilli comprising the remainder (7 lapilli). Approximately 25 otoliths of the total 257 are broken and/or abraded beyond identification.

SYSTEMATIC PALEONTOLOGY

The 257 otoliths from the late Cretaceous Ripley Formation represent at least 21 taxa of teleosts. The fossil otoliths were identified by comparisons to modern teleostean otoliths. Knowledge of Cretaceous otolith-based teleost faunas is extremely limited, with less than 20 valid species known for the entire Cretaceous worldwide (Nolf, 1985). Due to the lack of knowledge of Cretaceous otoliths, some specimens are identified only to the family level (or higher category). Some of the forms are identified in an open generic nomenclature system which is commonly used by Nolf and many other European otolith taxonomists. For each of the taxa in this study, the systematic classification is presented, followed by a description of the material and a discussion of the form.

DETAILED SYSTEMATICS

Class OSTEICHTHYES Huxley, 1880
Subdivision TELEOSTEI Muller, 1846
Order MEGALOPIFORMES Patterson and Rosen, 1977
Family MEGALOPIDAE Jordan and Gilbert, 1882

Megalopidae
Plate 1, figure 1

Material: 1 otolith (1 left sagitta)

Discussion: Although this specimen is probably a juvenile, it seems to be very closely related to the Holocene megalopids. It is very similar to the ?Megalopidae of Nolf and Dockery (1990), but this specimen is almost twice as large as their figured specimen. With only one juvenile specimen, which is slightly eroded on the inner face, identification can not be more precise.

Order ANGUILLIFORMES Regan, 1909
Family ALBULIDAE Bleeker, 1859

"genus? Albulidarum" *ensis* Nolf and Dockery, 1990
Plate 1, figure 2

Material: 7 otoliths (4 right and 3 left sagittae)

Discussion: These otoliths are quite distinct and compare well with the otoliths described by Nolf and Dockery (1990) from the Campanian Coffee Sand. The otoliths are thin and elongate with an elliptical outline. The sulcus is very large, covering well over half of the inner face of the otolith. The sulcus is undivided with no distinct ostium and cauda. The posterior end of the sulcus is deeply incised (a very typical albulid feature). Comparative material from the late Cretaceous Severn Formation of Maryland has a very similar, if not conspecific, albulid.

Albulidae
Plate 1, figure 3

Material: 2 otoliths (2 left sagittae)

Discussion: These two otoliths show definite characteristics of the Family Albulidae, especially in the sulcal configuration. However, they do not compare with "genus Albulidarum" *weileri* (Frizzell, 1965a) or "genus Albulidarum" *sohli* (Frizzell, 1965a), both known from the Gulf Coast Cretaceous. Also, the otoliths do not compare with "genus aff. *Albula*" sp. from the Campanian Coffee Sand (Nolf and Dockery, 1990). These albulids from the Ripley Formation are more rounded anteriorly, and the anterior end is broader than the posterior end. The otoliths show some erosion, especially on the dorsal margins, and identification is limited to the family level.

Family PTEROTHRISSIDAE Gill, 1893

"genus Pterothrissidarum" *griffini* Nolf and Dockery, 1990
Plate 1, figure 4

Material: 1 otolith (1 right sagitta)

Discussion: Although this otolith is smaller than the one figured by Nolf and Dockery (1990), this specimen has all the salient characteristics of this species. It is a robust, thick otolith with a more circular outline and a convex inner face. It has a strongly incised sulcus with a prominent crista superior.

Pterothrissus sp.
Plate 1, figure 5

Material: 3 otoliths (3 right sagittae)

Discussion: These otoliths are quite small (2-3 mm), but show distinct characteristics that seem to indicate *Pterothrissus*. They are more elongate in outline than Holocene forms such as *Pterothrissus belloci*. In outline, they resemble the pterothrissids from the lower Eocene of England identified by Stinton (*Pterothrissus protensus*). The specimens seem to be juveniles, and further identification without additional specimens would be tenuous.

Suborder ANGUILLOIDEI Regan, 1909
Family CONGRIDAE Kaup, 1856

Congridae
Plate 1, figure 6

Material: 4 otoliths (2 right and 2 left sagittae)

Discussion: Close examination of these specimens seems to indicate a small ostial channel that opens to the dorsal rim. The specimens are slightly eroded, especially the anterior area, but the presence of the ostial channel seems to suggest the Family Congridae.

Order SILURIFORMES Cuvier, 1817
Family ARIIDAE Gunther, 1864

Ariidae
Plate 1, figure 7

Material: 7 otoliths (1 right and 6 left lapilli)

Discussion: These specimens are quite small (all less than 4 mm) in comparison to modern ariid lapilli. The lapilli are fairly thin and have a very flat inner face. Comparative material from the Upper Cretaceous Severn Formation in Maryland has specimens identical to these. However, the inner faces of the larger specimens are not as flat and are more convex.

Order SALMONIFORMES Bleeker, 1859
Family ARGENTINIDAE Bonaparte, 1846

Argentinidae
Plate 1, figure 9

Material: 10 otoliths (2 right and 8 left sagittae)

Discussion: These otoliths show many characteristics of the osmerids (for comparison, see p. 159 of Gaemers and Schwarzhans, 1982) and the argentinids (for comparison, see p. 38 of Schwarzhans, 1984). Difficulty in identification arises due to the condition of the specimens. The otoliths are fairly flat and thin with a thin, projecting rostrum. The thin rostrum is broken on all but one of the specimens. Many of the specimens are also broken, and one is forced to work with a composite of the specimens. Holocene material obtained from the late John Fitch shows many of the osmerids with a more convex outer face. The argentinid material tends to have a flatter outer face which is more similar to the specimens. Also, many of the argentinids have a more pronounced dome located in the posterior dorsal area. The material is tentatively identified as Argentinidae.

?Salmoniformes
Plate 1, figure 10

Material: 1 otolith (1 left sagitta)

Discussion: This otolith is elongate and is characterized by a narrow, almost straight cauda that tapers to a point. A crista superior is present. The ostium is eroded, and the rostrum seems to be broken. Only one specimen was collected, and it shows signs of erosion and wear. Without better preserved material, identification is highly tentative.

Order STOMIIFORMES Regan, 1909
Family STERNOPTYCHIDAE Dumeril, 1806

Sternoptychidae
Plate 2, figure 1

Material: 5 otoliths (2 right and 3 left sagittae)

Discussion: These are very distinctly-shaped otoliths and are very similar to Cretaceous otoliths assigned to the Stomioidei by Huddleston and Savoie (1983). The otolith figured by Huddleston and Savoie (1983) seems to be very worn. The five specimens from the Ripley Formation are better preserved. In the Order Stomiiformes, the Family Sternoptychidae has several Holocene representatives with unusually-shaped otoliths that seem to be closely related to this Cretaceous form. Otoliths such as *Argyropelecus gigas* (see Nolf, 1985) and *Maurolicus aegrotus* (see Schwarzhans, 1984) have similar distinctive shapes and sulci. Modern hatchetfishes are thought of as only deepwater, but several forms occur in shallower water (Nelson, 1984).

Order AULOPIFORMES Rosen, 1973
Family SYNODONTIDAE Gill, 1872

"genus Synodontidarum" *pseudoperca* Nolf and Dockery, 1990
Plate 2, figure 2

Material: 56 otoliths (32 right and 24 left sagittae)

Discussion: These otoliths represent the second most abundant species in the Ripley Formation. They possess many of the salient characteristics described by Nolf and Dockery (1990). The sulcus is clearly divided into a broad ostium and a narrow cauda characterized by a crista superior and crista inferior. The crista superior is more pronounced than the crista inferior and has a distinct hollow area above it. The ventral rim shows fine serrations on many specimens.

Order GADIFORMES Goodrich, 1909
Family GADIDAE Rafinesque, 1810

Gadidae
Plate 2, figure 4

Material: 3 otoliths (2 right and 1 left)

Discussion: This elongate, narrow otolith has the salient characteristics of the Family Gadidae. The general outline and sulcus are typical of the gadids, such as the Holocene gadid *Merlangius merlangus*. Unfortunately, the sulcus is eroded on the specimens, and only the general outline of the sulcus can be observed. The ostium and cauda can not be distinguished. If better preserved material is obtained, generic identification should be possible.

Order OPHIDIIFORMES Berg, 1937
Family OPHIDIIDAE Rafinesque, 1810

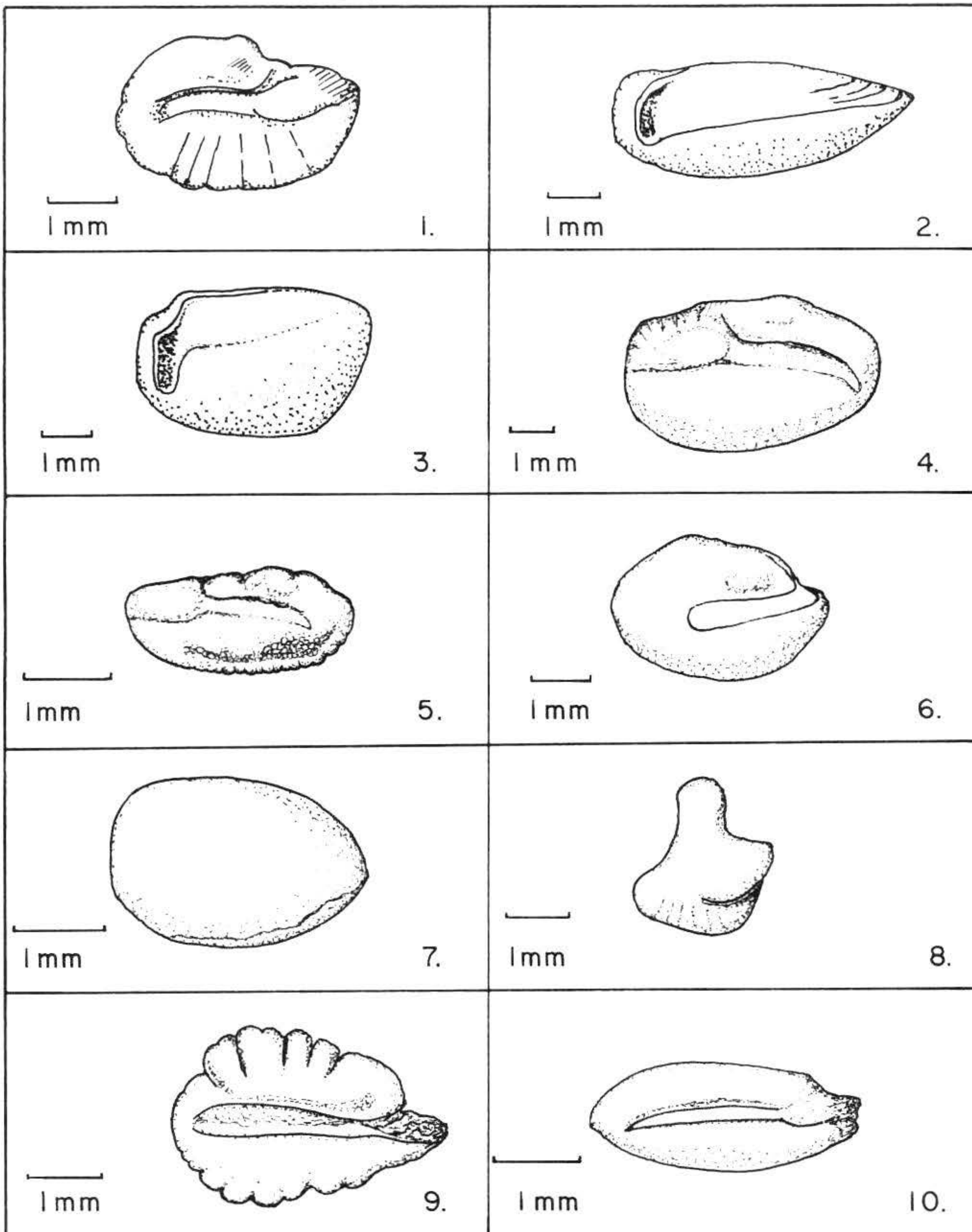
Ophidiidae
Plate 2, figure 3

EXPLANATION OF PLATE 1

Representative otoliths from the Ripley Formation, near Blue Springs, Union County, Mississippi.

Figure
1. Megalopidae; left sagitta.
2. "genus? Albulidarum" *ensis* Nolf and Dockery, 1990; left sagitta.
3. Albulidae; left sagitta.
4. "genus Pterothrissidarum" *griffini* Nolf and Dockery, 1990; right sagitta.
5. *Pterothrissus* sp.; right sagitta.
6. Congridae; left sagitta.
7. Ariidae; left lapillus.
8. Utricular otolith; taxonomic position unknown.
9. Argentinidae; left sagitta.
10. ?Salmoniformes; left sagitta.

PLATE I



Material: 2 otoliths (2 left sagittae)

Discussion: These otoliths show several characteristics that seem to indicate the Family Ophidiidae. The otolith has a prominent anterior dorsal dome. Unfortunately, the sulcus is worn, but a distinct ostium can be distinguished. There is a distinct depression in the posterior ventral rim. Nolf (personal communication) identified the otolith as an ophidiid, but the possibility of a holocentrid was also noted. Presumably with additional material this taxon can be more accurately identified.

Order BERYCIFORMES Regan, 1909
Family TRACHICHTHYIDAE Bleeker, 1859

"genus Trachichthyidarum" *coffeesandensis* Nolf and Dockery, 1990
Plate 2, figure 5

Material: 95 otoliths (52 right and 44 left sagittae)

Discussion: This species represents the most abundant taxa in the Ripley Formation at the Blue Springs locality. The specimens compare extremely well with the holotypes and paratypes figured by Nolf and Dockery (1990). The subpentagonal shape with a nearly flat inner face are quite characteristic. The ostium and the cauda are distinct with a prominent crista superior. Just above the crista superior, there is an obvious depressed area that accentuates the crista superior. Examination of comparative material from the Late Cretaceous Severn Formation of Maryland reveals a very similar form, possibly indicative of the same species.

Family POLYMIXIIDAE Gill, 1872

Polymixiidae
Plate 2, figure 6

Material: 10 otoliths (5 right and 5 left)

Discussion: The characteristics of this otolith seem to indicate the Family Polymixiidae. It compares favorably with the Polymixiidae from the Late Cretaceous Severn Formation in Huddleston and Savoie (1983). The otoliths from the Ripley Formation show many features similar to Holocene species of the Polymixiidae such as *Polymixia lowei* which is known from the Gulf of Mexico (see Nolf, 1985).

Order PERCIFORMES Bleeker, 1859
Family APOGONIDAE Jordan and Gilbert, 1882

Apogonidae sp. 1
Plate 2, figure 7

Material: 5 otoliths (4 right and 1 left sagittae)

Discussion: Apogonidae sp. 1 exhibits typical apogonid features as seen on Holocene species. Two different types of apogonids were recognized in the Ripley Formation. Apogonidae sp. 1 is more circular in outline than the second type. Length/width ratios on several of the Apogonidae sp. 1 average around 1.1 (almost circular). A ventral furrow is present on all specimens. Also, all of the specimens display finely crenulate margins around almost the entire periphery.

Apogonidae sp. 2
Plate 2, figure 8

Material: 3 otoliths (1 right and 2 left sagittae)

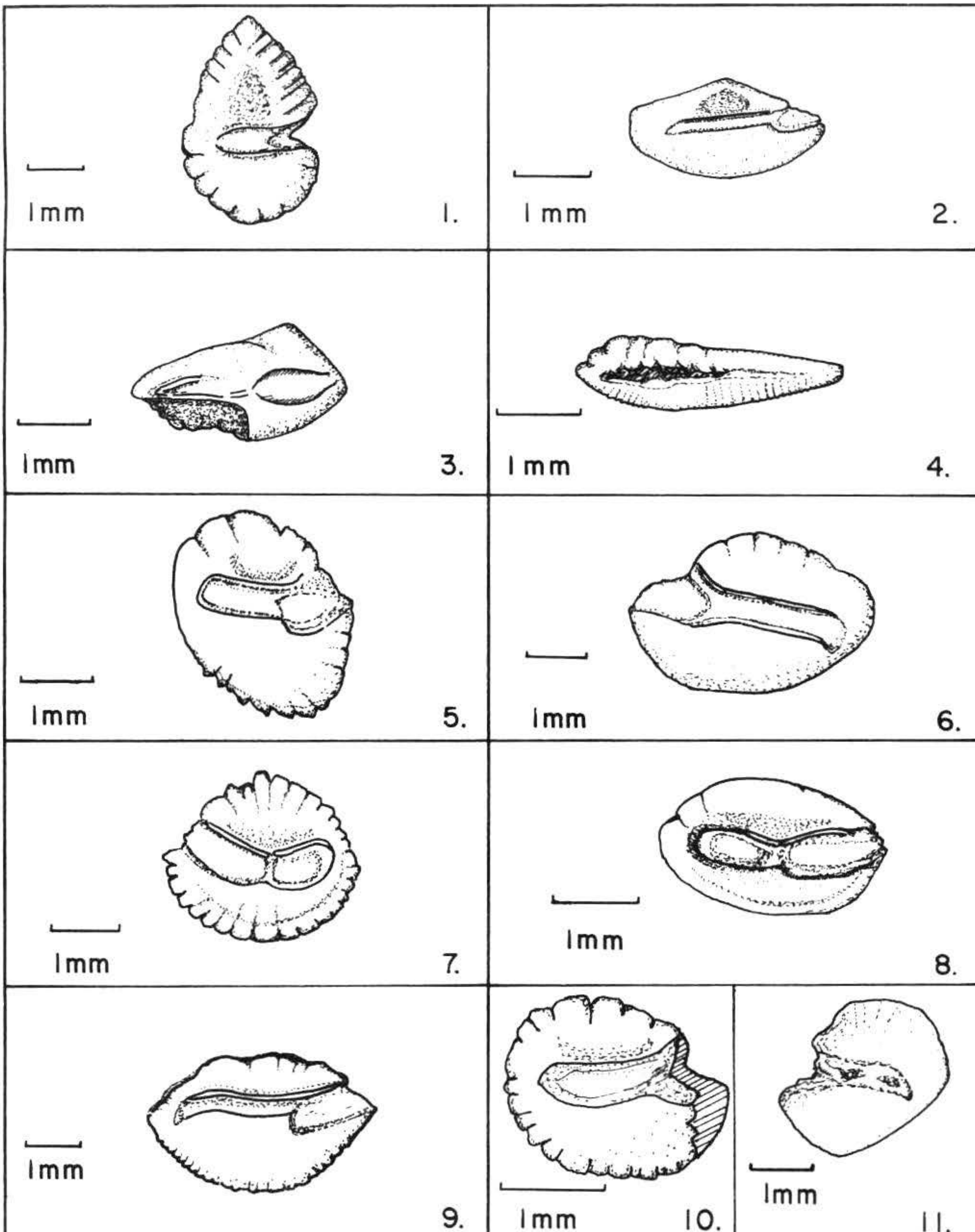
Discussion: Apogonidae sp. 2 can be distinguished from Apogonidae sp. 1 by several major characteristics. First and most importantly, Apogonidae sp. 2 tends to be more elongate and much less circular. Length/width ratios on the specimens of Apogonidae sp. 2 range from 1.3 to 1.6, indicating a greater length in comparison to width. Also, Apogonidae sp. 2 does not have the finely crenulate margins around the entire periphery. The two types are probably closely related, but distinct enough to differentiate. The Apogonidae of Nolf and Dockery (1990) is more similar to Apogonidae sp. 2. Both of the figured specimens have length/width ratios around 1.3, and both are more elongate than Apogonidae sp. 1. Apogonidae-A of Huddleston and Savoie (1983) also compares more favorably with Apogonidae sp. 2.

EXPLANATION OF PLATE 2

Representative otoliths from the Ripley Formation, near Blue Springs, Union County, Mississippi.

Figure
1. Sternoptychidae; right sagitta.
2. "genus Synodontidarum" *pseudoperca* Nolf and Dockery, 1990; left sagitta.
3. Ophidiidae; left sagitta.
4. Gadidae; right sagitta.
5. "genus Trachichthyidarum" *coffeesandensis* Nolf and Dockery, 1990; left sagitta.
6. Polymixiidae; right sagitta.
7. Apogonidae sp. 1; right sagitta.
8. Apogonidae sp. 2; left sagitta.
9. Pempherididae; right sagitta.
10. Percoidei sp. 1; left sagitta.
11. Percoidei sp. 2; right sagitta.

PLATE 2



Family PEMPHERIDIDAE Gill, 1862

Pempherididae
Plate 2, figure 9

Material: 11 otoliths (3 right and 8 left sagittae)

Discussion: This otolith compares quite well with the cf. Pempherididae of Huddleston and Savoie (1983). The sulcus is very similar to several Holocene species of pempherids, but the general shape of the otolith is more elongate. However, the otoliths are tentatively placed in the Family Pempherididae.

Family incertae sedis

Percoidei sp. 1
Plate 2, figure 10

Material: 2 otoliths (1 right and 1 left sagittae)

Discussion: The rostral portion of both specimens was broken, but other characteristics seem to indicate a percoid very similar to the form designated as Percoidei sp. 2 by Nolf and Dockery (1990). Further identification of these small otoliths is not possible with available material.

Percoidei sp. 2
Plate 2, figure 11

Material: 2 otoliths (1 right and 1 left sagittae)

Discussion: These two otoliths are quite eroded and worn. However, several features can be attributed to some type of percoid fish. They seem to differ from the other percoids in the Ripley Formation, but further differentiation is not possible.

Family incertae sedis
Utricular otoliths (genus unknown)
Plate 1, figure 8

Material: 2 otoliths

Discussion: These two otoliths are broken, but show distinct characteristics of utricular otoliths. However, their taxonomic position is not known. Nolf (personal communication) stated that the utricular otoliths could not be identified any further.

COMPARISON TO OTHER CRETACEOUS FAUNAS

Until the study of Nolf and Dockery (1990), only one Cretaceous otolith assemblage had been described from North America (Huddleston and Savoie, 1983). Now, with this study on the teleostean fauna of the Ripley Formation, comparisons of the otolith assemblages are possible. Obviously, there are certain stratigraphic and geographic constraints upon the comparisons of the three otolith faunas. The Coffee Sand otolith assemblage of Nolf and Dockery (1990) is slightly older since it is probably middle to late Campanian in age. The Severn Formation otolith assemblage of Huddleston and Savoie (1983) and the Ripley Formation otolith assemblage (present study) are essentially the same age (early to possibly middle Maastrichtian). Brouwers and Hazel (1978) in their studies of the ostracodes of the Severn Formation of Maryland correlated the Severn Formation with the upper part of the Ripley Formation in east-central Mississippi. However, all three assemblages are Late Cretaceous in age (approximately 68 - 75 Ma).

The Coffee Sand and the Ripley Formation assemblages are in close proximity to one another geographically. They are located in adjacent counties in northeastern Mississippi (Lee and Union counties) and are less than 20 km apart. The Severn Formation assemblage is located much farther north, in Prince Georges County, Maryland. This is a present latitudinal difference of about 4 degrees 30 minutes. Since the amount of sediment collected varied greatly (42 kg to 3000 kg), the number of specimens cannot be directly compared. However, the percentage of the total otoliths of certain taxa can be compared and can provide useful information.

Some very obvious differences exist between the Late Cretaceous faunas. The Severn Formation otolith assemblage is dominated by ariids. *Vorhisia* sp. accounts for over one-half of the total fauna (54.9%), and when an unidentified ariid is considered, the Family Ariidae comprises 62.5% of the total fauna. This is in strong contrast to the Coffee Sand and the Ripley Formation assemblages where ariids account for only 0.9% and 2.7% of the total fauna, respectively.

Additional differences exist when the major components of the faunas are considered. Almost 90% of the Severn Formation assemblage consists of ariids and apogonids. Only 3.2% of the Coffee Sand assemblage is comprised of ariids and apogonids, and the Ripley Formation has only 5.8% of its total fauna represented by ariids and apogonids. However, there are some similarities in the three assemblages. For example, all three assemblages have albulids, pterothrissids, ariids, apogonids, and trachichthyids.

The Coffee Sand and the Ripley Formation assemblages have much more in common. The two taxa "genus Trachichthyidarum" *coffeesandensis* and "genus Synodontidarum" *pseudoperca* comprise 45% of the Coffee Sand assemblage and 58.8% of the Ripley Formation assemblage. These two otolith assemblages also have the following taxa in common: Megalopidae, "genus? Albulidarum" *ensis*, "genus Pterothrissidarum" *griffini*, Congridae, Ariidae, Apogonidae, and Percoidei.

One of the major differences in the Coffee Sand and the Ripley Formation are the pterothrissids. Approximately 23% of the Coffee Sand assemblage is comprised of pterothrissids, but this group only accounts for 1.6% of the Ripley Formation assemblage. A *Pterothrissus* sp. is the second most abundant form in the Coffee Sand (22.6% of the total fauna). Another difference is the abundance of the trachichthyids. Although found in both assemblages, "genus Trachichthyidarum" *coffeesandensis* is much more important in the Ripley Formation, where this taxon is the most abundant form (37%) in the assemblage. However, this taxon comprises only 16.5% of the total fauna in the Coffee Sand assemblage.

ASSOCIATED FOSSIL MATERIAL

In addition to the teleosts represented by otoliths, a fairly diverse invertebrate and vertebrate fauna was found in the samples from the Blue Springs locality. This section is intended to present a general analysis of the associated fauna and is not purported to be comprehensive. Detailed studies of individual faunal groups would be necessary to completely describe the fauna.

The invertebrate fauna is dominated by molluscan species, Foraminifera, decapods, coelenterates, and ostracodes. The Foraminifera are represented only by benthonic species. The lack of planktonic Foraminifera may be related to the screen size utilized in sample preparation and not to a true absence of planktonics. Other benthonic Foraminifera may also have been present in the smaller mesh size. The foraminiferal fauna is dominated by *Lenticulina navarroensis* and *Vaginulina wadei*. Other species present include *Nodosaria affinis*, *Frondicularia frankei*, *Pseudopolymorphina cuyleri*, *Vaginulina cretacea*, *Lenticulina muensteri*, and *Lenticulina spissa-costata* (Cushman, 1946). The ostracodes are not as numerous as the Foraminifera and are represented by *Cytherella* sp., *Brachycythere* sp., and "*Bairdia*" sp.

Coelenterates are fairly common, but they are characterized mainly by one species, *Micrabacia hilgardi*. Spines from an unidentified echinoderm are also present. Arthropod specimens, mainly decapods (crabs), are quite abundant and diverse. Bishop (1983) described the decapod fauna from this area as one of the most diverse known in the United States. The fauna consists of ten species of decapods.

By far the most abundant of the invertebrate fauna are the mollusks. The washed samples are dominated by shell hash from mainly pelecypods and gastropods. Shell fragments of the oyster *Exogyra costata* are extremely common. A small gastropod species of *Turritella* is also quite common. Numerous specimens of a small (around 2-3 mm), enigmatic fossil were collected. These specimens are circular in shape, tapering to a point with prominent lateral furrows and may represent structures in the rostral-epirostral area of belemnoids (Breard, personal communication).

The non-otolith vertebrate fauna is not nearly as diverse as the vertebrate fauna represented by otoliths. However, as emphasized by Nolf (1985), the non-otolith vertebrate fauna and the otolith fauna seldom agree as to the taxa present, but the two are complementary. Specimens representing the Class Chondrichthyes and the Class Osteichthyes are present in the samples. One rhinobatoid and several shark species are present in the samples. The rhinobatoid material consists of one well-preserved tooth of *Ptychotrygon* aff. *Ptychotrygon triangularis* (see p. 156 of Cappetta, 1987). One well-preserved tooth of *Scapanorhynchus texanus* is also present. This genus is known from the Aptian to the Maastrichtian in North America (Cappetta, 1987) and is reported as the most common Upper Cretaceous shark in the Atlantic and eastern Gulf Coastal Plain deposits by Case and Schwimmer (1988). Lauginiger and Hartstein (1983) reported *Scapanorhynchus texanus* from the Atlantic Coastal Plain and from Texas. Two broken shark teeth compare favorably with *Cretolamna*, but their condition of preservation prohibits further identification.

Representative material from the Class Osteichthyes includes fish vertebrae and teeth. The unidentified fish vertebrae are four specimens of typical teleostean vertebrae which are quite small (0.5-2.5 mm). One partial pharyngeal tooth, probably belonging to *Hadrodus* sp., was also collected. The most abundant and best preserved fish material are five teeth from *Enchodus petrosus*?. Both dentary and palatine teeth are represented. The largest tooth is approximately 12 mm in length. *Enchodus* species are globally distributed in the Upper Cretaceous, and numerous species are recognized in North America (Case and Schwimmer, 1988).

It should be noted that the teleostean fauna would consist of only two species if based on the skeletal material (calcium phosphatic) from the locality. However, the teleostean fauna exceeds 20 taxa when otoliths are considered. The usefulness of the otoliths to better determine the teleosts in the fossil assemblage is quite obvious at this locality.

PALEOECOLOGY

Otolith assemblages have been utilized extensively in Tertiary and Quaternary strata to ascertain paleoecological parameters. Otolith associations have been found to reflect with reasonable certainty the ichthyological fauna inhabiting an area during a specific interval of geologic time (Stringer, 1986). Therefore, by utilizing data on the preferred habitats of comparable modern fishes, general paleoecological conditions can be determined.

The problem that arises with Cretaceous otoliths is the uncertainty of the relationship of the Holocene taxa to the fossil taxa. The paleoecological analysis based on otoliths for older sediments thus is more general. Nevertheless, the otoliths can be used in conjunction with other groups to more accurately determine paleoecological conditions. For example, do the otoliths indicate a similar paleoecology for the Ripley Formation at the Blue Springs locality as the Foraminifera and other groups?

Robins (1980) purports to list all marine species inhabiting the contiguous shore waters of the continental United States on or above the continental shelf (to a depth of 200 meters). Almost all of the families represented by otoliths in the Ripley Formation are reported by Robins (1980). Therefore, it seems reasonable to assume that mainly marine inshore fishes (found mainly in marine waters less than 200 meters) contributed otoliths to the sampled section of the Ripley Formation. The general nature of this statement should be noted. Obviously, the fossil species "genus Synodontidarum" *pseudoperca* is not listed. However, nine species in the Family Synodontidae are listed by Robins (1980).

The four families not listed by Robins (1980) are the Pterothrissidae, Sternoptychidae, Moridae, and Trachichthyidae. Closer examination of these families does not conflict with the indications of marine shelf conditions. The two Holocene species of *Pterothrissus* are found on the continental slopes of Japan and South Asia (below 200 meters) and off the coast of West Africa (mainly between 150 to 200 meters, but as shallow as 50 meters). However, fossil *Pterothrissus* are known from shallow-water deposits in the Paleocene and Eocene of the United States Gulf Coast (Stringer, unpublished data) as well as shallow-water deposits in Europe (Nolf and Dockery, 1990). The Sternoptychidae is often thought of as a deepwater family, but there are several forms found in shallower waters. *Argyropelecus* is common at 100 meters, and *Polyipnus* may be found as shallow as 50 meters (Nelson, 1984). Fossil species of *Polyipnus* are known from the Tertiary of the Caribbean (Nolf and Stringer, in review). The Moridae are deepwater fishes, but their juveniles have been reported on the shelf and would not be totally unexpected (Hoese and Moore, 1977).

The final family not reported by Robins (1980) is the Trachichthyidae, which represents the most abundant taxa in the Ripley Formation assemblage. The trachichthyids occur mainly in deep water according to Nelson (1984). However, Schwarzhans (1984) noted that representatives of this family are locally abundant and are found in more shallow environments in the older Tertiary sediments. Furthermore, a trachichthyid, *Hoplostethus mediterraneus* is reported from the marine waters in the Gulf of Mexico off Texas (Gallawayet al., 1972). This form has otoliths very similar to the trachichthyid from the Ripley Formation assemblage.

Considering the available data based on otoliths, a marine shelf environment for the Ripley Formation at the Blue Springs locality seems probable. The albulids and the ariids would seem to indicate a shallower shelf. Presently, ariids are commonly found in bays, passes, and the shallow Gulf of Mexico (Hoese and Moore, 1977), and albulids are known from the inter-tidal zone out to 39 meters in the Gulf of Mexico (Frizzell, 1965a). However, these forms are not abundant in the Ripley Formation assemblage, representing less than 6% of the fauna. There are no strong indications of very shallow water such as inner shelf (less than 20 meters).

A majority of the families of fishes based on otoliths indicate tropical to subtropical distribution (Nelson, 1984). Therefore, a shelf environment, possibly middle to outer shelf, with tropical to subtropical conditions seems reasonable. This would agree quite well with other paleoecological indicators. The Foraminifera seem to indicate water depths of about 25 to 40 meters which is middle shelf (Breard, personal communication). The ostracodes are indicative of middle to outer shelf (Kontrovitz, personal communication), and the decapods indicate mainly a shallow water fauna (Bishop, 1983).

CONCLUSIONS

Investigation of the otolith assemblage from the Ripley Formation at the Blue Springs locality resulted in the following conclusions:

1. An average of 6.12 otoliths per kilogram of sample indicates a fairly prolific concentration in the sediment. This is much higher than the concentration of 0.04 otoliths per kilogram reported for the Campanian Coffee Sand of Lee County, Mississippi, by Nolf and Dockery (1990).
2. There were at least 21 different taxa of teleosts, based on otoliths, present during the early Maastrichtian. Only two teleost taxa were identified on the basis of skeletal material. This is an indication of the value of otoliths for determining and interpreting teleostean fossil assemblages.
3. The fauna is characterized by a diversity of forms including albulids, pterothrissids, congrids, ariids, argentinids, trachichthyids, polymixiids, apogonids, pempheridids, and percoids.
4. The most abundant taxa are "genus Trachichthyidarum" *coffeesandensis* (37% of the total fauna) and "genus Synodontidarum" *pseudoperca* (21.8% of the total fauna).
5. The Ripley Formation assemblage of otoliths is markedly different from the Late Cretaceous Severn Formation otolith assemblage of Prince Georges County, Maryland (Huddleston and Savoie, 1983), in terms of abundance. Ariids account for 62.5% of the total fauna in the Severn Formation assemblage, while accounting for only 5.8% of the total fauna in the Ripley Formation assemblage.
6. The Ripley Formation otolith assemblage is much more closely related to the Coffee Sand otolith assemblage of Nolf and Dockery (1990) than to that of the Severn Formation. The two taxa "genus Trachichthyidarum" *coffeesandensis* and "genus Synodontidarum" *pseudoperca* comprised 45% of the Coffee Sand assemblage and 58.8% of the Ripley Formation assemblage. The two assemblages have at least 10 taxa in common.
7. The otolith assemblage of the Ripley Formation at the Blue Springs locality seems to indicate a marine shelf environment, possibly middle to outer shelf, with tropical to sub-

tropical conditions during the early Maastrichtian.

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