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111

FOSSIL OTOLITHS OF SOME LOWER CENOZOIC PERCIFORM FISHES  
OF THE GULF COAST

BY

MOSTAFA JUMA SALEM, 1945-

A THESIS

Presented to the Faculty of the Graduate School of the

UNIVERSITY OF MISSOURI-ROLLA

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Don L. Fairgell (Advisor) Paul L. Hale

acspeng

202857

## ABSTRACT

Nineteen perciform species from the lower Cenozoic and one Recent species are described, and included under eight genera. The main characters that were considered as generic are the outline of the sagitta and the structure of the sulcus. The other features of the otolith were regarded as secondary in importance. The characters that were believed to be valuable at specific level are almost the same as those for the genus but in more detail. These species are considered to be within the Suborder Percoidei. The fossil species of "Nemipterus" were put in the Family Nemipteridae as they resembled the Recent N. virgatus (Houttuyn). Genus E is found to resemble closely the Recent Boops boops (L.) of the Family Sparidae. Genus A resembles the Recent Brachydeuterus auratus of the Family Pomadasyidae. Genus D resembles Otolithus (Carangidarum) americanus Koken.

A survey of Recent perciform sagittae was made, specimens from 345 species having been examined. The morphological features of the otolith of the Order Perciformes were studied. The valuable characters for the subordinal, familial, generic, and specific levels were evaluated.

Lineages are suggested for "Nemipterus" and Genus E. In the first, three divergent lines are indicated: a main one ranging from Paleocene to Recent and containing five species; and two offshoots, one occurring in the upper part of the Vicksburg group, Oligocene. In Genus E three lines also are suggested: a main one ranging from middle Eocene to Oligocene, containing three species; and two offshoots, both occurring in the Oligocene. The changes that were recognized in these two lineages

are the outline of the sagitta, structure of the sulcus, and relative height of the otolith.



## ACKNOWLEDGMENTS

I wish to express my gratitude to Dr. Don L. Frizzell, Department of Geology and Geophysics, University of Missouri-Rolla, not only for his advice and supervision on this research but also for suggesting the problem and offering his own collections of Recent and fossil otoliths to be used in this study. I appreciate very much the financial support of the University of Libya, in the form of a scholarship for my advanced degree. Without that support I would not have been able to do this research. Thanks are extended to Mr. Machraoui Abdelaziz for offering his valuable time to help in translating some references. I acknowledge in addition my sponsors in Washington, D.C., The American Friends of the Middle East, for their kind and excellent services during my academic period in the United States.

## TABLE OF CONTENTS

	Page
ABSTRACT .....	ii
ACKNOWLEDGMENTS .....	iv
TABLE OF CONTENTS .....	v
LIST OF ILLUSTRATIONS .....	vii
I. INTRODUCTION .....	1
II. CHARACTERISTICS OF OTOLITHS .....	4
A. Kinds of Otoliths and Their Functions .....	4
B. Ossiculiths and Otoconia .....	5
C. Composition of Sagitta .....	5
D. Deformities of Sagitta .....	6
E. Morphology of Sagitta .....	7
F. Importance of Otoliths .....	8
III. SOURCES OF MATERIAL .....	12
A. Recent Material .....	12
B. Fossil Otoliths .....	30
IV. SAMPLE LOCALITIES .....	31
V. RECENT PERCIFORMS .....	37
A. Recent Perciform Fishes .....	37
B. Recent Perciform Sagitta .....	38
1. Ordinal Characters .....	38
2. Subordinal Characters .....	41
3. Familial Characters .....	42
4. Generic Characters .....	43
5. Specific Characters .....	44

	Page
VI. FOSSIL PERCIFORM SAGITTA.....	46
A. Generic Concepts.....	46
B. Generic Characters.....	47
C. Specific Concepts.....	48
D. Specific Characters.....	48
E. Suggested Phylogenies.....	48
VII. CONCLUSIONS.....	52
VIII. SYSTEMATIC DESCRIPTIONS.....	55
SELECTED REFERENCES.....	109
VITA.....	111

## LIST OF ILLUSTRATIONS

Figures	Page
1. Sketch of <u>Nemipterus delagoae</u> Smith.....	10
2. Diagram showing terminology and Orientation of Inner Face of Left Sagitta.....	10
3. Sketch Showing Location of Otoliths in Left Auditory Labyrinth.....	11
4. Suggested Phylogenetic Relationships within " <u>Nemipterus</u> " and Genus E.....	51
 Plates	
1. Sketches of Inner and Outer Faces and Dorsal Margin of Sagittae.....	105
2. Sketches of Inner and Outer Faces and Dorsal Margin of Sagittae.....	106
3. Sketches of Inner and Outer Faces and Dorsal Margin of Sagittae.....	107
4. Sketches of Inner and Outer Faces and Dorsal Margin of Sagittae.....	108

## I. INTRODUCTION

Otoliths are small calcareous structures secreted in the auditory labyrinth of teleostean fishes (Figure 3). Three pairs of these are formed. The first, termed the sagitta, is formed in the sacculus. It usually is the largest, and is the most important for paleontological studies, as it is mostly the kind that is found preserved as a fossil. A second otolith is the lapillus, situated in a part of the labyrinth called the utriculus. This otolith is usually smaller than the sagitta, except in the cypriniforms. The third otolith, found in the lagena, is termed the asteriscus. It is usually smaller and more delicate than the lapillus. These otoliths are described as they are oriented in the skull of the fish, with the inner face inward, and the outer face outward.

The sagitta is rare compared to other microfossils, but it is more abundant than any of the other fish remains, such as scales, teeth, and the skeleton. Otoliths therefore offer the advantage of being a good paleontological tool for teleostean studies.

Not much work has been done on the perciforms of the Gulf Coast, although the area has been known since the 19th Century as a good locality for fossil otoliths. The reason for that is probably that most paleontologists do not realize the importance of the otoliths, or that they do not have a good enough ichthyological background (see Frizzell and Dante, 1965).

The first worker on Cenozoic otoliths of the Gulf Coast area was Koken (1888), who described 23 species from the Claiborne, Jackson, and Vicksburg Groups of Mississippi and Alabama. Twenty-two of those

were new, and one was compared with a known European species (see Frizzell and Dante, 1965). Fourteen species were perciforms of the Families Carangidae, Apogonidae, Sparidae, Sciaenidae, Trachinidae, Cottidae, and Cepolidae. In 1929, Campbell translated Koken's paper and added an introductory discussion to it discussing the history of the otoliths and their features.

Since that time no work was done on perciforms of the area until 1965, when Frizzell and Dante reported on some of the lower Cenozoic otoliths of the Gulf Coast area. In their study, six species of perciforms were described. Three of them, of the families Serranidae and Sciaenidae, were new and three, belonging to the Family Sciaenidae, had been described by Koken.

The present research deals with a restricted group of fossil perciform otoliths from lower Cenozoic strata of the Gulf Coast. The problem was first to evaluate the morphologic features that characterize the group as a whole, second to try to find the most valuable generic and specific characters, and third to separate the group into species and genera.

Distribution of the group geographically was considered according to the areas that were sampled. The sampling was done at different times in different places in the Gulf Coast area, by D.L. Frizzell and others (see list of sample localities below).

The stratigraphic distribution of species within the group was emphasized. An attempt to show evolutionary changes, with suggested phylogenies, was made for two genera.

A comparison was made between the fossil species and the Recent perciform otoliths which were available at the time of this study, in

order to find a link between the Paleogene otoliths under study and the Recent. Morphological features of the perciform sagitta, at ordinal and lower taxonomic levels, also were studied in detail.

This project was restricted to lower Cenozoic fossils of the Gulf Coast. Studies of other stratigraphic and geographic units were beyond the scope of this research.

## II. CHARACTERISTICS OF OTOLITHS

Otoliths or earstones are small structures composed mainly of calcium carbonate in the form of aragonite. These structures are secreted by the auditory labyrinth in the skull of the teleost fishes (Figure 3).

### A. Kinds of Otoliths and Their Functions

The function of these structures is not exactly understood but it is believed that they aid the fish in hearing or in the sense of balance and stabilization (see Lamber, 1963). Three pairs of these earstones are present in the auditory labyrinth of the teleost fishes. Several kinds of labyrinths and otoliths are developed (Lamber, 1963; Berg, 1940, pp. 247, 248, 287; Campbell, 1929, p. 257; and Pointer, 1965, p. 8). Except in the Ostariophysi, the sagitta is the largest otolith. It has been extensively studied, and it is well preserved as a fossil and easy to remove from the skull of Recent fishes. The otolith is situated in the sacculus and occupies most of it. The second otolith is the asteriscus which is almost never preserved as a fossil and has not been studied except for the siluroid and cyprinoid fishes. The asteriscus occurs in the lagena of the auditory labyrinth, immediately posterior to the sacculus. The third otolith is the lapillus, which is to be found in the utriculus. It is usually thick and smaller than the sagitta, except in the Ostariophysi (see Frizzell and Dante, 1965, p. 693, text-Fig. 2; Frizzell, 1965, p. 179, Fig. 1; terminology of lapillus). It has not been widely studied, except for that of the siluroids, which has received some attention.



## B. Ossiculiths and Otoconia

In addition to the three mentioned above, other minute structures occur in the auditory labyrinth. Occasionally these particles are found surrounding the sagitta. These structures, the ossiculiths, are 0.05 to 0.5 mm. in diameter.

The name ossiculith came from "otolith" and "ossicle" (Frizzell and Exline, 1958). These structures are planoconvex, ellipsoidal, or irregular in shape, but vary widely in size and form, whereas otoconia (characteristic of the elasmobranchs) have crystal faces. The function of these tiny structures, if any, is unknown, although they are found regularly in some species (Lamber, 1963, Pointer, 1965). According to Frizzell and Exline (1958) this terminology prevents confusion between the ossiculiths and the true otoliths (sagitta, lapillus, and asteriscus).

## C. Composition of Sagitta

Dupont and Bercigli (in Chaîne and Duvergier, 1934, p. 69) made chemical analyses and indicated that most of the composition of the sagitta is calcium carbonate, with small amounts of calcium phosphate, silica, iron oxide, and alumina. The results of their analyses of the sagitta of Umbrina cirrhosa (Perciformes, Sciaenidae) are:

	<u>Dupont</u>	<u>Bercigli</u>
Calcium carbonate	95.80 per cent	94.87 per cent
Calcium phosphate	0.75 " "	0.35 " "
Organic Material	3.10 " "	4.27 " "
Silica	0.15 " "	
Iron oxides and alumina	0.20 " "	
Silica and iron oxides		0.51 " "

Although the percentage of organic substances in the composition is fairly low, its importance in the structure of the sagitta is remarkable. Hickling (according to Chaine, 1935) concluded that this material forms a network inside the inorganic structure of the otolith. He reported that the concentric growth layers are crossed by organic threads which run continuously from layer to layer. Other threads cross these vertically, forming an organic mesh embedded within the inorganic material of the sagitta.

Carlstrom (1963, according to D.L. Frizzell, personal communication) made a crystallographic study of some vertebrate otoliths. His X-ray studies showed that the teleostean sagitta is composed mineralogically of aragonite rather than calcite.

#### D. Deformities of Sagitta

Several workers on the sagitta have noted that sometimes the sagitta does not follow the characters of its species, as it has been deformed and had different morphological features. This change in the appearance of the sagitta cannot be considered as marking varieties, because the sagitta does not have any modifications from the main specific characters and shows the general form of the species.

That deformation sometimes effects only some parts of the sagitta while the rest of it appears natural. In other cases it includes the whole sagitta, so it doesn't show any relation to its species in its diagnostic features. Reibeisch (in Chaine and Duvergier, 1934) stated that deformities included three per cent of the elements observed.

### E. Morphology of Sagitta

The orientation of the sagittae in the skull is not always known, but they usually are longitudinal without being necessarily parallel to the regional axes. The two sagittae diverge to the back, and are slightly inclined toward the interior from top to bottom. The inner face is directed toward the center of the skull, adhering to the lining of the sacculus. The outer face is directed outward and does not adhere to the sacculus. Arbitrary horizontal and vertical axes have been suggested to eliminate confusion in orientation (Lamber, 1963). The different features of the sagitta are as follows (Figure 2). (1) Periphery: The upper outline of the sagitta is the dorsal margin, beginning at the anterior margin in front and the posterior margin behind. The latter form the anterior and posterior ends of the otolith. The lower outline of the sagitta is the ventral margin, beginning at the anterior margin and extending to the posterior margin. Two projections are present on the anterior margin. The lower is the rostrum and the upper, which is somewhat shorter, is the antirostrum; the incurved region between is the excisura. Excisural deposits may extend outward from the excisura. The dorsal margin may have an anterodorsal dome in its forward part, a dorsal dome at the center of the margin, and a posterodorsal dome in the posterior part of the margin. Comparable domes may occur on the ventral margin, but any or all of the marginal domes may be completely undeveloped. There is no exact limitation for the margins mentioned above, as they differ from case to case, and they overlap. (2) Inner face: It is usually convex, smooth, with the following features. (a) Sulcus - it usually runs along the horizontal line of the sagitta, horizontally or

obliquely downward, all straight, or with some of its posterior portion curving downward. The sulcus is typically divided into two parts: the anterior, which is the ostium, and the posterior, which is the cauda. The ostium usually opens anteriorly onto the anterior margin. The cauda sometimes ends before reaching the posterior end of the sagitta and may terminate in a shallow channel which is the postcaudal trough. That channel may end on the posterior margin or posteroventral part of the ventral margin. A secondary deposit of calcium carbonate in the ostium is called the anterior colliculum; when in the cauda, it is the posterior colliculum. (b) Area - The depressed or excavated region above the sulcus in some forms which extends along most of the cauda is termed the area. (c) Cristae - Raised ridges which border the sulcus on its upper and lower edges are called the crista superior and crista inferior, respectively. (d) Ventral furrow - A furrow situated toward the lower part of the sagitta, arching downward and extending along the horizontal axis of the sagitta. (3) Outer face: This face is usually concave, but it may be flat or convex. It lacks diagnostic features, except some sculpture which may consist of bosses, pustules, ridges, or lines.

#### F. Importance of Otoliths

The scientific importance of otoliths has not generally been realized. Among the uses of this structure: (1) They are a good key to lineages of fossil fishes, as they belong to the nervous system and are largely protected from environmental changes (Frizzell, 1965). (2) By studying the contents of the stomachs of predators, the kind and number of fishes eaten can be known. That may give clues to the ecology of the area. (3) The ring count method can show the age of the fish (Pointer, 1965,

Lamber, 1963). (4) In taxonomic studies of the teleostean fishes, otoliths are of potential help in classification.

## Figure 1

Sketch of Nemipterus delagoae Smith. Length, 248 mm. (modified after Smith, 1961, pl. 21, Fig. 672).

## Figure 2

Diagram showing terminology and orientation of inner face of left sagitta.

A	Area	E	Excisura
AC	Anterior Colliculum	ED	Excisural Deposits
ADD	Anterodorsal Dome	O	Ostium
AR	Antirostrum	PC	Posterior Colliculum
AVD	Anteroventral Dome	PCT	Postcaudal Trough
C	Cauda	PDD	Posterodorsal Dome
CI	Crista Inferior	PVD	Posterventral Dome
C'	Collum	R	Rostrum
CS	Crista Superior	S	Sulcus
DD	Dorsal Dome	VF	Ventral Furrow

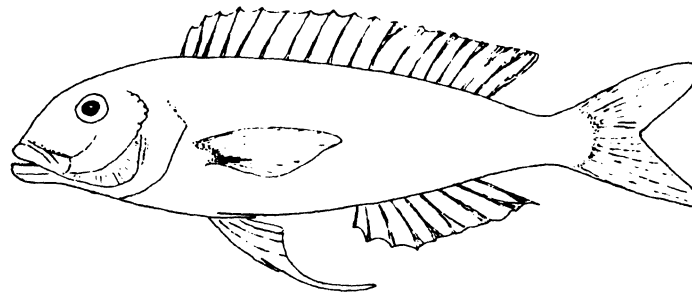


Figure 1

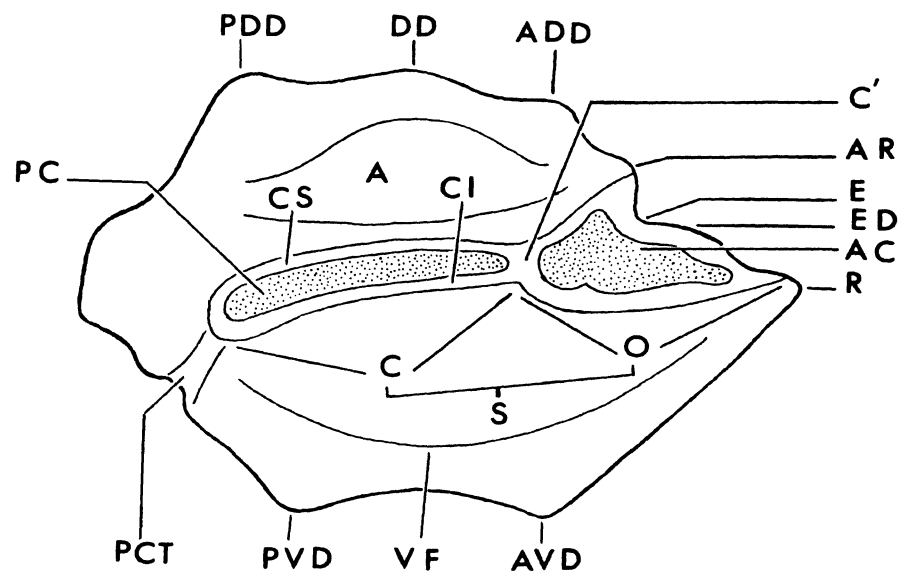


Figure 2

Figure 3

Sketch showing location of otoliths in left auditory labyrinth.

AST	Asteriscus
LAG	Lagena
LAP	Lapillus
SAC	Sacculus
SAG	Sagitta
SC	Semicircular canal
U	Utriculus



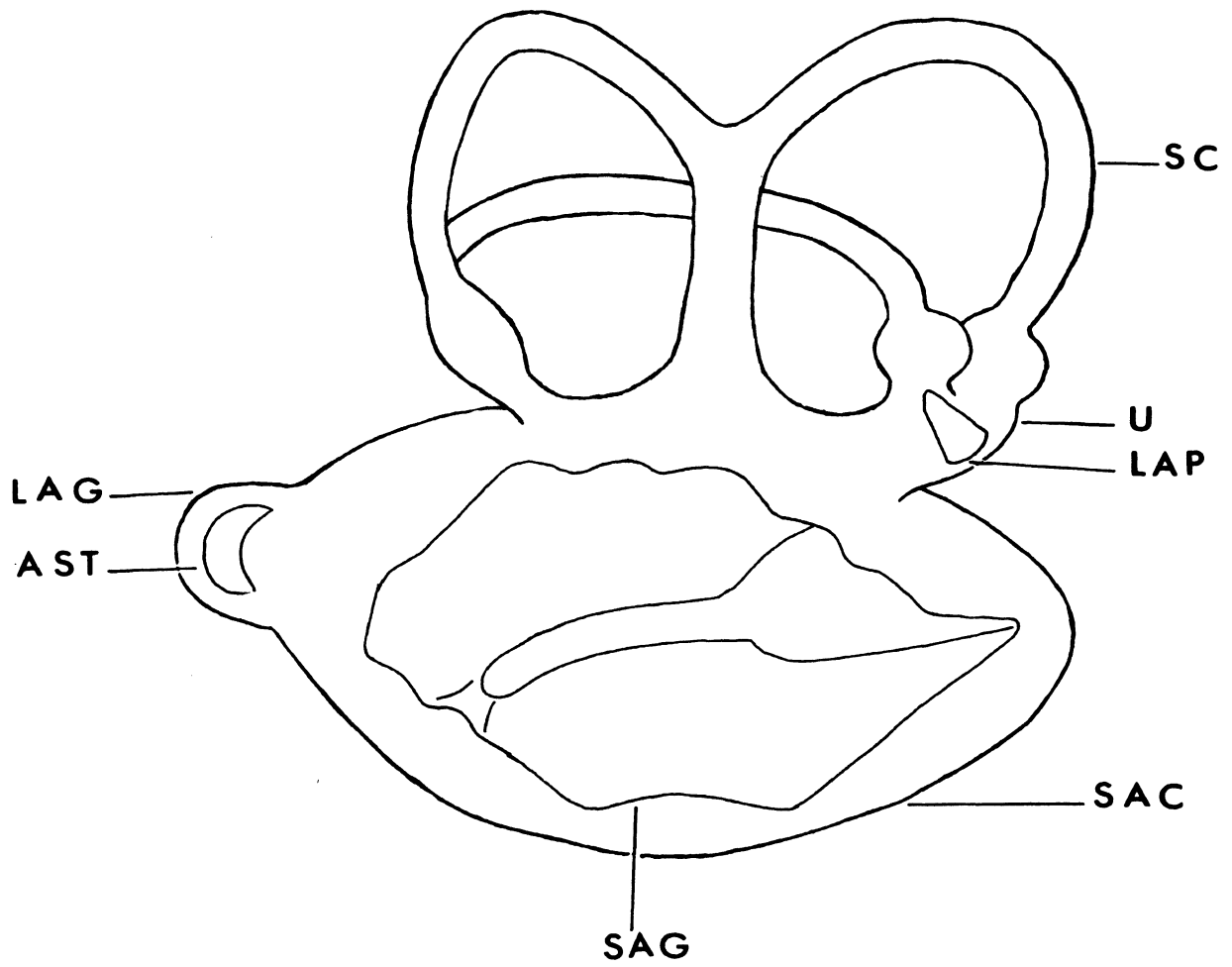


Figure 3

### III. SOURCES OF MATERIAL

The material that has been used for this research came from more than one source:

#### A. Recent Material

(1) Twelve centrarchid fishes were caught by D.L. Frizzell and me, using rod and line, at Frisco Pond, Rolla, Missouri. These include Lepomis cyanellus, L. pallidus, and L. sp. (probably hybrid of preceding). Some of the otoliths were removed from these the same day, others were frozen for two days.

The technique for extracting the otoliths was as follows. The head was cut from the body of the fish behind the gills. The lower jaws, gills, and opercula were removed. The flesh was scraped from the interior of the head with a very sharp scalpel until the skull was uncovered. The skull was split into halves by cutting along its midline and pulling the two sides slightly apart, so that the brain and auditory labyrinths were exposed. The brain material was displaced so that the otoliths would be visible. The otoliths were removed carefully from their membranes with a tissue forceps. They were put in a watchglass with water and carefully cleaned with a fine brush under the microscope. (More details on these techniques and those of fossil otolith preparation are found in Lamber (1963, pp. 15-18) and Pointer (1965, pp. 20-22)).

(2) Other comparative material studied is in the collection of the Department of Geology and Geophysics, University of Missouri-Rolla:

#### Order Clupeiformes

#### Family Engraulidae

#### Anchoa hepsetus (Bonnaterre)

## Order Salmoniformes

## Family Salmonidae

Salmo gairdnerii irideus Gibbons

## Order Batrachoidiformes

## Family Batrachoididae

Opsanus beta (Goode and Bean)

## Order Atheriniformes

## Family Atherinidae

Menidia berylina peninsulae (Goode and Bean)

## Family Cyprinodontidae

Fundulus sp.

## Order Perciformes

## Family Centrarchidae

Ambloplites rupestris (Rafinesque)Lepomis cyanellus RafinesqueL. macrochirus RafinesqueL. megalotis (Rafinesque)Micropterus dolomieu LacepedePomoxis nigromaculatus (Le Sueur)Roccus chrysops (Rafinesque)

3. The third source of Recent material was the personal collection of D.L. Frizzell. Except for the Family Sciaenidae, all perciform otoliths in that collection were examined under the microscope. The following list of species examined includes 15 of the 20 suborders in the Order Perciformes and 33 of the 71 families in the Suborder Percoidei. The species are predominantly from the Gulf of Mexico and the West Coast

of North America, but there is a limited world-wide coverage.

Suborder Percoidei

Family Centropomidae

Centropomus parallelus

C. pectinatus

C. poeyi Chavez

C. undecimalis (Bloch)

Family Serranidae

Centropristes ocyurus (Jordan and Evermann)

C. philadelphicus (Linnaeus)

C. striatus (Linnaeus)

C. ? sp.

Diplectrum formosum (Linnaeus)

D. macropoma (Günther)

D. sp.

Epinephelus adscensionis (Osbeck)

E. analogus Gill

E. labriformis (Jenyns)

E. striatus (Bloch)

Dicentrarchus labrax Linnaeus

Labrax lupus Cuvier

Niphon spinosus Cuvier and Valenciennes

Paralabrax auroguttatus Walford

P. clathratus (Girard)

P. maculofasciatus (Steindachner)

P. nebulifer (Girard)

Paracentropristis hepatus

Paranthias colonus (Valenciennes)

Lateolabrax japonicus (Cuvier & Valenciennes)

Petrometopon cruentatus (Lacepede)

P. panamensis (Steindachner)

Serranus atrobranchus (Cuvier)

S. cabrilla (Linnaeus)

S. cf. cabrilla (Linnaeus)

S. phoebe Poey

S. scribe Linnaeus

Roccus americana (Gmelin)

R. chrysops (Rafinesque)

R. saxatilis (Walbaum)

Family Grammistidae

Rypticus bicolor Valenciennes

R. coriaceus Cope

R. saponaceous (Bloch & Schneider)

Family Theraponidae

Therapon japonicus (Forsk.)

Family Centrarchidae

Ambloplites rupestris (Rafinesque)

Lepomis cyanellus Rafinesque

L. gibbosus (Linnaeus)

L. megalotis (Rafinesque)

Micropterus dolomieu Lacepede

M. salmoides (Lacepede)

Pomoxis nigromaculatus (Le Sueur)

Family Apogonidae

Apogon maculatus (Poey)

A. retrosella (Gill)

Howella sp.

Family Percidae

Acerina cerulea Linnaeus

Perca fluviatilis Linnaeus

Stizostedion sp.

Family Sillaginidae

Sillago sihama (Forsk.)

Family Branchiostegidae

Caulolatilus cyanops Poey

C. princeps (Jenyns)

Branchiostegus japonicus (Hout.)

Family Lactariidae

Lactarius lactarius

Family Echeneidae

Echeneis naucrates Linnaeus

Remora remora

Family Carangidae

Alectis crinitus (Mitchill)

Caranx caballus Günther

C. chrysos (Mitchill)

C. hippos (Linnaeus)

C. latus Agassiz

Chloroscombrus chrysurus (Linnaeus)

Ch. orqueta J. & G.

Elagatis bipinnulatus (Quoy & Gaimard)

Gnathodon speciosus (Forsk.)

Megalaspis cordyla (Linnaeus)

Oligoplites mundus Jordan & Starks

O. saurus (Block & Schneider)

Selar cruenophthalmus (Bloch)

Selene brevoorti Gill

S. vomer (Linnaeus)

Seriola colburni Evermann & Clark

Ser. dorsalis (Gill)

Trachinotus carolinus (Linnaeus)

T. glaucus (Bloch)

T. paitensis Cuvier

T. rhodopus (Gill)

Trachurus japonicus (Temminck & Schlegel)

Tr. symmetricus (Ayres)

Tr. trachurus Linnaeus

Vomer setapinnis (Mitchill)

Family Coryphaenidae

Coryphaena hippurus Linnaeus

Family Formionidae

Formio niger (Bloch)

Family Leiognathidae

Diapterus olisthostomus (Goode & Bean)

D. plumieri (Cuvier)

D. rhombeus (Cuvier)

D. sp.

Family Bramidae

Brama brama (Bonnaterre)

Family Lutjanidae

Hoplopagrus guntheri Gill

Ocyurus chrysurus (Bloch)

Lutjanus apodus (Walbaum)

L. argentiventris (Peters)

L. aya (Bloch)

L. blackfordii

L. griseus (Linnaeus)

L. peru (Nichols & Murphy)

L. synagris (Linnaeus)

L. viridis (Valenciennes)

L. spp.

Rhomboplites aurorubens (Cuvier)

Family Nemipteridae

Nemipterus virgatus (Houttuyn)

Family Lobotidae

Lobotes surinamensis (Bloch)

Family Gerridae

Eucinostomus argenteus Baird & Girard

E. elongatus Meek & Hildebrand

E. gracilis (Gill)



E. spp.

Family Pomadasyidae

Anisotremus davidsoni (Steindachner)

A. surinamensis (Bloch)

Bathystoma aureolineatum Cuvier

Brachydeuterus auritus

B. axillaris (Steindachner)

Conodon nobilis (Linnaeus)

C. serrifer Jordan & Gilbert

Haemulon flavolineatum (Demarest)

H. microstomum Günther

H. plumieri (Lacepede)

H. sciurus (Shaw)

H. sexfasciatum Gill

Lythrulon flaviguttatum (Gill)

O. rthopristis inornatus (Gill)

O. reddingi Jordan & Richardson

Orthostoechus maculicauda Gill

Parapristipoma mediterraneum

Pomadasys crocro (Cuvier)

P. hasta

P. macracanthus (Günther)

P. opercularis

Family Sparidae

Archosargus probatocephalus (Walbaum)

Boops boops (L.)

Cantharus lineatus  
Calamus taurinus (Jenyns)  
Chrysophrys major Temminck & Schlegel  
Dentex canariensis  
D. dentex (L.)  
D. filusus  
D. macrophthalmus  
D. maroccanus  
Diplodus annularis (L.)  
Di. cervinus (Lowe)  
Di. cf. sargus  
Di. trifasciatus  
Evynnis cardinalis Lacepede  
Pagellus acarne (C.)  
P. centrodontus de la Roche  
P. erythrinus Linnaeus  
P. mormyrus (Linnaeus)  
Pagrosomus major (Temminck & Schlegel)  
Pagrus ehrenbergi  
P. pagrus  
P. sedecim Ginsberg  
Puntazzo puntazzo (C. & V.)  
Sarpa salpa (Linnaeus)  
Sparus aurata  
Spondyliosoma cantharus (Linnaeus)

Family Sciaenidae

Aplodinotus grunniens Rafinesque

Cynoscion arenarius

Larimus fasciatus Holbrook

Micropogon ectenes (Jordan & Gilbert)

Sciaena aquila

Family Mullidae

Mullus barbatus

M. surmulletus Linnaeus

Upeneus parvus (Poey)

Family Kyphosidae

Hermosilla azurea Jenkins & Evermann

Kyphosus incisor (Cuvier)

K. lutescens (Jordan & Gilbert)

K. sectatrix (Linnaeus)

Medialuna californiensis (Steindachner)

Girella nigricans (Ayres)

Family Ehippidae

Chaetodipterus zonatus (Girard)

Family Chaetodontidae

Chaetodon capistratus Linnaeus

C. ocellatus Bloch

Holacanthus isabelita (Jordan & Rutter)

Pomacanthus arcuatus (Linnaeus)

P. aureus (Bloch)

P. paru (Bloch)

Family Oplegnathidae (according to Greenwood and others)

"Hoplegnathus" fasciatus (Temminck & Schlegel)

## Family Embiotocidae

Amphisticus argenteus Agassiz  
Brachyistius frenatus Gill  
Cymatogaster aggregata Gibbons  
C. gracilis Tarp  
Embiotoca jacksoni Agassiz  
E. lateralis Agassiz  
Hyperprosopon argenteum Gibbons  
Hypsurus caryi (Agassiz)  
Micrometrus minimus (Gibbons)  
Phanerodon furcatus Girard  
Rhacochilus toxotes Agassiz  
R. vacca (Girard)  
Zalembeus rosaceus (Jordan & Gilbert)

## Family Cichlidae

Cichlasoma sp.

## Family Pomacentridae

Chromis atrilobatus Gill  
C. chromis  
C. punctipinnis (Cooper)  
Hypsypops rubicunda (Girard)  
Microspathodon dorsalis (Gill)  
Pomacentrus fuscus (C. & V.)  
P. leucostictus Muller & Troschell  
P. rectifraenum (Gill)

## Family Cirrhitidae

Cirrhitus rivulatus (Val.)

## Family Cepolidae

Cepola rubescens Linnaeus

## Suborder Mugiloidei

## Family Mugilidae

Mugil cephalus Linnaeus

M. curema Valenciennes

## Suborder Sphyraenoidei

## Family Sphyraenidae

Sphyraena argentea Girard

S. barracuda Walbaum

S. gauchancho Cuvier

S. lucasana Gill

## Suborder Polynemoidei

## Family Polynemidae

Polydactylus approximans (Lay & Bennett)

P. octonemus (Girard)

P. opercularis (Gill)

P. virginicus (Linnaeus)

Pentanemus quinquarius Linnaeus

## Suborder Labroidei

## Family Labridae

Symphodus bailloni

S. mediterraneus

S. ocellatus Forskål

S. tinca Linnaeus

Labrus bergylta

L. mixtus

L. viridis

Oxyjulis californica (Günther)

Pimelometopon pulchrum (Ayres)

Pseudojulis notospilus

Thalassoma bifasciatum (Bloch)

T. lucasanum (Gill)

T. nitidum (Günther)

Halichoeres bivittatus (Bloch)

H. dispilus (Günther)

H. radiatus (Linnaeus)

H. semicinctus (Ayres)

Acantholabrus palloni

Coris julis

Ctenolabrus rupestris (Linnaeus)

Xyrichtys novacula

Family Scaridae

Nicholsina usta (Val.)

Scarus croicensis Bloch

Sparisoma rubripinne (Val.)

Xenoscarus denticulatus (Evermann & Radcliffe)

iborder Trachinoidei

Family Trichodontidae

Arctoscopus japonicus (Steindachner)

Trichodon trichodon (Tilesius)

Family Opisthognathidae

Opisthognathus rhomalea (Jordan & Gilbert)

Family Bathymasteridae

Bathymaster signatus Cope

Rathbunella hypoplectus (Gilbert)

Family Mugiloididae

Mugiloides numida Ribeiro

Family Trachinidae

Trachinus draco Linnaeus

Family Percophididae

Bembrops gobioides (Goode)

Family Dactyloscopidae

Myxodagnus opercularis Gill

Family Uranoscopidae

Astroscopus y-graecum (Cuvier)

Kathetostoma averruncus Jordan & Bollman

Uranoscopus bufo

U. scaber Linnaeus

Suborder Notothenioidei

Family Nototheniidae

Harpagifer bispinis (Schneider)

Notothenia cornucola Richardson

N. guntheri Norman

N. ramsayi Regan

N. sima Richardson

N. tessellata Richardson

Suborder Blennioidei

## Family Blenniidae

Blennius cristatus (Linnaeus)

B. gattorugine

B. ocellaris Linnaeus

B. pholis Linnaeus

B. sp.

Entomacrodus chiostictus (Jordan & Gilbert)

Hypsoblennius gilberti (Jordan)

Ophioblennius atlanticus macclurei Silvester

## Family Anarhichadidae

Anarrhichthys ocellatus Ayres

## Family Tripterygiidae

Enneanectes cteniceps Rosenblatt

## Family Clinidae

Acanthemblemaria macrospilus Brock

Alloclinus holderi (Lauderbach)

Axoclinus "walkeri Rosenblatt, MS"

A. sp.

Gibbonsia metzi Clark Hubbs

G. montereyensis Hubbs

Heterostichus rostratus Girard

Labrisomus kalisherae (Jordan)

L. multiporosus Hubbs

L. nuchipinnis (Quoy & Gaimard)

L. striatus Hubbs

L. xantusi Gill



Malacoctenus delalandi (Cuv. & Val.)

M. gigas Springer

M. hubbsi Springer

M. h. hubbsi S.

M. triangulatus Springer

M. zonifer (Jordan & Gilbert)

M. sp.

Neoclinus blanchardi Girard

N. uninotatus Hubbs

Family Stichaeidae

Delolepis gigantea Kittlitz

Epigeichthys atropurpureus (Kittlitz)

Plectrobranchus evides Gilbert

Poroclinus rothrocki Bean

Family Pholididae

Pholis schultzi Hubbs

Xererpes fucorum Gilbert & Starks

Suborder Icosteoidi

Family Icosteidae

Icosteus aenigmaticus Lockington

Suborder Ammodytoidei

Family Ammodytidae

Ammodytes cirerelus

A. lanceolatus

Suborder Callionymoidei

Family Callionymidae

Callionymus maculatus Bonap.

Suborder Gobioidei

Family Gobiidae

Acanthogobius flavinianus (Temm. & Schlegel)

Coryphopterus nicholsi (Bean)

Clevelandia ios (Jordan & Gilbert)

Eleotris pisonis (Gmelin)

Eucyclogobius newberryi (Girard)

Gobiomorus dormitator Lacepede

Gobionellus microdon (Gilbert)

Gobius niger

G. cf. niger

G. sp.

Lepidogobius lepidus (Girard)

Lythrypnus dalli (Gilbert)

L. zebra (Gilbert)

Quietula y-cauda (Jenkins & Evermann)

Typhlogobius californiensis Steindachner

Suborder Acanthuroidei

Family Acanthuridae

Acanthurus bahianus Castelnau

A. b./chirurgus (Bloch) (2 spp., mixed)

A. coeruleus Bloch & Schneider

Suborder Scombroidei

Family Gempylidae

Gempylus serpens (Cuvier)

## Family Trichiuridae

Lepidopus xantusi Goode & BeanTrichiurus lepturus Linnaeus

## Family Scombridae

Acanthocybium solandri (Cuvier)A. rochei (Risso)Auxis thazard (Lacepede)Euthynnus alleteratus (Raf.)E. lineatus KishinouyeKatsuwonus pelamis (Linnaeus)Pneumatophorus diego (Ayres)Sarda chiliensis (Cuvier)Scomber scombrus LinnaeusScomberomorus cavalla (Cuvier)S. concolor (Lockington)S. maculatus (Mitchill)S. sierra Jordan & StarksThunnus alalunga (Bonnaterre)T. obesus LoweT. thynnus (Linnaeus)

## Family Xiphiidae

Xiphias gladius Linnaeus

## Family Luvaridae

Luvarus imperialis Rafinesque

## Suborder Stromateoidei

## Family Nomeidae

Cubiceps natalensis

Psenopsis anomala (Temminck & Schlegel)

Family Stromateidae

Icichthys lockingtoni Jordan & Gilbert

Palometa simillima (Ayres)

Pampus argenteus (Euphrasen)

Poronotus triacanthus (Peck)

Family Tetragonuridae

Tetragonurus cuvieri Risso

B. Fossil Otoliths

All of the fossils that were used in this research are in the collection of D.L. Frizzell. They are from Cenozoic strata, in the Gulf Coast area, belonging to Paleocene through the Oligocene systems. Abundance of specimens and perfection of preservation vary widely among the field stations sampled.

## IV. SAMPLE LOCALITIES

## Oligocene

## Vicksburg Group

Byram Marl: Old Byram (type locality of formation), Hinds County, Mississippi; bank of Pearl River at suspension bridge; 2"-3" irregular beds of shell debris (fine coquina) within sandy shales of formation (Station F-59-1 - collectors: D.L. and H.E. Frizzell, August 21, 1959; Station F-60-1 - collectors: D.L. Frizzell and A.R. Troell, Jr., July 29, 1960).

Glendon Limestone: Brandon, Rankin County, Mississippi; quarry of Marquette Cement Company; 8"-18" irregular band of highly glauconitic shell marl in thin soft bluish-gray clay-marl above basal limestone bed of formation (Stations F-59-13, 15 - collectors: D.L. Frizzell and C.K. Lamber, November 26, 1959; Station F-60-2 - collectors: D.L. Frizzell and A.R. Troell, Jr., July 30, 1960). R. Greeley (D.L. Frizzell, personal communication) reported in 1964 that the quarry workings had been abandoned, and that the Glendon Limestone exposures were no longer accessible.

Mint Spring Marl: Vicksburg, Warren County, Mississippi; Vicksburg National Military Park and Cemetery, falls at head of Mint Spring Bayou (type locality of formation); sandy and argillaceous shell marls between the Forest Hills Shale below and the overlying basal stratum of

the Glendon Limestone (Station F-59-8 - collector: D.L. Frizzell, November 23, 1959; Station F-60-6 - collectors: D.L. Frizzell and A.R. Troell, Jr., August 1, 1960).

Red Bluff Clay: Hiwannee (formerly Red Bluff; type locality of formation), Wayne County, Mississippi; Chickasawhay River at old Red Bluff Landing; about 2' interval of brown marl, with sporadic pockets containing molluscan shells and otoliths, within green to weathered brown clay section exposed only when river is very low (Station F-60-11 - collectors: D.L. Frizzell and A.R. Troell, Jr., August 4, 1960).

Red Bluff Equivalent: St. Stephens, Washington County, Alabama; quarry of cement plant; glauconitic, greenish to white marl, lowest member exposed, 6"-10" below contact with ca. 5' indurated limestone with abundant pectinoids at top and oysters at base, marl said by quarrymen to reach thickness of 28'-32' (Station F-57-8 - collector: D.L. Frizzell, September 3, 1957). The stratigraphic position of the sample is somewhat doubtful: It is reported as having basal Vicksburg and re-worked uppermost Jackson benthonic foraminifera (D.L. Frizzell, personal communication).

## Eocene

### Jackson Group

Shubuta Clay: Shubuta (type locality of formation), Clarke County, Mississippi; bank of Chickasawhay River at old

iron bridge on logging road, about 2 miles by road from center of town; blue, massive, firm mudstone, with occasional streaks (ca. 1" thick) of fine shell drift and very small pockets of similar debris (1"-3" in diameter), otoliths present in shelly material and mudstone adjacent to it (Station F-59-5 - collectors: D.L. and H.E. Frizzell, August 24, 1959; Station F-60-9 - collectors: D.L. Frizzell and A.R. Troell, Jr., August 3, 1960).

Moodys Branch Marl: Jackson (re-selected type locality of formation), Hinds County, Mississippi; "Fossil Cliff, Nature Walk," Riverside Park; glauconitic marl ("green-sand"), sharply unconformable on blue shale of Cockfield beds below, which are penetrated by borings, gradational with Yazoo Clay above (Station F-59-11 - collectors: E. Adams and D.L. Frizzell, November 24, 1959; Stations WCH 861-3, 661-3 - collector: W.C. Horton, 1963). Midway, Yazoo County, Mississippi; bridge over Tsheva (or Tcheva, or Tscheva) Creek (first small stream crossing Mississippi Road No. 433 north of town), banks and bed of stream about 60' upstream from bridge; blue to blue-gray shelly sandstone with very abundant glycymeroids excellently preserved (Station F-60-3 - collectors: D.L. Frizzell and A.R. Troell, Jr., July 31, 1960). Montgomery, Grant Parish, Louisiana; downstream from ferry landing on Red River; marls unconformably overlying Cockfield strata,

otoliths evenly distributed throughout formation

(Station F-60-A1 - collectors: D.L. Frizzell, C K. Lamber, and W.C. Horton, November 23, 1960). None of these localities has the basal bed of shell debris found at the original (and now permanently inaccessible) type locality.

#### Claiborne Group

Wheelock Formation: Burleson County, Texas, at boundary with Brazos County; bank of Brazos River at bridge on Texas Highway 21, about 10 miles west of city of Bryan; dark, very abundantly glauconitic, extremely fossiliferous silty shales (no station number assigned; collectors: D.L. and H.E. Frizzell, October 19, 1951).

Stone City Beds: Burleson County, Texas; same locality as preceding; lithology indistinguishable from that of Wheelock formation, but strata below a marked depositional hiatus (Stations F-57-1, 2, 3, 4 - collector: D.L. Frizzell, August 16-17, 1957).

Weches Formation: Nacogdoches County, Texas; ca. 9 miles east of Melrose, 2.4 miles west of San Augustine County line, uphill from low bridge and rest park to east, on north side of Texas Highway 21; gray-green, slightly indurated glauconitic marl, with stringers of shell debris (Station CKL-61-3 - collector: C K. Lamber, June 12, 1961).

Pleasanton, Atascosa County, Texas; 200 yards west of bridge over Bonita Creek on U.S. Highway 281; north bank of creek on Harold Hufford property (no station number



assigned; collector: A.R. Troell, Jr., December, 1959).

Lisbon Formation: Claiborne, Monroe County, Alabama; old Claiborne Landing, about 30 yards downstream from east end of highway bridge across Alabama River (famous "Claiborne Bluff" locality); bed of abundant large Venericardia at water level, with glauconitic clays and sandstones above (Station F-57-12 - collector: D.L. Frizzell, September 4, 1957; Station F-60-12 - collectors: D.L. Frizzell and A.R. Troell, Jr., August 6, 1960).

#### Wilcox Group

Bashi Marl: Meridian, Lauderdale County, Mississippi; Highway U.S. Bypass 80, behind dredged creek back of "Red Hot" truck stop; lenticular 3'-4' bed of very coarse, glauconitic shell debris, overlain by a roughly 2' discontinuous band of indurated argillaceous limestone, underlain by 6'-10' of very fine, white sand, entire section intercalated within extensive non-marine shale sequence (Station F-60-8 - collectors: D.L. Frizzell and A.R. Troell, Jr., August 2, 1960; Station F-64-8 - collectors: D.L. and H.E. Frizzell, July 7, 1964).

Nanafalia Formation: Marengo County, Alabama; country road between Sweetwater and Half Acre, ca. 3-5 miles north of Sweetwater, cut on west side of road; shelly sand bed, ca. 10' thick, glauconitic, with discontinuous layer of large concretions at top (Station F-64-4 - collectors:

D.L. and H.E. Frizzell, June 21, 1964).

Paleocene

Midway Group

Porters Creek Formation, Matthews Landing Member: Wilcox County, Alabama; Pursley Creek, on side road turning southward from Alabama Highway 10 about 3 miles southeast of Estelle (non-existent in 1964) and roughly the same distance northwest of the Rosebud School; 1'-2' of strata below water level on south bank of creek, fine grained, very well sorted, very weakly indurated, glauconitic sandstone, very dark when wet, with abundant tiny and well disseminated molluscan shells (Station F-64-5 - collectors: D.L. and H.E. Frizzell, June 21, 1964).

## V. RECENT PERCIFORMS

### A. Recent Perciform Fishes

Perciforms constitute an order of fishes which is mainly marine. These fishes began in the late Cretaceous and are distributed all over the world with the exception of arctic and antarctic regions. They are of normal shape, resembling the common fish's appearance and features: elongate, tapering toward anterior and posterior ends, with eyes and skull symmetrical; fins usually with spines; two dorsal fins usually present; ventral fins with not more than six rays, these fins are thoracic, but may be jugular, mental or behind pectorals, caudal fin with not more than 17 principal rays (see Berg, 1947, p. 472; and Boulenger, 1922, p. 652). Some of the groups included in the Order Perciformes are comparatively primitive, but others are highly evolved comparing with the rest of the groups in the order.

Workers are not in agreement about the ancestry of the perciforms, whether polyphyletic or evolved mainly from the Order Beryciformes. Patterson (1964, according to Greenwood and others, 1966, p. 390) noted that some perciforms, as the Menidae, Carangidae, Acanthuroidei, Balistoidei, Chaetodontidae and Centrarchidae, might have been derived from the dinopterygoid stem. Others, as the Serranidae and Scorpididae, might have been derived from the polymixioid line. On that basis, the Suborder Berycoidei would not be related directly to the modern perciforms. Some of the primitive perciforms, as the Families Scorpididae, Monodactylidae, and Kyphosidae, have a strong resemblance to some of the beryciform polymixioids, which supports the idea that the Order

Perciformes may have evolved from the Beryciformes rather than from other groups (Greenwood and others, 1966, pp. 390-392; Lamber, 1963, pp. 25-31).

#### B. Recent Perciform Sagitta

An attempt was made to evaluate the morphological characters of the sagitta of living perciform fishes in terms of taxonomic significance at the various levels of classification. This has not been completely satisfactory for two reasons: (1) In addition to normally developed otoliths, some seem to be much more primitive and others much more highly evolved. Neither is likely to fit a generalized diagnosis of the order, although both mark lower-level taxa. (2) It is possible that the Order Perciformes is polyphyletic (compare Greenwood and others, 1966, Fig. 1, p. 349), and the similarity of the fishes therefore is not reflected in their otoliths.

The following account is based on the 345 species, listed above, that have been examined during the course of this research.

##### 1. Ordinal Characters

Perciform otoliths are defined as: Elongate sagittae, plano-, concavo-, or biconvex, varying in thickness and sculpture; rounded, acute, or truncate posteriorly, usually tapering anteriorly, typically with rostrum, antirostrum, and excisura; sulcus divided, extending almost horizontally, ostial borders parallel to those of cauda; ostium opening broadly on anterior margin, wider and typically shorter than cauda, dorsal and ventral or ventral borders sometimes with abrupt and marked curvature at junction with cauda; cauda completely or partly straight, horizontal or inclined downward or rarely sigmoidal, posterior end

usually rounded but in some forms opening into shallow postcaudal trough; area consistently developed.

Except for the Families Icosteidae, Ammodytidae, Gobiidae, Luvaridae, Dactyloscopidae, Uranoscopidae, Mugilidae, Sciaenidae, Apogonidae, Sillaginidae, and some of the Pomadasyidae, in which rostrum, antirostrum, and excisura are lacking or very much reduced, with the anterior margin generally rounded, all of the perciforms examined have a somewhat long, well developed rostrum, a shorter, well developed antirostrum, and an excisura which is variable in depth and angularity. The sagitta is moderately high but the height is usually less than length (height/length ratio less than 100 percent), except for the Family Icosteidae and most species of the Gobiidae, which have the sagitta higher than long. The posterior margin of the sagitta is rounded to angular in most of the species studied, but sometimes it is truncate vertically. The sagitta varies in thickness, and it is concavoconvex, planoconvex, or biconvex, with mostly a smooth inner face, and variably, irregularly sculptured outer face.

The sulcus is excavated or deeply depressed except for the Families Sillaginidae and Sciaenidae, where it is only incised; it is divided, extending along the horizontal line of the sagitta. The ostium is wider than the cauda. Except for the Families Gobiidae, Luvaridae, Trachinidae, Dactyloscopidae, Cepolidae, and Apogonidae, where the cauda is shorter than the ostium, all of the perciforms examined have the ostium shorter than the cauda. The difference in length between both varies from family to family. Except for the Families Sciaenidae and Gobiidae, in which the ostium ends before it reaches the anterior end of the sagitta,

all of the otoliths studied have the ostium opening widely onto the anterior margin. The ostium is subovate, subelliptic, subtriangular, or subquadrate, extending almost on the same horizontal line as the cauda. Its borders vary in their detail from group to group; sometimes ventral and dorsal being parallel until close to the cauda, then curving evenly, strongly or gently to meet it, as in the family Sparidae. At other times the dorsal boundary slopes gently toward the cauda while the ventral extends almost horizontally until it comes below the cauda, then curves upward almost vertically to it, as in the Families Nemipteridae and Serranidae. In some families, like the Labridae, the borders of the ostium diverge evenly away from the cauda, so that the ostium has its widest point at the anterior margin. In the Family Sciaenidae the ostium is subovate to subcircular, the dorsal border being slightly higher or on the same level as the cauda, the ventral being subrounded.

As noted above, the cauda usually is longer and narrower than the ostium, with borders on the same horizontal level as the ostium. As for the other characters at the ordinal level, the cauda has different forms: (a) In some groups that have been studied the cauda is straight and horizontal as in the Family Percidae, or oblique downward, long or short, as in the Families Gobiidae, Luvaridae, Trachinidae, Dactyloscopidae, Cepolidae, and Apogonidae. It usually terminates before reaching the posterior end of the sagitta. In that case it could be closed posteriorly or open into a shallow postcaudal trough. In some cases the cauda opens onto the posterior end of the sagitta, as in the Family Scaridae and some species of the Family Labridae. The borders of the cauda may be parallel, narrower in front and wider toward the back, or

even roughly subelliptical when the cauda is short, as in the Family Gobiidae. (b) The second main kind of cauda is that in which the structure is straight only in part, then curves downward in its posterior. The part that is curved downward varies from group to group: it may be just the end, or as much as half of the cauda. The curvature may be slight or strong, or forming a semicircle as in the Family Sciaenidae. The straight part may be horizontal or sloping slightly downward or upward. In most cases the cauda has parallel borders, but in some they diverge or converge especially in the curved part. The posterior end faces the posterior or ventral margin, sometimes ending in a postcaudal trough. (c) A few species have a sigmoidal cauda, in which a front part of the cauda arches down, then the posterior part arches up with the same degree at the anterior part or stronger, as in Trachinotus carolinus (L.), of the Family Carangidae. The degree of curvature varies.

The area varies in shape, size, and degree of depression from group to group, extending along the greater part of the cauda. The crista superior usually is well developed, but it varies from group to group. Its presence might be a good ordinal character, and its detailed structure should be considered for lower levels. The crista inferior and ventral furrow are less common. Their scarcity makes them not valuable as ordinal level character.

## 2. Subordinal Characters

Percoid otoliths are defined as: Perciform sagittae, usually subelliptical, subovate or subrectangular; with posterodorsal slope sometimes obliquely truncate toward posterior end which is rounded or acute;

anterior end usually with fairly long rostrum, anti-rostrum and somewhat deep and angular excisura; ostium wider and usually shorter than cauda, opening broadly onto anterior; dorsal and ventral or ventral borders usually with abrupt curvature at junction with caudal borders; cauda completely or partly straight, when partly straight the amount and degree of curvature variable; horizontal, inclining downward, or sigmoid. Posterior end rounded or angular, sometimes opening onto posterior end of sagitta. Postcaudal trough present or absent; crista superior and area always present, usually extending along more than half of the cauda.

### 3. Familial Characters

The characters that seem to be valuable at the family level in classification are as follows:

(a) The outline of the sagitta is important, as it is likely that each family has its own significant appearance. However, some families may look the same and in that case some other characters will be important for differentiating them from each other.

(b) Size of the sagitta is good only for some families, as most of the otoliths studied in this research were of medium size. Consequently this character might be important for moderately small sagittae, as in the Families Pholididae and Stichaeidae or large otoliths, as in the sciaenidae, rather than for the families with earstones of medium size.

(c) The posterior margin is also important for some families, as the Gobiidae, with the posterior margin curved inward to form a wide V, and the Family Scombridae, which has a truncate posterior margin. In the Family Carangidae, the posterior margin is likely to be angular, tapering backwards.



(d) Degree of development and length of the rostrum and antirostrum, and the depth and shape of the excisura are considered to be familial level characters. For example, in the Family Scombridae the rostrum is long, the antirostrum quite long, and the excisura somewhat deep and angular.

(e) The sulcus is a good character for the family as well as for lower and higher levels. Taking the cauda in consideration, a family will be consistent, as for example in the Percidae, where the cauda is straight and horizontal. In the Family Carangidae, in contrast, the cauda is straight and mostly horizontal, but curves downward. In the Gobiidae, the cauda is straight, horizontal and short. If the ostium is taken into consideration, characters like its length compared with the caudal length and its outline are significant.

(f) Thickness of the sagitta, its concavity or convexity, nature of sculpture, size of area, development of the cristae and ventral furrow are important in some families. These characters, however, usually are better for the lower levels rather than for family.

#### 4. Generic Characters

In the Recent species that have been examined otoliths seem to be adequate for generic identification in most instances. However, some genera are very similar to each other, so that it is hard to find differences between them. The characters that appear to be valuable at the generic level are:

(a) The outline or the general appearance of the sagitta: whether the ventral margin is evenly rounded or skewed, the posterodorsal angle domed or not, the dorsal margin high or low and with or without domes,

the margins smooth, rough, or digitate, sinuous or serrate; the roundness or angularity of the posterior margin. Measurements and proportions are helpful when enough specimens are available, especially length, height, height/length ratio, and thickness of the sagitta.

(b) The anterior margin with rostrum, antirostrum, excisura, and excisural deposits. In general appearance, there might be more than one genus with the same apparent features. Close examination should reveal which are valuable for general or even specific level discrimination.

(c) The ostium: shape, size, depth, degree and amount of curvature of borders and the way it joins the cauda.

(d) The cauda: length, width, degree of curvature if any, extent of downturning if any, whether horizontal or oblique; where posterior end of cauda terminates, whether facing posterior or ventral margin presence or absence of postcaudal trough.

(e) Size and shape of the area, presence or absence of cristae, and ventral furrow. Occasionally other characters occur in certain genera only. For example, Xyrichthys novacula of the Family Labridae is the only species examined that has a depression below the cauda. That was the only species of the genus that was studied, however, so the pit might be either a generic or a specific character. Degree of sculpture, and appearance of the outer face have not been commonly helpful for generic level differentiation, but might help in some cases.

##### 5. Specific Characters

Many of the characters that were discussed for the generic level are valuable for separating species. However, the recognition on minute detail is essential. The characters that seem to have specific

value are:

(a) Detailed features of the outline: development of dorsal domes if any, steepness of marginal slope toward anterior and posterior ends, degree of truncation, curvature of margins, posterodorsal angle, sculpture of margins, and whether posterior margin is rounded, acute, or truncate.

(b) Anterior margin: depth of excisura, length of rostrum and antirostrum, and excisural deposits.

(c) Sulcus: minor differences in cauda or ostium, such as parallelism of caudal borders, degree of angularity or roundness of posterior end, degree of curvature of different parts of ostial boundaries.

(d) Characters of outer face: degree of concavity, convexity, or flatness, sculpture.

(e) Dimensions and proportions: height, length, thickness, and height/length ratio.

(f) Area: degree of depression, outline, size, and location.

(g) Cristae: development of crista superior, presence or absence of crista inferior.

(h) Ventral furrow: presence or absence.

(i) Postcaudal trough: presence or absence, depth, width, and whether opening onto ventral or posterior margin.

## VI. FOSSIL PERCIFORM SAGITTA

### A. Generic Concepts

An otolith genus may be defined as consisting of the otoliths that have the critical morphological features of the various included species, those species being morphologically more similar to each other than to those of any other group. It is assumed to represent a genus of fishes. The otolith genus has certain characters which differentiate it from all other groups. The kind and number of these features differ in different taxa, and very much attention and care must be given to selection of the diagnostic characters.

The genus has to be based primarily on the main features of the otolith: the periphery and sulcus. At the same time, the secondary features must be considered: the area, cristae, sculpture of the outer face, concavity and convexity of faces, and dimensions (length, height, thickness, height/length ratio and length of sulcus). It is safer however, to depend on the main characters and to use the other features as a support for the first ones. Most of these characters, especially those described as main features, are valuable for the higher level classification (family, suborder, and order). As a result those features have to be treated here in more detail than at higher taxonomic levels.

Comparisons between Recent and fossil otoliths must be made to find the relationships of fossil genera. Lineages should be considered when enough evidence is available, especially when the genus is extinct, and a link between it and another genus needs to be sought.

To avoid confusion genera ideally should be named on other characters of the fishes. Fossil otoliths, however, rarely are found in situ. Other names have to be proposed for them instead.

I believe that little or no change in otoliths according to the outer environmental factors takes place, although that may happen to some of the other characters of the teleosts, as size, size of head compared to body, and perhaps color. Otoliths therefore may be considered as a good basis for classification of the teleost fishes. This does not mean that the genus will be based solely on the otoliths; where possible other factors have to be taken into consideration as well: classifications based on teeth, the skeleton, or scales, or other anatomical features (see Frizzell, 1965, pp. 91-93).

#### B. Generic Characters

Suites of specimens were examined under the stereoscopic microscope, and separated into groups according to their characters. Each group is assumed to be an otolith genus.

The main differences that were used and found useful for generic classification are: the periphery of the otolith and the structure of the sulcus. Although these features are important for the entire group of genera, their use here was more detailed. For example, "Nemipterus" has an outline with a truncation in the posterodorsal part of the margin, and the ventral margin is skewed forward; the sulcus extends almost horizontally along the horizontal line of the sagitta, the ostium having almost non-parallel dorsal and ventral boundaries, the cauda being almost horizontal and straight until its last third to fifth, where it curves variably downward. In genus E, the ostium is

a very important feature, as the ventral and dorsal borders are parallel until their posterior part, then converging evenly and quite strongly to meet the caudal boundaries. The outline in Genus E is less important than the sulcus as a generic character.

Other characters that were considered in the generic classification but seemed to be of secondary importance are the dimensions, postcaudal-trough, and the sculpture of the outer face.

#### C. Specific Concepts

An otolith species is a group of otoliths that are similar to each other in their morphological characters more than to any other group; this group is assumed to represent a species of fishes. The characters that should be considered vary from group to group, but they always are smaller and harder to find than those of the genus, and are easy to confuse with those marking varieties of the same species.

#### D. Specific Characters

The characters that were used for separation of the genera into species varied from genus to genus. In general the characters that were valuable are the sulcus, with more detail than at the generic level, the outline of the sagitta, considering the presence and degree of development of the marginal domes (dorsal and ventral), the shape of the posterior margin (rounded or acute), the length of rostrum and antirostrum, the shape of excisura, the dimensions, presence of the ventral furrow and postcaudal trough, the sculpture of the outer face, the crista superior and sometimes crista inferior.

#### E. Suggested Phylogenies

Evolutionary progressions seem to occur within "Nemipterus" and Genus E. Those lineages show changes in the outline of the otolith,

the sulcus (both ostium and cauda) and the proportions of the sagitta itself (height/length ratio) (Fig. 4).

#### 1. Lineage of "Nemipterus"

This genus, as recognized in Recent and fossil species studied, shows a pattern of divergence with three divisions: (a) The main line ranged from Paleocene to Recent. It includes four fossil and one living species. (b) An offshoot of "Nemipterus" sp. 5, from which arose "N." sp. 4, ranging from middle (Claiborne) to upper (Jackson) Eocene. This species might occur only in the Claiborne, as only one worn specimen from the Moodys Branch Marl (upper Eocene) is referred to it. (c) An offshoot of "N." sp. 3, "N." sp. 2, which occurs generally in the Vicksburg, Oligocene.

The changes that were noted within the lineage of this genus, from stratigraphically lower to higher are: (i) The outline increased in height. (ii) The ventral border of the ostium increased gradually in degree of curvature at the junction with the caudal border. (An exception is "N." sp. 4, which has the ostial ventral border forming an obtuse angle with the caudal border.) (iii) The anterior part of the dorsal border of the ostium, which is almost horizontal, increased in length. (iv) The amount and degree of curvature of the cauda generally increased. (v) The size of the otolith increased, an exception being "N." sp. 2. (vi) The length of the posterodorsal and anterodorsal slopes increases and that of the dorsal part of the margin decreases.

#### 2. Lineage of Genus E

Genus E showed three divergent lines within its five lower Cenozoic species. (a) A main stock, including three species, ranges from middle (Claiborne) Eocene into the Oligocene. (b) Genus E sp. 5 apparently

gave rise to Genus E sp. 3, of the Oligocene. (c) Another offshoot of Genus E sp. 5, Genus E sp. 2, also occurs in the Oligocene.

The progressive changes that characterize the lineage of Genus E are, (i) The sagitta becomes relatively higher. (ii) The posterodorsal angle decreases somewhat in its development. (iii) The dorsal and ventral borders of the ostium decrease in curvature at their junction with the caudal borders. (iv) The cauda becomes somewhat shorter, and its curvature somewhat stronger (Genus E sp. 2). In Genus E sp. 3 the cauda is shorter and somewhat oblique.

Both genera have their maximum number of species in the Oligocene (Vicksburg Group), Genus E apparently starting during the middle Eocene.



Figure 4

Suggested phylogenetic relationships within "Nemipterus" and Genus E. Stratigraphic range shown by solid line, suggested relationships by dashed lines. (Sketches not drawn to scale)

- a. "Nemipterus" sp. 5
- b. "N." sp. 6
- c. "N." sp. 4
- d. "N." sp. 1
- e. "N." sp. 3
- f. "N." sp. 2
- g. "N." virgatus (Houttuyn)
- h. Genus E sp. 4
- i. Gen. E sp. 5
- j. Gen. E sp. 3
- k. Gen. E sp. 1
- l. Gen. E sp. 2

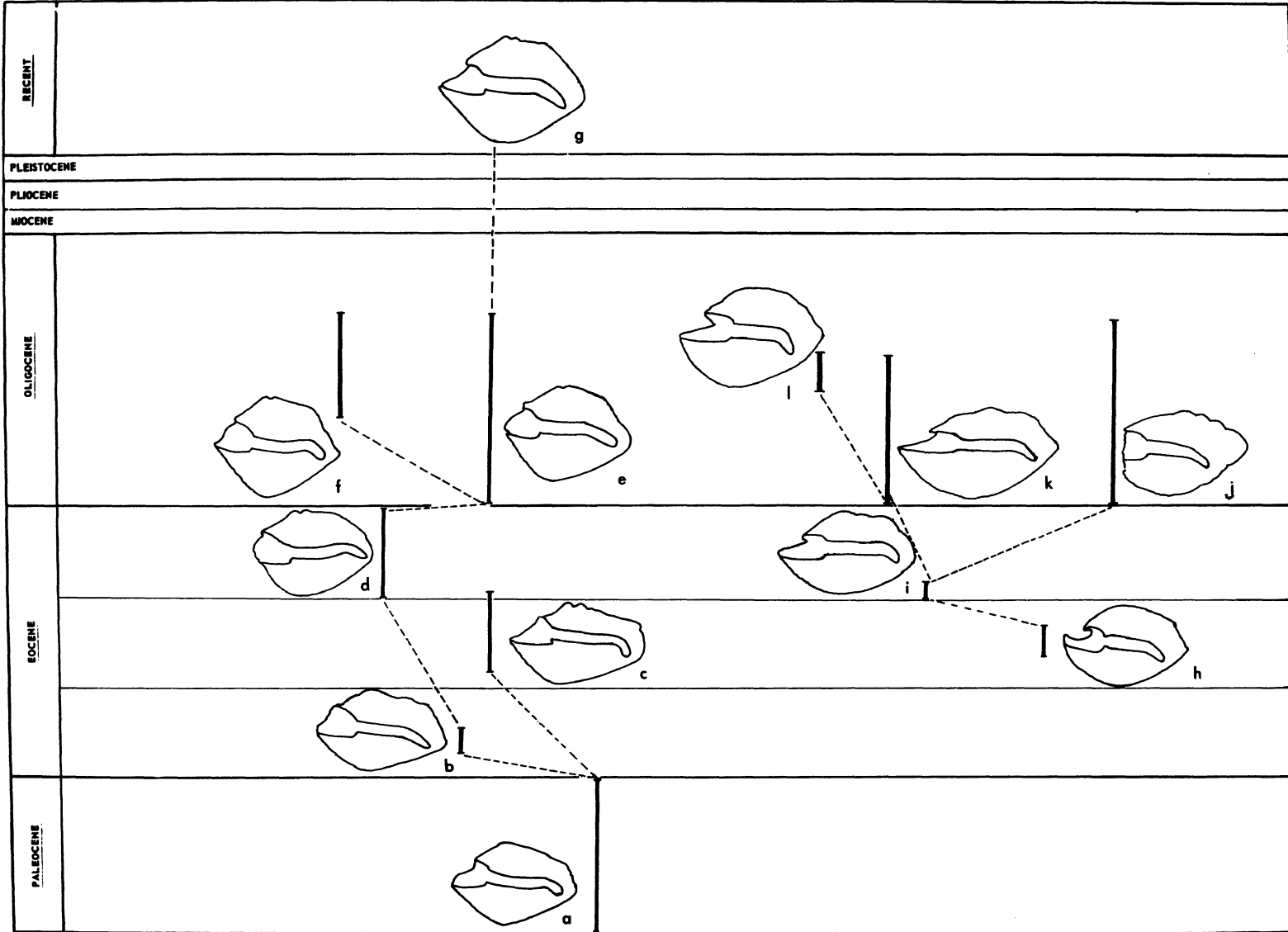


Figure 4

## VII. CONCLUSIONS

This is a taxonomic-morphologic project, dealing with a reasonably coherent group of otoliths of fishes of the Order Perciformes from the lower Cenozoic of the Gulf Coast of the United States. The study is restricted to this area, as other areas were considered to be beyond the scope of this problem, and available samples were all from that stratigraphic and geographic unit.

Morphological characters of the fossil sagittae were evaluated for their taxonomic significance. The diagnostic features for the group of species studied are: (a) All have the ventral margin skewed somewhat forward. (b) All species (except Genus A) have a somewhat long rostrum and antirostrum, and relatively shallow, angular excisura. (c) Except for Genus F sp. 1, which has a broadly rounded posterior margin, all of the species studied have the posterodorsal slope obliquely truncate toward the narrowly rounded or acute posterior end. (d) The ostium usually has a part of its dorsal border parallel to the ventral and to those of the cauda. (e) The cauda has parallel borders, and more than half of it is almost horizontal, the rest curving variably downward. (f) The area extends along the straight part of the cauda. (g) The crista superior is well developed, extending along the lower edge of area.

The characters that were useful for separation of genera are as follows: (a) The periphery and the sulcus are the most important features. (b) The characters which follow the preceding in importance are the sculpture of the outer face, convexity and concavity of faces,

dimensions, and the occurrence of the postcaudal trough. The characters that were used for separation of species are variable from genus to genus; they include (a) the sulcus with more details than at the generic level; (b) the outline of the sagitta, considering all of the features on the different margins; (c) the presence or absence and features of the crista superior and crista inferior; (d) the sculpture of the outer face; (e) the presence or absence of a ventral furrow, (f) the presence or absence of the postcaudal trough, (g) and the dimensions.

Otoliths were studied from 345 species of Recent fishes, of 34 families belonging to 15 suborders, for comparison with the fossil forms. Some of the otoliths examined are not typical, as they are either more primitive or highly evolved than the rest of the group. That suggests that the Order Perciformes may be polyphyletic rather than evolved from a single group.

Eight genera of perciform fishes are recognized in the lower Cenozoic, one of them ("Nemipterus") is still living in the Indo-Pacific region and another (Genus A) is closely allied to a West African genus (Brachydeuterus): while a third genus (Genus E) resembles Boops boops (L.) of the Family Sparidae. All species and all but one of the genera are regarded as new.

Phylogenies are suggested for the species of Genus E and "Nemipterus". These are largely hypothetical, being based, except for "N. virgatus", solely on otoliths encountered in samples from the Gulf Coast. For the Genus "Nemipterus" three lines are suggested. A main line which has five species, ranging from Paleocene to Recent. Two offshoots are postulated, one from the Paleocene species that occurs in the middle Eocene, and the other from the upper Eocene that occurs in the Oligocene.

Genus E is known to range from middle Eocene to upper Oligocene, containing five species, and having three lines. A main line, which has three species in it and ranges from middle Eocene to Oligocene, and two offshoots evolved from that line, both occurring in the Oligocene.

The changes that took place in these species from older to younger are: (a) The outline of the sagitta changes from lower to somewhat higher; subelliptical to subovate or subquadrate in "Nemipterus", and to subovate in Genus E. (b) The ventral border of the ostium increases in curvature at the junction with the cauda in "Nemipterus". (c) The dorsal and ventral borders of the ostium decrease in curvature at their junction with the cauda in Genus E. (d) The amount of the sub-horizontal part of the dorsal border of the ostium increases in "Nemipterus". (e) The amount and degree of curvature in the cauda increases in the case of "Nemipterus". In Genus E the cauda becomes somewhat shorter and its curvature stronger. (f) The size of the sagitta of "Nemipterus" increases. (g) The length of the posterodorsal and anterodorsal slopes increases and that of the dorsal part of the margin decreases in "Nemipterus". (h) The development of the posterodorsal angle decreases somewhat in Genus E.

## VIII. SYSTEMATIC DESCRIPTIONS

Order Perciformes

Suborder Percoidei

Family Nemipteridae

The fishes of the Family Nemipteridae are rather small, brightly colored, with elongate shape and fairly large scales. The mouth is moderate with jaws of small conical teeth. Pelvics and upper caudal lobe are sometimes with filamentous rays (see Smith, 1961, p. 257). These fishes are common in the Indo-Pacific region.

One of the fossil groups studied in this research is referred to the Family Nemipteridae, as it resembles the Recent "Nemipterus" virgatus (Houttuyn). The reasons for placing it in "Nemipterus" are: (1) From comparison between the Recent and fossil otoliths, the lower Cenozoic forms resemble the Recent one in their morphology. (2) "Nemipterus" virgatus was the only Recent species of the family that was available at the time of this research. (3) The Recent species was identified as Nemipterus by the collector of the specimens. (4) According to the literature (Weiler, 1968) no previous work has been done on otoliths of the Family Nemipteridae to compare with the species studied in this research.

Genus Nemipterus Swainson, 1839Type Species: Dentex filamentosus Cuvier and Valenciennes.Diagnosis: Sagitta medium size, to large, moderately high. Outer face concave to convex, sometimes with a projected boss around center. Inner

face smooth, with well developed, excavated, divided sulcus; ostium mostly subtriangular to subquadrate, sometimes subovate; ventral border almost horizontal or somewhat arching down, curving almost vertically at the junction with cauda, its dorsal border slopes gently and evenly towards cauda with anterior part almost horizontal; cauda mostly horizontal or slightly sloping downward toward the back, straight or slightly arching down in first two-thirds to four-fifths, inclining downward in last third to fifth. Dorsal margin arched, posterodorsal angle domed; posterodorsal slope obliquely truncate; ventral margin skewed forward; posterior margin mostly rounded, sometimes acute; rostrum, antirostrum and excisura usually present, area excavated, crista superior well developed along area. Anterior and posterior ends flexed outward.

Content: Six fossil species are known from the lower Cenozoic of the Gulf Coast.

Range and Distribution: Recent, Indo-Pacific; Oligocene, Vicksburg Group: Byram Marl, Old Byram, Hinds County, Mississippi; Glendon Limestone, Brandon, Rankin County, Mississippi; Mint Spring Marl, Vicksburg, Warren County, Mississippi; Red Bluff Clay, Hiwannee, Wayne County, Mississippi; Upper Eocene, Jackson Group: Shubuta Clay, Shubuta, Clarke County, Mississippi; Moodys Branch Marl, Jackson, Hinds County, Mississippi, Midway, Yazoo County, Mississippi, Montgomery, Grant Parish, Louisiana; Middle Eocene, Claiborne Group: Weelock Formation, Burleson County, Texas; Stone City Beds, Burleson County, Texas; Weches Formation, Nacogdoches County, Texas, and Pleasanton, Atascosa County, Texas; lower Eocene, Wilcox Group: Bashi Marl, Meridian, Lauderdale County,

Mississippi; Paleocene, Midway Group: Porters Creek Formation,  
Matthews Landing Member: Wilcox County, Alabama.

Comparisons: "Nemipterus" can be differentiated from Genus E by the following characters: (1) The sagitta is relatively higher in this genus than in Genus E. (2) The ostium has dorsal and ventral borders not parallel as the ventral curves more strongly to meet the cauda than the dorsal. In Genus E, the borders are parallel to each other until their posterior part, where they converge evenly to meet the caudal borders. (3) Relatively, the rostrum and antirostrum are shorter and shallower, and the excisure less angular. "Nemipterus" can be differentiated from Genus B by the following characters: (1) The sagitta is somewhat higher than that in Genus B. (2) The ventral margin in this genus is more skewed forward than that in Genus B. (3) The ostium here has the ventral border almost horizontal or somewhat arching down, curving almost vertically or with an obtuse angle in the back to meet the caudal border. The ostium in Genus B has the ventral border somewhat arching up curving almost vertically to meet the caudal border. (4) The ostium in this genus extends almost in the same plane horizontally as the cauda. In Genus B it slopes somewhat downward toward the front. (5) The cauda is straight or slightly arching downward, horizontal or slightly sloping downward toward the back in its first two-thirds to four-fifths, then curves downward. The cauda in Genus B is straight, somewhat sloping down backward in its first half to two-thirds, then curves downward in its last third to half. (6) This genus is relatively thicker and less in the concavity of its outer face than Genus B. (7) The anterior end in this genus is



variably flexed outward. The anterior end in Genus B is both flexed outward and twisted.

Remarks: Fossil specimens resemble very closely the Recent Nemipterus virgatus (Houttuyn). The differences are considered as merely at the specific level.

"Nemipterus" species 1

Plate 2 Figures 1a-c

Description: Sagitta moderately large (maximum length observed, 6.7 mm.), pyriform to subovate, moderately high (height/length ratios, 62-80 per cent). Outer face irregularly concave, inner face convex, smooth. Dorsal margin moderately arched in first two-thirds, anterodorsal and posterodorsal domes slightly formed with slight depression in posterior third; posterodorsal angle domed; posterodorsal slope obliquely truncate, ventral margin broadly rounded, skewed forward, sometimes a marked anteroventral slope developed, anterior margin generally rounded, rostrum and antirostrum slightly preserved; posterior margin mostly rounded, but sometimes acute. Inner face smooth, convex, showing long sulcus and depressed area; sulcus divided, opening onto anterior and extending nearly to posterior margin: ostium short, wider than cauda, partly filled with colliculum, subtriangular, dorsal border of ostium sloping somewhat strongly up from the cauda then turning almost horizontal when approaching anterior, with ventral border arching slightly down till its posterior part where it curves strongly forming almost an obtuse angle with cauda; cauda long, wide, deep, with parallel sides, slightly arched downward in first two-thirds, curved downward in last third, ending in a slightly depressed trough,

posterior end angular and facing posterior margin, crista superior well developed, crista inferior lacking. Outer face with small depressions, pustules, and sometimes small grooves radiating from central thick area toward margins; anterior and posterior ends flexed outward.

Dimensions in mm.:

<u>Length</u>	<u>Height</u>	<u>Thickness</u>	<u>Remarks</u>
1.4	1.1	0.25	worn, Shubuta clay
1.4	1.1	0.3	Shubuta clay
1.6	1.1	0.25	" "
1.75	1.2	0.3	" "
1.8	1.3	0.4	" "
1.9	1.4	0.3	" "
2.1	1.6	0.6	" "
2.2	1.75	0.4	" "
2.3	1.8	0.5	" "
2.4	1.8	0.5	" "
2.5	1.8	0.4	" "
2.7	2.0	0.6	" "
2.75	1.9	0.5	" "
2.9	2.2	0.6	" "
4.0	3.2	0.7	" "
4.1	3.3	0.7	" "
4.1	3.2	0.75	" "
4.6	3.5	0.8	worn, Shubuta clay
4.8	3.6	0.8	" " "
5.0	4.0	0.7	Shubuta clay
5.8	4.7	1.0	" "
6.0	4.2	1.0	" "
6.2	4.8	1.0	" "
6.7	5.0	1.0	" "
1.8	1.2	0.5	Moodys Marl
2.1	1.4	0.5	" "
2.0	1.3	0.3	" "
2.3	1.7	0.6	" "
2.4	1.8	0.5	" "
4.2	3.1	0.6	worn, Moodys Marl
4.75	3.5	0.75	" " "
1.75	1.25	0.4	" " "
1.9	1.3	0.4	" " "
2.1	1.5	0.4	" " "
2.1	1.5	0.5	" " "
2.2	1.5	0.5	" " "
4.5	2.8	0.6	" " "

Type Locality: Shubuta clay; Shubuta, Clark County, Mississippi.

Range and Distribution: Eocene, Jackson Group: Shubuta Clay; Shubuta, Clark County, Mississippi; Moodys Branch Marl; Jackson, Hinds County, Mississippi, Midway, Yazoo County, Mississippi; and Montgomery, Grant Parish, Louisiana.

Comparisons: This species is easy to confuse with "Nemipterus" sp. 3, unless the following differences are taken into account. 1. The outer face has some depressions and pustules and sometimes grooves radiating from a central thick area toward the margins and is concave, but in "N." sp. 3 there is a boss in the center of the outer face. 2. The posterior margin in "N." sp. 1 is mostly rounded, although in the other form it is acute. 3. The posterior border of the ostium in this species curves strongly to join the cauda, forming an obtuse angle. In "N." sp. 3 it is almost vertical but usually less than 90 degrees. 4. The dorsal border of the ostium in "N." sp. 1 goes more strongly upward from the cauda than in "N." sp. 3. 5. The posterior end of the cauda is angular rather than rounded, and the cauda ends almost at the posterior end of the sagitta. In "N." sp. 3 the cauda ends before that point, and the end is rounded.

"Nemipterus" sp. 1 can be differentiated from "N." sp. 4 by the following characters. (1) The sagitta generally is higher, (2) Only two-thirds of the cauda are almost straight (slightly arched downward), then the last third curves comparatively gently downward. (3) The posterior end of the cauda is angular, facing posterior margin; cauda ending almost at posterior end of sagitta. (4) The posterodorsal angle is domed, but with no reentrant behind it. (5) The rostrum and

antirostrum are not very well developed.

"Nemipterus" species 2

Plate 2 Figures 5a-c

Description: Sagitta medium size (maximum length observed, 4.2 mm.), subquadrate, moderately high (height/length ratios 72-77 per cent). Outer face somewhat concave, with anterior and posterior ends flexed outward; inner face smooth, convex, margins thick. Dorsal margin forming three straight almost equal parts, one sloping strongly toward anterior margin, one toward posterior margin, one almost flat or slightly sloping backward at dorsal area of margin; posterodorsal angle angular to domed; posterodorsal slope obliquely truncate with reentrant behind posterodorsal angle; anterodorsal and dorsal domes sometimes developed; ventral margin rough, broadly rounded, skewed forward; anteroventral slope usually present; anterior margin with somewhat long rostrum, antirostrum short and rounded, excisura shallow; posterior margin acute. Inner face smooth except toward ventral margin, where some low "humps" sometimes extend toward ventral margin, convex, with long, divided sulcus; ostium wide, short, suboval, partly filled with colliculum, opening widely onto anterior margin; dorsal border almost horizontal in front, sloping gently toward cauda in back, ventral border almost horizontal, slightly arching upward until it comes vertically under cauda, then curving upward strongly but less than vertically to meet cauda; cauda long, deep, horizontal, straight or slightly arched downward in first three-fourths, inclined strongly downward in last fourth, posterior end rounded, facing ventral margin, ending in shallow postcaudal trough; area excavated, extending along two-thirds

of cauda; crista superior well developed, extending along area, crista inferior slightly formed, ventral furrow present. Outer face with elongate "humps" extending toward margins, almost equal in thickness toward margins; margins thick; anterior and posterior ends flexed outward, anterior end flexed more. Dimensions in mm.:

<u>Length</u>	<u>Height</u>	<u>Thickness</u>	<u>Remarks</u>
2.9	2.1	0.5	Mint Spring Marl
3.8	2.8	0.8	" " "
3.9	2.8	0.8	" " "
4.0	3.0	0.8	" " "
4.2	3.1	0.8	" " "
3.8	2.7	0.7	Byram Marl
3.8	2.8	0.8	" "
3.5	2.5	0.7	worn, Glendon Limestone
3.0	2.2	0.6	Glendon Limestone
3.8	2.6	0.7	worn, Glendon Limestone
4.0	3.0	0.6	" " "
4.0	3.0	0.8	" " "
4.2	3.1	0.8	" " "

Type Locality: Mint Spring Marl; Vicksburg, Warren County, Mississippi.

Range and Distribution: Oligocene, Vicksburg Group: Byram Marl; Old Byram (type locality of formation), Hinds County, Mississippi; Glendon Limestone; Brandon, Rankin County, Mississippi; Mint Spring Marl; Vicksburg, Warren County, Mississippi.

Comparisons: This species can be differentiated from "Nemipterus" sp. 3 by the following characters. (1) The cauda is arched somewhat downward in the first three-fourths, then curved downward strongly in the last fourth, instead of in the last third. (2) This species is generally smaller. (3) It has a longer rostrum and more angular posterior margin. (4) The concave outer face is almost equal in thickness and thick margins, rather than having a central boss and thin margins. (5) The ventral furrow is common rather than occasional.

"Nemipterus" species 3

Plate 2 Figures 2a-c

Description: Sagitta medium size to large (maximum length observed 6.4 mm.), roughly subovate, moderately high (height/length ratios, 76-80 per cent). Outer face somewhat concave, inner face smooth, convex. Dorsal margin broadly arched, anterodorsal, dorsal and posterodorsal domes sometimes developed, with small reentrant behind anterodorsal dome, posterodorsal angle domed; posterodorsal slope obliquely truncate, sometimes somewhat incurved; ventral margin skewed forward, lowest point on front third; anteroventral slope developed on first third of margin; anterior margin with rostrum, antirostrum and shallow excisura, usually not well preserved; posterior margin acute. Inner face smooth, convex, sloping from center to margins, showing excavated area extending along straight part of divided sulcus; sulcus opening widely onto anterior margin, extending nearly to posterior margin; ostium wide, subovate, partly filled with colliculum, at junction with cauda its ventral border curves strongly, almost vertically to meet cauda, slope of dorsal border somewhat less strong, turning almost horizontal when reaching anterior end; cauda long, deep, almost straight, horizontal in first two-thirds with parallel sides, inclining downward in last third, posterior end rounded, facing posterior margin, ending in slight postcaudal trough; crista superior well developed, extending along area, crista inferior lacking; ventral furrow sometimes present. Outer face with central projection, highest point sometimes along ventral side; margins sinuous to rough; anterior and posterior ends flexed outward. Dimensions in mm.:

<u>Length</u>	<u>Height</u>	<u>Thickness</u>	<u>Remarks</u>
4.8	3.8	1.0	Glendon Limestone
5.0	3.8	1.0	Byram Marl
5.2	4.0	1.1	" "

Type Locality: Byram Marl; Old Byram (type locality of formation), Hinds County, Mississippi.

Range and Distribution: Oligocene, Vicksburg Group: Byram Marl; Old Byram, Hinds County, Mississippi; Glendon Limestone; Brandon, Rankin County, Mississippi; Mint Spring Marl; Vicksburg, Warren County, Mississippi; Red Bluff Clay; Hiwannee (formerly Red Bluff; type locality of formation), Wayne County, Mississippi.

Comparisons: This species resembles "Nemipterus" sp. 1 except that:

- (1) A central boss on the outer face is absent in the other form.
- (2) The posterior margin in this species is usually acute, but in "N." sp. 1 it is mostly rounded. (3) The curvature of the posterior part of the ventral border of the ostium is strong but usually less than 90°. In "N." sp. 1 it forms an obtuse angle. (4) The dorsal border of the ostium in "N." sp. 3 curves toward the cauda with a little less strength than the ventral, but in "N." sp. 1 it goes strongly up from the cauda further than in "N." sp. 3. (5) The posterior end of the cauda is rounded. It is angular in "N." sp. 1 and ends almost at the posterior margin. (6) The ostium is subovate in this species, but is subtriangular in "N." sp. 1. This species differs from "Nemipterus" virgatus (Houttuyn) in: (1) The outer face was a central boss. (2) The posterior end of the cauda is more rounded. (3) The ventral margin is skewed more forward than in the other species.

"Nemipterus" species 4

Plate 1 Figures 2a-c

Description: Sagitta medium size (maximum length observed, 3.7 mm.), subelliptical moderately high (height/length ratios observed, 65-74 per cent), concavo-convex, not thin. Dorsal margin broadly arched, highest point generally on front third, anterodorsal and dorsal domes usually present, posterodorsal dome sometimes very slight, posterodorsal angle domed, with a reentrant separating dorsal margin from posterior margin, margin sloping gently toward anterior margin; ventral margin broadly and unevenly rounded, skewed forward, sometimes somewhat sinuous, lowest point on front third; posterior margin rounded to somewhat acute; anterior margin somewhat tapering, with long rostrum, antirostrum short, excisura not well developed. Inner face smooth except above area somewhat undulating, convex, thickest point below cauda; sulcus long, divided, deep; ostium subtriangular; with ventral border somewhat arching downward, somewhat curved backward in posterior to meet cauda, forming S shape at junction; dorsal border sloping quite strongly downward toward cauda, almost horizontal when reaching anterior end, junction of dorsal border with cauda situated somewhat anterior to that of ventral border; cauda long, straight, horizontal in four-fifths, then curving strongly downward in last fifth, dorsal border straight on horizontal part of cauda, while ventral border arches downward very slightly, posterior end of cauda rounded, facing ventral margin, shallow post-caudal trough present; area excavated, extending along about three-fourths of cauda; crista superior well developed, extending along area, crista inferior sometimes slightly developed, ventral furrow sometimes present.



Outer face concave, thickest at center of sagitta, sculptured, with some small depressed areas along dorsal side, some "humps" toward dorsal margin, margins thin, anterior and posterior ends flexed outward, former more markedly. Dimensions in mm.:

<u>Length</u>	<u>Height</u>	<u>Thickness</u>	<u>Remarks</u>
2.3	1.6	0.5	Stone City Beds
2.5	1.8	0.7	" " "
3.0	2.0	0.6	worn, Stone City Beds
3.2	2.1	0.7	Stone City Beds
3.2	2.2	0.7	worn, Stone City Beds
1.75	1.3	0.3	Weches Formation
2.3	1.6	0.5	" "
3.7	2.6	0.7	" "
2.0	1.3	0.5	Wheelock Formation

Type Locality: Stone City Beds; Burleson County, Texas.

Range and Distribution: Eocene, Jackson Group: Moodys Branch Marl; Jackson (re-selected type locality of formation), Hinds County, Mississippi and Montgomery, Grant Parish, Louisiana; Claiborne Group: Wheelock Formation; Burleson County, Texas, at boundary with Brazos County; Stone City Beds; Burleson County, Texas; Weches Formation; Nacogdoches County, Texas, and Pleasanton, Atascosa County, Texas.

Comparisons: The differences between this species and "Nemipterus" sp. 1 are: (1) This species is lower (height/length ratios observed, 65-74 per cent; "N." sp. 1: height/length ratios observed, 72-80 per cent). (2) In "N." sp. 4 four-fifths of the cauda are horizontal and straight, with the dorsal border horizontal and the ventral border arched slightly downward, then curving strongly downward in the last fifth; the posterior end is rounded and faces the ventral margin. In the other species two-thirds of the cauda are almost horizontal but slightly arched downward, both borders are parallel, then curving downward in the last

third, not as strongly as in this species; the posterior end is angular, ending almost at the posterior end of the sagitta. (3) The reentrant behind the posterodorsal angle in this species is not present in "N." sp. 1. (4) The rostrum is long and the antirostrum short in this species, but neither is well developed in the other form.

Remarks: Only one worn specimen from the Moodys Branch Marl was identified with this species. The upper Eocene record therefore is open to question.

"Nemipterus" species 5

Plate 2 Figures 3a-c

Description: Sagitta medium size (maximum length observed, 4.2 mm.), subelliptical, moderately high (height/length ratios, 70-76 per cent); outer face somewhat convex, inner face smooth, convex. Dorsal margin forming low arch extending from antirostrum to posterodorsal angle, dorsal dome slightly developed, posterodorsal angle domed; posterodorsal slope obliquely truncate; ventral margin skewed forward, anteroventral slope developed; posterior margin acute; anterior margin with short rostrum, antirostrum present, excisura shallow and rounded. Inner face convex, smooth, with long, divided sulcus; ostium short, suboval, wider than cauda, partly filled with colliculum, opening onto anterior margin, dorsal and ventral borders not parallel, as the dorsal slopes gently toward cauda, while ventral extends almost horizontally until it comes below cauda, then curves vertically to meet cauda; cauda long, deep, horizontal or inclined slightly downward posteriorly, slightly arching down in first three-fourths, then curving downward gently in last fourth,

posterior end rounded, opening into a shallow post-caudal trough facing posterior part of ventral margin; area depressed, extending along two-thirds of cauda; crista superior well developed, extending along lower border of area, crista inferior lacking. Outer face irregularly convex with some excavated small depressions along dorsal side, as a whole, thickest point along ventral side, anterior and posterior ends flexed outward.

Dimensions in mm.:

<u>Length</u>	<u>Height</u>	<u>Thickness</u>
4.2	2.9	1.00

Type Locality: Porters Creek Formation, Matthews Landing Member; Wilcox County, Alabama.

Range and Distribution: Paleocene, Midway Group: Porters Creek Formation, Matthews Landing Member; Wilcox County, Alabama.

Comparisons: This species resembles the young specimens of "Nemipterus" sp. 6, but the following important differences can be recognized: (1) The cauda inclines down slightly backward; in "N." sp. 6 it usually is horizontal. (2) The dorsal margin forms an arch, with the dorsal dome slightly developed, in this species, but in "N." sp. 6 it is mostly straight, sloping gently backward, or with a gentle arch. (3) The posterior margin is mostly acute, being subrounded in "N." sp. 6. (4) The outer face is somewhat convex in this species, rather than concave.

"Nemipterus" species 6

Plate 2 Figures 4a-c

Description: Sagitta medium size to moderately large (maximum length observed, 6.2 mm.), subelliptical, moderately high (height/length ratio, 60-74 per cent); outer face concave, sculptured, inner face smooth or with some low ridges running toward margins. Dorsal margin mostly straight, sloping gently backward, sometimes forming low arch, mostly sinuous; posterodorsal angle domed; posterodorsal slope obliquely truncate; ventral margin skewed forward; posterior margin sub-rounded; anterior margin with somewhat short rostrum, antirostrum, and shallow excisura (usually not preserved). Inner face smooth, convex, with long, deep, divided sulcus; ostium short, wider than cauda, subtriangular, somewhat shallow, partly filled with colliculum, opening widely onto anterior margin; cauda long, in adult specimens straight or slightly arched downward, horizontal in first two-thirds, then curving downward gently in last third, in juvenile specimens straight to arching slightly downward, horizontal till last fourth, then curving down strongly, rounded at posterior end, which faces posterior part of ventral margin; area depressed extending along straight part of cauda; crista superior well developed, extending along lower border of area, crista inferior lacking; ventral furrow sometimes slightly developed. Outer face irregularly concave; a depressed area along dorsal side sometimes present, with deep, small depressions along dorsal side and some pustules toward dorsal margin; thickest point along horizontal line in middle of sagitta, in other specimens a thicker area exists along horizontal midline, with long ridges running from that line toward

dorsal and ventral margins; anterior and posterior ends flexed outward.

Dimensions in mm.:

<u>Length</u>	<u>Height</u>	<u>Thickness</u>	<u>Remarks</u>
2.4	1.4	0.7	
4.2	2.8	0.9	
5.1	3.3	0.9	
5.3	3.6	0.9	
6.2	4.1	1.0	specimen worn

Type Locality: Bashi Marl; Meridian, Lauderdale County, Mississippi.

Range and Distribution: Eocene, Wilcox Group: Bashi Marl; Meridian, Lauderdale County, Mississippi.

Comparisons: The differences between the adult (larger) specimens of this species and "Nemipterus" sp. 1 are: (1) The posterior end of the cauda sometimes faces the ventral margin in this species, but faces the posterior margin in "N." sp. 1. (2) "N." sp. 1 shows the cauda extending nearly to the posterior end of the sagitta. In this species it ends before that point. (3) "N." sp. 1 is higher than "N." sp. 6, especially in the dorsal margin. (4) The posterodorsal angle is more developed in "N." sp. 1 than here. (5) The cauda in this species is different in adult otoliths from that of juveniles, as in the former it is straight to slightly arched down, horizontal in the first two-thirds, then curving downward gently in the last third, whereas in the latter it is straight, horizontal to slightly arching down in the first three-fourths, then curving strongly in the last fourth. In "N." sp. 1 the cauda is straight, almost horizontal in the first two-thirds, then curving downward gently in the last third, in both adult and juvenile specimens.

Young specimens of this species resembles "Nemipterus" sp. 5. The differences are: (1) "N." sp. 5 has the dorsal dome slightly developed, while in this species it is lacking. (2) in "N." sp. 5 the cauda is straight, inclining gently down backward in its first three-fourths, then curving downward gently in the last fourth, but in this species it is straight to slightly arched downward and horizontal in its first three-fourths, then curving downward strongly in the last fourth. (3) The outer face is concave rather than convex. (4) Posterior margin is subrounded rather than acute.

"Nemipterus" virgatus (Houttuyn)

Plates 1 Figures 3a-c

Description: Sagitta medium large (length observed, 8.8 mm.), roughly subovate, moderately high (height/length ratio, 68 per cent); outer face concave, irregularly sculptured, inner face convex. Dorsal margin broadly arched, rough, sloping slightly backward in dorsal part; posterodorsal slope truncate obliquely to posterior margin; margin sloping forward in anteroventral area toward anterior margin; posterodorsal angle domed, anterodorsal dome present. Ventral margin broadly rounded, slightly skewed forward, somewhat serrate, anterior margin with long rostrum, short, rounded antirostrum, and angular excisura, excisural deposit protruding; posterior margin acute. Inner face smooth, with some low ridges extending toward dorsal margin; sulcus long, divided, deep; ostium wide, partly filled with colliculum, subtriangular, ventral border nearly vertical in posterior part where it joins cauda but sloping gently in dorsal border, then turning almost horizontal when it approaches anterior margin; cauda long, deep, with

parallel sides, slightly arched downwards in first two-thirds, curving downward in last third, rounded at end which faces ventral margin; crista superior well developed, crista inferior lacking, ventral furrow slightly developed; area excavated, extending along horizontal part of cauda. Outer face concave, irregularly sculptured, with thickest point along ventral side, some depressions and pustules toward dorsal area, anterior and posterior ends flexed outward. Dimensions in mm.:

<u>Length</u>	<u>Height</u>	<u>Thickness</u>
8.80	6.00	1.70

Locality: Taiwan; collector: Tunyow Huang, 1964.

Stratigraphic Position: Recent.

Comparisons: This species resembles the fossil "Nemipterus" species 3 the differences between these two are: (1) The ventral margin is skewed more forward in "N." sp. 3 than in this species. (2) A boss on the ventral side of the outer face in "N." sp. 3 is lacking on the Recent form. (3) The posterior end of the cauda in this species is less rounded than in "N." sp. 3.

#### Family Pomadasyidae

##### Genus A

Type Species: Genus A species 1.

Diagnosis: Sagitta medium size (maximum length observed, 4.4 mm.) moderately high; margins smooth or slightly sculptured, dorsal margin with domes or mostly with low arch sloping slightly backward; ventral margin smooth, skewed forward; anterior margin without rostrum or antirostrum. Inner face smooth, with divided excavated sulcus; ostium

subtriangular to subquadrate; cauda long, mostly straight, almost horizontal, area depressed, extending along about two-thirds of cauda, narrow, crista superior well developed extending along cauda. Outer face irregularly convex, depressed toward dorsal side with some "humps" extending toward dorsal margin.

Content: A single species is known.

Range and Distribution: Eocene, Wilcox Group: Nanafalia Formation; Marengo County, Alabama.

Comparison: This genus is separated from "Nemipterus" by the following differences. (1) The otolith is higher. (2) The rostrum and antirostrum are not developed. (3) The ostium is shallower, somewhat shorter, and with horizontal ventral border. (4) The cauda is straight, horizontal, and with parallel sides. (5) The area is shallower, subrectangular, and subequal in depth. (6) The crista superior extends behind the area to the end of the cauda. (7) The dorsal domes are more strongly developed. (8) The ventral margin is more markedly skewed forward. (9) The margins are smooth rather than sinuous or scalloped. (10) The otolith is relatively thicker.

Remarks: Genus A resembles closely the Recent Brachydeuterus auritus of the Family Pomadasyidae in: (a) The sulcus (ostium and cauda), (b) the curvature of the ventral margin, (c) the area, (d) and the sculpture of the outer face.

Genus A species 1

Plate 1 Figures 1a-c

Description: Sagitta medium size (maximum length observed, 4.4 mm.), subovate, moderately high (height/length ratios, 83-90 per cent).



In some specimens dorsal margin straight, sloping slightly backward, in others anterodorsal, dorsal, and posterodorsal domes distinct, with posterodorsal sloping slightly backward; anterodorsal slope curving slightly to anterior tip, posterodorsal slope curving slightly backward; anterior margin without rostrum or antirostrum; ventral margin smooth, skewed forward. Inner face smooth, showing long sulcus and excavated area, convex; sulcus divided, opening onto anterior and extending nearly to posterior margin, ostium short, wide, partly filled with colliculum, subtriangular to subquadrate; cauda long, straight or curved slightly downward at posterior tip, mostly horizontal, partly filled with colliculum, rounded at end; crista superior well developed; crista inferior lacking; area moderately deep, extending from beginning of cauda till about last third. Outer face irregularly sculptured, somewhat convex; depressed toward dorsal margin; thin at ventral margin; anterior and posterior ends flexed outward. Dimensions in mm.:

<u>Length</u>	<u>Height</u>	<u>Thickness</u>
2.3	1.9	0.5
2.3	1.9	0.5
3.1	2.8	0.8
3.4	2.9	0.9
3.9	3.4	0.9
4.2	3.8	1.0
4.4	3.8	1.1

Type Locality: Nanafalia Formation; Marengo County, Alabama

Range and Distribution: Eocene, Wilcox Group: Nanafalia Formation; Marengo County, Alabama.

Family position uncertain

Genus B

Type Species: Genus B species 1.

Diagnosis: Sagitta medium size to medium large, concavo-convex, elongate subovate. Dorsal margin irregularly arched, posterodorsal angle domed, posterodorsal slope obliquely truncate toward posterior margin; ventral margin slightly skewed forward; posterior margin acute; anterior margin with long rostrum, short rounded antirostrum, and shallow excisura. Inner face mostly smooth, convex; sulcus divided, long, deep; ostium wide, subquadrate, slightly sloping downward toward front, dorsal border curving evenly and gently downward in back to meet anterior part of cauda, ventral somewhat arching upward until its posterior part which it curves almost vertically up to meet cauda; cauda straight, sloping downward in first half to two-thirds, then curving downward in last third to half, posterior end subrounded, facing ventral margin; area excavated. Outer face concave, with some grooves extending from thick area along horizontal midline toward dorsal and ventral margins; anterior end twisted so dorsal part flexed outward more than ventral.

Content: One species is known.

Range and Distribution: Eocene, Jackson Group: Moodys Branch Marl; Jackson, Hinds County, Mississippi; Midway, Yazoo County, Mississippi; and Montgomery, Grant Parish Louisiana.

Comparisons: This genus can be distinguished from "Nemipterus" by the following differences: (1) The sagitta is generally somewhat lower. (2) The ventral margin is more skewed forward in "Nemipterus" than in

this genus. (3) The ostium here has a ventral border arching somewhat upward. In "Nemipterus" it is mostly horizontal or somewhat arching downward. (4) The ostium in this genus is slightly sloping downward toward the front. In "Nemipterus" the ostium is almost on the same horizontal plane as the cauda. (5) The cauda is straight, sloping downward in its first half to two-thirds, then curving down in the last third to half. In "Nemipterus", the cauda is usually horizontal or slightly sloping down straight or slightly arching down in its first two-thirds to four-fifths, then curving variably downward. (6) This genus is thinner, more concave on the outer face than in "Nemipterus." (7) The anterior end is flexed outward and twisted. In "Nemipterus" the anterior end is somewhat flexed out but not twisted.

Genus B species 1

Plate 4 Figures 3a-c

Description: Sagitta medium size to somewhat large (maximum length observed, 3.9 mm.) elongate subovate, moderately high (height/length ratios observed, 64-69 per cent), concavoconvex. Dorsal margin broadly and irregularly arched rough with posterodorsal angle slightly domed in mature specimens only, margin obliquely truncate behind posterodorsal angle, but not in young specimen where truncation less and no domes developed; ventral margin broadly arched, slightly skewed forward, slightly rough; posterior margin acute; anterior margin with long rostrum, short rounded antirostrum, and shallow excisura. Inner face smooth, convex, with some undulations toward margins, thickest point along horizontal line below sulcus; sulcus divided, long, deep; ostium

shorter and wider than cauda, deep, subquadrate, sloping slightly downward toward front, partly filled with colliculum, opening onto anterior margin, dorsal and ventral borders not parallel, dorsal curving evenly and gently downward to meet anterior part of cauda, ventral somewhat arching up generally until its posterior part where it curves almost vertically up to meet cauda; cauda long, deep, straight, partly filled with colliculum, sloping downward in first half to two-thirds, then curving downward in last third to half, posterior end subrounded, facing ventral margin, postcaudal trough absent; area excavated, extending along straight part of cauda; crista superior fairly well developed, extending along area, crista inferior and ventral furrow lacking. Outer face concave, irregularly sculptured, thickest point along ventral side, some grooves extending from horizontal thick midline toward dorsal and ventral margins; anterior and posterior ends flexed outward; anterior end more flexed, slightly twisted, so dorsal part flexed more than ventral. Dimensions in mm.:

<u>Length</u>	<u>Height</u>	<u>Thickness</u>
3.1	2.0	0.7
3.1	2.0	0.7
3.9	2.6	0.7

Type Locality: Moodys Branch Marl: Montgomery, Grant Parish County, Louisiana.

Range and Distribution: Eocene, Jackson Group: Moodys Branch Marl; Jackson, Hinds County, Mississippi; Midway, Yazoo County, Mississippi; and Montgomery, Grant Parish Louisiana.

## Family position uncertain

## Genus C

Type species: Genus C sp. 2

Diagnosis: Sagitta medium size, irregularly subovate to subquadrate. Outer face concave, with grooves running from a horizontal thick area toward dorsal and ventral margins; inner face convex. Dorsal margin with some or all domes, ventral margin with or without domes. Posterior margin somewhat acute, posterodorsal angle domed, posterodorsal slope truncate obliquely toward posterior margin; ostium subovate with ventral and dorsal borders sloping gently and almost evenly toward caudal borders, or ventral curves strongly and dorsal gently; cauda sigmoid, gently or somewhat strongly. Crista superior sometimes present; crista inferior lacking. Anterior and posterior ends flexed outward.

Content: Two species are known.

Range and Distribution: Oligocene, Vicksburg Group: Byram Marl; Old Byram, Hinds County, Mississippi; Red Bluff Clay; Hiwannee, Wayne County, Mississippi.

Comparisons: The differences between this genus and Genus G are: (1) the outline of Genus C is irregularly subquadrate to subovate, the outline of Genus G being roughly subquadrate. (2) The posterodorsal slope is obliquely truncate toward the posterior margin in Genus C. In Genus G it is obliquely truncate but forming an obtuse angle. (3) The posteroventral slope is more developed in Genus G than in Genus C. (4) The cauda is variably sigmoid in Genus C. In Genus G it is straight, slightly sloping downward in the first three-fourth, then curving downward strongly, forming a semicircle. (5) The postcaudal trough is present in Genus G, terminating at the posteroventral slope. In Genus C

the postcaudal trough is absent. (6) The outer face in Genus C has grooves running toward the dorsal and ventral margins from a horizontal thick area. In Genus G the outer face is depressed on the dorsal side, and the thickest point is situated along ventral side.

Genus C species 1

Plate 1. Figures 4a-c

Description: Sagitta medium size (maximum length observed, 4.5 mm.), subquadrate to subovate, moderately high (height/length ratios, 73-78 per cent). Outer face concave, inner face convex, smooth; thin. Dorsal margin slightly and irregularly arched, sloping gently forward with dorsal dome developed, posterodorsal angle domed, posterodorsal slope truncate obliquely, strongly toward posterior margin; ventral margin broadly rounded, skewed forward, with anteroventral, ventral, and posteroventral domes slightly developed; posterior margin somewhat acute; anterior margin with rostrum, antirostrum short and angular, excisura shallow, angular. Inner face smooth, convex, with thickest part below sulcus; sulcus divided; ostium short, wide, suboval, partly filled with colliculum, opening onto anterior margin, ventral and dorsal borders almost parallel in front, ventral curving more strongly toward cauda than dorsal; cauda long, slightly arched downward in first two-thirds, curving downward strongly in last third, posterior end rounded, facing ventral margin; area depressed, extending along first two-thirds of cauda; cristae absent. Outer face concave, with grooves extending from a horizontal thick area toward dorsal and ventral margins; margins sinuous, anterior and posterior ends flexed outward, anterior end more

strongly flexed than posterior. Dimensions in mm.:

<u>Length</u>	<u>Height</u>	<u>Thickness</u>	<u>Remarks</u>
4.5	3.3	0.3	specimen worn
3.7	2.9	0.3	" "

Type Locality: Red Bluff Clay; Hiwannee (formerly Red Bluff; type locality of formation), Wayne County, Mississippi.

Range and Distribution: Oligocene, Vicksburg Group: Red Bluff Clay; Hiwannee, Wayne County, Mississippi.

Comparisons: This species can be differentiated from Genus C sp. 2 by the following characters: (1) The cauda is strongly sigmoid here, but is is gently sigmoid in the other species. (2) Only the dorsal dome is present in this species. In Genus C sp. 2, the anterodorsal and dorsal domes are present. (3) The ventral border of the ostium slopes strongly to meet the cauda; the dorsal does not. In Genus C sp. 2 both borders slope gently and evenly to join the cauda. (4) The ventral margin has anteroventral, ventral, and posteroventral domes slightly developed. In Genus C sp. 2 no domes developed. (5) The posterodorsal angle is domed, and the posterodorsal slope obliquely truncate toward posterior margin more strongly than in Genus C sp. 2.

#### Genus C species 2

#### Plates 1 Figures 5a-c

Description: Sagitta medium size (maximum length observed 3.8 mm.) roughly subquadrate, moderately high (height/length ratio observed 76 per cent), concavoconvex, thin. Dorsal margin almost horizontal, with anterodorsal and dorsal domes developed, margin sloping gently from

anterodorsal dome toward anterior margin and behind posterodorsal angle toward posterior margin; ventral margin skewed forward, sinuous; posterior margin somewhat acute; anterior margin with short antirostrum, angular, shallow excisura. Inner face convex, generally smooth, except near margins where some elongate "humps" extending toward dorsal and ventral margins; thickest point below cauda; sulcus divided, long; ostium short, wider than cauda, subovate, dorsal and ventral borders almost parallel in front, converging evenly and gently backward to meet cauda, opening onto anterior margin; cauda long, deep, with parallel sides, arching downward gently in first two-thirds, then curving downward in last third, forming sigmoid shape, posterior end rounded, facing ventral margin; area excavated, extending along about two-thirds of cauda; crista superior well developed, extending along area, crista inferior lacking; ventral furrow absent. Outer face concave, with grooves running from horizontal area toward margins, anterior and posterior ends slightly flexed outward. Dimensions in mm.:

<u>Length</u>	<u>Height</u>	<u>Thickness</u>	<u>Remarks</u>
3.8	2.8	0.4	specimen broken

Type Locality: Byram Marl; Old Byram (type locality of formation), Hinds County, Mississippi.

Range and Distribution: Oligocene, Vicksburg Group: Byram Marl; Old Byram, Hinds County, Mississippi.

Comparisons: This species can be differentiated from Genus C sp. 1 by the following characters. (1) In this species anterodorsal and dorsal domes are present, whereas in Genus C sp. 1 only the dorsal dome occurs.



(2) The cauda is gently sigmoid in Genus C sp. 2. In the other form it is arched slightly downward in the first two-thirds, then strongly curving downward in the last third. (3) The borders of the ostium slope evenly backward to join the cauda. In Genus C sp. 1 the ventral border slopes more strongly to join the cauda than does the dorsal. (4) The ventral margin has no domes in this species. In Genus C sp. 1 anteroventral, ventral, and posteroventral domes are developed. (5) The posterodorsal slope is truncated in both species, but the inclination is much steeper in Genus C species 1 than in this species.

#### Family position uncertain

#### Genus D

Type species: Genus D species 1.

Diagnosis: Sagitta medium size, roughly subelliptical, moderately high, somewhat concavoconvex. Inner face smooth, convex; outer face somewhat concave, with thickest point along ventral side, dorsal side depressed. Dorsal margin with dorsal, posterodorsal, and anterodorsal domes slightly developed; ventral margin smooth, skewed forward; posterior margin acute, posterodorsal angle and slope present. Ostium subquadrate, wider than cauda, dorsal border sloping gently toward cauda, while ventral slopes strongly toward cauda. Cauda straight, almost horizontal, with parallel borders in first three-fourths, curving downward strongly forming 90° in last fourth. Area extending along straight part of cauda, crista superior developed along area. Anterior and posterior ends flexed outward.

Content: At least two species apparently belong to the genus.

Range and Distribution: Eocene, Jackson Group: Shubuta Clay; Shubuta, Clarke County, Mississippi; Moodys Branch Marl (?); Jackson, Hinds County, Mississippi (Koken; see below).

Comparisons: This genus can be distinguished from Genus G by the following characters: (1) The sagitta is somewhat lower. (2) The cauda curves strongly downward to make almost a right angle, but in Genus G it makes almost a semicircle. (3) The posterodorsal slope inclines strongly toward the posterior margin in this genus, but in Genus G it is stronger, forming an obtuse angle with the posterior margin. (4) The cauda is almost horizontal in the first three-fourths in this genus. In Genus G it is slightly oblique downward. (5) The posteroventral slope is lacking in this genus, but it is well developed in Genus G.

Remarks: The unique specimen of the type species of this genus is extremely similar to illustrations of "Otolithus (Carangidarum) americanus" Koken (1888, pp. 277-278, pl. 17, figs. 1-3), of the Jackson Eocene, and some otolithologists probably would regard the forms as specifically identical. It seems that they should, at least provisionally, be considered to be congeneric.

Genus D species 1

Plate 4 Figures 5a-c

Description: Sagitta medium size, (maximum length observed 3.4 mm.) subelliptical, moderately high, (height/length ratio 65 per cent), somewhat concavoconvex, quite thick. Dorsal margin low, arched, anterodorsal and posterodorsal domes slightly developed, dorsal dome

more prominent, posterodorsal angle broadly domed, sloping strongly to posterior margin, front margin sloping gently toward anterior; ventral margin broadly rounded, slightly skewed forward; anterior margin with short rostrum and antirostrum; posterior margin acute. Inner face convex, generally smooth except undulating toward dorsal margin; sulcus long, divided, somewhat narrow, ostium wider than cauda, subquadrate, with dorsal and ventral borders parallel to each other and to those of cauda, ventral border sloping strongly to join cauda, dorsal sloping gently; cauda long, with almost parallel sides, narrow, partly filled with colliculum, straight, almost horizontal or slightly arched downward in first three-fourths, then curving strongly downward to make almost right angle in last fourth, posterior end subrounded, facing ventral margin, without postcaudal trough; area depressed, extending along horizontal part of cauda; crista superior developed, crista inferior and ventral furrow lacking. Outer face somewhat concave, thickest point on ventral side along horizontal line, dorsal side depressed; margins smooth, thin; anterior and posterior ends flexed outward. Dimensions in mm.:

<u>Length</u>	<u>Height</u>	<u>Thickness</u>	<u>Remarks</u>
3.4	2.2	0.75	specimen worn

Type Locality: Shubuta Clay: Shubuta (type locality of formation), Clarke County, Mississippi.

Range and Distribution: Eocene, Jackson Group: Shubuta Clay; Shubuta, Clarke County, Mississippi.

Remarks: This specimen was inadvertently included in material supplied by D.L. Frizzell. Its relationships will be established by future

studies.

Family Sparidae

Genus E

Type Species: Genus E species 1.

Diagnosis: Sagitta small to medium size, subovate to subelliptical, concavoconvex or somewhat biconvex. Dorsal margin broadly arched, with posterodorsal angle sometimes domed, dorsal margin rough, smooth, or with grooves looped at margin; ventral margin broadly rounded, evenly or somewhat skewed forward, smooth or somewhat sinuous, with long rostrum, and antirostrum, excisura deep, angular; area depressed; ostium subovate or subquadrate, dorsal and ventral borders parallel, converging somewhat evenly to meet caudal borders; cauda straight, horizontal or inclined downward in first two-thirds, curved downward in last third; crista superior well developed, crista inferior usually absent; ventral furrow sometimes developed. Outer face irregularly concave, sometimes with grooves or "humps" radiating from thick central area toward margins, in other species depressed toward dorsal side with pustules toward dorsal margin and thickest point along ventral side.

Content: Five species known.

Range and Distribution: Oligocene, Vicksburg Group: Byram Marl; Old Byram (type locality of formation), Hinds County, Mississippi; Glendon Limestone; Brandon, Rankin County, Mississippi; Red Bluff Clay; Hiwannee (formerly Red Bluff, type locality of formation), Wayne County, Mississippi. Eocene, Claiborne Group: Wheelock Formation; Burleson County, Texas; Stone City Beds; Burleson County, Texas, Jackson Group: Moodys

Branch Marl; Jackson (re-selected type locality of formation), Hinds County, Mississippi; and Montgomery, Grant Parish, Louisiana.

Comparisons: To differentiate between this genus and "Nemipterus" the following differences must be considered: (1) The ostium here has parallel borders until the last part of the ostium, where they converge evenly to meet the caudal borders. In "Nemipterus" the borders of the ostium are not parallel, as the ventral curves more strongly than the dorsal. (2) The sagitta is relatively lower here than in "Nemipterus" (height/length ratio lower). (3) This genus has a relatively longer rostrum and antirostrum, and deeper, more angular excisura. (4) The size is relatively less.

Remarks: Genus E resembles the Recent genus Boops Cuvier of the Family Sparidae, to which this genus is referred. The sagitta of the type species, Boops boops (Linnaeus), differs from the fossil otoliths chiefly in having a higher dorsal margin that slopes more gently toward the anterior margin.

Genus E species 1

Plate 3 Figures 1a-c

Description: Sagitta medium size (maximum length observed, 3.3 mm.), subelliptical, moderately high (height/length ratios, 60-68 per cent), concavoconvex. Dorsal margin broadly arched, with low grooves running from area toward it, margin rough, posterodorsal angle sometimes domed, posterodorsal slope obliquely truncate toward posterior margin; ventral margin broadly arched, sometimes evenly, other times somewhat skewed forward, serrate, anterior margin with long rostrum, short antirostrum and

angular fairly deep excisura; posterior margin acute. Inner face mostly smooth below sulcus; sulcus divided, long; ostium shorter than cauda, with dorsal and ventral borders parallel, converging evenly and gently toward cauda, partly filled with colliculum, opening widely onto anterior margin; cauda long, deep, narrower than ostium, straight or slightly arched down horizontal till about last fourth where it curves downward, posterior end rounded, facing ventral margin; area excavated, extending along horizontal part of cauda; crista superior well developed, extending along area, crista inferior lacking. Outer face concave, thickest point along ventral side; dorsal side depressed, with pustules toward dorsal margin; anterior and posterior ends flexed outward but anterior end flexed more than posterior. Dimensions in mm.:

<u>Length</u>	<u>Height</u>	<u>Thickness</u>	<u>Remarks</u>
2.5	1.7	0.3	Glendon Limestone
2.3	1.3	0.3	worn, Red Bluff Clay
3.3	2.0	0.5	" " " "
3.0	2.0	0.5	Byram Marl

Type Locality: Red Bluff Clay: Hiwannee (formerly Red Bluff; type locality of formation), Wayne County, Mississippi.

Range and Distribution: Oligocene, Vicksburg Group: Byram Marl; Old Byram (type locality of formation), Hinds County, Mississippi; Glendon Limestone; Brandon, Rankin County, Mississippi; Red Bluff Clay; Hiwannee, Wayne County, Mississippi.

Comparisons: This species can be differentiated from Genus E sp. 3 by the following characters: (1) In this species the sagitta is longer and higher than in Genus E sp. 3. (2) The cauda is horizontal, straight in the first three-fourths, then curving downward strongly, but in the

other form it is inclined downward, straight in the first two-thirds, then curving gently downward. (3) The sculpture on the outer face is different, as there is no depressed area around the center and the "humps" are not common in this species.

This species can easily be confused with Genus E sp. 5 unless the following characters are considered: (1) The ostium is comparatively narrower here, so the ostial borders converge to join the cauda gently and not as strongly as in Genus E sp. 5. (2) The rostrum here is longer than that of Genus E sp. 5.

#### Genus E species 2

#### Plate 3 Figures 2a-c

Description: Sagitta medium size (maximum length observed, 3.3 mm.), subovate, moderately high (height/length ratios, 73-80 per cent), somewhat concavoconvex. Dorsal margin broadly rounded, sloping more steeply toward posterior margin than toward anterior, highest point around middle of margin, posterodorsal angle sometimes present, broadly arched, posterodorsal slope obliquely truncate toward posterior margin; ventral margin broadly rounded, skewed forward, lowest point on front third of margin; posterior margin acute; anterior margin with long rostrum, antirostrum short, excisura angular, shallow, excisural deposit straight, sloping forward. Inner face smooth, convex, thickest point below cauda; sulcus long, divided, opening onto anterior margin, ending far from posterior end of sagitta; ostium short, wider than cauda, subquadrate, dorsal and ventral borders usually parallel until posterior part where they converge, but in some juveniles

converging toward cauda; cauda long, straight, usually horizontal but in some young specimens inclined slightly downward, with parallel sides in first two-thirds, then curving downward strongly in last third, posterior end rounded, facing ventral margin, without postcaudal trough; area excavated extending along horizontal part of cauda; crista superior well developed only along area, crista inferior lacking, ventral furrow sometimes present. Outer face somewhat concave, irregularly, thickest point around center of otolith or somewhat toward ventral side; anterior and posterior ends flexed outward. Dimensions in mm.:

<u>Length</u>	<u>Height</u>	<u>Thickness</u>
3.0	2.2	0.7
2.0	1.6	0.5
3.3	2.4	0.7

Type Locality: Glendon Limestone: Brandon, Rankin County, Mississippi.

Range and Distribution: Oligocene, Vicksburg Group: Glendon Limestone; Brandon, Rankin County, Mississippi.

Comparisons: This species can be differentiated from Genus E sp. 3 by the following characters. (1) The otolith is higher than in that form. (2) The posterodorsal slope is stronger in its slope toward the posterior margin. (3) The cauda usually is horizontal in its first two-thirds rather than sloping downward. (4) The curvature of the last third of the cauda is stronger. (5) It has a longer rostrum and deeper, more angular excisura. (6) The margins are smooth rather than scalloped. (7) The outer face has its thickest point on the center or somewhat toward the ventral margin rather than being depressed at the center.



## Genus E species 3

## Plate 3 Figures 3a-c

Description: Sagitta small (maximum length observed, 2.8 mm.) subovate, moderately high (height/length ratios, 68-74 per cent), somewhat concavo-convex. Dorsal margin broadly arched in first two-thirds, then sloping strongly to posterior margin in last third, posterodorsal angle not well developed, margin irregularly sinuous, posterodorsal slope obliquely truncate; ventral margin broadly rounded, somewhat skewed forward, somewhat sinuous or scalloped in posterior part; posterior margin acute; anterior margin with short, rounded antirostrum and shallow excisura, (rostrum not preserved). Inner face smooth, with some low "humps" running toward margins especially dorsal; sulcus long; ostium wider than cauda, with dorsal and ventral borders parallel, converging evenly and gently to join cauda; cauda long, straight, inclined gently downward, straight until last third then curving downward gently, posterior end rounded, facing ventral margin; area excavated, extending along straight part of cauda, crista superior well developed, extending along area, crista inferior lacking, ventral furrow slightly developed. Outer face concave, sculptured with elongate "humps" radiating from depressed area in center toward margins; anterior and posterior ends flexed outward.

Dimensions in mm.:

<u>Length</u>	<u>Height</u>	<u>Thickness</u>	<u>Remarks</u>
2.6	1.8	0.4	specimen broken
2.8	1.9	0.5	" "

Type Locality: Byram Marl: Old Byram (type locality of formation), Hinds County, Mississippi.

Range and Distribution: Oligocene, Vicksburg Group: Byram Marl; Old Byram (type locality of formation), Hinds County, Mississippi; Glendon Limestone; Brandon, Rankin County, Mississippi; Red Bluff Clay; Hiwannee (formerly Red Bluff; type locality of formation), Wayne County, Mississippi.

Comparisons: The differences between this species and Genus E sp. 1 are: (1) In the latter the sagitta generally is longer and lower (height/length ratios in Genus E sp. 3 are 68-74 per cent, but in Genus E sp. 1 are only 60-68 per cent). (2) The cauda in this species inclines gently downward toward the back, straight in its first two-thirds then curving gently downward. In Genus E sp. 1 it is horizontal, straight in the first three-fourths, then curving downward more strongly than in Genus E sp. 3. (3) In this species the outer face has elongate "humps" radiating from a depressed area in the center toward the margins, but in Genus E sp. 1 the "humps" are less common and no depressed area is present around the center.

#### Genus E species 4

#### Plate 3 Figures 4a-c

Description: Sagitta small (maximum length observed, 3.0 mm.), subovate, moderately high (height/length ratios observed, 61-67 per cent), somewhat biconvex, fairly thick. Dorsal margin broadly rounded, with some crenulations or scallops with no domes developed, posterodorsal angle slightly formed or absent, margin sloping almost evenly and somewhat steeply toward anterior and posterior margins, highest point at about middle of margin; posterodorsal slope obliquely and gently inclined

toward posterior margin; ventral margin broadly rounded, somewhat skewed forward, serrate or with some crenulations, lowest point on front third of margin; posterior margin acute; anterior margin with somewhat long rostrum, pointing upward and sharp at front end, antirostrum short, somewhat rounded, excisura shallow, rounded. Inner face mostly smooth, except on dorsal side above area, where it is rough and sometimes with some low pustules ending at dorsal margin, thickest point below cauda; sulcus long, deep, divided, opening widely onto anterior margin; ostium short, wider than cauda, subovate, deep, dorsal and ventral borders parallel to each other and to those of cauda until posterior part of ostium, where they converge strongly and evenly to meet cauda; cauda long, deep, generally straight, horizontal in first two-thirds, then curving downward in last third, dorsal border straight in first two-thirds, but ventral slightly arching down, cauda narrower at junction with ostium, posterior end rounded, ending in shallow postcaudal trough, that reaches ventral margin; area excavated, extending along horizontal part of cauda; crista superior well developed, extending along area; crista inferior sometimes slightly developed, ventral furrow fairly well developed. Outer face somewhat convex, thickest point at about center or along a horizontal line below center, some elongate "humps" extend from central thick area toward margins; anterior and posterior ends flexed outward, former more flexed. Dimensions in mm.:

<u>Length</u>	<u>Height</u>	<u>Thickness</u>
3.0	2.0	0.6
2.6	1.8	0.4
2.0	1.3	0.3
2.0	1.3	0.3
1.8	1.2	0.25
1.8	1.2	0.25
1.7	1.1	0.2

<u>Length</u>	<u>Height</u>	<u>Thickness</u>
2.4	1.6	0.4
1.8	1.3	0.3

Type Locality: Wheelock Formation: Burleson County, Texas, at boundary with Brazos County.

Range and Distribution: Eocene, Claiborne Group: Wheelock Formation; Burleson County, Texas, at boundary with Brazos County; Stone City Beds; Burleson County, Texas, same locality as preceding.

Comparisons: The specimens of this species can easily be confused with young specimens of Genus E sp. 5. The differences between these two are: (1) This species is generally higher (height/length ratios, 61-67 per cent; Genus E sp. 5, 52-68 per cent). (2) The rostrum is shorter and somewhat tapering upwards; while Genus E sp. 5 is long and straight. (3) The excisura in this species is deeper than in Genus E sp. 5; the excisural deposit does not expand in front as in Genus E sp. 5. (4) The ventral furrow in this species is well developed, but not in Genus E sp. 5.

Genus E species 5

Plate 3 Figures 5a-c

Description: Sagitta small to medium size (maximum length measured, 3.0 mm.), subelliptical, moderately high (height/length ratios observed, 52-68 per cent), concavoconvex, somewhat thick. Dorsal margin broadly rounded, with dorsal, anterodorsal, and posterodorsal domes sometimes present, posterodorsal angle variably domed but posterodorsal slope always present, highest point at front third, at middle, or at posterior

third, posterodorsal slope descending sharply toward posterior margin, sometimes forming almost right angle, margin sloping gently toward anterior margin, margin sinuous; ventral margin broadly rounded, somewhat skewed forward, with lowest point on anterior third, mostly smooth anterior margin with fairly long rostrum, antirostrum short, excisura angular, excisural deposit protruding; posterior margin variably rounded or acute. Inner face mostly smooth on ventral side, with some undulations ending on dorsal margin, thickest point below cauda; sulcus long, divided, extending along most of sagitta; ostium wider than cauda, opening onto anterior, dorsal and ventral borders parallel to each other and to those of cauda, sloping somewhat strongly and evenly to meet cauda; cauda long, straight, with parallel sides, mostly horizontal in first two-thirds, then curving downward in last third, posterior end rounded, facing ventral margin, shallow postcaudal trough sometimes present terminating on ventral margin; area excavated, extending along horizontal part of cauda; crista superior well developed, extending along area, crista inferior lacking, ventral furrow absent. Outer face somewhat concave, thickest point on ventral side of sagitta, with some pustules ending toward dorsal margin, anterior and posterior ends flexed outward. Dimensions in mm.:

<u>Length</u>	<u>Height</u>	<u>Thickness</u>
1.7	1.1	0.2
1.75	1.0	0.3
1.8	1.1	0.25
1.8	1.0	0.3
1.9	1.2	0.25
1.9	1.1	0.3
1.9	1.1	0.3
1.9	1.1	0.25
1.9	1.1	0.4
1.9	1.1	0.25
2.0	1.3	0.3

<u>Length</u>	<u>Height</u>	<u>Thickness</u>
2.0	1.3	0.3
2.0	1.2	0.25
2.0	1.2	0.3
2.0	1.2	0.3
2.0	1.1	0.25
2.0	1.2	0.3
2.0	1.2	0.3
2.0	1.2	0.3
2.0	1.2	0.25
2.1	1.2	0.3
2.1	1.2	0.3
2.1	1.2	0.3
2.1	1.2	0.4
2.1	1.2	0.3
2.1	1.2	0.3
2.2	1.3	0.3
2.2	1.3	0.4
2.2	1.2	0.3
2.2	1.2	0.3
2.2	1.3	0.3
2.2	1.3	0.3
2.2	1.5	0.4
2.2	1.2	0.3
2.3	1.3	0.3
2.3	1.3	0.4
2.3	1.5	0.3
2.3	1.5	0.4
2.3	1.2	0.3
2.5	1.7	0.4
2.6	1.5	0.4
2.8	1.6	0.4
2.9	1.8	0.5
3.0	2.0	0.6

Type Locality: Moodys Branch Marl: Jackson (re-selected type locality of formation), Hinds County, Mississippi.

Range and Distribution: Eocene, Jackson Group: Moodys Branch Marl; Jackson, Hinds County, Mississippi; and Montgomery, Grant Parish, Louisiana. .

Comparisons: This species can be very easily confused with Genus E sp. 1, the only significant difference being that the ostium is somewhat wider than in that species, so that the curvature of the ostial

borders to meet the cauda in this form is not as strong as in Genus E sp. 1.

Young specimens of this species resemble Genus E sp. 4, the differences between both are as follows: (1) The ostium of the young of this species is narrower than that of the other form, the dorsal and ventral borders of the ostium sloping more strongly to meet cauda in Genus E sp. 4 than in this species. (2) The rostrum in Genus E sp. 5 is longer and extends straight forward. In Genus E sp. 4 it points somewhat upward at the tip. (3) The excisural deposit in this species protrudes, but it does not in adult otoliths of the other species. (4) The crista inferior and ventral furrow, lacking in Genus E sp. 5, are present in Genus E sp. 4.

Family position uncertain

Genus F

Type Species: Genus F species 1.

Diagnosis: Sagitta medium size to somewhat large, subelliptical, somewhat biconvex or planoconvex. Dorsal margin in some cases low, almost flat in dorsal part, obliquely truncate in posterodorsal part, posterodorsal angle developed; in other cases dorsal margin broadly and almost evenly rounded; ventral margin broadly rounded, with posterodorsal slope not truncate; ventral margin broadly rounded, slightly skewed forward; posterior margin widely rounded or acute; anterior margin with relatively long rostrum, and short antirostrum, excisura angular, somewhat shallow, margins scalloped. Inner face convex, with grooves running toward margins (dorsal, ventral, and posterior); ostium subovate,

ventral and dorsal borders not parallel, ventral curving somewhat stronger toward cauda than dorsal; cauda long, mostly horizontal or curved downward in last fifth, end rounded widely, square, or angular, post-caudal trough sometimes developed; crista inferior, ventral furrow slightly developed, crista superior well developed, extending along area, area excavated. Outer face somewhat convex, elongated "humps" running from central thick area toward margins, thickest point around center or below; anterior end flexed outward.

Content: Two species known.

Range and Distribution: Oligocene, Vicksburg Group: Byram Marl; Old Byram (type locality of formation), Hinds County, Mississippi; Glendon Limestone; Brandon, Rankin County, Mississippi; Red Bluff Clay; Hiwannee (formerly Red Bluff; type locality of formation), Wayne County, Mississippi; Red Bluff equivalent; St. Stephens, Washington County, Alabama. Eocene, Claiborne Group: Stone City Beds; Burleson County, Texas; Lisbon Formation; Claiborne, Monroe County, Alabama.

Comparisons: The differences between this genus and Genus E are: (1) The dorsal margin sometimes has no posterodorsal angle or slope, is scalloped, and the highest point is on the ventral third. (2) The posterior margin is sometimes widely rounded rather than acute. (3) The ostium is subovate, with the ventral border making a right angle or somewhat gently curving at the junction with the caudal border; the dorsal margin slopes gently and evenly toward the caudal border. (4) The cauda is straight or arching slightly down, almost horizontal or slightly curving down in its last fourth, sometimes somewhat strongly curving down in the last fifth; the posterior end is widely rounded,



square, or angular, terminating almost at the posterior end of the sagitta.

Genus F species 1

Plate 4 Figures 1a-c

Description: Sagitta medium size (maximum length observed, 3.8 mm.), subelliptical, moderately high (height/length ratios, 50-68 per cent), biconvex. Dorsal margin broadly arched, evenly or somewhat skewed forward, highest point on anterior third, scalloped, dorsal angle not developed; ventral margin broadly rounded, scalloped, with about same curvature as dorsal; posterior margin broadly rounded, with some scallops; anterior margin with relatively long rostrum, antirostrum short, excisura short, angular. Inner face smooth, convex, with some grooves running toward ventral dorsal and posterior margins; sulcus long, divided; ostium wide, partly filled with colliculum, subovate, dorsal and ventral borders diverge from back to front until almost parallel to each other and to those of cauda where they approach anterior end, posterior part of ventral border of ostium extending vertically to meet ventral border of cauda, ostium opening widely onto anterior margin; cauda long, mostly straight and horizontal, but sometimes curving down very slightly in last fourth, with parallel sides, deep, posterior end angular or square, when angular, angularity is a result of downward curvature of dorsal border of cauda, while ventral border stays straight, cauda ends almost at posterior margin of sagitta, sometimes with shallow postcaudal trough; area excavated, extending along about three-fourths of cauda; crista superior well developed,

extending along area, crista inferior slightly developed, ventral furrow present. Outer face convex, thickest point at center, with elongated "humps" running from horizontal thick zone in central area of sagitta toward ventral, dorsal and posterior margins; anterior end flexed outward. Dimensions in mm.:

<u>Length</u>	<u>Height</u>	<u>Thickness</u>
1.0	0.6	0.2
1.0	0.5	0.2
1.4	0.9	0.2
1.9	1.2	0.25
1.9	1.2	0.3
1.9	1.2	0.3
1.9	1.1	0.3
2.1	1.3	0.3
2.1	1.3	0.3
2.2	1.4	0.4
2.2	1.4	0.4
2.2	1.4	0.4
2.3	1.5	0.4
2.8	1.7	0.5
3.0	1.9	0.5
3.1	2.0	0.5
3.8	2.3	0.5

Type Locality: Red Bluff Clay: Hiwannee (formerly Red Bluff; type locality of formation), Wayne County, Mississippi.

Range and Distribution: Oligocene, Vicksburg Group: Byram Marl; Old Byram (type locality of formation), Hinds County, Mississippi; Glendon Limestone; Brandon, Rankin County, Mississippi; Red Bluff Clay; Hiwannee (formerly Red Bluff; type locality of formation), Wayne County, Mississippi; Red Bluff equivalent; St. Stephens, Washington County, Alabama.

Comparisons: Genus F sp. 1 differs from Genus F sp. 2 in the following characters: (1) The dorsal margin is high and almost evenly rounded; it is low, with an anterodorsal dome and posterodorsal angle developed in Genus F sp. 2. (2) The posterior margin is widely rounded in Genus F

sp. 1, but it is acute, with a truncation from the posterodorsal angle toward it, in Genus F sp. 2. (3) The shape of the sagitta is different, as the height decreases gradually and slightly in this species, but faster in the other. (4) The ventral border extends almost vertically to that of the cauda in this species, while in Genus F sp. 2 the ventral border slopes gradually until it joins the caudal border. (5) The cauda is mostly horizontal with parallel sides, angular or square at the end, being followed by a postcaudal trough. Genus F sp. 2 has the cauda horizontal or slightly arched downward in the first four-fifths, then curving down in the last fifth; it is wider in the last fifth, rounded at the end, and without postcaudal trough. (6) The otolith of this species is biconvex, relatively thick, the thickest point being on the outer face at the center. In Genus F sp. 2 it is plano- to biconvex and relatively thinner, the thickest point being at the center of the outer face or on a ventral line below the center.

#### Genus F species 2

#### Plate 4 Figures 2a-c

Description: Sagitta medium size to medium large, roughly subelliptical, not high, planoconvex to somewhat biconvex, somewhat thin. Dorsal margin low, almost horizontal to slightly sloping backward in dorsal part, anterodorsal dome slightly formed, posterodorsal angle domed, posterodorsal slope obliquely truncate toward posterior margin, sometimes a low reentrant between anterodorsal dome and posterodorsal angle, margin irregularly scalloped; ventral margin broadly rounded, skewed forward, lowest point at front third, rough; posterior margin acute;

anterior margin with somewhat long rostrum and antirostrum, excisura short angular. Inner face generally smooth, except toward margins where some pustules developed, convex, with long, deep, divided sulcus; ostium wider than cauda, subovate, with dorsal and ventral borders diverging from back to front with ventral less in divergence than dorsal as it is almost parallel to that of cauda, ostium partly filled with colliculum; cauda long, with almost parallel borders, straight and horizontal or slightly arching down in first four-fifths, then curving downward in last fifth, deep, at last fifth where curving down wider than rest, postcaudal trough lacking, posterior end rounded; area excavated, extending along about four-fifths of cauda, crista superior well developed along area, crista inferior not well developed, ventral furrow slightly developed. Outer face almost flat to somewhat convex, thickest point around center or on horizontal line below center of sagitta, some "humps" running toward margins; anterior end flexed somewhat outward.

Type Locality: Stone City beds: Burleson County, Texas, at boundary with Brazos County.

Range and Distribution: Eocene, Claiborne Group: Stone City Beds; Burleson County, Texas; Lisbon Formation; Claiborne, Monroe County, Alabama.

Comparisons: Genus F sp. 2 can be distinguished from Genus F sp. 1 by the following characters: (1) The dorsal margin is low, with slightly developed anterodorsal dome and well-domed posterodorsal angle in this species. The dorsal dome in the other is smoothly, evenly, and widely arched, and its curvature is almost the same as that of the ventral margin. (2) The posterior margin is acute and the posterodorsal slope

obliquely truncate toward the posterior margin in this species, while the posterior margin is rounded with no posterodorsal truncation, in Genus F sp. 1. (3) The height of the sagitta decreases more in Genus F sp. 2 from front to back than in Genus F sp. 1. (4) The ostium has no posterior border at the junction with the cauda, but in Genus F sp. 1 it has a posterior border which runs almost vertically from the ventral margin of the ostium to join the ventral border of the cauda. (5) The cauda in Genus F sp. 2 is curved and wider at the last fifth, with rounded end, and horizontal or slightly arched downward in the first four-fifths, while in Genus F sp. 1 the cauda is horizontal, or sometimes slightly curved downward in the posterior fourth, angular or square at the posterior end, and with a postcaudal trough. (6) This species is planconvex to biconvex, relatively thin, the thickest point on the outer face at the center or on a horizontal line below the center; in Genus F sp. 1 the sagitta is biconvex, thicker, and with the thickest point on the outer face at the center of the sagitta. (7) Fewer "humps" are present on the outer face.

#### Genus G

Type Species: Genus G species 1

Diagnosis: Sagitta medium size, roughly subquadrate, moderately high, dorsal dome present, posterodorsal angle domed. Posterodorsal slope obliquely truncate. Ostium subquadrate, with dorsal border sloping gently to join cauda, sloping strongly; cauda long, narrow, slightly sloping downward in first three-fourths, then curving downward strongly to form a semicircle.

Content: A single species known.

Range and Distribution: Eocene, Jackson Group: Shubuta Clay; Shubuta (type locality of formation), Clarke County, Mississippi.

Comparisons: This genus is different from Genus D in having the cauda oblique rather than horizontal in the first three-fourths, curving downward more strongly in the last fourth. The sagitta is generally higher, the posterodorsal slope inclines very strongly toward the posterior margin, making an angle of more than 90 degrees with the posterior margin, and the posteroventral slope is developed in this genus but not in Genus D.

The following characters differentiate this genus from Genus C:

- (1) The outline of the sagitta is roughly subquadrate.
- (2) The posterodorsal slope is obliquely truncate, forming an obtuse angle with the posterior margin.
- (3) The posteroventral slope is well developed.
- (4) The cauda is straight, oblique downward in its first three-fourths, then curving down strongly, forming a semicircle.
- (5) A postcaudal trough is present.
- (6) The outer face is depressed on the dorsal side, thick on the ventral.

Remarks: Only one broken specimen was encountered; more study on this genus is needed.

Genus G species 1

Plate 4 Figures 4a-c

Description: Sagitta medium size, (maximum length observed 3.0 mm.), subquadrate, moderately high, (height/length ratio observed, 70 per cent) concavoconvex dorsal margin gently arched upward, dorsal dome slightly developed, posterodorsal dome arched; ventral margin broadly rounded, ventral and posteroventral domes sometimes present, somewhat

skewed forward; posterodorsal angle domed, posterodorsal slope truncate very strongly to make obtuse angle with posterior margin, posterior margin broadly rounded. Inner face convex, smooth, with depressed area and long, divided sulcus; ostium short, wider than cauda, deep, subquadrate, dorsal border sloping gently to meet cauda, ventral sloping strongly to join cauda; cauda long, narrow, with parallel sides, straight, partly filled with colliculum, slightly sloping downward in first three-fourths, curving strongly downward to form almost a semicircle in last fourth, posterior end rounded, facing ventral margin; area extending along first two-thirds of cauda, depressed, with a steeper depression in its front part adjacent to connection between cauda and ostium; crista superior present along area, crista inferior lacking; postcaudal depression running from end of cauda to ventral margin; ventral furrow present. Outer face irregularly concave, depressed on dorsal side, thickest point along ventral side. Dimensions in mm.:

<u>Length</u>	<u>Height</u>	<u>Thickness</u>	<u>Remarks</u>
3.0	2.1	0.7	specimen broken

Type Locality: Shubuta Clay: Shubuta, (type locality formation), Clarke County, Mississippi.

Range and Distribution: Eocene, Jackson Group: Shubuta Clay; Clarke County, Mississippi.

## Plate One

## Explanation of Figures

1. Genus A sp. 1. Eocene, Wilcox Group, Nanafalia Formation, Alabama; 1a, inner face of right sagitta; 1b, outer face, 1c, dorsal margin; length, 4.2 mm., height, 3.8 mm.
2. "Nemipterus" sp. 4. Eocene, Claiborne Group, Stone City Beds; Texas; 2a, inner face of right sagitta; 2b, outer face; 2c, dorsal margin length, 2.9 mm., height, 2.6 mm.
3. "N. virgatus (Houttuyn). Recent; Taiwan; 3a, inner face of left sagitta; 3b outer face; 3c, dorsal margin; length, 8.8 mm., height, 6.0 mm.
4. Genus C sp. 1. Oligocene, Vicksburg Group, Byram Marl; Mississippi; 4a, inner face of left sagitta; 4b, outer face; 4c, dorsal margin; length, 4.4 mm., height 3.2 mm.
5. Genus C sp. 2. Oligocene, Vicksburg Group, Byram Marl; Mississippi; 5a, inner face of right sagitta; 5b, outer face; 5c, dorsal margin; length, 3.7 mm., height, 2.8 mm.



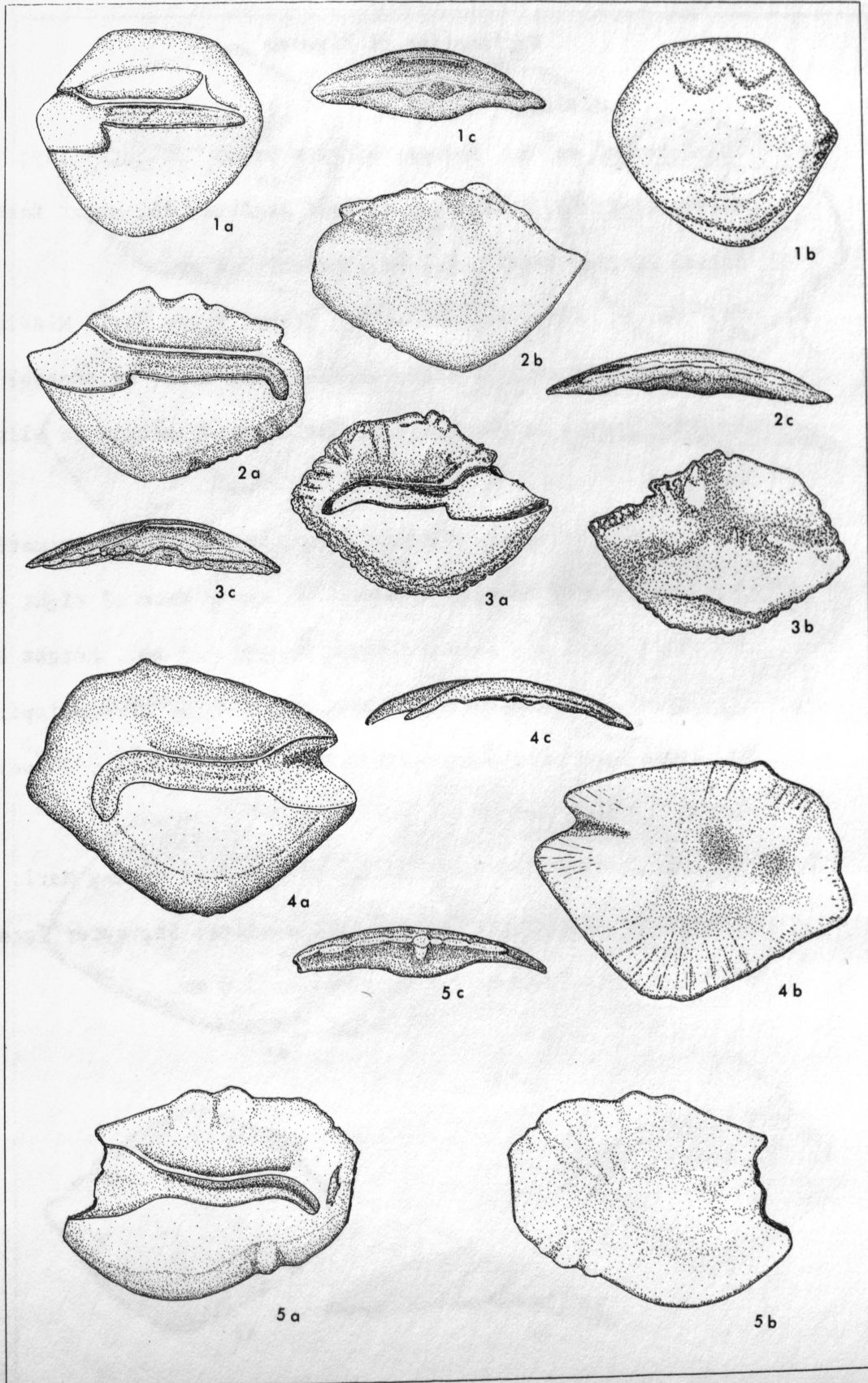


Plate 1

## Plate Two

## Explanation of Figures

1. "Nemipterus" sp. 1. Eocene, Jackson Group, Shubuta Clay; Mississippi; 1a, inner face of left sagitta; 1b, outer face; 1c, dorsal margin; length, 6.7 mm., height 5.1 mm.
2. "N." sp. 3. Oligocene, Vicksburg Group, Byram Marl; Mississippi; 2a, inner face of left sagitta; 2b, outer face; 2c, dorsal margin; length 6.3 mm., height 4.8 mm. The anterior margin is slightly restored.
3. "N." sp. 5. Paleocene, Midway Group, Porters Creek Formation, Matthews Landing Member; Alabama; 3a, inner face of right sagitta; 3b, outer face; 3c, dorsal margin; length 4.2 mm., height 2.8 mm.
4. "N." sp. 6. Eocene, Wilcox Group, Bashi Marl; Mississippi; 4a, inner face of right sagitta; 4b, outer face; 4c, dorsal margin; length 5.8 mm., height 3.8 mm.
5. "N." sp. 2. Oligocene, Vicksburg Group, Mint Spring Marl; Mississippi; 5a, inner face of left sagitta; 5b, outer face; 5c, dorsal margin; length, 4.0 mm., height 3.0 mm.

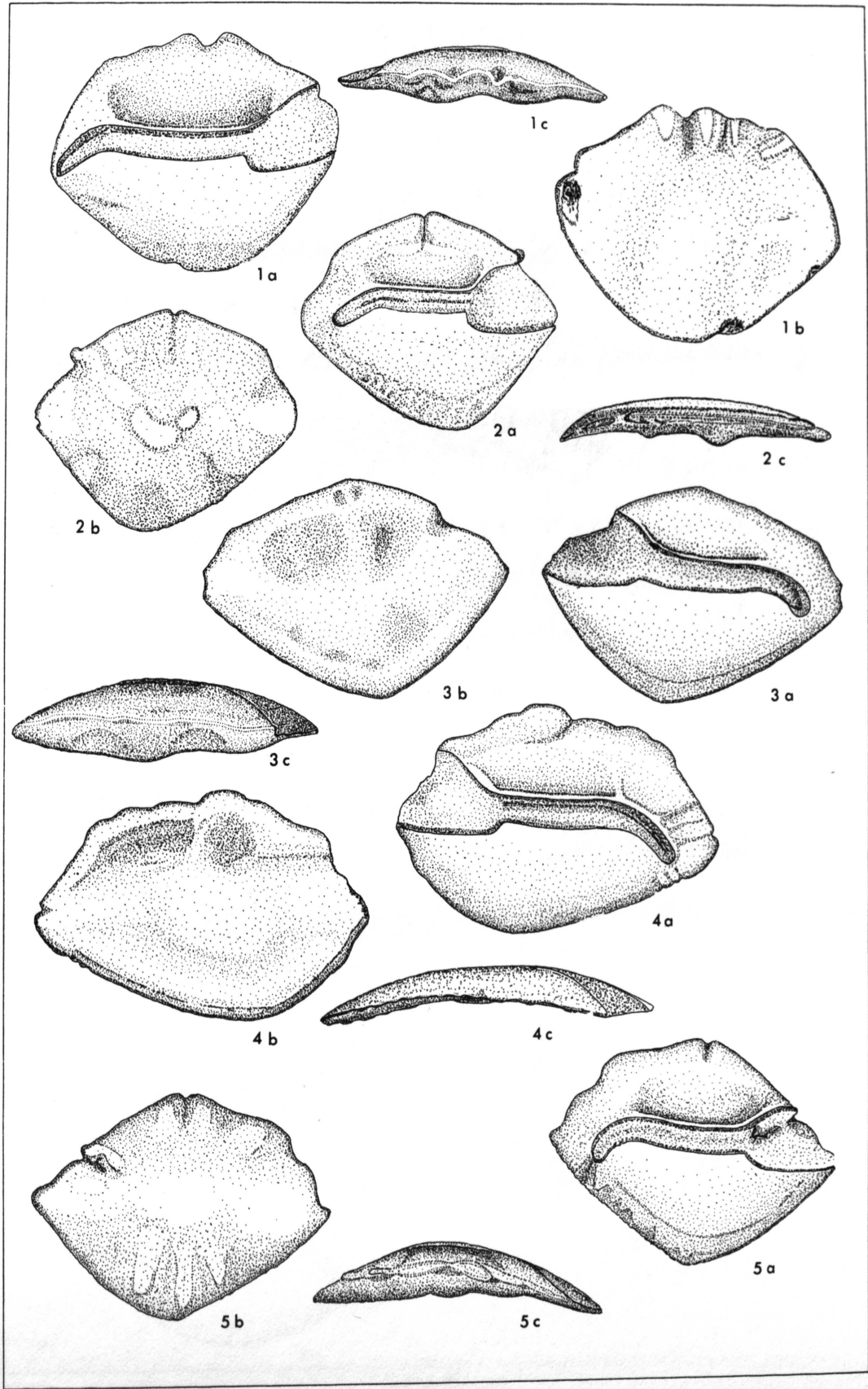


Plate 2

## Plate Three

## Explanation of Figures

1. Genus E sp. 1. Oligocene, Vicksburg Group, Red Bluff Clay; Mississippi, 1a, inner face of right sagitta; 1b, outer face; 1c, dorsal margin; length, 3.3 mm., height, 2.0 mm.
2. Genus E sp. 2. Oligocene, Vicksburg Group, Glendon Limestone; Mississippi; 2a, inner face of right sagitta; 2b, outer face; 2c, dorsal margin; length, 3.0 mm., height, 2.2 mm.
3. Genus E sp. 3. Oligocene, Vicksburg Group, Byram Marl; Mississippi; 3a, inner face of right sagitta; 3b, outer face; 3c, dorsal margin; length, 2.5 mm., height, 2.0 mm.
4. Genus E sp. 4. Eocene, Claiborne Group, Wheelock Formation; Texas; 4a, inner face of right sagitta, 4b, outer face; 4c, dorsal margin; length, 3.0 mm., height, 2.1 mm.
5. Genus E sp. 5. Eocene, Jackson Group, Moodys Branch Marl; Mississippi; 5a, inner face of right sagitta; 5b, outer face; 5c, dorsal margin; length, 3.0 mm., height, 2.0 mm.

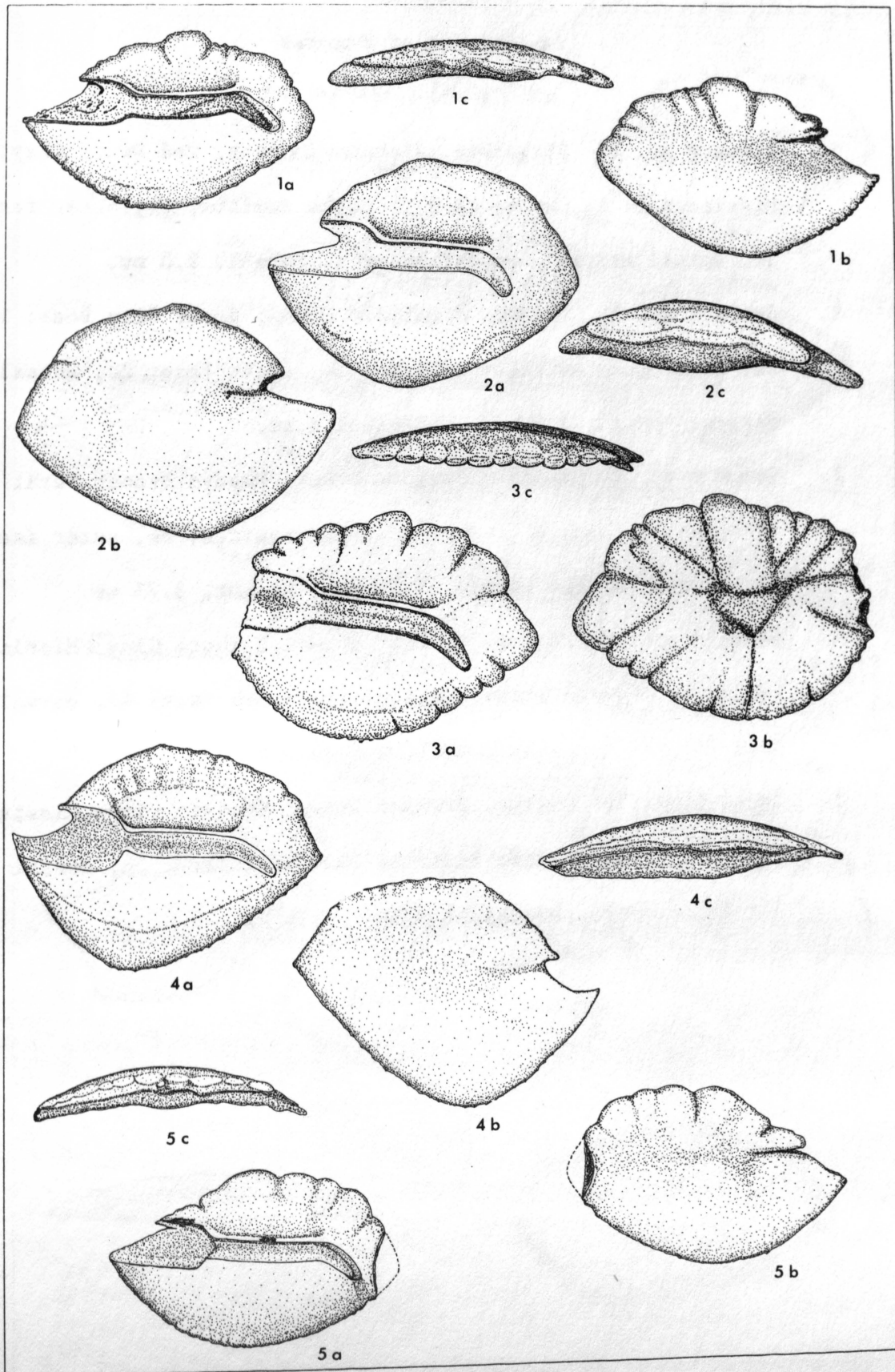


Plate 3

## Plate Four

## Explanation of Figures

1. Genus F sp. 1. Oligocene, Vicksburg Group, Red Bluff Clay; Mississippi; 1a, inner face of right sagitta; 1b, outer face; 1c, dorsal margin; length, 3.4 mm., height, 2.0 mm.
2. Genus F sp. 2. Eocene, Claiborne Group, Stone City Beds; Texas; 2a, inner face of right sagitta; 2b, outer face; 2c, dorsal margin; length, 2.5 mm., height, 1.4 mm.
3. Genus B sp. 1. Eocene, Jackson Group, Moodys Branch Marl; Mississippi; 3a, inner face of right sagitta; 3b, outer face; 3c, dorsal margin; length, 5.75 mm., height, 3.75 mm.
4. Genus G sp. 1. Eocene, Jackson Group, Shubuta Clay; Mississippi; 4a, inner face of right sagitta; 4b, outer face; 4c, dorsal margin; length, 2.8 mm., height, 2.0 mm.
5. Genus D sp. 1. Eocene, Jackson Group, Shubuta Clay; Mississippi; 5a, inner face of left sagitta; 5b, outer face; 5c, dorsal margin; length, 3.6 mm., height, 2.0 mm.



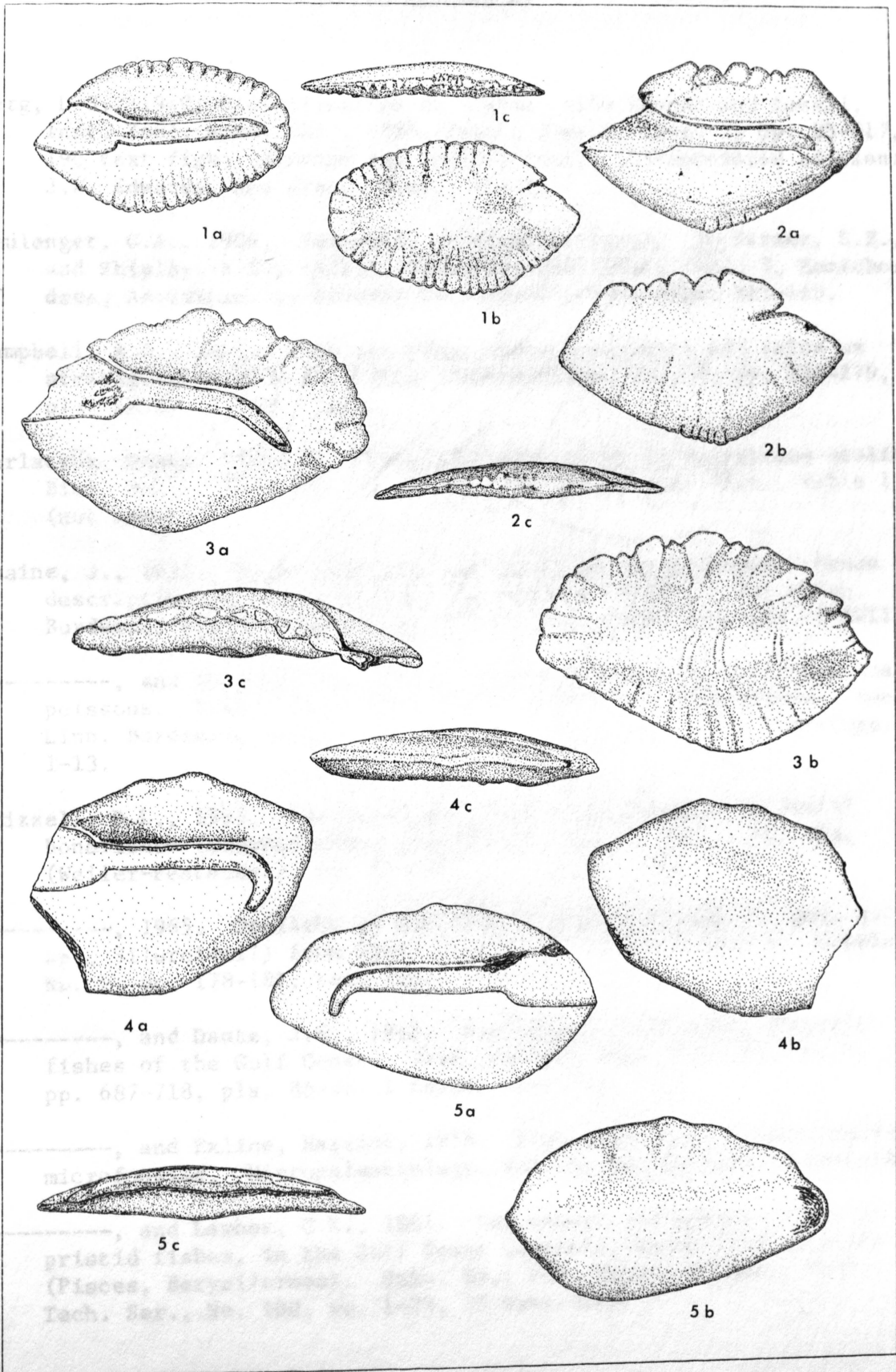


Plate 4

## SELECTED REFERENCES

- Berg, L.S., 1940, Classification of fishes, both Recent and fossil. Inst. Zool. Acad. Sci., URSS, Trav., Tome 5, livr. 2, pp. 85-517, 190 text figs. (Russian and English text). (Lithoprinted edition: J.W. Edwards, Ann Arbor, Mich., 1947).
- Boulenger, G.A., 1904, Teleostei (Systematic Part). In Harmer, S.F., and Shipley, A.E., (Eds.), Cambridge Nat. Hist., Vol. 7, Hemichordata, Ascidians..., Fishes, pp. 539-727, text-figs. 325-440.
- Campbell, R.B., 1929. Fish otoliths, their occurrence and value as stratigraphic markers. Jour. Paleontology, Vol. 3, pp. 254-279, pls. 28-30, 2 text-figs.
- Carlström, Diego, 1963. A crystallographic study of vertebrate otoliths. Biol. Bull., Vol. 125, No. 3, pp. 441-463, 5 text figs., table 1 (not seen).
- Chaine, J., 1935. Recherches sur les Otolithes des poissons. Etude descriptive de la sagitta des Teleosteens (suite). Soc. Linn. Bordeaux, Actes; tome 87, pp. 1-242, text-figs, 1-3, pls. I-XVIII.
- , and Duvergier, J. 1934. Recherches sur les otolithes des poissons. Etude descriptive de la sagitta des teleosteens. Soc. Linn. Bordeaux, Actes, tome 86, pp. 1-253, pls. 1-13, text-figs. 1-13.
- Frizzell, D.L., 1965. Otolith-based genera and lineages of fossil bonefishes (Clupeiformes, Albulidae). Senck. lefh., Bd. 46a, (Weiler-Festschr.), pp. 85-110, pl. 4, text figs. 1-2.
- , 1965. Otoliths of new fish (Vorhisia vulpes, n. gen. n. sp., Siluroidei?) from Upper Cretaceous of South Dakota. Copeia, No. 2, pp. 178-181, text-figs. 1-3.
- , and Dante, J.H., 1965. Otoliths of some early Cenozoic fishes of the Gulf Coast. Jour. Paleontology, Vol. 39, No. 4, pp. 687-718, pls. 86-88, 1 table, text-figs. 1,2.
- , and Exline, Harriet, 1958. Fish ossiculiths: unrecognized microfossils. Micropaleontology, Vol. 4, pp. 281-285, 7 text-figs.
- , and Lamber, C K., 1961. New genera and species of myripristid fishes, in the Gulf Coast Cenozoic, known from otoliths (Pisces, Beryciformes). Univ. Mo., Sch. Mines and Met., Bull., Tech. Ser., No. 100, pp. 1-25, 25 text-figs.



- , and -----, 1962. Distinctive "congrid type" fish otoliths from the lower Tertiary of the Gulf Coast (Pisces: Anguilliformes). Calif. Acad. Sci., Proc., 4th Ser., Vol. 32, pp. 87-101, 13 text-figs.
- Greenwood, P.H., Rosen, D.E., Weitzman, S.H., and Myers, G.S., 1966. Phyletic studies of teleostean fishes, with a provisional classification of living forms. Amer. Mus. Nat. Hist., Bull., Vol. 131, art. 4, pp. 339-455, pls. 21-23, text-figs. 1-9, charts 1-32.
- Koken, E., 1888 Neue Untersuchungen an tertiären Fischotolithen. Deutsche Geol. Gesell., Zeitschr., Vol. 40, pp. 274-304, pls. 17-19.
- Lamber, C K., 1963. Fossil and Recent beryciform otoliths; an adjunct to ichthyological classification. unpublished Masters thesis.
- Pointer, G.N., 1965. Taxonomic study of fossil and Recent otoliths of certain Cuskeels. Unpublished Masters thesis.
- Smith, J.L.B., 1961. The sea fishes of Southern Africa, 4th edition, (Cape Town, S. Afr.; Central News Agency, LTD.) pp. i-xvi, 1-580 pls. 1-111, Figs. 1-1232, A-V.
- Weiler, Wilhelm, 1968. Fossilium Catalogus, I:Animalia, Part 117, Otolithi piscium, pp. 1-196.

## VITA

Mostafa Juma Salem was born on September 12, 1945, in Zuara, Libya, North Africa. He received his primary and secondary education in Zuara, and his high school education in Zavia, Libya. In 1964 he entered the University of Libya - Faculty of Science in Tripoli. He received his Bachelors degree in Geology in May 1968. He was given an opportunity by the University of Libya on September 1968 to be a demonstrator in the Geology Department of the same institution. He was sent to enroll in the graduate school at the University of Missouri-Rolla for his Masters degree in September 1969.