Teleost Fish Otoliths from Lee Creek Mine, Aurora, North Carolina (Yorktown Formation: Pliocene)

John E. Fitch and Robert J. Lavenberg

ABSTRACT

Pliocene fossiliferous exposures at the Lee Creek Mine, Yorktown Formation, deposits yielded 8808 teleost otoliths. These represented at least 45 taxa distributed among 17 teleostean families including the following numbers of species by genus: Agonidae? (1), Ammodytidae (1), Bothidae (2, possibly 3), Branchiostegidae (1), Congridae (5), Cynoglossidae (1), Gadidae (5), Merlucciidae (3), Myctophidae (1), Ophidiidae (7), Pleuronectidae (1), Pomadasyidae (1), Pterothrissidae (1), Sciaenidae (7), Serranidae (4), Triglidae (2, possibly 3), Uranoscopidae (2). Generic names were assigned to 27 kinds of otoliths: *Ammodytes*, *Anisotremus*, *Astroscopus*, *Brotula*, *Centropristis*, *Ceratoscopelus*, *Citharichthys*, *Cynoscion*, *Diplectrum*, *Equetus*, *Gadus*, *Kathetostoma*, *Leiostomus*, *Lepophidium*, *Lopholatilus*, *Melanogrammus*, *Merlangiogadus*, *Merluccius*, *Microgadus*, *Micropogonias*, *Ophidion*, *Pogonias*, *Prionotus*, *Pterothrissus*, *Sciaenops*, *Symphurus*, *Urophycis*. Twenty-two of these represent the first North American Pliocene record for the genus (*Anisotremus*, *Astroscopus*, *Brotula*, *Centropristis*, *Cynoscion*, *Diplectrum*, *Equetus*, *Gadus*, *Kathetostoma*, *Leiostomus*, *Lepophidium*, *Lopholatilus*, *Melanogrammus*, *Merlangiogadus*, *Microgadus*, *Micropogonias*, *Ophidion*, *Pogonias*, *Prionotus*, *Pterothrissus*, *Symphurus*, *Urophycis*). Of these, six represent the initial fossil record anywhere (*Astroscopus*, *Diplectrum*, *Equetus*, *Kathetostoma*, *Leiostomus*, *Lopholatilus*). *Lopholatilus* represents the first fossil record for the family Branchiostegidae. Otoliths from at least two kinds of fish are from extinct genera (*Merlangiogadus* and sciaenid species A), and those of the 13 unnamed taxa may represent extinct species. Individuals of all of the listed taxa routinely inhabit waters shallower than 200 meters, except *Ceratoscopelus* and *Merluccius albidus*. Based upon the three most abundant kinds of fish otoliths (*Lepophidium*, *Merluccius*, and sciaenid species A), comprising 88 percent of the recovered otoliths, it is suggested that the Lee Creek Mine fauna may have been deposited in depths of 60 to 100 meters.

John E. Fitch (deceased). Robert J. Lavenberg, Section of Ichthyology, Natural History Museum of Los Angeles County, Los Angeles, California 90007.

Introduction

In November 1971, Peter J. Harmatuk sent one of us (JEF) 67 otoliths, representing four species, from Lee Creek Mine, and volunteered to collect additional material if we were interested. Subsequently, Mr. Harmatuk sent over 8000 additional otoliths and a sample of unscreened matrix from which we gleaned another 350. The otoliths sent by Mr. Harmatuk were picked up in the field from the fossiliferous Yorktown Formation, which overlies the phosphatic sands of the Pungo River Formation being mined by Texasgulf Inc., at Aurora, North Carolina. According to Bob H. Slaughter (personal communication), the otolith-bearing overburden being worked by Mr. Harmatuk lies above the basal Yorktown, which Slaughter found to be practically void of teleost otoliths. The 245 otoliths received from Jack H. McLellan in February 1973 added numerically to those sent by Mr. Harmatuk, but there were no additional species present.

In this report on the Lee Creek Mine otoliths, no new species will be described. In most cases inadequate comparative material and our limited firsthand knowledge of the extant Atlantic marine teleost fauna dictate the necessity for a prudent approach.

Some paleontologists have operated on the principle that any fish occurring as a fossil is unquestionably a new genus and species. Others appear to believe that all fossil fish remains of Eocene age and younger are extinct species referable to extant genera. It is our opinion that neither of these philosophies is acceptable.

In the marine Pliocene and Pleistocene of California, we have recovered perhaps 200,000 otoliths, which represent 161 species; yet only 6 of these 161 (2 gobies, 2 sciaenids, an embiotocid, and a morid) cannot be referred to living species. On the other hand, a Pliocene freshwater deposit in Kettleman Hills, California, has yielded 40,000 otoliths from 10 species, and at least 8 of these are extinct. Obviously, it has been more difficult for freshwater species to survive the rigors of their environment than their marine relatives.

In the California Miocene, we have not made any critical analyses of the otolith faunas, but it would appear upon cursory examination that fewer than 50 percent of the more than 100 kinds of otoliths that have been recovered from various deposits can be assigned to extant genera. On the other hand, otoliths recovered from the Miocene and Pliocene of Maryland, Virginia, North Carolina, and Florida appear to be referable to extant genera in more than 80 percent of the cases. If, upon analysis, these percentages hold up, it is obvious that conditions that relate to survival can be much harsher in one geographic area than in another. Thus, it would appear that factors other than time have been responsible for the extinction of various taxa during the most recent 20 to 25 million years of Earth's history.

In North American Oligocene and Eocene, we have little difficulty relating otoliths to present-day families, but usually only among some of the deep-sea forms are they referable to extant genera. Cretaceous otoliths, however, have little in common with any taxonomic unit below that of order. Regardless of the time period involved, a good comparative collection is an absolute necessity for making a meaningful appraisal of fossil components at any taxonomic level.

Meyer, Slaughter, Purdy, and McLellan's faunal list (in prep.), based upon fish remains other than otoliths, does not complement our list, but this was to be expected. It is well established that teleost faunas represented by teeth and various skeletal parts are at complete odds with those represented by otoliths from the same beds or formation (cf. Casier, 1966, and Stinton, 1966). Such lack of agreement sometimes reflects poor or mistaken judgment, but even when generic names have been erroneously applied, a re-evaluation of the fauna or faunas seldom will reduce the conflict.

During 1968, Fitch collected in exposures of the fossiliferous Yorktown Formation at Rice's Pit, Hampton, Virginia, and along the south bank of the James River (Day's Point) near Smithfield. In a number of systematic accounts (below), we have included information on otoliths from these two collections.

ACKNOWLEDGMENTS.—We gratefully acknowledge the assistance of Peter J. Harmatuk, Bridgeton, North Carolina; Jack McLellan, Austin, Texas; and Warren C. Blow, National Museum of Natural History, Smithsonian Institution, Washington, D.C., for providing fossil otoliths. Jack and Mary Hopkins, Eureka, California; Richard and Diane McGinnis, Tacoma, Washington; and Clayton E. Ray, National Museum of Natural History, Washington, D.C., sent us fossiliferous dirt. William M. Rice, Hampton, Virginia, permitted Fitch to excavate at Rice's Pit. Shelton Applegate, Instituto de Geologia, Ciudad Universitaria, México, D.F.; and Bob H. Slaughter, Southern Methodist University, Dallas, Texas, gave us information regarding fossil localities. Richard A. Fitch spent one summer digging, screening, and sorting fossiliferous material.

Several individuals provided otoliths from contemporary Atlantic Ocean fishes for comparative material during the investigation, including Fred Berry, Miami, Florida; James Craddock, Woods

Hole Oceanographic Institution, Woods Hole, Massachusetts; Donald P. de Sylva, Institute of Marine Science, Miami; John Musick and Charles Wenner, Virginia Institute of Marine Science, Gloucester Point; Frank Schwartz, Institute of Marine Sciences, Morehead City, North Carolina; and Noel Tibbo, Fisheries Research Board of Canada, New Brunswick. The National Science Foundation (NSF) has previously supported research grants to Fitch that have allowed the accumulation of comparative materials (otoliths) without which fossil forms could not be identified. To all of these individuals and the NSF we extend our appreciation for this help.

Jack W. Schott, California Department of Fish and Game (CDFG), Long Beach, took the excellent otolith photographs; Caryl Maloof, Natural History Museum of Los Angeles County (LACM), applied her artistry in making the figures; Lawrence Reynolds, LACM, prepared photographs of the figures; and Lamonica Beasley and Terri Togiai, LACM, and Micaela Wolfe, CDFG, typed various revisions of the manuscript for us. To each of them we extend our thanks.

Finally, during a visit with Fitch in 1980, P.A.M. Gaemers, Geologisch en Mineralogisch Instituut der Rÿksuniversiteit, Leiden, whose specialty is gadiform otoliths, examined all of the Lee Creek Mine cod and hake sagittae, corrected some of our identifications and confirmed the others. We are especially grateful for his assistance.

Systematic Account

Pterothrissidae

(Pterothrissid Bonefishes)

Pterothrissus species (Figure 1A): Otoliths of *Pterothrissus* have been described from numerous Cenozoic deposits throughout Europe (Weiler, 1968; Stinton, 1975), but none of those found in North America has been named as yet. The single otolith from Lee Creek Mine, a left sagitta 8.0 mm long, is distinct from sagittae of the two living species, *P. belloci* and *P. gissu. Pterothrissus belloci*, the nearest living pterothrissid, inhabits waters off the west coast of Africa. Until now, we have not seen otoliths of *Pterothrissus* from the North American Pliocene, but they are present, though never abundant, in many Oligocene and Eocene deposits.

Congridae

(Conger Eels)

Otoliths of conger eels are extremely abundant in North American Eocene deposits (Frizzell and Lamber, 1962; Frizzell and Dante, 1965:698; J.E. Fitch, unpublished data) and are plentiful in both Oligocene and Miocene, but it is very difficult to distinguish species from otoliths alone. Most of this difficulty lies in the fact that comparative material from Recent species is unavailable; without knowing the range of specific variation it is impossible to distinguish more than a minimum of the fauna. Most congrids are secretive in their habits and thus rarely are collected. Those which are collected usually are preserved intact—a standard operating procedure of eel specialists, but one which usually renders useless for taxonomic purposes the contained otoliths. Because of these factors, we do not envision a clarification of the fossil record for this family in the foreseeable future. However, papers such as that of Kotthaus (1968) will prove extremely helpful, because he illustrates otoliths of six of the eight congrid genera that he discussed from the Indian Ocean. Although somewhat etched by formalin preservation, these otoliths represent comparative material that will help to provide an understanding of fossil conger eels.

Robins et al. (1980) and Smith and Kanazawa (1977) list 11 species of congrids known to occur along the Atlantic and Gulf coastal states, and four of these also inhabit Bahaman waters (Böhlke and Chaplin, 1968:88–94). Among the 275 congrid otoliths on hand from Lee Creek Mine (Table 1), there are five discernible species.

Congrid species A (Figure 1B) is similar to "*Conger*" *sanctus* of Frizzell and Lamber (1962) (subsequently assigned to genus *Bathycongrus* by

TABLE 1.—Otoliths from the Yorktown Formation (Pliocene) of the Lee Creek Mine (dash indicates absent)

Family and species	Number of otoliths		Fossil record for the genus[3]	
	Eye[1]	Micro-scope[2]	First ever	First North American Pliocene
PTEROTHRISSIDAE				
Pterothrissus species	1	–		x
Congridae				
Congrid species A	99	1		
Congrid species B	164	7		
Congrid species C	–	2		
Congrid species D	1	–		
Congrid species E	–	1		
MYCTOPHIDAE				
Ceratoscopelus maderensis	13	31		
GADIDAE				
Gadus cf. *morhua*	1	–		x
Melanogrammus cf. *aeglefinus*	1	–		x
Merlangiogadus cognatus	16	3		x
Microgadus cf. *tomcod*	8	–		x
Urophycis tenuis	26	7		x
MERLUCCIIDAE				
Merluccius albidus	80	5		
Merluccius cf. *bilinearis*	481	12		
Merluccius species	373	11		
Unidentifiable *Merluccius*	103	21		
OPHIDIIDAE				
Brotula barbata	10	–		x
Lepophidium cf. *cervinum*	5610	130		x
Ophidion grayi	24	4		x
Brotulid species A	7	–		
Brotulid species B	3	1		
Ophidiid species A	–	2		
Ophidiid species B	3	2		
SERRANIDAE				
Centropristis cf. *striata*	3	–		x

[1] Gleaned by eye in the field.
[2] Found in washed screenings and examined under microscope.
[3] Includes only those otoliths for which a generic name is assigned.

Schwarzhans in 1976:473), but it has a more rounded posterior end and other subtle differences. Its exact generic placement cannot be determined without seeing comparative material from the congrids listed by Robins et al. (1980) and Smith and Kanazawa (1977). The 100 Lee Creek Mine otoliths that we have assigned to this species range in length from 2.8 to 10.2 mm; the figured specimen is 8.5 mm long.

Congrid species B (Figure 1c) has more than a slight resemblance to the fossil genus *Parbatmya* Frizzell, Lamber, and Dante, but we suspect that the Lee Creek Mine otoliths are referable to an extant genus. Therefore, we will leave their ge-

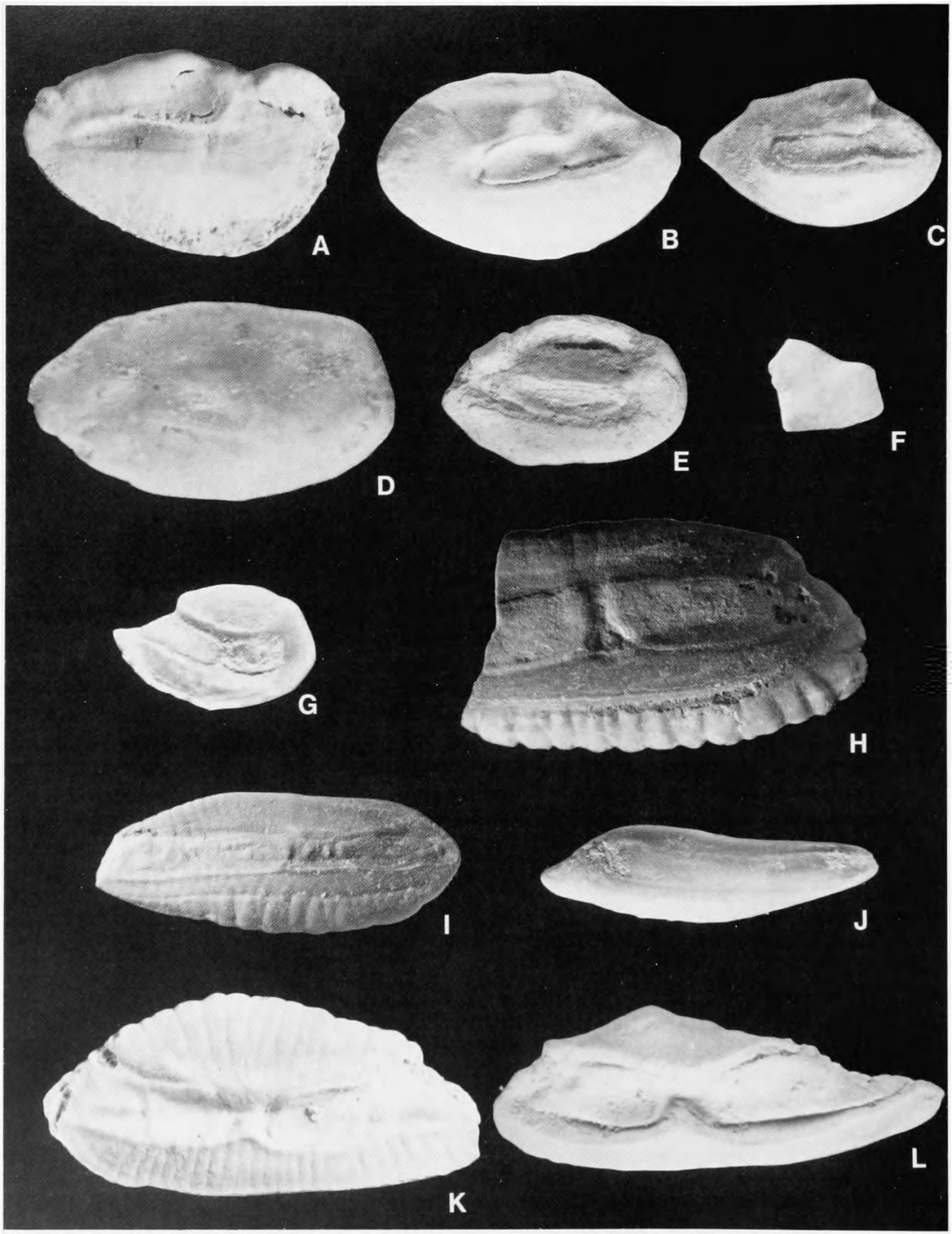
TABLE 1.—Continued.

Family and species	Number of otoliths		Fossil record for the genus[3]	
	Eye[1]	Micro-scope[2]	First ever	First North American Pliocene
Diplectrum cf. *formosum*	16	–	x	x
Serranid species A	2	–		
Serranid species B	1	–		
BRANCHIOSTEGIDAE				
Lopholatilus chamaeleonticeps	14	1	x	x
POMADASYIDAE				
Anisotremus species	16	–		x
SCIAENIDAE				
Cynoscion cf. *nebulosus*	308	11		x
Equetus cf. *umbrosus*	7	–	x	x
Leiostomus species	31	5	x	x
Micropogonias species	32	2		x
Pogonias cf. *cromis*	1	–		x
Sciaenops cf. *ocellata*	3	–		
Sciaenid species A	929	1		
URANOSCOPIDAE				
Astroscopus species	23	–	x	x
Kathetostoma species	12	–	x	x
AMMODYTIDAE				
Ammodytes hexapterus	1	6		
TRIGLIDAE				
Prionotus spp.	17	12		x
BOTHIDAE				
Citharichthys spp.	15	62		
PLEURONECTIDAE				
Pleuronectid	–	1		
CYNOGLOSSIDAE				
Symphurus species	1	10		x
AGONIDAE?				
Unknown	–	1		

neric assignment to the future. The 171 otoliths belonging to this species range in length from 2.0 to 7.3 mm; the figured specimen is 6.7 mm long.

Congrid species C (Figure 1D) has a relatively flat inner face and a deeply convex outer face. It is distinct from any of the species described by Frizzell and Lamber (1962) and cannot be assigned generically at this time. These two otoliths (Table 1) are 2.5 and 2.7 mm long, and the larger is figured.

Congrid species D (Figure 1E) is represented by a single right sagitta, 4.2 mm long, which, although somewhat abraded, is readily recognizable as belonging to this family.


A
B
C
D
E
F
G
H
I
J
K
L

Congrid species E (Figure 1F) is represented by the posterior half only of a right sagitta. This fragment is 2.7 mm long and is unquestionably from *Conger*, sensu stricto, which has a unique otolith, not only among congrids but among other eels regardless of family. One otolith from Rice's Pit, Virginia, is also from the genus *Conger*, but we have not attempted to relate the numerous other congrid otoliths from Rice's Pit and Day's Point to the other four species (A, B, C, and D, above) from Lee Creek Mine.

Myctophidae

(Lanternfishes)

Ceratoscopelus maderensis (Lowe), horned lanternfish (Figure 1G): The 44 lanternfish otoliths from Lee Creek Mine are all from this species, which today inhabits waters of the North Atlantic between north latitudes 22° and 50° (Bolin, 1959:38). Although Fitch (1969a:5) reported *Ceratoscopelus* otoliths from the Pliocene and Pleistocene of California, they were not from this species. The Lee Creek Mine otoliths are the first fossil record for the species. The 44 otoliths (Table 1) ranged in length from 2.1 to 3.8 mm with most exceeding 3.0 mm; the figured otolith is 3.4 mm long. The sagittae from a 72 mm standard length *C. maderensis* were 3.7 mm long.

Gadidae

(Cods)

Gadus cf. *morhua* Linnaeus, Atlantic cod (Figure 1H): A single, broken left sagitta was from a *Gadus*, probably *G. morhua* that inhabits the North Atlantic today, but in its broken condition exact specific assignment cannot be made with certainty. The southern limit of distribution for *G. morhua* in North American waters generally is noted as "off Cape Hatteras, N.C." (Leim and Scott, 1966:196). The Lee Creek Mine otolith is 11.8 mm long; it would have exceeded 16 mm if unbroken. There is no previous fossil record for the genus from North America, although sagittae of *G. macrocephalus* have been recovered from Ice Age deposits in the Aleutians (J. Fitch, unpublished data).

Melanogrammus cf. *aeglefinus* (Linnaeus), haddock (not figured): A single, broken left sagitta was from *Melanogrammus*, probably *M. aeglefinus*, which inhabits North American waters as far south as Cape Hatteras, North Carolina during winter months (Leim and Scott, 1966:203). In its broken condition, however, assignment to this species cannot be made with any degree of certainty. Gaemers and Schwarzhans (1973:215, pl. 1, figs. 22a, b, 23; pl. 4, figs. 5a, b) described and figured sagittae from an extinct species of *Melanogrammus* from the Pliocene of Belgium, and Gaemers (1976) restricted *M. aeglefinus* to the post-Pliocene. The broken fragment from the Lee Creek Mine is the anteriormost 11.9 mm of an otolith that would have exceeded 17 mm if entire. There is no previous fossil record for the genus from North America, although *Melanogrammus* otoliths were present also at Rice's Pit and Day's Point.

Merlangiogadus cognatus (Koken), extinct gadid (not figured): Nineteen otoliths (Table 1), mostly broken and badly eroded, were from this extinct gadid. This genus was established by Gaemers (1973) for Koken's *Otolithus cognatus*. The otoliths of *Merlangiogadus* are most similar in outline to those of *Merlangius* and *Micromesistius*, but they differ from these two genera in several salient features, according to Gaemers (1973). In the degree of convexity along the long axis, sagittae of *Merlangiogadus* are most similar to those of *Melanogrammus*, but again, there are differentiating characters. Gaemers (1973) assigns two species to the genus: *M. decorus* from European Oligocene

FIGURE 1.—Fish otoliths found in deposits from Lee Creek Mine, Yorktown Formation (length, in mm, is given for each otolith; notation is made regarding its position in the skull, left or right; otolith condition is noted if imperfect; all are sagittae, and all views are inner faces): A, *Pterothrissus* species, 8.0, l, worn; B, Congridae species A, 8.5, l; C, Congridae species B, 6.7, l; D, Congridae species C, 2.7, r; E, Congridae species D, 4.2, r; F, Congridae species E, 1.8, r, anterior half missing; G, *Ceratoscopelus maderensis*, 3.4, r; H, *Gadus* cf. *morhua*, 11.8, l, broken and worn; I, *Microgadus* cf. *tomcod*, 10.2, l, broken and worn; J, *Urophycis tenuis*, 9.4, l; K, *Merluccius albidus*, 12.3, r, broken and worn; L, *Merluccius bilinearis*, 17.6, r.

and *M. cognatus* from lowermost middle Miocene and upper Miocene. The Lee Creek Mine otoliths represent the first report of *Merlangiogadus* from North America, although Eastman (1904, pl. 32, figs. 17, 18) illustrated them from Calvert Cliffs, Maryland. Dante apparently considered the *Merlangiogadus* otolith figured by Eastman as being from sciaenids as noted in the following quotation from Dante (1953:878): "Eastman (1904, pl. 32, figs. 17–19), in his report on the Maryland Miocene, figured two otoliths but did not describe them. These otoliths appear to belong to a sciaenid." Actually, Eastman's figures 17 and 18 are of *Merlangiogadus*, and only his figure 19 is of a sciaenid. Fitch (ms) found that otoliths of *M. cognatus* are abundant in Calvert Cliffs, Maryland, deposits (St. Mary's and Calvert formations). If entire, the 19 Lee Creek Mine otoliths would have ranged from about 6.5 to 14 mm long.

Microgadus cf. *tomcod* (Walbaum), Atlantic tomcod (Figure 1I): Eight of the Lee Creek Mine otoliths (Table 1) could be assigned to *Microgadus*, but because all were worn and broken, their specific assignment cannot be made with certainty as they may represent an extinct species. Although gadid otoliths from the Eocene of England have been assigned to this genus (Stinton, 1977:91), a careful analysis probably will show that they are not congeneric. Otoliths of *M. proximus*, an extant species, have been reported from the Pleistocene of California (Fitch, 1967:10, 1970:27), but the Lee Creek Mine otoliths represent the first report of *Microgadus* from the Pliocene of North America. If entire, these 8 otoliths would have ranged in length from about 10 to more than 17 mm; the figured otolith is 10.2 mm long.

Urophycis tenuis (Mitchill), white hake (Figure 1J): The 33 *Urophycis* sagittae from Lee Creek Mine match only those of *U. tenuis* from among the six species listed by Robins et al. (1980) as inhabiting waters of the western North Atlantic. *Urophycis tenuis* (Koken) has been reported as a fossil from European deposits (Weiler, 1968:35; Dieni, 1969:266), but based upon material in the Fitch fossil collection, these may be from juvenile *Brotula*. If, however, they are assigned correctly at the generic level, they will need a new specific name, because *tenuis* of Mitchill predates Koken's *tenuis* by more than 75 years. The genus previously has not been reported as a fossil from North America. *Urophycis* otoliths (more than one species) were also found at Day's Point and Rice's Pit. The 33 otoliths from Lee Creek Mine were mostly broken and worn, but if entire they would have ranged from about 9.4 to 17 mm long; the figured specimen is 9.4 mm long.

MERLUCCIIDAE

(Hakes)

Merluccius albidus (Mitchill), offshore hake (Figure 1K): Of the 1086 *Merluccius* otoliths from Lee Creek Mine, 85 (Table 1) were from *M. albidus*, but none of these was in perfect condition. According to Ginsburg (1954:193) and Leim and Scott (1966:205), *M. albidus* ranges from off Georges Bank to Cape Canaveral, at least, and the adults generally are found in depths exceeding 200 m. *Merluccius* otoliths have been reported from Cenozoic deposits throughout much of the world, but only *M. productus* from the Pliocene and Pleistocene of California (Fitch, 1969b:72, 78, 1970:27) has been reported from North America. In one Pliocene deposit of California, *M. productus* otoliths comprised more than 13 percent of the total otoliths recovered; in the Lee Creek Mine material they comprised about the same percentage, but these figures are not comparable because otolith recovery methods differed. *Merluccius albidus* otoliths also were present at Rice's Pit and Day's Point in Virginia. If entire, the 85 *M. albidus* otoliths from Lee Creek Mine would have ranged in length from about 9 to more than 15 mm; the figured specimen, a broken right sagitta, is 12.3 mm long.

Merluccius cf. *bilinearis* (Mitchill), silver hake (Figure 1L): The most abundant *Merluccius* otoliths in the Lee Creek Mine material matched those of *M. bilinearis* sufficiently well that they unquestionably are from an extinct ancestor, if not from the extant *M. bilinearis*. In all, 493 (Table 1) of the 1086 *Merluccius* otoliths could be assigned

here; most were broken or badly eroded, or both, but if entire, they would have ranged in length from shorter than 10 to longer than 24 mm. Otoliths of this species were present at Rice's Pit and Day's Point, also.

Merluccius species, extinct hake (not figured): The Lee Creek Mine material contained 384 otoliths (Table 1) from an extinct species of *Merluccius*. Otoliths of these differ from sagittae of the two nominal species of *Merluccius* that inhabit the western North Atlantic in numerous features, most notable being the thickness of the otolith, the width and depth of the sulcus, the marginal ornamentation, and the predorsal angularity. In contrast to the other two species, a number of the otoliths from this extinct form were entire. Total lengths of the 384 otoliths would have ranged from about 10 to 28 mm in length.

Merluccius spp., unidentifiable: Among the 1086 hake otoliths from Lee Creek Mine, 124 were too badly fragmented or eroded to be assigned to any of the above three species.

Ophidiidae

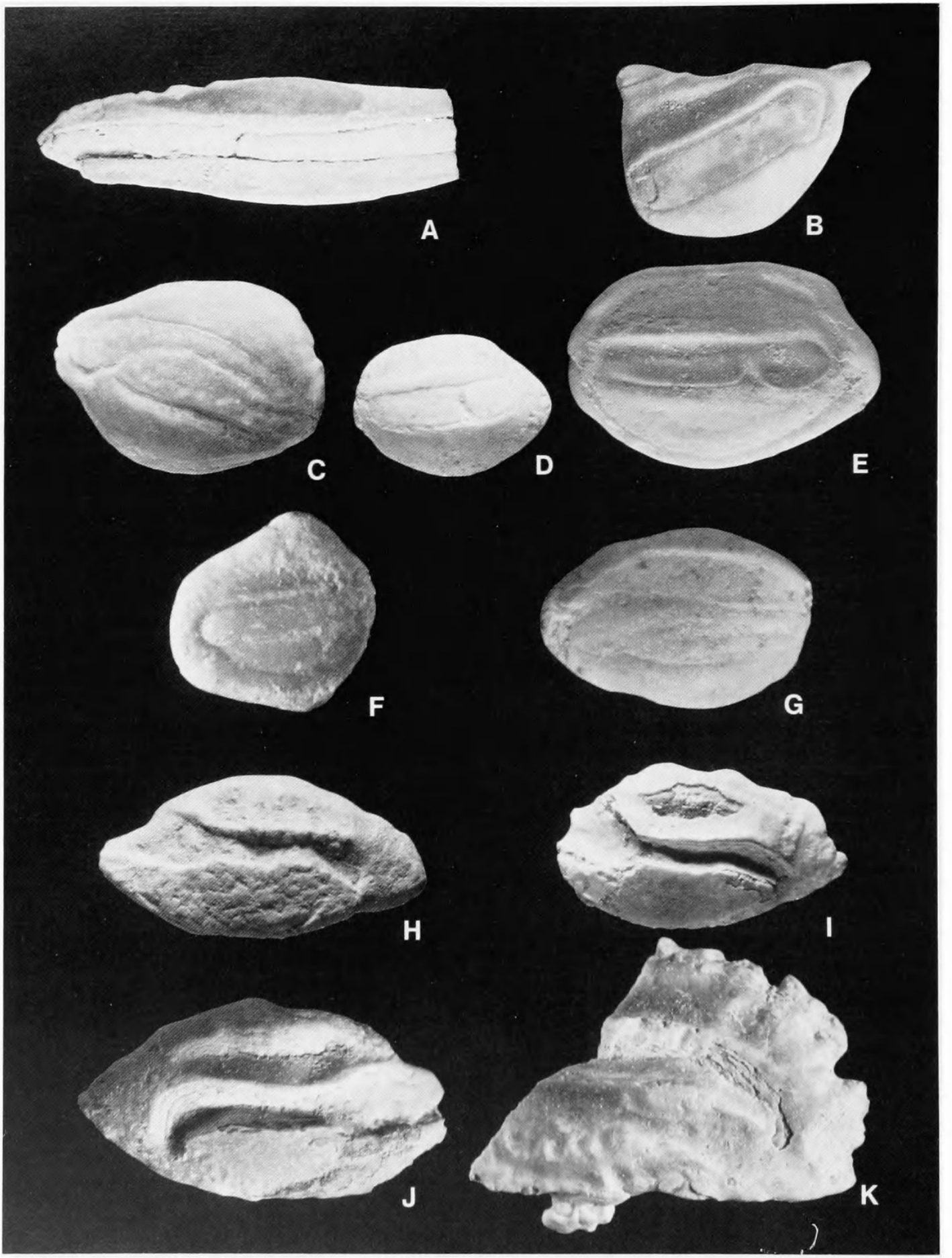
(Cusk-eels and Brotulas)

Cohen and Nielsen (1978) in defining the fish order Ophidiiformes included keys to families and genera, and gave estimates of numbers of species by genus. As they defined the order, it comprises 4 families, 82 genera, and some 300 to 400 species. Based upon their publication, Nolf (1980) figured with line drawings sagittae from 70 of the 82 recognized genera, and presented a "revision" of fossil ophidiids that have been described from otoliths. Unfortunately, his reassignment of several perfectly good fossil genera to taxonomically unacceptable categories (e.g., *Preophidium stintoni* Dante and Frizzell to "*Neobythitinarum*" *stintoni*, *Signata nicoli* Dante and Frizzell to "*Ophidiidarum*" *nicoli*) forces one to question the validity of many of his other generic assignments. Similarly, the philosophy of Nolf, and several other contemporary European paleontologists, that all fossil otoliths of Eocene or younger age must be assigned or equated to extant genera, often indiscriminately, casts serious doubt in the minds of many ichthyologists as to the usefulness of otoliths as taxonomic tools.

The seven kinds of ophidiid otoliths from Lee Creek Mine would appear to belong to family Ophidiidae as defined by Cohen and Nielsen (1978), but generic assignments cannot be made for some because we lack what we consider to be critical comparative material from the western North Atlantic.

Brotula barbata (Bloch and Schneider), bearded brotula (Figure 2A): Although otoliths of *Brotula* have been reported from the London Clay (Eocene) by Stinton (1966:430) and from the Miocene of Trinidad by Nolf (1976:723), they have not been reported from North America until now. Because of their resemblance to otoliths of some gadids (e.g., *Urophycis*), especially when small, we suspect that some of the European fossil gadid records that are based upon otoliths alone are actually *Brotula*. Fitch has sagittae from five species of *Brotula* in his comparative collection, but we can find no character or combination of characters for distinguishing any one of the five from the other four. Because of this, and since *B. barbata* is the only species presently known to inhabit waters off the Atlantic coastal states; it seems reasonable to assign that specific name. All 10 of the *Brotula* otoliths from Lee Creek Mine are broken, but if entire, they would have measured approximately 15 to 30 mm long; the figured specimen is 15.9 mm long to where broken.

Lepophidium cf. *cervinum* (Goode and Bean), fawn cusk-eel (Figure 2B): This was by far the most abundant otolith found in Lee Creek Mine (Table 1), comprising 71 percent of the collected sagittae. Unfortunately, we have comparative material from only 2 of the 13 western North Atlantic species of cusk-eels listed by Robins et al. (1980); but because of their unique shape, we hesitantly refer them to *L. cervinum* with which they agree rather closely. Some of the Lee Creek Mine "*L. cervinum*" otoliths are much more elongate and less high, however; and we suspect that these may represent a second species with a projecting (pointed) anterodorsal corner. A fair number of these *Lepophidium* otoliths from Lee Creek


A
B
C
D
E
F
G
H
I
J
K

Mine are freakishly developed and would have appeared glassy and crystalline if from living fishes. Frizzell and Exline (1958), Weiler (1959), Jónsson (1966), and Mugiya (1972) have noticed this phenomenon among fishes that they examined, but only Mugiya (1972) investigated the mineralogy of these aberrant otoliths. We have had a number of these freakishly developed glassy otoliths analyzed and all have turned out to be calcite and vaterite as compared to aragonite for their normally developed counterparts. Palmork, Taylor, and Coates (1963) reported upon the chemical composition of two types of these freakishly formed otoliths, which they found in the cod *Gadus morhua.* Based upon X-ray powder analyses, their Type 1 otoliths contained a mixture of vaterite and calcite, whereas accretions from their Type 2 contained calcite only. A reasonable assumption for living fishes is that something in the fish's environment is inhibiting its ability to metabolize calcium; the same could have been true for the fossils.

Among otoliths of ophidiids, the sulcus (groove on inner face) may be divided vertically or horizontally with several variations of proportion, width, or configuration. This division of the sulcus is unquestionably of taxonomic importance, but to what extent has not been investigated as yet. The 5740 *Lepophidium* otoliths from Lee Creek Mine ranged from 2.2 to slightly longer than 9.0 mm; the figured specimen is 7.6 mm long. Previously, otoliths of *Lepophidium* have been reported from the Pleistocene of California (Fitch, 1970:25) from the Pliocene and Miocene of Trinidad (Nolf, 1976:723), and from the Eocene of England (Stinton, 1965:407) and Belgium (Nolf, 1974). *Lepophidium* otoliths among those from Day's Point and Rice's Pit apparently are referable to *L. cervinum* also.

Ophidion grayi (Fowler), blotched cusk-eel (Figure 2C): Otoliths of this species have a concave outer face, and the sulcus is divided longitudinally. These two features in combination with their generally oval outline are sufficient to distinguish *O. grayi* sagittae from those of other cusk-eels that we have seen. Robins et al. (1980) list six species of *Ophidion* as inhabiting waters of the western North Atlantic, and Böhlke and Chaplin (1968:168) report a sixth at the Bahamas. Among these, we have comparative material only from *O. grayi*, *O. holbrooki*, and *O. welshi.* Otoliths of *O. grayi* are also present at Day's Point and Rice's Pit. The 28 sagittae from Lee Creek Mine range in length from 2.8 to 8.4 mm; the figured specimen is 7.6 mm long.

Otoliths have been assigned to this genus from fossil deposits in Europe and the Barbados, but not from North America proper. Those described from Barbados (Casier, 1958) do not appear to be from an ophidiid.

Brotulid species A (Figure 2D): Seven otoliths among the Lee Creek Mine material have a sulcus that is divided vertically near the posterior end, and a concave posterodorsal corner that gives it a slightly twisted appearance at that point. The sulcal surface (inner face) is evenly rounded dorsoventrally and from front to rear. These seven otoliths range in length from 5.2 to 6.4 mm; the figured specimen is 5.4 mm long.

Brotulid species B (Figure 2E): Four otoliths from Lee Creek Mine, which also have a sulcus that is divided vertically near its posterior end, lack the concave posterodorsal corner of the "brotulid species A" otoliths and have an almost flat inner face. These four otoliths range in length from 4.3 to 5.5 mm; the largest individual is figured.

Ophidiid species A (Figure 2F): Two small ophidiid otoliths from the Lee Creek Mine bulge in outline both dorsally and ventrally, and at that point are almost as tall as they are long. The sulcus is divided longitudinally. These otoliths,

FIGURE 2.—Fish otoliths found in deposits from Lee Creek Mine, Yorktown Formation (length, in mm, is given for each otolith; notation is made regarding its position in the skull, left or right; otolith condition is noted if imperfect; all are sagittae, and all views are inner faces): A, *Brotula barbata*, 15.9, r, broken; B, *Lepophidium* cf. *cervinum*, 7.6, r; C, *Ophidion grayi*, 7.6, l; D, Brotulidae species A, 5.4, r; E, Brotulidae species B, 5.5, r; F, Ophidiidae species A, 2.0, l; G, Ophidiidae species B, 2.8, l; H, *Centropristis* cf. *striata*, 8.2, r, worn; I, *Diplectrum* cf. *formosum*, 8.1, r, broken and worn; J, Serranidae species A, 10.5, l, broken, tip of rostrum missing; K, Serranidae species B, 11.2, r, broken, anterior portion missing.

2.0 and 2.1 mm long are similar if not identical to some ophidiid otoliths in the Pliocene Bowden Formation of Jamaica (J.E. Fitch, unpublished data).

Ophidiid species B (Figure 2G): Five of the Lee Creek Mine ophidiid otoliths with a longitudinally divided sulcus are teardrop-shaped and quite thick. The outer face of these otoliths, which range in length from 2.2 to 4.4 mm, is convex. These otoliths also occur at Day's Point and Rice's Pit. A lack of comparative material prevents our speculating as to generic or specific affinities of these and the preceding three kinds.

SERRANIDAE

(Sea Basses)

Centropristis cf. *striata* (Linnaeus), black sea bass (Figure 2H): Three otoliths are unquestionably serranids and among the serranid genera found in the western North Atlantic they agree in all salient features with *Centropristis*. Of the four species of *Centropristis* listed by Robins et al. (1980), comparative material was unavailable from *C. fuscula*; but among the other three, *C. striata* had the only otolith with a notch in the ventral profile beneath the terminus of the cauda or posterior portion of the sulcus. The fossil otoliths, however, are much thicker at comparable sizes than sagittae of living *C. striata*. Two of the three Lee Creek Mine otoliths have pieces missing, but if entire, they would have been about 7.1 to 9.0 mm long; the figured specimen is 8.2 mm long. Otoliths from several European deposits have been assigned to *Centropristis*, but the Lee Creek Mine specimens are the first fossil record from North America. Similar appearing serranid otoliths occur at Day's Point and Rice's Pit, but we have not attempted to determine generic affinities for these as yet.

Diplectrum cf. *formosum* (Linnaeus), sand perch (Figure 2I): These 16 otoliths (Table 1) superficially are quite similar to otoliths of *Centropristis*, but several subtle differences of configuration, proportions, and angles are consistent with the comparative material at hand. The 16 Lee Creek Mine otoliths are all either worn, broken, or both, but if entire, they would have ranged from about 6.5 to longer than 10 mm; the figured specimen is 8.1 mm long as is. Of the three species of *Diplectrum* inhabiting waters of the western Atlantic (Bortone, 1977:11, 22, 26), comparative material was unavailable from *D. bivittatum*, but it is a more southerly occurring species than *D. formosum*, to which we hesitantly assign the fossils. The Lee Creek Mine otoliths are much thicker at comparable sizes than those from living *D. formosum*, but otherwise they agree quite well. There is no previous fossil record for the genus.

Serranid species A (Figure 2J): Two otoliths, unquestionably from serranids, have a cauda that turns down at a 90° angle. Both have the rostrum tip missing; but if entire, they would have been about 10.5 and 13 mm long; the smaller specimen is illustrated. It is not possible to make a generic assignment from the material at hand.

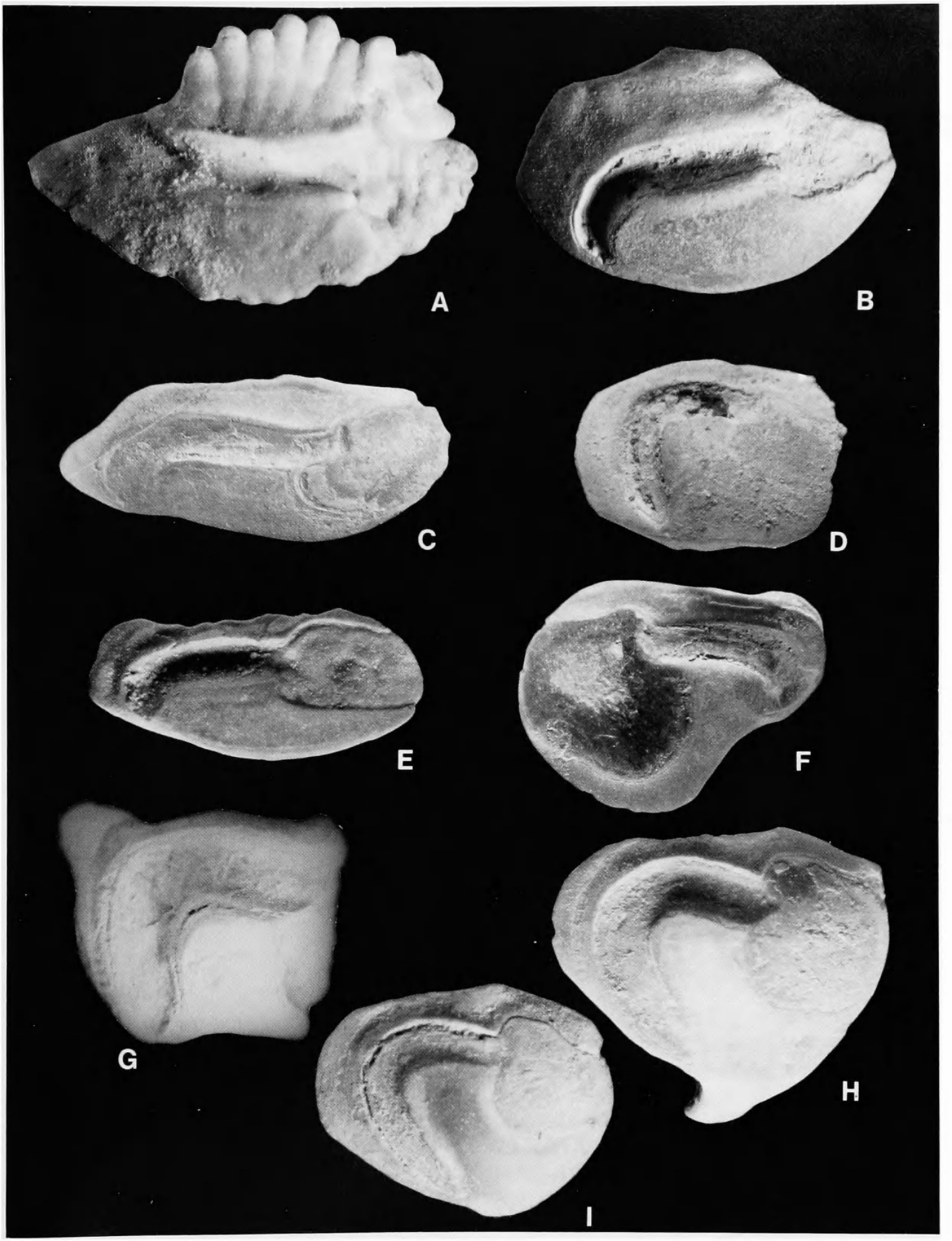
Serranid species B (Figure 2K): The straight ventral margin, frilly edges, rounded posterior end, large size, and extraneous projecting bits of aragonitic material, which are observable on this broken otolith suggest an affinity with either *Polyprion* or *Lobotes*. Without seeing the anterior half of this otolith, however, it is impossible to make a more definitive identification. The broken posterior portion is 11.2 mm long.

BRANCHIOSTEGIDAE

(Tilefishes)

Lopholatilus chamaeleonticeps Goode and Bean, tile fish (Figure 3A): At first glance, tilefish otoliths might be mistaken for those from some of

FIGURE 3.—Fish otoliths found in deposits from Lee Creek Mine, Yorktown Formation (length, in mm, is given for each otolith; notation is made regarding its position in the skull, left or right; otolith condition is noted if imperfect; all sagittae, and all views are inner faces): A, *Lopholatilus chamaeleonticeps*, 12.5, r, worn; B, *Anisotremus* species, 10.8, l, worn; C, *Cynoscion* cf. *nebulosus*, 11.0, l; D, *Equetus* cf. *umbrosus*, 6.7, l, worn; E, *Leiostomus* species, 8.3, l; F, *Micropogonias* species, 8.8, r; G, *Sciaenops* cf. *ocellata*, 17.0, l, broken; H, Sciaenidae species A, 8.4, l, with spur; I, Sciaenidae species A, 7.5, l, without spur.


A
B
C
D
E
F
G
H
I

the scorpaenids (Scorpaenidae), but the abrupt, straight-line termination of the crista superior (a ridge parallel to and rimming the sulcus dorsally) of *Lopholatilus* otoliths is unique. This characteristic crista superior, the massive otolith size, and general otolith outline preclude assigning these sagittae to any other genus. There is no previous fossil record for this family, and to our knowledge, tilefish otoliths have not been found in any other deposit. Wigley and Stinton (1973:28, 33, fig. 18L, 21) reported finding tilefish otoliths in bottom sediments taken from 113 m off Massachusetts, however. The 15 *Lopholatilus* otoliths from Lee Creek Mine are mostly broken, but if entire, they would have ranged in length from about 5 to 18 mm; the figured specimen is 12.5 mm long.

Pomadasyidae

(Grunts)

Anisotremus species (Figure 3B): We have no hesitation in assigning these 16 otoliths to the genus *Anisotremus*, but a lack of comparative material from western Atlantic species precludes making specific identifications. *Anisotremus davidsonii* has been reported from the Pleistocene of California (Fitch, 1970:17), but this is the first report of the genus from the Pliocene. These 16 otoliths are mostly worn or broken, but if entire, they would have ranged from about 7 to longer than 11 mm; the figured specimen is 10.8 mm long.

Sciaenidae

(Drums)

Cynoscion cf. *nebulosus* (Cuvier), spotted seatrout (Figure 3C): Of the four species of *Cynoscion* that presently inhabit waters of the Atlantic and Gulf coastal states (Robins et al., 1980), the 319 otoliths from Lee Creek Mine (Table 1) agree quite well with sagittae from *C. nebulosus*. Other species may be present among these fossils, but due to their generally poor condition, we did not make the necessary comparisons. The posterior ends of the other three species are much rounder and broader than those of *C. nebulosus*. If entire, these otoliths would have ranged in length from about 5 to 18 mm at least; the figured specimen is 11.0 mm long. *Cynoscion* otoliths are present at Day's Point and Rice's Pit, as well as in the Tertiary of Florida, but we have not tried to distinguish species for these as yet. Previously, two species of *Cynoscion* have been reported from the Pleistocene of California (Fitch, 1970:21) and the genus has been reported from the Miocene of Trinidad (Nolf, 1976:729), but this is the first record of the genus from North American Pliocene.

Equetus cf. *umbrosus* Jordan and Eigenmann, cubbyu (Figure 3D): The seven *Equetus* sagittae from Lee Creek Mine match those of *E. umbrosus* quite well, but we have not seen otoliths of *E. punctatus* from among the four species noted by Robins et al. (1980) as inhabiting waters of the western North Atlantic. There is no previous fossil record for the genus, and we did not find *Equetus* otoliths in the Virginia exposures. The Lee Creek Mine otoliths range in length from just under 6.0 mm to slightly over 9.0 mm; the illustrated specimen is 6.7 mm long.

Leiostomus species (Figure 3E): These 36 otoliths, while unquestionably from a species of *Leiostomus*, differ from *L. xanthurus*, the only extant species, in so many features that they probably represent an extinct form. These 36 otoliths range in length from 6.0 to 9.4 mm; the illustrated specimen is 8.3 mm long. There is no previous fossil record for the genus.

Micropogonias species (Figure 3F): Roux (1973) and Chao (1978) have presented convincing arguments for substituting *Micropogonias* for the fish genus name *Micropogon* that is preoccupied by the bird genus *Micropogon*. Otoliths of the two species known to inhabit western Atlantic waters also are discussed and illustrated (with line drawings) by Chao (1978:19, 32, 33; figs. 26,39). The 34 *Micropogonias* otoliths from Lee Creek Mine differ consistently in several salient features from those of *M. undulatus*, the only species now living in western Atlantic coastal waters north of Campeche Bay, Mexico. They differ even more widely from oto-

liths of *M. furnieri*, a more southerly ranging species in the western Atlantic. Previously, fossil otoliths found in the Californian Pleistocene (Fitch, 1970:27) and the Neogene of Sumatra (Frost, 1925:16) have been assigned to *Micropogonias*. Those from Sumatra, however, are very likely from one of the Indian Ocean genera, otoliths of which were illustrated by Mohan (1969, fig. 2) and Trewavas (1977). Most of the Lee Creek Mine *Micropogonias* otoliths are broken, but if entire, they would have ranged from about 5.5 to longer than 13.5 mm; the illustrated specimen is 8.8 mm long.

Pogonias cf. *cromis* (Linnaeus), black drum (not illustrated): One small (6.1 mm long), badly chipped otolith from Lee Creek Mine is unquestionably from *Pogonias*. The inner face is concave and it has a sharply pointed, slightly projecting posterodorsal corner that is unique to *Pogonias*. In these features and other characters it agrees well with otoliths of *P. cromis*. There is no previous North American record for this genus.

Sciaenops cf. *ocellata* (Linnaeus), red drum (Figure 3G): One nearly complete but badly worn otolith, and two half otoliths from Lee Creek Mine were from *Sciaenops*. The projecting spur on the posterodorsal corner, the shape of the cauda and angle of curvature, and the squared-off posterior margin are unique to *Sciaenops* and agree quite well with otoliths of *S. ocellata*. Previously, *S. eastmani* was described by Dante (1953) from Calvert Cliffs (Miocene) of Maryland; Fitch considers it to be a synonym of *S. ocellata* (Fitch, ms). The figured specimen from Lee Creek Mine is 17.0 mm to the break, and if entire, would have been longer than 30 mm; the smallest of the three was 11.0 mm long.

Sciaenid species A (Figure 3H,I): These disc-shaped otoliths with a sweeping loop in the cauda apparently represent an extinct genus. Perhaps 20 percent of the 930 otoliths have a projecting spur on the anteroventral corner (Figure 3H). Although none was found in the two Yorktown Formation outcrops in Virginia, there are 19 small otoliths of this species in some Miocene material from Calvert Cliffs, Maryland (Fitch, ms). The 930 Lee Creek Mine otoliths range in length from 5.2 to 11.1 mm; the figured specimens are 7.5 (without spur) and 8.4 mm long.

URANOSCOPIDAE

(Stargazers)

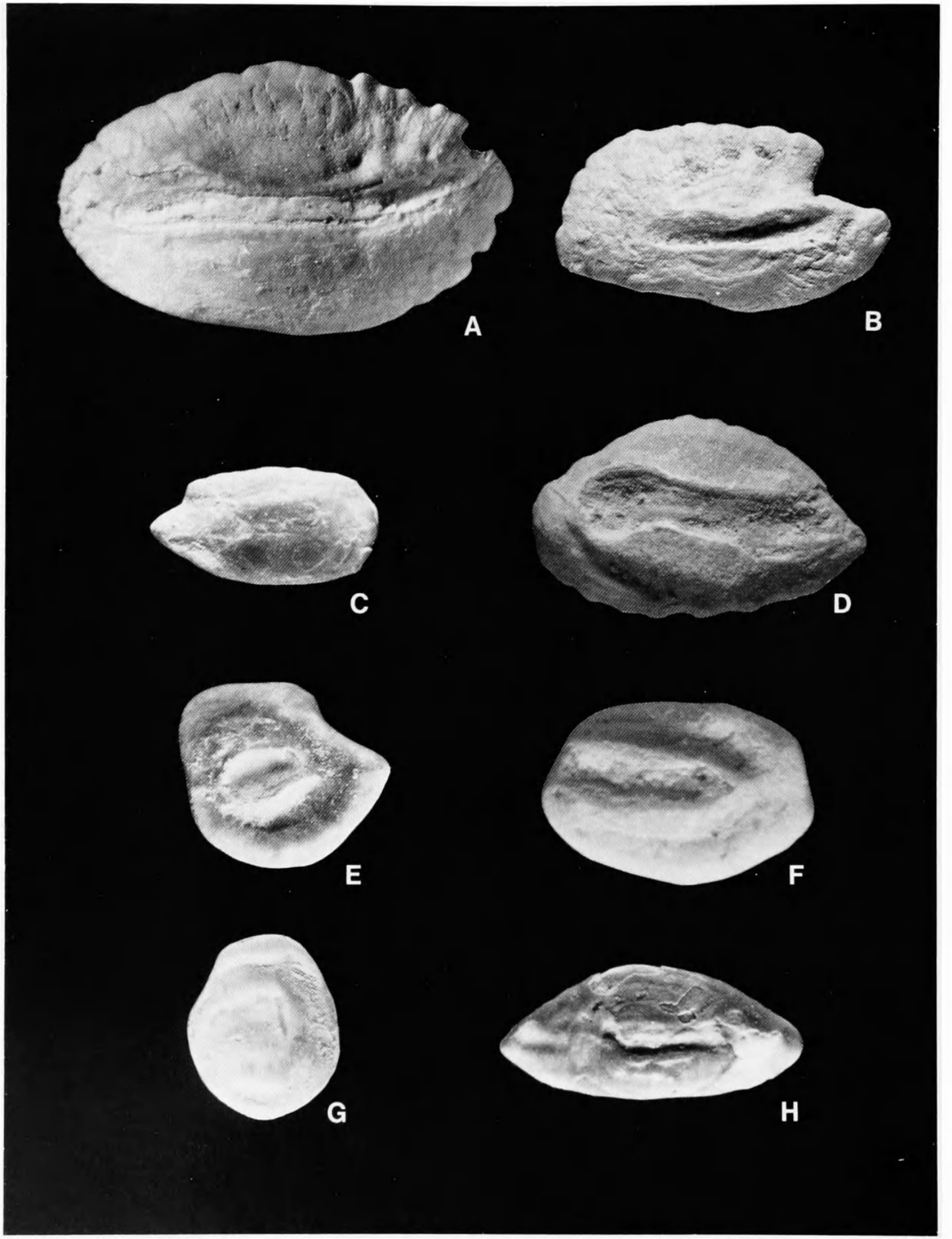
Astroscopus species (Figure 4A): These 23 otoliths from Lee Creek Mine agree very well with those of *Astroscopus* otoliths from the eastern Pacific, but we lack comparative material from the two species listed by Robins et al. (1980) from western North Atlantic; thus we cannot speculate as to their specific assignment. Otoliths of this species were present also at Day's Point and Rice's Pit. The 23 Lee Creek Mine *Astroscopus* otoliths range in length from slightly less than 6.0 mm to just over 15.0 mm; the figured specimen is 14.0 mm long. There is no previous fossil record for *Astroscopus*.

Kathetostoma species (Figure 4B): Only one species of *Kathetostoma* inhabits Atlantic waters within the area of concern (Robins et al., 1980), but since we lack comparative material of that species, we are unable to speculate as to the specific affinities of the fossils. These 12 Lee Creek Mine otoliths agree quite well with sagittae from *Kathetostoma* in the eastern Pacific, however; so we have no doubts regarding their generic assignment. *Kathetostoma* otoliths were not present in the Virginia deposits. The Lee Creek Mine *Kathetostoma* otoliths range in length from 5.0 to 9.7 mm; the figured specimen is 8.3 mm long. There is no previous fossil record for the genus.

AMMODYTIDAE

(Sand Lances)

Ammodytes hexapterus Pallas, common sand lance (Figure 4C): Although Robins et al. (1980) list three species of *Ammodytes* as occurring in the western North Atlantic within the area of concern, Richards, Perlmutter, and McAneny (1963) and Scott (1972) indicate that there are only two: *A. hexapterus* and *A. dubius*. According to Scott (1972:1675), these two species can be distinguished by their otoliths alone, but we believe


A
B
C
D
E
F
G
H

that it is desirable to compare the fossils carefully with sagittae from the living species. *Ammodytes* otoliths were the dominant sagittae (numerically) at Day's Point and were extremely abundant at Rice's Pit. Previously, *A. hexapterus* otoliths have been reported from Pliocene and Pleistocene deposits in California (Fitch, 1968:24, 1970:16), but this is the first fossil record from eastern North America. Numerous species have been reported from European fossil deposits (Weiler, 1968). The seven Lee Creek Mine *Ammodytes* otoliths ranged in length from 1.5 to 2.5 mm; the figured specimen is 2.4 mm long.

Triglidae

(Searobins)

Prionotus spp. (Figure 4D): Robins et al. (1980) list 12 species of *Prionotus* as inhabiting waters off the Atlantic and Gulf coastal states. By ratios of otolith thickness into length or height, and length into height, and by differences in marginal ornamentation, and overall shape and angles, we suspect that a number of these species could be distinguished by their otoliths alone, but we have not carried out the necessary studies to prove or disprove this hypothesis. The Lee Creek Mine otoliths are unquestionably from several species of triglids. Triglid otoliths, presumably mostly *Prionotus*, were also present at Day's Point and Rice's Pit. Based upon otoliths, two species of *Prionotus* have been reported from Pleistocene deposits in California (Fitch, 1970:32), but the genus has not been noted from North American Pliocene until now. The 29 Lee Creek Mine triglid otoliths ranged in length from 2.0 to 5.8 mm; the figured specimen is 5.2 mm long.

FIGURE 4.—Fish otoliths found in deposits from Lee Creek Mine, Yorktown Formation (length, in mm, is given for each otolith; notation is made regarding its position in the skull, left or right; otolith condition is noted if imperfect; all are sagittae, and all views are inner faces): A, *Astroscopus* species, 14.0, l; B, *Kathetostoma* species, 8.3, l; C, *Ammodytes hexapterus*, 2.4, r; D, *Prionotus* species, 5.2, l; E, *Citharichthys* species, 3.5, l; F, Pleuronectidae, 1.8, r, worn; G, *Symphurus* species, 2.6, r; H, Agonidae?, 3.6, r, worn.

Bothidae

(Lefteye Flounders)

Citharichthys spp. (Figure 4E): At least two species are represented among the *Citharichthys* otoliths from Lee Creek Mine, but since, for comparative purposes, we have only three of the seven Atlantic species listed by Gutherz (1967), we are not in a position to speculate as to the specific affinities of the fossils. Three species of *Citharichthys* have been reported from Pliocene and Pleistocene deposits in California (Fitch, 1970:19; Fitch and Reimer, 1967:82, 83), and the genus has been reported from the Miocene and Pliocene of Trinidad (Nolf, 1976:737); but this is the first record from the Pliocene of eastern North America. The 77 *Citharichthys* otoliths from Lee Creek Mine range in length from 1.4 to 4.1 mm; the figured specimen is 3.5 mm long. *Citharichthys* otoliths, more than one species, were also present at Day's Point and Rice's Pit.

Pleuronectidae

(Righteye Flounders)

Pleuronectid (Figure 4F): One Lee Creek Mine otolith, although small and worn, is unquestionably from a pleuronectid. By its small size (1.8 mm long), we presume that it is from a juvenile, but this is not necessarily so. In any event, because it is worn and because there is only one specimen, it would not be prudent to speculate as to its generic affinity.

Cynoglossidae

(Tonguefishes)

Symphurus species (Figure 4G): Robins et al. (1980) list 11 species of *Symphurus* as inhabiting waters off the Atlantic and Gulf coastal states; but since we have seen otoliths of only two of these (*S. diomedianus* and *S. plagiusa*), it is impossible to speculate as to the specific affinity of the fossils. The 11 Lee Creek Mine otoliths range in length from 1.0 to 2.6 mm; the figured specimen is 2.6 mm long. *Symphurus* otoliths have been

reported from the Pleistocene of California (Fitch, 1970:35) and from the Miocene of Trinidad; but this is the first record from the Pliocene of North America. Tonguefish otoliths were also present at Day's Point and Rice's Pit.

Agonidae?

One Lee Creek Mine otolith (3.6 mm long) is an enigma (Figure 4H). The sulcus suggests that it is from an agonid, cottid, or stichaeid, but a comparison with sagittae from species in these families that are known to occur in the western North Atlantic, within the area of concern, has brought no enlightenment. The concave outer face, attenuated anterior and posterior ends, ratio of height into length, and position and configuration of the sulcus will suffice to distinguish this otolith. Should its living congener turn up, we suggest that it will be an agonid.

Discussion

The 8808 Pliocene otoliths from Lee Creek Mine belong to 17 families and represent at least 45 species. The *Prionotus* and *Citharichthys* otoliths could have represented three species each, but we made no attempt to differentiate these. Ophidiids and sciaenids were the most speciose, with seven kinds each. Other families that were represented by more than one kind of otolith were congrids (5), gadids (5), serranids (4), merlucciids (3), and uranoscopids (2). Based upon our investigations elsewhere, we would anticipate that at least 8 to 10 additional kinds of otoliths could be found in Lee Creek Mine residue if fine-screening techniques, such as described by Fitch (1969c:56–60), were used on another 500 to 1000 pounds of fossiliferous matrix.

Among the 27 kinds of Lee Creek Mine otoliths for which generic names could be assigned, 22 were the first record for the genus in the Pliocene of North America, and of these, 6 represented the first fossil record (Table 1). For one of these, *Lopholatilus chamaeleonticeps*, there was no previous fossil record for the family.

Two kinds of otoliths (*Merlangiogadus* and sciaenid species A, Table 1) are from extinct genera, and there may be other extinct genera among the 13 unnamed otoliths, but decisions on these must wait additional comparative material from extant species. For all but one of the extant genera (i.e., *Pterothrissus*), there are one or more species inhabiting waters off the Atlantic and Gulf coastal states today; however, the nearest living pterothrissid, *P. belloci*, is found in waters off the west coast of Africa.

Because we are generally unfamiliar with the habits and habitat preferences of Atlantic Coast fishes, it would not be prudent for us to state categorically the water depth at the time of deposition of the Lee Creek Mine otolith fauna. Since such an assemblage of fossil otoliths represents a death assemblage only, and there is no first-hand documentation of conditions at the time of their demise, one must draw heavily upon intuition, a knowledge of present-day associations, and suggestions from colleagues, to synthesize any type of paleoecologic conclusion. Wigley and Stinton (1973:33) reported finding otoliths from six of these same species in bottom sediments off Massachusetts, mostly at depths exceeding 100 m. Depths reported for some of the species are: never shallower than about 82 m for *Lopholatilus* (Leim and Scott, 1966:244); 70 to 187 m for *Lepophidium cervinum* (Bigelow and Schroeder, 1953:518); strictly an inshore fish, seldom straying into depths greater than 4 to 6 m for *Microgadus tomcod* (Bigelow and Schroeder, 1953:197); and depths as shallow as 12 meters for *Urophycis tenuis* (Hildebrand and Schroeder, 1928:162). Sciaenids generally range from the intertidal into moderate depths offshore; brotulids and cusk-eels probably overlap at the deep end of the sciaenid distribution and range from there into depths exceeding 200 m; and congrids probably overlap the ophidiids and range into even greater depths.

With the exception of *Ceratoscopelus* and *Merluccius albidus*, all of the otoliths from Lee Creek Mine to which generic names could be assigned were from fishes that inhabit waters shallower than 200 m or they would not have been listed by Robins et al. (1980). Poll (1953:16–21,257)

gives depth distribution data for *Pterothrissus*. The finding of *Ceratoscopelus* otoliths is not unusual, since it is the rule rather than the exception to find myctophid otoliths in fossil faunas comprised of shallow- to moderate-depth species (Fitch, 1969a:1, 17). Presumably the presence of *Merluccius albidus* otoliths presents no more of an enigma than do those of myctophids. The three most abundant kinds, *Lepophidium* (5740 otoliths), *Merluccius* (1086 otoliths), and sciaenid species A (930 otoliths), comprise 88 percent of the recovered otoliths, and even though the recovery techniques (i.e., mostly gleaned by eye in the field) smack strongly of bias toward large otoliths, these three kinds provide the best index for speculating about depth at time of deposition. Based upon all the evidence at hand plus a large amount of intuition, a fauna such as this should represent deposition at 60 to 100 m, but could in fact have been much shallower or a great deal deeper.

This manuscript was completed in April 1973, and during the next 8 years it was updated as new or pertinent information became available. Our presentation contains whatever up-to-date information we felt was pertinent. There is a good chance, however, that we have missed some vital bit of information, or have failed to correct a statement made obsolete during the past eight years. We hope we will be forgiven if such oversights are found—they are not intentional.

The untimely death on 30 September 1982 of the senior author of this report has precluded full revision. The John E. Fitch Collection of fossils, including his notes, correspondence, and library, has been donated to the Natural History Museum of Los Angeles County.

Literature Cited

Bigelow, Henry B., and W.C. Schroeder
1953. Fishes of the Gulf of Maine. *U.S. Fish and Wildlife Service, Fishery Bulletin*, 53(74):1–577.

Böhlke, James E., and Charles C.G. Chaplin
1968. *Fishes of the Bahamas and Adjacent Tropical Waters*. 771 pages. Philadelphia: Academy of Natural Sciences of Philadelphia.

Bolin, Rolf
1959. INIOMI: Myctophidae, from the "Michael Sars" North Atlantic Deep-Sea Expedition 1910. *Report on the Scientific Results of the "Michael Sars" North Atlantic Deep-Sea Expedition 1910*, 4(pt. 2, no. 7):1–45, 7 figures.

Bortone, Stephen A.
1977. Revision of the Sea Basses of the Genus *Diplectrum* (Pisces: Serranidae). [U.S.] *National Oceanic and Atmospheric Administration Technical Report, National Marine Fisheries Service Circular*, 404:1–49, 15 figures.

Casier, Edgard
1958. Contribution à l'étude des poissons fossiles des Antilles. *Mémoires Suisses de Paléontologie*, 74:1–95.
1966. *Faune Ichthyologique du London Clay*. 496 pages, 80 figures, 68 plates. London: British Museum (Natural History).

Chao, Labbish Ning
1978. A Basis for Classifying Western Atlantic Sciaenidae (Teleostei: Perciformes). [U.S.] *National Oceanic and Atmospheric Administration Technical Report, National Marine Fisheries Service Circular*, 415:1–64, 41 figures.

Cohen, Daniel M., and Jørgen G. Nielsen
1978. Guide to the Identification of Genera of the Fish Order Ophidiiformes with a Tentative Classification of the Order. [U.S.] *National Oceanic and Atmospheric Administration Technical Report, National Marine Fisheries Service Circular*, 417:1–71.

Dante, John H.
1953. Otoliths of a New Fish from the Miocene of Maryland. *Journal of Paleontology*, 27(6):877–879, 6 figures.

Dieni, Iginio
1969. Gli Otoliti del Pliocene Inferiore di Orosei (Sardegna). *Atti e Memorie dell'Accademia Patavina di Scienze Lettere ed Arti, Padova*, 80(2):243–292, 3 plates, 2 figures.

Eastman, C.R.
1904. Pisces. *In* Systematic Paleontology, Miocene. *Maryland Geological Survey*, 2:71–93, plates 28–32.

Fitch, John E.
1967. The Marine Fish Fauna, Based Primarily on Otoliths, of a Lower Pleistocene Deposit at San Pedro, California (LACMIP 332, San Pedro Sand). *Los Angeles County Museum, Contributions in Science*, 128:1–23, 31 figures.
1968. Otoliths and Other Fish Remains from the Timms Point Silt (Early Pleistocene) at San Pedro, California. *Los Angeles County Museum, Contributions in*

Science, 146:1–29, 4 figures.

1969a. Fossil Lanternfish Otoliths of California, with Notes on Fossil Myctophidae of North America. *Los Angeles County Museum, Contributions in Science*, 173:1–20, 4 figures.

1969b. Fossil Records of Certain Schooling Fishes of the California Current System. *California Marine Research Committee, California Cooperative Oceanic Fisheries Investigations Report* (La Jolla), 13:71–80, 3 figures.

1969c. Fish Remains, Primarily Otoliths, from a Ventura, California Chumash Village Site (Ven-3). *In* Roberta S. Greenwood and R.O. Browne, A Coastal, Chumash Village: Excavation of Shisholop, Ventura County, California. *Memoirs of the Southern California Academy of Sciences*, 8(appendix A):56–71, 19 figures.

1970. Fish Remains, Mostly Otoliths and Teeth, from the Palos Verdes Sand (Late Pleistocene) of California. *Los Angeles County Museum, Contributions in Science*, 199:1–41, 6 figures.

Ms. The Teleost Otolith Fauna of the Calvert Cliffs (Miocene) of Maryland, with Comments on Paleoecologic Implications. In the files of the Section of Ichthyology, Natural History Museum of Los Angeles County, Los Angeles, California.

Fitch, John E., and Roger D. Reimer

1967. Otoliths and Other Fish Remains from a Long Beach, California, Pliocene Deposit. *Bulletin of the Southern California Academy of Sciences*, 66(2):77–91, 22 figures.

Frizzell, Don L., and John H. Dante

1965. Otoliths of Some Early Cenozoic Fishes of the Gulf Coast. *Journal of Paleontology*, 39(4):687–718, 2 figures, plates 86–88.

Frizzell, Don L., and Harriet Exline

1958. Fish Ossiculiths: Unrecognized Microfossils. *Micropaleontology*, 4(3):281–285.

Frizzell, Don L., and C. Kurt Lamber

1962. Distinctive "Congrid Type" Fish Otoliths from the Lower Tertiary of the Gulf Coast (Pisces: Anguilliformes). *Proceedings of the California Academy of Sciences*, 4th series, 32(5):87–101, 13 figures.

Frost, G. Allan

1925. Description of Fish Otoliths from the Tertiary Formations of Atcheen, Northern Sumatra. *Dienst van den Mijnbouw in Nederlandsch-Oost-Indië, Wetenschappelijke Mededeelingen*, 2:1–28, 2 plates.

Gaemers, P.A.M.

1973. New Otoliths from the Tertiary of the North Sea Basin. *Werkgroep voor Tertiaire en Kwartaire Geologie Mededelingen*, 10(2):58–75.

1976. New Concepts in the Evolution of the Gadidae (Vertebrata, Pisces), Based on Their Otoliths. *Werkgroep voor Tertiaire en Kwartaire Geologie Mededelingen*, 13(1):3–32.

Gaemers, P.A.M., and W. Schwarzhans

1973. Fisch-otolithen aus dem Pliozän von Antwerpen (Belgien) und Ouwerkerk (Niederlande) und aus dem Plio-Pleistozän der Westerschelde (Niederlande). *Leidse Geologische Mededelingen*, 49(2):207–257, 2 figures, 10 plates.

Ginsburg, Isaac

1954. Whitings on the Coasts of the American Continents. *U.S. Fish and Wildlife Service, Fishery Bulletin*, 96:187–208.

Gutherz, Elmer J.

1967. Field Guide to the Flatfishes of the Family Bothidae in the Western North Atlantic. *U.S. Fish and Wildlife Service Circular*, 263:1–47.

Hildebrand, Samuel F., and W.C. Schroeder

1928. Fishes of Chesapeake Bay. *United States Bureau of Fisheries Bulletin for 1927*, 53(1):1–388. [Reprinted 1972, THF reprints, Smithsonian Institution.]

Jónsson, Gunnar

1966. Contribution to the Biology of the Dab (*Limanda limanda* L.) in Icelandic Waters. *Rit Fiskideildar*, 4(3):1–36.

Kotthaus, Adolf

1968. Fische des Indischen Ozeans Ergebnisse der Ichthyologischen Untersuchungen Während der Expedition des Forschungsschiffes "Meteor" in den Indischen Ozean, Oktober 1964 bis Mai 1965, A: Systematischer Teil, III: Ostariophysi und Apodes. *"Meteor" Forschungsergebnisse*, series D, 3:14–56.

Leim, Alexander H., and W. Beverly Scott

1966. Fishes of the Atlantic Coast of Canada. *Fisheries Research Board of Canada Bulletin* (Ottawa), 155:485 pages.

Meyer, Robert L., B.H. Slaughter, J.H. McLellan, and R. W. Purdy

In prep. Neogene Ichthyofaunas from the Lee Creek Mine, Beaufort County, North Carolina.

Mohan, R.S. Lal

1969. A Synopsis to the Indian Genera of the Fishes of the Family Sciaenidae. *Indian Journal of Fisheries*, 16(1–2):82–98, 2 figures.

Mugiya, Yasuo

1972. On Aberrant Sagittas of Teleostean Fishes. *Japanese Journal of Ichthyology*, 19(1):11–14.

Nolf, Dirk

1974. De Teleostei-Otolieten uit het Eoceen van het Belgisch Bekken—Reconstructie van de Fauna en Biostratigrafische Toepassing. 173 pages. Doctoral dissertation, Rijksuniversiteit Gent.

1976. Les Otolithes des Téléostéens Néogènes de Trinidad. *Eclogae Geologicae Helvetiae*, 69(3):703–742, 5 figures, 12 plates.

1980. Étude monographique des otolithes des ophidi-

iformes actuels et revision des especes fossiles (Pisces, Teleostei). *Werkgroep voor Tertiaire en Kwartaire Geologie Mededelingen*, 17(2):71–195.

Palmork, Karsten H., M.E.U. Taylor, and R. Coates
1963. The Crystal Structure of Aberrant Otoliths. *Acta Chemica Scandinavica*, 17(5):1457–1458.

Poll, Max
1953. Poissons, III: Téléostéens Malacoptérygiens. In *Expédition Océanographique Belge dans les Eaux Côtierès Africaines de L'Atlantique Sud (1948–1949)*, 4(2):1–258. Brussels.

Richards, Sarah W., Alfred Perlmutter, and Donald C. McAneny
1963. A Taxonomic Study of the Genus *Ammodytes* from the East Coast of North America (Teleostei: Ammodytes). *Copeia*, 2:358–377.

Robins, C. Richard, Reeve M. Bailey, Carl E. Bond, James R. Brooker, E.A. Lachner, Robert N. Lea, and W.B. Scott
1980. A List of Common and Scientific Names of Fishes from the United States and Canada, 4th edition. *American Fisheries Society, Special Publication*, 12:1–174.

Roux, Charles
1973. Résultats scientifiques des campagnes de la "Calypso," Fax. X; Poissons téléostéens du plateau continental brésilien. *Annales de l'Institut Oceanographique* (Monaco), 49(supplement):23–207.

Schwarzhans, Werner
1976. Die Fossilen Otolithen der Gattung *Bathycongrus* (Meer-Aale; Congridae, Pisces). *Senckenbergiana Lethaea*, 56(6):469–477, 4 figures.

Scott, J.S.
1972. Morphological and Meristic Variation in Northwest Atlantic Sand Lances (*Ammodytes*). *Journal of the Fisheries Research Board of Canada*, 29(12):1673–1678, 2 figures.

Smith, David G., and R.H. Kanazawa
1977. Eight New Species and a New Genus of Congrid Eels from the Western North Atlantic with Descriptions of *Ariosoma analis*, *Hildebrandia guppyi*, and *Rhechias vicinalis*. *Bulletin of Marine Science of the Gulf and Caribbean*, 27(3):530–543.

Stinton, Frederick C.
1965. Teleost Otoliths from the Lower London Tertiaries. *Senckenbergiana Lethaea*, 46a:389–425, plates 30–33. [Published as a supplement to volume 46 as a festschrift in honor of Wilhelm Weiler.]
1966. Fish Otoliths from the London Clay. *In* Edgard Casier, *Faune Ichthyologique du London Clay*, pages 408–478. London: British Museum (Natural History).
1975. Fish Otoliths from the English Eocene, Part 1. *Palaeontographical Society Monograph* (London), 129(1):1–56, figures 1–12, plates 1–3.
1977. Fish Otoliths from the English Eocene, Part 2. *Palaeontographical Society Monograph* (London), 130(2):57–126, figures 13–24, plates 4–8.

Trewavas, Ethelwynn
1977. The Sciaenid Fishes (Croakers or Drums) of the Indo-West Pacific. *Transactions of the Zoological Society of London*, 33(4):253–541, 61 figures, 14 plates. [For illustrations of otoliths, see figures 1, 3, 4, 7c, 9, 18, 19, 21, 26, 27b, c, 29b, 30, 31, 33, 39, 47, 48, 61.]

Weiler, Wilhelm
1959. Über Ossiculithen und Otolithen bei Fischen. *Paläontologische Zeitschrift*, 33(3):148–151.
1968. Otolithi Piscium (Neubearbeitung). *In* Frank Westphal, editor, *Fossilium Catalogus, I: Animalia*, 117:1–196. s'Gravenhage, Netherlands: W. Junk N.V.

Wigley, Roland L., and F.C. Stinton
1973. Distribution of Macroscopic Remains of Recent Animals from Marine Sediments off Massachusetts. [U.S.] *National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Fishery Bulletin*, 71(1):1–40, 26 figures.