

FOSSIL MARINE MAMMALS OF THE LOWER MIOCENE POLLACK FARM SITE, DELAWARE¹

David J. Bohaska²

ABSTRACT

The Pollack Farm Site, a borrow pit (now covered) near Cheswold, Delaware, in the Cheswold sands of the lower Miocene Calvert Formation, produced a fragmentary marine mammal fauna. At least six cetaceans are present: five porpoises comprising a squalodont, *Squalodon calvertensis*, the squalodelphid *Phocageneus venustus*, the long-beaked platanistid *Zarhachis flagellator*, a rhabdosteid *Rhabdosteus* sp., and a small kentriodontid; and a sperm whale. Also present is a dugong, and one of the earliest records of a true seal, *Leptophoca lenis*. Although less diverse than the Calvert fauna as known from Maryland and Virginia, this is most likely a product of sampling. The absence of the common Calvert porpoise *Eurhinodelphis* from the Pollack Farm Site may be significant; the absence of mysticetes (whalebone or baleen whales) matches their unexplained absence from beds of similar age in the lower Calvert of Maryland and Virginia.

INTRODUCTION

The Pollack Farm Site (Delaware Geological Survey locality Id11-a), a borrow pit excavated near Cheswold, Delaware, for road bed material, exposed the Cheswold sands of the lower Miocene Calvert Formation (Ramsey et al., 1992). The site was the subject of intensive field study and fossil collecting from November 1991 through May 1992 by field crews from the Delaware Geological Survey, Virginia Museum of Natural History, and Smithsonian Institution, and members of the construction crews and amateur fossil collectors.

The beds at the site are equivalent in age to Bed 3A of the Fairhaven Member (diatomaceous earth) of the Calvert Formation in Maryland (Ward, 1993; Jones et al., 1995) and are discussed in more detail in other papers in this volume (Benson, 1998; Ramsey, 1998; Jones et al., 1998). On the basis of stratigraphic position, they are possibly the same age as the Popes Creek Sand Member (Gibson, 1983) of the Calvert Formation (Wetmore and Andrews, 1990; Gibson and Andrews, 1994), which does contain a diverse vertebrate fauna (largely unpublished). Specimens from the Popes Creek Sand are cited within this paper as the earliest occurrences of the represented taxa within the Calvert Formation in Maryland and Virginia and the nearest in age to those from the Pollack Farm Site. Unlike Bed 3A and the Popes Creek Sand, the Pollack Farm Site includes beds with a well preserved, abundant, and diverse molluscan fauna (Ward, 1998). The site also produced a diverse vertebrate fauna, distinguished from the other Chesapeake Group outcrops of Maryland and Virginia in containing a more diverse terrestrial mammal, terrestrial reptile, and amphibian assemblage, adding many new elements to the Calvert fauna. By contrast, the marine mammal collection, the subject of this paper, is more fragmentary and less diverse than the marine mammal fauna from the Calvert Formation of Maryland and Virginia, lacking the more nearly complete skulls and skeletons found there.

Acknowledgments

Field work at the Pollack Farm Site was a pleasant experience owing to the cooperation of the crews from the Delaware Department of Transportation, Pierson Engineering, and Century Engineering. Particular thanks go to Gordon

Simonson not only for providing many of the specimens used in this and other papers but for his logistical support.

Specimens cited in this paper were donated by David Duke, Gordon Simonson and Lauck W. Ward, and loaned by John Clark, Thomas R. O'Hagen and John Ricard. Additional cetacean specimens were donated by the above and Kenneth Webb, and loaned by David L. Anker, Michael Miskofsky, Mark L. Richerson, and Greg Turner.

Lauck W. Ward introduced me to the site, and Ralph E. Eshelman and Robert W. Purdy collected for the Smithsonian. Frederick Von Hofe Grady's skill in processing and picking the bags of concentrated matrix added several marine mammal specimens to the collection. Use of the Calvert Marine Museum collection was courtesy of curator Michael D. Gottfried. Norman L. Riker permitted examination of his Popes Creek Sand Member collection, and he donated *Phocageneus* specimens to extend the known range of that genus. William "Pat" Gotsis found the first known physterid in the Popes Creek Sand while this paper was in preparation.

Mario A. Cozzuol first recognized the complete periotic described as physeterid, and Clayton E. Ray the single seal bone. I discussed squalodonts with Alton Dooley, sirenians with Daryl Domning and sperm whales with James G. Mead.

Photography was by Peter Kroehler, Laurie Minor-Penland, and Victor Krantz.

Clayton E. Ray and Frank C. Whitmore, Jr., reviewed the manuscript and provided many useful comments.

Funding was provided by the National Geographic Society and the Remington and Marguerite Kellogg Memorial fund.

COLLECTING METHODS AND METHODS OF INVESTIGATION

Identifications of the scrappy material in this report are based primarily on comparisons with the Miocene Calvert fauna of Maryland and Virginia in the collections of the Department of Paleobiology, National Museum of Natural History, Smithsonian Institution (USNM) and of the Calvert Marine Museum (CMM-V). Since sampling techniques undoubtedly affect conclusions regarding relative abundances, a description follows.

¹ In Benson, R.N., ed., 1998, Geology and paleontology of the lower Miocene Pollack Farm Fossil Site, Delaware: Delaware Geological Survey Special Publication No. 21, p. 179–191.

Collecting was done by careful inspection of spoil piles, particularly those rich in material derived from the shell beds. Spoil pile and *in situ* shell bed matrix was screen washed and inspected in the field; all fine concentrate and most of the coarse concentrate was fully picked in the laboratory. Picking of some of the fine concentrate (particularly that collected late in the field work) was facilitated by dissolving most of the carbonate shell fragments with acetic acid following a first picking to remove most of the identifiable mollusks and otoliths. All vertebrate material collected by the three institutions was retained.

Although most material described in this report was found loose in spoil piles, or received with no specific data, most was probably derived from the lower shell bed (see Benson, 1998, fig. 2), since spoil of this material was most intensively inspected. All terrestrial mammals found are consistent with one age, early Hemingfordian (Emry and Eshelman, 1998), confirmed by the early Miocene age based on radiolarians from a sandy silt between the lower and upper shell bed (Benson, 1998) and the strontium-isotope age estimate of 17.9 Ma on mollusks from the lower shell bed (Jones et al., 1998).

Almost all of the vertebrate fossils found by amateurs were inspected by Smithsonian staff. Because cetacean bones and teeth tend to be simpler, they are inherently less identifiable from teeth, postcranial, and scrap material than terrestrial mammals. More nearly complete cetacean material (skulls, jaws, and skeletons) has been and is found regularly in Maryland and Virginia. For these reasons, cetacean scrap was not solicited for donation or loan as rigorously as terrestrial mammals, which are more poorly known from Maryland and Virginia. As a result, the cetaceans represented in the institutional Pollack Farm Site collections are lower in number of specimens than would be preserved relative to land mammals in a marine deposit. No actual counts were made, but cetacean scrap was observed more often in the field and in amateur collections than land mammals. Potentially identifiable cetacean specimens (teeth, and jaw, skull, and limb fragments) were solicited on par with terrestrial mammal specimens, but vertebrae and ribs generally were not. (Although again not quantified, the majority of marine mammal remains found in Maryland and Virginia Calvert outcrops are also isolated vertebrae and other scrap; however, good collections of skulls and skeletons have been accumulated over the years).

SYSTEMATIC PALEONTOLOGY
Order CETACEA
Suborder ODONTOCETI
SQUALODONTIDAE

***Squalodon calvertensis* Kellogg, 1923**

Specimens (8).—USNM 488600, crown of anterior incisor, collected by L.W. Ward; USNM 487253, partial crown and partial root of anterior incisor, collected by G. Simonson; USNM 487254, partial crown and root of anterior incisor, collected by G. Simonson; USNM 488601, cast of anterior incisor, original found by and in the collection of J. Clark; USNM 487255, partial crown of incisor, collected by G. Simonson; USNM 487256, partial crown and roots of molariform tooth, collected by G. Simonson; USNM 487257, fragment of crown of molariform tooth, collected by R.E. Eshelman; USNM 488602, cast of partial crown and

roots of molariform tooth, original found by and in collection of J. Ricard.

Description.—The presence of at least one of the heterodont squalodonts or shark-toothed porpoises is most evident in the several molariform teeth in the collection (Fordyce [1982] argued that premolars and molars cannot be differentiated in squalodonts, so the term “molariform” is used here). USNM 487256 (Plate 1A) and USNM 488602 (Plate 1B) preserve the double roots, and the triangular, laterally compressed, wrinkled enamel crowns of the molariform teeth. The characteristic cusps along the cutting edges can be seen as one cusp on the posterior edge of USNM 487256, parts of two and possibly three cusps on USNM 487257, and hints of cusps on the broken edges of USNM 488602. In both USNM 487256 and USNM 488602, the two roots are joined for a distance below the crown, more so in USNM 487256 (22 mm vs. 19 mm measured on the lingual side). USNM 488602 has swollen-appearing roots, owing to a thickened layer of cementum.

The conical anterior incisors (USNM 488600, Plate 1C,D; USNM 487253) are large (compared with typical porpoise teeth), have prominent anterior and posterior cutting edges (particularly visible on USNM 488600, Plate 1D), and wrinkled enamel. The enamel-root boundary is sigmoid (most visible on USNM 487253) typical of, but not restricted to, squalodonts. All are interpreted as anterior incisors because they are relatively straight; reconstructions of *Squalodon* show these teeth extending directly anteriorly from the end of the rostrum and mandibles.

USNM 487254 also appears to be a squalodont anterior incisor. The enamel-root boundary appears to be sigmoid (wear prevents this from being certain). The wrinkled nature of the enamel is only debatably visible; the little enamel preserved is almost entirely worn smooth. Like the molar USNM 488602, the root (single in this case) has a thick layer of cementum.

Part of the crown is missing on USNM 488601, revealing a 20-mm-deep conical cavity diminishing to a point toward the root. Were it not for a 4 mm x 4 mm patch of probable enamel preserved on the crown, the cavity could be interpreted as the pulp cavity in the root, and the tooth identified as physeterid. A similar cavity is visible in USNM 487254, where a larger, undebatable patch of enamel is present.

USNM 487255 is more curved than the other incisors and is interpreted as a more posterior incisor (or canine; homologies are uncertain except possibly in an intact jaw). The cutting edges are preserved. The enamel is more striated than wrinkled.

Kellogg (1923) described two squalodonts from the Calvert Formation, the smaller *Squalodon calvertensis* (estimated body length 10 ft or 3 m, Kellogg, 1957) and a larger unnamed species (more complete remains from Maryland and Virginia are currently under study by Alton Dooley). Both species are present in the Popes Creek Sand in Maryland (*S. calvertensis*: CMM-V-206, CMM-V-207; *Squalodon* species: CMM-V-182). The Pollack Farm Site specimens are tentatively referred to *S. calvertensis* based on size.

Squalodonts are generally considered more primitive because of the retention of a prominent heterodont dentition. In the Maryland and Virginia Miocene they are reliably present as high as Bed 12 of the Calvert Formation (CMM-V-930).

SQUALODELPHIDAE

Phocageneus venustus Leidy, 1869

Specimens (3).— USNM 487258, tooth, collected by G. Simonson; USNM 488603, USNM 488604, casts of teeth, originals found by and in the collection of J. Ricard.

Description.—The best evidence of the presence of this species at the Pollack Farm Site is a single tooth, USNM 487258 (Plate 1E,F), with highly wrinkled enamel. A number of Calvert Formation odontocetes show limited heterodonty (as opposed to the obviously heterodont *Squalodon*), with all the teeth single rooted, variably more or less wrinkled enameled teeth more posterior in the tooth row, and smoother more peg-like teeth anteriorly (with few exceptions, modern porpoises have a homodont dentition of smooth enameled, peg-like teeth throughout their jaws). USNM 487258 matches *Phocageneus* in size and high degree of enamel wrinkling, and in the characters noted by Kellogg (1957, p. 286–287):

base of enameled crown becomes narrower as it approaches the root, and complication of the wrinkled enamel surface by both vertical and oblique striae, posterior teeth more rugose on the basal portion of the lingual side of the tooth than the labial side, and anterior and posterior cutting edges present.

A second tooth (USNM 488603, Plate 1H) may be a more anterior tooth of this species; it is less rugose and somewhat larger than similar teeth in Kellogg's referred specimen (1957). It resembles phocid canines, but the cutting edges are less prominent and the rugosity more so. A third rugose tooth (USNM 488604 Plate 1G) is smaller and tentatively referred to *Phocageneus*.

Phocageneus venustus is a poorly known species originally described from a single tooth, which for at least the time being must be considered to be from an unknown horizon. The specimen referred to the species by Kellogg (1957) came from what is now known as Bed 3B of the Fairhaven Member, Calvert Formation. Two teeth (USNM 488609, USNM 488610) probably from the Popes Creek Sand closely resemble some of the posterior teeth of *Phocageneus* (USNM 21039, Kellogg, 1957) although they are somewhat smaller. The skull is as yet undescribed and the species is only tentatively referred to the Squalodelphidae (Kellogg, 1957).

PLATANISTIDAE

Zarhachis flagellator Cope, 1868

Specimens (4).—USNM 487259, mandibular symphysis fragment, approaching distal end, collected by G. Simonson; USNM 487260, section of symphyseal portion and ascending ramus of right mandible, collected by G. Simonson; USNM 487262, anterior process of right periotic, collected by G. Simonson; USNM 487263, anterior process of right periotic, collected by D.J. Bohaska.

Description.—A 252-mm section of mandibular symphysis (USNM 487259, Plate 2A,C) clearly came from one of the extremely long-beaked porpoises. The two longitudinal grooves on the ventral side (Plate 2C) are characteristic of *Zarhachis*, *Pomatodelphis* and several other modern and fossil genera, and the mandible is dorsoventrally flattened as in *Zarhachis* and *Pomatodelphis*. Another mandibular frag-

ment (USNM 487260, Plate 2E) has the ventral groove and shows the U-shaped, instead of V-shaped juncture of the free ends of the mandible characteristic of these two genera.

Two anterior processes of the periotic (USNM 487262, 487263) are massive, as in *Zarhachis* and *Pomatodelphis*, have a longitudinal groove on the bullar facet (also seen on rhabdosteids) and a U-shaped anteroexternal sulcus (also in rhabdosteids).

The only periotic associated with a lower Calvert *Zarhachis* skull is USNM 10485, a partial right periotic lacking the posterior process. A complete right periotic (USNM 187414) associated with a skull shows no significant differences from this fragment; this skull is from the Choptank Formation and has been referred to *Pomatodelphis* (Muizon, 1987). Although being at least a different species (see below), this specimen and others of the same species were the most appropriate available for comparison.

The closely related and possibly congeneric *Zarhachis* and *Pomatodelphis* cannot be distinguished from one another from fragments of these kinds, and the specimens from the Pollack Farm Site are referred to *Z. flagellator* on the basis of stratigraphic position. The concept of *Z. flagellator* used here is based on the two specimens described by Kellogg (1924, 1926), derived from the lower Calvert Formation (Bed 5, and Bed 6,7 or 8). Two periotics (USNM 299950, 299951) are known from the Popes Creek Sand Member at Popes Creek, Maryland. A second species of *Zarhachis* or *Pomatodelphis* occurs higher in the Calvert (Bed 10 or 11, and Bed 12) and Choptank (Bed 17) (Gottfried et al., 1994) and possibly a third in the St. Marys (Gottfried et al. 1994). Complicating identification is the poor quality of the type specimen of *Z. flagellator* (a worn caudal vertebra) from an unknown horizon. Resolution of the taxonomy of *Zarhachis* and its relatives is not appropriate here.

Zarhachis is an extremely long-beaked porpoise, in which both upper and lower jaws are the same lengths (their anterior tips meet), estimated at 5 m (16 feet) total body length (Kellogg, 1957). The supraorbital process of the frontal is greatly thickened dorsally. It has been referred to the river porpoises (Platanistidae) and generally regarded as closest to *Platanista* (Kellogg, 1924; Muizon, 1987), although interpreting the habitat and lifestyle by analogy with modern river porpoises is questionable; *Zarhachis* is clearly different from modern members of the family. Modern platanistoids (often grouped together in the single family Platanistidae) live in both fresh and, if *Pontoporia* is included, nearshore marine environments.

RHABDOSTEIDAE (=EURHINODELPHIDAE)

Rhabdosteus sp.

Specimen.— USNM 487264, mandibular symphysis fragment, approaching distal end, collected by G. Simonson.

Description.—Another species of long-beaked porpoise is represented by a 174-mm section of mandible (USNM 487264, Plate 2B,D). Like *Zarhachis*, there are two longitudinal grooves ventrally. Unlike *Zarhachis*, but like *Rhabdosteus* and *Eurhinodelphis*, the mandible is narrower (*Zarhachis* and the present specimen are illustrated at the same scale in Plate 2), and relatively deeper dorso-ventrally. At least some specimens of both *Rhabdosteus* (for example, USNM 206006 and 20668) and *Eurhinodelphis* (for exam-

ple, USNM 187623, CMM-V-14) have grooves on the ventral surface of the mandible. *Rhabdosteus* has larger, fewer tooth sockets, with the sockets well defined by well developed septa between sockets, as in USNM 487264 from the Pollack Farm Site. *Eurhinodelphis* has more tooth sockets more closely spaced, with less well developed septa between sockets (Myrick 1979).

Rhabdosteus latiradix Cope 1868 is the genotypic species. Myrick (1979) in manuscript described several new species in the genus. Muizon (1988) considered *Rhabdosteus* a *nomen dubium* and referred specimens referred to the genus (in manuscript and in collections) to *Schizodelphis*, unfortunately using one of Myrick's unpublished names. Tentatively, the name *Rhabdosteus* is retained here. According to Kellogg (1957), *Rhabdosteus* is the most numerous odontocete in the Calvert fauna, whereas Myrick (1979) shows *Rhabdosteus* and *Eurhinodelphis*, at the generic level, about equal in number of identified specimens. In any case, each of the two genera is more numerous than any other odontocete genus in the Calvert. The low numbers of *Rhabdosteus* and absence of *Eurhinodelphis* at the Pollack Farm Site are surprising, although the low sample size may be a factor. Additional specimens may be unidentified among the fragmentary remains in the collections, although one would have expected to find the easily recognized anterior caudal vertebrae of *Eurhinodelphis* in the collections. *Eurhinodelphis* is present in the Popes Creek Sand Member at Popes Creek, Maryland (CMM-V-347).

Rhabdosteus was estimated at just under 3.7 m (12 feet) in total body length (Kellogg 1957); the rostrum extends well beyond the distal end of the mandible, and the distal one-third of the rostrum is seemingly edentulous in old individuals (Kellogg 1957). In Maryland and Virginia, *Rhabdosteus* is restricted to the Calvert Formation and has been found in the Popes Creek Sand Member (USNM 206006). Myrick (1979) inferred pelagic habits based on the wide distribution of some species; at least one member of the family (but probably not the same genus) occurred in fresh water (Fordyce, 1983).

KENTRIODONTIDAE

Specimens (2).—USNM 487265, tooth, collected by D.J. Bohaska (found *in situ* in cross-bedded sandy shell bed); USNM 488605, tooth, collected by Smithsonian field party.

Description.—A tooth (USNM 487265, Plate 1I) most closely resembles that of *Kentriodon pernix* Kellogg (1927) among the published Calvert odontocetes in its small size and simple architecture: smooth crown, lacking any rugosity, and conical shape. Faint carinae are present on the anterior and posterior sides of the tooth; Kellogg (1927) mentions a lack of carinae in *K. pernix*, although faint carinae appear present in his plate 8, figure 2, and are present, although faint, on some of the actual teeth illustrated in that figure. The base of the crown and top of the root are the same diameter in the individual teeth of the holotype of *K. pernix* (USNM 8060) and the Pollack Farm Site USNM 487265, resulting in a smooth transition from enamel to root.

The second Pollack Farm Site tooth (USNM 488605, Plate 1J) is more worn than the first, but is roughly equal in size and simple shape. USNM 488605 is broader at the base of the crown, the crown is more tightly curved, and the root

is broader than the crown in some areas, owing to the presence of cementum. Cementum is deposited on the root continuously during the life of a porpoise, and can result in thicker, swollen roots in older individuals. The cementum can break off, as can be seen in one area on USNM 488605; in this area the enamel crown and the dentine of the root have a smooth transition as in the holotype of *K. pernix*.

USNM 487265 and USNM 488605 also resemble teeth in another undescribed species in the Calvert. This second species (USNM 25005, USNM 457211, USNM 171077) resembles *K. pernix* in its small size and general skull outline, but its skull roof is laterally constricted and resembles the larger *Liolithax pappus* (Kellogg) 1955, which would place it in another subfamily. Two teeth associated with USNM 457211, and three in USNM 171077, are also small, simple and have faint carinae. The roots are expanded on USNM 457211 owing to a heavier layer of cementum, resembling the second tooth from the Pollack Farm Site (USNM 488605) more closely. In the other skull (USNM 171077) of this possible new species the one tooth (of three present) on which some of the root is exposed, shows no cementum.

Identification of a porpoise solely on teeth, particularly such simple ones, must be considered tentative. Given the small sample of teeth associated with identifiable skulls of these two species, the variability of teeth within the jaws of one individual (Kellogg, 1927, plate 8) and between individuals of one species, and the similarity of the teeth in the two species, it appears that these two species cannot be distinguished on the basis of teeth alone. For that reason the two Pollack Farm Site teeth are identified to family only, and assignment even at that level is tentative.

Several skulls are known from the Popes Creek Sand Member near Popes Creek, Maryland, which is thought to be similar in age to the Pollack Farm Site. CMM-V-247 and CMM-V-886 have the *K. pernix* skull roof; no specimens displaying the second skull roof type were recognized in the USNM or CMM collections from this level.

K. pernix was a small (1.6 m or 5.5 feet long) short-beaked porpoise reconstructed as resembling modern porpoises (Kellogg, 1927). The Kentriodontidae are generally considered to contain the ancestors of the modern delphinids, although no ancestor-descendant relationships at the generic or specific levels have been hypothesized (Ichishima et al., 1995).

PHYSETERIDAE

Specimens (3).—USNM 487266, distal portion of tooth, collected by G. Simonson; USNM 488606, cast of tooth, original found by and in the collection of T.R. O'Hagan; USNM 488607, cast of right periotic, original found by and in the collection of J. Ricard.

Description.—The distal end of a tooth 6.5 cm in length (USNM 487266, Plate 1K) is recognizable as a tooth by its cross section; dentine and cementum layers are visible. Its large diameter (2.4 cm maximum), lack of enamel (present in some fossil sperm whales, particularly *Scaldicetus*), and longitudinal grooving show it to be a sperm whale. An approximately 2-cm dished-out area represents wear created during life, and is similar to wear often seen on odontocete teeth, but particularly sperm whales. Other wear less certainly originated in life. No pulp cavity is present, presumably due to the distal location of this fragment.

USNM 488606 (Plate 1L,M), although nearly complete, is more questionable. It is large (9.4 cm long, 2.3 cm maximum diameter), lacks enamel, and has a well developed pulp cavity. It does not show the longitudinal grooves seen in USNM 487266 and is in the size range of a large *Squalodon* incisor or canine. A dark line partially circles the crown approximately 2 cm below its tip. This is interpreted here as a stain above the gum line; similar stains are seen in some modern *Physeter* teeth and many fossil teeth.

Transverse bands in the dentine usually seen on *Orycterocetus* and used in its diagnosis are not visible on either of the Pollack Farm Site teeth, either through absence or a covering of cementum.

The periotic (USNM 488607, Plate 1N–Q), is the only complete periotic found at the site. The accessory ossicle, well developed in sperm whales and some other odontocete families, is missing in this specimen, not an unusual occurrence. There is a depression on the ventral surface of the anterior process (Plate 1O), anterior to the fossa for the head of the malleus, where the accessory ossicle was attached. The anterior end of the anterior process is squared off and has a groove (Plate 1O); as a result the process has two heads, resembling the handle of a crutch in Kellogg's terminology (1931). As in *Physeter* (Kasuya, 1973), the *aqueductus fallopii*, *foramen singulare*, *ductus endolymphaticus*, and *tractus spiralis foraminosus* all open into the one opening of the fundus of the internal auditory meatus (Plate 1N).

Orycterocetus crocodilinus Cope (1868), see Kellogg (1965), is the only sperm whale as yet reliably ascribed to the Calvert Formation, and is the largest odontocete in the fauna (Kellogg, 1957; Gottfried et al., 1994). Among the suite of teeth in a sperm whale from the Calvert Formation in Maryland, USNM 336585, are teeth resembling *O. crocodilinus*; others resemble the genotypic *O. quadratidens* "from the miocene formation of Virginia" (Leidy, 1853b). Questions of synonymy should be held until the stratigraphic origin of *O. quadratidens* is determined, if possible, and better specimens are obtained in that formation. Although most cetaceans from the type locality (Charles County, Maryland) of *O. crocodilinus* have been ascribed to the Calvert Formation, this must also be considered questionable (see Gottfried et al., 1994). Published records have *O. crocodilinus* as low as Bed 9 of the Calvert Formation in Maryland (Kellogg, 1965); a physeterid with enamel-crowned teeth was recently found in the Popes Creek Sand (USNM 489195). With the lack of definitive characters to assign the fragmentary specimens from Delaware to *Orycterocetus*, they are referred to family only.

Order CARNIVORA PHOCIDAE

Leptophoca lenis True, 1906

Specimen.— USNM 475898, partial left calcaneum, collected by G. Simonson.

Description.—A worn partial distal half of a left calcaneum (USNM 475898, Plate 2F) preserves the posterior articular surface and the anterior half of the anteromedial articular surface. The "prominent longitudinal ridge . . . on the dorsal table, between the trochlear process and the anteromedial articular surface, . . . [extending from] the posterior articular surface to the cuboid articular surface" char-

acteristic of the Phocidae (Robinette and Stains, 1970, p. 530) is present, although because the trochlear process is missing, only a shelf remains where the groove lateral to this ridge should be.

The oldest currently described phocid is a phocine, *Leptophoca lenis* True (1906), from the Calvert Formation (Repenning et al., 1979). Although the monochine *Monotherium? wymani* (Leidy, 1853a), see Ray (1976), was reported from the Calvert Formation of Richmond, Virginia, later work near the type locality shows that the holotype probably came from higher in the Chesapeake Group (Andrews, 1986), and all of the stratigraphically controlled phocid remains from the Calvert in Maryland and Virginia are phocine and are tentatively referred to *Leptophoca lenis* (Clayton E. Ray, pers. comm.), as is the specimen from Delaware. (The holotype of *L. lenis* is an isolated humerus. As yet, no *Leptophoca* humerus has been found associated with any other element, and there are no well preserved Calvert phocid calcanea available in collections to refer even tentatively to *Leptophoca* for comparison with the Pollack Farm Site specimen.) The lowest Calvert phocid is an upper premolar (USNM 412122) reportedly from Bed 5 of the Calvert Formation at Chesapeake Beach, Maryland. (The locality data and stratigraphic level, "base of cliff," leave the possibility that this specimen came from a level equivalent to uppermost Bed 3B, Bed 4, or lower Bed 5, since Bed 4 cannot be easily distinguished at this locality. In any case, the difference in time represented is negligible.)

This leaves the Calvert *Leptophoca lenis* as the oldest known member of the Phocidae, and the Pollack Farm Site specimens the oldest in the Calvert. Although intensive collecting in Maryland and Virginia has resulted in a fair number of *Leptophoca* specimens, they are rare, and it is not surprising that only one was found at the Pollack Farm Site. Other early records of the family include an undescribed new species from the middle Miocene of Argentina (Cozzuol, 1992), and two specimens from the late Oligocene of South Carolina (Koretsky and Sanders, 1997).

Order SIRENIA Family DUGONGIDAE

Specimens (2).—USNM 487268, fragment of rib, collected by G. Simonson; USNM 488608, fragment of rib, collected by L.W. Ward.

Description.—Both ribs are solid or nearly so in cross section (some spongy bone is present in USNM 488608). This condition, termed osteosclerosis (Domning and Buffrénil 1991), is characteristic of the Sirenia. The condition also occurs in archaeocetes, a Paratheyean cetothere, and some seals.

Only one sirenian is described from the Calvert Formation, *Metaxytherium crataegense* (Kellogg, 1966; Aranda-Manteca et al., 1994), although there is the possibility of one or more additional species. Eastern North American sirenians were all members of the family Dugongidae until the arrival of manatees (family Trichechidae) in the Pleistocene.

Only one other sirenian rib fragment from the Pollack Farm Site was seen in an amateur collection; sirenians are rare in the Maryland and Virginia Calvert, and this appears to be the case at the Pollack Farm Site also. They have been found in the Popes Creek Sand Member (USNM 241562, CMM-V-244). Sirenians tend to occur in fresh and near-

shore marine waters; with the exception of the recently extinct *Hydrodamalis*, they are more abundant in warm water. This pattern is seen in the Eocene through modern record of the North American east coast; sirenians are most abundant in Florida and rarer to the north.

CONCLUSIONS

The Pollack Farm Site provided a more diverse molluscan assemblage than seen at the presumed same stratigraphic level in Maryland (Popes Creek Sand Member), and a greater terrestrial mammal, terrestrial reptile and amphibian assemblage than seen in the entire Chesapeake Group (Old Church through Chowan River formations; Maryland, Virginia, and North Carolina). In contrast, the marine mammal collections are more fragmentary and less diverse. The site does extend the record into Delaware, confirms several patterns seen elsewhere, and extends the record of the Calvert Formation.

Although Gottfried et al. (1994) list 21 cetacean species for the total Calvert Formation, versus six species identified at the Pollack Farm Site, the difference is not as lopsided as it would first appear. Of the 21 species, five are mysticetes, absent in the Maryland lower Calvert, as they are in Delaware. Of the cetaceans present in Maryland but absent in Delaware, an additional four are rare, poorly known (at least regionally) genera (*Araeodelphis*, *Pelodelphis*, *Tretosphys*, *Notocetus*) and one (*Zarhachis* or *Pomatodelphis inaequalis*) occurs higher in the Calvert. "*Delphinodon*" *dividum*, *Liolithax*, and *Hadrodelphis* are known by more adequate specimens but are not common. None of these last eight has been found in the Popes Creek Sand. One rare Calvert genus, *Phocageneus*, has been found at the Pollack Farm Site.

Of the Pollack Farm Site marine mammals, *Squalodon calvertensis*, *Phocageneus venustus*, *Zarhachis flagellator*, *Rhabdosteus*, a small kentriodontid, a physeterid, and a dugong have been found in the Popes Creek Sand. The Pollack Farm Site provides a lower occurrence of *Leptophoca*. Only *Eurhinodelphis* and a larger *Squalodon* species are known at Popes Creek and not at the Pollack Farm Site. When the Calvert fauna is subdivided by its occurrences in the members and beds of the formation, sample sizes become much smaller. Much is yet to be learned about the Calvert fauna, so the ranges and especially negative evidence of these rare species within the formation should not be taken as significant at this time.

Despite the precaution noted above, several patterns do emerge, particularly when dealing with the more common elements of the faunas. As in the lower Calvert, long-beaked porpoises are dominant, although (questionably, given the small sample) *Zarhachis* is more common than the Rhabdosteidae (=Eurhinodelphidae). Surprisingly, no specimens of *Eurhinodelphis* were recognized, despite its abundance in the Calvert and its easily recognizable caudal vertebrae. (In all these estimates, abundance is an impression based on relative numbers of specimens. A more rigorous estimate of minimum numbers of individuals would result in counts of one individual per species, except two for *Zarhachis*). In the Choptank and St. Marys formations of Maryland, the Rhabdosteidae are absent and *Zarhachis* or a related genus (*Pomatodelphis*) becomes the most common odontocete. *Squalodon* is present (more common in the lower Calvert but seen as high as Bed

12), again arguably more common at the Pollack Farm Site, and there are hints of the remaining cetacean fauna (short-beaked kentriodontids, sperm whales, and one of the rarer porpoises, *Phocageneus*).

It should be noted that *Squalodon* teeth and *Zarhachis* mandible fragments are easily recognized, whereas other porpoise teeth, rostral fragments, and other elements found at the Pollack Farm Site have not been identified to genus. This provides an alternate explanation for the seemingly greater relative abundance of these two genera in Delaware than in Maryland and Virginia.

Also as in the lower Maryland sequence, mysticetes are not present. As noted in Gottfried et al. (1994), this is particularly surprising given their widespread occurrences in earlier and later strata on the East Coast, including the higher Calvert and the rest of the Chesapeake Group. Wetmore and Andrews (1990) show a more restricted extent of deposits and therefore a possibly more restricted Salisbury Embayment at this time; perhaps a lack of prey kept them out of this area. The restricted basin might make the stranding of floating carcasses unlikely. Against the explanation of a more restricted basin during Bed 3A time is the absence of mysticetes in the more open and widespread Beds 3B through Bed 8 (Gottfried et al., 1994; Wetmore and Andrews, 1990; Ward and Powars, 1989). The Pollack Farm Site presumably was closer to the open ocean than the Maryland portion, and presumably would be more likely to receive the remains of a stranded animal.

The presence of a true, or earless, seal, *Leptophoca*, is not only the lowest record regionally but among the oldest in the world.

Interpretation of environmental conditions based on fossil marine mammals is questionable, owing to lack of knowledge of their habits and to their potential to strand, or their carcasses to be washed up, far from where they normally lived (Kellogg and Whitmore, 1957). *Zarhachis* has been consistently placed in the Platanistidae, or river porpoises, whether in the restricted (modern *Platanista*) or more general sense (modern *Platanista*, *Lipotes*, *Inia*, *Pontoporia*). Under either interpretation, *Zarhachis* is clearly very different from other members of the family and, this alone would suggest using analogues cautiously. One modern platanistid or platanistoid (*Pontoporia*) occurs in both fresh river and coastal marine/estuarine environments. *Zarhachis* and the closely related *Pomatodelphis* (except the fragmentary and held questionable here *P. stenorhynchus* of Europe, Kellogg, 1959) occur from Delaware to Alabama (Kellogg, 1959; Morgan, 1994; Hulbert and Whitmore, 1997) in nearshore deposits. Most Neogene marine mammal localities are of nearshore origin, however. The limited range of *Zarhachis* and *Pomatodelphis* and the lack of clear records from elsewhere would suggest non-open ocean habits. *Zarhachis* and *Pomatodelphis* have a body plan resembling modern river porpoises: long snout and relatively long flexible neck, unlike the typical form of open ocean pelagic odontocetes. A dead river-dwelling porpoise could easily float downstream into the marine environment and be preserved, a not unexpected process at the Pollack Farm Site where terrestrial vertebrates were found.

A member of the Rhabdosteidae has been found in fresh water deposits, although probably a different genus than *Rhabdosteus* (Fordyce, 1983).

An alternate hypothesis interprets the distribution of modern river porpoises as a relict distribution of a previously widespread marine family.

Sirenians (with the exception of Steller's sea cow *Hydrodamalis*) are generally tropical to subtropical in distribution, although manatee remains are known as far north as the Pleistocene of New Jersey (Gallagher et al., 1989) and individuals have strayed north as far as Massachusetts and England. The Pollack Farm Site sirenian specimens are unidentifiable, but the Maryland Calvert Formation *Metaxytherium crataegense* is widely distributed, as far as Florida (Simpson, 1932) and the southeastern Pacific Ocean in Peru (Muizon and Domning, 1985).

REFERENCES CITED

- Andrews, G.W., 1986, Miocene diatoms from Richmond, Virginia: *Journal of Paleontology*, v.60, p. 497–538.
- Aranda-Manteca, F.J., Domning, D.P., and Barnes, L.G., 1994, A new middle Miocene sirenian of the genus *Metaxytherium* from Baja California and California: Relationships and paleobiogeographic implications, in Berta, A. and Deméré, T.A., eds., Contributions in marine mammal paleontology honoring Frank C. Whitmore, Jr.: Proceedings of the San Diego Society of Natural History v. 29, p. 191–204.
- Benson, R.N., 1998, Radiolarians and diatoms from the Pollack Farm Site, Delaware: Marine-terrestrial correlation of Miocene vertebrate assemblages of the middle Atlantic Coastal Plain, in Benson, R.N., ed., Geology and paleontology of the lower Miocene Pollack Farm Fossil Site, Delaware: Delaware Geological Survey Special Publication No. 21, p. 5–19.
- Cope, E.D., 1868, An addition to the vertebrate fauna of the Miocene period, with a synopsis of the extinct Cetacea of the United States: Proceedings of the Academy of Natural Sciences of Philadelphia, v. 19, p. 138–156.
- Cozzuol, M.A., 1992, The oldest seal of the southern hemisphere: Implications to phocid phylogeny and dispersal: *Journal of Vertebrate Paleontology*, v. 12 (Supplement to no. 3, Abstracts), p. 25A–26A.
- Domning, D.P., and Buffrénil, V. de, 1991, Hydrostasis in the Sirenia: Quantitative data and functional interpretations: *Marine Mammal Science*, v. 7, p. 331–368.
- Dooley, A.C., Jr., 1996, A newly recognized species of *Squalodon* (Mammalia, Cetacea) from the Miocene of the middle Atlantic coastal plain, in Repetski, J.E., ed., Sixth North American Paleontological Convention Abstracts of Papers: The Paleontological Society Special Publication No. 8, p. 107.
- Emry, R.J., and Eshelman, R.E., 1998, The early Hemingfordian (early Miocene) Pollack Farm Local Fauna: First Tertiary land mammals described from Delaware, in Benson, R.N., ed., Geology and paleontology of the lower Miocene Pollack Farm Fossil Site, Delaware: Delaware Geological Survey Special Publication No. 21, p. 153–173.
- Fordyce, R.E., 1982, Dental anomaly in a fossil squalodont dolphin from New Zealand, and the evolution of polydonty in whales: *New Zealand Journal of Zoology*, v. 9, p. 419–426.
- 1983, Rhabdosteid dolphins (Mammalia: Cetacea) from the middle Miocene, Lake Frome area, South Australia: *Alcheringa*, v. 7, p. 27–40.
- Gallagher, W.B., Parris D.C., Grandstaff, B.S., and DeTemple, C., 1989, Quaternary mammals from the continental shelf off New Jersey: *The Mosasaur*, v. 4, p. 101–110.
- Gibson, T.G., 1983, Stratigraphy of Miocene through lower Pleistocene strata of the United States central Atlantic Coastal Plain, in Ray, C.E., ed., Geology and paleontology of the Lee Creek Mine, North Carolina, I: Smithsonian Contributions to Paleobiology 53, p. 35–80.
- Gibson, T.G., and Andrews, G.W., 1994, Miocene stratigraphy of the Solomons Island, Maryland, corehole: U.S. Geological Survey Open-File Report 94-683, 35 p.
- Gottfried, M.D., Bohaska, D.J., and Whitmore, F.C., Jr., 1994, Miocene cetaceans of the Chesapeake Group, in Berta, A., and Deméré, T.A., eds., Contributions in marine mammal paleontology honoring Frank C. Whitmore, Jr.: Proceedings of the San Diego Society of Natural History, v. 29, p. 229–238.
- Hulbert, R.C., Jr. and Whitmore, F.C., Jr., 1997, Early Hemphillian mammals from the Mauvilla Local Fauna, Alabama: *Journal of Vertebrate Paleontology*, v. 17 (Supplement to no. 3, Abstracts), p. 54A.
- Ichishima, H., Barnes, L.G., Fordyce, R.E., Kimura, M., and Bohaska, D.J., 1995, A review of kentriodontine dolphins (Cetacea; Delphinoidea; Kentriodontidae): Systematics and biogeography: *The Island Arc*, v. 3, p. 486–492.
- Jones, D.S., Ward, L.W., Mueller, P.A., and Hodell, D.A., 1995, Correlation and temporal calibration of fossiliferous sequences in Florida, Maryland, and Delaware using strontium isotopes (abstract): Geological Society of America Abstracts with Programs, p. A-382.
- 1998, Age of marine mollusks from the lower Miocene Pollack Farm Site, Delaware, determined by ⁸⁷Sr/⁸⁶Sr geochronology, in Benson, R.N., ed., Geology and paleontology of the lower Miocene Pollack Farm Fossil Site, Delaware: Delaware Geological Survey Special Publication No. 21, p. 21–25.
- Kasuya, T., 1973, Systematic consideration of recent toothed whales based on the morphology of tympano-periotic bone: *The Scientific Reports of The Whales Research Institute*, v. 25, p. 1–103.
- Kellogg, R., 1923, Description of two squalodonts recently discovered in the Calvert Cliffs, Maryland; and notes on the shark-toothed cetaceans: *Proceedings of the United States National Museum*, v. 62(16).
- 1924, A fossil porpoise from the Calvert Formation of Maryland: *Proceedings of the United States National Museum*, v. 63(14).
- 1926, Supplementary observations on the skull of the fossil porpoise *Zarhachis flagellator* Cope: *Proceedings of the United States National Museum*, v. 67(28).
- 1927, *Kentriodon permix*, a Miocene porpoise from Maryland: *Proceedings of the United States National Museum*, v. 69(19).
- 1931, Pelagic mammals from the Temblor Formation of the Kern River Region, California: *Proceedings of the California Academy of Sciences, Fourth Series*, v. 19, p. 217–397.
- 1955, Three Miocene porpoises from the Calvert Cliffs, Maryland: *Proceedings of the United States National Museum*, v. 105, p. 101–154.
- 1957, Two additional Miocene porpoises from the Calvert Cliffs, Maryland: *Proceedings of the United States National Museum*, v. 107, p. 279–337.
- 1959, Description of the skull of *Pomatodelphis inaequalis* Allen: *Bulletin of the Museum of Comparative Zoology*, v. 121 (1).
- 1965, Fossil marine mammals from the Miocene Calvert Formation of Maryland and Virginia: The Miocene Calvert sperm whale *Orycterocetus*: *United States National Museum Bulletin* 247(2).
- 1966, Fossil marine mammals from the Miocene Calvert Formation of Maryland and Virginia: New species of extinct Miocene Sirenia: *United States National Museum Bulletin* 247(3).

- Kellogg, R., and Whitmore, F.C., Jr., 1957, Mammals *in* Ladd, H.S., ed., Treatise on marine ecology and paleoecology: Geological Society of America Memoir 67, v. 2, p. 1021–1024.
- Koretsky, I.A. and Sanders, A.E., 1997, Pinniped bones from the late Oligocene of South Carolina: The oldest known true seal (Carnivora: Phocidae): Journal of Vertebrate Paleontology, v. 17 (Supplement to no. 3, Abstracts), p. 58A.
- Leidy, J., 1853a, The ancient fauna of Nebraska: Smithsonian Contributions to Knowledge, v. 6(7), 126 p., 24 pls., 3 figs., frontispiece.
- _____, 1853b, [Observations]: Proceedings of the Academy of Natural Sciences of Philadelphia, v. 6, p. 377–378.
- _____, 1869, The extinct mammalian fauna of Dakota and Nebraska, including an account of some allied forms from other localities, together with a synopsis of the mammalian remains of North America: Journal of the Academy of Natural Sciences of Philadelphia, series 2, v. 7, p. 1–472, 30 pls.
- Morgan, G.S., 1994, Miocene and Pliocene marine mammal faunas from the Bone Valley Formation of central Florida, *in* Berta, A., and Deméré, T.A., eds., Contributions in marine mammal paleontology honoring Frank C. Whitmore, Jr.: Proceedings of the San Diego Society of Natural History, v. 29, p. 239–268.
- Muizon, C. de, 1987, The affinities of *Notocetus vanbenedeni*, an early Miocene platanistoid (Cetacea, Mammalia) from Patagonia, southern Argentina: American Museum Novitates, no. 2904, 27 p.
- _____, 1988, Le polyphétisme des Acrodelphidae, Odontocètes longirostres du Miocène européen: Bulletin du Muséum national d'Histoire naturelle, Paris, série 4, v. 10, section C, p. 31–88.
- _____, 1994, Are the squalodonts related to the platanistoids?, *in* Berta, A., and Deméré, T.A., eds., Contributions in marine mammal paleontology honoring Frank C. Whitmore, Jr.: Proceedings of the San Diego Society of Natural History, v. 29, p. 135–146.
- Muizon, C. de, and Domning, D.P., 1985, The first records of fossil sirenians in the southeastern Pacific Ocean: Bulletin du Muséum national d'Histoire naturelle, Paris, série 4, v. 7, section C, p. 189–213.
- Myrick, A.C., Jr., 1979, Variation, taphonomy, and adaptation of the Rhabdosteidae (=Eurhinodelphinidae) (Odontoceti, Mammalia) from the Calvert Formation of Maryland and Virginia: Los Angeles, University of California, unpublished Ph.D. dissertation, xxv+411 p.
- Ramsey, K.W., 1998, Depositional environments and stratigraphy of the Pollack Farm Site, Delaware, *in* Benson, R.N., ed., Geology and paleontology of the lower Miocene Pollack Farm Fossil Site, Delaware: Delaware Geological Survey Special Publication No. 21, p. 27–40.
- Ramsey, K.W., Benson, R.N., Andres, A.S., Pickett, T.E., and Schenck, W.S., 1992, A new Miocene locality in Delaware (abstract): Geological Society of America Abstracts with Programs, 24, no. 3, p. 69.
- Ray, C.E., 1976, *Phoca wymani* and other Tertiary seals (Mammalia: Phocidae) described from the eastern seaboard of North America: Smithsonian Contributions to Paleobiology 28, 36 p.
- Repenning, C.A., Ray, C.E., and Grigorescu, D., 1979, Pinniped biogeography, *in* Gray, J., and Boucot, A.J., eds., Historical biogeography, plate tectonics, and the changing environment: Corvallis, Oregon State University Press, p. 357–369.
- Simpson, G.G., 1932, Fossil Sirenia of Florida and the evolution of the Sirenia: Bulletin of the American Museum of Natural History, v. 59, p. 419–503.
- Robinette, H.R., and Stains, H.J., 1970, Comparative study of the calcanea of the Pinnipedia: Journal of Mammalogy, v. 51, p. 527–541.
- True, F.W., 1906, Description of a new genus and species of fossil seal from the Miocene of Maryland: Proceedings of the United States National Museum, v. 30, p. 835–840.
- Ward, L.W., 1993, Lower Miocene molluscs from the Kirkwood Formation of Delaware: First known collection: Virginia Journal of Science, v. 44, p. 157.
- _____, 1998, Mollusks from the lower Miocene Pollack Farm Site, Kent County, Delaware: A preliminary analysis, *in* Benson, R.N., ed., Geology and paleontology of the lower Miocene Pollack Farm Fossil Site, Delaware: Delaware Geological Survey Special Publication No. 21, p. 59–131.
- Ward, L.W., and Powars, D.S., 1989, Tertiary stratigraphy and paleontology, Chesapeake Bay region, Virginia and Maryland: 28th International Geological Congress, Field Trip Guidebook T216, 64 p.
- Wetmore, K.L. and Andrews, G.W., 1990, Silicoflagellate and diatom biostratigraphy in successive Burdigalian transgressions, middle Atlantic Coastal Plain: Micropaleontology, v. 36, p. 283–295.