Journal of Vertebrate Paleontology 30(5):1645–1651, September 2010

SHORT COMMUNICATION

A MIOCENE ZIPHIID (CETACEA: ODONTOCETI) FROM CALVERT CLIFFS, MARYLAND, U.S.A.

OLIVIER LAMBERT,[1,†] STEPHEN J. GODFREY*,[2] and ANNA J. FULLER[2,‡]; [1]Institut royal des Sciences naturelles de Belgique, Département de Paléontologie, Rue Vautier, 29, 1000, Bruxelles, Belgium, olambert@mnhn.fr; [2]Department of Paleontology, Calvert Marine Museum, P.O. Box 97, Solomons, Maryland 20688, U.S.A., Godfresj@co.cal.md.us

More than 600 species have been identified from Calvert Cliffs, Calvert County, Maryland, U.S.A. The vast majority of these marine species are now extinct. This diverse biota consists of diatoms, dinoflagellates, radiolarians, foraminiferans, sponges, encrusting hydrozoans, corals, an inarticulate brachiopod, abundant and diverse mollusks, annelids, barnacles, decapods, echinoderms, sharks and rays, bony fishes, turtles, crocodiles, pelagic birds, phocid seals, dugongid sea cows, and over 30 species of small- to medium-sized odontocetes and baleen whales (Gottfried et al., 1994; Whitmore, 1994; Godfrey and Barnes, 2008). The remains of the extinct terrestrial vertebrates confirm the presence of gomphotheres, rhinos, peccaries, horses, camels, dogs, and bear-dogs (Eshelman et al., 2007) in the forests that bordered this stretch of the Miocene Atlantic Ocean.

The three Miocene formations comprising Calvert Cliffs differ in their cetacean assemblages. The late early Miocene to lower middle Miocene (Burdigalian and Langhian) Calvert Formation has long been known to preserve one of the world's richest and most diverse extinct cetacean assemblages. Of the 19 recognized odontocete species from the Chesapeake Group, 12 are known exclusively from the Calvert Formation. Another three species are derived from both the Calvert and the middle Miocene (Serravallian) Choptank formations. Only three named species are currently known from the late Miocene (Tortonian) St. Marys Formation, although other fragmentary and enigmatic forms await description, both from this formation but also from the Calvert and Choptank formations (Gottfried et al., 1994; Kazár, 2002; Fuller and Godfrey, 2007; Godfrey and Barnes, 2008; Gerholdt and Godfrey, 2010).

Ziphiidae first appear in the fossil record in the Antwerp Sands, middle Miocene of the North Sea (Lambert and Louwye, 2006), although more fragmentary remains and a controversial specimen date from the early Miocene (Muizon, 1991; Bianucci et al. 2005). The derived morphology of these oldest-known ziphiids indicates that older, more archaic forms will likely come to light. Beginning in the Miocene, ziphiids became global in their distribution (McCoy, 1882; Owen, 1889; Eastman, 1906; Glaessner, 1947; Gaskin, 1968; Baker, 1972; Mead, 1975; Muizon, 1983; Tazaki et al., 1987; Bianucci et al., 1992; Bianucci, 1997; Lambert, 2005; Lambert and Louwye, 2006; Bianucci et al., 2007; Lambert et al., 2009). Extant beaked whales are characterized by a long and slender beak-like rostrum, elevation of the narial region, and a greatly reduced dentition in all modern genera except *Tasmacetus* (Hooker, 2001; Mead, 2002).

There are only two known ziphiids from the Chesapeake Group; the partial rostrum CMM-V-3138 from the St. Marys Formation referred to cf. *Messapicetus* sp. (Fuller and Godfrey, 2007), and the specimen represented by USNM 476359 and CMM-V-4267 (both casts of the original specimen) from the Calvert Formation, the partial skull described herein. Odontocete partial rostra previously referred to by Gottfried et al. (1994) as ziphiid remains from the Chesapeake Group probably derive from non-ziphiid odontocetes with rostral pathologies (periostitis) (Gerholdt and Godfrey, 2010). The general paucity of ziphiid remains from along Calvert Cliffs prompted this note. Furthermore, there is a modest degree of confidence in the stratigraphic information on USNM 476359, which is unfortunately often not the case for the numerous ziphiid remains dredged from the ocean bottom described so far (see Bianucci et al., 2007). If Miocene ziphiids inhabited deep-water marine habitats, as do their living counterparts, then the scarcity of ziphiid remains within the Chesapeake Group is potentially an environmental artifact relating to relatively shallow water depth within the Miocene Salisbury Embayment (Gottfried et al., 1994), rather than their absolute rarity within the Miocene western North Atlantic.

Institutional Abbreviations—CMM-V-, Calvert Marine Museum vertebrate paleontology collection, Calvert County, Maryland; **USNM**, United States National Museum of Natural History, Smithsonian Institution, Washington, D.C.

GEOLOGICAL SETTING

During parts of the early, middle, and late Miocene (18–8 Ma), a shallow arm of the Atlantic Ocean occasionally occupied the Salisbury Embayment extending as far west as Washington D.C. Sediments transported by rivers from the Appalachian Mountains and deposited into this vast basin are now exposed as wave-eroded bluffs known as Calvert Cliffs. These cliffs extend for approximately 50 km along the western shore of the Chesapeake Bay, Maryland, and are the best-exposed onshore record and the most complete sequence of marine Miocene sediments exposed on the East Coast of North America (Kidwell, 1984, 1989, 1997; Ward, 1992; Ward and Andrews, 2008). Calvert Cliffs include strata from three Miocene formations within the Chesapeake Group, in ascending order—the Calvert, Choptank, and St. Marys of Shattuck (1904)—and an additional 20 m of coarse channel-form deposits of fluvial and tidal origin of younger but uncertain age (Kidwell, 1997). The Calvert Formation is characterized by fully marine muddy inner to middle shelf deposits alternating with densely shelly sands of shoreface to inner shelf depth (Gernant et al., 1971; Kidwell, 1997; Ward and Andrews, 2008).

SYSTEMATIC PALEONTOLOGY

CETACEA Brisson, 1762
ODONTOCETI Flower, 1867
ZIPHIIDAE (Gray, 1850) Gray, 1865
Gen. et sp. indet.
(Figs. 1–3)

Referred Material—USNM 476359 and CMM-V-4267 (both casts of the original specimen), partial skull (rostrum and

---

*Corresponding author. †Current address: Muséum national d'Histoire naturelle, Département Histoire de la Terre, Rue Buffon, 8, 75005, Paris, France. ‡Current address: The Chapel, Teapot street, Wylye, Wiltshire, BA12 0QT, United Kingdom.

prenarial region). Note: The description and all figures are based on the original specimen, which is currently in a private collection. The location of the specimen is known and access to it will be granted. Interested researchers should contact the second author (S.G.).

Horizon and Locality—In 1975, a ziphiid partial skull was unexpectedly brought up from the bottom of the Chesapeake Bay by fishermen using hydraulic oyster tongs. The specimen was located approximately 180 m directly offshore (and maybe slightly south) from the B.G. & E. Nuclear Power Plant, Calvert Cliffs, Maryland. At that distance from shore, the water depth is only about 3 m. The Miocene-age sediments in the adjacent cliffs include only those from the Choptank and St. Marys formations. At this point along Calvert Cliffs, the Calvert Formation has dipped below beach level. Therefore, on the basis of where the partial skull was found, it could have come from any one of the three Miocene formations comprising the cliffs and their extensions out below the waters of the Chesapeake Bay (but see below).

The partial skull was broken in two near the base of the rostrum and later reassembled. J. Hutchinson received the specimen from a friend present during the oyster tonging. Later, J. Hutchinson took it to the National Museum of Natural History, Washington D.C., where several casts of the specimen were made and catalogued as USNM 476359 and CMM-V-4267. The heavy skull was mostly devoid of sediment except for a few small, indurated patches. This sediment was removed and analyzed for microfossils. Fewer than 3 dozen specimens were extracted from this very limited sediment sample. Unfortunately, most were fragmentary and without biostratigraphic value. There were, however, several specimens of the dinoflagellate *Hystrichosphaeropsis obscura* Habib, which according to de Verteuil and Norris (1996) is restricted in range along the East Coast of the U.S.A. to the Miocene and specifically the Calvert, Choptank, and St. Marys formations (Edwards, pers. comm, 2009). However, it has also been recorded near the base of the Eastover Formation (Edwards et al., 2005). There were also two fragments tentatively identified as *Cleistosphaeridium placacanthum* (Deflandre and Cookson). If correct, the sediments associated with this partial skull are no younger than middle of the middle Miocene and the only potential sources are the two members of the Calvert Formation. The highest occurrence of *C. placacanthum* defines the top of de Verteuil and Norris' (1996) Zone DN5 (Edwards, pers. comm., 2009). Zone DN5 includes the time represented by Beds 12–15 of the Plum Point Marl Member of the Calvert Formation (de Verteuil and Norris, 1996; Ward and Andrews, 2008). Therefore, this ziphiid is not likely younger than Bed 15 of the Calvert Formation. (Note: the Plum Point Marl Member now includes the Calvert Beach Member—see Ward and Andrews, 2008). Edwards (pers. comm., 2009) also noted that the most common dinoflagellate cysts present were *Spiniferites* spp. and *Lingulodinium machaerophorum* (Deflandre and Cookson), common in both Miocene and present day Chesapeake Bay sediments.

Description

The skull is incomplete and has undergone slight post-mortem abrasion (Figs. 1–3). Prior to being collected, it had been exposed on the bottom of the Chesapeake Bay for some time, as evidenced by a number of modern oysters and barnacles that had taken up residence on both sides of the specimen. The skull is essentially complete up to the level of the bony nares, at which point there is a clean transverse break through the skull. The extremity of the rostrum is also missing; the length of the lost anterior fragment is estimated at 55–90 mm. Fully fused sutures on the skull indicate that this individual was mature. The dimensions of the skull are: total length of the specimen as preserved = 480 mm; maximum width across the orbits = 398 mm; length of the preserved portion of the rostrum = 388 mm; width of the rostrum at its anterior end = 79.5 mm; and width of the rostrum at its base = 296 mm. Much of the surface of the bone is smooth, especially the dense premaxillae. The coarser texture of other abraded areas corresponds to bone with a higher porosity. Abrasion, however, did little to alter the appearance of sutures and foramina. The robust rostrum is considerably wider than high, with a distinctly flattened ventral surface. The supraorbital area is broad and essentially flat. The posterior transverse section of the specimen, roughly at the anterior level of the bony nares, illustrates the relationships of the different bones in this area and their internal porosities (Fig 1). The premaxillae and maxillae are compact, to a lesser extent the vomer is also compact, and this contrasts with the distinctly more porous frontals, palatines, and mesethmoid (Fig. 1).

Premaxilla—The premaxillae contact each other dorsomedially by way of an unfused suture for most of the length of the rostrum, being separated only for a short distance between the orbits in the area of the premaxillary sac fossae. Anteriorly, they form a median dome, semi-circular in cross-section, leaving open a mesorostral canal currently filled with indurated sediment. Both premaxillae widen posteriorly. Throughout all of its dorsal exposure, the right premaxilla is wider than the left (Fig. 2), crossing the midline to occupy some of the left hand side of the skull (Fig. 1B). This wide asymmetry, nearly reaching the anterior end of the specimen, is associated with the presence of a slightly concave area more anteriorly located on the right premaxilla than on the left (deepest area respectively at approximately 140 mm and 95 mm as measured in a straight line from each respective antorbital notch to the central area of the depression). The aforementioned concave surfaces and the premaxillae sac fossae are covered by a network of vascular furrows. The furrows are especially evident on the right premaxilla (Fig. 2). The anterior edge of the premaxillary sac fossa on each side is formed by a posterolateral sulcus that crosses the bone from the mesorostral groove to the suture with the maxilla. The right sulcus is wider and deeper than the left. No premaxillary foramen is visible, but it was likely located in a narrow depression between the premaxillae (i.e., the proto-prenarial basin). The right premaxillary sac fossa is considerably wider than the left (116 mm versus 69 mm at the level of the transverse posterior break). The anterior portion of the right fossa is swollen, forming a prominence between the posterolateral sulcus and the deepest part of the premaxillary sac fossa (Fig. 2). The floor of the fossa at its lowest level was crossed by a transverse sulcus, exiting the fossa medially just anterior to the bony nares (see also *Tusciziphius*; Post et al., 2008:fig. 1). The bone forming the medial margin of the left fossa is thickened. The floor of this fossa trends anteromedially and it is much less excavated than the right premaxillary sac fossa (Fig. 2).

Maxilla—On the anterior part of the rostrum, the dorsal surface of the maxilla forms a wide and nearly flat strip of bone. A shallow trough marks the premaxilla-maxilla boundary. Along this suture and adjacent to the posterolateral premaxillary sulcus are large dorsal infraorbital foramina (one on the left side and two on the right). At the base of the rostrum, additional smaller foramina enter the rostrum along the premaxilla-maxilla suture.

At the anterior end of the rostrum, the lateral edge of the maxilla is directed slightly ventrolaterally. Posteriorly, the lateral margins of the maxilla turn laterally then dorsolaterally, forming a low rostral crest at the rostrum base. Behind the level of the antorbital notch, the maxilla widens and curves gently ventrolaterally out over the supraorbital process of the frontal. Only a faint longitudinal depression marks the position of the alveolar groove (Figs. 1, 2). Abrasion along the lateral edge of the maxillae has probably decreased the original depth of this groove.

In ventral view (Fig. 3), the maxillae are separated by a 204 mm long ventral exposure of the vomer. From the anterior margin of the rostrum a straight vascular trough on both maxillae parallels the ventral exposure of the vomer. Each trough terminates as a

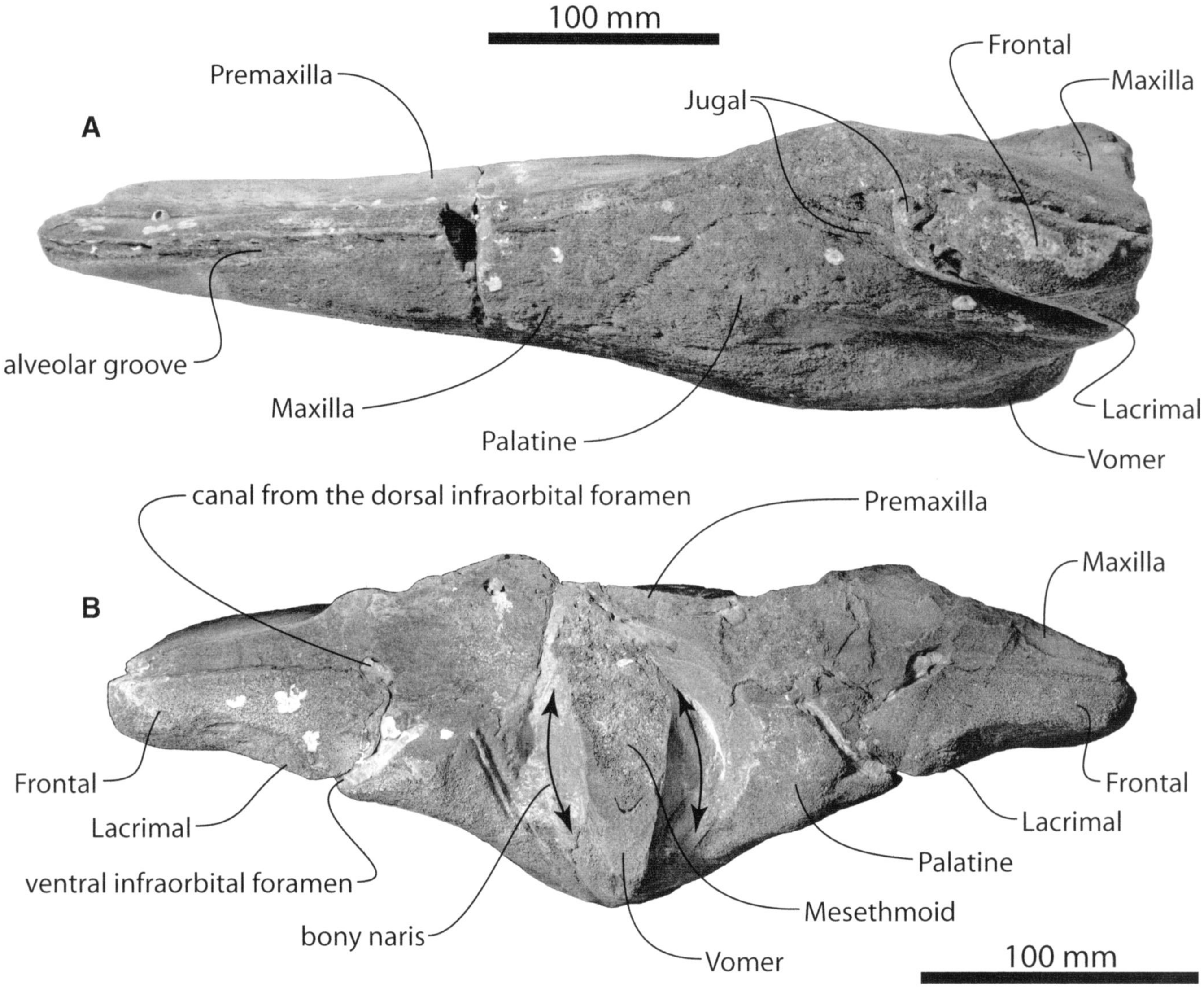

FIGURE 1. Ziphiidae, partial skull, gen. et sp. indet., from the Calvert Formation. **A**, left lateral view, and **B**, posterior view of the actual specimen. The fossil was lightly coated with sublimed ammonium chloride. The posterior transverse section of the specimen, roughly at the anterior level of the bony nares, illustrates the relationship of the different bones in this area, revealing compact premaxillae and maxillae, and to a lesser extent the vomer, contrasting with the distinctly more porous frontals, palatines, and mesethmoid. Scale bars equal 100 mm.

foramen that enters the maxilla adjacent to the anterior third of the vomer. Ventrally, the palatal exposure of the maxilla terminates just anterior to the level of the antorbital notch between the palatines (Fig. 3).

Palatine—The fan-shaped palatine is broad, covering most of the maxilla ventrally at the base of the rostrum so that the maxilla is only visible as narrow strips laterally and medially (Fig. 3). Greater palatine foramina occupy the anteromedial edge of each palatine. Posterolaterally, the palatine forms the ventromedial margin of the ventral infraorbital foramina. Posteriorly, the palatine contributes to the margin of the bony naris as it curves dorsally (Fig. 1B). Right and left palatines do not abut medially; they are separated by the re-exposure of the vomer posteriorly. The pterygoids were lost but a smooth concave area on the palatine suggests a large anterior portion for the pterygoid sinus fossa (Fig. 3).

Jugal—The jugal wedges into the maxilla by way of a complex zigzagging suture on the medial wall of the slightly worn antorbital notch (Figs. 1A, 3). It forms the ventral part of the posterior wall of the notch with a posteromedial strap-shaped exposure that terminates in the opening of the ventral infraorbital foramen. The jugal-lacrimal suture remains open.

Lacrimal—The lacrimal gains fairly wide exposure on the ventral surface of the supraorbital process immediately posterior to the jugal. Posteromedially, the lacrimal forms the posterolateral margin of the infraorbital foramen. At that level, a short segment of the lacrimal-frontal suture is still visible; laterally the two elements are fused over the orbit. In posterior view (Fig. 1B), the lacrimal is visible lateral to the trough formed by the ventral infraorbital foramen.

Frontal—This bone is only preserved in the area of the orbit where it is robust (Figs. 1–3). The lateral-most exposure of the supraorbital process is formed by the frontal. The suture between the frontal and maxilla is open and clearly seen in dorsal, lateral, and posterior views.

DISCUSSION

Even if the diagnostic area of the vertex is not preserved in this medium-sized ziphiid, the anterior portion of the neurocranium

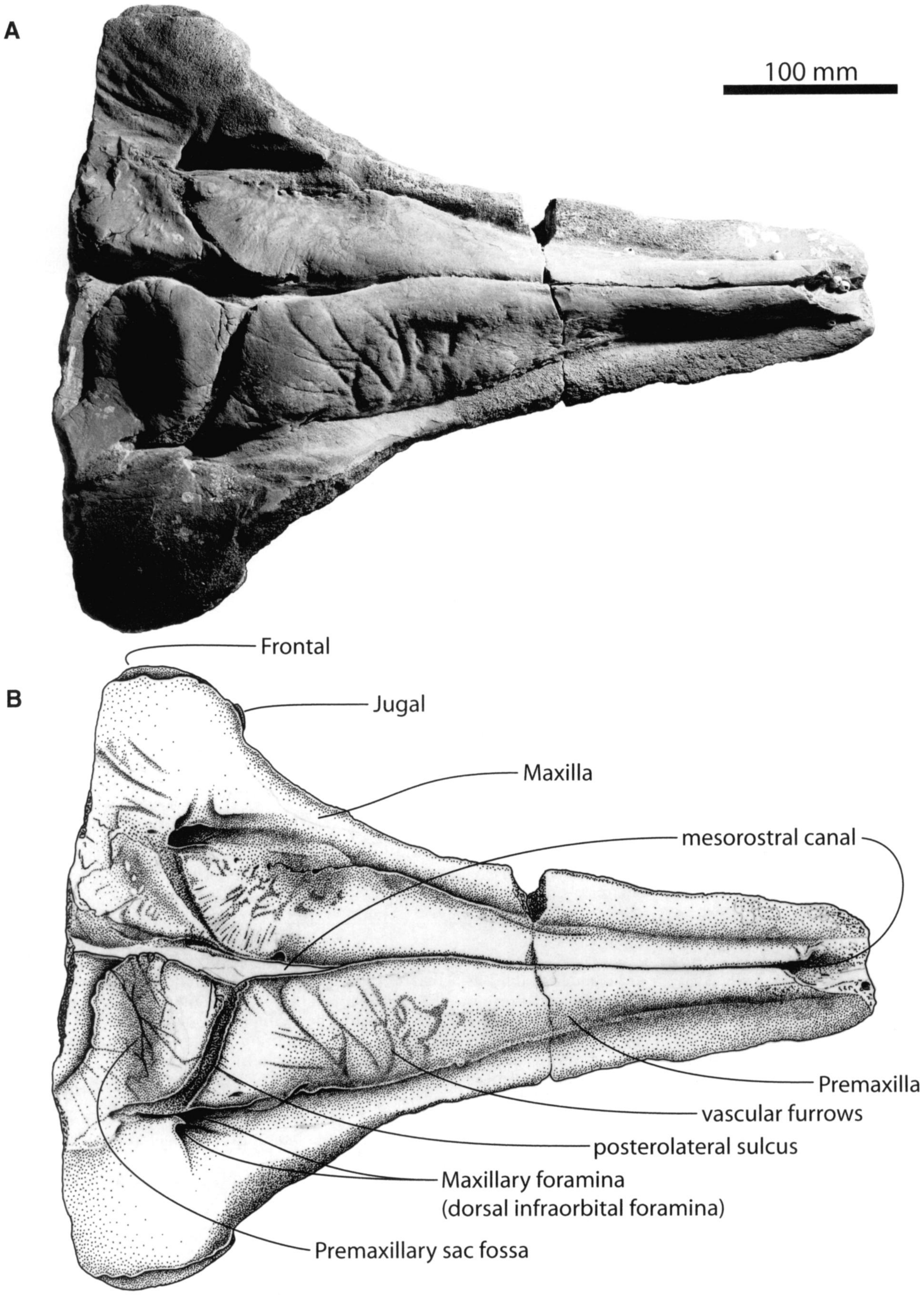

FIGURE 2. Ziphiidae, partial skull, gen. et sp. indet., from the Calvert Formation. **A**, dorsal view, and **B**, corresponding specimen drawing of the actual specimen. In **A**, the fossil was lightly coated with sublimed ammonium chloride. Scale bar equals 100 mm.

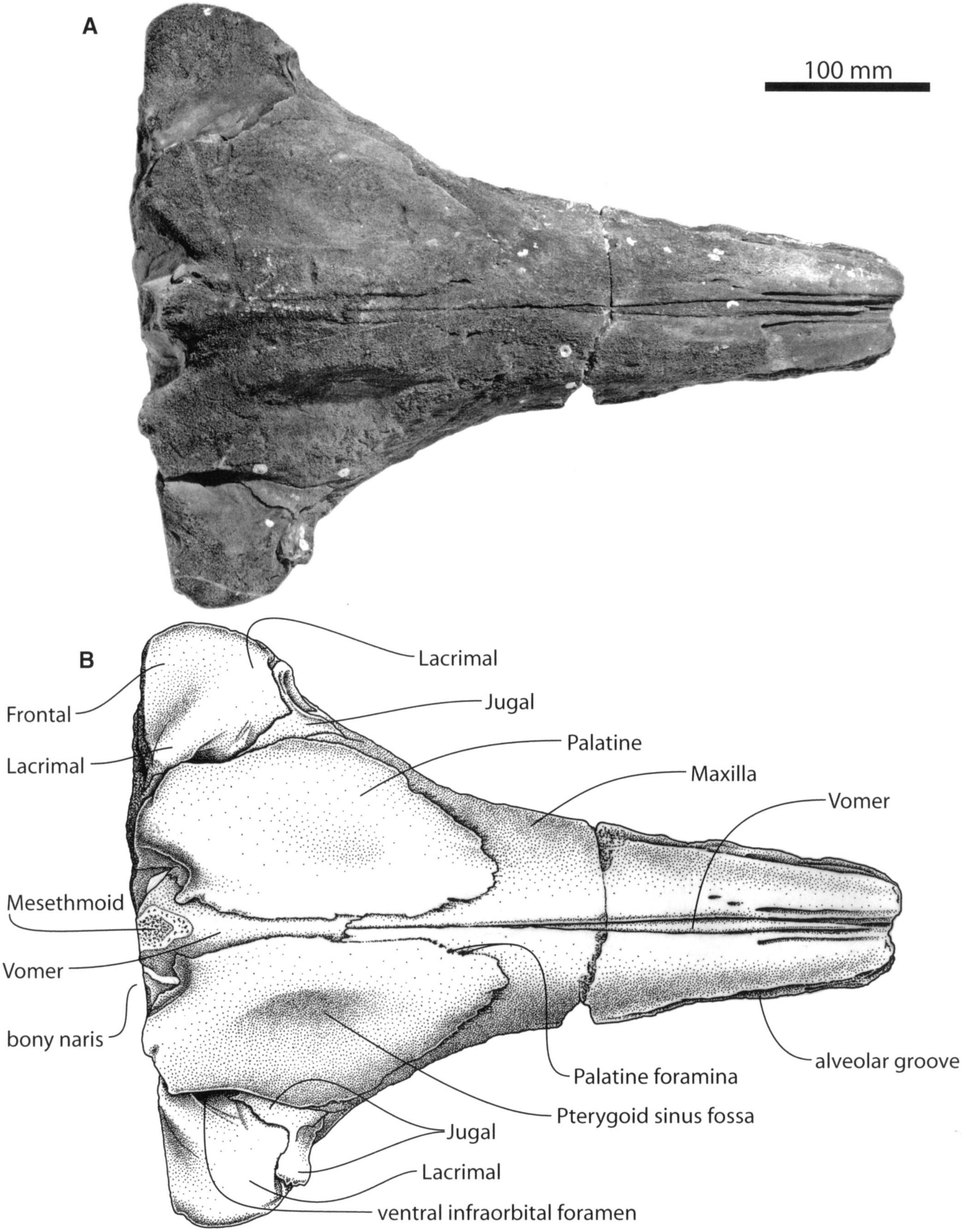

FIGURE 3. Ziphiidae, partial skull, gen. et sp. indet., from the Calvert Formation. **A**, ventral view, and **B**, corresponding specimen drawing of the actual specimen. In **A**, the fossil was lightly coated with sublimed ammonium chloride. Scale bar equals 100 mm.

and the rostrum allow for a discussion of its relationships with other fossil ziphiids. The strong asymmetry of the premaxillae and the nearly complete absence of a maxillary alveolar groove are the most obvious features supporting an attribution to the family Ziphiidae, although the osteosclerotic bones forming the dorsal surface of the skull are also often observed in ziphiids.

A sutural contact between the thick premaxillae dorsal to the mesorostral groove is only present in fossil members of the subfamily Ziphiinae (Lambert, 2005). The absence of a conspicuous prenarial basin distinguishes this specimen from the ziphiines *Aporotus* du Bus, 1868, *Beneziphius* Lambert, 2005, *Messapicetus* Bianucci et al., 1992, and *Ziphirostrum* du Bus, 1868. Furthermore, the medial separation of the premaxillary sac fossae differs from the condition in *Choneziphius* Duvernoy, 1851. The obvious difference in the widths of the premaxillary sac fossae and the development of a thick anterior margin of the right fossa is reminiscent of the condition seen in *Caviziphius altirostris* Bianucci and Post, 2005, *Eboroziphius coelops* Leidy, 1877, the fragmentary *Pelycorhamphus pertortus* Cope, 1895, and *Tusciziphius crispus* Bianucci, 1997 (see Post et al. 2008). Despite the similarity, these taxa display differences; the rostrum of *Caviziphius* is much deeper, the premaxillae of *Caviziphius* and *Eboroziphius* are hollowed by a pair of wide longitudinal grooves along the rostrum, a feature absent in USNM 476359 and *Tuscizphius*, and the right premaxillary sac fossa of *Pelycorhamphus* is considerably more excavated.

Tusciziphius additionally shares with USNM 476359 the wide subhorizontal maxillae on the dorsal surface of the rostrum and a transverse sulcus crossing the right premaxillary sac fossa. However, the premaxillae of USNM 476359 are less elevated, not as completely fused, and much wider at the base of the rostrum. Furthermore, *Tusciziphius* lacks any crest along the lateral margin of the rostrum base; it is smaller; and its rostrum is less dorsoventrally flattened. Even if some of the differences mentioned above could be explained by ontogeny or sexual dimorphism (a feature conspicuous on the skull of modern ziphiids and proposed in some fossil forms; Lambert et al., 2010), this specimen most likely belongs to a new taxon related to *Tusciziphius crispus*, a species recorded in the late Miocene to early Pliocene of Italy and the East Coast of U.S.A. Pending the discovery of new material that includes the vertex, we have decided to identify the specimen represented by casts USNM 476359 and CMM-V-4267 as Ziphiidae indet. This specimen represents the first record of a ziphiid in the middle Miocene Calvert Formation, Calvert Cliffs, Maryland.

ACKNOWLEDGMENTS

We are grateful to J. Hutchinson who brought the ziphiid partial skull to the USNM. D. Bohaska (USNM), J. Mead (USNM), and C. Potter (USNM) generously provided access to the collections of both fossil and extant ziphiids in their care. L. E. Edwards (U.S. Geological Survey) identified the microfossils; we are very grateful for her expertise. Comments by G. Bianucci, an anonymous reviewer, and JVP Editor J. H. Geisler improved the quality of an earlier version of this article. This publication would not have been possible without funding from the Board of Calvert County Commissioners, the Citizens of Calvert County, Maryland, and the Clarissa and Lincoln Dryden Endowment for Paleontology at the Calvert Marine Museum. We would also like to acknowledge the Citizenship and Immigration Services of the U.S. Department of Homeland Security for issuing the visa to A. Fuller, which allowed her to begin this study as a research intern at the Calvert Marine Museum. The work of O.L. at the IRSNB is financially supported by the Research Project MO/36/016 of the Belgian Federal Science Policy Office.

LITERATURE CITED

Baker, A. N. 1972. New Zealand whales and dolphins. Tuatara 20:1–49.

Bianucci, G. 1997. The Odontoceti (Mammalia: Cetacea) from Italian Pliocene. The Ziphiidae. Palaeontographia Italica 84:163–192.

Bianucci, G., and K. Post. 2005. *Caviziphius altirostris*, a new beaked whale from the Miocene southern North Sea basin. Deinsea 11:1–6.

Bianucci, G., O. Lambert, and K. Post. 2007. A high diversity in fossil beaked whales (Odontoceti, Ziphiidae) recovered by trawling from the sea floor off South Africa. Geodiversitas 29:561–618.

Bianucci, G., W. Landini, and A. Varola. 1992. *Messapicetus longirostris*, a new genus and species of Ziphiidae (Cetacea) from the late Miocene of 'Pietra leccese' (Apulia, Italy). Bolletino della Società Paleontologica Italiana 31:261–264.

Bianucci G., W. Landini, G. Valleri, L. Ragaini, and A. Varola. 2005. First cetacean fossil records from Ecuador, collected from the Miocene of Esmeraldas Province. Rivista Italiana di Paleontologia e Stratigrafia 111:345–350.

Blackwelder, B. W., and L. W. Ward. 1976. Stratigraphy of the Chesapeake Group of Maryland and Virginia. Geological Society of America, Southeast Section, Field Trip Guidebook, 55 pp.

Brisson, M.-J. 1762. Regnum Animale in classes IX distributum, sine synopsis methodica. Theodorum Haak, Paris, 296 pp.

du Bus, B. A. L. 1868. Sur différents ziphiides nouveaux du Crag d'Anvers. Bulletin de l'Académie Royale des Sciences de Belgique 25:621–630.

Cope, E. D. 1895. Fourth Contribution to the Marine Fauna of the Miocene Period of the United States. Proceedings of the American Philosophical Society 34:135–155.

de Verteuil, L., and G. Norris. 1996. Miocene dinoflagellate stratigraphy and systematics of Maryland and Virginia. Micropaleontology 42(supplement):1–172.

Duvernoy, G. 1851. Mémoire sur les caractères ostéologiques des genres nouveaux ou des espèces nouvelles de cétacés vivants ou fossiles. Annales de Sciences naturelles, Paris (3) Zoology 15:52–68.

Eastman, C. R. 1906. Shark's teeth and cetacean bones. Bulletin of the Museum of Comparative Zoology, Harvard 50:75–98.

Edwards, L. E., J. A. Barron, D. Bukry, L. M. Bybell, T. M. Cronin, C. W. Poag, R. E. Weems, and G. L. Wingard. 2005. Paleontology of the upper Eocene to Quaternary stratigraphic section in the USGS-NASA Langley core, Hampton, Virginia; pp. 1–47 in J. W. Horton Jr., D. S. Powars, and G. S. Gohn (eds.), Studies of the Chesapeake Bay Impact Structure—The USGS-NASA Langley Corehole, Hampton, Virginia, and Related Coreholes and Geophysical Surveys. U.S. Geological Survey Professional Paper 1688.

Eshelman, R. E., B. L. Beatty, and D. P. Domning. 2007. Terrestrial mammal remains from the Miocene Chesapeake Group of Calvert Cliffs, Maryland, and comparisons with Miocene terrestrial mammal faunas of the Mid-Atlantic Coast. Journal of Vertebrate Paleontology, 27(3, Supplement):72A.

Flower, W. H. 1867. Description of the skeleton of *Inia geoffrensis* and the skull of *Pontoporia blainvillii*, with remarks on the systematic position of these animals in the Order Cetacea. Transactions of the Zoological Society of London 6:87–116.

Fuller, A. J., and S. J. Godfrey, 2007. A Late Miocene ziphiid (*Messapicetus* sp.: Odontoceti: Cetacea) from the St. Marys Formation of Calvert Cliffs, Maryland. Journal of Vertebrate Paleontology 27:535–540.

Gaskin, 1968. The New Zealand Cetacea. Fisheries Research Bulletin 1:1–91.

Gerholdt, J. M., and S. J. Godfrey. 2010. Enigmatic osteology in Miocene odontocete rostra suggests periostitis. Marine Mammal Science 26:381–394.

Gernant, R. E., T. G. Gibson, and F. C. Whitmore, Jr. (eds.). 1971. Environmental history of Maryland Miocene. Maryland Geological Survey, Guidebook 3:1–58.

Gibson, T. G. 1983. Key foraminifera from Upper Oligocene to Lower Pleistocene strata of the Central Atlantic Coastal Plain; pp. 355–453 in C. E. Ray (ed.), Geology and Paleontology of the Lee Creek Mine, North Carolina, I. Smithsonian Contributions to Paleobiology 53.

Glaessner, M. F. 1947. A fossil beaked whale from Lakes Entrance, Victoria. Proceedings of the Royal Society of Victoria 58:25–34.

Godfrey, S. J., and L. G. Barnes. 2008. A new genus and species of Late Miocene pontoporiid dolphin (Cetacea: Odontoceti) from the St.

Marys Formation in Maryland. Journal of Vertebrate Paleontology 28:520–528.

Gottfried, M. D., D. J. Bohaska, and F. C. Whitmore, Jr. 1994. Miocene cetaceans of the Chesapeake Group; pp. 229–238 in A. Berta and T. A. Deméré (eds.), Contributions in Marine Mammal Paleontology Honoring Frank C. Whitmore, Jr. Proceedings of the San Diego Society of Natural History 29.

Gray, J. E. 1850. Catalogue of the Specimens of Mammalia in the Collections of the British Museum. Part I. Cetacea. British Museum, London 153 pp.

Gray, J. E. 1865. Notices of a new genus of delphinoid whales from the Cape of Good Hope, and of other cetaceans from the same seas. Proceedings of the Zoological Society of London 1865:522–529.

Hooker, S. K. 2001. Marine mammals: sperm whales and beaked whales; pp. 2863–2870 in J. Steele, S. Thorpe, and K. Turekian (eds.), The Encyclopedia of Ocean Sciences. Academic Press, London.

Kazár, E. 2002. Revised phylogeny of the Physeteridae (Mammalia: Cetacea) in the light of *Placoziphius* Van Beneden, 1869 and *Aulophyseter* Kellogg, 1927. Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre 72:151–170.

Kidwell, S. M. 1984. Outcrop features and origin of basin margin unconformities in the lower Chesapeake Group (Miocene), Atlantic Coastal Plain; pp. 37–58 in J. S. Schlee (ed.), Interregional Unconformities and Hydrocarbon Accumulation. American Association of Petroleum Geologists, Memoir 36.

Kidwell, S. M. 1989. Stratigraphic condensation of marine transgressive records: origin of major shell deposits in the Miocene of Maryland. Journal of Geology 97:1–24.

Kidwell, S. M. 1997. Anatomy of extremely thin marine sequences landward of a passive-margin hinge zone: Neogene Calvert Cliffs succession, Maryland, U.S.A. Journal of Sedimentary Research 67:322–340.

Lambert, O. 2005. Systematics and phylogeny of the fossil beaked whales *Ziphirostrum* du Bus, 1868 and *Choneziphius* Duvernoy, 1851 (Cetacea, Odontoceti), from the Neogene of Antwerp (North of Belgium). Geodiversitas 27:443–497.

Lambert, O., and S. Louwye. 2006. *Archaeoziphius microglenoideus*, a new primitive beaked whale (Mammalia, Cetacea, Odontoceti) from the Middle Miocene of Belgium. Journal of Vertebrate Paleontology 26:182–191.

Lambert, O., G. Bianucci, and K. Post. 2009. A new beaked whale (Odontoceti, Ziphiidae) from the Middle Miocene of Peru. Journal of Vertebrate Paleontology 29:910–922.

Lambert, O., G. Bianucci, and K. Post. 2010. Tusk-bearing beaked whales from the Miocene of Peru: sexual dimorphism in fossil ziphiids? Journal of Mammalogy 91:19–26.

Leidy, J. 1877. Description of vertebrate remains, chiefly from the Phosphate Beds of South Carolina. Journal of the Academy of Natural Sciences of Philadelphia 8:209–261.

McCartan, L., B. W. Blackwelder, and E. M. Lemon, Jr. 1985. Stratigraphic section through the St. Marys Formatin, Miocene, at Little Cove Point, Maryland. Southern Geology 25:123–139.

McCoy, F. 1882. *Ziphius* (*Dolichodon*) *geelongensis* (McCoy). Prodromus of the palaeontology of Victoria: or figures and descriptions of Victorian organic remains. Decade 7:23–26.

Mead, J. G. 1975. A fossil beaked whale (Cetacea: Ziphiidae) from the Miocene of Kenya. Journal of Paleontology 49:745–751.

Mead, J. G. 2002. Shepherd's beaked whale—*Tasmacetus shepherdi*; pp. 1078–1081 in W. F. Perrin, B. Würsig, and J. G. M. Thewissen (eds.), Encyclopedia of Marine Mammals. Academic Press, San Diego.

Muizon, C. de. 1983. Un Ziphiidae (Cetacea) nouveau du Pliocène inférieur du Pérou. Comptes Rendus de l'Académie des Sciences, Paris, série II 297:85–88.

Muizon, C. de. 1991. A new Ziphiidae (Cetacea) from the Early Miocene of Washington State USA) and phylogenetic analysis of the major groups of odontocetes. Bulletin du Muséum National d'Histoire Naturelle, Paris, (4) 12:279–326.

Owen, R. 1846. A History of British fossil Mammals and Birds. John Van Voorst, Paternoster Row, London, 560 pp.

Post, K., O. Lambert, and G. Bianucci. 2008. First record of *Tusciziphius crispus* (Cetacea, Ziphiidae) from the Neogene of the US east coast. Deinsea 12:1–10.

Shattuck, G. B. 1904. Geological and paleontological relations, with a review of earlier investigations; pp. 33–137 in W. B. Clark, G. B. Shattuck, and W. H. Dall (eds.), The Miocene Deposits of Maryland. Baltimore, Maryland Geological Survey.

Shideler, G. L. 1994. Sedimentological indicators of paleoenvironments and siliciclastic stratigraphic sequences in some Miocene deposits of the Calvert Cliffs, southern Maryland. Southeastern Geology 34:163–184.

Tazaki, K., H. Horikawa, and S. Miyazaki. 1987. Fossil Ziphiidae from Hyotan-Guri off Sado Island, Central Japan. Bulletin of the Sado Museum 9:219–223.

Ward, L. W. 1992. Molluscan biostratigraphy of the Miocene, Middle Atlantic Coastal Plain of North America. Virginia Museum of Natural History, Memoir 2:1–159.

Ward, L. W., and G. W. Andrews. 2008. Stratigraphy of the Calvert, Choptank, and St. Marys Formations (Miocene) in the Chesapeake Bay area, Maryland and Virginia. Virginia Museum of Natural History, Memoir 9:1–60.

Ward, L. W., and G. L. Strickland. 1985. Outline of Tertiary stratigraphy and depositional history of the U.S. Atlantic Coastal Plain; pp. 87–123 in C. W. Poag (ed.), Geological Evolution of the United States Atlantic Margin. New York, Van Nostrand Reinhold.

Whitmore, F. C., Jr. 1994. Neogene climatic change and the emergence of the modern whale fauna of the North Atlantic Ocean; pp. 223–227 in A. Berta and T. A. Deméré (eds.), Contributions in Marine Mammal Paleontology Honoring Frank C. Whitmore, Jr. Proceedings of the San Diego Society of Natural History, 29.

Submitted October 20, 2009; accepted February 1, 2010.