Maryland Geological Society
– Established 1991 –

A REVISION OF THE CROCODILIAN FAUNA OF THE UPPER PALEOCENE AQUIA FORMATION OF VIRGINIA AND MARYLAND

DENTON, Robert K. Jr., GeoConcepts Engineering Inc.; WEEMS, Robert E., Paleo Quest; GRIMSLEY, Gary J., Maryland Geological Society

GeoConcepts Engineering, Inc.

Abstract

In the past, *Eosuchus minor* Marsh 1870, was the only taxon of crocodilian identified to species from the upper Paleocene (Thanetian stage) near-shore marine Aquia Formation, although a second and undescribed larger crocodilian had also been reported. Recent collecting indicates there are more crocodilian taxa present in the Aquia Formation than previously recognized. The aforementioned larger crocodilian species is now tentatively identified as cf. *Thoracosaurus clavirostris* Morton, 1844, the holotype having been originally described from the upper Paleocene (Thanetian) Vincentown Formation of New Jersey. Both *E. minor* and *T. clavirostris* are found throughout the Aquia Formation. Additionally, a mandible of a dyrosaur (cf. *Hyposaurus* sp.) has been found in the lower Aquia (Piscataway Member) as well as teeth of an alligatorid that cannot be assigned as yet to any lower taxonomic level. In the upper Aquia (Paspotansa Member), heavily worn but seemingly ziphodont (laterally compressed and serrated) crocodilian teeth have been identified tentatively as a planocraniid (formerly Pristichampsidae). Thus, the number of putative crocodilian taxa known from the Aquia is increased from 2 to 5.

Eosuchus, *Thoracosaurus*, and in particular *Hyposaurus* were almost certainly marine-going crocodilians, but the alligatorid probably occupied a fresh or brackish water habitat. The planocraniids are thought to have been terrestrial carnivores with a similar habitus to the sebecosuchians. Both the alligatorid and planocraniid remains were likely transported into the nearshore marine depositional environment from an inland location by coastal rivers.

The species *Hyposaurus rogersii* Owen 1849, has long been know from the late Cretaceous (Maastrichtian) through early Paleocene (Danian) of New Jersey, South Carolina and Alabama, However, if the Aquia dyrosaur proves to be a species of *Hyposaurus* it is significant in that it would be the latest occurrence of the taxon known in the fossil record. The discovery of ziphodont crocodilian teeth in the Aquia Formation also suggests that a planocraniid may have been present in the fauna, however more material than isolated teeth must be found to establish its identity with any certainty.

Introduction

The Aquia Formation was named by Clark (1895), who defined the formation in well exposed marine strata exposed in the bluffs on the south side of Aquia Creek in Virginia. The Aquia Formation was long thought to pertain to the early Eocene (e.g., Clark and Martin, 1901; Gildersleeve, 1942), but it actually is late Paleocene in age (Loeblich and Tappan, 1957). The formation represents a shallow shelf depositional environment in which glauconitic quartz sand, silt and clay accumulated. Fossil remains are very abundant in this unit, consisting predominantly of marine mollusk shells but also including specimens of other phyla including marine vertebrates. Shark, ray, and teleost fish teeth are most commonly found. Remains of marine turtles (Weems, 1988) and crocodylians (Case, 1901) are less common. Rare remains have been found of a sea snake (Lynn, 1934), a land turtle (Weems, 1988), birds (Olson, 1994), and land mammals (Rose, 2000).

Crocodylian remains were first reported from the Aquia by Clark (1895), who named a new species (*Thecachampsa marylandica* Clark, 1896) based on a single tooth and its surrounding jaw. A few years later Case (1901) refigured this species and also figured teeth ascribed to *Thecachampsa sericodon*(?) Cope, 1867 and *Thecachampsa contusor* Cope, 1867.

None of this material is truly diagnostic and none actually pertains to *Thecachampsa*, which is strictly an Oligocene and Miocene genus of tomistomine crocodylian. It was not until 2006 that Brochu firmly identified a taxon of crocodylian from the Aquia, *Eosuchus minor* Marsh, 1870. This species originally was described from a specimen that probably came from the laterally equivalent late Paleocene Vincentown Formation in New Jersey. The tooth identified by Cope (1867) as "*Thecachampsa contusor*" pertains to this species. Until now, these has been the only crocodylians firmly identified from the Aquia. Our research now indicates that the crocodylian tooth named "*Thecachampsa marylandica*" by Case (1901) and the tooth identified as "*Thecachampsa sericodon*(?) by Cope (1867) probably both pertain to *Thoracosaurus clavirostris* (Morton, 1844), a species also named from the Vincentown Formation in New Jersey.

Geological Setting

The Aquia Formation has traditionally been divided into two members: a lower Piscataway member consisting of unconsolidated greensand and greensand marls with an argillaceous basal stratum and scattered layers of indurated marl; and an upper Paspotansa member which is lithologically similar to the lower member. There are scattered indurated shell beds located throughout the unit (Gildersleeve, 1942).

It's of note that a unique basal "Zone 1" member was first identified by Clark and Martin (1901), but they considered it as part of the Piscataway member; however a subsequent palynological study by Frederiksen (1979) verified the presence of a unique "Zone 1" basal member distinguishable from the overlying Piscataway.

For many years the formation was considered Eocene in age, based on the study of the invertebrate fauna, primarily marine pelecypods and gastropods (McGee, 1888; Clark & Martin, 1901; Gildersleeve, 1942) and comparison with correlative taxa from the Eocene of Europe. However, based on studies of the foraminiferal taxa, a Paleocene age was eventually established for the unit (Nogan, 1964; Page, 2004).

Similarly, there has been some disagreement over the environment of deposition represented by the Aquia sediments. Clark and Miller (1912) believed it was deposited in deep, quiet water; however Gibson (1980) felt that based on fossil evidence (foraminifera) that it was deposited under shallow, nearshore marine conditions. Nevertheless, lithological and structural analyses have tended to support Clark and Miller's original contention of a relatively deep, quiet water environment (Dischinger, 1987).

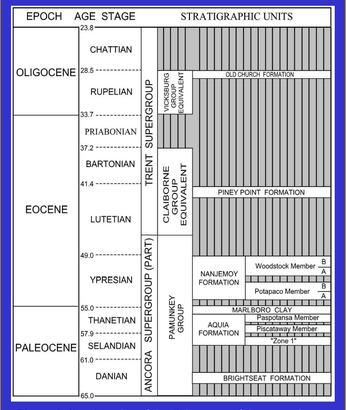

Figure 1. Stratigraphy of the Paleogene of the coastal plain of Virginia and Maryland.

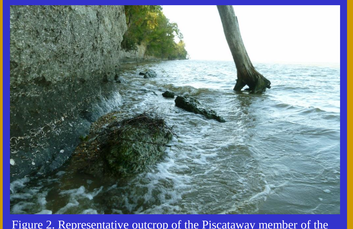

Figure 2. Representative outcrop of the Piscataway member of the Aquia Formation along the Potomac River in Charles County, MD. (Photo courtesy of Jayson Kowinski).

Dyrosauridae

Figure 3a. Anterior portion of the lower jaw of cf. *Hyposaurus* sp., from the Piscataway member of the Aquia formation.

Figure 3b. NJSM 10861, the nearly complete mandible of a juvenile of *Hyposaurus rogersii* from the Hornerstown Formation (Paleocene, Danian stage) of New Jersey.

An unusual crocodilian mandible was discovered during 1999 by one of the authors (G. Grimsley) in the Piscatway member of the Aquia Formation at Liverpool Point, Charles County, MD. The specimen consisted of the anterior-most portions of the (unfused) dentary and splenial bones, with a single tooth remaining in-situ, and a second identical tooth found in close association.

Based on the shape and outline of the dental alveoli, and the fact that the splenial formed the inner (medial) edge of the dental alveoli adjoining them, the mandible was identified tentatively as a mesoeusuchian dyrosaurid, possibly *Hyposaurus rogersii*, the only North American dyrosaur and a relatively abundant taxon in the Maastrichtian and Danian of the Atlantic and Gulf Coasts. Nevertheless, upon close comparison of the Aquia dyrosaur with specimens of *Hyposaurus* some distinct differences were noted including: an overall larger size; closer tooth spacing; and smaller teeth relative to the size of the dentary bones. Interestingly, the Aquia specimen seems most comparable in conformation to the mandibular elements of *Arambourgisuchus khouribgaensis* (Jouve, 2005) a close relative of *Hyposaurus* from the Paleocene of Morocco; and in size to *Dyrosaurus phosphaticus* from the Eocene of North Africa and possibly Europe.

The appearance of a seemingly unique (and possibly new) dyrosaur from the Aquia Formation is surprising, but not totally unexpected. There is evidence of significant change from the Early Paleocene (Danian stage) to the Late Paleocene and Eocene in the known fossil taxa of New Jersey, Maryland and Virginia from this time period, suggesting a possible faunal "turn-over", including the disappearance of some taxa and the sudden appearance of others previously known only from Africa and Europe (Weems, verb. comm., 2014). Although it is known from the Late Cretaceous through Early Paleocene of the Atlantic and Gulf Coast regions of Eastern North America, it is notable that no bona fide remains of *H. rogersii* have ever been found in post-Danian age deposits (Denton, et al., 1997). Thus, the Aquia dyrosaur may be a new taxon, however its specific affinities cannot be determined conclusively until additional fossils are discovered, in particular the post-rostral portions of the skull.

Gavialoidea

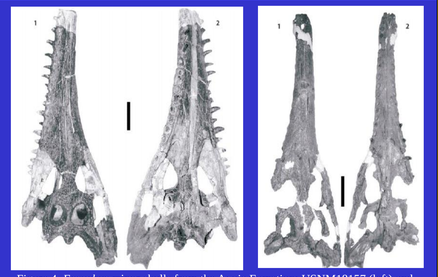

Figure 4. *Eosuchus minor* skulls from the Aquia Fomation: USNM18157 (left) and USNM299730 (right). (from Brochu, 2006)

Gavialoideans have been known from the Aquia Formation since the early 19th century under a variety of names, the most fully known and studied of these being *Eosuchus minor* (Figure 4). In addition, a second, and less common longirostrine crocodilian was initially identified as *Thoracosaurus neocesariensis*, a taxon abundant in the Maastrichtian and Danian nearshore marine deposits of New Jersey. However, S. G. Morton (1844) described a species of *Thoracosaurus* from the Vincentown Formation of New Jersey as *T. clavirostris*, on the basis of its possessing two foraminae (incorrectly described by some authors as "antorbital fenestrae") lying between the lacrimal and prefrontal bones. Now, at least two other specimens have been identified as cf. *T. clavirostris*: USNM 72, a large thoracosaur skull which was reposing quietly for over 150 years in the collection of the Smithsonian Museum, and a registered but uncatalogued specimen from Belvidere Beach which was donated to the New Jersey State Museum in 1985. In both cases the specimens show the presence of the lacrimal foraminae, which along with their large size and other diagnostic features allows them to be differentiated from *E. minor.*

Figure 5. *T. clavirostris* (ANSP 10079) as illustrated in Morton, 1844.

Figure 6. *T. clavirostris* from the Aquia Formation (USNM 72). Red circle is the larcimal foramina.

Figure 7a & 7b. NJSM Belvidere Beach skull. Red circle (right) shows the lacrimal foramina.

Tooth Types: Planocraniidae(?); Alligatoridae(?)

Figure 8a & 8b. Various tooth crocodilian tooth morphs from the Aquia Formation of Maryland, showing the unusual "narrow profile" (i.e. laterally compressed) shape. (Photo courtesy of Maryland Geological Society)

For many years, dedicated and observant amateur collectors have noted the occurrence of unusual, "narrow profile" (i.e. laterally compressed) crocodilian teeth, specifically in the Paspotansa member of the Aquia. Previously written off as "pathologic" or "anomalous", these teeth never could be associated with any of the known Aquia crocodilian taxa, and their origin remained a mystery. As often is the case with crocodilian teeth, most of the specimens were stripped of their enamel due to having passed through their former owner's digestive system after being shed. However in 2013 a relatively pristine specimen finally emerged (figure 10).

Figure 9. Laterally compressed teeth with possible worn serrated carinae (red ovals).

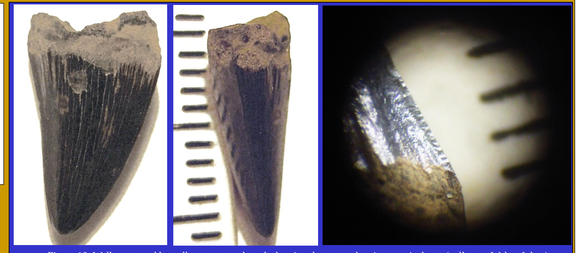

Figure 10. Well-preserved laterally compressed tooth showing the serrated carina near its base. (collector: Walter Johns)

The new specimen had smooth, unstriate enamel, was strongly laterally compressed, and had clearly visible serrated carinae, with the denticulations most visible near the gingival margin. If it had been found in the Late Cretaceous Severn Formation of Maryland it would have been assumed to be a shed tooth from a theropod dinosaur! In fact, when the teeth of the Paleocene planocraniid crocodilian "*Pristichampsus vorax*" (*Boverisuchus vorax*, Brochu 2013) were first discovered, they too were thought to be those of theropod dinosaurs. However, it is not surprising that the remains of a planocraniid crocodilian has been identified in the Paleocene of the Middle Atlantic, but the taxon cannot be fully described until more remains other than isolated teeth are found.

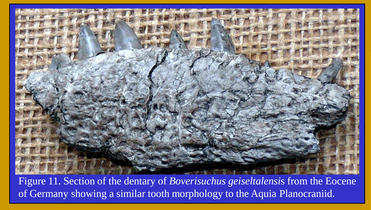

Figure 11. Section of the dentary of *Boverisuchus geiseltalensis* from the Eocene of Germany showing a similar tooth morphology to the Aquia Planocraniid.

Figure 12. Well-preserved crocodilian tooth identified as a putative "alligatorid". This tooth was in the process of being resorbed when its former owner died based on the presence of the large resorption pit at its bottom.

References Cited

BROCHU, C. A. (2013). "Phylogenetic relationships of Palaeogene ziphodont eusuchians and the status of *Pristichampsus* Gervais, 1853". *Earth and Environmental Science Transactions of the Royal Society of Edinburgh*

CASE, 1901, Md. Geol. Survey, p. 96, pl. x, fig. 4.

CLARK, W. B., 1895, Cretaceous deposits of the northern half of the Atlantic Coastal Plain: Geological Society of America Bulletin, v. 6, p. 479-482.

__ 1896, The Eocene deposits of the Middle Atlantic slope in Delaware, Maryland, and Virginia: U.S. Geological Survey Bulletin 141, 167 p.

CLARK, W. B., and Martin, G. C., 1901. The Eocene deposits of Maryland: Maryland Geological Survey, Eocene Volume, 331 p.

CLARK, W. B., and Miller, B. L., 1912. The physiography and geology of the Coastal Plain Province of Virginia: Virginia Geological Survey Bulletin 4, 27 4 p.

COPE, E. D. 1867. The fossil reptiles of New Jersey. American Naturalist, 1:23–30.

DENTON R. K. Jr., J. L. Dobie, and D. C. Parris. 1997. The marine crocodilian Hyposaurus in North America. In J. M. Callaway, E. L. Nicholls (eds.), *Ancient marine reptiles* 375-397

DISCHINGER, J.B., Jr., 1987, Late Mesozoic and Cenozoic stratigraphic and structural framework near Hopewell, VA: U.S. Geological Survey Bulletin, 1567, 48 p.

FREDERICKSEN, N. O. 1979, Paleogene sporomorph biostratigraphy, northeastern Virginia: Palynology, v. 3, p.129-167.

GIBSON, T. G., and others, 1980, Biostratigraphy of the Tertiary strata of the core, *in* Geology of the Oak Grove Core: Virginia Division of Mineral Resources Publication 20, part 2, p.14-30.

GILDERSLEEVE, B., 1942, Eocene of Virginia: Virginia Geological Survey Bulletin, no. 57, 43 p.

LOEBLICH, A. R. Jr. & H. N. Tappan. 1957. Planktonic Foraminifera of the Paleocene and Early Eocene age from the Gulf and Atlantic Costal Plains. USNM Bull. 215:173-198.

LYNN, W. 1934. A new snake Paleophis virginianus from the Eocene of Virginia. *John Hopkins University Studies in Geology* 11:245-249

MARSH, O. C. 1870. Notice of a new species of gavial, from the Eocene of New Jersey. American Journal of Science, 50:2–3.

McGEE, W. J., 1885, Geological formations underlying Washington and vicinity, *in* Report of Health Officer of the District of Columbia for the year ending June 30, 1885,p.19-21,23-25.

MORTON, S. G. 1844. Description of the head of a fossil crocodile from the Cretaceous strata of New Jersey. Proceedings of the Academy of Natural Sciences of Philadelphia, 2:82–85.

NOGAN, D. S., 1964, Foraminifera, stratigraphy, and paleoecology of the Aquia Formation of Maryland and Virginia: Cushman Foundation for Foraminiferal Research, Special Publication 7, 50 p.

OLSON, Storrs L. 1994. A Giant Presbyornis (Aves, Anseriformes) and Other Birds from the Paleocene Aquia Formation of Maryland and Virginia. *Proceedings of the Biological Society of Washington*, 107(3): 429-435.

OWEN, R. 1849. Notes on remains of fossil reptiles discovered by Prof. Henry Rogers of Pennsylvania, U.S., in greensand formations of New Jersey. Quarterly Journal of the Geological Society, 5:380–383.

PAGE, R. A., 2004. The Questionable age of the Aquia Formation (Maryland-Virginia). Journal of Paleontology, 33:2, p. 347-350.

ROSE, K. 2000. Land mammals from the Late Paleocene Aquia Formation: The first early Cenozoic mammals from Maryland. 113: 855-863.

WEEMS, R., 1988. Paleocene Turtles From The Aquia And Brightseat Formations, With A Discussion Of Their Bearing On Sea Turtle Evolution And Phylogeny, Proceedings of The Biological Society of Washington, vol. 101, p. 109-145.