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PLESIOSAURIAN REMAINS FROM THE ARKADELPHIA FORMATION–MIDWAY GROUP CONTACT (MAASTRICHTIAN–PALEOCENE) HOT SPRING COUNTY, NEAR MALVERN, ARKANSAS, U.S.A.

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ABSTRACT

The Arkadelphia Formation–Midway Group contact (Maastrichtian–Paleocene) near Malvern, Arkansas preserves one of the youngest plesiosaurian fossil assemblages yet reported from the Gulf Coastal Plain of the United States. The fossil assemblage consists of four vertebrae and two teeth recovered by scuba diving an outcrop along a meander bend of the Ouachita River. These plesiosaurian fossils are preserved in mollusc, coral and ammonoid coquina and derive from at least one animal having a total overall length of more than ten meters. Taphonomic conditions under which this coquina was deposited indicate that plesiosaurians may have inhabited a shallow, biohermal patch reef environment in southwestern Arkansas where they lived contemporaneously with ammonoids, osteichthyans and chondrichthyans such as *Placenticeras* sp., *Enchodus* sp. and *Serratolamna serrata* (Agassiz, 1843). The Arkadelphia Formation–Midway Group fossils extend the known geographic range of plesiosaurians in North America and indicate that these apex marine reptiles were living at, or near, the Cretaceous–Paleogene mass extinction boundary in the region.

INTRODUCTION

To date, only a few published reports on plesiosaurians exist from the Gulf Coastal Plain of the United States and only a single one exists from the state of Arkansas. This report is over one-hundred and fifty years old and was written by the Father of American Vertebrate Paleontology, Joseph Leidy, in 1854. In this report, Leidy (1854) described four incomplete vertebrae from near Greenville, Clark County, Arkansas. Leidy believed these vertebrae were sufficiently different from those belonging to the few other species described at this time and assigned them to the new taxon *Brimosaurus grandis*.

The present report describes an assemblage of plesiosaurian remains consisting of one cervical vertebra, two dorsal vertebrae, one caudal vertebra and two teeth. Moreover, these plesiosaurian specimens were recovered from the contact horizon of the Arkadelphia Formation–Midway Group (Figures 1, 2), which approximates the Cretaceous–Paleocene boundary in this region and provides reasonably good time control for the age of these plesiosaurian specimens. By comparison to other North American plesiosaurians, it also suggests that the individual or individuals from which the specimens derive may be among the geologically youngest yet reported from the Gulf Coastal Plain.

Institutional Abbreviations—ANSP, Academy of Natural Science Philadelphia.

MATERIALS AND METHODS

Geologic Setting, Age and Collecting Techniques—Details of the geologic setting for the Arkadelphia Formation–Midway Group contact near Malvern, Arkansas were originally reported by Becker et al. (2006) and in subsequent publications by Becker et al. (2010; 2011; 2012) that described the chondrichthyan and osteichthyan assemblages from the region. Fossil chondrichthyan and osteichthyan teeth as

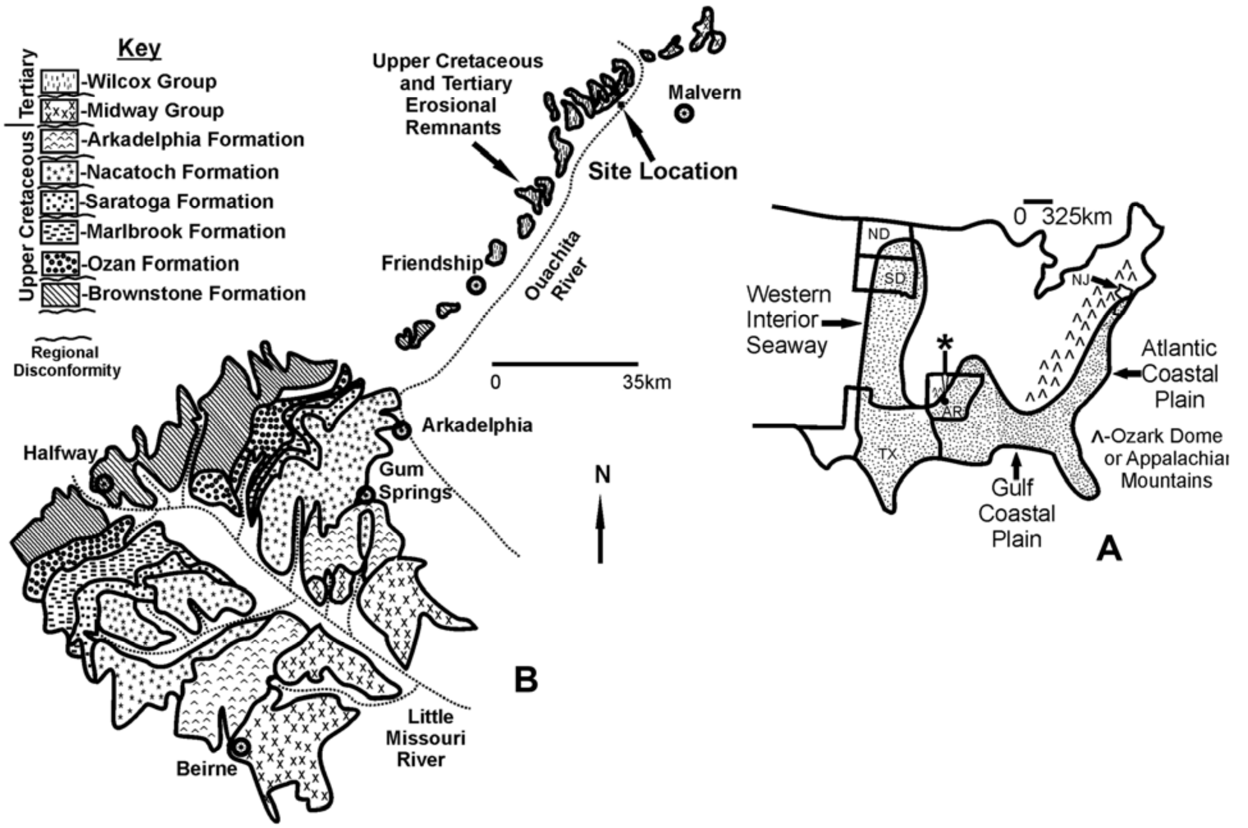

FIGURE 1. Location maps for ArkadelphiaFormation–Midway Group (Maastrichtian–Paleocene) plesiosaurian remains from Hot Spring County, Arkansas, (modified from Becker et al., 2006, 2010). A, Late Maastrichtian (*Jeletzkytes nebrascensis* Zone) paleogeographic reconstruction of the Atlantic and Gulf Coastal plains and Western Interior Seaway (redrawn from Kennedy et al., 1998; asterisk indicates the approximate location of Arkansas fossil site). B, geologic map of Upper Cretaceous formations in the study area of southwestern Arkansas.

well as molluscs, corals and ammonoids are abundant along the disconformable contact horizon and occur in a lag deposit that separates the Arkadelphia Formation from the overlying Midway Group (Figure 2). Outcrop exposures and distribution of vertebrate fossils in the region are strongly influenced by physical erosion of the Ouachita River and periodic release of water upstream from the Lake Catherine Dam.

Multiple lines of evidence support a Maastrichtian–Paleocene age assignment for the Arkadelphia–Formation Midway Group contact near Malvern, Arkansas. These include: (1) foraminifera (Cushman, 1949); (2) palynology (Jones, 1962); (3) magnetostratigraphy (Liddicoat et al., 1981); (4) geologic mapping (Haley et al., 1993; 2009); (5) ostracods (Pitakpaivan and Hazel, 1994); (6) dinoflagellates (Dastas et al., 2010); (7) chondrichthyans (Becker et al., 2006; 2011); and (8) osteichthyans (Becker et al., 2010; 2012). Additional discussion of the lithology and age of the Arkadelphia Formation and Midway Group in Southwestern Arkansas can be found in the Geologic Map of Arkansas by Haley et al. (1993) and in the accompanying stratigraphic summary by McFarland (2004). However, as discussed in Becker et al. (2006), it is not yet possible to pinpoint the position of the K–Pg boundary at this site, or to estimate the missing time from the section. The Malvern lag deposit is similar to other lag deposits created as a result of third order sea level cyclicity (e.g., Busch and Rollins, 1984; Case and Schwimmer, 1988; Brett and Baird, 1993; Kidwell, 1993; Sugarman et al., 1995; Becker et al., 1996; 1998; Shimada et al., 2006). Such lag deposits have been interpreted to represent hundreds of thousands up to a few million years in time. This would argue very strongly for a Maastrichtian–Paleocene age for the lag and for the plesiosaurian fossils described in this report.

The plesiosaurian specimens described in this paper were all recovered by scuba diving the Arkadelphia Formation–Midway Group (K–Pg) contact along the Ouachita River near Malvern, Arkansas. The vertebrae and teeth were discovered on separate slabs of

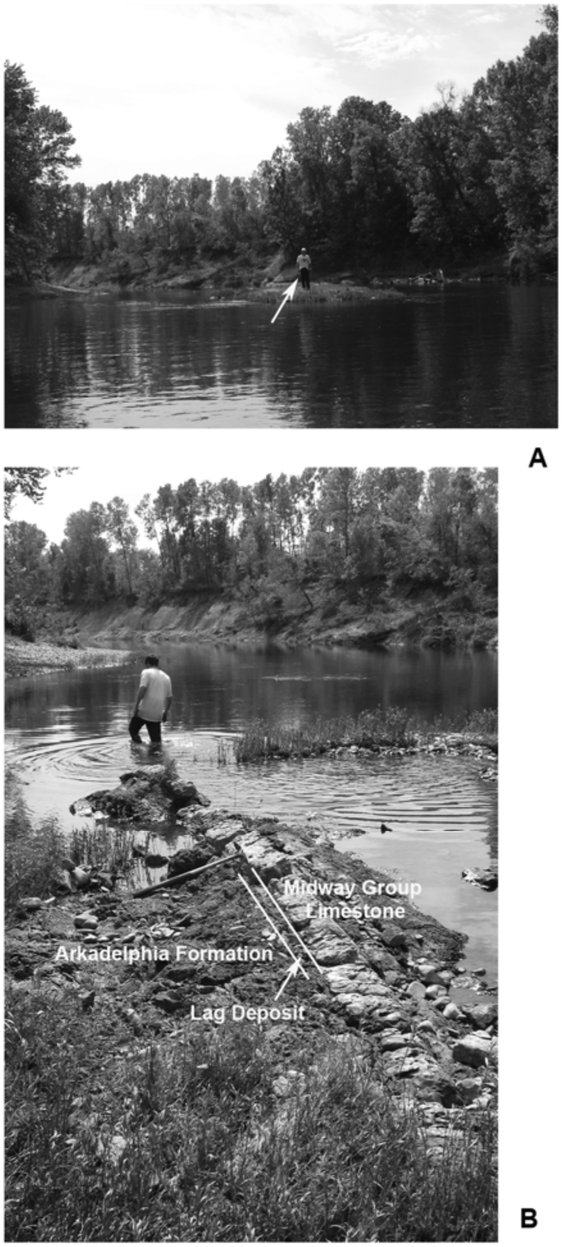

FIGURE 2. Outcrop exposures of the Maastrichtian Arkadelphia Formation and Paleocene Midway Group in Hot Spring County, Arkansas, containing the fossiliferous lag described in this report. A, Erosional remnant of the lag deposit within the Ouachita River during low water flow. B, Close-up of the same erosional remnant occurring between the Maastrichtian Arkadelphia Formation and Paleocene Midway Group. Note the steep inclination of the fold limb and oblique strike angle relative to river water flow. The arrow indicates the stratigraphic position of the lag deposit from which the plesiosaurian remains were recovered. Pick axe is approximately 1 m and the person is 1.8 m.

mollusc, coral and ammonoid coquina and were removed underwater via pry bars, sledge hammers and chisels (Figures 3–7). All plesiosaurian specimens derive from different anatomical locations of the skeleton and were recovered within approximately 25 m of each other. The cervical vertebra is situated in a block of coquina weighing 40 kg and required extensive laboratory preparation to partially expose the ventral foramina, rib facets, centrum face, neural canal and neural spine (Figure 4). The largest slab, which contains the larger dorsal vertebra, weighs 46 kg and required a minor amount of laboratory preparation to expose the anterior centrum surface, transverse processes and zygapophyses (Figure 5A). Outside of the minor application of epoxy to prevent desiccation cracking, the plesiosaurian specimens seen in Figures 3–7 are depicted as they were recovered in the coquina matrix. No deformation due to fossilization or diagenesis of the coquina matrix is observed in any of the Malvern plesiosaurian specimens. Specimens described here have been reposited in the fossil vertebrate collections of the Academy of Natural Science Philadelphia (ANSP).

SYSTEMATIC PALEONTOLOGY

Suborder Plesiosaruia de Blainville, 1835
Family Elasmosauridae Cope, 1869
gen. et sp. indet.
(Figures 3–7)

Referred Material—Two teeth in coquina matrix, ANSP 23397–23398 (Figure 3).

Description—The larger tooth is exposed in lateral view (ANSP 23397; Figure 3A, C). The crown bears no carina and has well-defined dorsoventral, wavy enameled ridges present from the tip of the crown to the crown base on all exposed tooth faces. The incomplete tooth base is oval in cross section, concave and measures 12 mm in diameter. Tooth dimension from crown apex to root base measures 38 mm and the overall tooth length is 54 mm.

The smaller tooth is exposed in lateral view (ANSP 23398; Figure 3B). The enamel near the crown apex and crown base is present while the enamel of the mid-section of the tooth has been exfoliated, exposing the underlying dentine. The crown bears no carina and dorsoventral enameled ridges are well-defined and are present from the crown apex to the crown base. The incomplete tooth base is oval in cross section, concave and measures 11 mm in diameter. Tooth dimension from crown apex to root base measures 37 mm and overall tooth length is 39 mm.

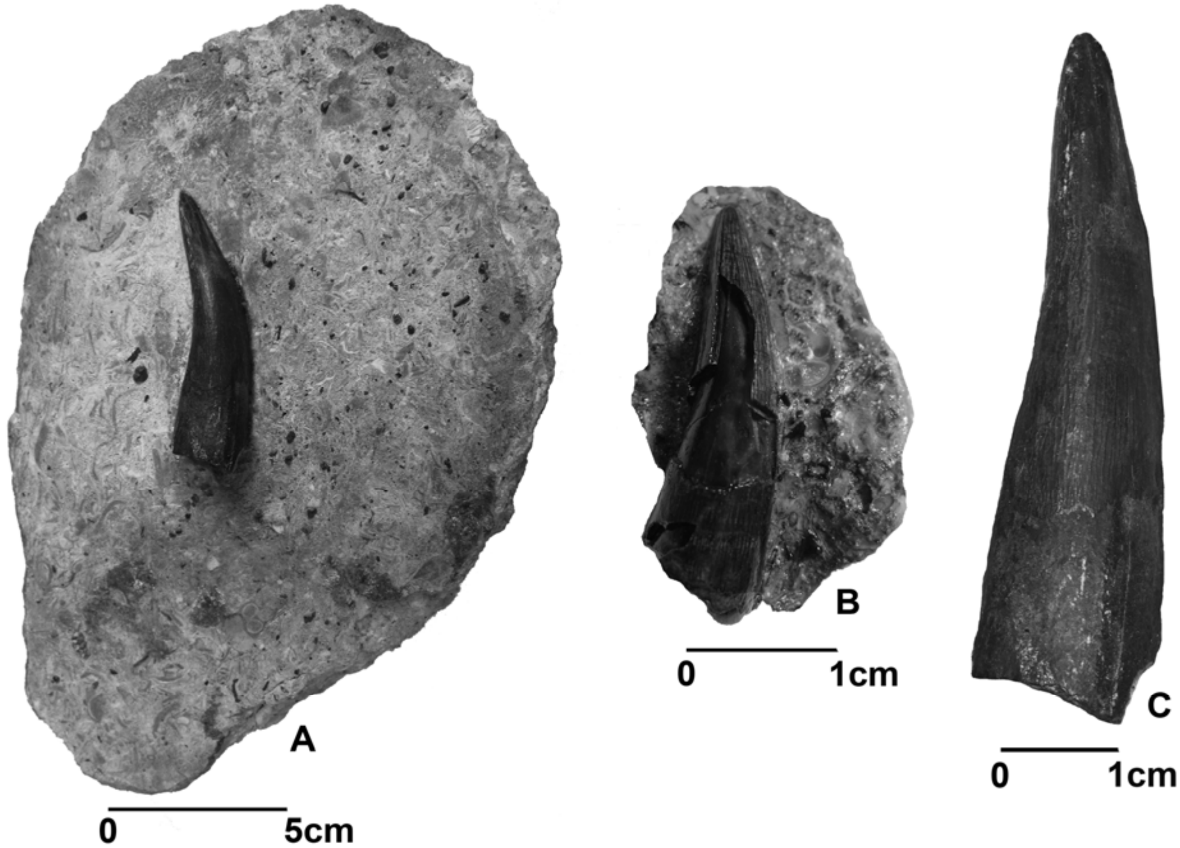

FIGURE 3. **A**–**B**, Lateral views of teeth ANSP 23397–23398 in coquina from the Arkadelphia Formation–Midway Group contact, Hot Spring County, Arkansas. **C**, Close-up of larger tooth, ANSP 23397, in anterior view displaying dorsoventral striations on the crown and section of the non-striated root base. Scale bar in **A** equals 5 cm and scale bars in **B** and **C** equal 1 cm.

Discussion—The overall length, lingual curvature, presence of dorsoventral striations, narrow concave base, lack of carina identifies the Malvern teeth as plesiosaurian teeth, and distinguishes them from teeth belonging to other contemporaneous reptiles such as mosasaurs and gharials (Welles, 1943, 1949; Parris, 1974; Adams, 1997; Sato and Wu, 2006; Vandermark et al., 2006). The more elongate and slender Malvern teeth are also similar to those belonging to piscivorous plesiosaurians (Massare, 1997).

Referred Material—Cervical vertebra in coquina matrix, ANSP 23399, (Figure 4).

Description—The cervical vertebra is preserved in posterior view exposing a platycoelus centrum face, neural canal, neural spine, partial left postzygopophysis, slightly concave rib facet and ventral nutritive foramina (Figure 4). The partial neural spine measures 172 mm in height and no sutures are seen where the neural arch is fused to the centrum. The neural canal is oval and measures 32 mm dorsoventrally and 28 mm laterally. The centrum face is bilobate and measures 110 mm in width, 85 mm in height and 65 mm in anteroposterior length. The diapophyses are circular, completely fused to the centrum body and are posteriorly positioned along the ventral surface of the centrum.

Discussion—In the Malvern cervical vertebra, the location of the rib facets, lack of elongate transverse processes, absence of lateral longitudinal ridges and absence of ventral notch indicates that it derives from the posterior region of the neck (Adams, 1997; Gasparini et al., 2003; Sato, 2003; Sato and Wu, 2006; Bardet et al., 2008; Otero et al., 2012). In cervical vertebrae, the length of the neural spine increases rapidly in the posterior direction in comparison to the height of the centrum (Sato, 2003). This feature is present in the Malvern specimen and further supports our interpretation that the vertebra derives from the posterior region of the neck. There are no observable

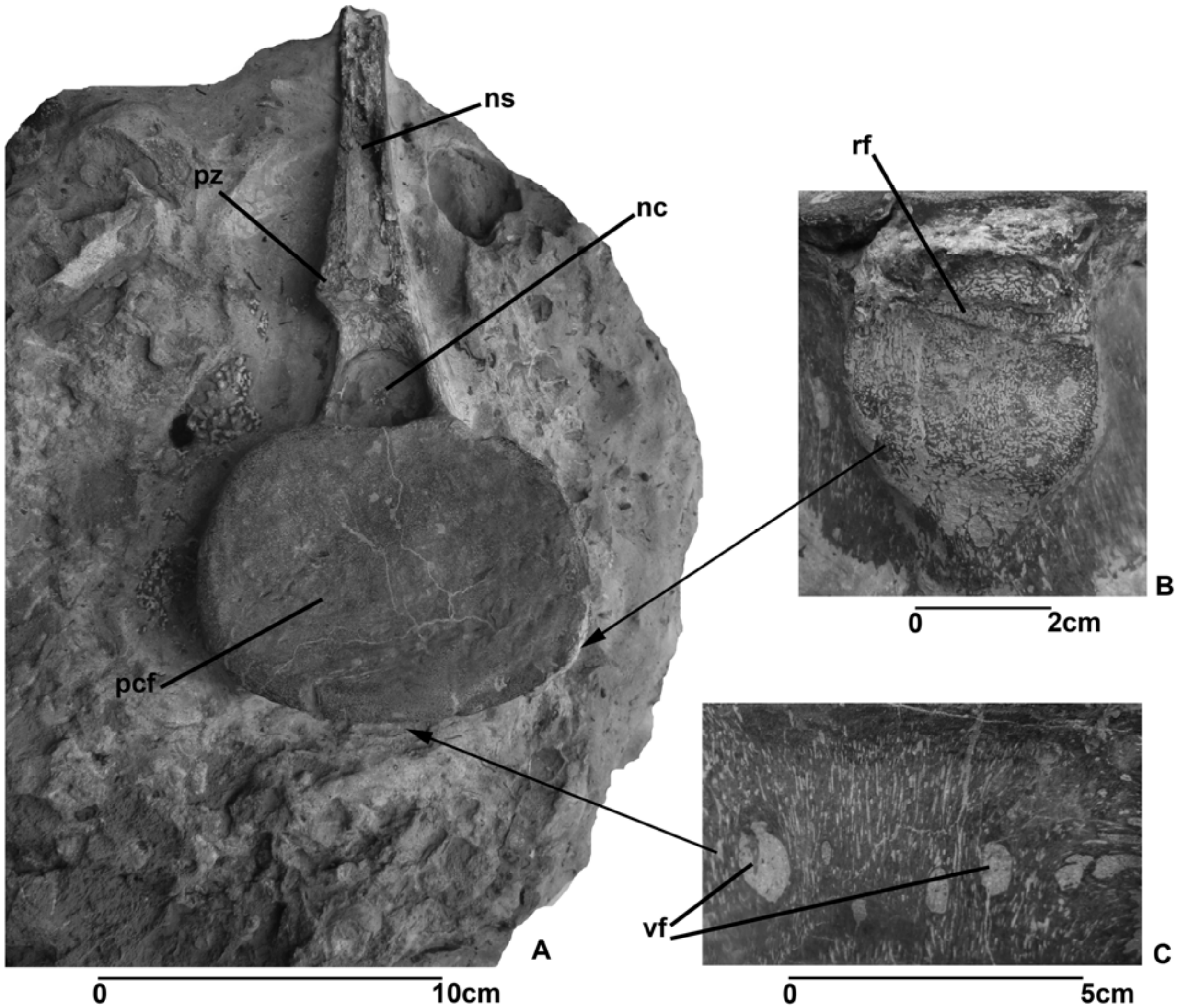

FIGURE 4. A, Posterior view of cervical vertebra ANSP 23399 from the Arkadelphia Formation–Midway Group contact, Hot Spring County, Arkansas. B, Close-up of articular view of right rib face. C, Close-up of ventral foramina. Note partial posterior zygapophysis on left side of neural spine. Abbreviations: acf, anterior centrum face; az, anterior zygapophysis**;** nc, neural canal; ns, neural spine; rf, rib facet; tp, transverse process. pcf, posterior centrum face; pz, posterior zygapophysis; vf, ventral foramina. Scale bar in A equals 10 cm, B equals 2 cm and C equals 5 mm.

sutures fusing the neural spine or diapophyses to the centrum body indicating that the Malvern cervical vertebra belonged to an adult animal (Bardet et al., 2008; Kubo et al., 2012).

Referred Material—Two dorsal vertebrae in coquina matrix, ANSP 23400–23401, (Figure 5).

Description—The larger dorsal vertebra is preserved in anterior view and exposes a platycoelus centrum face, neural canal, anterior portion of the transverse processes and anterior prezygapophyses (ANSP 23400; Figure 5A, B). A small portion of the neural spine is exposed in dorsal view within the coquina matrix where internal cancellous bone can be seen. The neural canal is circular and measures 30 mm in diameter. The circular centrum face measures 123 mm in width and 103 mm in height. The transverse processes are robust and measure 98 mm from the rib facet to the neural canal. The transverse processes extend laterally across the dorsal portion of the centrum to the plane of the centrum with only a slight posterior distal curvature. The left transverse process is nearly complete and has a slightly concave facet for articulation of the corresponding rib. The right transverse process is incomplete distally.

The smaller dorsal vertebra is preserved in anterior view (ANSP 23401; Figure 5C). The dense surface bone of this specimen is partially eroded, exposing internal cancellous bone of the centrum,

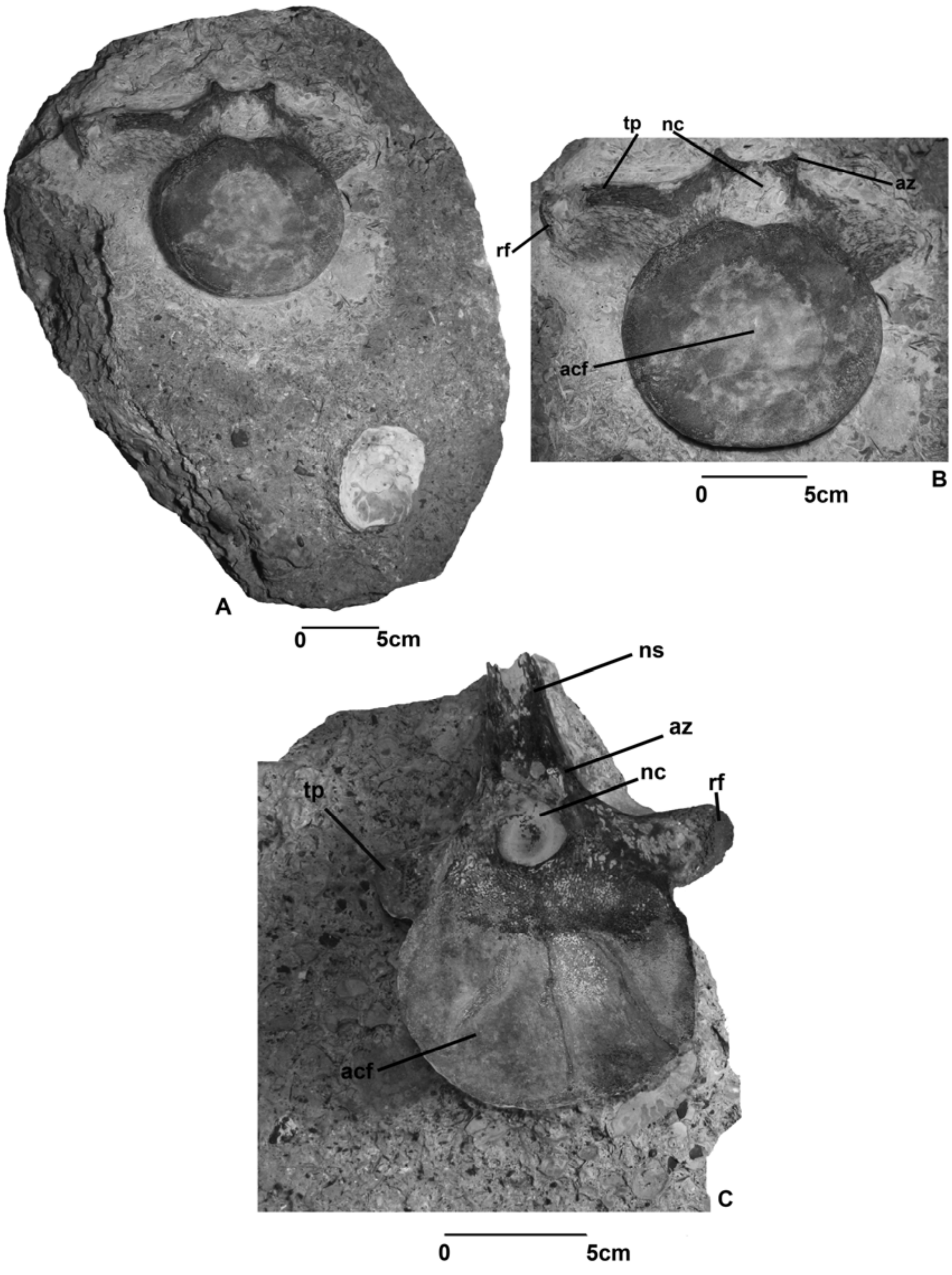

FIGURE 5. A, Anterior view of larger dorsal vertebra ANSP 23400 in coquina from the Arkadelphia Formation–Midway Group contact, Hot Spring County, Arkansas. B, Close-up of the larger vertebra, ANSP 23400, circular centrum face, zygapophyses and transverse processes. Note that the robust transverse processes originate near the top of the centrum. C, Anterior view of smaller dorsal vertebra ANSP 23401 in coquina from the Arkadelphia Formation–Midway Group contact, Hot Spring County, Arkansas with centrum face, zygapophyses, transverse processes and neural spine. Note that the transverse processes are smaller, angled in the posterior direction and originate slightly below the top of the centrum. Abbreviations: acf, anterior centrum face; az, anterior zygapophysis; nc, neural canal; ns, neural spine; rf, rib facet; tp, transverse process. Scale bars in A–C equals 5 cm.

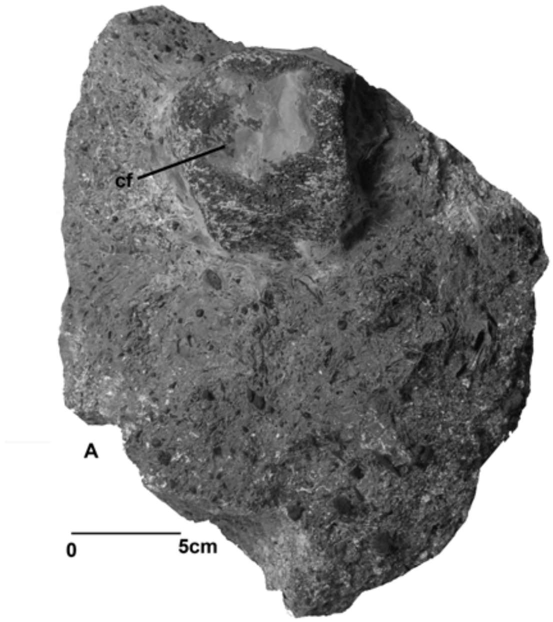

FIGURE 6. Centrum face of caudal vertebra ANSP 23402 in coquina from the Arkadelphia Formation–Midway Group contact, Hot Spring County, Arkansas. Abbreviation: cf, centrum face. Note pentagonal geometry across the centrum face. Scale bar in equals 5 cm.

neural canal, transverse processes, anterior zygapophyses, incomplete neural spine and ventral foramina. The neural canal is circular and measures 25 mm in diameter. The circular centrum face measures 97 mm in width, 81 mm in height and 72 mm in anteroposterior length. The transverse processes on the smaller dorsal vertebra are less robust than those seen on the larger dorsal vertebra, originate just below the dorsal portion of the centrum, measure 90 mm from the articular facet at its distal end to the neural canal, and are angled posteriorly. Nutritive foramina are present on the ventral surface of the centrum.

Discussion—In the Malvern dorsal vertebrae, the elevated location and shape of the transverse processes, together with their rib facets, indicate that the larger vertebra derives from the mid-dorsal region, while the smaller vertebra derives from the posterior location in the dorsal series (Massare and Sperber, 2001; Everhart, 2005). In general, the largest vertebrae in plesiosaurians are located in the center of the dorsal region where the centra are more circular in outline than other vertebrae in the spinal column (Everhart, 2005). Both Malvern dorsal vertebrae are also circular in outline and share length, width and height proportions consistent with those seen in other Late Cretaceous plesiosaurians (Werner and Bardet, 1996; Everhart, 2005; O'Keefe and Hiller, 2006; Kubo et al., 2012).

Referred Material—Caudal vertebra in coquina matrix, ANSP 23402, (Figure 6).

Description—The caudal vertebra and centrum face are roughly pentagonal in shape (Figure 6). The cancellous bone matrix is exposed on all surfaces of this specimen. The vertebra measures 84 mm in width and 63 mm in height across the articulation surface. The greatest exposed anteroposterior width of the vertebra measures 22 mm. No evidence of elongate vertebral processes are preserved.

Discussion—The overall pentagonal geometry across the centrum face in the Malvern vertebra is similar to vertebrae found in the caudal region in plesiosaurians (Andrews, 1910; Adams, 1997; Sato, 2003; Sachs, 2005; Schumacher and Everhart, 2005; Sato and Wu, 2006). This interpretation is further reinforced by the Malvern caudal vertebra's greater dimension in width than in height and by the absence of elongate vertebral processes (Welles, 1943). Caudal vertebrae have also been reported to have a more conical shape in the anteroposterior dimension, which is seen in the Malvern specimen (Schumacher and Everhart, 2005; Sato and Wu, 2006). In the Malvern caudal vertebra, a centrum face is exposed but it cannot be determined whether this is the anterior or posterior surface due to the weathered state of the specimen.

DISCUSSION

Taxonomy of the Malvern Plesiosaurian Assemblage—In North America, a few Late Cretaceous localities have yielded isolated Maastrichtian plesiosaurian remains similar to the Malvern assemblage (e.g., Parris, 1974; Hartstein et al., 1999; Gibson, 2008). Traditionally, such isolated anatomical elements have been assigned to *Cimoliasaurus magnus* Leidy, 1851 (nomen dubium), which was originally described from thirteen vertebrae recovered from Burlington County, New Jersey. Other Maastrichtian plesiosaurians from North America have been described from more complete skeletal remains in California and Alberta, and are assigned to at least four other species (Welles, 1943; Hilton, 2003; Sato and Wu, 2006).

The majority of plesiosaurian remains reported from the Gulf Coastal Plain states have been documented from the Mooreville and Demopolis Chalks of Alabama, Mississippi and Tennessee (Shannon, 1974; Wheatstone, 1977; Manning and Dockery, 1992; Carr et al., 2005; Manning, 2006). Analysis of these chalks indicates an early Santonian to early Campanian age assignment for the Mooreville Chalk and middle to late Campanian age assignment for

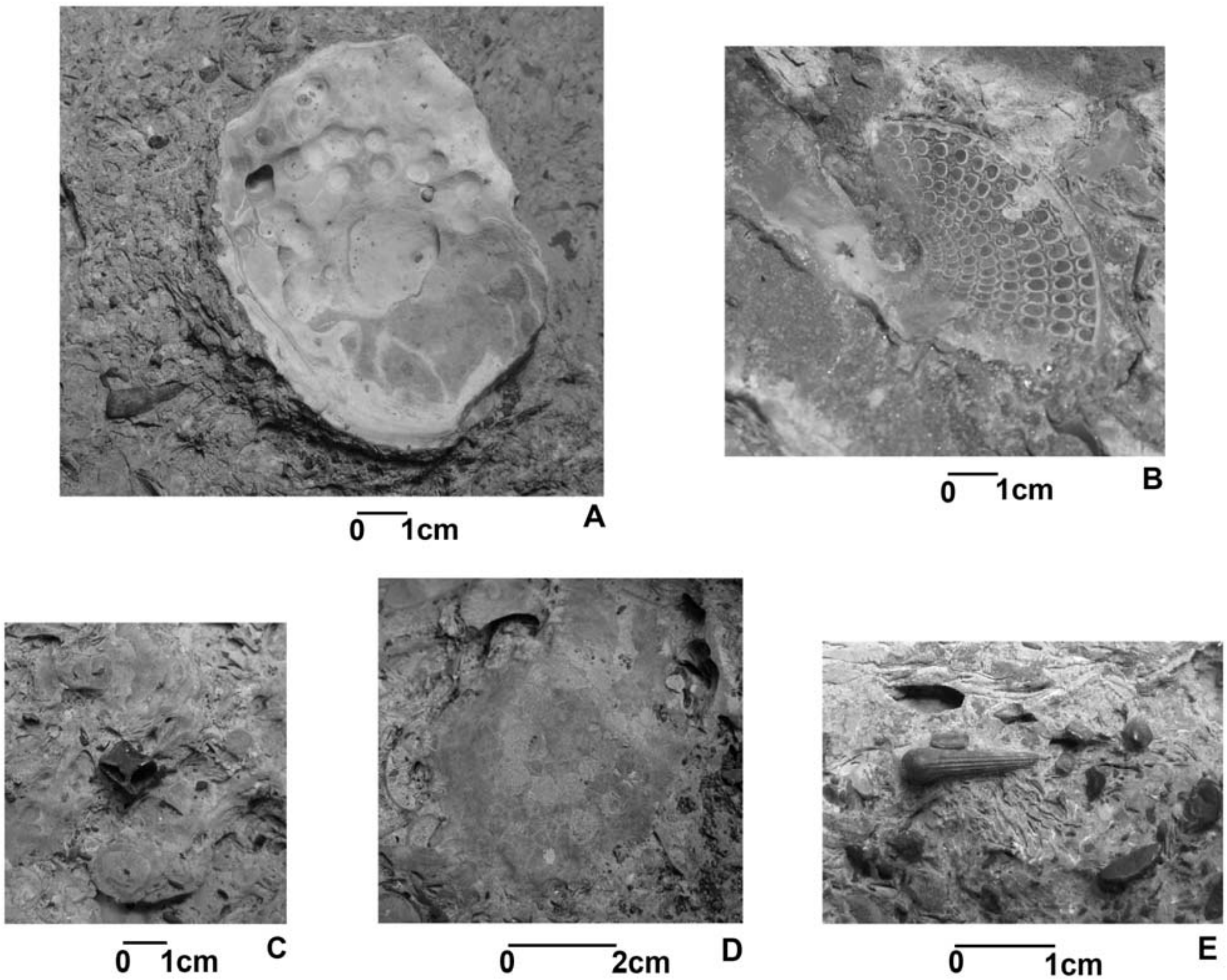

FIGURE 7. Associated fossils preserved in coquina with plesiosaurian remains from the Arkadelphia Formation–Midway Group contact, Hot Spring County, Arkansas. A, Oyster exposing internal valve surface. B, *Placenticeras* sp. ammonite exposing suture pattern. C, Associated fish vertebra located on the underside of the coquina. D, Branching hexacoral fragment. E, *Enchodus* sp. tooth. Scale bars in A–C, E equals 1 cm and D equals 2 cm.

Demopolis Chalk (Puckett, 1994; Mancini et al., 1996; Puckett and Mancini, 1998). All occurrences of plesiosaurians in Texas are pre-Campanian and have been documented from the Eagle Ford Shale and Lake Waco Formation (Williston, 1907; Welles, 1949; Thurmond, 1968).

The absence of any cranial bones and the disarticulated nature of the Malvern plesiosaurian assemblage precludes any higher order taxonomic assignment utilizing traditional anatomical analysis or modern cladistical methods based on characters (e.g., Leidy, 1854; Williston, 1907; Welles, 1943; Brown, 1981, Carter, 1991; O'Keefe, 2001; Sato, 2002; Ketchum and Benson, 2010; Kubo et al., 2012). However, many characters seen in this assemblage are specific to the elasmosaurids. The first of these anatomical characters is the platycoelous centrum faces seen in the cervical, dorsal and caudal vertebrae. Moreover, the overall shapes along with the relative proportions of the Width>Height>Length ratios of the centra are consistent with other Cretaceous elasmosaurids from North America and elsewhere globally (Table 1; Parris, 1974; Werner and Bardet, 1996; Everhart, 2005; O'Keefe and Hiller, 2006; O'Gorman, 2012; Otero et al., 2012). The incomplete neural spine on the posterior cervical vertebra is more than twice the length of the centrum height. This large neural spine would have supported a robust musculature and is similar to that seen in members belonging to the long-necked elasmosaurids. The two

Malvern teeth are slender, oval in basal cross section, elongate, distally curved and have narrow crowns. These characters resemble those commonly assigned to piscivorous elasmosaurids such as those described by Massare (1997) and Vandermark et al. (2006).

Taphonomy of the Malvern Plesiosaurian Remains—The Malvern plesiosaurian remains described in this report co-occur with chondrichthyan teeth, osteichthyan bones and teeth, molluscs, corals and rounded pebbles in a lag deposit draping a disconformity in the Maastrichtian, uppermost Arkadelphia Formation (Figure 7). All chondrichthyan and osteichthyan taxa in the Malvern lag are known to occur in the Upper Cretaceous and none are known to occur in the Paleocene (Becker et al., 2006). This indicates that this lag comprises either the uppermost Arkadelphia Formation or a locally preserved basal unit of the Midway Group with reworked Maastrichtian fossils.

The chondrichthyan and osteichthyan teeth associated with these plesiosaurian remains display sharp apical cusps, sharp cutting edges and lateral cusplets. Both plesiosaurian teeth display sharp apical cusps, dorsoventral enameled ridges and thick enamel. If either the chondrichthyan, osteichthyan or plesiosaurian teeth underwent any long-term tumbling or reworking, the delicate, angular tooth features would have been greatly diminished, resulting in winnowed, rounded and fragmentary specimens (e.g., Becker and Chamberlain, 2012). Additionally, preservation of the smooth centrum faces, neural spines, rib facets, transverse processes and zygapophyses, suggest that the remains underwent only limited reworking prior to final burial. It is also important to note that unlike some plesiosaurian remains (e.g., Everhart, 2005; O'Keefe and Hiller, 2006; Kubo et al., 2012), the Malvern specimens are not altered by warping, compression or extension as a result of diagenesis despite the complex series of folds present in the Cretaceous and Paleocene rocks near Malvern (Haley et al., 1993).

Animal size for the Malvern Plesiosaurian Assemblage—The largest vertebra in the type specimen of *Elasmosaurus platyurus* Cope, 1868 without deformation due to fossilization as reported by Everhart (2005) is 125 mm in width. Reconstructions of this type specimen indicate an animal up to 13 m in overall length (Dodson, 2012). Although it is not possible to determine the exact location of the larger Malvern vertebra within the mid-dorsal region, a centrum width of 123 mm conservatively suggests an animal with overall length of at least 10 m. A similar overall length estimate is achieved by comparing the centrum width of Malvern cervical vertebra (110 mm) to cervical vertebrae seen in other adult elasmosaurs from the Late Cretaceous of North America. For example, Sato (2003) indicated that the forty-third cervical vertebra in *Terminonatator ponteixensis* had a centrum width of 115 mm and belonged to an animal up to 9 m in overall length. It is also interesting to note that a vertebra of *Brimosaurus grandis* (nomen dubium) described by Leidy in 1854 from Arkansas is listed as having a 6 in (152 mm) breadth of articular surfaces and may have belonged to an even larger plesiosaur.

TABLE 1. Centrum measurements of the Malvern vertebrae reported in this paper.

SPECIMEN	L (mm)	H (mm)	W (mm)	L/W
Cervical	65	85	110	0.59
Large Dorsal	NA	103	123	NA
Smaller Dorsal	72	81	97	0.74
Caudal	22	63	84	0.26

Similar comparative analysis available in: Parris, 1974;Werner and Bardet, 1996; Everhart, 2005; O'Keefe and Hiller, 2006; O'Gorman, 2012; Otero et al., 2012.

Paleoecology of the Malvern Plesiosaurian Assemblage—The plesiosaurian remains documented here were recovered from a coquina lag deposit ranging from 1–5 cm thick. At this locality, the Arkadelphia Formation is dark colored, fossiliferous marl, while the overlying Midway Group beds exposed here consist of dark sandy marl interbedded with thin bands of limestone. The plesiosaurian remains are associated in the coquina lag with numerous fish bones, *Enchodus* sp. teeth, pycnodontiform teeth, teeth of *Serratolamna serrata* (Agassiz, 1843), branching scleractinian corals, and the ammonites, *Placenticeras* sp. and *Baculites* sp. The co-occurring chondrichthyan and osteichthyan teeth are from shallow marine, piscivores and shell-crushers with preferences for coral, shelly or rocky structures (Becker et al., 2010). Teeth and skeletal elements from *Enchodus petrosus* (Cope, 1874); *Enchodus gladiolus* (Cope, 1872) and *Enchodus ferox* Leidy, 1855 are extremely abundant at the Malvern site (Becker et al., 2010) and reinforce the possibility for piscivorous behavior among these plesiosaurians.

The lithology of the two units occurring at our site together with the invertebrate fossils, molluscs, ammonites and particularly corals, recovered in matrix with the plesiosaurian remains suggest the occurrence of a shallow lagoonal environment characterized by low biohermal mounds surrounded by anastomosing channels inscribed into a muddy or sandy bottom at our collecting site. The late Maastrichtian coastline as mapped by Kennedy et al. (1998) trends northeast-southwest probably a few tens of kilometers westward of our collecting site. Drainage off the adjacent land mass would have been southward, so that fluvial input to the area of the collection site may have been considerable. The occurrence of well-rounded pebbles and plant organics in the lag deposit supports the idea of nearby fluvial connections to this shallow marine environment. Fluvial input is also indicated by the presence in the Malvern lag assemblage of acipenserid and lepisosteid remains (Becker et al., 2010). The fossil and modern representatives of these fish are known to inhabit a broad range of salinities including fresh water.

Paleogeographic reconstructions of the Upper Cretaceous shoreline indicate that the eastern margin of the Western Interior Seaway was connected to the Gulf Coastal Plain near the base of the Ouachita Mountains and across southwestern Arkansas (Kennedy et al., 1998). This shoreline was also connected to the circum-equatorial Tethyan Seaway (Scotese et al., 1988; Chumakov et al., 1995) and provided a means by which the Western Interior Seaway could be accessed along its eastern margin. Maastrichtian climate data indicate that Arkansas and the majority of the United States were part of a northern mid-latitude warm, humid belt with subtropical water temperatures that extended from North and Central America through the Mediterranean region of western Europe and the Middle East (Chumakov et al., 1995; Zakharovet al., 2006). Such extensive environmental uniformity may account for the widespread occurrence of plesiosaurians in the Late Cretaceous of North America.

Taking into account the known occurrences of other Gulf Coastal Plain plesiosaurians, the Malvern plesiosaurian assemblage may be among the geologically youngest yet reported from the Gulf Coastal Plain. It is also possible based on the geologic age and Gulf Coastal Plain recovery location that that the Malvern assemblage represents a new and previously unreported species of plesiosaurians in North America. This assemblage extends the known geographic range of plesiosaurians in North America and indicates that these apex marine reptiles were living at, or near, the K–Pg mass extinction horizon in the region.

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