Elasmosaurid remains from the Pierre Shale (Upper Cretaceous) of western Kansas. Possible missing elements of the type specimen of *Elasmosaurus platyurus* Cope 1868?

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Abstract

When E.D. Cope described the type specimen of *Elasmosaurus platyurus* 1868 more completely in 1869, he noted that a number of dorsal vertebrae were missing, along with the gastralia, the limbs, and most of the skull. Although the military surgeon who discovered the remains, Dr. Theophilus H. Turner, made additional searches the missing material was never located. Interest in the specimen eventually faded as dinosaurs were discovered further west, and portions of the specimen, including the pectoral and pelvic girdles, were mysteriously lost. More recently, three collections of associated plesiosaur material, including dorsal vertebrae, ribs, gastralia, and large gastroliths were made from a second site near the type locality of *E. platyurus*. The additional material is curated in the Sternberg Museum of Natural History, Hays, KS, the University of Kansas Museum of Natural History, Lawrence, KS, and the Cincinnati Museum Center, Cincinnati, OH. Examination the more recently discovered remains in these three repositories, and comparisons with the those of the type specimen at the Academy of Natural Sciences of Philadelphia, a review of the letters and other historical documents related to the discovery of *E. platyurus*, and on–site evaluation of the stratigraphy of the both localities suggest that the more recently collected remains were originally part of the type specimen and were separated prior to burial when the floating carcass began to fall apart.

Contents

Abbreviations

ANSP	Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania
CMC VP	Cincinnati Museum Center, Vertebrate Paleontology, Cincinnati, Ohio
FHSM	Sternberg Museum of Natural History, Fort Hays State University, Hays, Kansas
KUVP	University of Kansas Vertebrate Paleontology Collection, Lawrence, Kansas
NJSM	New Jersey State Museum, Trenton, New Jersey
YPM	Yale Peabody Museum, Yale University, New Haven, Connecticut

1. Introduction

In the spring of 1867, Dr. Theophilus H. Turner (1841–1869) discovered the "skeleton of an extinct monster" eroding from a ravine "some fourteen miles (22 km) north" of Fort Wallace (Almy, 1987: 184). In late June, he gave three of the vertebrae that he had collected to John LeConte, a member of a party surveying the route for the Kansas (Union) Pacific Railroad (LeConte, 1868). Following the completion of the survey, LeConte delivered two(?) of the vertebrae to Edward D. Cope at the Academy of Natural Sciences of Philadelphia (ANSP) in November of 1867. According to Almy (1987: 184), Cope recognised the vertebrae as probably belonging to a large plesiosaur and wrote back to Turner in a letter dated December 3, 1867, asking him to procure the remainder of the specimen and send it to Philadelphia at the expense of the ANSP. With the help of others at Fort Wallace, Turner returned to the site of the discovery in late December, 1867, and secured some 900 pounds of bones and concretionary matrix. Turner noted in a letter dated February 2, 1868 (*ibidem*: 186) to his brother that he had collected "something over thirty–five feet of its vertebrae" and that "there is a large amount of bony matter contained in a very hard stone matrix, some of which retains its connection with the backbone."

Near the end of February, 1868, at the urging of Cope, Turner arranged to transport the specimen by military wagon train some 90 miles (145 km) east to where the approaching railroad was being built. From there, the crates containing the remains were shipped 1500 miles by rail to Philadelphia (Everhart, 2005b). It appears that Cope received the specimen by mid–March, examined the remains and made a hurried judgment as to the appearance of the animal that they represented. Then, at the March 24, 1868 meeting of the ANSP, he reported the discovery of "an animal related to the *Plesiosaurus*" which he called *Elasmosaurus platyurus* (Cope, 1868a: 92–93). A brief note from Cope (1868b), including the new name, was also published about the same time in LeConte's (1868) railroad survey report. In a letter to Turner dated March 25, 1868 (Almy, 1987: 189), Cope asked Turner "to look near where the belly of the animal may have been and see whether there are any slender bones [gastralia], such as may occur in the Plesiosauri." As reproduced by Almy (*ibidem*: 189) Cope's note also included a sketch of what he believed the gastralia would look like. Although Turner later returned to the site and recovered additional material that he sent to Cope in September, 1868 (*ibidem*: 193–194), the shipment apparently did not include gastralia. Gastralia are conspicuously absent from Cope's (1869: plate II, Fig. 1) original drawing of *E. platyurus* and he noted (*ibidem*: 44) that "the abdominal ribs [gastralia] seen in *Plesiosaurus* are probably wanting as none were found by the discoverer after a careful search." Cope's description of the remains in the first two versions of his monograph (1869: 47, 1870a: 48) indicated that he believed about 10 dorsal vertebrae were missing in view of the fact that "Dr. Turner found that a space of "three or four" feet intervened between the two portions of the skeleton, which was otherwise continuous."

The specimen (ANSP 10081) currently consists of a nearly complete vertebral column of a large elasmosaur, and various fragments of other bones. The pectoral and pelvic girdles, figured and described by Cope (1869, 1870a: fig. 7–8) were later lost (Williston, 1906: 225; Carpenter, 1999: 152). Several tooth–bearing fragments of the skull and lower jaws are present, along with the occipital condyle that is still attached to the atlas–axis vertebrae. There are only a few rib fragments remaining with the specimen and no gastralia.

In December, 1954, George F. Sternberg received a donation of seven large (9–10 cm diameter) elasmosaurid vertebrae and 'numerous' rib fragments (FHSM VP–398) from R.B. Hooker, a landowner in Logan County, Kansas. One vertebra had been cut lengthwise and the interior surfaces polished by Ralph Amstutz. It is unknown if Sternberg actually visited the site, 'north of McAllaster' or conducted further investigations. One or more of these vertebrae have been on display since that time in the Sternberg Museum of Natural History, Hays, Kansas. A recent examination of the records associated with FHSM VP–398 indicated that the locality given by Sternberg was in the vicinity of another elasmosaurid specimen discovered in 1991 by Pete Bussen of Wallace, Kansas in a small exposure about 1.5 km to the north and a little west of the now abandoned town site of McAllaster, KS. Two dorsal vertebrae, several rib fragments and a number of unusually large gastroliths (KUVP 129744) were recovered later that year by Larry Martin of the Museum of Natural History at the University of Kansas (Everhart, 2000). Three additional gastroliths were collected by the author from the site in 1994. Some of these gastroliths are the largest known, and their total weight (13.1 kg) is the heaviest ever documented from any animal (*ibidem*).

The dig was re–opened by Glenn Storrs and a field crew from the Cincinnati Museum Center in 1998, and portions of eight ribs, ten gastralia and a few probable gastroliths were recovered (CMC VP6865). Pete Bussen (pers. comm., 2002) indicated that a local resident had also discovered a single plesiosaur vertebra at the same site in the 1970s, but that it had been subsequently lost. There has been considerable erosion and excavation of the exposed Pierre Shale at the type locality since 1868, including construction of the railroad and U.S. Highway 40, which was originally located between McAllaster Butte and the right–of–way of the railroad. An exploration of this locality by the author in 1999 indicated that that no visible evidence remains of the original site where *Elasmosaurus platyurus* was discovered.

2. Material

ANSP 10081: Collected by Dr. Theophilus Turner, the specimen currently consists of a reasonably complete, articulated vertebral column (104 vertebrae, including one unnumbered and previously unreported fragment of a cervical vertebra, but lacking many of the dorsal vertebrae), the anterior portion of the upper and lower jaws (muzzle) that was preserved in articulation (figure 2) and illustrated by Cope (1869: Pl. 2, figs. 8, 8a, & 8b), and four other tooth–bearing fragments of the skull. Turner (Almy, 1987: 186) noted in a letter to his brother that he had "secured part of one of its jaws containing teeth." Aside from the large jaw fragment illustrated by Cope (1869, 1870a: Pl. 2, Fig. 9), however, these tooth–bearing fragments are not mentioned by Cope or later workers. The occipital condyle is also present (figure 1), and is still fused to the atlas–axis vertebra (Leidy, 1870: 9).

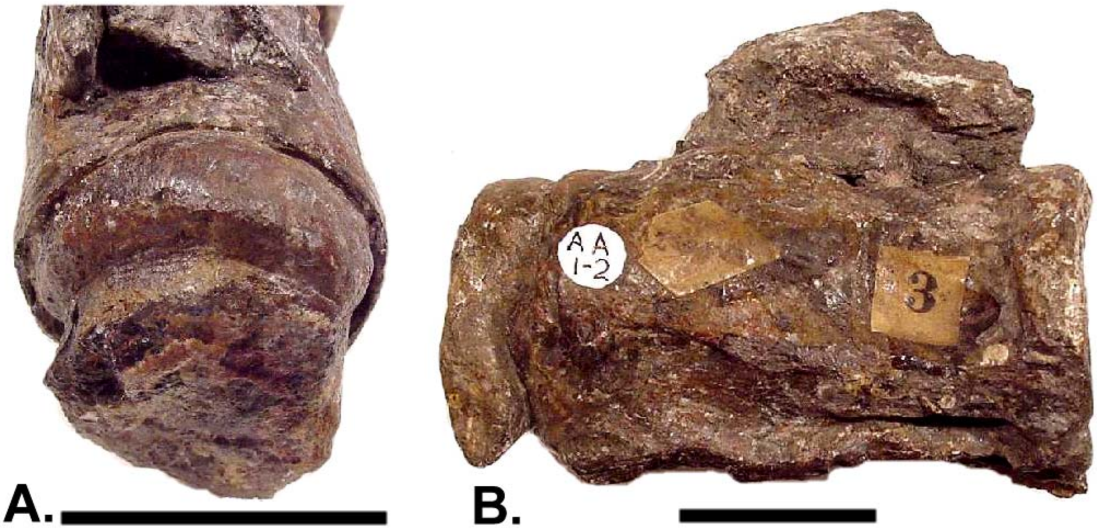

Figure 1. Anterior (A) and left lateral (B) view of the fused atlas and axis vertebrae of Elasmosaurus platyurus *(ANSP 10081). The fragment of the occipital condyle is still attached to the atlas. Note the three differing numbering systems used by various workers, including E.D. Cope. Scale bar = 2 cm. Photograph by the author.*

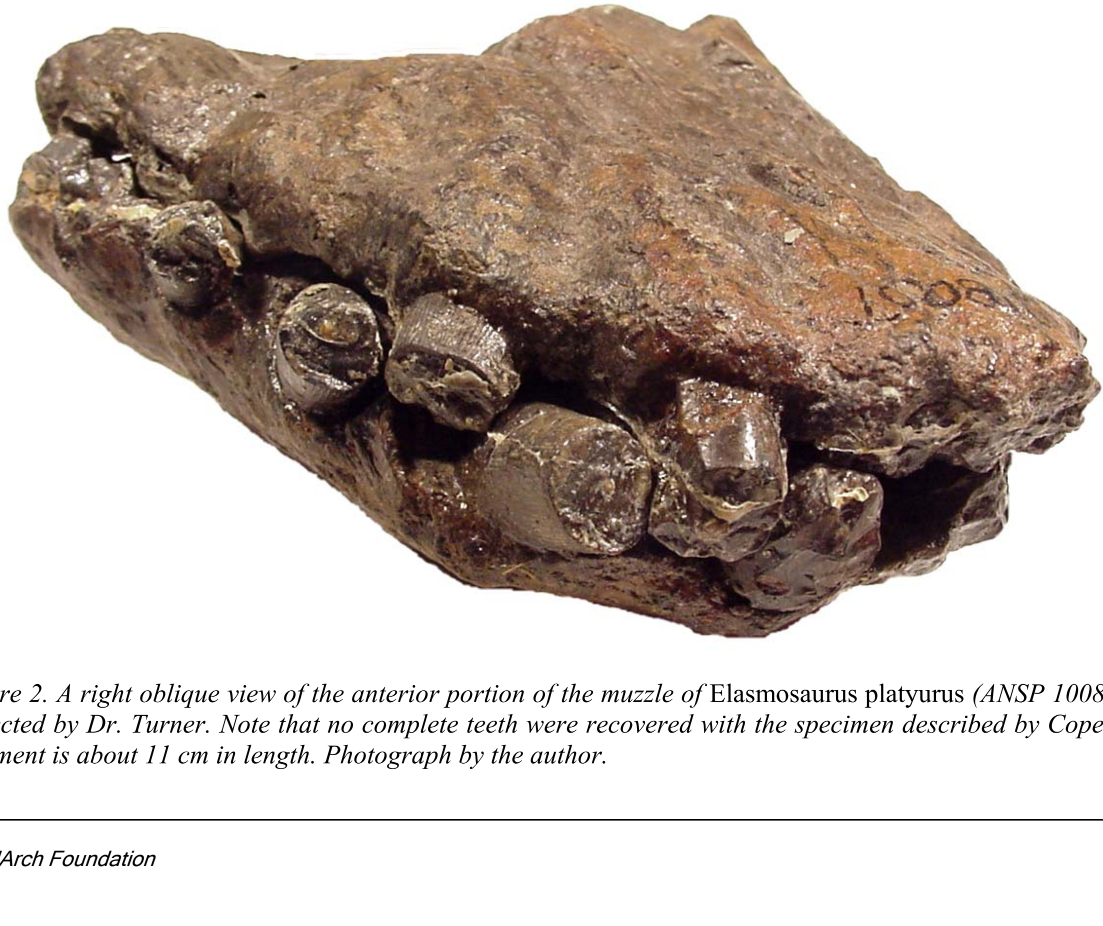

Figure 2. A right oblique view of the anterior portion of the muzzle of Elasmosaurus platyurus *(ANSP 10081) as collected by Dr. Turner. Note that no complete teeth were recovered with the specimen described by Cope. The fragment is about 11 cm in length. Photograph by the author.*

Cope (1875: 84) noted that the "heads of fourteen ribs are preserved, and a great number of shafts. The heads are simple, with elongate–oval articular face." However, there are only a few fragments of the ribs currently present in the specimen. The articulating surface of three remaining rib heads measured 5.5–6 cm across. Many of the dorsal vertebrae and the limb girdles were enclosed in hard, dark gray limestone concretions when collected. Some of the concretionary material associated with the specimen contains isolated fish teeth, scales and vertebrae that were originally described by Cope (1868a, 1868b) and interpreted by him as stomach contents. A single, small stone (21x10x8 mm, earlier noted as a piece of bone by Spamer *et al.,* 1995: 148) was found wedged in the neural canal of one of the distal caudal vertebra. Based on its smooth, polished appearance, and the lack of similar material occurring naturally in the Pierre Shale of western Kansas (Everhart, 2000), it is here interpreted to be a gastrolith.

FHSM VP–398: Seven, large (9–12 cm diameter), mid–dorsal vertebrae and fragments of two or more single headed ribs collected in 1954. The articular faces of the rib heads are oval and measure 5–6 cm across.

KUVP 129744: Two large (9–11 cm) posterior(?) dorsal vertebrae, fragments of single–headed ribs, two partial gastralia and 38 gastroliths collected in 1991 by Larry Martin (Everhart, 2000). The rib heads measure 5.5 cm. Martin (pers. comm., 2005), recalled that both vertebrae were discovered standing on end.

CMC VP6865: Five complete, single–headed ribs, three partial ribs, 10 complete or nearly complete gastralia, and seven additional gastroliths collected in 1998. The rib heads measure 5.0–5.5 cm across. The five complete ribs measure 66, 66, 64, 52 and 46 cm in length. The two largest gastralia are 49 cm in length, and the smallest is about 30 cm long.

Viewed as a single specimen, the second set of remains was scattered over a 4 m by 4 m area prior to burial. While several of the VP–398 vertebrae may have been preserved together, none of the ribs or gastralia were articulated. Most of the gastroliths, however, were located together in a single pile (Bussen, pers. comm., 1999), suggesting that they were still contained within the plesiosaur's digestive tract when deposited on the sea bottom. The jumbled condition of the remains indicates that they were most likely dropped from a floating carcass, and not scattered as the result of scavenging. There were no bite marks visible on the bones and no sharks teeth recovered that would support scavenging. While it is possible that the bones and gastroliths could have been the last remains of a more complete individual that had mostly weathered out many years ago, the observed taphonomy does not support that scenario.

3. Locality and stratigraphic occurrence

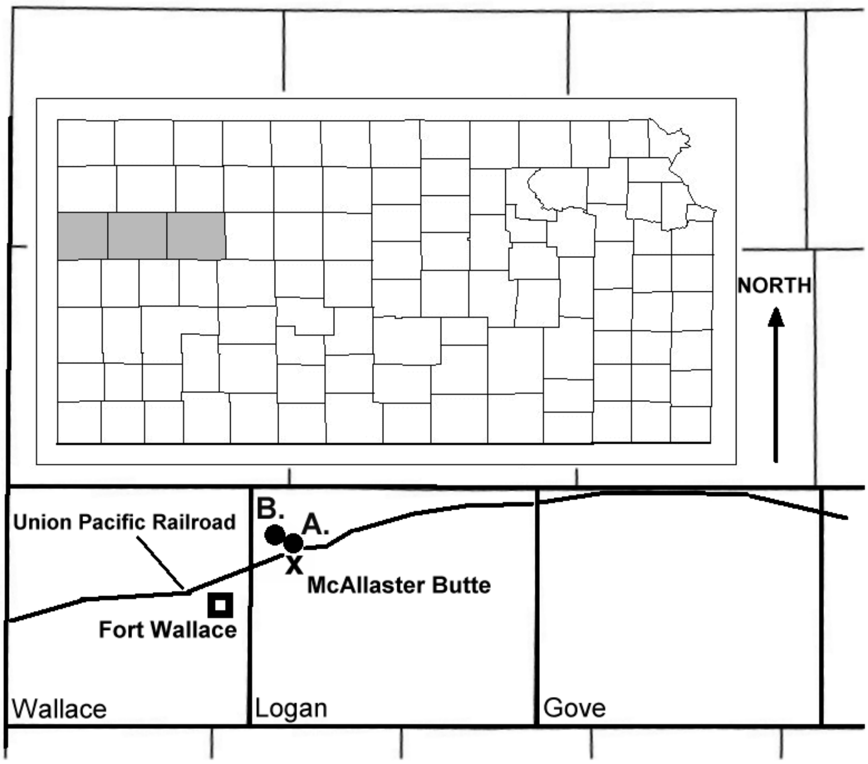

Figure 3. A map of Kansas (inset), and Wallace, Logan and Gove counties showing the approximate locations of: A. The type specimen of Elasmosaurus platyurus*; B. Three additional sets of elasmosaurid remains recovered since 1950; and X. McAllaster Butte. Note that the type locality is in the opposite direction from the one provided by LeConte (1868). Drawing by the author.*

From his review of the correspondence between Turner and Cope in Almy (1987), and his personal knowledge of the history and geography of Logan County, Pete Bussen (pers. comm., 1998) concluded that the type specimen of *Elasmosaurus platyurus* had been discovered at McAllaster Butte, a large exposure of Pierre Shale to the northeast of the abandoned McAllaster town site (figure 3). This is contrary to the misleading locality information provided by LeConte (1868: 11) but in keeping with the site as described in Turner's letters. On December 20, 1867, Turner (Almy, 1987: 184) wrote to his brother, Daniel, about "a party of us that started on the prairie ostensibly for the purpose of hunting but in reality for the purpose of procuring the skeleton of an extinct monster which is embedded some fourteen miles north of here [Fort Wallace]. It was found to rest in a slate hill similar in appearance to those which are found on the road between home and Newton [New Jersey]." In Turner's letter of May 24, 1868, to his brother (Almy, 1987: 191), he says that "[…] I think I shall do no more for the fossil till the working party of the Rail Road reaches the spot as the present survey runs directly to the hill and it is very probable opportunity will then offer a full exploration." These comments almost certainly describe the large exposure of the Sharon Springs Member of the Pierre Shale on the north side of what is now called McAllaster Butte in Logan County, the only notable hill along the right–of–way of the Union Pacific railroad in western Kansas.

Based on the historical documentation, the type specimen of *Elasmosaurus platyurus* (ANSP 10081) was collected in 1867–1868 from the north slope of what is now known as McAllaster Butte, northeast of the townsite of McAllaster, in western Logan County, Kansas. The town of McAllaster was not established until about 1893 and has since been abandoned. Although the exact stratigraphic occurrence of the type specimen is unknown, it is almost certainly near the base of a large exposure of the Sharon Springs Member on the north slope of McAllaster Butte. Turner (Almy, 1987: 185) noted that it "was located in an almost perpendicular bank of [a] slate hill which made up one side of a ravine. It was located near the bottom and required no small amount of labor in its excavation."

The other three specimens (FHSM VP–398; KUVP 129744 and CMC VP6865) were recovered from a smaller shale exposure, approximately 5 m below a layer of large, septarian concretions, and 1 m below a 2.5 cm yellow bentonite layer, about 1.5 km to the north–northwest of the McAllaster townsite. The Sharon Springs Member of the Pierre Shale (Middle Campanian) crops out on hillsides and along the drainage of the North Fork of the Smoky Hill River in the immediate vicinity, and the type locality of the member is located about 3 km to the northeast of McAllaster Butte (Elias, 1931).

The Sharon Springs Member was deposited in a shallow inland sea that covered much of the central United States and Canada during middle Campanian time. According to Parrish & Gaultier (1993), this lithostratigraphic unit is composed of soft, fissile, bituminous shale, contains numerous bentonites and septarian concretions, and is in the biostratigraphic zone of *Baculites asperformis* (Gill *et al*., 1972). More recently, however, Turner *et al.* (2001) reported that the invertebrate fossil assemblage in a concretion from the same stratigraphic level 3 km to the north of the type locality was dominated by *Baculites mclearni*.

All four of the plesiosaur specimens reported here occurred below the prominent layer of septarian concretions near the top of the Sharon Springs Member and are Middle Campanian in age. If the second set of remains were, in fact, originally part of the type specimen, then the current direction at the time of deposition would have been from the northwest to the southeast. *Baculites* examined by Carpenter (1996) occurring in a concretion from about the same stratigraphic level, 3 km north of the type locality, were aligned predominantly along a northwest–southeast axis, indicating a possible direction of the current in this portion of the Western Interior Sea.

4. Methodology

A considerable amount of historical literature is available regarding the type specimen *Elasmosaurus platyurus*. However, after Leidy (1870) noted that the original description of the specimen by Cope (1869) was reversed, Cope altered the figures and re–wrote the text of his original pre–print (Storrs, 1984). Unfortunately, many of the details in the description were not corrected by Cope (1870a, 1870b, 1871) in subsequent revisions, and a later publication (1875), and cast a shadow on their usefulness. Williston (1906) provided the next description of the type specimen but did not provide additional details or measurements of the vertebrae. Welles (1952) re–described the specimen, revised the order and the numbering of the vertebrae, and provided the first modern measurements of the individual vertebrae. However, he only provided length, width and height data for one of the vertebra that he considered to be from the dorsal series. More recently, Sachs (pers. comm., 2002) examined the remains and also revised the order of the vertebrae.

When I examined the type specimen in November, 2002, I noted that there were as many as four numbers on some vertebrae, including Cope's original markings. Following the most recent identification and numbering system used by Sachs, I measured the vertebrae, directly compared them with vertebrae from FHSM VP–398

Figure 4. A: Left lateral view of the best preserved, mid-dorsal vertebra (ANSP 10081-D3) from the type specimen of Elasmosaurus platyurus*, and; B: Left lateral view of a mid-dorsal vertebra from the second specimen (FHSM VP-398-D7). ANSP 10081-D3 was originally figured by Cope (1869: Plate 14, fig. 3, 3a). Scale bar = 10 cm. Photograph by the author.*

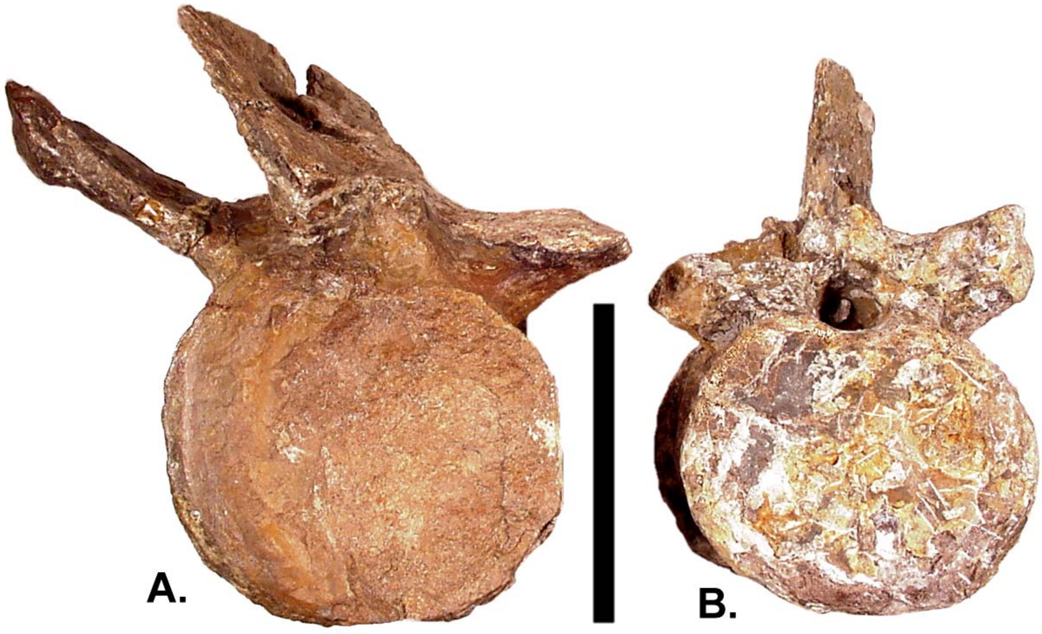

Figure 5. A: Posterior view of a dorsal vertebra from the type specimen (ANSP 10081-D4) and; B: Posterior view of a dorsal vertebra from the second specimen (FHSM VP-398-D4). The dorsal vertebrae of both specimens are similar in shape, size and preservation. Scale bar = 10 cm. Photograph by the author.

(figures 4 and 5), and photographed the specimen. I also examined bone fragments and other materials stored in a separate container, and the remaining pieces of the limestone concretion that enclosed some of the bones.

The gastroliths and vertebrae collected in association with KUVP 120744 were examined and described by Everhart (2000) and included information provided by Pete Bussen and Larry Martin. I made on–site measurements of the CMC VP6865 specimen as member of the 1998 field crew that recovered the last portion of remains (figure 6). In 2002, I noted that seven plesiosaur vertebrae (FHSM VP–398) in the Sternberg Museum collection had come from the same general locality as KUVP 129744 and CMC VP6865, and began comparing those specimens. Subsequent visits to the University of Kansas, the Academy of Natural Sciences of Philadelphia and the Cincinnati Museum Center provided me with the opportunity to measure, directly compare and photograph all four of the specimens described in this paper. Although the measurements of the dorsal vertebrae of the type specimen shown in table 1 are the most complete to date, the condition of those vertebrae, and that of the two other specimens (different orientations during preservation, in or out of concretions, etc.) convinced me that additional statistical analysis would not produce useful results. As an example, up to 1.5 cm of the 13 cm width of vertebra 10081–D5 appears to be due to dorsoventral crushing.

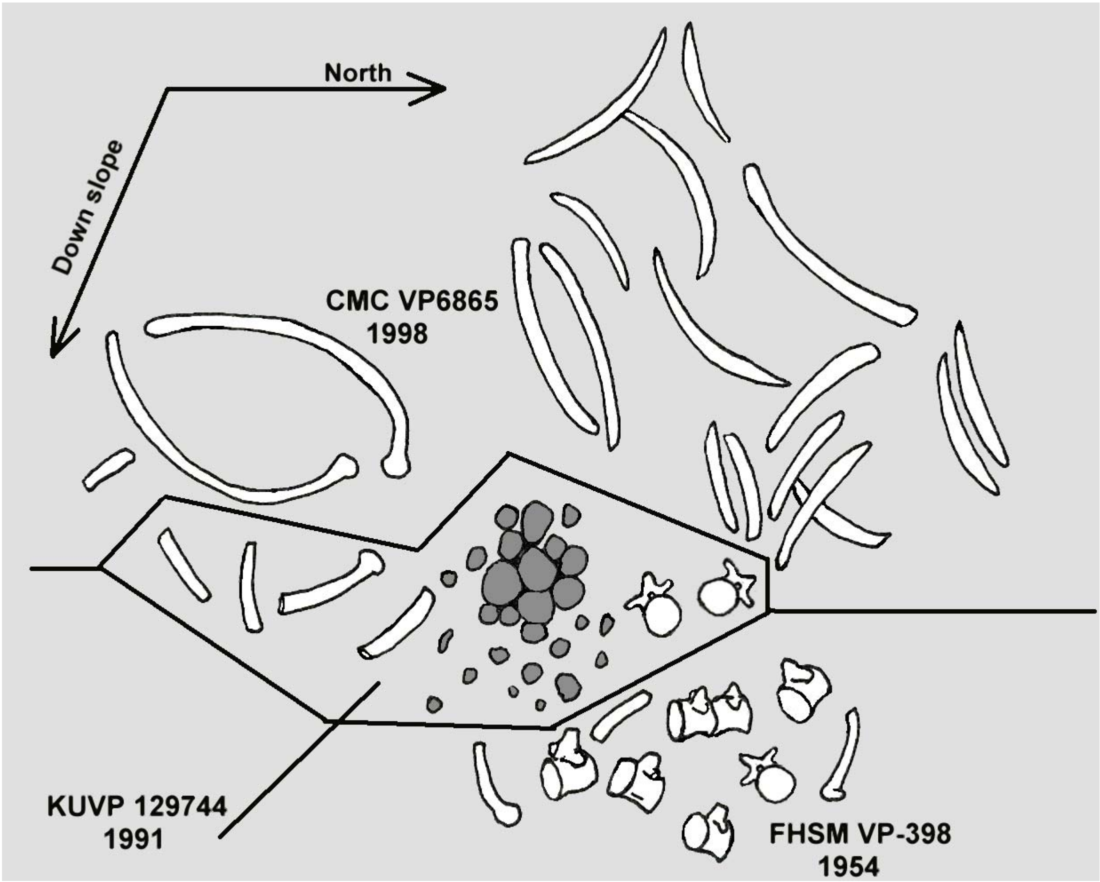

Figure 6. June 5, 1998 field sketch of the CMC VP6865 specimen by the author with the addition of the approximate locations of the previously removed KUVP 129744 material, and conjectural location of the seven FHSM VP-398 vertebrae. Dark gray objects near the center are gastroliths. Drawing by the author.

5. Discussion

In his letter of March 25, 1868 to Dr. Turner, after his initial examination of the remains, Cope (Almy, 1987: 189) wrote, "Indeed, I think that there must be a considerable number of the vertebrae of the dorsal and cervical series remaining in the cliff." He went on to question the orientation of the specimen and asked about the "slender bones" [gastralia] in the stomach region. From his knowledge of English plesiosaurs (Davidson, 2002), Cope clearly recognised that significant portions of the original *Elasmosaurus platyurus* specimen were missing from the first shipment of remains sent to him by Turner. Later, Cope (1869: 45–46) incorrectly concluded that the limbs must have been small, or in the case of the hind limbs, possibly non–existent, since he firmly believed that the animal moved by means of its long, serpent–like tail. His infamous, head–on–the–wrong–end reconstruction (1869: pl. II, fig. 1) does not include the rear paddles. It is likely, however, that the missing portions, including the limbs, had simply dropped off of the bloated, floating carcass or had been removed by scavengers before it finally came to rest on the sea bottom (Everhart, 2005a).

Carpenter (1996: 36) noted that in the Red Bird Member of the Pierre Shale, "the isolated bones and skulls of vertebrates were most likely derived from floating carcasses." Under the right conditions, the carcass of a relatively intact elasmosaur would likely have floated due to the decomposition gases that accumulated in the abdominal cavity (Carpenter, 1996; Everhart, 2000: 72–73). It is uncertain, however, whether the weight of the pectoral girdles, limbs and gastralia, or that of the vertebral column and ribs would have determined the orientation (right side up or upside down) of the floating carcass. No limb material was included in the *Elasmosaurus platyurus* remains. The loss of these nearly solid, bony paddles could have affected the final orientation of the floating carcass. In either case, the crop or stomach containing the gastroliths would have been located just behind the pectoral girdle (Cicimurri & Everhart, 2001). If the carcass was floating upside down, the weight of the gastroliths, and possibly the loosened gastralia would have been resting on the dorsal vertebrae. If the carcass was right side up, the weight of the gastroliths and the gastralia would have been pulling down on the arch formed by the dorsal vertebrae (Taylor, 1981). This weight would have pressed down on the abdominal wall and would have been a likely point of failure when the integument ruptured and released the gases of decomposition. Loosened dorsal vertebrae, gastralia and gastroliths could have then fallen out the carcass while residual pockets of gas kept the lightened remains afloat long enough to drift further to the southeast with the current. The loss of a large segment of dorsal vertebrae, ribs and gastralia from the mid–section may have caused the carcass to fold almost double, causing the long neck and head to reorient downward to a near vertical position, roughly parallel to the caudal vertebrae. Although lightened enough to remain suspended in the water column temporarily, the carcass would have then begun its final descent to the bottom. The 5–6 m long neck and attached skull would have most likely been the lowest point on the remains during the descent and would have struck the bottom first. The impact may have been sufficient to fracture the occipital condyle and other relatively fragile bones at the back of the skull, and to detach most of the head from the rest of the remains.

Type Specimen				
Vertebra #	**RI**	**Width**	**Height**	**Length**
10081-D1	.72	12.5	9.0	8.7
10081-D2	.81	12.0	9.7	9.1
10081-D3	.88	12.0	10.5	9.1
10081-D4	.83	12.0	10.0	8.7
10081-D5*	.69	13.0	9.0	9.2
10081-D6	.84	11.9	10.0	8.6
AVG (n=6)	.80	12.2	9.7	8.9
RANGE		11.9-13.0	9.0-10.5	8.7-9.2

Second Specimen				
Vertebra #	**RI**	**Width**	**Height**	**Length**
VP-398-D1	.91	10.4	9.5	8.5
VP-398-D2	.78	11.5	9.0	8.5
VP-398-D3	.79	12.0	9.5	9.3
VP-398-D4	.82	11.0	9.0	8.5
VP-398-D5	.92	11.5	10.0	9.0
VP-398-D6	.91	11.0	10.0	9.0
VP-398-D7	.88	11.9	11.9	9.1
129744-D1	.89	10.7	10.7	8.5
129744-D2	.85	10.6	10.6	8.3
AVG (n=9)	.86	11.2	9.6	8.7
RANGE		10.4-12.0	9.0-10.5	8.3-9.3
Combined total length = 78.7 cm / 31 in				

*Table 1. Measurements (cm) and the Roundness Index (RI=H/W) of the dorsal vertebrae from the type specimen (ANSP 10081), and the second specimen (FHSM VP-398 and KUVP 129744). * = crushed.*

While this scenario is only conjecture, it does explain many of the observations conveyed by Turner in his letters, and the condition of the remains as reported by Cope. According to Cope's (1869: 46) original description, "Its vertebrae were found to be almost continuous, except for a vacancy of some four feet in the anterior dorsal region. They formed a curved line a considerable part of whose convexity was visible on the side of a bluff of clay shale rock with seams and crystals of gypsum." Regarding the skull, Cope (*ibidem*) wrote, "The end of the muzzle was broken from a part or the whole of the cranium (figure 2), which has not been rediscovered, though Dr. Turner made a careful search. It was found in front of the vertebrae here regarded as cervical, at some distance from them." Although Cope's erroneous conclusion about the identification of those vertebrae (they were caudal vertebrae, not cervical) led, in part, to his infamous head–on–the–wrong–end reconstruction (Cope, 1869; figure 7), he failed to modify this statement in any of the three subsequent, partially revised re–publications of the paper (Cope, 1870a, 1870b, 1871). Since that time, the controversy that followed regarding the initial restoration of *Elasmosaurus* has completely overshadowed the fact that Dr. Turner had discovered and successfully collected one of the largest vertebrate fossils known at the time, with no prior experience in palaeontology, under primitive conditions on the plains of western Kansas. As a comparison, the collection of a large, nearly complete *Styxosaurus snowii* (NJSM 15435) from the Sharon Springs Member of the Pierre Shale (Cicimurri & Everhart, 2001; Everhart, pers. obs.) required several hundred hours of field time. Turner certainly deserves more recognition for this feat than he has received to date.

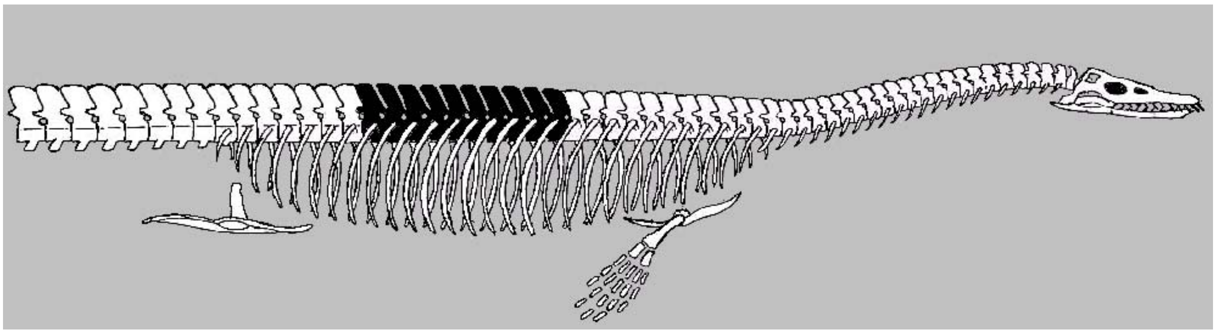

Figure 7. The anterior portion of the head-on-the-wrong-end version of Elasmosaurus platyurus *published by Cope (1869: Pl. II, Fig. 1). The ten dorsal vertebrae shown in black approximate those initially noted by Cope to be missing from the type specimen. Note that Cope did not include the hind paddles in this figure in part due to his erroneous belief that* Elasmosaurus *was propelled by its extremely long "tail". Drawing by the author.*

Cope (1869: pl. II) figured two of the four dorsal vertebrae that he identified without further explanation. The large vertebra (*ibidem*: fig. 3) shown by Cope is the most complete and least distorted of any in the vertebrae found in the type (figure 4A; 10081–D3, see table 1), or the second specimen. It is apparent that some minor surface repair and painting was done on this vertebra in Cope's time, but its presence and excellent condition accentuates the absence of ten or more other dorsal vertebrae from the type specimen. Note that Welles (1952) identified five dorsal vertebrae and more recently, Sachs (pers. comm., 2005) determined that six dorsal vertebrae were present. At issue here is deciding where the pectoral series ends and the dorsal series begins. While the point is arguable, the more recent examination by Sachs is accepted here.

In his description of *Elasmosaurus*, Cope (1869: 48) mentioned the "coarse cellular texture of the spongy bone" that he had observed inside the dorsal vertebrae where the edge of a centrum was damaged. The same spongy bone is visible in both the ANSP 10081 vertebrae and those of FHSM VP–398. In addition, VP–398–D5 was sectioned and polished (figure 8) by a friend of the collector and shows that that spongy bone texture completely fills the interior of the centrum. There is a large, medullary cavity near the centre that was apparently connected to the paired nutritive foramina that exit on the ventral side of the vertebrae.

A comparison of the seven dorsal vertebrae of FHSM VP–398 with the two dorsal vertebrae of KUVP 129744 shows that the centra are almost identical shape and preservation (table 1), with the centra of the two KU specimens being slightly smaller. The lower elevation of the transverse processes/rib facets on the KU specimens suggests that they are more posterior in the series than the FHSM material. Even though they were discovered almost 40 years apart, they apparently originated from the same locality and most probably are from the same animal. Since the KUVP 129744 and CMC VP6865 remains were known to have come from the same site, there is no doubt that they represent the same individual.

The composite of nine dorsal vertebrae, ribs and gastralia (hereafter referred to as the second specimen) includes many of the same elements that Cope (1869) noted to be missing from the type specimen of *Elasmosaurus platyurus*. Although Cope did not mention gastroliths, they are now known to be routinely associated with elasmosaur remains (Williston, 1893, 1904; Everhart, 2000; Whittle & Everhart, 2000; Cicimurri & Everhart, 2001). With the possible exception of the small stone noted above, gastroliths are noticeably absent from the type specimen. The unusually large size of the gastroliths located with the second specimen is consistent with an elasmosaur of the extreme length (45 ft; 13.7 m) suggested by Cope (1870a: 49). It should be noted here that Cope's estimate was somewhat exaggerated, and that later authors, notably Williston (1906: 226) and Welles, (1952: 54) reduced the estimated length. Based on his examination of the original material, however, Welles (1906) concluded that as many as 13 dorsal vertebrae were missing from the type specimen. Measurement of all the vertebrae of the type specimen by the author in 2001 indicated that about 9.1 m (30 ft) of the vertebral column were present. This length, of course, does not account for the length of the skull, missing cervical, dorsal and caudal vertebrae noted by Cope (1869) and others, and any allowances for intervertebral cartilages between the vertebrae.

Figure 8. Right and left halves of a dorsal vertebra of the second specimen (FHSM VP-398-D5) as sectioned and polished soon after their discovery. Note the spongy appearance. The lighter colored material is calcite infilling of void spaces within the bony matrix. The large open space near the center (medullary cavity) is connected to the two nutritive foramina that open on the ventral surface of the vertebrae. Scale bar = 10 cm. Photograph by the author.

Welles (1952) provided width, height and width measurements of the vertebral centra of *Elasmosaurus platyurus* (ANSP 10081) and other elasmosaurs. While few of the dorsal vertebrae of the type specimen were included, his data for other elasmosaurs demonstrates that the length of individual dorsal vertebrae varies by 10% or more in all of the specimens that were measured. Recent measurements of the vertebrae of the type and second specimen (table 1) provide an indication of both the similarity in size between the two sets of remains, and the degree of variation in the dimensions of individual vertebra in the same animal. Since most of the remaining dorsal vertebrae from the type specimen were apparently discovered within a concretion while those in the second specimen were not, some dimensional differences related to the mode of preservation would also be expected. The average length of the vertebrae (n=9) in the second specimen was about 2% (2 mm) shorter than the average length of the vertebrae (n=6) in the type specimen, while the average height is only 1% (1 mm) less in the second specimen.

The greatest difference in the measurements occurs between the average widths, with those of the second specimen being 8% (10 mm) narrower than those of the type. However, according to Massare & Sperber (2001), elasmosaur vertebrae are normally widest over the pectoral girdle where they would be associated with supporting the large muscles that powered the front limbs. If the widest dorsal vertebrae were also the most anterior ones in the type specimen, as suggested by Welles (1952), it is logical to assume that the ones missing from the centre of the vertebral column would be narrower.

The length of the centra of the six dorsal vertebrae in the type specimen differed by only 7% (6 mm) while the height differed as much as 17% (15 mm), emphasizing the variation in the dimensions of these vertebrae in life, their different positions in the vertebral column, the changes caused by deformation during preservation, and the small sample size. The range of differences measured in the second specimen was similar: length – 11% (10 mm); height – 16% (15 mm); and width – 13% (15 mm).

The average length of all the dorsal vertebrae in the type and second specimens is 88 mm. If Welles (1952) is correct and 13 dorsal vertebrae are missing from the type specimen, then the missing length of those vertebrae would have been about 1144 mm (45 in), not allowing for intervertebral cartilages. If a space of 5 mm (Sato, 2003: 91) is included for 13 intervertebral cartilages, the total length is increased by 65 mm (2.6 inches) to

1209 mm (47.6 in), slightly less than Cope's (1869: 47; 1870a: 48) original estimate of 4 feet. Williston (1906: 226) allowed 6 mm for intervertebral cartilages and Welles (1952: 54) suggested a distance of about 8 mm between the vertebrae respectively for their estimates of the total length of the type specimen.

Measurements of plesiosaur vertebral columns by Massare & Sperber (2002) indicate that the widest dorsal vertebrae are usually those located in the anterior part of the series, closest to the pectoral girdle and front paddles. While Welles (1952) considered the best–preserved vertebra of the type specimen (10081–D3) to be one of the anterior dorsals on the basis of it being larger than the rest that he was able to measure, Sachs (pers. com., 2005) suggested that it is one of the mid–dorsals due to the elevated location and greater length of the transverse processes. In view of the generally accepted idea that the transverse processes are located at their highest point in the mid–dorsal region of plesiosaurs, Sach's placement of this vertebra appears to be more correct, especially when the location of the transverse processes on 10081–D3 are compared with those of 10081–D1. One of the vertebrae from second specimen (VP–398–D7) is nearly identical to 10081–D3 in size and the upper location of the transverse processes, and is here also considered to be a mid–dorsal. Damage to the dorsal processes of most of the vertebrae in both the type specimen and the second specimen precludes a reconstruction of the vertebral column based on the location of the transverse processes with any degree of confidence.

The additional dorsal vertebrae (10081–D1) suggested by Sachs (pers. comm., 2005) is the fourth in the series of four pectoral vertebrae that were preserved together and listed by Welles (1952: Table 1) as numbers 73–76. It is the first vertebra in the series where the transverse process originates above the centrum, or about the level of the neural canal. It is also the widest of all the vertebrae, with the exception of 10081–D5 that appears to have been crushed. Welles (1952: 54) also noted that the pectoral and anterior dorsal vertebrae are the widest in the vertebral column of *Elasmosaurus platyurus*, and that the width is greater than the height is greater than the length through the dorsals, sacrals and anterior caudals. With the exception of 10081–D5, this is the case with all of the vertebrae in the type and second specimens.

Viewed in terms of a 'Roundness Index' (RI=Height/Width, where 1=a circle), the average 'RI' of the six dorsal vertebrae in the type specimen is 0.795 (table 1). If the crushed 10081–D5 vertebra (0.69) and the much rounder mid–dorsal 10081–D3 vertebra (0.88) are removed, the average anterior dorsal RI remains about the same (0.80). The average RI for the second specimen (mid–dorsal and posterior dorsal vertebrae) is 0.86, with three vertebrae scoring above 0.90. The vertebrae become rounder through the middle of the column and then begin to flatten out again as they approach the sacrum. This is indicted by the RI of the smallest (and probably most posterior) vertebra (129744–D2) in the second specimen decreasing to 0.83. From the width and height measurements provided by Welles (1952: Table 1) of four of the sacral vertebrae of the type specimen, the RI then decreases rapidly (0.78, 0.75, 0.71, 0.67) as the vertebrae flatten over the posterior set of paddles.

Along with the upper limb bones (propodials), the dorsal vertebrae are among the largest and most durable bones in an elasmosaur skeleton and are some of the most likely bones to be preserved due, in part, to their central location within the body. They are more difficult for scavengers to remove than heads, tails and limbs (Everhart, 2005a). The fact that most of the dorsal vertebrae, ribs and gastralia are missing from the type specimen suggests that something major happened to the carcass before the remains reached the sea bottom. While the remains of a *Styxosaurus snowii* specimen (NJSM 15435) discovered by Pete Bussen about 10 km to the southwest of McAllaster Butte were complete and generally articulated (Cicimurri & Everhart, 2001), another *Styxosaurus* specimen (CMC VP7023) recovered from the Sharon Springs Member about 3 km north of McAllaster Butte in 1999 was more scattered (Everhart, pers. obs.). In both specimens, however, the dorsal vertebrae were present and enclosed in hard limestone concretions. In contrast, Welles (1952: 83) reported that the type specimen of "*Elasmosaurus ischiadicus*" (YPM 1130, now *Styxosaurus snowii per* Carpenter, 1999) from the Smoky Hill Chalk (Lower Campanian) is missing most of the dorsal vertebrae.

It is important to note here that the review of the material included in the type specimen of *Elasmosaurus platyurus* Cope, 1868 in the collection of the Academy of Natural Sciences of Philadelphia, and that of the second specimen in the Sternberg, University of Kansas and Cincinnati museum collections did not produce any evidence, especially duplications of skeletal elements other than ribs, that would indicate that these were not the remains of the same animal. Larry Martin (pers. comm., 2005) disagrees with this premise and concluded that the catastrophic loss of this much of the skeleton from the centre of an elasmosaur would have essentially torn the animal in two and caused both halves to sink rapidly. However, Cope's (1869) observation that certain parts were missing from the remains sent to him by Dr. Turner, especially the four–foot gap near the centre of the otherwise nearly complete vertebral column, suggests that the two portions did remain attached long enough for the carcass to reach its final resting place. Although gastralia were only included in the second specimen, the ribs, and especially the heads of the ribs were nearly identical in size in the type and second specimens. The lithology of the gastroliths associated with the second specimen is similar to the single stone found wedged into the neural canal of a caudal vertebra in the type specimen (Everhart, pers. obs.). The similarity in size of the dorsal vertebrae, the relatively short distance between the two localities and the apparent identical stratigraphic occurrence support the premise that the type and the second specimen are the remains of the same elasmosaur.

6. Conclusion

While it may be impossible to prove beyond a reasonable doubt that the second specimen is, in fact, a portion of the remains originally noted to be missing from the type specimen of *Elasmosaurus platyurus* Cope, 1868, the evidence strongly suggests that the two sets of remains are from the same animal. The two sites are located within 2 km of each other and are at the same stratigraphic level. The two sets of remains came from large elasmosaurs of approximately equal size. The type specimen was mostly articulated when discovered while the second specimen was a jumbled pile of bones and associated gastroliths. There is no observable duplication of remains. With the notable exception of the more readily detachable limbs, most of the bones noted by Cope to be missing from the type specimen are present in the second specimen. Almost all of the dorsal vertebrae (10) noted as missing from the type by Cope (1869) were recovered in the second specimen (note that 13 vertebrae were estimated to be missing by Welles, 1952). Since the discovery of the type specimen, gastroliths have been shown to be routinely associated with elasmosaur remains (Williston, 1893; Everhart, 2000). The recovery of large gastroliths in the disarticulated second specimen, and their notable absence in the articulated remains of the type specimen begs further explanation, especially with the recent discovery of a polished, gastrolith–like pebble in direct association with a caudal vertebra in ANSP 10081.

Elasmosaur remains are uncommon fossils in the Western Interior Sea. It would appear to be more difficult to explain the circumstances that resulted in two sets of mutually exclusive arrays of bones from two different elasmosaurs which were buried at approximately the same time and place in mid–ocean than to conclude that they were from the same animal. In this case, the evidence strongly suggests that many of the pieces missing from Dr. Turner's original discovery of *Elasmosaurus platyurus* have been located.

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