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The largest mosasaur (Squamata: Mosasauridae) from the Missouri River area (Late Cretaceous; Pierre Shale Group) of South Dakota and its relationship to Lewis and Clark

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ABSTRACT

The Cretaceous Pierre Shale Group along the Missouri River has produced numerous mosasaur specimens since the western fossil discoveries of Lewis and Clark in 1804 that included a 45-foot "fish." Many of these marine reptile specimens represent the largest of mosasaurs, the tylosaurines. In 1990 the largest mosasaur heretofore recorded along the Missouri River was discovered near Nicholas Creek, Lyman County, central South Dakota. The specimen was recovered from a lag deposit representing an intra–Pierre Shale Group unconformity and consists of vertebrae, ribs, paddle elements, and a partial skull. The partial skeleton is referable to the subfamily Tylosaurinae, cf. *Tylosaurus* sp., based on large size, tooth structure, and long predental rostrum. Further identification must await resolution of the taxonomy of the Tylosaurinae. A lower jaw measures 1.6 m, indicating a projected body length of 11.5 m. Therefore, the large "fish" described by Lewis and Clark may have been a tylosaurine mosasaur.

Keywords: Pierre Shale Group, mosasaur, Tylosaurine, Missouri River, South Dakota.

INTRODUCTION

The Missouri River area of South Dakota is world renowned for its extensive exposures of the fossiliferous Pierre Shale Group (see Martin et al., this volume, for stratigraphic nomenclature). The Pierre Shale Group is an extensive marine Cretaceous lithostratigraphic unit that consists of gray to black, organic-rich shales interbedded with bentonites and concretionary zones found throughout the Northern Great Plains. The Campanian Sharon Springs Formation of the Pierre Shale Group is the oldest unit exposed in the Missouri River Trench in central South Dakota and is extremely fossiliferous. In particular, the marine reptile assemblages are well represented, including some of the largest mosasaurs, the tylosaurines. Tylosaurine material is relatively common in the lower Pierre Shale Group but becomes rare higher in the section in the Missouri River area. Relatively few specimens have been recovered from the underlying Niobrara Formation in contrast with the Niobrara Formation of Kansas (Schumacher and Martin, 1993), although this disparity is undoubtedly due to fewer scientific investigations in South Dakota (Martin et al., 1998). The tylosaurines

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were a very successful group of large mosasaurs that existed from the Coniacian to the late Maastrichtian, with some attaining lengths of >15 m. They attained a worldwide distribution, being found in North America, Africa, Europe, New Zealand, and Antarctica. Tylosaurines were opportunistic carnivores, as indicated by their stomach contents, some of which include other mosasaurs, birds, and fish (as summarized in Martin and Bjork, 1987; Martin, 1994).

Since 1989 a systematic survey of the Late Cretaceous marine rocks of the Missouri River Trench has been undertaken through the Museum of Geology and the New Jersey State Museum in cooperation with the U.S. Army Corps of Engineers, the Crow Creek Sioux Tribe, and the Bureau of Indian Affairs to gain an understanding of the geographic, stratigraphic, and temporal distribution of fossil vertebrates. Under the direction of the second author, and in collaboration with David Parris, New Jersey State Museum, extensive collections have been made that have been tied to local stratigraphic sections. These sections are characterized by the Niobrara Formation or the Pierre Shale Group, in which interbedded bentonite layers occur. Most fossil specimens have been documented in relation to these chronostratigraphic units. Therefore, the collections represent a major contribution to understanding the evolution of the Western Interior Seaway on the basis of precise stratigraphic control. The most abundant group of marine reptiles documented in this manner is the Mosasauridae. The mosasaurs are relatively common in both the Niobrara Formation and the Pierre Shale Group and represent a major chapter in understanding the history of life in the Western Interior Seaway.

Here, we report on the largest tylosaurine mosasaur collected thus far from the Missouri River area of South Dakota (Museum of Geology, South Dakota School of Mines [SDSM] 39966). The Jim Wilkens family located the specimen in the summer of 1990 along the Missouri River at water level near the mouth of Nicholas Creek in Lyman County, South Dakota. The specimen lay in the Boyer Bay Member of the newly elevated Sharon Springs Formation (see Martin et al., this volume, for revised Pierre Shale terminology) 0.61–0.66 m below a creamy white bentonite layer just above the Niobrara Formation. Here the Boyer Bay Member of the Sharon Springs Formation unconformably overlies the Niobrara Formation, with its basal portion being a lag deposit. The lower member of the Sharon Springs Formation, the Burning Brule Member, was eroded away. Above the lag deposit, thin bentonitic layers occur throughout the remaining exposure. However, the lower Boyer Bay Member composes the section in this area, because the overlying Sharon Springs members and the remainder of the Pierre Shale Group was eroded, leaving only a small cliff at the water's edge. Unfortunately, owing to high water conditions, the specimen could not be collected completely until 2000. Most of the preserved skeleton was removed in four large plaster jackets from an area of ~10 m^2. The largest plaster jacket contained both lower jaws and miscellaneous bone fragments. The frontal, premaxillae, and postcranial material were removed in the other three large plaster jackets (Fig. 1).

Some of the skeleton was undoubtedly lost to erosion, but the specimen was already severely damaged and disarticulated before fossilization owing to the high-energy environment of deposition. Most of the recovered mosasaur bones were broken and severely abraded. The lag-deposit matrix surrounding the specimen was composed of highly rounded particulate bone from this specimen and possibly several other organisms. Clay clasts were common, as were small pebbles composed of rock and bone. Microvertebrate material was abundant but fragmentary and was predominantly unidentifiable fish material. Notable exceptions were *Squalicorax, Odontaspis,* and *Xiphactinus* teeth.

SYSTEMATIC PALEONTOLOGY

Family Mosasauridae, Gervais, 1853
Subfamily Tylosaurinae, Williston, 1895, 1897
Tylosaurinae, gen. et sp. indet.
cf. *Tylosaurus* sp. indet.

Referred specimen. SDSM 39966, partial skeleton from locality SDSM V2000–19.

Description. Portions of the anterior skull—including a nearly complete frontal and premaxilla, a nearly complete lower right jaw, a left dentary broken posterior to the 11th tooth, 4 large vertebrae, several partial to complete ribs, and phalanges—were well preserved (Fig. 2). Unlike most fossils recovered from the Sharon Springs Formation, these bones were not secondarily impregnated by gypsum.

The premaxillae are well preserved and nearly complete (Fig. 2E, F), although dorsoventrally crushed. The anterior tooth-bearing apex was found isolated from the internarial bar, which remained in partial articulation with the frontal. Foramina are abundant and distributed around the dorsal and lateral sides of the premaxilla. The dorsoventral crushing probably accounts for the broken, unerupted teeth. The long predental rostrum (11.2 cm) is characteristic of the tylosaurines (Williston, 1898; Russell, 1967). The premaxillary-maxillary suture appears to be interdigitating, rather than a smoothly rising interface. This character has been associated with *Hainosaurus* (Lingham-Soliar, 1992), but more recent work (Lindgren and Everhart, 2000) suggests it to be characteristic of all tylosaurines from the medial Campanian through late Maastrichtian (Martin, this volume, Chapter 14).

Most of the frontal is preserved although highly fractured, especially at the sutural contact with the parietal in the region of the pineal opening (Fig. 2G). As a result, the sutural contacts are not distinguishable. This is unfortunate because the fronto-parietal suture is an essential character for distinguishing *Tylosaurus* from *Hainosaurus* (Russell, 1967; Martin, this volume, Chapter 14). A pineal opening within the parietal is characteristic of *Tylosaurus,* whereas an opening shared between the parietal and frontal would indicate assignment to *Hainosaurus.* Another character typical of tylosaurines is a dorsal crest on the frontal. SDSM 39966 has a crest on the anterior two-thirds of the frontal;

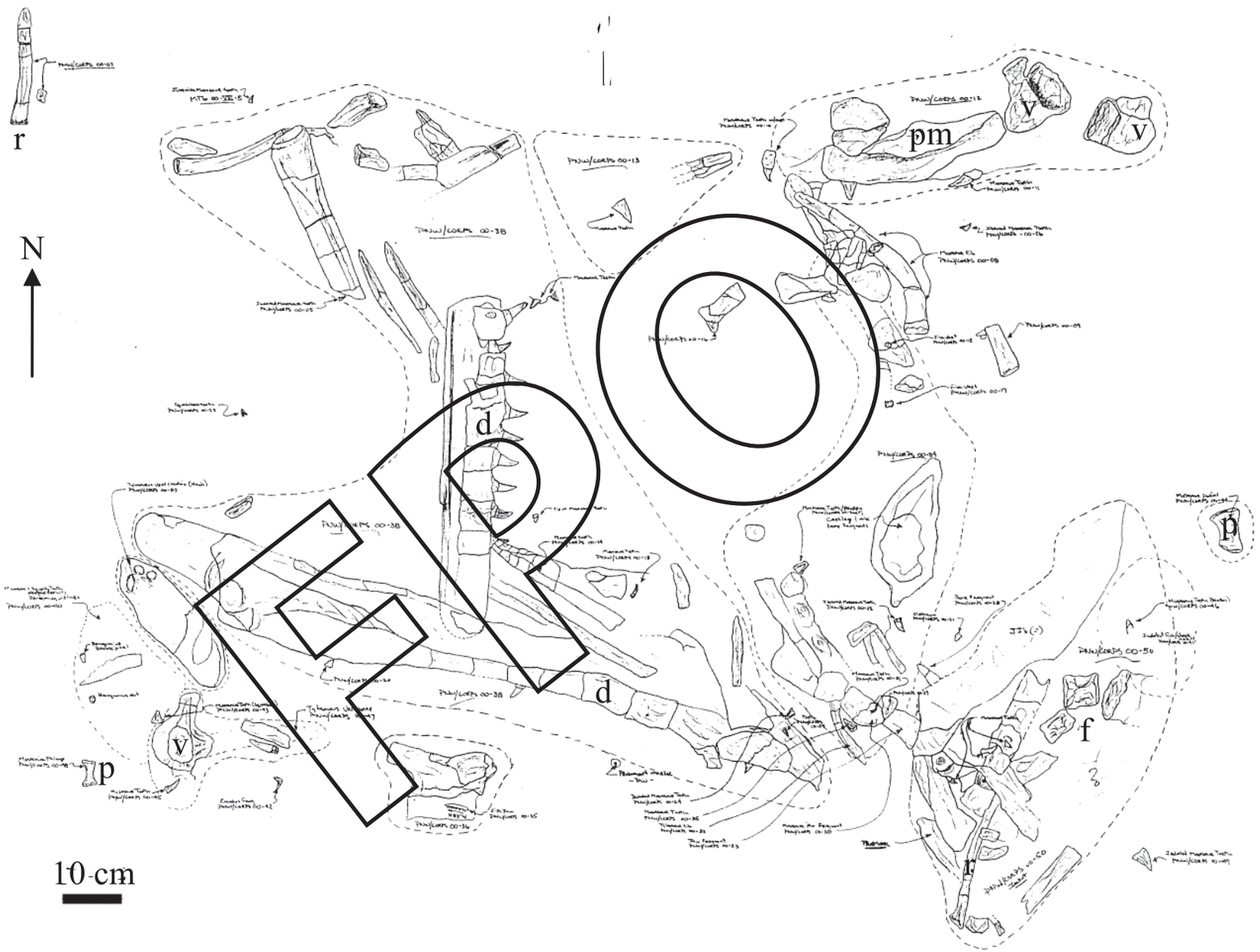
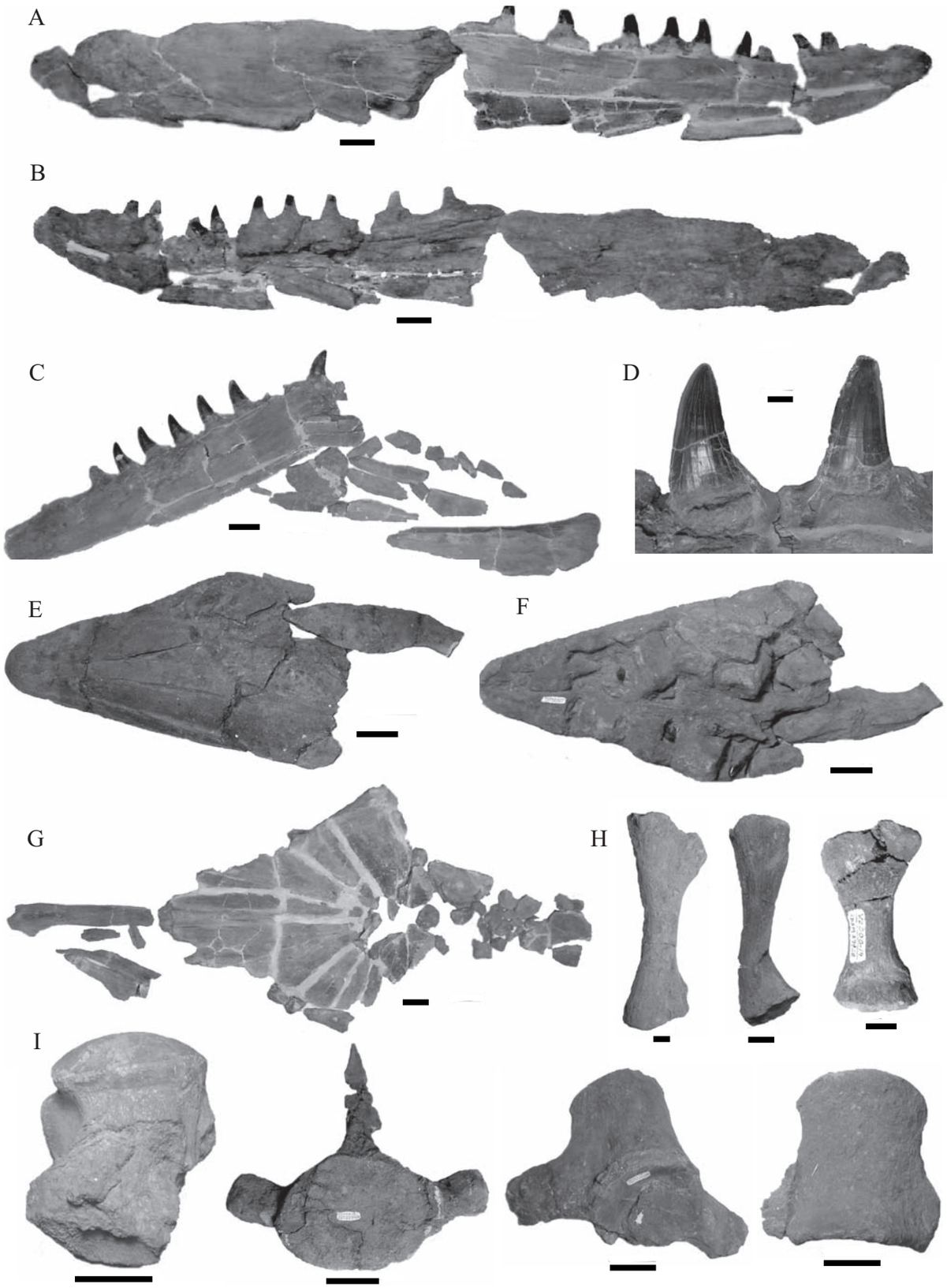


Figure 1. Field map of SDSM 39966. Dashed lines indicate plaster jackets removed. Abbreviations: pm—premaxilla; d—dentary; f—frontal; v—vertebra; p—paddle element; r—rib.



however, it appears more as a doubled crest with a medial valley. The posterior third of the midline is represented by a fissure. A fissure in a very large specimen, suggesting an adult level of ontogeny, indicates that a sagittal fissure on the parietal of mosasaurs may not represent an unfused juvenile condition. The posterior margin of the external nares is preserved on the frontal. The associated internarial bar possesses the anterior narial margin, indicating a narial length of ~30 cm.

The right lower jaw is virtually complete, with a representative portion of all seven bones (Fig. 2A, B). The splenial and angular are fragmentary, but the articular, surangular, prearticular, coronoid, and dentary are relatively complete. The total jaw length at minimum is 1.6 m, but its exact length cannot be stated with certainty because of breakage. In the right dentary, eight virtually complete teeth are preserved, although their tips are normally broken away. The following tooth positions retain teeth: 3, 4, 6–9, 11, and 13, and the tooth count in the lower jaw is 13. The left lower jaw consists of a well-preserved dentary with 7 teeth preserved, including tooth positions 4–9 and 11, but the remainder of the left jaw is broken away posterior to the 11th tooth (Fig. 2C). The symphyseal area exhibits a short predental area that is beveled medially with an oblique facet, a character of most tylosaurines and particularly well developed in *Taniwhasaurus* from New Zealand and Antarctica (Martin and Fernández, 2007). The beveled facet indicates a wide lateral flexion of the dentary during feeding.

The teeth (Fig. 2D) are well preserved, exhibiting most details. All teeth are bicarinate, and the carinae exhibit minute serrations. These carinae are not positioned on the extreme anteroposterior margins of the teeth but are normally asymmetrically positioned on the labial sides. As a result, the teeth are not symmetrical and also are not laterally compressed (although some, such as left dentary tooth 7, appear to be so as the result of postmortem crushing). Internally at the crown base, all teeth display distinct striations that fade about a third of the distance to the crown tip. Some striations also appear on the labial side of the tooth but are normally not as prominent. On this lateral face, facets dominate. Most are relatively short anteroposteriorly, so each tooth may have 8–10 facets.

Of the recovered postcranial material, most is well preserved (Fig. 2H, I) although crushed. The four trunk vertebrae, although incomplete, are very large (centra 25–30 cm in diameter), have ovate centra, and have large transverse processes that become dosoventrally thin posteriorly so that only a bladelike crest extends to the posterior condyle. Most of the rib material is fragmentary, but some is nearly complete. The metapodials and phalanges are also well preserved but provide little information with regard to generic identification.

DISCUSSION

A long predental rostrum, an interdigitating premaxillary-maxillary suture, extremely large size, and a frontal crest indicate assignment of the specimen to the Subfamily Tylosaurinae. Unfortunately, the most important elements for generic identification of tylosaurine mosasaurs are not preserved, i.e., the quadrate and parietal (Russell, 1967). However, the teeth are not well striated, indicating that the specimen could not be *Taniwhasaurus* (Martin and Fernández, 2005, 2007). Moreover, the teeth are not laterally compressed and symmetrical, suggesting that they do not represent *Hainosaurus* (Lindgren, 2005). Overall, the specimen most closely resembles *Tylosaurus proriger,* but a lack of certain diagnostic features prevents precise taxonomic assignment.

Russell (1967) provided several tylosaurine measurements, which were used by Schumacher and Martin (1993) to estimate the body length of a *Tylosaurus proriger* specimen collected from the Niobrara Formation of South Dakota along the Missouri River, south of the location of SDSM 39966. The length of the Niobrara specimen was estimated to be slightly >9.4 m. Until the discovery of the specimen described herein, it was the largest identifiable mosasaur specimen collected from the Missouri River area. Russell's (1967) measurements indicate that the dentary accounts for ~57% of the total lower jaw length. The lower jaw length in turn accounts for ~14% of the total length of the animal. Applying these estimates of body length to the new specimen suggests an individual of 11.5 m, >2 m longer than the Niobrara specimen.

The Lewis and Clark outbound expedition of 1804 to the Missouri River area of South Dakota recorded the first fossils known from this region. These early explorers found remains of a 45 ft animal and attributed them to a large fish. Unfortunately, the specimen was not collected or was lost, and verification of the identification is not possible. However, some workers (see Martin et al., 1998; Parris et al., this volume, Chapter 1) suggest that the specimen was not a fish but was instead a large marine reptile, perhaps a tylosaurine mosasaur. Cretaceous fish are well known from the Niobrara Formation–lower Pierre Shale Group deposits along the Missouri River, but none approach the 45 ft length recorded by Lewis and Clark. The largest fish known from this interval are *Xiphactinus,* but the largest are only approximately one-third of the length noted by Lewis and Clark. The large mosasaur reported here lends further support to the idea that the 45 ft "fish" of Lewis and Clark could have been a tylosaurine mosasaur. However, the possibility that the "fish" was an elasmosaurid plesiosaur cannot be discounted, even though these reptiles are much rarer along the Missouri River.

Figure 2. Preserved elements of SDSM 39966. (A) Labial view of right lower jaw. (B) Lingual view of right lower jaw. (C) Labial view of left lower dentary and jaw fragments. (D) Close-up of left lower dentary teeth. (E) Dorsal view of the anterior tooth-bearing apex of the premaxillae. (F) Ventral view of the anterior tooth-bearing apex of the premaxillae. (G) Dorsal view of the frontal and internarial bar of the premaxillae. (H) Paddle elements. (I) Vertebrae. Scale bar is 5 cm except for D and H, for which scale bar is 1 cm.

CONCLUSIONS

The specimen described herein is the largest mosasaur thus far collected from the Missouri River area of South Dakota, estimated at 11.5 m long. Precise identification of the mosasaur, SDSM 39966, is impossible at this time owing to revisions of tylosaurine taxonomy and the lack of diagnostic bones recovered. However, the specimen can be positively identified as a tylosaurine, probably *Tylosaurus,* owing to its large size, long rostrum anterior to the first premaxillary tooth, and the lack of laterally compressed, symmetrical teeth. The specimen certainly represents a tylosaurine, the largest mosasaurs to have existed. The occurrence of large mosasaurs in the Late Cretaceous Niobrara Formation–lower Pierre Shale Group section of South Dakota lends further evidence that the 45 ft fossil "fish" identified by Lewis and Clark in 1804 may have been a mosasaur, as suggested by Martin et al. (1998) and Parris et al. (this volume, Chapter 1). No fossil fish are known to have reached the size of these large marine reptiles. The only other possibility for Lewis and Clark's "fish" could be an elasmosaurid plesiosaur, but these taxa are rarer than tylosaurine mosasaurs from this portion of the Cretaceous along the Missouri River.

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