Paludicola 5(2):33-54 May 2005

A STRATIGRAPHIC AND TAXONOMIC REVIEW OF PLESIOSAURS FROM THE OLD "FORT BENTON GROUP" OF CENTRAL KANSAS: A NEW ASSESSMENT OF OLD RECORDS

Bruce A. Schumacher and Michael J. Everhart

Sternberg Museum of Natural History, Fort Hays State University, Hays, KS 67601

ABSTRACT

The old "Fort Benton Group" (Middle Cenomanian to Middle Turonian) in central Kansas has produced a relatively large number of plesiosaur specimens. In modern terminology, this historical stratigraphic term refers to the Graneros Shale, Greenhorn Limestone, and Carlile Shale of the Western Interior. In particular, the Fairport Chalk Member of the Carlile Shale has produced an unusually high number of partial plesiosaur skeletons in light of the fact that it is characteristically poorly exposed and minimally accessible. Polycotylids, including *Trinacromerum bentonianum*, are first documented in central Kansas from the upper Hartland Shale Member, Greenhorn Limestone (middle Upper Cenomanian), and appear to be especially well represented in the upper Greenhorn Limestone and lower one-half of the Fairport Chalk (Lower and Middle Turonian). Pliosaurids, including *Brachauchenius lucasi*, are known from the basal Lincoln Limestone Member, Greenhorn Limestone (Middle Cenomanian) to the middle of the Fairport Chalk. The occurrence of pliosaurs in the Fairport Chalk (early Middle Turonian) is at or near the last known occurrence of this group prior to their extinction. Elasmosaurid remains are rare throughout the "Fort Benton" interval, with only three firmly established records from the Graneros Shale and Greenhorn Limestone (Middle Cenomanian to Early Turonian) in Kansas.

INTRODUCTION

Plesiosaur skeletons were among the first vertebrate fossils collected from the Upper Cretaceous of west-central Kansas. As many named type specimens of plesiosaurs have originated from the Cretaceous marine beds of this area as from any comparable region in the world (Cope 1868, 1869; Cragin, 1888, 1891; Riggs, 1944; Williston, 1890, 1903; Williston and Moodie, 1917). Researchers, however, are perhaps more likely to associate Kansas plesiosaurs with the Pierre Shale and Niobrara Chalk of western Kansas in recognition of the better known and celebrated type specimens of *Elasmosaurus platyurus* Cope (1868) and *Dolichorhynchops osborni* Williston (1903). However, beginning with the collection of *Trinacromerum "anonymum"* by B. F. Mudge from Russell County in 1873 (Williston, 1903), a significant number of plesiosaur specimens, including the holotypes of *Brachauchenius lucasi* Williston (1903) and *Trinacromerum bentonianum* Cragin (1888), are known from the pre-Niobrara formations of central Kansas. Collections at the Sternberg Museum of Natural History, Hays, Kansas, in particular, house a much larger number of plesiosaur specimens from the old "Fort Benton Group" than from the Niobrara Chalk.

The imprecise stratigraphic data associated with specimens collected since 1873 in Kansas is difficult to decipher in a modern context. However, if historic locality information exists, such as a reference to a town or particular county, consulting geologic maps or visiting the general area greatly narrows the window of stratigraphic possibilities. In some cases, the original authors provided important stratigraphic observations of the localities, allowing more accurate assessments to be made. Specimen preservation can also provide clues. Those preserved in laminated carbonates and muds tend to exhibit flattened, plastically deformed preservation, whereas those recovered from bioturbated chalks and limestones, or concretions, retain their original dimensions more closely. In a few instances, the specimens have distinctive contextual invertebrate material and/or enclosing rock matrix curated with them, adding a further level of precision to assessment of historical stratigraphic data. In one case, we accompanied the original collector to the site of his discovery (see Acknowledgements). And in the case of a second, more recent discovery, photographs taken during collection of the remains were used to accurately determine the exact location and horizon of the site. The approximate geographic locations of specimens reported herein are shown in Figure 1. See Figure 2 for reference to geologic units and horizons of occurrence.

Abbreviations–AMNH, American Museum of Natural History, New York, NY; CMC, Cincinnati Museum Center, Cincinnati, OH; DMNH, Denver

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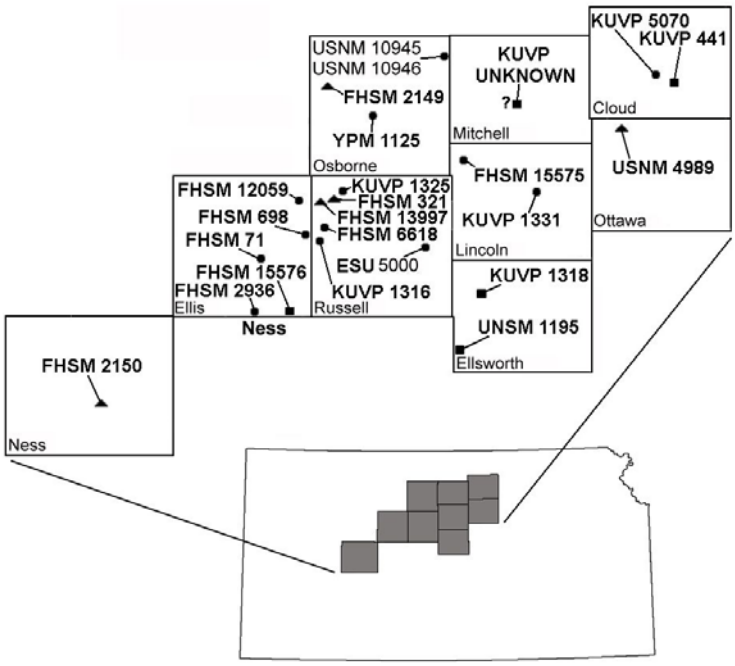

FIGURE 1. Approximate locations of plesiosaur specimens discussed in this report from central Kansas. Triangles, circles, and squares represent pliosaurs, polycotylids, and elasmosaurs respectively. Positions of icons preceded by a question mark are accurate only to county.

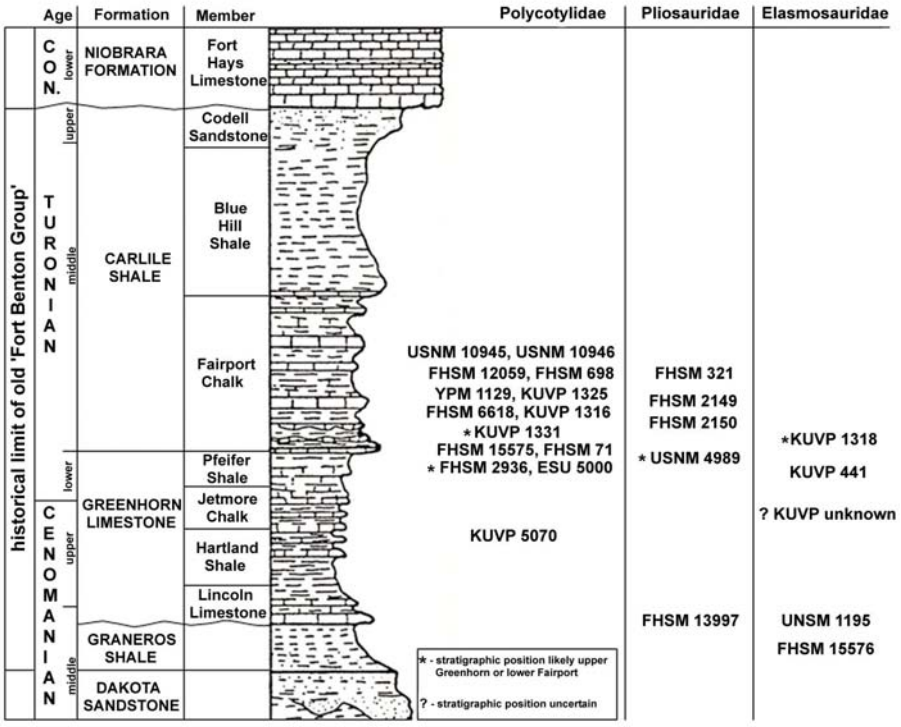

FIGURE 2. Biostratigraphic distribution of known plesiosaur specimens from the old "Fort Benton Group" of central Kansas. Stratigraphic column adapted from Shimada, 1996.

Museum of Natural History (now Denver Museum of Nature and Science), Denver, CO; ESU, Johnston Museum of Geology, Emporia State University, Emporia, KS; FHSM, Sternberg Museum of Natural History, Fort Hays State University, Hays, KS; KUVP, University of Kansas Vertebrate Paleontology Collection, Lawrence, KS; LACMNH, Los Angeles County Museum of Natural History, Los Angles, CA; MCZ, Museum of Comparative Zoology, Harvard, Cambridge, MA; UNSM, University of Nebraska State Museum, Lincoln, NE; USNM, United States National Museum (National Museum of Natural History), Washington, D.C.; UWM, University of Wisconsin, Madison, WI; YPM, Yale Peabody Museum of Natural History, New Haven, CT.

METHODS

We purposely restricted our study to specimens of "Fort Benton" plesiosaurs from Kansas, both to provide limits to the analysis, and to include relevant historical information for each specimen. The project was inspired to some extent by the large number of relevant specimens housed in the Sternberg Museum of Natural History (eleven of twenty-four). Although we have tried to be as comprehensive as possible in our review, it is likely there are specimens from central Kansas of which we are not aware. This study includes the discussion and assessment of two key pieces of information about each specimen, namely, stratigraphic occurrence and taxonomic identification. Our primary purpose is to refine the stratigraphic information of plesiosaurs collected prior to the establishment of a modern stratigraphic framework, and those whose precise context was never accurately recorded. Our approach to both stratigraphic and taxonomic assessment is detailed below. Geologic ages assigned to each discussed specimen were taken from Kaufmann et al. (1993).

HISTORY OF STRATIGRAPHIC NOMENCLATURE

Originally, the geologic interval between the Dakota Sandstone and the Niobrara Formation in Kansas was designated the Fort Benton Group by Meek and Hayden (1862). Although a type locality was not designated, the group was named for exposures near historic Fort Benton on the upper Missouri River, central Chouteau County, Montana. The Fort Benton Group name was in formal use until at least the work of Moore (1920), and it was not until Rubey and Bass (1925) published their classic report on the geology of Russell County that rocks in central Kansas were referred to in their modern status. Thus the stratigraphic assignments of marine vertebrate specimens from Cenomanian and Turonian deposits of the mid-continent prior to the 1930s are generally referred to as being from the Fort Benton, or Benton Cretaceous. The historic Fort Benton Group designation refers to the Graneros Shale, Greenhorn Limestone, and Carlile Shale. All of these units, along with the Niobrara Formation, form the current Colorado Group. Each of these formations is quite distinctive in terms of its characteristic lithology, key marker beds, and geomorphic expression. The relative ages of these units are tightly constrained by a wealth of molluscan and other invertebrate taxa that occur throughout the interval (Kauffman et al., 1993). For detailed information regarding the stratigraphy of these formations, we refer to the works of Hattin (1962, 1965, 1975). For a more thorough treatment of this history of nomenclature see Cobban and Scott (1972).

It is not our intent to formally resurrect the term "Fort Benton Group." Rather, we find informal reference to the term useful to distinguish between two major biozones, as well as depositional packages. The "Fort Benton" is a sequence bound, depositionally related group of rocks corresponding to the Middle Cenomanian to Middle Turonian Greenhorn Cyclothem (Kauffman, 1969), while the Niobrara Formation represents a separate sequence bound transgressive event of the Coniacian to Lower Campanian stage. The time limits of these chronostratigraphic packages compare to the broadly defined Woodbinian and Niobrarian "ages" of Russell (1993). The marine reptilian fauna as a whole is markedly different in the "Fort Benton" versus the latter half of the Colorado Group (Niobrara Formation). As will be demonstrated, this dichotomy is also prevalent amongst plesiosaurs.

TAXONOMIC METHODOLOGY

In the last ten years or so, there been a number of publications detailing the taxonomy and systematics of North American Cretaceous plesiosaurs (Adams, 1997; Carpenter, 1996, 1999; Storrs, 1999; Sato and Storrs, 2000; Druckenmiller, 2002; O'Keefe, 2001, 2004). In particular, many of these publications devote considerable attention to the systematics of polycotylids. As the majority of specimens from the Fort Benton group are polycotylids, our biggest taxonomic challenge was to designate each of the specimens, if possible, to an existing polycotylid taxon. Many of the specimens lack cranial material, and the majority of polycotylid taxonomy published to this point focuses on cranial characters. However, there are a number of taxonomically useful post-cranial characters we draw upon herein, including: number of cervical vertebrae; morphology and dimensions of vertebral centra; morphology of the humerus, femur,

proximal podials, and phalanges; and the nature of the ilium and pubis.

We adopt a conservative approach to the taxonomic identification of specimens. For specimens that have been taxonomically identified elsewhere, we generally defer to the assignments of the most previous work. For those specimens that have not been documented previously, we include a brief description of diagnostic morphologies and assign them to an existing taxon. None of the polycotylid specimens presented herein exhibit features markedly dissimilar from the three best known genera (*Trinacromerum*, *Dolichorhynchops*, *Polycotylus*). To date, *Trinacromerum bentonianum* is the only polycotylid reported from the "Fort Benton" interval in Kansas (Cragin, 1888, 1891; Williston, 1903, 1908; Riggs, 1944; Welles, 1962; Carpenter, 1996). Likewise, we find that all polycotylid specimens presented herein that are diagnostic below the familial level can be referred to *T. bentonianum* based upon diagnostic morphologies discussed in previous publications. However, we note that there is at least one poorly known polycotylid taxon reported from the base of the "Fort Benton" interval (Cenomanian) of the North American mid-continent (Von Loh and Bell, 1998; Schumacher, 1999) and Japan (Sato and Storrs, 2000). Although the only specific pliosaurid name we assign to the "Fort Benton" of central Kansas is *Brachauchenius lucasi*, we also recognize the use of *Plesiopleurodon* (Carpenter, 1996) and *Polyptychodon* (VonLoh and Bell, 1998) from the Cenomanian of the North American mid-continent. The taxonomic treatment of elasmosaurs is especially inadequate, due to a lack of diagnostic material, but we note the occurrence of *Thalassomedon haningtoni* (Welles, 1943; Carpenter, 1999) and *Libonectes morgani* (Welles, 1949; Carpenter, 1999) from the "Fort Benton" interval in other areas.

MATERIAL

Order PLESIOSAURIA de Blainville, 1835
Superfamily PLIOSAUROIDEA Welles, 1943
Family PLIOSAURIDAE Seeley, 1917
PLIOSAURIDAE
Figures 3, 4, 5, 6

FHSM VP-2149--The specimen consists of the proximal one-third of an exceptionally large propodial (Figure 3). The element is somewhat flattened, a state often produced due to burial in shaly chalk, and is sun-bleached due to prolonged exposure to the elements. The preserved portion of the element measures 32 cm in length, and scaled renderings based upon comparison with other plesiosaur paddles indicate that if complete the element would measure roughly 75 cm in total length. Due to its large size, this element is most likely pliosaurid in origin, because no known Cretaceous plesiosaurs other than members of the Pliosauridae achieve these dimensions.

FHSM VP-2149 was discovered by O.G. Guttery in Osborne County near the town of Alton, in northwestern Osborne County. The town is located just north of the south fork of the Solomon River. Geologic exposures in this area are dominated by the Fort Hays Limestone Member, Niobrara Formation, but a large band of Carlile Shale crops out along the south fork of the Solomon (Landes, 1930). Given that the specimen is likely pliosaurid, it is unlikely that it originated in the Fort Hays Limestone (Lower Coniacian), as there are no reported records of pliosaurs from post-Turonian horizons (Russell, 1993). Also, vertebrate remains in general occur only rarely in the Fort Hays Limestone. The specimen shows signs of crushing due to burial in shaly chalk, while nearly all of the Fort Hays Limestone is massive, bioturbated chalk, which generally preserves more three-dimensional specimens. Thus the specimen is probably from the Carlile Shale, and the carbonate matrix still clinging to the specimen suggests it came for the Fairport Chalk Member. The age of the specimen is likely early Middle Turonian.

FHSM VP-2150--This specimen consists of three cervical vertebrae, two cervical ribs, and four dorsal vertebrae. There is also a mass of thin, expansive bony elements with notable sutures crushed against the cervical vertebrae that appear to be elements of the skull roof, although the identity of individual elements is uncertain. The cervical ribs are short, flat, spatulate, and single headed. The cervical vertebrae are extremely foreshortened (Figure 4), with the centra three times as wide as long (12 cm by 4 cm). The dorsal vertebrae are more elongate, and although crushed, appear to be slightly longer than wide. All of the vertebral centra lack the ventral vascular foramina typical of plesiosaur vertebrae, as noted by Williston (1903, 1907; Lane, 1946). However, as noted by Tarlo (1960) and O'Keefe (2001), the ventral vascular foramina of most pliosaurs are present, but are small and laterally placed. All of the above characters, particularly those of the vertebrae, are consistent with those described by Williston (1903, 1907) for *Brachauchenius lucasi*.

The specimen (FHSM VP-2150) was collected by George Sternberg in December, 1962, six miles southeast of Ness City in Ness County. Sternberg listed the specimen as occurring in the Carlile or Greenhorn formation. The geologic map of Neuhauser et al. (1996) shows only the Fairport Chalk occurring in this portion of the county. Bits of matrix still clinging to the specimen are a white, powdery, non-laminated chalk, similar to lithology of the lower portion of the Fairport

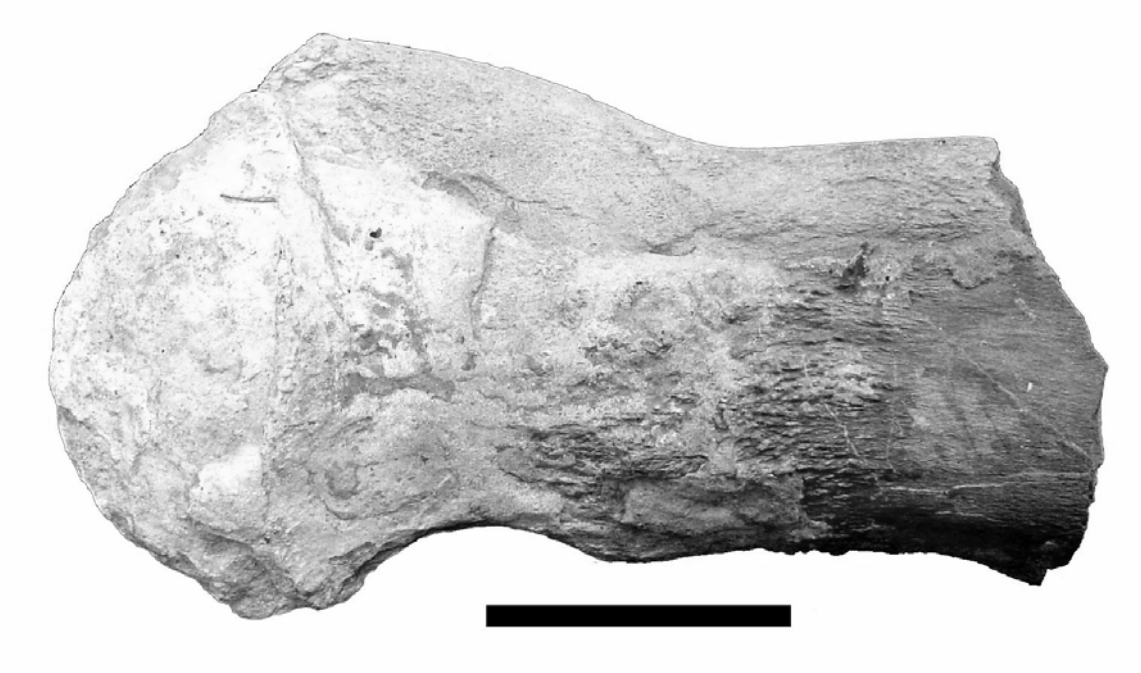

FIGURE 3. Pliosauridae indeterminate. FHSM VP-2149; ventral surface of left propodial. (Scale bar = 10 cm)

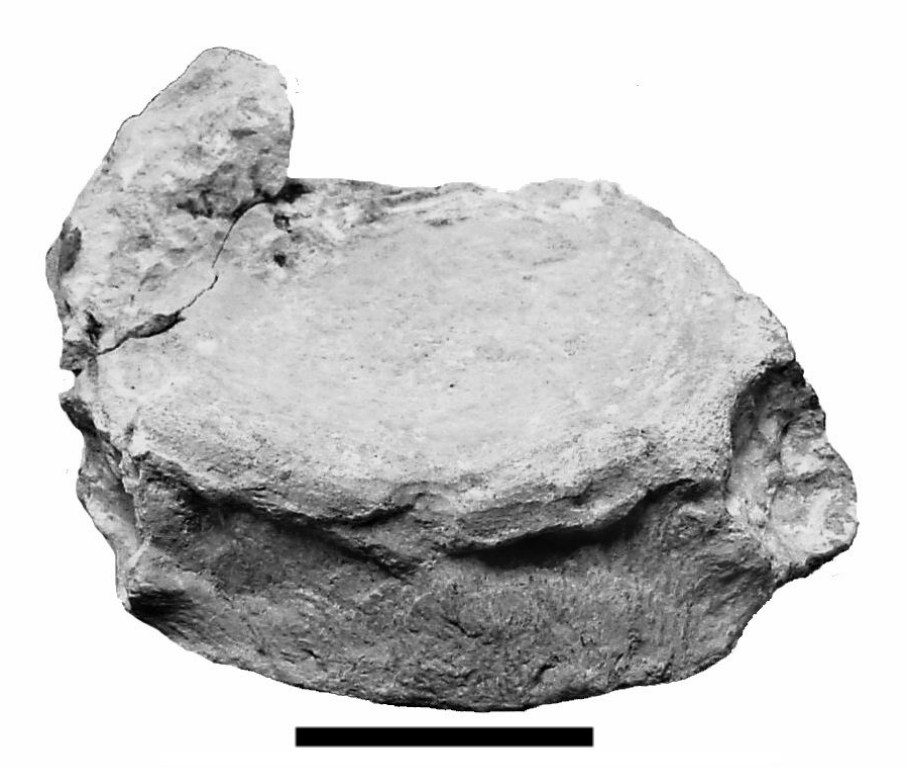

FIGURE 4. Pliosauridae indeterminate. FHSM VP-2150; cervical vertebrae in antero-ventral view. Note short length of centrum, and lack of ventral nutritive foramina. (Scale bar = 5 cm)

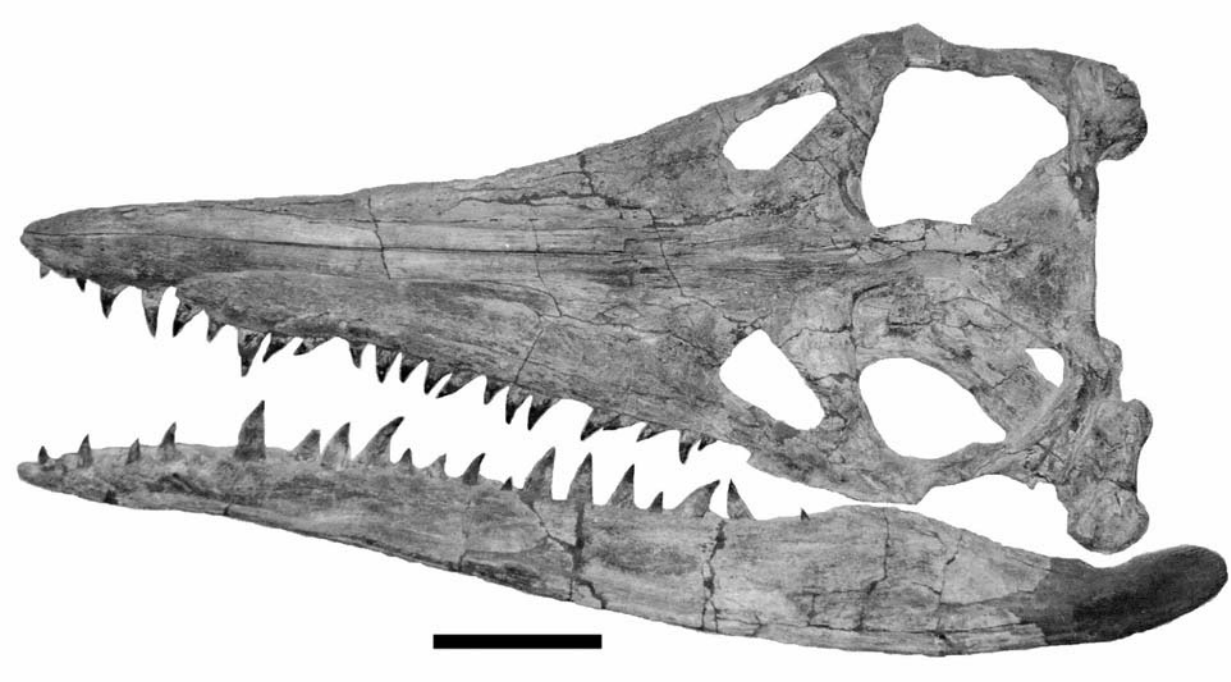

FIGURE 5. *Brachauchenius lucasi*. FHSM VP-321; skull in dorsal view. (Scale bar = 25 cm)

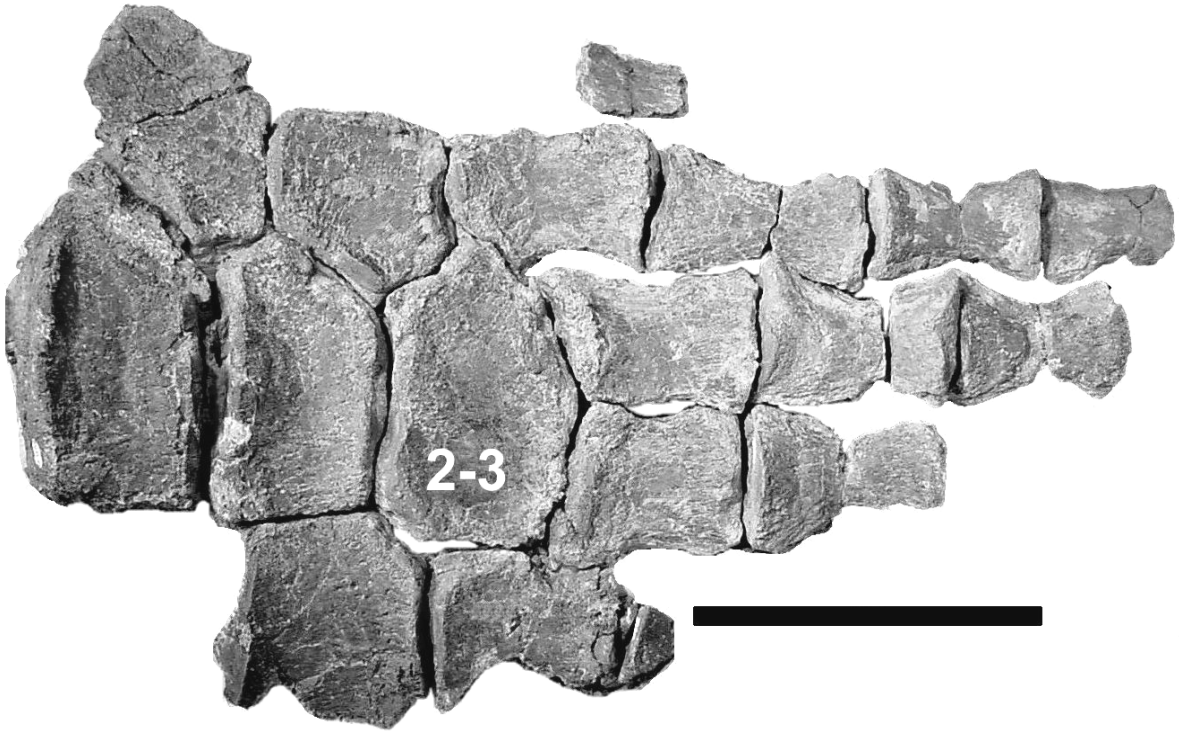

FIGURE 6. *Brachauchenius lucasi*. FHSM VP-13997; associated paddle material. The "2-3" denotes fused distal podials 2 and 3. (Scale bar = 20 cm)

member (Hattin, 1962). The age of the specimen is early Middle Turonian.

BRACHAUCHENIUS LUCASI Williston, 1903

USNM 4989--The type specimen of *Brachauchenius lucasi* consists of a complete skull and lower jaws, an articulated series of the first thirty-seven vertebrae and ribs (Carpenter, 1996). Williston (1907), however, reports a complete cervical series of thirteen followed by twenty-two dorsals for a total number of 35 vertebrae. Since the description by Williston (1903, 1907) the dorsal surface of the skull has been prepared, but it is poorly preserved (McHenry, pers. comm., 2004).

USNM 4989 comes from the "Benton Cretaceous" (Williston, 1903) near Delphos in Ottawa County, KS. Historical contextual information lists John Potts as the collector and states that the specimen was purchased by the National Museum from C. Sternberg in 1884. How Charles H. Sternberg came to possess the specimen is unknown. The geologic map of Mack (1962) shows that the Graneros, Greenhorn, and Carlile formations crop out west of Delphos in northwestern Ottawa County. In the original description, Williston (1903) stated, "I believe that some day it will be advisable to remove it entirely from its limestone bed". Williston's reference to limestone, along with preservation of the specimen, eliminates the likelihood that it originated in the Graneros Shale or Blue Hill Shale Member, Carlile Shale. Carpenter (1996) lists the specimen as being from the Greenhorn Limestone, but does not state how this was determined. Microscopic examination of the lithology and paleontology of the enclosing matrix would likely narrow down the horizon of occurrence. We propose here that the coherent, non-laminated (bioturbated) limestone bed in which the specimen was originally contained (since prepared largely free of matrix) may well correspond to the chalky limestone layers present upper Greenhorn Limestone or the lower Fairport Chalk (see Hattin 1962, 1975). If this assessment is correct, the specimen is early Middle Turonian in age.

FHSM VP-321--This specimen consists of a complete, 1.5 m skull and mandibles (Figure 5). The ventral surface of the skull and the left mandible are currently encased in plaster, as is typical of many mounted specimens prepared by both Charles H. and George F. Sternberg. The right mandible along with loose teeth and other fragments are in stored in the museum collections. The dorsal surface of the skull is well preserved, and reveals key features of pliosaurid taxa, such as covering of the premaxillary-parietal contact by the frontals. The specimen was originally identified as *B. lucasi* by G. F. Sternberg on a historic museum placard and formally assigned as such by Carpenter (1996).

FHSM VP-321 was discovered by Robert and Frank Jennrich in northwestern Russell County near the town of Fairport, and was collected by the Jennrich brothers, George F. Sternberg, and another unrecorded individual in October, 1950. Of historical note, the unnamed individual is apparently responsible for the loss of the posterior end of the left lower jaw (see also Carpenter, 1996, Fig. 1), when it was mistakenly dug up and thrown into the backpile (R. Jennrich, pers. comm., 2003). A frustrated Sternberg searched diligently for the missing portion before eventually giving up.

Carpenter (1996) listed the specimen as most likely from the Jetmore or Pfeifer members of the Greenhorn Limestone. However, in November, 2003, Robert Jennrich led members of the Sternberg Museum to the precise location where the specimen had been excavated more than 50 years earlier. The horizon of occurrence is in the middle of the Fairport Chalk, approximately 12 m above the Fencepost Limestone bed of the Greenhorn Limestone. The upper of two thin, marly chalk beds that form Hattin's (1962) marker unit 9 lies 1 m below the site. An external mold of *Collignoniceras woollgari* was collected in a gritty, resistant marl layer (marker unit 8 of Hattin, 1962) roughly 2.5 m below the site. Large valve fragments of *Inoceramus cuvieri* bearing a diverse assemblage of macro-invertebrate epizoans (Hattin and Hirt, 1991) appear in abundance about 2 m above the site. The confirmed age of the specimen is early Middle Turonian.

FHSM VP-13997--This specimen consists of an articulated set of sixteen articulated epipodial, mesopodial, and phalangeal elements. The partial paddle measures 60 cm in the proximodistal dimension and 35 cm in the antero-posterior dimension (Figure 6). Fused distal podials 2 and 3 form a massive element, markedly wider than long, and are larger in size than the overlying mesopodial. In most plesiosaurs, fused distal podials 2 and 3 are roughly equi-dimensional and are not nearly as large relatively. Most striking is the configuration of the fourth metapodial. Owen (1865) was the first to note that the fifth metapodial has shifted proximally into the distal mesopodial row in all plesiosaurs, a character that unites all members of the Order (Welles, 1943; Brown, 1981; O'Keefe, 2001). VP-13997 reveals that the fourth metapodial, and also the entire fourth digit, is shifted proximally into the mesopodial row. This results in the contact of the fused mesopodial 2-3 with seven other podials, including the fourth metapodial, a unique configuration among plesiosaurs (Caldwell, 1997). The same condition is present in the paratype specimen of *Brachauchenius lucasi* (USNM 2361) as figured by Williston (1907,

plate 36). Although only a portion of the mesopodial row is preserved in the paratype, the proximal shift of the fourth and fifth metapodials is clearly visible in this articulated specimen. Based upon this character, VP-13997 is referred to *B. lucasi* and the peculiar paddle morphology of this taxon is noted here for the first time.

The partial paddle (FHSM VP-13997) was collected by Greg Liggett and others from northwestern Russell County at the contact of the Lincoln Limestone Member, Greenhorn Limestone and the Graneros Shale (Liggett et al., 1997; In press). The specimen is Middle Cenomanian in age, and marks the earliest reported occurrence of pliosaurids in the Cretaceous of Kansas. Poorly preserved material from the Kiowa Shale (Albian) of Kansas in the FHSM and KUVP collections could include representatives of Pliosauridae.

Family POLYCOTYLIDAE Cope, 1869
TRINACROMERUM BENTONIANUM Cragin, 1888
Figures 7, 8, 9, 10, 11, 12, 13, 14

USNM 10945--The type specimen of *Trinacromerum bentonianum* Cragin includes a fragment of the snout with attached lower jaws, basicranium with attached atlas-axis, numerous vertebrae, portions of the pectoral and pelvic girdles, and portions of three paddles. The specimen, particularly the cranial morphology, has been addressed in detail by Cragin (1888, 1891), Williston (1903, 1907), Carpenter (1996) and O'Keefe (2001, 2004).

USNM 10945 was discovered near the fork of the Solomon River, in the vicinity of Downs, in Osborne County. Cragin (1888, p. 404) described the specimen as found "in limestone of the lower part of the Benton, a few feet below the base of the dark septaria-bearing shale". Carpenter (1996, p. 283) noted incorrectly that Cragin reported the specimen(s) from "a limestone *above* a dark septaria-bearing shale in the lower part of the Benton Formation," and interpreted this to mean the Fencepost Limestone at the top of the Greenhorn Limestone. However, Cragin's original description more likely refers to some distance below the Blue Hill Shale, a unit that characteristically contains large septarian concretions (Hattin, 1962). Also, Cragin's original description gives this stratigraphic information in reference to only the type specimen (USNM 10945), not to both it and the paratype specimen (USNM 10946, see below). The fork of the Solomon River is located about 9 km east of Downs in northwestern Mitchell County. The geologic map of Landes (1930) shows that the only geologic unit exposed in this vicinity is the Fairport Chalk. This matches well with Cragin's (1888) description of the geology, as a few feet below the base of the dark septaria-bearing shale (Blue Hill) is equivalent to within the Fairport Chalk Member of the Carlile Shale. The age of this specimen is early Middle Turonian.

USNM 10946--The paratype specimen of *T. bentonianum* Cragin (1891), includes a partial skull (lacking the anterior one-third of the snout) and lower jaws, and the attached atlas-axis vertebrae. The specimen has been discussed along with the type specimen of *T. bentonianum* by Cragin (1891), Williston (1903, 1907), Carpenter (1996) and O'Keefe (2001, 2004).

USNM 10946 is also reported as from the Fencepost Limestone of Osborne County by Carpenter (1996). In his original reference to the paratype specimen, Cragin (1891) says nothing about the horizon of occurrence, merely that he had secured two other skulls he believed were co-specific with the type specimen. Williston (1908) later noted that one of Cragin's "skulls" was actually clavicular elements of the type specimen, and that Cragin (1891) confused the clavicular foramen for the parietal foramen. Williston (1908) also states that the two skulls are "both from the same horizon and adjacent localities," thus indicating that he had resolved to his satisfaction that the skulls were both from the same geologic unit. Adjacent localities imply that the specimens were collected in the same portion of Osborne County. Thus what we know about the horizon of occurrence for the paratype specimen is suspect, coming second hand from Williston in a publication seventeen years after its original description. Given Williston's comments in 1908 we assume here that the specimen is from the Fairport Chalk of northeastern Osborne County, and that the specimen is early Middle Turonian in age.

ESU 5000--This specimen consists of a nearly complete and articulated right front paddle (Figure 7), which we refer to *T. bentonianum* based upon paddle morphologies including; only moderate postero-distal expansion of propodial, three epipodials with a triangular third epipodial, proximal podials (radius and ulna) nearly equal in length and width, relatively elongate phalanges with rounded cross sections (Schumacher, 2002). The specimen was discovered by Dr. Paul Johnston and was uncovered with the assistance of DeWayne Backus and students from Emporia State University, Emporia, Kansas in July, 1971. Originally the specimen included an articulated vertebral column, minus the skull and anterior cervical vertebrae. Also present were the pectoral and pelvic girdles, three paddles and ribs (Paul Johnston, pers. comm., 2003). Unfortunately, the most of the specimen was stolen before it could be collected by the ESU field party. The single extant paddle was still buried when the vandalism occurred.

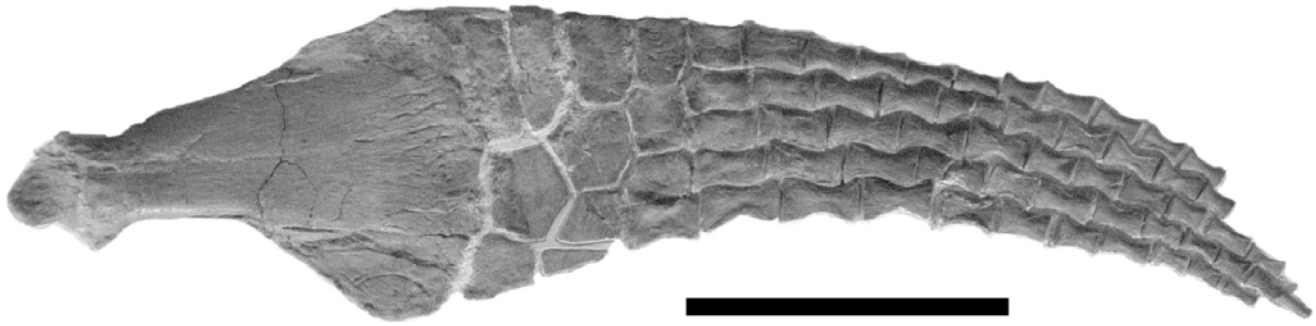

FIGURE 7. *Trinacromerum bentonianum*. ESU 5000; articulated right fore-paddle in dorsal view. (Scale bar = 25 cm)

FIGURE 8. *Trinacromerum bentonianum*. FHSM VP-71; ventro-lateral view of 5 articulated dorsal vertebrae in block of chalky limestone. (Scale bar = 10 cm)

FIGURE 9. *Trinacromerum bentonianum*. FHSM VP-71; ventral view of partial right scapula (left, preserved portion outlined) compared to the right scapula of FHSM VP-12059. (Scale bar = 10 cm)

FIGURE 10. *Trinacromerum bentonianum*. FHSM VP-698; cervical vertebrae one through six in right lateral view. (Scale bar = 10 cm)

ESU 5000 was recovered from a road-cut south of Wilson Lake Reservoir in east-central Russell County. The precise site of excavation is known, along with historical photographs of the excavation. The specimen originated in the uppermost Pfeifer Member, Greenhorn Limestone, about 2 m below the Fencepost Limestone. The age of the specimen is late Early Turonian.

FHSM VP-71--This specimen consists an articulated series of five dorsal vertebrae, a partial right scapula, and a rib portion contained in a block of limestone matrix (Figure 8, 9). The centra are roughly equi-dimensional (roughly 7 cm), and are only slightly concave on their lateral surfaces and central faces. This matches the condition of the vertebral centra observed in *Trinacromerum* (cylinder-like), versus the strongly constricted walls of vertebral centra of *Dolichorhynchops* and *Polycotylus* (Carpenter, 1996; Storrs, 1999; O'Keefe, 2004). The centra bear prominent vascular foramina on the lateral surface, in addition to smaller, paired sets of foramina on the ventro-lateral and ventral surfaces. In these respects the vertebrae are indistinguishable from USNM 10945 (type of *T. bentonianum*). The partial scapula matches well with another referred specimen of *T. bentonianum* (FHSM VP-12059, see below). This specimen is thus referred to cf. *T. bentonianum*.

Records associated with FHSM VP-71 state that it was discovered in a block of building stone being used to construct the stadium on Fort Hays State University campus in 1938. The area being used for quarry stone was on the W. Philip Ranch, in Ellis County, southeast of Hays, and most likely the block came from the Fencepost Limestone bed of the Greenhorn Limestone. This stone was used extensively to construct many of the buildings on the Fort Hays campus. The specimen is late Early Turonian or early Middle Turonian in age.

FHSM VP-698--This specimen consists of a nearly complete axial skeleton minus the skull, including a series of sixty-two vertebrae beginning with the atlas-axis (Figure 10) and extending into the anterior caudals. Also present are numerous cervical and trunk ribs, sacral ribs, the proximal head and distal end of a propodial(s), left ilium (Figure 11), girdle portions, and numerous loose podials and phalanges. Overall the skeleton is large and robust, with the ilium measuring 25 cm in length. The rib articulation for the twenty-second vertebra impinges across the neuro-central suture, thus the cervical count is twenty-one, a slight difference from that reported for *Dolichorhynchops osborni* (19 or 20 per Williston, 1903; 19 per Carpenter, 1996 and O'Keefe, 2001) and *Trinacromerum bentonianum* (20 per Carpenter, 1996 and O'Keefe, 2001). Vertebrae forty-seven through forty-nine form the "sacrum", and bear large facets for the attachment of sacral ribs. Thus the pre-sacral count of 46 is similar to that in *Trinacromerum* and *Dolichorhynchops* (Carpenter, 1996). The cervical vertebrae are relatively short (about half again as wide as long), while the dorsal vertebral centra are equi-dimensional and bear minor lateral and ventral constrictions. Chevron facets begin on the posterior margin of the fifty-second vertebra, and the ventral surface of all succeeding caudals bear distinct facets for the chevrons on both the anterior and posterior border. This character state has not been reported in *Trinacromerum,* but it is similar in *Polycotylus* (Williston, 1906; Carpenter, 1996; O'Keefe, 2004) and differs from *Dolichorhynchops* where chevrons are borne entirely on a single vertebra (Williston, 1903, Carpenter, 1996). The ilium is nearly straight with only a slight posterior curvature. The posterior edge bears a keel along its mid-line (similar in FHSM VP-12059, see below) and is spatulate on the sacral end as noted in *Dolichorhynchops* by Storrs (1999). The propodial head is massive, and the distal propodial end bears deep facets for articulation of the radius/ulna or tibia/fibula. The paddle elements are relatively elongate as compared to *Dolichorhynchops* (Schumacher, 2002; Irwin and Schumacher, 2003), and *Polycotylus* (Storrs, 1999), with phalanges that are rounded in cross section. With one notable difference (cervical count), the post-cranial morphology of this specimen most closely matches that of *T. bentonianum* Cragin. However, as indicated by Brown (1981), and again re-iterated by Carpenter (1996), although there is some variation in the number of vertebrae in the cervical and dorsal regions, the total presacral count remains consistent. The nature of the chevron articulations and relatively elongate podials and phalanges prevent referring this specimen to *Dolichorhynchops*.

FHSM VP-698 was discovered by George Dreher in east-central Ellis County, and was collected by George Sternberg, Myrl Walker, and Richard Bower in June, 1956. The quarter- section of the site is recorded, and a visit to the location revealed exposures of the middle Fairport Chalk. A fragment of *Inoceramus cuvieri* valve coated by small ostreids and bryozoans is curated with the specimen. Such invertebrate material is highly characteristic of the middle Fairport Chalk interval (Hattin, 1962) and verifies our findings in the field. Several bony elements, including the ilium, bear tooth marks attributable to scavenging by *Squalicorax* (Schwimmer et al., 1997), as we note on other specimens from the Fairport Chalk interval. The age of this specimen is early Middle Turonian.

FHSM VP-2936--This specimen consists of an articulated series of dorsal vertebrae and ribs contained within a chalky limestone concretion. The most visible portion of the specimen is a nicely arrayed series of dorsal ribs. Visible centra reveal equi-dimensional proportions (roughly 6 cm), slightly concave surfaces,

FIGURE 11. *Trinacromerum bentonianum*. FHSM VP-698; left ilium in lateral view. (Scale bar = 10 cm)

FIGURE 12. *Trinacromerum bentonianum*. FHSM VP-6618; four successive caudal vertebrae, three in ventral view, largest centrum at right in posterior view. Note the equal formation of chevron facets on adjacent vertebrae. (Scale bar = 10 cm)

FIGURE 13. *Trinacromerum bentonianum*. FHSM VP-12059; right ischium in ventral view (above) and right ilium in anterior view. (Scale bar = 10 cm)

FIGURE 14. *Trinacromerum bentonianum*. KUVP 5070; skull of "*Trinacromerum willistoni*" in left lateral view. (Scale bar = 10 cm)

and a prominent lateral foramen. This matches the condition of the vertebral centra observed in *Trinacromerum*, versus the constricted vertebral centra walls of *Dolichorhynchops* and *Polycotylus* (Carpenter, 1996; Storrs, 1999; O'Keefe, 2004), and this specimen is thus referred to cf. *T. bentonianum*.

FHSM VP-2936 is listed as from the Carlile or Greenhorn formations, near the town of Pfeifer, in southeastern Ellis County, where only exposures of the Greenhorn and older horizons occur (Neuhauser and Pool, 1988). The concretion containing the specimen is relatively large, measuring roughly 100 cm in length by 50 cm in width. Chalky limestone concretions such as this commonly occur in the uppermost Pfeifer Member, Greenhorn Limestone (Hattin, 1975) and the lower Fairport Chalk Member, Carlile Shale (Hattin, 1962), although they are generally more rounded and smaller. In this case, it appears that the plesiosaur skeleton served as a nucleus for growth of the concretion. The specimen is late Early Turonian or early Middle Turonian in age.

FHSM VP-6618--This specimen consists of a relatively complete axial skeleton with ribs minus the posterior caudal series. The cervical series is complete and includes nineteen or twenty vertebrae. The rib facet of the twentieth cervical/"pectoral" impinges only just slightly across the neuro-central suture. The dorsal vertebral centra lack lateral and ventral constriction as in *Trinacromerum* (Carpenter, 1996; Storrs, 1999; O'Keefe, 2004). The articular faces of some dorsal vertebrae possess a central dimple. No cranial, girdle, or limb material is present. The specimen is referred to *T. bentonianum* based upon the cervical count and morphology of the vertebral centra. The caudal vertebrae bear distinct chevron facets on both the anterior and posterior border (Figure 12), as was noted in FHSM VP-698, further supporting this as a valid character for *Trinacromerum*.

FHSM VP-6618 was found and collected by Michael Cox from a road-cut in west-central Russell County in February, 1981. A general description of the excavation site and location is recorded but proved difficult to precisely locate in the field. However, the only stratigraphic horizon exposed in the surrounding areas for at least a mile around is the lower Fairport chalk, 5 to 10 m above the Fencepost Limestone. The age of this specimen is early Middle Turonian.

FHSM VP-12059--This specimen (Figure 9, 13) consists of a complete pectoral girdle assemblage, the right half of the pelvic girdle, left humerus, right femur, and portions of both front and rear paddles. Every pectoral and pelvic element bears serrated scavenging marks produced by *Squalicorax* (Schwimmer et al., 1997) and a *S. falcatus* tooth is still attached to the humerus. Shark scavenging may account for the complete lack of an axial skeleton. The specimen was assigned to *T. bentonianum* by Schumacher (2002) based upon the morphology of paddle material (see ESU 5000, above), the nature of the coracoids (only comparatively minor postero-lateral expansion), the ilium (straight, lacking posterior curvature), the pubis (only a subtle indentation of the antero-lateral border), and the ischium (straight, only relatively elongate with a rounded posterior border).

FHSM VP-12059 was collected from a road-cut in east-central Ellis County, just south of the Saline River, by Bruce Schumacher in 1991. The horizon of occurrence is the middle Fairport Chalk, although no distinctive marker units as outlined by Hattin (1962) were noted in the thinly exposed interval. However, numerous valve fragments of *Inoceramus cuvieri* bearing barnacles and serpulid worm tubes and thin calcarenites bearing external molds of *Collignoniceras woollgari* (characteristic of the middle Fairport) are present at the horizon of occurrence. The age of this specimen is early Middle Turonian.

FHSM VP-15575--This specimen consists of an articulated series of four dorsal vertebrae, three of which are still contained in a block of chalky limestone matrix along with the mold of the fourth. The vertebral centra are equi-dimensional (6 cm), bear prominent foramina on the lateral walls, and are slightly concave on the lateral and ventral surfaces. This matches the condition of vertebral centra observed in *Trinacromerum* (Carpenter, 1996; Storrs, 1999; O'Keefe, 2004), and this specimen is thus referred to cf. *T. bentonianum*.

FHSM VP-15575 was located on the Burger farm in northwestern Lincoln County. The block containing the specimen lay in the bottom of a drainage area with no geologic exposures nearby (Burger, pers. comm., 2003). The geologic map of Berry (1952) depicts the Graneros Shale, Greenhorn Limestone, and Carlile Shale occurring in northwestern Lincoln County. However, the block containing the specimen is undoubtedly from the Fencepost Limestone bed, Greenhorn Formation. The block still contains a drill hole along one side, indicating it most likely originated in a limestone quarry. Perhaps the block was discarded after it had fractured irregularly around the bones. Given that limestone fence-posts in Kansas were often transported many miles from their respective quarry areas, the geographic data of this specimen is most likely erroneous. The specimen is late Early Turonian or early Middle Turonian in age.

KUVP 1316--This previously undescribed specimen consists of a single cervical vertebral centrum that was originally identified as *Polycotylus latipinnis*. The centrum is 12 cm high, 14 cm wide, and 8 cm in length, and bears the typical ventral vascular foramina of plesiosaur cervical vertebrae. The central faces are only slightly concave, smooth and flat. The

dimensions of the centrum indicate that it is polycotylid, and the lack of constricted lateral and ventral walls is like that of *Trinacromerum* (Carpenter, 1996; Storrs, 1999; O'Keefe, 2004). We refer this specimen to cf. *Trinacromerum bentonianum*.

The locality of KUVP 1316 is listed as four miles north of Gorham on Salt Creek, in the Benton Cretaceous. Exposures in this area are of the uppermost Greenhorn Limestone and lowermost Fairport Chalk. The specimen is late Early Turonian or early Middle Turonian in age.

KUVP 1325--The type of *Trinacromerum anonymum* Williston (1903) consists of a maxilla and dentary fragments, a partially articulated series of cervical vertebrae, several dorsal and caudal vertebrae, interclavicle, a propodial, and a partial coracoid and ilium, and two phalanges. Carpenter (1996) referred this specimen as a junior synonym of *T. bentonianum*. Overall the specimen is relatively small, and the dorsal vertebral centra are uncrushed, cylinder-like and equi-dimensional. The reconstructed ilium (lacking sacral end) is nearly straight, possessing only a slight curvature. The propodial is largely reconstructed and thus cannot be critically assessed, but distal end is simple in its gently curved and rounded margin, lacking deep facets for the articulation of epipodials. This is likely in part due to the juvenile nature of the individual. A caudal vertebra bears facets for chevron articulations on both the anterior and posterior margins, as was noted in other specimens referred to *T. bentonianum* above.

KUVP 1325 was collected by Professor Benjamin F. Mudge in 1873 (Mudge's "*Ichthyosaurus*") near Paradise Creek in northwestern Russell County. The horizon is listed as "Benton, Cretaceous." Carpenter (1996) considered the horizon of occurrence to be the Fencepost Limestone bed, Pfeiffer Shale Member of the Greenhorn Limestone. In this instance, in contrast of the usual practice of the day, Mudge recorded the quarter section from which he collected the specimen. This location was visited in 2003, and the only exposures here are of the middle Fairport Chalk Member, Carlile Shale. As noted with other specimens from the Fairport Chalk, many of the elements bear tooth marks of scavenging sharks attributable to *Squalicorax* (Schwimmer et al., 1997). The age of the specimen is early Middle Turonian.

KUVP 1331--The specimen consists of 2 cervical, 5 dorsal, and 1 sacral vertebrae, and the proximal portion of a propodial originally identified as *Polycotylus* sp. The cervical and dorsal vertebral centra are cylinder-like, wholly uncrushed and well preserved, and in the manner of *Trinacromerum* are equi-dimensional and possess only very slight constriction of the lateral and ventral surface. The dorsal centra possess a highly prominent foramen on their lateral walls, and some of the central faces of the dorsal and sacral vertebrae possess a central dimple, sometimes surrounded by a slight swelling. Storrs (1999) noted a raised, central mammilla on the articular faces of *Polycotylus* vertebrae. Based upon the cylinder-like, equi-dimensional dorsal vertebral centra we refer this specimen to cf. *T. bentonianum.*

Records indicate that KUVP 1331 is from the Benton Cretaceous, "collected in 1921, nine miles northeast of Lincoln Centre (sic) near a big spring" and also state "several people obtained vertebrae of this specimen as souvenirs". The geologic map of Berry (1952) depicts exposures of the Carlile Shale and lower horizons in this area. Uncrushed preservation (lack of compaction) suggests burial in a bioturbated chalky limestone unit, which tend to produce more three-dimensional specimens. Thus the specimen likely occurred in limestone beds of the Greenhorn Limestone or the Fairport Chalk, and is Middle Cenomanian to Middle Turonian in age.

KUVP 5070--The type of *Trinacromerum willistoni* Riggs (1944) consists of a complete skull with mandible (Figure 14), fifty vertebrae (fifteen cervicals including the atlas-axis), ribs, most of the pectoral girdle, both pubes and the ischia (Riggs, 1944). The skull was discussed and figured by Carpenter (1996) who considered the specimen to be a junior synonym of *T. bentonianum*. Riggs describes the vertebral centra as "lengths are approximately equal to their height throughout." The ischia are only moderately elongate and straight, with a rounded posterior border.

Riggs (1944) indicated that KUVP 5070 was discovered by a road construction crew in December, 1936, while making a cut on US Highway 81, just south of Concordia, in Cloud County. Carpenter (1996) states that the specimen is "from" the Jetmore Chalk at top of the Hartland Shale Member. However, Riggs (1944, p. 77; see also Lane, 1946) gave the horizon of the specimen as ten feet "below the Jetmore Chalk Member," in the Hartland Shale Member, Greenhorn Limestone. The geologic map of Bayne and Walters (1959) verifies this information, showing only the Greenhorn Limestone in central Cloud County south of Concordia. The age of this specimen is middle Late Cenomanian.

YPM 1129--This referred specimen of *Trinacromerum anonymum* Williston (1908) consists of a partial skull (including the muzzle, portions of the basicranium and skull roof, and the mandibles), and a partial skeleton including complete series of twenty cervical vertebrae, three "pectorals", and twenty-three dorsal vertebrae for a presacral count of forty-six (Williston, 1908). Also present are a complete humerus and femur as figured by Williston (1908). This

specimen is listed as a junior synonym of *T. bentonianum* by Carpenter (1996).

YPM 1129 was collected in 1873 by Mr. Joseph Savage from the Benton Cretaceous of Kansas, "three miles south of the Solomon" (Williston, 1908) in Osborne County. There are good exposures of the "Fort Benton" interval located south of the Solomon River in this area. Williston (1908) also states that "the type specimen collected by the late Professor Mudge [is] from nearly the same locality and doubtless the same horizon in the Upper Benton". From this information we assume that the specimen was collected from the Fairport Chalk in Osborne County. This is also one reference in which Williston refers specifically to the Upper Benton (i.e. – Fairport Chalk and perhaps the Blue Hill Shale; presumably the "Lower Benton" corresponded to the Graneros Shale and Greenhorn Limestone). If our (and Williston's) assumptions are correct, the specimen is early Middle Turonian in age.

Superfamily PLESIOSAUROIDEA Welles, 1943
Family ELASMOSAURIDAE Cope, 1869
ELASMOSAURIDAE
Figure 15

FHSM VP-15576--This specimen consists of an articulated series of nine elongate cervical vertebrae bearing prominent longitudinal ridges. The vertebrae are twice as long as wide (roughly 12 by 6 cm), and some bear short, hatchet-shaped ribs. The vertebrae are undoubtedly those of an elasmosaur, as evidenced by the prominent longitudinal ridges (Welles, 1943, 1952, 1962; O'Keefe, 2001) but the specimen is not diagnostic below a familial level.

A display placard with FHSM VP-15576 states that it was found by J.C. Harksen, 3 miles east of Pfeifer in the Graneros Shale, and that it was collected by Orville Bonner in 1962. The geologic map of Neuhauser and Pool (1988) depicts a large area of Graneros Shale in southeastern Ellis County, east of Pfeifer. The preservation of the specimen itself is dark and gypsiferous, owing to its shaly origin, although the precise position within the Graneros Shale is unrecorded. The specimen is Middle Cenomanian in age.

KUVP 441--The type of *Ogmodirus martini (*"*martinii*") Williston and Moodie (1913; 1917) was collected near the town of Aurora in Cloud County. We note here that the original name given to the specimen, *Ogmodirus martini* (Williston and Moodie, 1913), takes precedence over the occasionally used mis-spelling, "*O. martinii*" (Welles, 1943; Lane, 1946). The specimen consists of an incomplete juvenile skeleton lacking cranial material. Welles (1943) devoted some discussion to the specimen and later considered it a *nomen vanum* because he felt the juvenile morphology was not diagnostic (Welles, 1962). Storrs (1999) considered the specimen a *nomen dubium*. Based upon the cervical count which is minimally fifty-one (Williston and Moodie, 1917), there is little doubt that the specimen is elasmosaurid, and thus constitutes one of only three well substantiated records of long-neck plesiosaurs in the "Fort Benton" of central Kansas. As noted by Storrs (1999), the cervical vertebrae are shorter than is typical of elasmosaurids. This may constitute a valid character serving to distinguish the material as diagnostic, or may not, in light of potential ontogenetic variability.

The locality of KUVP 441 is listed as the Niobrara Cretaceous, but as noted previously, the Greenhorn Limestone is the youngest Cretaceous unit present in Cloud County (Bayne and Walters, 1959). Williston and Moodie (1917) state "This material was collected in 1909 by Mr. C. Boyce in Cloud County, Kansas, associated with the remains of another plesiosaur, and presented by him to the University of Kansas. Its horizon is probably the Fort Hays limestone of the basal Niobrara, though possibly, but improbably, from the uppermost horizon of the Benton." Why Williston felt that the specimen was from the Fort Hays Limestone is not clear, but the same dilemma was apparently considered by Schultze et al. (1985), who list the specimen as being from the Greenhorn Limestone. The remains are well preserved and uncrushed, suggesting preservation in non-laminated chalk or chalky limestone rather than shale or marl. This suggests the specimen is from the upper Greenhorn Limestone or lower Fairport Chalk, where non-laminated chalky limestone beds occur. Given that the Carlile Shale is not present in Cloud County, the specimen is likely from the upper Greenhorn Limestone. The age of this specimen is Early Turonian.

KUVP 1318--In his writings, Williston mentions two other occurrences of what are likely elasmosaurs from the "Benton" of central Kansas. He mentions one specimen twice, both in Williston (1893) and Williston (1903). In 1893 he states "Some of the pebbles were attached by the original soft limestone matrix to the ribs and thoracic vertebræ, so that that there could not be a shadow of doubt of the contemporaneity of deposition." In 1903 he states, "Nearly ten years ago some plesiosaur bones collected near Ellsworth, Kansas, from the Benton Limestone, were sent to the Kansas University museum, together with a lot of siliceous stones." The only specimen in the KU collections matching this description is KUVP 1318, consisting of nearly 90 gastroliths, and a rib fragment contained in chalky limestone matrix along with an additional gastrolith. We assume this specimen represents partial remains of an elasmosaurid, because gastroliths are much more commonly reported and in greater abundance with elasmosaur skeletons

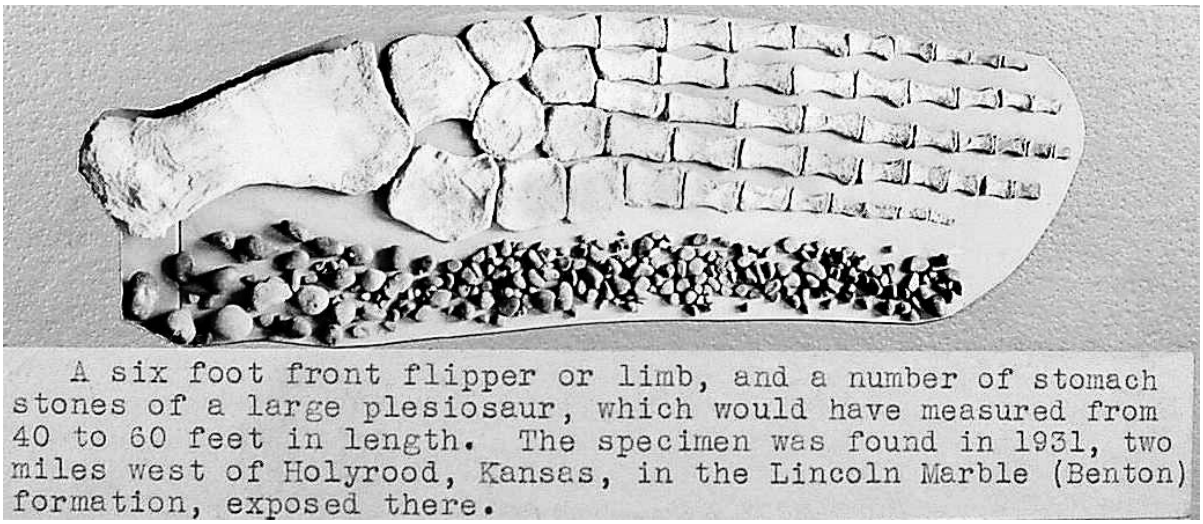

FIGURE 15. UNSM 1195; fore(?) paddle of indeterminate elasmosaur, along with numerous gastroliths and historical contextual data on placard from the archives of the Sternberg Museum of Natural History. (Approximate length = 1.6 m)

(Williston, 1893; Riggs, 1939; Welles and Bump, 1949; Darby and Ojakangas, 1980; Everhart, 2000) than with those of polycotylids (Kennedy and Martin, 1988; Schumacher, 1999). To our knowledge, there are only two references attributing gastrolith use to pliosaurids (Andrews, 1913; Whittle and Everhart, 2000).

Unfortunately no contextual information exists with KUVP 1318. The geologic map Bayne et al. (1971) shows that the youngest Cretaceous unit present in Ellsworth County is the Carlile Shale, so there is no possibility the specimen is from the Niobrara Formation. However, two other units that could possibly have produced the remains, the Graneros and Kiowa shale, are both present in Ellsworth County. An additional stratigraphic clue is Williston's mention of limestone in both of the above passages. These statements, plus the chalky matrix preserved around the rib fragment, suggest the specimen was likely collected from a carbonate unit of the "Benton". From this information we can deduce that this specimen is from Greenhorn Limestone or the Fairport Chalk. The age of this specimen could range from the Middle Cenomanian to Early Turonian.

Unknown KUVP Specimen--Williston (1903) alluded to "Another form known of which a considerable part of the vertebral column is preserved at the museum of the University of Kansas, is of great size, the dorsal centra measuring five inches or more in diameter, with a very long neck and small anterior cervicals. The specimen is from near Beloit. It represents a distinct species that may provisionally be referred to *Cimoliasaurus* or *Brimosaurus*." In his discussion of KUVP 1318 (above), he states that 1318 "is identical with that mentioned in the preceding pages as coming from the vicinity of Beloit." It is not at all certain why he felt these two rather loosely referred to specimens were con-specific, though perhaps he was referring to their stratigraphic positions as much as their morphology.

The geologic map of Hodson (1959) depicts mainly the Graneros and Greenhorn formations in the vicinity of Beloit, Mitchell County, with small patches of Carlile Formation. Without knowing which specimen Williston was referring to, it is impossible to determine more about the stratigraphic position, and the specimen is mentioned here for sake of completeness. The possible age of this specimen ranges from Middle Cenomanian to Middle Turonian.

USNM 1195--This specimen was discovered by Joe Purzer in 1931, and was collected by George F. Sternberg and M. V. Walker in September of that year. The original description indicates the specimen includes many vertebrae and ribs, a complete right front paddle, portions of the pectoral and pelvic girdles including at least one ilium, both femora, most of both rear paddles, and a large assemblage of gastroliths. This information was verified in 2004 by George Corner (University of Nebraska, Lincoln), who stated that the skeleton was in good condition and about 70% complete. Although lacking a skull, two teeth are present with the specimen. The paddle currently on display in UNSM was originally prepared and mounted in the Sternberg Museum as indicated by archival photographs (Figure 15), and was then acquired along with the remainder of the skeleton by the UNSM around 1935. The paddle material does not compare favorably with known elasmosaurid taxa. In particular,

it does not compare at all well with *Thalassomedon haningtoni*, the only other Western Interior elasmosaur taxon of comparable age. This specimen should be studied more closely as it may represent an undescribed taxon.

USNM 1195 was collected from the "Lincoln Marble" (Lincoln Limestone Member, Greenhorn Limestone) two miles west of Holyrood in southwestern Ellsworth County. The specimen is Middle Cenomanian in age.

DISCUSSION

Although the sample size presented here is relatively small, we feel that a number of important observations can be made about the relative abundance of the three plesiosaur morphotypes, especially when compared to the numbers reported from the Niobrara Chalk and the Pierre Shale in west-central Kansas. These statements apply to a very small part of what was an enormous ecosystem within the Western Interior Seaway, and the broad ecological generalizations drawn here are only intended to refer to the "Fort Benton" period of west-central Kansas. We note that the major collections of the continental United States house roughly 35 reported polycotylid specimens from the Niobrara Chalk and Pierre Shale (Coniacian – Early Campanian) of Kansas, and fewer than 15 reported elasmosaurid specimens (Everhart, 2005) from the same interval. This statement is made in reference to specimens housed in all of the previously referenced institutions, but also including the AMNH, CMC, LACMNH, MCZ, and UWM. As stated earlier, we are not aware of any pliosaurid material from post-Turonian horizons.

Similarly, there are a relatively large number of polycotylid specimens reported herein from the "Fort Benton" of central Kansas (fourteen), and only four (possibly five) records of elasmosaurs. Thus it seems that polycotylids are much better represented than are elasmosaurids from Cenomanian through Early Campanian time in central Kansas. The lesser number of reported pliosaurid specimens is understandable ecologically, as they likely filled the role of top predator, and as such should be fewer in number.

Plesiosaurs are poorly represented in the Graneros Shale, middle Greenhorn Limestone, and Blue Hill Shale. The Bonner elasmosaur (FHSM VP-15576) constitutes the sole specimen reported from the Graneros Shale, although two occurrences of *T. haningtoni* are known from the Graneros Shale in southeastern Colorado (DMNH 1588) and southeastern Nebraska (UNSM 50132). Two specimens (FHSM VP-13997 and UNMS 1195) are reported from the basal Lincoln Limestone calcarenites, Greenhorn Limestone. The basal Lincoln Limestone is resistant and moderately well exposed, and given the highly fossiliferous nature of the calcarenite layers (Hattin, 1975; Liggett et al., 1997; Shimada and Martin, 1993; Shimada and Schumacher, 2003; Shimada et al., 2003), further reconnaissance of this interval will undoubtedly produce more plesiosaur remains. Isolated teeth from the basal Lincoln Limestone Member attributable to cf. *Brachauchenius* are present in collections of the Sternberg Museum (FHSM VP-12058, FHSM VP-14782). The type of *Trinacromerum* "*willistoni*" (KUVP 5070) constitutes the only specimen we report from the middle Greenhorn interval. Younger horizons in the uppermost Greenhorn have produced only three well-substantiated cases of plesiosaur remains, all of them polycotylids.

The Fairport Chalk Member, Carlile Shale, has yielded a relatively large number of plesiosaur specimens in light of the fact that it is typically poorly exposed, and its total outcrop area is much smaller than that of the Smoky Hill Chalk (Hattin 1962, 1982). A combination of stratigraphic thickness, geomorphology, and lack of resistant limestone intervals has dictated that the Fairport, in particular the middle and upper portions of the unit, is poorly exposed. Even so, a minimum of seven relatively complete polycotylid skeletons are known from the Fairport Chalk, while only three are known from the whole of the Smoky Hill Chalk (Everhart, 2003). Five of the nine polycotylid partial skeletons and/or skulls reported herein were collected from the rather limited, artificial exposures along road-cuts, again testifying to the relative richness of plesiosaur remains in the uppermost Greenhorn Limestone and Fairport Chalk (Schumacher, 2004).

In addition to the plesiosaurs discussed herein, we note that the Fairport Chalk preserves abundant shark remains (Hattin, 1962; Everhart and Darnell, 2004), bony fish (Bardack, 1965; Martin and Stewart, 1977; Fielitz and Shimada, 1999), turtles (Stewart, 1978; Schumacher, pers. obs.), mosasaurs (Martin and Stewart, 1977) and the toothed bird, *Ichthyornis* (Martin and Stewart, 1978). If the Fairport Chalk were as well exposed over as large an area as the Smoky Hill Chalk, it is likely there would be as many vertebrate remains known from this unit as its younger, more westerly neighbor. The much greater number of plesiosaur specimens occurring in the upper Greenhorn and lower Fairport coincides with maximum transgression of the Greenhorn Cyclothem (Kauffman and Caldwell, 1993). No plesiosaur remains are noted from the Blue Hill Shale and it is likely that more favorable paleo-environmental conditions account for the disparity, with better circulated, well oxygenated waters present during the Lower and early Middle Turonian.

CONCLUSIONS

Stratigraphic units in central Kansas that were historically referred to as the Fort Benton Group (Graneros Shale, Greenhorn Limestone, Carlile Shale) have produced a relatively large number of plesiosaur specimens. Nearly half of the specimens reported herein (eleven of twenty-four) are housed in the Sternberg Museum of Natural History, likely due to its close proximity to old "Fort Benton Group" exposures. We find that the only diagnostic plesiosaur remains of the "Fort Benton" interval are attributable to *Trinacromerum* and *Brachauchenius*. Long-neck taxa are present, but they are poorly represented both in terms of number of specimens and diagnostic material. We report pliosaurs from the lower Upper Cenomanian to the lower Middle Turonian, a span of about 3 million years, and polycotylid specimens spanning nearly the same interval. It is probable that additional taxa will eventually be recognized within this time frame, as we are also aware of an unnamed polycotylid from Cenomanian deposits.

While not as well known as their relatives from the Niobrara Chalk and Pierre Shale (*Dolichorhynchops*, *Polycotylus*, *Styxosaurus, Elasmosaurus*), plesiosaurs of the old "Fort Benton Group" (*Brachauchenius*, *Trinacromerum,* and elasmosaurids) constitute a relatively rich record. The old "Fort Benton Group" is not as well expressed at the surface nor as intensely studied as the Smoky Hill Chalk badlands in western Kansas, yet it has produced nearly as many partial plesiosaur skeletons. The upper Pfeifer Shale Member, Greenhorn Limestone and the Fairport Chalk Member, Carlile Shale, in particular, have produced a significant number of pliosaurid and polycotylid skeletons. Polycotylids are especially well represented, accounting for sixty percent of the reported specimens. The lesser number of pliosaurid specimens is rationalized due to their ecological role as top predator. Elasmosaurs were about equally as abundant as pliosaurids, and were a relatively rare component of the fauna compared to the short-necked forms.

ACKNOWLEDGMENTS

We thank Bob (BJ) Jennrich for escorting members of the Sternberg Museum staff to the site where he discovered and assisted George Sternberg in exhuming FHSM VP-321. This skull continues to serve as one of the finest examples of a pliosaur yet known. The contributions of both BJ and his brother Frank to the legacy of paleontology in Kansas will have everlasting value. Dr. Paul Johnston (Emporia State University, Emporia, KS) provided a detailed description of the discovery and loss of the ESU specimen to vandals, and photographs of the dig site. Larry Martin (University of Kansas, Lawrence) provided access to specimens and assisted in researching historical locality information. Robert Purdy (National Museum of Natural History, Washington, D. C.) supplied contextual information regarding specimens of plesiosaurs from Kansas in the USNM collection. George Corner (University of Nebraska, Lincoln) kindly provided details about UNSM 1195. Richard Zakrzewski (Sternberg Museum) supplied information about FHSM VP-6618, and permitted the loan of specimens for study. Greg Liggett assisted in field checking historical localities and in locating previously uncatalogued specimens stored at Fort Hays State University campus. Comments by Drs. F. R. O'Keefe, A. R. J. Cruickshank, and K. Carpenter greatly improved earlier drafts of this paper.

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