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A mosasaur from the Lewis Shale (Upper Cretaceous), northwestern New Mexico

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Mosasaurs are an extinct group of giant marine lizards that flourished during the Late Cretaceous. Their fossilized remains are known from all the continents except Antarctica; the largest and best known collections come from the Niobrara Formation in Kansas. Although marine sediments of Late Cretaceous age are exposed throughout large areas of New Mexico, only three mosasaur specimens have previously been reported from the state. These specimens were found in south-central New Mexico in the Jornada del Muerto region (Cope, 1871a) and in northeastern New Mexico in the Raton Mesa region (Lee, 1917). Late Cretaceous marine deposits in other parts of New Mexico, including extensive exposures of the Lewis Shale in and around the San Juan Basin, until recently have failed to produce mosasaur remains. The discovery of a mosasaur in the Lewis Shale as reported herein is the fourth report of a mosasaur from New Mexico (fig. 1) and the first report of a mosasaur from the Lewis Shale. This discovery extends the geographic range of the mosasaurs into that part of the sea that covered northwestern New Mexico during the Late Cretaceous.

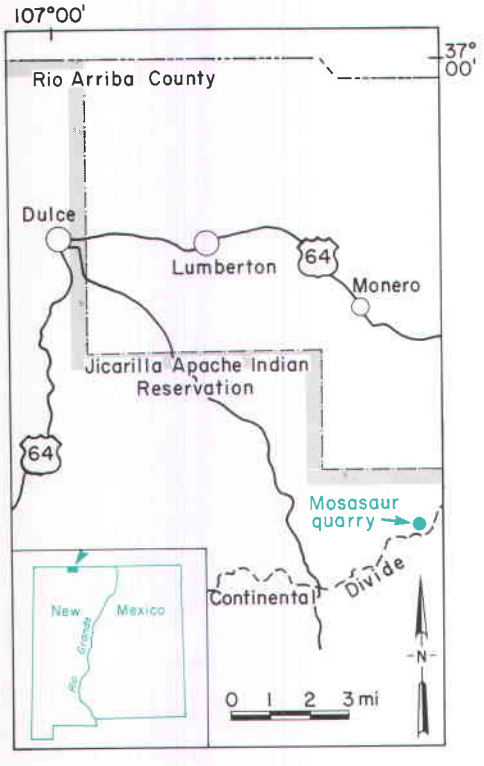

FIGURE 1—MAP OF PART OF NORTHWESTERN NEW MEXICO SHOWING THE LOCATION OF UNM-V-070, THE MOSASAUR QUARRY.

The following abbreviations are used in the text: AMNH—Department of Vertebrate Paleontology, American Museum of Natural History, New York; UNM—Department of Geology, University of New Mexico, Albuquerque; YPM—Peabody Museum of Natural History, Yale University, New Haven.

Lewis Shale and its fauna

The Lewis Shale was named by Cross and others (1899) for exposures around Fort Lewis, an old army post in the La Plata River valley in southwest Colorado. Primarily composed of dark-gray to greenish-gray shale with some sandy layers, limestone, and calcareous nodules, the Lewis Shale has been mapped throughout a large area in northwestern New Mexico and southwestern Colorado (Reeside, 1924; Dane, 1936; O'Sullivan and others, 1972). The Lewis Shale was deposited offshore in the regressing seaway that covered this region during the Late Cretaceous (Fassett and Hinds, 1971; Mannhard, 1976).

The fauna of the Lewis Shale is mainly a diverse assemblage of marine bivalves, gastropods, and cephalopods (Reeside, 1924; Dane, 1936; Cobban and others, 1974; Mannhard, 1976). Worm burrows and other trace fossils (for example, *Ophiomorpha*) also are present. The only vertebrates previously reported from the Lewis Shale are shark's teeth (for example, *Lamna* sp.) and bony fish scales (Mannhard, 1976).

Systematic paleontology

Class REPTILIA
Order SAURIA
Family MOSASAURIDAE Gervais, 1853
Subfamily PLIOPLATECARPINAE (Dollo, 1884) Williston, 1897
Tribe PLIOPLATECARPINI (Dollo, 1884) Russell, 1967
Genus *PLATECARPUS* Cope, 1869
cf. *Platecarpus* sp.

REFERRED SPECIMEN—UNM-LK-1; a partial skeleton consisting of 46 vertebrae (14 dorsals, (?)5 pygals, and 27 caudals) of variable preservation, two nearly complete thoracic ribs and fragments of others, and assorted lower(?) jaw and tooth fragments.

LOCALITY—UNM-V-070; in the NE¼ SW¼ sec. 9, T. 30 N., R. 1 E. on the Jicarilla Apache Indian Reservation southeast of Dulce, New Mexico (figs. 1-2).

COLLECTORS—Originally discovered by Adolph Julian and Darrell Paiz, members of the Jicarilla Apache Indian Tribe; collected by the authors.

HORIZON AND AGE—In dark-gray fissile shale of the Lewis Shale. Cobban and others (1974) recently reported a number of ammonites and other invertebrates from the Lewis Shale along the eastern edge of the San Juan Basin. UNM-V-070 is southeast of their locality D4151 and northeast of their locality D5087. Both D4151 and D5087 are stratigraphically higher in the Lewis Shale than UNM-V-070 and are placed by Cobban and others (1974) in the Late Campanian *Didymoceras cheyennense* ammonite zone. Probably UNM-V-070 is Late Campanian in age (no older strata are known in the Lewis Shale) (Cobban and others, 1974) and older than the *D. cheyennense* zone. Unfortunately, a diligent search of the limited Lewis Shale outcrops around UNM-V-070 yielded only undiagnostic fragments of inoceramid shells; hence, its age cannot be more precisely determined.

FIGURE 2—VIEW OF EXCAVATED MOSASAUR REMAINS AT UNM-V-070; the man is pointing at the posterior end of the articulated portion of the vertebral column.

DISCUSSION—The taxonomy of mosasaurs, like many groups of reptiles, is based heavily on cranial characters (Russell, 1967). The absence of any cranial remains of UNM-LK-1 other than jaw and tooth fragments thus renders difficult a precise identification of the specimen. Fortunately, subfamilies and tribes of mosasaurs can be diagnosed largely on the basis of vertebral characters (Russell, 1967). In addition, the tooth and jaw fragments of UNM-LK-1 aid in a tentative assessment of its generic identity.

The following considerations justify assignment of UNM-LK-1 to the Plioplatecarpinae as defined by Russell (1967): 1) UNM-LK-1 was a mosasaur of moderate size, probably about 6 m in overall length, based on comparison of the length of its incomplete dorsal series with vertebral and body lengths of various mosasaurs given by Russell (1967, tables 2-3). All plioplatecarpines are moderate-sized mosasaurs (Russell, 1967); UNM-LK-1 is well within the size range of all plioplatecarpine specimens in the YPM collections. Although undue emphasis should not be placed on size as a diagnostic character in reptiles (animals with indeterminate growth), no evidence exists to suggest that UNM-LK-1 was a particularly young individual; that it is just a small representative of one of the giant mosasaurs like *Mosasaurus* or *Tylosaurus* seems unlikely. 2) All caudal vertebrae of ☞

UNM-LK-1 have unfused haemal arches (fig. 3, C-E). The haemal peduncles are subcircular, centrally pitted, posteroventrally directed, and located near the posterior end of the centrum lateral to the ventral midline. This condition is seen in the plioplatecarpines but not in the mosasaurines in which the haemal peduncles typically are fused to the caudal centra (Russell, 1967). 3) Other vertebrae of UNM-LK-1 correspond well to those of plioplatecarpines, although by themselves they are not sufficient to diagnose the group. A typical median dorsal vertebra (fig. 3, J-L) has the synapophysis located on the anterodorsal aspect of the centrum, an anterior articular cup that is wider than tall, and a posterior articular ball that likewise is transversely oval. This vertebra closely resembles median dorsal vertebra of *Platecarpus* (Cope, 1875, pl. 20, figs. 1A-C, pl. 21, figs. 1A-B, 2; Williston, 1898, pl. 42, figs. 3-4). An anterior dorsal vertebra of UNM-LK-1 (fig. 3, G-I) is similar, although the centrum is slightly longer and the articular surfaces a little more circular, being less flattened transversely. This vertebra preserves the posterior zygopophyses which are small and located on the posterior edge of the base of the neural arch. The vertebra of this specimen also closely resembles anterior dorsal vertebrae of *Platecarpus* (Cope, 1875, pl. 20, figs. 5M-N). Most of the dorsal vertebrae of UNM-LK-1 are not as well preserved as this one; typically, the neural arch and spine is no longer present. No evidence of a zygosphene-zygantrum can be discerned on any of the vertebrae, but almost all of the vertebrae are so badly damaged that ascertaining whether or not at least a small zygosphene-zygantrum articulation was present at some point on the dorsal vertebral column is impossible. 4) As Russell (1967, p. 54) has pointed out, the marginal teeth of mosasaurs are "often generically diagnostic." Among the tooth and jaw fragments of UNM-LK-1 is a nearly complete tooth (fig. 3, A-B) that is long, slender, and has a pointed tip that is posteromedially recurved. This tooth has a subcircular cross section near the base of the crown and bears distinct anterior and posterior carinae that run the vertical length of the crown. The buccal aspect of this tooth bears six vertical facets whereas the lingual aspect bears numerous thin vertical striations. This type of tooth is typical of all plioplatecarpines (Russell, 1967).

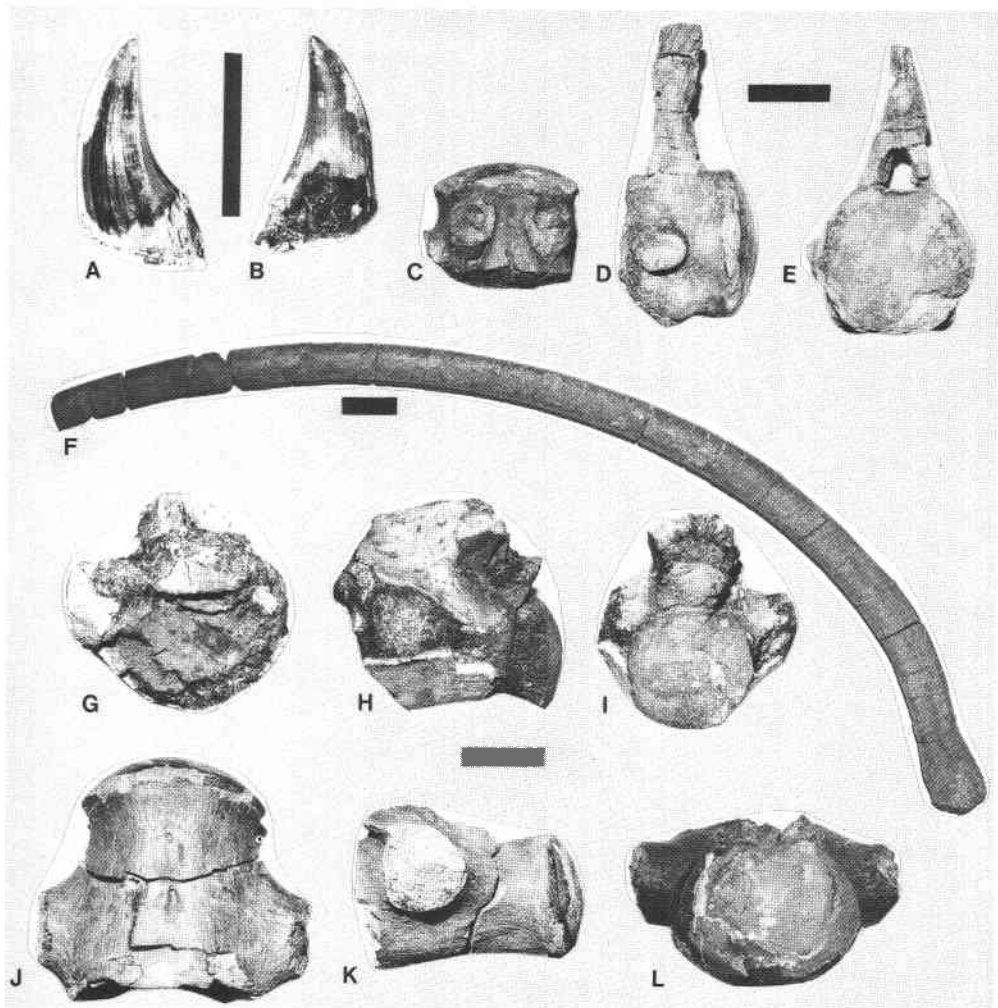

FIGURE 3—SELECTED ELEMENTS OF UNM-LK-1, A PARTIAL SKELETON OF CF. *PLATECARPUS* SP.; buccal **(A)** and lingual **(B)** views of a lower(?) tooth; ventral **(C)**, left lateral **(D)**, and posterior **(E)** views of an anterior caudal vertebra; **(F)** anterior view of a thoracic rib; anterior **(G)**, left lateral **(H)**, and posterior **(I)** views of an anterior dorsal vertebra; ventral **(J)**, left lateral **(K)**, and posterior **(L)** views of a median dorsal vertebra. Black bars are 3 cm long (one scale for A and B; one for C, D and E; one for F; and one for G, H, I, J, K, and L).

Assigning UNM-LK-1 as a plioplatecarpine to *Ectenosaurus, Plioplatecarpus,* or *Platecarpus* is difficult without good cranial material preserving the characters upon which these genera largely are differentiated. Nevertheless, some slight evidence from the postcrania argues against assignment to either *Ectenosaurus* or *Plioplatecarpus.* Thus, Russell (1967, p. 158), in his diagnosis of *Ectenosaurus,* noted that its pygal vertebrae have relatively long transverse processes. In contrast, the pygal vertebrae of UNM-LK-1 have relatively short transverse processes; comparison of two pygal vertebrae with nearly equal-sized centra of UNM-LK-1 and YPM 4672, a specimen referred to *Ectenosaurus* by Russell (1967), reveals that the UNM specimen's transverse processes are approximately 30 percent shorter than those of YPM 4672. Assignment of UNM-LK-1 to *Plioplatecarpus* seems to be precluded by two features: 1) Dollo (1893) stated that *Plioplatecarpus* has only 13 dorsal vertebrae, a claim reluctantly accepted by Russell (1967); UNM-LK-1 has 14 dorsals in its incomplete vertebral column,; and 2) according to Russell (1967, p. 159) the synapophyses of the anterior dorsal vertebrae of *Plioplatecarpus* are located in the center of the lateral aspects of the centra. The synapophyses of the anterior dorsals of UNM-LK-1, as noted above (fig. 3, G-I), are located on the anterodorsal edge of the lateral aspects of the centra; this is the same condition seen in *Platecarpus* (Russell, 1967). Assignment to *Platecarpus* is further justified by the fact that UNM-LK-1 closely resembles YPM 1256, 1258, 1264, 1269, 1272, and 1286, specimens referred to *Platecarpus* by Russell (1967).

Despite the above characters of UNM-LK-1 that seem to preclude its assignment to *Ectenosaurus* or *Plioplatecarpus,* we believe that there is enough uncertainty about the diagnostic utility of these characters due to potential variability that we only tentatively assign the specimen to *Platecarpus.* Assignment to a species of *Platecarpus* clearly is impossible because the species of the genus are distinguished by cranial characters (Russell, 1967) not preserved in UNM-LK-1.

Platecarpus (fig. 4) is a Campanian genus of mosasaurs known elsewhere in the Western Interior from the Pierre Shale in Wyoming, South Dakota, and Kansas (Russell, 1967). Extension of the genus southward into roughly time-equivalent, though probably slightly younger, deposits is not surprising in view of the great mobility of mosasaurs that gave them an extensive geographic distribution during the Late Cretaceous (Russell, 1967).

Taphonomy

Mosasaur remains commonly are found disarticulated to a degree similar to that of UNM-LK-1 (figs. 2, 5, 6); here we offer some observations and speculation on how this specimen came to be disarticulated and then buried. UNM-LK-1 was found in thinly lami-

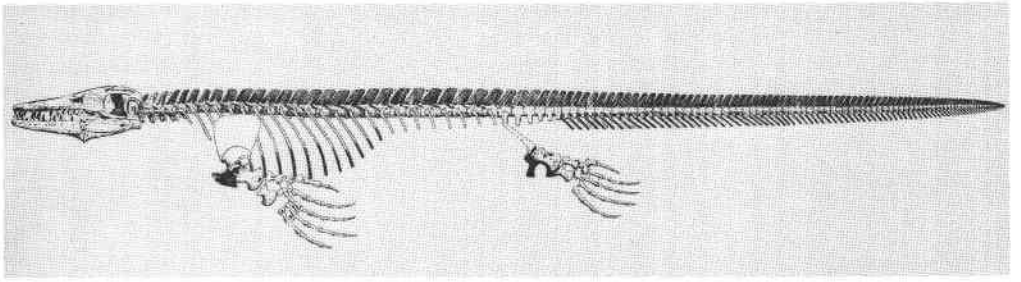

FIGURE 4—RECONSTRUCTED SKELETON OF *PLATECARPUS ICTERICUS*, ACTUAL LENGTH ABOUT 6 M (WILLISTON, 1898).

nated dark-gray shale suggestive of an offshore environment of relatively deep and quiet water. The anterior and medial dorsal vertebral column was found articulated, though slightly twisted in the middle. The posterior dorsal, pygal, and caudal vertebrae are nearly all disarticulated; they were probably less tightly bound together by bony processes, axial muscles, tendons, and ligaments than the more anterior parts of the vertebral column. The degree of disarticulation of UNM-LK-1 suggests a fairly long period of decomposition before final burial in the sediment. This decomposition may have occurred in part as the dead animal floated in the water column, but most decomposition probably occurred as the animal lay on the bottom, since the disarticulated bones show a preferential northwest-southeast alignment shared by the still articulated portion of the vertebral column. Mixed among the disarticulated vertebrae are invertebrate shell fragments, shark's teeth, and bony fish scales that could represent either gut contents of the mosasaur or organic debris present in the sediment where the dead animal came to rest, or both.

The orientation of most of the bones (a notable exception is the rib in the lower left hand corner of fig. 5) suggests the presence of a distinct, though most likely slight, bottom current probably flowing predominately to the northwest because most of the bones are scattered in this direction. The absence of the skull and cervical vertebrae of UNM-LK-1 may be because the anterior end of the animal first was exposed in an arroyo (fig. 5); these elements, if they were fossilized, have long since eroded away. The girdles and appendages, on the other hand, may have been removed in a number of ways.

A number of grooves and scratches on vertebrae and rib fragments of UNM-LK-1 may indicate scavenging, a plausible mechanism by which the girdles and appendages may have been removed. However, the specimen is so damaged by weathering and the roots of recent plant growth that we hesitate to support such a conclusion firmly. The girdles and appendages simply may have floated away once they became detached from the vertebral column or may have fallen off elsewhere when the decomposing animal was floating in the water column.

Most difficult to explain is how the jaw fragments came to be buried beneath the mixed-up posterior dorsal, pygal, and caudal vertebrae. Either the jaw of the animal fell first and the rest of the carcass fell on top of it, or the jaw broke up and was carried northwestward by bottom currents where it mixed with the vertebrae and sank deeper into a soft bottom than did the vertebrae. The former explanation is simpler, but the varied aspects of the disarticulated vertebrae exposed on the quarry surface (fig. 6) suggest tumbling and sinking at various angles into a soft bottom and might support the later explanation. A third possibility is that the jaw fragments are those of a different individual than the vertebrae and ribs. We see no clear way to decide among these three possibilities. Although nothing about the size and morphology of the Lewis Shale mosasaur remains to suggest that they belonged to more than one individual, this chastening possibility must always be entertained when dealing with fossil material in a state of disarticulation or incompleteness.

Summary of marine reptiles in New Mexico

Among the Reptilia three main groups adapted to life in the marine realm: ichthyosaurs, plesiosaurs, and mosasaurs. Some representatives of other reptile groups, notably turtles and crocodiles, have also invaded marine niches, but are not considered here.

Ichthyosaurs were a widespread group of fishlike marine reptiles during the Mesozoic. Although their remains have been found in Triassic, Jurassic, and Cretaceous deposits of western North America (McGowan, 1978), to our knowledge no ichthyosaurs have been reported yet from New Mexico.

Plesiosaur remains, on the other hand, have been reported from two localities in New Mexico. Cope (1887) described plesiosaur remains from what he termed the "Fox Hills bed of New Mexico." He assigned the following taxonomic names to these remains: *Piptomerus megaloporus* new genus and species, *P. microporus* new species, *P. hexagonus* new species, and *Orophosaurus pauciporus* new genus and species. Williston (1903, p. 11) later listed these taxa and summarized their supposed diagnostic characters. Welles (1952), in a revision of North American plesiosaurs, considered all of Cope's taxa to be based on indeterminate material and thus declared them to be *nomina vana* (vain or void names). The locality from which these plesiosaurs were collected was not given by Cope and the Fox Hills Formation is not present in New Mexico, being currently restricted to strata in North ☞

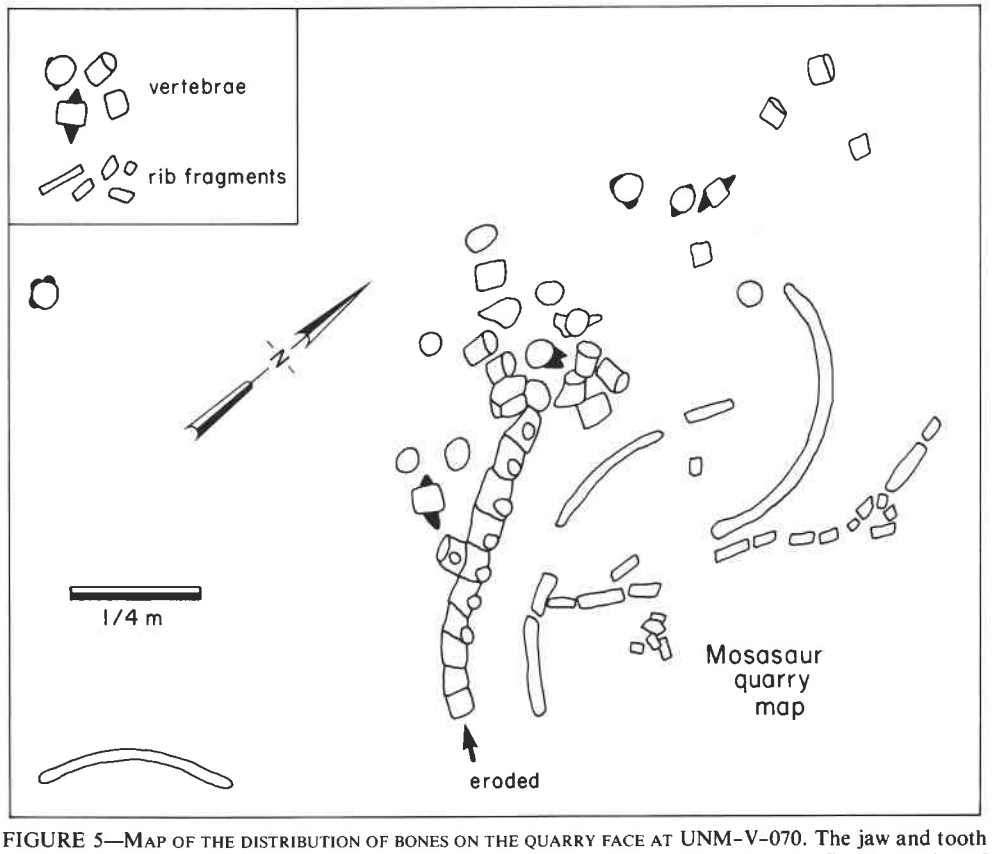

FIGURE 5—MAP OF THE DISTRIBUTION OF BONES ON THE QUARRY FACE AT UNM-V-070. The jaw and tooth fragments were found beneath the disarticulated vertebrae in the center of the drawing (fig. 6). Erosion of an arroyo first exposed the southern end of the articulated vertebral column and may have removed the skull and cervical vertebrae.

FIGURE 6—DORSAL, PYGAL, AND CAUDAL VERTEBRAE LYING MIXED UP AND DISARTICULATED ON THE QUARRY FACE AT UNM-V-070. These vertebrae are some of those just north of the articulated portion of vertebral column in fig. 5.

Dakota, South Dakota, Montana, Wyoming, and Colorado as far south as the Colorado Springs area (Waage, 1968). Despite this, two clues to the provenance of Cope's plesiosaurs are available: 1) the specimen label with the type of *Orophosaurus pauciporus,* AMNH 5692, states the locality as "Cretaceous. San Juan Basin, N.M." and 2) the term Fox Hills bed used by Cope (1887) would have referred to the uppermost marine Cretaceous below the continental coal-bearing strata of what was then called the "Laramie Formation," even outside the areas where these formations are now considered to be present (K. Waage, personal communication, 1980). The Laramie Formation in the San Juan Basin in Cope's day encompassed rocks now referred to the Fruitland and Kirtland Formations (Reeside, 1924). Cope's Fox Hills bed, which produced the plesiosaurs, must be what is now called the Pictured Cliffs Sandstone or Lewis Shale, or perhaps included parts of both. Cope's indefatigable collector David Baldwin, who worked in the San Juan Basin during the 1880's, most certainly found these specimens.

Cunningham (1966) published the second report of plesiosaur remains from New Mexico by mentioning eight vertebrae of a "Cretaceous vertebrate" from the Colorado Shale in the Big Burro Mountains of southwestern New Mexico. Subsequently, J. T. Gregory of the University of California (Berkeley) identified these as belonging to an elasmosaurid plesiosaur (J. Cunningham, personal communication, 1980).

The first previous report of a mosasaur from New Mexico mentioned at the beginning of this paper was Cope's (1871a, p. 572) brief description of a series of vertebrae from "near Fort McRae, New Mexico" to which he attached the name *Liodon dyspelor* n. sp. Cope (1871b, c) later described this specimen in greater detail, listing measurements of the vertebrae as well. Specimens from the Kansas Cretaceous referred to *L. dyspelor* were described and compared to the New Mexico specimen by Cope (1872), but it was Leidy (1873, pls. 35-36) who first illustrated the New Mexico specimen. Leidy (1873, p. 271-274) referred *L. dyspelor* to *Tylosaurus;* according to Russell (1967, p. 184), *T. dyspelor* is based on indeterminate material and thus is best considered a *nomen vanum.*

Cope's type specimen of *L. dyspelor* was collected by W. B. Lyon, a surgeon stationed at Fort McRae, an old army post that was just east of the present site of Elephant Butte Reservoir in south-central New Mexico (Cope, 1871b). In his final description of this specimen, Cope (1875, p. 167) explained that it came "from the yellow beds of the Niobrara epoch of the Jornada del Muerto, near Fort McRae, New Mexico." Cope probably was referring to beds of the Mancos Shale that are exposed in the Jornada del Muerto region (Kelley and Silver, 1952) and are, in part, a correlative of the Niobrara Formation.

Lee (1917, p. 46-47) can be credited with the other two previous reports of mosasaurs from New Mexico. He listed *Mososaurus* sp. (sic) from two localities in the Raton Mesa region: 1) "North wall of Cimarron Canyon, about 4 mi northwest of Cimarron; 100 ft below top of Pierre Shale and 2) "Van Bremmer Canyon, New Mexico, a mile from its mouth, in slide rock; at base of Trinidad Sandstone." Unfortunately, Lee did not describe or illustrate any specimens so their assignment to *Mosasaurus* remains unverified.

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