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A NEW SPECIES OF *TRILOPHOSAURUS* (DIAPSIDA: ARCHOSAUROMORPHA) FROM THE SONSELA MEMBER (CHINLE FORMATION) OF PETRIFIED FOREST NATIONAL PARK, ARIZONA

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ABSTRACT — We describe a new trilophosaurid, *Trilophosaurus dornorum* sp. nov., from the Upper Triassic (Late Carnian – Early Norian) Sonsela Member of the Chinle Formation in the Petrified Forest National Park, Arizona. Referred specimens of the new taxon are also known from the Cooper Canyon Formation (Norian) of west Texas. This large, robust trilophosaurid possesses distinct cingula on the transversely expanded, tricuspid teeth. Despite earlier reports to the contrary, this is the first well-preserved material of *Trilophosaurus* from Petrified Forest National Park. The discovery of the new taxon increases the known diversity of the trilophosaurids.

Keywords: Triassic, Petrified Forest, Chinle Formation, Dockum Group, Archosauromorpha, *Trilophosaurus*

INTRODUCTION

TRILOPHOSAURIDS ARE one of the earliest studied Triassic vertebrate groups from the southwestern U. S. A., with the genus *Trilophosaurus* erected by Case (1928a) for the type species, *Trilophosaurus buettneri*. The holotype, a dentary (UMMP 2338), was collected from the Tecovas Formation (Triassic: Carnian) at Walker's Tank in Crosby County, Texas, and was the only specimen referred to the species by Case (1928b). Gregory's (1945) detailed osteology of *Trilophosaurus* was based on specimens from a large collection of *Trilophosaurus* made by the Work Projects Administration in the 1930s under the supervision of Grayson Meade and deposited at the Texas Memorial Museum. This collection came from two localities near Otis Chalk in Howard County, Texas. The collection at the Texas Memorial Museum contains a large amount of cranial and postcranial material from numerous individuals. This collection is the subject of more recent studies by Parks (1969), Elder (1978), Demar and Bolt (1981), and Merck (1995, 1997). Demar and Bolt (1981) divided the teeth of *Trilophosaurus* into three types: anterior teeth (Type A), transversely expanded teeth (Type T), and the posterior tooth (Type P). Trilophosaurids have also been reported as part of faunas described by Murry (1982, 1986), Kirby (1989, 1991, 1993), Long and Murry (1995), Heckert (2001, 2004), Irmis (2005), and Parker (2005b). Lucas et al. (1993) described *T. buettneri* as part of the diverse fauna from a number of localities in the Otis Chalk area, including the Work Projects Administration quarries.

Murry (1987) described a new trilophosaurid from Arizona, *Trilophosaurus jacobsi*, based on several maxillary and mandible fragments from the *Placerias* quarry southwest of St. Johns, Arizona. *Trilophosaurus jacobsi* was later assigned to a new genus *Chinleogomphius* by Sues and Olsen (1993), because they thought it possibly represented a procolophonid. Heckert et al. (2003) reported a cache of *Trilophosaurus* specimens discovered in Borden County, Texas, during the early 1990s that they identified as *T. jacobsi* (Heckert et al., 2001; Heckert et al., 2004; Spielmann et al., 2004). Their examination of these specimens led to their conclusion that *T. jacobsi* was not a procolophonid and did belong to the genus *Trilophosaurus*.

A detailed examination of the trilophosaurids was initiated with the discovery by one of us (BDM) of a near complete left and right dentary of *T. jacobsi* in 1999 at MOTT VPL 3869. The first trilophosaurid specimen was collected from this locality in 1993. Numerous trilophosaurid specimens have been collected from this and other Museum of Texas Tech localities over the past decade. In 2003, R. Irmis and J. Shuman discovered a trilophosaurid specimen (PEFO 31165) in the Petrified Forest National Park of Arizona. The Museum of Texas Tech trilophosaurid study and the discovery of the Petrified Forest specimen lead to the examination of the trilophosaurid taxon described here.

Abbreviations.—MNA, Museum of Northern Arizona; MOTT, Museum of Texas Tech University; MOTT VPL, Museum of Texas Tech Vertebrate Paleontology locality; PEFO, Petrified Forest; PFNP, Petrified Forest National Park; PFV, Petrified Forest vertebrate locality; TMM, Texas Memorial Museum; TTU, Texas Tech University; UMMP, University of Michigan Museum of Paleontology; W.P.A., Work Projects Administration.

GEOLOGIC SETTING

The Chinle Formation in Petrified Forest National Park can be divided into five distinct members. From oldest to youngest, these are the Mesa Redondo, Blue Mesa, Sonsela, Petri-

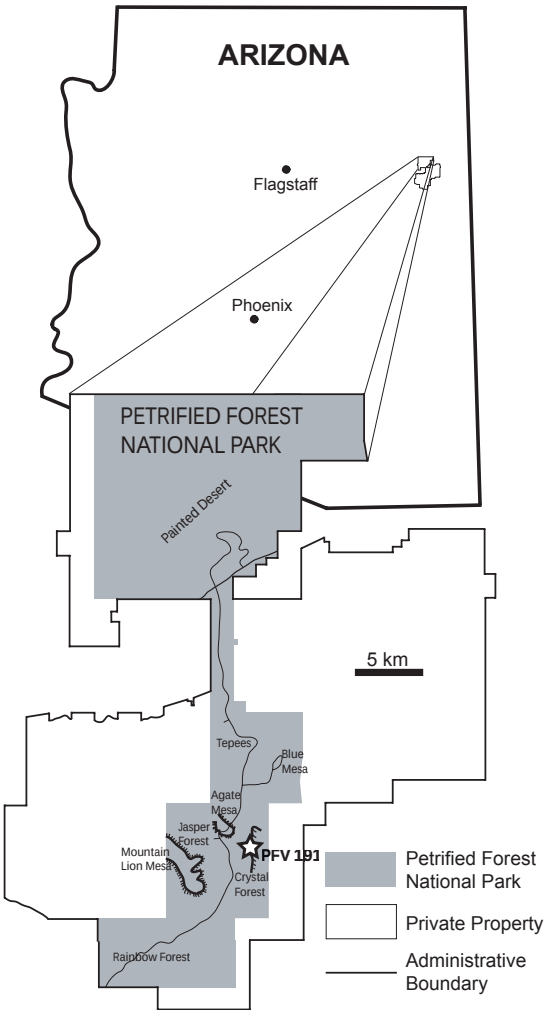

Figure *1*. Index map showing PFV 191 in Petrified Forest National Park, Arizona.

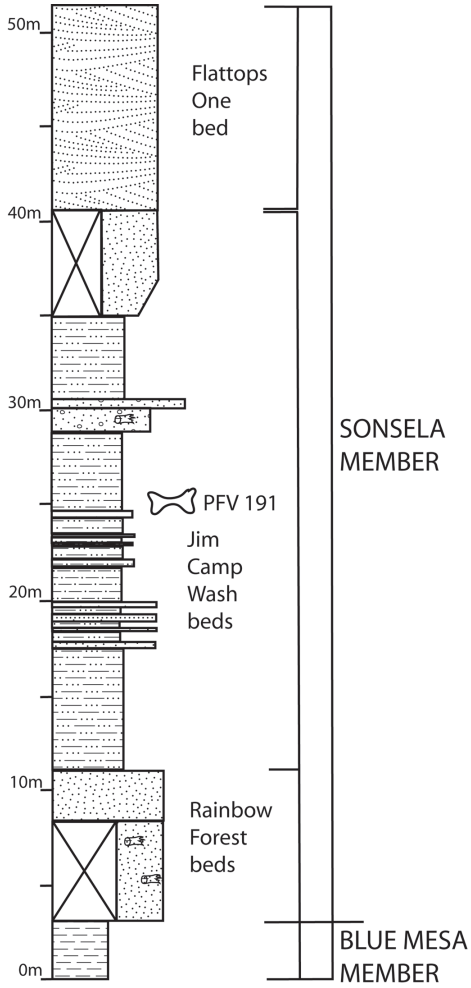

Figure *2*. Stratigraphic section of the Chinle Formation at PFV 191. Modified from Woody (2003).

fied Forest, and Owl Rock Members (Woody, 2003, this volume; Parker and Irmis, 2005). The Blue Mesa and Sonsela Members originally were considered basal units of the Petrified Forest Member (lower Petrified Forest Member of Billingsley, 1985); however, recent stratigraphic work has shown them to be lithologically distinct (Heckert and Lucas, 2002; Woody, 2003, this volume).

The Petrified Forest specimen (PEFO 31165) was collected from the Flag Canyon locality (PFV 191), approximately 1 mile NNE of Crystal Forest at the base of a long, north-south trending escarpment (Fig. 1). PEFO 31165 occurred as float from a series of low, gray, sandy mudstone hills approximately 15 meters beneath the capping sandstone (Fig. 2). Other vertebrate fossils from the locality include a crocodylomorph femur and vertebrae of an indeterminate "rauisuchid".

The capping sandstone can be traced northwards where it roofs Agate Mesa (Fig. 1) and represents the Flattops One bed (Woody, 2003, this volume). PFV 191 is within the Jim Camp Wash beds of the Sonsela Member and is located approximately 20 meters above the top of the Blue Mesa Member (Woody, 2003). The exact age of these beds cannot be currently unequivocally constrained, but the presence of the aetosaur *Paratypothorax* and the phytosaur *Pseudopalatus* at lower horizons in the nearby Crystal Forest (PFV 173) and Mountain Lion Mesa (PFV 295), respectively, suggests a Norian age (Lucas, 1998).

The Upper Triassic Dockum Group of West Texas is divided into four formations. From oldest to youngest they are: Santa Rosa Formation; Tecovas Formation; Trujillo Formation; and Cooper Canyon Formation (Lehman and Chatterjee, 2005). The Museum of Texas Tech specimens came from three localities: MOTT VPL 3624, MOTT VPL 3869, and MOTT VPL 3878. All three localities are located south of Post in Garza County, Texas, in the Cooper Canyon Formation (Norian) of the Dockum Group. Detailed locality information and Global Positioning System coordinates are on file with the Paleontology Division at the MOTT.

At MOTT VPL 3869, the trilophosaurid fossils occur in mudstone deposits representing an overbank flood-plain facies (Lehman and Chatterjee, 2005). The majority of the trilophosaurid specimens come from a mudstone less than one

meter above a carbonate granule conglomerate that is approximately eight meters above the base of the Cooper Canyon Formation. This zone contains abundant, well preserved fossils of small vertebrates.

The sediments at MOTT VPL 3624 (the Post Quarry) represent a flood deposit in an overbank flood-plain facies (Lehman and Chatterjee, 2005). This locality has produced a varied fauna from small temnospondyl amphibians to large "rauisuchids" and "poposaurids".

The fossils at MOTT VPL 3878 come from mudstones of an overbank flood-plain facies overlying a thin lenticular sandstone deposit (BDM pers. obs.). This locality occurs in the upper portion of the Cooper Canyon Formation, approximately 50 meters above the Post Quarry. This locality differs from the other two MOTT localities in that fossils at this locality are sparse and primarily consist of phytosaur and aetosaur remains. All three of the localities are considered Norian in age (Lehman and Chatterjee, 2005).

SYSTEMATIC PALEONTOLOGY

DIAPSIDA Osborn, 1903
ARCHOSAUROMORPHA von Huene, 1946 sensu Benton, 1985
TRILOPHOSAURIDAE Romer, 1956
TRILOPHOSAURUS Case, 1928a

Type Species.—*Trilophosaurus buettneri* Case, 1928a

Other species.—*Trilophosaurus jacobsi* Murry, 1987; *Trilophosaurus dornorum* sp. nov.

Distribution.—Upper Triassic; Late Carnian to Late Norian; Arizona, New Mexico, and Texas.

TRILOPHOSAURUS DORNORUM new species
Fig. 3-5

Trilophosaurus sp. Irmis 2005, p. 70.
Trilophosaurus sp. Parker, 2005a, p. 50.
Trilophosaurus sp. Parker and Irmis, 2005, p. 48.
Trilophosaurus sp. Parker, 2005b, p. 44-45.

Holotype.—PEFO 31165, partial left maxillary with teeth and partial left dentary with teeth.

Referred Material.—MOTT VPL 3624: TTU-P09497 (isolated tooth). MOTT VPL 3869: TTU-P10413 (partial right maxilla), TTU-P10582 (partial right maxilla), TTU-P10583 (partial left maxilla), TTU-P10586 (right and left dentary fragments). MOTT VPL 3878: TTU-P10447 (partial maxilla).

Etymology.—To honor PEFO Chief of Resource Management Karen Dorn, under whom the paleontology program of the park has been revitalized; and Chuck Dorn, a PEFO Law Enforcement ranger, for his ongoing protection of fossil resources.

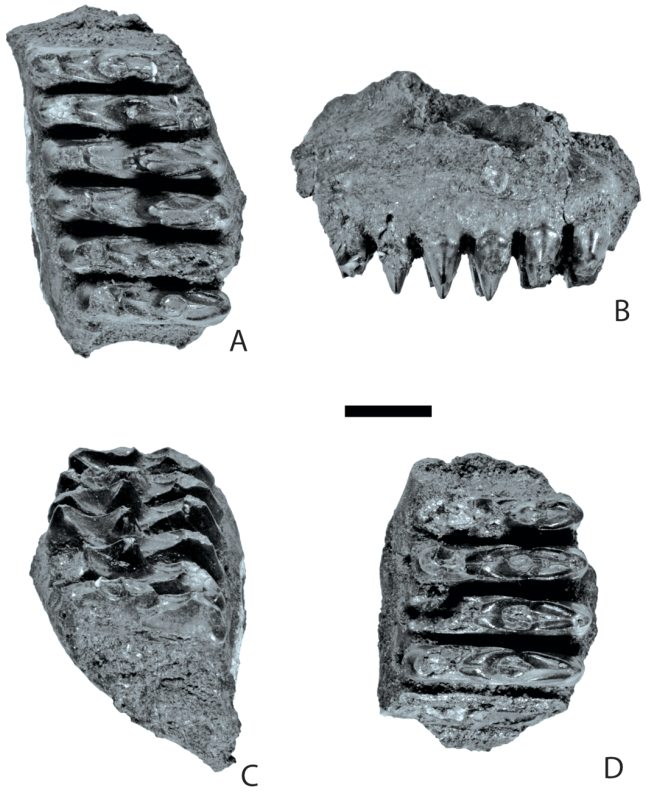

Figure *3*. Maxillary and dentary sections of PEFO 31165, the holotype of *Trilophosaurus dornorum* sp. nov. *A-C*. Maxillary section in *A*, occlusal, *B*, lateral view and *C*, oblique views; *D*. Dentary section in occlusal view. Scale bar = 1 cm.

Diagnosis.—Medial and lingual cusps are similar in size and the medial cusp is offset labially. Cingula form deep grooves on larger specimens. Anterior and posterior cingula connecting both labial and lingual cusps to medial cusp, three to three and one-half maxillary teeth posterior to lateral process of maxilla. Maxilla and dentaries more robust in structure than *T. buettneri* and *T. jacobsi*.

Type locality and horizon.—PFV 191, Petrified Forest National Park, Arizona. Global Positioning System coordinates are on record with the park. Jim Camp Wash beds, Sonsela Member of the Chinle Formation.

Age.—Late Triassic (Late Carnian – Early Norian).

Description.—The holotype jaw fragments (Fig. 3) were found as float on some small mudstone mounds at the base of an escarpment. No additional trilophosaur specimens have been collected from that locality. The two fragments, a partial maxilla and a partial dentary, are from the left side of the skull and belong to a large, robust trilophosaurid. TTU-P09497 and TTU-P10447 from the Cooper Canyon Formation are similar in size and are almost twice the size of the largest *Trilophosaurus* specimens from Otis Chalk. The specimens

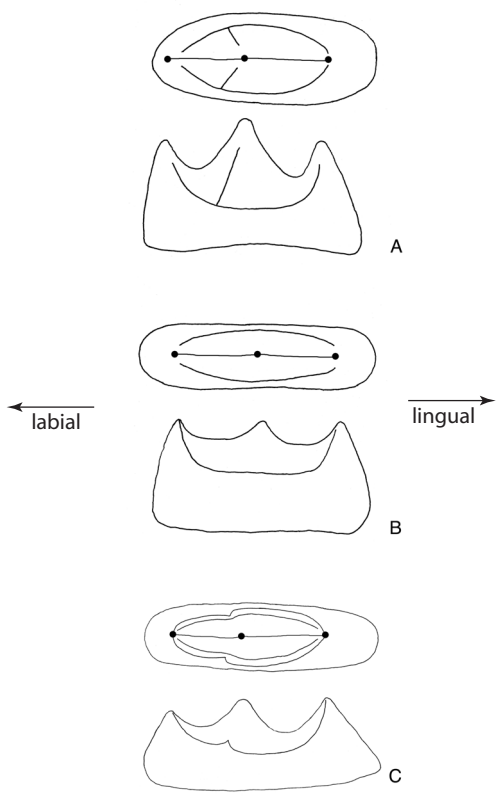

Figure *4*. Diagram illustrating the cingula and cusp structure on the teeth of three species of *Trilophosaurus*. *A*. *T. jacobsi*; *B*. *T. buettneri*; *C*. *T. dornorum*. Figures are not to scale.

from MOTT VPL 3869 vary in size. As in the other trilophosaurids examined, the Type A teeth and the Type P tooth differ from the Type T teeth, with the Type A and P teeth being subround to round in the occlusal view. The tricuspid, transversely expanded, Type T teeth vary slightly throughout the tooth row with the primary characters being consistant.

Compared to other species of *Trilophosaurus*, the teeth of *T. dornorum* are very distinct. The Type T teeth are transversely expanded, possess three cusps, and have a sharp occlusal ridge connecting the cusps along the crown of the tooth (Figs. 3, 4). There are cingula on both the anterior and posterior facets of the teeth. Anterior and posterior cingula connect the labial cusp to the medial cusp and anterior and posterior cingula connect the lingual cusp to the medial cusp (Fig. 4). In *T. dornorum*, the cingula usually connect on the labial portion of the medial cusp. The medial cusp is offset labially and equal in size to the lingual cusp. The facets formed by the cingula and the crest of the tooth are often concave.

The teeth are oriented at a slight angle to the line of the tooth row and perpendicular to the sagittal plane of the skull. The maxilla and dentary are more robust than those of *T. buettneri* or *T. jacobsi*. The maxillae of *T. dornorum* are dorsoventrally shorter than comparable elements of *T. buettneri* and *T. jacobsi*. The maxilla of *T. dornorum* possesses only three to three and one-half teeth posterior to the lateral process of the maxilla (Fig. 5). The posterior tooth of the maxilla is round to sub-round in occlusal view.

DISCUSSION

The holotype and referred specimens of *T. dornorum* were compared to 37 dentary or maxilla specimens of *Trilophosaurus* from the two Otis Chalk localities in the collection of the Texas Memorial Museum, the holotype and seven referred specimens of *T. jacobsi* from the Museum of Northern Arizona, the holotype of *T. buettneri* from the University of Michigan Museum of Paleontology, 62 dentary or maxilla specimens of trilophosaurids in the Museum of Texas Tech collection, and photographs of other trilophosaurid specimens. The analysis of all these trilophosaurid specimens is the subject of a more detailed manuscript that is in progress by BDM.

We concur with Heckert (2004) that all of the specimens from the Otis Chalk localities represent a single species of *Trilophosaurus*. The Otis Chalk *Trilophosaurus* specimens are very uniform in their morphological characteristics and the difference in sizes of the specimens does not affect the characters of the jaws and teeth. All Type T teeth examined exhibited three cusps that are similar in size, with equally spaced cusps, and cingula connecting the lingual and labial cusps (Fig. 4). The maxillae, when a complete posterior portion of the tooth row is preserved, possess five teeth posterior to the lateral process of the maxilla (Fig. 5).

Trilophosaurus dornorum is differentiated from the *T. buettneri* by several characters. Firstly, in *T. dornorum* the cingula connect the labial and lingual cusps to the medial cusp. Secondly, the maxilla of *T. dornorum* possesses three to three and one-half teeth posterior to the lateral process of the maxilla. Furthermore, *Trilophosaurus dornorum* is a more robust taxon than *T. buettneri*. The largest dentaries and maxillae of *T. dornorum* have teeth up to 21 mm in width compared to only 13 mm for the dentaries and maxillae of the largest Otis Chalk specimens of *Trilophosaurus*. In *T. dornorum* the maxilla is not as tall dorsoventrally as in comparable specimens of the Otis Chalk *Trilophosaurus*. Whereas we feel that the robustness of this taxon is significant, we realize that this, by itself, is not sufficient for taxonomic differentiation and rely on other characters to diagnose *T. dornorum*.

Eight specimens of *T. jacobsi* from the MNA were examined in detail and compared to the specimens of *T. dornorum*. Murry (1987, p. 774) described the teeth of *T. jacobsi* as "posterior teeth tricuspid, crowns of teeth forming sharp asymmetrical pyramids, well-developed medial and typi-

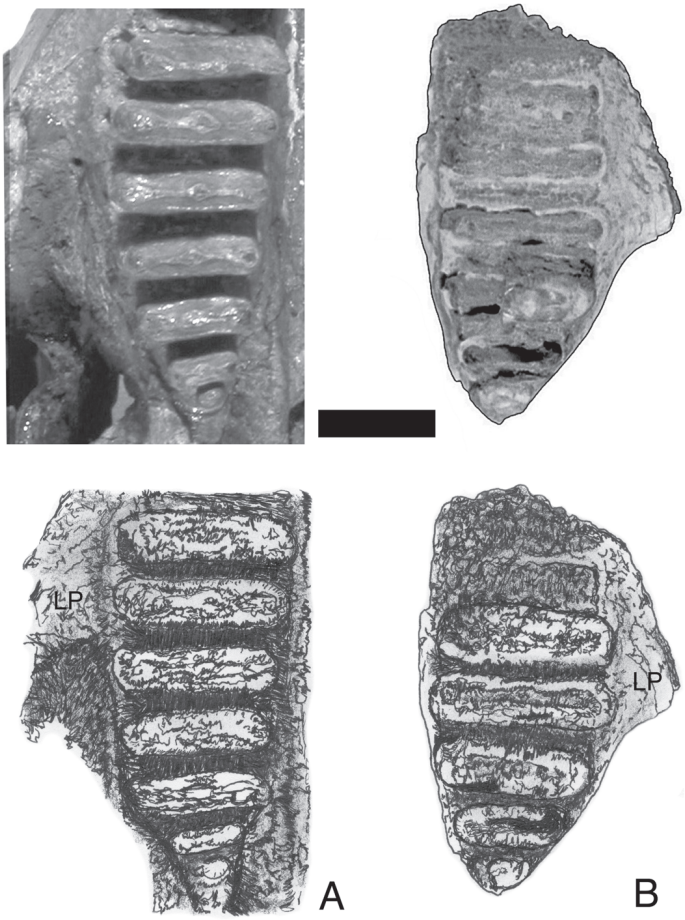

Figure 5. Photograph and diagram comparing the posterior maxilla configuration in occlusal view. *A*. *Trilophosaurus buettneri* (TMM 31025-140); *B*. *Trilophosaurus dornorum* (referred specimen TTU-P10413). LP, lateral process of maxilla. Scale bar = 1 cm.

cally with lateral cingula joining each cusp." Examination of the holotype and referred specimens of *T. jacobsi* confirmed that adequately preserved specimens possess cingula that connect the labial and lingual cusps of the tooth. The holotype, MNA V3192, is broken; however, the angle of the cingula is consistent with the structure of the best preserved tooth (MNA V9494) that clearly exhibits cingula connecting the labial and lingual cusps. Whereas MNA V9495 appears to have cingula connecting the lingual and labial cusps to the medial cusp, microscopic analysis of the cingula shows that this is an artifact of preservation. The tooth is worn and abraded, giving the false impression of cingula connecting to the medial cusp.

The medial cusp of *T. jacobsi* is more prominent than the lateral cusps, whereas in *T. dornorum* the medial cusp is equal in size to the lingual cusp. This character is consistent with the sample of trilophosaurids collected from MOTT VPL 3869 and identified as *T. jacobsi*. The medial cusp is slightly larger and more bulbous than the lateral cusps and, when abraded or worn, specimens 'appear' to have cingula connecting the labial and lingual cusps to the medial cusp. On unworn teeth, the cingula clearly traverse from the labial to the lingual cusps. The teeth of *T. jacobsi* from MOTT VPL 3869 are taller relative to tooth width than the teeth of *T. dornorum*. Heckert et al. (2003) and Heckert (2004) described the character of the tooth height being greater than the tooth width for specimens they identified as *T. jacobsi*. One of these specimens, a fragmentary tooth from the Upper Kalgary locality, NMMNH L1430, identified by Heckert (2004, p. 95, fig. 77 E–F) as *T. jacobsi*, appears to be referable to *T. dornorum* but the identification cannot be confirmed without direct examination of the specimen. Heckert described this as the only locality where *T. buettneri* and *T. jacobsi* are both found together; however, *Trilophosaurus buettneri*, *T. jacobsi*, and *T. dornorum* are all now known to occur at MOTT VPL 3869.

The transversely expanded teeth of *T. dornorum* are arranged in the jaw perpendicular to the sagittal plane of the skull. This arrangement is typical for *Trilophosaurus*. The teeth are oriented in the jaws at more of an angle than in *T. buettneri* but less than in *T. jacobsi*.

Trilophosaurids more robust than *T. buettneri* have been previously described. Long and Murry (1995) described a femur (TMM 31025-265) and humeri (TMM 31025-66) from Otis Chalk and three tibia and a pelvis with sacrum from the *Placerias* Quarry in Arizona. They referred this material to "a robust trilophosaurid." There is no association or reason to suggest this material belongs to *T. dornorum*. It merely supports the hypothesis that trilophosaurid taxa more robust than *T. buettneri* existed, and *Trilophosaurus dornorum* represents one such taxon.

The specimens of *T. dornorum* were compared to the published descriptions, diagrams, and photographs of several taxa exhibiting similar characters. *Teraterpeton hrynewichorum* has an edentulous premaxilla but the teeth do not compare with the dentition of *Trilophosaurus* (Sues, 2003). *Variodens inopinatus* possesses posterior tricuspid teeth (Robinson, 1957); however, they differ from those of *T. dornorum* in that the central cusp is larger than the lateral cusps. *Tricuspisaurus thomasi* also possesses tricuspid teeth (Robinson, 1957; Fraser, 1986); however, the teeth are not all tricuspid and their orientation in the jaw varies. These two characters differ from those of *Trilophosaurus*.

The evidence for the distribution and diversity of the trilophosaurids is greater than has previously been thought. *Trilophosaurus* is now known from more than 28 localities in the southwestern U.S.A. (Long and Murry, 1995; Heckert, 2001, 2004; Heckert et al, 2003; BDM pers. obs.). A variety of trilophosaurid specimens have recently been collected by the Museum of Texas Tech University including *T. buettneri*, *T. jacobsi*, *T. dornorum* sp. nov., and two unnamed trilophosaurid taxa. The increase in diversity and distribution of trilophosaurids is greater than has been previously reported

due to the discovery of localities such as MOTT VPL 3869 and PFV 191. MOTT VPL 3869 contains extremely well preserved fossils of many smaller vertebrates from the Triassic including procolophonids, sphenodontians, a protorosaur, trilophosaurids, a tritheledontid, small archosaurs including a sphenosuchid, and small ornithodirians along with fossils of larger metoposaurids, dicynodonts, phytosaurs, stagonolepidids, poposaurids, and rauisuchids (BDM, pers. obs.). The *Trilophosaurus* specimen collected at PFV 191 is the first unambiguous occurrence of *Trilophosaurus* in Petrified Forest National Park. The discovery of new localities like PFV 191 and MOTT VPL 3869, where the smaller vertebrates are well preserved, continues to expand our knowledge of trilophosaurids and the environments they lived in.

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